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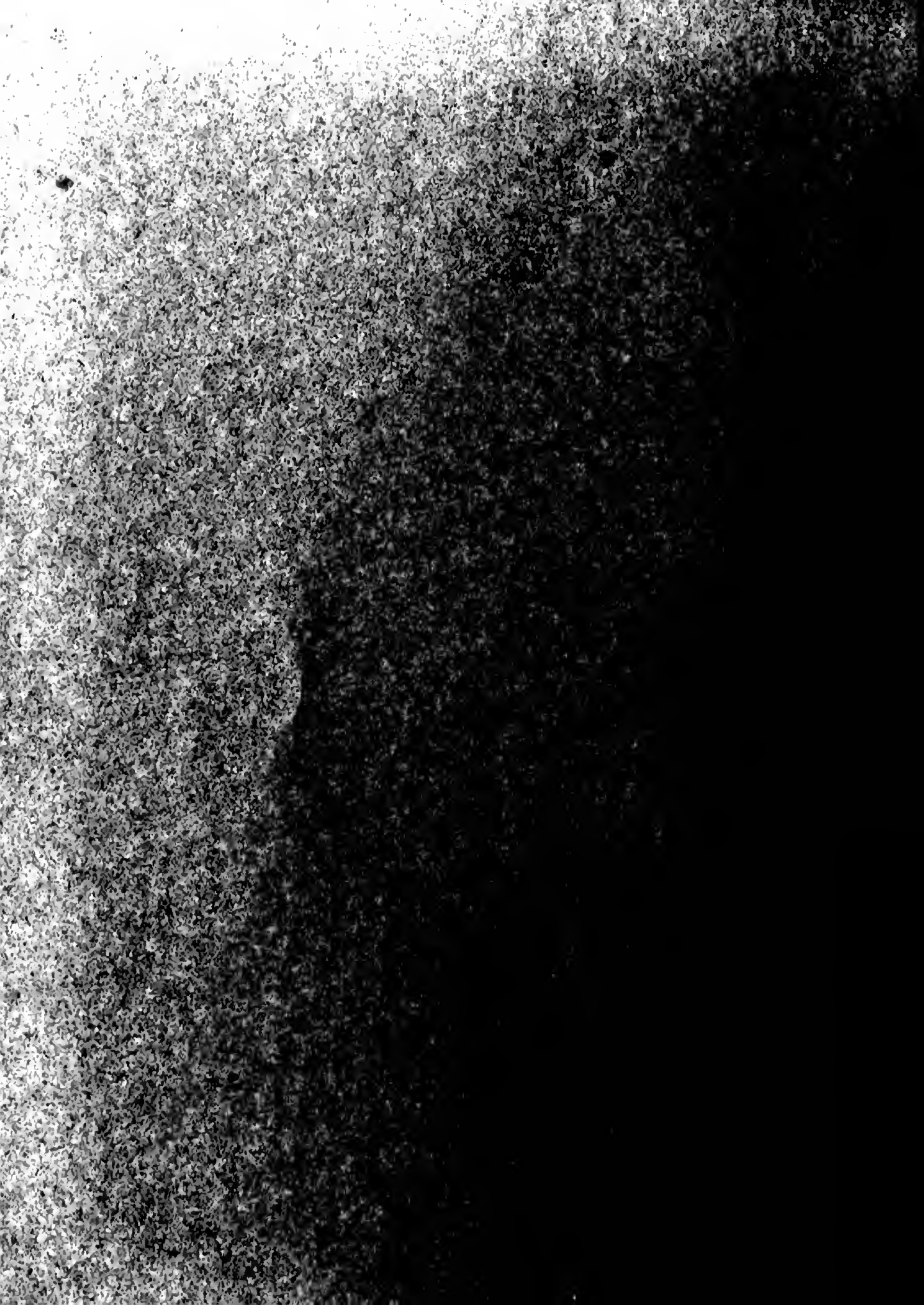
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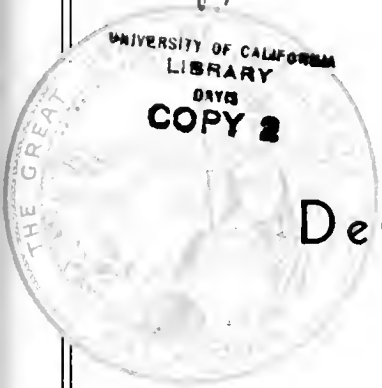
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THE RESOURCES AGENCY OF CALIFORNIA
Department of Water Resources

BULLETIN No. 111
SACRAMENTO RIVER
WATER POLLUTION SURVEY

APPENDIX D
BENTHIC BIOLOGY

AUGUST 1962

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EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Administrator
The Resources Agency of California
and Director
Department of Water Resources



State of California
THE RESOURCES AGENCY OF CALIFORNIA
Department of Water Resources

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A biological study of the scope attempted in the Sacramento River Water Pollution Survey requires the efforts of many people. Special thanks are due to Marvin Peyton of the Department of Water Resources, who assisted in most of the field collections upon which this report is based.

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CHAPTER I. INTRODUCTION

It is necessary to examine all aspects of water quality to gain a clear understanding of past and present characteristics of a stream. Chemical and physical measurements provide data on water conditions at a particular moment. On the other hand, biological observations reflect conditions that have existed for some time previously. A study of biological characteristics and the ecological relationships of plants and animals in a stream may therefore provide the best overall picture of past and present water quality conditions in that stream.

Various assemblages of organisms are known to be associated with particular types of water quality. For example, heavy concentrations of midge larvae or tubificid worms are often associated with organic enrichment. These organisms are quite tolerant of low dissolved oxygen concentrations and, in the absence of competition from other tolerant forms, may increase their numbers enormously. On the other hand, waters with little pollution may be characterized by smaller total numbers, but a much greater variety of animals. Thus, in clean-water streams, we may expect to find organisms such as mayflies, stoneflies, caddisflies, midge larvae, damselflies, and a host of other types. It must be noted, however, that aquatic forms often associated with poor water quality are also found in clean water areas but are far less numerous.

In addition to effects brought about by the chemical quality of water, the physical characteristics of the habitat are extremely important in modifying plant and animal life. Certain types of habitat are not conducive to large bottom fauna populations. A shifting sand bottom, for example, supports a much smaller biomass than does a silt or boulder habitat.

It should be apparent, from the foregoing statements, that careful interpretation of the data collected is extremely important in assessing the relationship between aquatic life and its environment. In this respect, the more factors that can be measured, and the more data on hand, the more meaningful this interpretation can become. Therefore, as time permitted, data from other segments of the Sacramento River investigation were used to supplement those gathered in the biological survey.

Because of time limitations, it has not been possible to make a complete ecological interpretation of the data collected during the biological phase of the Sacramento River Water Pollution Survey with data from other portions of the investigation.

Authorization of Study

The biological survey was conducted by personnel of the Departments of Water Resources and Fish and Game in accordance with Interagency Agreements No. 25141 and No. 25093.

Objectives and Scope of Study

The biological portion of the Sacramento River Water Pollution Survey was designed to: (1) establish a "base-line" of present biological conditions against which future changes can be measured, and (2) provide information necessary for setting waste discharge requirements for the protection of aquatic life.

In order to meet these objectives, biological sampling was conducted at monthly intervals from April 1960 through June 1961 at twenty-two "key" sampling stations from Shasta Dam to the confluence of the Sacramento and San Joaquin Rivers (Plate 1). Seven additional river stations were established to measure biological conditions in areas of particular interest. Two large agricultural irrigation drains were

also sampled during periods when they carried large amounts of drainage water.

It became apparent at about the middle of the field-collecting phase of the investigation that, with the resources at hand, the laboratory work would not be completed in the time available. The biological program was therefore reduced by approximately one-third for the remainder of the investigation. This was accomplished by discontinuing some stations, and sampling on a bimonthly basis at certain others.

In addition to sampling of bottom organisms and attached plants, the following measurements were made: temperature of water and air; weather conditions; dissolved oxygen at the surface and at the bottom of the river; dissolved oxygen in the gravels at selected locations known to be important for fish spawning activities; water transparency; plankton samples; and bottom sediment sizes. No attempt was made to collect or evaluate fish populations during the investigation.



CHAPTER II. METHODS

The methods used during this survey were, whenever, possible, adopted from procedures outlined in "Standard Methods" (1960), or Welch (1948).

Field Investigations

Sampling Stations

The locations of sampling stations are shown on Plate 1. Detailed maps showing locations of individual samples from each of the stations are on file at the Department of Fish and Game Field Station at Sacramento. Station descriptions are summarized below; unless otherwise stated, stations are on the Sacramento River.

Station 305.7 (Above Spring Creek). Keswick Reservoir near Matheson. Samples from 36 to 50-foot depths near banks. Fine sand and silt, frequently with large amounts of organic debris.

Station 297.7 (Above Redding Diversion Dam). Samples from 1.5 to 11-foot depths. Large cobbles.

Station 295.2 (Redding F & G Station 1). Shallow pits in flood plain. Samples from 9 to 13-foot depths. Sandy silt with organic debris overlying cobbles.

Station 294.0 (Above Cypress Avenue Bridge, Redding). Samples from 1.5-foot depth in riffle area near bridge and along right bank 0.3 mile upstream. Large cobbles with some sand.

Station 285.9 (Above Churn Creek). Riffle area. Samples from 1.5-foot depth near center of river. Cobbles, average 3-inch diameter.

Station 279.2 (Above Cow Creek). Near Anderson. Samples from 1.5-foot depth. Gravel.

Station 275.0 (Balls Ferry Bridge). Samples from 1.5-foot depths in riffle area near right bank. Cobbles, average 5-inch diameter.

Station 256.3 (Bend Bridge). Samples from 1.5-foot depth near left bank at first riffle downstream from bridge. Cobbles, average 30inch diameter.

Station 253.4 (Big Bend). Narrow, deep channel with boulders. Samples from 1.5 to 20-foot depth near right bank.

Station 241.0 (Below Red Bluff). Broad, shallow channel. Samples from 1.5 to 6-foot depth along right bank in riffle area and in backwater. Gravels in riffle, silt and fine sand in backwater.

Station 229.8 (Above Elder Creek). First riffle upstream from confluence. Samples from 1.5-foot depth near island. Sandy gravel.

Station 217.6 (Vina Bridge). Samples from 10 to 20-foot depths throughout stream. Sand and silty sand.

Station 199.6 (Hamilton City Bridge). Leveed section upstream from bridge. Samples from 5 to 11-foot depths, generally near banks. Gravel and cobbles at midstream, sand and silt near banks.

Station 184.5 (Ord Ferry). Samples from 6 to 12-foot depths upstream from ferry, generally near right bank. Silt and clay near right bank, sand in rest of stream bottom.

Station 168.2 (Butte City). Samples collected from 7 to 25-foot depths, generally near banks. Sand in midstream, silt and clay near banks.

Station 144.1 (Colusa Bridge). Leveed section. Samples from 10 to 18-foot depths. Sand.

Station 118.1 (Wilkins Slough). Leveed section. Samples from 10 to 26-foot depths. Clay to medium sand.

Station 90.5 (Above Colusa Basin Drain). Leveed Section. Samples from 18 to 22-foot depths. Sand in central portion, fine sand and silt near right bank.

Station 90.2R/0.1 (In Colusa Basin Drain). Samples from 7 to 10-foot depths about 500 feet below dam. Coarse sand and plant debris.

Stations 88.2 and 88.8 (Below Knights Landing). Leveed section. First two samples from lower station. Samples from 10 to 25-foot depths. Generally sand bottom, some fine sand and silt.

Station 81.5 (Above Sacramento Slough). Leveed section. Samples from 14 to 28-foot depths. Fine sand near midstream, hard clay near right bank.

Station 80.8L/0.1 (In Sacramento Slough). Samples from 11 to 20-foot depths. Silt and clay.

Station 62.6 (Bryte). Leveed section. Samples from 10 to 48-foot depths. Sand near midstream, clay near left bank.

Station 53.2 (Clay Bank Bend). Leveed section, about 1/2 mile below Sacramento Sewage Treatment Plant Outfall. Samples from 14 to 22-foot depths. Sand and organic debris.

Station 46.4 (Freeport). Leveed section. Samples from 15 to 23-foot depths. Sand near midstream, silt near banks.

Station 43.4 (Above Clarksburg). Leveed section with occasional tidal flow reversals. Samples from 16 to 45-foot depths near banks.

Station 37.2 (Snodgrass Slough). Leveed section. Samples from 16 to 34-foot depths. Sand near midstream.

Station 27.4 (Above Delta Cross Channel at Locke). Leveed section. Samples from 17 to 25-foot depths. Sand near midstream, silt and clay near banks.

Station 18.8 (Isleton). Leveed section with strong tidal flow reversals. Samples from 10 to 16 feet, generally near right bank. Sand near midstream.

Station 12.8 (Below Rio Vista Bridge). Leveed section about 0.4 mile wide. Samples from 14 to 24-foot depths. Silty sand with some organic debris.

Station 4.0 (Above Mayberry Slough). About 0.5 mile wide, hills near right bank, left bank leveed. Samples from 25 to 35-foot depths. Sand and silt with large amounts of organic debris.

Physical Determinations

Temperature. Air and water temperatures were determined with the use of a 5-1/2 inch mercury-filled thermometer graduated in degrees Fahrenheit and recorded to the nearest degree. Air temperatures were taken in the shade one or two feet above the water surface, holding the thermometer at least two feet away from any object. Water temperatures were determined by immersing the bulb in the stream until the mercury column exhibited no movement.

Temperatures of bottom waters or waters in the gravels were obtained immediately from 300-milliliter sample bottles.

Dissolved Oxygen. Dissolved oxygen determinations were made, using the Alsterberg (azide) modification of the Winkler method. Water was collected by means of a 2-liter Kemmerer water sampler at most stations. Surface dissolved oxygen samples were taken at approximately one- to two-foot depths. Bottom dissolved oxygen samples were taken from as near the bottom as possible. At sandy or gravel bottoms, the sampler was allowed to touch bottom, then the messenger released to trip the valves. Over mud or silt bottoms, samples were taken from about one foot off the bottom to eliminate collecting bottom material.

Water samples were collected by a different method at the stations between mile 294 and mile 229.8 where sampling was done in shallow water (one to two feet deep). Water was drawn into a 300-milliliter bottle by evacuating air from the bottle with a tube, causing a partial vacuum and pulling water into the bottle through another tube. Samples at these stations were taken at a depth of one inch from the surface, within one inch of the bottom, and, when possible, at a depth of 12 inches in the

gravel. In the latter case, water was withdrawn from a perforated pipe which was driven into the gravel.

Transparency. Water transparency was measured with a 20-centimeter Secchi disc. The depths at which the disc disappeared from sight and subsequently reappeared were recorded. The average of these two distances is considered the limit of visibility.

Bottom Particle Size. Stream bottom particle size was determined by two methods. Particle sizes were measured at the riffle stations with a 100-foot tape and graduated calipers. The tape was stretched across gravel which was judged representative in composition to that being sampled for bottom organisms. The intermediate axis of the gravel particle located directly under each foot-mark was measured by the use of calipers graduated in millimeters (Wolman, 1954). This method is useful in comparing the relative size of gravel in different areas, but has the disadvantage of not measuring the amount of sand and silt in the gravel.

Bottom sediment samples were taken at stations other than those located on riffles with a Petersen dredge. A pint sample of the material collected was retained and sent to the Department of Water Resources Soils Laboratory for determination of particle size distribution.

Biological Collections

Plankton. Quantitative plankton samples were taken from various stations throughout the survey. These samples were collected with a Kemmerer water sampler. Three samples were taken at midstream and at the quarter points across the river at a depth of two to three feet. The samples were composited in a one-gallon jug and fixed by adding sufficient formalin to result in a four percent solution.

Beginning in September 1960, two samples were taken at each station at third-points and composited in a half-gallon bottle.

All of the samples were sent to the Department of Public Health, Sanitation and Radiation Laboratory, Berkeley, for identification and enumeration. The results of this study are reported in Appendix C.

Attached Plants. Attached plants were collected at several locations by pulling the entire plant loose from the substrate and preserved in approximately five percent formalin solution.

Bottom Organisms. Bottom organisms were collected by means of a Surber sampler or dredge. Collections were made with a one square-foot Surber sampler at miles 297.7, 294, 285.9, 279.2, 275, 256.3, 253.4, 241.0, and 229.8. Three samples were taken on most occasions at these stations. The entire contents in the sampler, which included organisms, detritus, sand, small gravel, etc., were labeled and preserved in 10 percent formalin.

A Petersen dredge was used to collect bottom organisms at all of the stations other than those listed above, from May 1960, through the end of the sampling program. Station depths ranged from 4 to 30 feet. The area sampled by this dredge was 96 square inches, or approximately two-thirds square foot. From one to three dredge hauls were made for each collection. Attempts at using an Ekman dredge were unsuccessful.

Samples collected with the dredge were poured into soil sieves with openings of 0.589 mm (Standard U. S. Sieve No. 30). The organisms remaining on the screen were picked off with forceps, placed in vials, together with appropriate labels, and preserved in a 10 percent formalin solution.

Laboratory Procedures

Bottom Organisms

Bottom organism samples were delivered to the Bryte Laboratory of the Department of Water Resources for analysis. Samples of bottom organisms were placed in Petri dishes and examined under a binocular dissecting microscope.

