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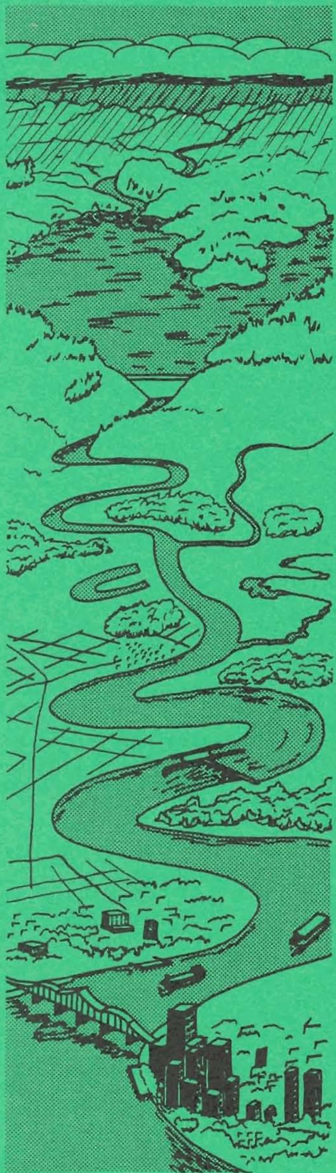

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OPERATIONAL STUDIES

TECHNICAL REPORT E-87-5

VERTICAL, HORIZONTAL, AND DIEL DISTRIBUTION OF INVERTEBRATE DRIFT IN THE LOWER MISSISSIPPI RIVER

by

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Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

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Lower Mississippi River macroinvertebrate drift densities and composition were determined at 3-hr intervals over 24-hr periods in mid-May and early June 1982. Samples were taken at the surface, middepth, and near the bottom at a nearshore sampling station and at the surface and middepth at a sampling station near the navigation channel. The overall mean drift density equaled 35.0 invertebrates/100 m^3 of water. Overall, *Chaoborus* larvae were the most common invertebrates collected, followed, respectively, by chironomid pupae, *Hydra* sp., *Hydropsyche orris*, and *Hexagenia* sp.

Chaoborus larvae did not exhibit increased drift nocturnally, but did show significantly higher densities at the nearshore station. *Hexagenia* was significantly more abundant both at the nearshore station and in the nighttime sampling. *Hydropsyche orris*, *Hexagenia*, and chironomid pupae were not uniformly distributed at the river's various

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depths, being present in greater densities in the middepth and/or bottom samples than at the surface. It is apparent that the use of only surface nets could seriously underestimate the actual drift densities of these taxa.

A number of unusual mayfly taxa were collected, including *Spinadis wallacei*, *Pseudiron* sp., and *Anepeorus* sp. A diverse assemblage of naidid worms was also present in the drift, with *Slavina appendiculata*, *Nais communis*, and *Wapsa mobilis*, respectively, being present in the largest numbers.

The abundances of various taxa in the Lower Mississippi River's drift seem to change markedly on a site-to-site basis, as a function of the physical characteristics of the river and its substrates in a certain area. This site-to-site heterogeneity, coupled with the lack of lateral homogeneity and the definite diel periodicity exhibited by some taxa, provides evidence that, even in an immense river such as the Mississippi, many of the organisms drift as they do in small streams, traveling relatively short distances with total movement rather saltatory.

Since the total number of drifting invertebrates in the system is a product of drift densities times river discharge, and the Lower Mississippi River has the largest discharge of any North American river, a very high number of macroinvertebrates drift down the river over even short time intervals. Over 24-hr periods in May and in June, approximately 405 million and 479 million macroinvertebrates, respectively, drifted past a transverse plane across the river through the sampling points. These large numbers of drifting invertebrates serve as a potential food source for fishes, as well as being potential colonizers of the river's substrates.

PREFACE

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

This report documents the composition, abundance, and distribution of drifting aquatic macroinvertebrates in a dike field and in the navigational channel of the Lower Mississippi River. Macroinvertebrates were collected on 19-21 May 1982 and 1-3 June 1982 at river kilometre 818.7.

This report was prepared by Dr. David C. Beckett and Mr. Richard L. Kasul, both of EL. The study was conducted under the supervision of Dr. Thomas D. Wright, Chief, Aquatic Habitat Group (AHG), and Dr. Conrad J. Kirby, Jr., Chief, Environmental Resources Division. Dr. Jerome L. Mahloch was Program Manager, EWQOS. Dr. John Harrison was Chief, EL.

Special appreciation is expressed to Ms. Linda E. Winfield of the AHG who provided valuable laboratory assistance and to Dr. Walter J. Harman of Louisiana State University, who verified the identifications of the samples' naidid oligochaetes. The report was edited by Ms. Jessica S. Ruff of the WES Publications and Graphic Arts Division.

Previous Director of WES was COL Allen F. Grum, USA. Commander and Director of WES is COL Dwayne G. Lee, CE. Technical Director was Dr. Robert W. Whalin.

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CONTENTS

VERTICAL, HORIZONTAL, AND DIEL DISTRIBUTION OF INVERTEBRATE DRIFT IN THE LOWER MISSISSIPPI RIVER

PART I: INTRODUCTION

Background

1. This study was conducted as part of the Environmental and Water Quality Operational Studies (EWQOS) Program, sponsored by the Office, Chief of Engineers, and managed by the US Army Engineer Waterways Experiment Station. Historically, the US Army Corps of Engineers has been deeply involved in the use and development of large rivers as navigable waterways. As a consequence of this involvement, the EWQOS Waterway Field Studies were initiated to perform ecological studies on a number of these large rivers. A principal objective of the EWQOS Waterway Field Studies was to provide data on how control structures for channel alignment, channel straightening, and bank stabilization affect waterway ecology. Such river control structures are found in navigable rivers in various parts of the United States, and are especially common in the Mississippi River and its tributaries.

Previous Lower Mississippi River Drift Studies

2. Invertebrate drift, or downstream transport of invertebrates, is a natural phenomenon that occurs across the whole range of lotic freshwater habitats. However, the study of invertebrate drift has been limited, for the most part, to small streams, because of the difficulties involved in sampling large, deep rivers (Wefring and Hopwood 1981). Consequently, little is known about the nature of drift in large rivers (Wefring and Hopwood 1981). Three previous Lower Mississippi River drift studies (Obi 1978; Bingham, Cobb, and Magoun 1980; Bowles 1985) yielded interesting information regarding this river's invertebrate drift. For example, Bingham, Cobb, and Magoun's (1980) EWQOS-sponsored

study, conducted just 32 km north of the present study's sampling area, resulted in the collection of 80 distinct taxa with an average total drift density, over all sampling times, of 140 invertebrates/100 m^3 of water. All three of these previous studies were limited, however, by the use of only surface tows, and the collection of samples only during the daytime (Bowles 1985) or at times separated by relatively lengthy time intervals (4 to 6 hr) (Obi 1978; Bingham, Cobb, and Magoun 1980).

Present Study Objectives

3. In the 1982 study reported herein, samples were taken over 24 hr with the time interval between samplings reduced to 3 hr; drift nets were simultaneously deployed at the surface, middle, and bottom of the water column; sampling took place both within a dike field and near the navigation channel; and samples were taken during two periods, mid-May and early June. The study had four objectives: (a) to determine the composition of macroinvertebrate drift in the Lower Mississippi River and to ascertain the numerically dominant species; (b) to determine macroinvertebrate drift densities, both for the individual species and for the total number of drifting macroinvertebrates; (c) to find if differences in composition or density occur vertically (surface, middepth, bottom), horizontally (in the dike field versus near the navigation channel), on a diel basis, or temporally (May versus June); and (d) to compare the results of this study with previous drift investigations conducted in the Lower Mississippi River and in other large North American rivers.

PART II: DESCRIPTION OF STUDY AREA AND METHODS

Lower Mississippi River Study Area

4. The Lower Mississippi River is a massive alluvial river and is North America's largest river (by discharge). Recorded discharges at Vicksburg,* Miss., have ranged from 2,700 m^3/sec at extremely low river stages to 64,500 m^3/sec during the 1927 flood. Main channel water velocity is usually between 1 and 2 m/sec with a maximum recorded velocity of 5 m/sec (Mississippi River Commission 1977). The river's present-day floodplain (3 to 10 km wide) is laterally confined by main-line levees constructed by the US Army Corps of Engineers. During the year of this study (1982), river stage had a range of 9.7 m (Figure 1).**

5. This study was conducted in the Lower Cracraft Dike Field area (river kilometres 815.0-822.2 = river miles 506.4-510.9) (Figure 2), located in the Lower Mississippi River, ca. 48 river kilometres downstream of Greenville, Miss. Lower Cracraft Dike Field has three stone dikes which extend perpendicularly from the bank toward the main channel. These dikes, constructed by the Corps of Engineers, help maintain the navigation channel by restricting secondary flow and directing it into the main channel.

