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# ACOUSTIC ASSESSMENT OF HERRING STOCKS IN ALASKA DURING 1975-1976

by

Richard E. Thorne

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Roy E. Nakatani
Associate Director

# ACOUSTIC ASSESSMENT OF HERRING STOCKS IN ALASKA DURING 1975-1976

## INTRODUCTION

Since 1971, the Fisheries Research Institute of the University of Washington has provided data analysis services for hydroacoustic surveys of herring stocks conducted by the Alaska Department of Fish and Game (ADF&G). Results of surveys during the past year were primarily reported to ADF&G by telephone, sometimes within 48 hours of the survey. This report serves to consolidate these results and to document the procedures used for analysis.

## PROCEDURES

Surveys were conducted primarily by ADF&G personnel in southeastern Alaska aboard ADF&G research vessels *Kittiwake*, *Auklet*, and *Sundance*. Surveys at Green Island in Prince William Sound were made from the ADF&G research vessell *Montague*. Additional data were collected in cooperation with the National Marine Fisheries Service (NMFS) at Auke Bay aboard various NMFS research vessels, especially the *John N. Cobb*. All vessels were equipped with Ross 200A hydroacoustic data acquisition systems as used in previous years.

Data analysis was by echo integration. Digital echo integration systems have been used on the ADF&G herring data since 1972. A new digital system based on a PDP 11/45 computer has been used the last two years. A manuscript describing the system and the results of analysis of some selected herring surveys from southeastern Alaska has been prepared for publication and is appended to this contract report. All results in this report are standardized to a target strength assumption of -33 dB/kg, the same standard used for Puget Sound herring studies. The hydroacoustic system calibration is done by the University of Washington Applied Physics Laboratory.

## RESULTS AND DISCUSSION

Table 1 presents the results of analysis of all surveys. A total of 55 surveys was conducted. The first 6 surveys from the RV *Sundance* were not analyzable because of a tape recorder malfunction in the data acquisition system, and one of the surveys aboard the *John N. Cobb* was not analyzable because of failure to record the calibration signal. Otherwise, the data were greatly improved in both quantity and quality over previous years. Problems due to tape saturation were reduced. Both diel and seasonal coverage were more complete. The largest estimate was again obtained from Green Island but substantial populations were located in several other areas, including Bocas de Finas for the first time since 1972.

With the increase in quantity of data and the number of data acquisition systems, it becomes increasingly important to obtain good calibration data and species composition information. Studies in Puget Sound have shown surprisingly large and variable non-herring components associated with areas which were traditionally believed to contain almost exclusively herring. An assumption of 100% herring in hydroacoustic population estimates can endanger even conservative management practices. The development of seine or midwater trawl capability for sampling is strongly recommended.

One annual calibration of the hydroacoustic data acquisition systems by the Applied Physics Laboratory is probably not sufficient to ensure the precision needed in the program. The need for development of on-site calibration capability by ADF&G has been recognized, and I would again encourage the timely achievement of that objective. In addition, I would recommend synoptic surveys with the various systems as a check of the calibration results.

The -33 dB/kg target strength standard provides a reasonable interim value for herring population estimates, but may continue to be refined as we gain further data on herring target strengths through our research program at the University. We are particularly concerned with how the value may vary with mean size of the herring population. Some special data collection with our dual-beam target strength measuring system on herring populations in Alaska which have well-known size characteristics may be worth future consideration.

Table 1. Summary of herring hydroacoustical estimates made in Alaska during 1975-76

| Date | | Run | Vessel | Density lbs/m$^2$ | Area m$^2$ | Biomass $10^6$ lbs |
|---|---|---|---|---|---|---|
| 10- 8-75 | Deer Island | 1 | *Auklet* | 2.3 | 2,100,816 | 5.8 |
| 10-10-75 | Anita Bay | 1 | *Auklet* | 5.6 | 2,400,933 | 13.3 |
| 10-11-75 | Scow Bay | 1 | *Auklet* | .93 | 4,555,337 | 4.2 |
| 10-13-75 | Pt. Camden | 1 | *Auklet* | .54 | 6,068,291 | 3.3 |
| 11- 7-75 | George Inlet | 1 | *Kittiwake* | .26 | 846,758 | .37 |
| 11- 7-75 | George Inlet | 2 | *Kittiwake* | .17 | 846,758 | .23 |
| 11-17-75 | Tongass Narrows | 1 | *Auklet* | 1.0 | 996,816 | 1.0 |
| 11-17-75 | Tonagss Narrows | 2 | *Auklet* | .34 | 996,816 | .3 |
| 11-19-75 | George Inlet | 1 | *Auklet* | 5.06 | 428,738 | 2.2 |
| 11-19-75 | George Inlet | 2 | *Auklet* | 5.04 | 428,738 | 2.2 |
| 11-21-75 | Deer Island | 1 | *Kittiwake* | .28 | 3,301,283 | 1.5 |
| 11-21-75 | Deer Island | 2 | *Kittiwake* | .33 | 3,301,283 | 1.8 |
| 11-22-75 | Anita Bay | 1 | *Kittiwake* | .95 | 7,202,798 | 11.5 |
| 11-22-75 | Anita Bay | 2 | *Kittiwake* | 1.20 | 7,202,798 | 14.3 |
| 12-11-75 | Stag Bay | 1 | *Kittiwake* | 3.04 | 1,500,000 | 4.7 |
| 12-11-75 | Stag Bay | 2 | *Kittiwake* | .22 | 1,500,000 | .3 |
| 12-11-75 | Stag Bay | 3 | *Kittiwake* | .40 | 1,500,000 | .61 |
| 12-16-75 | Katlian Bay | 1 | *Kittiwake* | 1.07 | 3,322,719 | 6.0 |
| 12-17-75 | Anita Bay | 1 | *Sundance* | NOT ANALYZABLE | | |
| 12-17-75 | Anita Bay | 2 | *Sundance* | " | " | |
| 12-18-75 | Deer Island | 1 | *Sundance* | " | " | |
| 12-18-75 | Deer Island | 2 | *Sundance* | " | " | |
| 12-18-75 | Deer Island | 3 | *Sundance* | " | " | |
| 1- 9-76 | George Inlet | 1 | *Sundance* | " | " | |
| 1-22-76 | Fritz Cove | 1 | *Cobb* | 1.8 | 4,373,127 | 7.9 |
| 1-22-76 | Fritz Cove | 2 | *Cobb* | 2.2 | 3,376,311 | 7.4 |
| 1-25-76 | Katlian Bay | 1 | *Kittiwake* | .6 | 4,823,303 | 4.8 |
| 1-27-76 | Katlian Bay | 1 | *Kittiwake* | .2 | 5,252,040 | 1.8 |
| 1-29-76 | Scow Bay | 1 | *Auklet* | .1 | 3,400,000 | 0.34 |
| 2- 5-76 | Auke Bay | 1 | *Kittiwake* | 3.6 | 2,529,554 | 9.1 |
| 2- 5-76 | Bocas de Finas | 1 | *Cobb* | NOT ANALYZABLE | | |
| 2- 5-76 | Bocas de Finas | 2 | *Cobb* | .64 | 15,606,063 | 10.0 |
| 2- 6-76 | Bocas de Finas | 1 | *Cobb* | 1.46 | 10,064,124 | 14.7 |
| 2- 6-76 | El Capitan | 1 | *Cobb* | .32 | 2,036,505 | .7 |
| 2- 6-76 | El Capitan | 2 | *Cobb* | .39 | 2,036,505 | .8 |
| 2-12-76 | Kassan Bay | 1 | *Sundance* | 1.1 | 2,829,670 | 3.1 |
| 2-12-76 | Kassan Bay | 2 | *Sundance* | 1.4 | 2,829,670 | 4.0 |
| 2-12-76 | Katlian Bay | 1 | *Kittiwake* | .9 | 4,608,934 | 4.1 |
| 2-12-76 | Katlian Bay | 2 | *Kittiwake* | 1.1 | 4,608,934 | 5.1 |
| 2-27-76 | Katlian Bay | 1 | *Kittiwake* | 1.26 | 4,073,011 | 5.1 |
| 3- 3-76 | Green Island | 1 | *Montague* | 1.66 | 13,290,878 | 22.1 |
| 3- 4-76 | Green Island | 1 | *Montague* | 2.05 | 10,289,712 | 21.1 |

