The Charles Stark Draper Laboratory

Cambridge, Massachusetts 02139

C-4523

THE APPLICATION OF HYDROACOUSTIC METHODS FOR AQUATIC BIOMASS MEASUREMENTS

PRELIMINARY REPORT OF THE FIRST JOINT USA-USSR-POLAND-GDR EXPERIMENTAL HYDROACOUSTICAL SURVEY IN THE ICNAF CONVENTION AREA 20 MARCH - 13 APRIL 1975

By

A.A. Gan'kov*, J. B. Suomala, Jr.

S.I. Saranchov* and K.A. Smith

*Final review of this report has not been completed.

The Preparation of this Document by The C.S. Draper Laboratory, Inc. was sponsored by the U.S. National Marine Fisheries Service, Contract No. 03-5-043-311 (CSDL Project No. 54062). The publication of this report does not constitute approval by the NMFS of the findings or conclusions herein. It is published only for the exchange and stimulation of ideas.

TABLE OF CONTENTS

SECTION		PAGE
1.0	Preface	1
2.0	Introduction	2
3.0	Description and Review of Experimental Hydroacoustical Survey	3
4.0	Hydroacoustical Equipment Calibration	11
5.0	Received Echo Signal Handling and Processing	24
6.0	Summary	56
7.0	Recommendations for Continuing Activities	59
8.0	Principal Instrumentation	64
9.0	Participating Personnel	65
References		66

LIST OF ABBREVIATIONS

PINRO - POLAR INSTITUTE OF FISHERIES AND OCEANOGRAPHIC RESEARCH, MURMANSK, USSR.

VNIRO - ALL UNION INSTITUTE OF FISHERIES AND OCEANOGRAPHIC RESEARCH, MOSCOW, USSR.

AtlantNIRO - ATLANTIC INSTITUTE OF FISHERIES AND OCEANOGRAPHIC RESEARCH, KALININGRAD, USSR.

NMFS/NEFC - NATIONAL MARINE FISHERIES SERVICE, NORTHEAST FISHERIES CENTER, WOODS HOLE, MA. 02543

CSDL - THE CHARLES STARK DRAPER LABORATORY, CAMBRIDGE, MA. 02139

ICNAF - INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES.

NOAA - NATIONAL OCEANIC AND ATMOSPHERIC AGENCY

1.0 PREFACE

The activities described in this document were made possible through discussions and agreements between the responsible authorities of the Governments of the USA, USSR, Poland, and the GDR.

The conduct and successful completion of the First Joint Hydroacoustical Experimental Survey could not have been accomplished without the competent and dedicated support of the operating personnel of the following vessels: R/V POISK, M.I. Pchelintsev, Master; R/V DELAWARE II, R. Landsvik, Master; R/V WIECZNO, R. Bogdanowicz, Master; and R/V ERNST HAECKEL, R. Stassewski, Master.

2.0 INTRODUCTION

The objectives of the Joint Hydroacoustical Experimental Survey were:

1. To conduct and evaluate the potential usefulness of Hydroacoustical Survey activities employing statistically stratified random sampling survey tracks.

2. To conduct and evaluate the practicability of two hydroacoustical data acquisition research vessels following identical survey tracks, within navigational uncertainties, with a nominal time interval of 12 hours.

3. To conduct and evaluate the practicability of Joint Hydroacoustical Survey activities employing research vessels dedicated to the task of hydroacoustical data acquisition and other research vessels dedicated to the task of the capture of the hydroacoustically detected and recorded targets, for species identification and the measurement of physical characteristics.

4. To conduct and improve, if required, calibration methods and procedures for all hydroacoustical equipment to be employed for aquatic biomass measurements during the survey.

5. To conduct and evaluate standardized in situ cross calibration procedures in order to normalize specific differences in hydroacoustical equipment deployed aboard vessels dedicated to the task of data acquisition.

6. To obtain hydroacoustical signals and other in situ data from aquatic animals (fishes). These data are to be used to evaluate the feasibility and potential usefulness of hydroacoustical methods to obtain pelagic and semi-demersal biomass estimations in the ICNAF convention area.

3.0 DESCRIPTION AND REVIEW OF THE EXPERIMENTAL HYDROACOUSTICAL SURVEY

General

The operation of the survey was planned and conducted so that two vessels, the R/V POISK and the R/V DELAWARE II followed identical stratified random sampling tracks, within navigational uncertainties, with a nominal time separation of 12 hours.

A map of the survey area and track lines followed by the vessels is shown in Figure 3.1. The survey region was partitioned into fifteen strata. Within each stratum, parallel track lines were located according to a random sequence. These track lines, referred to as transects or legs, generally terminated inshore in water depths of 20 meters or at 11 km, (6 nautical miles), from land, and in water depths of 250 meters offshore. The numerical form 13/2, given in this report, refers to Stratum 13, Leg 2.

Both vessels carried identical equipment to acquire and record the received echo signal equipment. In addition to real time recording of the echo signal, vessel attitude sensor data and time was recorded continuously.

The R/V WIECZNO and the R/V ERNST HAECKEL accompanied the R/V POISK and the R/V DELAWARE II and conducted mid-water trawl net operations, along the survey tracks, in areas of hydroacoustically insonified and recorded targets. The animals captured were intended to provide species identification and physical characteristics in order to enhance, if possible, the recorded hydroacoustical data.

The survey was conducted in two phases identified as A and B, respectively. Phase A was conducted in the southwest and southeast parts of Georges Bank, ICNAF area 5Ze, from 21 to 25 March 1975. This phase was to provide a short duration operation to allow participating elements to become familiar with the operating procedures

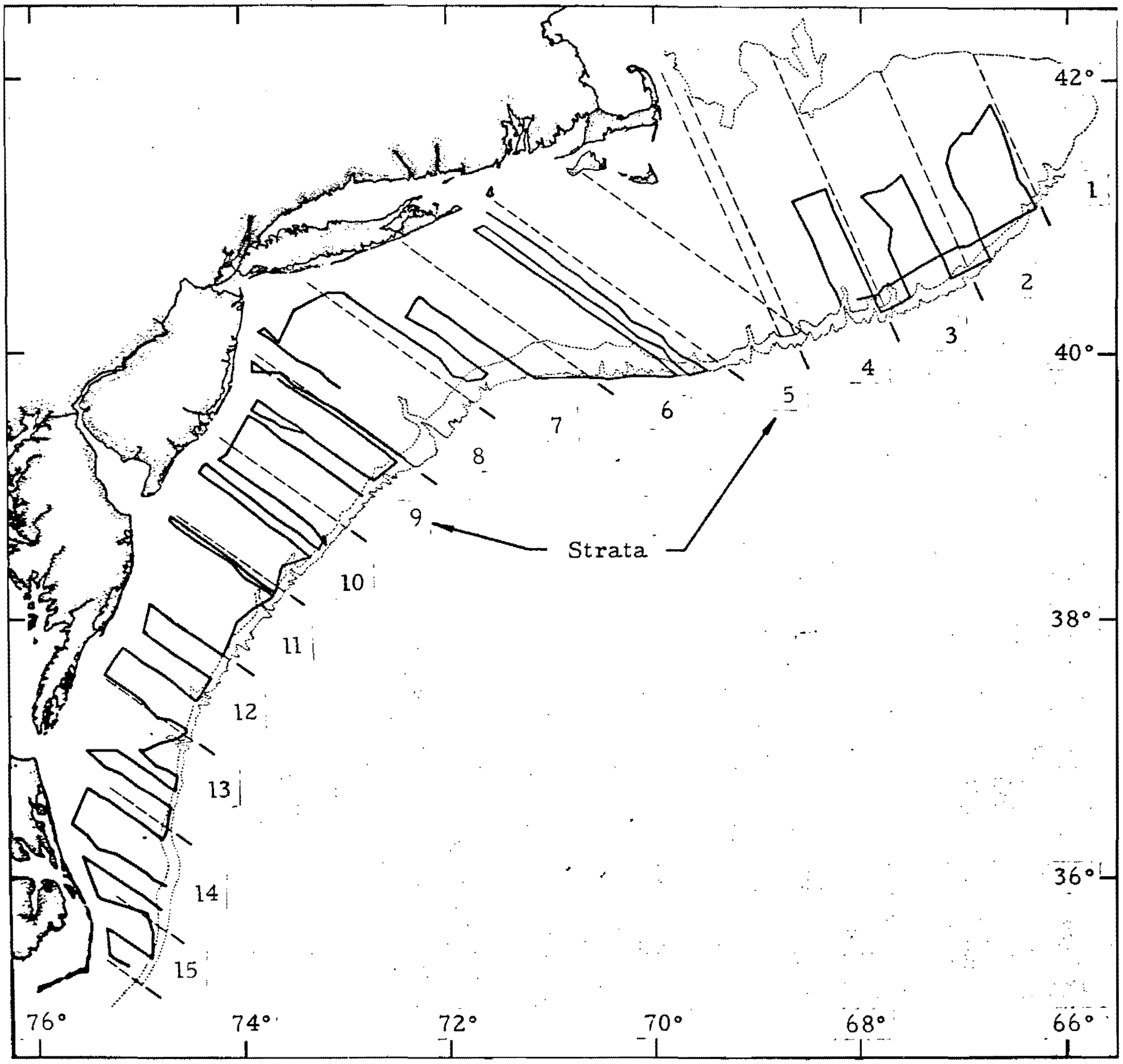


Figure 3.1 Vessel Track Lines - Experimental Hydroacoustical Survey - 75-3A and B 21-25 March and 28 March - 13 April 1975

and characteristics of the various equipment and instrumentation as well as the operation of a multi vessel cooperative joint survey. During this operation the R/V POISK was accompanied by the R/V ERNST HAECKEL and the R/V DELAWARE II was accompanied by the R/V WIECZNO.

The total operational time for Phase A was approximately 53 hours; the total operational track distance was approximately 438 nautical miles.

The approximate percentages of water depths versus operational track miles was: 20-50 meters 19%; 50-100 meters 40% and >100 meters 41%.

Upon completion of Phase A the R/V POISK and the R/V DELAWARE II returned to the NEFC, Woods Hole.

Phase B was conducted from Montauk Point, New York to Cape Hatteras, North Carolina, in the ICNAF Area 5Zw and Statistical Area 6A, B and C, from 28 March to 13 April 1975. During this operation the R/V POISK was accompanied by the R/V WIECZNO, the R/V ERNST HAECKEL had resumed other research activities, and the R/V DELAWARE II operated without the support of a vessel dedicated to the capture of hydroacoustically insonified and recorded targets.

The total operational time for Phase B was approximately 273 hours; the total operational track distance was approximately 2242 nautical miles.

The approximate percentages of water depths versus operational track miles was: 20-50 meters 44%; 50-100 meters 31% and >100 meters 25%.

The design of the survey tracks was developed by the Fisheries Engineering Division of the NEFC. This division also provided the necessary charts and logbooks which were carried aboard the participating vessels.

3.1 Phase A - Review

Widely scattered, low amplitude signals from targets were recorded over some portions of the survey tracks, however, no apparently dense target concentrations were recorded.

The R/V ERNST HAECKEL was requested to conduct three pelagic trawl net tows which were promptly executed. The net tows were requested in regions which appeared to contain significant, albeit low amplitude, received echo signals. However, it was subsequently found that it was not practicable to derive useful estimates of the value of volume backscatter for these target aggregations. The principal reason is that the ratio of received echo signal intensity to the received noise intensity was low, e.g., less than 5 to 1. This was due to a high ambient noise level created by the sea state conditions at the time of the observations.

Table 3.1 summarizes the net sampling results of Phase A.

3.2 Phase B - Review

Phase B began on 28 March on the vicinity of Montauk Point, N.Y., but on 4 April, off New York City, inclement weather necessitated termination of the survey activities. After awaiting at sea for two days weather continued unfavorable. The R/V POISK and R/V DELAWARE II then proceeded to the southern end of the survey area off Cape Hatteras, N.C. and at that point, recommenced the hydroacoustical survey operations. Generally, target concentrations appeared small and relatively insignificant. Over a considerable portion of the survey tracks, in water depths of from 20 to 50 meters, widely scattered low signal amplitude targets were recorded. The R/V WIECZNO was requested to conduct seven pelagic trawl net tows, which were promptly executed. Some difficulty was experienced deploying the midwater trawl net in shallow water, *

* The R/V WIECZNO is configured as a side trawler.

(< 50 meters). However, the R/V WIECZNO persisted and samples of what was believed to be the insonified and recorded animals were obtained from the seven tows*, and the data transmitted to the R/V POISK. Weather and sea conditions were ideal for hydroacoustical data acquisition during the latter part of Phase B and it is likely that any significant target concentration along the survey track would have been recorded.

