

malathion between the New Orleans laboratory colony and the highly susceptible Rockefeller strain of *Ae. aegypti*. Wild New Orleans *Ae. aegypti* were only 1.4 times more tolerant to malathion than the 4-year old New Orleans colony, indicating that resistance has not developed in the field population.

World Health Organization larval susceptibility tests indicate that the New Orleans colony was highly tolerant to DDT (Beard 1983)<sup>1</sup> possibly indicating cross-resistance to pyrethroids (Plapp and Hoyer 1968). The New Orleans *Ae. aegypti* colony and the Rockefeller strain of *Ae. aegypti* were similar in susceptibility to resmethrin-PBO; the New Orleans colony was only 2 times more tolerant. It is possible to explain this difference by comparing the different lengths of time the two strains have been colonized before testing. The Rockefeller strain was colonized in 1959 vs. the New Orleans in 1981. Colonization over an extended period tends to reduce heterogeneity which was likely to be more pronounced in the older colony (Mitchell 1983).

These results indicate that resmethrin-PBO and HAN-malathion would be adequate adulticides for *Ae. aegypti* control in the event of an emergency. Resmethrin-PBO is ca. 4 times the cost of HAN-malathion at the same level of effectiveness. Therefore HAN-malathion (2:1) is the most cost-effective adulticide against New Orleans *Ae. aegypti*.

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#### References Cited

- Centers for Disease Control. 1984. Dengue-Americas, 1983. Morbidity and Mortality Weekly Report 33:327-335.
- Finney, D. J. 1971. Probit analysis, 3rd edition. Cambridge Univ. Press. 333 pp.
- Fox, I. 1973. Malathion resistance in *Aedes aegypti* from pressure on adults. Mosq. News 33:161-164.
- Mitchell, C. 1983. Mosquito vector competence and arboviruses, pp. 63-92. In: K. Harris, (ed.) Current topics in vector research, Vol. 1. Praeger Publ. Co., New York.
- Mount, G., N. Pierce and K. Baldwin. 1976. A new wind tunnel system for testing insecticidal aerosols against mosquitoes and flies. Mosq. News 36:127-131.

Plapp, F. and R. Hoyer. 1968. Possible pleiotropism of a gene conferring resistance to DDT, DDT analogs and pyrethrins in the house fly and *Culex tarsalis*. J. Econ. Entomol. 61:761-765.

#### A NEW CAGE FOR OBSERVING MATING BEHAVIOR OF WILD *ANOPHELES GAMBIAE* IN THE LABORATORY<sup>1</sup>

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Control of anopheline vectors of malaria and filariasis in tropical areas, where their impact on human health is heaviest, has often failed. Research into the behavior and genetics of these mosquitoes, with the aim of developing alternative control methods; depends on successful laboratory colonization, however, a number of species do not mate successfully under laboratory conditions, which hinders colonization. This problem may be overcome by selection or by applying artificial mating techniques, but the resulting laboratory-adapted strains have limited value for studies regarding mating behavior under natural conditions. During my work on mating behavior of two sibling species of the *Anopheles gambiae* complex in northeastern Tanzania, it proved difficult to elicit mating in the laboratory in wild, unselected, mosquitoes. This paper describes a special cage in which a marked improvement in swarming and mating activity of wild material was obtained.

In mosquitoes mating is associated with swarming of the males (Downes 1969). For *Anopheles gambiae* Giles and *An. arabiensis* Patton all available information suggests that swarming is a prerequisite for mating (Jones and Gubbins 1978, Charlwood and Jones 1980). In nature swarming of these species typically occurs over flat, open ground under the open sky in villages and starts about 10 min after sunset, lasting for about 20 min (Marchand 1984). When the virgin offspring (larval stage reared in the laboratory) of wild-caught mothers were held in standard 30 × 30 × 30 cm cages under artificial

<sup>1</sup> Beard, B. 1983. The susceptibility of domestic and periodomestic strains of *Aedes (Stegomyia) aegypti* (L.) to organophosphate, organochlorine, and synthetic pyrethroid insecticides in New Orleans, LA. Master's thesis. Louisiana State University Medical Center, New Orleans, LA, 77 pp.

