ASSEMBLAGE CHARACTERISTICS AND SAMPLING CONSIDERATIONS FOR AQUATIC MACROINVERTEBRATES INHABITING A LOWER MISSISSIPPI RIVER STONE DIKE

by

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INTRODUCTION

The predominant method of open channel navigation control employed on the Lower Mississippi River involves the extensive use of dikes to align and maintain suitable channels for navigation (1). The principal uses of these structures; which are also referred to as wing dams, jetties or groins; are for adjusting channel width, depth, and alignment, and for the closure of secondary channels and chutes (2). The primary objectives of these efforts are to reduce the river's width and to direct the river's flow into a single channel of desired alignment (2). When the desired single channel alignment is achieved, the river is then relied upon to scour a channel that will maintain the required depths for navigation (2). Because of the heavy movement of bedload sediments through this waterway, dredging is not an effective means of maintaining suitable channel depths for navigation (3). Its use is restricted primarily to emergency sediment removal from particularly troublesome channel reaches during periods of moderate to low river discharge (3).

Most dikes within this waterway are constructed of impermeable stone rip-rap and are of the transverse type, which extend out from the river's bank, perpendicular to the predominant direction of flow, into the river past the point of highest current velocity (3). When at all possible, these structures are placed on the concave side of river bendways, or within other zones of natural sediment deposition, in order to provide a navigation channnel alignment which generally conforms to the natural flow characteristics of the river (3). These dikes are typically deployed in fields of from three to five structures, the actual number in each field depending on the length of bendway or other river reach under consideration and on site-specific hydraulic conditions (3). A typical dike deployment scheme is shown in Figure 1.

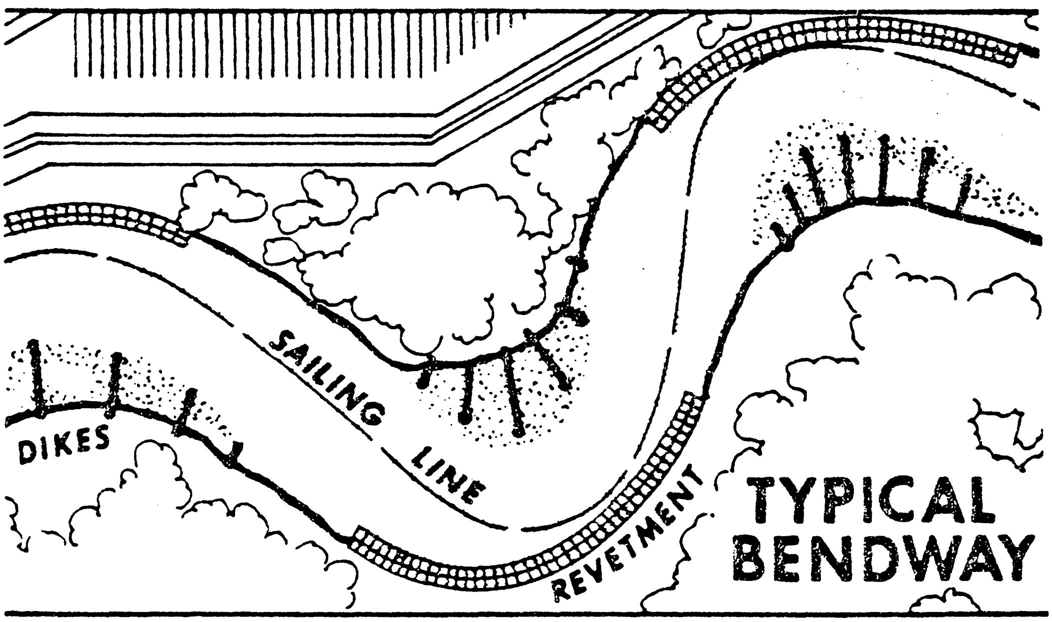

Figure 1. Typical dike deployment scheme used on the Lower Mississippi River.

At present, there is no apparent consensus on a single set of dike design and construction criteria which would optimize the effectiveness of these structures for navigation control (2,3,4). As such, dike design, construction and deployment methods vary considerably and are based largely on site-specific conditions and on the judgement and past experience of the local construction agency responsible for navigation control (2,3,4).

Recent research in this area has stressed the development of dike design and construction alternatives to minimize the adverse impacts of these structures on waterway aquatic ecosystems, while maintaining the effectiveness of the structures for navigation control (5-10). Because the structures assist in shunting water away from zones of natural deposition into a single, self-scouring navigation channel, sediment deposition within the dike fields is increased (6,11). This often results in a long-term net loss of productive off-channel aquatic habitat, such as sloughs and oxbow lakes, to the waterway aquatic ecosystem (5-9,12,13). This habitat loss is of particular concern within waterways such as the Lower Mississippi River where the combined action of levee, dike, and bank-stabilization revetment construction have resulted in a "fixed channel" system (6,11,13). As a result of this construction, these affected waterways are no longer allowed to meander or, in turn, to create new, off-channel aquatic habitats to replace those habitats which are lost due to natural or man-induced sedimentation (4,6,7,8).

The immediate, or short-term environmental impacts of dike construction however, are generally considered to be beneficial to the waterway aquatic ecosystem (6-10,12,14). These short-term benefits are attributed both to increased habitat (substrate) diversity provided by the stone structures for aquatic macroinvertebrates (6,13-15), and to the creation of middle (sand) bars immediately downstream from the dikes, with associated productive slack-water pools during moderate to low flow conditions (6-10,12,14).

Research to date has concentrated on alternative dike design, construction and deployment techniques to inhibit sediment build-up within these off-channel dike field pools and, in turn, to prevent the eventual loss of the pools as well as the dike substrate itself due to sedimentation (5,6,11,14). However, at present, there is no data base from which to assess the effect of various dike design and construction alternatives such as dike elevation, width, stone size, etc., on the suitability of the dikes themselves as habitat for aquatic macroinvertebrate organisms (5,6,14).

This study was undertaken as a necessary prerequisite to comparative aquatic macroinvertebrate habitat evaluations of available dike design, construction and deployment alternatives. Its primary objective was to identify and field verify a sampling technique which would provide quantitative estimates of aquatic macroinvertebrate assemblages inhabiting dike structures of the Lower Mississippi River. This technique would then be available for detailed ecological studies of these assemblages, including their actual or potential ecological role within the Lower Mississippi River aquatic system, and the extent to which various dike design alternatives might affect assemblage composition and structure.

As a secondary objective, the study was undertaken to provide basic data on spatial distribution patterns of aquatic macroinvertebrates over a dike structure for input to future experimental field sampling designs for studies of these dike-associated assemblages.

II. REVIEW OF LITERATURE

The few reported studies (6,13-15) of dike associated aquatic macroinvertebrates have been primarily descriptive in nature. The available data indicate that the dike-associated assemblage is predominately epilithic and rheophilic in composition (6,13,14).

Field observations by Johnson _et al_. (6) indicated that a diverse and productive stone-dwelling macroinvertebrate assemblage was associated with dikes on the Middle Mississippi River. They emphasized the need for additional study of these stone dike habitats; particularly to explore the possibility that these stable substrates may serve as primary areas of origin for drift organisms, a major food source for the river fishery. Bulkley _et al_. (15) conducted field investigations of stream alteration activities in Iowa and found that the stable substrates created by stone hard-point dikes, which are constructed for bank-stabilization purposes, provided a new and different substrate for aquatic macroinvertebrate growth, particularly for clinging mayflies and caddisflies. Mathis, _et al_. (14) collected substrate samples by hand from selected dikes within four dike fields on the Lower Mississippi River. Their data indicated that the dike assemblage was characterized by net-spinning caddisfly larvae, tube-building chironomid larve and clinging mayflies. However, they emphasized that these samples were of the surface layer of the dike substrate only and that the resulting data may not be totally representative of the actual dike assemblage structure or composition.

Hynes (16) stressed 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 (17) on the Upper Mississippi River. Fremling (17) 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.

Each of these reported studies was strictly survey-oriented and descriptive, with individual stone substrate samples collected by hand. No studies were found that attempted to quantify the actual composition and structure of the dike-associated aquatic macroinvertebrate assemblage.

As noted by Cummins (18), 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 aquatic macroinvertebrate habitat, and the selection of an appropriate technique is largely dependent on specific study objectives as well as on site-specific habitat conditions (18,19).

The following waterway and dike design-specific factors were paramount in defining an appropriate sampling technique for dike studies within the selected study area:

1. Substrate to be sampled - to obtain representative estimates of assemblage composition and structure, 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 selected study area since 1965 (3):

Stone Weight lbs	Kilograms	Cumulative Percent Smaller 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 was comprized primarily of stone less than 45 kg in weight and that the substrate was well sorted.

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

3. Physical regime- At river stages when water is passing over the dike structures, the current velocity is typically high and the vicinity of the dike may be extremely turbulent (14). This effectively prohibits the use of many conventional stream substrate sampling methods which involve sampler deployment and retrieval by wading or with the aid of divers (14). 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 1 m 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 collecting samples by hand, even for survey sampling purposes, to avoid collecting substrate that has only recently been inundated and not yet fully recolonized by macroinvertebrate organisms (14). In addition, sampling by hand would, at best, be limited to the extreme inshore portion of each dike structure. It is questionable as to whether representative estimates of the overall dike assemblage could be obtained in this manner.

Two additional factors of major significance in selecting an appropriate sampling technique for dike studies were identified from the review of literature. First, depth of sample appears to be an important consideration for obtaining representative samples of the dike associated assemblage. Field observations by Mathis et al. (14) indicated significant aquatic macroinvertebrate activity below the surface layer of stone substrate of dikes within the Lower Mississppi River. They stressed that samples of only the surface substrate of the dike may not provide representative estimates of the actual dike assemblage. A similar phenomenon has been reported from studies of aquatic macroinvertebrate assemblages inhabiting rock-gravel substrates of small rivers and streams (20-26). These findings indicate that significant benthic production (25 percent of estimated total density and biomass) may occur below the surface substrate of this habitat type. Several investigators have found significant macroinvertebrate activity to a depth of 50 cm or deeper within this substrate type (20,26).

