WATER QUALITY STATUS REPORT ● REPORT NO. 64

BILLINGSLEY CREEK
Gooding County, Idaho
1984

Prepared by
Tim Litke

Department of Health & Welfare
Division of Environment
Boise, Idaho

May 1986

WATER QUALITY STATUS REPORT • REPORT NO. 64

BILLINGSLEY CREEK

GOODING COUNTY, IDAHO

1984

PREPARED BY

TIM LITKE

IDAHO DEPARTMENT OF HEALTH AND WELFARE

DIVISION OF ENVIRONMENT

BOISE, IDAHO

MAY, 1986

TABLE OF CONTENTS

Abstract....i

List of Tables....ii

List of Figures....iv

INTRODUCTION....1
- Past Water Quality Studies....2
- Objectives....3
- Drainage Basin Description....4
- Monitoring Stations....4

MATERIALS AND METHODS....6

RESULTS AND DISCUSSION....7
- Stream Discharge....7
- Total Residue, Dissolved Solids, and Suspended Solids....8
- Settleable Solids....11
- Turbidity....11
- Biochemical Oxygen Demand, Total Organic Carbon and Dissolved Oyxgen....12
- Nutrients....14
- Bacteria....18
- Macroinvertebrates....21
  - General Considerations....21
  - Structure and Abundance of the Invertebrate Community....22
  - Biotic Condition Index....23
  - Functional Feeding Group Relationships....23
- Macroinvertebrate Summary....24

CONCLUSIONS....24

RECOMMENDATIONS....26

LITERATURE CITED....28

TABLES....31

FIGURES....52

APPENDIX 1....92

APPENDIX 2....93

ABSTRACT

Billingsley Creek, Gooding County, Idaho has been identified as a stream where fish farm discharges and other land use practices are degrading water quality. The Idaho Department of Health and Welfare, Division of Environment sampled Billingsley Creek to assess in-stream water quality and to determine the impacts of existing point (e.g., fish hatcheries) and agricultural non-point (e.g., feedlot runoff, grazing, soil erosion) pollution sources on water quality. Chemical and biological parameters were monitored at 9 stream stations and 6 fish rearing facilities throughout 1984.

Portions of Billingsley Creek exhibited symptoms of a stressed aquatic ecosystem, with the most severe water quality degradation observed in the mid-reaches of the creek near two major hatchery facilities. Water quality impacts associated with hatchery effluents included solids, nutrient, and bacteria loading of Billingsley Creek. Extensive anoxic sludge deposits were observed below major hatcheries. Elevated inorganic nitrogen (nitrite plus nitrate) concentrations (range 0.79 to 9.73 mg/l) and total phosphorus concentrations (range 0.05 to 0.25 mg/l) in the mid-reaches of the creek exceed established limits to prevent nuisance plant growth. Unionized ammonia concentrations approached toxic levels in hatchery effluents and the creek. Diel dissolved oxygen measurements revealed nighttime dissolved oxygen concentrations below the 6.0 mg/l State standard. Primary and secondary contact recreation fecal coliform standards were exceeded on various sampling dates. The macroinvertebrates collected indicated a benthic community composed primarily of pollution-tolerant organisms (e.g., chironomids, gastropods, etc.). Data also indicated water quality degradation due to feedlot runoff, grazing activities, and bank erosion or mass-wasting.

Hatchery effluents continue to impair Billingsley Creek water quality and threaten designated uses of the creek. Solids related impacts could be reduced by better operation and maintenance practices at the hatcheries. Previously identified Best Management Practices (BMPs) should be included in NPDES permits for Billingsley Creek fish rearing facilities. Confined animal feeding operations should collect runoff and process wastewaters in settling ponds for land application. Agricultural BMPs to reduce soil erosion should be implemented in the Billingsley Creek watershed. Stream bank areas prone to mass-wasting should be identified and stabilized.

LIST OF TABLES

Table 1. Sample station locations and descriptions....31

Table 2. Water quality data for Billingsley Creek survey stations....32 & 33

Table 3. Water quality data for fish hatchery effluents....34 & 35

Table 4. Annual total suspended solids load in hatchery effluent and at Statioon B7, Billingsley Creek....36

Table 5. Settleable solids in fish hatchery effluents....37

Table 6. Discharge, total organic carbon (TOC) concentrations, TOC loadings, biochemical oxygen demand (BOD_5), BOD_5 loadings, and dissolved oxygen in fish rearing facility effluents....38

Table 7. Annual nitrogen loading of Billingsley Creek by fish hatcheries....39

Table 8. Total phosphorus concentrations and loadings of fish hatchery effluents....40

Table 9. Mean annual discharge, orthophosphate concentrations, and orthophosphate loadings of fish hatchery effluents....41

Table 10. Total coliform, fecal coliform, and fecal streptococcus bacteria densities in Billingsley Creek and fish hatchery effluents....42

Table 11. Densities, tolerance quotients, and functional feeding groups of macroinvertebrates collected in Billingsley Creek, April 25, 1984....43 & 44

Table 12. Densities, tolerance quotients, and functional feeding groups of macroinvertebrates collected in Billingsley Creek, July 25, 1984....45 & 46

Table 13. Densities, tolerance quotients, and functional feeding groups of macroinvertebrates collected in Billingsley Creek, December 28, 1984.....47 & 48

Table 14. Species list of invertebrates collected in Billingsley Creek.....49 & 50

Table 15. Macroinvertebrate densities, species richness, community tolerance quotients, and Biotic Condition Index for Billingsley Creek stations.....51

LIST OF FIGURES

Figure 1. Billingsley Creek study area....52

Figure 2. Sampling stations for Billingsley Creek water quality survey, 1984....53

Figure 3. Stream discharge above and below the Jones Hatchery on the dates indicated, 1984....54

Figure 4. Mean annual total, filterable, volatile, and non-filterable solids concentrations at the Billingsley Creek survey stations, 1984....55

Figure 5. Total suspended solids concentrations measured in Billingsley Creek at Curren Springs and the Highway 30 bridge, and stream discharge at the Highway 30 bridge, 1984....56

Figure 6. Mean annual turbidity concentrations at the Billingsley Creek survey stations, 1984....57

Figure 7. Mean annual dissolved oxygen concentrations and BOD_5 for the Billingsley Creek survey stations, 1984....58

Figure 8. Dissolved oxygen and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek below Rangen's Hatchery....59

Figure 9. Dissolved oxygen and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek below Jones Hatchery....60

Figure 10. Dissolved oxygen and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek at Tupper Grade upstream of the Idaho Springs hatchery....61

Figure 11. Dissolved oxygen and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek below Fisheries Development Hatchery....62

Figure 12. Dissolved oxygen and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek above the Highway 30 bridge....63

Figure 13. Dissolved oxygen and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek below the Highway 30 bridge....64

Figure 14. Mean annual inorganic nitrogen, total kjeldahl nitrogen, and total ammonia concentrations at the Billingsley Creek survey stations, 1984....65

Figure 15. Mean annual total phosphorus and orthophosphate concentrations at the Billingsley Creek survey stations, 1984....66

Figure 16. Mean annual total coliform and fecal coliform bacteria densities at the Billingsley Creek survey stations, 1984....67

Figure 17. Mean annual fecal streptococcus densities at the Billingsley Creek survey stations, 1984....68

Figure 18. Bacteria densities in Billingsley Creek at Station B1, Curren Springs, 1984....69

Figure 19. Bacteria collected in Billingsley Creek at Station B2, below Rangen's Hatchery, 1984....70

Figure 20. Bacteria collected in Billingsley Creek at Station B3, above Jones Hatchery, 1984....71

Figure 21. Bacteria collected in Billingsley Creek at Station B4, below Jones Hatchery, 1984....72

Figure 22. Bacteria collected in Billingsley Creek at Station B5, above Idaho Springs Hatchery, 1984....73

Figure 23. Bacteria collected in Billingsley Creek at Station B5A, below Idaho Springs Hatchery, 1984....74

Figure 24. Bacteria collected in Billingsley Creek at Station B6, below Fisheries Development Hatchery, 1984....75

Figure 25. Bacteria collected in Billingsley Creek at Station B7, below the Highway 30 bridge, 1984....76

Figure 26. Bacteria densities in Rangen Hatchery combined raceway effluent, 1984....77

Figure 27. Bacteria densities in Rangen Hatchery settling pond effluent, 1984....78

Figure 28. Bacteria densities in Jones Hatchery combined raceway effluent, 1984....79

Figure 29. Bacteria densities in Jones Hatchery settling pond effluent, 1984....80

Figure 30. Bacteria densities in Idaho Springs Hatchery combined raceway effluent, 1984....81

Figure 31. Bacteria densities in Idaho Springs Hatchery rearing pond effluent, 1984....82

Figure 32. Bacteria densities in Fisheries Development Hatchery settling pond effluent, 1984....83

Figure 33. Bacteria densities in Spring Creek Ranch rearing pond effluent, 1984....84

Figure 34. Bacteria densities in Hidden Springs rearing pond effluent, 1984....85

Figure 35. Functional feeding groups of macroinvertebrates collected (percent occurrence by numbers of individuals) at Billingsley Creek Station B1 (Curren Springs), December 28, 1984....86

Figure 36. Functional feeding groups of macroinvertebrates collected (percent occurrence by numbers of individuals) at Billingsley Creek Station B4 (below Jones Hatchery), April 25, 1984....87

Figure 37. Functional feeding groups of macroinvertebrates collected (percent occurrence by numbers of individuals) at Billingsley Creek Station B4 (below Jones Hatchery), July 25, 1984....88

Figure 38. Functional feeding groups of macroinvertebrates collected (percent occurrence by numbers of individuals) at Billingsley Creek station B6A (above Fisheries Development), July 25, 1984....89

Figure 39. Functional feeding groups of macroinvertebrates collected (percent ocurrence by numbers of individuals) at Billingsley Creek Station B7A (above U.S. Highway 30 bridge), July 25, 1984....90

Figure 40. Functional feeding groups of macroinvertebrates collected (percent occurrence by numbers of individuals) at Billingsley Creek Station B7 (below U.S. Highway 30 bridge), December 28, 1984....91

INTRODUCTION

About 90 percent of commerical trout production in the United States may be attributed to 70 to 80 fish rearing facilities located in the State of Idaho. Discharges from these facilities can, due to design or operation deficiencies, adversely impact receiving water quality due to their elevated suspended solids, settleable solids, biochemical oxygen demand (BOD_5), and nutrient levels. Hatchery impacts on Idaho's water resources are intensified due to the geographical distribution of these facilities; the majority (approximately 60 facilities) are concentrated along the Snake River and its tributaries in Twin Falls, Gooding, and Jerome counties. This area is particularly suitable for aquaculture because of the large quantity and high quality of water available from springs arising from the Snake River Plain Aquifer along the northeast side of the Snake River canyon. Nonconsumptive water use for many of the larger hatcheries ranges from 200 to 500 cubic feet per second (cfs) with smaller hatcheries using 5 to 50 cfs.

Discharges from fish rearing facilities have the greatest potential impact on small receiving streams such as Billingsley Creek, which is a small spring-fed tributary of the Snake River. Located in southwestern Gooding County, Billingsley Creek has been identified as a receiving stream where fish rearing facility discharges are impacting water quality. Water use conflicts are common on the creek. There is competition between various uses including irrigation, stock watering, fish rearing, recreation, and homesite usage. Currently there are about 10 fish rearing facilities utilizing spring sources on the creek to raise rainbow trout. In addition, several ranches allow livestock direct access to the creek from pastures and feedlots, and there are localized areas of significant soil erosion and mass wasting. All of these uses impact or have a potential negative impact on the water quality of Billingsley Creek.

According to the Idaho Water Quality Standards and Wastewater Treatment Requirements (Idaho Department of Health and Welfare, 1985) Billinglsey Creek should be managed to provide a diversity of beneficial uses including: domestic water supply, agricultural water supply, cold water biota, salmonid spawning, and both primary and secondary contact recreation. In addition, Billingsley Creek was designated a special

resource water in 1980. This designation implies that the creek needs intensive protection to: a) preserve outstanding or unique characteristics, and b) to maintain current beneficial uses. Because of this designation, in-stream water quality, water quality impacts, and water uses need to be assessed to assure that ambient water quality is maintained and protected, and that designated beneficial uses are protected. Management strategies should therefore focus on activities in the watershed (e.g., fish rearing, grazing) that have an adverse impact on designated beneficial uses.

Past Water Quality Studies

The Idaho Department of Health and Welfare (IDHW) performed a cursory study in 1977 (Ralston, 1977). Water quality data from 1971 through 1976 was analyzed to see if Billingsley Creek met the 1973 Idaho Water Quality Standards and Wastewater Treatment Requirements. It was concluded that the creek did not meet State standards for total or fecal coliform bacteria. Although specific contributing sources could not be identified, probable sources including fish hatcheries, irrigation return water, and feedlots and dairies were mentioned.

A brief study by Ralston (1979) during September and October 1979 again indicated State standards for fecal coliform bacteria were not being met. In addition, diel dissolved oxygen monitoring indicated in-stream saturations less than the standard set to support a salmonid fishery.

The Idaho Department of Water Resources performed a study in 1981 (Winner, 1981) to assess the effects of water use on water quality and to estimate the impacts of future development on Billingsley Creek. This study consisted of sampling in March, June, July, and October of 1980. Winner (1981) concluded that; a) water quality is generally good but nutrients, sediments, and ammonia at times reach restrictive levels, b) high nutrient levels contribute to increased plant growth and indirectly to reduced oxygen tensions at night, c) fish rearing facilities elevate phosphorus, ammonia, bacteria, and sediment levels in the creek, and d) grazing and livestock watering (although not directly assessed) probably severely impact bank stability and contribute sediments, bacteria, and nutrients to the creek. Winner (1981) predicted that additional aquaculture on Billingsley Creek would further exacerbate the problems already mentioned. Management practices were proposed to mitigate some of the impacts.

JRB Associates under EPA contract performed an intensive water quality monitoring survey at seven Magic Valley hatcheries in May and June of 1983 (JRB Associates, 1984). Effluent data were collected and in-stream effects of discharges were assessed. In addition, JRB Associates performed an intensive 24 day study at several hatcheries retrofitted with screens as Best Conventional Pollutant Control Technology (BCT). This second study was initiated in March, 1984.

JRB Associates findings will be discussed in greater detail later in this report. Basically they recommended that screens be installed in the ends of raceways to improve solids collection. Total suspended solids and settleable solids would therefore be reduced, and a total suspended solids limit of 5 mg/l for raceway effluent was recommended. Stream survey data indicated that portions of Billingsley Creek exhibited symptoms of a stressed aquatic ecosystem, with elevated solids, ammonia, and orthophosphate levels downstream of hatcheries. In addition, the greatest impact of hatcheries on Billingsley Creek was concluded to be solids accumulations below hatchery facilities, which are conducive to eutrophication, deplete dissolved oxygen levels, and smother the benthos. Billingsley Creek also showed signs of stress due to agricultural impacts, primarily from feedlot runoff and grazing.

Each of the above studies were brief projects and most suggested that a year-long assessment of water quality be performed. The purpose of this water quality study is to provide a year-long ambient and critical period intensive survey to assess in-stream water quality and determine the impacts on water quality from existing point sources and agricultural non-point activities on Billingsley Creek.

Objectives

The objectives of this intensive water quality survey on Billingsley Creek were as follows:

A) Primary

1) Monitor and characterize the major sources that affect water quality and assess the impacts on beneficial uses.

2) Acquire data to be utilized for the establishment of allowable point source discharge limitations for fish rearing facilities.

B) Secondary

Assess the impacts on water quality, both negative and positive, from implementation of best management practices and proper operation of existing fish rearing facilities and land use activities.

Drainage Basin Description

Billingsley Creek is located in south-central Idaho near the town of Hagerman (Figure 1). Along its approximately 7 mile course, the stream drops about 350 feet in elevation and receives the flow of 15 to 20 springs. Spring flows are augmented during the irrigation season when agricultural return flows enter the stream. Annual flows fluctuate from about 20 to 45 cubic feet per second (cfs) at Curren Springs (the main source), and from about 50 to 200 cfs at the Highway 30 bridge north of Hagerman.

Land use in the watershed is diverse and includes fish rearing, agriculture, grazing, and some residential development. Soils in the area may be characterized as predominantly fine sandy loams and silty clay loams with moderate to high erosion potentials (U.S.D.A. SCS, 1981). The natural erosional process is enhanced by local ranchers permitting livestock to graze on stream banks with direct access to the creek. Winner (1981) estimated that riparian vegetation, which would act to retain soil, lined less than 15 percent of the creek.

The climate of the Hagerman valley is considered semi-arid, with the valley receiving about 20 cm of precipitation annually (Winner, 1981). Higher elevations receive substantially greater amounts of precipitation with most of this falling as snow in winter.

Monitoring Stations

Eight sampling stations were established along Billingsley Creek from its source at Curren Springs to U.S. Highway 30 to monitor water quality. These stations are referenced in Table 1 and identified in Figure 2. In addition, raceway, settling pond, and rearing pond effluents from six fish rearing facilities were sampled intensively (Table 1, Figure 2). These facilities are described below:

a) Rangen, Inc. - This facility uses water directly from Curren Springs. There are 55 rearing ponds with an in-stream waste settling pond to collect particulates. Mean annual discharge from this facility to Billingsley Creek is about 35 cfs, with about 70 percent and 30 percent of this flow attributable to raceways and settling ponds, respectively. A standpipe drain cleaning system is used to clean the fry raceways and upper production ponds; wastes are discharged to the settling pond. The lower production raceways are vacuumed with the cleaning wastes being discharged into an empty raceway. This raceway is periodically cleaned and the solids removed. Screens are present in most of the raceways to facilitate solids settling.

b) Spring Creek Springs Hatchery - This is a "farm pond" operation, and wastewater from this facility (mean annual discharge of 4 cfs) enters Spring Creek, a tributary of Billingsley Creek. This fish rearing facility operates on the batch system and is comprised of 3 rearing ponds and one settling pond. Groundwater flow through the facility originates in Spring Creek Springs. The settling pond solids are land applied after being dredged prior to restocking the next fish crop.

c) Jones Hatchery - This facility uses water from two spring sources. Weatherby Springs flows through the large ponds while Three Springs flows through the smaller raceways. This hatchery consists of 90 rearing ponds and an off-line cement waste treatment pond, and has a mean annual discharge of about 42 cfs to Billingsley Creek. About 95 percent of this flow may be attributed to the raceways. During the irrigation season the pond does not discharge and its supernatant along with raceway water is used to irrigate nearby crops. A standpipe cleaning system is used for some raceways and the lower production raceways are vacuumed. Screens are present in most raceways.

d) Idaho Springs - This facility obtains water from several sources including Saddle Springs, Tupper Springs, and Billingsley Creek. There are 18 raceways (several are earthen) and 4 rearing ponds. The springs feed the raceways while a portion of Billingsley Creek is diverted through the rearing ponds. Mean annual discharge

of this facility during the study was approximately 100 cfs with raceways and rearing ponds contributing about equal flows. There is no designated settling pond at this facility and raceways are supposedly vacuumed. During the current study this facility was not in operation so few fish were present. In addition, dam boards from the rearing ponds were removed allowing settled materials to erode and enter Billingsley Creek over time.

e) Hidden Springs Hatchery - This is a "farm pond" type of facility operating on batch system. Groundwater from several unnamed spring sources flows through this facility comprised of 10 ponds which discharge via two outfalls to Billingsley Creek. Average annual discharge is less than 20 cfs. Waste products generated by this operation settle out to the bottom of the ponds. Ponds are cleaned out at the time of harvest by diverting the water source to Billingsley Creek thereby dewatering the facility. Solids are dredged out of the ponds prior to restocking the next fish crop and are land applied.

f) Fisheries Development Company - This facility consists of 11 raceways which discharge through 2 sets of settling ponds in series then into Billingsley Creek. Owner plans to install standpipe cleaning systems and to retrofit the raceways with screens to aid in solids deposition. In addition, a vacuum system will be used in some raceways.

MATERIALS AND METHODS

Water quality surveys were run monthly throughout 1984 at the stations previously described. To characterize combined raceway effluent at a facility, samples were collected at common discharge points where effluent flows were well mixed.

Field parameters were analyzed with portable meters. These meters were calibrated prior to each survey. Dissolved oxygen and temperature were measured with a YSI Model 54A meter. Specific conductance was measured with a YSI Model 33SCT meter. The pH was determined with an Accumet Mini pH meter, Model 640A (Fisher Scientific Co.). Flow or stream discharge (Q, in cubic feet per second) was measured with a Marsh-McBirney Model 201 current meter.

Water samples for chemical analysis were collected as "grab" samples into 1 liter cubitainers. One liter was preserved with 2 ml H_2SO_4 for nutrient analysis. Samples were placed on ice and cooled to 4°C. Chemical analyses were conducted by the Idaho Department of Health and Welfare, Bureau of Laboratories, Boise, following Standard Methods (American Public Health Association, 1980).

Bacterial grab samples were collected into sterile 250 ml Nalgene bottles. These samples were cooled to 4°C and delivered to the Twin Falls Branch of the IDHW Bureau of Laboratories. Analysis of bacterial samples followed Standard Methods (American Public Health Association, 1980).

Macroinvertebrates were collected at various Billingsley Creek stations in April, July, and December with a Hess sampler (0.10 m^2). Three samples were collected at each station sampled. Samples were preserved in the field with 70 percent isopropyl alcohol and processed by the IDHW Bureau of Laboratories, Boise.

RESULTS AND DISCUSSION

Stream Discharge

Mean annual stream discharge ranged from around 30 cfs at Curren Springs to about 140 cfs at the Highway 30 bridge (Table 2). Because the stream is exclusively spring fed, dramatic hydrographic fluctuations due to snowmelt runoff or storm events are uncommon; however, seasonal variability is still considerable due to man induced changes. Stream flow generally reaches a maximum in the winter and declines in spring and summer. For example, at station B3 (above Jones Hatchery) flow decreased from 40 cfs in April to 4 cfs in May as a result of irrigation diversion.

In comparison, hatchery discharges were relatively constant. For example, Jones Hatchery combined raceway and pond discharge only decreased from 42 cfs to 34 cfs during the same period. Most stream flow below Jones Hatchery from May through August (about 90 percent) arises as effluent from this facility (Figure 3). Hatchery discharges would therefore be expected to have their greatest impact on Billingsley Creek during this

critical low flow period. For example, reduced current velocities in mixing zones below hatchery outfalls would favor solids deposition. These organic deposits would serve to reduce dissolved oxygen levels as they decompose, provide a source of nutrients to the stream, and smother benthic communities. These deposits would not likely be flushed from the stream due to the lack of high flows.

Total Residue, Dissolved Solids, and Suspended Solids

Total residue (or total solids) is a measure of both suspended (non-filterable residue) and dissolved (filterable residue) materials, which may be either organic and inorganic. Mean annual total residue concentrations were generally above 240 mg/l at the Billingsley Creek stations (Table 2, Figure 4). The dissolved fraction (total dissolved solids-TDS) represented usually greater than 95 percent of total residue at each station.

Total volatile solids concentrations may be used as an indication of the percentage of total residue that is organic in nature. Approximately 20 percent to 25 percent of measured total residue concentrations, regardless of location (Billingsley Creek or hatchery facilities) was organic in nature. Mean annual total volatile solids concentrations ranged from 48 to 65 mg/l at the Billingsley Creek stations (Figure 4).

Total dissolved solids, or salinity, is the sum of the ionic composition of the major cations (e.g., Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}) and anions (e.g., HCO_3^{-}, CO_2-2, SO_4-2, and Cl-) in mass per volume of water (Wetzel, 1983). Salinity may be considered a pollutant, especially if individual components such as the metal cations become toxic with increasing concentrations (Warren, 1971).

Mean annual TDS concentrations in Billingsley Creek ranged from about 230 to 270 mg/l, and are comparable to values calculated from Winner's (1981) specific conductance data (222 to 281 mg/l). Concentrations generally increased at stations B3 and B5. TDS concentrations of hatchery effluents were generally at or below in-stream concentrations. Values ranged from 226 mg/l in Hidden Springs rearing pond effluent to 251 mg/l in Idaho Springs pond effluent (Table 3). Data therefore indicate no net change in total dissolved solids concentrations as groundwater passes through the hatchery facilities; however, no data is available to assess changes in total dissolved solids composition due to hatchery usage.

Mean annual total suspended solids concentrations (TSS) ranged from 4.2 mg/l at Curren Springs to 11 mg/l at station B5 (Figure 4). These data are similar to values reported by JRB Associates (1984) and Winner (1981) for Billingsley Creek. An increase in total suspended solids concentration to 5.5 mg/l below Rangen's Inc. reflects solids additions from raceway effluents as well as the in-stream settling pond. Mean annual concentrations (and range) for this hatchery's raceways and settling pond were 6 mg/l (2 to 26 mg/l) and 10 mg/l (2 to 68 mg/l), respectively.

Highest mean annual TSS concentrations were calculated for stations B3 and B5. Winner (1981) measured TSS concentrations as high as 53.4 mg/l near station B5. Because stations B3 and B5 are above hatchery outfalls, some of the solids in transport probably arose from feedlots and other agricultural activities in these areas of the watershed.

Below both Rangen, Inc. and Jones facilities extensive organic deposits were observed. Additional deposits were observed further downstream in areas of reduced current velocity or macrophyte beds. A similar observation was reported by JRB Associates (1984). Furthermore, they stated that such deposits released a putrid odor when disturbed, and that associated with these deposits were thick mats of the sewage fungus Sphaerotilus natans.

Discharge and TSS concentration data may be used to calculate a suspended solids loading of Billingsley Creek by hatchery facilities. If Curren Springs water quality data are assumed representative of baseline groundwater conditions, hatchery effluent data may be corrected to reflect net changes in effluent water quality resultant from hatchery usage. Because of the limited data base, and because measured TSS concentrations typically were near the lower end of the practical range for the analytical methods used to measure this parameter, these calculations are approximate.

About 1240 metric tons of suspended solids were exported at station B7 during this study (Table 4). Of this amount, about 15 percent (184.5 metric tons per year) may be attributed to hatchery inputs. The single largest contributor was Rangen, Inc. with 85.2 metric tons annually (46 percent of total hatchery input). About 30 percent of total hatchery input may be attributed to Fisheries Development settling pond effluent.

During this study, fish were not being reared at Idaho Springs as evident in a negligible TSS loading (Table 4). In fact, the rearing ponds which receive water from Billingsley Creek were functioning as settling ponds (mean annual influent and effluent TSS concentrations were 11 and 6 mg/l, respectively). However, it might be expected that when rearing fish this facility would contribute a considerable solids loading to Billingsley Creek because of: a) its large size, b) high magnitude of effluent flows, and c) lack of any settling ponds or devices to retain solids in the raceway facilities.

While total hatchery output is only 15 percent of the annual TSS load at B7, the impact of this material on the stream ecosystem is dramatic. Because of the hydraulics of Billingsley Creek, most of the hatchery effluent suspended solids accrues to form thick deposits in the stream channel. This material accrues in pools and eddies during low flow periods (e.g., summer months) and is also trapped by algae and aquatic macrophyte beds. These deposits are eroded as flows increase during the fall and winter months. A comparison of TSS at two locations on Billingsley Creek during 1984 is presented in Figure 5. Note that over an annual cycle TSS concentrations near the mouth were usually greater than those measured at Curren Springs. Concentrations at the mouth increased dramatically in December and January as flows increased.

Suspended solids will have a diverse impact on the structure and function of aquatic ecosystems depending upon their location (e.g., suspended, sedimented) and chemical composition (e.g., organic, inorganic, nutrient content). Suspended solids in transport will reduce light penetration and thereby reduce primary production. Material in transport may also physically damage sensitive tissues of aquatic organisms (e.g., gill tissues) as well as exert an oxygen demand depending upon its organic content.

As the material is deposited in the stream channel, benthic invertebrate diversity declines. This is a result of physically smothering the organisms, a reduction in oxygen levels, a reduction in habitat diversity, and the formation of a physically unstable substrate. As a result of these conditions, pollution intolerant organisms such as stoneflies (Plecoptera), some mayflies (Ephemeroptera), and some caddisflies (Trichoptera) are replaced by tolerant forms such as dipterans, oligochaetes, and molluscs. Organisms indicative of degraded water quality such as Tubifex sp. become common (please see invertebrate summary).

The organics in storage represent particulates the stream cannot transport, and they are processed slowly (depending upon thickness probably anaerobically). These materials exert an oxygen demand and serve as a source of nutrients to the system. If the deposit becomes anaerobic, hydrogen sulfide and other gases may form producing noxious odors.

An additional major impact of Billingsley Creek's suspended solid load is evident in the Snake River reservoir above the Lower Salmon Falls Dam. This reservoir acts as a settling basin for Billingsley Creek's solids (Figure 2). Decomposing sediments may create anoxic conditions at the bottom of the reservoir and thereby limit benthic production and species diversity.

Settleable Solids

Settleable solids is the amount (volume or mass) of particulate matter that settles out of one liter of water in an hour. The NPDES permits for the fish rearing facilities along Billingsley Creek specify a daily average limit of <0.1 ml/l for raceway discharges. The fish rearing facility discharges usually had only a trace of settleable solids present (Table 5).

Turbidity

Turbidity indicates the presence of suspended matter in water (e.g., sand, silt, particulate organic matter, and microscopic plants and animals). Turbidity of Curren Springs over the annual cycle ranged from 0.2 to 0.9 FTU, with an annual mean of 0.44 FTU (Table 2) and is similar to values reported by Winner (1981). With downstream progression, turbidity generally increased (Figure 6) with a maximum annual mean of 1.55 FTU at the Highway 30 bridge. The highest monthly turbidity (4.6 FTU) was observed at the Highway 30 bridge in January, coincident with maximum discharge (213 cfs) and TSS (24 mg/l) for this station. Generally, in-stream turbidity measurements were positively correlated with TSS measurements (Figures 4 and 6).

