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Introduction.

In March, 1930, *Anopheles* (*Myzomyia*) *gambiae* Giles,† a species heretofore known only in the Old World, was discovered breeding within the city limits of Natal, Rio Grande do Norte, Brazil (Shannon, 1930). It is probable that the species is of recent introduction, and presumably was carried to the Brazilian Coast by one of the fast French mail steamers which make the trip between Dakar (French West Africa) and Natal in four days.

There is also a possibility that *A. gambiae* was brought to Brazil by aircraft. Natal is now the most important western terminus for airplane flights between Africa and South America.‡ Up to 1930, aircraft had made the South Atlantic crossing on eight occasions, most of them starting from Dakar, or its vicinity, and landing at Natal.

Anopheles gambiae is regarded as one of the most important transmitters of malaria throughout the tropical malarial belt in Africa. Up to 1930 it was known only in this continent and in Southern Arabia. It is remarkable that, coincident with its discovery in Brazil, Séguy (1930) encountered it in material collected the same year in Greece.

This is the first known case of a species of *Anopheles* pertaining to one faunal region being introduced into another. Its behavior in its new environment will be a matter of special interest.

* From the Yellow Fever Laboratory of the International Health Division of the Rockefeller Foundation, Bahia, Brazil.

† The name *costalis* is frequently used in place of *gambiae*. The latter, however, is considered to be the proper one by Edwards, Christophers and others and is therefore the one used here.

‡ "Below Cape São Roque stands Natal, the now well-known western terminus of Africa-Brazil flights. Here, too, converges the air net of plane paths which collect South American mail for Europe, sent from here to Dakar, Africa, by speedy French dispatch boats. . . . The French hope in time to set up a transatlantic airmail line between Natal and Dakar." (Simpich, 1931.)

In Brazil, until the beginning of 1931, it had been found only in the coastal city of Natal. However, a report from Dr. F. L. Soper (July, 1931) states that *A. gambiae* has been found near the coast, 180 kilometers north of Natal. A later report adds thirteen additional localities, all of which, however, are within the 180 kilometer radius of Natal.

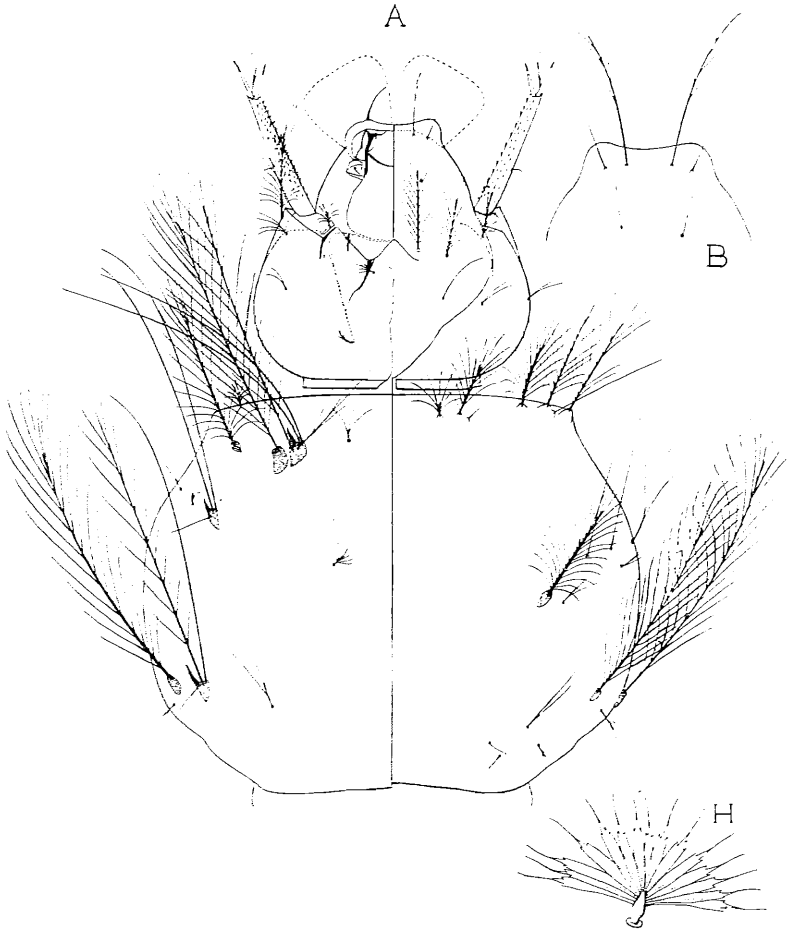


FIG. 1. *Anopheles gambiae* Giles.

A. Dorsal and ventral views of the head and thorax of the larva of *Anopheles gambiae*.

B. Anterior portion of the head showing the position of the clypeal hairs.

H. Abdominal palmate hair (third segment).

During the months of April, May, and June, 1930, there occurred, in the vicinity of the breeding area in Natal, an outbreak of malaria of a severity unprecedented in the annals of the city. At about the height of this outbreak (May), Davis (1931) made collections of the adult *A. gambiae* present in the nearby houses. Upon dissection he found that 108 out of a total of 172 specimens were infected with malaria, giving an infection rate of 62.8 per cent.

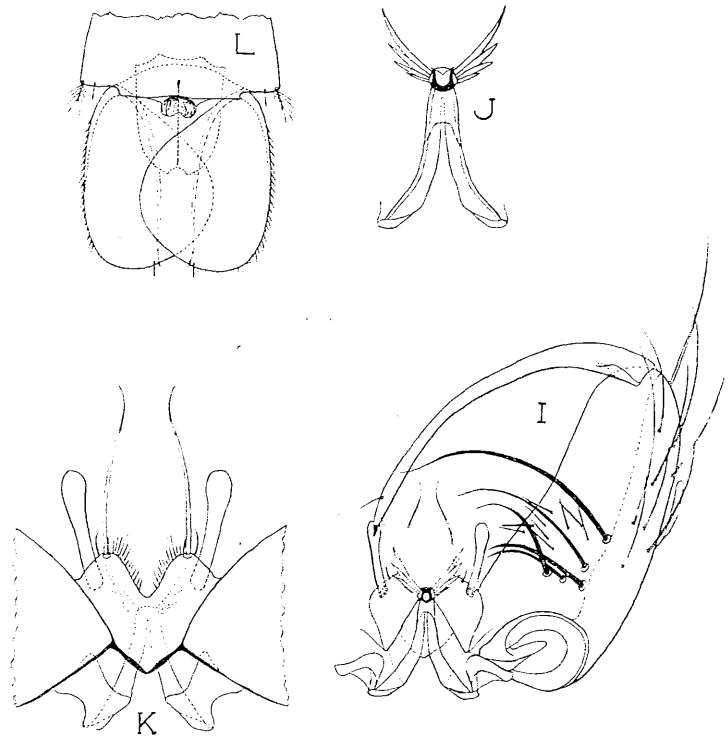


FIG. 2. *Anopheles gambiae* Giles.

I. Male terminalia of *Anopheles gambiae*.
J. Phallosome.
K. Ventral view of the claspette.
L. Terminal portion of the pupa.

This remarkable outbreak in itself probably constitutes sufficient evidence to show that the species did not exist in Natal before the year 1930.

Anopheles gambiae in Africa.

Considerable attention has been given to *A. gambiae* in Africa. In view of the importance of the investigations as a basis for the

study of the species, and because of the general inaccessibility of the literature in Brazil, the following brief resumé is submitted.

Old World distribution. Although *A. gambiae* has been reported from the north coast of Africa (Algiers and Morocco), from Arabia (Aden), Greece, and South Africa (Durban, Natal), it is evident that the principal home of the species is in the African tropical belt, extending from the southern border of the Sahara south to the Zambesi river (or about 20° south latitude). It also occurs on some of the islands off the east coast of Africa.

Seasonal prevalence. There is some contradiction in the reports of the various writers regarding the seasonal prevalence of *A. gambiae*, but evidently this results from the fact that their observations were made in different regions.

Lamborn (1925) states that in the tropics, where there is comparatively little variation in temperature, moisture, rather than temperature, is the controlling factor in mosquito production. This appears to be the case in many parts of Africa where *A. gambiae* is said practically to disappear during the dry season but to become abundant after the long rains are well advanced. (For supplementary observations see also Symes, 1926, 1928, and 1930; Bauvallet, 1928; Ingram and De Meillon, 1929; Garnham, 1929; Barber and Olinger, 1931.)

Lamborn further states that in the Shire Valley, Nyasaland, although the water may remain in certain places where *A. gambiae* bred in great abundance in the wet season, the larvae entirely disappear during the first few months of the dry season. The few females that he found during the dry season contained numerous fully developed eggs; on this basis he suggests the possibility that the unfavorable breeding conditions may bring about an inhibition of the oviposition instinct, which would account for the absence of larvae.

Garnham (1929), on the other hand, claims that in Kenya the larvae are to be found in considerable numbers during the dry season, while the adults are scanty in the extreme.