Table 3.2 presents a summary of the trawl net sampling, performed by the R/V WIECZNO, of the target aggregations insonified and recorded by the R/V POISK.

During the conduct of the entire survey no hydroacoustical equipment or data acquistition instrumentation failures were experienced.

---

* The R/V WIECZNO executed eight trawl net tows. It was necessary to abort one tow due to interference from another vessel.

TABLE 3.1

Date and Time (Day Hour)	Stratum Leg	Position	Target Depth (m)	Sample (Predominate Species)
3/21 2022	4/2	40°47'N 67°42'W	55	Herring $\overline{1}$ ~ 29cm Silver Hake 1 ~ 4-13 cm
3/22 0810	3/1	40°38'N 66°53'W	130 - 400 Scattering Layer	Jellyfish
3/23 2320	3/2	41°40'N 66°37'W	52	Longhorn Sculpin 1 ~ 6-33 cm

Summary of Net Sampling by the R/V ERNST HAECKEL

Phase A 21 - 25 MARCH 1975, George's Bank Area,

ICNAF Area 5Ze

TABLE 3.2

Date & Time	Stratum/ Leg	Position & Water Depth	Depth (m)*	Track (m)**	Net Sample (Predominate Species and Others)	Hydroacoustical Data***
3/29 2200	06/2	40°48'N 71°23'W 60m	20	<50	Herring $\bar{l}\simeq$29cm Silver Hake $\bar{l}\simeq$4-31cm +15	No reduction - insufficient number of samples
4/02 0349	08/2	39°37'N 75°04'W 70m	30	<60	Red Hake $\bar{l}\simeq$ 28-43cm Silver Hake $\bar{l}\simeq$7-48cm Little skate $\bar{l}\simeq$20-48cm +7	Ditto Demersal fish targets (68m)
4/06 2022	15/1	35°27'N 75°04'W	25	<60	Blue fish $l\simeq$39-85cm +11	Ditto Water depth (35m)
4/07 1910	14/2	35°44'N 74°52'W 100m	47	3.3km	Blue fish $l\simeq$40cm +4	Data reduced - 109 samples - volume backscatter and confidence interval. See Section 5
4/08 2300	13/2	36°48'N 74°56'W 40m	27	27km	Tow aborted	Data reduced-2048 samples - volume backscatter and confidence interval. See Section 5
4/09 0030	12/1	37°29'N 74°38'W 65m	--	--	Sea Robin $l\simeq$22-26cm Loligo $l\simeq$3-10cm +5	No data recorded in vicinity of this tow
4/09 1726	12/1	37°42'N 74°59'W 60m	25	<60	Alewife $l\simeq$20-29cm +8	No reduction - insufficient number of samples
4/10 0200	12/2	37°39'N 74°30'W 60m	25	26km	Spiny dogfish $l\simeq$63-94 cm Sea Robin $l\simeq$16-27cm Half beak $l\simeq$6-9cm	Data reduced - 1850 samples - volume backscatter and confidence interval. See Section 5

Table 3.2 (cont'd.)

Summary of Net Sampling by the R/V WIECZNO of Insonified and Recorded Hydroacoustical Target Aggregations by the R/V POISK, Phase B, 28 March - 13 April 1975, ICNAF Statistical Area 6

* Target depth is range from hydroacoustical transducer to region of the maximum amplitude of the echo signals received from the insonified target aggregation.

** Approximate track distance from which statistically independent echo signals are received from the insonified target aggregation.

*** Less than 50 samples are considered insufficient to derive useful information concerning the hydroacoustical properties of the insonified aggregation of targets.

4.0 HYDROACOUSTICAL EQUIPMENT CALIBRATION

During the period 10 March to 20 March 1975, extensive tests and calibration procedures were performed on hydroacoustical equipment aboard the R/V POISK and R/V DELAWARE II by PINRO engineers and engineers from the Fisheries Engineering Division of the NEFC, supported by diving specialists of the NOAA Man-Under-The-Sea Technology Branch at the NEFC.

The calibration activities included the following:

1. Transducer isolation
2. Transducer resonant frequency and impedance alignment
3. Transmitter carrier frequency
4. Transmitter power
5. Transmitted sound pressure (source level)
6. Transducer receiving sensitivity (voltage response)
7. Equipment receiving sensitivity (voltage response)
8. Equipment and ambient noise (at sea)

All procedures, tests and results were reviewed by US and USSR engineers. Joint agreement was reached on all points.

Measurements of receiving sensitivity (voltage response) by both pulse and continuous wave transmission was performed and no significant differences were noted.

Table 4.1 presents a summary of the principal characteristics of the hydroacoustical equipment employed during the experimental survey.

Comparison of the principal characteristics indicates that there are significant differences between the EK-18 (R/V POISK) and the EH3A (R/V DELAWARE II) in terms of the receiving voltage response and hydroacoustical source level.

The effect of these differences is that the received echo signal from an identical aggregation of insonified targets, in an ideal environment, e.g., noise free, a measure of the value of volume backscatter,

TABLE 4.1

Vessel	Hydroacoustical Equipment Operating Frequency	Hydroacoustical Source Level (dB//1 microbar/m)	Receiving Voltage Response (dB//1 volt/microbar)	Transmitter Pulse Duration (ms)	Transducer Receiving Bandwidth (KHz)	Transducer Dimension (cm x cm)
R/V POISK	EK-18 18.0 KHz	117.4	-70.2	0.69	3.7	28x28
R/V DELAWARE II	EH 3A 18.2 KHz	110.4	-75.6	0.58	2.5	28x28

Principal Characteristics of Hydroacoustical Equipment Derived From Calibration Procedures Performed Prior To Experimental Survey - R/V POISK and R/V DELAWARE II via the EH3A, will be a factor of 17, (12dB), lower than that from the EK-18.

In view of this situation it was considered that it would be unlikely that a direct quantitative comparison of the hydroacoustically derived data between the EH3A and the EK-18 would be possible except, perhaps, under the most favorable conditions.

On March 20, along a track leading to the position at which the survey was to begin, a series of noise level measurements were obtained. This activity was conducted in the same area, under similar environmental conditions, for both the R/V POISK and the R/V DELAWARE II.

The procedure followed was to monitor the C.R.T. oscilloscope display for 15 minutes at a constant vessel velocity to determine the maximum and average value of the voltage at the transducer terminals.

Table 4.2 is a tabulation of the voltage measured at the transducers. It will be noted that the average value of the voltage measured at the transducer terminals, at vessel velocities between 2 and 4 meters/second, was a factor of 2 less on the R/V POISK than that on the R/V DELAWARE II.

The above condition combined with the lower receiving voltage response of the EH3A transducer indicates that the self-generated noise of the R/V DELAWARE II is approximately a factor of 4 greater than that of the R/V POISK.

The conditions imposed by the lower hydroacoustical source level, the lower receiving voltage response and higher self-noise on the R/V DELAWARE II required that received echo signals from target aggregations would have to result in a value of volume backscatter of approximately $-56\,db /\!/ 1/M^3$ in order to provide a direct quantitative comparison between the hydroacoustical data acquired on the two vessels.

There was no *a priori* hydroacoustically derived information available concerning the maximum value of volume backscatter which might be observed in the survey area. However, it was decided that despite the limitations which were inherent in the performance of the hydroacoustical equipment on the R/V DELAWARE II, the survey would

TABLE 4.2

Indicated Velocity		RMS Voltage (Microvolts)	
Meters/Second	Knots	P/V *POISK*	R/V *DELAWARE* II
2	4	30	60
2.5	5	33	70
3.1	6	35	60
3.6	7	38	90
4.1	8	48	130
4.6	9	125	200
5.1	10	248	200

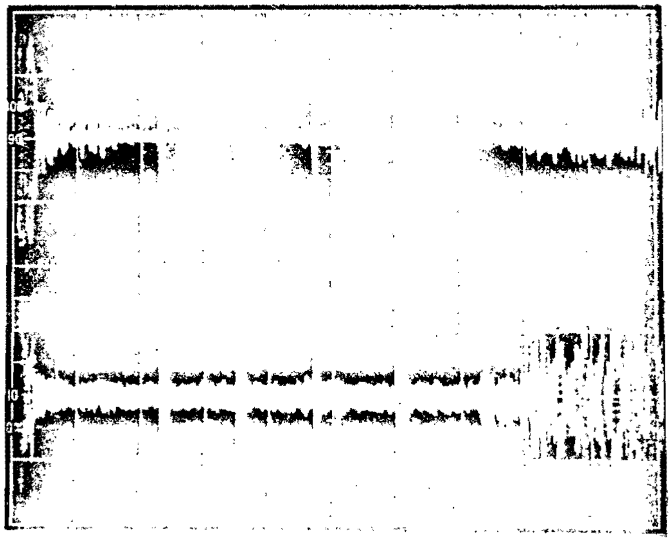
RMS Voltage Measured At Transducer Due
To Ambient And Self Noise - 20 March 1975 -
1950 to 2400 Hours - Approximate Position
41°08N - 70°38'W R/V POISK and R/V DELAWARE II

continue as planned, since it was expected that relative comparisons between the data gathered would possibly provide useful information concerning the diurnal migrations of any significant target concentrations that might be encountered.

In the southern region of the survey area, on 7 April, a measurement activity was undertaken to estimate the angular limit of the transducer directivity function, G, by recording and examination of the received echo signal from a 120 mmϕ spherical solid steel target. The target was a standard unit employed routinely by PINRO. Data from measurements conducted in a USSR laboratory indicated that, for all practical purposes, the target strength of the 120 mmϕ steel sphere was the same as the theoretical value of −30.5 db, at the nominal carrier frequency of 18 KHz employed during the survey. A target array including the 120 mmϕ spherical target was deployed at 35^{o} 54N - 74^{o} 50'W. The array was in the form of a free drifting surface float attached to a weighted line 90 meters long. Secured to this line at 30, 50 and 70 meters, approximately, was the 120 mmϕ spherical target, a 150 mmϕ solid steel sphere and a 200 mmϕ spherical hollow steel trawl float, respectively.

Figure 4.1 depicts a typical C.R.T. oscilloscope display of the received echo signal, to a range of 150 meters, in which is shown the three spheres and the weight located above a low amplitude echo signal received from a scattering layer beginning at a range of approximately 110 meters. The measurement procedure required that the R/V POISK conduct a series of passages, at various velocities, to within 2 meters of the surface float. A series of twelve passages were executed, ten of which produced recorded data sufficient for analysis.

Table 4.3 presents a summary of the data analyzed from the ten recorded intervals. It will be noted that for the minimum value of observed target strength the maximum target bearing angle is 16^{o}, approximately. These data indicates that a physical target with a scattering cross section of 112 cm^2 was detected and recorded at a range of



UPPER TRACE - RAW SIGNAL
LOWER TRACE - EK18 CALIBRATED OUTPUT

Figure 4.1 Typical C.R.T. Oscilloscope Display of Recorded Received Echo Signal From PINRO Target Array - Range 150 Meters - 7 April 1975 1340 Hours - Stratum 15 - R/V POISK

TABLE 4.3

Target Strength (dB)		Target Bearing Angle* (Degrees)		Vessel Velocity (Meters/Second)
Max.	Min.	Min.	Max.	
-44.1	-57.7	12	17	2.5
-43.8	-56.4	12	16	2.5
-38.7	-54.4	9	16	2.5
-38.9	-49.0	9	14	3.1
-41.4	-53.2	10	15	3.1
-39.1	-56.6	9	16	3.6
-40.8	-48.7	10	13	3.6
-40.8	-48.7	10	13	4.1
-43.3	-48.3	11	13	4.1
-37.4	-49.0	8	14	4.6

*Referenced to Transducer Axis, Actual Target Strength −30.5 dB, Transducer Directivity Function, G, Derived as in Ref. 1.

Maximum and Minimum Measured Target Strength From Recorded Received Echo Signal and Corresponding Estimated Target Bearing Angles - 120 mmϕ Solid Steel Spherical Target

R/V POISK

34 meters at an angle approaching 17° from the acoustic axis of the transducer.* It should be noted that upon passing the surface float the propellor thrust was terminated to avoid possible fouling of the weighted line. Under this condition self-generated noise was minimal which may have allowed the minimum received echo signal to be observed at a lower amplitude due to a lower received noise signal amplitude.

Figures 4.2 (a) and (b) depict C.R.T. oscilloscope displays, delayed and expanded, typical of those used to analyze the recorded data. Figure 4.2 (a) shows the maximum received echo signal and Figure 4.2 (b) the minimum from the 120 mmϕ spherical target.

It will be noted in Figures 4.2 (a) and (b) that the received echo signal has a time duration of approximately 1.5 milliseconds which is nearly twice the duration of the measured transmitted hydroacoustical pulse in water. The shape of the echo signal envelope is considerably rounded compared to the transmitted pulse, which was nearly rectangular.

