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THE 1958 MALARIAL EPIDEMIC IN ETHIOPIA

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During the period July - December 1958, a regional epidemic of unusual intensity and scope struck throughout most of the massive highland area of Ethiopia between elevations of 1200 and 2200 metres. At least four of the central highland provinces - Shoa, Gojjam, Beghemder, and Wollo - were severely affected, with numerous local districts experiencing outbreaks of a fulminating character, accompanied by high mortality. Morbidity exceeding 75% of the population was commonly observed in many of the local settlements and communities. Other provinces lying at lower elevations bordering on the Sudan, Kenya and Somalia were touched only in the highland parts of their territory where climate and topography are comparable to that found in the central plateau provinces. The federated state of Eritrea, which borders Ethiopia on the north and northeast, apparently escaped the epidemic, as no reports or records of unusual occurrence were documented by the Eritrean Public Health Department.

General Observations of the 1958 Epidemic

In retrospect, the malaria epidemic of 1958 can be said to have made its first appearance in late June of 1958, although no one in the medical services at the time knew or suspected that an epidemic of unusual proportions was in the beginning stages.

By coincidence, one of our malaria survey parties headed by Najjar discovered a malaria outbreak of unusual severity while conducting routine investigations in late June 1958, near the area of Bahar Dar, where the Blue Nile River makes its exit from Lake Tana.

The lake lies at 1,800 metres elevation and outbreaks of malaria of varying intensity occur regularly each year in the surrounding area, but the peak prevalence normally comes in the months of October and November, reflecting the intense malaria transmission of September. While it has been reported by Govell (1952) that small outbreaks do sometimes occur in June, just preceding the advent of heavy rains in July, the findings of Najjar and his party gave evidence of a widespread illness of uncommon severity. The local inhabitants were greatly distressed over the prevalence of illness, as June in most of their memories was not regarded as an unhealthy month. Various local residents living at a place called Ganje (1,850 metres elevation) on the Andessa River commented that the season was most unusual in that the malaria epidemic was under way now rather than the usual time in the September-November period.

Blood examinations of thirty-five suspected malaria cases at Ganje yielded twenty-two positive for P. falciparum, one P. vivax and three mixed infections. At Sebatamit, located a few kilometers outside Bahar Dar, an examination of forty-eight blood films yielded ten positives, nine of which were P. falciparum and one mixed infection. In Bahar Dar there were nine positive P. falciparum and one P. vivax out of 137 blood film examinations of school children and occupants of the local jail. The combined gametocyte rate for Ganje, Sebatamit and Bahar Dar was 31%.

Anopheles gambiae was the only vector species found in aspirator collections made from inside human dwellings. At Ganje an average of 100 engorged females was taken from five dwellings in collections limited to fifteen minutes per dwelling.

A few months later, in the September-November period, the whole of the Lake Tana region and the upper Blue Nile valley were the scene of a catastrophic epidemic which prostrated the majority of the population in most districts.

In the DDT residual sprayed Dembia Plain malaria pilot project covering an area of 2,500 square kilometers on the north end of Lake Tana, it is significant to note that only eighty cases were reported in an estimated population of over 60,000. No deaths from malaria were recorded, and there were no cases in the 0-1 age group.

The epidemic which developed in Beghemder Province was paralleled in general throughout most the highland areas within the boundaries of Shoa, Gojjam, Wollo and portions of Wollega, Arussi, Harrar, Sidamo and a few districts in Tigre Province.

In Shoa Province the epidemic was regional in scope with reports of epidemics coming from all districts. However, only a few districts out of the many which reported epidemics were visited by qualified investigators and then only briefly. In the Zuquala Plan (1,850 metres elevation) and Lake Akaki district (2,000 metres elevation) located about twenty kilometers south of Addis Ababa, more complete information was gathered than was usually possible.

The above affected areas cover about 3,500 square kilometers between Addis Ababa and the WHO-assisted Awash malaria pilot project, whose headquarters at Nazareth are situated about 100 kilometers south of Addis Ababa at an elevation of 1,500 metres.