Schwetz (1930) observes, however, that he found no well marked seasons of abundance during his investigations at Stanleyville, Belgian Congo. He adds, however, that there are no well marked dry seasons, although there are two short seasons of comparatively light rainfall. (See appendix for rainfall records of Gazi, Belgian Congo.)

Temperature proves to be of importance in the southern part of its range. Thomson (1929) states that in Southern Rhodesia adult *A. gambiae* is killed by the sudden drop in temperature occurring

about the beginning of June. (The Smithsonian "World Weather Records," 1927, give for Bulawayo, Rhodesia, for June and July, temperatures of 14.2° C. and 14.0° C. respectively. These are means based on 26 years of observations.)

It is also of interest to note that, dependent upon rainfall, the species is able to thrive at Khartoum, Sudan, one of the hottest localities known in the world (mean temperature 29.2° C.).

Breeding sources. *Anopheles gambiae* larvae have been found under a great variety of situations and conditions: in rock and gutter pools, drains, clay and borrow pits, open wells (water holes), stagnant ditches, casks, tanks, tins and other artificial receptacles, tree holes, crab holes, beached boats; along the margins and in the back waters of slow flowing streams; in riverside flood waters, swamps, rain pools (in natural depressions), flood water (temporary), lakes, beds of drying-up rivers and streams; in clear waters and in muddy or otherwise discolored waters, with or without vegetation; in brackish pools, etc.

Garnham (1929) records that although *A. gambiae* prefers stagnant waters, he has found the larvae in considerable numbers in a fast-flowing drain with little or no grass on the banks, and also at the edge of a lake where the narrow belt of vegetation was totally unable to protect the larvae from wave action and tidal flow. Further: "During the rains, *gambiae* breeds in anything and everywhere; in crowded parts of town as well as in districts far removed from human habitations. It will not despise the foulest water in latrine catch-pits or the thick scum of a drying-up pond, and yet it is to be found in crystal springs and the waves of the lake itself."

Lamborn (1925), on the other hand, on the basis of two years' investigations in Nyasaland, arrived at the conclusion that "*A. costalis* (*gambiae*) appears to be as particular in its selection of breeding places as many other anophelines, particularly Oriental species." He sums up the breeding habits as follows: "*Costalis* is essentially a small pool breeder, the larvae occurring in natural ground hollows, borrow pits, depressions at the sides of roads, animal hoof prints, and very occasionally in artificial receptacles."

It may be added that the observations recorded by Symes (1926 to 1931), Barber and his associates (1931, 1932), and others are in general accord with those made by Lamborn.

In spite of the great variety of breeding situations and intrinsic conditions of breeding which have been reported, the different investigators are, with but few exceptions, in accord in one very important respect, namely, that the water collections in which *A. gambiae* larvae

have been found have been more or less fully exposed to direct sunlight, at least during part of the day. Patton and Evans (1929) remark that occasionally specimens may be washed down into shaded parts of streams. Barber and Olinger (1931) found larvae thriving in a pool which was thoroughly shaded by palms and a broad-leaved tree. Schwetz (1930) states that at Stanleyville (Belgian Congo) he found *A. gambiae* larvae in almost all collections of water, whether shaded or not.

In connection with this last observation and the other differences in larval sources as noted above, it should be remarked that the investigations upon which the observations are based have been made in many parts of Africa and that some of the variation no doubt is due to the influence of weather conditions and possibly, too, to a difference in strain or variety of the species. The latter possibility is made more apparent by certain experiments conducted by Barber and Olinger. The following is a quotation from their paper.

> *A. costalis* var. *melas*. A form of *costalis* with very dark larvae and dark adults, some of which exhibit the four banded proboscis, occurs plentifully in the large coastal swamps surrounding Lagos. The limits of this form are not well defined; but that it is biologically different from the type of *costalis* common inland is indicated by certain experiments which were conducted in the laboratory:
>
> Eggs from adults of *costalis* collected near the coastal swamps develop normally when placed in either fresh or brackish water, while those from adults collected far inland (Ibadan) failed to develop further than to very small larvae in the same type of brackish water. Controls, of inland source, developed normally in fresh water. We repeated this experiment several times, always with the same result.

Influence of man on Anopheles gambiae breeding. The following observations recorded by Symes (1928), made in Kenya, appear to be of particular importance in that they show the influence of man upon the breeding habits of *A. gambiae:*

> Optimum breeding sources consist of open, stagnant, and sunlit waters of shallow pits, ditches, puddles, and stream beds, during and after rains. . . . Sunlit, stagnant and dirty waters are more frequently found in and around townships than in outside (natural) areas less influenced by man. In the latter the species is most frequently found along the edges and backwaters of slow streams where sunlight, stagnancy, and contamination are much less intense. In the former, extensive and intensive breeding goes on in borrow pits and excavations, ditches, drains, and canals. The "borrow pit" conditions are an intensification of the natural conditions under which *costalis* (*gambiae*) breeds in districts less influenced by man.

Elsewhere (1926) Symes remarks that "the extensive cultivation with crude drainage and irrigation supplements the natural breeding sources."

Habits of the adults. "Throughout East, Central, and West Africa, *A. gambiae* and *A. funestus* are generally recognized as being the chief malaria carriers, *A. gambiae* being the most important of the two." (Covell, 1931.) These species are likewise the preeminently domestic species in most parts of Africa.

Kerr (*vide* Barber and Olinger, 1931) in a series of experiments found that *A. gambiae* rarely bites outdoors, but constitutes the principal attacker indoors.

Symes (1931) states that out of 1,011 *A. gambiae* tested to ascertain the sources of their blood meal, 82.3 per cent were positive for human blood; also, although the species appears to feed quite readily and to thrive on domestic and wild animals, these animals do not afford any significant protection to humans. He adds that fairly reliable flight records show a distance of over three miles.

Anopheles gambiae in its new environment.

The establishment of the species in Natal. When *A. gambiae* was first discovered in Natal (Brazil) the larvae were found breeding in great numbers in a small, shallowly flooded, open field which is in close proximity to the Potengy River and about $2\frac{1}{2}$ kilometers from the boat anchorage near the mouth of the river. On this occasion approximately 2,000 larvae and pupae were collected in a few hours' time. (See map II, location 16.) Two months later (May, 1930) Dr. N. C. Davis found other larval habitats at approximately one kilometer beyond the original site (map II, numbers 17 and 20).

The unusual and severe outbreak of malaria which occurred in the vicinity of these breeding sources during the rainy season of 1930 suffices to show that by this time *A. gambiae* had already become well established.

Heretofore, the chief malarial zone in Natal was in the vicinity of two small lakes (Lagôa M. Phelippe and Lagôa Secca) about three kilometers from the location of the outbreak caused by *A. gambiae.* In this locality, the malaria, always of comparatively slight intensity, is no doubt maintained by one or more of the four common native species belonging to the subgenus *Nyssorhynchus,* which also occur within the city limits.

The breeding habits of Anopheles gambiae and its prevalence in Natal. In the months of December, 1930, and January, 1931, the writer made a more extended investigation regarding the occurrence of *A. gambiae* in Brazil, in order to ascertain whether the species had extended its range.

Map I shows the cities and towns visited. Although nine months had elapsed since its original discovery, the species was again found only in the city of Natal.