6. As in the case of most Lower Mississippi River dike fields, extensive sand and gravel bars, called middle bars, occur between succeeding dikes and downstream of the last dike (Figure 2). These middle bars, the main axis of which is parallel to the main channel flow, isolate extensive pools from main channel flow during low-discharge periods, confining the dike field pools between the dikes, the riverbank, and the middle bars. At higher river stages the middle bars and the stone dikes are underwater, and current velocities in the dike field areas approach those of the main channel. During the May and June drift

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* A major gauging location situated ca. 120 km downstream of the study area.

** As measured at the Greenville, Miss., gauge.

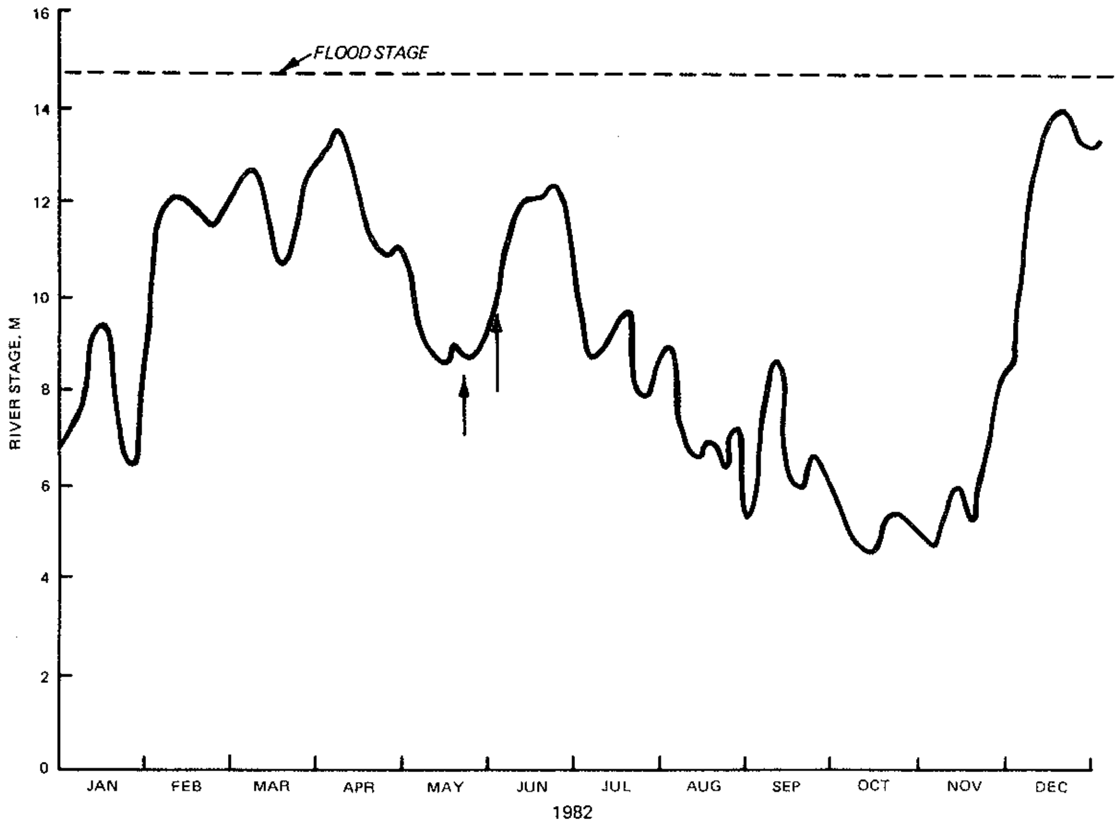

Figure 1. Lower Mississippi River stage readings for 1982, taken at Greenville. Drift sampling periods are indicated by the arrows along the hydrograph

sampling, the river was at moderate river stages (Figure 1). Parts of the middle bars were emergent, as shown in Figure 2; however, all three stone dikes were completely submerged at these times. Drift samples were taken at two locations, both near river kilometre 818.7 (ca. river mile 508.8, Figure 2). The inshore station was located between the riverbank and middle bar, slightly downstream from the third dike structure. The offshore station was located on the main channel side of the middle bar, near the edge of the navigation channel.

7. Current velocity at the offshore station equaled 70 cm/sec during the May sampling and 85 cm/sec during the June sampling. The inshore station, with its location nearer the riverbank, downstream of the submerged third dike, and inside the middle bar, had lesser current velocities, equal to 18 cm/sec in May and 30 cm/sec during the June sampling. Water temperature was 22.5° C at both stations during the May sampling and 24.3° C at both stations during the June sampling.

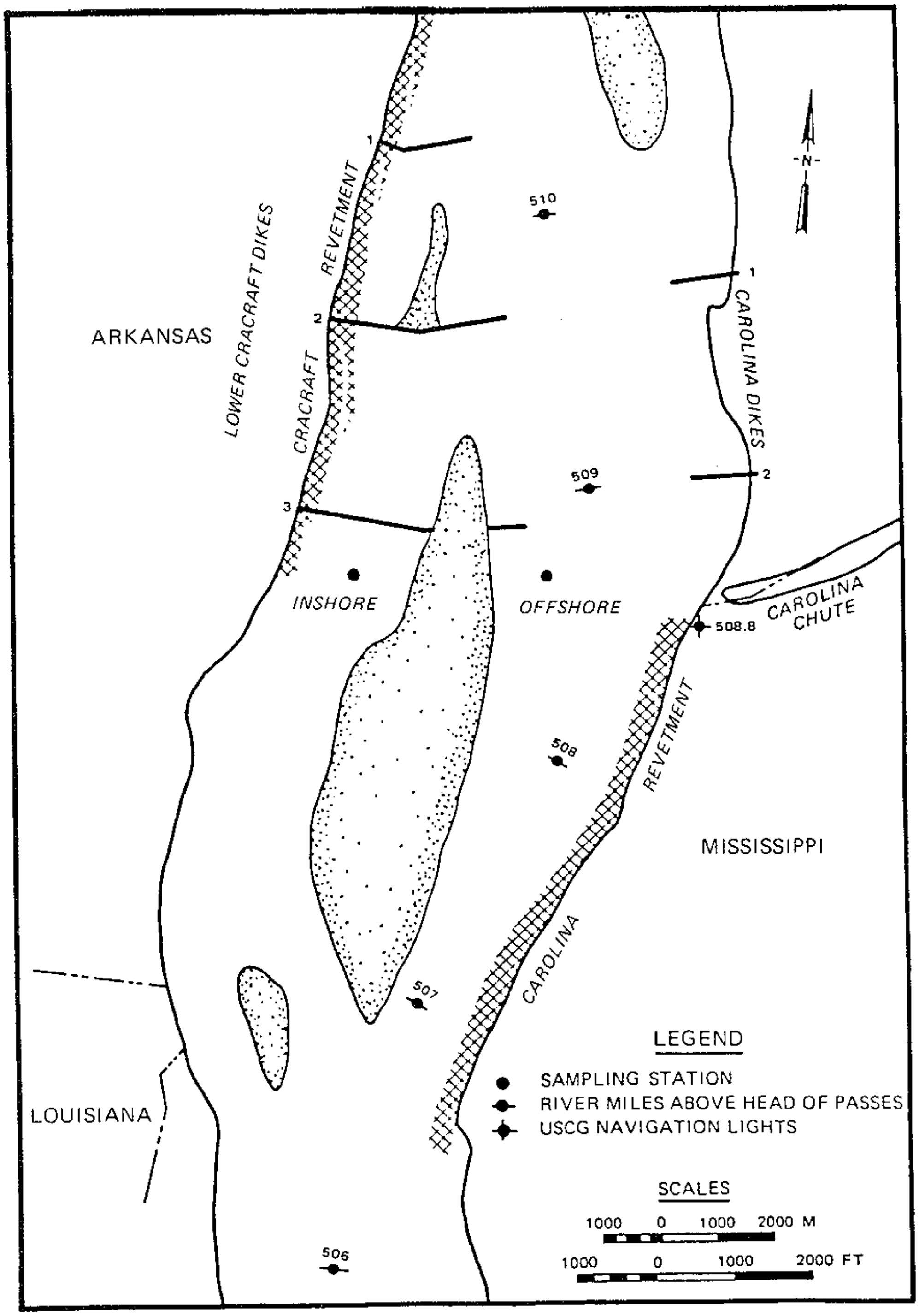

Figure 2. Invertebrate drift study site at Lower Cracraft Dike Field. Inshore and offshore sampling sites are indicated. The three stone dikes in this dike field were completely submerged at the time of sampling. (The stippled areas indicate the portions of the middle bars that were emergent at the time of sampling)

Sampling Methods

8. Macroinvertebrates were collected from a boat using conical nets with a mesh of 505 μm and an opening (mouth) diameter of 0.5 m. The boat was tethered to an anchored buoy during the drift collections. A General Oceanics digital flowmeter was suspended in the center of the mouth of each net so that the volume of water filtered could be estimated for each sample. A General Oceanics serial opening-and-closing apparatus was used along with nets at the surface (actually, 1 m below the surface), middepth, and bottom (1 m above the river bottom) (Figure 3, Table 1). The nets were all lowered in a closed position, then simultaneously opened (to begin collecting the samples) via a messenger and a double-trip mechanism. After a predetermined elapsed time (based on current velocity to achieve similar volumes of water sampled), the collection period was ended by closing all the nets via a second messenger and double-trip mechanism. The nets were then raised to the surface and the samples poured into plastic containers for return to the laboratory.

