[1] ICIPE Coastal Field Station, P.O. Box 80804, Mombasa, Kenya

[2] Department of Medical Entomology, Liverpool School of Tropical Medicine, Liverpool L3 5QA, England

[3] OMS/Onchocercose, B.P. 549, Ouagadougou, Upper Volta

The effect of domestic detergents on the population dynamics of the immature stages of two competitor mosquitoes, *Culex cinereus* Theobald and *Culex quinquefasciatus* Say (Diptera, Culicidae) in Kenya

R. SUBRA[1,3], M. W. SERVICE[2], F. W. MOSHA[1]

Summary

In some rural areas of Kenya pit latrines are the most important breeding places of *Culex quinquefasciatus*, but this vector is often rapidly displaced by a competitor, *Culex cinereus*, which then breeds prolifically in the latrines. In urban settlements, however, cesspools are the main breeding sites of *C. quinquefasciatus* and no such species replacement occurs. These latter habitats contain water contaminated with domestic detergents. When detergents were introduced into a pit latrine colonized only by *C. cinereus* this mosquito was eliminated after about 3 weeks. When both species were reared in water containing detergents *C. cinereus* had lower pupal yields than *C. quinquefasciatus*. In two pit latrines where *C. cinereus* normally displaced *C. quinquefasciatus*, the addition of detergent prevented this, and after their coexistence for a few weeks, *C. cinereus* eventually disappeared. – These observations suggest that during the last few decades domestic detergents, together with other pollutants such as insecticides, may have contributed to the elimination of competitors, such as *C. cinereus*, from *C. quinquefasciatus* breeding sites.

Key words: *Culex cinereus; Culex quinquefasciatus;* detergents; breeding places.

Introduction

Over large areas of the world *C. quinquesfasciatus* Say typically breeds in organically polluted water created by man's activities to get rid of his various

waste products (Hamon et al., 1967; Mattingly, 1962; Subra, 1975). Experiments in Nigeria suggested that until about the mid-1940's larval competitors such as *Culex nebulosus* Theobald limited the spread of *C. quinquefasciatus*, but that the introduction of organochlorine insecticides more or less eliminated *C. nebulosus*. At the same time *C. quinquefasciatus* increased in numbers because it developed insecticide resistance (Service, 1966). However, in other areas of West Africa Mouchet et al. (1968) reported that *C. quinquefasciatus* remained the dominant species in certain urban areas, despite still being susceptible to DDT. There are also several urban settlements where insecticidal control has been discontinued and yet in this absence of insecticidal pressure *C. quinquefasciatus* remains the principal mosquito breeding in polluted waters.

In some rural areas of the Kenya coast, however, populations of *C. quinquefasciatus* are unable to maintain themselves for more than a few weeks in larval habitats colonized by *C. cinereus* Theobald, a non-man biting mosquito that also tolerates high levels of pollution. In other situations, mainly urban, such species replacement does not occur, and Subra (1973) suggested that contamination of breeding places with detergents, which are now widely used, might prevent competitors such as *C. cinereus* from becoming dominant. The present study was undertaken to test this hypothesis.

Material and Methods

Study areas

Field observations and experiments were conducted in a rural zone, the Rabai area (15–20 km north-west of Mombasa), and in the Kongowea surburb of Mombasa town.

In the Rabai area the main potential breeding sites of *C. quinquefasciatus* and *C. cinereus* are recently built pit latrines (Subra, 1982) and the only water they hold comes from the water table. *C. quinquefasciatus* is the first mosquito to colonize these sites, but after a few weeks it is displaced by *C. cinereus* (Subra and Dransfield, submitted a). In Kongowea by contrast cesspools into which water containing variable amounts of domestic detergents drains are the prinicipal breeding sites of *C. quinquefasciatus*. In these habitats *C. quinquefasciatus* is the dominant species throughout the year. *C. cinereus* may occur in small numbers in a few of these sites, but usually for only a few weeks. Insecticides have never been applied to breeding sites in the Rabai area and have not been used on the sites studied in Kongowea for many years. Consequently, insecticides did not have any impact on the population dynamics of mosquitoes during the investigations.

Experiment I

There were two objectives. First to check whether the introduction of domestic detergents into a pit latrine colonized by *C. cinereus* caused any reduction in the numbers of emerging adults, and secondly to compare larval susceptibilities of the two species to domestic detergents.