Turbidity of fish rearing facility effluent was generally not significantly different from in-stream values. Mean annual values ranged from 0.5 FTU in Jones and Idaho Springs raceway effluents to 2.0 FTU in Jones settling pond effluent. These values fall within the range of 0.48 to 8.5 FTU

reported by Winner (1981) for Billingsley Creek hatcheries. Generally, elevated turbidities were associated with settling pond effluents. For example, mean annual turbidities for Rangen's, Jones, and Fisheries Development settling ponds were 0.8, 2.0, and 0.9 FTU, respectively. The highest monthly turbidity observed, 8.5 FTU, was observed in Jones settling pond effluent in October, coincident with maximum monthly TSS (27 mg/l) for this station. These elevated values probably reflect sediment disturbances and sludge resuspension due to biological or physical factors.

Biochemical Oxygen Demand, Total Organic Carbon, and Dissolved Oxygen

Biochemical oxygen demand (BOD_5) is dependent upon the quantity of oxidizable organic matter present in water as well as the composition, density, and activity of the microbial community (American Public Health Association, 1980; Cole, 1983). Instream BOD_5 levels generally exceeded background groundwater levels as measured at Curren Springs (Table 2). The largest increase in BOD was below the Rangen facility, where the mean annual concentration was 2.35 mg/l (Figure 7). Most of this demand can be attributed to raceway effluent (Table 6). Mean annual BOD_5 measurements for fish facility effluents ranges from 0.7 mg/l in Idaho Springs raceway effluent to 5.4 mg/l in Jones settling pond effluent.

The total oxygen demand to process the organic content of fish rearing facility wastes is approximately 230,000 lbs/year (Table 6). Major contributors of this load were Rangen's and Jones raceway effluents (approximately 56 percent of total). When rearing fish, Idaho Springs raceways and rearing ponds could be expected to have a similar loading if not greater due to a lack of solids settling facilities.

Total organic carbon (TOC) loading to Billingsley Creek during the study is estimated to about 220 metric tons. Of this amount, about 68 percent may be attributed to raceway effluents (Table 6). Note that Idaho Springs raceways, even when the facility is inactive, contributed 40.2 metric tons of carbon during the study (about 20 percent of total hatchery input to Billingsley Creek). With a negligible TSS loading (Table 4) and BOD loading (Table 6), these data suggest: a) fish wastes and uneaten food stored in

the raceways is the source of this carbon, b) that this carbon is in the dissolved fraction, and c) that this dissolved organic carbon (DOC) is refractory in nature and resistant to further microbial degradation. Because microbes rapidly utilize labile DOC compounds, the remaining soluble compounds and leachates from deposited fish metabolites and waste food would be expected to be refractory organic compounds.

Depending upon the particular facility, the TOC effluent loadings referenced in Table 6 might represent primarily particulate organic carbon or DOC. As indicated above, Idaho Springs raceways export primarily DOC. Similarly, Jones raceways, again with an negligible TSS output (Table 4) exports a significant TOC load (64.2 metric tons/year) which is probably mostly DOC. However, because fish are being reared in this facility more of this carbon would be expected to be labile, and therefore exert a BOD_5 as indicated in Table 6.

Mean annual dissolved oxygen (DO) concentrations generally exceed groundwater concentrations except below Rangens (Table 1 and Figure 7). Here in-stream DO concentrations decrease (9.45 to 8.1 mg/l) and the highest mean annual BOD_5 (2.35 mg/l) was measured. Mean annual DO concentrations also decrease below the Jones facility, in reponse to the elevated BOD_5 of hatchery effluent. However, all of these mean values exceed the 6.0 mg/l standard for cold water biota and salmonid spawning established by the Idaho Water Quality Standards and Wastewater Treatment Requirements (IDHW, 1985). Between stations B2 and B3, and between B4 and B5, oxygen concentrations increase as BOD's decrease. This indicates a reduction in oxidizable organic matter and subsequent increase in available dissolved oxygen.

On a diel basis DO concentrations fluctuate in response to numerous factors including: water temperature, community production and respiration, and atmospheric pressure. In Billingsley Creek, low DO levels occur at night when respiration of an abundant plant biomass combines with decomposing organic deposits to deplete oxygen concentrations to critical levels along the stream.

Trout will survive oxygen concentrations as low as 3 mg/l, but healthy populations require at least 6 mg/l (Winner, 1981; IDHW, 1985). The results of diel dissolved oxygen sampling in July 1984 are summarized in Figures 8 through 13. At three locations (e.g., above and below Jones Hatchery, and above Idaho Springs Hatchery) dissolved oxygen levels were less than 6 mg/l for several hours during the night. For example, below Jones Hatchery (Figure 9) DO dropped from 12.8 mg/l to 5.0 mg/l (about 70 percent saturation) over a 6 hour period (1600 hours to 2200 hours). Dissolved oxygen then remained at this low level for approximately 6 hours and did not recover until around 1000 hours the following day (12.2 mg/l). Dissolved oxygen measurements above Jones Hatchery, although not for a complete diel cycle, revealed a DO concentration of 4.9 mg/l at 2200 hours.

Nutrients

In aquatic ecosystems, the most important nutrient factors causing a shift from a lesser to more productive state are nitrogen (N) and phosphorus (P). These nutrients frequently limit plant growth due to a limited supply in contrast to a large demand (particularly during the summer). Where these nutrients are in abundant supply, enhanced productivity is sustained and plant biomass increases.

A concentration of 0.3 mg/l total inorganic nitrogen (NH_3, NO_2, NO_3) is usually considered the limit for preventing nuisance growths of aquatic algae and plants (IDHW, 1980). Usually NH_3 and NO_2 are quickly oxidized and NO_3 is therefore the major form considered when comparisons to this limit are made.

Springs contributing flow to Billingsley Creek have relatively high nitrate-nitrogen concentrations (see Winner, 1981). NO_2+NO_3 nitrogen in Curren Springs ranged from 0.82 to 1.30 mg/l with higher concentrations during or just after the irrigation season. This loading results in luxuriant growth of algae and vascular plants below this spring. Mean annual in-stream NO_2+NO_3 nitrogen values also indicate ample nitrogen available to support plant growth (Table 2). Values range from 0.96 at B7 to 1.87 mg/l at B4 (Figure 14).

There is no significant difference between NO_2+NO_3 nitrogen concentrations in Curren Springs and the hatchery discharges (Tables 2 and 3). Only from Idaho Springs rearing ponds was any NO_2+ NO_3-N added to the creek. Because dam boards were removed from the outfalls of these ponds, flow through the ponds increased. As a result, NH_3 produced in sludge deposits was probably being oxidized to NO_3 as oxygen tensions increased.

Ammonia is the primary nitrogenous waste product of aquatic vertebrates and invertebrates. When in water, a given amount of NH_3 reacts with the water to form ammonium ions (NH_4+), depending upon pH. Ammonia in the unionized form is toxic to aquatic life (Willingham et al., 1979). To protect beneficial uses including cold water biota and salmonid spawning, Billingsley Creek should exhibit unionized ammonia concentrations of 0.04 mg/l or less if water quality conditions are optional to support these uses. Under less than optional conditions, such as elevated carbon dioxide concentrations or reduced oxygen levels (see Willingham et al., 1979), unionized ammonia should be 0.02 mg/l or less (IDHW, 1985).

Mean annual unionized ammonia concentrations calculated for Billingsley Creek were all less than the 0.02 mg/l State criterion (Table 2). Only at station B4 (below Jones Hatchery) was this standard approached in November. During this period stream pH was about 8.5 resulting in less NH_3 being ionized.

Mean annual unionized ammonia concentrations calculated for the various fish facility effluents were all less than the 0.02 mg/l State standard except for Hidden Springs (0.021 mg/l). At Hidden Springs values ranged from 0.007 mg/l to 0.034 mg/l. Pond effluent discharges at several fish rearing facilities (Rangens, Jones, Fisheries Development, and Hidden Springs) exceeded this standard at some time during the study.

A positive correlation has been found between high sustained productivity and high concentrations of inorganic and organic nitrogen (Wetzel, 1983). In addition to elevated in-stream NO_3 nitrate concentrations, total Kjeldahl nitrogen (TKN) concentrations were also elevated. Curren Springs had a mean annual TKN concentration of 0.15 mg/l (range 0.1 to 0.3 mg/l).

Values increase with downstream progression with peak concentrations below Rangens and Jones facilities (0.56 and .60 mg/l, respectively) (Figure 14, Table 2). Mean annual effluent concentrations ranged from 0.13 mg/l in Idaho Springs raceway effluent to 1.1 mg/l in Jones settling pond effluent. The elevated concentrations in fish facility effluent represents organic nitrogen contained in uneaten food, fecal material, and fish metabolites. The organic N content of dried sludge from hatcheries is about 3 percent. The elevated TKN concentration for Jones settling pond effluent indicates that some sludge was not retained in the pond. A peak of 3.27 mg/l TKN in Jones settling pond effluent in October probably resulted when gas produced anaerobically in the sediments escaped, resuspending some sludge.

From the data collected, and by using Curren Springs as a groundwater reference, it is possible to estimate the N loading of Billingsley Creek by fish rearing facilities. Approximately 43.1 metric tons of organic nitrate are added to Billingsley Creek annually by hatcheries (Table 7). About half of this load, or 22.9 metric tons/year is as ammonia. About 60 percent of the total organic nitrogen load arises from raceway effluents and probably represents uneaten food and fish metabolites. Annual nitrate loading by hatcheries was estimated to be 4.1 metric tons; this originated from one source, Idaho Springs rearing pond.

In summary, the primary nitrogenous products released by fish facilities were ammonia and organic nitrogen. Once in-stream, these nitrogenous compounds are oxidized to nitrate and support high primary productivity. Due to plant uptake, nitrate levels decline downstream (Figure 14). Had Idaho Springs been in operation, elevated nitrate levels would likely have been observed further downstream.

Phosphorus is an essential nutrient and cellular constituent which often limits aquatic ecosystem productivity. Uncontaminated surface waters typically have total phosphorus concentrations between 0.01 to 0.05 mg/l. Ionic PO_4-3 is usually less than 5 percent of total phosphorus in most natural waters (Tarapchak et al., 1982; Prepas and Rigler, 1982). To control primary productivity and prevent nuisance algae growth, a limit of 0.05 mg/l is recommended for total phosphorus (U.S. EPA, 1977), particularly if the stream discharges to an impoundment. For streams not discharging into impoundments a limit of 0.1 mg/l is typically applied (Mackenthum, 1973).

Mean annual total phosphorus concentration in Curren Springs was 0.05 mg/l, and the concentration increased downstream (Figure 15). Mean annual values calculated for Billingsley Creek stations range from 0.08 mg/l at station B7 to 0.110 mg/l at station B5, and generally equal or exceed the 0.1 mg/l total phosphorus limit to avoid nuisance plant growth. This limit is generally exceeded in the mid-reaches of Billingsley Creek (stations B2 to B5) due to the impact of Rangen and Jones hatchery facilities. If Idaho Springs hatchery had been in operation, this impact would have probably extended further downstream.

Orthophosphate concentrations ranged from 0.007 mg/l at Curren Springs to 0.046 mg/l below Jones Hatchery (Figure 15). Values increase dramatically below Rangens, Inc. (0.007 mg/l to 0.031 mg/l or a 4 fold increase), and remain relatively high throughout the mid-reaches of Billingsley Creek. Only through the Fish and Game reach below Idaho Springs do phosphorus concentrations decline.

Phosphorus levels in fish farm effluents were also significantly higher than groundwater levels. Mean annual total phosphorus concentrations ranged from 0.09 mg/l in Spring Creek Ranch rearing pond effluent to 0.38 mg/l in Jones settling pond effluent (Table 3). Mean annual orthophosphate concentrations ranged from 0.004 mg/l in Rangen, Inc. settling pond effluent to 0.14 mg/l in Jones settling pond effluent. During the summer months Jones settling pond is sealed and the supernatant used for irrigation. Orthophosphate released by the anaerobic sludge in the pond is probably flushed into Billinglsey Creek when flows resume.

The significance of the fish rearing facilities on nutrient dynamics of Billingsley Creek is evident when phosphorus inputs or loadings are calculated. Approximately 11 metric tons of phosphorus were added to Billingsley Creek during this study, with about 30 percent of this phosphorus as orthophosphate (Tables 8 and 9). Of the total phosphorus loading, about 74 percent may be attributed to raceway effluents. The largest single contributor was Idaho Springs raceway with 3.8 metric tons annually (34 percent of total phosphorus load). This probably represents soluable organic phosphorus compounds leached from organic deposits left in the raceways. These deposits are about 3 percent phosphorus (dry weight). Studies of phosphorus release from lake sediments have shown

that phosphorus may migrate upward about 10 cm in 2 to 3 months through anoxic sediments. This movement is primarily diffusion mediated by chemical conditions within the sediments and not strongly regulated by microbes. In addition, phosphorus release from lake sediments has been documented to increase 2 fold as sediments are disturbed by turbulence (Wetzel, 1983). Similar mechanisms possibly regulate phosphorus release from the sludge deposits in the abandoned Idaho Springs raceways.

Phosphorus stored in the in-stream sludge deposits is likely released by diffusion, as well as by aquatic plants. Aquatic plants can act as "nutrient pumps" enhancing levels of inorganic phosphorus in the water column and thereby enhancing primary productivity (see McRoy et al., 1972). The sludge deposits in Billingsley Creek represent a source of nutrients (both nitrogen and phosphorus) which are slowly released to maintain high primary productivity as evidenced by large standing crops of aquatic plants and algae.

The fish rearing facilities on Billingsley Creek enhance nutrient levels in the creek as well as in the Snake River above lower Salmon Falls Dam. The biotic response to the nutrient loading (as well as solids loading), is exacerbated in the small bay above the dam because the bay acts as a nutrient and sediment trap. Continuous nutrient input by Billingsley Creek hatcheries to the Snake River will likely maintain and enhance eutrophic conditions above lower Salmon Falls Dam.

BACTERIA

Bacteria are ubiqutious in natural waters. Fecal contamination of water is indicated by the presence of coliform bacteria (i.e., gram negative, lactose fermenting, enteric rods). If fecal coliforms are present, contamination by warm-blooded animals is indicated, and it is possible that pathogenic microorganisms are present as well. In addition to fecal coliforms, a common bacterial indicator of fecal contamination used in the United States are strains of Streptococcus faecalis. S. faecalis do not survive in water as long as coliforms, so their presence indicates a recent pollution event (Atlas, 1984).

The ratio of fecal coliform bacteria to fecal streptococci is an indication of the likelihood of contamination by human wastes. If this ratio is less than 0.7 animal wastes are indicated; a ratio greater than 4 is indicative of contamination by human wastes (Clausen et al. 1977).

The IDHW has established water quality standards for fecal coliform bacteria in Billingsley Creek (IDHW, 1985). Standards for primary and secondary contact recreation specify that the geometric mean for fecal coliforms shall not exceed 50/100 ml and 200/100 ml, respectively.

Sources of coliform bacteria to Billingsley Creek are numerous. In addition to fish hatcheries, other possible sources include irrigation return flow, feedlots, areas where livestock have access to the creek, and a seasonal input due to large number of waterfowl.

Winner (1981) stated that coliform bacteria were not usually detected in Billingsley Creek springs during his study unless samples were collected a distance from the spring vent. Annual geometric mean densities at Curren Springs in the present study were 28/100 ml (range 6 to 111) and 76/100 ml (range 13 to 392) for fecal coliforms and fecal streptococcus bacteria, respectively. Annual in-stream geometric mean fecal coliform densities ranged from 42/100 ml below the Highway 30 bridge to about 200/100 ml below Rangens (Table 10). Calculated annual geometric means exceed the fecal coliform standard for primary contact recreation at stations B2, B3, B4, B5, and B5A (Figure 16). Below Rangens, the primary and secondary contact standards were exceeded on 30 percent and 20 percent of the sampling dates, respectively. Through the stream reach from station B2 to station B4, the primary contact standard was exceeded from July to September.

Fecal streptococci densities were also highest through this reach with peaks below Rangens and Jones hatcheries (Figure 17). These densities indicate fecal contamination, probably due to livestock grazing in these areas. Monthly curves (Figures 18 through 25) indicate fecal streptococcus peaks in mid-summer and late fall to winter. Summer peaks are probably due to livestock grazing in or near the creek; the latter peak is possibly due to elevated waterfowl densities and surface runoff through feedlots. Fecal coliform to fecal streptococcus ratios of .04 to .37 also suggest these sources of contamination (Table 10).

Mean annual total coliform densities ranged from about 1,600/100 ml above Idaho Springs to 6,600/100 ml below Jones, and were considerably higher than fecal coliforms (Table 10). Maximum densities for both groups were observed in the mid-reaches of the creek (Figure 16) indicating primary sources are located in this part of the watershed (e.g., Rangens, Jones Hatchery, feedlots and grazing areas near stations B2 and B4).

The fish hatchery effluent may be characterized as having high total coliform densities, considerably lower fecal coliform densities, and variable fecal streptococcus densities. Total coliform densities ranged from about 300/100 ml to 37,000/100 ml (Table 10). Lowest densities of all bacteria groups were calculated for Idaho Springs effluent where few fish were reared. The high coliform densities associated with the other facilities are probably due to bacteria growth on waste fish food, fish excretia, and fish metabolites. The high density associated with Jones settling pond effluent (36,808/100 ml - mean annual average) reflects an ample food supply combined with a low flush rate to enhance microbial productivity.

The presence of fecal coliforms and fecal streptococci indicate fecal contamination of fish facility flows. This contamination may arise from waterfowl, livestock, or other warm blooded sources. Elevated fecal streptococcus densities in Rangens, Jones, and Fisheries Development effluents indicate contamination of hatchery flows at some point in these facilities. At these facilities, peak fecal streptococcus densities were observed in summer and fall (monthly data for each facility are summarized in Figures 26 to 34). Summer peaks probably reflect livestock grazing near the creek, while winter peaks represent contamination by runoff from livestock grazing or feedlots as well as waterfowl fecal material.

These data indicate a sizeable bacteria loading of Billingsley Creek due to fish rearing effluents. It is also probable that fish pathogens (bacteria and viruses) not detected by routine bacteriological analysis are released by hatchery facilities. Healthy native trout are probably colonized by these pathogens without any apparent symptoms or disease progression due to their innate resistance. These pathogenic microorganisms may be isolated from apparently healthy fish and cultured (Huddleston, 1986). However, under conditions of stress such as reduced oxygen levels or elevated unionized ammonia concentrations, disease may result impacting resident fish populations. To date no data exists to document such effects in the Billingsley Creek fishery.

MACROINVERTEBRATES

General Considerations

The benthos is a key stream ecosystem component which serves to process organic material and thereby cycle nutrients, as well as to support resident fish populations. Macroinvertebrates are frequently used to assess environmental conditions because a) they are not very mobile and therefore reflect water conditions near the point of collection, b) they have short life spans (from a few months to a few years) and their presence therefore reflects recent stream conditions, and c) their presence reflects on integration of stream conditions through time not assessable by discrete physical/chemical "grab" sampling programs (Platts et al., 1983). A typical stream benthos is comprised predominantly of insects (Hynes, 1970) although other taxonomic groups such as annelids, molluscs, crustaceans, and flatworms are often present.

In Idaho, undisturbed streams typically have a diverse benthos with Ephemeroptera, Plecoptera, and Trichoptera numerically predominant, and total benthos densities of 1,000 to 10,000/m^2 are common (Platts et al., 1983). Rocky Mountain trout streams have been characterized as having benthic communities numerically dominated by mayflies (Andrews and Minshall, 1979).

A number of different numerical approaches have to be utilized in the literature to interpret benthic data. Frequently species diversity indexes (e.g. Shannon-Wiener) have been applied, although their use has received widespread criticism. In general, however, clean water would be expected to support a diverse benthos (i.e., high species richness and equitability).

Because of difficulties inherent in using and interpreting diversity indexes, other biotic indexes have been devised to help interpret benthic data. One index receiving considerable attention is the Biotic Condition Index (BCI) developed by Winget and Magnum (1979). Using four parameters (percent slope, alkalinity, sulfate concentration, and sediment composition) the model predicts a community tolerance quotient (CTQp). Values range from 50 to 108; high values predict the presence of a benthic community comprised of relatively pollution tolerant organisms.

Tolerance quotients are then determined for each species present in the benthos (values range from 2 to 108) and a mean actual community tolerance quotient is calculated (CTQa). The Biotic Condition Index (BCI) is equal to CTQp/CTQa x 100. A BCI greater than 100 indicates a community better than predicted (i.e., composed of less tolerant organisms and therefore indicative of clean water conditions), while a BCI of less than 100 indicates a more tolerant community is present due to degraded water quality.

Structure and Abundance of the Invertebrate Community

Benthos composition on each sampling date is summarized in Tables 11 through 13; a total of 39 taxa are represented. In terms of species richness, Trichoptera, Mollusca, and Diptera were best represented with 9, 8, and 6 taxa, respectively (Table 14). Many of the taxa were not identified to the species level, and the Chironomidae alone probably constitute many species. In terms of abundance, the data indicate a benthos that is dominated by dipterans and molluscs. For example, at station B4 (below Jones Hatchery) approximately 93 percent of all organisms collected in April 1984 were chironomids. In July 1984, 97 percent of the invertebrates collected at station B6A (Table 12) were molluscs (primarily the gastropod Fontellicella sp.). Similar trends are apparent at the other stations during each sampling period. The greatest caddisfly diversity was observed at station B7A (above the Highway 30 bridge) where increased gradient results in increased current velocity and a coarser substrate. Such conditions typically support a diverse insect community (e.g., Rabeni and Minshall, 1977; Mackay and Kalff, 1969). However, the six trichopteran species present represented only 25 percent of total benthos density. Approximately 67 percent of all organisms collected were molluscs.

Benthos densities generally increased below hatchery outfalls in comparison to other stream stations. For example, in April 1984 densities increased from 2,613/m^2 at B3 (above Jones) to 5,997/m^2 at B4 (below Jones) (Table 11). However, species richness and equitability decline at station B4 with most of the individuals collected belonging to a few common tolerant taxa (e.g., Chironomidae, Gastropoda).

Tubificids were collected at various stations on each sampling date. These oligochaetes are typically associated with organic sediments in eutrophic lakes or polluted reaches of streams where dissolved oxygen concentrations are low (Cole, 1983). Their presence indicates that anoxic conditions probably existed at various locations in Billingsley Creek at different times during the study. For example, in July (Table 12) these worms were collected below Rangen, Inc. and Jones Hatchery where hatchery wastes and abundant plant growth would deplete oxygen levels (Figure 9).

Biotic Condition Index

The community tolerance quotient (CTQa) calculated for each station, regardless of season, indicates that the benthos of Billingsley Creek is comprised primarily of tolerant species (Table 15). Below hatchery outfalls, the density of pollution tolerant species increases. For example, the CTQa increases from station B3 (above Jones) to station B4 (below Jones), and the BCI decreases each season indicative of degraded water quality below the Jones facility. From station B3 to station B4 the number of species present declines, or if the number of species remains constant the number of tolerant taxa increase at station B4. For example, in December, species richness remained the same between stations B3 and B4, but the number of species with a TQ of 108 increased at B4 to represent 94 percent of the taxa collected.

The Biotic Condition Index generally decreased with downstream progression, indicative of degraded water quality. With ameliorating conditions at station B7A, the BCI increases, CTQa decreases, species richness increases, and the number of tolerant species (those with a TQ of 108) decreases (Table 15).

Functional Feeding Group Relationships

The invertebrates collected were placed into functional feeding groups following Cummins (1973), Merritt and Cummins (1984), and Pennak (1978) (Tables 11 through 13). This classification scheme is based upon morphological/behavioral adaptations for food acquisition and not necessarily the type of food eaten (e.g., detritus, algae, etc). The particular type of food eaten will vary with season, food availability, and life stage of the organism. Such a classification, while only an approximation due to complex feeding relationships, helps to assess the trophic structure of a benthic invertebrate community.

Generally, the most abundant functional feeding groups observed in Billingsley Creek were scrapers and collector-gatherers (Tables 11 to 13). About 75 percent of the organisms collected in December at Curren Springs could be classified as scrapers (Figure 35). These organisms are primarily herbivorous and graze on the abundant plant growth in the spring.

Below Jones Hatchery (station B4) most of the benthos could be categorized as collector-gatherers in April and July (95.6 percent and 82.1 percent, respectively) (Figures 36 and 37). These organisms typically feed on decomposing fine particulates and their adherent bacteria. Abundant food resources would be available below hatchery outfalls.

The data also indicate a predominance of scrapers at stations B6A, B7A, and B7 (Figures 38, 39, and 40). At each station, the predominant organisms are gastropods which feed on attached periphyton. The above generalizations are valid regardless of season.

Macroinvertebrate Summary

Several factors interact to limit the benthos of Billingsley Creek to a fauna comprised primarily of pollution tolerant species. Elevated nutrient and organic carbon loadings, sedimentation, and periodic oxygen depletions serve to eliminate less tolerant invertebrates (e.g., Plecoptera, many Ephemeroptera, and Trichoptera) and encourage tolerant forms (e.g., chironomids, tubificids, molluscs). Functional feeding groups present reflect the available food resources; scrapers-herbivores which feed on the abundant plant growth due to elevated nutrient concentrations, and collector-gatherers which feed on fine particulate organic matter which is abundant in mixing zones below hatchery outfalls.

CONCLUSIONS

This survey supports the conclusion of Ralston (1977, 1979), Winner (1981), and JRB Associates (1984) that portions of the Billingsley Creek exhibit symptoms of a stressed ecosystem. Much of this water quality degradation may be attributed to aquaculture. Non-point pollution sources such as feedlot runoff and grazing activities also contribute to the problem. The data indicate that the major water quality impacts associated with hatchery effluents are solids, nutrients, and bacteria loading of Billingsley Creek. That water quality is degraded is evident by:

a) Extensive sludge deposits below Rangen and Jones hatcheries.

b) Elevated inorganic nitrogen concentrations in the mid-reaches of the creek which exceed established limits to prevent eutrophication. High concentrations occur as a result of the oxidation of organic nitrogen and ammonia which enter the creek in hatchery effluents.

c) Elevated total phosphorus concentrations in the mid-reaches of the creek which exceed established limits to prevent eutrophication.

d) Measurement of unionized ammonia concentrations near toxic levels in Billingsley Creek as well as in the effuents of several fish rearing facilities.

e) Diel dissolved oxygen measurements which indicate oxygen depletions below the 6 mg/l State standard to support salmonids.

f) Exceedance of the primary contact fecal coliform bacteria standard at stations B2, B3, B4, B5, and B5A.

g) Collection of a pollution tolerant benthic invertebrate community which is indicative of degraded water quality.

The data indicate that the greatest water quality impact during the study occurred in the mid-reaches of the creek between stations B2 to B5. Had Idaho Springs been in operation this impact (e.g., elevated nutrient levels, elevated bacteria densities, oxygen depletions over diel periods, etc.) would likely have extended further downstream. Furthermore, most of this impact was associated with raceway effluents. The data indicate that feedlots and grazing activities also degraded water quality in the mid-reaches of the creek. Elevated total suspended solids levels near B5 (above Idaho Springs) probably reflect the severe stream bank erosion in that area.

The U.S. Environmental Protection Agency (EPA) has issued NPDES pollutant discharge permits to fish rearing facilities in Idaho. The effluent limitations imposed on raceways, rearing ponds, and cleaning waste treatment ponds have been empirically determined and deemed attainable using Best Conventional Pollutant Control Technology (BCT). By July 1, 1984 all discharges were required to achieve effluent limitations that represent application of BCT. The EPA has determined, based upon a 1983 industry study and JRB study results (JRB Associates, 1984) that BCT consists of screened raceways with vacuum or standpipe drain cleaning and off-line treatment of cleaning wastes.

In addition to BCT, Best Management Practices (BMPs) have been identified which increase the effectiveness of BCT. As evident from the present study, hatchery effluents continue to impair Billingsley Creek water quality and threaten beneficial uses of the creek. Solids related impacts could be reduced by better operation and maintenance practices. Therefore, the BCT may be utilized, but to be effective the BMPs must be employed as well.

RECOMMENDATIONS

I. To reduce hatchery associated impacts on Billingsley Creek water quality it is recommended that:

   a) BCT be utilized at all facilities to capture solids.

   b) BMPs be incorporated into NPDES permits and therefore be enforceable. These BMPs are outlined in Appendix 1 and Appendix 2.

   c) Settling pond outfalls be examined and redesigned where needed to increase solids retention.

   d) Screens be installed to keep fish out of settling basins and when fish are found in settling basins they be removed.

II. To reduce water quality degradation associated with agriculture in the Billingsley Creek watershed it is recommended that:

a) Confined animal feeding operations should collect all runoff into treatment ponds to remove nutrients, solids, and bacteria.

b) Crops should not be planted immediately adjacent to the creek, or livestock permitted direct access to the creek.

c) A buffer zone of natural riparian vegetation should be established along the creek to capture eroded soils, to stabilize stream banks, and to provide shading and cover for the stream.

III. To assess and reduce water quality degradation associated with stream bank failure and mass wasting it is recommended that:

a) Studies on bank erosion be conducted to identify critical areas.

b) Critical areas should be stabilized using riparian vegetation as outlined above, or stabilized with riprap, gabions, or other structures.

IV. In-stream habitat improvements should also be considered to help improve Billingsley Creek water quality. These projects might include removal of the larger sludge deposits from Billingsley Creek, or installation of artificial barriers to reduce downstream migration of solids.

Many of the above recommendations have been suggested by previous Billingsley Creek water quality studies (e.g., Winner, 1981; JRB Associates, 1984). To date little action has been taken towards improving stream water quality based upon these recommendations. In order to insure that ambient water quality is improved and maintained, implementation of the above recommendations should occur without further delay.

LITERATURE CITED

American Public Health Association, 1980.
Standard Methods for the Examination of Water and Wastewater, American Public Health Association, AWWA, Water Pollution Control Federation, Washington, D.C., 15th Edition, 1,134 pages.

Atlas, R. M., 1984.
Microbiology: Fundamentals and Applications, Macmillan Publishing Company, New York, 879 pages.

Clausen, E. M., B. L. Green and W. Litsky, 1972.
Fecal Streptococci, Indicators of Pollution. In: A. W. Hoadley and B. J. Dutka, (Eds.), Bacterial Indicators/Health Hazards Associated with Water, American Society of Testing Materials No. 635:247-264.

Cole, G. A., 1983.
Textbook of Limnology, 3rd Edition. C. V. Mosby Company, St. Louis, 401 pages.

Cummins, K. W., 1973.
Trophic Relations of Aquatic Insects, Ann. Rev. Entomol, 18:183-206.