The animals were separated into the lowest most easily recognizable taxonomic group, and placed by group in Syracuse watch glasses for more refined determinations. Each group was then more closely examined and identified to the lowest possible taxonomic unit (e.g. genus and/or species). After identification, the numbers and volume of each kind of organism were tabulated. The sample material was then placed in a vial, together with a collection data slip, and preserved in alcohol for permanent storage. The laboratory form, storage vial, and collection data slip all have the same inscribed number so that cross references can be made. These samples are stored by the Department of Fish and Game at the Sacramento Field Station, and are available for future reference.

Two measurements were used in the quantitative analysis of the bottom fauna samples. These included numbers and volume of individuals. The volume of displacement was calculated by placing the portion of the sample to be measured on absorbent paper toweling and permitting the individuals to dry for one-half to one minute. A measured amount of distilled water was pipetted into a graduated cylinder. The blotted animals were then admitted. The volume of the organisms was recorded in cubic centimeters.

Bottom Sediment Size

Particle size analyses of bottom sediment samples were made in accordance with the procedure given in the Department of Water Resources'

"Manual of Testing Procedures for Soils", dated April 1962. Essentially this consists of taking a 100-gram aliquot from the sample and shaking this portion through a nest of sieves. The sieves used are United States Standard Sieves Nos. 8, 16, 30, 50, 100 and 200, and a pan. A lid is placed on the top sieve and the complete nest of sieves is shaken for about 30 seconds. The No. 8 sieve is then carefully removed from the other sieves, placed on an extra pan, and vibrated vigorously in a circular motion while being tapped on the side with one hand. This shaking is continued until all of the material finer than the No. 8 has passed the sieve. When this sieving is complete, the material retained is emptied into a pan, and the material that passed through the sieve is placed in the next smaller mesh sieve. This screening procedure is repeated for each sieve size and the weight of material retained on each sieve is determined and recorded.

Size distributions of material that passed through the No. 200 screen were determined with a hydrometer.



CHAPTER III. PHYSICAL CHARACTERISTICS

Physical characteristics of Sacramento River water were determined at the times of biological sampling. The results, which were generally consistent with those obtained during the water quality portion of the investigation (Appendix B), are summarized below.

Temperatures and Dissolved Oxygen

Figures 1 through 8, inclusive, show air and water temperatures, surface and bottom water dissolved oxygen concentrations, and dissolved oxygen concentrations in interstitial waters of gravels. Figures 9 and 10 show that the oxygen data are consistent with values obtained during other phases of the investigation.

Water temperatures at Keswick (mile 305.7) were generally about 50°F. Downstream water temperatures approached equilibrium with air temperatures at varying rates.

Dissolved oxygen concentrations increased during the first 15 to 25 miles below Keswick and then generally decreased throughout the rest of the river (Figures 9 and 10). Surface and bottom dissolved oxygen levels were generally about the same; of the 330 observations, significantly lower concentrations at the bottom occurred only about two percent of the time.

Within the gravels in riffle areas, oxygen concentrations varied from about 4 to 12 ppm with average values about 2 ppm less than those in the overlying water (Figure 11). Wide variations were noted between closely spaced sampling points, with lower values generally associated with greater percentages of fines in the gravel. This may explain why successful salmon spawning occurs in very localized areas within a general spawning reach.

FIGURE 1
SACRAMENTO RIVER WATER POLLUTION SURVEY
BIOLOGICAL SURVEY-PHYSICAL DATA
APRIL 1960

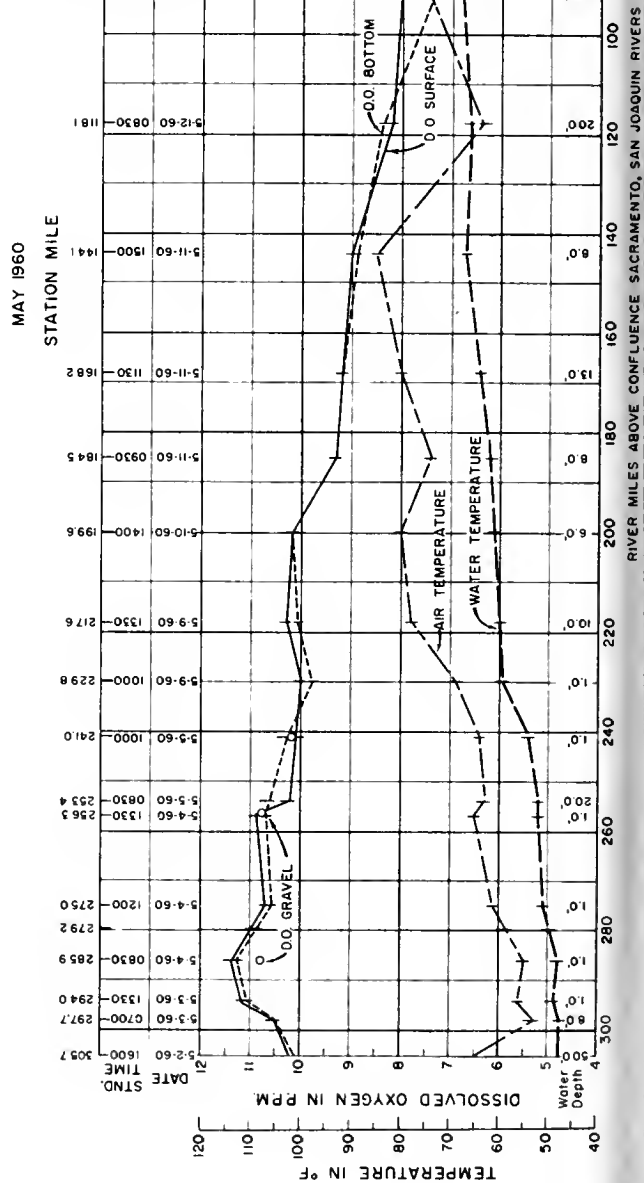
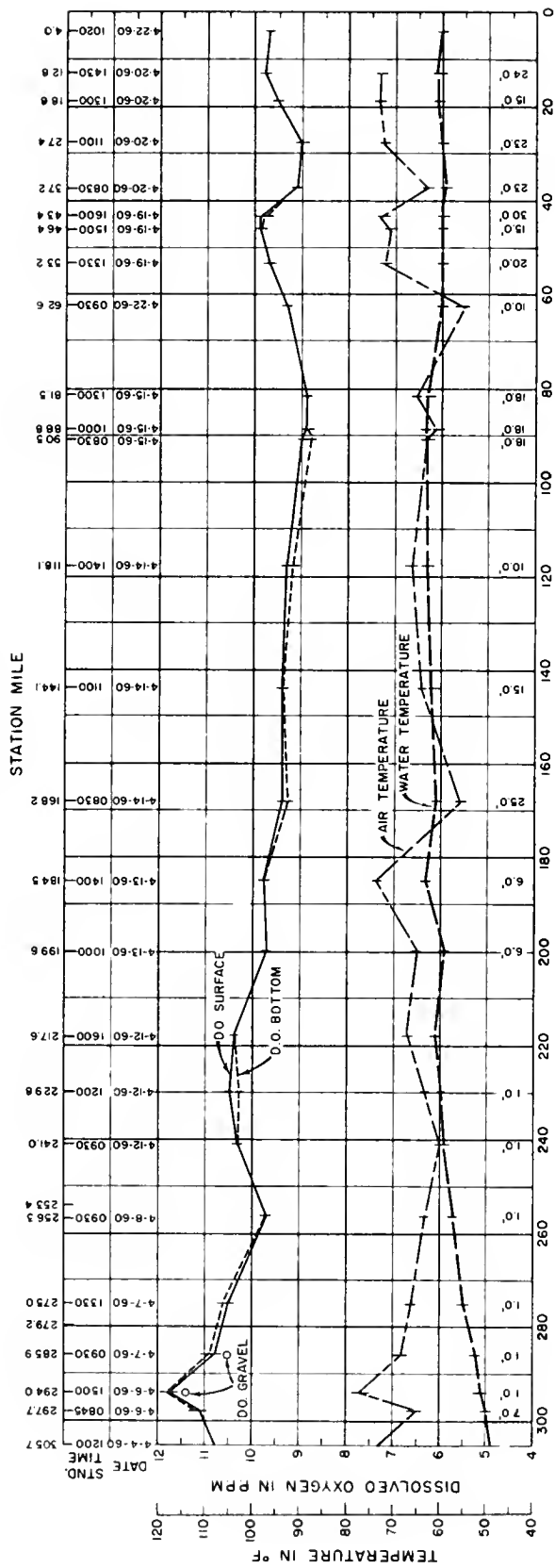


FIGURE 2
 SACRAMENTO RIVER WATER POLLUTION SURVEY
 BIOLOGICAL SURVEY-PHYSICAL DATA
 JUNE 1960

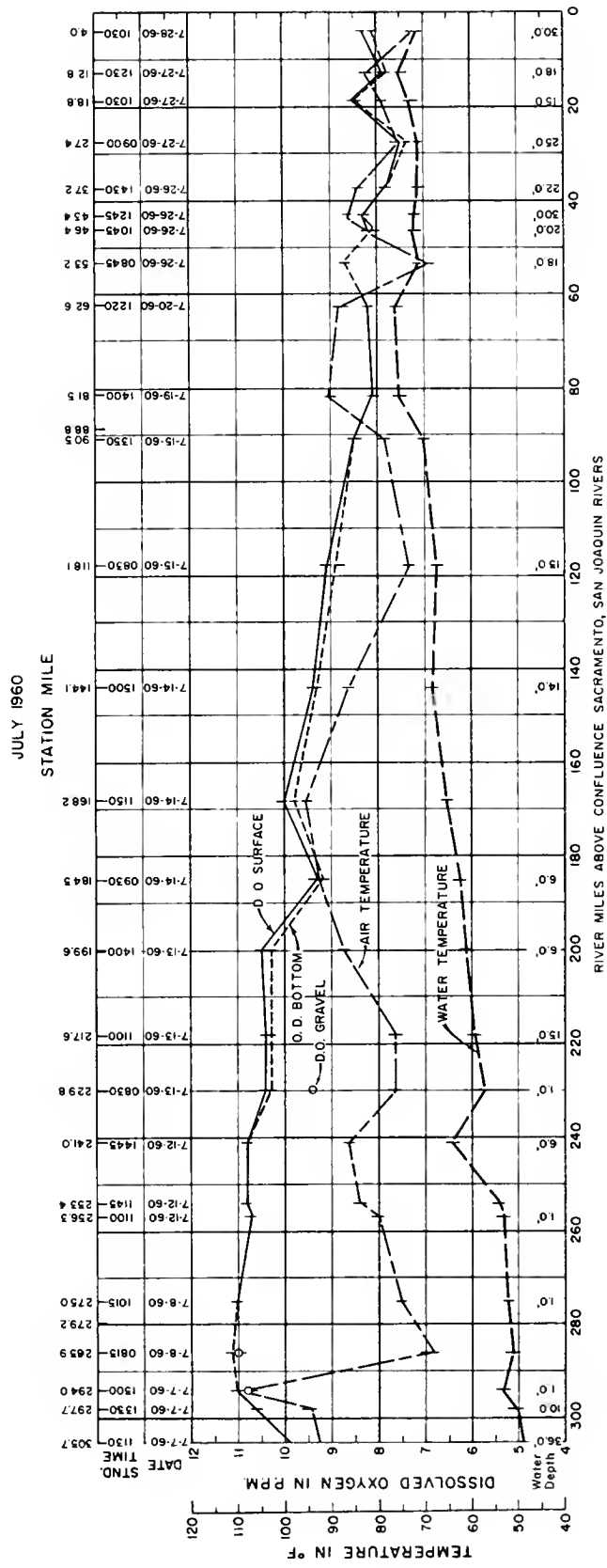
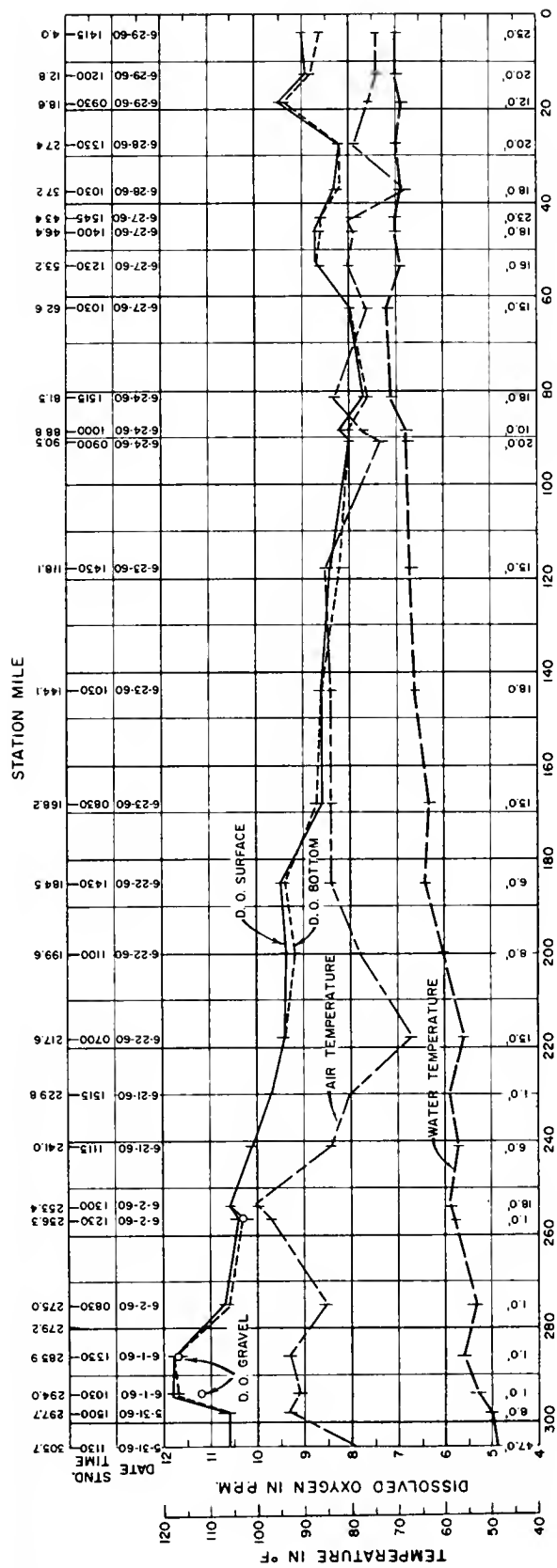