Table 1

Depths of Drift Samples and Depths of the River Bottom (m) at Sampling Sites in Lower Cracraft Dike Field, Lower Mississippi River, 19-21 May and 1-3 June 1982

	May		June	
	Inshore	Offshore	Inshore	Offshore
Surface net	1.0	1.0	1.0	1.0
Middepth net	4.6	2.9	4.6	2.5
Bottom net	8.2	*	9.1	*
River bottom	9.1	5.8	10.1	6.1

* No samples; offshore bottom net consistently failed to operate correctly.

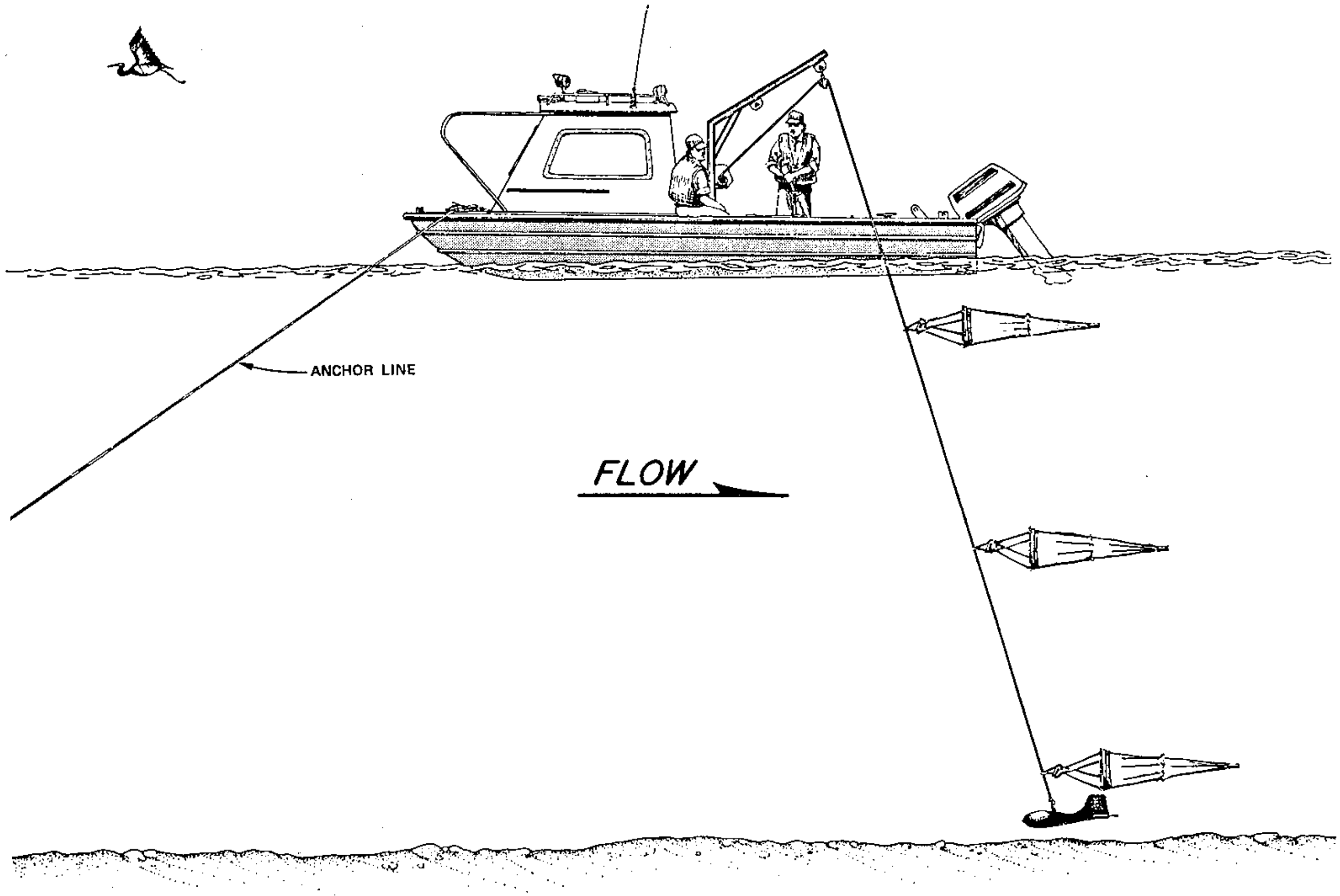

Figure 3. Setup of Lower Mississippi River drift sampling, showing surface, middepth, and bottom nets

9. Immediately after one set of samples (surface, middepth, and bottom) was processed, the sampling apparatus was rerigged and redeployed. Therefore two sets of samples, one set taken slightly after the other, were collected for a given location and time period (see Table 2). In both May and June, the drift samples were collected first at the inshore station, then at the offshore station 24 hr later (Table 2).

10. The duration of sample collection was dependent on current velocities in the sampling area, and was adjusted so that approximately 70 to 80 m^3 of water was filtered per sample. A sampling duration of 20 min was employed at the inshore station in May with a 5-min period at the offshore station; an 11-min, 20-sec period was used at the inshore station in June, whereas a 4-min, 15-sec sampling period was used at the offshore station. The depths at which the samples were taken, as well as the bottom depths at the sampling sites at the time of sample collection, are listed in Table 1. Although samples were successfully collected at all three depth levels (surface, middepth, and bottom) at the inshore station, high amounts of suspended silt and sand particles consistently fouled the trip mechanism and prevented the main channel (offshore) bottom net from operating correctly. Results from the main channel are therefore limited to the surface and middepth samples.

Analytical Methods

11. Terrestrial insects (fall-ins), terrestrial adults of aquatic insects, and zooplankton (cladocerans and copepods) were not included in the counts of drifting organisms. In those cases where both the family and species levels are listed in the taxa collected (Table 3, e.g. Hydropsychidae, *Hydropsyche orris*, and *Potamyia flava*), those individuals counted within the family listing indicate very small, immature organisms which could be identified only to family. The counts of invertebrates per sample were standardized to number of invertebrates/100 m^3 of water filtered, using the individual flowmeter readings to

Table 2

Macroinvertebrate Drift Sampling Times,* Lower Cracraft Dike Field, 1982

Site	Date (May)	Time	Event	Site	Date (June)	Time	Event
Inshore Site Sampled	May 19	1130*		Inshore Site Sampled	June 1	1136	
		1430				1437	
		1730	← Sunset at 1957			1730	← Sunset at 2005
		2030				2030	
		2330				2330	
	May 20	0230			June 2	0230	
		0530	← Sunrise at 0603			0530	← Sunrise at 0557
		0830				0830	
Offshore Site Sampled		1200		Offshore Site Sampled		1200	
		1430				1430	
		1730	← Sunset at 1958			1730	← Sunset at 2006
		2030				2030	
		2330				2330	
	May 21	0230			June 3	0230	
		0530	← Sunrise at 0602			0530	← Sunrise at 0557
		0830				0830	

* Times listed are the time at which the first of two replicate samples was collected. The second sample was collected shortly thereafter.

