

THE ANOPHELES OF THE AUSTRALIAN REGION, THEIR
BIONOMICS AND THEIR DISTRIBUTION

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THE literature on Australian Anopheles is very meagre. The papers by Mackerras (1927) and Hill (1925) are the most extensive in regard to specific detail. Neither of these papers, however, throw any considerable light on what may be termed the *annulipes* complex. It was hoped to bring together in the present paper all that has been written and in addition to make an attempt to give detailed descriptions of the larvæ of the various forms grouped under *A. annulipes* which occur in North Australia under exactly the same conditions as *A. amictus*.

These details must unfortunately be held over for a future paper as time was not available to carry out the necessary breeding experiments. The present paper, therefore, will contain technical descriptions, as far as possible, of all the Australian species with notes on their bionomics, their distribution and their known relationship to malaria.

Anopheles (Anopheles) bancrofti Giles.

Handb. Gnats or Mosq., Ed. 2, p. 511, 1902.

♀. Head black, clothed with brown upright dart-shaped scales, the latter white in the centre, with some pale hairs overhanging the eyes from the centre; palpi dark brown, densely clothed with black scales giving them a shaggy appearance; proboscis black with dusky brown scales on its basal half; antennæ dusky brown, basal lobe clothed with brown scales as also the following segment, clothed with pale pubescence.

Thorax black, clothed with dense pale golden hairs; prothoracic lobes black covered with golden hairs with mixed pale and black outstanding dart-shaped scales; pleuræ black with a few scattered pale scales.

Abdomen black, clothed with dense dusky hairs, segments one to seven not scaled, remaining segments with a few scales; venter dusky with scattered pale scales and brown hairs.

Wings with the veins clothed with black and creamy lanceolate scales, the former predominating; costa black scaled with a creamy spot opposite the middle of the stems of the fork-cells, with a slightly larger apical patch at the junction

of the first longitudinal vein, basal half of the latter mottled with creamy white scales; anterior branch of the second vein with the apex creamy white; a similar spot toward the base of the posterior branch, apex with pale spot; third longitudinal vein with a creamy patch toward the apex, rest of the vein mottled; anterior branch of the fourth vein with a patch of creamy scales, mottled toward the apex, posterior branch mottled; anterior branch of the fifth vein with an apical and basal creamy spot, rest of vein mottled; sixth vein usually with one prominent creamy apical area; fringe with pale areas where the veins join the costa except at the junction of the posterior branch of the second, third and sixth veins; halteres with pale stems and black knobs.

Legs with the femora, tibiæ and first tarsi densely mottled with pale creamy white and black scales, the former predominating except on the mid and hind tarsi, the second tarsal segment of the fore legs with a pale apical spot; first and second tarsi of mid legs with pale creamy white apical rings, tarsi one to five of hind legs with basal and apical pale creamy white banding; ungues equal and simple.

♂. Palpi black scaled, apex of basal third with a yellowish ring, apical third spatulate and covered with moderately dense dusky hairs; plumes of antennæ black; thorax, abdomen, wings and legs similar to ♀; ungues of fore legs unequal, the larger with a tooth, mid and hind equal and simple.

Edwards (1924) compares the ♂ hypopygium with that of *A. barbirostris* as follows:—‘*A. bancrofti* Giles. Leaflets very small and short, the longest less than a third as long as the ædæagus, the rest much shorter. Basal spines of side-piece on a large prominence, each with a well-marked tubercle at its base, spines about equal in length and both stout, with the tip suddenly narrowed and curved. Club very slender, almost like a blunt-ended spine, the two spines of which it is composed sometimes partly separated. *A. barbirostris*, v. d. W. Leaflets much longer and darker, two or three pairs being fully half as long as the ædæagus. Basal spines on a small prominence without tubercles, both rather slender, especially the outer one, which is longer than the inner and nearly straight. Club stout, distinctly enlarged apically.’

Length.—5-6 mm. without proboscis.

The description of the larva and pupa is taken from Cooling (1924 *b*) and is as follows:—‘Larva.—Length, 7 mm. Head and anal segment dark and heavily pigmented. Antennæ slightly curved, covered with many sharply pointed but simple spines the size of which latter decreases from base to apex. Proximal portion of antennæ slightly swollen. Antennal plume sub-median in position, consisting of about twelve branches; the branches are more or less equal in length and give the appearance of a radial grouping. Each antenna is tipped with two stout spine-like processes, weakly chitinized, also with an extremely delicate, branched seta of about five branches. Sub-antennal plume, feather-like about half the length of the antenna. Mouth brushes consisting of moderately chitinized simple “hairs.” Labrum clothed with minute slightly recurved and distally serrated setæ. Mandibles consisting of small but heavily chitinized teeth. Labial

plate roughly triangular, the base obtusely and symmetrically crenated; there are about three lateral, more or less irregular, blunt teeth and a median (apical) one of average size. An asymmetrically shaped foramen occurs on either side of the median line of the labial plate. The frontal "hairs" of the head exist as six well defined branched setæ. Inner anterior clypeal hairs, closely approximated, long, stout, and very minutely branched—the branches being few and hardly more than the diameter of the hair. Each of the outer anterior clypeal hairs consists of a tuft of much branching, tree-like hairs. Thorax: In addition to the usual chæto-taxic grouping, there is a group of three long simple hairs which arises from a moderately chitinized tubercle on the antero-lateral margins of the thorax, in the prothoracic region; at the base of each of these hair-tufts are two unequal spines, one markedly chitinized, the other (longer one) weakly so. On the inner side of these hair-tufts are two minute, branched setæ, one on each side of the median line; these comprise the anterior sub-median group of Stanton. There is a small but pronounced feathered hair on each side of the mesothorax and a smaller and less pronounced one on the antero-lateral aspect of the thorax. Several very minute palmate hairs are to be found on the thorax. The abdominal segments 1 to 3 have branched lateral setæ rather much like those of the thorax; segments 4 to 6 with long bifid setæ. All the abdominal setæ arise from distinct chitinous tubercles, and, in addition to the ordinary lateral setæ, there are much smaller branched ones arising near their bases. The typical palmate hair takes the form of rather large and mottled sharply tapering "leaves," the edges of which can be observed to be minutely serrated; from fifteen to nineteen such "leaves" go to make up one of the large palmate hairs. There are large palmate "hairs" on segments 3 to 7; minute ones (less notched) on segment 2, and still more minute ones on the thorax (two pairs). The thorax and abdominal palmate hairs show a gradual transition both in size and complexity, which is a good example in the development of the typical "palm" from a simple "hair-tuft." The spines of the pecten take the form of simple undifferentiated (except for size) spikes, large, roughly alternating with smaller ones. The number is about fourteen in each side, and altogether the comb is very similar to that of *Anopheles annulipes* Walker. The anal segment is of a mahogany colour and its surface is invested with numerous minute, sharp, simple spines, of almost the same shape and size as those existing on the shafts of the antennæ. Ventral beard arranged in about ten paired groups of typically branched hairs. Dorsal beard well represented, the "grappling hooks" consist of a plume of five or six branches on each side; swimming fans (anal papillæ) equal, moderately elongated and obtusely pointed.

