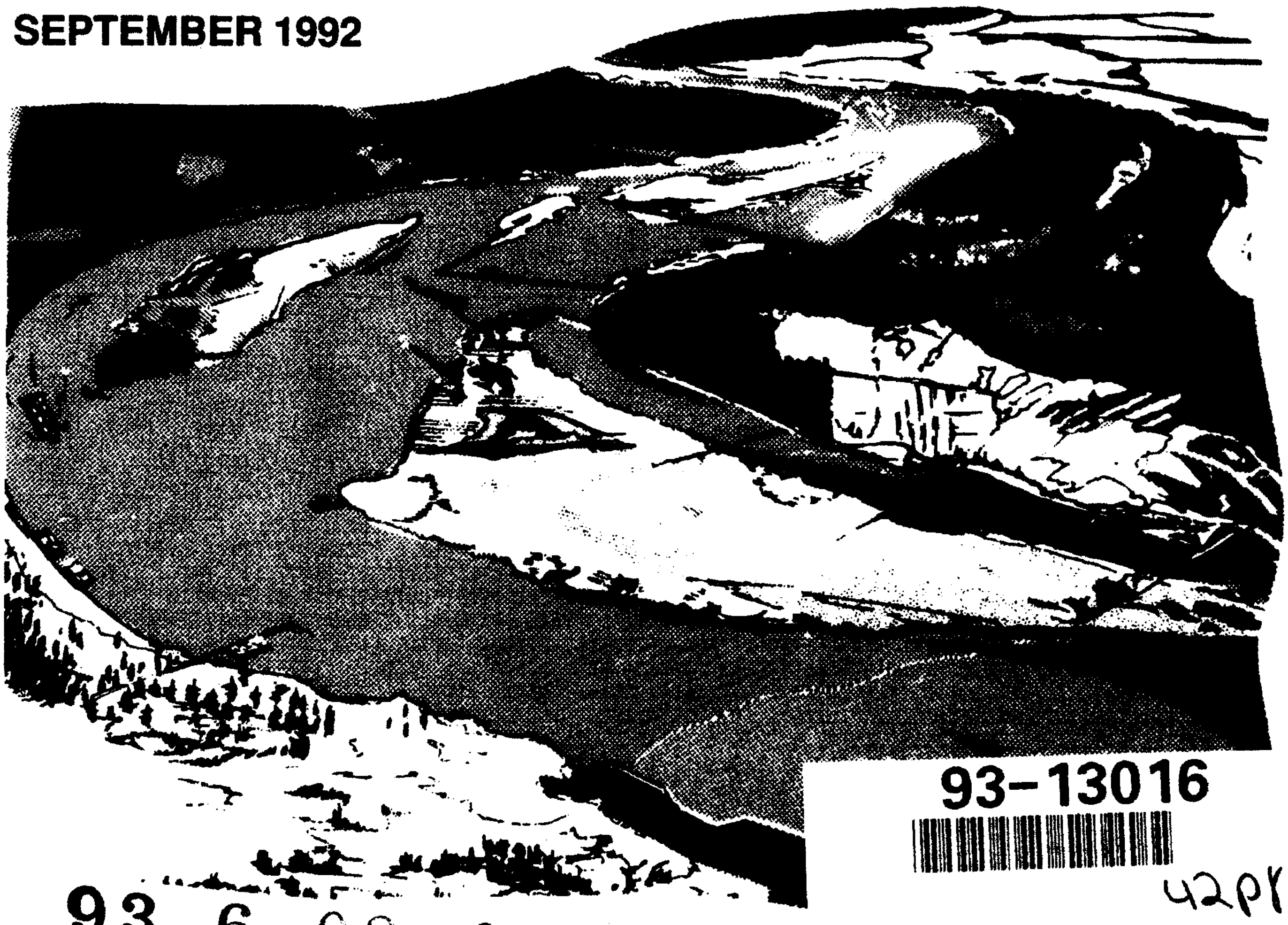
US Army Corps
of Engineers
Mississippi River
Commission

EFFECTS OF SURFACE TEXTURE OF ARTICULATED CONCRETE MATTRESS BLOCKS ON THEIR HABITAT VALUE

LOWER MISSISSIPPI RIVER ENVIRONMENTAL PROGRAM

REPORT 19

SEPTEMBER 1992



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13. ABSTRACT *(Maximum 200 words)*

The effects of minor alterations to the surface of articulated concrete mattress (ACM) blocks, used to protect the banks of the Lower Mississippi River from erosion, were examined with laboratory and field studies. Field studies were conducted at Marshall Point, RM 446.8, Issaquena County, Mississippi, on 18 July 1989 and at False Point Revetment, RM 443.1, Madison Parish, Louisiana, on 5 July 1990. Rough surfaces created a drag on moving water and increased turbulence in a very thin layer just above the surface of the block. Grooved surfaces provided velocity shelters for caddisflies and other macroinvertebrates. Total macroinvertebrate density on grooved blocks (3,882 individuals/sq m) was 2.3 ($p < 0.01$) and 1.6 ($p < 0.01$) times greater than on smooth (1,725 individuals/sq m) and rough (2,411 individuals/sq m) blocks, respectively. Density of trichopterans on grooved blocks (2,888 individuals/m^2) was significantly greater ($p < 0.05$) than on rough or smooth

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blocks. Most trichopteran cases and feeding nets were in the grooves and not the smooth area between grooves. Chironomidae and Trichoptera comprised more than 98 percent of the total macroinvertebrate fauna after the blocks were in the river for 7 days; densities of these two groups equaled 6,972.5 and 8,671.0 individuals/m^2, respectively. *Hydropsyche orris* was dominated by first instar larvae from May through August, and the population was never dominated by fourth and fifth instars. The midge *Rheotanytarsus sp*. was dominated by first, second, and third instars during the same time period. The newness of the blocks could have caused larvae to enter the drift soon after attachment, or low water during the study period induced drift followed by recolonization of small instars. In the LMR these blocks provide a stable, hard substrate that is inhabited by macroinvertebrates tolerant of moderate to high velocity water. These organisms on the ACM are important in the diet of fishes and other vertebrates of recreational and ecological value.

PREFACE

The Lower Mississippi River Environmental Program (LMREP) is being conducted by the Mississippi River Commission (MRC), US Army Corps of Engineers. It is a comprehensive program of environmental studies of the leveed floodplain of the Lower Mississippi River. The objectives of the LMREP are to develop an inventory of environmental resources for the study area and to develop environmental design considerations for channel training and levee features of the main stem Mississippi River and Tributaries Project.

One component of the LMREP considers the habitat value of articulated concrete mattress blocks (ACM) that protect the banks of the the Lower Mississippi River from erosion. This report presents results of a study undertaken to determine how slight modifications to the surface of these ACM blocks affect water velocity and aquatic biota. Data were collected at river miles 446.8 and 443.1 between 1 June 1989 and 30 November 1990.

These studies were conducted by personnel of the Aquatic Habitat Group, Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). This report was prepared by Drs. Carl M. Way, Andrew C. Miller, and Barry S. Payne, and by Mr. C. Rex Bingham under the direction of Dr. C. J. Kirby, Chief, Environmental Resources Division, and Dr. John Harrison, Director, EL. Dr. Albert Burky, University of Dayton, Dayton, OH, assisted Dr. Way in measuring water velocity over the three block types in the laboratory at WES.

This investigation was managed by the Planning Division of the MRC and was sponsored by the Engineering Division, US Army Engineer Division, Lower Mississippi Valley. Mr. Stephen P. Cobb, MRC, was the Program Manager for the LMREP. The investigation was conducted under the direction of the President of the Mississippi River Commission, BG Thomas A. Sands, EN.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet per second	0.02831685	cubic meters per second
feet	0.3048	meters
miles (US nautical)	1.852	kilometers
square miles	2.589988	square kilometers
tons (2,000 pounds, mass)	907.1847	kilograms

LOWER MISSISSIPPI RIVER ENVIRONMENTAL PROGRAM

Effects of Surface Texture of Articulated Concrete Mattress Blocks on Their Habitat Value

PART I: INTRODUCTION

Background

Mississippi River and Tributaries Project (MR&T)

Along the course of the Lower Mississippi River (LMR) and the associated floodplain, flooding has historically been a major deterrent to development. Destructive floods occurred in 1849, 1858, 1882, 1897, 1912, 1913, 1916, 1922, 1937, and 1973. The Mississippi River Commission (MRC) was established by Congress in 1879 to develop and implement flood control and navigation measures for the LMR that would be financed by the Federal Government.

The devastating flood of 1927 destroyed many existing levees, inundated large areas of farmland and numerous municipalities, and caused loss of human life and livestock in the Lower Mississippi Valley. This flood motivated the Congress to pass the Flood Control Act of 1928 that authorized the Mississippi River and Tributaries (MR&T) Project. The MR&T Project is a comprehensive plan for flood control and navigation works, concerned mainly with levee systems, channel improvements, and floodways. The MRC is responsible for carrying out the MR&T project.

Lower Mississippi River Environmental Program (LMRP)

The Lower Mississippi River Environmental Program (LMRP) is being conducted by the MRC. Objectives of the program are to collect baseline environmental data on the river and associated leveed floodplain, and formulate environmentally sound designs for channel training works such as dikes, revetments, and the main stem levee system. The LMRP was initiated in fiscal year 1981. Fish and wildlife populations and habitat are major concerns of the LMRP. The LMRP consists of five work units: (a) levee borrow pit investigations, (b) dike system investigations, (c) revetment investigations, (d) habitat inventories, and (e) development of a Computerized Resource Data System and a geographic information system containing environmental data. The study described in this report is part of the revetment investigations work unit.

Under the MR&T Project, the US Army Corps of Engineers authorized the construction of 968.16 miles* of revetment along the LMR. As of 1 January 1990, 937 miles of revetment had been placed. The remainder should be constructed before the channel improvement portion of the MR&T Project is completed in March, 2010. Approximately 2 percent of this revetment is repaired annually. When the currently authorized work is completed, about 50 percent of the LMR will have been revetted. Revetment construction constitutes a considerable change in riverine habitat, and the Corps has studied effects of this change (Pennington et al. 1983; Mathis et al. 1982; Bingham, Cobb, and Magoun 1980; Conner, Pennington, and Bosley 1983; Pennington, Baker, and Bond 1983; Pennington, Baker, and Potter 1983; Beckett, Bingham, and Sanders 1983; Baker et al. 1988). Aggus and Jenkins (1988) developed preliminary environmental design considerations for articulated concrete mattress (ACM) revetment.

Riverbank protection

Historically, riverbanks have been protected from the erosive forces of high-velocity water with willow mattresses, pilings, asphalt, automobile bodies, logs, and riprap. However, ACMs, which consist of a series of interconnected concrete blocks, are now being used almost exclusively on steep banks along the LMR. Because they are stable and used in areas with moderate to high water velocity, ACM blocks are colonized by periphyton, worms, crustaceans, immature insects, and gastropods. Many of the organisms that colonize block surfaces do not inhabit clay, shifting sand, and gravel, although they are found on tree limbs and snags in the river (Mathis, Bingham, and Sanders 1982). Attached macroinvertebrates retain and recycle organic materials that would otherwise be lost from the system. In addition, they are sources of food for fishes and birds with recreational, ecological, and economical value. The importance of stable, hard substratum in the LMR was noted by Wright (1982, and references therein), Cobb et al. (1984), Cobb and Magoun (1985), Aggus and Ploskey (1986), and Lowery et al. (1987).

In a study of revetted and natural banks in the LMR, Baker et al. (1988) reported that minor surface modifications to ACM blocks, shallow grooves

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

placed perpendicular to flow, increased macroinvertebrate density and species richness. Based on the findings of Baker et al. (1988), it was decided that additional studies on the effects of minor surface modifications to ACM blocks were warranted. Small-sized experimental ACM blocks were constructed to test the effects of minor surface modifications on colonization, density, and community composition of macroinvertebrates. Life history of dominant taxa that colonized ACM blocks would be compared with similar data collected from stone dikes in the LMR by Payne, Bingham, and Miller (1989). In addition, a thermistor velocity current meter was used in the laboratory to assess the effects of surface modifications on water velocity immediately above ACM blocks.

