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BENTHIC INVERTEBRATE UTILIZATION OF MAN-MADE AND NATURAL WETLANDS

Report to

Texasgulf Chemicals, Inc.

Aurora, North Carolina 27896

by

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SUMMARY

The benthic invertebrate communities of man-made and natural oligohaline wetlands were studied over time with the objectives of: (1) comparing faunal utilization of man-made and natural systems; (2) determining the rate of development of the faunal community in the man-made wetlands, and (3) identifying major factors controlling the rate of faunal community development in man-made wetlands.

The man-made wetland ("Project Area 2") is an eleven-acre site located at the junction of Drinkwater Creek and Jacobs Creek, in Beaufort County, North Carolina. Drinkwater Creek and Jacobs Creek are two subtributaries of the Pamlico River Estuary. Tooley Creek, Drinkwater Creek, and Jacks Creek were the natural oligohaline creeks which served as the control creeks for the study. Benthic grab samples (0.02 m^2) have been collected quarterly (January, April, July, and October) since July 1985 at an upstream, midstream, and downstream location in each area. This report covers the data obtained from samples collected between July 1985 and July 1988.

Benthic invertebrate utilization of man-made and natural wetlands was evaluated according to five criteria: (1) total faunal density; (2) species richness (average number of species per sample; (3) species composition; (4) the distribution and abundance of numerically dominant species; and (5) the absolute and relative abundance of all species present (community structure).

Total densities fluctuated widely among seasons. The temporal pattern of change in total density was consistent among all areas, in which densities were highest in the winter and spring, and lowest in the summer. Densities in the Project Area were generally equivalent to those of the natural creeks. The significant variations in abundance that did occur were primarily limited to single stations within the study areas during the summer seasons.

Similar temporal patterns of species richness (average number of species per sample) were observed in the Project Area and the natural creeks. The greatest number of species were present in the winter and spring; lower values of species richness were found during the remaining seasons. Differences in species richness among the man-made and natural areas were usually not significant. Occasions in which fewer species were found in the Project Area occurred during the summer seasons.

Information produced during this study, and the works of others in similar regions of the Pamlico River Estuary, indicate that the winter increase in density and diversity results from recruitment events. Causes of the spring-summer decline in both total fauna and species richness are probably more complicated, involving a combination of biological (e.g., predation by invertebrates and juvenile finfish) and abiotic (e.g., stressful levels of temperature, salinity and dissolved oxygen) factors.

The benthic invertebrate communities of the man-made and natural creeks consist of approximately forty taxa. The majority of the taxa are short-lived, prolific opportunists which rapidly colonize new or disturbed habitats. The majority of the taxa are deposit feeders.

In any given season, eight taxa constituted 90% or more of the total fauna in each creek. The identities of these numerically dominant taxa varied seasonally, and among the Project Area and the natural creeks. The species composition of this subset of the total taxa was usually more similar among the natural creeks than between the Project Area and any natural creek. Deviations in the composition of the numerically abundant taxa within the Project Area resulted from relatively high numbers of less common species (e.g. the burrowing anenome *Edwardsia sp.*, and the gastropod *Hydrobia sp.*), or exceptionally high densities of common species (e.g., the polychaete *Polydora ligni*, and the amphipod *Leptocheirus plumulosus*).

Seven taxa were particularly abundant and ubiquitous. These taxa included oligochaetes, the polychaetes *Mediomastus sp.*, *Laeonereis culveri*, *Hobsonia florida*, *Streblospio benedicti*, the amphipod crustacean *Leptocheirus plumulosus*, and chironomid insect larvae. Densities of these taxa varied greatly among creeks and within the same creek (i.e. among stations). Varia-

tion in the densities of *Mediomastus sp.*, *L. culveri*, *H. florida*, *S. benedicti*, and chironomid larvae among the natural creeks was substantial; as a result, the densities of these species within the Project Area were well within the range of densities established by the natural creeks. Oligochaetes were absent from the Project Area until winter 1987. Since that time they have been abundant but ephemeral in the Project Area. The population of *L. plumulosus* in the man-made area has steadily declined during the past two years despite an apparent global increase in the abundance of this species.

Analyses of species composition and community structure indicate that development of the benthic community of the Project Area has consisted of three phases to date: (1) an initial maturation period, lasting about three years , in which most of the local fauna became established; (2) a short (one year) period of general stasis in which the community of the Project Area was most similar to the natural creek communities; and (3) a current phase of diversification in which the community of the man-made system is diverging to some degree from the communities of the natural creeks. The current alterations in the Project Area community involve changes in the relative abundance or persistence of species within the local species pool, and does not involve the establishment of exotic taxa.

Available data suggest that the Project Area is capable of sustaining a benthic invertebrate community of a density and diversity which rivals that found in natural systems. Work in progress is directed toward understanding more about those factors which control the development of this community, and of those factors which are responsible for creating and maintaining differences in community structure among the man-made and natural areas.

INTRODUCTION

In 1986, Texasgulf Chemicals, Inc. acquired an ongoing mitigation study of the development of fish and invertebrate communities within natural and man-initiated wetlands. This study was originally supported by North Carolina Phosphate Corpporation (NCPC).

The overall goal of the mitigation research is to determine if man-made estuarine wetlands can play a role equivalent to that of natural wetlands within the estuarine ecosystem. In this report, structural features of the faunal communities of man-made and natural marshes are studied over time with the objectives of: (1) defining the faunal communities of natural and man-made wetlands; (2) determining the rate of development of the faunal community in man-made wetlands, and (3) identifying major factors controlling the rate of faunal community development in man-made wetlands. Structural features of the community consist of the distribution and abundance of the resident species, and their pattern of change over time.

Functional features of communities are relationships between members of the community (eg., competition and predation) which act collectively to influence species composition and relative abundance. A critical functional aspect of a man-made marsh is its ability to support commercially and recreationally important species of finfish and shell fish. The diverse diets typical of some of these species imply that man-made and natural estuarine wetlands may differ structurally, but not functionally. An understanding of both sets of features is needed in order to identify key factors governing wetland maturation, and to permit estimates to be made of the rate of convergence of the man-made and natural wetland communities. A functional study involving a comparison of growth and survival of the benthic feeding fish *Leiostomus xanthurus* ("spot") has been done and is included as a companion report (West, 1990).

The man-made wetland ("Project Area 2") was originally a forested region containing a mixture of softwoods and hardwoods located near the junction of Drinkwater Creek and Jacobs Creek in Beaufort County, North Carolina. These two creeks are tributaries of South Creek (Figure 1), which joins the Pamlico River near the confluence of the Pamlico River and Pamlico Sound. The Project Area was constructed as a single shallow channel (< 3m deep) with four minor tributaries (Figure 2). *Juncus roemerianus*, and three species of *Spartina (S. patens, S. cynosuroides*, and *S. alterniflora*) were planted along the margins of the waterways during 1982-1983. The Project Area was opened up to the rest of the estuary during spring 1984.

The collective surface area of the Project Area waterways is approximately 8, 361 m^2. Thus the size of the Project Area is small in comparison to the natural creeks used as control creeks in this study (Jacks Creek, 16,650 m^2; Drinkwater Creek, 31,330 m^2; Tooley Creek, 41,100 m^2). The bottom consists of clay overlain with a thin (1-10 cm) layer of fine sediment derived from local deposition and erosion processes. No attempt was made to alter, supplement or condition the sediment to enhance recruitment of larval and juvenile invertebrates.

MATERIALS AND METHODS

Collection of Samples. Invertebrates were collected seasonally (January April, July, October) using a 0.022 m^2 Ekman grab or Ponar grab at three stations (upstream, midstream, and downstream) located along the length of Jacks Creek, Drinkwater Creek, Tooley Creek, and the Project Area (Figures 1,2). Three grab samples were taken at each station. All benthic samples were sieved on a 0.5 mm mesh, and the residue remaining on the sieve was preserved in buffered 10% formalin containing the stain rose bengal (0.1 gm/L). Samples were returned to the lab, identified to the nearest taxonomic level and counted.

Data Analyses. Evaluation of (1) "total density" (average total number of organisms collected per sample), (2) "species richness" (average number of species collected per sample), and (3) the total assemblage of species present (based on the presence or absence of individual species), among the man-made area ("Project Area 2") and the natural creeks (Tooley, Drinkwater, and Jacks) was carried out by comparing the relevant data from Project Area 2 with the corresponding pooled data from the natural creeks. Pooling of the natural creek data was

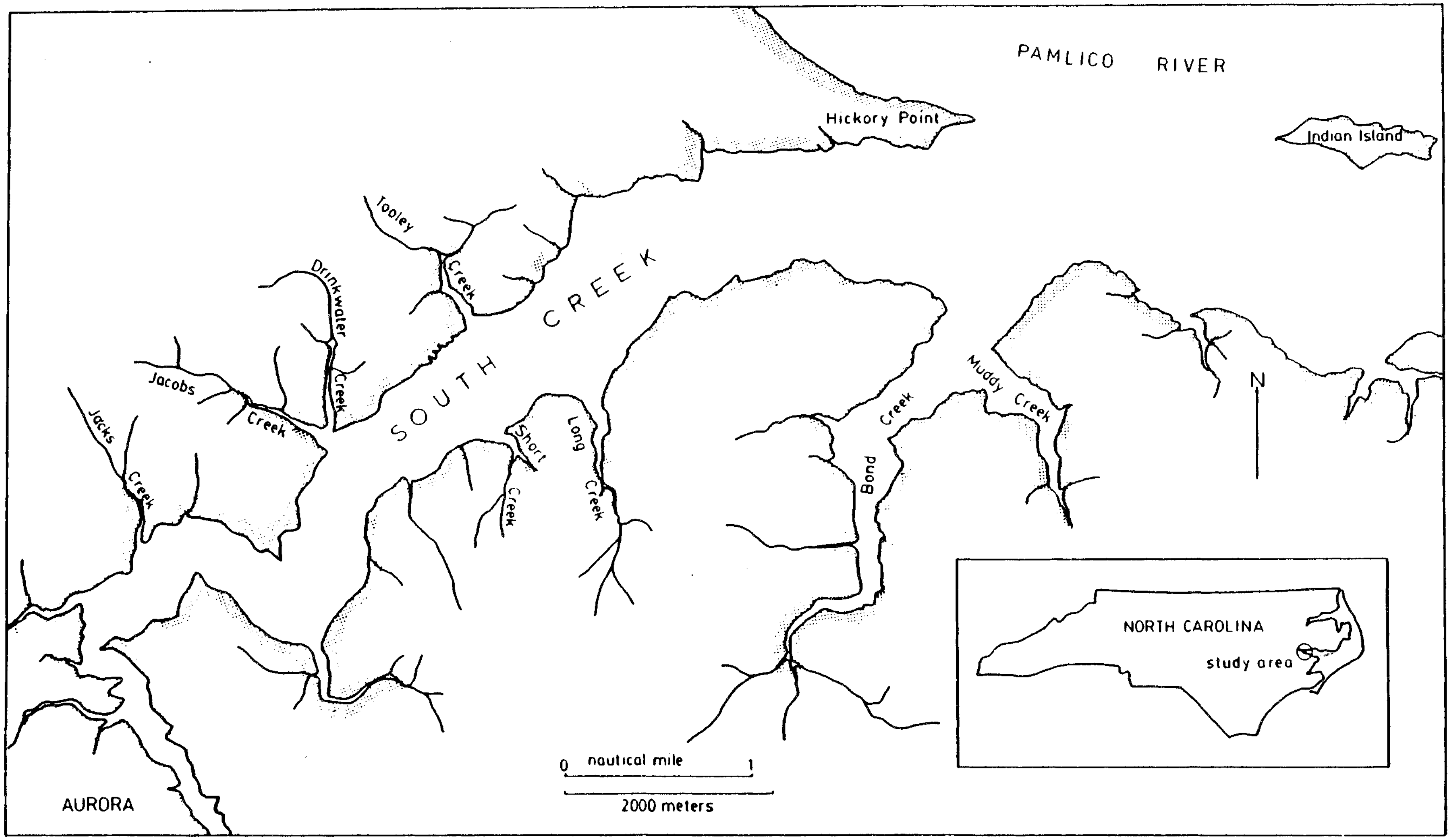

FIGURE 1. Location of the natural creeks used in the study. The man-made wetland is not shown on the map, but joins Drinkwater creek near the junction of Drinkwater Creek and Jacobs Creek.

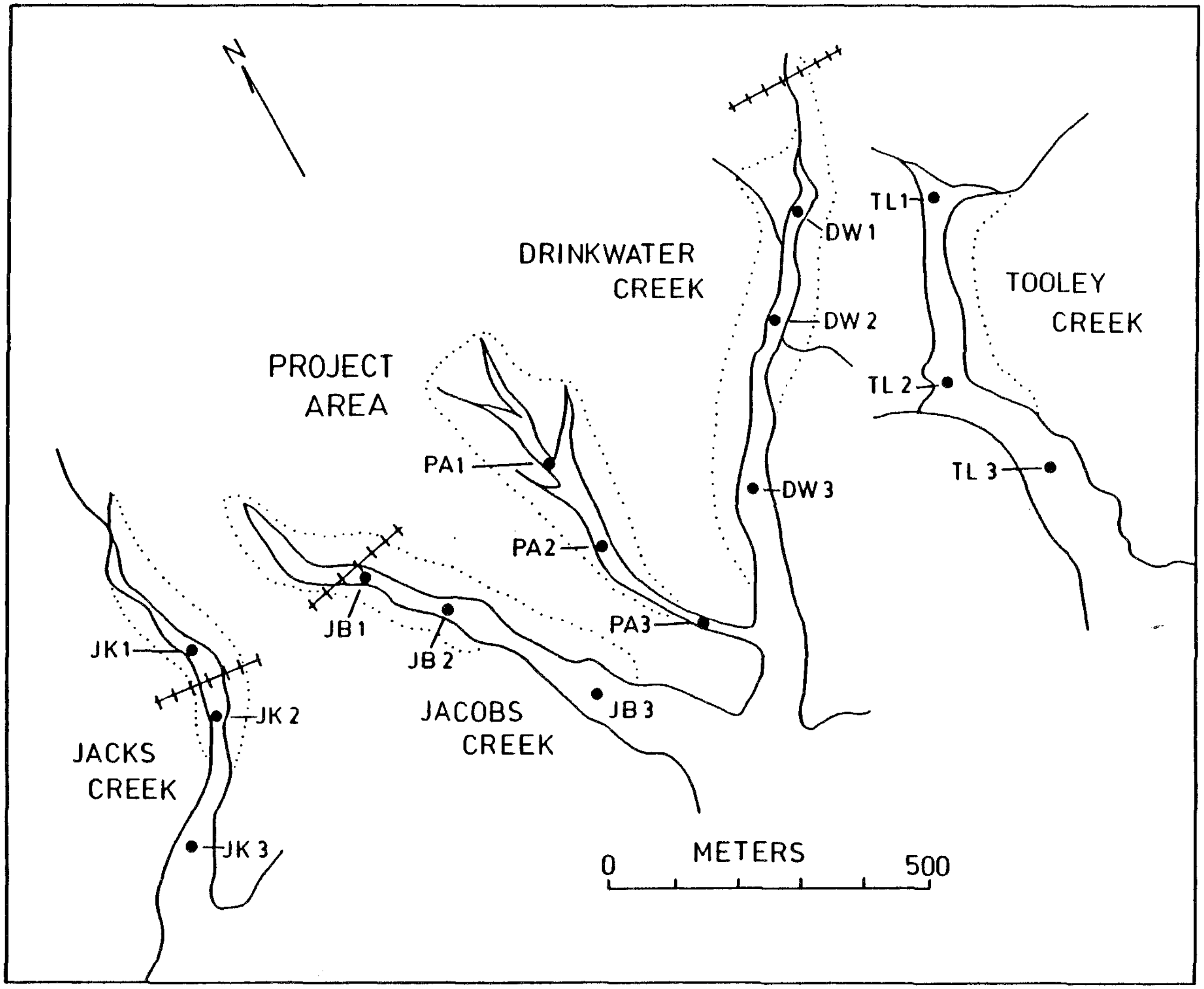

FIGURE 2. Location of the benthic invertebrate sampling stations. The dotted lines indicate the approximate boundaries of the marsh grasses (*Spartina spp., Juncus roemarianus*) which border the creeks.

justified on the basis that each creek represents a replicate "control"; pooling also permits a less complicated presentation of the data. However, data pertaining to individual natural creeks is also provided in order to account for differences between the project area and the natural creeks with regard to aspects of community structure, and to indicate the variation in community structure present among the individual control creeks. In addition, other pertinent data of the individual creeks are presented in the Appendices.

Two level nested analyses of variance (ANOVA) were used to test for differences in density or species richness among and within the creeks. The levels of nesting were stations within creeks and samples within stations. ANOVAs were run using SYSTAT software (Wilkinson, L. 1986). In the event of a significant ANOVA, *a posteriori* multiple pairwise comparisons (Tukey-Kramer method; Sokal and Rohlf 1981) were done using NTSYS-pc software (Rohlf, F.J. 1986)

Species composition of man-made and natural areas were compared using Jaccard's Index of Similarity (Sneath and Sokal, 1972; Pielou, 1985). This index uses binary (presence-absence) data and is calculated as

$$RI = a / a+b+c$$

where a = number of species present in both areas
b = number of species absent from both areas
c = number of species present in one of the two areas

Calculations of Jaccard's Index were done using the NTSYS-pc software.

Community structure of man-made and natural creeks was compared using cluster analyses. Clustering was done according to the Unweighed Pair-Group Method, with city-block distance (Manhattan metric) as the dissimilarity measure. Raw (non-normalized) data was used in all of the cluster analyses, and was in the form of the mean number of organisms of each species present per creek per season. Analyses of species composition and community structure were carried out using NTSYS-pc software (Rohlf 1986).

RESULTS 1. Water Quality (1985--1988).

Seasonal variation in temperature, salinity and dissolved oxygen was pronounced in the natural creeks (pooled data for Tooley, Drinkwater, and Jacks creeks) and the Project Area (Figure 3). Temperature ranged from 2-4 ^{O}C in winter to 30-33 ^{O}C in summer. Dissolved oxygen varied inversely with temperature, showing minimal summer values of 3-4 mg/L. Salinity typically rose in the summer and declined during the late winter and spring. The year 1987 was anomalous and evinced only a minor summer increase in salinity.

The data general similarities in water quality values among the natural creeks and the Project Area. It should be noted, however, that these data address only gross trends in temporal variation in water quality, because the time scale of sampling (trimonthly) far exceeded the time scale of significant change in water quality parameters (< 1 day). Nevertheless, the data are useful in providing some indication of spatial variation in water quality within the creeks. The direction and the magnitude of the salinity gradient was similar within both man-made and natural areas, increasing by 2-4 ppt between the upstream and downstream stations. Temperature often decreased in the downstream direction as a result of the increase in station depth. Station depth ranges were as follows: 50-100 cm (upstream); 70-120 cm (midstream); and 90-170 cm (downstream).

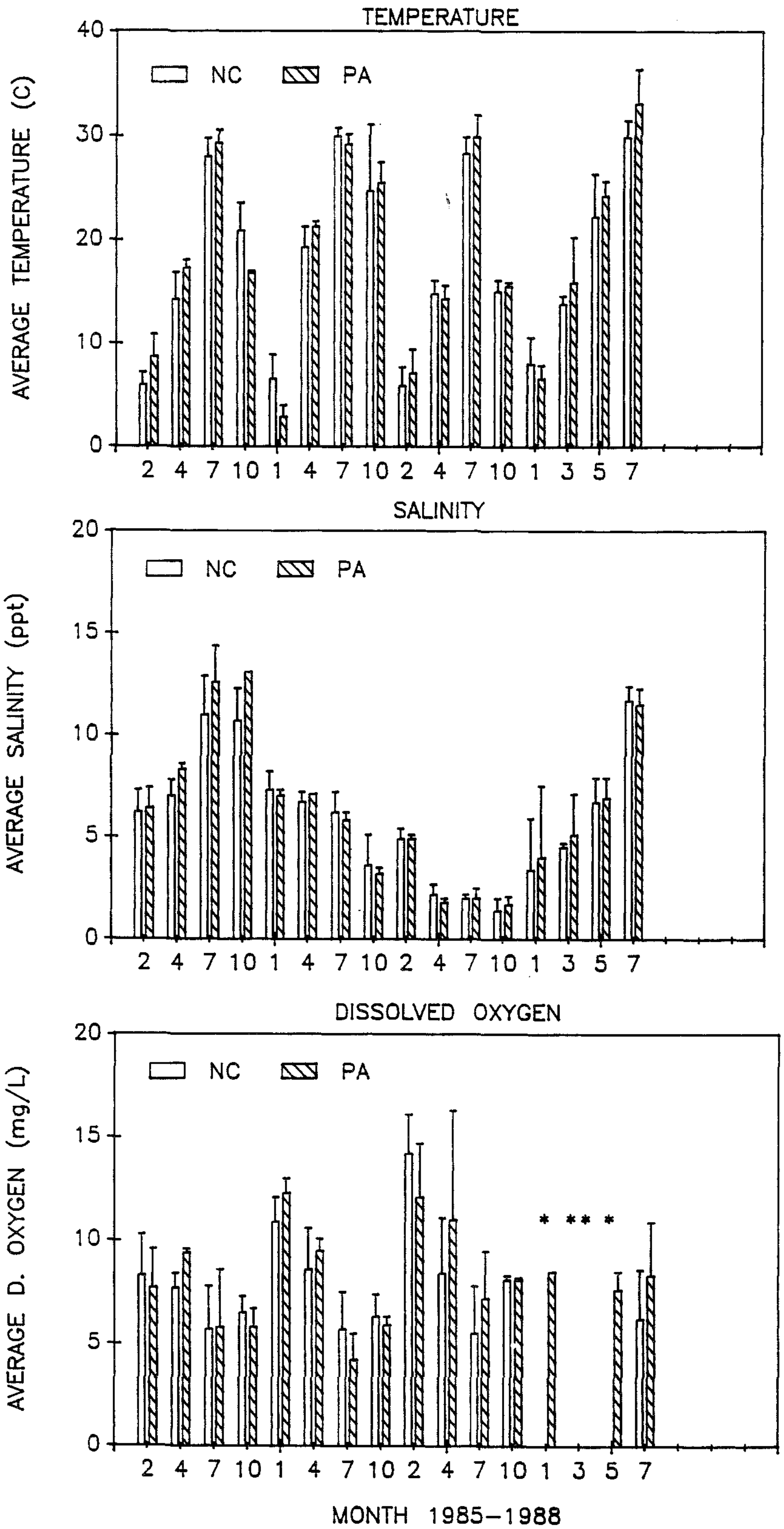

FIGURE 3. Seasonal variation in water quality in the natural creeks (NC; (Tooley, Drinkwater, and Jacks) and man-made creek (PA; Project Area 2) during 1985-1988. Values are the averages of readings taken at the upstream, mid-stream, and downstream stations in each area during the indicated month. *=no readings taken.

RESULTS 2a. Total Densities and Species Richness of Benthic Organisms. (July 1985-July 1986).

Due to the complexity of the data, descriptions of the faunal community in the natural and man-made areas are divided into three sections (Results 2a-e; 3a-e; 4a-e) according to the three annual July-to-July sampling periods between 1985 and 1988. Summaries are provided at the end of each subsection.

Total densities of benthic organisms varied with season and location within the study areas (stations) in both the Project Area and the natural creeks (Figure 4). The temporal patterns of change in total density were qualitatively similar in the man-made and natural areas. At the upstream station, densities were highest in the winter (January), intermediate in the fall (October) and spring (April), and lowest in the summer (July). This temporal symmetry was absent, however, from the midstream and downstream stations, which showed lowest densities in the summer of 1985, and fairly consistent, higher densities for most of the remainder of the year.

Total densities in the project area usually exceeded those in the natural creeks throughout the sampling period (Figure 4), with significant differences being obtained in each season except July 1985 and April 1986 (Table 1) However, with the exception of the October 1985 samples, *a posteriori* analyses (Multiple Paired Comparisons; Sokal and Rohlf, 1981) failed to reveal any significant differences in total density among equivalent stations in the man-made and natural creeks (e.g., Station 1 PA vs Station 1 NC, etc.) (Table 2). This discrepancy results from the small actual numerical differences between corresponding stations, and the less sensitive (more conservative) nature of the *a posteriori* tests. In October 1985, total density of the midstream station of Project Area was approximately three times that of the natural creeks.

Table 1 also indicates total densities differed significantly among stations within the natural creeks during April and July 1986. In these cases, densities were lowest at the upstream station.

Temporal changes in species richness were similar in the Project Area and the Natural Creeks during July 1985-July 1986 (Figure 5). Average numbers of species per sample were typically greatest in the winter, and lowest in the summer. Quantitative differences occurred only in the July 1986 samples, with significantly fewer species found at the midstream (2) station in the Project Area than in the corresponding station in the natural creeks (Tables 3,4).

RESULTS 2b. Community Composition: Representation of taxa. (July 1985-July 1986)

Table (5) lists the benthic fauna found in just the Project Area or just the natural creeks ("Lim"), and those common to both areas ("Ubiq") during each season between July 1985-1986. Similar listings pertinent to Project Area 2 and each natural creek are provided in the Appendices.

Faunal representation can be arranged into five categories: (1) taxa restricted to the natural creeks; (2) taxa restricted to Project Area 2; (3) ubiquitous taxa; (4) taxa found initially in the natural creeks and later in both areas; and (5) taxa with mixed representation in the study areas. Seven taxa were found only in the natural creeks throughout the study period. These taxa included three polychaetes (*Neanthes succinea*, *Capitella capitata*, and *Glycera dibranchiata*), two crustaceans (the isopod *Sphaeroma quadridentatum*, and an unidentified cumacean), and two molluscs (the gastropods *Hydrobia sp*., and the bivalve *Rangia cuneata*). All of these organisms were rare in that they were found infrequently and in low numbers. The only animal limited to the Project Area was the mud crab, *Rhithropanopeus harrisii*.

Six taxa were ubiquitous and present during each season. The polychaete species (*Mediomastus sp*., *Laeonereis culveri*, *Streblospio benedicti*, and *Hobsonia florida*), and the

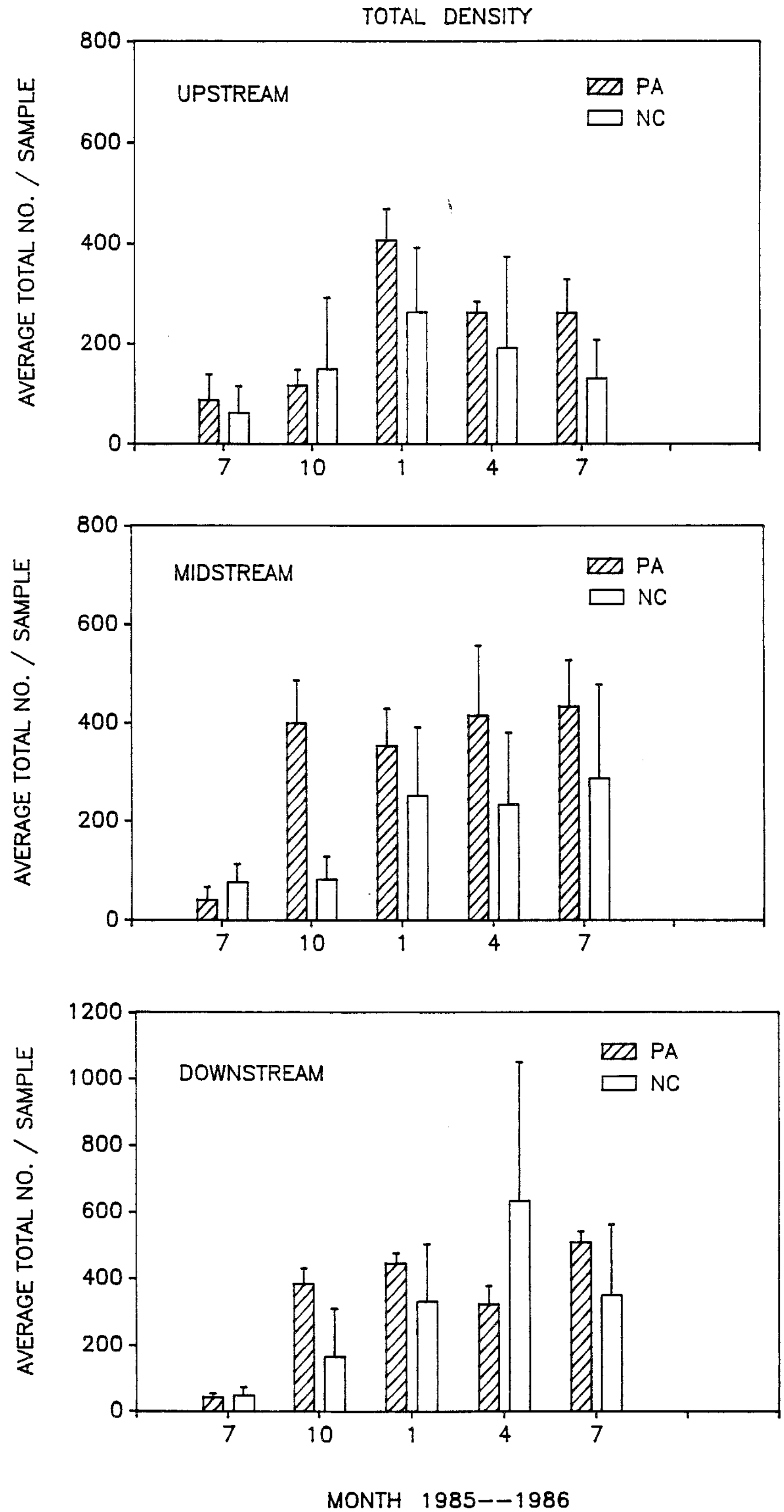

FIGURE 4. Total faunal densities of the natural creeks (NC) and Project Area 2 (PA) during July 1985-July 1986. Each area was sampled at an upstream, midstream and downstream station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation. Note the difference in the density scale for the downstream station.

TABLE 1. Comparisons of total densities of benthic invertebrates in the Project Area and natural creeks during July 1985-July 1986. Two level nested analyses of variance (stations nested within creeks, and samples nested within stations) were run on the seasonal data sets during July 1985--July 1986. Only the significant ANOVAs are shown. Probablility values (P) less than or equal to 0.05 are denoted by an asterisk.

OCTOBER 1985

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	1.160	1	1.160	12.531	0.001 *
AMONG STATIONS (PA)	0.562	2	0.281	3.036	0.064
AMONG STATIONS (NC)	0.220	2	0.110	1.188	0.319
ERROR	2.685	29	0.093		

JANUARY 1986

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.287	1	0.287	6.094	0.020 *
AMONG STATIONS (PA)	0.016	2	0.008	0.173	0.842
AMONG STATIONS (NC)	0.049	2	0.024	0.516	0.602
ERROR	1.317	28	0.047		

APRIL 1986

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.185	1	0.185	1.314	0.261
AMONG STATIONS (PA)	0.049	2	0.024	0.173	0.842
AMONG STATIONS (NC)	1.355	2	0.677	4.816	0.016 *
ERROR	3.937	28	0.141		

JULY 1986

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.609	1	0.609	7.129	0.012 *
AMONG STATIONS (PA)	0.139	2	0.069	0.813	0.453
AMONG STATIONS (NC)	0.712	2	0.356	4.168	0.025 *
ERROR	2.563	30	0.085		

TABLE 2. Results of the Tukey-Kramer pairwise multiple comparisons test (Sokal and Rohlf, 1983) for the significant ANOVA (October 1985) comparing total densities among and within the test areas during July 1985-July 1986 (Project Area=Pa; Natural Creeks=NC). Numbers refer to stations (1=upstream; 2=midstream; 3=downstream). Densities of underlined stations are not significantly different. Stations are ranked from left to right in order of increasing density.

