DOWNSTREAM DRIFT OF INVERTEBRATES IN NARO MORU RIVER, A TROPICAL RIVER IN CENTRAL KENYA

BY

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DECLARATION

I, Jude Mutuku Mathooko, hereby declare that this thesis is my own original work and has not been presented for a degree in any other University.

Date: 22/8/88.............. Signed: ....
Jude M. Mathooko

This thesis has been submitted for examination for the degree of Master of Science of the University of Nairobi with my approval as the University Supervisor.

Date: 22/8/1988 Signed: ....
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DEDICATION

To my sons

Muthiani, Mathooko

and

Ndundu

ACKNOWLEDGEMENTS

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ABSTRACT

Downstream drift of invertebrates was investigated in Naro Moru River, a tropical river in central Kenya, from November 1986 to October 1987 to establish the composition and structure of the drift fauna and benthos, the factors that affect drift, diel and seasonal fluctuations of the drift fauna in relation to the dry and wet seasons and, drift fauna as potential food for fish. Prior to embarking on the drift studies, a pilot survey was conducted on seven stations along the river to establish the expected composition of the benthos and to locate a suitable site for the study from among the seven stations. Two 24h. drift samples were collected from the study site every month for one year using six drift nets of 105 μm. mesh size.

The major components of the drift fauna were Ephemeroptera, Diptera, Hemiptera, Hymenoptera, Arachnida and Coleoptera. *Baetis* spp. (Ephemeroptera) comprised the highest proportion (50.91%) of the total drift. There was a clear bigeminus diel periodicity in the total drift. Mean river discharge ranged from 0.235 ± 0.001 to 3.873 ± 0.003 $m^3.sec.^{-1}$ Drift rate increased with increasing river discharge. However, the drift density did not increase with increasing river discharge. Dissolved oxygen concentration was in all cases high ($8.32 \pm 0.43 - 8.97 \pm 0.31$ $mg.\ell^{-1}$) and did not seem to play an important role in drift rate. The roles played by pH and conductivity were difficult to envisage.

Colonization experiments showed that maximum colonization of the embedded artificial substrate baskets took place after ten days of exposure. The numbers obtained were used to relate benthos with drift fauna. There was a positive correlation ($r_s = 0.76$, $P < 0.01$). Diptera (64.56%) and Ephemeroptera (24.37%) were found to be the predominant benthic organisms.

More animals drifted on the dark nights than on moonlit nights. However, moonlight did not have a depressant effect. There were seasonal fluctuations in the drift fauna and drift rates. Peak drift rates were observed in the wet seasons.

The composition of the diet of the resident rainbow trout, *Salmo gairdneri* Richardson was similar to that of the drift and benthos. The fish was feeding throughout the year and there was no evident seasonality in its feeding. It showed some selectivity in its feeding. There was lack of correlation between trout diet and drift ($r_s = 0.18$, $P > 0.05$).

CHAPTER I

GENERAL INTRODUCTION, AIMS AND OBJECTIVES, STUDY SITE AND LITERATURE REVIEW

1.1 General introduction

The origin of African limnology is probably to be found in the study of rivers because of their association with early civilizations. In practice the term "river" is applied to natural watercourses over five metres wide and anything below that width is a "stream" (Clegg 1974). Despite their importance, rivers have been largely ignored by limnologists over the past twenty years and as a consequence, the understanding of African rivers lags far behind that of natural and man-made lakes which are becoming increasingly frequent along the river courses (Breen *et al* 1981).

Unlike a lake, a river is not a single definable ecosystem. It comprises a series of not always well-defined regions which may differ greatly from each other according to the rate of flow, the nature of the substratum, the extent of the macrophytes through which it may flow and composition of the waters coming from the surrounding land (Beadle 1981). The chemical and biological features of each region are influenced by those of the one above it. Most of the river conditions on the African continent fluctuate very much with seasonal and long-term changes in rainfall in the catchment. Many rivers in semi-arid regions of Africa are periodically reduced to isolated pools or even dry up (Beadle 1981). The rainfall regime has got profound effect on the river fauna and flora.

Limnological studies of rivers and streams in Kenya are fewer than those dealing with standing water. Drift, the downstream displacement of invertebrates in river water currents, is a widespread and naturally occurring process in streams and rivers throughout the world (Hildebrand 1974). This is one of the phenomena which has been neglected in limnology and more so in Africa. There is paucity of information on the drift phenomenon in Kenya. It is a phenomenon of great importance in stream biology particularly because of its bearing on secondary production.

It has been firmly established that drift is affected by several factors such as sunlight, moonlight, current velocity, discharge, turbidity, oxygen, water temperature, conductivity, pH and benthic abundance. However, the effect of these factors on drift have not been studied in Kenya and no information is available on these factors although Van Someren(1952) only mentioned spate as a factor increasing the drift of Simuliidae and Baetidae in Sagana River in Kenya. There is a real need to establish which of the factor(s) is/are responsible for the drift of invertebrates in Naro Moru River.
Diel periodicity in stream invertebrates is well established in the temperate and arctic latitudes

but its existence in Kenya is yet to be established.

The exploitation of Africa's inland water fisheries has stimulated considerable research on fish geography, biology and ecology and yet there is paucity of information on fish in riverine situation and virtually no information is available on drift fauna as potential food for fish. Studies on the general biology of African riverine fishes, particularly non-cichlids, are rather few (Payne 1975). The feeding and energetics of fish in rivers has received scant attention. There is lack of pertinent literature on East Africa river systems as concerns drift phenomenon, the factors affecting the drift phenomenon, diel and seasonal fluctuations of the drift fauna and, drift fauna as potential natural food for fish. It is the lack of such vital information that provided a challenge for the present study.

1.2 Aims and Objectives

The objectives of the present study were to study the downstream drift of invertebrates to establish:

a) composition and structure of the drift fauna and benthos

b) the factors affecting the drift

e.g. i) water current velocity
ii) river discharge
iii) light-sunlight and moonlight
iv) water temperature
v) turbidity
vi) benthic fauna abundance
vii) dissolved oxygen concentration, conductivity and pH.

c) diel (24h. duration) and seasonal fluctuations of the drift fauna especially in relation to the dry and wet seasons and,

d) drift fauna as potential food for fish.

The main aim of this study was to gather the much needed information on high altitude river drift aspects such as drift composition and structure and its potentiality as natural food for fish. The information will be of great assistance to the fisheries managers, river surveillance officers and other ecologists. The results of the present study will provide a data base for future research on environmental perturbation in the area, population dynamics of the riverine fauna and the trophic ecology of the resident fish. The study will also provide baseline data for the possibility of future use of biological methods in assessing the water quality of Naro Moru River. In addition, the study will also form a basis for future comparative studies of tropical Africa rivers with those in the arctic and temperate regions where the drift phenomenon has been sufficiently studied.

1.3 Naro Moru River and study site

1.3.1 General characteristics of Naro Moru River

The main catchment areas and drainage channels of the African continent have existed for an immense length of time. East and Central Africa has been disrupted by dramatic earth movements, mainly since the Miocene, which have had profound hydrological, biological and human consequences (Beadle 1974).

Naro Moru River (Fig.1) is a fast flowing river formed when the North and South Naro Moru Rivers (Fig.2A) meet at 2180 metres above sea level. It flows on the western side of Mount Kenya in Nyeri District, Central Province, Kenya. It rises at an altitude of about 4587 metres above sea level and flows westwards for about 50km, up to its confluence with the Ewaso Ngiro River. It has a catchment area of about $83km^2$ (Fig.2B). The Ewaso Ngiro River discharges its water into the Lorian Swamp(Fig. 1).

Naro Moru River is fed by streams from Teleki Tarn, Lewis Glacier, Tyndall Tarn, Hut Tarn and Darwin Glacier, all on Mt. Kenya.

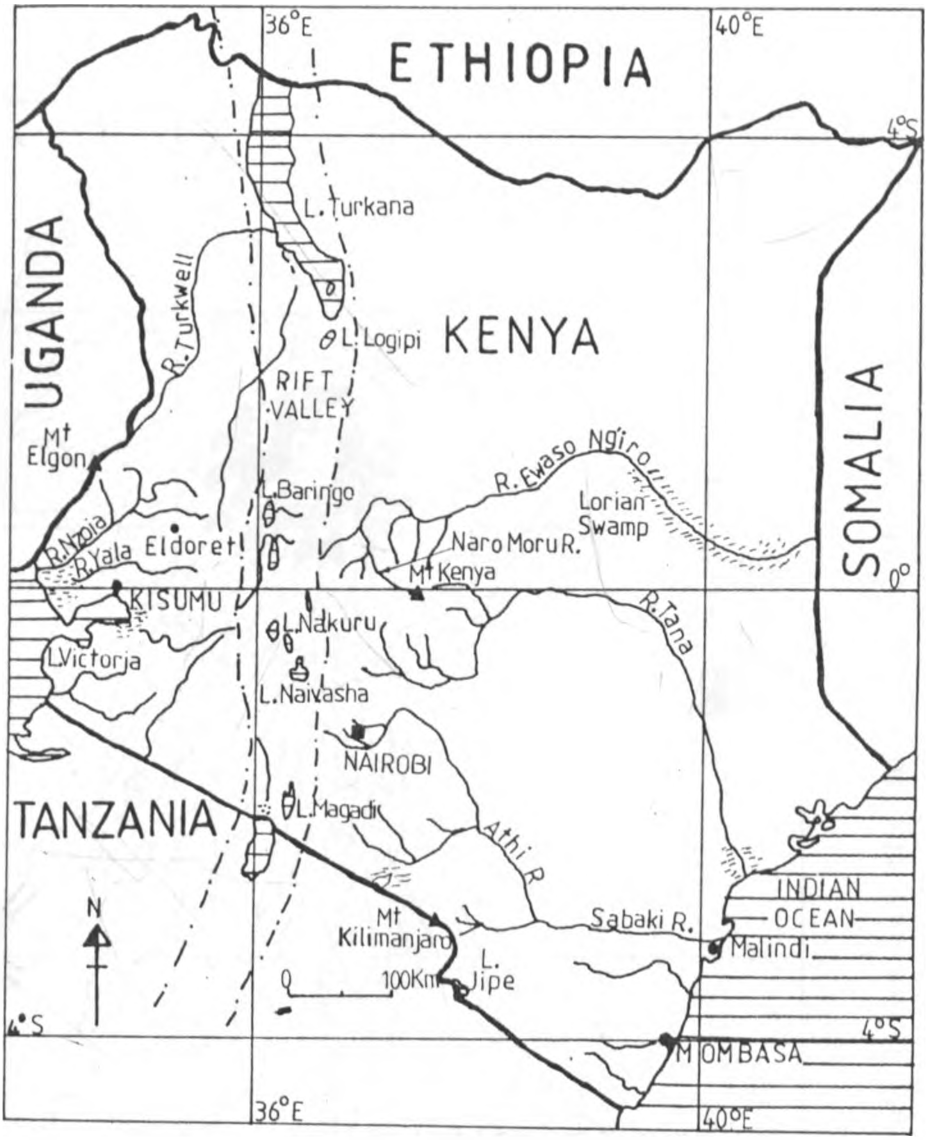


FIGURE I. Map of Kenya showing the location of Naro Moru River (Re-drawn from Survey of Kenya Map SK 72/1978)

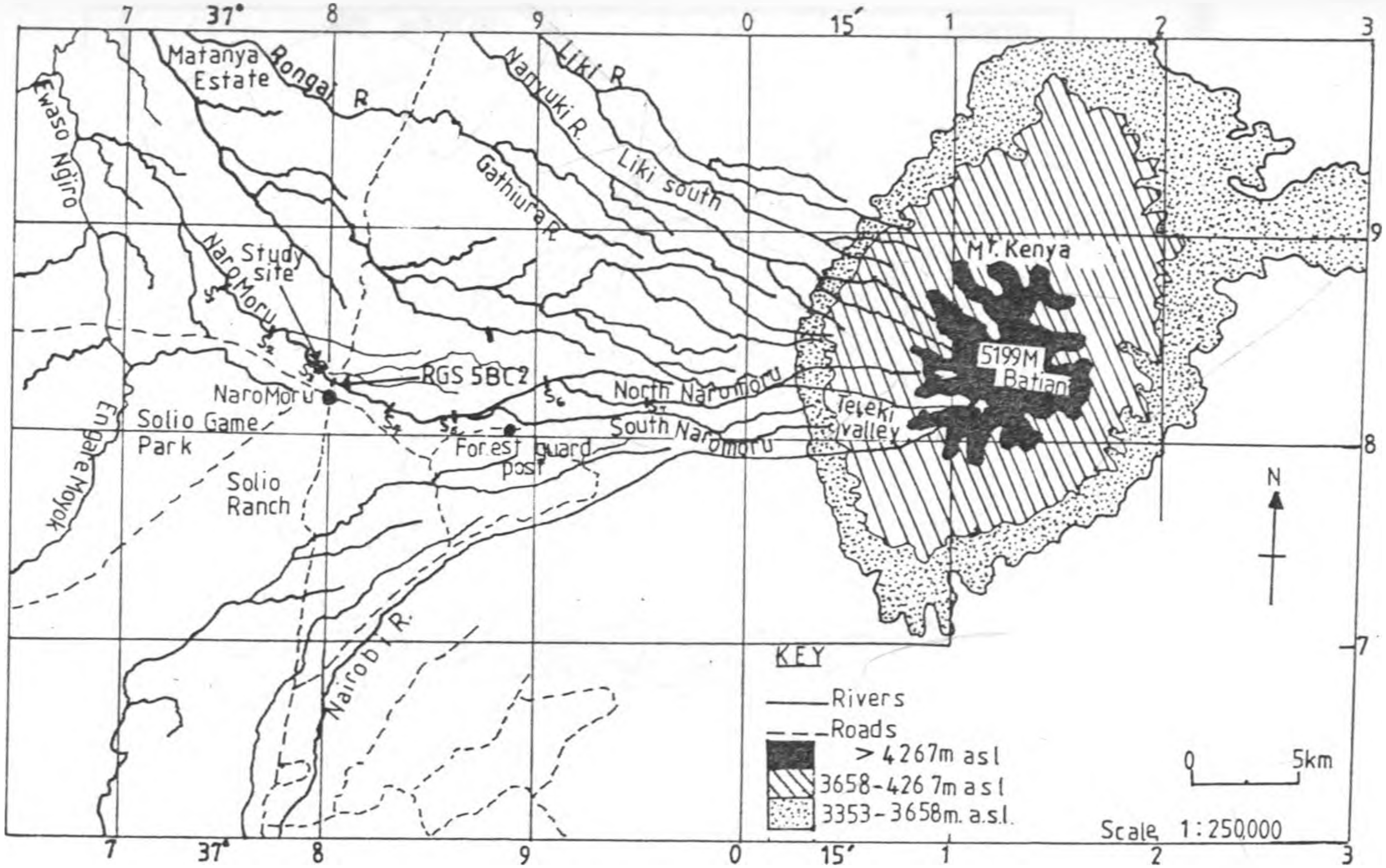


FIGURE 2A. Naro Moru River and the location of the study site, river gauging station 5BC2, the Forest Guard Post and the seven pilot survey stations (S_1-S_7). (Extract from: NYERI-Series Y503 Sheet SA-37-1 Edition 3-SK)

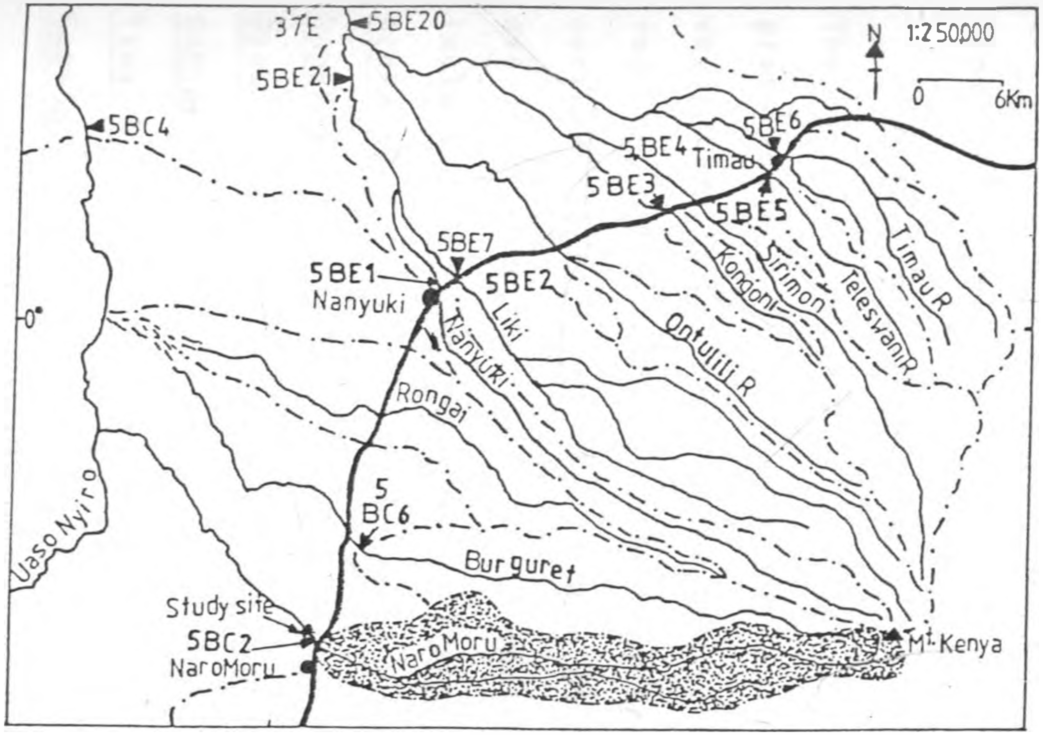


FIGURE 2B. Naro Moru River drainage area (hatched) and the associated drainage areas.
5BE7, 5BC6, etc. are river gauging stations
-·-·-·-·- drainage areas boundaries,
rivers, road

(Source: Leibundgut 1983)

Mt. Kenya is of volcanic origin and it consists of a plug of nepheline-syenite and kenyte left by the wearing down of the higher parts of the original mountain. The geology of the area over which the river flows consists of basalts, porphyritic and dense phonolites, kenyte lava, agglomerate and tuff. The soil is dark-grey to reddish-brown derived from schistose rock.

Phanerogamic water vegetation in the river is scarce. The banks are forested and sometimes covered by short grass and fringing reeds in the lower reaches. Overhanging vegetation is cut back in the public fishing reaches, but in closed reaches may form quite a dense overhang, forming canopies. Some of the riparian trees are exotic but the majority are indigenous. These include Podocarpus gracilior, Trichocladus ellipticus, Acokanthera longiflora, Albizia gummifera, Syzyium guineense, Rapanea rhododendrum, Cassia didymobotrya, Apodytes dimidiata, Olea africana, Vangueria linearisepala, Canthium rubrocostatum, Sapium ellipticum, Maesa lanceolata, Dovyalis abyssinica, Timeria tropica, Calodendrum capense, Nuxia conjesta and Cussonia spicata to mention but a few.

The general river system flows through heath and moorland, the bamboo forest and through the tropical rainforest before it enters the savanna zone.

Mean monthly rainfall amounts monitored at Naro Moru Forest Guard Post Station Number 9037064 ($0^{o}11'$S $37^{o}07'$E-River Discharge Area (RDA)-4A) indicate that the highest rainfall in the region where the river is located is recorded in the months of April-June and October-December. This corresponds with the highest water discharge amounts of Naro Moru River recorded at River Gauging Station (RGS) 5BC2. This means that floods occur in the long-rain season from April to June, and again in the short-rain season from October to December. After a prolonged period of heavy rainfall on the upper reaches, such floods become so torrential that they reach their maximum height in a matter of minutes laden with silt, logs and other forest debris. Subsidence is much slower and the river takes two to three days to fall to normal height. Physiographically, the river is composed of alternating pools and short gentle riffles (Van Someren 1952).

Many of the Aberdare and Mt. Kenya rivers are geologically of very recent formation, and have possibly been colonized by aquatic fauna dispersed upwards from South Africa, with little morphological change, and by those of the greatest dispersal powers and adaptability (Van Someren 1952). The river bed communities of Naro Moru River are completely dominated by the blackfly larva, *Simulium* sp. and the mayfly nymphs, *Baetis* spp; all other species occur in much less quantities.

1.3.2 The study site

The study site was on the Naro Moru River within the Naro Moru River Lodge's section, altitude 2035 metres above sea level ($0^{o}10'S$ $37^{o}01'E$). From the source up to the study site, the altitude drops by 2552 metres. Figure 2A shows the study site, the Naro Moru Forest Guard Post, the River Gauging Station 5BC2 and the pilot survey stations (S_1-S_7).

The riffle on which the major study work was carried out was 75 metres long and bordered by pools on the upper and lower ends which were about $8.03m^2$ and $4.17m^2$ in area and an average depth of 1.9m. and 1.3m. respectively during the rain seasons. The northeastern bank of the river was steeper than the southwestern bank (Fig.3). The average heights of the banks were 0.96m. and 0.48m. respectively. The river was about 8.0m. in width at the study site.

The substratum of the riffle was composed of gravel and pebbles and interspersed occasionally with larger rock outcrops. The forest on the southwestern bank was cleared and spotted with indigenous and exotic riparian trees whilst the northeastern bank had a thick riparian vegetation.

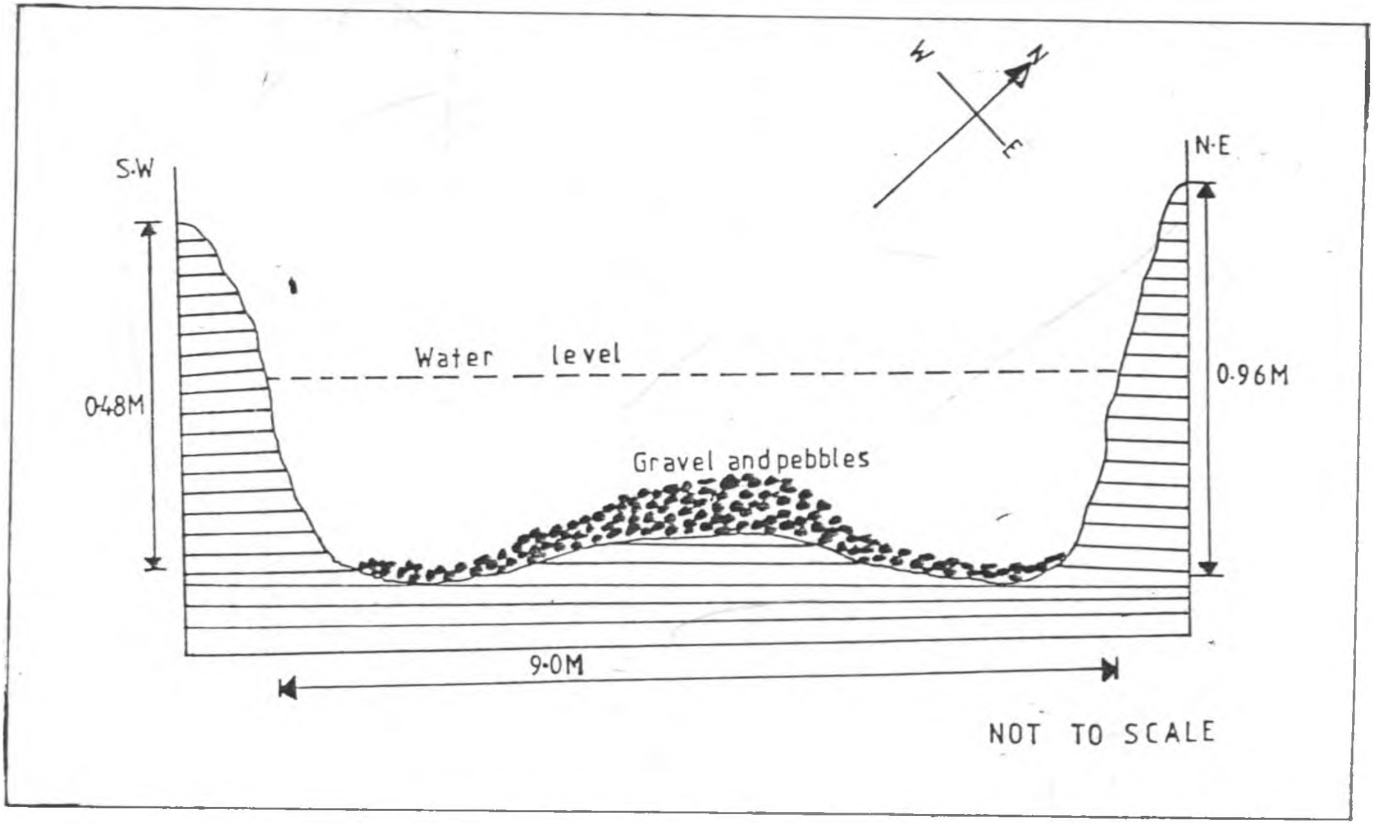


FIGURE 3. Cross-sectional profile of Naro Moru River at the study site

1.4 Literature review

The early work on African freshwater invertebrates was largely descriptive, with the development of an enormous and diverse literature over the past 90 years (Davies et al. 1980). Although an extensive literature has been accumulated on downstream drift of invertebrates in running water habitat, the bulk of it is from arctic and temperate latitudes. Tropical streams and rivers are still poorly known, taxonomically and ecologically.

Drift of invertebrates is a normal constant feature of lotic systems and is a widespread and naturally occurring process in streams and rivers throughout the world. Since 1920's it has been known that benthic organisms are transported downstream in the drift (McAtee 1925). While stream invertebrates are adapted by various means for maintaining their position in running waters, it is expected that the occasional individual will lose its attachment or orientation to its substrate and drift downstream. Waters (1965) subdivided the overall phenomenon of downstream drift of invertebrates into three components:

a) behavioural drift, a result of some behavioural characteristic of the animal, such as a response to changes in light intensity, which causes the diel periodicity in drift,

b) catastrophic drift, that which occurs as a result of floods or other physical disturbance, and

c) constant drift, composed of occasional individuals of all species that for various reasons lose their hold on the bottom and drift in low numbers without any regard to diurnal periodicity.

Research on the ecology of the drift phenomenon in all its form is too new to draw firm conclusions as to its full significance. However, Elliott (1965) stated that it has important implications in studies of behaviour and ecology of aquatic invertebrates.

Several intriguing patterns of drift behaviour are at present difficult to explain. While most taxa are night active, some are active by day and others are largely aperiodic. Anderson and Lehmkuhl (1968) found that larger specimens were abundant in the drift at night than during the day. Another source of complications is that the drift movements of a group of organisms are related to their entrance rate into the drift, the distances travelled therein, and their mode of resettlement on the stream bottom (Pegel 1980 cit. in Statzner et al. 1984). Müller (1963) stated "that the drift of organisms in a flowing body of water is not the result of their being passively carried along but rather constitutes a periodic behaviour pattern (change in activity) on the part of the animals". While food gathering may be the principal activity resulting in drift, other behaviour may effect a similar result. Crowding and subsequent loss of substrate as growth occurs may result in increased activity, dislodgement, and difficulty of reattachment. The suggestion that behavioural responses largely determine the magnitude and composition of the drift receives some support from observations in temperate rivers that mature specimens are more abundant in the drift than the larvae as reported by Ulfstrand (1968).

Nearly all detailed studies on tropical running waters were conducted on low latitude streams such as that reported by Stout and Vandermeer (1975) or the lower reaches of mountain systems as reported by Patrick (1966). Hynes (1975) argued that true drift should be less important in the tropics where single-species populations are never large due to the high diversity of stream communities. The phenomenon of drift is one which lends itself to experimentation in the field. But the statement of Townsend and Hildrew (1975) that so little has been made of this opportunity is still valid. However, studies involving field experiments have been carried out as relates the distance of drift (Elliott 1971), the relationship between drift and density of the benthos (Statzner & Mogel 1984), the influence of light on drift rates (Holt & Waters 1967), and the influence of temperature on drift rates (Wojtalik & Waters 1970).

Drift of benthic stream invertebrates is governed by a large number of factors with different intensities that is, some factors are potentially more important than others. Sunlight, moonlight, current velocity, discharge, turbidity, oxygen, water temperature, conductivity and benthic abundance govern natural drift in very diverse ways.

Bishop (1969) found that light intensity was the most critical factor responsible for the diel activity patterns of aquatic invertebrates. Various aspects of insect behaviour controlled by light factors have been extensively studied. These include diurnal periodicity of light summarized by Lewis and Taylor (1964) and emergence time of aquatic forms (Morgan & Waddell 1961). However, Harker (1953) and Müller (1965a) showed endogenous activity rhythms of Baetis, Hartland-Rowe (1955) for Povilla, Chaston (1968) for Ephemerella, Simulium and Isoperla and Elliott (1968) for five mayfly species that are light independent with natural activity cyles continuing in extended light or dark periods. It seems likely that endogenous locomotory rhythms are present to some degree and that these are synchronized, or entrained, by environmental phase-setting agents. The phase-setter most usually involved is light intensity. It apparently acts in an "on-off" fashion, triggering the invertebrates increased activity as it falls to some threshold level of intensity. Negative phototaxis, as observed in Ephemeroptera by Elliott (1967a), serves to maintain many invertebrates in areas of low light intensity. Linked to this are the strong positive thigmotaxis observed in many benthic forms, the definite orthokinesis during periods of illumination and the possible skototaxis (directional response to areas of low light intensity) observed by Hughes (1966). These mechanisms result in the firm attachment of most of the fauna to the undersides of stones during daytime. Experiments imposing artificial light patterns on insect populations in the field by Holt and Waters (1967) showed significant responses in drift that agreed in most part with the negative phototactic suppression of activity.

Moonlight has been shown to have a depressant effect on drift in some rivers while not in others. However, in a study carried out by Elliott et al. (1968) secondary peaks were observed in drift rate and Waters (1962) suggested that those secondary peaks could be due to the occlusion of moonlight on those nights when the moon had been occluded by clouds. Statzner et al. (1985) found lack of a depressant effect of moonlight on the drift of Cheumatopsyche falcifera Ulmer. This was not a surprise since literature reports are very diverse on the effect of moonlight. All in all, moonlight sometimes, but not always, depresses nocturnal drift.

Water velocities throughout a river channel are not uniform, but rather a decrease in current occurs wherever there is friction between water column and bank; this results in a layer, contiguous to the substrate, that is characterised by progressive reduction of flow as the distance to the solid phase is decreased. In a lotic habitat the current velocity is the dominant physical force controlling the maintenance of an organism in its niche. Elliott (1967a) hypothesized that current velocity contributes to the magnitude of the drift of a population by dislodging a certain number of individuals. Under conditions of high current velocity, the probability of dislodgement is increased and proportionately more individuals enter the water column. Ciborowski et al. (1977) conducted experiments in an artificial stream bed and found that significantly more nymphs drifted from an organic substrate at a mean current velocity of 28.5 $cm.sec^{-1}$ than at 18.5 $cm.sec^{-1}$. The positive relationship between drift and velocity could be the result of an increase in erodibility of larvae at higher velocities (Kovalak 1979) and an increase in the drift distances travelled (Elliott 1971a).

Discharge plays a major role in the magnitude of invertebrate drift rate and drift density. Mackay and Kalff (1973) found that the increases in discharge associated with flooding often disturb the stream bed and result in the displacement of benthic populations. The increase in discharge has a corresponding increase in the volume sampled by the sampler. Anderson and Lehmkuhl (1968) found that if the volume of water flowing through the sampler increased, the size of catch increased.

Floods and other physical disturbances can effectively reduce the abundance of organisms in the benthos and bring about an increase in their numbers in the drift. During peak discharge periods, many of the larger invertebrates and some of the smaller larvae are lost into the drift, as surface crevices and leaf and twig habitats are scoured and stones crushed and rolled. However, Buscemi (1966) found that a number of the fauna was capable of moving down into the vacant interstitial areas created by the removal of silt and detritus.

Several studies have shown that high water results in high numbers in the drift and that at low rates the numbers decrease. Large numbers of Simulium and Baetidae carried by spate were reported on Mount Kenya by Van Someren (1952). However, severe fluctuations in flow can have adverse effects on the biota of normally permanently flowing streams.

Reduced discharge has been shown to affect macro-invertebrates through loss of riffle habitat, reduced periphytic food and desiccation (Ladle & Bass 1981).

Water temperature has long been recognised as an important influence in stream ecology. The processes influencing temperature in small streams are many and varied. Pearson and Franklin (1968) found that there was an increase in drift with increase in temperature and this would be expected especially when the temperature increase was coupled with increased invertebrate activity. Water temperature was found to be the phase-setting mechanism for the day active drift pattern of a caddisfly, Oligophlebodes sigma (Waters 1968).

The drift response to sediment under typical field conditions would depend largely on the type of stream under study. The effect would be more pronounced in a stream with little autochthonous plant material and less important in those with abundant growths of mosses, algae or macrophytes which would provide alternate holdfasts for silt-inundated individuals. Nuttall(1972) stated that sediment input may drastically increase during spates and have adverse effects on benthic communities. Quantities of drifting debris such as fallen sticks and fallen leaves affect some of the groups drifting. The suspended non-faunal materials contribute to the drift and may carry invertebrates long distances downstream. Gammon (1970) found that drift levels of macroinvertebrates increased in proportion to the limestone solids added to a stream and suggested that the observed drift was a response to light extinction. Similarly, Pearson and Franklin (1968) ascribed high drift levels of *Baetis* to light extinction as a result of turbidity levels. Ciborowski *et al.*(1977) found that both drift numbers and drift density were greater in turbid water after the addition of large amounts of inorganic sediment. Rosenberg and Snow (1975) attributed high drift levels in a subarctic river to the settling of experimentally added silt.

