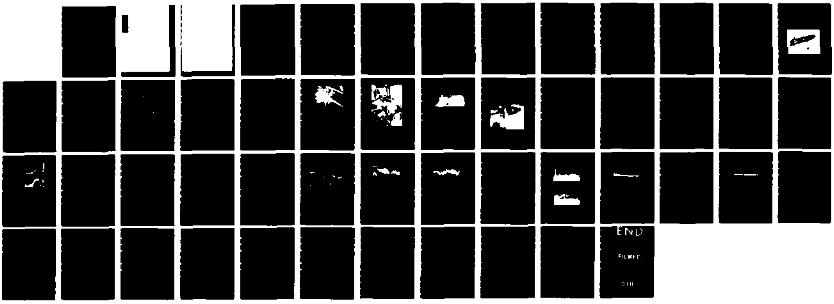
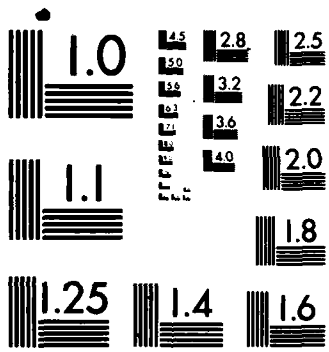
AD-A161 001 HYDROACOUSTIC FISHERY ASSESSMENT TECHNIQUES: A FEASIBILITY STUDY ON THE M... (U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS ENVIR 1/1

UNCLASSIFIED P KANCIRUK ET AL. AUG 85 WES/TR/E-85-10 F/G 8/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A161 001

12

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report E-85-10	2. GOVT ACCESSION NO. AD-A161 001	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HYDROACOUSTIC FISHERY ASSESSMENT TECHNIQUES: A FEASIBILITY STUDY ON THE MISSISSIPPI RIVER		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Paul Kanciruk C. H. Pennington		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Oak Ridge National Laboratory, Oak Ridge, Tennessee, 37830 and US Army Engineer Waterways Experiment Station, Environmental Laboratory, PO Box 631, Vicksburg, Mississippi 39180-0631		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS EWQOS Work Unit VII.B
11. CONTROLLING OFFICE NAME AND ADDRESS DEPARTMENT OF THE ARMY US Army Corps of Engineers Washington, DC 20314-1000		12. REPORT DATE August 1985
		13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) US Army Engineer Waterways Experiment Station Environmental Laboratory PO Box 631, Vicksburg, Mississippi 39180-0631		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Underwater acoustics--Instruments (LC)
Fishery management--Instruments (LC)
Fish detection. (LC)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In the past few years, advances in hydroacoustic fishery assessment techniques have been rapid and significant, and these techniques have been successfully applied to a variety of open-ocean, estuarine, lake, and northwestern-river environments. This study was initiated by the US Army Engineer Waterways Experiment Station to evaluate the usefulness of hydroacoustic techniques in large, alluvial river systems.

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

The lower Cracraft dike field on the lower Mississippi River near the Mississippi, Arkansas, and Louisiana state boundaries was selected as the site for study because it presented a variety of habitats to test the equipment and because its physical and biological characteristics were known.

The hydroacoustic equipment evaluated operated at a frequency of 420 kHz and included down- and side-facing transducers, dual-beam echo integrators, and digital recording equipment operated in mobile and stationary surveys. The equipment was applicable to a variety of habitats and survey objectives. It was found to be reliable, fairly easy to use (with adequate training), and provided information on fish abundance, distribution, and behavior patterns not easily attainable using conventional fishery assessment tools such as netting or electrofishing. The techniques worked well in this riverine environment and were not adversely affected by high turbidity and swift currents common around the dikes. In addition, the hydroacoustic equipment was able to provide information on sediment disturbance due to towboat passage and dredging, and potentially was able to characterize bottom sediment types.

The major technical drawback to hydroacoustic techniques is their inability to identify fish species. Where species identity is essential, this drawback can be overcome by combining hydroacoustics with more traditional assessment tools.

The major difficulties in implementation of hydroacoustics in a fishery assessment program are initial cost and operator training. However, these are balanced by the fact that the usefulness of the data obtained during a fishery survey is much enhanced when combined with hydroacoustic information and that the length of any survey will most likely be shortened (and therefore incur less labor costs) if hydroacoustic methods are employed. The training needed to operate the equipment and analyze the data is therefore justified.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

QUALITY INSPECTED 3

PREFACE

The study described in this report was sponsored by the Office, Chief of Engineers, US Army, under the Environmental and Water Quality Operational Studies (EWQOS) Program, Work Unit VII.B, Waterway Field Studies. The EWQOS Program has been assigned to the US Army Engineer Waterways Experiment Station (WES) under the direction of the Environmental Laboratory (EL). The OCE Technical Monitors for EWQOS were Mr. Earl Eiker, Dr. John Bushman, and Mr. James L. Gottesman.

This report presents results of a study designed to determine the feasibility of using hydroacoustic techniques for fish assessment in a large alluvial river. The study was done in the lower Mississippi River near river mile 506 during September 1983. The work was conducted by the WES and the Environmetrics Group, Oak Ridge National Laboratory (ORNL), under Intra-Army Order No. WESRF 81-95.

The report was prepared by Dr. Paul Kanciruk, ORNL, and Dr. C. H. Pennington, WES, under the supervision of Dr. Thomas D. Wright, Chief, Aquatic Habitat Group; Dr. Conrad J. Kirby, Chief, Environmental Resources Division; Dr. Jerome L. Mahloch, Program Manager, EWQOS; and Dr. John Harrison, Chief, EL. The report was edited by Ms. Jamie W. Leach of the WES Publications and Graphic Arts Division.

Special appreciation is expressed to Mr. Michael Potter, WES, for field support and to Drs. Bill Acker and Tom Carlson, BioSonics, Inc., Seattle, Wash., for their expert technical guidance.

During the preparation of this report, COL Tilford C. Creel, CE, and COL Robert C. Lee, CE, were Commanders and Directors of WES and Mr. F. R. Brown was Technical Director. At the time of publication, COL Allen F. Grum, USA, was Director and Dr. Robert W. Whalin was Technical Director.

This report should be cited as follows:

Kanciruk, P., and Pennington, C. H. 1985. "Hydroacoustic Fishery Assessment Techniques: A Feasibility Study on the Mississippi River," Technical Report E-85-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

CONTENTS

LIST OF FIGURES

HYDROACOUSTIC FISHERY ASSESSMENT TECHNIQUES: A FEASIBILITY STUDY ON THE MISSISSIPPI RIVER

PART I: INTRODUCTION

Rationale for the Study

1. The US Army Corps of Engineers (CE) spends a great deal of effort sampling fish populations in large river systems in order to evaluate impacts due to waterway construction and maintenance activities (A. T. Kearney, Inc. 1980; Upper Mississippi River Basin Commission (UMRBC) 1982). Fish sampling methods such as hoop netting, gill netting, trawling, electroshocking, and rotenoning have traditionally been used to estimate fish populations and fish distribution. Although excellent methods for providing species identification, their ability to quantitatively estimate fish abundance and distribution is questionable, especially in large, warmwater rivers. Recent advances in hydroacoustic equipment and techniques in general (Acker et al. 1975, Thorne 1977, Traynor and Ehrenberg 1979), and specifically riverine techniques (Acker and Hendershot 1982), have established hydroacoustic methods as important augmentation for traditional fish sampling methods. Recent reviews of hydroacoustic methods indicate that they are useful but underused fishery assessment tools (McElroy 1977, Kanciruk 1982).

2. The advantage of hydroacoustic techniques is that they can provide rapid, remote, nondestructive (fish are not handled), quantitative estimates of fish abundance and distribution (usually reported as relative biomass, number, or kilograms/unit volume of water). The main disadvantages are that they provide only inferential information on species identification and most fishery biologists are not trained in their use. However, successful application of hydroacoustic techniques in a variety of environments in recent years (oceans, estuaries, lakes, rivers, and streams) leaves little doubt that hydroacoustic techniques

can frequently provide information unattainable with any other approach.

3. Although hydroacoustic techniques have been applied to salmonids in streams and rivers, particularly in the Pacific Northwest and Alaska (Gaudet 1980; Carlson, Acker, and Gaudet 1981), the use of hydroacoustics to study nonsalmonid populations in large river systems has not been common. The study reported herein was undertaken with the primary objective of determining the role hydroacoustic techniques could play in CE biological surveys in large warmwater rivers.

4. Due to limited resources, it was decided to forego any attempt to "ground truth" the hydroacoustic data using trawls, hoopnets, etc., because it would severely limit the number of habitats sampled and techniques attempted. Additionally this decision was supported by the fact that the biological composition of the Cracraft dike field was well documented by previous studies and the accuracy of hydroacoustic techniques has been repetitively addressed in the literature.

Survey Objectives

5. The overall objective of determining the feasibility of hydroacoustic techniques applied to large river habitats was divided into the following components:

- a. How well could hydroacoustics quantify abundance of fish populations in large, turbid river systems?
- b. How well could this abundance be partitioned vertically, horizontally, and temporally in the environment?
- c. Could the technique be used to describe fish movements?
- d. What was the range of target sizes appropriate for hydroacoustic assessment?
- e. Could hydroacoustic techniques sample habitats such as revetted areas, the shallow areas upstream and downstream of the dikes proper, the deep swift main channel, narrow plunge pools behind the dikes, and brush-strewn channel edges?
- f. Could the equipment be deployed from existing vessels with little modification? Was the equipment reliable under

field conditions? Could it be operated by fisheries biologists with limited hydroacoustic training?

g. Could the economic investment in hydroacoustic equipment be justified?

h. Could hydroacoustics be used for in situ sediment characterization and delineation of towboat and dredge sediment disturbance?

Hydroacoustic Techniques

6. A short review of the principles of hydroacoustic techniques is presented in this section. Those interested in a more complete description should refer to general discussions of fisheries sonar (e.g., Mitson 1983) or reviews specifically focusing on scientific, fishery-assessment hydroacoustic techniques (e.g., Burczynski 1979, Kanciruk 1982).

7. Hydroacoustic techniques exploit the characteristics of sound in water. Sound waves are defined as spreading disturbances in a compressible medium that move in all directions from a source. In water, sound travels at approximately 1,500 m/sec. When sound waves encounter a change in the density of the medium through which they are traveling (such as fishes, the bottom, or air bubbles), they are reflected in all directions. Some energy is reflected back toward the source. This echo indicates that a target(s) exists. The time it takes for the original signal to return to the source from the target provides information on the distance to the target. The direction of the echo's return provides information on the location of the target. The intensity of the returning echo is proportional to target size, target acoustic properties, target orientation, and target position within the acoustic beam. It is these properties of sound in water that allow its use as a biomass estimation technique.