FIGURE 3
SACRAMENTO RIVER WATER POLLUTION SURVEY
BIOLOGICAL SURVEY-PHYSICAL DATA
AUGUST 1960

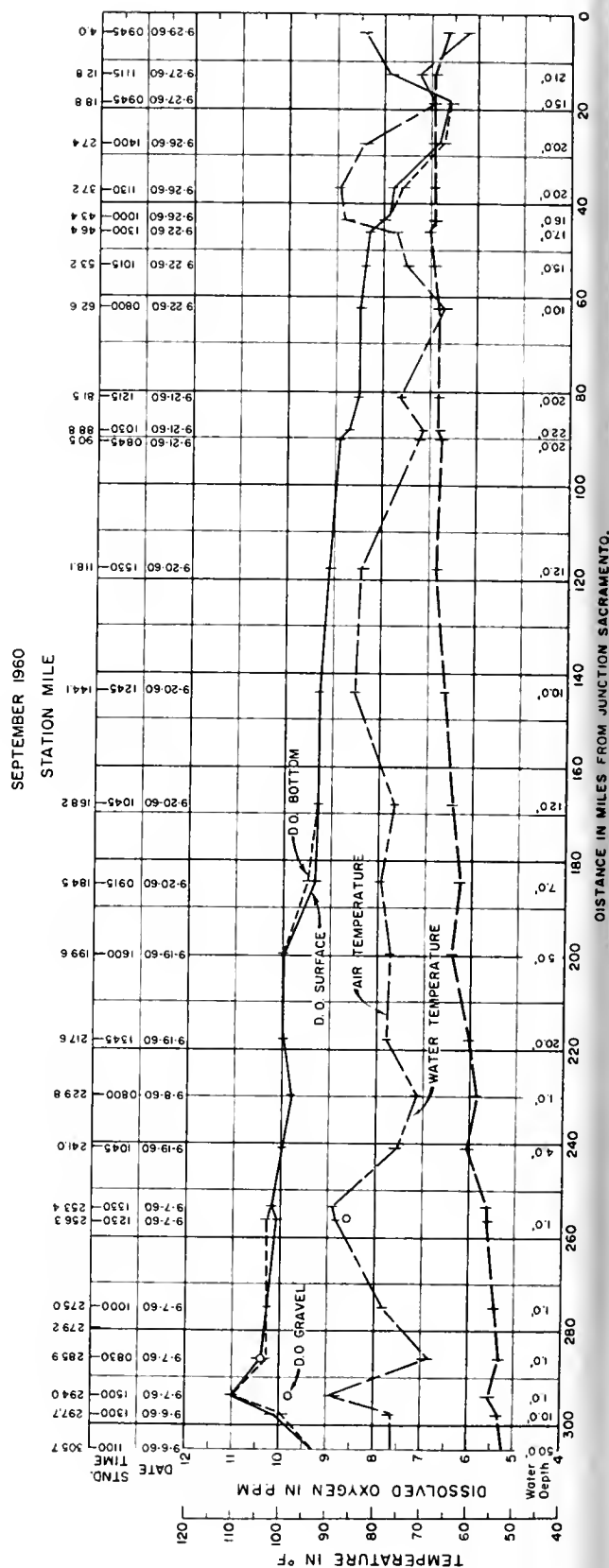
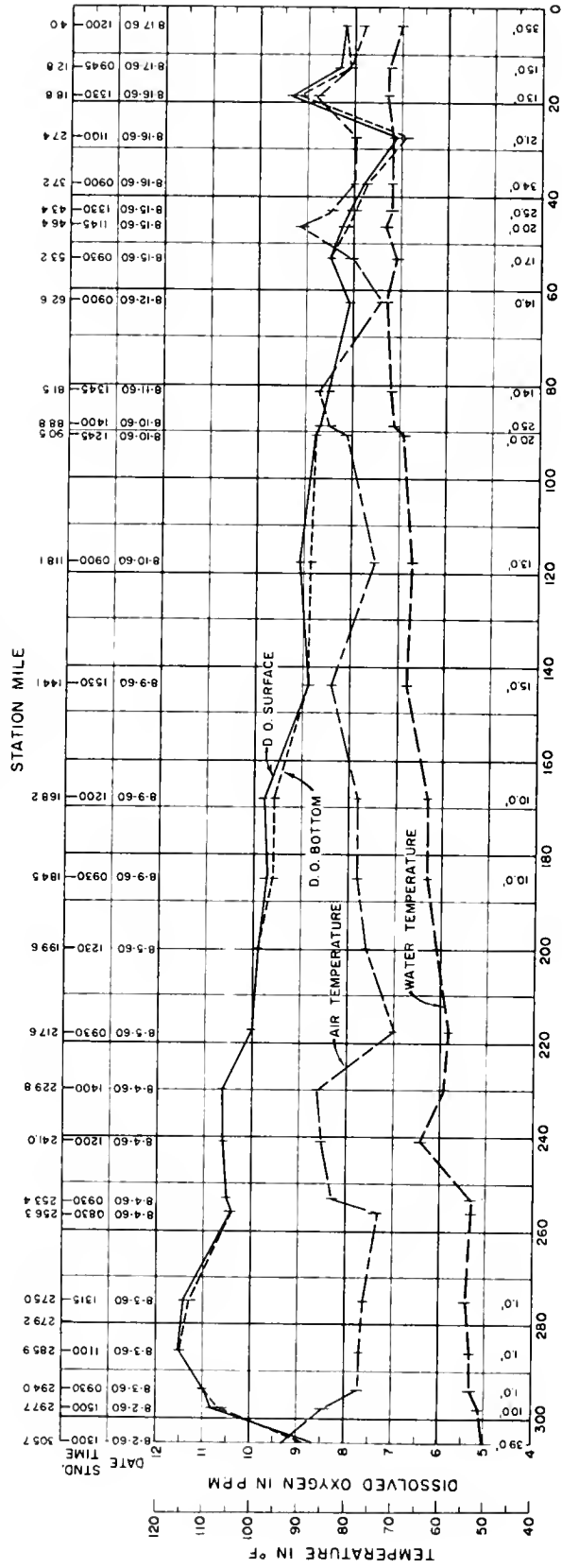
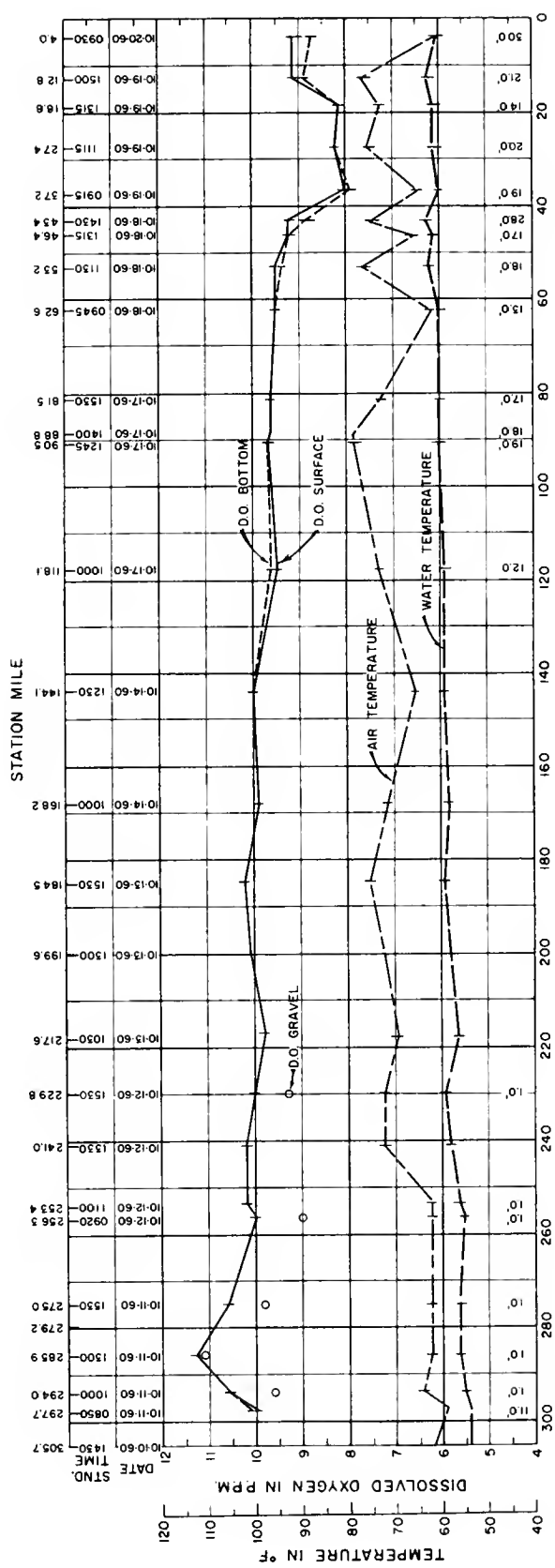


FIGURE 4
 SACRAMENTO RIVER WATER POLLUTION SURVEY
 BIOLOGICAL SURVEY - PHYSICAL DATA
 OCTOBER 1960



NOVEMBER 1960

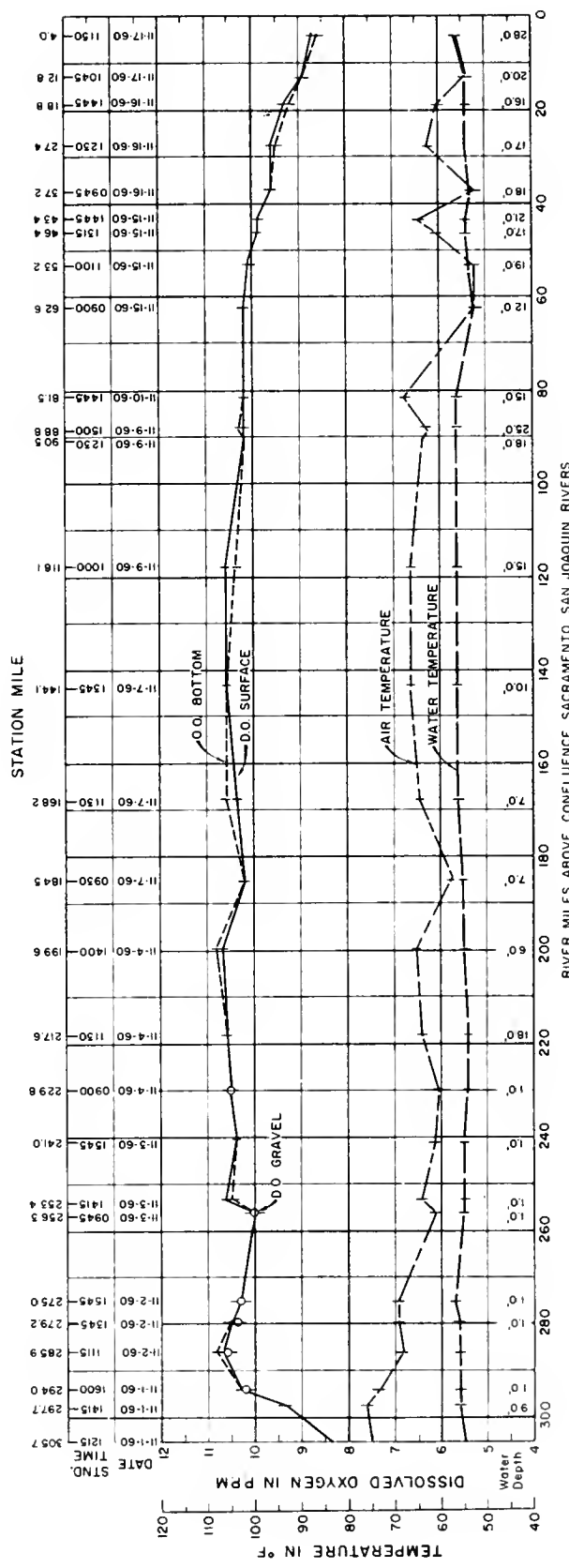


FIGURE 5
SACRAMENTO RIVER WATER POLLUTION SURVEY
BIOLOGICAL SURVEY - PHYSICAL DATA
DECEMBER 1960

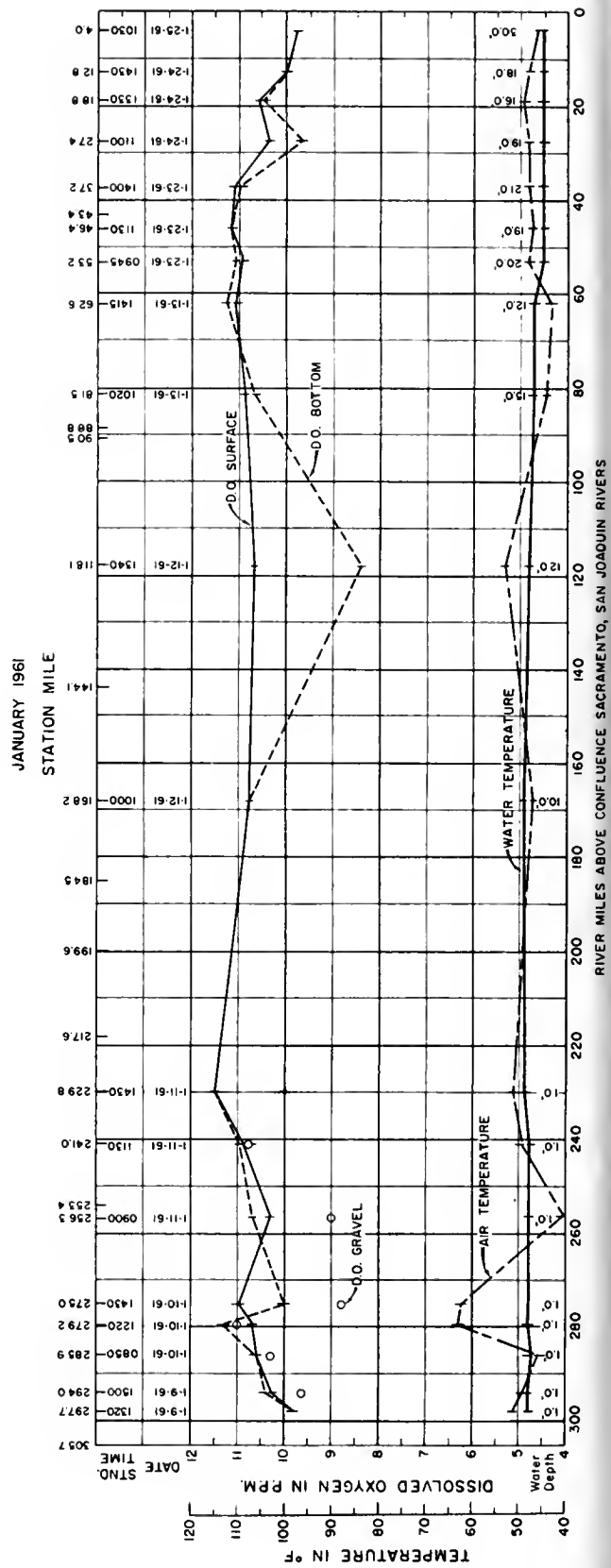
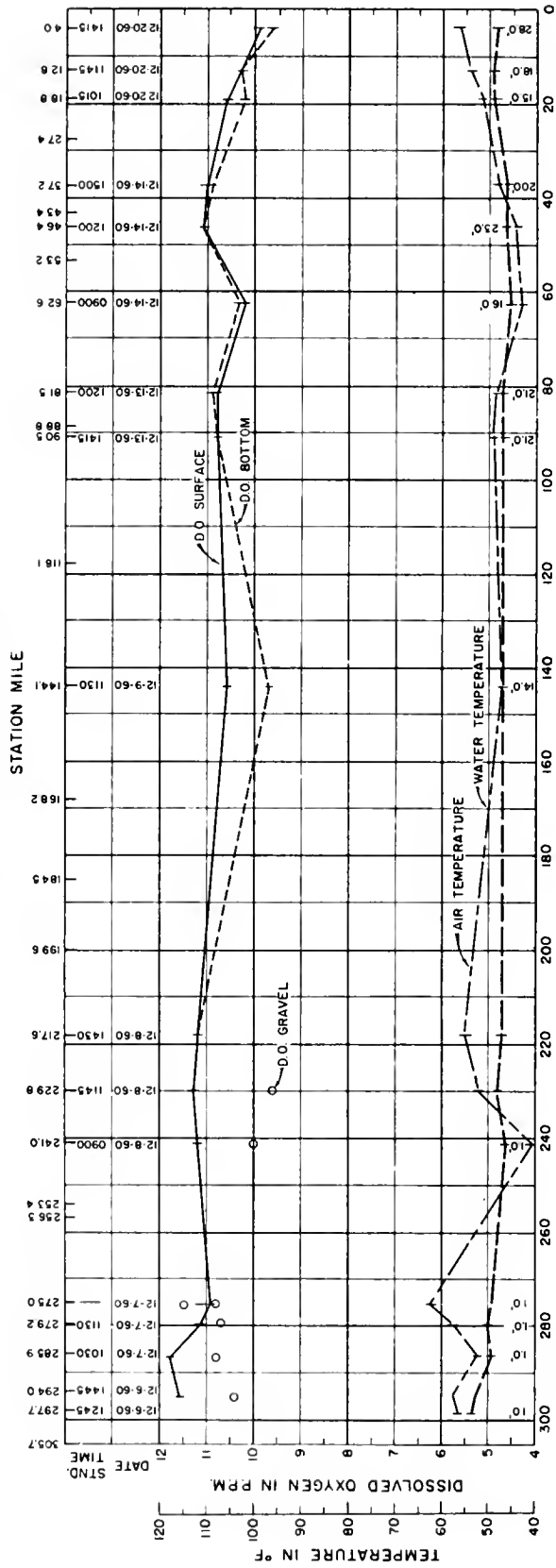


FIGURE 6
 SACRAMENTO RIVER WATER POLLUTION SURVEY
 BIOLOGICAL SURVEY - PHYSICAL DATA
 FEBRUARY 1961

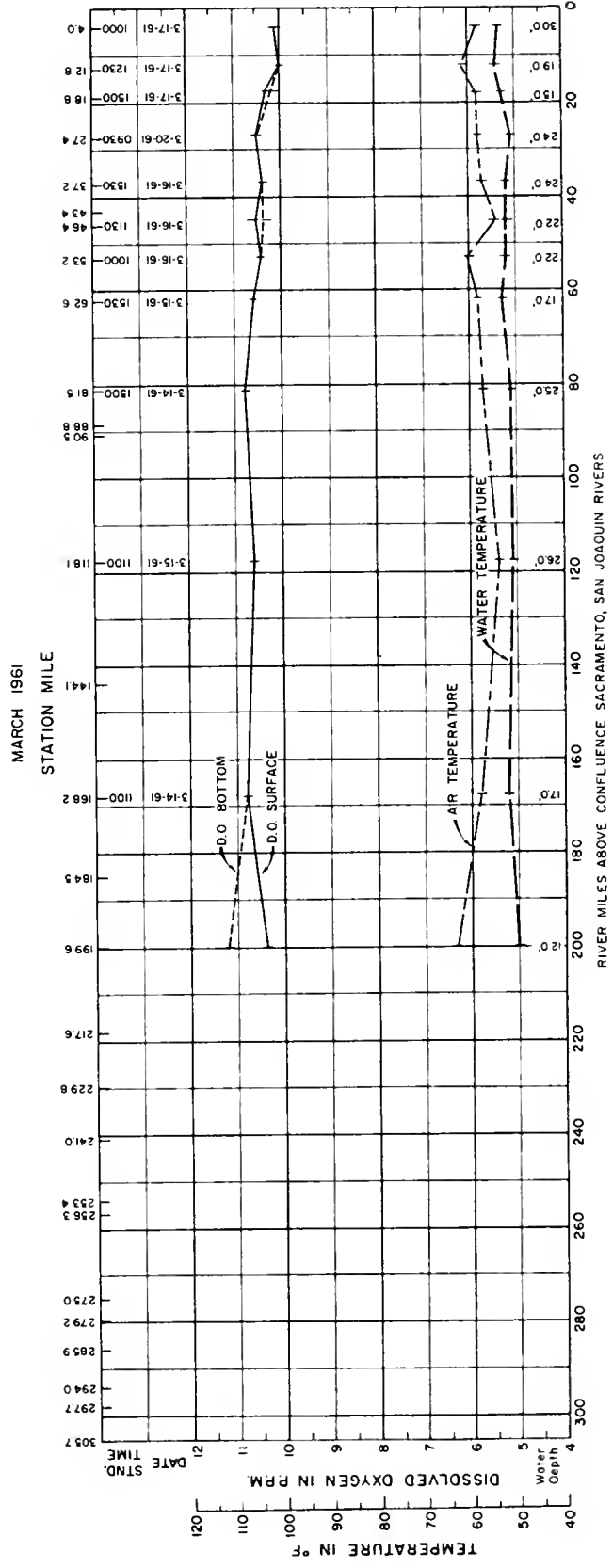
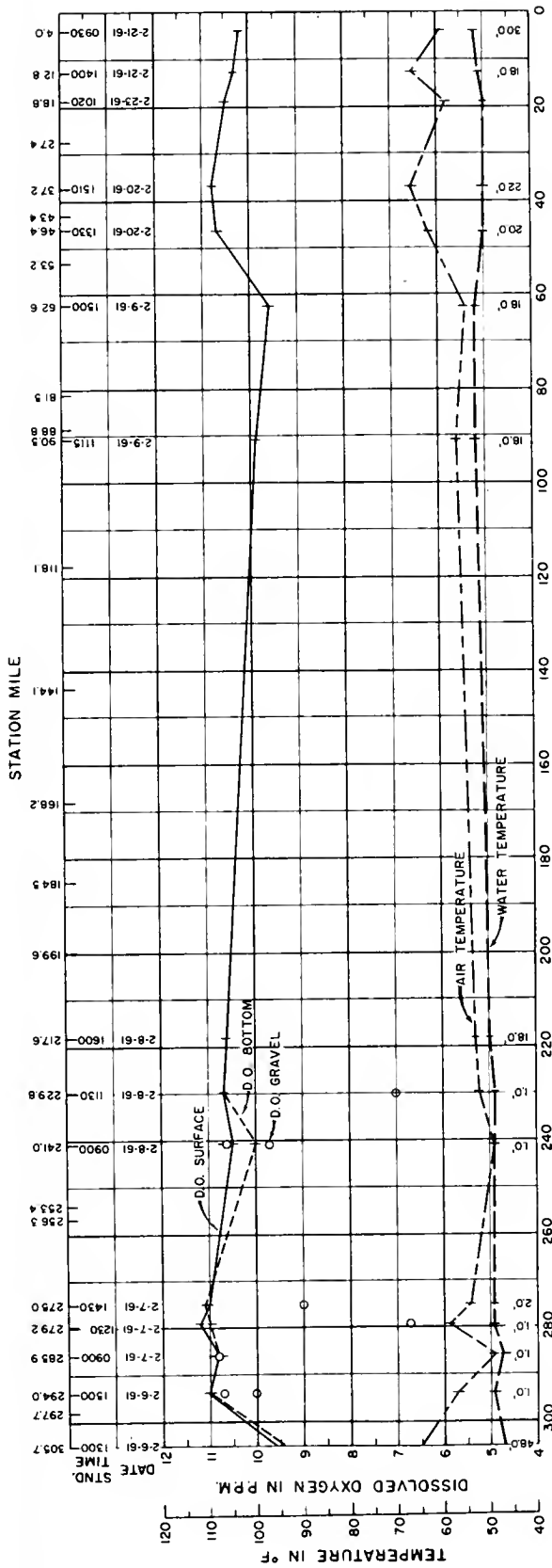


