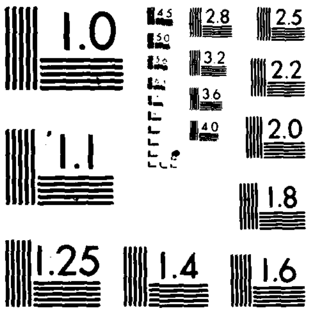
AD-A113 127   ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/2
ASSESSMENT OF IMPLANTED SUBSTRATE SAMPLERS FOR MACROINVERTEBRAT--ETC(U)
FEB 82 L G SANDERS
UNCLASSIFIED WES/MP/E-82-1 NL

1 of 1

END
DATE
FILMED
5-82
DTIC



MICROCOPY RESOLUTION TEST CHART

(12)

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Miscellaneous Paper E-82-1	2. GOVT ACCESSION NO. AD-A113 127	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ASSESSMENT OF IMPLANTED SUBSTRATE SAMPLERS FOR MACROINVERTEBRATES INHABITING STONE DIKES OF THE LOWER MISSISSIPPI RIVER		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David B. Mathis C. Rex Bingham Larry G. Sanders		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS EWQOS Work Unit VIIB
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE February 1982 13. NUMBER OF PAGES 55
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

DTIC
ELECTE
APR 6 1982

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

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5205 Port Royal Road, Springfield, Va. 22151

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

Dikes (Training structures)
Invertebrates
Mississippi River
Sampling
Substrates

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

The aquatic macroinvertebrate assemblage of a dike in the Lower Mississippi River was evaluated by implanting substrate basket samplers into the structure. The resulting data indicated that a diverse (38 taxa) and productive (average density = 101,968.4 organisms/m^2) assemblage was present, and was characterized by net-spinning caddisflies, tube-building chironomids, clinging mayflies, and isopods.

(Continued)

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

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

A comparison of the surface stones of the basket samplers with adjacent surface stones of the dike indicated that the implanted substrates provided representative estimates of both the composition and structure of the macroinvertebrate assemblage. These data also indicated significant macroinvertebrate activity below the surface substrate of the dike.

Differences in habitat conditions among dike positions (downstream, top, upstream) were the major contributors to overall sample variability. Thus, stratified random sampling based on dike position is recommended for future comparative studies.

PREFACE

The work described herein is part of the Environmental and Water Quality Operational Studies (EWQOS) conducted by the U. S. Army Engineer Waterways Experiment Station (WES) for the Office, Chief of Engineers (OCE), U. S. Army.

This study was part of a series of pilot investigations conducted within EWQOS Work Unit VIIB to develop and test sampling equipment, techniques, and methodologies specifically designed to assess the environmental impacts of Corps activities within large open-channel waterways.

This report was prepared by Messrs. David B. Mathis, C. Rex Bingham, and Larry G. Sanders, Environmental Systems Division (ESD), Environmental Laboratory (EL), under the direction of Dr. Thomas D. Wright, Chief, Waterways Habitat and Monitoring Group (WHMG), ESD, EL; Mr. Bob O. Benn, Chief, ESD; and Dr. John Harrison, Chief, EL. Dr. Jerome L. Mahloch was Program Manager of EWQOS.

COL Nelson P. Conover, CE, was Commander and Director of WES during field conduct of this study. Mr. Fred R. Brown was Technical Director of WES.

This report should be cited as follows:

Mathis, D. B., Bingham, C. R., Sanders, L. G. 1982. "Assessment of Implanted Substrate Samplers for Macroinvertebrates Inhabiting Stone Dikes of the Lower Mississippi River," Miscellaneous Paper E-82-1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	2.54	centimetres
miles (U. S. statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms

ASSESSMENT OF IMPLANTED SUBSTRATE SAMPLERS FOR MACROINVERTEBRATES INHABITING STONE DIKES OF THE LOWER MISSISSIPPI RIVER

PART I: INTRODUCTION

Background

1. The open channel method of navigation control employed on the Lower Mississippi River* involves the extensive use of dikes** and dike systems to align and maintain navigable channels (Henley 1966). The principal uses of dikes within this waterway are for adjusting channel width, depth, and alignment, and for the closure of secondary channels (Task Committee on Channel Stabilization Works 1965). The primary objectives of these efforts are to reduce the river's width, direct the flow into a desired alignment, and to induce bottom scour which will deepen and maintain the selected navigation channel (Task Committee on Channel Stabilization Works 1965). Because of the heavy movement of bedload material through this system, navigation control by dredging is restricted primarily to emergency sediment removal from particularly troublesome channel reaches during periods of moderate to low river discharge.†

2. Dikes are structures constructed of permeable wooden piles or, more typically in the last decade, of relatively impermeable stone riprap. Dikes may be singular or placed one after another along a bank forming a dike field. Within the Lower Mississippi River, dikes are generally of the transverse type which extend from the bank, perpendicular to the direction of flow, into the river channel past the point of

---

* Discussion applicable to Cairo, Illinois-Baton Rouge, Louisiana, reach of lower Mississippi River.

** Also referred to as wing dams, spur dikes, groins, and jetties.

† Personal communication, C. Elliot, Chief, River Stabilization Branch, Vicksburg District, U. S. Army Corps of Engineers, Vicksburg, Miss.

highest current velocities.* An extension, or L-head, may be placed at the channel end of the dike, parallel to the direction of flow, to retard scouring and turbulence. Vane dikes which are placed in the channel parallel to the bank line are also occasionally used.

3. Despite the increasing number of dikes and dike systems within this waterway, little is known of the ecological changes effected by these structures (Keeley et al. 1976, Keller 1976). The potential for adverse ecological impact is believed to be significant, due to increased sedimentation around these structures and the potential for permanent loss of aquatic habitat (Keller 1976, Robinson 1972, Robinson 1973, Johnson et al. 1974). However, through alternative dike designs to reduce or control sedimentation, the potential also exists for beneficial impacts through increased diversity in aquatic habitat and associated aquatic species diversity (Johnson et al. 1974, Bulkley et al. 1976, Schramm and Lewis 1974, Ragland 1974).

4. One area of major interest is the potential for increased aquatic macroinvertebrate habitat and species diversity created by the dike structures themselves. Field observations by Johnson et al. (1974) indicated that a diverse and productive stone-dwelling macroinvertebrate assemblage was associated with dikes on the Middle Mississippi River between St. Louis, Missouri, and Cairo, Illinois. They emphasized the need for additional study of these dike-associated habitats, particularly the possibility that these stable substrates may serve as primary areas of origin for drift organisms, a potential major food source for the river fishery. Bulkley et al. (1976) conducted field investigations of stream alteration activities in Iowa and found that the stable substrates created by stone hard-point dikes constructed for bank stabilization purposes provided a new and different substrate for aquatic macroinvertebrate growth, particularly for clinging mayflies and caddisflies. Unfortunately, neither of these studies involved a detailed assessment of the composition and structure of these macroinvertebrate assemblages.

---

* Personal communication, C. Elliot, Chief, River Stabilization Branch, Vicksburg District, U. S. Army Corps of Engineers, Vicksburg, Miss.

5. The potential for adverse environmental impacts directly associated with these dike structures has also been stressed. Hynes (1970) stated that all solid stable structures erected in rivers create excellent habitat for net-spinning caddisflies, several species of which may occur in pest proportions if proper regard to the consequences is ignored. He cited as an example an investigation by Fremling (1960) on the Upper Mississippi River. Fremling attributed the presence of nuisance swarms of net-spinning hydropsychid caddisflies in certain reaches of the Upper Mississippi River to the dense colonization of their aquatic larval forms on concrete cooling siphon gratings associated with hydroelectric plants. This same situation may also occur with extensive dike construction activity, particularly in waterway systems with managed, fairly stable water levels where the catastrophic drift of these dike-associated organisms may be minimized, thus reducing population control by reducing their availability as fish food.

6. At present, there is no data base from which to assess the actual or potential role of these dike-associated aquatic macroinvertebrate assemblages within inland waterway ecosystems. The establishment of such a data base will require intensive field sampling efforts, including comparative studies of various dike design and construction alternatives and the relative habitat quality characteristics of each for aquatic macroinvertebrates. Through these efforts, it is possible that dike construction may provide the dual benefit of effective navigation control as well as increased habitat and species diversity for macroinvertebrates and other aquatic biota within the Lower Mississippi River.

Objectives

7. At present, dike design and construction are based largely on judgment and experience and may vary considerably throughout the United States due to waterway- and site-specific factors (Task Committee on Channel Stabilization Works 1965).* These waterway- and site-specific

---

* Personal communication, C. Elliot, Chief, River Stabilization Branch, Vicksburg District, U. S. Army Corps of Engineers, Vicksburg, Miss.

design features may greatly influence the composition, distribution, and abundance of associated aquatic macroinvertebrates over the length and width of individual dikes and over dike systems, thus affecting field sampling design considerations, as well as appropriate sampling techniques for study purposes.

8. Therefore, the primary objective of this investigation was to identify and field verify a sampling technique which would provide quantitative estimates of the composition and relative abundance (structure) of aquatic macroinvertebrate assemblages inhabiting dike structures of the Lower Mississippi River. This technique would then be available for more detailed ecological investigations of these dike-associated macroinvertebrate assemblages, including comparative habitat quality studies of various dike design and construction alternatives.

9. As a secondary objective, the study was designed to provide basic data on spatial distribution patterns of aquatic macroinvertebrate populations over these structures for input into future comparative field sampling designs of selected dike design and construction alternatives.

PART II: DESCRIPTION OF STUDY AREA

10. The area selected for study was the Lower Cracraft Dike Field (Figure 1). It is located on the west bank of the Lower Mississippi River at river miles 507 to 511 (AHP).* This reach of river is bordered on the west by Chicot County, Arkansas, and on the east by Washington County, Mississippi. Eudora, Arkansas, a town of approximately 2000 people, is located 6 miles** upstream on the right bank of the river, outside of the leveed floodplain. Vicksburg, Mississippi, a major gaging and data collection point for the Lower River, is located 65 miles downstream.

11. The Lower Mississippi River is classified as an alluvial river with a drainage system in a stage of maturity with meanders and oxbow lakes (U. S. Atomic Energy Commission 1973). The river, at this locale, is confined on both sides by levees constructed for flood control purposes. The leveed floodplain is approximately 2 miles wide within the study reach and is predominantly bottomland hardwood.

12. The climate of the area is subtropically humid with a short cold season and a relatively long warm season. The predominant air mass is maritime tropical and originates over the Gulf of Mexico (Gulf South Research Institute 1973).

13. Precipitation occurs mainly as rain with annual snowfall normally averaging about 3.8 cm. Precipitation reaches a maximum in March with a monthly average of about 14.5 cm and a minimum in October when the monthly average is about 5.1 cm. Relative humidity is generally high throughout the year, averaging about 75 percent (Gulf South Research Institute 1973).

14. The average discharge of the Lower Mississippi River at

---

* AHP - Above Head of Passes. The Head of Passes from the Mississippi River to the Gulf of Mexico is referenced as mile zero on the Lower Mississippi River.

** A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3. U. S. customary units are used when it is anticipated that they are familiar to the reader; otherwise metric units are cited.

