GAME/NON-GAMEFISH RELATIONSHIPS IN THE STREAMS OF THE CLEAR LAKE BASIN

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Abstract. Fish distribution patterns in the streams tributary to Clear Lake, Lake County, California were investigated by electroshocking 120 block netted 30.5 meter sections during the summer and fall of 1975. Eleven species of fish occurred in the seven separate drainages. Five of these species occurred in enough abundance to warrant statistical testing. Results of a correlation analysis are discussed and related to environmental and seasonal variables that when ignored give misleading information about the ecology of the species present. Species distribution patterns show that species addition occurs proceeding downstream. Three distinct zones are visible, the Trout Zone, Trout-roach Zone and Cyprinid-catostomid Zone.

INTRODUCTION

Extensive amounts of data were collected during the 1975 K.G.R.A. (Known Geothermal Resources Area) Fishery Investigation carried out by Pacific Gas and Electric Company in conjunction with the California Department of Fish and Game. This investigation concentrated on Kelsey and Cole Creeks tributaries to Clear Lake, Lake County California. This study when combined with an investigation of the remaining streams of the basin offered unique opportunities to study basin wide distribution of fishes.

Due to the extensive nature of data collection and the fact that sampling was completed in one season this study also offers a unique look at seasonal variation and variation attributed to sampling schedule. Because these variables are often not documented, data is often analyzed disregarding the effect of season and sampling. Erroneous information can emerge from the data that can lead the investigator to draw the wrong conclusions regarding relationships between species and habitat preferences.

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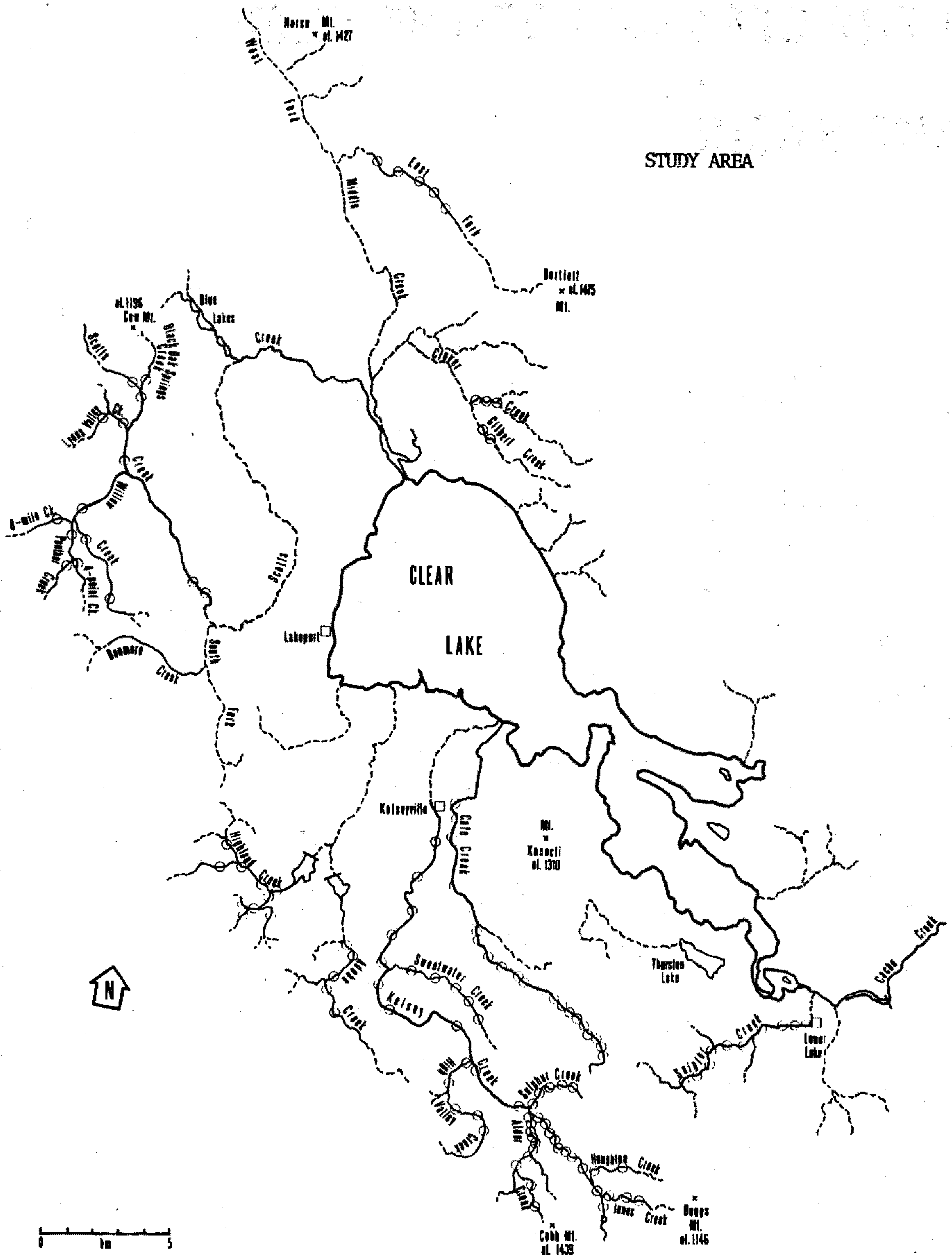
Fig. 1. The Clear Lake Basin study area.



