THE VERTICAL STRATIFICATION OF THE MACROBENTHOS IN THE BRAZOS RIVER, TEXAS

THESIS

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By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure	Page

CHAPTER I

INTRODUCTION

Quantification of stream macrobenthos populations has remained a perplexing problem in riverine ecology, despite numerous attempts at improvement. This is in part due to well documented variations in chemical and physical parameters locally and geographically, and resultant adapted macrobenthos populations.

Southwood (1968) and Hynes (1970a) have reviewed the various sampling techniques developed for the census of lotic macrobenthos populations. Needham and Usinger (1956), Chutter (1969), and others have pointed out the difficulty in obtaining adequate numbers of samples which will yield population estimates with desired statistical confidence, and still maintain some degree of sampling economy. Needham and Usinger (1956) and Gaufin et al. (1956) mentioned the "patchy" distribution of aquatic insect populations as the primary source of this difficulty. The concept of patchy distribution in insect populations was originally discussed by Andrewartha (1961). Attempts to improve confidence through improved sampling devices and techniques have led to development of numerous types of samplers. Cummins (1962) indicated that there were almost as many samplers as there were researchers.

Samplers and techniques described by Surber (1937) and Hess (1941) are probably the most used currently despite their limitations (Waters and Knapp, 1961; Kroger, 1972), and continued suggestions as to their deficiency for quantitative analyses (Hilsenhoff, 1969).

Coleman and Hynes (1970), Radford and Hartland-Rowe (1971), and Hynes (1970b) have shown that sampling gravelly-bottomed streams with devices that penetrate only the top few centimeters (e.g. Surber and Hess type samplers) do not include those significant portions of the macrobenthos present beneath the sampled stratum. Ford (1962) stated that vertical distribution must be considered in quantitative work, but only deep enough that time would not be wasted on nonproductive lower layers. This establishes the need for further knowledge of the vertical stratification characteristics of insects and other macrobenthic species.

It is then evident that in some instances a more deeply penetrating sampler than is generally employed should be used to obtain accurate estimates of insect populations. The phenomenon of vertical stratification is exhibited in most communities; vertical layers are characterized by certain species at certain times, with vertical movements between strata and horizontal movements within a stratum. Vertical movements could reflect organism responses to environmental changes or adaptive advantage in the life cycle through selection. The phenomenon of vertical stratification allows maximum utilization of available habitat, leading to greater species diversity and stability of the community (Smith, 1966; Odum, 1971).

In the most recent and definitive study of stratification of macrobenthos, Coleman and Hynes (1970) designed and used a sampler that made use of natural substrate and collected organisms to a depth of 30-cm. Samplers were composed of four horizontal layers about 7.5-cm deep and 25.5-cm in diameter; they were left in the stream bed for 1-28 days. Colonization of the samplers was possible both vertically and horizontally. Macrobenthos increased steadily with time and only 20% of the total organisms recovered were found in the top 7.5 cm layer. Other overall percentages were 27% in each of two middle layers, and 26% in the lowest layer. Most groups of animals recovered exhibited vertical distributions approximating these percentages.

The present study was undertaken with three major objectives in mind: (1) to design an improved residual multi-component sampler for determining populations of aquatic insects at 10-cm intervals down to 40-cm, (2) to determine the nature and extent of vertical stratification of riffle insect communities on the modified Brazos River in Palo Pinto County, Texas, and (3) to compare total populations sampled vertically down to 40-cm with those on the same area sampled with a modified Hess type surface sampler. In addition, seasonal periodicity of vertical stratification and its relationship with the emergence and life cycles of selected insect species were of special interest.

The study was made on a large, uniform riffle located above Texas State Hwy. 4 Bridge on the Brazos River, approximately 20 miles below Possum Kingdom Dam. This stretch of the Brazos River has been under investigation by several workers recently and detailed descriptions of the study riffle were given by Stewart et al. (1973), Vaught and Stewart (1973), Cloud (1973), and Rhame (1973).

CHAPTER II

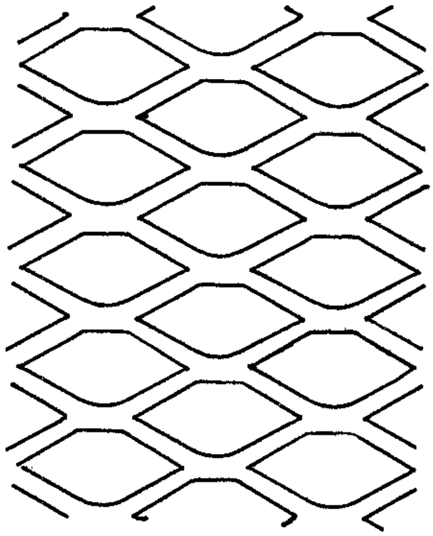
MATERIALS AND METHODS

The Sampler

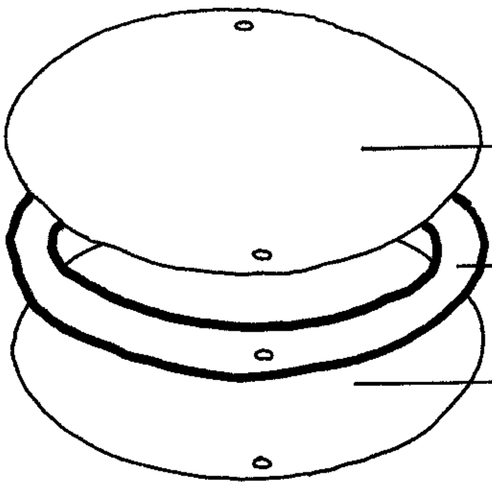
Ten samplers, modified after Coleman and Hynes (1970), were constructed from 18 ga flat rolled expanded steel, with diamond shaped holes approximately 0.5-cm x 1.5-cm (Figure 1 A.). Eight of the samplers consisted of eight inside pots 10-cm high and 16-cm i.d., with a solid steel bottom. Two other inside pots measured 30-cm high and 16-cm i.d.

Each inside pot fitted into a corresponding outside cylinder open at both ends, 21-cm i.d. and measuring 10, 20, 30, 40-cm high, depending on the depth of sample for which it was designed. All the metal parts of the samplers were coated with green epoxy paint for protection, and to reduce the possibility of their invoking any repelling action in burrowing insects.

Nets constructed from parachute nylon (33 threads/cm; 10 μ opening) were fitted to a copper ring approximately 17 cm i.d.; the net ring fit between the inner pot and the outer cylinder. All nets were 15-cm in length so that they



A.



B.

Fig. 1--A. Flat rolled expanded steel mesh.
B. Sampler partition.

extended 5-cm past the top and enclosed the inside pot when the samples were retrieved.

The bail used to raise the net around the inside pot ran through two holes in a partition which fit against the top of the inner pot in situ. The partition was a sandwich arrangement of two pieces of metal holding a rubber gasket between them (Figure 1 B.), which fitted tightly against the walls of the outside cylinder.

Installation of the Sampler

The outside cylinders were buried in the riffle with their tops level with the top of the substrate, and remained in place throughout the study. In preparation for each sampling period, the inside pots were filled with dry rubble and sand from the stream bank in proportions that closely matched the substrate at the level from which the sample was to be taken. Following is a summary of the placement of the inside pots for sampling different depths (Figure 3):

1. 0-10-cm--The filled inside pot was placed in the outside cylinder with the net ring and net positioned at the bottom of the sampler, and the bail just clearing the top of the inside pot.

2. 10-20, 20-30, and 30-40-cm--The filled inside pot was placed in the outside cylinder with the net ring positioned at the bottom of the sampler, and the partition slid down the bail to rest against the top of the inside pot. A plastic bag filled with rubble

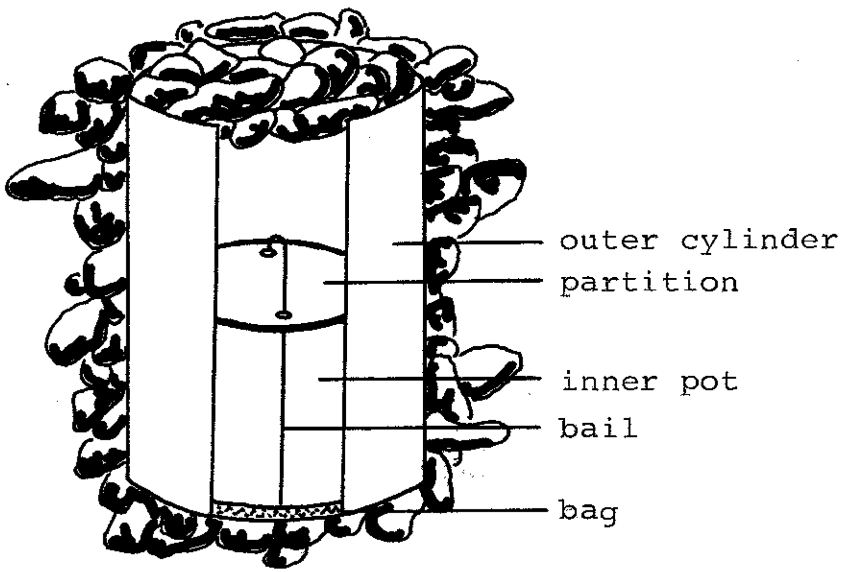
was used to fill most of the remainder of the sample hole, and loose rubble was used to fill the rest.

3. 0-30-cm--The same procedure as followed in the 0-10-cm sample was used.

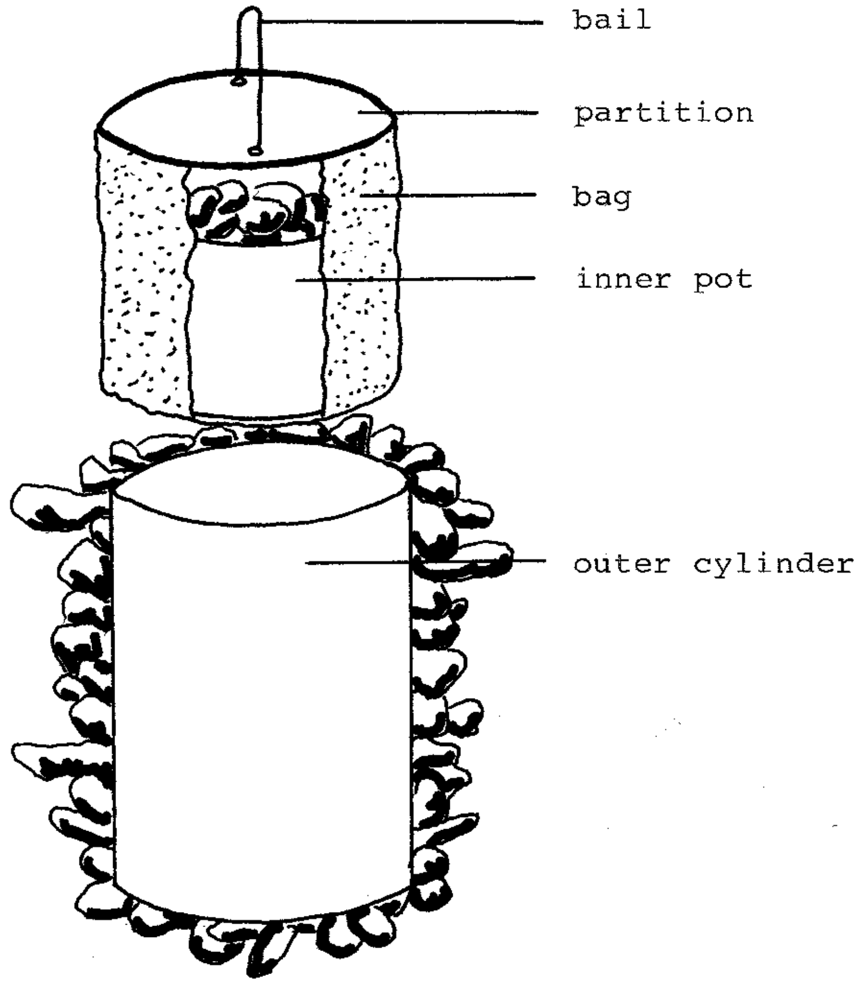
Positioning of the net and net ring at the bottom of the sampler between the inner pot and outside cylinder allowed access to the inside pot laterally from the surrounding substrate (Figure 2 A.). The top few centimeters of the in place samplers were covered with sand and rubble from the stream each time to effectively camouflage the samplers, since a preliminary study of this high-use riffle area had resulted in public retrieval and destruction of some samplers. The 10 samplers were placed along two transects across the riffle. The order of placement by different levels (0-10, 10-20, 20-30, and 30-40-cm) and distances between samplers were determined randomly with a table of random numbers. Two steel stakes and two trees marked the north and south ends respectively, of the two transects. Positions of samplers along the transect were located using a 50-meter tape.