Purpose and Scope

The purpose of this study was to examine the biological and physical effects of surface modifications to ACM blocks that are used in the LMR to protect natural banks from the erosive action of high-velocity water.

PART II: STUDY AREA AND METHODS

Study Area

The untamed river

The Mississippi River drains the fourth largest basin in the world, 1,245,000 square miles, exceeded in size only by the Amazon, Congo, and Nile Rivers. The Mississippi River drains 41 percent of the contiguous 48 states and a portion of Canada. The LMR originates at the confluence of the Ohio and Middle Mississippi Rivers at Cairo, IL. It flows south to the Gulf of Mexico, a distance of approximately 975 river miles (RM). At Vicksburg, MS, (RM 437), approximately the midpoint of the LMR, the mean annual discharge is 552,000 cfs. The maximum flow recorded at the Vicksburg gage was 1,806,000 cfs during the flood of 1927. The difference in river stage between the average minimum discharge and average maximum discharge is about 27 ft on the Vicksburg gage, although river stage can fluctuate more than 45 ft during a year. Suspended sediment transported by the river averages 161 million tons per year (Keown, Dardeau, and Causey 1981).

Study sites

Thirty blocks, ten each of three surface types, were placed on the upper slope of the bank at Marshall Point, RM 446.8, Issaquena County, Mississippi, on 18 July 1989 (Figure 1). Surface water velocity was 1.1 m/s, the river stage at Vicksburg was 12.5 ft, and the water temperature was 24 °C. Fifteen blocks (five of each surface type) were retrieved on 20 October 1989 when the river stage was 12 ft and the water temperature was 22 °C. Forty grooved ACM blocks were placed at False Point Revetment (RM 443.1), Madison Parish, Louisiana, on 5 July 1990 (Figure 1). The river stage was 8 ft and the water temperature was 24 °C. Five blocks were retrieved at specific intervals to analyze benthic invertebrates. The dates of retrieval, and the number of days passing since blocks were placed are as follows: 5 July (7 days), 12 July (14 days), 4 August (29 days), 29 August (54 days), 3 October (89 days), 23 October (109 days), and 20 November (137 days). These two sites are 10 and 6 miles upriver of Vicksburg, MS, respectively.

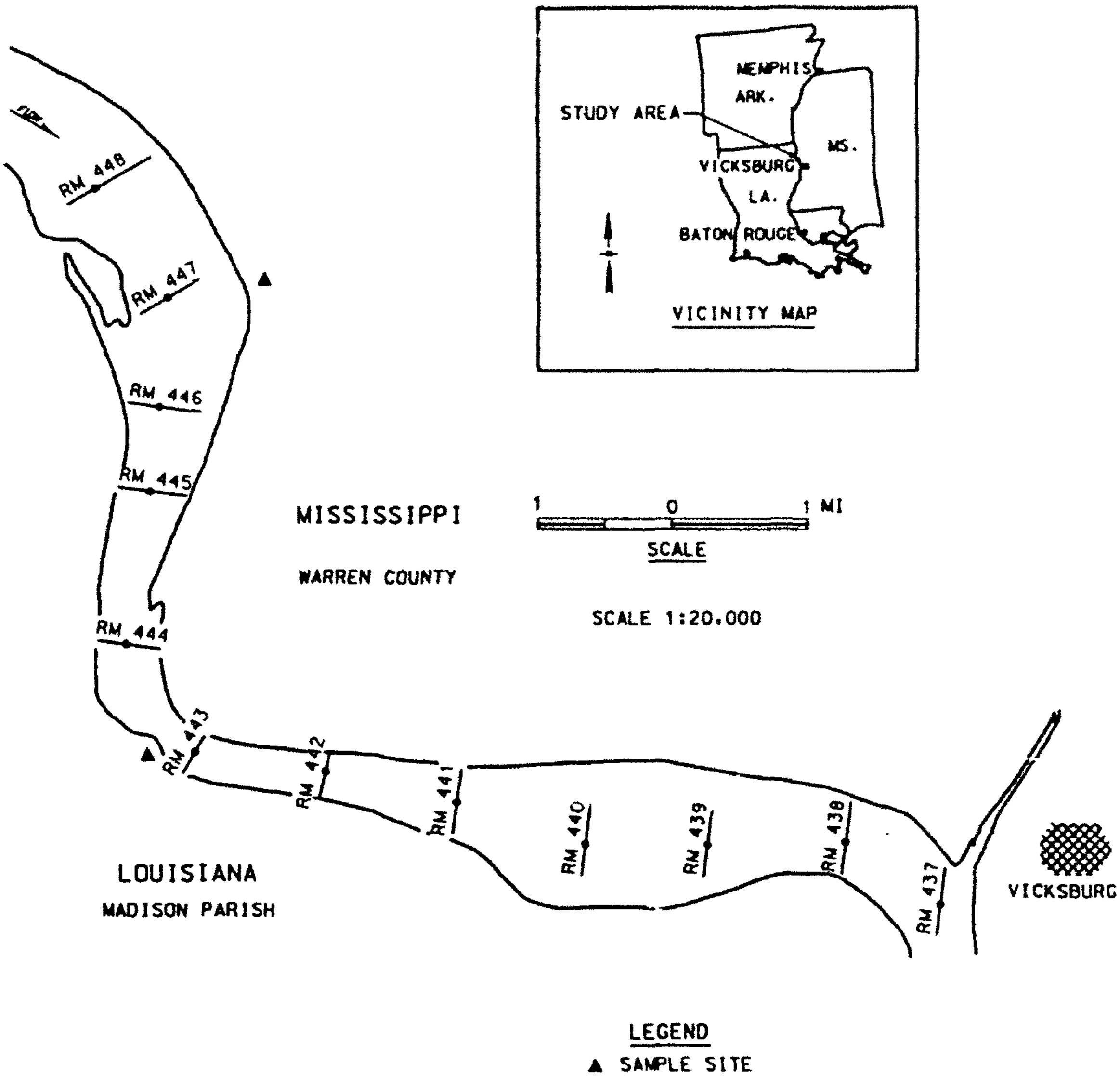

Figure 1. Study sites on the Lower Mississippi River

Methods

Construction of ACM blocks

Experimental ACM blocks were constructed using a cement mixture recommended by the US Army Engineer Division, Lower Mississippi Valley. The mixture was identical to that used for the full-sized blocks and consisted of 1.0 part water, 1.5 parts cement, 5.3 parts sand, and 8.1 parts crushed stone. Blocks were cast in 30.5- by 30.5- by 7.6-cm wooden molds. The shaft of an eye bolt was anchored in the center of one end of each block. The eye bolt was used to secure the block to a cable that was attached to a secure object on shore. Blocks with smooth, rough, and grooved surfaces were constructed (Figure 2). Smooth surfaces (Figure 2a.) were made by leveling the surface of the wet cement with a trowel. Rough surfaces (Figure 2b.) were made by brushing a coarse-bristled broom over the surface of the wet cement. This resulted in long, irregular, shallow grooves (< 2 mm deep) in the surface. Grooved blocks (Figure 2c.) were made by pressing a stainless steel mold containing evenly spaced projections on the surface of the wet cement Grooves were spaced every 1.9 cm, and were 1.3 cm deep and 1.3 cm wide. This groove depth was the maximum that could be used without compromising the strength of the block.

Field studies

Blocks were deployed using the following technique: on the shore, a coated, stainless steel cable was attached to the eye bolt on the block. Two individuals in a boat transported the block offshore to a depth of 2-4 m and carefully lowered it to the river bottom. A third person permanently secured the cable on shore. Grooved blocks were deployed from the boat using a steel box that had stabilizing fins on each side. This ensured that blocks were oriented with grooves perpendicular to the current. Blocks were retrieved at appropriate times with a boat-mounted winch. As soon as the block was on the boat, it was immediately placed in a large plastic tray. Organisms were removed from the surface by vigorous brushing and washing with distilled water. Organisms that were difficult to remove were collected with forceps or by hand. Brushed material was washed into a 250-μm sieve (US Geological Survey No. 60), placed in labeled bottles, and preserved with 10-percent buffered Formalin stained with Rose Bengal.

Laboratory analysis

Organisms from each sample were sorted under a dissecting microscope into major taxonomic groups (e.g., Chironomidae, Trichoptera, Ephemeroptera, etc.). Organisms in each group were then identified to the lowest possible taxonomic level (genus and species level except for nematodes, hydracarinids, hydrozoans, and collembolans). For samples that contained more than 200 individuals of a group, a random subsample of 150 individuals was chosen for taxonomic analysis. Chironomids were mounted CMCP-9 (Polysciences, Inc., Warrington, PA), stained with acid fuchsin, and allowed to clear for at least 24 hr before identification.

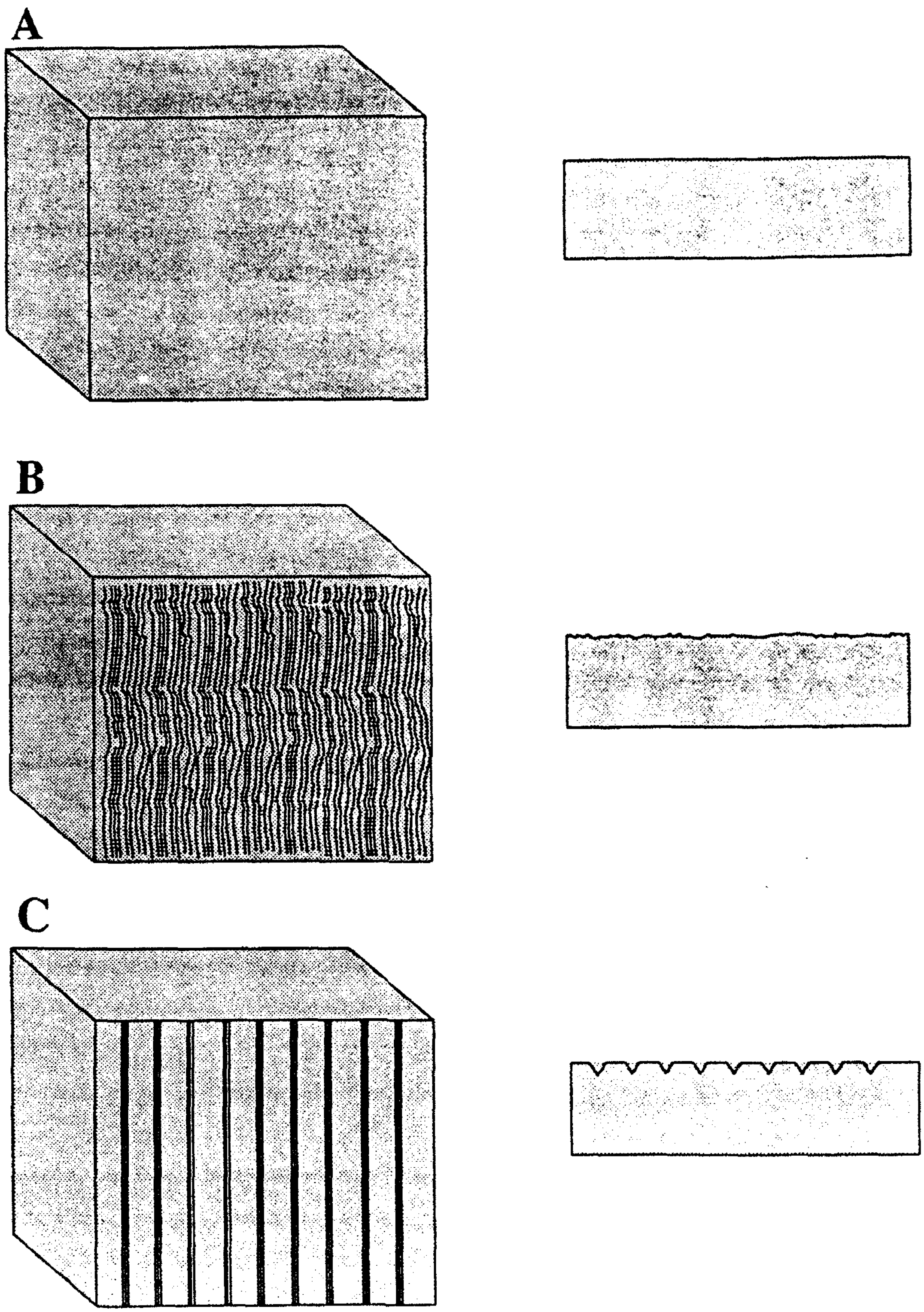

Figure 2. Representations of ACM blocks

Population structure (the number of organisms in each instar on a specific date) for two dominant macroinvertebrates (the caddisfly, *Hydropsyche orris* and the midge, *Rheotanytarsus* sp.) was determined for samples collected at False Point Revetment in 1990. A subsample of 100-150 *H. orris* and *Rheotanytarsus* sp. was obtained from one or more blocks. Interocular distance of each *H. orris* was measured to the nearest 1.0 μm using a dissecting microscope with an ocular micrometer. Labial plate width of each *Rheotanytarsus* sp. was measured to the nearest 0.25 μm using a compound microscope equipped with an ocular micrometer.

