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A Summary of Hydroacoustic Research in the Newfoundland Region

by

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TABLE OF CONTENTS

Abstract

A historical outline of the development of fisheries hydroacoustic research in the Newfoundland Region is presented, including a detailed description of the technical aspects of the hydroacoustic data acquisition system developed by the Region. The software developed and used for data reduction and analysis is described. In addition, the biological and statistical aspects of the hydroacoustic surveys conducted by the Region are presented. Future hydroacoustic research by the Region is also discussed.

Résumé

On présente un bref historique de la recherche en hydro-acoustique appliquée aux pêches dans la Région de Terre-Neuve et, entre autres choses, on décrit en détails les aspects techniques du système de mesure qu'on y emploie. On parle également du logiciel mis au point pour le traitement et l'analyse des données ainsi que des aspects biologiques et statistiques des études d'hydro-acoustique qu'on a effectuées dans la Région. Enfin, on examine dans quelles voies les services de la Région se proposent de poursuivre la recherche en hydro-acoustique.

1.0 Introduction

The Newfoundland Region has had an active interest in hydroacoustics since the early 1970's. This paper presents a historical outline of the development of fisheries hydroacoustic research in the Newfoundland Region as well as a detailed description of the technical aspects of the hydroacoustic system used and the biological and statistical aspects of the hydroacoustic surveys conducted. Future hydroacoustic research is also discussed.

2.0 Historical Background

Fisheries Research Branch, Newfoundland Region was part of the Tri-Lab Acoustic Group formed during the early 1970's. The group provided the recommendation to fund the development of the Computerized Echo Integration System (CEIS) which was a modified version of the Computerized Echo Counting System (CECS) developed by the Marine Ecology Lab (MEL). The system used the same hardware (a Honeywell 316 minicomputer and a Simrad EK50 echo sounder), but executed different software. The CECS ran a data acquisition and an echo counting program while the CEIS ran a data acquisition and an echo integration program. The Newfoundland Region was primarily interested in the CEIS for assessment of offshore capelin stocks. Several field trials of the CEIS were conducted prior to 1977 during capelin biomass surveys. Operation and maintenance support for the system was provided by Dick Dowd of MEL. Dr. Jim Carscadden and Edward Sandeman of the Newfoundland Region and Ross Shotton of MEL provided the scientific input. The person years provided through extended jurisdiction allowed the Newfoundland Region to hire a capelin biologist (Dan Miller) and an electronic technologist (Chris Stevens) to work primarily on fisheries hydroacoustic projects.

During 1977 and 1978 the Newfoundland Region conducted a number of capelin surveys using the CEIS and found that the computer hardware and software imposed serious limitations on the acquisition and analysis of data. The program contained mistakes and omissions that caused the real time density estimates to be inaccurate; therefore, it was necessary to correct the density estimates by hand. This required many extra hours of technical work. Also, the computer did not record raw data on the digital tape drive. Instead, all samples were squared, summed and averaged over layers of several meters thickness before being recorded. Therefore, the data on the tapes could not be adjusted to compensate for errors in the time varied gain (TVG) function of the echo sounder receiver. As a result, the estimates obtained by integrating the data recorded on the tapes contained unknown errors. In addition, the computer was not very well supported by its manufacturer and many hardware failures were experienced which resulted in lost survey vessel time.

To overcome these problems, the Newfoundland Region decided to develop a hydroacoustic data acquisition system (HYDAS). The system was designed to use the original Simrad EK50 echo sounder, a customized microcomputer, a printing terminal and a 9-track tape formatter and transport. Work was started in the fall of 1979 and the system was successfully field tested in June of 1981. The computer was designed to acquire raw data from the echo sounder at a 15 KHz rate and then store all digitized samples that exceeded an operator defined amplitude threshold on the magnetic tape. Additional software was developed for the computer which allowed it to acquire the data needed to determine the errors in the TVG function of the echo sounder.

During the winter of 1982-83, the hardware and software of the computer were modified to make the unit compatible with the new Simrad EK400 echo sounder which had been acquired by the Newfoundland Region. The modified system has been in use since April 1983.

The original software for the analysis of data acquired by HYDAS was developed by D. Miller in 1981. The program was written in Fortran for execution on an HP1000 computer. It was designed to correct the raw data for TVG errors and then perform echo integration over time intervals specified by the operator. The integrated results output at the end of the specified time intervals were written to disk files. The data contained in the disk files were then reduced to indices of abundance for each geographical area surveyed.

The program has been vastly improved by D. Miller during the past four years. The lastest version is written in Fortran 77 and allows the operator to easily select options and change parameters. It should be noted that this program was developed specifically for capelin and references data analysis to the transducer, not the ocean floor. Additional software was developed by B. Atkinson to allow data analysis to be referenced to the ocean floor.

The majority of the hydroacoustic field work conducted by the Newfoundland Region has been associated with capelin abundance surveys. For the past seven years, three capelin surveys per year have been carried out (approximately 65 days vessel time per year). The abundance estimates produced from the data acquired on these surveys have been presented via CAFSAC and NAFO. Because of the problems (outlined above) with the CEIS, it is now the opinion of the capelin biologists that abundance estimates derived using that system were unreliable. Much more confidence has been placed on biomass estimates derived using HYDAS and the HP-1000 analysis software. In fact, since 1981, acoustic estimates have played an important role in formulating advice for management.

Since 1981, estimates of variance associated with survey design have been calculated for each biomass estimate. These estimates are based on analysis conducted by B. Nakashima of the Newfoundland Region using a clustering sampling model.

The Newfoundland Region has been conducting a study in the Gulf of St. Lawrence since 1981, to determine the feasibility of estimating redfish abundance using hydroacoustic techniques. Major technical problems have been encountered due to the relatively small size of the fish (10 to 40 cm) and the depth at which they are found (200-450 meters). Significant progress was realized however during the 1984 redfish hydroacoustic cruise. The success was attributed to the acquisition of a heavy duty winch and an improved towing cable that allowed the towed body to be deployed to a depth of 150 meters. Further improvements will have to be made to the towing system in order to survey the deep water areas (up to 700 meters) of the Newfoundland Region frequented by redfish.

During 1983 and 1984, hydroacoustic surveys were conducted to assist in the study of the migration of northern cod from offshore banks to coastal areas of northeastern Newfoundland. It is anticipated that the hydroacoustic data will be used to describe the vertical, horizontal and density distribution of the cod in relation to geographic and temperature boundaries.

A complete list of the publications resulting from the hydroacoustic work conducted by the personnel of the Fisheries Research Branch, Newfoundland Region is given in Appendix A.

3.0 Technical Aspects

3.1 HYDAS General Description

The Newfoundland Region has developed the Hydroacoustic Data Acquisition System (HYDAS) for the collection of fisheries hydroacoustic data.

