WATER FLUCTUATION, A DETRIMENTAL INFLUENCE ON TROUT STREAMS

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ABSTRACT

Stream fluctuations strongly influenced the biotic populations of three Colorado trout streams during a three year water quality study conducted on the streams. Extreme water fluctuations (94% variation in surface area), combined with stream bedload accumulations, reduced a productive trout water to a non-productive series of intermittent pools during the course of the study. One study station produced the highest consistent production of benthos and the largest standing crops of trout in numbers. According to weight, however, the same station produced the fourth largest standing crops of trout. The discrepancy was attributed primarily to adverse feeding conditions for trout; a result of stream flow reductions during summer months. Rapid reductions in stream flow produced an abnormal concentration of benthos at another station, followed by a rapid decline in the benthos population within a two week period.

Unusual oxygen deficits were recorded in one instance, with oxygen levels lowest during photosynthetic periods and highest during periods of darkness. Oxygen concentration deficits were traced to two factors, decomposing cow manure in the stream and low stream flow.

Egg survival studies pointed out other adverse effects of stream fluctuation. Artificial redds and baskets containing rainbow trout eggs were placed in stream gravels of 2 of the 3 study streams. High stream flows at one station, due to a sudden release of water from an upstream reservoir, disinterred 75% of the buried eggs. Viability of the remaining eggs appeared to be lowered. Sharply declining water levels at a lower station on the same stream left all of the artificial trout redds and baskets free of water 1 or 2 days prior to fry emergence; after the eggs had withstood flood conditions. Cessation of water releases from the same reservoir that produced flood conditions caused the decline in water levels. At a third station located on a different stream, eggs were also exposed to air when the stream level receded. This time, water recession was due to natural rather than man caused conditions.

The only vascular plant common to all three drainages was *Veronica americana*. *Veronica* was found on moist ground, sand bars and emersed, seemingly well adapted for areas of extreme water fluctuation. Other macroscopic aquatic plants were common only in George Creek, the stream with the most stabilized stream flow.

INTRODUCTION

Abnormal water level fluctuations in trout streams can be induced by natural or unnatural causes. Under normal conditions instantaneous and long term variations in water levels are strongly affected by infiltration and surface area detention rates of the surrounding watersheds. In turn, infiltration and surface detention rates are affected by local soil compositions and textures, types and densities of vegetal cover and antecedent moisture levels (Meinzer, 1942).

Often, it is difficult to separate the factors that cause major stream fluctuations from those that produce stream erosion and sedimentation

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because of a close interrelationship. Reductions in vegetal cover, in many cases a result of overgrazing of livestock, tend to decrease surface area runoff detention rates. When this occurs, stream levels rise more rapidly and reach higher short term flood peaks. The tendency of affected streams to discharge more water in shorter periods of time means less water is available for release over extended time intervals. Commonly, during dry periods stream levels then recede below the minimal levels recorded prior to vegetative reductions. Decreased detention rates, along with a lesser abundance of vegetal matter to protect land from tractive forces of water, also lead to accelerated rates of soil and stream erosion. Doshchanov (1955), in studies conducted in the U.S.S.R., found that the density of vegetative cover considerably influenced the extent of surface runoff. In some instances, surface runoff was completely absent in plots having 90% vegetative cover. The same study proved the felling of trees, clearing of bushes, intensive cattle grazing and the plowing of steep slopes markedly increased erosive processes.

Impoundments placed on trout streams often have a major bearing on stream levels. Water release patterns generated by such impoundments can improve or detract from natural water level fluctuation patterns. More commonly they detract. Burkhardt (1964) stated impoundments and other water development projects may alter streams in four ways: (1) reduced flows, (2) increased flows, (3) rapid fluctuations, or (4) channel alterations. All four ways affect existing water levels. Irrigation practices of the West also lead in many cases to severe water fluctuations in trout streams.

Studies conducted on three Colorado trout streams during a three year water quality study revealed existing biotic populations were strongly influenced by water fluctuations. This paper summarizes the various adverse effects on biotic populations of trout streams that were isolated and documented as being due to fluctuating water levels.

DESCRIPTION OF STUDY AREAS

Three streams of the Colorado Front Range—Sheep, George and North Lone Pine creeks—were selected as study streams. The streams are situated in Larimer County, Colorado, and are in close proximity. Sheep Creek is the largest, followed by George and North Lone Pine creeks, respectively. Order of ranking from longest to shortest is North Lone Pine (25 miles), Sheep (15 miles) and George (9.5 miles) creeks (Figure 1).

Sheep Creek

Early in the 1900's Eaton Reservoir was constructed in the headwaters of Sheep Creek. Water is diverted from Sand Creek (a tributary of the Laramie River), stored in Eaton Reservoir, and released each spring and summer to meet irrigational needs. Except for the last three miles, Sheep Creek drains through a readily eroded Pikes Peak granite formation. Early water release patterns caused excessive stream erosion, widening the stream channel significantly. No daily stream flows exceeded 35 cfs over the three year study period although instantaneous flows as large as 175 cfs were recorded in earlier years. Summer flows generally varied from 10 to 20 cfs during the irrigation season, dropping to 3 to 6 cfs following each irrigation season. Normally, streamflow remained between these levels until the following spring.

Grazing of cattle in riparian lands removed and now prevent reestablishment of willows and other vegetative stream bank cover along the upper and middle portions of the creek. The lower three stream miles drain through an erosion resisting schist and biotite formation where riparian vegetation is well established. Little evidence of active erosion is visible in or along this stream sector.

George Creek

George Creek joins Sheep Creek approximately one-fourth mile before the confluence of Sheep Creek and the North Fork of the Poudre River.

Maximum elevation of George Creek is 9,400 ft., while the lowermost elevation approximates 7,550 ft. No impoundments are located on the creek. Stream flows averaged 2 to 3 cfs during the study with maximum flows never exceeding 8 cfs.

George Creek drains through erosion resisting schists of the Idaho Springs formation. The drainage is well forested and less riparian erosion existed than in the other two drainages studied. Nevertheless, some stream bank erosion occurred in the middle portion of the creek where cattle activities were heaviest. Stream banks near the selected study station exhibited a high degree of stability and no erosion was evident.

Extensive willow growths, steeply inclined canyon walls (which shortened exposure time of the stream surface to sunlight), and poor orientation for receiving available seasonal sunlight reduced water temperatures of George Creek below levels recorded at other study streams. In comparison with the other two study streams, these factors caused a several week lag in the rise in George Creek water temperatures each spring. An inverse relationship existed in the fall.

North Lone Pine Creek

North Lone Pine Creek originates at an elevation of 9,500 ft., merging with the South Fork of North Lone Pine Creek at an elevation of 6,600 ft. The only rock formation of the drainage is Silver Creek granite. Feldspars of this formation, like those of the Pikes Peak granite, fracture readily into tabular crystals which erode rapidly once the overlying topsoil is penetrated.

Maximum daily stream flows never exceeded 18 cfs during the duration of the study, while daily flows under 0.5 cfs were common each summer and early fall. Stream flows disappeared underground in certain sedimented stream sections during dry months.

Because of poor vegetative cover and varied gradient, well defined eroding and depositing zones are found in the stream. Overgrazing by livestock was common in the drainage until recent years when grazing allotments were curtailed severely. Riparian vegetation is returning and heavy willow growth completely shaded some creek portions at the study's inception.

METHODS AND MATERIALS

Study Stations

Five stations, each 220 yards in length, were established on the three previously selected study streams. Differing stages of sedimenting and eroding conditions existed at the five stations as the principal objective of the study was to determine the effects of sedimentation and erosion on stream life. Each station was subdivided into 10 yard subsections and each subsection was delineated with wooden stakes.

