Distribution and Abundance of Benthic Organisms in the Sacramento River California

U. S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-60

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Observation of 1972-73 data showed variable patterns in monthly changes at each site and downstream changes each month with number of organisms per square meter, number of taxa per square meter, and diversity index. Generally, the mean number of taxa per square meter and diversity index for all sampling periods were higher in the upper reach than the lower reach of the Sacramento River.

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DISTRIBUTION AND ABUNDANCE OF BENTHIC ORGANISMS IN THE SACRAMENTO RIVER, CALIFORNIA

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CONVERSION FACTORS

For readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

English	*Multiply by:*	*Metric (SI)*
ft (feet)	3.048×10^{-1}	meters
ft^2 (square feet)	9.290×10^{-2}	square meters
ft^3/s (cubic feet per second)	2.832×10^{-2}	cubic meters per second
in (inches)	2.540×10	millimeters
mi (miles)	1.609	kilometers

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ABSTRACT

Comparisons were made between benthic organism samples collected in 1960-61 and 1972-73 from five sites in the Sacramento River between Red Bluff and Knights Landing. The compositions of benthic organisms from both collection periods were similar. In both studies there was a general increase in mean number of organisms per square meter from May to September and a decrease from September to April. The mean number of organisms per square meter, mean number of taxa per square meter, and diversity index were larger for both studies in the upper reach than in the lower reach of the Sacramento River.

The 1972-73 data showed variable patterns at a lower taxonomic level in monthly changes at each site, and monthly downstream changes in number of organisms per square meter, number of taxa per square meter, and diversity index. Fluctuations in benthic organism composition at each site within each sampling period may have been caused by sampling different stages of the individual life cycles of each type, or by influences of drifting organisms either from the Sacramento River or its tributary streams.

INTRODUCTION

Seventy percent of the total streamflow in California occurs north of Sacramento, with the greatest part flowing in the Sacramento River (California Department of Water Resources, 1974). The Sacramento River is an important water resource in the Great Central Valley of California, and maintenance of good water quality is therefore essential. The California Department of Water Resources (CDWR) made a study of the Sacramento River in the early 1960's to establish guidelines for maintaining adequate levels of water quality. Criteria for these guidelines were based on physical, chemical, and biological conditions of the river.

In 1972, the U.S. Geological Survey, in cooperation with the California Department of Water Resources, made a followup study of the chemical, physical, and biological conditions of the Sacramento River. The purpose of the study was to determine water-quality changes that might have resulted from more intensive use of Sacramento River water since the early 1960's and to define the downstream changes in water quality.

This report describes methods of collection and analysis of benthic organisms during the study. Field collection of organisms was made from May 1972 through April 1973. General comparisons were made between benthic organism samples collected by the Geological Survey in 1972-73 and by the California Department of Water Resources in 1960-61. Changes in species composition with time and with downstream location are described.

STUDY AREA

The Geological Survey collected samples at five sites in the Sacramento River between Red Bluff and Knights Landing. Figure 1 shows the location of the sites (letters A through E) and table 1 gives a brief description of each site. The five sites and others were sampled by the California Department of Water Resources in 1960-61 (CDWR, 1962).

The five sites sampled in the Geological Survey study can be classified into three major environments as described by the California Department of Water Resources. Sites A and B are riffle areas in the upper reach, which consists of alternating pools and riffles. Site C is in a long pool at the downstream end of the upper middle reach, which contains few riffles and many long pools and runs. Sites D and E are in the lower middle reach, a dredged and leveed channel. Site B was sampled to determine the effect of environmental changes on species composition of benthic organisms that might be caused by Red Bluff diversion dam and waste effluent from Red Bluff sewage treatment plant and Diamond National Corporation. Site E was sampled to determine what effect Colusa Trough might have on the composition of benthic organisms in the lower middle reach of the Sacramento River.

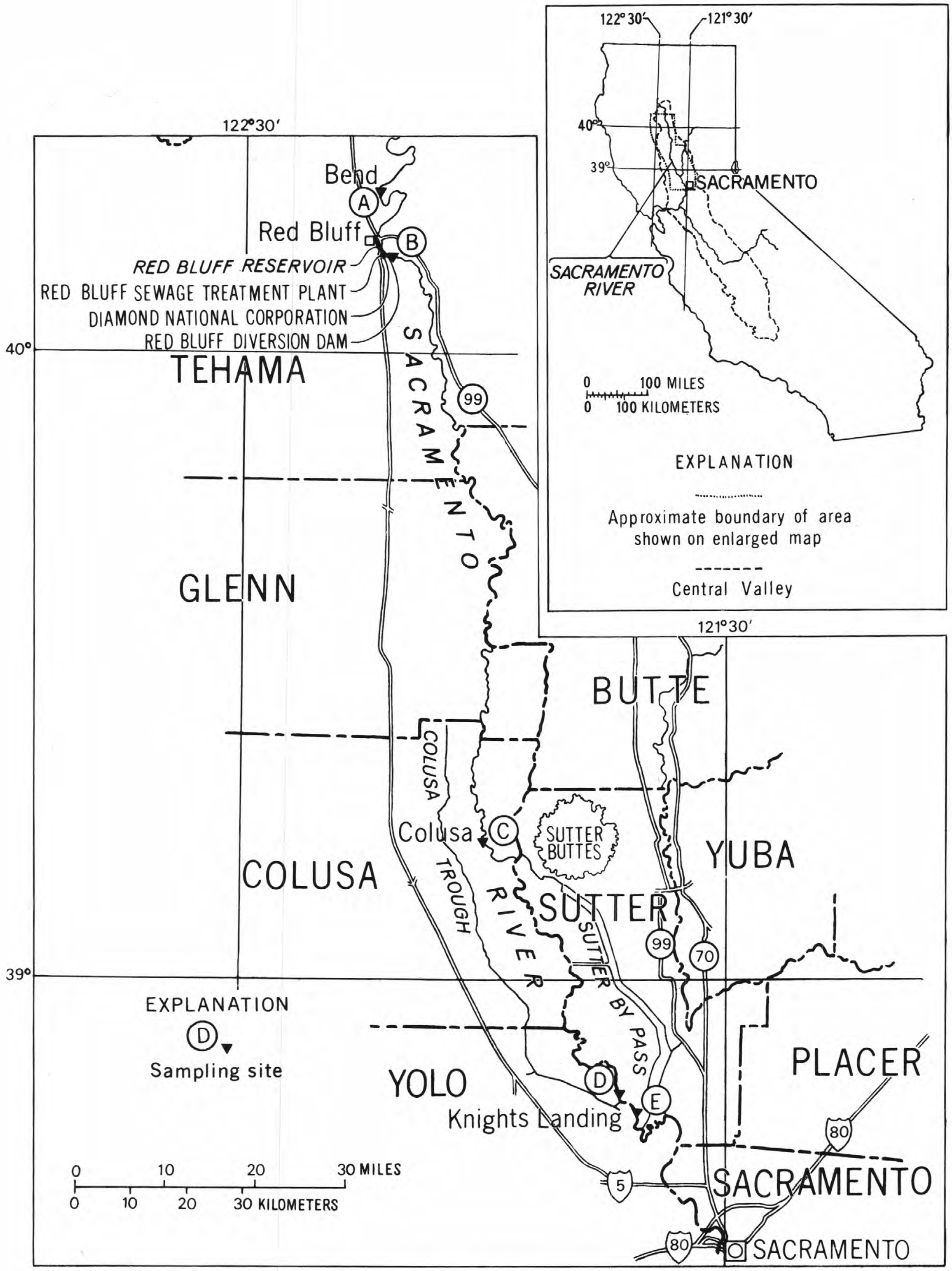


FIGURE 1.--Sacramento River study area and sampling sites.