Dissolved oxygen concentration, conductivity and pH are important parameters in river ecology studies. Dissolved oxygen concentration in water determines what fauna and flora will inhabit a given part of a stream. Statzner *et al*. (1984) tabulated data from other authors for the relationship between the drift of benthic macroinvertebrates and abiotic as well as biotic factors and indicated that there was a general trend of no relationship between the drift and an increase in oxygen concentration.

Riverine benthos is distributed along longitudinal abiotic gradients (Schaeffer *et al*. 1986). Numerous studies have attempted to document the existence and strength of such gradients (Cushing et al. 1983) and several basic tenets of stream ecosystem theory such as River Continuum Concept (Vannote et al.1980) rely on the existence of such abiotic gradients and their biotic counterparts. The main biotic factor thought to influence drift is the benthos density itself (Statzner et al. 1984). The distribution of benthic invertebrates varies considerably within a small section of stream. It can also vary around a single rock (Williams 1981). This microdistribution is the result of many factors, for example substrate type, food quality and abundance, light, temperature, water movements and chemistry, oviposition habits and predation, acting perhaps singly or, more likely, in combination (Minshall & Minshall 1978). Microdistribution and drift rate are interrelated; drift partially determines the pattern of micro-distribution and, conversely, the microdistribution at a particular time will affect the drift rate of a species (Lehmkuhl & Anderson 1972). In proposing his "recolonization cycle", Müller (1954) suggested that drift acted as a means of keeping population densities down to the carrying capacity of the stream bed, through competitive interactions for food or space. If this were the case, drift rates would be related in a density dependent way to benthic density. But some studies suggest that this is not the case for the benthos as a whole (Waters 1972). Waters (Op. cit.) stated that there does not exist a particular "drift fauna" as distinct from bottom fauna since most benthic organisms will at one time or another be picked up in the drift.

The continuous loss of animals into the water column reduces benthic density and since some species and size classes are more prone to drift than others, the composition of the local community is affected. The mode of resettling is one of the variable processes which is mainly influenced by the morphology and the behaviour of an organism in relationship to the physical environment (Ciborowski & Corkum 1980). The continuous settling out of animals from the drift plays an important colonizing role. Peckarsky (1983) supposed that the relative roles of biological interactions and physical-chemical factors in structuring stream communities depend on the physical harshness of a running water. However, Statzner et al. (1984) suggested that the only way to specifically explain the drift of benthic organisms is to arrange the governing factors into a hierarchical system.

Drifting of invertebrates in streams is a constant phenomenon occurring at all hours of the day and night. Virtually all insects respond in some way to temporal periodicity in their environment. Diel periodicity, hereinafter referred to as "a recurrent temporal pattern with a period of 24 hours" as well as annual periodicity in natural drift was confirmed by Adamus and Gaufin (1976) and is now accepted to be a general pattern. Among aquatic insects, diel activity phenomena have been investigated in relation to drift.

Drift periodicities commonly involve two peaks during the 24hr. period. In most cases, these include a major peak occurring early in the night, a somewhat exponential decrease through the middle of the night, and a minor peak just before dawn; this is termed a "bigeminus" pattern and the converse of this is the "alternans" pattern, wherein a minor peak occurs at first dark and then the drift builds up to a major peak prior to dawn. Many species simply show an increase at night without a well-defined pattern.

Earliest reported periodicities in drift took the form of low drift during daylight, high nocturnal drift, often including an explosive increase at about full darkness in the evening, and a sharp drop to daytime low levels at dawn (Waters 1972). Changes in drift rate are related to times of sunset and sunrise, although a lag of time appears between sunset and the onset of the principal increase in drift rate. The decrease occurring just before sunrise is a sharp drop, indicating that the organisms reattachment to the substrate is an active response to conditions of changing light. For those species that exhibit a high rate of daily drift, there is often a marked diurnal periodicity with highest drift rates occurring during hours of darkness. The mayfly genus Baetis was represented in diel drift periodicities reported from such widely separated areas as Japan (Tanaka 1960), Minnesota (Waters 1962), and Germany (Müller 1963). Statzner et al. (1985) found a nocturnal drift peak of Cheumatopsyche falcifera Ulmer larvae in Ivory Coast (Côte d' Ivoire).

High drift rates at night are probably due to greater activity of invertebrates. The animals leave their places of protection and concealment and swim freely and are swept downstream by the current. A low level of passive drift as a result of mechanical erosion of the stream bed is expected but the nocturnal peak observed in drift is generally the result of a behavioural change in the activity of the benthos, which increases the propensity for detachment and transport by the current. Hughes (1966) found under laboratory conditions that disorientation was caused by absence of an overhead light source and suggested that disorientation at night may be a contributing mechanism to the night peak in drift.

Seasonal variations in the drift are determined by a complex of factors such as the changes in age and density of the benthos and the physical parameters of the river. Elliott et al. (1977) found that seasonal peaks in the density of larvae in the drift frequently occurred in months when adults and especially pupae were present and the monthly fluctuations in numbers were partly due to variations in stream discharge. Since drift rate is, amongst other factors, a function of production rate (Waters 1961), the seasonal difference in drift rate may correspond to a similar seasonal difference in production rate.

The relationship between invertebrate drift and fish feeding has been of considerable interest to fisheries managers as well as to other stream ecologists. Utilization of "drift" foods by fish has been extensively studied. Fish constitute a sort of "drift sampler", (McLay 1970) utilizing drifting invertebrates because they are moving and therefore more accessible as prey. Availability dictates the proportion of the drift fauna lost to fish predation. Waters (1972) stated that the significance of this feeding on drift may be a greater efficiency in food transfer from the invertebrate to the carnivorous fish level, and thus higher fish production, than with bottom foraging alone.

A relationship between fish feeding and drift, in addition to the increased accessibility of the prey, is that drift may function to transport invertebrate foods. Such transport may occur from an area of the stream in which invertebrate production is high, such as a shallow riffle, to an area of high fish density, such as a pool. On the riffles fish are scarce since there is little cover but they tend to occupy a suitable pool below the riffle where they utilize incoming drift foods.

Many investigators have compared fish stomach contents with the composition of drift and benthos and found selective feeding on drift. Johnson and Johnson (1982) found fish to exhibit selectivity in the utilization of drift. Elliott (1970) found that young salmonid fry appeared to depend most heavily on drift and as the fish grew larger there was a greater dependence on bottom foraging. The catholic diet of trout is well known, and the larger fish probably take any readily available food in their immediate vicinity including invertebrate drift. Although drift food is probably of less importance in older trout, the habit of drift feeding persists throughout the life of trout.

Apart from the benthic and drift food sources fish also acquire additional food from the riparian vegetation. The chief source of energy to most stream communities is in the form of allochthonous organic matter (Cummins 1979). Tree canopies also form a source of terrestrial invertebrates falling into streams and it is known that invertebrates of terrestrial origin form a substantial part, at least seasonally, of the diet of salmonid fish (Hunt 1975). The trout consumes a wide variety of foods but relies largely on insects and higher plant fragments. Debris from the forest canopy is an important source of nutriment. The input of terrestrial origin may be equivalent to, or possibly greater than, the within-stream production of benthic invertebrates (Mason & Macdonald 1982). Furthermore, heavy rainfall washes considerable quantities of soil invertebrates, such as earthworms, into streams, at which time they form a substantial component of the diet of fishes (Hunt 1975). Hynes (1975), in an African stream,observed a terrestrial drift component of less than 1%, most of it made up of ants. Bishop (1973), on the other hand, collected large numbers of terrestrial invertebrates drifting in a Malayan river.

As well as providing food to the fish in the form of terrestrial invertebrates (which they take subaqueously or on the surface) and litter, riparian trees provide cover, stabilize flows and prevent excessive water temperatures (Mason &

Macdonald 1982). They also reduce macrophyte growth in rivers through shading (Dawson 1978) and form essential habitat for riverine animals.

CHAPTER 2

MATERIALS AND METHODS

2.1 Pilot survey

Prior to carrying out the actual drift studies, a pilot survey was carried out in seven stations (S_1-S_7) along the Naro Moru River to:

a) establish the nature and composition of the benthic fauna and,

b) locate a suitable site for the study from among the seven stations.

Three samples of the benthos were collected from each station between 5th November and 13th November 1986 using the kicking method (Armitage et al. 1974). The benthos was sampled from a 1 m^2 section of the river bed infront of a 105μm mesh net which had a mouth area of 1 m^2 for 60 seconds. Samples were put in polythene bags with 4% formaldehyde solution and then sorted in the field laboratory. Organisms were identified to the lowest taxon possible and enumerated under a dissecting microscope.

2.2 Routine collection of drift samples

Drift samples were taken from Naro Moru River using six nylon nets (without flowmeters) of mesh size of 105 μm. The nets were 16.0 cm. wide and 105.0 cm. long. The mouth opening of the nets was circular with a diameter of 6.7 cm.

and a mouth opening area of 0.35 m^2. Each net was fixed round the wide end of a conical plastic funnel with a plastic tape and closed with a manilla string at the far end during the collection of samples. They were placed across the river and fixed above the river bed and about 2.0 cm. below the water surface by iron rods which passed through the plastic funnel and driven into the river bed. Samples were always collected from the same location, a section of the river with a fairly swift current and a depth always great enough for the net to float. The site (Station 3) was at the lower end of an 75m. riffle.

The drift nets were placed across the river at 12.00h. and samples were taken every two hours for 24 hours twice per month at approximately two weeks intervals. It took 8-10 minutes to change the nets. Night time was from 18.30 hours to 06.30 hours approximately throughout the year with ten minutes variation, and the sampling periods were organised so that there were six samples from each of the day and night periods. By sampling for 24-hour period twice a month for twelve months, data on the diel, monthly and seasonal fluctuations of the drift invertebrates were obtained.

After the drift nets were withdrawn from the river the contents were poured into a top big funnel which was fitted into a bucket three-quarters filled with water (Fig.4). The funnel had a coarse sieve and its snout led into the snout of a removable inner smaller funnel which had a nylon sieve of mesh size 105µm. at the

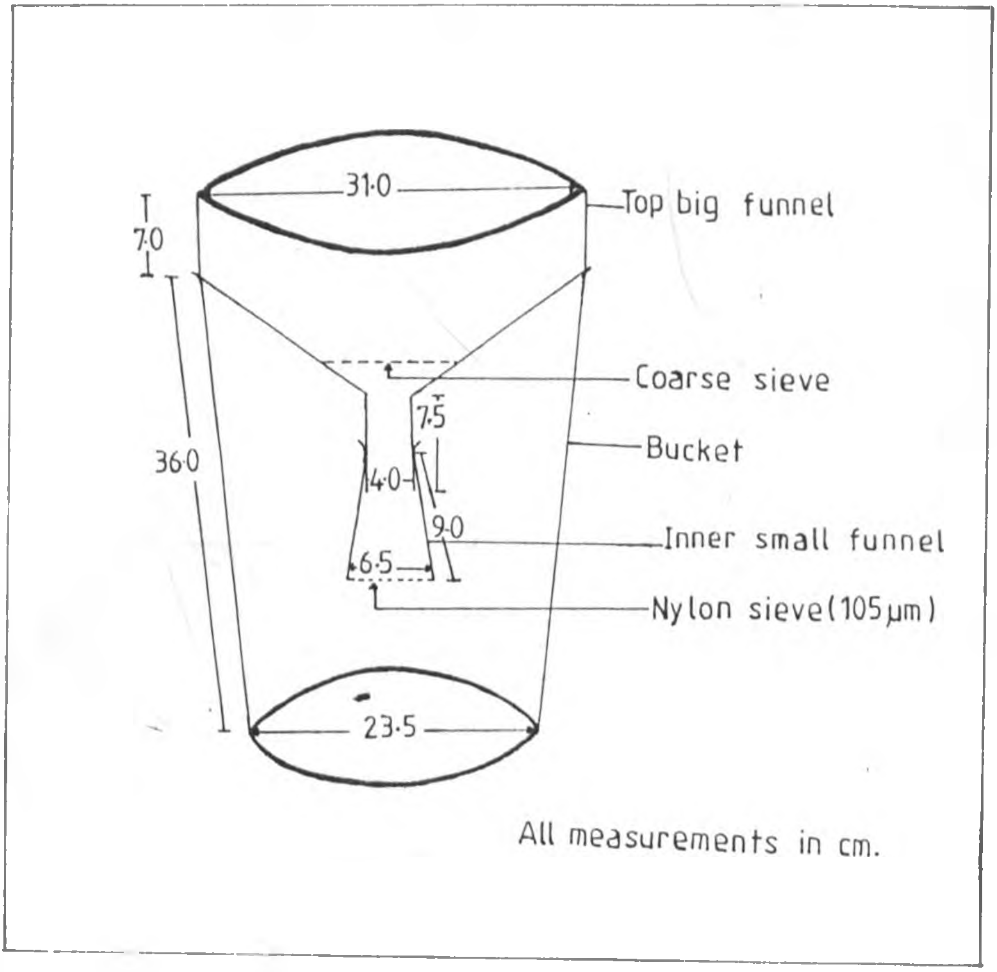


FIGURE 4. Diagramatic plan of the apparatus for drift and debris separation

lower wider part. The top big funnel was then raised and lowered several times in the water to sieve and separate the debris. After this, the inner smaller funnel was removed and the contents washed into transparent plastic containers and the debris washed into polythene bags for further washing to remove and enumerate the attached animals which were later added to the totals of the respective drift taxa sampled at a particular time. The contents were preserved in 4% formaldehyde solution. They were then taken to the field laboratory for analysis. All the specimens were counted and identified using appropriate keys (Macan 1977) and reference to Van Someren's 1952 work on Mt. Kenya rivers. Further sorting, identification and enumeration was made under a dissecting microscope.The drift fauna numbers collected at a given time with the six nets were pooled to obtain one sample.

2.3 Factors that affect diel and seasonal fluctuations of the drift fauna

2.3.1 Light intensity - sunlight and moonlight

Sunlight intensity was estimated using a photocell which was calibrated in microeinsteins per second per square metre ($\mu Es^{-1}m^{-2}$). The light intensity was measured just above the water surface.

There was no available photocell sensitive enough to measure moonlight intensity. However, every effort was applied to describe the appearance of the moon in terms of phases (Fig.5).

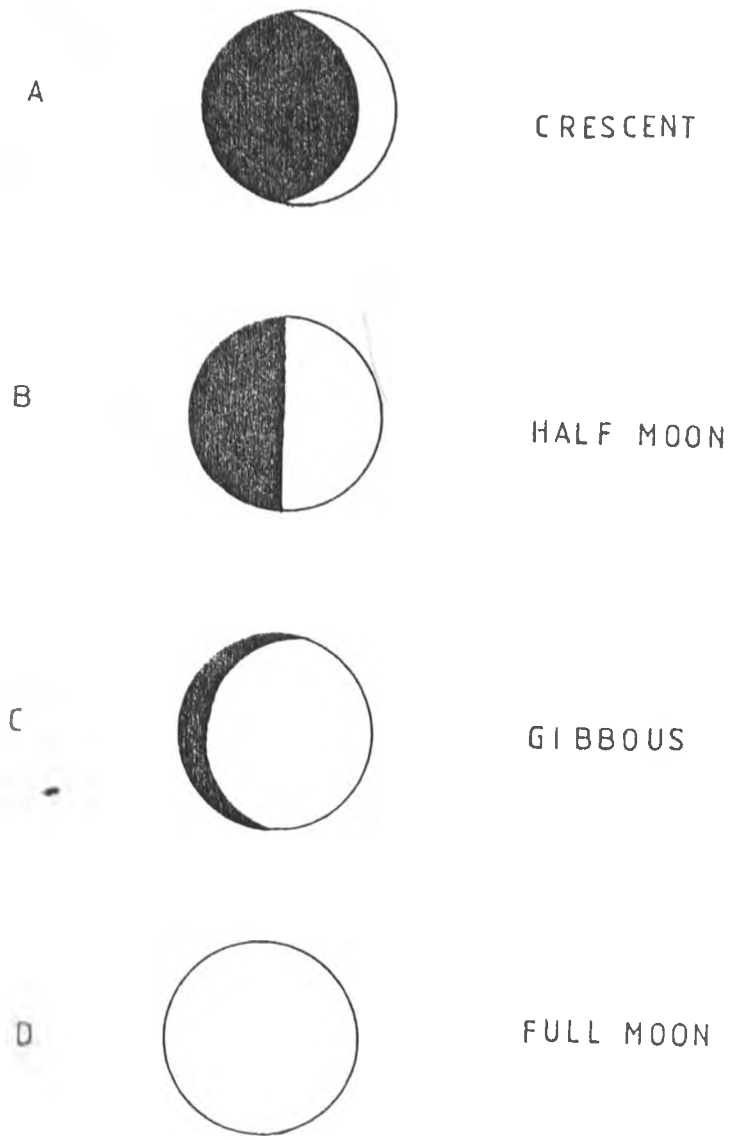


FIGURE 5. The phases of the moon

When there was absence of moonlight or total occlusion of the moon by clouds it was assumed that the night was dark.

2.3.2 Estimation of the water velocity at net mouths and river water velocity

The estimation of the water velocity at the net mouths was made using a pitot tube (Welch 1952) with a lumen of 0.6 cm. In its simplest form a pitot tube is an L-shaped glass tube with both ends open. When it is suspended vertically with the shorter end submerged in flowing water and pointed upstream, water enters the open end and rises a distance (height) above the water level outside. If the flow of the water is steady, the height of the water column within the tube remains practically constant; irregularities of flow cause fluctuations in height. The height is a measure of velocity of the water at or very near the open end. The tube used in this study was made by bending the ordinary laboratory glass tubing in a flame and was mounted onto a metre rule with suitable, easily readable set of graduations on the vertical arm. When so constructed the following formula provides an average constant (0.977) which represents more precise results.

$$V = 0.977 \sqrt{2gh}$$

Where V = velocity ($cm.sec^{-1}$)

h = height (cm) of column in tube above general water level outside, and

g = acceleration of gravity (981 $cm.sec^{-2}$)

The rise due to capillarity was taken into account. The upper end of the tube was dipped into the water and the rise of water due to capillarity was measured, and this value was subtracted from height (h) before computation of the velocity using the above formula.

River water velocity was, on the other hand, estimated by means of an orange set adrift in the river water current and the velocity of flow was determined by the time required to drift it a distance of 12.5m. This was repeated three times over each of the three selected river sections of equal distance on the study riffle. The mean river velocity was then computed from the nine water velocity readings.

2.3.3 River discharge and the volume sampled by the drift nets

Each discharge determination involved measuring the velocity using an orange float at a number of points in the cross-section of the river and the mean velocity determined. On each occasion water depth was also measured with a metre rule at one metre intervals along a standard transect across the width of the river at the site. This was at the same points where velocities were determined. The river discharge was then determined from the current velocity and the depth profile by multiplying the mean water velocity ($m.sec^{-1}$) by the cross-sectional area (m^2) calculated from the depths recorded.

The volume sampled by the nets was determined by the use of a flowmeter Model A-Ott Propeller No. 13873-1.

2.3.4 Turbidity

In the present study an improvised turbidimeter model (Fig.6) was used and this was standardized using an industrial turbidimeter Model 2100A. A transparent rubber tube was used and sealed at the bottom with a piece of glass marked with a cross (+) which was one millimetre thick and a source of light was supplied below it. The disappearance of the cross with the addition of the river water through the tube determined the turbidity. The whole structure was mounted on a one metre rule from where the height of the water in the tube could be read and the height thus read converted according to the industrial turbidimeter.

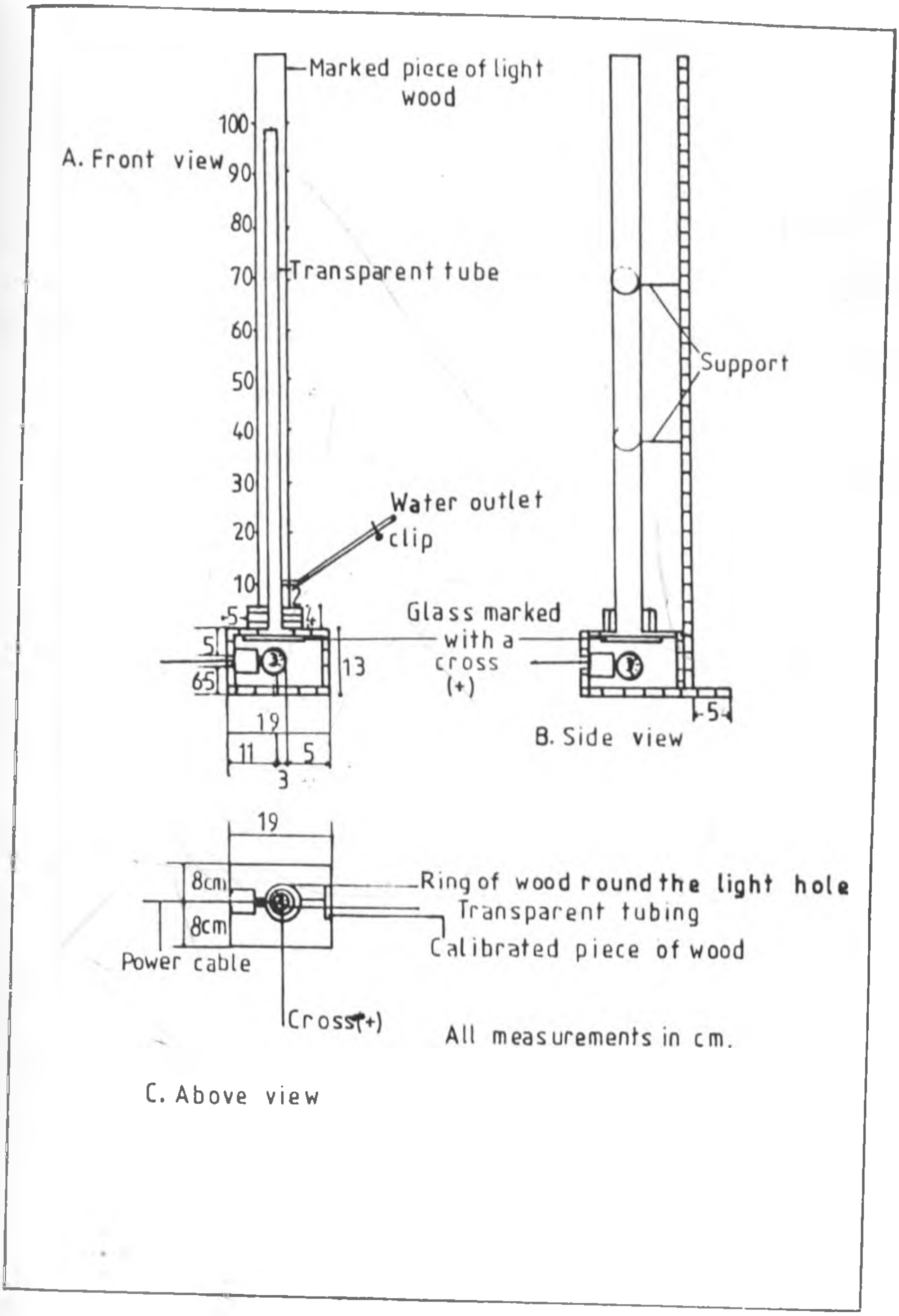


FIGURE 6. Plan of a simple turbidimeter
80 cm ≙ 6.9 N.T.U.

2.3.5 Benthic fauna abundance

In the present study 24 artificial substrate baskets were used. The baskets were placed in the substrata of the river bottom. The baskets were cuboidal in shape and made up of coffee tray wire of mesh size of 0.5 cm. The baskets were filled with smooth and rough black pebbles simulating the river bed substrata. The baskets had a mean length of 18.8 ± 1.1 cm., mean width 17.5 ± 1.0 mean height 6.6 ± 0.5 cm., mean area 1136.6 ± 69.7 cm^2 and mean volume of 2116.0 ± 177.8 cm^3. The artificial substrate baskets were placed in the river bed at random over the entire study site riffle. The baskets had numbered tags (01-24) and were retrieved at random in sets of two samplers at 2-day intervals for 24 days in a month. During the removal of the samples a net had to be placed downstream below them to avoid loss of animals. The baskets were put into buckets and then taken to the field laboratory.

The substrate baskets were then opened in buckets with water and flushed with water to remove the invertebrates. The pebbles were washed and dried in the sun before placing them back into the river substrata.

The organisms were then handpicked from the water in the bucket, identified, enumerated and preserved in 4% formaldehyde solution. Where difficulties arose in identification, a dissecting microscope was used at a magnification of X70. The number of organisms counted in each basket of the set were pooled to provide one sample. Taxonomic designation was determined using the available keys (Macan 1977) and reference to Van Someren's 1952 work on the Mt. Kenya rivers. The taxonomic designation of each group was uniform throughout the study. Each particular level of identification was considered as one taxon in the determination of total number of taxa.

For comparison purposes with drift organism numbers, each of the different organisms found in the benthos at the time of maximum colonization was used with the following assumptions. That:

a) the river substrate was uniform,

b) all taxa were exposed equally to the same physico-chemical changes in the environment,

c) all taxa had equal chances of colonizing the substrates, and

d) the representative taxa of the benthic community would be present at the time of maximum colonization.

2.3.6 Dissolved oxygen concentration

To determine dissolved oxygen concentration, the azide modified Winkler method was used. It was first described by Winkler in 1888. The collection of the water sample was carried out using a glass-stoppered B.O.D. bottle of 270 ml. capacity every time the drift nets were being placed across the river and removed from the water, making sure no air bubbles were trapped in the sample bottle. The samples were processed as soon as possible after collection while avoiding changes in temperature and exposure to bright sunlight which would alter the oxygen content. 1.35 ml. of manganous sulphate solution ($MnSO_4.4H_2O$) were added below the water surface of the sample, followed immediately by 1.35 ml. of the Winkler reagent just below the water surface. The bottle was carefully stoppered without trapping any bubbles and shaken vigorously to mix. A copious floccular precipitate of manganous hydroxide then formed. The samples were then taken to the field laboratory and the precipitate was let to settle to the lower third of the bottle, and then shaken again vigorously and the precipitate allowed to settle again. During this process the manganous hydroxide ($Mn(OH)_2$) would have absorbed the oxygen in solution. The stopper was then removed and 2.7 ml. of concentrated sulphuric acid were quickly added just below the surface. The stopper was then carefully replaced without trapping air bubbles and the bottle shaken until all the precipitate dissolved. The acid liberated iodine into solution in proportion to the oxygen absorbed by the formation of manganous hydroxide.

A 100 ml. aliquot of sample thus prepared was transferred into a 250 ml. erlenmeyer flask using a bulb pipette. This was then titrated using 0.0025N sodium thiosulphate solution until a pale straw-yellow colour appeared. Four drops of starch solution were then added at this stage and swirled to mix to a uniform blue colour. Then titration was continued until colourless endpoint, against a white tile, was reached. The volume of the titrant used was then recorded in ml. to one decimal place. Then the formula below was applied to estimate the dissolved oxygen in $mg.\ell^{-1}$ every time samples were titrated.

$$D.O\ mg.\ell^{-1} = \frac{VT \times N \times 8000}{VS \times \frac{VB - VM + WR}{VB}}$$

where D.O = dissolved oxygen; VT = volume of titrant used, N = normality of thiosulphate, VS = volume of sample titrated, VM = volume of manganous sulphate, and WR = volume of Winkler Reagent.

The values of dissolved oxygen concentration obtained were then corrected for an altitude of 2035 m.a.s.l. by multiplying with 1.28 as the correction factor, mean water temperature being $14.4 \pm 2.2^{o}C$.

2.3.7 Water and air temperatures

During the present study, water and air temperatures were monitored using ordinary mercury thermometers to the nearest $0.1^{o}C$. Air temperature was monitored at the surface of the water.

The maximum and minimum water temperatures were determined using maximum-minimum thermometers which were placed in a protective wire-mesh cage tied to an iron rod which was driven into the river bed. Once in position, they were re-set to be of the same temperature as that of the water at that particular time. The thermometers were placed in position at 12.00h. and read at 12.00h. the following day, corresponding to the time of starting and ending of the diel drift studies.

2.3.8 Conductivity

The ability of a solution to conduct electricity depends on the ions dissolved in it since the electricity is carried by the migration of these ions to the positive or negative electrode. Therefore a measure of the ease with which electricity is carried is related roughly, to the total ionic concentration of the water. In the present study, Hach conductivity meter was used and the units of recording were μmhos.cm^{-1}.

2.3.9 pH

The pH of the water was taken every time drift samples were being collected. The pH was taken using an industrial digital pH meter Model CG 818T.

2.4 Methods of assessment of the diet of trout

Most workers studying the food of freshwater fish have based their conclusions on the study of the contents of the stomach or more rarely, of the entire gut of captured fish (Hynes 1950). Digestion is less advanced in the stomach, and thus identification of the contents is usually more satisfactory. There has been great variety in the methods of analysing and presenting the data. Some of the methods used include the occurrence method (Hartley 1948), the numerical method (Frost 1946b), the dominance method (Frost & Went 1940), the volume and weight methods (Allen 1938), the fullness method (Frost & Went 1940) and the points method (Swynnerton & Worthington 1940).

The fish for the analyses in the present study were caught using a fish-line and rod from Naro Moru River within one kilometre either side of the study site. In all a total of 461 fish of the rainbow trout, Salmo gairdneri Richardson were examined during the one year study duration. All fish were measured to obtain the standard length and the fork length. Each fish was then dissected to remove the gut. The gut was opened and the contents preserved in 4% formaldehyde solution and sorted later under a dissecting microscope. Each food item was identified and enumerated and availability factor, numerical method and electivity index were used to analyse the data. To determine availability and selection of food by trout, availability factor, which is the ratio of the percentage of a particular species in the food of the fish to its percentage in the drift fauna (Allen 1942), was used and also the electivity index(E) of Ivlev (1961) in which:

$$E = \frac{"R_i" - "P_i"}{"R_i" + "P_i"}$$

where $"R_i"$ = relative value in percentage of any food item in the gut and,

"P_i" = relative value in percentage of the same food item in the environment (drift).

The values for E lie between -1 and +1 for total rejection and highly selected respectively. When the ratio of the availability factor is 1.0 there is selection, but if it is more than or less than 1.0 the prey is being preferentially selected or rejected respectively. In the numerical method the total numbers of individuals of each food item were expressed as percentages of the total number of organisms found in all fish examined (Neill 1938).

CHAPTER 3
THE CATCHMENT AND PHYSICO-CHEMICAL CHARACTERISTICS OF NARO MORU RIVER

3.1 The Catchment

Naro Moru River originates from Mt. Kenya and its catchment extends from this mountain to the savanna woodland in the river's lower reaches. On all the principal East African mountains, three distinct vegetational regions can be recognized. Montane forest on Mt. Kenya forms a belt that usually starts between 1700-2300 m. and extends to 3000-3300 m. The montane forest shows a development of zonation into a lower montane rainforest zone, an intermediate zone of bamboo, *Arundinaria alpina* and an upper *Hagenia*-*Hypericum* zone. There is also an ericaceous or moorland belt, with a lower limit at about 2600-3400 m. and an upper limit at 3350-4100 m. On the west side of Mt. Kenya the ericaceous zone is confined chiefly to the sides of ridges and along sheltered stream courses, sometimes creeping to the height of 4000 m. The Afro-alpine zone around the peak has a vegetation that varies from moist forest or arborescent species of *Senecio* *brassica* and *Lobelia* to open desert-like grass communities. The alpine zone of Mt. Kenya vegetation shows an interdigitation of moorland and alpine vegetation, owing to the deeply dissected nature of the slopes. The upper limit of flowering plants is marked by scattered and isolated occurrences of Helichrysum brownei on the main peaks, up to about 4890m. but lichens occur throughout the narrow nival belt, even to the summit of Batian itself at 5200 m. It is such a wide vegetal spectrum that Naro Moru River traverses.

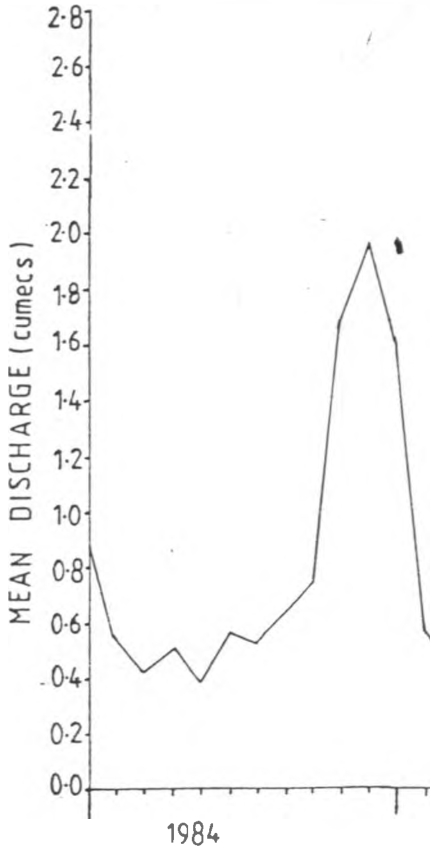
The overhanging riparian vegetation canopy and the gallerial forest in the upper reaches of Naro Moru River ensure a supply of allochthonous materials into the river. Much of the allochthonous material is found in the river during the dry seasons. The forest debris tends to accumulate both on the river bottom and also at the exit of the pools. The allochthonous materials decay and release humic acid and nutrients into the water. Soluble organic acids generally found in humus and decaying plant material may affect the chemistry of the water. Water emanating from a catchment is conditioned by the process occurring in the catchment. The geology and local climate of the catchment also determine the degree of mineralization.