Second, Mathis et al. (14) also found that substrate containers remotely deployed on top of the dike substrate at higher river stages when the dikes were submerged, did not provide representative samples of the dike assemblage. These samples were dominated by highly rheophilic taxa whose composition and structure differed considerably from those estimates obtained by analysis of assemblage estimates from surface stones of the dike structures. Mathis et al. (14) concluded that implanting of substrate samples into the dike structures would be required to obtain representative samples of the dike assemblage.

Substrate implanting, which is essentially placing the substrate container into an excavated hole so that the top of the container is flush with the surrounding substrate, has been evaluated by a number of investigators for aquatic macroinvertebrate studies within streams and small rivers with gravel and rock substrates (20,25,27-32). A review of these studies is provided by Edmondson et al. (33) as well as by Hellawell (34).

The technique has met with mixed success due, primarily, to the following factors:

1. In several of the reported studies (27,28,30,31), 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. Beak et al. (35), have suggested that, for measurements of biological parameters, it is often essential that natural bottom conditions be duplicated as closely as possible.

2. In each of these reported studies, the physical regime of the study area was such that the samples could be implanted by wading or with the aid of divers. Thus, the required exposure time for representative substrate colonization was a major unknown (33,34).

3. The type of substrate container used undoubtedly influences the composition and structure of the colonizing assemblage. For example, in several of these these investigations, (27,30,31), 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.

Several of these investigations (27,32) found that the implanted substrates collected much higher numbers of several aquatic macroinvertebrate taxa as compared to samples obtained with conventional stream sampling techniques such as the Surber sampler. These investigators suggested that the process of implanting substrate trays into excavated holes may create an artificial situation that favors increased colonization by certain taxa, particularly below the surface layer of substrate where excavating and replacing the substrate into trays reduces the natural compaction of the substrate. However, Hynes et al. (22) and William and Hynes (26) also found high densities of organisms below the surface layer of substrate of gravel streams by pushing a standpipe corer into the undisturbed substrate to obtain these samples.

As evidenced from these studies, the implanting of substrates for sampling purposes is still largely experimental with no clear consensus on whether or not the technique provides fully representative estimates of the assemblage to be sampled. However, it appears that many of the previously reported problems with the technique can be alleviated, to a great extent, by insuring that the substrate implants duplicate as closely as possible the physical characteristics of the substrate (habitat) to be sampled.

III. METHODS AND MATERIALS

Study Area

The area selected for study was the Lower Cracraft dike field (Figure 2). It is located on the west bank of the Lower Mississippi River at river miles 507 to 511 above the Head of Passes to the Gulf of Mexico, which is referenced as river mile zero on the Lower Mississippi River. 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 9.8 kilometers (km) upstream on the west bank of the river, outside of the leveed floodplain. Vicksburg, Mississippi, a major gaging and data collection point for the Lower River, is located 105 km downstream on the east bank of the river.

The average discharge of the Lower Mississippi River at Vicksburg, Mississippi, is about 15,886 cubic meters/sec (m^3/sec) (36). Recorded discharges have ranged from about 2,832 m^3/sec at extreme low river stages to 76,456 m^3/sec at high stages, with a stage differential of 18.3 m in water surface elevation at Vicksburg between extreme low and high water stages (37). The average water velocity within the main channel is between 1 and 2 m/sec with a maximum recorded velocity of 4.6 m/sec during extreme high riverflows (38). The estimated average sand transport at Vicksburg is one million cubic yards/day (37). The average hydrograph for the river at Vicksburg shows the highest discharge occurring from February through March and the lowest discharge occurring between July and October (39).

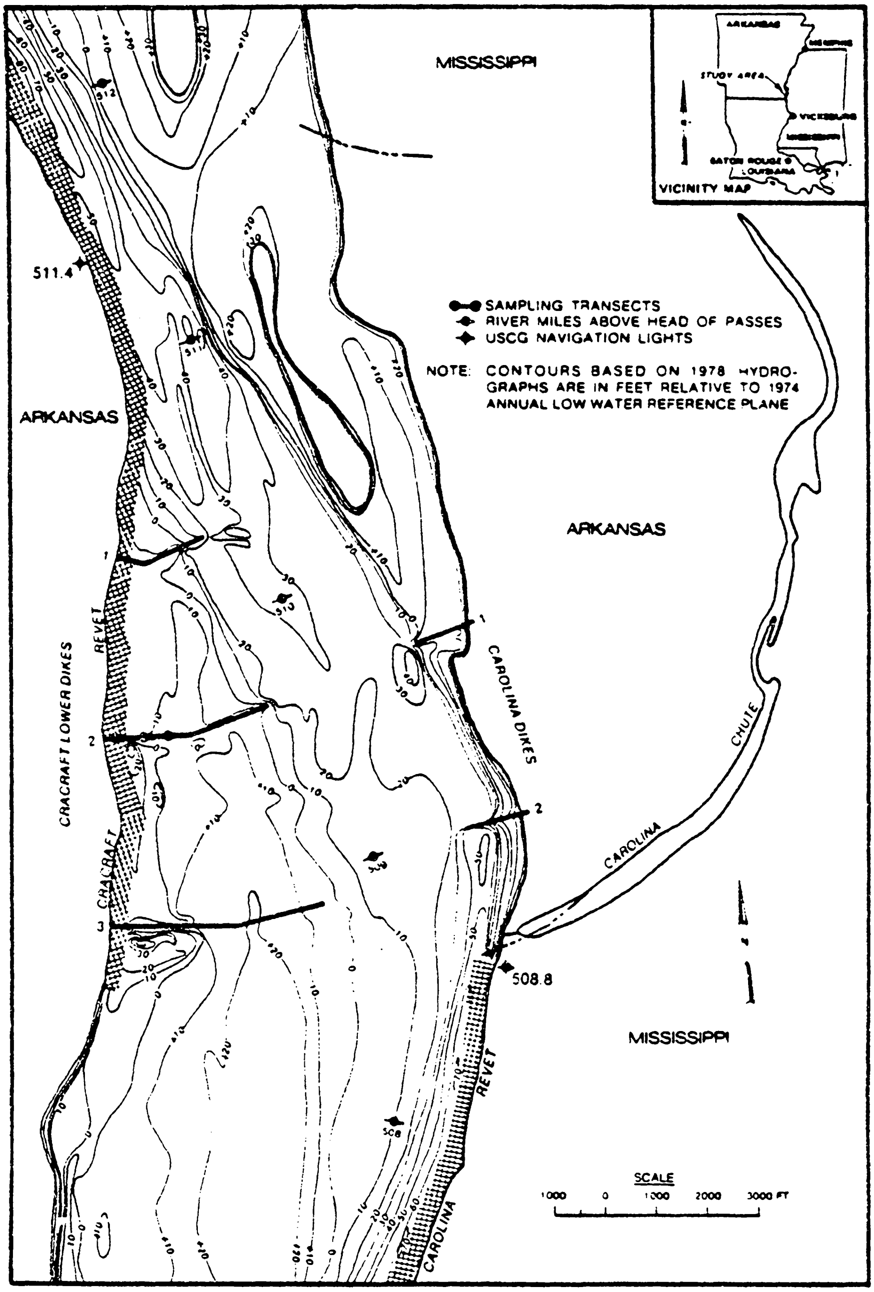

Figure 2. Location of study area and established sampling transects.

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 to close off flow into an adjacent, secondary channel during moderate to low river discharge (3). It is considered typical for this waterway reach in terms of both engineering design and function (3). 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 1,103 m for the middle dike, to 1,317 m for the downstream dike. Extensive sand and gravel middle bars have formed between succeeding dikes of the field. An extensive middle bar also occurs over an approximate 3.2 km 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.

The inshore section of the middle dike was selected for study purposes (Figure 2). Field observations indicated that a diverse and productive macroinvertebrate assemblage was associated with this structure (14). This was considered essential for the purposes of this study. Additionally, the possibility of substrate implant vandalism was reduced at this site because of its relative inaccessibility from land.

Selected Sampling Technique

Based on the review of literature, rock-filled, rectangular, wire baskets, 30.8 cm long by 30.7 cm wide by 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.

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 containers, the surrounding rock substrate, and the overlying water. This, coupled with the use of representative (well-sorted) substrate obtained directly from the surface of the dike, was used to provide representative conditions for colonizing macroinvertebrate populations. Although implanting of the substrate samples is restricted to low flow conditions when the dikes are emergent, the implanted substrates should experience the same rate of macroinvertebrate colonization as adjacent natural substrate.

The review of literature indicated that a sample substrate depth of 27 cm may result in underestimates of total assemblage density and biomass within this substrate type. However, due to 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 and would allow for standardized comparisons between sampling sites.

Field Procedures

A total of 36 substrate baskets were implanted into the dike structure during the period February 21-22, 1979. As indicated in Figure 3, the entire section of dike was emergent during this period (as required for accurate substrate implanting). The implanting technique consisted of excavating rock substrate from the dike, placing the excavated substrate into a wire basket container, and placing the rock-filled container into the excavated area so that the top of each implanted substrate was flush with the surrounding substrate. Additional rock was then packed around each implant in order to reestablish continuity of the dike substrate. A schematic of this procedure is shown in Figure 4.

