relative humidities might inhibit activity at this time.

Despite the fact that we have no replication, we have some evidence to suggest that G. pallidipes is moving between the inner woodland and its edge. We proceed in the next chapter to describe the activity of the flies that leads to such movement.

CHAPTER 10

ASSOCIATIONS BETWEEN CLIMATIC FACTORS AND ACTIVITY PATTERNS

10.1 INTRODUCTION

Laboratory studies have shown that climatic factors influence the activity pattern of tsetse flies (Barrass, 1970a, 1970b; Brady and Crump, 1978). For example, tsetse are positively phototactic below about 30°C (Popham and Vickers, 1979) and negatively phototactic above 30°C. Gruvel (1975) has observed that G. tachinoides activity decreased above 30.5°C. A model I regression has been used to relate activity to climatic factors but this method has often been used incorrectly. This method does not apply to cases where the errors are in both X and Y variables (Sokal and Rohlf, 1981). In the experiments discussed in this chapter we examine changes in fly activity in relation to climatic variables over several 24 hour periods using model II regressions where the relationship appeared linear.

10.2 MATERIALS AND METHODS

In Experiment A, hourly trap catches of G. pallidipes and G. longipennis were carried out in a

Nguruman thicket about 300m southwest of the release site RS2 (Figure 4.1) on July 30 and 31, September 6 and 7 and for one day on November 4, 1989. Two Nguruman traps, F4 and F5, baited with cow urine and acetone were used to catch the flies. The two traps were spaced about 100m apart. Climatic variables were monitored hourly using a Delta-T weather station at a camp about 5.5 km from the two traps. The relative humidity, air temperature, wind speed and rainfall were recorded on each experimental day. In addition, radiation was also monitored on November 4, 1989.

Experiment B was carried out at the release site RS4 (Figure 4.1) after considering that trap catches may be dependent on climatic conditions prevailing near a trap. A Nguruman trap baited with acetone, octenol and cow urine was used to monitor the activity of G. pallidipes in the morning and afternoon. An automated Delta-T weather station set at 5m away from the trap was used to monitor relative humidity, air temperature, wind speed and radiation every 10 minutes. The monitoring periods were 8:00 to 12:00 and 12:00 to 16:00 hours daily from January 8 to 11, 1990.

Catch numbers were transformed to the logarithm to base 10 as usual, and an alternative way of depicting the same data was to use the percentage of the total catch recorded in each hourly interval. The method of principal axes for model II regression analysis (Sokal and Rohlf, 1981) was used to describe linear functional relations between log-transformed trap catch numbers and climatic variables. Non-linear curves were fitted by eye and drawn in by free hand. Partial correlation coefficient analysis between climatic variables was done on data collected between November 1989 and August 1990. Daily mean weather readings for wind speed, air temperature, relative humidity and radiation were recorded.

10.3 RESULTS

Experiment A

The prevailing weather conditions during Experiment A are shown in Figures 10.1a,b,c,d. The hourly temperature readings were not statistically different between July 30 and 31 ($p>0.05$) nor for September 6 and 7 ($0.05<p<0.10$). Therefore, mean temperatures between days for each hour in each month were computed and plotted against time as shown in Figure 10.1a. Mean relative humidities were computed for September 6 and 7, because they did not differ