Table 1. Summary of herring hydroacoustical estimates made in Alaska during 1975-76 - Continued

| Date | Location | Run | Vessel | Density lbs/m$^2$ | Area m$^2$ | Biomass $10^6$ lbs |
|---|---|---|---|---|---|---|
| 3-17-76 | Kassan Bay | 1 | *Sundance* | .10 | 1,339,806 | .1 |
| 3-17-76 | Kassan Bay | 2 | *Sundance* | .12 | 1,822,136 | .2 |
| 3-25-76 | Nak. - Katlian | 1 | *Kittiwake* | .75 | 7,610,099 | 5.7 |
| 3-27-76 | Cascade Inlet | 1 | *Auklet* | 2.0 | 1,886,447 | 3.8 |
| 3-26-76 | Katlian Bay | 1 | *Kittiwake* | 1.47 | 900,349 | 1.3 |
| 3-26-76 | Katlian Bay | 2 | *Kittiwake* | 5.7 | 1,457,709 | 8.3 |
| 3-31-76 | Old Sitka Rocks | 1 | *Kittiwake* | 2.44 | 6,002,332 | 14.6 |
| 4- 1-76 | Old Sitka Rocks | 1 | *Kittiwake* | 1.2 | 6,002,332 | 7.2 |
| 4- 7-76 | Old Sitka Rocks | 1 | *Auklet* | 1.0 | 7,631,536 | 7.6 |
| 4- 7-76 | Lynn Canal | 1 | *Searcher* | 1.46 | 4,480,000 | 6.5 |
| 4-12-76 | Lynn Canal | 1 | *Kittiwake* | 2.42 | 4,480,000 | 10.8 |
| 4-14-76 | Lynn Canal | 1 | *Murre II* | 6.70 | 568,077 | 3.8 |
| 4-19-76 | Lynn Canal | 1 | *Kittiwake* | 1.90 | 4,480,000 | 8.5 |

APPENDIX

# A NEW DIGITAL HYDROACOUSTIC DATA PROCESSOR AND SOME OBSERVATIONS ON HERRING IN ALASKA

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## ABSTRACT

A new hydroacoustic data processor using a PDP 11/45 computer was developed and applied to some herring studies in southeastern Alaska. The new processor allows for analysis of up to 50 different depth intervals, has a threshold to eliminate noise, and has greater dynamic range than any previous hydroacoustic data processor.

The new system was used to analyze some data previously recorded on analog magnetic tape, including a series of 20 replicate hydroacoustic surveys over a 4-day period in Carroll Inlet. Comparisons were made with an earlier model digital integrator and with results of CRT measurements. The results of replicate surveys and comparisons between different areas demonstrated that the distributional characteristics of the herring can greatly affect the results of hydroacoustic surveys.

# A NEW DIGITAL HYDROACOUSTIC DATA PROCESSOR AND SOME OBSERVATIONS ON HERRING IN ALASKA[1]

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## INTRODUCTION

The last few years have seen considerable increase in the use of hydroacoustic techniques for fish population assessment, because of their powerful sampling capability and potential for real time estimates independent of fishery catch statistics. In particular, principles of echo integration have been applied in several fisheries surveys throughout the world (Thorne, 1973a, Johannesson and Robles, in press; Parrish, 1975). On the basis of experience with analog echo integrator systems, a digital integration system was developed and applied to population studies of Pacific hake in 1971 (Thorne, 1973b). This system, called DDAPS, was based on a PDP-8L computer. While DDAPS was a considerable improvement over previous analog systems in dynamic range, stability and versatility, it lacked the power needed for detailed environmental studies or more advanced processing techniques. This paper describes some studies on herring stocks in southeastern Alaska using a larger digital system based on a PDP 11/45 computer. Although the primary incentive for the development of the new system was the extensive processing needs of a coastal upwelling ecosystem study (Thorne et al.,

[1]Contribution No. , College of Fisheries, University of Washington, Seattle, Washington.

in press), the new processor has considerable potential for fishery resource assessment and has been adapted by the U.S. National Marine Fisheries Service for resource studies in the northeastern Pacific Ocean.

## MATERIALS AND METHODS

### The Digital Hydroacoustic Data Processor

The new system, as well as DDAPS, was designed to process hydroacoustic data either in real time or from analog magnetic tape from either one or two echo sounders. The system consists of three major sections: signal conditioning electronics, analog to digital converter section, and the central processor. The signal conditioning electronics change the signal from the echo sounders into a format suitable for the A-D converter section. The signal is first amplified to optimally match the dynamic range of the processor. The amplified signal is then detected and low-pass filtered. The cut-off frequency of the low-pass filter is selected to correspond to the length of the transmitted pulse of the echo sounder.

The analog to digital converter section consists of an eight channel multiplex, a 12-bit A-D converter, a programmable clock, two external event inputs, and the computer interface. The section allows sampling of up to eight input signals under program control, at a program selectable rate with an upper limit of 50 kHz.

The central processor is a Digital Equipment Corporation PDP 11/45 with floating point processor, 24 K memory, two 1.2 M word disk drivers, and various input-output devices including card reader, line printer, and teletypes. The primary program is an echo integration program written in machine language in which the acoustic signals are squared and integrated in user-selected depth and time intervals, and corresponding fish densities are calculated from input calibration and target strength information. Squaring is accomplished in software rather than in a hardwired multiplier as in DDAPS. The densities are both printed out and stored on disk for further manipulation. Initial input is provided by answering a series of 7 questions from the computer as shown in Fig. 1. The duration of the run is set by the number of pings in question 1, although the run may be terminated at any time by setting a sense switch. Question 2 allows for comment. If all input constant factors in the program are set to unity, the output of the system will be the average squared voltage of the input. The normalizing constant in question 3 is the factor required to convert this value to fish density, and is based on the target strength and acoustic system parameters (source level, gain, and transducer directivity and receiving response). Question 4 provides for a gate-type threshold to eliminate unwanted noise. Question 5 provides the depth intervals and range corrections. Up to 50 continuous intervals may be incorporated, as compared to 9 for DDAPS. The range corrections compensate for deviations from the required $20 \log R + 2\alpha R$ depth function. Question 6 provides input for the bottom tracking routine and is the height above the previous bottom depth where the integration of the signal will terminate. The restriction for the tracking routine is that the bottom depth must not change more than this buffer value between successive pings. Information on the position of the bottom signal can be provided by a white-

-line signal, by a manually positioned signal, or by the bottom signal itself if sufficiently large and discernible from other signals. Question 7 provides the initial position to start the tracking routine.

Example outputs are shown in Fig. 2. Each output includes the number of pings in the run, an information line documenting the time, threshold, and normalizing constant values, and the densities and proportions sampled for each interval. The proportion sampled is less than 1.0 if the bottom intrudes into the interval.

Major improvements over DDAPS are the greater number of depth intervals, the threshold feature and greater dynamic range. The PDP 11/45 and A-D converter have a dynamic range of 66 dB, compared with 38 dB for DDAPS. Presently the system is limited by the dynamic range of the signal conditioning electronics rather than the computer itself. A comparison of input versus output voltage for the entire system for a 5 kHz input signal is shown in Fig. 3.

The other major advantage is the increased flexibility and versatility possible due to the greater storage and processing power. The echo integration processing can operate in foreground, while a second program can be run in background. The system will be capable of simultaneous echo integration and target strength measurements, and the ability of the computer to access data files stored on disk makes possible further reduction and manipulation of the data using FORTRAN language programs.

## General Survey and Analysis Procedures for Herring in Southeastern Alaska

Acoustic surveys of overwintering stocks of herring in southeastern Alaska were initiated in 1970. A data acquisition system was developed which consisted of a 105 kHz Ross 200A Fineline Echosounder modified for collection of data on analog magnetic tape. Details of the system are given in Thorne, Nunnallee, and Green 1972. A 7.5° transducer was hull-mounted on the RV KITTYWAKE of the Alaska Department of Fish and Game. Survey procedures usually consisted of defining an area containing the fish school or stock of interest on the basis of previous experience or preliminary search, then running a series of oblique transects spaced evenly over the area. An example of a survey track in Carroll Inlet near Ketchikan, Alaska, is given in Fig. 4.

