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THE ANOPHELINE FAUNA OF PAPUA NEW GUINEA

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ABSTRACT. Surveys for anopheline mosquitoes were conducted throughout the mainland of Papua New Guinea from 1992 to 1998 with the aim of mapping the distribution of the anopheline fauna. Larval collections, adult trap, and human landing collections indicated the presence of seven species (other than those belonging to the *Anopheles punctulatus* group); these were *An. bancroftii, An. annulipes, An. karwari, An. longirostris, An. meraukensis, An. novaguinensis,* and *An. subpictus.* The distribution and ecology of these species is discussed.

KEY WORDS Anophelines, speciation, distribution, Papua New Guinea

INTRODUCTION

Malaria is highly endemic in the lowlands of Papua New Guinea (PNG) and epidemic in the highlands above 1,500 m (van Dijk and Parkinson 1974). A recent survey of the anopheline fauna of the country has shown that the members of the *Anopheles punctulatus* group are the dominant species (Cooper et al. 2002), and these are believed to be the main malaria vectors (Spencer et al. 1974, Burkot et al. 1988). However, several other species of *Anopheles* occur in the country, and recently a number of these have been implicated in malaria transmission (Hii et al. 2000). It is therefore relevant to the study and control of the disease in PNG that the distribution of these species be defined. Spencer et al. (1974) and Lee et al. (1987) provide reviews on the distribution of the anophelines of PNG, but no new field surveys to determine the distribution of the anopheline fauna have been attempted since the 1970s. The purpose of this work is to report on a number of recent surveys, made throughout PNG, defining the distribution of *Anopheles* species other than those in the *An. punctulatus* group.

MATERIALS AND METHODS

Climate and geography

PNG makes up the eastern half of the island of New Guinea, the western half being the Papua (formerly Irian Jaya) Province of Indonesia. The climate and geography of PNG is discussed in detail elsewhere (Cooper et al. 2002). Briefly, the climate for coastal and lowland areas (<1,000 m) is continuous hot/wet (McAlpine et al. 1983). Although a drier period is experienced from May to November, rainfall is generally above 2,500 mm and on average, rainless periods of more than 4 days are rare; average mean temperature is 26°C. Above 1,000 m the climate is cool/wet, with similar rainfall to that of the lowlands, but with an annual mean temperature of 20°C. Exceptions to this are the regions south of the Fly River in Western Province and in the coastal region around Port Moresby; in these locations the climate is distinctly monsoonal, with close affinities to the wet/dry seasonal climate of northern Australia. Rainfall in these areas is below 2,000 mm (Figs. 3 and 4). The geography of PNG is dominated by the central ranges and Owen Stanley Range, which run east–west down the center of the island and rise steeply to over 3,000 m above sea level (asl). To the north and south of these ranges are river valleys and coastal plains, the most extensive being those of the Fly, Sepik, and Ramu Rivers (Löffler 1982).

Survey methods

The mainland of PNG was surveyed for anopheline mosquitoes over the period 1992–1998, with a 4–6-week survey being conducted in each of these years. With the use of 1:100,000 scale topographic survey maps the country was systematically surveyed with helicopters (Bell Jet Ranger 204) and land vehicles utilizing the available road network. The country was divided up into survey areas of approximately 250 km^2 (the area of one 1:100,000 scale map). The adult anopheline population was sampled with the use of carbon-dioxide–baited encephalitis vector surveillance (EVS) light traps (Rohe and Fall 1979) these were set in the evening (1600–1800 h) and collected in the morning (0700–0900 h). In the coastal and lowland regions 10 EVS traps were set overnight in each survey area; in the highlands (>1000 m) weather and difficult terrain limited the number of traps set each night to 5. Traps were located with the aim of effectively sampling from the entire survey area. Several larval collections were also made in each survey area, again with the aim to cover as much of the area as possible; however, the availability of bodies of water often dictated the sampling procedure. Larval collections were made with standard 350-ml larval dippers (Clarke Mosquito Control Products); each site was surveyed for about 30 min