Table 3

Mean Drift Densities* (Numbers per 100 m^3) and Total Number of Individuals Collected per Taxon in the 1982 Lower Mississippi River Drift Study

Taxon**	May Inshore			May Offshore			June Inshore			June Offshore			Overall Total No. Collected	Overall Ranking (First Ten)
	Mean Day Density	Mean Night Density	Total No. Collected (Day & Night)	Mean Day Density	Mean Night Density	Total No. Collected (Day & Night)	Mean Day Density	Mean Night Density	Total No. Collected (Day & Night)	Mean Day Density	Mean Night Density	Total No. Collected (Day & Night)		
CNIDARIA														
Cordylophora lacustris	1.07	1.16	35								0.41	4	39	
Hydra sp.	9.36	21.93	347	2.35	2.61	67	1.31	1.28	40	1.19	1.77	29	483	3
OLIGOCHAETA														
Arcteonais lomondi				0.05		1							1	
Dero digitata		0.07	1	0.17		2							3	
Nais behningi	0.07	0.38	6	0.05		1							7	
N. communis	0.35	0.64	12										12	
N. pardalis	0.11	0.14	4		0.05	1					0.10	1	6	
Ophidonais serpentina		0.07	1	0.27	0.17	6							7	
Piguetiella michiganensis		0.14	2	0.05		1					0.20	2	5	
Pristina leidyi		0.07	1										1	
Slavina appendiculata	0.70	0.67	21	0.75	0.13	13				0.09	0.20	3	37	
Stylaria fossularis		0.05	1								0.10	1	2	
S. lacustris				0.10	0.06	3							3	
Tubificidae	0.11	0.14	4	0.16	0.08	3					0.20	2	9	
Wapsa mobilis		0.45	5	0.21		4							9	
NEMATODA	0.10	0.20	4	0.05	0.05	2				0.09		1	7	
CRUSTACEA														
Argulus sp.		0.13	2	0.04		1		0.06	1				4	
Corophium lacustre	0.06	0.26	4	0.16	0.14	4	0.07	0.06	2	0.20	0.21	4	14	
Crangonyx sp.	0.33	0.51	13	0.34	0.22	7	0.33		5	0.49	0.10	6	31	
Gammarus sp.	0.06		1	0.24	0.34	7	0.32	0.13	7	0.31	0.60	9	24	
Hyalella azteca	0.08	0.22	4	0.16	0.21	5	0.07	0.19	4	0.20	0.30	5	18	
Lirceus sp.	0.11	0.23	4	0.52	0.21	9	0.21	0.06	4	0.19	0.19	4	21	
Macrobrachium ohione					0.04	1	0.07		1				2	
Taphromysis louisianae	0.06		1	0.09	0.09	2				0.09		1	4	
HYDRACARINA	0.04	0.13	2	0.09		1	0.20		3	0.11		1	7	
PLECOPTERA														
Isoperla bilineata	0.24	0.33	7	0.18	0.34	7					0.10	1	15	
Perlesta placida	0.28	0.24	7	0.27	0.07	4	0.35	0.86	19	0.49	0.50	10	40	

(Continued)

* Includes results from nets at all depths: surface, middepth, and bottom at inshore site, and surface and middepth at offshore site.
** Listings for insect taxa refer to the densities of larvae or nymphs, unless otherwise noted. Taxa listed at the family level indicate very small, immature organisms which could be identified only to family.

(Sheet 1 of 4)

Table 3 (Continued)

Taxon**	May Inshore Mean Day Density	May Inshore Mean Night Density	May Inshore Total No. Collected (Day & Night)	May Offshore Mean Day Density	May Offshore Mean Night Density	May Offshore Total No. Collected (Day & Night)	June Inshore Mean Day Density	June Inshore Mean Night Density	June Inshore Total No. Collected (Day & Night)	June Offshore Mean Day Density	June Offshore Mean Night Density	June Offshore Total No. Collected (Day & Night)	Overall Total No. Collected	Overall Ranking (First Ten)
EPHEMEROPTERA														
Anepeorus sp.		0.05	1					0.06	1		0.10	1	3	
Baetis spp.				0.15		2	0.32	0.40	12	0.91	0.44	13	27	
Caenis spp.	0.12	0.41	6	0.09	0.05	2	0.34	0.12	7	0.29	0.09	4	19	
Heptagenia sp.	0.27	0.51	11	0.04	0.43	6	0.17	0.54	12	0.89	0.76	16	45	
Heptageniidae	0.07		1	0.18	0.39	7	0.35	0.22	9	0.30	0.10	4	21	
Hexagenia spp.	2.06	5.86	112	1.15	1.00	29	0.83	4.01	75	0.78	0.70	15	231	5
Isonychia sp.							0.07	0.28	6	0.20	0.21	4	10	
Pentagenia vittigera		0.20	3		0.12	1	0.07	0.35	7	0.10		1	12	
Pseudiron sp.	0.13	0.22	5	0.20	0.14	4	0.11		2				11	
Spinadis wallacei								0.20	3				3	
Stenacron interpunctatum							0.06		1				1	
Stenonema integrum	0.27	1.36	23	0.72	0.58	17	1.29	1.50	45	1.46	2.21	36	121	7
Stenonema sp. (early instars)	0.11		2										2	
Tortopus incertus	0.07		1				0.58	0.40	15	0.48	0.31	8	24	
ODONATA														
Argia sp.				0.07	0.08	2		0.06	1		0.11	1	4	
Coenagrionidae	0.11		1							0.10	0.10	2	3	
Gomphidae							0.23	0.27	7		0.10	1	8	
Gomphurus sp.								0.05	1				1	
Ischnura sp.										0.10		1	1	
HEMIPTERA														
Corixidae	0.17	0.34	8	0.09		1	0.36	0.48	13	0.20	0.30	5	27	
Trichocorixa sp.							0.07		1				1	
MEGALOPTERA														
Sialis sp.				0.04		1		0.06	1				2	
TRICHOPTERA														
Cyrnellus fraternus	0.17	0.07	4	0.16		2		0.12	2				8	
Hydropsyche orris	0.52	1.44	26	1.13	1.12	31	4.54	4.62	140	5.48	4.77	103	300	4
Hydropsychidae	0.29	0.27	6	0.10	0.09	3	0.96	1.05	31	0.89	1.48	24	64	9
Hydropsychidae pupae	0.11		1		0.11	2	0.08	0.09	2	0.20	0.38	5	10	
Leptoceridae										0.11		1	1	
Nectopsyche candida							0.06		1				1	
Neotrichia sp.							0.14		2				2	
Neureclipsis sp.	0.04		1				0.25	0.27	9	0.09	0.11	2	12	
Polycentropodidae								0.06	1	0.10		1	2	
Potamyia flava	0.54	0.51	13	0.52	0.79	18	0.73	0.75	24	1.28	0.99	23	78	8

(Continued)

(Sheet 2 of 4)

Table 3 (Continued)

Taxon**	May Inshore Mean Day Density	May Inshore Mean Night Density	May Inshore Total No. Collected (Day & Night)	May Offshore Mean Day Density	May Offshore Mean Night Density	May Offshore Total No. Collected (Day & Night)	June Inshore Mean Day Density	June Inshore Mean Night Density	June Inshore Total No. Collected (Day & Night)	June Offshore Mean Day Density	June Offshore Mean Night Density	June Offshore Total No. Collected (Day & Night)	Overall Total No. Collected	Overall Ranking (First Ten)
LEPIDOPTERA											0.10	1	1	
COLEOPTERA														
Berosus sp.										0.10		1	1	
Coptotomus sp.										0.11	0.09	2	2	
Dytiscidae adult											0.10	1	1	
Staphylinidae adult	0.05		1		0.08	1		0.06	1				3	
Staphylinidae										0.09		1	1	
Stenelmis sp. adult				0.09		1							1	
Stenelmis sp.		0.14	2		0.05	1	0.13	0.51	9	0.30	0.30	6	18	
DIPTERA														
Chironomidae														
Ablabesmyia annulata	0.54	0.42	14	0.51	0.22	9	0.20	0.43	9	0.11	0.10	2	34	
A. mallochi					0.08	1		0.05	1				2	
A. parajanta		0.15	2	0.07		1							3	
Chernovskiia orbicus	0.13	0.18	4	0.22	0.15	5	0.08	0.04	2	0.20	0.10	3	14	
Chironomidae pupae	4.17	9.58	184	3.09	5.53	116	3.43	5.05	132	4.92	6.05	111	543	2
Chironomus sp.	0.38	0.66	14	0.61	0.13	11	0.33	0.24	9	0.58	0.63	12	46	10
Coelotanypus sp.	0.10	0.21	4		0.06	1							5	
Cricotopus sylvestris group										0.10		1	1	
Cryptochironomus sp.	0.31	0.32	9	0.20	0.08	4		0.13	2		0.10	1	16	
Epoicocladius flavens								0.06	1				1	
Glyptotendipes sp.	0.29	0.25	8	0.33	0.36	10	0.11	0.06	3	0.19	0.29	5	26	
Harnischia sp.	0.22		2							0.11	0.10	2	4	
Lipiniella scopula	0.07	0.34	5										5	
Nanocladius distinctus	0.23	0.32	8	0.05		1				0.10		1	10	
Parachironomus frequens	0.07	0.12	2										2	
Polypedilum convictum	0.08	0.18	4	0.13		2	0.69	0.28	15	0.38	0.10	5	26	
P. halterale group	0.11		2	0.05		1							3	
P. illinoense	0.15	0.22	5		0.15	2				0.10	0.09	2	9	
Procladius sp.	0.61	0.63	19	0.46	0.21	10	0.35	0.22	9	0.19		2	40	
Rheotanytarsus sp.		0.08	1							0.33	0.20	5	6	
Robackia claviger	0.11	0.08	2	0.49	0.14	9	0.30	0.27	9	0.10	0.10	2	22	
Tanypus stellatus		0.15	2		0.07	1				0.09		1	4	
Thienemannimyia group	0.08	0.09	2										2	

