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LAKE TANGANYIKA: ASSESSMENT OF FISHERIES ACOUSTIC SURVEY EQUIPMENT

by

R.B. MITSON

FINNISH INTERNATIONAL DEVELOPMENT AGENCY

FOOD AND AGRICULTURE ORGANIZATION
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PREFACE

The Research for the Management of the Fisheries on Lake Tanganyika project (Lake Tanganyika Research) became fully operational in January 1992. It is executed by the Food and Agriculture organization of the United Nations (FAO) and funded by the Finnish International Development Agency (FINNIDA).

This project aims at the determination of the biological basis for fish production on Lake Tanganyika, in order to permit the formulation of a coherent lake-wide fisheries management policy for the four riparian States (Burundi, Tanzania, ZaÔre and Zambia).

Particular attention will be also given to the reinforcement of the skills and physical facilities of the fisheries research units in all four beneficiary countries as well as to the buildup of effective coordination mechanisms to ensure full collaboration between the Governments concerned.

Prof. O.V. LINDQVIST
Project Scientific Coordinator

Dr. George HANEK
Project Coordinator

LAKE TANGANYIKA RESEARCH
FAO
B. P. 1250
BUJUMBURA
BURUNDI

Telex: FOODAGRI BDI 5092
Tel.: (257) 229760
Fax.: (257) 229761

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1. Introduction

The Lake Tanganyika has an area of about 10000 n.m; the length is approximately 600 km. Maximum depth is 1470 m. For the purpose of an acoustic survey the maximum depth of water at which fish will be found is important. It appears that from the shoreline the depth quickly goes off to 200 m, and most of the bottom of the lake is more than 500 m deep. Temperature is reported to be within the range of 24-26°C (Hecky et al., 1978) and (Mathisen & Rufli, 1980) .

However, the vertical distribution of fish is governed by the surface layer where the water is well oxygenated. Chapman (1976) reports that in November 1973, the vertical extent of oxygenated water was 60 m in Burundi and 200 m in Zambia. Plankton blooms during the winter, from July to September; they can reduce visibly to 2-3 m from the more usual 15-20 m. Such blooms need to be taken into account during acoustic surveys because of the possible excess signal attenuation; the amount is dependent on the acoustic frequency being used.

Assuming that the maximum depth at which fish must be detected is 200 m, an estimate of the likely target strength distribution is needed so that suitable parameters can be calculated for the echo-sounder.

2. Management goals

The objectives set for fisheries assessment and management purposes partly determine the specification set for the acquisition and application of acoustic survey equipment. Although not all fisheries have identical characteristics, Pope (1982), considered a framework for different levels of acoustic survey. In summary he concluded that the overall accuracy of acoustic survey should attain the following levels:

2.1 exploratory survey (no *a priori* knowledge) ± 3 dB (±50%)

2.2 for a time series calibrated against VPA ± 2 dB (± 35%)

2.3 as the sole basis for setting a TAC ± 1 dB (± 20%)

These figures include **all errors** attributable to the survey as a whole, whether due to variations in fish target strength; random sampling; survey equipment; acoustic propagation or noise of any description. In addition to showing the constraints on the survey equipment this also emphasises the need for careful survey design and data analysis. Guidance on the latter is contained in Simmonds et al., 1992 (ICES Co-operative report 187). The criteria of (2.2) and (2.3) place severe constraints on the allowable error due to the electronic and acoustic parameters of the survey. The latter must calibrated to ± 0.5 dB at the worst in the case of (2.3) but preferably to ± 0.25 dB.

3. System Calibration

To calibrate: a dictionary definition states 'to check, adjust, or standardise systematically the graduations of a quantitative measuring instrument'. The total acoustic survey system, including the ship, is the quantitative measuring instrument which must provide an accurate relationship between the output from the signal processor and the fish being insonified. However, a good calibration, whilst being essential, cannot guarantee the precision of the biomass estimate, there are other factors involved in achieving a successful survey.

Surveys systems were initially calibrated using caged live fish (Johannesson, 1974) before other means of equipment calibration and in-situ target strength measurements had been developed. Measurements on caged fish are prone to error resulting from unnatural behaviour, due to the distribution within the cage and the orientation of individuals. The tendency is often for fish to swim around the outer perimeter of the cage, thus a proportion will be outside the acoustic beam but when the fish are relatively still, their tilt angles tend to be widely distributed. Both situations will cause unrepresentative TS distributions to be obtained (TS higher than the true values).

Substantial progress has been made during the past two decades and it is now possible to make a **static** calibration of acoustic systems to ± 0.25 dB by means of the standard target method.

A comprehensive guide to static calibration has been published in (Foote et al., 1987) ICES Co-operation Research series (No.144). This covers all the aspects of the available methods, give practical guidance and examples. There is also a need to make a dynamic calibration to determine the performance in relation to noise, whether it rises from self noise of the ship's hull, or a towed body, water discharge from the hull, or underwater radiated noise from the propeller and engines.

Echo-integration is almost universal as the method of signal processing. It relies on the received echo energy being proportional to the density of ensonified fish. But in order to make a conversion in terms of biomass it is necessary to have details of the fish target strength distribution. For this purpose calibrated dual-beam or split-beam transducer are used to obtain individual fish target strengths.

4. Acoustic propagation

Acoustic calibration relies on accurate data about the propagation of acoustic signals. Knowledge of temperature and salinity (or the local factors causing absorption) are essential for calculation of the absorption and speed of acoustic waves.

4.1 Absorption -the absorption factor (~) has been considered in the past to be low enough to ignore in so-called fresh water but with the increasing precision now possible for acoustic systems further consideration is now needed. Classical curves for absorption in distilled water show that a figure for - of about 4 dB/km is to be expected at 120 kHz for a temperature of 14°C. This means that at 100 m depth the two-way loss due to absorption would be 0.8 dB. Re-calculating for 28°C shows a reduction to 2.7 dB/km, i.e. 0.54 dB at 100 m. However, the lake is not filled with distilled water, it has a high mineral content but this is not taken into account because the effect on absorption is not known. It is a factor that should be investigated at a latter stage.

