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REPRODUCTIVE STATUS, CATCH AND AGE COMPOSITIONS OF A NATURAL POPULATION OF *GLOSSINA MORSITANS SUBMORSITANS* IN BAHR EL ARAB FLY BELT, SUDAN

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Abstract—Studies were conducted during the dry period February to May 1986 in River Shelliekha, Bahr El Arab fly belt, Sudan, to obtain baseline data on catch and age compositions, reproductive status and trypanosome infection rates of trapped and fly round samples of *Glossina morsitans submorsitans*. The objective was to assess the tsetse situation before the establishment of trypanosomiasis treatment stations at the northern limits of the fly belt. Trapped tsetse included significantly higher proportions of teneral and non-teneral females and a lower male:female ratio. Insemination rates were over 98% in both samples. In any one group, the frequency of pregnancy with egg predominated, followed by the second, first and lastly the third instar larva. There were significant differences between the two groups of females in the proportions of nullipars and pregnancy with any one of the larval instars. Abortion was the predominant reproductive abnormality and no relationship could be found between abortion rate and the sampling method, age or trypanosome infection rate of females. Age compositions were similar in the two samples, save for age categories 0 and 1 for females and two and four for males. Flies were infected with *Trypanosoma vivax* and *T. congolense* only, though *T. brucei* infections could also be diagnosed in livestock.

Key Words: *Glossina morsitans submorsitans*, traps, fly round, insemination, pregnancy, abortion, age, *Trypanosoma vivax, T. congolense, T. brucei*

Résumé—Des études ont été conduites durant la aison séche de Févier à Mai 1986, sur la riviére Shelliekha, dans la ceinture de mouches tsé-tsé de Bahr El Arab au Soudan, en que d'obtenir des données de base sur la capture et la composition en âges, sur la reproductivité et le taux d'infection au trypanosome par les mouches, *Glossina morsitans submorsitans*, capturées par piégeage et par écrans attractifs. L'objectif du travail était d'estimer la population de la mouche tsé-tsé avant d'installer des stations de traitement de trypanosome dans le nord de la ceinture de mouches. Les mouches tsé-tsé capturées comprenaient un nombré élevé de mouches à jeun et de femelles adultes et une faible proportion mâle:femelle. Les taux d'insémination étaint supérieurs à 98% dans les deux types d'echantillonnage. La fréquence de femelles gravides dans les deux groupes était prédominante, suivis par le second, premier et dernier stades larvaires. Il y avait de différences significatives entre les femelles de deux groupes échantillonés en ce qui concerne le nombre d'individus n'ayant pas pondu les oeufs et les femelles gravides, quels que soient les stades larvaires. L'avortement etait l'anomalie de reproduction prédominante, aucun rapport n'a été trouvé entre le taux d'avortement et la technique d'échantillonnage, l'âge ou le taux d'infection au trypanosome par les femelles. La composition en âges etait identique dans les deux échantillons à l'exception de la categorie d'âge 0 et 1 pour les femelles, et deux quatre pour les mâles. Les mouches tsé-tsé étaient essentiellment infestées avec *Trypanosoma vivax* et *T. congolense* bien que l'infection à *T. brucei* a pu être diagnostiquée chez le bétail.

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INTRODUCTION

Six *Glossina* spp. occur in the Sudan including *Glossina morsitans submorsitans, G. fuscipes, G. pallidipes, G. tachiniodes, G. fuscipleuris* and *G. longipennis* (Ford and Katondo, 1977). New information on the distribution of most of these species is generally lacking, although Katondo (1984) had suggested the retreat of *G. f. fuscipes* belt by up to 154 km in Southern Sudan. On the other hand *G. m. submorsitans* in Bahr El Arab of South Darfur Province has maintained its known northern limits (Abdel Razig and Yagi, 1973; Hall et al., 1984).

