STUDIES ON THE BIOLOGY OF RAINBOW TROUT (*SALMO IRIDEUS*) IN EAST AFRICA.

I.—Their Food in the Thiba, Keringa and Sagana Rivers, Kenya Colony.

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Introduction.

Although trout were first introduced into Kenya Colony in 1905, little published information exists as to the general food eaten by these trout, based on a number of trout from any one river. Copley (1940) has tabulated the food of 48 Brown Trout taken in the Gura River, and in Part II of the same paper discusses briefly the food of Rainbow Trout in general. A number of stomach-content examinations from various rivers have been made by the Game Department, Kenya, and are available in their files, and from time to time various keen anglers have opened up fish which they have caught to see on what they have been feeding.

The subject is of very considerable importance however, because trout are not fish which are indigenous to any East African river, and the introduction of any non-indigenous animal in numbers to a new environment may cause considerable upsets in that environment; it has been said, for example, by certain authorities that the introduction of non-native trout to the inland waters of New Zealand has in some cases so depleted the available aquatic life in these waters serving as trout food, that the trout are in danger of starving themselves to extinction—the increase in trout numbers having been so great due to lack of competition that the food supplies can no longer be sufficient for all. That this will ever be the case in Kenya is doubtful, except perhaps in parts of certain rivers, and trout are unlikely in the near future to become a nuisance to the lower river fishings because at present they are limited in their breeding range to temperatures below 58° F.

At the same time however, trout themselves are a tremendous sporting asset to the Colony, and earn a not inconsiderable revenue each year from the sale of trout-fishing licences; because of these facts any information relating to their general biology is of considerable importance from the point of view of conserving the fishings in the best possible manner.

The material on which the following notes are based was collected during a few days spent fishing in August, 1942, the stomach and intestines of the fish caught being cut out as soon as possible after landing the fish and preserved in 5 per cent formalin; all the material being examined at a later date.

All the fish examined were Rainbow Trout (*Salmo irideus*) only, taken from the Thiba and Keringa Rivers of the Kerugoya District of Mount Kenya, and the Sagana River in the Nyeri District of Mount Kenya. Details of the fish examined are listed in the appendix; they include 37 fish from the Thiba, and much smaller numbers from the Keringa and Sagana, eight and four respectively. For purposes of examination of food taken by the fish, only the stomachs were examined, from the oesophagus to the pyloric constriction, as the food in the intestines is usually much digested and mainly unrecognisable. The intestines were, however, examined for parasitic worms. The Thiba River material is analysed in two parts according to a natural division of the river; those from the forest Thiba (Upper Thiba) being taken from that stretch of the river from the public fishing camp upstream to the limit of fishing, about 6,800 to 7,200 feet, this part of the river flowing fairly rapidly with occasional, deep, rocky pools in fairly

shaded conditions in the lower rain-forest belt; and those from the lower Thiba being taken from the second large waterfall below the "D.C.'s Camp" (reached by Jokton's camp road) to the old posho mill pool some two miles upstream, from about 6,100 to 6,500 feet, this part of the river flowing between open grassy and shrubby banks, exposed to sunshine most of the day, without heavy shading trees; and being rapid in some parts, but also with many large, sometimes canal-like pools.

The Keringa fish were taken from the lower Keringa, upstream for about two miles from the very large waterfall pool from just above which the present irrigation scheme has its origin. This part of the river is not so open as the lower Thiba, with several forest patches and steep banks, many rapids and large rocky pools, the altitude being in general similar to that of the Lower Thiba.

The Sagana fish were taken from just below the railway bridge crossing to the junction with the Thego River in the forest, the lower ¾ mile being in open country with fairly well-exposed large pools and occasional short rapids; the upper stretch being in dry forest, fairly shaded with deep rocky pools and rapids; altitude about 5,800 to 6,000 feet. It must be very clearly emphasised that these results are limited in nature being taken from only a few fish, particularly in the Keringa and Sagana, in limited parts of the rivers, at only one time of the year and, therefore, may not be of general application. Subsequent examination of over 100 Rainbow stomachs from the Thego-Sagana River complex (this examination is not yet complete for a whole year) has, however, tended to confirm these results in general, and to emphasise the necessity for dividing the samples into upper and lower river fish, whose food appears to differ somewhat in composition, and perhaps also into even more exact divisions. These present results are recorded now mainly for reference purposes as there may be a possibility that over a period of years there is a change in the food composition owing to the grazing of the trout in any one particular river.