Analysis of size frequency distribution was used to determine cohort structure for each population on each sample date. The standing crop biomass on each date was determined by multiplying the total density of each species (individuals/m^2) by the percentage of individuals found in each instar. These values were multiplied by the mean individual dry mass (Payne, Bingham, and Miller 1989) to estimate standing crop biomass (mg/m^2) of each instar. Summing the standing crop biomass estimates for each instar on a given date yielded instantaneous population standing crop biomass.

Velocity studies

The effects of block surface type on current velocity was measured in a 12- by 0.5- by 0.5-m oblong, fiberglass racetrack flume (Frigid Units, Toledo, OH). A variable-speed electric trolling motor was used to generate velocities of 0.12, 0.23, and 0.44 m/s^{-1} in the flume. Water velocity at specific distances (from 1 to 65 mm) above each block was measured with a thermistor current meter. The meter was constructed by Instrumentation Services at the US Army Engineer Waterways Experiment Station and the probe was built by Dr. Albert Burky, University of Dayton.

The objective of this task was to document the effects of surface type on water velocity at specific distances above each block. During preliminary tests conducted in the flume it was noted that water running over the leading edge of a single block created a turbulent zone over most of its surface. This turbulence, which increased at higher velocity, masked effects of surface type on water velocity. To reduce turbulence caused by water running over the leading edge, three smooth blocks were placed end-to-end immediately upstream of the test block. The turbulent zone over the leading edge of the first smooth block dissipated by the time water reached the test block.

Rough and grooved blocks were placed in the flume so that grooves were perpendicular to flow. The velocity probe was held in position by a stainless steel micro-manipulator that permitted vertical and horizontal movements in 1-mm intervals. Vertical velocity profiles were measured at points centered 6, 12, and 18 cm from the leading edge of smooth and rough blocks. There were no significant differences between velocity profiles along a block surface or between replicate blocks (two-way ANOVA, $p > 0.05$) for each surface texture at all three velocities generated in the flume. Therefore, profiles measured at different distances from the leading edge were combined to provide a single profile for each surface type. Measurements for each profile were taken at distances 1, 2, 3, 4, 10, and 65 mm above the block surface. Velocity measurements taken 65 mm above the surface were considered to be ambient for the chamber since it was determined that they were unaffected by the block. Each velocity datum was based on an average of eight readings taken at 10-sec intervals. For a grooved block, profiles were measured at points centered on surfaces between grooves 2 and 3, 5 and 6, and 9 and 10. Velocity was also measured in and above grooves 3, 6, and 9, and at the midpoint and bottom of each groove.

PART III: RESULTS

Effects of Block Surface Type on Water Velocity

Velocities measured at all distances (1-65 mm) above the smooth block were not significantly different ($p > 0.05$) at flume-generated velocities of 0.12 or 0.23 m/sec (Figure 3). However, velocities measured along the vertical profile at the highest test velocity, 0.44 m/sec, were significantly different ($p < 0.05$). Water velocities measured 1 and 3 mm above the surface were significantly less than those measured 65 mm above the surface. There was a significant positive relationship between the magnitude of velocity created in the flume and the variance of velocity data (a measure of turbulence). Variances at 0.44 m/sec were three to six times greater than those measured at 0.12 m/s (Figure 3).

In contrast to data collected above the smooth block, there were significant differences in velocity data ($p < 0.05$) collected along the vertical profile above the rough block for flume-generated velocities of 0.12 and 0.23 m/sec as well as 0.44 m/sec (Figure 4). There was a positive relationship between flume-generated velocity and the variance of measured velocities. In addition, there was an inverse relationship between height above the block surface and the measured variances. Variances for individual velocity measurements were greater above the rough than the smooth surface.

Water velocities within grooves were significantly less ($p < 0.05$) than those measured immediately above the grooves for all flume-generated velocities (Figure 5). Variances in velocity were greatest 1.0 mm above the grooved block, and were slightly less than variances 1.0 mm above rough blocks.

Effects of Block Surface Type on Macroinvertebrates

Following 3 months of colonization at Marshall Point, the immature trichoptera (caddisflies) were the dominant macroinvertebrate group on the three surface types (Figure 6). Trichopterans comprised 60 to 80 percent of the fauna, whereas immature chironomidae (midges) and the amphipod *Corophium lacustre* made up 2 to 20 percent of the assemblage. These three groups represented more than 98 percent of the macroinvertebrate fauna on the blocks.

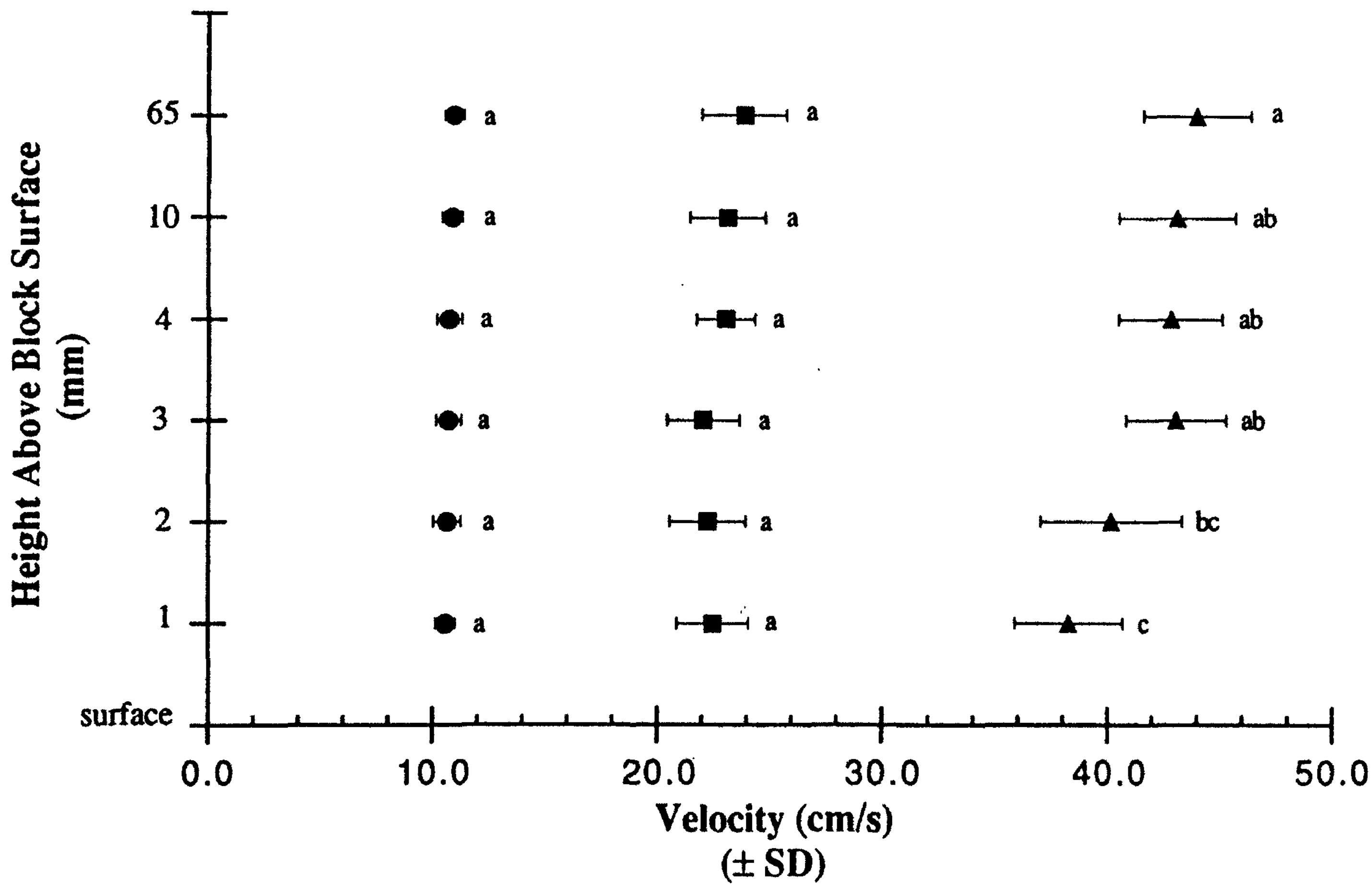

Figure 3. Water velocity data along a vertical profile above a smooth ACM block at three velocities generated in a circular flume (0.12, 0.23, and 0.44 m/sec). Data taken at a given velocity with the same letter are not significantly different ($p > 0.05$)