In South Darfur Province nomadic cattle come in contact with *G. m. submorsitans* and consequently become infected with trypanosomiasis during their annual southerly migration for dry season grazing (November to June) in Bahr El Arab tsetse belt (Hall et al., 1983). By the advent of rains in late June, cattle leave the infested bush to the tsetse-free north for wet season grazing. Since 1982 most of this traditional dry season pasture land of Bahr El Arab has been declared as Random Natural Reserve into which introduction of livestock is prohibited. Alternatively, most nomads have changed their annual migration routes in search of new dry season grazing areas. River Shelliekha at the Eastern border of Random Natural Reserve in Western Bahr El Ghazal province is one of these new available areas (Fig. 1).

Tsetse and trypanosomiasis situation along River Shelliekha as well as in the entire Bahr El Ghazal Region has not been studied before. This study is to obtain baseline data on population and age compositions, reproductive status and trypanosome infection rates of fly round and trapped samples of *G. m. submorsitans*, the only species of tsetse infesting this part of Bahr El Arab fly belt. The study was an integral part of other investigations required for the justification, planning and implementation of bovine trypanosomiasis treatment stations at the northern limits of Bahr El Arab tsetse belt in South Darfur Province (Mohamed-Ahmed et al., 1988).

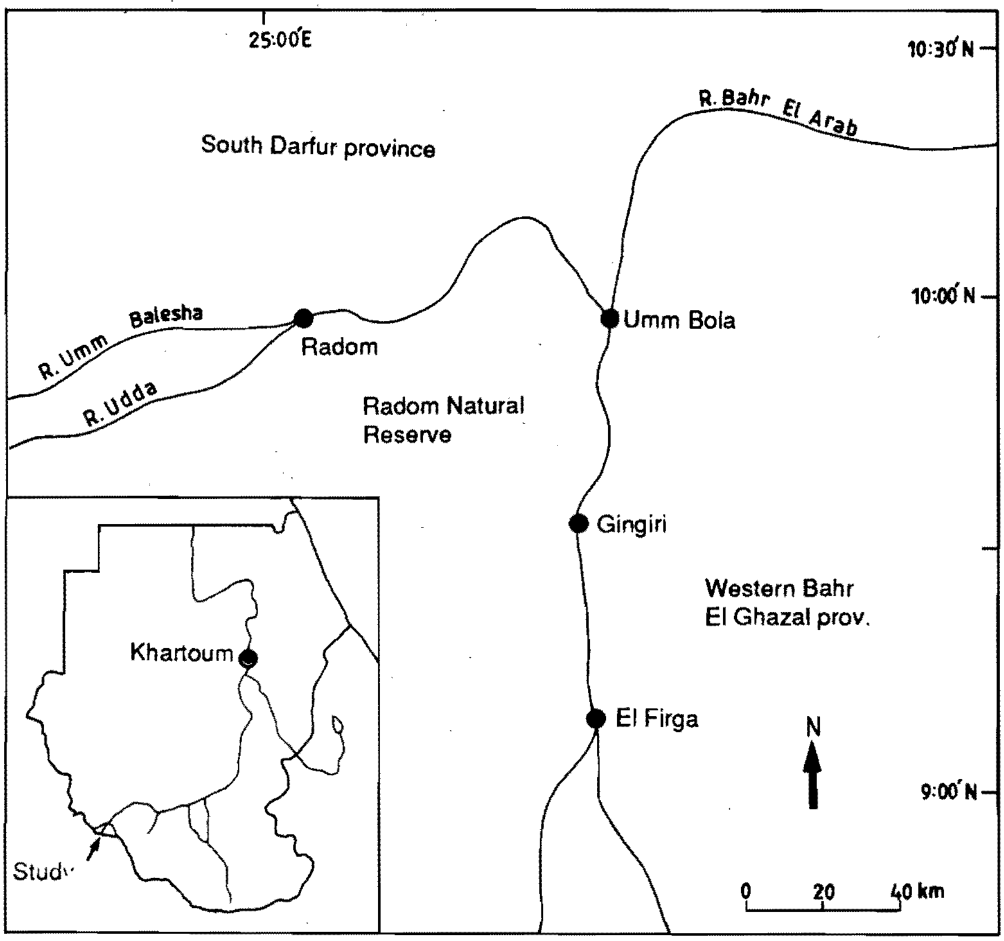

Fig. 1. Study site.