(Continued)

(Sheet 3 of 4)

Table 3 (Concluded)

Taxon**	May Inshore			May Offshore			June Inshore			June Offshore			Overall Total No. Collected	Overall Ranking (First Ten)
	Mean Day Density	Mean Night Density	Total No. Collected (Day & Night)	Mean Day Density	Mean Night Density	Total No. Collected (Day & Night)	Mean Day Density	Mean Night Density	Total No. Collected (Day & Night)	Mean Day Density	Mean Night Density	Total No. Collected (Day & Night)		
Other Diptera														
Aedes sp.				0.04		1							1	
Chaoborus sp.	12.36	12.24	348	5.09	6.97	160	1.25	0.84	33	0.60	1.66	22	563	1
Chaoborus pupae	3.34	4.18	114	1.98	3.34	71	0.33	0.52	13	0.78	0.50	12	210	6
Probezzia sp.	0.05		1	0.18	0.26	6		0.05	1		0.09	1	9	
Simulium sp.	0.04		1		0.07	1				0.10		1	3	
Tipulidae											0.10	1	1	
PELECYPODA														
Pisidiidae	0.16	0.07	3									3		
Totals	41.83	70.01	1477	24.53	27.66	706	21.74	27.41	766	26.99	29.04	559	3508	

(Sheet 4 of 4)

determine the volume of water sampled. Day and night drift densities, summarized for each of the two sampling periods and the two sampling stations (Table 3), were determined by averaging the drift densities from samples taken at all depths (surface, middepth, and bottom at the inshore station; surface and middepth at the offshore station).

12. The Wilcoxon Rank Sum Test (Remington and Schork 1970) (also called Wilcoxon's two-sample test) was used to compare drift densities by date, i.e., May versus June, and by time of day, i.e., day versus night, for the more commonly collected taxa (Table 4). These comparisons of differences by date or by time of day were done separately for the inshore and offshore station collections (Table 4). The numbers used in making these comparisons were generated by determining a mean water column density per set of samples (equal to $(S_i + M_i + B_i)/3$ for inshore samples and $(S_i + M_i)/2$ for offshore samples, where S_i, M_i, and B_i equal the density of drifting organisms collected at the surface, middepth, and bottom, respectively, of the water column).

13. Comparisons of drift densities by position, i.e., the inshore station versus the offshore station, were also performed using the Wilcoxon Rank Sum Test. Numbers used in making this comparison were again generated by determining a mean water column density per set of samples. However, because only surface and middepth sample results were available for the offshore station, only the results from the surface and middepth samples at the inshore station were used in making this comparison. These comparisons of differences by position were done separately for the May and June sampling periods for those taxa that had shown significantly higher drift densities in one of the two sampling periods (see paragraph 12 and Table 4). Similarly, those taxa that had shown significant differences in day/night drift densities (Table 4) had separate analyses performed, i.e., densities at inshore and offshore were compared for just the day samples, and then densities were compared for just the night samples. Those taxa that showed significant differences both by date and by time of day (Table 4) were analyzed for positional differences in both ways, i.e., by first analyzing the results

Table 4

Significant Differences and Levels of Significance, by Date, Time of Day, Position, and Depth for the More Common Drift Taxa

	By Date (May or June)		By Time of Day (Day or Night)		By Position (Inshore or Offshore)				By Depth (S, M, or B*)							
Taxon	Inshore	Offshore	Inshore	Off-shore	May	June	Day	Night	May Inshore	June Inshore	May Offshore	June Offshore	Day In-shore	Night In-shore	Day Offshore	Night Offshore
Chaoborus larvae	May > June $p < 0.01$	May > June $p < 0.01$			I** > O $p < 0.01$											
Stenonema integrum	June > May $p < 0.10$	June > May $p < 0.01$	Night > Day $p < 0.02$							S > M > B $p < 0.05$ 2.1/1.4/0.7		S > M $p < 0.05$ 3.0/0.7				S > M $p < 0.025$ 2.5/0.3
Chaoborus pupae	May > June $p < 0.01$	May > June $p < 0.01$			I > O $p < 0.10$											
Chironomid pupae	May > June $p < 0.10$		Night > Day $p \leq 0.01$						B > M > S $p < 0.025$ 9.2/6.6/4.9		M > S $p < 0.05$ 5.7/2.9				M > S $p < 0.05$ 5.3/2.7	
Hydra sp.	May > June $p < 0.05$		Night > Day $p < 0.05$						B > M > S $p < 0.05$ 31.4/8.7/6.9							
Potamyia flava		June > May $p < 0.05$			O > I $p < 0.10$							S > M $p < 0.05$ 1.6/0.7				

(Continued)

NOTES: Entries in the columns indicate a significant difference exists for that particular comparison for that taxon; no entry indicates that no significant difference exists for that comparison. (>) in the "By Depth" columns indicates the ranking of the depths in terms of mean densities of that taxon. Mean densities (per 100 cu m) at the various depths for that taxon are listed in this same order (largest to smallest) immediately below the significance level.

* S = surface, M = middepth, B = bottom; comparisons made are among S, M, and B at inshore station and between S and M at offshore station.

** I = inshore, O = offshore.

Table 4 (Concluded)

	By Date (May or June)		By Time of Day (Day or Night)		By Position (Inshore or Offshore)				By Depth (S, M, or B*)							
Taxon	Inshore	Offshore	Inshore	Off-shore	May	June	Day	Night	May Inshore	June Inshore	May Offshore	June Offshore	Day In-shore	Night In-shore	Day Offshore	Night Offshore
Hexagenia sp.			Night > Day p < 0.01					I > O p < 0.01	B > M > S p < 0.0005 6.0/3.7/2.2							
Hydropsyche orris	June > May p < 0.01	June > May p < 0.01			O > I p < 0.10				B > M > S p < 0.05 1.9/0.6/0.4		M > S p < 0.05 1.6/0.6					
Numbers of all taxa combined	May > June p < 0.01		Night > Day p < 0.05		I > O p < 0.01			I > O p < 0.01	B > M > S p < 0.005 81.2/48.4/38.1		M > S p < 0.05 29.7/22.6	S > M p < 0.005 34.5/21.5				

for May separately from June, then reexamining the data holding day results separately from the night results.

14. Comparisons of drift densities by depths were performed using the Friedman Two-Way Analysis of Variance by Ranks (Siegel 1956). The data were examined for density differences at the various depths for the four combinations of dates and positions (May inshore, May offshore, June inshore, June offshore) (Table 4). The data were then reorganized for an analysis of density differences at the various depths looking at the four combinations of time of day (day, night) and position (inshore, offshore) (Table 4).

PART III: RESULTS

15. Mean drift densities over the eight combinations of dates (May/June), time of day (day/night), and position (inshore/offshore) ranged from 21.74 to 70.01 macroinvertebrates/100 m^3 (Table 3), with an overall mean of 35.0 macroinvertebrates/100 m^3. The total drift density (all macroinvertebrates combined) at the inshore station was significantly higher in May than it was in June (Table 4). In addition, in May total drift densities were significantly higher at the inshore station than at the offshore station (Table 4).

16. Larval *Chaoborus* sp. (Diptera:Chaoboridae) was the most commonly collected taxon in the study, making up 16 percent of the total number of invertebrates collected. *Chaoborus* larvae were much more abundant in the drift in May than in June at both of the sampling stations. Day and night larval *Chaoborus* densities at the inshore station in May averaged approximately 12 times those of the June inshore densities, whereas densities at the offshore station in May were about 6 times those of the densities at the same location in June (Table 3). Inshore drift densities of *Chaoborus* were significantly greater than offshore densities during May when *Chaoborus* numbers were generally high at both stations (Table 4). Although *Chaoborus* larvae generally exhibit an upward nocturnal migration, moving from the sediments to near the surface of the water column (Pennak 1978), there was very little difference in day versus night drift densities during this study (Table 3). In addition, there were no significant differences among drift densities at the various sample depths for *Chaoborus* larvae.

