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Title:

Acoustic fish data analysis and recommendations related to survey procedures and acoustic data acquisition.

Consultant´s Report for the "Tunisian-German Fisheries Project", Tunis, Tunisia.

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Client´s reference:

"Tunisian-German Fisheries Project",
GTZ-I.N.S.T.O.P.
Project Manager George F. Losse

Project leader:

John Dalen

Summary:

During 5 to 23 February 1987 a consultancy was performed in La Goulette, Tunis for the "Tunisian-German Fisheries Project" on behalf of the Deutsche Gesellschaft für Technische Zusammenarbeid GmbH (GTZ) and the Institut National Scientifique et Technique d´Océanographie et de Pêche (I.N.S.T.O.P.). La Goulette, Republic of Tunisia. The scope of work comprised analyzing of acoustic fish abundance data and recommending of guidelines for future surveys and acoustic data analyses. The report describes the decisions and performance of the work tasks in addition to recommendations relevant to prospective problems and topical procedures of the project.

Indexing terms:

Fish stock assessment
Echo integration
Data analysis

Distributed to:

GTZ-I.N.S.T.O.P., Tunisia
Inst. of Marine Research, Bergen

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JD/guk/"Tunis-JD"

1. ITINERARY

5 February 1987;

Trondheim to Bergen

7-8 February 1987:

Bergen to Tunis via Oslo, Copenhagen, and Geneva.

21-22 February 1987:

Tunis to Bergen via Geneva, and Oslo.

23 February 1987:

Bergen to Trondheim.

2. INTRODUCTION

During 1985-86 initial communications took place between the GTZ-I.N.S.T.O.P. project and the Institute of Marine Research (IMR), Bergen, in relation to a consultancy within applied fisheries acoustics.

At the end of 1986 one of two scientists of IMR was announced available to the project from the end of January and onwards.

By mid-January the inquiry for the appointed consultancy was presented to IMR and a preliminary contract was agreed upon by end of January - all by telexing.

The terms of reference were:

1 - formulate and improve the methodology of acoustic data analysis,

2 - make recommendations for improved survey procedures and acoustic data acquisition.

Based on these references a more detailed plan comprising working tasks and schedule was settled for guiding the running activities during the consultancy.

During initiating and terminating phases of the consultancy period I had discussion on biological and technical matters with members of the "Dr. Fridtjof Nansen" survey team and survey engineers at IMR, Bergen.

The main topics of this report will be describing the major activities and experiences during the stay in Tunis, and making recommendations for potential improved operations of the hydro-acoustic instruments and optimum survey performance in Tunisian waters.

3. INITIATING AND *IN SITU* PREPARATION OF THE CONSULTANCY

I arrived at Tunis Airport mid afternoon on 8 February. There I was met by the project manager G.F. Losse. I got installed in La Marsa, a small village, about 22 km from Tunis and about 10 km from La Goulette where the I.N.S.T.O.P. was located in near access to the research vessel.

On 9 February I was presented to the other members of the project team;

- Abdallah B.M. Hattour, (biology, fisheries acoustics)
- Brahim B.H. Turki, (biology, fisheries acoustics)
- Fejri Belhi, (electronics)
- John Nockles, (electronics, technical acoustics)
- Uwe Rowedder-Klatt, (biology, computer science)
- Winfred Nau (socio-economy, marketing)

and other persons of I.N.S.T.O.P. differentially related to the project.

In advance of working out plans for the specific working tasks of my consultancy we made a guided tour onboard the R/V "Tareq II".

The research vessel, a previous training vessel of approx. 30 m length, was equipped with the following hydroacoustic instruments for fish monitoring and abundance observation:

a - SIMRAD EK400, 38 kHz echo sounder, the main sounder for fish abundance observation in connection with the echo integrator,

b - SIMRAD EK400, 120 kHz echo sounder, back-up sounder for fish and plankton observation as a stand-alone instrument, or might be connected to the echo integrator,

c - SIMRAD ES400, 38 kHz echo sounder, split-beam sounder for echo strength classification,