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illumination in the insectary, much flight activity was evident just after illumination ceased (photoperiod = 12L:12D), but matings did not occur in *An. arabiensis* and only rarely in *An. gambiae*. Increasing the cage volume (up to 2 m<sup>3</sup> indoors and 100 m<sup>3</sup> outdoors) gave no improvement. However, the interposition of a period of reduced light intensity ("twilight") between the light and dark phases, gave a slight, but statistically significant, increase of the insemination rate in *An. gambiae*. The mosquitoes always showed strong phototactic behavior, repeatedly striking the netting on the brightest side of the cage. Only very infrequently, and for short periods, did male *An. gambiae* show the characteristic 'dance-like' movements observed in natural swarming.

These observations led to the construction of a cage in which I tried to simulate a diffusely illuminated "sky" (Fig. 1). The top part of this cage was made of white drawing paper which was suspended from the outside in such a way that no ribs could be seen from inside. Twelve 40 W incandescent lamps (of which only 5 are visible in the sectional diagram of Fig. 1) were evenly distributed around and above the cage and illuminated the outside of the paper section. The lower part of the cage had a con-

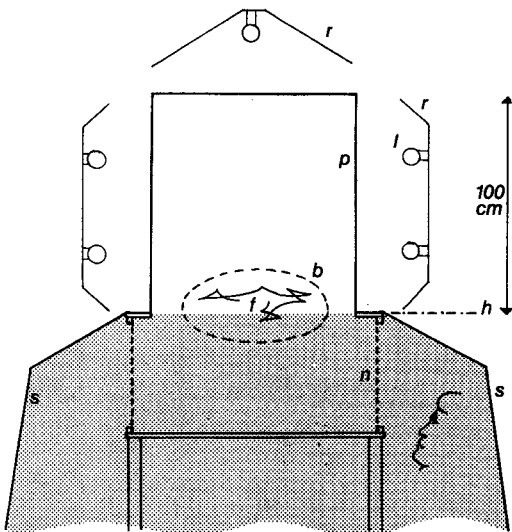


Fig. 1. Schematic drawing of the cage in which swarming and mating of wild *An. gambiae* and *An. arabiensis* was observed. The shaded area is dark during observations.

Legend: *b*, approximate boundary of swarming; *f*, typical flight path of an individual swarming male mosquito; *h*, plane of the artificial horizon; *l*, lamp; *n*, mosquito netting; *p*, drawing paper; *r*, reflector board; *s*, black screening.

ventional appearance, with mosquito netting sides and a wooden floor. Screens of black cloth prevented light from entering the cage through the lower part. Observations were made from under the screens, by looking upwards through the netting sides. The light regime was governed by a time switch with a simple device that created a gradual transition between light and dark. During this artificial "dusk" the decrease in light intensity could be stopped manually to prolong optimal visibility once swarming had started.

The results obtained in this cage show the importance of a visual pattern both in the release of swarming behavior and in defining the position of the swarms in *An. gambiae* and *An. arabiensis*. Flight activity started within minutes after the onset of "dusk," provided this dusk was in phase with the previous circadian photoperiod experienced by the mosquitoes. Initially long cruising flights were seen, especially near the ceiling of the cage. About 8 min after the onset of "dusk," corresponding to a light intensity of about 13 lux (measured by a Metrux-K luxmeter of Brown Boveri Corp.), one or a few males started "dancing" very near the horizontal plane that separated the light (upper) part from the dark (lower) part of the cage. Gradually more males joined to form a swarm, i.e., a cluster of dancing males. The swarms were spatially very stable, with the center always close to the plane of the artificial "horizons." When this "horizon" was situated higher in the cage by adding a strip of black paper, the center of swarming moved accordingly. The shape of the swarms could be influenced by patterns of black paper above the "horizon." However, when the pattern of a "horizon contrasting with luminous sky" was disrupted too much, the formation of swarms was inhibited. The swarming of *An. arabiensis* was more easily disturbed in this way than that of *An. gambiae*. The presence and position of contrasting objects on the floor of the cage ("ground markers") had little or no effect.

The behavior of wild, virgin, females was much less predictable than that of males. The amount of female flight activity during the swarming period varied from sample to sample and sometimes even between replicate experiments. Because males were never attracted to inactive females this variability resulted in highly variable insemination rates, independent of the level of male activity. Nevertheless maximum insemination rates (the percentage of females inseminated after one swarming period with twice as many males as females in the cage) of up to 45% were obtained for *An. arabiensis*, a species which never mated in the other cages tried. The colonization of this species has

generally given more difficulties than that of *An. gambiae* in the insectaries of the London School of Hygiene and Tropical Medicine (C. F. Curtis, personal communication).