8. Scientific hydroacoustic assessment equipment is only similar to commercial models in that they both employ basic acoustic theory. The difference is that scientific-grade equipment is calibrated,

accurate, and of high resolution whose characteristics are well defined, well controlled, and repeatable between surveys.

9. Hydroacoustic systems consist of a combination of the following equipment:

- a. A transmitter that creates the electronic pulse.
- b. A transducer (mounted through the hull or towed in a fin through the water) which converts the electronic pulses into sound and changes the returning echoes back into electronic signals.
- c. A receiver that times, amplifies, and filters the returning echoes (the transmitter and receiver are usually housed in the same box and called a transceiver or echo sounder).
- d. Display devices such as a paper chart recorder and/or an oscilloscope.
- e. Echo counters and integrators, which quantify the returning echoes into number or biomass of fish per unit volume of water.
- f. Devices to record the data for future reference such as audio or video tape recorders.
- g. A microcomputer for real-time data capture, analysis, and subsequent report generation.

10. Echo counters are used when the density of fish is relatively low. They can be used to estimate number of fishes per unit water volume. When fish densities are great, echo integrators (which integrate the total echo energy) must be used because of the problem of overlapping echoes (Kanciruk 1982). Echo integrators produce biomass estimates in relative biomass units, or in kilograms of fish per unit water volume when target strength-to-biomass values are available or can be calculated from empirical relationships (Love 1971, McCartney and Stubbs 1971). Either instrument can produce estimates partitioned into specified depth intervals (e.g., biomass in the top 10 m, 10 to 20 m, and 20 m to bottom).

11. Processing of hydroacoustic data can occur in real time onboard the vessel, or the signals can be recorded on tape and analyzed on shore. Usually the signals are displayed in real time on an oscilloscope and chart recorder, and are also recorded for detailed analysis at

a later time. Hydroacoustic systems can be relatively simple or complex, depending on the operating environment and survey objectives. Figure 1 shows deployment of hydroacoustic survey equipment from a small survey vessel. In this example, the transducer producing the acoustic signal is being towed alongside the small boat in a fiberglass fin with hydrodynamic properties that give it stability with towing speeds up to 10 knots (5 m/sec). The equipment in the boat consists of a dual-beam transceiver (with signal transmitter and receiver in one package), a dual-beam echo integrator to process the data, an oscilloscope to view the electronic echo, a paper chart recorder to graphically display the echoes, a digitizer and video tape recorder to record the signal for future reference, and a microcomputer for data analysis and storage.

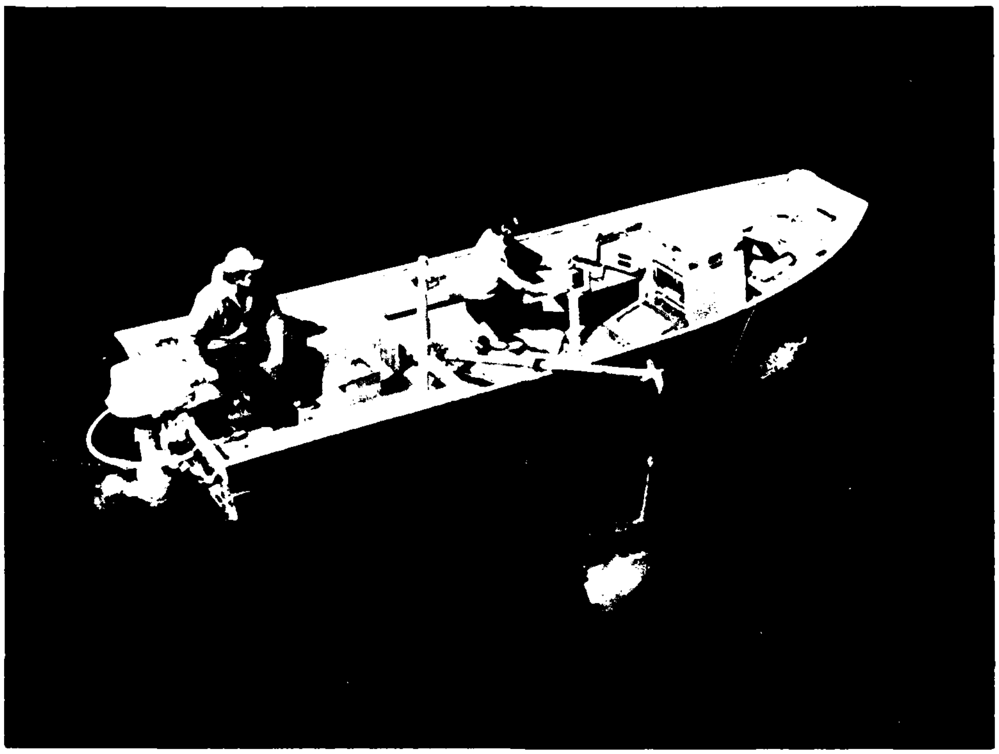


Figure 1. Deployment of hydroacoustic equipment from a small survey vessel. The transducer is mounted in a side-towed fin, the echo sounder and echo integrator are in the equipment box near the bow, the chart recorder is further back, and the oscilloscope and microcomputer are on the table (Source: BioSonics, Seattle, with permission)

12. This equipment is self-contained except for a power supply and is sufficient for data-gathering and data-processing functions. The cost of the above equipment (excluding the vessel) is approximately $70,000 to $80,000.

13. Recent advances in hydroacoustic equipment which make this technique more attractive include:

- a. Use of digital time-varied gain functions.
- b. Computerization and packaging of echo counting and echo integration equipment in small, self-contained portable units.
- c. Use of high-frequency (200 kHz), high-resolution transducers for freshwater surveys.
- d. Perfection of commercial dual-beam systems that allow in situ target strength measurements.
- e. Doppler systems for use in detecting migrating species in shallow waters and debris-clogged streams (Acker and Hendershot 1982).

Most of these advances have occurred in the past 3 years. In all, state-of-the-art hydroacoustic techniques are much improved in performance and convenience from those of only a few years ago. Recent advances make these techniques easier, more flexible, and more reliable to use.

PART II: MATERIALS AND METHODS

Study Site Description

14. The site selected for this feasibility study was the lower Cracraft dike field on the lower Mississippi River (river mile 510, Figure 2). This dike field (near the junction of the Mississippi, Arkansas, and Louisiana state borders) consists of three dikes which project perpendicularly into the river channel for 0.5 to 1 km. The dikes are completely submerged during high water and exposed during low water. In addition to the dike field, the study area also included revetted banks and sandbars. The lower Cracraft dikes were chosen because there have been numerous biological and hydrographic surveys of this area (Beckett et al. 1983; Conner, Pennington, and Bosley 1983; Pennington, Baker, and Bond 1983).

15. Particular areas of interest during this study were (Figure 2):

- Station A. The revetted section of river bank out to the main channel.
- Station B. The shallow area just upstream of dike 1.
- Station C. The area of the main river just off the tip of dike 1.
- Station D. The very shallow area directly behind dike 1.
- Station E. An area near the main channel where gravel dredging was being conducted.
- Station F. The entrance to the lower pool (below dike 3).
- Station G. The lower plunge pool.

River stage was quite low during this September study (about 2 m at the Vicksburg gauge) and the shallow pools between dikes 1 and 2, and between dikes 2 and 3 were inaccessible. Attempts to sample earlier in the summer during higher water stages (levels in the area can range over 15 m) were prevented by flooding and vessel unavailability.

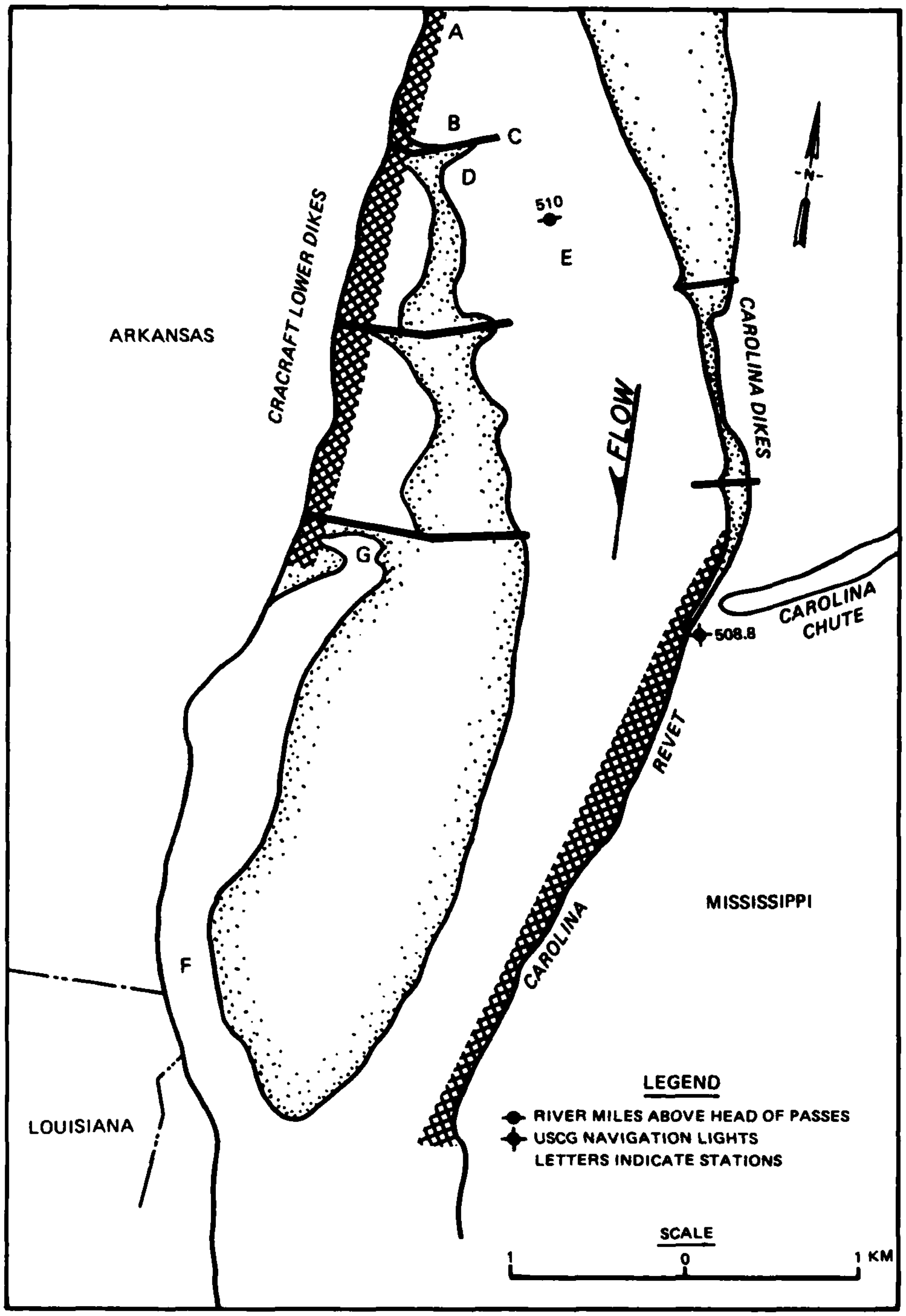


Figure 2. Map of the study site with stations indicated: Cracraft lower dikes, river mile 510, the lower Mississippi River

Equipment Selection

16. Since the study objective was to test some of the newer hydroacoustic equipment in a variety of habitats, some of the most modern equipment was selected. In this study, a high-frequency system was used to give better target resolution and the electronic echo signals were digitally recorded. Use of cassette or reel-to-reel recording was undesirable because they have limited dynamic range and can lose either low or high frequency signals. Both mobile and stationary surveys were attempted. Finally, real-time data processing (as well as laboratory analysis) was desired so a self-contained echo processor with printed output was used.