4.2 Speed of acoustic waves - given temperature, salinity, and depth, this factor can be calculated from a nine-term equation due to Mackenzie (1981). Speed of acoustic waves has an effect on the TS of calibration spheres, the timebase of echo-sounder and a minor effect on the transmission pulse duration. With the rather constant temperature of lake Tanganyika around 24-26°C the acoustic wave speed is likely to be about 1494 ms -1.

5. Fish target strength

A critical factor in any quantitative acoustic survey is knowledge of the fish target strength distribution, preferably by size for each species. In the past, determination of this factor has proven to be difficult, especially for lake species. It is now possible to measure the target strength of individual fish *in-situ* and to obtain target strength distributions from sufficiently low density aggregations. The indication from Chapman (1976) and Mathisen & Rufli (1980) are that at least some of the species of interest are found at night in layers with density low enough for *in-situ* target strength measurement oh be obtained. Some of the morning traces shown in the latter paper also indicate scattered individuals. Positive identification of fish species will still be required by fishing.

Six species of fish make up most of the pelagic ichthyomass (Chapman, 1976); they are:

	mature at (mm)	maximum length **(mm)**
Stolothrissa tanganicae	60-75	90
Liinnothrissa miodon	70-80	175
Luciolates stappersii	88	450
Lates microlepis	620	1000

L. angustifrons	660	900
L. mariae		780

Stolothrissa makes up most of the annual catch in traditional and industrial fisheries (Coulter, 1970). Without specific figures for the target strength of these species it is necessary to use results based on fish of similar morphology and physiology. *Stolothrissa* tanganicae and *Limnothrissa miodon,* being clupeoids, the initial variety of measurement yielding TS data. Note that this is related to a frequency of 38 kHz as no data are available for 120 kHz. It is likely that the true TS at 120 kHz will be slightly higher than 38 kHz values.

This equation has a standard error of 1 dB.

TS = **20** log *1* **-72 dB** where 1 is in cm.

Figure 1 shows the target strength from the caged fish experiments carried out in Lake Tanganyika by Johannesson in 1974 is considerably higher (slightly more than 6 dB) than the results calculated from the Foote equation.

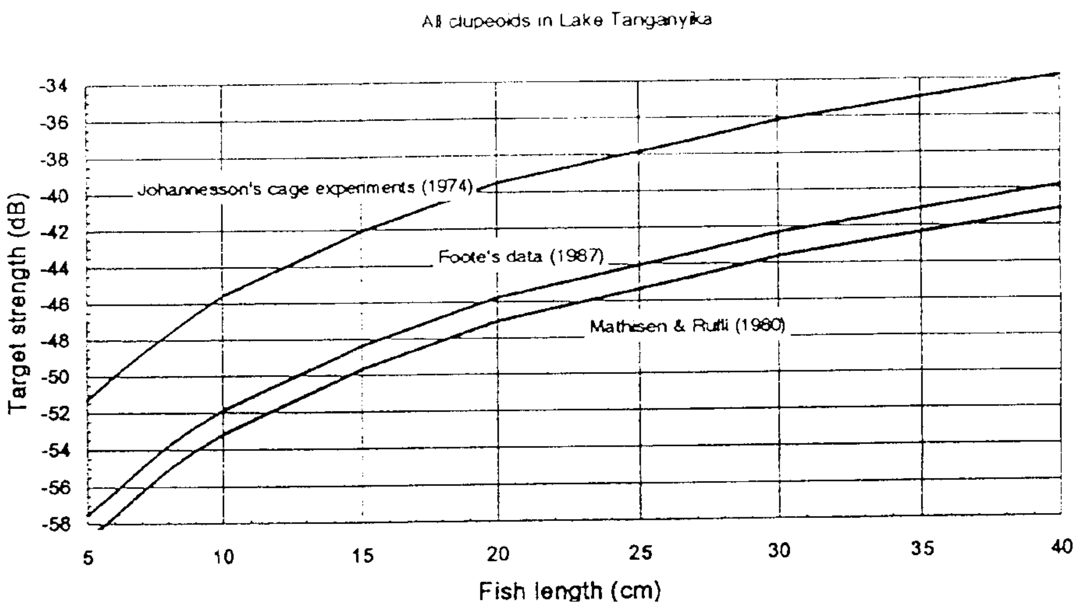

Figure 1

Mathisen & Rufli (1980) chose a value of -57 dB for their 'standard fish' which was a 75 mm long *Stolothrissa.* This TS was partly based on measurements of three-spine sticklebacks and the fact that it was in the range of TS for small clupeids determined by Nakken and Olsen (1977). The figure of -57 dB is 1.3 lower than that obtained from the 1987 Foote equation.

Taking the difference of 6.1 dB between the Foote values and accordingly reducing the 2.8 million tones (1974) gives a result of 0.7 million tonnes. Again, using the Foote target strength values as a reference, the overall results from the 1975 and 1976 surveys would be increased by 1.3 dB leading to figures of 0.63 and 0.91 million tonnes respectively.

Although Mathisen and Rufli consider the difference between Johannesson's and their results to be due to differences between analog and digital integrators, later controlled tests (not in the lake) showed that no significant difference could be measured between instrument of these two types. It is more likely that the results obtained in the survey by Johannesson differ because of the high value of TS obtained from the caged fish experiments.

6. Fish target strength measurements

There are two methods currently in use with commercial echosounding systems which are potentially suitable for the Lake Tanganyika project.

6.1 Dual-beam - this is comprised of a transducer with two concentric beams, one wide and the other narrow. Transmission is on the narrow beam, the main lobe of which covers the region of unit response of the wide beam. Signals received from each beam is processed independently, the ratio of signal strength for a given fish target being related to the angle of that fish to the beam centre. Because the whole beam patterns are involved in the signal collection process the dual-beam method is vulnerable to noise.

