DISTRIBUTION OF THE SIBLING SPECIES OF *ANOPHELES FARAUTI* IN THE CAPE YORK PENINSULA, NORTHERN QUEENSLAND, AUSTRALIA

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ABSTRACT. The sibling species of *Anopheles farauti s.l.* were collected in larval and adult surveys from 34 localities on Cape York Peninsula and were identified by isoenzyme electrophoresis. The most common species near the coast was *An. farauti* 1 which was often found breeding within 100 m of the sea in either brackish or freshwater habitats. Larvae of the other 2 species were not found in brackish water which accords with previous laboratory observations of their lower salinity tolerance. *Anopheles farauti* 2 appears to have the widest distribution of the 3 sibling species on Cape York Peninsula as it was common in both coastal and inland localities. *Anopheles farauti* 3 was rarely found near the coast. In one locality at Lockhart River near the east coast of the peninsula larvae of the 3 species were found together in a small muddy creek.

INTRODUCTION

Anopheles farauti Laveran is a major vector of malaria in the Southwest Pacific Region and has been incriminated as a vector in malaria outbreaks occurring in northern Australia (Mackerras 1947). Its distribution extends eastward from the Moluccas through the Melanesian islands of New Guinea, the Solomons and Vanuatu. In Australia *An. farauti s.l.* has been recorded in Queensland north of Townsville (latitude 19°S), the Northern Territory (Lee and Woodhill 1944) and one record from Western Australia (Liehne et al. 1976). Cross-mating and chromosome studies have shown that this taxon consists of 3 sibling species which have been designated: *An. farauti* 1, *An. farauti* 2, and *An. farauti* 3 (Bryan 1973, Mahon and Miethke 1982).

No reliable morphological characters have been found to distinguish between these sibling species in the field. Consequently, there is little available information on the larval and adult biology of the individual species and their relative importance as malaria vectors is not known. Similarly, there are few records of the geographical distribution of the member species. Only *An. farauti* 1 has been reported in Papua New Guinea (Charlwood et al. 1986), though the 3 species occur sympatrically at Innisfail, Queensland, Australia (Mahon and Miethke 1982).

In this paper we report the results of a survey to investigate the distribution of the *An. farauti* sibling species in the Cape York Peninsula area of northern Queensland. The individual species were identified using a starch gel isoenzyme electrophoresis method developed by Mahon (1984).

MATERIALS AND METHODS

Area covered: The Cape York Peninsula is a triangular tract of far north Queensland encompassing 25,000 km^2 of land extending from 10°30′S to 14°S bounded on the west by the Gulf of Carpentaria and the east by the Coral Sea. This is a sparsely populated region which was formerly malarious (Black 1972). It is considered to be an important area of floral and faunal interchange between Australia and New Guinea in which elements of the New Guinea rain forest penetrate southward and the Australian savanna extends northward (Taylor 1972). Collections of mosquitoes from Cape York Peninsula include records of *An. farauti s.l.* from several localities (Marks 1980).

Collecting methods: The survey was conducted during June 1986, following the north Australian wet season when mosquitoes are usually most abundant. Collections were greatly facilitated by the use of a Kiowa helicopter from the 162 Reconnaissance Squadron which permitted visits to inaccessible wilderness areas which could not have been covered by land vehicles. Sorties were made at an altitude of 100–300 m along the western and eastern coasts as well as inland to select suitable localities for adult and larval mosquito collections. The helicopter survey was supplemented by road parties in 4-wheel-drive vehicles. Adult mosquitoes of *An. farauti s.l.* were caught in carbon dioxide baited light traps and in man biting catches from localities throughout the survey area. Larvae were collected from breeding sites and were transported to a field laboratory at the town of Weipa. The anopheline larvae were reared to adulthood in trays of water from their respective collection sites. The salinity of coastal breeding sites was analyzed where possible with a salinity meter (Yellow Springs Instruments Co., Inc., model 33). Adult mosquitoes from both kinds of collections were examined with a stereomicroscope. Those identified as *An. farauti s.l.* were stored in liquid nitrogen and were subsequently subjected to starch gel electrophoresis in our laboratory at Ingleburn. The electrophoretic mobil-