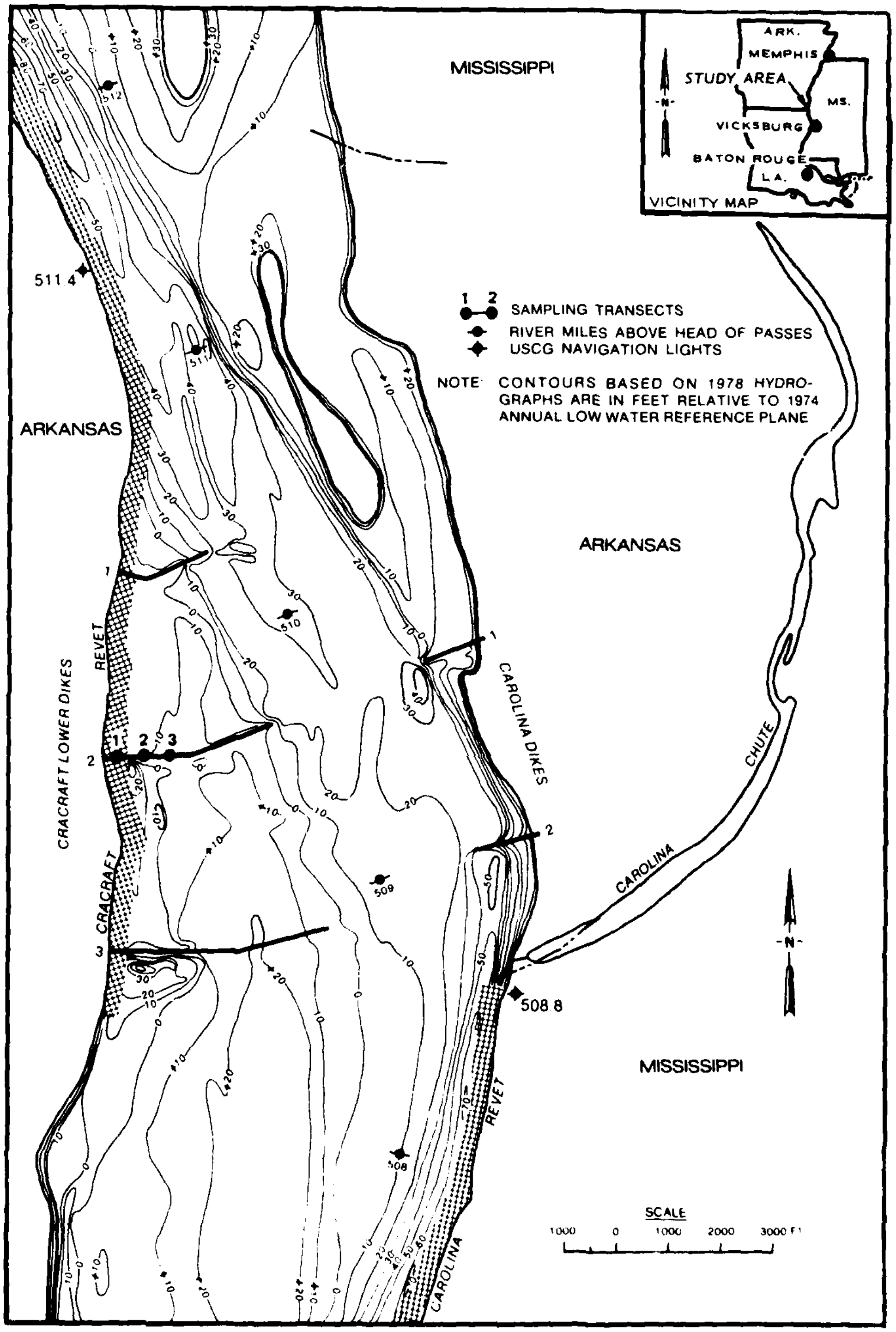


Figure 1. Lower Cracraft Dike Field

Vicksburg, Mississippi, is about 561,000 cfs (Everett 1971). Recorded discharges have ranged from about 100,000 cfs at extreme low river stages to 2,700,000 cfs at high stages, with a stage differential of 60 ft in water surface elevation at Vicksburg between extreme low and high water stages (U. S. Atomic Energy Commission 1973). The average water velocity within the main channel is between 3 and 6 fps with a maximum recorded velocity of 15 fps during extreme high river flows (Gulf South Research Institute 1973). The estimated average sand transport at Vicksburg is one million yd^3/day (U. S. Atomic Energy Commission 1973). The average hydrograph for the river at Vicksburg shows highest discharge occurring from February through March and lowest discharge occurring from July through October (Mississippi River Commission 1977).

15. The Lower Cracraft Dike Field was constructed in 1972 in a divided flow reach of the river. It was constructed for the dual purpose of navigation channel alignment and stabilization and for secondary channel closure.* It is considered typical for this waterway system in terms of both engineering design and function.* The field consists of three transverse, impermeable stone dikes of a stepped-down design. The dikes range in length from 565 m for the upstream dike, to 1103 m for the middle dike, to 1317 m for the downstream dike.* Extensive sand and gravel middle bars have formed between succeeding dikes. An extensive middle bar also occurs over an approximate 2-mile reach of river downstream from the third dike. Lakelike conditions exist within the remaining side channels between successive dikes and below the downstream dike during periods of lower river discharge.

16. The inshore section of the second dike was selected for study purposes (Figure 1). Field observations indicated that a diverse and productive macroinvertebrate assemblage was associated with this structure (Mathis et al. 1981). This was considered essential for study purposes. Additionally, the possibility of substrate sampler vandalism was reduced at this site because of its relative inaccessibility from land.

---

* Personal communication, C. Elliot, Chief, River Stabilization Branch, Vicksburg District, U. S. Army Corps of Engineers, Vicksburg, Miss.

PART III: METHODS AND MATERIALS

17. As noted by Cummins (1962), the number of different aquatic macroinvertebrate sampling techniques is nearly proportional to the number of investigations. At present, no one sampling device is adequate to sample all types of habitat, and the selection of an appropriate technique is largely dependent on specific study objectives as well as site-specific habitat conditions (Weber 1973).

18. The following waterway-specific factors were paramount in defining an appropriate sampling technique for dike studies within this waterway system:

a. Substrate to be sampled. For quantitative studies, the selected technique must adequately sample or replicate as closely as possible the substrate of the habitat. The following stone-size specifications have been used for all dike construction contracts within the Lower Mississippi River since 1965:*

Stone Weight		Cumulative Percent
lb	Kilograms	Finer by Weight
5000	2268	100
2500	1134	70-100
500	227	40-65
100	45	20-45
5	2	0-15
1	0.5	0-5

Field observations, however, indicated that the surface substrate of the dikes consisted primarily of stone less than 100 lb (45 kg) in weight and that the substrate was well sorted.

b. Physical regime. At river stages when water is passing over study area dike structures, the current velocity is typically high and the vicinity of the dike may be extremely turbulent. This effectively prohibits the use of many conventional stream substrate sampling methods which involve sampler deployment and retrieval by wading and/or with the aid of divers.

---

* Personal communication, C. Elliot, Chief, River Stabilization Branch, Vicksburg District, U. S. Army Corps of Engineers, Vicksburg, Miss.

c. Dike design. In the selected study area, the dikes are typically trapezoidal in shape with a flat crown (typically 3 m wide) and steeply sloping (usually 3:1) sides.* Additionally, the dikes are designed with a gradual decrease in elevation with distance from the bank.

d. Fluctuating river stage. With fluctuating stages of the river, the dike substrate may be well below the surface of the water or completely exposed. Since the elevation of the dikes varies with distance from the bank, the main channel end of the dike may be below water, while, close to the riverbank, the dike is above water. Additionally, daily fluctuations in river stage of 3.5 ft or more are not uncommon within the study area. This may greatly influence the method of data collection. For example, great care would have to be taken when obtaining samples by hand or by wading, even for survey sampling purposes, to avoid collecting substrate that has only recently been inundated and not yet fully recolonized by macroinvertebrate organisms.

Rationale for Selected Sampling Technique

19. As indicated above, the uniquely vigorous and dynamic physical regime associated with the Cracraft Dike Field precludes the use of a number of conventional lotic sampling methods. Therefore, a pilot investigation was undertaken prior to this effort to identify potential sampling techniques for use under these waterway-specific physical conditions.

20. During the pilot study, substrate basket samplers (Rock basket and barbeque baskets) were evaluated by remotely deploying the samplers on top of existing dike substrates when the dikes were submerged. The resulting samples, however, were not representative of either the composition or structure of the dike assemblage (Table 1). These results suggested the necessity for implanting the substrate samplers into the dike structure to obtain representative samples.

21. Implanted substrates have been evaluated by a number of investigators for aquatic macroinvertebrate studies within streams and

---

* Personal communication, C. Elliot, Chief, River Stabilization Branch, Vicksburg District, U. S. Army Corps of Engineers, Vicksburg, Miss.

small rivers with gravel and rock substrates (Radford and Hartland-Rowe 1971, Minshall and Minshall 1977, Shaw and Minshall 1980, Wene and Wickliff 1940, Ulfstrand et al. 1974, and Rabeni and Minshall 1977). A review of their use is provided by Edmondson et al. (1971), as well as Hellawell (1978). The technique has met with mixed success due primarily to the following factors:

- a. In several of the reported sudies (Minshall and Minshall 1977, Shaw and Minshall 1980, and Wene and Wickliff 1940), substrate of a uniform size or shape was used to minimize variability between replicate samples, thus facilitating statistical hypothesis testing. For the most part, the resulting data were not considered representative of the naturally occurring assemblage. Minshall and Minshall (1977) suggested that if the substrate of the implanted samplers more nearly matched that of the natural substrate, the sample assemblage would be representative of the dike assemblage.
- b. In each of these studies, the physical regime of the study area was conducive to sampler implanting by wading or with the aid of divers. Thus, the required exposure time for representative substrate colonization was a major unknown and was, in large part, a function of the season of the year (Hynes 1970, Ulfstrand et al. 1974).
- c. The type of substrate container used undoubtedly influenced the composition and structure of the colonizing assemblage. For example, in several of these investigations, substrate trays with solid sides were used, which possibly prevented representative ecological interaction between the implanted substrates and the surrounding aquatic habitat, thus creating a highly artificial and unrepresentative microhabitat for colonizing macroinvertebrates (Hellawell 1978).

22. Results of the pilot investigation indicated that sample size (surface area) as well as sample depth were also important considerations for studies of dike-associated macroinvertebrate assemblages. Individual stone samples obtained from the surface of the dike structure (Table 1) indicated substantial variation in total density estimates between individual stone samples (coefficient of variation (CV) = 97 percent), possibly due to the manner in which the individual dike surface stones were exposed to the overlying physical regime (Mathis et al. 1981). It was concluded that the surface area of discrete samples should be of

sufficient size to account for this between-stone variability, thus facilitating statistical comparisons by reducing variability between replicate samples.

23. Field observations during the pilot investigation also indicated significant aquatic macroinvertebrate activity to a depth of 50 cm or greater within the dike structure. This phenomenon has also been reported by a number of investigators from rock-gravel substrates of streams and small rivers (Hynes, Williams, and Williams 1976; Coleman and Hynes 1970; Bishop 1973; Morris and Brooker 1979; and Williams and Hynes 1974). Their findings indicated that significant benthic production ($\geq$25 percent of estimated total density and biomass) may occur within this substrate type to a depth of between 30-60 cm or possibly deeper.

24. Based on this information, rock-filled rectangular wire baskets, 30.8 cm × 30.7 cm × 27 cm deep (0.095 m^2 sample surface area), were selected for sampling purposes. These containers are quite sturdy, inexpensive, and easily obtainable in large quantities. They are constructed of 0.6-cm-steel weld wire and are open at the top. Spacing between adjacent support wires is approximately 5.1 cm.

25. These basket containers have sufficient spacing between adjacent support wires (5.1 cm) to allow for unimpeded movement of aquatic macroinvertebrates between the rock-filled container, the surrounding rock substrate, and the overlying aquatic regime. Open spacing of the support structure, coupled with the use of representative (well-sorted) substrate obtained directly from the surface of the dike, were used to provide representative conditions for colonizing macroinvertebrate populations. Although implanting of the substrate samplers is restricted to conditions when the dikes are emergent, this implanted substrate should experience the same rate of macroinvertebrate colonization as adjacent natural substrate. Thus, potential sampling error due to variable exposure time required for representative colonization of the implanted samplers may be avoided.

26. The rock basket samplers were selected for their surface area (0.095 m^2), which accommodated four or more representative dike surface stones, in an attempt to minimize variations in total density estimates

between replicate samples. A sample depth of 27 cm, although allowing for standardized comparisons, will undoubtedly underestimate total density and biomass. However, because of the interspersion of very large stones (>200 kg) throughout the length of these dike structures, a uniform sample depth of 27 cm was found to be most practical.

Field Procedures

27. Thirty-six substrate samplers were implanted into the dike structure during the period 21-22 February 1979 (Figure 2). The entire section of the dike was completely emergent during this period. The implanting technique consisted of excavating rock substrate from the dike's surface, placing the excavated substrate into a wire basket, and placing the rock-filled container into the excavated area so that the top of the sampler was flush with the surrounding substrate. Additional rock was then packed around each sampler in order to reestablish continuity of the rock substrate.

28. The samplers were deployed on three transects which were equally positioned along and perpendicular to the length of the dike structure (Figure 1). Twelve samplers were implanted on each transect: four each on the upstream side, the top, and on the downstream side of the dike.

29. The substrate samplers on each transect were then tied together much like a trotline with 1/8-in. vinyl-coated aircraft cable and cable sleeves. Approximately 30 ft of excess cable were used between samplers to prevent the disturbance of succeeding samplers during the retrieval process. This excess cable was then coiled and packed beneath surface stones of the dike to minimize entanglement of the cable with passing debris.