6.2 Split-beam - the transducer is split into four quadrants. Processing takes the four sets of signals combined in pairs, the phase differences between port and starboard half-beams and the fore and aft half-beams allow compensation for the position of the fish in the beam and a target strength to be obtained. This methods allows a high degree of angular resolution in target determination hence some immunity to noise. Because of the mode of operation, the transducer for this system requires rather more detailed calibration than that of single-beam echo-sounder (MacLennan and Svellingen, 1989).

7. Choice of Frequency

The points to be considered are:

7.1 Signal level - it is necessary to ensure that sufficient power can be transmitted at the selected frequency in order to provide an adequate signal-to-noise ratio at the receiver from the smallest individual fish at the greatest depth of interest to the survey. During planktonic blooms there will be a considerable increase in absorption which will attenuate the signals but at present this cannot be quantified. The higher the frequency , the greater will be the signals from plankton relative to fish.

7.2 Range discrimination - the higher the frequency the shorter is the pulse that can be generated. It is important to use the shortest possible pulse in order to ensure the best discrimination between loosely aggregated fish, especially when such small species are involved. This, in conjunction with a narrow beam, will give the optimum condition for in-situ measurement of fish target strength.

7.3 Noise level - the higher the frequency the less susceptible is the system to underwater radiated noise from the survey vessel. Experience has shown that some vessels with small, high-speed propellers and high pressure hydraulic systems can generate very high levels of noise over a wide frequency range and that these levels remain significant at 120 kHz and above. The situation is usually at its worst when vessels are working in shallow water where there is a firm bottom. This is because the radiated noise is then reflected from the bottom to the transducer.

In Lake Tanganyika, all indications are that, although the fish may be distributed down to a relatively shallow depth, the bottom will be deep, hence the reflected noise from the latter should be low. Direct pick-up of the propeller noise on transducer side lobes is possible but with a modern design of transducer and careful placement in the hull this can normally be made negligible. If a towed body is used for the transducer great care must be taken that the backward sensitivity is sufficiently low. High pressure hydraulics can usually be decoupled so as to reduce high frequency noise to an acceptable level. Particular care must be taken that underwater discharges from cooling pumps etc. do not generate excessive noise.

8. Signal processing

It is most important that a wide dynamic range of signals can be detected by the echo-sounder so that a balanced picture emerges of the relative abundance of small to large species. A stable echo-integrator is then needed to accurately process the signals to give biomass per unit distance or time.

It is important to avoid the use analogue tape recording in quantitative surveys because of the limited dynamic range , susceptibility to overload, difficulty of accuracy calibration and the lack of long term stability of the magnetic medium. Digital recording is free from these problems, other then susceptibility to magnetic fields and long term stability.

9. Presentation of data

It is necessary to have a dynamic display of the signals which has differentiation of acoustic intensity by colour. Also to use a paper recording system for the echo-sounding signals in conjunction with the echo-integrator to ensure that data can be checked for features of fish distribution, density aggregations, or unusual factors such as noise, whether continuous or intermittent. Use of colour is important to give a realistic picture of fish size and densities and near seabed concentrations.

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11. Report and Recommendations

The previous sections of this document were prepared as general background information prior to an assessment being made of the two commercially available acoustic survey systems.

During a short term consultancy (13-21 September 1992) discussions of the Simrad EY500 hardware, software and data processing were followed by a short survey using the equipment, including a small towed transducer, on Olso fjord, during which recordings were made. Post-processing was carried out ashore. Next the UK/SADCC project in Malawi was visited for demonstration of the BioSonics system when the vessel was on passage from Senga Bay to Monkey Bay. The performance, software and data processing were examined and details discussed with the project manager, Dr. A. Menz.

11.1 BioSonics

The survey vessel **USIPA** of the UK/SADCC project complete with its BioSonics equipment comprises most of the items given in the BioSonics quotation to FAO, dated 3 August 1992. Exceptions are that: (a) USIPA uses towed transducers only, one of which can be lowered to 50 m; and **(b)** a 3-level gray-scale recorder is used.

USIPA acoustics equipment is mounted in a standard rack about 1.75 m high; the computer and oscilloscope are separate. The ESP model 221/281 echo-integrator and dual beam processor is a single circuit board that plugs into on of the computer full length slots. Units in the rack are:

Model 102 echo-sounder; dual beam operation
" thermal chart recorder
" 171 tape recorder interface
Sony D.A.T. recorder

A towing fin and transducer (7° x 18°) are stored on deck.

As installed in the USIPA a considerable amount of space is required but the volume could be reduced by dispensing with a rack and mounting all essential items separately including an external flat-bed colour recorder. The whole system would then comprise:

Model 102 echo-sounder; dual beam operation
" 171 tape recorder interface
Sony D.A.T. recorder (micro Walkman)
Computer; Note full length slot for the ESP board is essential.

Flat-bed colour printer/recorder.

The other item is the transducer: although a hull mounted unit should be mounted on the new vessel for

Lake Tanganyika the following general points are emphasised:

- the moderate to poor weather conditions often found on the lake will produce short, sharp, seas and the transducer beam will gyrate with the motion of the vessel;
- because the beam is very narrow there will be poor correlation from transmission pulse to echo within transmissions and from ping-to-ping along a track, thereby distorting data;
- gyration of the beam will adversely affect or bias the collection of TS data. In addition there will be loss of signals due to aeration;
- use of a transducer will significantly reduce the effects listed above; and
- under some circumstances, when investigation of the fish size distribution is necessary, in relatively dense aggregations, it may be feasible to accomplish this only by placing a transducer fairly close to the fish, i.e. by using a towed transducer on a longer cable. This will help to ensure that echoes from individuals are properly discriminated for accurate TS measurements.