MATERIALS AND METHODS

Study area

The study was conducted at Gingiri base camp on River Shelliekha, during the dry period February to May 1986 (Fig. 1). River Shelliekha is a seasonal water course 100 km long. It originates from El Firga in Western Bahr El Ghazal province to join the main River Bahr El Arab at Umm Bola in South Darfur Province. The river is dry from November to May, save for a few permanent pools. The rainy season starts in June and ends in October with the effective rains from July to September. During the study period, shade maximum temperatures varied between 19–21°C at 0600–0800 hr and 34–38°C at 1500 hr; the corresponding relative humidities were 50–60% and 10–20%.

The vegetative cover is comprised of a deciduous Savannah woodland dominated by *Terminalia* spp., *Anogeissus* spp., *Combretum kordofanum*, *Acacia seyal* and *A. sebriana* together with scattered ever-green trees of *Ficus*, *Tamarindus*, and *Khaya* spp. There is a graduation in vegetative cover, being more dense, green and containing fewer *Acacia* spp. along the river banks.

Host animals as detected from direct sighting, spoors and dung were possibly comprised mainly of warthogs, baboons, cattle, sheep and goats. Reed buck, duiker, oribi, bush buck, hartebeest, eland, lion and hyena were also present.

Capture of tsetse

Flies were captured by fly rounds using a black-blanket screen and by continuous 24 hr trapping, using mainly six biconical traps (Challier and Laveissiere, 1973) together with six locally modified tsetse traps (Abdulkarim et al., in preparation). Traps were installed 150 m apart and baited with acetone (c. 200 mg/hr) throughout. Trapped tsetse were collected at 0900, 1500 and 1830 hr. Morning and evening fly round were conducted as described by Mohamed-Ahmed et al. (1989), but instead of 3000 m, transects of 6000 m perpendicular to the river bed were used. Morning fly rounds were carried out in the area between Gingiri and El Firga, while evening fly rounds and trapping were restricted to the area around the base camp. Trapped flies were pooled irrespective of time of collection, trap type or location as were morning and evening patrol catches.

Dissection

Tsetse caught by any one method were killed with forceps, counted, sexed and examined for tenerality. Males were aged by the wing fray method (Jackson, 1946). Females were aged by the ovarian method (Challier, 1965). During dissection, inseminations, uterine contents, abortions and ovarian abnormalities were recorded. An inseminated female with an empty uterus was designated as aborted irrespective of whether an ovariole contained a mature egg or not.

Probosces, guts and salivary glands of both males and females including tenerals were dissected so that each organ could be examined separately for trypanosome infections. Identification of the species was based on the location of the trypanosomes in the tsetse (Lloyd and Johnson, 1924). A trypanosome infection not found in the hypopharynx was designated as immature. Mixed infections were not accounted for in this study.

RESULTS

The catch compositions of the trapped and fly round samples of *G. m. submorsitans* are shown in Table 1. Trapped flies included significantly higher proportions of teneral and non-teneral females and a lower male/female ratio.

Insemination rates were 99.5 and 98.1% in females caught in traps and during fly rounds, respectively, with no significant difference between the two groups of females ($P > 0.05$). Roughly, 80% of the tenerals were inseminated in any one sample.

The proportions of nullipars and those at the various pregnancy stages of each group of females are shown in Fig. 2 a,b. The frequency of pregnancy with egg dominated in each sample, followed by the second, first and lastly the third instar larva. The trapped flies, however, included a significantly lower proportion of nullipars ($\chi^2 = 54.0$, d.f. = 1, $P < 0.001$) and higher proportions of females pregnant with the first instar ($\chi^2 = 4.8$, d.f. = 1, $P < 0.05$), second instar

Table 1. Catch compositions of screen and trapped samples of *G. m. morsitans* in River Shelliekha, Bahr El Arab fly belt, Sudan

Sample components	Traps	Fly round	χ^2 (d.f. = 1)
Total caught	1789	1034	–
Teneral males	53	36	0.5*
Non-teneral males	931	806	184.4***
Teneral females	18	9	4.3**
Non-teneral females	787	183	199.0***
Total tenerality (males + females)	71	45	0.3*
Sex ratio male:female	1.1:1	4.4:1	198.5***

*$P > 0.05$.
**$P < 0.05$.
***$P < 0.001$.