Table 1.--*Summary description of benthic organism sampling sites*

Characteristic	California Department of Water Resources, 1960-61	U.S. Geological Survey, 1972-73
	Sacramento River at Bend (Site A)	
Station number	256.3	11377200
Approximate river width	--	300 ft
Approximate river depth	--	5-20 ft
Maximum daily mean discharge	50,500 ft^3/s	64,000 ft^3/s
Monthly mean discharge	9,720 ft^3/s	14,200 ft^3/s
Minimum daily mean discharge	4,720 ft^3/s	6,560 ft^3/s
Sampling location	Left bank; first riffle below bridge	Left and right banks; 300 ft above bridge
Depth of sample	1.5 ft	4-9 ft
Substrate type	3-in. diameter cobbles	5-in. diameter cobbles to sand
Sampling device	Surber sampler	Peterson and Ponar grabs
	Sacramento River below Red Bluff diversion dam, near Red Bluff (Site B)	
Station number	241.0	11378930
Approximate river width	--	100 ft
Approximate river depth	--	3 ft
Maximum daily mean discharge	50,500 ft^3/s	63,920 ft^3/s
Monthly mean discharge	9,720 ft^3/s	13,020 ft^3/s
Minimum daily mean discharge	4,720 ft^3/s	6,100 ft^3/s
Sampling location	Right bank in riffle and backwater	2,000 ft below diversion dam, southern downstream point of island
Depth of sample	1.5-6 ft	3-5 ft
Substrate type	Gravels in riffle; silt and fine sand in backwater	3-in. diameter cobbles to sand
Sampling device	Surber sampler	Peterson and Ponar grabs, Surber sampler
	Sacramento River at Colusa (Site C)	
Station number	144.1	11389500
Approximate river width	--	200 ft
Approximate river depth	--	10-35 ft
Maximum daily mean discharge	32,900 ft^3/s	41,700 ft^3/s
Monthly mean discharge	9,450 ft^3/s	14,500 ft^3/s
Minimum daily mean discharge	4,930 ft^3/s	5,980 ft^3/s
Sampling location	Leveed section	Left bank; 500 ft upstream from Colusa Bridge
Depth of sample	10-18 ft	5-20 ft
Substrate type	Sand	Fine sand to clay
Sampling device	Peterson grab	Peterson and Ponar grabs

Table 1.--*Summary description of benthic organism sampling sites*--Continued

Characteristic	California Department of Water Resources, 1960-61	U.S. Geological Survey, 1972-73
Sacramento River above Colusa Trough, at Knights Landing (Site D)		
Station number	90.5	11390650
Approximate river width	--	200 ft
Approximate river depth	--	15-40 ft
Maximum daily mean discharge	26,000 ft^3/s	27,700 ft^3/s
Monthly mean discharge	9,385 ft^3/s	12,659 ft^3/s
Minimum daily mean discharge	3,160 ft^3/s	6,170 ft^3/s
Sampling location	Leveed section	Right bank of leveed section
Depth of sample	18-20 ft	7-25 ft
Substrate type	Sand in central portion; fine sand and silt near right bank	Sand, silt, clay
Sampling device	Peterson grab	Peterson and Ponar grabs
Sacramento River at Knights Landing (Site E)		
Station number	88.8; 88.2	11391000
Approximate river width	--	200 ft
Approximate river depth	--	15-40 ft
Maximum daily mean discharge	28,900 ft^3/s	29,200 ft^3/s
Monthly mean discharge	10,000 ft^3/s	13,600 ft^3/s
Minimum daily mean discharge	4,600 ft^3/s	6,460 ft^3/s
Sampling location	--	Right bank; 1.5 mi below Colusa Trough
Depth of sample	10-25 ft	4-25 ft
Substrate type	Fine sand, silt	Sand to clay
Sampling device	Peterson grab	Peterson and Ponar grabs

METHODS

The Geological Survey collected benthic organisms at each site with Peterson and Ponar grabs (Slack and others, 1973). In May, June, and July 1972, four samples from each site were collected with each grab and composited in the field. In August, September, and November 1972, and April 1973, three samples were usually collected with each grab. In July, September, and November 1972, additional samples were collected from a riffle section at site B using a 1-ft^2 Surber sampler (210-micrometer mesh opening) (Britton and Averett, 1974).

All samples were poured into a number 70 sieve (210-micrometer mesh opening). Organisms remaining on the sieve were transferred with forceps or washed with alcohol into collection bottles and preserved with 40 percent isopropyl alcohol.

The California Department of Water Resources used a 1-ft^2 Surber sampler to collect benthic organism samples at sites A and B. Three samples were taken on most occasions at these sites. At sites C, D, and E, the California Department of Water Resources used a Peterson grab to collect samples. The samples were poured into a number 30 sieve (589-micrometer mesh opening). Organisms remaining on the screen were transferred with forceps into vials and preserved with 10 percent formalin solution.

Samples were analyzed using methods described by the California Department of Water Resources (1962) for the 1960-61 data and by Slack and others (1973) for the 1972-73 data.

Diversity and similarity indexes were used in comparing the composition of benthic organisms from different samples. The total number of benthic organisms, number of taxa, and the number of individuals in each taxon are simultaneously included in the calculation of diversity index. The diversity index was calculated using the equation given by Wilhm and Dorris (1968),

$$\text{diversity index} = \bar{d} = -\sum_{i=1}^{s} \frac{n_i}{n} \log_2 \frac{n_i}{n},$$

where n_i is the number of individuals in each taxon, n is the total number of individuals, and s is the total number of taxa in each sample.

Diversity index, $\bar{d}$, can range from 0 to any positive number. When all individuals in a sample belong to the same species, the diversity index will equal 0. When each individual in a sample belongs to a different species, a maximum diversity index will be obtained, depending on the total number of individuals. Diversity index, $\bar{d}$, usually varies between 3 and 4 in clean-water streams and is usually less than 1 in polluted streams (Wilhm, 1970, p. 223).

The similarity index,

$$s = \frac{2z}{x+y},$$

where x is the number of taxa in sample x, y is the number of taxa in sample y, and z is the number of taxa common to both x and y (Odum, 1971), was calculated to compare taxa between selected pairs of samples. Similarity index values can range from 0 when two samples have no taxa in common to 1 where two samples have the same taxa.

A multiway analysis of variance (Sokal and Rohlf, 1969) was used to determine the effects of sampling period and site location on benthic organism composition. The number of organisms per square meter and the number of taxa per square meter were normalized by making a log transformation of the original data.

RESULTS

Comparison of 1960-61 and 1972-73 Data

When comparing results from different studies, conditions and methods sometimes vary to such an extent that only general comparisons are possible. Comparison of the 1960-61 and 1972-73 benthic organism data are limited by differences in the following:

(1) Substrate type from which samples were collected,
(2) Equipment used to collect samples,
(3) Sieve sizes used to handle samples, and
(4) Varying levels of taxonomic identification.

Flow regime changes after 1960-61 altered the substrate at some sites and precluded use in 1972-73 of the same sampling equipment used by the California Department of Water Resources.

Changes in substrate will change the composition of the benthic organism community (Hynes, 1972). The type of substrate and its possible effects on benthic organism composition must be considered when benthic organism samples are compared.

Improvements in handling procedures and analyses of benthic organism samples since the early 1960's dictated use of a smaller sieve-mesh size, and, in some cases, a more specific level of benthic organism identification in the 1972-73 study.

The use of different sampling equipment and sieve-mesh sizes affects the total number of organisms and the number of taxa collected per sample (Gaufin, Harris, and Walter, 1956; Flannagan, 1973; Slack, Nauman, and Tilley, 1976). Generally, the number of taxa will be less affected by these two sampling differences than the total number of organisms. Therefore, emphasis here is on a qualitative comparison between benthic organisms collected by the California Department of Water Resources and the Geological Survey using number of taxa, similarity index, and diversity index. Taxa whose occurrence and abundance differ greatly between the two studies are pointed out.

When comparing number of taxa and similarity and diversity index values among sites, organisms must be identified to the same taxonomic level. Because the level of taxonomic identification varied within and between the two studies, most taxa in both studies were compared at higher taxonomic levels than those levels at which they were originally identified. Taxa used in comparing the 1960-61 data with the 1972-73 data are in table 2. Changes in the composition of some organisms at the species level might not be expressed with comparisons made at these higher taxonomic levels.

The composition of benthic organisms in 1960-61 and 1972-73 was similar (table 2). A few taxa were found to occur more or less frequently and in different concentrations between the two studies. Oligochaetes were collected more often and in greater numbers in 1960-61 than in 1972-73 (table 2) (CDWR, 1962; Britton and Averett, 1974). This change in numbers and occurrence probably results from differences in sampling location and equipment used to collect the samples. At the upper reach sites (A and B), the California Department of Water Resources collected numerous oligochaetes using the 1-ft^2 Surber sampler. The Geological Survey did not collect any oligochaetes in its samples at site A but did collect them at site B where a Surber sampler was used.

In the lower middle reach of the Sacramento River, the California Department of Water Resources collected a greater number of oligochaetes than the Geological Survey even though sampling equipment and sampling sites were similar. This change in abundance could be an indication of water-quality changes or the result of sampling different locations at sites D and E. More intensive sampling is needed to define the distribution of oligochaeta at each site.