Retrieval of Samples

Retrieval consisted of: (1) removal of the camouflage and plastic bag of rubble (except the 0-10 and 0-30-cm samples), (2) lifting the bail which pulled the nylon net-ring up against the metal partition (Figure 2 B.), and (3) pulling



A.



B.

Fig. 2--A. Vertical sampler in place, 10-20-cm. B. Retrieved 10-20-cm sample.

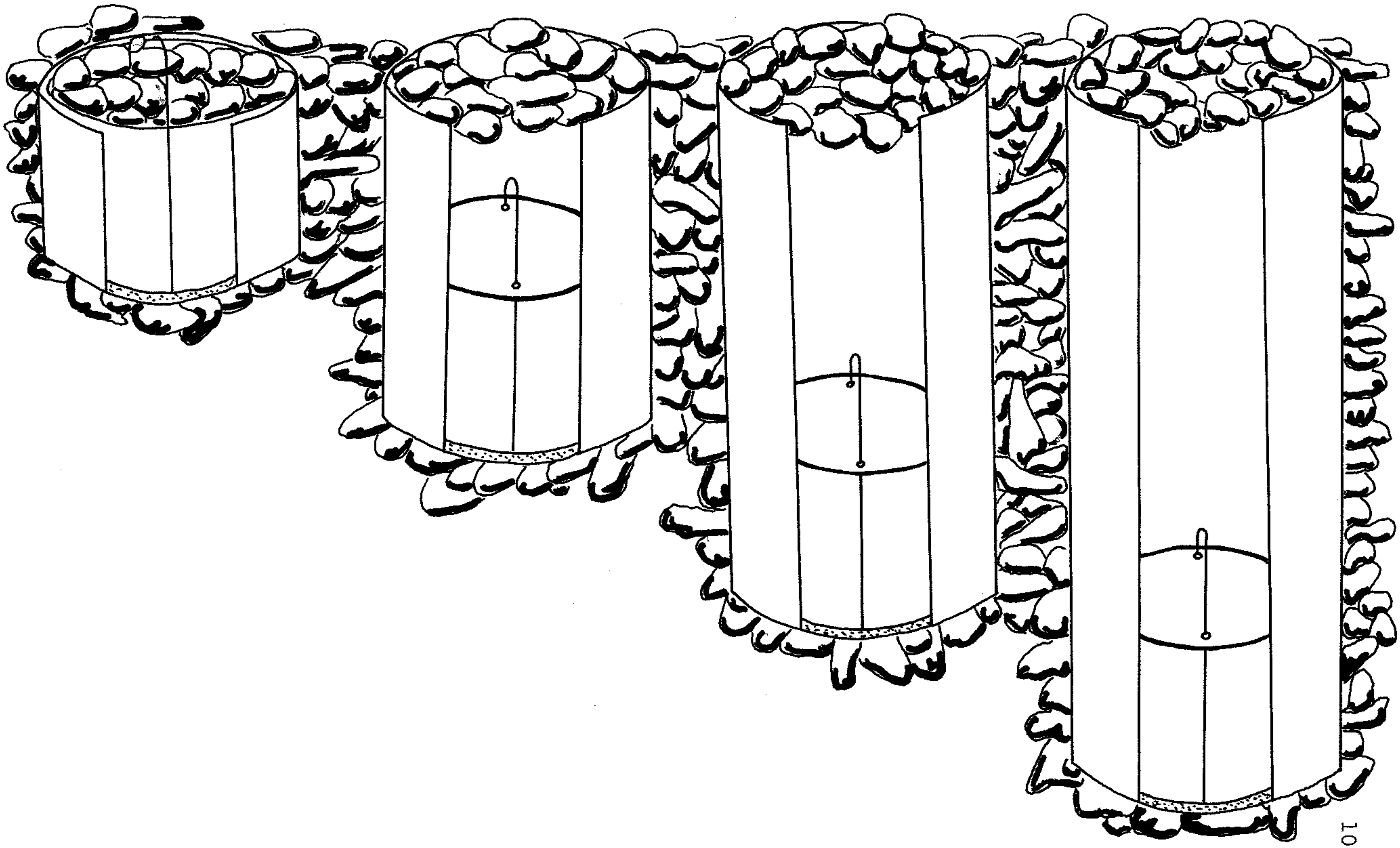


Fig. 3--Installed vertical samplers, 0-10, 10-20, 20-30, 30-40-cm; relative positions.

the bag-enclosed sample (inner pot) up out of the stream. The metal partition acted as a top for the bag-enclosed pot and prevented washout of the sample.

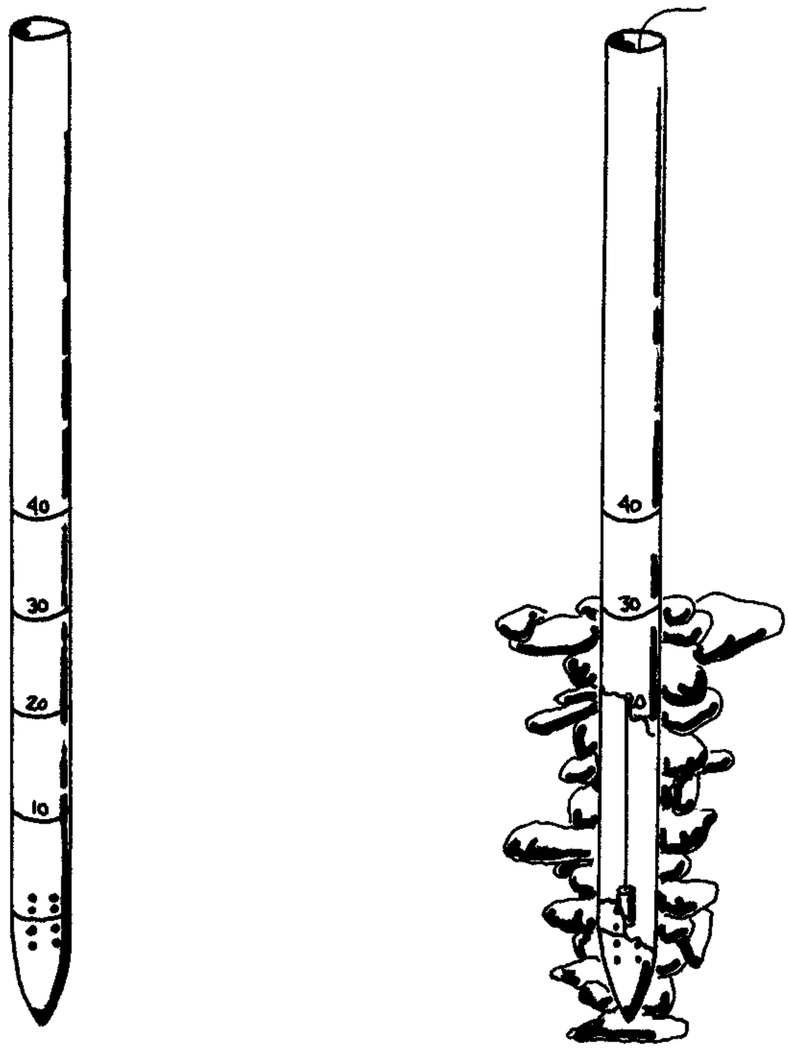
The sample and insects clinging to the inside of the net were placed in a Model 190 Wash Bucket (Wildlife Supply Co., Saginaw, Michigan), having a mesh opening of 516 microns; larger pieces of substrate were removed after carefully washing clinging insects back into the sample. The remaining substrate and insects constituting the condensed sample were placed in one liter jars of 70% isopropanol. The inside pot was then refilled with substrate and replaced in its outside cylinder, in the manner already described, to allow colonization for the next sample period.

Sampling Schedule

Original installation of samplers was made on July 7, 1972. Two samples for each 10-cm depth were retrieved seasonally on five subsequent dates: October 12, 1972, January 15, April 2, June 1, and August 1, 1973. The original intent was to take six semi-monthly samples, since preliminary studies on the riffle indicated that colonization of residual samplers stabilized within approximately eight weeks. However, prolonged spates on the river in September and December 1972, prevented retrieval according to schedule. It was decided that sampling for seasonal effect might be more desirable than adhering to a temporal schedule.

Three surface samples were taken between the two transects with a modified Hess sq. ft. sampler (Hess, 1941) on the same dates as retrieval of vertical layer samples. Dissolved oxygen and temperature were recorded in each 10-cm sampling level on retrieval dates of January, April, and June, 1973, vertical layer samples, with a YSI Model 54 Oxygen Meter. Access to each strata sampled by the probe was achieved through use of a perforated steel pipe (Figure 4 A.). The pipe was driven to the appropriate level, allowed to remain a minimum of 1 hour, and then the probe was lowered to the level of the perforations and agitated by hand for DO and temperature measurements (Figure 4 B.).

An attempt was made to determine if any water flow occurred within the substrata, by use of preweighed salt tablets. Two-minute dissolution rates of salt tablets at the surface with known flow rates, and in standing river water (in graduated cylinders at the same levels as measured experimentally) were used as controls. Dissolution rates at each 10-cm level were determined by lowering the pre-weighed



A. B.

Fig. 4--A. Pipe installation used for DO, temperature, and flow measurements. B. DO and temperature probe in position.

salt tablets, held by a stainless steel clip on a monofilament line, to the appropriate level and allowed to remain for two minutes. Surface flow immediately above the substrate was measured with a Kahl Pigmy Flow Meter.

Laboratory analysis of each vertical and surface sample included separation of insects from the remaining substrate by hand picking, sorting to different taxa, counting, drying at 80 C and weighing on a Mettler Balance. Prior to drying, the head capsule width of randomly subsampled individuals of the five predominant taxa were measured. This was accomplished through use of a gridded petri dish and table of random numbers. Dry weights were expressed as totals per taxa per level sampled.