Another very considerable difficulty which arises in work of this nature in trout rivers in East Africa is that much of the aquatic insect and other life in Kenya rivers is unstudied and unclassified, and it is possible in most cases to refer the food animal only to its order or family, with an occasional tentative generic classification which is provisional only until more is known about these animals in East Africa; and the results are based on a very generalised classification of the food which I hope will allow of a more exact classification later.

Analysis of Results.

The analyses of these stomach examinations are recorded in Figs. 1 and 2 in graphic form. Fig. 1 shows the percentage composition of recognisable food (exclusive of portions of food animals only doubtfully identifiable, and "mush" in the stomachs) taken in each locality by the trout, the different kinds of food being recorded as a percentage of the total number of food animals in all stomachs in each area. Fig. 2 shows for comparison between the forest Thiba and lower Thiba river, the percentage number of stomachs in each stretch containing the different kinds of food, which combined with the former percentage composition, is the only true way in which to record the "feeding potentiality" of the trout themselves (with a certain reservation mentioned below). The numbers of fish from the Keringa and Sagana Rivers are too few to enable a second analysis such as Fig. 2 to be made.

It is clear from Fig. 1 that the majority of food animals taken by the trout in both the forest and Lower Thiba stretches are *Baetis* nymphs (the

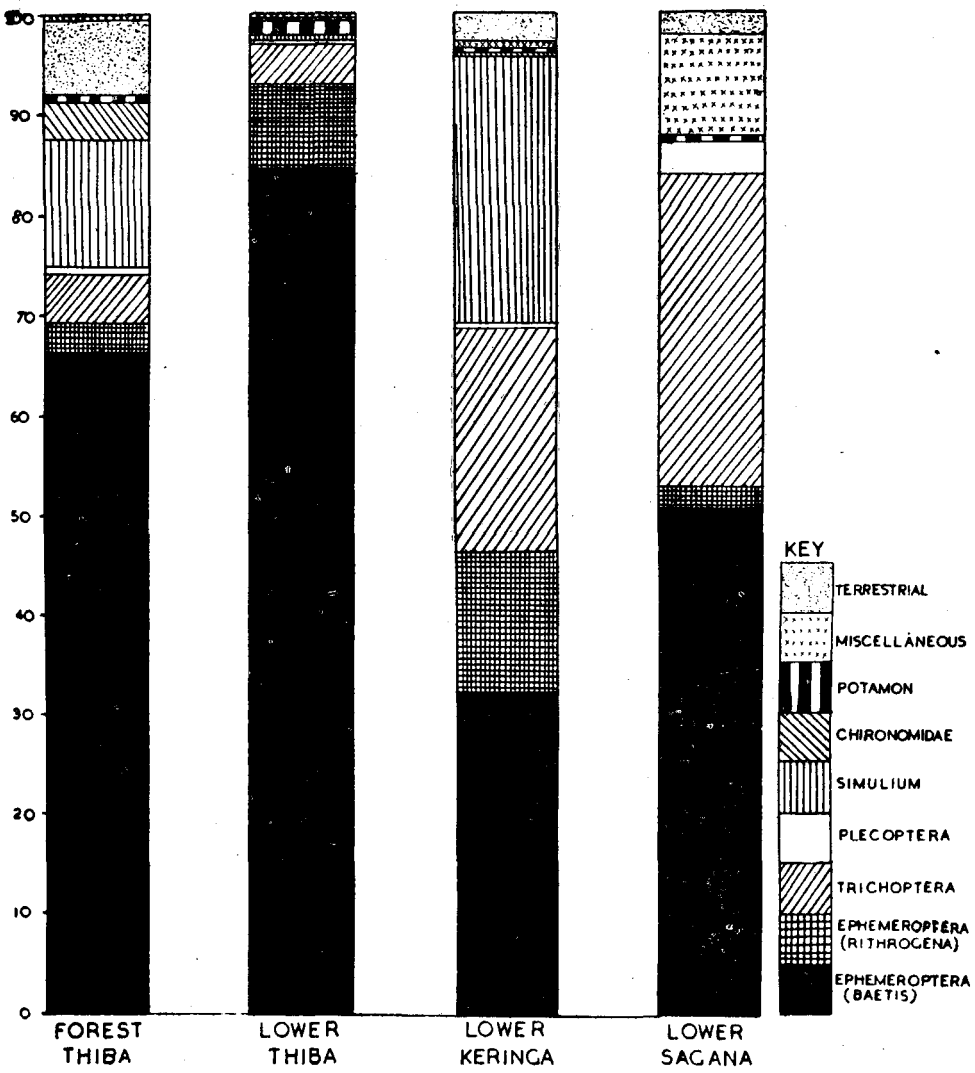

FIG. 1.

PERCENTAGE COMPOSITION OF TROUT FOOD.

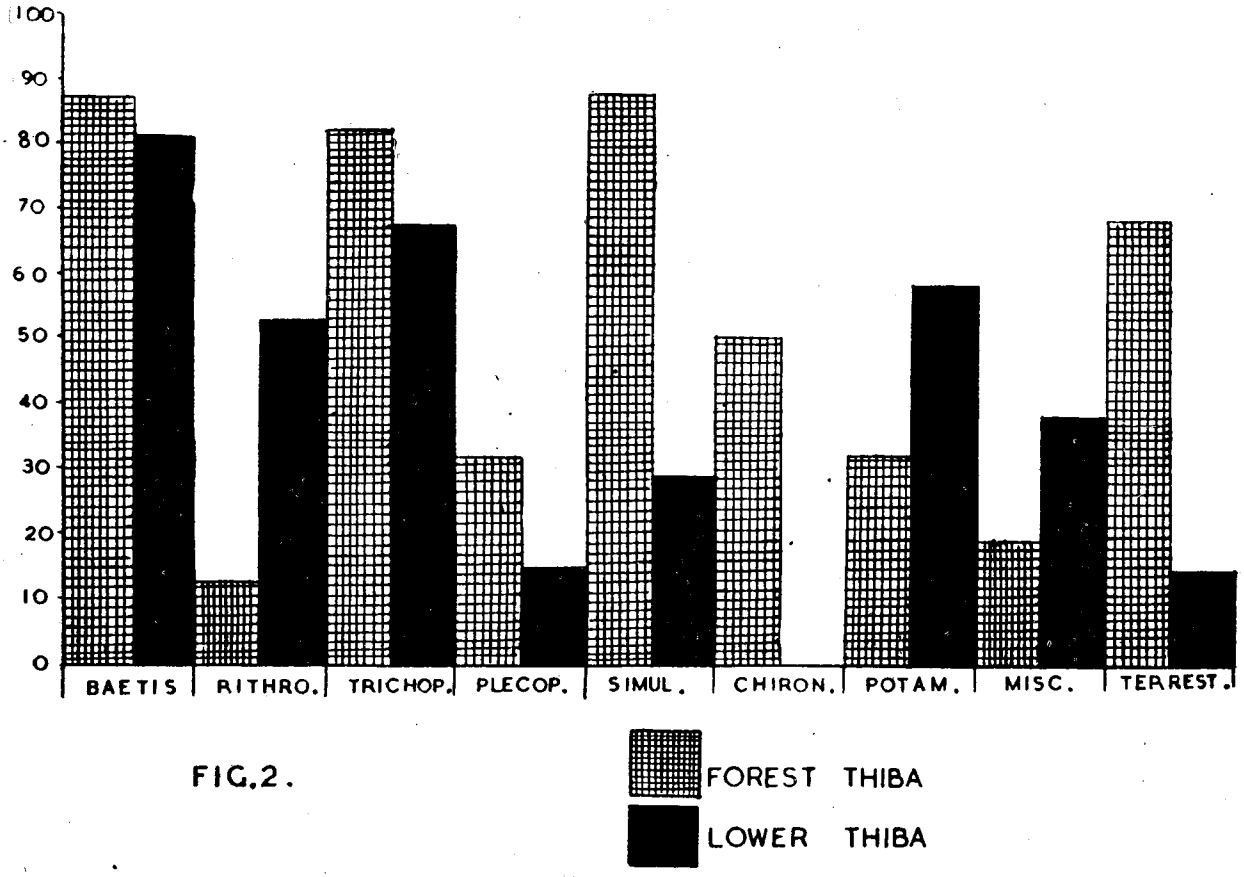

FIG.2.