Man is probably the greatest single biogenic factor affecting river water quality, both directly as a result of discharges into rivers and indirectly through his activities on land. Increasing development of subsistence agriculture in catchments, with consequent removal of vegetal cover and increase in erosion, is altering both the hydrology and water quality of African rivers (Edwards 1969). However, Naro Moru River is relatively unpolluted.

3.2 Physico-chemical characteristics of Naro Moru River

3.2.1 River discharge and rainfall

The hydrograph for Naro Moru River (Fig 7) shows two discharge peaks. The presence of two peaks is clearly reflected in the principal annual climatic pattern, which has two rainy/dry seasons. The months with the highest discharge are April/May and October/November. During these four months, approximately half the annual amount of water (46-53%) is discharged (Leibundgut 1983). In some cases, the months of June and December are also part of the rainy season discharge, and 55-68% of the annual amount is then discharged. Table 1 shows the details of discharge at various stations in the Mt. Kenya zone from 1960-1980 and Table 2 shows variation of discharge at RGS 5BC2 from 1986-1987.



2·8
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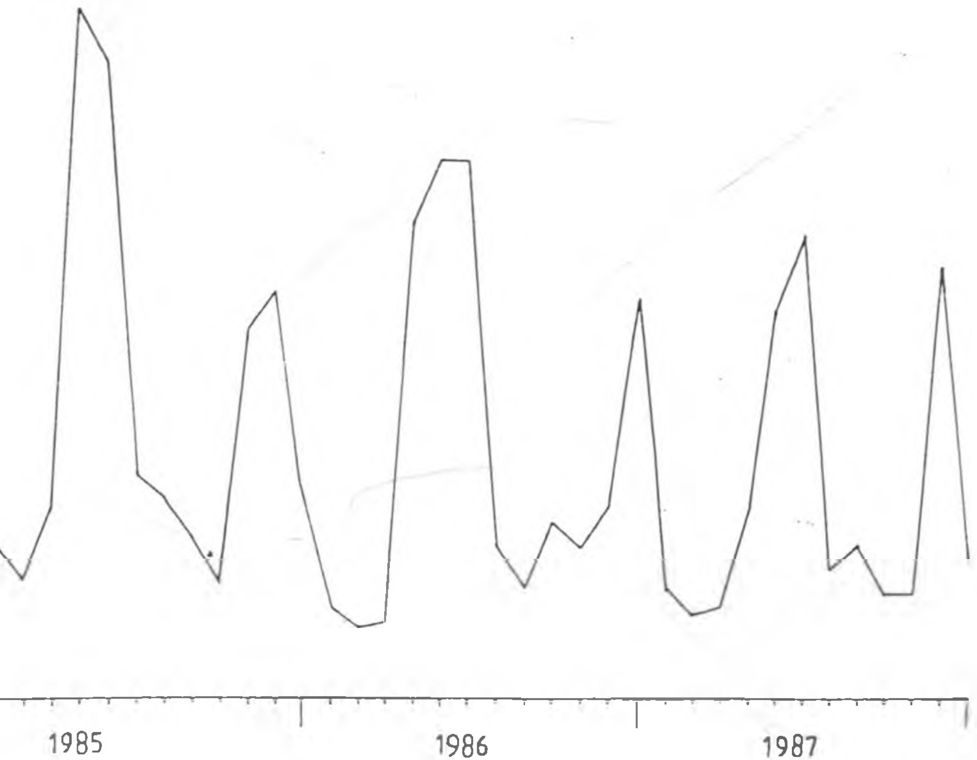
MEAN DISCHARGE (cumecs)
1984

FIGURE 7.



Discharge regime for Naro Moru River, 1984-1987
(By courtesy of Ministry of Water Development, Nairobi, Kenya)

TABLE 1. Naro Moru River discharge and other Mt. Kenya rivers for the period 1960-1980. MQ_{21} is annual average discharge. HQ_y is maximum annual mean discharge; NQ_y is minimum annual mean discharge

River	Station No.	Catchment Area (km^2)	MQ_{21} ($m^3.sec^{-1}$)	HQ_y ($m^3.sec^{-1}$)	NQ_y ($m^3.sec^{-1}$)
Naro Moru River	5BC2	83	1.15	2.13	0.439
Nanyuki River	5BE1	68	0.679	1.44	0.238
Liki River	5BE7	184	1.57	2.90	0.590
Ontulili River	5BE2	61	0.615	1.40	0.135
Sirimon River	5BE4	62	0.595	1.41	0.260
Kongoni River	5BE3	14.4	0.064	1.175	0.006
Teleswani River	5BE5	36	0.322	0.621	0.154
Uaso Ngiro River	5BC4	1865	4.13	12.2	1.30

(Source: Leibundgut 1983)

TABLE 2. Naro Moru River discharge at river gauging station 5BC2, November 1986 - October 1987 (By courtesy of Ministry of Water Development, Nairobi, Kenya)

	Minimum G.Ht(m)	Minimum "Q" (Cumecs)	Maximum G.Ht(m)	Maximum "Q" (Cumecs)	Mean "Q" (Cumecs)
November 1986	0.10	0.350	0.35	2.610	0.700
December 1986	0.11	0.407	0.46	4.040	1.450
January 1987	0.09	0.299	0.14	0.600	0.414
February 1987	0.09	0.299	0.18	0.897	0.308
March 1987	0.08	0.268	0.12	0.468	0.336
April 1987	0.08	0.268	0.40	3.230	0.690
May 1987	0.14	0.600	0.40	3.230	1.390
June 1987	0.14	0.600	0.55	5.380	1.681
July 1987	0.09	0.299	0.22	1.240	0.468
August 1987	0.09	0.299	0.23	1.330	0.564
September 1987	0.09	0.299	0.16	0.743	0.394
October 1987	0.10	0.350	0.15	0.670	0.387
Mean	0.10	0.362	0.28	2.037	0.732
S.D	0.02	0.118	0.15	1.620	0.488

G.Ht - Gauge height in metres

"Q" - River discharge

Cumecs - Cubic metre per second

Rainfall is one of the main controlling factors of the annual river regime. The long rains follow the most pronounced dry season. A large part of the rainwater within Naro Moru River catchment is used to replenish the underground reservoir. The refilled aquifer and the reduced evaporation, combined with the continental rains are able to supply the river discharge throughout the subsequent dry period such that, large quantities are discharged than during the first dry season. Obviously the aquifer only partially diminishes so that the short rains can produce the annual maximum discharge (Leibundgut 1983). Analysis of rainfall variability on a monthly basis for Naro Moru Forest Guard Post indicates that the mean annual rainfall is 751.6 mm (1980-87) and the coefficients of variation range from as much as 108.8% (July) to as low as 31.9% (December) (Fig. 8). This emphasizes the great variability associated with the rainfall in the general area. With the exception of a narrow zone about the equator, rainfall over most of Africa shows marked seasonal variation and this is reflected in river flow patterns.

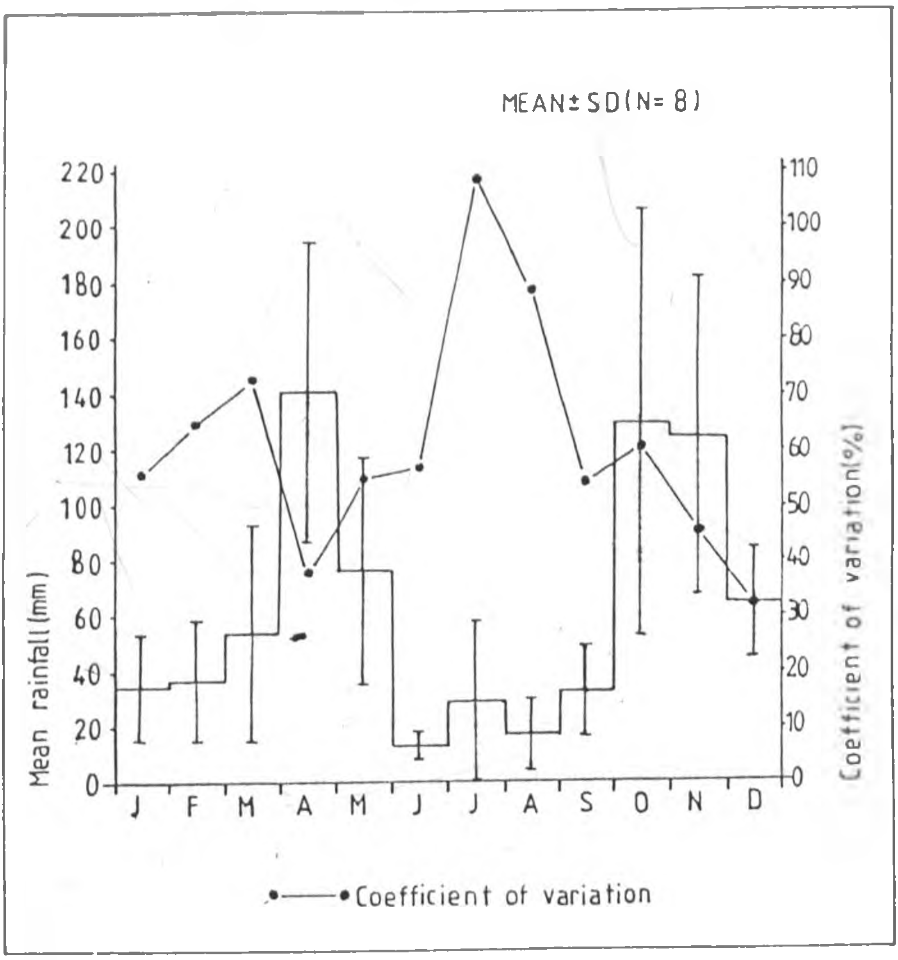


FIGURE 8. Mean monthly rainfall amounts recorded at Naro Moru Forest Guard Post Station Number 9037064, 0°11'S 37°07'E, altitude 2134 m.a.s.l., RDA-4A, 1980-1987 (By courtesy of the Meteorological Department, Dagoretti, Nairobi, Kenya)

3.2.2 Water and air temperatures

The water temperatures of Naro Moru River are moderated by the melting of the ice and also by the shading of the river by riparian vegetation canopy. Shaded waters tend to be cooler and more thermally uniform than those exposed to direct sunlight. The mean water temperature is of the order of $14^{o}C$, extreme temperatures can be as low as $10^{o}C$ and the highest $19.5^{o}C$. (Table 3). Diel range in temperature is rarely more than $7.0^{o}C$. The general picture emphasized by the coefficients of variation (C.V) (Table 4) is the lack of great variability of the water temperature. The river remains cool at all times of the year.

Turbulence associated with the flow of Naro Moru River due to its cascading nature ensures good mixing of the water so that it rarely shows thermal stratification. This also causes the water temperatures to follow the ambient air temperature fairly closely. The air temperatures of Naro Moru are lower than expected due to the cooling effect of evaporation and the cold breeze from Mt. Kenya.

TABLE 3. Maximum and minimum water temperatures recorded in Naro Moru River, 1986-1987

	Temperature (^oC)		
Date	Maximum	Minimum	Range
15/16 November 1986	15.2	11.0	4.2
26/27 November 1986	17.0	13.5	3.5
6/7 December 1986	16.8	11.5	5.3
14/15 December 1986	17.5	12.0	5.5
12/13 January 1987	18.4	13.9	4.5
23/24 January 1987	19.2	15.0	4.2
12/13 February 1987	17.6	13.8	3.8
23/24 February 1987	19.5	12.5	7.0
2/3 March 1987	18.0	14.1	3.9
11/12 March 1987	19.0	14.4	4.6
18/19 April 1987	17.0	13.0	4.0
23/24 April 1987	18.5	13.0	5.5
7/8 May 1987	19.0	12.8	6.2
18/19 May 1987	15.5	10.8	4.7
5/6 June 1987	16.2	10.0	6.2
15/16 June 1987	16.8	10.5	6.3
6/7 July 1987	16.0	11.0	5.0
26/27 July 1987	17.0	11.0	6.0
5/6 August 1987	16.3	11.0	5.3
25/26 August 1987	18.1	12.0	6.1
2/3 September 1987	17.5	12.2	5.3
19/20 September 1987	16.8	11.5	5.3
5/6 October 1987	18.0	12.0	6.0
18/19 October 1987	18.3	11.7	6.6
Mean $\pm$ S.D	17.5 ± 1.2	12.3 ± 1.3	5.2 ± 1.0

TABLE 4. Mean water temperature

Date			Mean water temperature (^{o}C)
15/16	Nov.	1986	14.3$\pm$0.6(13.5-15.0)
26/27	Nov.	1986	14.7$\pm$1.2(13.3-16.5)
6/7	Dec.	1986	12.6$\pm$0.6(11.5-13.7)
14/15	Dec.	1986	12.9$\pm$0.3(12.5-13.5)
12/13	Dec.	1987	15.9$\pm$1.5(13.9-18.0)
23/24	Jan	1987	17.1$\pm$1.4(15.1-18.9)
12/13	Feb.	1987	16.0$\pm$1.1(14.0-17.5)
23/24	Feb.	1987	14.8$\pm$1.6(13.0-17.5)
2/3	Mar.	1987	16.1$\pm$1.2(14.2-17.9)
11/2	Mar.	1987	15.9$\pm$0.8(14.5-16.9)
18/19	Apr.	1987	15.2$\pm$1.2(13.5-16.8)
23/24	Apr.	1987	15.2$\pm$0.9(13.9-16.5)
7/8	May	1987	14.5$\pm$1.0(12.9-16.0)
18/19	May	1987	12.4$\pm$0.6(11.4-13.2)
5/6	Jun.	1987	12.0$\pm$1.0(10.8-13.5)
15/16	Jun.	1987	12.3$\pm$1.2(10.8-14.0)
6/7	Jul.	1987	13.3$\pm$1.5(11.5-15.9)
26/27	Jul.	1987	14.3$\pm$1.4(11.9-16.2)

and mean air temperature in Naro Moru River

C.V(%)	Mean air temperature	C.V.(%)
4.2	14.9±3.2(11.5-19.5)	21.5
8.2	14.4±2.5(11.2-18.4)	17.4
4.8	13.8±2.5(10.0-18.0)	18.1
2.3	13.9±2.6(9.5-18.6)	18.7
9.4	15.1±5.4(7.0-22.5)	35.8
8.2	15.8±4.0(10.8-23.5)	25.3
6.9	15.3±3.1(11.5-22.0)	20.3
10.8	14.0±3.4(10.0-21.9)	24.3
7.5	15.8±4.5(11.5-23.2)	28.5
5.0	15.3±3.7(11.0-23.2)	24.2
7.9	14.7±2.6(10.5-19.5)	17.7
5.9	16.2±2.5(13.0-21.2)	15.4
6.9	16.4±3.1(12.0-20.9)	18.9
4.8	16.0±3.9(11.5-23.0)	24.4
8.3	15.5±3.8(11.0-23.0)	24.5
9.8	13.8±3.2(9.5-19.0)	23.2
11.3	13.5±3.4(9.8-18.1)	25.2
9.8	14.5±3.6(11.0-19.0)	24.8

TABLE 4. cont'd

5/6 Aug. 1987	13.9±1.2(11.5-16.0)	8.6	15.2±3.5(11.0-19.2)	23.0
25/26 Aug. 1987	13.8±1.1(12.0-15.2)	8.0	16.0±3.0(11.0-20.0)	18.8
2/3 Sept. 1987	14.8±1.6(12.5-17.0)	10.8	17.6±3.7(12.0-22.5)	21.0
19/20 Sept. 1987	14.1±1.7(12.0-16.5)	12.5	17.0±4.1(12.0-23.0)	24.1
5/6 Oct. 1987	14.9±1.5(12.4-17.5)	10.1	16.8±3.5(11.8-22.0)	20.8
18/19 Oct. 1987	14.7±1.5(12.2-17.0)	10.2	18.6±5.0(12.0-25.5)	26.9

Mean ± S.D. (N=12) for 24 h.

Figures in parenthesis indicate range for 24 h.

3.2.3 pH and conductivity

Evaporation is a major factor influencing both the concentration and composition of African river waters. Naro Moru River is slightly alkaline (pH 7.08-7.97) and the pH of the water is always above 7.0 (Table 5). The coefficients of variation of pH range from 0.5% to 3.2%. This is a small range and indicates that there is no much variation in pH in Naro Moru River throughout the year. The electrical conductivity of the water is affected by the total conentration of ions and by other factors such as the mobility of the individual ions. The conductivity coefficients of variation ranged from 1.4% to 12.5% and this variability is expected because of the variations in river discharge throughout the year.

The pH of Naro Moru River compares favourably with those of Tana River at RGS 4DE2 (Table 6) but there was a great difference in conductivity partially due to the varying substrate over which they flow and partially due to different rates of evaporation. Tana River traverses varying climatic zones.

TABLE 5. Mean pH, mean conductivity and their ranges and coefficients of variation (C.V) in Naro Moru River

Date			Mean pH	C.V.(%)	Mean Conductivity	C.V.(%)
15/16	Nov.	1986	7.80±0.08(7.72-7.91)	1.0	29±1(27-30)	3.4
26/27	Nov.	1986	7.60±0.11(7.29-7.72)	1.4	46±1(44-48)	2.2
6/7	Dec.	1986	7.66±0.08(7.55-7.81)	1.0	34±4(26-39)	11.8
14/15	Dec.	1986	7.66±0.06(7.59-7.79)	0.8	29±1(26-31)	3.4
12/13	Jan.	1987	7.62±0.06(7.54-7.70)	0.8	48±1(47-49)	2.1
23/24	Jan.	1987	7.62±0.09(7.49-7.79)	1.2	47±4(38-51)	8.5
12/13	Feb.	1987	7.80±0.09(7.67-7.97)	1.2	53±5(46-62)	9.4
23/24	Feb.	1987	7.81±0.07(7.74-7.92)	0.9	46±4(39-49)	8.7
2/3	Mar.	1987	7.62±0.15(7.44-7.85)	2.0	59±2(56-62)	3.4
11/12	Mar.	1987	7.62±0.09(7.45-7.74)	1.2	62±4(57-69)	6.5
18/19	Apr.	1987	7.62±0.12(7.57-7.77)	1.6	44±3(40-49)	6.8
23/24	Apr.	1987	7.50±0.09(7.35-7.63)	1.2	46±3(40-48)	6.5
7/8	May	1987	7.43±0.06(7.34-7.56)	0.8	28±2(24-29)	7.1
18/19	May	1987	7.30±0.04(7.26-7.39)	0.5	22±2(19-24)	9.1
5/6	Jun.	1987	7.35±0.10(7.22-7.54)	1.4	30±1(30-32)	3.3
15/16	Jun.	1987	7.56±0.24(7.25-7.81)	3.2	29±1(28-31)	3.4
6/7	Jul.	1987	7.63±0.13(7.44-7.88)	1.7	36±1(36-37)	2.8
26/27	Jul.	1987	7.61±0.16(7.36-7.83)	2.1	43±1(43-45)	2.3
5/6	Aug.	1987	7.47±0.09(7.27-7.65)	1.2	33±1(32-35)	3.0
25/26	Aug.	1987	7.44±0.20(7.08-7.70)	2.7	41±1(39-41)	2.4
2/3	Sept.	1987	7.48±0.14(7.20-7.67)	1.9	48-6(42-59)	12.5
19/20	Sept.	1987	7.81±0.06(7.71-7.90)	0.8	49±1(48-50)	2.0
5/6	Oct.	1987	7.70±0.09(7.57-7.91)	1.2	65±2(62-67)	3.0
18/19	Oct.	1987	7.55±0.06(7.43-7.65)	0.8	69±1(65-70)	1.4

Mean ±S.D. (N=12) for 24h.

Figures in parenthesis indicate range for 24h.

Conductivity for rainwater was 14 μmhos.cm^{-1}

TABLE 6. Water chemistry data for Naro Moru River and Tana River at river gauging station 4DE2(1974-1975)[a]

	Naro Moru River		Tana River	
	+Conductivity (umhos.cm-1)	+pH	Conductivity (umhos.cm^{-1})	pH
November 1986	37.6	7.70	84	7.6
December 1986	31.6	7.66	84	7.4
January 1987	47.2	7.62	96	7.8
February 1987	49.5	7.80	120	7.1
March 1987	60.3	7.62	108	7.9
April 1987	44.8	7.57	97	6.5
May 1987	24.5	7.36	75	6.7
June 1987	29.7	7.46	N.D	N.D
July 1987	39.9	7.62	84.3	7.4
August 1987	36.8	7.45	60	6.2
September 1987	48.6	7.64	91	7.0*
October 1987	66.8	7.62	90	7.0*

* Data for 1974

N.D = Not determined

\+ Average values (present study)

[a] Source of data: Nyambok et al. 1979

3.2.4 Turbidity

Turbidity in Naro Moru River fluctuates with the wet and dry seasons. Turbidity is low during the dry seasons and high during the wet seasons. It ranges from 5.7 to 36.5 (Table 7). Analysis of turbidity variability on a monthly basis indicates that the coefficients of variation range from 1.5% (March) to 65.1% (July) and this emphasizes the great variability in turbidity in Naro Moru River.

3.2.5 Dissolved oxygen concentration

Dissolved oxygen concentration is always high in Naro Moru River and ranges from 7.42 $mg.\ell^{-1}$ to 11.53 $mg.\ell^{-1}$. The high oxygen concentration is due to the cascading nature of the river and the low water temperatures moderated by the ice-melt water. The coefficients of variation range from 0.68% to 9.95% (Table 8) and this indicates that there is low variability in oxygen concentration throughout the year.

TABLE 7. Turbidity of Naro Moru River from November 1986 to October 1987

	Mean turbidity(NTU)	Coefficient of Variation (%)
November 1986	20.1±0.4(19.8-20.4)	2.0
December 1986	30.7±5.5(26.8-34.6)	17.9
January 1987	33.9±3.7(31.3-36.5)	10.9
February 1987	19.7±0.4(19.4-19.9)	2.0
March 1987	6.8±0.1(6.7-6.9)	1.5
April 1987	15.7±9.6(8.9-22.5)	61.1
May 1987	26.4±5.4(22.5-30.2)	20.5
June 1987	31.5±1.7(30.3-32.7)	5.4
July 1987	12.9±8.4(6.9-18.8)	65.1
August 1987	6.3±0.8(5.7-6.9)	12.7
September 1987	6.7±0.5(6.3-7.0)	7.5
October 1987	6.7±0.4(6.4-6.9)	6.0

Mean ± S.D. (N=12)

Figures in parenthesis indicate range

TABLE 8. Mean dissolved oxygen concentration, ranges and coefficient of variation(%) in Naro Moru River, 1986-1987

Date			Mean dissolved oxygen concentration ($mg\ell^{-1}$)	Coefficient of variation (%)
15/16	November	1986	9.22±0.17(8.99-9.56)	1.84
26/27	November	1986	8.72±0.18(8.46-9.02)	2.06
6/7	December	1986	8.56±0.10(8.46-8.77)	1.17
14/15	December	1986	9.17±0.20(8.93-9.66)	2.18
12/13	January	1987	9.26±0.61(8.42-10.39)	6.59
23/24	January	1987	8.55±0.35(8.09-9.27)	4.09
12/13	February	1987	8.08±0.31(7.71-8.45)	3.84
23/24	February	1987	9.45±0.94(8.37-11.53)	9.95
2/3	March	1987	8.16±0.39(7.42-8.78)	4.78
11/12	March	1987	8.48±0.43(7.87-9.12)	5.07
18/19	April	1987	8.50±0.16(8.29-8.78)	1.88
23/24	April	1987	8.52±0.08(8.33-8.62)	0.94
7/8	May	1987	8.63±0.12(8.47-8.86)	1.39
18/19	May	1987	9.01±0.21(8.79-9.38)	2.33
5/6	June	1987	9.01±0.12(8.83-9.24)	1.33
15/16	June	1987	8.89±0.15(8.60-9.20)	1.69
6/7	July	1987	8.48±0.12(8.35-8.72)	1.42
26/27	July	1987	8.63±0.19(8.39-8.97)	2.20
5/6	August	1987	8.32±0.21(8.09-8.77)	2.52
25/26	August	1987	8.50±0.47(7.53-9.10)	5.53
2/3	September	1987	8.67±0.18(8.28-8.97)	2.08
19/20	September	1987	8.71±0.11(8.57-8.93)	1.26
5/6	October	1987	8.81±0.10(8.68-8.98)	1.14
18/19	October	1987	8.82±0.06(8.73-8.91)	0.68

Mean±S.D(N=12) for 24h.

Figures in parenthesis indicate range for 24h.

3.2.6 Water current velocity

The water current velocity varies with river discharge. At high river discharge the current velocity increases while at low river discharge it decreases (Table 9). The coefficients of variation range from 1.4% to 39.1% and this is a wide velocity variability. This is explained by the great variation in discharge associated with Naro Moru River.

TABLE 9. Mean water current velocity of Naro Moru River and the monthly coefficients of variation, 1986-1987

	Water current velocity ($m.sec^{-1}$)	Coefficient of Variation (%)
November 1986	0.71±0.26	36.6
December 1986	1.41±0.02	1.4
January 1987	1.52±0.22	14.5
February 1987	0.99±0.04	4.0
March 1987	0.50±0.04	8.0
April 1987	0.86±0.19	22.1
May 1987	1.18±0.33	28.0
June 1987	1.60±0.04	2.5
July 1987	0.95±0.13	13.7
August 1987	0.69±0.27	39.1
September 1987	0.49±0.02	4.1
October 1987	0.50±0.03	6.0

Mean±S.D(N=12)

CHAPTER 4

COMPOSITION AND STRUCTURE OF THE BENTHOS IN NARO MORU RIVER

4.1 Results

4.1.1 Pilot survey-composition and structure of the benthos

Streams and rivers change along their length in respect of such properties as temperature, depth, current velocity and turbidity. The variations of these parameters along Naro Moru River are shown in Table 10. The highest mean benthic density was shown by Station 3 (1867.7$\pm$833.1 numbers per m^2) which was one of the stations within Naro Moru River Lodge and the lowest density was shown by Station 7 (927.7$\pm$48.7 animal numbers per m^2) which was high up on Mt. Kenya. The percentage composition of the benthic fauna for each station is shown in Table 11 and indicates that Baetis spp. and Simulium sp. dominated the benthos. A complete list of the benthos collected during the survey is shown in Table 12 and compared with some rivers studied by Van Someren (1952). The cross-sectional profiles of the seven stations and the description of the substratum and vegetation are also shown in Fig. 9 and Table 13 respectively.

Table 14 shows values of Kruskal-Wallis analysis of variance by ranks test (Siegel 1956) for the major taxa. The probability associated with the occurrence of a value as large as

TABLE 10. The variations of physico-chemical parameters along Naro Moru River

	Stations						
	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Altitude (m.a.s.ℓ)	1370	1950	2035	2135	2178	2215	2376
Mean width(m)	11.4±1.4	5.3±0.1	7.9±0.2	10.4±0.1	8.3±0.2	10.0±0.2	13.1±0.3
Mean water depth (cm)	17.4±5.4	25.9±12.4	13.8±5.2	25.1±4.6	14.8±6.1	19.8±8.8	27.9±12.1
Mean water temperature(°C)	18.8±0.2	16.6±0.4	16.5±0.1	16.7±0.3	15.9±0.2	15.6±0.5	15.3±0.1
Mean water velocity ($m.sec^{-1}$)	0.37±0.06	0.37±0.07	0.56±0.01	0.36±0.03	0.38±0.02	0.47±0.03	0.28±0.01
*Mean dissolved oxygen concentration($mg.\ell^{-1}$)	8.86±0.01(1.19)	8.28±0.04(1.26)	8.25±0.04(1.28)	8.96±0.13(1.30)	8.65±0.06(1.31)	8.58±0.03(1.31)	8.10±0.08(1.34)
Mean pH	7.72±0.02	7.69±0.03	7.72±0.02	7.73±0.04	7.81±0.05	7.79±0.12	7.74±0.03
Mean conductivity ($\mu mhos.cm^{-1}$)	50.0±1.0	50.7±0.6	48.7±0.4	49.3±3.1	50.0±2.6	47.3±1.5	49.0±2.0
Mean turbidity (N.T.U.)	6.8±0.3	5.5±0.4	5.8±0.5	6.0±0.7	5.7±0.1	6.3±0.4	6.4±0.3
Mean benthic animal density ($No.m^{-2}$)	1283.7±158.0	941.3±228.0	1867.7±833.1	1069.7±471.4	1636.7±902.2	1699.7±326.9	927.7±48.7

Mean±S.D (N=3)

* The figures in brackets indicate the correction factors for the various altitudes.

TABLE 11. Percentage composition of the benthic fauna along Naro Moru River

Taxa	Stations						
	S_1	S_2	S_3	S_4	S_5	S_6	S_7
EPHEMEROPTERA							
Baetis spp.	29.8	16.3	22.0	33.9	36.4	12.4	29.3
Afronurus sp.	10.3	16.0	12.6	10.8	8.2	12.3	6.6
Rhithrogena sp.	6.2	11.5	5.3	6.0	4.0	4.9	2.7
Caenis sp.	0.2	0.2	0.0	0.0	0.5	0.6	0.1
Euthraulus sp.	2.4	3.2	1.6	5.1	5.9	4.2	3.7
Centroptilum sp.	0.4	0.6	0.9	0.3	0.2	0.1	0.1
DIPTERA							
Dicranota sp.	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Simulium sp.	42.8	31.6	38.6	28.9	30.2	33.2	46.9
Limnophora sp.	2.2	3.4	3.6	4.2	1.6	0.7	0.7
Diamesa sp.	2.6	1.1	1.4	1.7	1.4	3.9	2.9
Tanypodinae	0.3	0.5	0.4	0.3	0.3	0.5	0.5
Ceratopogonidae	0.1	0.2	0.0	0.1	0.1	0.3	0.0
Culicidae	0.1	0.0	0.0	0.1	0.1	0.0	0.0
Others	0.0	0.0	0.0	0.1	0.1	0.0	0.0
TRICHOPTERA							
Chimarrha sp.	0.0	0.1	0.4	0.5	0.6	1.2	0.1
Hydropsyche sp.	0.6	4.5	1.6	0.8	1.5	8.8	2.2
COLEOPTERA	0.2	1.6	2.7	1.4	0.7	3.8	1.1
HEMIPTERA	0.5	4.9	5.3	2.7	3.7	3.5	1.4
HYMENOPTERA	0.0	0.0	0.0	0.1	1.0	0.1	0.0
ARACHNIDA							
Hydrachnellae	0.9	2.3	1.7	2.0	2.4	7.7	1.5
TURBELLARIA	0.2	0.1	0.7	0.2	0.2	0.3	0.1
CRUSTACEA	0.0	0.1	0.0	0.1	0.0	0.2	0.0
PLECOPTERA							
Neoperla sp.	0.0	0.6	0.4	0.2	0.0	0.8	0.1
ANNELIDA	0.0	0.3	0.1	0.2	0.3	0.0	0.0
ODONATA	0.3	1.1	0.3	0.2	0.3	0.3	0.0
MOLLUSCA	0.0	0.0	0.0	0.1	0.0	0.1	0.0

TABLE 12. List of all the benthic organisms collected during the pilot survey compared with those collected by Van Someren (1952) in other Mt. Kenya rivers.