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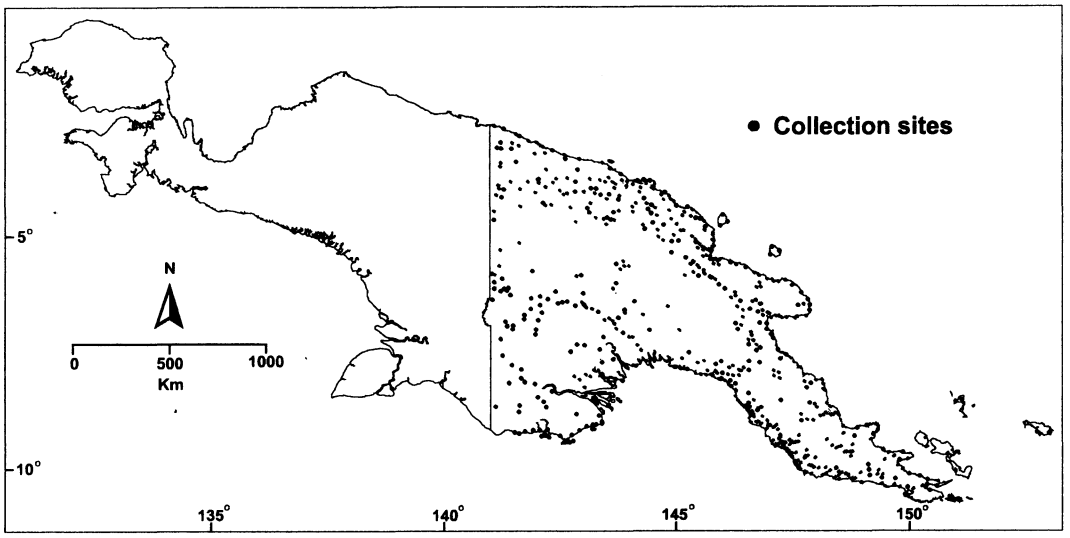

Fig. 1. All sites surveyed for Anophelines in Papua New Guinea.

or until about 50 larvae were collected. Where possible, EVS traps and larval collections were performed in and around villages. However, collections were also made in uninhabited areas. In most cases larval collections were made in the vicinity of trap collections to strengthen the collection data. Additionally, a limited number of anopheline landing catches were performed between 1900 and 0100 h, in which a collector bared his lower legs, ankles, and feet and, using an aspirator and torch, collected all anophelines that came to bite.

A survey form was created for each collection site; the form contained all relevant collection data, was given a unique site number, and identified by a 6-figure grid reference on the 1:100,000 scale survey maps. From these maps latitude and longitude coordinates were determined to 100-m^2 accuracy for each site and entered into a spatial data base (TNTmips® V5, Microimages Inc., Lincoln, NE). A coastal outline base map was created for the country by importing the Political/Oceans coverage of Digital Chart of the World (USA Defense Mapping Authority) into TNTmips. Localities were imported from TNTmips as point data onto these base maps. These were imported into a vector graphics program (Corel Draw™ V10, Corel Corporation, Ottawa, Ontario, Canada) where the appropriate text was added.

Processing of specimens

Larvae were reared to adulthood in their site water; where this could not be done they were preserved in 100% ethanol. Adults collected in EVS light traps, landing collections, or reared from larvae were killed by freezing and identified to species microscopically using the keys of Lee et al. (1987). Specimens were cryopreserved in vials labeled according to species, method of collection, site number, and date. At the Army Malaria Institute (AMI) the identity of some specimens was further analyzed by polymerase chain reaction–restriction fragment length polymorphism (PCR-RFLP) of the internal transcribed spacer 2 (ITS2) region of the ribosomal DNA with the methods of Beebe and Saul (1995).

RESULTS AND DISCUSSION

Anophelines were collected from 794 sites on the PNG mainland (Fig. 1). A total of 679 individual EVS traps were set, 473 of which were positive for anophelines; 421 larval collections were made and 26 anopheline landing collections were performed. From these collections 7 species, other than members of the *An. punctulatus* group, were identified. These were *Anopheles* (*Anopheles*) *bancroftii* Giles, *Anopheles* (*Cellia*) *annulipes* Walker, *Anopheles* (*Cellia*) *karwari* (James), *Anopheles* (*Cellia*) *longirostris* Brug, *Anopheles* (*Cellia*) *meraukensis* Venhuis, *Anopheles* (*Cellia*) *novaguinensis* Venhuis, and *Anopheles* (*Cellia*) *subpictus* Grassi. Table 1 shows the number of collection sites recorded for each species and the method of collection. Various ecological parameters associated with the distribution of each species, such as lowland/highland, coastal/inland, and the type of breeding sites utilized, are presented in Tables 2, 3, and 4, respectively.