PERCENTAGE STOMACHS CONTAINING FOOD.

Olive Dun nymphs of anglers), as many as 181 being counted in a single stomach from the forest Thiba, and 242 in a stomach from the lower Thiba; Fig. 2 shows that such baetid nymphs are taken by an equally high percentage of trout in each locality.

The second ephemerid taken as food in both stretches appears to be a nymph which is provisionally assigned to the genus *Rithrogena,* a nymph allied to the March Brown nymph of anglers, *Ecdyonurus.* In the forest Thiba this is eaten by trout both in smaller numbers and by fewer fish than in the lower Thiba, and it may well be that this nymph is not so abundant in the upper shaded waters.

Trichoptera larvae (the caddis fly grubs of anglers) form also an equally small percentage of the total food in each stretch, taken by approximately the same percentage of fish. These included mainly a species of hydropsychid, and a very few *Leptoceros* larvae taken with their characteristic cases—slightly curved and made only of sand grains—in both reaches.

Plecoptera (Stone Fly creepers) nymphs appear to be very scarce both in numbers and the number of fish grazing upon them; these have not yet been identified definitely as to genus or species.

Simulium (Buffalo gnat) larvae are taken by a greater number of fish in greater numbers in the upper reach, thus reversing the *Rithrogena* position and indeed are grazed upon in the upper reach by as many fish as graze upon baetid nymphs.

Chironomid (Midge) larvae, while forming quite a large portion of food for a quite large percentage of trout in the upper reach, are, surprisingly, completely absent in stomachs from the lower stretch.

The ordinary river crab, *Potamon,* represents only a very small percentage of the total food consumed in both stretches, but here such percentage results based on numbers only are liable to give an untrue picture; when based on bulk of food a different aspect is clear, since most of the other food organisms taken vary from ½ to 1 inch in length and are slender larvae or nymphs, while one single crab of reasonable size (the crabs taken measured from ½ to 2 inches across the carapace, and were, therefore, of considerable bulk) must be equal in bulk and probably food value also to several score of the smaller organisms. In an exact detailed survey, this bulk factor should also be considered.

All this food material so far discussed has been composed of aquatic organisms found on the river bed, on stones, under stones, or burrowing in the bottom silt, and as has been found in all other food surveys, a certain number of miscellaneous animals, generally occurring in the same type of habitat, are picked up. In the forest Thiba fish, these included two dixid larvae (a small dipterous Midge), two *Nepa* sp. (the water Scorpion, belonging to the aquatic bugs, or Hemiptera), and one Zygoptera Odonata nymph (Damsel Fly), and one very damaged specimen of a species of two-tailed ephemerid nymph. Miscellaneous food taken on the lower Thiba included fourteen Zygoptera nymphs, two large specimens of another genus of ephemerid nymph, and four libellulid (Dragon Fly) nymphs. In both reaches this underwater aquatic food forms over 90 per cent of the total food taken, indicating that the main food supply of the trout is found by bottom grazing, as has been repeatedly shown in trout food surveys in other parts of the world. The terrestrial and aerial food, obtained by some form of "rising," comprises the remaining small percentage of the food taken, being the "savoury" as so aptly termed by Allan (1936). Such terrestrial food, however, in the stomachs examined comprised a higher percentage both of total food and of trout taking such food in the upper than in the lower Thiba; it is interesting also that on nearly all occasions I have fished this river, the trout do rise more freely in the forest stretch

than in the lower. The composition is very mixed, obvious "casuals" being eaten by the trout as they fall into the river; in stomachs from the upper stretch these included two small carabid beetles, four staphylinid beetles, one spider, one grasshopper, one trichopteran adult and one adult *Simulium*, one small dipterous fly, four small Hymenoptera, four small black ants, and 36 "Siafu" (safari ants), found in three stomachs in lots of eleven, thirteen and twelve, and comprising both soldier and worker forms. These are in fact common enough in this stretch of the forest, and may have been casualties from one of the numerous "living bridges" they build across a small stretch of water. In addition one stomach contained one pigeon breast feather, and one small black seed.