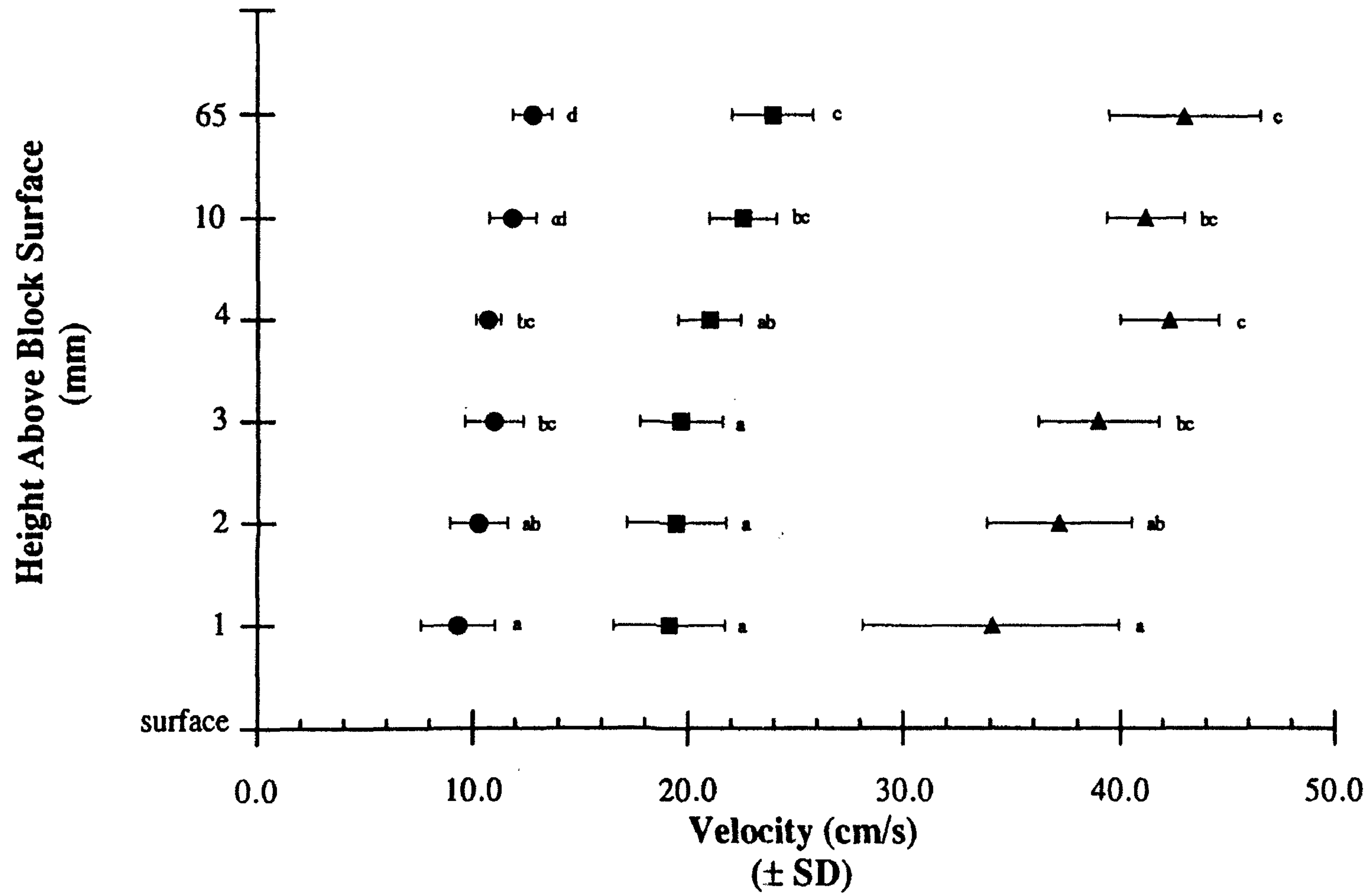

Figure 4. Water velocity data along a vertical profile above a rough ACM block at three velocities generated in a circular flume (0.12, 0.23, and 0.44 m/sec). Data taken at a given velocity with the same letter are not significantly different ($p > 0.05$)

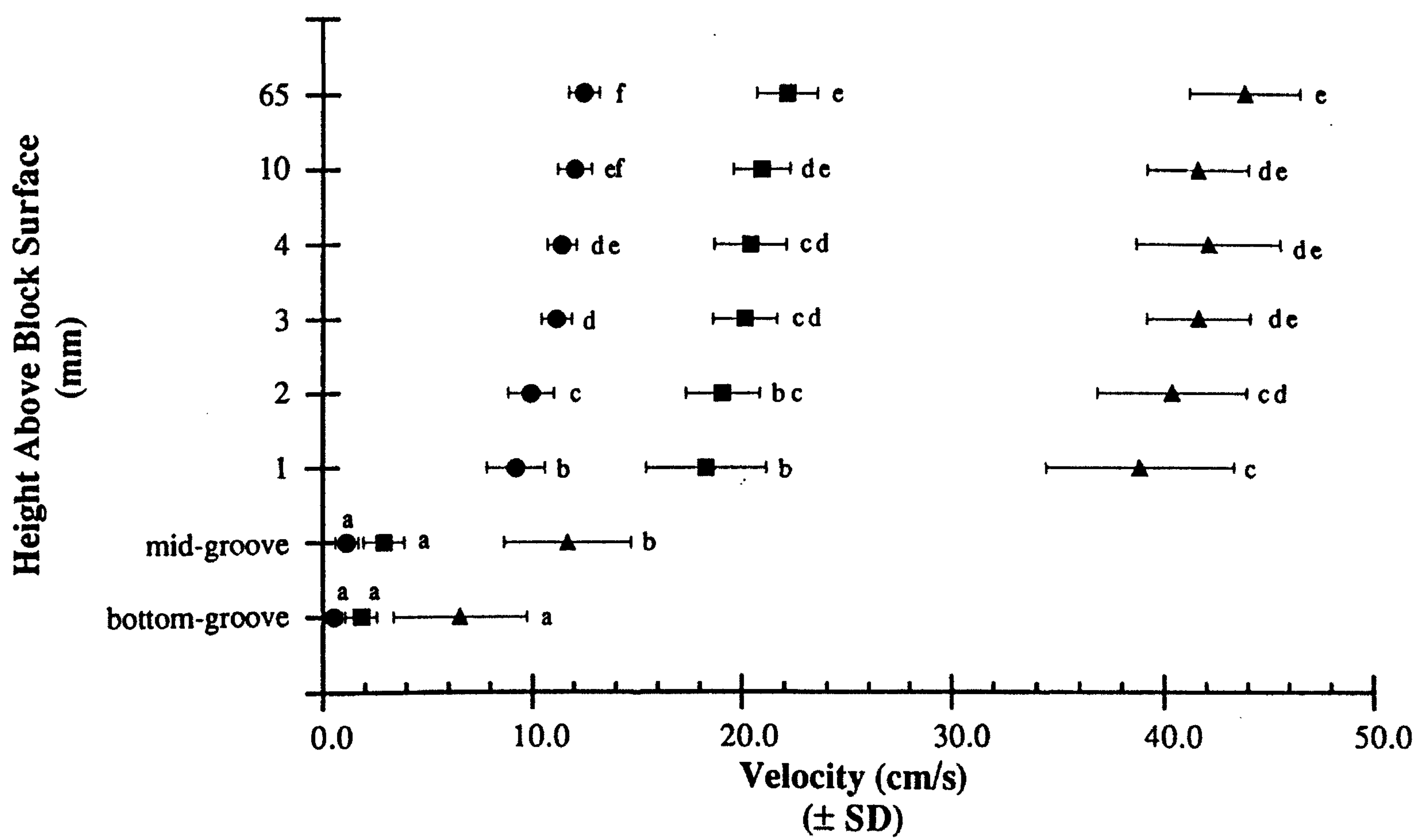

Figure 5. Water velocity data along a vertical profile above a grooved ACM block at three velocities generated in a circular flume (0.12, 0.23, and 0.44 m/sec). Data were also taken at the bottom and midpoint of a single groove. Data taken at a given velocity with the same letter are not significantly different ($p > 0.05$)

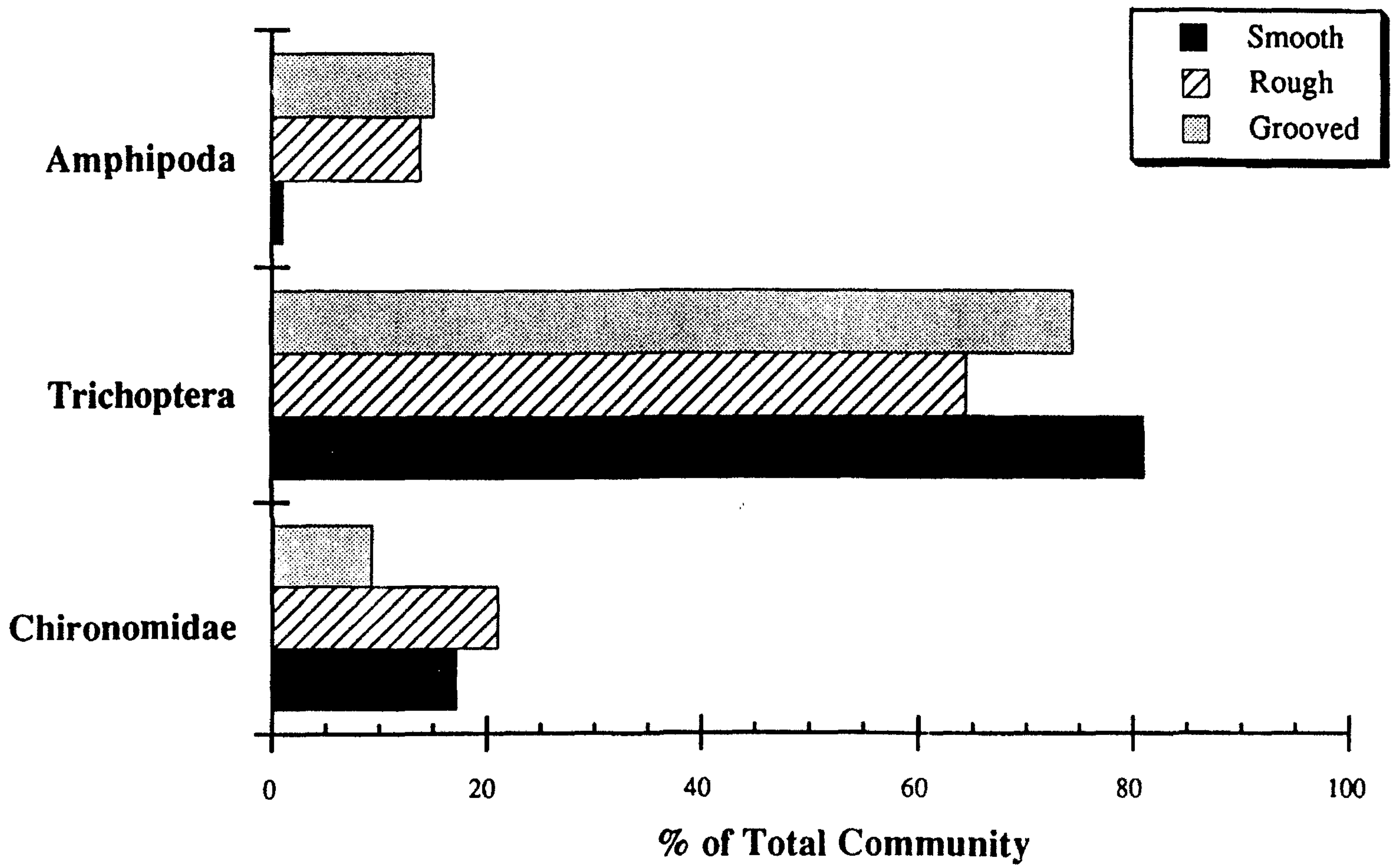

Figure 6. Percentage abundance of three dominant microinvertebrate groups on three types of blocks deployed at Marshall Point on the LMR, 1989