CHAPTER III

RESULTS AND DISCUSSION

Fifteen of the total 25 taxa recovered in vertical sampling devices exhibited vertical stratification below 10 cm (Table I). Low recovery of Tabanus, Tricorythodes, Hirudinea, Corydalus, Heptagenia and Erpetogomphys, all recovered only in the top 10-cm of substrate, would leave open to question whether they migrate below 10-cm. Palpomyia Chimarra, Neoperla clymene and Elophila appear to inhabit only the surface 10-cm (Table I).

The mayfly Neochoroterpes mexicanus Allen, the larvae of the riffle beetle Stenelmis, adult Stenelmis bicarinata, nematodes and oligochaetes exhibited a marked degree of stratification. Dominant insects recovered in vertical samples, indicated by % frequency occurrence (Table I), were chironomid larvae, Simulium larvae, Cheumatopsyche larvae, Neochoroterpes mexicanus, and Stenelmis larvae. Because of sampler design, colonization by all organisms at various levels occurred through horizontal movements.

Coleman and Hynes (1970) found that in the Speed River, Wellington Co., Ontario, about 20% of total recovered

TABLE I

ORGANISMS RECOVERED USING MULTI-LEVEL RESIDUAL SAMPLER, BRAZOS RIVER TEXAS, 1972-73

Period 1 (July 7 - October 12, 1973)

Taxa	Total Catch/m^2	% at each level				% Frequency Occurance
		1	2	3	4	
Diptera - larvae						
Chironomidae	431	94.2	1.4	1.5	2.9	4.0
Simulium sp	231	75.6	18.3	6.1	-	2.1
Simulium sp pupae	19	100	-	-	-	0.2
Tabanus sp	19	100	-	-	-	0.2
Palpomyia sp	156	100	-	-	-	1.4
Trichoptera - larvae						
Cheumatopsyche sp	1,369	94.9	1.82	1.82	1.46	12.7
Chimarra obscura	25	100	-	-	-	0.23
Hydroptilla icona	25	75.0	-	25.0	-	
Ephemeroptera - naiads						
Neochoroterpes mexicanus	138	81.8	13.6	4.6	-	1.3
Tricorythodes sp	6	100	-	-	-	0.06
Plecoptera - naiads						
Neoperla clymene	13	100	-	-	-	0.10
Coleoptera - adults						
Stenelmis mexicanus	6	-	100	-	-	0.06
Berosus sp	6	-	100	-	-	0.06
Coleoptera - larvae						
Stenelmis sp	8,338	55.6	28.2	10.6	5.6	77.3
Total Organisms	10,782	63.9	22.7	8.9	4.5	

TABLE I--Continued

Period 2 (October 12, 1972 - January 16, 1973)

Taxa	Total Catch/m^2	% at each level				% Frequency Occurance
		1	2	3	4	
Diptera - larvae						
Chironomidae	513	89.0	6.0	1.4	3.6	3.0
Chironomidae pupae	6	-	-	-	100.0	0.04
Simulium sp	563	81.0	15.5	-	3.5	3.3
Simulium sp pupae	63	60.0	40.0	-	-	0.36
Tabanus sp	6	100.0	-	-	-	0.04
Trichoptera - larvae						
Cheumatopsyche sp	594	81.0	14.7	-	4.3	3.4
Ephemeroptera - naiads						
Neochoroterpes mexicanus	1,800	90.6	7.3	1.7	0.4	10.1
Plecoptera - naiads						
Neoperla clymene	6	100.0	-	-	-	0.4
Coleoptera - larvae						
Stenelmis sp	13,606	58.3	21.3	7.5	12.9	78.82
Oligochaeta	38	66.6	16.7	16.7	-	0.22
Nematoda	50	-	25.0	25.0	50.0	0.3
Hirudinia	6	100.0	-	-	-	0.04
Turbellaria						
Dugesia sp	13	50.0	-	-	50.0	0.07
Total Organisms	17,264	64.0	19.0	6.4	10.6	

TABLE I--Continued

Period 3 (January 16 - April 12, 1973)

Taxa	Total Catch/m^2	% at each level				% Frequency Occurance
		1	2	3	4	
Diptera - larvae						
Chironomidae	4,994	93.8	1.3	1.5	3.4	22.6
Chironomidae pupae	281	95.5	-	-	4.5	1.3
Simulium sp	4,169	90.2	5.0	1.2	3.4	18.9
Simulium sp pupae	706	98.2	-	-	1.8	3.2
Palpomyia sp	44	100.0	-	-	-	0.2
Trichoptera - larvae						
Cheumatopsyche sp	481	89.6	1.3	-	9.1	2.2
Cheumatopsyche sp pupae	31	100.0	-	-	-	0.1
Hydropsyche simulans	13	100.0	-	-	-	0.06
Hydroptilla icona	13	100.0	-	-	-	0.06
Pycnopsyche sp	19	66.6	33.4	-	-	0.08
Ephemeroptera - naiads						
Neochoroterpes mexicanus	2,700	73.4	15.7	8.6	2.3	12.2
Tricorythodes sp	13	100.0	-	-	-	0.06
Plecoptera - naiads						
Neoperla clymene	19	100.0	-	-	-	0.08
Megaloptera - larvae						
Corydalus cornutus	6	100.0	-	-	-	0.03
Coleoptera - adults						
Stenelmis mexicanus	38	100.0	-	-	-	0.02
Stenelmis bicaranata	31	40.0	20.0	-	40.0	0.1
Berosus sp	6	100.0	-	-	-	0.03
Coleoptera - larvae						
Stenelmis sp	8,469	46.4	14.4	12.3	26.9	38.3
Oligochaeta	50	-	12.5	25.0	62.5	0.2
Nematoda	6	-	-	-	100.0	0.03
Total Organisms	22,089	72.3	8.8	6.4	12.5	

TABLE I--Continued

Period 4 (April 2 - June 1, 1973)

Taxa	Total Catch/m^2	% at each level				% Frequency Occurance
		1	2	3	4	
Diptera - larvae						
Chironomidae	1,025	92.6	4.3	0.06	3.1	8.3
Simulium sp	119	86.8	15.8	10.6	36.8	1.0
Palpomyia sp	6	100.0	-	-	-	0.05
Trichoptera - larvae						
Cheumatopsyche sp	1,506	97.5	0.4	-	2.1	12.2
Hydropsyche simulans	13	100.0	-	-	-	0.1
Ephemeroptera - naiads						
Neochoroterpes mexicanus	1,738	97.8	0.7	0.7	0.8	14.0
Heptagenia sp	6	100.0	-	-	-	0.05
Plecoptera - naiads						
Neoperla clymene	56	100.0	-	-	-	0.5
Lepidoptera - larvae						
Elophila sp	44	100.0	-	-	-	0.4
Odonata - naiads						
Erpetogomphus sp	6	100.0	-	-	-	0.05
Coleoptera - adults						
Stenelmis mexicanus	13	50.0	50.0	-	-	0.1
Coleoptera - larvae						
Stenelmis sp	7,756	72.3	17.9	3.2	6.6	63.0
Oligochaeta	25	100.0	-	-	-	0.2
Total Organisms	12,313	80.6	12.0	2.3	5.1	

TABLE I--Continued

Period 5 (June 1 - August 1, 1973)

Taxa	Total Catch/m^2	% at each level				% Frequency Occurance
		1	2	3	4	
Diptera - larvae						
Simulium sp pupae	6	100.0	-	-	-	0.1
Chironomidae	163	100.0	-	-	-	3.3
Trichoptera - larvae						
Cheumatopsyche sp	531	37.6	42.3	5.8	14.3	10.7
Hydropsyche simulans	19	33.3	33.3	-	33.3	0.4
Chimarra obscura	13	100.0	-	-	-	0.3
Ephemeroptera - naiads						
Neochoroterpes mexicanus	325	1.9	90.3	1.9	5.9	6.5
Isonychia sicca manca	6	-	100.0	-	-	0.1
Lepiodoptera - larvae						
Elophila sp	13	100.0	-	-	-	0.3
Coleoptera - adults						
Stenelmis bicaranata	25	-	100.0	-	-	0.5
Coleoptera - larvae						
Stenelmis sp	3,856	55.5	34.0	7.2	3.3	77.4
Oligochaeta	13	-	-	-	100.0	0.3
Turbellaria						
Dugesia sp	13	50.0	-	-	50.0	0.3
Total Organisms	4,983	51.2	37.5	6.3	5.0	

organisms sampled, occurred in the 0-7.5-cm level; about 26% occurred in the 22.5-30-cm level and the remainder were about equally distributed in the 7.5-15 and 15-22.5-cm levels. Mean percentages of total organisms in the Brazos River were 66.4%, 20.0%, 6.1% and 7.5%, respectively, in the progressive 10-cm levels, from top to bottom (Figure 5). These differences in stratification between the two studies are probably accounted for by differences in substrate characteristics and organism adaptations to the substrate.

Coleman and Hynes (1970) described the Speed River substrate as coarse and fine silty gravel, intermixed with stones ranging up to 10-cm diameter; apart from a few larger stones at the surface, the gravel did not vary greatly with depth. The Brazos substrate on the other hand, is composed basically of two layers: (1) the approximately top 10-20-cm composed of coarse gravel with a few scattered larger stones, and (2) 20-40-cm composed of scattered gravel and larger stones surrounded by fine, packed sand and silt; this is probably due in some degree to the shifting of top layers during the numerous spates on the river, since large rocks used to mark transect stakes disappeared after spates.

If insects have a behavioral tendency to migrate within the substrate, then one would expect the more even distribution

