TECHNICAL REPORT ON FISHERIES

OF THE RUSSIAN RIVER

Part of the Aggregate Resources
Management Study conducted by
the County of Sonoma

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INTRODUCTION

The gravel mining industry has been active in Sonoma County for the past fifty years. Gravel, sand, and crushed rock (i.e., aggregate) from the county have been extensively used in the construction of highways, dams, bridges, buildings, and homes of the North Bay and North Coast regions. In 1977, aggregate sales in the county totaled 3,289,701 tons. Twenty per cent came from quarries, 69 per cent from terrace pits, and 11 per cent from the Russian River and its tributaries (March 6, 1979 correspondence of Michael W. Manson, California Division of Mines and Geology, to Greg Carr, Sonoma County Planning Division). The year of highest aggregate production was in 1973 with 4,632,980 tons (15 per cent quarries, 72 per cent terrace pits, and 13 per cent river and tributaries). Prior to 1968, the Russian River and its tributaries were the primary sources for gravel and sand; from 1968 to the present, terrace pits have provided the bulk of the supply. The heaviest mining of the river occurred in 1962 with 6 per cent from quarries, none from terrace pits, 92 per cent from the river and 2 per cent from its tributaries (June 12, 1978 correspondence of Manson to John C. Nelson, Sonoma County Planning Division).

Instream mining of the river and its tributaries has declined greatly, prompted by increasingly strict regulations placed on the industry by county and state agencies. A major factor in the decline of instream mining of gravel was the Porter-Cologne Water Quality Control Act of 1973, which allowed the State and Regional Water Quality Control boards to effectively control the quality of waters in California. Of direct relevance to gravel extraction was the redefining of "waste" by the Attorney General (32 Ops. Cal. Atty. Gen. 139) to include "Changes in the physical or chemical characteristics of receiving waters caused by extraction of sand, gravel or other materials from a streambed."

The objectives of the fisheries investigation in the aggregate resource management study were as follows:

1. Make a preliminary survey of the major aquatic habitat types and areas of the Russian River system in Sonoma County essential for fish reproduction and growth that would be affected by gravel extraction.
2. Review existing literature on aquatic organisms of the Russian River, especially fishes, and identify any rare or endangered species that might be present.
3. Determine the relationships of stream and terrestrial habitat types to the life cycles of major aquatic species.
4. Determine the trophic (feeding) interactions of major aquatic species.
5. Predict possible impacts of the gravel industry on aquatic organisms.

6. Determine any acceptable levels of impact and the development of management recommendations to achieve them.

7. Develop recommendations for continued monitoring.

THE FISHERIES OF THE RUSSIAN RIVER SYSTEM

Fishes of the River and Its Estuary

The fishing resources of the Russian River system have been well publicized, but poorly understood scientifically. At least 46 species of fishes are known from the system and its estuary, of which 27 species are native (Hopkirk, 1979; Table 1). Only one native form, the Russian River tuleperch, *Hysterocarpus traskii pomo*, is endemic or peculiar to the drainage (Hopkirk, 1974).

The native anadromous species of the Russian River have always been of interest to man (both to the native American and to the "introduced" American). Anadromous species, or those that migrate to sea but return to freshwater for spawning, are usually much larger and sometimes, but not always, easier to catch than associated resident species. The steelhead or rainbow trout, of worldwide fame, king or chinook salmon, silver or coho salmon, and pink salmon, are known from the system. It was estimated in 1969 that 57,000 steelhead and 5,500 salmon use the drainage annually for spawning and nursery grounds (Vestal and Lassen, 1969). Much larger numbers undoubtedly occurred in the drainage prior to that time; much smaller numbers now occur. Pacific lamprey, river lamprey, white sturgeon, green sturgeon and the threespine stickleback are additional anadromous species native to the region. Introduced anadromous species include the American shad and the striped bass.

The native non-andromous or resident species include the California brook lamprey, western sucker, three, possibly five, species of minnows, the Russian River tuleperch, three species of sculpins, and possibly the Sacramento perch. The latter species and the two species of minnows may have been introduced into the system from the Central Valley (Hopkirk, 1974). Introduced species, primarily adapted for warmwater, include three species of minnows, four species of catfishes, the mosquitofishes, two species of crappies, three species of sunfishes, and two species of bass (Table 1).

Rough Fish Control

The only data of any value on the fishery resources of the river was gathered as incidental material that grew out of studies of rough fish control in the 1950's (Johnson, 1957; Pintler and Johnson, 1958) and early 1960's (Hansen, ?1964). Chemical treatment of the river was accomplished by rotenoning in the period 1952 through 1954. Fishes of the river were surveyed from 1954 to 1956. By the summer of 1958 rough fish populations had recovered; in the fall of 1958, 118 miles of tributary streams were poisoned. During the period between 1960 and 1963, rough fish dominance was again reported and sportsmen requested a continuation of the control program. Rather than attempt a large scale program, the California Department of Fish and Game in the early summer of 1963 selected ten streams for a projected five year study. These streams were Ackerman, Forsythe, and Robinson creeks in Mendocino County and Cummisky, Pieta, Pena, Warm Springs, Big and Little Sulphur, and Maacama creeks in Sonoma County. All ten streams were studied, chemically treated and re-studied in 1963 (Hansen, ?1964).

Twenty years later, Johnson (1975) reflected on the earlier project:

> In the planning and execution of this project no concerns were voiced for possible endangered aquatic resources or esthetics; the program was to improve the steelhead-trout habitat. Today such a program would be inconceivable because all features of the environment would have to be considered, particularly in light of the Public Law of 1970 regarding endangered species.
>
> Research on the dynamics of fish populations in a lotic habitat has provided sufficient data indicating that habitat niches used by non-game fish are not desirable for steelhead. Also, the predator-prey relationship between squawfish and steelhead-trout is only one facet in anadromous fish management. Therefore, the control of squawfish would not necessarily improve the steelhead fishery. A project to chemically treat a whole river system would be difficult to justify if the Endangered and Threatened Species Preservation Act of 1973 is considered.
>
> A five- to eight-year follow-up evaluation was planned for this program. However, only cursory field surveys and creel census data were collected for several years after the treatment, and no long-term systematic evaluation was made. All data indicated the non-game species of fish populations replaced the steelhead much faster than anticipated. The long-term evaluation planned would have been implemented if manpower and resources had been available.

During the entire rough fish control study, no attempt was apparently made to relate man's activities within the drainage to the succession of fish populations. Vestal and Lassen, in 1969, although still advocating rough fish control (p. 16), did make reference to the activities of man (pp. 12-13).

> Man is diverting water during the low summer flows; he is logging the upstream areas; he is building roads along the streams, allowing silt to go into the creeks during winter storms; he is changing the temperature regime of waters by his diversions and

> dams, and in some areas by his waste discharges into the waters. This loss of habitat is the primary limiting factor for our coastal stream fishery resources.

In regard to gravel mining, Vestal and Lassen stated (p. 13):

> Removal of valuable spawning gravels is another serious problem affecting fishery resources in this drainage. Gravel removal at its present rate may jeopardize the remaining steelhead and salmon spawning areas. Possible solutions to this problem would be to establish regulations on the gravel size, amount and/or areas of gravel removal.

Although of no great direct value in fish management, the rough fish control projects provided the following data on the fishery resources of the Russian River:

1. Distribution of fishes within the drainage
2. Percentage composition of species within fish populations
3. Size ranges of fishes within the populations
4. Estimates of standing crop (1963)
5. Water temperature data
6. Taxonomic data based on specimens deposited at the California Academy of Sciences in San Francisco (these were later used by Hopkirk in his research).

In the final analysis, the chemical control of rough fishes in the Russian River drainage showed quite conclusively that much of the drainage is dominated by suckers and minnows. Ecological conditions are right for them, wrong for trout and salmon. Trout were scarce then and are scarce now -- present only in the headwater areas of tributary streams. Coexistence of trout and non-game fish can occur, however, but man's activities tend to change the aquatic environment in favor of the non-game species.

Rare and Endangered Aquatic Organisms

The only fish endemic or restricted to the Russian River is the Russian River tuleperch, *Hysterocarpus traskii pomo*, described and named by Hopkirk in 1974. The status of this form is at present uncertain. It definitely is not common in the Russian River System. Only seven specimens of this species were seen during our investigation: four in the main river at Asti and three in Dry Creek at Westside Bridge. Donald M. Baltz, a graduate student at the University of California at Davis presently finishing his doctoral dissertation on the tuleperch, also found it to be uncommon in the river system. Thirty-six specimens were collected by Baltz in 1977 and 1978 between the townships of Hopland and Cloverdale (Baltz and Moyle, unpublished MS). Only 78 specimens were available to Hopkirk at the time of his research and 35 of the preceding had been collected in the early 1900's. On the basis of the preceding scarcity, it may soon be necessary to recommend placement of the Russian River tuleperch on the rare and endangered list of the California Department of Fish and Game.

The tuleperch is a main channel species that migrates into tributary streams for the delivery of its young. The young are delivered, at least in this part of California, during the first week of May. The entire period from March through June, however, is a critical one for this species. Any barrier to upstream or downstream migration, either for the reproducing adults or for the newly born young, would have an adverse effect on the future of this species. Summer dams and summer roads should therefore be removed from areas where this species is known to migrate.

A number of aquatic invertebrate species are endemic to the general region. Most of these are small and therefore poorly known. One of the slightly more "visible" species that is receiving attention, because of its rare status, is the freshwater shrimp, <u>Syncaris</u> <u>pacifica.</u> This species was not seen during the investigation.

POTENTIAL EFFECTS OF GRAVEL MINING ON AQUATIC ORGANISMS

Effects that could result from gravel mining are listed here so the reader may have them in mind. Each effect is discussed with reference to its actual level of occurrence in a later section.

The removal of gravel from a river system can directly or indirectly influence the fishes and other aquatic organisms of a river system. Direct effects of gravel mining are easy to observe and document; indirect effects are difficult to observe and document and may take years to be realized. Historical background on the aquatic organisms and the river system may also be insufficient to provide an accurate appraisal of recent effects due to the activities of man. Seasonal changes in a river are also so great that the damage from dry season mining can be rapidly concealed by winter flood flows and natural changes in the streambed. Superficially, it would appear as if no damage had occurred; only long term, detailed studies can show whether or not they have occurred.

<u>Direct Effects</u>

Direct effects, if allowed to occur, of gravel mining on aquatic organisms include the following:

1. Physical destruction or death of organisms due to direct physical harm brought about by the instream or inwater extraction of gravel.

2. Direct removal of substrate sizes necessary for reproduction (spawning, nest-building).

3. Direct removal or destruction of fish habitats, especially nursery areas.

4. Diversion of streams and reduction of streamflow which bring about the isolation of organisms into pools that eventually dry up during late summer (i.e., mortality is greatly increased).

5. Construction of summer dams or roads which either block upstream spawning migration on the river or migration into tributaries of the river.

<u>Indirect Effects</u>

Indirect effects of gravel mining on aquatic organisms include:

1. Release of fine sediment from the substrate during instream extraction or during the washing process which thereby:

   a) suffocates eggs and fry—either directly or by impeding the flow of water through nests;

   b) prevents emergence of fry from nests;

   c) clogs the gills of aquatic organisms and thus causes their death;

   d) fills the crevices between gravel and thus prevents aquatic organisms from using them for cover or shelter;

   e) covers gravel and other substrate types to such a degree that they cannot be used for spawning;

   f) alters the relative composition of substrate types so that the substrate is unsuitable for spawning;

   g) alters the substrate and thereby reduces secondary productivity (aquatic insects or other fish foods);

   h) covers aquatic plants or inhibits their ability to photosynthesize and thereby reduces primary productivity;

   i) causes turbidity that reduces the feeding activity of fishes and consequently, the condition of the population.

