# OBSERVATIONS ON THE BEHAVIOUR OF AEDES *ASHWORTHI* EDWARDS.

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Fourth Year Zoology 1971.

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CONTENTS.

# 1. INTRODUCTION.

A knowledge of the behaviour of adult mosquitos has been an important step in determining methods suitable for their control. Consequently most of the published work on mosquito behaviour concerns those of medical importance. These works have shown that unfavourable weather conditions may severely limit the activity of adult mosquitos. Aedes ashworthi is particularly dependent upon favourable weather conditions since its typically windy, seaside habit is devoid of protective vegetation. For this reason it was thought that wind would be an important factor limiting adult activity.

The aim of this study was to gain some knowledge of all aspects of the behaviour of Aedes ashworthi adults and to determine the extent to which their behaviour is influenced by physical factors, in particular wind.

# 2. BITING HABITS.

## INTRODUCTION.

Early observations at Triggs Island showed A.ashworthi females to be nocturnal in their biting behaviour, only biting during the daylight hours when disturbed from their resting places. It appeared that their activity was not crepuscular. The population was small to provide information on the effects of meteorological and astronomical variables on commencement, intensity and cessation of biting. A search was therefore made for a more suitable study area. The population at Radar Reef (Rottnest Island) was found to be the largest within a reasonable distance from Perth. All further observations on biting behaviour were made at this locality.

## MATERIALS AND METHODS.

Three nights (17th - 19th March inclusive) were spent sitting amongst the rocks in the Radar Reef study area catching biting females. Catching began half an hour before sunset and was terminated half an hour after sunrise. Only my left forearm was exposed for biting, my face being covered by mosquito netting, and the rest of my body well rugged. As soon as alighted females had begun to draw blood they were captured and kept separately in small phials. Each half hour's catch was kept in a separate, labelled bag. At the end of each half hour interval, wind strength, ambient temperature, and relative humidity were recorded. An anomometer was used to measure wind speed, and a wet and dry bulb thermometer to measure relative humidity. Each night's catch was subsequently examined to ensure that it included only *A.ashworthi* females and not females of some other mosquito species. Half hour collection intervals were chosen to best reveal the sudden sharp fluctuations in numbers biting in response to changes in illumination and wind strength.

To be able to capture biting mosquitos it was necessary to see them. On windy clear nights, when biting did not begin until after moonrise, this was possible. However on overcast nights individuals could not be seen without the aid of a light. Unfortunately A.ashworthi females were shy of torchlights, taking off as soon as the torch was switched on. An alternative method was to score the number of bites that I felt in each half hour interval. However so many bites were unfelt or imagined I was unable to use this method. No quantitive account of biting activity can therefore be given for nights of poor visibility.

RESULTS.

The nights of the 17th and 19th March were clear skyed, with strong and light sea-breezes respectively. There was sufficient illumination from the sky on both nights for blood-drawing females to be seen and captured. The results of each night's capture are shown in figures 1 and 2, with corresponding relative humidity, ambient temperature and wind speed recordings.

On the night of the 18th March the sky was overcast, making it impossible to capture biting females after darkness. Unlike the 17th and 19th March there was no breeze from early afternoon until early morning. There appeared to be a peak of biting activity during the hour after sunset, tapering off to a lower level for the following hour at which time the catch