Pupa.—A most striking feature of the pupa is the linear extensions of mottled or variegated colour-markings of the cephalothorax due to the chitinous incrustations of the pupal cuticula. Caudal fins rather striking by reason of their relative diminutiveness. The fans are also closely approximated and do not show any tendency to lateral spreading. Breathing trumpets small, broad, and triangular. There is a pair of large tree-like plumes of much branched setæ at the base of the

cephalothorax (i.e., on abdominal segment i). On each of the sides of abdominal segments 2 to 6 is a short, stout, bluntly pointed and strongly chitinized spur. Each segment has a pair of branched setæ each of which branches from a short stalk into five more or less equal and regularly disposed "hairs." There are also minute bifid and trifid "hairs" on each segment. The seventh segment bears a pair of small plumes and peculiarly branched hairs on the posterior angles. The leaves of the caudal fin are hyaline, each stiffened in the ordinary way by a midrib, which latter is very faintly striated transversely and terminates in a short chitinized spur or bristle.'

Habitat.—Queensland; North Australia; territory of New Guinea (Madang and Admiralty Islands); Philippine Islands; Ceylon (Strickland).

Breeding-places.—The larva of this species avoids localities subject to direct sunlight, moreover it has never been found in small collections of water, such as hoof-holes of animals, generally being found in moderately shallow water overgrown with vegetation. Larvæ of this species have also been found in slowly-running water.

Habits.—The adults taken by the writer have in every instance been captured in situations where direct sunlight did not penetrate. They rarely frequent houses. To the writer's knowledge it will bite freely from 2 until after 11 P.M. It is a gross feeder and a most vicious biter, 'striking' as soon as it alights and will continue to suck blood though apparently fully gorged passing tiny droplets of a clear fluid *per annum* until its abdomen is so replete with blood that it is unable to fly more than a few feet without resting.

A. bancrofti is very closely related to *A. barbirostris* and has been placed by the writer (1913) as a variety of the latter. Edwards (1924) states that '*A. barbirostris*, however, shows differences in the hypopygium which are almost certainly of specific value.' On the other hand the adults of *A. bancrofti* are closely related, also their habits and breeding-places are very closely related to those of *A. barbirostris*.

Christophers (1924) and Covell (1927) give *A. pallidus* Swellengrebel and Swellengrebel, from the Dutch East Indies as a synonym of *A. bancrofti* Giles, but a specimen of the former in the Institute Collection, determined by Dr. Brug, differs especially in the leg markings from *A. bancrofti*.

Christophers (1922) records *A. umbrosus* as from Australia but the writer considers this record is in reality meant for *A. bancrofti* especially since Christophers (1924) has not repeated the statement.

Relation to Malaria.—There is no evidence that this species is a vector.

Anopheles (Anopheles) stigmaticus Skuse.

Proc. Linn. Soc. N. S. Wales (2), Vol. III, p. 1758, 1888; *corethroides*
Theob., Mon.

Culicid., Vol. IV, p. 35, 1907; Edwards, *Bull. Ent. Res.*, Vol. XIV, p. 352, 1924.

♀. Head yellowish brown, clothed with narrow yellowish upright scales and hairs, the latter numerous in the centre and overhanging the eyes; antennæ brown, basal lobe dusky brown, second segment pale at the base; palpi brown, clothed with dusky scales, slightly shorter than proboscis, latter brown.

Thorax greyish brown with a broad dark brown median area extending from the anterior margin to about the middle of the scutum, where it broadens out to the lateral margins and extends to the posterior margin; covered with yellowish brown hairs; scutellum brown, border bristles yellow; prothoracic lobes prominent; pleuræ dusky brown.

Legs brown covered with violet brown scales; hind femora with the basal four-fifths pale yellow.

Wings: costa black; veins clothed with brown scales; first fork-cell longer and narrower than the second, base of the former nearer the base of the wing than that of the latter; stem of the first fork-cell about the length of its cell, stem of the second longer than the cell; anterior and anterior basal cross-veins parallel, the latter slightly less than its own length from the former; a dark patch covering the forking of R and Rs.

Abdomen dark brown, sparsely covered with golden hairs, denser at apex, venter brown.

♂. Similar to ♀. Antennæ brown, plumes brown and very dense; palpi brown slightly shorter than proboscis, last segment spatulate and clothed with short brown hairs; concerning the hypopygium of the ♂ type of *corethroides* Edwards (1924) states that it is in some respects rather peculiar. It has only one basal spine on the side-piece, which is set on a distinct tubercle (as in the Palæartic *A. algeriensis* Theo). The claspettes are conical, pointed, not lobed, with one long slender bristle at the tip, and one shorter one below it; the ædœagus is moderately long and slender, with about six pairs of very long and slender leaflets. To this Mackerras (1927) adds that the genitalia of both northern and southern forms agree with Edwards' description of the type of *A. corethroides* Theo. There is no doubt that the synonymy given by Edwards is correct, but the typical *corethroides* form is distinctly less well marked than typical *stigmaticus*.

Length.—4.5 to 5 mm.