The equipment configuration for HYDAS is shown in Fig. 1. The system transducer is an Ametek/Straza model SP187LT which has a single, six degree conical beam pattern and can be deployed to a depth of 200 m. The transducer is configured to look downward from its mounting position in a Fathom Oceanology 1.5 meter "Tow Fish" underwater towed vehicle (towed body). The towed body, with the transducer mounted in it, weighs approximately 130 kg in air. It is attached to a double armored, oceanographic towing cable via a Braincon Type 275 Tow Termination. The towing cable is stored on a Hydrauuk Brattvaag winch, model UMG164, that is welded to the deck of the vessel. The towed body and cable are deployed and retrieved by a Hiab articulating crane, model 1165AW, which is fitted with two InterOceans Systems snatch block pulleys, model 712-16. The electrical conductors of the towing cable are connected to the rotors of a slip ring assembly which is mounted to the axis of the winch drum. A deck cable, housed in conduit, provides the electrical connections between the stators of the slip ring assembly and the transceiver of the echo sounder which is located in the laboratory of the survey vessel.

The echo sounder is a 49 KHz, Simrad EK400 system comprised of two AR800 dry paper Recorder Units, a CF100 video Color Display, a MV101 Control Unit, an EK400 Test Panel, a Simrad three channel RMS Detector Unit, and a five kilowatt, TR101 Transceiver Unit modified to provide transmit pulse lengths of 0.3 msec, 0.6 msec, and 1.2 msec. with respective receiver bandwidths of 6.7 KHz, 3.3 KHz, and 1.7 KHz. Transducer Position #1 of the TR101 is connected to a hull mounted Simrad 49-26-E transducer which is used for test purposes and as a monitor. Transducer Position #2 of the TR101 is connected to the survey transducer housed in the towed body. Transducer Position #4 is connected to the Tx Output of the Test Panel. A fixed attenuator providing approximately 49.5 dB of attenuation is connected between the Test Input and the Tx Output of the Test Panel. The signals needed to check the TR101 receiver gain, bandwidth, TVG functions, etc. are injected via the Test Input and Transducer Position #4. The necessary test signals are supplied by a Tektronix FG 5010 Function Generator and are monitored by a Tektronix DM 5010 Digital Multimeter.

The calibrated 20 log R and 40 log R signals produced by the TR101 receiver are routed via the MV101 Control Unit and the EK400 Test Panel to separate channels of the Simrad RMS Detector Unit. If necessary, fixed gain amplifiers can be used to step up the signals before they are sent to the detector channels. The demodulated signals from the Detector Unit are sent to the Color Display, the oscilloscope monitor (Tektronix 7D20 Programmable Digitizer module housed in a Tektronix R7704 Oscilloscope) and to the HYDAS computer.

The Trigger and Bottom pulse outputs of the MV101 Control Unit are wired to the EK400 Test Panel. These control signals are sent from the Test Panel to the Color Display and to the oscilloscope monitor. Trigger and Bottom control pulses are sent to the HYDAS computer on a multi-conductor cable connected to the General Access Connector (J106) of the Control Unit. The position of the Tape/Normal and the Meter/Fathom switches of the Control Unit are also sent to the computer via this cable. In addition, the cable is used to send the signal from the Event Marker switch, which is located on the front panel of the HYDAS computer, to the Control Unit (signal Log marker I).

The HYDAS computer is interfaced to the Tektronix Model 4025 video terminal via a RS-232 serial link. The computer transfers data to the Pertec model FT 8640-98DF-45 magnetic tape Transport and Formatter via a parallel interface.

An unfaired towing cable approximately 800 m long is generally used for cod and redfish work. When the maximum amount of cable is deployed (750 m) and the survey vessel speed is maintained at six knots, the towed body will be approximately 150 m below the surface. A towing cable fitted with soft fairing has been used in attempts to increase the towed body depth for a given length of towing cable. No significant improvement in towing depth was realized but handling problems were experienced. Only part of the cable was faired and the level wind system for the winch could not be adjusted to compensate for the two cable diameters. In addition, the fairing caught in the pulleys and was torn from the cable. No attempt has been made to implement cable with hard fairing due to the high cost of this type of fairing and the winch needed to store it.

A 200 m towing cable is used for capelin surveys. For this work an unfaired cable is desirable so that the towed body may be positioned as far behind the survey vessel and as close to the surface as possible. This procedure allows the maximum amount of water column to be examined by the downward looking transducer with the minimum amount of interference from vessel and propeller noise. Generally capelin surveys are conducted at ten knots and the towed body is positioned between 5 and 20 m below the surface depending on weather conditions. The depth of the towed body must be increased during rough weather to reduce the acoustic noise level.

3.2 HYDAS Computer Structure

The HYDAS microcomputer is housed in a Tei Inc. chassis, model RM-22. The chassis contains a high quality, constant voltage transformer power supply and an actively terminated, 22-slot mother board. The circuitry of the computer is contained on nine S-100 cards. Six of these cards were developed in-house by the Electronics Development and Maintenance Section of the Fisheries Research Branch, Newfoundland Region. The remaining three cards were purchased from commercial suppliers.

A block diagram of the computer is shown in Fig. 2. A description of the function of each card follows:

Card Name	Description
Cromemco Central Processing Unit, Model ZPU	Contains the Z80A microprocessor that serves as the Master Processing Unit (MPU) for the the computer.
Industrial Micro System, 32K static random access memory (RAM), model 370.	Provides the first part of the data storage area for the MPU.
Industrial Mirco System, 16 K static RAM, model 510.	Provides the second part of the data storage area for the MPU.
EPROM and Serial Interface.	Developed in-house - contains three Intel electrically programmable read-only-memory (EPROM) integrated circuits which store the program and default parameters used by the MPU. The card also contains the RS-232 serial interface between the MPU and the system video terminal.
Pertec Interface.	Developed in-house - allows the MPU to read the status of and send commands and data to the Pertec magnetic tape transport and formatter. Data and commands are transferred in bit parallel, byte serial format.
Clock.	Developed in-house - functions as an independent microcomputer with its own Z80A microprocessor, RAM, program stored in EPROM and interface to the S-100 bus. Commands and data are received from the MPU and status information and data are sent to the MPU via the interface and the S-100 bus. The card keeps the time in hours, minutes, seconds and milliseconds and the date in days, months and years. Note that 1900 must be added to the years value. Presently the card is being modified to include an interface to the navigation system of the vessel so that navigational data may also be written to magnetic tape.
Sample Controller Cards, model SCC-401, SSC-402, and SCC-403.	Developed in-house - the three cards form an intelligent subsystem that functions as the interface between the Simrad EK400 echo sounder and the MPU. The cards control and perform the analog to digital conversion of the calibrated output signal from the Simrad

Detector Unit. They compare the amplitude of the digitized samples to the operator defined threshold level (THRS) and notify the MPU if samples equal or exceed the threshold level and should be save in the data buffer. They also track the water depth and monitor the position of the Tape/Normal and the Meter/Fathom switches of the echo sounder control unit.