30. For retrieval purposes, two of the samplers implanted into the top of the dike on each transect were then tied to a common trunk line which was secured to a construction alignment piling on the bank and extended out to the third transect sampler set. This approach was u in lieu of buoyed sampler retrieval lines. Buoyed retrieval lines were

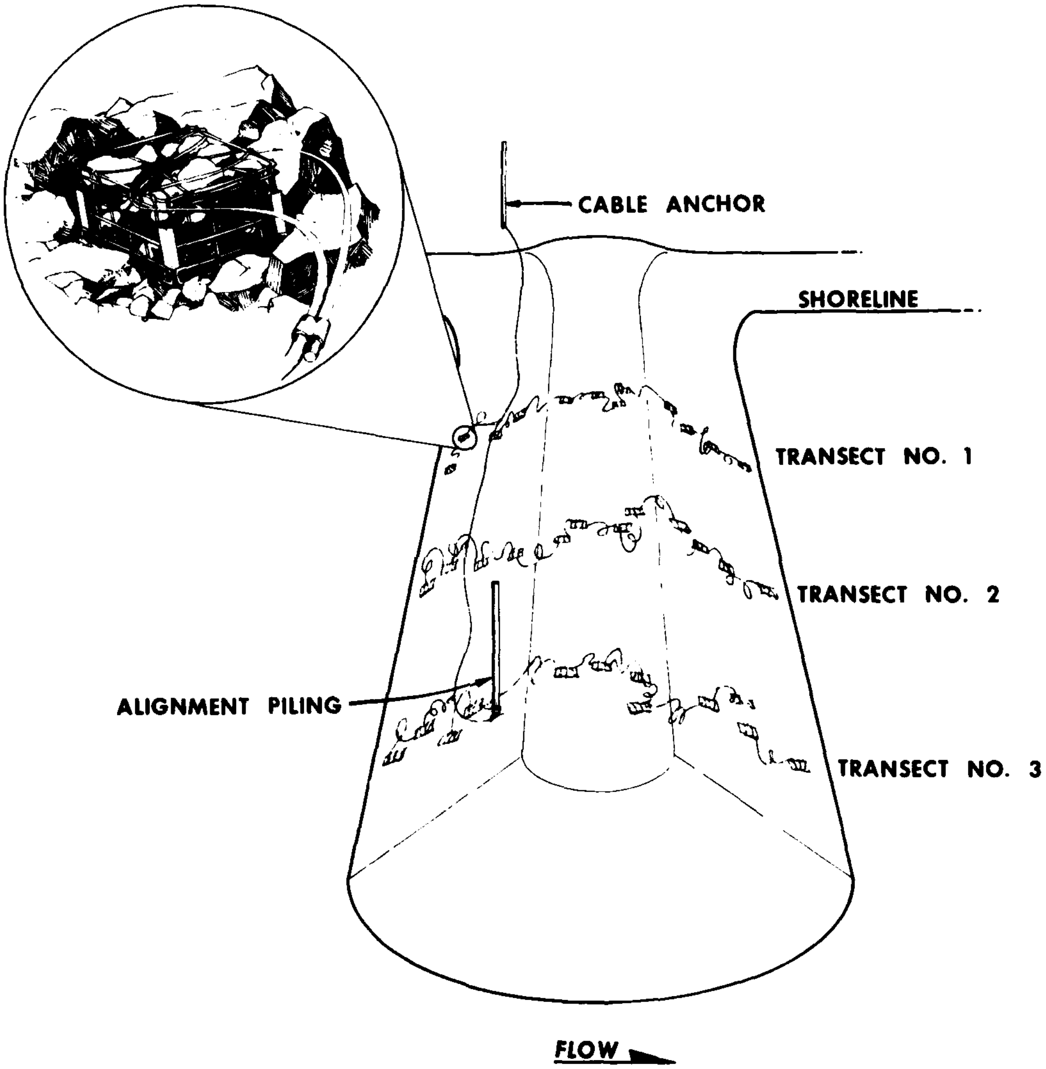


Figure 2. Implanting of substrate samplers

found to be highly susceptible to vandalism, passing debris, and towboats which routinely navigate through dike fields of the Lower Missis-sipi River during higher river stage conditions.

31. The samplers were completely inundated on 26 February 1979, at a river stage of +21.8 ft (Vicksburg gage). Surface current velocity data were obtained from transects upstream and downstream of the dike on 26 May 1979, during peak river discharge (Figure 3). Current velocity profiles were attempted during this period but were unsuccessful because of the extreme physical conditions encountered.

32. Sampler retrieval was undertaken during the period 28-30 June 1979, after an approximate 4-month period of continuous inundation (Figure 2). The river stage at this time was approximately +22 ft (Vicksburg gage), which was selected in order to obtain substrate by hand from the dike surface for sampler verification purposes. Immediately prior to sampler retrieval, surface current velocity and direction data, as well as water quality probe data (pH, dissolved oxygen, temperature, and conductivity), were obtained from transects both upstream and downstream of the dike.

33. Thirty-two of the thirty-six substrate samplers initially deployed were retrieved. The basic retrieval process was as follows: two large inflatable buoys were tied to the bank end of the trunkline and the buoyed line was then allowed to float downstream over the location of the inshore transect; a 21-ft boat rigged with a davit and 12-v anchor-windless was then anchored upstream from the transect and then positioned downstream over the transect with the aid of the anchorline. The samplers were then retrieved in a downstream direction by repositioning the anchorline. This procedure was then repeated for the two remaining transects.

34. Several samplers were lost on the outer two transects when the boat's anchor broke free and the retrieval lines were lost. A few of these samplers were eventually retrieved by grappling for the sampler lead lines. Several samplers were impossible to recover, particularly on the downstream side of the dike, when they were caught beneath shifting rock substrate.

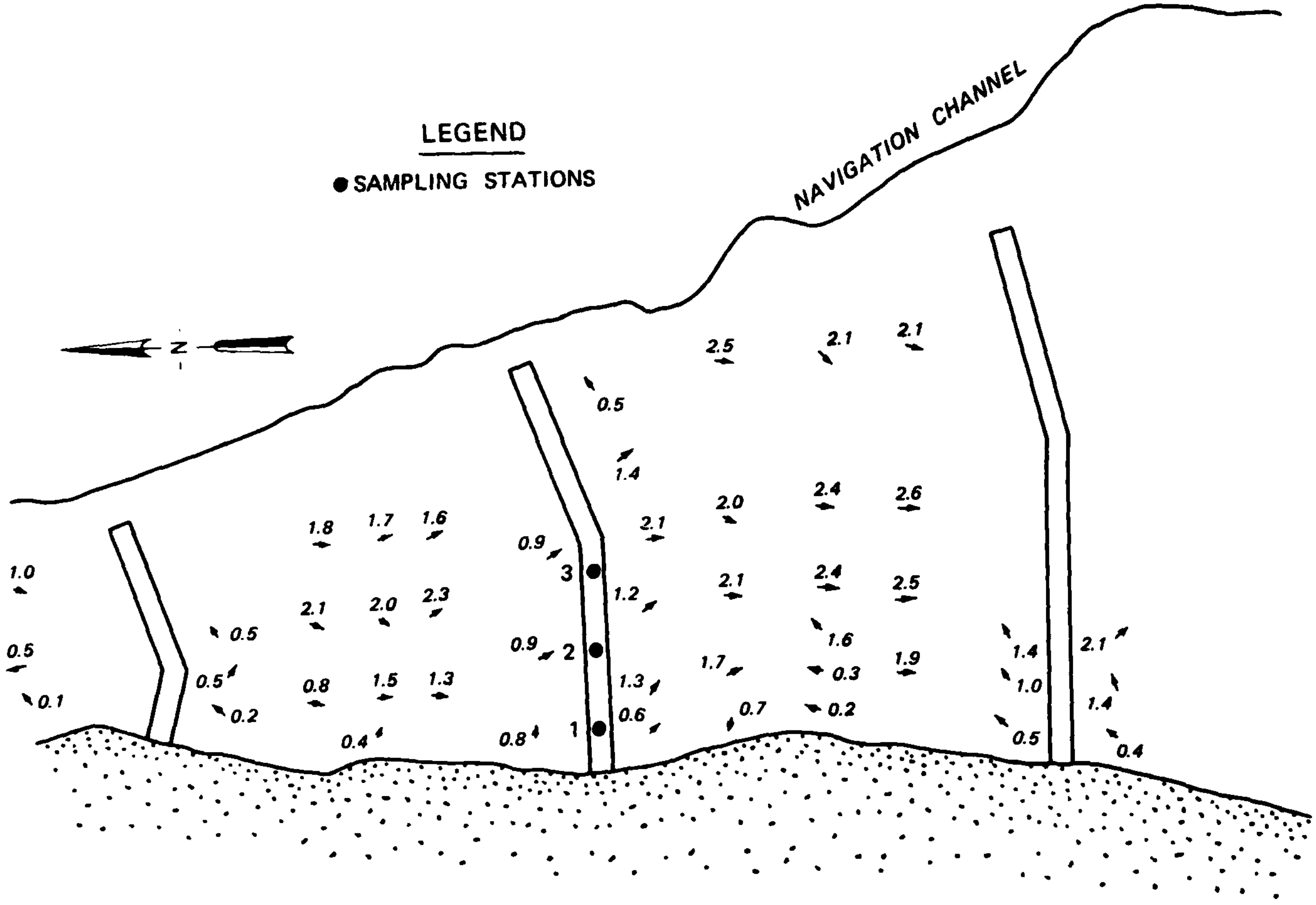


Figure 3. Current velocity and direction data during sampler retrieval

35. Each substrate sample was removed from the wire basket and placed into a No. 2 washtub. The substrate was then thoroughly scraped with a soft bristle wire brush. The resulting macroinvertebrate sample was then sieved through a 0.5-mm mesh screen and preserved in 10 percent formalin.

36. For technique verification purposes, the surface stones from five of the substrate samplers were removed and processed separately. For comparative purposes, the same number of surface stones of fairly similar size were obtained by hand from an area immediately adjacent to where each of the five substrate samplers had been obtained. These samples were then processed by the same procedures used for the substrate samplers.

37. Loss of organisms (dislodgement) during sampler retrieval is a potentially significant source of sampling error using this sampling technique (Edmondson et al. 1971). However, several investigators have reported only minimal organism loss when retrieving substrate samplers from shallow depths, with no significant sampling error in species composition or relative abundance estimates (Mason et al. 1973, Armitage 1976). This was also found to be the case during the pilot investigation which also involved substrate retrieval under shallow water depths.

38. Based on these results, organism loss during sampler retrieval was neither evaluated nor accounted for as part of this investigation because of the shallow water depths required to meet study objectives. However, it should be emphasized that low organism or taxon loss rate may not hold true for sampler retrieval at higher river stages.

Laboratory Procedures

39. In the laboratory, each macroinvertebrate sample was washed with water through a 0.5-mm sieve to remove the formalin and then transferred to a 70 percent ethanol solution.

40. A subsampling procedure for each unpicked substrate sample was required because of the large number of organisms in these samples; their entanglement with the numerous macroinvertebrate tubes, cases, and

capture nets associated with these samples; and the resulting ineffectiveness of flotation techniques for separating organisms from the total samples. The selected subsampling procedure was as follows:

a. Each total sample was initially scrutinized to scrape and remove stones, sticks, and other large organic and inorganic matter from the sample and to pick out rare taxa. In these samples, rare taxa were primarily large, predatory odonates and the river shrimp *Macrobrachium ohione*.

b. The remaining sample was allowed to drain through a 0.5-mm mesh sieve and blotted dry with paper towels.

c. A 10 percent subsample of the remaining total sample weight was then removed and analyzed for taxonomic composition and total counts for each distinct taxon.

d. Total sample density and composition were then estimated based on the subsample data and from counts for each rare taxon picked from the original total sample.

41. An analysis of this procedure, using five successive 10 percent subsamples from the same substrate sample, indicated a coefficient of variation between density estimates of 26.3 percent and between estimated total number of taxa of 15.2 percent (Table 2).

PART IV: RESULTS

42. River stages at Vicksburg, Mississippi, during the period the samplers were implanted are presented in Figure 2. The maximum recorded river stage during this period was 47.9 ft, which was 4.9 ft above flood stage at this gaging station. The maximum surface current velocity over the dike structure during peak river discharge was 4 m/sec (Table 3).