FIGURE 7
 SACRAMENTO RIVER WATER POLLUTION SURVEY
 BIOLOGICAL SURVEY - PHYSICAL DATA
 APRIL 1961

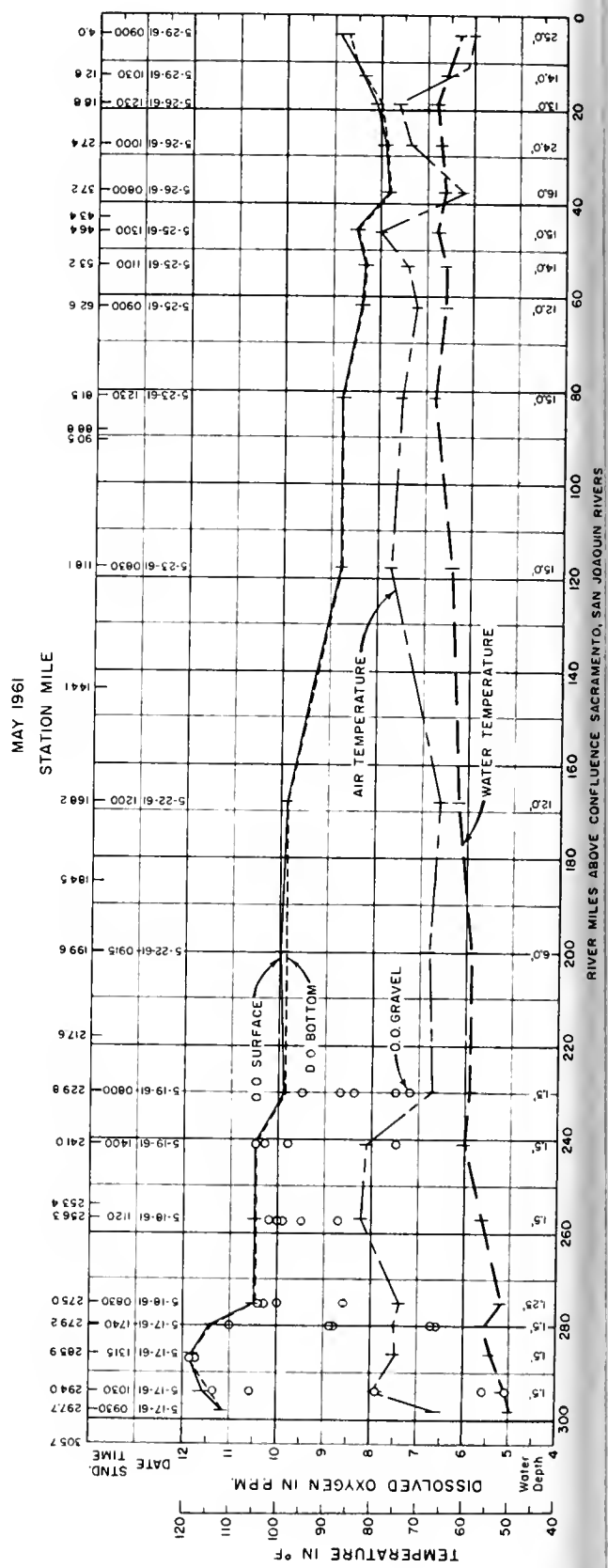
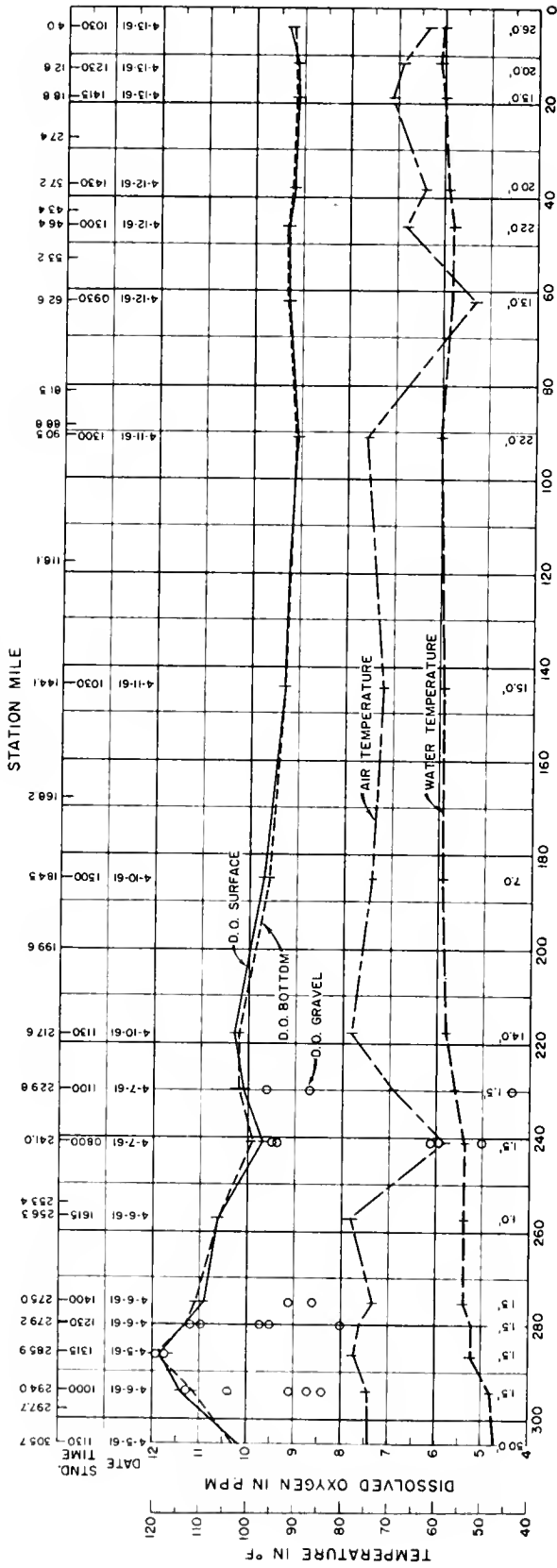


FIGURE 8
 SACRAMENTO RIVER WATER POLLUTION SURVEY
 BIOLOGICAL SURVEY-PHYSICAL DATA
 JUNE 1961

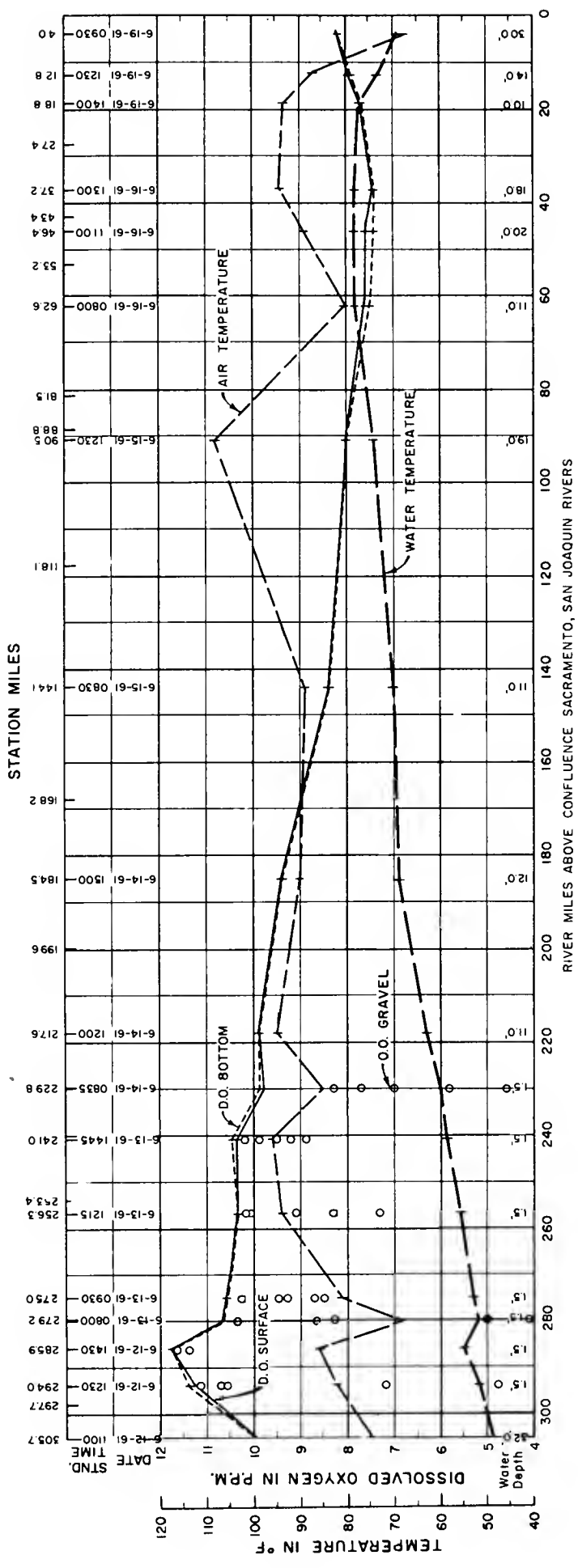
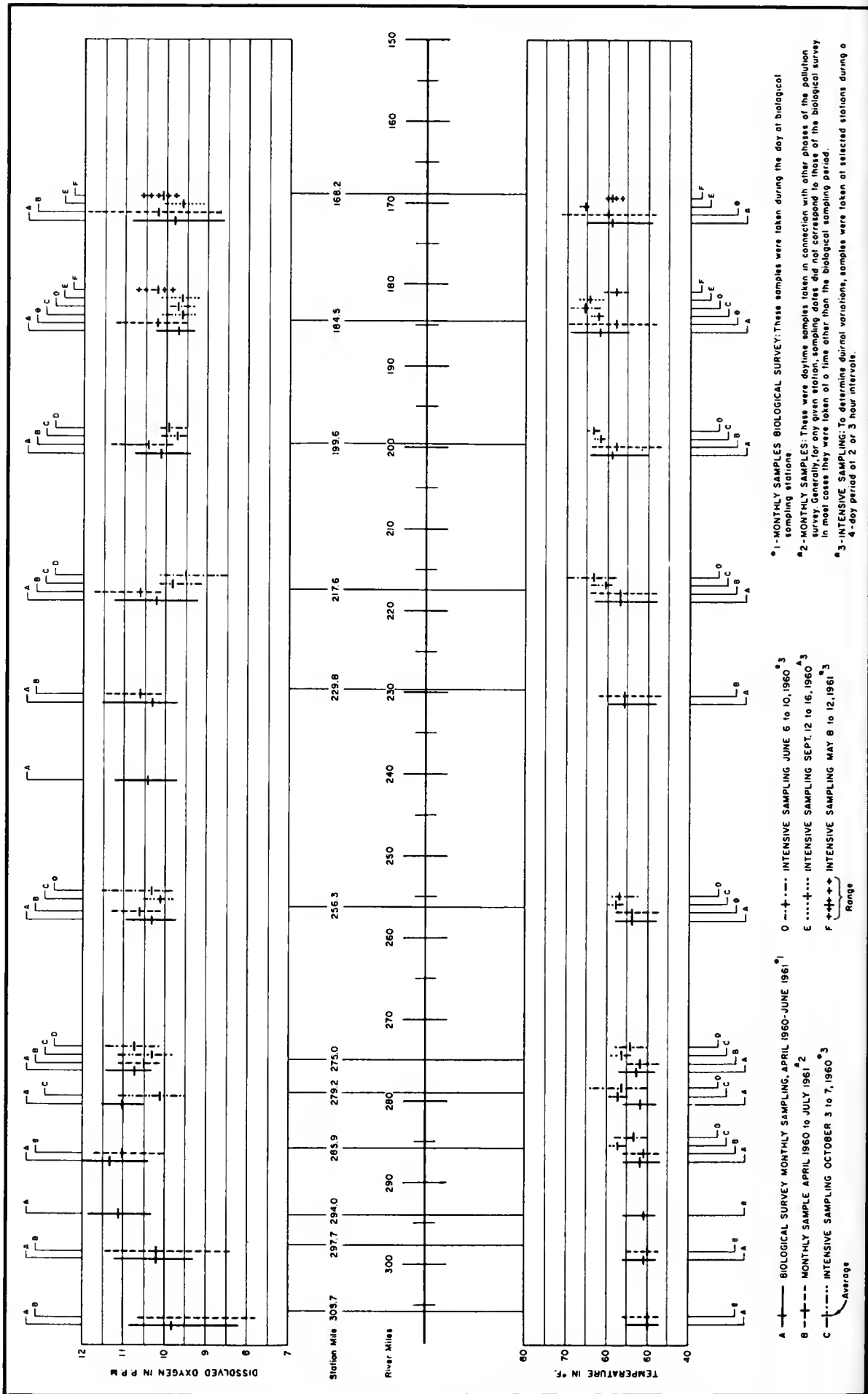


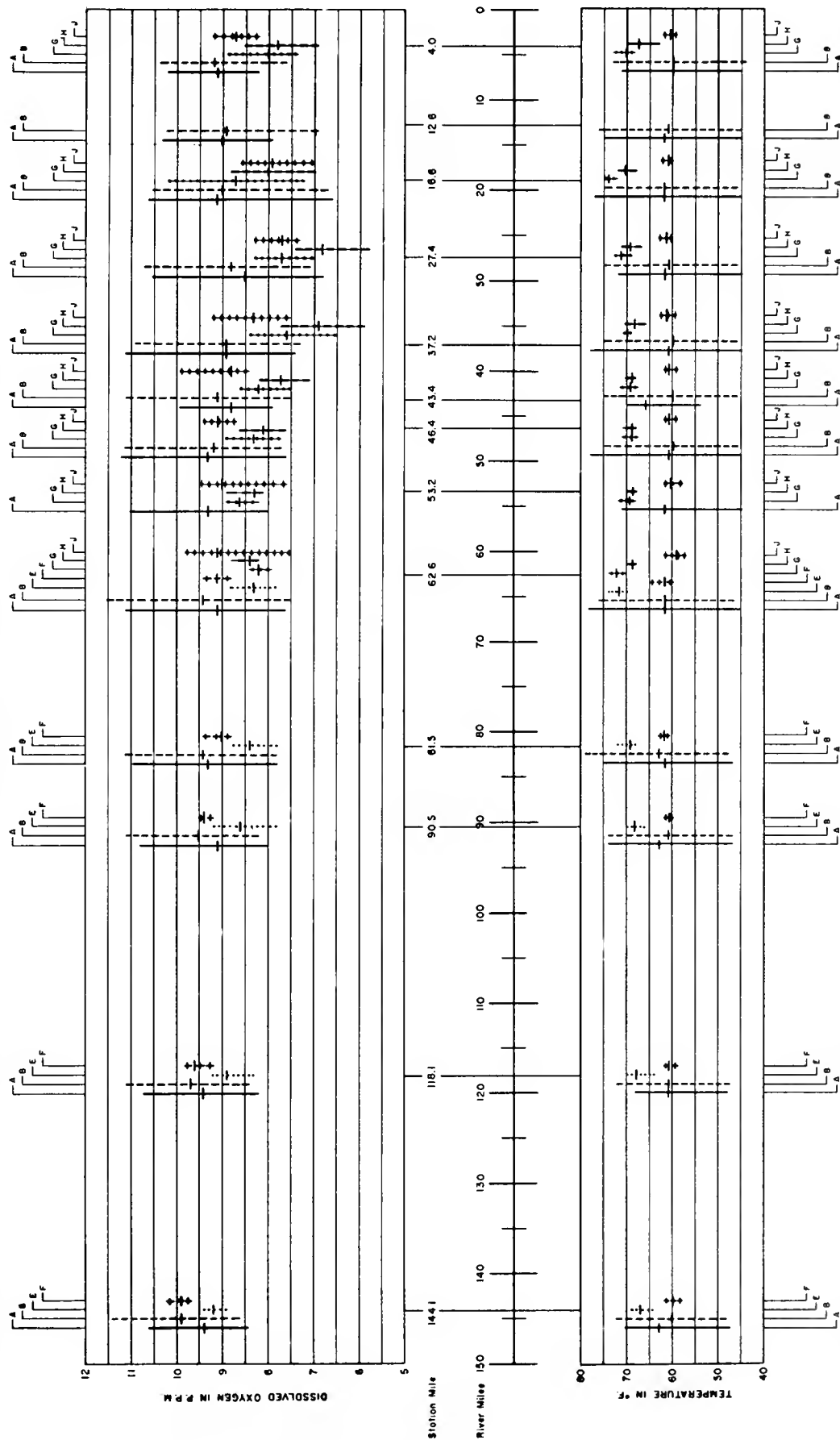
FIGURE 9
SACRAMENTO RIVER WATER POLLUTION SURVEY
DISSOLVED OXYGEN AND WATER TEMPERATURE AT SELECTED STATIONS
 River Mile 150 to 305.7



*1-MONTHLY SAMPLES BIOLOGICAL SURVEY: These samples were taken during the day at biological sampling stations
 *2-MONTHLY SAMPLES: These were daytime samples taken in connection with other phases of the pollution survey. Generally, for any given station, sampling dates did not correspond to those of the biological survey in most cases they were taken at 0 time other than the biological sampling period.
 *3-INTENSIVE SAMPLING: To determine diurnal variations, samples were taken at selected stations during a 4-day period of 2 or 3 hour intervals.

