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# DISTRIBUTION OF MEMBERS OF THE *ANOPHELES FARAUTI* COMPLEX IN THE NORTHERN TERRITORY OF AUSTRALIA

R. D. COOPER, S. P. FRANCES AND A. W. SWEENEY

*Army Malaria Research Unit, Liverpool Military Area, NSW 2174 Australia*

ABSTRACT. The distribution of members of the *Anopheles farauti* complex was studied in the Northern Territory of Australia during 3 surveys conducted in 1988, 1989, and 1990. At the time of these surveys *An. farauti s. l.* was common north of 15°S along the coast and up to 50 km inland. The sibling species *An. farauti* 1, *An. farauti* 2, and *An. farauti* 3 were identified from 126 adult and larval collections using allozyme electrophoresis and species-specific DNA probes. *Anopheles farauti* 1 was the most abundant species along the coast and was found in 45% of collections. *Anopheles farauti* 2 had a more restricted range, occurring in 12% of collections on the east coast and in the central area of the survey region. *Anopheles farauti* 3 had the widest distribution of the 3 species, occurring on the coast and throughout the coastal plain up to 100 km inland. It was found in 43% of the collection sites. The distribution of the 3 sibling species is discussed with regard to the possibility of malaria transmission in the area.

## INTRODUCTION

Members of the *Anopheles farauti* complex are important vectors of malaria throughout New Guinea, the islands of the Bismarck Archipelago, the Solomon Islands, and Vanuatu (Belkin 1962). In Australia members of the complex have been incriminated as vectors of malaria in northeastern Queensland (Mackerras 1947) and were regarded as suspected vectors in malaria outbreaks that, up until 1962, regularly occurred throughout the northern areas of the Northern Territory (O'Gower 1958, Black 1972).

Hundreds of imported malaria cases enter Australia each year, and although the Australian mainland is now malaria-free, the region north of 19°S is receptive to the disease. These imported cases have at times led to local transmission of the disease (Sweeney 1980, Musgrave 1987). The threat of future outbreaks has increased with expanding tourism and mining industries in this region, as these activities have resulted in a greater risk of man/vector contact. Thus, within this northern receptive area, it is important that the distribution of the members of the *An. farauti* complex be determined.

Early distribution records have been compiled for the Northern Territory (O'Gower 1958) and for northern Queensland (Marks 1980). However, in Australia this taxon is now known to consist of 3 sibling species that have been designated as *An. farauti* 1, 2, and 3 (Bryan 1973, Mahon and Miethke 1982). Little is known about the distribution, biology, or behavior of these species. Their relative importance as malaria vectors also is not known; however, all 3 species have been found to be capable of transmitting *Plasmodium vivax* under experimental conditions (Cooper 1994) and it is possible that all 3 may be competent vectors.

Sweeney et al. (1990) studied the distribution of the 3 species of *An. farauti* on Cape York Peninsula and Foley et al. (1991) reported the presence of *An. farauti* 1 and 3 in the Darwin area, Northern Territory. There are no records of their occurrence in other malaria-receptive areas of Australia. This paper reports on the distribution of the members of the *An. farauti* complex in the Northern Territory.

## MATERIALS AND METHODS

*Survey area:* The area of the Northern Territory surveyed was that north of 16°S, bounded in the west by the Timor Sea (128°E), and in the east by the Gulf of Carpentaria (136°30′E), a total area of approximately 300,000 km². This region is characterized by a coastal plain, varying from 50 to 100 km in width, and crossed by numerous large river systems that flow to the coast from an inland plateau region 200–300 m high. Two distinct climatic conditions affect the area. A wet season, which receives more than 95% of the annual rainfall (1,000–1,100 mm), occurs from December to April. This is followed by a dry season, with an average precipitation of 30–35 mm. During the wet season much of the coastal plain is inundated with water, which drains away during the early months of the dry season.