d - SIMRAD QD; Digital echo integrator, and

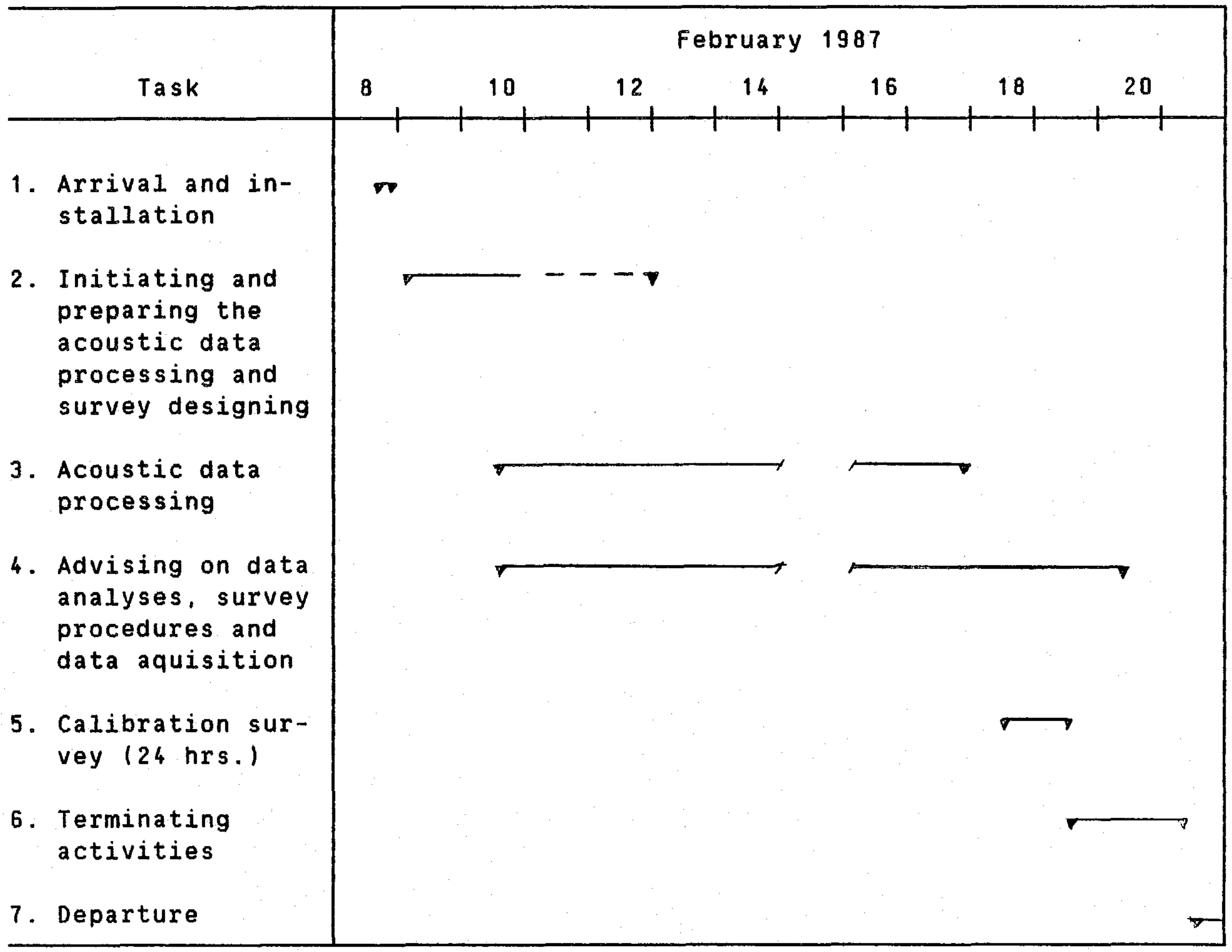
e - relevant test and performance monitoring instruments.

The instruments were mounted in a fairly functional and well arranged manner in a rather cramped instrument room just in front of the wheel house.

Upon requests from the project team it was decided that the major activities to give "flesh and blood" into the terms of reference, were to work through all the acoustical data and related biological samplings from cruise no. 5 of the project. This cruise took place 20-25 August 1986 in the Northern Tunisian waters from the Algerian border to Cape Bon. Members of the project team participating in the analyzing, evaluation and judging of the data should all the time be inspired and invited to interrupt the running judging in order to elucidate and go deeper into current problems and discuss related ideas and potential recommendations.

A tentative schedule, Table 1, was decided upon.

TABLE 1: Schedule of the consultancy periode in Tunis:



4. ANALYSIS OF ACOUSTIC DATA

To work myself into the position of being able to process the acoustic data, i.e. the echo integrator recordings and related echograms from the EK400 and ES400 echo sounders, I had to be informed into the closest details of other relevant and crucial information. From all members of the project team I searched for (task 2) information through questions and scenarioes about:

- descriptions of the biological and oceanographical particulars of the Tunisian coastal waters, particularily the Northern areas, i.e.

  - species compositions, fish and plankton, by areas, depths and seasons,

  - migration (e.a. spawning, feeding) of species by areas and seasons,

  - behaviour characteristics of the topical species, juveniles and adults, by day and night, depths and seasons,

  - species availabilities to biological sampling by different gear/trawls,

  - major current/wind circumstances by areas and seasons, and

  - major temperature and salinity distributions by areas, depths and seasons.

- descriptions of the bottom topography in relations to the fish distributions and the oceanographic particulars.

- descriptions of relevant particulars of the cruise and the acoustic data acquisition, i.e.

