

TOPOGRAPHY OF LAND IN RELATION TO MALARIA.

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Many species of *Anopheles* are specialised in regard to their breeding habitats and are adapted to breed in certain types of breeding places. The distribution would, therefore, be determined by the availability of the type of breeding place suitable for the particular species. Consequently, in a country with different topographical regions, the anopheline fauna shows considerable variation. The species responsible for the transmission of malaria would also differ in the respective regions and the problems connected with the control of malaria would, therefore, differ with the areas concerned.

The province of Bengal, which extends from the Himalayas to the sea, includes different types of country: the mountains, the foot-hill region, the dry undulating area, the deltaic area and the mangrove area. Barring certain species such as *Anopheles subpictus*, *A. vagus*, *A. annularis*, *A. barbirostris* and *A. hyrcanus*, which are more or less widely distributed, the other species have a restricted distribution.

MOUNTAINOUS AREA.

The mountainous areas afford little opportunities for mosquito breeding; the nature of the country is such that with the exception of rain pools, small streams and seepages, there are few breeding places. The characteristic anophelines of this region are *A. gigas*, *A. lindesayi*, *A. aikenii*, *A. willmori* and *A. annandalei*. Other species, such as *A. maculatus* and *A. minimus* found commonly in the foot-hill region lower down, are also occasionally met with. There is very little malaria in the hills because, besides the lack of extensive breeding grounds for *Anopheles* and the sparseness of the species capable of transmitting malaria, the weather conditions, which are temperate, are adverse for the extensive incidence of malarial infection and for the transmission of the infection.

SUB-MONTANE REGION.

In contrast with the mountainous region, the foot-hill area has a rich anopheline fauna and a high incidence of mosquitoes. Numerous seepages and streams occur in this area which flow continuously for nearly six months in the year. They are fed by the subsoil water in the hills higher up which escapes as seepages and springs in the sub-montane region. These streams form the chief breeding places of the Anophelines in this region which breed

chiefly in running water. The species of *Anopheles* occurring in this area are *A. minimus*, *A. maculatus*, *A. aitkeni*, *A. insulaeflorum*, *A. annandalei*, *A. kochi*, *A. leucosphyrus*, *A. majidi*, *A. jamesi* and *A. karwari*. In addition to these, which are characteristic of this region, we have several other species such as *A. splendidus*, *A. tessellatus*, *A. culicifacies* and *A. theobaldi* which are found in the lower regions as well.

This area was at one time extensively covered with a dense tropical rain forest. It has since been cleared of the forest and the land is mostly under tea cultivation. The land is very suitable for tea cultivation as there is a heavy rainfall, the drainage is rapid and the soil is fertile. The high-lying lands are planted with tea while the low-lying marshy areas are cultivated for rice.

The conditions here are favourable for a high incidence of malaria. There occurs an intensive breeding, during the wet season, of species which are highly susceptible to malarial infection in addition to conditions in the human population which are associated with what is known as 'tropical aggregation of labour.'

The clearing of the forest in this region brings about a marked change in the anopheline fauna. In dense forests the species found breeding are *A. aitkeni*, *A. insulaeflorum*, *A. barbirostris* and *A. leucosphyrus*; when the forest is cleared, these species are replaced by species like *A. maculatus* and *A. minimus* which often breed in enormous numbers. These observations suggest that the clearing of the forest brings about a suppression of the forest species, which are not concerned with the transmission of malaria, and offers facilities for the output of harmful species of *Anopheles*.

DRY PASTURAL REGION.

In this region the rainfall is low. The area is generally undulating with a soil composed of laterite or a mixture of clay and sand. It is traversed by small streams which are dry during summer. There are vast stretches of barren land covered with scrub jungle, dwarfed trees and grassy wastes.

The anopheline fauna of this region is different from that of the submontane region. *A. culicifacies* is the predominant species; others such as *A. theobaldi*, *A. listoni*, *A. pallidus*, *A. stephensi* and *A. splendidus* are characteristic of this region. Wells, which are frequently the source of water supply in this region, breed several species of *Anopheles*, e.g., *A. fluviatilis*, *A. varuna*, *A. culicifacies* and, less frequently, *A. stephensi*.