The first indication of a malaria epidemic in the Zuquala Plain came to the attention of the Point IV malaria team in early July, 1958, by way of a request for medical help from a large landholder whose workers were nearly all incapacitated by severe illness. Malaria was confirmed by laboratory diagnosis showing that most infections were caused by P. falciparum. The epidemic situation continued well into December, 1958, when malaria was still a common illness in nearly every settlement and village whose inhabitants had not been reached and given chloroquine tablets by anti-epidemic workers. The population of the Akaki-Zuquala area is probably no less than 150,000 inhabitants and only a minority of the population - probably less than 20% - escaped malaria and mortality was estimated at 10%. Anopheles gambiae was the only vector found in the dwellings inspected.

The towns of Akaki, Debre Zeit and Moggio on the main highway passing through Zuquala had been house sprayed with DDT in June, 1958, by the WHO malaria team. This work gave good protection to the local inhabitants, as no evidence of an epidemic was noted in these places.

Replies to enquiries made of the history of malaria in the area indicated that no epidemic of similar intensity and scope had occurred in at least fifteen years.

From Zuquala the epidemic extended many kilometers up the headquarters of the Awash River, where severe outbreaks were observed as high as 2,150 metres by Najjar (1958). He disclosed a number of locally transmitted outbreaks between 2,000 and 2,150 metres while conducting investigations in late November on the highway between Addis Ababa and Jimma, only thirty-five kilometers from Addis Ababa.

Northwest of Addis Ababa severe malaria outbreaks were reported early in August from the Mulu Community Development Unit, the Mugher River valley and other tributary river valleys of the Blue Nile. The topography of the area is characterized by elevated tableland 2,200 to 2,800 metres high, deeply cleft by canyons and valleys of 1,500 to 1,800 metres elevation. This land configuration is typical of the upper Blue Nile tributary system of which this country is a part. The valleys and canyons are seasonally malarious, while the surrounding highland is largely malaria free. It was reported from the Mulu community (Sanford, 1958) that while malaria is seen every year the 1958 season experienced the most severe outbreak ever observed since establishment of the community twenty years ago.

The experience at Mulu was but one of many hundreds of similar instances of fulminating outbreaks reported by anti-epidemic workers who distributed malaria drugs to villages and settlements throughout a vast region covering the upper Blue Nile River valley and its tributaries which drain the larger part of the central plateau covering four provinces.

Malaria epidemics of varying intensity developed in the towns and villages located along the slopes of the eastern escarpment between elevations of 1,400 and 2,000 metres. This geographical district extends nearly 600 kilometers north from Debra Sina in Shoa Province to Adigrat in Tigre Province. The main highway from Addis Ababa to Asmara, Eritrea, passes through much of the affected territory. Outbreaks of exceptional severity were observed at Lake Hiak (1,900 metres) near Dessie, Wollo Province, as well as in numerous other settlements, villages and towns as far north as Makelle, Tigre Province (Schaller, 1958).

Significantly, no malaria outbreaks were observed in the DDT residual sprayed villages of the ICA-assisted Kobo-Chercher malaria pilot project at Alamata, but severe epidemics occurred in adjoining unsprayed areas.

The malaria situation in the upper Takazze River valley and its tributary valleys in Tigre and Beghemder Provinces was not properly evaluated because of the remoteness of the greater part of this large drainage area. However, investigations made near Makelle and Samre indicated an unusual incidence.

Elsewhere in Ethiopia reports of unusual malaria occurrence were never confirmed because of the inaccessibility of the areas.

On the basis of reports received from medical missionary stations and government hospitals in Sidamo, Kaffa, Arussi, Harrar and Gemu Goffa Provinces, malaria appeared in the highlands of these provinces. The outbreaks were of sufficient intensity to elicit special attention and motivate seeking supplementary medical aid from the central Government.

Vector Prevalence

Records of the prevalence of vector mosquitoes during the epidemic period are incomplete. The shortage of qualified entomological personnel limited our observations to spot checks at various localities at different times. No sustained observations at one particular locality were possible, nevertheless, enough data was accumulated to clearly show that Anopheles gambiae was the only vector involved in epidemic transmission. All adult collections made from the Lake Tana area yielded Anopheles gambiae. These were also the findings in collections from the Blue Nile Valley and its tributaries, the upper Awash River valley and its tributaries,

the malarious areas of the eastern slope of the plateau along the main highway from Addis Ababa to Asmara, and the upper Takazze River watershed. Since collections and observations were made at irregular intervals from scattered localities, the data is insufficient for purposes of determining the vector Anopheles density at different localities during the course of the epidemic period.