2. Release of excessive amounts of sediment (effects listed above) into the river by the winter flooding of gravel wash ponds, terrace pit ponds, summer roads and levees.

3. Changes in the physical features of a river or of its tributaries so that bank and streambed erosion is in creased.

4. Removal of riparian or streamside vegetation which:
   a) shades and cools the water;
   b) stabilizes the stream bank;
   c) increases, through leaf litter, the nutrients in the water and the productivity of streams;
   d) increases, through terrestrial insects associated with riparian vegetation, the foods available to fishes;
   e) provides cover or shelter for aquatic organisms;
   f) influences, through natural dams formed by fallen trees, the ratio of riffles to pools.

5. Reduction of the physical space available, by the construction of instream dams, roads, and levees and the creation of ponds, for organisms adapted to lotic or running water habitats (i.e., stream or coldwater habitat is reduced or replaced by lake or warmwater habitat).

All of the preceding effects are documented in the literature.

METHODS

Study Sites

In surveying the middle reaches of the Russian River for study sites it became obvious that the river was no longer suitable as a summer nursery area for salmonids. This conclusion was based on field observations, previous data collected by the California Department of Fish and Game, and summer water temperature data given in Winzler and Kelly, 1978. Studies of the relationship of gravel extraction to salmonids, if investigated at all, had to be conducted elsewhere. Lower Austin Creek, above and below the gravel operation of Theseus Canelis, was therefore selected as an additional study site. The Russian River at Asti was also considered to be a control, of sorts, to compare with the river at Kaiser's South Plant. Two additional sites, deemed critical, were on Dry Creek: at Soiland's Cement: Operation near Westside Bridge and downstream at the confluence of the creek with the Russian River. Six study sites were therefore established:

Russian River at Asti. This study site is located in Alexander Valley adjacent to the Asti Winery residue settling ponds (river mile 56-57). It extends from 300 m downstream from the Washington Road summer crossing to 350 m upstream.

During the 1979 summer low flow period the main wetted portion of the stream occupied the extreme easternmost portion of the channel. A dessicating side or nursery channel was present along the west bank of the river.

Both sides of the channel are almost continuously lined with a thin strip of riparian vegetation (willows). During the 1979 low water period only the east edge of the wetted portion was in contact with this riparian cover.

No gravel extraction has occurred in this study area. It is subject to the disturbance of the annual construction of the Washington Road bridge in early summer (mid-May of 1979). Construction of this road crossing included redistributing substratum materials by bulldozer and displacing the wetted channel from the west to the east bank by the construction of a gravel levee upstream from the road crossing.

This study site was used as a launching point for canoeists by a commercial canoe rental concern during the 1979 low water period. As a result much of the exposed substratum in the center of the channel was accessible by and subject to the use of a large number of people and private vehicles.

Russian River at Kaiser South. This study site is located adjacent to Kaiser Sand and Gravel Company's southernmost plant and Basalt Rock Company's plant (river mile 25-26). It covers an area approximately 1500 m in length.

During the 1979 summer low flow period the wetted portion of the channel occupied the east side of the channel in the upstream 40 per cent of the study area and crossed to occupy the west side of the channel for most of the remainder of the study area.

Most of the west bank of the channel throughout the study area is covered with thick riparian vegetation. Only 15 to 25 per cent of the east bank in the study area supports riparian vegetation of significant density.

Until 1967 (?) the entire study area was subjected to annual instream gravel extraction operations in the channel. On the adjacent floodplain gravel extraction from terrace pit ponds continues. A small settling or wash water pond was excavated adjacent to the Kaiser plant in the summer of 1979 on the east side of the wetted portion of the channel.

Dry Creek at Soiland. This study site is located on Dry Creek and extends from the Westside Road Bridge to a point 100 m upstream. It is adjacent to the Reiman and Garrett Ready Mix Plant and the Healdsburg Sand and Gravel Plant on the east bank.

During the 1979 low flow period the wetted portion of the stream occupied the east side of the channel immediately upstream from the bridge and crossed to the west side downstream. The study site was completely exposed by late August.

There is a thin but dense, continuous band of riparian vegetation along the west bank of the study area. The east bank supports only scattered patches of sparse vegetation. During the low flow period of 1979 none of the wetted portion of the stream was influenced by riparian vegetation. Some cover was provided, however, by shade from the Westside Road Bridge.

The entire study area has been subject to in-channel (instream and dry) gravel extraction for years. In-channel extraction occurred during the study period, but only in non-wetted areas.

Dry Creek at Mouth. This study site consists of the Russian River channel at its confluence with Dry Creek (river mile 30-31) and Dry Creek from this confluence to 300 m upstream.

During the low flow period of 1979 the wetted area of the channel occurred along the south bank of the channel of Dry Creek. From the confluence with the Russian River to a point about 100 m upstream, the wetted channel was displaced to the north bank of Dry Creek by the Basalt Road Crossing. The wetted portion of the Russian River occurred along its west bank during the 1979 low flow period and included its confluence with Dry Creek.

In the study area Dry Creek supports a thick growth of riparian vegetation only on the south bank. There is dense riparian vegetation also on the west side of the river and north of the mouth of Dry Creek. In addition, the entire east bank of the river in this study area is covered with a thick band of riparian vegetation.

During the 1979 low water period only the south bank of the wetted portion of Dry Creek upstream from the Basalt Road Crossing derived cover from riparian vegetation. Only the west bank of the river upstream from the mouth of Dry Creek was in contact with riparian vegetation.

The study area is impacted by the annual construction of the Basalt Road Crossing over Dry Creek about 100 m upstream from its confluence with the Russian River. The result of this construction is the displacement of the wetted portion of Dry Creek (downstream from the crossing) from the south bank to the north bank of the channel. This is caused by the installation of culverts in the north end of the road crossing (not in the natural channel). An additional impact is the excavation of a deep pond in the channel on the south side of the wetted portion of Dry Creek, downstream from the road crossing. Dry Creek is isolated from this pond by an articicial levee along its south bank.

<u>Austin Creek above Gravel Plant.</u> This study site is located on lower Austin Creek and extends 100 m upstream from the Bohan-Canelis Gravel Plant.

During the spring of 1979 the wetted portion of the stream decreased and was displaced along the west bank of the channel. In the early summer of 1979 a summer dam was constructed at the downstream boundary of the study area, thus effectively transforming the creek into a large pond or pool in this area.

Until the construction of the summer dam at this site on June 25, the wetted portion of the stream occurred along the west bank of the channel and was covered by thick riparian vegetation over a significant portion of its area (20-25 per cent).

This study site is subjected to the impact of the annual construction of summer dams and has been for some time (possibly over 50 years).

<u>Austin Creek below Gravel Plant.</u> This study site is on lower Austin Creek and extends from 100 m downstream from county bridge 20-47 to 300 m upstream. Its upstream boundary is adjacent to the Bohan and Canelis gravel plant on the east bank of the creek (600 Austin Creek Road).

During the summer low flow period of 1979 the wetted area of the stream in the study area was reduced to a narrow channel (3-5 m wide) along the east bank. An additional wetted area in the form of an isolated in-channel pond was created by dredging toward the west side of the natural channel adjacent to the plant.

During the 1979 low flow period the east extreme of the wetted portion of the stream coincided with the natural flow and upper banks of the stream channel and was therefore covered by thick riparian vegetation throughout the study area. Most of the pond was exposed and with no riparian cover.

This entire area had been last disturbed by gravel extraction during 1978 (Theseus Canelis, personal communication to Howard Cunningham). The upstream portion of the study area is subject to gravel extraction on a yearly basis and was disturbed during the study period.

At each study site direct observations of general habitat conditions and changes were recorded; a photographic record was also made.

Water Quality

Water quality parameters measured were dissolved oxygen, water and air temperature, and turbidity. Dissolved oxygen was measured using the Winkler method (in accordance with Standard Methods). Water and air temperatures were taken with a field (mercury) thermometer. Turbidity samples were collected in 6 oz. jars and analyzed in the laboratory with a Bausch and Lomb "Spect 20" spectrophotometer. Triplicate turbidity subsamples were analyzed at 450 nm wavelength and the average of three readings was recorded as percentage transmittance.

Substrate Analysis

A review of the literature indicated that the percentage composition of different particle sizes in the substrate was more important to spawning fish than a specific particle size. In addition, the actual picture of the substrate was best revealed when examined to at least a depth of 6 inches. A McNeil sampler was therefore manufactured (after McNeil and Ahnell, 1960) to take "McNeil samples" of the substratum which would determine the suitability of the substrate for spawning, egg survival, and dry emergence. McNeil samples were taken in triplicate in water depths ranging from 0.5 to 1.5 feet and analyzed in the field. Samples were sorted through a series of Tyler screens of graduated size mesh: 22.43 mm, 11.20 mm, 5.61 mm, 2.79 mm, and 0.90 mm. The portion passing through the 0.90 mm mesh was allowed to settle for 10 minutes in graduated cylinders before its volume was calculated. For each size range volume was converted to per cent of total volume. The average of the triplicate samples was recorded.

Aquatic Organisms

Fishes. Fishes were collected with a 50 foot beach seine (V mesh), a 15 foot seine (1/8" mesh), dip net, and hook and line. Each collection site was surveyed for a number of biological and physical parameters: weather, vegetation, bottom characteristics, cover, temperature (air and water), current velocity, shore characteristics, distance offshore of capture, stream width, depth of capture, depth of water, and time of capture. The entire catch was analyzed in the field for species composition and size range. Subsamples of each catch were preserved in 10 per cent formalin. These were later measured, weighted, and sexed in the laboratory; stomachs were removed for an analysis of feeding habits.

Invertebrates. Benthic macro-invertebrates were collected with a dip net and a 15 foot minnow seine (1/8" mesh)(Table 2). Samples were preserved either in 75 per cent ethanol or in 10 per cent formalin and later analyzed in the laboratory. Species were determined with the aid of a dissecting microscope and an estimate made of their relative abundance.

MAJOR AQUATIC HABITATS OF THE RUSSIAN RIVER

Natural Aquatic Habitats

Main Stem. In the freshwater section of the main channel two major aquatic habitats can be recognized: pools and riffles. In the lower brackish-water section of the river, an enlarged pool or lagoon is formed by the yearly closure of the river mouth (Table 3).

Pools of the middle reaches of the river are presently dominated by two year old or more suckers, squawfishes, and hardhead. Large carp, green sunfish, bluegills, and large and smallmouth bass may also be present but in more reduced numbers. Cover or shelter for fish in the form of riparian vegetation, undercut banks, boulders, floating logs, etc., is scarce on the mainstem. Fish-eating birds (herons, egrets) are commonly noted by their footprints, if not actually seen; kingfishers by their rachet-like call.

Riffles and runs, if deep and cold enough, could support a few trout. Willows, if allowed to grow, would provide cover. Each summer the willows are destroyed by the Sonoma County Water Agency for flood-control purposes. Butler and Hawthorne (1968) demonstrated experimentally that cover becomes more essential as trout increase in size.

The mainstem of the river was divided by Winzler and Kelly (1978) into spawning and nursery habitats for trout and salmon. According to their survey, one arrives at the following conclusions:

1. Summer water temperatures (more than 20°C) exclude salmon and trout from the lower 76 miles of the river with only a few exceptions (river miles 66 and 70; Fig. VI-6 of Winzler and Kelly).

2. Pool: riffle ratios averaged 4.8:1 on mainstem, much greater than the 1:1 or 50:50 ratio cited in the literature that is typical of salmonid nursery habitat (Fig. V-4 of Winzler and Kelly).

Habitat requirements for the reproduction of steelhead, silver salmon, and king salmon, based primarily on Baracco, 1977 and Winzler and Kelly, 1978, are summarized in Table 4.