Hynes, H. B. N., 1970.
The Ecology of Running Waters, University of Toronto Press, Toronto, Ontario, 555 pages.

Idaho Department of Health and Welfare, 1980.
Water Quality Status Report, IDHW-Division of Environment, Boise, Idaho, 63 pages.

_____, 1985.
Idaho Water Quality Standards and Wastewater Treatment Requirements, IDHW-Division of Environment, Boise, Idaho, 72 pages.

J. R. B. Associates, 1984.
Development of Effluent Limitations for Idaho Fish Hatcheries, Submitted to U.S. Environmental Protection Agency, EPA Contract No. 68-01-6514, 119 pages.

MacKay, R. J. and J. Kalff, 1969.
Seasonal Variation in Standing Crop and Species Diversity of Insect Communities in a Samll Quebec Stream, Ecology 50:101-109.

Mackenthun, K. M., 1973.
Toward a Cleaner Environment, U.S. Environmental Protection Agency, Washington, D. C.

McRoy, C. P., R. J. Barsdate, and M. Nebert, 1972.
Phosphorous Cycling in an Eelgrass (Zostera marina L.) Ecosystem, Limnol. Oceanogr. 17:58-67.

Merritt, R. W. and K. W. Cummins, (Eds.), 1984.
An Introduction to the Aquatic Insects of North America, Kendall/ Hunt Publishing Company, Dubuque, Iowa, 722 pages.

Pennak, R. W., 1978.
Fresh-Water Invertebrates of the United States, 2nd Edition, Wiley-Interscience, New York, New York, 830 pages.

Platts, W. S., W. F. Megahan and G. W. Minshall, 1983.
Methods for Evaluating Stream, Riparian, and Biotic Conditions, Gen. Tech. Rept. INT-138, Ogden, Utah: U.S. Department of Agriculture, Forest Service, intermountain Forest and Range Experiment Station, 70 pages.

Prepas, E. E. and F. H. Rigler, 1982.
Improvements in Quantifying the Phosphorous Concentration in Lake Water, Can. J. Fish. Aquat. Sci. 39:822-929.

Rabeni, C. F. and G. W. Minshall, 1977.
Factors Affecting Microdistribution of Stream Benthic Insects, Oikos 29:33-43.

Ralston, G. L., 1977.
Water Quality Status Report: Billingsley Creek, Idaho Department of Health and Welfare, Division of Environment, Water Quality Series No. 21, 13 pages.

_____, 1979.
Results of Preliminary Water Quality Monitoring on Billingsley Creek, Ralston and Associates Report, 9 pages.

Tarapchak, S. J., S. M. Bigelow and C. Rubitschum, 1982.
Overestimation of Orthophosphorous Concentrations in Surface Waters of Southern Lake Michigan. Effects of Acid and Ammonium Molybdate, Can. J. Fish. Aquat. Sci. 39:296-304.

U.S. Department of Agriculture, Soil Conservation Service, 1981.
Preliminary Report of the Soil Survey and Interpretations for the Hagerman Planning Unit, Gooding County, Idaho, Gooding SCD, 22 pages.

U.S. Environmental Protection Agency, 1977.
Quality Criteria for Water, Office of Water and Hazardous Materials, U.S. EPA, Washington, D.C., 256 pages.

Warren, C. E., 1971.
Biology and Water Pollution Control, W. B. Saunder Company, Philadelphia, 434 pages.

Wetzel, R. G., 1983.
Limnology, 2nd Edition, Saunders Publishing Company, Philadelphia, 767 pages.

Willingham, W. T. (Coordinator), and J. E. Colt, J. A. Fava, B. A. Hillaby, C. L. Ho, M. Katz, R. C. Russo, D. L. Swanson, and R. V. Thurston, 1979.
Ammonia, pages 6-18. In: A Review of the EPA Red Book: Quality Criteria for Water. R. V. Thurston, R. C. Russo, C. M. Fetteroff, Jr., T. A. Edsall, and Y. M. Barber, Jr. (Eds.), Water Quality Section, American Fisheries Society, Bethesda, MD.

Winget, R. N. and F. A. Mangum, 1979.
Biotic Condition Index: Integrated Biological, Physical, and Chemical Stream Parameters for Management, U.S. Forest Service, Ogden, Utah, 51 pages.

Winner, J. E., 1981.
Billingsley Creek Water Quality, Idaho Department of Water Resources, 40 pages.

Table 1. Summary of Billingsley Creek and Fish Rearing Facility Survey Stations, 1984.

STATION #	DESCRIPTION	LEGAL DESCRIPTION	ELEVATION (ft)	STORET #
B-1	Curren Springs above Rangen	SW NE Sec 31 T 7S R 14E	3070	2060047
B-2	Billingsley Creek below Rangen	SW NE Sec 31 T 7S R 14E	3050	2060162
B-3	Billingsley Creek below Bridge above Jones	SE SE Sec 25 T 7S R 14E	3035	2060163
B-4	Billingsley Creek below Jones	NW SW Sec 30 T 7S R 14E	3035	2060164
B-5	Billingsley Creek above Tupper Grade Bridge	NW NW Sec 19 T 7S R 14E	3025	2060165
B-5A	Billingsley Creek below Idaho Springs	SW NW Sec 18 T 7S R 14E	3020	2060169
B-6	Billingsley Creek below Fisheries Develop.	NW NE Sec 13 T 7S R 13E	3010	2060166
B-6A	Billingsley Creek above Fisheries Develop.	SE NE Sec 13 T 7S R 13E	2986	2060167
B-7	Billingsley Creek below Highway 30 Bridge	SW NE Sec 11 T 7S R 13E	2925	2060046
B-7A	Billingsley Creek above Highway 30 Bridge	SE NE Sec 11 T 7S R 13E	2975	2060168
F-1	Rangen Raceway Effluent	SW NE Sec 31 T 7S R 14E	3050	2060174
F-1A	Rangen Settling Pond Effluent	SW NE Sec 31 T 7S R 14E	3050	2060175
F-2	Jones Raceway Effluent	NW SW Sec 30 T 7S R 14E	3035	2060176
F-2A	Jones Settling Pond Effluent	NW SW Sec 30 T 7S R 14E	3035	2060177
F-3	Idaho Springs Raceway Effluent	SW SW Sec 18 T 7S R 14E	3020	2060178
F-3A	Idaho Springs Rearing Pond Effluent	SW SW Sec 18 T 7S R 14E	3020	2060179
F-4	Fisheries Development Settling Pond Effluent	NW NE Sec 13 T 7S R 13E	3010	2060180
F-5	Spring Creek Ranch Rearing Pond Effluent	NE NW Sec 31 T 7S R 13E	3050	2060181
F-7	Hidden Springs Rearing Pond Effluent	NW SE Sec 13 T 7S R 13E	3000	2060183

Table 2. Water Quality Data For Billingsley Creek Survey Stations, 1984. Values Reported Are Annual Means (And Ranges)

PARAMETER	B-1	B-2	B-3	B-4	B-5	B-5A	B-6	B-7
Temperature (C°)	14.1 (13-15)	14.3 (13-16)	14.2 (12-18)	14.3 (11.0-17.3)	14.5 (12-17)	14.0 (11.1-17.5)	14.8 (12-18)	13.9 (11.0-17.5)
Temperature (F°)	57.4 (55.4-59.0)	57.8 (55.4-60.8)	52.6 (51.8-64.4)	57.7 (51.8-63.1)	58.1 (53.6-62.6)	58.6 (52-63.5)	58.6 (53.6-64.4)	57.0 (51.8-63.2)
Flow (CFS)	-	33.6 (23-45)	42.5 (21-60)	74 (42-121)	86 (45-136)	139 (112-180)	162 (99-255)	143 (32-213)
Turbidity (FTU)	0.44 (0.2-0.9)	0.65 (.03-1.3)	1.2 (0.6-2.0)	0.8 (0.4-1.5)	1.5 (0.6-3.7)	1.2 (.5-3.3)	1.4 (.7-2.7)	1.55 (0.8-4.6)
Conductivity Lab (Mmho)	323 (277-360)	328 (284-362)	340 (308-424)	358 (317-406)	357 (317-382)	346 (288-374)	346 (308-374)	348 (312-374)
Dissolved Oxygen (mg/l)	9.45 (7.3-10.2)	8.1 (6.2-9.4)	12.4 (9.7-19.5)	10.7 (9.4-11.9)	11.4 (8.2-14.8)	11.0 (9.6-13.2)	10.1 (8.9-11.2)	10.3 (9.6-11.4)
Dissolved Oxygen (% Saturation)	102.1 (78.7-110)	87.9 (66.6-103)	134.7 (101.4-185.5)	116.3 (94.6-137.1)	124.5 (85-170.8)	120.1 (98.7-147.5)	110.1 (95-126.5)	110.8 (96.1-126.6)
BOD5 (mg/l)	1.33 (0.3-8.8)	2.35 (1.6-5.1)	1.8 (1.1-3.0)	1.8 (1.3-2.6)	1.6 (0.7-3.7)	1.3 (.5-1.9)	1.3 (.4-2.5)	1.25 (0.6-2.7)
pH - Field	7.85 (7.4-8.3)	7.7 (7.3-8.2)	8.3 (7.7-9.0)	7.85 (6.9-8.5)	8.1 (7.7-8.8)	8.2 (7.6-8.6)	8.2 (7.8-8.7)	8.1 (7.6-8.5)
pH - Lab	8.1 (7.9-8.3)	8.0 (7.8-9.3)	8.3 (8.0-8.7)	8.2 (7.9-8.5)	8.2 (8.1-8.5)	8.2 (8.0-8.5)	8.2 (8.0-8.5)	8.2 (8.1-8.5)
Bicarb Alk (mg/l CaCO3)	134 (129-139)	135 (131-140)	150 (138-180)	147 (138-161)	146 (136-153)	142 (135-154)	141 (134-153)	142 (133-151)

Table 2. Water Quality Data For Billingsley Creek Survey Stations, 1984. Values Reported Are Annual Means (And Ranges)

PARAMETER	B-1	B-2	B-3	B-4	B-5	B-5A	B-6	B-7
Total Residue (mg/l)	246 (222-242)	241 (228-252)	278 (240-327)	237 (236-305)	264 (251-285)	252 (246-259)	253 (242-262)	253 (243-263)
Total Volatile Solids (mg/l)	48 (35-62)	52 (39-75)	65 (43-94)	58 (35-78)	56 (40-69)	51 (43-64)	54 (41-66)	52 (36-66)
TSS (mg/l)	4.2 (0-9)	5.5 (1.0-16)	9 (1-22)	7 (1-16)	11 (1-37)	8 (1-18)	9 (1-21)	9.7 (4-24)
NH3 + NH4 (mg/l)	.036 (.008-.091)	.270 (.176-.365)	.140 (.033-.391)	.230 (.189-.338)	.129 (.046-.194)	.088 (.023-.153)	.123 (.058-.231)	.085 (.034-.138)
Unionized NH3 (mg/l)	.0013 (.00-.002)	.005 (.002-.010)	.006 (.002-.011)	.006 (.001-.016)	.006 (.002-.013)	.004 (.001-.008)	.007 (.003-.012)	.004 (.001-.006)
TKN (mg/l)	.150 (.100-.300)	.557 (.390-.70)	.475 (.310-.800)	.601 (.470-.700)	.475 (.200-.710)	.360 (.240-.480)	.370 (.270-.450)	.319 (.200-.510)
NO2 + NO3 (mg/l)	1.03 (.82-1.30)	1.01 (.81-1.37)	1.47 (.96-2.51)	1.87 (.79-9.73)	1.06 (.72-1.19)	.98 (.85-1.09)	1.00 (.91-1.25)	.963 (.920-1.02)
Phosphorus - Total (mg/l)	.05 (.01-.10)	.105 (.06-.20)	.100 (.070-.150)	.104 (.070-.130)	.110 (.070-.250)	.090 (.060-.110)	.090 (.060-.120)	.08 (.05-.15)
Ortho - PO4 (mg/l)	.007 (.001-.034)	.031 (.009-.046)	.043 (.03-.063)	.046 (.021-.067)	.043 (.031-.070)	.031 (.022-.044)	.031 (.025-.045)	.032 (.022-.045)
Total Organic Carbon (mg/l)	0.4 (00-.7)	1.8 (1.2-3.2)	2.2 (1.4-3.0)	2.2 (1.3-3.1)	2.1 (1.4-3.7)	1.5 (1.0-2.1)	1.6 (1.1-3.1)	1.76 (1.1-3.8)

Table 3. Water Quality Data for Effluents of Billingsley Creek Fish Hatcheries, 1984. Values are Annual Means (Ranges).

PARAMETER	F-1	F-1A	F-2	F-2A	F-3	F-3A	F-4	F-5	F-7
Temperature (C°)	14.2 (13.2-16.0)	13.5 (11.0-15.8)	14.5 (13.5-16.0)	14.1 (12-16)	14.8 (12.1-17.0)	14.8 (11.6-18.0)	14.8 (12.0-17.5)	14.8 (13.0-16.5)	15.8 (14.0-17.5)
Temperature (F°)	57.7 (55.8-60.8)	56.2 (51.8-60.4)	58.1 (56.3-60.8)	57.3 (53.6-60.8)	58.6 (53.8-62.6)	58.6 (52.9-64.4)	58.6 (53.6-63.5)	58.6 (55.4-61.7)	60.4 (57.2-63.5)
Flow (CFS)	24 (3-41)	9 (3-24)	40 (23-57)	2 (0-4)	50 (38-60)	51 (11-116)	11 (7-16)	2 (1-3)	13 (7-18)
Turbidity (FTU)	.6 (.3-1.2)	.8 (.4-1.3)	.5 (.2-.9)	2.0 (.5-8.5)	.5 (.3-.8)	1.2 (.5-2.1)	.9 (.3-3.2)	.7 (.4-1.2)	.5 (.3-.7)
Conductivity (Mmhos)	325 (277-350)	337 (281-362)	346 (288-374)	346 (284-386)	322 (267-344)	359 (292-386)	345 (277-380)	370 (353-393)	340 (333-345)
Dissolved Oxygen (mg/l)	7.5 (6.9-8.5)	7.9 (5.4-9.8)	8.8 (7.5-10.2)	8.4 (7.1-9.8)	10.6 (9.8-11.6)	11.5 (9.4-14.0)	9.1 (6.8-10.8)	8.5 (7.1-9.9)	8.8 (7.3-10.2)
Dissolved Oyxgen (% Saturation)	81.1 (74.3-93.3)	83.8 (60.5-103.3)	95.8 (82.3-109.8)	90.1 (73.6-101.6)	115.3 (101.2-131.1)	126.5 (97.3-159.0)	101.0 (70.5-127.3)	93.4 (82.1-104.7)	97.8 (85.9-109.6)
BOD5	2.3 (1.6-3.7)	1.9 (1.0-4.3)	2.4 (1.6-4.1)	5.4 (2.0-11.3)	.7 (.1-2.0)	1.6 (.8-2.3)	2.7 (.2-6.1)	2.7 (1.7-4.3)	3.0 (1.1-5.7)
pH - Field	7.7 (7.1-8.1)	7.71 (7.0-8.5)	7.75 (7.2-8.4)	7.7 (6.9-8.3)	8.2 (7.8-8.6)	8.25 (7.9-8.8)	7.83 (7.3-8.3)	8.2 (7.9-8.4)	8.35 (8.3-8.4)
pH - Lab	8.0 (7.6-8.3)	8.1 (7.8-8.3)	8.0 (7.8-8.4)	8.0 (7.6-8.3)	8.2 (8.1-8.5)	8.3 (8.0-8.5)	8.0 (7.6-8.3)	8.2 (8.1-8.3)	8.2 (8.0-8.4)
Alkalinity (mg/l CaCO3)	136 (131-140)	138 (133-142)	144 (137-153)	145 (139-154)	134 (130-140)	146 (135-161)	143 (135-153)	147 (139-155)	135 (133-138)

Table 3. Water Quality Data for Effluents of Billingsley Creek Fish Hatcheries, 1984. Values are Annual Means (Ranges).

PARAMETER	F-1	F-1A	F-2	F-2A	F-3	F-3A	F-4	F-5	F-7
Total Residue (mg/l)	237 (226-248)	239 (219-256)	249 (237-255)	257 (247-265)	229 (216-237)	257 (245-268)	244 (238-255)	255 (246-265)	230 (220-236)
Total Volatile Solids (mg/l)	51 (23-69)	55 (37-77)	54 (40-63)	61 (51-70)	46 (34-57)	59 (45-69)	56 (45-67)	59 (42-71)	37 (3-61)
TSS (mg/l)	6 (2-26)	10 (2-68)	3 (1-7)	8 (2-27)	3 (1-9)	6 (2-22)	10 (1-72)	24 (1-66)	4 (1-6)
NH3 + NH4 (mg/l)	.258 (.193-.322)	.288 (.148-.594)	.292 (.207-.416)	.321 (.111-.982)	.026 (.016-.032)	.123 (.055-.198)	.319 (.064-.558)	.312 (.126-.433)	.36 (.090-.531)
Unionized NH3 (mg/l)	.005 (.001-.010)	.008 (.001-.046)	.007 (.002-.015)	.009 (.001-.045)	.001 (.000-.004)	.007 (.003-.013)	.009 (.000-.022)	.011 (.009-.012)	.021 (.007-.034)
TKN (mg/l)	.622 (.430-1.30)	.48 (.070-.900)	.606 (.410-.900)	1.115 (.410-3.27)	.127 (.060-.200)	.414 (.300-.600)	.722 (.300-1.00)	.640 (.032-.900)	.75 (.260-1.00)
NO2 + NO3 (mg/l)	.96 (.81-1.20)	.89 (.33-1.26)	.93 (.59-1.11)	.90 (.53-1.10)	.82 (.57-.97)	1.15 (.96-1.50)	.82 (.60-.97)	1.01 (.90-1.13)	.76 (.72-.82)
Total Phosphorous (mg/l)	.14 (.080-.550)	.10 (.050-.170)	.124 (.070-.200)	.38 (.130-.860)	.135 (.010-1.00)	.091 (.050-.150)	.148 (.050-.300)	.09 (.040-.140)	.13 (.040-.200)
Ortho - PO4 (mg/l)	.043 (.027-.068)	.004 (.010-.113)	.043 (.031-.057)	.143 (.044-.458)	.005 (.001-.011)	.044 (.028-.062)	.070 (.016-.148)	.047 (.026-.080)	.070 (.043-.090)
TOC (mg/l)	2.5 (1.4-6.5)	1.7 (.2-3.9)	2.2 (1.4-3.5)	5.9 (.6-14.8)	1.3 (0.1-8.4)	1.9 (1.5-2.8)	2.3 (1.0-3.7)	2.0 (1.6-2.5)	2.4 (.8-3.2)

Table 4. Total Suspended Solids (TSS) Load (Metric Tons/Year) in Hatchery Effluents and at Station B7, Billingsley Creek, 1984. ***Indicates Effluent Concentration Less Than Groundwater Concentration and Therefore no Hatchery Additions. Curren Springs Water Quality is Assumed Representative of Ambient Groundwater Conditions.

	TSS Load Metric Tons/Year	% of Total Hatchery Loading
Source		
Rangen		
Raceway Effluent	38.6	20.9
Pond Effluent	46.6	25.2
Jones		
Raceway Effluent	***	-
Pond Effluent	6.8	3.7
Idaho Springs		
Raceway Effluent	***	-
Pond Effluent[1]	***	-
Fisheries Development		
Pond Effluent	57.1	30.9
Spring Creek		
Pond Effluent	35.4	19.2
Hidden Springs		
Pond Effluent	***	-
TOTAL	184.5	
Billingsley Creek		
Station B7	1238.2	

[1] Pond effluent TSS concentration less than TSS concentration at Billingsley Creek Station B5.

Table 5. Settleable Solids in Effluents from Fish Rearing Facilities along Billingsley Creek, 1984. Values are in ml/l.

SAMPLE LOCATION	1/31/84	3/6/84	4/24/84	5/22/84	6/12/84	7/17/84	8/21/84	9/25/84	10/28/84	11/26/84	12/17/84
F-1 Rangen Raceway	1 Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
F-1A Rangen Settling Pond	Tr	Tr	0	Tr	Tr	Tr	Tr	0	0	Tr	Tr
F-2 Jones Raceway	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
F-2A Jones Settling Pond	Tr	0.1	Tr	Tr	Tr	Tr	0	-2	0.3	Tr	0
F-3 Idaho Springs Raceway	Tr	Tr	Tr	Tr	Tr	Tr	0	0	Tr	Tr	Tr
F-3A Idaho Springs Rearing Pond	Tr	Tr	0	0	Tr	0	Tr	Tr	Tr	Tr	Tr
F-4 Fisheries Development Settling Ponds	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0	Tr	Tr	Tr
F-5 Hidden Springs Rearing Pond	-	-	-	-	-	0	-	-	-	Tr	Tr
F-7 Spring Creek Rearing Pond	-	-	-	-	-	Tr	-	-	-	Tr	0

1 Tr=Trace 2 (-) = No Data

Table 6. Discharge (Q), Total Organic Carbon (TOC) Concentrations, TOC Loadings, Biochemical Oxygen Demand (BOD_5), BOD_5 Loadings, and Dissolved Oxygen (D.O.) in Fish Rearing Facility Effluents, 1984. Values are Mean Annual Values. TOC and BOD Concentrations Listed as "Net" Account for Background Groundwater Levels Using Curren Springs as a Reference (TOC = 0.4 mg/l, BOD = 1.33 mg/l). Loadings are Based Upon Corrected Values.

PARAMETER	UNITS	RANGENS RACEWAY	RANGENS POND	JONES RACEWAY	JONES POND	IDAHO SPRINGS RACEWAY	IDAHO SPRINGS POND[3]	FISHERIES DEVELOPMENT POND	SPRING CREEK POND	HIDDEN SPRINGS POND	R[1]/P	TOTAL
Q	cfs	24	9	40	2	50	51	11	2	13		
TOC (Gross)	mg/l	2.5	1.7	2.2	5.9	1.3	1.9	2.3	2.0	2.4		
TOC (net)	mg/l	2.1	1.3	1.8	5.5	0.9	-2	1.9	1.6	2.0		
TOC Loading	metric ton / year	45.0	10.4	64.2	9.8	40.2	-	22.6	2.8	23.2	149.4 / 68.8	218.2
BOD (Gross)	mg/l	2.3	1.9	2.4	5.4	0.7	1.6	2.7	2.7	3.0		
BOD (Net)	mg/l	0.97	0.57	1.07	4.07	-	-	1.37	1.37	1.67		
BOD Loading	metric ton / year	20.8	4.6	38.2	7.2	-	-	13.4	2.4	19.4	59.0 / 47.0	106.0
BOD Loading	pounds / year	45,864	10,143	84,231	15,876	-	-	29,547	5,292	43,777	130,095 / 103,635	233,730
D.O.	mg/l	7.5	7.9	8.8	8.3	10.6	11.5	9.1	8.5	8.8		

1. R-total raceway loading, P-total pond loading.

2. Corrected value <0.

3. Net values calculated using BOD_5, and TOC measurements at station B5 as reference.

Table 7. Annual Nitrogen Loading of Billingsley Creek by Fish Hatcheries. Concentrations Used to Calculate Loadings Are Corrected for Groundwater Levels Assuming Curren Springs Water Quality is Representative of Ambient Groundwater Conditions.

PARAMETER	UNITS	RANGENS RACEWAY	RANGENS POND	JONES RACEWAY	JONES POND	IDAHO SPRINGS RACEWAY	IDAHO SPRINGS POND	FISHERIES DEVELOPMENT POND	SPRING CREEK POND	HIDDEN SPRINGS POND	R[1]/P	TOTAL
Discharge (Q)	cfs	24	9	40	2	50	51	11	2	13		
$\overline{X}$ Annual $[NH_3-NH_4]$	mg/l	.22	.25	.26	.28	**[2]	**	.28	.32	.28		
Annual NH_3-NH_4 Loading	metric tons / year	4.76	2.02	9.14	.50	-	-	2.78	.58	3.2	13.9 / 9.08	22.9
$\overline{X}$ Annual [unionized NH_3]	mg/l	.0037	.0067	.0057	.0077	**	.001	.0077	.0197	.0097		
Annual unionized NH_3 loading	metric tons / year	.08	.06	.20	.014	-	.04	.076	.034	.112	.28 / .336	0.6
$\overline{X}$ Annual [Kjeldahl N]	mg/l	.47	.33	.46	.96	**	**	.57	.60	.49		
Annual Kjeldahl-N loading	metric tons / year	10.1	2.66	16.28	1.72	-	-	5.62	1.06	5.68	26.4 / 16.7	43.1
$\overline{X}$ Annual $[NO_2-NO_3]$	mg/l	**	**	**	**	**	.09	**	**	**		
Annual NO_2-NO_3 loading	metric tons / year	-	-	-	-	-	4.10	-	-	-	.0 / 4.10	4.1

1. R = total raceway output, P = total pond output.

2. ** indicates net concentration (outflow - inflow) is less than zero.

Table 8. Total P Concentrations and Loadings of Fish Hatchery Effluents. Loadings are Calculated Using Concentrations Corrected for Groundwater Levels. Curren Springs Water Quality is Assumed Representative of Ambient Groundwater Conditions.

	PARAMETER			
	Q (cfs)	Total P (mg/l)	Total P (mg/l) Corrected	Loading (metric tons/yr)
Rangen				
Raceway	24	.14	.09	1.92
Pond	9	.10	.05	.40
Jones				
Raceway	40	.124	.074	2.64
Pond	2	.38	.33	.58
Idaho Springs				
Raceway	50	.135	.085	3.8
Pond[1]	51	.09	xxx[3]	-
Fisheries Dev.				
Pond	11	.148	.098	.96
Spring Creek				
Pond	2	.09	.04	.07
Hidden Springs				
Pond	13	.13	.08	.92
R^2/P				8.36/2.93
Total				11.29

1. Background concentration assumed equivalent to concentration measured at station B5.

2. R = Total raceway output, P = Total pond output.

3. Net concentration (outflow-inflow) is less than zero.

Table 9. Mean Annual Discharge (Q), Orthophosphate (PO_4) Concentrations, and PO_4 Loadings of Billingsley Creek by Fish Rearing Facilities. Loadings Calculated Using Values Corrected for Groundwater PO_4 Concentrations. Curren Springs Water Quality Assumed Representative of Ambient Groundwater Conditions.

	PARAMETER				
	Q (cfs) X Annual	PO_4 (mg/l)	PO_4 (mg/l) Corrected	PO_4 Load	(Metric ton/yr)
Rangen					
Raceway	24	.043	.036	.76	
Pond	9	.004	xxx[3]	-	
Jones					
Raceway	40	.043	.036	1.28	
Pond	2	.143	.136	.24	
Idaho Springs					
Raceway	50	.005	xxx	-	
Pond[1]	51	.044	xxx	-	
Fisheries Dev.					
Pond	11	.070	.063	.62	
Spring Creek					
Pond	2	.047	.04	.07	
Hidden Springs					
Pond	13	.070	.063	.72	
R^2/P					2.04/1.65
					TOTAL= 3.69

1. Background concentration assumed equivalent to concentration measured at Station B5.

2. R = Total raceway output, P = Total pond output.

3. Net concentration (outflow-inflow) is less than zero.

Table 10. Total Coliform, Fecal Coliform, and Fecal Streptococcus Bacteria Densities (number/100 ml) in Billingsley Creek and Fish Farm Effluents, 1985. Means Listed are Annual Geometric Means.

SAMPLING STATION		TOTAL COLIFORM			FECAL COLIFORM			FECAL STREPTOCOCCUS (FS)			FC/FS RATIO
	n	Min	Max	$\bar{x}$	Min	Max	$\bar{x}$	Min	Max	$\bar{x}$	
B-1	10	36	560	143	6	111	28	13	392	76	.37
B-2	11	4	68,000	4,486	13	6,060	198	10	10,520	2,012	.10
B-3	10	400	44,000	5,584	30	5,260	183	79	6,200	616	.30
B-4	10	2,700	24,000	6,600	13	1,990	155	100	26,900	3,523	.04
B-5	10	360	21,300	2,387	11	370	86	60	5,360	443	.19
B-5A	9	370	8,700	1,669	9	1,000	67	70	7,800	732	.09
B-6	10	1,800	15,500	4,020	8	230	44	70	4,000	963	.04
B-7	10	230	17,300	1,493	5	200	42	90	3,300	598	.07
F-1 (raceway)	10	3,200	355,000	13,785	10	1,240	105	330	35,300	3,729	.03
F-1A (pond)	10	840	32,000	3,550	6	540	87	130	3,800	581	.15
F-2 (raceway)	10	1,500	41,000	7,871	28	223	78	200	120,000	11,048	.007
F-2A (pond)	9	3,200	185,000	36,808	16	1,440	67	1,496	140,000	31,791	.002
F-3 (raceway)	10	14	3,500	305	1	13	4	14	690	113	.04
F-3A (pond)	9	400	19,200	1,950	6	290	33	30	5,240	365	.09
F-4 (pond)	10	7,500	49,600	18,268	3	1,320	69	40	47,000	6,650	.01
F-5 (pond)	3	1,700	57,000	14,582	63	4,590	351	2,900	5,600	4,086	.08
F-7 (pond)	3	1,500	46,000	5,567	1	147	10	1,040	4,700	2,005	.005

Table 11. Mean Densities (number/m^2), Tolerance Quotients (TQ), and Functional Feeding Groups (FFG) of Macroinvertebrates Collected in Billingsley Creek, April 25, 1984. Tolerance Quotients are from Winget and Mangum (1979).