17. The equipment specified was leased and the assistance requested of two expert hydroacoustic operators for the 2-week study. BioSonics, Inc. (Seattle, Wash.), was chosen because they both manufactured some of the latest designs of hydroacoustic equipment specifically designed for fishery surveys and they had experience conducting hydroacoustic surveys under a variety of field conditions.

18. After discussing project requirements, BioSonics supplied the following equipment:

- a. Transducers: One 420-kHz dual-beam (6° and 15°) mobile transducer(s) mounted in a fin, and one dual 420-kHz narrow (2°) and wide (15°) transducer mounted on a dual-axis remotely controlled rotator for fixed transducer surveys.
- b. Transceiver: BioSonics model 101 echo sounder operating at 420 kHz.
- c. Echo processor: BioSonics model 121 dual-beam echo integrator.
- d. Chart recorder: EPC paper chart recorder.
- e. Tape recorder: JVC VHS video recorder driven by a SONY signal digitizer.

The dual-beam system is a relatively new transducer and receiver design that has the advantage of providing in situ target strength measurements (the inability to do so was one of the greatest weaknesses of previous hydroacoustic equipment (Kanciruk 1982)). The model 121 echo integrator allows both echo integration and echo counting.

Survey Team

19. The survey team consisted of a US Army Engineer Waterways Experiment Station staff scientist and a technician, a staff scientist from Oak Ridge National Laboratory, and two hydroacoustic experts from BioSonics.

Hydroacoustic Equipment

Transducers

20. The transducer used in the mobile-survey portion of this study was a BioSonics 420 kHz dual beam with 6° and 15° elements epoxied in a single cylindrical package. The dual-beam system works by transmitting the signal on the wide beam element and receiving the echoes on both. Each element has a different receiving pattern, and the dual-beam processor interprets the different return echoes from the same target to determine the target's exact location in the beam pattern. With single-transducer systems accurate location of targets within the beam is not possible, yet such information is necessary in determining target strength. The dual-beam system calculates target strength and, given target strength-to-biomass conversion factors, allows easy calculation of size frequency and biomass.

21. The two fixed transducers were of narrow (2°) and wide (15°) beam BioSonics design. All transducers used in this survey were specifically designed for fishery work and had reduced sidebeam patterns.

Transducer deployment

22. Four types of transducers were used in this survey, (a) a mobile, dual-beam transducer mounted in a hydrodynamic fin (Figure 3); (b) stationary, side-looking narrow and wide beam transducers mounted on a dual-axis rotator (Figure 4); (c) a stationary, downward-looking

Figure 3. A fin-mounted, downward-looking transducer mounted in the nose of the delta-shaped hydrodynamic fin

transducer mounted on a pole and placed over the side; and (d) a stationary, upward-looking transducer fixed to a support anchored to the river bottom.

23. Mobile transducers should be placed ahead or along the side of the survey craft to avoid the disturbed water in the wake where entrapped air bubbles provide excellent targets for the hydroacoustic signals and, therefore, interfere with sampling. The mobile transducer/fin was deployed on the larger survey vessel by attaching it to a beam lashed to the foredeck extending about 2 m in front of the vessel. This allowed the fin to be deployed in the undisturbed water in front of the bow wave. It also minimized boat-induced fish avoidance. On the small skiff the foredeck supported the alternating current (AC) generator to power the equipment, so a small davit on the port side was used to tow the fin alongside the craft (Figure 5). In both instances, the fin was

Figure 4. Side-looking fixed transducer fixed to a bottom support and attached to a remotely controlled dual-axis rotator

stable and towed about 10 cm below the water at speeds of between 5 and 15 km/hr. The mobile transducer was used in the fish abundance and distribution surveys, and in the plunge-pool study when the boat was stopped and the fin stabilized.

Figure 5. The small survey vessel with transducer and fin being towed close off the port beam. The hydroacoustic electronics are in the cockpit, and the AC generator is on the foredeck

24. The fixed transducers were attached to a dual-axis, remotely controlled rotator which was lowered into position on the bottom. The fixed transducer and rotator were connected to the stationary support vessel by long coaxial cables. The direction and azimuth of the transducers could be remotely controlled from the vessel. They were used in the side-scanning mode.

25. The upward-looking transducer was mounted to a support and lowered to the bottom. It was aimed slightly off vertical and was not remotely movable. Both the twin side-looking transducers and the fixed-upward-looking transducer were used in the behavioral studies.

26. A 2° narrow-beam transducer was rigged to a pole and held over the side of the vessel in an attempt to quantify sediment type using echo integration.

Electronic equipment

27. The electronic equipment is shown in Figure 6. The heart of any hydroacoustic system is an echo sounder (BioSonics Model 101) specifically designed for fishery assessment work. It is crystal controlled, with an operating frequency range of 25 to 550 kHz (420 kHz used in this survey), digitally controlled time varied gains (TVG) for 20 and 40 log R operation, output for tape recording the signal, and a detected output for oscilloscope signal display. It also has built-in calibration (continuous and pulsed), adjustable transmission frequency and pulse length, adjustable receiver bandwidth, and amplifier gain and transmit power (maximum power of 1 kw). The receiver used was modified by the factory for dual-beam use.

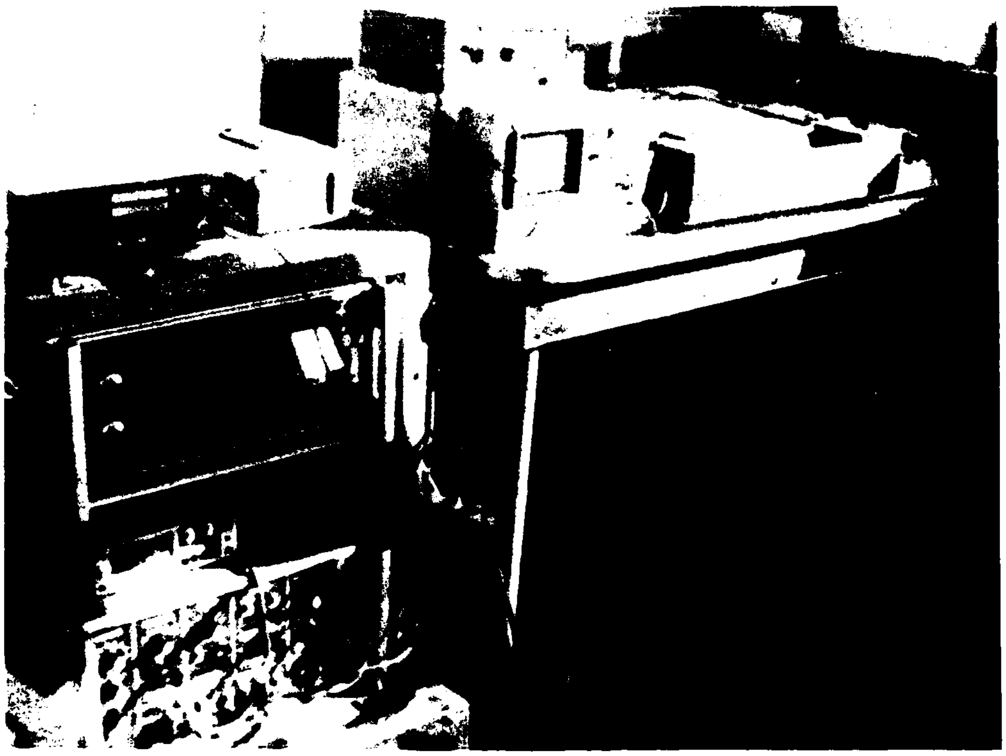


Figure 6. Hydroacoustic electronic equipment used in this study. The equipment used consisted of an echo sounder (bottom rack), an audio digitizer (middle rack), a dual-beam echo integrator/fish counter (top rack), a video tape recorder (top left of rack box) and its power supply (to right), an oscilloscope (left table), and a paper chart recorder (right table)

28. The echo integrator used was the BioSonics Model 121 dual-beam processor. Its specifications include paper tape printed output (Figure 7), presentation of fish density by depth interval (bottom or surfaced locked), programmable input parameters, manual and automatic bottom tracking (preventing false integration of bottom echoes), and output for digital recording of the input signal.

```
09:02:55 31-OCT-83
FILE NUMBER 0001
SEQUENCE # 031
PING # 0150
01 0.000 00  100%
02 0.000 00  100%
03 0.000 00  100%
04 0.000 00  100%
05 2.883 -04  100%
06 5.196 -03  100%
B  1.092 -02  00.2%
```

```
1) FILE NUMBER  0001
3) # SEQUENCES  100
4) # OF PINGS   0150
5) THRESHOLD    040
6) SURFACE LOCK
7) # OF RANGES   06
 01) 001-002  B= 14
 02) 002-003  B= 5.2
 03) 003-004  B= 2.6
 04) 004-005  B= 1.6
 05) 005-006  B= 1.1
 06) 006-007  B= .77
8) A CONSTANT   1
9) BOT. WINDOW  1
12) RECORDER IS OFF
13) PRINTER IS ON
14) RS-232 IS OFF
15) LORAN IS OFF
```

Figure 7. Example of echo integrator output. The Model 121 dual-beam echo integrator produces paper-tape output of both its setup parameters and the actual echo integration values by depth (Source: BioSonics, Seattle, with permission)

Electronic equipment deployment

29. On the large vessel the electronic equipment (echo sounder, oscilloscope, chart recorder, digital video tape recorder, and echo integrator) was housed in the vessel's large enclosed cabin and fed by an AC generator lashed in the stern. The equipment was insensitive to the fluctuations of the small portable generator's output.

30. The hydroacoustic equipment on the small skiff was housed in the open cockpit and powered by a portable AC generator lashed to the foredeck. This setup could be used only in fair weather.

Vessels

31. The vessels were typical of the type generally used in CE river surveys: a 12-m, twin diesel/twin screw leased survey vessel and a 7-m CE-owned outboard skiff. Neither of these craft had any permanent modifications as hydroacoustic survey craft.