Corophium sp. and *Gammarus* sp. (scuds) were collected in the lower middle reach; however, *Corophium* sp. was collected only once, at site E, in 1960-61. *Corophium* sp. was not collected at all during the 1972-73 study. Conversely, the Geological Survey collected *Gammarus* sp. five times at site D and six times at site E; *Gammarus* sp. was not collected by the California Department of Water Resources in 1960-61. The occurrence of *Corophium* sp. in 1960-61 as opposed to *Gammarus* sp. in 1972-73 might be the result of differences in taxonomic identification.

Table 2.--*Composite list of the types of organisms found in the 1960-61 and 1972-73 studies*

[Types of organisms found in the 1960-61 and 1972-73 studies are denoted by an x. The taxonomic level used in comparing the 1960-61 data with the 1972-73 data is denoted with a numeral which indicates the number of sampling periods that taxon was found at each site]

Taxa	California Department of Water Resources, 1960-61					U.S. Geological Survey, 1972-73				
	Site					Site				
	A	B	C	D	E	A	B	C	D	E
COELENTERATA (hydroids, jellyfish)										
Hydra sp.	1	-	-	-	-	-	-	-	-	-
NEMATA (round worms)	3	1	-	1	-	-	-	-	-	-
ANNELIDA (segmented worms)										
OLIGOCHAETA (aquatic worms)	4	4	-	6	2	-	4	-	4	3
Opisthopora (aquatic earthworms)	-	-	-	-	-	-	x	-	x	-
Plesiopora										
Naididae	-	-	-	-	-	-	x	-	-	x
Chaetogaster sp.	x	-	-	x	-	-	-	-	-	-
Nais sp.	x	-	-	-	-	-	-	-	-	-
Tubificidae										
Branchiura sowerbyi	-	-	-	x	-	-	-	-	-	-
B. sp.	-	-	-	-	-	-	-	-	x	-
HIRUDINEA (leeches)										
Glossophoniidae	-	1	-	-	-	-	-	-	-	-
ARTHROPODA										
CRUSTACEA										
Copepoda										
Harpacticoida	1	-	-	-	-	-	-	-	-	-
Malacostraca (scuds, sowbugs, oppossum shrimp, crayfish)										
Corophium	-	-	-	-	1	-	-	-	-	-
C. spinicorne	-	-	-	-	x	-	-	-	-	-
Gammarus sp.	-	-	-	-	-	-	-	-	5	6
Neomysis awatchensis	-	-	-	-	-	-	-	-	-	1
INSECTA										
Ephemeroptera (mayflies)										
Baetidae	7	3	-	-	-	3	5	2	2	1
Baetis sp.	x	x	-	-	-	x	x	-	-	-
Pseudocleon sp.	x	x	-	-	-	-	-	-	-	-
Heptageniidae	-	-	-	-	-	2	2	1	3	1
Epeorus sp.	-	-	-	-	-	-	-	-	-	x
Ephemerellidae										
Ephemerella euterpe	-	1	-	-	-	-	-	-	-	-
Tricorythidae										
Tricorythodes fallax	1	1	-	-	-	-	1	-	1	-
Ephemeridae	-	-	-	-	-	1	1	2	-	-
Hexagenia limbata	-	-	-	-	-	-	-	x	-	-
Odonata (dragonflies, damselflies)										
Gomphidae	1	-	-	-	-	-	-	1	1	-
Erpetogomphus sp.	x	-	-	-	-	-	-	-	-	-
Coenagrionidae										
Argia sp.	1	-	-	-	-	-	-	-	-	-
Plecoptera (stoneflies)										
Capniidae	-	-	-	-	-	-	2	-	-	-
Capnia sp.	-	-	-	-	-	-	x	-	-	-
Nemouridae	1	-	-	-	-	-	-	-	-	-
Zapada columbiana	x	-	-	-	-	-	-	-	-	-
Pteronarcidae	2	-	-	-	-	-	-	-	-	-
Pteronarcys californica	x	-	-	-	-	-	-	-	-	-

Table 2.--*Composite list of the types of organisms found in the 1960-61 and 1972-73 studies*--Continued

Taxa	California Department of Water Resources, 1960-61					U.S. Geological Survey, 1972-73				
	Site					Site				
	A	B	C	D	E	A	B	C	D	E
INSECTA										
Plecoptera (stoneflies)										
Perlodidae	5	1	-	-	-	5	2	1	-	-
Isogenus fontinalis	x	-	-	-	-	-	-	-	-	-
Isogenus sp.	x	x	-	-	-	x	-	-	-	-
Isoperla trictura	x	-	-	-	-	-	-	-	-	-
Isoperla sp.	x	x	-	-	-	-	-	-	-	-
Chloroperlidae	-	-	-	-	-	2	2	-	-	-
Chloroperla sp.	-	-	-	-	-	x	x	-	-	-
Hemiptera (true bugs)										
Naurcoridae (creeping water bugs)										
Ambrysus mormon	1	-	-	-	-	-	-	-	-	-
Trichoptera (caddisflies)										
Rhyacophilidae	7	3	-	-	-	5	5	-	-	-
Agapetus sp.	x	x	-	-	-	-	-	-	-	-
Glossosoma sp.	-	-	-	-	-	x	x	-	-	-
Rhyacophila sp.	x	-	-	-	-	-	-	-	-	-
Psychomyiidae										
Polycentropus sp.	1	-	-	-	-	1	-	-	-	-
Hydropsychidae	7	2	-	-	-	7	5	2	-	-
Hydropsyche sp.	x	x	-	-	-	x	x	-	-	-
Hydroptilidae	1	2	-	-	-	2	4	-	-	-
Hydroptila sp.	-	-	-	-	-	x	x	-	-	-
Ochrotrichia sp.	x	x	-	-	-	-	-	-	-	-
Phryganeidae	-	-	-	-	-	-	1	-	-	-
Limnephilidae	-	-	-	-	-	1	-	-	-	-
Lepidostomatidae	1	-	-	-	-	1	1	-	-	-
Lepidostoma sp.	x	-	-	-	-	-	-	-	-	-
Brachycentridae	-	-	-	-	-	3	3	-	1	-
Brachycentrus sp.	-	-	-	-	-	x	x	-	-	-
Coleoptera (beetles)										
Dytiscidae	-	-	1	-	-	2	-	-	-	-
Hydrophilidae	-	-	-	-	-	-	-	-	1	-
Dryopidae										
Helichus sp.	1	-	-	-	-	-	-	-	-	-
Elmidae	1	-	-	-	-	-	1	-	-	-
Narpus sp.	x	-	-	-	-	-	-	-	-	-
Psephenidae										
Psephenus sp.	2	-	-	-	-	1	-	-	-	-
Diptera (two-winged flies)	7	7	7	7	4	7	7	7	7	7
Tipulidae (craneflies)	-	x	-	-	-	x	x	x	x	-
Antocha sp.	x	x	-	-	-	x	x	-	-	-
Tanyderidae (primitive craneflies)	-	-	x	-	-	-	x	-	-	-
Simuliidae (blackflies)	-	-	-	-	-	-	x	x	x	-
Simulium sp.	x	x	-	-	-	-	-	-	-	x
S. argus	-	x	-	-	-	-	-	-	-	-
Chironomidae (Tendipedidae, nonbiting midges)	x	x	x	x	-	x	x	x	x	x
Tanypodinae (Pelopiinae)										
Pentaneura sp.	x	-	-	-	-	-	-	-	-	-
Procladius sp.	-	x	-	-	-	-	-	-	-	-
Diamesinae	-	-	x	-	-	-	-	-	-	-
Diamesa sp.	-	x	-	-	-	-	-	-	-	-
Prodiamesa sp.	-	x	x	-	-	-	-	-	-	-

Table 2.--*Composite list of the types of organisms found in the 1960-61 and 1972-73 studies*--Continued

