THE EFFECTS OF CATTLE GRAZING
ON AN AQUATIC SYSTEM

by

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ABSTRACT

The effects of cattle grazing on two spring creeks in Southern Idaho, Cattle and Wilson Creeks, were studied. I chose these streams because they were similar in all respects except grazing intensity. Wilson Creek was fenced and was grazed at a much lower intensity than Cattle Creek. Any differences between streams, then, should be attributable to the different levels of grazing on each stream.

Streams were examined for differences in primary production, benthic fauna and invertebrate drift.

Cattle Creek had higher levels of algal drift, organic sediment, and macrophyte production than Wilson Creek. This suggests increased nutrient enrichment and primary production in Cattle Creek relative to Wilson.

Benthic biomass was two or three times greater in Cattle than Wilson Creek, suggesting higher invertebrate production in Cattle Creek also. Chironomids dominated the benthic fauna of Cattle Creek, while mayflies dominated in Wilson Creek. This faunal difference suggests higher levels of enrichment in Cattle, and may be a result of the heavy organic sediment layer formed in Cattle Creek. Other orders did not show significant differences between streams.

Invertebrate drift biomass was 30 to 70 percent greater in Wilson than Cattle Creek. Mayflies dominated the drift biomass in Wilson, and to a lesser extent in Cattle Creek. Chironomids were grossly underrepresented in the Cattle Creek drift biomass, relative to their benthic biomass.

The importance of cattle in affecting levels of stream enrichment is discussed, and phosphorous is suggested as the major factor determining the grazing related changes between streams. Management evaluations and recommendations are given based on the findings of this study.

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This thesis is dedicated to my dog, Sparky, who died in late January after 16 years of being the best friend anyone has ever had.

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I. GENERAL INTRODUCTION

Silver Creek is a unique and delicate spring creek ecosystem in Southern Idaho, and supports one of the finest trout fisheries in the world.

The Nature Conservancy, a large, non profit organization which purchases and manages ecologically valuable land, bought a major portion of Silver Creek (some 479 acres) in 1976, to preserve this unique habitat and protect the quality of the fishery.

Since this time, the Silver Creek Preserve has been beset with problems, one of the greatest being uncontrolled grazing along major tributaries outside the preserve proper. At present, the Conservancy is trying to implement a fenced easement program along all such tributaries, in an attempt to reduce the effects of grazing and other agricultural practices on these waters.

Studies have shown that cattle grazing can have significant impacts on aquatic systems. One of the main effects appears to be through enrichment of surrounding soils and surface and groundwater, with significant increases in nitrogen and phosphorous levels in these areas (Turner et al., 1977; Filip and Middlebrooks, 1976; Biggar and Cory, 1969; Sartz and Tolstead, 1974; Sharpley and Seyers, 1979; Cook and Williams, 1970; Wetzel et al., 1969). Such enrichment can affect primary and secondary productivity both in amount and composition, and can alter the whole ecology of the stream (Hynes,1960; Cummins 1974; Patrick 1975).