For this reason a towed transducer with about 50 to 80 m of cable is recommended (for phase II of the project) although it would normally be used on a much shorter length. This transducer would be in addition to the hull mounted unit (see the specification).

The UK/SADCC project does not consider the 2 feet BioSonics towed fin' to be satisfactory because of its tendency to become unstable. This may be due to the very electrical heavy cable whose drag tend to dominate the system; It is possible that a smaller cable could be used if the pre-amplifiers were not fitted in the fin (BioSonics recognise this as a possibility) . The project has two transducers one on a short cable, the other on a long one for lowering to the depth. of the two, the longer has been used little because the fish have generally been well dispersed during surveys to date and the additional effort involved in its use has not been justified.

One point of note is that if the transducer cable is damaged and must be shortened, or a length inserted, the whole system must be returned to Seattle for repair and recalibration.

BioSonics have not provided a quotation for a towed transducer. Endeco are probably the best manufacturers of towed bodies for the present purpose.

11.1.1 General remarks

Apart from the towed fin the UK/SADCC project is very pleased with the performance of the Biosonics equipment. one failure has occurred for which an engineer was sent from Seattle (replacement of the ESP board, which cost $32,000).

The 12 Echo-sounder is very versatile, being designed for use in many different situations but in some respect it is an 'overkill' because only one set of features can be used in a given situation. For example it is capable of operating at a number of frequencies but only one is possible for a given transducer. the design is about eight years old and the important factor of Time Varied Gain is implemented by hardware. This means that there are several complex electronic circuits with the potential for failure and whose limits of precision and stability are marginal for modern survey requirements.

Use has been made of the Digital Audio Tape-recorder (DAT) for backing up data on board the vessel and to allow processing to be done ashore without the rest of the equipment. The miniature cassettes have a capacity of ninety minutes, or two hours. capacity is an vital factor to consider for any storage medium where so much data are being collected. Typical of current use is about 1.44M floppy disks for 10 days survey (-12 hours per day).

During past surveys the water column has been divided into 25 layers on the echo-sounder but this is thought to be excessive and the number will probably be reduced.

Dual beam recording for TS distribution generates vast amount of data so is only used at selected times, not in parallel with normal survey operation.

Documentation is very good for all of the BioSonics equipment.

Apricots computers have been used and have proved to be robust under the severe conditions of shock and vibration often encountered in poor weather conditions.

The CRUNCH processing program supplied by BioSonics is said to be too crude for most purposes, the TS program is most used.

BioSonics offer several optional items under the heading BioMap. This system allows the presentation of a survey route together with a current echo-gram and a kind of fish density plot. For the reason given below it is recommended that consideration of mapping systems should be deferred until the project has established its survey methods and data processing. Only then will it be possible to assess the real requirements and to determine if the implementation of mapping is feasible or worthwhile.

By the nature of acoustic survey (as with many other data) collection systems it is essential to verify results against a paper record and to correct where noise or false bottom echoes have intruded, before attempting to process data. This matter of verification is one reason why caution should be observed if mapping systems are to be considered. With different form of data going into the system in parallel it could be difficult and time consuming to do corrections if indeed it is possible at all.

11.2 Simrad

Simrad have just developed a new portable scientific echosounder to be known as the EY500; its component parts are

Transceiver
Notebook computer Flat-bed colour recorder Towed split-beam transducer (towed body may only be suitable for near surface).

A 70 kHz version was available for the purpose of demonstration and it was fitted into a tiny cabin cruiser for a short survey in Olso fjord. Several fish schools, thought to be small herring, were detected, their signals were recorded and later processed. The notebook computer used on the vessel was a Toshiba 4400 SLX with liquid crystal colour display.

A continuous paper record in colour was taken. This is annotated automatically at regular intervals with the following information:

Frequency Time Date S_a values for preselected layers.

Numbers of fish by TS class and layer.

In principle this information alone is sufficient for many survey purposes. Data were transferred to 1.44 Mb files.

11.2.1 Data post-processing

This could have been undertaken on the vessel but instead, the latest version of the EP500 (HADAS) system was installed on a desktop computer in a Simrad office.

The EP500 processes the data file created by the EY500 in several steps, first by compressing and converting to a new format. No information is lost by the compression so the quality and precision of data are retained. In normal operation 600 consecutive pings are displayed at one time but a global picture of a transect can be obtained by a feature which displays only one of each N consecutive pings (N is selected according to the total number of pings in the transect).

Log results can be displayed with the echo-gram with lines defining the corresponding area.

Three modes of analysis are possible from the echo size distribution and three from the echo-integrator results.

Size distribution

a) in a pelagic layer: User selects part of the echogram, boxes it in and analyses the echoes contained in the box. Results appear as numbers and a TS Histogram.

b) in surface layer (10 max.)

c) in bottom layers (10 max.)

Echo-integration

d) in a Pelagic layer: Again, are sizeable box can be laced in the area of interest on the echogram after which an analysis is made.

e) in surface layers (10 max.)

f) in bottom layers (10 max.)

Results are displayed in numbers and in graphical form. The size distributions can be either per hectare or nautical mile.

The program permits TS distributions to be extracted from single beam signals (in the absence of a split-beam transducer). Data from layers can be converted into ASCII form and transferred into a spreadsheet such as Excel or Lotus 1-2-3 where suitable formulae can be applied to give the required output format.

11.2.2 Future development

Simrad have an extensive development programme underway in conjunction with the Chr. Michelsen Institute (Bergen) and the Institute of Marine Research (Bergen) . This is based on the BI500 - Map Preparation Module, the principles of which were explained and a partial demonstration was given. This is a substantial piece of work which should ultimately lead to a very advanced and powerful form of mapping covering many forms of multiple data presentation on geographic bases. It includes a comprehensive map of the world, including the lakes, all to an accuracy of 10 km.