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            NC      NC      PA      NC      PA      PA

            2       1       1       3       3       2
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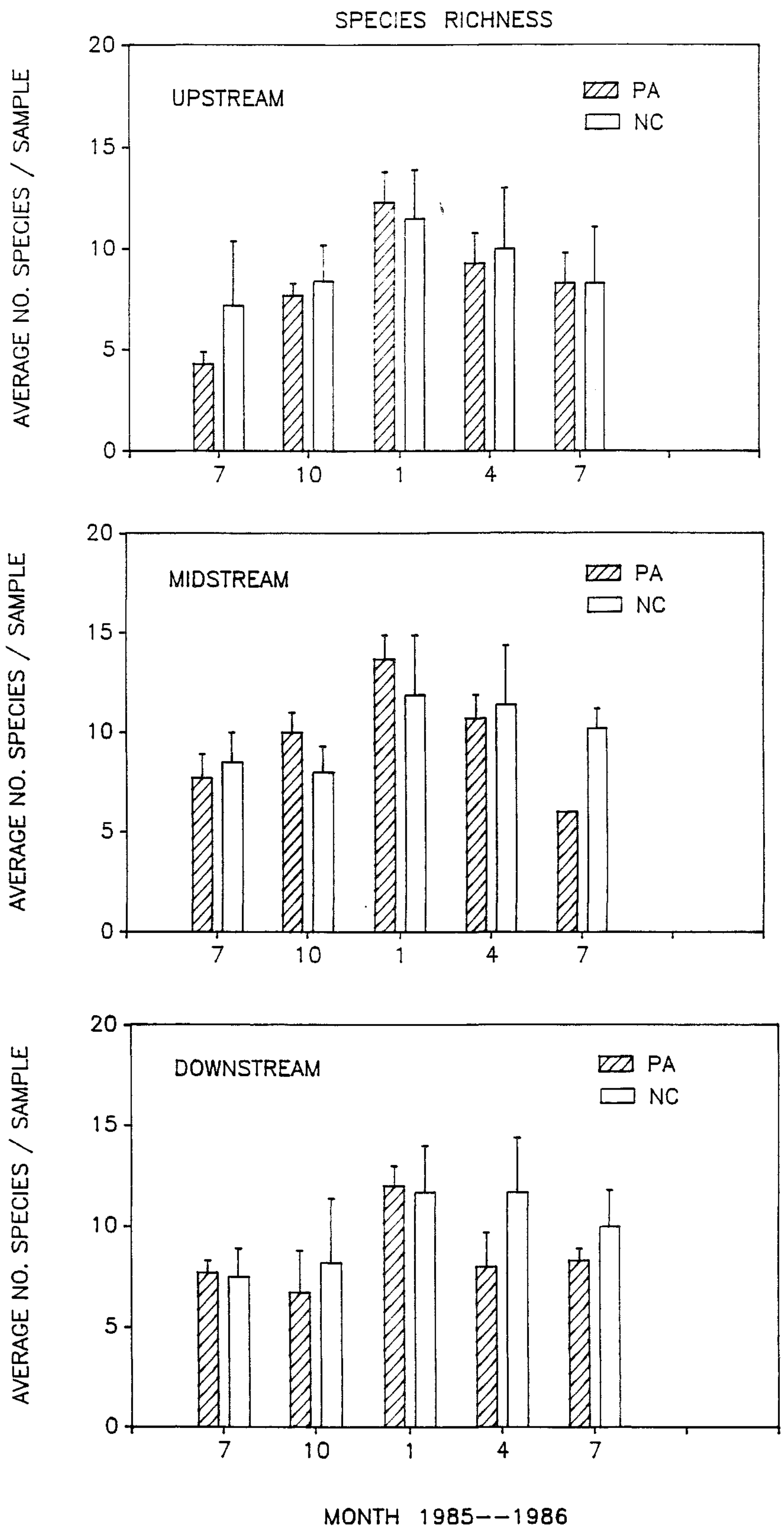

FIGURE 5. Species richness of Project Area 2 (PA) and the natural creeks (NC) during July 1985-July 1986. Each area was sampled at an upstream, midstream and downstream station. Species richness is presented as the mean number of species per 0.0225 M^2 sample + 1 standard deviation.

TABLE 3. Comparisons of species richness (mean number of species/sample) benthic invertebrates in the Project Area and Natural Creeks. Two level nested analyses of variance (stations nested within creeks, and samples nested within stations) were run on the seasonal data sets during July 1985--July 1986. Only the significant ANOVAs are shown. Probablility values (P) less than or equal to 0.05 are denoted by an asterisk.

JULY 1986

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	26.009	1	26.009	7.734	0.009 *
AMONG STATIONS (PA)	10.889	2	5.444	1.619	0.215
AMONG STATIONS (NC)	19.185	2	9.593	2.852	0.073
ERROR	100.889	30	3.363		

TABLE 4. Results of the Tukey-Kramer pairwise multiple comparisons test for the significant ANOVA (July 1986) comparing species richness (mean number of species/sample) among and within the test areas during July 1985-July 1986 Project Area=Pa; Natural Creeks=NC. Numbers refer to stations (1=upstream; 2=midstream; 3=downstream). Species richness of underlined stations are not significantly different. Significance was determined by the Tukey-Kramer method (Sokal and Rohlf, 1983). Stations are ranked from left to right in order of increasing species richness.

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PA    PA    PA    NC    NC    NC
2     1     3     1     3     2
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TABLE 5. Representation of benthic invertebrates in the test areas during July 1985-July 1986. For a given season, taxa are indicated as being either limited ("Lim") to just Project Area 2 (PA) or just the Natural Creeks (NC), or ubiquitous ("Ubiq") and found in both areas. The NC listings indicate parenthetically the number of natural creeks in which a given species as found. Two natural creeks were sampled in July 1985; three natural creeks were sampled during the remaining seasons.

	7/85		10/85		1/86		4/86		7/86	
Species/Taxon	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq
ANNELIDA-Oligochaeta	NC(2)			x		x		x	NC(3)	
ANNELIDA-Polychaeta										
Mediomastus sp.		x		x		x		x		x
Heteromastus filiformis	NC(1)			x	NC(1)				NC(3)	
Laeonereis culveri		x		x		x		x		x
Neanthes succinea	NC(1)									
Polydora ligni		x		x		x		x	PA	
Scolecolepides virides	PA		NC(1)			x		x	PA	
Streblospio benedicti		x		x		x		x		x
Hobsonia florida		x		x		x		x		x
Eteone heteropoda			NC(3)		NC(3)		NC(3)			x
Capitella capitata					NC(1)					
Glycera dibranchiata									NC(1)	
ARTHROPODA-Uniramia										
Chironomidae		x		x		x		x		x
Insect A			PA						NC(1)	
ARTHROPODA-Crustacea										
Mysidopsis bigelowi		x	PA		PA		NC(1)			
Neomysis americanus										x
Cyathura polita	NC(1)				NC(1)					x
Corophium lacustre	NC(1)			x		x	PA			
Leptocheirus plumulosus		x	PA		PA		PA			x
Gammarus mucronatus					PA		NC(1)			
Gammarus tigrinus	NC(1)					x		x	PA	
Edotea sp.		x		x		x	NC(3)			
Hargeria rapax	NC(1)								PA	
Spaheroma quadridentatum			NC(1)		NC(1)					
Palaemonetes pugio						x				
Palaemonetes vulgaris										
Cumacea			NC(1)				NC(1)			
Rithropanopeus harrisii							PA			

Table 5 (Continued). Representation of benthic invertebrates in the test areas during July 1985-July 1986. For a given season, taxa are indicated as being either limited ("Lim") to just Project Area 2 (PA) or just the Natural Creeks (NC), or ubiquitous ("Ubiq") and found in both areas. The NC listings indicate parenthetically the number of natural creeks in which a given species as found. Two natural creeks were sampled in July 1985; three natural creeks were sampled during the remaining seasons.

Species/Taxon	7/85 Lim	7/85 Ubiq	10/85 Lim	10/85 Ubiq	1/86 Lim	1/86 Ubiq	4/86 Lim	4/86 Ubiq	7/86 Lim	7/86 Ubiq
MOLLUSCA-Bivalvia										
Macoma balthica						x		x		x
Macoma phenax	NC(2)			x		x				x
Munidea lateralis			NC(1)		PA		PA			x
Rangia cuneata									NC(1)	
MOLLUSCA-Gastropoda										
Hydrobia sp.							NC(1)			
CNIDARIA-Anthozoa										
Edwardsia sp.							NC(1)		PA	
PLATYHELMINTHES					NC(1)		NC(1)		PA	
RHYNCOCOELA	NC(1)			x			PA			x

chironomid (insect) larvae are often very abundant, and consequently they tended to dominate the collections during most of the year. The spatial and temporal distribution of the particularly abundant organisms are discussed in more detail below (Numerical Dominants). The bivalve *Macoma balthica* was also very common but did not achieve the densities of the other taxa.

Eteone heteropoda and *Heteromastus filiformis* (polychaetes) and *Cyathura polita* (isopod) were found only in the natural creeks during three of the four sampling seasons. The remaining 21 taxa showed irregular representation in both areas during all or part of the study period. Some of these species also occurred in high densities (e.g. oligochaetes, the polychate *Polydora ligni*, and the amphipod crustaceans *Corophium lacustre* and *Leptocheirus plumulosus*).

Results 2c. Numerical Dominants (July 1985-July 1986)

Eight species accounted for at least 90% of all fauna collected in the Project Area and Natural Creeks during each season (Table 6). The species composition of the numerical dominants showed the greatest variation among all study creeks during the spring (April), when densities and species richness are near their annual peak levels (Table 7). The cadre of abundant organisms in Jacks Creek often varied from that of the other natural creeks by containing different species (e.g. the bivalves *Macoma balthica*, *M. phenax*, and the isopod crustacean *Edotea sp.*), or by having a markedly different rank order of abundance (e.g. the polychaete *Mediomastus sp.* did not achieve comparably high densities in Jacks Creek).

The numerically abundant species in the Project Area were in part distinct from those of the natural creeks. Compositional differences between the Project Area and the natural creeks in this regard were the result of a poor representation of oligochaetes in the Project Area, and the occurrence in the Project Area of relatively high numbers of the amphipod *Leptocheirus plumulosus* (July 1985-April 1986), the polychaete *Scolecolepides viridis* (July 1985), and the solitary burrowing anemone *Edwardsia sp.* (April and July 1986). The Project Area also showed highly skewed densities of its numerical dominants in July and October 1985, in which a single species (*L. plumulosus*, and *Mediomastus sp.*, respectively) accounted for nearly 60% of the total fauna.

Although the identities of the numerically dominant species varied with time and creek, six species consistently occurred in relatively high numbers throughout most of the year. These species consisted of Oligochaeta, the polychaetes *Mediomastus sp.*, *Hobsonia florida*, *Streblospio benedicti*, and *Laeonereis culveri*, and Chironomid larvae. The distribution and abundance of each of these species within the Project Area and the natural creeks are presented in Figures (6-11).

Densities of oligochaetes, *Mediomastus sp.*, and *L. culveri* varied significantly both among and within the creeks during all seasons sampled (Table 8). Differences in the abundance of these species in the control creeks were pronounced owing to their low densities in Jacks Creek and high densities in Tooley Creek and Drinkwater Creek. As a result density profiles of *Mediomastus sp.* and *L. culveri* in the Project Area fell well within the range defined by the natural creeks. Oligochates were exceptional in this regard owing to their virtual absence from the Project Area during most of the year.

In contrast to the large differences in density of *Mediomastus sp.* and *L. culveri* among the various creeks, the distribution of these species within the creeks was consistently similar. Thus *Mediomastus sp.* and *L. culveri* occurred in greatest numbers at the downstream station and upstream station, respectively, in the natural creeks and the Project Area.

Densities of chironomid larvae, and especially *H. florida*, and *S. benedicti*, were more similar among and within the creeks than were those of the oligochaetes, *Mediomastus sp.* and *L. culveri*. Among creek differences in densities of *H. florida* and *S. benedicti* were significant in only two of the five sampling periods (Table 8). All three of these species showed a more even distribution within the creeks than oligochaetes, *Mediomastus sp.*, and *L. culveri*. Thus there

TABLE 6. Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1985--July 1986. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

JULY 1985

DRINKWATER			JACKS		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Laeonereis culveri	26.4	175	*Laeonereis culveri*	42.1	198
Oligochaeta	15.2	101	Chironomidae	20.6	97
Chironomidae	15.1	100	*Hobsonia florida*	13.2	62
Mediomastus sp.	13.0	86	Oligochaeta	6.8	32
Streblospio benedicti	6.9	46	*Streblospio benedicti*	4.9	23
Polydora ligni	6.5	43	*Mysidopsis bigelowi*	4.5	21
Hobsonia florida	5.6	37	*Edotea sp.*	3.2	15
Mysidopsis bigelowi	2.6	17	*Mediomastus sp.*	1.7	8
SUM	91.1	605		97.0	456
TOTAL	100.0	664		100.0	470

PROJECT AREA 2

SPECIES	%	NUMBER	SPECIES
Leptocheirus plumulosus	58.4	301	
Hobsonia florida	9.1	47	
Mysidopsis bigelowi	7.0	36	
Streblospio benedicti	5.6	29	
Polydora ligni	4.9	25	
Laeonereis culveri	4.9	25	
Mediomastus sp.	3.9	20	
Scolecolepides viridis	3.9	20	
SUM	97.7	503	
TOTAL	100.0	515	

TABLE 6 (Continued). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1985--July 1986. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

OCTOBER 1985

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	31.9	287	*Mediomastus sp.*	47.2	731
Mediomastus sp.	19.6	177	Oligochaeta	16.8	261
Hobsonia florida	19.1	172	*Streblospio benedicti*	10.5	163
Streblospio benedicti	11.3	101	*Hobsonia florida*	9.5	147
Laeonereis culveri	8.2	74	Chironomidae	6.3	98
Chironomidae	5.7	52	*Laeonereis culveri*	5.8	90
Corophium lacustre	0.8	7	*Polydora ligni*	0.8	12
Edotea sp.	0.8	7	*Macoma phenax*	0.8	12
SUM	97.4	878		97.7	1514
TOTAL	100.0	901		100.0	1550

JACKS			PROJECT AREA		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Hobsonia florida	36.0	278	*Mediomastus sp.*	67.1	1816
Chironomidae	17.9	138	*Hobsonia florida*	16.6	448
Streblospio benedicti	16.3	126	Chironomidae	6.4	173
Mediomastus sp.	7.4	57	*Streblospio benedicti*	5.3	143
Polydora ligni	7.0	54	*Laeonereis culveri*	2.0	54
Laeonereis culveri	6.5	50	*Corophium lacustre*	0.7	19
Oligochaeta	3.4	26	Rhyncocoela	0.6	15
Corophium lacustre	2.6	20	*Leptocheirus plumulosus*	0.4	11
SUM	97.0	749		99.0	2679
TOTAL	100.0	772		100.0	2705

TABLE 6 (Cont). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1985--July 1986. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

JANUARY 1986

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	31.5	544	*Mediomastus sp.*	32.0	8817
Oligochaeta	19.1	329	*Streblospio benedicti*	20.2	516
Streblospio benedicti	17.7	305	Oligochaeta	15.0	382
Hobsonia florida	11.3	195	*Hobsonia florida*	14.5	370
Chironomidae	8.6	148	Chironomidae	9.8	251
Laeonereis culveri	3.9	67	*Corophium lacustre*	1.7	44
Macoma balthica	2.5	43	*Laeonereis culveri*	1.6	40
Corophium lacustre	2.1	36	*Eteone heteropoda*	1.5	39
SUM	96.7	1668	SUM	96.3	2459
TOTAL	100.0	1725	TOTAL	100.0	2553

JACKS			PROJECT AREA		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Hobsonia florida	44.3	275	*Hobsonia florida*	29.8	1077
Chironomidae	23.3	662	Chironomidae	20.7	748
Streblospio benedicti	18.1	514	*Mediomastus sp.*	17.0	617
Corophium lacustre	4.5	129	*Streblospio benedicti*	11.2	407
Polydora ligni	3.2	91	*Corophium lacustre*	7.4	266
Oligochaeta	2.9	83	*Leptocheirus plumulosus*	6.5	234
Laeonereis culveri	2.4	67	Oligochaeta	4.1	150
Mediomastus sp.	2.1	60	*Laeonereis culveri*	1.1	38
SUM	95.6	2719		97.7	3537
TOTAL	100.0	2843		100.0	3619

TABLE 6 (Continued). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1985--July 1986. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

APRIL 1986

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	33.0	1247	*Mediomastus sp.*	31.4	1481
Oligochaeta	31.1	1173	*Leptocheirus plumulosus*	20.6	969
Hobsonia florida	8.7	327	Oligochaeta	12.6	592
Streblospio benedicti	8.5	322	*Hobsonia florida*	12.4	584
Gammarus mucronatus	4.6	175	*Streblospio benedicti*	11.4	535
Chironomidae	4.0	152	Chironomidae	5.8	273
Gammarus tigrinus	3.4	129	*Laeonereis culveri*	1.7	78
Laeonereis culveri	2.2	81	*Macoma balthica*	0.9	44
SUM	95.5	3606	SUM	96.7	4556
TOTAL	100.0	3778	TOTAL	100.0	4711

JACKS			PROJECT AREA		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Hobsonia florida	44.3	275	*Mediomastus sp.*	28.5	857
Streblospio benedicti	23.6	146	*Streblospio benedicti*	16.9	509
Chironomidae	15.0	93	Chironomidae	16.1	484
Laeonereis culveri	5.0	31	*Gammarus tigrinus*	14.2	425
Oligochaeta	3.8	24	*Hobsonia florida*	11.8	355
Polydora ligni	2.5	16	*Corophium lacustre*	4.5	136
Macoma balthica	1.8	11	*Laeonereis culveri*	4.2	125
Mediomastus sp.	1.6	10	*Edwardsia sp.*	1.3	39
SUM	97.6	606		97.6	2930
TOTAL	100.0	621		100.0	3003

TABLE 6 (Cont). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1985--July 1986. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

JULY 1986

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	58.2	1400	*Mediomastus sp.*	61.4	2237
Oligochaeta	17.4	420	*Laeonereis culveri*	12.4	452
Leptocheirus plumulosus	12.9	311	*Leptocheirus plumulosus*	9.6	351
Chironomidae	3.5	85	Oligochaeta	6.4	232
Laeonereis culveri	2.7	65	Chironomidae	5.8	210
Mysidopsis bigelowi	1.1	27	*Streblospio benedicti*	1.5	53
Streblospio benedicti	1.0	25	*Hobsonia florida*	0.7	26
Rhyncocoela	0.6	15	Rhyncocoela	0.6	22
SUM	97.5	2348		98.3	3583
TOTAL	100.0	2407		100.0	3645

JACKS			PROJECT AREA		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	32.3	284	*Mediomastus sp.*	66.0	2383
Laeonereis culveri	28.7	252	*Laeonereis culveri*	22.8	825
Mediomastus sp.	16.8	148	*Leptocheirus plumulosus*	4.0	145
Chironomidae	5.2	46	Chironomidae	1.9	67
Macoma phenax	3.5	31	*Polydora ligni*	1.8	66
Leptocheirus plumulosus	3.2	28	*Hobsonia florida*	1.7	63
Capitella capitata	2.5	22	*Streblospio benedicti*	0.8	30
Hobsonia florida	1.9	17	*Edwardsia sp.*	0.4	14
SUM	94.2	828		99.4	3593
TOTAL	100.0	879		100.0	3613

TABLE 7. Similarity of species composition of the numerically abundant fauna in the man-made and natural creeks during July 1985-July 1986. The values presented are Jaccard's similarity indices. A value of 1.00 denotes identical species composition.

JULY 1985

	DW	JK	PA
DW	1.00		
JK	0.77	1.00	
PA	0.60	0.45	1.00

OCTOBER 1985

	DW	JK	TL	PA
DW	1.00			
JK	0.77	1.00		
TL	0.60	0.77	1.00	
PA	0.45	0.60	0.60	1.00

JANUARY 1986

	DW	JK	TL	PA
DW	1.00			
JK	0.77	1.00		
TL	0.77	0.77	1.00	
PA	0.77	0.77	0.77	1.00

APRIL 1986

	DW	JK	TL	PA
DW	1.00			
JK	0.77	1.00		
TL	0.60	0.60	1.00	
PA	0.45	0.45	0.60	1.00

JULY 1986

	DW	JK	TL	PA
DW	1.00			
JK	0.77	1.00		
TL	0.60	0.60	1.00	
PA	0.60	0.45	0.45	1.00

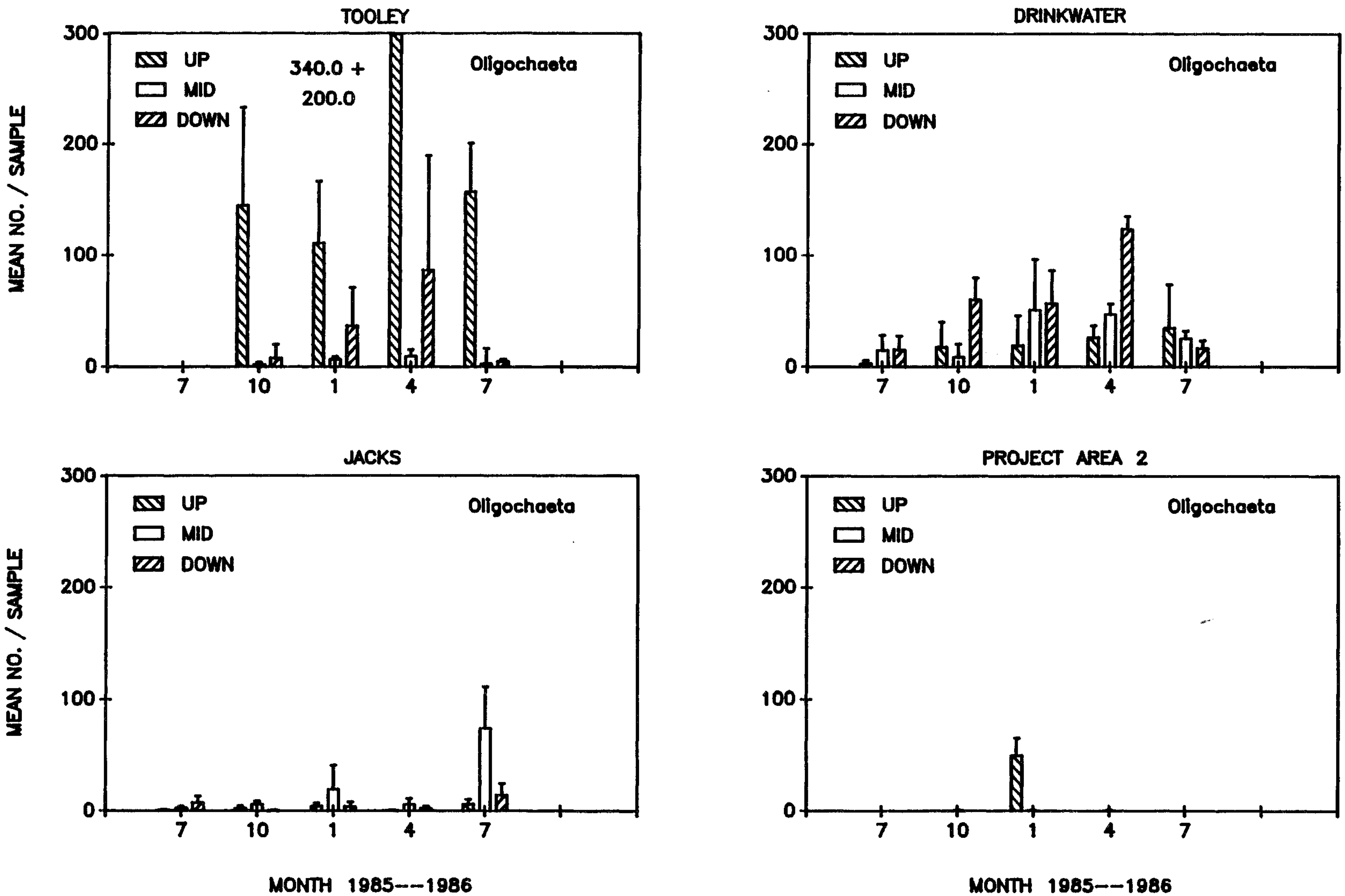

FIGURE 6. Distribution and abundance of the Oligochaeta in the natural creeks and Project Area 2 during July 1985-July 1986. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

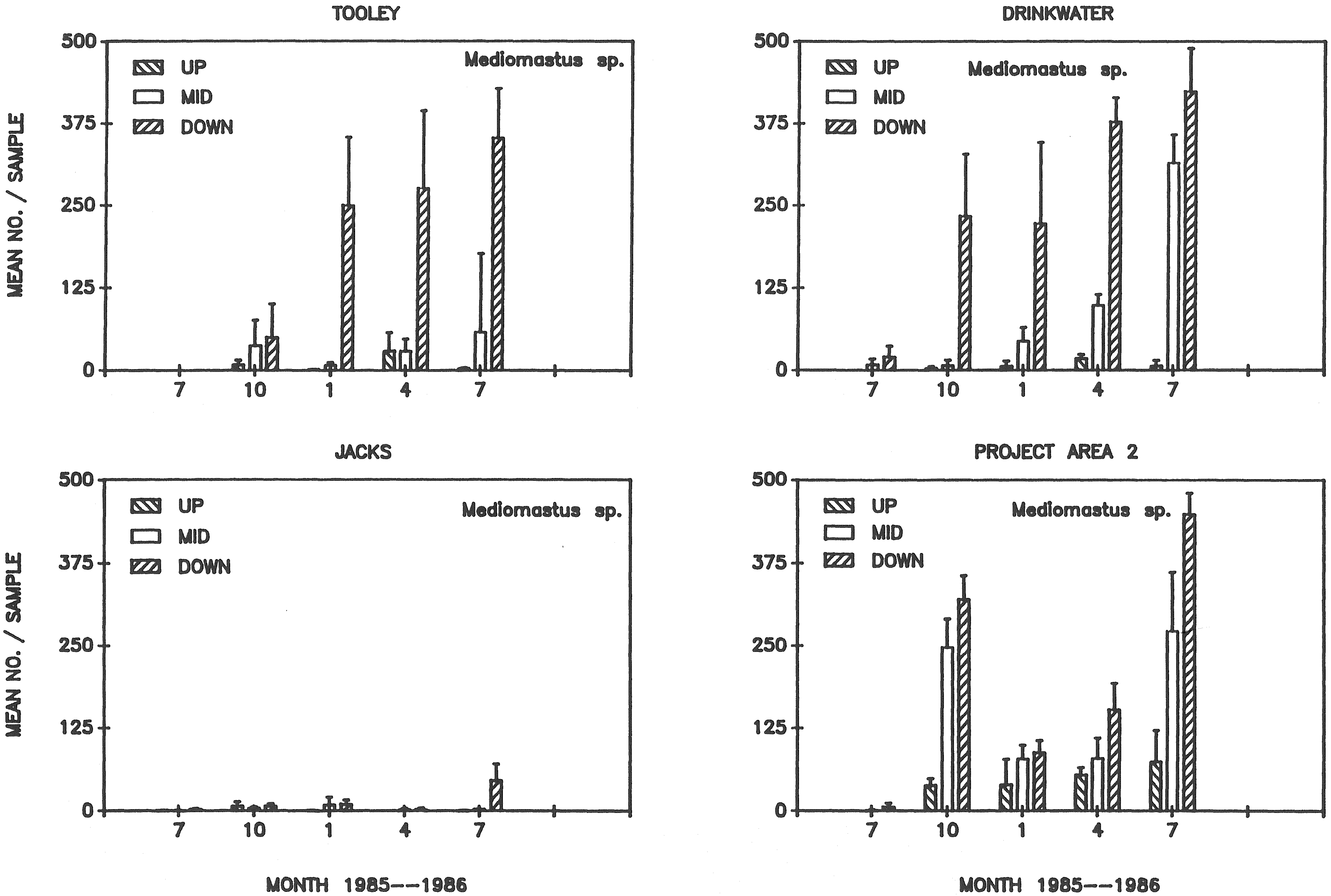

FIGURE 7 Distribution and abundance of *Mediomastus sp.*in the natural creeks and Project Area 2 during July 1985-July 1986. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

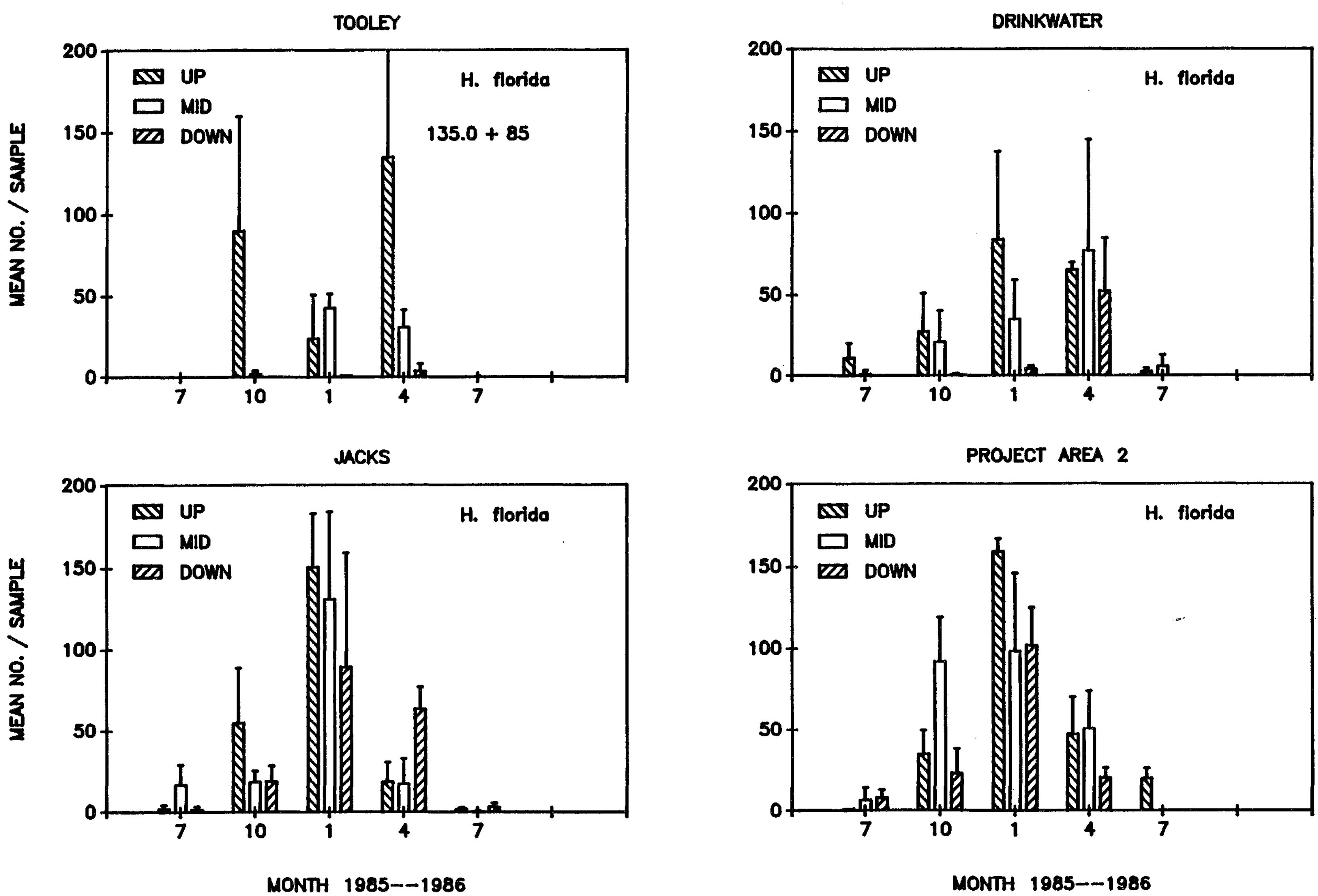

FIGURE 8. Distribution and abundance of *Hobsonia florida* in the natural creeks and Project Area 2 during July 1985-July 1986. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