The available data indicated that A.gambiae was abundant in some areas in June through September, 1958, with the numbers falling off rapidly thereafter. In November and early December, a month or more following the end of the rainy season, it was a common experience to find from 50% to 75% of a village population prostrated with malaria, with an average vector index of only two Anopheles gambiae or less per dwelling. In many areas neither the adult Anopheles nor their breeding places was evident within many miles of a malaria stricken village. Investigators were often puzzled by the apparent paradox of widespread malaria in the absence of vectors. Situations such as these were merely indicative of the brevity of the transmission season in much of the malarious areas of the country, particularly at high altitudes and in semi-arid tracts. Investigators previously mentioned, especially Covell, Melville and Wilson, observed and remarked on the brevity of transmission as one of the important epidemiological features of malaria in Ethiopia.

Climatological Factors

The weather of 1958 was significantly higher in rainfall, temperature and relative humidity than previous years, according to the Imperial Ethiopian Government meteorological reports and records (Lissicine, 1959).

It was reported that precipitation in 1958 was generally higher than any previous year on record, particularly in the highlands and western slopes. The high total, however, was not so much a result of an enormous rainfall during the wet season as it was the distribution of rain, which fell in appreciable amounts during normally dry months before and after the normal wet season of July through September.

In Shoa Province rainfall exceeded all previous years on record. This was also true for the provinces of Beghemder and Gojjam, where the epidemic reached disastrous proportions. In the highlands tracts of Harrar, Sidamo, Wollega, Illubabor and Arussi Provinces, rainfall exceeded all previous years on record.

In Wollo Province rainfall showed wide variations at different stations, but the average for the provinces was more than the average of previous years.

In Tigre Province, which borders Eritrea on the south, the annual rainfall was generally less than average; however, the record at some stations exceeded previous years.

The average daytime temperature in 1958 was higher than any previous year on record at most stations. Maximum daytime temperatures were also higher than usual and nights were warmer. This was reflected in the limited and slight frost observed in 1958 as compared to previous years in which widespread heavy frost occurs regularly in most mountainous places and in many high valleys.

The yearly average relative humidity was higher in 1958 than previous years on record. This is attributed to the fact that rainfall was distributed in the normally dry months, resulting thereby in a generally higher relative humidity for all the months.

During the dry season, the average relative humidity in the highlands is usually less than 50%. In 1958, it approached 60% and very often exceeded this figure. During the wet season average relative humidity varied between 80 - 90%.

Plasmodia

Plasmodium falciparum predominated in all the epidemic areas investigated during the early stages and up through October at the time of peak prevalence. The following are examples of Plasmodium species distribution found in widely separated localities at different times:

Blood examination of 231 fever cases from sprayed and unsprayed villages in the northern area of Lake Tana yielded forty-five positive slides from September through November, of which 89% were P.falciparum, 4% P.vivax, 2% P. malariae and 4% multiple infections.

In the Kobo-Charcher area seventy blood examinations of fever cases in October, 1958, yielded thirty-two positives, of which P.falciparum accounted for 87% of the infections.

Out of 1600 blood examinations of fever cases and cases with fever history made during the period September 1 through December 12, 1958, from all areas, there were 675 positives. P.falciparum accounted for 71% of the infections, P. vivax 22%, P. malariae 3% and multiple infections 4%. There was no significant difference noted in the parasite incidence in the different age groups, thus indicating a lack of communal immunity among the population examined.

In preliminary surveys covering the same general areas made in all seasons of the year from September, 1955, throug September, 1957, 3,808 blood examinations yielded 618 positives. In this series P. falciparum accounted for 56% of all infections. On a seasonal basis P. falciparum fluctuated from a low of 25% during the dry season months of the spring to 62% in the peak malaria season of the autumn following the summer wet season.

Morbidity and Mortality

Only estimates of mortality and morbidity are available for the epidemic, as no reliable system of disease reporting or registrations

of death has been established in Ethiopia. The available information is based largely on reports of field investigations by Ministry of Public Health personnel and international specialists who participated in an anti-epidemic control programme. The programme primarily involved the distribution of antimalaria drugs by an organization of over 500 people who were drawn from public health agencies, government hospitals, Point IV cooperative agencies, the various medical missionary establishments, WHO, the police and the Ethiopian Red Cross. In this programme about four million chloroquine tablets were distributed at an average of four tablets per patient.

