THE BIOLOGY OF NATURALIZED RAINBOW TROUT, *Oncorhynchus mykiss* (WALBAUM), IN KENYA COLD WATER STREAMS AND IMPLICATIONS FOR FUTURE MANAGEMENT

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by

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Abstract

In this study I present information on the presence, current status and historical distribution of rainbow trout, *Oncorhynchus mykiss* (Walbaum), in three third order streams on the southwestern slope of Mt. Kenya, namely the Naro Moru, Sagana and Thego. The composition, distribution, and status of fish species within the study streams are different than they were in the 1950s. Although there are still self-sustaining rainbow trout populations their distribution range is reduced and populations are in decline.

Multiple regression analyses indicated that altitudinal and seasonal variables had little influence on rainbow trout length specific condition among streams. Rainbow trout are growing about as fast as they did during the 1930s to 1950s - perhaps even faster - but population levels appear to be much lower and most of the fish are small with few reaching more than 2 years of age. Brown trout (*Salmo trutta*), another salmonid with a similar history in Kenya as rainbow trout, has also been affected and is presently found only in the upper reaches of the Sagana indicating that its distributional range has decreased faster than that of rainbow trout. Compared with the past, mountain catfish (*Amphilius uranoscopus*) and other native species have expanded their distributional range upstream from where they were in the 1930s to 1950s. Rainbow trout, brown trout and catfish exhibited overlap in their diet suggesting the competitive interactions between the species may be a factor in their changing distributional patterns. In the three streams, composition of benthic invertebrate fauna showed altitudinal and seasonal variation. There were more dipterans in the upstream stations and more ephemeropterans in the downstream stations. There was no marked

difference between fauna composition in the present study and that reported for one of the study stream (the Sagana) by Van Someren (1952) in the 1950s.

Factors associated with the variation in rainbow trout distribution among sites included temperature changes, and other environmental parameters, overlap with other species and over-exploitation. The main reasons appear to be environmental changes influenced by anthropogenic effects and fish over-exploitation i.e. heavy fishing pressure and high vulnerability of rainbow trout to anglers.

Because much of the trout habitat has been altered, areas supporting rainbow trout populations are now critical for conservation management. Management strategies should incorporate societal values and recognize that good trout habitat is a reflection of better managed watersheds. Where land management has degraded stream habitats, acquisition of riparian corridors and instream management are necessary to rehabilitate and provide recreational fisheries. Enforcement of regulations on the trout fisheries appear to have become more liberal and more stringent legislation may now be required. Rebuilding trout populations is necessary to re-introduce recreational fisheries and by extension "pristine" environment. This study supports the hypothesis that rainbow trout distributional range will continue to decline unless corrective measures on catches and harvesting, as well as watershed management are considered.

Dedication

To my family; Mary Waithera, Virginia Nyambura and Daniel Ngugi whose marks I carry proudly and permanently as husband and father.

Acknowledgement

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Chapter 1: Introduction

1.1 Rainbow trout distribution

The rainbow trout (*Oncorhynchus mykiss*, Walbaum) (Figure 1.1), also called steelhead, Kamloops trout or silver trout, is native to western North America (Behnke 1992). Endemic populations are found in Pacific coastal watersheds from California to Alaska except for the Yukon River system. They were first introduced outside their native range in 1874. Since then their range has been extended from western North America to include waters on all continents except Antarctica (Dymond and Logier 1932; MacCrimmon 1971).

The reasons for rainbow trout introduction varied from country to country and included: improvement of wild stock, aquaculture, sport, accidental release, ornamental and other unknown reasons (Holcik 1991). Accidental introductions include escapees from fish farms, which can pose serious environmental problems. In Norway, for example, the number of Atlantic salmon (*Salmo salar*, L) escapees from sea cages as reported by Gausen and Moen (1991) is thought to be considerably greater than the total number of wild fish in the streams of the middle coastal region.

Rainbow trout were imported as ova from the United Kingdom to South Africa in 1897 and successfully hatched at the Jonkershoek hatchery, Cape Town. In Africa, and especially in Kenya, rainbow trout were first introduced for sport and recreation and only later for aquaculture. Presently, populations of rainbow trout represent a recreational resource in South Africa, Ethiopia, Lesotho, Madagascar, Malawi, Morocco, Zimbabwe and Kenya (Moreau 1997). Rainbow trout introductions failed to establish self-reproducing

Fig. 1.1 Photograph showing a mature female rainbow trout electrofished from one of the study streams.

populations in other parts of Africa, e.g. Congo, Cameroon, Namibia and Mozambique (MacCrimmon 1971).

Rainbow trout were first introduced into Kenya in 1912 (Copley 1938). The offspring from these trout were liberated in the Nairobi stream on the southwestern slope of Mount Kenya and in the Amboni on the northern slope of the Aberdares. Naturalized populations of rainbow trout were later spread to all cold water streams in the central and western parts of the country. By about 1927, rainbow trout had been transplanted into most suitable waters of Kenya (Copley 1938).

Another salmonid with a long history of human introductions outside of its native range is the brown trout (*Salmo trutta*). Elliott's (1994) review on the biology of brown trout, indicates that it has been introduced into at least 24 countries outside Europe. The earliest introduction occurred in 1852 in eastern Russia. In Africa, brown trout, like rainbow trout, were established first in South Africa, in 1890 (MacCrimmon 1971). The report of the Committee on the Control and Development of Fishing in Kenya (Copley 1938) indicates that brown trout were introduced in Kenya in 1905. Subsequently, rainbow and brown trout were transplanted into many of the same streams.

In 1932, following a successful conference of Angling Associations in Nairobi, Copley (1938) remarked: "The importance of Kenya as an attractive Colony to the angler cannot be exaggerated. There is abundant evidence to show that, certainly as far as the resident and also the sportsman visitor is concerned, the big game shooter and trophy hunter is rapidly being superseded by the big game photographer, the birder and the angler". Certainly, Copley was looking at fisheries as a sector that would rival and even out-compete wildlife. At that time there were over 2,500 km of rainbow trout stream in the country. The naturalized distribution of salmonids included the streams flowing down from Mount Kenya, streams in the Aberdare Ranges, streams of the Mau escarpment and the streams of the Cherangani mountains and Mount Elgon. Rainbow and brown trout successfully established self-sustaining populations in most of these waters (Copley 1938).

1.2 Studies of naturalized populations

Naturalized populations of rainbow and brown trout have been studied extensively in North America where they now occur in sympatry with native species. A few examples include the work of Cunjak and Green (1983, 1984, 1986) and Gibson and Cunjak (1986) in Newfoundland, Fausch (1988) in Sagehen Creek, California and the Great Smoky Mountains National Park in Tennessee, and Rincon and Grossman (1998) in North Carolina.

The performance and exploitation of self-sustaining populations of rainbow trout in the Great Lakes region have been reported by Marshall and MacCrimmon (1970) and MacCrimmon and Gots (1972). Elsewhere, naturalized populations have been studied in New Zealand and Australia (Allen 1951; McDowall 1968; Jowett 1990) where they are found in sympatry with native species including *Galaxias fasciatus*, *G. postvectis*, *G. brevipinnis* and *Anguilla dieffenbachii*.

The uncertain performance of introduced salmonids in non-native habitats was one of the factors which led to the establishment of hatcheries directed towards supplementing wild populations through regular stocking. It was for this reason, for example, that a trout hatchery and rearing facilities were constructed on the Sagana stream on Mt. Kenya in the 1940s. However, as reported by MacCrimmon (1971), there are what one may refer to as success stories with introductions of exotic salmonids. These include both rainbow and brown trout, as well as other species of the genus *Oncorhynchus* (i.e. Pacific salmon) (Wingate 1991).

A good example of a successful introduction from the stand point of economic benefit occurred with Pacific salmon (*Oncorhynchus*) in Lake Superior. In Duluth, Minnesota, the economic value of the sport fishery increased from near zero in 1976 to \$3.5 million in 1991 in direct expenditure and over \$9.0 million in related expenditure (Wingate 1991). Holcik (1991) states that among exotic fish species generally accepted as having resulted in beneficial effects, it is the rainbow trout and Chinese herbivorous carps (but see Krueger and May 1991) which have received a good reputation in most places where they were introduced. Wingate (1991) however, cautions that while there have been successes, introductions have not been without adverse effects on native species.

1.3 Exotic salmonids vs indigenous fish

The extent of competition between exotic salmonids and indigenous fish species has been, and continues to be, a controversial issue (Fausch 1988; Allendorf 1991; Crossman 1991; Ogutu-Ohwayo and Hecky 1991). For example, the disappearance of brook trout from some streams of the southern Appalachian mountains, U.S.A. is attributed to competition with naturalized rainbow trout by Krueger and May (1991), who observed that rainbow trout excluded brook trout from preferred habitats.

In contrast, Cunjak and Green (1983) reported that introduction of rainbow trout into Newfoundland streams had not caused any observable habitat shift by brook trout and that both species showed stream microhabitat preferences which allowed them to coexist. Cunjak and Green (1984, 1986) subsequently hypothesized that rainbow trout had an exploitative advantage for resources such as food and space at high stream temperatures and that might provide them with a localized dominance allowing them to displace brook trout to a narrower niche.

Krueger and May (1991) noted that the outcome of potential competitive interactions between rainbow trout and brook trout often have been unclear. Fausch (1988) reported on sympatric populations of brook and rainbow trout in two locations, Sagehen Creek, California and the Great Smoky Mountains National Park in Tennessee and North Carolina. The species showed similar distribution patterns along elevation gradients in the two regions. Brook trout were found in allopatry in the upstream, higher gradient, lower temperature reaches, below which there was a zone of sympatry between rainbow trout and brook trout. Further downstream, in lower gradient and higher temperature reaches, only rainbow trout were found. The two species are sympatric throughout the interior of the western United States, where neither is native (Fausch 1988), and in the northeastern United States (Appalachian mountains) where brook trout are native (MacCrimmon 1971).

In Coweeta, North Carolina, exotic rainbow trout and native rosyside dace (*Clinostomus funduloides*) exhibit substantial overlap in microhabitat use. The competitive interactions between these two species was studied by Rincon and Grossman (1998) to determine if rainbow trout were having a negative impact on the native species. They concluded that rainbow trout had little effect on the behaviour of dace and intraspecific aggression was much more common than interspecific aggression.

In Australia and New Zealand native species mainly of the Family Galaxiidae appear to successfully compete with and/or survive in the presence of exotic brown trout (McDowall 1968). However, Kusabs and Swales (1991) and Jowett and Richardson (1996) observed that rainbow trout in part caused the decline of some species of the family Galaxiidae in New Zealand streams. In South Africa, Skelton (1993) suggested that predation by introduced species, including rainbow trout, has led to a decline in the mountain catfish *Amphilius natalensis*, in some streams.

1.4 Rainbow trout in Kenya

Information on the biology of rainbow trout in Kenya is limited to studies completed prior to 1950 (Copley 1938, 1940a, 1940b, 1947, 1950a, 1950b, Copley and Van Someren 1951 and Van Someren 1952), with most of the research being done on the Sagana stream. In the Sagana, rainbow trout were distributed between 1670 and 2800 m elevation (a.s.l.). Below 1670 m altitude they were limited by high temperature whereas the upstream limit was impassable waterfalls.

Early liberation of rainbow trout was done by individuals or angling associations until 1926 when the government placed trout management under the Department of Game and Fisheries. By about 1927, rainbow trout had been transplanted into most suitable waters of Kenya. After the initial liberation in these streams, maintenance of rainbow trout populations was mainly dependent on natural reproduction. The subsequent history of rainbow trout liberation can be traced from Copley's Reviews of Kenya Fisheries Annual Reports (Copley 1947, 1950a, 1950b, 1951, 1952) and Van Someren's (1952) manuscript on the Biology of Trout in Kenya Colony. This information provides the only basic data on trout liberation, propagation and biology in Kenya streams.

The end of the British rule in 1963 ushered in profound political, economic, social, and demographic changes in Kenya. Land acquisition and human settlement in headwaters of trout streams increased rapidly after independence. The southwestern slopes of Mount Kenya experienced an increase in new settlements and agricultural activities. The population that settled on the watersheds in this region since the early 1960s placed increased demands for water resources. Demand for arable land increased, especially in forested upland areas, causing considerable environmental changes in the watersheds, through the removal of riparian vegetation and buffer strips.

Farmers began to settle in the Sagana and Thego watersheds on Mt. Kenya after 1964, and this development continues to present. Currently there are three settlement schemes, namely Kimahuri, Madoya and Sagana, with a population of about ten thousand persons.

Despite fertile volcanic soils on the southwestern slopes of Mount Kenya, rainfall is not sufficient for the high-yielding crop varieties preferred by the farmers.

Land users have brought increased demands for water resources such as diversion for domestic use, livestock and irrigation. Converting forest land to agricultural use has caused widespread removal of natural vegetation within the watersheds and has changed the quality and quantity of water in streams. Presently, there is no information documenting these anthropogenic impacts on aquatic and riparian habitats and the possible long term effect on the self-sustaining populations of trout in Mt. Kenya streams. Lack of a comprehensive legal framework on both the river bank right of way for the purpose of fishing and maintenance of a well-defined buffer strip has exacerbated the problems. Agricultural activities have also increased the use of fertilizers, herbicides, pesticides and the demand for wood as fuel for cooking.

The situation is now of particular concern given the increased loss of trout habitat as a result of reduced water flow and general loss of forest cover coupled with ever increased demand for arable land. Increased demand for resources is causing habitat degradation through low stream flow, elevated stream temperatures, increased sediment load, and the introduction of pollutants. As a result, trout populations in the streams flowing from the southwestern and southeastern slopes of Mt. Kenya (e.g. the Nanyuki, Liki, Burguret, Naro Moru, Nairobi, Thego, Sagana, and Thiba) have changed and recreational fisheries are on the decline. It is important to prevent further degradation since we know that once degraded, watersheds take years to recover or may never recover.

Rainbow trout thrived in the streams on the southwestern slope of Mt. Kenya before the watersheds were opened for settlement. Anglers were able to catch rainbow trout below this altitude at least as far as the junction of the Thego with the Sagana. Major Kingdom (reported in Van Someren 1952) maintained a 22 year record of rainbow trout caught in the Thego between its confluence with the Sagana and the Thego Fishing Camp. Rainbow trout in the Sagana were distributed over 50 km of the stream, over 42 km in the Thego, about 46 km in the Nairobi and close to 40 km in the Naro Moru (Table 1.1).

Unfortunately it has not been possible to obtain useful information on recreational fisheries and environmental changes that took place between 1952 and 1963. Hostilities that intensified in the 1950s led to declaration of a state of emergency in 1952 which was relaxed just before independence in 1963. During this time one would imagine that very little attention was given to trout streams. After 1963, a new phase in fisheries administration began with Kenyans taking over trout management. A gradual extension of the belief that regular importation of trout eggs was sufficient to maintain the populations, as was practiced in Europe and North America, led to a progressive increase in liberation of rainbow and brown trout in the streams. Some information regarding recent stocking of trout streams with rainbow and brown trout can be obtained from records at the Kiganjo Trout Research Station.

It is difficult to quantify the value and the benefits of recreational fisheries to the country. The most pragmatic way of approximating social and economic benefits of recreational fisheries is by defining the experience in terms of time, expenditure on transportation, food, lodging, tackle, bait, aesthetic quality and improved health and visitors'

Table 1.1 The Naro Moru, Sagana, and Thego streams and other neighbouring trout streams from the Aberdares and Mount Kenya showing range of trout stream in km, date first liberation done and trout species stocked. Data is from Copley (1938). Trout ranges are presently smaller in all streams studied than they were in the 1930s.

Stream	Trout km	Date stocked	Initial stocking	Trout stocked later
Amboni	48	1912	Rainbow	Brown
Burguret	62.5	1931	"	"
Chania	80	1905	"	"
Chania-Thika	94.4	1926	Brown	"
Gatamaiyu	25.6	1925	Rainbow	Rainbow
Gikira	8	1928	"	Brown
Gura	80	1905	"	Brown
Karuru	16	1933	"	Rainbow
Katungu	17.6	1925	"	Rainbow
Kyama	14.4	1926	Brown	Brown
Liki	64	1919	Rainbow	Brown
Maragua	54.4	1926	Brown	Brown
Meri	40	1923	Rainbow	Rainbow
Moya	30.4	1932	"	"
Mukendu	19.2	1933	"	"
Nairobi	46.4	1912	"	"
Nanyuki	88	1919	"	Brown
Naro Moru	52.8	1931	"	Brown
Ndarugu	40	1925	"	Rainbow
Ngobit	44.8	1932	"	Rainbow
North Mathioya	41.6	1926	Brown	Brown
Ontolili	25.6	1925	Rainbow	Rainbow
Ragati	11.2	1932	"	"
Rongai	62.4	1931	"	"
Ruiru	6.4	1921	"	"
Sagana	49.6	1925	"	Brown
Sirimon	18	1925	"	"
South Mathioya	64	1926	Brown	"
Thego	41.6	1923	Rainbow	Rainbow
Thiba	28.8	1932	Rainbow	Rainbow
Thika	41.6	1926	Brown	Brown
Thiririka	33.6	1925	Rainbow	Rainbow
Timau	17.6	1934	"	"
Uaso Ng'iro	9.6	1932	"	"
Zuti	19.2	1928	"	Brown

benefits to the local community. Above all, the social value of recreational fisheries is intertwined with pristine environments where temperatures are cool, there is high diversity of wildlife, streams have clean water and areas of evergreen indigenous forest exist. In the words of Hunter (1991), "the climate, geology and elevation of our montane regions; the shape of the stream banks, the mix of sediment, rock and gravel on the stream bed, the cool water temperature and characteristics; the insects that live in and near the stream, and the associated terrestrial and aquatic vegetation are some of the factors that have defined the evolutionary adaptations of trout to their pristine environment". The ecosystem health and integrity of these watersheds, if well-maintained, should provide sustainable social and economic benefits to the local community and an increased foreign exchange to the country.

Preliminary electrofishing observations for the present study indicated that the distributional range of rainbow trout has contracted since the early 1950s. In the Thego, for example, no rainbow trout were caught at or below the Thego Fishing Camp. These electrofishing surveys also showed that the mountain catfish (*Amphilius uranoscopus* Pfeffer; Siluriformes: Amphiliidae), which had not previously been reported above 1650 m, had expanded its range upstream. Several factors may be contributing to the reduction in the distribution of rainbow trout in these streams, among them:

i) general decrease in water quality,

ii) the presence of other species and,

iii) over-exploitation of the rainbow trout stock.

In view of the fact that Kenya's tourism is gaining in importance and that capture fisheries are going through an unpredictable future, the need to provide more recreational angling cannot be over emphasized. There is need for responsible, integrated and rational management, and a desire to enhance trout stocks in the face of competing needs for aquatic resources.

The overall objective of this study is to obtain information on rainbow trout population biology and to use this information to forward the development of a management plan for rainbow trout. The study summarizes much of the available historical and recent information on the life history, population distribution, abundance, age and growth, and food of rainbow trout; overlap with other fish species and changes in populations correlated to environmental changes that have taken place since rainbow trout introduction into the country. This study will examine the present performance of rainbow trout in three similar streams on the southwestern slopes of Mount Kenya (the Naro Moru, Sagana and Thego). Based on these findings management directions and options will be presented with a view to restoring and enhancing the value of trout resources in Kenya.

Chapter 2: Materials and methods

2.1 Study area

Based on 1:250 000 scale maps of the area, three similar third order streams (the Naro Moru, Sagana, and Thego) on the southwestern slope of Mount Kenya were chosen as the primary study area. These streams share the same climatic 'zone' but have different levels of upstream human activity on their watersheds.

These streams were chosen in part because of the existing trout culture facilities in the area. These include the Kiganjo Trout Research Station (Figure 2.1), the Kiganjo Trout Hatchery (Figure 2.2) and the Thego Fishing Camp. These facilities, currently under the Department of Fisheries, can be used to facilitate trout rehabilitation. The Kiganjo Trout Research Station was built in 1947 on the Sagana stream at an altitude of about 1790 m above sea level. The station currently maintains a brood stock to sustain a supply of fish for restocking trout streams and to supply trout fingerlings for sale to trout farmers. Upstream on the Sagana, at an altitude of about 2285 m, is the Kiganjo Trout Hatchery where trout eggs are hatched and fry reared before they are brought down to the rearing facilities at the Kiganjo Trout Research Station as fingerlings. About five km by road from the Kiganjo Trout Research Station on the Thego stream (a tributary of the Sagana) is a government fishing camp. The Thego Fishing Camp is among several fishing camps build in the 1930s on trout streams in response to demand for accommodation by anglers. Information from Copley (1950a, 1950b), a fish warden then, indicates that this camp was regularly used by anglers who fished the Sagana, Nairobi, Chania, and Thego trout streams.

Fig. 2.1 Photograph showing the Kiganjo Trout Research Station raceways and rearing ponds. The station currently maintains brood stock to supply fish for restocking trout streams and for rainbow trout farmers.

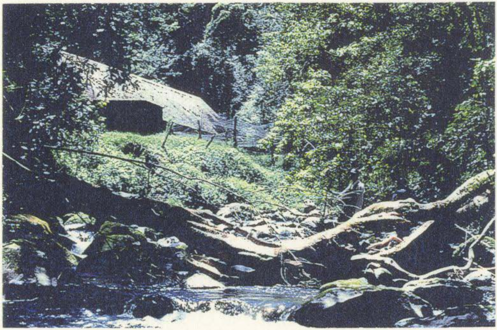


Fig. 2.2 The Kiganjo Hatchery built in 1947 stands at an altitude of about 2285 m above sea level. Rainbow trout eggs are hatched in this hatchery. Later fry are grown to fingerlings before being transfered to the Kiganjo Trout Research Station.

Other trout facilities in the area include the privately owned Tam Trout fish farm (Figure 2.3) and the recently constructed Tam Trout hatchery. The fish farm is on the Burguret stream, a tributary of the Naro Moru, about 50 km on the Nairobi - Nanyuki road from the Kiganjo Trout Research Station. The Tam Trout hatchery is located at an elevation of about 2285 m on the Naro Moru. Another reason for choosing these study streams was the availability of historical data from the earlier works of Van Someren (1952) and Mathooko (1995, 1996) for the Sagana and Naro Moru, respectively.

Mt. Kenya, a Tertiary volcanic mountain situated on the equator, is the second largest mountain in Africa with a peak altitude of 5200 m above sea level. Most of the peak area is composed of ice and bare rock in the Afro-Alpine zone above 4200 m. Vegetation is sparse and soils are shallow. The moorland zone, stretching from around 4200 to 3300 m, is characterized by tussock grassland and giant groundsel in the upper part and a heath belt in the lower part. The evergreen montane forest - bamboo zone extends from the upper tree line around 3300 m down to around 2600 m.

Riparian vegetation changes gradually as one moves from the bamboo zone to the low altitude plains. The riparian zone consists of tropical rain forest species, including, *Brachylaena huilensis*, *Clerodendron capense*, *Croton megalcarpus*, *Dombeya torrida* and *Podocarpus spp.*, that provide litter and canopy cover to streams. On the slopes, plantations of exotic trees have replaced indigenous forest. Under natural conditions, the indigenous forest would extend down to about 2000 m, but it has been removed and either replaced by

Fig. 2.3 Tam Trout fish farm is a privately owned rainbow trout commercial fish farm. It is situated on the Burguret stream about 50 km from the Kiganjo Trout Research Station on the Nairobi - Nanyuki road.

exotic pine (*Pinus patula*) or cypress (*Cypress spp.*) forest or converted to agriculture in all catchments.