3.3 HYDAS Computer Operation

When the computer is powered up and after it has completed a data collection sequence (RUN), the computer prompts the operator for all the information required to start a new RUN. This information is maintained in a RAM area of memory called the Parameter Table and it is copied to magnetic tape at the start of a RUN as a separate record called the Parameter Record. If the operator changes any parameters during a RUN, an updated copy of the Parameter Table is written to magnetic tape as a Parameter Record. The Parameter Table and the Parameter Record contain the following information:

Parameter Name	Default Value	Units	Description
SHIP	GADUS ATLANTICA	N/A	Vessel used for survey - up to 24 alphanumeric characters can be entered.
TRIP #	100	N/A	Sequential vessel trip number - up to 6 alphanumeric characters can be entered.
INTV[1]	10	Minutes	Interval summary period - the interval of time the computer waits during a RUN before displaying a summary of the data it has acquired. The interval period can be set from one to ten minutes.
RSDB	-86.0	dB	Acoustic system receive sensitivity - measured during calibration.
SLDB	123.5	dB	Acoustic system source level - measured during calibration.
EMDB[1]	0	dB	Additional gain or attenuation that the operator can select (i.e. the additional amplifier located before the Detector Unit or the internal attenuator settings of the EK400).

PLDB	-35.2	dB	10 log of transmit pulse length.
DOFF[1]	5	meters	Depth offset - at the start of each ping, the depth offset value is added to the water depth value that was measured for the previous ping to set a new Maximum Sampling Depth (MSD). If the echo sounder fails to detect the ocean floor by the time sampling has reached the MSD, the computer suspends sampling for the present ping. DOFF can be set from one to twenty meters.
DTFS[1]	5	meters	Depth to first sample - the depth below the transducer at which the computer will start sampling. DTFS can be set from 5 to 200 meters.
THRS[1]	50	millivolts	Amplitude threshold - digitized echoes with amplitudes equal to or greater than the THRS value are saved and recorded on the magnetic tape. THRS can be set to one of the following millivolt values: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 250.
TAPE #	0	N/A	Sequential magnetic tape number - up to 6 alphanumeric characters can be entered.
RUN #	1	N/A	Sequential run number - each data collection sequence is given a unique name or number - up to 6 alphanumeric characters can be entered.
TRAN	Ametek/ Straza SP-187- LT-11	N/A	Name and model number of transducer mounted in the towed body - up to 30 alphanumeric characters can be entered.

A [1] at the end of a parameter name means that its value can be change while a RUN is in progress.

The program allows the operator to enter text on the system terminal and have this information written to the magnetic tape as a Comment Record. The maximum size of a Comment Record is six lines with eighty characters per line. The operator can enter text for the Comment Records at any time during a RUN.

The program executes the following commands:

Command Name	Description
START	Begin a data collection sequence (RUN).
STOP[1]	End a RUN.
COMM[1]	Allow the operator to enter text via the system terminal and write this information to magnetic tape as a Comment Record.
LIST[1]	Display the system parameters and their values.
STEP	Display each system parameter with its value and allow the operator to change the value.
MARK	Write a filemark on the magnetic tape and rewind the tape.
DATE	Display the date and allow the operator to change it.
TIME	Display the time and allow the operator to change it.
MAP	Execute the TVG data acquisition function which acquires the data needed to determine the errors in the TVG amplifiers of the echo sounder receiver.

A [1] at the end of a command name means that it can be executed while a RUN is in progress.

The program can write up to six record types to magnetic tape when executing a data collection sequence (RUN). All HYDAS records are written at 800 BPI in NRZI format. In addition, all record types have the same record header format. The header is composed of the following 7 words (16 bits) recorded in unsigned binary:

Word #	Description
Word 0	Record Sequence Number - incremented by one for each record on the tape.
Word 1	Record Type - a different number is used to define each record type.
Word 2	Record length in words.
Word 3	Time - high byte is hours, low byte is minutes.
Word 4	Time - high byte is second, low byte is least significant byte of milliseconds word.
Word 5	Time - high byte is most significant byte of milliseconds word, low byte is days.
Word 6	Time - high byte is months, low byte is years minus 1900.

Note that the time words describe the time at which the record was written to magnetic tape.

A description of each record type follows:

Record Type	Description
100 Hex	Start of RUN Record - an ASCII record containing the RUN number and the HYDAS program name and version number. The record length is 37 words. The Start of RUN Record is the first record written to tape during a data collection sequence.
200 Hex	Parameter Record - an ASCII record containing the complete Parameter Table (see the description of the Parameter Table and the Parameter Record). The record length is 144 words. The Parameter Record

is the second record written to tape during a data collection sequence. It is also written to tape each time a parameter is changed during a RUN.

300 Hex — Comment Record - an ASCII record containing the text entered by the operator via the system terminal. The record length can be up to 263 words. Comment Records can be written to magnetic tape at any time during a RUN.

400 Hex — End of Run Record - an ASCII record containing the RUN number and the HYDAS program name and version number. The record length is 36 words. The End of Run Record is the last record written to tape during a data collection sequence.

500 Hex — Lost Lock Record - an ASCII record containing a message to inform the operator that the HYDAS program and the echo sounder were unable to correctly detect the ocean floor echo and that sampling has been suspended. This record is written after the number of attempts (pings) specified by the DOFF parameter have been completed. The record length is 37 words. Note that an End of Run Record (type 400 hex) always follows a Lost Lock Record.

1000 Hex — Sample Data Record - an unsigned binary record containing one or more sub records called Ping Records. Each Ping Record contains the digitized samples acquired during one echo sounder transmit-receive period (ping). At the end of each ping, the program determines the amount of sample buffer space required to store that Ping Record and the total amount of sample buffer space used to store Ping Records since the last Sample Data Record was written to magnetic tape. If more than 1 K words (2048 bytes) of sample buffer space has been used, the contents of the buffer are written to magnetic tape as the Sample Data Record.

A typical Sample Data Record is described below:

