WATERSHED CONDITIONS OF THE ETHIOPIAN HIGHLANDS AND THE FISHES OF THE LITTLE GHIBBIE RIVER, ETHIOPIA

By

ROBERT HENRY LOOMIS

Bachelor of Science
University of Georgia
Athens, Georgia
1947

Master of Science
Oklahoma Agricultural and Mechanical College
Stillwater, Oklahoma
1951

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Thesis Approved:

W. H. Irwin
Thesis Adviser

Roy W. Jones

H. I. Featherly

Geo. A. Moore

F. M. Baumgartner

Robert MacVicar
Dean of the Graduate School

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CHAPTER I

INTRODUCTION

The investigation with which this paper is concerned was an ecological study of watershed conditions of the Ethiopian highlands and the fishes indigenous to one of the rivers. On the Ethiopian Plateau erosion has produced rugged terrain, with the rivers located in the areas of deepest erosion. The surface of the plateau is cut with deep ravines and gorges revealing that vast amounts of soil had been washed away. A study was made to associate the characteristics of the watersheds with the economy of the rivers. Any stream character, whether it be type of water, volume of water, productivity or appearance, is formed and modified by the watershed.

Since the watershed is important in an ecological study of a river and its flora and fauna, consideration of the physiography, soil formations, run-off, and climate together with the natural soil covers, agricultural crops, and agricultural practices which affect the watershed were included.

The writer lived for two years in the city of Jimma, which is located in the southwestern portion of Ethiopia on the Ethiopian Plateau. He was associated with the Jimma Agricultural Technical School, a Junior College and Branch Experiment Station of the Imperial Ethiopian College of Agricultural and Mechanical Arts. One of the assigned duties was the establishment, maintenance, and operation of a weather station at Jimma. Items of study included temperatures, rainfall, relative humidity and sunshine which were correlated with crop and soil conditions.

Time and transportation facilities precluded the inclusion of all rivers, therefore, one was selected as representative of the highland region. The Little Ghibbie River was chosen for study because; (1) it was located on the Ethiopian highlands; (2) the river and its watershed were typical for the plateau; (3) it was one of the smaller river systems which made possible a more complete coverage of its waters; (4) its proximity to Jimma made repeated visits possible; and (5) it was the only river which could be reached at several points. Among the items originally included in the river study were the fishes that were present, the other macrofauna and flora, the temperature and turbidity of the water, the shape of the channel, and the nature of the bottom.

Inasmuch as only two species of fishes, Barbus duchesnii Boulenger and Labeo cylindricus Peters, were collected from the Little Ghibbie, it was decided, early in the investigation, to include a study of the age and growth-rate and food habits of B duchesnii. L cylindricus was not obtained in sufficient numbers to yield statistically significant data. Later, it was learned that Barbus duchesnii is restricted in its distribution to Ethiopia particularly to the Ethiopian highlands. Possible explanations for its limited distribution are presented.

Information pertaining to characteristics of the highland watersheds was obtained between September, 1952, and July, 1954. Fish collections and observations concerning the channel of the Little Ghibbie River and its water were made between February 14, 1954, and June 5, 1954.

CHAPTER II

REVIEW OF THE LITERATURE

Watershed conditions have been and are being studied to control erosion, run-off, and soil fertility. Our libraries abound with literature which deals with practices designed to improve and preserve the productive potential of a watershed, but literature which deals with the effect of a watershed on the productivity of the rivers is scarce. None was found concerning Ethiopia. Erosion-silt has been implicated as the chief factor in the modification of aquatic environments (Ellis, 1931, 1936). H. H. Bennett (1939) summarized the literature concerned with watershed problems including such items as erosion, run-off, slope, soil type, land-use, vegetational cover, and climate.

Rapid run-off destroys the water-holding capacity of a watershed; destroys spawning beds in rivers; and erodes soil, inundates vegetation, and sweeps away organic material both on a watershed and in a stream (Tarzwell, 1937; Tody and Clark, 1951; Olson, Clark, and O'Donnell, 1955). Studies have been made which concern the effects of a watershed on the fishes of its streams, but such studies have been associated with cold-water rather than warm-water fishes.

There is little literature relative to the fishes of Ethiopia. Most of the literature published deals with taxonomic and distributional data. European ichthyologists have published on the fishes collected from the Blue Nile, Awash, and Omo River systems, and Lakes

Tana, Abbe, and Rudolf (Pellegrin, 1905, 1906, 1931; Boulenger, 1909, 1911; Chappius, 1939). Other workers (Gunther, 1864; Boulenger, 1905, 1906) when considering near-by localities have described fishes which range into Ethiopian waters. No reference was found on life history, age and growth-rate, or other ecological studies pertaining to the fishes of Ethiopia. The only report found of an age and growth rate study concerning a species of the genus Barbus was made on collections from the Vistula River, Poland (Starmach, 1947). The scales of African cyprinid fishes have been described and illustrated by Cockerell (1910).

Factors recognized as affecting the growth of fishes are: temperature and latitude (Hile, 1936, 1941; Eddy and Carlander, 1940; Jones, 1941; Van Oosten, 1944); food (Ricker, 1947; Van Oosten, 1944); rainfall (Hile, 1941); physical-chemical factors (Eddy and Carlander, 1940; Smith, 1940; Chandler, 1942; Swingle, 1944; Van Oosten, 1944); and density of population (Hile, 1936; Eddy and Carlander, 1940; Van Oosten, 1944).

The use of explosives as a method of fish collection was suggested by Hubbs and Lagler (1947). Investigations by Gowanloch and McDougall (1945), Alpin (1947), Personnel of the Chesapeake Biological Laboratory (Anon., 1949), Coker and Hollis (1950), and Hubbs and Rechnitzer (1952) have brought forth information concerning the effects of underwater explosions on aquatic organisms.

CHAPTER III

METHODS

Every opportunity was taken to gather information concerning the watersheds of the rivers which rise in the Ethiopian highlands.

Information Pertaining to Watersheds

Information pertaining to the watersheds of the highland rivers of Ethiopia was obtained from four sources. Personal observations were made while in residence during which time extensive motor trips were made covering much of the highland country. The trips covered practically the entire central portion of the Ethiopian Plateau from Maji, in southwestern Ethiopia, northward to Asmara, Eritrea, a distance of about 1,200 miles. Numerous other trips were made between Addis Ababa and Jimma, and from Jimma in various directions covering an area with a radius of about 50 miles. Approximately 3,000 miles of auto travel, exclusive of collecting trips, were covered during which time information concerning physiography, soils, vegetational cover, relative amounts of run-off, and activities of the people who lived on the watersheds was obtained. In addition, many valuable impressions concerning features of the watersheds, which otherwise might have been missed, were obtained by flying over extensive areas of the plateau. Conversations with persons who had traveled extensively on the Ethiopian Plateau, especially to areas which were not personally visited, not only gave a broader picture of the region, but also substantiated impressions previously gathered. Further information concerning geology and other watershed conditions was obtained from various source materials (Angerer et al., 1954; Buxton, 1949; Perham, 1948). Finally, information concerning the size of watersheds, elevations, and locations of the rivers of Ethiopia was obtained by study of maps of the country.

Collecting Procedures

Methods for the collection of fishes usually employed in the United States were, on the whole, impracticable in the Little Ghibbie River. One major problem in undertaking the investigation involved the acquisition of suitable collecting gear. Equipment such as gill nets, hoop nets, and seines had to be imported. Judging from the time required for laboratory equipment to arrive when ordered for the school, 12 to 18 months might be expected to elapse before collecting gear would become available. However, one trammel net and one small seine were obtained; but because of the time involved in procurement of additional equipment, the decision was made to use materials locally obtainable.

Collecting stations were chosen by studying maps of Ethiopia, and noting the points at which a road approached the Little Ghibbie River. Attempts made to reach the river at the selected locations were not always successful because the roads were sometimes impassable (Fig. 1).

The main method employed in sampling the fishes was the explosion of a one-pound charge of dynamite for each sample collected. The use of dynamite as suggested by Hubbs and Lagler (1947) was accepted because authorities in Kaffa Province did not object to its use, and because it offered the best readily available means to capture fishes from the river.

Figure 1. Road to a Station on the Little Ghibbie River

Recent seismographic exploration in the Gulf of Mexico, the coastal waters of Southern California, and naval ordnance testing in Chesapeake Bay have stimulated considerable research upon the effects of underwater explosions on aquatic organisms. Gowanloch and McDougall (1945) found that charges of 200 to 800 pounds of dynamite were effective over a radius of less than 200 feet from the shot-point. A report from the Chesapeake Biological Laboratory (Anon., 1945) stated that 30 pounds of dynamite were effective up to 400 feet from the shot-point, and suggested a possible error of technique used by Gowanloch and McDougall to explain the apparent discrepancy of results. Charges of 250 to 1,200 pounds of HBX, a high explosive more powerful than TNT failed to produce a killing effect beyond 100 yards (Coker and Hollis, 1950).

However, according to Hubbs and Rechnitzer (1952), charges of one-half pound of dynamite kill fish, and the lethal effects of dynamite vary as the one-third power of the weight of the charge. Furthermore, they asserted that dynamite gives a very high and instantaneous initial pressure which is almost as quickly dissipated, and the rapid compression and rarefaction is responsible for the death or injury of the fishes. Alpin (1947) suggested that variations in the number of fishes killed is dependent upon the number of the fishes within the effective range of the charge rather than the size of the charge and depth of the water. Hubbs and Rechnitzer (1952) introduced the additional variable of type of explosive.

The actual cause of death or injury, resulting from an underwater explosion, was found by all of the investigators cited, to be due to hemorrhaging, ruptured air-bladders, and disruption of viscera, especially liver and gonads.

Dynamite employed in the present study was used in the following manner. A one-liter glass bottle was half filled with powdered dynamite, an eight-inch fuse with a cap attached was inserted, and enough dynamite to fill the remainder of the bottle was added. A tight-fitting cork with a notch at one side to accommodate the fuse was then forced into the neck of the bottle. After the fuse was ignited, the bottle of dynamite was thrown into the deepest water available. After an explosion, several native helpers entered the water and aided in collecting the fishes that floated to the surface.

Experience proved that the best localities on the river to sample the fishes with dynamite were in areas where sharp bends in the river occurred. In such localities reasonably shallow and deep waters were found close together. Such situations facilitated access to the fishes once they were killed or stunned. A seine or a trammel net was stretched across the river downstream from the point of explosion, and many specimens were captured in this manner. If the station was chosen wisely, eddy currents tended to carry the fishes upstream, close to the bank before they were swept away in the main current.