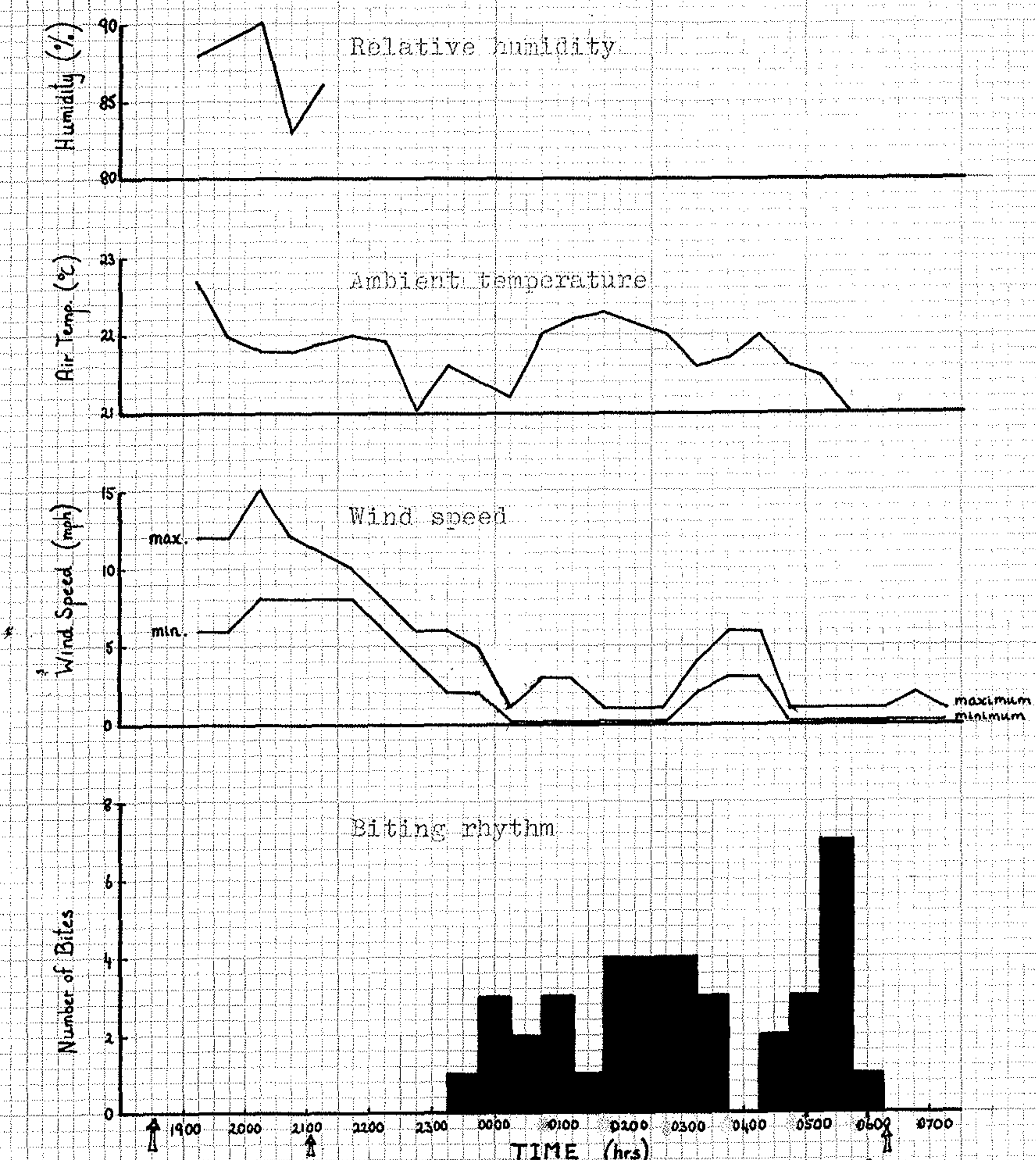


Fig. 1. Aedes ashworthi biting cycle with corresponding humidity, temperature and wind speed recordings. for 17-18 March 1971, Radar Reef (Rottnest Island).