FIGURE 10.1a

Prevailing air temperatures during Experiment A

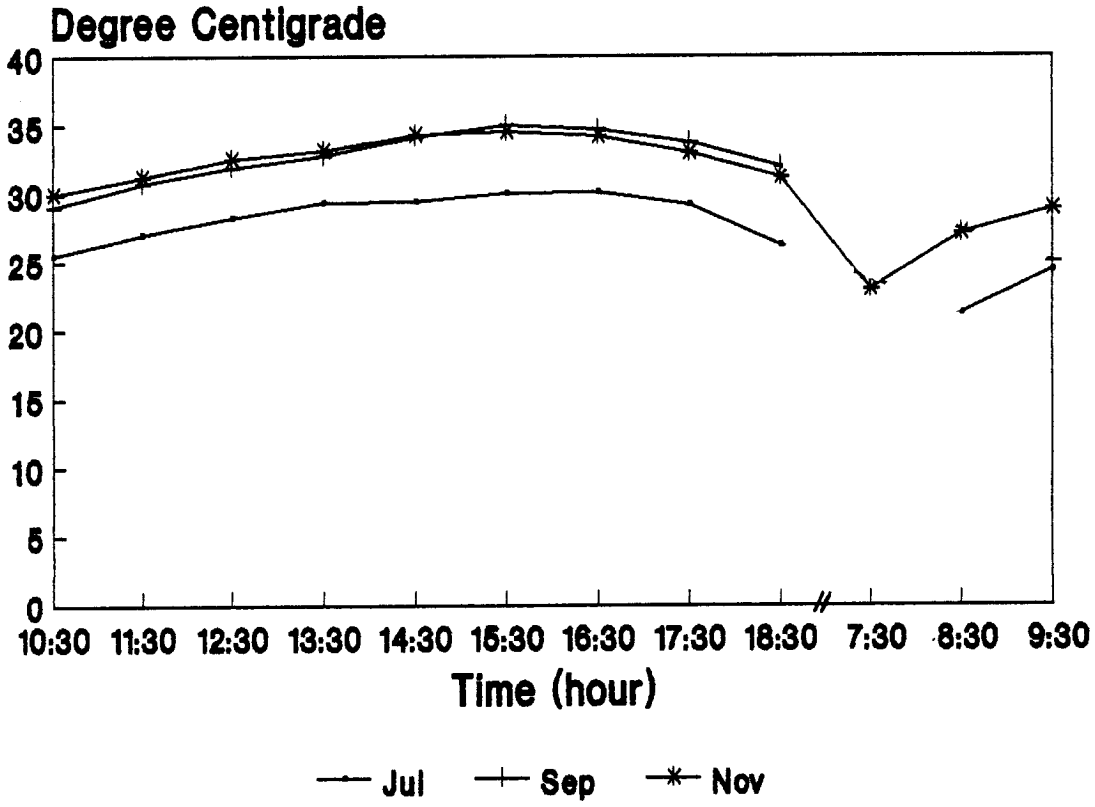


FIGURE 10.1b

Prevailing relative humidities during Experiment A

