REFERENCES

CRIBB, A. B. (1966). The algae of Heron Island, Great Barrier Reef, Australia. Part I. A general account. **Pap. Heron I. Res. Sta., Univ. Qd 1**(1):1-23.

MACGILLIVRAY, W. D. K. & RODWAY, F. A. (1931). Plants on islands of the Bunker and Capricorn Groups. **Rep. Gt Barrier Reef Comm. 3**(7):58-63.

STEERS, J. A. (1938). Detailed notes on the islands surveyed and examined by the Geographical Expedition to the Great Barrier Reef in 1936. **Rep. Gt Barrier Reef Comm. 4**(3) No. 7:51-104.

WHITE, C. T. & MACGILLIVRAY, W. (1926). The biology of North-west Islet, Capricorn Group. (H.). Botany. **Aust. Zool. 4**(4):251-52.

EXPLANATION OF PLATES

1. Aerial view of western part of reef and cay; cleared track in reef flat on northern side of cay is visible.
2. **Pisonia** forest, bare of understory, with the floor marked by entrances to the burrows of Wedge-tailed Shearwaters.
3. Build up area at S.W. edge of cay; **Wedelia biflora** and **Spinifex hirsutus** seawards, **Tournefortia argentea** and **Casuarina equisetifolia** var. **incana** landwards.
4. Eroded area on southern side of cay with fallen Casuarinas, and with shell and coral rubble marking the junction of beach and reef flat.
5. Middle reef flat to the SW. of the cay, the coral mainly **Porites.**
6. Moat with even topped coral platform dissected by sandy pools.
7. Heaped coral fragments of the rubble crest.
8. Large negro head on northern side of cay.
9. Shallow terraces of the seaward slope.

THE RHIZOBIUM MICROFLORA OF NORTH WEST ISLAND

It is intriguing to wonder how legumes on coral islands establish and survive in low nutrient coral sands. Nodulation would seem essential for their survival. Do the root nodule bacterial which form part of the symbiosis travel with the seed by way of the sea, or do mammals, man or birds carry them there? Similar thoughts come to mind on the survival of **Casuarina** which, although not a legume, nodulates prolifically on the sandy foreshores.

The recent trip to North West I. provided an opportunity to look at the soil microflora for the presence of that important group of bacteria of the genus **Rhizobium** responsible for forming nodules on legumes and in turn utilizing atmospheric nitrogen. Two soil samples were collected by Mr. J. C. Johnson and made available for testing; one from the strand zone bordering the island (pH 8.2) on which the legume **Canavalia** occurs and the other from the centre of the island (pH 7.9). Seven tropical and sub-tropical legumes were sown as "bait" plants to see whether they would nodulate naturally in these soils. These were centro (**Centrosema pubescens**), glycine (**Glycine javanica**), desmodium (**Desmodium uncinatum**), phasey bean (**Phaseolus lathyroides**), **Canavalia ensiformis, Canavalia maritima** and **Neptunia gracilis.** After one-and-a-half months growth the plants were removed from the soil and their roots examined.

The paucity of nodulation in these legumes was astounding, all except phasey bean failed to nodulate in either soil. The nodulation of phasey bean was sparse in the soil from both sites and not all the plants were nodulated. The nodules formed were small and white-centred. They proved of very little benefit to plant growth and could be classed as ineffective in nitrogen fixation. The bright red pigment, leg-haemoglobin, which is characteristic of actively functioning nodules was absent from all the nodules inspected. Other sources of nitrogen in the strand zone with low numbers of rhizobia might be from decomposing seaweed or marine animals or even from sea spray. The question of how nodule bacteria suited to phasey bean arrived on the island remains a mystery, although it is most unlikely that they drifted with seed or debris since they are generally intolerant of saline conditions. My guess would be that bacteria could be carried in soil adhering to legs of birds.

—A. DIATLOFF

MOSQUITOES (CULICIDAE) ON QUEENSLAND'S CORAL CAYS

By ELIZABETH N. MARKS*

The coral sand cays associated with the Great Barrier Reef vary considerably in size, in vegetation cover, and in distance from the mainland, but all are quite small islands whose maximum elevation seldom exceeds about 12-13 ft above extreme high water of spring tides; many of them are National Parks. They are late Pleistocene to recent in age; during the most recent maximum rise in sea-level about 4000 years ago all would have been submerged, and none would have been connected with the mainland since.