Physical Determinations

Water surface area information was obtained by stretching a cord, marked in 1 ft. intervals, from stream bank to stream bank at the various 10 yard subsection stakes. Information at each 1 ft. interval was periodically recorded.

Stream flow gages of the recording type were installed on the three study streams, providing continuous stream flow information for spring, summer and fall periods.

Oxygen and Temperature Determinations

A Yellow Springs oxygen analyzer, Model 51, was employed for all oxygen readings. Corrections were made for elevational differences existing between different stations, but no corrections were made for daily barometric variations. The effect of barometric changes introduced no more than a 0.5 ppm maximum error between readings according to the manufacturer. The analyzer was also employed to obtain water and air temperature readings.

Collection of Benthic Organisms

Benthic fauna was collected from four of the five 220-yard sampling stations using a Surber square foot sampler. Samples from the lower North Lone Pine Creek station were collected with an Ekman dredge because of the presence of fine bedload materials and low stream velocities. Collections were made May to August, 1963, and July to October, 1964. Ten samples per station were collected at each visitation, with no more than two samples collected in any 10 yard subsection.

Fauna were sorted, blotted on paper towelling and weighed. Prior to final sorting, a sieve with approximately 20 openings to the inch was used to eliminate minute organisms and debris. Organisms were weighed and recorded by segregated groups consisting of six major groupings, with one group subdivided into six subdivisions (Diptera).

Collection of Fish

Electrofishing apparatus employing pulsating d-c current was used to collect fish samples at the study stations. Samples were collected on five occasions from lower Sheep, upper Sheep and lower North Lone Pine Creek stations during the three year study. Stream flow was so erratic at the lower North Lone Pine Creek station that samples could be collected on only 3 of the 5 sampling periods. All stations were sampled as close together in time as was possible for a given sampling period.

Mark and recovery studies were conducted in June and July, 1964, at 3 of the 5 study stations. Fish captured in the three stream sections were fin clipped and returned to the water. Stations were resampled in 1 to 7 days and the numbers of marked and unmarked fish were recorded.

Fish Population Evaluation Methods

Information collected regarding fishes inhabiting the various study stations was transferred to IBM cards and processed through a 407 tabulator. Collected information was summarized in a number of different ways; by section, subsection, size and weight classes, species and overall category totals.

Estimates of the total brook and rainbow trout present at the time of the first sampling were made by employing a modified Petersen estimator. This estimator, as given by Bailey (1951) is $N = \frac{(m + 1)\ (C + 1)}{R + 1} - 1$;
where M is the number marked and released, C is the number subsequently examined for marks, R is the number of marks found in the sample C, N is the total (and unknown) number in the population and N is the Petersen estimator of N.

Confidence intervals at the 95% level were derived for the total population estimates by referring to confidence belt graphs (Adams, 1951). The lower, medial and upper population estimators were then multiplied by appropriate average trout weights to arrive at standing crops of fish in pounds. In the case of upper Sheep Creek station, where mark and recovery studies were not made, the apparent sampling efficiency for lower Sheep Creek station (assumed to be comparable), times the average crop obtained by electrofishing, was used to determine standing crops of fish. Estimates of standing crops of fish for lower North Lone Pine Creek station were estimated in the same manner, but were based on a sampling efficiency of 80%.

Fish Egg Survival Studies

Eggs were obtained from sexually mature rainbow trout captured at the inlet of Parvin Lake, Larimer County, Colorado. Prior to being transported to previously selected stream sections the eggs were fertilized and water hardened. One spawning redd site was located in the upper Sheep Creek study station (brook trout waters); the second approximately three miles below the upper redd site (rainbow trout waters), and; the third redd site was located in the upper Pine Creek study station (brook and rainbow trout waters). Maximum travel distance from Parvin Lake to the farthest redd site (upper Sheep Creek) was less than 35 miles. Elevational differences between Parvin Lake and the redd sites (which could indirectly affect rates of egg maturation) were minimal; upper Lone Pine Creek—100 ft., lower Sheep Creek—400 ft. and upper Sheep Creek—600 ft.

Four artificial redds, containing 500 eggs each, were established at the upper North Lone Pine Creek station on May 16, 1964. Four artificial redds containing 250 eggs each and 4 wire baskets containing 200 eggs each (Figure 2) were emplaced at the lower Sheep Creek redd site on May 22, 1964. On the following day, May 23, 4 artificial redds and 4 wire baskets containing 200 eggs each were planted at the upper Sheep Creek station. Eggs and baskets were buried under 3 to 4 inches of gravel and then marked with willow switches (Figure 4). A representative sample from each lot of eggs was placed in the Belvue State Fish Hatchery (Watson Lake Rearing Unit) for control purposes.

Aquatic Flora Collection

Collections of aquatic flora were obtained from the three study streams during October, 1963. Both macroscopic and microscopic forms were collected. Plants and diatoms were identified to species whenever possible.

RESULTS

Low Flow Conditions

Surface Area Changes

The water surface of lower North Lone Pine Creek station varied greatly during the three year study period. A 94% variation in surface area, between the normal Spring water level and the late Summer low, was recorded in 1964. The total water surface area declined from 9,700 $ft.^2$ to 580 $ft.^2$. Excessive water surface variations were due to a combination of low stream flows and the presence of large deposits of bedload material in the original stream channel.

Abnormally large bedload deposits accumulated at the study station as a result of massive upstream erosion two years prior to the study (Corning and Farmer, 1965). Below normal snowpacks and rainfall during the period of study reduced stream flows to low levels and emphasized sedimented conditions.

Portions of the stream were completely dry during the period of low flow in the vicinity of the station. Flowing water was observed upstream from the station in areas where heavy sedimentation had not occurred. Narrow bands of stream flow were also visible at the study station, with water flowing a few feet before disappearing into the sedimented streambed. The original stream bed, relatively free from deposited gravels, was visible wherever free flowing water was observed. When the top few inches of dry stream gravel were removed at the lower North Lone Pine Creek station, intragravel water was present. The presence of intragravel water indicated some stream flow followed the original stream channel at all times. However, at low flow conditions water often passed downstream as intra-stream-gravel flow in heavily sedimented reaches of the stream.

George Creek station was located in the watershed having the densest vegetal cover. This station varied the least in surface area during the Spring-Fall period of 1964. A 26% variation was recorded, from a high of 10,490 $ft.^2$ to a low of 7,990 $ft.^2$. George Creek station also maintained the best pool-riffle ratios, even at low stages. Stream gage information disclosed that George Creek stream stages did not rise as rapidly following storms, compared to other stations, nor were stage crests as pronounced.

The remaining three study stations displayed a range of surface area variations that fell somewhere between those noted for lower North Lone Pine Creek and George Creek stations; upper North Lone Pine Creek—60%; upper Sheep Creek—56%, and; lower Sheep Creek—32% Maximum variations were caused by low stream flows rather than by extreme floods. No major floods occurred during the study.

Affects of Low Flows on Benthos

Benthos production was not directly related to low flow conditions in free flowing stream sections, but to stream bed materials (Table 1). The overall production of benthos at any given station was reduced in accordance with reductions in the total wetted surface area. No *long term* increases in benthos concentrations were noted at any station as a result of declining water levels.

Upper North Lone Pine Creek station, with the second largest stream surface variation (mainly induced by low stream flow), maintained the largest standing crop of benthic fauna. By contrast, lower North Lone Pine Creek maintained the smallest standing crop of benthos (Table 1).