Other sources of information on the epidemic were the unprecedented number of requests for medical assistance received by the Ministry of Public Health from provincial and local district officials. The origin of the requests provided a basis for roughly determining the geographical distribution of the epidemic and when placed together made possible a crude assessment of the relative severity of epidemics at different localities.

In the early stages of the epidemic in the July-August-September period, it was assumed by many local officials that the reported outbreaks were epidemic typhus or epidemic relapsing fever because of the relatively high altitude of the affected areas. In some instances emergency anti-epidemic measures were instituted against these diseases before it was discovered through laboratory diagnosis that malaria was the cause of the problem.

Of all the numerous reports received, the estimates of mortality and morbidity from epidemic districts of Beghemder Province are the most complete and reliable. The provincial capital at Gondar is the site of the Gondar Public Health College, whose director and a number of his professional staff also provide public health services for the province. The college staff, including senior students and interns, were involved in conducting investigations and control measures throughout the epidemic period and were instrumental in securing documentation of the scope and intensity of the epidemic, particularly around Lake Tana and adjoining districts. However, in the absence of a reliable population census of the various settlements and villages investigated, any vital statistics reported must be necessarily regarded as rough estimates, even when made by qualified medical investigators.

Makonnen (1958), reporting on his investigations of nine villages near Lake Tana, indicated that out of a combined population of nearly 4,000 inhabitants 3,000 contracted malaria and 496 died during the first four months of a six-month epidemic period.

Wasti (1958), reporting on nine districts near Lake Tana with a combined estimated population of 170,000, gave the number of malaria cases as 83,000 and the deaths in excess of 5,000.

Ryder (1955), reporting on investigations made in 326 villages with a combined estimated population of 131,000, gave the number of malaria cases as 75,100 in a three-month period and the number of deaths attributed to malaria as 4,736.

Schaller (1958) reported 203 deaths and 959 clinically diagnosed malaria cases from seven villages (population unreported) in the vicinity of Lake Hiak, Wollo Province. The area lies at 1,900 metres elevation.

Kassaye (1958), reporting on investigations made in the Ganje district with an estimated population of 10,000, gave the number of malaria cases as 5,287 from October 13 through December 17, 1958. The number of deaths attributed to malaria in this district were 1,064 from May through September, 1958.

The admission records of the Seventh Day Adventist Hospital at Debra Tabor, Beghemder Province, indicates a most unusual year for malaria. The hospital is situated on the highlands above and to the west of Lake Tana at 2,600 metres elevation. This is well above the highest limits of malaria transmission. In 1958 there were 2,780 malaria cases diagnosed and treated. Of this total number 2,513 were treated in October, November and December, 1958. In the preceding ten-year period, which is as far as the records go, the number of malaria patients only exceeded 100 cases in 1953 and 1954 when 271 and 159 cases, respectively, were noted. The higher totals in both these years coincide with an epidemic of malaria reported from the Lake Tana area in 1953 (Najjar, 1956). According to the case history records, none of the patients were residents of Debra Tabor. All of them travelled or were carried by friends and relatives to the hospital from settlements and villages lying at elevations between 1,800 and 2,200 metres surrounding Debra Tabor.

At Debra Zeit, Shoa Province, forty-five kilometers southeast of Addis (elevation 1,850 metres), 2,553 cases of malaria were treated at the government hospital during October and November, 1958, as compared to 417 in the same period of 1957, 490 in 1956, 537 in 1953 and 574 in 1952.

A similar picture is revealed from the S.I.M. Hospital at Soddo, Wollamo Province, where 347 malaria cases in October and November, 1958, were recorded, as compared to 139 cases in the same period of 1957 and 135 cases in 1956.

From the Lekemt Swedish Mission Hospital, 1,212 malaria cases were recorded during the period of October and November, 1958. During the same period of 1957 the records show 593 cases of malaria.

The combined records of malaria cases recorded by five Addis Ababa hospitals show a total of 2,512 diagnosed and treated during 1958. Records of previous years are not available. While many of

the cases were reported as being indigenous to Addis Ababa, there is insufficient evidence in the case history records to conclusively support such a determination.