It is of interest to compare a typical received echo signal from the 120 mmϕ physical target with that from an assumed biological target insonified under similar, but not exactly, the same circumstances.

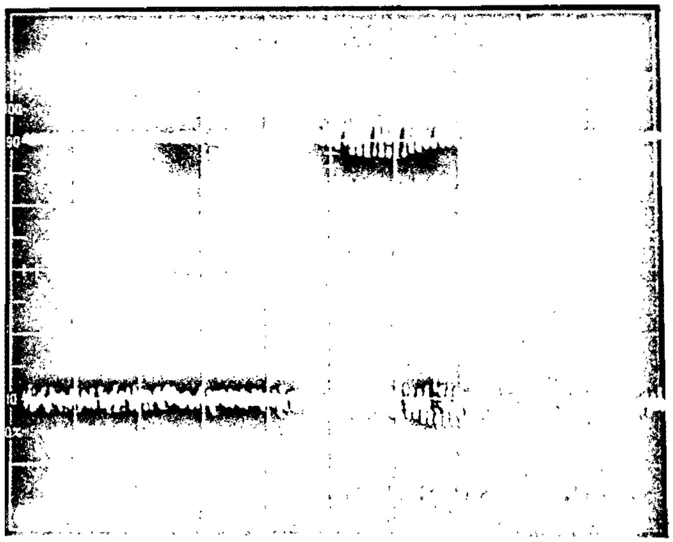
Figures 4.3 (a) and (b) depict received echo signals displayed on the C.R.T. oscilloscope. Figure 4.3 (a) is the received echo signal from the 120 mmϕ target, at a range of 34.5 meters, and Figure 4.3 (b) is the echo signal received from a target, believed to be a fish, at a range of 32.9 meters. The vessel velocity at the time of both observations was 2.3 meters/second, approximately; the hydroacoustical equipment was transmitting pulses of 0.69 millisecond in time duration at a rate of 96 pulses/minute. The vessel attitude and rate of change of attitude was, for all practical purposes, identical. The amplitude of the target signals are nearly identical and the amplitude of the echo signal in the immediate vicinity of the targets is also nearly equivalent.

---

* The determination of the bearing angle requires a value for G, the transducer directivity function.
The determination of the value of G is described in Reference 1.

UPPER TRACE - RAW SIGNAL
LOWER TRACE - EK 18 CALIBRATED OUTPUT

Figure 4.2(a) Typical Delayed and Expanded C.R.T. Oscilloscope Display of Recorded Maximum Received Echo Signal From 120 mmϕ Solid Steel Spherical Target - Range 33.3 Meters - 7 April 1975 - 13:40:16 - Stratum 15 - R/V POISK

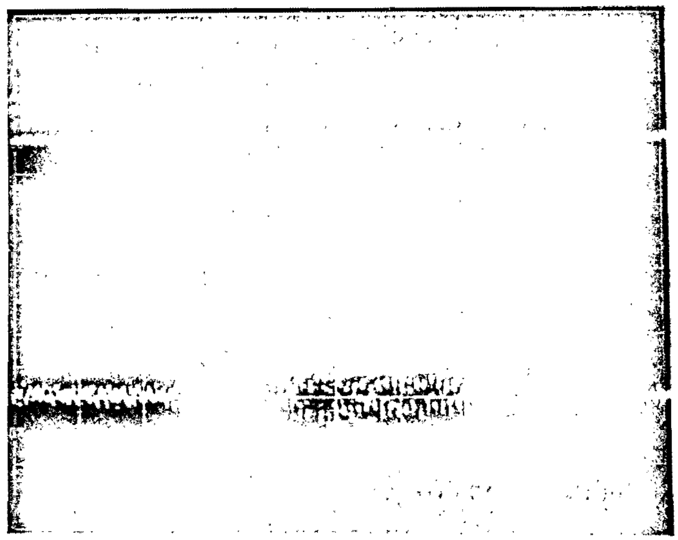


UPPER TRACE - RAW SIGNAL
LOWER TRACE - EK18 CALIBRATED OUTPUT

Figure 4.2(b) Typical Delayed and Expanded C.R.T. Oscilloscope Display of Recorded Minimum Received Echo Signal From 120 mmϕ Solid Steel Spherical Target - Range 34.9 Meters - 7 April 1975 13:40:12 - Stratum 15 - R/V POISK

UPPER TRACE - RAW SIGNAL
LOWER TRACE - EK18 CALIBRATED OUTPUT

Figure 4.3(a) Delayed and Expanded C.R.T. Oscilloscope Display of Recorded Received Echo Signal From 120 mmϕ Solid Steel Spherical Target - Range 33.4 Meters - 7 April 1975 - 14:35:54 - Stratum 15 - R/V POISK



UPPER TRACE - RAW SIGNAL
LOWER TRACE - EK18 CALIBRATED OUTPUT

Figure 4.3(b) Delayed and Expanded C.R.T. Oscilloscope Display of Recorded Received Echo Signal From Aquatic Target - Range 32.3 Meters - 9 April 1975 - 01:00:52 - 13/2 - R/V POISK

This observation indicates that the observed self-generated noise of the R/V POISK in the situation concerning the assumed biological target,(Figure 4. 3(b)), when the vessel was under constant propellor thrust, was not significantly greater than the noise under a condition of no thrust,(Figure 4. 3(a)). Therefore, under other similar conditions it is reasonable to expect that the maximum target bearing angle of 16° may be employed as a useful approximation of the angular resolution of the hydroacoustical equipment consisting of the EK-18 transmitter, transducer and the C. R. T. oscilloscope/differential amplifier receiver. It should be noted that this angle of resolution is approximately twice the 8° half power beamwidth bearing angle of the transducer.

5.0 RECEIVED ECHO SIGNAL HANDLING AND PROCESSING

On the R/V POISK and the R/V DELAWARE II the received echo signals were recorded from a point prior to the preamplifier in the receiver of the hydroacoustical equipment.* This signal was then amplified via a broadband amplifier and recorded on magnetic tape. All of the tapes which contained data from survey regions, in which target activity was noted, were examined for the suitability for processing and useful data content. This examination employed the C.R.T. oscilloscope in a memory holding configuration which allowed effective, but time consuming, visual editing of the data tapes. The criteria for processing suitability requires a stable initial signal level from the received echo signal or a separate data tape channel which can be employed as an external trigger for the automatic selection of statistically independent hydroacoustical signals.** The recorded data acquired aboard the R/V POISK provided a separate external trigger tape channel, whereas, the data recorded aboard the R/V DELAWARE II did not. The lack of an external trigger tape channel effectively negated the automated processing of the hydroacoustical echo signal data acquired aboard the R/V DELAWARE II. The criteria for selection of the portion of a tape which contained useful data was based upon the following considerations. When the calculated mean value of volume backscatter, for ten independent hydroacoustical samples, (received echo signals), increased by a factor of 10, (10 dB), greater than the mean value of volume backscatter, observed in survey regions which exhibited no significant target activity, it was assumed that echo signals received from aquatic targets of interest were being recorded. Further,

* The receiving bandwidth, (–3dB), at this point was the same as that of the transducer. (See Table 4.1) The receiving bandwidth of the recording instrumentation was: (–3dB), high frequency - 100KHz, low frequency - 100 Hz.

** The vessel velocity and the transmission rate of the hydroacoustical equipment were not synchronized to provide independent samples. In most cases serial transmissions were not processed.

a limiting value of the confidence interval statistic was selected to accompany the mean value of volume backscatter and finally, ideal, or nearly ideal, sea conditions were required at the time of observation. Expressed in numerical terms the selection criteria equated to a mean value of volume backscatter which exceeded $-71 dB // 1/M^3$ with an accompanying confidence interval statistic of greater than 0.05 and a roll/pitch resultant angle of less than 4^o during the entire observation period. It should be noted that the above parameters and their associated values were derived after considerable study and analysis of the survey data tapes. It is entirely possible that these values represent an arbitrary artifice, however, the raw data tapes exist for further tests and analysis that may be appropriate.

The data selection criteria described above eliminated many of the total of 166 data tapes recorded during the survey. Thirty-one data tapes or 19% of the recorded data met the data selection criteria. It was noted earlier that the data tapes frcm the R/V DELAWARE II could not be processed automatically due to an unstable trigger. This situation required difficult and time consuming visual examinations of the received echo signals to derive values of volume backscatter. It was not practical to perform a quantitative comparison of these values of volume backscatter with those derived from the R/V POISK data tapes because the higher ambient noise level of the R/V DELAWARE II masked nearly all the received echo signals from the aquatic targets, except those of high amplitudes. This condition had the effect of introducing an uncertainty factor of from 10 to 50, (+10 to +17 dB), in the lower limit of the mean value of the volume backscatter observed in regions previously traversed by the R/V POISK. In view of the above, it is considered highly unlikely that further examination of data tapes acquired aboard the R/V DELAWARE II will yield useful comparative survey information except in terms of the presence or the absence of targets. Therefore, the following discussion will be confined only to that survey data acquired aboard the R/V POISK.

The following is provided to illustrate certain other facets of the concept of useful hydroacoustical data from which the selection criteria, discussed above, was derived. Figure 5.1 depicts a typical C.R.T. oscilloscope display of a recorded received echo signal from the hydroacoustical transducer to the sea bottom echo at a range of 51.4 meters. In Figure 5.1 it will be noted that for the initial 10 milliseconds, (7.5 meters) the signal amplitude has exceeded the dynamic range of the recorder amplifier. Therefore, no useful data exists in this interval. For the following 10 millisecond interval the signal amplitude appears tobe the result of initial volume reverberation, due to the relatively high hydroacoustical pressure, and possible aquatic targets. Beyond a time interval of from 0 to 20 milliseconds, (0 - 15 meters), the echo signal appears to be the result of the insonification of resolved, (individual) and unresolved, (aggregated) targets. The received echo signal from range intervals which exhibit no significant amplitude variations are assumed to contain no aquatic targets. Examination of Figure 5.1 in these intervals shows that the amplitude is approximately 0.2 cm peak to peak.

This peak to peak measurement results in a mean value of volume backscatter of approximately $-79 dB//1/M^3$ in a range interval of from 20 to 50 meters. The average value of the volume backscatter observed, under similar circumstances, for the periods of hydroacoustical data acquisition which met the data selection criteria was approximately $-78 dB//1/M^3$. It must be noted that there is a high probability that these values of volume backscatter are uncertain by approximately a factor of two due to the practical limits associated with hydroacoustical equipment and measurement tolerances.

It is useful to examine the received echo signal depicted in Figure 5.1 in greater detail to verify the previous observations.

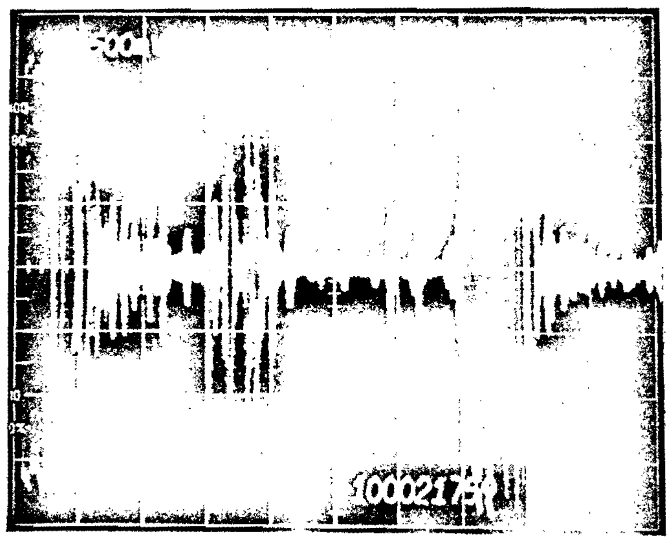
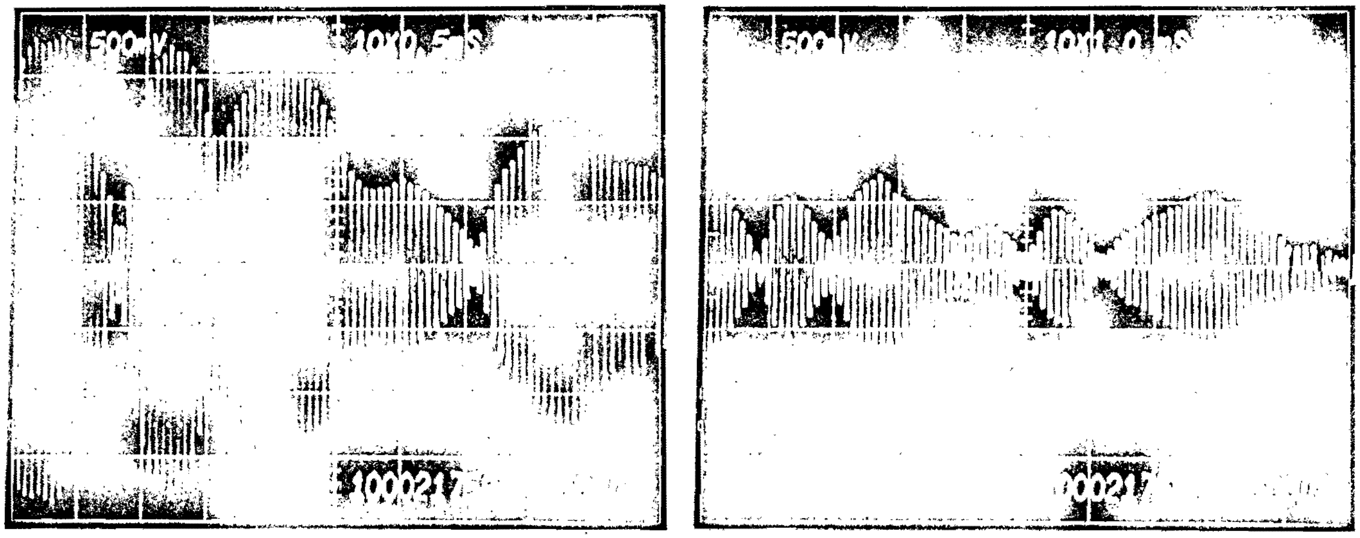