The areas of study shown in Figures 2.4 and 2.5 are located on three streams: the Naro Moru, the Sagana and the Thego. The Naro Moru study area is located at 0^0 10′ S, 37^0 6′ E. (next to the Forest Guard Post) to 0^0 8′ S, 37^0 00′ E. (below the Naro Moru River Lodge). The Sagana study area is between 0^0 17′ S, 37^0 11′ E. (at the Kiganjo Trout Hatchery) and $0^0$22′ S, 37^0 03′ E. (at the Kiganjo Trout Research Station), and the Thego study area is located between 0^0 16′ S, 37^0 09′ E. (at Kabaru Forest Station) and 0^0 21′ S, 37^0 02′ E. (at the Thego Fishing Camp).

The Naro Moru, with a catchment area of about 109 km^2, has two main tributaries, the North and South Naro Moru. It flows west from the southeastern slope of Mount Kenya to discharge into the Ewaso Ng'iro River. The Sagana has a catchment of about 119 km^2 and rises at about 4000 m from the southeastern slope. It drains westward and later turns east to discharge into the Indian Ocean as the Tana River. The Thego, with a catchment of about 114 km^2, is a major tributary of the Sagana and also rises from the southeastern slope of Mt. Kenya at about the same altitude. It initially drains west and later joins the Sagana to flow east. The three streams have channels of similar width that varies with the altitude and season, generally ranging from about 9.0 m upstream to about 14.5 m downstream during the rainy season. They exhibit a continuous flow with variation in depths and velocity that is influenced by rainfall pattern.

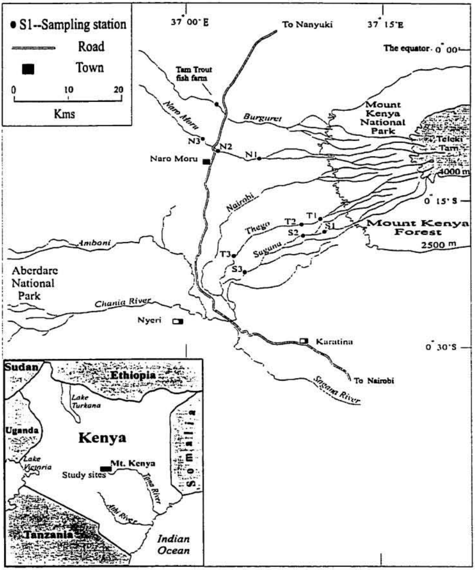


Fig. 2.4 The location of study sites on the Naro Moru (N1, N2 and N3), Sagana (S1, S2 and S3) and Thego (T1, T2 and T3) streams. The map also shows the Tam Trout fish farm and the Amboni and Nairobi streams where rainbow trout were first liberated.

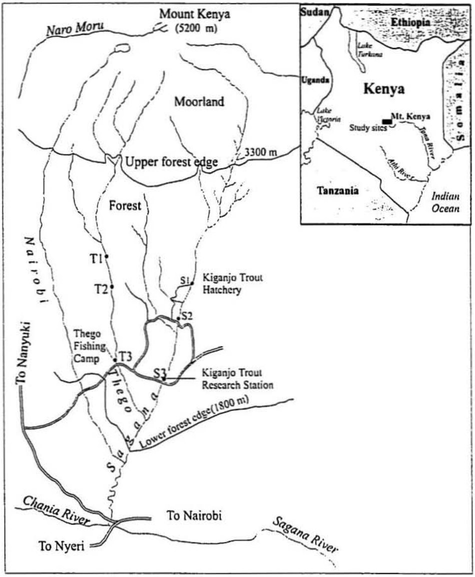


Fig. 2.5 The location of study stations on the Sagana (S1, S2 and S3) and Thego (T1, T2 and T3) streams. The map also shows the Kiganjo Trout Research Station, Kiganjo Trout Hatchery and the Thego Fishing Camp.

Although rivulets from Teleki Tarn (4270 m), Tyndall (4475 m), and Hut Tarn (4488 m) supply the Naro Moru tributaries with water throughout the year, on Mt. Kenya most of the water which flows into the streams comes from rain falling on the moorland belt and from melting snow which finds its way to the streams through infiltration. Rainfall is highest in the upper forest to lower moorland zone and decreases towards the alpine and savannah zones (Liniger 1995). There are generally two rainy seasons per year, from April to June and from October to December, with January-February and September being the driest months.

Three representative sections in each stream were selected as sampling sites. They are referred to as upstream (N1, S1, and T1), midstream (N2, S2, and T2) and downstream (N3, S3, and T3) stations and were at about the same elevation in each stream at altitudes between about 2290 m and 1645 m (Table 2.1). These stations were representative of a range of habitats (riffles, runs and pools). They also represented contrasting changes in stream cover and riparian vegetation. They showed dense cover, with healthy riparian vegetation that provided good protection and bank stabilization in upstream stations and laterally unstable channels due to lack of riparian vegetation and less canopy cover in downstream reaches. The three stream exhibited similar sinuous patterns with large boulders that create turbulence upstream grading into pebbles and gravel sand downstream. Further, they were also selected because of their accessibility and proximity to trout facilities.

Table 2.1 Designations and altitudes of the three stations (upstream, midstream, and downstream) on each of the study streams.

Section "Zone"	Upstream			Midstream			Downstream		
Stream	Naro Moru	Sagana	Thego	Naro Moru	Sagana	Thego	Naro Moru	Sagana	Thego
Station	N1	S1	T1	N2	S2	T2	N3	S3	T3
Altitude (m)	2225	2285	2255	2100	2195	2160	1920	1790	1800

2.2 Methods

2.2.1 Stream habitats variables

Physical and chemical habitat variables recorded for each of the three streams included; stream channel width (measured from forest edge to edge), wetted cross-sectional area, depth (from bank to bank), velocity, stream temperature, dissolved oxygen, pH, conductivity, calcium carbonate and turbidity.

2.2.2 Stream velocity and discharge

Discharge was calculated by measuring water depth and velocity across the wetted width at each station. A measuring tape stretched across the stream was divided into metre intervals. Stream water depth was measured at the centre of each interval with a meter stick. Stream cross sectional area was then calculated as the product of stream width and average water depth derived from interval measurements.

Stream surface velocity (Vs) measurements were taken by a float method as described by Hauer and Lamberti (1996). A reach length (L) of stream equal to at least 20 meters was taken. An orange was used as a float and was introduced a slight distance upstream of the upstream mark so as to reach the speed of the water before the first mark. A stop watch was then used to record the time (t) this float took to cover the marked distance. Three passes were done, one from each side and one from the middle of the stream, and their mean taken. Surface velocity was calculated as $Vs = L/t$. Mean velocity (V) was calculated using a correction factor of 0.85 as suggested by Hauer and Lamberti (1996).

Discharge from the riffle, runs and pools were calculated as the total volume of water flowing in cubic meters per second (discharge). Discharge was calculated as

$$Q = A * V$$

where Q represents discharge (in cubic metres per second); A, cross sectional area of the channel at a certain transect; and V, the corrected mean water column velocity at the same transect.

Stream discharge data for the Thego were recorded daily as water depth (mm) from a weir near the Fish Camp (Figure 2.6). Water velocity and depth measurements were done during low, medium and high flow to establish a relationship between discharge and water depth as shown in Figure 2.7. This relationship was used to estimate discharge over the weir. Stream discharge data for the Naro Moru were obtained from the Laikipia Research Program gauging station (NM) situated between N1 and N2 at an elevation of about 2160 m.

2.2.3 Temperature

Temperature was recorded monthly with a hand-held thermometer (10 °C - 110 °C) at all stations except T3 where it was recorded daily. Stow-away temperature loggers (Onset Computer Corporation 1996) with an optic coupler and an optic base station were also launched and deployed in the Sagana and the Thego streams at stations S1, S2, S3, and T3. Temperature measurements at these stations were recorded at half-hour intervals between February and December 1998.

Fig. 2.6 Weir in the Thego stream above the Thego Fishing Camp. Notice its height which was not a barrier to upstream movement of radio-tagged, Floy-tagged and fin-clipped rainbow trout that were released below it. However, it may be a barrier to upstream movement of mountain catfish. The weir has two slots with a width of 4.3 and 3.7 m and a depth of 0.6 m. The slot where water is flowing over is 3.7 m wide.

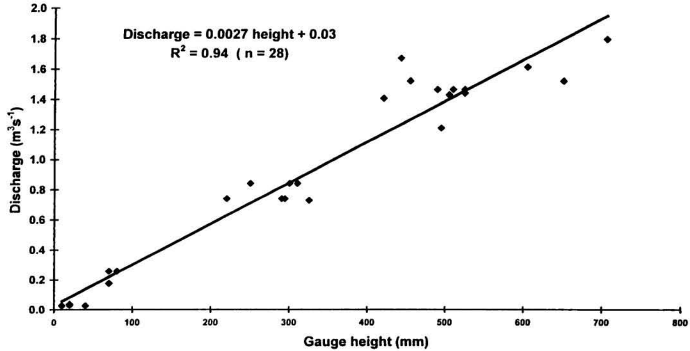


Fig. 2.7 Relation between water discharge and gauge height recorded at the Thego weir. The regression relationship was developed from data collected over a period of 28 days during low, medium and high water levels.

2.2.4 Dissolved oxygen

Dissolved oxygen was measured by the modified Winkler method through titration. Later measurements were taken with a hand-held D.O. meter model YSI 55 from Yellow Springs Instruments Company Inc. USA.

2.2.5 pH

Measurements of pH were taken with a portable probe meter (pH/mv/ ^{0}C equipment) from Oakton, Singapore.

2.2.6 Conductivity and $CaCO_3$

Conductivity measurements, as indicators of carbonates and other mineral elements present in water, were taken with a model HI 8033 conductivity meter from Hanna Instruments, Germany.

2.2.7 Turbidity

Turbidity was measured by the Palin Turbidity tester that uses a specially calibrated plastic tube. The test kit sp504 includes a tube graduated at 30 -500 turbidity units calibrated by the Department of Public Health Engineering, University of Newcastle upon Tyne, England. Measurements were recorded in Jackson Turbidity Units (JTU), approximately equivalent to the suspended solids content measured in mg/l.

2.3 Fish Biology

2.3.1 Fish Sampling

Sampling was done with a pulse DC Smith-Root model 12 battery powered backpack electrofisher. During fishing, the electrofisher was set for just enough voltage to obtain the desired response from among all sizes of fish without causing injuries. The frequency (pulse rate) was set at 30 Hz throughout as recommended by Murphy and Willis (1996). Voltage was set at a range of 300-500 and depended on the stream depth and conductivity. Upstream stations whose water conductivity was usually low, required higher voltage than downstream stations where water conductivity was above 100 μS. Electrofishing was done to collect fish of all sizes. The time required to fish a site depended upon the density of the fish present. Catch per unit effort (CPUE) was calculated based on the time electrofished, i.e. the number of fish per hour electrofished. Usually it took about an hour to fish a stream section. All species and individuals captured were noted and measured. Some specimens were preserved to provide biological data.

Fishing was done using standard electrofishing procedures as described by Scruton and Gibson (1995). Each section was fished starting at the downstream limit and fishing upstream against the current in a zigzag pattern with one person carrying the electrofisher, another holding the bucket or container for carrying the fish caught and a third person carrying a D-net to transfer the fish into the bucket. Electrofishing extended from March 1996 to December 1998. Stations were fished monthly with a break of 9 months (September 1996 to May 1997) when I was away at Memorial University for course work. Sites were also not sampled when the weather did not allow access to the sites (impassable roads) or during high floods.

2.3.2 Fish length and weight measurements

Fish were measured using a measuring board calibrated in centimeters (to the nearest 0.1 cm) with a fish lying on its right side. Measurement was from the tip of the snout to the median rays of the forked part of the tail fin (fork length). Fish were weighed with a portable electric balance to the nearest 0.1 g. Initially fish caught were anaesthetized with benzocaine but later it was found that anaesthetizing them with CO_2 using an Alka Seltzer tablet dissolved in a few litres of water, improved their recovery. All anaesthetized fish were placed in a recovery plastic cage and later transferred to a temporary recovery pool in the stream made by arranging rocks in a circle.

2.3.3 Weight: Length analyses

Data on lengths and weights were used to calculate a length - weight relationship. The generally accepted formula: $W = aL^b$, logarithmically transformed to $\text{Log } W = \text{Log } a + b \text{ Log } L$, where W = wet weight of the fish, L = fork length of the fish was used.

The regression coefficients (slopes) of rainbow trout from the three streams were tested with Analysis of Covariance (ANCOVA) to check if there were population differences among the three streams. Further analyses to determine effects of category variables such as stream, altitude and season on populations slopes were investigated using 'dummy' variables in a multiple regression model (Hull and Nie 1981). By using 'dummy' variables it was possible to determine whether the stream, altitude or season was a significant determinant of fish condition, and to what extent they influenced the population (Sokal and Rohlf 1988; Zar 1984). Each binary dummy variable was coded as "1" if a fish was caught there and "0" if no fish was caught, and tested in a multiple regression of log length - log weight to see if the variable explained additional significant variation. The multiple regression model was of the general form:

$$\text{Log Wt} = A + B_1 D_1 + B_2 D_2 ... + B_N * \text{Log FL}$$

Where Wt is the body mass, FL is the fork length, A is the intercept, B_i are the regression coefficients and D_i are the 'dummy' variables such as stream, altitude, year or season (months).

The effect strength of the category variable (i.e. the effect of nominal scale variable on the dependent variable) was calculated by converting back to linear form. For example, the linear form of a model with only one dummy variable (D_1) representing stream would be:

$$WT = 10^{A} * FL^{BN} * 10^{B1D1}$$

If the regression coefficient B_1 for D_1 (stream) had a value of 0.03027 then the effect strength of the dummy variable would be $10^{0.03027} = 1.072$. This would indicate that the fish in that stream were on average 7.2 % heavier at any specific length. One fish whose length weight relationship gave a large residual value was excluded from the analysis.

2.3.4 Fish distribution

To examine rainbow trout population size distributions, samples for all three streams zones were combined for analyses after determining that there was no difference in regression slopes among the streams. Samples from streams were small and pooling them by zones with similar habitat variables increased the power of analyses. Stations of about the same altitude were grouped as upstream (N1,S1,T1), midstream (N2,S2,T2) and downstream (N3,S3,T3). The symbols N, S and T represent the Naro Moru, the Sagana, and the Thego, respectively.

2.3.5 Reproduction

Breeding biology data included sex, age at breeding where possible and fecundity. Gonads were examined for sex and state of maturity. Absolute fecundity was recorded as the total number of ripe eggs counted numerically from each female as described by Ricker (1968). Eggs were collected from stream caught rainbow trout and from fish held at the Kiganjo Trout Research Station and the Tam Trout fish farm.

2.3.6 Fish movement (tracking with radio telemetry)

Radio and dummy transmitters were surgically implanted in 26 rainbow trout between March and September 1998 to obtain information on the survival and movements of individual fish. The radio tags (Lotek model # MCFT-3EM) had a battery life of approximately 180 days. They measured 11 mm in diameter, 49.3 mm in length, and weighed 4.8 g in water. The fish used weighed more than 500 g on average and consequently transmitters were always less than 2.0 % of the body weight as recommended by Winter (1983). Since fish of this size could not be caught in the streams, specimens for tagging were obtained from the Kiganjo Trout Research Station and the Tam Trout fish farm.

Eight fish were first implanted with dummy transmitters and placed in a cage kept in a raceway at the Kiganjo Trout Research Station (Figure 2.8). Dummy transmitters were used to observe the effect of implanted tags on fish, especially how long it took them to resume feeding and for the wound to heal. Observation of the dummy-tagged fish in cages showed that some fish suffered injuries as a result of contact with the sides and bottom of the cages. Consequently, most radio-tagged fish were released directly into the stream following tagging. Radio tags were implanted in February 1998 for the fish transferred to station S1 (hatchery) and station S2 (Mt. Lodge bridge) in the Sagana. Fish transferred into the Thego (T3) were implanted with radio transmitters in May, June, July and August 1998.

Transmitters were surgically implanted using the method described by Lucas (1989) and McKinley *et al.* (1992). Fish were anaesthetized with clove oil dissolved in absolute ethanol. After about 3 minutes, the fish lost their equilibrium and were then transferred to a surgery board. A near mid-ventral incision about 2.5 cm long was made just anterior to the pelvic girdle. This area has been found to provide enough muscle to make it less likely that sutures will pull out (McKinley *et al.* 1992). The radio tag was then gently inserted and pushed anteriorly into the body cavity. The incision was closed with 3-4 sutures of non-absorptive silk. Surgery took an average of 6 minutes. After surgery, fish were allowed to

Fig. 2.8 Raceways at Kiganjo Trout Research Station where fish implanted with dummy and radio tags were held in a cage to determine the time it took for the incision to heal and for implanted fish to resume feeding. Raceways are silted after light rain due to human activities upstream.

recover in a plastic cage placed in flowing water. They were given about 5-10 minutes after they regained equilibrium, which took 2-3 minutes while in the plastic cage, before they were placed in a cage or into a container for transfer to a stream.

The fish released in the Thego were surgically implanted with transmitters at the Thego Fishing Camp and released into the stream immediately after they recovered from the anaesthesia. Other fish were implanted with transmitters at the Kiganjo Trout Research Station and transported by vehicle to the upstream sites on the Sagana, a distance of about 20 km (S1) and 17 km (S2). The location of each fish was determined using a hand held receiver (Lotek model # SRX-400) with a dipole antenna. When necessary, a yagi antenna was also used. The minimum distance a fish had traveled since its last known position in the stream was calculated after each tracking session.

2.3.7 Fish age and growth

Information on growth was obtained by the following methods: a) Floy tagging and fin clipping, b) ageing and back-calculation using scales, and c) pond experiments using fish of known age.

2.3.7.1 Floy tagging and fin clipping

Tagging was done using FTF-69 Fingerling Tags from Floy Tag Mfg., Inc, Seattle, Washington, USA. The tag was threaded with vinyl and needle under the cartilage located anterior to the dorsal fin. The major objective of tagging fish with Floy tags was to follow the fate of individuals for growth determination as increase in length from the time tagged to the time recaptured. Rainbow trout were tagged in the Sagana (S1,S2,S3), Naro Moru (N1), and Thego (T1). Captive rainbow trout of known age were tagged at the Kiganjo Trout Research Station. At Kiganjo, 156 fish of a population of about 300 that were being monitored for growth in a raceway were Floy-tagged. Thirty of the these Floy-tagged fish were later released in the Thego at T3 (Fishing Camp) along with 30 non-tagged fish which were fin-clipped at the time of their release.

2.3.7.2 Back-calculation of annular growth using scales

Fish scales collected from wild and captive fish were used to evaluate age and growth. Scales were scraped with a sharp blade from the left side of each fish between the base of the dorsal fin and the lateral line. Scales were moistened with a few drops of water and then placed on a petri dish and covered with a glass slide. The number of annuli were counted using a model 1000 Ken A-vision microreader at 16X magnification. Measurements of the radius of the scale, and the radius of the scale to the outer edge of each annulus were made with a digital vernier caliper accurate to the nearest 0.01 mm.

Using length of fish at capture, the radius of the scale at capture, and the radius of the scale to the outer edge of each increment (annular ring), growth information was derived from back-calculated annual growth (Carlander 1982; Murphy and Willis 1996). The Fraser-Lee direct proportion method (Program Disbcal version 7.0 by Frie 1987) was used to estimate mean annual back-calculated length increments and mean back-calculated lengths for each year class.

2.3.7.3 Captive fish

Growth experiments were done with fish of known age that were held and monitored at the Tam Trout holding facilities on the Burguret stream and at the Kiganjo Trout Research Station between July 1997 and June 1998. Because of the exchange of fish that has occurred in the past between these facilities and the streams, these fish were assumed to be genetically similar.

In Kiganjo, a sample of fish (ranging in number from 30 to 106) from the 300 captive fish had their lengths and weights measured monthly. At Kiganjo Trout Research Station, 156 fish were marked with Floy tags in their 5^{th} month. After nine months some of the tagged and non-tagged fish were released in the Thego at the fishing camp area (station T3) as mentioned above. The purpose was to assess the growth of fish in a stream section where no wild rainbow trout were present. Prior to this release, captive fish were held in a cage in the stream at the Thego Fishing Camp for a month to assess their survival.

2.3.7.4 Growth comparisons: captive vs stream fish

Growth of captive rainbow trout in the Kiganjo Trout Research Station and Tam Trout fish farm, Thego tagged fish that were previously in the Kiganjo raceways and wild tagged fish were compared. A t-test was used to assess differences in the growth of these four groups of fish as recommended by Zar (1984). Specific growth of radio-tagged fish released in the Thego at the Thego Fishing Camp (station T3) and later recaptured was also calculated.

2.4 Stream macroinvertebrates

Qualitative and quantitative samples of stream macroinvertebrates were collected from each of the study streams throughout the study period. Information on sites and times of benthic sampling is shown in Table 2.2. A 0.1 m^2 Surber sampler with 250 μm mesh net was used. Samples were collected from the same sites where electrofishing was done. At each station, three replicate Surber samples were taken across the stream; one sample in the middle and one from near each of the banks. Quantitative samples were collected from a range of microhabitats mainly from the riffle sections of the streams. The samples were taken over a reach with velocities of about 0.01 - 1.25 ms^{-1} and depths of about 0.06 - 0.75 m. Depths over 0.75 m were avoided because they were difficult to sample. The three samples from each station were identified separately, combined and an average taken to calculate population densities. Qualitative samples were also obtained by the foot-kick method using a hand held net at all sites. Frequency of occurrence of benthic taxa both by number and percentage were recorded. Macroinvertebrates were identified by reference to relevant identification keys and persons (Merritt and Cummins 1996; Mathooko 1998; D. Larson pers. com.).

2.6 Stomach analysis

The stomachs of 76 rainbow trout were examined to determine the range of food ingested. Immediately after capture, the stomach contents were preserved in 75% alcohol or 4% formalin. Prey items were later identified to the family level and counted under 10-40X magnification using a binocular microscope. Percentage occurrence of the prey items were

Table 2.2 The number of visits made for each station and dates visited to collect benthic macroinvertebrates with a Surber sampler.

Stream	Naro Moru			Sagana			Thego		
Date Sampled	N1	N2	N3	S1	S2	S3	T1	T2	T3
15/4/96				+					
20/6/96		+	+						
21/6/96						+			+
22/6/96				+					
22/7/96									+
7/8/96					+				+
8/8/96							+		
10/8/96	+								
15/8/96		+	+						
23/8/96				+					
25/8/96						+			
27/6/97			+						
29/6/97				+					
30/6/97									+
1/7/97		+	+						
3/7/97					+		+	+	
4/7/97						+			+
12/8/97					+		+	+	
13/8/97				+					
16/8/97						+			
17/8/97									+
18/8/97		+	+						
22/8/97	+								
20/9/97							+	+	
21/9/97									+
23/9/97						+			
24/9/97				+	+				
25/9/97	+	+	+						
11/11/97			+						
12/12/97									+
18/5/98									+
15/6/98									+
17/6/98				+				+	
28/6/98						+			
27/7/98				+	+		+	+	
28/7/98	+	+	+						
29/7/98						+			
30/7/98									+
26/8/98						+	+		+
27/8/98	+								
28/8/98				+	+				
29/9/98	+			+			+		
30/9/98					+	+			+
5/10/98	+			+	+				
6/10/98						+			+
26/11/98									+
7/12/98	+								
8/12/98								+	
12/12/98						+			+

analyzed as described by Bagenal (1978). To determine the selection and availability of food items to rainbow trout, the electivity index (E) of Ivlev (1961) was used in which:

$$E = Ri - Pi / Ri + Pi$$

where Ri = relative proportion of any food item in the stomach and Pi = relative proportion of the same food item in the benthic samples. The values of E lies between -1 for total rejection and approaches +1 for highly selected food items.