The accompanying Tables I and II provide data on malaria admissions for 1958 and the previous years on record as reported from a number of principal hospitals in Ethiopia:

Table I

Number of Malaria Cases Diagnosed and Treated in 1958
Compared to the Average of Previous Years on Record
As Reported from Ten Hospitals in Ethiopia

Name of Hospital	City and Province	Number Malaria Cases	Average No. Malaria Cases for Previous Years
1. Seventh Day Adventist	Debra Tabor, Beghemder	2780	126
2. Government	Debra Zeit, Shoa	4094	948
3. Government	Jimma, Kaffa	670	186
4. S.I.Mission	Soddo, Sidamo	1348	713
5. Swedish Mission	Lekemt, Wollega	4366	2070
6. Addis Ababa *	Addis Ababa, Shoa	2512	Not available

* Addis Ababa hospitals are as follows: Empress Zauditu, Ethio-Swedish, Princess Tsehay, Dejazmatch Balcha and Tekle Haimanot.

Table II

Number of Malaria Cases

Diagnosed and Treated by Month of Admission

For 1958

Name of Hospital	J	F	M	A	M	J	J	A	S	O	N	D	Total
1. Seventh Day Adventist	20	6	20	19	30	51	58	22	41	549	1545	419	2780
2. Government Hospital	42	51	133	33	90	130	155	98	465	1413	1140	344	4094
3. Government Hospital	4	4	2	5	10	14	10	10	1	197	304	109	670
4. S.I.Mission	23	44	85	143	189	136	74	55	54	128	219	198	1348
5. Swedish Mission	367	478	441	289	281	217	191	234	367	733	479	289	4366
6. Addis Ababa	183	204	300	151	148	162	132	77	123	316	428	288	2512

The number of malaria cases and deaths can only be estimated, as such records are not maintained except in the few hospitals and clinics which serve only a relatively small proportion of the population.

The population of Ethiopia is officially reported as 18,000,000, of which an estimated 8,000,000 live in malarious areas. Of this number, it appears that at least 3,000,000 to 3,500,000 contracted malaria during the six-month epidemic period of 1958. The case fatality rate was known to have reached as high as 25% among the ill-nourished population of many villages in the famine area. In other districts available information based on sample checks and enquiries indicated a case fatality of from five to ten per hundred cases. Using a minimum of five deaths per hundred cases and 3,000,000 cases as our total morbidity, the deaths due to malaria would amount to 150,000.

Although the basis for determining morbidity and mortality is admittedly fragmentary from a statistical standpoint, nevertheless, when such information is weighed together with the subjective evidence, the estimated morbidity and mortality appear reasonably conservative.

The severity of the epidemic makes a more lasting impression in reading the narrative descriptions contained in the reports of anti-epidemic malaria personnel who worked in the rural areas conducting investigations and administering antimalaria drugs.

Taddese (1958), in reporting on investigations made in late October in areas of the Blue Nile valley, wrote, "It is hard to find a healthy person in a family. There are not enough healthy individuals remaining to fetch water for the sick. Many people are dying-- as many as twenty persons out of a hundred sick. The crops which are unattended for lack of guards are being destroyed by baboons, wild pigs, birds and other wild life."

Mamo (1958), in reporting on investigations made south of Lake Tana (Bahar Dar to Ganje), commented as follows: "On October 13 we treated many malaria patients at Bahar Dar-- everywhere we went we met cases of the same complaint. On the 14th we went to Ganje, treating many patients on the way. As we approached the interior of Ganje we came close to a big and deep river which we could not cross. We remained on this side of it and visited villages called Dishet, Wandata and Sarualka. We saw many patients in their beds, practically everybody is sick. Over 500 people died since the epidemic outbreak three months ago. The people said there is a slight epidemic every year but once a serious outbreak was only known about thirty years ago."

Mogues (1958), conducting investigations in the north of Gojjam Province in late October, wrote: "In each house we were able to find three or four patients who complained of subjective

symptoms, such as chilling, severe headaches, sweating, pain in the back and extremities. The objective symptoms were jaundice, anemia, emaciation, high fever. After four or five relapses, the headaches and pain became unbearable for many patients, who then exhibited a muddling delirium with coma, ending in death. Most of the patients were between the ages of five and twenty years; second in frequency were infants and pre-school children. Since they are far away from even the simplest clinic, which means no possibility of saving their lives, they are dying like bees in a smoked hive."