Taxa	California Department of Water Resources, 1960-61					U.S. Geological Survey, 1972-73				
	Site					Site				
	A	B	C	D	E	A	B	C	D	E
INSECTA										
Diptera (two-winged flies)	7	7	7	7	4	7	7	7	7	7
Chironomidae (Tendipedidae, nonbiting midges)	x	x	x	x	-	x	x	x	x	x
Orthocladiinae (Hydrobaeninae)										
Cardiocladius sp.	-	x	-	-	-	-	-	-	-	-
Corynoneura sp.	x	-	-	-	-	x	-	-	-	-
Cricotopus sp.	x	-	-	x	-	x	x	-	-	-
Eukiefferiella sordens	-	-	-	-	-	x	x	-	-	-
Eukiefferiella sp.	-	-	-	-	-	x	x	-	-	-
Hydrobaenus sp.	-	x	-	-	-	-	-	-	-	-
Metriocnemus sp.	-	x	-	-	-	-	-	-	-	-
Orthocladius thienemanni	-	-	-	-	-	-	x	-	-	-
Orthocladius sp.	-	-	-	-	-	x	x	-	-	-
Psectrocladius sp.	-	-	-	-	-	x	x	-	-	-
Spaniotoma sp.	-	x	-	x	-	-	-	-	-	-
Trichocladius sp.	-	-	-	-	-	x	-	-	-	-
Chironominae (Tendipedinae)	-	-	-	x	x	-	-	-	-	-
Chironomini										
Chironomus sp.	-	-	-	-	-	x	-	x	x	-
Cryptochironomus nais	-	-	-	-	-	-	x	-	-	-
Chironomus spp.	-	-	x	x	-	x	-	x	x	-
Dicrotendipes sp.	-	-	-	-	-	-	x	-	-	-
Pentapedilum spp.	-	x	-	x	-	-	-	-	-	-
Polypedilum spp.	-	x	x	x	-	-	-	-	-	-
Stictochironomus sp.	-	-	-	-	-	x	-	x	x	x
Endochironomus sp.	-	-	-	x	-	-	-	-	-	-
Tendipes decorus	-	x	-	-	-	-	-	-	-	-
T. plumosus	-	x	-	-	-	-	-	-	-	-
T. spp.	-	x	x	x	-	-	-	-	-	-
Tanytarsini										
Calopsectra flavellus	x	-	-	-	-	-	-	-	-	-
C. sp.	x	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	-	-	-	-	-	-	x	-	-	-
Ceratopogonidae (biting midges)	-	-	-	-	-	-	x	x	-	x
Rhagionidae (snipe flies)	-	-	-	-	-	x	-	-	-	-
Empedidae (dance flies)	-	-	-	-	-	-	-	x	-	-
Hemerodromia sp.	x	-	-	-	-	-	x	-	-	-
ARACHNIDA (spiders, scorpions, ticks, mites)										
Acari (Hydracarina)(water mites)										
Sperchon sp.	2	-	-	-	-	1	1	-	-	-
Neumania sp.	-	-	-	-	-	-	x	-	-	-
Libertia sp.	-	-	-	-	-	-	x	-	-	-
MOLLUSCA	-	-	-	-	-	x	x	-	-	-
Sphaeriidae										
Sphaerium sp.	-	-	-	-	1	-	-	-	2	2
Corbiculidae	-	-	-	-	-	-	-	-	-	x
Corbicula manilensis (fluminea)	-	-	-	3	5	-	-	1	2	1
VERTEBRATA (backboned animals)										
Lampetra	-	1	2	-	1	-	1	3	3	6
L. tridentata	-	-	-	-	-	-	-	x	x	x
L. sp.	-	x	x	-	x	-	x	-	-	-

At site A, a larger number of Plecoptera (stoneflies) were collected in the 1960-61 study than in the 1972-73 study. This difference could be attributed to differences in sampling location and equipment. The California Department of Water Resources used a Surber sampler in a gravel riffle, and the Geological Survey used a grab in sandy areas close to the left bank. At site B in 1960-61, stoneflies were collected in only one sampling period. At this station in 1972-73, stoneflies were collected in four sampling periods. In both studies most stoneflies were collected with a Surber sampler in the same type of habitat, a riffle. The greater occurrence of stoneflies at site B in 1972-73 compared to 1960-61 might be the result of a larger number of immature forms retained on the smaller sieve-mesh size used in 1972-73.

Large numbers of caddisflies of the family Brachycentridae were collected at site A, with fewer collected at site B, in 1972-73. Brachycentridae were not reported in 1960-61 at any of the five sites.

Corbiculidae (fresh-water clams) were collected at sites C, D, and E in 1972-73 and at sites D and E in 1960-61. Corbiculidae occurred more often and in larger numbers in 1960-61 than in 1972-73. The presence of Corbiculidae at site C in 1972-73 indicates that the range of habitat for fresh-water clams has been extended in the Sacramento River. The low concentrations of Corbiculidae in the 1972-73 samples, however, do not suggest extensive production as indicated in 1960-61.

The similarity indexes of taxa between the two studies for all samples combined at each site are as follows:

Site	A	B	C	D	E
Similarity index	0.53	0.60	0.33	0.38	0.67

The low similarity indexes at sites C and D result partly from the few taxa collected in 1960-61 compared with the number of taxa collected in 1972-73. The similarity index calculated by compositing the taxa at all sites for both studies was 0.68, indicating similar species in the two studies.

Comparison of the Geological Survey and the California Department of Water Resources data also can be made by looking at the entire community of benthic organisms. A more diverse community of organisms often indicates a more stable community. A useful measurement of the community diversity is the diversity index developed by Shannon and Weaver (1949).

Within the limitations of benthic organism identification for both studies, the diversity index was calculated for each sampling period at each site. The number of organisms and the number of taxa also were calculated for each sampling period at each site on a per-square-meter basis.

Table 3 shows the mean number of organisms per square meter, mean number of taxa per square meter, and diversity index for all sites in each sampling period. In both studies a general increase in mean number of organisms occurred from May to September and a decrease from September to April. There were no distinguishable patterns of change that apply to both studies with mean number of taxa and the diversity index in each successive sampling period. At these levels of classification in 1972-73, a gradual increase in the mean number of taxa occurred from May to November. Except for the June and April sampling periods, the diversity index values were lower in 1960-61 than 1972-73.

Table 3.--*Mean number of organisms per square meter, mean number of taxa per square meter, and diversity index for all sampling sites in each sampling period*

Month	1960-61			1972-73		
	Mean number of organisms	Mean number of taxa	Diversity index $\bar{d}$	Mean number of organisms	Mean number of taxa	Diversity index $\bar{d}$
May	224.8	2.8	0.91	104.6	4.4	1.20
June	586.6	3.8	1.15	136.0	4.4	.81
July	353.8	2.6	.77	188.4	5.0	1.19
August	638.2	3.4	.82	294.8	5.6	1.45
September	1,070.4	3.0	.46	1,134.6	5.8	.92
November	875.6	4.2	.06	421.0	6.6	1.65
April	529.4	5.4	.93	224.2	2.8	.60

The mean number of organisms per square meter, mean number of taxa, and diversity index for all sampling periods per square meter, at each site are given in table 4. These three variables were larger for both studies in the upper reach (sites A and B) than in the lower reach (sites C, D, and E). In addition, the lowest mean number of taxa and lowest mean diversity index in both studies occurred at site C.

Table 4.--*Mean number of organisms per square meter, mean number of taxa per square meter, and diversity index for all sampling periods at each sampling site*

Site	1960-61			1972-73		
	Mean number of organisms	Mean number of taxa	Diversity index $\bar{d}$	Mean number of organisms	Mean number of taxa	Diversity index $\bar{d}$
A	1,622.7	8.3	1.67	748.0	6.3	1.52
B	843.7	3.9	1.09	589.9	6.9	1.51
C	119.4	1.4	.15	231.3	2.9	.41
D	385.6	2.4	.90	106.7	4.6	1.09
E	99.1	2.0	.54	111.7	4.1	1.06

Changes in Species Composition of Benthic Organisms in 1972-73

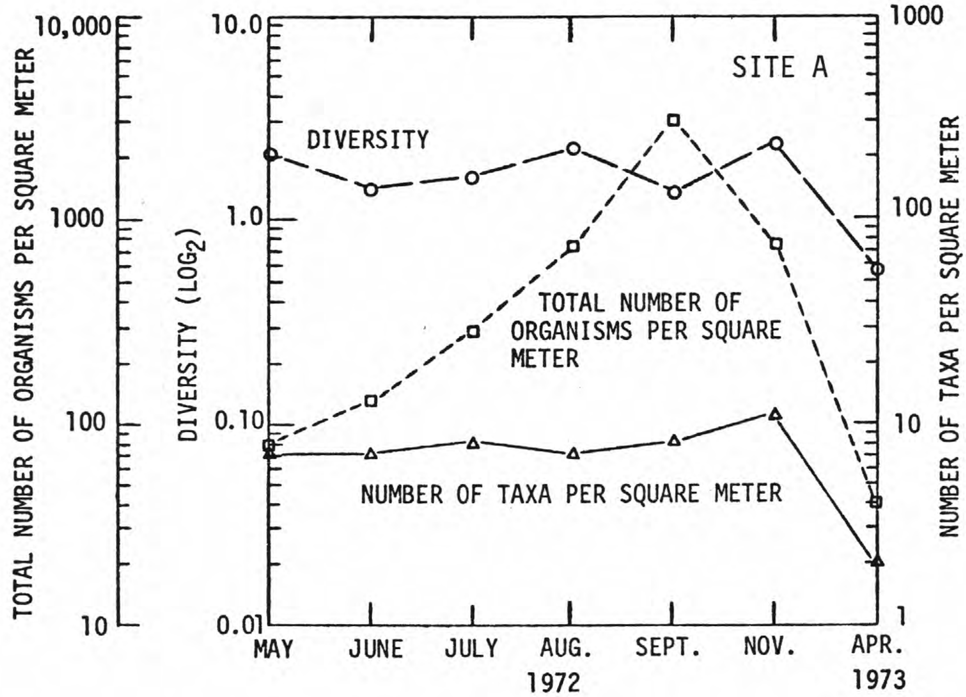
When the benthic organisms collected in 1972-73 are considered alone, comparisons among sites and among sampling periods can be made at a lower taxonomic level. Moreover, methods of collection at each site were similar. For each set of samples, the number of organisms per square meter, the number of taxa per square meter, and the diversity index were calculated.