Side channels of the Russian River, at least in Sonoma County, are the shallow water nursery areas (usually less than one foot in depth) for non-game species. These side channels are much higher in water temperature, often approaching air temperature, than the main channel and are the preferred habitat of young-of-the-year suckers, squawfish, roach, hardhead, and sticklebacks. Large masses of filamentous algae eventually coat and choke the side channel if flow becomes reduced and no shade is present.

Because of controlled flows from Coyote Dam and the removal of large riparian trees, deep, tree-shaded "holes" and ox-bow lakes are absent. These deep holes were undoubtedly cool refuges for cold-adapted trout and salmon. One of these deep holes was the basis of the name of a Southern Pomo village, "Salmon Hole," that existed at the mouth of Sulphur Creek. David Peri, anthropologist at Sonoma State University, has been informed by Indians of the Healdsburg area that a lake, presumably an overflow lake, once existed in that region.

Tributaries. Summer water temperatures on the mainstem are so high, at the present time, that nursery areas for salmonids are non-existent. Most of the salmonid reproduction of the past, except for that of pink and king salmon, probably occurred either in the tributaries or the upper reaches of the mainstem.

The tributaries of the Russian River can be categorized according to their position within the river system. Primary tributaries are those that flow into the mainstem; secondary tributaries enter primary tributaries; tertiary tributaries feed into secondary tributaries.

The most critical part of any tributary is its mouth, because through it pass fish on their way upstream to spawn. Some authors define anadromy in a broad sense to include any migration into a tributary stream for spawning. If we follow that definition, probably 95% of our native freshwater species are anadromous. Another important function of the tributary mouth, even if the tributary dries up during the summer, is that it forms an embayment on the mainstem, where water velocity is reduced and young fish and small prey species can seek shelter from mainstem predators. The roach, a small minnow native to the system, was recorded by Pintler and Johnson (1957) as being common on the mainstem only around the mouths of tributaries. Even the tuleperch, a native live-bearing species, enters the mouths of tributaries to deliver its young.

Primary tributaries that are within 10 miles of the coast, such as Austin Creek and Willow Creek, are cooled by coastal fog and redwood forests and are therefore, or once were, good salmonid streams. Dry Creek and other intermittent primary tributaries of the middle reaches of the river are marginal salmonid streams with annually and seasonally fluctuating flows. In these streams we find most of the species found in the mainstem but of a smaller size. Squawfish and suckers still dominate the fish population. Hopkirk (1967; 1974) named this type of fish community or association as the "sucker zone."

Secondary tributaries are usually permanent streams that are dominated by roach ("roach zone" of Hopkirk, 1967). Warm Springs Creek is a good example of a roach stream (see Hopkirk, 1979). Riparian vegetation (alders, maples, laurels) often shades 50% of the wetted streambed. Water temperatures range between 70 and 75 degrees Fahrenheit during the summer. Rainbow trout are present, but do not dominate the fauna.

Tertiary tributaries are small, cold and inconsequential creeks of great beauty and permanence. Riparian vegetation (especially willows) is so dense that it may be difficult to locate the water and 100% of the stream is shaded. These are often our best streams for the spawning of resident rainbow. Rainbow trout fry are dominant in these streams. Water temperatures always remain less than 70 degrees Fahrenheit. Rancheria Creek, a tributary of Warm Springs Creek, is a good example of the "trout zone" (Hopkirk, 1967; 1974).

Artificial Aquatic Habitats

Artificial aquatic habitats are those constructed (bulldozed or dredged) by man. On the Russian River and its tributaries, one finds during the summer dry period a number of these which disappear, either by being bulldozed away or by being washed away, with the onslaught of the rainy season. Terrace pit ponds and impoundments last throughout the year and are therefore permanent or semipermanent in nature.

Temporary or "Summer" Aquatic Habitats. One of the most perplexing problems of the Russian River system, at least to fishery biologists, is the summer dams and ponds formed for recreational use. The Healdsburg Recreational Dam, constructed in 1951, has created passage problems for shad, king salmon and steelhead during their spawning migration (Vestal and Lassen, 1969). Summer dams, which adversely affect salmonids, have been constructed on Austin Creek for almost 70 years. Forty dams were constructed in 1972 affecting eleven miles of stream (Forester and Jones, 1973); thirty-three dams were constructed in 1978 (Alan Baracco, April 7, 1978 memorandum to Region 3 Fisheries Management Supervisor).

Although not usually a barrier to the migration of fishes, summer road crossings on the mainstem function as partical dams and slow down the flow of water to form ponds. These ponds toward the end of summer become full of filamentous algae and serve as nursery areas for suckers and minnows, in addition to those present in the side channels. Summer road crossing ponds, similar to the one seen at Asti, also function as recreational ponds; conversely, dams that form recreational ponds, such as those on Austin Creek, serve as summer road crossings.

Instream mining ponds are now uncommon on the river and its tributaries. They are formed by the action of "skimmers," bulldozers, and drag-lines. Aerial photographs taken in 1976 reveal their presence on Dry Creek near Westside Bridge. A conspicuous one is also formed by dragline every year by Basalt Rock Company in the streambed of the river at the mouth of Dry Creek. Shallow instream ponds, less than three feet in depth, are formed every summer by Bohan-Canelis on Austin Creek. Instream ponds accumulate silt during the extraction of gravel. No cover is present. Fishes longer than one inch in length were absent in the Bohan and Canelis pond and presumably removed by avian predators. The only fish observed in these ponds were young sticklebacks and roach.

Diversion channels are required in Austin Creek and elsewhere by the California Department of Fish and Game's "Streambed Alteration Agreement" to allow for the free passage of fish around a dam or any artificial obstruction of the stream. These diversion channels are supposed to follow the natural channel and be directed toward a bank with riparian vegetation ("Recommendation" of Klampt, 1972). During the late summer, however, flow in the creek becomes reduced and the diversion channel becomes a series of interrupted pools. Fishes are able to survive only if pools remain under the shade and cover of riparian vegetation.

Permanent or Semipermanent Artificial Aquatic Habitats. Two major types of ponds, waste water and terrace pit, are presently created by gravel operations that mine the terraces along the river. Gravel is removed by drag lines to form terrace pit ponds — some of which become more than a square city block in size. The gravel is trucked to the sorting plant where it is sorted, washed and stock-piled by size. Wash water accumulates in a waste water pond, the bottom and sides of which are pure silt. Waste water ponds are usually constructed on top of the terrace and hopefully outside of the flood zone of the river. Our studies did not include waste water ponds or terrace pit ponds, but concentrated on the mainstem and its tributaries. Fishes of these ponds are mostly warm water species (catfish, suckers, squawfish, smallmouth bass, bluegill, green sunfish) that have managed to arrive there via flooding, construction activities, planting, etc. Waste treatment ponds were present, but not investigated, near the Asti study site. Warm Springs Dam (under construction) and Coyote Dam form, or will form, sizeable reservoirs on the system. These were outside the scope of study and therefore not investigated.

WATER QUALITY PARAMETERS

The quality of the water, in relation to the needs of fishes, was briefly analyzed at the six study sites. Surface water temperature, turbidity, and dissolved oxygen were recorded. Dissolved oxygen data were not significant and therefore not included in this report.

Water Temperature

The most important factor limiting the distribution and abundance of fishes is water temperature. Fishes orient themselves to or swim toward specific water temperature gradients, spawn at specific temperatures, hatch out of the egg at specific temperatures, and require specific temperatures for optimum growth and development.

Water temperature requirements for trout and salmon, based on the literature (especially Winzler and Kelly, 1978 and Baracco, 1977), are as follows (see also Table 4):

Passage or Migration Upstream for Spawning: 7.2° to 15.5°C (45°F to 60°F)

Spawning: 5.8° to 12.8°C (42°F to 55°F)

Nursery Habitat: 0 to 12.5°C (32°F to 55°F) for fry; less than 20°C (68°F) for fingerlings and adults of trout and salmon

Downstream Migration: less than 15°C (59°F)

King salmon females require temperatures below 13°C (55°F) during migration for proper development and viability of the eggs. Baracco (1977) calculated, based on water temperatures taken at Guerneville from 1964 through 1973, that migration could not occur, on the average, until the middle of November. The preceding temperature occurs usually at a time period when the mouth of the river is open at Jenner. Our data is insufficient for the period of November and December, but it can be seen that a dry warm winter would have disastrous effects on king salmon (Fig. 1).

The spawning period of the king salmon ranges from November through January, silver salmon from October or November to late February, steelhead from November through April. Water temperatures by the middle of March in 1979 were already in excess of the maximum for spawning and as a nursery habitat for fry (Fig. 1).

Adverse water temperatures, exceeding that required for juvenile and adult salmonids (20 C or 68°F), occur from June through October (100 days) in the mainstem, May through October (180 days) in Dry Creek, mid-May through mid-September (120 days) in lower Austin Creek (Fig. 1). It should be noted that the temperature of the main channel (running water habitat) in Austin Creek was much cooler than the summer ponds and had only 45 days of adverse water temperatures.

Juveniles of anadromous salmonids undergo a minor metamorphosis, referred to as smoltification (= the development of the silvery or smolt stage), prior to their seaward journey. Zaugg, et. al. (1972) have shown that temperatures below 15°C (59°F) are necessary for this process. Baracco (1977) calculated that temperatures in the lower river exceed, on the average, 15°C (59°F) after the middle of April. In 1979, temperatures exceeding 15°C began in early April on the mainstem, April 1 on Dry Creek, and late April on Austin Creek (Fig. 1). Smoltification and downstream migration therefore has to occur prior to mid-April for salmonids in most of the system. If smoltification does not occur, the young salmonids have to contend with stressful, and often fatal, high summer temperatures in their wait for the next migratory period.

Although water temperature requirements for sane of our native non-game species are inadequately known, it is obvious, based on their present abundance, that water temperatures throughout much of the system are ideal for their growth and reproduction — and not for salmonids.

<u>Turbidity</u>

Turbidity is a measure of the amount of inorganic and organic material in suspension. Various methods have been proposed for the measurement of turbidity — all of which, at times, prove to be unsatisfactory.

A spectrophotometer or photo-electric meter was used to measure turbidity. This instrument measures the proportion of incident light transmitted through the water sample. One value of this method is that the instrument provides a reading which is free from error of judgment (Knight, 1950). Unfortunately, most of the research and literature in water quality have not used this method. The Jackson turbidimeter is the instrument that is used by most aquatic biologists. It uses a standard candle as a source of light and will measure turbidities that are visible to the eye.

Our measurements of turbidity are in terms of per cent transmittance of light at a wavelength of 450 nm. Measurements of turbidity in the literature are either in Jackson turbidity units or parts per million. Readings ranged from

0 per cent transmittance with a sample of gravel wash water from a seepage into the river at Kaiser's South Plant to 100 per cent transmittance in standing water of summer ponds collected in June from Dry Creek and Austin Creek (Fig. 2).

Fluctuations in turbidity in the mainstem were rather uniform through the river. Asti and Kaiser South were similar in their patterns of turbidity (Fig. 2).

Dry Creek had the greatest amount of turbidity (6 per cent transmittance at Soiland on February 22). Kaiser South, on the same day, had 27 per cent transmittance.

Austin Creek exhibited a great deal of variability within its system. On March 1, East Austin Creek had a per cent transmittance of 97, while the mouth of Austin Creek had a per cent transmittance of 69 per cent. Whether this increase in turbidity is the result of erosion of West Austin Creek, following the Cazadero Fire, or of gravel mining and other instream alterations, will require additional sampling.

With a reduction in summer flow, fine sediments settled out and turbidity levels dropped (i.e., per cent transmittance approached 100). One notable exception was the small pond that formed in the mouth of Dry Creek. Turbidity levels were apparently elevated in that pond because of the swimming activity of tadpoles (Fig. 2). Summer turbidity levels elsewhere were acceptable; water quality improved at the expense of the substrate and stream productivity. Substrate levels of fishes gradually increased (Table 5) and macro-benthic aquatic insects decreased. Winter turbidity levels appear to be high and undoubtedly have an adverse effect on trout and salmon reproduction.