my wife, Alexandra, who was the other half of the field crew on all streams not associated with P.G.&E.'s study streams. Dr. Peter B. Moyle has also assisted me in the direction of the study and the preparation of this paper.

STUDY AREA

The Clear Lake Basin is a relatively small drainage unit of 1368 Km^2 located in the coast range about 150 km north of San Francisco. The basin is situated east of the Maycamas Mountains and south of Mendocino National Forest. Elevations in the basin range from 404 meters at lake surface to 1475 meters on the perimeter of the basin. Foothill woodland-chaparral covered slopes surround the lake. Higher elevations in the basin as well as north slopes harbor stands of conifers. The small drainage areas on the east and northeast edge of the lake are so steep that no permanent streams exist here. All permanent streams are located on the north, west and south perimeter of the lake where the slope is more gradual. Many springs in this area contribute to stream permanence. There are seven major drainages, (1) Seigler Creek, (2) Cole Creek, (3) Kelsey Creek, (4) Adobe Creek, (5) Highland Creek, (6) Scotts Creek and (7) Middle Creek (Figure 1). All study streams contain some stretches of permanent water. The lower reaches of all streams except Cole Creek dry up usually by early June. All streams are typified by large fluctuations in flows throughout the year with the peak flows occurring during the rainy season and low flows in late summer or early fall.

Most streams in the Clear Lake Basin are moderate to low in conductivity (28-480 μmho's/cm), slightly basic and clear. The dissolved oxygen levels are high enough and temperatures low enough to support the fish occurring there. Adobe, Cole and Seigler Creeks contain tea stained waters. Cole Creek has conductivities comparable with the other streams in the basin but Seigler and Adobe Creeks have higher conductivities (525 to 5250 μmho's/cm). Seigler Creek is unique for its *Juncus* choked stream channel and the fact that it has a reverse conductivity profile--higher conductivities in the headwaters than downstream. Adobe Creek is similar to other streams except for the high conductive nature of the water and the many mineral seeps that enter the stream. Cole Creek is distinctive in that there is almost no bedrock or boulder in the stream channel. The stream appears to drain an alluvium watershed. The channel was often choked with dense riparian growth (*Salix*) that restricted access to many parts of the stream.

Fish occurred at 117 out of the 120 stations sampled. Of these three sites that had no fish two exhibited chemical conditions unsuitable to fish. The upstream station on Houghton Creek showed a pH of 6.0, had very small volume and may have been above a fish barrier. The middle site on Sulphur Creek had a pH of 6.5, D.O. of 1.4 ppm, turbidity of 47NTU and a water temperature of 23°C. The third site located on Alder Creek contained water of good quality but was above the upper fish limit of the stream.

METHODS

Prior to commencement of field collection all streams were surveyed either from the air or from nearby ridgelines. Streams were classified into four types from these observations. These types were determined by surrounding vegetation associations. The four types were, (1) agriculture, (2) foothill woodland-chaparral, (3) conifer forest and (4) mountain meadow. Five stations per stream per vegetation type were established as the sample size. Streams that appeared similar and are geographically close were sometimes lumped together as one stream. In these cases the five sample sites were split up among the two streams.

Station sites were located on 7 1/2 minute U.S.G.S. topographic maps. Sites were distributed evenly along each stream or vegetation type in order to assure that each stretch of stream was sampled evenly along its length. Field collection began on May 7, 1975 and continued sporadically until November 2, 1975.

Fig. 2. Vegetation zones of the Clear Lake Basin.