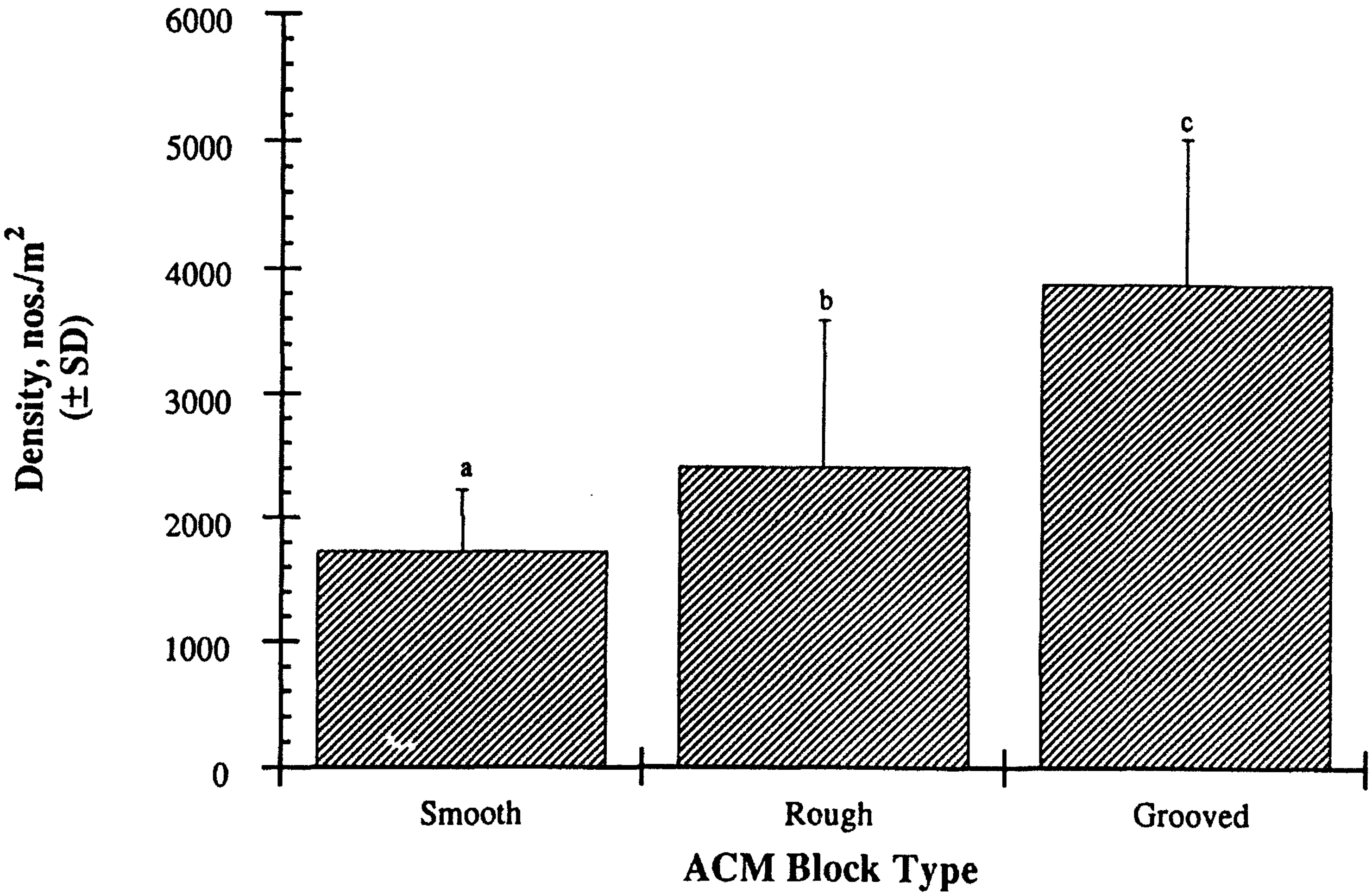

Figure 7. Total density (and standard error bars) for macroinvertebrates collected on three ACM block types deployed at Marshall Point on the LMR, 1989

There were significant differences in total macroinvertebrate density among three ACM block types (Figure 7). Total density on the rough blocks was 1.4 times greater than on smooth blocks ($p < 0.05$). Total density on grooved blocks was 2.3 ($p < 0.01$) and 1.6 ($p < 0.01$) times greater than on smooth and rough blocks, respectively. Total densities were 3,882, 2,411, and 1,725 individuals/m^2 on the grooved, rough, and smooth blocks, respectively.

Density of trichopterans on grooved blocks (2,888 individuals/m^2) was significantly greater ($p < 0.05$) than on rough or smooth blocks (Figure 8). There were no significant differences in trichopteran density differences ($p > 0.05$) between rough and smooth blocks (1,555 and 1,398 individuals/m^2, respectively). Most trichopteran cases and feeding nets were found in the grooves (and not the smooth area between grooves, Figure 2) of the blocks. Chironomidae density differences were not significant ($p > 0.05$) among the three block types (361, 505, and 297 individuals/m^2 on grooved, rough and smooth blocks, respectively). On grooved blocks, density of the amphipod *C. lacustre* (583 individuals/m^2) was 30 ($p < 0.001$) and 1.8 times ($p < 0.05$) higher than on smooth and rough blocks, respectively. Total amphipod density on rough blocks (332 individuals/m^2) was 17 times higher ($p < 0.001$) than on smooth blocks (20 individuals/m^2).

Colonization Rates on Grooved Blocks

The macroinvertebrate assemblage on the grooved ACM blocks retrieved from False Point Revetment in 1990 consisted of trichoptera, chironomidae, ephemeroptera, odonata, collembola, amphipoda, isopoda, hydracarinia, gastropoda, bivalvia, naididae, hydrozoa, nematoda, and nemertina. Thirty-seven taxa were identified, although seven taxa represented more than 95 percent of the total macroinvertebrate fauna on a given date (Table 1). The dominant species on the grooved blocks were the trichopteran, *Hydropsyche orris*, the chironomids, *Nanocladius crassicornus*, *Polypedilum convictum*, and *Rheotanytarsus* sp., the ephemeropteran, *Stenonema integrum*, the amphipod, *C. lacustre*, and the triclad, *Dugesia tigrina*. *Rheotanytarsus* sp. and *H. orris* were the two most abundant organisms, comprising more than 85 percent of the fauna.

On 12 July 1990, after 7 days in the river, 18 macroinvertebrate taxa were identified on grooved blocks. Average density was 15,925.1 individuals/m^2 (Figure 9). Total density was significantly less ($p < 0.05$) between

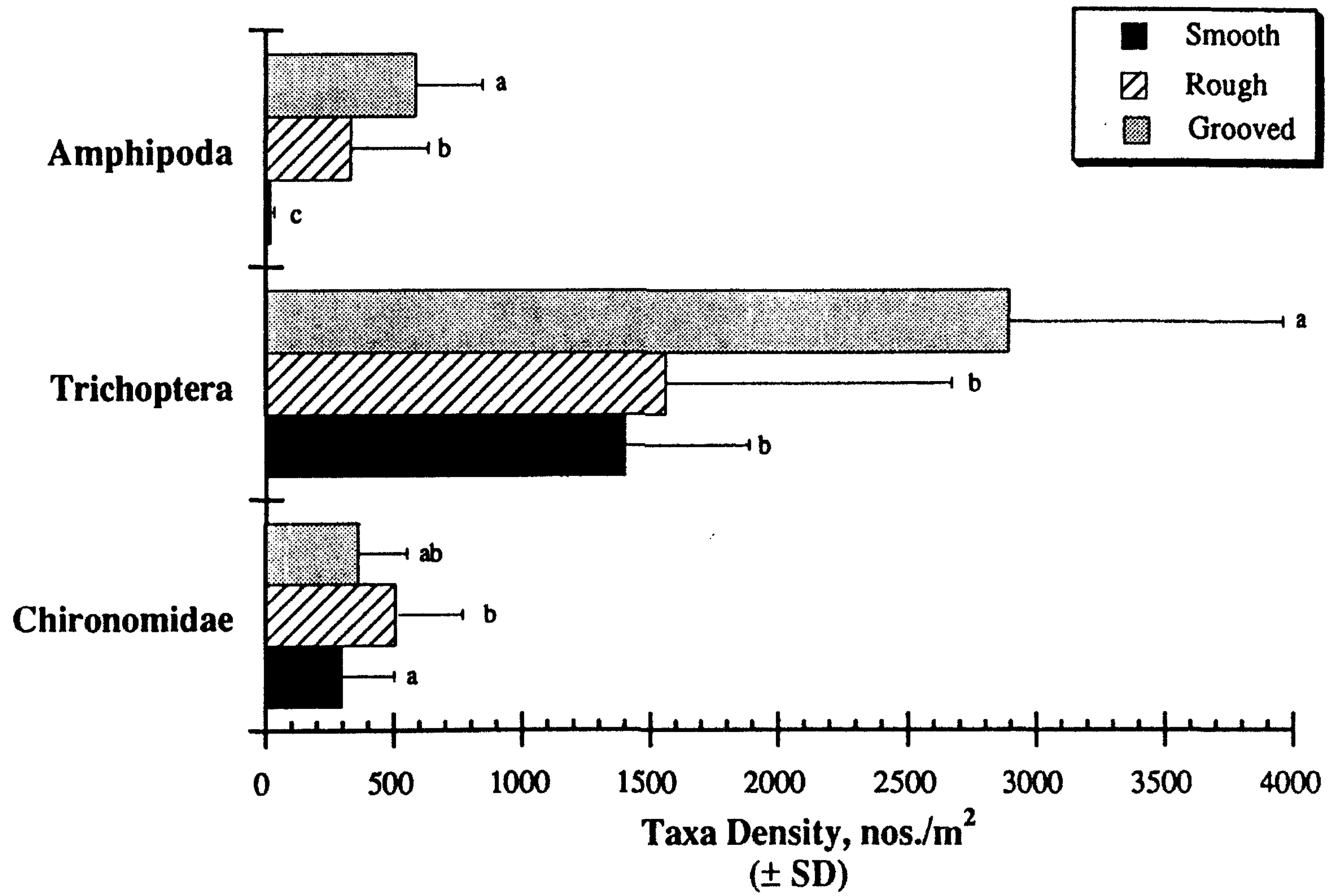

Figure 8. Density of three dominant macroinvertebrate groups on three types of blocks deployed at Marshall Point on the LMR, 1989. Data with the same letter are not significantly different ($p > 0.05$)

Table 1

Macroinvertebrate Taxa on Grooved ACM Block Replicas at the False Point Revetment, Mississippi River, 1990

Dominant Taxa (Representing > 95% of the Total Community)

Taxonomic Group	Species
Arthropoda	
Insecta	
Diptera	*Polypedilum convictum*
	Rheotanytarsus sp.
Ephemeroptera	*Stenonema integrum*
Trichoptera	*Hydropsyche orris*
Crustacea	
Amphipoda	*Corophium lacustre*
Platyhelmenthes	
Tricladida	*Dugesia tigrina*

Other Taxa (Representing < 5% of the Total Community)

Taxonomic Group	Species
Arthropoda	
Insecta	
Trichoptera	*Ceraclea* sp.
	Cyrnellus fraternus
	Neotrichia sp.
	Neureclipsis sp.
	Pentagenia vittagera
	Potomyia flava
Diptera	*Coelotanypus* sp.
	Dicrotendipes sp.
	Nanocladius crassicornus
	Natarsia sp.
	Parachironomus abortives
	Polypedilum illinoense
	Thiemaniella sp.
Ephemeroptera	*Baetis* sp.
	Caenis sp.
	Heptagenia sp.
	Isonychia sp.
	Stenocron sp.
Odonata	*Neurocordulia molesta*

(Continued)

Table 1 (Concluded)

Taxonomic Group	Species
Collembola	Unknown sp.
Cruscacea	
Amphipoda	*Gammarus* sp.
Isopoda	*Lirceus* sp.
Arachnoidea	*Hydracarina* sp.
Mollusca	
Gastropoda	
Prosobranchia	*Valvata* sp.
	Pleurocera sp.
Bivalvia	*Corbicula fluminea*
Annelida	
Oligochaeta	
Naididae	Unknown sp.
Cnidaria	
Hydrida	*Cordylophora lacustris*
Nematoda	*Prostoma rubrum*
Nemertea	Unknown sp.