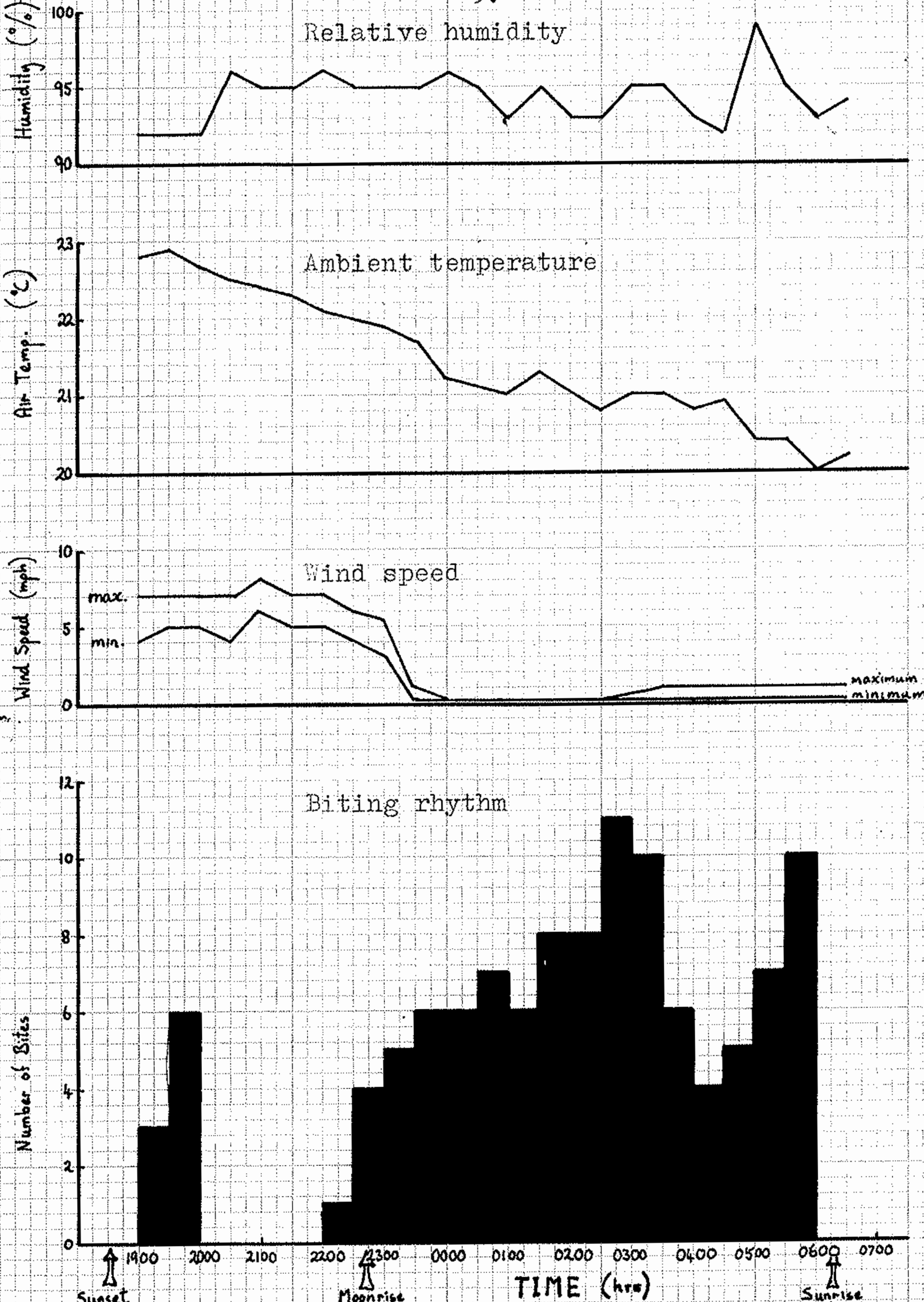


Fig. 2. Aedes ashworthi biting cycle with corresponding humidity, temperature and wind speed recordings for 19-20 March 1971, Radar Reef (Rottnest Island).

was discontinued.

The second stay at Rottnest Island (15th - 19th April) was less fruitful. Although the early hours each morning (approximately 0300 to 0600 hours) were suitable for biting activity - breezes less than 4 m.p.h. - very few adult mosquitoes were found at Radar Reef, or elsewhere around the coastline of Rottnest Island.

## DISCUSSION.

*Aedes ashworthi* females are nocturnal in their biting habits. As evidenced by figures 1 and 2, no biting occurs before sunset or after sunrise. With suitable weather conditions, there is intense biting activity shortly after sunset and shortly before sunrise. These peaks of activity are more pronounced than would appear from figures 1 and 2. For example, the eleven bites shown in figure 1 between 0514 and 0614 (sunrise) actually occured between 0540 and 0547. Because measurement and recording of relative humidity, ambient temperature and wind speed took up five minutes of each half hour's catching time it was not possible to use shorter catch-time intervals to better reveal these peaks.

The results also indicate that biting rate declines to a low level following the peak after sunset and preceeding the peak before sunrise. This decrease in activity before or after a period of intense activity has been described for many mosquito species.

As anticipated, wind inhibits biting activity of females. No biting occured with wind speeds in excess of 7 m.p.h.. Figure 3 illustrates the inverse relationship that exists between wind speed and intensity of biting activity.

