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AQUATIC HABITAT STUDIES ON THE LOWER MISSISSIPPI RIVER, RIVER M--ETC(U)
DEC 80 C R BINGHAM, S P COBB, A D MAGOUN

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A diel periodicity study of drifting benthos in the lower Mississippi River at mile 529 resulted in the collection of 5090 macroinvertebrates consisting of 80 taxa. Samples collected with 505-μm mesh, 0.5-m (mouth diameter) plankton nets at midnight (0100 hr), dawn (0600 hr), noon (1200 hr), afternoon (1600 hr), and dusk (2100 hr) on 27-28 June 1978, had an average total drift density over all sampling times of 140 organisms/100 m^3 of water filtered. Total drift

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density did not fluctuate markedly over the five sampling times, except that concentrations were significantly lower ($P < 0.05$) at dawn than at other times. The lack of pronounced diel periodicity in total drift resulted from the offsetting of dominant day active versus night active species. *Hydropsyche* spp., the most abundant taxon, was nocturnally active. *Hydra* sp., a diurnal drift component, was the second most dominant taxon. Species diversity in the drift exhibited diel periodicity and was significantly lower ($P < 0.05$) during daylight hours and highest at dusk, midnight, and dawn. Of the nine most dominant taxa, five were most abundant at midnight, two most abundant at dusk, one most abundant at afternoon, and one most abundant at noon. Various taxa exhibited behavioral drift characteristics. The total transport of benthic drift downstream in a 24-hr period was calculated as 2.9×10^{10} organisms/day based on a river discharge of 12,063 m^3/sec. Total diel drift standardized by river discharge was 2.44×10^6 organisms/day/m^3/sec, slightly higher than reported for other rivers but of the same order of magnitude.

PREFACE

This study was conducted as part of a pilot study of major riverine macrohabitats comprising a 50-mile stretch of the lower Mississippi River between Greenville, Mississippi, and Lake Providence, Louisiana. This is Report 4 of the series "Aquatic Habitat Studies on the Lower Mississippi River, River Mile 480 to 530." The work was funded by the Office, Chief of Engineers, U. S. Army Corps of Engineers, under Environmental and Water Quality Operational Studies (EWQOS), Work Unit VIIB (31615).

This study began under the direction of Dr. John Harrison, Chief, Environmental Laboratory (EL); Dr. Pete Kirby, Chief, Environmental Resources Division (ERD), EL; and Dr. Walt Gallaher, Chief, Waterways Habitat Monitoring Group (WHMG), ERD, EL.

This report was prepared by Messrs. C. Rex Bingham and Stephen P. Cobb and Dr. A. Dale Magoun under the direction of Dr. Thomas D. Wright, Chief, WHMG, ERD, EL; Mr. Bob O. Benn, Chief, Environmental Systems Division (ESD), EL; and Dr. John Harrison, Chief, EL. Dr. Jerome L. Mahloch was Program Manager of EWQOS.

Dr. Michael P. Farrell contributed the statistical program design. Mr. David B. Mathis contributed significantly to the overall riverine study description and Mr. Larry G. Sanders and Ms. Eva McLemore contributed significantly to the taxonomic identification of the organisms.

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

CONTENTS

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

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

Multiply	By	To Obtain
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres

AQUATIC HABITAT STUDIES ON THE LOWER MISSISSIPPI RIVER, RIVER MILE 480 TO 530

DIEL PERIODICITY OF BENTHIC MACROINVERTEBRATE DRIFT

PART I: INTRODUCTION

Background

Comprehensive field investigation

1. The U. S. Army Engineer Waterways Experiment Station (WES) is currently conducting a 4-year, comprehensive field investigation within a 50-mile reach of the Lower Mississippi River between Lake Providence, Louisiana, and Greenville, Mississippi (river mile 480 to 530). The overall objective of the study is to assess the relative ecological importance of dike and revetment structures to the riverine ecosystem in terms of aquatic habitat value with a view toward providing guidelines for designing and modifying similar structures to meet environmental quality objectives.

2. The general approach to the study makes use of the concept of definable habitats, wherein the reach of the river under investigation is subdivided into discrete habitats that are then characterized as to both biotic and abiotic variables. Dike fields and revetted banks, although man-made, are treated as habitats, in addition to other distinct biological habitats, e.g., the main channel, natural steep clay banks, sandbars, chutes, river borders, point bar cutoffs, and abandoned river channels. The ecological importance of each macrohabitat is evaluated according to its basic water quality; production of benthic organisms; use as spawning, nursery, and feeding areas for fishes; and production of suspended particulate organic matter. The function and relative value of dike fields and revetted banks as aquatic habitats within the river ecosystem are defined using this information as a basis for various river stages and seasons of the year.

3. As part of the pilot survey, several specialized studies have been undertaken to investigate phenomena of interest, such as the determination of the composition and distribution of particulate organic matter at various river stages and seasons, spawning periods and locations of fishes, movement of fishes at various river stages and seasons, benthic macroinvertebrate drift during various river stages and seasons, and secondary production estimates during various river stages for organisms living on structural materials. Such studies will aid in the evaluation of engineering alternatives for waterway, flood control and bank stabilization structures to maximize their environmental value as aquatic habitat.

Diel periodicity study

4. The diel periodicity study, with which this report is concerned, was a multipurpose effort to examine the composition and structure of both drifting benthos and larval fishes exhibited by one major habitat--the river's main channel--and to evaluate the possibilities of drift sampling as one field approach for use in future habitat studies.

5. This paper is concerned with the drifting macroinvertebrates, i.e., the downstream transport of macroinvertebrates in stream currents. A separate paper will address the results of the study of larval fishes in the river's main channel.

Macroinvertebrate drift studies

6. The study of drifting macroinvertebrates is a relatively new field in stream ecology. Given impetus by Dendy (1944), Müller (1954), and Waters (1961, 1972), it has grown rapidly and offers new approaches to a better understanding of many aspects of stream ecology.

7. Macroinvertebrate drift is an important element of the stream ecology, but the macrofaunal drift cannot be considered as distinct from the bottom fauna (Dendy 1944, Waters 1972). Though macroinvertebrate benthic drift is a continuous phenomenon, the drift of any individual macrobenthic invertebrate is intermittent (Elliott 1971) and results from either voluntary or accidental release from its normal substrate habitat. Consequently the substrate macroinvertebrate community is the source of the drift phenomenon. In addition to bottom fauna, some

investigators consider terrestrial insects that get trapped in stream currents a part of the drift (Dendy 1944, Elliott 1969).