This region has little malaria. The occurrence of malaria is localised in a few areas where greater opportunities are offered for *Anopheles* breeding. Such conditions are produced in different ways. Streams are frequently impounded for irrigation and for water supply. The sides of hills and beds of streams are converted into terraced rice fields. Wells are sunk for water supply. Another factor is the subsidence of land in colliery districts and the interference with the natural drainage. All these factors offer increased facilities for *Anopheles* breeding and thus increase the incidence of malaria.

In this region, areas with a high subsoil water show a higher incidence of malaria than areas with a lower subsoil water level. This, as will be seen later, is contrary to what happens in deltaic areas. The years with a heavy rainfall have a comparatively higher malaria incidence than years with a low rainfall. In this point also, these dry areas differed from the deltaic areas where the contrary was found to prevail.

DELTAIC REGION.

This region is the delta formed by the two rivers, the Ganges and the Brahmaputra. It is now traversed by the beds of successive channels into which the Ganges distributed itself from time to time. Owing to various causes, many of the channels in the western section of this region have gone into decay while those in the eastern section are alive. The latter area is subject to extensive flooding during the rainy season while the western section is not subject to such flooding. The main causes for the decay of the channels in the western part of the delta appear to be (1) the silting up of the heads of these channels, (2) obstruction to the overflow of spill water from the rivers by the construction of embankments, and (3) the attempts to keep the rivers to a particular course by the construction of high banks. The western region, where the distributaries of the River Ganges are in a moribund condition, has highly endemic malaria while, on the other hand, the eastern section is practically free from malaria.

We find also that in the deltaic region areas with a high subsoil water level have little or no malaria while those with a low subsoil water level are intensely malarious. Contrary to what has been observed with regard to the pastoral zone, years with heavy rainfall are characterised by a low incidence of malaria while those with a low rainfall have a high malarial incidence.

The species of *Anopheles* found in this area are *A. stephensi*, *A. pallidus*, *A. philippinensis*, *A. culicifacies*, *A. varuna*, *A. pseudojamesi*, *A. tessellatus* and *A. theobaldi*. Species like *A. stephensi*, *A. culicifacies*, *A. pallidus* and *A. philippinensis* are characteristic of the drier parts of the region. *A. stephensi* breeds in wells in the dry areas.

ESTUARINE REGION.

This region is situated on the sea board and consists of a mangrove area subject to flooding by saline tides. This region was at one time completely covered with dense mangrove forests but now a large part of it has been cleared of forests and the islands embanked all round to prevent the ingress of saline tides. In areas where such clearing and embanking have not been carried out anophelines do not breed, while in the cleared and embanked areas *A. sundaricus* is very common and causes a high incidence of malaria.

This species of *Anopheles*, although quite characteristic of the mangrove area, has in recent years been observed to invade the interior of the delta. This is evidently due to changes occurring in these areas, and also to facilities

offered in the transport of mosquitoes by boats from the estuarine area into the interior along the river routes.

CONCLUSIONS.

We have seen how in different parts of Bengal the anopheline fauna varies considerably. Although we have a few species which are found all over Bengal, several species have a restricted distribution. This is largely due to the selective habitats of the different species.

These studies also bring out the interesting fact that in several of the regions of Bengal the operations of man are largely responsible for the increased facilities for the breeding of the harmful species of *Anopheles*. In the virgin state, it is probable that the incidence of malaria was comparatively low. In many of the regions, the high incidence of malaria is largely the result of human operations. The occurrence of malaria in the sub-montane regions is probably largely due to the extensive forest clearance operations for the purpose of tea and rice cultivation. The clearance of the forests have eliminated the harmless species of *Anopheles* and have offered facilities for the intensive breeding of the harmful species. In the pastoral region with little or no malaria, the localised foci are the results of attempts to alter the natural conditions, as for example, creating terraced plots for rice cultivation, colliery operations, impounding of rivers and the digging of wells for water supply. In the deltaic area, the construction of embankments to prevent the flooding of the land by rivers in flood or by the tides largely contribute to the establishment of endemic conditions. In the estuarine area, the clearing of the forests and the prevention of the tidal flushing are responsible for the establishment of malarial endemicity through intensive breeding of *A. ludlowi*. In most of the cases these results are due to interference with natural conditions without due precautions being taken against the natural consequences of such interference.