  - the procedures and ways of logging the acoustic data,

  - setting of the instruments,

  - running checks and control of the performance of the instruments,

  - any logging of instrument performance anomalies,

  - short-time aimed changes of the instrument settings to increase the understanding of the current data acquisition during for instance changing fish distribution patterns,

- biological sampling by gear, frequence and catch composition,

- cruise tracks in relation to the shelf and bank areas, and

- weather conditions.

Based on previous knowledge and experience and recently gained information I formulated guidelines for the scrutinizing, evaluation and judging of the echo integrator and the echo sounder data in a manner to involve and engage the member(s) of the team participating in the process (task 2). The guidelines followed the major procedures of DALEN and NAKKEN (1983) adjusted to the procedures of acoustic abundance estimation by echo integration in tropical and subtropical areas, e.a., see STRØMME (1984). This is summarized by the flow chart of App. 1 and the guidelines of App. 2.

During this planning and formulating of data processing guidelines it became demonstrated that the way the manufacturer of the topical scientific acoustic instruments is training new and not well-experienced research teams in applied acoustic fish abundance techniques is rather unsufficient and to some degree misleading. For instance in areas where we have merged echo integrator contributions from several different species it is very difficult and extremely time consuming to deal with the "highly advertised" measure of mean volume backscattering strength.

To the manufacturer: As long as the QDs are "alive", please work out and advise in how to incorporate the topical value of C_I in the recordings, for instance by manipulating the echo integrator gain. Thus the present measure of the "mm deflection" can be adjusted to represent an absolute linear measure of the integrated backscattering contributions from the targets inside each depth interval, conf. 6.2 and 6.3.

The data processing which resulted in distrubution maps of echo abundance of the topical groups of species was finished 17 February (task 3). The final estimations of fish abundance could not be carried through untill the conversion factor (C) between acoustic abundance and fish abundance has been established. This is the instrumentation factor C_I from standard target echo integrator calibration and the fish species factor C_F from the effective target strengths representing the topical groups of species.

5. CALIBRATION SURVEY

Already the 9 February we planned to carry out a 24 hrs. survey during the mid of the second week of my consultancy. The scope of work for the survey was as follows:

1 - to undertake a standard target calibration of the echo integrator to establish the instrumentation factor C_I of the conversion factor C.

2 - to try out balanced settings of the echo sounder (EK 400) and of the parameters of the echo integrator to gain better correspondence between the echo integrator recordings and the appearance of plankton, midwater and bottom located fish distributions of the echograms.

The survey took place from 1100 hrs 18 February to 1300 hrs 19 February. Although the weather conditions were excellent at departure they rapidly grew bad (fresh breeze) so the first attempt of calibration during the afternoon was rather unsuccessful.

For some hours during the night we cruised at 8 knts. to examine the echograms at different control settings, but the wind and thereby the bubble attenuation were so high that the findings were of minor value.

The next morning the wind had calmed and the standard target calibration was repeated from 0630 hrs. Unfortunately the high swell made it very difficult to keep the calibration sphere stable in the echo sounder beam so the obtained results were not recommended for "C_I-application".

Fish distributions during daytime conditions were not favourable for echogram examining so the cruise was terminated after the calibration at 1030 hrs 19 February.

6. RECOMMENDATIONS

6.1. Preparing charts of relative and absolute fish abundance

In order to classify and demonstrate the particulars of the occurring groups of species it is recommended to establish iso-line charts both for relative i.e. acoustic fish abundance and absolute fish abundance instead of any system of geographical/ statistical squares with attached averaged echo abundances. The applied "group of pelagic species" which comprices a considerable number of species can effectfully be devided into subgroups each comprising fewer species by stratifying the surveyed area by depth.

When comparing data and results from several succeeding surveys this depth stratification and abundance isolining may provide useful information about seasonal species migration and changes of abundance.

When deciding on what specific integrator value to attach to each isoline this should be based on the total dynamic range of the judged integrator recordings and a rational division of this range into subranges i.e. quantitative abundance ratings of low, medium, high and very high abundance. These notations are preferred to elsewhere applied notations of very scattered, scattered, dense and very dense recordings.

A particular data processing journal for estimating absolute fish abundances from isoline charts of echo abundances was worked out during the consultancy. This journal is not presented in the report.

6.2. Estimation of the convertion factor (C) in relation to echo integration

When applying echo sounder and echo integrator for absolute fish abundance estimation the succeeding equation is commonly used:

$$\varrho_A = C_F C_I M \qquad (1)$$

where

- ϱ_A - area fish density, i.e. numbers/weight of fish per unit area (e.a. square nautical mile),
- C_F - fish (species) factor, part of the conversion factor $C = C_F C_I$,
- C_I - instrumentation factor,
- M - echo integrator recording ("mm deflection") without adjustment due to the instrumentation factor.