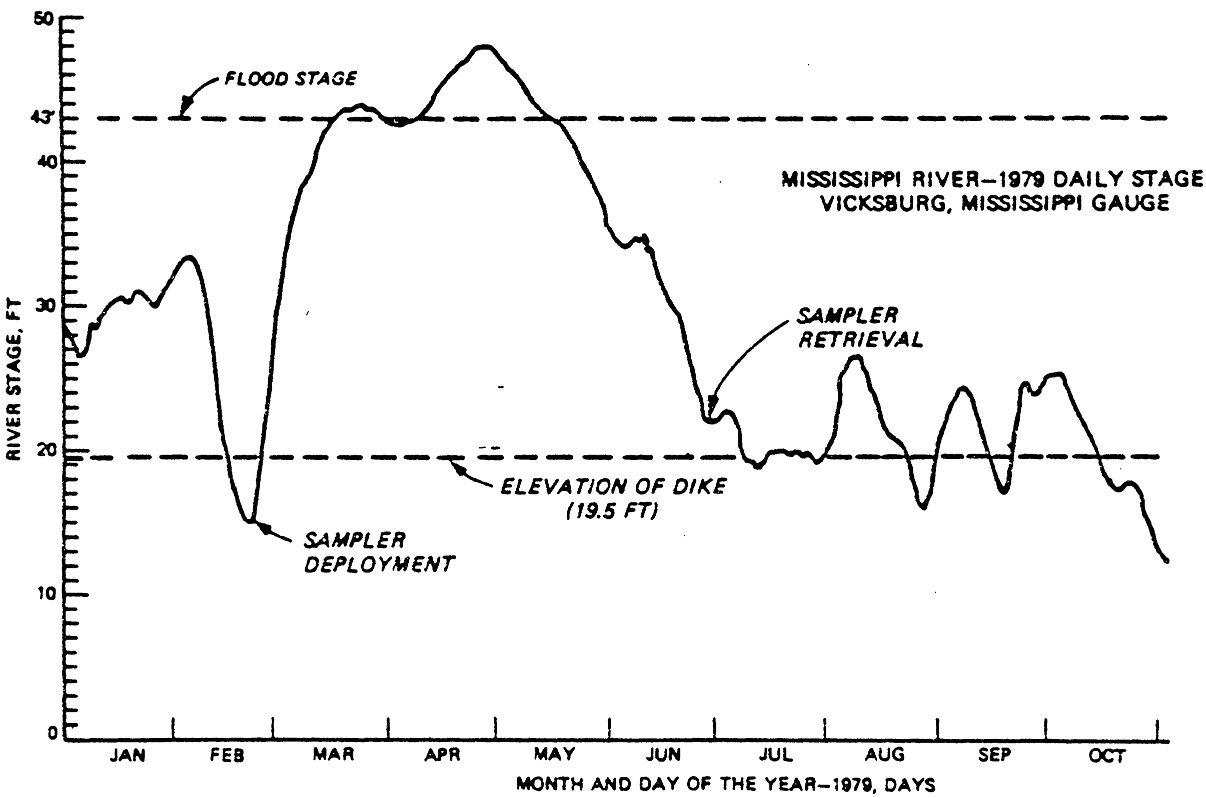

FIGURE 3. River stage conditions during the period the samples were implanted.

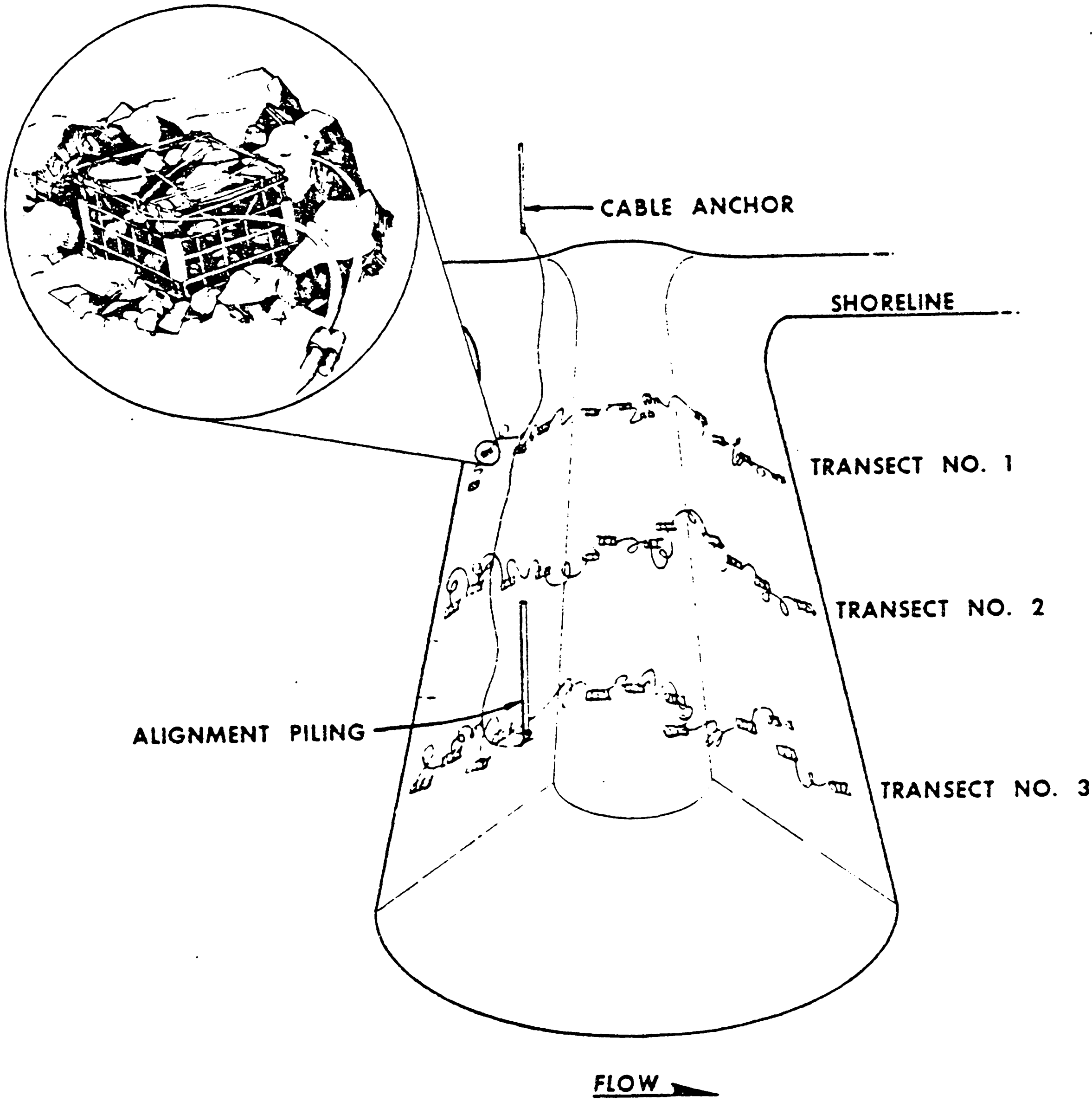

Figure 4. Schematic of substrate implanting procedure.

The substrates were deployed on three transects which were randomly positioned along and perpendicular to the length of the dike structure (Figure 4). Twelve substrates were implanted on each transect; four on the upstream side of the dike, four on the top of the dike, and four on the downstream side of the dike.

To facilitate retrieval, the implanted substrates on each transect were linked together with 0.32 cm diameter vinyl-coated aircraft cable and cable sleeves. Approximately 9 meters of excess cable were used between each implant in order to prevent the disturbance of succeeding implants during the retrieval process. This excess cable was then coiled and packed beneath surface stones of the dike in order to minimize entanglement of the cable with passing debris. Two of the substrate baskets implanted on the top of the dike at each transect were then tied to a common trunk line which extended from a construction alignment piling on the bank, out to the third transect implant set (Figure 4). This approach was used in lieu of buoyed sample retrieval lines, which were found to be highly susceptible to vandalism, passing debris, and to towboats, which routinely navigate through dike fields of the Lower Mississippi River during higher river stage conditions.

The implants were completely inundated on February 26, 1979, at a river stage of 6.6 m (Figure 3) (Vicksburg, Mississippi gage). Surface current velocity measurements were obtained from transects up- and downstream of the dike on April 26, 1979, during peak river discharge. Current-velocity profiles were attempted during this period but were unsuccessful due to the extreme physical conditions encountered.

The implanted substrates were retrieved by boat during the period June 28-30, 1979, after an approximate four-month period of continuous inundation (Figure 3). The river stage at the time of sample retrieval was approximately 6.7 m. (Vicksburg, gage). This approximate river stage was selected in order to obtain substrate concurrently by hand from the dike surface for sampling technique verification purposes. Immediately prior to implant 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 up- and downstream of the dike.

Thirty-two of the 36 implanted substrates initially deployed were retrieved. Several of the implants on the outer two transects were lost when the boat's anchor broke free and the retrieval lines were lost. A few of these implants were eventually retrieved by grappling for the implant lead lines. Several implants on the downstream side of the dike were impossible to recover, as they had become lodged beneath the shifting surface substrate of the dike.

During retrieval of each sample implanted on the top of the structure at transect 1, a hand net, modified with 0.5 mm mesh netting was placed downstream and under each implant during retrieval to evaluate the extent of organism loss during sample retrieval. Each of these net samples was sieved through a 0.5 mm mesh screen, and processed separately from the basket implants to evaluate the extent of organism loss during retrieval.

Each retrieved 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 aquatic macroinvertebrate sample was then sieved through a 0.5 mm mesh screen and preserved in 10 percent formalin.

To evaluate the effectiveness of the implanted substrates in representing natural habitat conditions of the dike, the surface stones from five of the implanted substrates were removed and analyzed separately. For comparative purposes, the same number of surface stones of fairly similar size were collected by hand from an area immediately adjacent to where each of the five substrate implants had been retrieved. These samples were then processed by the same procedures used for the implanted substrates.

Laboratory Procedures

In the laboratory, each macroinvertebrate sample was sieved through a 0.5-mm screen to remove the formalin and then transferred to a 70 percent ethanol solution.

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 present within the samples, and the resulting ineffectiveness of floatation techniques for separating organisms from the total samples. The selected subsampling procedure was as follows:

1. 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 primarliy large, predatory odonate nymphs and the river shrimp *Macrobrachium ohione.*

2. The remaining samples were then sieved through a 0.5 mm mesh screen, allowed to drain and blotted dry with paper towels.

3. 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.