A trammel net fifty feet long by four feet deep with a mesh size of one-half inch bar measure was used. It was set perpendicular to the shore line, with one end being tied near the shore and the other end being anchored in deep water with weights. The net was permitted to ride the bottom, and depths sampled ranged from 0 to 18 feet.

Temperature and Turbidity

Prior to collecting the fishes, air and surface water temperatures were measured with a centigrade laboratory thermometer which was calibrated from -20 to 150 degrees. Readings were taken at the edge and in the middle of the stream; but since no variation in temperatures between the edge and the middle was found, only one measurement was recorded.

An indication of the turbidity of the water was obtained by using bottom visibility as described by Hubbs and Lagler (1947).

Recording Field Data and Preparing Specimens for Study

Observations pertaining to the stations were made and recorded before the fishes were collected. Field notations included collection number, province, locality, estimation of turbidity, type of habitat (shore vegetation, and bottom type), water and air temperatures, estimation of current (i.e. sluggish, swift, etc.), width of the stream, depth of the water, method of capture, date, time of day, and original preservative, if any was used.

All fish samples were examined while they were fresh, either directly in the field at the time of capture, or in the laboratory to which they were transported in ten-gallon cream cans. Weight in grams to the nearest whole gram and total length to the nearest millimeter were recorded under an accession number for each specimen. Scale samples for age and growth determination were collected from 550 individuals and preserved in scale envelopes. The scales were taken from the left side of the fish between the dorsal origin and the lateral line. In addition, stomachs of 171 specimens were collected. The stomachs were removed from the fishes, wrapped in cheese cloth with a tag bearing the accession number and preserved in four-per cent formalin.

Shipping the Specimens to the United States

A small sample of whole fishes and the stomachs of other fishes collected were wrapped in cheese cloth, tagged (with the proper accession number), preserved in four-per cent formalin, and placed in five-pound milk cans on which the tops were soldered. The cans, together with the scale envelopes, were then packed in a water-proofed wooden box and shipped from Jimma, Ethiopia, to the United States.

Food, Age, and Growth-Rate Studies

After the specimens arrived in the United States, the fishes were identified, and determination of the ages and annual growth rates of

Barbus duchesnii were computed from the year marks on the scales. Standard procedure in age and growth determination was followed (Van Oosten, 1929). The stomach contents were diluted with water and examined in petri dishes under various magnifications. A low-power stereopticon and a higher-power compound microscope as needed were used for the analyses. The recorded length-data of the specimens from which the stomachs were removed were arranged in 20-millimeter intervals, and the length range for each group was recorded. Plant and animal materials from the stomachs were treated separately, and the frequency of both plant and animal materials was tabulated.

CHAPTER IV

SITUATION INVESTIGATED

Ethiopia is located in the east-central portion of Africa between 35 and 45 degrees east longitude and 5 to 15 degrees north latitude (Fig. 2). The country contains 350,000 square miles, an area roughly a third larger than the state of Texas (O'Brien, 1953).

Ethiopia is a mountainous country. The main agricultural region consists of a high tableland, which is divided by the Rift Valley into the Ethiopian Plateau on the northwest and west and the Somali Plateau on the southeast. The remainder of the land is lower in altitude and is largely desert.

The Ethiopian Plateau has an extremely irregular surface. Large areas, 5,000 to 6,000 feet high with mountains towering above and with valleys 3,000 feet deep, are common. The highest mountains, Ras Dashan (15,158) and Mt. Kollo (14,100 feet), are found in the northern portion in the vicinity of Gondar. Numerous small mesas contribute further to the irregular surface of the highlands. The plateau is delimited on the west by an escarpment 7,000 to 8,000 feet above sea level, and is continuous with the western edge of the Rift Valley. For the most part, the plateau slopes downward from east to west. The western escarpment, although lower than that of the east, stands 4,000 to 5,000 feet above sea level. The northern edge of the plateau is contained within Eritrea.

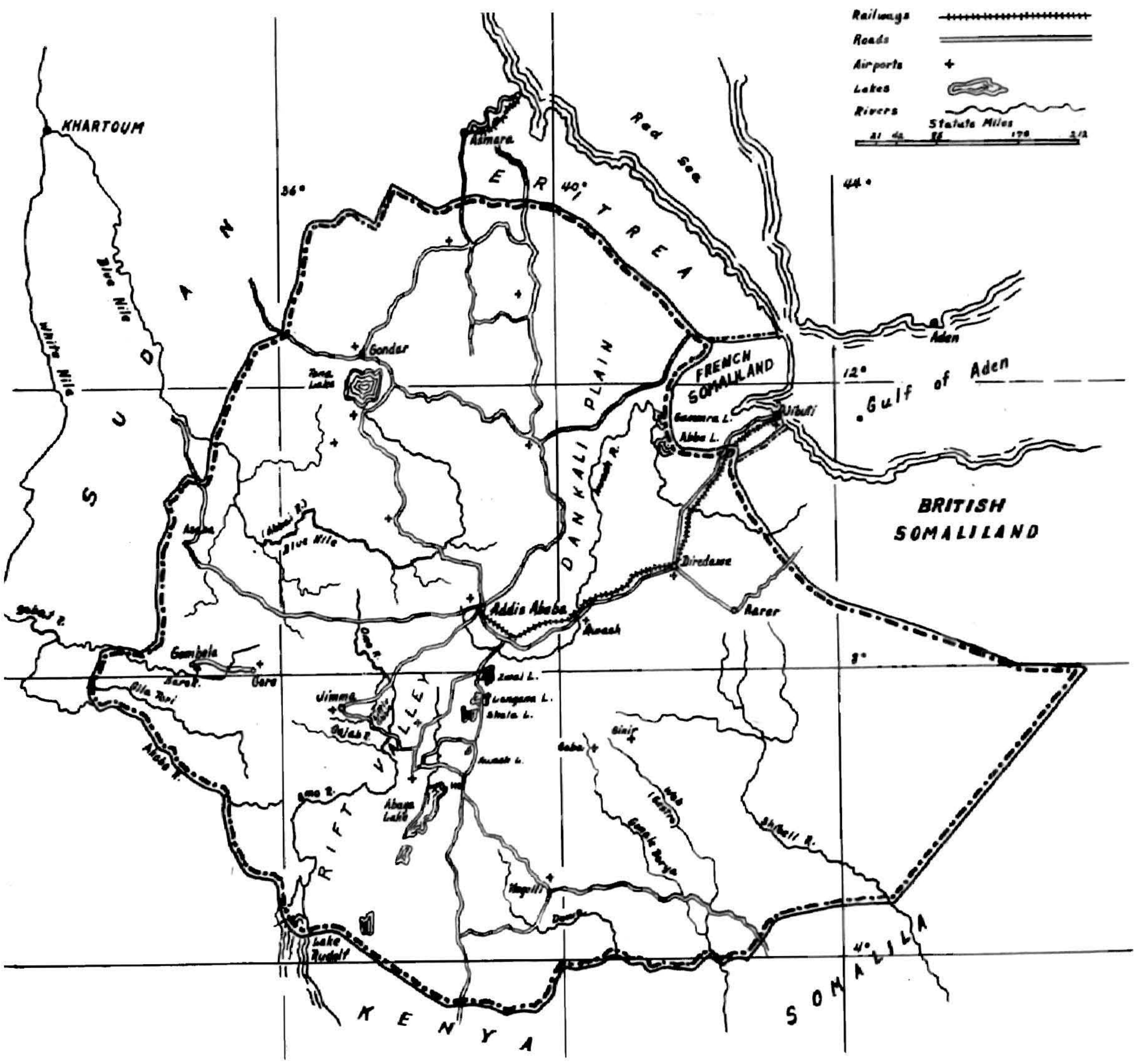

Figure 2. Ethiopia and Surrounding Territories. (Based on: "Ethiopia, Provinces in 1935" by Perham, 1948; "Africa Orientale Italiana" Consociazione Turistica Italiana-Milano, 1940, XVIII; and "Africa and the Arabian Peninsula," March, 1950, The National Geographic Magazine, Vol. XCVIII).

Watersheds

Several rivers drain Ethiopia, which for convenience, is divided into seven main watersheds. Five are located on the Ethiopian Plateau; because of the slope from east to west, much of the area drains to the Nile River. The waters of the Nile River come from the northwest by way of the Takazze, from the west-central portion by way of the Blue Nile, and from the southwest by way of the Akobo, Gila Tori, and Baro rivers.

Little hydrographical data exists for the rivers of Ethiopia. Stream work has been inaugurated, but Clark[1] (personal communication) stated that many years will be required for the collection and tabulation of data concerning stream discharge, sediments, and other related studies. These data, when complete, will serve as an indication of watershed conditions as they affect the rivers of the Ethiopian highlands.

The Blue Nile River is the largest river in the Nile Drainage of Ethiopia. The Blue Nile is 850 miles long and joins the White Nile River at Khartoum, Anglo-Egyptian Sudan. Limited information concerning hydrographical data from the river shows that at Khartoum, the Blue Nile varies in volume from about 200 cubic meters per second with 2-per cent suspended solids during the dry season to an excess of 6,000 cubic meters per second with 17-per cent suspended solids during the rainy season (Ludwig, 1937).

In order to further clarify information concerning watershed

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[1]T. A. Clark, Director, Water Resources, U.S.A. Operations Mission to Ethiopia.

conditions prevalent on the highland regions of Ethiopia, a comparison of the sediments carried by the Blue Nile River was made with rivers in the United States and elsewhere, using suspended sediments as an indication of the conditions. Several rivers carry a higher per cent of suspended solids than the Blue Nile. According to Lane (1940) the maximum sediments recorded for the rivers mentioned below were as follows: the San Juan River at Goodridge, Utah, 40.8 per cent; the Rio Puerco River at Rio Puerco, New Mexico, 52.3 per cent; the Rio Grande River at San Marcial, New Mexico, 21.36 per cent; the Yellow River at Sanchow-Honan, China, 39 per cent; and the Yung Ting River, China, 55.7 per cent.