($\chi^2 = 4.8$, d.f. $=1$, $P < 0.05$) and the third instar larva ($\chi^2 = 9.6$, d.f. $= 1$, $P < .01$).

The abortion rates were 4.4 and 4.6% with no significant difference between the two groups of females (Fig. 2a, b, $\chi^2 = 0.1$, d.f. $= 1$, $P > 0.05$). In the combined data, there were also no significant differences in abortion rates between females in the different age groups from 1 to 7+ or between young females at age category 1 to 3 and older ones at 4+ to 7+ (Table 2). Linear regression of abortion rate at each age category (y) on their respective age category (x) revealed no significant correlation between abortion rate and age of flies ($y = 4.47 + 0.01x$, d.f. = 12, $P > 0.1$). Moreover, none of the females which had aborted was found infected with trypanosomes, probably, suggesting the absence of any link between a trypanosome infection and pregnancy in *G. m. submorsitans*. Five more females (0.7% of the pooled data) displayed reproductive abnormalities other than abortion: two apparently uninseminated females, one in age category 1 and the other at 5+, one female with degenerated left ovary, one female in age category 5+ with two serial relics in ovariole B and an inseminated female with empty uterus and four apparently mature eggs retained in the ovaries.

The age compositions of females caught in traps and by fly round are shown in Fig. 3 a,b. Overall, there was a significant difference between the two age compositions ($\chi^2 = 47.8$, d.f. $= 6$, $P < 0.001$).

Table 2. Effect of female age on abortion rate (%) of *G. m. submorsitans* in River Shelliekha, Bahr El Arab fly belt, Sudan (a.c. = age category)

Age category	1	2	3	4+	5+	6+	7+	Total
No. examined	114	104	99	156	124	89	52	738
No. aborted	5	3	6	6	9	3	2	34
Abortion rate	4.4	2.9	6.1	3.8	7.2	3.4	3.8	4.6
χ^2-test (d.f. = 1)	0.1	1.2	0.3	2.3	1.2	0.4		–
Abortion rate:								
Young: a.c. 1–3			4.4					
Old: a.c. 4+–7+							4.7	
χ^2-test Young/old (d.f. = 1)					= 0.14			

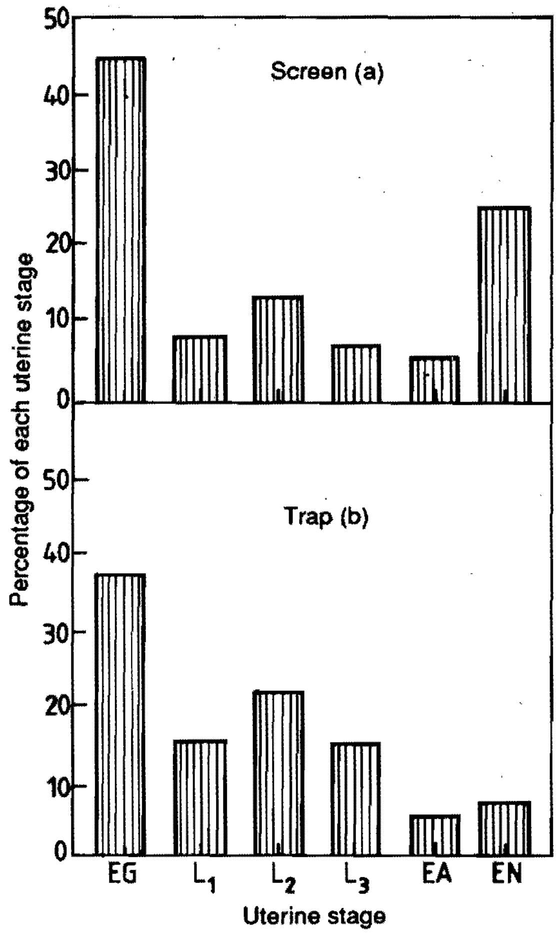

Fig. 2. Uterine stages of screen and trapped samples of *G. m. submorsitans* in River Shelliekha, Bahr El Arab fly belt, Sudan. E—egg, L1—first larva, L2—second larva, L3—third larva, EN—nullipars, EA—abortion.