2.7 Other fish species

Brown trout (*Salmo trutta*), mountain catfish (*Amphilius uranoscopus*) and cyprinids (*Labeo spp.* and *Barbus sp.*) caught in the Naro Moru, Sagana and Thego were examined and treated the same way as rainbow trout.

Chapter 3: Results

3.1 Physical habitats

3.1.1 Stream section

Physical and chemical characteristics for the 3 stations in each stream are presented in Tables 3.1, 3.2, and 3.3 as monthly minima and maxima (range). Figure 3.1 shows sections of stream flowing through an indigenous deciduous forested area at station S1 on the Sagana and is similar to that at the upstream stations on the Naro Moru (N1) and Thego (T1). The upstream stations had similar characteristics such as stream gradient, channel morphology, high canopy cover, well-vegetated large riparian buffer zones, and riffle-run-pool sections characterised by moderate turbulence. They also exhibited clean gravel interspersed with large granite boulders. Stream width at the upstream stations ranged from 9.0 m to 12.5 m and stream depths from about 13 cm to 68 cm.

The stream section shown in Figure 3.2 is representative of midstream stations N2, S2, and T2. They exhibited a general loss of canopy cover and slightly higher stream temperatures. Midstream sections had widths that ranged from about 10 m to 14.5 m and depths that ranged from 9 cm to 75 cm. Midstream sections, especially in the Thego, had some adjacent agricultural activity where there were little or no buffer strips. These stream sections also showed increased timber harvesting in their watersheds and water abstraction for irrigation and domestic use. Figure 3.3 is representative of sections of the three downstream stations (N3, S3, and T3). Here, all the streams showed some reduction in canopy cover,

Table 3.1 Monthly minimum and maximum values of physical and chemical habitat variables recorded in the Naro Moru based on measurements made in 1996 to 1998. Total numbers of samples taken for all visits are in parentheses.

Naro Moru		**N1 (n = 15)**		**N2 (n = 12)**		**N3 (n = 12)**	
Variable		**min**	**max**	**min**	**max**	**min**	**max**
Stream width	(m)	9.0	12.5	10.0	14.5	10.5	13.5
Wetted width	(m)	7.9	12.0	6.80	12.5	6.50	12.5
Depth	(m)	0.13	0.68	0.09	0.75	0.06	1.30
Velocity	(m/s)	0.18	0.82	0.08	0.86	0.01	1.25
Discharge	(m^3/s)	0.16	5.90	0.06	6.90	0.00	8.51
Water temp	(^0C)	10.2	15.6	12.8	18.5	12.8	17.8
Air temp	(^0C)	18.5	23.5	17.5	24.5	20.5	24.0
D.O.	(mg/l)	7.5	9.80	7.50	8.90	7.40	8.50
pH		7.1	7.90	7.00	8.20	7.00	7.70
Conductivity	(μS)	20.2	95.2	27.3	126	42.1	142.1
$CaCO_3$	(mg/l)	0.0	0.04	0.00	0.04	0.01	0.08
Turbidity	(mg/l)	0.0	0.00	---------		10.0	385

Table 3.2 Monthly minimum and maximum values of physical and chemical habitat variables recorded in the Sagana based on measurements made in 1996 to 1998. Total numbers of samples taken for all visits are in parentheses.

Sagana		**S1 (n = 14)**		**S2 (n = 11)**		**S3 (n = 27)**	
Variable		**min**	**max**	**min**	**max**	**min**	**max**
Stream width	(m)	9.50	11.5	9.00	12.5	10.0	14.8
Wetted width	(m)	7.02	9.80	6.80	10.2	5.40	14.0
Depth	(m)	0.11	0.68	0.12	0.64	0.15	1.36
Velocity	(m/s)	0.18	0.40	0.22	0.92	0.13	0.88
Discharge	(m^3/s)	0.12	2.27	0.19	5.11	0.09	9.54
Water temp	(^0C)	10.2	12.6	10.9	15.1	13.6	21.9
Air temp	(^0C)	14.0	18.0	17.2	19.5	17.5	23.5
D.O.	(mg/l)	8.20	9.30	7.50	8.70	6.92	8.90
pH		7.30	7.90	7.40	7.90	6.84	8.07
Conductivity	(μS)	17.6	72.2	15.1	54.2	54.2	208
$CaCO_3$	(mg/l)	0.00	0.01	0.00	0.07	0.00	0.09
Turbidity	(mg/l)	0.00	0.00	0.00	0.00	10.0	360

Table 3.3 Monthly minimum and maximum values of physical and chemical habitat variables recorded in the Thego based on measurements made in 1996 to 1998. Total numbers of samples taken for all visits are in parentheses.

Thego	**T1 (n = 10)**			**T2 (n = 12)**			**T3 (n = 24)**		
Variable	**min**		**max**	**min**		**max**	**min**		**max**
Stream width (m)	9.00	-	10.6	9.40	-	12.0	10.0	-	14.8
Wetted width (m)	4.60	-	8.50	5.00	-	11.0	8.40	-	14.2
Depth (m)	0.21	-	0.44	0.15	-	0.58	0.12	-	1.28
Velocity (m/s)	0.15	-	0.42	0.04	-	0.79	0.07	-	1.10
Discharge (m^3/s)	0.12	-	1.34	0.03	-	3.06	0.90	-	8.90
Water temp (°C)	9.40	-	11.5	10.8	-	14.0	12.8	-	19.4
Air temp (°C)	17.0	-	18.5	17.0	-	21.5	14.5	-	22.5
D.O. (mg/l)	8.20	-	10.4	7.50	-	8.90	7.50	-	8.80
pH	7.08	-	8.98	7.08	-	8.90	6.80	-	8.90
Conductivity (μS)	15.1	-	40.6	17.6	-	55.40	32.9	-	230
$CaCO_3$ (mg/l)	0.00	-	0.02	0.00	-	0.02	0.01	-	0.12
Turbidity (mg/l)	0.00	-	0.00		---------		0.00	-	300

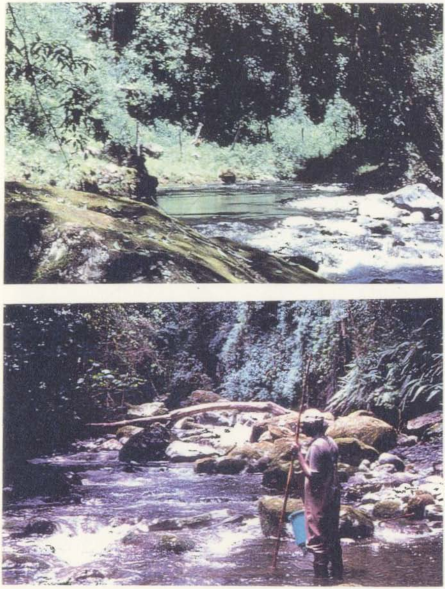


Fig. 3.1 These photographs of the Sagana are representative of upstream stations (N1, S1 and T1.). This is still an area little interfered with by humans. The stream has clean gravel, stabilized banks and little or no silt.

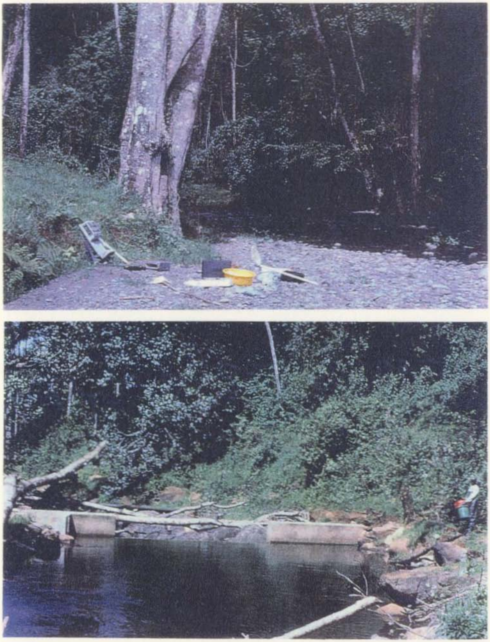


Fig. 3.2 These photographs of the Sagana are representative of midstream stations (N2, S2 and T2). There is a general loss of canopy cover, streams are dammed to provide domestic water but the water quality is still good.

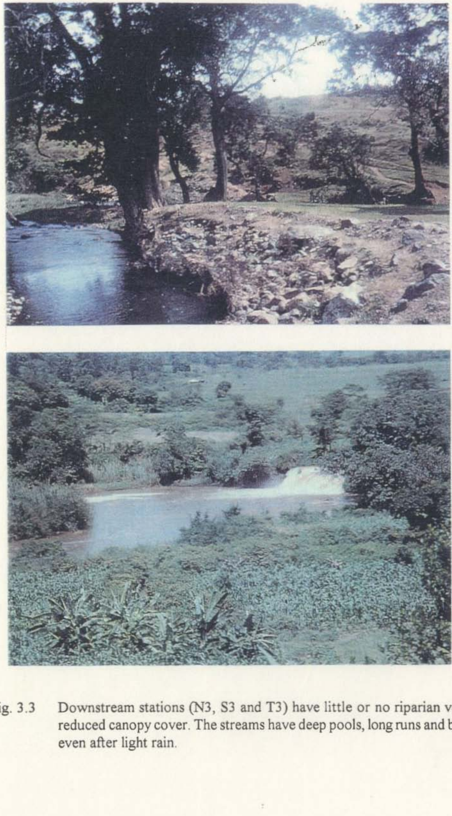


Fig. 3.3 Downstream stations (N3, S3 and T3) have little or no riparian vegetation and reduced canopy cover. The streams have deep pools, long runs and become turbid even after light rain.

little or no riparian vegetation, relatively higher water temperatures, large deep pools, long runs with slower flows and more stream sediment.

3.1.2 Rainfall

Figure 3.4 shows monthly rainfall for each month from January 1997 to June 1998 for the Sagana near station S3. Monthly rainfall for 1997 showed a correlation ($r^2 = 0.53$) with monthly rainfall for 1974 and also showed a correlation with monthly rainfall for 1951 ($r^2 = 0.59$). There was no significant difference in mean monthly rainfall for 1951 and 1974 as shown in Figure 3.5 (t-test gave $t = 0.44$ and $p = 0.66$). Rainfall showed the same general seasonal trend for 1951 and 1974.

3.1.3 Stream Discharge

Mean, maximum and minimum daily discharge showed a seasonal pattern as shown in Figure 3.6 for the Thego as would be predicted by the seasonal pattern of rainfall. Although rainfall within these watersheds appears to have increased over the last 27 years, means of monthly discharge for the Naro Moru at station N2 over the last 36 years showed no concomitant increase (Figure 3.7).

3.1.4 Stream Temperature

There was a significant difference in mean daily noon water temperatures (Figure 3.8) among weeks within months (ANOVA, $F = 5.44$ and $p < 0.001$) for the Thego. There was

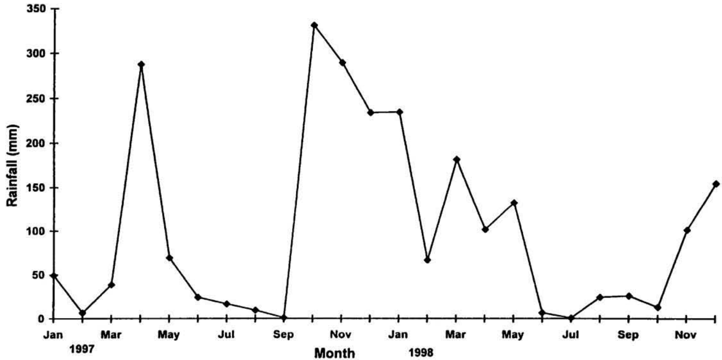


Fig. 3.4 Total rainfall for each month recorded at the Sagana State Lodge weather station near station S3 from January 1997 to December 1998.

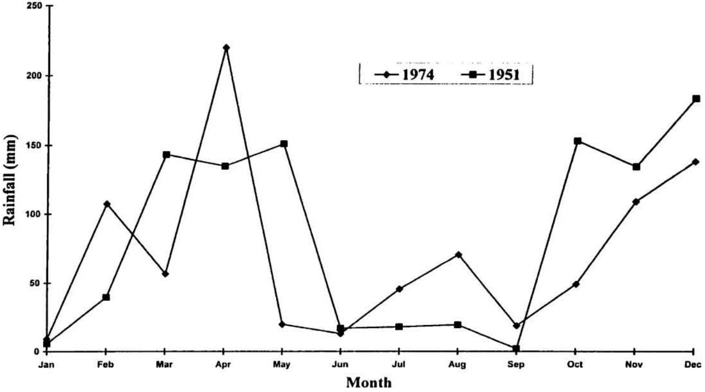


Fig. 3.5 Monthly rainfall for 1951 and 1974 recorded at the Kiganjo Trout Research Station and at the Sagana State Lodge weather station, respectively. Data are from the Ministry of Water Resources, Hydrology section.

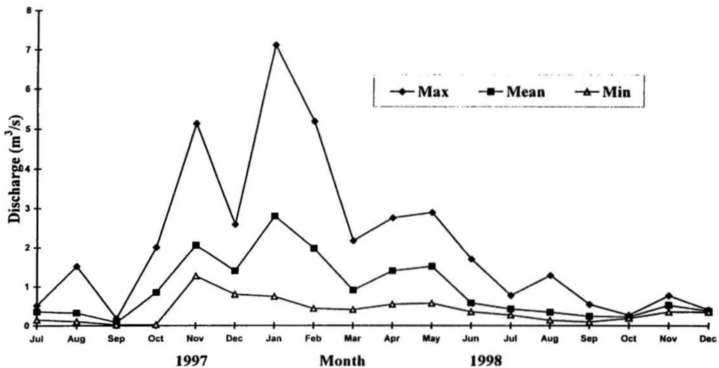


Fig. 3.6 Mean, maximum and minimum daily discharge per month in the Thego recorded at the weir above the Thego Fishing Camp at station T3 from July 1997 to December 1998.

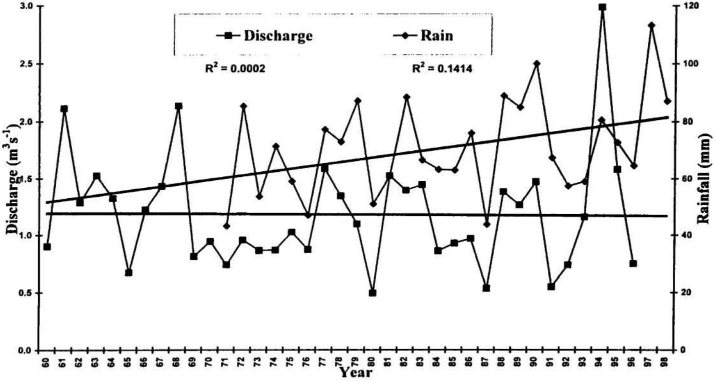


Fig. 3.7 Mean monthly discharge and rainfall for the Naro Moru from 1960 to 1988. Data is from Laikipia Research Program and was recorded at station NM in the Naro Moru situated between stations N1 and N2 at about 2600 m. Regression trendlines have been used to forecast rainfall and discharge patterns.

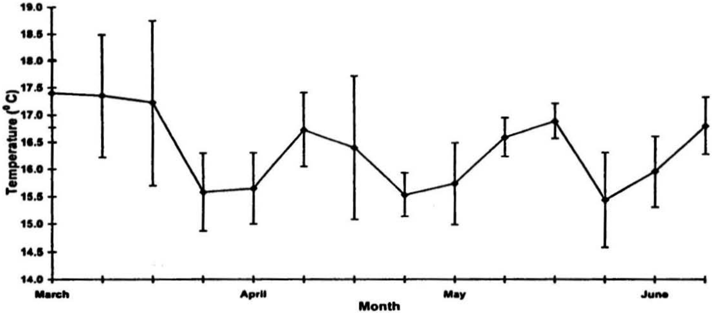


Fig. 3.8 Weekly means and standard deviations of the noon (12.00) temperature in the Sagana recorded daily for three months (March to end of May 1998) at the Kiganjo Trout Research Station (S3).

also a significant difference in daily noon water temperatures between days within weeks (t-test, $t = -2.38$ and $p = 0.049$). A comparison between the mean daily water temperatures for the Sagana at station S3 and Thego at T3 showed no significant difference within months (ANOVA, $F = 0.11$ and $p = 0.739$). There was, however, a significant difference in mean daily noon temperatures within months between the downstream station (S3) and upstream station (S1) on the Sagana (Figure 3.9) (ANOVA, $F = 296.46$ and $p < 0.001$). This significant difference was based on data collected over a longer period than shown in Figure 3.9.

3.2 Fish species distribution

The percentage contribution made by the various fish species to all electrofishing catches at each station between 1996 and 1998 is shown in Figures 3.10 - 3.12. Only trout were caught in the upstream stations, whereas mountain catfish (*Amphilius uranoscopus*) and cyprinids (*Labeo spp.* and *Barbus sp.*) were caught in lower stations. Catfish were the only species taken during electrofishing at the Thego Fishing Camp (T3) and were also taken at the downstream station (S3) in the Sagana. Relatively few specimens of cyprinids were caught over the three year period. *Labeo* were caught in the midstream and downstream stations of the Naro Moru (N2 and N3). *Barbus* were caught in the Sagana downstream station (S3). Brown trout were only captured in the upstream (S1) and midstream (S2) stations of the Sagana.

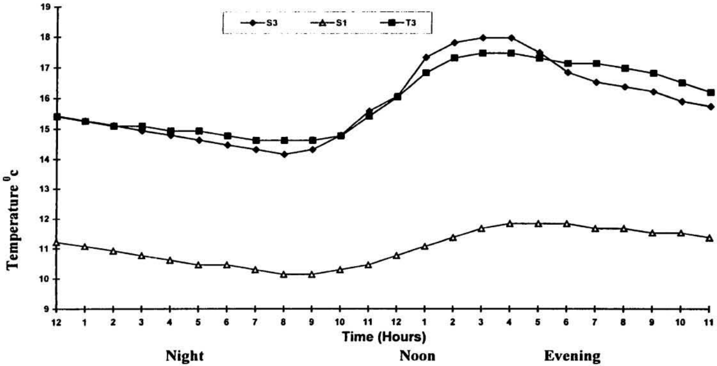


Fig. 3.9 Mean hourly temperature recorded in the Sagana upstream (S1), downstream (S3) and Thego downstream (T3) compared over a 24-hour period. Data are means of six months of temperature records from each station.

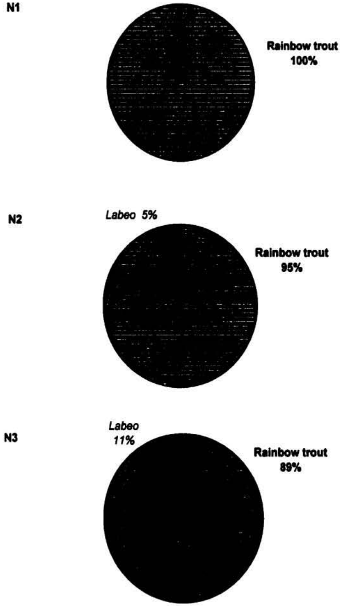


Fig. 3.10 Percentage composition by species of fish caught in the Naro Moru stations N1, N2, and N3 by electrofishing from 1996 to 1998.

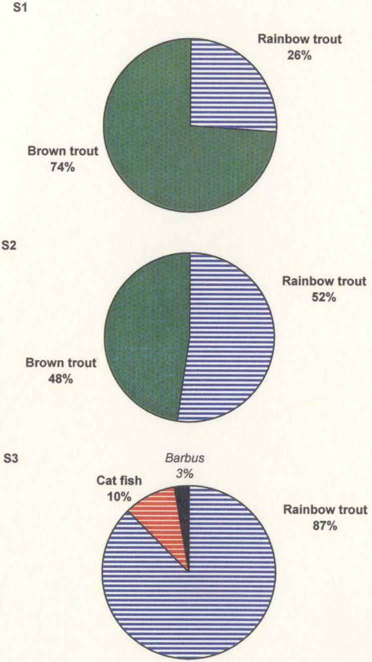


Fig. 3.11 Percentage composition by species of fish caught in the Sagana stations S1, S2, and S3 by electrofishing between 1996 and 1998.

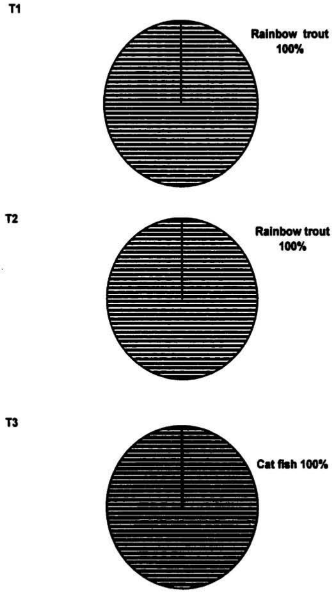


Fig. 3.12 Percentage composition by species of fish caught in the Thego stations T1, T2, and T3 by electrofishing between 1996 and 1998.

3.2.1 Rainbow trout distribution and abundance

The number of visits made to each station, dates visited, number of rainbow trout caught (Appendix 1) and catch per unit effort are summarized in Table 3.4. Mean number of rainbow trout caught per hour of electrofishing (Table 3.5) was lower in the Thego compared with the Naro Moru and the Sagana (t-test, $t = 3.98$, $p = 0.002$). A comparison between CPUE in the Naro Moru (t-test, $t = 3.57$, $p = 0.003$) and the Sagana showed no significant difference in catches between the two streams (t-test, $t = 0.18$, $p = 0.86$), however there was a significant difference in catch per unit effort among the Naro Moru, Sagana and the Thego (ANOVA, $F = 7.57$, $p = 0.002$). The Zippin (1958) method in the Sagana at 1700 m estimated 116 fish (with a mean weight of 26 g) within a 250 m stretch or about 32.6 g of fish in a square metre. While this estimate should be treated with caution, it does provide a basis for comparison with Van Someren's earlier estimates (1952) in which 362.7 g of rainbow trout per square metre was reported for the same location.

Table 3.4 Number of visits made and fish species caught in upstream (N1, S1 and T1), midstream (N2, S2 and T2) and downstream (N3, S3 and T3) stations in the Naro Moru, Sagana and Thego.

Stream	**Zone**	**Station**	**No. of visits**	**Rainbow trout**	**Brown trout**	**Catfish**	***Labeo***	***Barbus***
Naro Moru	upstream	N1	9	298	0	0	0	0
" "	midstream	N2	3	62	0	0	3	0
" "	downstream	N3	2	66	0	0	8	0
Sagana	upstream	S1	7	112	314	0	0	0
"	midstream	S2	7	159	146	0	0	0
"	downstream	S3	10	313	0	35	0	10
Thego	upstream	T1	5	45	0	0	0	0
"	midstream	T2	4	3	0	0	0	0
"	downstream	T3	12	0	0	404	0	0
Total			59	1058	460	439	11	10

Table 3.5 Number of rainbow trout caught per hour of electrofishing (CPUE), number of visits and mean catch per unit effort for each station sampled. Data for 1998 were not included because the electrofisher timer was not working. Number of visits and rainbow trout caught when electrofishing time was not recorded are included in Table 3.4.