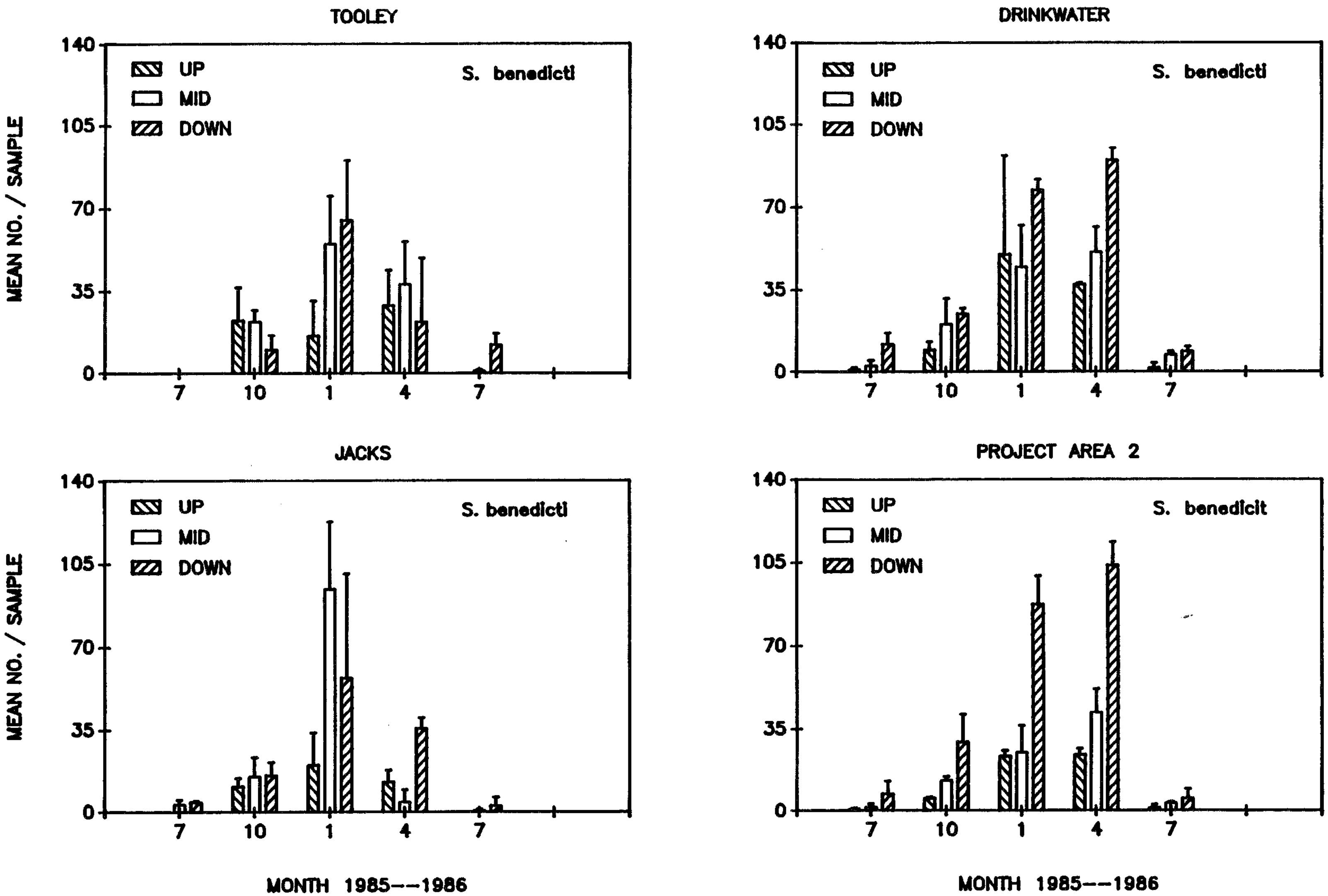

FIGURE 9. Distribution and abundance of *Streblospio benedicti* in the natural creeks and Project Area 2 during July 1985-July 1986. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

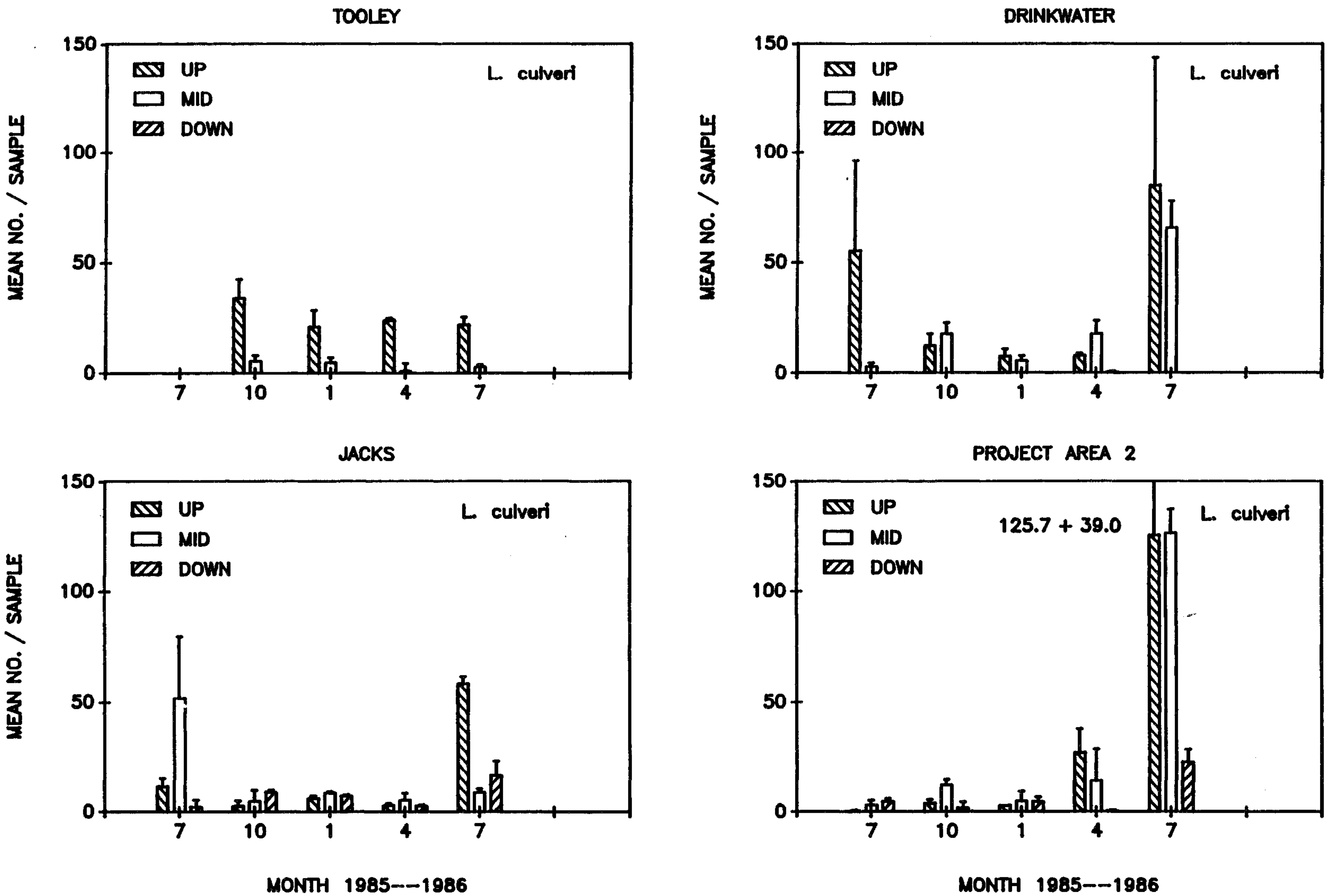

FIGURE 10. Distribution and abundance of *Laeonereis culveri* in the natural creeks and Project Area 2 during July 1985-July 1986. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

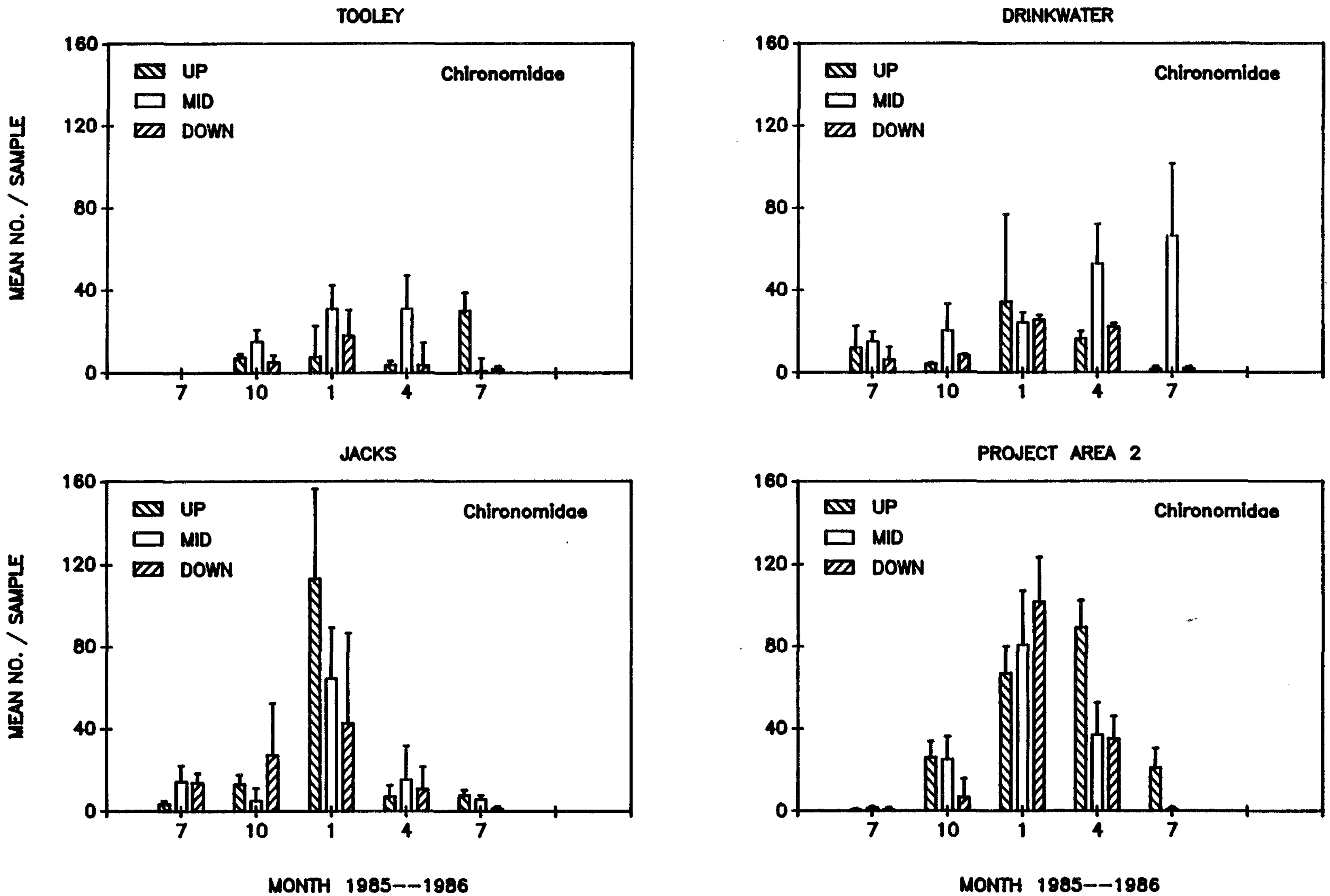

FIGURE 11. Distribution and abundance of chironomid larvae in the natural creeks and Project Area 2 during July 1985-July 1986. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

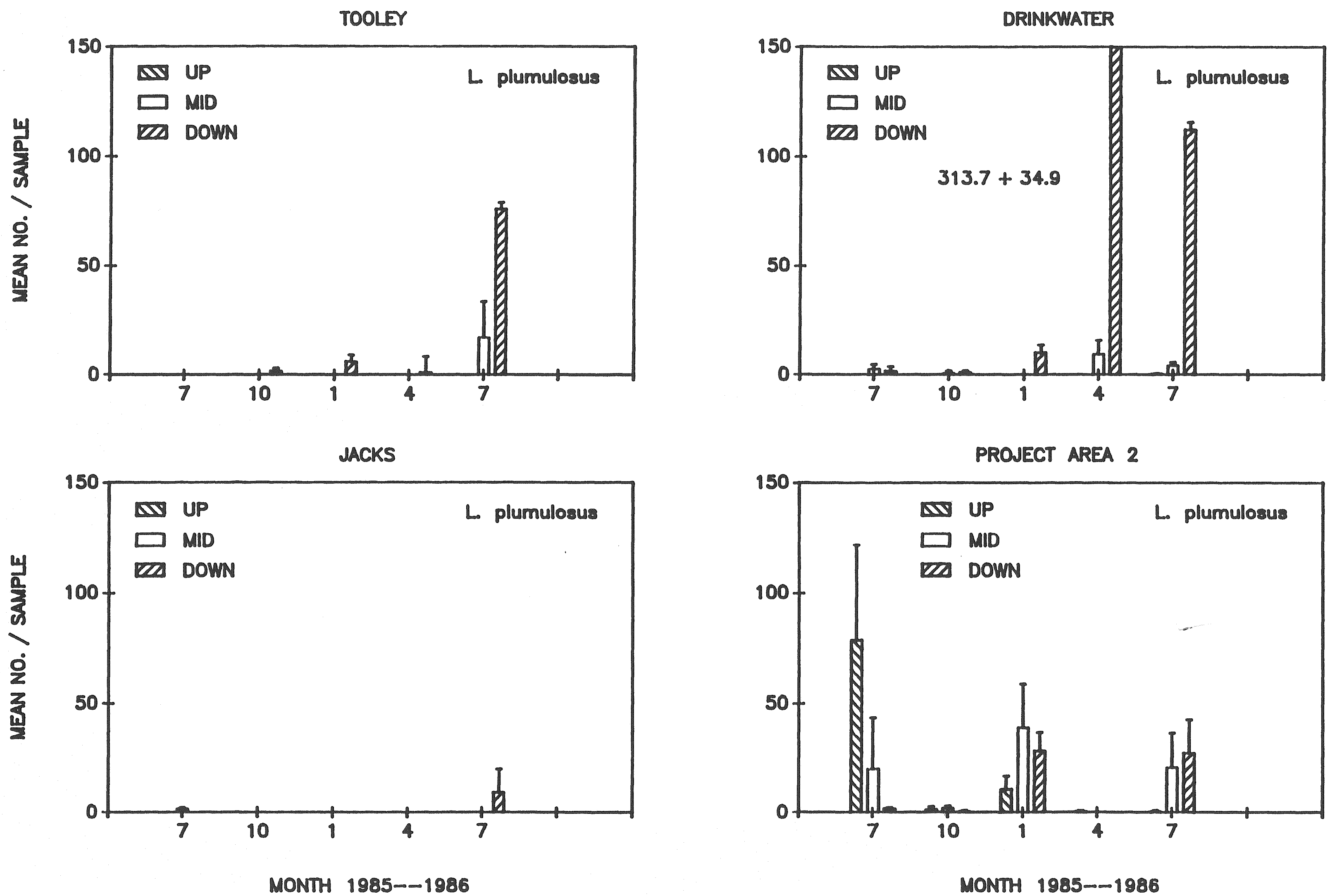

FIGURE 12 . Distribution and abundance of *Leptocheirus plumulosus* in the natural creeks and Project Area 2 during July 1985-July 1986. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

TABLE 8. Summary of the significant ($P < 0.05$) nested ANOVAS comparing the density of numerically abundant species among and within the study creeks. Creeks listed within the "Within Creek" column showed significant among station variation in mean densities for the designated species and season during July 1985-July 1986.

SPECIES	DATE	SOURCE OF VARIATION AMONG CREEKS	WITHIN CREEKS
Oligochaeta	7/85	*	
	10/85	*	DW, TL
	1/86	*	PA, TL
	4/86	*	DW, TL
	7/86	*	JK, TL
Mediomastus sp.	7/85	*	DW
	10/85	*	DW, JK, TL
	1/86	*	DW, PA
	4/86	*	DW, TL
	7/86	*	DW, PA, TL
Laeonereis culveri	7/85	*	DW, JK
	10/85	*	DW, PA, TL
	1/86	*	DW, TL
	4/86	*	DW, PA, TL
	7/86	*	DW, JK, PA
Hobsonia florida	7/85	ns	DW, JK
	10/85	ns	PA, TL
	1/86	*	DW
	4/86	ns	TL
	7/86	*	PA
Streblospio benedicti	7/85	ns	DW, PA
	10/85	ns	DW, PA
	1/86	ns	JK, PA
	4/86	*	DW, JK, PA, TL
	7/86	*	DW, TL
Chironomidae	7/85	*	JK
	10/85	ns	JK, PA
	1/86	*	JK
	4/86	*	DW, PA, TL
	7/86	*	DW

were fewer incidences of significant differences in density among stations within the creeks (Table 8).

The distribution and abundance of *H. florida* and chironomid larvae in the natural creeks appeared to vary systematically with respect to creek location. Densities of chironomids increased steadily from Tooley Creek to Jacks Creek. Representation of *H. florida* along the length of a creek showed a similar geographical trend, in which abundance at the midstream and downstream stations increased from Tooley Creek to Jacks Creek (Figure 8). The chironomid and *H. florida* populations in the Project Area did not fit into this geographical trend, and their densities and distribution were more similar to Jacks Creek than to the adjacent Drinkwater Creek.

RESULTS 2d. Community Structure. (July 1985-July 1986)

Comparisons of community structure by cluster analysis indicated a pervasive seasonal influence on the character of the benthic invertebrate communities of the Project Area and the natural creeks. Hence creeks generally aggregated by time of the year rather than by creek (Figure 13). Creek communities were most dissimilar in the spring, when densities and species richness were at or near their annual peak for all of the creeks.

A second important component of the variation in community structure stemmed from intrinsic differences in the communities of the individual creeks. Among the natural Creeks, Jacks Creek seldom clustered with either Tooley Creek or Drinkwater Creek. Community structure of the Project Area was distinct from that of the natural creeks for most of the seasons of the study period. Similarities in the communities of the Project Area and the natural creeks were greatest in the summer, when densities and diversity were universally low.

RESULTS 2e. SUMMARY OF THE BENTHOS: July 1985-July 1986

Temporal and spatial patterns of total density and species richness were similar among the man-made and natural creeks. Both density and species richness were greatest in the winter-spring, and lowest in the summer. Values of total density and species richness in the Project Area were usually equivalent to those of the natural creeks.

A total of thirty-six taxa were collected in the man-made and natural systems. Seven of these taxa were found only in the natural creeks. These taxa included the polychaetes *Neanthes succinea*, *Capitella capitata*, and *Glycera dibranchiata*, the crustaceans *Sphaeroma quadridentatum* and an unidentified cumacean), and the molluscs *Hydrobia sp.*, and *Rangia cuneata*. A single crustacean (*Rhithropanopeus harrisii*) was found only in the Project Area.

Eight species accounted for 90% or more of the total faunal present at given creek and time. The species composition of these numerically dominant species was similar among the Project Area and the natural creeks.

Six taxa consistently occurred in relatively high numbers throughout most of the year. These species consisted of Oligochaeta, the polychaetes *Mediomastus sp.*, *Hobsonia florida*, *Streblospio benedicti*, and *Laeonereis culveri*, and chironomid larvae.

Oligochaetes were virtually absent from the Project Area during the year, whereas densities *L. plumulosus* were highest in the Project Area. Densities of the remaining species in the Project Area fell within the range of variations set by the natural creeks.

Cluster analyses of the creek communities indicated that community structure was affected by time (season) and location (creek). The communities of the Project Area and Jacks Creek were distinctive, and as a result they segregated individually according to location. The remaining natural creeks clustered together according to season.

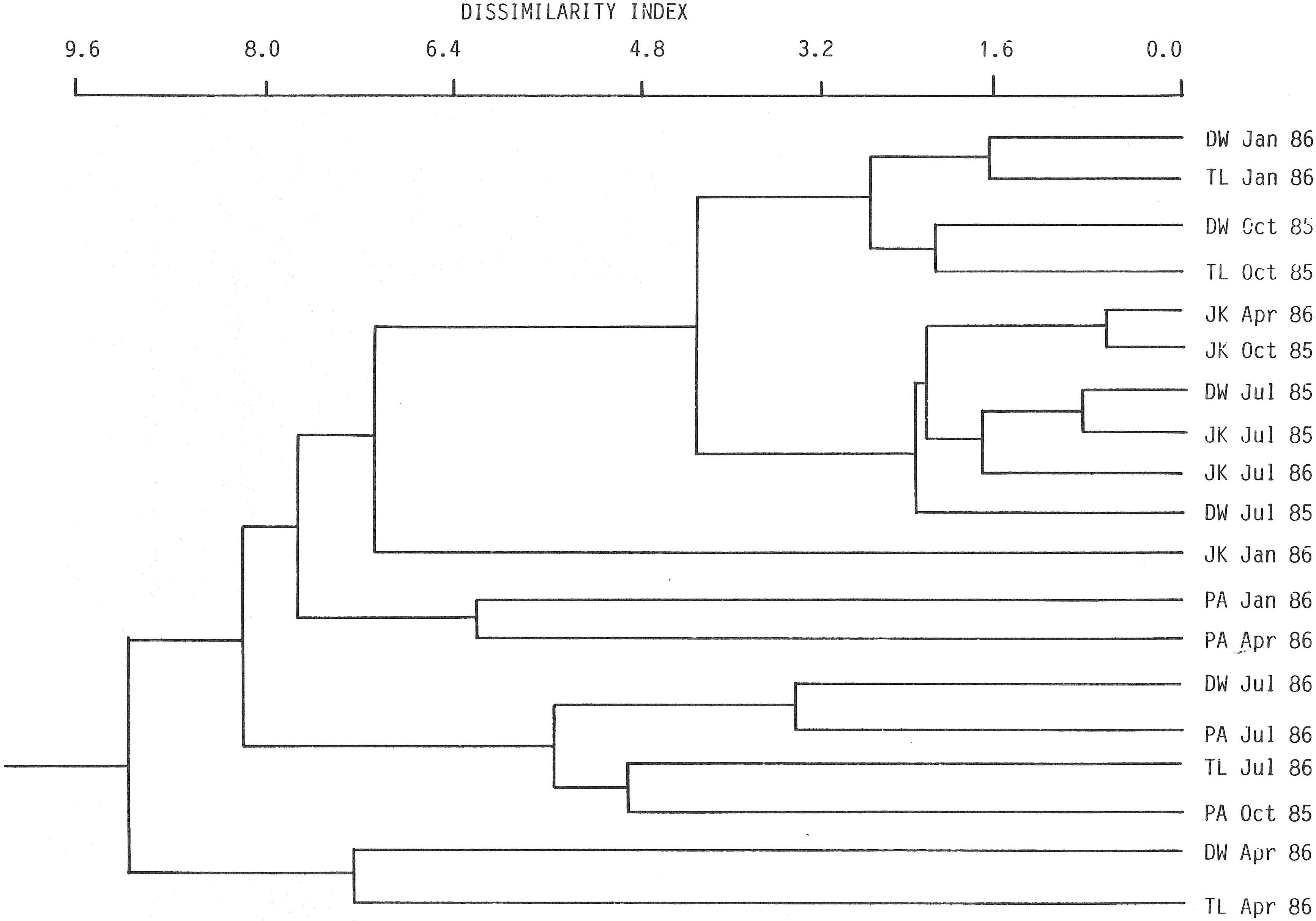

Figure 13. Relationships between the communities of the man-made (PA) and natural creeks during July 1985-July 1986. The dendrogram was obtained by cluster analysis using non-normalized densities of the species present in each creek during each season. Note that the communities are compared using a dissimilarity index. PA= Project Area 2; DW=Drinkwater Creek; JK=Jacks Creek; TL=Tooley Creek.

RESULTS 3a. Total Density and Species Richness of Benthic organisms. (July 1986-July 1987)

Total densities of benthic invertebrates varied strongly according to season and location within the study areas. The temporal pattern of seasonal variation in total density was nearly identical in the Project Area and the Natural Creeks (Figure 14), and closely resembled that which occurred during the previous year (July 1985-July 1986; Figure 4). Densities increased steadily between July 1986 and April 1987, and fell precipitously between April and July 1986 at the upstream stations in both areas. Densities were more uniform throughout the year at the midstream and downstream stations of natural creeks owing to the absence of a well defined spring peak. Densities at the same stations in the Project Area showed a similar temporal pattern with the exception of the summer 1987 collections, in which total fauna decreased sharply in the Project Area but not in the natural creeks.

Variations in total faunal density among the Project Area and the natural creeks were significant only during the summers of 1986 and 1987 (Table 9). In July 1986, numbers of organisms at the upstream stations were greater in the Project Area than in the natural Creeks. The opposite occurred in July 1987, in which the density at the downstream station the Project Area was markedly lower than that in the natural creeks (Table 10).

Seasonal trends in species richness were similar in the Project Area and the natural creeks (Figure 15). Numbers of species were greatest during the winter (February 1987) and spring (April 1987), and lowest in the summer (July 1986, 1987).

Differences in species richness among the Project Area and the natural creeks were significant during the summer and fall of 1986 and during the winter of 1987 (Table 11). In all cases fewer species were present in the Project area than in the natural creeks. *A posteriori* tests indicated that these differences in species richness were confined to single stations in each season; i.e, the midstream stations in July 1986, and the downstream stations in October 1986 (Table 12). The February *a posteriori* analyses were not significant. The significance of the original ANOVA evidently reflected the lower mean values at the midstream station in the Project Area at this time.

RESULTS 3b. Community Composition: Representation of Taxa. (July 1986- July 1987)

Table (13) lists the benthic fauna found only in the Project Area or the natural creeks ("Lim"), and those common to both areas ("Ubiq") during each season between July 1986 and July 1987. Similar taxa lists for the Project Area and each of the natural creeks are provided in the Appendices.

Representation of taxa can be arranged into five categories: (1) taxa restricted to the Natural Creeks; (2) taxa restricted to Project Area 2; (3) ubiquitous taxa; (4) taxa found initially in the Natural Creeks and later in both areas; and (5) taxa with mixed representation in the study areas.

A single taxon was limited to the natural creeks--the Culicidae (mosquito larvae). This finding is very different from the previous year, when seven taxa were found only in the natural creeks (cf. Table 5). Four species were found only in the Project Area. These species consisted of the polychaete *Scolecolepides viridis*, the amphipod crustacean *Gammarus tigrinus*, the crab *Sesarma reticulatum*, and the gastropod mollusc *Hydrobia sp.*. The densities of these species were low, and given that all taxa except *S. viridis* have previously been found in the natural creeks, their presence in just the Project Area is probably more a result of random sampling error than being indicative of fundamental differences in the habitats of these two areas.

Six taxa were present during each season of the year. Of these six species, the polychaetes *Mediomastus sp.*, *Laeonereis culveri*, and *Hobsonia florida*, the chironomid insect larvae, and the amphipod *Leptocheirus plumulosus* often occurred in high numbers. These species form part of the assemblage of numerically dominant species, and are discussed in

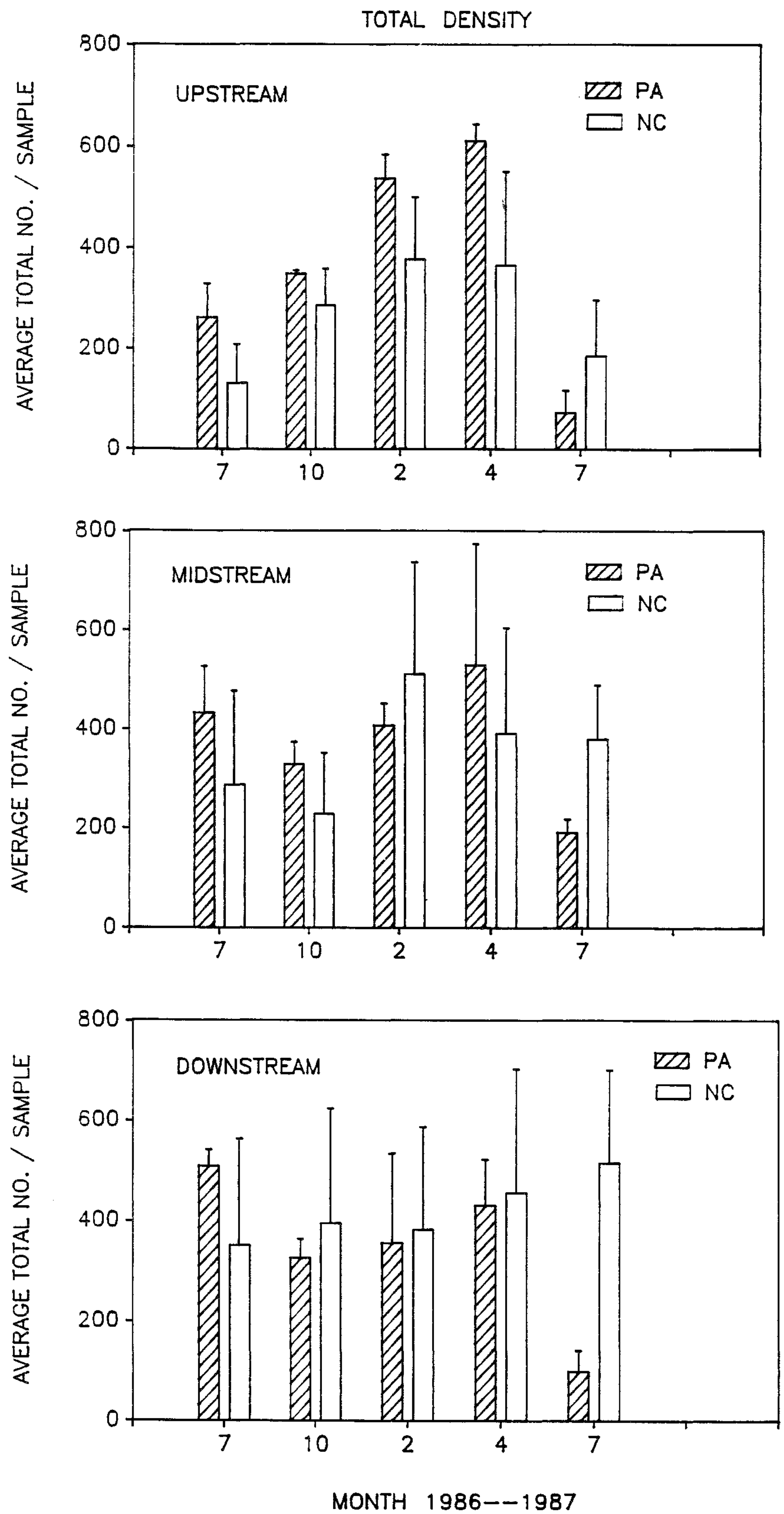

FIGURE 14. Total faunal densities of the natural creeks (NC) and Project Area 2 (PA) during July 1986-July 1987. Each area was sampled at an upstream, midstream and downstream station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

TABLE 9. Comparisons of total densities of benthic invertebrates in the Project Area and natural creeks during July 1986-July 1987. Two level nested analyses of variance (stations nested within creeks, and samples nested within stations) were run on the seasonal data sets during July 1986--July 1987. Only the significant ANOVAs are shown. Probablility values (P) less than or equal to 0.05 are denoted by an asterisk.