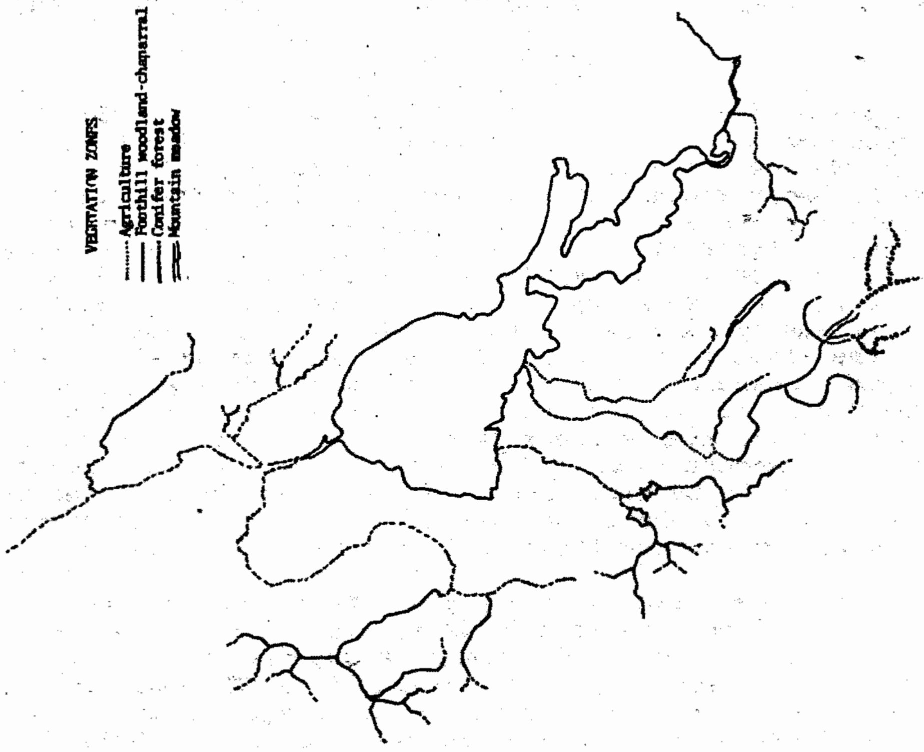
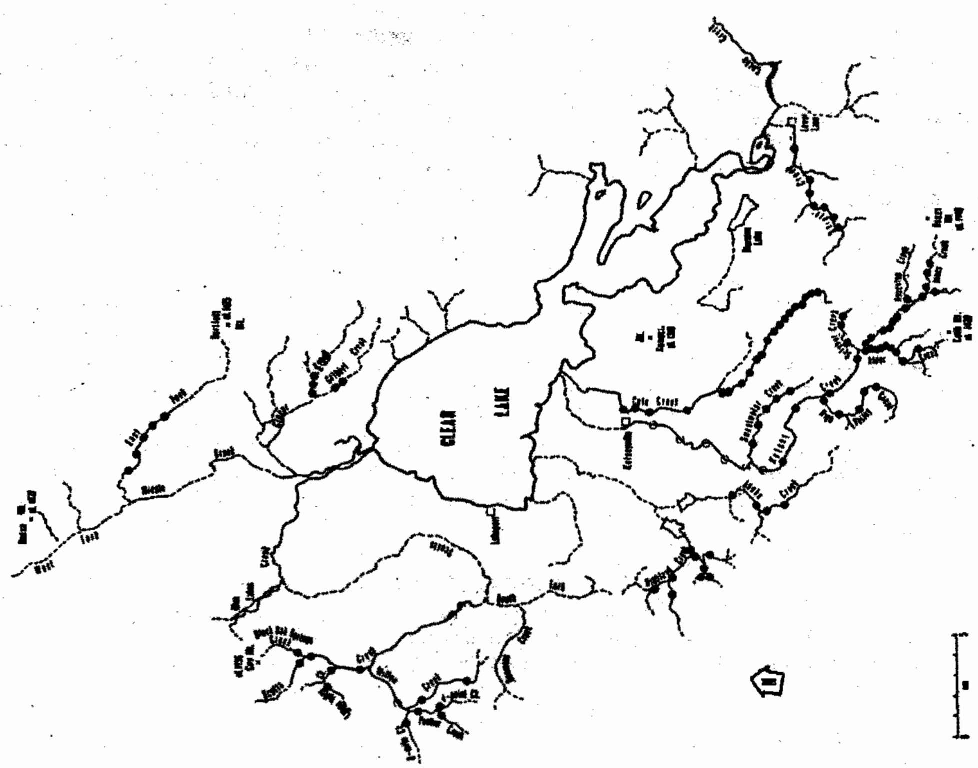


Fig. 3. Distribution of rainbow trout in the Clear Lake Basin.