SUBSTRATE ANALYSIS

Introduction

Most stream fishes require channel sediments that have a variety of particle sizes. This is especially true for salmonids which deposit their eggs in sediments of a particular size class (Platts, et. al., 1979). McNeil and Ahnell (1964) demonstrated that fine sediment particles in the streambed reduce permeability and thus cause higher mortality of eggs and fry. Hall and Lantz (1969) found that an increase of 5 per cent in fine sediment smaller than 0.83 mm (0.033 in) in diameter in redds (= nests) decreased survival of emergent silver or coho salmon fry. Platts and Megahan (1975) discovered that large increases in fine sediment loads into stream channels can create intolerable channel modifications in salmonid spawning areas.

Substrate Analysis

One of the "standard" problems encountered in the study of substrates is that a uniform classification is not followed. The "fines" of Hall and Lantz are not the "fines" of Platts. Each governmental agency has devised its own classification of particles or sediments. The term "sediments" has been restricted by one researcher to inorganic particles less than 4 mm; others use the word in a broad sense for particles of any size category. Baracco (1977) in surveying the types of substrates present in Dry Creek, failed to define his categories and consequently his data is difficult to interpret. He did indicate, however, that his "small gravel" had a maximum size of approximately 0.15 m (6 in.). "Spawning gravels" were listed separately from "small gravel." Duff and Cooper (1976) included fine gravel (0.1 to 1.0 inches in diameter) and coarse gravel (1.0 to 3.0 inches in diameter) under the category "spawning gravels."

Because of the sieves available to us, our "fines" represent a diameter of less than 0.90 mm, rather than less than 0.93 mm as defined by Hall and Lantz. If we interpret our substrate data for May and early June (Table 5) in terms of coho (silver) salmon per cent survival to emergence (Fig. 11 of Hall and Lantz), we arrive at the following calculations:

Russian River at Asti: 23% fines or 39% survival of silver salmon.

Russian River at Kaiser South: 29% fines or 13% survival.

Dry Creek at Soiland: 13% fines or 80% survival.

Austin Creek above gravel plant: 17% fines or 64% survival.

Austin Creek below gravel plant: 15% fines or 72% survival.

If we define "fines" in terms of Platts and Megahan (1975) as being less than 4.7 mm (for us less than 5.61 mm) with 10 to 20 per cent present for optimum king salmon spawning, we find that our data indicates:

Russian River at Asti: 47% to 48% fines

Russian River at Kaiser South: 53% fines

The preceding percentages of fines are comparable to those found by Platts and Megahan at the beginning of their study in 1966 on the South Fork of the Salmon River. At that time period, "fines" were 55% and caused dunes to form on the channel bottom and only the tails (downstream end) of some of the king salmon redds remained exposed. A moratorium on logging and road construction in the upper SFSR drainage resulted in a decline of fines to 29% by 1974.

Van Woert and Smith (1962) stated, based on knowledge of Sacramento River king salmon redds, that gravel less than one inch in size may not make up more than 50% of the total sample. If we follow that criterion, we find (using our 22.43 mm sieve as equal to one inch):

Russian River at Asti: 76-83% less than one inch

Russian River at Kaiser South; 82-93% less than one inch

Dry Creek at Soiland: 83-91% less than one inch.

The only conclusion one can arrive at is that our study sites located on the Middle Reaches of the Russian River and Dry Creek no longer have substrate suitable for the spawning of king salmon. According to data provided by ethnographers (Theodoratus, et. al. 1975), king salmon once spawned on Dry Creek. Baracco (1977) recorded what he considered to be suitable spawning habitat for king salmon at 8 transects on Dry Creek, steelhead habitat at 9 transects, and silver salmon at 10 transects. Twenty transects were made in total on Dry Creek, from the mouth upstream to its confluence with Warm Springs Creek. These were based on a superficial analysis of surface sediments, rather than on cores or McNeil samples. Baracco found spawning-sized gravel throughout the study area, but noted that it diminished in quantity below the West Side Road bridge. Our Dry Creek sample site was at this bridge. Additional McNeil samples are needed from above West Side Bridge to fully understand the suitability of Dry Creek for the spawning of salmonids.

Mark West Creek was analyzed for sediment types as a comparison to Austin Creek. It was theorized that it would be a second example of a steelhead stream. Examination of the sediments indicated a high percentage of large particles (averaging 32 per cent) was present, more so than at any other locality sampled. A strong correlation could be made between trout abundance and spawning and the per cent of particles over one inch in diameter. Particles larger than one inch also provide a more appropriate type of substrate for trout foods. The most productive type of substrate is rubble (3 to 12 inches in diameter; see Table 4).

The presence of large particles on the surface of the substrate does not automatically imply a good substrate for salmonid reproduction and for salmonid foods. Surface particles may conceal a large percentage of fines. It is also possible that once the fines are covered, they are much more difficult to remove from the substrate by high flows. Cordone and Pennoyer (1960) also emphasized the importance of the substrate being "loose," i.e., not bound up by clay or silt particles. Clay particles could greatly inhibit the cleansing action of peak flows. Many workers have emphasized that porosity and permeability are as important as particle size and per cent composition.

Pelzman (1973) recommended for streams with controlled flows a decreasing flow in the spring to prevent riparian plant species from becoming established. Tennant (1975) and Hoppe and Finnell (1970) recommended high flushing flows on an annual basis to prevent riparian encroachment and to remove fine material in spawning areas. Baracco (1977) suggested that flushing flows may be valuable in preserving spawning areas if initiated on an annual basis immediately at the onset of controlled flows. The value of riparian plants in providing cover and in cooling the water does not seem to be appreciated by the preceding authors.

SURVEY OF AQUATIC ORGANISMS

Fishes

Fishes collected or observed during the study period are shown in

Table 6. The dominant species, in terms of numbers, for all of the study sites was the Sacramento sucker. Because of its ecological role as a primary consumer (consumer of algae and aquatic plants), the dominance of this species is to be expected. The accompanying figure (Fig. 4), borrowed from Moyle (1975), illustrates the feeding relationships in a pool of the sucker zone or community (see also Hopkirk, 1967; 1974).

Seasonal fluctuations in the numbers of suckers are great. The annual recruitment or "young-of-the-year" in the population was extremely noticeable from April through September. Most of these undoubtedly became the food of other fishes (especially the squawfish) or of fish-eating birds. Large adult suckers and carp were usually seen at Kaiser South and at Healdsburg above the summer-dam. Carp were the dominant species in terms of size.

The Sacramento squawfish, in its role as a secondary consumer of young suckers, was the second most numerous species observed.

Bluegills, green sunfish, and smallmouth bass were not as common as might be expected. These species prey on young suckers and squawfish. Their primary habitat is large pools, or, if present, summer ponds. Johnson (1957) found the smallmouth bass to increase in abundance below Mirabel Park.

The California roach, a small omnivorous species of minnow that is common in intermittent foothill streams, was seen in some abundance in Dry Creek and in Austin Creek. In the side channels of the main river, young roach were a minor part of the large schools of young suckers and squawfish.

The steelhead or rainbow trout was seen in moderate numbers in Austin Creek, but rare or uncommon elsewhere (Table 6). Trout in Austin Creek became reduced in numbers as the summer progressed. The presence of trout appears to be more strongly related to cold water temperatures than with the status of the non-game species populations. The feeding relationship of trout to suckers, as interpreted by Moyle (1975), is shown in Fig. 5. The aquatic invertebrates (mayflies, Caddisflies, and stoneflies) preferred by trout were noticeably absent, along with trout, in areas of heavy siltation (Russian River at Kaiser South).

The omnivorous hardhead minnow, a close ecological associate of squawfish and sucker, was present in small, but expected, numbers at some sites. The hardhead prefers the warm main channel and lower reaches of primary tributaries.

The tuleperch, discussed under the section on "Rare and Endangered Aquatic Organisms," was nowhere common. Johnson (1957) found it to be uncommon during the period of 1954 to 1956. The tuleperch represented 3.0% of the catch between Ukiah and Healdsburg and 3.5% of the catch between Mirabel Park and Duncan Mills. During our sampling in 1979 it represented only 0.9% of the total catch.

Sculpins were only seen on Austin Creek. Sticklebacks were more numerous in primary tributaries than in the main river.

Aquatic Invertebrates

Aquatic insects were most diverse at the Asti sampling site (Table 2). Side channels and riffles of the main channel revealed a healthy fauna. The least productive site for aquatic insects was the Kaiser South sampling site. A strong correlation must exist between substrate size and species diversity in aquatic insects: the larger the particle size, the greater the diversity. Realize though that the preceding is valid only for streams and only for the macro-benthic insects, such as mayflies, stoneflies, Caddisflies, damselflies, and dragonflies.

The Oriental clam was present in areas of heavy siltation, such as the Russian River at Kaiser South. The absence of this species could be used as an indication of a healthy, unsilted stream. Other species of mollusks were also present but not identified because of time restrictions.

IMPACT OF GRAVEL MINING ON THE AQUATIC ORGANISMS OF THE RUSSIAN RIVER SYSTEM

In an earlier section we discussed the possible effects, direct and indirect, on aquatic organisms. Let us look at those effects again, but this time in terms of the aquatic organisms of the Russian River system.

Direct Effects

1. Physical destruction or death of organisms due to the direct effects of gravel mining activities. This effect was not witnessed but undoubtedly occurs. Because most instream mining has been discontinued, the direct destruction of organisms is not as great as it was in times past. The construction of summer dams on Austin Creek by property owners probably causes the direct death of more organisms than any other type of instream activity (see Forester and Jones, 1973).

2. Direct removal of substrate sizes necessary for reproduction (spawning, nest-building). During the dry season, gravel operators skim off the gravel from bars and berms. This process removes gravel that is appropriate for concrete (0.5 to 1.5"); particles over 2 inches are also taken but have to be crushed. Because spawning gravels range in diameter from 0.1 to over 6 inches, depending upon the species, it would appear that gravel extraction directly removes spawning gravels from the streambed. In our studies of the substrate, large particles were scarce around gravel operations. The extraction pond of Bohan-Canelis on Austin Creek on October 5 (Table 5) revealed a great reduction (average of 2.8 per cent) in coarse particles over 22.43 mm and a great increase (up to 69% in one sample) in fines. The removal of larger particle sizes, especially rubble, also reduces secondary productivity (mayflies, stoneflies, Caddisflies) or the foods available to trout. Rubble (3 to 12 inches) and gravel (1/8 to 3 inches in diameter) are the preferred sediments for these aquatic insects (see Table 4).

3. Direct removal or destruction of fish habitats. During the past few years, overt destruction of fish habitat has been accomplished by the Piambo Plant located north of Geyserville

Bridge. The mouth of Gill Creek was mined out and a new mouth and creek channel formed upstream from the plant. Adjacent side channels of the river were graded off and cleared of riparian vegetation.

The streambed procedures used by Piambo are typical ones. The main channel is redirected and constricted to expose a greater amount of dry streambed. The surface of the berm between channels is planed off. When winter flows arrive, they tend to spread out and widen the streambed through bank erosion. With a reduction in velocity over the extremely widened berm, fine sediments settle out and accumulate on spawning beds.

Every spring, Basalt Rock Company, a subsidiary of Dillingham Corporation, constructs an instream pond on the river near the mouth of Dry Creek. This pond is apparently dug in the wettable bed of the river. Evidence to support this hypothesis was the presence of native non-game species (roach and squawfish) in the pond. This activity may also interfere with the downstream migration of fishes out of Dry Creek.