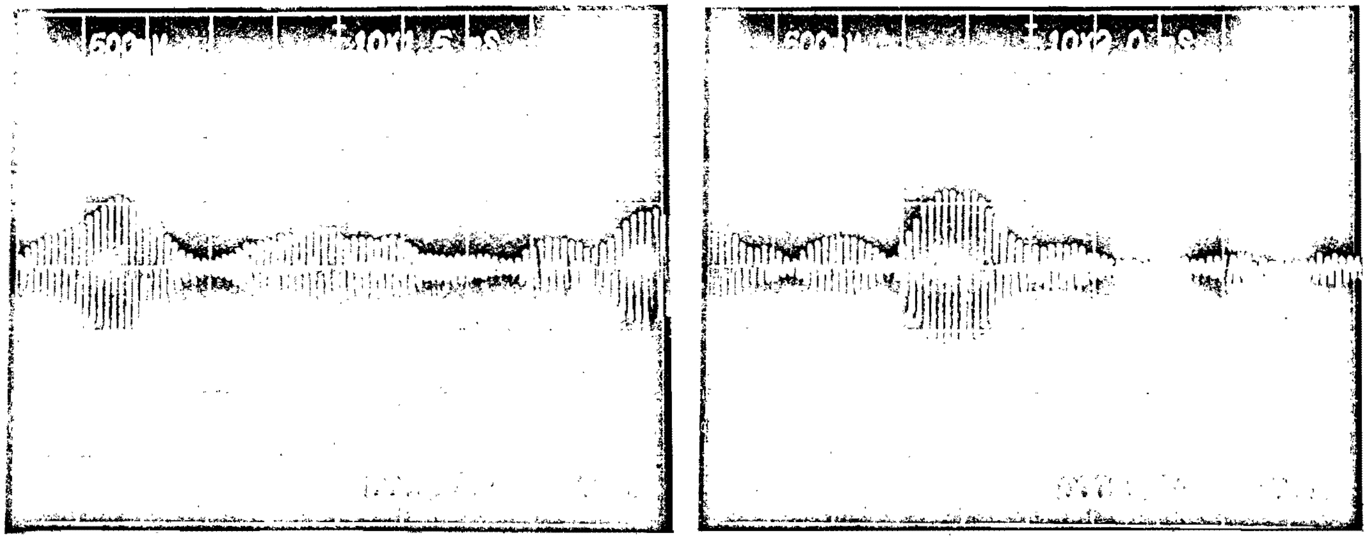
Figure 5.1 Typical C.R.T. Oscilloscope Display of Recorded Received Echo Signal - Transducer to Sea Bottom Echo - Range 51.4 Meters - 10 April 1975 02:17:59 - R/V POISK

Figures 5.2(a) thru 5.2(m) depict the same C.R.T. oscilloscope display, at 3.75 m range intervals, over a total range of 3.75 to 51.4 meters from the transducer. In Figure 5.2(a) the characteristics of the echo signal, which may contain useful aquatic target information, also appears to exhibit a component of initial volume reverberation. For the purposes of this discussion it is reasonable to state that it is highly unlikely that any useful information, concerning the presence of aquatic targets, can be obtained from the initial 10 milliseconds (7.5 meters) of the received echo signal. In Figure 5.2(b) the uncertainty between initial volume reverberation and target echo signals remains. The results of processing the range interval from 7.5 to 15 meters produced a nearly constant value of volume backscatter which resulted in a confidence interval statistic of nearly zero. Accordingly, for the received echo signal handling and processing conduced to date, it has been determined that no useful information concerning aquatic biomass can be derived in the range interval of 0 to 15 meters from the hydroacoustical transducer. In Figures 5.2(c) thru 5.2(m) the details of the received echo signals from various targets can be seen. In Figures 5.2(f) and 5.2(k) it will be noted that the characteristics of the signals are not unlike those illustrated in Figure 4.3(a), a known physical target and Figure 4.3(b), an assumed biological target. Also, it will be noted in Figures 5.2(d), 5.2(l) and 5.2(m) there are signals which are of a shorter time duration than that of the transmitted pulse. This situation suggests that the number of scatterers contributing to the received echo signal is greater than one but probably less than five. In Figure 5.2(m) it can be noted that the amplitude of the echo signal received from the sea bottom again exceeds the recorder dynamic range. In this Figure it will also be noted that a target signal appears to be partially masked by the bottom signal. For all practical purposes it should be noted that the resolution of the hydroacoustical equipment, the recording and processing instrumentation



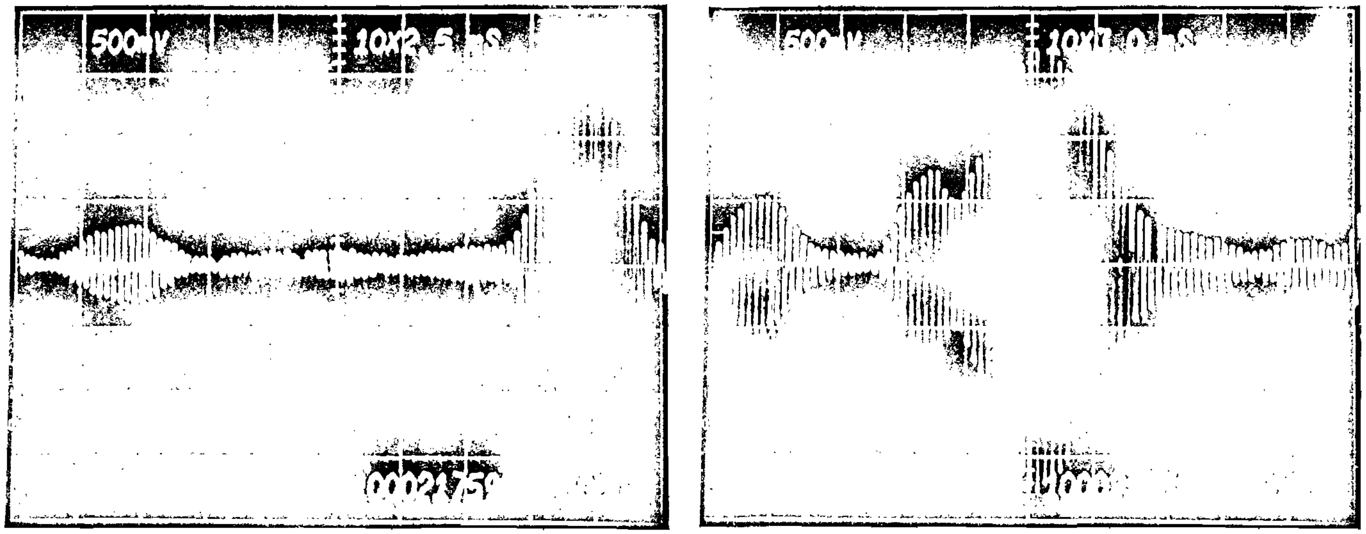
(a) (b)

Figure 5.2 C.R.T. Oscilloscope Display of Recorded Received Echo Signal - 3.7 to 11.2 Meters 10 April 1975 02:17:59 - R/V POISK



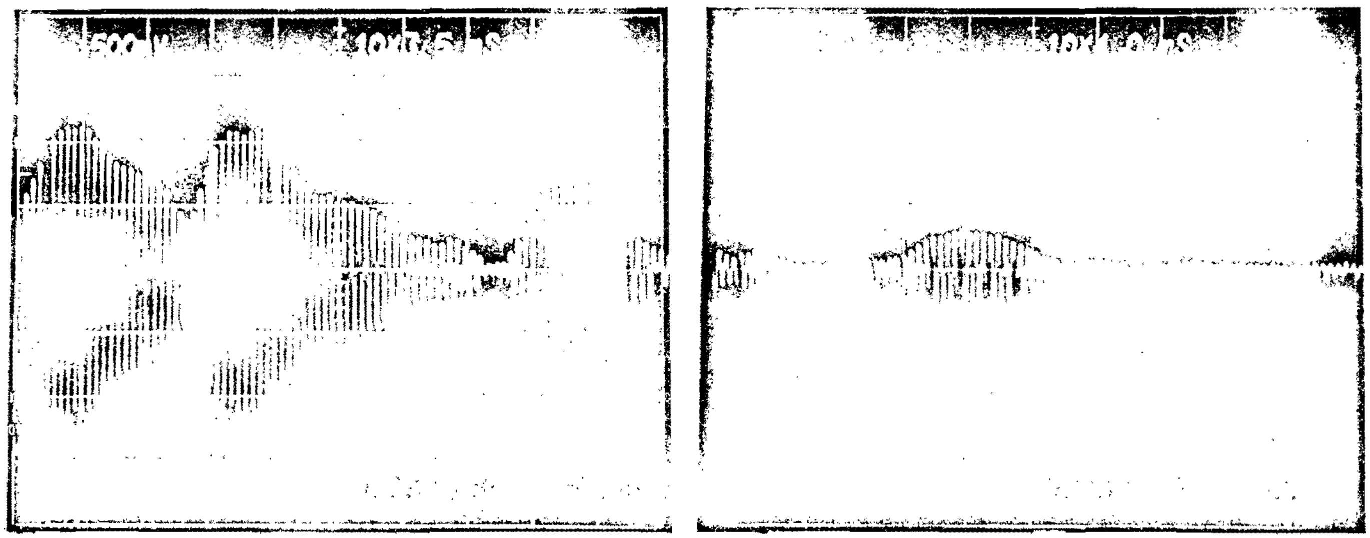
(c) (d)

Figure 5.2 C.R.T. Oscilloscope Display of Recorded Received Echo Signal - 11.2 to 18.7 Meters 10 April 1975 02:17:59 - R/V POISK



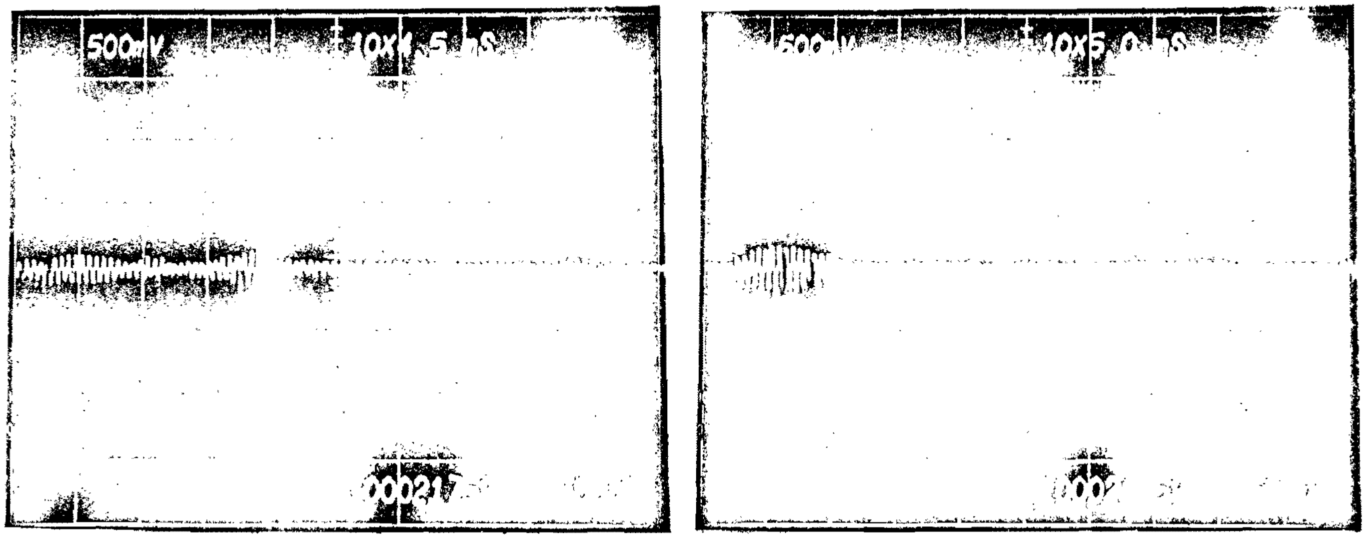
(e) (f)