43. From the first of May 1979 until the end of June 1979 when the samplers were retrieved, there was a continuous and fairly gradual fall in water level (Figure 2). During sampler retrieval, the river stage was +22.0 ft and relatively steady. Because of the gradual channelward decrease in slope of the dike, the samplers implanted on the top of the dike were located in water depths of from 0.5 m at transect 1 to approximately 1.2 m at transect 3. The samplers implanted on the side of the dike were in water depths of from 1.8 to 2.5 m.

44. Current velocity and direction data collected at transects above and below the dike just prior to sampler retrieval are presented in Figure 3. Eddy currents were present along the inshore section of the dike (including transect 1) and both upstream and downstream of the structure. Current velocity generally increased with distance from shore and with depth of water over the dike. Although a 0.3- to 0.7-m head of water was present on the upstream side of the dike at transects 2 and 3, there were only minor differences in current velocity between the upstream and downstream sides of the structure at either transect. However, water turbulence was substantially greater over the top and downstream stations, as compared to the upstream stations at both transects 2 and 3.

45. Heavy accumulations of fine sand-silt-clay were observed in each basket sampler retrieved from the downstream station at transect 1. This was apparently due to eddy currents and reduced current velocities encountered at this station (Figure 3). Heavy accumulations of coarse sand and gravel were observed in each sampler retrieved from all three upstream positions and from the samplers located on the top of the dike structure at transect 1. Small accumulations of firm clay were also

observed in several samplers retrieved from the upstream stations. Little or no sediment accumulation was found in samplers retrieved from the top and downstream stations at transects 2 and 3.

46. Surface water quality data, obtained immediately prior to sampler retrieval, are presented in Table 4. There were no apparent differences in the water quality variables measured, either immediately upstream or downstream of the structure, or with distance from the bank. These data did indicate, however, a marked increase in dissolved oxygen concentrations and conductivity at the transect located 450 m downstream from the structure. A corresponding increase in current velocity was also noted at this transect (Figure 3).

Rock Basket Data

47. A total of 309,990 aquatic macroinvertebrates* were collected from the 32 rock basket samples, representing 6 classes, 15 orders, and 38 distinct taxa (Table 5).

48. Class Insecta was by far the dominant group representing over 97 percent of the organisms collected. Immature insects collected included 8 taxa of Ephemeroptera (mayflies), 6 taxa each of Trichoptera (caddisflies) and Diptera, 3 taxa of Odonata (dragonflies and damselflies), and 1 taxon each of Coleoptera (water beetles), Collembola (springtails), Plecoptera (stoneflies), and Lepidoptera (aquatic moths).

49. Crustaceans collected included 2 taxa of Amphipoda and 1 taxon each of Decapoda and Isopoda. Also collected were 3 taxa of Oligochaeta, 2 taxa of Pelecypoda, the leeches Hirudinea, and the water mites Hydracarina.

50. The average overall sample density (Table 6) was 9687 organisms/sample (CV = 91.2 percent). The average overall numer of taxa collected was 15.6/sample (CV = 30.7 percent).

51. The net-spinning caddisfly *Hydropsyche* spp. was the most abundant taxon collected, representing 60.1 percent of the total sample

---

* Based on the subsampling procedure used for lab analysis.

density (Table 5). It was collected in each of the 32 basket samples. Next in order of abundance were the tube-building chironomid *Rheotanytarsus* sp., the net-spinning caddisfly *Potamyia flava*, the tube-building chironomid *Polypedilum* sp., the isopod *Lirceus* sp., and the sprawling mayfly *Baetis* sp., representing 19.1, 8.4, 5.1, 2.1, and 0.9 percent of the total sample density, respectively. Each was collected in over 80 percent of the substrate samples (Table 5).

Verification of Sampling Technique

52. Data obtained to evaluate the applicability of the rock basket samplers for dike studies are presented in Table 7. These data are not expressed quantitatively since no attempt was made to measure the surface area of each individual stone sample obtained. The data are, however, amenable to testing the effectiveness of the basket samplers for providing representative estimates of the composition and relative abundance of aquatic macroinvertebrates associated with the dike structure.

53. Eighteen distinct taxa were collected from the individual stone samples removed from the dike's surface (Table 7). Fifteen distinct taxa were collected from the surface stones of the rock baskets. Fourteen taxa were common to both sample sets. These taxa comprised over 99.5 percent of the total number of organisms collected from each sample set.

54. Four taxa were collected from the dike structure samples which were not collected from the surface stones of the rock baskets. However, each was collected infrequently and in small numbers in or upon the substrate below the surface stones in the rock basket samples. These included the Dipteran *Atherix variegata*, the stonefly *Neoperla* sp., Naid worms, and the leeches Hirudinea. Each of these taxa was collected in only one of the dike substrate samples, and each was also collected infrequently and in small numbers from the rock basket samples (Table 5).

55. A comparison of the estimated relative abundance rankings of the 19 total taxa obtained from both sample sets (Table 7) was made using Spearman's (1904) nonparametric test of association after Hellawell

(1978). This test indicated a significant (R = 0.76 , $\alpha \leq 0.01$) level of association in relative abundance rankings of these taxa between the dike structure samples and the surface stones of the rock basket samplers. Additionally, numerically dominant taxa and the relative percent of total sample density for each also showed close agreement between the two sample sets (Table 7).

Evaluation of Sample Depth

56. The macroinvertebrate assemblage collected from surface stones of the rock baskets, which were processed separately, were compared to the remainder of each corresponding assemblage collected in the rock basket sample to evaluate the importance of sample depth for dike macroinvertebrate sampling purposes (Table 8). As stated previously, no attempt was made to measure the surface area of each individual stone; thus, only a qualitative evaluation was possible.

57. The average sample density for the surface rocks was 5091.7 organisms/sample (CV = 74.8 percent), as compared to an average of 13,983.3 organisms/sample (CV = 41.3 percent) for the remainder of the basket sample (Table 8). Thus, on an average basis, only 26.7 percent of the total rock basket sample density was found in the top layer, or surface stones, of the basket samples. Additionally, variability in density estimates between samples was much less in the lower sections of the samples, even though density estimates were much higher.

58. Thirteen distinct taxa were obtained from the surface stones of the samplers as compared to twenty-three taxa obtained from the remainder of these samples. The average numer of distinct taxa per sample for the surface stones was 11.0 (CV = 15.7 percent), as compared to 16.3 taxa/sample (CV = 18.7 percent) for the remainder of the sample.

59. The aquatic moth *Parargyractis* sp. was the only taxon collected from the top rocks that was not obtained for the remainder of the basket samples. Conversely, 11 distinct taxa were collected from the lower portion of the samplers that were not obtained from the surface layer. These included the Dipteran larvae *Ablabesmyia* sp., *Atherix variegata*,

and *Stenochironomus* sp., the pelecypod *Corbicula* sp., the amphipod *Corophium* sp., the amphipod *Gammarus* sp., the springtail *Isotomurus* sp., the stonefly *Neoperla* sp., the odonate *Didymops transversa*, the water mite Hydracarina and the Hirudinea leeches.

60. Twelve taxa were common to both data sets (subsurface) and each showed close agreement in relative abundance, based on ranked percent of total sample density (Spearman R = 0.96 , $\alpha = 0.01$).

Assemblage Distribution over the Structure

61. A fixed-effect, two-way analysis of variance (parametric, without transformation) (Sokal and Rohlf 1969) was used to test for significant differences in average total sample density and average total number of taxa per sample among transects and among dike positions (downstream, top, and upstream). This analysis (Table 9) indicated significant differences ($\alpha \leq 0.05$) in both average sample density and average number of taxa per sample among dike transects as well as among dike positions. Additionally, there was no significant interaction between transect or position effects for either average density or taxa (Table 9). This indicated that both distance from the bank (transect) and position on the dike directly and independently influenced the spatial distribution of aquatic macroinvertebrates on the dike structure.

Assemblage Distribution by Transect

62. The average sample density for transect 1 (Table 10) was 5,912.4 organisms/sample (CV = 121.4 percent) and ranged from a minimum of 239 organisms/sample to a maximum of 21,391 organisms/sample. Thirty distinct taxa were collected from this transect (Table 11) with an average number of taxa per sample of 12.8 (CV = 22.8 percent, range 8 to 17 taxa/sample). Five taxa were collected at transect 1 which were not collected from the two offshore transects. These included the oligochaete *Limnodrilus* spp., the damselfly *Ischnura* sp., the burrowing mayfly *Hexagenia limbata*, the springtail *Isotomurus* sp., and the net-spinning caddisfly *Cheumatopsyche* sp.

63\. The average density per sample for transect 2 was 9,472.3 organisms (Table 10) and ranged from a minimum of 1,208 organisms/sample to a maximum of 19,653 organisms/sample (CV = 70.5 percent). Twenty-eight taxa were collected from this transect (Table 11) with an average number of taxa per sampler of 15.8 (CV = 35.9 percent, range = 7 to 25 taxa/sample). No taxa were collected that were unique to this transect (Table 11).

64\. The average density per sample for transect 3 (Table 10) was 13,980 organisms and ranged from a minimum of 566 organisms/sample to a maximum of 31,067 organisms/sample (CV = 75.7 percent). Thirty-two taxa were collected from this transect (Table 11) with an average number of taxa per sample of 15.0 (CV = 34.3 percent, range = 7 to 24 taxa/sample). Five taxa were collected from transect 3 which were not obtained from the two other transects (Table 11). These included the pelecypod *Sphaerium* sp., the aquatic moth *Parargyractis* sp., the midge *Psectrotanypus* sp., the burrowing mayfly *Tortopus incertus*, and an immature brachycentrid caddisfly.

65\. Duncan's Multiple Range Test (Sokal and Rohlf 1969) was used to test for significant differences ($\alpha \leq 0.05$) in average total density and average number of taxa per sample between individual transects (Table 10). This test indicated that the average density per sample was significantly higher at transect 3 than at transect 1. There was no significant difference in average density per sample between transects 1 and 2 or between transects 2 and 3. The average number of taxa per sample obtained at transect 2 was significantly higher than at transect 1. There was no significant difference in average numbers of taxa between transects 2 and 3 or between transects 1 and 3 (Table 10).

66\. Twenty-four taxa were common to all three transects. These taxa accounted for over 99 percent of the total number of organisms collected at each transect.

67\. Spearman's nonparametric test of association was used to determine the degree of association in relative abundance rankings of these 24 common taxa between transects. This test (Table 10) indicated a significant ($\alpha \leq 0.01$) degree of association in ranked relative abundance for these individual taxa between transects. The actual R values derived from this test were highest for the test between transects 2 and 3 (R = 0.86), lowest between transects 1 and 3 (R = 0.71), and intermediate between transects 1 and 2 (R = 0.76).

Assemblage Distribution by Position

68. The average sample density obtained for the downstream side of the dike was 4,001.7 organisms/sample (Table 12) and ranged from a minimum of 239 organisms/sample to a maximum of 18,087 organisms/sample (CV = 156.4 percent). Twenty-five taxa were collected from the downstream side of the structure (Table 13) with an average number of taxa per sample of 10.2 (CV = 22.7 percent, range = 7 to 14 taxa/sample). Three taxa were collected exclusively from the downstream side of the structure. These included the oligochaeta *Limnodrilus* spp., the damselfly *Ishnura* sp., and the burrowing mayfly *Hexagenia limbata*.

69. The average density per sample for the top of the dike was 15,971.8 organisms/sample and ranged from a minimum of 2,801 organisms/sample to a maximum of 31,067 organisms/sample (CV = 56.6 percent). Twenty-seven taxa were collected from the top of the structure (Table 13) with an average number of taxa per sample of 14.6 (CV = 19.4 percent, range = 10 to 20 taxa/sample). Three taxa were collected exclusively from the top of the dike (Table 13). These included the net-spinning caddisfly *Cheumatopsyche* sp., the midge *Psectrotanypus* sp., and the aquatic moth *Parargyractis* sp.

70. The average density per sample for the upstream side of the dike was 9,026.6 organisms/sample and ranged from a minimum of 2,714 organisms/sample to a maximum of 25,134 organisms/sample (CV = 75.2 percent). Thirty-two taxa were collected from the upstream side of the dike (Table 13) with an average number of taxa collected per sample of 18.8 (CV = 20.6 percent, range = 14 to 25). Six taxa were collected exclusively from the upstream side of the structure (Table 13). These included the pelecypods *Corbicula* sp. and *Sphaerium* sp., the springtail *Isotomurus* sp., the burrowing mayflies *Pentagenia vittigera* and *Tortopus*

incertus, and an immature brachycentrid caddisfly.

71. Duncan's Multiple Range Test was used to test for significant differences ($\alpha \leq 0.05$) in average total sample density and average number of taxa between positions (Table 12). This test indicated that average total density of macroinvertebrates was significantly higher on the top of the structure as compared to either the upstream or downstream positions. There was no significant difference in average sample density between the upstream and downstream positions.