The vegetation throughout the region is tropical woodland in which the upper stratum consists of *Eucalyptus* species. The ground stratum is grassland and tussock grassland with *Sorghum* and *Eriachne* species predominating. Dense vegetation, ranging from open to closed forest, occurs along permanent water courses and around swamps and consists mainly of *Melaleuca* species. Mangroves are common along the coastline and in areas of tidal influence; these areas are

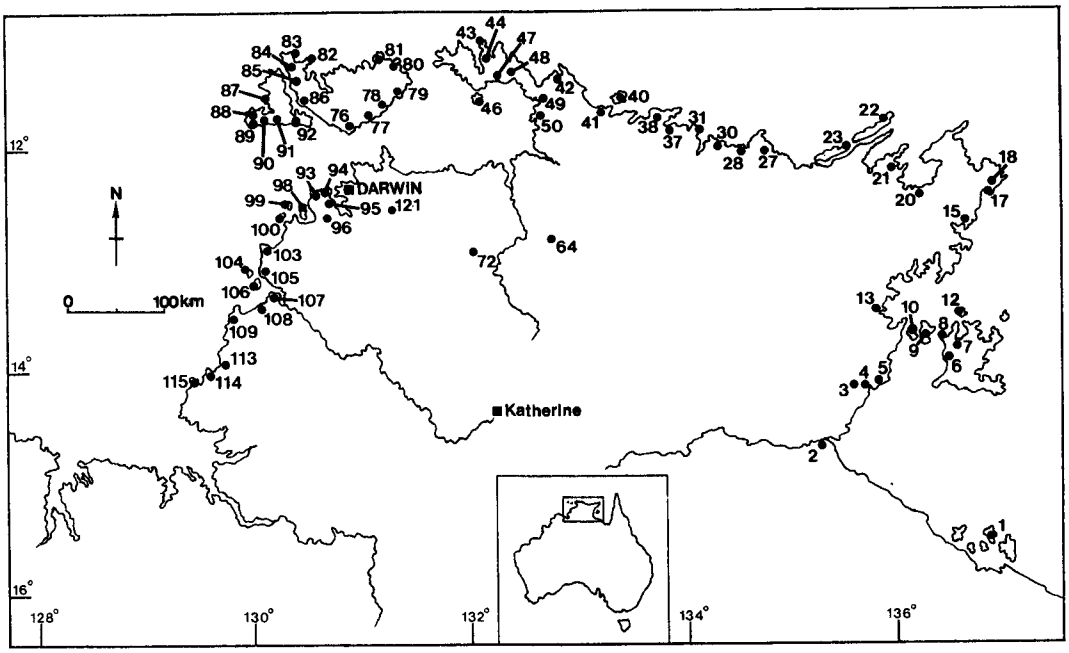


Fig. 1. Map of the Northern Territory showing collection sites positive for *Anopheles farauti* 1.

often associated with extensive saline mudflats. During the dry season much of the woodland areas are subject to bush fires. These fires are quite intense and are checked only by the moist conditions around permanent water sources.

*Collection methods:* In order to cover this vast area 3 surveys were conducted. The first in 1988 surveyed the eastern part of the region (sites 1–14 in Figs. 1 and 2), the 2nd in 1989 surveyed the central part of the region (sites 15–75 in Figs. 1, 2, and 3), and the 3rd in 1990 surveyed the western part of the region (sites 76–123 in Figs. 1, 2, and 3). Each survey was carried out at the end of the wet season in May–June when it was anticipated that mosquito densities would be at their peak. Adult mosquitoes were collected in $CO_2$ baited light traps set overnight in shaded, sheltered localities near potential oviposition sites. Larvae were collected from a range of temporary and semipermanent bodies of water and subsequently reared to adults for identification. Collection sites were selected to provide mosquito samples from the various vegetation and terrain types in the survey area.