JULY 1986

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.609	1	0.609	7.129	0.012 *
AMONG STATIONS (PA)	0.139	2	0.069	0.813	0.453
AMONG STATIONS (NC)	0.712	2	0.356	4.168	0.025 *
ERROR	2.563	30	0.085		

FEBRUARY 1987

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.073	1	0.073	1.596	0.217
AMONG STATIONS (PA)	0.049	2	0.025	0.534	0.592
AMONG STATIONS (NC)	0.532	2	0.266	5.782	0.008 *
ERROR	1.243	27	0.046		

JULY 1987

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	1.383	1	1.383	35.548	0.000 *
AMONG STATIONS (PA)	0.324	2	0.162	4.166	0.025 *
AMONG STATIONS (NC)	1.241	2	0.620	15.948	0.000 *
ERROR	1.167	30	0.039		

TABLE 10. Results of the Tukey-Kramer pairwise multiple comparisons test (Sokal and Rohlf, 1983) for the significant ANOVAs comparing total densities among and within the test areas during July 1986-July 1987. Project Area=Pa; Natural Creeks=NC. Numbers refer to stations (1=upstream; 2=midstream; 3=downstream). Densities of underlined stations are not significantly different. Stations are ranked from left to right in order of increasing density.

```
==========================================================

July 1986

        NC      NC      PA      NC      PA      PA

        2       1       1       3       3       2
       ---------------------------
               -----------------------------------

----------------------------------------------------------

February 1987

        NC      PA      PA      NC      NC      PA

        3       3       2       1       2       1
        -------------------
                ---------------------------------

----------------------------------------------------------

July  1987

        PA      PA      NC      PA      NC      NC

        1       3       1       2       2       3
        --------------------------
                ------------------
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                                ----------
                                        ----------

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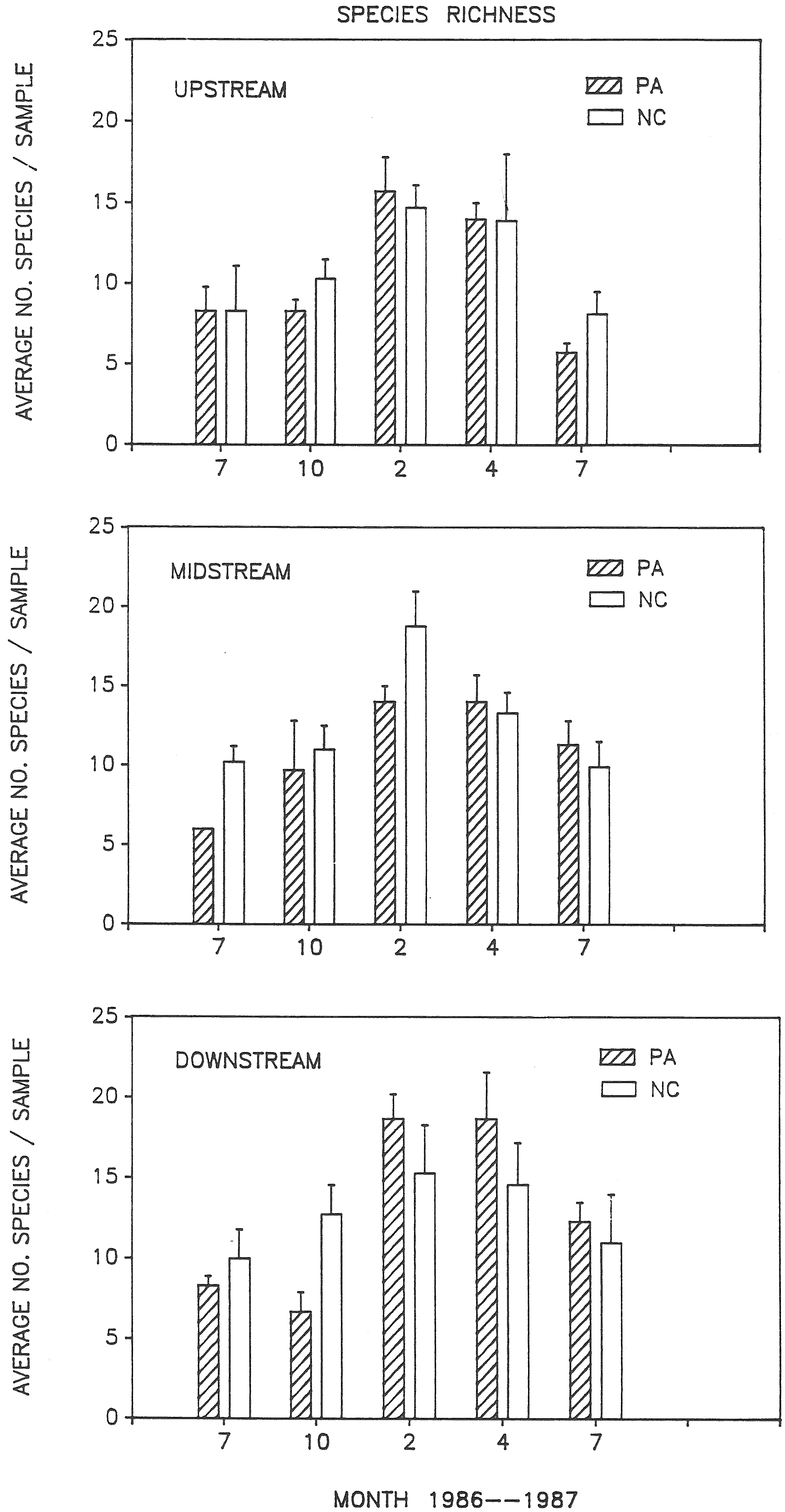

FIGURE 15. Species richness of Project Area 2 (PA) and the natural creeks (NC) during July 1986-July 1987. Each area was sampled at an upstream, midstream and downstream station. Species richness is presented as the mean number of species per 0.0225 M^2 sample + 1 standard deviation.

TABLE 11. Comparisons of species richness (mean number of species/sample) benthic invertebrates in the Project Area and Natural Creeks. Two level nested analyses of variance (stations nested within creeks, and samples nested within stations) were run on the seasonal data sets during July 1986--July 1987. Only the significant ANOVAs are shown. Probablility values (P) less than or equal to 0.05 are denoted by an asterisk.

JULY 1986

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	26.009	1	26.009	7.734	0.009 *
AMONG STATIONS (PA)	10.889	2	5.444	1.619	0.215
AMONG STATIONS (NC)	19.185	2	9.593	2.852	0.073
ERROR	100.889	30	3.363		

OCTOBER 1986

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG CREEKS	43.367	1	43.367	15.637	0.001 *
AMONG STATIONS (PA)	16.167	2	8.083	2.915	0.073
AMONG STATIONS (NC)	25.717	2	12.859	4.637	0.019 *
ERROR	69.333	25	2.773		

JANUARY 1987

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	53.971	1	53.971	5.412	0.028 *
AMONG STATIONS (PA)	12.667	2	6.333	0.635	0.538
AMONG STATIONS (NC)	33.897	2	16.948	1.699	0.202
ERROR	269.270	27	9.973		

JULY 1987

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.083	1	0.083	0.022	0.884
AMONG STATIONS (PA)	77.556	2	38.778	10.048	0.000 *
AMONG STATIONS (NC)	38.222	2	19.111	4.952	0.014 *
ERROR	115.778	30	3.859		

TABLE 12. Results of the Tukey-Kramer pairwise multiple comparisons test for the significant ANOVAs comparing species richness (mean number of species/sample) among and within the test areas during July 1986-July 1987 Project Area=Pa; Natural Creeks=NC. Numbers refer to stations (1=upstream; 2=midstream; 3=downstream). Species richness of underlined stations are not significantly different. Significance was determined by the Tukey-Kramer method (Sokal and Rohlf, 1983). Stations are ranked from left to right in order of increasing species richness.

July 1986

	PA	PA	PA	NC	NC	NC
	2	1	3	1	3	2
	----	----	----	----		
		----	----	----	----	----

October 1986

	PA	PA	NC	PA	NC	NC
	3	2	1	1	2	3
	----	----				
		----	----	----	----	
			----	----	----	
				----	----	----

July 1987

	PA	NC	NC	NC	PA	PA
	1	1	2	3	2	3
	----	----				
		----	----	----	----	

TABLE 13. Representation of benthic invertebrates in the test areas during July 1986-July 1987. For a given season, taxa are indicated as being either limited ("Lim") to just Project Area 2 (PA) or just the Natural Creeks (NC), or ubiquitous ("Ubiq") and found in both areas. The NC listings indicate parenthetically the number of natural creeks in which a given species was found. Three natural creeks were sampled each season.

	7/86		10/86		2/87		4/87		7/87	
Taxon	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq
ANNELIDA-Oligochaeta	NC(3)			x		x		x		x
ANNELIDA-Polychaeta										
Mediomastus sp.		x		x		x		x		x
Heteromastus filiformis	NC(3)		PA			x		x		x
Laeonereis culveri		x		x		x		x		x
Neanthes succinea										
Polydora ligni	PA			x		x		x	PA	
Scolecolepides virides	PA						PA			x
Streblospio benedicti		x		x		x		x	PA	
Hobsonia florida		x		x		x		x		x
Eteone heteropoda		x	NC(3)			x	PA			
Capitella capitata			NC(3)			x		x		x
Glycera dibranchiata	NC(1)		PA		NC(1)					
ANNELIDA-Hirudinea								x		
ARTHROPODA-Uniramia										
Chironomidae		x		x		x		x		x
Ceratopogonidae			NC(1)			x		x		x
Culicidae					NC(1)					
Insect A	NC(1)				NC(1)				PA	
ARTHROPODA-Crustacea										
Mysidopsis bigelowi										x
Neomysis americanus		x		x	PA					
Cyathura polita		x	NC(1)					x		x
Corophium lacustre						x		x		x
Leptocheirus plumulosus		x		x		x		x		x
Gammarus mucronatus						x	PA			
Gammarus tigrinus	PA				PA		PA			x
Gammarus sp.										
Edotea sp.			NC(3)		NC(3)			x	PA	
Hargeria rapax	PA					x		x	NC(1)	
Palaemonetes pugio						x			NC(1)	
Cumacea				x		x	PA			
Sesarma reticulatum					PA					

TABLE 13 (Continued). Representation of benthic invertebrates in the test areas during July 1986-July 1987. For a given season, taxa are indicated as being either limited ("Lim") to just Project Area 2 (PA) or just the Natural Creeks (NC), or ubiquitous ("Ubiq") and found in both areas. The NC listings indicate parenthetically the number of natural creeks in which a given species was found. Three natural creeks were sampled each season.

	7/86		10/86		2/87		4/87		7/87	
Taxon	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq
MOLLUSCA-Bivalvia										
Macoma balthica		x				x	PA			x
Macoma phenax		x		x		x		x		x
Munidea lateralis		x								
Rangia cuneata	NC(1)		NC(1)		PA			x		x
MOLLUSCA-Gastropoda										
Hydrobia sp.					PA		PA		PA	
CNIDARIA-Anthozoa										
Edwardsia sp.	PA		NC(1)			x	PA		PA	
PLATYHELMINTHES	PA		NC(1)				PA			
RHYNCOCOELA		x	NC(3)			x		x		x

greater detail below. The bivalve *Macoma phenax* was also ubiquitous, but it never was found at densities near to those of the other five common species. Several other taxa were both widespread and abundant. This group consisted of the polychaetes *Streblospio benedicti*, *Capitella capitata*, and *Polydora ligni*, and the amphipod *Corophium lacustre*.

The isopod crustacean *Edotea sp*., and the bivalve *Rangia cuneata*, were collected only from the natural creeks during the summer and fall of 1986, but appeared in both areas thereafter. The remaining taxa lacked any noticeable affiliation with either the Project Area or the natural creeks.

RESULTS 3c. Numerical Dominants. (July 1986-July 1987)

The eight most abundant species collected from each creek during July 1986-July 1987 are listed in Table (14). These species accounted for approximately 90% or more of the total fauna present during each season.

Variation in the species composition of the numerically dominant organisms among all creeks was greatest during the summer (July) 1987 when densities were generally low, and was least during the winter and spring 1987, when densities and species richness were highest. Compositional differences among the natural creeks were comparatively small for most of the year; as a result, the natural creeks were more similar to each other that to the Project Area (Table 15). Deviations between the Project Area and the natural creek reflected the presence of novel dominants such as *Polydora ligni*, *Hydrobia sp*., and *Edwardsia sp*., and the periodically poor representation of oligochaetes and the amphipod *Leptocheirus plumulosus*.

Greater differences occurred in the relative abundances of the numerical dominants among the natural creeks than in their species composition. The top three or four species in Drinkwater Creek and Tooley Creek were similar during most of the year. Jacks Creek differed from the other natural creeks in having relatively larger numbers of the polychaete *Capitella capitata*, and comparatively low numbers of *Mediomastus sp*. and *Leptocheirus plumulosus*. The Project area showed highly skewed densities of *Mediomastus sp*. during July and October 1986, when this species represented 66% and 85%, respectively, of the total fauna.

Seven species were particularly abundant and widespread during most of the year. These species included oligochaetes, the polychaetes *Mediomastus sp*., *Streblospio benedicti*, *Hobsonia florida*, *Capitella capitata*, and *Laeonereis culveri*, and the amphipod *Leptocheirus plumulosus*. The distribution and abundance of these species in the study creeks are compared in Figures (16-23). Chironomidae have been included in this group in order to provide comparisons with the previous year's data.

Densities of these species varied significantly among and within the creeks during most of the seasons (Table 16). The bulk of the among creek variation in the densities of *Mediomastus sp*., *L. plumulosus*, *L. culveri*, *C. capitata*, and chironomid larvae were caused by differences in their abundance among the natural creeks. *Mediomastus sp*. and *L. plumulosus* were prominent in Tooley Creek and Drinkwater Creek, but poorly represented in Jacks Creek. Conversely, densities of *C. capitata* and chironomids in Jack's Creek and Drinkwater Creek were 2 to 3 times those in Tooley Creek. The densities of these species in the Project Area were well within the range of densities among the natural creeks.

Densities of *S. benedicti* and *H. florida* were more similar among and within creeks than the above species. Among creek densities were not significant different during the winter and summer of 1987 for *S. benedicti*, and during fall (1986) and summer (1987) for *H. florida*.

Oligochaetes were the only numerically dominant organisms not comparably represented in the Project Area. Oligochaetes were among the most abundant members of the natural creek communities throughout the year, but were abundant in the Project Area only during Winter and Spring 1987.

TABLE 14. Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1986--July 1987. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

JULY 1986

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	58.2	1400	*Mediomastus sp.*	61.4	2237
Oligochaeta	17.4	420	*Laeonereis culveri*	12.4	452
Leptocheirus plumulosus	12.9	311	*Leptocheirus plumulosus*	9.6	351
Chironomidae	3.5	85	Oligochaeta	6.4	232
Laeonereis culveri	2.7	65	Chironomidae	5.8	210
Mysidopsis bigelowi	1.1	27	*Streblospio benedicti*	1.5	53
Streblospio benedicti	1.0	25	*Hobsonia florida*	0.7	26
Rhyncocoela	0.6	15	Rhyncocoela	0.6	22
SUM	97.5	2348		98.3	3583
TOTAL	100	2407		100	3645

JACKS			PROJECT AREA 2		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	32.3	284	*Mediomastus sp.*	66.0	2383
Laeonereis culveri	28.7	252	*Laeonereis culveri*	22.8	825
Mediomastus sp.	16.8	148	*Leptocheirus plumulosus*	4.0	145
Chironomidae	5.2	46	Chironomidae	1.9	67
Macoma phenax	3.5	31	*Polydora ligni*	1.8	66
Leptocheirus plumulosus	3.2	28	*Hobsonia florida*	1.7	63
Capitella capitata	2.5	22	*Streblospio benedicti*	0.8	30
Hobsonia florida	1.9	17	Edwardsia	0.4	14
	94.2	828		99.4	3593
	100	879		100	3613

TABLE 14(Continued). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1986--July 1987. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

OCTOBER 1986

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	38.0	1203	Oligochaeta	51.3	1520
Mediomastus sp.	36.4	1151	*Mediomastus sp.*	20.7	614
Streblospio benedicti	8.1	256	*Streblospio benedicti*	9.0	265
Leptocheirus plumulosus	7.2	227	*Leptocheirus plumulosus*	7.0	208
Capitella capitata	4.1	131	*Capitella capitata*	4.3	129
Chironomidae	1.3	40	*Laeonereis culveri*	2.7	79
Laeonereis culveri	1.0	33	*Hobsonia florida*	1.6	47
Cumacean	0.6	19	Chironomidae	1.4	42
SUM	96.7	3060		98.0	2904
TOTAL	100	3166		100	2962

JACKS			PROJECT AREA 2		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	36.2	486	*Mediomastus sp.*	84.6	2356
Capitella capitata	27.3	367	*Laeonereis culveri*	5.4	150
Streblospio benedicti	13.2	177	*Capitella capitata*	3.9	109
Mediomastus sp.	8.6	116	*Streblospio benedicti*	2.9	80
Hobsonia florida	4.2	56	Chironomidae	1.1	31
Laeonereis culveri	3.9	53	*Hobsonia florida*	1.0	27
Chironomidae	3.6	48	*Polydora ligni*	0.2	6
Leptocheirus plumulosus	1.0	13	Edwardsia	0.2	6
SUM	98.0	1317		99.3	2766
TOTAL	100	1343		100	2786

TABLE 14 (Continued). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1986--July 1987. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

FEBRUARY 1987

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	20.5	470	*Mediomastus sp.*	24.7	852
Oligochaeta	19.5	447	*Streblospio benedicti*	13.8	475
Hobsonia florida	14.9	343	*Hobsonia florida*	12.7	438
Streblospio benedicti	14.9	341	*Leptocheirus plumulosus*	12.3	424
Leptocheirus plumulosus	12.0	277	Oligochaeta	12.2	420
Chironomidae	4.8	111	*Capitella capitata*	9.0	310
Rangia cuneata	2.1	49	Chironomidae	4.4	152
Eteone heteropoda	2.1	48	*Corophium lacustre*	3.8	131
SUM	90.9	2087		92.8	3202
TOTAL	100	2295		100	3452

JACKS			PROJECT AREA 2		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Hobsonia florida	19.1	855	*Mediomastus sp.*	20.2	829
Capitella capitata	18.7	835	*Hobsonia florida*	16.3	670
Oligochaeta	15.9	709	Oligochaeta	15.4	634
Streblospio benedicti	12.1	544	*Streblospio benedicti*	13.2	543
Chironomidae	7.8	349	Chironomidae	7.9	323
Corophium lacustre	7.7	346	*Capitella capitata*	7.1	292
Leptocheirus plumulosus	3.6	160	*Laeonereis culveri*	6.0	249
Mediomastus sp.	3.5	155	*Corophium lacustre*	3.3	134
SUM	88.4	3953		89.3	3674
TOTAL	100	4474		100	4112

TABLE 14 (Continued). Relative abundance of the numerically dominant species collected from the Natural Creeks and Project Area 2 between July 1986--July 1987. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species which collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

APRIL 1987

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	33.4	1544	*Mediomastus sp.*	30.6	1113
Oligochaeta	26.5	1229	Oligochaeta	23.1	840
Streblospio benedicti	18.5	856	*Streblospio benedicti*	9.9	359
Hobsonia florida	6.9	321	*Leptocheirus plumulosus*	9.7	354
Leptocheirus plumulosus	5.3	245	*Hobsonia florida*	9.0	328
Capitella capitata	1.7	78	*Capitella capitata*	7.8	284
Corophium lacustre	1.1	53	*Laeonereis culveri*	2.0	71
Macoma phenax	1.1	49	*Heteromastus filiformis*	1.7	62
SUM	94.5	4375		93.7	3412
TOTAL	100	4629		100	3642

JACKS			PROJECT AREA 2		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	34.3	495	*Mediomastus sp.*	21.9	1033
Streblospio benedicti	17.1	246	*Streblospio benedicti*	17.1	808
Capitella capitata	14.9	215	Oligochaeta	17.0	801
Hobsonia florida	13.7	197	*Hobsonia florida*	14.4	678
Laeonereis culveri	7.0	102	*Capitella capitata*	7.0	330
Chironomidae	1.5	21	*Leptocheirus plumulosus*	6.3	298
Gammarus tigrinus	1.3	19	*Laeonereis culveri*	5.6	265
Leptocheirus plumulosus	1.3	19	Chironomidae	3.9	183
SUM	91.0	1315		93.1	4396
TOTAL	100	1444		100	4720

- TABLE 14 (Continued). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1986--July 1987. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

JULY 1987

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	44.5	1458	*Mediomastus sp.*	53.1	1709
Oligochaeta	26.9	883	Oligochaeta	17.2	553
Leptocheirus plumulosus	20.3	667	*Leptocheirus plumulosus*	11.3	365
Laeonereis culveri	2.4	79	Chironomidae	6.8	220
Macoma phenax	1.7	55	*Laeonereis culveri*	5.4	172
Chironomidae	1.0	33	*Capitella capitata*	2.3	74
Capitella capitata	0.6	20	*Hobsonia florida*	1.1	34
Macoma balthica	0.6	20	*Mysidopsis bigelowi*	0.6	19
SUM	98.0	3215		97.8	3146
TOTAL	100	3279		100	3218

JACKS			PROJECT AREA 2		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	46.3	1497	*Mediomastus sp.*	56.0	613
Leptocheirus plumulosus	16.3	527	*Leptocheirus plumulosus*	19.4	212
Laeonereis culveri	13.7	444	*Hydrobia sp.*	11.3	123
Chironomidae	5.5	177	*Laeonereis culveri*	3.9	43
Mediomastus sp.	3.2	104	Chironomidae	1.9	20
Capitella capitata	2.2	71	*Cyathura polita*	1.0	11
Gammarus tigrinus	1.9	62	*Hobsonia florida*	1.0	10
Mysidopsis bigelowi	1.9	62			
SUM	91.0	2943		94.4	1033
TOTAL	100	3236		100	1094