Affects of Low Flows on Fish Populations

Fishes were collected at lower North Lone Pine Creek station September 1962, June 1963 and August 1963. Results do not reflect fish populations existing at the time the station was first established. *Dewatering* of the normal stream channel concentrated fishes into isolated pools shortly before the first electro-fishing commenced, September 1962 (Figure 3). The stream zone supported good fish populations consisting of different age groups prior to *dewatering*, but increased vulnerability to raccoons practically annihilated resident fishes once isolated pools were formed (Corning and Farmer, 1963). Nearly all fishes captured were young of the year or age group 1 at the time of the initial sampling because of the previous predation. Fishes older than age group 1 were seldom captured at the station during the study. It is doubtful if young fishes at the station originated from local spawning activities except for those captured in the first sample. More likely, young fish were a result of downstream drift.

Brook trout predominated in the trout population existing at lower North Lone Pine Creek station (Table 2), but the overall trout population was very small on all sampling occasions. The estimated standing crop of trout was estimated to be around 12 pounds per surface acre during June 1964.

Upper North Lone Pine Creek station maintained along with the largest standing crop of benthic fauna, the largest *number* of trout of any station. Contrastingly, the total pounds of trout estimated to be present ranked fourth, well below the highest estimated station average (112 pounds for lower Sheep Creek station). (Table 5).

Affects of Low Flows on Fish Egg Survival

Eight artifical redds were dug in a stream zone located three miles above lower Sheep Creek station. Eggs in the redds were subjected to flooding on May 25, 1964, but no eggs or baskets containing eggs were dislodged. Twenty days after eggs had been placed in the gravel (June 11) one redd containing eggs was disinterred. At that time, 34.6% of the eggs were viable. Two more redds were opened June 26, 35 days after interment. Thirty-seven percent of the eggs in an egg-only redd and 11.5% of the eggs in an egg basket were viable. Eye spots were present. The covering of gravel over the basket had decreased to a depth of 1.5 inches and all interstices in the gravel were filled with fine sand and gravel.

Water releases from Eaton Reservoir (25 cfs) ceased June 27, 1964. Between June 27 and June 29 receding stream stages exposed most of the redd area (Figure 4 and 5). Two redds, one containing eggs and one containing an egg basket, were still covered with 2 to 3 inches of water on July 29, 1964. The following percentage of viable eggs were contained in the two redds: egg-only redd- 13.5%; wire basket- 12.5%. Distinct movement and a general outline of the embryos contained were visible in living eggs. All other redds, including those already disinterred, were dry or covered with no more than 1 inch of water. Water flow was imperceptible and no viable eggs were recovered from the remaining three redds. Eyespots were visible in a relatively large but undetermined portion of the eggs (indicating development past the eyed stage). By June 30, water levels had receded until the whole transitory zone redd site was dry. Eighty seven percent of the eggs taken to a fish hatchery were hatched successfully.

Four artifical redds were dug May 16, 1964 in a selected stream subsection (15) of upper Lone Pine Creek station (Figure 6). Stream gravel in the section appeared to provide suitable spawning habitat for rainbow trout. Five hundred fertilized eggs were placed in each redd and the eggs were covered with approximately 3 inches of gravel.

Eighteen days after emplacement one redd was opened and all live eggs counted. The percentage of live eggs recovered, 88.7%, was close to the final hatch-off of 2,000 eggs placed in a fish hatchery for control purposes (90%).

Thirty-three days from the time eggs were placed in the gravel (June 18) the redds were again re-visited. Declining water levels had dropped below the site from which eggs had been removed, as well as below one of the unopened redds (Figure 7). No live eggs were found when the exposed redd was opened. The remaining two redds had 1 to 2 inches of water above the covering stream gravel. One redd, with a slight movement of water visible over the surface, contained a total of 12.3% viable eggs. Egg survival in the remaining redd was 8.9%. Any survival to the swim-up fry stage would have been questionable since the water level at the station continued to recede.

Spring stream flow records, of a gaging station located just above the upper North Lone Pine Creek station, were plotted for 1963, 1964 and 1965 (Figure 8). Based upon graph and 1964 findings, the hatch from resident rainbow trout eggs was poor to none for the 1963 and 1964 seasons. Egg hatches were probably successful in 1965, unless higher than normal stream flows washed eggs away.

These findings pre-supposed that eggs of resident and artifically emplanted eggs hatched at about the same rates and that they were deposited at about the same time. Elevational and latitudinal differences were very similar between the egg source in 1964 and the redd sites; less than 100 ft. in elevation and 9 miles in distance.

Affect of Low Flows on Oxygen Levels

Biochemical relationships of upper North Lone Pine Creek station were affected indirectly when stream flow receded below normal. Oxygen values of the stream were reduced from a saturated condition to 5 ppm [below a minimal level recommended for trout life by Stroud (1965)] during at least one period of below normal stream flow.

On August 8 and 9, 1964, 24-hour oxygen profiles of the stream at upper North Lone Pine Creek station were recorded. Oxygen readings, in percent saturation, illustrated an oxygen sag profile directly opposite to the norm; oxygen levels were lowest during the day (3 PM—71%) and highest during the night (12—98%) (Figure 9). It was concluded oxygen deficits were due to nonphotosynthetic life processes since maximal deficits took place during daylight hours. Cattle manure and low stream flows were isolated as the contributing factors.

High Flow Conditions

Surface Area Changes

No major changes in water surface areas of the various stations were due to excessively high flows during the study. A rapid increase in stream flow of Sheep Creek, from approximately 8 to 35 cfs, did produce flood conditions for a period of time at the Sheep Creek station. Nevertheless, the maximum flow attained by Sheep Creek was far below high flows of many previous years.

Affects of High Flows on Fish Egg Survival

Eight artifical redds were constructed at upper Sheep Creek station May 23, 1964. The redds were dug in a gravel bar that was used extensively by spawning brook trout the previous fall. Two days after the eggs and egg baskets were placed in the gravel bar a flow of 25 cfs was released from Eaton Reservoir. Traction created by the water release reached levels high enough to transport most bedload material of the size deposited at the redd site. Eleven of 16 standpipes interspersed among the redds, two baskets containing eggs and all eggs not contained in baskets were washed away (Figure 10 and 11).

One of the two remaining egg baskets was removed eight days after the trout eggs were placed in the gravel. Fine sand and silt, not present at the time of egg interment, had filled interstices of the gravel that had been added along with the eggs. Only 8.5% of the trout eggs were viable. The remaining egg basket was disinterred 35 days after initial emplacement and within a few days of hatching time. Although a relatively large amount of sand and silt had accumulated in interstices of the gravel, 13% of the eggs were still viable. Eyes and notochord developments were clearly visible in viable eggs. Eighty-five percent of the control eggs held at a fish hatchery were hatched successfully.

Rapid Fluctuations in Flow

Surface Area Changes

Upper Sheep Creek surface area changes were a function of Eaton Reservoir water releases in most instances. The reservoir is located 1 mile upstream from the station. Waters from the reservoir were released in the Spring, Summer and Fall, varying with downstream needs (Table 4). Station flow preceding water releases generally varied from 3 to 6 cfs. Flow increased sharply to 25 or more cfs when waters were released. Bedload movements were abnormally heavy shortly after initial flow surges and stream bed conformations changed rapidly (Figure 10 and 11). Water flow often receded as fast as initial surges began once desired quotas of water were attained. Reductions in flow, from under 25 cfs to near minimal flow, reduced wetted surface areas of upper Sheep Creek by an estimated 56% in the Spring-Fall period of 1964.