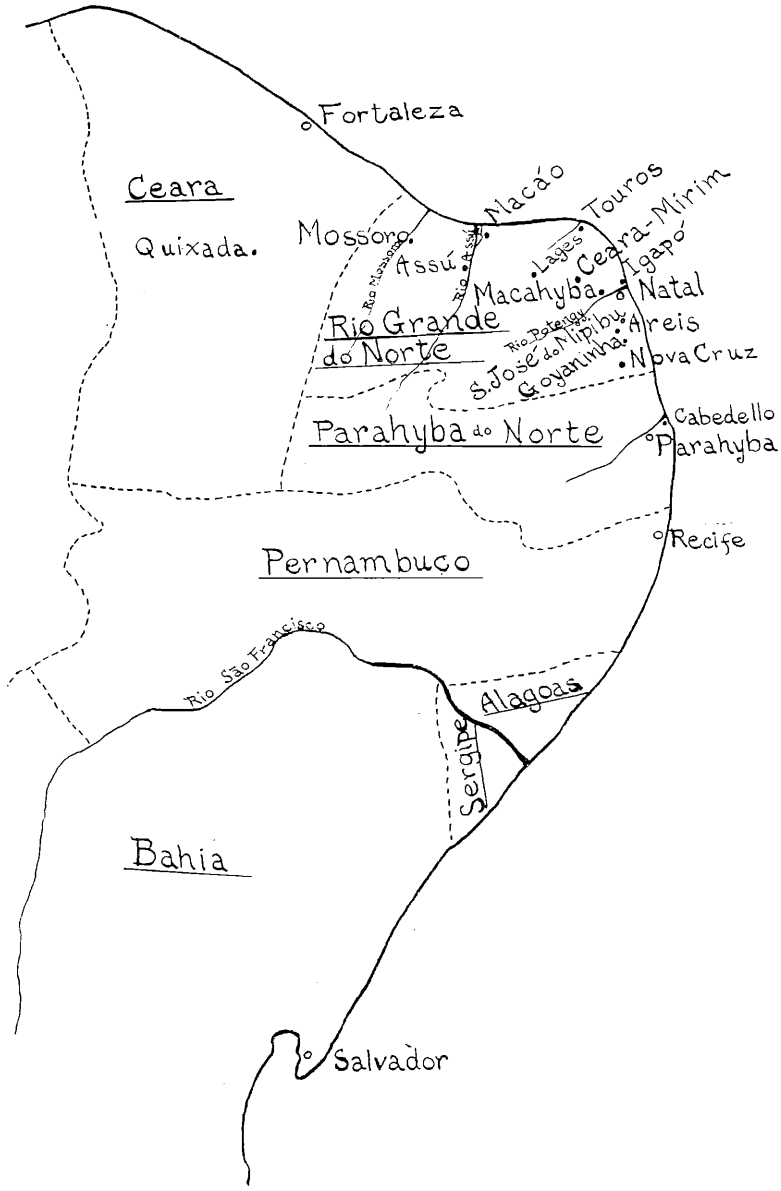
It should be emphasized, however, that the investigation here reported was made at about the middle of the dry season; and in view of the fact that in certain parts of Africa the species more or less completely disappears during the dry season, its absence from the other localities may have been more apparent than real. On the other hand, the very limited supply of water existing in the region at large made the search for larvae comparatively simple, and, judging by their absence, it may be stated that if the species did exist outside of Natal, it did so in very limited numbers.

Anopheline breeding sources found in the gambiae infested zone. A further factor which may have had an influence in its lack of distribution at this time is that of choice of larval habitat.

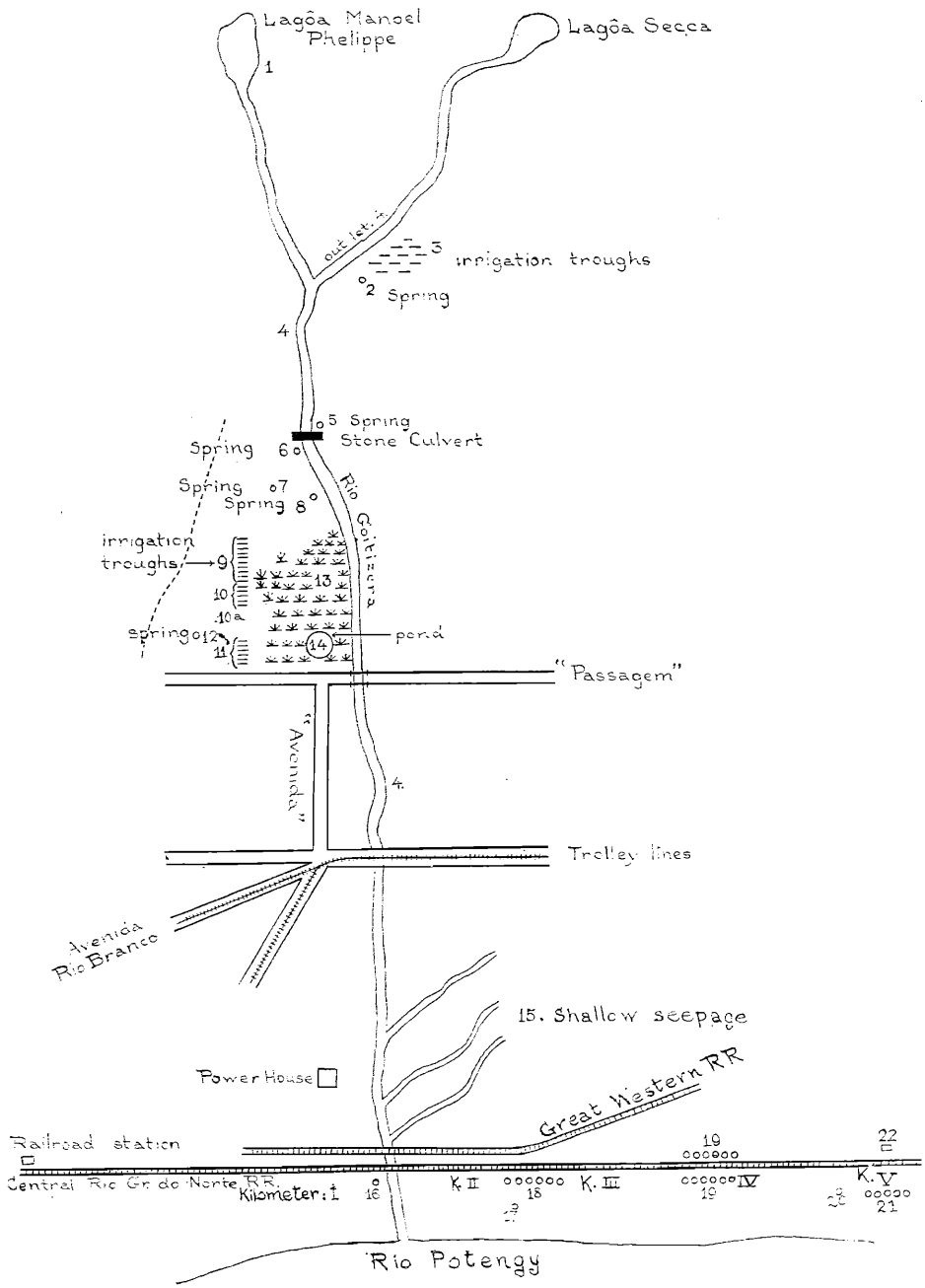
As shown in the following account of the anopheline breeding sources present in the *A. gambiae* zone in Natal at this time, anopheline larvae (including the native species) were found in only two general types of water:

1. Small shallow collections of seepage and surface springs (fed by superficial seepage) usually fully exposed to the sun. The pooled collections of these waters were practically without living vegetation and predators, although the outlet streams usually contained predators and were more or less shaded by grass and other low vegetation.

The seepage outcrops were found to be definitely limited to the northeastern section of the city (along the lower portion of the Goitezera valley, below the stone culvert, as shown on sketch map II, and along the railroad, sites 16 to 21 on the map) and their distribution, in turn, apparently limited that of *A. gambiae*. All the *A. gambiae* larvae found during the survey were present only in certain of these collections of seepage water, while larvae of the native anophelines were, as a rule, absent. It may be noted further that the pools containing *A. gambiae* larvae were usually very shallow, from one-half to about ten inches in depth, although on one occasion a single larva was found in a spring 18 inches in depth; number 6, map II. The water in these shallow pools is quickly heated by the sun. In practically all those inhabited by *A. gambiae* larvae the water was clear, with comparatively little debris. One pool, however, in which the highest concentration of larvae was found, had been fouled by waste plant material (seeds, rinds, etc.) and, in addition to the *A. gambiae* larvae, contained numerous rat-tailed maggots (*Eristalis* sp.).



MAP I. Middle Coast States of Brazil, showing the localities in which investigations were made.



MAP II. Location of the anopheline breeding sources in the Goitezera valley and along the railroad, December, 1930.

2. Ponds, streams, and marsh waters. These, practically throughout, contained numerous predators (chiefly small fish). All, except certain portions of the streams, were more or less fully exposed to the sun; and many parts contained an abundance of vegetation. Only larvae of the native species of *Anopheles* were found in these collections.

In spite of the rather limited number of water collections, anopheline breeding of any of the species was not very intensive. Probably with the diminishing of the water supplies there is a corresponding increase of enemies, both fish and insect.

However, the fact that *A. gambiae* larvae were found only in pools formed by seepage waters, while the native anophelines were chiefly found in the pond, stream, and marsh waters, would indicate that there is a fundamental biological difference between the African and the native Brazilian species. Possibly this marked distinction, as found, is only brought out by the dry season conditions, when, because of the general scarcity of breeding sources and the absence of intermediate types of water collections, the different species are forced to choose the type most favorable for their development. Also, the existence of numerous predators in the waters favored by the native species may indicate that *A. gambiae* is unable to adapt itself to their presence.

In view of the observations made on *A. gambiae* in Africa, to the effect that at the beginning of the "long" rains they take advantage of every bit of open water provided by the rains and increase rapidly in numbers, it is to be expected that the advent of the rainy season at Natal will provide the species with considerable opportunity to spread. In fact, this appears to have taken place during the 1931 rainy season, as in June the species was found at São Bento, 180 kilometers from Natal. A later report (September, 1931) states that Dr. Souza Pinto found *A. gambiae* in thirteen additional localities, all of which, however, are within the 180 kilometer radius of Natal: Municipio of Taipu and village of Taipu, Gamelleira, Poco Branco, Boa Vista, Serra Pellada, Pitombeiras, Baixa Verde (the entire region along the river bank), Municipio of Ceará-Mirim (not in village), Varzea de Dentro, Capella, Itapassaroca, Gravatá and Engenho de Valle (unpublished communication by Dr. Soper).