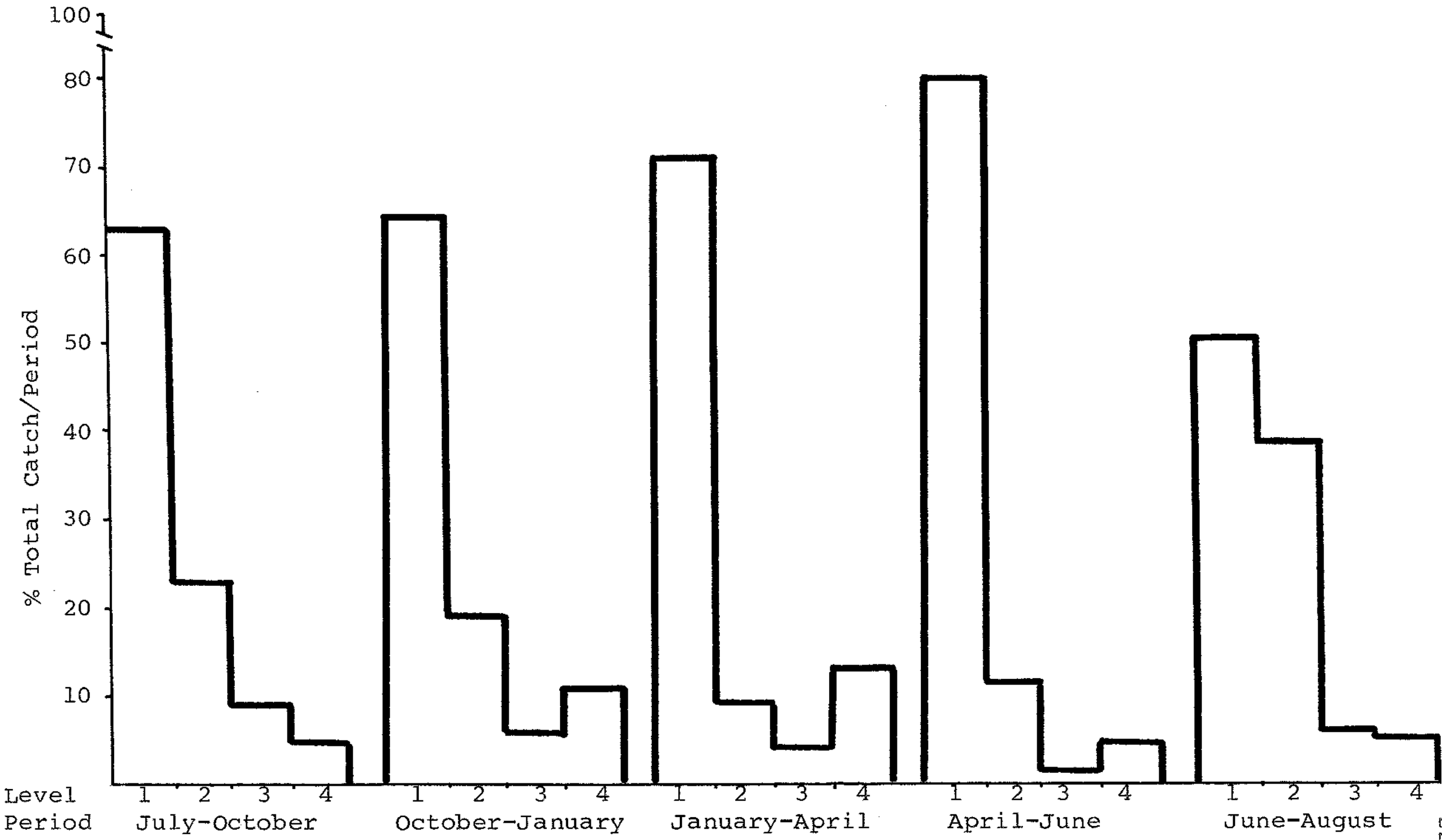


Fig. 5--Percent of organisms per sample date per level, Brazos River, Texas, 1972-73.

observed by Coleman and Hynes (1970) in the less-layered substrate. In the Brazos, restriction of such movements by the packed sand and silt would be consistent with the observed predominance of insects in the surface 0-10 and 10-20-cm layers.

Although the behavioral tendency of the Brazos species to migrate vertically in substrate is not known, it might be assumed that they have had less time to adapt to such behavior than the organisms of western and northern rivers such as the Speed River. The open nature of the surface layers of substrate in the Brazos has prevailed for only approximately 33 years, since Possum Kingdom Dam was closed in 1940. The river prior to that time was intermittent and substrate was more a silt-sand nature. Southwestern species of insects now composing the community may not yet have fully adapted to a more cryptic life style as compared with northern forms associated with more stable river conditions.

Stratification characteristics indicated in Table I and Figure 5 probably were not related to temperature, since a maximum of only 3 C difference existed from the surface to the lowest 10-cm layer, on dates measured. During warmer months, water was colder in subsurface layers and the converse was true during the one winter measurement.

Oxygen and flow characteristics may have limited colonization of lower layers. Dixxolved oxygen characteristically dropped from saturation (8.5-12.8 ppm) at the surface, progressively to as low as .4 ppm in the 30-40-cm sample of January 16 (Figure 6). Flow, based on the two-minute dissolution rates of salt tablets became virtually non-existent in the subsurface strata (10-40-cm).

Other than substrate differences and the frequency of spates, the Brazos River and Speed River study sites were generally similar, i.e. size of the study riffle, depth and hardness of water and land use characteristics of the watershed.

Immediately prior to the removal of the June-August sample a very heavy rain (approximately 14-cm) on the watershed below Possum Kingdom Dam, introduced a heavy silt load into the river and created flooding conditions. The subsequent sample (Figure 5) indicated that insects retreated into the 10-20-cm layer, possibly an escape response to heavy silting and scouring effects. Numerous conventional surface samples, taken after spates on the study site in previous years have indicated a depleted fauna, suggesting scouring and catastrophic drift. However, rapid recovery, not accountable by drift (possibly because of location of the Dam and

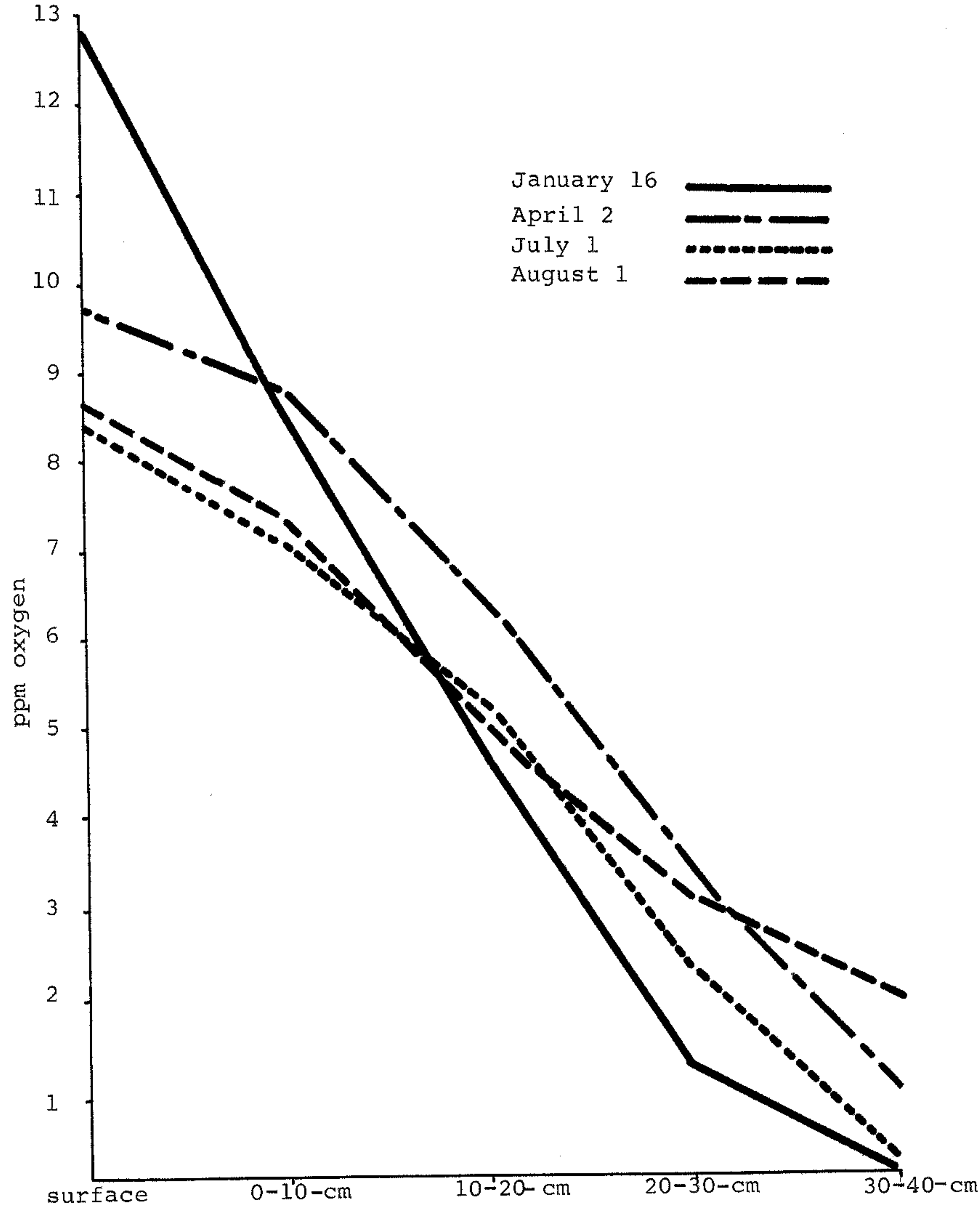


Fig. 6--Oxygen measurements per 10-cm level on four dates, Brazos River, Texas, 1972-73.

even greater expected scouring upstream) remained a mystery. This observed movement into deeper strata during unfavorable surface conditions could explain such recovery.

The composite residual samples of 0-30 cm, installed in the river, were not retrieved. Silting in between the outer and inner cylinders, in effect quadrupling the effective friction depth during retrieval, and the unforseen weight of the 40-cm inner pot in relation to the bail strength precluded removal of an undisturbed sample.

The five most abundant insects recovered from the vertical sample, Chironomidae, Simulium sp., Cheumatopsyche sp., Neochoroterpes mexicanus and Stenelmis sp. were examined more closely to determine possible relationships between vertical stratification and life cycles.

As expected with its burrowing habits and body form, Stenelmis sp. larvae were the most prevalent insects recovered from deeper strata. Numbers/m^2 varied seasonally at different levels (Figure 7), with largest populations always occurring in the 0-10-cm layer. Numbers in the 10-20-cm layer were high (9400-11,600/m^2) in the fall and winter (October-January) samples, and moderate (4900-5500/m^2) in the three samples recovered during the spring and summer (April, June, August). Smallest numbers in the 20-30 and 30-40-cm layers were