8. Waters (1972) summarized prior drift literature and gave these drift classifications based on mode of origin: catastrophic--resulting from the fauna's inability to maintain its grip on the substrate in the face of external forces; behavioral--resulting from the performance of a physiological function, i.e., feeding, pupation, etc.; or constant--the continuous stream of representatives of all species. Though these categories may seem somewhat indistinguishable at times, many of thei characteristics are recognizable. Catastrophic drift is characterized by an abnormally high drift, caused by rapidly changing river stage, upstream substrate disturbance, a water pollution pulse, and possibly other phenomena. Behavioral drift is characterized by cyclic changes in drift rate generally over a diel period or at particular life stages, such as just prior to pupation. Constant drift is characterized by the lowest drift rates, when there is no evidence of either catastrophic or behavioral drift rates.

9. Behavioral drift has come to be studied primarily as a result of diel periodicities in drift rate, first noted by Müller (1954). This phenomenon has captured the imagination of many researchers, and their efforts have elucidated facts determining that diel peaks result from behavioral patterns (apparently keyed to light intensity) of various fauna, resulting in their being swept away by stream currents. The activities of the various species occur during various diel time periods, producing a number of peaks in overall stream drift. Literature reviewed by Waters (1972) showed that activity had "a sharp increase at about the time of full darkness, some pattern of change during the night, and a sharp return to daytime levels at dawn." However, some species showed higher drift rates during the daytime. Since peaks in drift result from various different fauna, drift composition is changing throughout any diel period, therefore, sound knowledge of a stream's drift composition requires sampling over a diel period. However, once the rhythm of the various species is established, one should be able to sample more efficiently for discrete purposes.

Purpose and Scope

10. This survey reported herein was conducted to determine the composition and structure of macroinvertebrates, primarily benthic in origin, comprising the downstream drift in this section of the Lower Mississippi River during summer medium flow conditions.

11. The survey was to give direction to a more intensive study of the various habitats contributing to the stream macroinvertebrate drift by determining:

a. The systematic taxa comprising the drift.

b. Those taxa predominating, by number, the drift and the relative abundance of those taxa.

c. Diel changes in relative abundance in order to choose specific time periods for future specific sampling.

d. Through species-preferred habitat association, relative contribution of the various habitat types to the stream drift.

PART II: TEST METHODS AND ANALYSIS

Study Site

12. The study site was located at the Sunnyside Revetment on the Lower Mississippi River at river mile 529 (AHP), approximately 6 miles downstream from Greenville, Mississippi. This site was chosen because it is representative of the main channel and should contain species representative of backwater and riverine sites in this reach of the river, although relative numbers of individual species may vary among sites. The river channel at this point is straight, narrow, and well defined (Figure 1). The channel is approximately 1200 m wide between the top banks, but the width of the water surface area changes greatly with river stage.

13. The discharge of the Mississippi River at the Arkansas City, Arkansas, gaging station was 12,034 m^3/sec on 27 June 1978 and 12,091 m^3/sec on 30 June 1978. The average of these two discharge values (12,063 m^3/sec) was used as the sampling period discharge, since sampling was accomplished on 27 and 28 June 1978. The river stage was basically steady during the sampling period, rising less than 0.04 m. However, the river stage had experienced a steady decline from its spring peak flow condition during the time preceding the sampling effort.

14. Water chemistry data, taken during the study, at Temporary Channel Kentucky Bend (about 9 miles downstream) consisted of hydrolab readings of temperature, dissolved oxygen (DO), pH, and conductivity at the top, middle, and bottom of the water column. Previous sampling and analysis of the data for these parameters indicated that no differences could be detected either horizontally or longitudinally within the main channel throughout the 50-mile study reach. Therefore, the values given in Table 1 are considered generally comparable to the study site.

15. The diel study was conducted about 30 m from the west bank of the river. Although near shore, main channel conditions exist here, since the steep bank slopes sharply to the floor of the channel. Water depth at the station averaged about 9 m; surface current averaged 150 cm/sec.

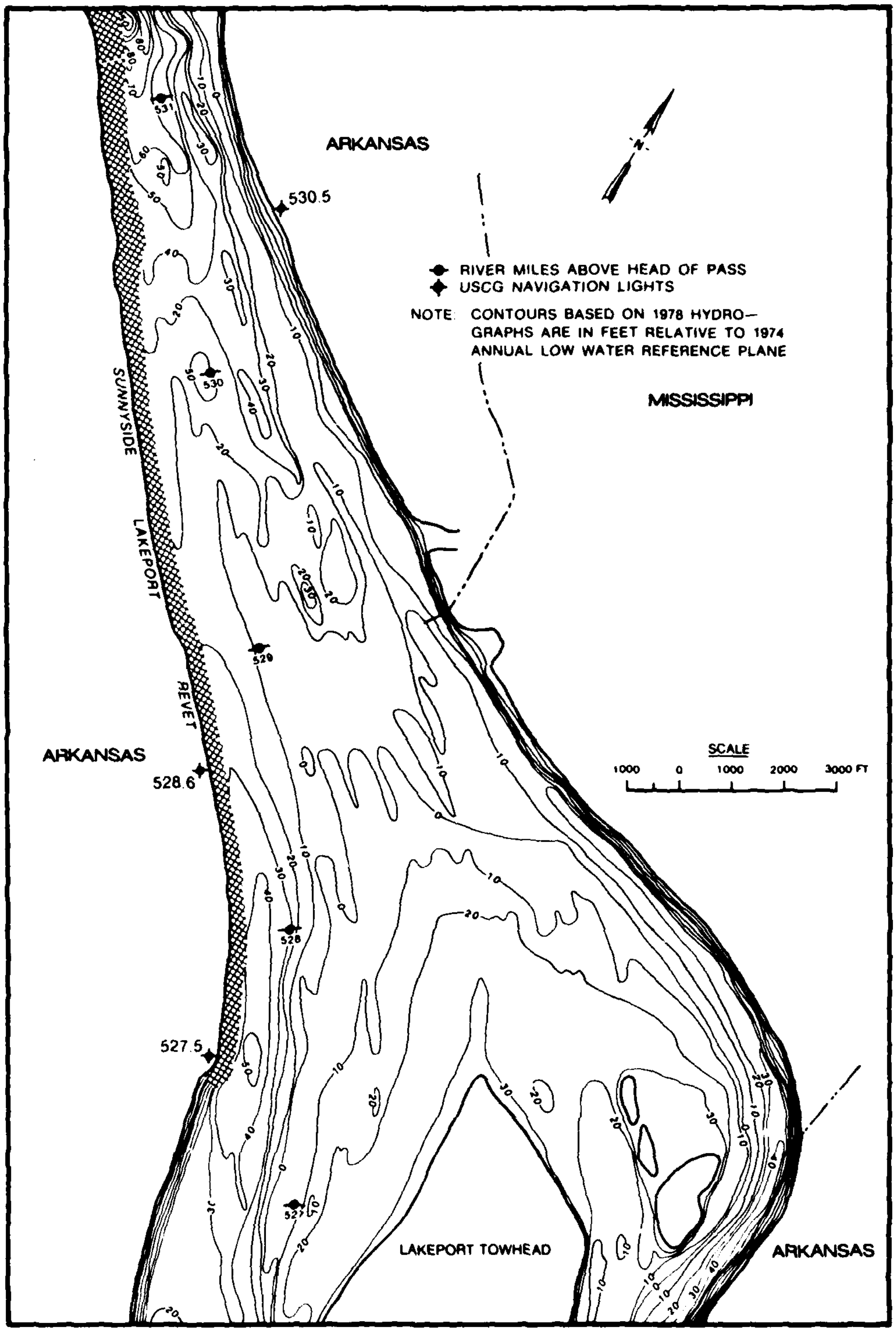

Figure 1. Lower Mississippi River, showing Sunnyside Lakeport Revetment, mile 529 (location of the study site)