The region was covered using 4-wheel-drive land vehicles and helicopters. The road system within the Northern Territory is not extensive and many tracks could only be used at the end of the dry season. Thus much of the area and many of the communities scattered throughout the region are quite isolated. Helicopters were used to access remote areas, both inhabited and uninhabited. Weight and range restrictions on the helicopters limited the size of the survey team and the time spent at any one site. For these reasons helicopters were used for adult collections, with 5 traps, placed 15–20 km apart, being set each evening and retrieved the next morning. Land vehicles, although restricted to the road system, did not have a weight and range problem, and a greater number of larval collections could be made even though they were more time consuming.

All live adult mosquitoes collected in traps or reared from larvae were immobilized using chloroform or by freezing at −20°C. Using a pictorial key, adapted from the binomial keys of Lee and Woodhill (1944), specimens of the *An. farauti* complex could be readily separated, using 4 easily recognized morphological characteristics, from the 6 other species of *Anopheles* found in the region. All members of the complex were stored in liquid nitrogen for transporting to our laboratory at Ingleburn where specific identifications were made using starch gel electrophoresis (Mahon 1984), or $^{32}$P-labelled, species-specific, DNA probes (Cooper et al. 1991). The majority of adults retrieved from the traps were alive and in a condition suitable for morphological examination and allozyme analysis. Dead and dried specimens were subjected to DNA probe analysis. Degradation of the DNA in desiccated speci-

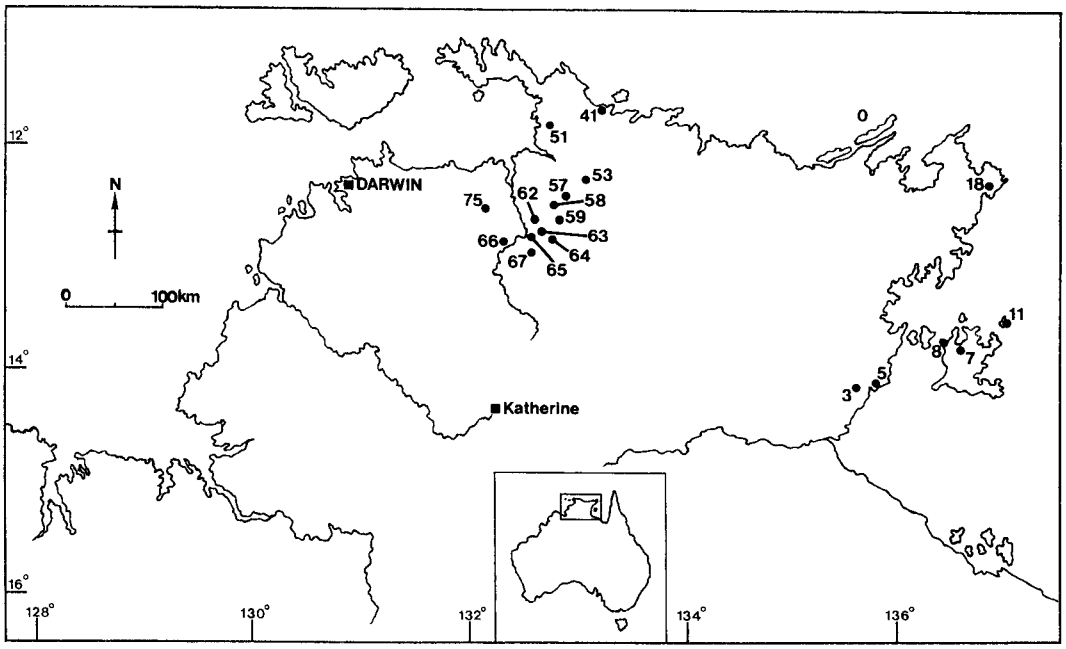


Fig. 2. Map of the Northern Territory showing collection sites positive for *Anopheles farauti* 2.

mens was not a problem, even when squash blots were used, due to the high sensitivity of the probes. Laboratory reference colonies provided controls for both of these methods.