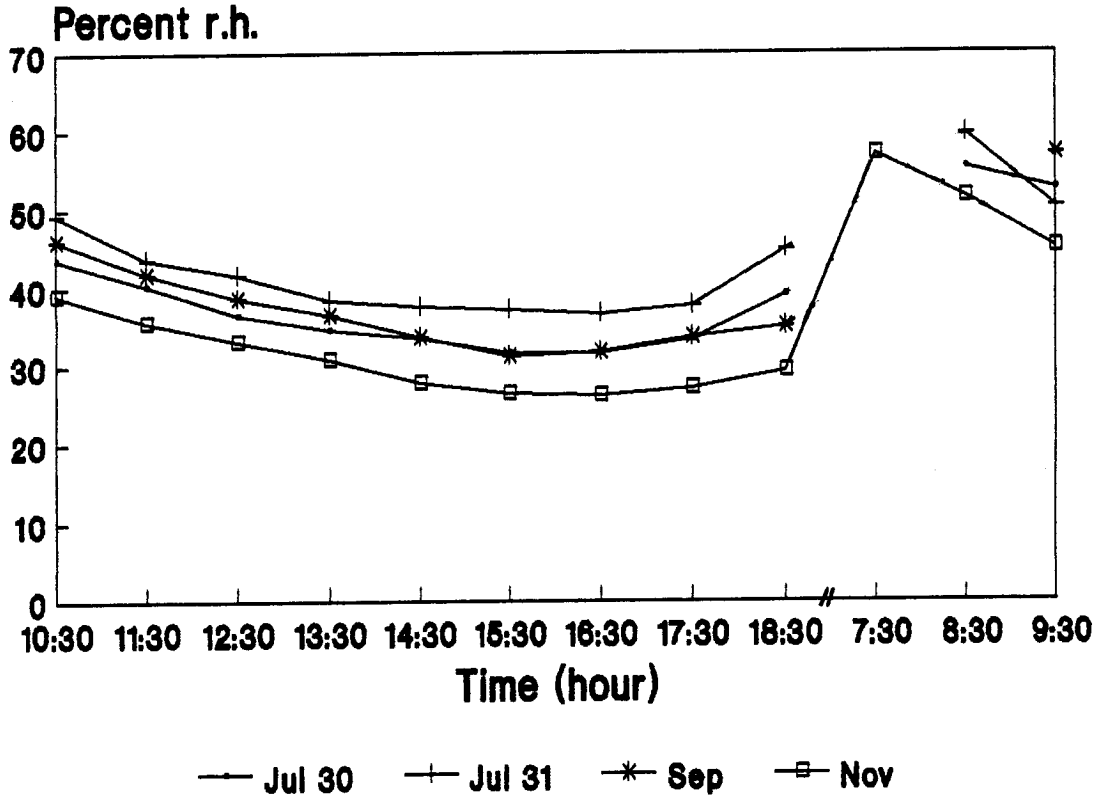


FIGURE 10.1c

Prevailing wind speeds during Experiment A

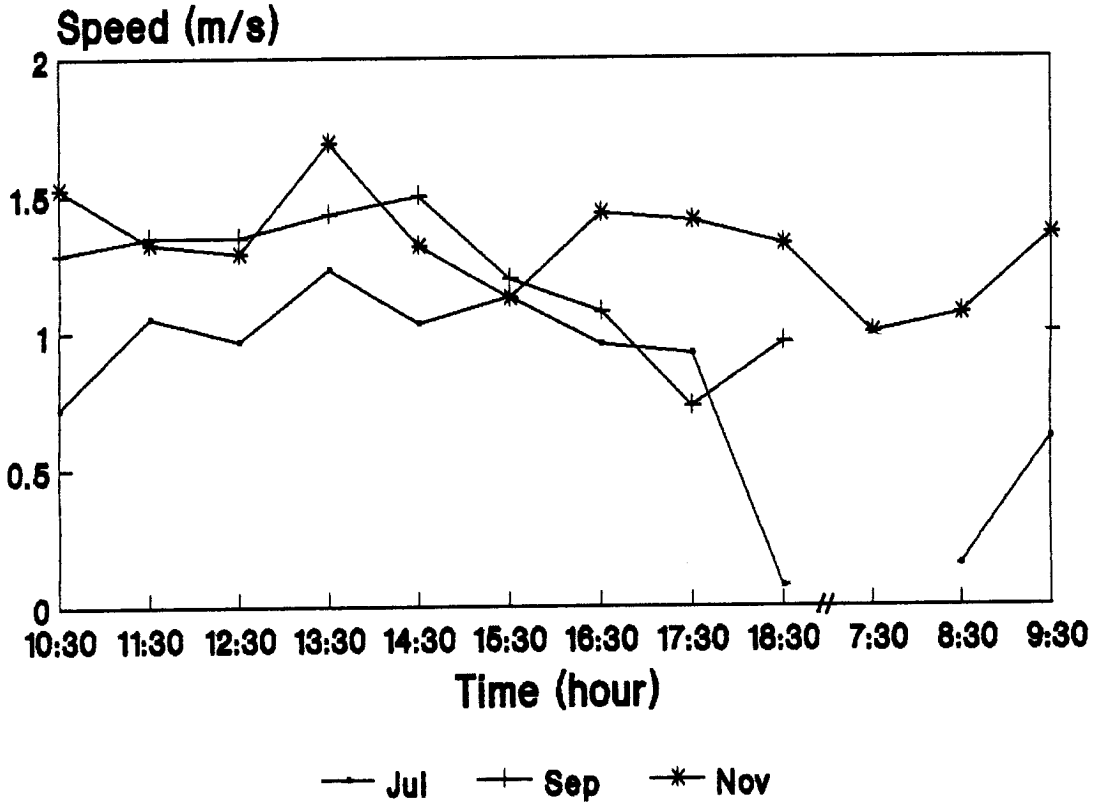
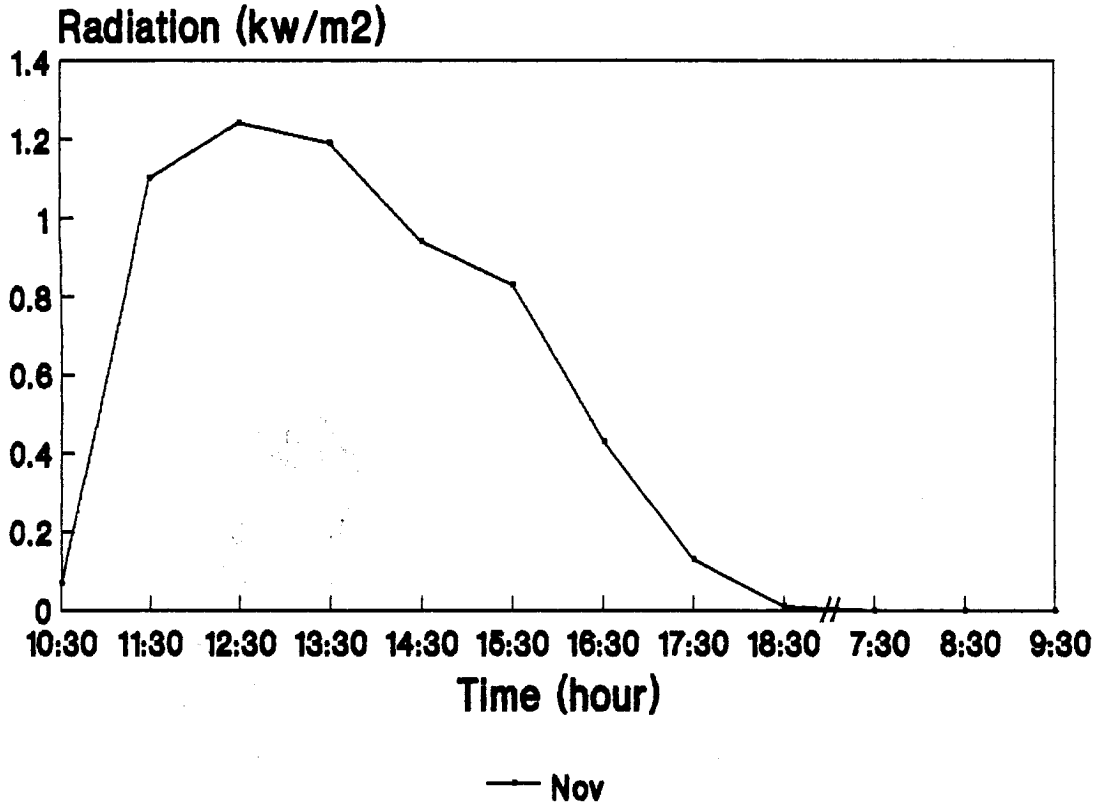