Survey Methods

32. Three survey methods were used in this feasibility study:

a. Mobile surveys using a fin-mounted down-looking transducer towed in front of or alongside the large or small survey vessels (Figures 1 and 5).

b. Stationary surveying using either a side-looking transducer mounted on a remote-controlled positioner set on the bottom or an upward-looking transducer mounted to a support set on the bottom (Figure 4).

c. Stationary surveying using a down-looking transducer (fin mounted or fixed to a support) used from a drifting or anchored vessel.

Analysis Methods

33. Analysis methods used in hydroacoustic assessment techniques fall into three broad categories:

a. Real-time visual analysis of oscilloscope traces and paper echogram output. This allows real-time information to be obtained on the presence or absence of fishes (targets), vertical and horizontal distribution of targets, and some measure of biomass (target size and number). With stationary up-, down-, or side-looking transducers, information can be obtained on the movement patterns of fishes or other targets. During any survey, the majority of qualitative information and a good subjective "feel" for the abundance and distribution of fish is usually obtained in this manner. It is a technique for quickly surveying large areas. The skills needed for this type of analysis are (in addition to the ability to operate the equipment) easily learned through field experience.

b. Real-time target counting and/or echo integration using microprocessor-based equipment. This computer-based, real-time analysis allows quantitative estimation of biomass, which is important, for example, in setting weekly fishing quotas in certain regions. The required training ranges from moderate to considerable (using general purpose microcomputers or minicomputers and requiring significant programming development skills). The use of dedicated equipment designed for echo-counting and/or integration is therefore encouraged.

c. Laboratory data analysis. In this type of analysis hydroacoustic data are recorded on audio or video tape (as well as displayed in real time) to be analyzed in detail in the laboratory. The data can be used to re-create paper echograms, visually present the signals on an oscilloscope, and analyze the echograms using echo counters and integrators. The output from all these sources can be analyzed further (descriptively or statistically) by general-purpose microcomputers. This provides flexibility and a depth of understanding not obtainable in real time. In actual use, echo signals are routinely recoded to allow laboratory analysis, if necessary. The training required for this type of analysis varies with the required depth of analysis.

34. All three types of analysis methods were used in this feasibility study. The real-time in situ analysis provided rapid, qualitative information on fish distribution and density, and the laboratory analysis refined the quantitative description.

PART III: RESULTS

35. This section is divided into discussions of the mobile surveys (where the vessel towed the transducer through the water) and stationary surveys (where the vessel was stopped or anchored and the transducer was hung over the side or fixed to the substrate). In general, the equipment functioned well with the exception of the chart recorder which needed frequent stylus cleaning. The resolution for biological target sizes ranged from insect larvae to large fish. In addition, the instruments were able to detect suspended sediment stirred up by passing tows and gravel dredging equipment, an unexpected ability with potential application to future studies.

36. General comments on the equipment, the techniques, and their application which pertain to all the results follow:

- a. The equipment was quickly and easily adapted to both sizes of survey vessels with little effort except for recabling which could be confusing. Setup time on a new vessel would be about one half of a working day. Thereafter, setup would require about 20 min.
- b. The equipment functioned well (except for the chart recorder as noted above) even when disconnected and moved between vessels every 2 hr during the nocturnal study.
- c. The equipment was insensitive to voltage fluctuations inherent with portable AC generators.
- d. The equipment, although transportable, was not portable. It was of significant bulk and weight, and necessitated some effort in transport and setup. The myriad of wires connecting the assorted boxes could become confusing. (Color coding, labeling, and/or bundling of these connecting cables would reduce hookup errors.)
- e. It became apparent that a competent field biologist with a technical inclination and structured coursework in hydroacoustics and some field training could set up and operate the equipment, and interpret the results for many surveys. This is not to say that the equipment is at the "black box" stage (it is not comparable to a depth-sounder where one turns on the sounder, adjusts the gain, and reads the bottom depth). On the contrary, a lack of basic understanding of hydroacoustic principles or carelessness in operation or calibration will lead to erroneous results.

Mobile Surveys

37. In general, mobile surveys were possible anywhere the depth of water allowed boat passage (although fish avoidance must be considered). Even in a side-channel area strewn with brush and trees (Station F) the hydroacoustic techniques worked well and fish could be distinguished close to the submerged limbs.

Revetted banks

38. Revetted areas are sections of shoreline which have been covered with articulated concrete mattress to prevent erosion. An evaluation of the suitability of this substrate as habitat for fish was attempted using hydroacoustics. Transects were made parallel and perpendicular to the shore (Station A) using the small skiff (because of its shallow draft). The hydroacoustic equipment in general was effective at distinguishing hard from soft bottoms (Figure 8). Hard bottoms produce multiple echoes on the paper echogram because much of the acoustic energy is reflected back off the hard bottom to the water surface, bounces off the air-water interface, and travels a second or third time to the bottom. These reverberations between the hard bottom and the surface produce characteristic double or triple bottom echoes. In Figure 8, fishes were observed primarily over soft bottom (note the poor secondary echo) and not over the hard, revetted substrate (dense second and even third echoes present). However, in a second transect leg, the reverse was found. In general, no clear-cut pattern of fish preference for the revetted or soft bottom areas was observed during this short (inconclusive) survey.

Dike fields

39. Although the Cracraft lower dikes consist of three dike structures jutting out perpendicularly from the bank, during this low water level study only dike 1 was accessible on its upstream margin and a portion of its downstream margin. The areas studied were the upstream, low water current velocity area (Station B), the main channel area off the

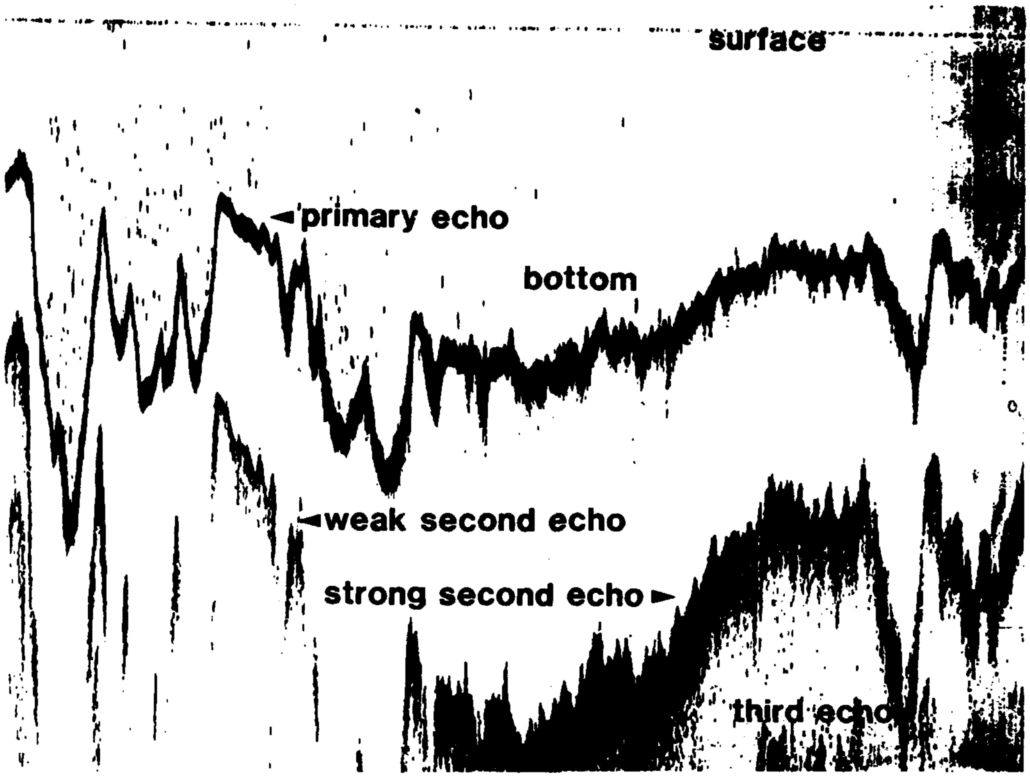


Figure 8. Echogram of revetment transects over hard and soft bottom. The equipment easily distinguished between hard and soft bottoms by the thickness of the bottom echo and the presence or absence of secondary bottom echoes. The left part of this echogram shows a thin bottom echo and a weak or missing secondary echo due to the softness of the bottom. The echo in the right part of this echogram shows a thicker bottom trace and strong second and third bottom echoes due to the hardness of the bottom

tip of the dike (Station C), and the shallow slack-water area downstream of the dike (Station D).

40. The area above the dike (Station A) was typified by a soft silt bottom, low water velocities, and a depth of 3 to 10 m. Initial surveying provided information on depth, bottom type, and fish distribution. A zigzag survey of the entire area then quantified the size distribution and relative fish biomass by depth. Data were digitized and recorded on video tape, then analyzed in the laboratory by the echo integrator which provided information on target strength (in decibels) and relative biomass. Processing these data in the laboratory allowed

the use of custom programs written for a microcomputer (connected to the integrator via a RS-232 cable and transmitting information as ASC II characters) to be used to analyze and plot the data.

41. Figure 9 shows the size-frequency results of the Station B survey. The mode and average signal strength of the 1,894 targets measured (over all depths) was about -42 dB. Target strengths are proportional to target size. The largest target measured in this area was -36 dB, and the size-frequency distribution trailed off to small targets in the -50 to -64 dB range.