Other rivers, in southwestern United States carry a lower per cent of suspended solids than the Blue Nile River. The maximum load of suspended sediment recorded on the South Canadian River of Texas and Oklahoma, was 14.7 per cent on May 3, 1941 at Amarillo, Texas, and the maximum sediment carried by the Red River at Gainsville, Texas, was found to be 3.5 per cent.[2] According to Howard (1947), the maximum load of suspended sediment carried by the Colorado River near Grand Canyon, Arizona, was 13.1 per cent in 1927.

One watershed is drained by the Awash River, which flows northeast for 500 miles to the French Somaliland border and empties into the land-locked basins of Lakes Gomarri and Abbe. The river on the Dankali Plain is at places 200 feet wide and four feet deep during the dry season. During the rainy season, the water may rise 50 to 60 feet and flood thousands of acres of desert land.

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[2]"Arkansas-White-Red River Basins Report, Part II, Section 9." (Unpublished report, Tulsa District, Corps of Engineers, 1955) pp. 66 and 73.

Another watershed is drained by the Omo River, which flows 370 miles from its origin through central Ethiopia to the Kenya border and empties into the land-locked basin of Lake Rudolf. The river gradient is steep, falling almost 6,000 feet along its course. The rivers of the Ethiopian Plateau originate in the same general area and flow outwardly in different directions.

The Rift Valley forms an effective break in the drainage areas, and the waters from the southeastern mountains drain toward the Indian Ocean. The headwaters of both the Guiba and Webi Shebi rivers rise in the Somali Plateau and flow down the coast of former Italian Somaliland, but the waters of the Webi Shebi become absorbed by irrigation projects before reaching the sea (Buxton, 1949).

The plateau country, which contains the watersheds, is rent by the main streams and tributaries of the river systems. Huge chasms, hundreds of feet deep, have been formed by the rushing waters. In some places the chasm walls are so abrupt that one may walk to the very brink without suspecting that a chasm lies ahead (Buxton, 1949). The deep gorges tend to isolate one district from another particularly at flood stages which may last for one-third or more of the year.

The Little Ghibbie River

The Little Ghibbie River rises in the vicinity of 36 degrees, 40 minutes east longitude, and 7 degrees, 30 minutes north latitude and meanders in a northeasterly direction for about 80 miles, where it empties into the Omo River at about 37 degrees, 30 minutes east longitude, and 8 degrees, 15 minutes north latitude.

The watershed of the Little Ghibbie River is bounded on the east, south and west by high mountains with peaks that range in elevation from 5,000 to 9,000 feet. The watershed is broad until it approaches a junction with the Omo River, where it tapers to a narrow gorge.

Numerous tributaries, most of which are unnamed, lead into the Little Ghibbie River. The Meti, Bulbul, and Nada rivers are the main tributaries and join the Little Ghibbie in the order named. Above the junction of the Meti River, the Little Ghibbie is small and sluggish during dry weather, ranging in width from six to eight feet and in depth from three to five feet. The river increases in volume from inflowing tributaries until it is 300 feet wide above the gorge. Tributaries along the western edge of the gorge form waterfalls as they flow from the valley rim.

The banks of the river, even above the gorge, are steep, often dropping vertically 10 to 25 feet to the water (Fig. 3). Shallow water

Figure 3. Little Ghibbie River Near Station 1.

is seldom found even in the dry season, since the banks below the surface of the water continue to be steep.

The river bottoms that were explored varied in composition from large, black, volcanic boulders to clay. In some areas there was deep silt overlying the volcanic rocks. In one place, which was used as a ford, bedrock formed the river bottom, the water was shallow, one and one-half to two feet deep, and the bottom was completely covered with large boulders. Here the velocity of the water increased but not enough to consider the area a rapids.

The flood plain area of the Little Ghibbie River is small, with some notable exceptions confined to steeply sloping pasture lands (Fig. 4). Two areas were found in the vicinity of Jimma, where a wide

Figure 4. The Little Ghibbie River and a Portion of the Watershed.

expanse of bottom land was associated with the river. During the rainy season the bottom lands flood, and temporary lakes covering several hundred acres are formed.

The waters of the Little Ghibbie River are turbid. Although turbidity readings in parts per million were not recorded, the depth at which the bottom was visible gave an indication of the turbidity of the water. The river bottom was visible only at Station Number 1, where on three occasions it was seen through six, three and two inches of water.

There was little evidence that the river had a high productive potential. Needham (1930) stated that streams supporting growths of aquatic plants were found to be seven times more productive than were stream bottoms bare of vegetation. No vascular aquatic plants were observed growing in the Little Ghibbie River.

Perhaps even more indicative of low productivity were the relatively few animals found in the water. Etheria elliptica, a pelecypod, and hippopotami were the only animals, other than the fishes, actually observed in the river water. Hippopotami do not necessarily depend upon aquatic organisms for food. Examination of stomach-contents of the fishes showed the presence of organisms such as zooplankters, sponges, Lyngbya, and larvae of Diptera and Caddis flies.

The equipment was not available to make chemical analyses of the water; however, the presence of a fresh water mussel with a thick heavy shell gave evidence that the waters were probably alkaline in reaction.

Five stations along the Little Ghibbie River were selected for sampling (Fig. 5). The choice of station was influenced by accessibility to the river from the highway, height of bank, and depth of

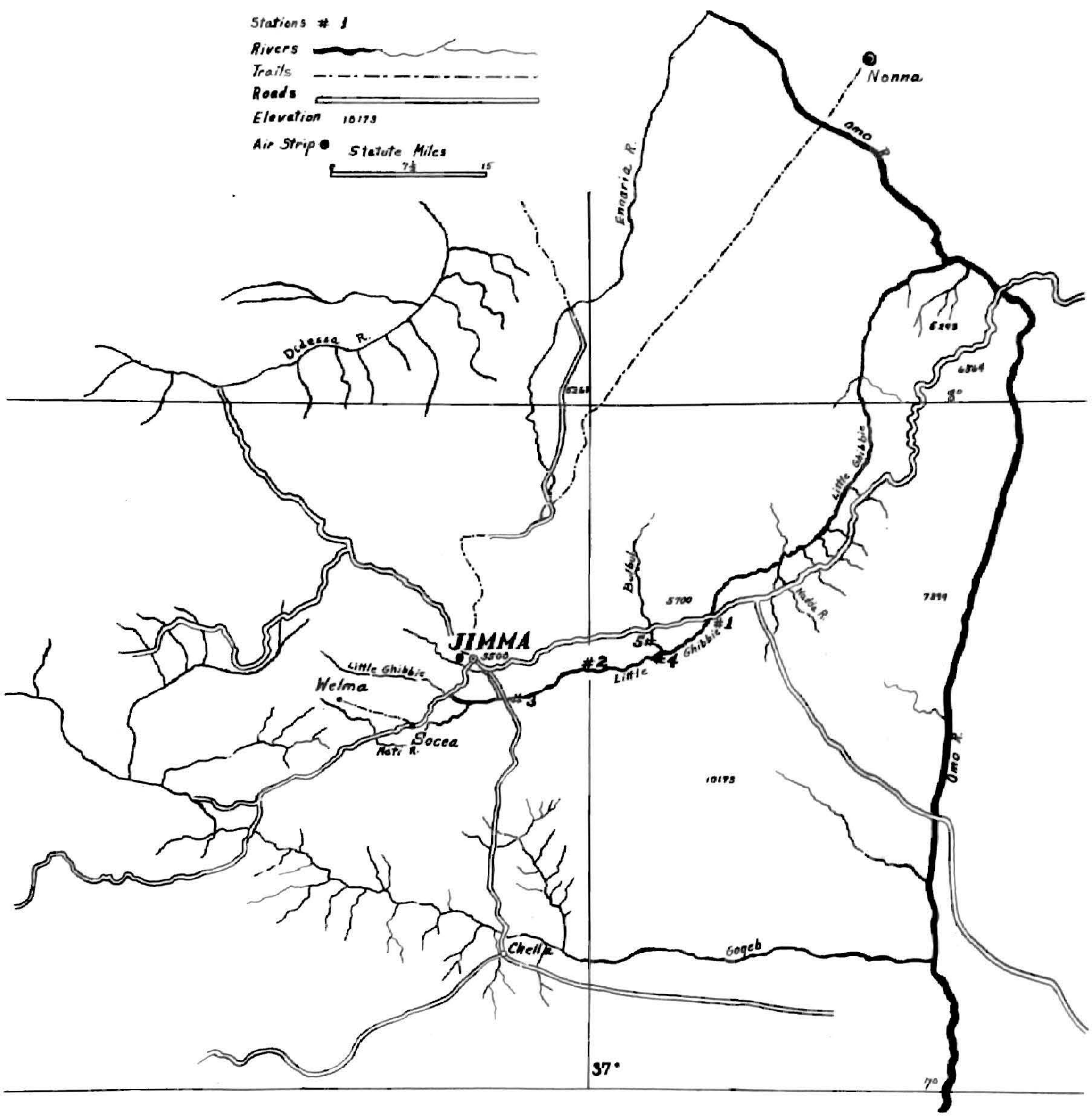

Figure 5. Collecting Stations on the Little Ghibbie River. (Based on "Africa Orientale Italiana," Consociazione Turistica Italiana-Milano, 1940, XVIII).

water.

Station Number 1 was located 100 yards south of a bridge and 42 miles northeast of Jimma near the highway from Addis Ababa to Jimma. Collections were made in a large pool upstream from the "ford" formed by a pile of black volcanic boulders (Fig. 6). There was a moderate growth of small trees and flowering shrubs on top of steep banks which

Figure 6. Station Number 1 on the Little Ghibbie River, 42 Miles Northeast of Jimma, Ethiopia.

were eight to ten feet high. The river bottom was covered with small to medium-sized boulders. The river, 75 feet wide and averaging five feet deep, had a sluggish current. Collections were made in 1954 between 10 A.M. and 12 noon on February 14; from 10:30 to 11:30 A.M. on April 17; from 10 to 11 A.M. on May 15; and from 2 to 3 P.M. on June 5.

Station Number 2 was located 6.3 miles east of Jimma and one mile south of the Addis Ababa-Jimma highway. The tops of the vertical river banks were 15 feet above the water and were overhung with a dense growth of shrubs and small trees. The river bottom was composed of a thick layer of silt overlying volcanic boulders. The river, 30 feet wide and from four to ten feet deep, had a sluggish current. Collections were made in 1954 from 4 to 6 P.M. on March 21; from 3 to 5 P.M. on May 8; and from 2 to 4 P.M. on May 30.