Two pit latrines which had originally been colonized by *C. quinquefasciatus* were selected in a village in the Rabai area. The experiments started on 3 November 1980, a few weeks after *C. quinquefasciatus* had been completely replaced by *C. cinereus*, so at the time of these experiments this latter mosquito was the only species in the latrines. From 3 November to 20 January 1981, one hundred grams of OMO, the most commonly used detergent on the Kenya coast, were introduced daily into one of these latrines. This represented, at the beginning of the experiment, an average concentration of 60 g/m³. The second latrine served as a control and no detergent was added. The

70

Table 1. Pupal yield from 1st-instar larvae of *C. cinereus* and *C. quinquefasciatus* reared in latrine water containing domestic detergent

Species		No. of 1st-instar larvae	Pupal yield	Pupal mortality
			No. of pupae	No. of pupae
C. cinereus	Control	160	135 (84.4%)	5 (3.7%)
	Detergent added .	240	0 (0%)	–
C. quinquefasciatus	Control	160	155 (96.9%)	4 (2.6%)
	Detergent added .	240	27 (11.3%)	15 (55.6%)

effects of adding detergent were assessed by fitting an exit trap to monitor the numbers of male adults emerging from the latrines. Collections were made over 24 h once every 3 days.

Four weeks after the detergent was first introduced into the latrines, water samples were collected and 200 ml placed in a series of plastic containers in the laboratory. Batches of 20 1st-instar larvae of either *C. quinquefasciatus* or *C. cinereus* were introduced into these containers. Larvae were fed with "Farex", a proprietary baby food, and pupae were removed daily and adults allowed to emerge.

Experiment II

The objective was to determine whether in the presence of detergents *C. quinquefasciatus* could maintain itself in breeding sites recently invaded by *C. cinereus*. Three pit latrines in which both species were present, were selected in two villages in the Rabai area. Two latrines (L_1 and L_2) received at the beginning of the experiments a daily average of 30 g/m^3 and 50 g/m^3 of detergent (OMO) respectively. For logistic reasons detergents were added once every two days. When the experiments started in June 1981 the most abundant species in latrine L_1 was *C. quinquefasciatus* while *C. cinereus* was commonest in latrine L_2 and also latrine (L_c), which received no detergent and served as a control. The effects of adding detergents were assessed weekly by sampling emerging males as already described.

Experiment III

The aim was to compare pupal yields of 1st-instar larvae of the two species reared in water which had become naturally polluted with detergents. For this, water was collected from four cesspools (C_1–C_4) in the Kongowea area of Mombasa, and was used in the laboratory to rear pupae from 1st-instar larvae of *C. quinquefasciatus* and *C. cinereus*. Rearing procedures were similar to those used in experiment I, except that water was renewed every day with water collected from the respective breeding sites. This exposed larvae to fluctuating dosages of detergents as would be encountered by wild larvae in cesspools. Wild preimaginal stages contained in the daily collections of water samples were identified.

Results

Experiment I (Table 1)

From 9th October to 2nd November 1980, before detergents were added, and when *C. cinereus* was the only mosquito in the pit latrines a mean of 834 ± 171 *C. cinereus* males were collected (over 3 days) in the exit trap fitted to
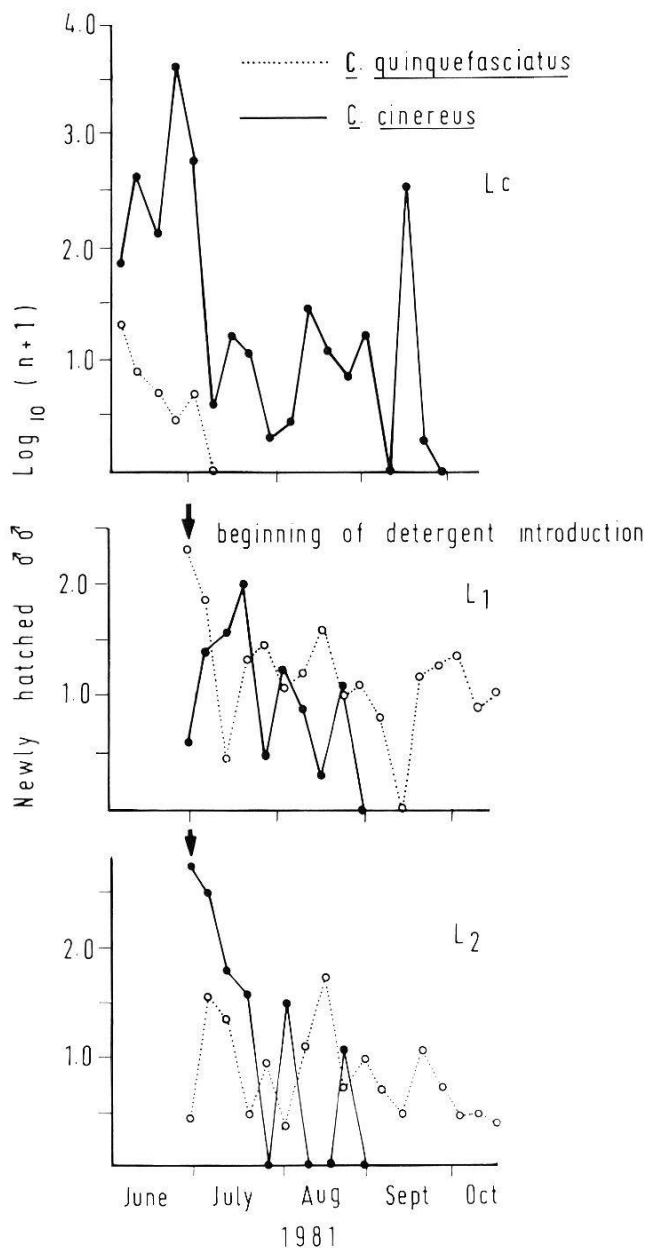
Fig. 1. Effect of detergent introductions on the productivity of breeding sites (latrines) colonised by *C. quinquefasciatus* and *C. cinereus*. Lc = control latrine, no added detergents, L_1 and L_2 = latrines with 30 and 50 g/m³ added.