Changes in Species Composition of Benthic Organisms at Each Sampling Site

The total number of organisms per square meter, the number of taxa per square meter, and the diversity index for successive sampling periods were plotted for each site (fig. 2). The total number of organisms per square meter gradually increased from May to September at site A and from May to November at site B. No definite pattern in the changes of total number of organisms occurred at sites C, D, and E from May to September. At sites C, D, and E, however, the total number of organisms per square meter decreased from September to November and then increased from November to April. The two-way factorial analysis of variance showed no significant difference [$F_{95}(6,24)$] among the mean log number of organisms from all sites for each month, indicating that the monthly patterns of change were not statistically consistent among all the sites (fig. 2).

The number of taxa at sites A and B peaked in November, then decreased from November to April. At sites C, D, and E, the number of taxa peaked in August. The number of taxa generally decreased each month after August at sites C and D but remained constant at site E until April, when it decreased by one taxon. The two-way factorial analysis of variance using the mean log number of taxa per square meter showed a significant difference [$F_{95}(6,24)$] among sampling months. Generally, the mean number of taxa increased from May to August and decreased from August to April.

The change in diversity index with each successive sampling period was not consistent at each site. The two-way factorial analyses of variance showed a significant difference [$F_{95}(6,24)$] among the mean diversity indexes for all sites calculated for each month. The mean diversity indexes for spring (April, May, and June) were generally lower than the diversity indexes for summer and early autumn.



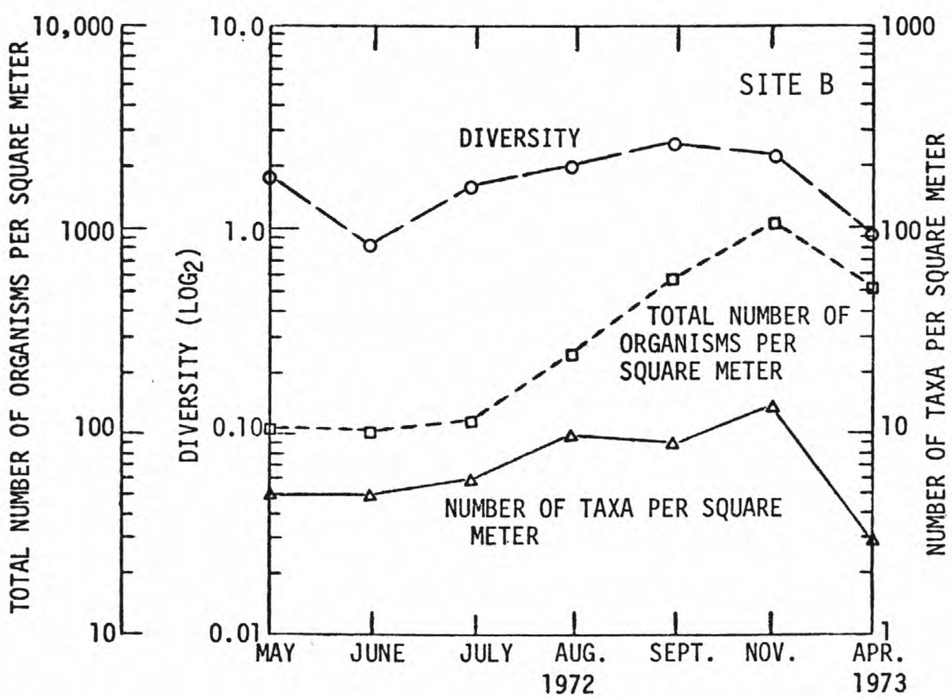
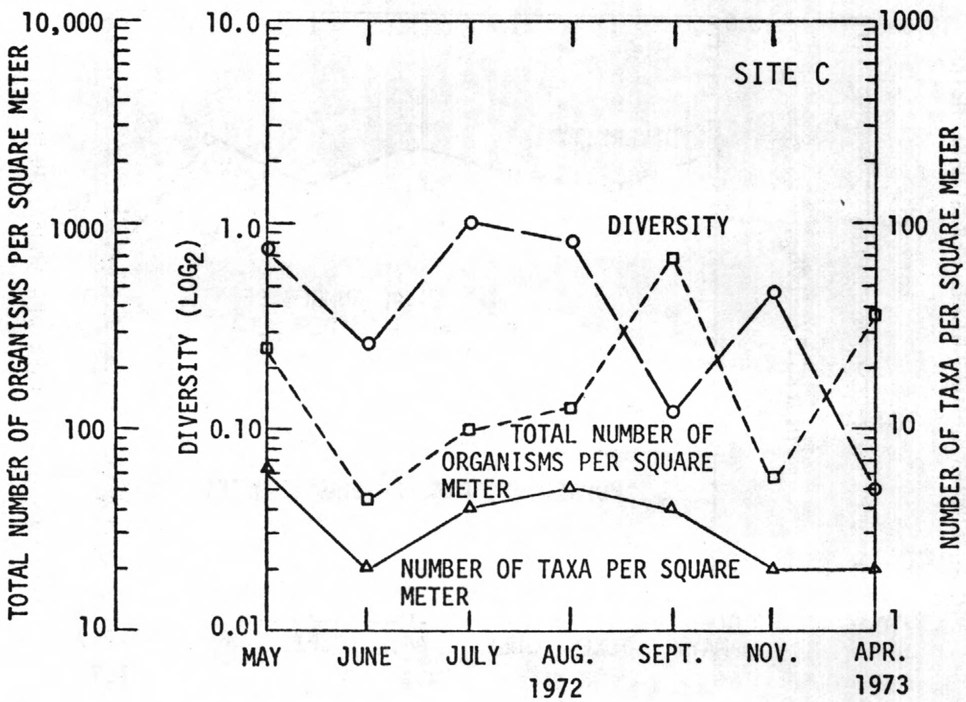


FIGURE 2.--Total number of organisms per square meter, number of taxa per square meter, and diversity index for samples collected in 1972-73 at sampling sites A through E.



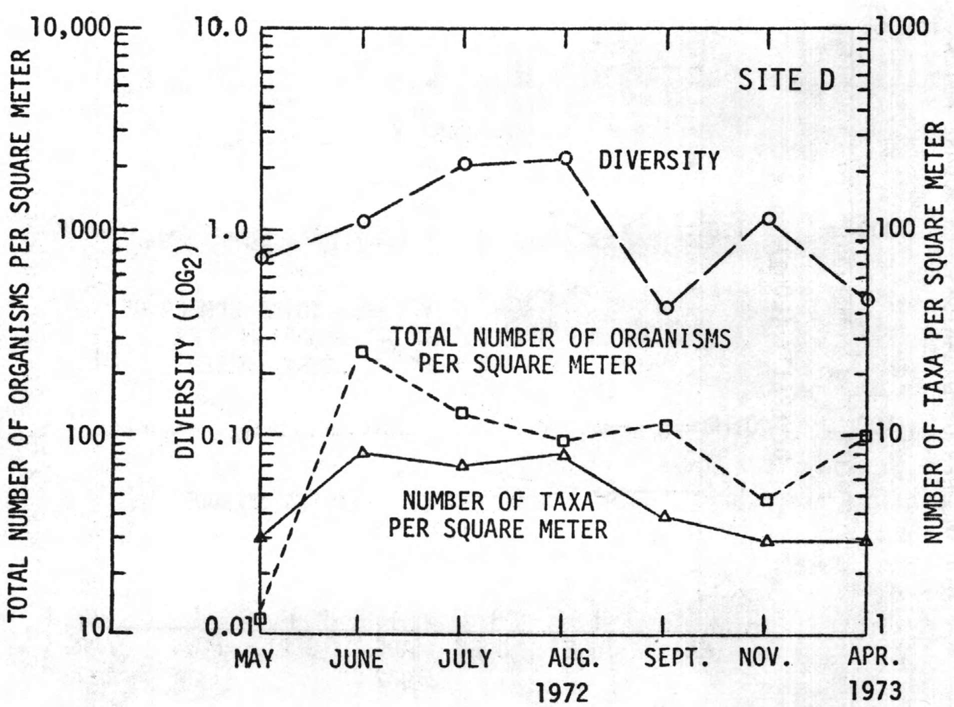


FIGURE 2.--Total number of organisms per square meter, number of taxa per square meter, and diversity index for samples collected in 1972-73 at sampling sites A through E--Continued.