Larvæ dark brown and superficially resemble small specimens of *A. annulipes*, Walk., naked eye separation of the two being impossible. The antennæ are creamy, darker at the tip and bear apically two spines and a single fine hair which is forked distally; the antennal hair is situated at the junction of the basal and middle thirds of the antennal length and is very short and finely branched. The head is uniformly dark brown in colour and both compound and simple eyes are present. The inner anterior clypeal hairs are long, bare, and set close together; the outer anterior clypeal hairs are a little more than half the length of the inner and are bare; the posterior clypeal hairs are short and single, or divided into two or three very terminal branches. The frontal and sub-antennal hairs are normal. The inner occipital hair is bifid and the outer lies well anterior to it and is trifid. The

chaetotaxy of the thorax and abdomen is not unusual. Palmate hairs occur on segments 2 to 7 of the abdomen, are well developed and conspicuous and each consists of 20 to 25 leaflets which are long, slender, pointed, and not serrated. The pecten is composed of regularly alternating long and short teeth. The ventral sub-dorsal hairs bear the usual grappling hooks.

The pupal skin is a clear pale brown and the trumpet is not pigmented nor are there any zones of pigmentation on the cephalothorax. This stage may usually be separated from that of *A. annulipes* Walker, by its smaller size and paler colour. The trumpet is longer and not so broad, and the abdominal chaetotaxy is not so striking. From *A. atratipes* Skuse, it may be distinguished by its smaller size, absence of pigmentation, much narrower trumpet and different chaetotaxy. The pupal stage lasted two to four days under the experiments.

Habitat.—S. Queensland : Burpengary, Brisbane ; N. S. Wales ; Blue Mountains, National Park (Near Sydney).

This a very distinct species, the hind femora being very conspicuous. It cannot be confused with the other Australian Anophelines. Mackerras (1927) states that the resting attitude is almost horizontal and the palpi are carried closely appressed to the proboscis, so that they resemble, when alive, a small species of *Culex* much more than an Anopheline. Northern and southern specimens vary somewhat *inter se* but they entirely conform in specific characters.

The larval and pupal descriptions have been copied *in toto* from Mackerras.

Relation to Malaria.—No evidence. It is extremely improbable that this species would ever play any part as a vector on account of its extreme rarity.

Anopheles (Anopheles) atratipes Skuse.

Proc. Linn. Soc. N. S. Wales (2), Vol. III, p. 1755, 1888.

♀. Head covered with white upright forked scales, and similar black ones laterally, a conspicuous tuft of long white and creamy hairs overhanging the eyes from the centre ; antennæ brown, verticillate hairs brown, basal lobe dusky, second segment about the length of the third ; palpi brown with outstanding dusky scales on the basal third, appressed brownish ones on the apical two-thirds ; proboscis black.

Thorax black with a broad median reddish brown stripe from the anterior margin to the middle of the scutum sparsely clothed with small pale scales and dark hairs ; scutellum pale creamy yellow, the centre black, sparsely covered white, narrow scales, border bristles dusky ; pleuræ yellowish brown, darker posteriorly.

Abdomen black covered with dense yellowish brown hairs.

Wings : costa, subcostal and first longitudinal vein densely clothed with dusky brown scales. There are patches of dusky brown scales at the bases of the fork-cells, at the base of the third, and at the base of the fork of the fifth, the sixth vein is covered with pale scales except for about the apical fifth ; there is a patch of white scales in the middle and a small white spot near the base of the third, the

upper branch of the fourth has the apical two-thirds white, the middle third of the posterior branch is white, the vein is also lightly mottled with white scales for a short distance posterior to the base of the fork, the fifth to the base of the fork-cell is white scaled with a prominent patch of dusky scales in the centre, both branches of its fork-cell are mottled with brown and white scales.

Legs covered with dark brown scales.

♂. Palpi with the terminal segment swollen, and with a patch of long hairs ventro-laterally on the basal half of the terminal segment and extending on to the apical part of the penultimate segment; antennæ with long, dense, silky, brown plumes; otherwise resembling the ♀ in all essentials. The hypopygial characters are in some respects intermediate between *A. bancrofti* Giles, and *A. stigmaticus* Skuse, but show much closer affinities with the latter in the single basal spine of the side-piece, in the pointed rather than lobed claspettes, and in the replacement of the club by a row of four basal spines set on the lobe. It resembles *A. bancrofti* Giles, in bearing three sub-equal spines on the claspette. There are about two pairs each of longer medial and shorter lateral leaflets.

The larvæ are darker than those of *A. annulipes* Walker, but do not afford any naked eye characters of value for differentiating them. The antennæ are brown, notably stout and short, and bear apically two spines and a fine trifid hair. The antennal hair is situated slightly basal to the middle, is fully half the length of the antenna and is strongly branched. The head is very heavily and uniformly pigmented and no trace of eyes could be made out in any of the preparations. The anterior clypeal hairs resemble those of *A. stigmaticus* Skuse, but the posterior are very short and single. The frontal hairs are strongly plumed and are sub-equal in length. The sub-antennal plume is normal. The inner occipital hair is divided into four very fine branches. The outer lies well anterior to the middle and is trifid. The thoracic and abdominal chætotaxy is not remarkable except for the entire absence or great reduction of the palmate hairs. These structures may be represented by certain short hairs on a few of the abdominal segments, but are certainly not present in the form seen in other Anopheline larvæ. The pecten consists in general of long spines alternating with two very short ones. Grappling hooks are developed.

The pupa appears to be closest to Cooling's description of *A. bancrofti* Giles. The skin is brown with strong lines of black pigment on the wing sheath along the course of the veins and with transverse dark bars in a row along the antennal sheath. The trumpet is very broad, triangular in shape and is deeply pigmented.

Habitat.—Queensland: Stradbroke Is., Caboolture to Enoggera; N. S. Wales: Berowra; Sydney district.

This species bears a superficial resemblance to *A. bancrofti* Giles, but the clothing of the palpi, wing and leg markings render it easily separable. It is similar in habits in that it is a sylvan day-biting species (Mackerras) and rests at an angle of about 80 per cent with the surface. It is most prevalent in the coastal districts of N. S. Wales and South Queensland in the spring and early summer, apparently

disappearing completely in the season when other Anophelines are most abundant. In the Sydney district it occurs most frequently in the sandstone gullies and in the vicinity of sluggish creeks running through the Pleistocene sand flats.

It is a vicious biter causing considerable pain.

The larvæ were taken in a small, sluggish, slightly muddy creek with a fine silt bottom. The pH of a sample of the water was 7.5. Some aquatic vegetation was present, but not a great deal. Other mosquito larvæ were entirely absent.

The affinities of the larvæ are with *A. stigmaticus* Skuse, from which it is to be separated by its larger size, much darker colour, much stronger antennal plume, and by the absence of eyes and palmate hairs.