The BI500 is effectively a fisheries management tool which takes data from the EK500 (or EY500) if required. It requires considerable back-up in terms of expert staff and in the availability of additional data, e.g. the proposition of fish species, etc.

Although a simplified version of this system will be ready by the end of 1992 it is recommended that any consideration of its application to the Lake Tanganyika project is deferred until after the project is well underway and has established its survey methods and data processing.

11.3 Final considerations

11.3.1 Frequency of operation

Under Section 6, three factors were listed as being important to the efficient operation of the equipment, the conclusion being that a high frequency was most likely to give optimum performance.

The other important factor is that all previous quantitative measurements on Lake Tanganyika have used a frequency of 120 kHz and the current surveys on Lake Malawi use the same frequency. Thus there is a very strong argument on scientific grounds for continuing with this frequency because true target strengths of the many species found in the lake are not known and there may be variation with frequency between species. To change to another frequency at this stage would prevent comparisons with earlier data and, perhaps most important, between the two lakes in geographically close proximity.

It remains therefore to ensure that the chosen echo-sounder can transmit sufficient power to detect target strengths of -55 to -60 dB at depths down to 200 m. The Technical Specification (Separate document takes this requirement into account by quoting a minimum source level. Although the Simrad leaflet states only 60 W for 120 kHz the company has said that it will supply 200 W at no extra cost and this will give sufficient source level with the 70x 70 transducer.

11.4 Comments on the Equipment Criteria

11.4.1 Reliable estimates of numbers and biomass of pelagic species.

Both the BioSonics and Simrad equipment's have the potential to meet this criterion. However, if the relative precision of the two is considered it is clear that the Simrad benefits from the incorporation of more recent technology, particularly in the important matter of time varied gain stability and precision.

11.4.2 Ease of use

This is a subjective matter and as the systems have different forms of construction configuration and control, some description is given below-

BioSonics

Installation: The units are bulky and are interconnected by means of various cables so a permanent fitting is to be preferred in the interests of reliability and logistics.

Control: Rotary and thumbwheel controls are used for the transceiver but input by menu is used to the computer. Some of the controls on the transceiver are not used at all and those that are, can mostly be set once and do not need to be changed. It is not possible to guard against unauthorised movement of these controls and a strict protocol must be set and observed to prevent the surveys results from being distorted through incorrect settings. According to BioSonics the absorption control should be set to the freshwater position which gives zero correction to the signals. Clearly this is incorrect (see Section 4.1) now that greater precision is possible in the calibration of survey equipment. However, it should be feasible to use the marine position once the factor for absorption is obtained.

Calibration: Standard targets are available but practical difficulties arise in locating these targets in the beam, particularly when the transducer is hull-mounted. The Biosonics system uses the ESP display to estimate when the target is in the centre of the beam (from the size of the signal) and an oscilloscope to measure the actual signal amplitude. Target strength can then be calculated and compared with system parameters to check that calibration is correct. BioSonics offer tungsten carbide standard targets. At 120 kHz the sphere has a diameter of 33 mm which at a sound speed of 1495 ms-1 has a TS of -40.6 dB.A limitation of the BioSonics calibration is would be required. Reports have been made that this type of shiny sphere sometimes attracts fish, so preventing calibration.

Simrad

Installation: The units are smell and few cables are needed between them. It is quite feasible to remove the complete system from the vessel after each period of use for security purposes, or to make use of it in checking data ashore.

Control : All control is via menu´s accessed through the notebook computer keyboard. Parameters that have been set can be displayed at any time and if necessary, changed. Any such changes are automatically compensated for by the operating system.

Calibration: There is the same practical difficulty in adjusting the target under the vessel but in this system it is aided by a circle on the display representing a cross-section of the beam/ cross-wires are shown intersecting with the centre of the circle and the echo appears as a dot. It is then a simple matter to adjust the target and internal calibration data are set, or reset. Simrad supply copper spheres for calibration and at 120 kHz the sphere is 23 mm dia. with a TS of -40.9 dB for a 0.1 ms pulse. The copper tarnishes quickly and is unlikely to attract fish.

11.4.3 Training facilities

At extra cost both companies offer on-site and factory training.

11.4.4 Interfacing with other instruments

The BioSonics equipment has 2 serial ports and the Simrad 1 serial and one parallel port. Interfacing a GPS unit for positioning is no problem for either company.

Caution is advised when considering interfacing other instruments because of the necessity of verifying and correcting acoustic data: if it is inter-mixed with other data there could be difficulty in making corrections.

It will be necessary to use several instruments in the survey work but it will be very important to ensure that sufficiently sensitive items are purchased. For example many of the composite instruments produced for marine work are quite unsuited for measuring levels found in lakes.

BioSonics have listed an instrument to measure salinity, whereas low levels of conductivity must be determined. It is also doubtful if the quoted instrument contains a fluorometer of sufficient sensitivity. Dissolved oxygen is notoriously difficult to measure **in-situ.**

It is inadvisable to consider interfacing this type of instrument or combining its measurements with the echo-survey data in the foreseeable future.

11.4.5 Reliability under field conditions

Biosonics

It has been shown in the Lake Malawi project that the BioSonics equipment has performed reliably during the 7 months of operation apart from the breakdown of one circuit board. Construction in robust but care is needed with the cables.

Simrad

Development has recently been completed so there is no reliability. The construction of the transceiver/processor is very robust: a "ruggedised" notebook computer is desirable, despite the extra cost.

11.4.6 Data Processing to be undertaken at project HO in Burundi

The method of data collection for both the BioSonics and Simrad systems will allow processing ashore.

Biosonics

The EY500 system is small and compact, it can be readily removed from the vessel and post-processing carried out ashore. For security reasons the notebook computer would be taken ashore by preference. If the equipment has to remain on-board, another computer may be needed for processing depending on the accumulation of data.

Conclusion

When the UK/SADCC Lake Malawi project was planned in 1987 the Biosonics equipment was the most suitable then available. Since then no development has taken place and it is essentially the same equipment that is being offered today.