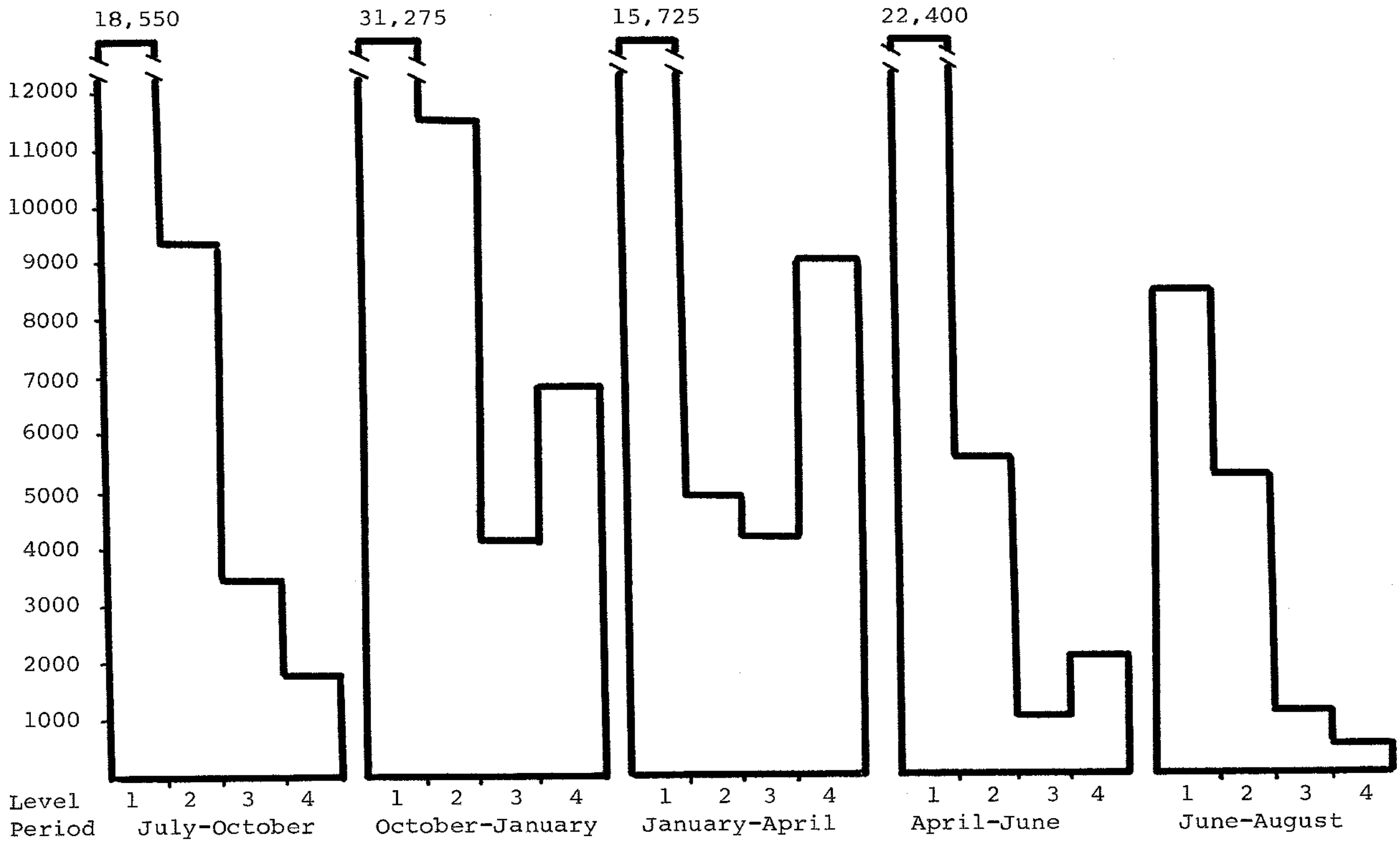


Fig. 7--Vertical distribution of Stenelmis sp. larvae, Brazos River, Texas, 1972-73.

recovered in June and August (Figure 7), probably reflecting migration into upper strata during summer emergence. Largest numbers occur in these deeper strata during winter and early spring (January, April). One might conjecture that this reflects migration to warmer and more protective cover for overwintering, but such an explanation would not account for the January 0-10-cm population of 31,275/m^2, largest recovered during the entire study at any level. At any rate, a proportion of the Stenelmis larval population migrated to deeper strata in the fall and most of these appear to have migrated back to the surface in the summer.

Smaller larvae, measuring .17-.28 mm head capsule width (Size class I), were most numerous in the 0-10-cm level (Figure 8). Size class II (.34-.45 mm) was most predominant in the 0-10-cm level and of moderate abundance in the three deeper 10-cm levels. The largest larvae, size class III (.51-.62 mm) were most numerous in the three deeper strata and of moderate abundance at the surface (Figure 8). Comparison of Figures 10, 12, 14 and 16 indicates that Stenelmis larvae were the most evenly distributed among the various levels in all size classes, of the five predominant groups. The greatest numbers of Cheumatopsyche sp. larvae were recovered from the top 0-10-cm layer in all sample periods except the

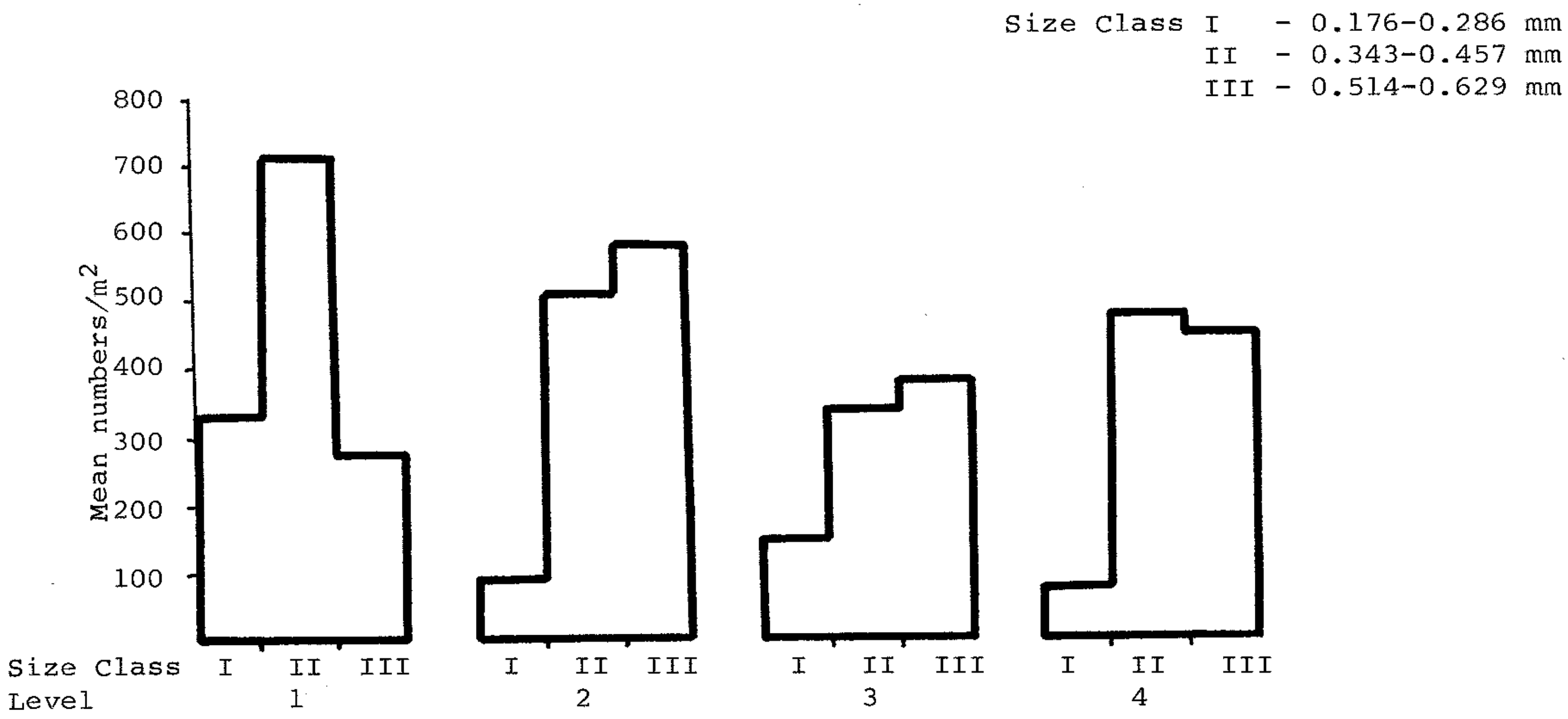


Fig. 8--Stratification of pooled seasonal samples by size classes of Stenelmis sp. larvae, based on subsamples, Brazos River, Texas, 1972-73.

last (June-August); numbers recovered ranged from 800-5875/m^2 (Figure 9). Population fluctuations from this layer correspond with known April-May, July-August emergence of <u>Cheumatopsyche</u> on the study site (Rhame, 1973) (Figure 9).

During the last sample period (June, August) the 10-20 cm layer contained the greatest number of organisms, 900/m^2; the range of recovery from this layer in the previous four samples was 25-350/m^2 (Figure 9). This sudden increase in numbers during the June-August sample was probably a result of high water and heavy silting conditions brought about by the flood on the river, described earlier. The relatively large population observed during the October-January sample could reflect migration to a lower strata for overwintering, and low populations during summer could indicate migration to upper strata for emergence.

Populations were lowest in the 20-30-cm range, and on some sample dates (January, April, June) no <u>Cheumatopsyche</u> at all were recovered from this level. This is difficult to explain since the 30-40-cm level held a fairly constant population of 75-300/m^2 throughout the study. An increase in these lower levels is evident during the August sample due again possibly to unfavorable surface conditions.

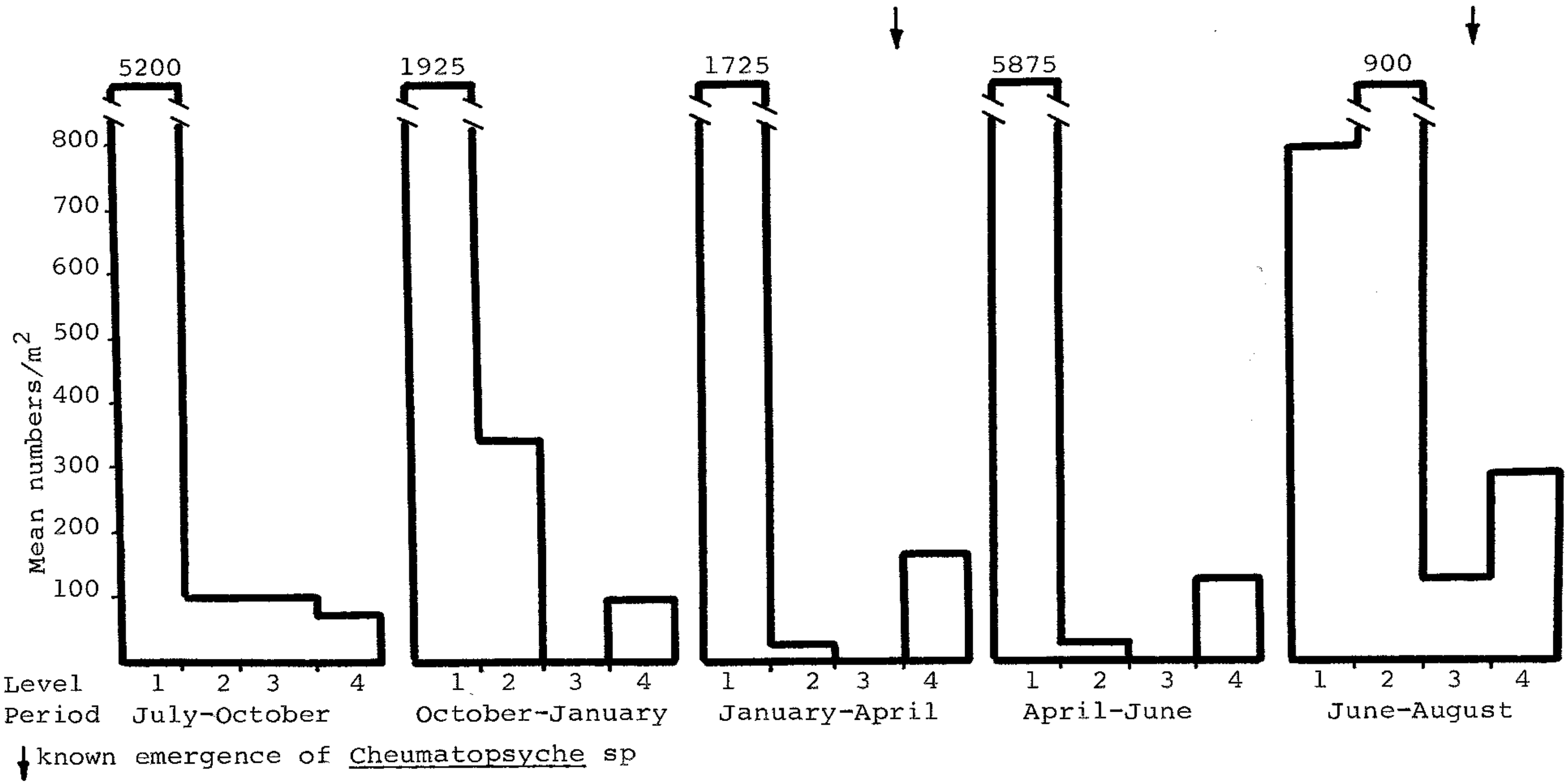


Fig. 9--Vertical distribution of <u>Cheumatopsyche</u> sp. larvae, Brazos River, Texas, 1972-73.