Affects of Rapid Flow Fluctuations on Benthos

The standing crop of benthic fauna at upper Sheep Creek station averaged 32 lb. per surface acre on the July 1963 collection date. Benthic fauna was also collected at upper Sheep Creek station July through September, 1964. Averaged samples indicated benthic fauna attained standing crops of 128, 31 and 22 lb. per surface acre during the months of July, August and September, respectively (Tables 1 & 3). The July estimate reflected a forced concentration of organisms. Water flow was reduced from approximately 30 to 8 cfs two weeks prior to the time the first July set of samples was obtained. At the time of the first sample, the standing crop of benthos averaged 175 lb. per surface acre, while the second set of July samples indicated a standing crop of 80 lb. per surface acre existed. August samples disclosed that the standing crop of benthos had dwindled to 31 lb. per surface acre.

Affects of Fluctuating Flows on Plant Life

Veronica americana was the most common macrophytic plant found in all three streams. This plant was found growing partially submerged, on moist ground near streams and on sandbars adjacent to streams. In Sheep Creek, the species was mainly confined to sandbars and other areas infrequently or never submerged. Two other macrophytes were found in all three drainages: *Marchantia polymorpha* and a *Philonotis* species. Rarely if ever were these two species found in a submerged condition.

Several macrophytes not found in Sheep and North Lone Pine creeks were observed in George Creek, the stream having the least amount of stream fluctuation. *Ranunculus* and *Callitriche* were the most common.

Nostoc verrucosum and a *Cladophora* species were common to all three study streams. Both species were found in limited numbers in Sheep Creek. *Vaucheria* was present at one or more sampling stations on George and North Lone Pine creeks but could not be located in Sheep Creek. *Rhopalodia gibba, Rhopalodia ventricosa,* assorted *Navicula, Cocconeis placentula, Rhoicosphenia curvata* and *Closterium tumidum* were the most commonly identified diatoms.

DISCUSSION AND SUMMARY

Affects of Stream Fluctuation on Benthos

Standing crop estimates of benthic fauna inhabiting the various stations during 1963 and 1964 substantiated the detrimental effects of water fluctuation. While benthos production was not directly related to stream flow fluctuations in the free flowing stream sections, overall production of benthos was reduced in accordance with reductions in total wetted surface area. No long term increases in benthos concentrations, by migrations from dewatered areas, were noted as a result of declining water levels.

Short term increases in benthos concentrations resulting from declining water levels were noted. Water flow receded from 30 to 5 cfs at the upper Sheep Creek station two weeks before the first benthos samples were collected at the station in July 1964. An unbelievable standing crop of 175 lb. per surface acre was recorded for the first sampling date. In comparison, lower North Lone Pine Creek station (the most comparable of other stations) maintained an estimated standing crop of 20 lb. per surface acre during the same period.

Gravel outcroppings providing suitable habitat for most aquatic insects were scarce at upper Sheep Creek station. When water levels receded, mobile fauna were forced to concentrate at the few available outcroppings. Standing crops increased far above normal carrying capacities, accounting for the large poundage recorded. A sharp reduction from 175 to 80 lb. ensued by the time the next set of samples was collected (also in July). Stream flow increased once more on August 1, 1964, and further dispersion of benthic fauna (or losses) was indicated. Standing crops receded from 80 to 31 lb. per surface acre. Storage releases diminished slowly during the last release and were terminated August 23, 1964. Two weeks later, a standing crop of only 22 lb. per surface acre was recorded.

Affects of Stream Fluctuation on Fish Populations

Bedload accumulations allowed stream flow to go underground at the lower North Lone Pine Creek station during the summers or falls of 1962, 1963 and 1964. Extreme water fluctuations, from high flows to intermittent pools, resulted. A 94% variation in water surface was recorded for the 1964 spring-summer-fall period. Fish populations dwindled from sizable numbers (mid-summer 1962) to insignificant levels (1963 and 1964). The formation of intermittent pools during August 1962 allowed raccoons to decimate the normal fish populations.

Fish populations during the latter two years of extreme water fluctuations were maintained only by annual downstream drifts of young fishes. In the above situation, without heavy bedload accumulations the fish populations would not have been so drastically affected. On the other hand, without extensive stream fluctuations relatively insignificant changes in fish population structures would probably have resulted (based on study station results).

Stream fluctuations at the eroding zone station, upper North Lone Pine, created feeding problems for fishes. Water flow was sufficient to maintain the largest standing crops of benthic fauna recorded at any station. Despite declining water levels the average standing crops of benthos for May to August 1963 and for July to October 1964 were 147 and 129 lb. per surface acre. Both averages exceeded standing crop levels of other study stations and were somewhat higher than the May to October (five year period) standing crop average of 109 pounds recorded for Convict Creek, California (Maciolek and Needham, 1951). Nevertheless, larger fishes at the station were apparently unable to utilize many of the most productive riffle areas.

Field observations disclosed that many of the productive riffle areas of upper North Lone Pine Creek station were not frequented at low flows by any but young of the year trout. Low flow conditions and shallow water prevented entrance and exit of larger fishes, as the water in many cases never exceeded 3 inches in depth. Increased drift rates, if they occurred, did not offset the inability of larger fishes to utilize the riffles that were rich in benthic organisms. As a result, large numbers of small trout survived. On the average, trout from the eroding zone station were the smallest of any study station. Average trout length was only 4.2 inches (combined species), while in weight a total of 33.3 were required to weigh a pound. The standing crop of trout for this station, 62 lbs., ranked fourth (of 5 stations) (Table 5). This ranking was in accord with the severity of water fluctuations experienced at the station.

An inverse relationship between increased growth and foraging effectiveness is implied for trout of the upper North Lone Pine Creek station. Such a relationship would account for most of the discrepancy noted between the largest standing crop of benthos and the fourth largest standing crop of fishes in pounds. It would also account for the highest standing crop of trout according to numbers. Some increase in survival rates for young fish could be expected if they did not have to compete with older age groups for food.

Affects of Stream Fluctuation on Oxygen Levels

Unusual oxygen deficits occurred at upper North Lone Pine Creek station. Contrary to most oxygen deficits oxygen was lowest during the photosynthetic periods and highest at night. Deficits were traced to a combination of low stream flow and decomposition of cow manure in the stream.

Lands surrounding the station were controlled by the U. S. Forest Service and cattle grazing allotments were granted. Although a large amount of land was available per cow alloted, cattle congregated along the stream during warm periods of the day, moving out with cooling temperatures. Abnormal concentrations of manure accumulated along and within the nearly "dewatered" stream as an outcome of grazing patterns.

Excreted cow manure is low in dissolved oxygen and contains an abundance of *Eshchericia coli, Aerobacter, Lactobacilli, Streptococcuss,* and *Micrococcus* bacteria (Berry, 1966). Heavy oxygen demands are produced by these bacteria as they carry out the metabolic breakdown of cattle excreta. Five day biochemical oxygen demands (20°C) for beef cattle manure, in population equivalents, were found to be 6.0 per 1,000 pounds of cattle live weight; in studies conducted by Witzel, McCoy, Polkowski, Attoe and Nichols (1966). Berry (1966) indicated the temperature relation of microbial reactions was important, for enzymes responsible for intracellular an extracellular reactions with organic materials follow the van't Hoff rule (in general). Reaction rates for bacterial enzymes would therefore decrease according to the same van't Hoff relationship.

Differentials in biochemical oxygen demand, resulting from temperature changes, accounted for the oxygen deficits recorded. Maximum deficits occurred during daylight hours when water temperatures and microbial activities were highest and grew smaller as temperatures declined (Figure 9). Higher and more stable stream flows, an attribute of most watersheds not showing evidences of erosion and sedimentation, would probably have been able to assimilate the observed cattle wastes without any adverse effect on oxygen concentrations.