List of breeding sources found.

The *A. gambiae* breeding zone in Natal may be divided into two areas, (1) the Goitezera valley area, and (2) the section along the railroad tracts. These are shown on sketch map II. Practically all

the anopheline breeding pools found are indicated, both for the native species and for *A. gambiae*.

The Goitezera valley is only about 3 kilometers in length, and herein is the only permanent stream (aside from the tidal Rio Potengy) that occurs within the city limits. Two large ponds at the head of the stream supply it with water. The stone culvert marks the upper limit of *A. gambiae* breeding as found at this time. All the seepage outcrops occur below the culvert.

The following anopheline breeding sources were found in the valley:

1. Lagôa Manoel Phelippe: *A. albitarsis* larvae (27) found along the grassy portions of the margins. Numerous small fish present.

2. A small water hole about 18 inches in depth, well shaded: Only *A. argyritarsis* larvae (82) found.

3. A series of shallow irrigation troughs containing stream water: *A. argyritarsis* (32) and *A. albitarsis* (2) larvae found.

4. Vegetated and non-shaded portions of the outlet of Lagôa Secca (that of Lagôa M. Phelippe dry), also the upper section of the "rio": Three *A. argyritarsis* and twenty-eight *A. albitarsis* larvae found. The "avenida" section of the stream is more or less shaded; only widely scattered *A. argyritarsis* larvae were found here.

5. Spring, cement-lined, shaded, on upper side of stone culvert: No larvae were found.

6. Spring, earth-lined, about 18 inches in depth, unshaded: Ten *A. argyritarsis*, one *A. albitarsis* and one *A. gambiae*.

7. Covered spring: No larvae.

8. Spring, small opening, uncovered: Twenty *A. argyritarsis* larvae found.

9. A series of shallow irrigation troughs, not confluent with each other or with water in the nearby marsh: Rather numerous larvae; 60 examined (32 *A. argyritarsis*, 22 *A. gambiae* and 6 *A. albitarsis*).

10. Water troughs in the same series as the foregoing, but the water confluent with that of the marsh: Few larvae found (12 *A. albitarsis*, 3 *A. argyritarsis*).

10*a*. The last trough in the series: The water is isolated from that of the marsh, but is completely shaded by a palm tree. Only *A. albitarsis* larvae (14) found.

11. Shallow water troughs of seepage water: Twenty-seven *A. gambiae* larvae found.

12. Spring, about two and one-half feet in depth, opening about 18 inches: No larvae found.

13. Marsh adjacent to sites 10, 11, and 12: Eleven *A. bachmanni* and 39 *A. albitarsis*.

14. Pond of more or less open water located within the above-mentioned marshy area: Six *A. tarsimaculatus* and 67 *A. albitarsis.*

15. Very shallow, clear and non-vegetated seepage streams with sandy beds: Numerous larvae; 50 examined, all *A. gambiae.*

BREEDING SOURCES ALONG THE RAILROAD.

Aside from the Goitezera stream, which passes under the railroad near site 16, and the tidal Rio Potengy, all of the water present along the railroad area (i.e. between the station and the bridge crossing the river, 6 kilometers distant from the station) consists of well, seepage, and spring waters and some brackish marshes.

Between the station and the first *A. gambiae* breeding site (number 16), $1\frac{5}{16}$ kilometers distant from the station, there are only deep wells. These were entirely free of *Anopheles* larvae. Also the few wells on the city side of the tracks of the Great Western Railroad are deep and without larvae.

The seepage outcrops and springs occur at intervals along the railroad, chiefly on the river side of the tracks. The *Anopheles* breeding sources found here are as follows:

16. Small shallow pools of seepage water: Moderate numbers of *A. gambiae* (about 100) were found. The first discovery of *A. gambiae* larvae in Brazil was made near this site. At that time, March, 1930, what now constitutes breeding source number 16 consisted of a small reservoir of seepage water. The outlet of the reservoir was used to overflow a small, slightly grassed field. Numerous fish were present in both the impounded water and the outlet stream, but not in the shallow flooded field where thousands of *A. gambiae* larvae were present. After the cause of the malaria in this vicinity had been ascertained, the reservoir was filled with earth. In spite of this, however, a small but constant amount of free water persists on the surface of the fill, sufficient to permit moderate *A. gambiae* breeding. The field, where thousands of larvae were formerly present, was found on this last occasion to be dry save for a tiny stream originating from the filled-in reservoir. Small pockets of water occurred at intervals along the stream but these were without larvae, probably owing to the presence of fish.

17. Small pool in field: Larvae were found here by Davis in May, 1930, but in December the field was entirely dry.

18. A series of about fifteen shallow springs fed by seepage: No fish present. Some were sheltered by small roofed houses, and these were without larvae. The unhoused springs had larvae in varying numbers; one had at least 200.

19. A second series of open springs, occurring on both sides of the tracks: Some had numerous *A. gambiae* larvae.

20. An abandoned spring: *A. gambiae* larvae found here by Davis, May, 1930.

21. A series of seven shallow springs: Two *A. gambiae* larvae found.

This is the last site along the railroad in which *A. gambiae* larvae were found.

22. Excavations in a clay quarry, unshaded: Numerous insect predators, chiefly aquatic Hemiptera, were present in the pools. Six *A. argyritarsis* larvae were found but no *A. gambiae*.

Further investigations made in other sections of Natal where springs, ground pools, and wells are located did not reveal any additional gambiae breeding sources. Search was also made at Ígapo, a small town on the opposite side of the river, and elsewhere in the vicinity of Natal. Although moderate numbers of the native anophelines were present in some of the water collections, no *A. gambiae* larvae were found.

Investigations in other towns and cities. Although *A. gambiae* were not found outside of Natal, the other localities visited are mentioned specifically in order to show their condition during the dry season, and to indicate the types of breeding sources in which the native anophelines were found.

1. Recife, Pernambuco: During the rainy season, there are a number of fresh-water marshes, ponds, streams, etc., about the outskirts and suburban parts of the city, but by the end of the rainy season practically all these have disappeared or have become very foul or possibly have too great an admixture of salt water to permit anopheline breeding. Only one fresh-water area was found, at Jacará, Rua Agua Fria. This was somewhat extensive and consisted of one main stream, several side streams and ditches, and one fairly large pond with marshy margins. Also, there were several nearby surface wells. Only larvae of the common species of *Nyssorhynchus* were found.

2. Cabedello, Parahyba do Norte: Only two water holes were present in the vicinity of the town, both foul. No larvae. Nearly all the houses have wells. The water surface of these is several feet below the ground surface; many are covered, and all are kept stacked with larvivorous fish. No anophelines found.

3. Parahyba, Parahyba do Norte: Of the other cities visited, Parahyba appears to be the most favorable for the propagation of *A. gambiae*. There is an extensive seepage area (at Buriquinha)

which appears highly suitable for the species during the dry season. Only *A. argyritarsis* and *A. albitarsis*, however, were found.

The stream arising from this outcrop flows past the edge of town, and all along its course there are smaller seepage areas, marshes, and a few scattered springs. One spring, with vegetation, had two *A. argyritarsis* larvae. Three other springs without vegetation were also without larvae. *A. albitarsis* and *A. bachmanni* were fairly abundant in the marshy areas.

Several moderately grassed marshes with slightly brackish water, located near the railroad station, contained numbers of *A. albitarsis* (127 collected) and *A. tarsimaculatus* (70) larvae and a few *A. argyritarsis* larvae (8).

There are a number of backyard wells about three kilometers from the station. Nearly all were stocked with fish, but three without fish yielded 22 *A. argyritarsis* larvae.

A fresh-water stream at the Praia de Tambú had a few *A. argyritarsis*, *A. albitarsis*, and *A. bachmanni* larvae.

4. Macahyba, Rio Grande do Norte: The water supply for the town is derived from two main sources, an artesian well and a water-supply house receiving piped water from a large spring area about four kilometers distant. *Anopheles* larvae were found only in the streams arising from the spring and the surrounding marshes. These consisted of 37 *A. albitarsis*, 27 *A. argyritarsis*, and one *A. tarsimaculatus*.

In addition, several water holes and three backyard wells were examined; no larvae were found.

5. Ceará-Mirim, Rio Grande do Norte: A large spring supplies the town. The spring is housed and well stocked with fish. The outlet is heavily choked with vegetation but also has a great abundance of small fish. Fifteen *A. albitarsis* and 14 *A. tarsimaculatus* larvae were collected from the stream.

Six backyard wells were free of larvae; but 10 *A. albitarsis* larvae were found in two water holes, both of which had numerous fish.