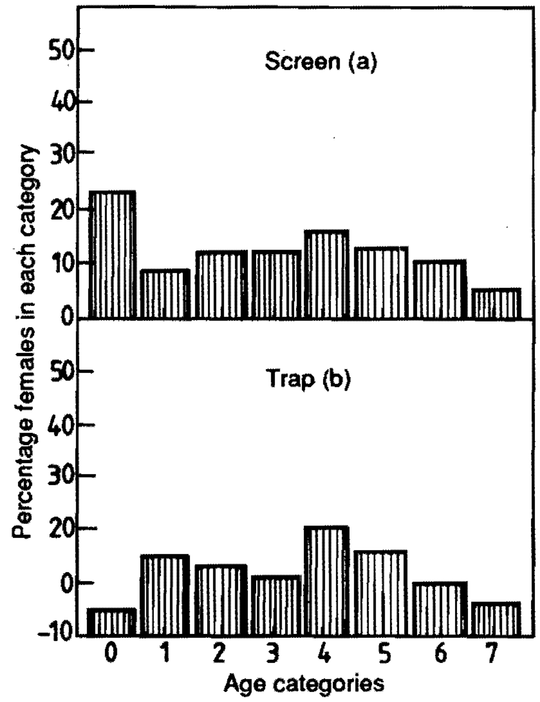

Fig. 3. Age compositions of screen and trapped samples of *G. m. submorsitans* in River Shelliekha, Bahr El Arab fly belt, Sudan.

Table 3. Age compositions of screen and trapped samples of male *G. m. submorsitans* in River Shelliekha, Bahr El Arab fly belt, Sudan

Wing fray category	Traps	Fly round	χ^2-test (d. f. = 1)
1	172	122	3.3
2	363	255	8.4**
3	261	258	3.7
4	138	156	6.9**
5	74	77	1.7
6	7	11	2.3
Total	1015	872	

**$P < 0.01$.

However, apart from young females in age category 0 ($\chi^2 = 49.2$, d.f. = 1, $P < 0.001$) and category 1 ($\chi^2 = 4.1$, d.f. =1, $P < 0.05$), there were no significant differences between the samples of females in any one age group from 2 to 7+ ($P > 0.05$), although there was a noticeable increase of females at 4+ in both samples (Fig. 3 a, b).

Table 3 shows the age compositions of the two samples of males. Overall, there was a significant difference between the two age structures ($\chi^2 = 19.7$, d.f. = 5, $P < 0.001$). Also relatively young males (1 to 3 wing fray groups) comprised over 70% of either sample of flies. Further comparisons between males in each wing fray category showed significant differences between the fly round and traps, in the proportions of males in categories 2 ($\chi^2 = 8.4$, d.f. = 1, $P < 0.01$) and 4 ($\chi^2 = 6.7$, d.f. = 0.1, $P < 0.01$).

Table 4. Trypanosome infection rates of screen and trapped samples of *G. m. submorsitans* in River Shelliekha ,Bahr El Arab fly belt

Sampling method	No. examined	No. infected	Infection rate %	*T. vivax* M	*T. vivax* IM	*T. congolense* M	*T. congolense* IM
Traps	1789	43	2.3	17	4	16	6
Fly round	1034	14	1.4	6	2	4	2
Total	2823	57	2.0	23	6	19	8

M = mature infection.
IM = immature infection.