42. The relative biomass of fishes was obtained from the same set of data by summing relative target strengths over depth intervals. The results (Figure 10) show a peak in biomass in the deep areas with a steady tapering off of biomass towards the surface except for a increase at about 3.5 m. In order to obtain absolute biomass values, target strength/biomass correlations for the species in question would be necessary. Alternatively, empirical relationships derived by Love (1971) and McCartney and Stubbs (1971) can be used to generally estimate fish length from target strength values. Love's formula is

$$TS = 19.2 \log (L) - 0.9 \log (f) - 62 \quad (1)$$

where

TS = measured target strength, dB
L = fish length, cm
f = frequency, kHz

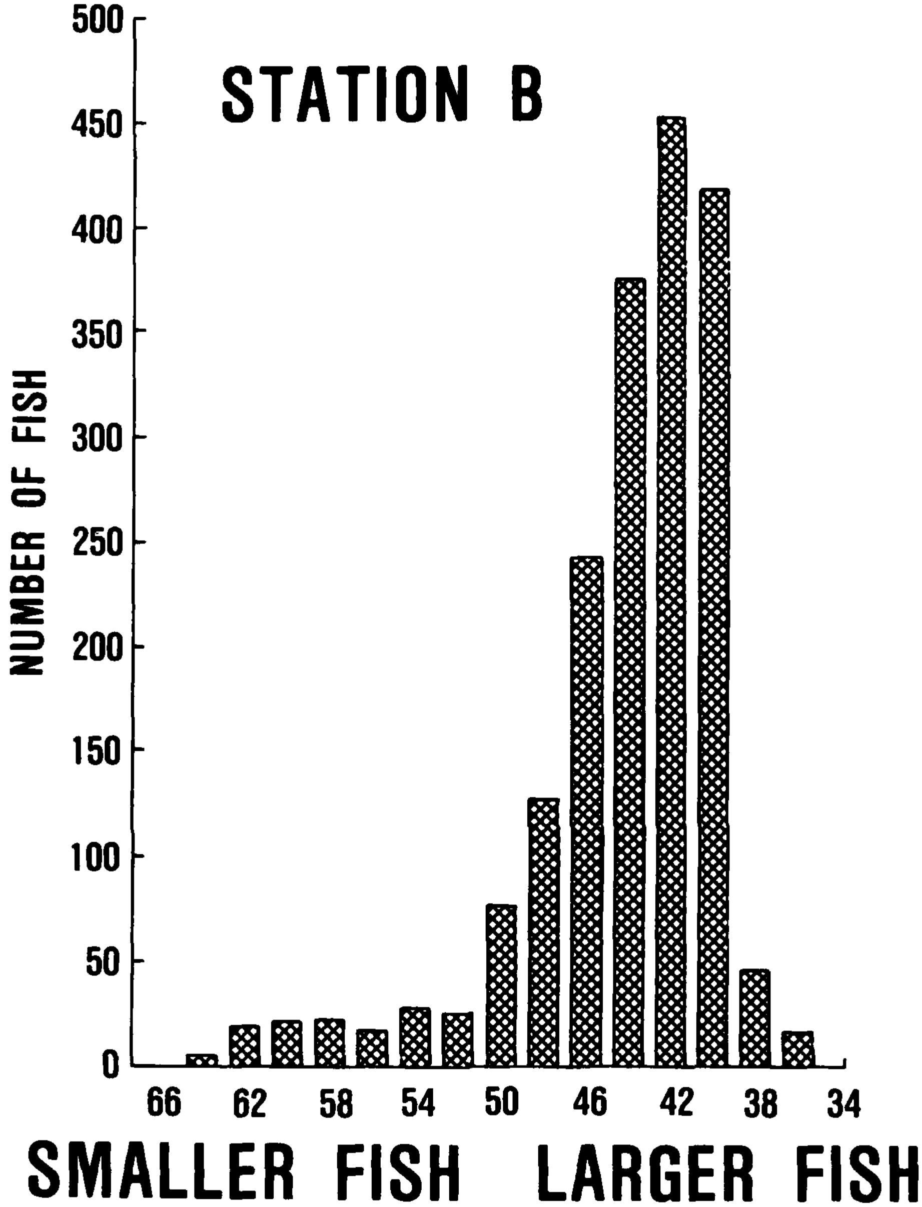


Figure 9. Size frequencies obtained by fish counting (n = 1,894 fish). Fish size is represented as signal strength in decibels--larger fish have stronger return signals. (A -36 dB fish is larger than a -46 dB fish.) Actual fish sizes can be estimated using empirical relationships derived by Love (1971) and McCartney and Stubbs (1971). Here the model size fish is -42 dB, and represents about a 16-cm fish using Love's formula

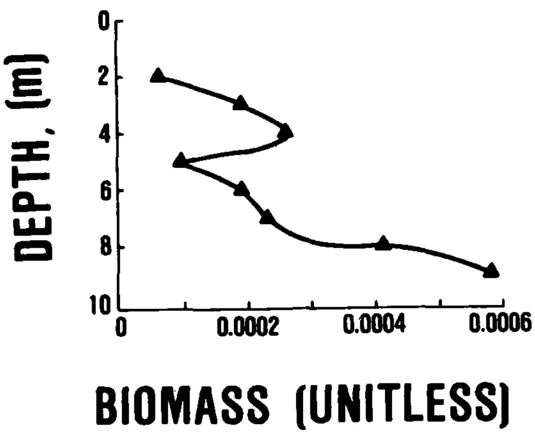


Figure 10. Relative biomass by depth. Size-frequency data (Figure 9) can be analyzed to obtain relative biomass estimates by depth

43. The relationship between measured TS and estimated fish length using a frequency of 420 kHz has been tabulated by Burczynski and Dawson (1984):

TS, dB	Fish Length, cm
-25	115.0
-30	63.0
-35	34.5
-40	18.9
-45	10.3
-50	5.7
-55	3.1
-60	1.7
-65	0.9

In this area, the largest fish was -36 dB (about a 32-cm fish), the smallest -645 dB (about a 1-cm fish), and the mode -42 dB (about a 16-cm fish).

Main channel

44. Station C (Figure 2) was chosen to be surveyed because it was in the main channel of the river (but not in the navigational channel proper). It was characterized by swift currents (approximately

4 to 5 km/hr) and turbulent upwellings or "boils." As the hydroacoustic equipment documented, the dike extended underwater perpendicular to the bank through this station and a deep plunge pool had formed directly downstream of the submerged dike (Figure 11). This station would have been very difficult or impossible to sample using traditional sampling methods due to the swift and turbulent water conditions and deep plunge pool. However, the hydroacoustic equipment easily surveyed this area. Repeated surveys revealed that large fish were almost always found just upstream of the submerged dike and in the plunge pool area. These echoes were some of the largest targets in the entire survey.

Turbidity plumes

45. The extent of sediment disturbance and increased turbidity is important when considering the effects of dredging or changes in towboat activity. These effects are: (a) dredging of river areas directly increases turbidity, and (b) the turbulent wake left by towboat passage can suspend bottom sediment in shallow areas. Quantifying the area impacted by such sediment suspension is difficult. It was thought that the resolution of the high-frequency equipment used in this study might be able to detect the suspended sediment in water disturbed by towboat passage or dredging operations. Hydroacoustics proved flexible and surprisingly successful in measuring both sediment sources.

46. Figure 12 shows the echogram produced when the wake of a passing towboat and barge was repeatedly crossed by the large survey vessel using the down-looking mobile transducer. The survey vessel crossed the wake of the towboat at right angles at "A" about 1 min after tow passage and headed towards the shore at "B." The river bottom in general was disturbed due to high water velocity and the heavy traffic in this stretch of the river, but note that at "A" sediment is disturbed from the bottom to mid-depth (dark cloud). Near the surface at "A" entrapped air bubbles in the wake provided strong surface echo traces. The river depth here is about 12 m. The survey vessel continued to the shoreline at "B," reversed course and recrossed the wake at "C" about 5 min after

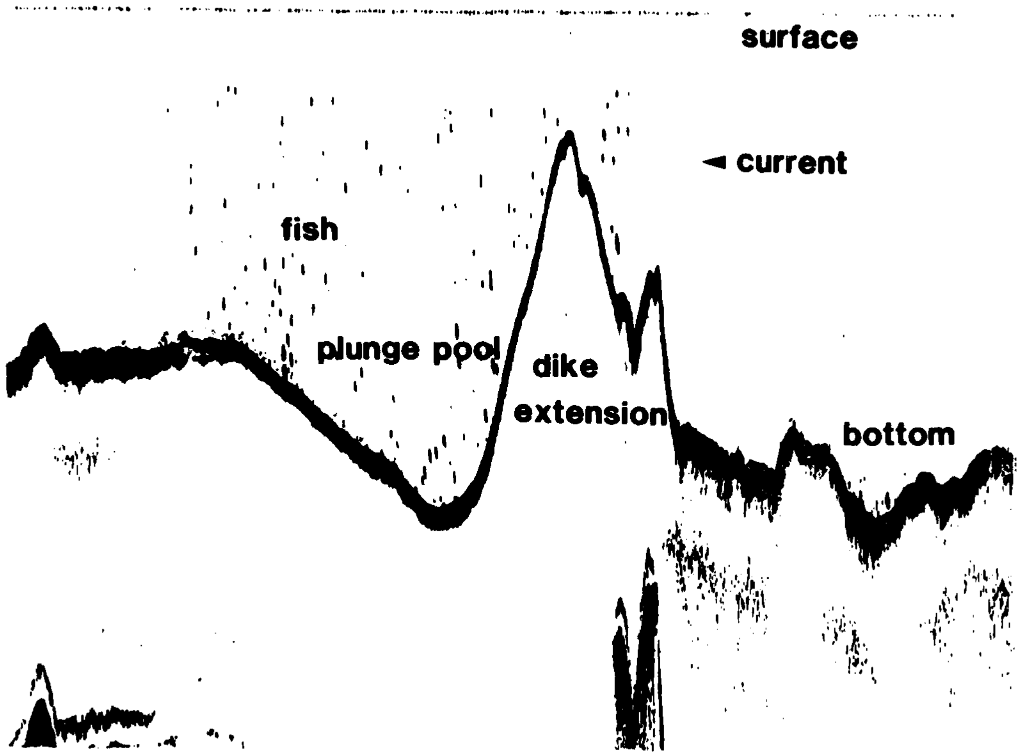


Figure 11. Echogram of plunge pool downstream of the channel end of dike 1 (Station C)

tow passage. By this time, the sediment had noticeably settled and the air bubbles trapped in the surface were no longer apparent.

47. In a separate survey, the hydroacoustic equipment was able to identify the extent of increased turbidity caused by a gravel dredge. A gravel dredge was anchored and working near the dike field but in the main channel. It discharged silt-laden process water over the side, leaving a noticeable surface trail downstream (Figure 13). The survey vessel used the mobile down-looking transducer and zigzagged across the wake to delineate the extent of increased turbidity in the plume. The survey vessel crossed the plume three times (A, B, and C) from downstream, each time closer to the anchored dredge (Figure 13). The echogram showed that at the point farthest from the discharge (point A, about 150 m from the dredge), the least turbidity was observed. The second crossing, at "B" (about 100 m from the dredge), showed more

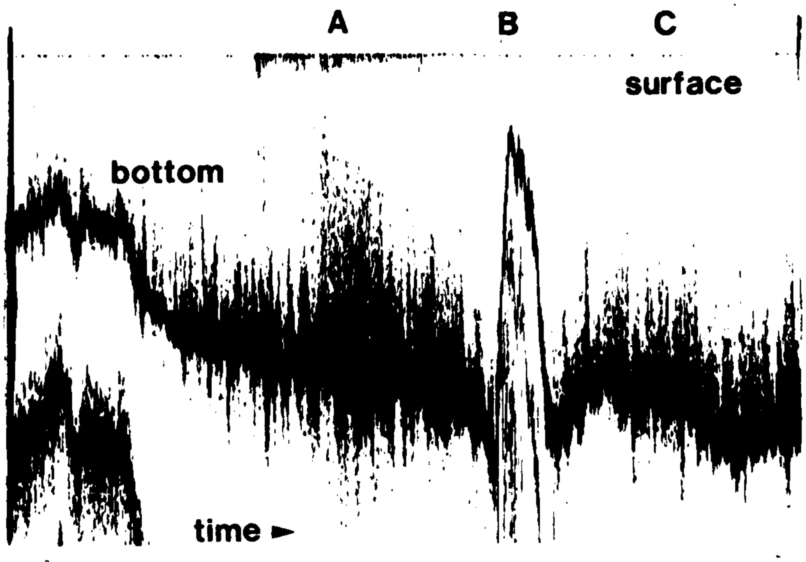


Figure 12. Echogram of towboat passage. This echogram was made cross-channel to the wake of a passing towboat with barges. The first pass through the wake (A) shows trapped air bubbles at the surface and resuspended sediment in mid-water produced by the towboat's wake. The survey vessel continued to the shoreline (B), and then came about to pass through the wake a second time (C). By this time, the air bubbles at the surface were no longer evident, and much of the sediment in the water column had settled out

disturbance, while the third (nearest the dredge) showed increased turbidity throughout the entire water column. The ability of hydroacoustics to determine the extent of elevated turbidity due to dredging using the same instrumentation and basic survey techniques used in fish surveys highlights the versatility of this assessment tool.