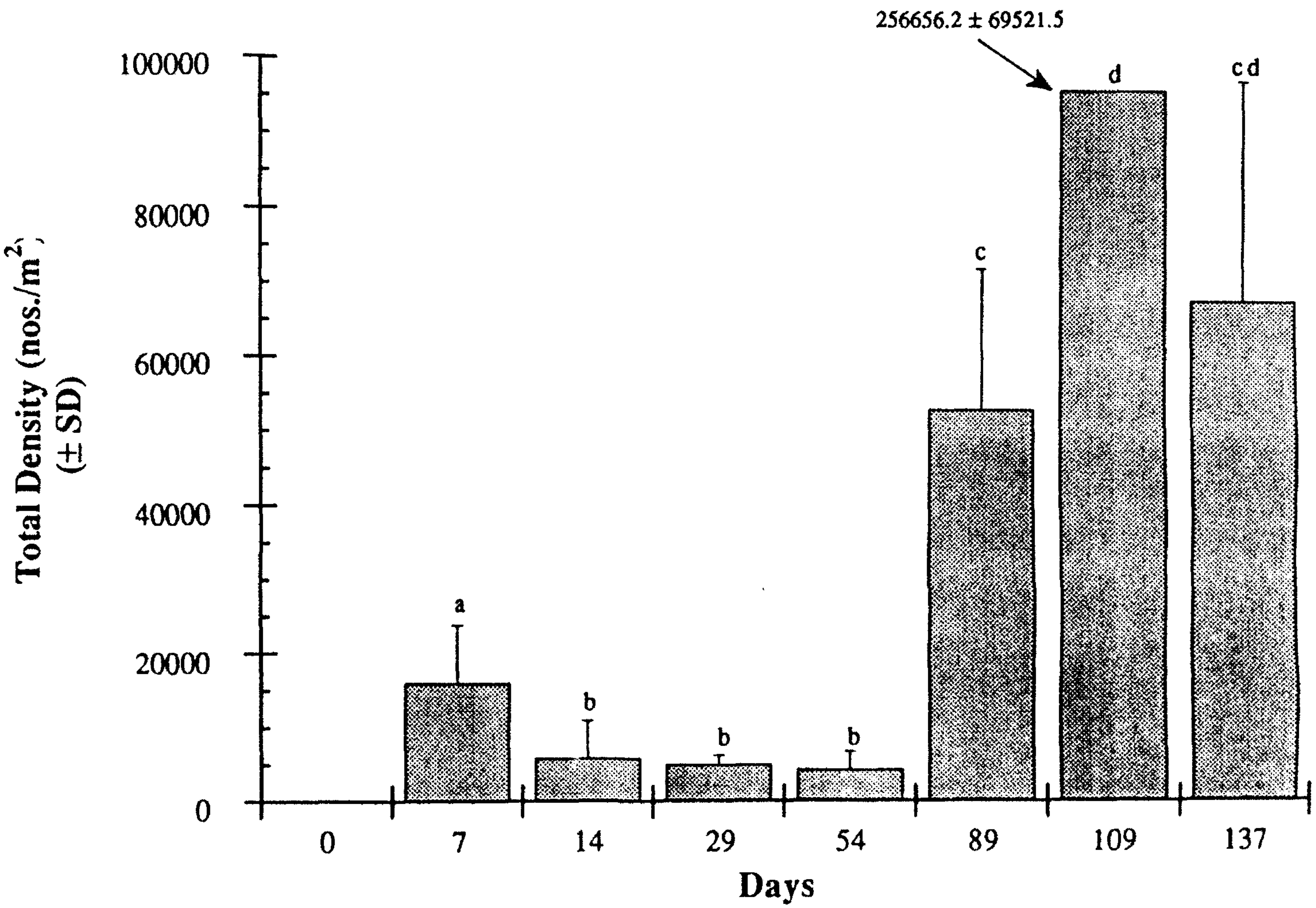

Figure 9. Total density of macroinvertebrates on grooved ACM blocks placed in the LMR at False Point Revetment, 1990. Densities with the same letter are not significantly different ($p > 0.05$)

12 and 19 July (Day 7 to Day 14), then did not change significantly between 19 July and 3 or 29 August (Days 29 and 54). Density increased significantly from 29 August to 3 October (Day 89) and from this latter date to 23 October (Day 109), when total densities reached a maximum of 256,656.2 individuals/m^2. Densities on 23 November (Day 137) were not significantly less ($p > 0.05$) than those on 23 or 3 October. The density increase after 29 August and the peak at 23 October were caused by successful recruitment of the chironomid, *Rheotanytarsus* sp.

Chironomidae and trichoptera comprised more than 98 percent of the total macroinvertebrate fauna after the blocks were in the river for 7 days; densities of these two groups equaled 6,972.5 and 8,671.0 individuals/m^2, respectively, on 12 July 1990 (Figure 10). Density of chironomidae did not significantly change until 3 October, after 89 days had passed. The peak on 23 October was significantly greater than on 3 October or 20 November. Trichopterans were uncommon throughout the summer until 23 October. Ephemeroptera were uncommon on the blocks; representatives of this group were found only on 29 August, 3 October, and 23 October. The highest density (1,675.1 individuals/m^2) was found on 23 October 1990, after the blocks had been in the water for 109 days.

After 7 days of colonization, density of the trichopteran *H. orris* was 7,531.5 individuals/m^2 on grooved blocks. Density then remained significantly less for the next four sampling periods, until 23 October, 109 days after the blocks were placed in the river (Figure 11). Density of the midge *Rheotanytarsus* sp. was 5,826.5 individuals/m^2 on 12 July 1990, 7 days after the blocks were deployed (Figure 11). Densities remained virtually unchanged for the next three sampling dates. On 3 October, 23 October, and 20 November *Rheotanytarsus* sp. dominated, with densities greater than 40,000 individuals/m^2.

Hydropsyche orris on the grooved blocks was dominated by first and second instars during the first four sampling dates (Figure 12). Between 3 October and 23 October, emergence occurred. On 3 October the population was dominated by first and second instars, although all five instars were present on the previous sampling date. Samples collected on 20 November indicated that *H. orris* probably overwintered as second and third instars. During the first four sampling periods *Rheotanytarsus* sp. showed no clear cohort dominance (Figure 12). The sample collected on 3 October was dominated by fourth instars, which had emerged when the 23 October sample was collected. Samples taken on this latter date were dominated by second instar larvae, although

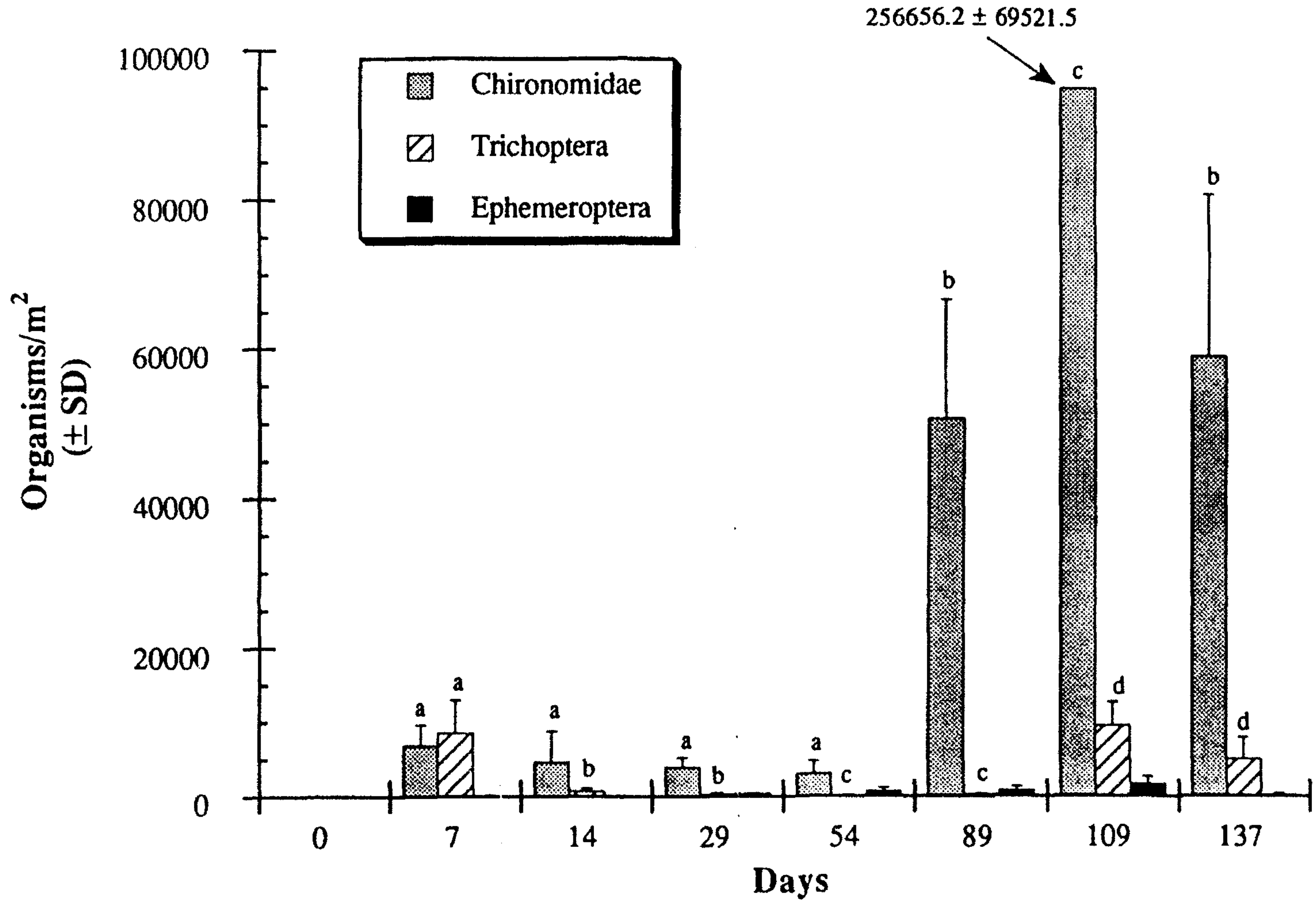

Figure 10. Total density of three dominant macroinvertebrate groups on grooved ACM blocks placed in the LMR at False Point Revetment, 1990. Densities of chironomids and trichopterans with the same letter are not significantly different ($p > 0.05$)

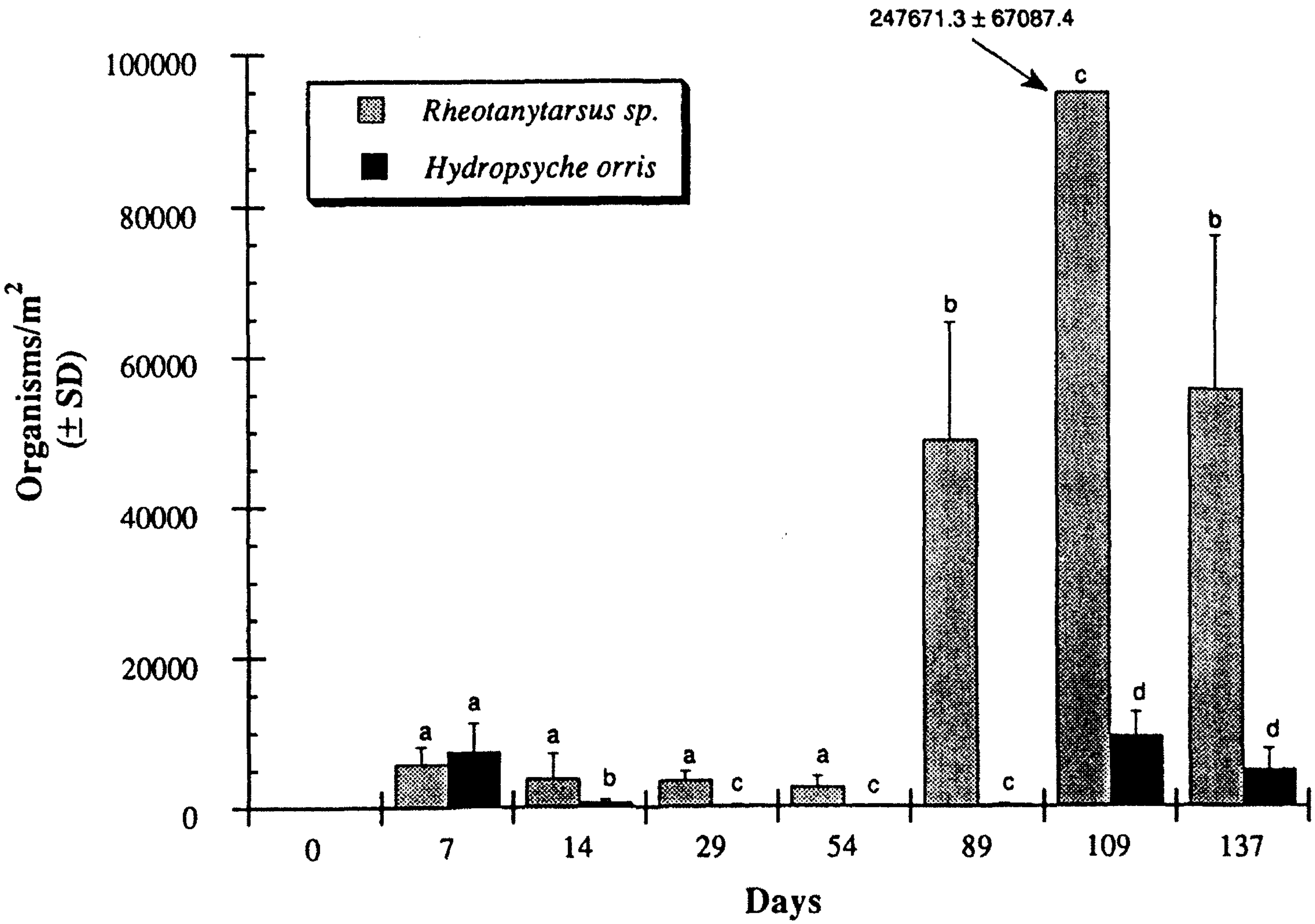

Figure 11. The density of *Hydropsyche orris* and *Rheotanytarsus* sp. on grooved ACM blocks placed in the LMR at False Point Revetment, 1990. Densities with the same letters are not significantly different ($p > 0.05$)