Initially, data analysis consisted of visual observations with an oscilloscope (CRT). The average amplitude of echoes from a school and the size of the school were measured (Thorne, in press). Digital echo integration was first applied on part of the data in 1972 and has been used exclusively since 1974, with the new digital processing system superseding DDAPS in 1975.

## Selection of Data for Evaluation of the New Digital Processing System

Sampling problems have been a major concern for the hydroacoustic surveys in Alaska. In order to examine the extent of these problems, a series of 20 replicate surveys over a 4-day period were conducted in December 1972 on the overwintering herring population in Carroll Inlet. The annual commercial harvest on this stock averaged about 7,000 metric tons over the 8 years prior to the surveys. Ten of these surveys were analyzed in 1973 by CRT, and 7 of these 10 were also analyzed by DDAPS. Since the replication experiment had been partly analyzed, the entire series was selected for evaluation of the new digital processing system. An additional 7 surveys which were run in Carroll Inlet later that winter were also included in the analysis. Five of these had previously been analyzed by CRT. In addition, 4 surveys conducted in December 1972 at Bocas de Finas, west of Prince of Wales Island, were reanalyzed. The Bocas de Finas surveys, previously analyzed by CRT, had resulted in the largest population estimates in southeastern Alaska during that year. The herring stock at Bocas de Finas provided an interesting contrast as they were distributed in an extensive layer rather than a school.

Procedures for Analysis with the New Digital Processing System

Echo integration and corresponding fish density estimates were made within a format which consisted of 10 m intervals from 10 to 150 m and 5 min durations. The estimates were based on a target strength assumption of -33dB/kg, which is presently used for herring surveys in both Puget Sound and Alaska with the 105 kHz system and 7 1/2° transducer. This value was originally determined indirectly by comparisons with net catches in 1972, but has provided reasonable agreement with catch and spawning ground estimates as well as the initial results with the newly developed dual beam target strength measuring system (Ehrenberg, 1974).

After the basic analysis, the data were further treated by a program which summed the densities over the depth intervals to obtain an average density per unit surface area for each survey. These values were multiplied by the surface areas involved in the surveys to obtain the population estimates.

## RESULTS AND DISCUSSION

The results of the 27 surveys in Carroll Inlet are shown in Table 1. There was considerable variation among the surveys, which is not surprising considering the short duration of the runs (average 26 min) and the nature of the distribution. Some of the variation results from changes in distribution relative to the survey area. Both nights in December, the school divided into at least 2 parts. Three of the night surveys on December 14 were run on only 1 of these schools. On at least 3 other occasions the survey area excluded a significant portion of the population. However, even neglecting these 6 runs, the standard deviation of the observations was 67% of the mean in December and 52% of the mean in February. The mean in February was about twice as high as in December, and probably represents a real increase as further recruitment into the area is expected in that time period. The diel changes in distribution were dramatic, as illustrated in Figs. 5-8. Figs. 5 and 6 show echogram and corresponding vertical density profiles from three crossings of the school during run 4 on the day of February 1. The fish are stratified between 80 and 120 m with a peak of about 100 m. Figures 7 and 8 illustrate similar stratification at night in December, but with peak abundance at about 40 m. The densities are lower at night, but the horizontal extent is greater. The echogram in Fig. 7 also illustrates a strong shoreward bias which is commonly observed at night at Carroll Inlet as well as other locations in southeastern Alaska (Thorne, in press). The lower estimates at night could be explained by distribution too nearshore to be included in the boundaries of the survey.

Figure 7 shows the comparison with the 7 estimates from Carroll Inlet in December, which were made previously with DDAPS. Both systems are referenced to the -33dB/kg target strength assumption. The agreement is extremely good. The mean of the 7 runs was $0.57 \times 10^6$ kg from the 11/45, $0.54 \times 10^6$ kg from DDPAS. The largest component of variability is probably associated with bottom tracking, which was done manually in both cases.

The comparison between the 16 estimates from the PDP 11/45 system and corresponding CRT estimates for Carroll Inlet, December and February, are shown in Fig. 10. Seven of the series include 2 CRT estimates from different readers. The agreement is not particularly good. The CRT method has considerable variability, and biases in reading may even result in non-linearity. The problems of deriving the population estimate from visually estimated amplitudes is compounded by the fact that the density is related to the squared amplitude (Forbes and Nakken 1972, Ehrenberg and Lytle 1972). Thus bias is associated with attempting to estimate the average squared amplitude from estimates of the average amplitude, and errors in reading are squared. The results of the comparison confirm our suspicion that the CRT method is not sufficiently accurate, which was the reason for the initial change to DDAPS in 1972.

An echogram and vertical density profile from Bocas de Finas is shown in Figs. 11 and 12. The depth stratification is even more pronounced than Carroll Inlet and the horizontal extent is much greater. The more uniform distribution is reflected in the results of the population estimates given in Table 2. The 4 runs were in much better agreement than for Carroll Inlet, with the standard deviation of the 4 observations only 17% of the mean. The corresponding CRT estimates were 25% higher with a standard deviation 35% of the mean.

## CONCLUSIONS

The most apparent advantage of the PDP 11/45 system over DDAPS in this study was the ability to access the data files on disk for rapid data reduction. The greater dynamic range is less important for tape recorded data, since optimal amplification can be set from a knowledge of the recorded levels, and even DDAPS is as good as most analog recorders in dynamic range. Similarly, the detailed information on vertical distributions and diel variations is very interesting from behavioral and ecological aspects, but unimportant for total stock assessment of a single species population. Nevertheless, the capability of the system is clearly demonstrated even for the specific requirements of herring stock assessment. There are presently six acoustic systems which collect data on herring in Washington and Alaska, often with requirements for data analysis within 24 hours, so the greater storage and processing capability is a significant advantage.

Analog data recording is practical for the herring surveys which are typically short duration on inside waters. The advantages of the PDP 11/45 system are more apparent when considering the complex processing requirements of major offshore resource assessment surveys. Simultaneous echo integration and target strength measurement are virtually a necessity in the typical multispecies marine environment. The capability for additional programs, such as readily incorporating trawl data or even historical records in order to partition abundance by species, provides a processing ability previously unavailable in resource assessment research.


## ACKNOWLEDGMENTS

The development of the new digital hydroacoustic data processing system was primarily supported by Grant GX 33502 of the U.S. National Science Foundation as part of the IDOE Coastal Upwelling Ecosystem Analysis (CUEA) Program. Additional support was provided by the Washington Sea Grant Program under the U.S. National Oceanic and Atmospheric Administration, Department of Commerce. Mr. James H. Green of the University of Washington Applied Physics Laboratory was the primary designer of the system.

The surveys in southeastern Alaska were conducted and supported by the State of Alaska Department of Fish and Game. Special thanks are due the ADF&G biologists who aided in the data collection, especially Stan Moberly, the herring project leader, and also to the crew of the RV KITTIWAKE.

REFERENCES

Ehrenberg, J. 1974. Two applications for a dual-beam transducer in hydroacoustic fish assessment systems. Proc. 1974 IEEE Conf. on Eng. in the Ocean Environ. 1:152-155.

Ehrenberg, J., and D. Lytle. 1972. Acoustic techniques for estimating fish abundance. IEEE Trans. Vol. GE-10, pp. 138-145.

Forbes, S., and O. Nakken. 1972. Manual of methods for fisheries resource survey and appraisal. Part 2. The use of acoustic instruments for fish detection and abundance estimation. FAO (Food Agr. Organ. U. N.), Rome. 138 pp.

Johannesson, K., and O. Losse. [In press]. Some results of observed abundance estimations in several UNDP/FAO resource survey projects. Cons. Perma. Int. Explor. Mer, Rapp. et Proc.-Verb. Réun., Vol. 170.

Parrish, B. 1975. Progress report of ACMRR ad hoc group of experts on the facilitation of acoustics research. FAO Fish. Circ. 324. 20 pp.

Thorne, R. 1973. Application of acoustics to the assessment of the Pacific hake population in Port Susan, Washington, 1969-1973. Proc. 1973 IEEE Conf. on Eng. in the Ocean Environ. 1:249-252.

Thorne, R. 1973. Digital hydroacoustic data-processing system and its application to Pacific hake stock assessment in Port Susan, Washington. NOAA Fish. Bull. 71:837-843.