FIGURE 10.1d

Prevailing solar radiations during Experiment A



statistically ($p>0.05$); but relative humidity readings for July 30 and 31 were statistically significant ($p<0.001$). Figure 10.1b shows the changes in the relative humidities during the experiment. No statistically significant differences were observed of mean wind speeds between July 30 and 31 ($p>0.05$) nor for September 6 and 7 ($p>0.05$). Therefore, mean wind speeds were computed for each hour in each month and plotted against time as shown in Figure 10.1c.

The highest hourly temperature reading of about $35^{o}C$ was recorded at 15:30h on September 6 and 7, and the least recorded hourly temperature reading of about $21^{o}C$ was at 8:30h on July 30 and 31, 1989. The period was almost completely dry with only traces of rainfall of about 0.2 mm on November 4 and September 6. Hourly minimum relative humidity of about 20% r.h. was recorded on November 4. Hourly wind speeds were always less than 1.7 m/s, while hourly solar radiation was less than 1.3 kW/m^2 (Figure 10.1d).

In the mornings of September 6 and 7, Trap F4 was in the shade while Trap F5 was in the sun, and vice versa in the afternoon.

Hourly trap catches of G. longipennis may not have reflected clearly its normal activity pattern. The baits used are not effective for this species of Glossina (Kyorku, 1989), and the vegetation in which the experiments were conducted is not the preferred one for G. longipennis (see Chapter 9). No G. longipennis were trapped between 9:30 and 18:30h but an average of 4 male and 6 female G. longipennis was trapped per day between 18:00 and 9:00h throughout the sampling period. This evidence accords with Kyorku's (1989) finding that G. longipennis are only active for one hour in the morning and one hour in the evening. Enough trap data was available only for G. pallidipes' analysis.

JULY

Hourly catches of G. pallidipes show that the number of females trapped was almost always greater than the number of males trapped (Figures 10.2a,b and 10.4a,b). The daily activity pattern varied between sampling sites and days (Figures 10.3a,b and 10.5a,b) with the peak of the activity of female G. pallidipes either occurring at the same time or before that of males. The activity patterns were unimodal on July 30 and 31, 1989, probably due to moderate temperatures, falling as low as 21^{o}C between 18:30