Smaller larvae (Size class I) were most abundant in the 0-10 cm layer (Figure 10), as were size classes II and III. In the deeper strata, especially in the 10-20 and 30-40-cm levels the larger size classes predominated.

As with all five dominant organisms, Simulium was recovered in greatest abundance from the 0-10-cm level (Figure 11). Numbers in the 10-20-cm layer varied from a high of $800/m^2$ in the January-April sample to none in the July-August sample. Population levels in these two upper strata follow a trend that would be expected with the observed early spring emergence. The absence of Simulium from any sample in August would suggest that all individuals were in the egg or very early larval stage; apparent emergence and long egg dormancy on the Brazos correspond with life cycle notes on Prosimulium vernale Shervell by Tarshis and Stuht (1970). Sampling variability might explain the large population of $575/m^2$ at 30-40-cm in April.

The moderate numbers of Simulium found in the lower strata are puzzling, when the generally accepted filter-feeding habit is considered. Coleman and Hynes (1970) found that Simulium that colonized their samplers disappeared from lower strata after 7 days. They theorized that this was due to silting in of the substrate rendering it less desirable or

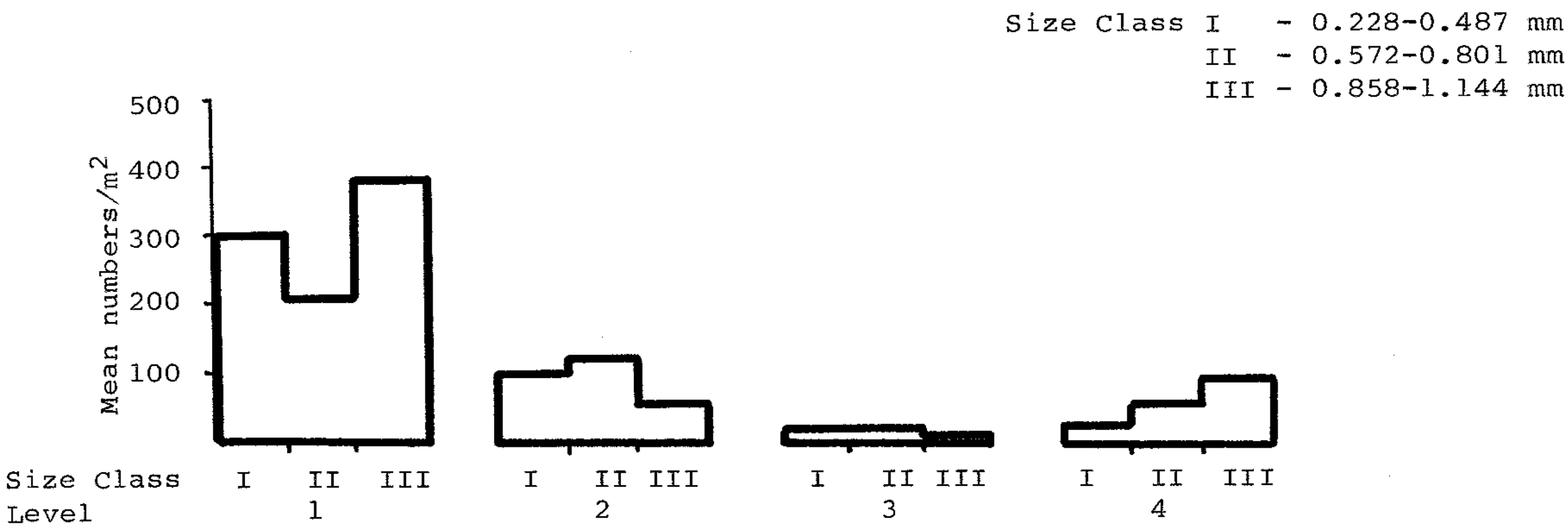


Fig. 10--Stratification of pooled seasonal samples by size classes of <u>Cheumatopsyche</u> sp. larvae, Brazos River, Texas, 1972-73.

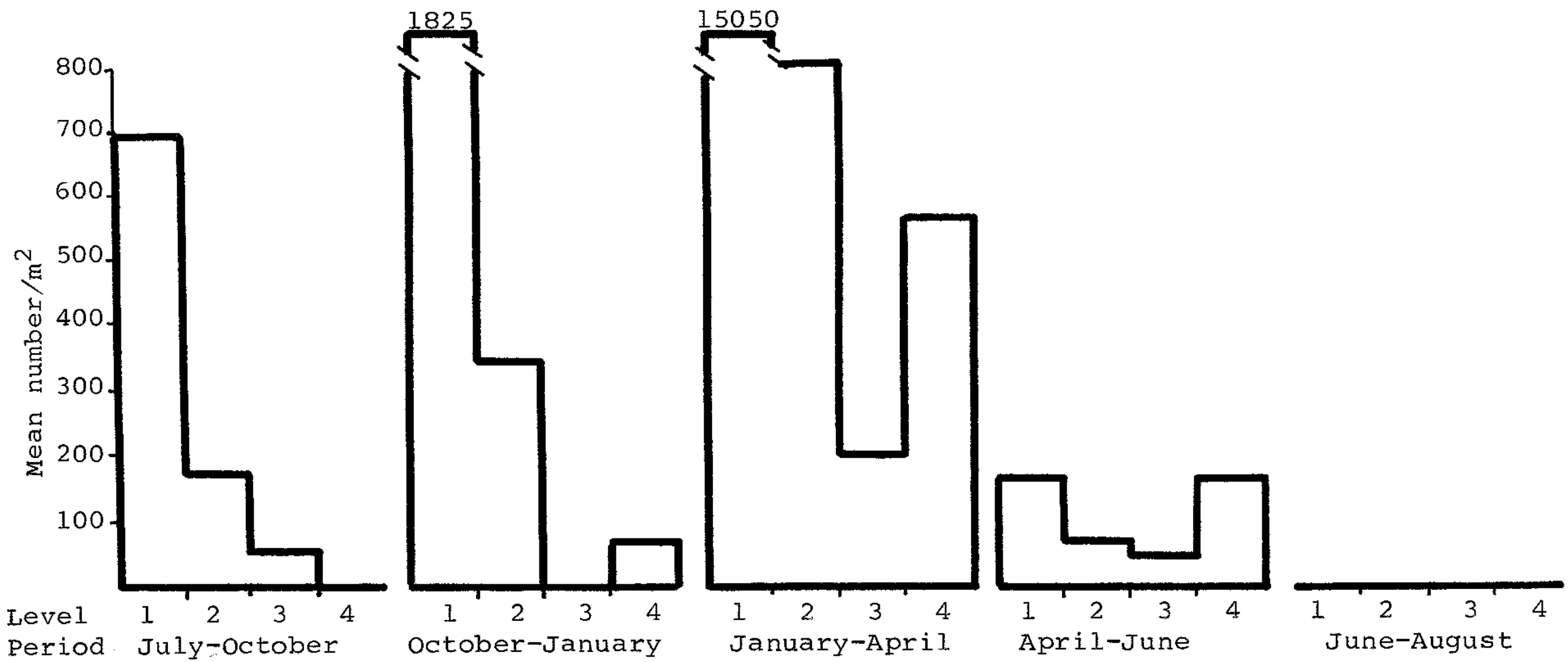


Fig. 11--Vertical distribution of <u>Simulium</u> sp. larvae, Brazos River, Texas, 1972-73.

uninhabitable by Simulium. The fact that Simulium was present at the end of a 60-day residual period for the samplers, and that their colonization would have occurred from outside the sampler at the same levels, would suggest that there were minimal differences between the substrate inside and outside the samplers.

The largest numbers of all three size classes of Simulium were present in the 0-10-cm level (Figure 12). The smallest larvae (Size class I) were least abundant in all levels and decreased markedly from level I to the other three 10-cm levels (Figure 12). Size class II was the most abundant encountered at all levels. Presence of size class III decreased with depth.

The largest populations of Neochoroterpes mexicanus were found in the upper level although the numbers at the different levels varied with season (Figure 13). The numbers in the 10-20 cm layer were moderate, $450/m^2$-$1700/m^2$, during the fall to spring samples and low $25/m^2$-$50/m^2$ in the October and June samples. Numbers in the 20-30 level were generally low $25/m^2$ to $125/m^2$ with a high of $925/m^2$ during the April sample. As might be expected, the 30-40-cm level contained the lowest numbers of Neochoroterpes. Highest numbers in all levels occurred in the January-April sample (Figure 13) followed by

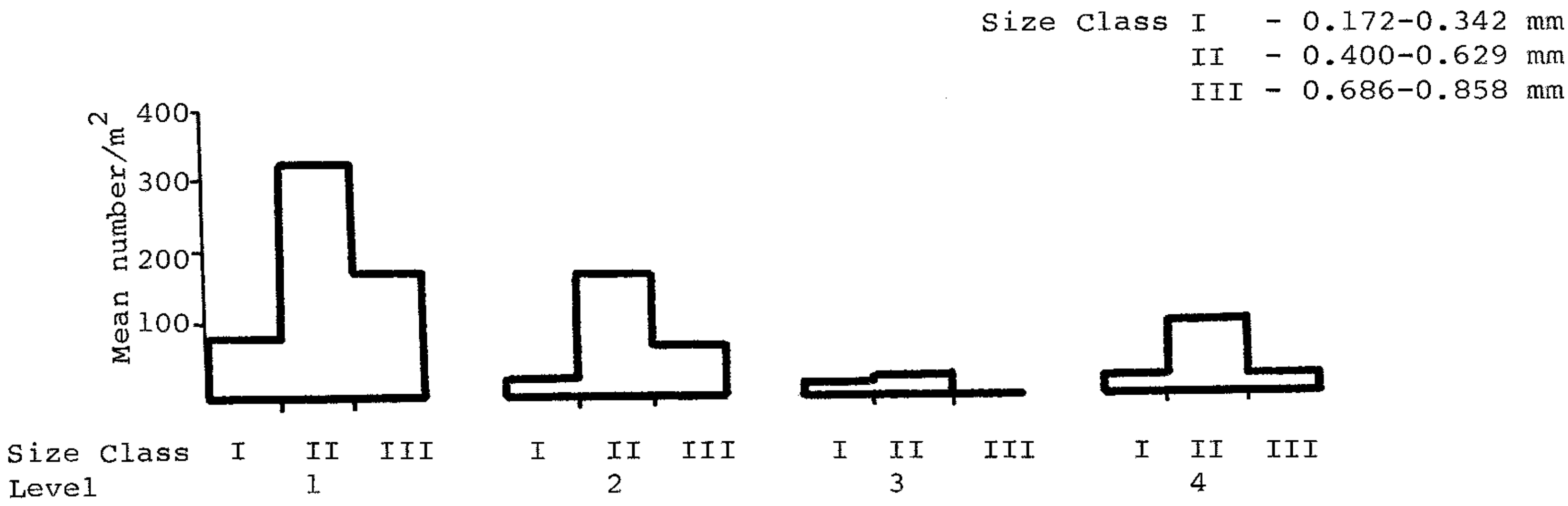


Fig. 12—Stratification of pooled seasonal samples by size classes of Simulium sp. larvae, based on subsamples, Brazos River, Texas, 1972-73.