Thorne, R. [In press]. Acoustic assessment of Pacific hake and herring stocks in Puget Sound and Southeastern Alaska. Cons. Perma. Int. Explor. Mer, Rapp. et Proc.-Verb. Réun., Vol. 170.

Thorne, R., E. Nunnallee, and J. Green. 1972. A portable hydroacoustic data acquisition system for fish stock assessment. Washington Sea Grant Publ. (72-4):15 pp.

Thorne, R., O. Mathisen, R. Trumble, and M. Blackburn. [In press]. Distribution and abundance of pelagic fish off Spanish Sahara during CUEA Expedition JOINT I. Deep Sea Res.

# LIST OF TABLES

Table 1. Results of acoustic surveys in Carroll Inlet

| Date | Run | Starting time | Area ($10^3 m^2$) | Biomass ($10^6 kg$) | Comment |
|---|---|---|---|---|---|
| 12/13/72 | 1 | 1400 | 892 | 1.19 | |
| | 2 | 1419 | 892 | 0.54 | |
| | 3 | 1445 | 892 | 0.27 | |
| | 4 | 1620 | 892 | 0.09 | |
| | 5 | 1731 | 893 | 0.48 | |
| | 6 | 1818 | 1303 | 0.88 | School dividing |
| | 7 | 1847 | 995 | 0.25 | |
| 12/14/72 | 8 | 1755 | 823 | 0.05 | Missed main body |
| | 9 | 2139 | 1475 | 0.39 | 2 separate schools |
| | 10 | 2243 | 412 | 0.10 | Surveying only 1 school |
| | 11 | 2304 | 412 | 0.05 | " " " " |
| | 12 | 2333 | 617 | 0.25 | " " " " |
| 12/16/72 | 13 | 1259 | 652 | 0.08 | Missed main body |
| | 14 | 1320 | 652 | 0.02 | " " " |
| | 15 | 1425 | 1406 | 1.17 | |
| | 16 | 1458 | 1406 | 0.44 | |
| | 17 | 1532 | 1406 | 1.94 | |
| | 18 | 1605 | 1441 | 0.87 | |
| | 19 | 1633 | 1441 | 1.05 | |
| | 20 | 1702 | 1441 | 0.72 | |
| 2/1/73 | 1 | 1508 | 1269 | 0.92 | |
| | 2 | 1553 | 995 | 1.91 | |
| | 3 | 1626 | 514 | 1.64 | |
| | 4 | 1639 | 617 | 1.72 | |
| | 5 | 1749 | 480 | 1.18 | |
| 2/2/73 | 6 | 1814 | 515 | 0.73 | |
| | 7 | 1844 | 995 | 0.22 | |

Table 2. Results of acoustic surveys in Bocas de Finas

| Date | Run | Start time | Area ($10^6 m^2$) | Biomass ($10^6 kg$) | Original CRT estimate ($10^6 kg$) |
|---|---|---|---|---|---|
| 12/2/72 | 1 | 1232 | 8.3 | 8.0 | 7.1 |
| | 2 | 1425 | 8.3 | 11.7 | 16.5 |
| 12/3/72 | 3 | 1215 | 7.2 | 10.9 | 15.2 |
| | 4 | 1308 | 7.2 | 8.8 | 10.6 |

LIST OF FIGURES

```
1.   NUMBER OF PINGS ?
 :   600


2.   COMMENT ?
 :    adf bocas de finas - 4 runs


3.   NORMALIZING CONSTANT ?
CHAN 0   :   1

CHAN 1   :   0


4.   THRESHOLD VOLTAGE ?
CHAN 0   :   .07


5.   LIST DEPTHS AND BETA(S)

   D :   50

   D :   60
     BO :   .714

   D :   70
     BO :   .833

   D :   80
     BO :   1

   D :   90
     BO :   1.25

   D :   100
     BO :   1.6

   D :   110
     BO :   2

   D :   120
    BO :   2.6

   D :   130
     BO :   3.3

   D :   140
     BO :   4

   D :   150
     BO :   4.8

   D :   -1


6.   BOTTOM TRACKING BUFFER ?
 :   9


7.   CURRENT BOTTOM DEPTH ?
 :   159
```

Fig. 1. Example of the input format for the PDP 11/45 hydroacoustic data processor.

```
-1      8,      15:54:23     1,0, 0.100E 01, 0.000E 00, 0.700E-01, 0.000E 00
 P =    600                     CHAN # 0                      CHAN # 1
  50.0-    60.0              0.000E 00    1.000
  60.0 -    70.0              0.421E-06    1.000
  70.0 -    80.0              0.169E-05    0.951
  80.0 -    90.0              0.452E-04    0.842
  90.0 -   100.0              0.414E 00    0.744
 100.0 -   110.0              0.468E 00    0.635
 110.0 -   120.0              0.404E-02    0.599
 120.0 -   130.0              0.799E-03    0.459
 130.0 -   140.0              0.428E-03    0.185
 140.0 -   150.0              0.000E 00    0.000

-1     9,     15:59:22     1,0, 0.100E 01, 0.000E 00, 0.700E-01, 0.000E 00
 P =    600                     CHAN # 0                      CHAN # 1
  50.0 -    60.0              0.521E-06    1.000
  60.0 -    70.0              0.000E 00    0.953
  70.0 -    80.0              0.335E-06    0.839
  80.0 -    90.0              0.245E-04    0.761
  90.0 -   100.0              0.252E-03    0.698
 100.0 -   110.0              0.367E-02    0.660
 110.0 -   120.0              0.295E-02    0.622
 120.0 -   130.0              0.935E-03    0.577
 130.0 -   140.0              0.760E-03    0.493
 140.0 -   150.0              0.105E-02    0.193
```

Fig. 2. Example of outputs from the PDP 11/45 system.