Word #	Description
Words 0 through Word 6	Standard HYDAS record header with word 1 having the value 1000 hex.
Words 7 through Word 12	Standard Ping Record Header - made up of the six words defined below:
Word 7	Ping Record sequence number - incremented by one for each ping of a RUN.
Word 8	Time - high byte is hours, low byte is minutes.
Word 9	Time - high byte is seconds, low byte is least significant byte of milliseconds word.
Word 10	Time - high byte is most significant byte of milliseconds word, low byte is days.
Word 11	Time - high byte is months, low byte is years minus 1900. Note that the time words of the Ping Record header describe the time at which the echo sounder transmission occurred.
Word 12	The number of samples collected during the ping - each sample is recorded as a depth (first word) and an amplitude (second word). The total number of words in a ping record is equal to, two times the number of samples plus eight (i.e. total words = 2 (word 12) + 8).
Word 13 through Word K-2	If the Ping Record contains any samples they will be placed here.
Word 13	Depth of the first sample in the Ping Record - an unsigned binary value - to convert it to meters, multiply it by 0.05. Note that all HYDAS data sampling is done at 15 KHz. Therefore if it is assumed that the speed of sound in seawater is 1500

	meters per second, sampling will be carried out at 5 centimeter intervals.
Word 14	Amplitude of the first sample in the Ping Record - an unsigned binary value - to convert it to RMS volts, multiply it by 0.0025.
Word 15	Depth of the second sample in the Ping Record.
Word 16	Amplitude of the second sample in the Ping Record.
Word 17	Depth of the third sample in the Ping Record.
Word 18	Amplitude of the third sample in the Ping Record.
Word K-3	Depth of the last sample in the Ping Record.
Word K-2	Amplitude of the last sample in the Ping Record.
Word K-1	The maximum water depth measured for the ping - the depth at which sampling was stopped.
Word K	Ping Record status word for the first ping - definition: 0000 Hex - the program found no errors. 0001 Hex - the echo sounder was unable to identify the ocean floor echo and the program terminated sampling when the Maximum Sampling Depth (MSD) defined by the Depth Offset (DOFF) parameter was reached. Word K is the last word of the first Ping Record. Other Ping Records will follow if the sample buffer did not contain more than 1 K of words.
Words K+1 through K+6	Ping Record Header for second ping.
Words K+7	Depth of the first sample of the second ping.
Words K+8	Amplitude of the first sample of the second ping.

Words K+n	Ping Record status word for the second ping. Word K+n will be the last word of the Sample Data Record if the sample buffer contained more than 1 K words. If not, at least one additional Ping Record will be included in the Sample Data Record.

Note that Sample Data Records can contain a maximum of 12 K words.

3.4 HYDAS Computer TVG Data Acquisition Function

The HYDAS program has a function called MAP which acquires the data needed to determine the errors in the TVG amplifiers of the echo sounder receiver. When the MAP function is selected, the operator is instructed, by message on the system terminal, on the procedure to follow to initialize the necessary equipment. The operator must inhibit the transmitter of the EK400 echo sounder, select Transducer Position #4 and inject a 49 KHz signal with a constant amplitude of approximately - 20 dB reference 1 volt RMS. The exact amplitude of the input signal used by the operator is entered via the system terminal and written to tape as a Comment Record.

Once all the equipment has been initialized, the program will sample for thirty collection sequences and then return control to the operator for further instructions. For each collection sequence, the TVG amplifier is made to ramp through its full depth range. The program samples the output of the Detector Unit at 0.1 meter intervals from 3 meters to 500 meters (4971 samples). Each sample (a depth word and an amplitude word) acquired during a collection sequence is saved in a memory buffer in the computer. At the end of the collection sequence, the contents of the memory buffer are written to magnetic tape.

The MAP function writes records to magnetic tape using the record header format previously described. A description of the record types used by the MAP function follows:

Record Type	Description
100 Hex	Start of Run Record - an ASCII record containing the RUN number and the name and version number of the MAP function. The record length is 37 words. The Start of RUN Record is the first record written to tape by the MAP function.

Note that the term "RUN" is used here to describe the data acquired during 30 collection sequences.

300 Hex	Comment Record - an ASCII record containing the amplitude of the input signal used for this RUN. The record also contains any additional text entered by the operator. The record length can be up to 263 words. The Comment Record will always be the second record written to tape by the MAP function. The operator can also enter text for a Comment Record at the end of a Run.
500 Hex	End of RUN Record - an ASCII record containing the RUN number and the name and version number of the MAP function. The record length is 36 words. The End of RUN Record is the last record written to tape by the MAP function. If the operator entered text for a Comment Record at the end of a collection sequence, the Comment Record will be written just before the End of Run Record.
1010 Hex	Sample Data Record Number One - an unsigned binary record containing the 971 samples collected from 3.0 meters to 100.0 meters. Each sample contains a depth word followed by an amplitude word. The record length is 1949 words.
1020 Hex	Sample Data Record Number Two - an unsigned binary record containing the 1000 samples collected from 100.1 meters to 200.0 meters. The record length is 2007 words.
1030 Hex	Sample Data Record Number Three - an unsigned binary record containing the 1000 samples collected from 200.1 meters to 300.0 meters. The record length is 2007 words.
1040 Hex	Sample Data Record Number Four - an unsigned binary record containing the 1000 samples collected from 300.1 meters to 400.0 meters. The record length is 2007 words.
1050 Hex	Sample Data Record Number Five - an unsigned binary record containing the 1000 samples collected from 400.1 meters to

500.0 meters. The record length is 2007 words.

During the execution of the MAP function, the five data records for each collection sequence are written to tape sequentially. Then the five data records from the next collection sequence are written to tape. This process is repeated until all 30 collection sequences have been completed. Each time the MAP function executes a RUN, a minimum of 153 records are written to tape (154 if a final comment is entered).

3.5 Calibration

The source level and the receive sensitivity of the hydroacoustic system are measured at the start of each survey and during the survey if any critical instrumentation in the system is exchanged or repaired. To perform the measurements, the top of a rigid frame is attached to the towed body and then a hydrophone is positioned at the bottom of the frame, on the acoustic axis of the transducer. The distance from the transducer face to the hydrophone is approximately 3 meters. The hydrophone is one of the two Bruel and Kjaer model 8100 units owned by this Region. The hydrophones are calibrated once per year.

The transmit pulse length, receiver gain and receiver bandwidths of the echo sounder are measured at the start of each survey and during the survey, if any critical instrumentation in the echo sounder is exchanged or repaired. The data needed to check the error in the TVG amplifiers is collected by the MAP function of the computer at the start of each survey and during the survey, if any critical instrumentation in the echo sounder is exchanged or repaired.

3.6 Acoustic Analysis Software

A series of computer programs for estimating acoustic parameters and analyzing acoustic data has been written. All programs are written in FORTRAN 77 and run on an HP/1000 computer system using the RTE-6/VM operating system. A brief description of each of these programs follows.

1) <u>Transducer Beam Pattern Determination</u>: This program calculates the average squared beam pattern factor $\bar{b}^2$ for a transducer by numerically integrating data obtained from the transducer beam pattern using the formula:

$$\bar{b}^2 = \int_0^{\Pi/2} b^2(\Theta) \sin\Theta \, d\Theta$$

This program was contributed at an acoustics course at the Applied Physics Lab, University of Washington.

2) TVG Map: This program compares the TVG output of an EK400 echo sounder to an ideal 20 log R TVG function, provides correction factors by 1 meter depth intervals and estimates the fixed gain of the EK400 sounder (Miller and Stevens 1984).

3) Target Strength Estimation: This program uses a target strength-length regression to provide an estimate of target strength weighted by the length distribution of the target species (obtained by trawl sampling during the acoustic survey).