SACRAMENTO RIVER WATER POLLUTION SURVEY DISSOLVED OXYGEN AND WATER TEMPERATURE AT SELECTED STATIONS

River Mile 0 to 150



Range $\overline{\text{---}}$

A $\overline{\text{---}}$ BIOLOGICAL SURVEY MONTHLY SAMPLING, APRIL 1960-JUNE 1961¹ F $\overline{\text{---}}$ INTENSIVE SAMPLING MAY 8 to 12, 1961³

B $\overline{\text{---}}$ MONTHLY SAMPLE APRIL 1960 to JULY 1961² G $\overline{\text{---}}$ INTENSIVE SAMPLING JUNE 20 to 24, 1960³

C $\overline{\text{---}}$ INTENSIVE SAMPLING SEPT. 12 to 16, 1960³ H $\overline{\text{---}}$ INTENSIVE SAMPLING AUG. 29 to SEPT. 2, 1960³

J $\overline{\text{---}}$ INTENSIVE SAMPLING OCTOBER 24 to 28, 1960³

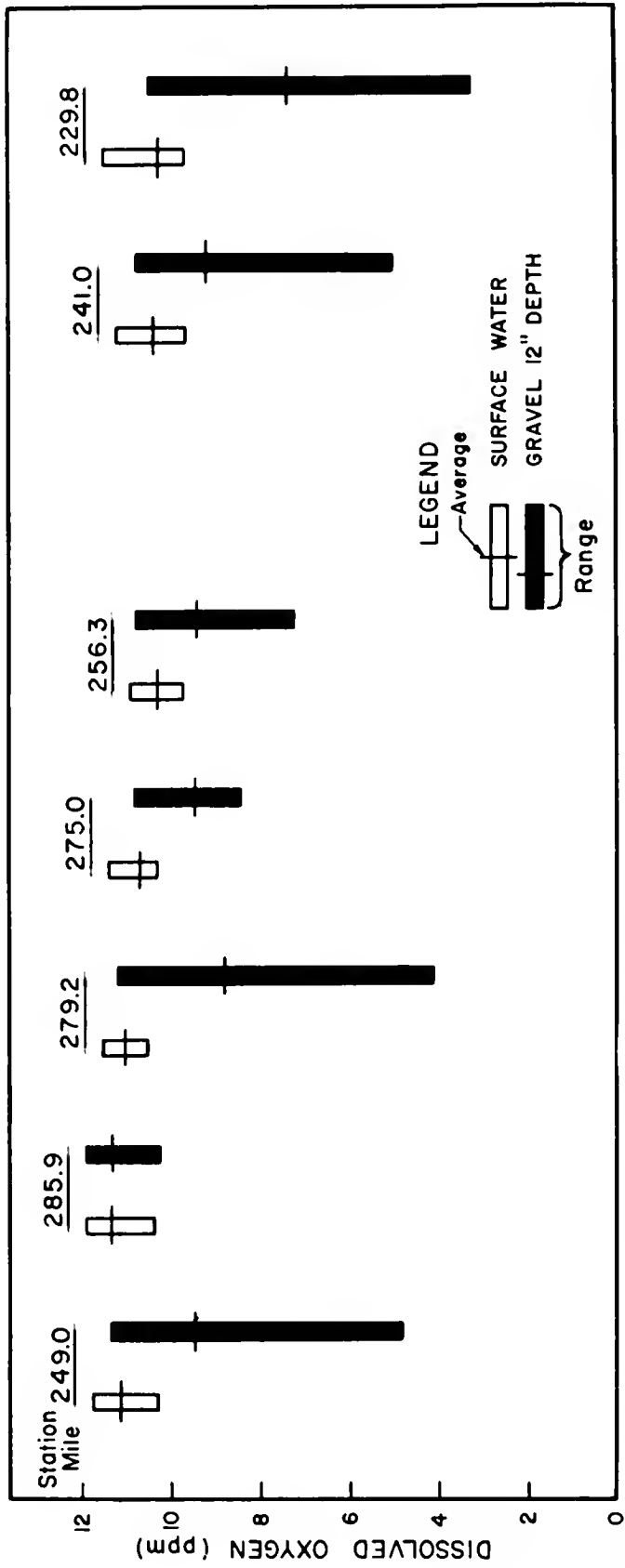
Average $\overline{\text{---}}$

1-MONTHLY SAMPLES BIOLOGICAL SURVEY These samples were taken during the day of biological sampling stations

2-MONTHLY SAMPLES These were daytime samples taken in connection with other phases of the pollution survey. Generally, for any given station, sampling dates did not correspond to those of the biological survey in most cases they were taken of a time other than the biological sampling period

3-INTENSIVE SAMPLING To determine diurnal variations, samples were taken of selected stations during a 4-day period of 2 or 3 hour intervals

FIGURE II
 RANGES OF DISSOLVED OXYGEN CONCENTRATIONS IN RIFFLE AREAS



Water Transparency

Water transparency was measured by use of a 20-centimeter Secchi disc. The depth at which the disc disappeared from sight was recorded. Although this reading is subject to a number of errors, it is a useful qualitative indication of water clarity. Figure 12 shows that transparency was reduced from a range of about 80 to 200 inches at Keswick to from 10 to 40 inches at and below Sacramento. Seasonal reductions are due to unregulated storm inflows during the winter and to plankton levels and to waste discharges during the summer. The relationships between transparency, turbidity, and light transmission characteristics are discussed in greater detail in Chapter IV, Appendix B.

Sediments

Bottom particle sizes were determined at all stations. Although there were local differences between closely-spaced sampling points, the averaged data shown in Figures 13 and 14 indicate the general pattern of particle size distributions in the river. Stations at miles 217.6, 168.2, 144.1, 90.5, 81.5, 62.6, 37.2, 18.8, and 12.8 were resampled at varying intervals; seasonal variations at individual stations were about the same as variations between closely-spaced points sampled at one time.

FIGURE 12
 SACRAMENTO RIVER WATER POLLUTION SURVEY
 SECCHI DISC READINGS - SACRAMENTO RIVER 1960-61

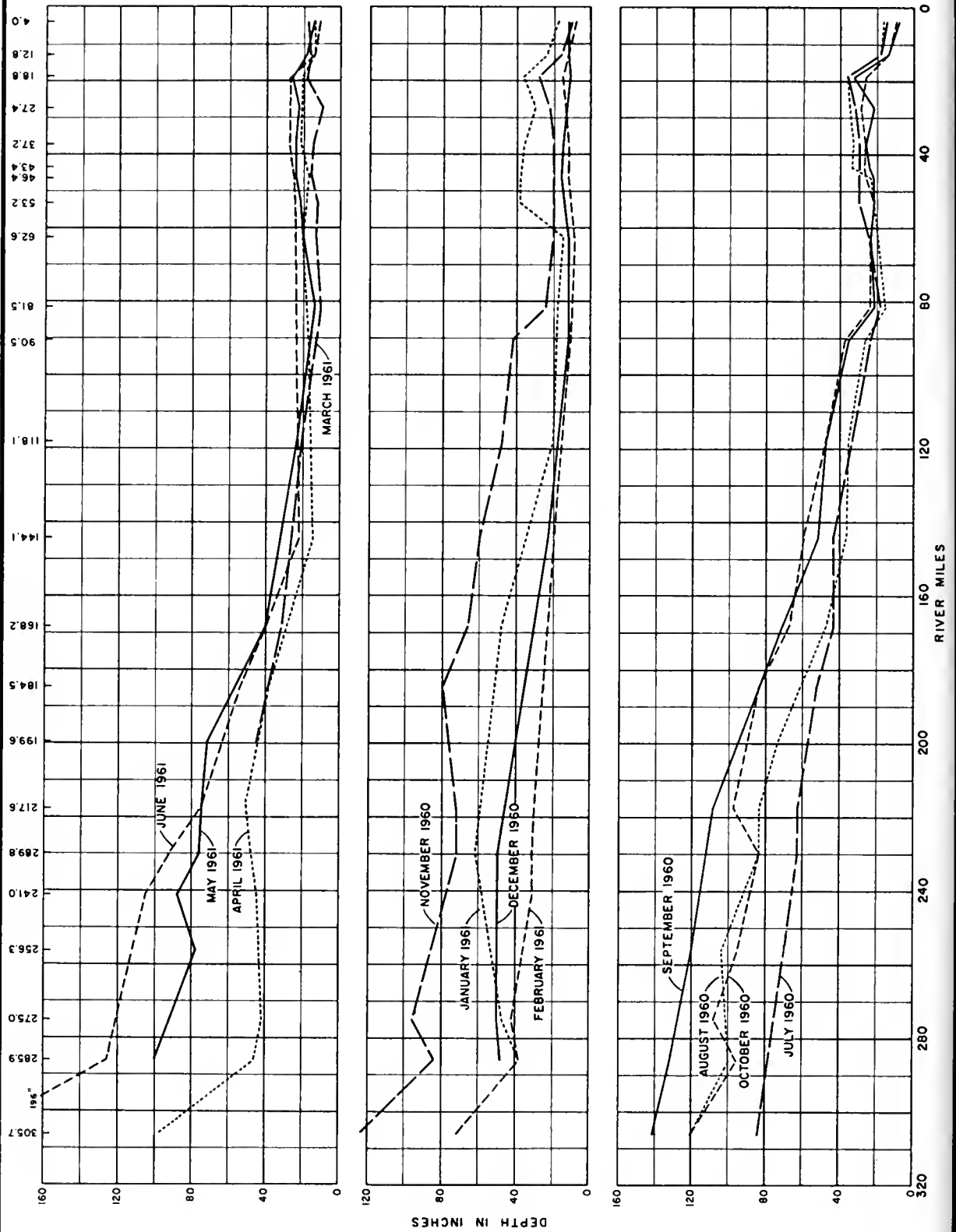


FIGURE 13
 SACRAMENTO RIVER WATER POLLUTION SURVEY
 GRAVEL SIZE DISTRIBUTION AT SELECTED RIFFLE STATIONS
 MILE 297.7 TO MILE 229.8

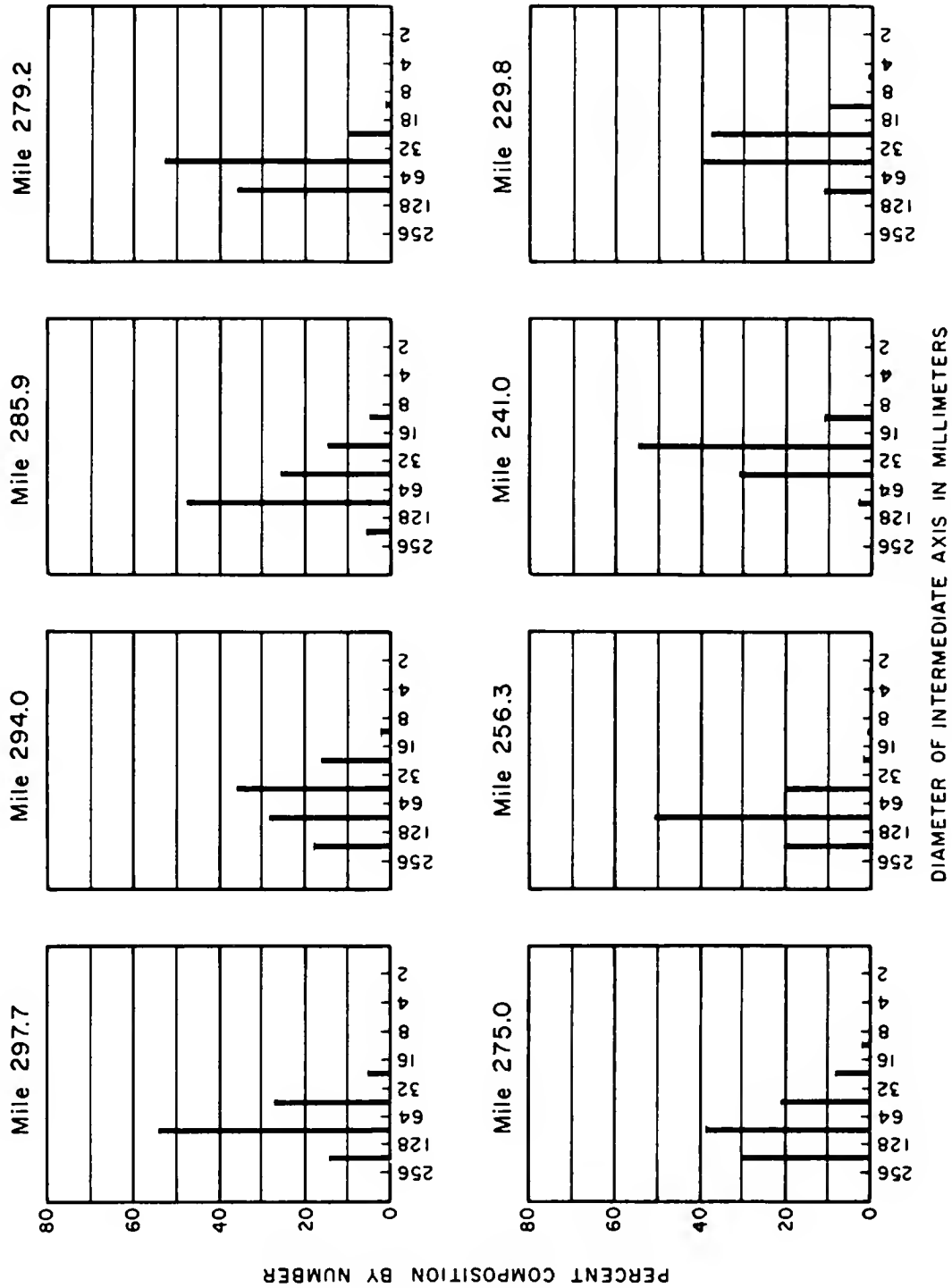
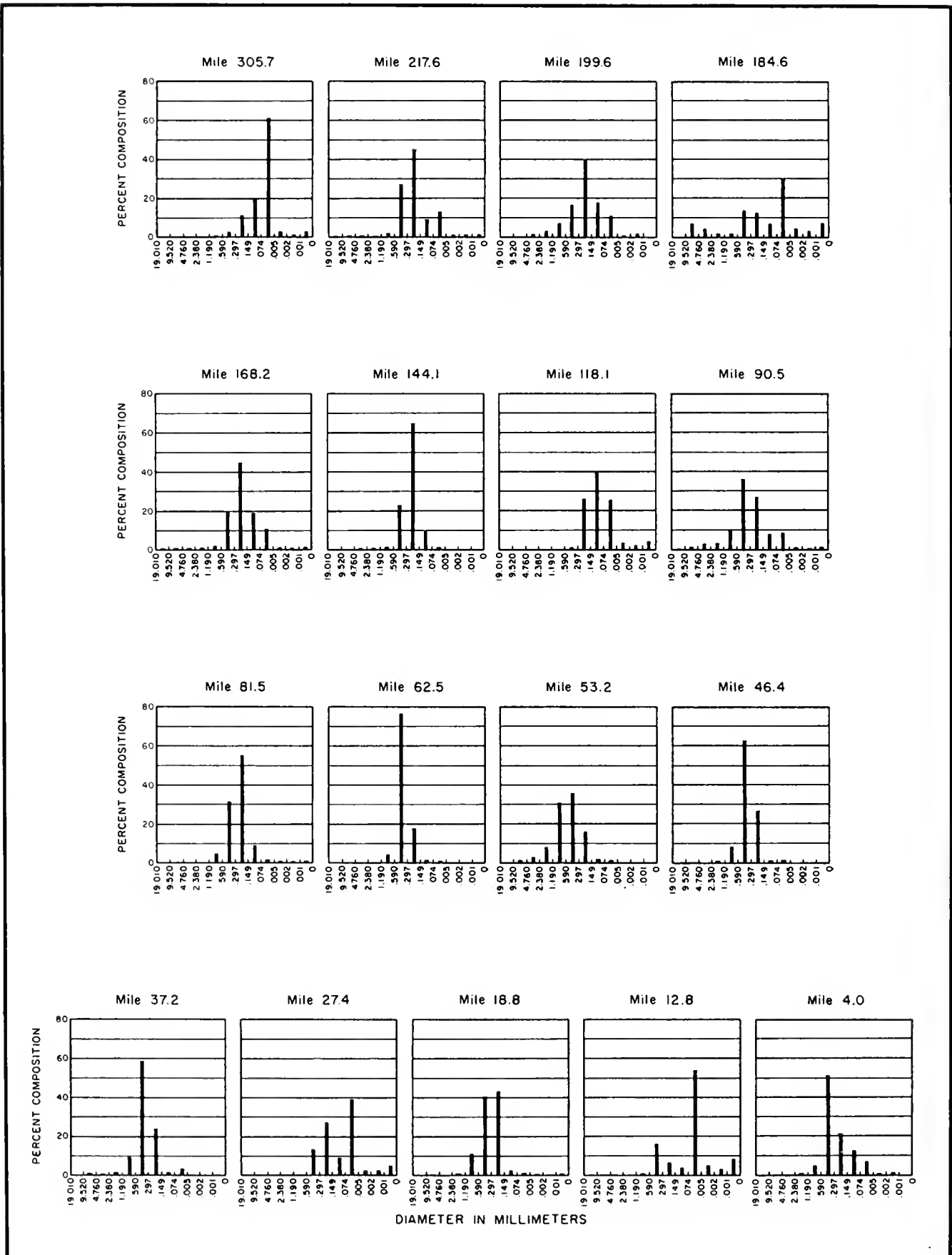