Relation to Malaria.—There is no evidence, and very probably would never play any part in the rôle of a vector on account of its rarity.

Anopheles (Myzomyia) annulipes Walker.

Ins. Saund., Dipt. i, p. 433, 1856; *musivus* Skuse, Proc. Linn. Soc. N. S. W. (2), Vol. III, p. 1754, 1888; *mastersi* Skuse, op. cit., p. 1757, 1888.

♀. Head dusky, clothed with pale scales and dusky ones laterally, a tuft of white hairs projecting over the eyes from the centre; antennæ brown, first two segments with small white scales, pubescence pale, verticillate hairs dark; proboscis with slightly more than the basal half blackish brown, remainder creamy white; palpi with segments two to four with broad white apical bands.

Thorax grey black clothed with numerous pale creamy white scales and scattered pale hairs; scutellum dusky, white scaled, marginal hairs long, dark.

Abdomen dusky brown, densely clothed with yellowish hairs; segments two to seven with narrow pale creamy white scales, most numerous on segments six and seven.

Wings with the veins covered with conspicuous patches of black and cream coloured scales, the costa with three small cream and two small black basal patches followed by a larger black and a smaller cream one, then a black one about twice the length of the previous black one in the centre of the costa followed by cream and black ones of about the same length, then a small cream one and a longer black one; the first long black patch of the costa extends to the subcostal and first long vein, the second embraces the subcostal, the third and fourth embrace the first long vein; the junctions of the veins with the costa are creamy; first fork-cell longer and narrower than the second, base of the former nearer the base of the wing than that of the latter.

Legs covered with dark brown scales; femora and tibiæ with numerous white rings; tibiæ of mid and hind legs with apical white banding; first tarsal of fore legs with basal and apical banding and a broad white band in the middle which has a small brown patch in its centre, second tarsal with basal and apical banding, remaining tarsi of fore legs unbanded; tarsi of mid legs unbanded; first tarsal of hind legs with two narrow white bands about the apex of the basal fifth then follow

six small white spots about equally divided in distance along the remainder of the tarsus, tarsi one to four with basal and apical banding, the fifth with basal banding only.

♂. Palpi: apex of basal third with a narrow white band, likewise the base of the middle third, apical third spatulate with numerous pale hairs, base black scaled remainder white scaled above with a small median black spot; antennæ with dense, light brown plumes.

Side-piece of hypopygium bears four basal spines. The leaflets four or five in number and rather broad; about half the length of the ædœagus; claspette rounded with a long apical hair and a single accessory one which is at least half as long as the apical one. This is a variable character and Mackerras (1927) says the length of at least one or two of the accessory hairs is constantly as much as half the length of the main hair in all specimens examined, an important point of distinction from *A. amictus* Edwards, in which these accessory hairs are never more than a quarter the length of the main hair.

Length.—4.5 mm.

Head of larva brown with the pigment arranged in a definite and characteristic pattern; antenna with a short sub-lateral spine about its middle length; inner anterior clypeal hairs well apart, much nearer the outer anterior clypeal hairs than to each other, sometimes bearing two or three extremely short fine plumes; outer anterior clypeal hairs about two-thirds the length of the inner and strongly plumose; posterior clypeal hairs are wider apart than the inner anterior, are four-branched, short, and not projecting as far as the anterior border of the head; inner occipital hair trifold, the outer with a few plumes; leaflets of palmate hairs resembling the shape of a cabbage palm leaf (Cooling, 1924a); pecten variable, with three long teeth.

Pupal skin brown without specially pigmented areas, except the trumpet which is lightly powdered with pigment; the stout lateral spines of the abdomen decrease in size proximally and are very short on the basal segments. The trumpet is oblong in shape and slightly shorter and broader than that of *A. stigmaticus* Skuse (Mackerras, 1927).

Habitat.—Queensland: Cairns to Brisbane; N. S. Wales; Victoria; Tasmania; South Australia; Southern West Australia; Central Australia; Alice Springs; Charlotte Waters.

This species has been recorded from several localities to the north and west of Cairns. It is most probable that these records belong to *A. amictus* Edwards, those in North Australia and the north-west of West Australia also most probably refer to *A. amictus* Edwards.

It is a variable species and closely related to *A. amictus* Edwards.

Nicoll (1918) writes of *Anopheles maculipennis* as being present in North Queensland. This is quite erroneous and no credence whatsoever can be placed on his entomological statements. His remarks refer to either *A. annulipes* or *A. amictus*.

Habits.—This species bites at all times of the day and night. In Victoria where the writer (1917) found this species very abundant, they were found to bite most freely at sunset and for about an hour afterwards. Adults enter houses quite freely.

Breeding-places.—The breeding-places, *par excellence*, are hoof marks of cattle and horses containing either muddy or clear water without vegetation; other breeding-places are grass grown channels, small casual collections of water, street gutters containing slowly-running water. Large expanses of even shallow water do not seem to be favoured as a breeding-ground.

Relation to Malaria.—There is no conclusive evidence, it is entirely presumptive though possible on epidemiological grounds (Breinl and Taylor, 1918; Money, 1926).

That this species does not occur in Formosa has been definitely proved by Koidzumi (1924) and Yamada (1925), therefore the work of Kinoshita (1906) fails in relation to *A. annulipes*, the species with which he worked being established as *A. tessellatus* Theob.

Anopheles (Myzomyia) amictus Edwards.

Bull. Ent. Res., Vol. XII, p. 71, 1921.

A larger and more yellowish species separated in the ♀ from *A. annulipes* by an entirely dark proboscis and numerous moderately broad scales on segments two to seven of the abdomen and in the male by its hypopygium, the main characteristic being the presence of two or three fine short hairs which are always less than one-quarter the length of the main hair. The scales on the abdomen in both sexes are broad, flat and creamy yellow in colour. Hill (1925) states that he bred typical ♀ *A. annulipes* Walker, among the progeny of *A. amictus* Edwards, females. This the writer is inclined to believe was due to the presence of a true ♀ *annulipes* unknown to Hill. If not, then there is a most complex question to settle for the larva of the true *A. amictus* Edwards is very different from that of the true *A. annulipes* Walker.

For this reason the writer submits no detailed description of *A. amictus* Edwards, until he or another worker has definitely established the validity of *A. amictus* Edwards.