4) Echo Integration Analysis: This program provides estimates of fish density per square meter of surface area and density per cubic meter by 1 meter depth intervals from HYDAS 9-track data tapes. Density can be expressed as numbers or biomass. Operator specified options include bottom and surface offsets, threshold level, target strength, percent target species, length of analysis interval, time varied gain correction, and fixed system gain. HYDAS collection parameters such as receive sensitivity, source level, etc., are read from parameter records included on the HYDAS data tapes. Data are output to a disc data file for further analysis.

5) Acoustic Survey Statistical Parameter Estimation: This program uses the disc data files output by the echo integration analysis program and provides estimates of mean density, the coefficient of variation, and an indicator of variance heterogeneity (Nakashima 1981).

6) Acoustic Survey Track and Fishing Set Plotting: This program provides a plot of the acoustic survey track and survey blocks along with the location of fishing sets made during the acoustic survey.

3.7 Equipment List

The present equipment used by the Newfoundland Region for hydroacoustic data acquisition consists of:

1) Transducers:

   (a) One Ametek/Straza model SP187LT with 6 degree and 12 degree conical beam patterns.

   (b) One Ametek/Straza model SP187LT with 6 degree and 25 degree conical beam patterns.

2) Towed Bodies:

(a) Three Fathom Oceanology Ltd. 4.5 ft. "Tow Fish" units. Each unit is configured to hold one Ametek/Straza SP187LT transducer for downward looking operation. Each unit, with a transducer mounted in it, weighs approximately 130 kg. in air.

3) Oceanographic Towing Cable:

(a) Three cables, each 200 m long, with four 18 guage electrical conductors. The outside diameter of the cable is 11.5 mm.

(b) One cable, 800 m long, with four 18 guage electrical conductors. The outside diameter of the cable is 11.5 mm.

4) Deployment and Retrieval System for the Towed Body:

(a) Hiab articulating crane, Model 1165AW, with a Hydrauuk Brattvaag winch, model UMG164. The crane and winch are part of the equipment supplied with the charter vessel GADUS ATLANTICA.

5) Slip Ring Assembly:

(a) Two Hydrauuk Brattvaag units. Each has the capacity to handle four electrical conductors.

6) Echo Sounder:

(a) Simrad EK400 Unit With

(i) one MV101 Control Unit
(ii) two TR101, 49 KHz Transceiver Units
(iii) one 49 KHz, 40 log R Receiver Unit
(iv) two AR800 Recorder Units
(v) one CF100 Colour Display
(vi) one EK400 Test Panel
(vii) one Detector Unit, with three channels.

The transmitter and receiver sections of the EK400 have been modified to provide transmit pulse lengths of 0.3 msec, 0.6 msec, and 1.2 msec with respective receiver bandwidths of 6.7 KHz, 3.3 KHz, and 1.7 KHz.

7. Data Acquisition Computer:

   (a) Two HYDAS microcomputers. Each is capable of 15 KHz, single channel data acqusition with resolution to 12 bits.

   (b) One Tektronix 4025 video terminal.

   (c) Two Pertec, 45 inch per second, read after write, 800 BPI (NRZI) and 1600 BPI (PE) tape transports and formatters, model FT8640-980F-45.

8) Calibration, Test and Monitor Equipment:

   (a) Two Bruel and Kjaer Model 8100 hydrophones.

   (b) Tektronix 7704 Oscilloscope with 7D20 Programmable Digitizer Module.

   (c) Tektronix TM 5006 Mainframe with DM5010 Programmable Digital Multimeter and FG5010 Programmable Function Generator.

   (d) Simrad Calibration Sphere, model 819-067176.8.

9) Development Equipment:

   (a) Tektronix 8550 Microprocessor Development Lab with Trigger Trace Analyzer, Z80A Assembler and Emulator.

4.0 Biological Basis for Surveys

4.1 Capelin

Capelin acoustic surveys offshore have been conducted for a number of years. The timing and location of the surveys reflect the biology of capelin and the historical fishery pattern for capelin. In the mid 1970's two capelin surveys were conducted annually, one survey during June on the Southeast Shoal (NAFO Div. 3NO) of the Grand Banks and one during the fall off the northeast coast of Newfoundland and southern Labrador (NAFO Div. 2J3K). These surveys have continued although the June survey has been expanded to cover areas on the central and northern Grand Banks (NAFO Div. 3L). In 1982, a third survey conducted on the Grand Banks (NAFO Div. 3L) during April-May was initiated.

a) Survey in Div. 3L during April-May - Historically an offshore fishery occurred in this area, beginning in approximately mid March. This fishery was largely a midwater trawl Soviet fishery and caught prespawning capelin believed to belong to two stocks. These capelin were beginning a spawning migration to either the beaches along the east coast of Newfoundland (NAFO Div. 3L) or the sandy bottom on the Southeast Shoal (NAFO Div. 3NO) of the Grand Banks. Vessels in this fishery followed the capelin towards the spawning grounds and continued fishing during the spawning season on the Southeast Shoal.

The survey was initiated in 1982 for the following reasons. A survey already conducted in Div. 3L and Div. 3NO during June provided biomass estimates for the spawning stock in Div. 3NO but less reliable estimates for the mature stock in Div. 3L since most of the mature capelin had moved on or near the beaches at the time of the June survey. However, the June survey in Div. 3L did provide an estimate of the immature portion of the stock inhabiting the offshore areas. Thus, the April-May survey was initiated to provide an earlier estimate of mature biomass and an additional estimate of prerecruits. The major disadvantage of this survey appears to be ice which limits the coverage on the Northern Grand Banks.

b) Survey in Div. 3NO during June - Originally this survey covered only the Southeast Shoal (Div. 3NO) but the acquisition of additional ship time has permitted coverage of portions of Div. 3L. As already noted, the Div. 3L portion of the survey provides information on distribution and abundance of immature capelin. The Div. 3NO survey provides biomass estimates of the spawning population which once supported a major fishery.

c) Survey in Div. 2J3K during October - In recent years, this survey has occurred during late September and October, although in some earlier years it occurred in November. During the 1970's a major offshore fishery prosecuted largely by Soviet midwater trawlers occurred in this area. The fishing season was somewhat variable but could last from late August to December with peak catches occurring in October and November. The capelin were actively feeding at this time and most of the capelin taken in the fishery were maturing to spawn the following spring.

As already noted, major offshore capelin fisheries occurred on three major capelin stocks - the Div. 3L stock, the Div. 3NO stock, and the Div. 2J3K capelin stock (see Carscadden and Misra 1980 and Misra and Carscadden 1984 for a discussion of stock discrimination). These fisheries were severely reduced (Div. 2J3K) or eliminated (Div. 3L, 3NO) in the late 1970's as a result of a reduction of capelin stocks and the entry of Canadian fishermen who were able to catch the entire TAC. However, capelin acoustic surveys continued (also conducted by USSR). The surveys in Div. 3L and Div. 2J3K provide estimates of prerecruits. Since these same fish move inshore to spawn and hence, support the inshore fishery for roe capelin, an estimate of these prerecruits offshore is useful in providing management advice.