Affects on Fish Egg Survival

Seventy-five per cent of the fertilized rainbow trout eggs placed in artificial redds and baskets at upper Sheep station were washed away shortly after emplacement. Most of the gravel bar in which they were emplaced also washed away. Viability of the remaining eggs appeared to have been lowered, with 13% viable after 35 days of interment. High water levels and strong tractive forces, resulting from a rapid release of impounded waters, caused the egg and gravel movements. The deleterious conditions could have originated just as easily from natural flash flooding. Needham and Jones (1955) did report an analogous situation which resulted from natural flood conditions. Drastic changes in the stream channel of Sagehen Creek, a California mountain stream, were noted following flooding, and the loss of three brook trout spawning beds containing incubating eggs were reported. Zero age brook and brown trout were almost completely missing in population samples recovered from the stream during the ensuing summer season. According to Royce (1959), Hobbs (1937) believed that floods were responsible for the low survival rates of certain year classes of trout in New Zealand trout waters.

Sharply declining water levels uncovered artificial rainbow trout redds and baskets placed in another section of Sheep Creek unaffected by high flows (Figures 4 and 5). Cessation of storage water releases caused declining water levels. One day before water levels declined, 37.0% of the eggs in one redd and 11.5% of the eggs in one basket were viable. Two redd sites were still covered with 2 to 3 inches of flowing water two days after flow from Eaton Reservoir ceased. Although 12.5% to 13.5% of the eggs were viable, the ability of sack fry to emerge was questionable. Two days later no water cover remained at the redd sites. Human manipulation of water flow, like the loss of eggs through high stream stages, had again adversely affected rainbow trout egg and fry survival within the stream. A nearly identical situation was recorded at the eroding zone study station—upper North Lone Pine (Figures 6 and 7). This time, receding water levels were due to natural causes.

AFFECTS OF STREAM FLUCTUATIONS ON PLANT LIFE

The lack of true submerged plants and the presence of plants that are often found out of water tend to indicate Sheep and North Lone Pine Creeks were adversely affected by fluctuating water levels and or stream bed instabilities. Water fluctuations may exert a strong influencing factor on aquatic plant populations of these streams.

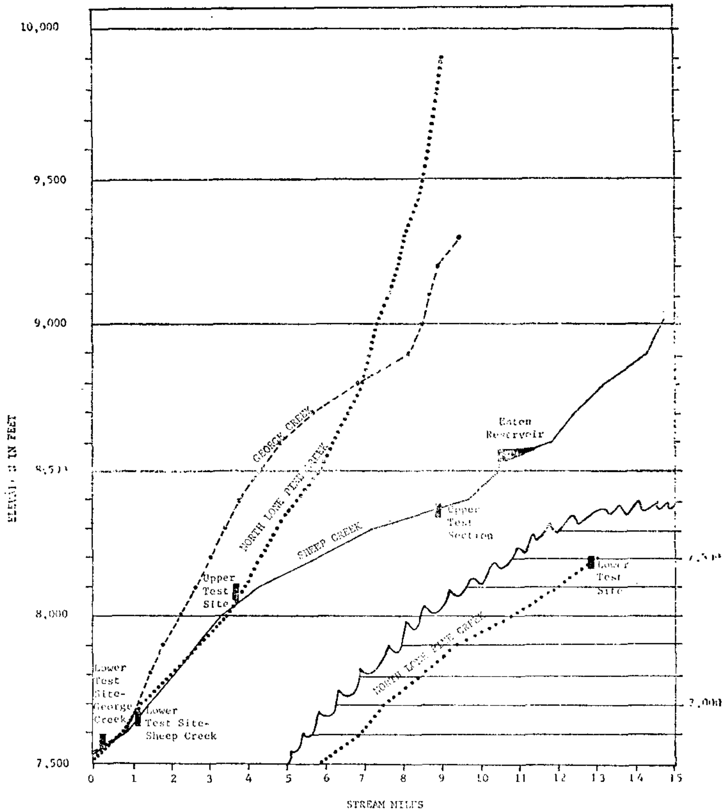

Figure I--Stream profiles of Sheep, George and North Lone Pine Creeks. Average stream gradients for Sheep, George and North Lone Pine Creeks are 1, 9, 3, 5, and 3, 6 percent, respectively.

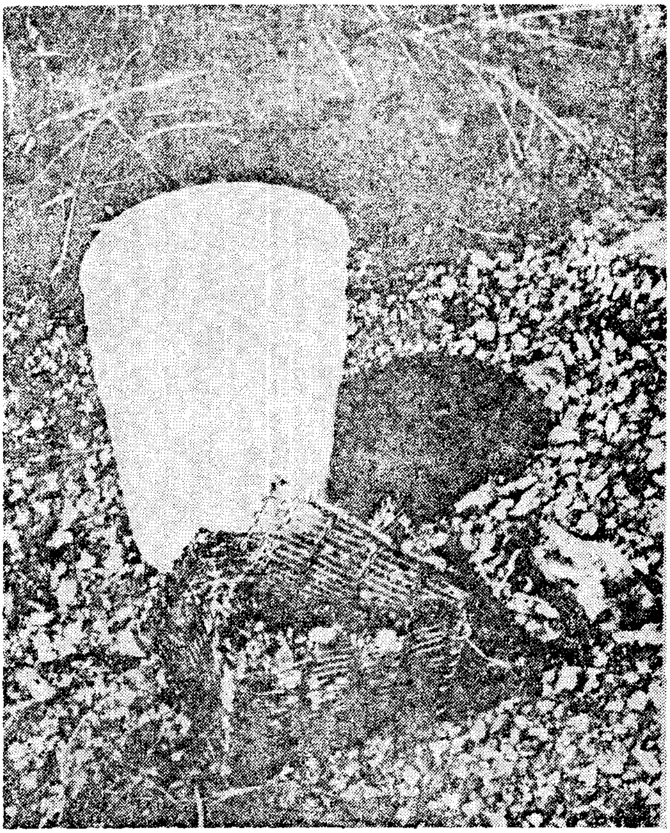

FIGURE 2. A wire egg basket of the type used for artificial trout redd studies. Gravel in the basket illustrates infiltration of fine sand between larger gravel particles.

TABLE 1. The average standing crops of benthic fauna, in pounds per surface acre, that were present at the study stations during each month of sampling.

	Zones				
	Sedimenting		Eroding	Transitory	
	Stations				
Date	Upper Sheep	Lower North Lone Pine	Upper North Lone Pine	Lower Sheep	George
1963					
April [1]	..	..	...	101	..
May	..	..	140	131	89
June	..	14	160	127	68
July	32	7	140	61	82
Average [1]	..	..	147	106 [1]	80
1964					
July [1]	128	21	99	65	45
August	31	No water	116	46	67
September	22	No water	172	57	39
Average [2]	60	..	129	56	50

1 The 1963 average excludes the month of April.

2 One of the two samples collected by Upper Sheep Creek station during July, 1964 was abnormally high. Reasons are given in the text.