Diversion of streams and isolation of organisms into dessicating pools. In Austin Creek, the main channel was reduced by a small gravel levee to a width of 10 feed and directed toward the shaded east side of the streambed. This allowed the operator, Bohan - Canelis, to extract gravel from the center of the streambed. Trout had been present in large numbers (100 plus) at the beginning of summer in that section of the stream. As the summer progressed and flows became reduced, fewer trout were seen. No trout or large fish were seen in the instream pond. At the end of summer, the main channel was a series of disconnected pools, almost completely concealed by riparian vegetation. Because of downgrading of the creek in that section, undercut banks were poorly developed and provided little cover.

Construction of summer dams and roads which block migration. The construction of summer road crossings by gravel operators is a real problem. Summer dams and summer road crossings interrupt the migration of salmonids, shad, and native non-game species. Basalt Rock Company has constructed a road across the mouth of Dry Creek every dry season. In 1979, the road was already in position by the 10th of May. Past mining activities in the river that downgraded the mouth of Dry Creek, and present road construction and instream pond construction have destroyed the mouth of the creek as a fish habitat. Other summer activities at the mouth of the creek (swimming, off-road vehicles, motorcycles) have not helped the fishes. Species such as the squawfish, sucker, roach, tuleperch may be prevented from migrating upstream or into the mouth of the creek. Early construction of the Dry Creek summer roads, prior to the 5th of May, would block tuleperch from delivering their young in the creek mouth. The presence of the "summer" road into fall (present on November 17 in 1978) and its manner of removal, by the first major storms of winter, cause additional problems for migratory species and for those that frequent the mouths of tributaries.

Indirect Effects

1. Release of fine sediments into the river during instream extraction or during the washing of gravel. Fine sediments can be present either in suspension or in settled form. In suspension, fines increase turbidity, which reduces light penetration (hence photosynthesis and primary productivity), reduces visibility, and clogs the respiratory structures of organisms. Organisms that rely more on olfaction and touch (suckers, some minnows) do better in turbid water than those that rely on vision (trout, salmon). In settled form, fines fill crevices between gravel, thereby reducing the cover and surface area available for aquatic insects and young fish, and alter the relative composition of the substrate, thereby decreasing the value of the substrate for spawning.

   The substrate in the vicinity of Kaiser South had a high percentage of fines in comparison to other sample sites. Suckers were also extremely abundant, Oriental clams were common, and lotic benthic insects (mayflies, stoneflies, caddisflies, damselflies, and dragonflies) were essentially absent. A major cause of the excess fines in the substrate is the occasional release of seepages of gravel wash water into the river. On March 13, 1979, a seepage with a flow of 0.2 cfs and a turbidity of 0% light transmittance was observed. A small wash water pond, parallel to the wetted stream channel and within 10 to 20 feet of it, was present throughout the summer. Water that entered the pond flowed in an upstream direction and eventually seeped through gravel and into the river.

2. Release of excessive amounts of fine sediments into the river by the flooding of gravel wash ponds, terrace pit ponds, summer roads, and levees. Huge amounts of fine sediments are dumped into the river if a terrace pit pond floods or if a gravel wash pond floods. Ponds of the preceding type accumulate fine sediments. On February 22 of 1979, the south pond of the Kaiser North Plant was observed with a 50 foot break in the levee which had separated it from the river. The California Department of Fish and Game feels that these flooded ponds may also trap upstream migrants and prevent them from spawning.

   Fine sediments are also released from instream ponds during winter flooding. An old instream pond in a flood channel of the river near the mouth of Hop Kiln Creek was noted during the early summer of 1979. It could be seen that fine sediments, probably clay, had fanned out of the pond on its downstream side and after drying, had compacted the substrate.

The water in the pond was quite turbid, indicating that a large amount of fine sediment was still present and would remain a problem for many years to come.

3. Changes in the physical features of a river or of its tributaries so that bank and streambed erosion is increased. The past downgrading of the streambed through gravel extraction has already been well documented. Bank erosion is increased, as mentioned earlier in this section, by the planing-off of the berm or by constricting the channel of the river. Most tributaries of the river in the vicinity of gravel mining have been downgraded. A prime example is Hop Kiln Creek. A six-foot downgrading of the stream occurred following the extraction of gravel from the river. Evidence in support of this recent event is that the roots of riparian trees form a canopy four to five feet over the bed of the creek.

   The improper placement and removal of culverts in the summer road across Dry Creek allows early winter flows to be directed toward the north bank of the creek. This results in the erosion of large amounts of topsoil. A "soilberg" six feet long slumped into the creek on January 8, 1979. The summer road itself undoubtedly contributes a large amount of silt into the river.

   Because of gravel mining activities, large pools or deep holes are no longer present on the river. Clem Vanoni, a long time resident of the Geyserville area, in an interview with Howard Cunningham, claimed that at one time deep clear pools existed in his region of the river. Salmon could be seen in these pools, some of which were up to 25 feet in depth and surrounded by riparian growth. A deep cold water layer could have existed in these holes, especially if springs were present at their bottom. Winzler and Kelly (1978) recorded the presence of a deep pool, maximum depth of 42 feet, at river mile 5. Surface water temperatures were 26.0°C, at 20 feet the temperature was 19.0°C, and at 42 feet the temperature was 17.5°C. No canopy was present. Water at the bottom was slightly saline.

4. Removal of riparian vegetation. The removal of riparian vegetation increases water temperature, removes cover or shelter for fishes, reduces the food supply (insects) for fishes, reduces the enrichment of the stream, and on small streams, reduces the formation of pools and riffles.

   Hall and Lantz (1969) found that the maximum water temperature in a coastal stream of Oregon went from 16°C to 30°C following the clearcut logging of the watershed. Maximum diurnal fluctuation went from 1.5°C to 16°C.

   Water temperature data from Austin Creek on September 7, 1979 indicated that the riparian canopy lowered the water temperature from 4° to 10°F (1.7° to 5.6°C) depending upon water depth and velocity. On other dates the effect of canopy or shade was about the same. A wide spectrum of water temperatures was recorded on September 7 (air temperature of 77°F or 25°C):

77°F (25.0°C): exposed, isolated shallow pool formed by wheels of dump trucks; water boatmen and young sticklebacks present.

73.4°F (23.0°C): exposed shallow riffle below summer pond.

72.0°F (22.2°C): partially shaded main channel; schools of small roach and suckers.

71.6°F (22.0°C): exposed summer pond ("Austin Creek above gravel plant" study site); young suckers, roach, and squawfish present; mats of filamentous algae cover bottom of pond and some extent to surface.

70.0°F (21.1°C): exposed and isolated instream gravel extraction pond of Bohan-Canelis; less than 3 feet deep; a few young sticklebacks seen.

68°F (20.0°C): completely shaded flowing water in diverted main channel ("Austin Creek below gravel plant" study site); steelhead trout, about 4 inches long, dead in middle of channel.

66°F (18.9°C): completely shaded flowing water in diverted main channel, immediately upstream from preceding; wet bank indicated entrance of spring seepage at this point; a few trout present, one about six inches long.

The gravel operator, Bohan-Canelis, appears to be quite conscientious about procedures, i.e., riparian vegetation was not removed, side channel was formed properly, long-term records have been kept of stream changes. Summer recreational ponds on Austin Creek appear to be more of a problem in warming the water than the gravel extraction. Riparian vegetation on Austin Creek, and elsewhere, lowers water temperature, provides shade (of importance to large trout), and, more important perhaps than any other factor, provides cover or protection from predators. Fish-eating birds are common on the Russian River system. Removal of riparian vegetation, even if only a few willows, provides fish-eating birds with improved visibility and means, in the final analysis, fewer trout in the system.

5. Reduction of lotic or running water habitat and its replacement by lentic or standing water habitat. The construction of instream ponds, roads, and levees creates impoundments that are favorable for warm water species (suckers,

squawfish, sunfishes, basses) and poor for coldwater species (trout and salmon).

Klampt (1972) and Forester and Jones (1973) record the changes brought about by the construction of summer recreational ponds on Austin Creek. Because trout and silver salmon cannot tolerate the warm water of the summer ponds, they are forced into the greatly restricted lotic habitats that are present between ponds. Recommendations arrived at in 1972 are still valid now.

Although the gravel industry does not contribute directly to the preceding problem, except perhaps in the physical construction of the dams, they do benefit from any stream alteration that increases the dry surface of the streambed— the surface that under present regulations they are allowed to mine.

MANAGEMENT RECOMMENDATIONS

Mining Procedures

The California Department of Fish and Game has prepared a list of twenty-two recommendations which can be agreed upon with the operator in the alteration of streams or lakes ("Agreement Regarding Proposed Stream or Lake Alteration"). This list, if conscientiously followed, would suffice for most gravel operations. Unfortunately, not all operations are diligent in following the recommendations. Second, an illustrated handbook of "do's" and "don'ts", comparable to that prepared by the State Motor Vehicle Department, would better enable operators to understand the recommendations of the Fish and Game Department.

Our own recommendations are slightly more extreme:

1. Elimination of instream mining of sand and gravel, except for purposes of flood control; if for flood control, it should be under the strict supervision of the California Department of Fish and Game and other state agencies. Small instream operators should be given a five-year extension but with extraction not to exceed the amount taken in 1979.

2. Reduction and eventual elimination, of summer dams and ponds.

3. Elimination of all instream settling ponds.

4. Elimination of all vehicular travel, except for emergency or flood control purposes, from the streambeds of the Russian River and its tributaries.

5. Elimination of wastewater ponds, gravel wash ponds, and eventually terrace-pit ponds, from the natural floodplain

of the river. Adequate levees should be constructed around the ponds that are presently being operated. Operators not in compliance with the preceding should lose their permit to operate in the county of Sonoma.

6. Elimination of summer road crossings, and of any other gravel mining activity, from around the mouths of tributaries for a distance of one mile on either side (upstream or downstream) on the river.

7. Complete protection of any riparian forests, shrubs, etc., that now exist along the river and its tributaries; only exception would be for flood control and then, under the strict supervision of Fish and Game personnel.

Reclamation and Mitigation

Gravel operators should be required to pay for the costs of any improvements that are necessary to rehabilitate areas that they have mined. Terrace pit ponds and other major changes in the landscape, especially those that are within the natural floodplain of the river, should be restored to their original condition (with vegetation indigenous to the region). Structures or methods (levees, diversion channels, etc.) should be devised to direct fine sediments, present in ponds, mounds, whatever, away from the river.

Gravel operators should provide funds to monitor the river for a ten-year period. This study would include a complete mapping, inventory, and survey of areas that had been previously mined. State water quality stations should be established, if not already present, near areas of mining to record changes in water quality.

An intercounty commission or agency should be established to deal with the problems of the river and its watershed. Members should include not only appointees from each county, but also members from all of the governmental agencies or groups that have an interest in the natural resources of the Russian River system.

Monitoring

The 10-year monitoring of the fisheries, if established, should include the following:

1. Water quality; sampling should be done with each sampling of aquatic organisms.

2. Aquatic organisms: fishes and benthic invertebrates; sampling should be done throughout the year with appropriate methods and include sites of past mining (mainstem, tributaries, terrace ponds, washwater ponds).

3. Size and composition of particles in the substrate of mainstem and tributaries; sampling should be done throughout the year with the aid of a McNeil sampler and a sampler yet to be devised, that samples a larger area and particle size.

4. Transects of the streambed of the main stem and tributaries.

    a. Photographic transects that record changes in surface particles — made at sites of McNeil sampling.

    b. Depth and extent of channels, at the beginning of summer and at the end of summer, that record changes in the substrate, especially under bridges which form semipermanent markers.

5. Limnological studies of selected ponds that have been created through gravel extraction.

6. Recreational use of the fisheries resource.

SUMMARY

The gravel industry of Sonoma County has, since the time period following World War II, adversely affected the quality of the Russian River and its associated biota. Major downgrading of the streambed through past mining has removed large particle sizes (needed for fish reproduction and food organisms) and increased the percentages of "fines" in the substrate. This has greatly reduced the quality of the sport and commercial fishery for trout and salmon; native non-game species have benefited from the mining and sedimentation. Removal of riparian vegetation along the river and its tributaries has increased summer water temperatures and removed cover necessary for trout. Construction of dams and increased human demands for water during the summer have also brought about adverse summer water temperatures.