ities of lactate dehydrogenase (LDH) and octanol dehydrogenase (ODH) of test specimens were compared with those of reference colonies of the 3 species which are maintained in our insectary. *Anopheles farauti* 1 adults are homozygous for a unique allele at the LDH locus and *An. farauti* 3 individuals are homozygous for an allele at the ODH locus. Simultaneous staining for both enzyme systems permits unambiguous identification for each of the 3 sibling species (Mahon 1984). The site numbers indicated in the results and discussion correspond to the numbers in Table 1 and the numbers (within squares) in Fig. 1.

RESULTS

During this survey anopheline mosquitoes were found in 64 localities, 34 of which contained *An. farauti s.l.* (Fig. 1). Of these 22 were larval sites, 7 were sites of adult collections, and in the remaining 5 sites both larvae and adults were collected. The species composition of collections according to their proximity to the coast are shown in Table 1. All of the adult collections and 17 of the larval collections were made within 5 km of the sea or estuaries, whereas the remaining 10 larval collections were made from 7 to 68 km from the coast. Most of the coastal

Table 1. Larvae and adults of *Anopheles farauti* sibling species collected on Cape York Peninsula.

Site	Location	Locality	Type of collection	Distance from sea	Species		
					1	2	3
1	10°48′S;142°34′E	Saldogoo Beach	Larvae	<100 m	—	2	—
2	10°50′S;142°33′E	Kilbie Beach	Larvae	<100 m	1	—	—
3	11°18′S;142°07′E	Vrilya Point	Larvae (br)	<100 m	4	—	—
4	11°28′S;142°05′E	Doughboy Creek	Larvae	<100 m	7	—	—
4	11°28′S;142°05′E	Doughboy Creek	Adult	<100 m	3	—	—
5	11°37′S;142°51′E	Captain Billy Landing	Larvae (br)	<100 m	1	—	—
6	11°54′S;141°57′E	Port Musgrave	Adult (t, b)	<100 m	2	—	—
7	11°58′S;141°53′E	Port Musgrave	Adult (t)	<100 m	6	17	—
8	12°48′S;143°21′E	Quintel Beach	Larvae	<100 m	2	—	—
9	12°54′S;141°40′E	Boyd Point	Larvae	<100 m	—	1	—
10	13°05′S;141°37′E	False Pera Head	Larvae	<100 m	1	—	—
11	13°19′S;141°40′E	Aurukun	Larvae (br)	<100 m	3	—	—
11	13°19′S;141°40′E	Aurukun	Adult (t)	<100 m	108	—	—
12	10°51′S;142°22′E	Red Island Point	Adult (t)	1 km	7	—	1
13	11°18′S;142°07′E	Vrilya Point	Larvae	1 km	—	2	—
14	11°42′S;142°01′E	Skardon River	Adult (t)	1 km	1	—	—
15	12°12′S;141°45′E	Pennefather River	Adult (t)	1 km	3	—	—
16	12°06′S;141°47′E	Pennefather River	Adult (t)	1 km	—	9	—
17	12°42′S;141°55′E	Weipa	Adult (t)	1 km	31	16	—
17	12°42′S;141°55′E	Weipa	Larvae	1 km	5	—	—
18	13°11′S;141°38′E	Ina Creek	Larvae	1 km	3	3	—
19	14°10′S;141°36′E	Kuchendoopen	Larvae	1 km	1	—	—
20	12°48′S;143°20′E	Lockhart River	Larvae	3 km	—	2	—
20	12°48′S;143°20′E	Lockhart River	Adult (t)	3 km	1	3	—
21	14°22′S;141°36′E	Hersey Creek	Larvae	4 km	1	—	—
22	12°47′S;143°19′E	Lockhart River	Larvae	5 km	1	1	4
23	13°31′S;141°44′E	Archer River	Adult (t, b)	5 km	16	38	4
23	13°31′S;141°44′E	Archer River	Larvae	5 km	1	1	—
24	11°37′S;142°48′E	Captain Billy Landing	Adult (t)	5 km	1	—	—
25	12°18′S;141°45′E	Pennefather River	Larvae	7 km	—	1	—
26	12°44′S;143°17′E	Claudie River	Larvae	10 km	—	3	—
27	12°44′S;143°16′E	Claudie River	Larvae	13 km	—	5	1
28	14°06′S;143°26′E	Whiphandle Creek	Larvae	27 km	—	1	1
29	12°10′S;142°18′E	Ducie River	Larvae	30 km	—	2	2
30	12°43′S;142°25′E	Cox Creek	Larvae	35 km	—	6	4
31	12°42′S;142°36′E	Batavia Downs	Larvae	58 km	—	6	6
32	12°40′S;142°40′E	Lydia Creek	Larvae	64 km	—	11	7
33	12°44′S;142°48′E	Wenlock River	Larvae	67 km	—	—	1
34	12°34′S;142°43′E	Wenlock River	Larvae	68 km	—	—	2