Although other workers have described the influence of wind on mosquito activity patterns none to my knowledge have carried their work any further than confirming that wind is unfavourable. This is because the species which have been most closely studied are those in regions where wind is not as important an environmental factor. This is not necessarily due to there being less wind, but rather because adults are afforded shelter from wind influence by vegetation e.g. forest canopy. The extent to which wind affects the behaviour of one biting insect however has been revealed by D.S. Kettle (1969). Kettle has shown Culicoides fureno and C.barbosai ("sandflies") to bite with bursts of activity at dawn and dusk and with variable activity during the night. He found biting activity to be inversely related to wind speed; no biting occurring with wind speeds in excess of 8.3 m.p.h.

Unfortunately, the biting pattern for a completely windless night could not be obtained. From the results of this

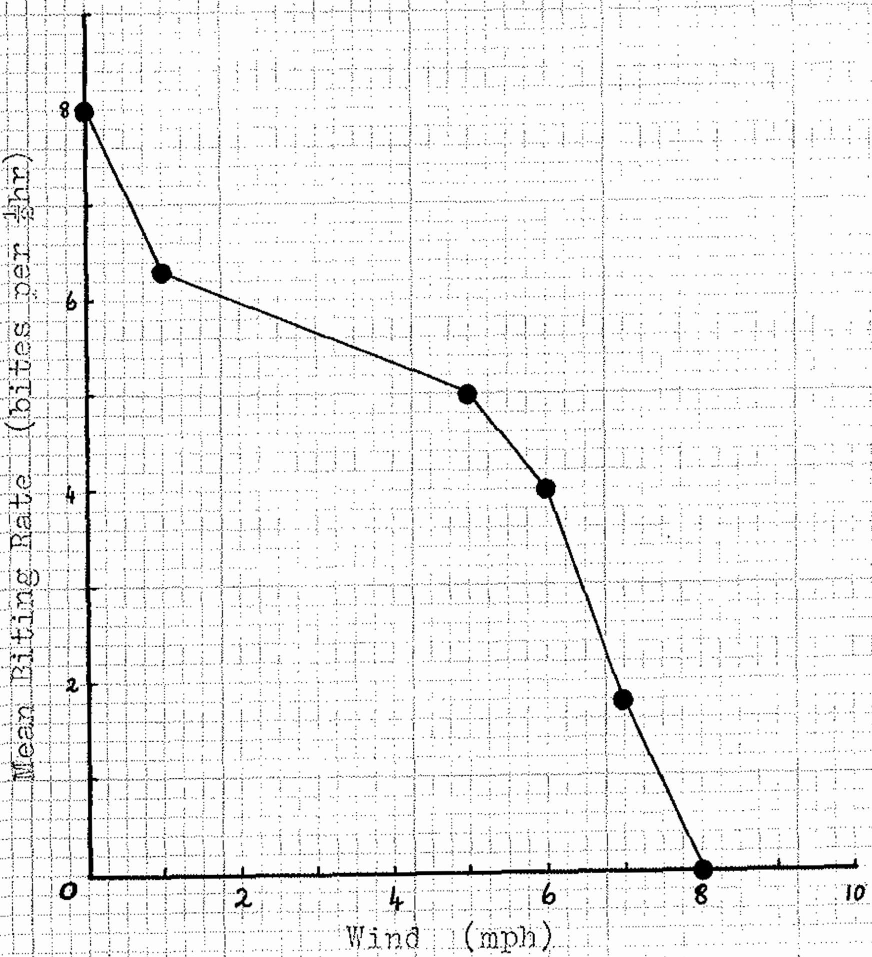


Fig. 3. Effect of wind speed on biting rate of Aedes ashworthi (19-20 March 1971).

study it is expected that on such a night biting would begin with a peak after sunset, then one or a number of peaks during the night, concluding with a peak shortly before sunrise. The influence which relative hunidity and ambient temperature may exert on the biting activity of A.ashworthi was masked by the apparently more important factors, light intensity and wind speed.

An attempt was made to identify the preferred host(s) of A.ashworthi females. The intention was to catch blood-fed females by light trap and to examine their blood meal to determine whether it contained nucleate or enucleate erythrocytes, thus establishing whether the principal host was mammalian or not. However, since A.ashworthi females turned out to be shy of lights, light trapping was not successful. It is suggested that a future worker use a carbon dioxide - emitting trap. Judging from my observations the most likely hosts (excluding man) are Pied Cormorants (Phalacrocorax varius) and Silver Gulls (Larus novaehollandiae). These birds roost around rock pools in the splash-zone at night.