The spawning stock in Div. 3NO which overlaps the 200-mile limit was severely depleted probably because of fishing during poor recruitment. This fishery was closed in 1979 and has not been reopened because the estimated biomass since the closure has not reached historical (mid 1970's) levels.

4.2 Redfish

Although 24 hour stratified-random bottom trawl surveys have been (and still are) routinely carried out for redfish, the behavior of these fish present a couple of relatively unique problems. Both their distinctly "clumped" distribution and their diel movements (off the bottom at night) result in a very skewed distribution of catches and high variances associated with the estimates of biomass. In addition, the estimates of mean biomass may fluctuate widely from one year to the next.

Since the successful use of hydroacoustics would overcome these problems, investigative studies were initiated by the Newfoundland Region in Hermitage Bay in the mid to late 1970's. Data were collected using the echo counting technique (C.E.C.S.) (Shotton and Dowd MS 1975), maintaining the towed body 20-30m below the surface. These data were never analysed.

In 1980, studies were again initiated by the region to investigate the feasibility of using hydroacoustics to enumerate redfish.

In 1980 the hardware used was the same as that used in the Canadian computerized echo counting system (C.E.C.S.). Miller (1981) has described the modified system (C.E.I.S.) and its use in the Newfoundland Region.

From 1981-1984, the data acquisition system (HYDAS) developed at the Northwest Atlantic Fisheries Centre, St. John's, Newfoundland has been used. Analysis of the data using echo integration is as described by Miller et al. (MS 1982).

Redfish inhabit depths of 150-600+m so no one area could be examined in its entirety unless the maximum depth did not exceed 450 m (unless considerable funds were made available for new equipment). In addition, it was deemed desirable to examine an area where standard trawl surveys were being conducted at approximately the same time. The northern Gulf of St. Lawrence (NAFO Div. 4RS north of 49°00'N and east of 64°00'W, Zones 1 and 2 of Fig. 3) satisfied both of these criteria. The maximum depth is only slightly over 400 m and annual trawl surveys were being conducted throughout the area in July-August. Another advantage of working in this area at depths greater than 140 m was that the main fish species encountered is redfish, with other species only being present in minor amounts. (It should be noted that a possible disadvantage is the presence of shrimp and euphausiids in commercial quantities).

All surveys have been conducted using the GADUS ATLANTICA and can be summarized as follows:

Year	Dates	Comments
1980	Aug. 27-Sept. 8	C.E.I.S. considered unreliable - no estimates.
1981	Aug. 27-Sept. 8	$120X10^3$t acoustic est. vs $128X10^3$from trawl survey
1982	Aug. 27-Sept. 07	Technical difficulties - no estimate
1983	Sept. 02-Sept. 19	Technical difficulties - no estimate
1984	Aug. 02-Aug. 22	Best survey to date technically-analysis ongoing at present

For all of these surveys, the towed body was maintained within 200m of the bottom and the TS used was -33.0dB (Atkinson MS 1982).

It is hoped that with the 1984 survey, our technical difficulties are behind us and we can start to build up a time series of data that will indicate the feasibility of this technique in providing reliable estimates of redfish abundance.

4.3 Cod

During May 12-25, 1983 and May 25-June 13, 1984 combined acoustic and otter trawl surveys were conducted for cod in NAFO Div. 3L. The surveys were designed to determine the behaviour of cod during their annual inshore migration and their reaction to the cold core of the Labrador Current, if the cold water poses a barrier and their strategy for evading or passing through the thermal barrier.

During 1983 about 2700 km were surveyed using the HYDAS system. No concentrations of cod were encountered as the cruise was conducted prior to the main inshore migration.

During 1984 about 3300 km of track were surveyed. Large concentrations of cod were encountered near the coast at the mouth of Bonavista and Trinity bays. This concentration was monitored for about 5 days. The concentrations were in depths of 260-310 m and in water temperatures higher than -0.5°C while the densest concentrations were in temperatures of 1-4°C. These concentrations sometimes extended from the bottom up to 50 m off the bottom but generally always remained where the temperature was higher than -0.5°C (i.e. below the cold core of the Labrador current). Occasionally, individual cod were observed, up to 80 m off bottom and in temperatures as low as -0.8°C.

Two other smaller concentrations at Woolfall Bank and the north cape of the Grand Bank were also monitored but no migrations from these areas were evident.

5.0 Statistical Basis

Survey Design and Variance Estimation

Sources of potential bias associated with density estimates derived from acoustic surveys have been identified elsewhere (eg. Shotton 1979; Taylor and Kieser 1980). However, our ability to measure and account for these errors has lagged behind the technological advances. Variation due to target strength error and species composition are largely unknown but believed to be quite significant. Calibration errors are probably small. In the area of survey design and methods to sample clustered distributions there have been some important advances in error estimation procedures. For fish populations, particularly those which school, survey strategy and variance models must account for non-randomly distributed aggregations (Kimura and Lemberg 1981). As fish distributions tend towards patchiness variances estimated from assuming random distribution tend to underestimate the true sample variance (Shotton 1979). This difference increases with the degree of auto-correlation measured along a survey track (Williamson 1982). More reliable estimates may also be derived from employing a stratification scheme when distribution is observed to be heterogeneous.

A variety of survey tracks have been employed in hydroacoustic fish surveys and their advantages and disadvantages have been extensively discussed (eg. Fiedler 1978; Francis 1984; Kimura and Lemberg 1981; Shotton 1979). Kimura and Lemberg (1981) concluded that at low sampling intensities a systematic zig-zag pattern gave lower confidence intervals than a systematic parallel design. In a recent critique of their results, Francis (1984) reported that the systematic parallel survey resulted in smaller confidence intervals than the zig-zag track if the cross-transects between parallel tracks were not included in the analysis. The capelin acoustic survey utilizes a stratified systematic zig-zag survey design. This design was chosen on the strength of a field test of the two survey types during a capelin survey on the Southeast Shoal in 1980 (Nakashima 1981). From the results which indicated that either pattern would give acceptable confidence intervals (< 20%) and small coefficients of variation (< 10%), we concluded that either design could be employed. Because the zig-zag survey utilized all the data collected along the cruise track and Kimura and Lemberg's (1981) analysis supported a zig-zag pattern at low sampling intensities, we chose the systematic zig-zag design. It was noted that further field tests were required to examine this comparison when population densities would be much higher than found in the 1980 survey.

The clustering sample method of Hansen et al. (1953) is employed to estimate variances and confidence intervals around hydroacoustic estimates of capelin densities (eg. Miller et al. 1982). Details of the model and its application in our surveys are documented in Nakashima (1981). The model better estimates variances than would result from random distribution models because it appears to account for serial correlation effects (Shotton 1979; Taylor and Kieser 1980; Williamson 1982).

Density estimates from capelin surveys are analyzed on the basis of a stratification scheme which takes into account differences in distribution according to size and to depth. Surveys use a block design based upon observations of capelin distribution from earlier surveys. The three capelin surveys usually occur annually at the same time and cover the same areas. Should the distribution change, the stratification scheme can be altered *a posteriori* and reanalyzed.