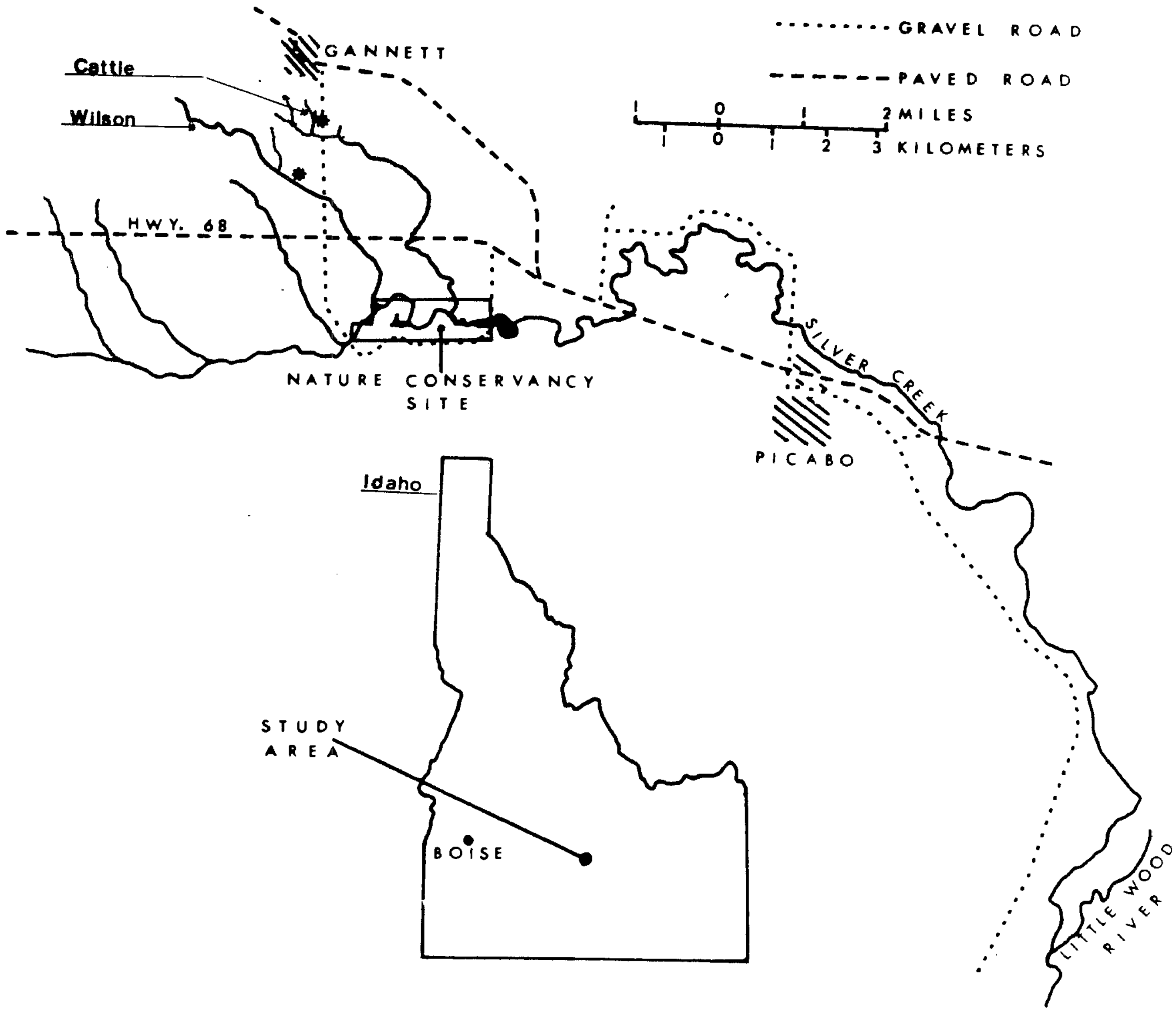
Increased erosion and sedimentation, is another important effect of cattle grazing, and can cause physical alterations of the stream and higher levels of enrichment (Jenkins, 1979; Guy Bonnivier, personal communication).

The purpose of this study was to determine the biological effects of cattle grazing on an aquatic system, particularly the grazed, unfenced tributaries of the Silver Creek watershed. The study had a number of related objectives:

1) To determine the biological effects of cattle grazing on streams, and the types of changes grazing can cause.
2) To document these changes, as little work has been done on the biological changes owing to grazing and associated nutrient enrichment.
3) To determine how cattle-induced changes are brought about.
4) To provide the Conservancy with needed information with regard to their grazing policies, and to justify present management and fencing programs.
5) To provide information allowing improvement or development of new management strategies to reduce the impact of cattle grazing.

Wilson and Cattle Creeks, two similar streams with different grazing intensities, were selected to investigate the effects of Cattle grazing. Primary production, benthic fauna, invertebrate drift and sediment composition was studied to determine differences between streams attributeable to grazing.

In general, Cattle Creek, the more heavily grazed of the two streams, should show higher levels of enrichment and sedimentation relative to Wilson Creek. This should be evident



Location of Silver Creek in Blaine County, Idaho.

through quantitative and qualitative changes in the above areas, (i.e. primary production, bottom fauna, drift, and sediment levels).

In the following account, after describing the study site and grazing history, I consider three aspects as separate chapters under the headings: primary production, benthic fauna, and invertebrate drift.