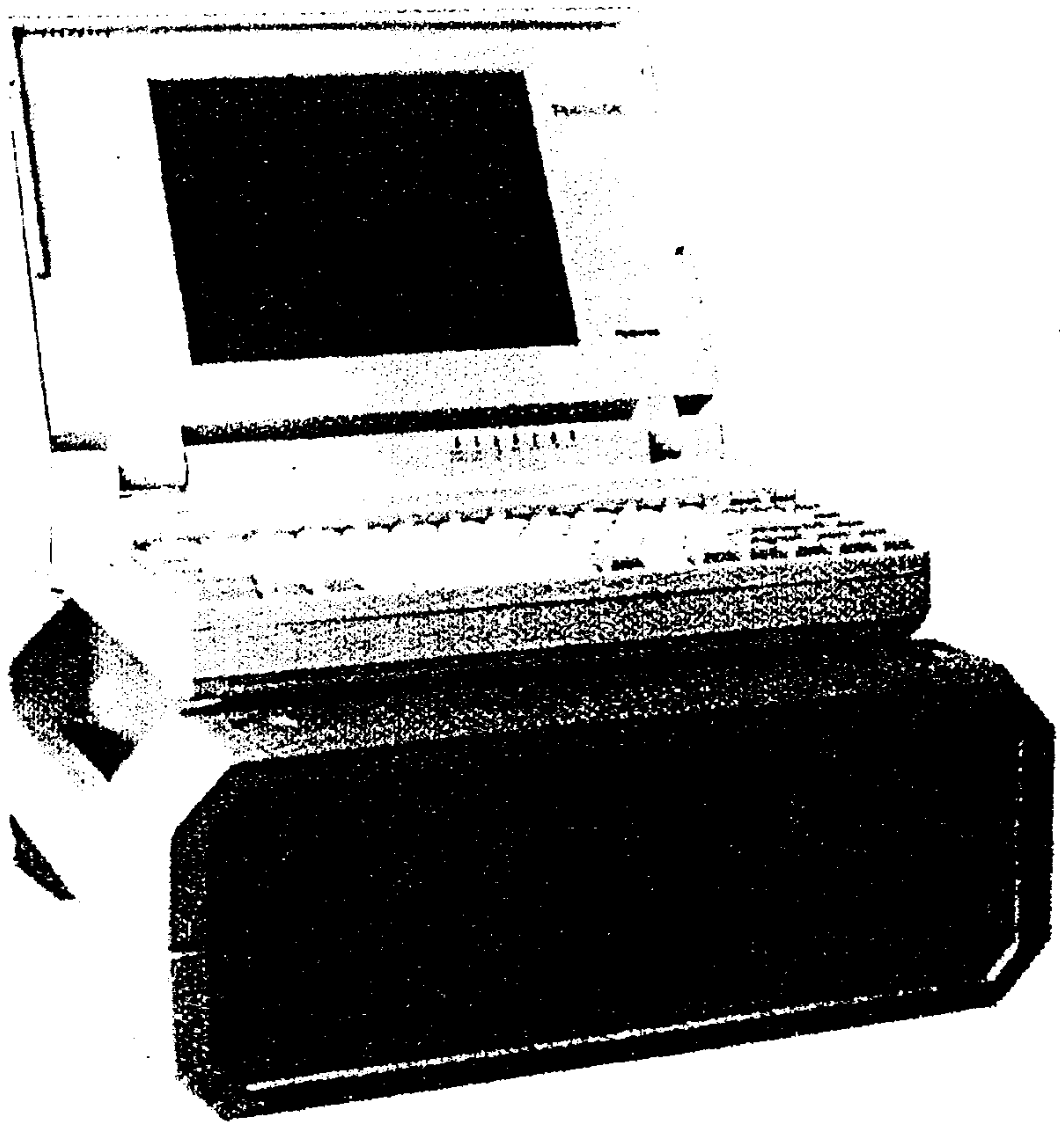
However, the Simrad EY500 plus the EP500 is a modern, technically advanced but simple to use system for which additional information is given in Appendix 1. It is capable of greater precision than the BioSonics units, for which information and prices are already in the possession of FAO. Comparing the current price lists the Simrad equipment is about $30, 000 cheaper than the nearest comparable set of units from BioSonics (adding the same cost for a HP Paintjet printer (z $3800 including spares) into the BioSonics quotation as given in the Simrad list, BioSonics have just confirmed a price of z $3000 for the printer, excluding spares.

If surveys are to start soon using a small chartered vessel the portability of the Simrad makes it the only practical option but all the evidence points to a purchase of the Simrad EY500 and EP500 data processor for the Lake Tanganyika project (necessary items underlined in red on the price list in Appendix 1).

Simrad leaflets and Price List

SIMRAD EY 500 Portable Scientific Sounder System

September 1992



New portable scientific echo sounder system, designed for applications where portability and low power consumption is a must.

Typical applications:

Fish stock assessment in lake8, rivers and shallow waters
Fish behaviour studies (the split-beam method allows tracking and
counting of individual fish) Monitoring biomass from buoys
Pollution monitoring
Dam surveillance systems

10 CALIBRATION SPHERES

Simrad supply copper spheres as reference targets for the calibration of scientific sounders. Copper is selected because it is a metal which can be made electrolytically with high purity. The spheres are machined to the perfect spherical form with great accuracy. The sphere diameter is different for each frequency in order to obtain a target strength with **minimum** dependence of temperature. A curve showing the varations of the taract strength follows each sphere.