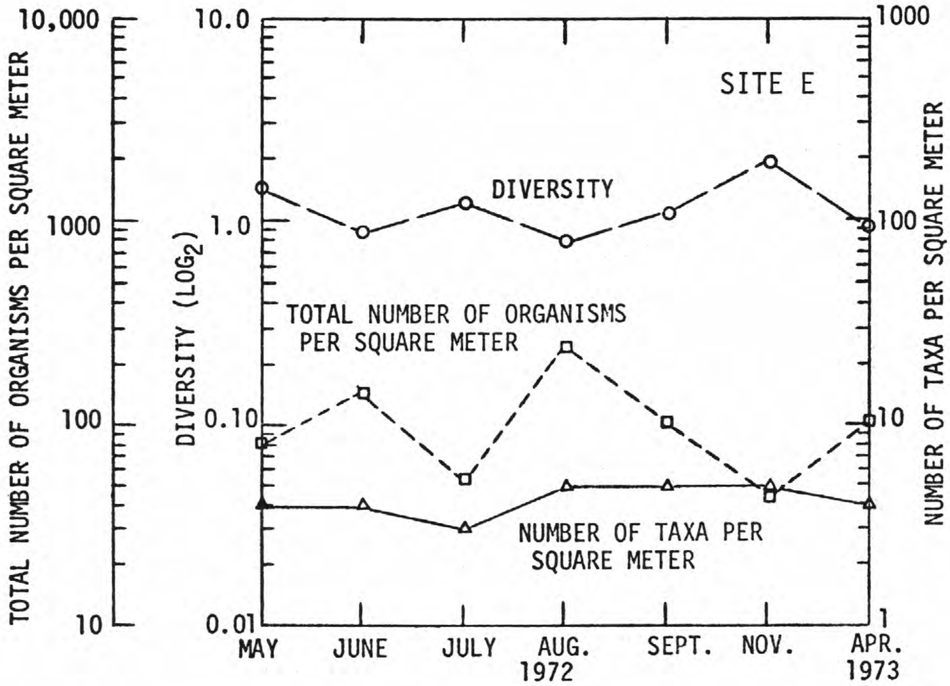


FIGURE 2.--Total number of organisms per square meter, number of taxa per square meter, and diversity index for samples collected in 1972-73 at sampling sites A through E--Continued.

Downstream Changes for Each Sampling Period

The monthly downstream changes in the number of organisms per square meter, number of taxa per square meter, and the diversity index are shown in figure 3. No definite downstream pattern of change occurred in the number of organisms per square meter in each sampling period. Although the mean number of organisms was larger at sites A, B, and C than at sites D and E, these differences were not statistically significant [$F_{95}(4,24)$].

The number of taxa generally decreased from the upper reach to the middle reach of the Sacramento River for each sampling period. In most of the sampling periods the number of taxa at site C was the lowest. A two-way factorial analysis of variance showed a significant difference [$F_{95}(4,24)$] among the mean log number of taxa for each site.

The diversity index generally decreased from site A to site D; however, the diversity index at site C was consistently one of the lowest values in each sampling period. In all sampling periods except June, July, and August, the diversity index increased from site D to site E. The two-way factorial analysis of variance test showed a significant difference [$F_{99.9}(4,24)$] among the mean diversity indexes calculated for each site. The upper reach had the largest mean diversity (site A = 1.71, site B = 1.76) and the upper middle reach had the lowest mean diversity index (site C = 0.51). The lower middle reach had diversity indexes of 1.20 at site D and 1.19 at site E.

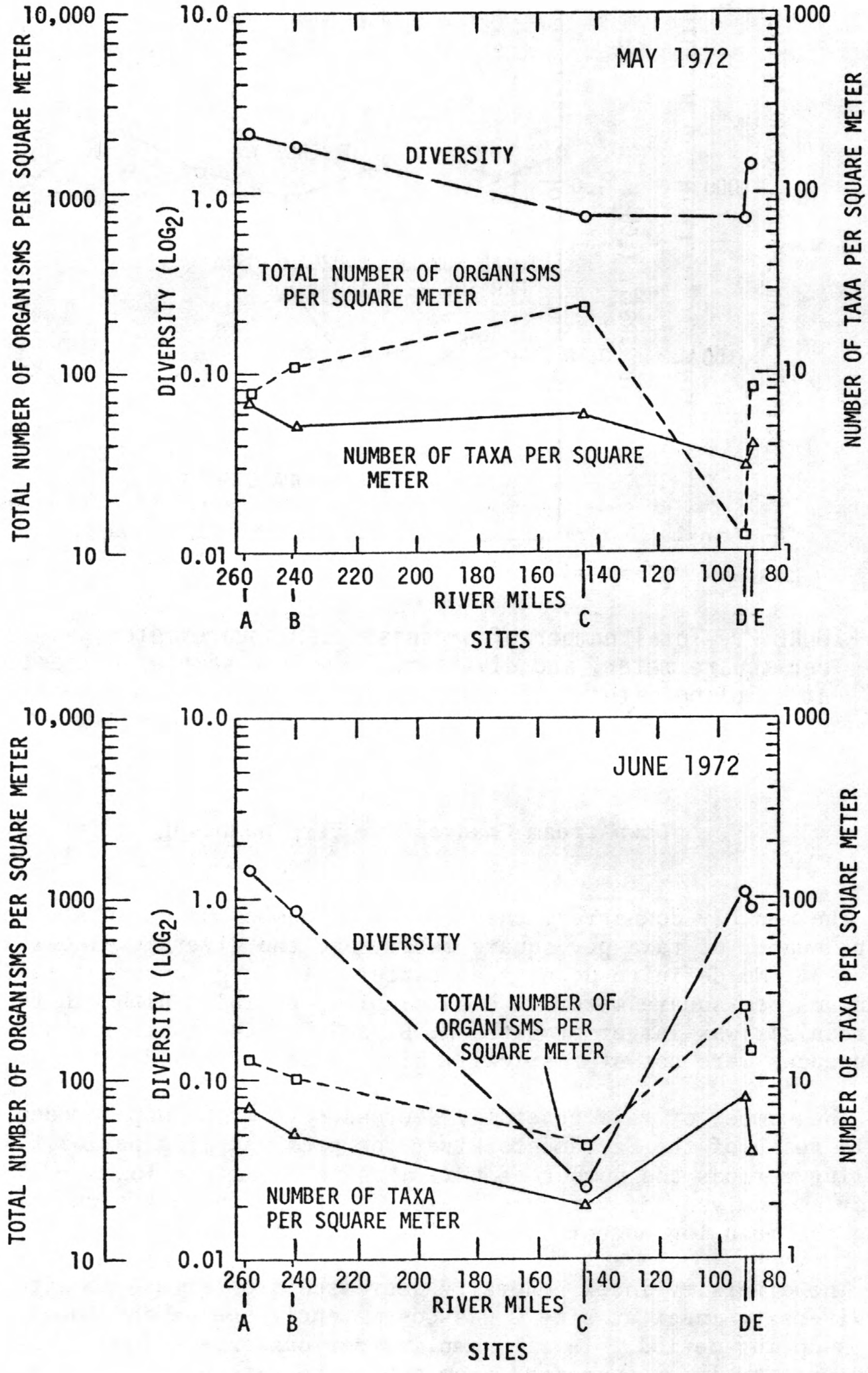
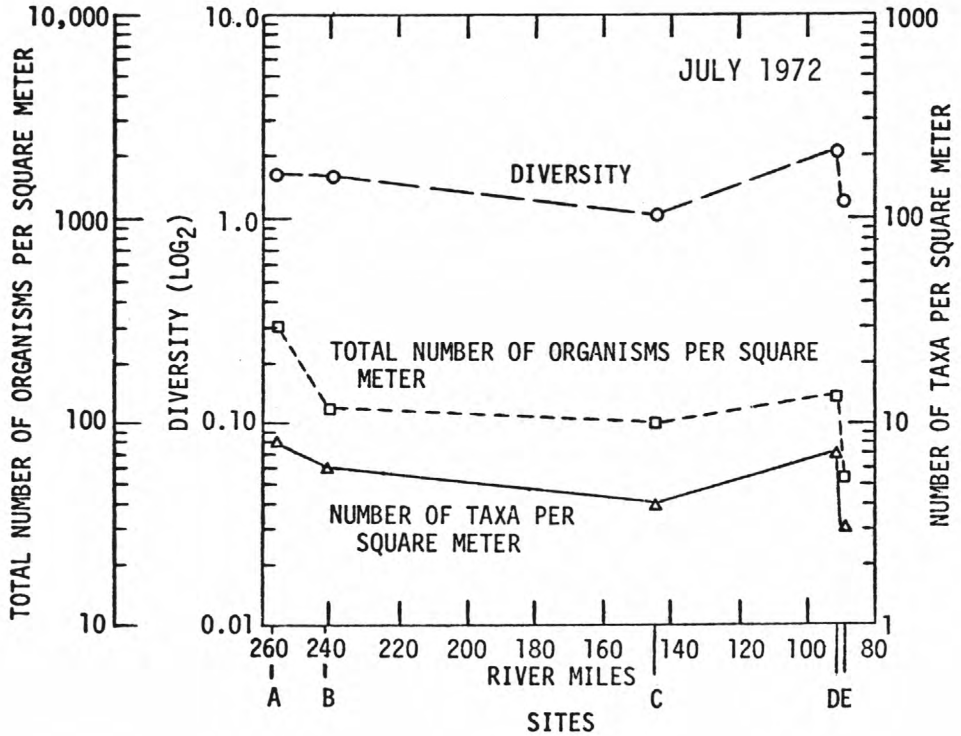