Many other reports along the same vein were made by malaria workers from widely seperated areas of the country.

Chloroquine tablets were used, primarily in the anti-epidemic work, with gratifying results. In three to four days after treatment, many seriously ill patients recovered sufficiently to assist in the harvest.

Discussion

The regional nature of the 1958 malaria epidemic is well established. It covered a region of no less than 100,000 square miles of the heavily populated rural districts of Ethiopia and lasted from the end of June until the middle of December. It reached into high elevation areas rarely ever invaded by the disease and overwhelmed a large susceptible population whose last previous major contact with the disease probably goes back at least a decade and possibly longer. This is indicated by the acute, widespread illness and high mortality observed, together with information on the epidemic history given by the local people and Europeans of long residence in Ethiopia.

In some districts of Shoa and Gojjam Provinces, the high mortality was undoubtedly aggravated by famine conditions resulting from a depleted harvest in 1957. The natural defenses of a considerable population were thus ill prepared to resist the onslaught of a virulent falciparum parasite. While such factors as famine and parasite virulence may have exerted considerable influence on the mortality rate seen in some districts, the effects of unusual weather conditions in 1958 favouring the development of the main vector and the parasite offers a more plausible basis for explaining the cause of this epidemic.

As mentioned previously, the weather of 1958 was unusual in that the recorded precipitation, temperature and relative humidity were higher than past years on record in the highland provinces where the epidemic was most pronounced. Another significant difference recorded was in the distribution of rain, which in 1958 fell during normally dry months in appreciable quantities.

Considering these weather factors in the light of vector mosquito preference, it is evident that the propagation, longevity and dispersal of the principal malaria vector mosquito, Anopheles gambiae, was enhanced. Such factors would also favour development of the extrinsic cycle of the parasite Plasmodium falciparum. Taking this combination of vector and parasite operating under optimum conditions of development in a large, susceptible human population, we have then the essential ingredients for the generation and explosive rise of an epidemic such as was seen in 1958.

In explaining the cause of the regional epidemic inNorthern Sind, India, in the autumn of 1929, Covell (1936) stressed the importance of environmental factors favouring the propagation, longevity and activity of the vector mosquito in an area inhabited by a population in which the communal immunity to malaria was at a low level. Excessive rainfall which preceded the Northern Sind epidemic was attributed to be the precipitating factor since it produced favourable conditions for the development of the vector Anopheles culicifacies.

We feel that these factors elucidated by Covell-- favourable weather conditions for the vector and lack of communal immunity among the population at risk-- were the underlying basis for the Ethiopian epidemic of 1958.

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(The 1958 Malaria Epidemic Ethiopia - Annex I)

BACKGROUND INFORMATION TO THE MALARIA PROBLEM IN ETHIOPIA

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Description of the Country

Ethiopia lies between 4° and 16° north latitude in East Africa. It is bordered on the east and southeast by the Somalia territories, on the south by Kenya, on the west and north by the vast lowlands of the Sudan, and on the northeast by the Red Sea. The total area of the country, including the federated state of Eritrea, covers nearly 400,000 square miles, a larger territory than France and Germany combined. Ethiopia is essentially a highland country, as the altitude generally exceeds 1500 meters and there is comparatively little terrain below 1000 metres.

The outstanding land feature is the massive plateau and mountainous terrain which caps most of the central and northern area of the country. This is usually referred to as the "highlands", and it rises by a series of step-like escarpments from desert and semi-desert lowland on the east and southeast. The highest peaks exceed 4,000 metres and extensive mountain ranges traverse the land. The altitude of plateau tracts is variable with the highest tableland ranging between 2,500 and 2,800 metres. The configuration of the plateau is sculptured by an irregular pattern of deep chasms, canyons and valleys whose contours follow the direction taken by the major rivers and their tributaries. Many of the deeper canyons drop a sheer 1,000 metres from the surrounding tableland, and cleavages of 500 metres deep are common. The great Rift Valley, which extends in a northeasterly direction from Lake Rudolph to the Red Sea, bisects the plateau into sub-equal parts. The differential in the altitude between the rims of canyons and valleys and their bottoms is such as to result in marked differences in climate ranging from tropical conditions in the canyons to a temperate climate in the tablelands, all within a few kilometers apart. In some areas of the country, the rise from lowlands to highlands is more sloping, and changes of climate and life zones are less sharply defined.