## RESULTS

The complimentary use of helicopters and land vehicles proved to be a most efficient means of systematically surveying the vast and remote areas of northern Australia. The 3 surveys yielded *Anopheles* species from 289 localities. Members of the *An. farauti* complex were found in 123 of these sites from 126 separate collections (Figs. 1–3). The majority of these collections were from the coast and coastal plain. Very few sites yielding members of the *An. farauti* complex were found more than 50 km inland, despite extensive sampling (Table 1). In the 1988, 1989, and 1990 surveys 14, 61, and 48 sites were found with *An. farauti s. l.*, respectively. Of the 126 collections 100 were of adults and 26 were of larvae. The number of *An. farauti s. l.* in the adult collections ranged from 1 to 468/trap/night. The majority of collections (83/126) were less than 25/trap. Numbers per trap were between 25 and 100 in 27 collections and were greater than 100 in 16 collections. The latter 16 sites were scattered throughout the survey area and were not restricted to any one particular species.

The sibling species identified from these collections are shown in Table 2. The number of collections of *An. farauti* 1 and 3 were similar, being 45.1% (74/164) and 43.3% (71/164), respectively. *Anopheles farauti* 2 was recorded in only 11.6% (19/164) of the collections. *Anopheles farauti* 1 was collected almost exclusively from coastal locations with 65 of the 73 sites for this species being within 1 km of the coastline (Fig. 1 and Table 1). *Anopheles farauti* 2 was collected from the east coast and from the central part of the survey region where it was relatively abundant. In one area it was the dominant species present (Fig. 2, sites 62–65 and 67) but it was not found in the western part of the survey area (Fig. 2). *Anopheles farauti* 3 was the most widespread of the 3 species. Except for the far southeastern part of the survey area, this species was common along the coast and throughout the inland regions (Fig. 3).

Adult trap collections were more productive than larval collections. At the time of the 1989 survey much of the region was inundated with receding flood waters and although adults of *An. farauti s. l.* were plentiful in the area, larvae were difficult to locate due to the amount of water present. During this survey *An. farauti s. l.* were found in 61 of 85 adult trap collections, but in only 9 of 77 anopheline larval collections.

All 3 species utilized a wide range of permanent and semipermanent water bodies for oviposition. The majority of these sites were natural