- TABLE 15 Similarity of species composition of the numerically abundant fauna in the man-made and natural creeks during July 1986-July 1987. The values presented are Jaccard's similarity indices. A value of 1.00 denotes identical species composition.

JULY 1986

	DW	JK	TL	PA
DW	1.00			
JK	0.77	1.00		
TL	0.60	0.60	1.00	
PA	0.60	0.45	0.45	

OCTOBER 1986

	DW	JK	TL	PA
DW	1.00			
JK	1.00	1.00		
TL	0.77	0.77	1.00	
PA	0.60	0.60	0.45	1.00

FEBRUARY 1987

	DW	JK	TL	PA
DW	1.00			
JK	1.00	1.00		
TL	0.60	0.60	1.00	
PA	0.77	0.77	0.45	1.00

APRIL 1987

	DW	JK	TL	PA
DW	1.00			
JK	0.60	1.00		
TL	0.77	0.77	1.00	
PA	0.60	0.45	0.60	1.00

JULY 1987

	DW	JK	TL	PA
DW	1.00			
JK	0.80	1.00		
TL	0.30	0.30	1.00	
PA	0.50	0.38	0.30	1.00

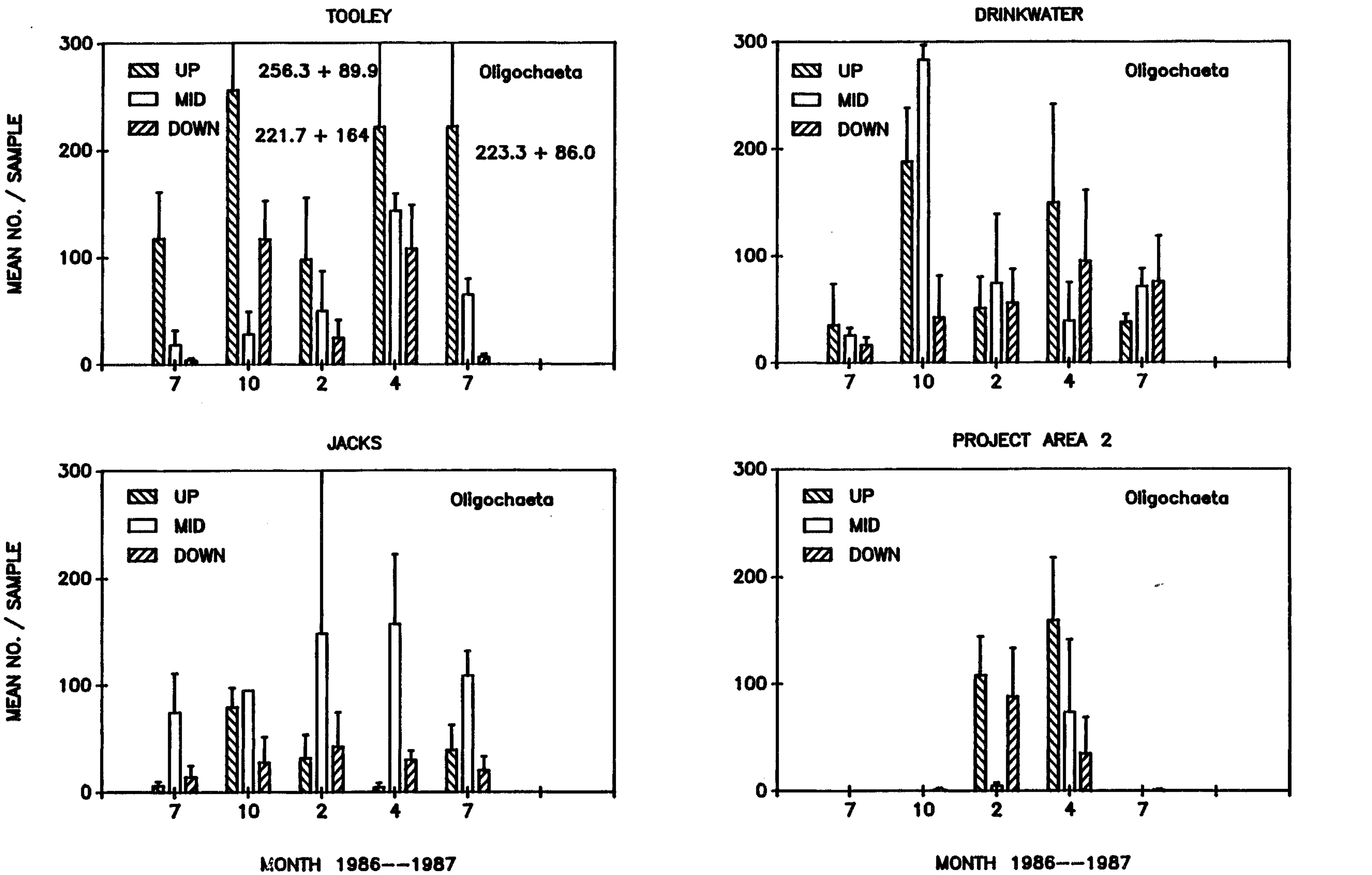

FIGURE 16. Distribution and abundance of the Oligochaeta in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

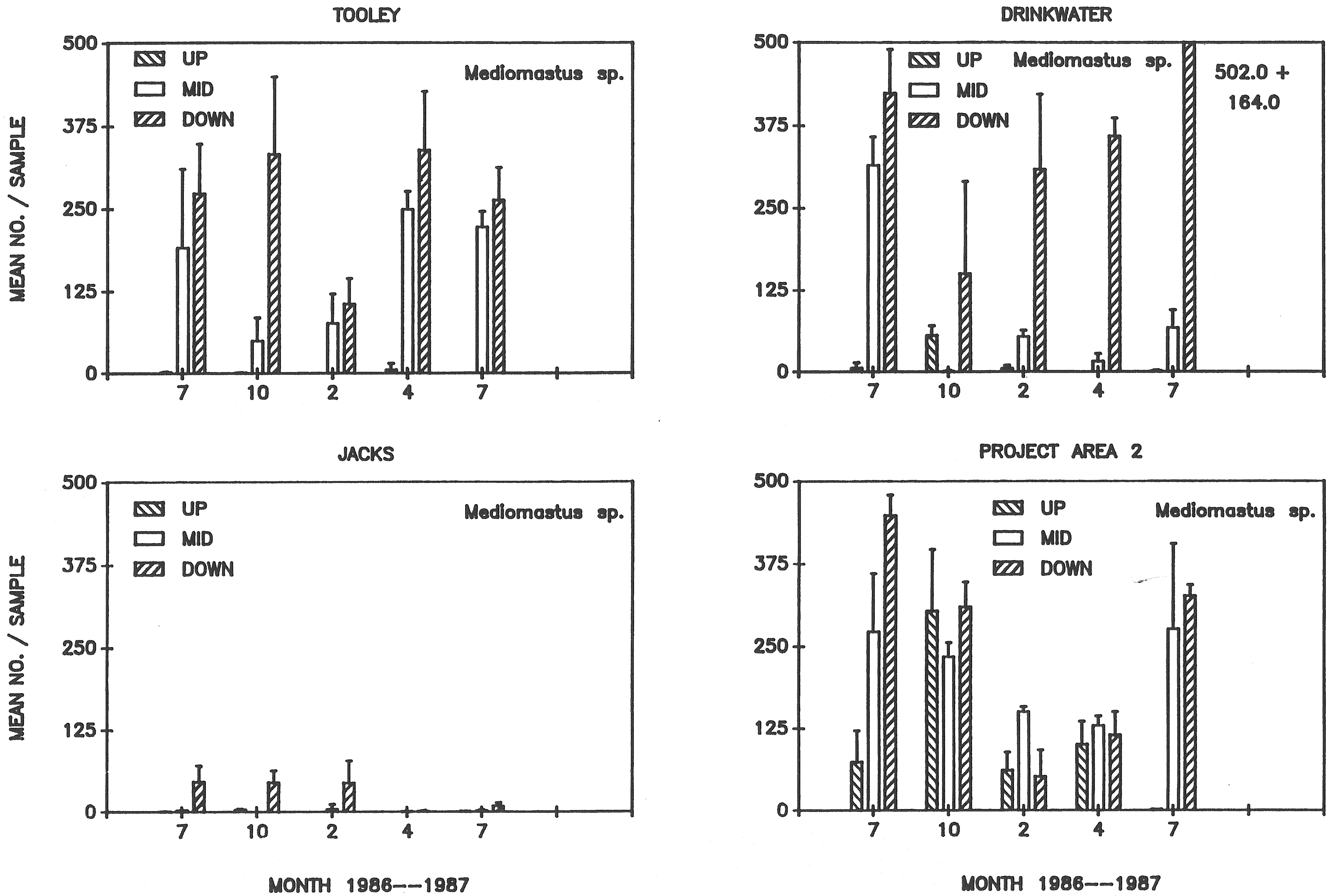

FIGURE 17 . Distribution and abundance of *Mediomastus sp.* in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

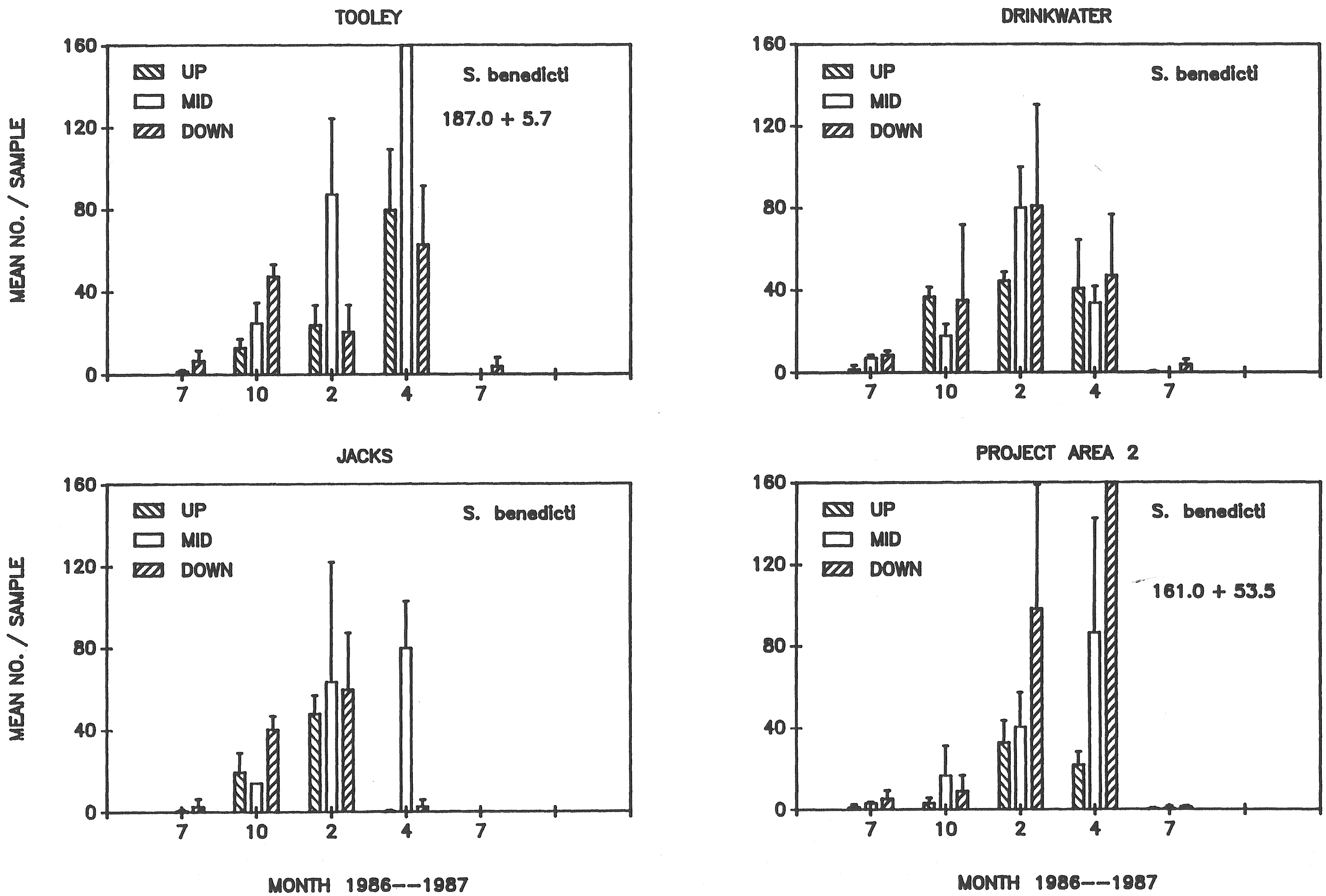

FIGURE 18 . Distribution and abundance of *Streblospio benedicti* in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

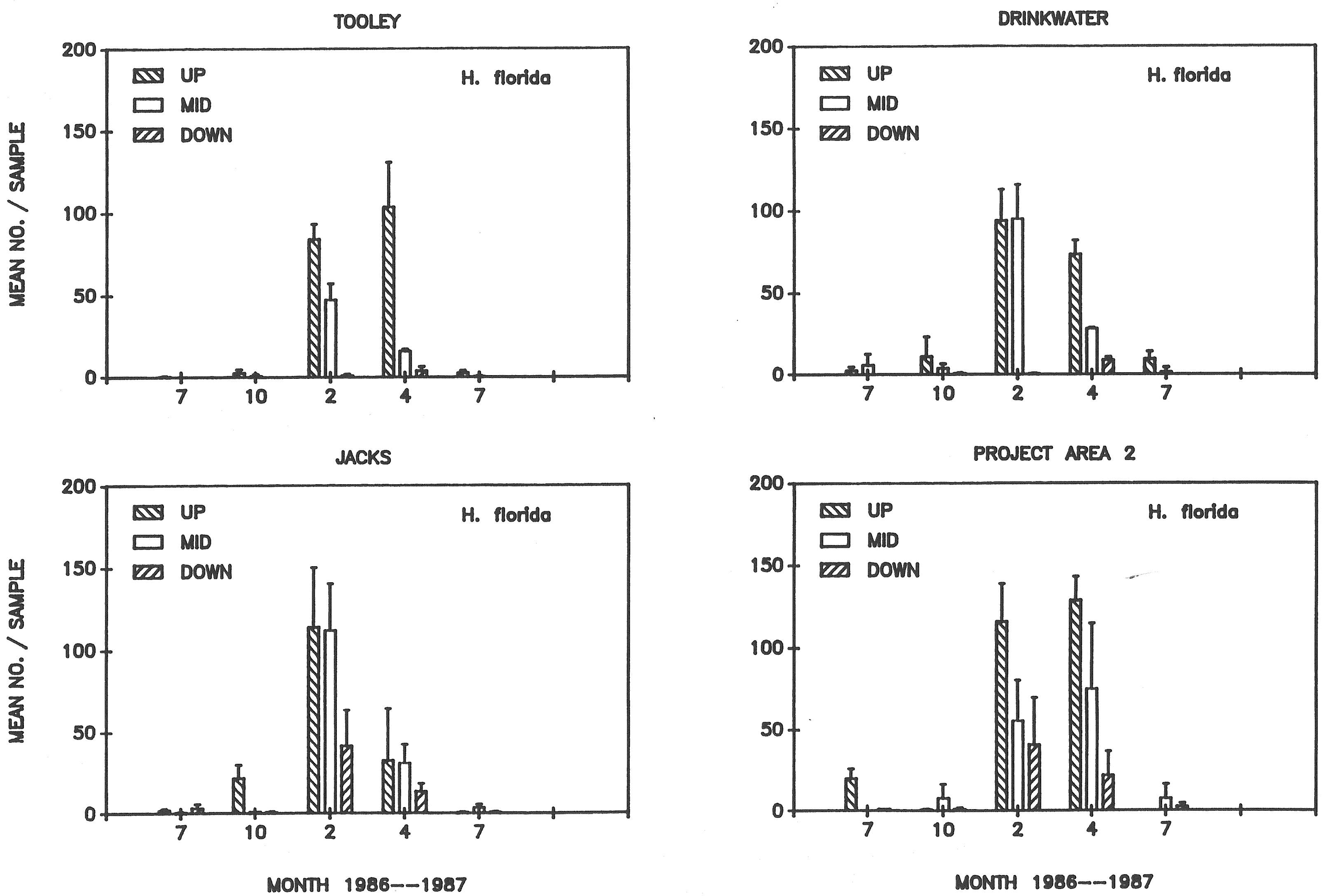

FIGURE 19. Distribution and abundance of *Hobsonia florida* in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

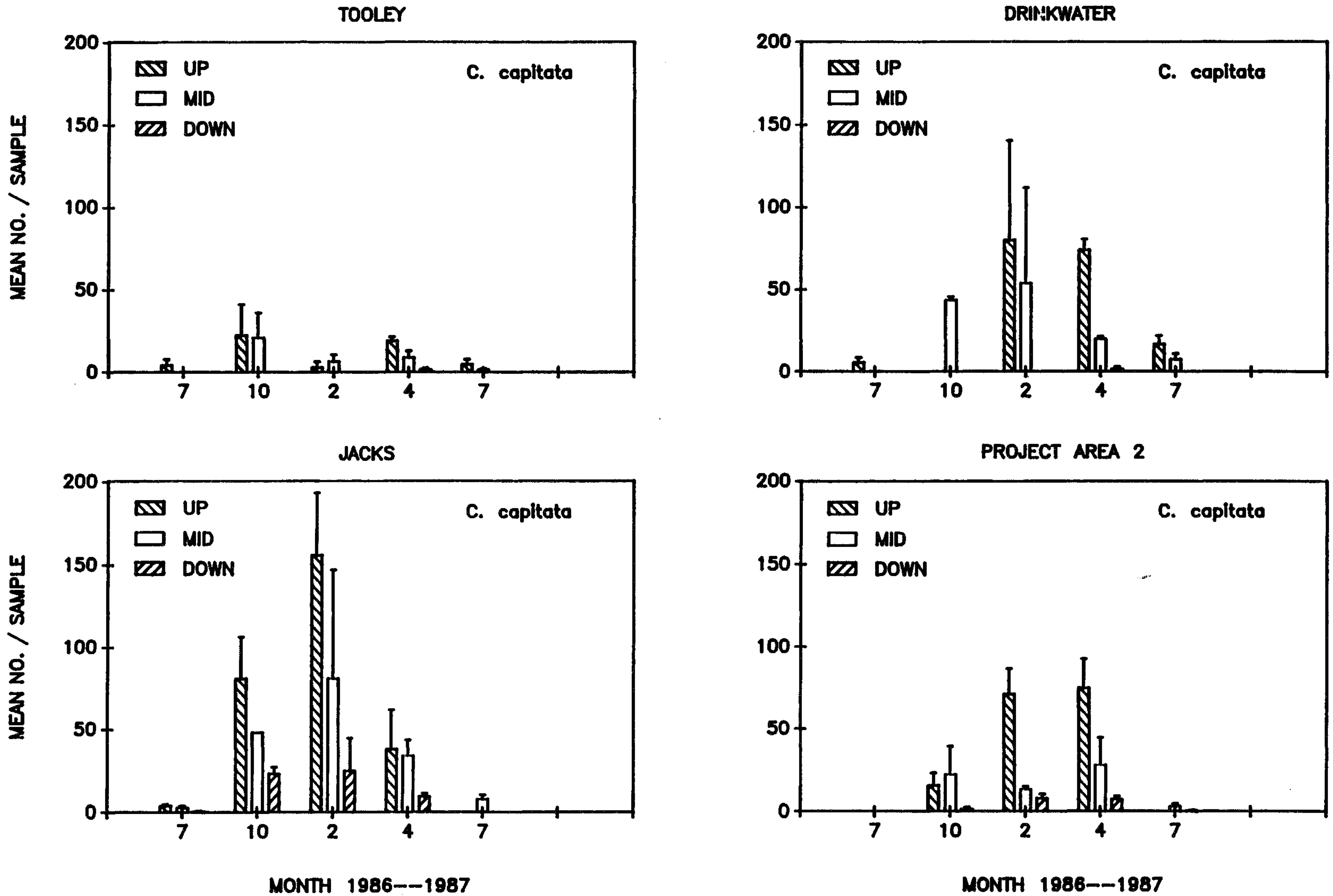

FIGURE 20. Distribution and abundance of the *Capitella capitata* in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

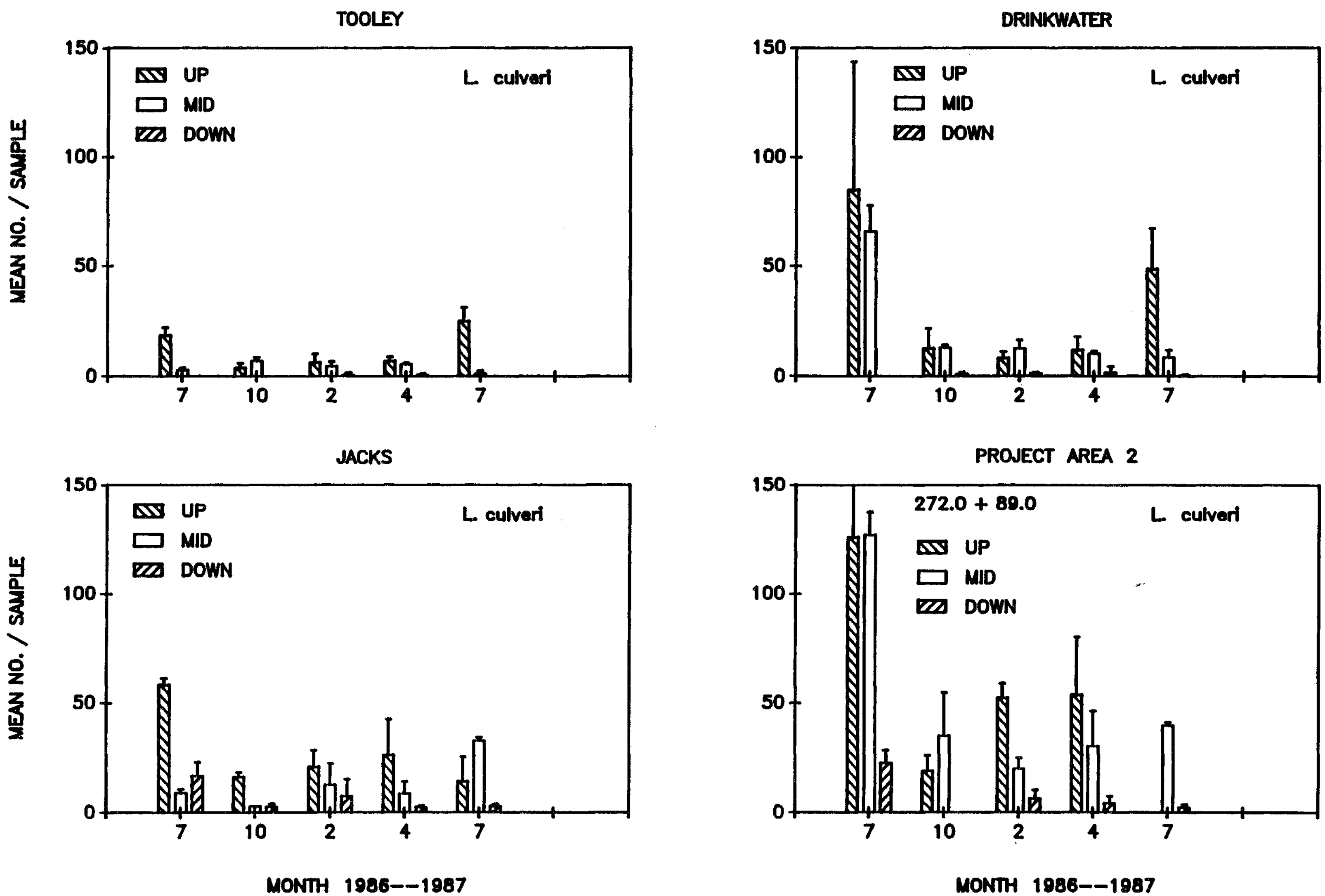

FIGURE 21. Distribution and abundance of *Laeonereis culveri* in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

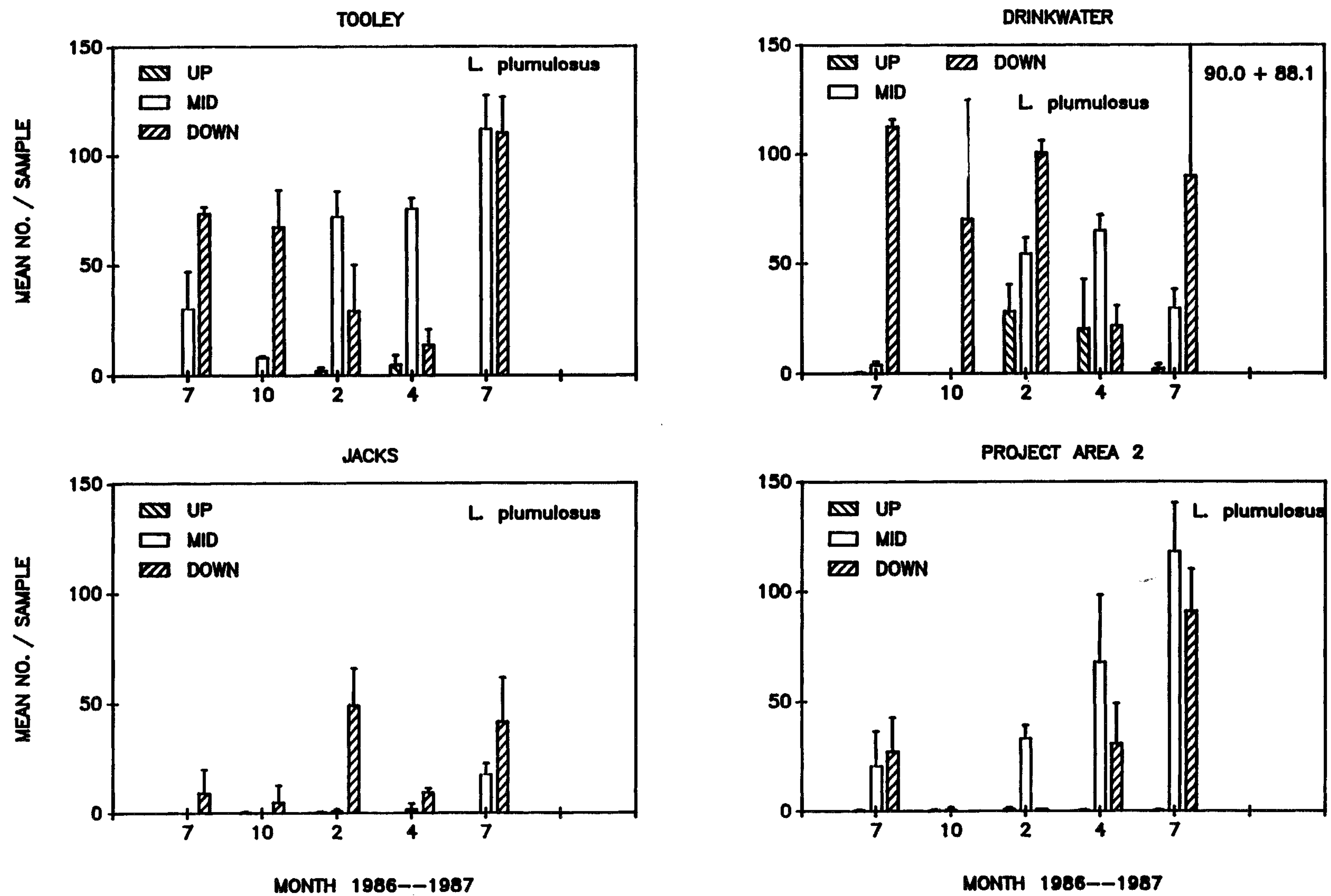

FIGURE 22 . Distribution and abundance of *Leptocheirus plumulosus* in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

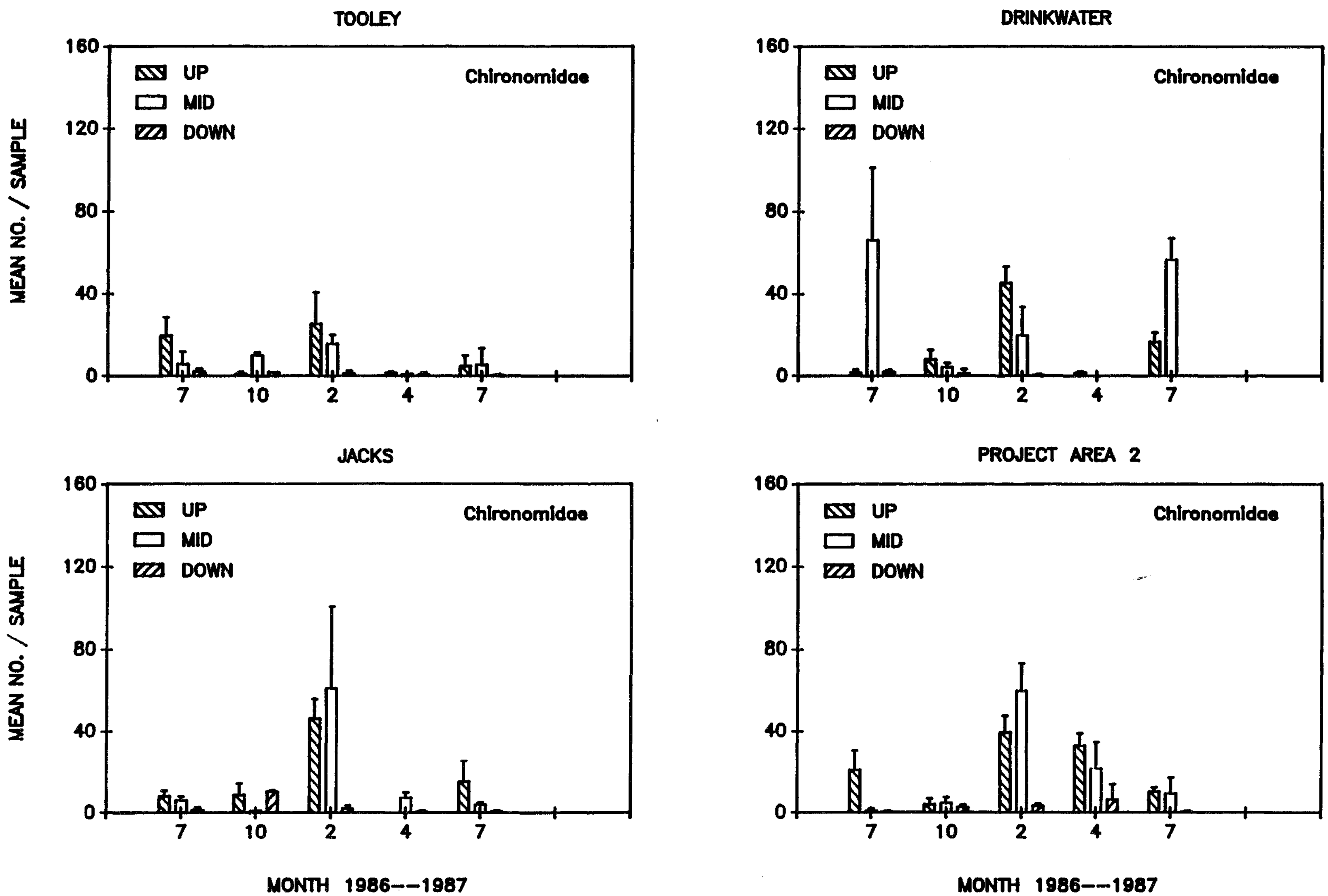

FIGURE 23 . Distribution and abundance of chironomid larvae in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

TABLE 16. Summary of the significant ($P < 0.05$) nested ANOVAS comparing the density of numerically abundant species among and within the study creeks. Creeks listed within the "Within Creek" column showed significant among station variation in mean densities for the designated species and season during July 1986-July 1987.

SPECIES	DATE	SOURCE OF VARIATION AMONG CREEKS	WITHIN CREEKS
Oligochaeta	7/86	*	DW, JK, TL
	10/86	*	DW, TL
	1/87	ns	JK
	4/87	ns	JK
	7/87	*	JK, TL
Mediomastus sp.	7/86	*	DW, PA, TL
	10/86	*	DW, PA, TL
	1/87	*	DW, PA, TL
	4/87	*	DW, TL
	7/87	*	DW, PA, TL
Laeonereis culveri	7/86	*	DW, JK, PA
	10/86	*	PA
	1/87	*	DW, JK, PA
	4/87	*	PA
	7/87	*	DW, JK, PA, TL
Hobsonia florida	7/86	*	DW, PA
	10/86	ns	JK
	1/87	*	DW, PA, JK, TL
	4/87	*	DW, PA, TL
	7/87	ns	DW, PA
Streblospio benedicti	7/86	*	DW, TL
	10/86	*	DW, TL
	1/87	ns	PA, TL
	4/87	*	JK, PA, TL
	7/87	ns	PA, TL
Chironomidae	7/86	*	DW, PA
	10/86	ns	JK, TL
	1/87	*	DW, JK, PA
	4/87	*	PA
	7/87	*	DW, JK
Leptocheirus plumulosus	7/86	*	DW, PA, TL
	10/86	*	DW, PA, TL
	1/87	*	DW, JK, PA, TL
	4/87	*	DW, PA, TL
	7/87	*	DW, PA, TL

-TABLE 16. (Continued). Summary of the significant ($P < 0.05$) nested ANOVAS comparing the density of numerically abundant species among and within the study creeks. Creeks listed within the "Within Creek" column showed significant among station variation in mean densities for the designated species and season during July 1986-July 1987.

SPECIES	DATE	SOURCE OF VARIATION AMONG CREEKS	WITHIN CREEKS
Capitella capitata	7/86	*	DW, JK
	10/86	*	DW, JK
	1/87	*	DW, JK, PA
	4/87	*	PA
	7/87	ns	

RESULTS 3d. Community Structure. (July 1986-July 1987)

Cluster analysis indicated a mixture of seasonal and locational (creek-dependent) effects on community structure during July 1986-July 1987 (Figure 24). Time-related effects were apparent from the aggregation of all of the creeks into a distinct winter (February) 1987 cluster and a distinct summer (July) 1986-1987 cluster. The latter group was in turn subdivided into two annual subgroups, each of which contained all creeks except Jacks Creek.

The fall and especially the spring communities were heterogeneous, and separated out by creek rather than by season. Locational effects were best represented by Jacks Creek, in which all seasons save winter 1987 were combined into a single group.

RESULTS 3e. SUMMARY OF THE BENTHOS: July 1986-July 1987

Temporal and spatial patterns of total faunal density and species richness were similar among the Project Area and natural creeks, and showed patterns consistent with the previous year. Quantitative differences in density and diversity were uncommon and restricted to the summer months.

A total of thirty five taxa were collected from the creeks during the year. In contrast to the previous year, differences in total species composition among the man-made and natural areas were minor, and probably resulted from random sampling error.

Eight species represented approximately 90% of the total fauna found at any given creek or season. Oligochaetes, the polychaetes *Mediomastus sp.*, *Streblospio benedicti*, *Hobsonia florida*, *Capitella capitata*, and *Laeonereis culveri*, and the amphipod *Leptocheirus plumulosus* were particularly abundant throughout most of the year. With the exception of Oligochaetes, the greatest differences in the densities of these taxa occurred among the natural creeks.

Overall abundances of oligochaetes, and especially *L. plumulosus*, and *C. capitata*, in the natural creeks were higher than the previous year. Densities of oligochaetes and *C. capitata* in the Project Area were similarly elevated, but representation of *L. plumulosus* showed a decline from 1985-1986.

Community structure of the Project Area was more similar to that of the natural creeks than during the previous year, especially during the winter and summer. Jacks Creek remained distinct from the other creeks during most of the seasons.

RESULTS 4a. Total Density and Species Richness. (1987-1988)

Total faunal density varied with season and location within the study areas. The pattern of seasonal variation differed slightly among the natural creeks and the Project Area (Figure 25). In the natural creeks, density at the upstream station was unimodal with a well defined winter peak bounded by low summer values, while the midstream and downstream stations were bimodal, with a major peak in the spring 1988 and a minor peak during the previous summer (July 1987). In contrast, densities at each station in the Project Area were unimodal; highest densities occurred in the winter at the upper two stations, and at the downstream station during the spring.

Total fauna varied significantly among the natural creeks and the Project Area during the summer (1987, 1988) and winter (Table 17). Project Area densities were lower in the summer (downstream station, July 1987; upstream and midstream stations, July 1988), but higher in the winter (Table 18). Total fauna also varied significantly within each area. The pattern of variation was the same in both the natural creeks and the Project Area in which density increased in the downstream direction.

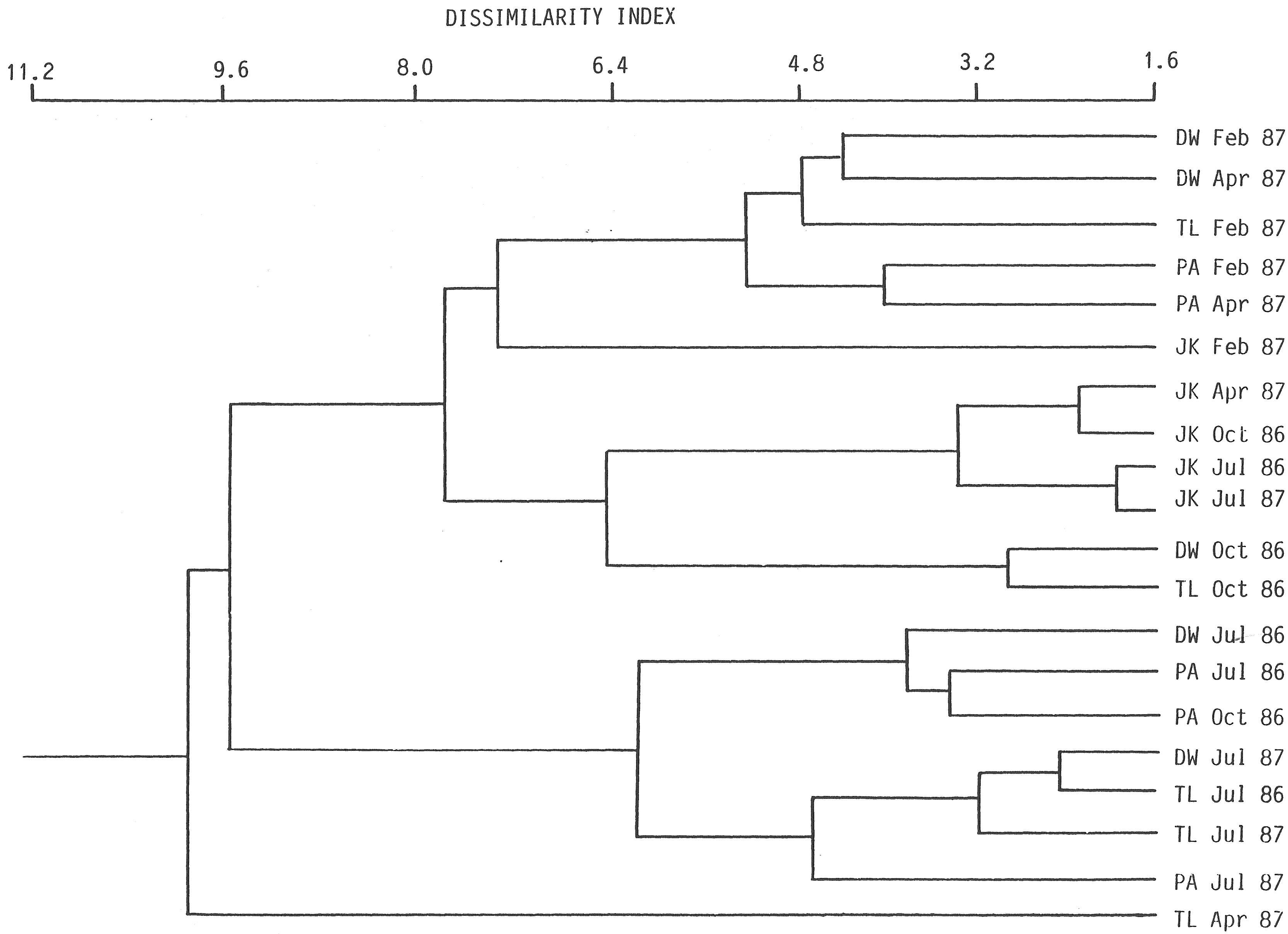

Figure 24. Relationships between the communities of the man-made (PA) and natural creeks during July 1986-July 1987. The dendrogram was obtained by cluster analysis using non-normalized densities of the species present in each creek during each season. Note that the communities are compared using a dissimilarity index. PA= Project Area 2; DW=Drinkwater Creek; JK=Jacks Creek; TL=Tooley Creek.

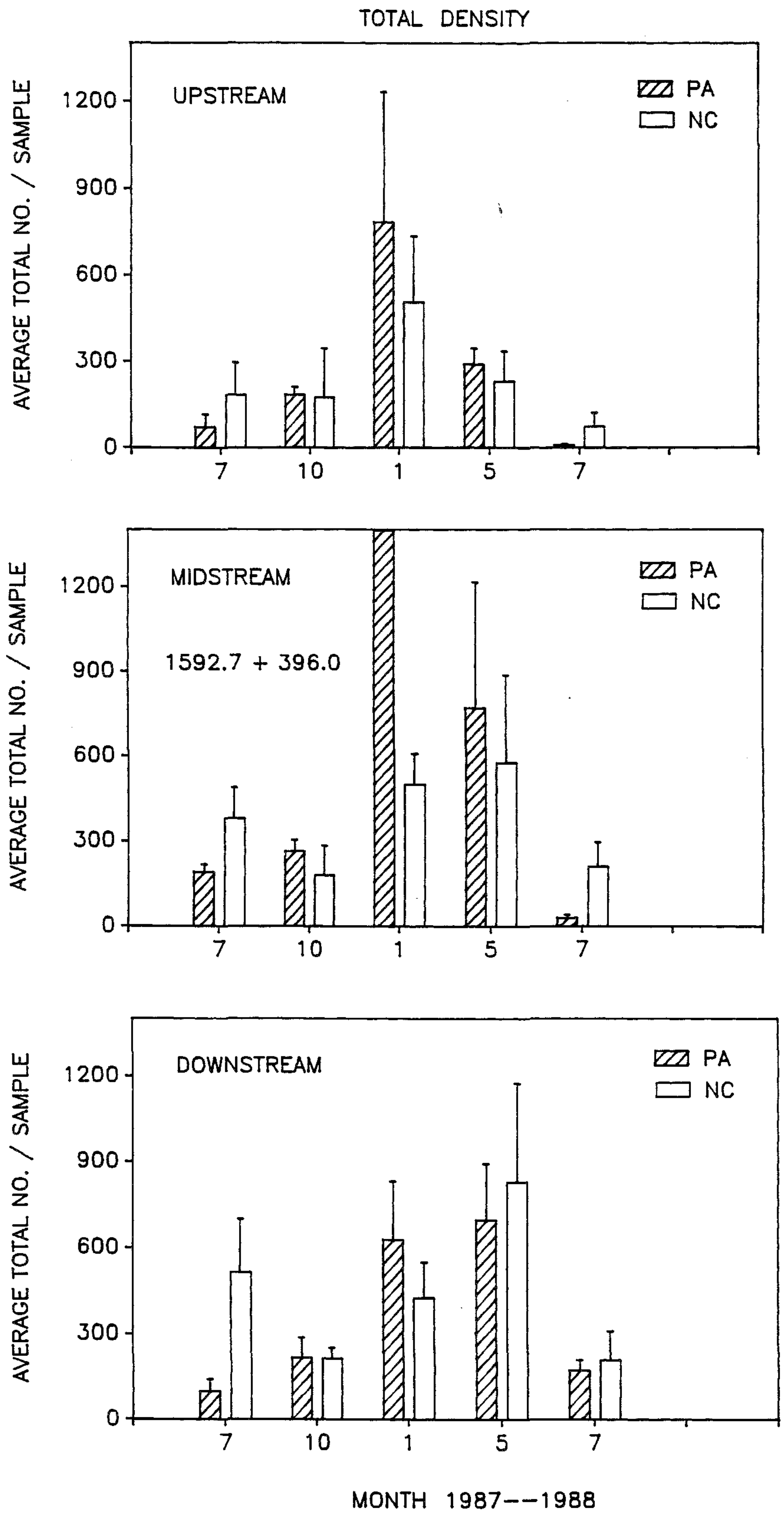

FIGURE 25 . Total faunal densities of the natural creeks (NC) and Project Area 2 (PA) during July 1987-July 1988. Each area was sampled at an upstream, midstream and downstream station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

TABLE 17. Comparisons of total densities of benthic invertebrates in the Project Area and natural creeks July 1987-July 1988. Two level nested analyses of variance (stations nested within creeks, and samples nested within stations) were run on the seasonal data sets during July 1987--July 1988. Only the significant ANOVAs are shown. Probablility values (P) less than or equal to 0.05 are denoted by an asterisk.

JULY 1987

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	1.383	1	1.383	35.548	0.000 *
AMONG STATIONS (PA)	0.324	2	0.162	4.166	0.025 *
AMONG STATIONS (NC)	1.241	2	0.620	15.948	0.000 *
ERROR	1.167	30	0.039		

JANUARY 1988

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.569	1	0.569	20.357	0.000 *
AMONG STATIONS (PA)	0.287	2	0.144	5.138	0.012 *
AMONG STATIONS (NC)	0.029	2	0.014	0.518	0.601
ERROR	0.839	30	0.028		

MAY 1988

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.040	1	0.040	0.846	0.365
AMONG STATIONS (PA)	0.284	2	0.142	2.969	0.067 *
AMONG STATIONS (NC)	1.483	2	0.742	15.519	0.000 *
ERROR	1.434	30	0.048		

JULY 1988

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	2.225	1	2.225	35.654	0.000 *
AMONG STATIONS (PA)	2.655	2	1.328	21.278	0.000 *
AMONG STATIONS (NC)	1.328	2	0.664	10.645	0.000 *
ERROR	1.872	30	0.062		

TABLE 18. Results of the Tukey-Kramer pairwise multiple comparisons test (Sokal and Rohlf, 1983) for the significant ANOVAs comparing total densities among and within the test areas during July 1987-July 1988. Project Area=Pa; Natural Creeks=NC. Numbers refer to stations (1=upstream; 2=midstream; 3=downstream). Densities of underlined stations are not significantly different. Stations are ranked from left to right in order of increasing density.

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===============================================================================

JULY 1987

             PA    PA    NC    PA    NC    NC
             1     3     1     2     2     3
             --------
                  ----------------
                         ---------
                               ---------------

-------------------------------------------------------------------------------

JANUARY 1988

             NC    NC    NC    PA    PA    PA
             3     1     2     3     1     2
             ---------------------------

-------------------------------------------------------------------------------

JULY 1988

             PA    PA    NC    PA    NC    NC
             1     2     1     3     3     2
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                  ---------
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                              ----------------

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Temporal changes in species richness were similar in the Project Area and the Natural Creeks (Figure 26). Mean numbers of species were typically highest in the winter and lowest in the summer. Significantly more species were found at the midstream station of the Project Area in the winter, while significantly fewer species occurred at the upstream and midstream station of the Project Area during the summer (Tables 19,20). In both the natural creeks and the Project Area, species richness increased in the downstream direction throughout the year.

RESULTS 4b. Community Composition: Representation of Taxa. (July 1987-July 1988).

Table (21) lists the benthic fauna found within the Project Area and the natural creeks during each season between July 1987 and July 1988. A single taxon was unique to each area; i.e., the mysid *Neomysis americanus* in the natural creeks, and the gastropod mollusc *Hydrobia sp*. in the Project area.

Eleven species were found in both areas throughout the year. These species consisted of oligochaetes, the polychaetes *Mediomastus sp*., *Laeonereis culveri*, *Polydora ligni*, *Hobsonia florida*, and *Capitella capitata*, chironomid and ceratopogonid insect larvae, the isopod *Cyathura polita*, and the amphipods *Corophium lacustre* and *Gammarus tigrinus*.

The remaining twenty taxa lacked any noticeable affiliation with either the Project Area or the natural creeks.

RESULTS 4c. Numerical Dominants. (July 1987-July 1988)

Eight species accounted for 90% or more of the total fauna of each creek during each season (Table 22). Differences in species composition among the creeks were greatest in the summer (July 1987,1988) and least in the winter (January). As with the previous year, compositional differences among the natural creeks were generally smaller than those between the Project Area and each of the natural creeks (Table 23). These differences resulted in part from the presence of novel numerical dominants within the Project Area. These species included the polychaetes *Polydora ligni* (July and October, 1987), gastropod *Hydrobia sp*. (July 1987), the amphipod *Corophium lacustre* (May 1987), and the tanaid crustacean *Hargeria rapax* (July 1988). During the course of the year the Project Area also lacked certain species which were common in the natural creeks. Noteable among this latter group of fauna was *Streblospio benedicti* (May 1988), and oligochaetes (July and October 1987).

Although the species composition of the numerical dominants varied seasonally within each creek, five species were particularly abundant over the course of the year. Seasonal variations in the distribution and abundance of these species (e.g. Oligochaeta, *Mediomastus sp*., *Laeonereis culveri*, *Hobsonia florida*, and chironomid larvae) within the study creeks are diagrammed in Figures 27-36. *Leptocheirus plumulosus* (amphipod), and *Capitella capitata* and *Streblospio benedicti* (polychaetes) are also included so comparisons can be made with the previous year's data.

Densities of oligochaetes, *Mediomastus sp*., and *Leptocheirus plumulosus* varied significantly among the creeks during each season (Table 24). Oligochaetes were poorly represented in the Project Area during each season except January 1988. This is a change from the previous year (July 1986-July 1987), when oligochaetes were abundant in the Project Area during the winter and the spring. Numbers of oligochaetes during 1987-1988 were generally lower in all creeks relative to July 1986-July 1987. Oligochaetes showed an irregular distribution within the creeks, occurring at high densities at each of the stations at least once during the year.

Among creek variation in *Mediomastus sp*. densities was primarily the result of its low abundance in Jacks Creek throughout the year. Densities of this species in the Project Area were similar to those of Tooley Creek and Drinkwater Creek between summer 1987 and winter 1988,

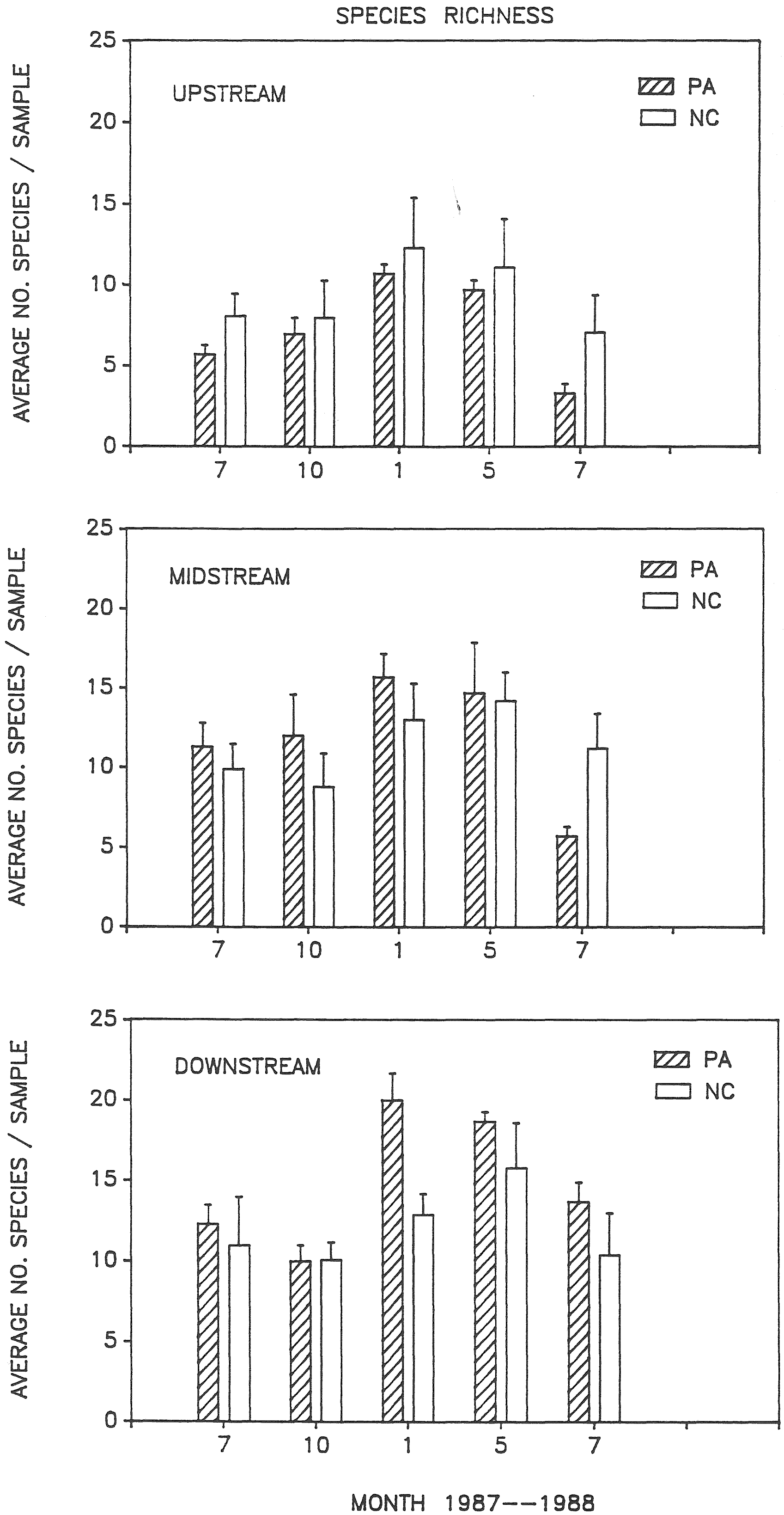

FIGURE 26. Species richness of Project Area 2 (PA) and the natural creeks (NC) during July 1987-July 1988. Each area was sampled at an upstream, midstream and downstream station. Species richness is presented as the mean number of species per 0.0225 M^2 sample + 1 standard deviation.

TABLE 19. Comparisons of species richness (mean number of species/sample) benthic invertebrates in the Project Area and Natural Creeks. Two level nested analyses of variance (stations nested within creeks, and samples nested within stations) were run on the seasonal data sets during July 1987--July 1988. Only the significant ANOVAs are shown. Probablility values (P) less than or equal to 0.05 are denoted by an asterisk.

JULY 1987

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	0.083	1	0.083	0.022	0.884
AMONG STATIONS (PA)	77.556	2	38.778	10.048	0.000 *
AMONG STATIONS (NC)	38.222	2	19.111	4.952	0.014 *
ERROR	115.778	30	3.859		

OCTOBER 1987

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	3.167	1	3.167	0.866	0.360
AMONG STATIONS (PA)	38.000	2	19.000	5.195	0.012 *
AMONG STATIONS (NC)	18.227	2	9.114	2.492	0.101
ERROR	102.413	28	3.658		

JANUARY 1988

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	49.343	1	49.343	10.408	0.003 *
AMONG STATIONS (PA)	130.889	2	65.444	13.805	0.000 *
AMONG STATIONS (NC)	2.296	2	1.148	0.242	0.786 *
ERROR	142.222	30	4.741		

APRIL 1988

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	2.676	1	2.676	0.436	0.514
AMONG STATIONS (PA)	122.000	2	61.000	9.946	0.000 *
AMONG STATIONS (NC)	101.630	2	50.815	8.285	0.001 *
ERROR	184.000	30	6.133		

TABLE 19 (Continued). Comparisons of species richness (mean number of species/sample) benthic invertebrates in the Project Area and Natural Creeks. Two level nested analyses of variance (stations nested within creeks, and samples nested within stations) were run on the seasonal data sets during July 1987--July 1988. Only the significant ANOVAs are shown. Probablility values (P) less than or equal to 0.05 are denoted by an asterisk.

JULY 1988

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AMONG AREAS	28.009	1	28.009	6.148	0.019 *
AMONG STATIONS (PA)	176.222	2	88.111	19.341	0.000 *
AMONG STATIONS (NC)	85.852	2	42.926	9.423	0.001 *
ERROR	136.667	30	4.556		

TABLE 20. Results of the Tukey-Kramer pairwise multiple comparisons test for the significant ANOVAs comparing species richness (mean number of species/sample) among and within the test areas during July 1987-July 1988 Project Area=Pa; Natural Creeks=NC. Numbers refer to stations (1=upstream; 2=midstream; 3=downstream). Species richness of underlined stations are not significantly different. Significance was determined by the Tukey-Kramer method (Sokal and Rohlf, 1983). Stations are ranked from left to right in order of increasing species richness.

JANUARY 1988