Organisms	Mt. Kenya rivers			
	Sagana	Naro Moru	Burguret	Sirimon
Baetis sp.	+	+	+	+
Afronurus sp.	+	+	+	+
Acentrella sp.	+	*	*	*
Prosopistoma sp.	+	+	*	*
Elassoneuria sp.	+	*	*	*
Lithogloea sp.	+	*	*	*
Tricorythus sp.	+	*	*	*
Centroptilum sp.	+	+	*	*
Caenis sp.	+	+	+	+
Neoperla sp.	+	+	*	*
Hydropsyche sp.	+	+	*	+
Chimarrha sp.	+	+	*	*
Goerodes sp.	+	*	+	+
Leptocerus sp.	+	*	+	+
Limnophora sp. (?)	*	+	*	*
Rhithrogena sp. (?)	*	+	*	*
Hydroptila sp.	*	+	*	*
Ceratopogonidae	*	+	*	*
Culicidae	*	+	*	*
Simulium sp.	+	+	+	+
Chironomidae	+	+	+	+
Misc. Diptera	+	+	+	*
Coleoptera	+	+	+	+
Hemiptera	+	+	*	*
Hydrachnellae	+	+	+	*
Mollusca	+	+	*	*
Potamon sp.	+	+	+	*
Euthraulus sp.	+	+	+	+
Turbellaria	+	+	+	+
Odonata	+	+	*	*
Annelida	*	+	*	*
Hymenoptera	*	+	*	*

+ Present
* Not recorded

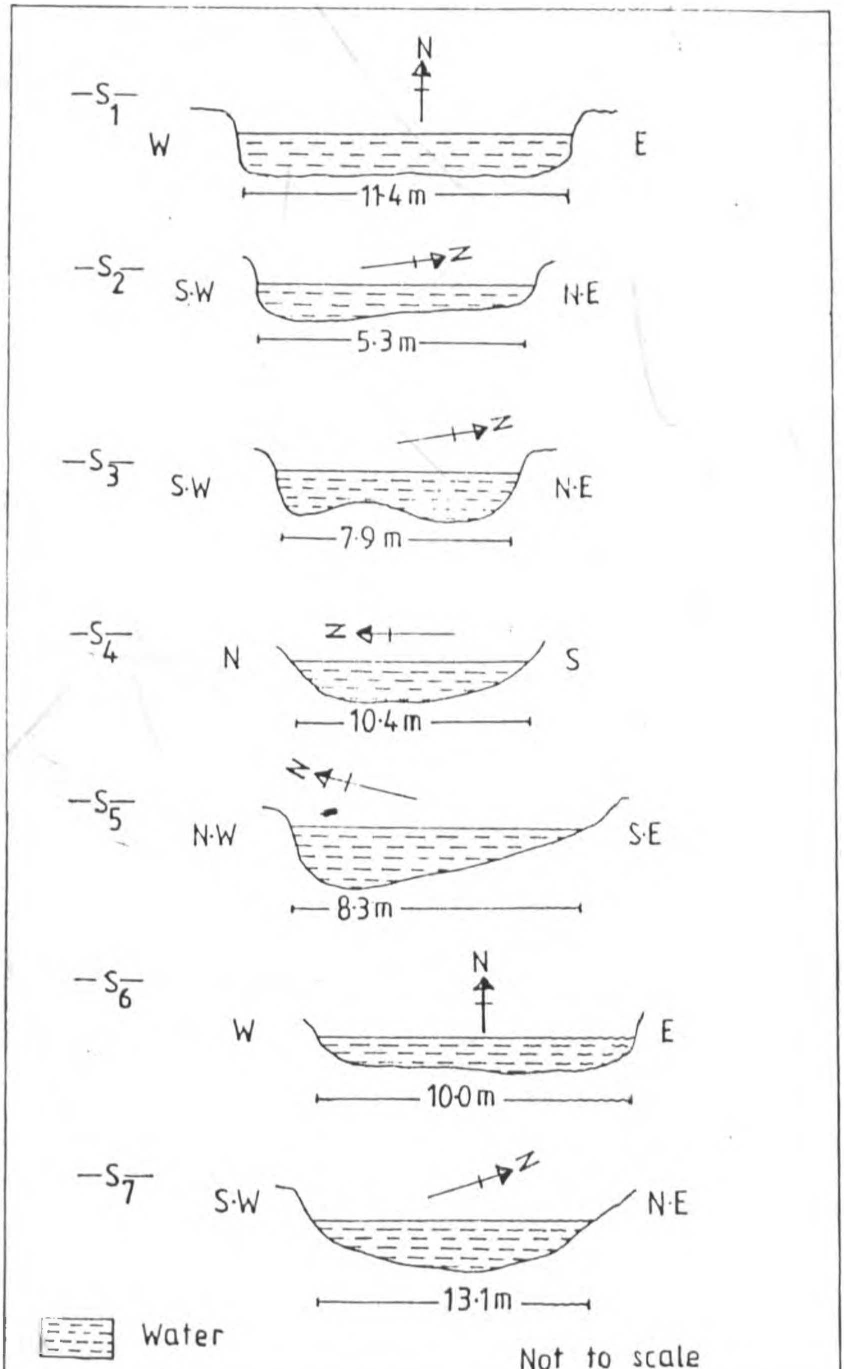


FIGURE 9. Cross-sectional profiles of pilot survey stations (S_1-S_7)

TABLE 13. Salient characteristics of the substrata and vegetation of the pilot survey stations along Naro Moru River

Station	Altitude(m)	Substratum	Vegetation
1	1370	Gravel, sand and large stones	Open, no canopy present.
2	1950	Gravel, sand and large stones	Canopy presnt formed by Podocarpus gracilior, Maesa lanceolata, etc.
3	2035	Gravel, pebbles and rock out-crops	Less dense canopy present formed by P. gracilior.
4	2135	Gravel and pebbles.	Canopy present formed by P.gracilior, Olea africana and Sapium ellipticum.
5	2178	Gravel, pebbles and boulders	Open, no canopy present.
6	2215	Pebbles, gravels and large stones	Canopy present formed by P.gracilior and Arundinaria alpina.
7	2376	Large rocks, gravels, rock outcrops and pebbles.	Canopy present formed by P.gracilor and A.alpina.

TABLE 14. Kruskal-Wallis analysis of variance by ranks test values (H) of the major benthic taxa in Naro Moru River

Taxa	N	df	H	Probability
Diptera	21	6	15.83	P < 0.05
Ephemeroptera	21	6	24.27	P < 0.001
Hemiptera	21	6	1.38	P > 0.05
Trichoptera	21	6	7.75	P > 0.05
Total	21	6	19.64	P < 0.001

$H = 24.27$, $df = 6$ for Ephemeroptera was $P < 0.001$. Since this probability was smaller than the set level of significance, $\alpha = 0.05$, it was concluded that the numbers of Ephemeroptera varied significantly with the location of stations. For Diptera $H = 15.83$, $df = 6$ and this was significant at $P < 0.05$ and therefore the numbers varied significantly with the location of stations. When the total for all taxa was considered it was found that the probability associated with the occurrence of a value as large as $H = 19.64$, $df = 6$ was $P < 0.001$. It was therefore concluded that the total of all taxa in the various stations varied significantly with the location of the stations. Hemiptera and Trichoptera numbers did not vary significantly with the location of stations ($P > 0.05$).

Having examined the salient characteristics for each station, Station 3 was chosen as the site for the present study because of its relatively high benthic density and relatively undisturbed substratum. It was a site which was very accessible and free from human and animal interference. Coupled with this was the presence of security and lack of vandalism.

4.1.2 Colonization experiments at Station 3

Table 15 shows the results for the mean number of animals per basket against the exposure period. The results indicated that maximum colonization took place after ten days of exposure (Fig.10). Multiple regression analysis showed that the increase with exposure was not significant ($F_{(1,10)} = 0.039$, $P>0.05$) (Table 16). Exposure period accounted for only 0.4% of the variability in the number of organisms. However, multiple regression analysis on the mean number of taxa for the whole year and the exposure period indicated that there was a significant increase in the number of taxa with exposure ($F_{(1,10)} = 3.870$, $P< 0.05$) (Table 17). Exposure period accounted for 27.90% of the variability in the number of taxa and the multiple correlation coefficient (R) was 0.53.

4.1.3 Composition of the benthos collected at the time of maximum colonization of the artificial substrate baskets

The major components of the benthos in Naro Moru River on the tenth day of exposure were Diptera (64.56%), Ephemeroptera (24.37%), Hemiptera (4.10%), Trichoptera (2.74%), Arachnida (2.13%) and Turbellaria (1.03%).

TABLE 15. Mean numbers of benthic animals per basket and mean numbers of taxa per basket in Naro Moru River, 1986-1987

Exposure period (days)	Mean numbers of animals per basket	Mean numbers of taxa per basket
2	302.9±170.3	16.4±3.6
4	336.7±132.5	18.1±3.3
6	487.9±157.2	19.8±2.8
8	403.1±126.3	19.5±2.3
10	682.5±209.6	20.8±2.8
12	462.0±153.7	19.3±2.6
14	506.7±217.8	20.4±3.0
16	391.8±148.9	18.5±2.9
18	367.7±117.0	19.3±2.3
20	346.4±164.4	19.9±2.2
22	328.0±166.4	19.2±2.5
24	284.8±115.7	18.8±2.6

Mean±S.D (N=12)

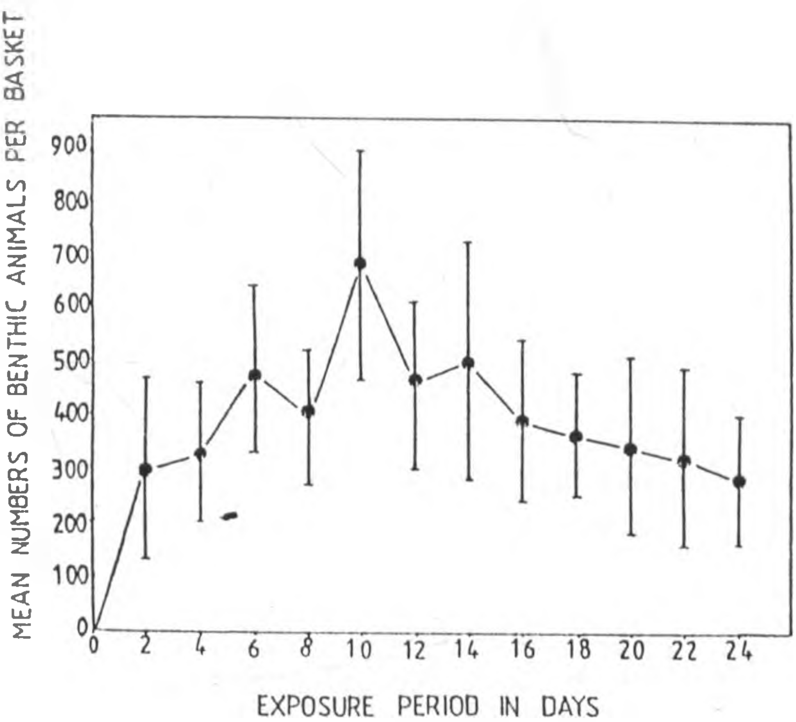


FIGURE 10. Mean numbers of benthic animals per basket against exposure period (days)

TABLE 16. Mean numbers of benthic animals and exposure period (days) analysis of variance

Sources of variation	df	Sum of squares	Mean square	F
Regression	1	2977.316	2977.316	0.039
Residual	10	754878.934	75487.893	-

$F_{(1,10)} = 0.039$, $P > 0.05$

TABLE 17. Mean number of taxa and exposure period (days) analysis of variance

Sources of variation	df	Sum of squares	Mean square	F
Regression	1	7.161	7.161	3.870
Residual	10	18.506	1.851	-

$F_{(1,10)} = 3.870$, $P < 0.05$

Others which formed very small fractions included Coleoptera (0.43%), Crustacea (0.10%) Plecoptera (0.11%), Odonata (0.04%), Annelida (0.02%) and Mollusca (0.01%). Hymenoptera (0.35%) and Isoptera (0.01%), though of terrestrial origin, found themselves trapped in the baskets.

Of the Diptera, Simulium sp. contributed 54.97% of all the benthos (Table 18). This was the only highest percentage for a single genus. Baetis spp., the only abundant Ephemeroptera, constituted 15.66%. Other Diptera which contributed appreciable proportions included Diamesa sp. (4.79%), Tanypodinae (1.86%) and Limnophora sp. (1.56%). For Ephemeroptera, Afronurus sp. contributed 3.35%, Euthraulus sp. 2.22% and Rhithrogena sp. 2.27%. Hydropsyche sp. contributed 2.15% for Trichoptera while other members contributed negligible proportions. Hemiptera contributed 4.10% while water mites, Hydrachnellae, contributed 2.13%. The only plecopteran genus, Neoperla sp., contributed 0.11%. Annelida, Hirudinea and Oligochaeta, comprised 0.02%, Mollusca 0.01% and Odonata 0.04%.

TABLE 18. Composition of the benthos collected at the time of maximum colonization of the artificial substrate baskets in Naro Moru River, 1986-1987

Taxa	Mean numbers of animals per basket	Range in monthly samples	% total
EPHEMEROPTERA			
Baetis spp.	106.8±64.8	10-190	15.66
Afronurus sp.	22.8±21.4	3-83	3.35
Rhithrogena sp.	15.5±13.8	1-41	2.27
Caenis sp.	5.8±6.8	0-24	0.85
Euthraulus sp.	15.2±11.3	0-32	2.22
Centroptilum sp.	0.2±0.4	0-1	0.02
DIPTERA			
Simulium sp.	375.1±195.1	169-872	54.97
Limnophora sp.	10.7±12.4	1-39	1.56
Diamesa sp.	32.7±37.5	3-98	4.79
Ceratopogonidae	2.3±1.4	0-5	0.33
Tanypodinae	12.7±7.3	4-33	1.86
Dicranota sp.	4.1±6.6	0-20	0.60
Culicidae	1.8±1.2	0-4	0.26
Others	1.3±1.8	0-6	0.20
TRICHOPTERA			
Chimarrha sp.	2.8±3.2	0-8	0.40
Hydropsyche sp.	14.7±11.1	1-36	2.15
Hydroptila sp.	1.3±2.3	0-6	0.18
COLEOPTERA	2.9±3.3	0-11	0.43
HEMIPTERA	28.0±33.6	2-94	4.10
HYMENOPTERA	2.4±1.6	0-5	0.35
ARACHNIDA			
Hydrachnellae	14.5±11.0	3-34	2.13
TURBELLARIA	7.0±7.9	0-23	1.03
CRUSTACEA	0.7±0.7	0-2	0.10
PLECOPTERA			
Neoperla sp.	0.8±0.8	0-2	0.11

TABLE 18 cont'd

ISOPTERA	0.1 ± 0.3	0-1	0.01
ANNELIDA	0.2 ± 0.4	0-1	0.02
ODONATA	0.3 ± 0.5	0-1	0.04
MOLLUSCA	0.1 ± 0.3	0-1	0.01

4.1.4 Seasonal variations in the benthic abundance of the major taxa

Though the sampling was not quantitative in the strict sense, the samples could be comparable one to the other and, thus could reflect trends in benthos variations. These fluctuations are illustrated in Figure 11 The total fauna followed a trimodal pattern of abundance during the year. In November 1986 only 612 specimens per set were collected and 507 specimens per set were collected in December 1986 on the tenth day of exposure. The density of the fauna then increased abruptly in January 1987 (1103 specimens per set). This was a twofold increase from the collections in December. An important decrease followed in February and March 1987 and then there was an abrupt recovery in April (836 specimens per set) and then another drop in May 1987. In June 1987 there was another increase after which there was a decrease in July and this level was maintained in the subsequent months. The same trimodal pattern shown by the total benthos was also shown by Diptera and weakly by Hemiptera. Ephemeroptera portrayed a bimodal pattern. Trichoptera had no defined pattern.

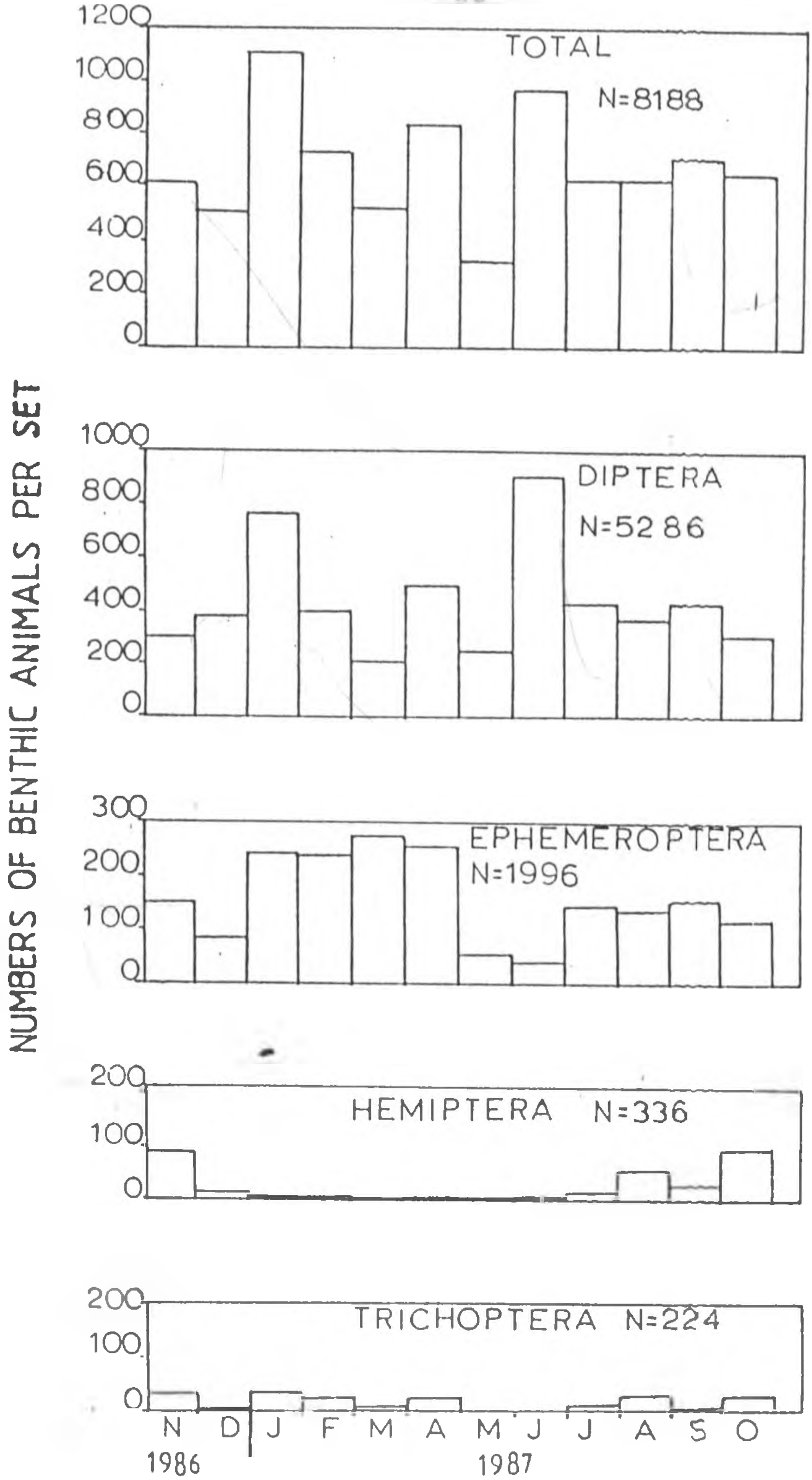


FIGURE 11. Monthly variations in the density of the major groups of the benthos in Naro Moru River, 1986-1987

The relative composition of the benthic fauna changed as well during the year (Fig.12). Ephemeroptera represented 24.37% of the total fauna. In March Ephemeroptera represented the largest proportion of the total fauna (52.4%). Diptera dominated the benthos in most of the year with the highest in December (74.9%) and June (93.3%).

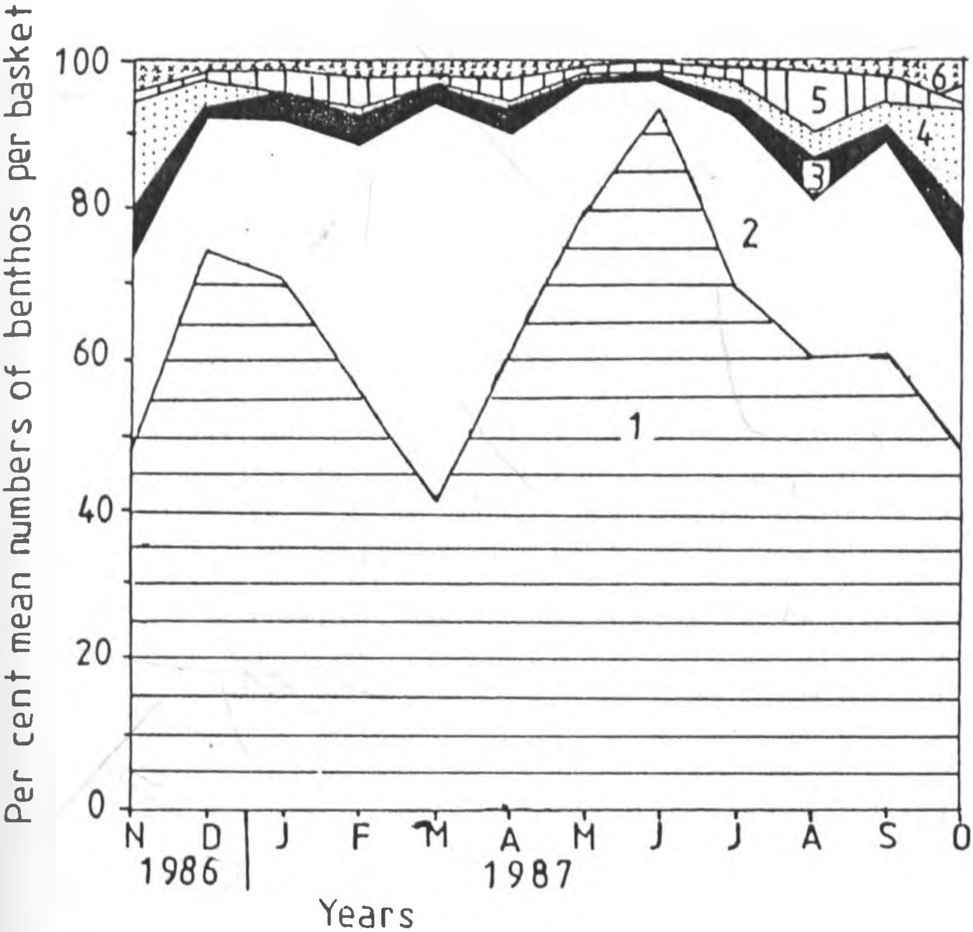


FIGURE 12. Monthly benthic composition (per cent mean numbers of benthos per basket) and seasonal benthic abundance variation of the dominant taxa in Naro Moru River, 1986-1987. 1-Diptera, 2-Ephemeroptera, 3-Trichoptera, 4-Hemiptera, 5. Arachnida, 6-Others.

4.2 Discussion

A clear longitudinal zonation existed for Diptera and Ephemeroptera which were essentially the major taxa of the benthos. The benthos composition closely resembled that found by Van Someren (1952) in Sagana River. The artificial substrate samplers are used by benthic abundance investigators because of several advantages. These include their light weight, ease in handling, simplicity in construction and they provide favourable habitats with quite uniform and reproducible substrate composition and area. Artificial substrates eliminate much of subjectivity and permit flexibility and efficiency in sampling programmes (Meier et al 1979). Artificial substrate samplers depend to a large extent upon chance colonization by the benthos.

Waters (1964) showed that the number of organisms drifting was sufficient to colonize an empty habitat to carrying capacity in ten to fourteen days, agreeing in times recorded by Surber (1937) and Müller (1954). Townsend and Hildrew (1975) recorded a slower rate of 37.5 days and Meier et al. (1979) recorded another slower rate of 39 days. Ulfstrand (1968) used trays containing natural substrate. Working in Lapland streams, he reported peaks in the number of organisms after only eight days. In the present investigation the mean number of organisms per basket taken on each sampling occasion was related to the time of exposure for up to ten days, after which there was an apparent decrease in the total number of individuals. The decline could be explained by competition for space and food. These caused an early departure from the baskets by the benthic organisms and were the plausible explanations for the decline.

There was no levelling off in taxa over the 24 days and this was in contrast to the trend exhibited by the mean number of organisms per basket. The absence of an obvious levelling off in taxa during the course of the 24 days was attributed to the creation of new niches within the artificial substrate baskets. The growth of the "Bewuchs" community on the samples enhanced the colonization by new species. The initial increases in the numbers of taxa after previous periods of sparseness supported the suggestion that new niches were created with increasing periods of exposure by the growth of periphyton.

Seasonal variations in the benthic abundance of the major taxa were observed in the present investigation. The variations of Diptera seemed to be related to the wet and dry seasons. The numbers were high during the wet seasons. This was the time of high discharge and Diptera such as Simulium sp.

moved away from the strong current forces. This was the same trend which was also shown by total benthos and the increase during the high discharge could be explained by their retreat from the surface to the inner interstices. Ephemeroptera were more in the benthos during the dry season and their decrease in number in December 1986 and June 1987 could be expained by their being washed away by the water. These, especially Baetis spp., are current-loving organisms and do not hold onto the substrate firmly like Simulium sp. and hence they are easily washed away. In the dry seasons the current forces were low and water and air temperatures relatively high. The presence of Ephemeroptera in large numbers in the benthos suggested that these organisms retreated to the cooler surfaces of the stones to avoid the direct sunlight. Another possible explanation could have been that the dry season was the major hatching period of these organisms.

Hemiptera and Trichoptera seemed to follow no strict seasonality although Hemiptera numbers were high at the end of each dry season and the start of the rain seasons. This was the time the river bed had a lot of allochthonous materials in form of leaves and twigs. These might have provided the Hemiptera with some nutriment and hence lead to the high increase in the benthos. All in all, Diptera, since they followed the pattern of the total benthos, could be said to be responsible for the pattern shown by the total benthos.

In the temperate latitudes, benthic density fluctuations are usually explained by the loss of organisms through flushing during the spring thaw or the summer emergence of insects. Under tropical climates, other factors intervene. Hynes (1975a) observed a marked reduction in the benthos of a Ghanaan stream during the dry season because of the interruption of flow. There was also a reduction of the benthos in Naro Moru River during the dry season when the flow was low. Bishop (1973) explained fluctuations of densities in a Malayan river by the recurrence of floods which reduced the fauna. However, as the high discharge persisted in Naro Moru River there was a build-up of benthos before it started being eroded. The lack of synchronism in life histories of most benthos dwellers in tropical areas eliminates life-cycle patterns as a major cause of the fluctuations of benthic densities.

CHAPTER 5

COMPOSITION, STRUCTURE, SEASONAL AND DIEL FLUCTUATIONS OF DRIFT FAUNA IN NARO MORU RIVER

5.1 Results

5.1.1 Composition and structure of the drift fauna

The major components of the drift fauna were Ephemeroptera, Diptera, Hemiptera, Hymenoptera, Arachnida and Coleoptera. Ephemeroptera were the major drift components throughout the year. Much of the drift fauna was contributed by the larvae and nymphs of the current-loving mayflies, *Baetis* spp. comprising 50.91% of the drift fauna collected throughout the year. Other Ephemeroptera included *Caenis* sp.(6.33%), *Euthraulus* sp. (3.52%), *Afronurus* sp. (2.73%), *Rhithrogena* sp. (1.18%) and *Centroptilum* sp. (0.08%) (Table 19).

Diptera were also important drift components. *Simulium* sp. was the most important Diptera in the drift. This comprised 6.73% of the total drift in the whole year. Other important dipterans in the drift included *Limnophora* sp. (3.14%), *Diamesa* sp. (3.78%) and Tanypodinae (1.41%). Others under Diptera included Ceratopogonidae (0.27%), Culicidae (0.92%) and *Dicranota* sp. (0.31%).

TABLE 19. Pooled total numbers of drift animals per 2h. collected during the 24 sampling occasions in Naro Moru River, November 1986-December 1987

	Time (h)													
	1400	1600	1800	2000	2200	2400	0200	0400	0600	0800	1000	1200	Total	% total
EPHEMEROPTERA														
Baetis spp.	4125	4609	5386	6578	6110	4462	4116	4366	5745	4148	3769	4115	57529	50.91
Afronurus sp.	281	301	311	339	246	146	139	170	362	209	275	308	3087	2.73
Rhithrogena sp.	105	140	183	134	89	81	61	95	130	77	103	138	1336	1.18
Caenis sp.	283	286	402	1077	861	831	765	522	846	527	418	333	7151	6.33
Euthraulus sp.	102	83	269	642	604	389	350	381	694	247	130	88	3979	3.52
Centroptilum sp.	2	2	3	20	4	7	8	15	13	7	1	6	88	0.08
DIPTERA														
Simulium sp.	520	411	556	856	817	698	506	734	951	550	509	493	7601	6.73
Limnophora sp.	253	248	359	279	278	233	240	293	402	411	292	261	3549	3.14
Diamesa sp.	374	475	500	396	343	341	230	217	390	377	388	233	4264	3.78
Ceratopogonidae	43	43	50	28	16	15	5	7	15	37	18	29	306	0.27
Tanypodinae	128	136	176	189	150	82	84	104	158	165	112	105	1589	1.41
Culicidae	73	72	82	140	154	93	72	69	91	48	57	93	1044	0.92
Dicranota sp.	27	32	21	42	48	19	17	20	33	31	32	28	350	0.31
Others	126	137	85	116	70	25	36	28	49	66	58	112	908	0.80

TABLE 19 cont'd

TRICHOPTERA					
Chimarrha sp	24	18	12	13	11
Hydroptila sp.	6	14	20	6	4
Hydropsyche sp.	43	47	30	30	27
COLEOPTERA	110	128	158	171	130
HYMENOPTERA	773	827	871	658	357
HEMIPTERA	402	432	532	892	933
ARACHNIDA					
Hydrachnellae	284	389	400	296	196
ANNELIDA					
Hirudinea	2	2	4	6	4
Oligochaeta	10	17	13	16	18
MOLLUSCA	5	5	5	14	4
PLECOPTERA					
Neoperla sp.	15	4	6	13	1
CRUSTACEA	6	2	3	14	9
ISOPTERA	3	2	10	4	1
ORTHOPTERA	0	1	0	0	1
TURBELLARIA	1	1	0	1	5
ODONATA	1	3	2	0	2
TOTAL	8127	8867	10449	12970	11493

6	9	9	16	7	4	16	145	0.13
14	7	1	31	50	6	16	175	0.16
28	29	27	33	36	41	32	403	0.36
115	73	101	223	114	94	89	1506	1.33
205	255	223	287	284	401	624	5765	5.10
1277	1253	1042	918	438	222	325	8666	7.67
183	114	97	221	338	298	245	3061	2.71
6	4	4	7	4	2	3	48	0.04
13	7	6	20	10	4	8	142	0.13
5	2	9	2	6	3	5	65	0.06
8	5	6	21	12	4	6	101	0.09
4	11	7	12	3	4	3	78	0.07
1	1	0	2	0	1	1	26	0.02
0	0	0	1	0	0	0	3	0.00
1	0	1	1	0	2	1	14	0.01
0	2	0	3	0	2	0	15	0.01
9288	8401	8554	11677	8202	7250	7716	112994	100.00

Trichoptera were dominated by <u>Hydropsyche</u> sp. It comprised only 0.36% of the total drift. Other Trichoptera which were collected included <u>Chimarrha</u> sp. (0.13%) and <u>Hydroptila</u> sp. (0.16%).

Plecoptera were represented by <u>Neoperla</u> sp. and this was the only genus encountered in Naro Moru River. It comprised 0.09% of the total drift fauna encountered during the study duration. Coleoptera were dominated mostly by Hydrophilidae, Elmidae and Dytiscidae. As a whole, Coleoptera constituted 1.33% of the total drift fauna collected. However, the presence of Coleoptera was sporadic.

Arachnida were also present in the drift and were mostly dominated by the water mites, Hydrachnellae (2.71%). Annelida were represented by Hirudinea (0.04%) and Oligochaeta (0.13%). Mollusca(0.06%) were represented by the pulmonate snails and crustacea (0.07%) by the freshwater crab, <u>Potamon</u> sp. Turbellaria (0.01%), though very rare in the drift, were dominated by <u>Dugesia</u> sp. Both Anisoptera and Zygoptera represented Odonata (0.01%). These were also rare drift components.

Terrestrial organisms were frequent in the drift (5.12%); those taken were largely black ants, Hymenoptera, Formicoidea (5.10%) and Isoptera (0.02%), with a few adult Coleoptera and Arachnida. Although Orthoptera were collected in the drift, they formed an insignificant proportion. The terrestrial component was somewhat greater just before and at the onset of the short and long rain seasons and at the first high river discharge period. It was composed of duff inhabitants that were trapped as the water level rose, and arboreal insects and black ants carried into the river on additional leaf fall that was caused by the rain. This was seen in the drift of Hymenoptera in November 1986 when this comprised 8.6% of the total drift in that month. This was the month when the short rains started. In April and May 1987 this was 8.5% for both months. This was also the time when there were unexpected showers in readiness for the long rains (Table 20).

5.1.2 Seasonal fluctuations of the drift fauna

Seasonal fluctuations of the drift fauna in Naro Moru River were based on the alternation of the dry and wet seasons. The first wet season (short rains) was experienced from November 1986 to January 1987 and this was followed by the first dry season from February to April 1987. The second wet season (long rains)

TABLE 20. Percentage composition of total drift fauna in Naro Moru River, 1986 -1987

	1986	1987										
Taxa	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.
Ephemeroptera	49.4	55.2	64.8	65.8	71.1	67.0	70.0	72.7	66.0	65.4	63.1	57.8
Diptera	18.3	26.9	23.1	17.2	12.8	15.3	14.7	11.9	15.6	19.5	18.3	16.9
Trichoptera	1.0	0.4	0.1	0.1	0.2	0.4	0.3	0.3	0.6	1.7	2.2	0.9
Coleoptera	1.6	1.0	1.1	2.0	1.5	1.4	0.8	0.7	1.5	1.6	1.4	1.8
Hymenoptera	8.6	3.7	2.1	4.6	4.4	8.5	8.5	3.6	6.2	4.0	3.5	5.9
Hemiptera	20.0	10.5	5.6	4.5	4.1	4.1	3.3	7.6	6.3	6.0	9.3	14.7
Arachnida	0.3	1.7	3.1	5.3	5.7	3.2	2.1	3.0	3.2	1.1	1.5	1.0
Annelida	0.4	0.3	0.1	0.2	0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.4
Mollusca	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Plecoptera	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.2	0.3
Crustacea	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2
Isoptera	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Odonata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

started in May and ended in July and then the second dry season followed from August to October 1987. All these seasons had profound effects on the number of drift fauna and the benthos.