17. *Chaoborus* pupae were also commonly found in the drift and were the sixth most abundant taxon collected. *Chaoborus* pupae showed a drift distribution pattern similar to that of *Chaoborus* larvae: pupae showed greater numbers in the May drift than in June; greater densities in inshore samples than offshore samples in May; very little difference between day and night densities; and no significant differences among bottom, middepth, and surface collections (Tables 3 and 4). Another group of dipterans, chironomid pupae, were also quite common in the

drift, comprising 15 percent of the total number of macroinvertebrates collected. Unlike *Chaoborus* larvae and pupae, chironomid pupae were significantly more abundant at night than during the day at the inshore station and were also consistently (and significantly) more abundant in the deeper samples than those taken near the surface.

18. The stalked coelenterate, *Hydra* sp., was the third most common taxon collected in this study, with densities especially high in the May inshore night samples ($\bar{x}$ = 21.9 individuals/100 m^3). At the inshore station in May, when *Hydra* were most common in the drift, numbers were significantly greater at night than during the day, and drift densities were higher at the greater depths (Table 4).

19. Hydropsychid caddisfly larvae made up 12.6 percent of the total drift numbers and were represented by two species, *H. orris* and *P. flava*, which were the fourth and eighth most common taxa, respectively, collected in the study. The first and second instar hydropsychid larvae, which could not be identified to species but undoubtedly consisted of a mixture of *H. orris* and *P. flava* larvae, were also commonly present in the drift (Table 3). Both *H. orris* and *P. flava* were significantly more abundant in the June collections than the May collections (Table 4). In addition, *H. orris* was not uniformly distributed at the river's various depths; greater numbers were present in the bottom and middepth samples than at the surface (Table 4).

20. The two most common mayfly species in the drift, *Hexagenia* sp. (*Hexagenia* sp. as discussed here refers to *H. limbata* and/or *H. bilineata*; characters used to differentiate these two species at the nymphal stage have proved to be unreliable according to Edmunds, Jensen, and Berner 1976) and *Stenonema integrum*, were both significantly more abundant in the nighttime samples than in the daytime samples at the inshore station (Tables 3 and 4). Drift density counts of *Hexagenia* exceeded 10 individuals/100 m^3 for five samples (total n = 160). All five samples came from middepth or bottom nets taken inshore at night.

21. Naidid worms have, unfortunately, often been grouped together in drift studies, being identified only to family. Our study showed a diverse collection of naidids to be present in the drift, with 12

species represented (Table 3). *Slavina appendiculata* was the most common naidid, followed by *Nais communis* and *Wapsa mobilis*. A diverse assemblage of chironomid larvae was also present in the drift, with 22 species collected. *Chironomus* sp. was the most abundant species, followed by *Procladius* sp. and *Ablabesmyia annulata*. The collection of relatively large numbers of *A. annulata* in the drift was particularly interesting since this species had been collected only very infrequently in Lower Mississippi River embenthic (Beckett, Bingham, and Sanders 1983) and epibenthic (Mathis, Bingham, and Sanders 1982) studies.

22. Three predaceous mayfly species were also collected in the drift nets: *Spinadis wallacei*, *Pseudiron* sp., and *Anepeorus* sp. All three species are rather uncommon and have been collected only very infrequently (Edmunds, Jensen, and Berner 1976). Two stonefly species were collected: *Perlesta placida* and *Isoperla bilineata*. *Perlesta placida* was relatively abundant in the drift and was, overall, the twelfth most commonly collected taxon (Table 3).

23. Since the two sampling stations (positions) formed a line perpendicular to the river's flow (Figure 2), it was possible to estimate the total number of macroinvertebrates drifting in a 24-hr period past an imaginary cross-sectional plane cutting across the Lower Mississippi River. We used the eight mean drift densities presented in Table 3 (which took into account the samples from all depths) and known river discharges provided by the US Army Corps of Engineers, and multiplied by factors to reflect the contributions of day (14 hr) and night (10 hr), the cross-sectional area inside the middle bar (inshore) and in the navigation channel (offshore), and the relative current speeds in the two sampling positions. It was estimated that approximately 405 million macroinvertebrates drifted past the cross-sectional plane across the river at the study sampling line in a 24-hr period during the May sampling. Similarly, in June, approximately 479 million macroinvertebrates drifted past this point in the river in a 24-hr period.

PART IV: DISCUSSION

24. The most abundant taxa in our study, *Chaoborus* larvae and pupae, chironomid larvae and pupae, *Hydra* sp., hydropsychid caddisflies (*H. orris* and *P. flava*), and the mayfly *Hexagenia* have also been found to dominate drift collections in other studies of large North American rivers. In an April-August 1977 drift study of the Lower Mississippi River at river kilometre 429 (ca. 390 km downstream of our study site), Obi (1978) found, as we did, that *Chaoborus* larvae were the most abundant of the macroinvertebrate taxa in the drift. Chironomid pupae were the second most commonly collected taxon in Obi's study, with *Hydra* (fifth most common) and hydropsychid caddisflies (*H. orris* - sixth, *P. flava* - seventh) also abundant. *Hydropsyche orris*, *Hydra*, *P. flava*, and *Chaoborus* sp. were the most abundant taxa, respectively, in a June 1978 Lower Mississippi River drift study conducted at a point 32.5 km upstream of our study site (Bingham, Cobb, and Magoun 1980).

25. In an April-October 1980 Lower Mississippi River drift study at Lower Cracraft Dike Field (the same study site as ours), Bowles (1985) found *Hydra* to be the most abundant invertebrate in the drift, with *Chaoborus* and *H. orris* the third and fifth most common taxa, respectively. In an Upper Mississippi River study, Seagle, Hutton, and Lubinski (1982) found their drift samples were dominated by hydropsychid caddisflies, *Hexagenia* sp., chironomids, and *Chaoborus*, while in the swift waters of the channelized Missouri River, Carter, Bazata, and Andersen (1982) found that *H. orris* and *P. flava* were the most numerically abundant drift taxa.

26. It was somewhat surprising to find the larvae of *Chaoborus* as the most common taxon in our study, even though *Chaoborus* larvae are one of the dominant macroinvertebrates in the mud substrates of Lower Mississippi River backwaters (Beckett, Bingham, and Sanders 1983). The floodplain of the Lower Mississippi River has been laterally confined by Corps-constructed levees, preventing the inundation of low-lying areas. In addition, although some lentic abandoned channels and oxbow lakes remain connected to the river, many abandoned channels and oxbow lakes

were cut off from the river by the construction of the levees. Also, the use of revetments and dike fields by the Corps of Engineers has locked the river into an alignment such that lentic abandoned channels and oxbow lakes are no longer being created. Yet, numbers of drifting *Chaoborus* in the Lower Mississippi River equaled or exceeded the *Chaoborus* drift densities determined by Eckblad, Volden, and Weilgart (1984) in the backwater-rich Upper Mississippi River. Interestingly, a study of the heavily channelized Missouri River showed *Chaoborus* to be practically nonexistent in the drift (Carter, Bazata, and Andersen 1982; Bazata*). This lack of *Chaoborus* is most likely the result of channelization which subsequently caused the elimination of the Missouri River's backwaters.

27. *Hydra* sp. may not have been counted and reported in some drift studies. However, it is obvious from our study and the investigations of Obi (1978) and Bowles (1985) on the Lower Mississippi River and Eckblad, Volden, and Weilgart's (1984) Upper Mississippi River study that *Hydra* is a very important component of the drift, at least in the Mississippi River. In addition, *Hydra* can be present in extremely high densities, as shown by Bowles (1985) who determined mean drift densities of approximately 235 individuals/100 m^3 in a Lower Mississippi River dike field in June 1980. In our 1982 study in the same dike field, *Hydra* densities exceeded 50 individuals/100 m^3 in two of the samples (59.5 and 51.0/100 m^3).

28. Our work has shown that a diverse group of naidid worms are present in the drift. Examination of the total number of naidids collected also revealed that 86 individuals were collected in the May samples while only 7 naidids were present in the June collections (Table 3). This presence of much higher numbers of naidids in the drift earlier in the year corroborated a rather puzzling seasonal pattern of naidid drift noticed both by Obi (1978) and Bowles (1985) in their Lower Mississippi River studies. Bowles, in an April-October 1980 study

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* Personal Communication, 1985, K. R. Bazata, Department of Environmental Control (EPA), State of Nebraska, Lincoln, Nebr.