## 3. SWARMING.

### INTRODUCTION.

Many species of insects are known to swarm. The swarming habits of some mosquito species, especially of those of medical importance, have been studied in detail. The literature on swarming of crepuscular and diurnal forms has been reviewed by Nielsen and Haeger (1960), Chiang (1961) and Chiang and Stenroos (1963).

The purpose of this study was to determine whether *A.ashworthi* adults swarmed, and the manner and extent to which such swarms might be influenced by certain physical factors. Throughout the period of study, no swarms were found along the coastline between Watermans Bay and Point Peron, or at Rottnest or Garden Islands. Swarming was first observed at Wyadup (3 miles south of Yallingup) on the evening of the 22nd of April.

Wyadup is a headland on the coastline between Cape Naturalist and Cape Leeuwin. It is formed by enormous boulders of igneous rock. Crevices and depressions in the rock form breeding pools for A.ashworthi. The headland is completely devoid of vegetation.

All observations on the swarming habits of A.ashworthi were made at this locality during this and the following three days.

OBSERVATIONS.

a). Resting Places.

Male A.ashworthi arrived at the swarming site from crevices in nearby rock formations. The dark, moist nature of these crevices affords protection against dehydration during daylight hours. Males could be driven into the open during the day by scraping a pencil along these crevices. Individuals disturbed in this manner flew directly to nearby crevices.

b). Flights Before Swarming.

Some male flight activity before swarming was observed. Most flights to the swarming site were interupted by brief stops at rocks along the flight path. Although all males in each swarm appeared to come from crevices within a ten foot radius of the marker, the nature of the terrain made it difficult to observe longer flights to the swarm. Supposed male movements could also be attributed to females active in the area.

c). Swarming Sites and Markers.

Male swarms were generally observed in the following locations.

a) Between boulders at the water's edge within 1 ft. of the water's surface.

b) Under the lip of overlying boulders 2 - 4 ft. from the ground and up to 25 ft. above sea level.

Swarming sites were typically areas in the lee of rock outcrops and thus well protected from the prevailing breezes.

Swarms were found in the same limited number of locations on windy and windless nights although with windless conditions far more sites would have been suitable for swarm formation. Even on windy nights there were many more sites suitable for swarming than were used. Thus it appears that male A.ashworthi make use of specific "swarm markers" as do most other species of mosquitoes, and do not swarm just anywhere where conditions are suitable.

Most swarms use particular protrusions from sheltering rock formations as swarm markers. Swarms were always formed to leeward of these markers. The position of the swarms relative to their markers has no constant relationship with light direction.

On one occasion a swarm was observed which did not use this type of swarm marker. This swarm was over and close to the surface of a rock pool which was without surrounding boulders and which contained <u>A.ashworthi</u> larvae. Notably it was a windless night.

d). <u>The Swarms.</u>

Although it is difficult to estimate the number of individuals in a swarm, most swarms appeared to contain between 100 and 500 individuals.

The shape of the swarm depends largely on the shape of the swarm marker. Swarms formed over a single rock jutting to a point are roughly spherical in shape. A number of small swarms of this shape may form at the same swarming site. These swarms may be as little as 2 ft. from each other. Each to use a different rock protrusion as its swarm marker. Spherical swarms are commonly 2 ft. in diameter, but may vary between 1 ft. and 3 ft. in diameter.

Where the marker is an elongated rock overhang the swarm may be drawn out into a cylindrical shape or may be broken into a series of smaller spherical swarms.

Individuals within a swarm did not fly in any fixed patt Each male flies in an apparently random zigzag manner such that it flies through all regions of the swarm.

Swarms were sampled on four occasions with a sweep net to determine the male/female ratio of the swarm. Of fifty- six animals sexed, only one was female.

No audible noise was emitted by the swarm.

e). Ecological Factors.

For each of the four nights on which swarming was observed, weather conditions were very similar, there being a light breeze (0 - 10 m.p.h.) and completely clear skies. For this reason little precise information could be gathered on the effects of meteorological variables on swarming behaviour. (i.e. cloud cover, wind speed, rain, ambient temperature, relative humiditv). However, since topographical variations produced localized differences in illumination and wind strength, some assessment could be make of the extent to which these two factors influende swarming behaviour.

1 Wind. Male swarming occured only in areas well protected from the wind, Wind strength in these areas was less than 2 m.p.h. although the prevailing winds at the time were 5 - 10 m.p.h.