The intensity of the drift fauna varied during the year (Fig.13). The total numbers of animals drifting per 24 hours were relatively constant from one sampling occasion to the next within the same month and this ranged from 3448-6896 drift animals for all the sampling occasions, except on 23/24 January 1987 when there was an exceptionally high drift animal number (7619 drift animals per 24 h.) as compared to the previous sampling occasion (4940 drift animals per 24h.).

The composition of the drift animals also varied during the course of the year. Ephemeroptera (49.4-72.7%), Diptera (11.9-26.9%), Hemiptera (3.3-20.0%), Hymenoptera (2.1-8.6%), Arachnida (0.3-5.7%) and Coleoptera (0.7-2.0%) were always the main components of the drift fauna (Fig. 14). Other groups, such as the Trichoptera, Annelida, Mollusca, Plecoptera, Crustacea, Isoptera and Odonata were more sporadic and tended to gain importance in some

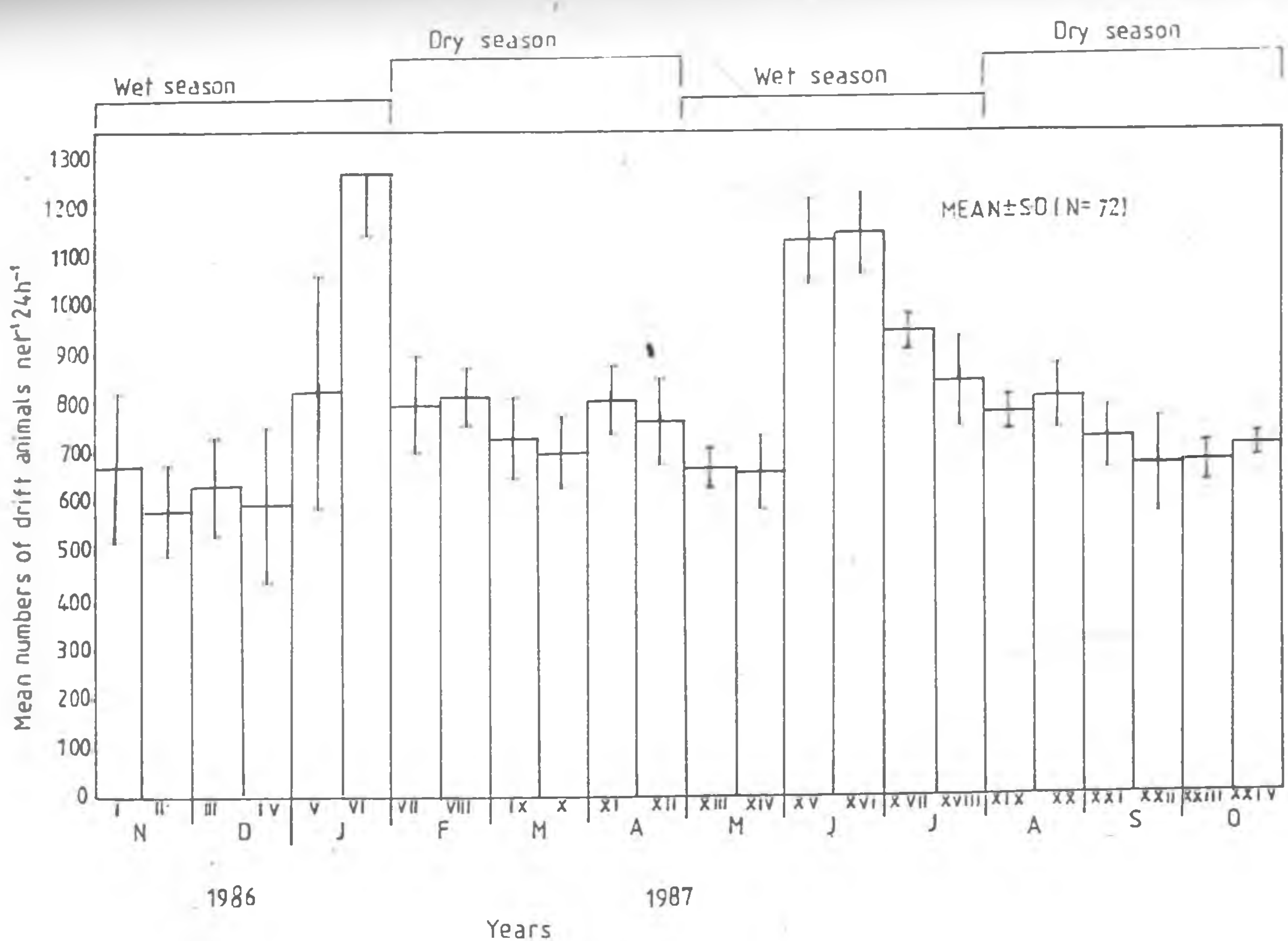


FIGURE 13. Seasonal variation in diel drift in Naro Moru River, 1986-1987.

1-XX1V Sampling Occasions

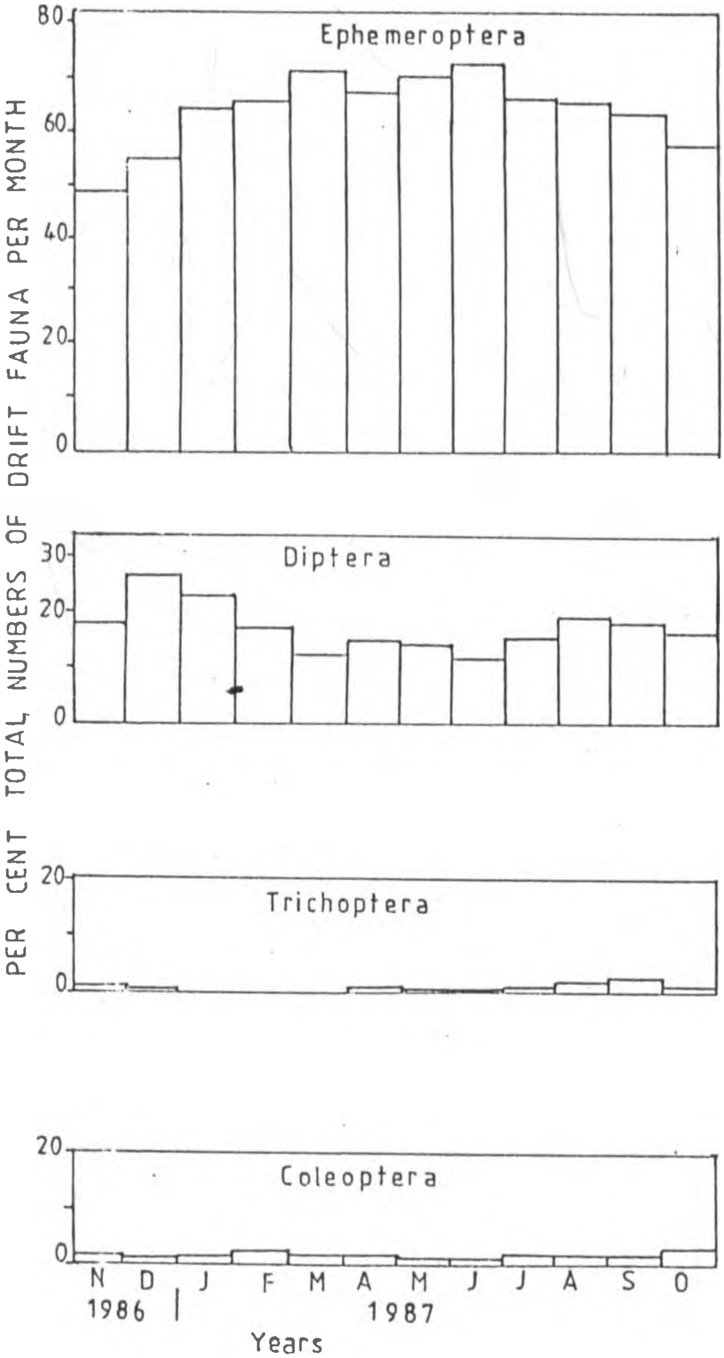


FIGURE 14. Percentage composition of total drift invertebrates in Naro Moru River, 1986-1987

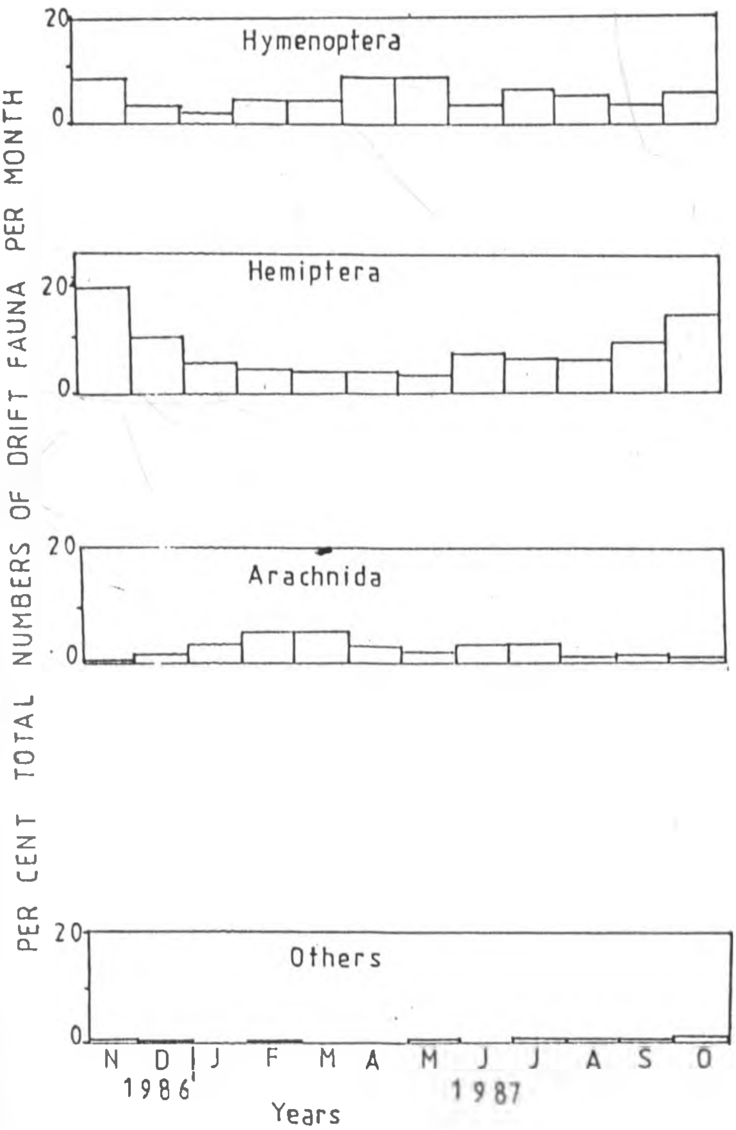


FIGURE 14 Cont'd.

months. Ephemeroptera showed a unimodal drifting pattern for the whole year. Diptera showed a weak bimodal drifting pattern whilst Hemiptera and Arachnida showed a unimodal pattern.

Maximum drift of Diptera occurred in December 1986 and this was one of the times with high river discharge. Large numbers of Hemiptera drifted in November 1986 and October 1987, both months in which there was a large amount of debris and most of these were attached to the debris. High numbers of Arachnida, mostly Hydrachnellae, appeared in the drift in great numbers in February and March 1987. This was during the dry season. Trichoptera and Coleoptera showed no clear-cut seasonality in drifting throughout the year although maximum drift of Coleoptera occurred in February and October 1987 and more so in the dry season. This was also the time when there were leaves and twigs in the drift. Trichopteran drift was largely seasonal with low numbers moving downstream during the dry season when the water levels were low. This was so in the months of February and March although some absence was noticed in January 1987. Hymenoptera distribution indicated that the numbers were high just before and at the first fall of rains. The numbers were high in November 1986 and in April/May 1987. The increases corresponded with the beginning of the short and long rain seasons. After the rains begun, the numbers decreased and started to build-up during the dry season that followed until a peak was reached at the first fall of rain.

A randomized block design analysis was used to test whether there was variation in numbers of drift between the dry and wet seasons and variations as a result of net positions across the river. The results indicated that there was a significant variation between the seasons and there was no spatial variation in drift numbers across the river (Table 21). More animals drifted during the wet seasons than in the dry seasons.

5.1.3 Diel fluctuations of the drift fauna

The diel variation in drift rates is shown in Figure 15. The general trend shown was that of a two peak diel periodicity. Drift periodicities commonly involve two peaks during the 24h. period(Waters 1972). The general trend in the present study was that of a major peak occurring early in the night and a gradual decrease through the middle of the night and then a

TABLE 21. Effect of seasons and net positions on drift fauna analysis of variance

Sources of variation	Sum of squares	df	Mean square	F	Sig. of F
Main effects	1059322.333	8	132415.292	3.503	0.001
Season	637870.528	3	212623.509	5.626	0.001
Net	421451.806	5	84290.361	2.230	0.056
2-way interactions	229249.639	15	15283.309	0.404	0.976
Season net	229249.639	15	15283.309	0.404	0.976
Explained	1288571.972	23	56024.868	1.482	0.089
Residual	4535473.333	120	37795.611	-	-
Total	5824045.306	143	40727.590	-	-

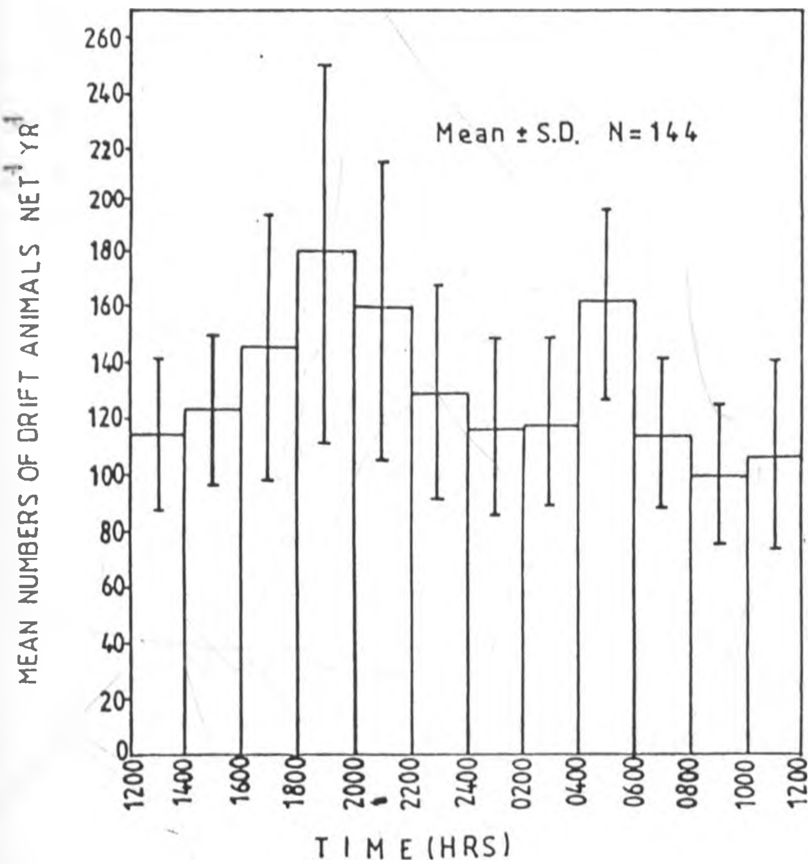


FIGURE 15. Diel variation of drift rates in Naro Moru River, 1986-1987

minor peak just before dawn. This is termed the bigeminus pattern as opposed to the alternans pattern wherein a minor peak occurs after sunset and then the drift builds up to a major peak prior to dawn.

Although the general pattern portrayed by the invertebrates in Naro Moru River was a bigeminus pattern, there were some isolated cases of alternans pattern. This was shown on 14/15 December 1986 (Fig.16). On this date there was an early morning freshet which increased the river discharge from 3.504 $m^3.sec^{-1}$ to 3.511 m $.sec^{-1}$. Another alternans pattern was shown on 12/13 January 1987. This was a day when there was a full moon which rose at 1814h. and set at 0457h. After moonset it was dark. This was also the time when the mean water temperature rose after a month of low mean water temperatures. 12/13 February 1987 was also a sampling occasion when an alternans pattern was evident. This was also a time of full moon which rose at 1850h. and set at 0556h. Table 22 summarizes the approximate times (East Africa Standard Time) for sunset, sunrise, moonrise and moonset on all sampling occasions.

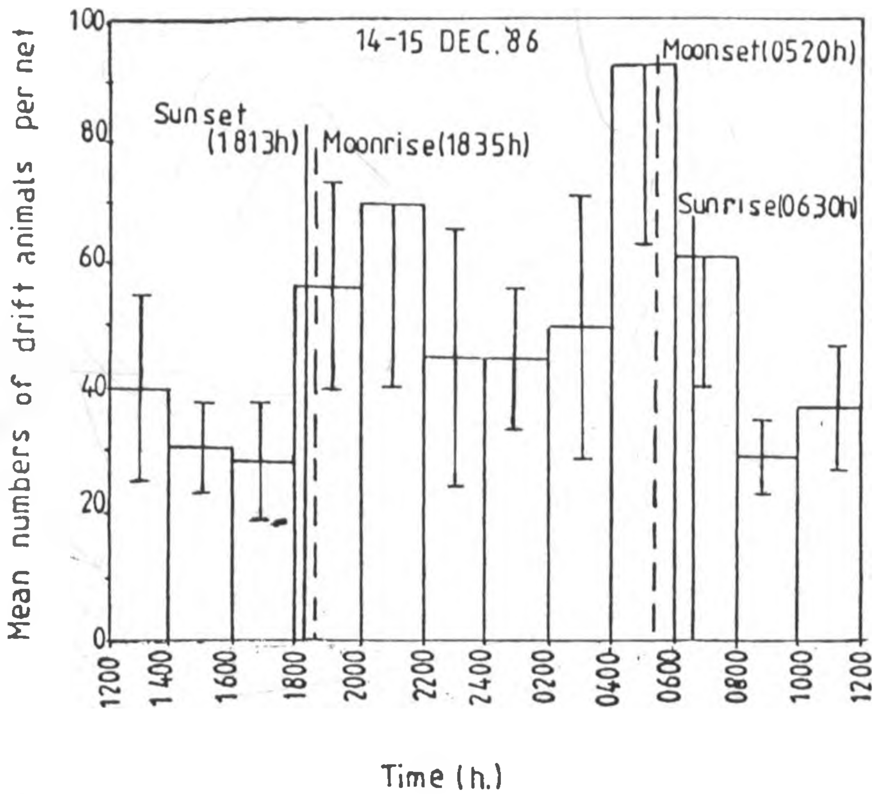


FIGURE 16. Diel variation of drift rates in Naro Moru River for 14/15 December 1986 showing an alternans pattern Mean ± S.D. (N=6)

TABLE 22. Summary of the approximate times (East Africa Standard Time (h.))of sunset, sunrise, moonrise and moonset as observed at Naro Moru River Lodge (study site)

Date			Sunset	Sunrise	Moonrise	Moonset
15/16	November	1986	1814	0624	1830	0512
26/27	November	1986	1822	0628	-	-
6/7	December	1986	1817	0632	-	-
14/15	December	1986	1813	0630	1835	0520
12/13	January	1987	1827	0649	1814	0457
23/24	January	1987	1831	0653	-	-
12/13	February	1987	1847	0659	1850	0556
23/24	February	1987	1848	0659	-	-
2/3	March	1987	1843	0648	-	-
11/12	March	1987	1836	0627	1905	0559
18/19	April	1987	1826	0647	2356	-
23/24	April	1987	1838	0653	-	-
7/8	May	1987	1817	0637	"Cloudy"	0458
18/19	May	1987	1817	0632	-	-
5/6	June	1987	1835	0637	-	-
15/16	June	1987	1840	0639	"Cloudy"	"Cloudy"
6/7	July	1987	1835	0637	-	-
26/27	July	1987	1835	0640	1845	0530
5/6	August	1987	1834	0633	2318	-
25/26	August	1987	1837	0632	-	-
2/3	September	1987	1826	0628	1817	0503
19/20	September	1987	1820	0631	-	-
5/6	October	1987	1823	0629	1845	0535
18/19	October	1987	1822	0620	-	-

— means absence of moonlight

"cloudy" means moon occluded

Daily fluctuations in the quantity and composition of the drift fauna were evident, but not uniform. Proportionately more aquatic invertebrates were collected during the dark period in all samples except on 12/13 January 1987, 23/24 February 1987, 2/3 March 1987, 18/19 and 23/24 April 1987, 7/8 May 1987 and 6/7 July 1987 (Fig. 17). Paired t-test indicated that there was a highly significant difference between day and night time drift collections ($t = 4.12$, $P < 0.001$).

Table 23 shows the mean numbers of day and night drift animals and their overall day and night ratios. A number of studies on a variety of rivers in which a diurnal rhythm of drift has been found indicate that Plecoptera, Ephemeroptera and Simulium drift maximally at night and that Hydrachnellae are day active. Diamesa sp. and Tanypodinae drifted more during the day. The six mayfly nymphs encountered in the present study were always more prevalent in the drift at night except Afronurus sp. and Rhithrogena sp. which appeared to be drifting more during the day. Caenis sp., Euthraulus sp. and Centroptilum sp. had definite tendencies to be night drifters. With the exception of Simulium sp., Culicidae and Dicranota sp., all

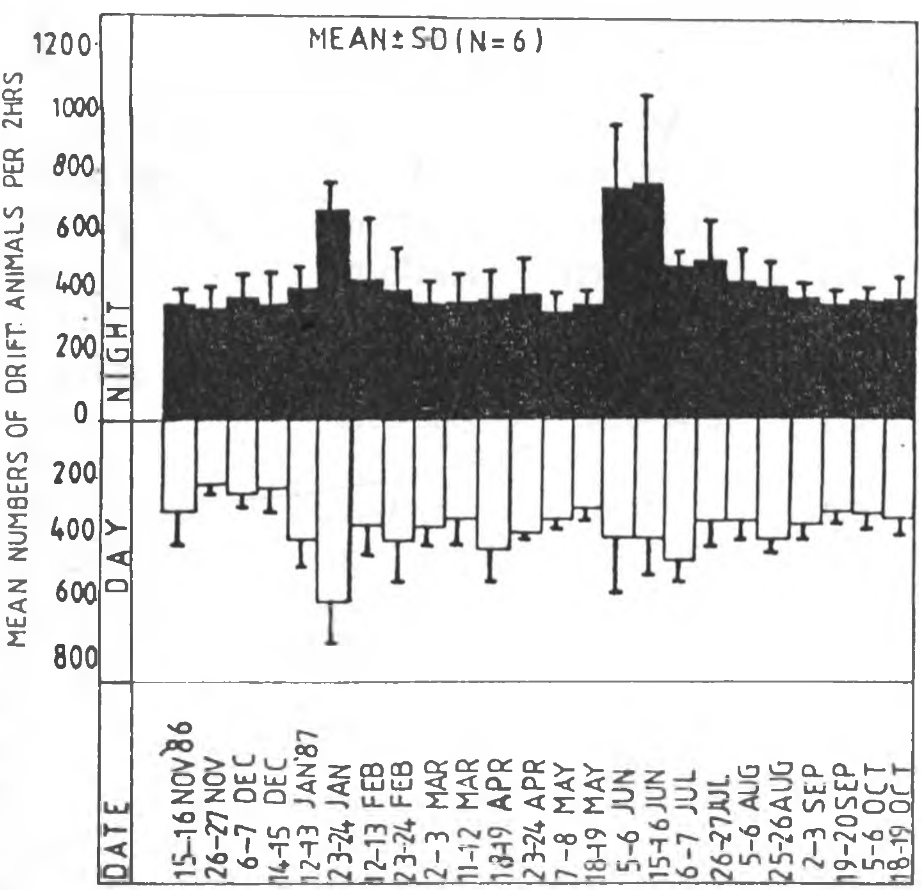


FIGURE 17. Day and night fluctuations of the drift rates in Naro Moru River, 1986-1987

TABLE 23. Mean numbers of day and night drift animals per 2h. and their overall ratios in Naro Moru River, 1986-1987

Taxa	Mean numbers of animals drifting per 2h. Day	Night	overall ratio Day	Night
EPHEMEROPTERA				
Baetis spp.	4358.7±569.9	5229.5±1042.5	1	1.2
Afronurus sp.	280.8±38.1	233.7±98.4	1.2	1
Rhithrogena sp.	124.3±37.3	98.3±28.5	1.3	1
Caenis sp.	374.8±93.6	817.0±179.1	1	2.2
Euthraulus sp.	153.2±83.1	510.0±153.0	1	3.3
Centroptilum sp.	3.5±2.4	11.2±5.9	1	3.2
DIPTERA				
Simulium sp.	506.5±52.6	760.3±153.6	1	1.5
Limnophora sp.	304.0±66.6	287.5±60.9	1.1	1
Diamesa sp.	391.2±94.2	319.5±77.9	1.2	1
Ceratopogonidae	36.7±11.5	14.3±8.1	2.6	1
Tanypodinae	137.0±28.4	127.8±44.1	1.1	1
Culicidae	70.8±16.3	103.2±35.6	1	1.5
Dicranota sp	28.5±4.2	29.8±13.2	1	1.0
Others	97.3±32.5	54.0±34.5	1.8	1
TRICHOPTERA				
Chimarrha sp.	13.5±7.4	10.7±3.5	1.3	1
Hydroptila sp.	18.7±16.3	10.5±10.9	1.8	1
Hydropsyche sp	38.2±6.6	28.8±2.4	1.3	1
COLOEPTERA	115.5±25.1	135.5±53.8	1	1.2
HYMENOPTERA	630.0±240.6	330.8±169.0	1.9	1
HEMIPTERA	391.8±106.6	1052.5±172.5	1	2.7
ARACHNIDA				
Hydrachnellae	325.7±61.2	184.5±72.8	1.8	1
ANNELIDA				
Hirudinea	2.8±1.0	5.2±1.3	1	1.9
Oligochaeta	10.3±4.4	13.3±5.8	1	1.3

TABLE 23. cont'd

MOLLUSCA	4.8±1.0	6.0±4.7	1	1.3
PLECOPTERA				
Neoperla sp.	7.8±4.6	9.0±7.1	1	1.2
CRUSTACEA	3.5±1.4	9.5±3.6	1	2.7
ISOPTERA	2.8±3.7	1.5±1.4	1.9	1
ORTHOPTERA	0.2±0.4	0.3±0.5	1	1.5
TURBELLARIA	0.8±0.8	1.5±1.8	1	1.9
ODONATA	1.3±1.2	1.2±1.3	1.1	1

Mean±S.D (N=24)

the other Diptera were day active. The overall ratios for *Simulium* sp. and Culicidae were both 1:1.5 in favour of night activity. *Dicranota* sp. had 1:1 ratio and this indicated there was no preference. Ceratopogonidae were predominantly day drifters. All the Trichoptera were day drifters. They showed a consistent deviation from a 1:1 ratio. Coleoptera, Hemiptera, Annelida, Mollusca, Plecoptera, Crustacea and Turbellaria were night drifters while Hymenoptera, Hydrachnellae, Isoptera and Odonata were day drifters. *Baetis* spp. were the pre-eminent component of the night drift in terms of numbers, making 50.3% of the total animals drifting at night. The ratios from the drift data in Table 23 indicated the following general divisions of the fauna:

Day drifters	Night drifters	No preference
Afronurus sp.	*Baetis* spp.	*Dicranota* sp.
Rhithrogena sp.	*Caenis* sp.	
Limnophora sp.	*Euthraulus* sp.	
Diamesa sp.	*Centroptilum* sp.	
Ceratopogonidae	*Simulium* sp.	
Tanypodinae	Culicidae	
Chimarrha sp.	Coleoptera	
Hydroptila sp.	Hemiptera	
Hydropsyche sp.	Hirudinea	

Hymenoptera	Oligochaeta
Hydrachnellae	Mollusca
Isoptera	Plecoptera
Odonata	Crustacea
	Turbellaria

Baetis spp. exhibited high drift rates in a marked diel periodicity and the pattern appeared to be the bigeminus-type. Although the total drift numbers in the day samples were often large for the more abundant genera in the drift, they were always less than the total drift animal numbers in the corresponding night samples.

5.2 Discussion

5.2.1 Composition and structure of the drift fauna

The community of the riffle studied was dominated by Ephemeroptera, Diptera, Hemiptera, Hymenoptera, Arachnida and Coleoptera. This community structure was much like the communities observed in temperate rivers. Baetidae and Simuliidae were found to account for the largest proportion of the drift fauna. It is more likely that the greater concentrations of *Baetis* spp. in Naro Moru River's drift samples were a result of several factors, particularly substratum, food availability and stream bed area. Since the river lacked moss and algae to facilitate the reattachment of the animals after they were released from the substratum, the animals found it difficult to regain their "footing" relatively rapidly and this explained their dominance over all the other drifters. The presence of only one genus of Plecoptera in the present study was not surprising since the status of this group in Africa is unknown though at least one genus, Neoperla sp. is known from high mountain streams in Kenya. However, the fauna collected from Naro Moru River closely resembled that described by Van Someren (1952) in Mt. Kenya streams.

The majority of temperate aquatic invertebrates are univoltine, and some have life cycles taking longer than a year to complete. However, growth in the tropics is generally more rapid, and Hynes and Williams (1962) found that most larvae and nymphs were fully grown after a month in a river in Uganda which had been treated with D.D.T. Hynes (1975) found that the life cycles of invertebrates in the Pawmpawm River in Ghana were approximately 2½ months duration. It is suggested here that the lack of clear-cut seasonality in life stages in Naro Moru River was as a result of the almost continuous life cycles found in the tropics.

This was emphasized by the fact that nearly all the stages of life histories were collected during all sampling occasions.

Tree canopies were considerably more extensive than herbaceous canopies in Naro Moru River. Vagaries of weather, such as strong winds and heavy rain, are likely to increase the hazard of falling into the river to many terrestrial invertebrate groups. Detailed weather records were not made, but peaks in terrestrial input in November 1986 and April and May 1987 were all associated with storm conditions. The overhanging riparian vegetation and banks coupled with wind disturbance were responsible for the high terrestrial component in the drift. During the first fall of rains, this washed the terrestrial components into the river together with the leaves that fell as a result of rain. The first high river discharge also led to a high proportion when it washed the sides and stones exposed during the dry season. Unexpected showers especially at midday had the same effect of increasing the terrestrial drift component. Sunny weather was sometimes responsible for large proportions of Hymenoptera especially in the afternoons. Furthermore, heavy rainfall washed considerable quantities of soil invertebrates, such as earthworms, into the river, at which time they formed a substantial component of the diet of the trout.

The terrestrial component of the drift was important by the numbers of animals it comprised. Hynes (1975a), in an African stream, observed a terrestrial component of less than 1%, most of it made up of ants; Bishop (1973), on the other hand, collected large numbers of terrestrial invertebrates drifting in a Malayan river, in fact the terrestrial component formed nearly 33% of the total numbers drifting. Turcotte and Harper (1982) found that terrestrial invertebrates in a high Andean stream formed 16.14% of the total drift. Cowell and Carew (1976) did not mention terrestrial animals perhaps because they were relatively insignificant in their data-series. In the present study the terrestrial component comprised about 5.12% of the total drift and was comparable with the proportion observed by Hynes (1975a) in an African stream.

5.2.2 Seasonal fluctuations of the drift fauna

Seasonal patterns or variations in drift have been shown to fluctuate with changes in age (life stage), growth rate, population density, and physical parameters of the stream. Clifford

(1972) found that there was an overall trend toward low drift rates during winter in temperate streams but Pearson and Kramer (1972) found subsequent increases accompanying rising water temperature during spring and summer. In the present study seasonal variations were examined in terms of wet and dry seasons. The data showed peak drift rates in the rain seasons with minimal values during the dry seasons. During the first dry season from February to April 1987 the river bed was 33% covered by water and in the second dry season (August-October) it was 65% covered. It seemed that the hot and dry conditions experienced during these months had considerable effects on the aquatic invertebrates. Although there was lack of information on the effects of hot and dry conditions on the aquatic fauna of Naro Moru River, the results of the present study confirmed that these conditions might cause considerable changes within the aquatic ecosystem. One of the major effects of these conditions on the aquatic invertebrates was the overall decrease in the potentially colonizable habitats due to the reduction in depth and width of the river. The reduction in wetted bed area is known to have long-term implications since many adult insects lay eggs in fast flowing or broken water (Sawyer 1950) and if suitable areas are reduced subsequent populations may be affected (Hynes 1958). Pearson and Franklin (1968) observed the highest drift rate when 25% of the stream bed was exposed after five months' immersion. They related this high drift rate to a reduction in living space leading to an increase in behavioural drift. In the present study there was no evidence of increase in drift rates due to river bed exposure. It is suggested here that lack of such increase was due to the presence of a water film just below the stone surfaces in which most of the benthos passed the dry season conditions. Those which were collected in the drift were those living in the periphery and that section of the river where the water was still flowing. In the wet seasons, when the river bed was 100% covered by water as a result of increase in discharge, the animals left their places in which they passed the dry seasons' conditions and got entrained into the water column.