```
PA    NC    NC    NC    PA    PA
 1     1     3     2     2     3
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MAY 1988

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PA    NC    NC    PA    NC    PA
 1     1     2     2     3     3
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JULY 1988

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PA    PA    NC    NC    NC    PA
 1     2     1     3     2     3
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TABLE 21. Representation of benthic invertebrates in the test areas during July 1987-July 1988. For a given season, species are indicated as being either limited ("Lim") to just Project Area 2 (PA) or just the Natural Creeks (NC), or ubiquitous ("Ubiq") and found in both areas. The NC listings indicate parenthetically the number of natural creeks in which a given species was found. Three natural creeks were sampled each season.

Species/Taxon	7/87 Lim	7/87 Ubiq	10/87 Lim	10/87 Ubiq	1/88 Lim	1/88 Ubiq	5/88 Lim	5/88 Ubiq	7/88 Lim	7/88 Ubiq
ANNELIDA-Oligochaeta		x		x		x		x		x
ANNELIDA-Polychaeta										
Mediomastus sp.		x		x		x		x		x
Heteromastus filiformis		x		x		x		x	NC(3)	
Laeonereis culveri		x		x		x		x		x
Polydora ligni	PA			x		x		x		x
Scolecolepides virides		x			PA			x	NC(2)	
Streblospio benedicti	PA			x		x		x		x
Hobsonia florida		x		x		x		x		x
Eteone heteropoda						x	NC(1)		NC(1)	
Capitella capitata		x		x		x		x		x
ANNELIDA-Hirudinea						x	PA			
ARTHROPODA-Uniramia										
Chironomidae		x		x		x		x		x
Ceratopogonidae		x		x		x		x		x
Insect A	PA			x		x		x		x
ARTHROPODA-Crustacea										
Mysidopsis bigelowi		x					NC(2)			x
Neomysis americanus							NC(1)			
Cyathura polita		x		x		x		x		x
Corophium lacustre		x		x		x		x		x
Leptocheirus plumulosus		x		x		x		x	NC(3)	
Gammarus mucronatus			NC(1)			x		x	PA	
Gammarus tigrinus		x		x		x		x		x
Edotea sp.	PA		NC(2)			x		x		x
Hargeria rapax	NC(1)			x						
Palaemonetes pugio	NC(1)							x	PA	
Sesarma reticulatum						x	NC(1)			

TABLE 21 (Continued). Representation of benthic invertebrates in the test areas during July 1987-July 1988. For a given season, species are indicated as being either limited ("Lim") to just Project Area 2 (PA) or just the Natural Creeks (NC), or ubiquitous ("Ubiq") and found in both areas. The NC listings indicate parenthetically the number of natural creeks in which a given species was found. Three natural creeks were sampled each season.

	7/87		10/87		1/88		5/88		7/88	
Species/Taxon	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq	Lim	Ubiq
MOLLUSCA-Bivalvia										
Macoma balthica		x	PA			x		x	PA	
Macoma phenax		x		x		x		x	NC(3)	
Rangia cuneata		x		x		x		x	NC(2)	
MOLLUSCA-Gastropoda										
Hydrobia sp.	PA									
CNIDARIA-Anthozoa										
Edwardsia sp.	PA			x		x		x		x
PLATYHELMINTHES			NC(1)			x				
RHYNCOCOELA		x				x	NC(2)		NC(2)	

TABLE 22 . Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1987--July 1988. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

JULY 1987

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	44.5	1458	*Mediomastus sp.*	53.1	1709
Oligochaeta	26.9	883	Oligochaeta	17.2	553
Leptocheirus plumulosus	20.3	667	*Leptocheirus plumulosus*	11.3	365
Laeonereis culveri	2.4	79	Chironomidae	6.8	220
Macoma phenax	1.7	55	*Laeonereis culveri*	5.4	172
Chironomidae	1.0	33	*Capitella capitata*	2.3	74
Capitella capitata	0.6	20	*Hobsonia florida*	1.1	34
Macoma balthica	0.6	20	*Mysidopsis bigelowi*	0.6	19
SUM	98.0	3215		97.8	3146
TOTAL	100	3279		100	3218

JACKS			PROJECT AREA 2		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	46.3	1497	*Mediomastus sp.*	56.0	613
Leptocheirus plumulosus	16.3	527	*Leptocheirus plumulosus*	19.4	212
Laeonereis culveri	13.7	444	*Hydrobia sp.*	11.3	123
Chironomidae	5.5	177	*Laeonereis culveri*	3.9	43
Mediomastus sp.	3.2	104	Chironomidae	1.9	20
Capitella capitata	2.2	71	*Cyathura polita*	1.0	11
Gammarus tigrinus	1.9	62	*Hobsonia florida*	1.0	10
Mysidopsis bigelowi	1.9	62			
SUM	91.0	2943		94.4	1033
TOTAL	100	3236		100	1094

TABLE 22 (Continued). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 between July 1986--July 1987. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species which collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

OCTOBER 1987

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	51.4	997	Oligochaeta	54.8	1101
Mediomastus sp.	28.9	560	*Mediomastus sp.*	13.7	275
Chironomidae	3.7	71	*Polydora ligni*	6.9	139
Laeonereis culveri	1.8	35	Chironomidae	6.3	127
Hobsonia florida	1.8	34	*Hobsonia florida*	2.9	59
Cyathura polita	1.2	24	*Corophium lacustre*	2.6	52
Capitella capitata	1.0	20	*Laeonereis culveri*	1.5	31
SUM	94.9	1840		96.0	1928
TOTAL	100	1939		100	2009

JACKS			PROJECT AREA		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	61.6	495	*Laeonereis culveri*	28.3	569
Chironomidae	22.9	184	*Mediomastus sp.*	23.9	481
Hobsonia florida	7.0	56	*Hobsonia florida*	16.8	337
Corophium lacustre	3.1	25	*Hydrobia sp.*	10.8	217
Ceratopogonidae	2.4	19	Chironomidae	7.6	153
Heteromastus filiformis	0.9	7	*Polydora ligni*	5.7	115
Mediomastus sp.	0.5	4	*Cyathura polita*	2.0	41
Laeonereis culveri	0.4	3	*Capitella capitata*	1.7	34
SUM	98.8	793		96.9	1947
TOTAL	100	803		100	2009

TABLE 22 (Continued). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 between July 1986--July 1987. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

MAY 1988

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Leptocheirus plumulosus	44.7	2807	*Leptocheirus plumulosus*	42.1	2388
Oligochaeta	20.0	1259	Oligochaeta	32.0	1816
Mediomastus sp.	13.6	852	*Mediomastus sp.*	10.6	601
Hobsonia florida	5.3	331	Chironomidae	5.3	300
Cyathura polita	3.5	223	*Gammarus tigrinus*	2.2	123
Chironomidae	3.1	195	*Streblospio benedicti*	2.2	122
Edwardsia	2.6	162	*Hobsonia florida*	1.7	99
Streblospio benedicti	2.3	144	Edwardsia	0.9	52
SUM	95.1	5973		97.0	5501
TOTAL	100	6283		100	5672

JACKS			PROJECT AREA 2		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Chironomidae	29.9	838	Chironomidae	32.4	1713
Oligochaeta	27.8	777	*Gammarus tigrinus*	21.5	1135
Hobsonia florida	26.1	729	*Hobsonia florida*	16.7	881
Gammarus tigrinus	3.6	101	*Corophium lacustre*	9.1	480
ANEM	2.2	62	*Mediomastus sp.*	6.0	315
Polydora ligni	2.1	60	*Polydora ligni*	3.0	161
Ceratopogonidae	1.7	48	Oligochaeta	2.3	119
Streblospio benedicti	1.7	48	*Gammarus mucronatus*	1.6	87
SUM	95.2	2663		92.6	4891
TOTAL	100	2798		100	5282

TABLE 22 (Cont). Relative abundance of the numerically dominant species collected from the natural creeks and Project Area 2 during July 1986--July 1987. "%" refers to the designated species' proportion of the total number of organisms collected at a particular creek and time. "Number" represents the actual number of individuals of that species collected. The overall abundance of the numerical dominants ("sum") is also given as a percentage of the total number of animals collected ("total") at the stated creek and time.

JULY 1988

TOOLEY			DRINKWATER		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Mediomastus sp.	38.6	771	Oligochaeta	33.0	563
Leptocheirus plumulosus	24.3	486	*Mediomastus sp.*	26.0	443
Oligochaeta	23.0	459	*Leptocheirus plumulosus*	20.7	352
Chironomidae	3.5	69	Chironomidae	5.5	93
Polydora ligni	2.1	42	*Capitella capitata*	3.9	66
Hobsonia florida	1.8	35	*Corophium lacustre*	3.3	57
Laeonereis culveri	1.7	33	*Mysidopsis bigelowi*	2.5	43
Capitella capitata	1.4	28	*Laeonereis culveri*	1.2	21
SUM	96.3	1923		96.1	1638
TOTAL	100	1997		100	1704

JACKS			PROJECT AREA 2		
SPECIES	%	NUMBER	SPECIES	%	NUMBER
Oligochaeta	41.0	323	*Mediomastus sp.*	31.7	202
Chironomidae	17.6	139	Chironomidae	19.7	126
Hobsonia florida	11.8	93	*Polydora ligni*	9.7	62
Polydora ligni	7.4	58	*Corophium lacustre*	9.1	58
Laeonereis culveri	4.9	39	Oligochaeta	7.4	47
Corophium lacustre	3.0	24	*Hobsonia florida*	7.1	45
Macoma phenax	2.7	21	*Laeonereis culveri*	4.7	30
Mediomastus sp.	2.2	17	*Hargeria rapax*	1.9	12
SUM	90.6	714		91.2	582
TOTAL	100	788		100	638

TABLE 23. Similarity of species composition of the numerically abundant fauna in the man-made and natural creeks during July 1985-July 1986. The values presented are Jaccard's similarity indices. A value of 1.00 denotes identical species composition.

JULY 1987

	DW	JK	TL	PA
DW	1.00			
JK	0.80	1.00		
TL	0.30	0.30	1.0	
PA	0.50	0.38	0.30	1.00

OCTOBER 1987

	DW	JK	TL	PA
DW	1.00			
JK	0.63	1.00		
TL	0.63	0.50	1.00	
PA	0.50	0.38	0.63	1.00

JANUARY 1988

	DW	JK	TL	PA
DW	1.00			
JK	0.63	1.00		
TL	0.80	0.50	1.00	
PA	0.63	0.63	0.80	1.00

MAY 1988

	DW	JK	TL	PA
DW	1.00			
JK	0.63	1.00		
TL	0.80	0.50	1.00	
PA	0.50	0.50	0.38	1.00

JULY 1988

	DW	JK	TL	PA
DW	1.00			
JK	0.50	1.00		
TL	0.63	0.63	1.00	
PA	0.50	0.80	0.63	1.00

TABLE 24. Summary of the significant (P < 0.05) nested ANOVAS comparing the density of numerically abundant species among and within the study creeks. Creeks listed within the "Within Creek" column showed significant among station variation in mean densities for the designated species and season during July 1987-July 1988.

SPECIES	DATE	SOURCE OF VARIATION AMONG CREEKS	WITHIN CREEKS
Oligochaeta	7/87	*	JK, TL
	10/87	*	DW
	1/88	*	PA
	5/88	*	DW
	7/88	*	DW, JK
Mediomastus sp.	7/87	*	DW, PA, TL
	10/87	*	DW, PA, TL
	1/88	*	DW, PA, TL
	5/88	*	DW, PA, TL
	7/88	*	DW, PA, TL
Laeonereis culveri	7/87	*	DW, PA, JK, TL
	10/87	*	PA, TL
	1/88	*	PA, TL
	5/88	*	DW, PA, TL
	7/88	ns	DW, PA, TL
Hobsonia florida	7/87	ns	DW, PA
	10/87	*	PA
	1/88	*	DW, JK, PA, TL
	5/88	*	PA
	7/88	*	JK, PA, TL
Streblospio benedicti	7/87	ns	PA, TL
	10/87	ns	DW
	1/88	*	DW, TL
	5/88	*	DW, JK, PA, TL
	7/88	ns	DW, TL
Chironomidae	7/87	*	DW, JK
	10/87	*	DW, JK, PA
	1/88	*	DW, PA
	5/88	*	JK, PA
	7/88	ns	PA, TL
Leptocheirus plumulosus	7/87	*	DW, PA, TL
	10/87	*	DW
	1/88	*	DW, TL
	5/88	*	DW, TL
	7/88	*	DW, TL

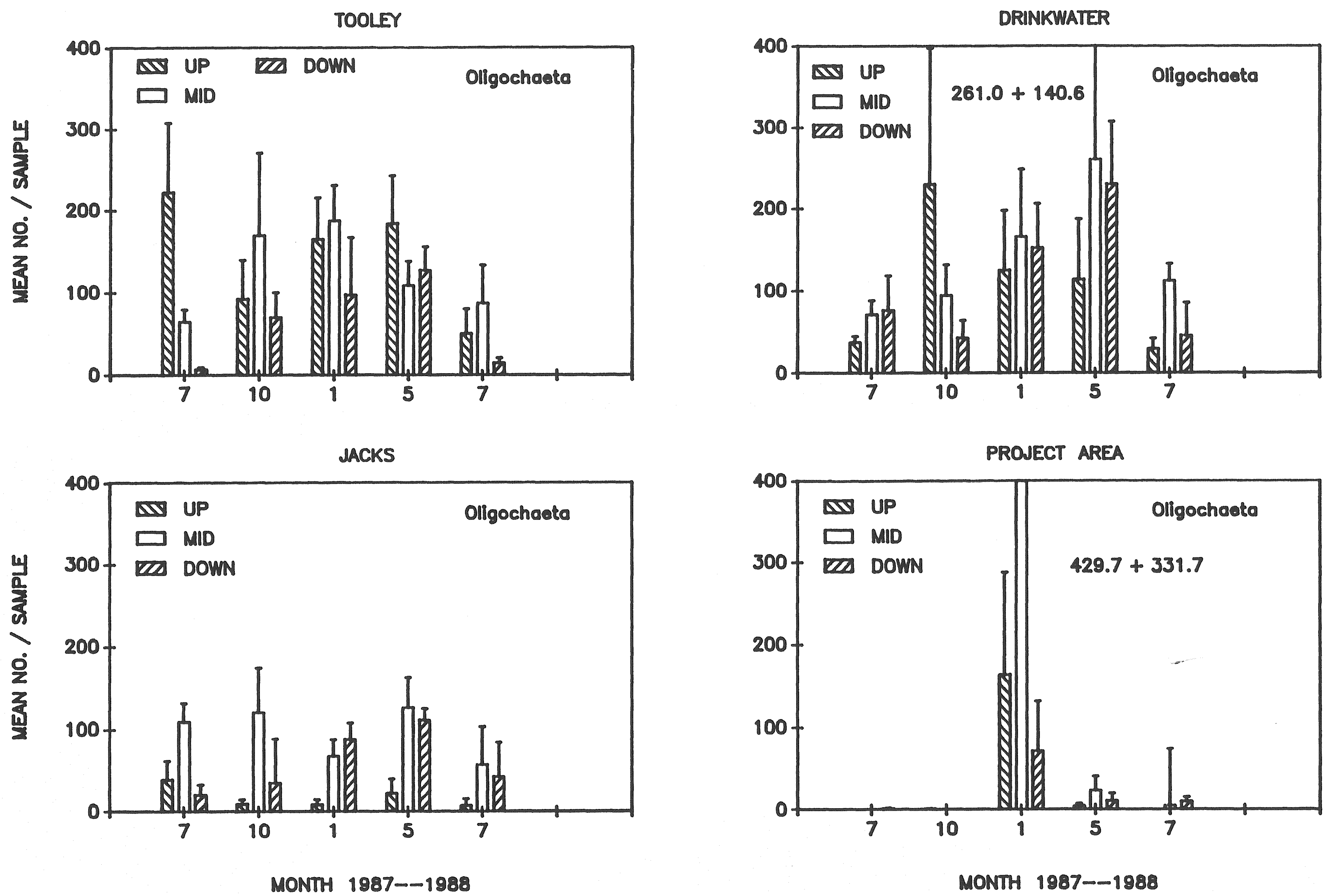

FIGURE 27. Distribution and abundance of the Oligochaeta in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

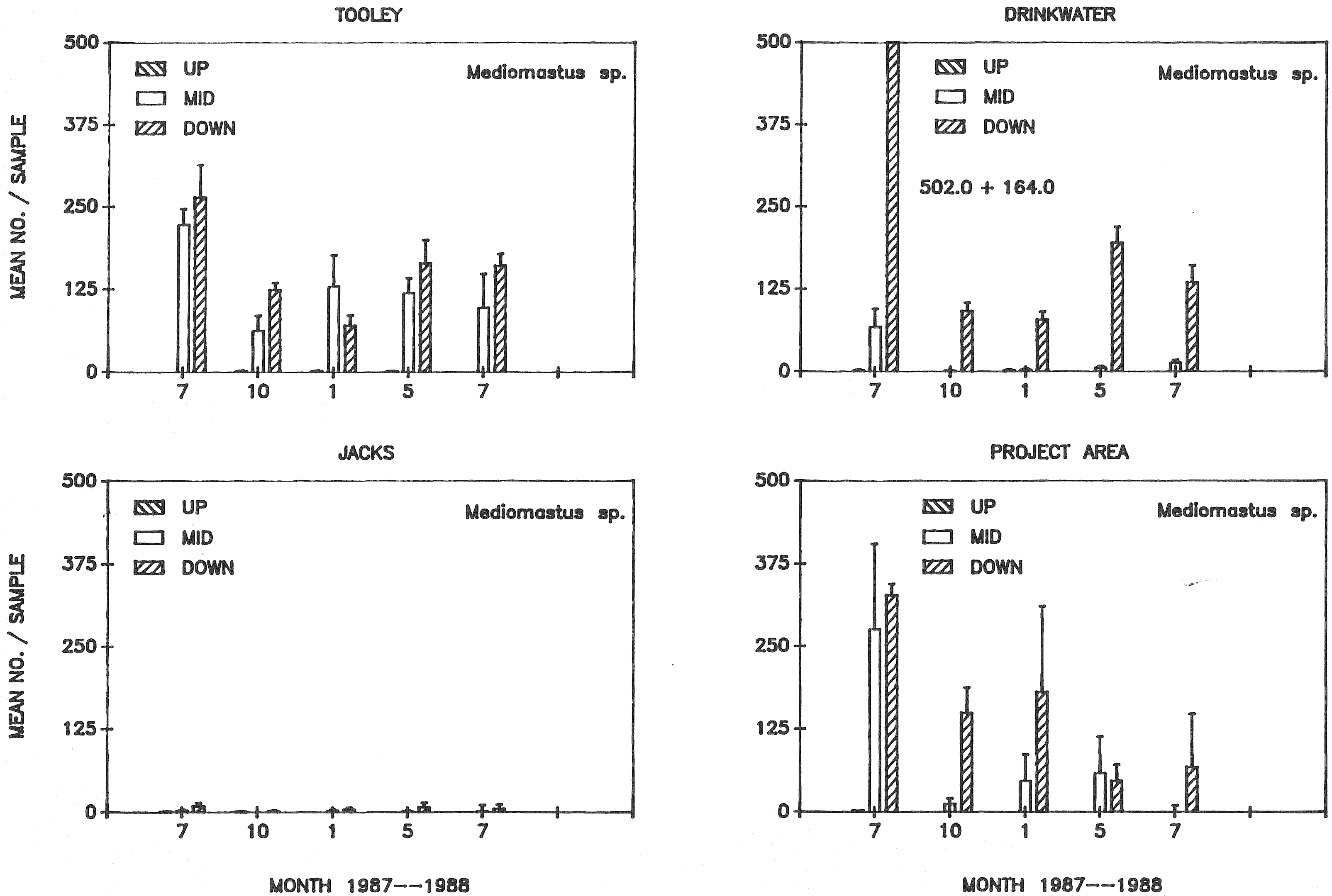

FIGURE 28. Distribution and abundance of *Mediomastus sp.* in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