A demonstration of the effect of wind strength on swarming behaviour was afforded by a swarm which formed downward of myself while I was crouched amongst the rocks at the water's edge. The swarm was using my back as its marker. By standing up I moved from a sheltered position into a 5 m.p.h. wind. The swarm at first followed me up, then broke up due to the wind's influence, the participants dropping down into the protection of the rocks. By repeatedly standing up and crouching down I was able to promote the formation and break-up of the swarm.

11. Time and Illumination. The developement of four adjacent swarms was studied on two consecutive evenings (23 rd and 24 th April). Three of these swarms were in open positions amongst boulders at the water's edge. The fourth sheltered from much of the sky's illumination by the ledge of a rock overhang.

On each of the two nights swarm formation in the more open positions began at 1802 hours, 15 minutes after sunset (crep value = 0.56)- see Appendix for explanation). The swarm in the shadow of the rock overhang formed 4 minutes earlier. It is important to realise that illumination decreases rapidly over such a four minute period.

The number of individuals in each swarm increased rapidly, reaching mazimum size 12 - 15 months after formation (crep value = 1.04). Numbers then declined steadily until complete collapse of the swarms 23 minutes after formation (crep value = 1.42).

Swarming at dawn was observed on one occasion by S.M. Stanley. The sky was heavily overcast and swarm formation did not begin until shortly after sunrise, lasting for almost half an hour.

DISCUSSION.

Male A.ashworthi swarmed at dawn and dusk only. Although some females joined the swarms no copulation was observed.

The importance of wind in affecting swarming behaviour has been shown. Swarming is prevented by winds of 5 m.p.h. or more. Wind speed and direction influence choice of swarming sites and markers, and the size and shape of swarms. Since swarming activity is confined to dawn and dusk, and since breezes at dusk are normally over 5 m.p.h. (or at least were, during the period of study), swarming would appear to be more dependent upon sheltered positions being available than other aspects of adult behaviour. eg. female biting activity.

The habitats of Triggs Island, Pt. Peron, Garden Island

and Rottnest Island provide very little suitable shelter and this is believed to be largely responsible for no swarming being observed at these localities. In contrast, the habitats of Wyadup, Injidup ( a headland similar to Wyadup and 1 mile further south ) provided many suitable sites for swarming.

*A.ashworthi* is a late-swarming mosquito, commencing swarming after many other species have ceased. Nielsen and Nielsen (1963), whilst recording observations on Danish mosquitos, have shown seven other *Aedes* species to commence swarming between -1.60 and 0.2 crep and to cease between 0.00 and 0.35 crep. Only three species are known to swarm as late as *A.ashworthi*; these are *Mansonia perturbans*, *Aedes taeniorhyncus* and *Culex theileri*. No explanation is offered for interspecific differences in swarming times.

It was thought that the late swarming of *A.ashworthi* might be related to a decline in wind speed after sunset. However since wind speeds at swarming sites were low enough to permit swarming well before sunset, this explanation is discounted.

As copulation in or near swarms was not observed, the significance of swarming by male A.ashworthi is not known. This is also true for many other mosquito species. Nielsen and Nielsen (ibid) have shown that, at least for the species they studied, "the vast majority of mating occurs at times other than during swarming".

## 4. GENERAL CONCLUSIONS.

Aedes ashworthi is restricted to a typically windy, seaside habitat which is devoid of protective vegetation.

Adult females of this species are nocturnal in their biting habits. Given favourable weather conditions, they show peaks of activity at dusk and dawn, and at one or more times during the night.

Male adults are crepuscular in their swarming habits.

Wind inhibits the activity of both males and females.

It bacame evident during the study that the mosquito populations at Wyadup, Injidup and Canal Pocks were much larger than those at Rottnest, Garden and Trigg's Islands, and Point Peron. The former locations are more favourable habitats for A.ashworthi since they provide a great deal more shelter.

Although other factors undoubtedly contribute, the suitability of a particular habitat for A.ashworthi would appear to depend largely upon adequate shelter from wind being available so that adults may continue their activities during all but the strongest breezes.