Table 1

Water Chemistry Values at Temporary Channel Kentucky Bend

Location in Water Column	Sample Depth m	Maximum Water Depth, m	Temperature °C	DO mg/ℓ	pH	Conductivity μmhos/cm
Top	2.0	--	27.5	6.9	--	530
	2.0	--	27.5	6.7	--	530
Middle	5.5	11	26.1	6.8	7.8	402
	4.5	--	26.2	6.7	7.8	402
Bottom	11.0	11	26.1	6.7	7.8	407
	8.5	--	26.0	6.6	7.7	402

Sampling Methods

16. Drift samples were collected by towing 0.5-m (mouth diameter) conical plankton nets of 505-μm mesh netting equipped with a General Oceanic Model 2041 digital flowmeter. Surface tows (of approximately 0.5-m depth) were taken. Two nets were towed simultaneously downstream, one on each side of the sampling boat. The nets were fastened by the mouth ring to outriggers located just aft of midship. This arrangement allowed the nets to be raised from or lowered into the water quickly, thereby increasing the precision and reproducibility of towing times. Boat towing speed (engine rpm) was standardized to decrease variability in volumes of water filtered per tow. However, failure to standardize across boats resulted in greater volumes filtered during tows with the larger boat. Samples were collected during daylight hours with a 21-ft open Boston Whaler boat. For safety reasons, the three night sampling periods were accomplished from a 43-ft river survey boat. Sampling was conducted for the 24-hr period 1200 hr on 27 June 1978 to 0600 hr on 28 June 1978.

17. Since light intensity appears to be a phase setter for apparent endogenous locomotory rhythms possessed by benthic organisms that comprise stream drift and since burst of locomotion is thought to be responsible for the rhythmic diel peaks in drift density, sampling

periods were selected to roughly correspond with various light intensities and with reported peaks and lows in stream diel macroinvertebrate drift. The selected sampling periods are shown superimposed on hourly radiation data from the National Weather Service Center, Stoneville, Mississippi, located within 15 miles of the study site (Figure 2).

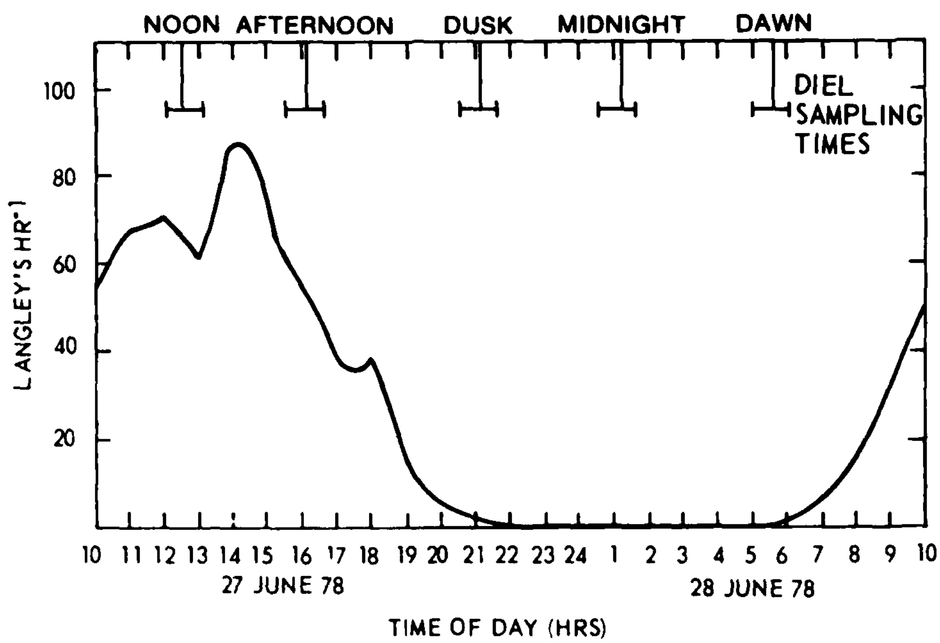

Figure 2. Solar radiation amounts for period of sampling (Data supplied by National Weather Service Center, Stoneville, Mississippi.)

18. Five sets of duplicate tows were collected during each of five intervals during the diel period: 1200 hr (noon), 1600 hr (afternoon), 2100 hr (dusk), 0100 hr (midnight), and 0600 hr (dawn). Each tow was 5 min in duration. Approximately 45 min was required to complete the collection of a set of five tows. A total of 50 samples were generated by this strategy; one sample was lost in transit to the laboratory. Samples were washed from the nets and preserved onboard with 5-percent buffered formalin. Initial and final flowmeter readings were recorded for each tow.

Laboratory Methods

19. Aquatic and terrestrial invertebrates were hand-sorted from samples under a dissecting microscope. Aquatic macroinvertebrates were identified to their species or generic level when possible and in all cases to the lowest possible taxon. Terrestrial insects and dipteran pupae were identified to order only in the interest of economy.

Data Analysis

20. The volume of water filtered during each net tow was calculated by converting flowmeter readings to flow velocities using the calibration curve furnished by the manufacturer. Flow velocities were substituted into the following equation to obtain the volumes filtered:

$$V = FTA$$

where

V = volume of water filtered, m^3

F = flow velocity, m/sec

T = towing time, sec

A = area of the net opening, m^2

21. Organism counts were converted to number of organisms per 100 cubic metres of water filtered (density) for analysis. The Statistical Analytical System (SAS) was used to conduct statistical analyses of the data. A one-way analysis of variance (ANOV) was performed for the variables' total density, number of taxa, and dominant species densities, using the general "linear models procedure" of SAS. The diel sampling period was the model or treatment term, and replicates within a diel sampling period were used as the error term. Duncan's Multiple Range Test (Steel and Torrie 1960) was used to determine significant differences among diel sampling period means for the different variables. All multiple comparisons were based on the 0.05 probability (P) level. A nested ANOV was computed in order to evaluate the contribution of the

different variance components to the total variance. In the ANOV, a zero count was considered as no sample. Few zero counts occurred in the variables analyzed.