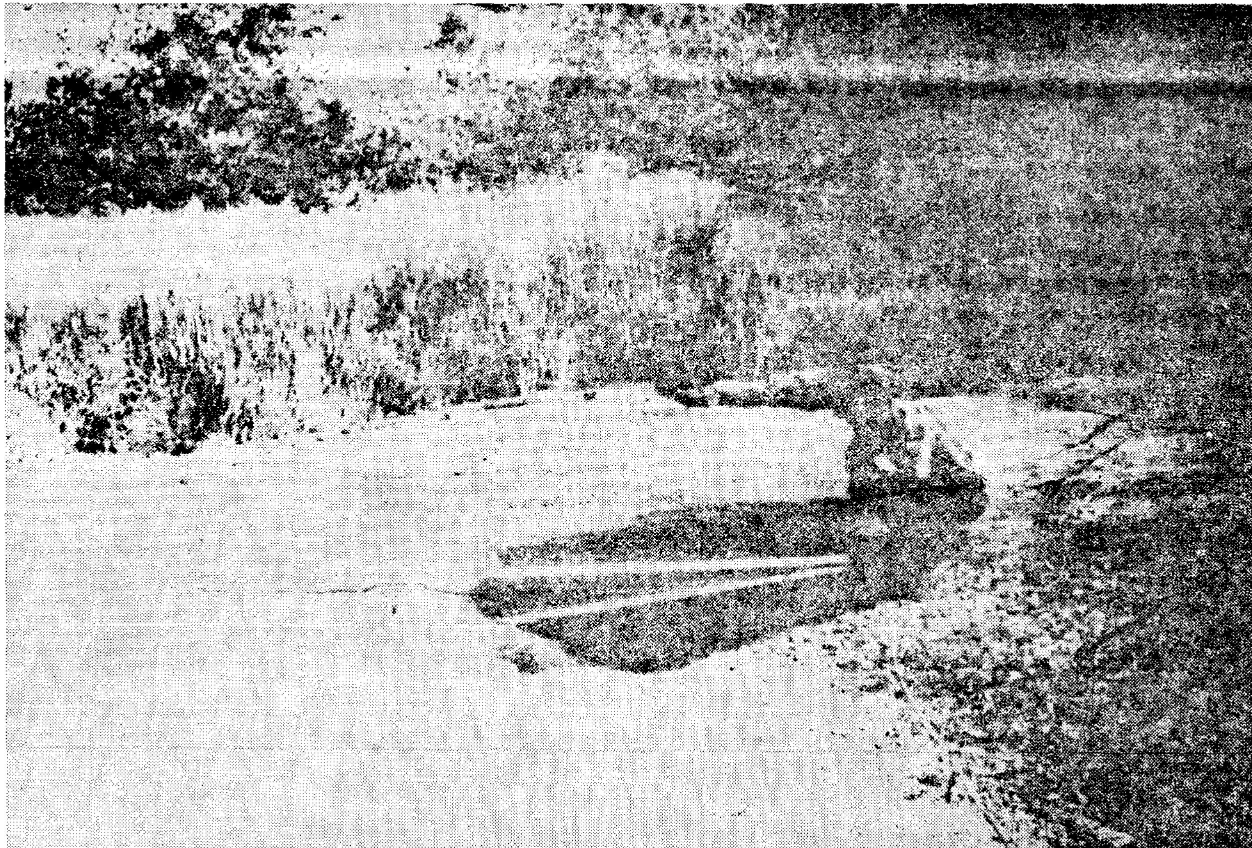

FIGURE 3. Lower North Lone Pine Creek station, September, 1962; the first year flow was reduced to intragravel stream flow only at the station. Note the heavy gravel deposits to the front and rear of the pool.

TABLE 2. Expanded fish sampling data, collected by electrofishing, for the study stations.

Date of sample	No. of trout/S.A.	Lbs. of trout/S.A.	Percent (No.)	Rainbow Trout Weight	Percent (No.)	Brook Trout (Weight)	Percent (No.)	Brown Trout (Weight)
Upper North Lone Pine Creek Station								
Sept. 5, 1962	2,752	50	9.3	28.7	90.7	71.3	..	..
June 20, 1963	816	27	19.6	28.7	80.4	71.3	..	..
Aug. 27, 1963	1,760	75	7.7	13.3	92.3	86.7	..	..
June 17, 1964	928	30	11.3	17.3	88.8	82.7	..	..
June 18, 1964	680	24	8.2	13.3	91.8	86.7	..	..
Average	1,387	41	11.2	20.3	88.8	79.7	..	..
Upper Sheep Creek Station								
June 19, 1963	928	50	2.4	1.8	96.6	91.9	1.0	6.3
Aug. 23, 1963	1,294	57	0.3	0.2	99.7	99.8	..	..
June 18, 1964	163	11	..	..	97.2	74.2	2.8	25.8
Average	795	39	0.9	0.7	97.8	88.6	1.3	10.7
George Creek Station								
Sept. 13, 1962	1,279	60	69.5	71.6	30.5	28.4	..	..
June 20, 1963	809	71	59.1	67.1	40.9	32.9	..	..
Aug. 22, 1963	647	61	67.1	57.8	31.8	38.6	1.1	3.5
June 10, 1964	404	37	27.3	47.6	72.7	52.4	..	..
June 16, 1964	340	25	37.0	37.4	54.4	50.1	8.7	12.5
Average	696	51	52.0	56.3	46.1	40.5	2.0	3.3
Lower Sheep Creek Station								
Sept. 13, 1962	200	37	83.7	79.4	13.5	5.0	2.7	15.6
June 18, 1963	184	20	79.4	71.9	17.7	14.3	2.9	13.8
Aug. 26, 1963	546	76	95.1	94.6	3.0	3.9	2.0	1.5
July 1, 1964	226	19	75.6	85.2	9.8	9.7	14.6	5.1
July 8, 1963	205	22	76.3	66.3	7.9	6.5	15.8	27.1
Average	272	35	82.0	79.5	10.4	7.9	7.6	12.6
Lower North Lone Pine Creek Station								
Sept. 7, 1962	88	6	10.0	24.0	90.0	76.0	..	..
June 21, 1963	32	2	25.0	...	75.0	...	..	..
Aug. 23, 1963	304	6	5.3	11.5	94.7	88.5	..	..
Average	141	5	13.4	...	86.6	88.5	..	..

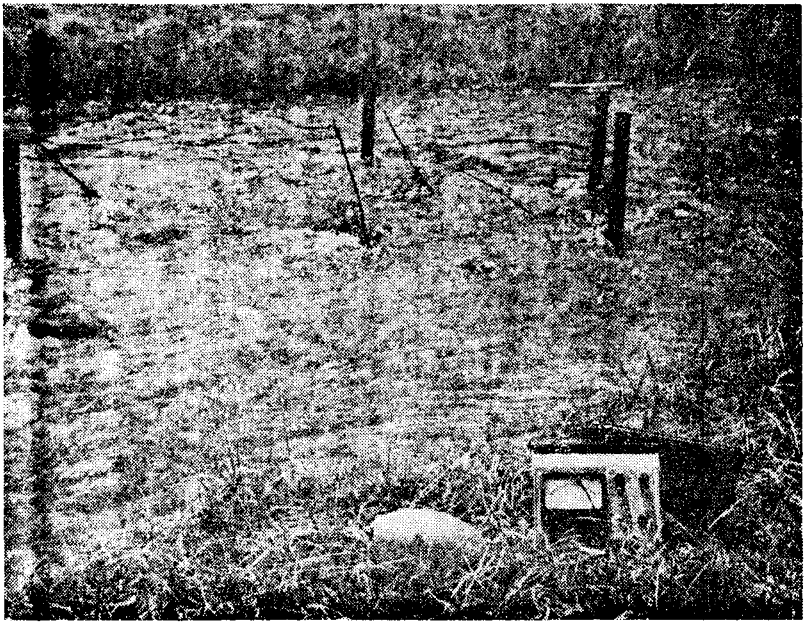

FIGURE 4. Stream stage of the transitory zone at the time artificial rainbow trout redds were constructed, May 22, 1964.