Station Number 3 was located six miles south of Jimma, 50 yards upstream from a bridge on the Jimma-Chella road. The tops of the banks were covered with a dense growth of small trees and shrubs, some overhanging the bank which had a vertical drop of 18 feet to the edge of the water. A collection was made between 2 and 3 P.M. on April 4, 1954, from a pool formed by a narrowed channel choked with dead tree limbs and other debris. The river, 40 feet wide and from three to five feet deep, flowed sluggishly over a gravel bottom.

Station Number 4 was located at the junction of the Little Ghibbie and Bulbul rivers, 24 miles east of Jimma by the Addis Ababa-Jimma highway. A collection was made between 12 o'clock noon and 1 P.M. on May 15, 1954, from a pool formed by an isolated rock stratum which crossed the river just below the entrance to the Bulbul River. The banks ranged from three to ten feet in height and were covered with a sparse growth of shrubs and small trees. The river, 20 feet wide and from four to five feet deep, flowed sluggishly over a muddy bottom.

Station Number 5 was located on the Bulbul River, 1.2 miles downstream from a bridge on the Addis Ababa-Jimma highway. A collection was made between 3:30 and 4:00 P.M. on May 15, 1954, from a pool below a small waterfall. The banks, which were covered with a growth of tall weeds and small trees, were 15 feet high and very steep. The river, about ten feet wide and three feet deep, was relatively swift and flowed over a mixed gravel and silt bottom.

CHAPTER V

CONDITIONS ON THE WATERSHED WHICH INFLUENCE RUN-OFF AND EROSION

That conditions on the watersheds are intimately related to the productivity of the water in a river has recently gained increased recognition. Streams are a direct result of precipitation over the entire watershed, and poor watershed conditions result in streams of low productivity (Tody and Clark, 1951). Good water habitat (food, cover, and other requirements) depends upon the conditions of the watershed of which it is a part, and fertility of the waters reflect the fertility of the watershed (Olson, Clark, and O'Donnell, 1955). According to Ellis (1931), erosion silt is the major factor producing changes in the fauna of a river. Ellis (1936) added that erosion silt alters aquatic environments by screening light and by changing the rate of heat radiation.

Bennett (1939) teaches that factors which influence water erosion and run-off are slope of the land, type of the soil, use of the land, type and amount of cover, and amount, intensity, and distribution of rainfall. He further maintains that these factors are aggravated by cultivation, by overgrazing, and by burning and that increased slope intensifies the pernicious effect. Tarzwell (1937) stated that vegetational cover on the watershed is essential to decrease the run-off rate, thus preventing floods in the streams which sweep away rich organic materials necessary for the production of bottom fauna. Floods scour the stream bottom, and destroy plant food and spawning beds, while rapid run-off prevents the watershed from absorbing enough water to maintain stream flow during periods of dry weather (Olson, Clark, and O'Donnell, 1955). Tody and Clark (1951) suggested that the geology of the area should be included in a study of the watershed because the geology of the soil determines the type and extent of cover that can be developed in a climatic situation.

Soil erosion is a serious problem in Ethiopia. A glance at any river shows that soil is being removed from the land at a tremendous rate. Hillsides formerly cultivated but now abandoned can be seen in almost every portion of the Ethiopian Plateau. In some areas foot trails, donkey trails, and even roads have been eroded into hugh gullies. Because of the heavy clay soil, however, much of the plateau appears to be resistant to gully formation, but is subject to serious sheet erosion.

Geological Origin and Soil Types

The Ethiopian Plateau is large, comprising more than half of the national area, and rises abruptly from the surrounding desert. Different parts of the plateau apparently had separate geological origins since at least two distinct areas, the Crystalline Highlands and the Lava Plateau, comprise the greater portion of the area.

Seven physiographical areas of Ethiopia are recognized on the basis of soil types. However, since the watersheds of the highland rivers are associated with only two of these areas, it will be necessary to discuss only the Crystalline Highlands and the Lava Plateau.

The Crystalline Highlands comprise the northern provinces of

Ethiopia and the northwestern portion of Eritrea. The valleys along the many rivers are usually steep-sided which not only adds to the ruggedness of the terrain, but limits the size of the flood plains of the rivers.

The parent materials of the soils of the Crystalline Highlands are a mixture of schists, granites, gneisses, lava, and sedimentary materials. The soils are thin and acid (Angerer et al., 1954). The watersheds of the Takazze and the Blue Nile rivers are found in this region.

The Lava Plateau is divided into two parts by the Rift Valley. One area includes most of the central and southern portion of the Ethiopian Plateau, and the other is composed of the Chillalo Mountains, which form the southeastern escarpment of the Rift Valley. The Lava Plateau is characterized by the presence of soils 600 or more feet thick originating from lava flows (Angerer et al., 1954).

Geologists ascribe the origin of the Lava Plateau to a series of volcanic eruptions which occurred during Cretaceous and Eocene times (Riggs, 1950). The eruptions piled trachytes, basalts, tuffs, volcanic ashes, and pumice into an extensive series of peaks that are interspersed with deep valleys (Perham, 1948; Angerer et al., 1954). The volcanic material overlies sedimentary shales, sandstones, and a few limestone strata. The soils are principally clay-loam. The upland soils are well-drained and tend to be of a deep, red lateritic type; the lowland soils are poorly drained, dense and gray or black in nature. The watersheds of the Akobo, Gila Tori, Baro, Awash, Omo, Little Ghibbie, and Gojeb rivers are found in this area.

Climate

The climate of Ethiopia varies with elevation. The latitude would suggest a tropical climate; but the high mountains, plateaus, and prevailing winds have modified the climate greatly. The plateaus have a "temperate" climate, but the valleys and lowlands are tropical.

An important climatological feature is an alternation of dry seasons followed by rainy seasons. The long dry season normally occurs from October through February. The months of March and April constitute a period of so-called "Little Rains," and May and June are usually dry. The season of the "Big Rains" normally is in July, August, and September, when 80 per cent of the yearly rainfall occurs.

The reason for the regular change from the dry to the rainy season is poorly understood, but is thought to be associated with a shift of the Monsoon winds from north to south and south to north. During most of the year the prevailing winds blowing across the Arabian Desert are northeasterly and dry. As the winds shift southward, they blow from the east and usher in the period of the "Little Rains." The winds continue to shift to the south, and the "Big Rains" occur when the prevailing winds are southeasterly from the Indian Ocean (Angerer et al., 1954).

Throughout Ethiopia the rainfall pattern has a marked effect upon the rivers; this pattern affects depth of water, rate of flow and silt load. Normally, the rivers are swollen and more silt laden during the rainy season, but they decrease in volume and rate of flow during the dry season. The apparent red color of the water is caused by suspended soil particles, and this color becomes increasingly pronounced upon advent of the rainy season.

Ethiopia has a high rate of evaporation. The annual free-water evaporation varies from 60 to 74 inches. An explanation for the high evaporation rate may involve the presence of such factors as intense solar radiation, strong winds, and a highly aggregated soil with an excellent crumb structure (Angerer et al., 1954). The soils become parched and cracked as the dry season progresses.

Although the Ethiopians recognize nine climatic zones based on altitude and the influence of the surrounding areas, several of the zones can be combined into three broad climatic regions. The watersheds of the highland rivers are influenced by two of these regions.

The first climatic region is the cold region and includes that part of the country ranging in altitude from 7,500 to 15,000 feet. Rainfall averages 45 inches a year (range 33 to 74 inches). Usually above 9,000 feet there is little cultivation, and the uplands are covered with a thick wiry grass.

The second climatic region is found between 5,000 and 7,500 feet and has south-temperate and subtropical climates. The area is located south of about nine degrees north latitude on the Lava Plateau from Harrar on the east to Gore and Gambela on the west. These valleys are broad, and the slopes less precipitous than those of the area farther north.

Rainfall data, recorded between January 1, 1953, and July 28, 1954, and temperature data recorded between July 1, 1953, and July 28, 1954, at Jimma, Ethiopia, are shown in Table 1 and Figure 7. A total of 54.94 inches of rain fell during 1953, and 43.61 inches of rainfall were recorded through July 28, 1954. The average temperature for the period between July 1, 1953, and July 28, 1954, was 19.20 degrees

TABLE 1.

MONTHLY TEMPERATURES IN DEGREES CENTIGRADE, JIMMA, ETHIOPIA, JULY 1, 1953 TO JULY 28, 1954.

Month	Average Temp. Degrees C.	Maximum Temp. Degrees C.	Minimum Temp. Degrees C.
Jul.	18.14	25.00	11.00
Aug.	18.64	26.00	11.00
Sept.	19.48	26.00	11.00
Oct.	19.20	28.00	9.00
Nov.	18.14	28.00	6.00
Dec.	18.90	29.00	3.00
Jan.	17.95	31.00	1.00
Feb.	20.46	31.00	8.00
Mar.	21.80	31.00	13.00
Apr.*	--	--	--
May	20.87	30.00	12.00
June	18.89	27.00	12.00
Jul.	18.02	21.00	11.00
Ave. Temps.	19.20	27.75	9.00