Figure 5.2 C.R.T. Oscilloscope Display of Recorded Received Echo Signal - 18.7 to 26.2 Meters 10 April 1975 02:17:59 - R/V POISK



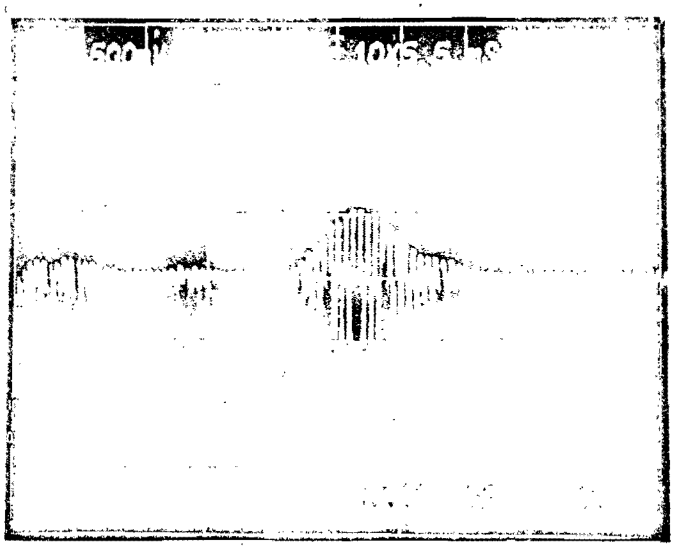
(g) (h)

Figure 5.2 C.R.T. Oscilloscope Display of Recorded Received Echo Signal - 26.2 to 33.7 Meters 10 April 1975 02:17:59 - R/V POISK

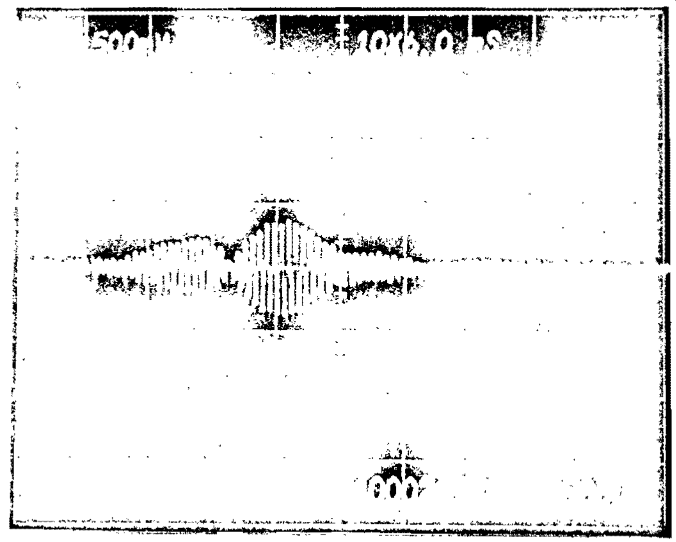


(i) (j)

Figure 5.2 C.R.T. Oscilloscope Display of Recorded Received Echo Signal - 33.7 - 41.2 Meters 10 April 1975 02:17:59 - R/V POISK

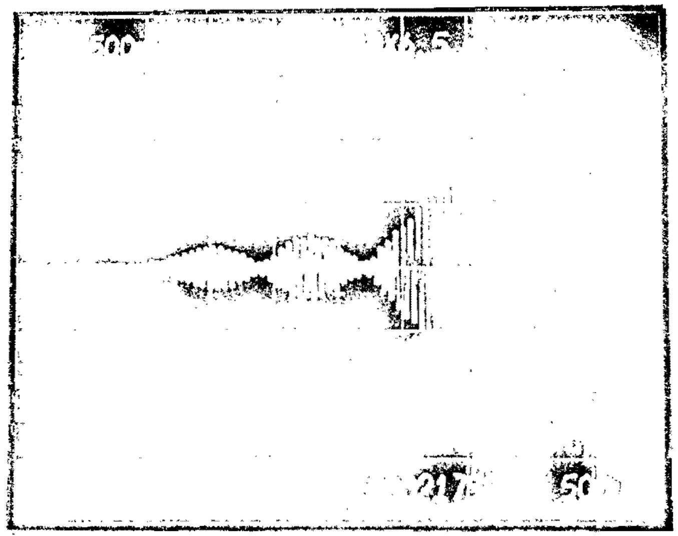


(k)



(l)

Figure 5.2 C.R.T. Oscilloscope Display of Recorded Received Echo Signal - 41.2 to 48.7 Meters 10 April 1975 02:17:59 - R/V POISK



(m)

Figure 5.2 C.R.T. Oscilloscope Display of Recorded Received Echo Signal 48.7 to 51.4 Meters 10 April 1975 02:17:59 - R/V POISK effectively precludes the extraction of useful information concerning aquatic biomass from a region which is 3 to 4 meters from the actual surface of the sea bottom. A brief discussion of this situation is contained in Reference 1

To summarize, for the purposes of this report no useful information concerning aquatic biomass was derived in the range interval of 0 - 15 meters from the hydroacoustical transducer or from a region which is within 4 meters of the sea bottom surface.

The recorded data tapes were processed employing the identical instrumentation carried aboard the R/V POISK during the survey. It was originally planned to perform experimental real time processing of the received echo signals during the survey, but the recorder scale factors, electronic circuitry peculiar to the processing operation and calculator programs were not completely verified at the commencement of the survey. A simplified block schematic diagram of the hydroacoustical equipment and data gathering instrumentation employed during the joint hydroacoustical experiment survey is shown in Figure 5.3.

Upon completion of the survey the onboard data acquisition and recording instrumentation with verified scaling, electronics and calculator programs was employed to process the data tapes. The analog recorded echo signal was introduced into the digital processing C.R.T. oscilloscope through an envelope detector circuit. The resulting analog echo signal envelope is digitized via a microprocessor within the oscilloscope. The digitized echo signal envelope is then amplitude sampled at specific intervals according to a program in the calculator, through the microprocessor interface. The calculator performs the necessary arithmetical manipulations to provide a value of the volume backscatter. This value of volume backscatter is derived according to the formula and process described in References 2 and 3.* The

*C.R.T. oscilloscope photographs were also obtained to perform manual echo signal envolope processing to verify the results of the automated processing.

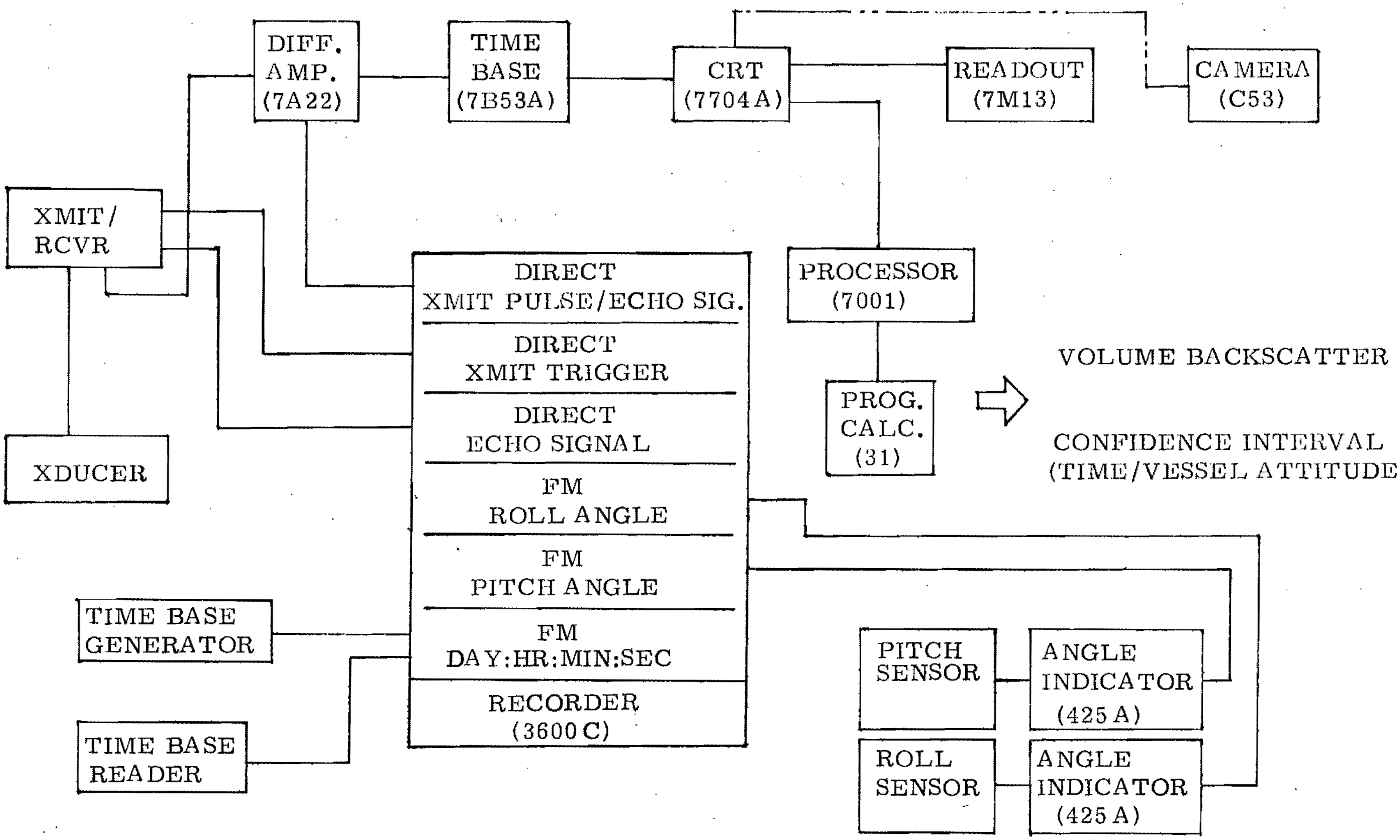


FIGURE 5.3 Simplified Block Schematic Diagram of Received Echo Signal Handling and Processing Equipment - Joint USA-USSR Hydroacoustical Experimental Survey

calculator is also programmed to provide a confidence interval statistic described in Reference 3. Graphic information concerning the value and the variation of the value of volume backscatter, within specified range intervals, is displayed on the C. R. T. oscilloscope from a permanent memory. The value of volume backscatter is calculated from statistically independent samples as a function of the vessel velocity, the transmission rate of the hydroacoustical equipment and the integrated transducer directivity function. The integrated transducer directivity function is derived according to the formula and process described in Reference 3. The C. R. T. oscilloscope display is updated in recorded real time and a calculator printout of the value of the volume backscatter and the confidence interval statistic for a specified sampling interval is also generated.

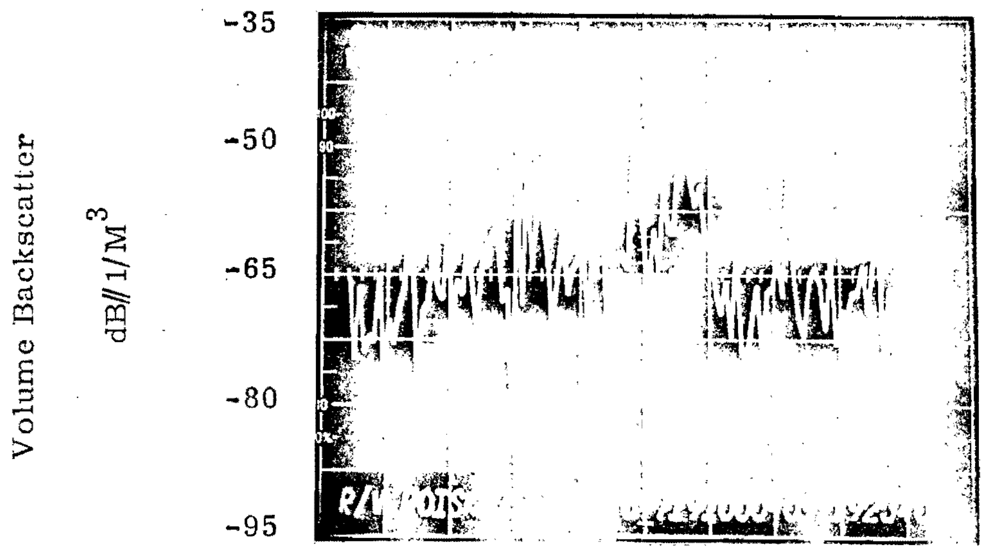
The following is a discussion of the specific occasions given in Table 3. 2 at which time hydroacoustically insonified targets were recorded and the data was processed.