Anopheles bancroftii was found predominantly throughout the inland, lowland ($\chi^2 = 81.4$, $P < 0.001$) regions of PNG (Fig. 2). Though not found in the highlands (>1,000 m above sea level [asl]) during the present survey, it has in the past been recorded from Minj (1,500 m asl) but it was not common (Peters and Christian 1960). It was found in the D'Entrecasteaux Islands in our survey and

Table 1. Collections (number sites and type) of *Anopheles* species made in Papua New Guinea.

Species	CO_2 trap	Larval	Landing catch	Total (%)[1]
An. bancroftii	82	10	3	95 (11.9)
An. annulipes HL[2]	4	50	0	54 (7.4)
An. annulipes PM[2]	0	5	0	5 (0.60)
An. karwari	12	0	0	12 (1.5)
An. longirostris	75	1	4	80 (10.0)
An. meraukensis	4	0	0	4 (0.5)
An. novaguinensis	0	2	0	2 (0.25)
An. subpictus	12	7	1	20 (2.5)

[1] Percentage based on the 794 sites found positive for anophelines.
[2] HL = highland genotype, PM = Port Moresby genotype.

by Spencer (1965), so it is capable of crossing modest sea barriers (50 km). *Anopheles bancroftii* had a preference for ovipositing in large, permanent water bodies (9/10; $\chi^2 = 6.4$, $P < 0.05$) such as swamps and large ponds, where the larvae were found along the edges in thick vegetation. Though widespread, it was only common in the flood plains of the Fly, Sepik, and Ramu rivers, where favored breeding sites were plentiful. However, even in these locations EVS trap collections above 100/trap/night were uncommon, Peters (1957) notes *An. bancroftii* as being "abundant" along the Fly River, and Van den Assem and van Dijk (1958) recorded the distribution of this species in Papua Province (previously Irian Jaya), Indonesia. These workers found that *An. bancroftii* was widespread throughout the lowlands of the province, but only abundant in areas of swamps and flood plains, such as the southern plains, where in some locations it was the dominant anopheline.

Anopheles bancroftii appears to be quite zoophilic and in the present survey it was collected in only 3 of 26 landing collections off human bait and then only in small numbers. In 1,276 paired indoor/outdoor whole-night landing collections conducted by Hii et al. (1997) in the Maprik area on the northern edge of the Sepik River flood plain, *An. bancroftii* made up only 0.7% of the 85,197 anophelines collected. Peters and Christian (1960) working in the Minj area of the Wahgi Valley recorded *An. bancroftii* as making up 5.8% of 22,591 anophelines collected in exit window traps.

Table 2. Lowland and highland distribution of *Anopheles* species in Papua New Guinea.

Species	Number of lowland and highland collection sites—elevation in meters (highest)	
	Lowlands <300 m	Highlands >1000 m
An. bancroftii	93 (240)	0
An. annulipes HL[1]	0	5 (1740)
An. annulipes PM[1]	54 (300)	0
An. karwari	10 (160)	0
An. longirostris	76 (200)	0
An. meraukensis	5 (40)	0
An. novaguinensis	2 (40)	0
An. subpictus	20 (40)	0

[1] HL = Highland genotype, PM = Port Moresby genotype.

Analysis of the ITS2 region of the rDNA by PCR-RFLP has revealed at least 4 different genotypes within the *An. bancroftii* taxon; these have been designated A, B, C, and D (Beebe et al. 2001). Genotype A was found in northern Australia and southern Western Province, Genotypes B and C occurred in the lowland areas in the southeast of PNG and Genotypes C and D occurred in the lowlands north of the central ranges (Fig. 2). Populations of Genotypes B and C, and Genotypes C and D, occurred sympatrically with no evidence of hybridization, and may represent independently evolving species (Beebe et al. 2001).

Anopheles bancroftii, along with *An. pseudobarbirostris,* make up the Bancroftii group. The two species have been separated by the black-and-white scaling of the wing fringe (Lee and Woodhill 1944); however, Knight and Stone (1977) noted this character to be quite variable and the status of *An. pseudobarbirostris* to be uncertain. In the material examined in this study the wing fringe pattern was also found to be variable, and *An. bancroftii, An. pseudobarbirostris, An. barbirostris* van der Wulp, and *An. barbumbrosus* Strickland and Choudhury could be identified. Additionally, there was no agreement between the wing fringe patterns and any of the genotypes identified (Beebe et al. 2001). It is considered that all the material collected in this study is *An. bancroftii,* though this taxon may prove to be a complex of several species.