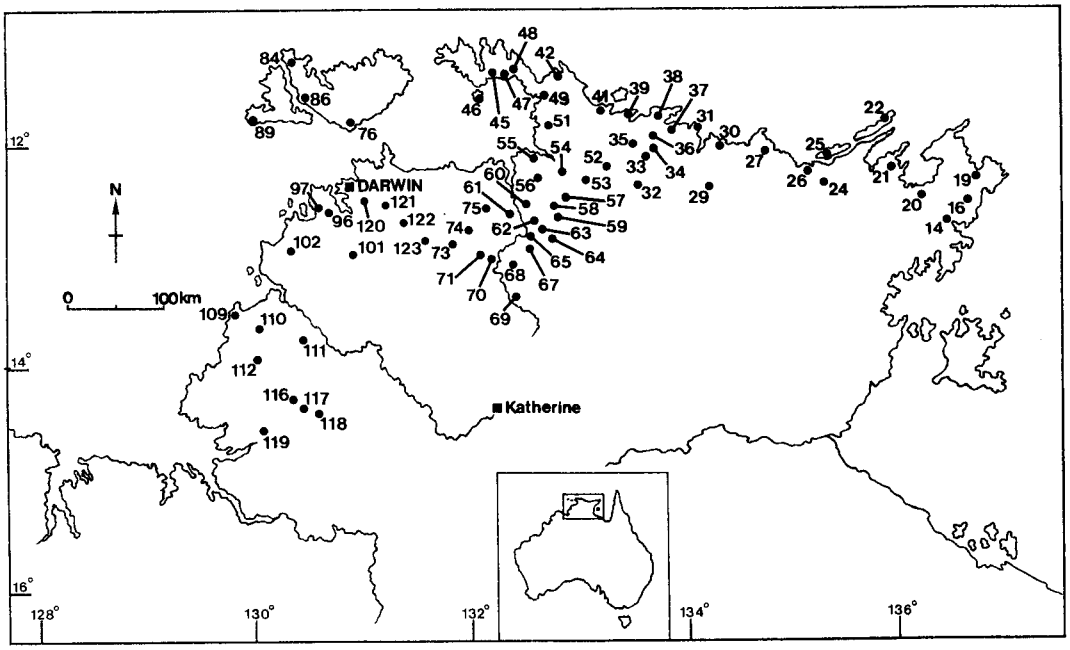


Fig. 3. Map of the Northern Territory showing collection sites positive for *Anopheles farauti* 3.

or animal-made. However, man-made sites (borrow pits, road side ditches, wheel ruts, and concrete drains) were also utilized. All sites contained vegetation in the form of algal mats or emergent reeds and grasses. In small pools as well as in larger water bodies, such as swamps, larvae were found around the edges of the site in water less than 0.1 m deep and always in or amongst floating or emergent vegetation. Of the 17 larval sites positive for *An. farauti* 1, 10 were brackish with salinities as high as 35 ppt. This species was also found in association with *An. farauti* 2 in 3 sites and with *An. farauti* 3 in one site. The larvae of *An. farauti* 2 and 3 were found together in only one site.

Table 1. Collection sites of *Anopheles farauti* 1, 2, and 3 and their proximity to the coast.

| Distance from the coast (km) | Species | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 0–<1 | 64 | 9 | 23 |
| 1–<5 | 6 | — | 9 |
| 5–<10 | — | 1 | 2 |
| 10–<20 | — | 1 | 8 |
| 20–<30 | 1 | 5 | 7 |
| 30–<40 | 1 | 2 | 6 |
| 40–<50 | 1 | — | 3 |
| 50–<60 | 1 | — | 4 |
| 60–<70 | — | 1 | 1 |
| 70–<80 | — | — | 3 |
| 80–<90 | — | — | 2 |
| 90–<100 | — | — | 2 |

## DISCUSSION

The southern limit for the members of the *An. farauti* complex in these surveys was 15°30'S in the eastern part of the survey area and 14°30'S in the west. North of these latitudes *An. farauti s. l.* was common along the coast and on the coastal plain up to 50 km inland. The distribution of *An. farauti s. l.* found during these surveys

Table 2. *Anopheles farauti* 1, 2, and 3 identified from 126 larval and adult collections made in the Northern Territory.

| Sibling species | Type of collection | | Sibling species | | |
|---|---|---|---|---|---|
| | Adult | Larval | 1 | 2 | 3 |
| 1 | 35 | 12 | 47 | — | — |
| 2 | 1 | 1 | — | 2 | — |
| 3 | 34 | 7 | — | — | 41 |
| 1 + 2 | 3 | 3 | 6 | 6 | — |
| 1 + 3 | 17 | 2 | 19 | — | 19 |
| 2 + 3 | 8 | 1 | — | 9 | 9 |
| 1 + 2 + 3 | 2 | — | 2 | 2 | 2 |
| Totals | 100 | 26 | 74 | 19 | 71 |

is similar to that recorded by O'Gower (1958). However, O'Gower recorded several *An. farauti s. l.* sites near the inland town of Katherine; in the present surveys no positive sites were found in this area, which is 240 km from the coast. It is possible that the range of these species varies from year to year depending on the length and intensity of the wet season. The wet season prior to the 1988 survey had below average rainfall and, in that year, only 14 sites with *An. farauti s. l.* were found. However, the 1989 and 1990 surveys, which were made after good wet seasons, yielded 61 and 48 sites positive for *An. farauti s. l.*, respectively.