## 6. BIBLIOGRAPHY.

1. BATES, M. (1949). "The Natural History of Mosquitos", 379 pp. (New York:MacMillan Company).
2. BOORMAN, J.P.T. (1961). Mosquitos of Plateau Province, N.Nigeria, particularly Aedes vittatus. Bull.ent.Res.52:709-726.
3. CHIANG, H.C. (1961). Ecology of insect swarms. I. Experimental studies of the behaviour of Anarete near felti Pritchard in artificially induced swarms (Cecidomyiidae,Diptera). Animal Behaviour. 9 (3-4):213-219.
4. ___ (1962). Ecology of insect swarms.III. Intraspecific interference in the swarms of Anarete sp.near felti Pritchard (Cecidomyiidae,Diptera). Proceedings of the Minnesota Academy of Science. 30 (1):31-33.
5. ___ (1963). Ecology of insect swarms.IV. Comparison of the swarms of two closely related midges, Anarete johnsoni and A.sp.near johnsoni (Diptera:Cecidomyiidae). Ann. ent. Soc. Am. 56:748-751.
6. ___ and STENROOS, O. (1963). Ecology of insect swarms.II. Occurence of swarms of Anarete sp. under different field Conditions (Cecidomyiidae,Diptera). Ecology 44 (3):598-600.
7. CLEMENTS, A.N. (1963). "The Physiology of Mosquitos", 393 pp. (Oxford:Pergamon Press).
8. CORBET, P.S. (1962). The age-composition of biting mosquito populations according to time and level: a further study. Bull. ent. Res. 53:409-416.
9. ___ (1964). Observations on the swarming and mating of mosquitos in Uganda. Proc.R.ent. Soc. Lond. (A). 39 (1-3):15-22.
10. CUNNINGHAM-VAN SOMEREN, G.R. (1965). Male mosquito swarms: some observations in Kenya. Proc.R.ent.Soc.Lond. 40 (7-9):89-91.
11. DOBROTWORSKY,N.V. (1965). "The Mosquitos of Victoria". (Diptera, Culicidae), 237 pp. (Melbourne University Press).
12. GILLIES, M.T. (1961). Studies on the dispersion and survival of Anopheles gambiae Giles in East Africa, by means of marking and release experiment. Bull.ent.Res. 52:99-127.
13. ___ and FURLONG, M. (1963). An investigation into the behaviour of Anopheles parensis at Malindi: on the Kenya Coast. Bull. ent. Res. 55:1-16.
14. ___ and WILKES, T.J. (1965). A study of the age-composition of populations of Anopheles gambiae Giles and A.funestas Giles in north-eastern Tanzania. Bull. ent. Res. 56:237-262.
15. GWADZ. R.W. (1970). Monofactorial inheritence of early sexual receptivity in the mosquito, Aedes atropalpus. Anim.Behav. 18:358-361.
16. HADDOW, A.J. (1954). Studies on the biting habits of African mosquitos. An appraisal of the methods employed, with special reference to the twenty-four hour catch. Bull.ent.Res.45:199-242.
17. ___ (1959). Studies on the biting habits and medical importance of East African mosquitos in the Genus Aedes.I. - Subgenera Aedimorphus, Banksinella and Dunnius.Bull.ent.Res. 50:759-779.