Anopheles annulipes s.l. was found at 59 sites in PNG (Fig. 3). Two distinct populations, representing 2 different genotypes, appear to exist, one in the highlands (5 sites, all above 1,500 m asl, the highest 1,749 m asl) and one in the Port Moresby area (54 sites). They differ in ITS2 size (highland genotype = 580 bp and Port Moresby genotype = 590 bp), and the ITS2 region gives two distinct RFLP patterns when digested with restriction enzyme Msp1. The highland population appears restricted to the cool/wet climate found in PNG above 1,500 m asl, while the Port Moresby population was predominantly coastal (within 1 km of the coast, $\chi^2 = 50.0$, $P < 0.001$) though it was not

Table 3. Coastal and inland distribution of *Anopheles* species collected in Papua New Guinea.

Species	Number of coastal and inland collection sites (distance from the coast in km)		
	Coastal <1 km	Inland >1 km	*P*
An. bancroftii	3	90	$\chi^2 = 81.4$, $P < 0.001$
An. annulipes HL[1]	0	5	
An. annulipes PM[1]	53	1	$\chi^2 = 50.0$, $P < 0.001$
An. karwari	0	10	
An. longirostris	3	73	$\chi^2 = 64.4$, $P < 0.001$
An. meraukensis	2	2	
An. novaguinensis	0	2	
An. subpictus	15	5	$\chi^2 = 5.0$, $P < 0.05$

[1] HL = Highland genotype, PM = Port Moresby genotype.

found breeding in brackish water. The Port Moresby population was most abundant throughout a small enclave of monsoon-type climate (distinct wet and dry seasons with rainfall <1,600 mm) that exists along the coast east and west of Port Moresby (Fig. 3). *Anopheles annulipes* s.l. is a species complex and is known to consist of at least 10 species distributed throughout Australia (Green 1972, Booth and Bryan 1986, Booth et al. 1987). It is likely that the 2 populations described here represent 2 independently evolving species, and it is unlikely that either of them will be represented in Australia considering their spatial and temporal isolation.

In this study the majority of *An. annulipes* collections were made as larvae; both genotypes were rarely collected in EVS traps, and the Port Moresby genotype was not collected in any of the 10 night catches that were performed in the Port Moresby area, where the larvae of this species were common. Peters and Christian note similar behavior in the highland population where in the Minj area *An. annulipes* made up 73.3% of the total larval collections (3,069) but made up only 0.12% of exit window trap collections and was never collected biting humans (Peters and Christian 1960). The most commonly used larval habitats were small, temporary pools (43/55; $\chi^2 = 17.47$, $P < 0.001$); most sites were naturally formed bodies of water; however, human-made sites such as drains and wheel ruts were also utilized. Larger bodies of water, such as the edges of creeks and swamps, were used less frequently.

Other distribution records for members of this species are from around the eastern part of the Papuan peninsula (Lee and Woodhill 1944), the D'Entrecasteaux Is. (Spencer et al. 1974) and from the Milne Bay area (R. D. Cooper, unpublished data). There is one unconfirmed and doubtful record from the north coast of Papua, Indonesia

Table 4. Types of breeding sites used by anophelines in Papua New Guinea.

Type of Site	Sites sampled	Species[1]						
		ban	ann	lon	kar	mer	nov	sub
Small, temporary bodies of water (<2 m²):								
Pools	235	0	29	0	0	0	0	0
Wheel tracks	45	0	4	0	0	0	0	0
Pig wallows	15	0	1	0	0	0	0	0
Wells	7	0	0	0	0	0	0	0
Foot/hoof prints	6	0	2	0	0	0	0	0
Rubbish pits	1	0	0	0	0	0	0	0
Rock pools	1	0	0	0	0	0	0	0
Drains	42	1	7	0	0	0	0	1
Large, permanent bodies of water (>2 m²):								
Ponds–brackish	23	0	0	0	0	0	0	5
Swamps	17	5	2	1	0	0	1	0
Creeks/rivers	15	1	9	0	0	0	0	0
Ponds–fresh	7	2	1	0	0	0	1	1
Fish ponds	7	1	0	0	0	0	0	0
Total	421	10	55	1	0	0	2	7
Human made		1	15	0	0	0	0	1
Natural		9	40	1	0	0	2	6

[1] ban = *An. bancroftii*, ann = *An. annulipes*, lon = *An. longirostris*, kar = *An. karwari*, mer = *An. meraukensis*, nov = *An. novaguinensis*, sub = *An. subpictus*.