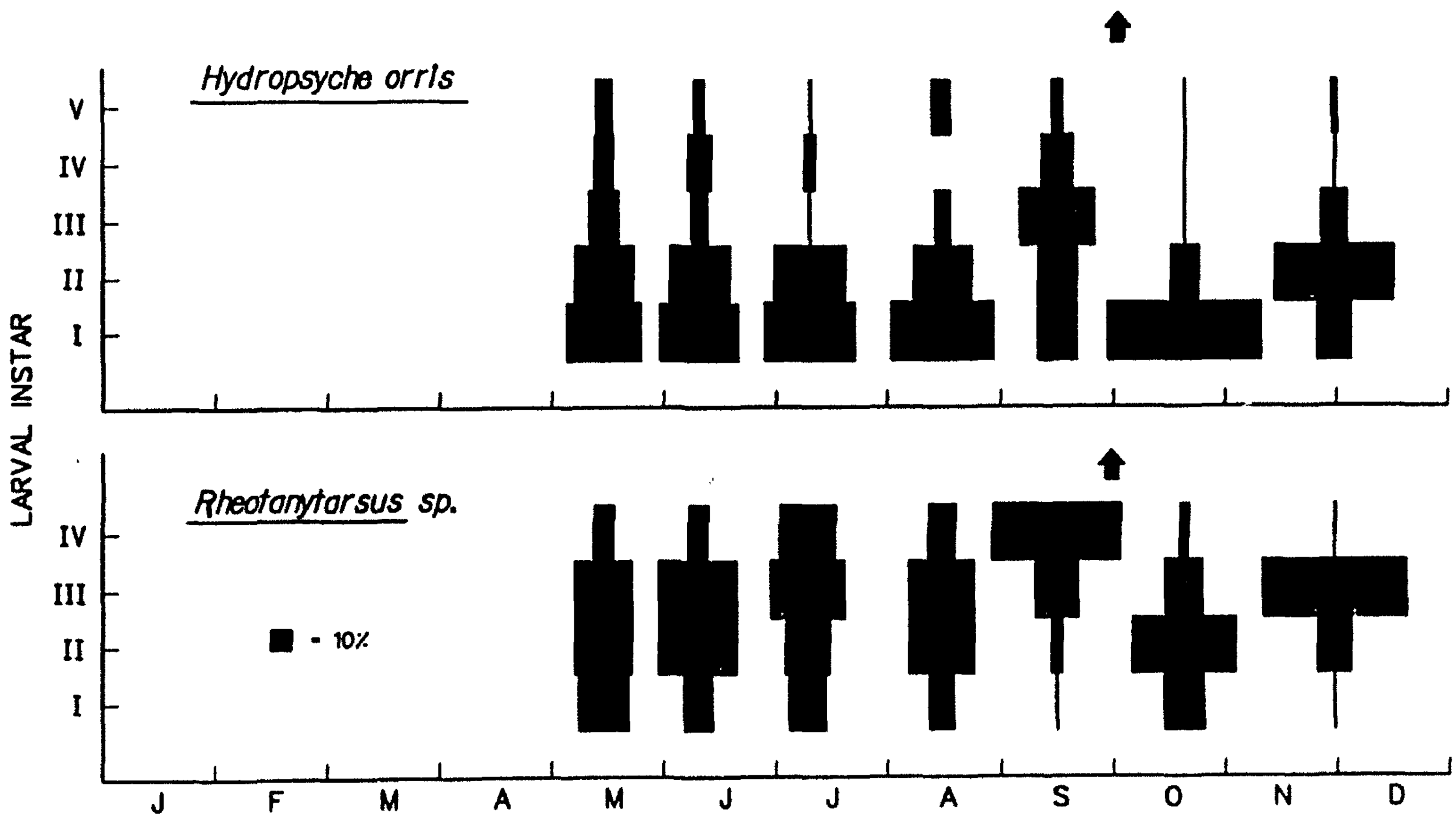

Figure 12. Length-frequency histograms for *Hydropsyche orris* and *Rheotanytarsus* sp. on grooved blocks placed in the LMR at False Point Revetment, 1990

first and third instars were also present. Based on data collected on 20 November 1990, *Rheotanytarsus* sp. overwintered principally as second and third instars.

Percentage of each cohort present, cohort density, and standing crop biomass (SCB) for *Rheotanytarsus* sp. and *H. orris* appear in Tables 2 and 3, respectively. The instantaneous population SCBs, calculated by summing individual biomass for each date, appear on Tables 2 and 3 and Figure 13 for both taxa. The SCB for *Rheotanytarsus* sp. was low (< 31 mg/m^2) through 29 August. On 3 October the SCB increased more than 30 times to 791.5 mg/m^2. Standing crop biomass for *H. orris* was 2,386.1 mg/m^2 on 12 July; then remained low for most of the year (Figure 13). The comparatively high value (1,405.0 mg/m^2 on 20 November) corresponded to high density values for this species (Figure 11).

Table 2

Estimated Densities and Instantaneous Standing Crop Biomass (SCB) for the Cohorts of *Rheotanytarsus* sp. at the False Point Revetment, Mississippi River, 1990

Date	Cohort Percent I	II	III	IV	Density (Individuals/sq m) I	II	III	IV
11 Jul	28	30	29	13	1,631.4	1,748.0	1,689.7	757.4
18 Jul	14	37	38	11	538.2	1,422.4	1,460.8	422.9
02 Aug	9	24	38	29	324.3	864.8	1,369.3	1,045.0
28 Aug	12	36	36	16	319.2	957.5	957.5	425.5
2 Oct	2	4	23	71	978.4	1,956.8	11,251.9	34,734.0
22 Oct	22	52	20	6	54,487.7	128,789.1	49,534.3	14,860.3
19 Nov	1	18	79	2	556.0	10,008.8	43,927.6	1,112.1

Date	Standing Crop Biomass (ug) I	II	III	IV	Total SCB (mg)
11 Jul	832.0	2,744.3	8,786.4	15,906.3	28.3
18 Jul	274.5	2,233.1	7,596.1	8,880.1	19.0
02 Aug	165.4	1,357.8	7,120.3	21,944.7	30.6
28 Aug	162.8	1,503.2	4,978.8	8,936.3	15.6
2 Oct	499.0	3,072.2	58,509.6	729,413.6	791.5
22 Oct	27,788.7	202,198.8	257,578.2	312,065.8	799.6
19 Nov	283.6	15,713.8	228,423.3	23,353.9	267.8

Table 3

Estimated Densities and Instantaneous Standing Crop Biomass (SCB) for the Cohorts of *Hydropsyche orris* at False Point Revetment, Mississippi River, 1990

	Cohort Percent					Density (Individuals/sq m)				
Date	I	II	III	IV	V	I	II	III	IV	V
11 Jul	38	30	14	10	8	2,862.0	2,259.5	1,054.4	753.2	602.5
18 Jul	42	34	6	12	6	277.2	224.4	39.6	79.2	39.6
02 Aug	48	40	2	6	4	122.8	102.4	5.1	15.4	10.2
28 Aug	56	32	8	0	4	24.1	13.8	3.4	0.0	1.7
2 Oct	19	20	39	15	7	55.6	58.5	114.0	43.9	20.5
22 Oct	81	16	1	1	1	7,647.0	1,510.5	94.4	94.4	94.4
19 Nov	18	63	14	2	3	891.6	3,120.5	693.4	99.1	148.6

	Standing Crop Biomass (mg)					
Date	I	II	III	IV	V	Total (mg)
11 Jul	25.8	92.6	1,845.2	422.5	864.0	2,386.1
18 Jul	2.5	9.2	69.3	44.4	56.8	125.4
02 Aug	1.1	4.2	9.0	8.6	14.7	22.9
28 Aug	0.2	0.6	6.0	0.0	2.5	6.8
2 Oct	0.5	2.4	199.6	24.6	29.4	227.1
22 Oct	68.8	61.9	165.2	53.0	135.4	348.9
19 Nov	8.0	127.9	1,213.5	55.6	213.1	405.0

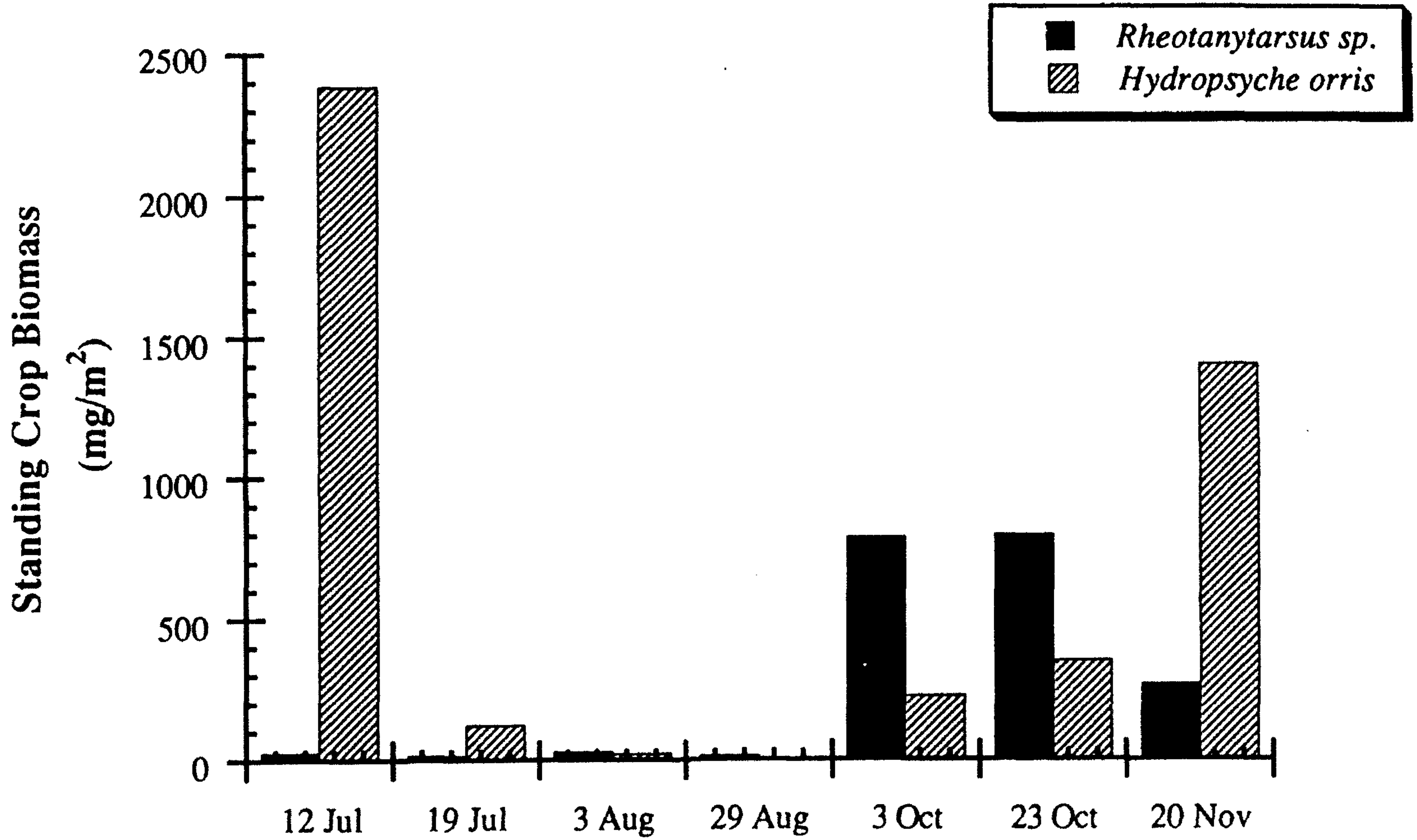

Figure 13. Standing crop biomass estimates for *Hydropsyche orris* and *Rheotanytarsus* sp. on grooved blocks placed in the LMR at False Point Revetment, 1990