4. Total organism numbers and composition were then estimated on the basis of subsample data and from counts for each rare taxon picked from the original total sample.

An analysis of this procedure, using five, successive 10-percent subsamples from the same substrate sample, indicated a coefficient of variation between total organism number estimates of 26.3 percent and between estimated total number of taxa per sample of 16.4 percent (Appendix A). The calculation for the coefficient of variation is discussed in the following section on data analyses.

Data Analyses

Field Sampling Design

The dike selected for this study is trapezoidal in cross-section, with a flat crown or top and steeply sloping sides (design slope of three vertical to one horizontal). In addition, the dike was constructed with a gradual decrease in crown elevation or heigth with distance from shore. As both of these design features are typical of dike construction within this reach of river (3), the implanted substrates were deployed to evaluate the influence of each dike design feature on the spatial distribution of the aquatic macroinvertebrate assemblage over the structure. The deployment scheme is shown in Figure 4.

Statistical Methods

The data were analyzed to evaluate the effectiveness of the implanted substrates in representing natural habitat conditions for aquatic macroinvertebrates associated with the dike and to test for significant differences in assemblage composition, density and structure over the dike section selected for study purposes. For all statistical tests, an alpha level of ≤ 0.05 was established as being statistically significant for purposes of hypothesis testing. For most analyses, the data were standardized to numbers per implanted substrate.

Summary data used for statistical comparisons included: average number of oganisms collected/substrate; average number of distinct taxa collected/substrate, and the relative percent of average or total sample density represented by each distinct taxon collected in the samples.

The use of "distinct taxa", as opposed to "species", was necessary for several reasons, including the unavailability of specific taxonomic keys for a number of aquatic macroinvertebrate groups collected from the dike, physical damage to specimens during sample collection and processing, and the presence in the samples of early instar stages of several taxa which had not yet developed the distinctive taxonomic characteristics required for specific identification. As example, the free-living leeches collected from the dike were only identifiable to subclass Hirudinea with available keys and this level was considered as a distinct taxon for data analyses. Conversely, taxonomic identification of the later instars of the caddisflies (Trichoptera) was possible to the generic level. Therefore, for this group, genera were considered as distinct taxa. The pupae of this group were usually identifiable only to family, and these were not considered as distinct taxa for data analyses as this group often represented more than one genus of caddisflies of that family within the samples.

A coefficient of variation (C.V.) was calculated for each computed sample average. This statistic is simply the computed standard deviation(s), expressed as a percentage of the estimated mean ($\bar{X}$) as:

$$C.V. = \frac{s \times 100}{\bar{x}}$$

The coefficient of variation, as expressed as a percentage, provides a standardized measure of sample variability, independent of the unit of measurement employed (40). As such, this statistic is useful for comparing the relative efficiency of a sampling technique under different habitat conditions, or for comparing the relative efficiency of different sampling techniques under similar habitat conditions (40).

Sampling Technique Evaluation

For this evaluation, assemblage estimates obtained from the surface stones of selected substrate implants were compared with assemblage estimates derived from adjacent surface stones of the dike. Comparisons included total numbers and type of distinct taxa collected (assemblage composition), and a statistical comparison of estimates of assemblage structure based on the relative percent of total sample density represented by each distinct taxon collected. A direct comparision of average, sample-density estimates was not possible as no attempt was made to measure the actual surface area of each individual stone obtained for this analysis.

The degree of association between these data sets for estimates of assemblage structure was tested using

Spearman's nonparametric test of association (41) after Hellawell (34). For this test, all distinct taxa collected from both sample sets were used for data analysis. Within each data set, the ranked relative abundance of each taxon was estimated based on the percent of total sample density of each within the data set. A Spearman's rank correlation coefficient (r) was then computed from the differences in estimated rankings of each distinct taxon between the data sets as:

$$\text{Spearman } r = \frac{12\sum^{N}\left[R_1-(N+1/2)\right]\left[R_2-(N+1/2)\right]}{N(N^2-1)}$$

Where: N = total number of distinct taxa collected from both sample sets.

R_1 = relative ranking of taxon y in the implanted substrate surface sample based on percent of total sample density accounted for by taxon y.

R_2 = relative ranking of taxon y in the dike surface stone sample based on percent of total dike substrate sample density accounted for by taxon y.

Corrections for tied rankings were made using the method described by Hollander and Wolfe (42).

Evaluation of Sample Depth

Assemblage estimates obtained from the surface layer of stones that were removed from the five substrate implants were compared to assemblage estimates obtained from the remainder of the substrate sample contained in each of the five implant baskets.

This evaluation was made to determine, to what extent, samples of the surface substrate of the dike could be used to obtain representative estimates of the aquatic macroinvertebrate assemblage inhabiting these dikes. Data comparisons were the same as those described above for the sampling technique evaluation.

Analysis of Assemblage Distribution

A fixed-effect, two-way analysis of variance (ANOVA), with replication (40), and without data transformation (normality assumed), was used to test for significant differences in average sample density and average number of distinct taxa/substrate between dike transects (distance from shore or depth of water) and between dike positions (downstream, and upstream sides of structure and top). The basic computation for this test is shown in Table 1.

An *a priori* assumption of this method of ANOVA is that a given dike position and a given dike transect distance from shore will each influence the distribution of organisms over the dike structure and that the influence of each of the two variables tested will add their effects without influencing each other (40). The degree of dependence of each variable's effect on the other or, conversely, the degree of inhibition of each variable's effect on the other, in influencing the distribution of organisms is termed "interaction" under this method of ANOVA. The extent of interaction is tested by the interaction term of Table 1. If the computed interaction Mean Square is found to be "not significant" statistically, then the assumption holds that each variable tested is acting more or less independently to influence the spatial distribution of organisms over the dike (40).

TABLE 1. Two-Way ANOVA

Source of Variation	Degrees of Freedom	Expected Mean Square (Model I)*
Transects (A)	a - 1	$\sigma^2 + \frac{nb}{a-1} \sum^{a} \alpha^2$
Dike Positions (B)	b - 1	$\sigma^2 + \frac{na}{b-1} \sum^{b} \beta^2$
Interaction (AxB)	(a-1) (b-1)	$\sigma^2 + \frac{n}{(a-1)(b-1)} \sum^{ab} (\alpha\beta)^2$
Error	ab (n-1)	σ^2
Total	abn-1	

* For a Model I or fixed-effect ANOVA, all mena squares are tested over the error MS.

Where statistically significant differences were indicated by the ANOVA test, a Duncan's Multiple Range Test (43) was used to locate where significant differences occurred between dike transects and/or between dike positions.

RESULTS

Physical Data

River stage conditions at Vicksburg, Mississippi, during the period the substrates were implanted, are shown in Figure 3, presented earlier. The maximum recorded river stage during this period was 47.9 ft (14.6 m) which occurred on April 26, 1979. This stage is 4.9 ft (1.5 m) above flood stage at this gaging station. The maximum surface-current velocity over the dike structure recorded during this period was 4 m/sec (Table 2).

From the first of May until the end of June when the implants were retrieved, the river level fell continuously and fairly gradually (Figure 3). At the time of implant retrieval, the river stage was +22.0 ft (6.7 m) and relatively steady. Due to the gradual channelward decrease in the slope of the dike, the substrates 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 substrates implanted on the side of the dike were in water from 1.8 to 2.5 m deep.

Current-velocity and direction data obtained at transects above and below the dike just prior to sample retrieval are presented in Figure 5. Eddies, or backflows, 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 no appreciable 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

TABLE 2. Surface current velocity measurements over dike structure during peak river discharge (velocity - m/sec).

Transect	Station[a] 1	2	3	4	5	6
Upstream						
750M	1.8	1.6	2.2	3.6	3.8	3.8
450M	1.8	1.6	2.2	2.2	2.6	2.8
150M	2.0	2.2	2.4	3.0	3.4	3.2
Dike[b]	1.8	4.0	3.4	4.0	4.0	3.8
Downstream						
150M	1.8	1.8	3.4	3.0	3.8	3.2
450M	3.0	3.4	3.2	3.0	2.8	3.4
750M	2.2	2.4	3.2	3.4	3.0	3.4

[a] Stations located at 90-meter intervals along each transect - all station and transect positions established with Del Norte microwave positioning system.

[b] Measurements obtained directly over structure.

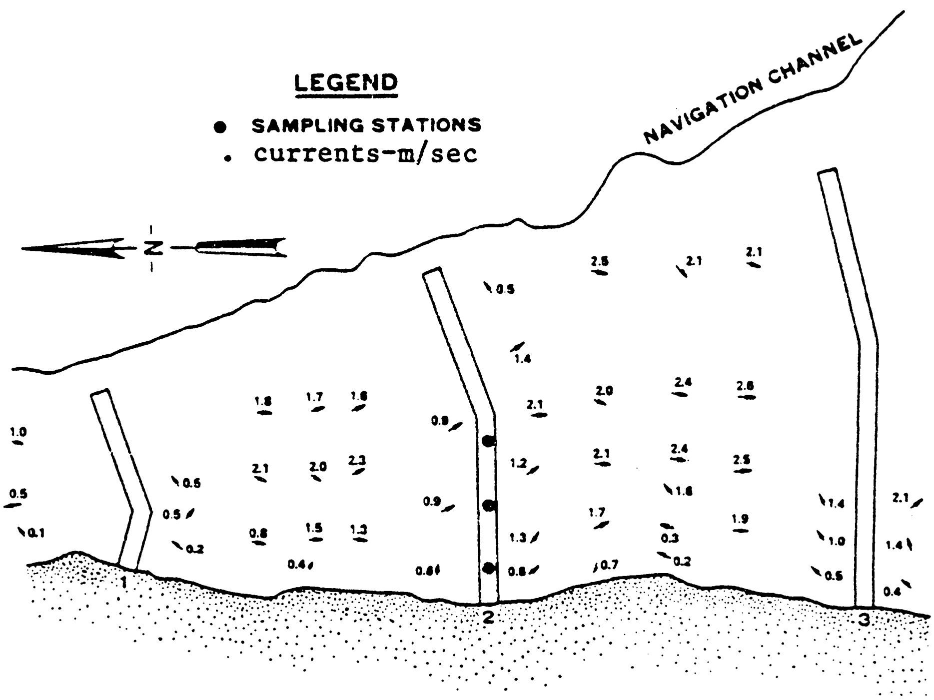

Figure 5. Current velocity and direction data around structure just prior to sample retrieval

compared to the upstream stations at both transects 2 and 3.