Date	Station	No of rainbow trout	Time (hrs.)	CPUE	Mean CPUE for each station
20/4/96	N1	85	0.94	90.4	
20/6/96	"	9	1.10	8.20	
10/8/96	"	75	1.14	65.8	
15/8/97	"	25	0.96	26.0	
22/8/97	"	25	1.01	24.8	
25/9/97	"	18	0.84	21.4	39.4
16/3/96	N2	45	0.80	56.3	
15/8/97	"	12	0.55	21.8	
18/8/97	"	5	0.47	10.6	29.6
17/4/96	N3	44	1.10	40.0	
18/8/97	"	22	1.05	21.0	30.5
15/4/96	S1	11	2.01	5.50	
18/4/96	"	7	0.77	9.10	
24/9/97	"	27	1.14	23.7	
5/7/97	"	17	1.50	11.3	
13/8/97	"	23	1.15	20.0	13.9
7/8/96	S2	21	0.45	46.7	
23/9/97	"	67	1.24	54.0	
12/8/97	"	5	0.32	15.6	38.8
17/3/96	S3	67	1.06	63.2	
16/8/97	"	13	0.79	16.5	
22/9/97	"	68	1.47	46.3	42.0
13/4/96	T1	18	1.52	11.8	
3/7/97	"	0	0.76	0.0	
23/9/97	"	22	1.26	17.5	
12/8/97	"	4	0.42	9.50	9.70
3/7/97	T2	0	0.81	0.0	
12/8/97	T2	1	0.37	2.7	1.35
All dates electrofished	T3	0	0	0	0

3.2.2 Seasonal size comparison among streams and altitudes

Monthly ranges in fork length of rainbow trout for upstream (N1,S1,T1), midstream (N2,S2,T2), and downstream (N3 and S3) stations are shown in Table 3.6. Monthly size frequency histograms of rainbow trout for pooled upstream (N1,S1,T1), midstream (N2,S2,T2), and downstream (N3 and S3) stations are shown in Figure 3.13 -3.16. Fork length distribution modes of rainbow trout were skewed to the left for all stations. The smallest-sized fish were caught in September. The largest specimen electrofished was a 39.6 cm fork length (850 g) female caught in the upstream station (S1) of the Sagana. The second largest specimen, measuring 39.5 cm (832 g), was taken in the downstream station (S3) of the Sagana. Throughout this study, electrofishing sessions caught very few large fish. A comparison among mean monthly fork length of rainbow trout in the upstream (N1,S1,T1), midstream (N2,S2,T2), and downstream (N3 and S3) stations showed no significant difference (ANOVA, $F = 0.56$, $p = 0.58$). There was however a significant difference in mean monthly fork length between months in each zone with some months showing larger fish than others (upstream stations ANOVA, $F = 15.65$, $p < 0.001$; midstream stations ANOVA, $F = 7.27$, $p < 0.001$; and downstream stations ANOVA, $F = 21.23$, $p < 0.001$). There was no significant difference in mean monthly fork lengths between rainbow trout caught in upstream (N1,S1,T1) stations and those caught in downstream (N3 and S3) stations (t-test, $t = -0.03$, $p = 0.98$). Analysis of covariance (ANCOVA) indicated that there was no significant difference in the slopes of the weight length regressions among the streams (ANCOVA, $F = 2.26$, $p = 0.11$). The data

Table 3.6 Monthly range in fork length of rainbow trout from upstream (N1,S1,T1), midstream (N2,S2,T2), and downstream (N3 and S3) stations. Data are combined for the three streams.

Month	Range (cm)	Mean FL (cm)	Number of fish
upstream (N1,S1,T1)			
Jan	13.4 - 25.30	20.8	4
Mar	------------	----	--
Apr	4.80 - 39.60	17.1	121
Jun	6.80 - 26.40	16.4	56
Jul	6.80 - 24.00	13.6	17
Aug	5.70 - 29.80	16.7	152
Sep	2.49 - 29.90	11.8	67
Oct	6.80 - 21.60	14.9	20
Dec	12.6 - 35.10	23.9	17
midstream (N2,S2,T2)			
Jan	8.10 - 16.40	10.6	10
Mar	7.30 - 30.00	13.9	45
Apr	13.6 - 24.60	19.1	2
Jun	10.6 - 22.10	15.5	16
Jul	10.9 - 23.30	15.3	11
Aug	8.00 - 28.00	18.2	44
Sep	2.68 - 24.00	11.7	67
Oct	6.50 - 24.00	16.0	29
Dec	------------	-----	----
downstream (N3 and S3)			
Jan	----------	-----	--
Mar	8.50 - 19.70	13.9	72
Apr	8.10 - 29.20	17.6	56
Jun	4.20 - 23.60	15.5	88
Jul	----------	----	--
Aug	9.60 - 28.50	18.4	60
Sep	4.60 - 21.80	10.4	68
Oct	7.80 - 24.00	16.3	31
Dec	14.0 - 39.50	25.5	4

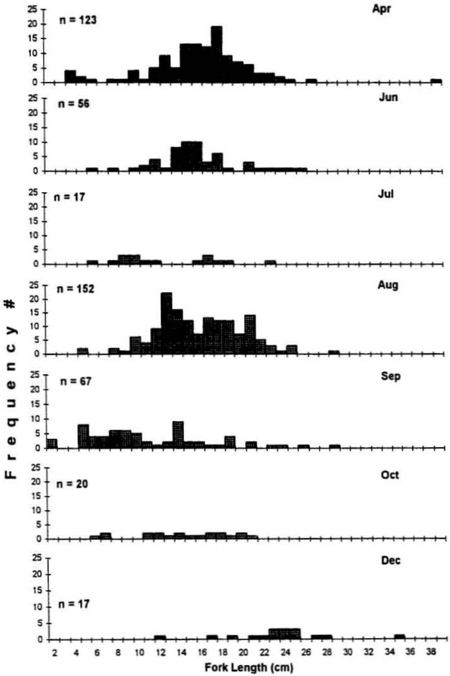


Fig. 3.13 Length frequency histograms of rainbow trout caught by electrofisher for all upstream stations (N1,S1,T1) in 1996-1998.

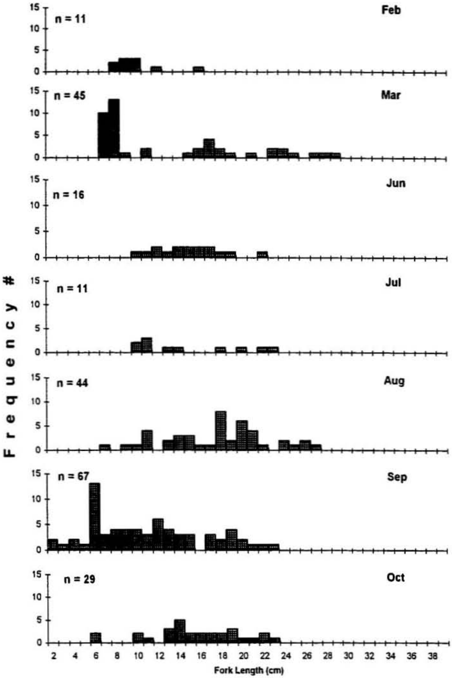


Fig. 3.14 Length frequency histograms of rainbow trout caught by electrofisher for all midstream stations (N2,S2,T2) in 1996-1998.

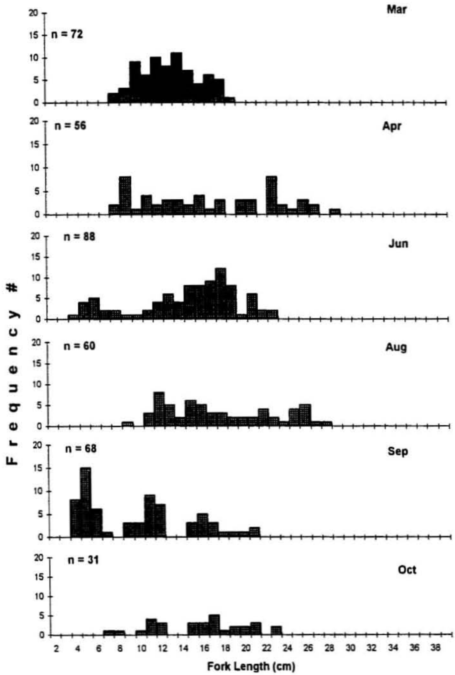


Fig. 3.15 Length frequency histograms of rainbow trout caught by electrofisher for all downstream stations (N3 and S3) in 1996-1998.

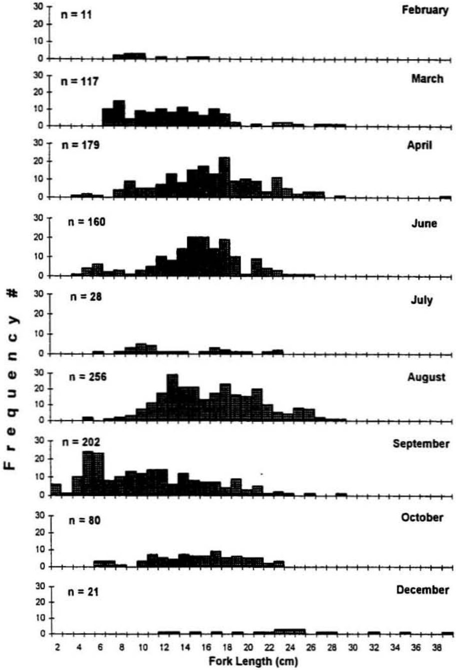


Fig. 3.16 Length frequency histograms of rainbow trout caught by electrofisher for all stations grouped by month of capture in the Naro Moru, Sagana and Thego in 1996-1998. January fish excluded due to sample size.

for all streams was therefore combined to explore the potential effects of altitude and months on fish condition (length-specific weight) using dummy binary variables.

3.2.3 Influence of 'dummy' variables on length and weight

The influence of variables on the length specific weight is summarized in Tables 3.7 and 3.8. Stream effects were not significant, as confirmed by ANCOVA analysis. The Thego trout tended to be slightly heavier at length (3.57%) but the effect was not quite significant at the 5% level ($p = 0.059$). The effect of altitude was small, although it was statistically significant for midstream and downstream stations. Fish from downstream (N3 and S3) stations were 1.8% heavier than average while fish from midstream stations were 2.1% lighter than average. There were significant seasonal differences in four out of ten months when sampling was done (Table 3.8). There was a general seasonal trend (Figure 3.17) with length specific weight tending to be below average from September through to March (except in December) and above average from April through August. It must be remembered that these data do not represent a true chronological sequence; sampling occurred over a three-year interval. However, seasonal pattern as shown by length specific weight reflect environmental changes including rainfall.

Table 3.7 Summary data of categorical variables (streams and altitudes) used as 'dummy' variables in a multiple regression model to determine their effects on rainbow trout fork length and body weight relationship (regression). Significant level at $p < 0.05$ is shown in bold.

CATEGORY	T VALUE	SIGNIFICANCE	COEFFICIENT	EFFECT (%)
Stream				
Naro Moru	1.125	0.410	1.0067	0.67
Sagana	-1.535	0.125	0.9881	-1.19
Thego	1.891	0.059	1.0357	3.57
Altitude (zones)				
upstream	-0.380	0.704	0.997	-0.3
midstream	-2.575	**0.010**	0.978	-2.1
downstream	2.436	**0.015**	1.019	1.8

Table 3.8 Summary data of categorical seasonal variables (months) used as 'dummy' variables in a multiple regression model to determine their effects on rainbow trout fork length and body weight relationship (regression). Significant level at $p < 0.05$ is shown in bold.

CATEGORY	T VALUE	SIGNIFICANCE	COEFFICIENT	EFFECT (%)
Month				
Jan	-1.185	0.236	0.873	-12.7
Feb	-3.541	**0.001**	0.927	-7.3
Mar	-0.507	0.613	0.939	-6.1
Apr	-0.999	0.318	0.988	0.003
Jun	2.116	**0.035**	1.025	2.5
Jul	1.314	0.189	1.033	3.3
Aug	2.665	**0.008**	1.028	2.8
Sep	-0.511	0.609	0.994	-0.6
Oct	-1.986	**0.047**	0.971	-2.9
Dec	0.507	0.612	1.012	1.2

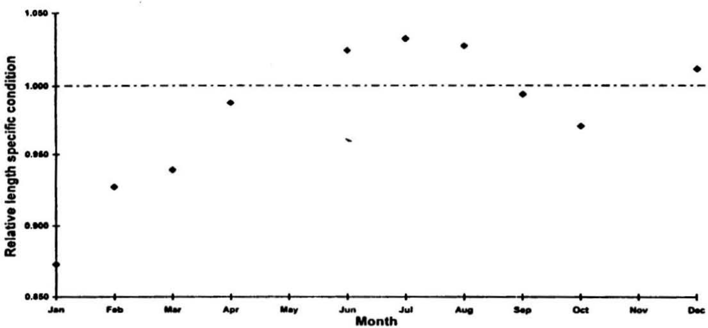


Fig. 3.17 Seasonal pattern of relative length specific condition of fish sampled during 1996-1998. Dotted line at 1.0 represents the overall average condition. These are monthly coefficients from Table 3.8.

3.3 Reproduction (Fecundity)

Absolute fecundities for both wild and farmed rainbow trout are shown in Appendix 2. Fecundity for the wild fish ranged from 265 eggs for an 18.0 cm (fork length) female to 1915 for a 38.5 cm (fork length) female. Fecund captive fish were relatively large with the largest fish (49.0 cm) having about 3250 eggs. Comparison between the body length and number of eggs for wild and captive rainbow trout showed no significant difference (ANOVA, $F = 0.54$ and $p = 0.47$).

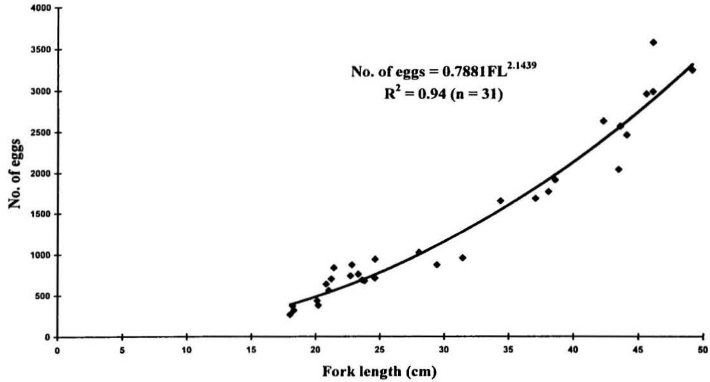


Fig. 3.18 Relationship between fork length (cm) and fecundity for both wild and captive rainbow trout.

3.4 Tagged and fin clipped fish

Based on observations of fish implanted with dummy transmitters and held at the Kiganjo Trout Research Station surgical wounds healed, on average, within eight days and fish fed three days after surgery. The movements of radio-tagged rainbow trout are summarized for the Sagana stations S1 and S2 and for the Thego station T3 in Tables 3.9 and 3.10 respectively. The proportions of those fish moving upstream was higher in all the stations than those moving downstream. Estimated distances traveled between observations varied from 0 to 1.2 km in the Sagana and from 0 to 1.09 km in the Thego. In the Thego, fish with tag numbers F0 and F7 moved upstream soon after the water level rose. Radio-tagged fish in the Sagana were monitored for a much shorter time than those in the Thego. All the fish released in the Sagana were caught by illegal fishers within a period ranging from 2 days to less than a month as evidenced by recovery of tags from the anglers (from February 25th to March 14th). Radio-tagged rainbow trout in both streams showed a tendency to move upstream, however there were a few that remained in the same pool where they were released or moved downstream. The Thego fish were not poached and so they were tracked for a longer period ranging from three weeks to three months. Ten of the eleven radio-tagged fish in the Thego were recovered compared to none in the Sagana. Based on recapture data, Floy-tagged and fin-clipped fish in the Thego spread in both upstream and downstream directions but stayed within about 1 km in either direction. Recovery of wild Floy-tagged and fin-clipped fish was very low, 1.8% in the Naro Moru and Sagana. Only 3 fish from 167 Floy-tagged rainbow trout were recovered.

Table 3.9 Distances moved by radio-tagged rainbow trout monitored in the Thego (station T3). Distances are in metres estimated from the point of release. Positive numbers indicate upstream movement and negative numbers indicate downstream movement. R indicates the recapture of a fish and + indicates a fish that moved upstream out of range. Total is the sum of the distance traveled in all directions. Four of the eleven radio-tagged fish were not tracked but were recaptured and their specific growth recorded.

	Radio transmitters tag codes for fish tracked in the Thego						
Date	**015**	**S1**	**S4**	**F0**	**F7**	**F8**	**F9**
24/8/98	0	0	0	0	0	0	0
25/8/98	0	30	0	0	-50	0	0
26/8/98	0	0	30	50	50	0	30
27/8/98	0	520	0	0	0	30	70
28/8/98	0	0	70	695	695	0	0
29//8/98	0	0	-70	0	0	0	0
30/8/98	0	0	0	100	100	0	0
31/8/98	0	0	0	50	50	0	-70
1/9/98	0	0	0	0	50	0	0
3/9/98	0	0	0	0	0	-30	0
4/9/98	0	0	0	0	0	0	0
5/9/98	0	0	0	0	0	0	0
8/9/98	0	0	0	50	R	0	70
9/9/98	0	0	0	+		0	0
12/9/98	0	0	0	+		0	-70
21/9/98	0	55	0	+		280	0
25/9/98	0	0	0	+		0	0
27/9/98	0	0	0	+		0	0
28/9/98	0	100	0	+		0	0
1/10/98	0	0	0	+		0	780
5/10/98	0	0	0	+		0	0
6/10/98	R	R	0	+		0	R
9/10/98			R	+		0	
18/12/98				+		R	
Total	0	705	170	945+	995	340	1090

Table 3.10 Distances moved by radio-tagged rainbow trout monitored in the Sagana (stations S1 and S2). Distances are in metres measured from the point of release and P indicates the removal of the fish from the stream by poaching. Total is the sum of the distances traveled in all directions.

	Radio transmitters tag codes for fish tracked in the Sagana						
Date	**925-4**	**895**	**025**	**856**	**925-5**	**845**	**855**
23/2/98	0	0	0	0	0	0	0
24/2/98	150	750	200	50	-50	0	20
25/2/98	0	0	0	0	**P**	**P**	**P**
27/2/98	0	100	50	0			
11/3/98	200	350	250	30			
14/3/98	**P**	**P**	400	**P**			
27/7/98			**P**				
Total	350	1200	900	80	50	0	20

3.5 Age and growth of rainbow trout

3.5.1 Age determination using scales

Scales (Figure 3.19) taken from fish of known age held at Kiganjo Trout Research Station and from wild fish were used to determine rainbow trout length at age and estimate mean annual length increments. Age distributions based on scale analyses are presented in Table 3.11. Mean back-calculated rainbow trout lengths at age for upstream (N1,S1,T1), midstream (N2,S2,T2) and downstream (N3,S3,T3) stations and for males and females caught in upstream station N1 are shown in Tables 3.12 - 3.15. There was no significant difference in pooled mean back-calculated lengths at age for all years between fish in upstream and downstream stations (t-test, $t = -0.01$, $p = 0.99$). Neither was there a significant difference in mean back-calculated lengths at age between sexes (t-test, $t = -0.27$, $p = 0.80$).

When samples from midstream stations were tested against upstream and downstream stations there was a significant difference in mean back-calculated length at age (ANOVA, $F = 4.26$, $P = 0.24$) but the sample size was small. The significant difference was between midstream stations and upstream stations (t-test, $t = 3.04$, $p = 0.0078$). Mean back-calculated lengths at age for fish held at the Kiganjo Trout Research Station are shown in Table 3.16 and compared with mean back-calculated fork lengths at age for fish in upstream and downstream stations as shown in Figure 3.20.

There was no significant difference in mean back-calculated fork lengths at age between wild rainbow trout caught downstream and those held in the Kiganjo Trout Research

Fig. 3.19 Scale taken from a 14 month old immature female rainbow trout measuring 31.6 cm fork length. The fish was held at the Kiganjo Trout research Station for 9 months then released in the Thego near the Thego Fishing Camp. The scale was taken after recapture on 30th July 1998 and shows one annulus.

Table 3.11 Summary data on number of rainbow trout whose scales were used for back-calculation of length at age and measurements of mean annual length increments.

Source	Year	Age in Years					Total
		0	1	2	3	4	
upstream	1996	7	12	11	1	-	31
	1997	14	19	9	-	-	42
	1998	9	4	12	3	-	28
midstream	1997	-	13	9	-	-	22
downstream	1996	4	3	5	-	-	12
	1997	5	10	-	-	-	15
	1998	2	7	2	3	2	16
captive fish	1997	1	9	7	-	3	20
	1998	1	2	-	-	-	3

Table 3.12 Mean back-calculated lengths (mm) for each age class of rainbow trout for upstream stations in 1996 -1998.

Upstream stations (N1,S1,T1) in 1996.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1995	1	12	50.0	113.26			
1994	2	11	45.8	117.88	166.52		
1993	3	1	4.20	108.50	215.10	266.84	0
All		24	100.0	115.18	170.57	266.84	0

Upstream stations (N1,S1,T1) in 1997.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1996	1	19	67.86	131.89			
1995	2	9	32.14	138.59	210.82	0	0
All		28	100.0	134.04	210.82	0	0

Upstream stations (N1,S1,T1) in 1998.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1997	1	4	21.0	118.63			
1996	2	12	63.2	134.98	191.56		
1995	3	3	15.8	129.66	196.43	252.89	0
All		19	100.0	130.7	192.53	252.89	0

Table 3.13 Mean back-calculated lengths (mm) for each age class of rainbow trout for midstream stations in 1997.

Midstream stations (N2,S2,T2) in 1997.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1996	1	12	54.5	119.16			
1995	2	10	45.5	120.45	180.04		
All		22	100.0	119.75	180.04	0	0

Table 3.14 Mean back-calculated lengths (mm) for each age class of rainbow trout for downstream stations in 1996 -1998.

Downstream stations (N3 and S3) in 1996.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1995	1	3	37.5	121.06			
1994	2	5	62.5	117.61	195.60		
All		8	100.0	118.90	195.60	0	0

Down stream stations (N3 and S3) in 1997.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1996	1	10	100.0	131.75	0		
All		10	100.0	131.75	0	0	0

Down stream stations (N3,S3,T3) in 1998.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1997	1	7	50.0	158.07			
1996	2	2	14.3	147.64	235.61		
1995	3	3	21.4	155.77	246.17	315.13	
1994	4	2	14.3	123.56	200.69	275.03	352.95
All		14	100.0	151.15	230.16	299.09	352.95

Table 3.15 Mean back-calculated lengths (mm) for each age class of rainbow trout for males and females from upstream station N1.

Males caught in December 1998.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1997	1	0	0.0	0			
1996	2	7	87.5	135.65	189.65		
1995	3	1	12.5	112.66	177.96	234.96	0
All		8	100.0	132.66	188.18	234.96	0

Females caught in December 1998.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1997	1	0		0			
1996	2	5	71.4	134.04	194.24		
1995	3	2	28.6	138.16	205.66	261.86	0
All		7	100.0	135.22	197.50	261.86	0

Table 3.16 Mean back-calculated lengths (mm) for each age class for rainbow trout held at the Kiganjo Trout Research Station in 1997.

Year Class	Age group	No. of fish		Mean back-calculated lengths at age			
		Total	%	1	2	3	4
1996	1	9	47.4	191.44			
1995	2	7	36.8	156.79	242.35		
1994	3	0	0	-	-	-	-
1993	4	3	15.8	179.87	267.57	359.19	423.24
All		19	100.0	176.85	249.92	359.19	423.34

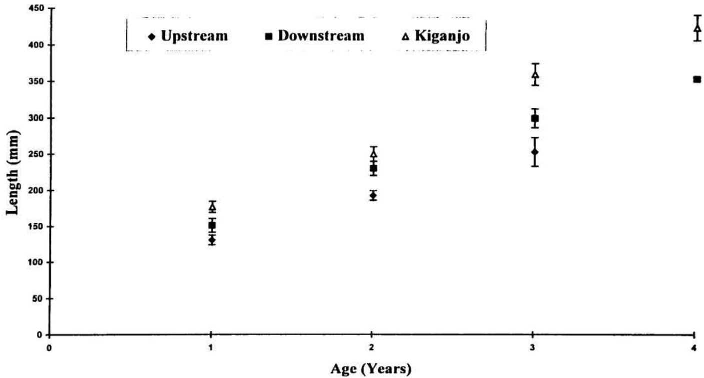


Fig. 3.20 Mean back-calculated length for each age class of rainbow trout for upstream, downstream and fish held at the Kiganjo Trout Research Station.