6. Touros, Rio Grande do Norte: A large spring, situated in a small town 15 kilometers inland from Touros, gives rise to a stream of good size, which enters the ocean at Touros. The stream affords the main supply of water for the town, but there are in addition a public well, a few surface springs (collecting stream seepage), and two fairly large ponds. About 150 *A. albitarsis* larvae were collected from the stream (which teems with small fish) but the other water collections were without *Anopheles* larvae.

7. Lagos, Rio Grande do Norte: As there are no local springs and only one water hole (impounded water), it is necessary to bring the house water supply to the town by train. No *Anopheles* larvae were found here.

8. Assú, Rio Grande do Norte: Recent rains had produced a moderate stream in the river bed, but the sides were without vegetation. No larvae found.

9. Mossoro, Rio Grande do Norte: Situated 35 kilometers inland on the Rio Mossoro. The chief water supply is obtained from a section called Ocanto, a few kilometers from the main part of the town. Pits have been dug in the sand to a depth of six to eight feet, and the seepage collects in sunken wooden boxes. About 30 such "springs" are located here. All were examined; but though some swarmed with *Culex* larvae no anophelines were found.

The nearby river shore was examined, as was also the portion of the river near the center of town. No anophelines found. Recent rain pools were likewise without anophelines.

10. Macau, Rio Grande do Norte: Near the mouth of the Rio Assú, 15 kilometers inland. There are no bodies of fresh water near the town; therefore it is necessary to import the town's water supply. This is brought by boat from a source 35 kilometers distant and is stored in large completely covered cement tanks provided with spigots. A few shallow wells of brackish water on the outskirts of the town were without larvae.

11. Nova Cruz, Rio Grande do Norte: The town is supplied with water from springs situated in a nearby valley. Most of the overflows and streams are heavily shaded by trees, etc. Some exposed pools, chiefly in cultivated fields, contained a few *A. argyritarsis* larvae.

12. Lagôa Papary, Rio Grande do Norte: The Rio Papary was densely covered with water hyacinth. A few *A. albitarsis* and *A. bachmanni* larvae were found.

13. Areis, Rio Grande do Norte: The spring located here is housed. No larvae found in the outlet.

14. Goyaninha, Rio Grande do Norte: The Rio da Ponte, a small stream, furnishes the town with water. One *A. argyritarsis* and 15 *A. albitarsis* larvae were found along the margins.

15. Fortaleza, Ceará: About 40 small wells and surface springs situated in different sections of the city were searched, but only small numbers of *A. argyritarsis* larvae were collected. About 200 larvae of the same species were obtained from a stream and an adjoining marsh.

16. Acarapé, Ceará: The reservoir located here appeared to be entirely without mosquito larvae. No anophelines were found in a nearby stream.

17. Quixada, Ceará: *A. albitarsis* larvae were found in some abundance in the irrigation ditches.

18. Therezina, Piauhy: Only *A. albitarsis*, *bachmanni*, and *tarsimaculatus* were found here.

19. São Bento, Maranhao: *A. tarsimaculatus* only was found here.

20. Belém, Pará: No evidence of the occurrence of *A. gambiae* was found here.

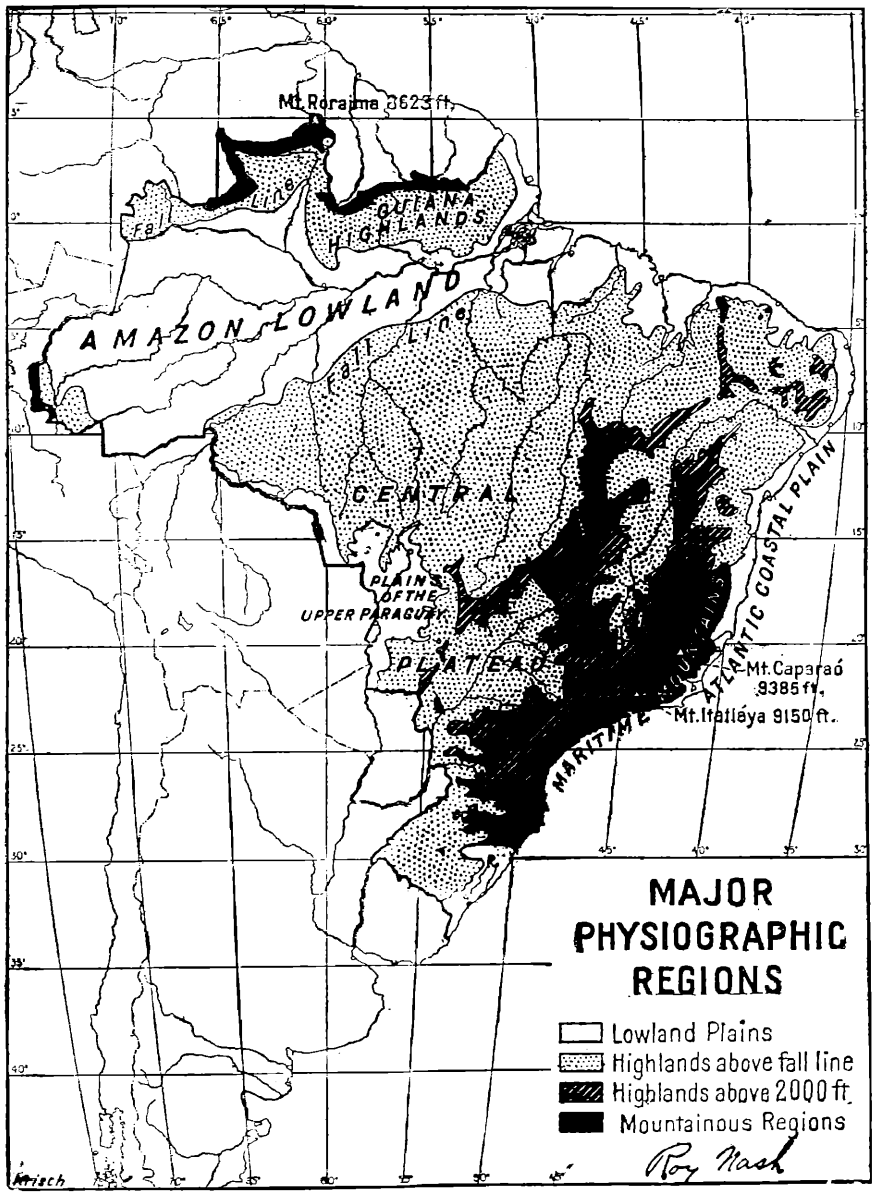
General characteristics of Northeastern Brazil. Map III shows the general extent of the coastal plain of Northeastern Brazil, while map IV indicates the general distribution of rainfall. The chief feature of the northeastern section is the centralized large desert-like and semi-arid region. The aridity is made the more marked by the prolonged dry season, lasting from eight to ten months of the year or longer (according to locality). However, the fact that the rains are mainly confined to a few months makes it possible for large lakes to form, and even large areas become generally flooded. Upon the advent of the dry season these temporary water collections are greatly diminished in size or disappear completely. This is particularly the case in the interior of the states of Ceará, Rio Grande do Norte, Parahyba, Pernambuco, and northern Bahia.

In general, the rainy season for this region occurs in the months of March to July. At the time of the survey (December to January) but few remnants of the past season's rain-water supplies were seen. A number of large but widely scattered springs, however, were observed in the interior of Rio Grande do Norte, and these give rise to small but permanent streams. Several deep lakes occur in the more southern parts of the state, but it is said that only one occurs in the northeastern part, about 15 kilometers from Touros.