Although instream mining has declined, the release of fine sediments from terrace pit and settling ponds is a continual hazard, due to their improper location within the flood plain and poor levee construction. A number of recommendations are made to protect the fishery. Monitoring of the fisheries in past areas of mining is advised for a 10-year period. Information is to be gathered on water quality, aquatic organisms, size and composition of particles in the substrate, streambed characteristics, limnology of gravel mining ponds, and recreational use of the fisheries resource.

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TABLE 1. FISHES OF THE RUSSIAN RIVER SYSTEM*

Family Petromyzontidae — lampreys		
	Lampetra ayresii (river lamprey)	A,N
	L. pacifica (Coastrange brook lamprey)	R,N
	L. tridentata (Pacific lamprey)	A,N
Family Acipenseridae — sturgeons		
	Acipenser medirostris (green sturgeon)	A,N
	A. transmontanus (white sturgeon)	A,N
Family Clupeidae — herrings		
	Alosa sapidissima (American shad)	A,I
	Clupea pallasii (Pacific herring)	E,N
Family Engraulidae — anchovies		
	Engraulis mordax (northern anchovy)	E,N
Family Osmeridae — smelts		
	Hypomesus pretiosus (surf smelt)	E,N
Family Salmonidae — trouts		
	Oncorhynchus gorbuscha (pink salmon)	A,N
	O. kisutch (coho or silver salmon)	A,N
	0. tshawytscha (chinook or king salmon)	A,N
	Salmo gairdnerii (steelhead or rainbow trout)	A or R,N
	S. trutta (brown trout)	R, I
Family Cyprinidae — minnows		
	Carassius auratus (goldfish)	R,I
	Cyprinus carpio (carp)	R,I
	Hesperoleucus symmetricus (California roach)	R,N
	Lavinia exilicauda (hitch)	?I,R
	Mylopharodon conocephalus (hardhead)	R,N
	Orthodon microlepidotus (Sacramento blackfish)	?I,R
	Ptychocheilus grandis (Sacramento squawfish)	R,N
Family Catostomidae — suckers		
	Catostomus occidentalis (Sacramento sucker)	R,N
Family Ictaluridae — catfishes		
	Ictalurus catus (white catfish)	I,R
	I. melas (black catfish)	?I,R
	I. nebulosus (brown catfish)	I,R
	I. punctatus (channel catfish)	I,R

*List compiled from
Hopkirk, 1979; Hubbs, Follett and Dempster, 1979; Moyle, 1976.

A = anadromous; I = introduced; E = estuarine;
R = resident; N = native to Russian River

Table 1, continued

Family	Poeciliidae -- livebearers	
	Gambusia affinis (mosquitofish)	I,R
Family	Atherinidae -- silversides	
	Atherinops affinis (topsmelt)	E,N
Family	Gasterosteidae — sticklebacks	
	Gasterosteus aculeatus (threespine stickleback)	A,N
Family	Syngnathidae — pipefishes	
	Syngnathus leptorhynchus (bay pipefish)	E,N
Family	Cottidae — sculpins	
	Cottus aleuticus (Coastrange sculpin)	R,N
	C. asper (prickly sculpin)	R,N
	C. gulosus (riffle sculpin)	R,N
	Leptocottus armatus (Staghorn sculpin)	E,N
Family	Serranidae — sea basses	
	Roccus saxatilis (striped bass)	A,I
Family	Centrarchidae — sunfishes	
	Archoplites interruptus (Sacramento perch)	?I,R
	Lepomis cyanellus (green sunfish)	I,R
	L. macrochirus (bluegill)	I,R
	L. microlophus (redear sunfish)	I,R
	Micropterus dolomieu (smallmouth bass)	I,R
	M. salmoides (largemouth bass)	I,R
?	*Pomoxis annularis* (white crappie)	I,R
	P. nigromaculatus (black crappie)	I,R
Family	Embiotocidae — Surfperches	
	Cymatogaster aggregata (shinerperch)	E,N
	Hysterocarpus traskii pomo (Russian River	R,N
Family	Grobiidae — gobies	
	Clevelandia ios (arrow goby)	E,N
?	*Acanthogobius flavimanus* (yellowfin goby)	I,E
?	*Eucyclogobius newberryi* (tidewater goby)	E,N
Family	Pleuronectidae — righteyed flounders	
	Platichthys stellatus (starry flounder)	E,N

TABLE 2, AQUATIC INSECTS IDENTIFIED FROM BOTTOM SAMPLES

Order EPHEMEROPTERA (mayflies)	
Family Heptageniidae	(stream mayflies)
Cinygma	Primary tributary; riffle
Heptagenia	Primary tributary; riffle
Ironodes californicus	Primary tributary; riffle
Iron albertae	Main stream; riffle
Family Baetidae	(small mayflies)
Serrata tibialis	Primary tributary; riffle
Isonychia velma	Primary tributary; riffle
Order ODONATA	(dragonflies and damselflies)
Suborder ANISOPTERA	(dragonflies)
Family Gomphidae	(club-tailed dragonflies)
Hagenius	Primary tributary; riffles and pools
Erpetogomphus compositus	Primary tributary; pools
Family Aeshnidae	(common darners)
Anax junius	Main stream; lentic-side channel
Family Libellulidae	(skimmer)
Helocordula	Main stream; pool
Pseudoleon superbus	Main stream; lentic-side channel
Suborder ZYGOPTERA	(damselflies)
Family Agrionidae	(broad winged damselflies)
Hetaerina americana	Main stream; pool
Family Lestidae	
Lestes unguiculatus	Main stream; lentic-side channel
Family Coenagrionidae	
Chromagrion	Main stream; lentic-side channel
Amphiagrion abreviatum	Main stream; pool
Order PLECOPTERA (stoneflies)	
Family Nemouridae	(spring stoneflies)
Isocapnia grandis	Primary tributary; riffle

Table 2, continued

Order HEMIPTERA	(true bugs)
Family Corixidae	(water boatmen)
Graptocorixa californica	Main stream; lentic-side channel
Family Naucoridae	(creeping water bugs)
Ambrysus mormon	Mainstream; pool and lentic-side channels
Family Belostomatidae	(giant water bugs)
Belostoma flumineum	Main stream; lentic-side channels
Family Nepidae	(water scorpions)
Ranatra brevicollis	Main streams; lentic-side channels
Order COLEOPTERA	(beetles)
Family Psephenidae	(Water-penny beetles)
Psephenus haldemani	Main stream; riffle
Order TRICHOPTERA	(caddis flies)
Family Hydropsychidae	(net-spinning caddisflies)
Diplectrona	Main stream-riffle; primary tributary-riffle

TABLE 3. MAJOR AQUATIC HABITATS OF THE RUSSIAN RIVER

Natural Aquatic Habitats

- Mainstem
  - Main Channel
    - Riffle
    - Pool
    - Estuarine Lagoon
  - Side Channel
    - Streambed Side Channel
    - Flood Channel ("Deep Holes," Ox-bow Lakes)
- Tributaries
  - Mouth
  - Primary (composed of main channel, side channel, riffle and pool habitats)
  - Secondary
  - Tertiary

Artificial Aquatic Habitats

- Temporary or "Summer"
  - Recreational Pond
  - Road Crossing Pond
  - Instream Mining Pond
  - Diversion Channel
- Permanent or Semipermanent
  - Waste Water Pond (Wash Water Pond)
  - Waste Treatment Pond (Municipal; Winery)
  - Terrace Pit Pond
  - Reservoir (Pond or Lake)

TABLE 4. HABITAT REQUIREMENTS FOR THE REPRODUCTION OF STEELHEAD, SILVER SALMON, AND KING SALMON*

Upstream Migration, or "Passage" Requirements:

Steelhead: water temperature 45° to 60°F (7.2 to 15.5°C); minimum water depth 0.6 feet (0.18 m); maximum water velocity 8 feet (2.4 m) per second; flow 75 cubic feet per second (cfs) (2.1 m^3/sec)

Silver Salmon: same as that of steelhead

King Salmon: minimum water depth 0.8 feet (0.24 m); maximum water velocity 8 feet/second; flow 105 cfs (2.94 m^3/sec)

Spawning Habitat:

Steelhead: water temperature 42° to 55°F (5.8 to 12.8°C); minimum water depth 0.8 feet (0.24 m), mean of 1.4 feet; water velocity 1.27 to 3.0 feet (0.4 to 0.91 m)/sec measured 0.5 feet (0.15 m) above streambed; gravel averages between 0.5 to 4 inches (12.7 to 101.6 mm) in diameter.

Silver Salmon: minimum water depth 0.5 feet (0.15 m); water velocity 0.7 to 2.3 feet (0.2 to 0.7 m)/sec; gravel size same as steelhead

King Salmon: minimum water depth 0.8 feet (0.24 m), mean of 1.3 feet; water velocity 0.98 to 2.5 feet (0.3 to 0.7 m)/sec; gravel size ranges between 1 and 6 in (25 to 152 mm) in diameter with 30% or less measuring 6 to 12 in, 10% or less 3 to 6 in, 50% or less 1 to 3 in and no more than 50% of total sample less than 1 in

Nursery Habitat:

Steelhead: water temperature for fry 32-55°F (0-12.5°C); water temperature for downstream migrants less than 59°F (15°C); maximum water temperature less than 68°F (20°C); minimum water depth 0.5 ft (0.15 m) for fry, usually 0.5-4 ft for juveniles; water velocity 0.5-3.5 fps (0.15-1.1 mps) for young; minimum flow 2.0 m^3/sec, optimum 3.1 m^3/sec; substrate most productive of foods (based on Pit River): rubble (3-12" in diameter) rated 1.0 or highest, gravel 1/8-3" in diameter) rated 0.6, silt rated 0.2, sand rated 0.1 or lowest; minimum cover 10% of wettable area; shade preference increases with size of fish

Silver Salmon: water temperatures and depth similar to those of steelhead; water velocity optimum 0.7 fps; minimum flow 2.0 m^3/sec; substrate as with steelhead; juveniles avoid excessive shade

*Compiled primarily from Winzler and Kelly, 1978 and Baracco, 1977

Table 4, continued

King Salmon: water temperatures and depths similar to those of steelhead and silver salmon; optimum temperature for juveniles released from hatchery 7.7°C ±1.6°C; minimum flow 2.9 m^3/sec, optimum 3.1 m^3/sec (110 cfs)