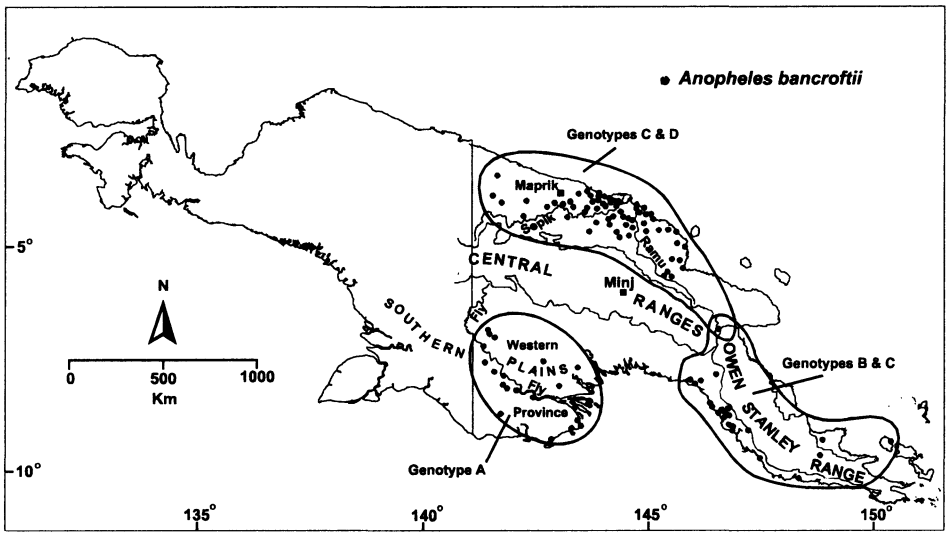

Fig. 2. Collection sites for *Anopheles bancroftii* in Papua New Guinea.

(Brug, cited in Lee and Woodhill 1944). Both Black (1954) and Peters and Christian (1963) have previously recorded *An. annulipes* from the Minj area (1,570 m) of the highlands.

The status of *An. annulipes* as a malaria vector is unknown. It was not found biting humans in this study, and there are few previous records of such behavior. This species may not play a role in malaria transmission in PNG.

Anopheles karwari is one of two Oriental species that have recently penetrated the Australian region. It was 1st recorded in the Jayapura/Lake Sentani area Papua Province, Indonesia in the 1930s (see Lee et al. 1987 for history), where it was believed to be rather common (Bonne-Wepster and Swellengrebel 1953). Peters and Standfast (1957) 1st recorded *An. karwari* in PNG from one specimen taken in the Maprik area in 1957, and indicated that it was spreading into northern PNG from Indonesia. Further collections have been made in this area since then by Hii et al. (1997) who found that it was the 3rd most common anopheline in their study area (Maprik), making up 14.3% of 85,197 anophelines collected over a 4 year period (1990–1993). There is also a reference to Bryan (unpublished data cited in Lee et al. 1987) collecting specimens