The integrator recording M is now a measure of the relative acoustic abundance of fish. In order to adjust the integrator recording to become an absolute measure of the acoustic abundance of fish we will do this by taking account of the performance of the echo sounder and echointegrator, i.e. establish a certain value of C_I by a standard target calibration. The procedure of this is described in detail by FOOTE et al. 1987, and is recommended to be followed during the calibration.

We want the integrator recordings to be of the form:

$$s_A = C_I M \qquad (2)$$

where s_A is the area backscattering coefficient related to the area backscattering strength, S_A, by the equation (URICK 1977)

$$S_A = 10 \log s_A \tag{3}$$

The instrumentation factor C_I is represented by:

$$C_I = \frac{3.43\ 10^6\ \sigma_{bs,sp}}{k\ M_{sp}\ D_{sp}^2\ \psi} \tag{4}$$

where

"3.43 10^6" - number of m^2 of one square nautical mile,

$\sigma_{bs,sp}$ - backscattering cross-section [m^2] of the standard target/the sphere,

k - correction for potential TVG-deviation at the depth of the standard target,

M_{sp} - integrator recording from the standard target, [mm deflection],

D_{sp} - depth of the standard target, and

ψ - the equivalent beam angle of the topical echo sounder transducer.

The backscattering cross-section, $\sigma_{bs,sp}$, of the sphere is related to the target strength (CLAY & MEDWIN 1987) of the sphere by:

$$TS_{sp} = 10 \log \sigma_{bs,sp}/A_{ref} \quad [dB] \tag{5}$$

where $A_{ref} = 1\ m^2$ is the reference area. When applying the previous definition (e.a. URICK 1977) of the target strength

$$TS_{sp} = 10 \log \sigma_{bs,sp}/4\pi \quad [dB] \tag{6}$$

C_I of eq. (4) has to be multiplied by 4π.

The fish (species) factor C_F is represented by

$$C_F = 1/\langle\sigma_{bs,i}\rangle \tag{7}$$

where $\langle\sigma_{bs,i}\rangle$ is the effective backscattering cross-section of the species "i"/group of species "i", of which we want to estimate absolute abundance of fish. The effective target strength $\langle TS_i\rangle$ is similarely related to the effective backscattering cross-section $\langle\sigma_{bs,i}\rangle$ by;

$$\langle TS_i\rangle = 10 \log\langle\sigma_{bs,i}\rangle/A_{ref} \quad [dB] \tag{8}$$

If the previous definition of target strength, Eq. (6) is applied, C_F of Eq. (7) has to be devided by 4π.

A weight normalized effective backscattering cross-section, $\langle\sigma_{bs,i,w}\rangle$ might as well be applied in Eq. (7). This normalized version is obtained by

$$\sigma_{bs,i,w} = \sigma_{bs,i}/w \quad [m^2/kg] \tag{9}$$

where w is the weight of the specimen of species "i" having the backscattering cross-section $\sigma_{bs,i}$. The corresponding weight normalized target strength $\langle TS_i\rangle_w$ has the denomination [dB/kg] and is related to $\langle\sigma_{bs,i,w}\rangle$ by an equation equivalent to Eq. (8).

By applying the specimen related effective backscattering cross-section, Eq. (8), the absolute fish estimate will be in number of fish per square nautical mile while the weight normalized one, Eq. (9), yields weight of fish per square nautical mile.

Summing up:

The integrator recording, s_A, represents the accumulated backscattering cross-sections exceeding a controlled threshold of all the targets, i.e. fish and plankton, of the integrated depth interval over the integrated distance. The area backscattering coefficient, s_A, Eq. (2), has now dimension m^2 per square nautical mile.

6.3. Balanced settings of the echo sounder controls and the system variables of the echo integrator

The project team excellently represented by their electronics engineer, Mr. J. Nockles, had a highly qualified understanding and knowledge about the technical details and functioning of all the instruments. But due to few and to some extent short surveys the team had unfortunately not got the required opportunities to adapt all the technical skill and biological knowledge into quite satisfactory applied survey techniques.

On the basis of the experience during the acoustic data processing favourable changes of the applied settings of the echo sounder (EK400) controls in relation to the dynamics of the echo integrator recordings, should be discussed and prospective decisions of new settings should be made. The overall objectives of this was to gain better correspondence between the echo integrator recordings and the appearance of fish and plankton of the echograms, and to relate the available total dynamic range of the echo sounder and integrator to the acoustic dynamic range of the fish (and plankton) targets.

The main parameters considered were those related to gain/attenuation of both the echo sounder and the integrator.

Echo sounder time varied gain (TVG):

Although the 40 log R may be used for certain studies during ordinary echo integration surveys (20 log R on the integrator) it is recommended to run the echosounder on 20 log R too for sake of correspondence.