Table 5. SUBSTRAT ANALYSIS: MCNEIL SAMPLES

Date	Particle Size >22.43 mm	>11.20mm	>5.61mm	>2.79 mm	>0.90mm	Fines	Suspended Fines
ussian River (Asti):							
June 10	23.6 (17.6–31.6)	13.8 (12.9–14.9)	14.2 (11.1–17.8)	11.0 (4.6–14.7)	14.4 (12.2–16.6)	22.9 (21.2–25.5)	0.8
uly 22	17.5 (11.5–21.7)	18.9 (16.6–20.1)	16.4 (13.3–18.6)	13.6 (12.1–16.3)	12.0 (10.6–13.6)	21.6 (20.1–23.3)	<1.0
ussian River (Kaiser South):							
ay 10	7.0 (3.1–10.1)	11.4 (8.1–14.6)	14.3 (13.1–17.0)	10.4 (8.9–11.4)	28.1 (21.2–34.3)	28.7 (25.7–32.6)	
uly 3	12.8 (7.7–16.2)	15.4 (12.1–18.0)	16.0 (13.9–19.8)	13.5 (10.6–16.4)	14.1 (12.5–16.4)	28.2 (22.8–32.3)	0.4
ct. 14	18.3 (13.6–21.5)	14.4 (12.3–16.2)	14.0 (11.9–15.0)	10.0 (7.6–12.9)	8.5 (6.1–11.3)	34.8 (31.7–37.7)	
ry Creek (Westside Rd. Bridge):							
ay 31	16.4 (12.2–20.8)	27.4 (25.3–30.8)	19.8 (17.4–23.3)	11.0 (10.0–11.8)	12.3 (7.2–20.6)	13.1 (8.9–16.1)	<.8
uly 10	9.0 (6.8–11.1)	19.0 (14.8–26.8)	20.8 (17.6–24.7)	14.4 (13.2–15.2)	16.0 (10.8–23.3)	20.7 (17.5–22.3)	0.3
ustin Creek (above gravel plant):							
ay 17	18.8 (11.1–27.5)	13.9 (6.2–28.0)	11.0 (10.8–11.1)	14.6 (6.5–21.2)	24.6 (13.8–35.8)	17.2 (13.5–19.6)	
une 24	18.4 (9.8–26.1)	17.4 (10.2–23.2)	15.5 (9.6–21.1)	12.8 (9.7–15.0)	15.8 (12.2–19.3)	20.1 (18.4–21.8)	0.5
ustin Creek (below gravel plant):							
ay 17	22.2 (15.3–29.4)	20.0 (18.8–22.3)	13.3 (11.1–14.5)	12.7 (12.0–13.1)	16.9 (12.4–19.9)	14.9 (13.2–16.5)	
une 24	21.5 (16.8–27.6)	21.7 (17.8–29.4)	14.7 (12.8–17.3)	10.1 (8.5–10.9)	14.0 (12.5–15.6)	18.0 (15.6–20.3)	
ug. 11	12.9 (4.5–19.3)	23.2 (17.5–29.4)	16.1 (15.7–16.4)	12.2 (11.1–12.7)	11.8 (8.6–13.7)	23.9 (13.9–36.2)	<1.0
ct. 5 (instream Pond)	2.8 (0–5.2)	9.6 (1.1–13.8)	13.4 (8.8–17.2)	13.4 (8.8–17.2)	11.6 (9.5–15.2)	49.0 (36.3–69.2)	

Table 5—continued:

Date	Particle Size >22.43 mm	>11.20 mm	>5.61 mm	>2.79 mm	>0.90 mm	Fines	Suspend Fine
Mark West Creek:							
Nov. 9	31.9 (6.7–46.1)	10.4 (8.0–14.6)	15.0 (11.9–18.8)	13.9 (10.7–19.2)	13.4 (7.3–23.4)	15.4 (13.1–17.3)	

TABLE 6. FISHES COLLECTED OR OBSERVED AT SIX STUDY SITES ON THE RUSSIAN RIVER IN 1979

Study Site	Date	steelhead	carp	roach	squawfish	hardhead	sucker	stickleback	green sunfish	bluegill	smallmouth bass	tuleperch
Russian River (Asti)	4/21						11					
	6/10			6	34		(LS)					
	6/22	2			(LS)*		(LS)					
	7/22			17	27		91					
	8/19			35	44		4					
	9/14			2	12	10	1					
Russian River (Kaiser South)	5/10			6	5		47					
	8/19				(LS)							
	9/14				3	5				12		
Dry Creek (West Side Bridge)	3/12			(S)*								
	3/22			(LS)36	21		6	14				
	4/17			3	111			11	2			
	5/10			5	2		9	1				
	5/15			20	7		(LS)9	(S)15				
	5/31			11	1				1			
	7/10			8	1		1	13				3
Dry Creek (mouth)	6/22	2		13	11		7			4		
	8/5				(S)	(S)	(S)			(S)		
	9/7	1	1		17	8	33			5		
Austin Creek (above gravel plant)	3/29	4		20	4							
	6/24	5					(LS)3					
	9/7	1										
Austin Creek (below gravel plant)	4/21	1					(LS)					
	6/24	3		(LS)			(LS)					
	8/5	(LS)14		(S)11			(S) 5	19				
	8/11							(S)				

* S = school observed LS = large school observed

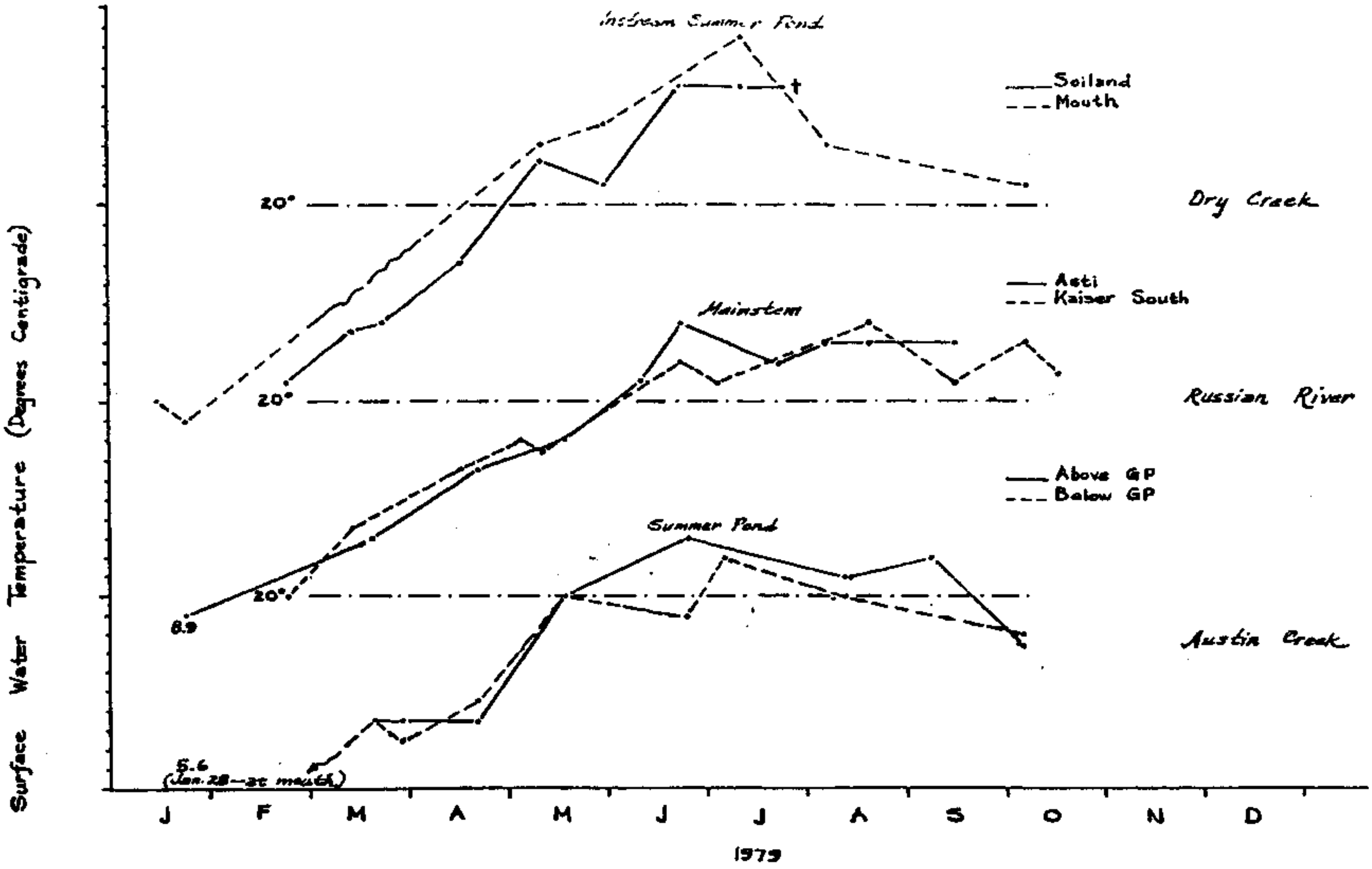

Figure 1. Seasonal Changes in Surface Water Temperature at Six Study Sites on the Russian River System in 1979.

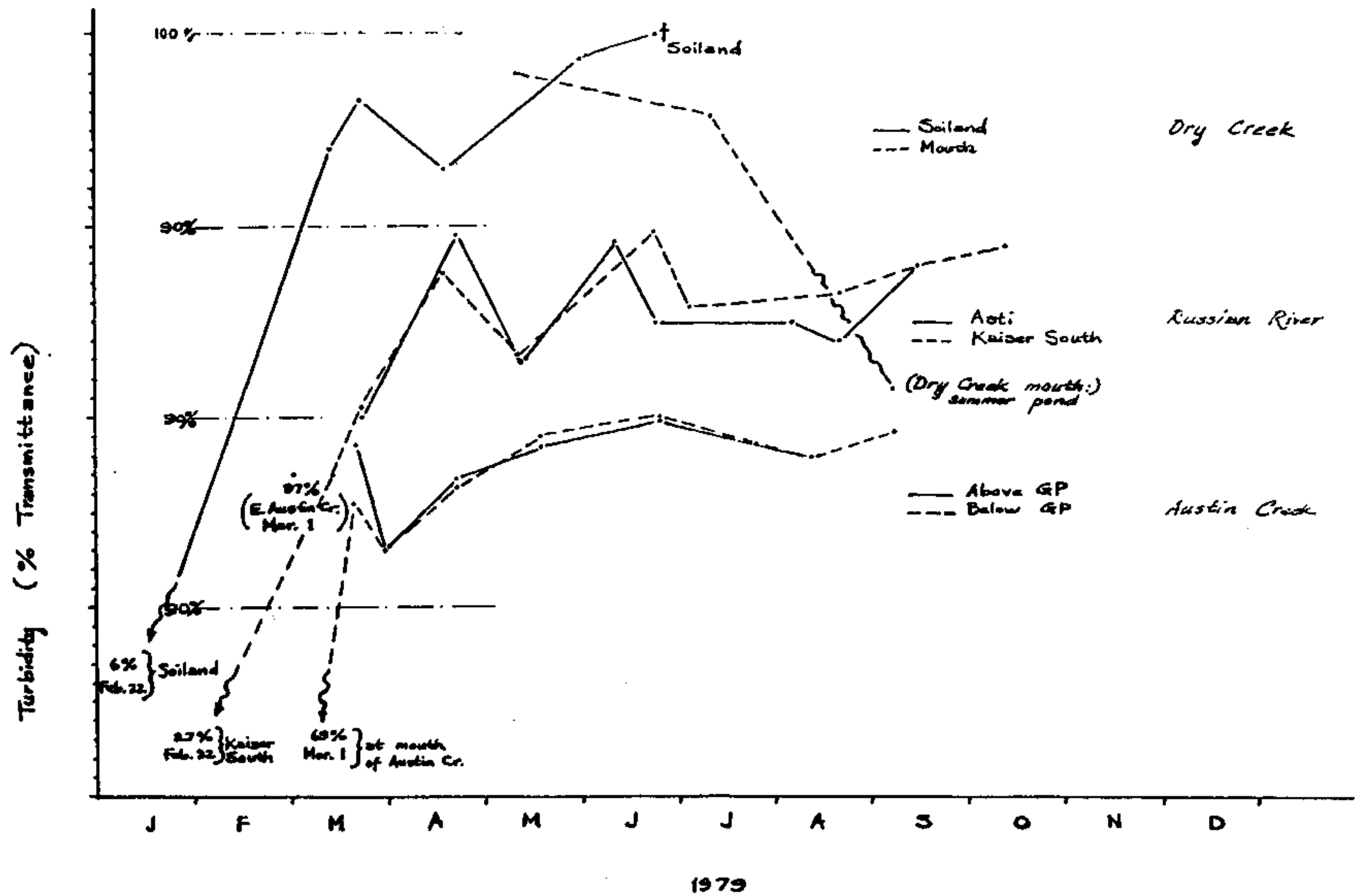

Figure 2. Seasonal Changes in Turbidity (% Transmittance) at Six Study Sites on the Russian River System in 1979.