	STATION					
TAXON	B3	B4	B6A	B7	TQ	FFG
Ephemeroptera						
Baetis tricaudatus	140	16.7	960	363.3	72	SC
Ephemerella inermis	-	6.7	-	93.3	48	SC,C-G
Trichoptera						
Brachycentridae	-	-	33.3	10	24	C-F,SC
Helicopsyche borealis	10	-	40	403.3	18	SC
Hydropsyche sp.	-	-	106.7	46.7	108	C-F
Hydroptila sp.	123.3	30	60	3.3	108	P-H,SC
Micrasema sp.	-	-	-	3.3	24	S-H/D
Ochrotrichia sp.	-	106.7	-	-	108	C-G,P-H
Diptera						
Chironomidae	1646.7	5576.7	126.7	40	108	C-PR
Ceratopogonidae	3.3	3.3	-	-	108	PR,C-G
Stratiomyidae	-	-	-	10	108	C-G
Coleoptera						
Optioservus sp.	3.3	-	16.7	-	108	SC,C-G
Crustacea						
Amphipoda						
Hyalella azteca	53.3	10	20	-	108	C-G
Isopoda						
Ascellus sp.	106.7	43.3	-	-	108	C-G
Ostracoda	-	3.3	3.3	-	108	C-F
Hirudinea						
Batrachibdella sp.	6.7	-	-	-	108	PA/PR
Dina parva	-	-	3.3	-	108	PA/PR
Oligochaeta	33.0	-	20	190	108	C-G
Tubifex sp.	-	-	76.7	50	108	C-G
Nematoda	33.3	-	-	-	108	PA,P-H
Bivalvia						
Piscidium sp.	20	10	-	-	108	C-F
Sphaerium sp.	10	-	73.3	10	108	C-F

Table 11 Continued.

TAXON	STATION B3	B4	B6A	B7	TQ	FFG
Gastropoda						
Fluminicola virens	266.7	73.3	1596.7	140	108	SC
Fontellicella sp.	-	-	1653.3	420	108	SC
Fossaria sp.(*Lymnaea* sp.)	-	3.3	6.7	-	108	SC
Gyraulus sp.	3.3	3.3	23.3	-	108	SC
Parapholyx effusa	103.3	110	143.3	-	108	SC
Physa sp.	-	-	23.3	-	108	SC
Turbellaria						
Planariidae	50	-	3.3	-	108	PR,C-G
Total #/m^2	2613.2	5996.6	4989.9	1783.2	-	

Key:

SC = Scraper
C-G = Collector/Gatherer
C-F = Collector/Filterer
P-H = Piercer/Herbivore
PR = Predator
S-H/D = Shredder-Herbivore/Detritivore
PA/PR = Parasite/Predator
H = Herbivore

Table 12. Mean Densities (number/m^2), Tolerance Quotients (TQ), and Functional Feeding Groups (FFG) of Macroinvertebrates Collected in Billingsley Creek, July 25, 1984. Tolerance Quotients from Winget and Mangum (1979).

	STATION					
TAXON	B3	B4	B6A	B7A	TQ	FFG
Ephemeroptera						
Baetis tricaudatus	13.3	-	16.7	146.7	72	SC
Ephemerella inermis	-	-	-	76.7	48	SC,C-G
Heptageniidae	-	-	-	3.3	108	C-G
Tricorythodes minutis	-	-	-	3.3	108	C-G
Trichoptera						
Brachycentrus sp.	-	-	-	3.3	24	C-F, SC
Glossosoma sp.	-	-	-	110	24	SC
Helicopsyche borealis	16.7	-	13.3	373.3	18	SC
Hydropsyche sp.	-	-	20	350	108	C-F
Hydroptila sp.	1060	250	6.7	3.3	108	P-H,SC
Leucotrichia sp.	26.7	-	-	-	108	C-G
Rhyacophila sp.	-	-	-	3.3	18	PR
Diptera						
Chironomidae	16.7	1180	-	10	108	C-PR
Empididae	-	-	-	13.3	108	PR
Simulium sp.	-	66.7	-	23.3	108	C-F
Tipula sp.	-	-	-	3.3	36	S-H/D
Coleoptera						
Optioservus sp.	-	-	-	3.3	108	SC,C-G
Crustacea						
Amphipoda						
Hyalella azteca	103.3	80	-	33.3	108	C-G
Isopoda						
Ascellus sp.	353.3	2316.7	-	3.3	108	C-G
Hirudinea	3.3	-	-	-	108	PA/PR
Oligochaeta						
Tubifex sp.	90	93.3	-	-	108	C-G
Nematoda	-	3.3	-	-	108	PA/P-H
Bivalvia						
Piscidium sp.	-	-	3.3	-	108	C-F
Sphaerium sp.	-	13.3	36.7	3.3	108	C-F

Table 12 Continued

TAXON	B3	B4	B6A	B7A	TQ	FFG
	STATION					
Gastropoda						
Fluminicola virens	176.7	60	166.7	633.3	108	SC
Fontellicella sp.	-	-	3883.3	1696.7	108	SC
Gyraulus sp.	-	-	3.3	3.3	108	SC
Parapholyx effusa	293.3	366.7	46.7	-	108	SC
Physa sp.	-	40	13.3	3.3	108	SC
Turbellaria						
Planariidae	463.3	-	6.7	10	108	PR,C-G
Total #/m^2	2616.6	4470.0	4216.7	3512.9		

Key:
SC = Scraper
C-G = Collector/Gatherer
C-F = Collector/Filterer
P-H = Piercer/Herbivore
PR = Predator
S-H/D = Shredder-Herbivore/Detritivore
PA/PR = Parasite/Predator
H = Herbivore

Table 13. Mean Densities (number/m^2), Tolerance Quotients (TQ), and Functional Feeding Groups (FFG) of Macroinvertebrates Collected in Billingsley Creek, December 28, 1984. Tolerance Quotients are from Winget and Mangum (1979).

	STATION					
TAXON	B1	B3	B4	B7	TQ	FFG
Ephemeroptera						
Baetis tricaudatus		50	13.3	260	72	SC
Ephemerella inermis				13.3	48	SC,C-G
Trichoptera						
Helicopsyche borealis		6.7		50	18	SC
Hydroptila sp.	3.3		3.3		108	P-H,SC
Leucotrichia sp.		3.3	16.7		108	C-G
Diptera						
Chironomidae	113.3	13.3	40		108	C-PR
Simulium sp.		76.7	10	3.3	108	C-F
Tipula sp.	3.3				36	S-H/D
Coleoptera						
Optioservus sp.	6.7				108	SC,C-G
Odonata						
Ischnura sp.	10	3.3			72	PR
Crustacea						
Amphipoda						
Hyalella azteca	230	13.3	3.3	383.3	108	C-G
Decapoda						
Pacifastacus sp.	6.7				108	C-G,H
Isopoda						
Ascellus sp.		13.3	6.7	3.3	108	C-G
Hirudinea			13.3		108	PA/PR
Oligochaeta		10		80	108	C-G
Tubifex sp.		10		80	108	C-G
Nematoda	16.7	6.7	10		108	PA,P-H
Bivalvia						
Piscidium sp.		6.7	23.3		108	C-F
Sphaerium sp.		13.3	10	13.3	108	C-F

Table 13 Continued.

STATION

TAXON	B1	B3	B4	B7	TQ	FFG
Gastropoda						
Fluminicola virens	1163.3	403.3	203.3	93.3	108	SC
Fontellicella sp.			23.3	1366.7	108	SC
Gyraulus sp.		3.3	3.3		108	SC
Parapholyx effusa		50	86.7	6.7	108	SC
Physa sp.	33.3	3.3	10	30	108	SC
Turbellaria						
Planariidae		123.3	2013.3	10	108	PR,C-G
Total #/m^2	1586.6	799.8	2489.8	2313.2		

Key:

SC = Scraper
C-G = Collector/Gatherer
C-F = Collector/Filterer
P-H = Piercer/Herbivore
PR = Predator
S-H/D = Shredder-Herbivore/Detritivore
PA/PR = Parasite/Predator
H = Herbivore

Table 14. Species List of Invertebrates Collected from Billingsley Creek on the Dates Indicated, 1984.

	4/25	7/25	12/28
Ephemerophera			
Baetis tricaudatus	X	X	X
Ephemerella inermis	X	X	X
Tricorythodes minutus		X	
Heptageniidae		X	
Trichoptera			
Brachycentrus sp.	X	X	
Glossosoma sp.		X	
Helicopsyche borealis	X	X	X
Hydropsyche sp.	X	X	
Hydroptila sp.	X	X	X
Leucotrichia sp.		X	X
Micrasema sp.	X		
Ochrotrichia sp.	X		
Rhyacophila sp.		X	
Diptera			
Chironomidae	X	X	X
Ceratopogonidae	X	X	
Empididae		X	
Simulium sp.		X	X
Stratiomyidae	X		
Tipula sp.		X	X
Coleoptera			
Optioservus sp.	X	X	X
Odonata			
Ischnura sp.			X

Table 14 Continued.

	4/25	7/25	12/28
Crustacea			
Amphipoda			
Hyalella azteca	X	X	X
Decapoda			
Pacifastacus sp.			X
Isopoda			
Ascellus sp.	X	X	X
Ostracoda	X		
Hirudinea		X	X
Bactrachibdella sp.	X		
Dina parva	X		
Oligochaeta			
Tubifex sp.	X	X	X
Nematoda	X	X	X
Bivalvia			
Piscidium sp.	X	X	X
Sphaerium sp.	X	X	X
Gastropoda			
Fluminicola virens	X	X	X
Fontellicella sp.	X	X	X
Fossaria sp. (*Lymnaea* sp.)	X		
Gyraulus sp.	X	X	X
Parapholyx effusa	X	X	X
Physa sp.	X	X	X
Turbellaria			
Planariidae	X	X	X

Table 15. Density (number/m^2), Number of Species of Macroinvertebrates, Community Tolerance Quotients (CTQa), and BCI for Billingsley Creek Stations on the Dates Referenced.

	STATIONS					
	B1	B3	B4	B6A	B7A	B7
4/25/86						
#/m^2	-[1]	2613	5997	4990	-	1783
# species	-	17	14	20	-	14
# species w/TQ 108	-	15	12	17	-	9
% species w/TQ 108	-	88	86	85	-	64
CTQa	-	94.6	101.4	98.6	-	83.6
BCI	-	63	59	51	-	63
7/25/84						
#/m^2	-	2617	4470	4217	3513	-
# species	-	12	11	12	23	-
# species w/TQ 108	-	10	11	10	15	-
% species w/TQ 108	-	83	100	83	65	-
CTQa	-	97.6	108	98	82.9	-
BCI	-	61.5	55	52	61.5	-
12/18/84						
#/m^2	1607	800	2490	-	-	2313
# species	10	17	17	-	-	13
# species w/TQ 108	8	14	16	-	-	10
% species w/TQ 108	73	82	94	-	-	77
CTQa	98	98.5	105.8	-	-	94.6
BCI	51	60.9	56.7	-	-	56

[1]Samples not collected at this station on this date.

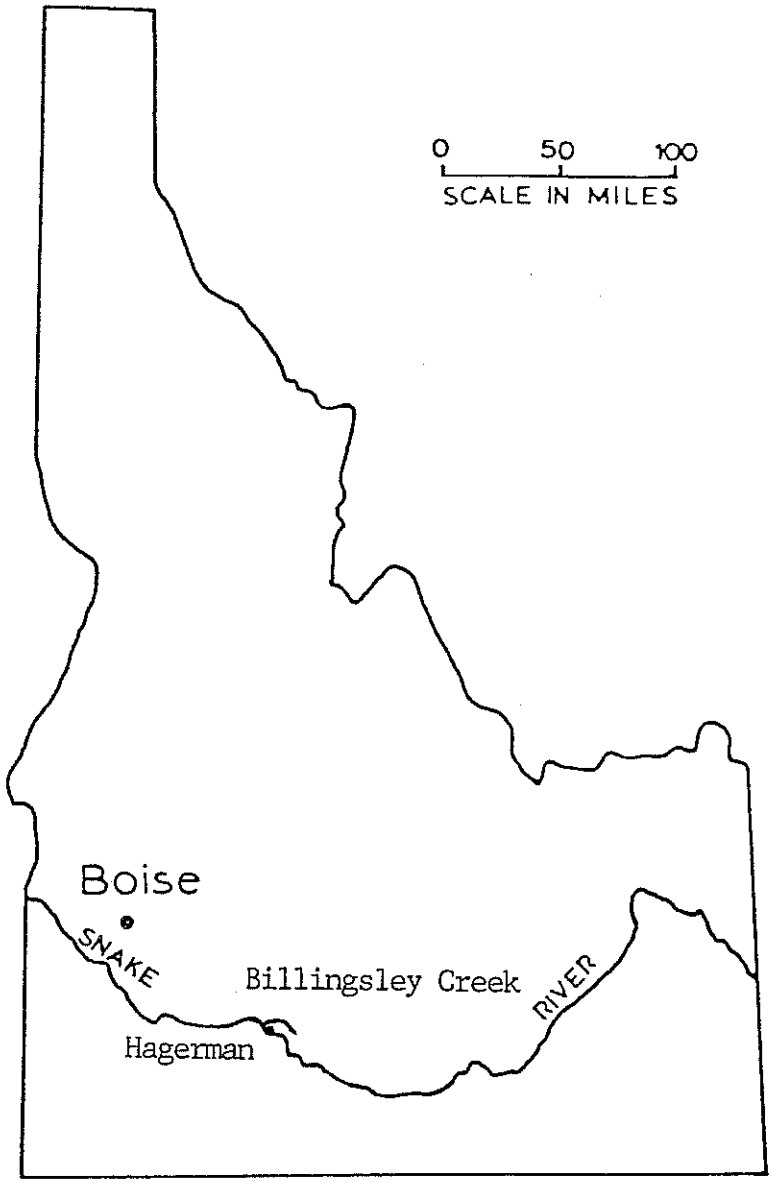

Figure 1. Billingsley Creek study area.

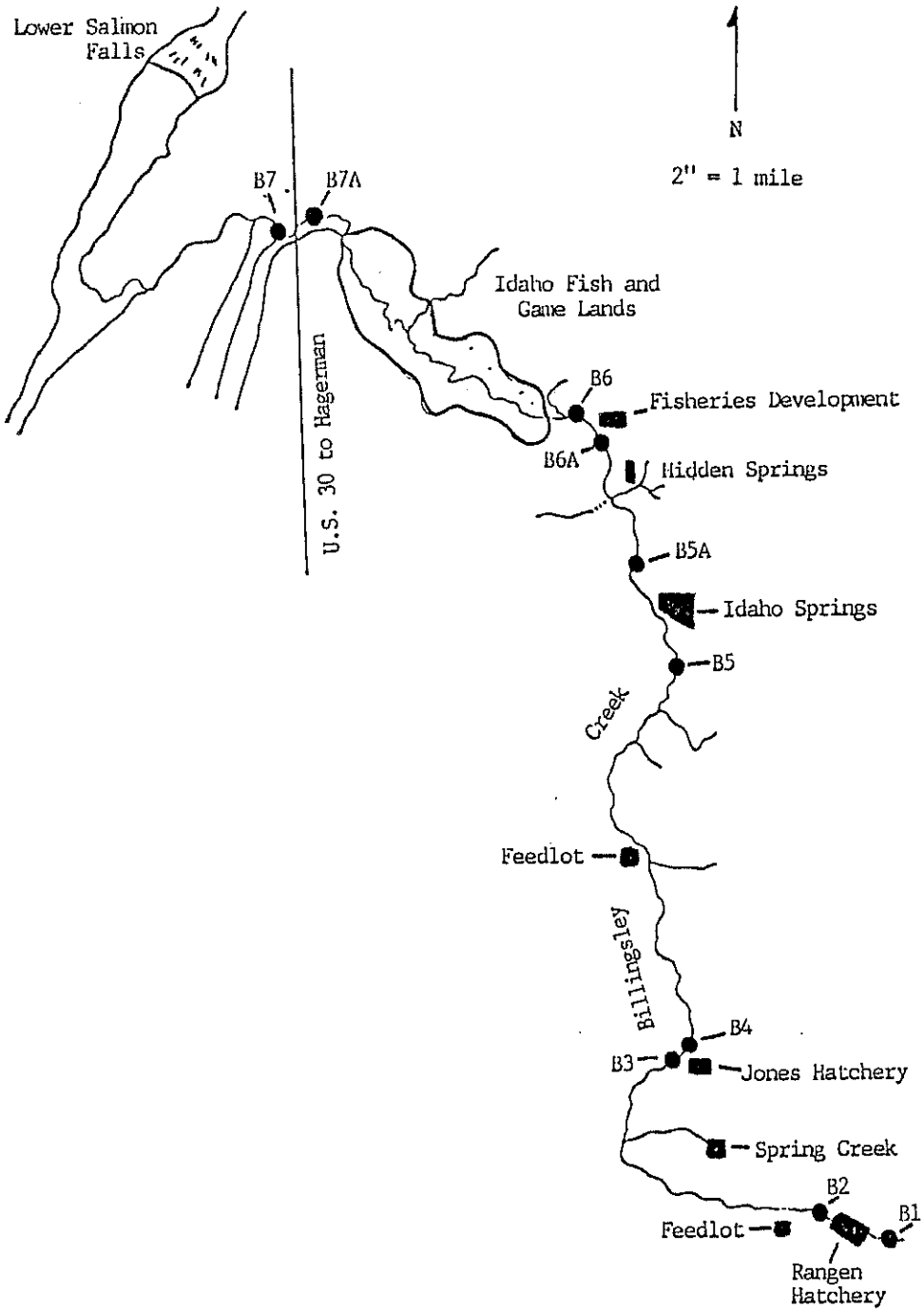

Figure 2. Sampling stations for Billingsley Creek water quality survey, 1984 (modified from JRB Associates (1984)).

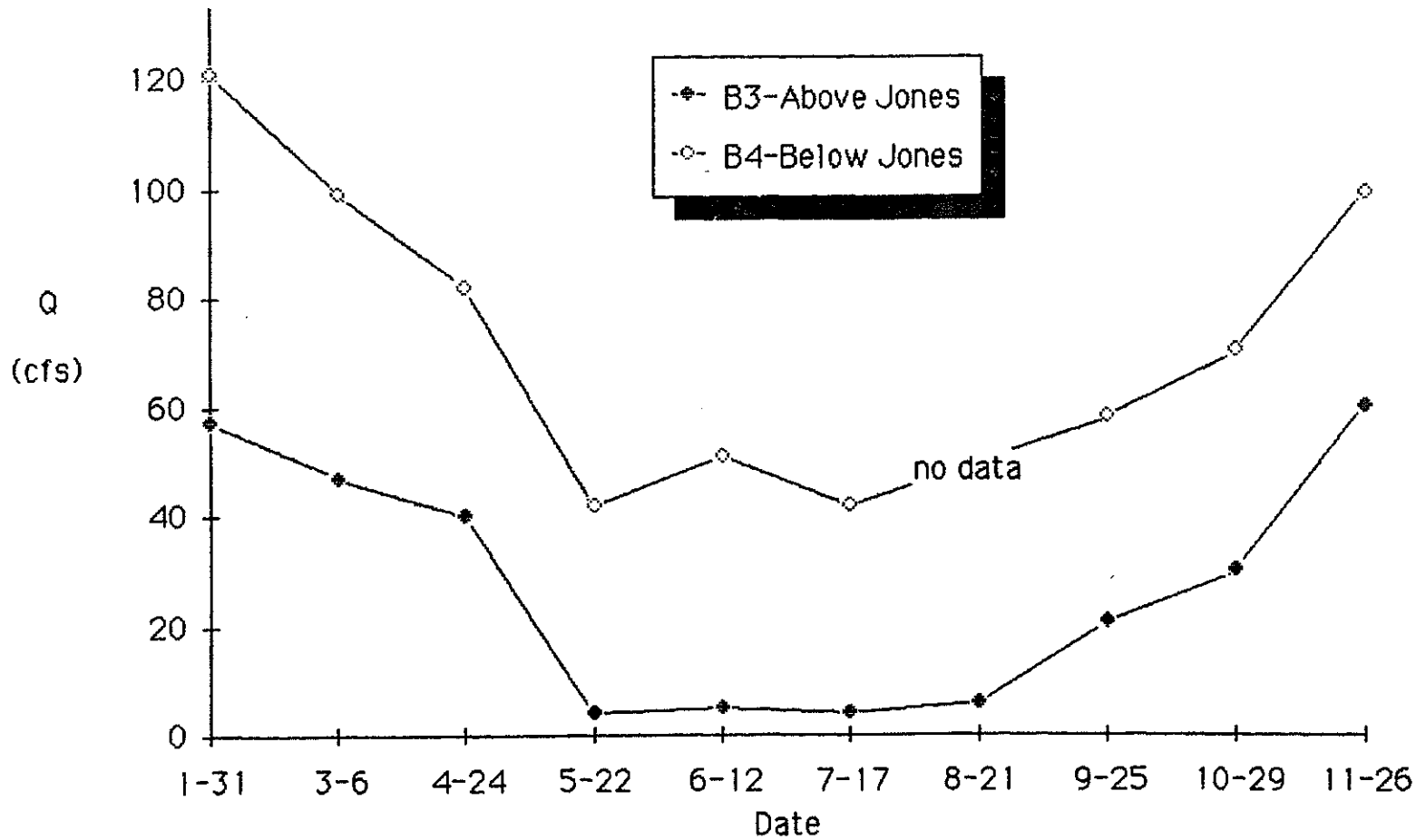

Figure 3. Stream discharge (Q) in cubic feet per second (cfs) above and below the Jones Hatchery on the dates indicated, 1984.

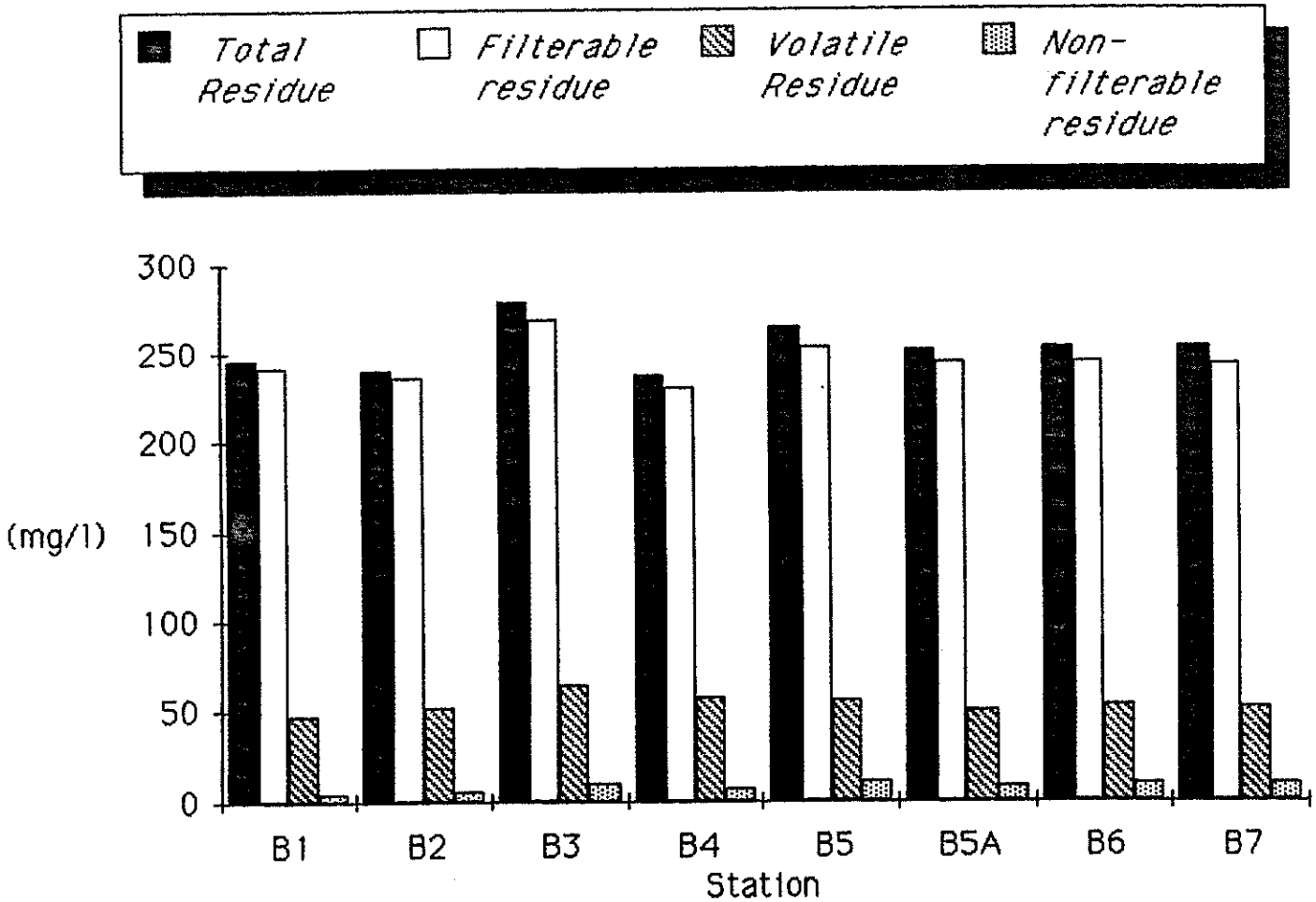

Figure 4. Mean annual total, filterable, volatile, and non-filterable solids concentrations at the Billingsley Creek survey stations, 1984.

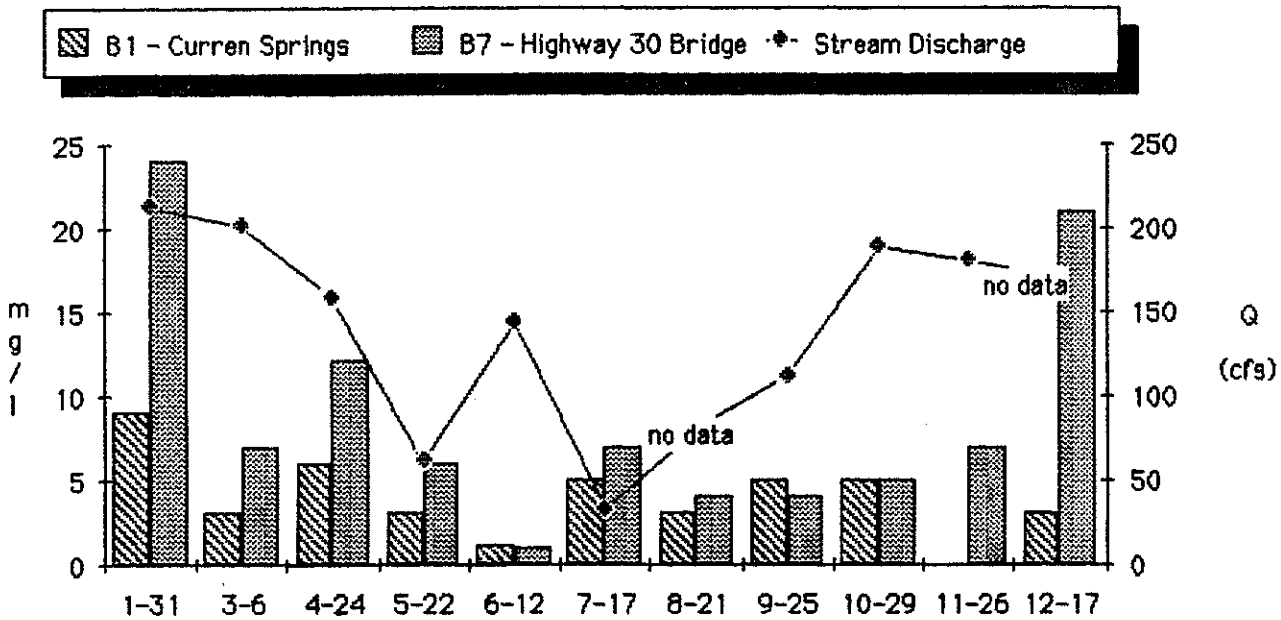

Figure 5. Total suspended solids (in mg/l) measured in Billingsley Creek at Curren Springs and the Highway 30 bridge, and stream discharge (Q, in cubic feet per second (cfs)) at the Highway 30 bridge, 1984.

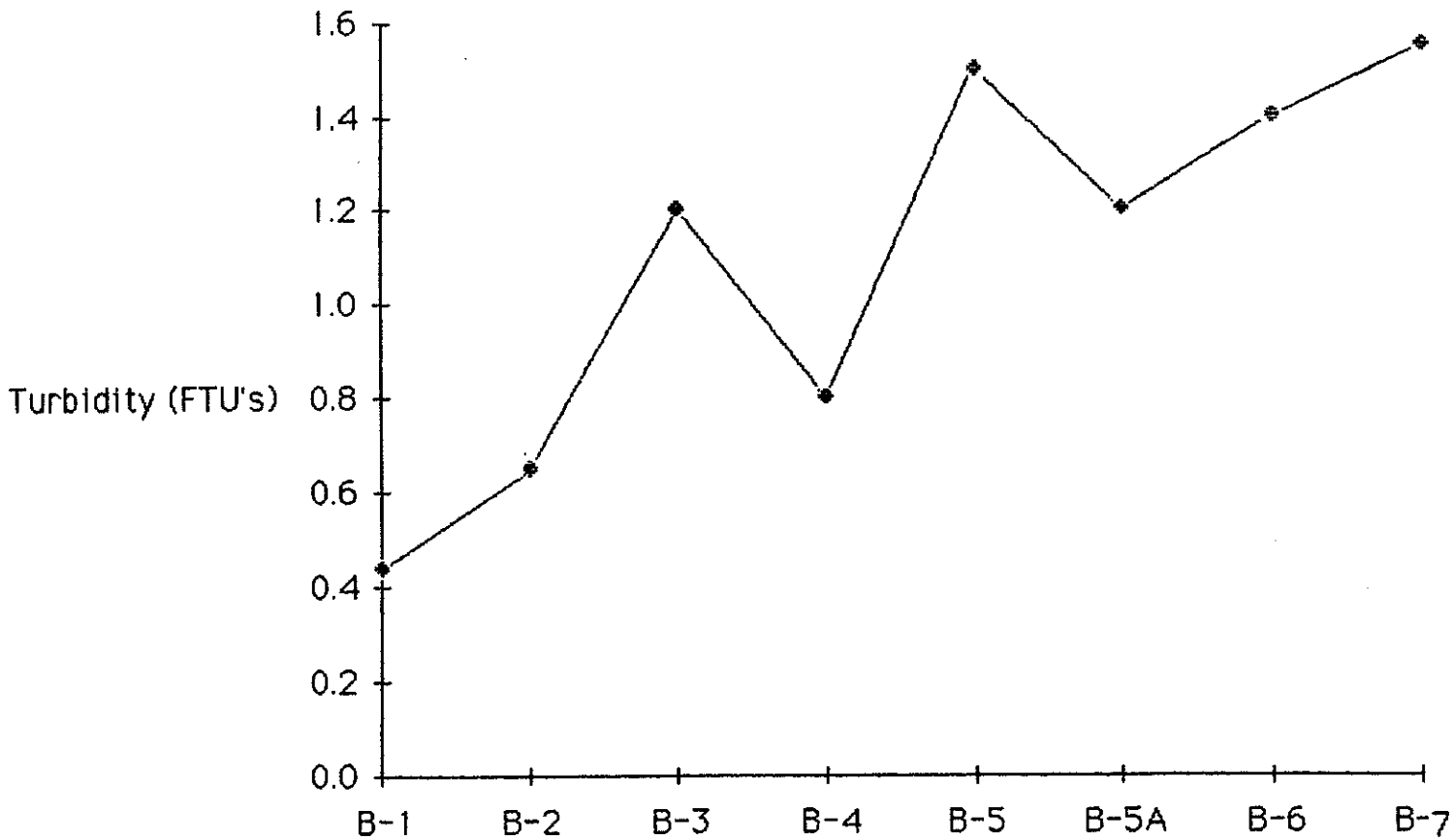

Figure 6. Mean annual turbidity concentrations at the Billingsley Creek survey stations, 1984.