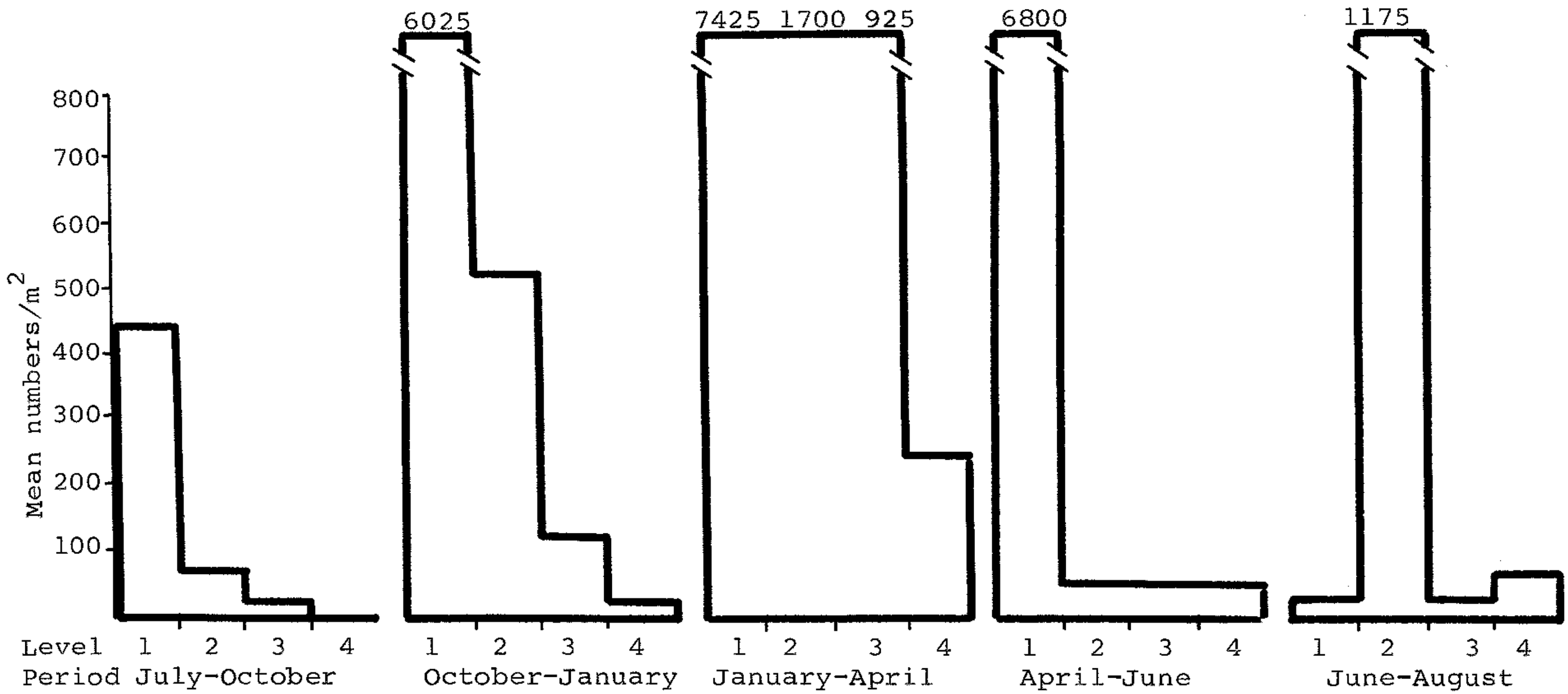


Fig. 13--Vertical distribution of <u>Neochoroterpes mexicanus</u> naiads, Brazos River, Texas, 1972-73.

a drop in the 10-40-cm levels, possibly indicating a movement to the surface for feeding and in preparation for a summer emergence. This is substantiated by the drop in the surface populations between the June and August samples (Figure 13). The great increase in Neochoroterpes in the 10-20-cm layer in August is probably an escape response to avoid unfavorable surface conditions brought about by the large flood already described.

The smaller larvae, size class I, were present in large numbers in the 0-10-cm strata and decreased progressively with depth down to 40-cm. Size class II was present in moderate numbers in the upper layer and also decreased progressively with depth. The third size class varied little with depth but the two upper levels 0-10 and 10-20-cm contained more than the lower two layers 20-30 and 30-40-cm (Figure 14).

As in the other organisms, the 0-10-cm layer contained the greatest populations of Chironomids in each sample, and were consistently high compared to the three lower levels (Figure 15). The 10-20-cm strata contained few organisms, $0/m^2$-$172/m^2$, through most of the study except the April-June sample which had a population of $300/m^2$. The 30-40-cm level also contained few organisms, again with the exception of the

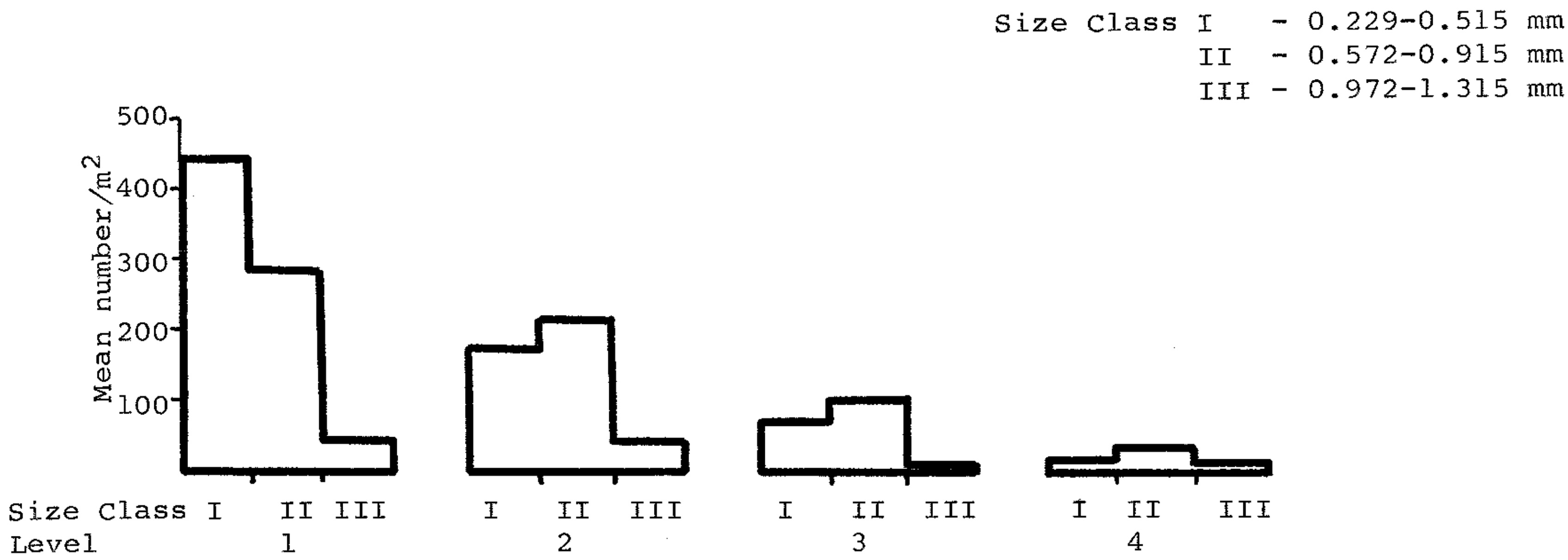


Fig. 14--Stratification of pooled seasonal samples by size classes of *Neochoroterpes mexicanus* naiads, based on subsamples, Brazos River, Texas, 1972-73.

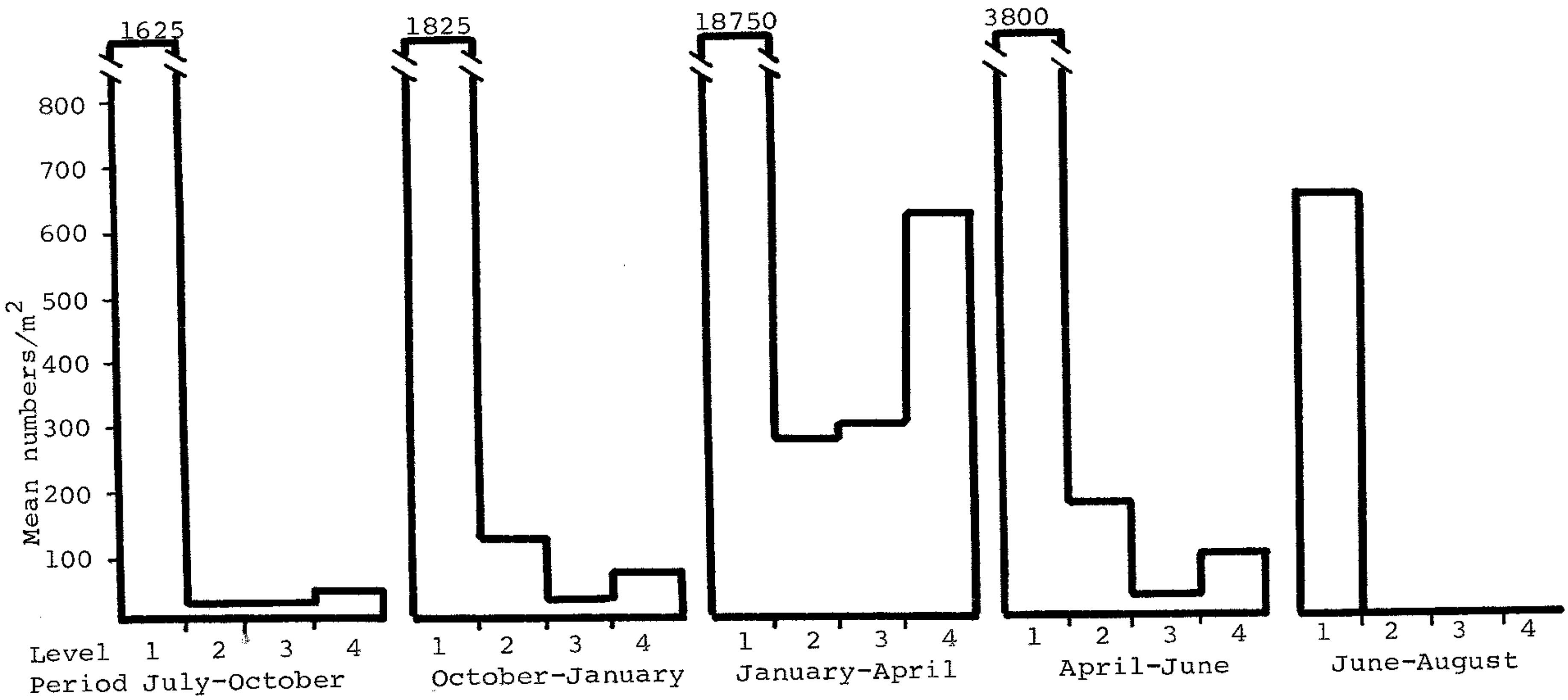


Fig. 15--Vertical distribution of Chironomidae larvae, Brazos River, Texas, 1972-73.