Maps were carried into the field and approximate sample sites were located using salient features from the map. Some original sites had to be shifted due to access problems or lack of aquatic habitat. A representative 30.5 meter section was then chosen for sampling. The station was isolated using two 6M x 1.2M x 8mm seines, some larger nets were used in lower Kelsey Creek. Immediately above the upstream block net pH and conductivity were measured. Sample bottles for ammonia and dissolved oxygen were filled and fixed. A 500 ml bottle was filled for turbidity determination. Turbidities on Scotts Creek, Middle Creek and Clover Creek were estimated by eye at stream side to the nearest 0.5NTU, all three drainages had very clear water. Air temperature in °F was taken in the shade at streamside. Water temperature was taken on the surface and at the bottom in the deepest part of the section to be sampled. Time for each temperature reading was recorded. Subjective measurements were made of, (1) percent pool-riffle-run, (2) percent cover available to fish, this included undercut banks or tree roots, spaces under boulders or overhang by *Salix* or *Juncus*, (3) percent canopy--an index of the amount of shade falling on the 30.5 meter section and (4) substrates by percent of the following groups; clay, silt (which included organic detritus); sand < 0.3 cm. gravel 0.3 cm ≥ 7.6 cm, rubble 7.6 cm ≥ 30.5 cm. boulder > 30.5 cm and bedrock, any rock surface contiguous with the bottom. A detailed explanation of methods is found in Price and Kubicek (1975, 1976).

Electrofishing using a backpack electroshocker was then carried out. Passes began at the downstream end of the station and moved upstream. As fish were shocked they were dip netted out and placed in a holding bucket. At the end of each pass all fish captured were weighed, counted and measured in millimeters fork length by species. Some species occurred in such abundance that subsamples were drawn for length measurements; all fish, however, were counted and weighed. At the end of two passes a table developed from Seber and LeCren (1967) by Price and Kubicek (1975) was used to determine whether or not a third pass was needed to obtain an estimation of less than 10 percent error of the fish population present. After electroshocking was completed the 30.5 meter section was transected. At each 3.05 meter interval a width transect from wetted bank to wetted bank perpendicular to stream flow was made. These 10 measurements were averaged to give a mean width for the section. On each width transect 3 depth measurements were made, one at the mid point and one at each quarter. These 30 measurements were averaged with 10 measurements of 0 at one stream bank to give an average depth at the station.

Flow determinations were taken using the method of Robbins and Crawford (1954). Visual estimation of flow was also made at streamside.

Elevations and gradients were taken from 7 1/2 minute U.S.G.S. topographic maps. Gradient was determined for each site dividing the vertical drop of the stream by the linear length of the stream between the two contour lines on either side of the station.

Sequential day was a variable introduced to get some idea of seasonality of the study. The first day of field collection was day one and each calendar day thereafter was numbered consecutively. Sequential day was then recorded for all sampling dates.

Initial data from the field was worked up at the Department of Engineering Research branch of Pacific Gas and Electric Company. Data output from this work-up which included stream channel measurements, population estimates and mean length computations was entered on IBM computer punch cards. Analysis was run on the Burrough's B6700 at the University of California at Davis. Attempts to transform the variables to a normally distributed curve were unsuccessful and, as such, the data was left untransformed for analysis. The correlation matrix which is part of the output of Version 5 SPSS Factor Analysis Program is used in the analysis. Data appears in Taylor (1977).

Fig. 4. Distribution of the Sacramento squawfish in the Clear Lake Basin.