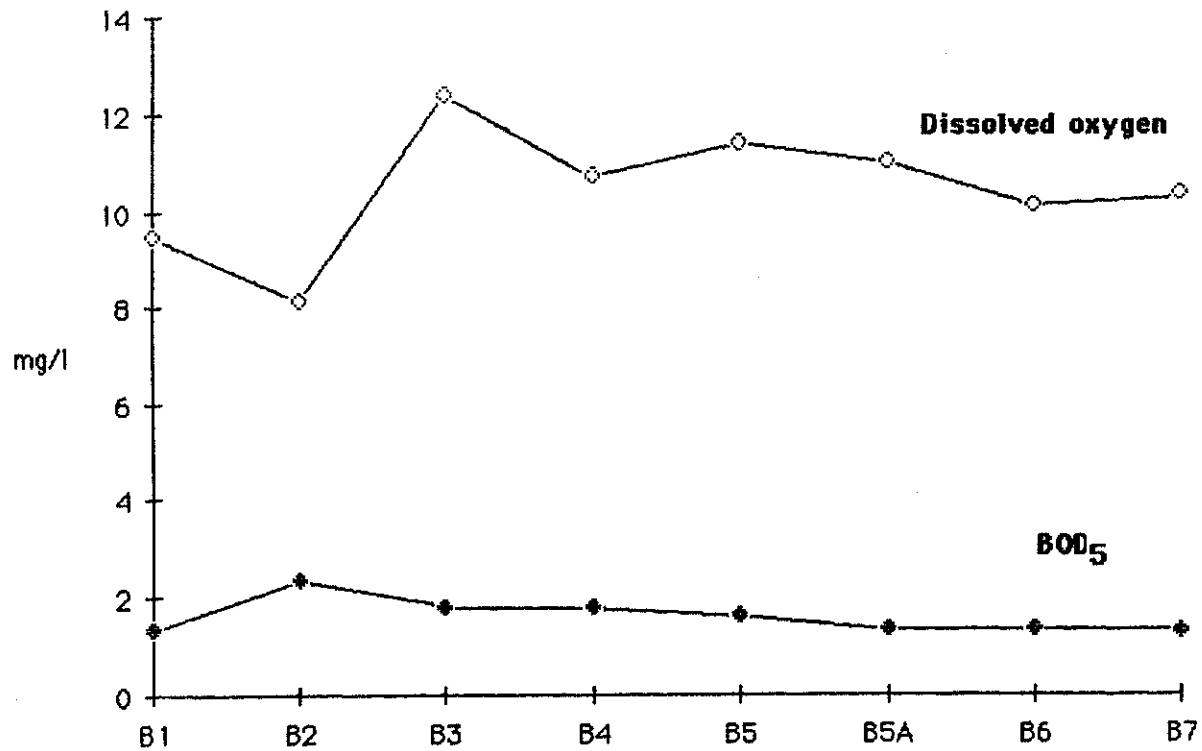

Figure 7. Mean annual dissolved oxygen concentrations and BOD5 for the Billingsley Creek survey stations, 1984.

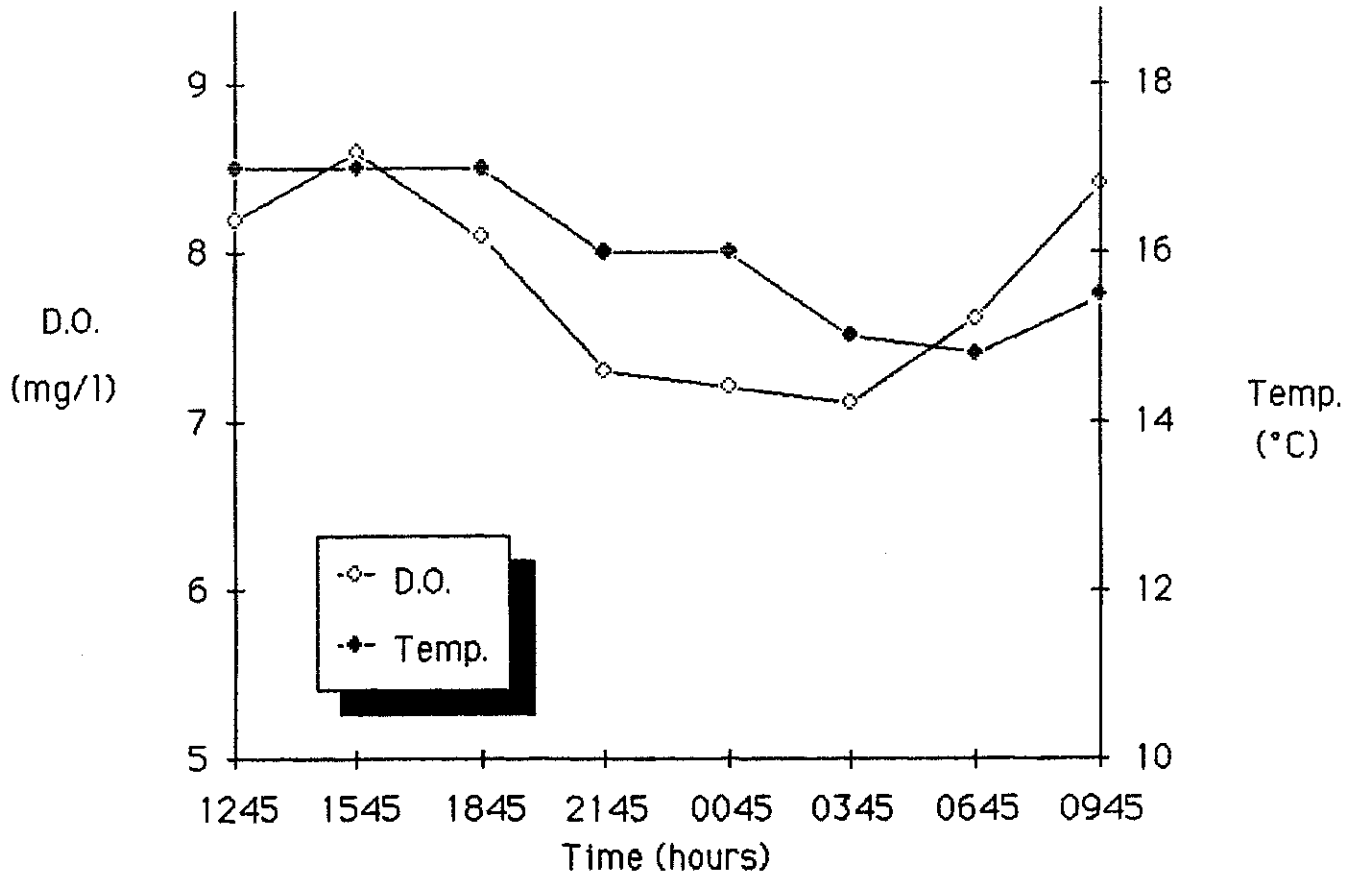

Figure 8. Dissolved oxygen (D.O.) and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek below Rangen's Hatchery.

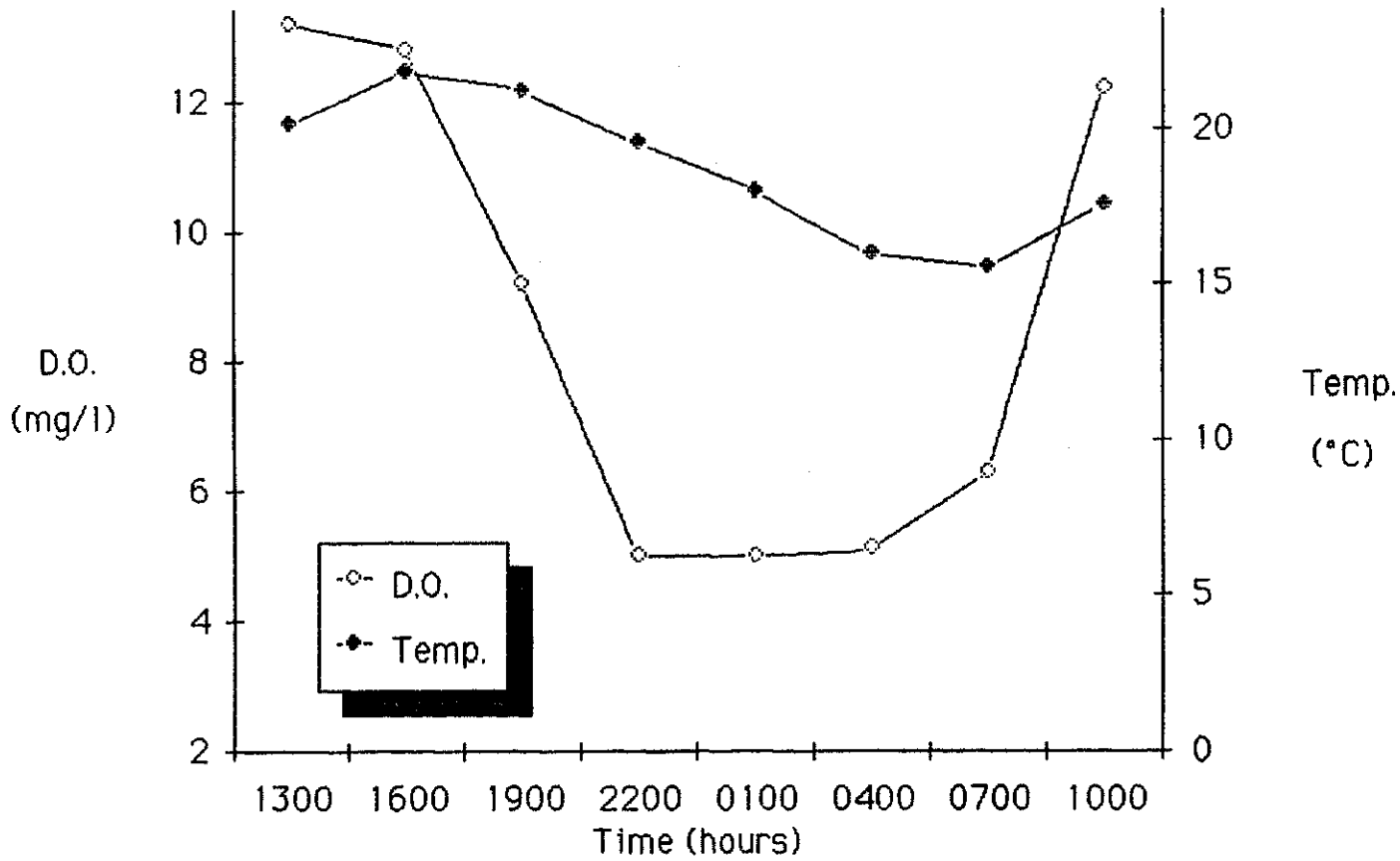

Figure 9. Dissolved oxygen (D.O.) and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek below Jones Hatchery.

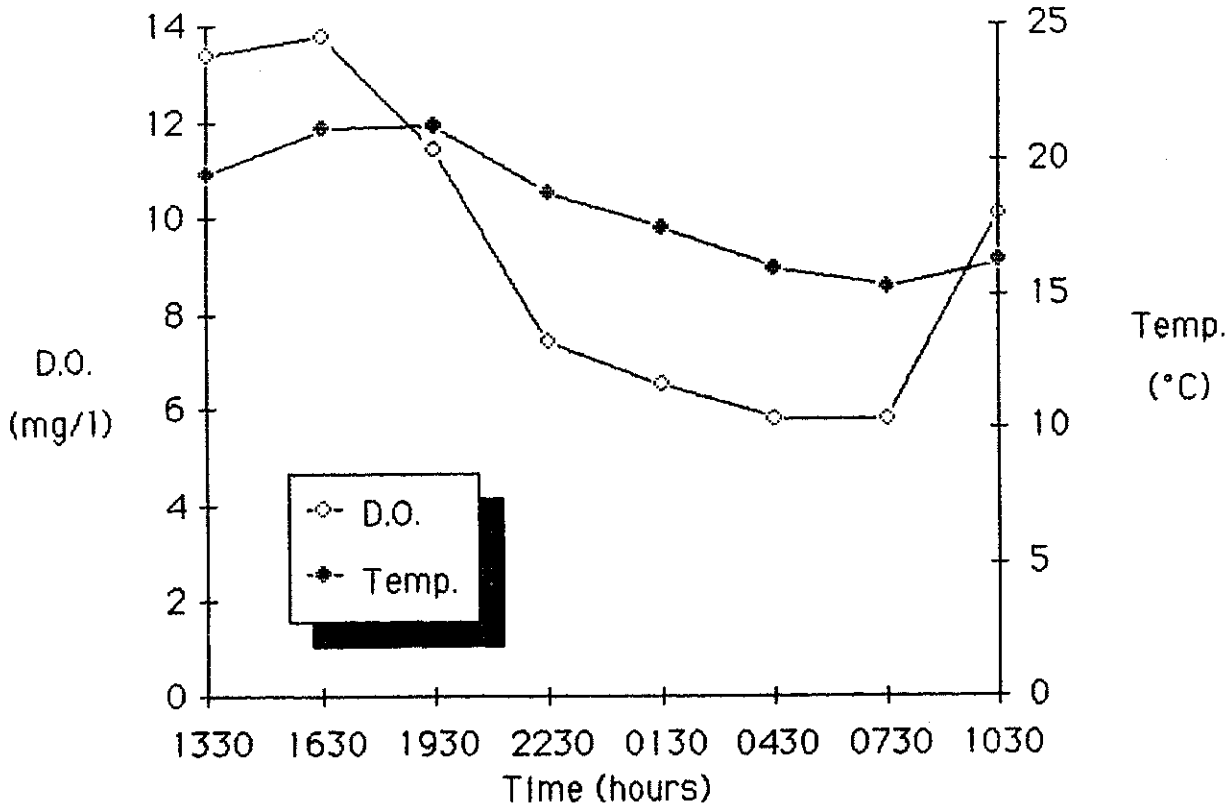

Figure 10. Dissolved oxygen (D.O.) and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek at Tupper Grade upstream of the Idaho Springs Hatchery.

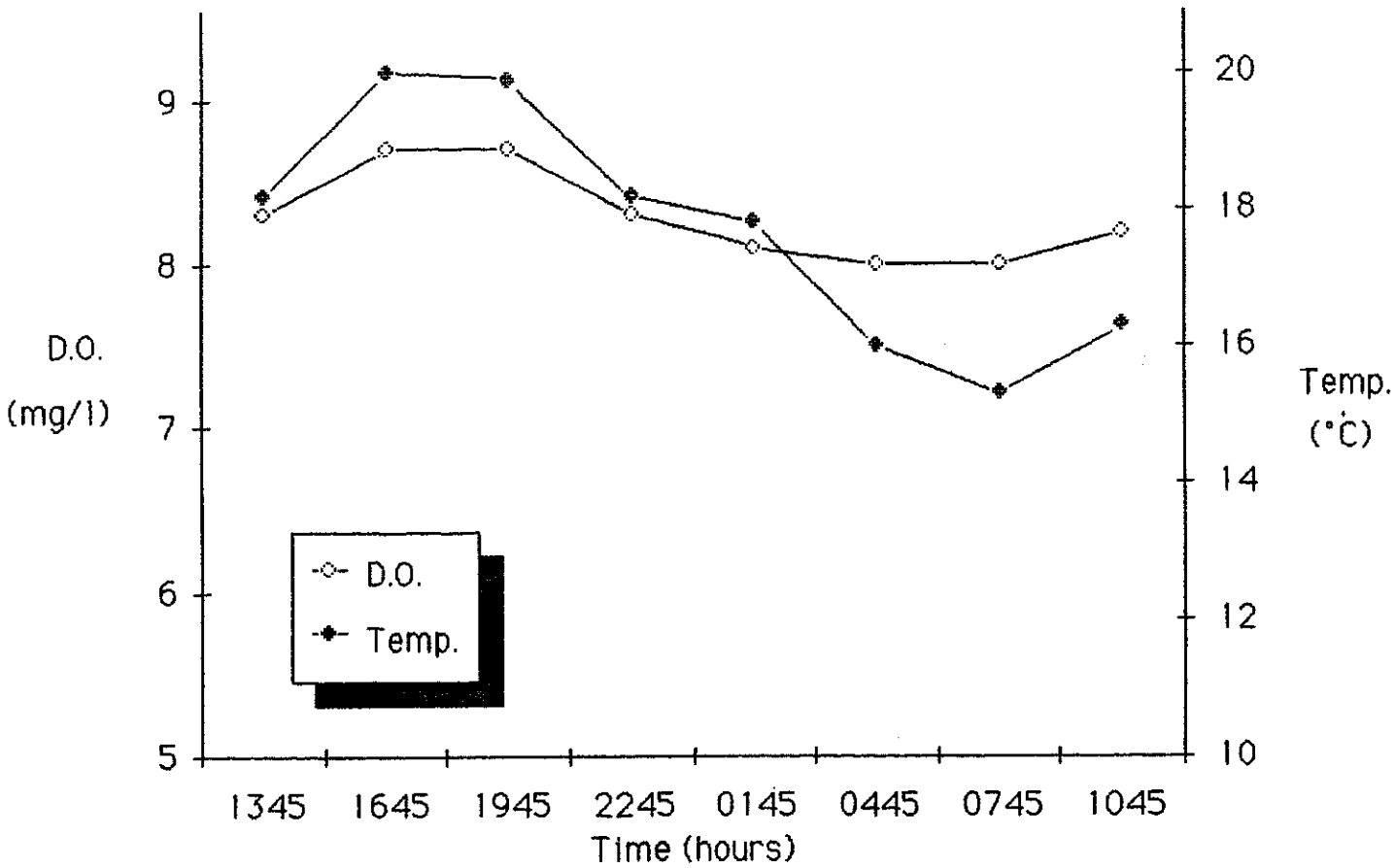

Figure 11. Dissolved oxygen (D.O.) and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek below Fisheries Development Hatchery.

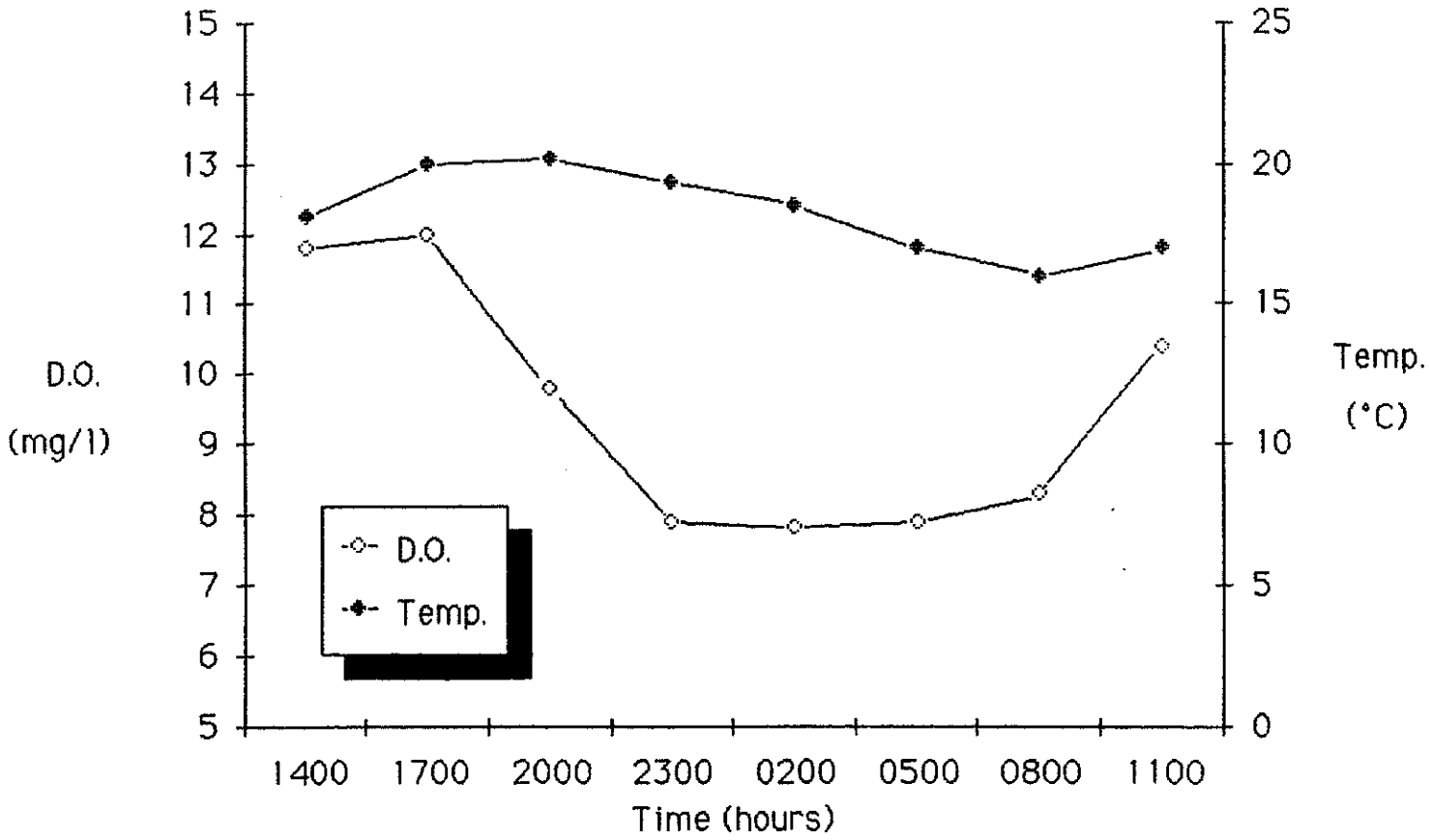

Figure 12. Dissolved oxygen (D.O.) and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek above the Highway 30 bridge.

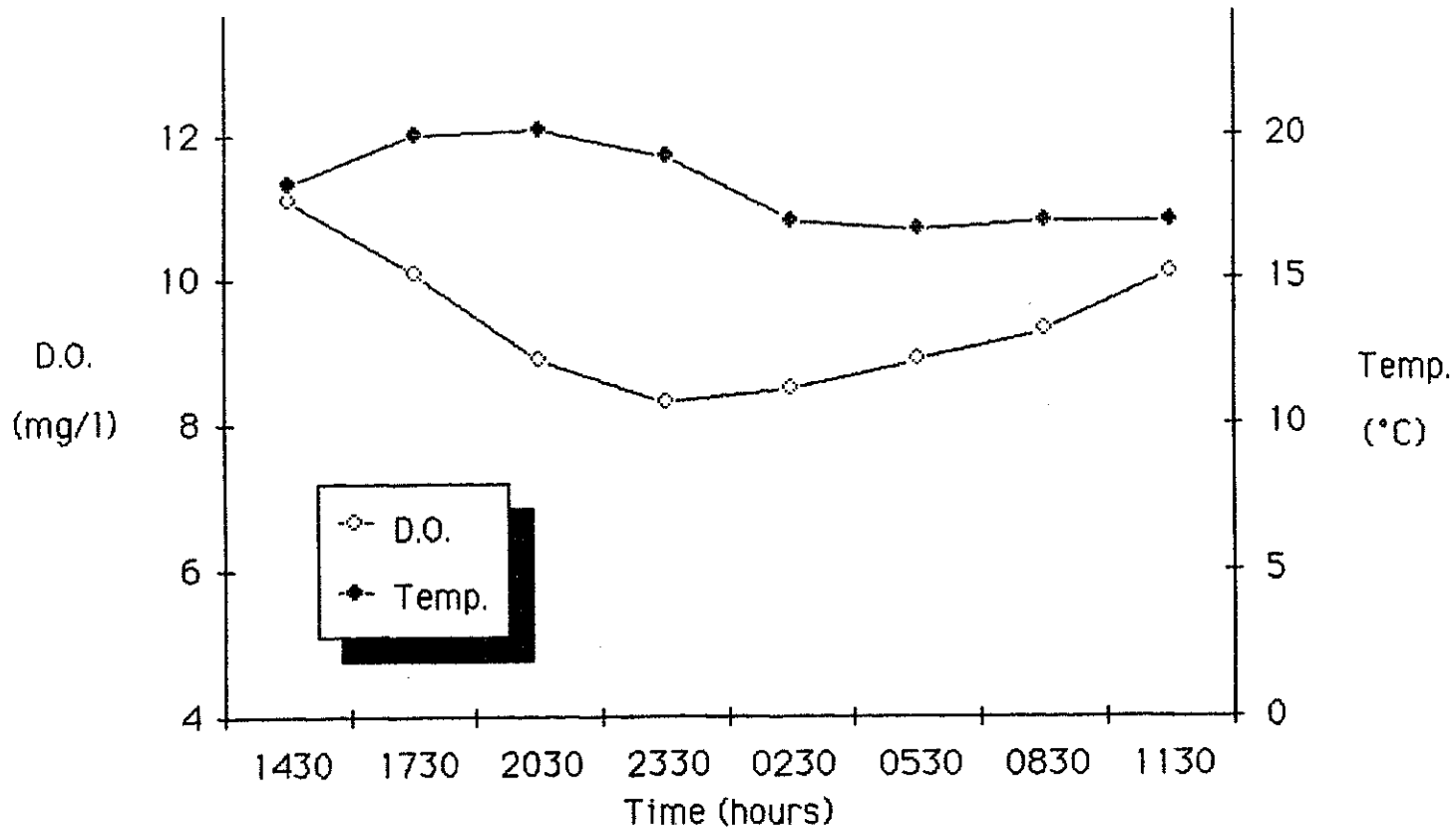

Figure 13. Dissolved oxygen (D.O.) and stream temperature over a diel cycle, 7-25 to 7-26-84, Billingsley Creek below the Highway 30 bridge.

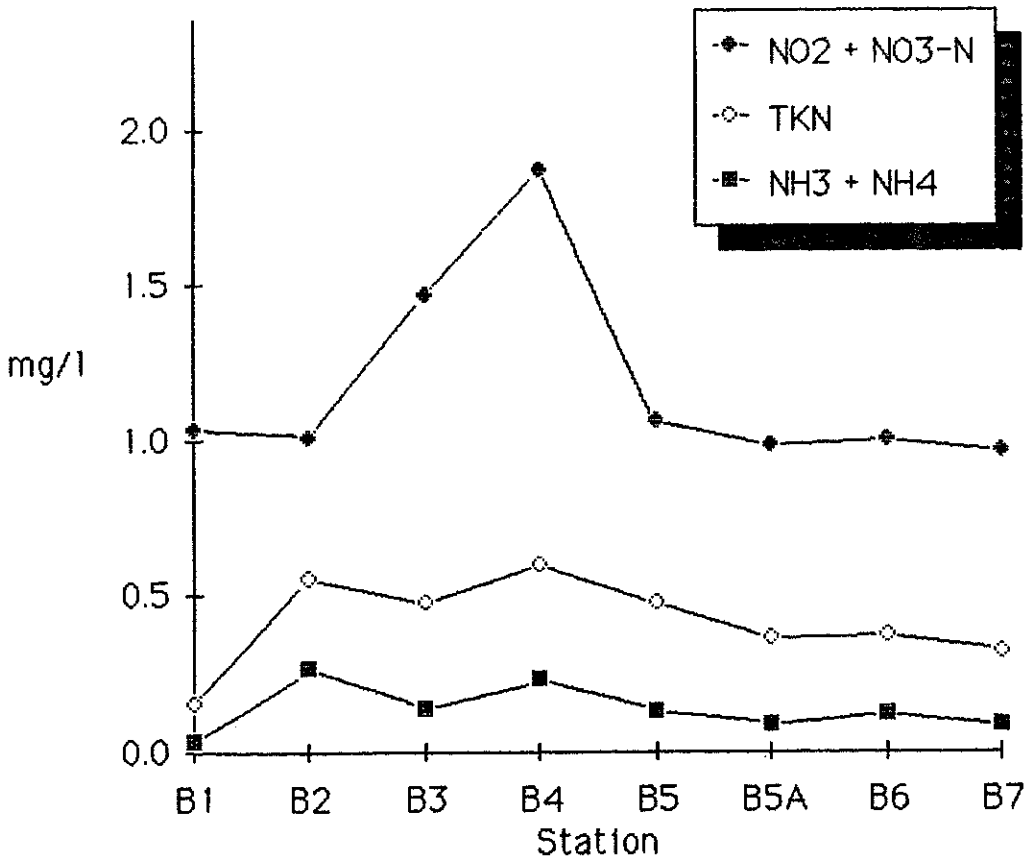

Figure 14. Mean annual NO2 + NO3, total kjeldahl nitrogen (TKN), and NH3 + NH4 concentrations at the Billingsley Creek survey stations, 1984.