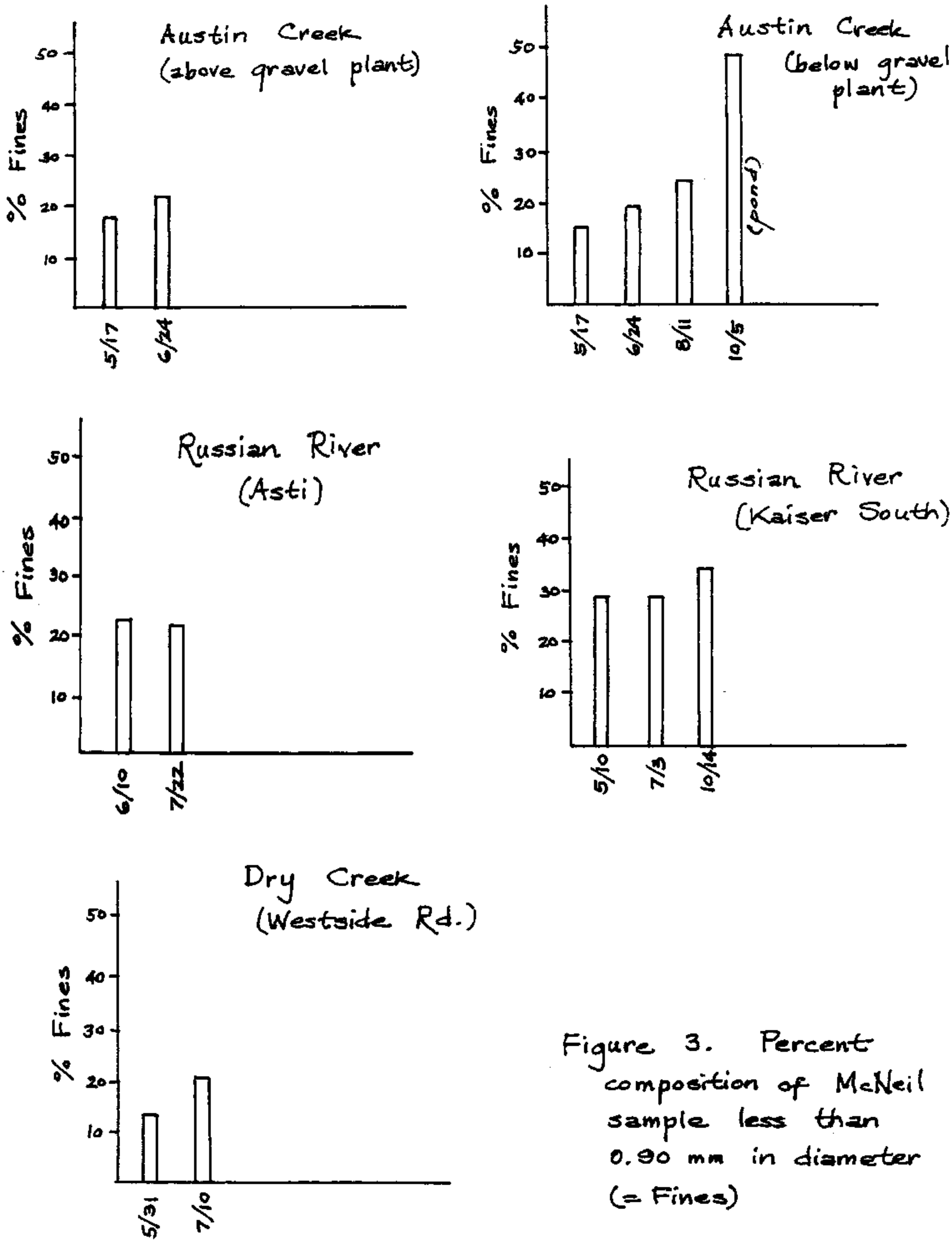

Figure 3. Percent composition of McNeil sample less than 0.90 mm in diameter (= Fines)

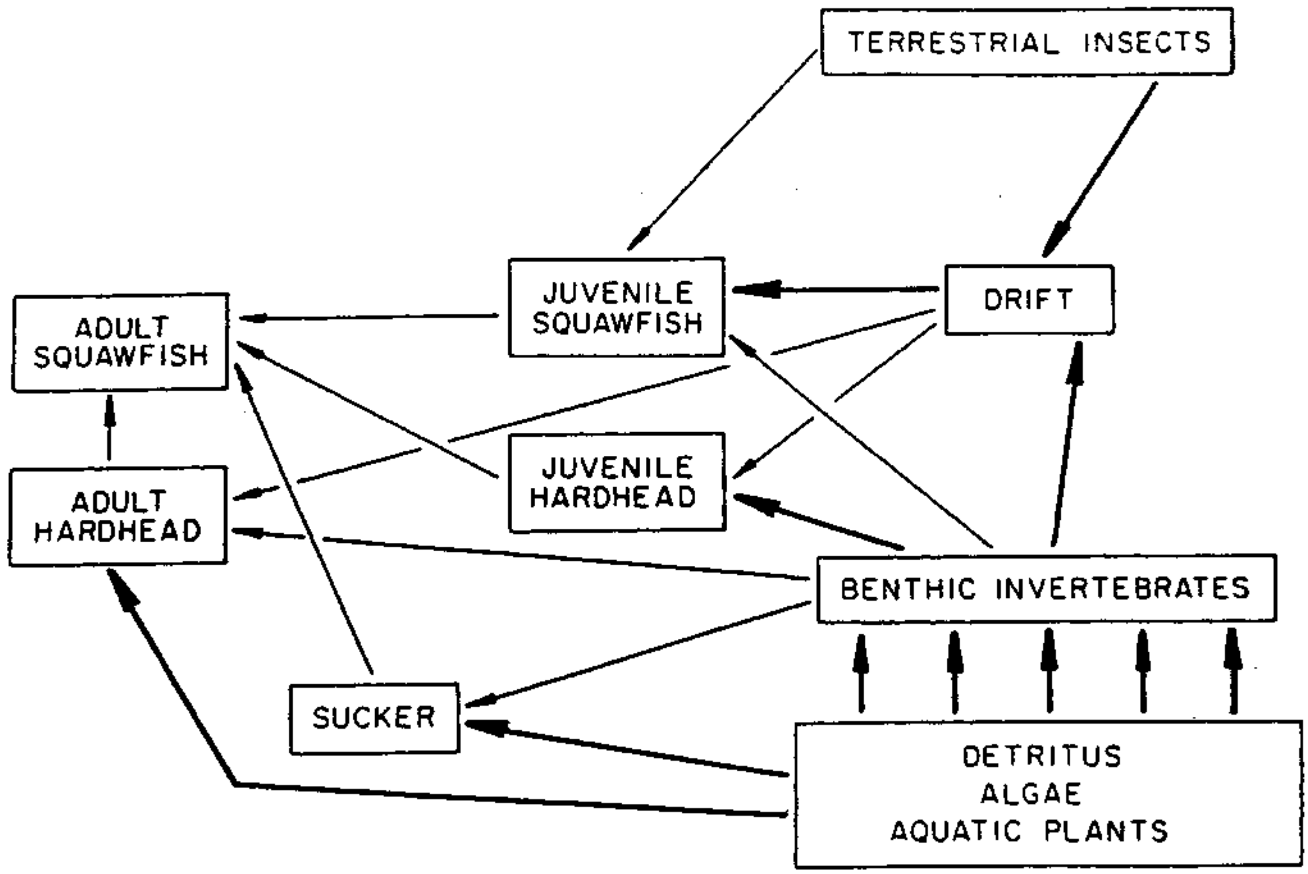

Figure 4. Feeding Relationships in a Pool of the Sucker Zone or Community (Moyle, 1975).

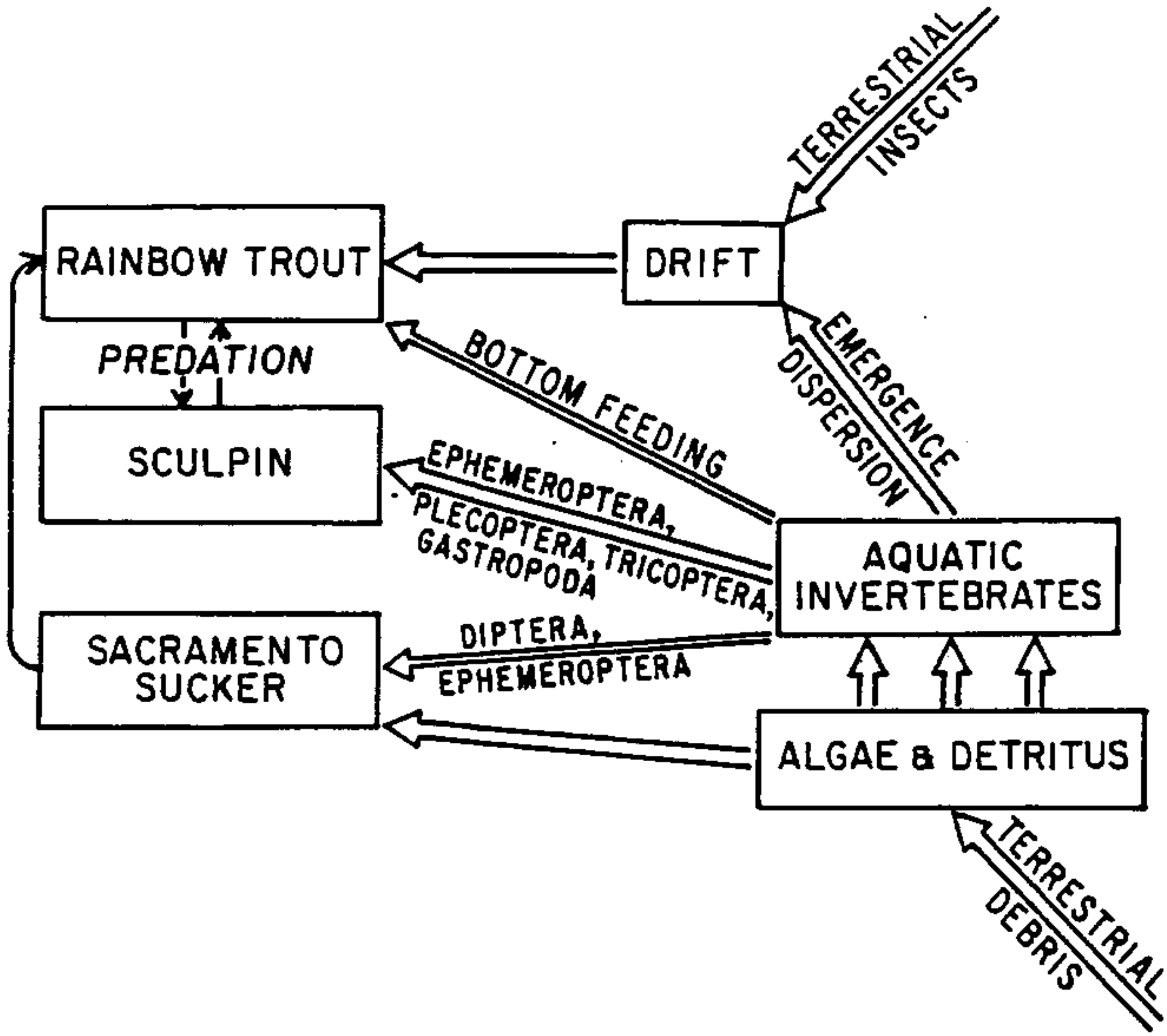

Figure 5. Feeding Relationships in California Trout Streams, as Indicated by Recent Research (Moyle, 1975).