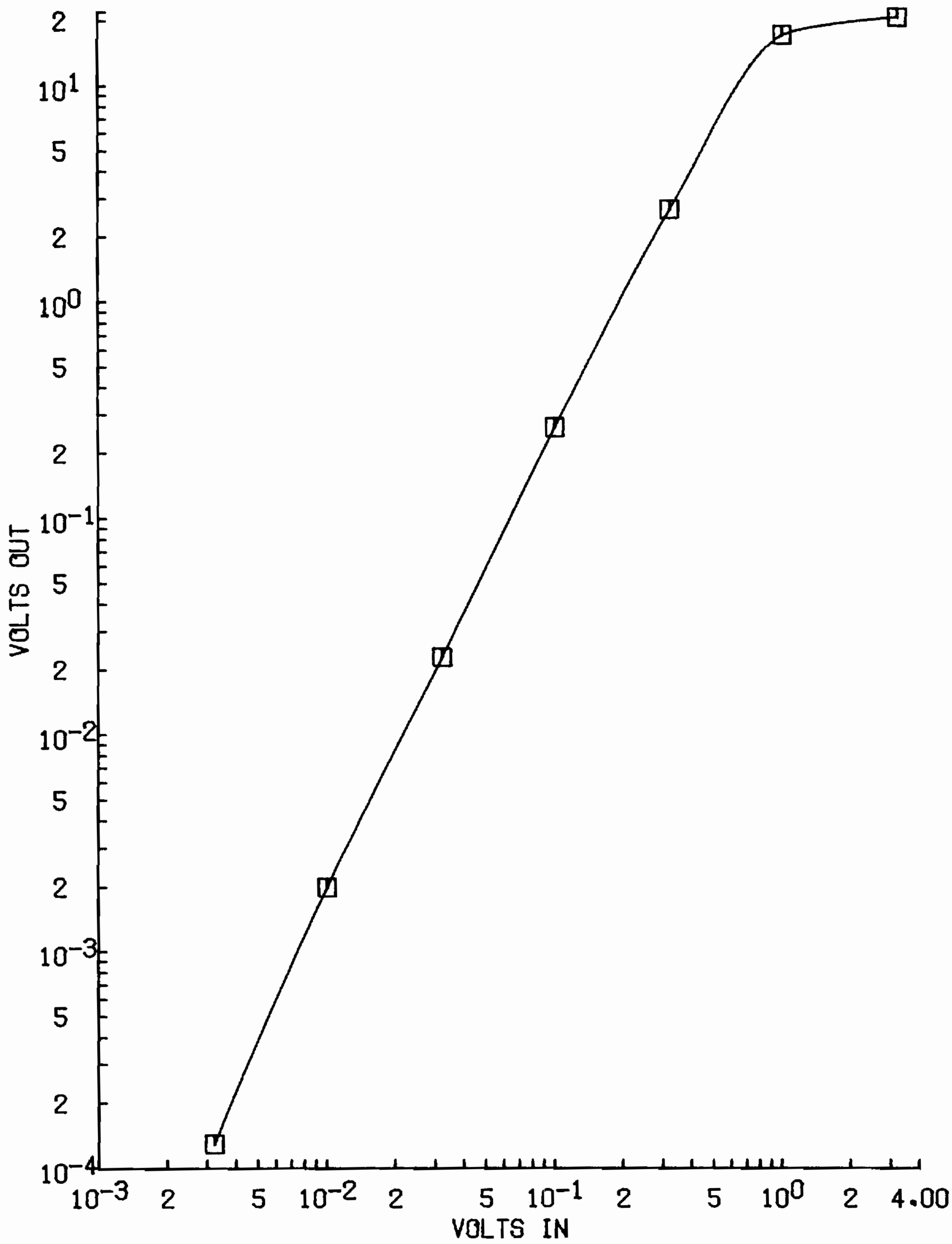


Fig. 3. Relation between input and output voltage for the PDP 11/45 system.

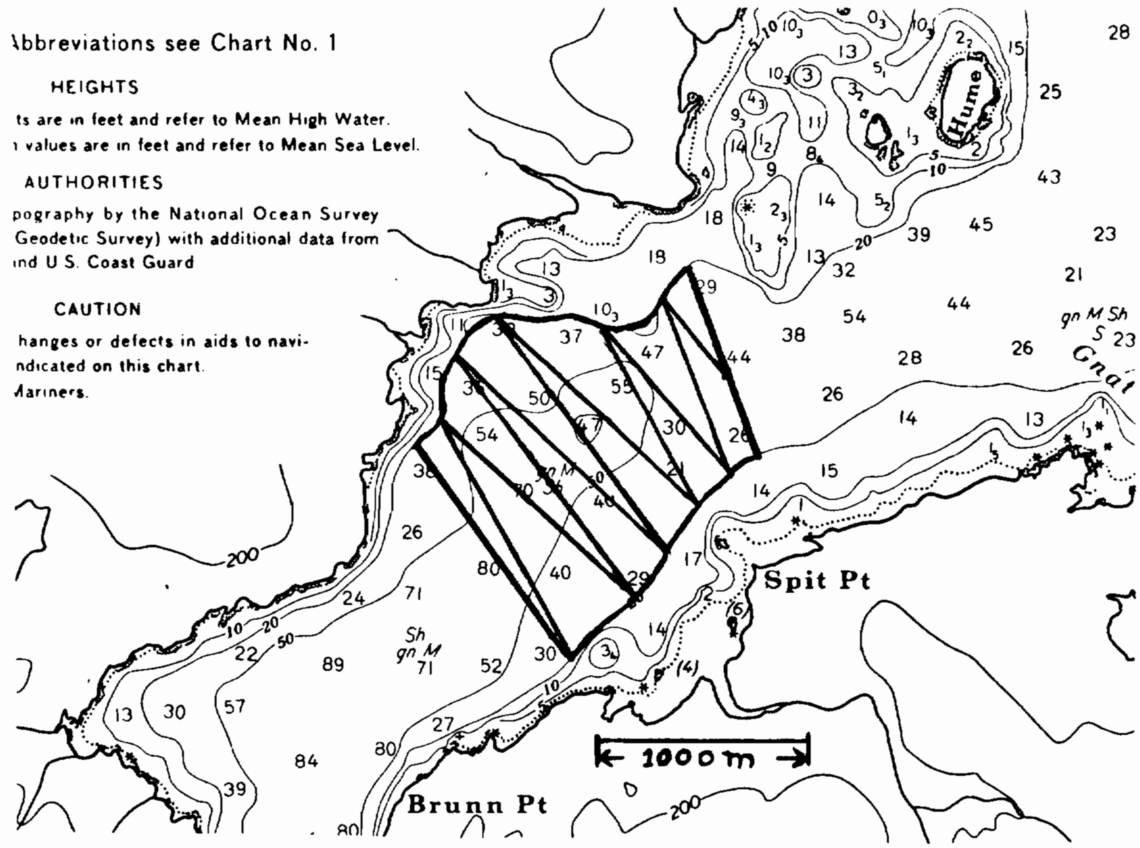


Fig. 4. Example of acoustic survey track in Carroll Inlet.

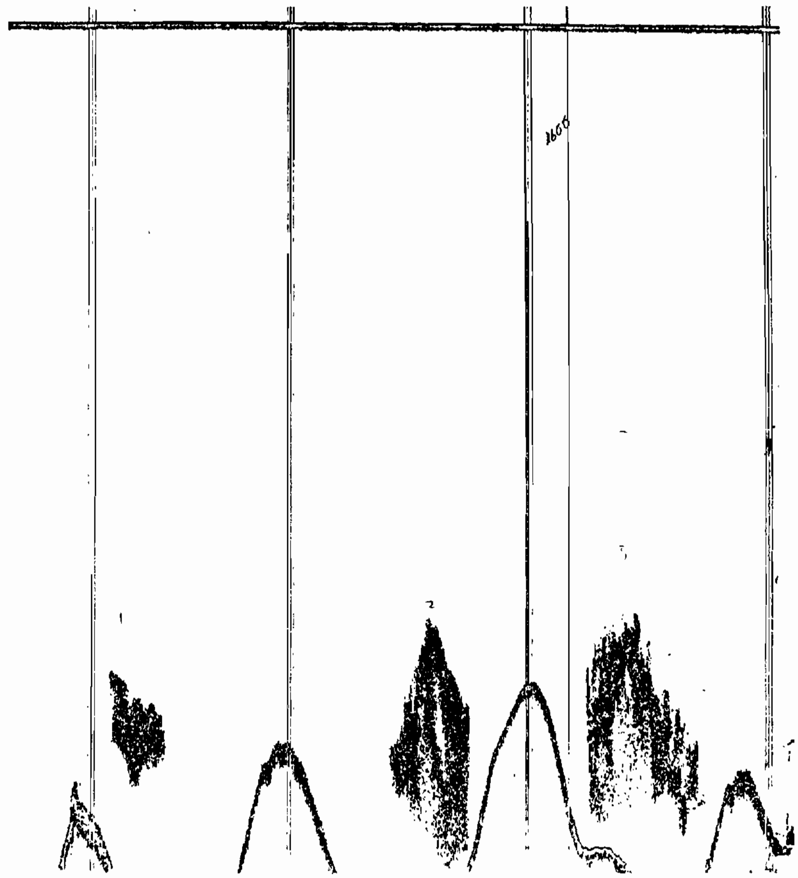


Fig. 5. Echogram from run 4 in Carroll Inlet during day, February 1, 1973 (Scale 0 to 60 fathoms).