br = larvae collected in brackish water; t = adults collected in CO_2 baited trap; b = adults collected in man biting catch.

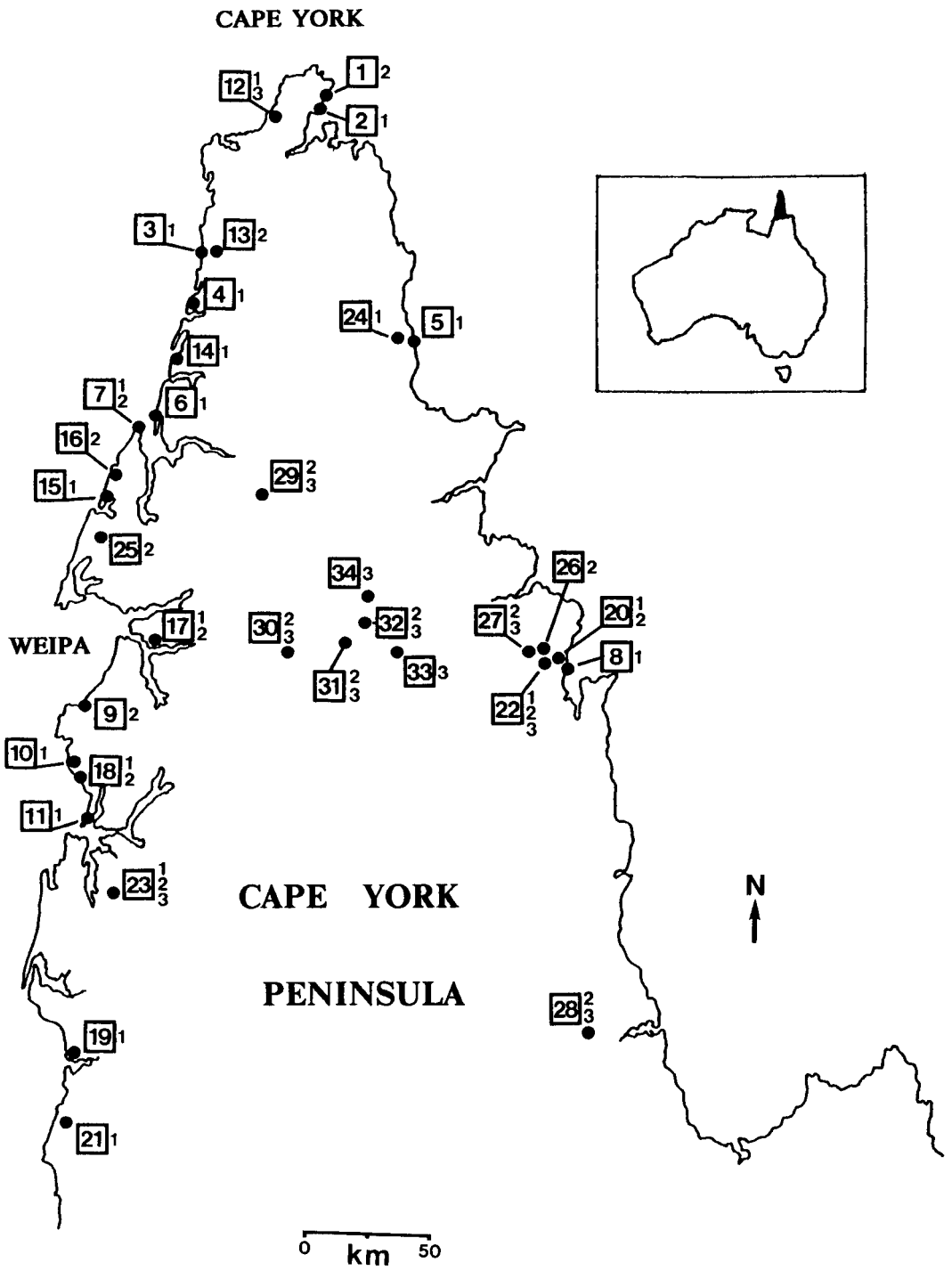

Fig. 1. Distribution of *Anopheles farauti* sibling species in Cape York Peninsula. Numbers within squares refer to collection sites of Table 1. Numbers placed vertically adjacent to right side of squares indicate sibling species collected in that locality.

localities were on the west coast of the peninsula (11 larval and 10 adult collections), with smaller numbers on the east coast (6 larval and 2 adult collections).

The most common species collected on the coast was *An. farauti* 1 (13 larval and 11 adult collections). *An. farauti* 2 was also common on the coast (7 larval and 5 adult collections), whereas *An. farauti* 3 was relatively rare (1 larval and 2 adult collections). The inland larval surveys yielded approximately equal numbers of *An. farauti* 2 and 3 (8 collections of each species). *An. farauti* 1 was not collected inland.

Larvae were found in a variety of ground water sites, usually close to the edges among emergent vegetation, algal mats or floating plant debris. Seven larval collections of *An. farauti* 1, and 2 collections of *An. farauti* 2 were made within 100 m of the coast. Five collections of the former species were made in coastal lagoons formed