Heavy accumulations of a mixture of fine sand, silt, and clay were observed in each implant basket retrieved from the downstream station at transect 1. This was apparently due to eddy action and reduced current velocities encountered at this station (Figure 5). Heavy accumulations of coarse sand and gravel were observed in each basket implant retrieved from each of the three upstream stations, and from the top station at transect 1.

Small accumulations of firm clay were also observed in several samples retrieved from the upstream stations. Little or no sediment accumulation was found in implant baskets retrieved from the top and downstream stations at transects 2 and 3.

Water Quality Data

Surface water quality data, obtained immediately prior to implant retrieval, are presented in Table 3. There were no apparent differences in the water quality variables measured, either immediately up- 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 5).

Substrate Data

Based on the subsampling procedure used for lab analysis, a total of 309,990 organisms were collected from the 32 implanted substrates which were retrieved. These organisms represented 38 distinct taxa, 15 orders, and 6 classes of aquatic macroinvertebrates (Appendix B).

TABLE 3. Surface water quality data[a] obtained just prior to sample retrieval - 27 Jun 1979.

Location[b]		Temperature	Dissolved		Conductivity
Transect	Station[c]	(°C)	Oxygen (mg/l)	pH	(umhos)
450 m above dike	90 m	26.0	7.3	7.5	430
	270 m	26.0	7.3	7.5	430
150 m above dike	90 m	25.5	7.4	8.1	425
	270 m	25.5	7.4	8.1	425
150 m above dike	90 m	26.0	7.4	8.2	418
	270 m	26.0	7.4	8.2	418
450 m below dike	90 m	26.0	8.6	7.9	460
	270 m	26.0	8.6	8.0	460
760 m below dike	90 m	26.0	8.7	8.0	460
	270 m	26.0	8.7	8.0	460
	450 m	26.0	8.6	8.0	460

[a] Data obtained 1 meter below water's surface with a Hydrolab water quality probe system.

[b] Transect and station locations established with a Del Norte microwave positioning system.

[c] Stations represent distance from bank along each transect.

Class Insecta was by far the dominant group in the sample, representing over 97 percent of the total 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).

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.

The average overall number of organisms collected (Table 4) was 9,687 organisms/substrate (C.V. = 91 percent). The average overall number of taxa collected was 15.6/substrate (C.V. = 31 percent). Station level data are also presented in Table 4.

The net-spinning caddisfly, Hydropsyche spp., was the most abundant taxon collected, representing 60.1 percent of the total number of organisms collected (Appendix B). It was obtained in each of the 32 substrate 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, 8, 5, 2, and 0.9 percent of the total organisms collected, respectively. Each was collected in over 80 percent of the substrate samples (Appendix B).

TABLE 4. Station level statistics for implanted substrates.

		Organism Number		Taxa	
Station[1]	N	Ave.	C.V.[2] (%)	Ave.	C. V. (%)
1D	4	514	42.0	11.3	15.2
2D	3	6,707	105.1	17.0	13.6
3D	4	5,461	154.4	11.3	25.5
1T	4	11,752	83.0	14.0	15.4
2T	3	15,714	38.1	18.0	16.7
3T	4	20,385	49.9	16.0	17.7
1U	4	5,472	55.6	17.0	13.6
2U	3	5,996	35.8	22.3	22.5
3U	3	16,797	45.8	22.3	11.3
Total Dike	32	9,687	91.2	15.6	30.7

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

2. C.V.--coefficient of variation.

Verification of Sampling Technique

Data obtained to evaluate the representativeness of the implanted substrate data are presented in Table 5. As previously discussed, these data are not expressed quantitatively as no attempt was made to measure the surface area of each individual stone sample obtained.

A total of 18 distinct taxa were collected from the individual stone samples removed from the dike's surface (Table 5). A total of 15 distinct taxa were collected from the surface layer samples of the substrate implants. 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.

Four taxa were collected from the dike structure samples which were not collected from the surface layer samples of the implanted substrates. 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 32 implanted substrates (Appendix B).

A comparison of the estimated relative abundance rankings of the 19 total taxa obtained from both sample sets (Table 5) was made using Spearman's (41) nonparametric test of association after Hellawell (34). This test indicated a significant ($r = 0.76$) degree of positive association in relative abundance rankings of these taxa between the dike structure samples and the surface layer samples of the substrate implants. Additionally, numerically dominant taxa and the relative percent of total sample density for each also showed close agreement between the two sample sets (Table 5).

TABLE 5. Data obtained to verify the implanting substrate technique.

Taxon	Dike Substrate: Total Organisms	Dike Substrate: % of Total	Top Rocks of Subtrate Implants: Total Organisms	Top Rocks of Subtrate Implants: % of Total
Hydropsyche spp.	7,725	65.2	9,960	65.2
Rheotanytarsus sp.	1,900	16.0	3,402	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
Stenonema 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
Total distinct taxa		18	15	

Spearman R = 0.76; α = 0.0001

N = 19

Evaluation of Sample Depth

The surface-layer samples of the substrate implants, which were analyzed separately, were compared to the remainder of each corresponding substrate implant to evaluate the importance of sample depth for characterizing the dike-associated macroinvertebrate assemblage (Table 6). As stated previously, no attempt was made to measure the surface area of each individual stone; thus, the data are not expressed quantitatively.

The average number of organisms collected from the surface layer samples was 3,055 organisms/substrate (C.V. = 75 percent), as compared to an average of 8,930 organisms/substrate (C.V. = 41 percent) for the remainder of the samples (Table 6). Thus, on an average basis, only 27 percent of the total organisms collected in each substrate implant were found in the top layer, or surface stones, of the implants. In addition, variability in the number of organisms between samples was much less in the lower sections of the implants, even though average counts were much higher.

Fourteen distinct taxa were obtained from the surface layer samples of the substrate implants as compared to 23 distinct taxa obtained from the remainder of these samples. The average number of distinct taxa per substrate for the surface layer samples was 11.0 (C.V. = 15.7 percent), as compared to 16.3 taxa/sample (C.V. = 18.7 percent) for the remainder of the samples.

The aquatic moth, *Parargyractis* sp., was the only taxon collected from the surface layer samples which was not obtained from the lower portions of the samples. Conversely, 11 distinct taxa were collected from the lower portion of the implant basket samples which were not obtained from the surface layer samples. These included the dipteran larvae, *Ablabesmyia* sp., *Atherix variegata*, and *Stenochironomus*, the pelycypod, *Corbicula* sp., the isopod, *Corophium* sp., the amphipod, *Gammarus* sp., the springtail, *Isotomurus* sp., the

TABLE 6.. Data obtained to evaluate sample depth as a sampling consideration for dike studies.

	Summary Data			
	Surface Substrate of Basket		Remainder of Basket	
Taxon	Total Organisms	%	Total Organisms	%
Hydropsyche spp.	9,960	65.6	26,950	64.2
Rheotanytarsus sp.	3,402	22.4	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
Hydropyschid pupae	162	1.1	333	0.8
Stenonema int.	36	0.2	204	0.5
Isonychia sp.	13	>0.1	154	0.4
Stenochiron sp.	0	—	80	0.2
Neureclipsis sp.	23	0.1	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 varieg.	0	—	10	>0.1
Didymops trans.	0	—	2	>0.1
Hirudinea	0	—	1	>0.1
Neoperla sp.	0	—	1	>0.1
Parargyractis sp.	21	0.1	0	—

	Summary Statistics			
	Surface Substrate	C. V. (%)	Remainder of Basket	C. V. (%)
Average No. Organisms	3,055	74.8	8,390	41.3
Average No. taxa	11.0	15.7	16.3	18.7

Spearman's R = 0.96; ∂ = .0001;

stonefly, Neoperla sp., the odonate, Didymops transversa, the water mites, Hydracarina, and the leeches, Hirudinea.

Twelve taxa were common to both data sets and each showed close agreement in relative abundance, in terms of the relative percent of the total collected organisms represented by each taxon (Spearman's r= 0.96; Table 6). In addition, these twelve taxa accounted for over 99 percent of the total number of organisms collected in each data set.

Loss of Organisms During Retrieval

Few organisms were collected in the dip net during retrieval of the substrate implants from the top section of the dike. However, each of the net samples was obtained from substrate implants retrieved from shallow water. Thus, these results may not be indicative of actual organism loss during implant retrieval from the sides of the dike (deeper water) during this effort, or if the substrates had been retrieved under higher river stage conditions. In addition, with this approach, it was impossible to determine if the organisms collected were actually displaced from the substrate implants, from adjacent substrate of the dike, dislodged during the removal of the substrate implants, or a combination of these or other factors. Therefore, these data were not added back to the total sample counts for the individual substrate implants selected for this analysis.

The only potentially significant trend from this effort was the frequent collection of the river shrimp, Macrobrachium ohione, in the net samples. These are relatively large organisms compared to other taxa collected from the dike. This indicates that, if biomass estimates were required for future studies, significant underestimates may result if organism loss during implant retrieval is not minimized.

Assemblage Distribution over the Dike

The results of the two-way analysis of variance to test for differences in average number of organisms and average number of taxa per sample between dike transects and positions are presented in Table 7.

This analysis indicated significant differences in both average organism numbers and average number of taxa per substrate between dike transects as well as between dike positions. Additionally, there was no significant interaction between transect or position effects for either average organism numbers or average number of taxa/substrate (Table 7). These results indicated that, for this sampling period, both distance from the bank (transect) and position on the dike were acting more or less independently to influence the spatial distribution of aquatic macroinvertebrates over the length of dike structure sampled.