FIGURE 14
SACRAMENTO RIVER WATER POLLUTION SURVEY
BOTTOM PARTICLE SIZE DISTRIBUTION AT SELECTED NON-RIFFLE STATIONS



CHAPTER IV. BENTHIC BIOLOGY

Although both plants and animals were collected, emphasis was given to the collection, identification, and enumeration of the bottom fauna.

Results

Aquatic Plants

A list of the incidence of aquatic plants collected during the survey is given in Table 1. With two exceptions, all of these collections were made with a Surber bottom sampler. Two species of pondweed (Potamogeton pectinatus and P. crispus) were collected in a still pool near the sampling station at mile 295.2, and several specimens from a large growth of Ranunculus aquatilis were collected near shore in Keswick Reservoir at mile 305.7

Fragments of Potamogeton collected at four of the riffle stations were washed into the sampling net by the current, and were not growing in the river at the sampling location. Similarly, Lemna found at two stations were also washed into the collecting net.

The moss, Fissidens, was present throughout the year at all of the riffles which were sampled for bottom organisms. These plants became more or less dormant during the winter (December-February), but were extremely abundant during the summer and early fall months.

Twenty-seven genera of algae were identified from the bottom samples. Representatives of green, blue-green, red, and yellow algae, and diatoms were included. Algae was identified to genus when it was encountered in a sample. No attempt was made to determine the volumes of algae which, in most of the samples, was less than 0.1 cc.

Table 1

SACRAMENTO RIVER WATER POLLUTION SURVEY
AQUATIC PLANTS

Aquatic Plants	Station Mile												
	305.7	297.7	295.2	294.0	285.9	279.2	275.0	256.3	253.4	241.0	229.8	118.1	18.8
ALGAE^{1/}													
Grass-Green Algae (Chlorophyta)													
Cladophoraceae													
<u>Cladophora</u> sp.	x	x		x		x	x	x	x	x	x	x	x
Chlorococcaceae													
<u>Chlorococcum</u> sp.		x											
Chaetophoraceae													
<u>Stigeoclonium</u> sp.		x		x					x				
<u>Microthamnion</u> sp.				x							x	x	
Desmidiaceae													
<u>Desmidium</u> sp.							x						
Dichotomosiphonaceae													
<u>Dichotomosiphon</u> sp.											x		
Hydrodictyaceae													
<u>Pediastrum</u> sp.									x				
Microsporaceae													
<u>Microspora</u> sp.											x		
Palmellaceae													
<u>Gloecystis</u> sp.									x				
Tetrasporaceae													
<u>Tetraspora</u> sp.		x		x									
Ulothrichaceae													
<u>Ulothrix</u> sp.	x	x	x	x	x		x	x			x		
Zygnemataceae													
<u>Spirogyra</u> sp.				x	x	x	x	x	x		x	x	
Blue-Green Algae (Cyanophyta)													
Chroococcaceae													
<u>Coccochloris</u> sp.					x								
Nostocaceae													
<u>Nostoc</u> sp.		x			x			x	x			x	
<u>Anabaena</u> sp.					x								
Scytonemataceae													
<u>Scytonema</u> sp.											x	x	
<u>Tolypothrix</u> sp.	x			x	x	x	x	x	x	x	x	x	
Oscillatoriaceae													
<u>Oscillatoria</u> sp.		x		x	x	x	x				x	x	
<u>Lyngbya</u> sp.				x	x	x					x		x
<u>Spirulina</u> sp.						x							
Red Algae (Rhodophyta)													
Batrachospermaceae													
<u>Batrachospermum</u> sp.		x		x		x					x		
Chautransiaceae													
<u>Audouinella</u> sp.	x	x		x	x	x	x	x			x	x	x

Table 1

SACRAMENTO RIVER WATER POLLUTION SURVEY
AQUATIC PLANTS
(continued)

Aquatic Plants	Station Mile													
	305.7	297.7	295.2	294.0	285.9	279.2	275.0	256.3	253.4	241.0	229.8	118.1	18.8	
ALGAE (continued)														
Yellow-Green Algae (Chrysophyta)														
Vaucheriaceae														
<u>Vaucheria</u> sp.	x	x		x	x		x	x	x		x			
Diatoms (Chrysophyta)														
Achnanthaceae														
<u>Cocconeis</u> sp.													x	
Coscinodiscaceae														
<u>Stephanodiscus</u> sp.													x	
<u>Melosira</u> sp.	x	x											x	
Naviculaceae														
<u>Navicula</u> sp.													x	x
Gomphonemaceae														
<u>Gomphonema</u> sp.													x	
MOSSES^{1/} (Bryophyta)														
<u>Eurhynchium</u> sp.					x									
<u>Fissidens</u> sp.	x	x			x	x	x	x	x	x	x	x	x	
<u>Fontinalis</u> sp.					x									
VASCULAR PLANTS^{2/}														
Lemnaceae														
<u>Lemna</u> sp. ^{3/}					x		x							
Potamogetonaceae														
<u>Potamogeton</u> sp.			x	x		x			x				x	
Ranunculaceae														
<u>Ranunculus</u> sp.	x													

^{1/} Taxonomy from Ward and Whipple (1959).

^{2/} Taxonomy from Muenscher (1944).

^{3/} Floating plants, but not in same category as phytoplankton.

Very few aquatic plants were found at the sampling stations below mile 229.8. One species of red algae was found at station 118.1, and a blue-green alga was collected at mile 18.8. Otherwise, no identifiable plant material was collected.

In the lower-most portions of the river, emergent plants such as cattail (*Typha*) and tule (*Scirpus*) are present in shallow water areas along the river banks. These plants were not included in Table 1.

Bottom Fauna

Results of bottom samples taken to determine the benthic fauna of the Sacramento River are given in Tables 2 through 16. These tables present the numbers of organisms collected per square foot at the various stations during each month of the survey. The volumes of organisms are not indicated; however, this information is available at the Department of Fish and Game Field Station in Sacramento.

An examination of Tables 2 through 16 indicates the large variety of aquatic organisms that exists in the Sacramento River. Representatives of ten phyla, ranging from the sponges to the chordates were collected. At least 164 separate species of invertebrates were represented in the collections in addition to one species of lamprey. It must be pointed out that a large number of individual specimens were not identified to species. Some organisms were not classified below order due to lack of time, facilities, and adequate keys.

Numbers and Volume at Selected Stations

The Sacramento River between Shasta Dam and the mouth was divided into four major environments. These are: (1) the upper river, which consists of alternate pools and riffles (approximately mile 297 to mile 229); (2) the upper-middle river, which contains a few riffles but mostly

TABLE 2 (Continued)
 SACRAMENTO RIVER WATER POLLUTION SURVEY
BOTTOM ORGANISMS
 Adjusted number per square foot
 APRIL 1960

CLASSIFICATION	RIVER MILES																													
	305.7	297.7	295.5	294.0	285.9	279.2	272.2	265.4	253.4	241.0	229.4	217.6	205.6	194.1	182.1	90.5	90.2	88.2	86.5	80.8	62.6	51.2	46.4	43.4	37.2	27.4	18.8	2.8	4.0	
Mollusca Sphaeriidae Pisidium sp. Corbicula Corbicula fluminea			312															.6	1.8		18	4	7.5			6	9			1.5

TABLE 4
 SACRAMENTO RIVER WATER POLLUTION SURVEY
BOTTOM ORGANISMS
 Adjusted number per square foot
 JUNE 1960

CLASSIFICATION	RIVER MILES																
	85.7	86.7	87.5	88.5	89.5	90.5	91.5	92.5	93.5	94.5	95.5	96.5	97.5	98.5	99.5	100	4.0
Remains																	
Nematodes																	
Amelids																	
Collembola																	
subficidae																	
Branchiura sowerbyi																	
Telmatoctonus sp.																	
Neridae																	
Neanthes limicola																	
Arthropoda																	
Crustacea																	
Malacostraca																	
Aspidopoda																	
Corophium spanicomie																	
Insecta																	
Plecoptera																	
Psephenidae																	
Perlodidae																	
Isoperla trictura																	
Odonata																	
Gomphidae																	
Combus olivaceus																	
Ephemeroptera																	
Baetidae sp.																	
Baetis olivaceus																	
Trichoptera																	
Hydroptilidae																	
Agabus sp.																	
Psychomyiidae																	
Psychomyia sp.																	
Hydroptilidae																	
Hydroptilid sp.																	
Hydroptilidae																	
Cobrotrichia sp.																	
Leptoceridae																	
Leptostomatidae																	
Leptostoma sp.																	
Coleoptera																	
Gyrinidae																	
Blarina sp.																	
Psephenidae																	
Psephenus sp.																	
Diptera																	
Tipulidae																	
Antocha sp.																	
Psychodidae																	
Psychoda severini																	
Simuliidae																	
Simulium sp.																	
Tendipedidae																	
Dixaea																	
Tendipede																	
Tendipes tentans																	
Tendipes spp.																	
Chironomidae																	
Polydora sp.																	
Pentapetium spp.																	
Cryptochironomus spp.																	
Hydrobaeninae																	
Cricotopus sp.																	
Helicidae																	
Callicoides sp.																	
Ephyridae																	
Acari																	
Hydracarina																	
Halteracaridae																	
Mollusca																	
Physidae																	
Physa sp.																	
Physa																	
Gyraulus sp.																	
Sphaeriidae																	
Planorbidae																	
Planorbis sp.																	
Corbiculidae																	
Corbicula fluminea																	
Vestibulidae																	
Vestibulum																	
Vestibulum																	
Lampetra sp.																	

SACRAMENTO RIVER WATER POLLUTION SURVEY

BOTTOM ORGANISMS

Adjusted number per square foot
AUGUST 1960

CLASSIFICATION	RIVER MILES																												
	30.7	29.7	29.5	29.4	28.9	27.9	27.5	25.3	24.0	22.9	21.6	19.6	18.2	14.4	10.5	9.2	8.2	8.5	8.6	6.2	4.2	4.4	3.7	2.7	1.8	1.2	1.2	4.0	
Menetus sp. Spirochaeta Planidium sp. Corbiculidae Corbicula fluminea	7.5														.8		1.5	.8		1.5	.33	3	46.4	43.4	37.2	27.4	18.8	12.8	4.0

SACRAMENTO RIVER WATER POLLUTION SURVEY

BOTTOM ORGANISMS

Adjusted number per square foot
OCTOBER 1960

CLASSIFICATION	RIVER MILES																																	
	305.7	297.7	295.5	294.0	285.9	279.2	275.0	256.3	253.4	241.0	229.8	227.6	199.6	184.5	168.2	144.1	118.1	90.5	88.2	81.5	80.8	62.6	46.4	43.4	37.2	27.4	.88	12.8	4.0					
Diamesa spp.	1.5										.7																							
Polydora			4.5							9																								
Chaetoptera																																		
Tendipes																																		
Tendipes plumosus																																		
Calopsectra spp.			13.5																															
Tanytarsus sp.																																		
Polydellum sp.																																		
Cryptobryozoa																																		
Cryptobryozoa stylifera																																		
Cryptobryozoa spp.																																		
Hydrobaenidae																																		
Corynoneura sp.																																		
Hydrobaenus sp.																																		
Metriconeura sp.																																		
Cardiocladius sp.																																		
Oristopus sp.																																		
Ephippidae																																		
Ephippium																																		
Ephippium sp.																																		
Hydrillia sp.																																		
Jelomyzidae																																		
Sepdon sp.																																		
Acarid																																		
Hydracarina																																		
Mollusca																																		
Planorbidae																																		
Gyraulus sp.																																		
Sphaeriidae																																		
Pisidium sp.																																		
Corbiculidae																																		
Corbicula fluminea																																		
Vertebrata																																		
Gobiidae																																		
Cottus asper																																		

SACRAMENTO RIVER WATER POLLUTION SURVEY

BOTTOM ORGANISMS

Adjusted number per square foot
NOVEMBER 1960

CLASSIFICATION	RIVER MILES																																			
	305.7	297.7	295.5	294.0	285.9	279.2	275.0	256.3	253.4	241.0	229.8	217.6	199.6	184.5	168.2	144.1	118.1	90.5	90.2 R/O.1	88.2	81.5	80.8 L/O.1	62.6	53.2	46.4	43.4	37.2	27.4	19.8	12.8	4.0					
Tendipedidae																																				
Limnoses																																				
Tendipes spp.		9																																		
Calopsectra flavellus																																				
Calopsectra spp.													3	1.5																						
Tanytarsus (endochironomus) sp.																																				
Tanytarsus (stictochironomus) sp.																																				
Polypedilum flavus																																				
Pentapedilum spp.																																				
Limnobia sp.																																				
Limnobia sp.																																				
Limnobia sp.																																				
Hydrobiontinae		.7				1																														
Corynoneura sp.																																				
Cricotopus sp.								.7																												
Orthocladius sp.						1		3.3																												
Speitochona (eukiefferlella) sp.						1																														
Empididae		1		.7	1	1	2	.3																												
Limnephilidae																																				
Limnephora aquifrons					.7	1																														
Acarci		5		.3	25.7	2	23																													
Hydracarina		1																																		
Halacaridae																																				
Mollusca																																				
Physa																																				
Physa sp.																																				
Planorbidae																																				
Cyralus sp.																																				
Physa sp.																																				
Sphaeriidae																																				
Corbiculidae																																				
Corbicula fluminea																																				
Verticillata																																				
retrogonioidae																																				
Lampyris sp.																																				