On the lower Thiba, terrestrial food included only one grasshopper, one syrphid fly and one zygopteran adult.

The question naturally arises in such food surveys as to whether the trout are exercising any selection with reference particularly to the aquatic food; whether, for example, they are grazing upon one species of organism to the exclusion of other species which may be equally abundant in the same stretch and equally obtainable. Such a question can only be answered by a survey, both qualitative and quantitative, of the river bed fauna taken preferably at the same place and the same time at which the fish are presumed to have been feeding. Such faunal surveys are urgently required, particularly in unstocked rivers to give some idea of the "faunal balance" into which the trout are being introduced, and from the results of such surveys, in conjunction with a survey of the other river conditions, it is relatively easy to assess the success or failure of a stocking before it is undertaken, and later to trace possible causes of depreciation in a stock already introduced.

Copley (*loc. cit.* Part II) gives a very interesting table of the types of river food available at various altitudes on the Thiba River. The "Forest" sample given in this table of Copley's was taken at an altitude considerably higher than that at which the fish stomachs recorded in this present paper were caught, and for purposes of comparison I have taken his 7,000 feet (Bracken) sample as corresponding to my forest Thiba fish, and his 5,800 feet (Native Reserve) sample as corresponding to my lower Thiba fish; these slight differences in habitat (and also microhabitats of the organisms involved, which differ between species) should be borne in mind as the comparison cannot be exact unless the samples are taken in the same area as the fish sample. For comparison I append the tables herewith.

Copley Thiba River, 7,000 feet.	%	% in trout stomachs (*v S.*).
Ephemeroptera Baetidae	60.7 ...	66.4
Ephemeroptera Ecdyonuridae	11.4 ...	2.9
Ephemeroptera Leptophlebiidae	7.1 ...	—
Plecoptera Perlidae	7.1 ...	0.7 (Perlidae ?)
Trichoptera Hydropsychidae	3.5 ...	4.9
Trichoptera Leptoceridae	3.5 ...	4.9
Diptera Chironomidae	3.5 ...	3.7
Diptera Simuliidae (none recorded, but 11.8% are recorded from the 8,200 feet sample)	... ...	12.9

Thiba River, 5,800 feet.	%	% in trout stomachs.
Ephemeroptera Baetidae	13.5 ...	84.5
Ephemeroptera Ecdyonuridae	43.0 ...	8.5
Ephemeroptera Oligoneuridae	2.2 ...	—
Plecoptera Perlidae	2.2 ...	0.2 (Perlidae ?)
Trichoptera Hydropsychidae	2.2 ...	3.75
Diptera Chironomidae (none recorded) ...	... ...	—
Diptera Simuliidae	37.0 ...	0.45

Allowing for sampling errors inevitable in such work, the fact that the river samples were taken a few years previous to the fish samples, and the reservations made above, the agreement between the food actually present and the food eaten by the trout is very close in most instances. I doubt, however, in the present state of knowledge, whether one is justified in drawing closer comparisons from these two tables as much remains yet to be discovered about the ecology of these aquatic organisms in different parts of the same river at the same altitude, with particular reference to their availability as trout food in respect of their habits, and also of the feeding habits of the trout themselves.