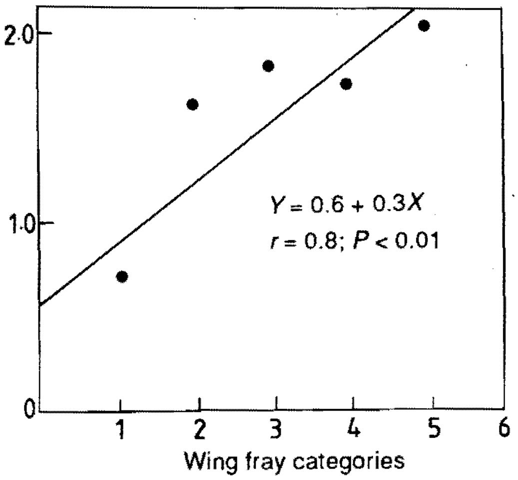

Fig. 4. Relationship between physiological age and trypanosome infection rate of male *G. m. submorsitans* in River Shelliekha, Bahr El Arab fly belt, Sudan.

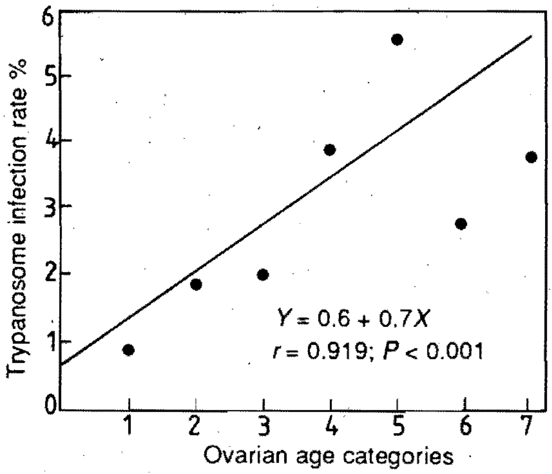

Fig. 5. Relationship between ovarian age and trypanosome infection rate of female *G. m. submorsitans* in River Shelliekha, Bahr El Arab fly belt, Sudan.

The pooled trypanosome infection rate of *G. m. submorsitans* was 2.0% (Table 4) of which 0.5% were immature trypanosome infections. Trapped flies (males + females) had a higher, but not a significantly different trypanosome infection rate than flies caught off the screen ($\chi^2 = 3.1$, d.f. = 1, $P > 0.05$). Females in any one sample had higher trypanosome infection rates than males, although the differences were also not statistically significant ($P > 0.05$). However, trypanosome infections were observed to increase linearly with the physiological age of males (Fig. 4) and females (Fig. 5). Males and females were infected with only the *vivax* and *congolense* trypanosomes (Table 4). The *vivax*/*congolense* ratios were 1:1 and 1.3:1 in traps and screen, respectively. There were 14.3% immature *vivax* and 28.6% immature *congolense* infections in trapped flies, whereas the corresponding figures for the screen were 25.0 and 33.3%. It was thus obvious that a higher *vivax* ratio and fewer mature trypanosome infections were discovered in tsetse sampled by the fly rounds compared with traps.

DISCUSSION

Screen fly rounds were used in conjunction with traps to sample *G. m. submorsitans*, for the first time, along River Shelliekha, Western Bahr El Ghazal Province, Bahr El Arab fly belt, Sudan. As traps have rarely been used previously in Bahr El Arab (Hall et al., 1984; Mohammed-Ahmed et al., 1989), patrols with the screen were useful for comparative purposes as well as the detailed information on terrain, vegetation, and host animals. Fly rounds are also more attractive to teneral tsetse than traps (Buxton, 1955) thus indicating local concentrations of breeding sites of tsetse within the fly belt. On the other hand, traps are superior to fly rounds because they operate around the clock unattended; and their efficiency can further be enhanced by odour baits (Dransfield et al., 1986).

Most trapped flies in the present work came from the biconical trap (Challier and Laveissiere, 1973). Although the latter trap was originally designed for riverine tsetse (*palpalis* group), satisfactory numbers of *G. m. submorsitans* (up to 60 flies/trap/day) were caught (Abdulkarim et al., in preparation). This result contradicts Takken (1985) and Snow (1977), who conclude that the blue biconical trap is unsuitable for *G. m. morsitans* and *G. m. submorsitans*, respectively. The result, however, agrees with Hargrove (1977) and Vale (1980) who noted significant increase in catches of *G. m. morsitans* and *G. pallidipes* in odour-baited biconical traps in Zimbabwe.