FIGURE 3.--Downstream changes in total number of organisms per square meter, number of taxa per square meter, and diversity index in 1972-73.



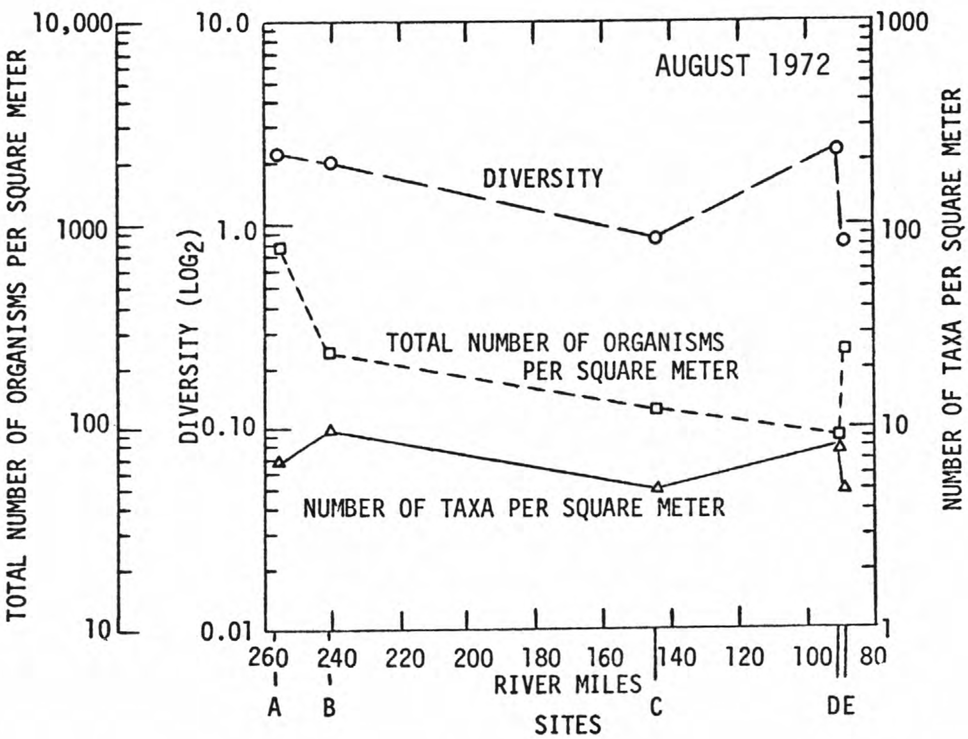


FIGURE 3.--Downstream changes in total number of organisms per square meter, number of taxa per square meter, and diversity index in 1972-73--Continued.

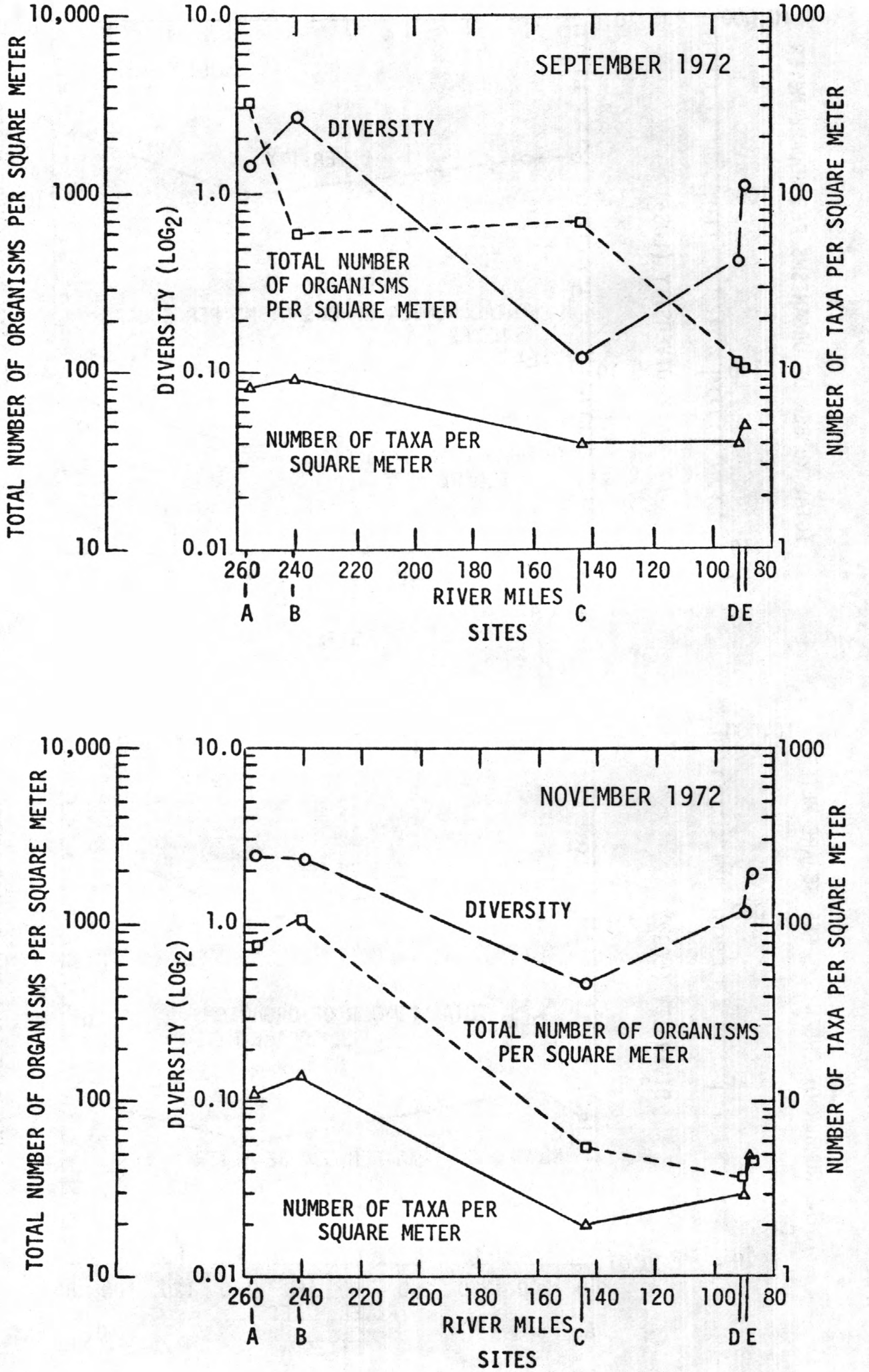


FIGURE 3.--Downstream changes in total number of organisms per square meter, number of taxa per square meter, and diversity index in 1972-73--Continued.