Mosquitoes are small, active insects likely occasionally to be caught up and carried by wind and air currents. Some species are also known to move in mass flights from their breeding places. Thus, disregarding the possibility of transport by human agency, it is not surprising that some have reached the Reef islands.

In order to become permanently established on an island, a mosquito species must have available either temporary or permanent water suitable for completion of its aquatic larval and pupal stages; most species also require a food-source of vertebrate blood for females to produce viable eggs. Seabirds, which commonly abound on cays, could provide a blood source, and it is likely that the principal limiting factor to successful colonisation is availability of breeding places, shelter also being important.

Published lists of insects of Masthead I. (Musgrave 1926) and Heron I. (Chadwick 1962) do not include mosquitoes. Stephenson et al (1931) observed only occasional mosquitoes on Low Isles but gave no identifications. Mackerras & Sandars (1954) recorded the species of Yorke I. and Nepean I. and Cribb (1965) those of Wilson I.

This study was supported by a grant from the Queensland Health Department and some of the records discussed here appeared in Annual Reports of the National Mosquito Control Committee published in **Rep. Hlth med. Servs Qd** 1951-52, 1958-59, 1964-65, 1967-68, 1968-69.

For some years I have been asking visitors to Queensland's coral cays to look for and collect mosquitoes. A recent sample was taken by Mr. J. Wright on the Queensland Naturalists' Club excursion to North West I. I am grateful to him, to Dr. A. B. Cribb who in addition to specimens has provided information on island vegetation, to Professor D. Hill for discussion of the age of cays, and to all the others who have helped in this project. It is hoped that an assessment of the findings to date may stimulate future collecting on the same and on other cays.

Torres Strait Islands

COCOANUT I. (10°3'S, 143°4'E) About 58 miles S. New Guinea and N. E. Cape York. Area approximately 90 acres. Permanently inhabited by about 200 Torres Strait islanders. Water from one well and concrete rainwater storage tanks.

Collection: 20.vi.1969, A. Harper.

Aedes aegypti (Linn.) breeding in outdoor artificial containers.

YORKE I. (9°45'S, 143°25'E). About 50 miles S. New Guinea and 84 miles N.E. Cape York. Area approximately 500 acres. Well vegetated. Permanently inhabited by about 100 Torres Strait islanders. Water obtained from shallow wells.

Collections: iv.1953, M. J. Mackerras and D. F. Sandars; 21.vi.1969, A. Harper.

Aedes scutellaris scutellaris (Walker) breeding in 44-gallon drums of rainwater iv.53.

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A. aegypti breeding in outdoor artificial containers vi.69.

NEPEAN I. (9°34'S, 143°40'E) About 44 miles S.E. New Guinea. Has the appearance of a cay but is not a true one, having a core of volcanic rock. Area approximately 8 acres. Thickly vegetated, mainly with coconut palms. Inhabited by one family of Torres Strait islanders. Water obtained from one well.

Collection: 1.vii.1952, E. N. Marks and M. J. Mackerras.

A. scutellaris scutellaris breeding in domestic water tank and barrel and in clam shells near the well and the house.

North Queensland Islands

LOW ISLES (16°22'S, 145°33'E). 9 miles N.E. Port Douglas. Two isles at either end of a horseshoe-shaped reef; the eastern consists of about 50 acres of mangrove swamp and two small vegetated shingle ridges, the larger of which was called "Green Ant I." by the Yonge expedition; the northwestern is a well vegetated sand cay about 200 yds x 100 yds with casuarinas, palms etc. and is permanently inhabited by lighthouse personnel. No fresh ground water.

Collection: 14-25.viii.1954, E. N. Marks, M. J. Mackerras and A. B. Cribb.

Aedes notoscriptus (Skuse) breeding in about 1 inch of water in an old iron tank on "Green Ant I.", with rotting leaves and a dead bird. No water in tank 14.viii.54, after which heavy rain fell; fourth instar and some first instar larvae present 23.viii.54.