The larva differs from that of *A. annulipes* Walker, in the following respects (Mackerras 1927): 'The sub-lateral spine of the antenna is definitely beyond the middle; the outer anterior clypeal hairs are single (unplumed) and the posterior clypeal hairs are single, or sometimes bifurcate and extend well beyond the anterior margin of the head; the inner occipital hair is single and the outer is trifid; the comb differs slightly in the arrangement of the long spines, but is variable; in other respects, including the palmate hairs, there is little or no distinction.'

Habitat.—Queensland; North Australia; north-western area of W. Australia.

Habits.—The biting and resting attitudes of this species are similar to those of *A. annulipes* Walker, so far as the experience of Mackerras and the writer goes.

Breeding-places.—These all appear to agree with those of *A. annulipes* Walker, the two being found alongside of one another.

Though there is as yet no data, the writer believes that this species will eventually be found in northern and western N. S. Wales.

Relation to Malaria.—There is no evidence, but it is possible that it may play a part as a vector since the writer (Breinl and Taylor, 1918) certainly confuse it with *A. annulipes* Walker, in the survey of Cairns.

Anopheles (Myzomyia) punctulatus Dönitz.

Insectenborse, Vol. XVIII, p. 372, 1901.

The main distinctions of the type form from its variety *moluccensis* may be given as follows:—The white scales on the head are mainly confined to the fore-part, all the rest being black; palpi: apex of basal third with a narrow white ring, rest black and somewhat shaggy, apex of middle third with a narrow black ring and just basal to it a narrow white ring, rest black, base with black ring, elsewhere white, except for a sub-apical black ring; proboscis with the basal two-thirds black, apical third white scaled except for a narrow black apical ring, labellæ reddish brown; ground colour of thorax and scutellum greyish black; femora, tibiæ and first tarsi not so profusely marked with incomplete rings and the tarsi are unbanded; the costa of the wing has three small yellow spots basally, then a much larger black one which extends to the first long vein; followed by a small yellow spot which expands on to the subcostal and first long veins, this is followed by a long black patch which includes the subcostal vein, then a small yellow patch followed by a black patch slightly shorter than the preceding black one, followed by a fairly long yellow patch, occupying a position about the middle of the first fork-cell, a similar black one, about the length of the last yellow one, follows which embraces the first long vein; the veins are much more evenly mottled there being fewer yellow scales than in var. *moluccensis* on the veins, especially is this noticeable on the sixth which has the base black scaled, then follow three small black and three small yellow patches alternately to about the apical fourth which is black scaled, except the extreme apex which is yellow; the basal half of the anterior branch of the fifth is black scaled, there is a similar patch, about the same length, extending from the base of the fork towards the base of the vein.

The above data are taken from a ♀ specimen kindly presented to the Institute by Dr. S. L. Brug, the label bearing the following ' *N. punctulatus* Don. nec Theo. Pionierbivak (N. Guinea) early in 1922,' as the Institute does not possess specimens of this species from New Guinea or Australia.

Habitat.—N. Australia: Borroloola; Papua: Moresby; Lakekamu Goldfield; Mekeo district; Sariba; Cape Nelson; Samarai Is.; Woodlark Is.; territory of

New Guinea : Rabaul ; Toma ; Beining district ; Dutch New Guinea : Pionierbivak ; Kaimana ; Moluccas ; Solomon Is. ; New Hebrides : ? Santa Cruz Group : Vanikoro Is. (a specimen from Dr. Deland was damaged in the post and could not be identified with certainty).

Breeding-places.—Heydon (1923) records the larvæ from New Britain in temporary puddles and shallow pools of rain water, often muddy but not foul, in hoof marks or in local depressions of the ground in localities where the soil is not too porous to retain such water. Buxton (1926) and Covell (1927) found them in swamps and stagnant surface water in the New Hebrides.

Habits.—The adults are found in houses and feed throughout the night. Breeding occurs throughout the year.

Relation to Malaria.—Heydon (1923) infected this species experimentally with *M. T.* parasites (sporozoites in two specimens out of seven dissected). He notes that it was uncertain whether the five remaining specimens had fed.

Covell (1927) states that De Rook found oöcysts in 12 specimens out of 448 dissected in nature in New Guinea (2.9 per cent) and considers the species to be an important vector. Covell also states that Buxton considers that *A. punctulatus* is responsible for the malaria in the New Hebrides, as it is the only species recorded in the whole of Melanesia.

The record of this species from Borrooloola, N. Australia, by Hill (1925) is very interesting and exceedingly important from the aspect of malaria epidemics and has been discussed under *A. punctulatus* var. *moluccensis*.

Anopheles (Myzomyia) punctulatus Dönitz, var. *moluccensis*.

Swell. and Swell., Bull. Ent. Res., Vol. XI, p. 78, 1920.

♀. Head clothed with white upright scales, with some whitish hairs overhanging the eyes from the centre, lateral scales brown. Antennæ light brown, basal segment with small white scales, pubescence and verticillate hairs white ; proboscis dark brown, a few dark brown outstanding scales at the base, more pronounced ventrally, apex pale yellow ; palpi : first segment dusky brown with white apex, second segment dusky brown with a broad white band on the apical half, its apex with a narrow yellowish one, penultimate and apical segments with a narrow dusky brown basal band, the remainder creamy yellow.

Thorax greyish (ground colour apparently brown) with a dark spot on each side about one-third from the anterior border, one in front of the scutellum and another small one in the centre on the apex of the anterior third, clothed with fairly dense white narrow scales and sparse yellowish hairs ; scutellum pale, centre brownish clothed with white narrow scales, border bristles yellow ; pleuræ brown to dusky with a few pale narrow scales ; halteres white, apex of knob black scaled.

Abdomen dark brown, clothed with numerous pale yellow hairs, last three segments with numerous narrow yellow scales, apex with a few black ones in addition.

Legs dark brown; femora, tibiae and first tarsi with numerous incomplete white rings, tarsi one to three with apical and basal banding, fourth with basal banding, fifth unbanded, in the hind legs the fifth is apically pale, fourth and fifth tarsi of mid and hind legs pale ventrally.