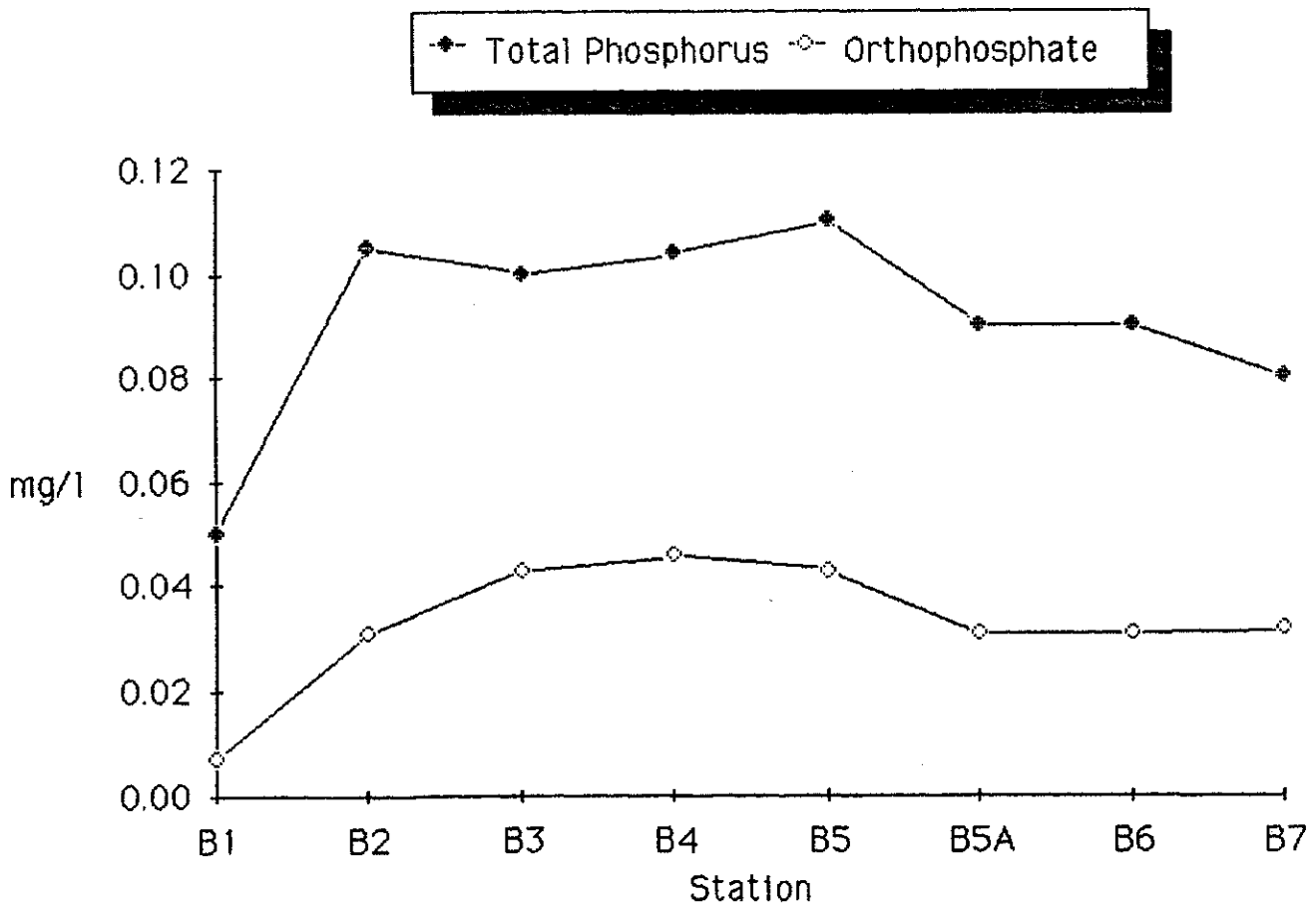

Figure 15. Mean annual total phosphorus and orthophosphate concentrations at the Billingsley Creek survey stations, 1984.

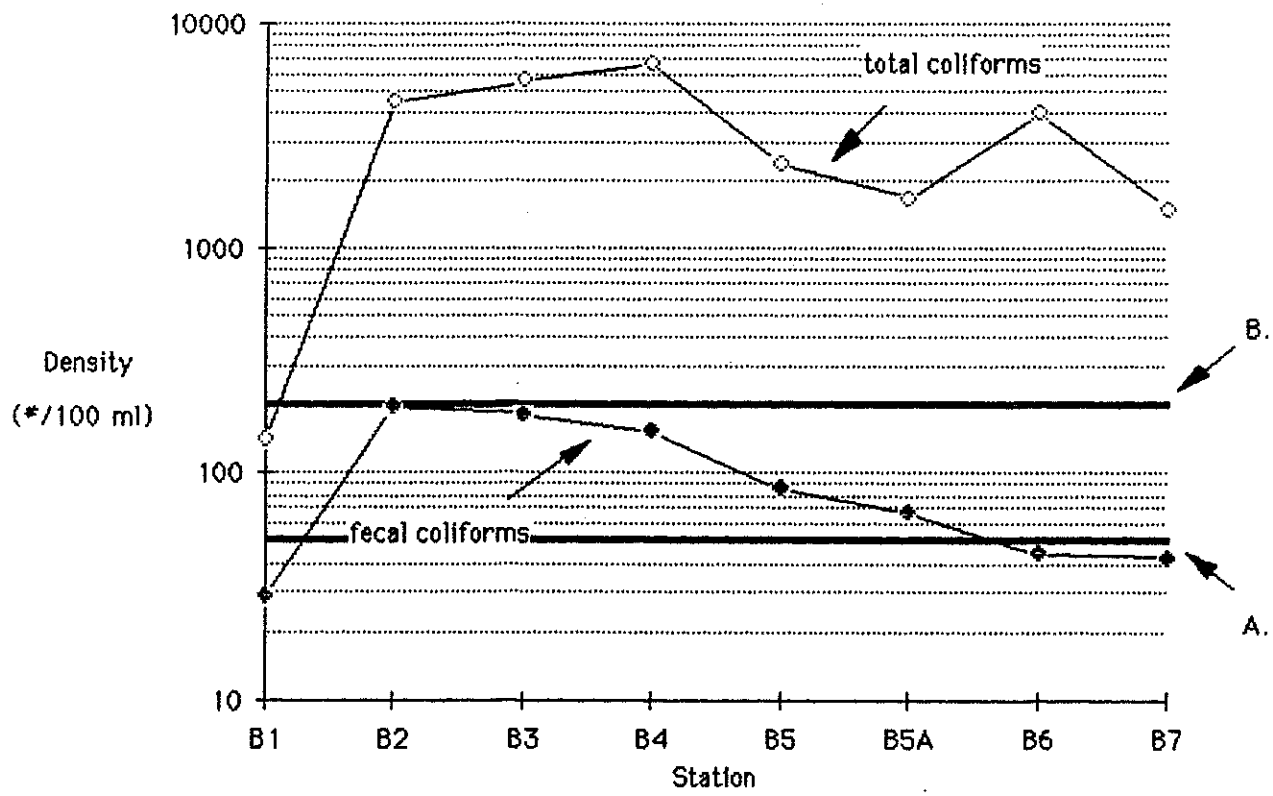

Figure 16. Annual geometric mean densities of total coliform and fecal coliform bacteria at the Billingsley Creek survey stations, 1984. A - primary contact recreation standard, B - secondary contact recreation standard.

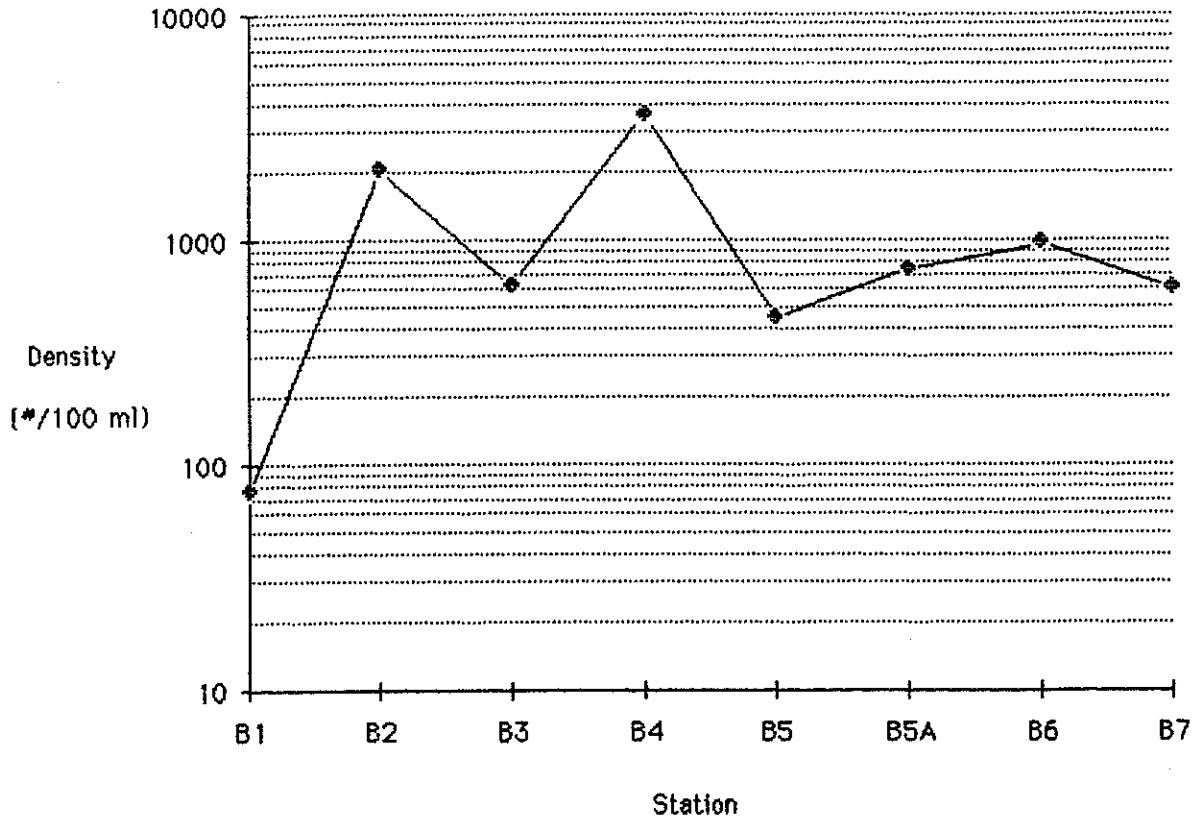

Figure 17. Annual geometric mean densities of fecal streptococcus bacteria at the Billingsley Creek survey stations, 1984.

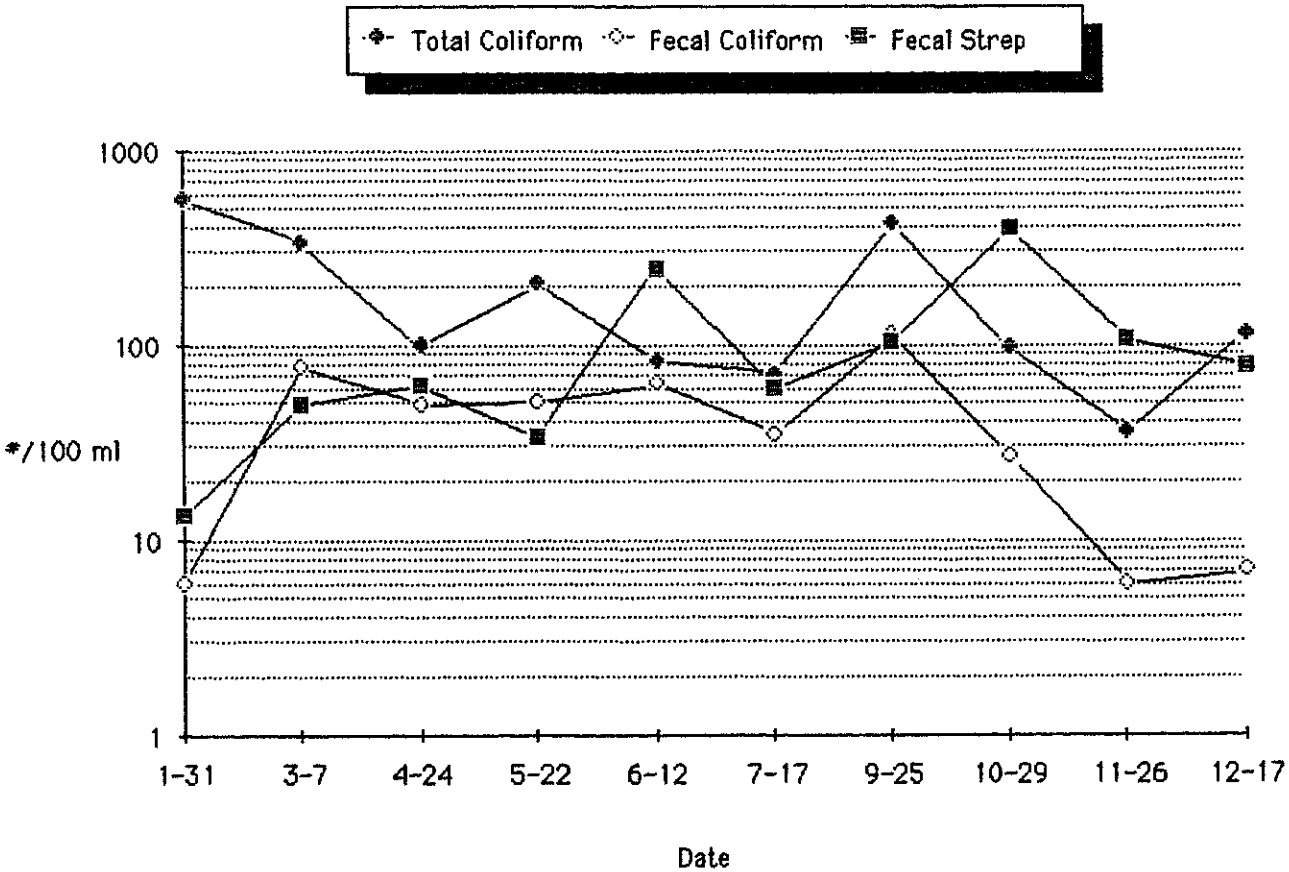

Figure 18. Bacteria densities in Billingsley Creek at Station B1, Curren Springs, 1984.

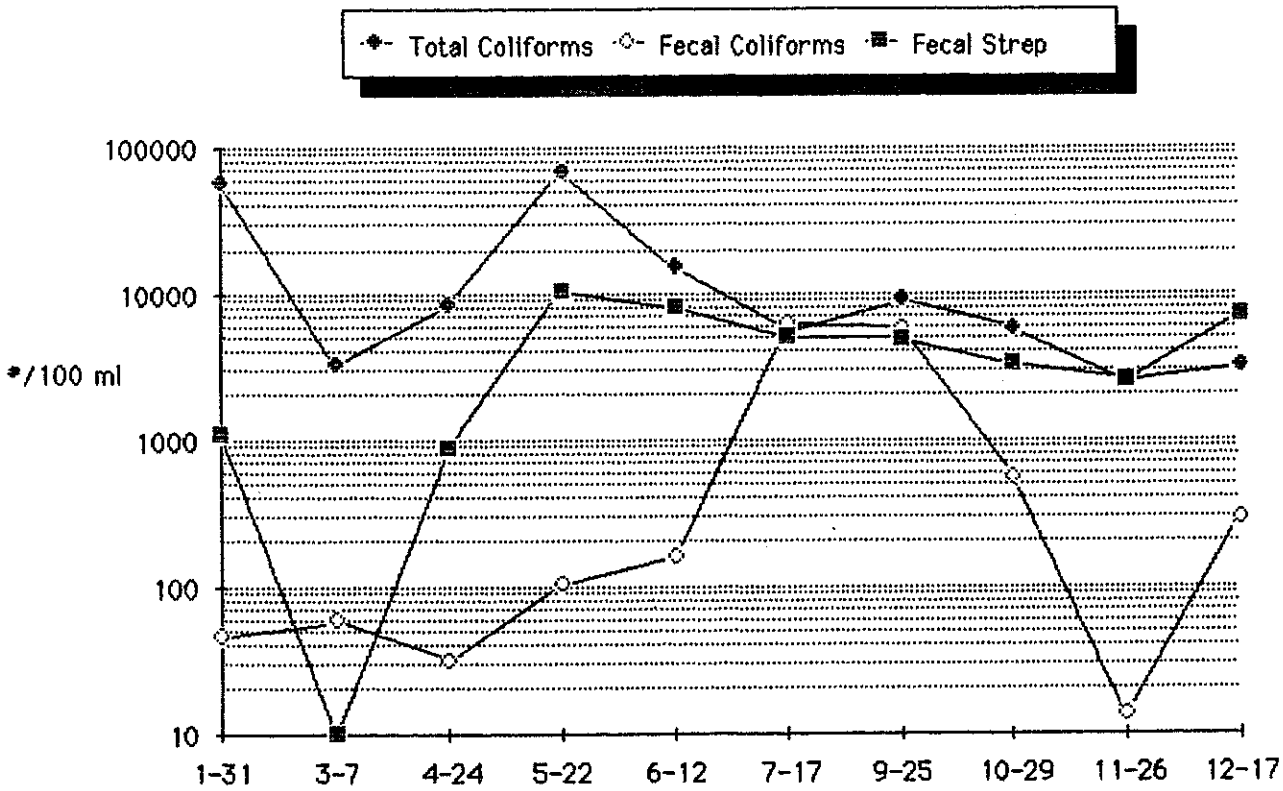

Figure 19. Bacteria collected in Billingsley Creek at Station B2, below Rangens Hatchery, 1984.

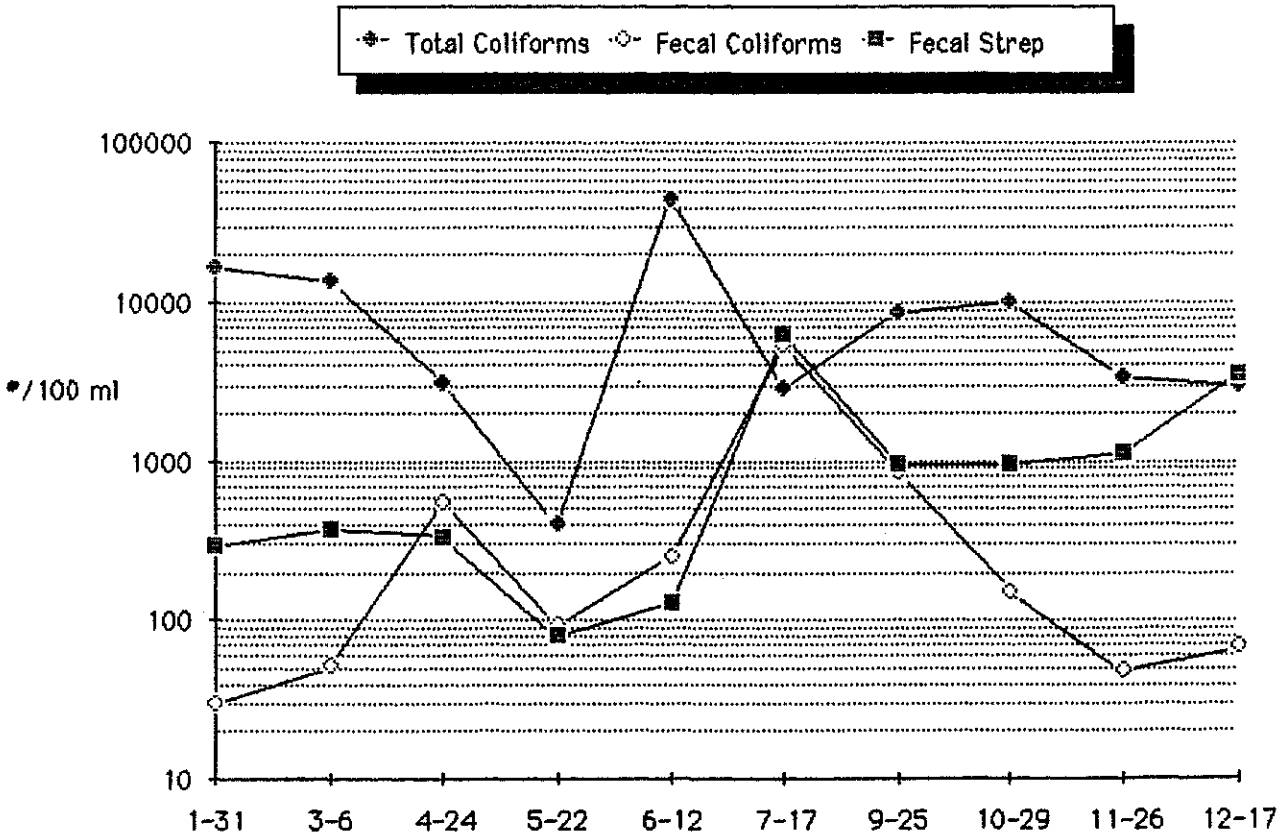

Figure 20. Bacteria collected in Billingsley Creek at Station B3, above Jones Hatchery, 1984.

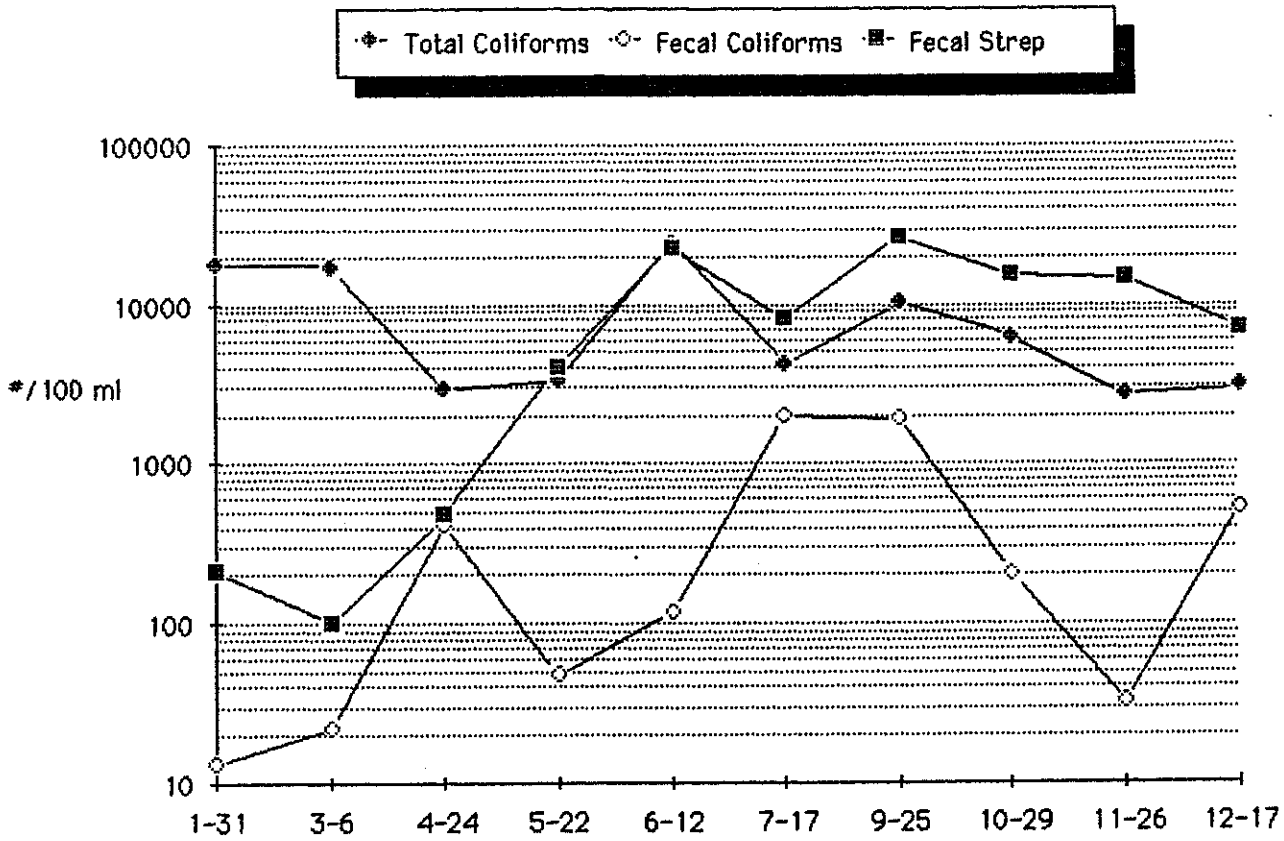

Figure 21. Bacteria collected in Billingsley Creek at Station B4, below Jones Hatchery, 1984.

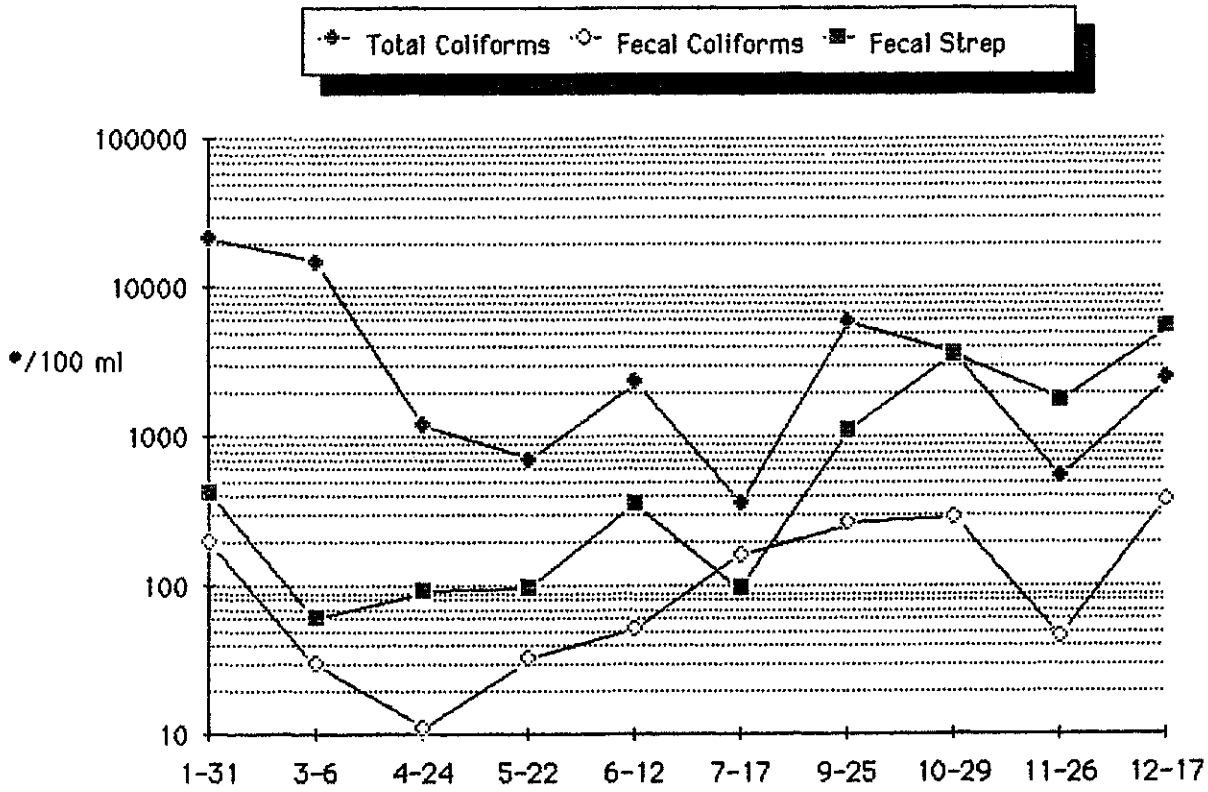

Figure 22. Bacteria collected in Billingsley Creek at Station B5, above Idaho Springs Hatchery, 1984.

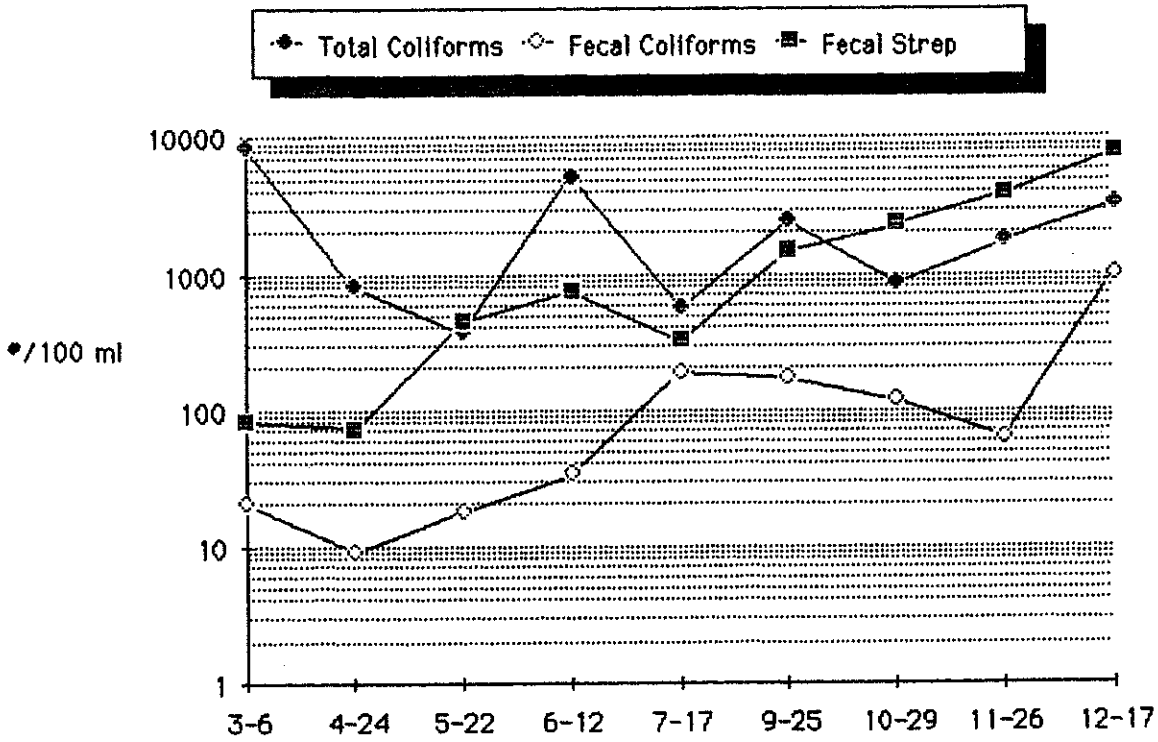

Figure 23. Bacteria collected in Billingsley Creek at Station B5A, below Idaho Springs Hatchery, 1984.