Assemblage distribution by transect

The average number of organisms collected from transect 1 (Table 8) was 5,912 organisms/substrate (C.V. = 121.4 percent) and ranged from a minimum of 239 organisms/substrate to a maximum of 21,391 organisms/substrate. A total of 30 distinct taxa were collected from this transect (Table 9) with an average number of taxa per substrate of 12.8 (C.V. = 22.8 percent; range, 8 to 17 taxa/substrate). Five taxa were collected at transect 1 which were not collected from the two offshore transects. These included the oligochaete, *Limnodrilus* spp., the damselfly, *Ishnura* sp., the burrowing mayfly, *Hexagenia limbata*, the springtail, *Isotomurus* sp., and the net-spinning caddisfly, *Cheumatopsyche* sp.

The average number of organisms collected from transect 2 was 9,472 organisms/substrate (Table 8) and ranged from a minimum of 1,208 organisms/substrate to a maximum of 19,653 organisms/substrate (C.V. = 70.5 percent). Twenty-eight distinct taxa were collected

TABLE 7. Results of two-way analysis of variance[a] for transect and position effects on average number of organisms and taxa per sample.

Treatment	Average Number of Organisms	
	F Value	Pr. > F
Transect	3.98	0.033
Position	7.54	0.003
Transect X Position interaction	0.60	0.668

Treatment	Average Number of Distinct Taxa Collected	
	F Value	Pr. > F
Transect	3.94	0.034
Position	27.79	0.0001
Transect X Position interaction	1.34	0.284

[a]Parametric, fixed-effect, unequal sample size without data transformation.

TABLE 8. Summary data for dike transects.

Dike Transect	N	Summary Statistics: Organism Number: Ave.	Organism Number: C.V.[1] (%)	Taxa: Ave. No.	Taxa: C.V. (%)
1	12	5,912	121.4	12.8	22.8
2	9	9,472	70.5	15.8	35.9
3	11	13,980	75.7	15.0	34.3

1. C.V.--Coefficient of Variation.

TABLE 9. Assemblage distribution by sampling transect.

Taxon	Transect 1 Average Total Organisms	Transect 1 % Average Total Organisms	Transect 2 Average Total Organisms	Transect 2 % Average Total Organisms	Transect 3 Average Total Organisms	Transect 3 % Average Total Organisms
Hydropsyche spp.	2,993.8	50.6	4,944.3	52.2	9624.1	68.8
Rheotanytarsus sp.	1,673.7	28.3	2,336.6	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
Hydropsycid 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 int.	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
Hydracarina	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 varieg.	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
Lumbricidae	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.	0	—	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	0	—	0	—
Gomphus sp.	0.5	>0.1	0.4	>0.1	0.09	>0.1
Didymops trans.	0.3	>0.1	15.4	0.2	2.1	>0.1
Limnodrilus spp.	4.2	>0.1	0	—	0	—
Pentagenia vitt.	3.0	>0.1	1.6	>0.1	0	—
Hexagenia lim.	2.3	>0.1	0	—	0	—
Ishnura sp.	1.9	>0.1	0	—	0	—
Cheumatopsyche sp.	0.8	>0.1	0	—	0	—
Tricorythodes 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 oh.	0	—	0.3	>0.1	0.3	>0.1
Stenelmis sp.	0	—	3.6	>0.1	1.8	>0.1
Tortopus incert.	0	—	0	—	1.8	>0.1
Sphaerium sp.	0	—	0	—	0.09	>0.1
Brachycentridae	0	—	0	—	0.09	>0.1
Paragyractis sp.	0	—	0	—	2.1	>0.1
Psectrotanypus sp.	0	—	0	—	1.7	>0.1
Total Distinct Taxa Collected by Transect	30		28		32	

from this transect (Table 9) with an average number of taxa per substrate of 15.8 (C.V. = 35.9 percent, range, 7 to 25). No taxa were collected that were unique to this transect (Table 9).

The average number of organisms collected from transect 3 (Table 8) was 13,979 organisms/substrate and ranged from a minimum of 566 organisms/substrate to a maximum of 31,067 organisms/substrate (C.V. = 75.7 percent). Thirty-two distinct taxa were collected from this transect (Table 9) with an average number of taxa per substrate of 15.0 (C.V. = 34.3 percent; range, 7 to 24). Five taxa were collected from transect 3 which were not obtained from the two inshore transects (Table 9). These included the pelycypod, Sphaerium sp., the aquatic moth, Parargyractis sp., the midge, Psectrotanypus sp., the burrowing mayfly, Tortopus incertus, and an immature, Branchycentrid caddisfly.

The results of the Duncan's Multiple Range Test (43), used to test for significant differences in the average number of organisms and average number of taxa/substrate between transects are presented in Table 10. This test indicated that the average number of organisms collected from transect 3 was significantly higher than at transect 1. There was no significant difference in average organism numbers between transects 1 and 2 or between transects 2 and 3. The average number of taxa/substrate obtained at transect 2 was significantly higher than at transect 1. There was no significant difference in average number of taxa between transects 2 and 3 or between transects 1 and 3 (Table 10).

Twenty-four distinct taxa were collected from all three transects. These taxa accounted for over 99 percent of the total number of organisms collected from each transect.

Spearman's nonparametric test of association was used to evaluate the degree of association in relative abundance rankings of the 24

TABLE 10. Transect level statistical analyses.

Duncan s Multiple Range Test[1] (Alpha = 0.05)

A. Comparison of Average Number of Organisms/Sample

	Transect		
	3	2	1
Ave.	13,980	9,472	5,912

B. Comparison of Average Number of Taxa/Sample

	Transect		
	2	3	1
Ave.	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	α = 0.0001
1 vs. 3	r = 0.71	α = 0.0001
2 vs. 3	r = 0.86	α = 0.0001

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

taxa common to each transect. This test (Table 10) indicated a significant positive 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 dike position

The average number of organisms collected from the downstream side of the dike was 4,002 organisms/substrate (Table 11) and ranged from a minimum of 239 organisms/substrate to a maximum of 18,087 organisms/substrate (C.V. = 156.4 percent). Twenty-five distinct taxa were collected from the downstream side of the structure (Table 12) with an average number of taxa per substrate of 10.2 (C.V. = 22.7 percent, range, 7 to 14). Three taxa were collected exclusively from the downstream side of the structure. These included the oligochaete, *Limnodrilus* spp., the damselfly, *Ishnura* sp., and the burrowing mayfly, *Hexagenia limbata*.

The average number of organisms collected from the top of the dike was 15,972 organisms/ substrate and ranged from a minimum of 2,801 organisms/substrate to a maximum of 31,067 organisms/substrate (C.V. = 56.6 percent). Twenty-seven distinct taxa were collected from the top of the structure (Table 12) with an average number of taxa per substrate of 14.6 (C.V. = 19.4 percent; range, 10 to 20). Three taxa were collected exclusively from the top of the dike (Table 12). These included the net-spinning caddisfly, *Cheumatopsyche* sp., the midge, *Psectrotanypus* sp., and the aquatic moth, *Parargyractis* sp.

The average number of organisms collected from the upstream side of the dike was 9,027 organisms/substrate and ranged from a minimum of 2,714 organisms/substrate to a maximum of 25,134

TABLE 11. Summary data for dike positions

Position on Dike	N	Organism Number Ave.	Organism Number C.V.[1] (%)	Taxa Ave. No.	Taxa C.V. (%)
Downstream	11	4,002	156.4	10.2	22.7
Top	11	15,972	56.6	14.6	19.4
Upstream	10	9,027	75.2	18.8	20.6

1. C.V.--Coefficient of Variation.

TABLE 12. Assemblage distribution by sampling position.

Taxon	Position					
	Downstream		Top		Upstream	
	Average Total Organisms	% Average Total Organisms	Average Total Organisms	% Average Total Organisms	Average Total Organisms	% Average Total Organisms
Hydropsyche spp.	2,231.9	55.8	9,859.2	61.7	5,328.7	59.0
Rheotanytarsus sp.	926.5	23.2	3,396.2	21.3	1,153.3	12.8
Lirceus sp.	53.2	1.3	74.5	0.5	507.4	5.6
Hydropsychid pupae	63.6	1.6	125.0	0.8	144.7	1.6
Stenonema int.	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
Potamyia sp.	372.5	9.3	1,226.5	7.7	852.0	9.4
Isonychia sp.	20.3	0.5	92.5	0.6	56.4	0.6
Limnodrilus spp.	4.5	0.1	0	—	0	—
Pentagenia vitt.	3.2	>0.1	0	—	1.4	>0.1
Neureclipsis sp.	5.4	0.1	46.6	0.3	36.8	0.4
Hexagenia lim.	2.5	>0.1	0	—	0	—
Ishnura sp.	2.1	>0.1	0	—	0	—
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	0	—	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 trans.	0.1	>0.1	12.8	>0.1	2.3	>0.1
Hydracarina	1.0	>0.1	35.5	0.2	29.0	0.3
Macrobrachium oh.	0.2	>0.1	0	—	0.4	>0.1
Parargyractis sp.	0	—	2.1	>0.1	0	—
Psectrotanypus sp.	0	—	1.7	>0.1	0	—
Neoperla sp.	0	—	9.8	>0.1	2.9	>0.1
Stenelmis sp.	0	—	0.9	>0.1	4.2	>0.1
Corophium sp.	0	—	3.1	>0.1	12.3	0.1
Atherix varieg.	0	—	8.8	>0.1	8.3	>0.1
Lumbricidae	0	—	0.2	>0.1	21.4	0.2
Cheumatopsyche sp.	0	—	0.9	>0.1	0	—
Corbicula sp.	0	—	0	—	5.1	>0.1
Isotomurus sp.	0	—	0	—	1.0	>0.1
Tortopus incert.	0	—	0	—	1.9	>0.1
Sphaerium sp.	0	—	0	—	0.1	>0.1
Brachycentridae	0	—	0	—	0.1	>0.1
Total Distinct Taxa by Position	25		27		32	

organisms/substrate (C.V. = 75.2 percent). Thirty-two distinct taxa were collected from the upstream side of the dike (Table 12) with an average number of taxa collected per substrate of 18.8 (C.V. = 20.6 percent, range, 14 to 25). Five distinct taxa were collected exclusively from the upstream side of the structure (Table 12). These included the pelycypods, *Corbicula* sp. and *Sphaerium* sp., the springtail, *Isotomurus* sp., the burrowing mayfly, *Tortopus incertus*, and an immature, Branchycentrid caddisfly.