Previous observations of the distribution of the 3 sibling species of *An. farauti* made on Cape York Peninsula (Sweeney et al. 1990) indicated that *An. farauti* 1 was mainly a coastal species, with *An. farauti* 2 occurring on both the coast and inland, and with *An. farauti* 3 being more prevalent inland. In the present study *An. farauti* 1 was again found to have a predominantly coastal distribution. *Anopheles farauti* 2 was neither as common nor as widespread in the Northern Territory as it was on Cape York Peninsula. It was found in large numbers in only one area (Fig. 2, sites 62–65 and 67) and was absent from the western part of the survey region. *Anopheles farauti* 3 had the widest distribution of the 3 sibling species in the Northern Territory. It was commonly found inland and, unlike the observations on Cape York Peninsula, it was regularly collected from coastal areas.

The affinity of *An. farauti* 1 for the coast is no doubt promoted by the ability of the larvae to develop in brackish water (Sweeney 1987). During the present study, larvae of this species were collected from a number of sites with salinities up to 35 ppt. However, this species will also utilize fresh water sites and in a number of larval collections, *An. farauti* 1 was found in association with *An. farauti* 2 and 3 (Table 2). Both of these latter species will not tolerate saline conditions (Sweeney 1987).

The distribution of *An. farauti* 1, 2, and 3 throughout the Northern Territory is not restricted to areas of human habitation, but extends to remote and uninhabited areas, where in a number of cases high densities were recorded (Fig. 1, sites 22, 26, 88, and 105). A similar pattern of distribution was found in north Queensland (Sweeney et al. 1990), which implies that these 3 species are not dependent on man as a blood source. Observations in the Darwin area by Foley et al. (1991) showed that *An. farauti* 1 and 3 preferred pig and calf to man. In Papua New Guinea, *An. farauti* 1 was highly anthropophilic, with a human blood index of 83%, in villages where few other animals were present (Charlwood et al. 1985). However, this index dropped to 9% in villages where pigs and dogs were plentiful. In the Northern Territory feral pigs, water buffaloes, and goats, as well as cattle and native marsupials, are present throughout the range of *An. farauti* 1, 2, and 3 and thus it is unlikely that the availability of blood sources would limit mosquito numbers.

Malaria is no longer endemic in the Northern Territory and it is unlikely that it will ever become so again. However, the possibility of local transmission occurring as a result of imported cases is a concern for health authorities in the area (Currie et al. 1990). Past malaria outbreaks in the Northern Territory were identified with areas of human activity such as mining and land development projects (Black 1972). In more recent years the tourist industry has expanded with all-weather roads increasing the number of people camping in remote areas. The wetland areas of Kakadu National Park (Figs. 2 and 3, sites 62–67) are popular destinations. This region receives approx 75,000 visitors (20% being from overseas) during April to August. The early months of this period coincide with high numbers of *An. farauti s. l.* and, during the 1989 survey, collections of more than 50 *An. farauti s. l.*/trap/night were recorded from several of these camping areas.

A vector species was not identified at the time that malaria was endemic in the Northern Territory. *Anopheles farauti* was listed only as a suspected vector (O'Gower 1958) because at the time it had not been found in appreciable numbers and malaria workers considered other *Anopheles* species to be responsible for transmission in the region (Mackerras 1947). The findings reported here show that moderate to high densities of *An. farauti* 1, 2, and 3 could be found throughout the northern region of the Northern Territory following normal wet season conditions.

Little is known about the biology and behavior of these 3 sibling species, so it is difficult to explain their distribution and the variation that was noted in their abundances. Suitable oviposition sites, adult resting sites, and blood meal sources appeared to be available throughout the survey area, both inland and below 15°S. However, the distribution of the 3 species did not extend into these areas. This implies that there may be subtle differences in the environmental requirements of the 3 species that mediate their distribution and prevalence.

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