In Table 3. 2 there are three occasions specified when hydroacoustically insonified targets were recorded and the resulting data subsequently processed. Of the remaining five events given, four did not produce a sufficient number of data samples to yield meaningful results. The remaining event was a trawl net tow conducted sometime after the passage of the R/V POISK. The data from this tow may or may not be representative of the aquatic targets recorded earlier.

7 April 1975 1910 to 1923 Hours

The circumstances concerning this interval combined to provide a nearly ideal situation for the capture of the insonified and recorded targets. This target concentration was detected by the R/V

WIECZNO proceeding toward an area to aid in the search of an aircraft reported to be in distress. At this time the R/V POISK and the R/V DELAWARE II were also proceeding to this area. After being released from the search activity the R/V POISK insonified and recorded the received echo signals from this concentration which was then sampled by a trawl net towed by the R/V WIECZNO. The R/V WIECZNO had already commenced the trawl net tow and the R/V POISK maneuvered to be just forward of the R/V WIECZNO. The location of this activity was approximately 5km from the nearest survey track. Figure 5.4 depicts the C.R.T. oscilloscope display of the value of and the variation of the value of volume backscatter for 109 statistically independent hydroacoustical samples. It will be noted that this Figure includes a vessel track distance of approximately 3.3 km. The selection of this track distance was performed according to the criteria described earlier in this section. This criteria was derived by repeated examination and processing of the data tape for the indicated time interval and is believed to be representative of the most useful data in terms of maximum apparent target density and vessel track distance. The trawl net sample contained 98% bluefish, (325 specimens; length from 31 to 49 cm, average length 40 cm). The remainder of the catch consisted of 6 smooth dogfish, 6 butter fish, 6 loligo squid and 6 stomatidae. This data suggests that it may be possible to derive the density of the insonified animals, specifically the bluefish, if it can be assumed that the net sample was typical of the species distribution within the insonified aggregation. In Figure 5.4 it will be noted that the average value of volume backscatter is given as $-61.9\ dB/\!/1/M^3$ and the confidence interval statistic for the 109 samples is 0.19. Noting that the combination of the mean value of the target strength and the mean value of the target density is the mean value of the volume backscatter it may be concluded that a confidence interval statistic of 0.19 implies the following, If the target strength



Track Distance - 3.3 km

Number of Samples - 109

Mean Volume Backscatter - (-61.9) dB// $1/M^3$

Confidence Interval Statistic - 0.19

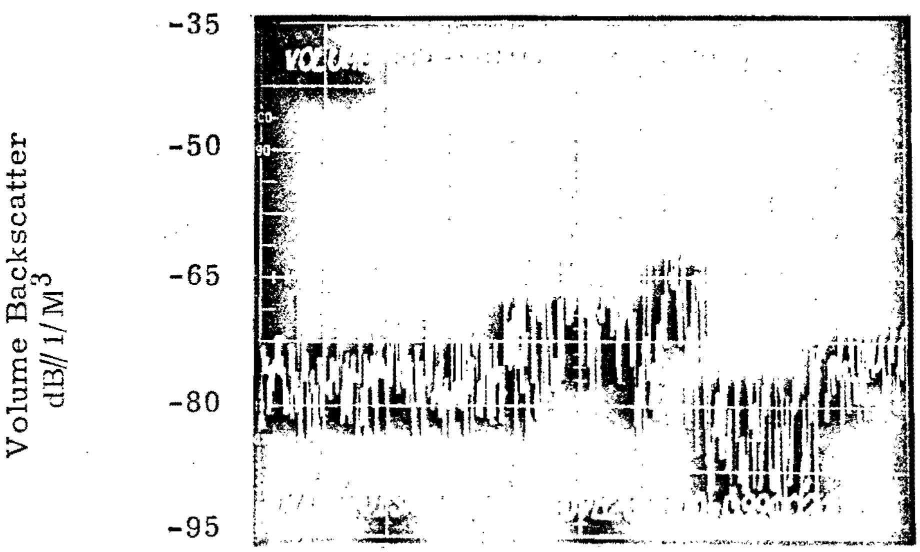
Figure 5.4 Digital Processing C.R.T. Oscilloscope Display of Values of Volume Backscatter Versus Time - 7 April 1975 - 1910 to 1923 Hours - R/V POISK was known absolutely, e.g., zero error, then it follows that the density of the target aggregation could be within a factor of two of the true value with a confidence of 95%. Conversely, if the target density was known absolutely, the target strength could be within a factor of two of the true value with the same confidence. A detailed discussion on and derivation of the confidence interval statistic is given in Reference 3. The above discussion illustrates the uncertainties inherent in attempting to derive an aquatic biomass estimate of the target aggregation. Nevertheless, it is instructive to establish a possible upper and lower boundary of a target density estimateion. Limited fish target strength measurements, Reference 4, show that the target strength of fish, approximately 40 cm long with a buoyancy regulating organ, exhibit a variation of nearly a factor of two about a mean value of -30.5 dB. In this situation the density of the insonified target aggregation could be from 1.45 to 0.4 per 1000 cubic meters.

The credibility of the above postulated characteristics of the insonified target aggregation cannot be verified at this time.

8 April 2328 Hours to 9 April 0114 Hours

The received echo signals in this region appeared to be characteristic of scattered individual and small groups of targets and the maximum values of volume backscatter occurred in ranges of between 25 and 30 meters from the transducer.

Figures 5.5(a) and (b) depict the values of and the variation of volume backscatter observed over a vessel track distance of approximately 27 km. In Figure 5.5(a) it will be noted that there was a considerable variation, approximately a factor of 6, (8 dB), in the value of volume backscatter over a portion of the vessel track. The circumstances relevant to this variation have been carefully examined and the conclusion, to date, is that no instrumentation drift



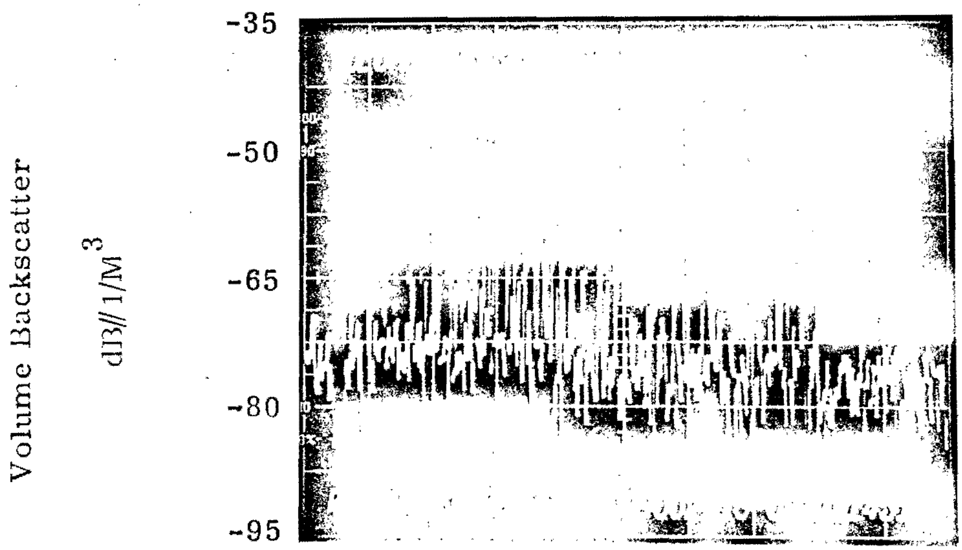
Track Distance - 13.8 km

Sampling Interval 100/1.4 km

Mean Volume Backscatter - (−71.3)dB// $1/M^3$)

Confidence Interval Statistic 0.16

Figure 5.5(a) <u>Digital Processing C.R.T. Oscilloscope Display of Values of Volume Backscatter Versus Time - 8 April 2328 to 9 April 0021 Hours - Strata 12/2 - R/V. POISK</u>



Track Distance - 13.3 km

Sampling Interval 100/1.4 km

Mean Volume Backscatter - (-69.7) dB// 1/M^3

Confidence Interval Statistic - 0.15

Figure 5.5 (b) <u>Digital Processing C. R. T. Oscilloscope Display of Values of Volume Backscatter Versus Time- 9 April 0021 to 0114 Hours - Strata 13/2 R/V POISK</u>

or malfunction occurred at the time, therefore, it is postulated that the observed variation of the observed value of volume backscatter may be due to a biological phenomena; possibly a void in the scattering layer due to a species segregation. The net sampling tow of this aggregation being performed by the R/V WIECZNO was aborted due to navigational hazards imposed by another vessel and examples of the insonified targets were not available for examination.

It is, however, instructive to examine the observed value of volume backscatter and the resulting confidence interval statistic to assess the precision of an estimate of aquatic biomass. It has been assumed that 50 statistically independent, hydroacoustical samples for a 0.7 km interval, along the vessel track, was sufficient to derive this statistic. Tables 5.1 and 5.2 are summaries of the values of volume backscatter as a function of vessel track distance for the abovementioned interval. It will be noted that confidence interval statistic varies between 0.08 and 0.2 with an average of 0.16 for 2048 samples. As it was discussed earlier in this section a confidence interval statistic of 0.16 derived from the values of volume backscatter implies that an estimate of biomass could be within $\pm$ 50% and a factor of 2, in relation to the true value, with a confidence of 95%. This would, of course, be valid only if the density and density distribution or the target strength and target strength distribution in the insonified target concentration was known.

10 April 1975 0156 to 0417 Hours

The received echo signals in this region were characteristic of scattered individual and small groups of targets. Figures 5.6 (a), (b) and (c) depict the values of and the variation of volume backscatter over a vessel track distance of approximately 26 km. During the time interval represented in Figure 5.6(a) the vessel velocity was approximately 2.3 meters/second and the hydroacoustical equipment was

Table 5.1

Track Distance (km)	Mean Volume Backscatter ($dB // 1/M^3$)	Confidence Interval Statistic
0. - 1.4	-75.3	0.14
1.4 - 2.8	-75.1	0.16
2.8 - 4.1	-73.5	0.11
4.1 - 5.5	-74.7	0.12
5.5 - 6.9	-69.7	0.11
6.9 - 8.3	-66.2	0.17
8.3 - 9.7	-64.5	0.26
9.7 - 11.0	-77.3	0.21
11.0 - 12.4	-78.0	0.21
12.4 - 13.8	-71.3	0.14
0. - 13.8	-71.3	0.16

Range - 25 to 30 Meters

Sampling Interval - 100/1.4 km

Water Depth - 33 to 51 Meters

Volume Backscatter Versus Vessel Track Intervals - 8 April 2328 to 9 April 0021 Hours - Strata 13/2 R/V POISK

Table 5.2

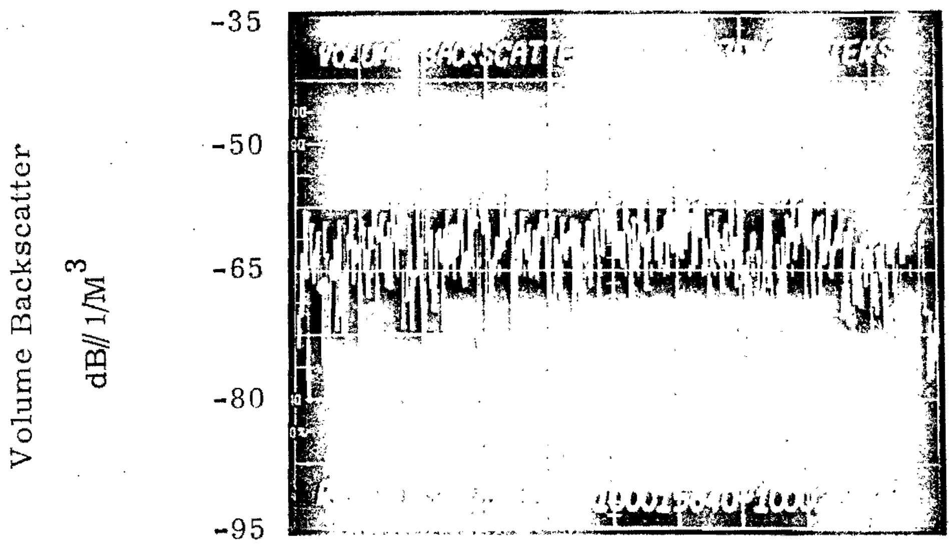
Track Distance (km)	Mean Volume Backscatter ($dB /\!/ 1/M^3$)	Confidence Interval Statistic
0. - 1.4	-74.6	0.14
1.4 - 2.8	-70.0	0.22
2.8 - 4.1	-67.1	0.18
4.1 - 5.5	-65.9	0.10
5.5 - 6.9	-67.2	0.16
6.9 - 8.3	-70.4	0.15
8.3 - 9.7	-73.2	0.13
9.7 - 11.0	-71.3	0.16
11.0 - 12.4	-73.7	0.08
12.4 - 13.8	-73.6	0.17
0. - 13.8	-69.7	0.15