STUDY AREA

Wilson Spring Creek and Cattle Creek, were chosen as study areas because they were well suited to showing the differential effects of cattle grazing. They are similar in underlying biology and geology, but are different in their grazing histories.

These two streams form a natural experimental situation. The degree of grazing is the only major difference between them and any observed differences are attribut able to grazing, as other influences should be negligible.

GRAZING HISTORY

Cattle and Wilson Spring Creeks were historically, and are presently subject to different degrees of grazing intensity and management.

Wilson Creek has a history of light grazing over the past 25 years, and presently, only one side of the stream is being grazed by a herd of 30 heifers. Fencing, through farmer co-operation, has established a 100 foot ungrazed buffer zone along each bank, keeping cattle off banks and out of the water. Riparian and field vegetation is well established within these easements.

Cattle Creek has a history of much heavier grazing than Wilson Creek over the last 25 years. Presently, more than 900 beef cattle are grazed over a more extensive area and at higher intensity than Wilson Creek (Guy Bonnivier, Tommy Shaw, personal communications). Unlike Wilson, Cattle Creek is unfenced and cattle are allowed to water along the entire stream, grazing the banks freely.

SIMILARITIES BETWEEN STREAMS

Wilson and Cattle Creeks are separated by less than 400 meters. They are influenced by the same geological and biological factors, with the exception of those influences due to grazing differences, discussed earlier.

Both have similar daily temperature fluctuations. Water clarity is excellent and flows are constant throughout the year, with no major water level fluctuations (neither stream experiences a spring runoff) (Francis and Bjornn 1979).

Both streams arise from the same limestone aquifer, and are entirely spring fed. Baseline chemical composition of water within this aquifer should be identical between streams (Moreland, 1977). However, local influences, such as pasture seepage, may change the final surface composition of this water and this will be discussed later. Both are alkaline and rich in calcium (Schwiebert, 1973) which is typical of limestone-type streams.

Stream character is similar, both showing the wide shallow nature (less than 16 cm deep in most areas) typical of streams subject to prolonged grazing and bank erosion (Guy Bonnivier, personal communication). Depth and velocities are comparable but Cattle Creek is roughly 1 meter wider in most areas. Gravel size and distribution is also similar between streams, consisting of gravel mixed with sand in most areas (see the "Methods-Benthic Samples" section later for a complete description of the actual study sites on both streams).

Both streams are untreed and flow through grassland areas, giving maximum sun exposure. The climate here is dry, with hot summers (up to 30°C) and cold winters, well below freezing. Precipitation is low, but brief, heavy thunderstorms dropping up to an inch of rain are not uncommon in the summer. Winds are usually a daily feature of the area.

DIFFERENCES BETWEEN STREAMS

Wilson Creek had relatively clean gravel and sedimented areas were found only in slow backwaters or along the bank. sediment was usually low in organic matter. Cattle Creek was noticeably different in this respect, with a layer of organic sediment of variable thickness and distribution covering much of the gravel. The thickness of this layer appeared to be variable throughout the year.

Wilson Creek had well vegetated, intact banks. Extensive floating moss beds paralleled the length of the stream and represented areas of small bank side spring seeps. Cattle had little bank vegetation, with much bank erosion and exposed soil. Mossy spring seeps were replaced by compacted soils and open, eroding spring seeps, with little or no vegetation. Three of the five major springheads on Cattle Creek were reduced to mudholes, while all springs on Wilson Creek were healthy and vegetated. Despite the frequent areas of mud or soil along Cattle Creek, water clarity remained excellent, except during occasional periods of heavy rain.

The species of aquatic plants were the same between the two streams, both containing Potamogeton, Watercress, Chara, Ranunculus and Fontinalis. However, the total amounts and proportions of each species was different. Cattle Creek had a greater coverage of macrophytes, particularly Potamogeton. Algae was also more prevalent than in Wilson, both attached and in drift.

The concentration of manure was also three times higher around Cattle Creek than Wilson. There was no evidence of manure in the fenced buffer zone of Wilson Creek, while on Cattle, droppings tended to increase in density with proximity to the water, as cattle spend much of their summer grazing near water.

GENERAL METHODS

Study sites were selected on each stream, so as to be comparable in flow, depth and substrate composition. Benthic sediment and drift samples were taken within these study areas, along with measures of primary productivity. Detailed descriptions for each method are given in their respective sections.