Echo sounder attenuation (A):

When applying a high powered transmitter it is recommended to run the attenuation on 10 or 20 dB//1V at 38 kHz. Based on the performance of the topical equipment the already applied attenuation of $A = 10$ dB seemed to be correct. The available attenuation levels of EK400 in steps of 10 dB are often too rough. It should be favourable to have the steps in changes of 5 dB.

Echo sounder gain (recorder):

The values of the recorder gain should be evaluated and decided upon in relation to the TVG and attenuation. Due to the great differences between the daytime (dawn-dusk) and night time (dusk-dawn) fish recordings the recorder gain may well be different for the two periods (as is already applied).

Echo integrator gain (G):

This gain, G [dB//1V], should be considered in relation to the attenuator setting of the echo sounder:

I: When the topical value of C_I is decided to be incorporated (into the integrator) before printing out the echo integrator recordings, a neat and favourable way is to operate the echo sounder - echo integrator chain at a 1:1 level troughout. This means that for $A = X$ dB put $G = -X$ dB. Then the echo integrator recordings with C_I included will exactly represent s_A, the accumulated area backscattering per square nautical mile, conf. 6.2. Please note that in this case the "S_V-recordings" will be incorrect (due to the internal handling of G in the QD).

II: If C_I is not to be incorporated before printing out the integrator recordings but taken into account later in the data processing, then we may put $G = -(X + 10 \text{ or } 20)$ dB. These 10 or 20 dB additional gain is to produce a convenient dynamic range of the echo integrator recordings for data evaluation and judging. NB! If this last procedure is applied, please remember to devide the acoustic fish abundance (echo abundance) by the real number corresponding to (10 or 20 - X) dB during the absolute fish abundance estimation.

A few examples of gain settings during different kinds of operation shall be considered:

Standard target calibration:

As previously mentioned this is to establish the C_I. The echo sounder attenuation should be the one applied during surveys, e.a. A = 10 dB. During the calibration put G = -10 dB. The obtained integrator recording of the standard target is now the value of M to put into Eq. (4). Calculate C_I from Eq. (4) after having recorded/calculated the other parameters of this equation. For instance let us assume this yields $C_I = 50$.

Surveying:

I: From our example we have $C_I = 50$ which yields $10 \log C_I =$ 17.0 dB. The adjusted echo integrator gain which we now enter should be $G_{C_I} = -(10 + 17)$ dB = -27 dB. The integrator recordings will now represent s_A of Eq. (2).

II: With A = -10 dB enter G = -10 or -20 dB. If G = -20 dB is applied, devide the evaluated and judged echo abundance by 10 during the final fish abundance estimation.

Echo integrator threshold (u_{tr}):

Figure 1 shows a copy of the heading of the CD-journal. This copy is from the first shakedown cruise which means that several parameters which are being entered manually (not measured and calculated by the QD itself) have been adjusted to more proper values during the later cruises.

```
COMMAND : START

--------------------------------------------------------------------------------------

Vessel:         TAREQ 2                                              Page  1

Place:          TUNISIA NORTH                                        Date: 86.4.25
Comments:       SHAKEDOWN CRUISE NO. 01
--------------------------------------------------------------------------------------
Sounder No.:          2      Frequency:     38.0 kHz   Source Level:      132.7 dB
Pulse Duration:    0.40 ms   Transducer 3 -20.3 dB     Voltage Response:    0.0 dB
Pulse Rep.Freq.:     83 p/m  TVG:           64.6 dB    Gain:                0.0 dB
Max.Range:          503 m    Sv-Suppress:   -100 dB    C-Echosounder:     -42.6 dB
--------------------------------------------------------------------------------------
Layer    0      I      II     III     IV      V      VI     VII    VIII      IX      X
Upper-Lim     5.0   20.0   40.0   60.0   80.0  120.0  180.0  250.0B+  6.2B+   3.2
Lower-Lim    20.0   40.0   60.0   80.0  120.0  180.0  250.0  350.0B+  3.2B+   0.2
Thres.mVp      20     20     20     20     20     20     20     20
Rec.Ch. 1                                                                       2
Scale  10                                                                  100.00
--------------------------------------------------------------------------------------

Log/Total
LO ? ________ (ENTER)

SEMI-AUTOMATIC LOG MODE >>> VESSELSPEED=   3.6 KNOTS
```

Figure 1. Heading of the QD-journal.

Concerning the echo integrator threshold, u_{tr} [mV], this should be manipulated to avoid contributions from system generated electronic noise, volume reverberation, echoes from very small organisms/particles and vessel generated noise. Since these noise contributions are being amplified by the TVG, the u_{tr} should be increased by increasing depth. Based on experience from Norwegian research vessels the succeeding relationship has been found to work well.

$$u_{tr} = u_0 + 0.2\ R^{\sqrt{0.5}} \quad [\mathrm{mV}] \qquad (10)$$

where

u_0 - threshold voltage of the upper integrating interval (layer). u_0 = 10-15 mV is recommenced for most application.