Range - 25 to 30 Meters

Sampling Interval - 100/1.4 km

Water Depth - 51 to 119 Meters

Volume Backscatter Versus Vessel Track Intervals - 9 April 0021 to 0114 Hours - Strata 13/2 - R/ V POISK



Track Distance - 7.4 km

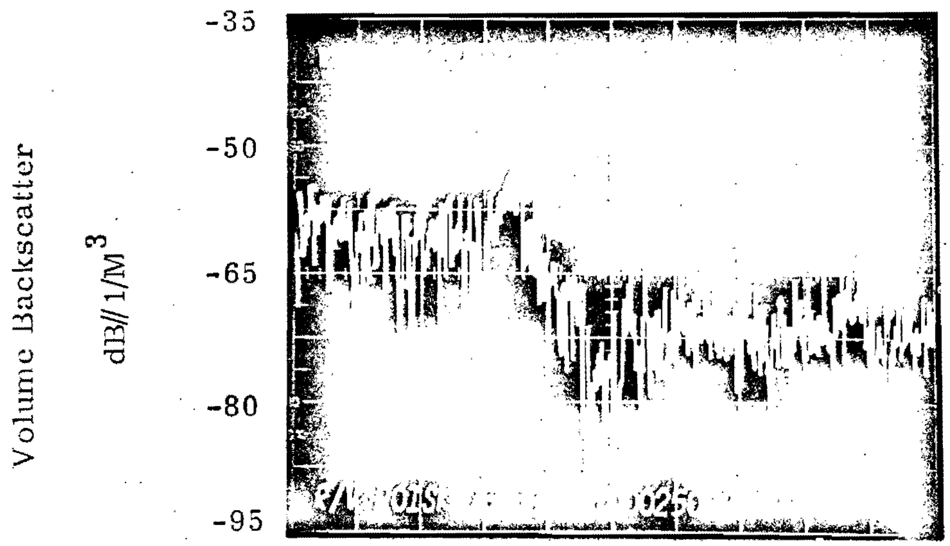
Sampling Interval 50/0.7 km

Mean Volume Backscatter - (-61.6) dB// 1/M^3

Confidence Interval Statistic - 0.18

Figure 5.6(a) Digital Processing C.R.T. Oscilloscope Display of Values of Volume Backscatter Versus Time - 10 April 1975 0156 to 0250 Hours - Strata 12/2 - R/V POISK transmitting at a rate of 96/minute. In Figure 5.6(b) it will be noted that a considerable variation in volume backscatter is shown, however, part of this variation is not due to phenomena associated with the marine environment. The events associated with this variation are described below.

At approximately 0255 hours the amplitude of the received echo signals were observed to diminish. At this time a decision was made to increase the vessel velocity from 2.3 to 4 meters/second and to decrease the pulse transmission rate of the hydroacoustical equipment from 96 to 48/minute. At 0306 hours this change was initiated and the echo signal was observed to contain a significant noise component which persisted for approximately 3.5 minutes. At the onset of this noise the differential amplifier gain was lowered a factor of 2.5, (8 dB). At 0316 hours the vessel velocity was constant at approximately 4.3 meters/second, the noise in the received echo signal was not evident and the amplifier gain was returned to the initial value, e.g., that prior to 0306 hours. The sequence of events described above and the associated hydroacoustical effects precludes the extraction of any useful value of volume backscatter from the recorded data for approximately 10 minutes during the data gathering period under discussion. In Figure 5.6(c) the vessel velocity was constant at approximately 4.3 meters/second. The maximum value of volume backscatter continued at a range of from 25 to 30 meters until 0417 hours at which time the amplitude of the received echo signal from the sea bottom masked the received echo signal from the insonified targets. At this point data reduction was terminated. It is not known, however, if this layer of targets ended at this point or continued further along the sea bottom. Table 5.3 contains a summary of the values of volume backscatter and associated confidence interval statistics along a track distance of 9.6 km. The value of the mean volume backscatter for 0.7 km intervals is the mean

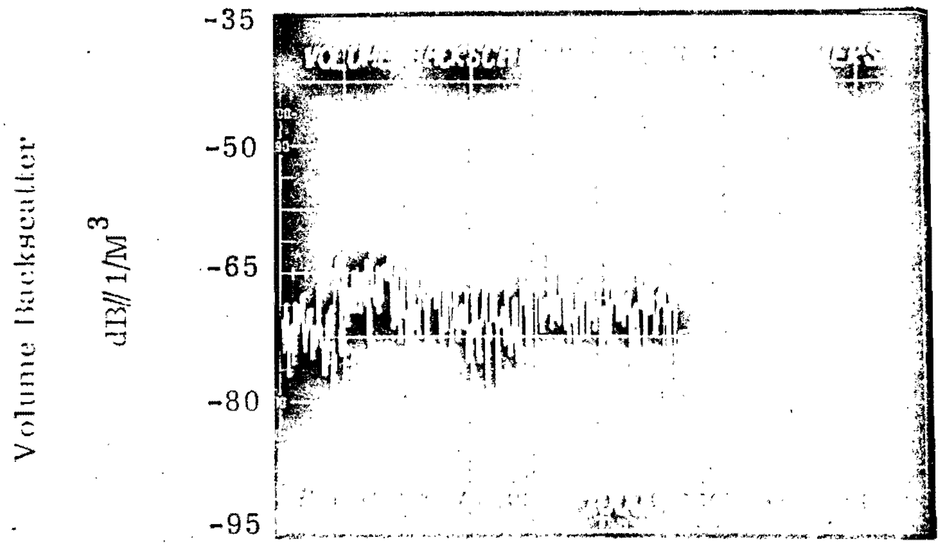


Track Distance - 10.8 km

Sampling Interval - 50/0.7 km

(See Section 5.4 and Tables 5.3 and 5.4)

Figure 5.6 (b) <u>Digital Processing C.R.T. Oscilloscope Display of Values of Volume Backscatter Versus Time - 10 April 1975 0250 to 0343 Hours - Strata 12/2 - R/V POISK</u>



Track Distance - 7.8 km

Sampling Interval 50/0.7 km

Mean Volume Backscatter - (-67.8) dB// 1/M^3

Confidence Interval Statistic - 0.08

Figure 5.6 (c) Digital Processing C.R.T. Oscilloscope Display of Values of Volume Backscatter Versus Time - 10 April 1975 0343 to 0417 Hours - Strata 12/2 R/V POISK

Table 5.3

Track Distance (km)	Mean Volume Backscatter ($dB//1/M^3$)	Confidence Interval Statistic
0. - 0.7	-63.3	0.16
0.7 - 1.5	-61.1	0.15
1.5 - 2.2	-61.2	0.15
2.2 - 3.0	-60.8	0.14
3.0 - 3.7	-61.3	0.17
3.7 - 4.4	-60.0	0.09
4.4 - 5.2	-59.9	0.12
5.2 - 5.9	-62.3	0.16
5.9 - 6.7	-61.0	0.14
6.7 - 7.4	-61.6	0.18
7.4 - 8.1	-58.6	0.09
8.1 - 8.9	-60.2	0.14
8.9 - 9.6	-59.9	0.16
0. - 9.6	-60.7	0.14

Range - 25 to 30 Meters

Sampling Interval - 50/0.7 km
Water Depth - 60 to 40 Meters

Values of Volume Backscatter and Confidence Interval Statistic Versus Vessel Track Intervals - 10 April 1975 0156 to 0306 Hours - Strata 12/2 R/V POISK of 50 statistically independent hydroacoustical samples. It can be shown that the variance of this value over the entire 9.6 km is smaller than the mean, but this is not consistent with the 50 sample intervals which indicate otherwise. The confidence interval statistic of 0.14 given in Table 5.3 implies that an estimate of aquatic biomass could vary between $\pm$50% and a factor of 2 in relation to the true value with a confidence of 95-99%. Table 5.4 contains a summary of the values of volume backscatter and associated confidence interval statistics along a track distance of approximately 14 km. It will be noted that the mean value of volume backscattering is -68.8 dB//1/M^3. With an associated confidence interval of 0.07 these values just satisfy the useful hydroacoustical data criteria described previously. A confidence interval statistic of 0.07 implies that an estimate of aquatic biomass derived from these data could be within $\pm$30% of the true value with a confidence of 95%. These values should be regarded with caution, since they approach the limit established to define useful data. It is highly likely that these data reflect a measurement uncertainty of approximately a factor of two due to the practical limits associated with the hydroacoustical equipment and measurement tolerances.

The previous discussion was concerned with specific events during the survey, at which time the received and recorded echo signals were related to a trawl net sample. Detailed examination and subsequent processing of the survey data tapes, according to the selection criteria described earlier, showed that the best data for measurements of the value of volume backscatter from the received and recorded echo signal occurred in Strata 11 thru 14. At the time of passage of the survey vessels through this region, from April 7 to April 10, 1975, the sea conditions were moderate to calm and between the hours of 2300 to 0330 hours the target aggregations appeared to form a nearly continuous scattering layer at ranges between 22 and 30 meters.

Table 5.4

Track Distance (km)	Mean Volume Backscatter (dB//1/M^3)	Confidence Interval Statistic
0. - 1.3	-71.0	0.09
1.3 - 2.6	-69.9	0.06
2.6 - 3.9	-70.9	0.07
3.9 - 5.2	-69.3	0.07
5.2 - 6.5	-70.5	0.07
6.5 - 7.8	-69.6	0.07
7.8 - 9.1	-66.1	0.07
9.1 - 10.4	-67.7	0.08
10.4 - 11.6	-69.7	0.09
11.6 - 12.9	-66.9	0.07
12.9 - 14.2	-68.1	0.08
0. - 14.2	-68.8	0.07

Range - 25 to 30 Meters
Sampling Interval 100/1.3 km
Water Depth - 40 to 30 Meters

Values of Volume Backscatter and Confidence Interval Statistic Versus Vessel Track Intervals - 10 April 1975 0316 to 0417 Hours - Strata 12/2 R/V POISK

Accordingly, it is reasonable, at this time, to suggest that the processed recorded data, obtained aboard the R/V POISK, in conjunction with a critical examination of the recorded data, obtained aboard the R/V DELAWARE II, may be utilized to provide an approximation of the boundary of a region which exhibits a favorable environment for future hydroacoustical investigations. The approximate boundary of this region is depicted in Figure 5.7. This region extends approximately 167 km, (90 NMI), between the 35 and 150 meter depth contours off the coasts of North Carolina, Virginia and Maryland, in the ICNAF statistical areas 6B and 6C. The maximum and minimum values of volume backscatter observed in this region were approximately -51 dB// $1/M^3$ and -71 dB// $1/M^3$, respectively, at ranges between 22 and 35 meters. Since the number of survey track lines were minimal it is not possible to delineate in detail the areas or regions associated with these values of volume backscatter. The trawl net sampling data given in Table 3.2 suggests that the scattering layer in the region depicted in Figure 5.7 may be composed of several fish species with widely varying length distributions. If it can be assumed that the trawl net samples are representative of the fish species which occur in the mid depths of this region it is not feasible, employing extant hydroacoustical techniques, to describe the spatial distribution of these species without considerable a priori information regarding the hydroacoustical characteristis in conjunction with the biological behavioral characteristics of these animals. In view of this situation it is appropriate to consider the measurement of volume backscatter as a potential indicator of aquatic biomass. The relative difference between the maximum and minimum values given above is 20 dB, or a factor of 100.