Stationary Surveys

48. In stationary hydroacoustic studies, the vessel and transducer are motionless with respect to the environment. The vessel may just be anchored with the transducer at the surface looking downward (as in the plunge pool and sediment analysis studies below), or the

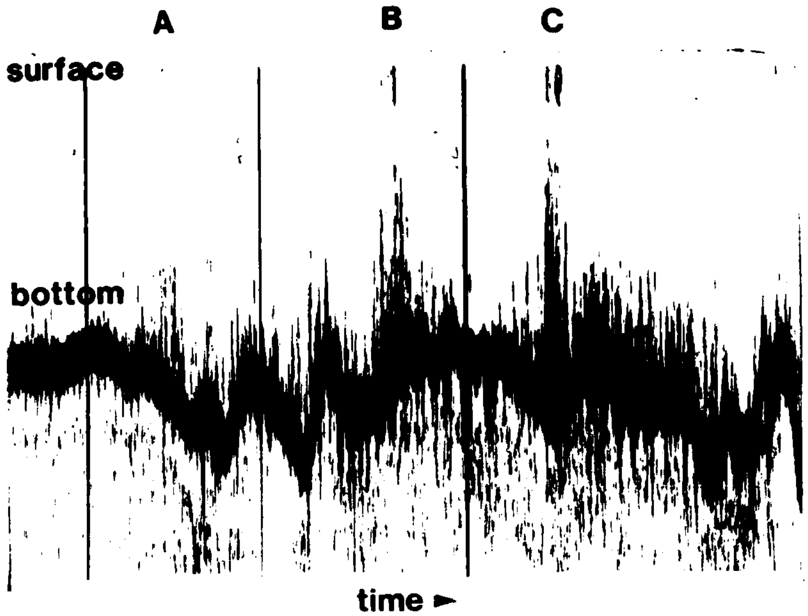


Figure 13. Echogram of a survey of dredging turbidity plume. The survey vessel made three passes across the downstream effluent plume of an anchored working gravel barge dredging in mid-channel (A, B, and C above, each pass closer to the dredge). In C, air bubbles and fine sediment near the surface and heavier sediment in mid-water and near the bottom are evident. In B, less surface air/sediment is observed, and the deeper sediment has settled some and the plume has widened. In A, surface air/sediment is almost gone, and the bottom sediment has settled and spread

transducer(s) may be fixed to a support and placed on the bottom looking upward or sideways (the dike field study below). The primary advantage of a study using stationary transducers is that relative target motion and patterns of fish movement near fixed structures can be determined. This is difficult information to obtain using traditional fishery assessment techniques.

Plunge pool

49. The simplest method of undertaking a stationary hydroacoustic survey is to anchor the vessel and let the fin-mounted transducer sit motionless at the surface looking downward. This technique was used in this study to monitor the diurnal vertical migration of insect larvae in

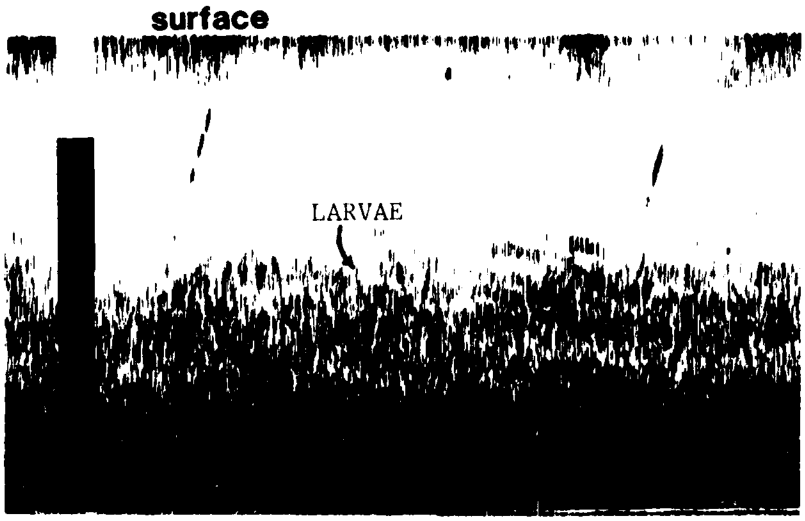
the deep (11 m) plunge pool downstream of the third dike (Figure 2, Station G). An afternoon mobile survey of this pool indicated a large mass of very small targets within a metre of the bottom. It was speculated that the targets probably represented *Chaoborus* larvae because of their air sacks which would make good acoustic targets and because they are known to undergo vertical migrations at dusk. (Unfortunately sampling gear was not available to confirm species identity.)

50. The small survey vessel returned to the pool an hour or so before dark and anchored over the deepest part. The fin-mounted transducer was left in the water hanging from the port davit and the fin was stabilized with additional lines to the boat. The equipment was turned on and an echogram and recorded records were obtained over the next 2 hr.

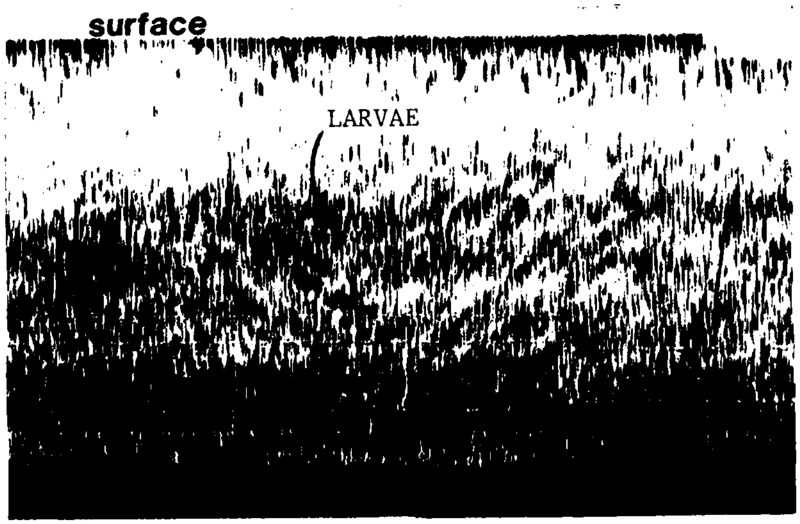
51. The results of this stationary survey are shown in Figures 14-16. At 1835 hr (Figure 14a), the larvae have already risen off the bottom to a depth of 6.5 m (the afternoon mobile survey showed the larvae at about 9 m). Figure 14b shows the larvae have risen to 3.6 m, and by 1930 hr (Figure 14c), the larvae were within 0.5 m of the surface. The larvae moved approximately 0.1 m per minute between 1835 and 1930 hr. The equipment used in this stationary survey was the same gear used throughout the survey with only minor adjustments to increase receiver gain.

Dike field

52. The area above the first dike (Station B) surveyed using mobile techniques was also surveyed using stationary upward- and side-looking transducers. The transducer locations and fields of insonification in relationship to the dike are shown in Figure 15. The transducer at location 1 was placed on the bottom in about 6 m looking upward slightly off the vertical. Its function was to provide information on vertical fish movement. Its field of insonification is shown as a dotted circle slightly off-center from the vertical. At location 2 a narrow beam (2°) transducer was placed on the bottom in about 2 m of water and was horizontally aimed out towards the main channel as shown. Its range was about 75 to 100 m. Both transducers were connected via

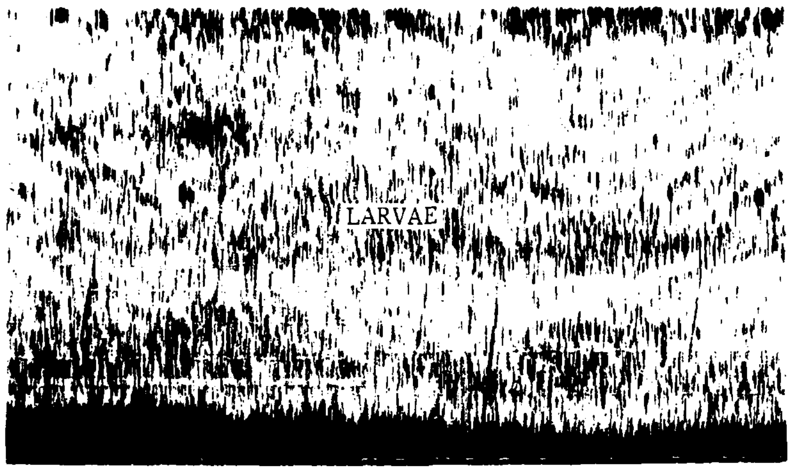


a. 1835 hr



b. 1900 hr

Figure 14. Detection of insect larvae migration at 1835, 1900, and 1930 hr in the plunge pool downstream of dike 3 (Station G) (Continued)



c. 1930 hr

Figure 14. (Concluded)

cable to the survey vessel moored to the dike at location 2. These transducers were monitored from about 1800 hr one evening until 0800 hr the next morning (concurrent with a nocturnal study in the riveted area). Any nocturnal vertical or inshore-offshore fish movement could thus be detected.