72. For average number of taxa per sample, this test indicated significant differences between each position (Table 12). Average number of taxa collected per sample was significantly higher from the upstream side as compared to both the top and downstream positions. Additionally, the average number of taxa collected from the top of the structure was significantly higher than from the downstream side of the structure.

73. Nineteen taxa were common to all three dike positions (Table 13). These taxa accounted for over 99 percent of the total number of organisms collected from each position.

74. Spearman's nonparametric test of association was used to determine the degree of association in relative abundance rankings of the 19 common taxa between dike positions (Table 12). This test indicated a significant ($\alpha \leq 0.01$) degree of association in relative abundance for these taxa between positions. The actual R values derived from the test were highest (R = 0.79) between the upstream and top positions, and equivalent (R = 0.67) for the upstream and downstream and the top and downstream position comparisons.

PART V: DISCUSSION

75. The Cracraft dike was inhabited by a diverse and productive aquatic macroinvertebrate assemblage during this sampling period. The assemblage was distinctly lotic and predominantly epilithic in composition and was characterized by net-spinning caddisflies, tube-building chironomids, clinging mayflies, and isopods.

76. Thirty-eight taxa were collected from the structure. The caddisfly *Hydropsyche* spp. was the most abundant and ubiquitous taxon collected, representing 60.1 percent of the total sample density. This genus is known to frequently dominate the insect biomass of rivers with high sediment loads (MacKay 1979). Schuster and Etnier (1978) have found that several species of this genus are often encountered in very high densities within silt-laden rivers, with individual larval retreats and pupal cases literally stacked on top of one another. The clinging mayflies Ephemeroptera, although the most diverse (8 taxa) and ubiquitous macroinvertebrate group collected from the structure, was generally found at low levels of abundance, and collectively comprised less than 2.5 percent of the total sample density.

77. Several macroinvertebrate taxa were collected from the structure which are not considered characteristic inhabitants of dikes within the Lower Mississippi River. These taxa included the damselfly *Ishnura* sp., which is typically associated with vascular hydrophytes (Merritt and Cummins 1978), and the oligochaete *Limnodrilus* spp., the mayfly *Hexagenia limbata*, and the pelecypod *Sphaerium* sp., which are typically associated with backwater habitats (Mathis et al. 1981). *Ishnura* sp., *Limnodrilus* spp., and *Hexagenia limbata* were collected exclusively from the samplers downstream of transect 1. Fine-grained sediments and organic debris found in samples obtained from this position provided suitable habitat for these organisms. Thus, the presence of these taxa on the structure was probably due to their passive introduction through main channel macroinvertebrate drift and a transit local condition suitable for habitation.

78. The average overall substrate sample density obtained during

this effort, extrapolated to numbers per square metre of dike structure surface area, was 101,968.4 organisms/m^2. The *maximum sample density* obtained was 327,021 organisms/m^2. This high average sample density may have resulted in part from the fairly gradual and continuous fall in water level which preceded sampling efforts. The major factors controlling stream macroinvetebrate distribution are: (a) substrate type, (b) current velocity, and (c) temperature (Hynes 1970). Since substrate type and temperature were relatively uniform and current generally increased with distance from shore, it is likely that the increased macroinvertebrate densities away from shore resulted from colonization by drifting macroinvertebrates that evacuated upstream areas made unsuitable by receding water levels and reduced inshore currents.

79. The high density, as well as diversity estimates obtained during this effort, however, are indicative of the potential ecological value of dike structures within the Lower Mississippi River for aquatic macroinvertebrates and, ultimately, as a food source for river fishes. This ecological potential can be attributed, in large part, to increased diversity in habitat (substrate) provided by these stone structures. Because of the large quantities of bedload material transported through the Lower Mississippi River and the characteristically shifting and unstable main channel sediments of the river, this ecological potential is probably also related in part to the habitat (substrate) stability provided by these structures.

Assessment of Sampling Technique for Dike Studies

80. Study results indicated that the implanted substrate samplers provided representative estimates of both the composition of the dike assemblage as well as estimates of the relative abundance of individual taxa comprising the assemblage. Thus, the technique is considered appropriate for comparative studies of dike assemblages within the Lower Mississippi River.

81. The fact that representative estimates of both assemblage composition and structure were obtained is attributed to several factors.

These include (a) implanting of individual substrate samplers into the dike structure, (b) the use of representative (well-sorted) substrate obtained directly from the dike structure, and (c) the substrate container itself, which apparently provided for representative interaction between the implanted substrate and the surrounding aquatic environment. Additionally, the samplers were deployed when the dike structure was completely emergent. Thus, with rising water levels and inundation of the dike structure, the implanted substrates were afforded the same rate of exposure to colonizing aquatic macroinvertebrates as the adjacent dike substrate.

82. Sample depth within the substrate appears to be an important consideration for studies of dike-associated aquatic macroinvertebrates. For sampling purposes, these results indicate that variability in density estimates between replicate samples may be appreciably reduced by increasing the depth of substrate sample. Additionally, on an average basis, only 27 percent of the total sample density of each substrate sample was obtained from the surface layer of substrate within the rock baskets. Although there was a high degree of association in ranked relative abundance estimates of taxa common to both data sets, both the rock basket and surface stone, 11 taxa were collected from the lower portion of the samplers which were not obtained from the surface stones. These data suggest that significant errors in estimating dike assemblage composition may result by considering only the surface substrate for sampling purposes.

83. Although these implanted substrate samplers appear suitable for comparative dike assemblage studies, a number of actual or potential sampling problems are associated with the technique, as used in this study. The major disadvantage, which was apparent from study results, was the large number of organisms collected. Although a subsampling approach was used, an inordinate amount of laboratory time was still required to accurately pick, sort, and enumerate the organisms from each subsample to the lowest possible taxonomic level. This indicates that either a smaller sample surface area or a reduced laboratory subsample

size would be necessary for dike studies requiring a large number of samplers for study purposes.

84. Pilot investigation data indicated that a large sample surface area would be required to reduce variability between replicate dike substrate samples. The results of this study, however, indicate that increased sample depth, as well as a stratified sampling approach (see following sections), may be of equal or greater importance than increased sample surface area in reducing data variability between samples. Reducing the surface area of individual substrate samples would, in turn, reduce the required laboratory analysis time for each sample, and, possibly, the requirement for subsampling which, in itself, is an additional source of sampling error.

85. Typically, high current velocities and extreme water turbulence are encountered around dike structures of this waterway when they are submerged. These conditions effectively restrict sampler implanting efforts to periods of lower water when the dikes are emergent. This restriction may potentially create severe logistic problems in that periods and duration of low river flow are often unpredictable, low flow periods may or may not coincide with project schedules which are quite often inflexible, and, during any given year, required low flow conditions may not occur at all. Additionally, for quantitative comparative studies, a large number of samplers may have to be implanted at one time to provide adequate sample replication and for seasonal or other sampling design considerations.

86. Finally, the technique must be modified to prevent undue loss of organisms if sampler retrieval is required during higher river stages, or for assemblage comparisons between dikes constructed to different controlling elevations. It should be emphasized, however, that such a design modification may in itself create an additional source of sampling error. This potential error may include capture of drifting macroinvertebrates and/or organisms dislodged from adjacent substrate during the retrieval of implanted substrates and variable mechanical efficiency of the selected modification during the retrieval of individual samples.

87. A sampling design similar to that developed by Coleman and Hynes (1970) may be best suited to prevent loss of organisms during sampler retrieval from these dike structures. This design basically employs a net bag (with net mesh aperture of the same size as used for sieving purposes) which is placed at the base of each sampler during implantation. This net is then drawn up to enclose the substrate sampler prior to retrieval. In order to reduce variable mechanical efficiency of the net inclosure between samples, such a modification would probably require the use of circular substrate containers instead of the rectangular baskets used during this study.

Assemblage Distribution over the Structure

88. A number of factors appeared to contribute to the observed differences in assemblage distribution over the structure during this sampling period. These factors included the combined effect of (a) dike design, (b) falling water level prior to sampler retrieval, (c) presence or absence, as well as type of, sediment accumulation within the substrate samplers, and (d) differences in stability of the dike substrate between dike positions. Differences in current velocity and/or turbulence between transects and positions were also apparent contributors to the distribution of a number of macroinvertebrate taxa over the structure.

Distribution by sampling transect

89. Observed differences in assemblage distribution between sampling transects appeared to be related primarily to the combined effect of falling water level prior to sampler retrieval and dike design. As previously discussed, dikes on the Lower Mississippi River are designed with a gradual decrease in elevation toward the channel. This design results in earlier exposure of the shoreward dike portions and more rapidly decreasing currents in this locality as opposed to offshore dike portion. The slower currents and accumulating silt are less suitable to the filter-feeding and grazing organisms characteristic of the stone dike structures. Thus these organisms evacuate the inshore

dike as these conditions arise but may well recolonize with higher river stages.

90. Because of falling river stages, eddy currents were present on both the up- and downstream side of the structure at transect 1. As a result, current velocities were reduced on both sides of the structure at this sampling transect and deposits of fine-grained sediments were present on the downstream side of the transect. Rapidly settling silts are unsuitable for most benthic macroinvertebrates and reduced currents are unfavorable to the filter feeders and grazers that comprised the major portion of the benthic macroinvertebrate community of the dike. With the receding waters and reduced currents these conditions resulted in the lowest average sample density, the lowest average number of taxa per sample, and highest variability in density estimates between samples at this transect.

91. Eddy currents appear to be a characteristic feature of the immediate inshore section of dikes within the Lower Mississippi River and over a wide range of river stages because of the dike design used (Walters 1974). However, at any given river stage, the influence of eddy currents is probably limited to only a very small percentage of the total available dike structure habitat for aquatic macroinvertebrates.

92. The observed linear increase in average sample density with sampling transect distance from shore was principally due to the retreat-building caddisflies. Based on field observations, these taxa appear to have very limited capability for lateral movement over the structure to compensate for fluctuating water levels. Thus, the observed transect differences for these taxa were probably due to their release from the shallower inshore transects due to a continuous fall in river stage.

93. The 24 macroinvertebrate taxa common to all three sampling transects accounted for over 99 percent of the total assemblage density obtained from each transect. Additionally, the ranked relative abundance of each of these taxa was quite similar between transects. These results indicate that, if sampling had been accomplished at a higher river stage when currents and substrates were more similar over the dike, differences in assemblage distribution between transects may have been

much less. These results also suggest a potentially greater food-source availability of certain components (principally the dominant caddisflies) of the dike assemblage to the river fishes, the macroinvertebrate drift, during a continuous fall in river stage. The extent of utilization of these macroinvertebrate taxa by the river fishes should be easily assessed by analyses of stomach contents of fishes collected under continuous falling river stage conditions.

Distribution by dike position

94. The 19 taxa common to all three dike positions during sampling efforts accounted for over 99 percent of the total sample density obtained from each position. Additionally, the ranked relative abundance of total position sample density for each of these taxa was similar between positions.

95. These results suggest that, for this sampling period, the basic dike macroinvertebrate assemblage was similar across the three dike positions. However, physical habitat differences between positions appeared to directly influence the distribution of a number of taxa over the structure which, in turn, contributed to increased variability in overall estimates of assemblage density and composition for the structure.

96. The lowest average density per sample, the lowest total and average number of taxa, and the highest variability between estimates of assemblage density were obtained from the downstream side of the structure. This is attributed primarily to eddy currents at the downstream station at transect 1, and to substrate instability on the downstream side of the structure at the outer two dike transects.

97. This substrate instability was observed both when the substrate samplers were initially implanted at low water and again during sampler retrieval efforts when several samplers from the downstream side were difficult or impossible to retrieve due to shifting stone substrate. This variable substrate stability was probably a result of the 0.3- to 0.7-m head of water which occurred just upstream of the structure during sampling efforts. This head of water is apparently

characteristic of dike structures within this waterway,* even at higher flows, and, undoubtedly, contributed to substrate instability due to the downward thrust of water and increased turbulence over the downstream side of the structure.

98. The highest average density per sample was obtained from the top position of the dike structure. *Hydropsyche* spp. and *Rheotanytarsus* sp., the two most abundant taxa collected from the structure, were also found in highest numbers on the top of the structure. Both genera are predominantly filter feeders (Merritt and Cummins 1978), and their higher abundance on the top of the structure was probably related to preferential feeding activity.