Station (ANOVA, $F = 0.05$, $p = 0.83$). There was also no significant difference in mean back-calculated length at age among years for the period from1996 to 1998 (ANOVA, $F = 0.05$, $p = 0.95$) for upstream stations. The minimum mean back-calculated length at age for age one rainbow trout was 10.9 cm in upstream stations above 2200 m altitude and 15.1 cm for downstream stations.

3.5.2 Mean annual back-calculated length increments

Mean annual back-calculated length (mm) increments for each age class of rainbow trout for downstream stations (N3, S3, T3) and fish held at the Kiganjo Trout Research Station are shown in Figure 3.21. Fish held at the Kiganjo Trout Research Station showed higher mean annual back-calculated length increments than those from upstream (N1, S1, T1) stations and also those from downstream (N3, S3, T3) stations. Midstream data were excluded from this analysis because they were few. Female fish also showed higher mean annual back-calculated length increments than male fish caught from the same site at the same time (Figure 3.22). There was no significant difference in mean annual length increments of fish caught by Van Someren in 1947/48 in the Thego and in 1949 in the Sagana with those caught in 1998 in the same locality (ANOVA, $F = 0.10$, $p = 0.905$).

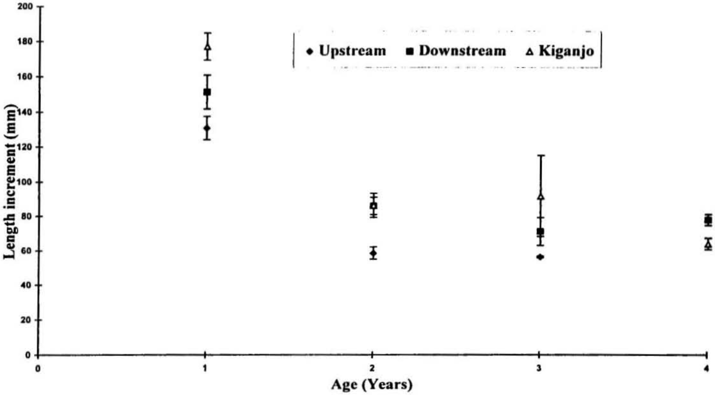


Fig. 3.21 Mean annual back-calculated length increments of rainbow trout for upstream and downstream stations and for fish held at the Kiganjo Trout Research Station.

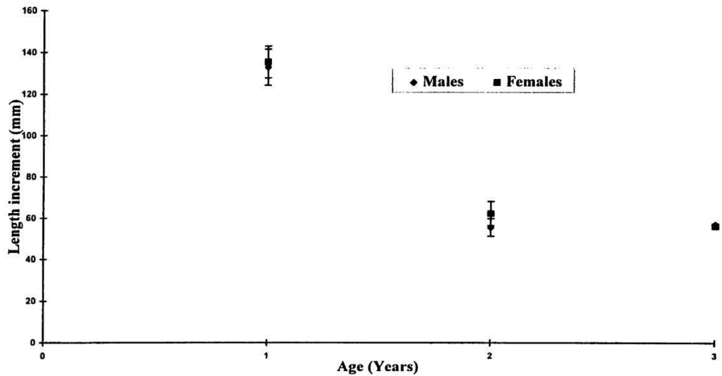


Fig. 3.22 Mean annual back-calculated length increments of male and female rainbow trout for upstream stations.

3.5.3 Growth of rainbow trout at the Kiganjo Trout Research Station and Tam Trout fish farm

Length frequency histograms of rainbow trout monitored in raceways at the Kiganjo Trout Research Station and Tam Trout fish farm are shown in Figures 3.23 and 3.24, respectively. The histograms showed a gradual shift to the right over time. Mean daily length (cm) increments of fish for Kiganjo and Tam Trout farm are shown in Tables 3.17 and 3.18. There was no significant difference in mean daily length increments between Kiganjo and Tam Trout fish overall (t-test $t = 1.52$, $p = 0.15$), however the Tam trout mean increment was higher and the fish were significantly larger from day 250 onwards, as indicated by the lack of overlap of the standard deviations (Figure 3.25 and 3.26).

3.5.4 Comparative growth of captive and wild fish

Growth of rainbow trout monitored in the Kiganjo Trout Research Station and Tam Trout fish farm was compared with fish that were initially in raceways at Kiganjo and then released in the Thego at station T3 (Thego Fishing Camp). Average daily length increments for these groups are shown in Tables 3.19-3.21.

There was a significant difference in growth (length increment per day) between the captive (Kiganjo and Tam trout), Thego recapture (fish released in the Thego) and recovered wild tagged fish (ANOVA, $F = 9.80$, $p < 0.001$). There was no significant difference in growth between the Thego recaptured fish and fish held at Kiganjo (t-test, $t = -1.07$, $p = 0.31$), and those at Tam Trout fish farm (t-test, $t = 0.97$, $p = 0.36$). Thego recapture fish grew significantly faster than wild tagged fish recaptured in the Naro Moru and the Sagana (t-test, $t = 14.09$, $p < 0.001$). Fish that were in the Kiganjo Trout Research Station before their release into the Thego (Thego recaptured fish) showed the highest growth rate as shown in Figure 3.27.

Growth data from the radio-tagged fish in the Thego (Table 3.22) showed that these fish grew, indicating that they recovered well from surgery, and actively foraged following the implantation of the radio tags.

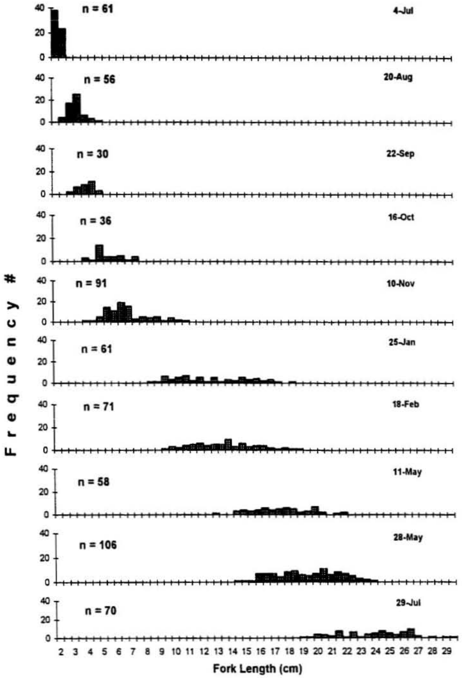


Fig. 3.23 Length frequency histograms of rainbow trout that were monitored for growth in Kiganjo Trout Research Station from July 1997 to July 1998.

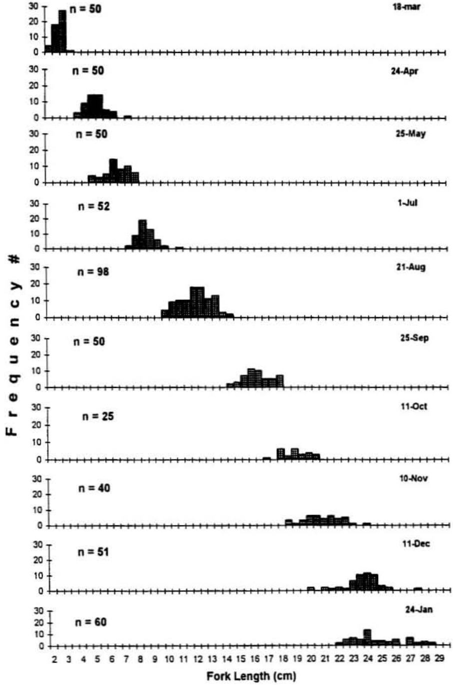


Fig. 3.24 Length frequency histograms of rainbow trout that were monitored for growth at Tam Trout farm from March 1997 to January 1998.

Table 3.17 Mean growth (cm) of rainbow trout kept at Kiganjo Trout Research Station. Fish were one month old when measurements commenced and they were monitored for 392 days. These fish were hatched on 4th June 1997. Data for 27/2/98 has been excluded from Figure 3.23 because it was close to 18/2/98.

Date	**FL (cm)**	**Age (Days)**	**Period (days)**	**Growth (cm)**	**Growth (cm/day)**
4-7-97	2.54	1	1	-	-
20-8-97	3.75	48	47	1.21	0.026
22-9-97	4.49	81	33	0.74	0.022
16-10-97	6.01	105	24	1.52	0.063
10-11-97	7.25	130	25	1.24	0.050
25-1-98	13.2	207	77	5.93	0.077
18-2-98	14.1	231	24	0.88	0.037
27-2-98	14.3	240	9	0.23	0.026
11-5-98	18.0	313	73	3.71	0.051
28-5-98	19.7	330	17	1.74	0.102
29-7-98	24.3	392	62	4.54	0.073

Table 3.18 Mean growth (cm) of rainbow trout held at Tam Trout fish farm. Fish were two months old when measurements commenced and they were monitored for 313 days. March to May data were from the farm records. These fish were hatched on 18th January 1997.

Date	**FL (cm)**	**Age (days)**	**Period (days)**	**Growth (cm)**	**Growth (cm/day)**
18-3-97	3.08	1	1	-	-
24-4-97	5.53	38	37	2.45	0.066
25-5-97	7.05	69	31	1.52	0.049
1-7-97	9.00	106	37	1.96	0.053
21-8-97	12.5	157	51	3.48	0.068
25-9-97	16.7	192	35	4.25	0.121
11-10-97	19.4	208	16	2.66	0.167
10-11-97	21.2	238	30	1.84	0.061
11-12-97	24.0	269	31	2.80	0.090
24-1-98	25.1	313	44	1.10	0.025

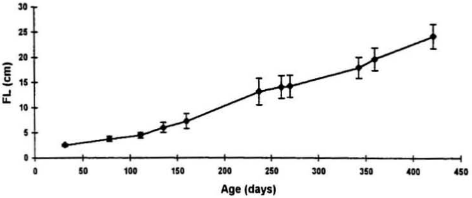


Fig. 3.25 Mean Length at age (days) of rainbow trout monitored in a raceway at the Kiganjo Trout Research Station. Fish were one month old when first measured and were monitored for 392 days.

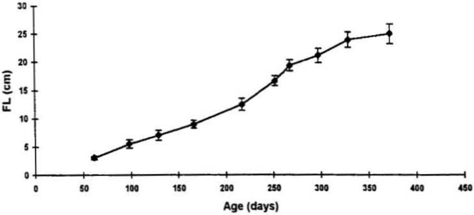


Fig. 3.26 Mean length at age (days) of rainbow trout monitored in a pond at Tam Trout fish farm. Fish were two months old when first measured and were monitored for 313 days.

Table 3.19 Average daily length increments of Floy-tagged fish monitored at the Kiganjo Trout Research Station in 1997-1998.

Tag No.	Initial FL (cm)	Final FL (cm)	Period (days)	Growth (cm)	Length increment (cm/day)
001	16.1	17.0	25	0.9	0.04
006	14.8	15.2	99	0.4	0.004
022	19.0	19.2	25	0.2	0.008
022	19.2	23.0	99	3.8	0.04
026	10.1	10.5	25	0.4	0.02
026	11.3	16.6	99	5.3	0.05
027	10.5	11.3	25	0.8	0.03
030	17.6	18.8	25	1.2	0.05
031	14.3	14.7	25	0.4	0.02
032	16.3	17.1	25	0.8	0.03
034	13.4	13.8	25	0.4	0.16
039	16.8	16.9	25	0.1	0.01
041	13.7	14.4	25	0.7	0.03
042	11.7	13.2	25	1.5	0.06
046	17.5	18.1	25	0.6	0.02
046	18.1	23.2	74	5.1	0.07
046	23.2	27.0	87	3.8	0.04
101	13.5	24.8	161	11.3	0.07
119	13.1	20.1	99	7.0	0.07
119	20.1	24.4	62	4.3	0.07
121	15.2	20.2	99	5.0	0.05
121	20.2	22.8	62	2.6	0.04
122	18.4	23.0	99	4.6	0.05
122	23.0	26.6	124	3.6	0.06

Table 3.20 Growth of Floy-tagged fish that were initially held at the Kiganjo Trout Research Station for nine months then released into the Thego in February 1998 and later recaptured. Initial fork length used to estimate growth was based on a randomized mean of the group of fish released into the Thego. Fish were 9 months old at the time of their release. Period (days) is the length of time between release at age 9 months and recapture.

Initial FL (cm)	Final FL (cm)	Period (Days)	Growth (cm)	Growth (cm/day)
14.3	32.0	144	17.7	0.12
14.3	29.0	152	14.7	0.10
14.3	26.8	152	12.5	0.08
14.3	31.6	153	17.3	0.11
14.3	32.4	153	18.1	0.12
14.3	31.3	153	17.0	0.11
14.3	30.8	153	16.5	0.11
14.3	31.3	153	17.0	0.11
14.3	32.6	153	18.3	0.12
14.3	30.0	173	15.7	0.09
14.3	28.2	180	13.9	0.08
14.3	30.1	174	15.8	0.09
14.3	29.7	174	15.4	0.09
14.3	29.4	174	15.1	0.09
14.3	28.1	174	13.8	0.08
14.3	32.0	177	17.7	0.10
14.3	30.8	194	16.5	0.09
14.3	34.5	267	20.2	0.08
14.3	33.8	268	19.5	0.07
14.3	25.8	284	11.5	0.04
14.3	36.5	292	22.2	0.08
14.3	35.5	292	21.2	0.07

Table 3.21 Specific growth of wild rainbow trout marked with Floy tags and recaptured in the Naro Moru and the Sagana.

Tag No.	**Initial FL (cm)**	**Recapture FL (cm)**	**Period (Days)**	**Growth (cm)**	**Growth (cm/day)**
948	16.0	17.9	112	1.90	0.017
939	15.4	18.2	112	2.80	0.025
932	20.0	21.7	112	1.70	0.015
mean growth rate					**0.019±0.005**

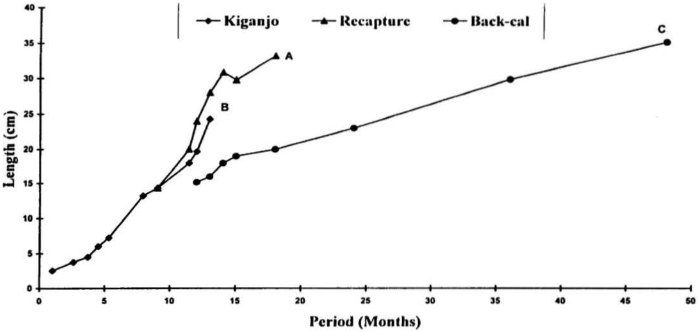


Fig. 3.27 Mean length at age (months) of rainbow trout recaptured in the Thego (A), compared with captive fish held at the Kiganjo Trout Research Station (B) and back-calculated fish (C).

Table 3.22 Specific growth of radio-tagged rainbow trout released into the Thego at station T3 (Thego Fish Camp). '*' indicates fish whose movements were tracked daily.

Code	Sex	Initial FL (cm)	Final FL (cm)	Period (days)	Growth (cm)	Growth (cm/day)
000	F	32.5	37.0	152	4.5	0.030
001	F	34.0	38.5	218	4.5	0.021
056	M	35.0	39.8	193	4.8	0.025
S1 *	M	34.5	35.5	46	1.0	0.022
S4 *	F	36.2	37.5	49	1.3	0.027
F7 *	M	36.0	36.2	18	0.2	0.011
F8 *	F	36.5	44.0	120	7.5	0.063
F9 *	F	35.2	37.0	46	1.8	0.039
015 *	M	28.5	32.8	69	4.3	0.062
895	M	28.0	32.0	76	4.0	0.053
mean growth rate						**0.035±0.018**

3.6 Benthic macroinvertebrates

A total of 44 taxa were identified from 81 Surber samples collected from the study sites in the Naro Moru, Sagana and Thego. Occurrence of macroinvertebrates within stations is shown in Table 3.23. Occurrence by average numbers and percentages is also shown in Appendices 3 and 4. The abundance of major groups (Orders) of taxa found in these sites is presented in Tables 3.24 - 3.26. The most abundant taxa were Simuliidae (Diptera), Baetidae (Ephemeroptera), and Hydropsychidae (Trichoptera). The taxa showed an altitudinal change as shown in Figures 3.28 - 3.30. There were more dipterans in the upstream stations and more ephemeropterans in the downstream stations. The distributional pattern also showed an increase in taxonomic diversity from 31 taxa in upstream stations to 39 in downstream stations. Diversity of taxa at family level is consistent with that reported by Van Someren (1952) which ranged from 21 to 30 in samples collected in 1947 to 1949. He reported that Simuliidae dominated in upstream as well as downstream stations of the Sagana, while the next commonest taxa was Baetidae.

Table 3.23 Presence (+) or absence (0) of macroinvertebrates in benthic samples collected from the Naro Moru, Sagana and Thego streams.

Taxon	N1	N2	N3	S1	S2	S3	T1	T2	T3
EPHEMEROPTERA									
Baetidae	+	+	+	+	+	+	+	+	+
Caenidae	+	+	+	+	+	+	+	+	+
Heptageniidae	+	+	+	0	0	+	+	+	+
Leptophlebiidae	+	+	+	+	+	+	+	+	+
Oligoneuriidae	+	0	0	0	0	+	+	+	+
Tricorythidae	+	+	+	+	+	+	0	+	+
DIPTERA									
Athericidae	0	+	0	+	+	+	0	0	+
Chironomidae	+	+	+	+	+	+	+	+	+
Ceratopogonidae	0	+	0	+	0	+	0	0	+
Dixidae	0	0	+	0	0	0	0	0	0
Empididae	+	0	0	+	+	0	0	0	0
Muscidae	0	0	0	0	+	0	0	0	0
Simuliidae	+	+	+	+	+	+	+	+	+
Tabanidae	0	+	0	0	0	+	+	0	+
Tipulidae	+	+	+	+	+	+	+	+	+
Misc. Diptera	0	0	0	0	0	0	+	0	+
TRICHOPTERA									
Ecnomidae	0	+	+	0	0	0	0	0	+
Hydropsychidae	+	+	+	+	+	+	+	+	+
Hydroptilidae	+	0	0	+	0	+	0	0	+
Lepidostomatidae	+	+	+	+	+	+	+	+	+
Leptoceridae	+	+	+	+	+	+	+	+	+
Philopotamidae	+	0	0	0	0	0	0	0	+
Rhyacophilidae	0	0	0	0	+	0	0	+	+
COLEOPTERA									
Dytiscidae	+	+	0	0	0	0	0	0	0
Elmidae	0	+	+	+	0	+	0	+	+
Gyrinidae	0	0	+	0	0	+	0	0	+
Hydraticus	0	+	0	0	0	0	0	0	+
Psephenidae	0	0	0	0	0	+	0	0	+
Scirtidae	+	+	+	+	+	+	+	+	+
PLECOPTERA									
Perlidae	+	+	+	0	0	0	0	0	+
ODONATA									
Aeshnidae	0	+	0	0	0	0	0	0	0
Protoneuridae	0	+	+	0	0	+	0	0	+
HEMIPTERA									
Gerridae	0	+	0	0	0	0	0	0	0
Naucoridae	0	+	0	0	0	0	0	0	0
Nepidae	0	+	+	0	0	0	0	0	+
Notonectidae	0	+	0	+	0	0	0	0	+
Veliidae	0	+	0	0	0	0	0	0	0
DECAPODA	+	+	+	0	0	+	0	0	+
GASTROPODA	0	+	0	+	0	+	0	0	0
NEMATODA	0	0	+	+	+	0	+	0	0
MISC. MOLLUSC	0	+	0	0	0	+	0	0	+
OLIGOCHAETA	+	+	+	+	+	+	+	0	+
PLANARIA	+	+	+	+	+	+	+	+	+
Terrestrials**	0	+	+	0	+	+	0	+	+

** Includes organisms such as ants, bees, grasshoppers and spiders.

Table 3.24 Average number of individuals per taxa of macroinvertebrates in the upstream stations (N1,S1,T1) of the Naro Moru, Sagana and Thego streams. N = 26 for all months indicated.

Taxon	**Apr (n=1)**	**Jun (n=3)**	**Jul (n=4)**	**Aug (n=9)**	**Sep (n=5)**	**Oct (n=2)**	**Dec (n=2)**
EPHEMEROPTERA							
Baetidae	12	69.7	121.8	87	95	79.5	89.5
Caenidae	2	9.7	13.3	9.9	9.8	2	3
Heptageniidae			2.3	3.2	1.6	0.5	7.5
Leptophlebiidae	1	7.7	47.5	12.4	14		3.5
Oligoneuriidae				0.1	0.2		0.5
Tricorythidae		2.3	2	0.2	2.2	7.5	0.5
DIPTERA							
Athericidae				4.1	8.4		
Chironomidae	21	18	18.5	16.3	34.6	13.5	8.5
Ceratopogonidae				0.1			
Empididae		1.3		0.1	1.6		
Simuliidae	202	147.3	66.8	480	802.4	258	3552
Tabanidae				0.1	0.2		
Tipulidae	2	1.3	7.3	1	2.2	2	0.5
Misc. Diptera				0.1	0.4		
TRICHOPTERA							
Hydropsychidae	6	4	22.5	14.6	22.4	16	70
Hydroptilidae		0.3		0.1			
Lepidostomatidae	2	12	26.8	15.1	32.4	20	17
Leptoceridae	2	4	3.3	3.3	3.8	4	0.5
Philopotamidae							1
COLEOPTERA							
Dysticidae				0.2	0.2	0.5	
Elmidae	1						
Scritidae	6	16	52	20.1	28	20	39.5
PLECOPTERA							0.5
Perlidae				0.1			
HEMIPTERA							
Notonectidae				0.1	0.4		
DECAPODA				0.1		0.5	1
GASTRPODA				0.1			
NEMATODA			0.5	0.2			
OLIGOCHAETA		0.7		0.4	0.2		
PLANARIA		0.3	1.3	3.6	5.2	3	
Misc. Mollusca		1.3	4				
Misc. Terrestrials**					1.2		
Total	**257**	**295.9**	**389.9**	**672.6**	**1066.4**	**427**	**3795**

** Include organisms such as ants, bees, grass hoppers and spiders.

Table 3.25 Average number of individuals per taxa of macroinvertebrates in the midstream stations (N2,S2,T2) of the Naro Moru, Sagana and Thego streams. N = 20 for all months indicated.