PART III: RESULTS

Filtered Water Volumes

22. Volumes of water filtered by the nets ranged from 29 to 122 m^3 (mean - 79.0 m^3) for 49 samples. The large range resulted from using different boats to accomplish the sampling. Twenty volumes filtered using the smaller boat ranged from 29 to 47 m^3 (mean - 39.3 m^3), whereas 30 samples filtered using the larger vessel ranged from 75 to 122 m^3 (mean - 106.3 m^3). The greater volumes filtered using the larger vessel resulted mainly from the difference in towing speed of the two vessels since other variables were held approximately constant over all tows. Boat speeds should be standardized across boats in addition to across tows for an individual boat. There was an average difference in volumes filtered between the paired replicate tows (left versus right side of the boat) of 8.6 m^3 (Coefficient of variation (CV) = 43 percent). Effects of boat motion and/or flowmeter discrepancies are among possible causes of the differences. Subsequent calibration of the flowmeters could not account for water volume differences between the nets. Maintaining relative position to the river side required that the boat bow be pointed slightly channelward to compensate for current roll which tended toward the right bank, thus pushing the boats in that direction. The act of maintaining attitude in the current could conceivably account for differences seen in water volumes filtered between the two nets.

Analysis of Drift

23. The colonial hydriod Cordylophora sp. was numerically the dominant species in the drift samples as a whole. Initially, attempts were made to quantify this colonial organism by counting individual zooids or polyps. Six samples analyzed for Cordylophora had counts ranging from 150 to 300 zooids per sample. However, this effort was abandoned, since it was decided that the value of this data for purposes

of this study did not merit the inordinate amount of manpower required to complete the analysis.

24. The 49 samples contained 5090 specimens comprising 80 taxa (Appendix A) classified as macroinvertebrate drift. Holoplankton and ichthyoplankton were not included in the analysis. Two taxa, Hydra sp. (Cnidaria) and Hydropsyche spp. (Trichoptera), comprised 26 and 29 percents, respectively, of the total number of organisms. Potamyia flava (Trichoptera), Chaoborus sp. and Polypedilum spp. (Diptera), Tortopus incertus and Pentagenia vittigera (Ephemeroptera), Diptera pupae, and terrestrial Coleoptera comprised 29 percent, and the other 16 percent of the total number was composed of all remaining taxa listed.

25. Total density of drifting macroinvertebrates averaged 140.8 organisms/100 m^3 with a standard deviation of 47.6 organisms/100 m^3 over the 49 samples. The average total densities of drift per period did not exhibit pronounced or well-defined day-night fluctuations (Figure 3). However, differences in average total densities were significant ($P < 0.05$). The dawn (0600 hr) sampling period had a lower average density than the other four periods; however, there was no difference among averages for the latter periods.

26. The average number of taxa per 100 cubic metres of water filtered (herein referred to as the diversity) was 12.08 with a standard deviation of 2.704. It varied significantly ($P < 0.05$) over the diel period (Figure 4). Drift diversity was greatest during dusk, midnight, and dawn, in that order and was lowest at noon; the average number of taxa per 100 cubic metres of water filtered was significantly ($P < 0.05$) less for the noon and afternoon sampling periods than for the remaining periods. Diversity was significantly less at dawn than at dusk. Diversity did not differ significantly ($P < 0.05$) from dusk to midnight, nor from midnight to dawn.

27. Hydra sp. exhibited a distinct diel periodicity, with densities greater during daytime than at night (Figure 5). Maximum concentrations of Hydra sp. occurred during the noon sampling period (117.64 organisms/100 m^3). Significantly lower numbers of the Hydra sp. occurred at midnight, dawn, and dusk than during other sampling periods.