II. PRIMARY PRODUCERS

INTRODUCTION

As mentioned earlier, numerous studies have shown that cattle can greatly increase the nitrogen and phosphorous content of surrounding soils and surface and ground waters.

Nitrogen and phosphorous are the major nutrients involved in plant growth, and this increase in nutrients tends to affect the growth of primary producers (algae, diatoms and macrophytes mainly). Such growth responses can be through changes in amount or composition, and can indicate the degree of enrichment of a system (hence, the idea of indicator species for estimating water quality, for example Whitton, 1977; Patrick 1975).

Besides being indicators of enrichment, changes in primary producers can have important consequences to the system itself, and warrant investigation on these grounds alone. Because of the natural trophic structure of such systems, changes in primary producers will also affect secondary productivity (Cummins 1974). These effects will be discussed later.

A number of parameters were investigated to determine if primary production gave any indication of the degree or difference of enrichment between the two streams owing to differential grazing.

Quantitative and qualitative compositions of primary producers in Cattle Creek should be typical of water having increased nitrogen and phosphorous, as outlined in the literature. Wilson Creek should show relatively lower levels of enrichment than Cattle Creek.

A number of predictions can be made from this hypotheses:

1) Cattle Creek should show higher levels of enrichment, both through the presence/absence of indicator species, and through increased primary production.
2) Cladophora, and other algal indicators of nutrients enrichment should compose a large proportion of the drifting algae in Cattle Creek.
3) The organic sediment in Cattle Creek should be a result of high rates of primary production, and may be a buildup of filamentous algae (particularly Cladophora) or some other primary producer.

METHODS - Primary Producers

Methods for measuring primary productivity were intended to be more qualitative than quantitative here. While algae and diatoms form an important part of the story on a gross level, the methods chosen were sufficient to illustrate the major results and between stream differences.

Filamentous algae was collected in conjunction with invertebrate drift on both streams (see "Drift-Methods" section for a complete description of sampling methods). Drift samples were sorted and algae was separated out and preserved in 10% formaldehyde. Samples were later drained and rinsed for two minutes in a fine meshed bag, and then placed in a temperature controlled drying oven at 65°C for 3 days.

Wet samples were subsampled and species compostion was recorded along with presence-absence data.

Organic sediment was measured with a fine scale ruler. Measurements were taken at the same time as Surber samples. (see later section on benthic sampling methods).

Organic sediment samples were taken from both streams by skimming portions of this upper organic layer off the gravel with a 6 dram vial. Samples were then preserved in 10% formaldehyde and examined for compostion.

Macrophyte compostion between streams was also recorded, using percent bottom coverage of line transects as an index of abundance of each species.

RESULTS - Primary Producers

Wilson and Cattle Creeks differed greatly in their relative abundances of different algae, diatoms and macrophytes.

(1) Algal Drift

Algal drift samples yielded major biomass differences between Cattle Creek and Wilson Creek. Cattle Creek had very high biomasses of drifting algae between June and July, averaging 9.3 g per 1½ hour sample and 13.3 g per sample respectively, with a marked decline by August 20 to less than .4 g per 1½ hours (see Figure 1.).

In Wilson Creek, algal drift was almost non existant in June and July, averaging less than .3 g per 1½ hour sample, some 40 times lower than Cattle Creek biomasses for the same period. In August, algal biomass increased slightly to .7 g