* Data not available

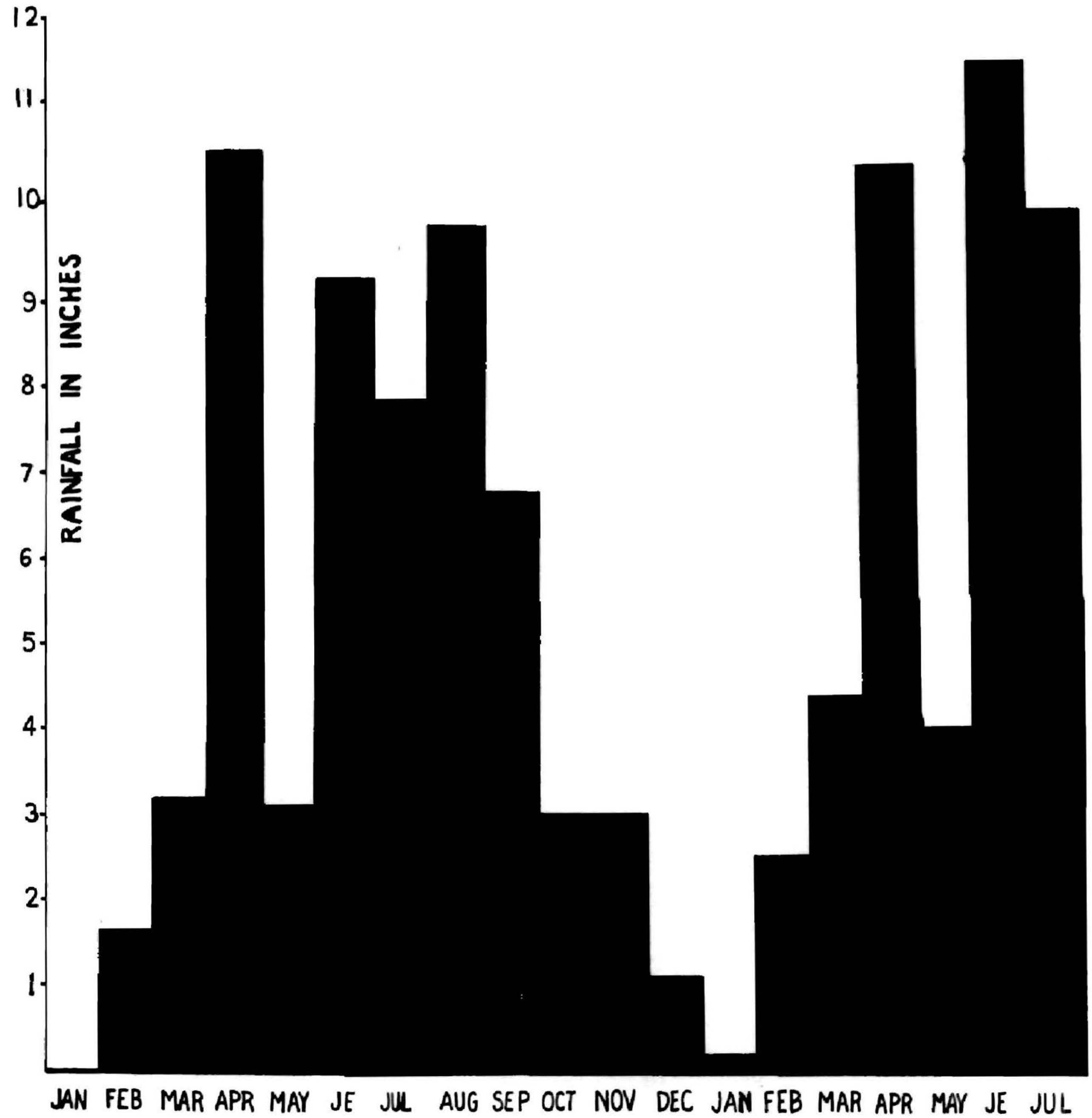

Figure 7. Monthly Rainfall Distribution, Jimma, Ethiopia, January, 1953 through July, 1954.

centigrade.

Vegetational Characteristics of the Watershed

Native vegetation, which varies with soil-type, altitude, and land-use practices influences the drainage area and eventually the fertility of the rivers. The soil-cover types of Ethiopia have been divided into five vegetational associations (Angerer *et al.*, 1954). The watersheds of the highland rivers contain four of these areas.

1. The highland forests, at elevation of 6,000 to 9,000 feet and above, are today replaced by grasses, sedges, rushes, and herbs. The clearing of the land for agricultural use and the harvesting of trees for needed fuel have resulted in the removal of most of the native trees. The grasses indigenous to the high plateaus are generally unsuitable for grazing.

2. The tall-grass savanna area, ranging in elevation between 4,000 to 6,000 feet, is smaller than the highland areas but is capable of supporting a larger population of livestock. It is the most important grazing area of the country.

The dominant grass is Red Oat Grass (*Themeda triandra*). Many other genera of grasses are found in association with particular soil types. Overgrazing and burning have caused the more desirable grass genera to be replaced by poverty grasses, such as *Aristida*, *Eragrostis*, and *Harpachne*, a situation that may not only destroy the best grazing in the country, but which has already had a deleterious effect upon the watershed.

3. The desert-grass savanna, located below 4,000 feet, covers a large portion of southern and western Ethiopia. Most of the ground is bare. The dominant vegetation is composed of tufts of sturdy perennial

grasses scattered among widely spaced trees and thornbushes. The most common genera of grasses are _Aristida_, _Eragrostis_, _Chrysopogon_, _Chloris_, _Digitaria_, and _Harpachne_.

4. Marsh lands exist in certain limited parts of the Lava Plateau, the Rift Valley, and along the edges of the rainforests. Herbs intermixed with species of _Cyperus_, _Cynodon_, _Pennisetum_, _Sorghum_, and _Panicum_ compose the dominant vegetation of the region.

The highland forest region with its abundant rainfall and its generally precipitous nature is subject to considerable erosion. However, the region is covered, for the most part, with grasses which are unsuitable for grazing, and the amount of cultivated land in the area is limited. These factors tend to reduce the rate of run-off and decrease, to a certain extent, the silt loads deposited in the rivers. The tall-grass savanna contains overgrazed pastures, and large areas of cultivated fields. Even though lower in altitude than the highland forest region, some isolated areas receive as much as 80 inches of rainfall per year. The area, because of climatological features, land-use practices, and rugged terrain, is subject to accelerated run-off which contributes large amounts of erosion silt to the rivers. The desert-grass savanna adds little erosion silt to the rivers. The region is principally a desert and receives a maximum of about 16 inches of rainfall per year. The area, located in southern and western Ethiopia, is lower in altitude than the highland region or the tall-grass savanna, and the rivers contain the bulk of their silt load as they leave the highlands. The marsh-land area is limited in extent and occupies small portions of the watersheds in the immediate vicinity of the rivers. The region adds little erosion silt to the rivers.

Activities of the People

The major occupation of the people of Ethiopia is farming. Agricultural practices have removed much of the vegetable matter from the soil and returned none. The effects of such practices have been harmful to both the land and the rivers. The apparent lack of concern prevalent among the Ethiopian farmers for the conservation of the watershed cannot help being detrimental to the total economy of the region. To overemphasize the injurious effects would be difficult.

Several factors illustrate agricultural practices which are detrimental to the watershed. The steep hillsides are tilled, and much of the flatter area is pastured. Often the crop residues are removed from the fields because of the need for fuel and building material. Cattle are allowed to graze the short stubble that remains following harvest. Contour farming and crop rotation are uncommon, and the hillsides are plowed parallel to the slope. The preparation of seed beds and other work on cultivated fields are done when the soil is wet. This practice causes puddling and prevents maximum water intake since the wet clay particles are packed and adhere to one another forming an impervious layer on the surface of the soil which increases the rate of run-off. All legume crops are harvested for grain or forage, and there is little green manuring. Animal manure is dried and used for fuel instead of being spread on the fields. Even much of the acacia is being cut for fuel. Year-round pasturing and the concentration of livestock overgrazes the better pastures and is another serious cause of erosion.

Although a few of the methods employed by the Ethiopian farmer helps to check some erosion, improved agricultural methods could reduce a great deal of the soil loss. Eucalyptus is being extensively cultivated in an attempt to reforest some of the hillsides. Plowing with an ox-drawn plow that leaves high ridges and deep furrows and the cultivation of small fields with grass-strip borders help somewhat to retard soil loss.

CHAPTER VI

FISHES OF THE LITTLE GHIBBIE RIVER

The fish population of the Little Ghibbie River was sampled during the dry season when the river could be reached by driving across fields or along secondary roads that were impassable during the rainy season.

Species and Distribution

Two genera and two species of fishes were found in the Little Ghibbie River. A total of 842 fishes was captured, of which 772 individuals or 91.69 per cent were Barbus duchesnii Boulenger (Fig. 8). The remainder were Labeo cylindricus Peters (Table 2).

Distributional records of Barbus duchesnii lead one to believe he species is common throughout and restricted to Ethiopia. The ublished records of distribution include data concerning the occurence of the fish in Lake Tana and the upper tributaries of the Blue ile River, the Awash River System and Lake Abaya, the Omo River System nd Lake Stephanie. No records of the reported occurrences beyond the orders of the Empire were found. The specimens collected ranged from 2 to 478 millimeters in total length. The maximum length heretofore eported was 300 millimeters (Boulenger, 1911).

Several individuals of Barbus duchesnii were used as food by the ollecting party. Even though the fish had lived in turbid water, they

TABLE 2.

NUMBER OF FISHES TAKEN IN EACH COLLECTION

FROM THE LITTLE GHIBBIE RIVER,

ETHIOPIA, 1954

Collection Number	Date 1954	No. *Barbus duchesnii*	No. *Labeo cylindricus*	Station Number
1	Feb. 14	97	63	1
2	Mar. 21	284	1	2
3	Apr. 4	17	..	3
4	Apr. 17	26	4	1
5	May 8	165	..	2
6	May 15	77	..	1
7	May 15	10	..	4
8	May 15	21	..	5
9	May 30	47	2	2
10	June 5	128	..	1
Total		772	70	
Grand Total (all fishes). 842				

were found to have a firm and flaky flesh with an excellent flavor. Numerous intermuscular bones made a fish meal very tedious, but proper preparation and cooking could have eliminated much of the difficulty.

The intestinal tract of the fish is relatively long. A specimen 207 millimeters in total length had a gut 350 millimeters long, the central portion of which was repeatedly coiled. The length of the gut may be indicative of the dietary habits of the fish.

Labeo cylindricus has a wider distribution, having been collected from Ethiopia to Zambesi and from Lakes Tanganyika and Nyassa (Boulenger, 1909). The specimens collected ranged from 24 to 200 millimeters in

Figure 8. Barbus duchesnii from the Little Ghibbie River, Ethiopia.

total length. The fish is reported to reach 400 millimeters in total length (Boulenger, 1909). The intestinal tract of the fish is relatively much longer and more coiled than that of Barbus duchesnii. A specimen 126 millimeters in total length had a gut 640 millimeters long.

A most interesting feature of the fishes of the Little Ghibbie River was the presence of marks resembling annuli on the scales. A superficial examination of a sample of the scales collected showed that they might fit the considerations necessary for an age and growth rate study. Since year marks have been explained to be the result of growth interruptions from low temperatures, one would not expect to find such marks on scales of a fish growing in a region where the average minimum monthly air temperature is nine degrees centigrade (48.20 F.). The water temperature (Table 3) varied from a minimum of 21 degrees to a maximum of 24 degrees centigrade, thus showing that the water had a relatively uniform temperature. The marks on the scales were so distinct that an age and growth study of Barbus duchesnii was undertaken.