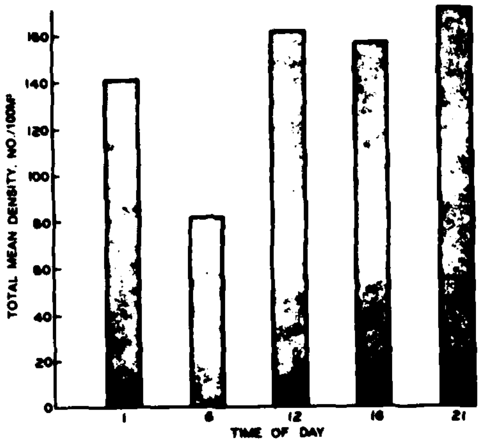

Figure 3. Total mean densities of macroinvertebrates at different times

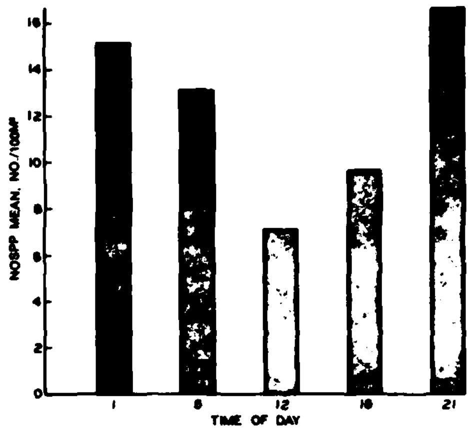

Figure 4. Mean of number of species at different times

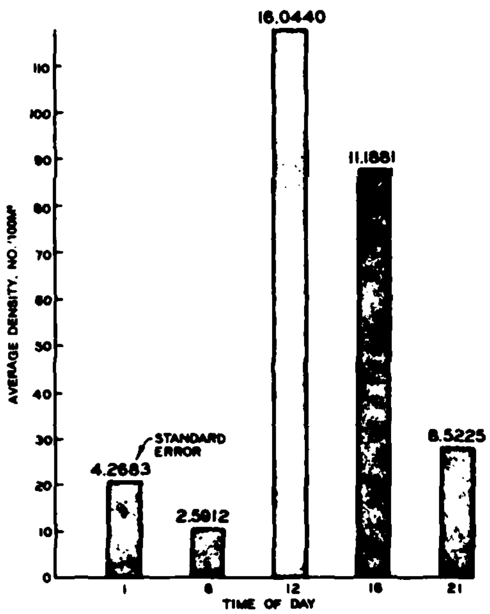

Figure 5. Average densities of Hydra sp. at different times

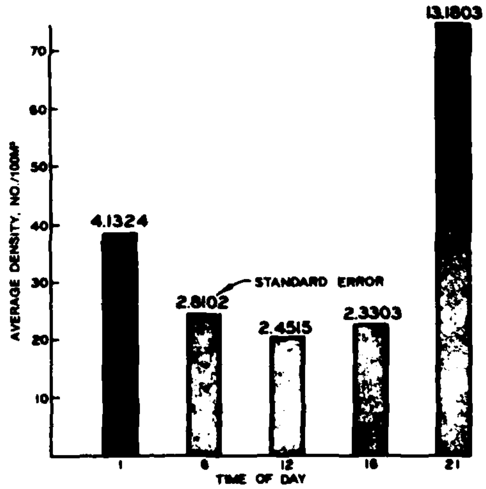

Figure 6. Average densities of Hydropsyche spp. at different times

Although *Hydra* sp. are sessile organisms, they can move over the substrate by gliding on the pedal disc, somersaulting, or looping. The organisms are also capable of secreting a gas bubble in the basal disc and thereby floating to the surface (Pennak 1953). The diel variation of *Hydra* sp. density in the drift probably results from the effects of currents carrying the organisms into the water column when they are exhibiting movement of various types. Thus *Hydra* sp. may be classified as exhibiting behavorial drift. The distinct diel periodicity is probably a result of *Hydra* sp. greater activity during daylight hours, which makes it more subject to being swept away by currents. It is not known at this time whether the source of these *Hydra* sp. is the main stem of the river, backwater areas, or both; however, *Hydra* sp. are known to inhabit many waters, e.g., lakes and streams, that have sufficient oxygen supply (Pennak 1953).

28. Periodicity was evident in the density of drifting *Hydropsyche* spp. (Figure 6). *Hydropsyche* spp. densities were significantly ($P < 0.05$) lower during the dawn, noon, and afternoon sampling periods than at other times. *Hydropsyche* spp. displayed maximum drift concentrations at dusk. Although *Hydropsyche* spp. are sessile, case-building caddisflies, the present data indicate a strong behavioral drift component for this organism.

29. *Potamyia flava*, a case-building caddisfly, generally occurred sympatrically with *Hydropsyche* spp. in the study area, but was less abundant in the drift (average relative abundance = 7 percent). This species also had a significantly ($P < 0.05$) higher drift intensity at midnight, dawn, and dusk than in the daytime (Figure 7). The data indicate that *P. flava* exhibits strong behavioral drift characteristics. Morris et al. (1968) reported *P. flava* in drift samples from the lower Missouri River and Fremling (1960) collected the species in the upper Mississippi River.

30. Larvae of the phantom midge, *Chaoborus* sp., were also common in the drift samples. Midnight and dawn densities were significantly ($P < 0.5$) greater than afternoon densities. Normal densities were greater in the afternoon than at dusk (Figure 8); however, the variation

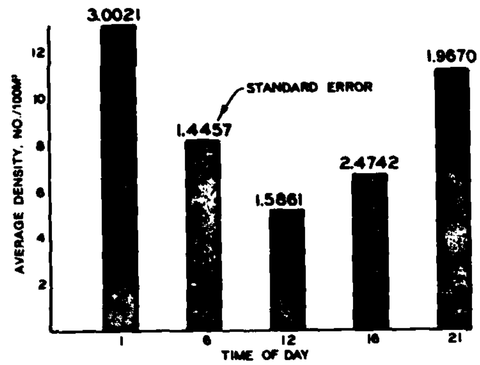

Figure 7. Average density of Potamyia flava at different times

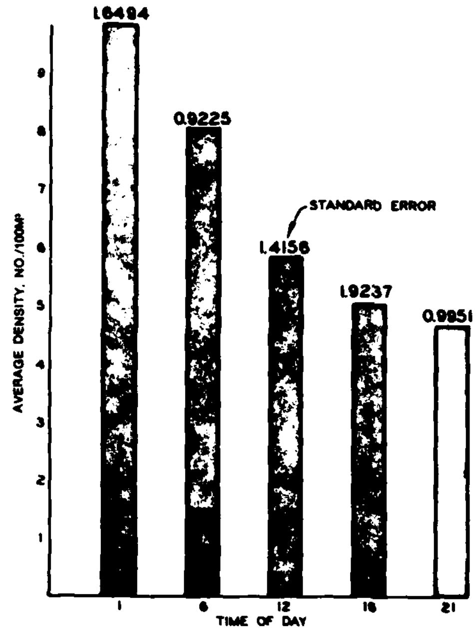

Figure 8. Average densities of Chaoborus sp. at different times

in individual sample readings was greater as reflected in the relatively high value for the standard error. This resulted from abnormally high numbers in one sample. Actually the afternoon samples had the lowest average density. A behavioral pattern related to diel periodicity is evident for Chaoborus sp. This species occurs primarily in slack-water habitats of the study area: oxbow lakes and dike fields at low water. The presence of this species in the drift is evidently a result of expatriation from its normal habitat by currents during daily nocturnal vertical foraging migrations into the water column.

31. Diptera pupae, although a mixture of species, showed diel periodicities with significantly greater numbers occurring near midnight, approximately equal and intermediate numbers at dusk and dawn, and equal and lowest numbers occurring during daylight sampling periods (Figure 9).

32. Density of the burrowing mayfly Tortopus incertus in the drift was significantly ($P < 0.05$) greater at midnight than at other times of

the day (Figure 10). This species comprised, numerically, 4.15 percent of the samples. Drift concentrations of *T. incertus* were lowest for daytime sampling periods; a small increase in drift density occurred at dusk (Figure 10). The data indicate that *T. incertus* is a component of the behavioral drift. This species is considered to be a filter feeder or collector, and its diel periodicity may be related to density factors.

33. *Pentagenia vittigera*, another burrowing mayfly, showed a diel periodicity similar to that of *T. incertus*. Concentrations of *P. vittigera* were greatest at midnight and lowest during daytime (Figure 11). Analysis of variance showed maximum ($P < 0.05$) densitites at midnight, zero densities at noon, and intermediate densities at dawn and dusk. The activity of *P. vittigera* in the drift was behavioral in nature and is possibly density-dependent. This species comprised 2.8 percent of the numerical total drift abundance.

34. Larvae of the Chironomid *Polypedilum* spp. made up 1.5 percent of the total drift density. This taxon had its greatest drift density in the afternoon (Figure 12) sampling period, which was significantly different ($P < 0.05$) from all others. There was no difference in densities among other sampling periods.