There was seasonality in the composition and numbers of the drift animals. While some were present throughout the year, others were more sporadic and tended to gain importance in some months. The presence of a high number of

Simulium sp. in the drift during the rain seasons was as a result of their being brushed away by the strong current forces. In November 1986 and October 1987 there were large amounts of leaves and twigs following the shedding of leaves by some of the riparian trees. The presence of these allochthonous materials explained the presence of large numbers of Hemiptera since most water bugs were mostly attached on them. Such observations were also found in Pawmpawm River in Ghana by Hynes (1975) where Hemiptera were found attached to debris. The dry seasons seemed to dictate the drift numbers of Hydrachnellae, Coleoptera and Trichoptera. Coleoptera were found clinging on leaves and twigs during the dry seasons. Hydrachnellae seemed to prefer clear water and this was available during the dry seasons. The turbidity was low and the water temperatures relatively high. Trichoptera were low in the drift during the first dry season. This could be explained by the lack of enough food during this time when water levels were low. Trichoptera, especially Hydropsychidae, are known to be collector-filterers and feed on other drifting invertebrates (Smith-Cuffney et al. 1987). They were few during the dry seasons in the present study. The seasonality shown by Hymenoptera could be related to the first rain fall.

The numbers had a gradual build-up during the dry seasons until a peak was reached at the first rain fall. Discharge and the year round life histories, coupled with other aquatic conditions, were probably responsible for the difference in seasonal patterns.

5.2.3 Diel fluctuations of the drift fauna

Invertebrate drift in Naro Moru River was generally night-active and the major component, as in most temperate streams, was mayfly nymphs, *Baetis* spp. The occurrence of a pattern which includes maximum drift at night was also confirmed by Clifford (1972).

Higher drift rates at night in Naro Moru River were probably due to greater activity of the aquatic invertebrates. It is suggested here that the animals left their places of concealment and protection after sunset and swam or otherwise moved about more freely and were then swept downstream by the water current. Changes in drift rate were related to times of sunset and sunrise, although a time lag of about two hours appeared between sunset and the onset of the principal increase in drift rate in Naro Moru River. Hughes (1966) found under laboratory conditions that disorientation at night may be a contributing mechanism to the night peak in drift. This could also be a possible explanation for the high drift rates at night in Naro Moru River.

The presence of a clear diel periodicity in the total drift in Naro Moru River was not surprising since similar patterns have been observed again and again the world over, in the tropical latitudes by Bishop (1973) as well as elsewhere. Nymphs and larvae in the present investigation preferred to hide under stones and vegetation debris during daytime, but at night on release of the exogenous light control they became more active in foraging for food and in such more exposed positions they became dislodged and swept into the water current. This caused higher drift rates two hours after sunset. This explained the presence of the first major peak after sunset. Under natural conditions foraging activity follows the onset of darkness with concomittant high drift rates. As the invertebrates in the present study became satiated, activity and drift subsided and this explained the middle of the night depression. A second feeding-drifting pulse at the end of the digestion period followed. However, with the increase of daylight at dawn, these animals started moving back to their hiding areas of low light intensity. It was during this dawn return that they became disorientated and then swept away by the current. This explained the second minor peak which was observed in the drift in Naro Moru River.

In Hynes' (1975) data series, many aquatic invertebrates did not exhibit very clear periodicities. This was observed with many of the invertebrates in the present study. *Baetis* spp. exhibited the bigeminus-type pattern and these results, in concert with other published reports on stream invertebrates drift, suggest that this genus is universal in exhibiting diel periodicities in drift. Indeed, the first report of a diel periodicity in drift by Tanaka (1960) and those from widely separated regions of the world all included the genus *Baetis*.

CHAPTER 6

FACTORS THAT AFFECT DIEL AND SEASONAL FLUCTUATIONS OF DRIFT FAUNA IN NARO MORU RIVER

6.1 Results

6.1.1 Light intensity-sunlight and moonlight

The relationships between sunlight intensity and numbers of drift animals per net are given in Table 24 and Figure 18 shows the effect of sunlight intensity on the total numbers of animals per 2h. on 5/6 June 1987. The simple correlation coefficients calculated for each sampling occasion indicated that there was always a negative correlation between animal drift per net and sunlight intensity except on 2/3 March 1987 when it was positive ($r=0.13$, $P>0.05$). It seemed that animal drift correlated more with sunlight intensity during the rain seasons than in the dry seasons. None of the correlations during the dry seasons were significant ($P>0.05$).

The effect of light intensity was emphasized more when day and night collections were compared. The mean numbers for the day drift animals per net was 353.96 ± 79.08 and for the night drift was 435.17 ± 117.47. When paired t-test was applied it was found that the two means differed significantly ($t=4.12$, $P<0.001$).

TABLE 24. The relationship (r) between numbers of drift animals per net and some physico-chemical factors as indicated by the correlation coefficients

	1986							
Month	Nov.		Dec.		Jan.		Feb.	
Sampling Occassion	I	II	III	IV	V	VI	VII	VIII
Light intensity ($\mu Es^{-1} m^{-2}$)	-0.62*	-0.75**	-0.73**	-0.58*	-0.08	-0.35	-0.25	-0.26
water temp. (^{o}C)	0.31	-0.35	-0.42	-0.46	-0.18	-0.06	0.17	0.88**
pH	-0.09	-0.13	-0.44	-0.46	0.01	-0.45	0.32	0.45
Dissolved oxygen conc. ($mg.\ell^{-1}$)	-0.54	-0.58*	-0.62*	-0.06	0.18	-0.16	0.15	0.09
Conductivity ($\mu mhos.cm^{-1}$)	0.16	-0.59*	-0.10	-0.12	-0.37	0.11	-0.05	-0.24

	1987							
Month	Mar.		Apr.		May		Jun.	
Sampling Occasion	IX	X	XI	XII	XIII	XIV	XV	XVI
Light intensity ($\mu Es^{-1} m^{-2}$)	0.13	-0.33	-0.13	-0.10	-0.20	-0.78**	-0.74**	-0.69**
water temp. (^{o}C)	0.24	0.30	0.46	0.35	0.43	0.40	0.08	0.16
pH	0.26	0.25	0.10	0.03	0.43	-0.25	-0.75**	0.08
Dissolved oxygen conc. ($mg.\ell^{-1}$)	0.26	0.42	-0.41	0.27	-0.34	-0.78**	-0.79**	-0.14
Conductivity ($\mu mhos.cm^{-1}$)	-0.29	0.23	-0.14	-0.08	0.22	-0.53*	-0.08	0.08

TABLE 24. cont'd

	1987							
Month	Jul.		Aug.		Sept.		Oct.	
Sampling Occassion	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV
Light intensity ($\mu Es^{-1}m^{-2}$)	-0.34	-0.61*	-0.52	-0.18	-0.23	-0.65*	-0.55*	-0.51
water temp. (^{o}C)	-0.35	0.39	-0.55*	-0.22	0.15	-0.01	0.35	0.08
pH	0.19	0.10	-0.15	-0.22	0.47	-0.50	-0.54*	-0.01
Dissolved oxygen conc. ($mg.\ell^{-1}$)	0.04	-0.67**	-0.44	-0.53*	0.47	-0.37	0.03	-0.09
Conductivity ($\mu mhos.cm^{-1}$)	0.19	-0.43	0.33	-0.13	-0.38	-0.12	-0.15	-0.44

N for all sampling occasions = 12

Levels of significance are indicated by asterisks: * = $P < 0.05$

** = $P < 0.01$

*** = $P < 0.001$

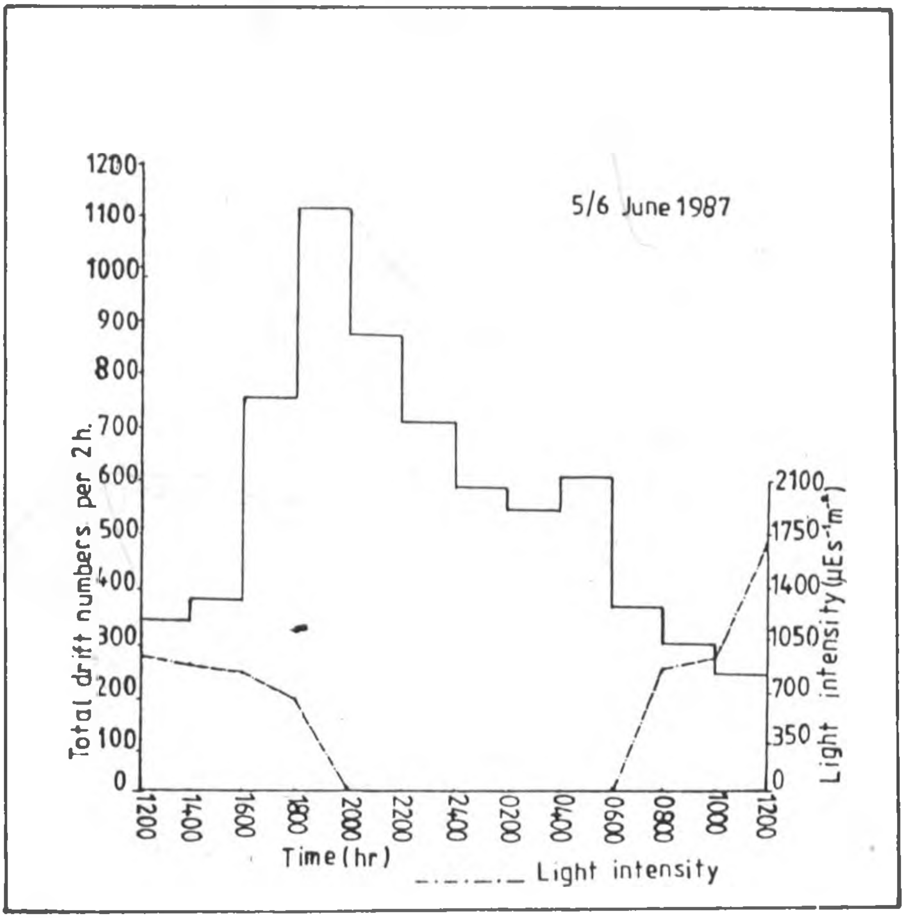


FIGURE 18. Relationship of sunlight intensity to the total number of drift per 2h. on 5/6 June 1987

Full moon conditions occurred in eleven sampling occasions (Fig. 19). On 5/6 August 1987 the moon was half and yet it caused a depression. The depressant effects were clearly seen on 15/16 November 1986, 12/13 January and 12/13 February 1987. In most cases there was a dawn peak after moonset. On 7/8 May and 15/16 June 1987 there was a full moon present but it was occluded by heavy cloud cover. Therefore, moonlight did not disturb the normal nocturnal drift pattern.

The mean number of drift animals per net for the dark night collections was 444.4 ± 126.7 and for the moonlit nights was 425.9 ± 112.4. However, when a paired t-test was applied on these means, it was found that moonlight did not have a significant effect on the number of drift animals ($t=0.85$, $P>0.05$).

6.1.2 <u>River discharge and the volume sampled by the drift nets</u>

The mean river discharge of Naro Moru River was 1.370 ± 1.158 $m^3.sec^{-1}$ for all the sampling occasions. It ranged from 0.235 ± 0.001 to 3.873 ± 0.003 $m^3.sec^{-1}$ during the sampling occasions. Peak discharge occurred on 23/24 January 1987 during the peak of the short rains and the minimum discharge on 2/3 March 1987 during the peak of the first dry season (Fig. 20). There was a

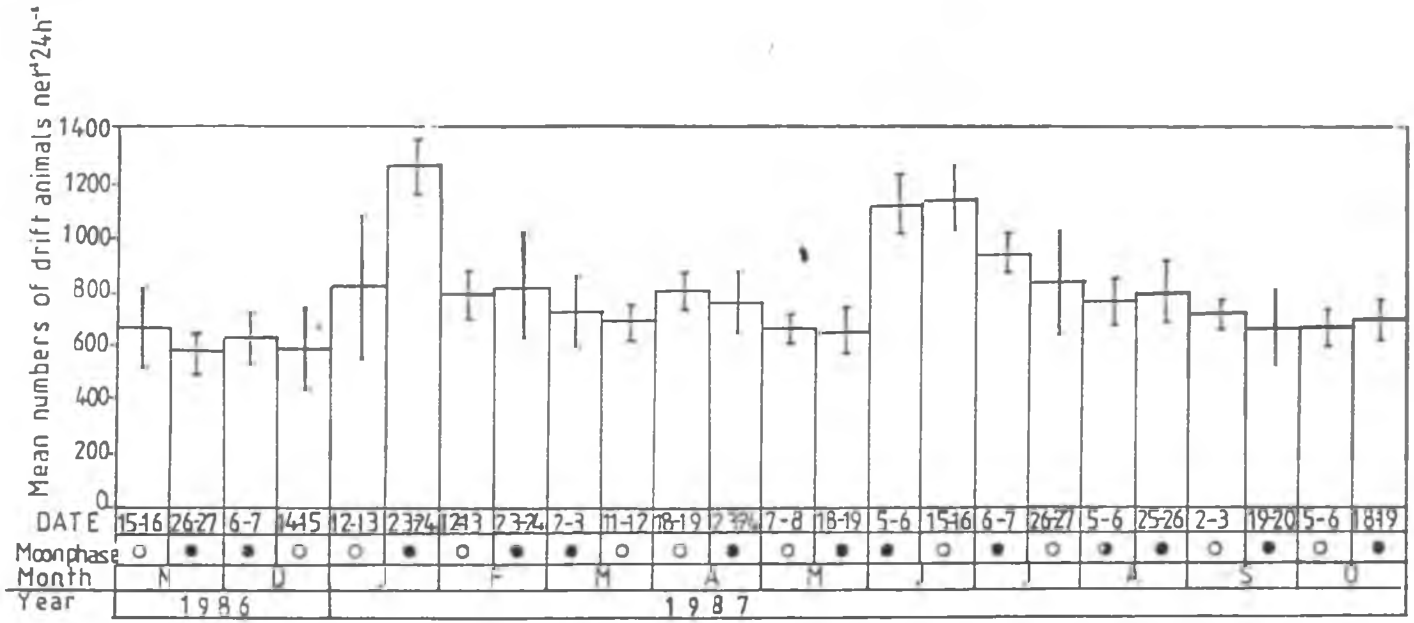


FIGURE 19. Effect of moonlight on the drift animals in Naro Moru River, 1986-1987

Mean ± S.D. (N=72)

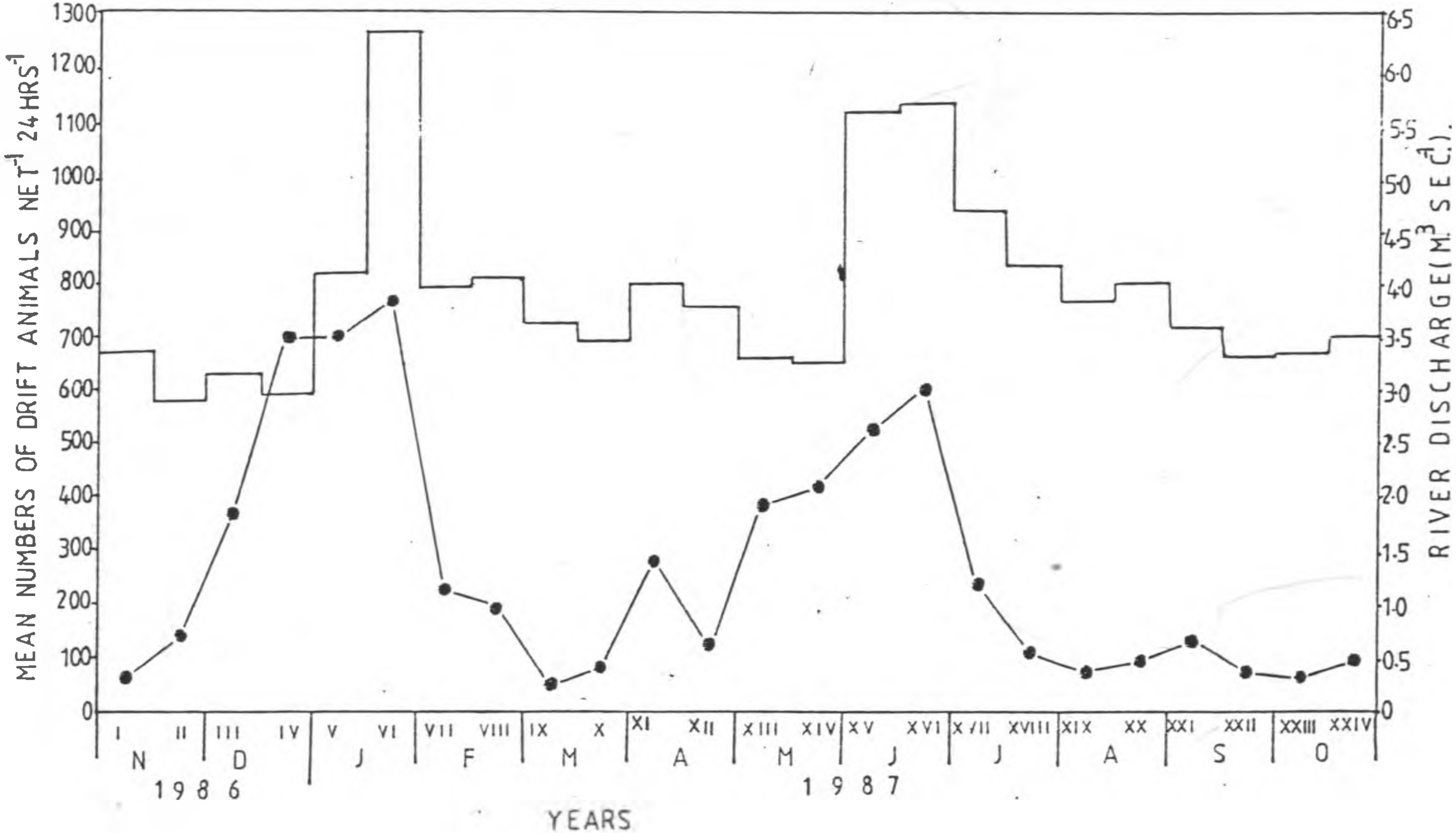


FIGURE 20. Seasonal fluctuations of the river discharge and the numbers of drift animals in Naro Moru River, 1986-1987

Mean $\pm$ S.D. (N=72)

•——•——• River discharge

positive correlation between the total drift per 24h. and the river discharge ($r=0.504$, $P<0.05$). River discharge accounted for 25.4% of the variability in the drift numbers. The regression equation was $Y=462.4X + 3874.7$ (Fig. 21). However, when the drift density was correlated with the river discharge, the correlation coefficient was negative ($r=-0.423$, $P<0.05$) and this accounted for 17.4% of the variability in the drift density. The regression equation was $Y = -0.02X + 0.32$.

When the river discharge increased the mean volume sampled by the net per 2h. increased. The drift density varied from 0.19 to 0.42 animals per m^3. There was a highly significant correlation between the mean volume sampled by the net per 2h. and the river discharge ($r=0.740$, $P<0.001$). Stepwise multiple regression indicated that river discharge, together with the mean volume sampled by drift net per 2h. and 24h., oxygen concentration and turbidity accounted for 59.3% of the variability in mean numbers of drift animals per net ($F_{(5,18)} = 5.25$, $P<0.001$). The multiple correlation coefficient (R) was 0.770. Stepwise multiple regression indicated that the volume sampled by the nets yielded the highest effect on the mean numbers of drift animals ($F_{(1,22)} = 22.14$, $P<0.001$) (Table 25).

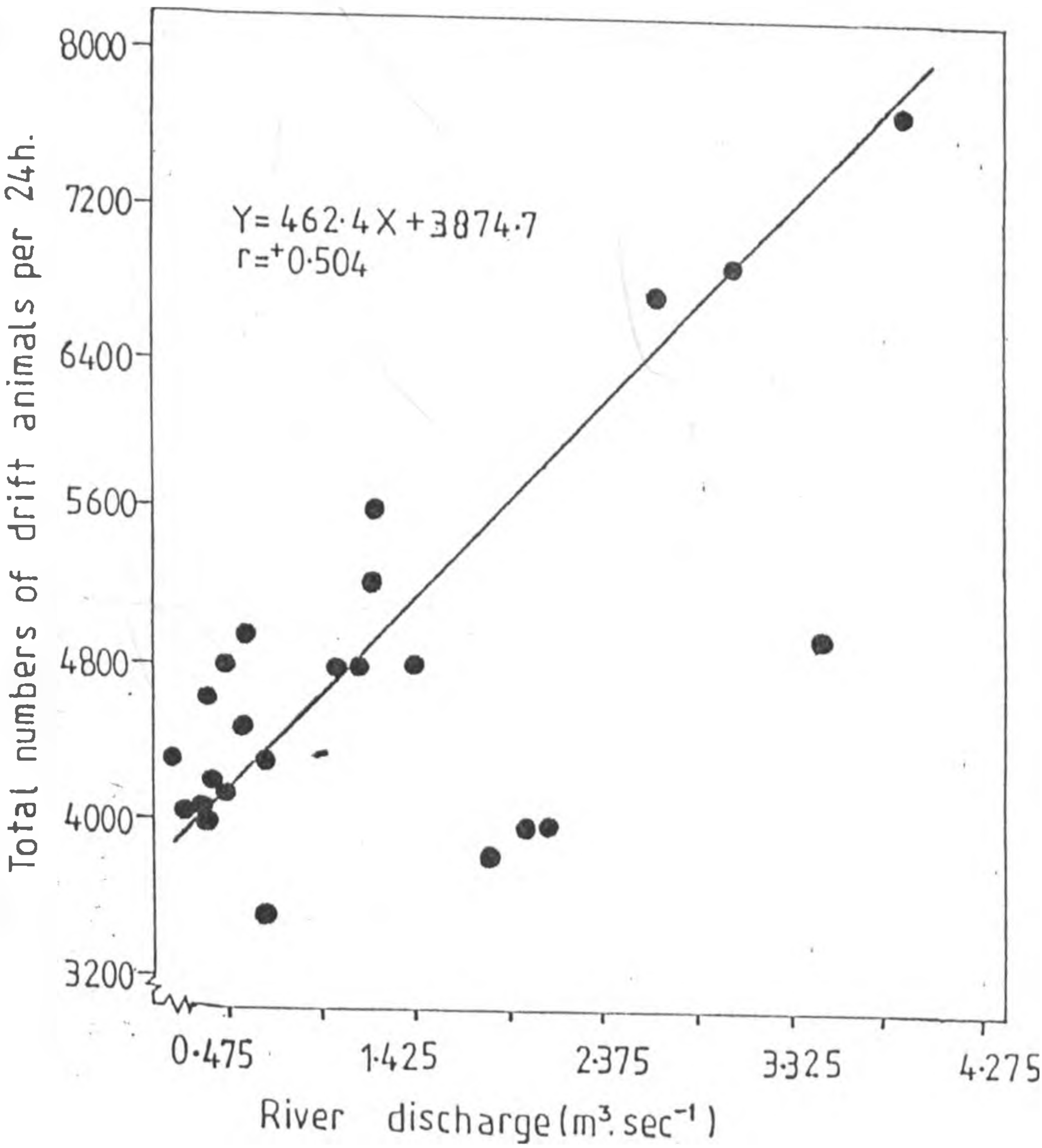


FIGURE 21. The relationship between river discharge and the total numbers of drift animals per 24h. in Naro Moru River

TABLE 25. Volume sampled by nets and mean numbers of drift animals per net analysis of variance

Sources of variation	df	Sum of squares	Mean square	F
Regression	1	355016.75	355016.75	22.14
Residual	22	352795.87	16036.18	-

$$F_{(1,22)} = 22.14, \quad P<0.001$$

It accounted for 50.2% of the variability in mean numbers of drift animals per net. The multiple correlation coefficient (R) was 0.708.

6.1.3 Dissolved oxygen concentration

Dissolved oxygen concentrations were in all cases high. Mean monthly fluctuations ranged from 8.32 ± 0.43 to 8.97 ± 0.31 mg.ℓ^{-1} (Table 26). There was no significant correlation between the total drift animals per 24h. and the dissolved oxygen ($r=-0.021$, $P>0.05$) and the regression equation was $Y = -66.1X + 5284.4$. There was also no significant correlation between the drift density and mean dissolved oxygen. The correlation coefficient was $r = -0.170$, $P>0.05$ and dissolved oxygen accounted for 2.9% of the variability in drift density. The regression equation was $Y = -0.03X + 0.53$. Stepwise multiple regression indicated that oxygen concentration and the volume sampled by the net accounted for 51.9% of the variability in mean numbers of drift animals per net($F_{(2,21,)} = 11.33$, $P<0.001$) and the multiple correlation coefficient (R) was 0.720.

TABLE 26. Some chemical characteristics of Naro Moru River recorded from November 1986 to October 1987

	1986		1987			
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Mean water temp. (°C)	14.5±0.9	12.7±0.5	16.5±1.6	15.4±1.5	16.0±1.0	15.2±1.0
Mean air temp. (°C)	14.7±2.8	13.8±2.5	15.5±4.6	14.6±3.3	15.5±4.0	15.5±2.6
Mean pH	7.70±0.14	7.66±0.07	7.62±0.08	7.80±0.08	7.62±0.12	7.57±0.10
Mean dissolved oxygen (mg.ℓ$^{-1}$)	8.97±0.31	8.86±0.35	8.90±0.61	8.76±0.98	8.32±0.43	8.51±0.12
Mean conductivity (μmhos.cm^{-1})	37.6±8.8	31.6±4.1	47.2±2.9	49.5±5.4	60.3±3.2	44.8±2.9

	1987					
	May	Jun.	Jul.	Aug.	Sept.	Oct.
Mean water temp. (°C)	13.5±1.3	12.2±1.1	13.8±1.5	13.9±1.1	14.5±1.6	14.8±1.5
Mean air temp. (°C)	16.2±3.5	14.6±3.6	14.0±3.4	15.6±3.2	17.3±3.9	17.7±4.3
Mean pH	7.36±0.08	7.46±0.21	7.62±0.14	7.45±0.15	7.64±0.19	7.62±0.10
Mean oxygen (mg.ℓ$^{-1}$)	8.82±0.26	8.95±0.15	8.56±0.17	8.41±0.37	8.69±0.15	8.81±0.08
Mean conductivity (μmhos.cm^{-1})	24.5±3.6	29.7±1.0	39.9±3.6	36.8±3.8	48.6±4.2	66.8±2.5

6.1.4 Turbidity

Turbidity fluctuated with the seasons. It ranged from 6.3 ± 0.8 to 33.9 ± 3.7 N.T.U. (Table 27). There was a positive correlation between total drift per 24h. and turbidity. The correlation was $r = 0.403$, $P < 0.05$. Turbidity accounted for 16.3% of the variability in total drift per 24h. The regression equation was $Y = 39.6X + 3991.5$. There was a negative correlation between the drift density and turbidity ($r = -0.375$, $P < 0.05$) and turbidity accounted for 14.1% of the variability in the drift density. The regression equation was $Y = -0.002X + 0.325$. The relationship between the mean numbers of drift animals per net and turbidity was shown by the regression equation $Y = 6.5X + 671.8$ and the correlation coefficient was $r = 0.400$, $P < 0.05$, and this accounted for 16.0% of the variability in the mean numbers of drift animals per net.

6.1.5 pH and conductivity

Mean monthly hydrogen-ion concentration (pH) ranged from 7.36 ± 0.08 to 7.80 ± 0.08 (Table 26). This is also indicated in Figure 22. This indicated that this was a well buffered river system. There was a decrease in pH and an increase in conductivity on 26/27 November 1986. The discharge also increased two-fold from the

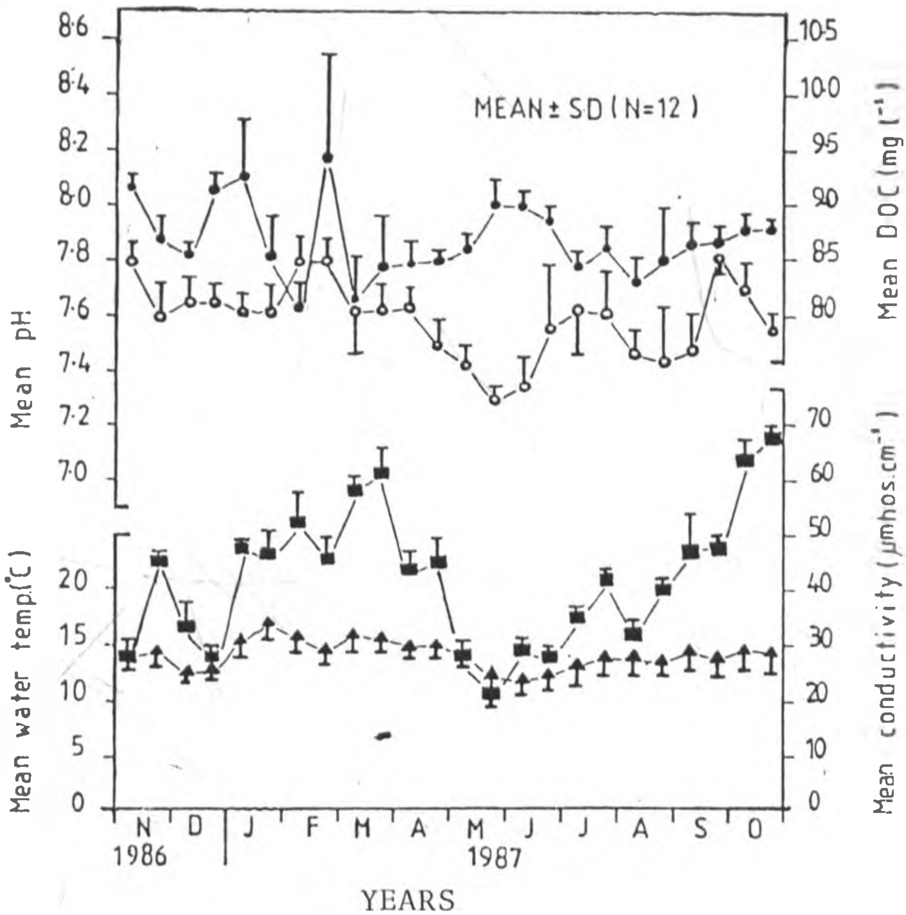


FIGURE 22. Graphs showing some of the limnological changes which took place during the study period (1986-1987) in Naro Moru River

●—● Dissolved oxygen conc. (DOC)

○—○ pH

■—■ Conductivity

▲—▲ Water temperature

one recorded from the previous sampling occasion. This was just after the start of the short rains.

There was no significant correlation between the total drift animals per 24h. and the mean pH. The correlation coefficient was $r = -0.166$, $P>0.05$, and this accounted for only 2.7% of the variability in the total numbers of drift animals. There was a positive correlation between drift density and mean pH ($r = 0.300$, $P>0.05$) and pH accounted for 9.0% of the variability in drift density.

Conductivity ranged from 22 ± 2 to 69 ± 1 $\mu mhos.cm^{-1}$ when all the sampling occasions were considered. Mean conductivity for the whole year was 43 ± 13 $\mu mhos.cm^{-1}$. Conductivity did not have any significant effect on the drift animals in Naro Moru River.

6.1.6 Water temperature

The mean monthly water temperature ranged from 12.2 ± 1.1^{o} C. to $16.5 \pm 1.6^{o}C$. When the mean water temperatures were considered for each sampling occasion, it was found that the lowest mean water temperature was $12.0 \pm 0.1^{o}C$. recorded on 5/6 June 1987 and the highest mean water temperature was $17.1 \pm 1.4^{o}C$ recorded on 23/24 January 1987. The dry seasons water temperatures generally increased whilst the wet seasons water temperatures decreased under the influence of the ambient air temperatures. Mean minimum water temperature for the whole year was $12.3 \pm 1.3^{o}C$. and the mean maximum was $17.5 \pm 1.2^{o}C$. Mean monthly air temperatures ranged from 13.8 ± 2.5 C. to $17.7 \pm 4.3^{o}C$. Water temperature did not have a significant effect on the numbers of drift animals ($r = 0.08$, $P>0.05$).

6.1.7 Water current velocity

The river current velocity ranged from 0.49 ± 0.02 to 1.60 ± 0.04 $m.sec^{-1}$. There was a positive correlation between the total numbers of drift animals per 24h. and the mean current velocity at the net mouths. The correlation coefficient was $r = 0.711$, $P<0.001$, and the current velocity accounted for 50.6% of the variability in the numbers of drift. The regression equation was $Y = 5515.8X + 1658.3$. (Fig. 23). However, there was a negative correlation between the drift density and mean current velocity ($r = -0.524$, $P<0.05$) and it accounted for 27.5% of the variability in the drift density.