the latrine to which detergents were to be added later. The trap fitted to the control latrine caught 1243 ± 278 male *C. cinereus*.

The addition of detergent did not show an immediate effect on mosquito productivity, but after 11 days emergent males rapidly decreased, and by 23 days production ceased, and over the following 52 days only 2 male *C. quinque-fasciatus* and 16 male *C. cinereus* were collected from this latrine. In contrast the control latrine yielded a mean of 1076 ± 243 males per trap during this period. When detergent introductions ceased *C. cinereus* numbers increased steadily; and the last exit trap collection at the end of February 1981 comprised 348 males.

72

Table 2. Pupal yield from 1st-instar larvae of *C. cinereus* and *C. quinquefasciatus* reared in used water collected from 4 potential breeding sites of Mombasa town

Breeding sites		Pupal yield				d test for comparison of percentages
No.	Species present	*C. cinereus*		*C. quinquefasciatus*		
		No. of 1st-instars used	% of pupae*	No. of 1st-instars used	% of pupae*	
C_1	*C. quinquefasciatus*	160	25.5	240	62.7	8.08***
C_2	*C. quinquefasciatus* (= 87.5%) *C. cinereus* (= 12.5%)	160	65.9	240	75.7	2.10**
C_3	No. of larvae or egg rafts	160	22.7	240	53.2	6.60***
C_4	*C. quinquefasciatus*	160	35.8	240	83.8	6.82***

* calculated after correcting pupal mortality by Abbott's formula
** $0.01 < P < 0.05$ *** $P < 0.001$

Experiments on pupal production from 1st-instar larvae of *C. cinereus* and *C. quinquefasciatus* reared in water collected from the latrine containing detergent started on 5th December 1980, by which time there were no larvae in this latrine. None of the *C. cinereus* larvae reared in water containing detergent was able to reach the pupal stage (Table 1). Only 11.3% of the 1st-instar larvae of *C. quinquefasciatus* gave rise to pupae, of which 55.6% died, so that the final pupal productivity was only 5%.

Experiment II (Fig. 1)

In the latrine (L_c) receiving no detergents, the population of *C. quinquefasciatus* rapidly became extinct, whereas *C. cinereus* remained until the breeding site dried out at the end of September 1981. In latrine L_1 (30 g detergent/m³) the two species coexisted for 8 weeks following the introduction of detergents, after which *C. cinereus* disappeared leaving *C. quinquefasciatus* as the only mosquito being produced until observations ended some 8 weeks later. In latrine L_2, where detergent concentration (50 g/m³) was higher, *C. cinereus* numbers declined rapidly and productivity ceased after 4 weeks, but on two occasions breeding restarted and males were trapped. *C. quinquefasciatus* successfully maintained a population in this latrine until the experiment was terminated.

Experiment III (Table 2)

During daily collections of water for laboratory tests from the four cesspools a note was made of the mosquitoes breeding in them. Cesspools C_1 and C_4

73

were colonized only by *C. quinquefasciatus,* but cesspool C_2 was unusual in that it contained larvae of *C. cinereus* in addition to *C. quinquefasciatus,* the latter was, however, the dominant species. Neither larvae nor egg rafts were collected from cesspool C_3. Pupal productivity of both species was considerably lower when larvae were reared in breeding water compared with virtually total pupation in tap water. In water from all four cesspools *C. quinquefasciatus* had a significantly higher pupal yield than *C. cinereus.*

Discussion

As expected none of the *C. cinereus* larvae reared in detergent contaminated water during the first experiment reached the pupal stage, but *C. quinquefasciatus* productivity was also much reduced. This might explain why virtually no adults (only 2 were trapped) of this species were produced from the latrine after *C. cinereus* had been eliminated by detergents. However, it is also possible that the addition of detergents rendered the latrine non-attractive as an oviposition site, a phenomenon already observed by Subra and Dransfield (submitted b) in another breeding site.