Different sampling methods produce catches of tsetse which differ in numbers, physiology and trypanosome infections (Jordan, 1974; Randolph and Rogers, 1981; Mohamed-Ahmed et al., 1989). Nevertheless, in the present work there was a slight but insignificant difference between the proportions of inseminated females caught in traps and fly rounds. Moreover, the high insemination rates recorded in both samples of flies reflected a healthy population of *G. m. submorsitans* in River Shelliekha which guaranteed high male/female encounters to ensure insemination of virtually all non-teneral females. The finding that up to 80% of tenerals were inseminated suggests that female *G. m. submorsitans* in Bahr El Arab, mates successfully within 24 hr of eclosion, even before obtaining their first blood meal. The insemination rates recorded for females in the present study are higher than those reported for *G. m. morsitans* (Okiwelu, 1977) and *G. m. centralis* (Ryan and Molyneux, 1982).

Significant differences existed between the two samples of *G. m. submorsitans* in the proportions of nullipars and pregnancy with any one of the three larval instars (Fig. 2 a, b). Although generally the frequency of encounter of pregnancy stages in a sample of tsetse occurs in the order of egg, first, second and the third instar larva (Saunders, 1962; Randolph and Rogers, 1981; Mohamed-Ahmed and Dairri, 1987), in the present work higher proportions of females pregnant with the second than the first or third larval instars were found in any one sample of flies. To explain this unusual sequence the 9-day reproductive cycle of tsetse is partitioned according to the duration of each pregnancy stage in the uterus (Denlinger and Ma, 1974). Thus, the egg in *G. m. submorsitans* will occupy 3.5 days, the first larva 1 day, the second larva 2.5 days and the third larva 2 days. Assuming that the availability to capture of a fly pregnant with a particular stage is proportional to the duration of that stage, the probability of encountering each instar will therefore become 0.339, 0.278, 0.222 and 0.111 for the egg, second, third and the first instar larva, respectively. Accordingly, flies pregnant with the second stage larva appear to have a higher probability of capture than those with other larval stages. Further support to the above argument comes from mark-release-recapture experiments (Turner, 1987). The latter author showed that the activity of pregnant *G. pallidipes* peaks; and hence becomes available to capture just after larviposition, before the moult of the second to the third instar larva and then at a variable time during the cycle. On the other hand, the preponderance of flies pregnant with the first instar larva over those with the third, despite the higher capture probability of the latter, can be explained by the fact that late pregnant females do not feed (Denlinger and Ma, 1974) and remain relatively inactive until larviposition and hence become unavailable to capture methods in the field (Rogers, 1978).

There was a negligible difference between the proportions of aborting female *G. m. submorsitans* caught in traps and fly round in River Shelliekha. However, the abortion rates noted for both groups of flies are within the range observed for *G. m. centralis* and *G. m. morsitans* in Zambia (Okiwelu, 1977; Ryan and Molyneux, 1982) and *G. pallidipes* in Kenya (Turner and Snow, 1984). The fact that there was no significant heterogeneity in abortion rate between young and old females (Table 2), disagrees with Glasgow (1963) who suggested that abortion in tsetse increases with age. The result also varies from that of *G. pallidipes* which has higher frequency of abortion during the first cycle, presumably resulting from failure to fertilize the first egg (Langley and Hall, 1984).

In a natural population of tsetse, reproductive abnormalities other than abortion are rare (Saunders, 1962; Madubunyi, 1978; Turner and Snow, 1984). The type and frequency of ovarian abnormalities noted in the present study (pooled data) are close to those recorded for *G. morsitans* subspecies in Zambia (Okiwelu, 1977; Ryan and Molyneux, 1982) and for *G. pallidipes* in Kenya (Turner and Snow, 1984). However, since control measures have never been employed against tsetse in Bahr El Arab fly belt, the abortions and reproductive abnormalities described above, are probably the main causes of natural reproductive loss in the population of *G. m. submorsitans* in the area.