Culex sitiens (Wiedemann) one female flying indoors 18.viii.54.

Capricorn Group

NORTH WEST I. (23°18'S, 151°43'E) About 48 miles N.E. Gladstone, 34 miles N.E. Curtis I. Area approximately 227 acres. Well vegetated, principally with **Pisonia,** also **Ficus, Casuarina** and **Pandanus.** Inhabited in past; at present visited by campers. No fresh ground water.

Collection: 18-20.viii.1968, J. Wright.

A. notoscriptus breeding in tree holes in **Pisonia** and in **Ficus opposita;** usually narrow holes in fork of tree, but one hole in **Pisonia** yielded about 3 pints water.

WILSON I. (23°18'S, 151°55'E) About 56 miles N.E. Gladstone, 45 miles N.E. Curtis I. Area approximately 12 acres. Well vegetated principally with dense groves of **Pandanus,** also **Ficus, Casuarina** and **Pisonia.** Uninhabited. No fresh ground water.

Collection: 12.v.1964, A. B. Cribb.

Culex australicus Dobrotworsky & Drummond breeding in the hollow of a **Pisonia** trunk; about 25 larvae collected including all instars.

Aedes kochi (Donitz) biting or attempting to bite at dusk; troublesome for a short period.

HERON I. (23°27'S, 151°55'E) About 50 miles N.E. Gladstone, 43 miles E. Curtis I. Area approximately 40 acres. Well vegetated, principally with **Pisonia,** also **Ficus, Casuarina** and **Pandanus.** Permanently inhabited with tourist resort and research station. No fresh ground water.

Collections: 24.v.1947, J. L. Wassell; 4.iv.1947, 17-19.xii.1958, E. N. Marks; 10-14.xi.1957, T. E. Woodward; 24.viii.1964, I. M. Mackerras; 20.v.1965, T. Young; 21.xii.1967, S. R. Curtis.

Tripteroides punctolateralis (Theobald) biting xi.57; breeding in rot hole in fallen **Pisonia** and biting in bush xii.58.

A. notoscriptus breeding in **Pisonia** treeholes v.47, xii.58; biting in bush xii.58, viii.64, and 16 females taken 7-9 p.m. xii.67.

Aedes vigilax (Skuse) biting iv.47, viii.64, 7-9 p.m. xii.67.

Aedes procax (Skuse) biting viii.64.

Culex annulirostris (Skuse) biting viii.64.

Culex fatigans (Wiedemann) breeding in artificial containers round machinery sheds (but not found in old tins in bush), adults taken in dwellings, xii.58; breeding in fresh water with decaying vegetable matter in **Pisonia** treehole, depth 5-6 inches, diameter 3 inches, within 3 ft of ground at some considerable distance from habitation v.65.

MASTHEAD I. (23°32'S, 151°44'E) About 35 miles N.E. Gladstone, 31 miles E. Curtis I. Area approximately 160 acres. Vegetation similar to Heron I.

Collections: 29.v.1965, S. McDonald; 11.v.1968, A. B. Cribb.

A. vigilax biting during day v. 65.

A. notoscriptus biting v.68.

Bunker Group

FAIRFAX I. (23°51'S, 152°23'E) About 70 miles E. Gladstone, 38 miles N.E. Round Hill Hd. Area approximately 40 acres. Smaller cay with dense **Pisonia** forest, almost no **Pandanus.** Larger cay with small patch of **Pisonia,** remainder a desert (eaten out by a herd of goats). The reef is used as a bombing range by the Royal Australian Navy, and the island is inhabited from time to time by Navy personnel.

Collection: 20.i.1965, A. B. Cribb.

A vigilax breeding on the larger cay in a sunlit pool in coral rubble approximately 300 x 66 ft and up to 1 ft deep in a depression probably excavated by guano miners. The water was clear and strongly brackish, the edge slightly muddy; numerous unicellular green algae mainly formed a bottom layer. A herd of 50 goats on the cay possibly caused some pollution but this was not obvious. The nearest tree in the **Pisonia grandis** forest west of the pool was about 50 ft distant with very sparse herbaceous ground cover between, but none on the moist edge of the pool. About 6 larvae per square yard; 4 third instar larvae collected.