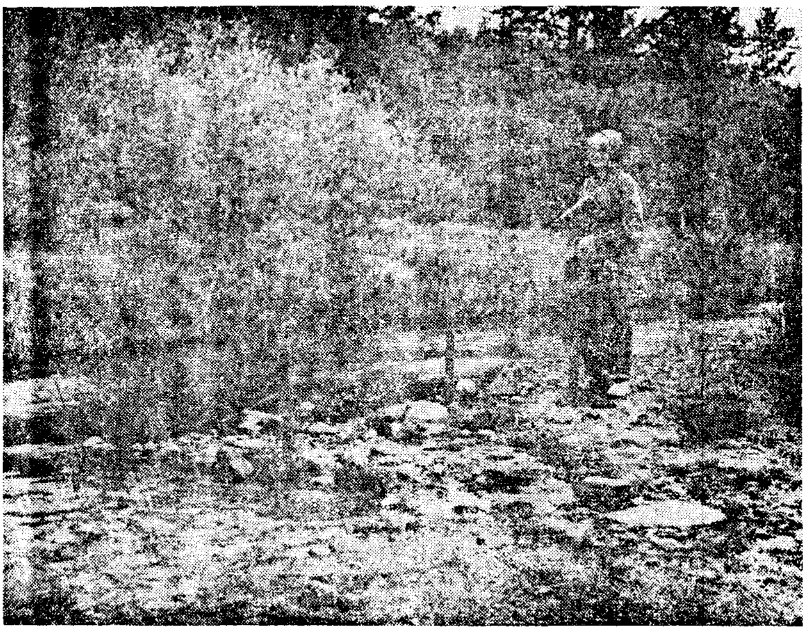

FIGURE 5. The author's wife is standing at the same trout redd site shown in Figure 18, June 29, 1964. Storage releases from an upstream impoundment had ceased two days earlier.

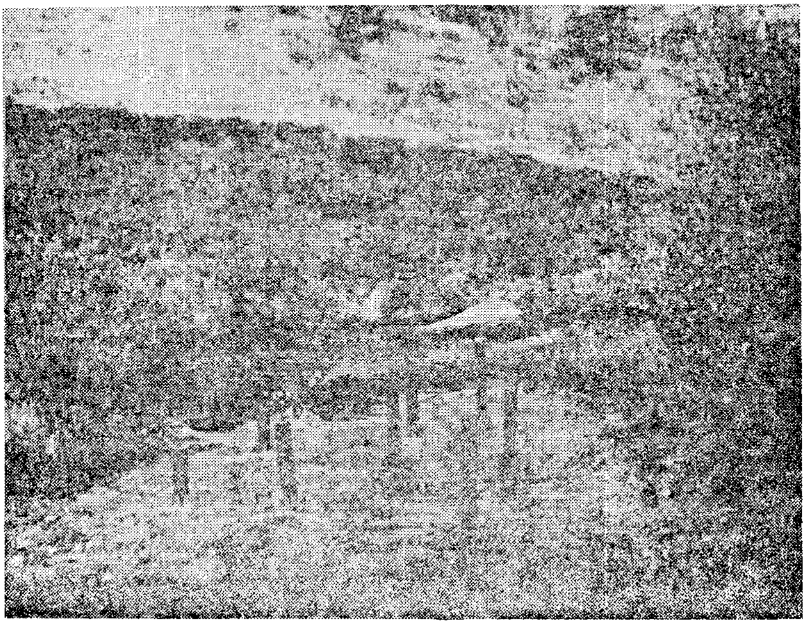

FIGURE 6. A portion of upper North Lone Pine Creek station that was used in trout egg survival studies, artificial redds and egg baskets were interspersed around visible standpipes. Note the eroding stream bank in the background of the photograph.

FIGURE 7. The same portion of upper Lone Pine Creek as is shown in Figure 6. Note how the water level had receded between photographs.

TABLE 3. Average standing crops of benthic fauna in pounds per surface acre, that were estimated to be present at the study stations during each sampling interval.

Date	Sedimenting U. Sheep	Eroding U.N.L.P.	Sedimenting L.N.L.P.	Transitory L. Sheep	Stabilized George
1963					
April	...	...	...	101	..
May (1st half)	...	103	...	118	..
May (2nd half)	...	177	...	144	89
June	...	160	14	127	68
July	32	140	7	61	82
1964					
July (1st half)	175	111	20	...	39
July (2nd half)	80	86	22	65	50
August	31	116	No water	46	67
September	22	172	No water	57	39

TABLE 4. Eaton Reservoir water release patterns for the years 1960 to 1965. Amounts, timing and duration of releases affected zoobenthos and nekton of upper and lower Sheep Creek study stations.

Year of Water Release	Average Water Release, in cfs.	Duration of Water Release
1960	25	May 20 to August 9
1961	25	June 26 to September 2
1962	25	May 4 to May 17
	50	May 17 to June 4
	25	June 4 to June 19
	50	June 19 to June 22
	25	July 14 to July 28
1963	25	July 3 to August 2
1964	25	May 25 to June 27
	25	August 1 to August 23

TABLE 5. Estimated standing crops of trout, in numbers and pounds per surface acre, existing at the study stations; June, 1964. Trout under 3.3 inches were excluded from the estimates. Numbers of trout per station were estimated by mark and recovery methods and, subsequently expanded to numbers per surface acre.

Study Station	Estimated Standing Crop		Lower Confidence Limit		Upper Confidence Limit	
	No.	Lbs.	No.	Lbs.	No.	Lbs.
George	1,257	104	852	(71)*	2,169	(180)*
Lower Sheep	881	112	551	(70)*	1,892	(240)*
Upper Sheep	(2,000)*	(110)*	....	.....	....	......
Upper North Lone Pine	2,056	(62)*	1,672	(50)*	2,752	(83)*
Lower North Lone Pine	(176)*	(12)*	....	.....	....	......

* These figures represent estimates based on confidence limit data.