FIGURE 10.2a

Hourly catch of G.pallidipes on July 30, 1989 at F4 position

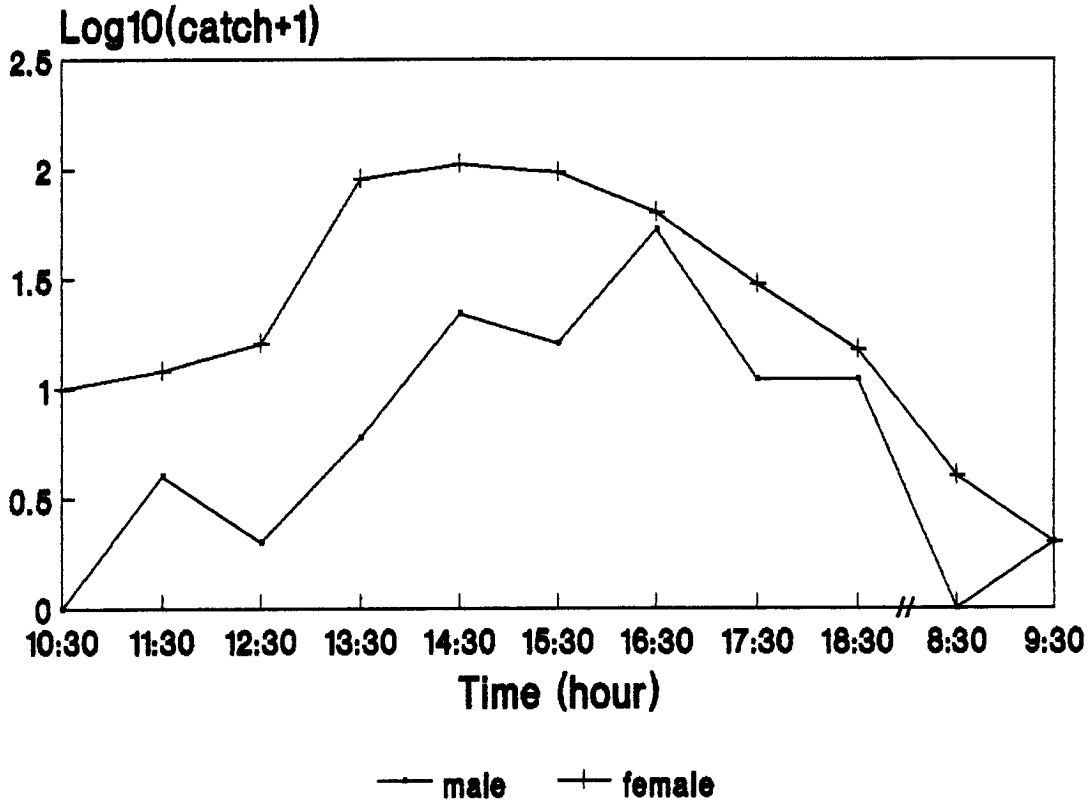


FIGURE 10.2b

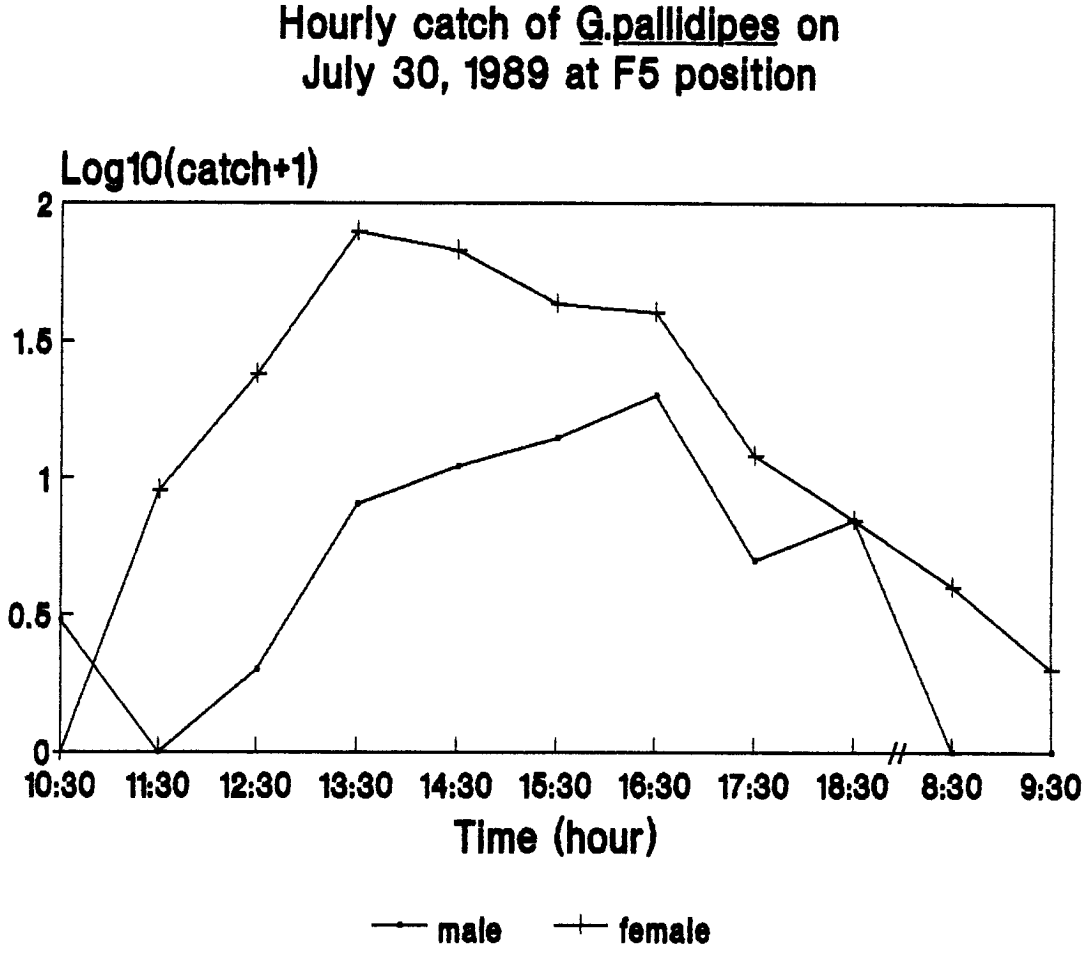

Hourly catch of G.pallidipes on
July 30, 1989 at F5 position
Log10(catch+1)