R - mean depth of an integrating intervall.

Integrating depth intervals:

When considering the integrating depth intervals (layer limits) the intervals should be directed to the most important water columns, i.e. where the important fish distributions appear. Take also into account the expected total depth extensions of the survey area during the layer limits entering. The upper limit of the first layer should not be less than 4 or rather 5 m due to system generated noise which otherwise will be integrated in layer 1. The bottom related intervals (layer IX and X) should be decided upon from fish distributions, if the echo abundance of these intervals is to be correlated to the bottom trawl catches or to other particular considerations.

Based on the topical requirements of this project layer IX should be 10-20 m, layer X 3-5 m, and the bottom offset should be decided upon due to bottom roughness and weather conditions. Low bottom offset value, 0.1-0.2, for smooth bottom and good weather and higher values for rough bottom and windy weather.

7. ACKNOWLEDGEMENTS

I am very greateful to the Project Manager George F. Losse for his friendly and stimulating support and actions during the consultancy. The enthusiastic efforts and involvements of John Nockles, Uwe Rowedder-Klatt, Abdallah B.M. Hattour, and Brahim B.H. Turki are greatly appreciated. They made it possible obtaining good progress during the daily work and by feedback showing gained competence for future acoustic surveying and data processing.

I will also thank the Director of the Institut National Scientifique et Technique d'Océanographic et de Pêche for leaving their whole library at our disposal during the concultancy.

The Captain and the crew of R/V "Tareq II" are acknowledged for their friendly and proper cooperation during our mini-survey.

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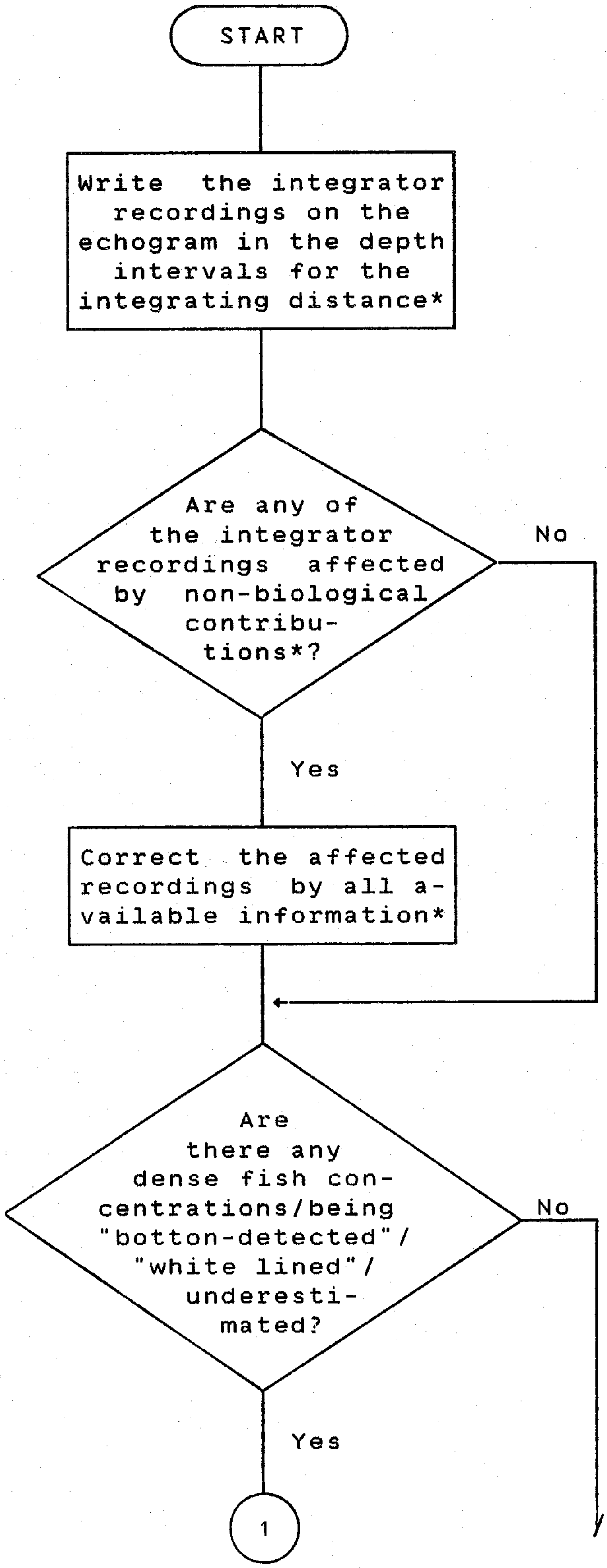
APPENDIX 1: Scrutinizing of Acoustic Data from Echo Integration