Overall, age compositions of males and females differed considerably between the trapped and fly round samples of *G. m. submorsitans* (Fig. 3 a, b; Table 3); a finding which agrees with studies on other *Glossina* spp. elsewhere in Africa (Saunders, 1962; Harley, 1967 a, b; Mohammed-Ahmed et al., 1989). However, in the present study the proportions of females in age category 4+ dominated over older categories in both groups of flies (Fig. 3 a,b). In tsetse it is possible to age females accurately by the ovarian method (Challier, 1965) up to age group 3 (4th reproductive cycle). The remaining flies are composite groups from which it is almost impossible to tell whether an individual is in age category 4 (5th reproductive cycle) or 4+ (= 9th...13th...etc cycles). The same is applicable for females at age category 5 or 5+, 6 or 6+ and 7 or 7+. Assuming a similar sampling bias for females at 4+ to 7+ categories, it appears that relatively fewer females of *G. m. submorsitans* in River Shelliekha survive after reaching 4+ (probably the 9th reproductive cycle) age group. Had they lived longer, females in age categories 5+, 6+ and 7+ would have been represented equally to flies in 4+. One reason for the lower survival rate of such older females might have been the excessive wing fray resulting, presumably, from organic degradation of wings with age. Allsop (1985) observed that old female *G. m. centralis* in Botswana had higher degree of wing fray which limited their survival opportunities. Excessive wing fray in tsetse and its limitation on its longevity, perhaps, explains why young males (1–3 wing fray groups) comprised over 70% of either sample of *G. m. submorsitans* (Table 3).

According to Jordan (1974), the trypanosome infection rate in a population of tsetse may vary with sex, age and the sampling method. Although in the present study the infection rates were higher in trapped flies and females in any one sample, in both, the differences were not statistically significant ($P > 0.05$). However, the increase in infection rate of males and females with age (Figs 4 and 5) is consistent with Harley (1967 a, b) who found that different samples from the same *G. pallidipes* population included the highest proportion of infected flies when they had been caught in traps. Harley (1967 a, b) attributed this variation partly to the older trap samples.

On the other hand, the overall trypanosome infection rate (2.0%, Table 4) is much lower than what was previously recorded for *G. m. submorsitans* in the area (Hall et al., 1984; Mohammed-Ahmed et al., 1989). This disagreement can, probably, be explained by the fact that all past studies were conducted inside the Random Natural Reserve which harbours an abundant game population, probably, including better natural reservoirs of trypanosomes among the preferred hosts of tsetse. Thus, possibly, resulting in higher infections of flies. The absence of *T. brucei* infections in flies (Table 4) might have been real or a dissection artefact, due to the failure of the method of Lloyd and Johnson (1924) in detection of all *brucei* group infections. It has already been shown by Otieno (1983) that the latter method underestimates *T. brucei* infections in tsetse. This is, probably, true, because two cows and one donkey in the study area, and which must have been fed upon by tsetse, were found infected with *T. brucei* (Mohamed-Ahmed et al., 1988).

The data presented above show that adequate samples of *G. m. submorsitans* in Bahr El Arab, Sudan can be obtained by traps or fly rounds. Evidence from reproductive, ageing and parasitological data, using either method, reflects a healthy tsetse population which can maintain itself and, presumably, impose a high trypanosomiasis challenge to nomadic cattle in the area during their annual dry season grazing (November to June). Since tsetse control in Bahr El Arab is not feasible in the near future (Hall et al., 1984), chemotherapy and chemoprophylaxis appear to be the only sound approach for the control of trypanosomiasis in the area. The proposed trypanosomiasis treatment stations along the northern tsetse limits in South Darfur (Mohamed-Ahmed et al., 1988) are therefore expected to provide an essential treatment service for stock owners inside the tsetse belt and again when herds are leaving for the tsetse-free wet season grazing land at the beginning of rains in early June. The latter is given as a sanitary treatment to halt the spread of the trypanosomiasis by mechanical vectors further north.

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