35. The abundance of unidentified species of terrestrial Coleoptera in the drift was greater at dusk by an order of magnitude than at other

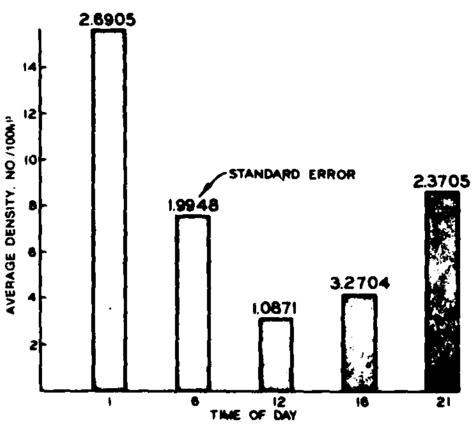

Figure 9. Average density of Diptera pupae at different times

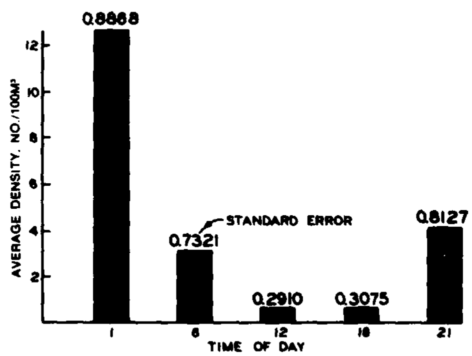

Figure 10. Average density of *Tortopus incertus* at different times

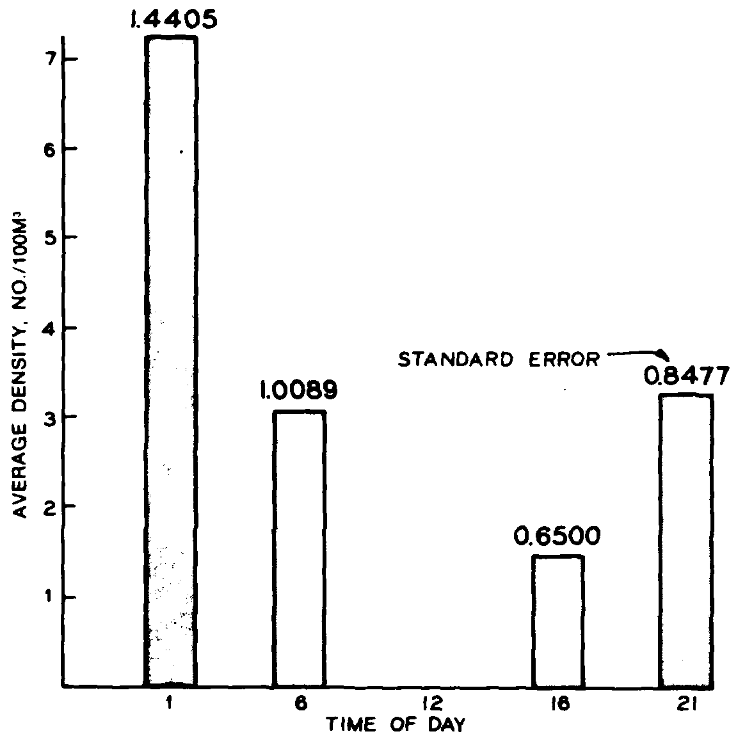

Figure 11. Average densities of <u>Pentagenia vittigera</u> at different times

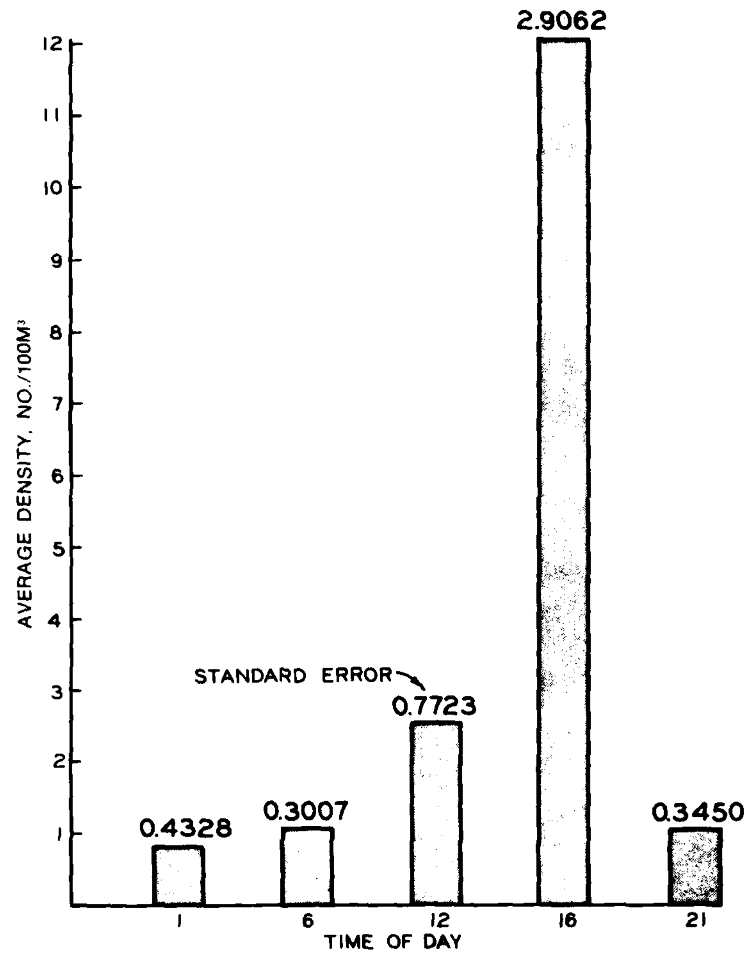

Figure 12. Average densities of <u>Polypedilum</u> spp. at different times

times; however, because of large natural variation, no statistical differences were observed. No Coleoptera were collected during the noon sampling. Coleoptera comprised only 1.3 percent of the total drift on the average. The data suggest that a distinct diel behavioral pattern, probably related to movement, resulted in the incidental and large occurrence of terrestrial Coleoptera in the river.

PART IV: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

36. Taxa comprising the Lower Mississippi River stream drift were identified as listed in Appendix A. Eighty taxa are listed.

37. Of the 80 taxa contributing to the stream drift, 9 taxa contributed 84 percent of the total number of organisms. *Hydropsyche* spp. was the most dominant comprising 29 percent of the total drift numbers, while *Hydra* sp. contributed 26 percent. Other dominant taxa and their percentage composition were: *Potamyia flava*, 7 percent; Diptera pupae, 7 percent; *Chaoborus* sp., 6 percent; *Tortopus incertus*, 4 percent; *Pentagenia vittigera*, 3 percent; *Polypedilum* spp., 2 percent; and terrestrial Coleoptera, 1 percent. It is likely that several of these taxa will shift their relative position of dominance with changing river stages and seasons. Others of the remaining taxa could occupy a position of dominance as river stages and seasons change.

38. The greatest number of species, the greatest total number of organisms, and the greatest number of *Hydropsyche* spp. and terrestrial Coleoptera drifted in the early evening (2100 hr). The greatest numbers of *Tortopus incertus*, *Pentagenia vittigera*, *Potamyia flava*, and Diptera pupae drifted near midnight (0100 hr). The greatest number of *Polypedilum* spp. drifted in the afternoon (1600 hr) and greatest number of *Hydra* sp. drifted at noon (1200 hr).