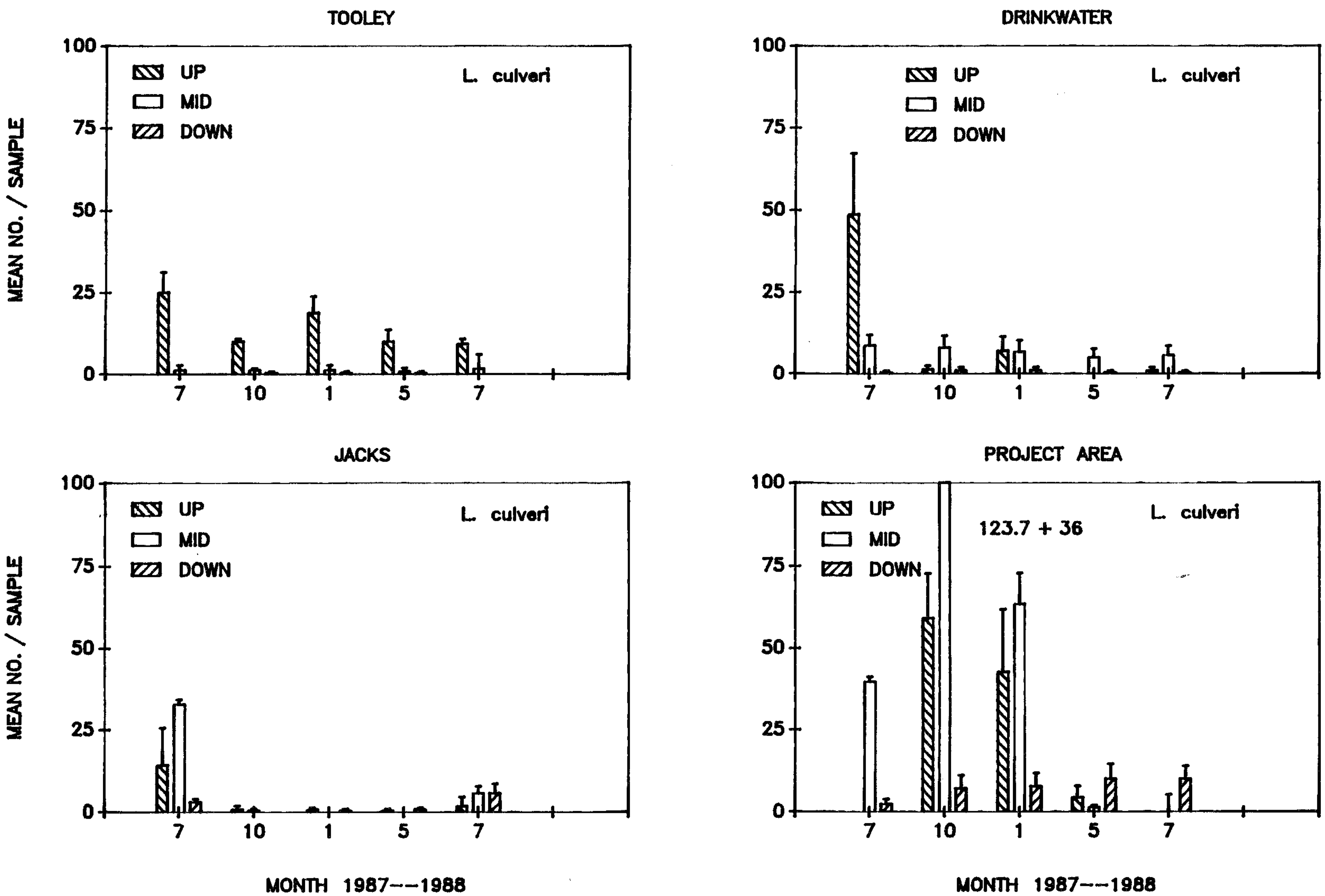

FIGURE 29 . Distribution and abundance of *Laeonereis culveri* in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

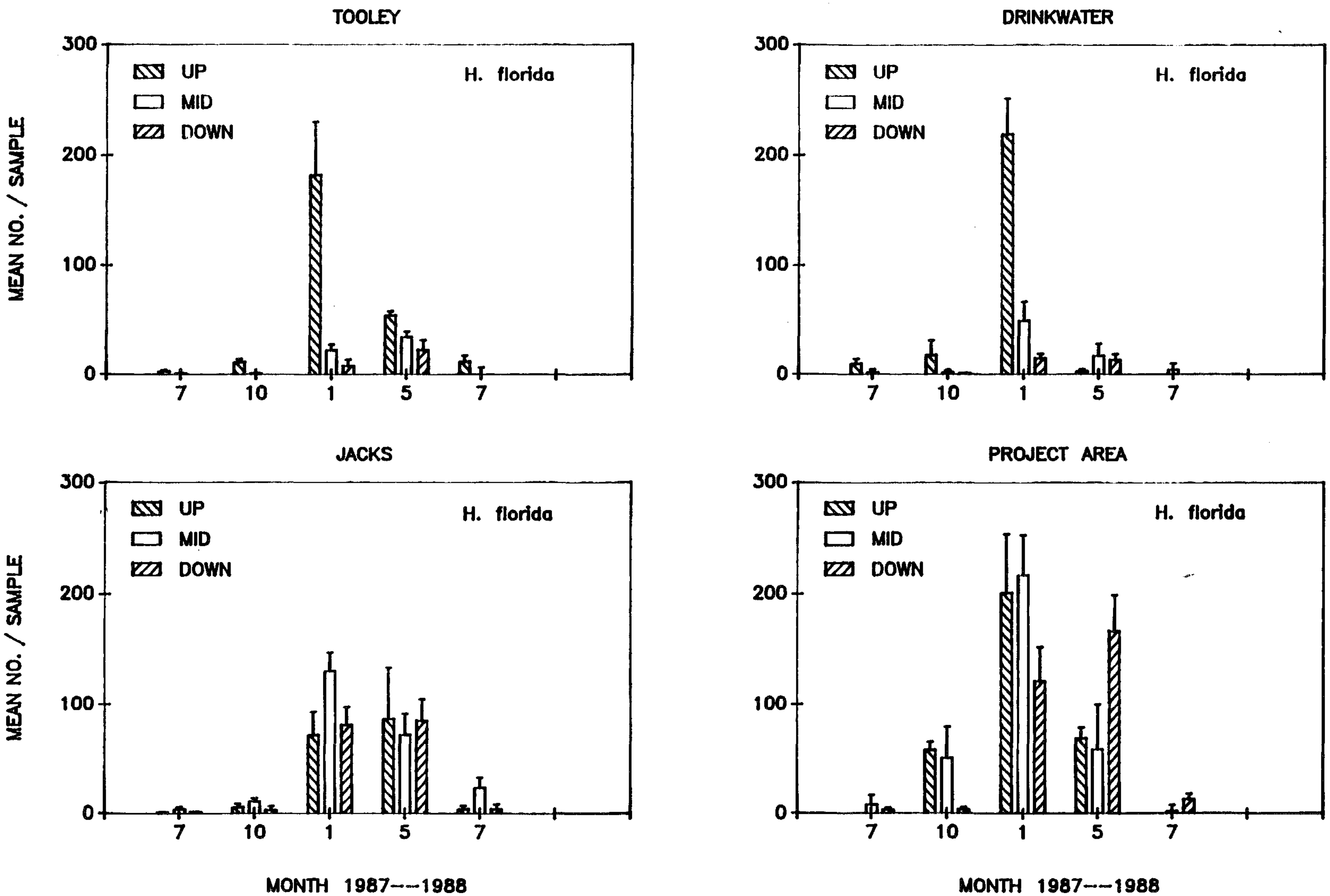

FIGURE 30. Distribution and abundance of *Hobsonia florida* in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

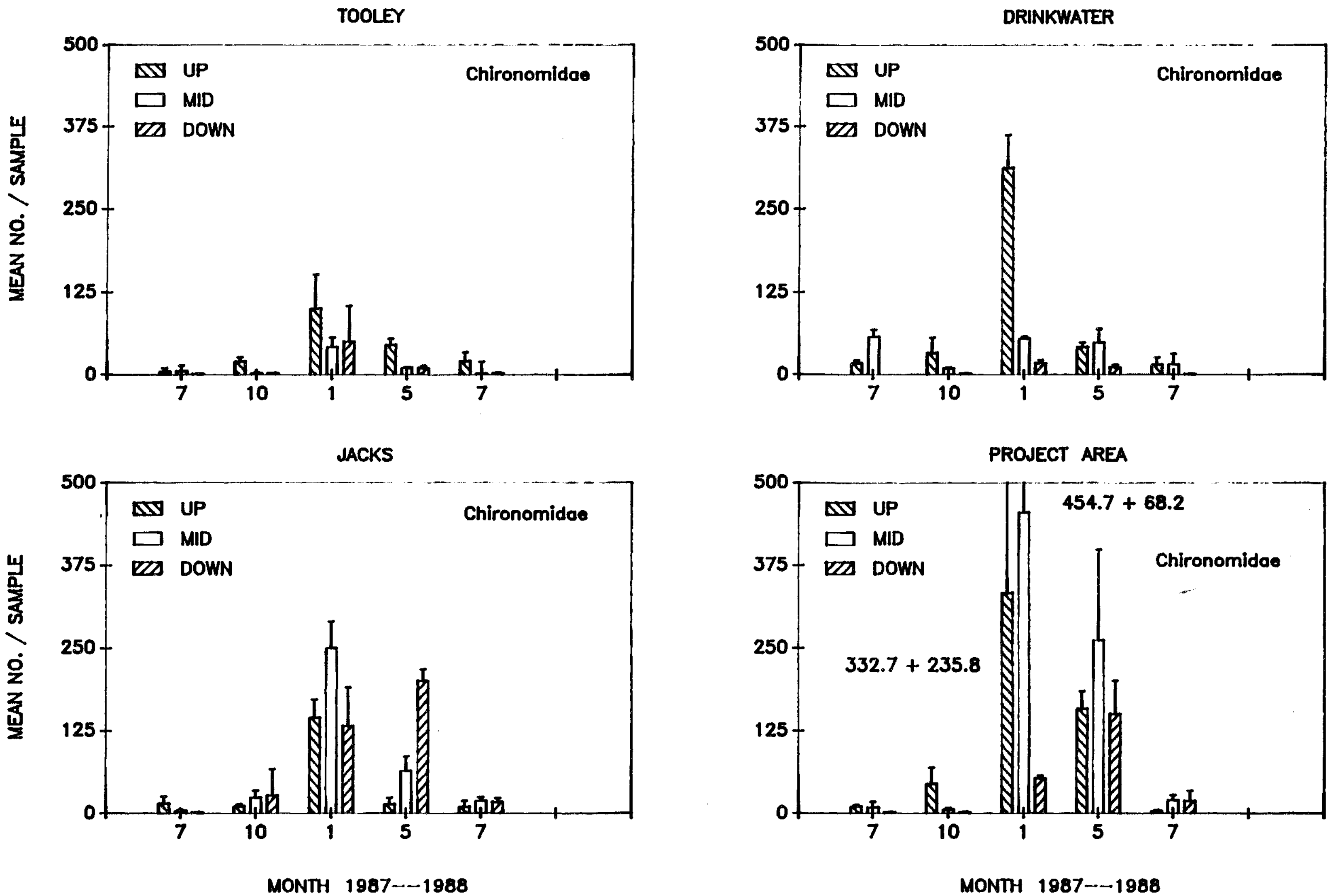

FIGURE 31 Distribution and abundance of chironomid larvae in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

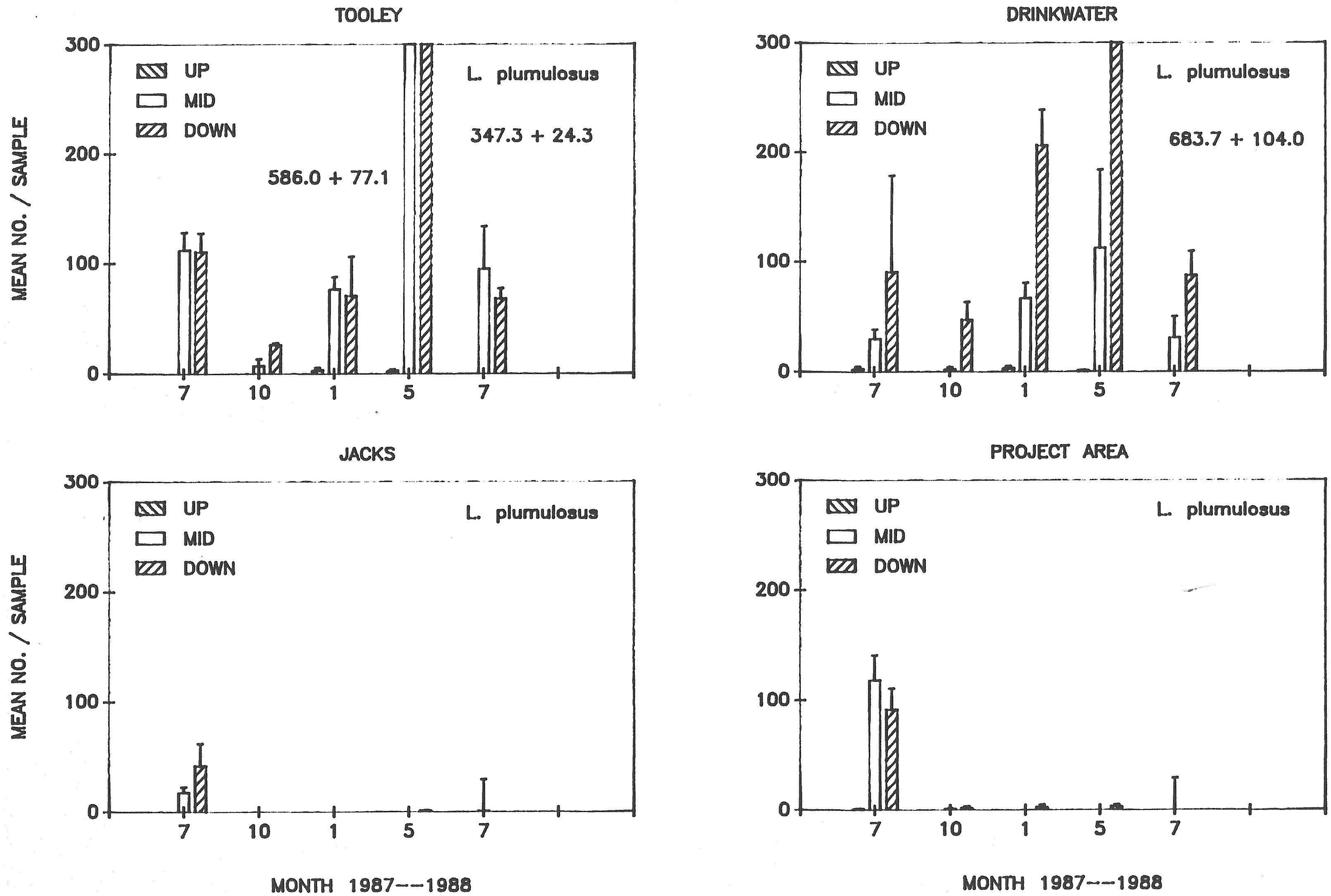

FIGURE 32. Distribution and abundance of *Leptocheirus plumulosus* in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

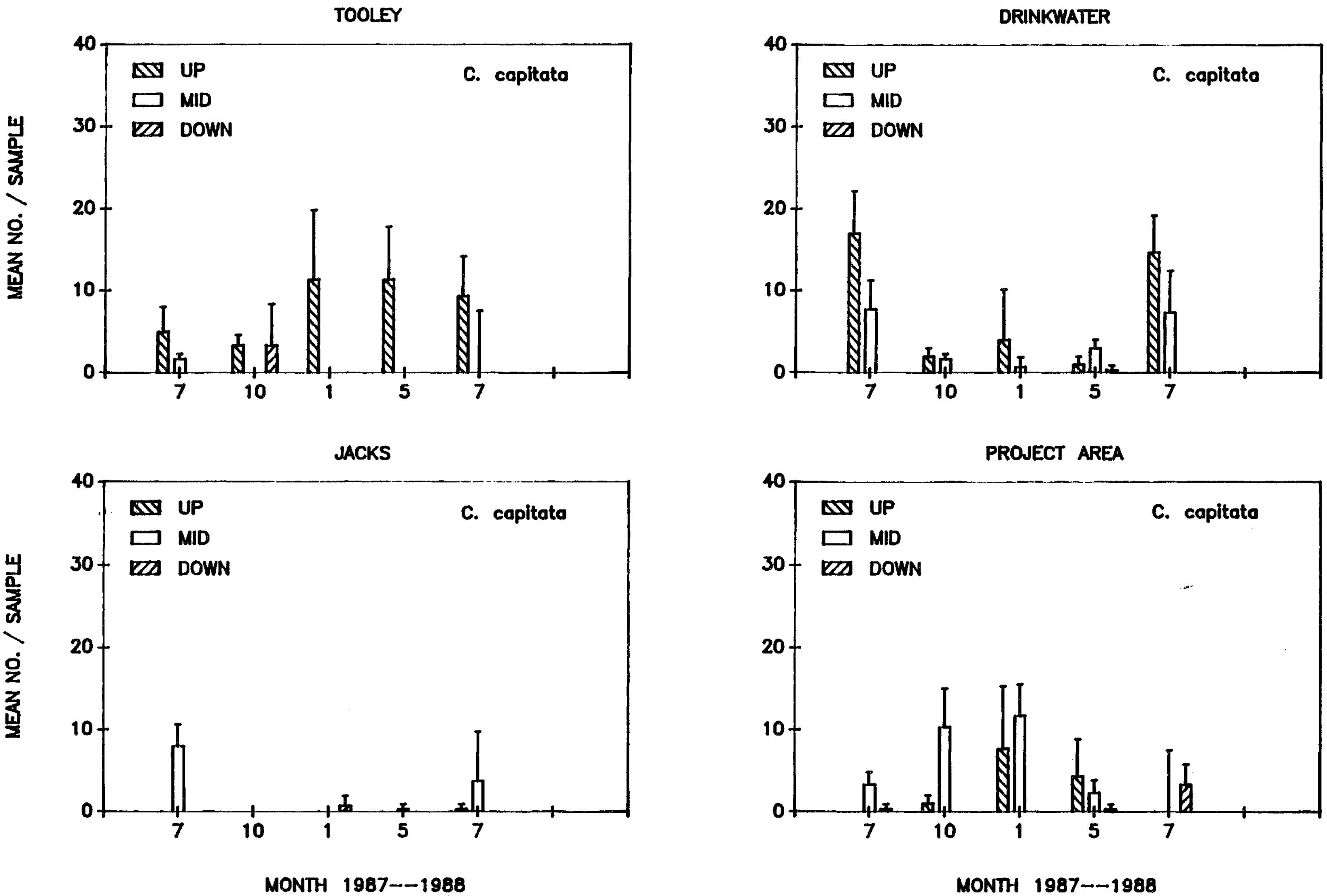

FIGURE 33 . Distribution and abundance of *Capitella capitata* in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

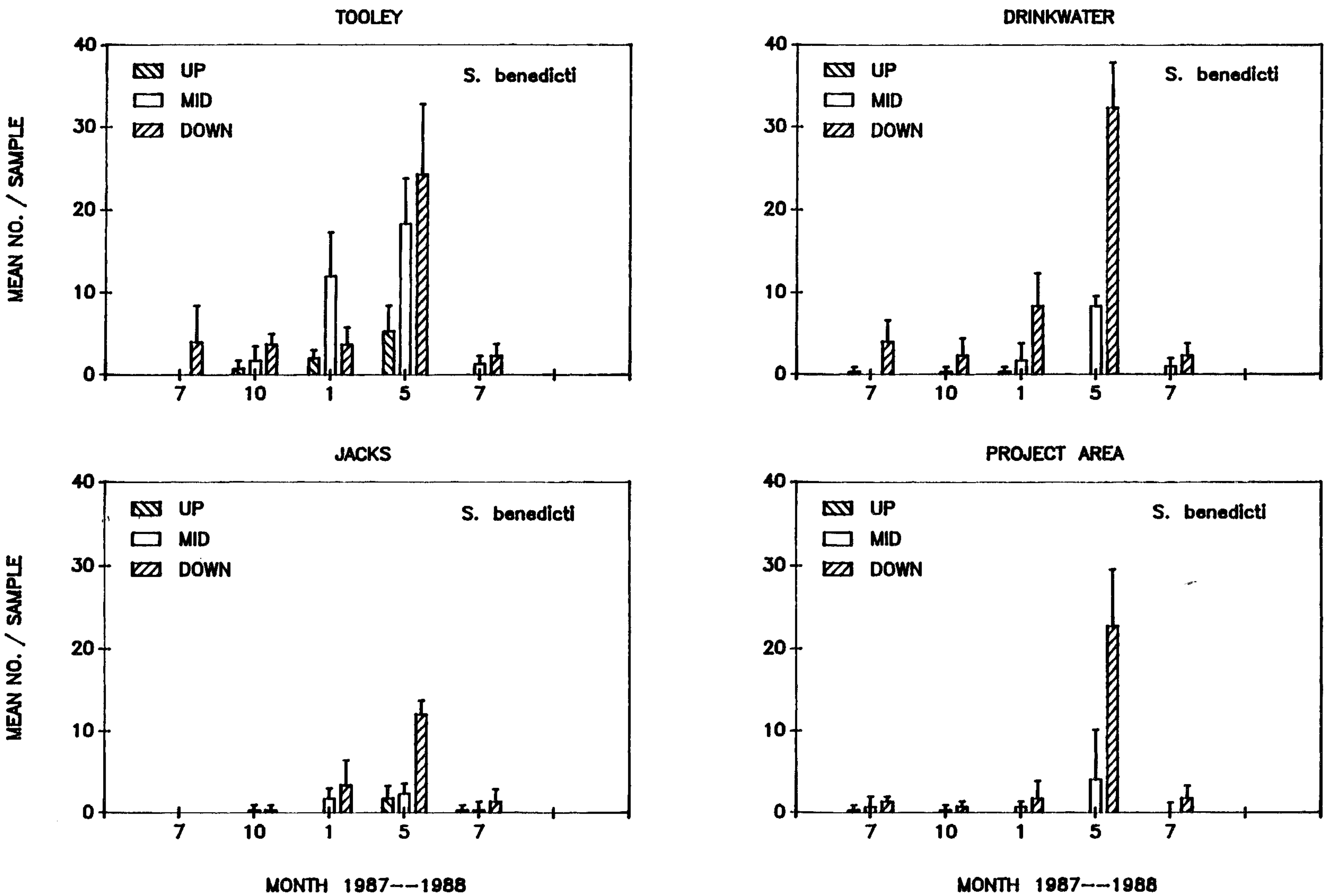

FIGURE 34. Distribution and abundance of *Streblospio benedicti* in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

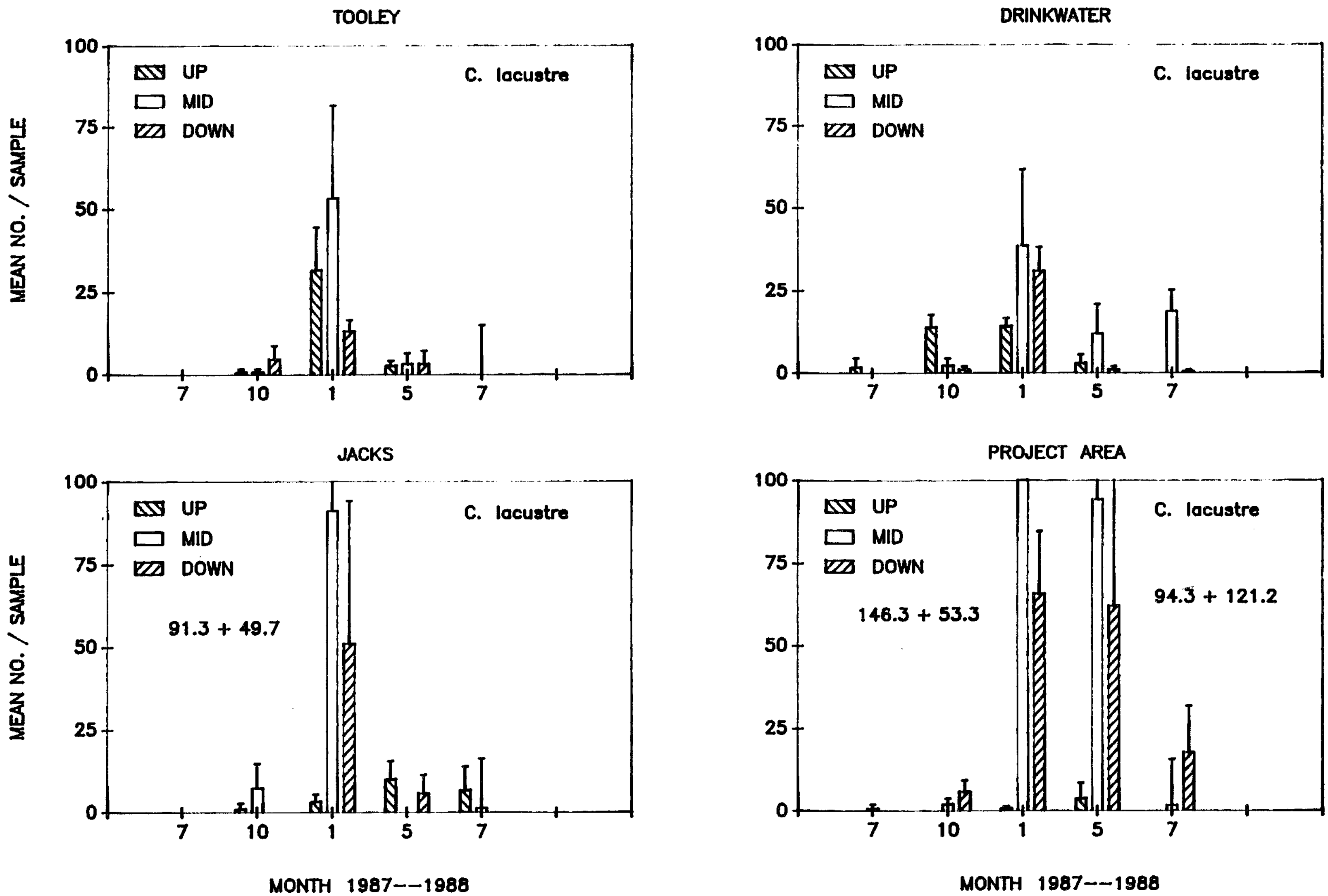

FIGURE 35 . Distribution and abundance of *Corophium lacustre* in the natural creeks and Project Area 2 during July 1987-July 1988. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

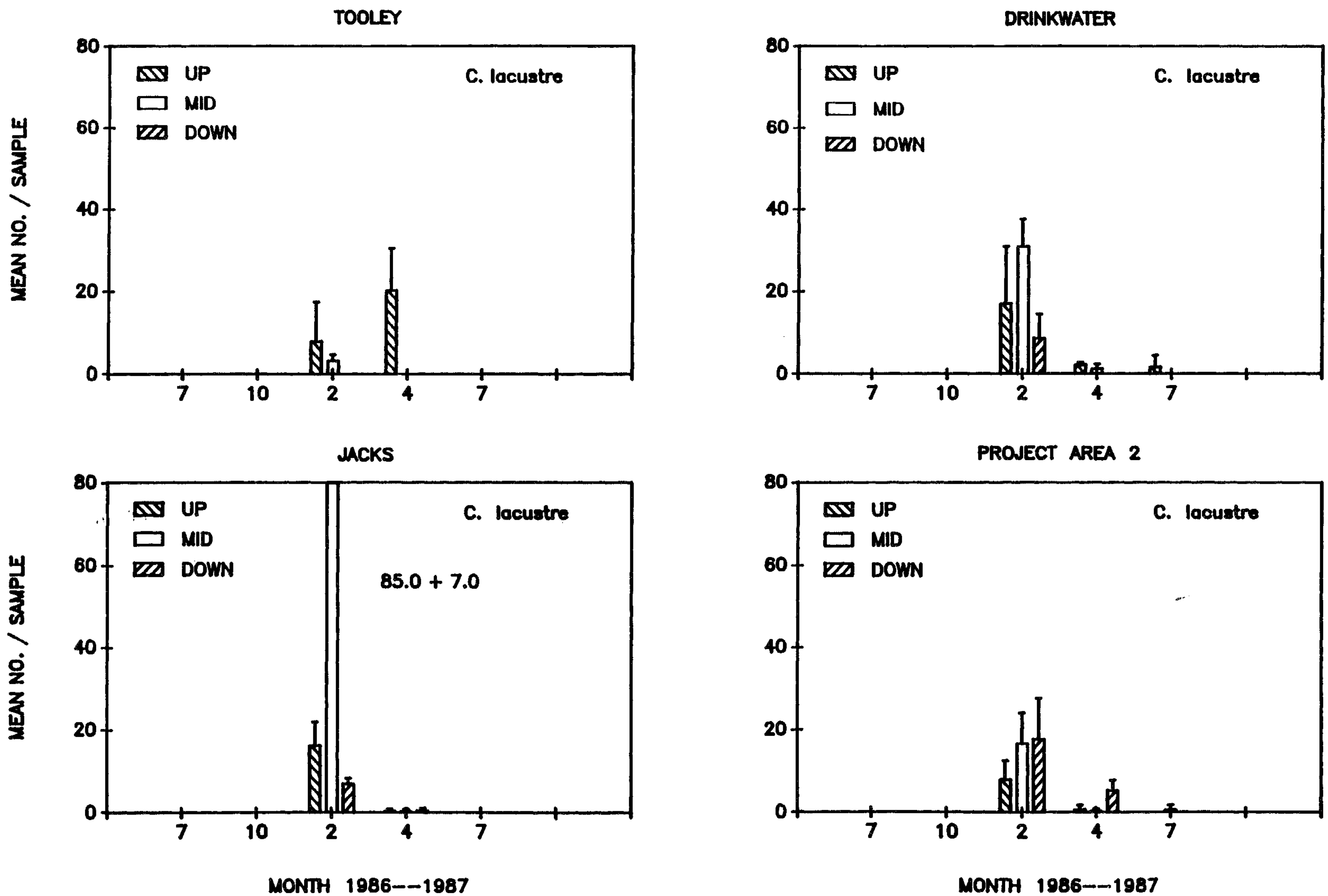

FIGURE 36. Distribution and abundance of *Corophium lacustre* in the natural creeks and Project Area 2 during July 1986-July 1987. Within creek distribution was determined by sampling at an upstream (UP), midstream (MID), and downstream (DOWN) station. Densities are shown as the mean number of individuals per 0.0225 M^2 sample + 1 standard deviation.

TABLE 24 (Continued). Summary of the significant ($P < 0.05$) nested ANOVAS comparing the density of numerically abundant species among and within the study creeks. Creeks listed within the "Within Creek" column showed significant among station variation in mean densities for the designated species and season during July 1987-July 1988.

SPECIES	DATE	SOURCE OF VARIATION AMONG CREEKS	WITHIN CREEKS
Capitella capitata	7/87	ns	
	10/87	*	PA, TL
	1/88	*	TL
	5/88	*	DW, TL
	7/88	*	DW, JK, TL

but were approximately half those in the natural creeks in the spring and summer 1988. *Mediomastus sp.* was abundant at the midstream and downstream stations in Tooley Creek and the Project Area, and at the downstream station in Drinkwater Creek. Densities of this species in all creeks was reduced by about 50% from the previous year.

Leptocheirus plumulosus was common in Tooley and Drinkwater creek throughout the year, but abundant in Jacks Creek and the Project Area only during summer 1987. The absence of high numbers of this species from Jacks Creek--and especially the Project Area---during the winter, spring and summer seasons is a change from the previous year. However, coincident with the low densities of *L. plumulosus* in the Project Area and Jacks Creek was exceptionally high densities of another amphipod, *Corophium lacustre* (Figure 35). *C. lacustre* was not as abundant in the other natural creeks. High densities of *C. lacustre* during the previous year was limited to a single episode in the winter (February) 1987 for all creeks (Figure 36).

Densities of *Streblospio benedicti* decreased in a systematic fashion from Tooley Creek to Jacks Creek (Figure 34). Differences in among creek densities were significant only during winter and spring 1988 (Table 24). Densities of *S. benedicti* in the Project Area were at or below those of Jacks Creek for all seasons except for spring (May) 1988, when they were similar to the numbers occurring in Tooley Creek and Drinkwater Creek. In all creeks, the highest densities of *S. benedicti* occurred at the downstream station. Substantial numbers were also found at the midstream station in Tooley Creek during winter and spring 1988. Numbers of *S. benedicti* were generally lower in all creeks during 1987-1988 than during the previous year.

The remaining numerically dominant species, *Laeonereis culveri*, *Hobsonia florida*, and chironomid larvae, *Capitella capitata*,occurred in the Project Area at densities equivalent to or greater than any of the natural creeks (Figures 29,30,31,33, respectively). These species were more evenly distributed along the lengths of Jacks creek and the Project Area than in Tooley Creek and Drinkwater Creek.

RESULTS 4d. Community Structure. (July 1987-July 1988).

During July 1987-July 1988, community structure of the creeks varied primarily as a function of time (season) rather than location (creek) (Figure 37). The communities of Drinkwater Creek and Tooley Creek aggregated together into five discreet seasonal pairings. Community structure of the Project Area was similar to those of Tooley and Drinkwater Creeks during July 1987, and to that of Jacks Creek during fall 1987, and spring and summer 1988. Structural differences among the creeks during these seasons reflected local variations in species composition. These various seasonal clustering patterns can be predicted from the Jaccard similarity values in Table 23.

The Project Area community in winter (January) 1988 was distinct from all other communities; in fact, differences in community structure between the Project Area and Drinkwater and Tooley Creek at this time established the boundaries of the dissimilarity range for the entire year (Figure 37). The isolation of the winter Project Area community from those of the natural creeks was a consequence of vast numerical differences among the two areas, and was not a result of major differences in species compostion. At this time, densities in the Project Area were 2-3 times higher than those in the natural creeks.