Wings with four long black patches on the costa and three short ones basally, a short black spot between the first and second long ones, the second to fourth long patches (from the wing base) extend to the subcosta; all the longitudinal veins mottled with alternating patches of pale yellow and black scales, there are three moderately long pale yellow patches on the apical half of the costa; apical half of the third vein pale yellow, a long pale yellow patch about the middle of the anterior branch of the fifth, posterior branch with three small regularly spaced black patches, the first sub-basal, the second almost central, the apical one about its length from the apex, sixth vein pale scaled with four small patches of black scales, the first and fourth not quite basal and apical respectively, the remaining two equally spaced; the costa at the points of junction of the veins pale yellow, elsewhere the fringe is dusky; base of first fork-cell near the base of the wing than that of the second fork-cell, stem of the latter about the length of its cell, stem of the former more than twice the length of the cell, anterior basal cross vein about twice its length from the anterior.

♂. Palpi with first segment dark brown mixed with white scales; slightly less than the apical half of second white scaled above with a narrow dark brown ring in its middle, some pale apical forwardly projecting hairs ventrally, club with the basal half white scaled except for a narrow brown basal ring, another similar ring in the middle, rest of club yellowish.

Length.—5 mm.

Habitat.—North Australia: Darwin to Katherine; territory of New Guinea: Rabaul; Madang; Admiralty Islands; Papua: Mekeo district; Lakekamu Goldfield (Central Division); Dutch New Guinea; Moluccas.

Habits.—This variety frequents houses where they are to be found during the daytime. The females bite throughout the night. They rest on the walls often near the ground, on the undersides of beds, on wooden floors near the walls and in sheltered and usually dark situations generally. 'In places visited by the writer (Heydon, 1923) this species never bites by day or even at early dawn or early evening, but it is said to do as in localities where it is very numerous.'

Breeding occurs throughout the year, the adults becoming more numerous after the onset of the wet season and scarcer as the dry advances.

Larvæ are found in swampy pools and ditches. They appear to be indifferent as to whether the water is fresh or brackish, polluted or otherwise, natural or artificial.

Relation to Malaria.—Heydon (1923) at Rabaul infected this variety with B. T. parasites (7 out of 15 dissected) and with M. T. (7 out of 7). In nature he found a total sporozoite rate of 3.9 per cent (206 specimens) and a total oöcyst rate of 3.6 per cent (220 specimens), the sporozoite and oöcyst rates among specimens taken in native quarters being 6.4 per cent and 6.2 per cent respectively (a small proportion of specimens dissected probably belonged to the type form). De Rook (Covell, 1927) also considers that this form is an important carrier of malaria.

The writer after mature consideration considers that this form has been, in the past, responsible for the epidemics which have occurred in North Australia, since Hill (1925) definitely states that it is common between Darwin and Katherine, which being so it probably extends throughout N. Australia. It is also suggested here, that this mosquito has, perhaps with the type form, been responsible for the severe epidemics which occurred on the Palmer Goldfield in the early 'eighties. It is admitted that neither this form nor *A. punctulatus* have ever been recorded from Cape York Peninsula, but against that it has to be borne in mind that, what few Anophelines have been taken on the far distant parts of this peninsula, have not been critically examined by a competent authority and no longer exist. The writer considers that when the shaded area on the Map (*see end of paper*) is carefully searched, under favourable conditions, either or both of the above-mentioned mosquitoes will probably be found there.

Anopheles (Myzomyia) subpictus Grassi.

Atti d. R. Acad. d. Lincei, Ser. 5, Vol. VIII, sem. 1, fas. 3, p. 101, 1899 (Feb.); *rossi*
Giles, Jnl. Trop. Med. and Hyg., Vol. II, p. 63, 1899 (Oct.), Edwards,
Bull. Ent. Res., Vol. X, p. 129, 1920.

♀. Head blackish, with pale scales in front, and with a tuft of pale hairs projecting forwards, black scales at the top and sides; eyes black; antennæ brown, with pale hairs and pubescence; basal joint ochraceous brown, with a few creamy scales; proboscis dark brown, apex sometimes pale; palpi dark scaled, apically white, and with two other pale bands near the apices of the second and third joints; clypeus pale brown.

Thorax pale yellowish brown to ochraceous brown, with greyish reflections, with traces of a median line, covered with scattered pale scales and hairs; scutellum pale, sometimes dusky in the middle, with pale scales and brown bristles much as in *superpictus*; metanotum pale yellowish brown to brown; pleuræ with a dark line of spots above, pale below, with patches of pale scales.

Abdomen dusky, densely clothed with golden brown or ochraceous hairs, which are especially thick at the apex, giving it an ochraceous appearance.

Legs yellowish, with brown scales, and with pale apical and basal bands to some of the tarsi, except the last tarsus, which is always black. The tarsal scales are very dark, sometimes having a deep purplish brown hue. Fore tarsi basally and apically banded yellow, except the last joint; metatarsus apically banded

only ; in some specimens there may be seen a very narrow basal, as well as apical, banding to the hind legs.

Wings yellowish, with the costa broken by four large patches of dark brown or black scales, and two or three smaller basal ones. The large middle spot has a small dark spot below in the centre, giving a T-shaped appearance to it. First sub-marginal cell a little longer and narrower than the second posterior cell, their bases nearly level with one another, that of the first sub-marginal if anything nearer the base of the wing. The stem of the second posterior cell about the same length or a little longer than the cell. The posterior cross vein nearly twice its own length distant from the mid cross vein. Scales on the veins creamy yellow, with small black patches, as follows : at the tips of all the veins, one on each branch of the first fork cell, one at the base of the third long vein ; two on the upper and one on the lower branch, and two on the stem of the fourth vein ; three on the upper branch, one on the lower, and one near the base of the stem of the fifth vein ; two spots on the sixth long vein of small size. Fringe yellow at the apex and at the ends of the fourth and fifth veins ; remainder blackish.

♂. Palpi swollen at the end, yellow, with a broad black band at the base, a broad black band in the middle, and a small broken one near the apex of the same joint, and a narrow ring of black at the base of the last two joints ; hair tufts short, pale ; the base of the palpi densely black-scaled ; proboscis dark brown, pale at the tip ; antennæ with silky golden brown plumes. Wings marked much as the ♀, but in many ♂'s, especially in those from South India, there is a small additional spot beneath the second costal spot, besides the one forming the T, and in a few ♀'s I have noticed the same. First posterior cell a little longer and much narrower than the second posterior cell, its base if anything a little nearer the apex of the wing than that of the latter, its stem equal to the length of the cell, the same length as that of the second posterior cell ; supernumerary cross vein nearly its own length in advance of the mid cross vein ; posterior cross vein at least twice its own length distant from the mid cross vein ; fore unguis unequal, the larger one twice toothed ; mid and hind equal and simple, the mid rather the longer.