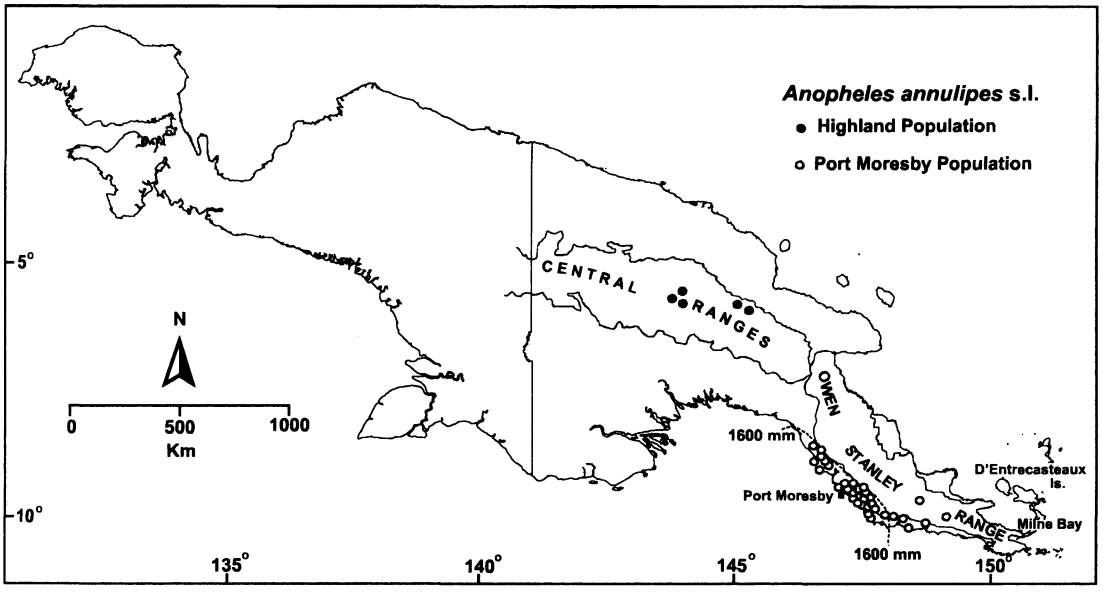

Fig. 3. Collection sites for *Anopheles annulipes* in Papua New Guinea.

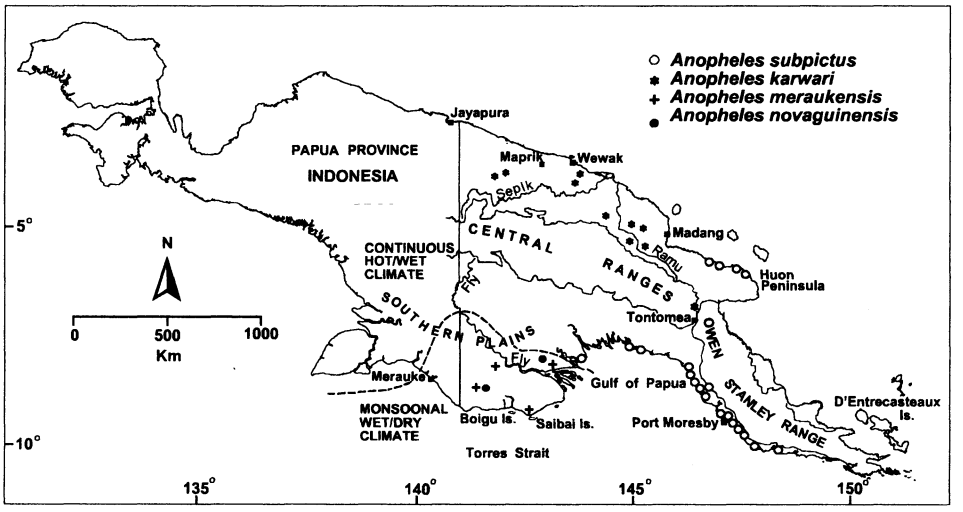

Fig. 4. Collection sites for *Anopheles meraukensis, Anopheles novaguinensis, Anopheles subpictus,* and *Anopheles karwari* in Papua New Guinea.

in Madang Province. In the mid 1970s *An. karwari* was regularly collected in Tontomea village in the Upper Watut Valley, but at the time these specimens were misidentified as *An. subpictus* (Afifi et al. 1980). In the present surveys, the most southeasterly collection of *An. karwari* was from the Lower Watut Valley. This species has not been recorded south of the central ranges, either in PNG or Papua, Indonesia (van den Assem and van Dijk 1958).

In this present study, most collections of *An. karwari* (9/10) were made from the Sepik and Ramu river flood plains; the Lower Watut Valley site was the most elevated at 160 m asl (Fig. 4). However, Tontomea village is at 960 m asl, and the ability of this species to exist in upland river valleys may facilitate its spread southeast across the central ranges.

Malarial infections were recorded in *An. karwari* collected from Tontomea (but misidentified as *An. subpictus* in Afifi et al. 1980), supporting Metselaar's (1955) findings that this species can play a role in malaria transmission. Sporozoite-infected specimens have since been collected from the Maprik area by Hii et al. (2000).