A similar cage as here described may facilitate the colonization of other species as well. For instance, some "dancing" was observed in this cage in pilot experiments with males of *An. funestus* Giles, a species notoriously difficult to breed. Some success at least could be expected with this medically important mosquito since it was seen to form swarms in the field in places and at times that partly overlap with those of *An. gambiae* and *An. arabiensis* (Marchand, unpublished data). For successful colonization of *An. funestus* however, the problems of rearing its larvae would have to be solved as well.

Another interesting application of this type of cage may arise in tests of genetic control methods for members of the *An. gambiae* complex. In field trials of genetic control with other mosquito species it is often found that the released males, when derived from laboratory colonies, are not fully competitive with wild males (Reisen et al. 1980, Grover et al. 1976, Milby et al. 1980). Laboratory adapted strains of *An. gambiae* (KWA, originating from Kwale in Tanzania and the R70 translocation strain (Curtis et al. 1976) with KWA genetic background, kindly supplied by C. F. Curtis of the London School of Hygiene and Tropical Medicine), when tested in the "swarm-cage" formed similar swarms as wild material. However, they obviously do not require the special visual cues to do so because they swarmed in all cage types, and even in complete darkness. A tendency of laboratory-adapted males to start swarming in the field at non-specific sites may diminish their competitiveness considerably. The cage would offer the possibility of breeding a laboratory population in which the mating behavior of the males is as near as possible to that of wild males. This reduced selection pressure would probably not hold for female behavior because the activity of wild females in this cage was still lower than that of females from laboratory adapted strains. Any genetic association between male and female mating behavior would, therefore, still imply changing male behavior during prolonged colonization in this cage. However, experiments (to be reported elsewhere) indicated that the behavioral difference between wild and adapted males is inherited from father to son and is possibly controlled by genes on the Y-chromosome.

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#### References Cited

- Charlwood, J. D. and M. D. R. Jones. 1980. Mating in the mosquito, *Anopheles gambiae* s.l. II. Swarming behaviour. *Physiol. Entomol.* 5:315-320.
- Curtis, C. F., J. Akiyama and G. Davidson. 1976. A genetic sexing system in *Anopheles gambiae* species A. *Mosq. News* 36:492-498.
- Downes, J. A. 1969. The swarming and mating flight of Diptera. *Annu. Rev. Entomol.* 14:271-298.
- Grover, K. K., C. F. Curtis, V. P. Sharma, K. R. P. Singh, K. Dietz, H. V. Agarwal, R. K. Razdan and V. Vaidyanathan. 1976. Competitiveness of chemosterilized males and cytoplasmically incompatible translocated males of *Culex pipiens fatigans* Wiedemann (Diptera, Culicidae) in the field. *Bull. Entomol. Res.* 66:469-480.
- Jones, M. D. R. and S. J. Gubbins 1978. Changes in the circadian flight activity of the mosquito, *Anopheles gambiae* s.l. in relation to insemination, feeding and oviposition. *Physiol. Entomol.* 5:315-320.
- Marchand, R. P. 1984. Field observations on swarming and mating in *Anopheles gambiae* mosquitoes in Tanzania. *Neth. J. Zool.* 34:367-387.
- Milby, M. M., R. L. Nelson and P. T. McDonald. 1980. Release of heterozygous translocated adult males for genetic control of *Culex tarsalis* at an isolated site. *Mosq. News* 40:83-90.
- Reisen, W. K., R. K. Sakai, R. H. Baker, H. R. Rathor, K. Raana, K. Azra and S. Niaz. 1980. Field competitiveness of *Culex tritaeniorhynchus* Giles males carrying a complex chromosomal aberration: A second experiment. *Ann. Entomol. Soc. Am.* 73:479-484.

#### BEECOMIST SERVOFLO VARIABLE FLOW PUMPING SYSTEM: A PRELIMINARY REPORT

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In May 1984, it was decided to replace the insecticide delivery system on one of our old Leco machines. The pressure system, in spite of its relative simplicity, had a number of drawbacks, the main one being the routing of chemical into the cab of the spray vehicle. In June 1984, Beecomist introduced a new variable flow pumping system which utilized a modification