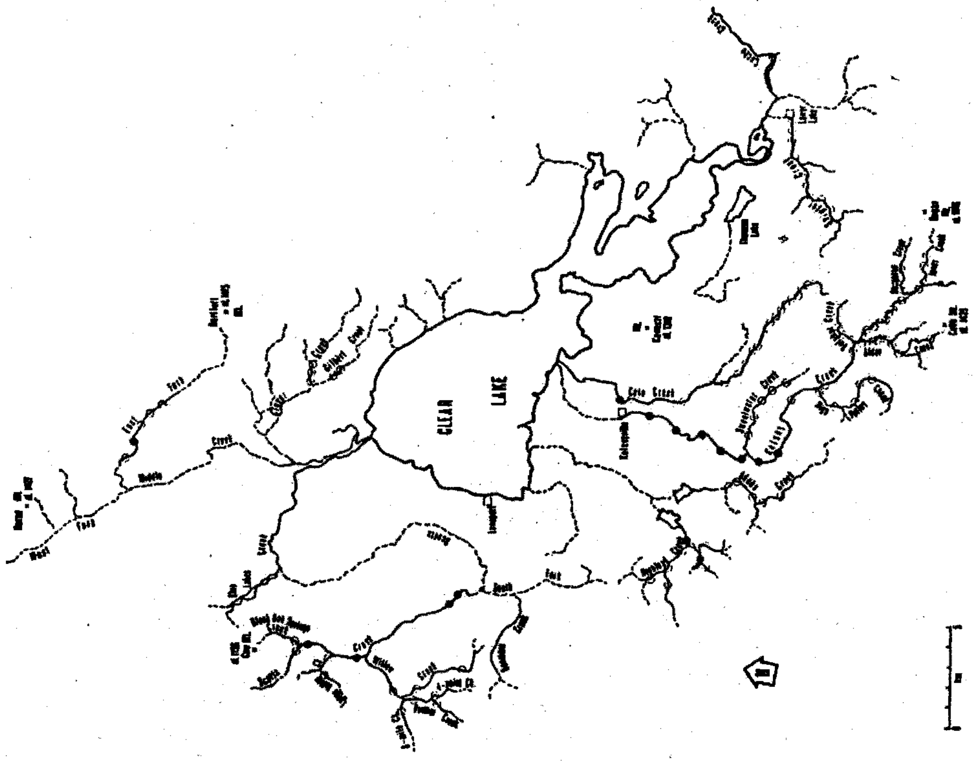
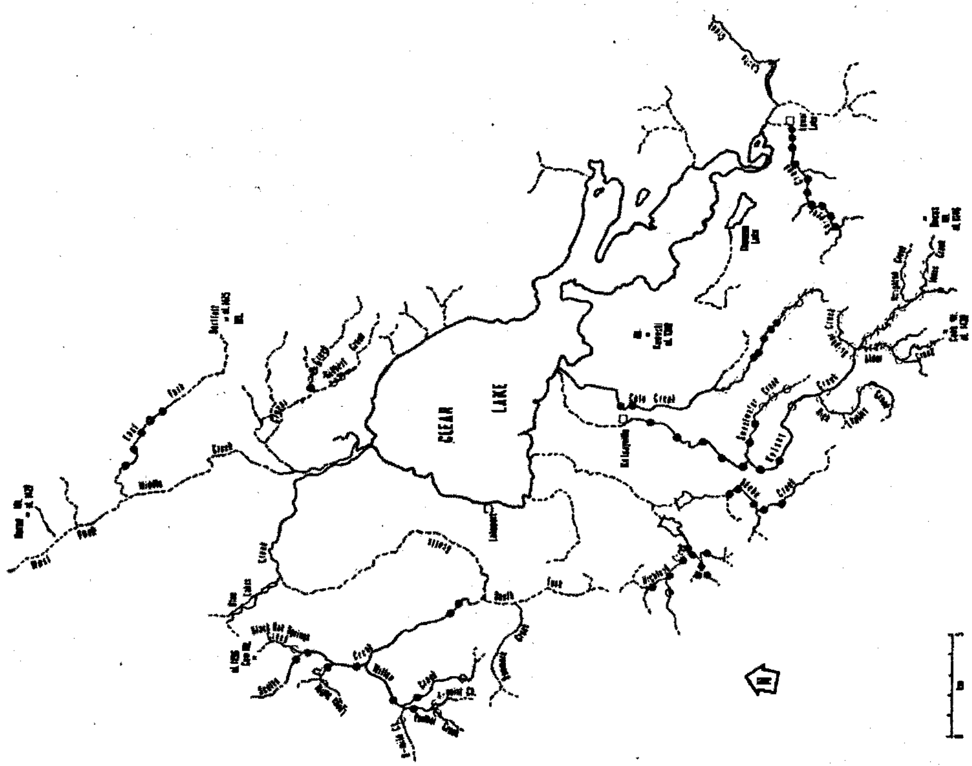


Fig. 5. Distribution of the California roach in the Clear Lake Basin.



RESULTS AND DISCUSSION

Environmental Variables

The variable sequential day correlated positively with conductivity, pH, percent silt, sand, bedrock and pool. Negative correlations occur with type, elevation, flow, width, percent clay, riffle and cover. These correlations can be explained in two ways, (1) effect of sampling procedure and (2) effect of seasonality. Since elevation, type and percent substrates do not change seasonally the alternate explanation is offered. Data collection began on the headwaters of Kelsey Creek and proceeded downstream. One drainage was sampled at a time. Cole Creek was sampled in late September. Both creeks have the only type 3 and 4 sections of stream in the entire drainage basin and Kelsey Creek has 2 to 3 times the number of sample sites within a type than does Cole Creek. Kelsey Creek also has the highest elevations in the basin. Kelsey Creek had the highest amount of clay whereas Cole Creek had very high amounts of silt. Percent sand and bedrock was higher in Clover, Middle and Scotts Creeks which were sampled in August and September. Since flows decreased over the summer the percent pool increased while the percent riffle decreased. Average width also decreased and as such overhangs and undercuts were no longer available for cover and it also decreased. The high conductivity streams, Adobe and Seigler Creeks, were sampled at the end of the study (October and November) and give a false impression of seasonal increases in pH and conductivity, though this may be somewhat true. Water temperature was highly variable relative to season, time of day and percent canopy.

Attempts were made to construct a predictive equation for temperature using time of day, sequential day and percent shade as predictors on air temperature. The attempts were unsuccessful and, as such, the effects of temperature must be regarded only while considering seasonal and daily fluctuations.

