ANIMAL INFLUENCE ON MAN-BITING RATES AT A MALARIOUS SITE IN PALAWAN, PHILIPPINES

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INTRODUCTION

Zooprophylaxis is a technique in which animals are used to divert mosquitoes, seeking a blood meal, away from man. By placing cattle sheds between houses and mosquito breeding sites, *Anopheles*, which are primarily zoophilic, have been diverted to their preferred host. However, the success of this technique has varied greatly. In Malaysia, for example, the extent of malaria has varied inversely to the number of cattle present (Russell *et al.*, 1963). This technique is now rarely used because of the widespread use of insecticides.

From March 1986 to April 1988, extensive malaria epidemiological and vector surveys were conducted on the western coast of central Palawan by the U.S. Naval Medical Research Unit. From January through April 1988, over 30% of the population was infected with malaria at any given time (Oberst, unpublished data). *Anopheles flavirostris*, the primary malaria vector, had high biting rates during this period, averaging 22 bites/man/night (Schultz, unpublished data). This active transmission is occurring in spite of spraying the houses with DDT every 6 months. This preliminary investigation on zooprophylaxis was undertaken to determine if this technique might be effective in augmenting the current malaria control program while new vector control methods are being developed.

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MATERIALS AND METHODS

The effect that nearby animals have on man-biting rates was tested in the village of Sto. Nino, 32 km west of Puerto Princesa, the capital of Palawan. Sto. Nino is a small village of about 500 people. Their houses are made of split bamboo with roofs of thatched grass, which provide ready access to mosquitoes. Aside from a few pigs and dogs, few animals were present. The villagers owned three carabaos (water buffalo) which were usually kept outside the village at night. An elementary school was located in the center

of the village and surrounded by a large, open field where our experiments were conducted. Collections were done on 8 consecutive nights from 7–14 February, and repeated from 28 February–6 March 1988. Outdoor collections were done during the first 4 nights, while mosquitoes were collected inside houses on the last 4 nights.

Two sites, about 100 m apart, were chosen at opposite corners of the field. Four men at each site collected mosquitoes from their own legs using oral aspirators and red-filtered flashlights. Each group collected exactly the same length of time each night from 2100–0000 and 0015–0300. Mosquitoes were placed in carton cages and later identified. On the first night 2 carabaos were tied about 4 m on either side of the men at one site, while the other group had no animals nearby. On the second night the 2 groups switched places while the carabao remained at the original site. On the third night the two carabaos were moved to the opposite site while the men remained as before. On the fourth night the men once again changed sites while leaving the carabao at the same place as the previous night. Each possible combination of men, both with and without carabao at each site, was used during the 4 nights to prevent bias in collecting abilities or site differences. During nights 5–8 the same schedule was used except both groups collected inside of huts on opposite ends of the field, and the 2 carabaos were tied outdoors on either side of the house.

Two additional experiments were conducted from 18–22 March and 12–21 April 1988. The purpose of these was to determine the ability of carabao to dilute the population of infective vectors. Mosquitoes were collected on concurrent nights from man-biting and carabao-baited traps. *Anopheles flavirostris* was dissected and examined for sporozoites in its salivary glands. Sporozoite rates were compared for each method of collection.

RESULTS AND DISCUSSION

Under outdoor collecting conditions, fewer mosquitoes were found biting man when a carabao was nearby (1353) than when none were present (2687) (Table 1). *Anopheles flavirostris* bites were reduced when carabao were present (617), and greater when none were nearby (1052). In this situation, zooprophylaxis was succesful in reducing mosquito bites. Both men and carabao release certain "attractive factors," such as warmth, moisture, carbon dioxide, various body odors, and visual stimuli (Clements, 1963). It is known that for almost all of the species listed, 1 carabao will attract a much greater number of each species than 1 man collecting some distance away. For example, at this site, for every *An. flavirostris* collected from man, about 4 are collected from a carabao; and for every *An. annularis* collected from man, 83 are collected from a carabao (Schultz, unpublished data). Almost all of these mosquitoes are zoophilic to some degree. This may be due to the carabao releasing a greater quantity of "attractive factors," or the carabao may release several specific factors that are highly attractive to mosquitoes. Nevertheless, virtually all of the species that feed on carabao also feed on man, so both hosts share at least some if not most of these factors.

When 4 men are placed at a site, a certain quantity of "attractive factors" are present. The airborne factors travel downwind, and mosquitoes are activated, fly upwind, and

Table 1
Ratio of mosquitoes caught biting man with a carabao present to no carabao present