99. The highest total number of taxa as well as the highest average number of taxa per sample were obtained from the upstream side of the dike. This is attributed to the presence, as well as types, of accumulated sediment within each of the upstream substrate samplers. The greater substrate diversity and stability provide greater recruitment potential. Additionally, greater numbers of organisms probably make physical contact with the upstream side and contact is more easily maintained.

100. Significant accumulations of coarse sand and gravel were found in each of the upstream substrate samplers. Preferences for this accumulated sediment were particularly evident for the oligochaetes Naidae and Lumbricidae, as well as the pelecypod *Corbicula* sp. and the crustaceans *Lirceus* sp., *Gammarus* sp., and *Corophium* sp. This substrate association is of particular interest within the Lower Mississippi River as previous studies of coarse sand and gravel substrates have shown these sediment types to be depauperate of aquatic macroinvertebrates (Mathis et al. 1981, Conners and Bryan 1975). This finding has been attributed to the unstable, shifting nature of coarse sand and gravel sediments within this waterway (Mathis et al. 1981). The observed preference of a number of macroinvertebrate taxa for this substrate

---

* Personal communication, C. Elliot, Chief, River Stabilization Branch, Vicksburg District, U. S. Army Corps of Engineers, Vicksburg, Miss.

type was probably due to the substrate type's increased stability within the dike structure.

101. The burrowing mayflies *Tortopus incertus* and *Pentagenia vittigera* were collected in several samples from the upstream side of the structure. These taxa are characteristic of firm clay and appreciable current within the Lower Mississippi River and do not appear to be adaptive with regard to sediment type (Mathis et al. 1981). Each of these samples contained deposits of firm clay sediments suitable to these organisms.

102. The distinct differences in physical habitat conditions between dike positions appeared to be significant contributing factors to the variability in estimates of both dike assemblage composition and density obtained during this investigation. Thus, for future comparative studies of dike-associated macroinvertebrate assemblages, a stratified random sampling scheme based on dike position appears necessary in order to reduce variability between replicate samples and to facilitate statistical hypothesis testing. Because of the instability of the stone substrate on the downstream position of these structures and the resulting greater variability in density estimates between replicate samples, a larger number of replicate samples will probably be required from this sampling position.

PART VI: SUMMARY AND CONCLUSIONS

103. The rock basket sampler evaluated during this investigation provided representative estimates of both the composition and structure of the dike-associated macroinvertebrate assemblage. The success of the rock basket sampler was attributed to sampler implantation into the structure, the use of representative substrate obtained directly from the dike, the construction features of the selected substrate sampler deployment when the dike was emergent.

104. The Cracraft Dike Field was inhabited by a diverse and productive macroinvertebrate assemblage, characterized by net-spinning caddisflies, tube-building chironomids, clinging mayflies, and isopods. The caddisfly *Hydropsyche* spp. was the most abundant and widespread taxon collected, comprising 60.1 percent of the overall sample density.

105. The basic macroinvertebrate assemblage was similar across all dike transects and positions sampled during this investigation. However, a number of factors appeared to influence the spatial distribution of several individual taxa over the structure which, in turn, influenced overall estimates of average assemblage density and number of taxa per sample.

106. The observed linear increase in average sample density with transect distance from shore was attributed to the combined effect of dike design and falling river stage prior to sampling effort. This linear increase in density could possibly be attributed to the drift of net-spinning caddisflies from the shallower, slower current inshore transects with falling river stage. If sampler retrieval had been undertaken during higher river stage conditions, it is likely that densities among transects would have been more uniform due to more uniform current velocities over all transects.

107. Differences in physical habitat conditions among dike positions (top of dike structure, upstream side of dike, or downstream side of dike) had a significant effect both on estimates of total assemblage composition and relative abundance. The lowest average sample density, lowest average number of taxa per sample, and the highest variability in

density estimates between samples were obtained from the downstream side of the dike. This was attributed primarily to the instability of the stone substrate on the downstream side of the structure. The highest average sample density was obtained from the top of the dike structure. *Hydropsyche* spp. and *Rheotanytarsus* sp., the two most abundant taxa collected from the dike, were also found in highest numbers on the top of the structure. Both genera are filter feeders, and their higher abundance on the top of the structure was probably related to preferential feeding activity. The highest total number of distinct taxa as well as as the highest average number of taxa per sample were obtained from the upstream side of the structure. This was attributed primarily to individual preferences of a number of macroinvertebrate taxa for the stable coarse sand and gravel sediment which had accumulated within each of the upstream substrate samplers as well as to possibly greater frequency of contact and ease of maintaining position.

108. This investigation, as well as field observations, indicate significant macroinvertebrate acitivity below the surface substrate of the dike. These results suggest that significant errors in assemblage composition and relative abundance estimates may occur by considering only the surface substrate of these dikes for sampling purposes.

109. The results of this investigation explicitly show the potential habitat value of dike structures for aquatic macroinvertebrates within the Lower Mississippi River. This habitat potential is attributed both to increased habitat (substrate) diversity provided by these stone structures as well as to habitat stability.

110. The distinct differences in physical habitat conditions between dike positions appeared to be the major contributing factors to variability in overall sample estimates of dike assemblage composition and density. Therefore, for future comparative studies of dike-associated aquatic macroinvertebrate assemblages, a stratified random sampling scheme, based on dike position, is recommended to reduce data variability and, in turn, to facilitate statistical hypothesis testing.

REFERENCES

Armitage, P. D. 1976. "A Quantitative Study of the Invertebrate Fauna of the River Tees Below Cow Green Reservoir," Freshwater Biology, Vol 6, pp 229-240.

Bishop, J. E. 1973. "Observations on the Vertical Distribution of the Benthos in a Malaysian Stream," Freshwater Biology, Vol 3, pp 147-156.

Bulkley, R. V. et al. 1976. "Warmwater Stream Alteration in Iowa: Extent, Effects on Habitat, Fish, and Fish Food, and Evaluation of Stream Improvement Structures (Summary Report)," U. S. Fish and Wildlife Service, OBS-76/16, Washington, D. C.

Coleman, M. J. and Hynes, H. B. N. 1970. "The Vertical Distribution of the Invertebrate Fauna in the Bed of a Stream," Limnology Oceanography, Vol 15, pp 31-40.

Connors, J. V. and Bryan, C. F. 1975. "Review and Discussion of Biological Investigations in the Lower Mississippi and Atchafalaya Rivers," Proc. Annu. Conf. Southeast Assoc. Game and Fish Comm., White Sulphur Springs, W. Va.

Cummins, K. W. 1962. "An Evaluation of Some Techniques for the Collection and Analysis of Benthic Samples with Special Emphasis on Lotic Waters," The American Midland Naturalist, Vol 67, No. 2, pp 477-504.

Edmondson, W. T. et al. 1971. "Secondary Production in Fresh Waters," IBP Handbook No. 17, International Biological Program, Blackwell Scientific Publications, Oxford and Edinburgh.

Everett, D. E. 1971. "Hydrologic and Quality Characteristics of the Lower Mississippi River," Technical Report No. 5, U. S. Department of the Interior, Geological Survey.

Fremling, C. R. 1960. "Biology and Possible Control of Nuisance Caddisflies of the Upper Mississippi River," Res. Bull. Iowa Agri. Exp. Station, No. 483, pp 857-879.

Gulf South Research Institute. 1973. "Environmental Inventory for the Mississippi River--Cairo, Illinois, to Venice, Louisiana," Vol I, New Orleans, La.

Hellawell, J. M. 1978. "Biological Surveillance of Rivers," Water Research Centre, Stevenage, England.

Henley, J. E. 1966. "Channel Stabilization Work in the Vicksburg District," in: Symposium on Channelization Problems, Committee on Channel Stabilization, U. S. Army Corps of Engineers, Vol 4, Chapter 1.

Hynes, H. B. N. 1970. "The Ecology of Running Water," University of Toronto Press, Toronto.

Hynes, H. B. N., Williams, D. D., and Williams, N. E. 1976. "Distribution of the Benthos Within the Substratum of a Welsh Mountain Stream," Oikos 27:2, pp 307-310, Copenhagen.

Johnson, J. H. et al. 1974. "Environmental Analysis and Assessment of the Mississippi River 9-Foot Channel Project Between St. Louis, Missouri, and Cairo, Illinois," Technical Report Y-74-1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Keeley, J. W. et al. 1976. "Reservoirs and Waterways, Identification and Assessment of Environmental Quality Problems and Research Program Development," U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Keller, E. A. 1976. "Channelization: Environmental, Geomorphic, and Engineering Aspects," in: Geomorphology and Engineering, pp 115-140.

MacKay, R. J. 1979. "Life History Patterns of Some Species of *Hydropsyche* (Trichoptera:Hydropsychidae) in Southern Ontario," Canadian Journal of Zoology, Vol 57, pp 963-975.

Mason, W. T. et al. 1973. "Factors Affecting the Performance of Basket and Multiplate Macroinvertebrate Samplers," Freshwater Biology, Vol 3, pp 409-436.

Mathis, D. B. et al. 1981. "Aquatic Habitat Studies on the Lower Mississippi River, River Mile 480 to 530; Report 3, Benthic Macroinvertebrate Pilot Studies," Miscellaneous Paper E-80-1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Merritt, R. W. and Cummins, K. W. 1978. "An Introduction to the Aquatic Insects of North America," Kendall/Hunt Publishers, Dubuque, Iowa.

Minshall, G. W. and Minshall, J. N. 1977. "Microdistribution of Benthic Invertebrates in a Rocky Mountain (U.S.A.) Stream," Hydrobiologia, Vol 55, 3, pp 231-249.

Mississippi River Commission. 1977. "Channel Improvement Feature, Flood Control, Mississippi River and Tributaries Project," U. S. Army Corps of Engineers, Vicksburg, Miss.

Morris, D. L. and Brooker, M. P. 1979. "The Vertical Distribution of Macroinvertebrates in the Substratum of the Upper Reaches of the River Wye, Wales," Freshwater Biology, Vol 9, pp 573-583.

Rabeni, C. F. and Minshall, G. W. 1977. "Factors Affecting Microdistribution of Stream Benthic Insects," Oikos 29, pp 33-43, Copenhagen.

Radford, D. S. and Hartland-Rowe, R. 1971. "Subsurface and Surface Sampling of Benthic Invertebrates in Two Streams," Limnol. Oceanogr., No. 16, pp 114-117.

Ragland, D. V. 1974. "Evaluation of Three Side Channels and the Main Channel Border of the Middle Mississippi River as Fish Habitat," Contract Report Y-74-1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Robinson, J. W. 1972. "Population Sampling of Commercial Fish--Middle Mississippi River," Final Report, Project No. 4-3-R-7, State of Missouri, Colombia, Mo.

Robinson, J. W. 1973. "Missouri River Habitat Study," Work Plan 21, Job No. 3, National Marine Fishery Project 4-3-R-8, pp 1-29, Colombia, Mo.

Schramm, H. L., Jr. and Lewis, W. M. 1974. "Study of Importance of Backwater Chutes to a Riverine Fishery," Contract Report Y-74-4, U. S. Engineer District, St. Louis, Mo.

Shaw, D. W. and Minshall, G. W. 1980. "Colonization of an Introduced Substrate by Stream Macroinvertebrates," Oikos 34, Copenhagen.

Shuster, G. A. and Etnier, D. A. 1978. "A Manual for the Identification of the Larvae of the Caddisfly Genera *Hydropsyche* (Pictet) and *Symphitopsyche* (Ulmer) in Eastern and Central North America (Trichoptera: Hydropsychidae)," Report No. EPA-600/4-78-060, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Sokal, R. R. and Rohlf, F. J. 1969. Biometry, W. H. Freeman, San Francisco, Calif.

Spearman, C. 1904. "The Proof and Measurement of Association Between Two Things," American Journal of Psychology, Vol 15, pp 72-101.

Task Committee on Channel Stabilization Works. 1965. "Channel Stabilization of Alluvial Rivers, Progress Report of Task Committee on Channel Stabilization Works," in: Journal of Waterways and Harbors Division, American Society of Civil Engineers, Vol 91, No. WW 1, pp 7-37.

Ulfstrand, S. et al. 1974. "Composition and Diversity of Benthic Species Collectives Colonizing Implanted Substrates in a South Swedish Stream," Entomologica Scandinavica, Vol 5, No. 2, pp 115-122.

U. S. Atomic Energy Commission. 1973. "Environmental Statement, Grand Gulf Nuclear Station, Mississippi Power and Light Co.," pp 2-10 - 2-28, Washington, D. C.