Age and Growth

Scales from 488 specimens of Barbus duchesnii were examined to determine ages and growth rates. The scales apparently fit the primary considerations upon which the scale method of age and growth determination is founded (Van Oosten, 1929). The scales were constant in identity for the various specimens collected. The number of scales in the lateral line, used as an indication of the permanency of scales on fishes, did not vary significantly for the species. Although latinucleate scales were encountered, the focus for all age groups was structurally the same, and identification of the focus was not difficult.

The body-scale relationship for Barbus duchesnii was determined by plotting body length against the scale radii (anterior) and a straight line fitted to the data. The fish lengths were grouped by 20-millimeter

TABLE 3.

AIR AND WATER TEMPERATURES IN DEGREES CENTIGRADE

AT THE LITTLE GHIBBIE RIVER

Collection Number	Date of Collection 1954	Air Temp. Degrees C.	Water Temp. Degrees C.	Station Number
1	Feb. 14	20	21	1
2	Mar. 21	21	24	2
3	Apr. 4	26	23	3
4	Apr. 17	25	24	1
5	May 8	29	24	2
6	May 15	26	24	1
7	May 15	29	24	4
8	May 15	30	24	5
9	May 30	28	24	2
10	June 5	23	24	1

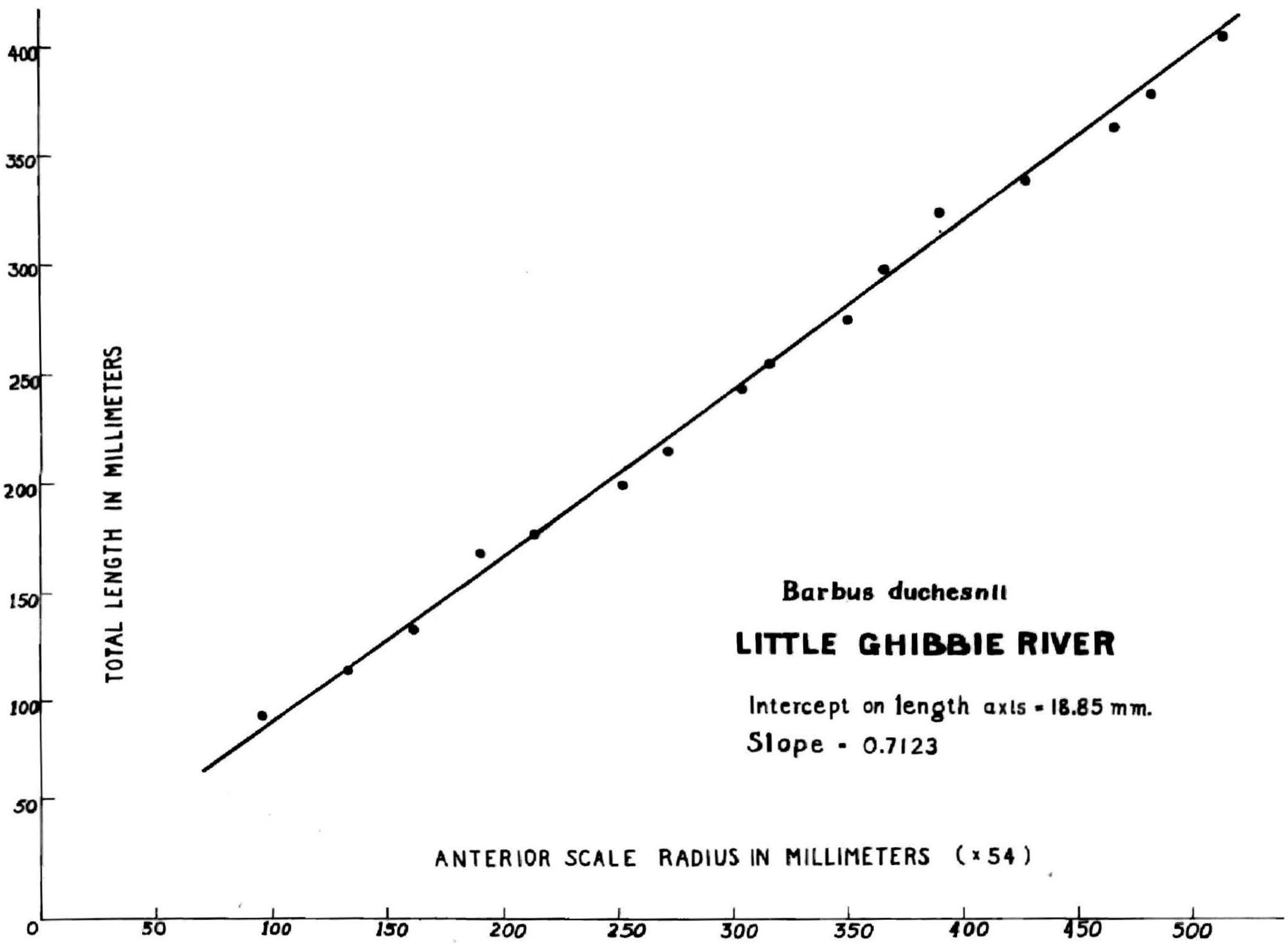

Figure 9. Body-Scale Relationship of <u>Barbus duchesnii</u>. Fish Grouped by 20-Millimeter Total Length Intervals.

intervals. Averages were determined for the total lengths and scale radii for specimens in each interval using a total of 369 specimens. A line with a slope of 0.7123 and with an intercept on the length axis of 18.82 millimeters appeared to represent the body-scale relationship (Fig. 9).

Identification of the annulus was not particularly difficult (Fig. 10).

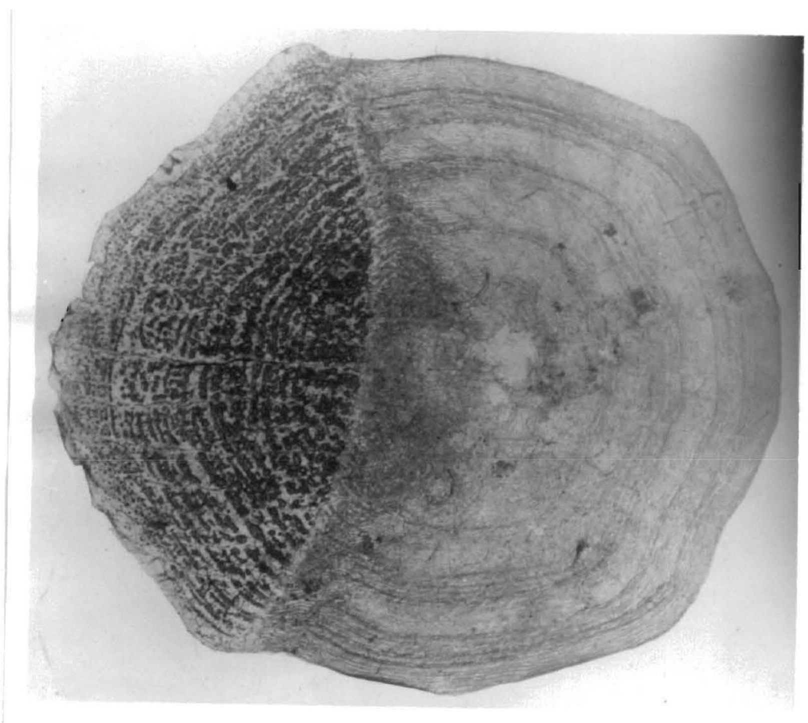

Figure 10. Scale of Barbus duchesnii from the Little Ghibbie River.

Cockerell (1910) described the scales of Barbus duchesnii as being as broad as they are long with fairly strong laterobasal angles. Discontinuity of circuli was most apparent along the lateral radii on the scale. Checks or false annuli were apparent particularly on scales from larger fish. The false annuli normally took the form of a group of closely appressed circuli that intercepted the annulus along the lateral radii. Considerable scale growth was evident beyond the most recently completed annulus on the majority of the scales examined.

The first two or three annuli on the scales were quite distinct, but the more recently formed annuli of older fishes were characterized by a relatively broad area of broken lines showing erosion. Perhaps the most outstanding characteristic was the regularity of occurrence of the annular marks. The fact that the marks had the same relative positions on all the scales examined increased confidence in the interpretation of the marks as annuli.

Greater annual increases in length occurred in the year classes 0, I, V, VI, and VII. The years of smaller growth were reflected in all age groups, a fact that lends further support to the assumption that the marks on the scales are true annuli (Table 4). Erickson (1952) stated that in the growth of fishes the average annual increment decreases gradually through the later years of the fishes' lives. Barbus duchesnii apparently does not follow this pattern. Whether the growth pattern found is characteristic of the species or the result of environmental conditions for the corresponding year can not be determined from the data in hand.

The most abundant age classes (0, II, III, and IV) in the collection comprised 73.3 per cent of all the fishes examined. The next most abundant year class (I) contained 11 per cent of the fishes studied. A satisfactory range of data for computation was obtained in age groups 0, II, and III without using all measurements recorded. Use of all these recorded data would have increased the number of measurements without

TABLE 4.

AVERAGE CALCULATED TOTAL LENGTHS AND ANNUAL INCREMENTS IN MILLIMETERS OF *BARBUS DUCHESNII* FROM THE LITTLE GHIBBIE RIVER, 1954.

Class	Number Examined	Calculated Length at Each Annulus 1	2	3	4	5	6	7	Total Length At Capture Mean	Range
O . . .	119	...	...	...	...	...	...	...	82	61-104
I . . .	55	72	...	...	...	...	...	...	125	105-150
II. . .	81	77	127	...	...	...	...	...	144	117-175
III . .	81	79	129	151	...	...	...	...	172	149-215
IV. . .	77	78	127	152	178	...	...	...	203	178-241
V . . .	37	79	127	152	180	206	...	...	246	195-278
VI. . .	14	79	127	152	181	207	249	...	298	235-365
VII . .	6	78	127	153	181	208	251	297	348	320-389
Grand Average (488 fish). . . .		77	127	152	180	207	250	297		
Average Annual Increment		50	25	28	27	43	47	51		

affecting range or mean.

Scales of 30 specimens of Labeo cylindricus ranging in total length from 39 to 126 millimeters were examined for the presence of annuli. Five of these specimens were in their second year of life. Most of the specimens collected were obviously the young of the year and were under 75 millimeters in total length. Since only 70 specimens were collected, an age and growth study was not made of the species.