The results of Duncan's Multiple Range Test for significant differences in average number of organisms and average number of taxa between positions are presented in Table 13. These results indicate that the average number of organisms collected from the top of the structure was significantly higher as compared to either the up- or downstream positions. There was no significant difference in average organism numbers between the up- and downstream positions.

This test also indicated significant differences between each position in the average number of taxa collected per substrate (Table 13). Average numbers of taxa collected per substrate were significantly higher from the upstream side compared to those from 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.

Nineteen distinct taxa were collected from all three dike positions (Table 12). These taxa accounted for over 99 percent of the total number of organisms collected from each position.

The results of Spearman's nonparametric test of association to determine the degree of association in relative abundance rankings of the 19 common taxa between dike positions are presented in Table 13. This test indicated a significant positive association in ranked, relative-abundance estimates for these taxa between positions. The

TABLE 13. Position level statistical analyses.

Duncan's Multiple Range Test[1] (Alpha = 0.05)

A. Comparison of Average Number of Organisms/sample

	Top(T)	Upstream(U)	Downstream(D)
Position Ave.	15,972	9,027	4,002
	•	________	________

B. Comparison of Average Number of Taxa/Sample

	Upstream(U)	Top(T)	Downstream(D)
Position Ave.	18.8	14.6	10.2
	•	•	•

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

U vs. T	$r = 0.79$	$\alpha = 0.0001$
U vs. D	$r = 0.67$	$\alpha = 0.0001$
T vs. D	$r = 0.67$	$\alpha = 0.0001$

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

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 up- and downstream and the top and down-stream position comparisons.

IV. DISCUSSION

Dike Assemblage

The Cracraft dike was inhabited by a diverse and productive aquatic macroinvertebrate assemblage during this sample 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.

Thirty-eight distinct macroinvertebrate 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 organisms collected. This genus, which was represented on the structure by sand-grain retreat building forms, is known to frequently dominate the insect biomass of rivers with high sediment loads (44). Schuster and Etnier (45) have found that several species of this genus are often encountered in very high numbers 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 distinct taxa) and ubiquitous macroinvertebrate group collected from the structure, were generally found at low levels of abundance, and collectively comprised less than 2.5 percent of the total organisms collected.

Several macroinvertebrate taxa were collected from the structure which are not considered characteristic inhabitants of dikes within this waterway. These taxa included the damselfly, Ishnura sp., which is typically associated with aquatic vegetation (46), and the oligochaete, Limnodrilus spp., the mayfly, Hexagenia limbata, and the pelycypod, Sphaerium sp., which are typically associated with backwater habitats (14). Ishnura sp., Limnodrilus spp., and Hexagenia limbata, were collected exclusively from the downstream station of transect 1. Deposits of fine-grained sediments were also found in each sample obtained from this station. Thus, the presence of these taxa on the structure was probably due to their passive introduction through main channel drift.

The average overall number of organisms/sample obtained during this effort, extrapolated to numbers per square meter of dike structure surface area, was 101,968 organisms/m^2. The maximum sample density obtained was 327,021 organisms/m^2. By contrast, results of a pilot study of infaunal macroinvertebrate habitats within this same river reach and during similar river stage conditions and season of the year, indicated that abandoned river channels contained the highest average sample densities of the infaunal habitats surveyed (14). The highest average sample density obtained from these infaunal habitats was 1900 organisms/m^2 (14).

The high numbers of organisms obtained during this effort may have resulted in part from the fairly gradual and continuous fall in water level which preceded sampling efforts. Although undocumented, these conditions undoubtedly increased assemblage concentrations on lower elevation structures such as this Cracraft dike, due to the continuous, catastrophic abandonment of organisms from higher elevation structures upstream.

The high average numbers as well as diversity estimates obtained during this effort, however, are indicative of the potential ecological value of dike structures within this waterway for aquatic macroinvertebrates, which are, in turn, a major food source for riverine fishes. This ecological potential can be attributed, in large part, to increased diversity in habitat (substrate) provided by these stone structures. Due to the large quantities of bedload material transported through this waterway and its characteristically shifting and unstable main channel sediments, this ecological potential is probably also related in part to the habitat (substrate) stability provided by these structures.

Effectiveness of Substrate Implants

Study results indicated that the implanted substrates provided representative estimates of both the composition of the dike assemblage and the relative abundance of individual taxa comprising the assemblage. Thus, the technique appears suitable for comparitive habitat studies of dike design alternatives within this waterway.

The fact that representative estimates of both assemblage composition and structure were obtained is attributed to several factors. These factors include the implanting of individual substrate samples into the dike structure; the use of representative (well-sorted) substrate obtained directly from the dike structure, and the substrate container itself, which apparently provided for representative interaction between the implanted substrate and the surrounding aquatic environment. Additionally, the substrates 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.

Sample depth within the substrate appears to have been an important consideration for studies of dike-associated aquatic macroinvertebrates. Results of this study indicate that variability in density estimates between replicate samples may be appreciably reduced by increasing the depth of substrate sample. In addition, on an average basis, only 27 percent of the total sample density of each substrate implant was found in the surface layer of substrate.

There was a significant positive association in ranked relative abundance estimates of taxa common to both data sets. In addition, these "common" taxa accounted for over 99 percent of the total oragnisms in each data set. However, 11 taxa were collected from the lower portion of the substrate implants which were not obtained from the surface layer of substrate. These data suggest that, although reliable estimates of assemblge structure may be obtained from samples of the surface substrate of these dikes, significant errors in estimating dike assemblage density and composition may result by considering only the surface substrate for sampling purposes.

Although these substrate implants 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 samples for study purposes.

Typically, high current velocities and extreme water turbulence are encountered around dike structures of this waterway when they are submerged. These conditions effectively restrict substrate implanting efforts to periods of lower water when the dikes are emergent. This restriction may 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, the required low-flow conditions may not occur at all.

Additionally, for quantitative comparative studies, a large number of substrates may have to be implanted at one time (when the dikes are emergent) to provide adequate sample replication and for seasonal or other sampling design considerations.

In addition, the technique must be modified to prevent undue loss of organisms if sample 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.

For future sampling efforts, a basket of cylindrical design with double walls to incorporate a net bag is recommended to minimize loss of organisms during sample retrieval. The net bag (with net mesh aperture of the same size as used for sample sieving purposes) can be placed at the base of the substrate sample at the time of implanting and then drawn up to inclose the sample prior to retrieval. Similar but smaller sampler designs have been reported by O'Conner (20) and Coleman and Hynes (23).

Assemblage Distribution over the Structure

A number of factors appeared to contribute to the differences in assemblage distribution over the structure observed during this sampling period. These factors included: the combined effect of dike design and falling water level prior to substrate retrieval, presence or absence, as well as type of, sediment accumulations within the implanted substrates; and differences in stability of the dike substrate between dike positions. Differences in current velocity and 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

Observed differences in assemblage distribution between sampling transects appeared to be related primarily to the combined effect of falling water level prior to sample retrieval and to dike design. As previously discussed, dikes within this reach of the Lower Mississippi River are designed with a gradual decrease in elevation toward the channel.

Eddies or backflows, 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. These conditions resulted in the lowest average sample density, the lowest average number of taxa per substrate, and the highest variability in density estimates between substrate samples at this transect.

Eddy action appears to be a characteristic feature of the immediate inshore section of dikes within this waterway and over a wide range of river stages because of the dike design used (47). However, at river stages when the dikes are submerged, the influence of this eddy action is probably limited to only a very small percentage of the total available dike structure habitat for aquatic macroinvertebrates.

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 differences between transects for these taxa were probably a result of their catastrophic release from the shallower, inshore transects due to a continuous fall in river stage.

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 length of the dike, differences in assemblage distribution between transects may have been much less. In addition, a number of the taxa collected from the dike during this investigation, have been previously collected from water depths of greater than 15 m within this reach of river (14). This suggests that increased river stage and water depths would not, at least directly, be a limiting factor in the spatial distribution of a number of aquatic macroinvertebrate taxa over the dikes.

The terrestrial adult forms of the dike-associated hydropsychid caddisflies have not been reported in pest proportions within the Lower Mississippi River, although their aquatic larvae stages appear to occur within the river at extremely high densities. In contrast, the adult forms of this caddisfly are on occasion, reported in pest proportions within the pooled reaches of the upper Mississippi River (17). It is possible that, under the more stable river stage conditions of the pooled reaches of this waterway, the catastrophic drift of these organisms is minimized, thus reducing effective population control of these taxa by reducing their availability to fish and other predators. This possibility is further supported by unpublished data of Pennington _et al_ (48) on fish stomach content analyses of a number of species of fish inhabiting this reach of the Lower Mississippi River. These data indicate that a number of the fish species analyzed readily feed on aquatic macroinvertebrates taxa which were collected from the dike during this study, including the case-and tube-building forms. However, stomach analyses have not as yet revealed the presence of the organisms' cases and tubes in the fishes stomachs. These findings indicate that the fish do not graze directly on the dike substrate, but obtain these food organisms by other means; presumably from the water column during periods such as falling river stages when these organisms become part of the drift assemblage.

Distribution by dike position

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

These results suggest that, for this sampling period, the structure of the dike macroinvertebrate assemblage was basically similar across the three dike positions. However, physical habitat differences between positions appeared to directly influence the density 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.