18.___ (1961). Studies on the biting habits and medical importance of East African mosquitos in the genus Aedes. Bull.ent.Res. 52:317-351.
19. ___ (1964). Observations on the biting habits of mosquitos in the forest canopy at Zika, Uganda, with special reference to the crepuscular periods. Bull.ent.Res. 55:589-608.
20.___ and GILLET, J.D. (1957). Observations on the oviposition-cycle of Aedes (Stegomyia) aegypti. (Linnreus). Ann.trop.Med. Parasit. 51(2):159-169.
21.___ and SSENKUBUGE YOVANI (1962). Studies on the biting habits of East African mosquitos in the genera Uranotaenia, Ficalbia and Hodgesia. Bull.ent.Res. 53:639-652.
22.JAYEWICKREME, S.H.(1953). Nocturnal mating in Taeniorhynchus (Mansanoides) uniformis (Theobald). Nature, Lond. 171:577.
23.KETTLE, D.S. (1969). The biting cycle of Culicoides furons (Poey) and C.barbosai. Wirth and Blanton.I. The 24-h cycle, with a note on the differences between collectors. Bull.ent.Res.59:21-31.
24.___ and LINLEY, J.R. (1968). The biting habits of some Jamaican Culicoides. I.C. barbosai. Wirth and Blanton. Bull.ent.Res. 58:729-753.
25.LAWRENCE, B.R. (1960). The biology of two species of mosquito, Mansonia africana (Theobald) and Mansonia uniformis (Theobald), belonging to the subgenus Mansonoides (Diptera, Culicidae). Bull.ent.Res. 51:491-517.
26.LEE, D.J., CLINTON, K.J., and O'GOWER, A.K. (1954). The blood sources of some Australian mosquitos. Aust. J.biol.Sci. 7:283-301.
27.MACKERRAS, I.M. (1926).Mosquitos of the Sydney district. Journal of the Naturalists' Society of N.S.W. 6 (3):33-42.
28.MAYER, M.S. and JAMES, J.O. (1968). Attraction of Aedes aegypti (L): responses to human arms, carbon dioxide, and air currents in a new type of olfactometer. Bull ent.Res. 58:629-642.
29.McCLELLAND, G.A.H. (1959). Observations on the mosquito, Aedes (Stegomyia) aegypti (L), in East Africa.I.- The biting cycle in an outdoor population at Entebbe, Uganda. Bull.ent.Res. 50:227-235.
30.___ (1959). Observations on the mosquito Aedes (Stegomyia) aegypti (L). in East Africa. II.- The biting cycle in a domestic population on the Kenya coast. Bull.ent.Res. 50:687-696.
31.NIELSON, H.T. (1964). Swarming and some other habits of Mansonia perturbans and Psorophora ferox (Diptera:Culicidae). Behaviour. 24 (1-2):67-89.
32. ___ and HAEGER, J.S. (1960). Swarming and mating in mosquitos. Misc. Publ. Entomol. Soc. Amer. 1:72-95.
33.O'GOWER, A.K. (1958). The oviposition behaviour of Aedes australis (Erickson). Proc. Linn. Soc. N.S.W. 83:245-50.
34.PARKER, A.C.M. and ROZEBOOM, L.E. (1960). The effect of temperature and illumination on mating of Culex pipiens pipiens L. and C.p.fatigans Wied. Am. J. Med. Hyg. 9 (3): 331-335.

35. REID, J.A. (1961). The attraction on mosquitos by human or animal baits in relation to the transmission of disease. Bull.ent.Res. 52: 43-62.

36. ROSAY, B. (1960). Advances in behavioural studies. Proceedings and papers of twenty-eighth annual conference. California Mosquito Control Association.: 88-89.

37. ___ (1969). Anatomical indicators for assessing age of mosquitos: dissection techniques and field application of methods. Mosquito News. 29 (3): 419-423.

38. SAMARAWICKREMA, W.A. (1967). Biting cycles and parity of the mosquito Mansonia uniformis in Ceylon. Bull.ent.Res. 58:299-314.

39. SERVICE, M.W. (1963). The ecology of the mosquitos of the Northern Guinea Savannah of Nigeria. Bull.ent.Res. 54:601-632.

40. ___ (1964). The identification of blood-meals from Culcine mosquitos from Northern Nigeria. Bull.ent.Res. 55:637-643.

41. VAN SOMEREN, E.C.C. and FURLONG, M. (1964). The biting habits of Aedes (Skusea) pembaensis Theo. and some other mosquitos of Faza, Pate Island, East Africa. Bull.ent.Res. 55:97-124.

42. WILLIAMS, M.C. (1963). Studies on mosquitos (Diptera, Culicidae) biting birds, using twenty-four-hour catches, in the Entebbe area, Uganda. Bull.ent.Res. 54: 407-424.

43. WOODHILL, A.R. (1936). Observation and experiments on Aedes concolor. Bull.ent.Res. 27:633-648.

44. WORTH, C.B., DE SOUSA, J., and WEINBREN, M.P. (1961). Studies on the life history of Aedes pembaensis. Bull.ent.Res. 52:257-261.

# APPENDIX.

The duration of civil twilight is the number of minutes required for the position of the sun to change from $-0^{\circ}50'$ to $-6^{\circ}00'$. One crep is defined as the number of minutes which under given conditions corresponds to the duration of civil twilight. When the sky is clear a certain illumination corresponds to any given value of crep (Nielsen 1961). Since insect activity around sunset is related to changing light intensity, crep is a useful unit for the comparison of threshold light intensities for initiation and completion of swarming of different species of twilight - swarming insects.