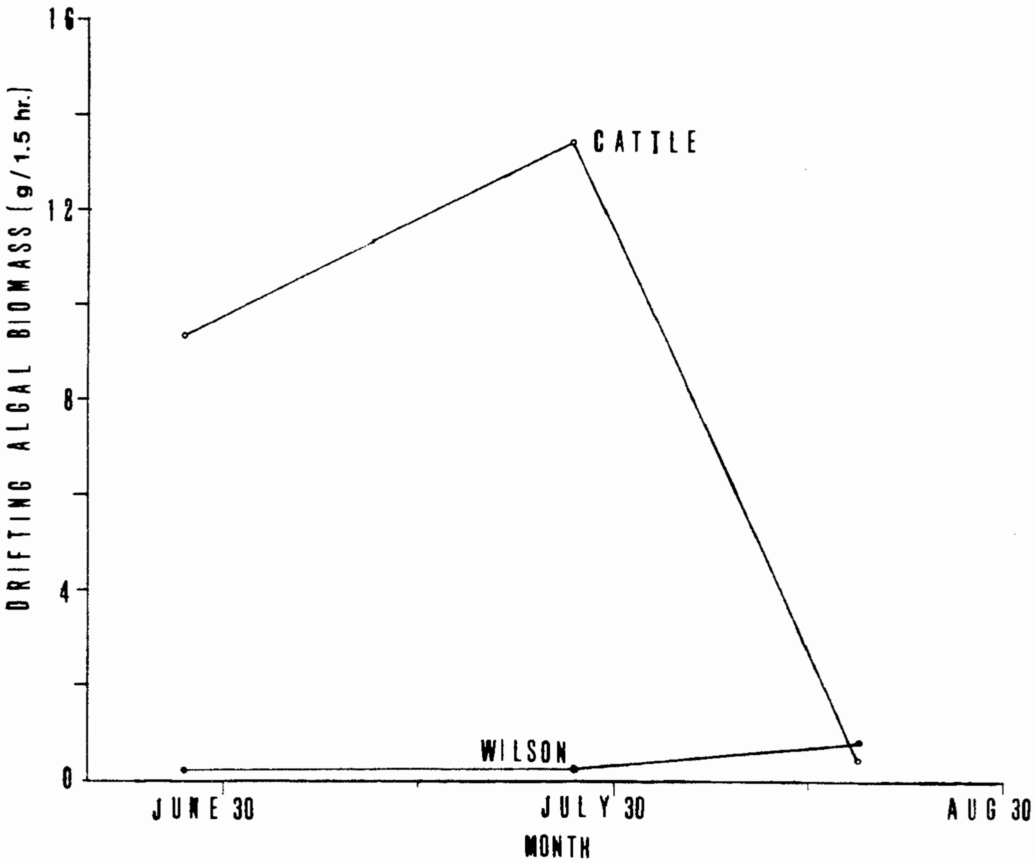


Figure 1. The change in drifting algal biomass between June and August in Wilson and Cattle Creeks.

per sample, which was actually slightly greater than the August Cattle drift (see Figure 1.).

Spirogyra was the predominant algae in the drift, with Ulothrix and Cladophora making up significant proportions also (all Class Chlorophyceae). Filamentous blue green algae was also present in small amounts (Phylum Cyanophyta).

(2) Organic Sediment Composition

Organic sediment was essentially non-existant in Wilson Creek. While small amounts of algae and diatoms could be found on gravel or in small, between-gravel pockets, their depth was unmeasurable from June through August. However, in Cattle Creek, organic sediment covered large patches of gravel and occured in most gravel interstices. June sediment depth averaged 8mm at the greatest depths, and increased slightly to 10mm by mid July (see Figure 5). By August 20th, sediment depth had dropped off sharply to 2 to 3 mm, occurring in small localized patches. Most gravel and macrophytes still had a thin surface layering of filamentous algae.

Organic sediment composition was dominated almost exclusively by diatoms, making up an estimated 90 to 98% of the sediment biomass. Higher macrophytes, Spirogyra, Cladophora, and other filamentous algae comprised the remaining portion, along with some terrestrial-type detritus (grasses mainly).

The bulk of the diatom portion of the sediment was made up of roughly six species of golden brown diatoms, all mainly acentric forms, with occasional centric species. Many of the diatoms in this organic layer were empty frustules.

Diatom compostion of organic sediment from surber samples was similar to the above sediment samples, but had a higher composition of filamentous algae, particularly Cladophora, Spirogyra, and Ulothrix.

(3) Macrophyte Composition

Both Cattle Creek and Wilson Creek contained the same species of macrophytes, discussed in the "Differences Between Streams" section earlier. However, the relative abundance of macrophytes was much higher in Cattle Creek, covering 3 to 4 times more of the stream bed than in Wilson.

The major coverage difference was due to differences in the abundance of Potamogeton. Potamogeton covered roughly 30 to 70% of the stream bed in Cattle Creek by August, while it covered only between 5 to 15 percent in Wilson Creek.