The lowest average number of organisms the lowest total and average number of taxa, and the highest variability between estimates of organism numbers were obtained from the downstream side of the structure. This is attributed both to eddy action at the downstream station at transect 1, as described previously, and to substrate instability on the downstream side of the structure at the outer two dike transects.

This substrate instability was observed both when the substrate samples were initially implanted at low water and again during sample retrieval efforts when several substrates implanted on 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 was observed just upstream of the structure during sampling efforts. This head of water is apparently characteristic of dike structures within this waterway (3,47), 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.

The highest average number of organisms was obtained from the top position of the dike structure. Both 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 (46), and their higher abundance on the top of the structure was probably related to preferential feeding activity.

The highest total numbers of distinct taxa, as well as the highest average number of taxa per substrate 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 samples. Significant accumulations of coarse sand and gravel were found in each of the upstream substrate samples. A preference for this accumulated sediment was particularly evident for the oligochaetes, Naidae and Lumbricidae, as well as for the pelycypod, Corbicula sp., and the crustaceans, Lirceus sp., Gammarus sp., and Corophium sp. This substrate association is of particular interest within this waterway, as previous studies of coarse sand and gravel substrates have shown these sediment types to be generally depauparate of aquatic macroinvertebrates (13,14,49). This finding has been attributed to the unstable, shifting nature of

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The burrowing mayflies, Tortopus incertus and Pentagenia vittigera, were collected in several substrate samples from the upstream side of the structure. Each of these samples also contained deposits of firm clay sediments. These taxa are characteristic of steep, eroding clay banks within this waterway and do not appear to be adaptive with regard to sediment type (14).

The distinct differences in physical habitat conditions between dike positions appeared to be a significant contributing factor to the overall variability in estimates of both dike assemblage composition and organism numbers obtained during this investigation. Thus, for future comparative studies of dike-associated macroinvertebrate assemblages within this waterway, 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.

VI. SUMMARY AND CONCLUSIONS

Stone-filled, wire baskets were implanted into a dike structure on the Lower Mississippi River in late February, 1979, when the dike was emergent. The substrate implants were retrieved in late June, 1979, after an approximate four month period of continuous inundation. The resulting data indicated that a diverse (38 distinct taxa) and productive (average density = 101,968 organisms/m^2) assemblage was present and was characterized by net-spinning caddisflies, tube-building chironomids, clinging mayflies, and isopods. The net-spinning caddisfly, Hydropsyche spp., and the chironomid, Rheotanytarsus sp., were the two most abundant taxa collected, representing 60.1 percent and 19 percent, respectively, of the total organisms collected.

The effectiveness of the implanted substrates in representing natural habitat conditions of the dike was tested by comparing assemblage estimates from the surface stones of the implanted substrates with assemblage estimates obtained from adjacent surface stones of the dike. This comparison indicated close agreement between the two data sets in estimates of both assemblage composition and structure.

To evaluate the significance of depth of sample in obtaining representative estimates of the dike-associated assemblage, assemblage estimates from the surface substrate layer of selected implanted baskets were compared to estimates obtained from the remainder, or lower portion, of these substrate baskets. This comparison indicated that, for the eleven taxa common to both data sets, there was a statistically-significant, positive association (Spearman $r = 0.96$) in the ranked relative abundance of each of these taxa between data sets. In addition, these eleven common taxa accounted for over 99 percent of the total organisms obtained in each data set. However, on an average basis, less than thirty percent of the total organisms collected in these substrate implants were found in the surface substrate layer. In addition, eleven taxa were found in the lower section of the implants which were not found in the surface substrate.

Within the reach of the Lower Mississippi River selected for this study, dikes are designed with a trapezoidal cross-section and with a decrease in top or crown elevation with distance from the river's bank. This study evaluated the influence of each of these dike design features on the spatial distribution of organisms over the structure.

Data analyses indicated that, in terms of numerically-dominant taxa and assemblage structure, the dike-associated assemblage was similar across all stations sampled. However, statisically-significant differences in both average number of organisms and average number of taxa per sample were found between dike transects (distance from shore, or depth) and dike (cross-section) positions (downstream, top, upstream). No statistically-significant interaction was found between these two variables, indicating that both were directly and independently influencing the distribution of organisms over the dike structure during sampling efforts.

Observed differences in physical habitat conditions between dike positions appeared to be a major factor in influencing the distribution of organisms over the structure and, in turn, overall data variability. Observed differences included the presence or absence, as well as type, of sediment accumulation within the baskets, substrate stability, and current-velocity and/or turbulence.

The observed linear increase in average number of organisms/sample with transect distance from shore could possibly be attributed to the release and drift of organisms from the shallower, slower-current, inshore transects with falling river stages. It is likely that, if sample retrieval had been undertaken at higher river stages, the average organism numbers between sampling transects would probably have been more uniform due to more uniform current-velocities over the structure.

Conclusions based on the results of this study are as follows:

1. The basic assemblage, in terms of numerically-dominant taxa and assemblage structure, was similar across all stations sampled, and with sample depth. Therefore, samples obtained by hand from the surface substrate layer of the dike appear suitable for qualitative or descriptive studies of the dike-associated, aquatic macroinvertebrate assemblage. However, due to significant assemblage activity found below the surface substrate during this study, data obtained from the surface substrate only will not provide quantitative estimates of total assemblage composition, density or biomass.

2. The implanted substrates evaluated during this study provided representative estimates of both the composition and structure of the dike assemblage. Therefore, implanted substrates are considered appropriate for quantitative studies of these dike-associated, aquatic macroinvertebrate assemblages.

3. For quantitative studies of aquatic macroinvertebrate assemblages inhabiting dikes of a trapezoidal cross-section design, a stratified random sampling scheme, based on dike position (top and up-and downstream side of dike) appears necessary to reduce overall data variability and to, in turn, facilitate hypothesis testing.

4. Study results explicitly demonstrate the potential value of dike structures within the Lower Mississippi River as habitat for aquatic macroinvertebrate organisms, and, in turn, as a potentially significant food-source for riverine fish. This habitat potential is attributed both to increased habitat (substrate) diversity provided by dike construction and to substrate stability.

5. The aquatic larval forms of several taxa of Insecta were encountered on the dike in very high numbers. As the adult stages of these taxa have occasionally been reported in pest proportions within areas of the Upper Mississippi River, future studies of these assemblages should include actual or potential mechanisms of population control, including alternative dike design, construction and deployment techniques.

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APPENDIX A

ANALYSIS OF LABORATORY SUBSAMPLING APPROACH USED FOR DIKE SUBSTRATE SAMPLES

APPENDIX A. Results of laboratory subsampling approach used to analyze dike substrate samples.

Taxon	Number of Organisms				
	1	2	3	4	5
Rheotanytarsus sp.	414	364	824	445	334
Hydropsyche spp.	268	165	252	213	148
Polypedilum sp.	113	91	78	104	125
Potamyia flava	28	31	39	69	42
Stenonema integrum	8	7	4	9	7
Hydropsychidae pupae	4	3	7	3	2
Hirudinea	2	0	2	2	2
Baetis sp.	2	2	4	8	4
Orthotrichia sp.	2	4	6	3	2
Neureclipsis sp.	1	2	4	4	4
Heptagenia sp.	1	5	0	2	2
Neoperla sp.	1	0	0	1	0
Ablabesmyia sp.	0	3	3	0	0
Atherix variegata	0	0	4	0	0
Gammarus sp.	0	0	1	1	1
Isonychia sp.	0	0	1	2	1
Tricorythodes sp.	0	0	1	0	0
Lirceus sp.	0	0	0	1	1
Hydracarina	0	0	0	3	0
Total organisms/sample (Ave. 859.2; C.V. = 26.3%)	844	677	1,230	870	675
Total Distinct Taxa/sample (Ave. 12.6; C.V. = 16.4%)	11	10	14	15	13

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

APPENDIX B

TOTAL DENSITY, RELATIVE ABUNDANCE, AND FREQUENCY OF OCCURRENCE OF AQUATIC MACROINVERTEBRATES COLLECTED

APPENDIX B. Total density, relative abundance, and frequency of occurrence of aquatic macroinvertebrates collected from the Lower Cracraft Dike No. 2-June,1979.

Taxa	Total Number	Percent of Total Number	Frequency of Occurrence*
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

(Continued)

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

(sheet 1 of 3)

APPENDIX B. (Continued)

Taxa	Total Number	Percent of Total Number	Frequency of Occurrence
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
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

(sheet 2 of 3)

APPENDIX B. (Concluded)

Taxa	Total Number	Percent of Total Number	Frequency of Occurrence *
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

Total No. Taxa = 38 309 990 (sheet 3 of 3)

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

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

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ASSEMBLAGE CHARACTERISTICS AND SAMPLING

CONSIDERATIONS FOR AQUATIC MACROINVERTEBRATES

INHABITING A LOWER MISSISSIPPI RIVER STONE DIKE

by

David B. Mathis

(ABSTRACT)

This study was undertaken to assess the effectiveness of implanted substrates in sampling aquatic macroinvertebrate assemblages associated with stone dikes on the Lower Mississipppi River and to obtain basic information on assemblage composition, structure, and patterns of distribution over a dike. For study purposes, stone-filled baskets were implanted into a dike near Vicksburg, Mississippi, in February 1979, and retrieved four months later. The resulting data indicated the presence of a diverse and productive assemblage (38 taxa; average of 101,968 organisms/m^2), characterized by net-spinning caddisflies, tube-building chironomids, isopods, and clinging mayflies. The caddisfly, Hydropsyche spp., accounted for over 60 percent of the total organisms collected.

A comparison of assemblage data obtained from the surface stones of the implanted substrates with data obtained from adjacent surface stones of the dike indicated close agreement in estimates of both assemblage composition and structure. However, on an average basis, over seventy percent of the total organisms collected in the substrate implants were found below the surface layer of substrate. The importance of this finding to future sampling efforts is discussed.

Statistically significant differences in assemblage estimates were encountered over both the length and width of the structure sampled. These findings are discussed both in terms of their potential ecological significance and in terms of future sampling design considerations.