Biological Variables

Eleven species of fish were collected during the study. Rainbow trout, *Salmo gairdneri*; California roach, *Lavinia symmetricus*; Sacramento sucker, *Catostomus occidentalis*; Sacramento squawfish, *Ptychocheilus grandis* and brown trout; *S. trutta* were the 5 main species that occurred in enough abundance to make analysis meaningful. The 6 other species that occurred sporadically or solitarily in the basin were green sunfish, *Lepomis cyanellus*; bluegill, *L. macrochirus*; brown bullhead, *Ictalurus nebulosus*; threespine stickleback, *Gasterosteus aculeatus*; mosquito fish, *Gambusia affinis* and a species of lamprey probably of the genus *Lampetra*.

Rainbow trout and roach numbers increased seasonally, whether this was a result of crowding due to decreasing flows or a result of high conductive streams being more productive remains to be seen. Kelsey Creek is not abundant in trout and this may influence the strength of the correlation.

Actual fish collections were fairly accurate relative to the populations present. Most small streams gave up all or nearly all their occupants within 2 passes. The larger sections gave up proportionately nearly equal amounts and a regression of actual catch (X) on estimated catch (Y) yields a regression equation of $\hat{Y} = -2.7137 + 1.1431X$ with an $r = 0.9799$ as such actual catch, biomass and mean length were used as biological variables in the correlation analysis. Only the very large pools on Kelsey and Scotts Creeks went unsampled. Mean sizes of squawfish and suckers are probably underestimated in these stretches since the really large individuals went uncaptured. Squawfish were also observed to leap out and over the block nets on several occasions.

Rainbow trout and California roach occurred in every drainage in the basin. Suckers were absent from Adobe, Middle and Clover Creeks. Squawfish occurred mainly in Scotts Creek and lower Kelsey Creek, solitary individuals were captured in Cole and Middle Creeks and only juveniles were collected in Highland Creek. Brown trout were restricted to upper Kelsey Creek and its tributaries, High Valley, Alder and Jones Creeks.

Of all the species rainbow trout were the most widely distributed, occurring at 101 sites. Roach occurred at 55, suckers at 47, brown trout at 20 and squawfish at 15. Squawfish have a wider distribution than do brown trout even though they occur at fewer localities.

Fish Habitats

From correlation analysis and from mapping species occurrence certain qualitative statements can be made concerning habitat preferences for the five species of interest. Rainbow trout because they occur at 101 sites do not correlate strongly with many environmental variables. They are effectively highly variable relative to any constant habitat. Significant positive correlation (>0.99) occurs with trout mean length and percent boulder. Trout numbers, biomass and mean length are all negatively correlated with average width. Trout numbers are negatively correlated with depth, percent riffle and dissolved oxygen. The riffle correlation is an artifact of seasonality. The stretches of water that had high D.O.'s were usually cold headwater areas where trout numbers were low. Drying sections of streams often had crowded pools of trout and hence lowered dissolved oxygen concentrations. Trout numbers were negatively correlated with squawfish numbers and trout mean length was negatively correlated with squawfish numbers, biomass and mean length. No correlations existed with any other species.

Squawfish showed strong positive correlations to all measurements of stream size (width, depth, flow, volume) and temperature. Negative correlations exist with elevation, percent cover and canopy. Squawfish numbers and mean length are positively correlated with pH. Mean length is positively correlated with percent sand and negatively with percent rubble. Observations show that larger squawfish occur in larger pools although no correlations exist for this relationship. This is due to the fact that percent pool-riffle-run was nearly consistent throughout the drainage, so that a measurement of the amount of pool by percent is by no means a measurement of the size of the pool. Some indication of pool size would be a better indicator. In large pools the fine particles carried by the stream tend to settle out (Platts 1974) and thus there is a strong positive correlation between percent pool and percent sand. Percent sand is also positively correlated to squawfish mean length. Most sections of squawfish inhabited waters had low values for percent rubble (15.0 ± 14.3 vs 24.7 ± 17.6) when compared with the overall average. The stream bottom was mostly sand and gravel with boulders and bedrock. Squawfish size is negatively correlated with gradient. Squawfish numbers, biomass and mean length are all positively correlated with roach numbers, biomass and mean length. Squawfish numbers and mean length also correlate positively with sucker numbers and mean length.

Roach numbers, mean length and biomass all correlate negatively with elevation, percent riffle and percent rubble. Roach correlate positively in all respects to pH. There are no correlations with stream size. Roach numbers and biomass correlate positively with temperature and percent pool while roach numbers and mean length correlate positively with conductivity. Roach mean length is negatively correlated with gradient, percent clay and positively so with percent sand. Roach numbers correlate negatively with percent cover and canopy and positively with percent bedrock. There are no associations with any fish other than squawfish.

Suckers show strong positive correlations with fish size in relation to stream size. High numbers of suckers are associated with warm, wide, but not deep streams indicating nursery habitat areas. Large suckers are negatively correlated with elevation and gradient, positively so with percent clay, pH and dissolved oxygen. A negative relationship exists with numbers and mean length to percent canopy. Mean length of brown trout is correlated positively with sucker mean length.