Length.—4—6 mm.

Habitat.—Papua : near Port Moresby ; Mekeo district (60 miles west of Port Moresby) ; India ; Malaya ; Siam ; Dutch East Indies ; Philippine Islands.

Theobald's description of *A. rossi* has been utilized as the only Papuan specimen, a ♀ taken by Hill in the Port Moresby district in the Institute Collection lacks the abdomen and one wing. The head, thorax and remaining wing are, however, quite typical, the legs are all abraded.

Breeding-places.—The larvæ are found in pools, often muddy rain pools and in almost any temporary or permanent collection of water, frequently heavily contaminated with sewage. The breeding-places are most frequently found in the vicinity of villages (Covell, 1927). Hill (1925) found the larvæ in large numbers in beached native canoes within easy flight of a large native village and the official

residential area of Port Moresby. The identification was made by Edwards from specimens sent to him by Hill.

Habits.—The adults of this species are found in large numbers in cattle-sheds and in human habitations, and feed readily on man even if cattle are present (Covell, 1927).

Relation to Malaria.—This species has been experimentally infected with all three forms of the malaria parasite. Hill (1925) states there is the strongest circumstantial evidence that it is the species responsible for an infection of benign tertian malaria contracted by the writer, and it is possibly an important factor in the transmission of the disease in that portion of the possession, where canoes have not been suspected hitherto of affording a breeding-place for *Anopheles*. Against this statement it must be remembered that Hill was in malarious districts both in Papua and the territory of New Guinea where he may have contracted the infection, such lying dormant until after he had left the Port Moresby district, since the part played by this species in the transmission of malaria is extremely doubtful, as the malaria parasite has never, in India at least, been found in 'wild' dissected specimens. Covell (1927) says this species has, however, been found infected in the Dutch East Indies, though it may perhaps be doubted whether the '*A. rossi*' referred to is identical with the Indian form. He further states that Rodenwaldt and Essed conclude that malaria there (Dutch Indies) is transmitted by *A. ludlowii* and that next to this '*M. rossi* Giles,' plays a certain part as a carrier only however in the case of the epidemic being kept up by *A. ludlowii*. Covell gives further extensive information on the subject on work done in India.

Bironella gracilis Theobald.

Ann. Mus. Nat. Hung., Vol. III, p. 69, 1905; Mon. Culicid., Vol. IV,
p. 121, 1907.

♂. Head brown with numerous yellowish and black upright fork-scales, the latter very thin with bifid apex, the former broader with expanded apex with numerous serrations, and apparently a few irregular narrow outstanding pale scales of similar size throughout their length.

Proboscis moderately long and thin, clothed with deep brown almost black scales, labellæ very acuminate; palpi not quite as long as the proboscis, scaled with deep brown scales, swelling gradually towards the apex, the apical segment large, one joint only can be detected, but probably a basal one exists. Antennæ brown with pale bands below the whorls of verticillate hairs, hairs deep brown.

Thorax dark brown with slatey sheen and with short dull golden curved hairs projecting backwards; scutellum pale yellowish brown; metanotum deep brown.

Abdomen black, nude, but with black hairs, narrow basally, but expanded apically; genitalia densely hairy. Hypopygium: side-pieces short and stout, less than twice as long as their width at the base, basal membrane large and apparently striated; from the outer basal corner of each side-piece arises a stout curved

finger-like process, which is more than half as long as the side-piece, finely pubescent towards its base, otherwise bare, its apical half strongly chitinized, tip blunt and slightly lobed. Apart from these processes there are no spines on the side-pieces. Claspers rather long, nearly cylindrical, with a post-median lump on either side, terminal claw short and broad. Ninth tergite a narrow, transverse oval, posterior margin simple. Anal segment membranous, elongate-conical, two-thirds as long as the side-piece. Aedœagus (theca) a long, slender, cylindrical tube, with a single pair of reflexed leaflets at its tip, the leaflets a little over a quarter as long as the tube.

Legs long and thin, brown, covered with small scales, the coxæ and under side of femora pale ochreous. Ungues apparently all equal and simple.

Wings with brown scales. The subcostal cell tinged with brown, rest of the membrane transparent; the first sub-marginal cell very small, its stem more than four times the length of the cell; the posterior cell about two and a half times the length of the former and about twice its width, stem of the second posterior cell a little longer than the cell, curved about its centre; the third long vein also curved, continued to the base of the wing as a distinct pseudo-vein; fifth vein with its upper branch distinctly waved, after its junction with the posterior cross-vein; sixth long vein nearly straight until its apex, where it curves abruptly, a distinct pseudo-vein between the fifth and sixth; marginal cross vein very long and prominent; the supernumerary very small, the mid as long as the marginal, joining the supernumerary; the posterior not as long as the mid and close to it. Halteres with the pale stem much swollen basally, constricted apically, the knob black.

♀. Proboscis black, straight, labella dark grey. Palpi black, with grey hairs at the apex; the apical fourth slightly swollen; length nearly equal to two-thirds of the proboscis. The segments of the palpi are scarcely distinct, even with the specimens mounted in balsam and magnified $\times 300$.

The length of the palpi in the ♀ is found to be 60 per cent, 64 per cent, 64 per cent, 65 per cent, 66 per cent, 66 per cent, and 67 per cent of that of the proboscis.

Antennæ composed of 14 segments, of a dark greyish brown, without scales, with short, grey hairs equally distributed, whorls of hairs black at each joint with the exception of the basal segment, which is glabrous and of the second on which the hairs are irregularly placed. The length of the apical segment is one and a half that of the penultimate. Segments 2 to 13 are about equal in length.

Occiput.—There is an enlarged tuft between the eyes, composed of long white, straight and curved scales and yellow hairs; further back with long, grey lanceolate scales, finally with dark grey and black upright forked scales.

Thorax.—Prothoracic lobes well developed, covered with golden brown hairs. Mesonotum with a median tuft of lanceolate scales, greyish in front, elsewhere with numerous, short, golden incurved tufts. Smooth, paramedian lines on the anterior two-thirds of the mesonotum and lateral smooth ones on the posterior

half. Very dark hairs above the wing roots. Scutellum simple, not trilobed, yellowish grey and covered with long golden yellow hairs.