Chara, Watercress, Fontinalis, and Ranunculus, were more abundant in Wilson than Cattle Creek, and, while alone, these species did not cover a significant area, together they covered an additional 5 to 9% of stream bed in Wilson. In Cattle, their densities were low and they covered less than 2% of the sampled areas. In general, Wilson Creek aquatic vegetation was more diverse than Cattle Creek.

DISCUSSION - Primary Producers

Qualitative and quantitative differences in primary productivity between streams showed clear evidence of greater nutrient enrichment in Cattle Creek relative to Wilson, as hypothesized.

The large drifting algal biomass in Cattle Creek is typical of the higher productivity of enriched waters, and supports predictions of increased primary production in Cattle Creek (Patrick, 1975 ; Maloney et al.,1974 ; Powers et al., 1974). Algal blooms are a characteristic of such enrichment and are the basis for premature degradation of aquatic habitats (Frost, 1968; Filip and Middlebrooks, 1976).

The composition of this algal drift also indicates eutrophic tendencies, with Spirogyra, Cladophora, and Ulothrix being the dominant components. All three of these genera are favoured by higher than normal nutrient conditions and are reliable indicators of enrichment, as predicted, (Patrick, 1975; Hynes, 1969;). They provide further support for the hypothesized higher nutrient levels in Cattle Creek. Bird and Hynes (1981) in their study of a shallow, agriculturally enriched stream also reported large growths of Cladophora in the summer.

Physical appearance of Cladophora can also be used as an indicator of nutrient levels, with growths from enriched waters developing a dark green colouration and long filamentous form (Hynes, 1974), as was found in Cattle Creek.

The low algal biomass and reduction in relative proportions of indicator species such as Cladophora and Spirogyra, in the Wilson Creek drift suggests lower levels of enrichment, relative to Cattle. The Cladophora that did occur in the Wilson Creek drift was pale green with short filaments, typical of forms from waters containing normal nutrient levels (Hynes, 1974).

It is possible that peak algal production and drift had not yet occurred in Wilson, as algal biomass did show a slight rise in August. However, levels were still insignificant relative to Cattle Creek, and enrichment generally tends to accelerate algal growth (Hynes, 1974). I would expect a growth peak similar to that of Cattle Creek if the two streams were similar in nutrient content.

As predicted, the organic sediment layer of Cattle Creek was a result of high rates of primary production. Diatoms formed the major component of the sediment, covering much of the bottom gravel. This layer was absent in Wilson Creek.

Before microscopic examination, this sediment layer was thought to be composed of organic matter from soil erosion and decomposing filamentous algae. However, these items made up only a small percentage of this sediment, diatoms forming the major component.

Like filamentous algae, diatoms also respond to increased nutrient levels through increased production (Hörnström, 1981; Rosen, 1981), this probably accounting for the extensive diatomaceous sedimentation in Cattle Creek.

Studies have suggested (Rosen, 1981; Patrick, 1975) that the number of centric to pinnate diatoms is higher in eutrophic waters. However, sediment analysis showed that the majority of diatoms in Cattle Creek were pinnate (acentric) forms.

One possible explanation is that while enrichment may be higher in Cattle than Wilson Creek, it may not represent truly eutrophic conditions. Generally, eutrophic refers to more extreme cases of enrichment, and nutrient levels may not have reached proportions high enough to cause a shift in Cattle Creek diatom composition.

In addition, Neill (personal communication) and Wetzel (1969) both suggest that such simple ratios of gross taxonomic groups are not reliable, as the variance involved is generally too high to provide a meaningful index.

Besides being an indicator of higher nutrient levels, this diatom layer greatly altered the physical conditions of the streambed, smothering much of the gravel and between gravel spaces. It may play an important role in altering faunal composition between the two streams. This effect will be discussed later.

Macrophyte production gave even further evidence supporting the hypothesized greater enrichment of Cattle Creek, relative to Wilson. Aquatic macrophytes were 2 to 4 times more abundant in Cattle than Wilson, covering much larger bottom areas. Low concentrations of nutrients can be sufficient to give algal growth, but not increased macrophyte growth. Macrophytes require relatively higher concentrations of nitrogen and phosphorous to give significant increases in biomass (Vollenweider, 1968). This suggests higher nutrient levels in Cattle Creek to account for the greater macrophyte production.