LADY MUSGRAVE I. (23°54'S, 152°24'E) About 71 miles E. Gladstone, 35 miles N.E. Round Hill Hd. Area approximately 50 acres. Tree vegetation mainly **Pisonia grandis,** numerous **Pandanus.**

Collection: 30-31.v.1969. A. B. Cribb.

A. vigilax numerous biting in the central part of the cay at 4.00 p.m. and breeding in a slightly brackish pool about 24 ft in diameter and at least 1 ft deep surrounded by dense **Sesuvium portulacastrum.** It seems likely that this depression was man-made.

Discussion

Mosquitoes might reach an island in several ways: adults by purposive flight, or carried on wind or air currents, or while sheltering in a boat or aircraft; larvae and pupae transported by boat or air in the vessels in which they are breeding. Eggs of **Aedes** are laid singly and in general can withstand some drying (probably **Tripteroides** can also); container-breeders might be carried as eggs in dry as well as water-holding vessels; possibly these and also the eggs of species which oviposit in mud of drying pools might be carried on the feet of birds. **Culex** spp. eggs are laid in rafts and do not withstand drying, so are unlikely to remain viable unless transported in water-holding vessels.

A. scutellaris scutellaris is a common species in New Guinea, breeding in treeholes and fallen coconuts as well as artificial containers. It seems likely it reached Torres Strait coral islands by human agency, but this may not have been recent for the islanders on their voyages formerly carried fresh water in very large bailer shells, and this mosquito also sometimes breeds in rain water lying in dugout canoes.

A. aegypti, the dengue mosquito, is an introduced species that breeds in artificial containers and treeholes and is closely associated with

man, who has certainly distributed it among the Torres Strait islands. As it was not taken on Yorke I. in 1953 it may have been introduced there since, and it would be interesting to know the extent to which it has displaced **A. scutellaris scutellaris.**

A. notoscriptus is a common species breeding in treeholes and artificial containers. **T. punctolateralis** has similar habits but is less common. It is quite likely that they too have reached islands by human agency. Variability in **A. notoscriptus** from North West I. suggests there might have been more than one colonisation, but the significance of variations in this species needs further study.

A. vigilax is the common salt-marsh mosquito. Often it breeds in tremendous numbers after spring tides, and adults move inland on a purposive flight. It is unlikely that there would be purposive flights seaward, but highly probable that large numbers are carried out to sea at times on off-shore winds. This would seem to be the source of adults taken on the Capricorn Group where there are no suitable breeding places, and the means by which the species reached the Bunker Group. It would be interesting to know whether the colonies of **A. vigilax** on Fairfax I. and Lady Musgrave I. are permanent ones.

C. sitiens breeds in the same sites as **A. vigilax; C. annulirostris** breeds in fresh water and may occur in great numbers after flood rains; **A. procax,** which breeds in temporary rain-filled pools, is less frequently encountered in large numbers; all three are known to travel considerable distances over land and are likely to be blown out to sea; there are no suitable breeding sites for them on the cays where they were collected.

C. fatigans is an introduced species closely associated with man and his habitations. It was not taken at Heron I. in 1947 and 1957 and may have reached it subsequently. In late 1958 mosquitoes were reported to be troublesome at the resort and the research station, and an investigation was made at the request of the Chairman of the Great Barrier Reef Committee. **C. fatigans,** the pest species involved, was found breeding close to buildings but not in the bush and simple control measures were recommended which should have eliminated it if thoroughly applied at that time. However, by 1965 this species was established in treeholes at some distance from habitation where, since it feeds readily on birds, it can probably persist. Prospects of eradicating it now are dim.

Adults of **C. fatigans** shelter in dark corners indoors and thus are likely to have been transported by launch to Heron I.; aquatic stages might have been similarly carried in a breeding vessel.