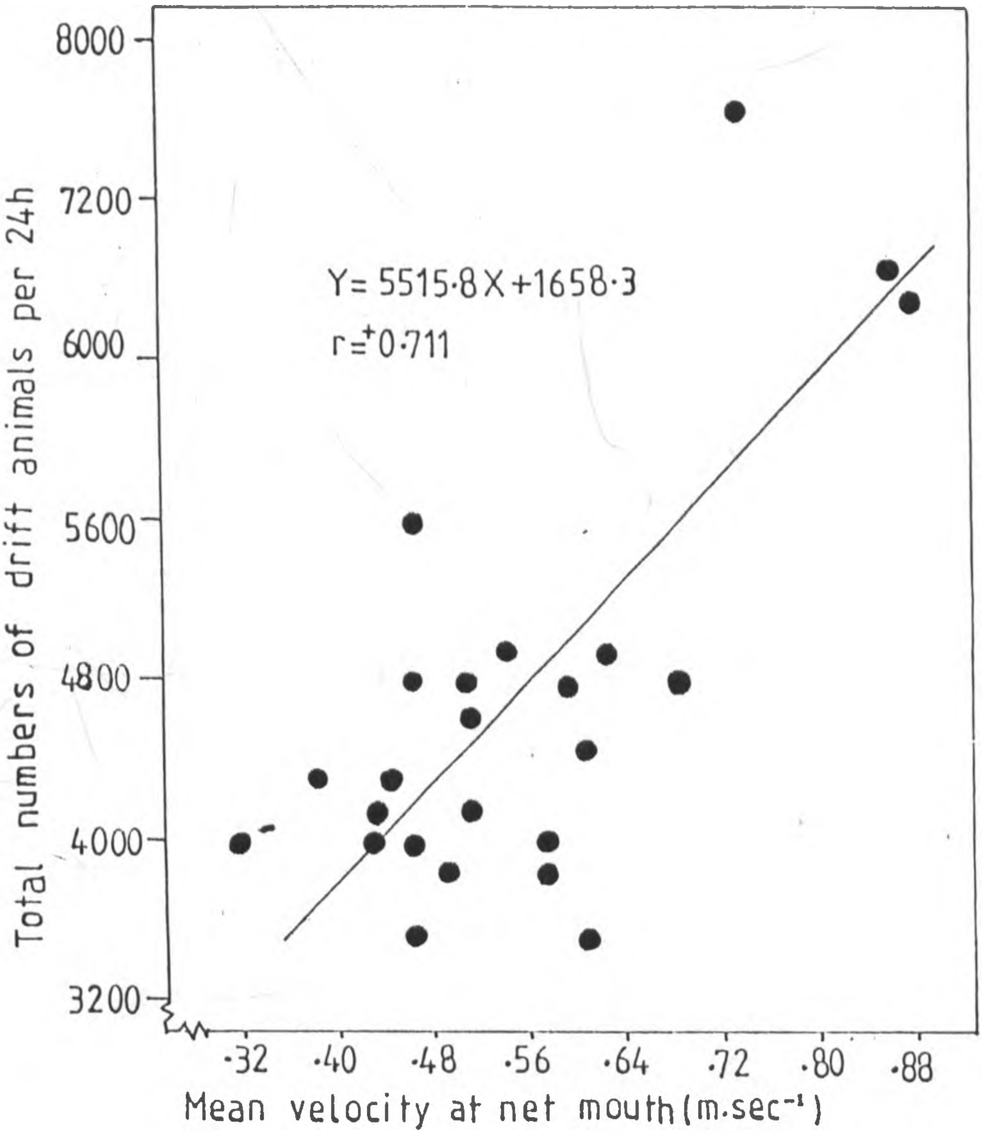


FIGURE 23. The relationship between mean velocity at net mouth and the total numbers of drift animals per 24h. in Naro Moru River

6.1.8 Benthic fauna abundance

All species collected from the bottom samples were also taken in the drift samples. Orthoptera were taken in the drift and not in the benthos. This was expected since they have no aquatic life stage. The drift numbers of Orthoptera were negligible. Tricladida, mostly Dugesia sp., were also taken in the drift. Table 27 includes all taxa collected from both the drift and bottom samples from November 1986 to October 1987.

The percentage composition of the drift fauna showed some variations from that of the benthos. The proportions of Baetis spp. in the drift were greater than those in the benthos, whereas the converse was true of Simulium sp. Figure 24 shows the relationship between drift fauna and benthos. It shows that when the benthic abundance was high there was a corresponding increase in the drift ($r_s = 0.76$, $P \leq 0.01$). The drift was high in January and June 1987. This was at the height of the rain seasons and high river discharge. In periods of low benthic density the drift fauna was correspondingly low. Table 28 shows the proportion of bottom fauna present in the drift samples. The proportion of the benthos in the drift was calculated using the modified formula x/(X-x) used by Radford

TABLE 27. Percentage composition of pooled numbers of drift animals and pooled numbers of benthic animals at the time of maximum colonization in Naro Moru River, 1986-1987

	Drift		Benthos	
Taxa	Pooled total	%	Pooled total	%
EPHEMEROPTERA				
Baetis spp.	57529	50.91	1282	15.66
Afronurus sp.	3087	2.73	274	3.35
Rhithrogena sp.	1336	1.18	186	2.27
Caenis sp.	7151	6.33	70	0.85
Euthraulus sp.	3979	3.52	182	2.22
Centroptilum sp.	88	0.08	2	0.02
DIPTERA				
Simulium sp.	7601	6.73	4501	54.97
Limnophora sp.	3549	3.14	128	1.56
Diamesa sp.	4264	3.78	392	4.79
Dicranota sp.	350	0.31	49	0.60
Ceratopogonidae	306	0.27	27	0.33
Tanypodinae	1589	1.41	152	1.86
Culicidae	1044	0.92	21	0.26
Others	908	0.80	16	0.20
TRICHOPTERA				
Chimarrha sp.	145	0.13	33	0.40
Hydropsyche sp.	403	0.36	176	2.15
Hydroptila sp.	175	0.16	15	0.18
COLEOPTERA	1506	1.33	35	0.43
HEMIPTERA	8666	7.67	336	4.10
HYMENOPTERA	5765	5.10	29	0.35
ARACHNIDA				
Hydrachnellae	3061	2.71	174	2.13
TURBELLARIA	14	0.01	84	1.03

TABLE 27. cont'd

CRUSTACEA	78	0.07	8	0.10
PLECOPTERA				
Neoperla sp.	101	0.09	9	0.11
ISOPTERA	26	0.02	1	0.01
ANNELIDA	190	0.17	2	0.02
ODONATA	15	0.01	3	0.04
MOLLUSCA	65	0.06	1	0.01
ORTHOPTERA	3	0.00	0	0.00

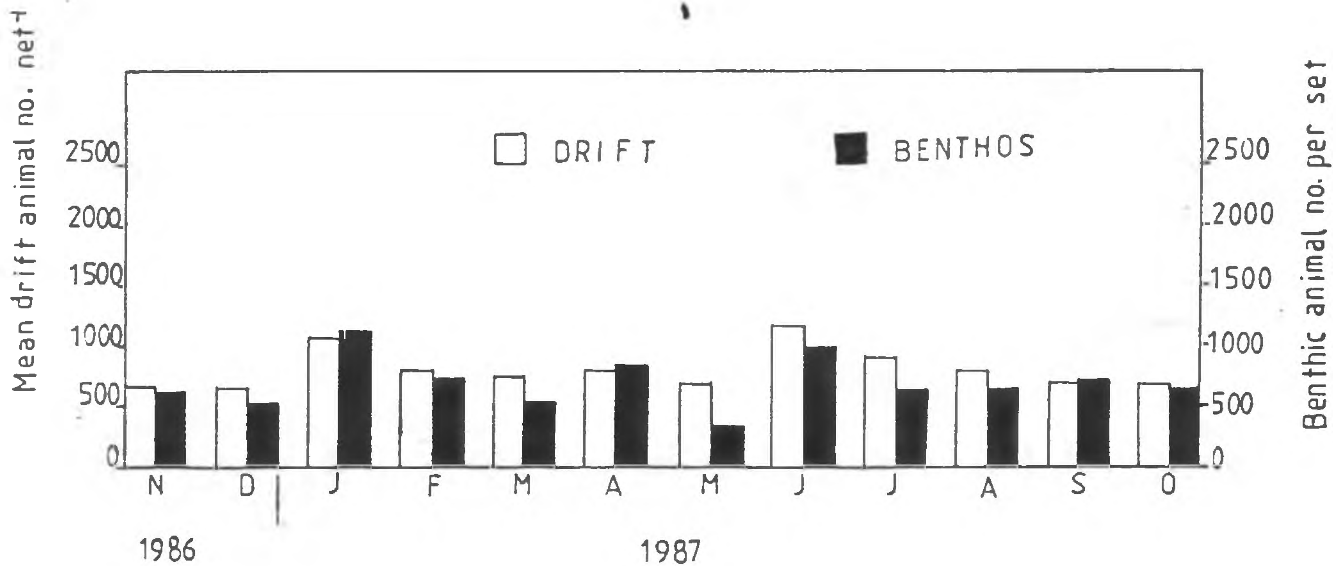


FIGURE 24. The relationship between invertebrate drift and benthic abundances in Naro Moru River

TABLE 28. The proportion of benthos present in drift samples in Naro Moru River, 1986-1987

Month		Mean river discharge ($m.^3sec^{-1}$)	Drift density (No. m^{-3})	Benthos+ (No.set^{-1})	Proportion of benthos in drift
November	1986	0.526±0.260	0.33	612	0.0005
December	1986	2.669±1.181	0.22	507	0.0004
January	1987	3.690±0.259	0.30	1103	0.0003
February	1987	1.077±0.107	0.29	727	0.0004
March	1987	0.333±0.139	0.34	523	0.0007
April	1987	1.007±0.575	0.24	836	0.0003
May	1987	2.044±0.110	0.23	321	0.0007
June	1987	2.813±0.267	0.26	966	0.0003
July	1987	0.863±0.462	0.36	623	0.0006
August	1987	0.448±0.074	0.32	623	0.0005
September	1987	0.544±0.199	0.32	703	0.0005
October	1987	0.427±0.120	0.28	644	0.0004

\+ Benthos collected on the tenth day of exposure of artificial substrate baskets (i.e. the time of maximum colonization)

"Set" means two artificial substrate baskets retrieved on the tenth day (the data for the two baskets were pooled to obtain number per set).

and Hartland-Rowe (1971) where x = numbers per m^3 in the drift and X = numbers of benthic animals per set. The values obtained were rather low. However, it should be noted that the drift animals used for the comparison with the benthos might not necessarily have originated from the immediate benthos but might have originated some distance upstream.

6.2 Discussion

6.2.1 Light intensity - sunlight and moonlight

Hughes (1970) found that light was a dominant factor controlling the behaviour of many aquatic nymphs and larvae especially Ephemeroptera. The fact that light intensity played a significant role in the drift of invertebrates in Naro Moru River was in agreement with other studies carried out elsewhere. The numbers of drift increased as light intensity decreased making night drift to be higher than day drift. Negative phototaxis served to maintain the organisms in areas of low light intensity during the day. Linked to this were the strong positive thigmotaxis which has been observed in many benthic forms, the definite orthokinesis during periods of light and the positive skototaxis observed by Hughes (1966). These mechanisms resulted in the firm attachment of most of the riverine fauna to the undersides of the gravels and pebbles during daytime. Hughes (1966) found that Simulium, Baetis and Rhithrogena did not avoid the light but were generally inactive once they found a microniche in which suitable current conditions overrode orthokinetic responses. Nymphs of Baetis were described by Hughes (1966) to have dorsal light response and this may be common to swimming benthic fauna for maintaining orientation. Without this control, in darkness, nymphs become disequilibrated and are unable to "land" properly after swimming. This may explain the higher night drift rate of Baetis spp. observed in Naro Moru River and other mayflies that are known to be more active at night. Chaston (1969) showed that Simulium, Isoperla and Ephemerella have fluctuating innate rhythms of activity which are suppressed by light. The onset of darkness releases the rhythm and the animals drift most readily at their times of peak activity of which there may be one or more depending upon the length of the cycle and the duration of the night especially in the temperate latitudes. The decrease in drifting invertebrates which occurred just before sunrise in Naro Moru River was a gradual drop which indicated that the organisms' reattachment to the substrate was an active response to conditions of changing light.

Holt and Waters (1967) discussed the problems involved in determining threshold intensities of light that set the activitiy phase, and concluded that since drift response to light changes is not immediate, drift cannot be used to delimit these values. The relative position of the organism, whether on top of the substrate in a suprathreshold intensity, or under a rock in a subthreshold intensity, determines the delay in its response.

As light is clearly involved in much of the behaviour of riverine invertebrates it is understandable that it has been reported that nocturnal illumination, or even full moon, reduces the amount of drift, and that artificial darkening before nightfall brings the maximum night drift forward (Anderson 1966). Moonlight has been shown to have a depressant effect in some rivers and not in others. Generally, it did not have a depressant effect on the drift fauna in Naro Moru River partially due to the presence of a dense canopy upstream of the study site and partially due to the intermittent occlusions of the moon.

6.2.2 River discharge and water current velocity

Horton (1961) and Bailey (1966) reported high drift numbers at times of spate and Van Someren (1952) reported large numbers of Simuliidae and Baetidae carried by spates on Mt. Kenya in East Africa. The present investigation indicated that whenever there was a high discharge there was a corresponding increase in the drift numbers as surface crevices and leaf and twig habitats were being disturbed. The only instances in the present study when such a phenomenon could have occurred was in January and June 1987. Although flow rates were not unusually strong, the drift rates were high and there was a marked increase in the benthos from the previous month. However, the drift density did not increase with increasing river discharge. The presence of a low drift density of 0.19 to 0.42 animals per m^3 was not a surprise since these compared favourably with other estimates made in the tropics (1.56-1.79 in Malaya (Bishop 1973); 0.1-1.9 in Ghana (Hynes 1975); 0.03-0.49 in Florida (Cowell & Carew 1976) and 0.85-3.28 in Ecuador (Turcotte & Harper 1982)).

Elliott (1967a) hypothesized that current velocity contributes to the magnitude of the drift of a population by dislodging a certain number of individuals. Under conditions of high current velocity, the probability of dislodgement is increased and proportionately more individuals enter the water column. However, Cordone and Kelley (1961) found that some of the fauna were capable of moving down into the vacant interstitial areas created by the removal of silt and detritus. This was also observed in Naro Moru River during the present study. The benthic density was high during the times of high discharge in January and June 1987. In April 1987 there was also an increase in discharge and this led to an increase in benthic density in that month. From field observations by Bishop and Hynes (1969) the zone where the benthos is concentrated may be 10-15 cm. below the normal surface level after a flood. This hyporheal biotope at a dynamic depth may harbour the fauna for considerable periods after a spate. But since the benthos in Naro Moru River seemed to be high during the time of high discharge it is suggested here that the number of animals collected during high discharge, though high, was an underestimation since the behaviour of much of the benthic fauna seemed to be such as to reduce their likelihood of being carried into the drift as current velocities increased with increased discharge. This would only happen provided the rate of water flow did not rise above a critical level. The high river discharges were not strong enough to scour, crush and roll the stones but were able to remove the silt and leaf and twigs from the river bed. However, the few animals which happened to be caught up by the high discharges increased the drift numbers. This gradual erosion of the animals as the flood persisted led to reduction of the benthos in the subsequent samplings. Egglishaw (1964) found that the fauna returns to the surface layers as detritus and the microflora are replenished in these areas and Bishop and Hynes (1969) found that this process may take 6-8 weeks, a period labelled as recovery time. Generally, it is far from being clear whether the appearance of animals in the drift is due simply to their being dislodged mechanically or represents a positive migratory activity. Catastrophic drift seemed to be responsible for the high drift rates during the times of high river discharge in Naro Moru River.

6.2.3 Dissolved oxygen concentration

As expected the dissolved oxygen concentration was in all cases high. This was as a result of the water being added from the melt ice from the mountain and the cascading flow of the water. But since oxygen concentration was in most cases high, it did not play an important role in the number of animals drifting. There was no time when there seemed to be an oxygen stress to the animals which would suggest an increase in drift. Oxygen is rarely a factor in the ecology of invertebrates in unpolluted waters because it hardly drops to low levels (Hynes 1972). In small turbulent rivers, like Naro Moru River, the oxygen is normally near, or above, saturation.

6.2.4 Turbidity

Turbidity was high during the rain seasons and low during the dry seasons. Turbidity increased with the increase in discharge. The effect of turbidity on the numbers of drift fauna was difficult to envisage since its role was being overshadowed by discharge.

6.2.5 Water temperature

Naro Moru River had a rise in temperature during the dry season reflecting the influence of air temperature. With a rise in temperature, increases in drift would be expected, especially when coupled with increased invertebrate activity. However, effects of temperature on drift rates as reported by Waters (1968) may be significant in specific populations, notably in light indifferent Trichoptera or positively phototactic insects like Baetis. In the present study the water temperature was being moderated by ice-melt water from the mountain. Lack of significant effect of water temperature on drift rates could be explained by the moderating effect of the ice-melt water.

6.2.6 pH and conductivity

The pH of Naro Moru River indicated that this was a well buffered river system. The pH of Naro Moru River was comparable to that of Nzoia River (7.3-7.8) and Gilgil River (7.1) (Njuguna 1978). The marked fall in pH observed during high water was probably caused by an influx of organic matter and free CO_2 from runoff. There was a decrease in pH and an increase in conductivity on 26/27 November 1986 and at this time the discharge was high. This could have been as a result of the flushing out of the accumulating soluble substances from the soil of the forest floor which accumulated during the dry season. The acidity of the water issuing from the soil into the river was probably due to the acquisition of soluble organic acids generally found in humus and decaying plant material, and possibly also to cation base exchange with the organic matter in the soil, as suggested by

Hynes (1970). It is difficult, from field studies, to distinguish the effects of high concentrations of hydrogen ions from those of generally low base-content (Hynes 1972). From the results obtained from the present study pH seemed to have negligible effect on the drift rates and densities. Its failure to have a significant effect could be explained by its being overshadowed by other factors such as river discharge.

As expected, electrical conductivity showed an inverse correlation with volume flow because flood waters diluted the concentration of soluble electrolytes. The conductivity was at a minimum of 22.0 $\mu mhos.cm^{-1}$ during the second rain season whilst towards the end of the second dry season it attained a value of 69.0 $\mu mhos.cm^{-1}$ as a result firstly of the reduced water flow which allowed more time for salts from the rocks and soil to dissolve in the water, and secondly of mineralization from decay of the accumulating plant material in the river. Like pH, the role played by conductivity was difficult to envisage. It seemed as if its role was overridden by that of discharge.

6.2.7 Benthic fauna abundance

As Waters (1972) pointed out, there does not exist a particular drift fauna and most of the benthic organisms will at one time or another be picked up in the drift. In the present study all the organisms in the benthos were also picked up in the drift emphasizing that there does not exist a "drift fauna" as distinct from bottom fauna.

The correlation between benthic density and drift fauna is still not clear. The question remains whether certain species drift more because they occur at higher densities in the substrate or simply because they have a greater tendency to drift. Direct relationship between drift rate and benthic density was observed by Lehmkuhl and Anderson (1972). The presence of a correlation between drift rate and benthic density in the present investigation was therefore not surprising. In the present instance it could be concluded only that drift was limited when there was a small benthic population although there was a small proportion of benthos in the drift at any particular time. The relationship between drift and benthic density was made complicated by the behaviour of the organisms which tended to move into the substrate interstices during high river discharge.

CHAPTER 7

DRIFT FAUNA AS POTENTIAL FOOD FOR FISH

7.1 Results

7.1.1 Composition of trout diet

The only species of fish found in Naro Moru River is rainbow trout, *Salmo gairdneri* Richardson, 1836 (Genus *Salmo* Linnaeus, 1738), Family Salmonidae.

Virtually all aquatic vertebrates move to locate and/or consume food. The relative importance of location versus consumption of food depends on item-specific characteristics (Webb 1984). An important feature of the food of the trout in Naro Moru River was that some of the invertebrate material was in small fragments, for example, pieces of head capsules, pieces of legs, wings or elytra, but there were some whole invertebrates or identifiable remains. Furthermore, some of the fragments were heavily chitinized and probably of terrestrial origin. The fragmentary nature of the gut contents could have been due not only to the action of the vomerine teeth possessed by the trout, but also to the fragmentary nature of some of the invertebrate remains in the river and those which fall from the overhanging trees into the river.

The trout in Naro Moru River fed mostly on Diptera, Ephemeroptera, Trichoptera, Coleoptera, Hymenoptera, Hemiptera, Crustacea and Isoptera (Table 29). Others encountered in the fish gut included Arachnida, Annelida, Mollusca, Plecoptera, Orthoptera and Odonata. In some guts, inedible items such as sticks, stones, plant seeds and feathers were also found.

Among the Ephemeroptera, Baetis spp., Afronurus sp. and Caenis sp. were the most important genera in the fish guts. Simulium sp. was the most important food item among the Diptera and even when all the food items were considered.

The chief source of energy to most stream communities is in the form of allochthonous organic matter and tree canopies form a source of terrestrial invertebrates falling into streams. These terrestrial invertebrates form a substantial part of the diet of salmonid fish. Mason and Macdonald (1982) found that terrestrial invertebrates were equivalent to 5-10% by weight of the litter input to streams. Food of terrestrial origin formed a very important portion of the total food taken by trout in Naro Moru River. It formed 13.51% of the total trout food in the present study. This terrestrial food source comprised of Orthoptera, Isoptera, Arachnida, Hymenoptera and Coleoptera.

TABLE 29. Seasonal variation in the diet of trout in Naro Moru River, November 1986 - October 1987

	1986	1987												
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Total	% total
Number of fish analysed	54	56	48	43	30	60	30	27	18	40	36	19	461	
EPHEMEROPTERA														
Baetis spp.	348	360	324	346	502	438	397	317	264	311	298	222	4127	17.13
Afronurus sp.	81	94	80	146	462	104	301	263	197	123	93	61	2005	8.32
Rhithrogena sp.	70	59	11	18	32	11	20	19	9	9	51	83	392	1.63
Caenis sp.	110	115	56	79	74	96	123	87	46	37	40	97	960	3.99
Euthraulus sp.	84	91	5	18	0	35	11	20	3	11	49	68	395	1.64
Centroptilum sp.	48	63	27	46	32	7	15	36	13	9	22	33	351	1.46
DIPTERA														
Simulium sp.	1061	772	475	52	126	1038	787	1121	878	933	713	567	8523	35.38
Limnophora sp.	0	2	6	5	44	20	11	8	13	2	7	3	121	0.50
Diamesa sp.	13	23	41	11	16	41	20	16	25	17	10	15	248	1.03
Ceratopogonidae	14	7	3	0	6	10	2	4	11	3	3	5	68	0.28
Tanypodinae	14	14	25	5	17	28	21	24	16	9	11	19	203	0.84
Culicidae	5	8	6	0	14	15	13	6	8	11	0	2	88	0.37
Dicranota sp.	14	36	25	13	24	12	3	27	13	13	7	13	200	0.83
Others	51	65	246	63	50	27	43	54	32	17	20	33	701	2.91

TABLE 29. cont'd

TRICHOPTERA					
Chimarrha sp.	35	20	1	0	0
Hydroptila sp.	28	21	0	0	0
Hydropsyche sp.	0	10	25	49	63
COLEOPTERA	38	84	95	89	62
HYMENOPTERA	191	312	245	208	288
HEMIPTERA	87	89	31	29	36
ARACHNIDA					
Hydrachnellae	20	13	9	9	3
ANNELIDA					
Hirudinea	4	4	2	0	0
Oligochaeta	20	27	2	4	0
MOLLUSCA	7	7	17	4	21
PLECOPTERA					
Neoperla sp.	7	3	0	0	0
CRUSTACEA	28	28	45	64	32
ISOPTERA	32	137	5	2	0
ORTHOPTERA	2	4	5	6	6
ODONATA	0	0	2	3	6
	2412	2468	1814	1269	1916

12	3	7	4	1	0	3	86	0.36
0	1	5	2	4	11	21	93	0.39
9	7	16	19	11	8	0	217	0.90
75	56	41	44	23	49	40	696	2.89
210	297	275	263	188	201	167	2845	11.81
35	32	76	51	43	22	100	631	2.62
12	16	20	15	11	8	13	149	0.62
2	1	1	0	1	3	6	24	0.10
2	5	10	9	4	4	11	98	0.41
8	11	7	13	3	3	4	105	0.43
0	4	1	5	0	0	1	21	0.09
36	25	33	27	24	22	28	392	1.63
9	11	46	21	0	0	7	270	1.12
4	7	5	9	1	3	0	52	0.22
2	3	5	3	0	1	1	26	0.10
2298	2246	2550	2013	1819	1659	1623	24087	100.00

Naro Moru River is forested along its banks. Canopies are also present formed by the riparian vegetation. From these trees and shrubs there inhabits ants, spiders, grasshoppers, beetles and others. However, Hymenoptera, Formicoidea, were taken in far greater quantities than the other terrestrial food sources. In the present study Hymenoptera comprised 11.81% of the total food items. Tree haunting ants of other species were not uncommon in the guts of trout. Beetles of various kinds also formed an important terrestrial food source (2.89%) and were common inhabitants of the forest floor and readily fell into the water. Isoptera and Orthoptera comprised only 1.12% and 0.22% respectively. The composition of the terrestrial foods was clearly a reflection of the forested bank environment of Naro Moru River and this emphasized the fact that debris from the forest canopy could also be an important source of nutriment to trout.

7.1.2 Seasonal variation of aquatic and terrestrial trout diet.

Table 29 shows the seasonal variation in the diet of trout in Naro Moru River from November 1986 to October 1987. Among the Ephemeroptera, Baetis spp., Afronurus sp. and Caenis sp. were the most important food items, comprising 17.13%, 8.32% amd 3.99% of the yearly total for all the food items respectively. Other Ephemeroptera included Rhithrogena sp. (1.63%), Euthraulus sp. (1.64%) and Centroptilum sp. (1.36%). This indicated that Ephemeroptera comprised 34.17% of the total food items consumed by trout. The trout was feeding more on Baetis spp. in February and March 1987 and the least in November 1986 and in June, July and October 1987. It fed on Afronurus sp. in March and on Rhithrogena sp. in October although the percentages were relatively uniform throughout the year. Caenis sp. also showed uniform percentage values although trout seemed to feed on it mostly in February and May 1987. Euthraulus sp. was consumed more in November and December 1986 and September and October 1987. The consumption of Centroptilum sp. by trout seemed to be throughout the year although there was intensified feeding on it in February 1987. Close examination of the data and Figure 25 indicates that there was no clear evidence that there was seasonality in feeding of trout as concerns Ephemeroptera. The trout fed on Ephemeroptera throughout the year with peak feeding activity in February and March 1987 when the water was less turbid.

Diptera formed the highest percentage of the total items consumed by trout. They comprised 42.14% of the total annual food consumed by the

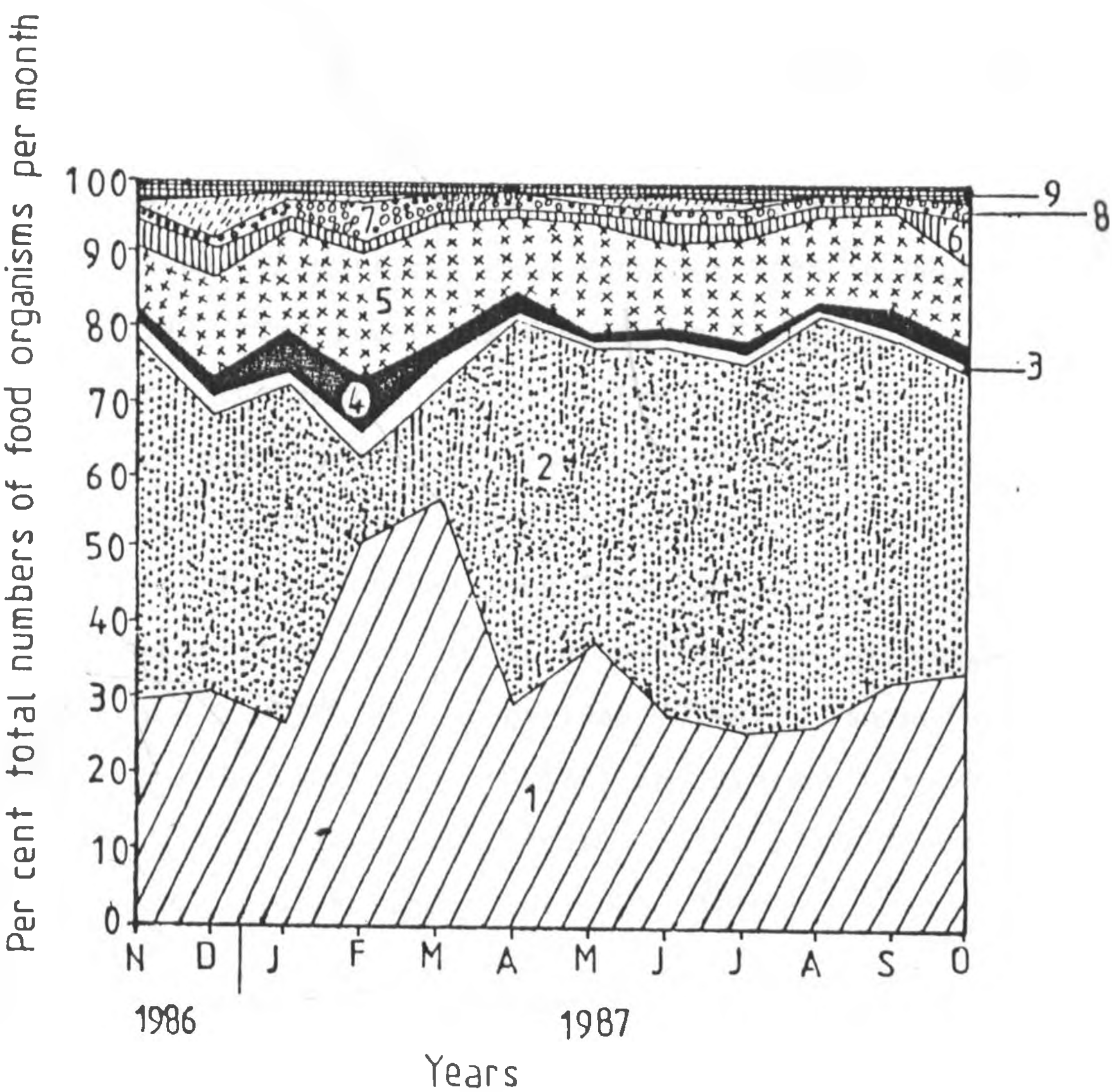


FIGURE 25. Trout food composition (per cent total) and seasonal variation of the dominant food organisms in Naro Moru River, 1986-1987. 1-Ephemeroptera, 2-Diptera, 3-Trichoptera, 4-Coleoptera, 5-Hymenoptera, 6-Hemiptera, 7-Crustacea, 8-Isoptera, 9-Others

trout. This was interesting since the majority of the Diptera were not actively moving in the water like the current-loving Baetis spp. However, Simulium sp. was the dominant food item and contributed 35.38% of the total food items consumed by the fish from November 1986 to December 1987. The trout was feeding on Simulium sp. throughout the year except in February and March 1987 when the percentages were low. At this time the food items were dominated by Baetis spp. The only other important dipteran food item included was Diamesa sp. comprising only 1.03%; others such as Limnophora sp.(0.50%), Ceratopogonidae (0.28%), Tanypodinae (0.84%), Culicidae (0.37%) and Dicranota sp. (0.83%) comprised low proportions. "Others" included adult Diptera and comprised 2.91%.

The trout consumed much of Limnophora sp. in March (2.3%). However, it seemed that the trout fed on this food item uniformly throughout the year. Diamesa sp. showed the same trend as Limnophora sp. having as its highest value of the total food items as 2.3% in January 1987. Ceratopogonidae were not an important food source for trout although consumption was uniform throughout the year with the highest percentage (0.6%) in November and complete absence in February. Tanypodinae seemed to be well placed as a food source than Ceratopogonidae but the proportions were low, the highest being 1.4% in January and the lowest 0.4% in February 1987. Culicidae had low values and were also not an important food source for the fish. Dicranota sp. was consumed somewhat uniformly throughout the year.

Trichoptera, though not as important as Ephemeroptera and Diptera, comprised 1.65% of the food items. Hydropsyche sp. dominated the whole order with only 0.90%. The other members were Chimarrha sp. (0.36%) and Hydroptila sp. (0.39%). Chimarrha sp. formed low percentages throughout the year with the trout feeding more on it in November 1986. Consumption of Hydroptila sp. by the trout followed the same trend. There was a uniform consumption of Hydropsyche sp. throughout the year. Trichoptera did not seem to be a very important source of trout food.

Generally, Coleoptera formed an important food source to trout. Most of them were hydrophilids but very few dytiscids and elmids were encountered. Coleoptera formed 2.89% of the total food items in the fish. In most cases whole beetles were encountered in the gut of the trout. There was no definite annual variation in trouts' feeding on this food item.

Other food items in the gut of the trout included Hemiptera (2.62%), Arachnida especially the water mites, Hydrachnellae (0.62%), Annelida which included Hirudinea (0.10%) and Oligochaeta (0.41%), Mollusca comprising mostly Ancylastrum sp. (0.43%), Plecoptera, Neoperla sp. (0.09%), Crustacea, Potamon sp. (1.63%) and Odonata, both Anisoptera and Zygoptera (0.10%). Isoptera (1.12%) and Orthoptera (0.22%) were also present. Most of these appeared sporadically in the food of trout. However, they contributed an important proportion of the food for trout.