Potamogeton, the dominant aquatic plant in Cattle Creek, is also well known as an indicator of enriched, eutrophic conditions, preferring high levels of nitrogen and phosphorous, though not being restricted to such waters (Hynes, 1967, 1974). Its high densities on Cattle Creek relative to Wilson again suggest significantly higher nutrient levels in Cattle Creek.

The generally low density of other macrophytes in Cattle may be owing to a greater competitive ability of Potamogeton, or to selective grazing of certain species by cattle. On a number of occasions I watched cattle display such selectivity, showing a definite preference for Watercress.

Primary producers, particularly algae, diatoms and macrophytes, show major between stream differences in composition and quality, and may have significant influence on the bottom faunas of the two streams. These differences in primary productivity give strong biological evidence in support of the hypothesized higher levels of nutrients in Cattle Creek, relative to Wilson. However, this is indirect evidence, as actual measure ments of nutrients wer not taken to confirm this.

With nitrogen and phosphorous being the critical nutrients involved in plant growth, chemical sampling should turn up higher levels of both in Cattle Creek. However, the two are not of equal importance, phosphorous generally being the limiting resource for all aquatic primary production, nitrogen usually having a secondary influence (Vollenweider, 1968; Fuhs, 1971; Maloney et al., 1971; Powers et al., 1971). Phosphorous, then, should show between-stream concentration differences consistant with the different levels of primary production observed.

Effects of changes in primary productivity on the benthic fauna will be discussed later, as will factors influencing nitrogen and phosphorous entrance into the stream.

III. BENTHIC FAUNA

INTRODUCTION - Benthic Fauna

The health of the benthic community is critical to a stream and is one of the first areas to reflect important changes in stream quality (Hynes, 1960). Much useful work has been done to provide a relative guage of stream health based on the composition of this bottom fauna.

Of particular interest here is the use of stream invertebrates as biological indicators of water quality. As with algae, species composition and relative abundance of macroinvertebrates can act as indicators of enrichment levels or problems in a stream, (e.g. Parrish, 1975; Hawkes, 1977). Changes in relative abundance (i.e. density or biomass increases) usually occur in early stages of enrichment, with alteration of species composition occurring at higher nutrient levels (Hynes, 1974).

The purpose of this portion of my study was to determine the effect the different levels of grazing have had on the two streams and their respective bottom faunas.

While much work has been done on the general response of invertebrates to aquatic pollution, little work has been done specifically on the effects of grazing and agricultural enrichment on aquatic invertebrates. It appears to be an important, but neglected field.

As discussed earlier grazing appears to increase the nutrient levels in streams and increase the sediment load.

Enrichment can act on the benthic community in several ways:

1) Nutrient levels: Certain species may be reduced owing to low tolerances to nitrogen and phosporous - other species may be enhanced ((Hynes, 1974). Either way, this is difficult to demonstrate. Studies have shown that invertebrate diversity tends to increase with higher levels of enrichment, despite an increase in production (Wilhm and Doris, 1968).

2) Primary production: Primary production may be altered in abundance or composition as discussed earlier. This can alter the food type or supply to the next trophic level (i.e. macroinvertebrates) and can give a corresponding change in abundance or composition (Cummins, 1974). Large increases in primary production can also alter the physical environment, such as through the formation of organic sediments or detritus.

Increased sedimentaition through physical erosion can act directly:

1) By changing the physical characteristics of the stream (e.g. through smothering of gravel habitat (Chutter, 1968)).

or indirectly:

2) By aiding transport of nutrients and organic matter to the stream, particularly phosphorous (Burwell et al., 1976.)

Bottom faunal differences between the two streams should reflect higher levels of enrichment in Cattle Creek, relative to Wilson. In particular:

1) Cattle Creek should contain greater numbers of organisms

acknowledged in the literature as indicators of enrichment. Preliminary observations suggest higher densities of chironomids in Cattle Creek, which would be consistant with this prediction.

2) Diversity should be higher in Wilson than cattle Creek, owing to the hypothesized lower levels of enrichment and the smaller amounts of organic sediment in Wilson.