Walters, W. H. 1974. "Evaluation of Stone Dike Systems and Their Locations on the Lower Mississippi," in: Symposium on Channel Stabilization Problems, U. S. Army Corps of Engineers, pp 113-135, Washington, D. C.

Weber, C. I. ed. 1973. "Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents," U. S. Environmental Protection Agency, Cincinnati, Ohio, EPA 670/4-73-001.

Wene, G. and Wickliff, E. L. 1940. "Modification of a Stream Bottom and Its Effect on the Insect Fauna," The Canadian Entomologist, LXXII, pp 131-135.

Williams, D. D. and Hynes, H. B. N. 1974. "The Occurrence of Benthos Deep in the Substratum of a Stream," Freshwater Biology, Vol 4, pp 233-256.

Table 1

Summary of Aquatic Macroinvertebrate Data Collected from a Lower Mississippi River Dike during Pilot Investigations of August, 1978

	Summary Data					
	Individual Stones from Dike Surface*		Rock Baskets**		Bar BQ Baskets†	
Taxon	Average Density	Percent	Average Density	Percent	Average Density	Percent
Hydropsyche spp.	399.5	82.8	113.3	62.6	74.0	40.9
Polypedilum sp.	30.6	6.3	7.0	3.9	29.5	16.3
Rheotanytarsus sp.	25.8	5.3	15.7	8.7	1.0	0.6
Stenonema integrum	10.5	2.2	12.3	6.8	28.0	15.5
Potamyia flava	6.1	1.3	2.0	1.1	19.5	10.8
Baetis sp.	5.3	1.1	6.3	3.5	11.0	6.1
Heptagenia sp.	3.3	0.7	0.7	0.4	2.0	1.2
Isonychia sp.	1.0	0.2	0.7	0.4	10.0	5.5
Argia sp.	0.1	>0.1	0	--	0.5	0.3
Didymops transversa	0.1	>0.1	0.7	0.4	3.0	1.7
Neureclipsis sp.	0.1	>0.1	0	--	0.5	0.3
Ablabesmyia sp.	0.1	>0.1	0	--	0	--
Physa sp.	0.1	>0.1	0	--	0	--
Corbicula sp.	0.2	>0.1	0	--	0	--
Hirudinea	0	--	21.7	12.0	0	--
Macrobrachium ohione	0	--	0.3	0.1	0	--
Isotomurus sp.	0	--	0.3	0.1	0.5	0.3
Orthotrichia sp.	0	--	0	--	1.0	0.6
Neoperla sp.	0	--	0	--	0.5	0.3

	Summary Statistics					
Samples	N	Average No. Organisms	CV percent	Average No. Taxa	CV percent	Total Taxa
Dike substrate	10	482.8	96.6	7.9	26.6	14
Rock baskets	3	181.0	59.7	8.0	57.5	12
Bar BQ baskets	2	181.0	51.5	11.0	0	14

---

* Individual stones (40 lb each) collected by hand from dike surface.

** Rectangular baskets filled with 4 stones of comparable weight to surface stones collected from dike. Samples remotely placed on dike's surface at high river stage.

† Conventional Bar BQ basket filled with small diameter stones, samples remotely placed as with rock baskets.

Table 2

Analysis of Laboratory Subsampling Approach Used to Process Dike Substrate Samples

Taxon*	Number of Individuals in Subsamples, in tens Sample 1	2	3	4	5
Rheotanytarsus sp.	4140	3640	8,240	4450	3340
Hydropsyche spp.	2680	1650	2,520	2130	1480
Polypedilum sp.	1130	910	780	1040	1250
Potamyia flava	280	310	390	690	420
Stenonema integrum	80	70	40	90	70
Hydropsychidae pupae	40	30	70	30	20
Hirundinea	20	0	20	20	20
Baetis sp.	20	20	40	80	40
Orthotrichia sp.	20	40	60	30	20
Neureclipsis sp.	10	20	40	40	40
Heptagenia sp.	10	50	0	20	20
Neoperla sp.	10	0	0	10	0
Ablabesmyia sp.	0	30	30	0	0
Atherix variegata	0	0	40	0	0
Gammarus sp.	0	0	10	10	10
Isonychia sp.	0	0	10	20	10
Tricorythodes sp.	0	0	10	0	0
Lirceus sp.	0	0	0	10	10
Hydracarina	0	0	0	30	0
Summary					
Total density per sample	8440	6770	12,300	8700	6750
Total distinct taxa per subsample	11	10	14	15	13

$\bar{X}$ density = 8592.0
CV = 26.3 percent

$\bar{X}$ no. of taxa = 12.6
CV = 16.4 percent

---

* List does not include rare taxa picked from total sample.

Table 3

Surface Current Velocity Measurements over Dike Structure during Peak River Discharge

	Velocity, m/sec Station No.*					
Transect	1	2	3	4	5	6
Upstream						
750 m	1.8	1.6	2.2	3.6	3.8	3.8
450 m	1.8	1.6	2.2	2.2	2.6	2.8
150 m	2.0	2.2	2.4	3.0	3.4	3.2
Dike**	1.8	4.0	3.4	4.0	4.0	3.8
Downstream						
150 m	1.8	1.8	3.4	3.0	3.8	3.2
450 m	3.0	3.4	3.2	3.0	2.8	2.6
750 m	2.2	2.4	3.2	3.4	3.0	3.4

---

* Stations located at 90-m intervals along each transect. All station and transect positions were established with Del Norte microwave positioning system.

** Measurements obtained directly over structure.

Table 4

Surface Water Quality Data* Obtained Just Prior to Sampler Retrieval, 27 June 1979

Location**		Temperature °C	Dissolved Oxygen, mg/ℓ	pH	Conductivity μmhos
Transect	Station†				
450 m	90 m	26.0	7.3	7.5	430
above dike	270 m	26.0	7.3	7.5	430
150 m	90 m	25.5	7.4	8.1	425
above dike	270 m	25.5	7.4	8.1	425
150 m	90 m	26.0	7.4	8.2	418
below dike	270 m	26.0	7.4	8.2	418
450 m	90 m	26.0	8.6	7.9	460
below dike	270 m	26.0	8.6	8.0	460
760 m	90 m	26.0	8.7	8.0	460
below dike	270 m	26.0	8.7	8.0	460
	450 m	26.0	8.6	8.0	460

---

* Data obtained 1 m below water's surface with a Hydrolab water quality probe system.

** Transect and station locations established with a Del Norte microwave positioning system.

† Stations represent distance from bank along each transect.

Table 5

Total Density, Relative Abundance, and Frequency of Occurrence of Aquatic Macroinvertebrates Collected from the Lower Cracraft Dike No. 2, June 1979

Taxon	Total Density	Percent of Total Sample Density	Frequency of Occurrence* percent
Insecta			
Trichoptera			
Hydropsyche spp.	186,289	60.1	100
Potamyia flava	26,109	8.4	94
Neureclipsis sp.	770	0.3	59
Neureclipsis pupae	170	0.1	22
Hydropsychidae pupae	3,522	1.1	97
Orthotrichia sp.	842	0.3	78
Cheumatopsyche sp.	10	0.1	3
Brachycentridae (immature)	1	0.1	3
Diptera			
Rheotanytarsus sp.	59,083	19.1	91
Polypedilum sp.	15,645	5.1	94
Stenochironomus sp.	996	0.3	56
Ablabesmyia sp.	415	0.1	59
Psectrotanypus sp.	19	0.1	3
Atherix variegata	200	0.1	28
Ephemeroptera			
Baetis sp.	2,875	0.9	81
Isonychia sp.	1,805	0.6	84
Stenonema integrum	1,594	0.5	88
Heptagenia sp.	220	0.1	31
Tricorythodes sp.	66	0.1	28
Pentagenia vittigera	49	0.1	9
Tortopus incertus	19	0.1	6
Hexagenia limbata	27	0.1	6
Odonata			
Didymops transversa	165	0.1	25
Ishnura sp.	23	0.1	3
Gomphus sp.	10	0.1	19
Collembola			
Isotomurus sp.	10	0.1	3

(Continued)

---

* Percent of total sample within which each taxon was collected.

Table 5 (Concluded)

Taxon	Total Density	Percent of Total Sample Density	Frequency of Occurrence percent
Insecta (Continued)			
Plecoptera			
Neoperla sp.	137	0.1	28
Coleoptera			
Stenelmis sp.	66	0.1	13
Lepidoptera			
Parargyractis sp.	23	0.1	6
Molluska			
Pelecypoda			
Corbicula sp.	51	0.1	22
Sphaerium sp.	1	0.1	3
Annelida			
Oligochaeta			
Lumbricidae	216	0.1	28
Naidae	944	0.3	34
Limnodrilus spp.	50	0.1	6
Crustacea			
Isopoda			
Lirceus sp.	6,478	2.1	91
Amphipoda			
Gammarus sp.	147	0.1	31
Corophium sp.	157	0.1	37
Decapoda			
Macrobrachium ohione	6	0.1	13
Hirudinea	89	0.1	25
Arachnoidea			
Hydracarina	691	0.2	50

Summary

Total no. taxa = 38 Total no. of individuals = 309,990

Average taxa = 15.6/sample (coefficient of variation = 30.7 percent)

Average density = 9686.7/sample (coefficient of variation = 91.2 percent)

Table 6

Station Level Statistics for Implanted Rock Baskets

Station*	N	Average Density per Sample	Standard Deviation	CV percent	Average Taxa	Standard Deviation	CV percent
1 D	4	513.5	215.7	42.0	11.3	1.7	15.2
2 D	3	6,707.3	7,046.2	105.1	11.0	3.0	27.3
3 D	4	5,460.8	8,432.4	154.4	11.3	2.9	25.5
1 T	4	11,752.3	9,752.0	83.0	14.0	2.2	15.4
2 T	3	15,714.0	5,994.7	38.1	18.0	3.0	16.7
3 T	4	20,384.8	10,178.5	49.9	16.0	2.8	17.7
1 U	4	5,471.5	3,043.8	55.6	17.0	2.3	13.6
2 U	3	5,996.0	2,145.9	35.8	22.3	5.0	22.5
3 U	3	16,797.3	7,687.0	45.8	22.3	2.5	11.3
Totals	32	9,686.7	8,831.8	91.2	15.6	4.8	30.7

---

* D--signifies downstream position on dike, T--signifies top position of dike, U--signifies upstream position on dike.

Table 7

Data Obtained to Verify the Implanted Substrate Sampling Technique

Taxon	Rock Substrate Total Density	Rock Substrate Percent of Total	Top Rocks of Substrate Samplers Total Density	Top Rocks of Substrate Samplers Percent of Total
Hydropsyche spp.	7725	65.2	9960	65.2
Rheotanytarsus sp.	1900	16.0	3402	22.3
Potamyia flava	763	6.4	750	4.9
Polypedilum sp.	513	4.3	608	4.0
Lirceus sp.	233	2.0	72	0.5
Hydropsychidae pupae	190	1.6	162	1.1
Baetis sp.	120	1.0	103	0.7
Hydracarina	86	0.7	50	0.3
Stenochironomus sp.	75	0.6	40	0.2
Stencnema integrum	71	0.6	36	0.2
Orthotrichia sp.	42	0.4	21	0.1
Isonychia sp.	41	0.3	13	0.09
Heptagenia sp.	22	0.2	11	0.07
Naidae	20	0.2	0	--
Neureclipsis sp.	11	0.09	23	0.1
Hirudinea	11	0.09	0	--
Atherix variegata	11	0.09	0	--
Parargyractis sp.	11	0.09	21	0.1
Neoperla sp.	2	0.02	0	--
Tricorythodes sp.	0	--	3	0.02

Note: Total distinct taxa:

18 (rock substrate)
15 (top rocks of substrate samplers)
Spearman R = 0.76; $\alpha \leq 0.01$
N = 19

Table 8

Data Obtained to Evaluate Sample Depth as a Sampling Consideration for Dike Studies

	Summary Data			
	Surface Substrate of Basket		Remainder of Basket	
Taxon	Total Density	Percent	Total Density	Percent
Hydropsyche spp.	9960	65.2	26,950	64.2
Pheotanytarsus sp.	3402	22.3	6,727	16.0
Potamyia flava	750	4.9	4,950	11.8
Polypedilum sp.	608	4.0	1,413	3.4
Lirceus sp.	72	0.5	513	1.2
Baetis sp.	103	0.7	406	1.0
Hydropyschidae pupae	162	1.1	333	0.8
Stenonema integrum	36	0.2	204	0.5
Isonychia sp.	13	>0.1	154	0.4
Stenochironomus sp.	0	--	80	0.2
Neureclipsis sp.	23	0.2	45	0.1
Hydracarina	0	--	40	0.1
Ablabesmyia sp.	0	--	21	>0.1
Gammarus sp.	0	--	20	>0.1
Orthotrichia sp.	21	0.1	20	>0.1
Corophium sp.	0	--	14	>0.1
Corbicula sp.	0	--	13	>0.1
Heptagenia sp.	11	>0.1	12	>0.1
Tricorythodes sp.	3	>0.1	11	>0.1
Isotomurus sp.	0	--	10	>0.1
Atherix variegata	0	--	10	>0.1
Didymops transversa	0	--	2	>0.1
Hirudinea	0	--	1	>0.1
Neoperla sp.	0	--	1	>0.1
Parargyractis sp.	21	0.1	0	--

	Summary Statistics			
Averages	Surface Substrate	CV, percent	Remainder of Basket	CV, percent
Sample density	5091.7	74.8	13,983.3	41.3
No. taxa	11.0	15.7	16.3	18.7

Spearman's R = 0.96; $\alpha \leq 0.01$; DF = 12.