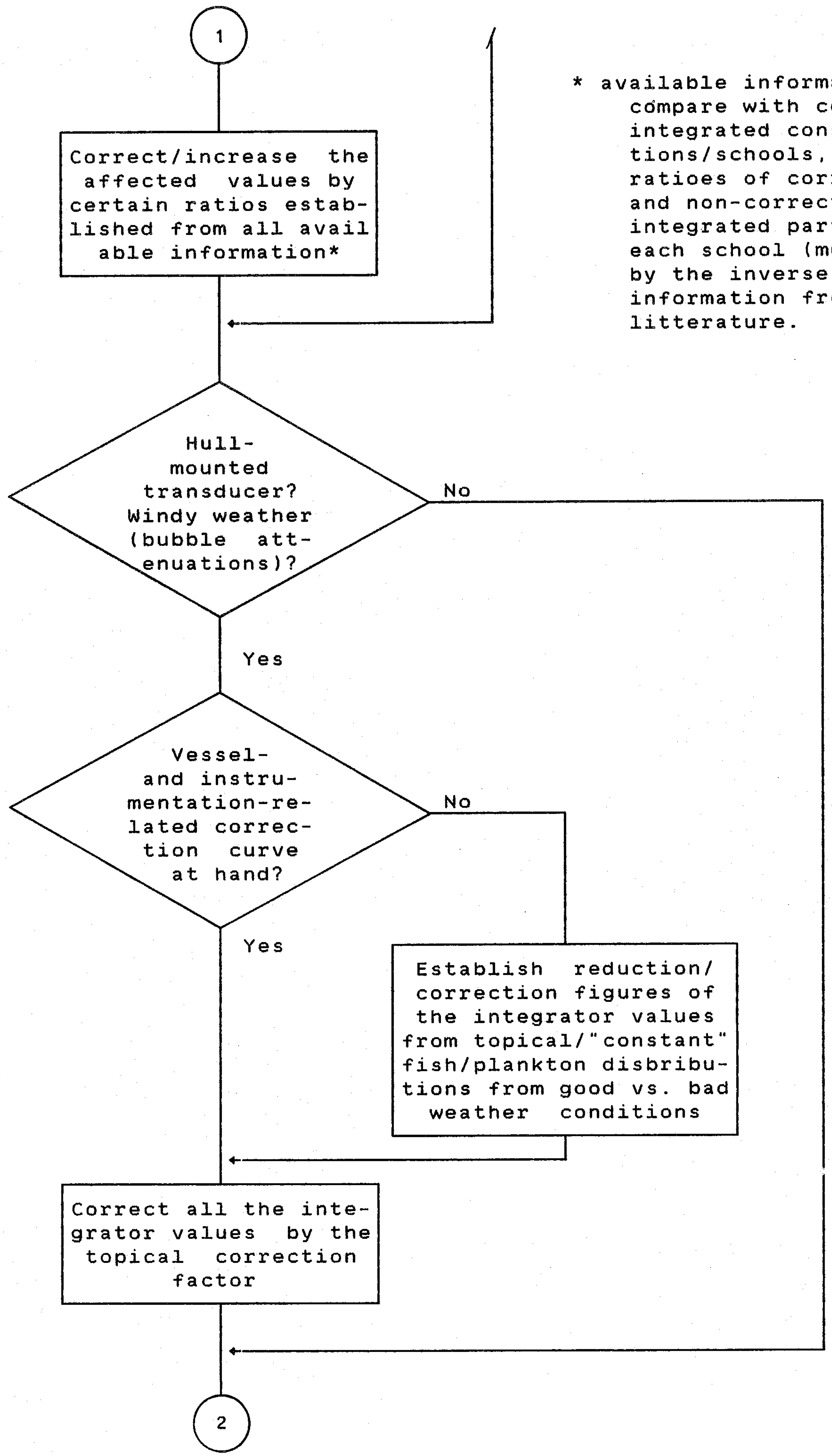
A1.1 Flow Chart of the evaluation and judging process