The few Keringa stomachs examined again show over 90 per cent of aquatic food as forming the bulk of the diet, but on the whole this diet would appear to show a more balanced appearance, the various food organisms being taken in comparatively equal numbers; though the large proportion of *Simulium* larvae eaten in this river is of interest when compared to the similar stretch of the Thiba River. Crabs again, though few in number, would provide food in large bulk in a single organism. Plecoptera are again scanty. Miscellaneous aquatic food included one beetle (probably an aquatic type), and one libellulid nymph. Terrestrial food comprised seven adult Trichoptera, one adult *Simulium,* one small beetle, three ladybird beetles, three froghoppers (Hemiptera) and one small acraeid caterpillar. The Keringa fish (a river only recently stocked in 1938) are considered by many anglers to be better fish than those of the lower Thiba, and it would be interesting to discover whether, as a result of having been grazed upon for a short period only by the trout, a "balanced" underwater fauna as is suggested leads to better fish.

The Sagana River fauna, grazed upon by the few trout examined from this river, presents a slightly different aspect to either of the foregoing rivers. Baetid nymphs again form just over 50 per cent of the total food organisms taken, but the total numbers are small when compared with those from the smaller Thiba fish, 38 nymphs being the maximum recorded from any one stomach. Ecdyonurid nymphs again form only a small part of the food, but trichopteran larvae (mainly hydropsychids) form a large percentage, unlike the Thiba River, and more comparable with the Keringa. Plecoptera nymphs are more numerous in the few stomachs examined than in either of the preceding rivers. *Potamon* crabs are scarce.

Miscellaneous food forms a quite large percentage of the total underwater food. This consisted of one dytiscid water beetle, five libellulid nymphs, two aeschnid (Odonata) nymphs, one zygopteran nymph and two notonectid water bugs.

Terrestrial food, as generally, forms only a very small percentage of the total food, and comprised one winged form of an ant, one adult trichopteran, while a 1-lb. 6-oz. fish had in its stomach a small vole, about 4 inches long. It was impossible to identify this properly or to say whether this had been taken alive or dead as the surprisingly powerful gastric juices had already digested away the flesh and partly macerated the bones of the skull and spine.

Amongst miscellaneous oddments picked up by the fish, one stomach contained a stick $1\frac{3}{4}$ inches long and about $\frac{1}{8}$ inch in diameter—this "stick-eating" habit has proved to be not uncommon in stomachs subsequently examined from this river, and will be discussed in a later note. Another stomach contained four breast feathers from a pigeon and a francolin.

Discussion.

No parasitic worms were found in the intestines or stomachs of any of the fish examined, but one four-ounce fish from the upper Thiba had a nematode worm about 2 inches long in its stomach, but this was not preserved properly and I cannot state to which species it belongs or even whether it is parasitic or accidental. This lack of parasites is very interesting, and may perhaps be expected as the trout is only a comparatively recent introduction to this country, being established first in the form of eyed ova, and, therefore, having had no chance of bringing its own parasites with it from the introducing country; moreover, they have probably had insufficient time in these Kenya rivers to have become parasitised by worms, particularly so since they live in stretches of rivers uninhabited by any other indigenous fish except a small fish belonging to the cat-fish type (*Amphilius grandis* from 6,000 to 6,800 feet), whose parasites may in time adapt themselves to trout.

It is encouraging to note that, judging from these stomach contents only, there appears to be an adequate and varied food supply in these rivers, even in the Sagana which has been stocked since 1921, but without a survey of the river fauna *per se* one cannot state whether the trout find this quantity and quality of food difficult to find, or whether there is an actual abundance. There is also, generally speaking, a size selection of food by trout, the larger trout tending to take the larger food organisms and the stomachs of small and large fish may show a quite different picture of the fauna eaten. This is discussed in general terms by Copley (*loc. cit*), who has also pointed out the absence of helminth parasites, both in Kenya Rainbow and Brown Trout.

It is probable that seasonal differences in the food taken also exist, hence it is clear that many factors have to be taken into consideration when examining trout stomachs; these results present only one small aspect of the whole story.

From the practical anglers' point of view, however, these results indicate that probably Kenya Rainbow are in no way markedly different from European trout in the food taken within the limits of the waters, and while lures of bright colours and large size are undoubtedly successful in catching these Rainbow Trout, there is no reason why small "pattern" flies of the dun and spider type should not be equally successful as imitating the bulk of the trouts' underwater food more closely and in as natural a manner as possible; and indeed in skilled hands such patterns are quite as successful in Kenya rivers as the lure type.