Table 9

Results of Two-way Analysis of Variance* for Transect and Position Effects on Average Macroinvertebrate Sample Density and Number of Taxa

Treatment	Average Macroinvertebrate Density			
	Degree of Freedom	Sum of Squares	F** Value	Pr. > F
Transect	2	392,655,940.6	3.98	0.033
Position	2	745,137,097.8	7.54	0.003
Transect × position interaction	4	117,958,220.1	0.60	0.668

Treatment	Average Number of Distinct Taxa Collected			
	Degree of Freedom	Sum of Squares	F Value	Pr. > F
Transect	2	59.22	3.94	0.034
Position	2	417.46	27.79	0.0001
Transect × position interaction	4	40.35	1.34	0.284

---

* Parametric fixed effect, unequal sample size without data transformation.

** $F = \frac{\text{variance of mean}}{\text{variance of individuals}}$.

Table 10

Transect Level Statistics for Dike Substrate Samples

Sampling Transect	Summary Statistics						
	N	Average Density	Standard Deviation	CV, percent	Average No. Taxa	Standard Deviation	CV, percent
1	12	5,912.4	7,179.7	121.4	12.8	2.92	22.8
2	9	9,472.4	6,675.0	70.5	15.8	5.61	35.9
3	11	13,980.0	10,585.2	75.7	15.0	5.14	34.3

Results of Duncan's Multiple Range Test*

A. Comparison of average total density ($F = 3.79$); $\alpha = 0.5$; $DF = 23$; $MS = 49,387,707$

Transect no. -	3	2	1
Transect density -	13,980	9,472.4	5,912.4

B. Comparison of average no. of taxa ($F = 3.36$); $\alpha = 0.5$; $DF =23$; $MS = 7.511$

Transect no. -	2	3	1
Transect average -	15.8	15.0	12.8

Spearman's correlation coefficients for ranked relative abundance of taxa rankings between transects.

1 vs 2	$R = 0.76$	$\alpha \leq 0.01$
1 vs 3	$R = 0.71$	$\alpha \leq 0.01$
2 vs 3	$R = 0.86$	$\alpha \leq 0.01$

---

* Transect averages underscored by the same line are not significantly different.

Table 11

Assemblage Distribution by Sampling Transect

Taxon	Transect 1 Average Total Density	 % Average Total Density	Transect 2 Average Total Density	 % Average Total Density	Transect 3 Average Total Density	 % Average Total Density
Hydropsyche spp.	2993.8	50.6	4944.3	52.2	9624.1	68.8
Rheotanytarsus sp.	1673.7	28.3	2336.6	24.7	1633.6	11.7
Polypedilum sp.	369.5	6.2	715.6	7.6	433.7	3.1
Potamyia flava	335.7	5.7	723.2	7.6	1415.6	10.1
Baetis sp.	58.3	1.0	83.9	0.9	129.1	0.9
Hydropsychidae pupae	102.3	1.7	118.2	1.2	111.8	0.8
Lirceus sp.	136.4	2.3	148.9	1.6	318.3	2.3
Stenochironomus sp.	21.7	0.4	33.3	0.4	39.6	0.3
Stenonema integrum	57.6	1.0	61.7	0.7	31.6	0.2
Isonychia sp.	26.2	0.4	75.2	0.8	74.0	0.5
Hydrocarina	20.8	0.3	34.4	0.4	11.8	>0.1
Orthotrichia sp.	34.7	0.6	25.3	0.3	18.0	0.1
Neureclipsis sp.	19.9	0.3	56.1	0.6	17.9	0.1
Atherix variegata	7.8	0.1	7.3	>0.1	3.7	>0.1
Ablabesmyia sp.	6.8	0.1	11.1	0.1	21.3	0.1
Gammarus sp.	0.08	>0.1	6.0	>0.1	8.5	>0.1
Lubriculidae	5.5	>0.1	8.1	>0.1	7.0	>0.1
Naidae	20.3	0.3	30.0	0.3	39.1	0.3
Neoperla sp.	NS*	--	10.0	>0.1	4.3	>0.1
Heptagenia sp.	0.9	>0.1	8.1	>0.1	12.4	>0.1
Corophium sp.	3.7	>0.1	7.8	>0.1	3.9	>0.1
Corbicula sp.	2.2	>0.1	1.1	>0.1	1.4	>0.1
Isotomurus sp.	0.8	>0.1	NS	--	NS	--
Gomphus sp.	0.5	>0.1	0.4	>0.1	0.09	>0.1
Didymops transversa	0.3	>0.1	15.4	0.2	2.1	>0.1
Limnodrilus spp.	4.2	>0.1	NS	--	NS	--
Pentagenia vittigera	3.0	>0.1	1.6	>0.1	NS	--
Hexagenia limbata	2.3	>0.1	NS	--	NS	--
Ishnura sp.	1.9	>0.1	NS	--	NS	--
Cheumatopsyche sp.	0.8	>0.1	NS	--	NS	--
Trichorythodes sp.	0.8	>0.1	1.7	>0.1	3.7	>0.1
Hirudinea	0.2	>0.1	3.2	>0.1	5.3	>0.1
Macrobrachium ohione	NS	--	0.3	>0.1	0.3	>0.1
Stenelmis sp.	NS	--	3.6	>0.1	1.8	>0.1
Tortopus incertus	NS	--	NS	--	1.8	>0.1
Sphaerium sp.	NS	--	NS	--	0.09	>0.1
Brachycentridae	NS	--	NS	--	0.09	>0.1
Parargyractis sp.	NS	--	NS	--	2.1	>0.1
Psectrotanypus sp.	NS	--	NS	--	1.7	>0.1
Total distinct taxa collected by transect	30		28		32	

---

* NS = Not sampled.

Table 12

Position Level Statistics for Dike Substrate Samples

	Summary Statistics						
Position on Dike	N	Average Density	Standard Deviation	CV, percent	Average No. Taxa	Standard Deviation	CV, percent
Downstream	11	4,001.7	6260.2	156.4	10.2	2.32	22.7
Top	11	15,971.8	9040.4	56.6	14.6	2.84	19.4
Upstream	10	9,026.6	6786.1	75.2	18.8	3.88	20.6

Results of Duncan's Multiple Range Test*

A. Comparisons of average density (F = 8.00); $\alpha = 0.05$; DF = 23; MS = 49,387,707

$$\text{Position average} - \overset{T}{15{,}971.8} \qquad \underline{\overset{U}{9{,}026.6} \qquad \overset{D}{4{,}001.7}}$$

B. Comparisons of average no. of taxa (F = 26.37); $\alpha = 0.05$; DF = 23; MS = 7.511

$$\text{Position average} - \overset{U}{18.8} \qquad \overset{T}{14.6} \qquad \overset{D}{10.2}$$

Spearman's correlation coefficients for taxon relative abundance rankings between positions

U vs T	R = 0.79	$\alpha \leq 0.01$
U vs D	R = 0.67	$\alpha \leq 0.01$
T vs D	R = 0.67	$\alpha \leq 0.01$

---

* Averages underscored by the same line are not significantly different.

Table 13

Assemblage Distribution by Sampling Position

	Position					
	Downstream		Top		Upstream	
Taxon	Average Total Density	% Average Total Density	Average Total Density	% Average Total Density	Average Total Density	% Average Total Density
Hydropsyche spp.	2231.9	55.8	9859.2	61.7	5328.7	59.0
Rheotanytarsus sp.	926.5	23.2	3396.2	21.3	1153.3	12.8
Lirceus sp.	53.2	1.3	74.5	0.5	507.4	5.6
Hydropsychidae pupae	63.6	1.6	125.0	0.8	144.7	1.6
Stenonema integrum	37.7	0.9	57.8	0.4	54.3	0.6
Orthotrichia sp.	19.8	0.5	23.2	0.1	36.9	0.4
Polypedilum sp.	180.0	4.5	790.3	4.9	497.2	5.5
Potomyia sp.	372.5	9.3	1226.5	7.7	852.0	9.4
Isonychia sp.	20.3	0.5	92.5	0.6	56.4	0.6
Limnodrilus sp.	4.5	0.1	NS	--	NS	--
Pentagenia vittigera	3.2	>0.1	NS	--	1.4	>0.1
Neureclipsis sp.	5.4	0.1	46.6	0.3	36.8	0.4
Hexagenia limbata	2.5	>0.1	NS	--	NS	--
Ishnura sp.	2.1	>0.1	NS	--	NS	--
Baetis sp.	47.1	1.1	138.3	0.9	83.6	0.9
Ablabesmyia sp.	2.8	>0.1	11.3	>0.1	26.1	0.3
Gomphus sp.	0.4	>0.1	NS	--	0.6	>0.1
Naidae	0.4	>0.1	0.9	>0.1	93.0	1.0
Stenochiron sp.	11.2	0.3	33.9	0.2	50.0	0.6
Heptagenia sp.	9.8	0.2	8.4	>0.1	2.0	>0.1
Hirudinea	4.0	0.1	3.3	>0.1	1.0	>0.1
Gammarus sp.	1.0	>0.1	3.1	>0.1	10.2	0.1
Trichorythodes sp.	1.0	>0.1	3.3	>0.1	2.0	>0.1
Didymops transversa	0.1	>0.1	12.8	>0.1	2.3	>0.1
Hydrocarina	1.0	>0.1	35.5	0.2	29.0	0.3
Macrobrachium ohione	0.2	>0.1	NS	--	0.4	>0.1
Parargyractis sp.	NS*	--	2.1	>0.1	NS	--
Psectrotanypus sp.	NS	--	1.7	>0.1	NS	--
Neoperla sp.	NS	--	9.8	>0.1	2.9	>0.1
Stenelmis sp.	NS	--	0.9	>0.1	4.2	>0.1
Corophium sp.	NS	--	3.1	>0.1	12.3	0.1
Atherix variegata	NS	--	8.8	>0.1	8.3	>0.1
Lumbriculidae	NS	--	0.2	>0.1	21.4	0.2
Cheumatopsyche sp.	NS	--	0.9	>0.1	NS	--
Corbicula sp.	NS	--	NS	--	5.1	>0.1
Isotomurus sp.	NS	--	NS	--	1.0	>0.1
Tortopus incertus	NS	--	NS	--	1.9	>0.1
Sphaerium sp.	NS	--	NS	--	0.1	>0.1
Brachycentridae	NS	--	NS	--	0.1	>0.1
Total distinct taxa by position	25		27		32	

---

* NS = not sampled.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Mathis, David B.
Assessment of implanted substrate samplers for macroinvertebrates inhabiting stone dikes of the Lower Mississippi River / by David B. Mathis, C. Rex Bingham, Larry G. Sanders (Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1982.
42, [14] p. : ill. ; 27 cm. -- (Miscellaneous paper ; E-82-1)
Cover title.
"February 1982."
Final report.
"Prepared for Office, Chief of Engineers, U.S. Army under EWQOS Work Unit VIIB."
At head of title: Environmental and Water Quality Operational Studies.
Bibliography: p. 40-42.

1. Dikes (Training structures). 2. Invertebrates. 3. Mississippi River. 4. Sampling. 5 Substrates.

Mathis, David B.
Assessment of implanted substrate samplers : ... 1982.
(Card 2)

I. Bingham, C. Rex. II. Sanders, Larry G. III. United States. Army. Corps of Engineers. Office of the Chief of Engineers. IV. Environmental and Water Quality Operational Studies. V. U.S. Army Engineer Waterways Experiment Station. Environmental Laboratory. V. Title VI. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; E-82-1.
TA7.W34m no.E-82-1