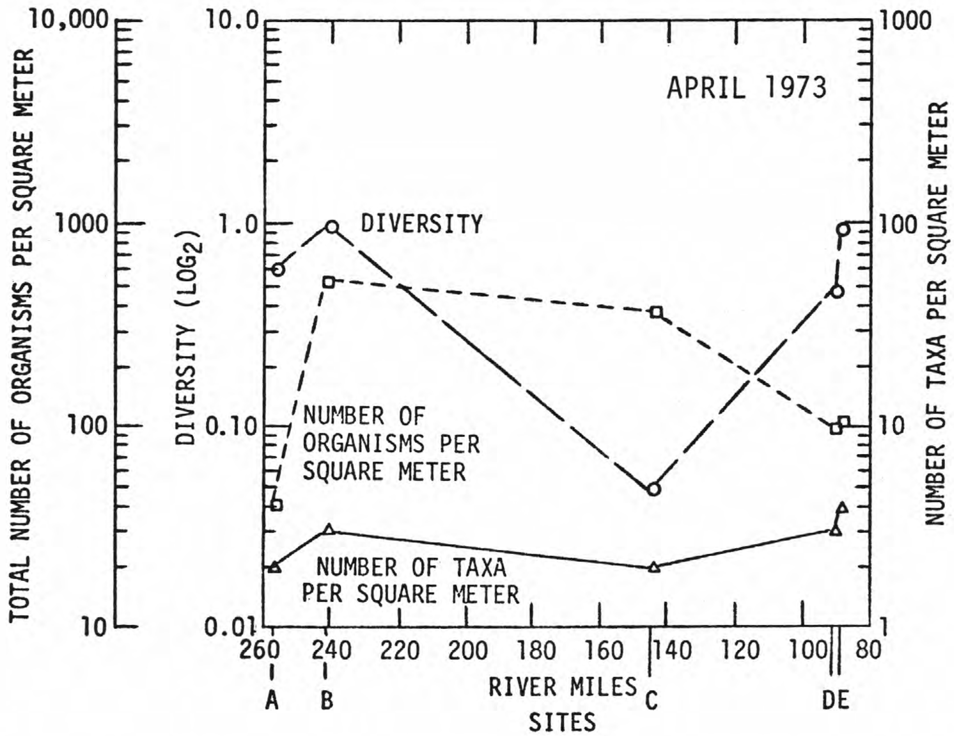


FIGURE 3.--Downstream changes in total number of organisms per square meter, number of taxa per square meter, and diversity index in 1972-73--Continued.

Similarity Index of Taxa Found at Each Sampling Site

The similarity index was calculated for each paired combination of sites (table 5). Adjacent sites had higher similarity indexes than sites separated by large distances. This indicated a gradual change in species composition of benthic organisms moving from the upper reach to the middle reach of the Sacramento River.

Table 5.--*Similarity index for paired sites*

Paired sites	A - B	B - C	C - D	D - E
Similarity index	0.62	0.53	0.52	0.74
Paired sites	A - C	B - D	C - E	
Similarity index	.39	.44	.58	
Paired sites	A - D	B - E		
Similarity index	.29	.32		
Paired sites	A - E			
Similarity index	.19			

CONCLUSIONS

The composition of benthic organisms sampled in 1960-61 did not differ greatly from that in 1972-73. When comparing the taxa of both studies, any notable differences between the two periods of collection can be explained by differences in sampling location, collection equipment, and handling of the samples. Also, some taxa collected in 1972-73 were not reported in 1960-61. The occurrence of additional taxa in 1972-73 does not indicate adverse environmental conditions. Generally, numerous taxa (diverse community of organisms) colonized in an area indicate that the community is stable and reflects good water quality.

Patterns of change with time and downstream order for total number of organisms, number of taxa, and diversity index were the same for both studies. Although these three criteria support the hypothesis that there has been no significant change in the benthic community between 1960-61 and 1972-73, the values are based only on counts, and there is no comparison of types of organisms included. For example, the same number of taxa might have existed in the same proportions, but could be completely different taxa in both studies. Considering each taxon separately can show differences, but differences are more easily seen by the use of the similarity index (Odum, 1971). The similarity index for both studies was large, indicating similar species and therefore no significant change. Calculations for both studies were made using a high level of taxonomic classification which could result in more similar numbers of taxa per sample and diversity indexes and which tends to bring the similarity index close to the maximum value of 1.

The inconsistent fluctuations at each site with total number of benthic organisms, number of taxa, and diversity index for successive sampling periods in 1972-73 indicate changes caused by something other than water quality. Water-quality changes in this short period of time generally would cause a unidirectional change in these three criteria, either an increase or decrease. The inconsistent fluctuations could be caused by sampling different stages in the individual life cycles of each taxon, or by influences of drifting organisms from farther upstream in the Sacramento River and its tributary streams. In addition, sampling error could have affected the estimated benthic organism composition.

To define more accurately the cause of seasonal variation in benthic organism composition at each site, a larger number of samples should be taken each sampling period. The sampling periods should occur during the spring, summer, and autumn, times when population shifts will be distinct for most taxa. Selected dates for sampling periods should coincide with the emergence of selected taxa. Sampling should be repeated the following year to determine whether or not observed seasonal variation in species composition is caused by different life cycles of each taxon. Knowing the amount of variation and reasons for variation in one year will help evaluate differences that might occur 10 years later.

Downstream differences in species composition in the Sacramento River follow those expected with slower water velocities and differences in substrate size (Hynes, 1972). The slower water velocities of the lower river reaches allow the settling of smaller particles, which results in a substrate more suitable for burrowing forms of organisms. Fast-water areas in the upper reaches that contain more rubble are typically colonized by clinging forms of organisms that rely on food sources brought by faster water velocities.

Benthic invertebrate samples from sites in the upper reach of the Sacramento River generally had a higher diversity index than those from the middle reach. The headwaters of streams commonly have a greater variety of organisms because of the greater variety of habitats afforded by the substrate. In the lower reaches, the smaller the size of substrate particles in relation to the size of benthic organisms, the more uniform the habitat (Hynes, 1972). Therefore, fewer types of organisms colonize in one area. This can easily be seen by the general decrease in the number of taxa per unit area when comparing the sites in downstream order. Although the middle reach of the Sacramento River did not have as many types of organisms as the upper reach, there was a larger number of organisms in each taxon, resulting in a similar number of benthic organisms per square meter. This has been observed in similar studies (Hynes, 1972).

REFERENCES CITED

Britton, L. J., and Averett, R. C., 1974, Water-quality data on the Sacramento River, California, May 1972 to April 1973: U.S. Geol. Survey open-file rept., 59 p.

California Department of Water Resources, 1962, Sacramento River water pollution survey, App. D, benthic biology: Bull. 111, 78 p.

______1974, California State water project: Bull. 200, v. 1, 173 p.

Flannagan, J. F., 1973, Efficiencies of various grabs and corers in sampling fresh-water benthos: Fisheries Research Bd. Canada Jour., v. 27, no. 10, p. 1691-1700.

Gaufin, A. R., Harris, E. K., and Walter, H. J., 1956, A statistical evaluation of stream bottom sampling data obtained from three standard samplers: Ecology, v. 37, no. 4, p. 643-648.

Hynes, H. B. W., 1972, The ecology of running waters: Toronto Univ. Press, 555 p.

Odum, E. P., 1971, Fundamentals of ecology (3d ed.): Philadelphia, W. B. Saunders Co., 574 p.

Shannon, C. E., and Weaver, W., 1949, The mathematical theory of communication: Urbana, Ill., Illinois Univ. Press, 177 p.

Slack, K. V., Averett, R. C., Greeson, P. E., and Lipscomb, R. G., 1973, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geol. Survey Techniques Water-Resources Inv., book 5, chap. A4, 165 p.

Slack, K. V., Nauman, J. W., and Tilley, L. J., 1976, Evaluation of three collecting methods for reconnaissance of stream benthic invertebrates: U.S. Geol. Survey Jour. Research, v. 4, no. 4, p. 491-495.

Sokal, R. R., and Rohlf, J. F., 1969, Biometry: San Francisco, W. H. Freeman and Co., 776 p.

Wilhm, J. L., 1970, Range of diversity index in benthic microinvertebrate populations: Water Pollution Control Federation Jour., v. 42, no. 5, pt. 2, p. 221-224.

Wilhm, J. L., and Dorris, T. C., 1968, Biological parameters for water quality criteria: Biol. Sci., v. 18, p. 477-481.

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