PART IV: DISCUSSION

Velocity Studies

Altering surface texture of the ACM blocks had a measurable effect on water velocity and variance immediately above the concrete surface. Variance of velocity readings, measure of turbulence, increased by creating higher water velocity in the flume. In addition, the variance in velocity readings was affected by block surface. Variance close to the surface of the smooth blocks was comparatively low at all flume-generated velocities. Variance closest to the substrate-water interface was slightly higher for rough-textured blocks than for grooved blocks; both exhibited higher variances at all flume-generated velocities than the smooth blocks. Water velocity within the grooves was significantly less than above the surface of the block. These velocity data illustrate the importance of altering surface texture of the blocks for benthic organisms. The majority of the *H. orris* cases were in the grooves with the anterior opening containing the feeding nets extending up into the moving water near the substrate-water interface.

Macroinvertebrate Density

Total macroinvertebrate density was significantly higher in the grooved than on the rough blocks, and these blocks supported a significantly greater total macroinvertebrate density than did smooth blocks. Density of the caddisfly *H. orris* was two times greater on grooved blocks than either of the other block types. Periodic high-velocity water in the LMR probably reduced successful attachment of caddisflies to the rough or smooth blocks. The grooves created a velocity shelter that was shallow enough to allow feeding structures to come in contact with flowing water near the substrate water interface. The increased water turbulence immediately above the substrate-water interface circulated and distributed food particles slightly better than unidirectional currents.

McShaffrey and McCafferty (1987) reported that the water penny beetle, *Psephenus herricki*, a common macroinvertebrate in eastern North American streams, usually inhabited velocity refuges on the undersides of rocks and crevices between rocks. Clifford, Gotceitas, and Casey (1989) reported significantly higher density of two trichopterans, *Ceraclea* sp. and *Rhyacophila* sp., and chironomids on rough tiles when compared to similar-sized smooth tiles placed in first- and second-order streams in Alberta, Canada. Wetmore, Mackay, and Newbury (1990) reported that the caddisfly, *Brachycentrus occidentalis*, and the blackfly, *Simulium vittatum*, were found in transitional velocity zones (areas of increased turbulence and decreased flows) in a stream in Manitoba, Canada.

The presence of revetments, stone dikes, and ACMs provides a noteworthy amount of the available hard substrate in the LMR. These man-made structures have been shown to be important sites for macroinvertebrates, which, in turn, are sources of food for fishes (Cobb and Magoun 1985; Baker et al. 1988; Mathis, Bingham, and Sanders 1982; Payne, Bingham, and Miller 1989). Johnson et al. (1974) reported a diverse and abundant stone-dwelling macroinvertebrate assemblage associated with dikes on the middle Mississippi River. They concluded that dikes were important sources of macroinvertebrate drift. Buckley et al. (1976) reported that dikes in Iowa provided valuable heterogeneous substrate for caddisflies and mayflies. Mathis, Bingham, and Sanders (1982) found a diverse macroinvertebrate community dominated by mayflies (eight species), caddisflies (six species), and chironomids. The mean density of organisms was 9,687 organisms/sample with the caddisfly, *H. orris* comprising 60-percent of the fauna. Mathis et al. (1982) reported that average total densities on the surface of the rocks was 5,092 organisms/sample, whereas densities on the undersides of the rocks was 13,983 organisms/sample (a 275-percent increase). This was probably the result of reduced water velocity below the stones (Mathis, Bingham, and Sanders 1982; Wright 1982; Payne, Bingham, and Miller 1989).

Mackay and Waters (1986) reported that the average densities of *H. orris* in a riffle ranged from 101 to 2,509 organisms/m^2 above and 482 to 87,584 organisms/m^2 below an impoundment on a stream in Minnesota. Benke et al. (1984) reported densities of 4,017 and 8,149 organisms/m^2 for the caddisflies, *H. elissoma* and *H. incommoda*, and 2,132 to 2,308 organisms/m^{-2} for tanytarsini midges on snags in the Saltilla River, Georgia. Payne, Bingham, and Miller (1989) reported on a 2-year study of the macroinvertebrate community found on rocks from two dikes in the LMR. They found that four species made up 95 percent of the total macroinvertebrate assemblage (*H. orris*, *Rheotanytarsus* sp., *C. lacustre*, *D. tigrina*) on any sampling period. *Hydropsyche orris* comprised 95 percent of the trichopterans and *Rheotanytarsus* sp. comprised 72 percent of the chironomids. Payne, Bingham, and Miller (1989) found that macroinvertebrate assemblages were highest in summer and early fall and lowest in late fall and spring. Total densities ranged from a low of 4,892 organisms/m^2 in September, 1987 to a high of 51,103 organisms/m^2 in September, 1988.

Total densities estimated from smooth, rough, and grooved blocks placed at Marshall Point in 1989 were 1,725, 2,411, and 3,882 individuals/m^2. These values are similar to those reported in the literature for riffles and snags in small streams, but lower than those reported for dikes in the Mississippi River (Payne, Bingham, and Miller 1989). Densities on grooved ACM blocks placed at False Point Revetment in 1990, however, ranged from a low of 4,169 organisms/m^2 in August to a high of 256,656 organisms/m^2 in October. These values are within the range of densities reported by Payne, Bingham, and Miller (1989) for dikes in the LMR.

Analysis of Size Demography of Dominant Taxa

Due to the repetitive nature of sampling in this study, size demography of *H. orris* and *Rheotanytarsus* sp. populations on blocks from May through November could be characterized. Payne, Bingham, and Miller (1989) studied the life history of the same two species on stone dikes in the LMR. Their data contrast with the results of the present study with respect to expected demographic patterns in late spring and summer. Although apparent for both species, these differences are more pronounced for *H. orris* than for *Rheotanytarsus* sp.

A bivoltine life cycle for *H. orris* was clearly evident in the dike study (Figure 6 in Payne, Bingham, and Miller 1989), with dominance by individuals of the first instar only during May and September after emergence of adults in April and August. Furthermore, growth of the spring generation was clearly portrayed as the population progressed from dominance by first instars in May, through dominance by second and third instars in June, to dominance by fourth and fifth instars in July prior to August emergence. In contrast, *H. orris* samples from the present study were dominated by first instar larvae from May through August, and the population was never dominated by fourth and fifth instars (Figure 12). From mid-October through late November, the size demography of *H. orris* more closely followed the pattern that was expected based on the life history observed by Payne, Bingham, and Miller (1989). In the present study, samples were dominated by first instars in mid-October, whereas samples taken in late November were dominated by second instars and had few first instars. In both studies, fall data characterized the late summer recruits as a pre-wintering population comprised principally of instars in the intermediate stages (second instars in this study, and second to fourth instars in the 2 years reported by Payne, Bingham, and Miller 1989).

A trivoltine life history for *Rheotanytarsus* sp. in the LMR was indicated in data reported by Payne, Bingham, and Miller (Figure 7 in their 1989 report). Both May and June samples of that life history study showed dominance by fourth instars (the final larval stage of *Rheotanytarsus* sp.). Highly synchronous emergence and recruitment were clearly indicated in late June and early July, as the population made an abrupt transition from dominance by fourth to dominance by first and second instars. Larval growth was rapid, and by mid-August the summer generation was dominated by fourth instars. As for the spring generation from May to June, the summer generation remained dominated by the fourth instar from August to September. Then, highly synchronous emergence and recruitment in late September and early October were indicated by the abrupt transition from dominance by fourth to dominance by second and third instars. Demographic patterns were markedly different from May through August of the present study (Figure 12). In stark contrast to expected dominance of fourth instars during May and June, samples in the present study were dominated by first, second, and third instars. Replacement of the spring generation by a summer generation was clearly evident in the life history reported by Payne, Bingham, and Miller (1989). In the present study, shift from moderate dominance by third and fourth instars in early July to dominance of second and third instars in mid-August provided equivocal evidence of replacement of a spring generation by a summer generation. From mid-September through late November, the present study was in strict accord with the life history reported by Payne, Bingham, and Miller (1989). Both studies clearly indicated highly synchronous emergence of the summer generation in late September, as the population abruptly shifted from heavy dominance by fourth instars in late September to dominance by second instars in October. Furthermore, pre-winter dominance by third instars was evident in both studies.

Late spring and summer deviation from expected size demography of both species involved sustained over-abundance of small instars and under-representation of large instars. There are two likely explanations for the differences noted on the ACM blocks in spring and summer. The newness of the blocks could have caused larvae to enter the drift rather than complete their growth on the blocks that were not yet aged. Size demography of fall samples generally reflected patterns expected from the reported life histories (Payne, Bingham, and Miller 1989). It is possible that similarity of fall demography to expected patterns reflected that adequate conditioning of the blocks had occurred by fall. A second possibility is that low-water periods in the LMR in late spring and summer brought about unsuitably low current velocities that induced drift followed by recolonization of small instars, but that the ACM blocks remained in suitably swift currents throughout the fall. Whatever the cause, conditions on the ACM blocks did not support populations reflecting the expected life history pattern until fall of the present study.

Data from the present study indicated that both species exhibited synchronous emergence between 3 and 23 October, 1990. The final sample taken on 20 November indicated that *H. orris* probably overwintered principally as second instars. Payne, Bingham, and Miller (1989) reported that in the LMR, *H. orris* overwintered principally as third and fourth instars. These differences are minor and probably result from annual differences in the precise seasonal pattern of water temperature, which affect growth and emergence. Physical differences between natural rock substrate on the dikes and the concrete blocks could also be a factor.

Fremling (1960) reported that *H. orris* in the Upper Mississippi River near Keokuk, IA emerged from mid-August to mid-September and overwintered as fifth instars. The earlier emergence in this population can be attributed to temperature differences between the more northern and southern populations. Beckett (1982) reported a late summer-early fall emergence for *H. orris* in the Ohio River, and late fall samples were dominated by third and fourth instars. Payne, Bingham, and Miller (1989) noted a highly synchronous, late summer-early October emergence from the dikes, which supported results of this study.

Summary

There are 937 miles of natural banks in the LMR that are covered by ACM mattress blocks. Although ACMs cover productive clay banks and sand/gravel substrates, they provide a stable, hard substrate that is inhabited by macroinvertebrates tolerant of moderate- to high-velocity water. In addition, considerable natural substrate exists below the ACM blocks (Baker et al. 1988), as well as between blocks. Regardless of where they are found, attached macroinvertebrates in the LMR that require flowing water must have either physical adaptations or behavioral attributes that protect them from the erosive action of high flow. The grooved and rough surfaces, which represent minor modifications to the ACM blocks, improve habitat quality for macroinvertebrates. This study indicated that 1 sq m of grooved ACM blocks supported, on average, 3,882 macroinvertebrates, which is more than double the density on smooth blocks. Macroinvertebrates produced on the ACM blocks are important in the diet of fishes and other vertebrates of recreational and ecological value. A consideration of the tremendous total surface area of these blocks in the Lower Mississippi River illustrates their potential value for aquatic biota.

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