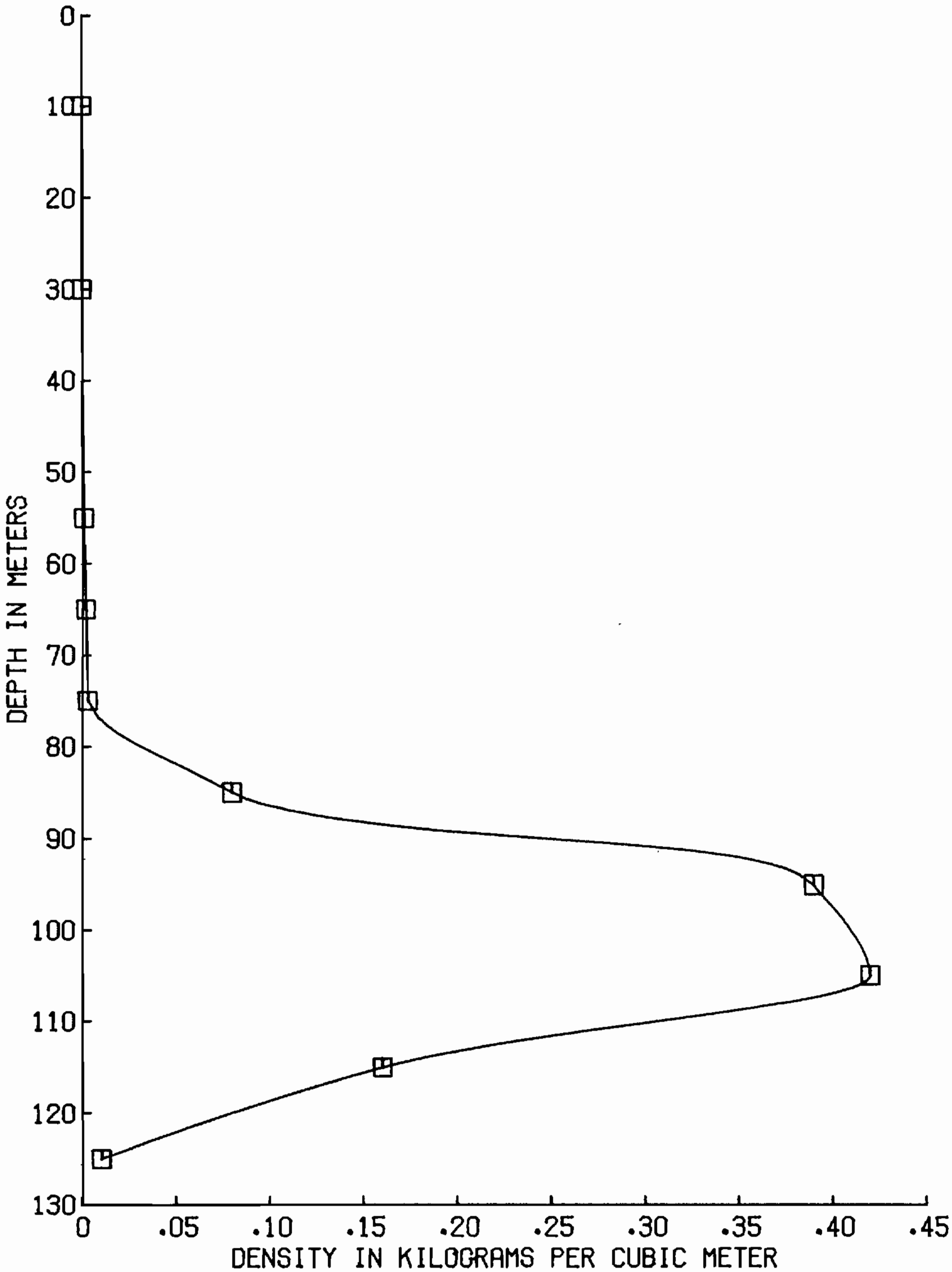


Fig. 6. Vertical density profiles from run 4 in Carroll Inlet during day, February 1, 1973.

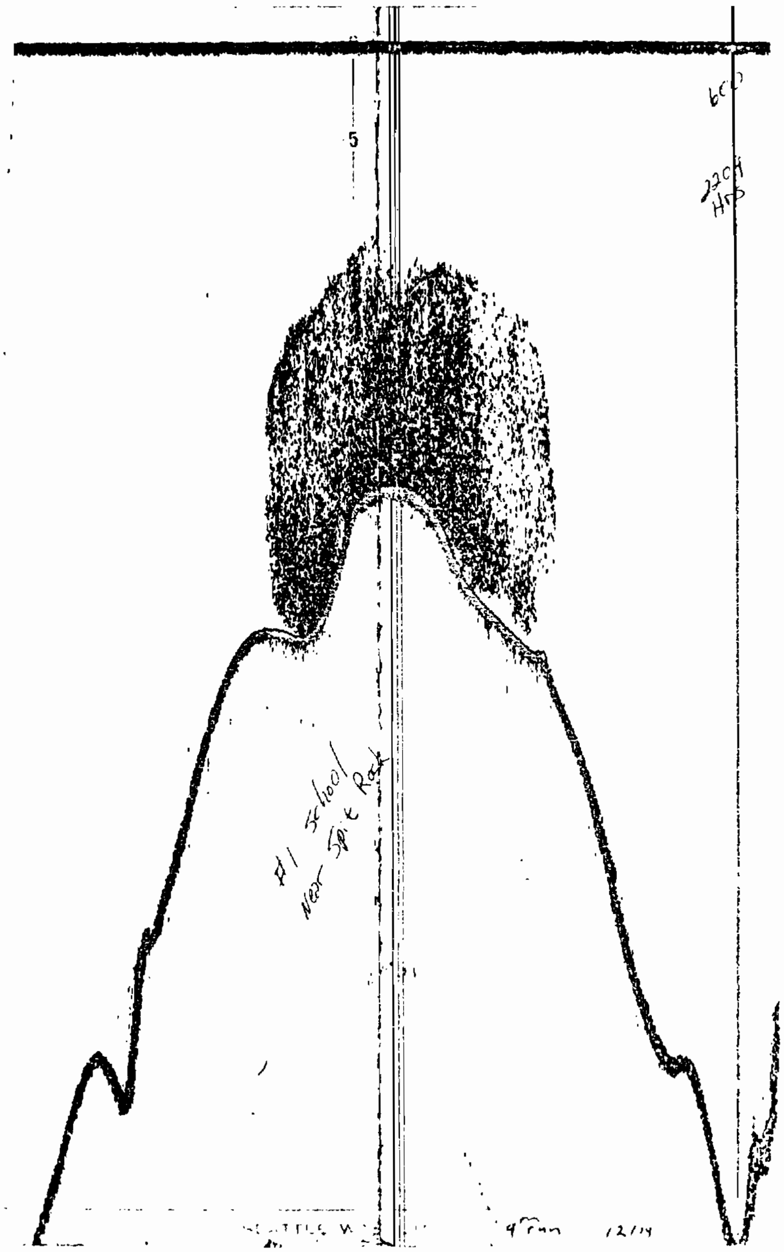


Fig. 7. Echogram from run 9 in Carroll Inlet during night, December 14, 1972 (Scale 0 to 60 fathoms).