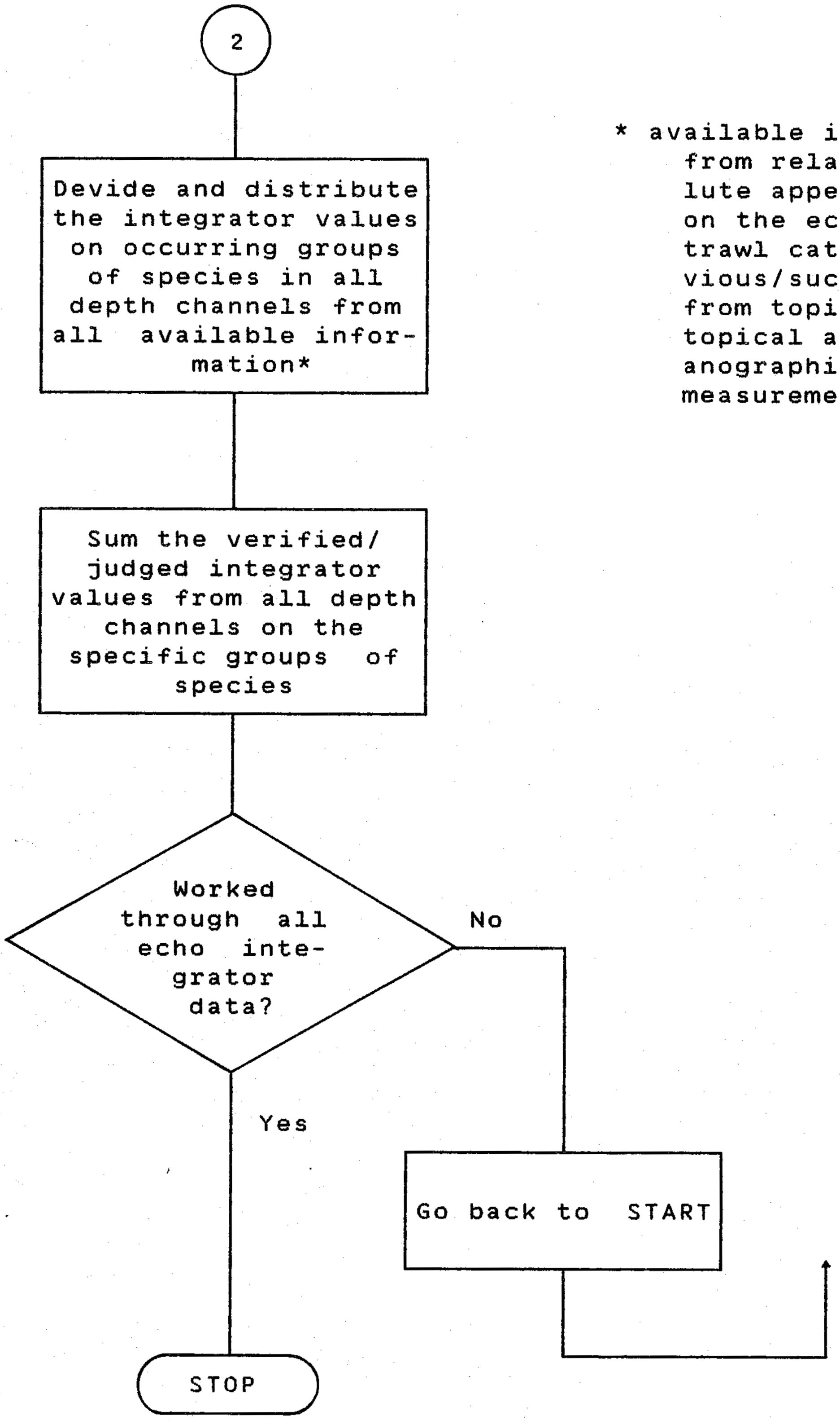
* integrating distance: either 1 mile-values or averaged 2 or 5 miles-values (your choice) decided upon from particulars of the fish distribution patterns and bottom topography.

* non-biological contributions: instrument-noise in the upper channel, bubble contributions in the upper channel, bottom contributions in the bottom channel.

* available information: ringing of the transducer, TVG-generator noise, weather data/ bubbles in the surface layer, compare with previous/succeeding miles, rough bottom, steep seabed.



* available information: compare with correctly integrated consentrations/schools, area-ratioes of correctly and non-correctly integrated parts of each school (multiply by the inverse ratioes), information from the litterature.



* available information: from relative and absolute appearance/strengths on the echograms, from trawl catches, from previous/succeeding miles, from topical season, topical area, from oceanographic observations/measurements.

Tunis 190287

APPENDIX 2: GTZ-I.N.S.T.O.P. Cruise 5, 20-25 August 1986. Brief Guidelines for the Processing of Acoustic Data.

1) Concentrate the processing of data on the observations during dusk till dawn i.e. 1600/1700 hrs. till 0700/0800 hrs. when most of the fish is off bottom.

2) Due to low contributions from typical demersal fish species in the northern areas don't separate the recordings of pelagig ssp. and demersal ssp. but only apply the group of pelagic spp. and make remarks when demersal ssp. may clearly be present.

3) Contributions from planktonic organisms may be considerable parts of the total integrator recordings in certain depth intervalls in some areas. Mostly for instructive reasons the integrator values of plankters will be judged and recorded in the journal.

4) For pelagic spp. the judged integrator recordings of both the total water column (Ch. I to Ch. X) and the bottom channel (Ch. IX + Ch. X) will be recorded in the journal.