Taxon	**Jun (n=2)**	**Jul (n=6)**	**Aug (n=6)**	**Sep (n=4)**	**Oct (n=1)**	**Dec (n=1)**
EPHEMEROPTERA						
Baetidae	73	49.3	87.3	142.3	102	142
Caenidae	12.5	21.3	8.7	16.5		
Heptageniidae	31	2.8	4	9.8		20
Leptophlebiidae	12.5	8.3	9.3	18	3	
Oligoneuriidae	2		3	5.5		9
Tricorythidae	1.5	3.8	1.2	3.3	21	
DIPTERA						
Athericidae		0.2	0.3	11.5		
Chironomidae	11	13.8	13.8	44.8	2	12
Ceratopogonidae		2.5				
Empididae				2		
Muscidae			0.2		1	
Simuliidae	19	154	273	806.3	162	7
Tabanidae	0.5					
Tipulidae		1.3	1	1	3	3
Misc. Diptera						
TRICHOPTERA						
Hydropsychidae	19	9.2	12.5	4	13	29
Hydroptilidae						
Lepidostomatidae	3	14	6.5	21.8	8	42
Leptoceridae	1	2.2	1.3	5.8	1	3
Philopotamidae						
Rhyacophilidae					3	4
COLEOPTERA						
Dysticidae	2.5				6	
Elmidae	2	0.7	0.7			
Hydraticus	0.5					
Scritidae	3.5	6.3	10	21		70
PLECOPTERA						
Perlidae	2.5	0.7	0.5			
ODONATA						
Aeshnidae	0.5					
Protoneuridae	0.5					
HEMIPTERA						
Gerridae	0.5					
Naucoridae	0.5					
Nepidae	0.5					
Notonectidae	0.5			0.5		
Veliidae	0.5					
DECAPODA	1					
GASTRPODA	0.5	0.8	0.2	0.3		
NEMATODA	0.5	0.2				
OLIGOCHAETA			1.2	0.8	1	
PLANARIA	2.5	1.7	3	5.5		
Misc. Terrestrials		0.7	0.7		1	2
Total	**205**	**293.8**	**438.4**	**1121**	**327**	**343**

Table 3.26 Average number of individuals per taxa of macroinvertebrates in the downstream stations (N3,S3,T3) of the Naro Moru, Sagana and Thego streams. N = 35 for all months indicated.

Taxon	May (n=1)	Jun (n=7)	Jul (n=7)	Aug (n=8)	Sep (n=5)	Oct (n=2)	Nov (n=2)	Dec (n=3)
EPHEMEROPTERA								
Baetidae	52	105	114.3	177.1	255.4	158.5	103	198
Caenidae	12	20.4	21.3	12.5	31.6	4.5	4	5.7
Heptageniidae	21	46.7	24.9	62.1	103.2	166	30.5	105
Leptophlebiidae		16.7	8	3.6	1	3	1.5	4.3
Oligoneuriidae		1.9	0.6	1.1		2		0.7
Tricorythidae		12.1	12.9	21.5	33.8	5	6	0.7
DIPTERA								
Athericidae		2.1		0.5				4.3
Chironomidae	7	10	15.6	16	36.2	9	15	25.3
Ceratopogonidae				0.3				1
Dixidae		0.1						
Simuliidae	51	33.7	99.3	69.4	82	51	70	43.7
Tabanidae				0.3				1
Tipulidae	6	5.1	2.6	2.8	5.2	2	0.5	3.7
Misc. Diptera				0.1				
TRICHOPTERA								
Ecnomidae		0.1		0.1				
Hydropsychidae	48	50.9	71.7	60.4	97.8	30.5	24.5	49.3
Hydroptilidae				0.3				
Lepidostomatidae	14	6.1	4	3	3.6	5	1.5	5.7
Leptoceridae		7.3	0.3	0.3	2	3.5	6	2.3
Philopotamidae		0.3		0.1				0.3
Rhyacophilidae				0.1	0.2	0.5	0.5	0.7
COLEOPTERA								
Elmidae		2.1	4.7	3.4	2.8	3	1	1
Gyrinidae		0.6						
Dytiscidae				0.1	0.4			
Psephenidae		1.1		0.4	0.6	1	2.5	5.3
Scritidae		11.4	4.3	5.8	9.4	1.5	4	8.7
PLECOPTERA								
Perlidae		1.1	6.6	0.6	2.2			
ODONATA								
Protoneuridae		0.3		0.1	0.8			
HEMIPTERA								
Nepidae		0.9	0.4	0.1				
Gerridae		0.1						
Notonectidae				0.1	0.4			
DECAPODA		1.7	1.4	0.9	2.8	2.5	0.5	1
GASTRPODA			0.1					
NEMATODA			0.7	0.1	0.6			
OLIGOCHAETA		1.6		0.1	1		1.5	0.7
PLANARIA		0.9	3.4	1.5	2.2	4	3.5	1.3
Misc. Mol/Terrestials			0.9	0.1	2	1.5	0.5	0.7
Total	**211**	**340.3**	**398**	**444.9**	**677.2**	**454**	**276.5**	**470.4**

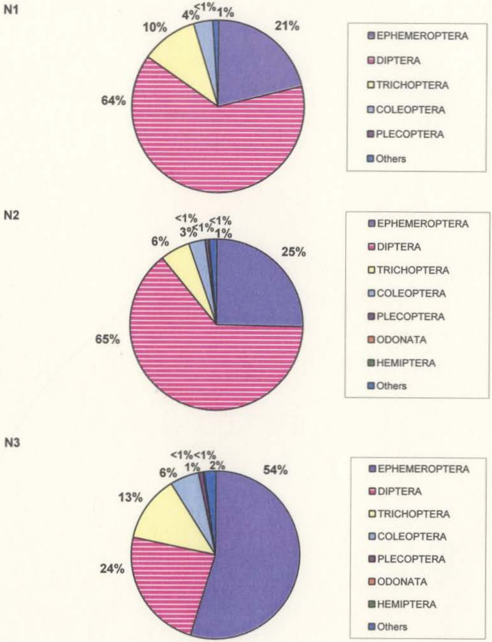


Fig. 3.28 Percentage composition of macroinvertebrate Orders in upstream, midstream, and downstream benthic samples from the Naro Moru (N1,N2, and N3).

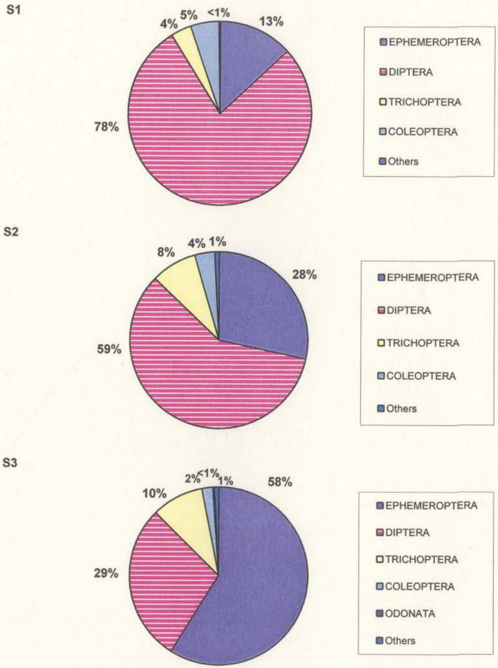
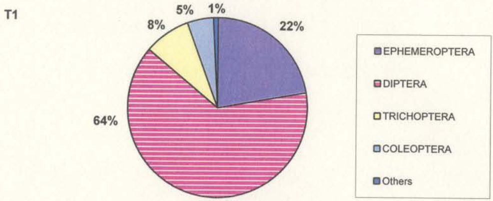
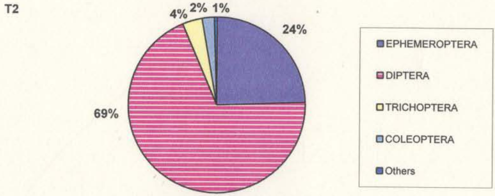


Fig. 3.29 Percentage composition of macroinvertebrate Orders in upstream, midstream, and downstream benthic samples for the Sagana (S1,S2,S3).





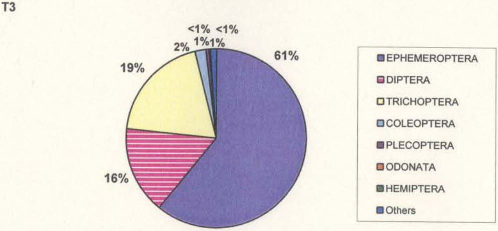


Fig. 3.30 Percentage composition of macroinvertebrate Orders in upstream, midstream, and downstream benthic samples for the Thego (T1,T2,T3).

3.6.1 Macroinvertebrates as prey of rainbow trout

Composition of prey items found in the stomachs of rainbow trout by months is shown in Table 3.27. The major prey items were from the Orders Ephemeroptera (61%) and Diptera (31%) with minor percentages from other Orders. Although the occurrence of prey items was a general reflection of macroinvertebrate taxa present within the stream section, Ivlev's (1961) Electivity Index shows that the abundance of prey items in the stream was not represented proportionately in the rainbow trout stomachs (Table 3.28). Stomachs from fish caught in the Naro Moru at N1 as representative of upstream stations showed that some taxa, e.g. the Families Heptageniidae and Chironomidae, were positively selected while the Family Simuliidae tended to be selected against. Stomach samples from Sagana S2, taken to represent midstream stations, indicated that Chironomidae had the highest selection value while Simuliidae were again selected against. In the lower stations, as represented by rainbow trout from the Thego at Station T3, Simuliidae were in low abundance and actually tended to be over-represented in the stomachs while Hydropsychidae were selected against. In some stomachs from all sites there were also other items such as sticks, stones, and plant seeds which presumably were ingested along with the benthic organisms.

Table 3.27 Average number of prey items in the stomachs of rainbow trout examined each month as shown during the study period. A total of 76 stomachs were examined.

Taxon	Jan (n=3)	Mar (n=6)	Apr (n=10)	Jun (n=3)	Jul (n=10)	Aug (n=14)	Sep (n=5)	Oct (n=8)	Dec (n=17)	Total
EPHEMEROPTERA										
Baetidae	33.3	64	28.7	15	31.0	57.8	241.8	174.5	73.5	719.6
Caenidae	1.7	1.5	0	0	0	2.2	8.8	3.5	0.1	17.8
Heptageniidae	4	11.8	0	0.7	0	3.1	16.2	1.6	5.4	42.8
Leptophlebiidae	0.7	0	1.2	0	0.7	0	1.4	0	0	4.0
Tricorythidae	1.7	0	0	0	0	0	0	0	3.7	5.4
DIPTERA										
Chironomidae	2	4.3	7.5	1.3	40.8	1.6	62.8	3.5	1.4	125.2
Simuliidae	197.3	8.7	13.1	8	37.6	3.1	46.2	37.8	31.9	383.7
Tipulidae	0	0	0	0	0	0.1	0	0.4	0.2	0.7
TRICOPTERA										
Hydropsychidae	2.7	1.3	0	4	0.1	0.4	24	5.8	6.5	44.8
Lepidostomatidae	0	0	0.2	2	1.1	0	1.6	0.4	1.2	6.5
Leptoceridae	0	0	0.2	0	1.2	0	0	0	9.9	11.3
COLEOPTERA										
Elmidae	0	1.2	0	0.7	0	1.1	2.6	0.1	1.8	7.5
Gyrinidae	0	0	0	0	0	0.1	0	0.9	0.2	1.2
Dytiscidae	0	0	0	0	0	0	0	0.5	0.2	0.7
Psephenidae	0	0	0	0	0	0	0	0	0.3	0.3
Scirtidae	0	0	1.0	0	0.7	0.1	1.8	0	0.7	4.3
PLECOPTERA										
Perlidae	0	0	0	0	0	0	0.4	0	0	0.4
ODONATA										
Gomphidae	0	0	0	0	0.1	0	0	0	0	0.1
HEMIPTERA										
Nepidae	0	0	0	0	0	0	1	0	0	1
DECAPODA	0.7	0	0	0	0	0	0	0.6	0	1.3
GASTROPODA	0.7	0	0	0	0	0	0	0.1	0.2	1.0
PLANARIA	0	0	0	0	0.1	1.1	0.8	0.1	0.6	2.7
Terrestrials**	0	0	0.6	0.3	0.4	2.6	1.4	0.4	0.1	5.8
Total	**244.8**	**92.8**	**52.5**	**32.0**	**113.8**	**73.3**	**410.8**	**230.2**	**137.9**	**1388**

** includes organisms such as ants, bees, grasshoppers and spiders.

Table 3.28 Ivlev's electivity index indicating rainbow trout preference for benthic organisms as observed from stomachs of rainbow trout caught at the same time when benthic samples were collected. Benthic samples and fish were collected at the same stations. Naro Moru samples (22/8/97), Sagana Samples (3/7/97) and Thego Samples (6/10/98).

Stream / Taxon	**Rainbow trout stomachs examined**							
Naro Moru	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Baetidae	0.53	0.52	0.58	0.54	0.57	0.47	0.55	0.57
Caenidae	0.41	0.68	0.70		0.81	0.82		
Heptageniidae	0.90	0.83	0.70	0.71	0.72	0.94	0.85	0.89
Chironomidae	0.81	0.91	0.89	0.89	0.85	0.91		0.78
Simuliidae		-0.74		-0.65		-0.85	-0.86	-0.91
Tipulidae	0.81		0.70					
Hydropsychidae		-0.22	0.01				-0.05	
Elmidae	0.93					0.86	0.82	0.61
Scirtidae		-0.18						
PLANARIA	-0.07	-0.22		0.23			-0.05	-0.45
Sagana (S2)								
Baetidae	0.49	0.26	0.08	-0.02	0.23	0.27	0.23	
Leptophlebiidae			-0.69	-0.76				
Chironomidae	0.53	0.66	0.68	0.79	0.48	0.55	0.63	
Simuliidae		-0.36	-0.30	-0.60	-0.12	-0.37	-0.24	
Hydropsychidae	0.93							
Lepidostomatidae					0.53	0.31		
Leptoceridae			0.79		0.24	0.89		
Scirtidae			0.03				0.17	
Thego (T3)								
Baetidae	0.33	0.33	-0.04	0.40	0.44	0.06		
Caenidae					-0.75			
Simuliidae		0.68	084	0.39	-0.30	0.88		
Tipulidae	0.16							
Hydropsychidae	0.24	-0.89	-0.04	-0.68	-0.82	-0.88		
Lepidostomatidae		-0.31						
Elmidae	0.47	0.13	0.67	-0.01				
DECAPODA			0.88		-0.47		-0.2	
GASTROPODA			0.43					

3.7 Brown trout (*Salmo trutta*)

Brown trout were only caught in the upstream and midstream stations of the Sagana (stations S1 and S2). Summary data on the number and mean size caught are presented in Tables 3.29 and 3.30. Brown trout ranged in length from 4.0 - 37.5 cm at station S1 and 4.8 - 32.0 cm at station S2. The smallest brown trout were caught in April and July as shown in the histograms in Figure 3.31.

Mean back-calculated length for each age class of brown trout for station S1 in 1996 is shown in Table 3.31. Mean back-calculated length at age and mean annual back-calculated length increments are shown in Figures 3.32 and 3.33. No four year old brown trout were caught at S1 in 1996.

The types of food found in the stomachs of 14 brown trout are presented in Table 3.32 as number of individuals, and frequency of occurrence of prey items. Ephemeroptera (Family: Baetidae) were the principal food item. Brown trout also preyed on Trichoptera (Families: Lepidostomatidae and Leptoceridae). Terrestrial insects (ants, bees, and grass-hoppers), spiders and some other items such as sticks and gravel were also found in the stomachs.

Table 3.29 Summary data by months on number, length and weight of brown trout captured in the Sagana at S1.

Months	No. of fish	Range Min	Range Max	Mean FL (cm)	Mean Wt (g)
Feb	4	7.3	23.6	16.5	65.7
Apr	117	4.0	37.5	17.6	83.6
Jun	28	13.2	27.3	18.7	91.3
Jul	34	7.2	28.0	17.6	89.3
Aug	37	4.7	24.1	16.7	70.6
Sep	59	9.6	27.8	16.1	60.4
Oct	35	7.8	28.3	19.6	97.5
All	314	4.0	37.5	17.5	80.3

Table 3.30 Summary data by months on number, length and weight of brown trout captured in the Sagana at S2.

Months	No. of fish	Range Min	Range Max	Mean FL (cm)	Mean Wt (g)
Feb	15	7.2	16.3	10.6	15.8
Jun	14	9.8	20.8	15.5	48.7
Jul	6	4.8	22.4	16.0	63.6
Aug	42	9.3	27.1	18.6	96.7
Sep	51	6.0	32.0	16.6	75.0
Oct	18	10.5	24.8	16.9	62.8
All	146	4.8	32.0	16.5	70.7

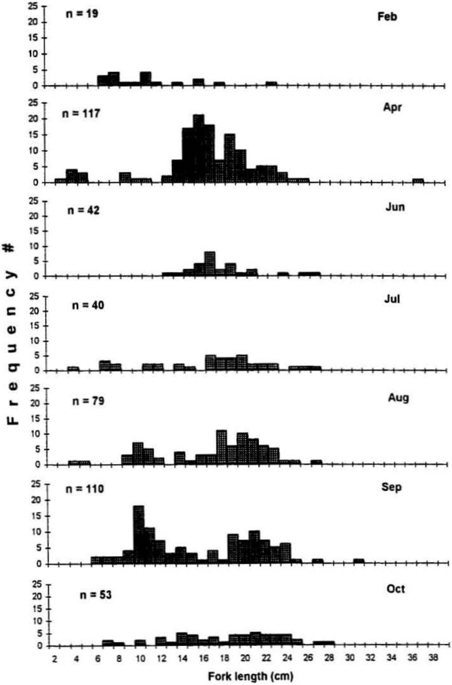


Fig. 3.31 Length frequency histograms of brown trout captured at the upstream and midstream stations (S1 and S2) in the Sagana.

Table 3.31 Mean annual back-calculated lengths (mm) based on analysis of scales for each age class of brown trout caught at station S1 in 1996.

Year Class	Age group	No. of fish	Back-calculated mean lengths at age (mm)			
			1	3	3	4
1995	1	1	126.09			
1994	2	2	126.06	169.92		
1993	3	2	121.33	164.30	200.41	0
All		5	124.17	167.11	200.41	0

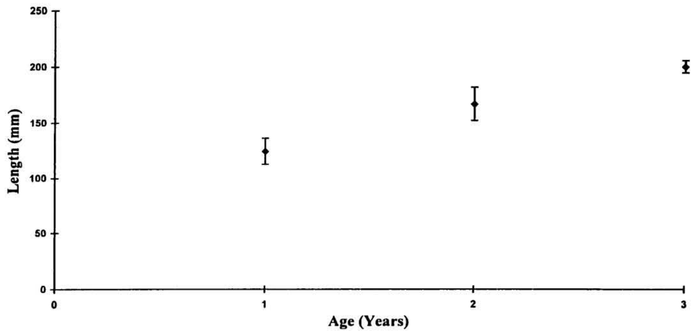


Fig. 3.32 Mean back-calculated length at age for each age class of brown trout from the Sagana station S1.

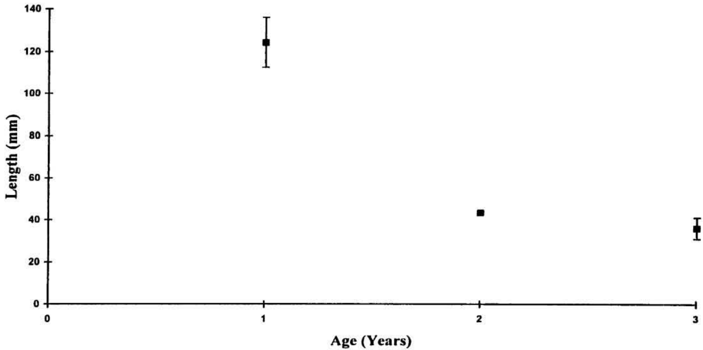


Fig. 3.33 Mean annual back-calculated length increments of brown trout from the Sagana S1.

Table 3.32 Number of individuals and percentage occurrence of prey items in the stomachs of brown trout (N=14) captured in the Sagana at stations S1 and S2.

Taxon	Number of individual prey	Percent (%)
EPHEMEROPTERA		
Baetidae	427	45.38
Caenidae	8	0.85
Heptageniidae	24	2.55
Tricorythidae	1	0.11
DIPTERA		
Chironomidae	8	0.85
Simuliidae	178	18.92
TRICHOPTERA		
Hydropsychidae	6	0.64
Lepidostomatidae	186	19.77
Leptoceridae	84	8.93
COLEOPTERA		
Elmidae	2	0.21
Misc. Terrestrials**	17	1.81
TOTAL	941	100.0

** Includes organisms such as ants, bees, grasshoppers and spiders.

3.8 Mountain catfish (*Amphilius uranoscopus)*

Mountain catfish were caught only in downstream stations in the Sagana and Thego (stations S3 and T3). Summary data on the number of mountain catfish caught per hour of electrofishing in the Sagana and Thego are shown in Table 3.33. There were more catfish captured in the Thego than in the Sagana but the number of visits and hours spent electrofishing in the Thego were more than in the Sagana. Catfish that were caught ranged in size in the Thego and the Sagana (Tables 3.34 and 3.35) from 3.8 to 23.6 cm and 10.5 to 22.1 cm respectively. Length frequency distributions for catfish captured in the Thego are shown in Figure 3.34. The smallest catfish (3.8 cm) captured in the Thego was caught in September (1997). Allometric relationships among total length, fork length, standard length and mouth gape are summarized in Table 3.36 based on data in Appendix 5. Log transformed data on body length and weight showed a logarithmic relationship (Log Wt = -1.77 Log FL, $r^2 = 0.938$).

Number and occurrence of prey items in the stomachs of the mountain catfish are shown in Table 3.37. Due to the advanced stage of prey digestion in most specimens, only 8 stomachs were examined. The dominant prey were aquatic insects of the Orders Ephemeroptera, Trichoptera and Diptera.

Table 3.33 Summary data on the number of mountain catfish (*Ampilius uranoscopus*) caught and catch per hour of electrofishing (CPUE) in the Sagana at station S3 and Thego at station T3. '-' represents sessions when electrofishing time was not recorded.

Date	Station	No. of fish caught	Time (hrs)	CPUE No./hr
Thego (T3)				
14/3/96	T3	20	-	-
14/4/96	T3	8	0.91	8.8
21/6/96	T3	13	0.75	17.3
30/6/97	T3	119	1.77	67.2
30/6/97	T3	49	0.83	59.0
17/8/97	T3	72	1.16	62.1
21/9/97	T3	21	-	-
22/9/97	T3	59	1.07	55.1
19/8/98	T3	8	-	-
20/8/98	T3	9	0.31	29.0
23/8/98	T3	24	-	-
Sagana (S3)				
17/3/96	S3	5	1.06	4.7
22/4/96	S3	2	-	-
21/6/96	S3	1	-	-
28/6/96	S3	1	-	-
16/8/97	S3	2	0.79	2.5
22/9/97	S3	26	1.47	17.7

Table 3.34 Summary data by month on number (N), mean fork length (cm) and mean weight (g) and the size range (minimum and maximum) of mountain catfish caught in the Thego in 1996-1998.

Month	N	Range FL (cm)	Mean	
			FL (cm)	Wt (g)
March	20	7.50 - 23.50	14.5	38.8
April	10	8.80 - 22.70	14.1	38.0
June	181	8.00 - 23.00	14.4	28.9
August	113	8.20 - 22.50	14.6	31.5
September	80	3.80 - 23.60	14.2	28.7
All	404	23.6 - 23.60	14.3	30.3

Table 3.35 Summary data by month on number (N), mean fork length (cm) and mean weight (g) and the size range (minimum and maximum) of mountain catfish caught in the Sagana in 1996-1998.

Month	N	Range FL (cm)	Mean	
			FL (cm)	Wt (g)
March	5	17.5 - 21.5	18.7	69.9
June	2	14.1 - 21.6	17.9	49.2
August	2	10.5 - 18.5	14.5	36.5
September	26	12.2 - 22.1	17.1	44.7
All	35	10.5 - 22.1	17.2	48.1

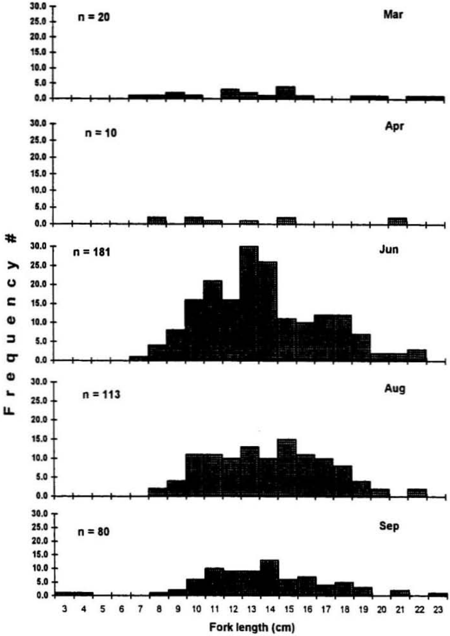


Fig. 3.34 Length frequency histograms of mountain catfish captured in the Thego at the Thego Fishing Camp (T3). Data are combined across years (1996-1998).