Conclusions

39. A distinct diel periodicity in the macroinvertebrate drift intensity and diversity was found prevailing in the Lower Mississippi River. The diel pattern of the drift intensity in the Lower Mississippi River, as indicated by this study, is similar to that reported for other rivers and streams (Waters 1972, Elliott 1969), having a mixture of drift species with nocturnal or diurnal peaks in drift rates. Total drift intensity was lowest at dawn (Figure 3). All but two of the

80 drift taxa had a greater nocturnal intensity than occurred during daylight hours; Hydra sp. and Polypedilum spp. had higher drift rates during the daylight hours. The relatively coarse intervals (4-6 hr) between sampling periods, however, did not reveal any fine-grained periodicity patterns that may exist. Elliott (1969) showed that the increasing of diel sampling intervals from 1 to 3 hr masked minor secondary peaks in drift rates of several species but that general diel trends were revealed by the less intense sampling schemes.

40. Data on stream drift in large alluvial rivers in the United States are meager. Studies on the Lower Missouri River (Morris et al. 1968, Berner 1951) are the most relevant for comparison of the lower Mississippi River data as both streams may be considered alluvial, warmwater, turbid rivers. There are, however, many differences in these two rivers.

41. The total number of macroinvertebrates drifting downstream in the Lower Mississippi River in a 24-hr period was estimated at 2.9×10^{10} organisms. Berner (1951) calculated that 6.4×10^{7} organisms drifted downstream in a day in the Lower Missouri River. The large difference in discharge of the Lower Mississippi and Missouri Rivers probably accounts for much of this difference in total drift transport. Total drift transport for 24 hr divided by river discharge is a standardized measure of drift intensity for comparing drift rates between rivers (Waters 1972). The standardized drift intensity for the Mississippi River site was 2.4×10^{6} organisms/day/m^3/sec. This number reduces to 28.2 organisms/m^3 averaged over a 24-hr period. This standardized rate is nearly identical to that reported for the Lower Missouri River (2.6×10^{6}) by Berner (1951) and is similar to that for several smaller streams (Waters 1972). However, different drift net mesh sizes, sampling times, and techniques make comparison of drift data among rivers involving various investigators speculative.

42. Macroinvertebrate taxa present in the drift are common in the various benthic habitats of the river system in the study area (Mathis et al. 1980) with the general exception of terrestrial Coleoptera. Hydra sp. are not mentioned in the reference; however, improved sampling and

sorting techniques have shown it to be quite common in the various habitats. The nine most abundant drift taxa exhibited behavioral drift characteristics (Waters 1972) in that some behavioral pattern resulted in a diel periodicity in drift intensity. The type of behavior resulting in the diel drift periodicity probably differs widely among the taxa. Increased movement associated with feeding or other activities is probably a principal cause of the behavioral drift in the Lower Mississippi River. These activities are probably keyed to photoperiod, although other factors may be involved. Density dependence is a likely factor in the drift of several species, e.g., burrowing mayflies and caddisflies.

43. For taxa such as Chaoborus sp., a normal inhabitant of slack-water areas, the behavioral drift characteristic may be secondary to expatriation by overbank flows producing catastrophic drift. However, small concentrations of Chaoborus sp. are found in various habitats of the river's main stem where a suitable silt-clay sediment exists in conjunction with relatively low current velocities.

44. Although considerable numbers of allochthonous insects were taken in the drift (terrestrial adult Coleoptera), virtually all larval species taken have also been taken by grab samples from the main-stem river or brushed from stones comprising waterway channelization dikes. Although the Mississippi River drift undoubtedly carries a large number of allochthonous drifting benthos during certain catastrophic periods, a major portion of its drift arises from its own inherent habitats.

45. Distances traveled downstream by drifting organisms is undoubtedly much greater in the Lower Mississippi River than that reported for small streams (Elliott 1971) because of the depth of the main channel and its current velocity and turbulence. Also the coarse, shifting sand sediment composing the main channel bed is not a suitable habitat for macroinvertebrates. Consequently, drifting macroinvertebrates must be carried by eddies, current divergences, or other means into favorable habitats for resettlement. Thus drifting benthic organisms may be transported considerable distances downstream before resettling, even though many are strong swimmers.

46. The Lower Mississippi River undergoes large annual fluctuations in stage (9-15 m) in the fall, winter, and spring. Drift organisms are, very likely, an important source of recolonization for the vast area of riverine substrate that is exposed during typical summer and fall low-flow conditions. The recolonization of denuded substrates by benthic drift has been suggested for other stream systems (Waters 1964).

47. The various habitats, swift-water dike and revetment areas, natural clay banks, riverine backwaters (slack-water lentic conditions) with silt, clay, and sand sediments were well represented in the drifting benthos through the preferred-habitats association. The most immediate and a very dominant macrohabitat, swift-water revetted bank, was represented by *Hydropsyche* spp. and *Potamyia flava*; they are also dominant dike representatives. Dikes were well represented by *Polypedilum* spp. and other species in addition to those mentioned. Natural clay banks were represented by *Tortopus incertus* and *Pentagenia vittigera*, and slack-water areas were represented by a variety of taxa including *Chaoborus* sp. and Diptera pupae. However, many Diptera pupae are not confined to slack-water areas, though they are generally prominent there. The preferred habitat of *Hydra* sp. is yet to be established in this river section.

Recommendations

48. The predominance of organisms as specified earlier in the downstream drift and the paucity of sand bottom-associated organisms is one measure of the relative importance of the various biotic habitats. Discrete drift sampling conducted above and below certain habitats, e.g., dike fields, offers a straightforward means of measuring the contribution of the particular habitat to the stream drift. Such sampling is suggested for future invertebrate studies of the habitats.

49. It is recommended that future sampling efforts conducted during the summer on this section of the Lower Mississippi River utilize these data to establish discrete sampling periods within a diel period

in order to reduce total sampling effort and expense. It is further recommended that additional diel drift studies be conducted during other seasons and river stages to determine seasonal or river stage shifts in macroinvertebrate activity resulting in stream drift.

50. Variability due to sampling methods should be reduced by anchoring the sampling vessel if possible. However, river traffic may preclude anchoring in the navigation channel. When vessel motor power must be used to accomplish sampling, a reliable current meter should be used to determine relative current velocities at net locations.

51. Various net mouth openings (0.5 to 1.0 m) should be evaluated at various boat speeds for catch efficiency in order to determine whether evasion of smaller nets by drifting macroinvertebrate benthos occurs at various speeds.

REFERENCES

Berner, L. M. 1951. "Limnology of the Lower Missouri River," Ecology 32:1-12.

Dendy, Jack S. 1944. "The Fate of Animals in Stream Drift When Carried into Lakes," Ecological Monographs, Vol 14, No. 3, pp 333-357.

Elliott, J. M. 1969. "Diel Periodicity in Invertebrate Drift and the Effect of Different Sampling Periods," Oikos 20:524-528, Copenhagen.