Species	Ratio of number of mosquitoes when carabao present: carabao absent	
	Outdoor	Indoor
Anopheles flavirostris	617:1052	473:327
An. annularis	412:661	177:15
An. tessellatus	39:30	1:0
An. peditaeniatus	17:34	3:0
An. subpictus	3:6	2:0
An. karwari	2:5	0:0
An. maculatus	2:2	2:0
An. litoralis	1:6	1:0
An. philippinensis	1:1	3:1
An. pseudobarbirostris	1:0	1:0
An. balabacensis	0:3	0:2
An. kochi	0:2	0:0
An. franciscoi	0:1	2:0
An. ludlowae	0:1	0:0
Culex vishnui	145:542	91:77
Cx. whitmorei	17:52	4:1
Cx. gelidus	10:29	3:3
Cx. tritaeniorhynchus	7:13	13:4
Cx. pseudovishnui	7:4	1:4
Cx. sinensis	1:2	0:0
Cx. sitiens	1:0	2:8
Cx. bitaeniorhynchus	0:3	2:0
Cx. fuscocephala	0:2	0:0
Cx. quinquefasciatus	0:1	13:8
Aedes vexans	20:145	4:3
Ae. albopictus	9:11	2:3
Ae. lineatopennis	7:13	0:0
Ae. longirostris	5:7	0:2
Ae. flavipennis	2:1	0:0
Ae. poicilius	1:1	0:0
Mansonia uniformis	17:51	7:12
Armigeres flavus	5:5	1:0
Ar. subalbatus	3:0	1:0
Aedeomyia catasticta	1:0	0:0
Coquillettidia ochracea	0:1	0:0
Total	1353:2687	809:470

seek a blood meal. When 2 carabaos are placed next to these 4 men, a much greater quantity of these factors travels downwind and attracts a greater number of mosquitoes to their site. This is clearly evident when approaching a carabao at night and seeing the large number of mosquitoes in its vicinity. Although the men/carabao combination attracts a much greater number of mosquitoes to its area, the men receive fewer mosquito bites. Since the carabao is the preferred host and is readily available, it diverts the majority of mosquito attacks to itself. The smaller number of mosquitoes that are attracted to 4 men sitting alone would not be diverted to another host.

Under indoor collecting conditions the opposite results are obtained, that is, more mosquitoes were found biting man when a carabao was nearby (809) than when none were close (470) (Table 1). *Anopheles flavirostris* bites increased when a carabao was close (473) and were less frequent when none were nearby (327). As before, many more mosquitoes are attracted to the site with the 2 carabaos. Some of these will enter the house, not only because of the odors emanating from the men, but also because the house may be between them and the carabao. One possible explanation is that once inside the house, they are partially isolated from their preferred host. Any movement by the workers in the dimly-lit huts could be

detected, whereas the carabao's movement is obstructed. Therefore, the placement of carabao near the house is clearly disadvantageous. A similar observation was made in Indonesia. Villages in which cattle were kept away from human dwellings had less malaria than those where cattle were kept next to the houses (Kirnowordoyo and Supalin, 1986).

Dissections of *An. flavirostris* from man-biting collections showed a sporozoite rate of 1.55% (81 out of 5210), while from carabao-baited traps it was 0.75% (14 out of 1878). The difference in the two rates is significant ($p < 0.01$). One possible explanation is that *An. flavirostris* in this area could consist of 2 genetically different subpopulations : one with zoophilic tendencies and the other more anthropophilic. Another possibility is that after a mosquito takes its first blood meal, its behavior is modified and it will be more likely to seek subsequent blood meals from the same type of host. Evidence for such genetic and/or behavioral modification has been shown for other species such as *An. balabacensis* (Hii, 1985) and *An. minimus* (Nutsathapana *et al.*, 1986). Regardless of the mechanism involved, the carabao does dilute the transmission of malaria within an area. Many of the 14 sporozoite-positive mosquitoes caught in carabao traps probably would have fed on man had no carabao been present, since there were few other mammals in the village.

In West Africa, the 2 sibling species of the *An. gambiae* complex differ in their vectorial efficiency when cattle are present (White *et al.*, 1972). *An. gambiae* (species A) is more anthropophilic than *An. arabiensis* (species B). When cattle are not present, the sporozoite rates between these 2 species within an area show little difference since the mosquitoes have little to feed on but man (White and Rosen, 1973). In contrast, villages with cattle show *An. gambiae* to have significantly higher sporozoite rates than *An. arabiensis* (Molineaux and Gramiccia, 1980). A similar situation could be occurring between 2 subpopulations of *An. flavirostris* in the Philippines.

Another factor to be considered is that a mosquito, deprived of its preferred host, can, over several generations, shift its behavior to prefer a second host. Colonies of laboratory-reared mosquitoes, fed on a non-preferred host for several generations, developed a preference for their new hosts (Laarman, 1958; Brouwer, 1960). *Anopheles flavirostris*, in the vicinity of a village with no carabao, could after many generations, develop an anthropophilic tendency. Placing several carabao around the village away from houses could play a significant role in reducing malaria by diluting the transmission of malaria and providing an alternate host.

SUMMARY

The effect of nearby animals on man-biting rates was tested under both outdoor and indoor conditions. Under outdoor conditions, fewer mosquitoes were found biting man when a carabao was nearby than when none were close. When collecting indoors, the opposite results were obtained. Therefore, placing a carabao near a house is disadvantageous. Sporozoite rates of *Anopheles flavirostris* were twice as high from man-biting collections as those caught from carabao. Placing carabao around a village but away from the house could play a significant role in reducing malaria transmission.

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