3) Major faunal differences should be observed between both streams, owing to the layer of organic sediment covering much of the gravel in Cattle Creek. Preliminary observations suggest a major shift in the dominat organisms between the two streams, from mayflies, in Wilson, to chironomids in Cattle.

4) Biomass should be greater in Cattle Creek, reflecting the higher nutrient levels and associated increases in primary and secondary productivity.

My observations suggest that the direct effects of inorganic sedimentation will be rather unimportant, with no major accumulations present in either stream. I do not feel it will play an important role in altering physical habitat or benthic invertebrate populations. Indirect effects (i.e. nutrient transport to the stream) were not specifically measured.

METHODS - Benthic Fauna

Study areas on both streams were selected to be as similar to each other in physical characteristics as possible (See Table I).

TABLE I. The physical similarities of the study areas of both streams.

	Depth (cm)	Velocity (m/sec)	Flow (m^3/sec)	Width (m)
Cattle Creek	13	.40	.10	7-8
Wilson Creek	14	.39	.11	6-7

Gravel size was similar in both study sections. A layer of brown organic sediment covered variable areas of gravel in the Cattle Creek section, while the Wilson Creek gravel was very clean in composition. Plant growth was heavier in the Cattle Creek section, with Potamogeton covering three or four times more bottom area in Cattle than Wilson, as noted earlier in the RESULTS section for primary producers.

A number of parameters were examined to try and determine the between stream differences attributeable to the different degrees of grazing. Using benthic samples, macroinvertebrate composition, density and biomass was determined and compared between stream.

One transect was established across each 60 foot study area. Transect placement was random, co-ordinates being generated using a random number button on a calculator.

All bentic samples were collected systematically, four samples being spaced evenly along each transect. I moved each successive series of samples upstream .3 m to avoid sampling previously disturbed areas.

All samples were taken with a Surber sampler. I chose this over other substrate samplers for a number of reasons. It is better adapted to sampling gravel bottoms than most portable samplers, and this was an important practical consideration, as study sights were reached by 10-speed, and on foot. Also, it was the easiest and fastest sampler to use (compared to a Hess sampler), and was not tedious or difficult to work with, which after many hours can affect the accuracy and thoroughness of sampling.

Mesh size was 20 meshes/cm and sampling area was one square foot ($.093m^2$). Mesh fold-out siding prevented lateral loss of insects, especially in shallow waters. The top of the sampler was well above water level for all samples, preventing loss this way also.

Stirring of the substrate was thorough and consistant between samples. All rocks large enough to harbour attached insects were scrubbed quickly in the net mouth. Silt was rinsed out of the sample by moving the mesh bag back and forth in the current. A number of test rinses were run in 5 gallon, white buckets to determine if there was an appreciable loss of insects through the mesh during washing or sampling, but no significant losses occurred.

Preliminary samples were taken starting June 10th, and actual sampling started June 23rd. Following samples were taken every 3 to 4 weeks until August 25th, giving a total of three sets of samples for each stream. Eight samples were taken per stream in the first sampling period, and four per stream in each following period. Oversampling was intentional to insure against loss or breakage of samples, and because it was uncertain how many samples could be processed in the given time. Samples were discarded randomly, and the number of samples processed was the maximun possible in the given time. (July Wilson Creek samples were not sorted, owing to time constraints. They were examined briefly for major changes in faunal composition).

All samples were preserved in either pint or quart canning jars, using 10% formaldehyde solution to preserve and fix colour.

I sorted all samples by hand, some in the field and some in the lab. A 2.5 x magnifying lamp and a white enamel sorting pan were used. All samples were rinsed for 5 minutes in mosquito mesh screen to remove formaldehyde and the remaining silt and sand particles. I checked all rinse water carefully for specimens that washed through the meshing.

After separation from the sample, I sorted the insects into categories of order, family or genus, and then counted the number in each category. All sorted insects were stored in 6 dram vials containing 10% formaldehyde.

Biomass measurements were taken using preserved dry weight. The degree of leaching of organic oils by the formaldehyde was checked by running series of single species of both Ephemeroptera nymphs and Chironomid larvae through a four day, stepwise, progression of solutions of increasing percentages of glycerol (10% to 90%). This was designed to replace body oils lost to the formaldehyde solution, to see if this loss