Wings.—First sub-marginal cell short, one-tenth the length of the wing, one-third the length of its stem; second posterior cell well developed, about one-fourth the length of the wing, the stem about two-thirds the length of the cell. Third long vein very slightly curved inwards; fifth a little more so. The part of the fourth long vein, which forms the stem of the second posterior cell, shows an obtuse angle, directed backwards. There are two or three well marked pseudo-veins. All veins covered with dark brown spatulate scales; fringe composed of straight, grey, pointed linear scales. There are no spots, the scales being of a uniform colour.

Abdomen black, without scales, covered with golden yellow hairs, more numerous on the first segment. The hairs of this segment are broader than those of the other segments. There is but one spermatheca composed of a spherical portion and a chitinous tube, the length of which represents nearly two-fifths the diameter of the sphere.

Legs deep yellow brown, without bands; ungues simple.

Length.—5.5 mm.

The larva in life assumes the typical position of *Anopheles*. The living larva is distinguished macroscopically by three clear zones on the dorsal surface. These zones are situated on the thorax, on the fourth and eighth segments of the abdomen.

For descriptive purposes we adopt the nomenclature proposed by Stanton (1915).

The antennæ show a median, plumose fine hair.

The internal, anterior clypeal hairs are situated close to the median line. They are simple. The external anterior clypeal hairs are plumose and situated on the same transverse line as the internal ones and as long as the latter. The posterior clypeal hairs are small, bifurcate and situated backward from the external anterior hairs.

The frontal hairs are six in number and all plumose. There are four occipital hairs, all bifurcate and of the same length. The situation of the internal pair is well behind that of the external pair; arranged in a semi-circle with the concavity anteriorly.

The submedian thoracic hairs form two groups composed of three hairs; a small, simple, external one, one slightly plumose, which is the most developed and an internal plumose one.

There are two pairs of palmate hairs on the thorax; none on the first abdominal segment; segments 2 to 7 each have a pair. The lamellæ of all these hairs are narrowly lanceolate and simple, that is, without denticles.

There is no respiratory siphon.

The teeth of the comb alternate irregularly; one or two short teeth being placed between two long teeth, this character is variable in different individuals. The teeth do not show the basal fringe of spines. Anal papillæ are four in number and well developed.

The internal buccal organs: maxillæ, mandibles and mentum are seen in figures 2, 4 and 5 (Brug and De Rook).

Habitat.—Territory of New Guinea: Muina (Biro); Beining district (Heydon and Hill); Dutch New Guinea; Pionierbivak, Mamberano River (Brug and De Rook).

The material in the Institute collection, a damaged male, does not permit the drawing up of a description, therefore those of Brug and De Rook, Edwards and Theobald have been used. It is a very distinct species which, according to Edwards, merits its retention in the genus *Bironella* instead of being merged into *Anopheles*.

Brug and De Rook found the larvæ in very peaty marshes. The larvæ, being only slightly active and not readily disturbed, were easily captured.

Heydon and Hill found the larvæ in the backwash of a small mountain stream, a tributary of the Nambung River in New Britain, which contained a considerable quantity of decayed vegetable matter.

Brug and De Rook state that, though their camp was but a short distance from the breeding ground, adults were never taken, whereas those of *A. punctulatus* var. *moluccensis* were abundant.

Relation to Malaria.—No evidence. Brug and De Rook state that it probably plays no part in the transmission of malaria.

CONCLUSIONS.

The life-histories of the majority of the species are fairly well known, though in some their variations have not been finally determined.

There is yet a considerable amount to be done in connection with the distribution of the various species before their range becomes well known.

It has been shown that the species of the subgenus *Anopheles* are fairly closely related, and that *annulipes* and *amictus* of the subgenus *Myzomyia* still require considerable research before the status of the various forms is finally established.

Bironella gracilis, Theob., has for the present at least been retained as generically distinct from *Anopheles*.

The definite relation borne by the various species to malaria has been shown to be entirely lacking, except in the case of one species *A. punctulatus* and its variety *moluccensis* which were proved by Heydon to be natural vectors at Rabaul. The evidence concerning *A. annulipes*, though presumptive, is not convincing inasmuch as we know that the blood of the patient had not been examined before he settled in the Sydney district (Money, 1926), therefore we do not know that he was free from the malaria parasite which may have been latent in his blood, even though he had not lived in a malarious country, and the Sydney district cannot under any circumstances be considered such.

Concerning *A. amictus* and *A. bancrofti* the position is rendered even more obscure since we know that *A. punctulatus* and var. *moluccensis* are both found in North Australia where both *amictus* and *bancrofti* are to be found in numbers,

and where, moreover, epidemics of malaria have from time to time occurred. Therefore, we cannot exclude the two latter species as vectors.

Coming now to Queensland, and North Queensland in particular, we find that apparently the prevailing species is *A. amictus* with a mixture of *A. bancrofti* and to a much less degree, if at all, of *A. annulipes*. In addition we cannot exclude the possibility of the presence of *A. punctulatus* and var. *moluccensis*. *Punctulatus* occurs well down the western side of the Gulf of Carpentaria as most probably also does its variety, therefore, it is not difficult to believe that it may be found on the Cape York Peninsula. Should they so be found, their presence would explain the epidemics which have occurred in the past. It may be asked with reason why has malaria practically died out from Cairns for instance? To the writer's mind the answer lies in the fact that all the important Anopheline breeding-places in that locality have been filled in or destroyed in recent years.

It was hoped to have illustrated this paper with drawings and photographs dealing with the adults, their life-histories and breeding-places, but time would not permit of their preparation.

A map of Australia has been prepared which gives the known distribution of *Anopheles* species. Where localities are close together, one of them has been omitted when harbouring the same species. All doubtful specific localities are likewise omitted.

In conclusion, I desire to tender my sincere thanks to Col. J. Cunningham for his kind invitation to contribute this paper, to Dr. J. S. C. Elkington, Director of the Division of Tropical Hygiene, for permission to do so, and also to my friend Dr. Mackerras, B.Sc., for the gift of specimens of *A. atratipes* Skuse, and *A. stigmaticus* Skuse.

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MAP.