Order no.	**Frequency**	**Target Strength**
SRT-07-@516	12kHz*	TS -40.4 dB
SRT-07.)512	18 kHz	TS -34.4 dB
SRT-073513	27 kHz	TS -37.9 dB
SRT-073514	38 kHz	TS -33.6 dB
SRT-073516	49kHz*	TS -36.4 dB
SRT-073516	50kHz*	TS -36.2 dB
SRT-073517	70 kHz	TS -39.2 dB
SRT-088098	120 kHz	TS -40.4 dB
SRT-073519	200 kHz	TS -45.1 dB

* Same sphere

Delivered with suspension

Recommended retail price per sphere...................3.800,-

Transducer Foil Mounting Description

GENERAL

If a fixed installation of an echo sounder transducer is not possible, a towed operation is made possible by means of the SIMRAD Transducer Foil unit. This foil is adapted to transducer types 70-24-FP and 74AP.

Mounting of transducer 70-24-FP (11^{o} beam width)

Refer exploded view overleaf.

- Thread the transducer cable through the holes in the aluminium wedge (3) and the lexan foil (1). Insert the rear steel bolt (5a) with mounting accessories (5b) and (5c).
- Tighten the attached nut (5d) carefully.
- Place five of the bronze weights (7) on top of the foil nose. Insert the front steel bolt (5a) with mounting accessories (5b) and (5c).
- Tighten the attached nut (5d) carefully.
- Complete the transducer mounting by inserting the two cork plugs (5e). These cork plugs prevent interference from water turbulance when the transducer is towed through the water and should be levelled with the transducer surface.
- Press the towing hook (2) together and position it in hole number three in the nylon bars (10), as illustrated.
- Fasten the transducer cable to the foil by means of the cable clamp (6), and seize it to the towing hook with tape.
- Make slack in the transducer cable on both sides of the cable clamp before tightening the clamp and seizing the cable. The towing hook should move freely from an upright position to a horizontal position, as well as being able to be adjusted to any of the eleven holes in the nylon bars.

The towing rope, which is not supplied by the manufacturer, should be seized to the transducer cable. Allow approximately 30 cm. between each seizing.

The transducer foil is adjusted for a surveying speed of up to 8 knots with this transducer type, when the towing hook is placed in hole number three. Higher surveying speeds are not recommended.

However, if a higher surveying speed is necessary or desired, additional weights should be applied and/or the towing hook position should be adjusted one to two holes backwards. The combination of the adjustable towing hook and more (or fewer) weights enables the operator to achieve a stable movement of the foil through the water and thereby to receive a distinct echo sounder diagram or recording.

During operation the transducer foil should be towed at a depth of at least one metre, and it should furthermore be kept away from the wake of the vessel.

Mounting of transducer 74AP (22^{o} beam width)

Refer exploded view overleaf.

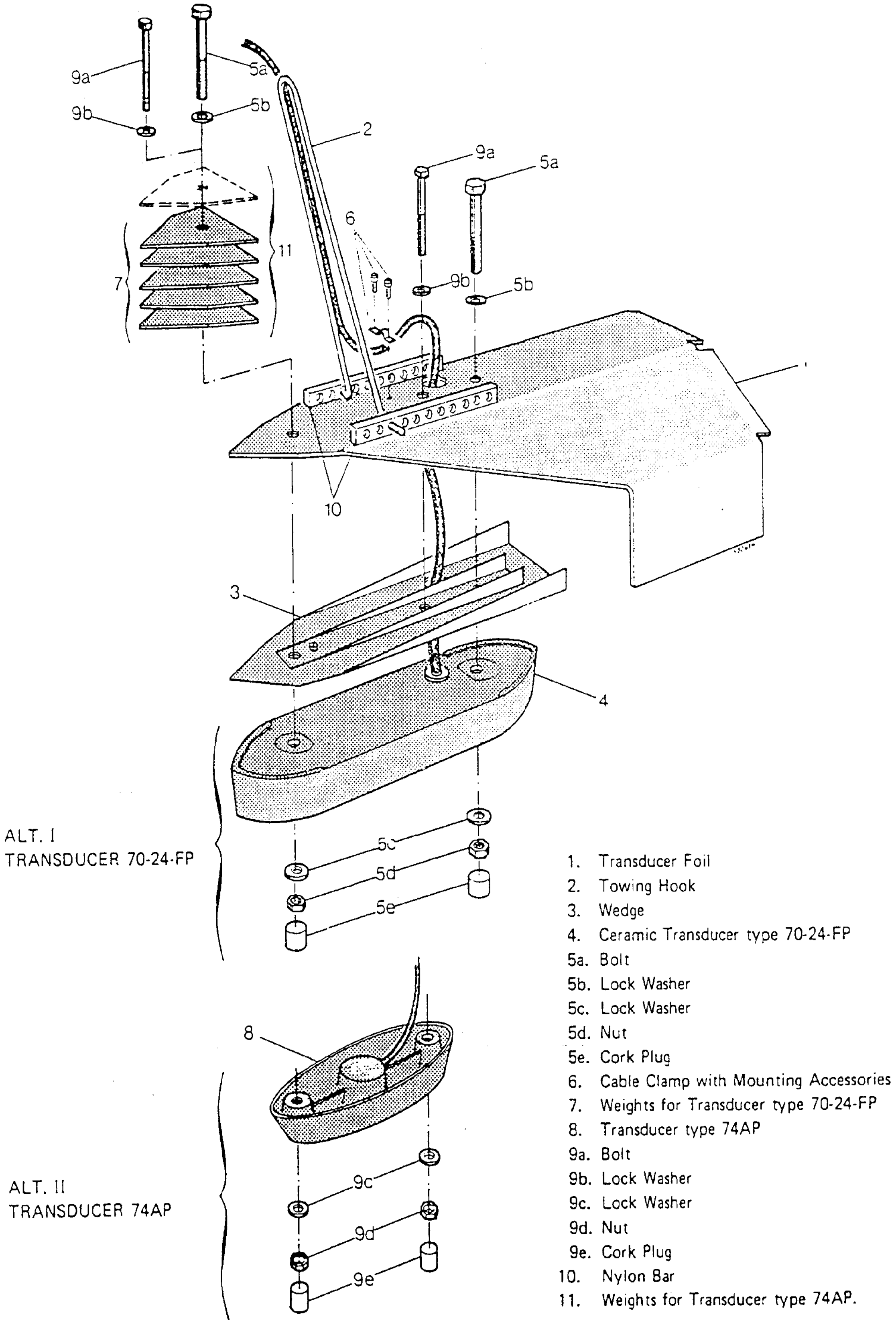
- Thread the transducer cable through the holes in the aluminium wedge (3) and the lexan foil (1). Insert the rear steel bolt (9a) with mounting accessories (9b) and (9c).
- Tighten the nut (9d) carefully.
- Place six of the bronze weights (11) on top of the foil nose. Insert the front steel bolt (9a) with mounting accessories (9b) and (9c)
- Tighten the attached nut (9d) carefully.
- Complete the transducer mounting by inserting the two cork plugs (9e). These cork plugs prevent interference from water turbulance when the transducer is towed through the water and should be levelled with the transducer surface.
- Press the towing hook (2) together and position it in hole number eight in the nylon bar (10).
- Fasten the transducer cable to the foil by means of the cable clamp (6), and seize it to the towing hook with tape.
- Make slack in the transducer cable on both sides of the cable clamp before tightening the clamp and seizing the cable. The towing hook should move freely from an upright position to a horizontal position, as well as being able to be adjusted to any of the eleven holes in the nylon bars.