Brown trout are an introduced species and because of this their distribution in Kelsey Creek is probably limited by their competitive advantage and/or the frequency or seasonality of floods (Seegrist and Gard, 1972). All of the environmental factors correlating with brown trout are indicative of the sampling time or location. Since they are not widely distributed any statement about their preferred habitat would be meaningless. They did not show any relationships with other fish except suckers.

CONCLUSIONS

Once the effects of sampling design and seasonality are taken into consideration a pattern of fish distribution becomes clear. The different species occur in different habitats and where these habitats coexist--so do the species associated with them.

Rainbow trout prefer small streams where they grow to larger sites and occur in greater abundance. They show no correlations to temperature, gradient or elevation and occur in all stream types but are the sole residents of most type 3 and 4 streams as well as the headwater sections of type 2 streams. They also occur with squawfish, suckers and roach in type 2 sections of Scotts and Kelsey Creeks and type 1 sections of Cole Creek. Their distribution (Figure 3) in the basin is a result of their ability to move large distances and invade the upstream areas for spawning. This insures that young of the year fish will be able to make the best use of the length of stream in and below the spawning area.

Squawfish show strong preferences for large, open (hence warm) stream sections. Their abundance is related to roach abundance positively which was not observed in the Sierra Nevada Foothills by Moyle and Nichols (1973). Because the adult squawfish are piscivorous (Taft and Murphy, 1950; Vanicek and Kramer, 1969), roach are probably their main source of food in the Clear Lake Basin. Though gradient may be a limiting factor in most cases in the Clear Lake Basin stream size decreases markedly at points where gradients increase. In Scotts Creek gradients are low all the way up to the junction of Scotts Creek and Black Oak Springs Creek. Above this confluence gradient increases from 20 to 5.5 meters per kilometer and average stream width decreases from 3.93 meters to 2.04 meters. As their distributional pattern shows (Figure 4) they have very little overlap with rainbow trout distribution. On the basis of these 2 species being mutually exclusive it is not wise to assume that these fish are competitors. There is evidence that Oregon squawfish prey on young salmonids (Forster and Ricker, 1942) and that Sacramento squawfish do the same in Deer Creek, California (Don Alley, personal communication). But by the principle of competitive exclusion 2 species that have coevolved in the same stream would not still be existing today if they were indeed competing.

Roach distributions (Figure 5) and their correlations suggest that they prefer warm, shallow, exposed stretches of quiet water. They are much more numerous in waters of high conductivity but do not grow to as large a size, possibly due to intraspecific competition. In stretches of stream that are primarily bedrock (and hence shallow) roach are the only species present. The small size of roach allow them to inhabit areas that larger species cannot utilize.

Suckers (Figure 6) prefer large sections of stream with low gradients. In addition suckers prefer some degree of stream persistence. Since suckers feed by grazing on diatoms and invertebrates from the stream bottom (Moyle, 1976) it is obvious that for a stream to be attractive to a sucker it must have a healthy colony of bottom flora and fauna. Because the lower sections of many of the streams are ephemeral they contain no such food for much of the year. When these sections are flowing stream channels are wide, shallow and rapid. The channel substrate, mostly gravel, is in a state of dynamic equilibrium at any one point. A sucker entering into one of these stretches would find little to feed on and would probably not pursue the matter to any great length. Some measurement of distance between persistence would probably help in explaining sucker exclusion from the Middle Creek drainage. It is still a mystery as to why suckers exist above Kelsey Creek falls and squawfish or roach do not. Suckers may have been transported around this barrier by the Indian or the white man.

Trout, roach, suckers and squawfish tend to exist in certain associations or zones. These zones have previously been described by Huet (1959) and Moyle (1973). Though the zones are not as extensive as those described by previous investigators they are, nonetheless, distinctive. A Trout Zone exists in most streams. This zone is in extreme headwater sections of type 2 and generally encompasses most of the type 4 streams and all of the type 3 streams. Downstream from the headwater sections trout are often found associated with roach. In Kelsey Creek, however, this is a Trout-sucker Zone, this association continues downstream to the next zone or it ends at the lower end of the smaller streams. The final zone is the Cyprinid-catostomid Zone. In the Clear Lake Basin this is occupied by squawfish, suckers and roach. Trout usually inhabit the upper reaches of this zone.

While this study is offering insight into the understanding of some of the variables that affect fish distributions there are some variables that cannot be easily assessed. Floods, forest fires, impoundments, diversions and road building are some of the problems that occur in the Clear Lake Basin. These problems are difficult to assess individually, much less cumulatively.

LITERATURE CITED

Foerster, R.E. and W.E. Ricker. 1942. The effect of reduction of predaceous fish on survival of salmon at Cultus Lake. J. Fish. Res. Bd. Con., 5(4):315-336.