Although experiment III has shown that water containing domestic detergents reduces the survival rates of the immature stages of both species, the susceptibility of *C. cinereus* is much greater. Consequently, when detergents are present in breeding sites *C. cinereus* is unable to completely displace *C. quinquefasciatus* and the two species may coexist for some time. Coexistence of these species had already been observed in some cesspools in Bobo-Dioulasso, Upper Volta, and led Subra (1971) to believe that there was no competition between them. However, a reappraisal of the relationship between these two mosquitoes is now needed because of the role of detergents. It seems that normally *C. quinquefasciatus* is displaced in many polluted habitats by *C. cinereus* because the latter is a better larval competitor (Subra and Dransfiled, submitted b) but the presence of detergents prevents this.

Widespread use of detergents, as well as insecticides, might be one of the factors responsible for the relatively recent spread of *C. quinquefasciatus* in parts of tropical Africa. Nevertheless, this can not explain why in the early 1900's long before detergents were used, *C. quinquefasciatus* was already a very common mosquito in some urban settlements along the East African coast (Aders, 1917), nor why *C. cinereus* is absent today from many breeding sites in Mombasa and other African towns. Experiments have indicated that a small proportion of immature stages of *C. cinereus* in natural habitats should be able to withstand detergent pollution, but it may be that such habitats are unattractive as ovipositiom sites and hence this may be why many potential sites are not breeding *C. cinereus* but only *C. quinquefasciatus.*

The possible effects of detergents on mosquitoes have rarely been investigated but van Seventer (1970) considered that the increase in use of anionic

detergents in the Netherlands was in part responsible for the decrease in populations of *Anopheles atroparvus* van Theil.

Finally, this study has clearly shown that man's impact on the environment, including changes of the ecology of urban areas, can create unexpected problems, in this instance the replacement of a non-biting mosquito with a vector such as *C. quinquefasciatus.*

Aders W. M.: Insects injurious to man and stock in Zanzibar. Bull. ent. Res. *7,* 391–401 (1917).

Hamon J., Burnett G., Adam J. P., Rickenbach A., Grjebine A.: *Culex pipiens fatigans* Wiedemann, *Wuchereria bancrofti* Cobbold, et le développement économique de l'Afrique tropicale. Bull. Wld Hlth Org. *37,* 217–237 (1967).

Mattingly P. F.: Population increases in *Culex pipiens fatigans* Wiedemann. A review of present knowledge. Bull. Wld Hlth Org. *27,* 579–584 (1962).

Mouchet J., Déjardin J., Subra R.: Sensibilité aux insecticides de *Culex pipiens fatigans* en Afrique de l'Ouest. Méd. trop. *28,* 374–394 (1968).

Service M. W.: The replacement of *Culex nebulosus* Theo. by *Culex pipiens fatigans* Wied. (Diptera, Culicidae) in towns in Nigeria. Bull. ent. Res. *56,* 407–415 (1966).

Subra R.: Etudes écologiques sur *Culex pipiens fatigans* Wiedemann, 1828 (Diptera, Culicidae) dans une zone urbaine de savane soudanienne ouest-africaine. Dynamique des populations préimaginales. Cah. ORSTOM, Sér. Ent. Méd. Parasit. *9,* 73–102 (1971).

Subra R.: Etudes écologiques sur *Culex pipiens fatigans* Wiedemann, 1828 (Diptera, Culicidae) dans une zone urbaine de savane soudanienne ouest-africaine. Dynamique des populations imaginales. Cah. ORSTOM, Sér. Ent. Méd. Parasit. *11,* 79–100 (1973).

Subra R.: Urbanisation et filariose de Bancroft en Afrique et à Madagascar. Cah. ORSTOM, Sér. Ent. Méd. Parasit. *13,* 193–203 (1975).

Subra R.: The distribution and frequency of *Culex pipiens quinquefasciatus* Say 1823 (Diptera, Culicidae) breeding places on the Kenya coast in relation to human sociological factors. J. trop. Med. Hyg. *85,* 57–61 (1982).

Subra R., Dransfield R. D.: Field observations on the competitive displacement, at the preimaginal stage, of *C. quinquefasciatus* (Say) by *C. cinereus* (Theobald) (Diptera, Culicidae) (submitted to Bull. ent. Res. a).

Subra R., Dransfield R. D.: Laboratory studies on competition between two mosquitoes, *C. cinereus* Theobald and *C. quinquefasciatus* Say (Diptera, Culicidae) (submitted to Bull. ent. Res. b).

van Seventer H. A.: Anionic detergent and chlorine concentrations in polder ditches in a former malarious area: the island of Walcheren, province of Zeeland, The Netherlands. Environ. Pollut. *1,* 105–117 (1970).