In conclusion, I am very much indebted to Mr. Hugh Copley of the Kenya Game Department for reading the M.S. of this paper, and for many helpful criticisms, and to Dr. E. B. Worthington for helpful criticism of the subject matter and arrangement.

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APPENDIX.

Details of Rainbow Trout Examined.

Name of River and Date.	Weight.	Length.	Sex.
FOREST THIBA:			
16/8/42	4 ozs.	10¼ ins.	♀ immature.
16/8/42	6 ozs.	11 ins.	♀ spent.
16/8/42	3 ozs.	9 ins.	♂ ripe.
16/8/42	4 ozs.	9¾ ins.	♂ ripe.
16/8/42	4 ozs.	9¾ ins.	♂ ripe.
16/8/42	3 ozs.	9 ins.	♂ ripe.
16/8/42	4 ozs.	9¾ ins.	♀ ripe.
16/8/42	5 ozs.	10¼ ins.	♀ spent.
16/8/42	4 ozs.	9¾ ins.	♂ ripe.
16/8/42	12 ozs.	11¼ ins.	♂ ripe.
16/8/42	4 ozs.	9½ ins.	♂ ripe.
16/8/42	4 ozs.	10 ins.	♀ immature.
16/8/42	4 ozs.	9¾ ins.	♂ ripe.
16/8/42	4 ozs.	10 ins.	♂ immature.
16/8/42	7 ozs.	10½ ins.	♀ ripe.
16/8/42	13 ozs.	12 ins.	♀ immature.
LOWER THIBA:			
3/8/42	32 ozs.	17¾ ins.	♂
3/8/42	12 ozs.	12½ ins.	♂
3/8/42	7 ozs.	10 ins.	♀ immature.
3/8/42	8 ozs.	11 ins.	♀ immature.
3/8/42	20 ozs.	14 ins.	♀ immature.
3/8/42	12 ozs.	11¾ ins.	♀ ripe.
3/8/42	12 ozs.	11 ins.	♂
3/8/42	12 ozs.	11½ ins.	♀
3/8/42	12 ozs.	11¾ ins.	♀ immature.
3/8/42	24 ozs.	14½ ins.	♀ immature.
3/8/42	16 ozs.	13½ ins.	♀ ripe.
3/8/42	9 ozs.	11 ins.	♀ immature.
3/8/42	12 ozs.	11¾ ins.	♀ immature.
3/8/42	12 ozs.	11¾ ins.	♂ immature.
17/8/42	12 ozs.	12 ins.	♀ immature.
17/8/42	10 ozs.	11¾ ins.	♀ immature.
17/8/42	16 ozs.	13½ ins.	♂ spent.
17/8/42	12 ozs.	12 ins.	♀ immature.
17/8/42	16 ozs.	13 ins.	♀ immature.
31/8/42	16 ozs.	12½ ins.	♀ immature.
31/8/42	14 ozs.	12¼ ins.	♀ immature.

Name of River and Date.	Weight.	Length.	Sex.
LOWER KERINGA:			
2/8/42	32 ozs.	17 ins.	♀ spent.
2/8/42	16 ozs.	13 ins.	♂ immature.
2/8/42	16 ozs.	12¼ ins.	♂ immature.
2/8/42	18 ozs.	13½ ins.	♂ immature.
2/8/42	20 ozs.	14½ ins.	♂ ripe.
2/8/42	28 ozs.	15 ins.	♂
2/8/42	12 ozs.	11½ ins.	♂
30/8/42	10 ozs.	11¾ ins.	♂ ripe.
LOWER SAGANA:			
9/8/42	16 ozs.	13¼ ins.	♀ immature.
11/8/42	41 ozs.	18½ ins.	♀ immature.
12/8/42	20 ozs.	14¼ ins.	♀ immature.
13/8/42	22 ozs.	14¾ ins.	♀ immature.

River.	Average Weight.	Average Length.
Forest Thiba	5.3 ozs.	10.3 ins.
Lower Thiba	14.9 ozs.	12.4 ins.
Lower Keringa	19 ozs.	13.6 ins.
Lower Sagana	24.7 ozs.	15.2 ins.