(samples taken once per month), collected a variety of naidids in April through June. With the exception of a few *Dero* sp. (collected in September), Bowles found no naidids in his drift samples from July through October. In an April-August 1977 study (sampling again conducted monthly), Obi (1978) collected *Paranais frici* (=*Wapsa mobilis*), *Ophidonais serpentina*, *Nais behningi*, and *Arcteonais lomondi* only in his April and May samples. When present, these species were found in fairly high numbers (e.g., Obi collected a total of 93 individuals of *P. frici* in April and May 1977). All four of these species were collected in our study, with a total of 24 individuals collected in May, but none in June.

29. Obi (1978) theorized that these four species originated in the extreme northern United States and Canada and had been flushed out by meltwater and carried southward by vernal floods. This idea was supported by the fact that the worms appeared only in April and May, when flood conditions existed. The theory that the worms are flushed out of their habitats by spring floods seems a tenable one, although it is tempered by the fact that in our study, river stage was actually higher during our June sampling than in May (Figure 1). Perhaps the presence of naidids in May 1982 was the result of high water in April (Figure 1). In any case, we find it doubtful that the numbers of naidids in the drift have their origin as far away as the northern United States and Canada. It is much more likely that these naidids occur locally in either the Lower Mississippi River main stem or possibly in connected backwaters.

30. The abundances of various taxa in the Lower Mississippi River's drift seem to change markedly on a site-to-site basis, depending on the physical characteristics of the river and its substrates in a certain area. For example, in both the June 1980 (Bowles 1985) and June 1982 (this study) investigations at Lower Cracraft Dike Field, mean drift densities of *Pentagenia vittigera* or *Tortopus incertus* (both burrowing mayfly species) did not exceed 1.0 individual/100 m^3. Yet, at Obi's study area in June 1977, mean drift densities of *T. incertus* equaled 34.92 individuals/100 m^3. Similarly, in June 1978, Bingham,

Cobb, and Magoun (1980) collected mean densities of 4.1 *T. incertus*/ 100 m^3 and 3.0 *P. vittigera*/100 m^3. *Tortopus incertus* and *P. vittigera* have very specific substrate requirements, living in the clay banks of large rivers (Edmunds, Jensen, and Berner 1976; Beckett, Bingham, and Sanders 1983). Such clay substrates were in much greater abundance in Obi's study area (Obi 1978) than in the Lower Cracraft Dike Field area (see Figures 12-14 of Beckett et al. 1983).

31. This site-to-site dissimilarity is also apparent from a comparison of *H. orris* drift densities. Bowles (1985) reported a mean drift density of approximately five *H. orris*/100 m^3 in June 1980 in Lower Cracraft Dike Field, while our investigation in the same study area in June 1982 showed similar densities, ranging from 4.54 *H. orris*/ 100 m^3 inshore during the day to 5.48 *H. orris*/100 m^3 offshore during the day. However, Bingham, Cobb, and Magoun (1980) reported approximately 36 *H. orris*/100 m^3 in June 1978 from their study site near Sunnyside Revetment on the Lower Mississippi River. Revetment on the Lower Mississippi River consists of massive fields (often miles long) of articulated concrete blocks. In strong current areas, these blocks are colonized by dense populations of *H. orris*. Bingham, Cobb, and Magoun's study site was close to shore, over the underwater revetment with strong currents present.* The elevated densities of caddisflies in the drift were probably a localized effect due to high *H. orris* densities in the area.

32. The site-to-site comparisons made above included data collected only in June of various years. Only June comparisons were made because the data in our study indicated that time of year has a strong influence on drift composition and density. Although our sampling periods were only 2 weeks apart, *H. orris* densities were significantly greater in June than in May at both the inshore and offshore stations ($p < 0.01$) (Table 4, see also densities in Table 3). *Potamyia flava*, the other hydropsychid caddisfly found in the drift, was also

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* Personal Communication, 1985, C. R. Bingham, Limnologist, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

significantly more abundant in June than in May at the offshore sampling station.

33. The colonizing abilities of *H. orris* via drift have been shown to change strikingly in the Ohio River over the year, especially between May and June (Beckett 1982). Throughout the winter and spring of 1979 only very low numbers of *H. orris* colonized rock baskets deployed in the Ohio River for 4 to 5 weeks, averaging between one and three animals per basket. In contrast, rock baskets recovered in October after a 5-week period in the Ohio River had been colonized by over 14,000 *H. orris* per rock basket. In early May, *H. orris* numbers averaged between one and two animals per basket in the Ohio River, while in early June, *H. orris* numbers averaged 174 animals per basket. Therefore, as reflected in both the Ohio River rock basket study and our Lower Mississippi River drift study, the May-June time period is a critical one in which *H. orris* markedly increases its propensity to drift.

34. The appearance of the mayfly *Anepeorus* sp. and the stonefly species *P. placida* in our Lower Mississippi River drift samples also indicates that drift composition varies seasonally. Despite fairly extensive artificial substrate sampling during 1976 in the Ohio River, *Anepeorus* nymphs were collected on only one date, 1 June 1976 (Beckett 1977). Sampling with artificial substrates every 5 weeks in the Ohio River in 1979 again produced *Anepeorus* on only one date, 2 June 1979. *Anepeorus* appears to follow a fast seasonal cycle (Hynes 1970) in large rivers in North America, and its collection in our mid-May and early June Lower Mississippi River drift samples was a result of sampling during the relatively short period of time when the nymphs of this species were active in the system. *Perlesta placida*, a common component of our May-June Lower Mississippi River drift collections (Table 3), was collected on artificial substrates in the Ohio River only in May and June of 1979, despite extensive sampling over the other months of the year (Beckett 1986). It is apparent that seasonal effects can markedly change the density (e.g., *H. orris*) and composition (e.g., *Anepeorus* and *P. placida*) of invertebrate drift in large rivers such as the Mississippi and Ohio.

35. A number of large-river studies have shown that some taxa exhibit a diel periodicity in their drift patterns. *Hexagenia* nymphs were found in significantly higher numbers in the nighttime drift (than during the day) in our study (Tables 3 and 4) and in those of Seagle, Hutton, and Lubinski (1982) and Eckblad, Volden, and Weilgart (1984) in the Upper Mississippi River. Obi (1978) found *Hexagenia* drift densities at night to be 5.2 times those of daytime densities in the Lower Mississippi River. He also found pupae of Tanypodinae and Chironominae (subfamilies of Chironomidae) to drift at night at densities of 10.7 and 5.2 times, respectively, their daytime densities. While the differences between nighttime and daytime drift densities for chironomid pupae were less in our study than in Obi's, our study did show significantly greater nighttime densities of chironomid pupae at the inshore sampling site.

36. *Hexagenia* is heavily utilized as a food item by fishes in the Mississippi River (Hoopes 1960), and its nocturnal drifting may be a strategy to escape predation. It is interesting to note that although the two other large, burrowing mayfly species in the Lower Mississippi River, *P. vittigera* and *T. incertus*, were rather uncommon in our samples, they were commonly collected by Obi (1978) and Bingham, Cobb, and Magoun (1980). Both of their investigations showed that these two species drift in much higher densities during the night than the day. Because *Hexagenia, Pentagenia,* and *Tortopus* are similar in terms of size and morphology, they are probably perceived identically by fish predators. Nighttime drift may be a common strategy of these mayflies to avoid predation.

37. While some taxa displayed nocturnal drift preferences, other common taxa, such as *H. orris* and *Chaoborus*, did not. Although Matter and Hopwood (1980) stated that "the *Hydropsyche-Cheumatopsyche* group... showed nocturnal peaks in abundance" in the Upper Mississippi River, our study and those of Obi (1978), Bingham, Cobb, and Magoun (1980), and Seagle, Hutton, and Lubinski (1982) showed large numbers of *H. orris* drifting during both the day and night in the Mississippi River. The ratio of mean densities of *H. orris* drifting during the night divided by

mean density of daytime drifters equaled 0.8 in Obi's study (therefore weakly favoring daytime drifting), while nighttime/daytime numbers were roughly equivalent in our study. Our rather unexpected finding that *Chaoborus* drift densities were equivalent in the day and night was shared by Obi (1978). In his Lower Mississippi River study, Obi found the night/day ratio for mean densities of *Chaoborus* equaled 0.8 (night $\bar{x}$ = 18.47 *Chaoborus*/100 m^3 and day $\bar{x}$ = 23.75 *Chaoborus*/100 m^3).

38. Both the phantom midge *Chaoborus* and the burrowing mayfly *Hexagenia* were collected in significantly greater numbers at the inshore sampling position, indicating that drift densities were not homogeneous across the river. Benthic grab sampling in 1979-1980 in Lower Cracraft Dike Field, our drift study site, showed that appreciable numbers of *Hexagenia* and *Chaoborus* were confined to mud (silt) substrate patches (Beckett, Bingham, and Sanders 1983). In addition, substrate mapping of Lower Cracraft Dike Field showed that at moderate flows, such as existed during our drift study, mud substrates were limited to shore areas where slower currents exist (Beckett et al. 1983). Drift densities for these two taxa were higher, therefore, at the sampling position closer to the area in which these animals were found in the benthos. These findings suggest that a large proportion of the drift is local in origin, and is not entirely a homogeneous turmoil of organisms being swept for long distances downstream.