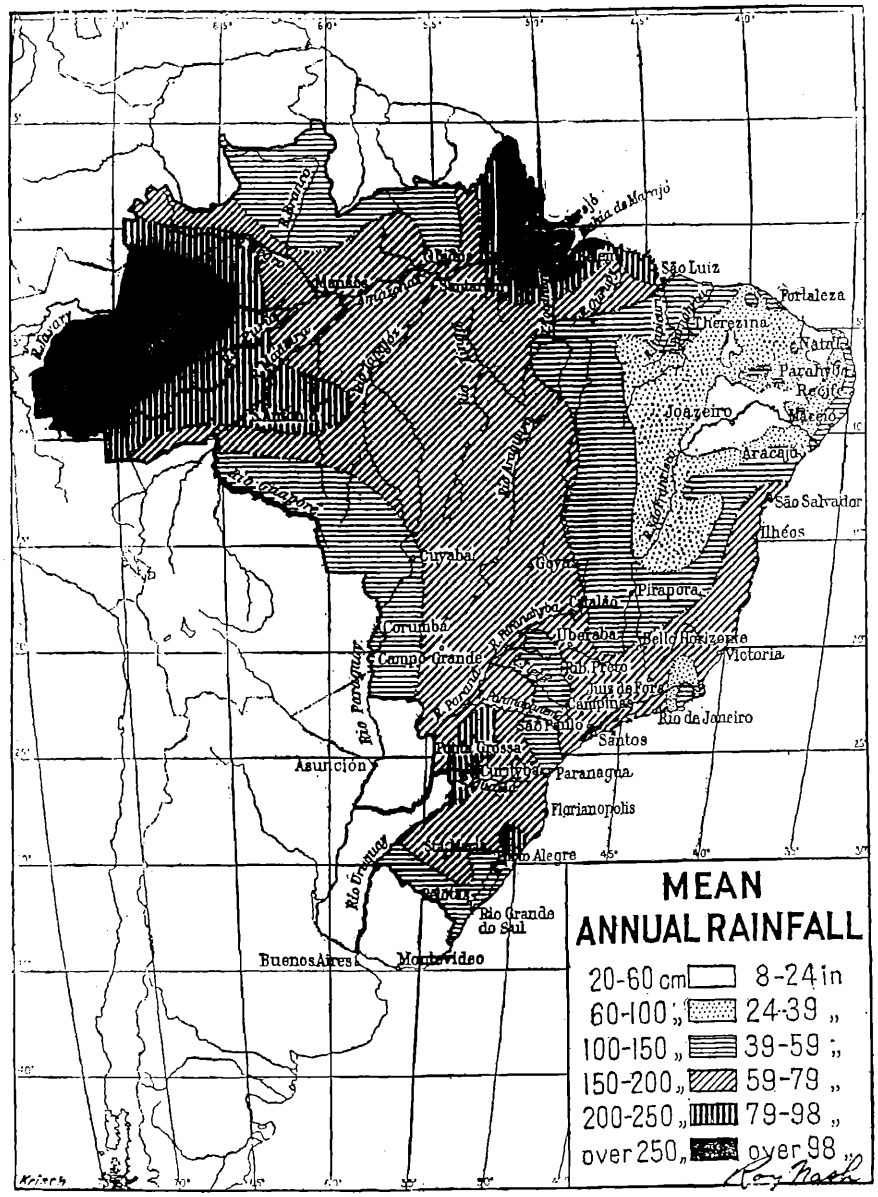
The fact that typical seepage outcrops were found only in the cities of Natal and Parahyba would indicate that such are of rather rare occurrence in the region in general.

In a large part of the region, dry farming is necessarily the chief agricultural method. In the interior of Ceará, several large reservoirs with extensive irrigation systems have been constructed.

In view of these conditions as a whole, it would seem probable that, if *A. gambiae* were to succeed in extending its range to other parts of northeastern Brazil, there would be great areas in which it



Map III. The main physiographic regions of Brazil. Reproduced from *The Conquest of Brazil*, by Roy Nash, Harcourt, Brace, and Company, 1926.



Map IV. Mean annual rainfall of Brazil. Reproduced from *The Conquest of Brazil*, by Roy Nash, Harcourt, Brace, and Company, 1926.

could not permanently establish itself and therefore its distribution here would tend to be highly localized.

Finally mention should be made of the possible spread of the species to other parts of Brazil by artificial means.

An average of two or three large coastwise vessels, which regularly travel from one end of the Brazilian coast to the other, arrive at the larger cities every week. In addition, smaller boats touch at many of the lesser ports. It is therefore possible that boats may serve as distributors of *gambiae* to other parts of the country. Railroads and automobiles may help its spread to interior parts. Three airplane lines are now in operation along the greater part of the coast. These may likewise prove of importance as possible agents of distribution.

Rainfall and gambiae breeding.

From the review given of *A. gambiae* in Africa and the results of the dry season survey made of the species in Brazil, it is apparent that rainfall has a very important bearing on the biology of the species.

Reports are available of a few observations which are of particular importance in bringing out this rather direct relation. Through them it is possible to give a general indication of the amount of rain that is required to form rainpools of sufficient permanence to permit *A. gambiae* breeding. Data of this nature should prove of value for regions having a limited wet season, such as is the case in Northeastern Brazil.

Observations made at Lagos, West Africa. The following has been abstracted from a paper by Barber and Olinger (1931): *A. costalis* (*gambiae*) will develop from egg to adult in seven or eight days, probably seven days in ponds or shallow pools exposed to the sun. This permits them to take advantage of very temporary collections of water. At Lagos, a dry season occurs which is especially marked in December, January, and February; and there is a wet season culminating in June. There is a remission of rainfall during August, which in 1930 was more marked than in average years. In that year we could properly speak of a dry season in August (16 mm.) followed by a period of "little rains" (September, 67 mm.); very high rains in October (330 mm.) and very little in November (47 mm.) and December (40 mm.). During this year, the anopheline density in the vicinity of Lagos was very high in the rainy period, May to July, 1930, then fell rapidly in August. The variations for the rest of the year are of less significance.

Observations made in Brazil. Extended observations dealing with the relation of rainfall to *A. gambiae* breeding in Brazil are yet to be

made. However, the general fitness of Northeastern Brazil (the larger portion of which is a hot, open, generally flat region with loose or light soil) for *A. gambiae* breeding will perhaps be made clearer by considering the breeding habits of the mosquitoes belonging to the genus *Psorophora* and the subgenus *Ochlerotatus* (*Aëdes*), which occur in this general region. The larvae of the species of these groups are typically rainpool breeders. The eggs are laid in depressions in the ground, where they await (even throughout an entire dry season) the occurrence of rain. Subsequent development is rapid, requiring five to seven days.

During two years spent in Salvador, Bahia, the writer made frequent trips to certain favorable localities to seek the larvae. It gradually became evident that there is usually but one large brood of these species a year and that it appears shortly after the first heavy rains of the wet season.

Occasionally during the latter part of the dry season there are heavy showers, but, as a rule, the rainpools disappear within two or three days. This is probably due chiefly to the excessive dryness of the loamy soil, which quickly absorbs it. Even 24-hour rains of from two to three inches quickly disappear. However, one very unusual rain of seven inches in 24 hours, occurring in late November, 1930, was sufficient to produce a brood, but the rainpools had entirely disappeared in about seven days' time.

Observations made in other parts of the mid-coastal states show that there, too, the chief breeding season for these species is a very limited one, restricted almost entirely to the early rainy season.

As intimated above, the species of *Psorophora* and *Ochlerotatus* are able to survive the prolonged dry season because of the ability of the eggs to resist desiccation. But the anophelines, whose eggs lack this ability, must, in tropical countries, depend upon the process of continuous breeding to maintain their existence, or else the adults must be able to enter into at least a partial state of aestivation during the dry season.

If *A. gambiae* is primarily dependent upon frequent rainfall for major production (as apparently is the case) and, lacking this, is forced to breed in waters arising from seepage outcrops (or more or less similar types of water), then it is probable that the species can survive the dry season only in special localities which chance to have favorable breeding conditions. As the middle coast states cannot support prolonged breeding conditions for the species of *Psorophora* and *Ochlerotatus*, it probably cannot do so for *A. gambiae*. It should be

borne in mind, however, that *A. gambiae* is more catholic as regards choice of larval habitat than are the Aëdine groups here noted, and that it may discover dry-season breeding sources other than the ones above recorded. The extensive reclamation projects in the interior (chiefly in Ceará) may further provide *A. gambiae* with opportunities for dry-season breeding.

Comparison of the wet and dry seasons of tropical Africa and Northeastern Brazil. According to the foregoing observations made in Bahia, it would appear that, as a rainfall of 178 millimeters (seven inches) is required to form pools of sufficient permanence to permit a brood of mosquitoes to develop, this figure should indicate the distinction between the wet and dry seasons, so far as mosquito breeding is concerned.

It is well known, however, that the permanence of rain water supplies, aside from the influence of such primary factors as frequency and quantity, is dependent upon a number of secondary factors: topography, soil texture, plant cover, rate of evaporation; and also upon certain artificial factors such as impounding, extent and character of irrigation, etc. These secondary factors, as well as the primary ones, will vary considerably from region to region.

Although a rainfall of 178 millimeters per month is taken as the criterion in the following table to show the extent of the two seasons, it can only be regarded as a tentative figure, the chief value of which will be to indicate the presence and influence of secondary factors.

The fact that several of the African localities (in which *A. gambiae* occurs) are entirely without a wet season, in the sense here implied, indicates very clearly that the species is not always dependent upon rainfall. Observations on the occurrence of *A. gambiae* at Khartoum (following the table) show clearly the influence of the character of the soil on the breeding of the species.

Observations made at Khartoum, Sudan. This locality is of particular interest, as it has the least rainfall of any included in the table, and also is known as one of the hottest localities in the world.

Mention has already been made of Balfour's (1912) observations that both adults and larvae of *A. gambiae* are sometimes brought to Khartoum by the river boats. The same author in a later paper (1913) writes:

> Last year (1912) was especially interesting, for, so far as can be told, the climatic conditions favored a prevalence of malaria, and Khartoum, which has enjoyed a very considerable immunity in past years from the disease, did not altogether escape being visited by a small epidemic following the occurrence of a short but heavy rain-

TABLE 1.

Precipitation during dry and wet seasons.
(Localities arranged according to total rainfall.)