Anopheles longirostris was collected from 76 locations throughout PNG (Fig. 5); from these sites 1 larval, 75 EVS trap and 4 human landing collections were made. This species was widespread throughout the coastal and inland lowland areas of

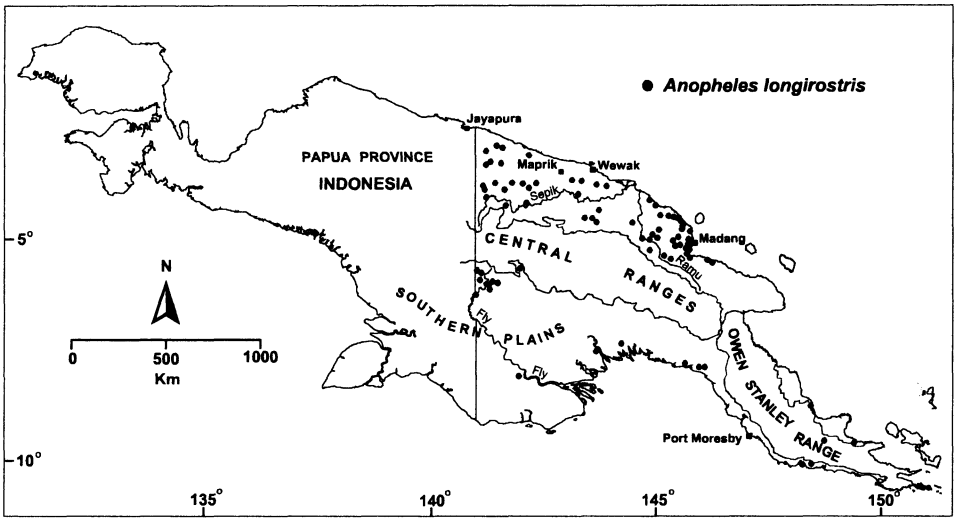

Fig. 5. Collection sites for *Anopheles longirostris* in Papua New Guinea.

PNG; the majority of sites were below 150 m asl and more prevalent inland than on the coast ($\chi^2 = 64.4$, $P < 0.001$). It was only common throughout the extensive flood plains of the Sepik and Ramu Rivers north of the central ranges; in this area, trap catches of up to 200 specimens/trap/night were recorded. However, generally throughout its range its numbers were low and 81% (61/75) of trap collections contained <5 specimens. South of the central ranges it was sparse except for a small area in the northwestern part of the southern plain. In Papua, Indonesia, van den Assem and van Dijk (1958) also found it widespread but never in large numbers and most prevalent on the southern plains.

In PNG, little was known about the distribution of *An. longirostris* before the present surveys. Lee and Woodhill (1944) cited 3 locations, Peters and Christian (1963) mentioned it from 1 location near Wewak, and 10 years later Spencer et al. (1974) added only 1 more locally.

The breeding sites of *An. longirostris* are difficult to locate, from 421 larval collections made in PNG during these surveys only 1 was found to contain this species. Peters and Christian (1963) made 1,019 separate larval collections in the coastal and lowland regions of PNG and failed to locate *An. longirostris,* and Bick (1951) made 1 collection of *An. longirostris* from 1,508 larval habitats examined. The 1 collection made during the present surveys was from a swamp, which, in association with jungle or dense vegetation, appears to be the typical larval habitat used by this species (Lee and Woodhill 1944).

Anopheles longirostris is considered primarily a zoophilic species, having little association with humans (Lee and Woodhill 1944, Charlwood et al. 1985, Lee et al. 1987). However, it has been recorded biting humans (Peters and Christian 1963, Hii et al. 1997). In the present surveys, it was found to be the dominant *Anopheles* species in human-landing catches in 2 villages in the Madang area in April 1995; yet in other villages close by it was rarely collected. Recently Hii et al. (1997) reported sporozoites in this species in the Maprik region, and infected specimens have been found in other parts of its range (R. D. Cooper, unpublished data). This species appears to be a competent, if secondary, vector of malaria.

The type locality of both *An. meraukensis* and *An. novaguinensis* is the southern plains of Papua Province (Indonesia), but in this area van den Assem and van Dijk (1958) found their distribution to be limited and neither species were found in large numbers. The present surveys provide the 1st records of these species in PNG (Fig. 4), though their presence there is not unexpected, given that the southern plains region extends across both countries and the habitat and climate are similar. Additionally, *An. meraukensis* has been collected on Boigu and Saibai Islands within 5 km of the coast of PNG in the Torres Strait (Booth 1988).

In both Indonesia and PNG the distribution of *An. meraukensis* and *An. novaguinensis* is limited to a region of monsoon climate that prevails in the southern part of the southern plains (Fig. 4). This climate type, with its pronounced wet and dry seasons, is typical of northern Australia, where both these species are very common (Cooper et al. 1996). It appears that both species cannot penetrate the typical continual hot/wet climate that occurs throughout most of PNG.