39. In a similar vein, Obi (1978) noted much higher drift densities of the burrowing mayflies *Tortopus* and *Pentagenia* in collections along both the east and west shores of the Lower Mississippi River than in midriver collections (nearshore densities equaled 3.6 and 4.6 times midriver densities for *Tortopus* and 4.2 and 12.3 times midriver densities for *Pentagenia*). In the Lower Mississippi River, *Tortopus* and *Pentagenia* are found primarily in the river's clay banks; hence, drift collections near the banks are closer to the points of origin for these mayflies.

40. This lack of lateral homogeneity, plus the additional facts that a large amount of site-to-site heterogeneity occurs in the Lower Mississippi River drift, as pointed out above, and that a definite diel

periodicity is exhibited by some taxa, provides evidence that much of the drift is of local origin. If local drift were of only very minor importance, i.e., if almost all the drift consisted of organisms swept helplessly from substrates far upriver, then the drift would be much more uniform longitudinally (site to site), laterally, and dielly. Undoubtedly some of the drifting organisms in the Lower Mississippi River are transported at the mercy of the river's currents and turbulences; e.g. some *Chaoborus*, *Hexagenia*, *Pentagenia*, and *Tortopus* were collected in the midriver drift in both Obi's (1978) and our study. However, it seems probable that, even in an immense, powerful river such as the Mississippi, many of the organisms drift as they do in small streams, traveling relatively short distances with total movement rather saltatory (Waters 1972).

41. *Stenonema integrum*, the most common nonburrowing mayfly collected in our study, was present in increased densities at the upper strata of the water column (Table 4). In the Upper Mississippi River, Matter and Hopwood (1980) found that at night the nonburrowing mayflies *Pseudocloeon* and *Baetis* were also consistently more abundant in near-surface nets than in middepth and bottom nets. With the possible exceptions of *P. flava* and *Chaoborus*, all the other commonly collected taxa in our study were shown, in at least one of the depth comparisons (Table 4), to have significantly different densities among depths, with the higher densities nearer the river bottom.

42. In an Upper Mississippi River drift-vertical distribution study, Wefring and Hopwood (1981) found markedly higher total (all invertebrates included) drift densities nearer the bottom of the water column than near the top. Greater drift densities in bottom nets were especially evident for hydropsychid caddisflies in the Upper Mississippi River (Matter and Hopwood 1980, Wefring and Hopwood 1981). This agrees with our findings that *H. orris*, a very common hydropsychid caddisfly throughout the Mississippi River, was not uniformly distributed at the various depths and that greater numbers of *H. orris* were collected in the bottom and middepth nets than the surface samples. The majority of large river drift studies have been conducted using only

surface nets. It is clear that the use of only surface nets could seriously underrepresent the actual drift densities of some taxa.

43. The grand mean drift density in this study, 35.0 macroinvertebrates/100 m^3, was roughly equal to or somewhat lower than overall mean drift densities of other large-river studies. The Lower Mississippi River investigations of Obi (1978), Bingham, Cobb, and Magoun (1980), and Bowles (1985) had grand mean drift densities of 82.3, 140, and 74.4 macroinvertebrates/100 m^3, respectively. Eckblad, Volden, and Weilgart (1984) reported a grand mean of 71.3 macroinvertebrates/100 m^3 from sampling in the main channel of the Upper Mississippi River (mean taken from sampling sites upstream of side channel influence), while a Missouri River study (Carter, Bazata, and Andersen 1982) had a mean of 41.4 macroinvertebrates/100 m^3. Two Upper Mississippi River investigations have reported markedly higher drift densities; the study of Wefring and Hopwood (1981) had a mean of 256.9 individuals/100 m^3, and that of Seagle, Hutton, and Lubinski (1982) had means of 405.0 and 777.5 individuals/100 m^3 for two locations. Although seasonal effects may play a part, it is not clear why two of the Upper Mississippi River studies had such relatively high drift densities.

44. In his review of the drift of stream insects, Waters (1972) pointed out that drifting invertebrates provide a colonization potential of great magnitude and that, although total numbers of drifting invertebrates are generally higher at night than in the day, a "constant" drift, i.e., a continuous stream of representatives of many species, occurs at all times. Water's statements were based on small-stream work; however, it is apparent from our study that they also apply to a huge river such as the Lower Mississippi. Although a number of the most abundant taxa showed significantly greater drift densities at night, overall mean day and night drift densities were similar, i.e., a continuous stream of representatives of many species did occur at all times. The estimates of 405 million macroinvertebrates in May and 479 million macroinvertebrates in June drifting past a transverse plane along our sampling points in a 24-hr period present an extremely large pool of

potential colonizers being continuously moved across the river's substrates.

45. In a 1979-1980 benthic macroinvertebrate study of the Lower Mississippi River (Beckett, Bingham, and Sanders 1983), the bottom substrates in dike field areas showed large changes in biotic composition over the different flow regimes. These compositional changes correlated with changes in river stage and resultant alterations in current and substrate (Beckett, Bingham, and Sanders 1983). Since the physical changes and the concomitant faunal changes occurred over just a few months, it is likely that the very large pool of drifting invertebrates served as the source for colonization of the dike fields' substrates.

46. These large numbers of drifting invertebrates also serve as a potential food source for the river's fishes. While drifting, these invertebrates are very vulnerable to predation; e.g., the burrowing mayflies are no longer protected within their burrows, hydropsychid caddisflies have left the relative safety of their cases, *Chaoborus* larvae are no longer hidden in the sediments, and chironomid larvae are no longer enveloped within their tubes. Food habit studies of fishes in large rivers should consider drift as a source of plentiful, vulnerable food items, and models or appraisals of riverine invertebrate communities as "fish food organisms" should include drift organisms along with embenthic and epibenthic valuations in resource assessments.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

47. Summarized below are the conclusions drawn from the May-June 1982 invertebrate drift study.

- a. The overall mean macroinvertebrate drift density equaled 35.0 organisms/100 m^3 of water. Overall, larval *Chaoborus* was the most common invertebrate collected, followed by chironomid pupae, *Hydra* sp., *Hydropsyche orris*, and *Hexagenia* sp., respectively.
- b. A number of unusual mayfly taxa were collected, including *Spinadis wallacei*, *Pseudiron* sp., and *Anepeorus* sp. A diverse assemblage of naidid worms was also present in the drift, with *Slavina appendiculata*, *Nais communis*, and *Wapsa mobilis*, respectively, being present in the largest numbers.
- c. Somewhat surprisingly, *Chaoborus* larvae did not exhibit any increased drift nocturnally, but did show significantly higher densities at the nearshore sampling station than at the sampling station near the navigation channel. *Hexagenia* was significantly more abundant both at the nearshore station and in the nighttime sampling.
- d. Some macroinvertebrates were not uniformly distributed at the river's various depths. *Hydropsyche orris*, *Hexagenia*, and chironomid pupae were present in greater densities in the middepth and/or bottom samples than at the surface. The use of only surface nets could therefore seriously underestimate the actual drift densities of these taxa.
- e. The lateral, diel, and site-to-site heterogeneity of drift abundances for various taxa in the Lower Mississippi River provides evidence that many of the organisms in this river drift as they do in small streams, traveling relatively short distances with total movement rather saltatory.
- f. A very high number of macroinvertebrates drift down the Lower Mississippi River. Over 24-hr periods in May and June, approximately 405 million and 479 million macroinvertebrates, respectively, were estimated to drift past a transverse plane across the river along the sampling points. These large numbers of drifting invertebrates serve as a potential food source for fishes as well as being potential colonizers of the river's substrates.

Recommendations

48. Recommendations regarding future studies are as follows:

a. For the reasons discussed in paragraph 47d, if accurate drift densities throughout the water column are required, sampling should be performed at middepth and near-bottom, as well as near the surface.

b. None of the Lower Mississippi River drift studies have investigated drift for the part of the year from November to March. A study at a single site over an entire year would show how much the composition and abundance of drifting macroinvertebrates change from the warm-weather months to the winter.

c. The relative contribution of organisms from the Lower Mississippi River's backwaters to the river's total drift numbers is unknown at this time. An investigation to determine this contribution would show to what extent organisms drift out of the backwaters and whether these organisms make up a substantial portion of the total number of animals drifting down the main stem of the river.

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