Stomach Contents

Stomachs from 171 specimens of Barbus duchesnii were examined for contents (Table 5). The fishes ranged in total length from 50 to 347 millimeters. The percentages of animal and plant material recorded are shown in Table 6.

Terrestrial animal material occurred more frequently in the stomachs of the fish examined than did aquatic animal material. Parts of insects, predominantly wings, legs, and internal organs, too disarticulated to permit identification, were the most numerous items of terrestrial animal material. Most of the insect material complete enough for identification belonged to the order Coleoptera, some of which were identified as Scarabidae. The stomachs of a few fish contained large numbers of insect eggs. One partially digested insect contained eggs in its reproductive system. Ants were the least numerous terrestrial insect material observed. A down feather was found in the stomach of one fish and scales from a butterfly wing were found in the stomach of another.

Although aquatic animal material occurred less frequently than terrestrial animal material, it appears that members of the order Cladocera and Caddis fly larvae play an important role in the diet of the

TABLE 5.

FREQUENCY OF OCCURRENCE OF FOOD ITEMS IN STOMACHS OF 171 SPECIMENS OF *BARBUS DUCHESNII* COLLECTED FROM THE LITTLE GHIBBIE RIVER, ETHIOPIA, 1954.

	Length Range of Fish in Millimeters													
	50-69	70-89	90-115	120-139	140-159	160-179	180-199	200-219	220-239	240-259	260-279	308-308	347-347	Totals
No. of fish stomachs examined	9	7	11	24	41	23	15	17	9	7	6	1	1	171
Number empty	..	..	..	2	2	2	1	4	3	1	..	..	..	15
	Frequency of Occurrence by Length Range													
Total Animal Material	16	10	13	27	43	23	17	14	10	8	6	2	2	191
Caddis fly larvae	8	2	1	..	..	..	..	..	..	..	..	..	..	11
Ostracoda.	..	..	..	..	1	..	..	..	..	..	..	..	..	1
Cladocera.	8	3	1	4	4	..	..	..	1	..	..	..	..	21
Insect eggs. . . .	..	1	1	..	..	1	1	1	..	..	..	1	1	7
Coleoptera*. . . .	..	..	2	9	16	8	7	4	1	1	..	..	..	48
Scarabidae	..	..	2	2	6	1	..	..	2	..	..	..	..	13
Formicidae	..	..	1	..	..	..	..	..	1	1	..	..	..	3
Insect parts** . .	..	4	6	10	14	11	5	8	5	4	6	..	1	74
Diptera larvae . .	..	..	..	..	1	..	..	1	..	2	..	..	..	4
Sponge spicules. .	..	..	..	..	1	2	2	..	..	..	..	1	..	6
Feather.	..	..	..	..	..	..	1	..	..	..	..	..	..	1
Lepidoptera*** . .	..	..	..	..	..	..	1	..	..	..	..	..	..	1
	Frequency of Occurrence by Length Range													
Total Plant Material	..	..	..	13	18	10	14	18	8	9	12	..	1	103
Leaves	..	..	..	1	2	..	2	6	1	3	6	..	..	21
Vascular elements.	..	..	..	11	11	10	10	11	7	6	6	..	1	73
Lyngbya.	..	..	..	1	5	..	2	1	..	..	..	..	..	9

*Other than Scarabidae **Unidentified ***Based on wing scales

TABLE 6.

PER CENT OF OCCURRENCE OF FOOD ITEMS IN STOMACHS OF 171 SPECIMENS OF *BARBUS DUCHESNII* COLLECTED FROM THE LITTLE GHIBBIE RIVER, ETHIOPIA, 1954.

Type of Food Item	Per cent	Origin	Per cent	Kinds of Organisms	Per cent
Animal Material	65	Terrestrial	50.05	Insect eggs	2.60
				Coleoptera*	16.25
				Scarabidae	4.55
				Formicidae	1.30
				Unid. Insect Parts	25.35
		Aquatic	14.95	Caddis fly larvae	3.90
				Ostracoda	0.65
				Cladocera	7.15
				Diptera larvae	1.30
				Sponge spicules	1.95
Plant Material	35	Vascular	31.50	Leaves	7.00
				Vascular elements	24.50
		Non-vascular	3.50	*Lyngbya*	3.50
Totals	100		100.00		100.00

*Other than Scarabidae

smaller fish. These organisms were found in 100 per cent of stomachs of 23 specimens ranging in length from 50 to 94 millimeters, while stomachs of only 39 per cent of the same individuals contained other types of food. Diptera larvae were found in the stomachs of only four individuals.

Four individuals, 150 to 308 millimeters in length, contained spong spicules in their stomachs.

Both vascular and nonvascular plant material occurred in the stomachs. Vascular material occurred more frequently than did nonvascular material. The vascular material was composed of partially disintegrated plant parts, predominantly xylem elements from tender portions c plants. Small pieces of dicotyledonous leaves completely filled many c the stomachs. Leaves were found particularly in the stomachs of specimens measuring 210 to 297 millimeters in length. Some of the stomach contents were bright green in color, even after having been preserved for six months in four-per cent formalin. Stomata, vascular bundles, and other tissues in the leaves were easily recognizable.

A species of Lyngbya, an alga, was the only nonvascular plant observed. It was found in some of the specimens which ranged in length from 130 to 208 millimeters.

Nematodes were found in twelve of the stomachs examined. Ten contained from one to six each; one had 20 and the other had 36. Whether or not the nematodes were food items or parasites was not determined. If they were food items, they were not found in quantities sufficient to play an important part in the diet. If they were parasites, the infestation was light and probably had little effect upon the activity of the fish.

Stomachs from six of the larger specimens of *Labeo cylindricus* were examined for contents. No additional food items were found that had not been found in *Barbus duchesnii*. Since the remainder of the fish specimens were small (less than three inches in length), and no evidence of new food items was in prospect, the remainder were not examined.

CHAPTER VII

DISCUSSION

Fisheries investigations in Ethiopia present at least three problems not encountered in the United States. The conditions of the roads made impossible the collecting from rivers other than the Little Ghibbie, even though many attempts were made to do so. Visits to one accessible river were not undertaken because of the hostility of some of the tribes of Ethiopia. Trips to some secluded river valleys were not made because of the difficulty of procuring interpreters.

Maps showed roads crossing the Omo River at four places along its course. One road led east from the Addis Ababa-Jimma highway and crossed a mountain range which was 6,700 feet above sea level. Much of the roadbed was hewn out of the rocky side of a mountain. A quarter-mile stretch of the road on the side of the mountain had been destroyed by Italian Army demolition tactics. Since no detour could be found around this portion of the road, attempts to reach the Omo River at this point were abandoned. Efforts to reach the Omo River on the old Addis Ababa-Jimma road were successful; however, the dynamite caps available were defective and six charges failed to explode. Although only 224 miles were traveled, the trip took four days. The time required to reach the station made a return trip impossible.

Several attempts were made to reach the Gojeb River. One road crossed the river about 30 miles due south of Jimma. The road bed was so badly eroded that it was impassable for motor vehicles, and a mule trip took three days. Attempts to reach the Gojeb River about 50 miles southwest of Jimma were successful; however, an assistant who could not swim fell into the river and dropped the cans containing the collection. The cans could not be recovered. The road led through a rain forest, and truck travel following early rains made the route impassable to light vehicles and prevented revisitation.

Trips to other rivers might have been made, but all the members of the collecting party were reluctant to leave the area of the Ethiopian Plateau, where many of the people are basically friendly. Some were of great assistance in field collecting, and were eager to help remove the fishes from the water. On the other hand, the people of the hot, dry, lowland regions, east and southeast of the Ethiopian Plateau are nomadic and tend to resist intrusion of their areas by strangers. Stories pertaining to the hostility of the Dankali people living in the area of the mouth of the Awash River discouraged an attempt to visit the region.

Many of the people of Ethiopia speak several languages, but to find an interpreter who can converse with people living in isolated districts was difficult. The official language is Amheric, but O'Brien (1953) reported some 40 different languages and dialects spoken in the country. As the necessity to maintain the good will of the people was paramount, the decision was made to collect only in areas where an explanation of the purpose of the collection could be made and understood.

Other problems were encountered. Three collecting methods other than dynamite were attempted. Toxophene was used as a poison on three occasions. Concentrations of the insecticide apparently were insufficient or were carried away too quickly to produce any observable effect upon the fishes. Since no fishes were captured in this manner, further attempts to collect with toxophene were discontinued.

Seining was also attempted, but several factors combined to make the method impractical. The high, steep, banks afforded no opportunity to bring the seine onto the shore after a haul was made. Often, water 10 to 15 feet deep prohibited the use of the seine. Finally, in areas where the water was shallow and the banks less steep, the river bottom was littered with large volcanic boulders which prevented the effective use of the seine.

Three over-night sets of the trammel net failed to capture any fishes, therefore that method of collection was discontinued.

In spite of the difficulties in travel, in obtaining suitable gear for collection, and the relative inaccessibility of the river itself, ten collections were made at five stations on the Little Ghibbie River. Collections made by the use of dynamite resulted in the capture of a total of 842 fishes and averaged 84.2 specimens per collection. It seems that the use of dynamite proved its worth as a collecting method.

The small number of only seven kinds of aquatic organisms, in addition to the fishes, found either in the river water or in the fish stomachs strongly suggests that environmental conditions were poor.

The fact that only two species of fishes were found in the Little Ghibbie River is evidence of the rigorous conditions imposed upon the fishes living in the river. The Omo River, of which the Little Ghibbie River is a principal tributary, is known to contain other species of fishes. There are no physiographical barriers along the Little Ghibbie River and it is a permanent stream. It appears that an explanation for the absence of other fish species in the river must include the possibility that Barbus duchesnii and Labeo cylindricus were able to exist in the poor environment of the Little Ghibbie River. Other species must have been discouraged from becoming established by lack of food or other necessities.

The waters of the Little Ghibbie River are turbid. At Station Number 5 on March 21, 1954, a white 3 by 5 inch index card was held under the water. The river water was so turbid that the card was invisible the moment its upper surface became wet. Smith (1940), Chandler (1942), and Swingle (1949), reported that reduction of fish population may occur with high turbidity. Ellis (1931) stated that erosion silt limits the kinds of fishes in a river to those species capable of feeding on organisms living in a silt environment. It appears, therefore, that one factor contributing to the poor environment of the Little Ghibbie River is turbidity caused by suspended silt. Turbidity may explain, in part, why fish species other than Barbus duchesnii and Labeo cylindricus, and other organisms normally associated with aquatic habitats, were absent from the Little Ghibbie River.