__________. 1971. "The Distance Traveled by Drifting Invertebrates in a Lake District Stream," Oecologia (Berl.) Vol 6, pp 350-379.

Fremling, Calvin R. 1960. "Biology and Possible Control of Nuisance Caddisflies of the Upper Mississippi River," Res. Bull., Iowa State Univ. Sci. Tech. 483:853-879.

Mathis, David, et al. 1980. "Aquatic Habitat Studies on the Lower Mississippi River, River Mile 480 to 530; Report 3, Benthic Macroinvertebrate Studies--Pilot Report," Miscellaneous Paper E-80-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

McLay, Colin. 1970. "A Theory Concerning the Distance Traveled by Animals Entering the Drift of a Stream," Journal, Fisheries Research Board of Canada, Vol 27, No. 2, pp 359-370.

Morris, K. A., et al. 1968. "Effects of Mainstem Impoundments and Channelization upon the Limnology of the Missouri River, Nebraska," Transactions American Fisheries Society, 97:380-388.

Müller, K. 1954. "Investigations on the Organic Drift in North Swedish Streams," Rep. Inst. Freshwater Res. Drottningholm, 35:133-148.

__________. 1966. "Die Tagesperiodik von Fliesswasserorganismen," A. Morphoh Oekol. Tiere 56:93-142.

Pennak, Robert W. 1953. Freshwater Invertebrates of the United States, The Ronald Press Company, New York.

Steel, Robert G. D., and Torrie, James H. 1960. Principles and Procedures of Statistics, McGraw-Hill, New York, pp 107-114.

Waters, Thomas F. 1961. "Standing Crop and Drift of Stream Bottom Organisms," Ecology, Vol 42, No. 3, pp 532-537.

__________. 1964. "Recolonization of Denuded Stream Bottom Areas by Drift," Transactions of the American Fisheries Society, 93:311-315.

__________. 1972. "The Drift of Stream Insects," Scientific Journal Series Minnesota Agricultural Experiment Station, Paper No. 7630, pp 253-272.

APPENDIX A: LIST OF TAXA CAPTURED

INSECTA

DIPTERA

Diptera pupa
Diptera adult
Diptera terrestrial

Chironomidae

Ablabesmyia sp.
Calopsectra sp.
Chernovskiia sp.
Chironomidae mutilated
Chironomus
Coelotanypus sp.
Cryptochironomus sp.
Dicrotendipes sp.
Glyptotendipes sp.
Polypedilum spp.
Rheotanytarsus sp.
Tanytarsus sp.
Trichocladius sp.
Xenochironomus festivus

Culicidae

Chaoborus sp.

Psychodidae

Psychoda

Tipulidae

Tipulidae sub-imago

TRICHOPTERA

Trichoptera mutilated adult
Trichoptera mutilated larva

Hydropsychidae

Cheumatopsyche sp.
Hydropsyche sp.
Hydropsychidae mutilated adult
Hydropsychidae mutilated larva
Parapsyche sp.
Potamyia flava

Polycentropodidae

Neureclipsis sp.

EPHEMEROPTERA

Ephemeroptera mutilated

Baetidae

Baetidae mutilated
Baetis sp.
Cloeon sp.
Pseudocloeon sp.

Caenidae

Caenis sp.

Ephemeridae

Ephemera sp.
Hexagenia bilineata
Hexagenia limbata
Pentagenia vittigera
Litobrancha sp.

Heptageniidae

Heptagenia sp.
Heptageniidae mutilated
Heptagenia marginalis
Spinadis wallacei
Stenonema annexum
Stenonema femoratum
Stenonema integrum
Stenonema mutilated sp.
Stenonema Pulchellum group
Stenonema tripunctatum

Leptophlebiidae

Habrophlebia vibrans
Leptophlebiidae mutilated

Polymitarcyidae

Tortopus incertus

Siphlonuridae

Isonychia sp.

COLEOPTERA

Coleoptera terrestrial
Coleoptera adult

Dryopidae

Helichus sp.

Dytiscidae

Agabus sp.
Coptotomus sp.
Derovatellus sp.
Laccophilus sp.

Elmidae

Stenelmis sp.

Hydrophilidae

Helophorus sp.

ODONATA

Libellulidae

Erythemis sp.
Libellula sp.

HEMIPTERA

Hemiptera mutilated

Corixidae

Graptocorixa sp.
Neocorixa sp.

COLLEMBOLA

Isotomidae

Isotomurus sp.

PLECOPTERA

Plecoptera adult

LEPIDOPTERA

Noctuidae

Arzama obliqua

HYMENOPTERA

Hymenoptera adult
Ichneumonidae

ARACHNIDA

ACARINA

COELENTERATA

HYDROZOA

Hydroida

Cordylophora lacustris
Hydra sp.

CRUSTACEA

AMPHIPODA

Gammaridae

Gammarus sp.
Crangonyx floridanus

Corophiidae

Corophium sp.

ISOPODA

Asellidae

Lirceus sp.

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27, [4] p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; E-80-1)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under EWQOS Work Unit VIIB.
References: p. 27.

1. Aquatic habitats. 2. Benthos. 3. Lower Mississippi River. 4. Mississippi River. 5. Periodic variations. I. Cobb, Stephen P., joint author. II. Magoun, A. Dale, joint author. III. United States. Army. Corps of Engineers. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; E-80-1.
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Errata Sheet

No. 1

AQUATIC HABITAT STUDIES ON THE LOWER MISSISSIPPI RIVER,
RIVER MILE 480 TO 530

Report 4

DIEL PERIODICITY OF BENTHIC MACROINVERTEBRATE DRIFT

Miscellaneous Paper E-80-1

December 1980

1. Form 1473, Abstract, page 2, line 12: Change 2.9×10^{10} to 1.5×10^{9}.
2. Form 1473, Abstract, page 2, line 14: Change 2.44×10^{6} to 1.2×10^{5}.
3. Page 23, paragraph 41, line 2: Change 2.9×10^{10} to 1.5×10^{9}.
4. Page 23, paragraph 41, line 10: Change 2.4×10^{6} to 1.2×10^{5}.

(Continued)

Errata Sheet No. 1 (Continued) for
Miscellaneous Paper E-80-1,
Report 4, December 1980

5. Page 23, paragraph 41, line 11: Change

   28.2 to 1.4.

6. Page 23, paragraph 41, line 12: Change

   "nearly identical to" to "an order of magnitude less than."

7. Page 23, paragraph 41, line 13: Change

   "similar to" to "less than."

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

Microprogrammable processor, control logic for 32175 computer mocro coding of ASPT simulator.

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

This project resulted in a report detailing specific guidelines for writing and testing custom micro-programs for the 32/75 computer. The micro-program instruction format is analyed in detail and then illustrated by a concrete example.

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