Desert and semi-arid tracts form a large part of the country. The Ogaden and Haud districts cover an extensive area of semi-arid territory in southeast Ethiopia. The Danakil country is a torrid wasteland of lava and bare volcanic peaks which extends many kilometers from the base of the eastern escarpment of the central highlands to the Red Sea. On the west, the highlands descend by a series of broad terraces to a narrow belt of grassy savannah country bordering the Sudan.

Climate

The variable topography which characterizes the land features has a direct effect on climate which is likewise variable, depending on the altitude and particular geographical location. Broadly speaking, the climate of Ethiopia is divided into a dry and wet season, the latter occurring during the months of June through September, coinciding with the moisture laden south-east monsoon. At Addis Ababa, Gondar, Dessie and Lekempt, which lie above 2,200 metres elevation, rainfall generally exceeds 1,000 mm annually, with nearly 80% of the precipitation occurring during the four wet season months. The amount of rain decreases with drops in elevation. For example, at Debre Zeit, which lies at 1850 metres, annual rainfall averages about 200 mm less than Addis Ababa, while at 1500 metres at Awash, it is 400 mm less than Addis Ababa. In the Gore and Jimma districts in the highlands of the western provinces, rainfall is heavy and is more uniformly distributed throughout the year, generally exceeding 1,900 mm annually. A different seasonal pattern of rainfall occurs in the Ogaden and Haud districts adjoining the Somali country. Here rains fall between March and May and again during October and November, but total precipitation is under 400 mm in most places. Below elevations of 600 metres rainfall is usually light. In the low-lying Danakil desert in the northeast, annual precipitation is under 100 mm.

In Eritrea, rainfall in the highlands is considerably less than in comparable elevations in Ethiopia. In Asmara, which lies at 2300 metres altitude, the average rainfall is less than 500 mm.

While most of the highlands experience a distinct wet and dry season, intermittent rains of variable quantity may fall from February through May.

Because of the seasonal rainfall and mountainous terrain, rivers and streams are generally swift flowing and subject to wide fluctuations in depth. Floods are common during the rainy season.

Temperatures, as with rainfall and humidity, are closely associated with altitude. In the highlands of the north central

provinces, at Addis Ababa, Dessie and Gondar, the average yearly temperature is between 15° and 18° C. The warmest months are March, April and May, before the wet season. The coldest are November, December and January, when minimum temperatures may fall to 1° C. During the rainy season, the minimum range is 6° to 10° C. As elevations decrease, temperatures rise rapidly, and relative humidity falls. In the lowlying Danakil desert and along the Sudan border, temperatures often exceed 40°C. At elevations of 300 - 400 metres, the amplitude of annual mean temperature is 24° - 28°C.

In the northern tableland the yearly average relative humidity is between 50 - 70% and decreases in the dry season to 30 - 40%. It is considerably less at lower elevations.

Population

The population of Ethiopia has been variously estimated at 12 to 20 million. The official estimate reported is 18,542,700 inhabitants. The highland areas above 1,500 metres elevation are the most densely settled areas. The population at risk to malaria is believed to be about 8,000,000 persons. In the central and northern highland provinces of Shoa, Beghender, Wollo, Gojjam and Wollega, where the 1958 epidemic was most pronounced, the population is estimated to number nearly 9 million. However, a considerable proportion of the inhabitants live above the altitudinal limits of malaria transmission; that is, except those who temporarily descend to lower elevations for farming or other purposes. This is often the pattern of local movement by many highland inhabitants. While people have learned to avoid malaria by erecting their dwellings on the highest ground available in a particular locality, they often contract the disease while remaining overnight to tend their crops which are planted in the richer valley land where environmental conditions permit malaria transmission.

Because of the rather cool evenings and the frequency of rainfall, people invariably sleep indoors in the epidemic malarious areas. The typical dwelling is a circular hut built of mud (chika) walls supported by staves set upright from the ground. The roof is usually made of thatch or, sometimes tin sheets are used. Mosquitoes readily enter these huts to feed and rest under shelter.