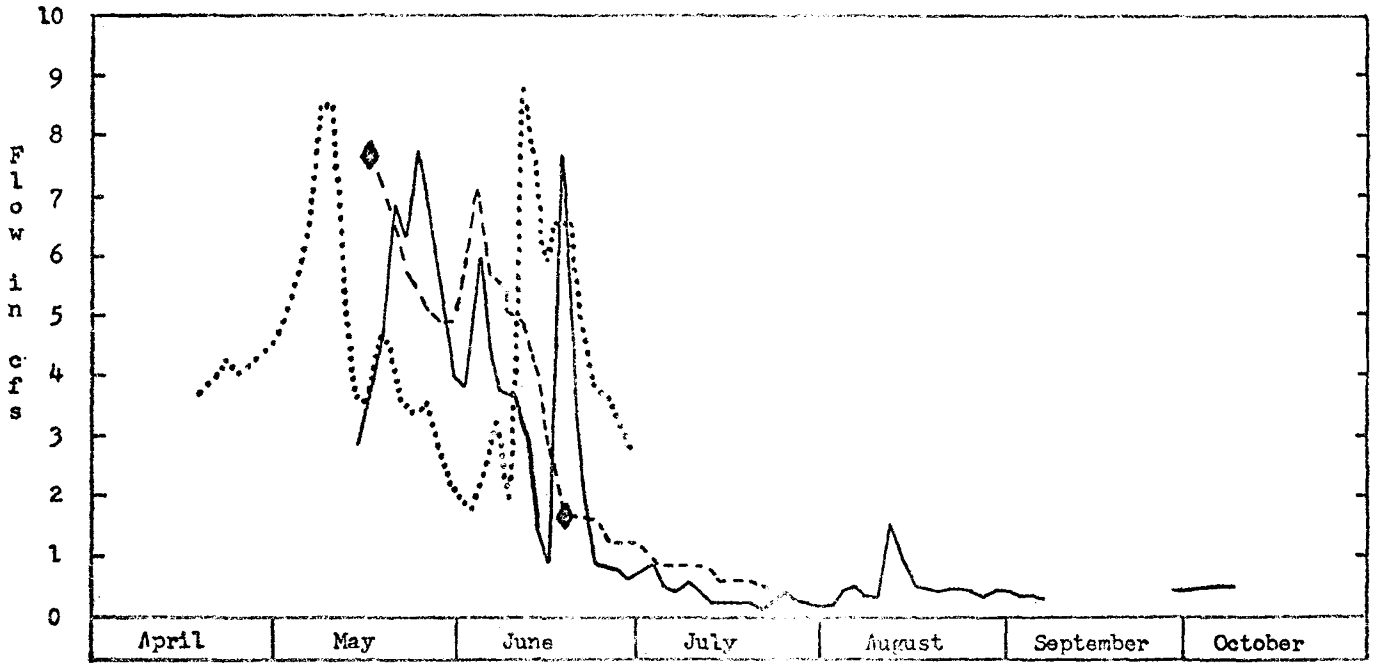

Figure 8. Average daily stream flows at the upper North Lone Pine Creek gaging station; 1963, 1964 and 1965. Stream flow information for 1963 is delineated with a solid line, 1964 information by a dashed line, and 1965 information by a dotted line. Diamonds indicate the dates on which rainbow trout eggs were placed in or removed from stream gravels.

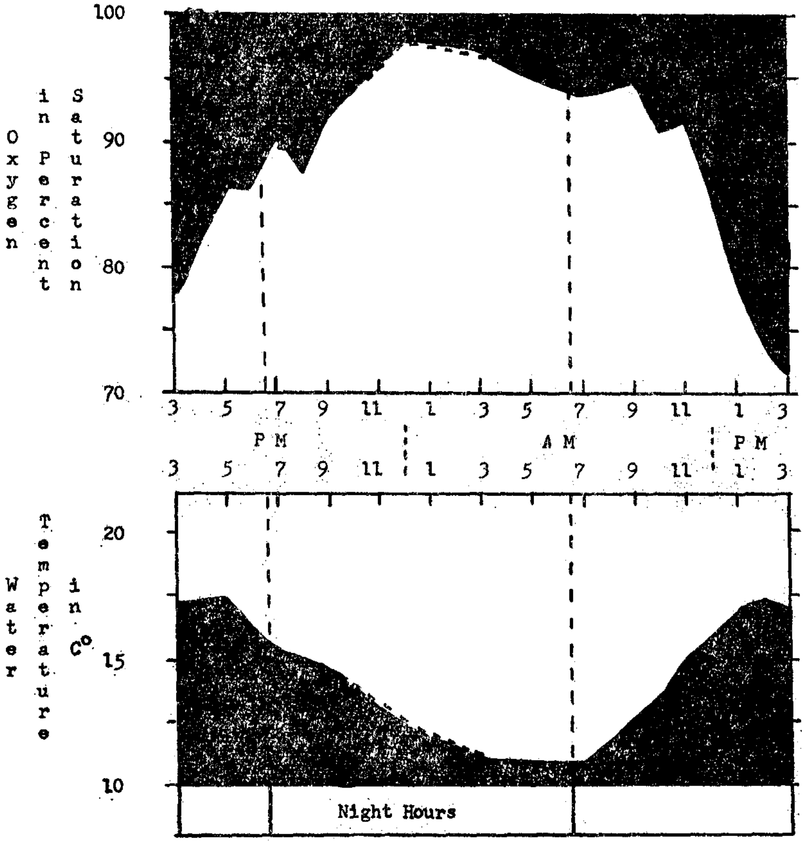

Figure 9. Oxygen levels, in percentage saturation, and water temperature information that was recorded at upper North Lone Pine Creek study station, August 8 and 9, 1964. The oxygen deficit decreased during night hours as water temperature declined and increased with increasing water temperature during the daylight hours.

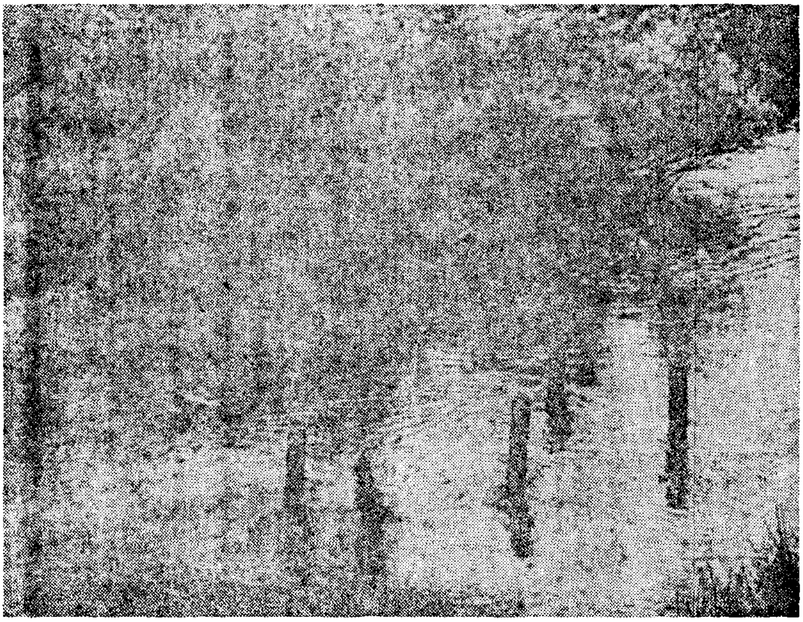

FIGURE 10. Sixteen standpipes, in rows of 4, had been installed two days before water rose to the level pictured. Erosion of the gravel bar by high stream flows reduced the number remaining upright to six

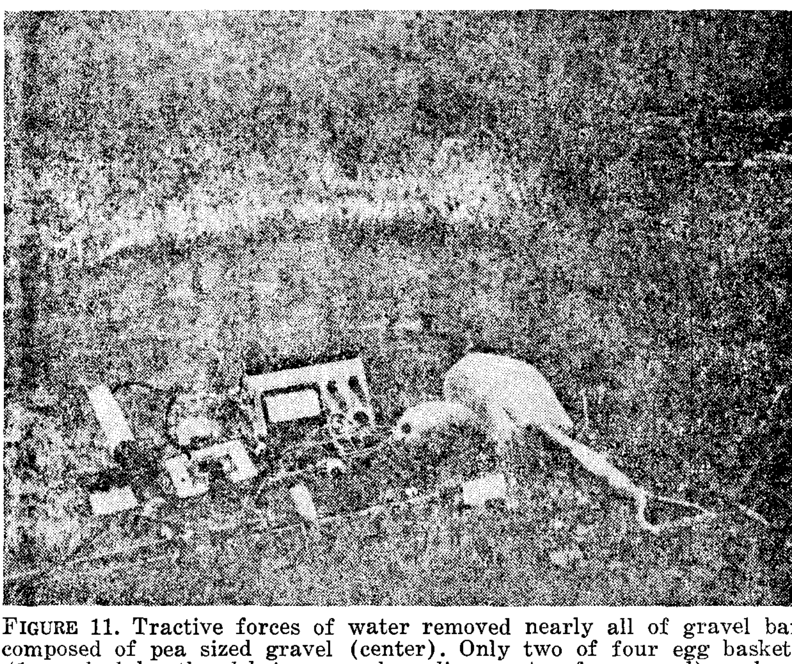

FIGURE 11. Tractive forces of water removed nearly all of gravel bar composed of pea sized gravel (center). Only two of four egg baskets (1 marked by the debris covered sapling center foreground) and no artificial redds containing trout eggs remained.

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