Locality	Total mm. per year	*No. of months with less than 178 mm. per month	Total mm. for these months	Average per month (mm.)	No. of months with more than 178 mm. per month	Total mm. for these months	Average per month (mm.)	Month with highest record
Khartoum (Af.)	145.0	12	145.0	12.0	0			Aug., 66 mm.
Bulawayo (Af.)	600.0	12	600.0	50.0	0			Jan., 152
Accra (Af.)	683.0	11	506.0	46.0	1	178.0	178.0	May, 140
Quixeramobim (B.)	950.0	10	510.0	51.0	2	442.0	221.0	Apr., 227
Dar-Es-Salaam (Af.)	1075.0	10	600.0	60.0	2	480.0	240.0	Apr., 300
Bathhurst (Af.)	1209.0	9	180.0	20.0	3	1029.0	343.0	Aug., 498
Natal (B.)	1410.0	8	528.0	66.0	4	884.0	221.0	June, 317
Entebbe (Af.)	1473.0	10	1010.0	101.0	2	462.0	231.0	Apr., 247
Recife (B.)	1653.0	8	612.0	76.5	4	1040.0	260.0	May and June, 280
Lagos (Af.)	1819.0	8	616.0	77.0	4	1204.0	301.0	June, 472
Gazi (Af.)	1840.0	7	815.0	116.5	5	1025.0	205.0	Sept. and Nov., 216
Bahia (B.)	1876.0	8	936.0	117.0	4	940.0	235.0	May, 262
Bélem (B.)	2362.0	7	812.0	116.0	5	1555.0	311.0	Mar., 380
Freetown (Af.)	3993.0	6	312.0	52.0	6	3678.0	613.0	Aug., 929

* These records are for consecutive months, except the ones for Lagos and Gazi (see table in the appendix). In the case of Natal, the month of May has but 152 mm. As this record occurs between months having more than 178 mm., it is here considered as belonging to the wet season.

fall. Moreover, the town is undoubtedly suffering from the fact that until recently very little attention was paid to the irrigated areas along the Nile.

The surface soil is of such nature that, when thoroughly soaked, it takes on a clay-like consistency and, where there are depressions, presents ideal conditions for the formation of pools. Heavy rain showers [occurring in August] following each other at brief intervals converted some of these pools into miniature lakes, great stretches of land being under water. As there was no drainage, these persisted for lengthy periods.

In this case, these conditions resulted from only 98.1 millimeters of rain, falling over a period of eleven days, which is but about one-half of the amount taken as the standard rainfall for regions having loose or light soil.

Observations made at Stanleyville, Belgian Congo. Schwetz (1930) claims that at Stanleyville there are no marked wet and dry seasons, save for two comparatively light wet seasons occurring in December to February and June to July (see appendix, records given for Gazi, a substitute station for Stanleyville). As the rainfall occurring during these particular months is less than 178 millimeters, they have been classified as dry season months in the foregoing table. The author states, however, that when the river (Congo) is low, the larvae of *A. gambiae* are found in numbers in the stone recesses of the river bed. (This would indicate a change of habitat according to season.)

Dry-season breeding sources as observed in Africa. Lamborn (1925) states that in Nyasaland the River Shire and its immediate neighborhood form the main permanent breeding sources for *gambiae.*

Symes (1928) writes: "During the dry season its [*gambiae*] numbers decrease in proportion to the drying up of the shallow surface pools; but though it can be found throughout the year in pools remaining in stream beds and the larger excavations, there appears to be no appreciable increase at the time of the short rains in November."

Patton and Evans (1929) state: "In Freetown, during the dry season, the pools left in the stream beds form the chief breeding places of *gambiae.*"

Barber and Olinger (1931) remark: "The only permanent dry-season breeding place of *gambiae* we could find [at Otta Town] consisted of small pools formed in the laterite bed of a ravine situated at the edge of the town."

Summary and conclusions.

In March, 1930, the African malarial vector, *Anopheles* (*Myzomyia*) *gambiae* Giles, was discovered breeding in the city of Natal, Rio Grande do Norte, Brazil. Its presence here appears to have been made possible either by aircraft or by means of the rapid mail boats, which require but four days to make the trip from Dakar, Africa, to Natal.

Shortly after its discovery in Natal, there occurred an unusually severe outbreak of malaria in the vicinity of its breeding grounds.

Investigations made nine months after it was first found, covering the coastal area of Brazil from Recife, Pernambuco, to Bélem, Pará, indicated that the species was still restricted to Natal. The fact that in certain parts of Africa which have marked wet and dry seasons the species is said practically to disappear during the latter may, at least in part, explain its absence outside of Natal.

The dry season in Natal lasts from about the first of August to March or April. In December, when the survey was made, there were in the *A. gambiae* infested zone but two general types of water which were breeding anophelines. One type consisted of stream, pond, and marsh waters, the other of seepage outcrops and shallow pools and springs fed by seepage. In the first, only native anophelines (four species of *Nyssorhynchus*) were found; while *A. gambiae* larvae occurred only in the latter. The native species were found in only a few of the seepage water supplies and such were closely adjacent to a marshy area in which they (the native species) were fairly abundant.

This distinction in choice of larval habitat may indicate a fundamental difference in the biology of the African species as compared with that of the native species. It is probable, however, that this distinction is so definitely marked only during the late dry season, when, owing to the lack of intermediate types of water, the different species are forced to choose the habitat most favorable to their development. Also the fact that predators (fish and insect) were very abundant in the stream, pond, and marsh waters, and generally absent in the seepage collections, may indicate that the reason for the absence of *A. gambiae* larvae in the former is due to an ability on their part to adapt themselves to the Brazilian larval enemies.

Certain other facts relating to *A. gambiae* in Africa apparently afford clues to indicate how the species will adapt itself to its new environment.

1. Owing to the generally favorable temperature throughout the year in tropical Africa, and to the marked difference between the wet and dry seasons in many regions, moisture, rather than temperature, is the more important factor.

2. In the regions having marked wet and dry seasons, *A. gambiae* is known to be chiefly a wet-season breeder.

3. Development from egg to adult requires but seven to eight days. This permits them to take advantage of very temporary water collections.

4. Although the larvae have been found under a great variety of conditions, they thrive best in shallow rainpools and other small collections such as occur in borrow pits and pooled collections in and along the sides of irrigation ditches and small streams.

5. Their breeding pools are almost invariably well exposed to sunlight.

6. Artificial reservoirs and water courses greatly augment the breeding grounds in the vicinity of towns, and these, owing to the

more permanent nature of the water supplies, may afford the larvae dry-season breeding conditions.

With these facts, and others relating to the character of the coastal states of Brazil, certain direct possibilities may be indicated.

1. Northeastern Brazil (except Maranhão and Pará) has a prolonged dry season. The region is generally flat with a loose or light soil, and is characterized by a centralized desert and semi-arid region (map IV). During the dry season the water collections, directly dependent upon rainfall, are greatly diminished in size and number, while the permanent waters are usually widely scattered. On the basis of certain observations made in Bahia, a rainfall of about 178 millimeters (24 hours) is required to form pools of sufficient permanence (about seven days) in loamy soil to permit a brood of mosquitoes to develop. This figure is subject to variation according to frequency of rains and character of soil, etc., but is believed to be generally applicable for Northeastern Brazil. Such rains usually occur only during the main rainy season. It is to be expected that the rainy season will afford the chief opportunity for *A. gambiae* to spread in this particular region. Such appears to have been the case in 1931, as during the rainy season it was found 180 kilometers distant from Natal. But, owing to the general scarcity of permanent water supplies, and should the character of larval habitat as found in Natal prove of significance, it is to be expected that the distribution of *A. gambiae* in Northeastern Brazil will remain highly localized, probably occurring chiefly in the vicinity of towns and cities which are usually located in the vicinity of such water supplies. [*Note:* During the survey, typical seepage outcrops were found only in Natal and Parahyba. This indicates that they are of rather rare occurrence in the region at large. Very probably, however, the species is capable of utilizing other types of dry-season water supplies.]

2. Regions of higher rains and more prolonged wet seasons occur in the northern coastal states (Maranhão and Pará) and in certain localities south of northern Bahia (see appendix). Should the species arrive in these areas, it will probably find permanent breeding sources. Considerable transportation facilities are afforded by the coastwise vessels, and the coastal airplane traffic may afford additional opportunities for spread. Trains and automobiles may be the means of conveying the species to the interior of the coastal states.

3. Finally, the fact that the larvae occur chiefly in sun-exposed waters indicates the danger that would arise, should the species arrive in forested regions, from indiscriminate land clearing.

Bibliography.

BALFOUR, A.
1912. Mosquitoes and river vessels. Lancet, *1*, 1048–1051.

BALFOUR, A.
1913. A year's antimosquito work at Khartoum. Journ. Trop. Med. and Hyg., *16*, 225–232.