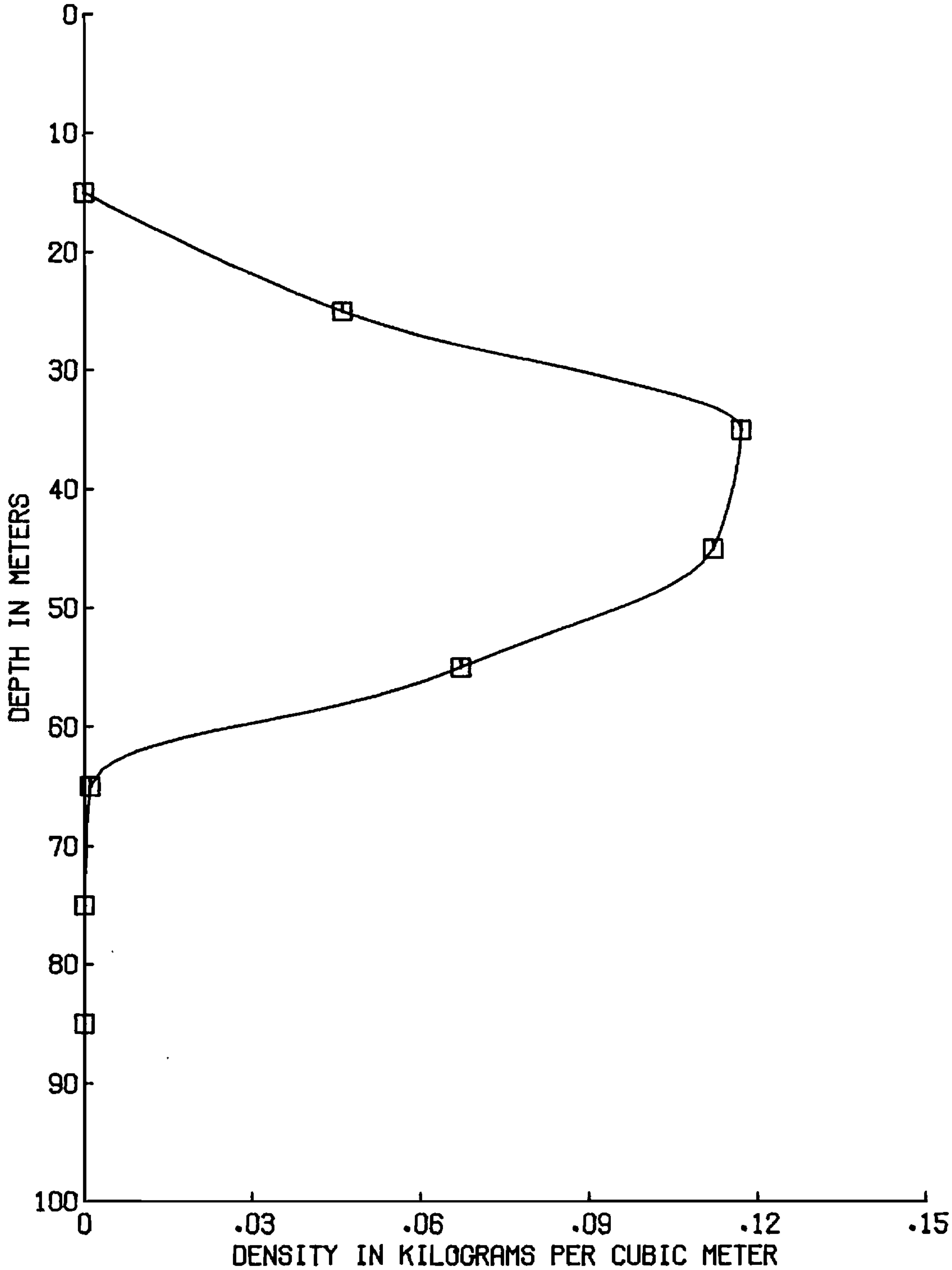


Fig. 8. Vertical density profile for run 9 in Carroll Inlet during night, December 14, 1972.

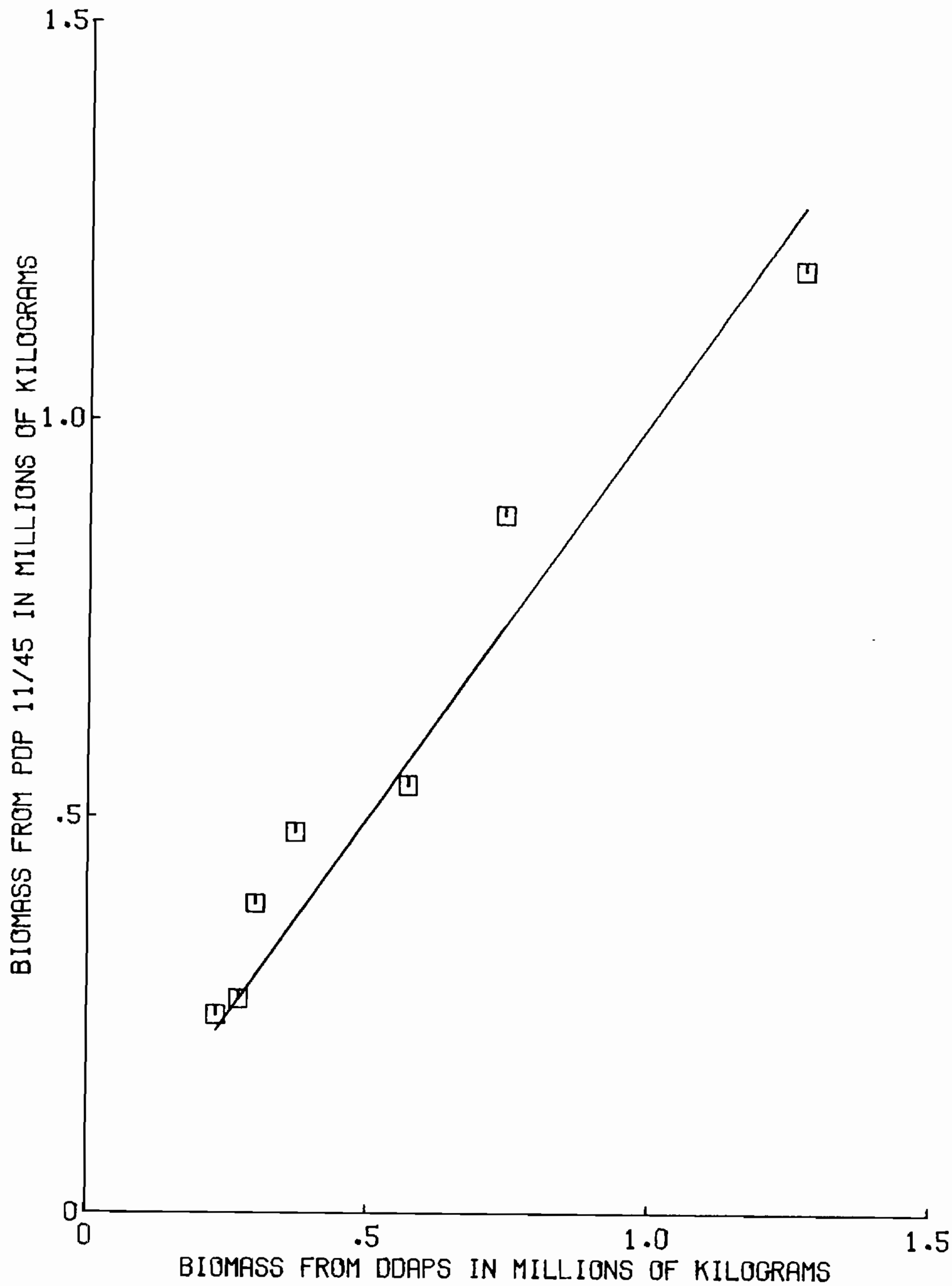


Fig. 9. Comparison between population estimates in Carroll Inlet, December 1972 from DDAPS and PDP 11/45 system.