The towing rope, which is not supplied by the manufacturer, should be seized to the transducer cable. Allow approximately 30 cm. between each seizing.

The transducer foil is adjusted for a surveying speed of up to 7 knots with this transducer type, when the towing hook is placed in hole number eight. Higher surveying speeds are not recommended.

However, if a higher surveying speed is necessary or desired, additional weights should be applied and/or the towing hook position should be adjusted one to two holes backwards. The combination of the adjustable towing hook and more (or fewer) weights enables the operator to achieve a stable movement of the foil through the water and thereby to receive a distinct echo sounder diagram or recording.

During operation the transducer foil should be towed at a depth of at least one metre, and it should furthermore be kept away from the wake of the vessel.



Transducer Foil, exploded view.

EY500 Portable Scientific Sounder System.

Prices:

Transceiver Unit, Split Beam	NOK 220.000,=

10-40V DC or 110-220V AC with:

- -Power Supply
- -PC Interface Board
- -Digital Interface Board
- -Transceiver Board, Split Beam
- -Software for split beam target strength measurement, echo integration and file management

Transceiver Unit, Single Beam	NOK 110.000,=

10-40V DC or 110-220V AC with:

- -Power Supply
- -PC Interface Board
- -Digital Interface Board
- -Transceiver Board, Single Beam
- -Software for echo integration and file management

Transducers.

ES120F, split beam, 10xl0 degr.	NOK 41.000,=
ES120-7F, split beam, 7x7 degr.	NOK 45.000,=
120-25-F, single beam, l0x10 degr.	NOK 26.000,=
Colour Printer HP Paintjet	NOK 17.000,=
Accessories for HP Paintjet incl. -Fan fold paper 4x250 sheets -1 ea black ink cartridge -1 ea 3-colour ink cartridge	NOK 4.500,=
Towing foil, max. 6 knots	NOK 9.900,=
EP500 Post Processing System[rev. HADAS)	NOK 55-000,=
PC, Toshiba *4400*	NOK 60.000,=

Appendix 2

Equipment Specification

Specification for Fisheries Acoustic Survey Equipment

Frequency: 120 kHz (nominal)

Transmitter
- sourcelevel:not < 216 dB rel 1µPa @ 1m
- pulse duration: 0.1 to 1 ms (in three or more selectable steps)
- pulse repetition rate: variable to minimum of 0.6 pps

Receiver
- bandwidth (matched to pulse duration)
- dynamic range > 145 dB
- Time Varied Gain (operating to 350 m depth)
- $40 \log R + 2 \alpha R$
- $20 \log R + 2 \alpha R$
- precision (better than ± 0.5 dB with stability of ± 0.25 dB)
- absorption correction (α), variable in 0.1 dB steps to maximum of 20 dB/km

Displays
- dynamic multi-colour display of signals and depth intervals (layers)
- chart recorder-, minimum of 12 colours related to signal intensity: also to print depth intervals, time, date and S_a and TS distributions by layer when required

Transducer/s
For **phase I** of the project (small charter vessel)

- towed body capable of operation at 8 knot speed fitted with a dual (7° x 18°) or split beam (7° x 7°) transducer and 10 - 15 m of electrical/towing cable (depending on vessel)
- depth capability (100 m)

For **phase II** (new project vessel available)

- one off: dual (7° x 18°) or split beam (7° x 7°) hull mounted transducer
- m of extension cable for towing transducer at depth (>3 knots)

***In-situ* target strength measurements**

- Twenty or more target strength classes In 1 dB, or max. of 2 dB steps, by numbers of fish, by depth interval.

Calibration

- ease of calibration: precision expected to be ± 0.35 dB or better

standard target of TS ≈ -40 dB complete with calibration data for 0.1 to 1 ms pulse transmissions

Data collection/processing/storage

- integration of signals in a minimum of 10 depth intervals, surface or bottom locked
- S_a values and TS distributions for each depth interval
- suitable software for processing high density signals and single fish TS
- or 486 EBM compatible computer with math co-processor
- - 120 N4b hard disk on computer
- - 8 Mb RAM
- floppy disk drive for 1.44 Mb minimum capacity disks
- serial port to input navigation data
- (phase II of project) tape recorder or tape streamer

Power

- capable of operating on 20-40V DC and/or l10-220V AC

- uninterruptable power supply unit (UPS) for all units except recorder

- line noise filter

Construction

- transceiver and computer units to be rugged
- continuous operation in ambient temperature of up to 40°C