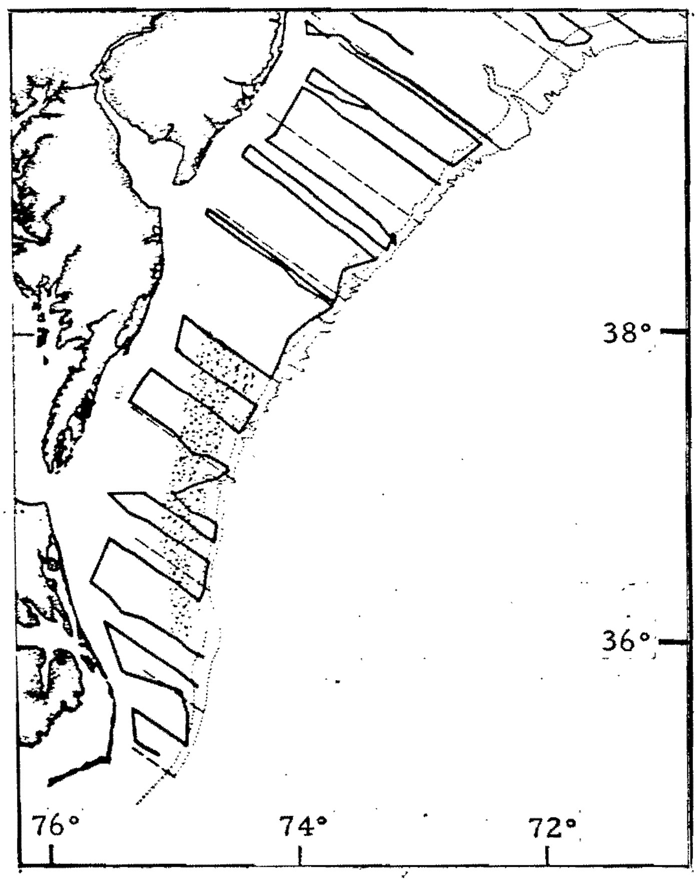


Figure 5-7 Approximate Region of Scattering Layer - Depth Interval 22-35 Meters - Experimental Hydroacoustical Survey 75-3B 7-10 April 1975 2300 - 0330 Hours

6.0 SUMMARY

In terms of the objectives of the hydroacoustical experimental survey described in Section 1.0, all were achieved except one, but with varying degrees of success.

The following discussion summarizes experimental survey activities in relation to the objectives with appropriate comments.

The objective to evaluate the potential usefulness of a hydroacoustical survey following statistically stratified random sampling tracks is considered only partly successful in that weather conditions and the time of vessel availability effectively limited the implementation of more transects per stratum. The limitation of three transects in each stratum in all probability precluded optimized sampling, however, since there was little a priori information concerning the probable location of target aggregations it is not clear that an additional one or two transects would have improved the results significantly. In any event, this could not have been implemented due to time constraints. It is reasonable, at this time, to expect that considerably more transects in a given stratum are mandatory in order to delineate areas or regions of relative aquatic biomass concentrations by means of the measurements of volume backscatter.

The objective to evaluate the practibility of two hydroacoustical data acquisition vessels following similar survey tracks with a nominal time interval of 12 hours is considered to be partly successful, since the hydroacoustical related characteristics and parameters of the two vessels were sufficiently dissimilar to preclude direct comparison of the data acquired during the survey. In terms of the vessels following identical tracks, this objective was achieved successfully, in periods of moderate to calm sea conditions.

The objective to evaluate the practibility of joint hydroacoustical survey activities employing research vessels dedicated to this task of the capture of the targets contributing to the received and recorded echo signals is considered to be partly successful. It should be noted that the relatively shallow depths, (sea surface to bottom) in which nearly all target activity was observed, created considerable difficulty in the deployment of the pelagic trawl net from the side of a vessel. This difficulty results in time delays between hydroacoustical target data acquisition and capture and the possibility of the capture of hydroacoustically undetected targets, adjacent to the sea bottom, at the initiation and termination of the towing operation.

The objective to optimize the calibration methods and procedures for all hydroacoustical equipment, employed for aquatic biomass measurements during the survey, was achieved. This activity is currently performed on a routine basis.

The objective to evaluate standardized in situ cross calibration procedures in order to normalize specific differences between hydroacoustical equipment deployed aboard vessels dedicated to the task of hydroacoustical data acquisition was not met. The dissimilarity between the hydroacoustical characteristics and equipment parameters combined with technically unacceptable recorded data, in the case of one vessel, resulted in conditions which precluded direct comparison and subsequent normalization of differences.

The objective to obtain hydroacoustical signals and other in situ data from aquatic targets was achieved. The recorded data was processed to estimate the value of volume backscatter from various target aggregations. In terms of the potential usefulness of these data to estimate the aquatic biomass in a region of interest, the following conditional comment is given. Using data similar to that acquired during the experimental survey, under favorable conditions, it may be possible that an estimate of aquatic biomass to within a factor of two, of the true value, with a 95 to 99% confidence may eventually be achieved if the received hydroacoustical echo signals from the insonified animals obey the rules set forth in extant scattering theory.

It should be noted, however, that conclusive verification or refutation of the validity of current scattering theory for purposes of aquatic biomass measurements has not, at this time, been accomplished.

7.0 RECOMMENDATIONS FOR CONTINUING ACTIVITIES

The following recommendations are presented in the light of the experience and observations to date.

Hydroacoustical Equipment Calibration

Standard, comprehensive calibration procedures to verify the basic parameters, e.g., source level, receiving voltage response, bandwidth, etc., have been routinely implemented. In addition, an in situ procedure to verify the transducer directivity function employing a known physical target was performed.

Recommended:

> Continuation of the current calibration procedures including adoption of the PINRO in situ procedure to verify the transducer directivity function. It is appropriate to generate a formal document of these activities based upon the informal documentation developed by the US and USSR engineers for the joint survey.

Echo Signal Handling and Processing

The real time recording in broadband analog form of the raw, unfiltered echo signal, along with other environmental data, provides the means to examine the events which occurred, without loss of vital data, which may be of value in the light of further understanding of the problems associated with aquatic biomass measurements. The use of a high frequency, delayed sweep, CRT oscilloscope with a broadband differential amplifier is equally vital for real time evaluation of the quality of the data being gathered. In addition, the utilization of a digital processing oscilloscope to process the received echo signal can provide a rapid and convenient verification of the potential usefulness of the data being recorded.

Recommended:

The continuation of the use of the received echo signal handling instrumentation equivalent to that employed during the survey for future collaborative research activities. Also, that US and USSR engineers continue to collaborate in the application of the automated processing of received echo signals from aquatic targets to assess the potential accuracy of aquatic biomass estimations by hydroacoustical methods.

Survey Area

The experimental survey reported in this document identified a region which exhibited a favorable environment for further hydroacoustical investigations. Detailed knowledge of the species and the distribution of the aquatic animals insonified in the mid depths of this region is, at this time, uncertain.

Recommended:

That the region outlined in Figure 5.7 of this document be considered as a primary operational area for a future hydroacoustical survey.

Survey Time

The time of future hydroacoustical investigations in the recommended region should, in the absence of other pertinent information, be during the same interval, i.e., March-April. This activity should be conducted only in periods during which the effects of weather on hydroacoustical data acquistion and the aquatic animals of interest are minimal.

Recommended:

The development of plans to conduct further hydroacoustical investigations in the recommended region. These plans are to include both primary and alternate operational procedures as may be required by unfovorable weather conditions.

Survey Sampling Protocol - Hydroacoustical

At this time the optimum number of survey transects, or legs, to provide the best data is unknown. It is highly likely, however, that, in order to identify spatial variations in the values of volume backscatter, the mean distance between the randomly spaced transects should be considerably less than those executed during the past survey. In the region recommended for further hydroacoustical investigations it may be reasonable to increase the number of independent hydroacoustical samples by a factor of 100 to 1000 to effectively resolve spatial variations in the value of volume backscatter. This hydroacoustical data acquistion should be conducted at a time when the received echo signals from the targets of interest are not masked or cluttered by components of reverberation or the sea bottom echo. In the region recommended, this time was between the hours of 2300 and 0400, approximately 7-10 April, 1975.

Recommended:

The development of a hydroacoustical sampling protocol for the recommended region. This should include studies and plans to identify vessel tracks which will tend to optimize the probability of resolving spatial variations of relative aquatic biomass by means of the measurement, in near real time, of the value of volume backscatter.

Survey Sampling Protocol - Trawl Net

It is mandatory that an appropriately sized trawl net be deployed rapidly and effectively sample a specific depth interval. Depending upon the resolution of the hydroacoustical sampling protocol it may be possible to partition a region into statistically stratified volumes which could allow a vessel detailed to the task of trawl net sampling to operate somewhat independently, in location and time, of the hydroacoustical data acquisition vessel.

Recommended:

The development of a trawl net capture sampling protocol for the recommended region. This is to be accomplished concurrently with a hydroacoustical sampling protocol. This work should include studies and plans to identify vessel tracks which will optimize the capability of a trawl net sampling vessel in relation to a hydroacoustical data acquisition vessel and to minimize, if possible, the requirement to follow hydroacoustical data acquisition transects.

Applied Research

It has been noted that despite considerable rigorous analytical studies on the scattering of the hydroacoustical energy assumed to occur from and within an insonified aggregation of aquatic animals (fishes), there is little direct evidence, in terms of biomass measurements, that the specific theoretical models are representative of the environment. In certain specific situations physical measurements, in situ or in specially contrived environments, the resulting hydroacoustical measurements have suggested confirmation of some of the theory. However, these confirmations, while indicating trends and magnitudes, have not suggested the order of accuracy of the measurements of aquatic biomass that may be obtained by hydroacoustical methods. At this time it is prudent to initiate a systematic study and critical review of the complex interaction between the biological, technological and physical factors inherent in the measurements of aquatic biomass by hydroacoustical methods. The principal goal of this activity should be to establish a definitive and credible estimate of the current state of development of hydroacoustical methods for aquatic biomass measurements, the identification of potential improvements, if any, that may result from further applications and most important, the effectiveness of hydroacoustical methods in relation to other techniques for purposes of fisheries resource assessment.

Recommended:

That the appropriate individuals with expertise in the biological, technological and physical disciplines inherent in fisheries resource assessment in the US and USSR collaborate in this activity. The form of this collaboration could be effected coincident with the ICNAF special and annual meetings.

8.0 PRINCIPAL INSTRUMENTATION

	R/V POISK	R/V DELAWARE II
Hydroacoustical		
EK-18	X	
EH3A		X
Echo Signal Handling and Recording		
7704 A C.R.T. Oscilloscope	X	X
P7001 Acquisition Unit	X	
7A22 Differential Amplifier	X	X
7B53A Time Base	X	X
SP425 TS Tape Reader	X	
SP425 A/B Time Code Generator	X	X
C53 Camera	X	X
3600 C Tape Recorder	X	X
Vessel Attitude		
871 Attitude Sensor (Pitch and Roll)	X	X
Test		
VTVM, Signal Generator, DVM, Frequency Counter and Attenuator	X	X
Type LC-10 and LC-32 Hydrophone		

9.0 PARTICIPATING PERSONNEL

R/V POISK

A. A. Gan'kov	PINRO, Principal Investigator
J. B. Suomala, Jr.	CSDL, Principal Investigator
S. I. Saranchov	VNIRO
H. A. Globa	NMFS/NEFC
A. V. Ivanov	AtlantNIRO
E. N. Gavrilov	PINRO
V. N. Isaev	PINRO
P. J. Twohig	NMFS/NEFC
V. I. Zubov	PINRO

R/V DELAWARE II

E. W. Bowman	NMFS/NEFC
A. J. Blott	NMFS/NEFC
J. M. Crossen	NMFS/NEFC
P. B. Loiseau, Jr.	NOAA
W. D. Handwork	NMFS/NEFC

NOAA/MAN-UNDER-THE-SEA TECHNOLOGY PROGRAM

C. D. Newell

K. J. Pecci

REFERENCES

1. Suomala, J.B., Jr. - 1975, A Short Note on the Applicability of Hydroacoustic Methods for Domersal Fish Counting and Abundance Estimations, ICNAF Res. Doc. 75/95 .

2. Lozow, J. and J.B. Suomala, Jr. - 1971, The Application of Hydroacoustic Methods for Aquatic Biomass Measurements, A Note on Echo Envelope Sampling and Integration, Mass. Institute of Technology, C.S. Draper Laboratory, Cambridge, Ma., Report R-712.

3. Yudanov, K.I., J.B. Suomala, Jr., V.M. Vorobyov and K.A. Smith - 1974, Preliminary Report of the First Joint USA-USSR Hydroacoustic Experiment in the ICNAF Convention Area, C.S. Draper Laboratory Report, Cambridge, Ma., Engineering Note C-4117.

4. Nakken, O. and K. Olsen - 1973, Target Strength Measurements of Fish, ICES/FAO/ICNAF Symposium on Acoustic Methods in Fisheries Research, Paper #24.