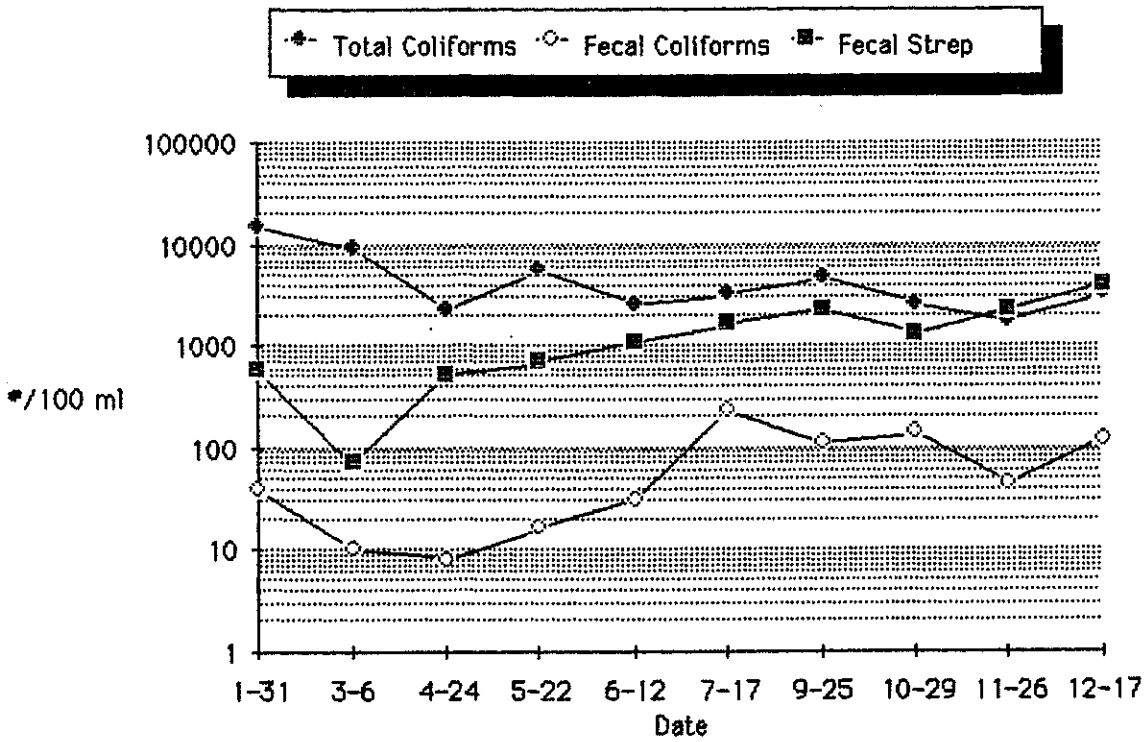

Figure 24. Bacteria collected in Billingsley Creek at Station B6, below Fisheries Development Hatchery, 1984.

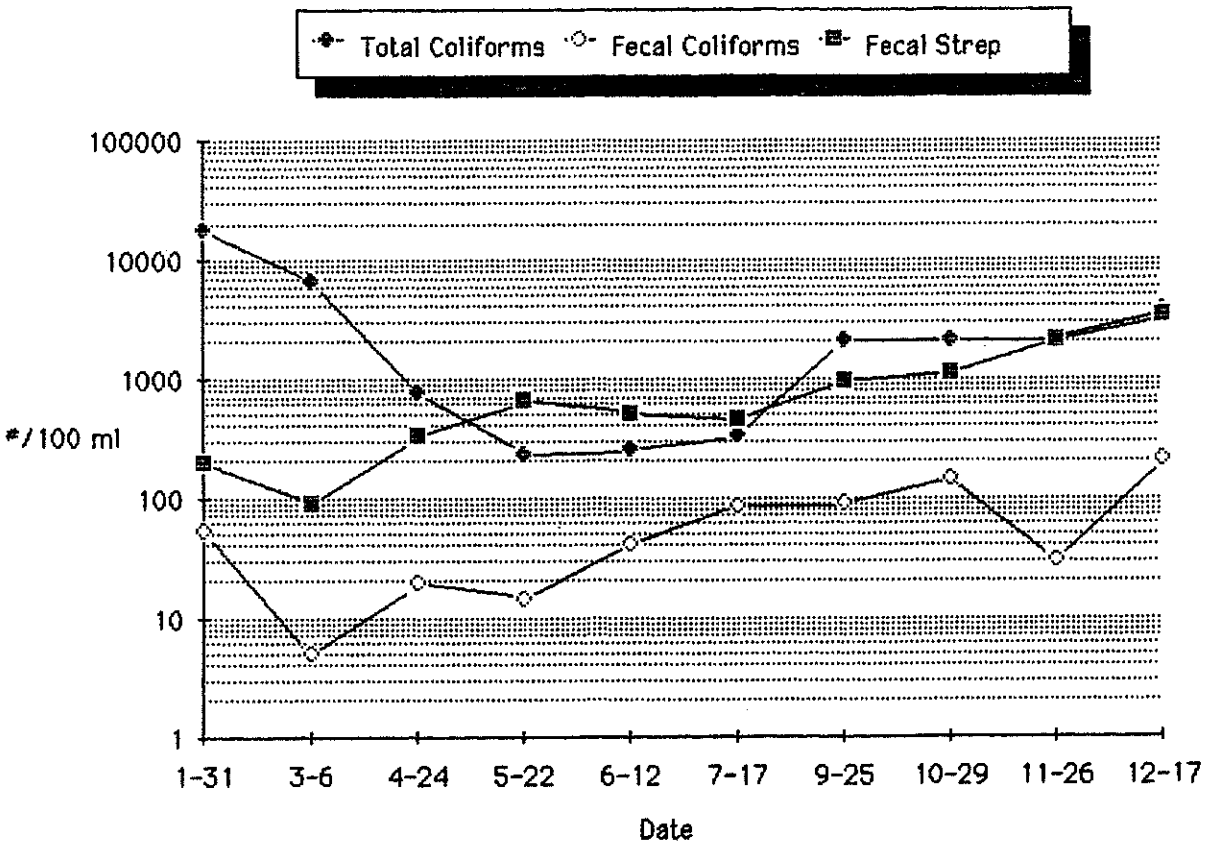

Figure 25. Bacteria collected in Billingsley Creek at Station B7, below the Highway 30 Bridge, 1984.

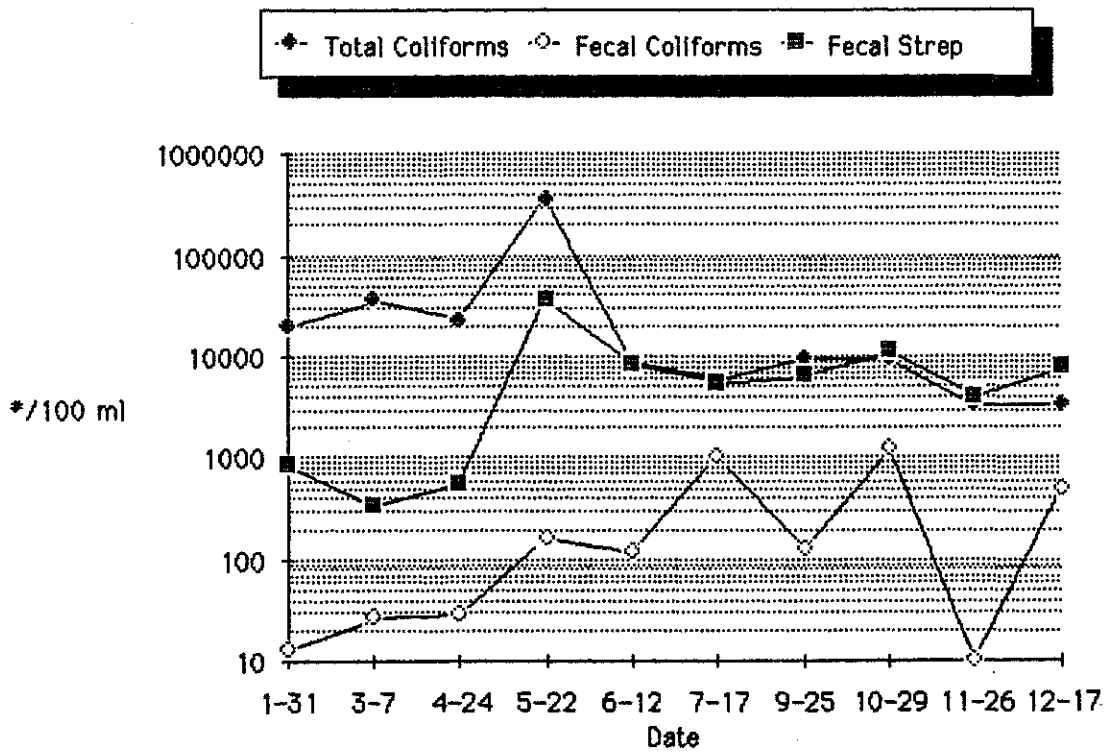

Figure 26. Bacteria densities in Rangen Hatchery combined raceway effluent, 1984.

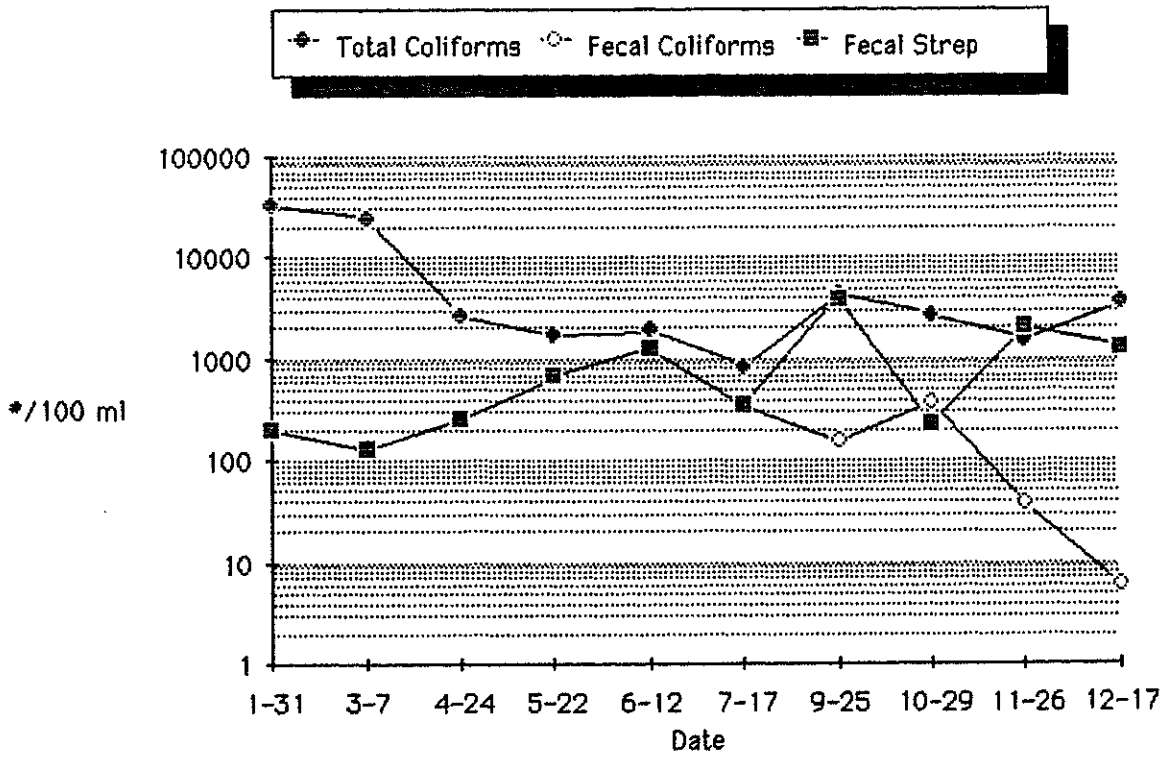

Figure 27. Bacteria densities in Rangen Hatchery settling pond effluent, 1984.

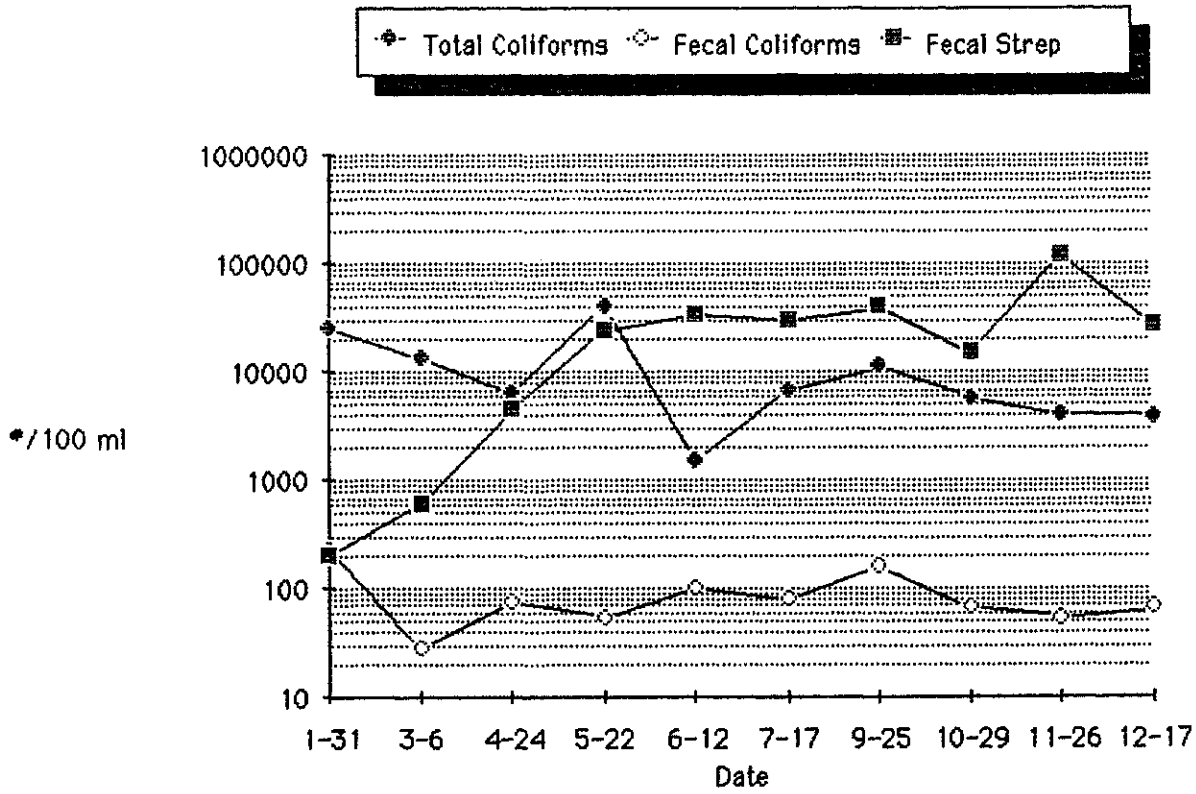

Figure 28. Bacteria densities in Jones Hatchery combined raceway effluent, 1984.

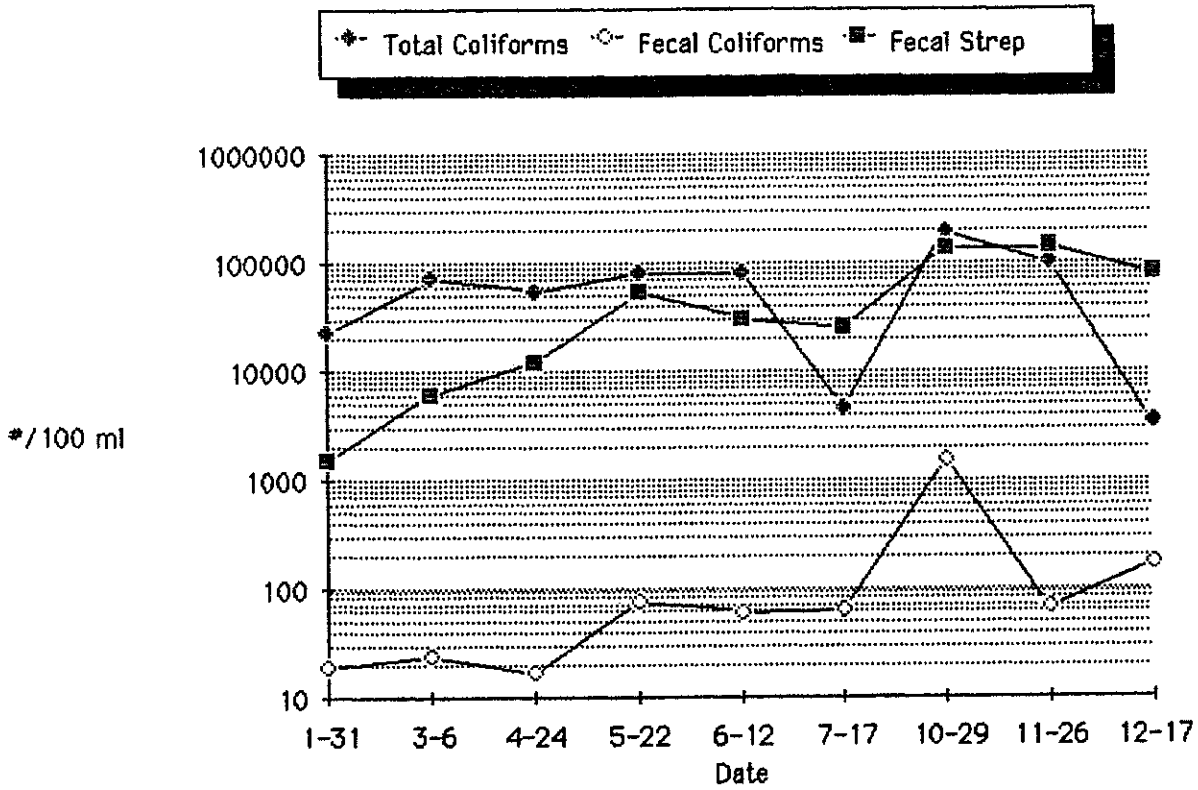

Figure 29. Bacteria densities in Jones Hatchery settling pond effluent, 1984.

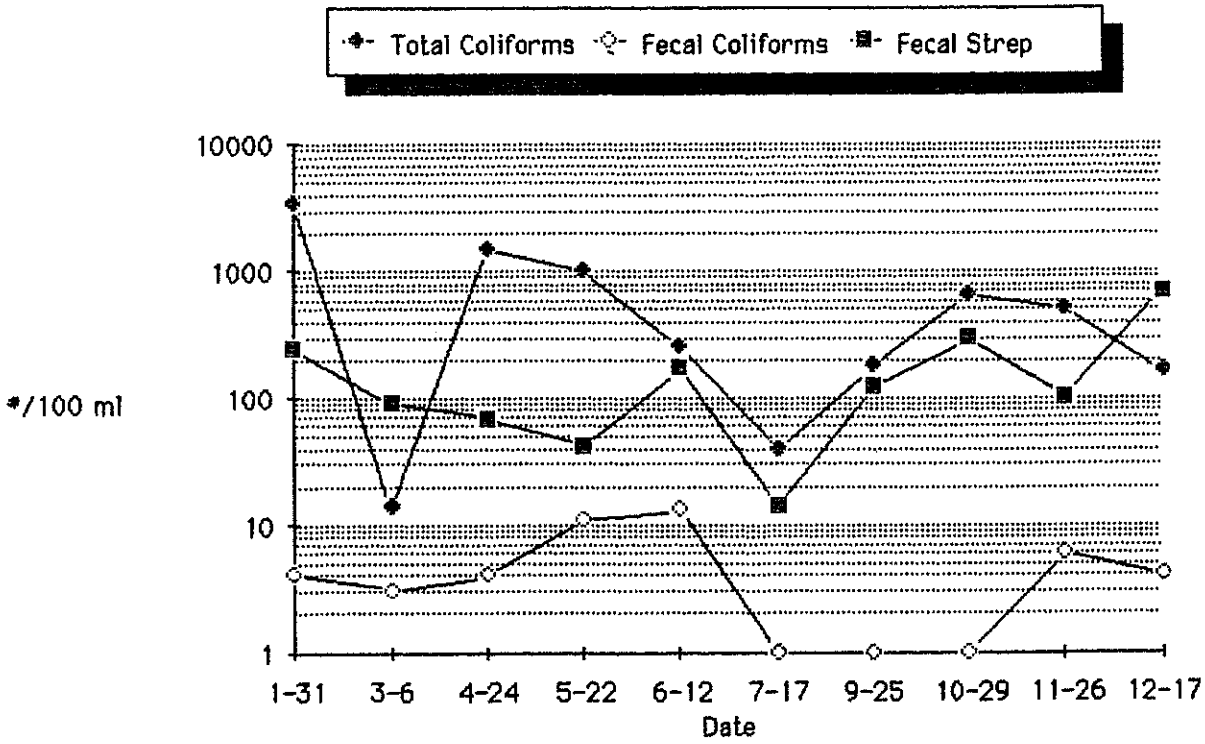

Figure 30. Bacteria densities in Idaho Springs Hatchery combined raceway effluent, 1984.

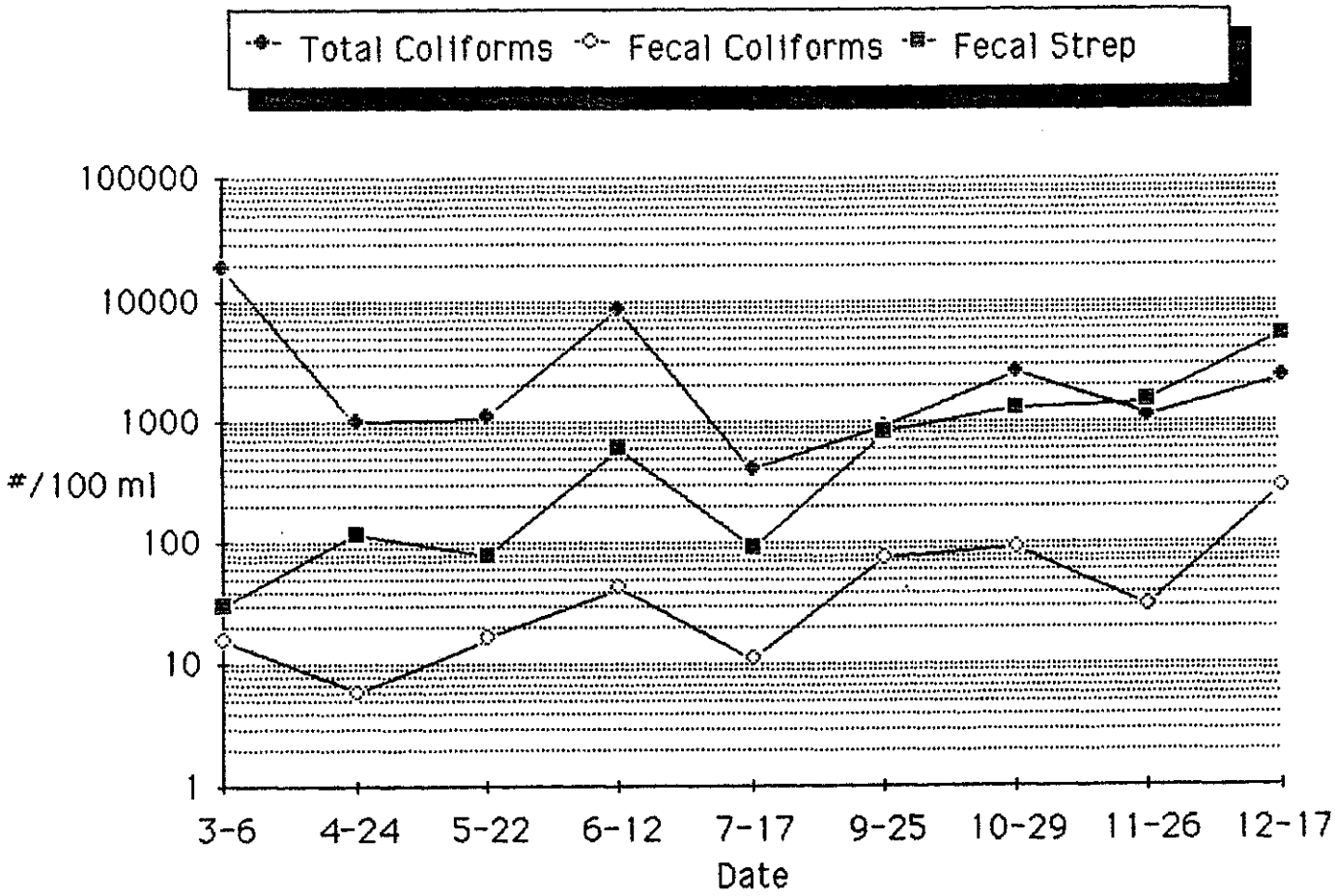

Figure 31. Bacteria densities in Idaho Springs Hatchery rearing pond effluent, 1984.

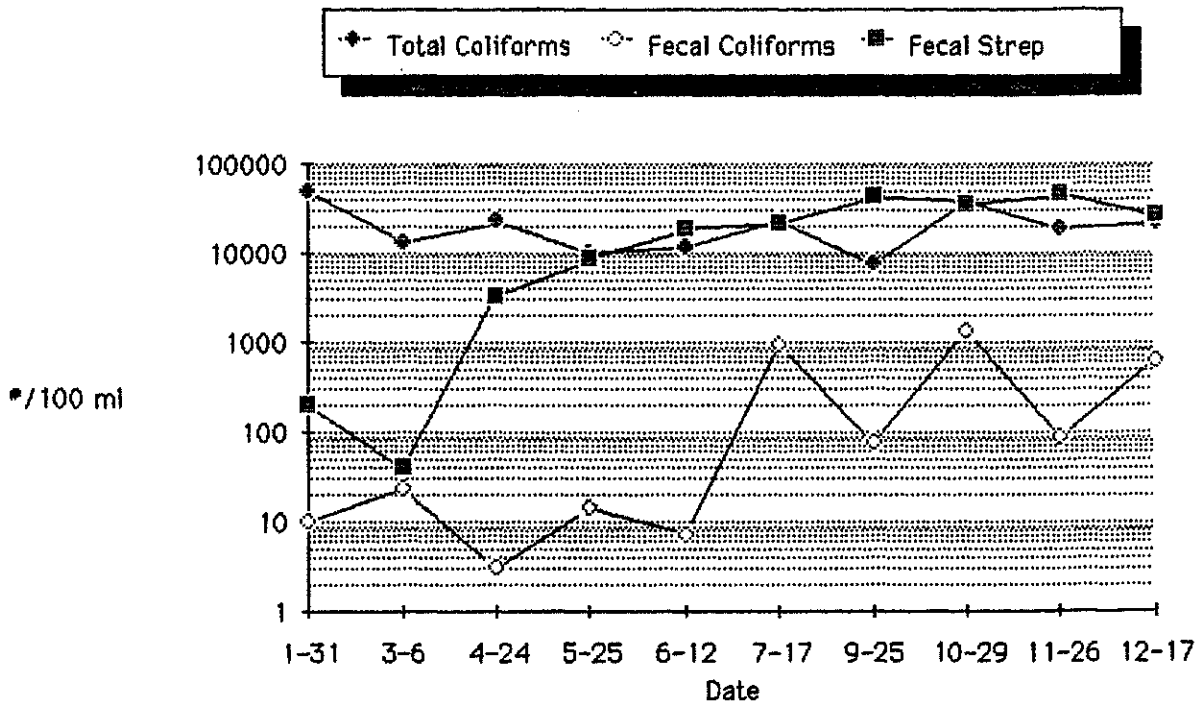

Figure 32. Bacteria densities in Fisheries Development Hatchery settling pond effluent, 1984.

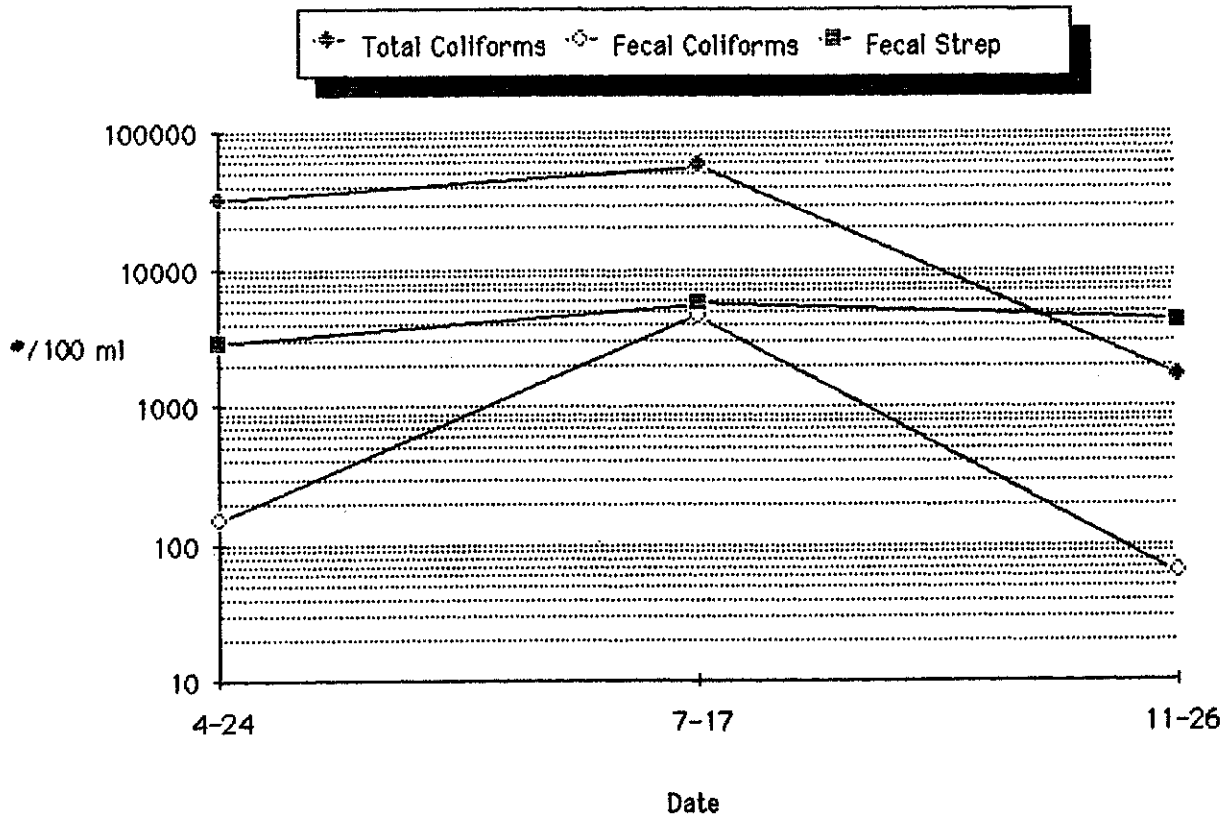

Figure 33. Bacteria densities in Spring Creek Ranch rearing pond effluent, 1984.