53. The primary analysis method for behavioral data is real-time visual inspection of echograms (examples in Figures 16 and 17). Figure 16 is a typical echogram produced by the upward-looking transducer in location 1. Since the transducer is at the bottom and not the surface, the echogram is inverted with the surface of the water represented at the bottom of the chart. The fish echoes are represented as large targets in the echogram because of the short vertical scale (about 8 m) and because of the stationary nature of the transducer, which caused the fish to be insonified many times in succession until the fish moved out of the beam. Note that in Figure 16 the thick trace (A) resolves into two fish, one moving horizontally in the beam and one moving downward (up on the echogram) before leaving the beam. Most fish were seen at or near the surface, but echogram analysis should take into account that the beam width is widest at the surface. Note also the light diagonal

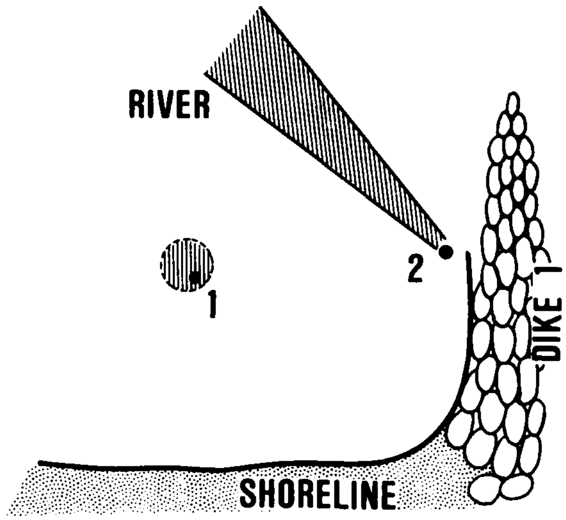


Figure 15. Location of stationary transducers near dike 1. Stationary transducers were aimed vertically (at 1 above) and horizontally (at 2) in order to determine fish movement patterns in a nocturnal study near dike 1. The hatched areas represent cones of insonification ("field of view") for each transducer. The transducer at 2 was mounted on a remotely controlled rotator and could be aimed in any direction

line indicating a small target rising rapidly from the bottom to the surface. These traces confused the operators until it was noticed that the thick mucky bottom in this area was releasing gas bubbles. It was probably the bubbles that accounted for these traces. They were easy enough to disregard on the echogram, but if not accounted for could bias any fish counting or echo integration of data from this area.

54. Figure 17 shows a typical echogram from the long-range side-looking transducer at location 2. As the range here was an order of magnitude longer than that in Figure 16, fish targets produced much smaller traces. The top of the echogram represents the transducer location; the bottom of the echogram is about 100 m distant out towards the main channel. There is no echo trace at the bottom of the echogram because the acoustic energy radiated out into the deep main channel towards the far shore and was dissipated. The long thin trace at A

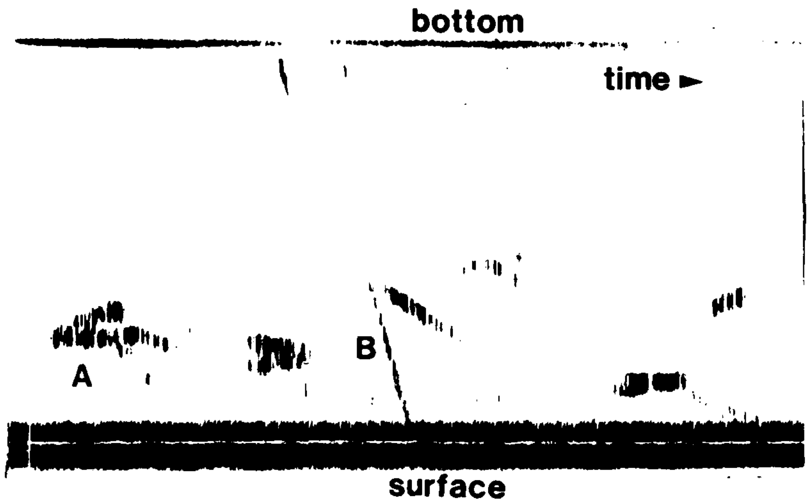


Figure 16. Upward-looking stationary transducer echogram. In the echogram of a bottom-mounted, upward-looking transducer, the water surface is represented at the bottom and the substrate at the top of the chart. The trace at A is of two fish, at first swimming together, but then separating before leaving the transducer beam. The thin diagonal trace at B is of an air bubble rising to the surface

represents a fish that was in the beam for about 5 min moving slowly toward the transducer at an angle before moving out of the beam.

55. The stationary survey at the first dike disclosed no clear vertical or inshore-offshore migration of fish, but it did demonstrate the feasibility of this technique in investigating fish movement along dike structures in large rivers.

In-situ sediment analysis

56. At this point in the study the hydroacoustic equipment had worked well on targets ranging from large fish to insect larvae to suspended sediments. The survey team next attempted to quantify the differences in bottom type observed on the echogram by integrating the echo returns from the substrate. Hard bottom, in general, should return more acoustic energy than soft bottom.

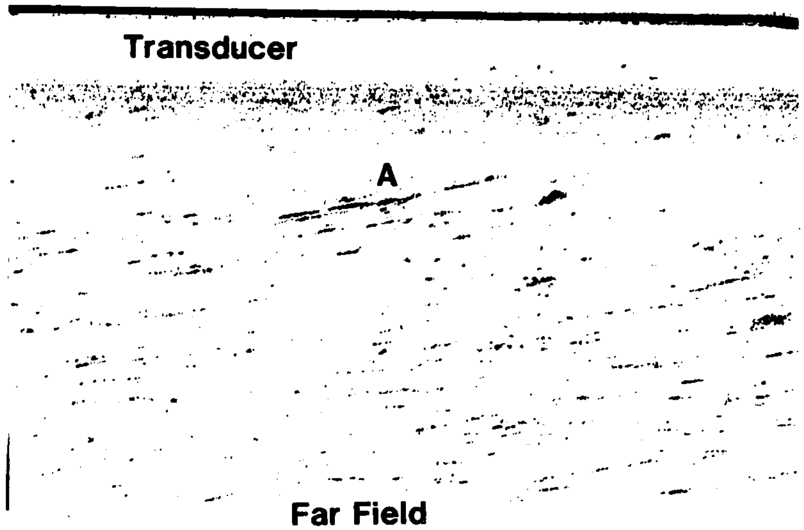


Figure 17. Stationary side-looking transducer echogram. Here, the top of the echogram represents the area close to the transducer while the bottom is the far edge of insonified water. The trace at A is of a fish slowly moving toward the transducer while passing through the transducer beam. The range here is about 100 m, hence the smallness of each target as compared with Figure 18 where the range is about 8 m

57. The survey vessel was positioned over varying substrate types and slowly drifted while readings were taken from a small downward-looking narrow beam (2°) transducer attached to a pole held off the side of the vessel. After a few minutes of echo soundings, a bottom grab sampler was used to obtain a sediment sample. The sediment samples were analyzed at WES, and the bottom echoes were integrated from tape at the BioSonics facility. The results are shown in the Table 1 and Figure 18.

58. The data in the table show a three-order-of-magnitude range both for grain size and echo integration values over the dozen sediment samples examined. The plot of the relationship in Figure 18 shows a general positive relationship between grain size and echo intensity, especially at lower particle sizes. The scatter observed for grain sizes is perhaps explainable in that many properties (e.g. skewness,

compaction, depth, etc.) of sediment which can affect echo intensity were not measured in this study and could have greatly influenced the results.

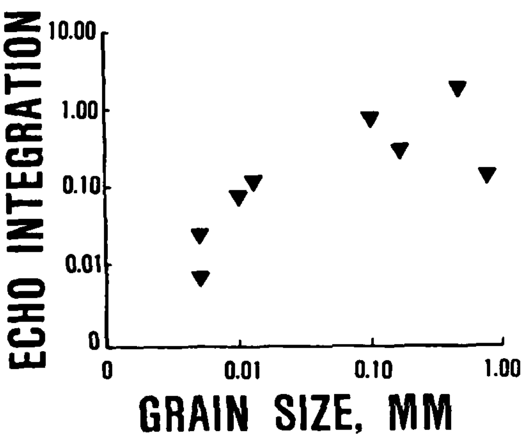


Figure 18. In situ sediment analysis. Bottom echoes were analyzed using echo integration to try to remotely estimate bottom hardness. Here bottom echo integration is plotted against grain size (as measured from grab samples). Echo integration values increased with increasing grain size

Table 1

In Situ Sediment Analysis Results

Sample No.	Integration Value, unitless	Median Grain Size, mm*	Sediment Classification**
1	1.53×10^{-1}	0.02*	Clay (CH)
2	5.12×10^{-1}	0.30	Sand (SP)
3	8.14×10^{-3}	0.007*	Clay (CL)
4	2.26×10^{-1}	0.90	Gravelly clayey sand (SC)
5	4.36×10^{-2}	0.007*	Clay (CH)
6	8.82×10^{-2}	0.010*	Clay (CH), trace of gravel
7	8.82×10^{-1}	0.100	Clayey sand (SC)
8	1.34	N/A	N/A
9	4.89×10^{-2}	N/A	N/A
10	3.29	N/A	N/A
11	3.45	0.70	Sand (SP)
12	2.62×10^{-1}	1.50	Gravelly clayey sand (SC)

* A significant portion of the sample was less than 0.001 mm; therefore, the median grain size was estimated from incomplete gradation curves.

** Classification followed Unified Soil Classification codes, American Society for Testing and Materials (ASTM) D 2487-66T).

PART IV: DISCUSSION

59. The hydroacoustic equipment used in this study worked well under field conditions, and was adaptable to a variety of habitats, methods of deployment, and survey objectives. Like any assessment tool, hydroacoustics have some weaknesses (described in Part V), but the results of this evaluation indicate that, when they are competently applied toward reasonable objectives, hydroacoustics are complementary fishery assessment tools providing information not obtainable with more traditional methods.

Mobile Fish Surveys

60. Mobile fish surveys are the traditional method of application of hydroacoustic techniques. Hydroacoustic techniques are a useful, rapid means for providing information on relative biomass and fish distribution. These techniques allowed a quick determination of fish presence/absence over a large area (at speeds of about 8 km/hr) using only visual outputs (oscilloscope and chart recorder). In this mode hydroacoustic methods are unsurpassed for the rapid survey of an area where the determination of species composition is not essential. Where species identification is needed, concurrent fish subsampling can be employed.

61. The major problem encountered during the mobile fish surveys was the misinterpretation of gas bubbles (rising from muddy substrate) as fish targets. The presence of gas bubbles in the water column was first observed during a stationary transducer study of the same area (Figure 17), and later upon careful observation of the water's surface. The presence of gas bubbles in the water column would bias upward any fish-counting or echo-integration estimates of biomass for this area, although the bias could possibly be electronically gated out during analysis by ignoring the gas bubble target size class.

Stationary Fish Surveys

62. Stationary transducers were successfully deployed in this evaluation for monitoring fish movement near and around a dike. Although individual fish and their relative movements could be detected, no definite pattern of fish movement relative to the dike structure was observed. It was clear however that had there been a preferred direction of movement, the stationary transducers would have been able to document the pattern.