The methods being employed in our surveys require further field testing and more detailed statistical analysis, especially since these acoustic estimates are now being considered as absolute estimates of stock size. A field study needs to be conducted to test the effect of zig-zag and parallel patterns on density estimates over a range of observed densities. The study conducted in 1980 only compared the two in a low density situation. We also require an analysis of the effect of a systematic versus a randomized survey track on variance estimates from the clustering sample method. Although assumed to be significant, we have yet to document the degree of serial correlation that is observed during capelin surveys. There is a need to determine using a cost-benefit analysis the most efficient and practical survey design to employ for hydroacoustic surveys of capelin, cod, and redfish.

Variances associated with other parameters in hydroacoustic surveys should also be addressed at some time since these errors may be more important than those associated with survey design and sampling. The use of dual-beam echo integration techniques would be one solution to quantify and to greatly reduce the error from empirically-derived target strength measurements.

6.0 Future Work

6.1 Technical Developments

The Newfoundland Region is strongly committed to the development of a dual beam hydroacoustic system capable of surveying the cod and redfish stocks which inhabit many of the deep water (200-700 meters) areas of the Region. To date the Region has committed funds for the purchase of two dual beam transducers. Each unit will have a 6 degree and a 15 degree conical beam pattern and be capable of operating at a maximum depth of 500 meters.

During 1985 and 1986 the Region plans to acquire the equipment needed to complete the dual beam data acquisition system.

6.2 Survey Developments

Inshore pelagic studies will be seeking ways to estimate the biomass of herring and capelin in shallow water (< 80 m). Two approaches are currently being considered. One is a portable, dual-beam echo integration system to be used on small research vessels and long-liners. The other is a method to obtain school size and volume density estimates from sonars.

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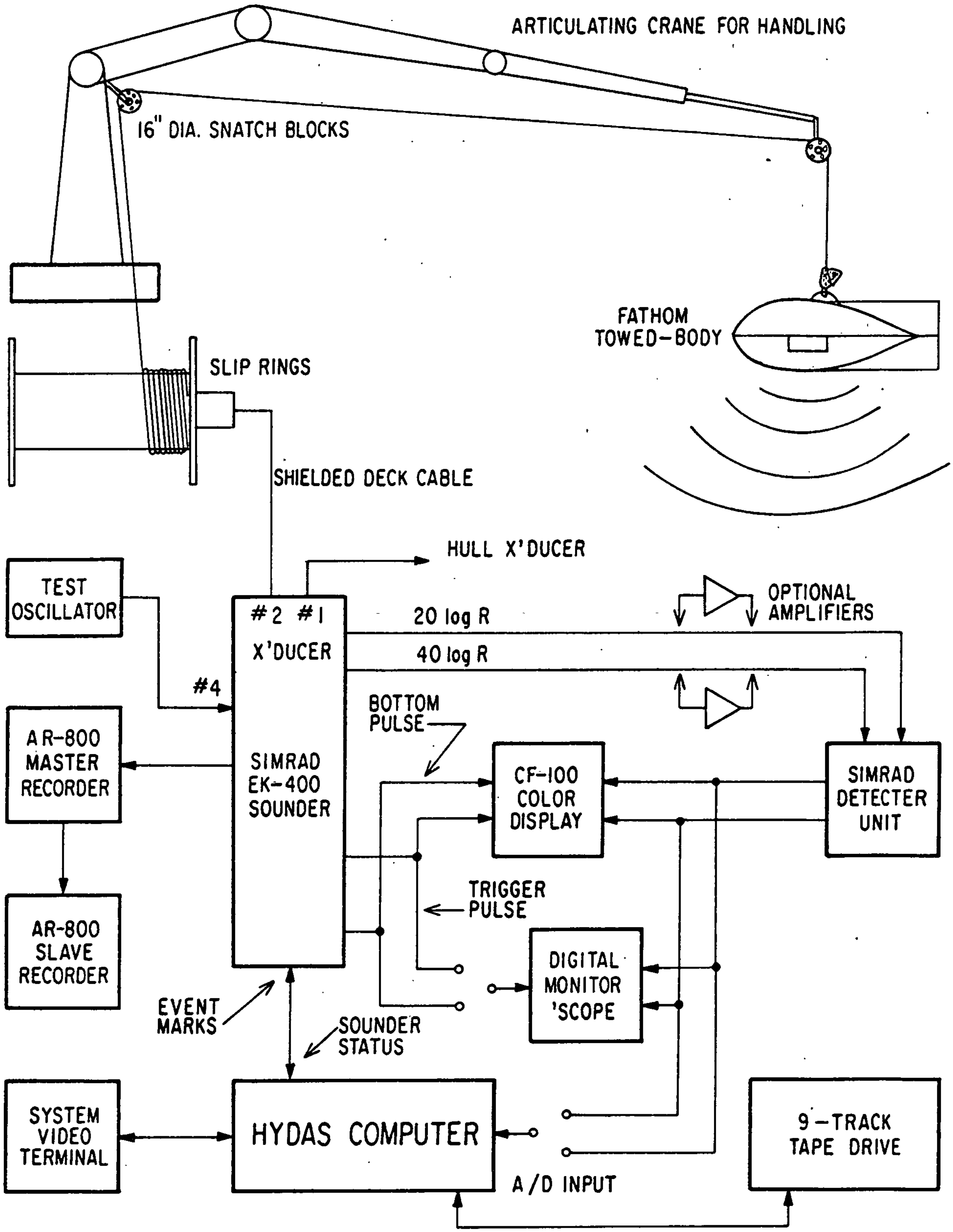