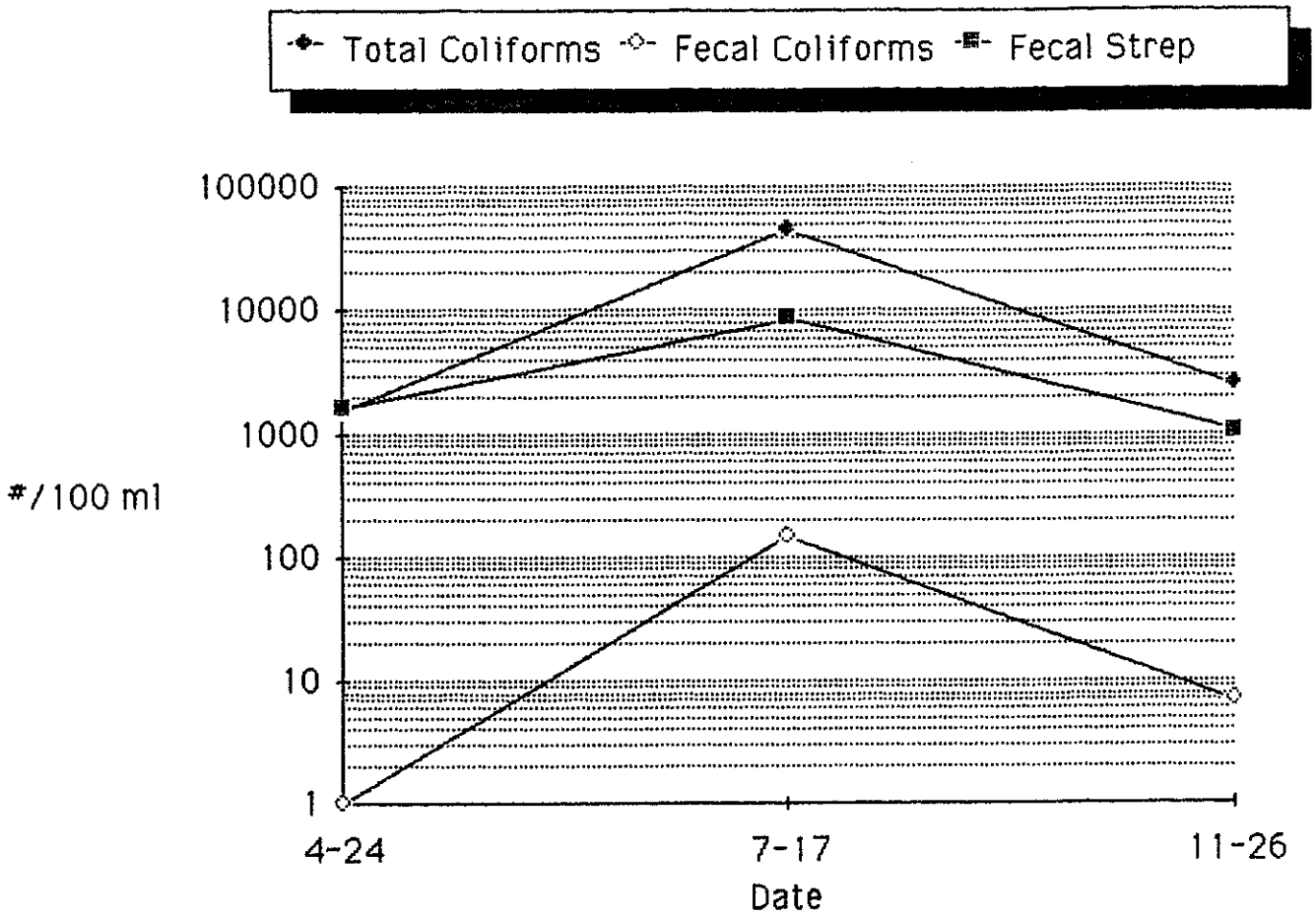

Figure 34. Bacteria densities in Hidden Springs rearing pond effluent, 1984.

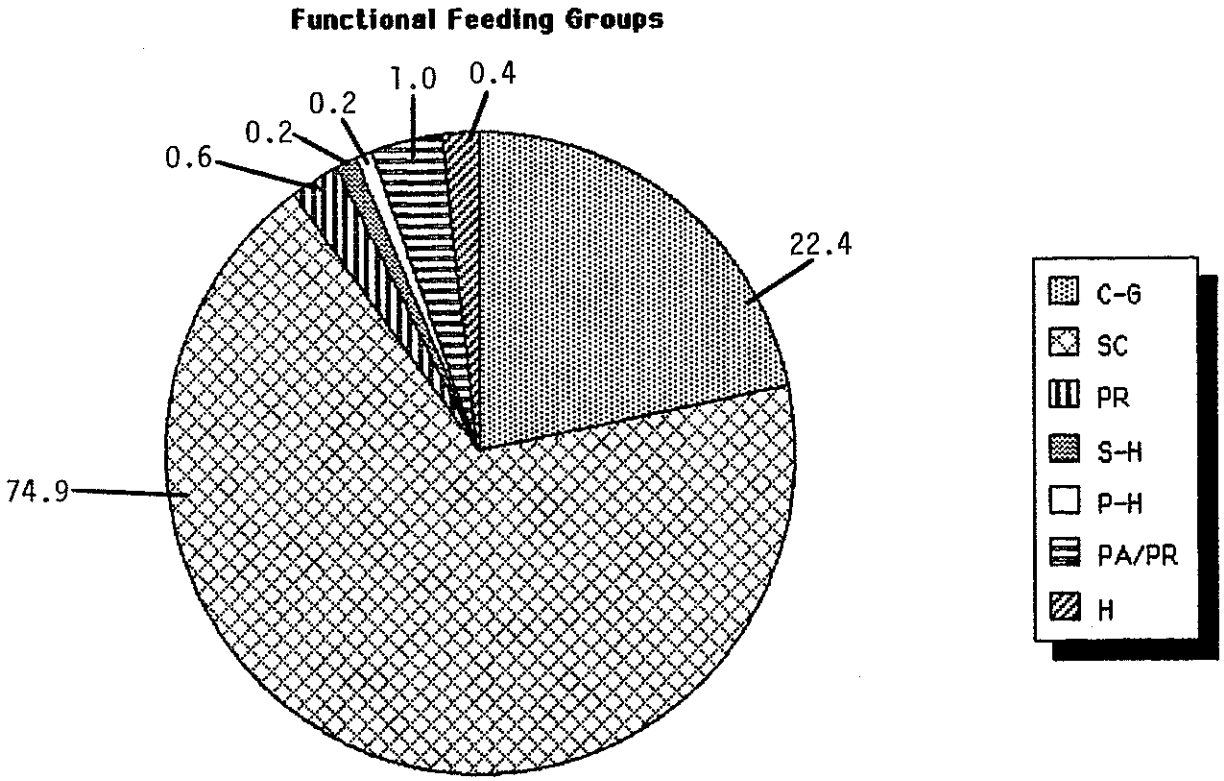

Figure 35. Functional feeding groups of macroinvertebrates collected (% occurrence by numbers of individuals) at Billingsley Creek station B1 (Curren Springs), December 28, 1984.

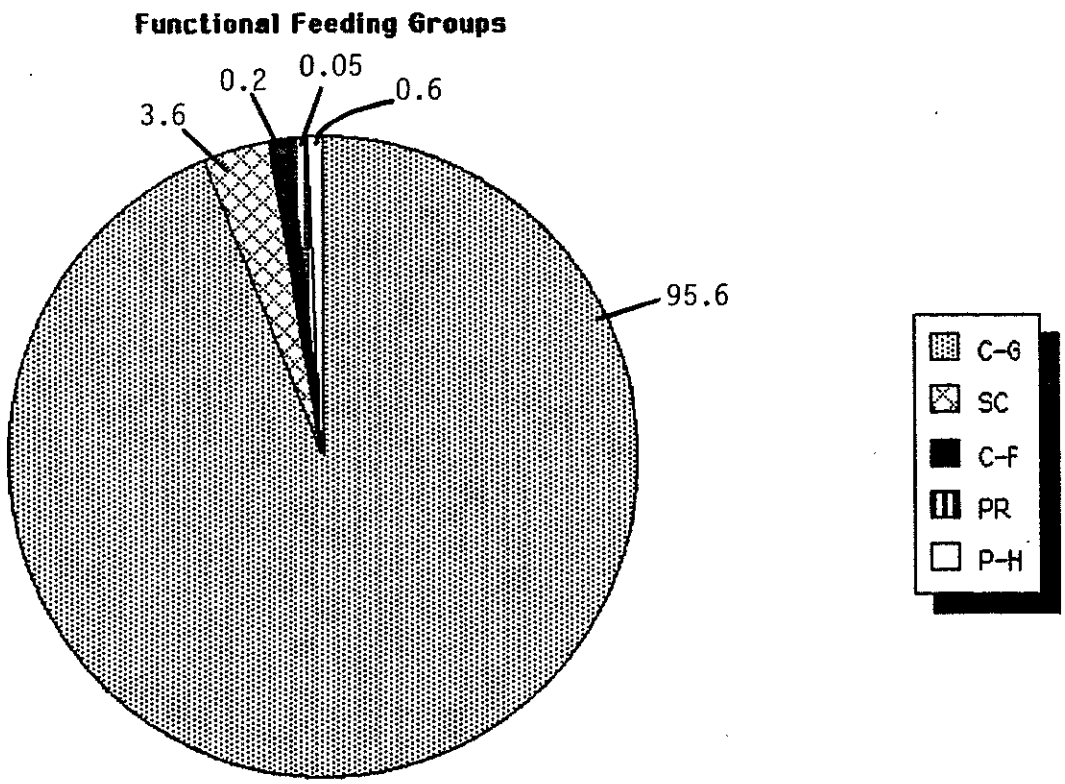

Figure 36. Functional feeding groups of macroinvertebrates collected (% occurrence by numbers of individuals) at Billingsley Creek station B4 (below Jones Hatchery), April 25, 1984.

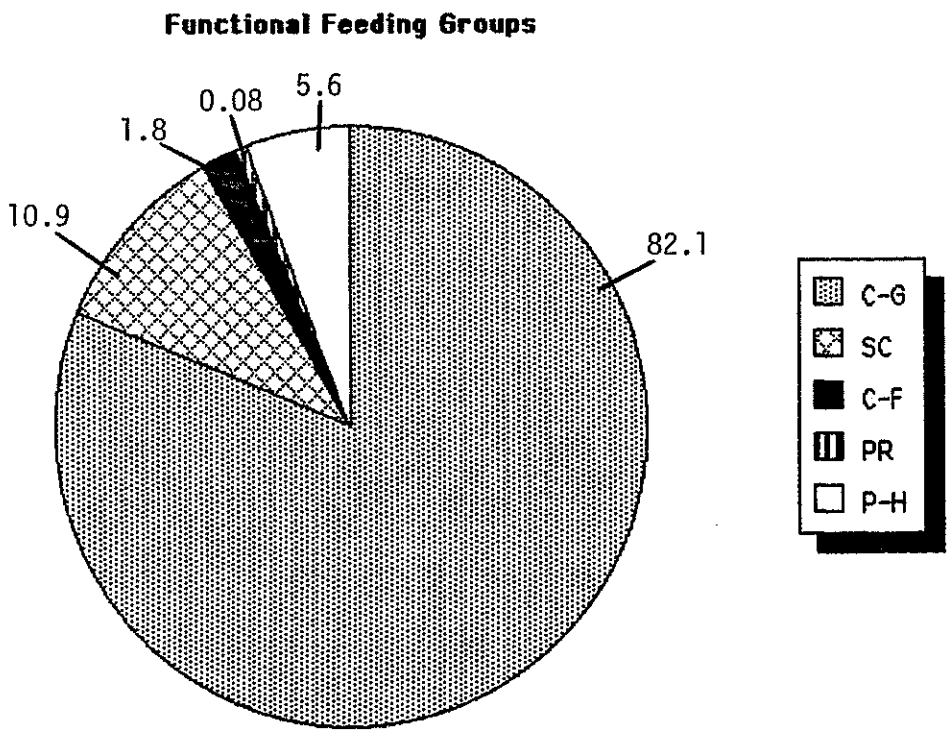

Figure 37. Functional feeding groups of macroinvertebrates collected (% occurrence by numbers of individuals) at Billingsley Creek station B4 (below Jones Hatchery), July 25, 1984.

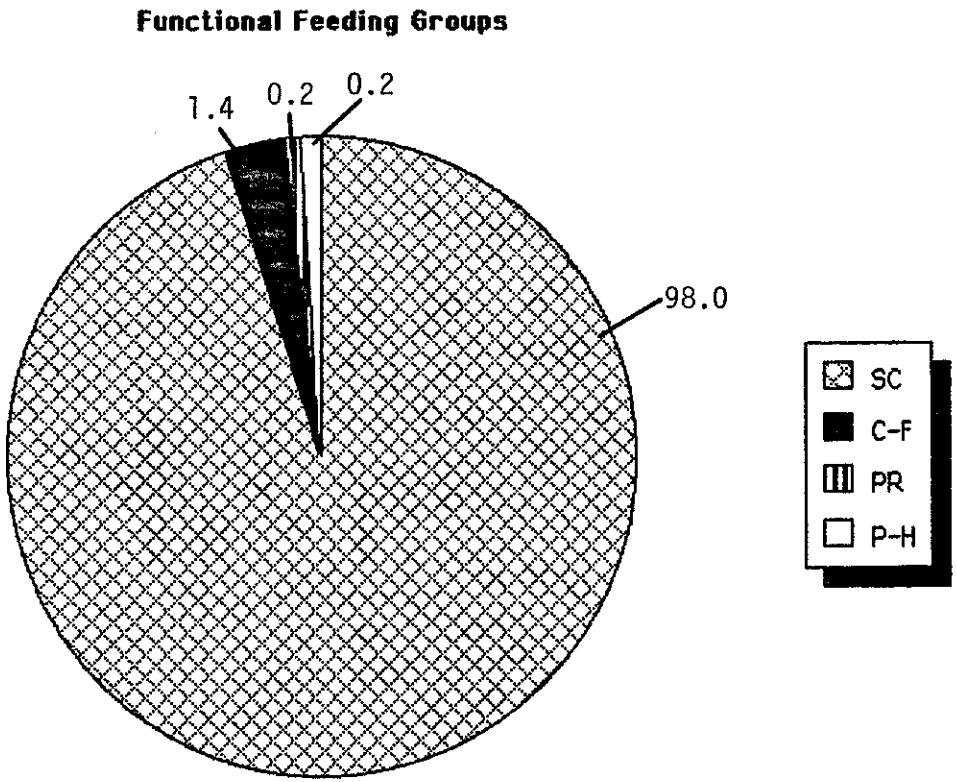

Figure 38. Functional feeding groups of macroinvertebrates collected (% occurrence by numbers of individuals) at Billingsley Creek station B6A (above Fisheries Development), July 25, 1984.

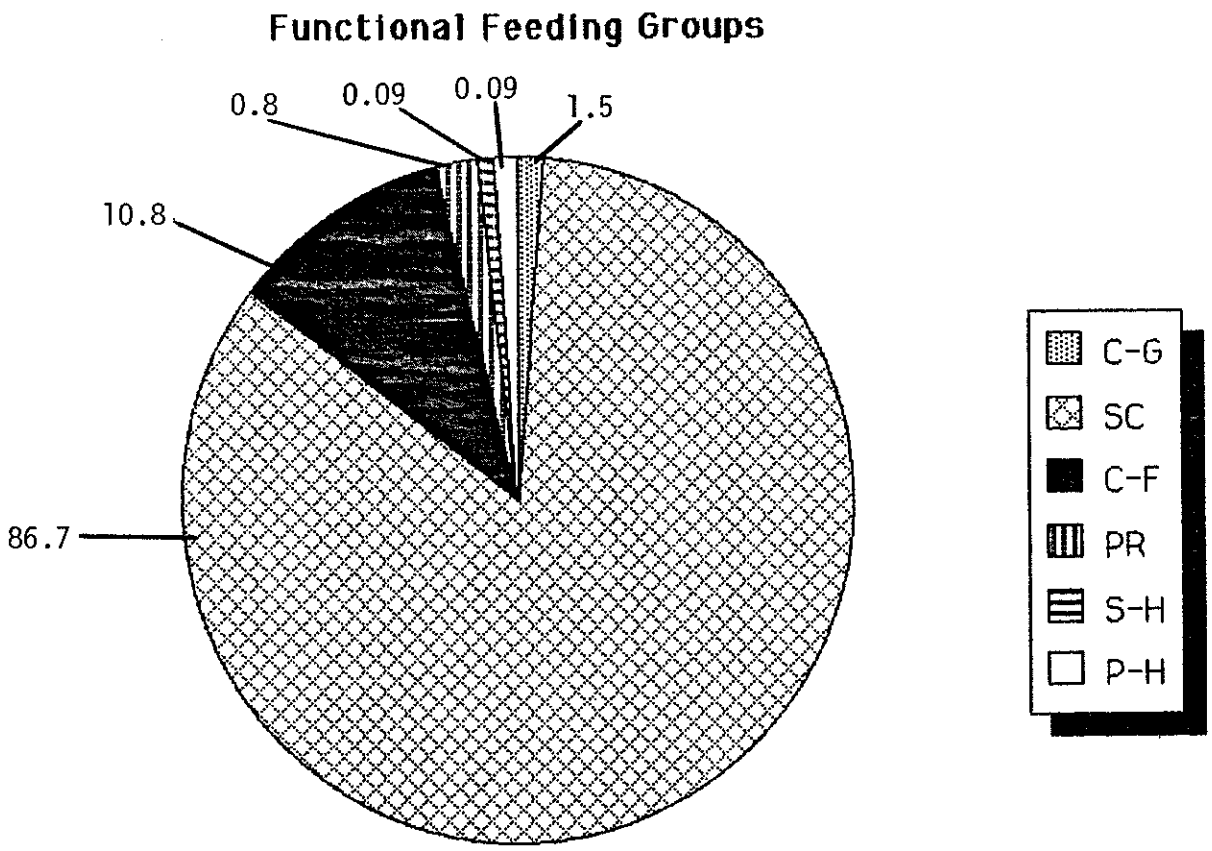

Figure 39. Functional feeding groups of macroinvertebrates collected (% occurrence by numbers of individuals) at Billingsley Creek station B7A (above U.S. Highway 30 bridge), July 25, 1984.

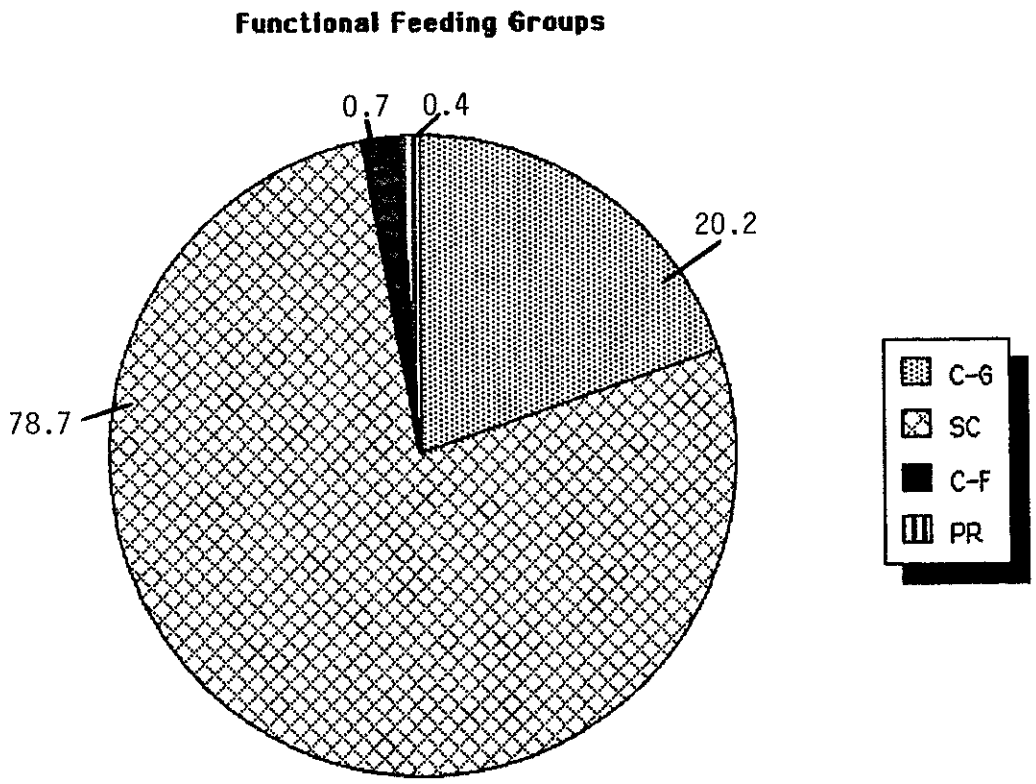

Figure 40. Functional feeding groups of macroinvertebrates collected (% occurrence by numbers of individuals) at Billingsley Creek station B7 (below U.S. Highway 30 bridge), December 28, 1984.

APPENDIX 1

Excerpt concerning BMPs for solids control taken from NPDES permit for trout rearing facilities issued in December, 1985

NOTE: BMP provisions proposed were contested by the fish raisers and eliminated as an enforceable requirement of the permit

NPDES Permit No.: TYPE A-1 PERMIT

United States Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101

AUTHORIZATION TO DISCHARGE UNDER THE

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Federal Water Pollution Control Act, as amended, (33 U.S.C. §1251 et seq; the "Act"),

TROUT CULTURING FACILITY

(Non-Farm Pond with processing and
annual production > 500,00 pounds)

is authorized to discharge from a facility located in _____, Idaho

to receiving waters named

in accordance with effluent limitations, monitoring requirements and other conditions set forth herein.

This permit shall become effective on October 29, 1984.

This permit and the authorization to discharge shall expire at midnight, October 30, 1989.

Signed this 27th day of September 1984.

/s/ Robert S. Burd
Director, Water Division, Region 10
U.S. Environmental Protection Agency

The effective date of this revised permit is December 9, 1985.

Signed this 9th day of December 1985.

Robert S Burd
Director, Water Division, Region 10
U.S. Environmental Protection Agency

C. Best Management Practices (BMP) Plans

1. A plan shall be developed which establishes Best Management Practices (BMPs) to be followed in operating the facility, cleaning the raceways and/or ponds, and removing and disposing of the solids. The purpose of the plan is to identify and describe practices which minimize the amount o pollutants discharged to surface waters.

2. The plan shall be signed and certified as required in Part IV.G and be submitted to EPA within thirty (30) days of the effective date of this permit.

3. The plan is automatically approved, unless EPA notifies the permittee in writing that the plan does not meet one or more of the minimum requirements of Part I.C.6., below. The permittee shall have 15 day after receipt of such notification from EPA to make the changes necessary to comply with Part I.C.6., and to submit the revised plan to EPA.

4. Upon approval, the BMP plan becomes an enforceable part of thi permit and shall be implemented by the permittee.

5. The permittee shall amend the BMP plan whenever there is a change in facility design, construction, operation, or maintenance which affects the potential for the discharge of pollutants to waters of the Unite States. Amendments to the BMP plan shall be reviewed and approved by EPA in the same manner as Part I.C.3. above.

6. The BMP plan shall include, as a minimum, the following items:

a. During Operations:

- A description of the pollution control equipment or methods used to enhance solids collection. An example is the use of screens to create a quiescent zone in the downstream end of ponds or raceways, and the use of a suction device to remove accumulated solids to a settling pond.

- A description of how excessive solids buildup will be identified to trigger more frequent cleaning frequencies such that the accumulated solids do not erode from the bed of soli and wash up and over the dam boards.

- A description of the methods used in feeding, such as self feeders, to minimize the amount of excess feed in the dischar

- A description of the preventive maintenance program for the cleaning equipment so delays in cleaning due to equipment failure are avoided.

- Identification of those operating activities that take plac in raceways or ponds, and describe what steps will be taken t the people who perform these activities to minimize the disturbance of accumulated solids. An example is that a pac will be cleaned before grading high in the pond by

~~b. Discharge of Cleaning Waste or Flow Thru Settling Ponds:~~

- Details about the settling pond design capacity, such as the volume, reserve volume for precipitation, design settling time, and actual settling times.

- Describe in detail how the accumulated solids are to be removed, and methods for disposal. The following measures shall be implemented to the extent possible:

  the water level in the pond should be lowered slowly to prevent the escapement of accumulated settled material; and

  during the removal of material there will be no discharges from the pond.

- Describe where the removed material is to be placed to prevent it from re-entering the pond or any waters of the United States.

c. Other Practices:

- Describe the training to be provided for employees to assure that they understand the goals and objectives of the BMPs, requirements of the NPDES permit, and their individual responsibilities for complying with the goals and objectives of the BMP plans and this NPDES permit.

- List all drugs or chemicals that are applied in the raceways or ponds. For each drug or chemical identify:

  - what the drug or chemical is used to treat,
  - the method of application,
  - the dosage rate,
  - the method(s) used to detoxify the wastewater before discharge, and
  - information on the drug or chemicals's persistence and its toxicity.

C. ~~B~~. Other Requirements and Conditions

1. Solids, sludges, filter backwash, or other pollutants removed in the course of treatment or control of waste-waters shall be disposed of in a manner so as to prevent any pollutant from such materials from entering waters of the United States.

2. Discharging untreated cleaning wastes (e.g. obtained from a vacuum or standpipe bottom drain system) to waters of the United States is prohibited.

APPENDIX 2

Excerpt concerning BMPs for solids control taken from a Fact Sheet issued by the U.S. Environmental Protection Agency on May 21, 1984, regarding issuance of NPDES permits to trout rearing facilities

MAY 23 '8
DIVISION O
ENVIRONMEN

FACT SHEET

United States Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101
(206) 442-1214

Date: May 21, 1984

PROPOSED ISSUANCE OF NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMITS TO DISCHARGE POLLUTANTS PURSUANT TO THE PROVISIONS OF THE CLEAN WATER ACT

This fact sheet includes the tentative determination of the Environmental Protection Agency (EPA) to issue NPDES permits, information on public comment, public hearing and appeal procedures, and the technical information which provides a description of the activity, characterization of the discharges, proposed limitations, and other conditions and requirements.

Region 10 has tentatively determined to issue NPDES permits to 63 individual trout culturing facilities in the State of Idaho.

Persons wishing to comment on the tentative determinations contained in the proposed permits must do so by the expiration date of the Public Notice. Comments should be submitted as described in the Public Comments section of the attached Public Notice.

A public hearing will be held on June 21, 1984 in Twin Falls, Idaho. Paragraph 4 of the attached Public Notice contains information on the hearing.

After the expiration date of the Public Notice, the Director, Water Division, will make final determinations with respect to the permit issuance. The tentative determinations contained in the draft permit will become final conditions if no substantive comments are received during the Public Notice period.

The permit will become effective 30 days after the final determinations are made, unless a request for an evidentiary hearing is submitted within 30 days after receipt of the final determinations. An evidentiary hearing will be granted only if it meets all the requirements of 40 CFR 124.74.

The proposed NPDES permit and other related documents are on file, may be inspected, and copies made in Room 11D, 1200 Sixth Avenue, Seattle, Washington, 98101, at any time between 8:30 a.m. and 4:00 p.m., Monday through Friday. Copies and other information may be requested by writing to Sylvia Kawabata at the above address to the attention of the Water Permits Section M/S 521, or by calling (206) 442-1271. This material is also available in Boise and Twin Falls, Idaho as specified in the Public Notice. A copying machine is available in the Seattle Office for public use at a charge of 20 cents per copy sheet. There is no charge if the total cost is less than 25 dollars.

10. Best Management Practices (BMP)

In addition to BCT, the implementation of best management practices (BMP) will assist in reducing the discharge of solids. These recommended BMPs are as follows:

a. Field observations and analytical data have shown positive correlation between high effluent TSS and hatchery maintenance events. Care in cleaning practices can help minimize solids discharge. In vacuum cleaning, whether mechanical or siphon, floats can be attached to vacuum hoses to prevent dragging of hose lines along raceway floors amid the solids accumulations. Where possible, vacuum operators should remain outside the raceway, or where necessary to enter the water, the operator should move slowly so as to minimize the disturbance of solids. During all activities requiring operator presence or activity in the raceway (sorting, grading, sample counting, cleaning), adjustment of dam boards or influent gates during the maintenance activity to reduce water velocities will minimize solids loss over effluent weirs.

b. Field observations have also found deposits of fish offal in receiving waters downstream of a few facilities. The probable causes are inadequate sludge removal and disposal practices associated with the settling ponds. In most facilities a backhoe digs out the settled waste from the ponds and places it next to the ponds. When it rains, part of the solids may be washed into a nearby receiving water body. This type of practice is prohibited. Part III.A. of the permit requires for the removal and disposal of sludge so that it does not enter any surface water body.

11. Compliance Schedules

The BCT permit effluent limitations must be achieved on the effective date of the permit. Some facilities may already achieve those limits. On the other hand some facilities may need time to purchase materials to construct screens, or vacuuming equipment.

Those applicants who are unable to meet this deadline are asked to notify EPA of their situation by the end of the comment period, June 29, 1984. The notification should include a discussion on why they are unable to meet the deadline, information on what needs to be done to meet the permit limits, and the shortest reasonable period of time required.

12. State Certification

Section 401 of the Clean Water Act requires that the State of Idaho certify that Federally issued permits are in compliance with State water quality standards.

These permits are for wastewater discharges to waters within the State of Idaho. Discharges, according to the proposed permit limitations and conditions, are not expected to adversely affect the protected uses of the receiving waters at most operations. The certification provisions of Section 401 must be satisfied before these permits may be issued.