63. Although stationary transducers were easy to deploy, interpretation of the echograms, especially estimating position and direction of fish movement relative to the environment, was nonintuitive and would develop only with field experience. Even so, the ability to remotely detect movement patterns of fish is a unique characteristic of hydroacoustic techniques which should be useful in assessing the impact of man-made structures on fish movement patterns.

Turbidity Plume Analysis

64. The fact that hydroacoustics could document the extent of induced water turbidity due to towboat passage and dredging activity was a result of the higher frequencies this modern equipment employs. The questions of the effects of dredging near sensitive habitats or increased river traffic are often raised when river construction projects are proposed (A. T. Kearny, Inc. 1980; UMRBC 1982; US Army Corps of Engineers 1982). Hydroacoustic techniques could quickly describe (and perhaps quantify) both the temporal and spatial extent of such activities as they are influenced by water depth, vessel speed, substrate composition, etc. They could greatly improve the ability to resolve turbidity related issues.

65. The ability of hydroacoustic techniques to remotely observe suspended sediment in water has been reported for marine habitats. Proni et al. (1975, 1976) were able to track suspended sediment

downcurrent from a hydraulic dredge working in Government Cut, Miami. There a 20-kHz LODAR hydroacoustic echo sounder was able to follow the sediment "cloud" over a distance of 1,000 m from the dredge site. Proni et al. (1976) were also able to track the turbidity plume from ocean-dumped sewage sludge in the New York Bight area for several hours using 20- and 200-kHz echo sounders.

In Situ Sediment Analysis

66. The use of the echo integrator to estimate the energy contained in the bottom echo as an indication of bottom type was an unplanned yet interesting offshoot of this study. The use of acoustics by geologists to map sediment type has been attempted before (mostly in marine environments) with varied success (Hampton 1966, Menzie et al. 1982). The biologist however is usually interested in characterizing only the surface sediment, which has biological significance. Although our data do show a three-order-of-magnitude difference in bottom echo strength, which appears to reflect differences in bottom hardness (Figure 18, Table 1), there are a number of tests of total bottom hardness which were not used to analyze these samples (the samples were just sieved and the median grain size used as a measure of bottom hardness). Also, the total number of samples is small. However, the ability to obtain sediment information during a mobile survey of fish biomass and location is a potentially useful tool.

PART V: CONCLUSIONS AND RECOMMENDATIONS

67. The use of hydroacoustic techniques to estimate fish biomass, distributions, and movement patterns has been successfully applied in a variety of marine and freshwater environments towards a wide range of purposes. The results of this brief feasibility study indicate that these techniques are highly adaptable and can be successfully applied to surveys in large, turbid rivers. Newly developed techniques and equipment provide ease of measurement and analysis not previously available (e.g., dedicated on-board microprocessor equipment). Information not heretofore obtainable (in particular, dual-beam in situ TS measurements) can also be gathered. Specific conclusions and recommendations are detailed below, but in general it is difficult to imagine a fishery survey project which would not benefit from the application of hydroacoustic techniques.

Advantages of Hydroacoustic Methods in Large Rivers

68. The advantages of using hydroacoustic methods in large rivers are a combination of the general characteristics of hydroacoustic techniques (as discussed in Kanciruk 1982) and the sampling requirements specific to riverine environments. These include:

- a. Hydroacoustics provide quantitative estimates of fish biomass which are as good or superior to more traditional methods such as catch per unit effort.
- b. Surveys can be conducted at high speed and over long transects, providing better spatial and temporal coverage.
- c. The techniques allow behavioral observations to be obtained (e.g., diurnal migrations in and around man-made structures).
- d. Multiple depth intervals and target sizes can be sampled simultaneously.
- e. Large quantitative databases (i.e., sample size) can be obtained which improve statistical interpretation and comparison of data.

f. Good sampling power (summation of points a-d above) and low manpower requirements can reduce overall survey costs by increasing efficiency.

g. The techniques provide independence from net-avoidance problems.

h. Real-time data acquisition and interpretation are possible.

i. Hydroacoustic techniques are nondestructive and noninvasive (neither destroying the sampled fish nor disturbing the environment).

69. Advantages specific to CE river surveys include:

a. Ease of sampling deep, swift, turbid mainstream areas where depth and current would preclude traditional sampling techniques.

b. Ability for the equipment to be deployed from small as well as large vessels.

c. Use of stationary and mobile surveys to document habitat selection and movements around dike fields, plunge pools, and revetted areas.

d. Potential of hydroacoustics to document and quantify the effects of dredging and towboat operations on sediment disturbance, both important issues in many studies.

Disadvantages of Hydroacoustic Methods in Large Rivers

70. Disadvantages of hydroacoustic techniques include:

a. Species identification can only be inferential unless supplemented by traditional methods.

b. Quantification of fish target strength for echo integration is difficult unless dual-beam systems are used, in which case target strengths are easily calculated.

c. Specialized equipment is needed.

d. Specialized training is required.

e. Understanding and acceptance by field biologists, educational materials (texts), and formal university hydroacoustic instruction are lacking at this time.

Recommendations

71. The hydroacoustic equipment used in this evaluation was reliable, fairly easy to use with adequate training, and provided information on fish abundance, distribution, and behavior patterns not easily attainable using conventional fishery assessment tools such as netting, trawling, or electrofishing. The techniques worked well in the lower Mississippi River and were not adversely affected by turbidity or swift currents common in and around dike fields. In addition, the hydroacoustic equipment was able to provide information on sediment disturbance due to towboat passage and gravel dredging, and was potentially able to characterize bottom sediment types. The major technical drawback to hydroacoustic techniques is their inability to assess species identity. This can be overcome by combining them with more traditional assessment tools. The major impediments to their use are the initial cost of the equipment and the training necessary to acquire the knowledge to operate the equipment. These are balanced by the facts that the data obtained during a fishery survey are much enhanced when combined with hydroacoustic information, and that increased efficiency will most likely shorten any survey if hydroacoustic methods are employed.

72. It is recommended that hydroacoustic techniques be used in any fishery survey where the accurate estimation of fish density and distribution is necessary, or the behavioral response to an alteration in the environment must be estimated/evaluated. The techniques should be used in concert with traditional fishery methods to provide information on species identity and target sizes.

REFERENCES

Acker, W. C., and Hendershot, R. G. 1982. "New Concepts in Riverine Sonar," Symposium of Fisheries Acoustics, 1982.

Acker, W. C., Lewis, H. W., Brune, F. A., and Thorne, R. E. 1975. "A Towed Dual-Frequency Hydroacoustic Fish Assessment System," Ocean '75: The Institute of Electrical and Electronics Engineers Council on Oceanic Engineering, San Diego, Calif., 5 pp.

A. T. Kearney, Inc. 1980. "Analysis of Environmental Aspects of Waterways Navigation," Element M of the National Waterways Study, US Army Engineer Institute for Water Resources, Water Resources Support Center, Fort Belvoir, Va.

Beckett, D. C., Bingham, C. R., Sanders, L. G., Mathis, D. B., and McLemore, E. M. 1983. "Benthic Macroinvertebrates of Selected Aquatic Habitats of the Lower Mississippi River," Technical Report E-83-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Burczynski, J. 1979. "Introduction to the Use of Sonar Systems for Estimating Fish Biomass," FAO Fisheries Technical Paper 191, Rome, Italy, p 89.

Burczynski, J., and Dawson, J. 1984. "Dual-Beam Techniques for Fish Sizing and Quantity Estimates," Technical Note 104, BioSonics, Seattle, Wash., 8 pp.

Carlson, T. J., Acker, W. C., and Gaudet, D. M. 1981. "Hydroacoustic Assessment of Downstream Migrant Salmon and Steelhead at Priest Rapids Dam in 1980," APL-UW 8016, University of Washington, Seattle, Applied Physics Laboratory, pp 1-68.

Conner, J. V., Pennington, C. H., and Bosley, T. R. 1983. "Larval Fish of Selected Aquatic Habitats on the Lower Mississippi River," Technical Report E-83-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Gaudet, D. M. 1980. "Hydroacoustic Sampling of Salmon Escapements in Trunk Streams of Bristol Bay, Alaska," M.S. Thesis, University of Washington, Seattle.

Kanciruk, P. 1982. "Hydroacoustic Biomass Estimation Techniques," Oak Ridge National Laboratory, ORNL/TM-8304, Oak Ridge, Tenn., 279 pp.

Love, R. H. 1971. "Dorsal-Aspect Target Strength of an Individual Fish," Journal of the Acoustic Society of America, Vol 49, pp 816-823.

McCartney, B. S., and Stubbs, A. R. 1971. "Measurement of the Acoustic Target Strengths of Fish in Dorsal Aspect, Including Swim Bladder Resonance," Journal of Sound Vibrations, Vol 15, pp 397-420.

McElroy, P. T. 1977. "Acoustics in Marine Fisheries - An Underused Tool," Oceanus, Vol 20, No. 2, pp 59-66.

Menzie, C. A., Ryther, J., Jr., Boyer, L. F., Germano, J. D., and Rhoads, D. C. 1982. "Remote Methods of Mapping Seafloor Topography, Sediment Type, Bedforms, and Benthic Biology," Marine Pollution Papers, Oceans '82, NOAA, Rockville, Md.

Mitson, R. B. 1983. Fisheries Sonar, Fishing News Books Ltd., Farnham, Surray, England, pp 287.

Pennington, C. H., Baker, J. A., and Bond, C. L. 1983. "Fishes of Selected Aquatic Habitats on the Lower Mississippi River," Technical Report E-83-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Proni, J. R., Newman, F. C., Rona, D. C., Drake, D. E., Berberian, G. A., Lauter, C. A., Jr., and Sellers, R. L. 1976. "On the Use of Acoustics for Studying Suspended Oceanic Sediment and for Determining the Onset of the Shallow Thermocline," Deep-Sea Research, Vol 23, pp 831-837.

Proni, J. R., Rona, D. C., Lauter, C. A., Jr., and Sellers, R. L. 1975. "Acoustic Observations of Suspended Particulate Matter in the Ocean," Nature, Vol 254, No. 5499, pp 413-415.

Thorne, R. E. 1977. "A New Digital Hydroacoustic Data Processor and Some Observations of Herring in Alaska," Journal of the Fishery Research Board of Canada, Vol 34, No. 12, pp 2288-2294.

Traynor, J. J., and Ehrenberg, J. E. 1979. "Evaluation of the Dual Beam Acoustic Fish Target Strength Measurement Method," Journal of the Fishery Research Board of Canada, Vol 36, pp 1065-1071.

Upper Mississippi River Basin Commission (UMRBC). 1982. "Comprehensive Master Plan for the Management of the Upper Mississippi River System," Upper Mississippi River Basin Commission, Minneapolis, Minn.

US Army Corps of Engineers. 1982. "Tennessee-Tombigbee Waterway," Final Supplement to the Environmental Impact Statement, US Army Engineer District, Mobile, Mobile, Ala.

END

FILMED

12-85

DTIC