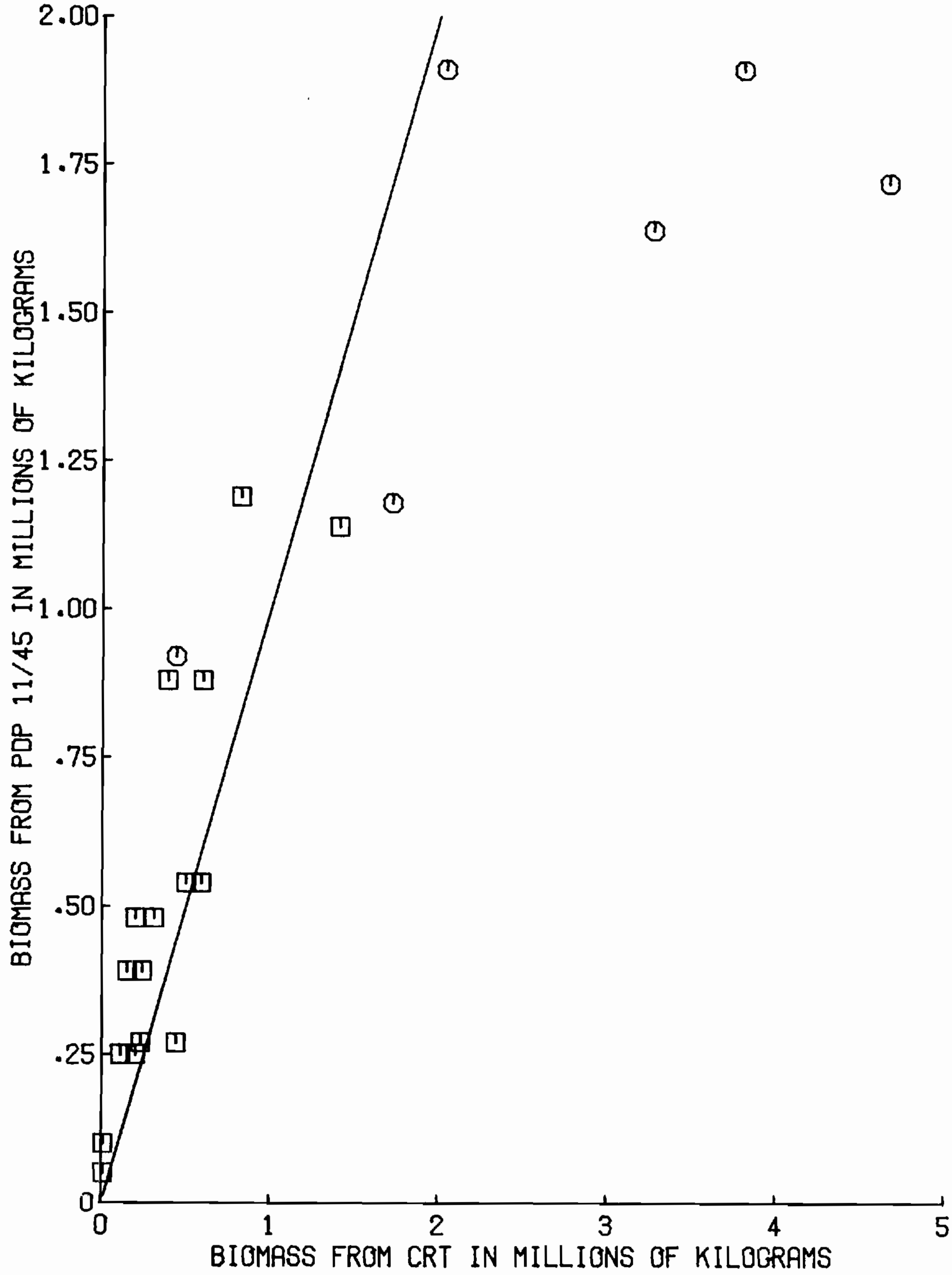


Fig. 10. Comparison between population estimates in Carroll Inlet, December (squares) and February, from CRT and PDP 11/45 system.

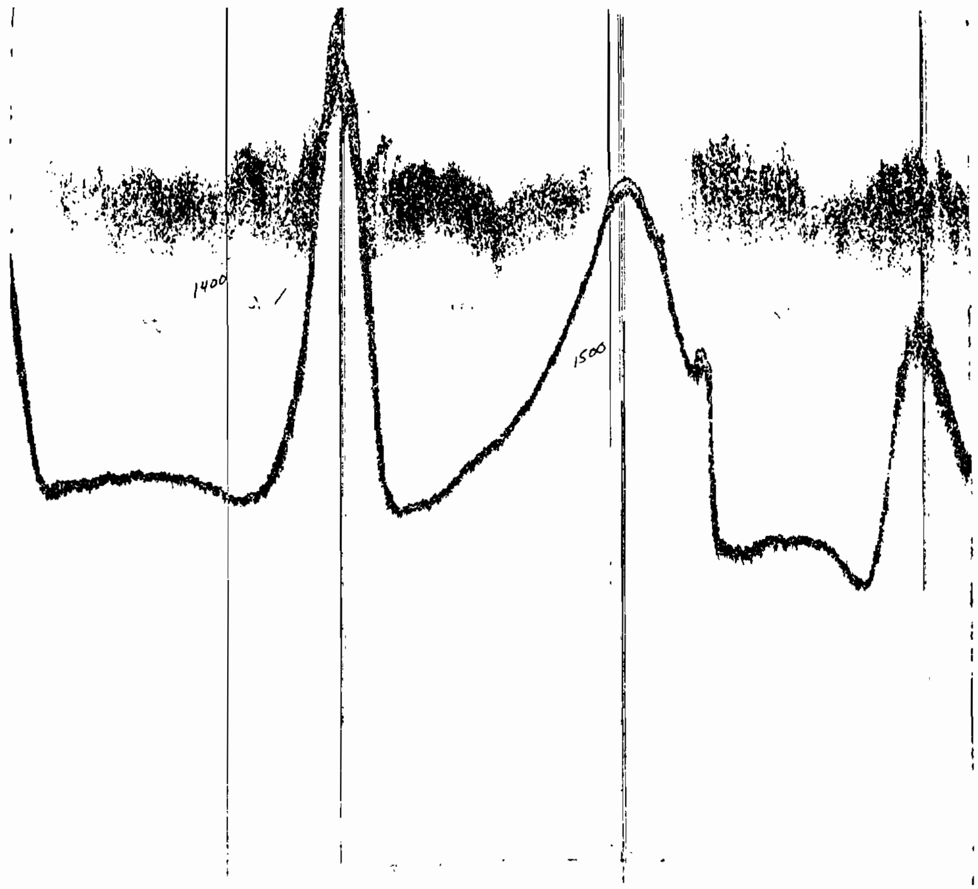


Fig. 11. Echogram from run 3 in Bocas de Finas during day, December 3, 1972 (Scale 50 to 110 fathoms).

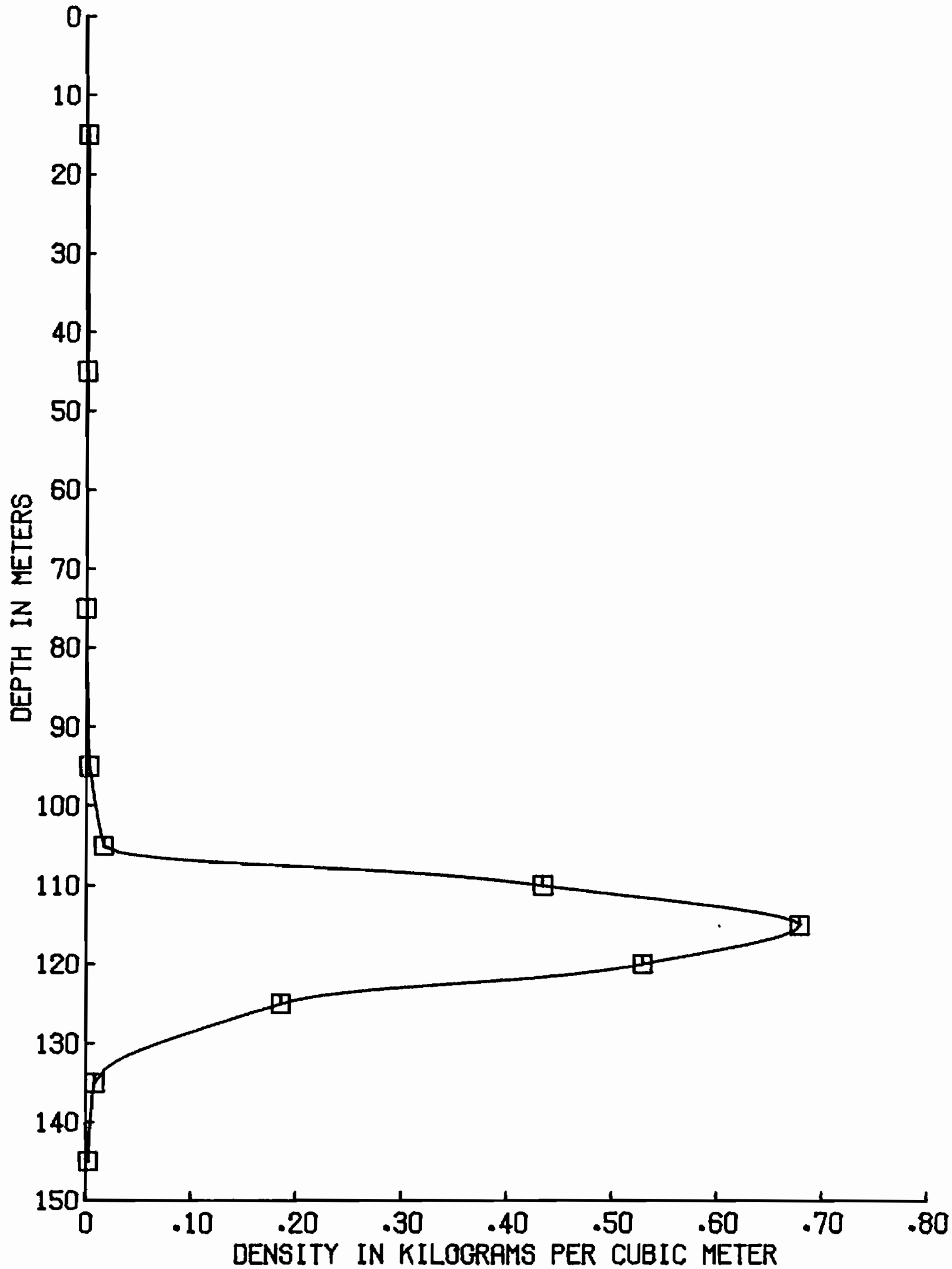


Fig. 12. Vertical density profile from run 3 in Bocas de Finas during day, December 3, 1972.