Huet, M. 1959. Profiles and biology of western European streams as related to fish management. Trans. Amer. Fish. Soc., 88:155-163.

Moyle, P.B. and R.D. Nichols. 1973. Ecology of some native and introduced fishes of the Sierra Nevada foothills in Central California. Copeia, (3):478-490.

______________. 1976. Inland fishes of California. U.C. Press, Berkeley, California, 403 pp.

Platts, W.S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification with application to ecosystem classification. U.S. Forest Service Surface Environment and Mining Program, June 1974.

Price, D.G. and P.F. Kubicek. 1975. An inventory of fishery resources in the Kelsey Creek drainage. Pacific Gas and Electric Company, Dept. of Engineering Res. Report 7784.5-75.

______________. 1976. An inventory of fishery resources in the Cole Creek drainage. Ibid., Report 7784.6-76.

Robbins, C.R. and R.W. Crawford. 1954. A short accurate method for estimating the volume of stream flow. J. Wildl. Mgmt., 18(3):366-369.

Seber, G.A.F. and E.D. LeCren. 1967. Estimating population parameters from catches large relative to the population. J. Animal Ecology, 36:631-643.

Seegrist, D.W. and R. Gard. 1972. Effects of floods on trout in Sagehen Creek, California. Trans. Am. Fish. Soc., 101(3):478-482.

Taft, A.C. and G.E. Murphy. 1950. The life history of the Sacramento squawfish (Ptychocheilus grandis). Calif. Fish and Game, 1950 30(2): 147-184.

Taylor, T.L. 1977. Fish distribution and ecology in the streams of the Clear Lake Basin. M.S. Thesis, University of California, Davis.

Vanicek, C.D. and R.H. Kramer. 1969. Life history of the Colorado squawfish, Ptychocheilus lucius and the Colorado chub, Gila robusta, in the Green River Dinosaur National Monument. Trans. Am. Fish. Soc., 98(2): 193-208.

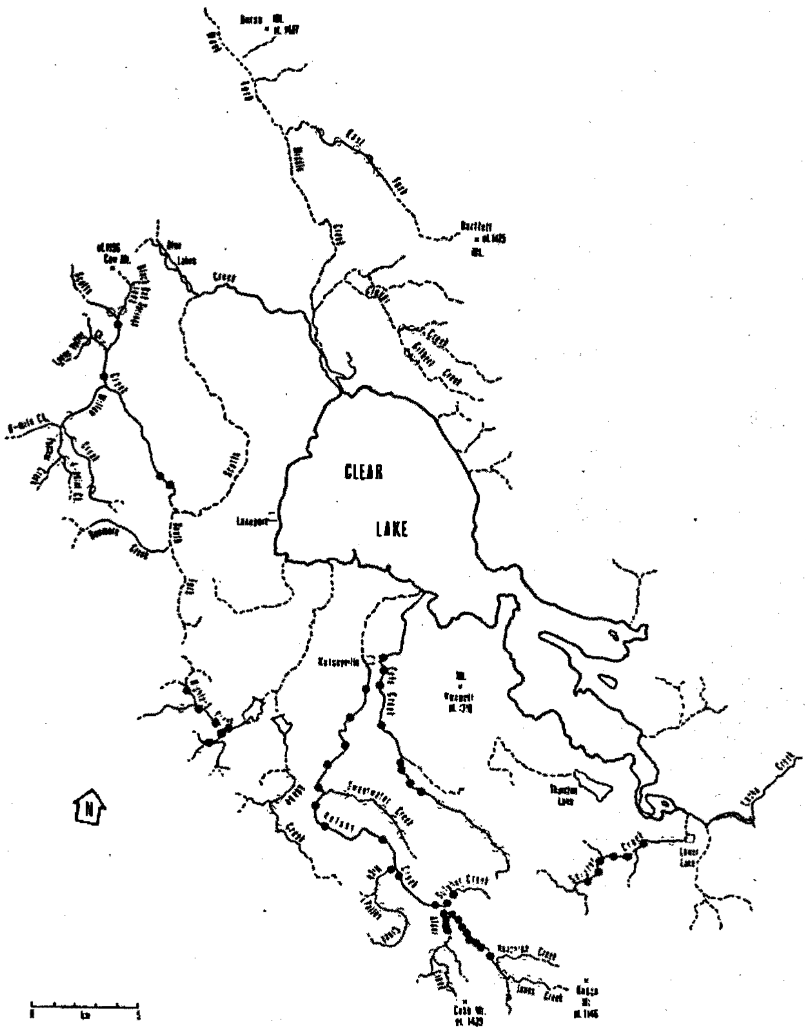


Fig. 6. Distribution of the Sacramento sucker in the Clear Lake Basin.