January-April sampling period when the Chironomid population was 625/m^2 in the lowest level. The population increase during the January-April sample is probably in preparation for summer emergence. This explains the drop in population in all levels during the April-June and June-August samples (Figure 15).

The 0-10 cm level contained the greatest number of all the size classes (Figure 16). Size class I decreased steadily with depth except for the 30-40-cm level which showed a slight increase over the 10-20 and 20-30-cm levels. Size class II had the highest numbers in the 0-10-cm level of any of the size classes and decreased with depth, with the exception of the 30-40-cm level which also showed an increase in numbers. The third size class was in low numbers in every level and 0/m^2 in the 30-40-cm level (Figure 16).

A comparison by Student's "t" test of both biomass and numbers of the total benthic fauna recovered from the different levels, from all levels combined, and from the modified Hess square foot sampler is presented in Table II.

Level 1 (0-10-cm) contained significantly more organisms than any other level, although it did not generally contain significantly greater biomass. This is a reflection of data in Figures 7, 9, 11, 13 and 15, indicating a predominance of

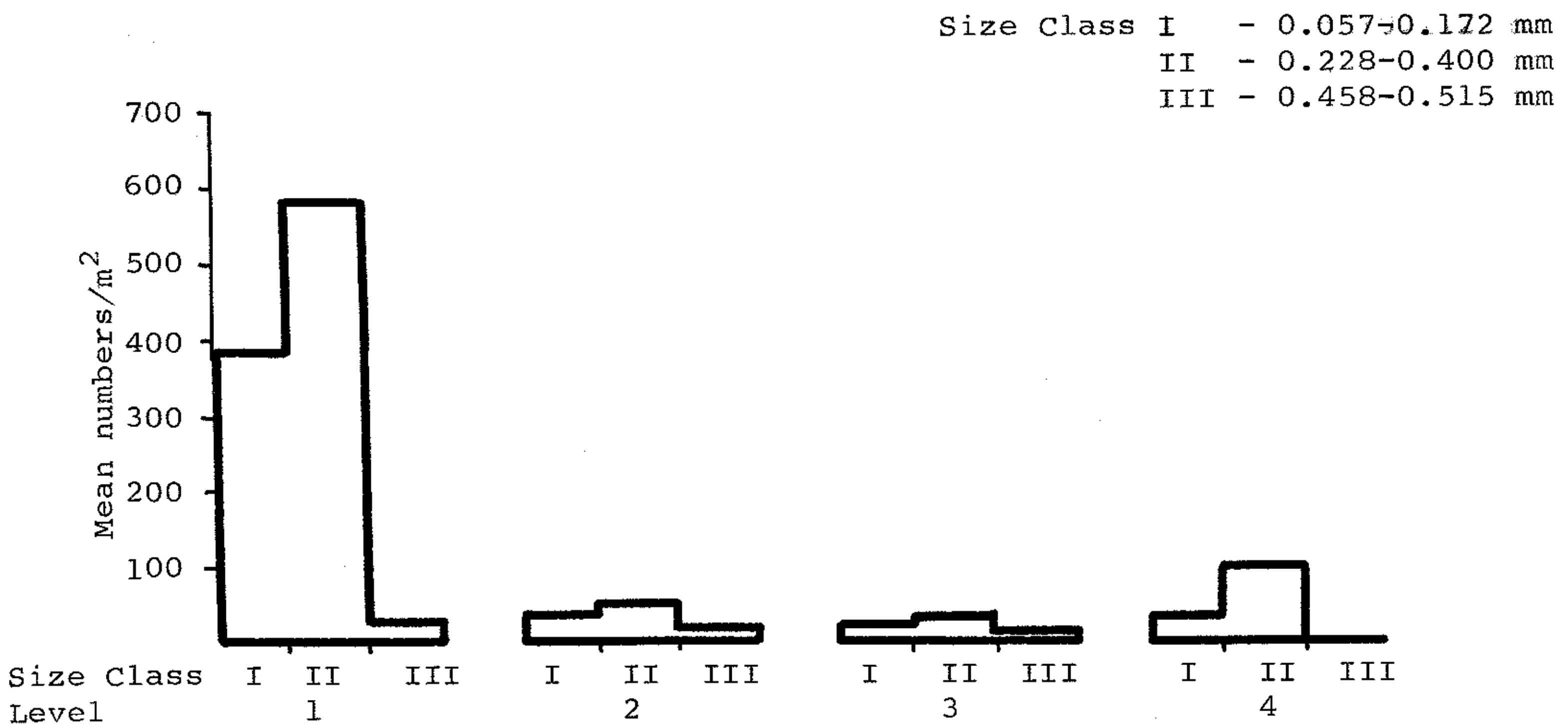


Fig. 16--Stratification of pooled seasonal samples by size classes of Chironomidae larvae, based on subsamples, Brazos River, Texas, 1972-73.

TABLE II

COMPARISON BY STUDENT'S "t"[1] OF MEAN WEIGHTS AND NUMBERS OF ORGANISMS RECOVERED IN VERTICAL AND SURFACE SAMPLES

	Mean ± sd	N	All Levels	Level 4	Level 3	Level 2	Level 1
Hess	2.96 ± 1.42 / 15,198 ± 14,570	15 / 15	0.09 / 0.33	2.28*[2] / 2.14*	3.50**[3] / 2.33*	0.87 / 1.31	2.57* / 3.07**
Level 1	7.14 ± 6.10 / 37,105 ± 21,198	5 / 10	1.95 / 3.62**	2.08 / 4.66**	2.36* / 4.68**	1.72 / 4.08**	. . / . .
Level 2	2.35 ± 1.07 / 8,820 ± 5,549	5 / 10	0.29 / 0.81	1.36 / 1.62	3.42** / 1.72	. . / . .	. . / . .
Level 3	0.65 ± 0.47 / 3,235 ± 2,710	5 / 10	1.24 / 1.76	1.02 / 0.48	. . / . .	. . / . .	. . / . .
Level 4	1.30 ± 1.34 / 4,786 ± 5,575	5 / 10	0.87 / 1.52	. . / . .	. . / . .	. . / . .	. . / . .
All Levels	2.86 ± 3.91 / 13,486 ± 17,138	20 / 40	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .

[1] "t" values are expressed as weight/number
[2] Significant at the 5% level
[3] Significant at the 1% level

smaller size classes in the upper layers. Level 1 also contained significantly greater densities than all 10 cm levels combined; it did not exhibit greater biomass than all levels combined.

Levels 2 (10-20-cm), 3 (20-30-cm) and 4 (30-40-cm) showed no significant difference among themselves, except the weights of level 2 were significantly greater than those of level 3 (Table II). This was expected, since level 3 generally showed consistently lower numbers of all size classes than other levels. The greater numbers of benthos at level 4 than level 3 in most samples (Figure 5), while not significantly different (Table II) was probably due to greater numbers of <u>Stenelmis</u> in the lowest level.

Comparison of the mean organism/m^2 sampled by the modified Hess with those from the various 10-cm levels indicated that it took significantly more organisms than the residual multi-level samplers at 20-30 and 30-40-cm, but not more than the residual samplers at the 0-10, 10-20-cm levels. This is in part due to there being more animals available to the Hess at the surface than to the residual samplers at 20-30 and 30-40-cm. However, in view of the significant difference in numbers between levels 1 and 2, the lack of significance between the Hess sample and the 10-20-cm samples indicates that use of the Hess omits a significant proportion of the population per unit of area sampled. Further, the significantly greater number/m^2 sampled by the 0-10-cm residual sampler over the Hess suggests that the vertical residual sampler is the most efficient. Arguments as to the possibility of the residual sampler, as described herein, providing a "haven" for organisms are adequately discussed by Coleman and Hynes (1970). Addition of a 5-10 cm metal ring (Waters and Knapp, 1961) around the bottom of a Hess sampler might increase its efficiency. Because of the large variance displayed by the different levels of the vertical sampler, there was no significant difference between Hess samples and the combined 10-cm levels.

In agreement with Ford (1962), these data suggest that on the Brazos River, either a residual sampler or a further modified surface Hess-type sampler, that would effectively census the 0-20-cm level, would give population estimates with acceptable accuracy while taking into account economy of sampling effort.

CHAPTER IV

SUMMARY

1. Vertical stratification samplers modified after those of Coleman and Hynes (1970) were used to sample macrobenthos at 10-cm levels down to 40-cm in the substrate of the Brazos River, Texas, from July 1972-August 1973. Observations concerning emergence, reaction to physical parameters, and life histories as connected with vertical movements within the substrate were recorded. Sampling efficiencies of a modified Hess square foot sampler and the vertical samplers were also compared.

2. Of the 25 species recovered during the study, 15 were found in samples below 10-cm. Mean percentages of the total organisms per 10-cm level showed 66.4% in the 0-10-cm level, 20% in the 10-20-cm level, 6.1% in the 20-30-cm level, and 7.5 % in the 30-40-cm level.

3. Frequency analysis showed the dominant insects in the vertical samples were chironomid larvae, *Simulium* larvae, *Cheumatopsyche* larvae, *Neochoroterpes mexicanus* naiads, and Stenelmis larvae. These dominant groups were then studied to reveal aspects of vertical stratification.

4. Population peaks in the top 10-cm of substrate correspond with observed emergence of the 5 major groups. Head capsule measurements indicate that the surface level 0-10-cm predominately contains the smaller insects. The larvae of *Stenelmis* were the most evenly distributed among the various levels in all size classes of the five predominant groups.

5. Migration to a lower substrate level following a large spate on the Brazos River immediately prior to removal of the last sample, especially by *Cheumatopsyche* and *Neochoroterpes mexicanus*, was possibly a reaction by the insects to escape the adverse conditions of swift flood water and a heavy silt load.

6. Measurements of oxygen and temperature within the substrate were measured on four sampling dates (January 16, April 2, July 1, August 1) and oxygen appeared to be the most limiting factor to vertical stratification. Oxygen measurements in the substrate showed a drop from saturation (8.5-12.8 ppm) at the surface to a minimum (0.4-0.7 ppm) at 30-40-cm. Temperature differences ranged a maximum of only 3 C between the surface and the 30-40-cm level on the dates measured. Flow measurements using an indirect salt tablet dissolution method on the last sample date suggested that little flow was present below 10-cm.

7. A students "t" analysis of the benthic populations recovered by the modified Hess square foot sampler and the vertical stratification sampler, indicated that the vertical stratification sampler recovered significantly greater populations than the Hess in the 0-20-cm range. A comparison of the Hess and 0-40-cm combined vertical sampler shows no significant difference between the two.

8. The results of these studies indicate that the most efficient sampler for riffle studies on the Brazos River would be a residual sampler which penetrated from 0-20-cm, giving an accurate assessment of the population and an economy of sampling.

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