C. australicus, a widespread species, breeds in semipermanent fresh or slightly brackish swamps and pools, which may be polluted to some extent, and also, but less commonly than **C. fatigans,** in artificial containers. It feeds mainly on birds and does not bite man, but is attracted by light and will enter houses. It has been taken on Curtis I., and may have reached Wilson I. by wind, or else by launch as sheltering adults or as aquatic stages in a container. This is the only record of its breeding in a treehole. Presence of all instars of larvae suggests they had hatched from more than one egg raft. It would be interesting to know whether **C. australicus** is permanently established in treeholes on Wilson I., and if so, whether a race with a preference for laying in treeholes is developing there.

A. kochi is a small speckled mosquito that breeds in water-holding leaf axils, especially those of **Pandanus.** It has been collected on Curtis I. If eggs or larvae were brought to Wilson I. it must have been in a whole plant or a leaf crown. The species has been found in **Pandanus** on exposed headlands as well as in sheltered sites, and although adults generally do not seem to move far from the breeding places no doubt they might be carried by wind, or on a launch. Why has it colonised Wilson I. but apparently not Heron I. 9 miles away? If present at Heron I. **A. kochi** should at least have been taken in the dusk collection which

Miss S. R. Curtis specially made in the **Pandanus** grove. The species may by chance have reached only one island, or it may have reached both and found suitable conditions for establishment of a permanent colony among the dense **Pandanus** of Wilson I. but not among the smaller and more open and exposed groves on Heron I.

In the general area of Heron I., there was a change in wind direction on 24.viii.1965, with north to north-west winds blowing at about 15 knots, which may have brought **A. vigilax, A. procax** and **C. annulirostris** taken biting that day. In the same area there was a sharp change of wind direction on the evening of 20.xii.67, bringing strong south to south-east winds, and perhaps also **A. vigilax** taken biting next evening; it is even possible these came not from the mainland but from colonies on the Bunker Group.

There is opportunity here for a resident of a cay to collect specimens and keep careful records of time and date whenever there is a sudden influx of mosquitoes. These, correlated with meteorological data, could provide valuable information concerning mosquito movements which is not at present available for Australian species, and which cannot readily be obtained from mainland collections.

Summary

Three treehole and container species, two **Aedes** and one **Tripteroides,** and one plant-axil **Aedes** have established apparently permanent colonies on coral cays. Larvae of two facultatively container-breeding **Culex** have been found in treeholes and larvae of a ground-pool **Aedes** in brackish pools in man-made excavations in coral; possibly these also are permanently established. Two **Culex** and one **Aedes** species, all ground-pool breeders, are considered casual invaders only, probably wind borne.

REFERENCES

CHADWICK, C. E. (1962). Some insects and terrestrial arthropods from Heron Island, Queensland. **Proc. Linn. Soc. N.S.W. 87**:196-9.

CRIBB, A. B. (1965). The marine and terrestrial vegetation of Wilson Island, Great Barrier Reef. **Proc. R. Soc. Qd 77**:53-62.

MACKERRAS, M. J. & SANDARS, D. F. (1954). Malaria in the Torres Strait Islands. **Tech. Pap. S. Pacif. Commn 68**:1-27.

MUSGRAVE, A. (1926). The Biology of North-West Islet, Capricorn Group. (E) Insects. **Aust. Zool. 4**:241-6.

STEPHENSON, T. A., STEPHENSON, A., & TANDY, G. (1931). The structure and ecology of Low Isles and other reefs. **Scient. Rep. Gt Barrier Reef Exped. 3**:17-112.

TICKS AT LADY MUSGRAVE ISLAND

In May 1969 at Lady Musgrave I., Dr. A. B. Cribb collected two ticks, one attached to and one crawling on himself, and on return to Brisbane found a third, which had induced a slight redness, swelling and soreness at its site of attachment. He thought it likely that they had come from Noddies (**Anous minutus** Boie) which were numerous on the island. The first two specimens were identified by Dr F. H. S. Roberts as nymphs of **Amblyomma loculosum** Neumann, a parasite of Noddies. It is known from an island in mid-Indian Ocean and from the Coral Sea area (where both adults and nymphs have been taken attacking man). Hitherto the southernmost Queensland record was Lindeman I., but this tick can be expected to occur in other localities where noddies are plentiful.

—E. N. MARKS