Table 3.36 Allometric relationships among total length, fork length, standard length and mouth gape. Measurement are from a sample of catfish caught on 22nd September 1997 in the Thego at T3.

Equation	r^2	**n**
TL = -0.004 + 1.03 FL	0.997	20
TL = 0.123 + 1.12 SL	0.981	20
FL = 0.143 + 1.09 SL	0.981	20
Mouth gape = 0.597 + 0.143 TL	0.861	20

Table 3.37 Number and percentage occurrence of food found in the stomachs of mountain catfish caught on 22nd September 1997 in the Thego at T3.

TAXON	No. of food items in 8 specimens examined									
	1	2	3	4	5	6	7	8	Total	%
EPHEMEROPTERA										
Baetidae	24	107	106	2	102	62	23	87	513	82.3
Heptageniidae	6	2	0	1	12	8	2	4	35	5.6
DIPTERA										
Chironomidae	2	4	1	3	2	1	0	2	15	2.4
Simuliidae	8	12	0	3	1	4	0	14	42	6.8
TRICHOPTERA										
Hydropsychidae	1	0	2	5	0	1	0	1	10	1.6
COLEOPTERA										
Elmidae	0	1	0	0	1	0	0	1	3	0.5
OTHERS**	1	1	1	1	0	0	0	1	5	0.8
TOTAL	42	127	110	15	118	76	25	110	623	100.0

** Includes organisms such as crabs, ants, bees, grasshoppers and spiders.

3.9 Overlap in the diet of rainbow trout and other species

Percentage occurrence of those macroinvertebrates found as prey in the diets of rainbow trout, brown trout and mountain catfish are presented in Figures 3.35. Rainbow trout stomachs contained more macroinvertebrate taxa than either the brown trout or the mountain catfish. While rainbow trout stomachs were from fish taken from upstream, midstream, and downstream stations, brown stomach samples were only from fish caught in upstream and midstream stations of the Sagana. Mountain catfish stomachs were from specimens electrofished in the Thego (T3) in September 1997 only. The stomachs of all fish species contained a high percentage of organisms of the Order Ephemeroptera.

3.10 Other indigenous fish

A small number of fish belonging to the genera *Labeo* and *Barbus* were caught in the midstream and downstream stations of the Naro Moru and in the downstream station of the Sagana respectively. Their length and weights and dates of capture are shown in Table 3.38. *Labeo* were caught in the main stream while *Barbus* were caught near the mouth of a small tributary that joined the Sagana just downstream of the Kiganjo Trout Research Station.

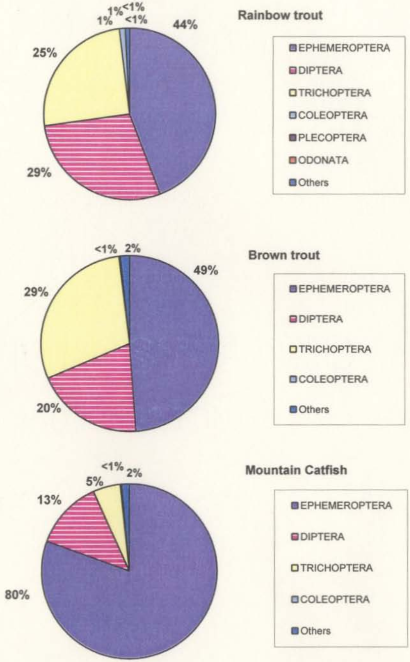


Fig. 3.35 Summary data on the percentage occurrence of macroinvertebrates in the stomachs of rainbow and brown trout caught in the Sagana stations S1 and S2 and in the catfish caught in the Thego station T3.

Table 3.38 Length and weight data for specimens of the genus *Labeo* caught in the Naro Moru (N2 and N3) and the genus *Barbus* caught in the Sagana (S3).

***Labeo* (N2 AND N3)**				***Barbus* (S3)**		
Date collected	TL (cm)	Wt (g)		Date collected	TL (cm)	Wt (g)
16/3/96	11.2	15.1		28/6/97	7.2	5.5
"	11.2	13.7		"	7.4	5.4
19/4/96	13.1	23.1		"	8.4	7.7
"	14.1	32.7		"	5.0	1.8
"	13.5	24.5		"	5.4	3.0
"	13.4	23.8		"	6.8	4.8
"	11.3	18.0		"	7.4	5.2
"	9.4	9.1		"	5.5	2.5
"	10.3	9.6		22/9/97	7.4	5.6
"	14.0	39.4		"	7.5	6.0
20/6/96	13.4	29.8				

Chapter 4: Discussion

4.1 Rainbow trout distribution

Based on the writings of Copley and Van Someren (1951) and Van Someren (1952), there were no native fishes in those sections of the streams originating from the slopes of Mt. Kenya stocked with rainbow trout. It is clear that rainbow trout initially performed very well in these streams. Evidence from anglers' catches indicate an abundance of fish in these streams and a high angling activity from the 1930s to the 1950s as shown in Table 4.1. Van Someren (1952) reported that rainbow trout thrived in these streams in the mid 1900s at altitudes above about 1670 m. He stated that they were absent below this elevation because of the higher water temperature and obstructions. According to his records, indigenous species including eels, cyprinids and catfish were abundant below the falls located about 3 km above Karatina (see Figure 2.4) but did not occur above them (Van Someren 1952).

My present work indicates that there have been significant changes in the distribution patterns of both salmonid species as well as native species in some of these streams since the 1950s and that trout populations have declined. The occurrence of mountain catfish (*Amphilius uranoscopus*) in the Sagana and Thego 'trout zone', the presence of *Barbus sp.* and *Labeo spp.* in the Sagana and Naro Moru, the absence of rainbow trout in the lower Thego, and the restriction of brown trout to reaches in the Sagana above about 2130 m are changes in distribution patterns that have occurred since the 1950s. Several factors may have

Table 4.1 Records of rainbow and brown trout caught in 1950 from streams of the Aberdares and Mount Kenya including the Sagana and Thego. Data are from Copley (1951).

Stream	No. of fish	Weight (kg)	Rod days	Average wt (kg)	Fish per Rod day	Trout species
Gura	4261	990	1194	0.23	3.60	Rainbow/Brown
Chania-Nyeri	882	353	811	0.38	1.09	Rainbow/Brown
Sagana	575	209	552	0.36	1.04	Rainbow
Thego	686	181	354	0.23	1.90	Rainbow
Thiba	1560	401	531	0.25	2.90	Rainbow
Chania-Thika	2269	665	396	0.30	5.70	Brown
Maragua	650	320	289	0.49	2.25	Brown
Sirimon	252	74	126	0.29	2.00	Rainbow
Nanyuki	141	47	126	0.33	1.10	Rainbow/Brown

contributed to these changes in distribution patterns, among them being: 1) environmental changes associated with human settlement in the watersheds, 2) competition with native species, and 3) removal of salmonids by humans through uncontrolled fishing.

Major environmental changes have occurred during the last 30 years in the watersheds of streams on the southwestern slope of Mount Kenya resulting from the establishment of human settlements. The flow characteristics of the streams have changed with time as exemplified by Naro Moru discharge records (Figure 3.7). Increased precipitation in the Naro Moru watershed is not reflected in stream discharge which in fact has decreased due to water being diverted for irrigation and domestic use. The decrease in stream discharge may also be due in part to a reduction in canopy cover and increased evaporation. Monthly minimum and maximum stream temperatures ranged from 12.4^{0}C to 16.8^{0} C at the Kiganjo Trout Research Station in 1947 (Van Someren 1952). In contrast, temperatures recorded during the present study (13.6^{0} C to 21.9^{0}C), indicates an increase of maximum temperatures of about 5^{0} C. Stream conductivity has also increased from a range of 14-40 μS in 1947 to the present day range of 54.2 -208 μS recorded at the Kiganjo Trout Research Station (station S3) indicating, in part, an increase in the release of nutrients from agricultural activities into the stream. There is also no doubt that silt levels have risen as exemplified by the amount of silt that now regularly needs to be flushed from the Kiganjo Trout Research Station raceways (P. Mwangi pers. comm.) [Figure 2.8]. Less canopy cover and low stream flow reduces stream wetted areas and elevate stream temperatures. A combination of these and other environmental factors can influence the distributional range of a species.

The present study found that rainbow trout were absent from the lower part of the Thego from above the Thego Fishing Camp to where it joins the Sagana. This stretch of stream had a large population of mountain catfish as indicated by the number electrofished and their high CPUE. Specimens of catfish collected in the Sagana and the Thego included both juveniles and mature adults. These data indicate that catfish are well-established at higher altitudes than they were in the 1950s. According to past records (Van Someren 1952) no catfish occurred in the Thego up until at least the 1950s and perhaps much later (E. Kariuki pers. com.). It is possible that the presence of catfish is a factor in the absence of trout. On the other hand, the absence of trout may have allowed catfish to colonize this area of the stream. Skelton (1993) and Marriott *et al.* (1997), suggested that this is the case in South Africa where *A. uranoscopus* and *A. natalensis* are native species (Skelton 1984). Skelton (1993) has documented several areas of South African streams (especially in Natal province) where *Amphilius* populations have declined after the introduction of rainbow trout.

While it is often difficult to determine if one species is competitively excluding another, and more work needs to be done to clarify the possible interactions between mountain catfish and rainbow trout in Mt. Kenya streams, some evidence suggests that catfish are not having a negative impact on the trout. For example, trout released in the Thego at the Fishing Camp during the present study performed very well in terms of growth. This included Floy-tagged, fin clipped and radio-tagged individuals. The occurrence of both species in the Sagana in the vicinity of the Kiganjo Trout Research Station may also indicate that one species cannot competitively exclude the other.

The analysis of stomach samples did reveal that rainbow trout and catfish prey composition overlapped considerably, and both species appear to be generalists and opportunistic in their foraging habits. However, as long as prey is abundant both species can probably coexist with one another. The fact that mountain catfish appear to be nocturnal feeders (Marriott *et al.* 1997) while trout are primarily diurnal may reduce interference competition between the species. In this connection, it will be interesting to see whether *Amphilius* continues to do well in the lower part of the Thego if trout populations are restored. It will also be interesting to determine whether catfish continue to expand their distributional range in these streams.

A more likely explanation for the decline of rainbow trout is that the anthropogenic changes that have occurred in the Thego (and in the other streams), while perhaps favouring native species (including catfish), have had a negative impact on trout. Although the physico-chemical conditions in the three study streams are still suitable for trout and the streams still have self-sustaining populations of rainbow trout, water quality has declined and this shift may favour local species. Water quality, however, is not the only factor, and possibly not the most important, that has had a negative impact on trout. Over-exploitation appears to be an important factor contributing to rainbow trout decline in some streams.

Over-exploitation is indicated by both the fate of radio-tagged fish released in the Sagana and the present age structure of the population That all the radio-tagged fish released in the upper part of the Sagana were recovered from illegal anglers, is clear evidence of uncontrolled angling activity. Uncontrolled fishing was less common in areas that were relatively less accessible to anglers, for example the upstream reaches of the Sagana and the Naro Moru. Also, a good population of rainbow trout was recorded at station N3 where fishing is closely controlled since it is under the management of the Naro Moru River Lodge.

The low catch per unit of effort in the upstream and midstream stations of the Thego may indicate easy access to the stream by anglers. Much of the Thego now has reduced bank vegetation, dense human settlement and appears to have an increased illegal angling activity that has influenced fish recruitment. Poaching of radio-tagged fish did not occur in the lower Thego, probably because of close monitoring of fishing activity by staff at the Thego Fishing Camp. Along with the heavy exploitation, the existence of artificial barriers on the Thego may impede movement of young fish to repopulate the lower sections of the stream. Fish stocks in the Thego were generally low compared to other streams as exemplified from catch per unit effort data (see Table 3.5).

A comparison of data in Van Someren's (1952) report with the present data indicates that there has been a marked decrease in average age and contraction of the age distribution and mean size of rainbow trout in the study streams since the 1950s. A sample of rainbow trout from the Sagana caught with an electrofisher as reported by Copley and Van Someren (1951) consisted of 6.2% age 1, 63% age 2, 21% age 3, 8.6% age 4 and 1.2% Age 5. This can be compared with samples from upstream in the Sagana that were caught in the present study with an electrofisher in 1998 consisting of 21% age 1, 63.2% age 2 and 15.8% age 3. Whereas in the 1950s three and four year old fish contributed significantly to anglers' catches, very few older fish now occur in the study streams (Figure 4.1). Age distribution has an influence on the number of fish recruited per season. Size as illustrated in section 3.3 determines fish fecundity, survival and population size.

Copley (1950) reported that anglers caught large rainbow and brown trout in the streams on the slopes of the Aberdares and Mt. Kenya in the 1920s to 1950s. Among them were the catches by a Mr. Kent in 1932 of a rainbow trout weighing 5.8 kg in the Tulaga stream on the southwestern slope of the Aberdares, a Mr. James Walker of a rainbow trout weighing 3.5 kg in 1932 in the Sagana and a Major J. Kingdom of a rainbow trout weighing 3.2 kg in the Thego in 1927. In contrast, the largest specimen I electrofished was a 39.6 cm fork length (850 g) female caught in the upstream station (S1) of the Sagana. The second largest specimen, measuring 39.5 cm (832 g), was taken in the downstream station (S3) of the Sagana. In general, there are now fewer and younger fish than reported by Van Someren (1952).

It is likely that a combination of environmental factors and over-exploitation have affected the distribution and abundance of rainbow and brown trout as well as indigenous species in these cold water streams. However, specific causes for changes that have taken place in their ranges and populations are difficult to isolate without more detailed observations and experimental manipulation. None the less, the environmental changes that are occurring appear to be initially favouring native species (cyprinids and catfish) to the detriment of rainbow and brown trout.

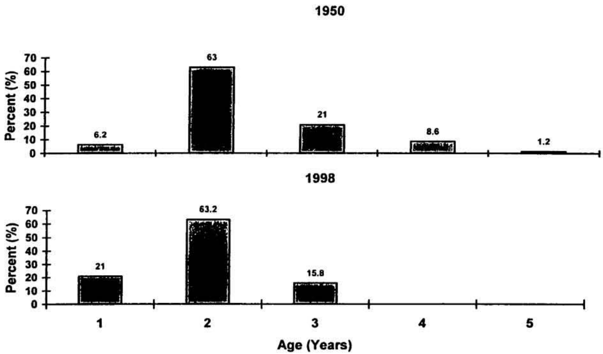


Fig. 4.1 Percentage age distribution of rainbow trout in the Sagana in 1950 and in 1998. Data for 1950 is from Van Someren (1952).

A neighbouring stream worthy of mention here, although not a part of the study is the Nairobi. It was one of the two streams where rainbow trout were first released in 1912. The Nairobi flows from Mount Kenya and its habitats have been severely degraded by human settlement to the point where no catches of rainbow trout have been recorded by anglers for many years in the lower part of the stream (J. Ndogoni pers. com.). An electrofishing survey I conducted on the Nairobi at an altitude of about 1700 m in April 1996, caught only mountain catfish. Water abstraction is a major problem on this stream; flow ceases during the dry season and the only water available is in pools. What has already happened to the Nairobi could happen to the three study streams if corrective action is not taken soon.

While there is hope to rehabilitate and improve the performance of rainbow trout in Mt. Kenya streams, brown trout populations have already completely disappeared from many of the streams. There is evidence from the report by Copley and Van Someren (1951) that as early as the 1950s the status of brown trout would be more affected by local fishing and environmental factors than that of rainbow trout. In their report titled 'Some Kenya Trout Problems', Copley and Van Someren (1951) had this to say:

> "Several virgin rivers in Kenya have recently been stocked with brown trout only, as they are obviously a first choice if the river appears at all suitable; but should the brown fail for natural reasons or by virtue of too heavy a fishing pressure, then rainbow trouts will take their place. ...We know that brown trout rivers in Kenya will not stand up to the unlimited fishing which many rainbow trout rivers will stand, nor do they recover so quickly after a poor spawning year. ...It is well known from other experimental work that the brown trout is less tolerant of warm water conditions which are caused by lessened flows, than is the rainbow trout; some brown trout rivers may be already doomed. The reduction in river flows through natural means, or by increasing artificial

abstraction, will have a far more serious effect on brown trout rivers than on rainbow trout rivers".

It is apparent that the distributional range of the brown trout has, as hypothesized by Copley and Van Someren (1951) decreased faster than that of rainbow trout. The present study found brown trout in only the mid and upstream sections of the Sagana. No brown trout were caught in the Naro Moru or the Thego although both previously had self-sustaining populations (Copley 1950b). It is also evident that trout populations generally are in decline and that native fishes that once were present only at lower altitude are now established in the "trout zone". Given that mountain catfish appear to be favoured by higher stream temperature and are more tolerant to increased siltation and lower levels of dissolved oxygen, it seems likely that it will continue to expand its range unless these environmental changes are reversed. As hypothesized by Marnell *et al.* (1987), superior adaptation of indigenous species to a local suite of environmental factors, as appears to be the case for *Amphilius uranoscopus*, and possibly *Labeo* and *Barbus*, may render an exotic 'impotent'.

In Kenya streams, the significance of competition between rainbow trout and indigenous species, especially mountain catfish (*A. uranoscopus*) and cyprinids, should be an important area of study. There is urgent need for more detailed study of the life history strategies of the indigenous species and how environmental changes are affecting them.

4.2 Rainbow trout growth

Growth is a useful metric with which to evaluate habitat suitability, prey availability, or the influence of management activities on a target species because growth provides an integrated assessment of the environmental and endogenous conditions affecting a fish (Devries and Frie 1996). Most literature on fish growth is restricted to changes in mean length or weight, using arithmetic or geometric means. Although fish have indeterminate growth (Weatherley and Gill 1987), growth declines with increasing body size (Ricker 1981). Energy is the ultimate resource for which fish compete, and it is their unequal energy intake that produces individual variation in growth, size and survival (Elliott 1990). The most important factors controlling the growth of fish are temperature, body size, access to food and, in streams, water velocity. Growth rate decreases at suboptimal temperatures (Elliott 1975; Jensen 1985; Jobling 1995).

In the present study several methods were used to obtain information on age and growth of rainbow trout so that their performance could be compared with earlier data and to assess growth performance in stream sections where electrofishing indicated that there were no rainbow trout. The first method was to assess length at age by ageing individual fish using annual marks on their scales. Secondly, using fish of known age, rainbow trout growth was monitored over specific periods for both captive and stream fish. Growth rates derived from these methods corresponded favourably.

Both the previous work of Van Someren (1952) and my study revealed that there was considerable overlap among age groups in back-calculated length at age in which calculated length range for one year group overlaps that of younger and older year classes. The wide range in back-calculated length at age of rainbow trout in these streams is explained, in part, by an extended spawning season. Unlike rainbow trout populations in the northern hemisphere that spawn in the spring, data from the present study suggest that on the equator rainbow trout spawning occurs mainly from July to August with a subsidiary peak in November-December. However, Van Someren (1952) reported that spawning can take place throughout the year and data I obtained from both the Kiganjo Trout Research Station and the Tam Trout fish farm indicate that some fish are in spawning condition every month.

Clearly, the most impressive growth was that of rainbow trout released in the Thego. They grew faster and attained larger size than either wild or captive fish. Growth rates and length at age of rainbow trout caught from upstream, midstream, and downstream stations of the Naro Moru, Sagana, and Thego were not significantly different from one another. Possibly, altitudinal temperature differences were not sufficiently different to influence growth rates. The distance from upstream to downstream stations in each stream was about 20 km.

The rate of growth in length in both studies was rapid for one year old fish then declined in the second and third years. Probably fish grew rapidly, then their rate of growth declined when maturity was attained. Lower fish densities and/or the higher stream temperature could account for the slightly higher growth rates than reported by Van Someren (1952). The present study suggests that, although anthropogenic activities have influenced stream temperature and flow, individual fish growth has not significantly declined from that previously reported by Van Someren (1952).

Van Someren (1952) commenting on growth and exploitation of rainbow trout remarked:

> "the growth rate of rainbow trout since 1943-45 has not significantly altered, nor has the instantaneous growth rate changed. Growth has obviously stabilized itself in the Sagana, with the conditions and fishing pressure to which it has been subject to now. Further, in survey of other rivers, I have evidence that a state of purely local overfishing may be produced in short stretches which are heavily overfished; but provided a river has sufficiently long closed stretch, within which breeding can be successful above the public water, and provided the downstream migration in flood periods is sufficiently good, this temporary population lack can rectify itself. No apparent change to a higher average weight will however be possible if fishing continues heavy".

This statement on fishing pressure and repopulation appears to be just as true now as it was then. The absence of fish in the lower part of the Thego (Thego Fishing Camp at station T3) suggests that repopulation from upstream is not taking place because movement of young fish is possibly inhibited by man made barriers or because young fish are illegally caught before they travel far downstream. Unregulated fishing removes large fish first and as pressure increases smaller fish are also targeted resulting in lack of annual recruitment. Once this happen it is unlikely that the population will return to historical levels.

4.3 Rainbow trout management

Rainbow trout performance has witnessed profound changes since the beginning of the century when they were first liberated in Kenya cold water streams. Their management has also witnessed considerable changes. In the early 1920s, the efforts of a few individuals helped establish self-sustaining populations of rainbow trout by planting relatively small numbers of fish in cold water streams on the slopes of Mount Kenya and the Aberdares. Later, the colonial government took over trout management.

As exemplified from Copley's annual reports and by Van Someren's manuscript (1952), regulations such as bag limit, size limit, and closed stream sections can result in an increase in trout populations and their distributional breadth. Through the initiatives of the government salmonids established themselves by natural movements and extended their distributional range beyond planting areas, and, consequently, local self-sustaining populations developed in more than 60 trout streams in the country. As noted from Van Someren's report (1952) subsequent stocking from a variety of geographic origins were planted in the streams on the southweastern slope of Mt. Kenya on an irregular basis to supplement natural stream production.

During the emergency period and the Mau Mau war of independence (from 1952 to 1960) little attention was given to trout management although there is no doubt that increased human population caused environmental changes and an increased demand for resources. Soon after independence, there was a change of personnel with more Kenyans taking over fisheries management. Fisheries regulations, especially those for trout, did not change. Unfortunately, these regulations were not adequate to protect trout in the face of anthropogenic demands for new settlements and increased needs for food and other resources.

Human activities that have occurred on "trout zone" watersheds, such as agriculture (Figure 4.2), overgrazing (Figure 4.3), and the removal of riparian forest as wood fuel (Figure 4.4) have contributed to degradation of the riverine and near-river habitat causing alteration of habitats for young and adult rainbow trout. Dams constructed for purposes of abstracting

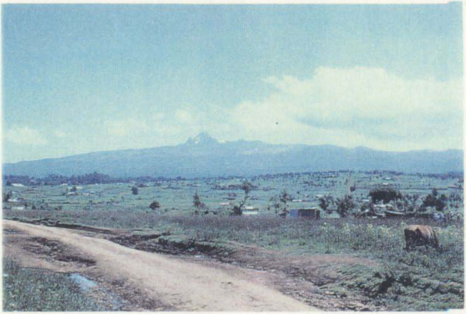


Fig. 4.2 Agriculture and other anthropogenic activities observed in the "trout zone" on the slopes of Mt. Kenya during the present study.