at the mouth of creeks dammed by beach sand dunes. Three contained fresh water (sites 4, 8 and 12) and the other 2 were brackish with salinities of 50% sea water (site 11) and 80% sea water (site 3). One of the remaining 2 sites of *An. farauti* 1 within similar proximity to the coast was a freshwater ground pool (site 2) and the other was a brackish swamp (site 5). The collections of *An. farauti* 2 were made from fresh water sites: one in a ground pool (site 9) and the other within a swamp (site 1).

Larvae of both *An. farauti* 1 and 2 were also found (both singly and together) in fresh water sites between 1 and 5 km of the coast (Table 1). Four of these sites were in hoofprints and pig wallows on the edge of swamps (sites 13, 19, 21 and 23). The 3 sibling species were found together 5 km from the coast in a muddy creek at Lockhart River Settlement (site 22). The most common inland larval habitats (7/10 sites) were in ground pools within creek beds. *Anopheles farauti* 2 and 3 larvae were collected together in 5 of these localities (sites 28, 29, 30, 31, 32). *Anopheles farauti* 3 was found in one collection in a rockpool on an escarpment near the Wenlock River (site 34).

The sites yielding *An. farauti s.l.* ranged from 1 to 86 km (average = 26 km) from permanent human settlements. Seven were within 5 km of human habitations.