Fig. 1

HYDAS EQUIPMENT CONFIGURATION

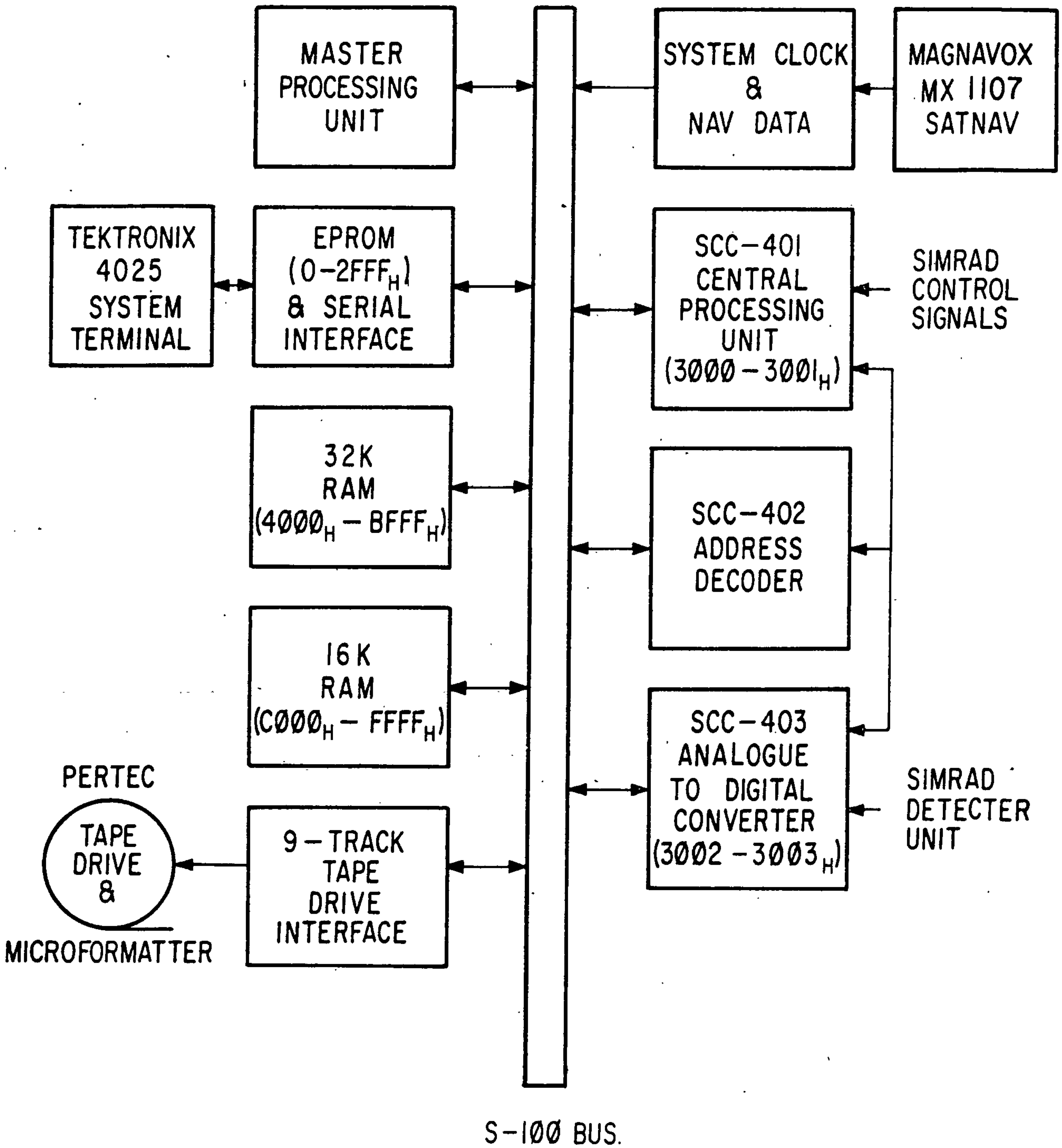

Fig. 2

BLOCK DIAGRAM OF HYDAS COMPUTER

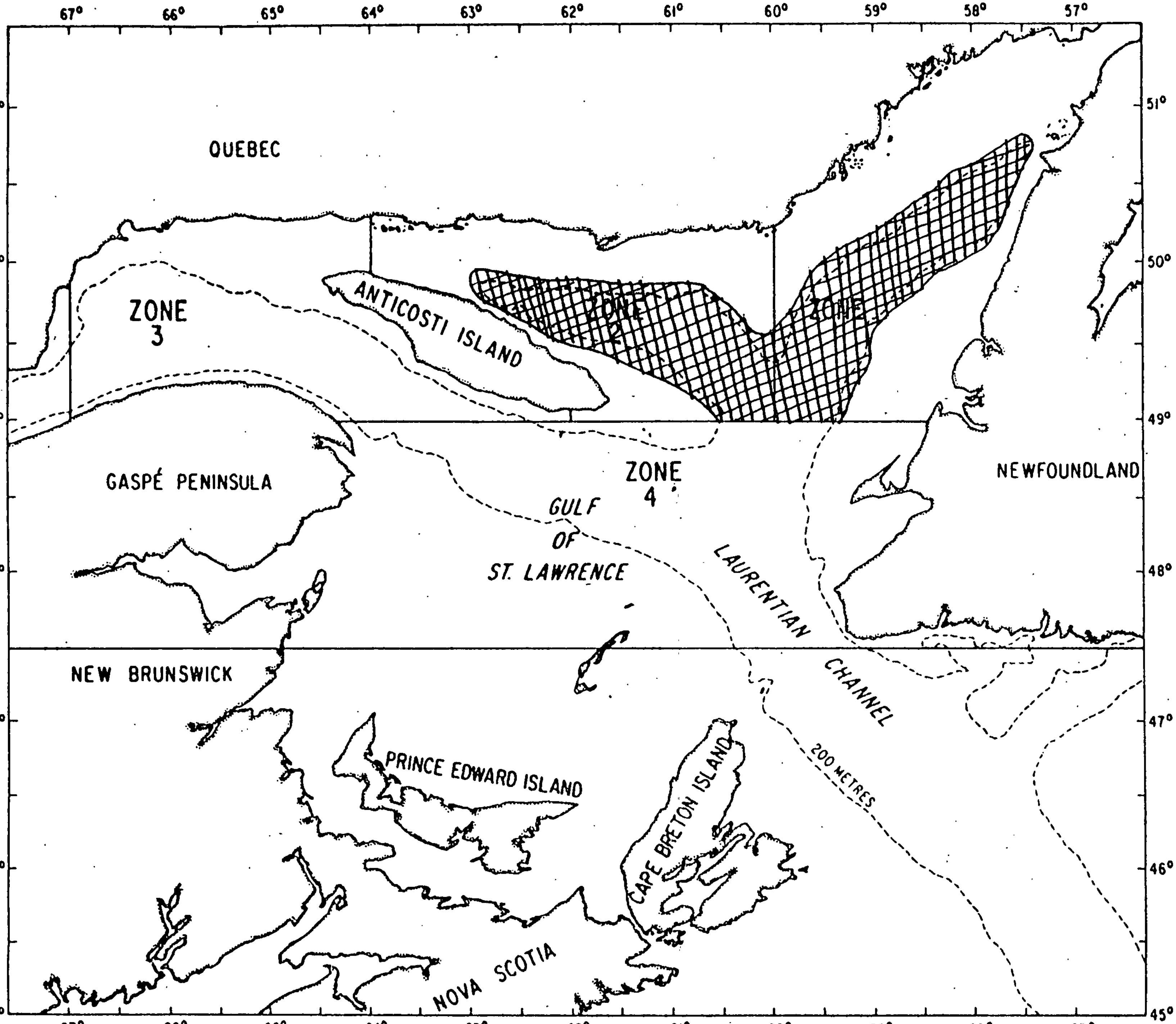

Figure 3. Gulf of St. Lawrence showing area covered during redfish hydroacoustic cruises.

APPENDIX A

Publications related to fisheries hydroacoustic work by personnel from Fisheries Research Branch, Newfoundland Region:

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