TABLE 11

SACRAMENTO RIVER WATER POLLUTION SURVEY
BOTTOM ORGANISMS
 Adjusted number per square foot
 JANUARY 1961

CLASSIFICATION	RIVER MILES													
	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	
<u>Elphelminthes</u>														
Planariidae														
Dugesia sp.														
<u>Nematelminthes</u>														
Nematoda														
<u>Arenaria</u>														
Oligochaeta														
Naididae														
Chaetogaster sp.														
Nais sp.														
Publittidae														
Berenchura sawabyi														
Nereidae														
Nereis limicola														
<u>Arlingfordia</u>														
Crotalaria														
Copepoda														
Gammaridae														
Gammarus pulex														
Malacostraca														
Decapoda														
Corophium sp.														
Corophium sp. n. sp. n.														
Insecta														
Placosternum														
Placosternum														
Nemoura columbiana														
Nemoura														
Periodidae														
Isogenus frontalis														
Isogenus														
Isogenus sp.														
Isoperla sp.														
Ephemeroptera														
Baetidae														
Baetis sp.														
Neuroptera														
Stalidae														
Stalid sp.														
Tanypus														
Tanypus sp.														
Hydroptilidae														
Azaenatus sp.														
Hydroptilidae														
Hydroptilidae														
Hydroptilidae														
Hydroptilidae														
Cebrotichia sp.														
Leptoceridae														
Leptocera sp.														
Collembola														
Dytiscidae														
Credoceros														
Diptera														
Tanytarsidae														
Tanytarsus sp.														
Tanytarsus														
Tentipeditidae														
Tentipedia														
Procladius sp.														
Peloplineae														
Pentaneura spp.														
Pentaneura														
Tentipedia														
Tentipedia sp.														
Tentipedia (endochironomus) sp.														
Tentipedia														
Tentipedia														
Polypodium sp.														
Pentapodium spp.														
Pentapodium														
Cryptochironomus sp.														
Hydrobaeninae														
Hydrobaena sp.														
Stenochironomus sp.														
Stenochironomus														
Stenochironomus sp.														
Helicidae														
Helicidae (pulexformis) sp.														
Dasylella sp.														
Dasylella														
Emphididae														
Emphidromia sp.														
Acari														
Hydracarina														
<u>Mollusca</u>														
Corbiculidae														
Corbicula fluminea														

TABLE 14 (Continued)
 SACRAMENTO RIVER WATER POLLUTION SURVEY
BOTTOM ORGANISMS
 Adjusted number per square foot
 APRIL 1961

CLASSIFICATION	RIVER MILES																																
	103.7	99.7	295.5	294.0	285.9	279.2	275.0	256.3	253.4	241.0	229.8	227.6	159.6	184.5	68.2	44.1	8.1	90.5	52.2	88.2	81.5	8.8	62.6	53.2	46.4	43.4	37.2	27.4	18.8	12.9	4.0		
<i>Verticillium</i> <i>petersonioides</i> <i>Laspetra</i> sp.																.8																	

TABLE 15 (Continued)
SACRAMENTO RIVER WATER POLLUTION SURVEY
BOTTOM ORGANISMS
Adjusted number per square foot
MAY 1961

CLASSIFICATION	RIVER MILES																																					
	305.7	297.7	295.5	294.0	285.9	279.2	275.0	256.3	253.4	24.0	229.8	217.6	199.6	184.5	168.2	144.1	118.1	90.5	52.2 R/O.	88.2	81.5	80.6 L/O.	62.6	53.2	46.4	43.4	37.2	27.4	18.8	12.8	4.0							
Limnophora aquifrons																																						
Ephyraeidae																																						
Hydracarina																																						
Mollusca																																						
Corbiculidae																																						
Corbicula fluminea						4		1																														
Hydracarina																																						
Hydracarina sp.																																						
Limnophora sp.																																						

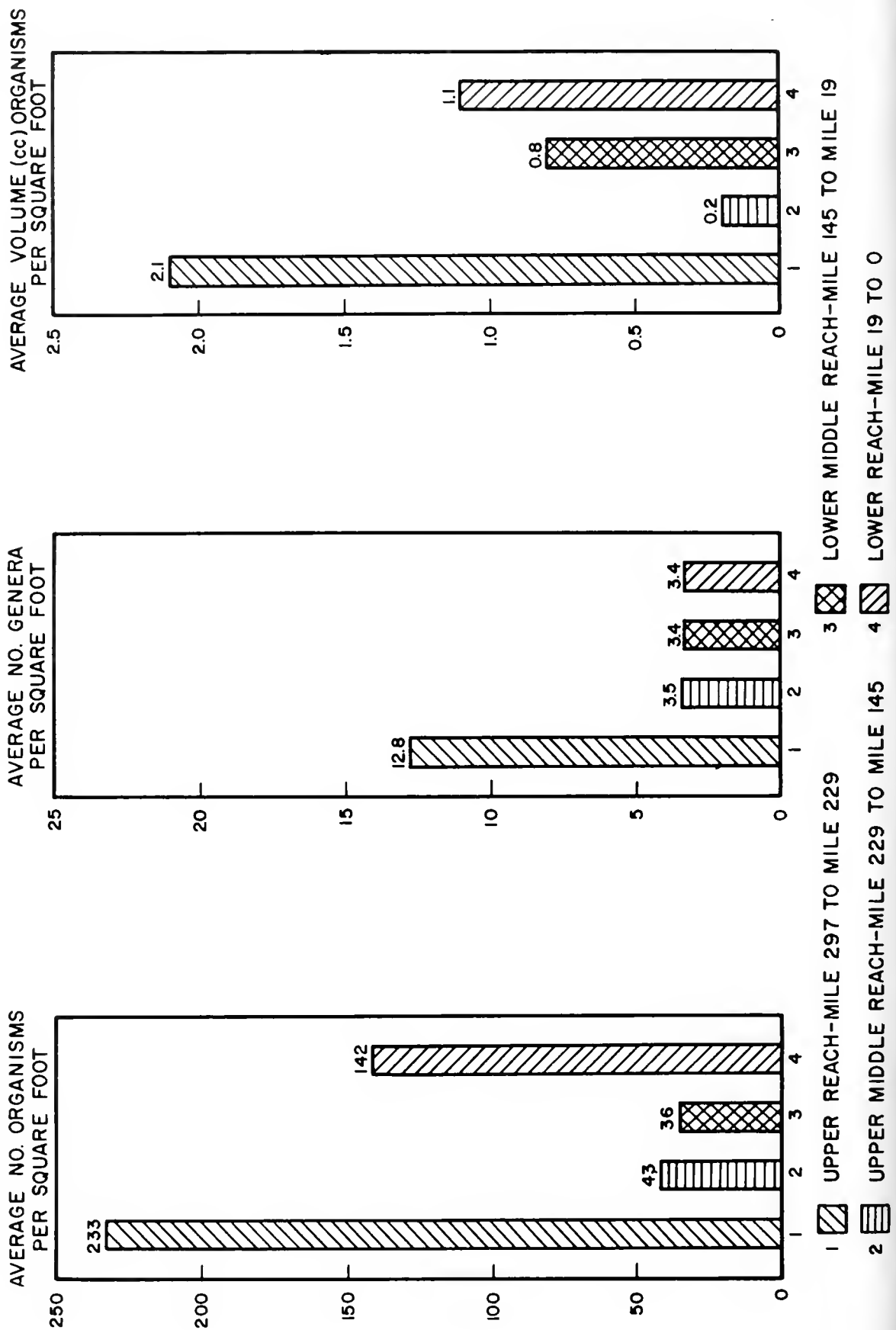
long runs and pools (approximately mile 229 to mile 145); (3) the lower-middle river, which consists of a dredged channel with levees (approximately mile 145 to mile 19); and (4) the lower river, which consists of a broad tidal channel, also dredged and with levees.

Upper Reach. Aquatic organisms collected from the river bottom exhibited wide variations from reach to reach. Three representative stations were selected from each reach and the average numbers of organisms, and genera, and average volumes per square foot for each reach were determined. This information is presented in Figure 15.

Thirty-nine collections were made during the survey at the three stations in the upper reach. Station locations were at mile 285.9, mile 275.0, and mile 229.8, all of which were located on riffle areas. The average numbers of organisms, genera, and average volume of these samples was much greater than that for any of the other reaches. Riffle areas are generally considered to be more productive of aquatic organisms than pool areas. Dominant organisms in this reach were oligochaetes and insects. Of the insects, the orders Plecoptera, Odonata, Ephemeroptera, Tricoptera, and Diptera were the most important. Families of Diptera collected most often were Tendipedidae, Tipulidae, and Simulidae.

Upper-Middle Reach. Thirty-three samples were taken from stations in the upper-middle reach. These stations were located at mile 217.6, mile 199.6, and mile 168.2. All of these samples were taken from pool areas near shore in water from 7 to 25 feet deep. No attempt was made to sample organisms in the riffle areas of this reach. The numbers of organisms collected were rather low, with few kinds present. The volume of these organisms was extremely low, averaging only 0.2 cc. per square foot of bottom sampled. This was only one-fourth to one-tenth the volume

FIGURE 15
 NUMBERS, DIVERSITY AND VOLUMES OF AQUATIC ORGANISMS
 APRIL, 1960 THROUGH JUNE, 1961



found in the other reaches. All of the organisms collected in this reach were quite small. Most of those collected were oligochaetes and midge larvae (Tendipedidae).

Lower-Middle Reach. The lower-middle reach was represented by 42 samples taken at mile 90.5, mile 62.6, and mile 37.2. This stretch of river is characterized by a rather uniform sandy bottom this quite unproductive of bottom organisms. The numbers of organisms per unit of area were lower in this reach of the river than in any of the others, but the volume was higher than in the upper-middle reach. The collection of a few large clams, Corbicula, was primarily responsible for the increased volume over the reach immediately upstream. There was little variety in types of organisms present. Most of those collected were clams, oligochaetes, and midge larvae.

Lower Reach. The lower reach is located in an area heavily influenced by tidal action. Bottom material is composed of sand, silt, and organic matter. The 41 samples collected at mile 18.8, mile 12.8, and mile 4.0 were used to characterize this reach. This reach contained approximately two-thirds as many organisms per square foot as the upper reach, but the volume of these organisms was just over one-half as much as those from the upper reach. Numbers and volume, however, were greater in this reach than in either of the middle reaches. There were few kinds of different organisms present. Most of those collected were clams, amphipods, oligochaetes, and midge larvae.

Seasonal Variations

Detailed seasonal variations in population density and composition have not been evaluated. An examination of the total numbers of

organisms during each month at the twelve selected stations indicates that sampling error can account for a large amount of variation (Table 17). Results at the stations during April, May, and June 1960 are considerably different from those during the same months in 1961.

There was a significant change in numbers over the period of study in the upper reach. From a low average number of 47.5 organisms per square foot in July 1960, the populations built up to a high of 933.9 organisms per square foot in November 1960, and then dropped to 86.2 in December and 52.6 in January 1961. Heavy rains, resulting in high river flows, occurred in late November and may have been largely responsible for the decrease.

A corresponding decrease was observed in the upper-middle reach between November and December 1960. There was no comparable decrease in total numbers of organisms in the lower-middle and the lower reaches.

Discussion

The most important contribution of the biological phase of the Sacramento River Water Pollution Survey has been the collection of information concerning present biological conditions in the Sacramento River. The main value will be realized in future years when the effect of water quality degradation due to additional development in the Sacramento Valley can be quantitatively assessed.

An attempt has been made to select a limited number of animals that might possibly be used as potential environmental indicators. The selection of these organisms was based on the regularity and frequency with which they were collected. The adaptations and requirements of many of these organisms need to be determined.

Table 17

SACRAMENTO RIVER WATER POLLUTION SURVEY
NUMBERS OF BOTTOM ORGANISMS AT SELECTED STATIONS

Station	1961															
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Average	
285.9	122.4	38.6	203.0	38.2	187.6	329.2	689.0	731.8	101.9	71.0	174.8	---	---	288.9	---	248.0
275.0	76.7	47.0	30.9	65.0	135.7	483.9	1,125.0	1,884.0	153.9	74.9	254.3	---	---	168.5	---	317.8
229.8	123.6	21.0	76.6	39.2	154.7	293.6	193.0	185.8	2.7	11.9	3.2	---	---	18.2	119.0	67.1
Average	107.8	35.5	103.5	47.5	159.7	368.9	669.0	933.9	86.2	52.6	144.1	---	---	93.3	203.9	192.5
217.6	68.0	136.5	40.5	24.0	9.8	34.6	20.4	21.9	5.5	---	39.1	---	---	21.0	---	35.4
199.6	0	4.0	243.0	80.4	46.5	37.5	192.0	34.5	---	---	---	---	---	9.1	---	132.0
168.2	79.2	6.0	15.5	10.6	17.3	75.3	48.0	15.0	---	8.3	---	---	---	10.7	---	24.0
Average	49.1	48.8	99.7	38.3	24.5	49.1	86.8	23.8	5.5	8.3	39.1	9.9	21.0	78.0	35.4	43.2
90.5	12.6	18.5	38.3	33.1	33.2	55.5	51.0	4.5	25.5	---	27.0	---	---	67.5	---	18.0
62.6	33.0	10.0	24.0	5.3	6.0	55.5	76.5	58.5	22.5	19.0	10.5	7.5	94.5	45.0	25.7	32.9
37.2	8.0	23.1	43.6	8.3	25.5	18.0	27.0	30.0	15.0	39.0	33.0	42.0	37.5	247.5	49.5	43.1
Average	17.9	17.2	35.3	15.6	21.9	43.0	51.5	31.0	21.0	29.0	23.5	24.7	66.5	146.2	31.1	36.3
18.8	0	1.0	4.0	9.9	35.3	48.0	67.0	159.0	141.0	135.0	106.5	2.3	18.0	43.5	22.5	48.8
12.8	10.5	97.6	42.4	78.0	132.0	118.5	153.0	186.0	222.0	---	147.0	---	---	121.5	---	119.5
4.0	---	135.0	40.5	261.0	235.5	298.5	379.5	170.0	246.0	351.0	592.5	352.5	136.5	153.0	319.5	262.2
Average	5.2	77.9	29.0	116.3	134.3	155.0	199.8	171.7	203.0	243.0	282.0	118.3	92.0	98.2	156.0	142.4

The animals described in this section are probably the most important ones to be studied in the future. If there should be a major change in numbers, or if any of them should disappear from the river, it would be an indication that some change in the chemical, physical, or biological conditions had occurred.

Annelida

Oligochaeta. The oligochaetes (worms) occur in both aquatic and terrestrial habitats. Members of this class were found throughout the length of the river. Specific identification of these animals is extremely difficult and positive recognition often necessitates performing serial sections. This was not possible during the present study.

Polychaeta. Most of the polychaetes are marine or estuarine, but a few are known from fresh water. Neanthes limnicola was found in the Sacramento River as far upstream as mile 81.5 (above Sacramento Slough). The greatest numbers, however, were found in the lower area of the river within the zone of tidal influences.

Crustacea

Amphipoda. A species of amphipod, Corophium spinicorne, was found from mile 118.1 to 4.0. This species is generally considered to be a salt or brackish water form, and has not been previously reported from fresh water.

Large numbers of Corophium were taken from the station located at mile 81.5. At this location the organisms were consistently found burrowed into the clay bottom. A few organisms were found at stations between mile 118.1 and mile 18.8, where it again was found in

significant numbers. It was also present in large numbers at the two lowest stations.

Insecta

Trichoptera. The caddisflies are an order of insects that are indicators of clean water with high dissolved oxygen content. They undergo complete metamorphosis, progressing from egg to larvae to pupae to adult. Four genera were selected as possible indicator organisms.

Ochrotrichia belongs to the family Hydroptilidae, the "Microcaddis". All members of this family are small. They build a tiny (2-4 mm.) case, shaped like a flattened bean, and slit at each end. The case is usually constructed of silk with sand or minute bits of rock adhering to the exterior. When ready to pupate, the individual closes the slits at each end and completes its metamorphosis.

Hydropsyche belongs to the family Hydropsychidae. This organism builds a net which it attaches to rocks or twigs so that the opening is perpendicular to the stream flow. After constructing the net, the larvae retreats into the bag of the net or under some nearby rock to await food particles which are swept onto the net. Hydropsyche is an omnivore, consuming anything that is edible. When this organism is ready to pupate, an elliptical dome-shaped cocoon is spun with pebbles and bits of rock neatly fitted to the exterior. Only the bottom which is glued to a large rock is left unadorned.

Agapetus is a member of the family Glossosomatidae. This animal builds a case shaped much like a turtle shell out of small stones. The elliptical dome-shaped case, with a flat bottom, has a bridge of small

stones across the underside which leaves an opening at each end. Agapetus extends head and legs out one end and posterior prolegs or anal claws out the other and crawls along the surface of larger stones feeding on the algae and mosses growing there. When ready to pupate, Agapetus cuts away the bridge at the bottom of its case and carefully seals the case to a large stone. Inside, a reddish brown, bean-shaped chitenized covering encloses the larva. How this develops is unknown, but presumably the larva secretes this material. One quick method of determining which pupal case contains either Hydropsyche or Agapetus, since their cases are very similar in appearance, is this chitenized covering. Hydropsyche, as previously stated, spins a cocoon of silken fibers, and the difference between the two cases is at once apparent from the underside.

Lepidostoma belongs to the family Lepidostomatidae. This animal constructs a case that is a circular tapered tube of sand grains when quite small. As the animal grows, however, flat particles of plant material are substituted for sand, and the case becomes square in cross-section. Contrasted with Agapetus, Lepidostoma has only the head and legs free, while the anal claws secure the animal to its case. At pupation, each end of the case is sealed with plant and stone material bound together with silk.

Ochrotrichia and Lepidostoma are found in greatest numbers in the upper area of the upper reach (above mile 279.2), but also occur at all the riffle stations. Agapetus apparently does best in the central area of the upper reach (mile 279.2 to 253.4), and Hydropsyche occurs more frequently in central to lower portions of the upper reach (mile 279.2 to 229.8). Hydropsyche pupae were found during each month of the survey, although they were most prevalent between May and September.

Agapetus pupae were found during each month except July. From a gross analysis of the data, more specimens of Agapetus seem to be in the pupal stage during the winter months, and probably a greater proportion of these animals emerge in early spring.

Occasionally other Trichoptera, including Psychomyia, Brachycentrus, Leptocerus, Leptocella, and Polycentropus were found.

Plecoptera. The stoneflies are an ancient, primitive order of insects which undergo incomplete metamorphosis. The succession is egg to nymph to adult. All of the nymphs of this order are aquatic, and all but a few require running water for their development. The development from egg through adult may take from one to three years. Most stonefly nymphs are phytophagous, or plant eaters, but members of the family Perlodidae are carnivorous. This order of insects indicates cold, clean water conditions. Stations at miles 256.3, 241, and 229.8 produced the greatest numbers of species and individuals.

The family Pteronarcidae is represented in California by two species, Pteronarcys californica and P. princeps. These are extremely large-sized nymphs (up to two inches), and their immature stages may take two or three years for complete development. The species found during the present survey was probably P. californica.

The two dominant members of the family Perlodidae found during the survey were of the genus Isogenus. One of these, Isogenus (Isogenoides) has not previously been reported from California.