7.1.3 Availability and selection of terrestrial and aquatic drift food sources by trout

When a prey species is abundant in a habitat it does not necessarily form an important part of the diet of a fish which eats it (Hynes 1972). Fish are to some extent selective in what they eat, and once a particular specimen has started feeding on one type of organism it tends to continue to do so.

Table 30 indicates the values of numerical method, availability factor and electivity index of the trout gut contents. Among the Ephemeroptera, Baetis spp. showed the highest value (17.13%) for the numerical method. Afronurus sp. and Caenis sp. showed values of 8.32% and 3.99% respectively.

TABLE 30. Analyses of the diet of trout in Naro Moru River using numerical method (NM), availability factor (AF) and electivity index (E)

Food organism	% fish gut contents	% drift	NM	AF	E
EPHEMEROPTERA					
Baetis spp.	17.13	50.91	17.13	0.3	-0.5
Afronurus sp.	8.32	2.73	8.32	3.0	+0.5
Rhithrogena sp.(?)	1.63	1.18	1.63	1.4	+0.2
Caenis sp.	3.99	6.33	3.99	0.6	-0.2
Euthraulus sp.	1.64	3.52	1.64	0.5	-0.4
Centroptilum sp.	1.46	0.08	1.46	18.3	+0.9
DIPTERA					
Simulium sp.	35.38	6.73	35.38	5.3	+0.7
Limnophora sp.	0.50	3.14	0.50	0.2	-0.7
Diamesa sp.	1.03	3.78	1.03	0.3	-0.6
Ceratopogonidae	0.28	0.27	0.28	1.0	0.0
Tanypodinae	0.84	1.41	0.84	0.6	-0.3
Culicidae	0.37	0.92	0.37	0.4	-0.4
Dicranota sp.	0.83	0.31	0.83	2.7	+0.5
Others	2.91	0.80	2.91	3.6	+0.6
TRICHOPTERA					
Chimarrha sp.	0.36	0.13	0.36	2.8	+0.5
Hydroptila sp.	0.39	0.16	0.39	2.4	+0.4
Hydropsyche sp.	0.90	0.36	0.90	2.5	+0.4
COLEOPTERA	2.89	1.33	2.89	2.2	+0.4
HYMENOPTERA	11.81	5.10	11.81	2.3	+0.4
HEMIPTERA	2.61	7.67	2.62	0.3	-0.5
ARACHNIDA					
Hydrachnellae	0.62	2.71	0.62	0.2	-0.6
ANNELIDA					
Hirudinea	0.10	0.04	0.10	2.5	+0.4
Oligochaeta	0.41	0.13	0.41	3.2	+0.5
MOLLUSCA	0.43	0.06	0.43	7.2	+0.8

TABLE 30 cont'd

PLECOPTERA					
Neoperla sp.	0.09	0.09	0.09	1.0	0.0
CRUSTACEA	1.63	0.07	1.63	23.3	+0.9
ISOPTERA	1.12	0.02	1.12	56.0	+1.0
ORTHOPTERA	0.22	0.00	0.22	0.0	+1.0
TURBELLARIA	0.00	0.01	0.00	0.0	-1.0
ODONATA	0.10	0.01	0.10	10.0	+0.8

Other members of the same group included *Rhithrogena* sp. (1.63%), *Euthraulus* sp. (1.64%) and *Centroptilum* sp. (1.46%). However, availability factor values indicated that although *Baetis* spp. had the highest numerical method value, it had an availability factor value of 0.3. This indicated that *Baetis* spp. was being rejected by the fish. This was further emphasized by the electivity index of -0.5. This showed that the food was not being selected by the fish. Although *Baetis* spp. constituted the largest percentage of the total drift for the whole year (50.91%), they formed only 17.13% in the fish gut. This indicated that although present in large numbers in the environment they were not being consumed in a corresponding proportion. *Centroptilum* sp. had the highest availability factor value of 18.3. However, it formed the lowest drift percentage (0.08%) among the ephemeropteran members. It also yielded the highest electivity index value (+0.9). It was preferentially selected and the trout needed it most as compared to the other ephemeropteran members. *Afronurus* sp. and *Rhithrogena* sp. were also preferentially selected with availability factor values of 3.0 and 1.4 and electivity index values of +0.5 and +0.2 respectively. *Caenis* sp. and *Euthraulus* sp. contributed substantial values for numerical method (3.99% and 1.64% respectively) and yet they were being rejected by the fish. Electivity index values for these food items were $^-0.2$ and $^-0.4$ respectively. Generally, Ephemeroptera were being preferentially rejected (availability factor = 0.5) and not being selected by the trout (electivity index = $^-0.3$) (Figure 26).

Diptera were also important food items for the trout. Simulium sp. comprised 35.38% of the total gut contents of all fish examined. It comprised only 6.73% of the total drift. However, it was preferentially selected by the fish and had an availability factor value of 5.3. It had an electivity index value of $^+0.7$. This showed that the fish consumed it whenever it was available in the drift. Dicranota sp. was also being selected by the trout and had an availability factor value of 2.7 and electivity index value of $^+0.5$. Ceratopogonidae was being selected although it was not an important food source for the trout. Other dipterans were all being rejected. Such food items included Limnophora sp., Diamesa sp., Tanypodinae and culicidae. Diptera had the highest value for the numerical method (42.14%) of all the food items for the whole year. They were preferentially being selected by the fish (availability factor = 2.4) and were also being sought for by trout (electivity index = $^+0.4$). Therefore Diptera were a very important food item

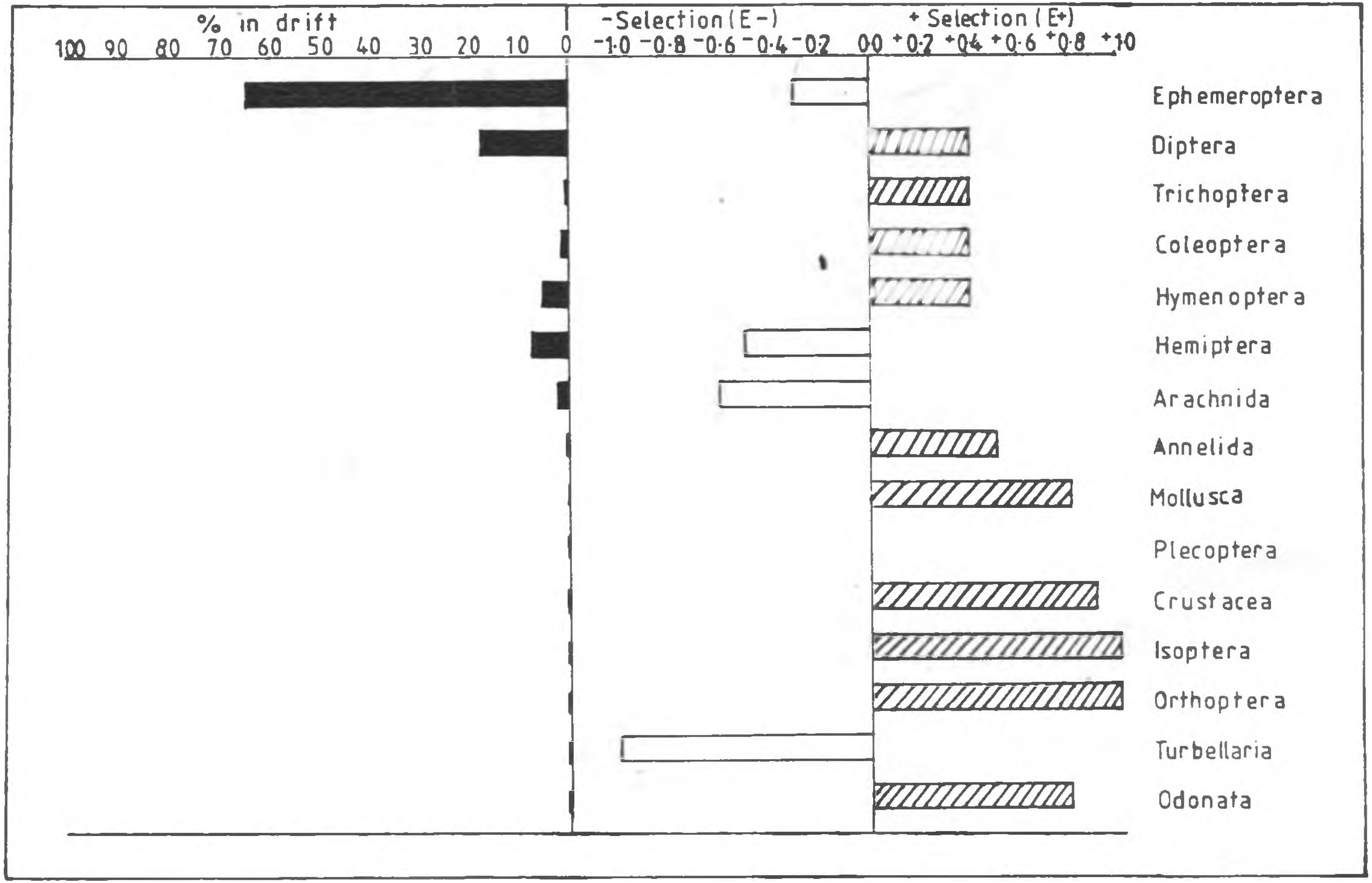


FIGURE 26. Food selectivity by trout in Naro Moru River using electivity index (E)

for the trout.

Chimarrha sp., *Hydroptila* sp. and *Hydropsche* sp. were all being preferentially selected by the fish with availability factor values of 2.8, 2.4 and 2.5 respectively although they contributed very low values of 0.36%, 0.39% and 0.90% respectively for the numerical method. Trichoptera had a value of 1.65% for numerical method, 2.8 for availability factor and $^{+}0.4$ for the electivity index.

Coleoptera and Hymenoptera were all being preferentially selected by trout. Hemiptera, though present at a high percentage in the drift (7.67%) and in the gut (2.61%), was being rejected by the fish. This also applied to Hydrachnellae. Others which were being preferentially selected included Hirudinea, Oligochaeta, Mollusca, Crustacea, Isoptera and Odonata. Turbellaria were totally rejected by the fish. Orthoptera were rare food items in the environment and once available, especially during the rains, were highly consumed by the trout. From the foregoing information it was found that there was no significant correlation between fish gut contents and drift (r_s = 0.18, $P > 0.05$) and also between fish gut contents and benthos (r_s = 0.07, $P > 0.05$).

7.2 Discussion

The most widespread and important foodstuffs of running-water fishes is undoubtedly invertebrates which form most of the diet of a great range of types of fish. The range of invertebrates eaten is very wide; most species are very catholic in their diet, and in general it can be said that they eat what is available. There are, however, some fairly well-defined influences of feeding habits on the diets. Feeding varies to some extent with the season and the availability of food. The changing seasons also indicate very clearly that fishes are very opportunist and eat what is available at the time.

The invertebrates drifting down from small rivers such as Naro Moru River provide an important source of food for the fish living there, especially since salmonids are dependent on drift for nutrition (Elliott 1973). The results of the present study provide an evidence that rainbow trout, *Salmo gairdneri* Richardson was feeding on invertebrate drift and the benthos in Naro Moru River.

Tree canopies form a source of terrestrial invertebrates falling into streams and it is known that invertebrates of terrestrial origin form a substantial part, at least seasonally, of the diet of salmonid fish (Hunt 1975). Terrestrial food was a very important diet item for the trout and this formed 13.51% of the total trout food in the present study. The only possible explanation for this large percentage was the presence of the riparian vegetation which was inhabited by ants, spiders, grasshoppers and termites and beetles were found on the forest floor. The largest proportion was provided by Hymenoptera. These are common in forest land, and much addicted to forming living bridges over small stretches of water, and climbing trees overhanging the river in order to cross from where they are easily dislodged into the water (Van Someren 1952). Terrestrial invertebrate input was maximal just before and at the first rain fall and such animals, in an alien environment, were easy prey to fish. In terms of food for fish, terrestrial invertebrates might be better compared with stream invertebrates (Mason et al. 1982). Egglishaw (1967) found that Diptera, Hemiptera and Hymenoptera made up 50% of the diet of brown trout, Salmo trutta L. in one Scottish stream and 80% in another. These three taxa comprised 57% of the diet of rainbow trout, Salmo gairdneri Richardson in Naro Moru River. Hunt (1975) stressed the importance of terrestrially derived food in the diets of salmonids and could sometimes account for anything up to 90% of the food at certain times.

Bailey (1966), Elliott (1967) and Maciolek and Needham (1952) compared fish stomach contents with the composition of drift and benthos and found selective feeding on drift. However, the degree of such selectivity differs among fish species as found by Keenleyside (1962) and Müller (1954). Warren et al. (1964) found that there was a varying utilization of bottom foods as well as drift. Therefore, the selectivity by trout in the present study was in line with previous findings elsewhere. Salmonids, particularly, select and defend territories which are best suited for the interception of drift. Jenkins (1969) and Mason (1969) found that the size and location of the territory is determined by the drift density and patterns of drift in the water currents.

The composition of the diet of the trout in the present investigation was similar to that of drift and benthos. Simulium sp. was the most important food item and formed the largest proportion in the benthos and Baetis spp. formed the largest proportion in the drift. In February and March 1987 the trout fed more on Baetis spp. although Simulium sp. continued to be a major food item throughout the year. It was because of the trout's selectivity that Simulium sp. was very important as a food item. The reason why Baetis spp.

was a major food item in February and March 1987 was because of the water clarity which made it easier for the trout to see the ever active mayfly. Close examination of the results, therefore indicated that the trout concentrated more on Diptera as the major food source.

Chaston (1968) suggested that correlations of feeding and drift may be due to the fish foraging, from the tops of rocks, those kinds of organisms that are also in the drift, but not feeding on the drift itself. In the present study there was lack of correlation between trout food and drift. This was not surprising since similar results were obtained by Chaston (1969) where he reported lack of such correlation. One of the possible reasons why there was lack of correlation could have been the high selectivity shown by the trout. Baetis spp. which formed the highest proportion in the drift was not being utilized according to its proportion in the drift. The trout was feeding more on Simulium sp. which was very abundant in the benthos but not so abundant in the drift. Most of the drift organisms did not form important food sources for the trout. This still emphasized the high selectivity portrayed by trout in Naro Moru River. It was this imbalance in the utilization of the drift organisms which could be the plausible explanation for the lack of correlation between trout diet and drift. However, the general picture which emerged of the feeding habits of trout was a fish which could utilize a wider range of food materials, both in the drift and benthos, although in different proportions. It was dependant on the drift fauna, benthos and on the debris and animals which fall from the forest canopy. The fish did not seem to suffer an acute shortage of food at any time of the year as most of the fish analysed had full stomachs. It was feeding throughout the year and there was no evident seasonality in the feeding of the trout.

CHAPTER 8

GENERAL DISCUSSION AND CONCLUDING REMARKS

The present investigation has brought to light some limnological aspects which are of cardinal importance to river ecology in the tropics. It established the existence of a longitudinal zonation in Naro Moru River and diel periodicity as an integral part of the ecology of Naro Moru River. The fauna collected from the study riffle and the pilot survey stations resembled that which was described by Van Someren (1952) in Mt. Kenya rivers. Baetidae and Simuliidae were found to account for the largest proportion of the drift fauna. Baetis spp. (Ephemeroptera) was the dominant genus in the drift and its dominance over all the other drifters could be explained by the lack of water plants which would facilitate their reattachment after they were released from the substratum. This made it hard for the animals to regain their "footing" relatively rapidly.

Several factors that affect drift were studied during the present investigation. It was found that some factors were potentially more important than others. Light intensity appeared to be the most important factor affecting drift rate in Naro Moru River since drift rate increased with decrease in light intensity irrespective of what other factors were operating at that particular time. Discharge tended to affect the volume sampled by the samplers. Increase in discharge led to an increase in the volume sampled and this increased drift rates. The other factors played important roles although it was difficult to ascertain fully their roles since they were being overshadowed by light intensity and discharge.

Diel and seasonal fluctuations were also investigated in the present study. Diel periodicity in aquatic invertebrates is well established in the temperate and arctic latitudes. The discovery of diel periodicity in the present study added to our present knowledge on limnological studies in Kenya. It is usually postulated that night-active trait is the result primarily of nocturnal foraging behaviour. Presumably, this has evolved with the selective value to the invertebrate of being able to forage with maximum protection against predators in the dark. This does not, however, explain why some species are day-active. Seasonal fluctuations could not be explained in terms of life cycles since all the life stages were included in the diel collections all the time although there were few adults. There was lack of synchronism in their life histories.

Drift and benthos were sources of food for trout. These food sources were supplemented by the terrestrial organisms which fell from the riparian vegetation. Where fish are absent, drifting invertebrates could be used as food by collector-filterer macroinvertebrates such as the larvae of Hydropsychidae (Trichoptera) as found by Smith-Cuffney et al. (1987). Higher carrying capacities of stream fish have been observed in natural and experimental stream sections having higher incoming drift. The drift mechanism facilitates fish utilization of stream invertebrates and also, along with increased accessibility, tends to maximize fish production (Waters 1972).

The present study has not exhausted all the aspects of drift phenomenon. More research is required on the ecological significance of drift to fish production biology and the trophic ecology of the resident fish in this river ecosystem should be carried out to elucidate the relative importance of allochthonous and autochthonous organic matter as sources of energy for secondary producers. However, the present results will form baseline data for future studies on drift in the tropics and a reference for comparative studies with rivers in the temperate latitudes and elsewhere.

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APPENDICES

APPENDIX A

River discharge, mean velocity at drift net mouth, mean volume sampled by net per 2h. and drift density

Date			Discharge ($m^3.sec^{-1}$)	Mean velocity at net mouth ($m.sec^{-1}$)	Mean volume sampled by net per 2h. (x $1000m^3$)	Drift density ($N.m^3$)
15/16	Nov.	1986	0.342	0.32±0.03	0.81±0.02	0.42
26/27	Nov.	1986	0.710	0.47±0.002	1.18±0.02	0.24
6/7	Dec	1986	1.834	0.50±0.04	1.26±0.04	0.25
14/15	Dec.	1986	3.504	0.61±0.11	1.54±0.03	0.19
12/13	Jan.	1987	3.507	0.63±0.12	1.59±0.03	0.26
23/24	Jan.	1987	3.873	0.74±0.07	1.86±0.04	0.34
12/13	Feb.	1987	1.152	0.59±0.07	1.49±0.04	0.27
23/24	Feb.	1987	1.001	0.52±0.09	1.31±0.05	0.31
2/3	Mar.	1987	0.235	0.39±0.03	0.98±0.03	0.37
11/12	Mar.	1987	0.431	0.44±0.03	1.11±0.12	0.31
18/19	Apr.	1987	1.413	0.69±0.04	1.74±0.05	0.23
23/24	Apr.	1987	0.600	0.61±0.05	1.54±0.03	0.25
7/8	May	1987	1.966	0.58±0.07	1.46±0.04	0.23
18/19	May	1987	2.121	0.58±0.09	1.47±0.01	0.23
5/6	Jun.	1987	2.624	0.88±0.04	2.22±0.10	0.25
15/16	Jun.	1987	3.001	0.87±0.04	2.19±0.04	0.26
6/7	Jul.	1987	1.190	0.47±0.03	1.18±0.06	0.40
26/27	Jul.	1987	0.536	0.54±0.03	1.36±0.07	0.31
5/6	Aug.	1987	0.396	0.51±0.08	1.29±0.05	0.30
25/26	Aug.	1987	0.500	0.47±0.10	1.18±0.04	0.34
2/3	Sept.	1987	0.684	0.45±0.04	1.13±0.05	0.32
19/20	Sept.	1987	0.403	0.43±0.03	1.08±0.06	0.31
5/6	Oct.	1987	0.342	0.47±0.09	1.18±0.04	0.28
18/19	Oct.	1987	0.511	0.51±0.10	1.29±0.03	0.27

APPENDIX B

Total drift animal numbers taken in six nets for 24 hours in in Naro Moru River, 1986-1987.

Date			Net number							
			I	II	III	IV	V	V1	Total	$\bar{X} \pm$ S.D.
15/16	Nov.	1986	769	540	905	490	664	656	4024	670.7±151.4
26/27	Nov.	1986	602	504	728	536	512	566	3448	574.7±83.4
6/7	Dec.	1986	750	741	642	589	526	538	3786	631.0±97.8
14/15	Dec.	1986	780	776	584	580	383	449	3552	592.0±163.4
12/13	Jan.	1987	1091	850	802	1140	561	496	4940	823.3±264.2
23/24	Jan.	1987	1356	1420	1176	1140	1254	1273	7619	1269.8±105.7
12/13	Feb.	1987	868	957	797	675	758	678	4733	788.8±110.3
23/24	Feb.	1987	917	863	813	718	750	770	4831	805.2±74.6
2/3	Mar.	1987	938	747	615	645	700	693	4338	723.0±114.9
12/13	Mar.	1987	646	768	686	638	787	637	4162	693.7±67.6
18/19	Apr.	1987	886	785	741	881	863	647	4803	800.5±94.9
23/24	Apr.	1987	755	751	816	695	762	745	4524	754.0±132.3
7/8	May	1987	759	576	660	697	634	634	3960	660.0±62.6
18/19	May	1987	677	692	665	601	667	648	3950	658.3±95.3
5/6	Jun.	1987	1280	1139	998	1131	1001	1221	6770	1128.3±113.9
15/16	Jun.	1987	1261	1184	1122	1101	1105	1123	6896	1149.3±62.3
6/7	Jul.	1987	1022	932	942	981	789	1012	5678	946.3±85.1
26/27	Jul.	1987	990	811	793	764	751	912	5021	836.8±94.2
5/6	Aug.	1987	928	703	722	767	665	853	4638	773.0±99.6
25/26	Aug.	1987	980	824	754	760	606	887	4811	801.8±128.0
2/3	Sept.	1987	829	707	705	739	623	704	4307	717.8±66.7
19/20	Sept.	1987	717	688	635	665	585	692	3982	663.7±47.4
5/6	Oct.	1987	717	629	687	646	666	658	4003	667.2±76.5
18/19	Oct.	1987	725	744	708	562	668	811	4218	703.0±83.6

APPENDIX C

Day-night drift totals of all invertebrate types in Naro Moru River (Nov.1986-Oct.1987)

	Total	Day	Night
EPHEMEROPTERA			
Baetis spp.	57529	26152	31377
Afronurus sp.	3087	1685	1402
Rhithrogena sp.	1336	746	590
Caenis sp.	7151	2249	4902
Euthraulus sp.	3979	919	3060
Centroptilum sp.	88	21	67
DIPTERA			
Simulium sp.	7601	3039	4562
Limnophora sp.	3549	1824	1725
Diamesa sp.	4264	2347	1917
Ceratopogonidae	306	220	86
Tanypodinae	1589	822	767
Culicidae	1044	425	619
Dicranota sp.	350	171	179
Others	908	584	324
TRICHOPTERA			
Chimarrha sp.	145	81	64
Hydroptila sp.	175	112	63
Hydropsyche sp.	403	229	174
COLEOPTERA	1506	693	813
HYMENOPTERA	5765	3780	1985
HEMIPTERA	8666	2351	6315
ARACHNIDA			
Hydrachnellae	3061	1954	1107
ANNELIDA			
Hirudinea	48	17	31
Oligochaeta	142	62	80

APPENDIX C cont'd

MOLLUSCA	65	29	36
ORTHOPTERA	3	1	2
TURBELLARIA	14	5	9
ODONATA	15	8	7
PLECOPTERA			
Neoperla sp.	101	47	54
CRUSTACEA	78	21	57
ISOPTERA	26	17	9

APPENDIX D

Total number of benthic organisms per set in Naro Moru River, 1986-1987

	1986		1987										
Exposure period (days)	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Total
2	185	135	374	382	306	758	320	151	396	203	223	202	3635
4	168	184	398	539	444	379	431	161	453	377	338	168	4040
6	540	365	894	557	322	384	450	302	528	470	467	576	5855
8	348	222	360	345	434	288	355	716	539	418	432	380	4837
10	612	507	1103	727	523	836	321	966	623	623	703	644	8188
12	252	481	559	255	498	338	540	682	629	557	519	234	5544
14	280	403	921	306	380	811	434	411	515	802	503	314	6080
16	234	328	570	445	334	746	358	490	365	294	271	266	4701
18	273	372	660	320	365	392	467	421	311	340	187	304	4412
20	244	159	565	434	351	713	366	246	295	145	262	377	4157
22	202	151	633	523	392	576	335	194	225	180	291	234	3936
24	172	140	454	498	294	279	351	174	152	252	345	306	3417

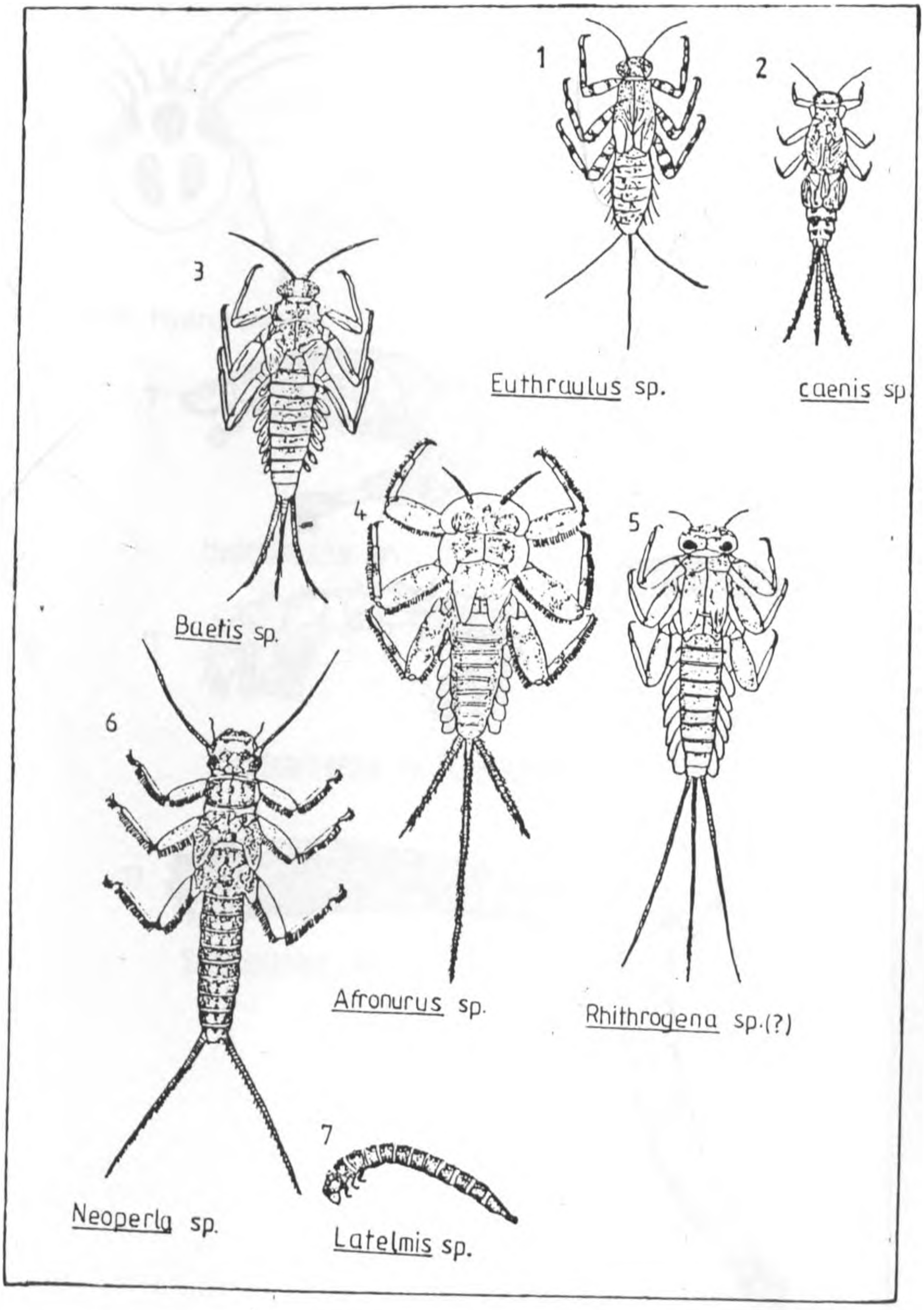
APPENDIX E

Total number of benthic taxa per set in Naro Moru River, 1986-1987

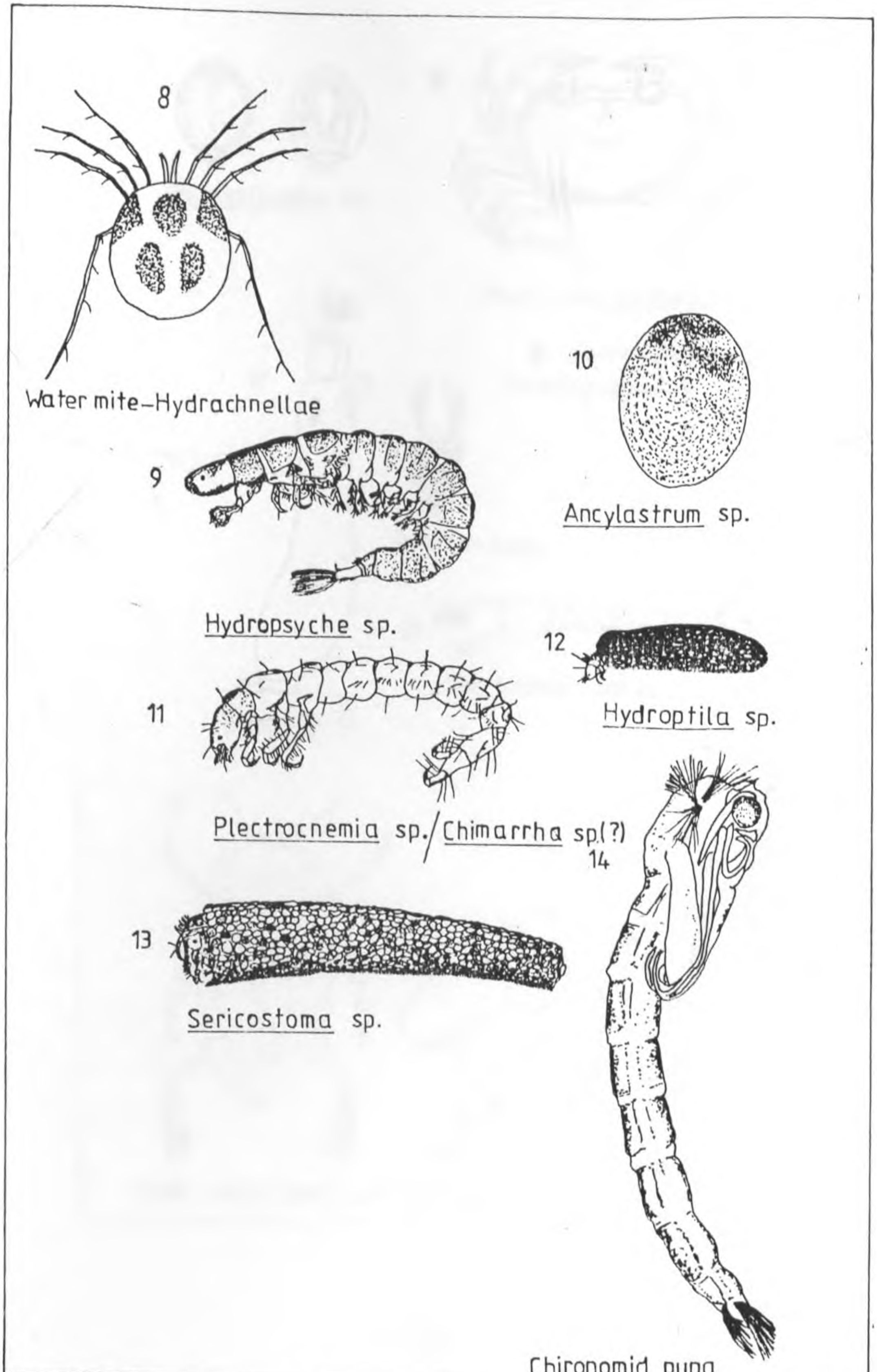
Exposure period	1986		1987										
(days)	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Total
2	9	18	15	13	16	20	14	20	15	22	19	16	197
4	15	21	17	18	14	17	17	13	23	19	23	20	217
6	19	22	20	22	18	17	14	18	20	21	25	21	237
8	22	19	19	17	20	19	15	18	22	19	21	23	234
10	18	20	19	21	22	24	18	15	22	23	23	24	249
12	19	21	21	18	20	20	16	16	15	21	24	21	232
14	23	22	20	16	21	21	16	16	20	22	25	23	245
16	17	21	16	14	18	17	18	15	21	21	24	20	222
18	22	20	19	18	18	14	18	19	21	19	23	20	231
20	21	21	17	20	20	16	19	19	20	19	24	23	239
22	21	19	17	22	17	18	18	17	17	19	25	20	230
24	20	18	18	20	15	19	20	16	17	17	24	22	226

APPENDIX F

Some of the riverine benthic fauna collected in Naro Moru River, 1986-1987 (Source: Van Someren(1952), Macan(1977) and personal observations)



APPENDIX F cont'd



APPENDIX F cont'd