Vectors

Anopheles gambiae is the main vector in Ethiopia. Anopheles funestus plays a definite secondary role, but in localities of endemic malaria near lakes, rivers and marshes situated in the deep valleys and lowlands, it may exceed Anopheles gambiae in importance. A.pharoensis is also a vector but evidently a minor one insofar as epidemic transmission is concerned. A. gambiae is found at all levels of elevation but rarely above 2,100 metres

and then only for brief periods when temperature and breeding conditions are suitable. Its general adaptability to a wide variety of aquatic habitats gives it a big advantage over other vectors in biotic potential. During the dry season when breeding places are scarce, specimens are difficult to find except in proximity to permanent rivers, springs and some marshes and lakes. With the advent of the wet season, the species rapidly extends its range and increases in number as it finds new breeding places in almost every type of temporary water collection, including seasonal swamps, seasonal streams and flooded areas. The higher relative humidity and more generally favourable temperatures during the wet season favour dispersal and adult longevity. In September, near the close of the wet season, A. gambiae populates most of the highlands, plains and valleys below 2,000 metres elevation. Transmission is thereby extended and accelerated at a rapid rate, being limited mainly by colder temperatures of higher altitudes. With the drying of the breeding sources and lowering of the daily mean temperature and humidity following the end of the rains, the A. gambiae population is quickly decimated and the species once again becomes restricted to its narrow dry season range.

Parasite Species

P. falciparum is by far the predominant species throughout Ethiopia. This has been made evident in previous findings of Italian and British investigators and more recently by Point IV and WHO malaria survey teams who have gathered data from many districts of the country at all seasons of the year. However, seasonal variations in frequency have been observed. During the dry season months of March, April and May, P. vivax and P.malariae are either equally common or the former may exceed P. falciparum in frequency.

The typical proportions of species frequency found on the average are: P. falciparum, 60%; P.vivax, 25%; and P.malariae, 15%. Mixed infections are quite common. P.ovale has not been identified in Ethiopia as far as is known.

Two strains of P. falciparum exist, the dominant classical strain and the occasionally observed Abyssinian type. The morphology of the latter is similar to the Malayan strain which is characterized by the large chromatin dot and an intensely stained and above average size cytoplasm (Macgraith, 1958). On the basis of many hundreds of blood film examinations during the epidemic of 1958, the Abyssinian strain was the more frequently observed.

Epidemiology of Malaria in Ethiopia

The occurrence of a regional epidemic would not come as a surprise to malariologists who have studied the malaria problem in Ethiopia. Covell (1957), reporting on the results of malaria

investigations made during the autumn of 1955, concluded that malaria is predominantly an epidemic disease in the greater part of Ethiopia. Earlier investigators -- notably Melville, Wilson, et al (1945) and Corradetti (1938) -- also presented evidence of the epidemic character of malaria. More recent studies of the malaria problem in three ICA - and WHO - assisted malaria pilot projects in Ethiopia further corroborate these findings.

Malaria is markedly seasonal in incidence and is governed by the pattern of rainfall. As the heavy rains of the southeast monsoon draw to a close in September, malaria incidence rises sharply, reaching a peak prevalence in the October-November period. By mid-December the main malaria season is over. During the subsequent six-month dry season, transmission is negligible in most areas for lack of vectors, their numbers having been greatly reduced by the paucity of suitable breeding places. In the Haud and Ogaden districts where rains occur in both the spring and fall, there are two malaria seasons.

Centers of endemic and hyperendemic malaria are found mainly along the deep valleys of the major rivers and also in close proximity to springs, marshes, ponds and some lakes which are conducive to year-round anopheline vector breeding. These prominent endemic centers and other less well defined and scattered foci maintain transmission during the prolonged dry season and provide a source of infection for the spread and recurrent annual increase in malaria incidence associated with the wet season. In years exceptionally favourable for the propagation of vector mosquitoes, malaria may be diffused far beyond its regular seasonal range, thus resulting in a cyclic epidemic occurrency of regional extent.

Malaria exhibits a discrete distribution reflecting the variability in temperature, rainfall and topography. The degree of endemicity may vary markedly within relatively limited areas. For example, highly endemic malarious areas such as are found along river valleys lying at 1,000 to 1,500 metres are sometimes situated only a few kilometers away from epidemic areas or malaria-free areas in nearby tablelands. Geographical barriers such as mountain ranges and deserts often isolate one malarious area from another.