Members of the family Nemouridae are phytophagous. The nymphs of the several subfamilies are difficult to identify, especially the Capniinae. They are primarily small, winter-emerging species. The taxonomic problems are greatly increased when adults as well as immatures are not collected.

Diptera. The true flies are one of the largest and most diverse of the orders of insects. As is apparent by the name, its members are typified by the presence of two wings. Ordinarily, Diptera develop through complete metamorphosis, egg to larva to pupa to adult. Approximately 50 percent of this order have aquatic stages in their life cycle, and many of these are important fish-food organisms.

Tanyderidae. A most unusual larva was discovered during the course of the survey. At mile 229.8 the larva of Protanyderus sp., the immature stages of which have never previously been reported, were found with great regularity. A diligent, but unsuccessful, effort was made to locate the pupal form. This is an archaic or prototype crane-fly, the larvae of which are similar to those of Protoplasa fitchii, the only previously recorded larva in this rare family. Protanyderus is characterized by a fully sclerotized head capsule, long prolegs with retractable claws at the posterior end only, but most striking are the six long filaments at the caudal end of the body. In February 1961, one of these larvae was collected that appeared to be commencing pupation. Unfortunately, high flows in the river the succeeding two months did not permit sampling at this station. By April only relatively small individuals were present.

Tipulidae. Most of the crane flies are semi-aquatic or terrestrial in their immature stages, but a few such as Antocha and Hexatoma are strictly aquatic. Only a single genus (Antocha) of this family was collected with any degree of regularity, and the pupa of this animal is different from any previously described in that the first branch of the respiratory organ is swollen and curves around to the front rather than pointing upward. Johannsen (1934) reports that members of this genus construct larval cases. No silken larval cases were discovered in this

survey but the pupae occurred in stone-covered silk cocoons with the underside bare of stones, and the anterior end open so that the respiratory organs protrude. The larvae feed mainly on algae. They were most commonly found from mile 285.9 to mile 229.8.

Simuliidae. The black flies are phytophagous in their larval stages. The larvae have a fan of hairs around the mouth with which to brush bits and pieces of plant material toward the mouth. Near the anterior end are prolegs which enable the animal to move about. At the posterior portion of the abdomen is a sucker-like disc surrounded by rows of hooks. The function of this disc is to assist the animal to retain its position on a rock in rapid water. The pupa is partially ensheathed in a cocoon and normally the respiratory organs extend out of the pupal case. Some species of this family have been characterized as pollution indicators, but most of this group is found in rapidly flowing waters with high dissolved oxygen content. In some trout streams, animals may be sufficiently numerous to make rock surfaces slippery and hazardous to anglers.

Tendipedidae. The midges are one of the most diverse groups in the order Diptera. Four of the six subfamilies were collected from the Sacramento River. Only Podonominae, restricted to high mountain country, and Clunioninae, which is almost exclusively a marine, were not seen. The larvae of these animals occupy a wide range of terrestrial and aquatic habitats. Certain species tend to be confined to particular environments. Greater knowledge of life histories and physical and chemical requirements, members of this group may be useful as pollution indicators.

Diamesinae. The immature stages of this subfamily are primarily cold water inhabitants and are phytophagous. Several species of this group were found in riffle areas. They have not previously been recorded in California.

Tendipedinae. Members of this subfamily, particularly Tendipes plumosus, have frequently been identified as pollution indicators. However, this species occurred in obviously unpolluted water at Redding (mile 295.5).

In the Sacramento River, Calopsectra was found in the riffle areas. Members of this genus are phytophagous. They spin a horn-shaped case which holds a fine web for collecting algae and detritus for food. The posterior portion of the case is anchored to a rock for about one quarter of its length, while the remainder usually turns upwards and faces the current. At pupation, the open end is covered with silk, except for a small hole in the middle which permits the exposure of the pupal respiratory organs.

The larvae and pupae of several species of Cryptochironomus were found regularly, but one deserves particular notice. The immature stage of this species certainly, and the adult in all probability, remain undescribed. The taxonomic distinctiveness of this individual makes it recognizable at a glance. The antennae are quite long, and the antennal blade arises at the distal part of the second segment. The maxillary palpi are equally as long as the antennae, lending the first impression of two pairs of antennae. The anterior pair of prolegs does not appear to be present, but rather appears as two brown longitudinal rods interior to the integument on the prothoracic segment. The posterior prolegs are

usually long with extremely fine claws which are in most instances retracted so as to be discerned only with careful examination.

Ecologically, this species seems to be one of four of the Tendipedidae which has been able to adapt to life in the grinding, shifting sands of the river bed load, and this one is found most regularly. The others are members of the following genera: Pentapedilum, Polypedilum, and Cricotopus. Most members of the genus Cryptochironomus are found in slower moving waters, and some are miners in the stems and leaves of aquatic plants.

Larvae and pupae of Pentapedilum and Polypedilum were found most regularly in the upper-middle reach and occasionally in the lower-middle reach.

Mollusca

Pelecypoda. The asiatic clam Corbicula fluminea, has become a serious pest in certain California rivers and canal systems. There did not appear to be any thick beds of these clams in the Sacramento River such as occur in some other streams and canals. Corbicula does, however, appear to be able to maintain a significant population under severe conditions of a moving bed load and was found as far upstream as mile 90.5 and in Colusa Basin Drain (mile 90.2R). Far greater numbers of small individuals were found than full grown clams. It is possible that as yet undiscovered concentrations of these individuals exist in the river, or the population is just beginning to bloom. At any rate, it will be important to follow the development of this population of small clams.

Future Work

The identification of several of the groups of animals presented serious difficulties. It is probable that some of the organisms have not yet been described.

The life histories and environmental requirements of many of the species are imperfectly known. Increased knowledge in this respect would be tremendously important in selecting indicator organisms for assessing water quality.

Additional work is warranted to give a better understanding of the existing conditions in the Sacramento River. A tremendous amount of data was collected during this survey. An evaluation should be made of the many physical conditions, such as flow, temperature, dissolved oxygen, etc., and their relationships to the biology of the river. This includes both benthic organisms and plankton.

It is expected that taxonomic information and data on range extensions and ecology will be reported in Department of Fish and Game publications or other technical journals.

Future biological monitoring of the Sacramento River is necessary to detect changes in the river environment. In view of the presently anticipated development of the Sacramento Valley, it is suggested that comprehensive investigations be made at intervals of about five years. Such investigations may be restricted to 10 or 12 stations occupied seasonally.

The extreme variability of the dissolved oxygen content of water in gravels is a factor that warrants further investigation. Adequate dissolved oxygen is particularly important in development of salmon and steelhead eggs in the gravel riffles.

CHAPTER V. SUMMARY AND RECOMMENDATIONS

A study of the biological conditions in the Sacramento River was made over the period April 1960 through June 1961. The purposes were to establish a "base line" of present conditions, provide the basis against which future changes can be measured, and provide information for use in setting appropriate requirements for present and future waste discharges.

Summary

Water temperatures in Keswick Reservoir were relatively constant throughout the period of investigation (50 - 55°F). During winter months, temperatures decrease as the water moves downstream. Temperatures rise below Keswick during the remainder of the year and reach highest values just above Sacramento.

Dissolved oxygen concentrations are high in the upper reach and gradually decrease throughout the length of the river. Large variations of dissolved oxygen were found at closely spaced sampling points at several of the riffle stations. In the gravels, the lower oxygen levels were usually associated with higher silt concentrations.

The transparency of water in the Sacramento River generally decreased from the upper area to the mouth.

Attached plants are uncommon in the river proper. A species of moss (Fissideus) is present in the riffles in the upper section of the river. Emergents such as Typha and Scirpus are present along the banks in the lower sections. Benthic algae are present in the riffles in the upper reach of the river, but were rarely found in other areas.

At least 165 separate species of animals, representing 10 phyla, were collected from 29 river stations during the survey. The dominant

organisms were oligochaetes (worms) and insects. Most of the latter were immature stages of the orders Diptera (flies) and Trichoptera (caddisflies).

The river was divided into four major environments.

The upper reach of the river (above mile 229) was characterized by animals which inhabit clean, fast-flowing water, such as caddisflies, mayflies, stoneflies, true flies, and oligochaetes. This reach contained the greatest average number of organisms, average numbers of genera, and average volumes of organisms per square foot of sampled area.

The lower reach (mile 18.8 to mouth of river) was the next most productive area. This reach contained primarily clams, amphipods, oligochaetes and midge larvae.

The two middle reaches were relatively unproductive. Most of the organisms collected were oligochaetes, midge larvae, and clams.

One large seasonal variation in animal abundance was noted. Production of bottom organisms steadily increased from July through November 1960 in the reach above mile 229. A sharp drop in numbers was noted in December 1960 and January 1961. This drop in numbers followed very high river flows in late November.

Recommendations

1. Knowledge of the taxonomy and life histories of many of the organisms collected during the survey should be expanded.
2. A more complete evaluation should be made of the data collected during the Sacramento River Water Pollution Survey in order to establish the relationships between biological populations and their environments.

3. Future biological monitoring of the Sacramento River should be done at intervals of about five years. Ten or 12 stations should be sampled intensively during each season of the year.

Local studies, in connection with specific waste discharges or problems, must be scheduled as needed.

4. The causes and significance of variations in dissolved oxygen within stream gravels should be determined.

5. Future investigations should be planned so that adequate time is available to evaluate the data and write the report. It is suggested that from three to five man-days of laboratory time be provided for each man-day spent in the field. In addition, a minimum of two man-days of professional time in the office for each day in the field are required from the outset of the investigation for evaluation of the data, and at least two more man-days are required during the final evaluation and report-writing stage.



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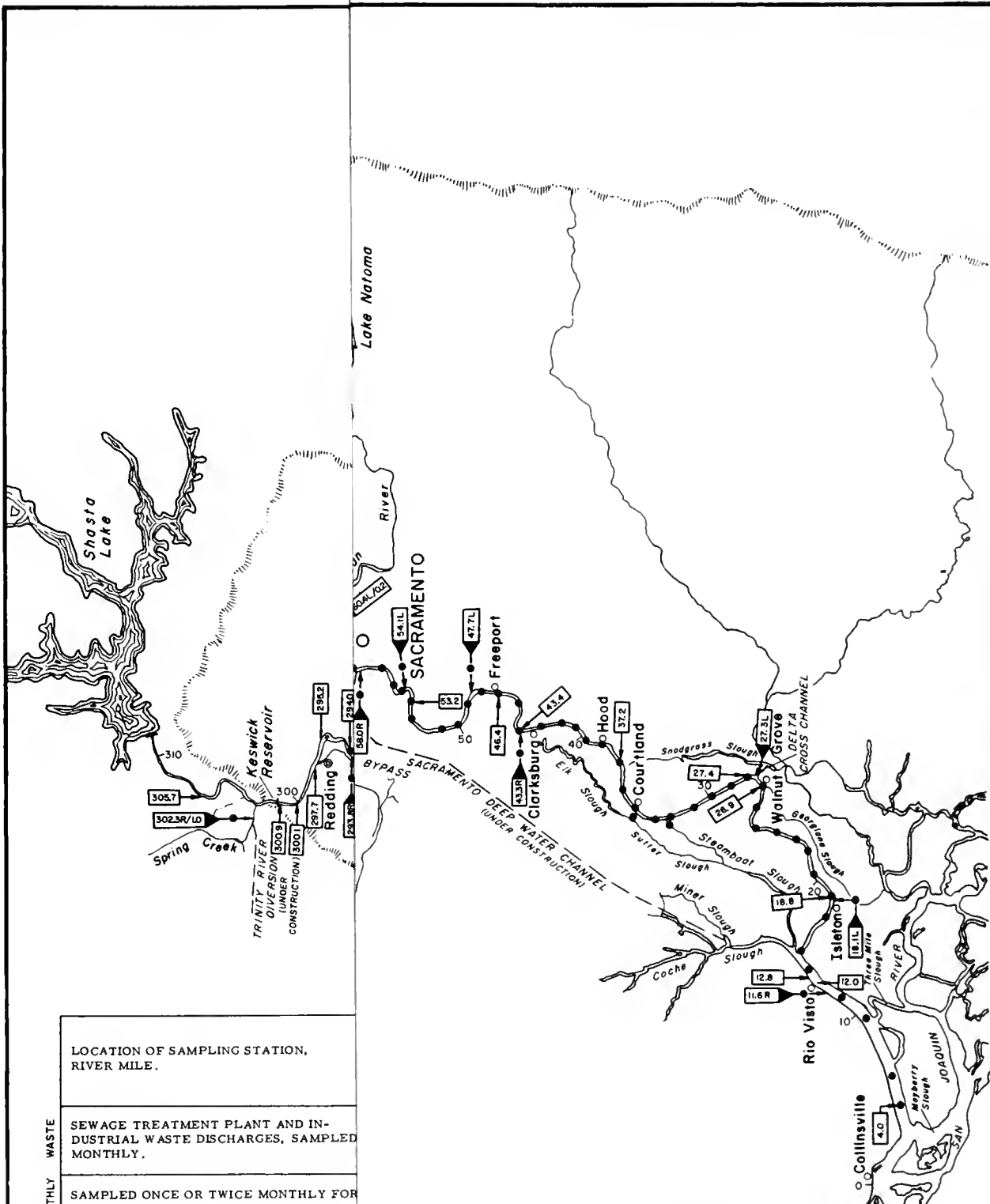
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	LOCATION OF SAMPLING STATION, RIVER MILE.
WASTE	SEWAGE TREATMENT PLANT AND INDUSTRIAL WASTE DISCHARGES, SAMPLED MONTHLY.
MONTHLY	SAMPLED ONCE OR TWICE MONTHLY FOR PHYSICAL, CHEMICAL, AND OXYGEN ANALYSES.
DAILY	SAMPLED MONTHLY OR BIMONTHLY FOR PLANKTON, BOTTOM ORGANISMS, SEDIMENT GRADATION, DISSOLVED OXYGEN AND TEMPERATURE.
BIOLOGIC	SAMPLED DAILY FOR TEMPERATURE AND ELECTRICAL CONDUCTANCE. CHEMICAL ANALYSES OF COMPOSITE SAMPLES.
ORGANIC	PERIODIC ORGANIC ANALYSES SAMPLING USING CARBON ADSORPTION METHOD.
E.C.	CONTINUOUS ELECTRICAL CONDUCTIVITY RECORDER.

STATE OF CALIFORNIA
 THE RESOURCES AGENCY OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 DELTA BRANCH
SACRAMENTO RIVER WATER POLLUTION SURVEY
SAMPLING PROGRAM
 AND
AREA OF INVESTIGATION
 1960-61



LOCATION OF AREA OF INVESTIGATION



	LOCATION OF SAMPLING STATION, RIVER MILE	SEWAGE TREATMENT PLANT AND INDUSTRIAL WASTE DISCHARGES, SAMPLED MONTHLY	SAMPLED ONCE OR TWICE MONTHLY FOR PHYSICAL, CHEMICAL, AND OXYGEN ANALYSES	SAMPLED MONTHLY OR BIMONTHLY FOR PLANKTON, BOTTOM ORGANISMS, SEDIMENT GRADATION, DISSOLVED OXYGEN AND TEMPERATURE	SAMPLED DAILY FOR TEMPERATURE AND ELECTRICAL CONDUCTANCE. CHEMICAL ANALYSES OF COMPOSITE SAMPLES	PERIODIC ORGANIC ANALYSES SAMPLING USING CARBON ADSORPTION METHOD	CONTINUOUS ELECTRICAL CONDUCTIVITY RECORDER
	300, 300.7		x				
	300.9		x				
	300.7						
	297.7						
	295.2		x				
	284.0		x				
	281.9		x				
	279.2		x				
	275.0		x				
	256		x				
	253.4		x				
	243.4		x				
	241.0		x				
	239.6		x				
	238.2		x				
	236.8		x				
	235.4		x				
	234.0		x				
	232.6		x				
	231.2		x				
	229.8		x				
	228.4		x				
	227.0		x				
	225.6		x				
	224.2		x				
	222.8		x				
	221.4		x				
	220.0		x				
	218.6		x				
	217.2		x				
	215.8		x				
	214.4		x				
	213.0		x				
	211.6		x				
	210.2		x				
	208.8		x				
	207.4		x				
	206.0		x				
	204.6		x				
	203.2		x				
	201.8		x				
	200.4		x				
	199.0		x				
	197.6		x				
	196.2		x				
	194.8		x				
	193.4		x				
	192.0		x				
	190.6		x				
	189.2		x				
	187.8		x				
	186.4		x				
	185.0		x				
	183.6		x				
	182.2		x				
	180.8		x				
	179.4		x				

- LEGEND**
- [Symbol: River line] RIVER STATION
 - [Symbol: Arrow pointing to river] TRIBUTARY, IRRIGATION DRAIN OR WASTE DISCHARGE STATION
 - [Symbol: Circle with dot] STATION SAMPLED AT 2-HOUR INTERVALS FOR 24-HOUR PERIODS
 - [Symbol: Line with '60' above it] 60 MILES ABOVE COLUINSVILLE
 - [Symbol: Line with 'R.M.' above it] RIVER MILE AND BANK
 - [Symbol: Line with '100' above it] 100 MILES UPSTREAM FROM MOUTH
 - [Symbol: Dashed line] APPROXIMATE EDGE OF VALLEY FLOOR

STATE OF CALIFORNIA
 THE RESOURCES AGENCY OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 DELTA BRANCH
SACRAMENTO RIVER WATER POLLUTION SURVEY
SAMPLING PROGRAM
 AND
AREA OF INVESTIGATION
 1960-61
 SCALE IN MILES

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