Anopheles subpictus was collected from 20 localities (Fig. 4); from these sites 7 larval, 12 trap, and 1 human landing collection were made. This species was uncommon on the north side of the central ranges, being recorded from 4 closely related sites on the Huon Peninsula, although other workers have recorded this species from Wewak (Peters and Christian 1963) and Madang (Afifi et al. 1980). South of the ranges during the present surveys, it was found it to be fairly common along the Papuan Gulf and on the southern side of the Papuan Peninsula. This southern distribution is in agreement with the records of other workers (Spencer 1975), though the present surveys increase its range to the western side of the Gulf of Papua. It has also been recorded from the D'Entrecasteaux Islands off the tip of the Papuan Peninsula (Spencer 1965). Hill (1925) 1st described *An. subpictus* in PNG in 1925 from the Port Moresby area. Its distribution in PNG is widespread but patchy, and is difficult to explain. It is only found in reasonably large numbers on the eastern side of the Gulf of Papua (Bang et al. 1947, and this survey). It is possible that military operations during the Second World War facilitated its introduction into coastal areas of PNG.

Anopheles subpictus is an Oriental species, which, along with *An. karwari,* has invaded the island of New Guinea. However, although *An. subpictus* is recorded from the Moluccas and islands to the west of Papua Province, Indonesia, there are no records of it occurring in Papua Province (Bonne-Wepster and Swellengrebel 1953, van den Assem and van Dijk 1958). All collections of this species in the Australian Region are from on or near the coast. The inland location near Wau, mentioned in Afifi et al. (1980), was a misidentification of *An. karwari.* The larvae of *An. subpictus* will tolerate brackish water (Bonne-Wepster and Swellengrebel 1953), and in the present survey the most commonly used breeding sites were brackish coastal lagoons (5/7 sites) though this preference was not statistically significant ($\chi^2 = 1.28$, $P > 0.05$). The coastal, brackish water breeding habits of this species may have facilitated its dispersal throughout the island chain of Indonesia into New Guinea (Service 1997). A similar concept has been suggested for the dispersal of *An. farauti,* another coastal salt water breeding species, throughout the islands of the southwest Pacific (Belkin 1962).

In this survey *An. subpictus* was recorded biting

humans, and other workers have noted a similar behavior (Bang et al. 1947, Spencer 1975). There is 1 record of *An. subpictus* infected with oocysts (Bang et al. 1947) and this species may play a minor role in malaria transmission.

On the Indian subcontinent *An. subpictus* is known to be a complex of 4 reproductively distinct species (Suguna et al. 1994). One species, *An. subpictus* B, is a common coastal species that will breed in brackish water and, unlike the other species, will readily bite humans and is a minor vector of malaria. Thus the ecology and biology of *An. subpictus* B is similar to that of *An. subpictus* recorded here and it is possible that they are same species.

CONCLUSIONS

Previous studies on the anophelines of PNG have focused on the members of the *Anopheles punctulatus* group, these being considered the most important vectors of malaria. The surveys reported on here bring up to date the distribution of several other species that occur in the country. The findings indicate that the species reported on here were, in the main, uncommon and had restricted distributions. *Anopheles bancroftii* and *An. longirostris,* the 2 most common and widely distributed species, were found in only 11.9% and 10.0%, respectively, of the 794 sites positive for anophelines. The findings support the concept that the members of the *Anopheles punctulatus* group are the dominant anopheline fauna of PNG (Cooper et al. 2002).

Of the 7 species collected in these surveys, *An. bancroftii, An. longirostris, An. karwari,* and *An. subpictus* have previously been incriminated as vectors of malaria. Given the limited attention these species have received in past malaria surveys, their role in transmission may be underestimated, particularly in areas where favorable local conditions may promote higher densities and greater human contact.

Two species not collected in these surveys, but previously reported from New Guinea, are *Anopheles* (*Anopheles*) *papuensis* Dobrotworsky and *Anopheles* (*Cellia*) *hilli* Woodhill and Lee (Lee and Woodhill 1944, van den Assam and van Dijk 1958, Lee et al. 1987). Both are uncommon species with restricted distributions, *An. hilli* occurs in the Merauke area (Indonesia) of the southern plains, it has not been found in PNG; however, like *An. meraukensis* and *An. novaguinensis,* it probably occurs there. *Anopheles papuensis* has been recorded from several locations in the highlands of the central ranges of PNG all above 1,500 m asl.

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