BARBER, M. A., AND OLINGER, M. J.
1931. Studies on malaria in Southern Nigeria, with an appendix by Persis Putnam Ann. Trop. Med. and Parasit, *25*, nos. 3 and 4, 461–508.

BARBER, M. A., RICE, J. B., AND BROWN, J. Y.
1932. Malaria studies on the Firestone Rubber Plantation in Liberia, West Africa. Amer. Jour. Hyg., *15*, 601–633.

BAUVALLET, H.
1928. Essai de lutte antilarvaire par l'emploi de poudre larvicide dans une zone inondée du Bas Dahomey. Bull. Soc. Path. exot., *21*, 323–325.

COVELL, G.
1931. The present state of our knowledge regarding the transmission of malaria by the different species of anopheline mosquitoes. Records of the Malaria Survey of India, *2*, 1–48.

DAVIS, N. C.
1930. A note on the malaria-carrying anophelines in Bélem, Pará, and in Natal, Rio Grande do Norte, Brazil. Revista di Malariologia, Anno *10*, 1–11.

GARNHAM, P. C. C.
1927. Malaria in Kisumi, Kenya. Journ. Trop. Med. and Hyg., *32*, 207–216, 221–231.

INGRAM, A., AND DE MEILLON, B.
1929. A mosquito survey of certain parts of South Africa with special reference to the carriers of malaria and their control. Part I. Publ. South African Inst. Med. Res., no. 22, 1–81.

INGRAM, A., AND DE MEILLON, B.
1929. As above, but Part II, 4, 83–170.

LAMBORN, W. A.
1925. The seasonal habit of the common anophelines of Nyasaland. Bull. Ent. Res., *15*, 361–376.

PATTON, W. S., AND EVANS, A. M.
1929. Insects, ticks, mites, and venomous animals of medical and veterinary importance. Part I—Medical.

SCHWETZ, J.
1930. Les moustiques de Stanleyville. Ann. Soc. belge Med. trop., *10*. 25–65.

SEGUY, E.
1930. Notes sur les moustiques III. Encyc. ent., sér. B, II. Dipt. 5, 177–178.

SHANNON, R. C.
1930. O apparecimento de uma especie africana de anopheles no Brasil. Brasil Medico, *44*, 515–516.

SIMPICH, F.
1931. Skypaths through Latin America. National Geographic Magazine. January, 1931.

SYMES, C. B.
1926. The mosquito problem in Kenya. Kenya Med. Jour., *3*, 93–103.
1927. Section of Medical Entomology. Rep. Med. Res. Lab. Kenya, 1926, 23–28.
1928. Notes on anopheles and malaria in Kenya. Kenya and East African Med. Jour., *5*, 138–183.
1930. Anophelines in Kenya. Kenya and East African Med. Jour., *7*, 2–11.
1931. Report on anophelines and malaria in the Trans-Nzoia District. Kenya and East African Med. Jour., *8*, 64–77; 108–121.
THOMSON, J. G.
1929. Endemic and epidemic malaria in Southern Rhodesia. Proc. R. Soc. Med., *22*, 1051–1058.

APPENDIX

Rainfall records of selected stations in Africa and Brazil.

Owing to the importance of rainfall in connection with the biology of *Anopheles gambiae,* and the general inaccessibility of extended records, tables giving the mean monthly and annual precipitation of a number of stations in Africa and Brazil have been prepared for inclusion here.

These records have been obtained from the Weather Bureau (Washington, D. C.) through the kindness of Mr. W. W. Reed.

Mean monthly and annual precipitation of selected stations in Africa.

(Millimeters.)

Locality	Years obs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Accra, Gold Coast	33	17.0	25.0	45.0	92.5	140.0	178.0	42.5	15.0	25.0	51.0	37.5	17.5	683
Bathhurst, Gambia	37	0.0	0.0	0.0	0.0	4.0	75.0	277.0	498.0	255.0	93.0	5.0	2.0	1209
Bulawayo, Rhodesia	27	152.0	101.0	80.0	16.0	7.5	1.0	1.0	1.0	2.6	23.0	83.0	127.0	600
Dar-Es-Salaam, East Africa	16	83.0	54.0	122.0	300.0	188.0	28.0	42.0	28.0	29.0	32.0	72.6	95.0	1075
Entebbe, Uganda	21	65.8	91.0	147.0	247.0	215.5	130.0	75.0	76.2	76.4	88.5	127.0	130.0	1473
Freetown, Sierra Leone	46	11.0	7.5	27.5	101.0	292.0	508.0	904.0	929.0	723.0	319.0	129.5	35.4	3993
* Gazi, Belgian Congo	12	67.0	98.0	132.0	211.0	183.0	140.0	144.0	130.0	216.0	200.0	216.0	101.0	1840
Khartoum, Sudan	24	0.0	0.0	0.0	0.0	3.0	8.0	45.0	66.0	18.0	5.0	0.0	0.0	145
Lagos, Nigeria	29	25.5	51.0	93.7	145.0	264.0	472.0	275.0	70.0	130.0	192.0	65.0	20.0	1819

* Records for Stanleyville, Belgian Congo, not available. The station of Gazi, situated in the general region, is therefore substituted.

Mean monthly and annual precipitation of selected stations in Brazil.
(Millimeters.)

Locality	Years obs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Manaos, Amazonas	15	240.	225.	235.	231.	172.	111.	66.	30.	50.	114.	130.	210.	1819
Porto Velho, Amazonas	6	431.	360.	455.	234.	128.	40.	15.	53.	80.	213.	286.	406.	2682
Bélem, Pará	29	294.	330.	380.	310.	240.	170.	157.	113.	84.	70.	68.	152.	2362
Goyaz, Goyaz	6	307.	279.	290.	127.	10.	12.	0.2	11.	42.	120.	220.	266.	1686
São Luis, Maranhão	10	185.	260.	421.	365.	302.	140.	160.	40.	13.	8.	38.	76.	2000
Paulista, Piauhy	8	105.	101.	109.	76.	5.	1.0	1.5	4.	5.	28.	67.	55.	556
Therezina, Piauhy	7	232.	160.	262.	244.	101.	23.	8.	20.	10.	20.	40.	116.	1238
Fortaleza, Ceará	72	83.	177.	300.	342.	244.	119.	53.	28.	17.	13.	15.	38.	1430
Quixeramobim, Ceará	30	78.	127.	215.	228.	146.	67.	21.	12.	2.	2.	12.	18.	950
Macau, Rio Grande do Norte	15	355.	140.	167.	132.	101.	40.	37.	18.	10.	3.	5.	13.	721
Natal, Rio Grande do Norte	14	59.	120.	142.	220.	152.	317.	195.	122.	28.	12.	13.	26.	1410
Fernando de Noronha	9	362.	111.	182.	248.	220.	114.	56.	33.	8.	7.	7.	15.	1056
Soledade, Parahyba	8	35.	60.	91.	63.	35.	45.	33.	20.	5.	15.	5.	3.	409
Recife, Pernambuco	47	52.	83.	164.	216.	280.	280.	266.	162.	67.	26.	27.	30.	1653
Maceio, Alagôas	10	76.	90.	190.	145.	345.	284.	236.	172.	109.	43.	28.	57.	1778
Aracajú, Sergipe	9	38.	45.	106.	86.	168.	130.	119.	68.	40.	63.	23.	58.	945
Caetite, Bahia	11	140.	84.	81.	65.	15.	11.	9.	5.	25.	70.	130.	152.	787
Salvador, Bahia	11	82.	122.	140.	250.	262.	245.	185.	120.	82.	117.	119.	152.	1876
Ilheos, Bahia	11	202.	226.	217.	264.	224.	171.	146.	129.	150.	91.	188.	153.	2161
Belle Horizonte, Minas Geraes	10	330.	228.	162.	70.	16.	14.	10.	23.	27.	140.	208.	279.	1511
Rio de Janeiro	75	127.	114.	135.	111.	79.	58.	42.	45.	65.	84.	101.	140.	1100
Therezopolis, Rio	6	323.	263.	337.	163.	96.	68.	55.	104.	137.	272.	342.	373.	2534
Rio Doce, Espirito Santo	12	114.	73.	170.	126.	102.	89.	60.	84.	79.	132.	143.	185.	1358
São Paulo, São Paulo	31	230.	216.	156.	75.	72.	56.	34.	53.	87.	114.	133.	192.	1418
Santos, São Paulo	24	300.	241.	345.	214.	162.	178.	114.	123.	142.	182.	200.	248.	2445
Paranagua, Parana	10	269.	258.	125.	88.	98.	56.	76.	138.	167.	141.	208.	230.	1850
Therezopolis, Santa Catharina	10	248.	235.	195.	96.	43.	110.	86.	110.	223.	116.	127.	119.	1704
Porto Alegre, Rio Grande do Sul	15	106.	85.	94.	113.	100.	123.	109.	130.	113.	76.	79.	101.	1229
Cuyaba, Matto Grosso	25	248.	211.	211.	101.	56.	8.	5.	30.	50.	113.	150.	206.	1389