The steep banks of the river, the scarcity of shallow water, and the presence of high turbidity would be detrimental to aquatic vegetation. It is doubtful that rooted aquatic plants could exist in the river because of the tremendous fluctuation in the water level and rate of flow. Plants, if existent during low water, would be washed away during periods of floods.

The small number of organisms which frequent the river is further evidence of the existence of a low productivity. One would ordinarily expect to find certain other animals associated with an aquatic habitat. Conspicuous by their absence were shore birds, turtles, water snakes, frogs, and toads. Shore birds were present in nearby marshy regions but were never observed on the river. Snails, resembling the genus Physa, were abundant in a clear spring located on the watershed but were not found in the river. Large flocks of ducks, resembling the North American Teal, were present on the back-water lakes, which formed along the Little Ghibbie River during the rainy season, but were not observed on the river proper. Had food been abundant, it appears likely that a greater number and a greater variety of organisms would have occupied the river.

The scale method of age and growth determination depends upon changes in the metabolic rate during certain periods of the year (Rounsefel and Everhart, 1953). Most fishes of temperate climates show little growth during winter (Eddy and Carlander, 1940), a situation which may effectively explain the occurrence of annular growth marks on scales and other hard parts of the fishes. On the other hand, Rounsefel and Everhart (1953) stated that the annulus may be ommitted entirely in species occupying an environment with uniform temperature. Length of the growing season of several species of fishes in southern waters of the United States has been correlated with latitude and with a longer growing season in the south, but Jones (1941) stated that the growing season for fishes does not necessarily coincide with the length of the agricultural growing season. Van Oosten (1944) reported that in addition to temperature, several ecological factors such as food, rainfall, and physical-chemical factors, have been demonstrated as affecting the growth rate of fishes in temperate climates. Hile (1931) and Eddy and Carlander (1940) considered density of population as another factor influencing the growth of fishes. Growth is usually rapid for fishes when food is abundant (Eddy and Carlander, 1940). Hile (1941) correlated increased growth rate with above-average rainfall, the run-off of which carried additional organic material into the water.

True winter in Ethiopia, that is December 21 to March 21, is characterized by great daily variation in air temperature. The lowest minimum air temperature recorded in 1954 (1 degree centigrade) and the highest maximum air temperature (30 degrees centigrade) occurred during the month of January. Water temperatures recorded during the period of collection show a relative uniformity (range 21 to 24 degrees centigrade).

The stomach contents of Barbus duchesnii have been shown to be at least 50 per cent terrestrial organisms on the basis of frequency of occurrence. The vascular material found in the stomachs examined was considered to be terrestrial plant material because no vascular aquatic plants were observed in the water. Therefore, 81 per cent of the food in the stomachs of the fishes came directly from the land and was either washed into the water or became available to the fishes when the river flooded and inundated surrounding lowlands. The lakes formed along the Little Ghibbie River by flooding provided an increased feeding area. Not only the supply of food but also the space available to the fishes was increased with the advent of the rainy season. These conditions may produce an environment conducive to rapid growth.

The reverse situation is true upon the cessation of the rains. Run-off was very rapid, the lakes disappeared, and the fishes were relegated to the rather small confines of the river channel which was unproductive of fish food. Thus, the food supply from the watershed was decreased, and the amount of food produced in the river was small, leaving the fishes, until the next rainy season, on reduced rations consisting primarily of leaves and insects which probably came from the shrubs and small trees that overhung the river banks.

A watershed exerts a profound influence upon the stream into which it drains. The physiography, soil-type, rainfall, and soil cover are items that affect the rate and volume of run-off water. The physiography of all highland watersheds of Ethiopia, including that of the Little Ghibbie River, are extremely rugged. There are mountains, plateaus, valleys, and gorges which cause rapid flows of surface water. The soils are for the most part clays, which absorb water slowly and are subject to erosion. The rainfall varies from dry periods, when the soil is parched, to periods of torrential downpours, which, when combined with steep gradient and clay soils, accentuates the hydraulic effects of the run-off water. The soil covers are not only modified by physiography, soil-types, and rainfall but also by the activities of the people who live on the watershed. Among the activities which modify the soil cover are deforestation, overgrazing, removal of all crop residues, cultivation with the slope of the land, the tilling of steep hillsides, and extensive burning of fields and pastures.

The rivers receive large volumes of water at one season and small volumes at another. When the run-off is increased, great volumes of erosion soils are added to the rivers. The river bottoms are scoured, inundated to great depths, and subjected to heavy loads of moving silt. The resultant effects would seem to reduce the potentiality of the rivers for the production of aquatic organisms. Terrestrial animals and plants are carried to the rivers in increased numbers as run-off increases.

They provide a large volume of food for aquatic animals.

The fish collections were made during the dry season when travel was possible on some of the secondary roads or across fields. Since collections were not made in each month of the year, the actual time of annulus formation could not be determined. Considerable growth had occurred beyond the most recently completed annulus. This growth suggested that annulus formation must have been occurring at the time the collections were made.

The fact that annuli occurred is significant. The decrease in metabolic rate necessary for the production of year marks apparently was not associated with low temperature. The presence of annuli on the scales of the fishes of the Little Ghibbie River is probably associated with periods when food was scarce followed by periods when food was abundant. The annual variation in food supply probably correlated with the annual cycle of dry and rainy seasons. Wet seasons increased the size of the fish habitat and the amount of available foods; dry seasons sharply reduced the habitat and restricted the food supplies.

The reported existence of *Barbus duchesnii* in many of the river systems and lakes of Ethiopia and its absence from other areas presents an interesting item for speculation.

The rivers known to contain *Barbus duchesnii* rise in central Ethiopia and radiate outwardly to diverse destinations. Some of the rivers flow into the Nile River; others flow into land-locked lakes in the Rift Valley. Thus, the rivers now afford *Barbus duchesnii* no opportunity to migrate from one stream to another.

Two possible explanations can be postulated for the general distribution of *Barbus duchesnii* in Ethiopian waters. One entails the geologic history of the section of Africa in which Ethiopia is found. Riggs (1950) stated that during Triassic and Jurassic times the ancient crystalline rocks of the area were submerged. During Cretaceous and Eocene periods emergence took place but was accompanied by violent volcanic activity, which covered much of the area with trap rock and was instrumental in the formation of the Ethiopian highlands. The time of origin of Barbus duchesnii is unknown; however, the possibility exists that the fish was present in the region when the area was submerged and some could have survived the volcanic activity and formed the ancestral stock of the fish living in the presently unconnected streams. The other explanation includes the possibility that the fish at one time had access to various watersheds through the origin of the rivers. Following Cretaceous and Eocene times, the rivers have cut hundreds of feet below the plateau surfaces. An assumption may be made that the channel bottoms of the rivers may have been considerably higher in past geologic time. Since the rivers tend to originate in the same general vicinity of the Ethiopian highlands and since large, temporary lakes are now formed during the rainy season, it appears that lakes could have been much larger in earlier periods and that the backwaters of adjoining watersheds could have merged, thus offering the fish access to the different rivers and lakes in which they are found today.

CHAPTER VIII

SUMMARY

1. The physiography, climate, vegetational cover, and land-use influences upon the rate of run-off and erosion on the watersheds of the highland rivers of Ethiopia is presented. Evidence also is shown that turbid streams which fluctuate greatly in volume and in silt load at different seasons of the year are produced.
2. A comparison of the percentages of suspended sediments carried by the Blue Nile River was made with rivers in the United States and elsewhere.
3. The characteristics of the Little Ghibbie River are presented as being representative of the rivers of the highland area; the river was accessible at several points, but difficulties in making fish collections were encountered.
4. Two species, Barbus duchesnii and Labeo cylindricus, were the only fishes found in the Little Ghibbie River.
5. Marks, believed to be annuli, were found on the scales of Barbus duchesnii and Labeo cylindricus.
6. The existence of seasonal fluctuations in the amount of food available to the fishes is suggested.
7. Terrestrial organisms comprised most of the food items found in the 171 stomachs from Barbus duchesnii.
8. Annulus formation apparently occurs in the dry season when the food

supply is low.

9. An age and growth-rate study of *Barbus duchesnii* shows a growth pattern similar to that of North American fishes except that the fish grew well during its first year of life; the rate of growth was slower during its second, third, and fourth years, and increased greatly in its fifth, sixth, and seventh years.

10. The presence of a small number of only seven kinds of aquatic organisms in addition to the fishes, high turbidity of the river water, the scarcity of shallow water, and the absence of rooted aquatic plants suggest that the potentiality for production of aquatic organisms in the Little Ghibbie River is low.

11. The highland river systems and their watersheds are located and and possible explanations for the distribution of *Barbus duchesnii* in Ethiopian waters are suggested.

12. The results of using dynamite as a method of collecting fishes from the Little Ghibbie River are presented.

CHAPTER IX

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VITA

Robert Henry Loomis

Candidate for the Degree of

Doctor of Philosophy

Thesis: WATERSHED CONDITIONS OF THE ETHIOPIAN HIGHLANDS AND THE FISHES OF THE LITTLE GHIBBIE RIVER, ETHIOPIA

Major Field: Zoology

Biographical:

Personal data: Born in Atlanta, Georgia, November 9, 1923, the son of C.B. and Eva A. Loomis.

Education: Attended grade school in Long Island City, Long Island, New York, Leonia, New Jersey, and Atlanta, Georgia; graduated from Greenville, South Carolina, Senior High School in 1941; received the Bachelor of Science degree from the University of Georgia with a major in Zoology, in August, 1947; received the Master of Science degree from the Oklahoma Agricultural and Mechanical College, with a major in Zoology, in May, 1951; completed the requirements for the Doctor of Philosophy degree in August, 1956.

Professional experience: Entered the teaching profession in 1947 as Instructor of Biology, Piedmont College, Demorest, Georgia; have taught at Central State College, Edmond, Oklahoma, and Northeastern State College, Tahlequah, Oklahoma; was appointed, in 1952, Head of the Science Department, Jimma Agricultural Technical School, Jimma, Ethiopia (USA Operations Mission to Ethiopia, formerly Point IV Program). Since 1949, have been conducting fisheries investigations, a part of which are described in this thesis.