RESULTS 4e. SUMMARY OF THE BENTHOS: (July 1987-July 1988)

Temporal patterns of total density varied slightly among the Project Area and the natural creeks, owing to the comparatively high densities in the natural creeks during July 1987. Greatest numbers of organisms and species occurred in the winter-spring in all creeks. Density and

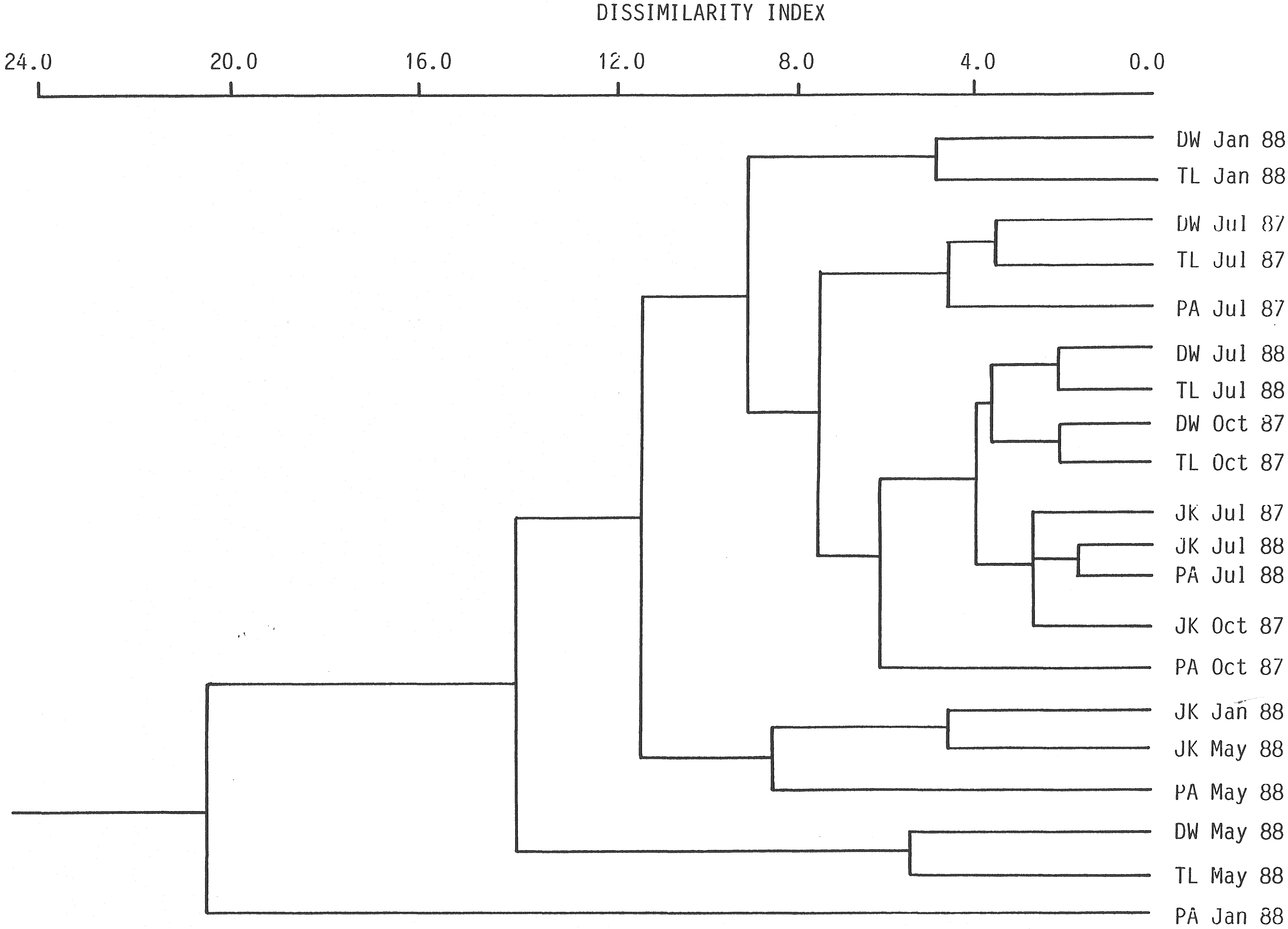

Figure 37. Relationships between the communities of the man-made (PA) and natural creeks during July 1987-July 1988. The dendrogram was obtained by cluster analysis using non-normalized densities of the species present in each creek during each season. Note that the communities are compared using a dissimilarity index. PA= Project Area 2; DW=Drinkwater Creek; JK=Jacks Creek; TL=Tooley Creek.

species richness in the Project Area were significantly higher during the winter, and significantly lower during the summer.

A total of 32 taxa were found in the study areas; representation of taxa among man-made and natural systems was essentially the same.

DISCUSSION

Benthic invertebrate utilization of man-made and natural olighaline wetlands has been evaluated according to five criteria: (1) total faunal density; (2) species richness; (3) the kinds of species present (species composition); (4) the distribution and abundance of numerically dominant species; and (5) the absolute and relative abundance of all species present (community structure).

Total faunal densities in the natural creeks and the Project Area fluctuated widely during the course of a year. Densities were lowest in the summer, and highest in the winter and spring. Similar temporal patterns of abundance of benthic invertebrates have been reported for other areas of the Pamlico River Estuary (Tenore 1972; West 1985), other estuaries within North Carolina (Cammen 1976, 1979; Chester, et al. 1983), and for estuaries in Delaware (Watling 1975), Virginia (Boesch 1977), Georgia (Teal 1962), and Florida (Mahoney and Livingston 1982).

Available evidence suggests that the increase in densities during the late fall and winter results from recruitment events (Tenore 1972; Table 25). Causes of the decline in densities between spring and summer have been attributed to abiotic stress (e.g., temperature, salinity, dissolved oxygen) (Tenore 1972; Livingston 1976; Boesch 1977), and predation by invertebrates and benthic feeding fish (Virnstein 1977; Wilste et al. 1984; Peterson 1979; Summerson and Peterson 1984).

Total faunal densities in the Project Area were usually equivalent to those in the natural creeks. Differences that did occur were primarily confined to the summer, when densities were universally low. Summer densities in the Project Area during 1987 and 1988 were significantly lower than those in the natural creeks at specific stations. The stations in question were different in each year (downstream in 1987 and upstream in 1988).

The data suggest that these observed differences in total density between the Project Area and the natural creeks were produced by comparatively large Project Area declines in the numbers of oligochaetes and *Capitella capitata* during 1987, and of oligochaetes and *Mediomastus sp.* in 1988. The extent to which the disparity in total fauna among the Project Area and the natural creeks results from (a) factors which are responsible for the annual decline in numbers from winter to summer (e.g. predation, abiotic stress), or (b) from factors which determine recruitment success, is not well understood. The role of recruitment as a determinant of community structure in the Project Area and the natural creeks is currently under investigation (cf. Ambrose, 1990).

Seasonal changes in species richness followed the same pattern in both areas, and at all locations within the study areas. Numbers of species were greatest in the winter and lowest in the summer. Quantitative differences in species richness between the Project Area and the natural creeks were limited to summer 1986 (midstream station), fall 1986 (downstream station), summer 1987 (downstream station), winter 1988 (downstream station), and summer 1988 (upstream and midstream stations). Significantly more species were found in the Project Area during summer 1987 and winter 1988, while significantly fewer were found in the Project Area during the other seasons.

Among area differences in species richness appear to be caused by two different sets of factors. Lower numbers of species in the Project Area during 1986 could be explained by the need for a minimal amount of time for an unfaunated region to develop a community comparable to the older natural creek communities. Project Area 2 was opened up to the estuary in the spring of 1984, and therefore was slightly over two years old when samples were collected

Table 25. Recruitment times of common invertebrate taxa of the Project Area and natural creeks. Recruitment times are derived from seasonal samples in all creeks; additional monthly samples [in Tooley Creek, Project Area 2, Drinkwater Creek; and bimonthly samples in Bond Creek, Long Creek, and Short Creek.

Taxon	Recruitment Period
Oligochaeta	February, May
Mediomastus sp.	April, June, September
Laeonereis culveri	April, June
Hobsonia florida	February, April, June
Streblospio benedicti	January, February, September
Capitella capitata	February, August, December
Polydora ligni	March, August, November
Eteone heteropoda	April, June
Leptocheirus plumulosus	March, December
Corophium lacustre	February, April, November
Gammarus tigrinus	March, July, December
Gammarus mucronatus	April, December
Chironomidae	May, June
Cyathura polita	April
Edotea sp.	April
Mysidopsis bigelowi	May, June
Macoma balthica	February, June
Macoma phenax	April, June, September
Rangia cuneata	January, October

during July 1986. Between July 1985 and July 1987, the number of taxa found only in the natural creeks decreased from seven to one. Thus after approximately three years, the species composition of the man-made and natural communities were highly similar.

This progressive maturation of the Project Area community is evident in a comparison of the cluster analyses of creek community structure during July 1985-1986, and July 1986-1987 (Figures 12,23).

Recent (1987-1988) differences in species richness involve the presence or absence of species known to be part of the local species pool. Table (26) lists those species found only at the downstream station in the Project Area during winter 1988 when species richness was greater in the Project Area, and those species missing during summer 1988 from those stations in the Project Area which had relatively fewer species. With the exception of an unidentified insect, *Edwardsia sp.* (burrowing anenome), and *Hargeria rapax* (tanaid crustacean), the remaining species are common but do not typically acheive high densities in this region of the Pamlico River Estuary (cf. Tenore 1972). Conversely most of the species missing from the upstream and midstream stations of the Project Area during July 1988 are among the most abundant and ubiquitous.

These recent developments concerning the species richness of the Project Area are coincident with the colonization of the Project Area by two species of submerged aquatic vegetation -- *Ruppia maritima* (widgeon grass) and *Myriophyllum spicatum* (Eurasian millfoil). Studies done in more saline regions of estuaries have demonstrated that submerged aquatic vegetation alters the character of the sediment (e.g. sediment grain size and sedimentation rate), and can enhance epifaunal and infaunal diversity by affording a refuge from predation (Peterson 1979). Thus the winter increase in species diversity in the Project Area may be the result of an enhancement of the annual recruitment or an improvement in the survival of the new recruits. It is also clear that predatory fishes can similarly benefit from the presence of submerged aquatic vegetation (Heck and Thoman 1984; Heck et al., 1989). Hence the loss of some of the abundant species between spring and summer 1988 may be due to vegetation related increases in predation pressure, or possibly to increases in abiotic stress by reducing the dissolved oxygen to low levels during the evenings of the warm months.

Although 35 to 40 taxa inhabit the Project Area and natural creeks during the course of a year, 8 taxa at any given season constitute 90% of the total fauna. The identities of these "numerical dominants" vary among creeks and seasonally. Among creek variation in the species compostion of the numerical dominants was typically least during the winter or spring (when densities and species richness are highest), and greatest during the summer (when densities and species richness are lowest). Within a particular season, there was usually less variation in the composition of the numerical dominants among the natural creeks than among any natural creek and the Project Area. The Project Area differed from the natural creeks in having high numbers of less common taxa (e.g. *Edwardsia, sp.*, *Hydrobia sp.*), or by having unusually high numbers of a common species (e.g. *Corophium lacustre*, *Leptocheirus plumulosus*, *Polydora ligni*).

A recurrent group of 7 taxa were particularly abundant throughout the study. These taxa consisted of oligochaetes, the polychaetes *Mediomastus sp.*, *Hobsonia florida*, *Streblospio benedicti*, and *Laeonereis culveri*, the amphipod *Leptocheirus plumulosus*, and chironomid insect larvae. These taxa range in size from a few millimeters (oligochaetes) to several centimeters (*L. culveri*). The first four taxa are deposit feeders; *L. culveri* and *L.plumulosus* are omnivores, and the chironomid larvae may be omnivores (cf. Table 27). Several of these species are important constituents of the diets of predatory fishes (e.g. spot, *Leiostomus xanthurus*, and croaker, *Micropogonias undulatus*) which recruit into these creeks in large numbers (Rulifson 1985, 1990; West 1985; Table 28).

These species showed large within creek variations in density. The pattern of each particular species spatial distribution was usually consistent among all creeks. Differences in distributional patterns were occassionally manifest as a progressive change in the distribution of a taxon (e.g., oligochaete, *Mediomastus sp.*, *L. culveri*) within the creeks as one moves along South Creek from Tooley Creek to Jacks Creek. Similar geographically related shifts in species densities were also observed (e.g. *H. florida*, *C. capitata*, chironomids). Both phenomena

TABLE 26. Taxa found at the downstream station (3) of only the Project Area during winter 1988 (A), and taxa absent from the upstream (1) and midstream (3) stations of the Project Area during Summer 1988 (B). In Table B, a parenthesis indicates the station the taxa was absent from in the event that particular organism was present at one of the two stations.

A. TAXA PRESENT	B. TAXA ABSENT
Gammarus mucronatus	Oligochaeta
Insect	*Mediomastus sp.*
Hargeria rapax	*Hobsonia florida*
Rangia cuneata	*Laeonereis culveri*
Platyhelminthes	*Polydora ligni*
Edwardsia sp.	*Streblospio benedicti*
Hirudinea	*Heteromastus filiformis*
	Capitella capitata
	Corophium lacustre
	Gammarus tigrinus
	Edotea sp.
	Rangia cuneata

TABLE 27. Feeding type of common taxa of the natural and man-made systems. (Adapted from Ambrose, 1990)

Taxon*		Feeding Type
(AO)	Oligochaeta	Deposit feeder
(AP)	*Mediomastus sp.*	Deposit feeder
(AP)	*Laeonereis culveri*	Omnivore
(AP)	*Hobsonia florida*	Deposit feeder
(AP)	*Streblospio benedicti*	Deposit, suspension feeder
(AP)	*Polydora ligni*	Deposit feeder
(AP)	*Capitella capitata*	Deposit feeder
(AP)	*Heteromastus filiformis*	Deposit feeder
(AI)	Chironomidae	Omnivore
(AC)	*Cyathura polita*	Deposit feeder, carnivore
(AC)	*Edotea sp.*	Deposit feeder, omnivore
(AC)	*Leptocheirus plumulosus*	Deposit suspension feeder
(AC)	*Corophium lacustre*	Deposit feeder
(AC)	*Gammarus tigrinus*	Omnivore
(AC)	*Hargeria rapax*	Carnivore
(AC)	*Mysidopsis bigelowi*	Omnivore
(MB)	*Macoma balthica*	Deposit, suspension feeder
(MB)	*Macoma phenax*	Deposit, suspension feeder
(MG)	*Hydrobia sp.*	Deposit feeder
(CA)	*Edwardsia sp.*	Carnivore

* (AO)=Annelida Oligochaeta; (AP) Annelida Polychaeta; (AI) Arthropoda Insecta; (AC) Arthropoda Crustacea; (MB) Mollusca Bivalvia; (MG) Mollusca Gastropoda; (CA) Cnidaria Anthozoa

References: Barnes 1968; Biernbaum 1979; Bousefield 1973; Brinkhurst 1982; Merritt and Cummins 1978; Sanders, et al. 1962; Virnstein 1979; Young and Young 1977.

TABLE 28. Absolute and relative abundance of dietary items of the benthic feeding fish spot (*Leiostomus xanthurus*) and croaker (*Micropogonias undulatus*) during March to May, 1985. All items were recovered from examining the gut contents of formalin preserved individuals. The table is a compilation of pooled size class data (20 -100 mm, total length) of 1400 spot and 400 croaker. The fish were caught in Tooley, Long, and Bond Creeks, all tributaries of South Creek.

Leiostomus xanthurus

Taxon	Number	%
Copepoda	24946	51.6
Chironomidae	5814	12.0
Ostracoda	4639	9.6
Nematoda	3304	6.8
foraminifera	2523	5.2
Gammarus tigrinus	1714	3.5
Oligochaeta	1655	3.4
clam siphon	1439	3.0
Leptocheirus plumulosus	1159	2.4
Hobsonia florida	261	0.5
Insect	249	0.5
Corophium lacustre	207	0.4
Laeonereis culveri	142	0.3
Neomysis americanus	100	0.2
Scolecolepides viridis	38	0.1
Ceratopogonidae	25	0.1
Eteone heteropoda	17	0.0
Gammarus mucronatus	8	0.0
Polydora ligni	8	0.0
Streblospio benedicti	4	0.0
Neanthes succinea	2	0.0

Micropogonius undulatus

Taxon	Number	%
Copepoda	1080	36.6
Chironomidae	931	31.6
Neomysis americanus	263	8.9
Leptocheirus plumulosus	180	6.1
clam siphon	133	4.5
Ostracoda	111	3.8
Gammarus tigrinus	94	3.2
Insect	53	1.8
Corophium lacustre	38	1.3
Scolecolepides viridis	18	0.6
foraminifera	15	0.5
Nematoda	8	0.3
Ceratopogonidae	6	0.2
Gammarus mucronatus	2	0.1
Eteone heteropoda	2	0.1
Hobsonia florida	1	0.0
Laeonereis culveri	1	0.0

suggest that the distribution and abundance of these organisms are affected by a factor that varies in a systematic fashion along the spatial scale bounded by Tooley Creek and Jacks Creek (e.g. salinity).

Among creek differences in the densities of these organisms were usually highly significant. Most of the variation in abundance of *Mediomastus sp.*, *H. florida*, *S. benedicti*, *L. culveri*, and chironomid larvae were generated by differences among the natural creeks, and their densities within the Project Area fell within the range set by the natural creeks.

Oligochaetes were not abundant in the Project Area during 1985 and 1986; in 1987 and 1988, high densities were limited to the winter and spring, and winter, respectively. Densities of *L. plumulosus* were substantial in the Project Area between July 1985 and July 1987, but were not abundant during the latter part of 1987 and all of 1988. The marked decline in *L. plumulosus* densities in the Project Area was coincident with an equally pronounced increase in the abundance of another amphipod, *Corophium lacustre*.

Causes of the differences in representation of oligochaetes and *L. plumulosus* in the Project Area and the natural creeks remain to be determined. Low initial numbers of oligochaetes may have been a reflection of the "immature" condition of the Project Area habitat. The large increase in the oligochaete population in the Project Area during winter and spring 1987 may have thus resulted in part from age-dependent improvements in the Project Area milieu (e.g., sediment grain size, sediment chemistry, food availability), as well as from an overall increase in oligochaete densities across all creeks (compare Figures 6,16. However, after spring 1987, other factors must have come into play which resulted in the disappearance of oligochaetes for the remainder of 1987, and which limited their period of abundance during 1988 to a single season. *L. plumulosus* became less abundant in the Project Area after July 1986 even though this species also showed a general increase in abundance between July 1986 and July 1987 in the natural creeks (Figures 12,22,32). The factors underlying the disparity of the oligochaete and *L. plumulosus* populations between the Project Area and the natural creeks may have involved differences in survival, or recruitment success, among the creeks (cf. Ambrose 1990).

CONCLUSIONS

The evidence presented above delineates three phases in the development of the benthic invertebrate community of the Project Area: an initial developmental phase, lasting about three years, during which most of the local taxa became established; a second phase of overall equality in community structure among the Project Area and the natural creeks which lasted approximately one year; and a third (current) phase of additional structural change, forced perhaps by the invasion of submerged aquatic vegetation. These recent changes in community structure consist of adjustments in the relative abundance of common taxa, not the introduction of exotic species.

Available data imply that the Project Area is capable of sustaining a benthic community with a structural and trophic complexity comparable to that of local natural creeks. Deviations between the natural and man-made systems are largely limited to the summer months, when total fauna and species richness of the Project Area are lower than those of the natural creeks. These differences occur after most of the resident benthic feeding finfish have migrated from the creeks to the deeper cooler waters of South Creek and the Pamlico River (cf. Rulifson 1985, 1990). Thus the timing of the structural differences in the natural and man-made communities does not affect their functional roles as nursery areas.

It is of some interest and importance to appreciate the fact that approximate parity in community structure has developed in a system which differs markedly from the natural creeks with respect to size, nature of the substratum (Craft, et al. 1986), watershed area, flow regimen, and ambient vegetation. The development of similar communities in areas with such widely divergent physical features suggests that these particular physical aspects of the habitat do not play a critical role in the colonization and establishment of the local fauna. This in turn implies that the local community is a collection of highly tolerant, short-lived, opportunistic taxa capable of rapid expansion into new habitats. "New" habitats are created each year via large scale episodes of mortality caused by the influx of large numbers of benthic predators (e.g. fish and crabs), and seasonally stressful levels of temperature, salinity and dissolved oxygen. The success of mitigation may therefore be as much a function of where in the estuary it is done as how it is done.

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APPENDIX 1 . Representation of benthic invertebrates in Drinkwater Creek during July 1985-1988. An "x" indicates the present of the taxon.

Species/Taxon	7/85	10/85	1/86	4/86	7/86	10/86	2/87	4/87	7/87	10/87	1/88	4/88	7/88
	Date of Collection												
ANNELIDA-Oligochaeta	x	x	x	x	x	x	x	x	x	x	x	x	x
ANNELIDA-Polychaeta													
Mediomastus sp.	x	x	x	x	x	x	x	x	x	x	x	x	x
Heteromastus filiformis				x	x	x	x	x	x	x		x	x
Laeonereis culveri	x	x	x	x	x	x	x	x	x	x	x	x	x
Neanthes succinea	x	x											
Polydora ligni	x	x	x	x	x	x	x	x		x	x	x	x
Scolecolepides virides												x	x
Streblospio benedicti	x	x	x	x	x	x	x	x	x	x	x	x	x
Hobsonia florida	x	x	x	x	x	x	x	x	x	x	x	x	x
Eteone heteropoda		x	x	x	x	x	x	x					x
Capitella capitata						x	x	x	x	x	x	x	x
Glycera dibranchiata					x	x							
ANNELIDA-Hirudinea								x			x		
ARTHROPODA-Uniramia													
Chironomidae	x	x	x	x	x	x	x	x	x	x	x	x	x
Ceratopogonidae							x	x	x	x	x	x	
Culicidae													
Insect	x	x	x			x	x			x		x	
ARTHROPODA-Crustacea													
Mysidopsis bigelowi	x	x			x	x	x		x			x	x
Neomysis americanus													
Cyathura polita				x	x		x	x	x	x	x	x	x
Corophium lacustre	x	x	x	x			x	x	x	x	x	x	x
Leptocheirus plumulosus	x	x	x	x	x	x	x	x	x	x	x	x	x
Gammarus mucronatus							x	x			x	x	

APPENDIX 1 . Representation of benthic invertebrates in Drinkwater Creek during July 1985-1988. An "x" indicates the present of the taxon.

	Date of Collection												
Species/Taxon	7/85	10/85	1/86	4/86	7/86	10/86	2/87	4/87	7/87	10/87	1/88	4/88	7/88
Gammarus tigrinus	x			x			x	x	x		x	x	x
Gammarus sp.													
Edotea sp.	x	x	x	x	x	x	x	x	x	x	x	x	x
Hargeria rapax	x						x	x		x			x
Spaheroma quadridentatum		x											
Palaemonetes pugio												x	
Palaemonetes vulgaris													
Cumacea			x										
Rhithropanopeus harrisii													
Sesarma reticulatum											x		
MOLLUSCA-Bivalvia													
Macoma balthica			x	x	x	x	x	x	x		x	x	
Macoma phenax	x	x	x	x	x	x	x	x	x	x	x	x	x
Munidea lateralis		x	x										
Rangia cuneata					x		x	x	x	x			
MOLLUSCA-Gastropoda													
Hydrobia sp.				x			x						
PLATYHELMINTHES								x					
CNIDARIA-Anthozoa													
Edwardsia sp.						x				x	x	x	
RHYNCOCOELA		x	x	x	x	x	x	x				x	

APPENDIX 2 . Representation of benthic invertebrates in Jacks Creek during July 1985-July 1988. An "x" indicates the presence of the taxon.

Species/Taxon	7/85	10/85	1/86	4/86	7/86	10/86	2/87	4/87	7/87	10/87	1/88	5/88	7/88
	Date of Collection												
ANNELIDA-Oligochaeta	x	x	x	x	x	x	x	x	x	x	x	x	x
ANNELIDA-Polychaeta													
Mediomastus sp.	x	x	x	x	x	x	x	x	x	x	x	x	x
Heteromastus filiformis	x	x	x		x		x	x	x	x	x	x	x
Laeonereis culveri	x	x	x	x	x	x	x	x	x	x	x	x	x
Neanthes succinea					x								
Polydora ligni	x	x	x	x			x	x		x	x	x	x
Scolecolepides virides		x	x					x				x	
Streblospio benedicti	x	x	x	x	x	x	x	x		x	x	x	x
Hobsonia florida	x	x	x	x	x	x	x	x	x	x	x	x	x
Eteone heteropoda		x	x	x	x	x	x				x		
Capitella capitata			x		x	x	x	x	x		x	x	x
Glycera dibranchiata													
ANNELIDA-Hirudinea													
ARTHROPODA-Uniramia													
Chironomidae	x	x	x	x	x	x	x	x	x	x	x	x	x
Ceratopogonidae							x	x	x	x	x	x	x
Culicidae													
Insect	x	x	x										x
ARTHROPODA-Crustacea													
Mysidopsis bigelowi	x	x		x			x		x			x	x
Neomysis americanus					x	x						x	
Cyathura polita	x		x		x			x	x	x	x	x	x
Corophium insidosum													
Corophium lacustre		x	x				x	x		x	x	x	x
Corophium simile						x							

APPENDIX 2 . Representation of benthic invertebrates in Jacks Creek during July 1985-July 1988. An "x" indicates the presence of the taxon.

Species/Taxon	Date of Collection 7/85	10/85	1/86	4/86	7/86	10/86	2/87	4/87	7/87	10/87	1/88	5/88	7/88
Leptocheirus plumulosus	x				x	x	x	x	x			x	x
Gammarus mucronatus							x			x	x	x	
Gammarus tigrinus			x	x			x	x	x		x	x	x
Gammarus sp.													
Edotea sp.	x	x	x	x		x	x	x		x	x	x	x
Hargeria rapax								x	x				x
Spaheroma quadridentatum			x										
Palaemonetes pugio			x						x				
Palaemonetes vulgaris													
Cumacea		x											
Rithropanopeus harrisii													
Sesarma reticulatum							x				x		
MOLLUSCA-Bivalvia													
Macoma balthica			x	x	x		x		x		x	x	
Macoma phenax	x	x	x		x	x	x	x	x		x	x	x
Munidea lateralis				x	x	x							
Rangia cuneata								x	x		x		x
MOLLUSCA-Gastropoda													
Hydrobia sp.							x						
PLATYHELMINTHES			x				x				x		
CNIDARIA-Anthozoa													
Edwardsia sp.							x				x	x	
RHYNCOCOELA	x	x	x		x	x	x	x			x		x

APPENDIX 3 . Representation of benthic invertebrates in Tooley Creek during July 1985--July 1988. An "x" indicates the presence of the taxon.

Species/Taxon	Date of Collection											
	10/85	1/86	4/86	7/86	10/86	2/87	4/87	7/87	10/87	1/88	5/88	7/88
Leptocheirus plumulosus	x	x	x	x	x	x	x	x	x	x	x	x
Gammarus mucronatus			x			x	x			x	x	
Gammarus tigrinus			x					x	x		x	x
Gammarus sp.												
Edotea sp.	x	x	x	x	x	x	x	x	x	x	x	x
Hargeria rapax							x					x
Spaheroma quadridentatum												
Palaemonetes pugio						x						
Palaemonetes vulgaris												
Cumacea		x	x		x	x						
Rhithropanopeus harrisii												
Sesarma reticulatum						x				x	x	
MOLLUSCA-Bivalvia												
Macoma balthica		x	x	x	x	x	x	x	x	x	x	
Macoma phenax	x	x	x	x	x	x	x	x	x	x	x	x
Munidea lateralis		x	x		x							
Rangia cuneata					x	x	x	x	x		x	x
MOLLUSCA-Gastropoda												
Hydrobia sp.												
PLATYHELMINTHES			x		x	x	x			x		
CNIDARIA-Anthozoa												
Edwardsia sp.			x							x	x	x
RHYNCOCOELA	x		x	x	x	x	x	x	x		x	x

APPENDIX 3 . Representation of benthic invertebrates in Tooley Creek during July 1985--July 1988. An "x" indicates the presence of the taxon.

	Date of Collection											
Species/Taxon	10/85	1/86	4/86	7/86	10/86	2/87	4/87	7/87	10/87	1/88	5/88	7/88
ANNELIDA-Oligochaeta	x	x	x	x	x	x	x	x	X	x	x	x
ANNELIDA-Polychaeta												
Mediomastus sp.	x	x	x	x	x	x	x	x	x	x	x	x
Heteromastus filiformis			x	x	x	x	x	x	x	x	x	x
Laeonereis culveri	x	x	x	x	x	x	x	x	x	x	x	x
Neanthes succinea	x											
Polydora ligni	x	x	x	x		x	x		x	x	x	x
Scolecolepides virides			x					x			x	x
Streblospio benedicti	x	x	x	x	x	x	x	x	x	x	x	x
Hobsonia florida	x	x	x	x	x	x	x	x	x	x	x	x
Eteone heteropoda	x	x	x	x	x	x	x			x	x	
Capitella capitata				x	x	x	x	x	x	x	x	x
Glycera dibranchiata					x	x						
ANNELIDA-Hirudinea												
ARTHROPODA-Uniramia												
Chironomidae	x	x	x	x	x	x	x	x	x	x	x	x
Ceratopogonidae					x	x	x	x	x	x	x	
Culicidae						x			x			
Insect				x	x					x		
ARTHROPODA-Crustacea												
Mysidopsis bigelowi				x	x			x				x
Neomysis americanus					x							
Cyathura polita			x	x	x	x	x	x	x	x	x	x
Corophium insidosum												
Corophium lacustre	x	x	x			x	x		x	x	x	
Corophium simile												

APPENDIX 4 . Representation of benthic invertebrates in Project Area 2 during July 1985-July 1988. An "x" indicates the presence of the taxon.

Species/Taxon	7/85	10/85	1/86	4/86	7/86	10/86	2/87	4/87	7/87	10/87	1/88	5/88	7/88
	Date of Collection												
ANNELIDA-Oligochaeta		x	x	x		x	x	x	x	x	x	x	x
ANNELIDA-Polychaeta													
Mediomastus sp.	x	x	x	x	x	x	x	x	x	x	x	x	x
Heteromastus filiformis		x				x	x	x	x	x	x	x	
Laeonereis culveri	x	x	x	x	x	x	x	x	x	x	x	x	x
Neanthes succinea													
Polydora ligni	x	x	x	x	x	x	x	x	x	x	x	x	x
Scolecolepides virides	x		x	x	x		x	x	x		x	x	
Streblospio benedicti	x	x	x	x	x	x	x	x	x	x	x	x	x
Hobsonia florida	x	x	x	x	x	x	x	x	x	x	x	x	x
Eteone heteropoda					x		x	x					
Capitella capitata							x	x	x	x	x	x	x
Glycera dibranchiata						x							
ANNELIDA-Hirudinea								x			x	x	
ARTHROPODA-Uniramia													
Chironomidae	x	x	x	x	x	x	x	x	x	x	x	x	x
Ceratopogonidae								x	x	x	x	x	
Culicidae													
Insect		x							x	x	x	x	x
ARTHROPODA-Crustacea													
Mysidopsis bigelowi	x	x	x						x				x
Neomysis americanus					x	x	x						
Cyathura polita					x			x	x	x	x	x	x
Corophium insidosum													
Corophium lacustre		x	x	x			x	x	x	x	x	x	x
Corophium simile						x		x					

APPENDIX 4 . Representation of benthic invertebrates in Project Area 2 during July 1985-July 1988. An "x" indicates the presence of the taxon.

Species/Taxon	7/85	10/85	1/86	4/86	7/86	10/86	2/87	4/87	7/87	10/87	1/88	5/88	7/88
						Date of Collection							
Leptocheirus plumulosus	x	x	x	x	x	x	x	x	x	x	x	x	
Gammarus mucronatus			x				x	x			x	x	x
Gammarus tigrinus			x	x	x		x	x	x	x	x	x	x
Gammarus sp.							x						
Edotea sp.	x	x	x					x	x		x	x	x
Hargeria rapax					x		x	x		x			
Spaheroma quadridentatum								x					
Palaemonetes pugio			x				x				x	x	x
Palaemonetes vulgaris													
Cumacea						x	x	x					
Rhithropanopeus harrisii				x									
Sesarma reticulatum							x				x		
MOLLUSCA-Bivalvia													
Macoma balthica			x	x	x		x	x	x	x	x	x	x
Macoma phenax		x	x		x	x	x	x	x	x	x	x	
Munidea lateralis			x	x	x								
Rangia cuneata			x				x	x	x	x	x	x	
MOLLUSCA-Gastropoda													
Hydrobia sp.							x	x	x				
PLATYHELMINTHES											x		
CNIDARIA-Anthozoa													
Edwardsia sp.				x			x	x	x	x	x	x	x
RHYNCOCOELA		x		x	x		x	x	x		x		