Fig. 4.3 Removal of buffer strips and overgrazing lead to erosion of stream banks as shown in these photographs taken from the Thego station T2 **(a)** and the Sagana station S3 **(b)**, respectively.

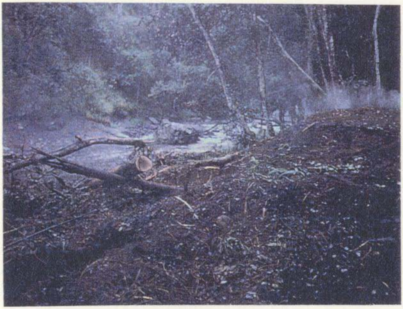


Fig. 4.4 Increased charcoal burning as observed in the Thego at station T3 has occurred along trout streams as demand for wood fuel rises.

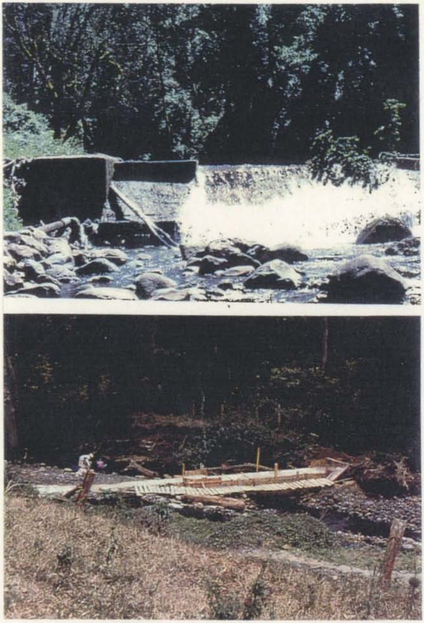


Fig. 4.5 Damming and water diversion (observed in all the study streams) for domestic use and irrigation have influenced the quality of water and reduced stream flow.

water for irrigation and domestic uses have also been built on many streams including those used in the present study (Figure 4.5). These barriers to the upstream spawning movement of mature rainbow trout are probably a significant factor limiting natural reproduction. In recognition of the current status of rainbow trout and the potential importance of the resource to the country, a comprehensive study and a new management strategy are required to help rehabilitate rainbow trout populations.

A trout fishery management strategy should include habitats, fish populations and people. Growth information indicates that trout can do well in Kenya cold water streams but they now need help. This help includes, revitalization and rehabilitation of trout streams, environmental conservation, regulations, and enforcement.

Based on their life history, rainbow trout in the stream will respond to any changes that affect the stream flow, stream biota, sediment loading, substrate composition, canopy cover and temperature. These factors result from stream and land linkage (Petersen and Cummins 1974; Hynes 1975; Cummins *et al.* 1984; Minshall *et al.* 1985; Hartman *et al.* 1996) as well as watershed management strategy (Likens and Bormann 1995). Although the river continuum model (Vannote *et al.* 1980) conceptualizes a stream as an integrated ecological unit, the valley rules the stream in many ways (Hynes 1975). So, any physical disturbance of the watershed impacts on the stream biotic and abiotic factors.

The sensitivity of rainbow trout to general environmental degradation has special significance to Kenya, because the quality of habitats for trout is one reflection of the general state of being of the environment. Although rainbow trout growth rates suggest current habitat is suitable in most sections of streams, changes in stream water quality affects the quality of water available to the community and also affects fish survival. Improvement of water quality will help to rehabilitate rainbow trout populations allowing them to recolonize habitats and increase their distributional range. Rainbow trout should be viewed as having social and economic value to the community which are intertwined with 'pristine' environments where temperatures are cool, habitats where a high diversity of wildlife exist, and streams with clean water and areas of evergreen indigenous forest occur.

Conflict in water and land use need to be addressed if further habitats loss is to be minimized. Water quality management should incorporate, riparian vegetation, minimum stream flow, and water abstractions for domestic use, livestock, and irrigation. Where barrier removal, or construction of fishways is not feasible, an alternative plan should be to stock suitable stream sections above such barriers on a 'put and take' basis. Statutory requirements under the fish industry act should consider reviewing existing regulations on trout catch records, and closed stream sections to protect spawning habitats.

Management strategies try to provide a sustainable yield to a user group. This yield can come from self-sustaining populations, from hatchery fish or both (although this is probably not practical in the long term). When the major threat to the sustainability of a specific fishery has been harvest related and not habitat related, Ross (1997) recommends that species-based management should be applied. However, in many instances, which include observations from the present study, habitat deterioration and loss in species' distributional ranges require both conservation and management tools to sustain fish populations. Over-exploitation must be curtailed if yield is to be maximized otherwise, management needs to shift to stocking rather than depending on natural recruitment.

A basic tool of stream management as explained by Moring (1985), is fish stocking to supplement natural fish production or provide 'put and take' fisheries in heavily used streams. Catch rates in such heavily fished waters are influenced more by angler pressure than by numbers of fish stocked. However, if the percentage return and angling pressure remain essentially the same, catch rates should be directly related to numbers of fish stocked.

An instructive example of the interactions among recreational fisheries, habitat alteration by man, and hatchery management in a major drainage system is the Upper North Platte Comprehensive Fisheries Study: Creel Survey and Stocking Evaluation done in 1995 to 1996 (management began in 1992) in the state of Wyoming, USA. Detailed information on the study is available in the paper by Mavrakis and Yule (1998). Its purpose was to evaluate angling success through creel, aerial and land surveys by estimating catch and harvest. The information was to be used to help define management changes to improve or maintain angler success while optimizing the use of hatchery fish. A management plan of stocking larger but fewer trout as opposed to many fingerlings was adopted (Mavrakis and Yule 1998).

Management efforts centred largely on the establishment and maintenance of rainbow and cutthroat trout strains in the river reaches to enhance angling and establish spawning runs. From their study they observed that the largest fish were caught in the river where 83% of the anglers practised catch and release, even though this river section recorded the highest angling pressure. Stocked trout made up 97% of the total catch in the river. Stocking of advanced fingerling resulted in the highest value of pounds caught by anglers versus pounds stocked for the entire system.

Performance evaluation is a necessary first step before stocking recommendations can be made. Selection of strains for a recreational fishery should be based on both hatchery and field performance data (Hudy and Berry 1983). Many 'put and take' rainbow trout fisheries are evaluated according to the contribution to the recreational fishery, specifically by recapture frequency and growth rate (Hudy and Berry 1983). Both relate directly to the economy of a stocking program and angler satisfaction with the fishery. Consequently, survival to the creel and growth should be the most important evaluation criteria in the study.

An example of evaluating survival and growth to the creel through release of hatchery fish is the work of Miller (1952) on cutthroat trout in streams of the eastern slope of the Rocky Mountains. He monitored survival rate and weight changes in six lots of hatchery-reared cutthroat trout where a resident population existed. Transplanted wild trout showed survival rates of 46.0 % to 29.0 % to the second and third summer, respectively. Fish lost weight when released in a stream stretch that had a resident population. This loss was more severe and was regained more slowly in pond-reared trout than transplanted wild trout. These fish survived and grew well where there were no wild fish before hatchery fish were introduced. Released cutthroat trout that overlapped with a resident population lost weight immediately and this loss continued for about 30 or 40 days. Thereafter, the fish held their own or gained in average weight.

The Thego experiments indicated that released fish spread from their point of release but stayed within about 1 km (see section 3.4). Tagged fish stocked in an area that had no trout grew rapidly to catchable size (section 3.5.4). Also, staff at the camp were able to patrol the area and thus no fish were poached as compared to tagged fish released in the upstream Sagana at station S1 and midstream Sagana station S2 where all radio-tagged fish were caught by illegal anglers.

This encouraging observation can now be tried in other stream sections starting with the Sagana and the Thego where Government facilities already exist. The upstream reaches of the Sagana, near the Kiganjo Trout Hatchery, would be an ideal section since it is an area with 'pristine' environment. Some downstream areas of the Sagana (S3) and Thego (T3) are also good sections for trial releases since they are next to government facilities and are accessible throughout the year. Trials can also be extended to institutions such as the Naro Moru River Lodge where fishing activity can be closely monitored.

Currently there are angling clubs and institutions, including the Kenya Fly Fishers and the Naro Moru River Lodge, that have been permitted to manage limited sections of trout streams. It is apparent that sections under institutional management such as clubs or hotels have sustained trout populations within their area of jurisdiction. Their management performance, going from past records, appears good, and should be encouraged.

It would be important to evaluate the survival of different sizes of hatchery fish in the streams; how fast they adjust to translocation; how fast they grow if, for example, they were released into a resident population of rainbow trout, and how fast anglers harvest them. These are some of the questions generated by the growth performance of the rainbow trout released in the Thego and, in part, the survival and growth of the cutthroat trout in streams of the eastern slope of the Rocky Mountains discussed earlier.

It is essential that the catch of rainbow trout of each stream be known, if stream management policies are to be evaluated. Figures obtained can readily be used as an indicator of the success or failure of trout populations from season to season. Use of punched cards (Giles 1989) or any form of record done by anglers is the first step for estimating if the catch of rainbow trout in one stream is better than that of another.

Hatcheries can and should play a major role to increase the benefits of sport fisheries in Kenya. The preliminary step is to identify wild rainbow trout genetic stocks from trout streams in Kenya that can be propagated in the hatchery. Wild fish infuse new genes into the hatchery populations and break the selection for domestication (Goodman 1991) and may increase survival rate of released fish. They can be bred in the hatchery, grown to medium sized (about 10-15 cm) and released into a section of stream on a 'put and take' basis. The goal is to ensure survival of fish after release into the wild to a creel size that anglers can catch at a fee. If fish are stocked in a stream section personnel may be required to patrol the area, clear the paths and guide the anglers to fishing sites.

Data about peoples' attitudes, beliefs, and values helps managers understand what people think and feel about a fishery resource and its importance. Measuring satisfaction allows the fisheries manager to determine to what extent people's needs and desires were met through the fishery resource. Importance of the fishery to people may also be measured through economic assessments. The concept of stake holders reflects the view that people hold a variety of stakes in fisheries resource management.

Fisheries managers may also require information from licensed anglers when considering how to create management programs responsive to user needs. In creating public awareness, people will also have to be educated on the need to conserve their environment. They also need to know that water quality preservation and conservation is good for them now and in future just as it is for fish.

The key elements in trout rehabilitation management should include:

1. Revitilization and rehabilitation of rainbow trout. Identification of stream sections that can be stocked with fingerling, sub-catchables and catchables as exemplified in the Upper North Platte Study.
2. The identification and protection of both rainbow and brown trout populations through habitat preservation.
3. Liaison with forestry and agriculture departments to ensure that fisheries of particular importance have adequate environmental protection.
4. Promotion of an educational package emphasizing the need for the community to protect the environment and especially forest and water catchments.
5. Continuation of effort to prevent illegal fishing.
6. Introduction of new size limits and closed seasons to protect immature and breeding fish in the streams.

7. Provision and promotion of advice on methods of reducing anglers' harvest through the introduction of catch and release fisheries.

8. Recognition of the landscape/stream linkage and the development of an integrated procedure for the preservation of the watersheds that will include all stake holders.

9. Recognition of the fact that fish protection means 'pristine' environment for better recreational fisheries, income to the community and the social values to the riparian owners.

4.4 Conclusions

My study focused on three trout streams from over 60 Kenya streams that became populated with rainbow trout during the first half of this century. The streams included in this study are perhaps among the few that still have self-reproducing rainbow trout populations.

This study shows that rainbow trout growth rates in streams on the southwestern slope of Mt. Kenya are similar to those in the 1940s but population levels are lower and most of the fish are small with few reaching more than 2 years of age. Rainbow trout stock size reflects the balance of birth versus deaths which are influenced by factors including breeding, stock size, environmental factors and over-exploitation rate. Environmental changes have degraded habitats in some areas but rainbow trout can still grow well although they may not reproduce there. The study also shows that there are reasons for optimism about the future of trout populations in these streams but concerted efforts are required to rehabilitate the populations. The pressure of human population and economic growth are already so great that major options on rainbow trout rehabilitation, conservation and management are already quickly vanishing. Conflicts in water and land use need to be addressed if further habitat loss is to be minimized. Difficult decisions on water usage and recreational fisheries have to be made before all options are gone. It is recommended that those streams that still hold self-sustaining populations of rainbow trout be rehabilitated as a priority. Severe over-exploitation must be curtailed if rehabilitation is to succeed.

It is hoped that a small management program on the study streams can be expanded in future to provide a more comprehensive review of rainbow trout growth performance in other streams and lead to a better trout management strategy aimed at achieving a sustainable environment for rainbow trout in the country.

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Appendices

Appendix 1. Number of rainbow trout caught during each sampling trip to the stations in the Naro Moru, Sagana and Thego.

Stream	Naro Moru			Sagana			Thego		
Date	N1	N2	N3	S1	S2	S3	T1	T2	T3
15/3/96						5			
16/3/96		45							
17/3/96						67			
12/4/96						12			
13/4/96							18		
15/4/96				11					
17/4/96			44						
18/4/96				7					
20/4/96	85								
22/4/96								2	
20/6/96	9								
21/6/96						59			
22/6/96				7					
7/8/96					21				
10/8/96	75								
12/8/96						25	4	1	
27/6/97	41								
28/6/97						29			
3/7/97					11				
5/7/97				17					
12/8/97					5				
13/8/97				23					
15/8/97	25	12							
16/8/97									
18/8/97		5	22			13			
22/8/97	25								
18/9/97	18								
22/9/97						68			
23/9/97					67		22		
24/9/97				27					
12/2/98					10				
25/2/98	4								
17/6/98					16				
5/10/98				20	29				
6/10/98						31			
7/12/98	16								
8/12/98							1		
11/12/98						4			
Total (1058)	**259**	**62**	**66**	**112**	**159**	**313**	**45**	**3**	**0**

Appendix 2. Fecundity of stream caught rainbow trout and also of fish from the Kiganjo Trout Research Station and the Tam Trout fish farm. Stream samples were from upstream (N1,S1,T1), midstream (N2,S2,T2) and downstream (N3 and S3) stations of the Naro Moru, Sagana and Thego. Eggs from the Kiganjo Trout Research Station and those from Tam Trout fish farm were from fish being held for stripping. * indicate capture fish from Kiganjo and Tam trout.

Collection date	FL (cm)	WT (g)	No. of eggs
22/6/96	18.0	84.3	265
22/6/96	18.2	80.8	371
20/4/96	18.3	83.8	318
20/4/96	20.1	102.0	435
20/7/96	20.2	102.3	380
10/8/96	20.8	137.5	640
15/8/97	21.0	125.4	562
10/8/96	21.2	133.2	704
10/8/96	21.4	140.4	839
10/8/96	22.7	149.1	742
15/8/97	22.8	126.8	875
10/8/96	23.3	184.5	762
10/8/96	23.6	165.8	692
20/4/96	23.8	175.8	680
15/8/97	24.6	182.4	942
20/4/96	24.6	234.5	714
18/8/97	28.0	330.8	1024
6/10/98	37.0	659.2	1685
24/8/98	38.5	697.0	1915
26/6/97	34.3*	650.0	1655
26/6/97	42.2*	1200	2633
26/6/97	43.4*	1100	2045
26/6/97	43.5*	1200	2572
26/6/97	45.5*	1380	2962
24/9/97	38.0*	750.0	1769
24/9/97	44.0*	1500	2464
4/7/97	46.0*	1500	3580
4/7/97	46.0*	1250	2990
4/7/97	49.0*	1250	3250

Appendix 3. Average number and percentage of macroinvertebrates from benthic Surber samples collection from the Naro Moru (N=22), Sagana (N=30) and Thego (N=29).

Stream	Naro Moru		Sagana		Thego	
Taxon	No.	%	No.	%	No.	%
Baetidae	81.7	17.9	93.4	19.6	166.1	28.5
Caenidae	16.3	3.57	10.6	2.22	13.9	2.38
Heptageniidae	26.2	5.73	18.5	3.88	47.0	8.05
Leptophlebiidae	7.4	1.62	11.2	2.35	11.8	2.02
Oligoneuriidae	0.04	0.01	0	0.0	2.9	0.5
Tricorythidae	4.8	1.05	8.5	1.78	10.0	1.71
Athericidae	2	0.44	3.3	0.69	0.7	0.12
Chironomidae	13.3	2.91	20.8	4.36	20.7	3.55
Ceratopogonidae	0.7	0.15	0.1	0.02	0.1	0.02
Dixidae	0.04	0.01	0	0.0	0	0.0
Empididae	0.04	0.01	0.7	0.15	0	0.0
Muscidae	0	0.0	0.07	0.01	0	0.0
Simuliidae	233.1	51.0	255.5	53.6	206.9	35.5
Tabanidae	0.04	0.01	0.1	0.02	0.1	0.02
Tipulidae	1	0.22	2.4	0.5	3.9	0.67
Misc. Diptera	0	0.0	0	0.0	0.1	0.02
Ecnomidae	0.04	0.01	0	0.0	0.03	0.01
Hydropsychidae	31.6	6.91	13.1	2.75	62.9	10.8
Hydroptilidae	0.04	0.01	0.03	0.01	0	0.0
Lepidostomatidae	10.3	2.25	13.8	2.89	10.3	1.77
Leptoceridae	1.6	0.35	3.8	0.8	2.5	0.43
Philopotamidae	0.1	0.02	0	0.0	0.1	0.02
Rhyacophilidae	0	0.0	0.1	0.02	0.3	0.05
Dytiscidae	0.44	0.10	0	0.0	0.1	0.02
Elmidae	2.2	0.48	0.7	0.15	1.7	0.29
Gyrinidae	0.04	0.01	0.03	0.01	0.03	0.01
Psephenidae	0	0.0	0.1	0.02	0.3	0.05
Scirtidae	15.3	3.35	16.7	3.5	13.1	2.24
Perlidae	1.5	0.33	0	0.0	2.3	0.39
Aeshinidae	0.04	0.01	0	0.0	0	0.0
Nepidae	0.4	0.09	0	0.0	0.07	0.01
Protoneuridae	0.1	0.02	0.6	0.13	0.2	0.03
Gerridae	0.04	0.01	0	0.0	0	0.0
Naucoridae	0.04	0.01	0	0.0	0	0.0
Notonectidae	0.1	0.02	0.1	0.02	0.1	0.02
Veliidae	0.04	0.01	0	0.0	0	0.0
DECAPODA	0.5	0.11	0.3	0.06	1.3	0.22
GASTROPODA	0.3	0.07	0.07	0.01	0	0.0
NEMATODA	0.4	0.09	0.07	0.01	0.03	0.01
MISC.MOLLUSCA	0.04	0.01	0.03	0.01	0.2	0.03
OLIGOCHAETA	1.4	0.31	0.4	0.08	0.2	0.03
PLANARIA	3.0	0.66	1.6	0.34	3.4	0.58
Terrestrials	0.8	0.18	0.2	0.04	0.2	0.03

Appendix 4 Average numbers of macroinvertebrates in Surber samples from the Naro Moru, Sagana and Thego.

Taxa	N1	N2	N3	S1	S2	S3	T1	T2	T3
Baetidae	109.4	63.2	69.1	58.4	83.1	135.8	93.4	135.7	209.3
Caenidae	3.3	20	26.6	8.4	13.1	10.9	16	4.8	16.4
Heptageniidae	3.6	27.8	47.6	0	0	50.5	4.6	3.8	81.7
Leptophlebiidae	14.1	7.0	0.8	13.4	18.4	3.9	120.1	3.7	11.2
Oligoneuriidae	0.1	0	0	0	0	0.4	0.6	8.8	1.8
Tricorythidae	3	1	9.4	1.8	5.9	17	0	2.5	17.3
Athericidae	0	7.3	0	7.2	0.6	1.4	0	0	1
Chironomidae	8.1	17.5	15.4	25.4	25.4	12.9	24.1	13.2	22
Ceratopogonidae	0	2.5	0	0.1	0	0.2	0	0	0.2
Dixidae	0	0	0.1	0	0	0	0	0	0
Empididae	0.1	0	0	1.1	1	0	0	0	0
Muscidae	0	0	0	0	0.3	0	0	0	0
Simuliidae	386.5	272.3	50.5	447.9	219.9	88.9	349.1	436.5	58.6
Tabanidae	0	0.2	0	0	0	0.3	0.3	0	0.1
Tipulidae	2.5	0.2	0.1	2.1	2.5	2.5	2.3	0.7	5.9
Misc. Diptera	0	0	0	0	0	0	0.4	0	0.1
Ecnomidae	0	0.2	0.1	0	0	0	0	0	0.1
Hydropsychidae	37	21.5	34.0	3.9	7.5	26.4	26.3	11.2	98.4
Hydroptilidae	0.1	0	0	0.1	0	0.1	0	0	0.1
Lepidostomatidae	24.5	3.5	1	15.4	22	6.4	21.7	11.7	4.9
Leptoceridae	3	1	0.6	4.3	4.5	2.9	1.7	1.3	3.3
Philopotamidae	0.3	0	0	0	0	0	0	0	0.2
Rhyacophilidae	0	0	0	0	0.4	0	0	0.7	0.4
Dytiscidae	0.5	1	0	0	0	0	0	0	0.2
Elmidae	0	2	4.1	0.1	0	1.7	0	0.3	2.9
Gyrinidae	0	0	0.1	0	0	0.1	0	0	0.1
Psephenidae	0	0	0	0	0	0.4	0	0	0.6
Scirtidae	21.9	11.3	11.9	30.2	15.5	4.3	27.9	13.0	6.7
Perlidae	0.3	2.2	2.1	0	0	0	0	0	4.1
Aeshinidae	0	0.2	0	0	0	0	0	0	0
Nepidae	0	0.3	0.1	0	0	0	0	0	0.1
Protoneuridae	0	0.2	0	0	0	1.7	0	0	0.4
Gerridae	0	0.2	0	0	0	0	0	0	0
Naucoridae	0	0.2	0.9	0	0	0	0	0	0
Notonectidae	0	0.5	0	0.3	0	0	0	0	0.3
Veliidae	0	0.2	0	0	0	0	0	0	0
DECAPODA	0.8	0.3	0.5	0	0	0.9	0	0	2.4
GASTROPODA	0	1.2	0	0.1	0	0.1	0	0	0
NEMATODA	0	0	1.1	0.1	0.3	0	0.1	0	0
MISC.MOLLUS	0	0.2	0	0	0	0.1	0	0	0.4
OLIGOCHAETA	0.4	2.2	1.9	0.5	0.6	0.1	0.7	0	0.1
PLANARIA	6.3	1.3	1.1	1.1	2.8	1.2	3.4	4	3.3
Terrestrials	0	1.3	1.3	0	0.1	0.4	0	0.3	0.3
Total	625.8	470	280.4	621.9	423.9	371.5	692.2	652.2	554.9

Appendix 5 Total length, fork length, standard length and mouth gape data for mountain catfish (*Amphilius uranoscopus*) from the Thego.

TL (cm)	FL (cm)	SL (cm)	Mouth gape (cm)
7.7	7.6	7.2	0.7
10.1	9.7	8.8	0.8
10.1	9.8	8.6	0.9
10.2	10	9.2	0.9
10.2	10	9.3	0.8
10.3	9.8	9.1	0.8
10.7	10.5	9.2	0.9
11.1	10.9	9.5	1.1
11.4	11.2	10.2	1.1
11.5	11.2	10.3	1.1
13.2	12.5	11.4	1.6
13.2	13.0	11.8	1.2
13.4	13.2	11.8	1.2
14.1	13.8	12.5	1.3
14.5	14.1	13.1	1.1
14.6	13.8	13.0	1.3
15.2	15.0	13.2	1.4
17.4	17.0	15.0	2.0
17.4	16.8	14.7	2.1
17.5	17.0	15.2	1.8
18.0	17.6	17.0	2.3