DISCUSSION

Larvae of *An. farauti s.l.* occur in a wide variety of aquatic situations which are usually semi-permanent, partly shaded and with emergent vegetation. These include natural bodies of ground water (creeks, ground pools and swamps); pools made by animals (hoofprints and pig wallows); as well as manmade sites (borrow pits and roadside ditches). Brackish sites of up to 70% salinity of seawater are common near the coast (Daggy 1945, Belkin 1962). The larval habitats located in the present survey encompassed the typical range of sites found throughout the distribution range of this species complex.

Laboratory experiments with colonies and field collected individuals of the sibling species showed that larvae of *An. farauti* 1 have a higher salinity tolerance than those of the other 2 species (Sweeney 1987). This implies that *An. farauti* 2 and 3 may be restricted to freshwater habitats and that *An. farauti* 1 is the species found in saline sites. The present study provided further evidence for this possibility as the latter species was the only member of the group found in brackish water (in 3 of 7 collections made within 100 m of the sea). In a previous study *An. farauti* 2 was found in a freshwater ground pool within 100 m of the beach at Red Island Point near Bamaga, Cape York Peninsula (Sweeney 1980). Larvae of this species were found in similar proximity to the sea on two occasions during the present survey but only in fresh water (sites 1 and 9). *Anopheles farauti* 3 larvae were not collected close to the coast.

Although *An. farauti* 1 was common in freshwater larval sites and in adult collections within 5 km of the coast, we find it particularly interesting that it was not found further inland. This suggests that this species may be predominantly coastal. Similarly, it appears from the results of the present survey that *An. farauti* 2 may be widely distributed in both coastal and inland localities and that *An. farauti* 3 may prefer inland habitats. Nevertheless, these findings need to be interpreted with caution as the present survey covered only a small part of the geographical area in which *An. farauti s.l.* occurs. Further work in other regions is required before definite conclusions can be made about the coastal and inland distribution of the sibling species.

Apart from salinity and distance from the coast, there was no clear evidence that the individual sibling species exhibited differences in their preference for particular larval habitats. *An. farauti* 1 and 2 were often found together in the same sites and so were *An. farauti* 2 and 3. In one site at Lockhart River Settlement, the 3 species were found together in a ground pool within a freshwater creek (site 22).

The Great Dividing Range extends northward close to the eastern seaboard of the Cape York Peninsula and the major river systems flow westward to the Gulf of Carpentaria. The swamps and tributaries associated with these

rivers provide considerable larval habitats for mosquitoes along the western coast. The present survey was made when the south easterly winds associated with the north Australian dry season had already commenced. The dry windy conditions which prevailed at this time were not conducive to adult mosquito activity on the east coast. It is therefore not surprising that a larger number of collections (both larval and adult) were made on the western coast even though comparable surveys were made on the eastern coast.

Early observations on *An. farauti s.l.* in Australia indicated that it tended to concentrate near human settlements, but that it was an opportunistic feeder which readily fed on man and other animals with no particular preference between them (Mackerras 1947). The use of a helicopter in the present survey permitted larval and adult collections in very isolated areas far from roads and permanent human dwellings. Many of these areas would be visited from time to time by small numbers of people including aborigines, stockmen, prospectors and fishermen. Nevertheless, man would not provide a reliable source of blood meals for mosquitoes in the majority of *An. farauti s.l.* localities in this survey. The 3 species were found biting man in an adult catch in a very isolated site near a tributary of the Archer River (site 23), but it would appear that the primary blood sources available in such places would be animals such as cattle, feral pigs, birds and marsupials.

The implications of these observations for malaria epidemiology are not yet clear as the vectorial capacities of the individual species are not known. Nevertheless, the finding of all members of the group far from human habitations suggests that the malaria receptive area of northern Australia is not restricted to towns and settlements. There is the possibility of the disease being reestablished if increased tourism and mining activities, together with the introduction of gametocyte carriers, extend into formerly isolated areas.

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