2
1.5
1
0.5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
8:30
9:30
Time (hour)
male
female

FIGURE 10.3a

Percent hourly catch of G.pallidipes on July 30, 1989 at F4 position

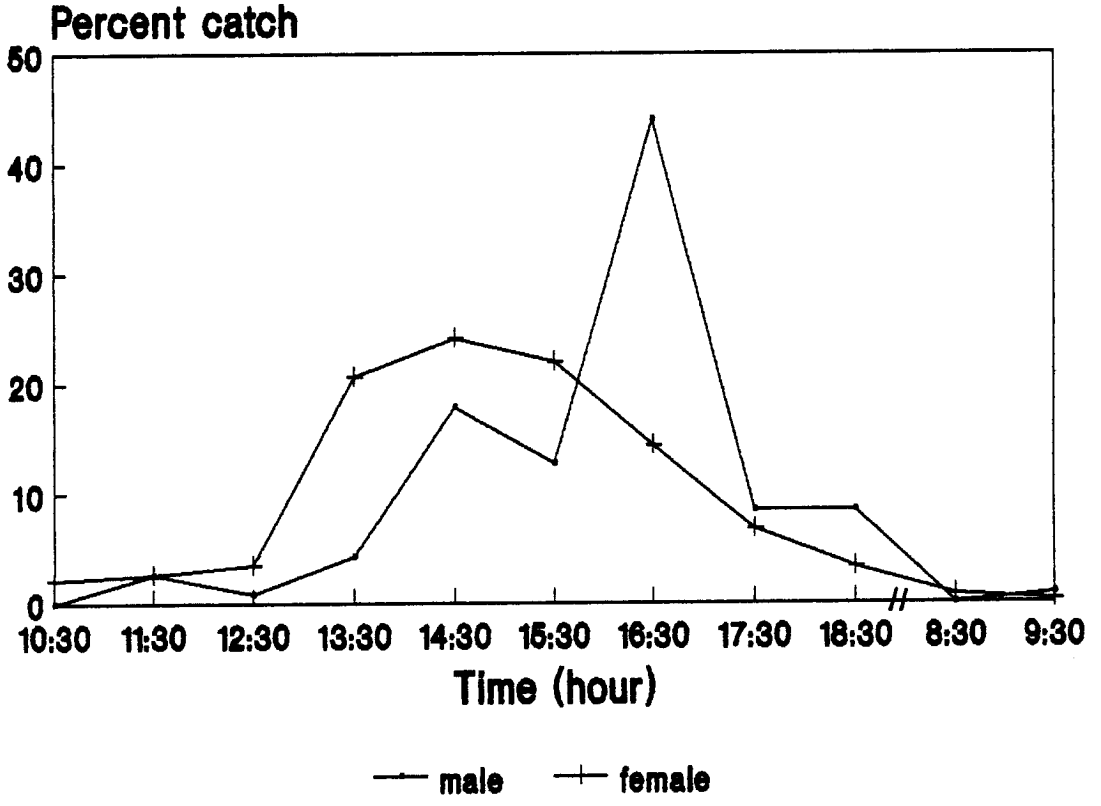


FIGURE 10.3b

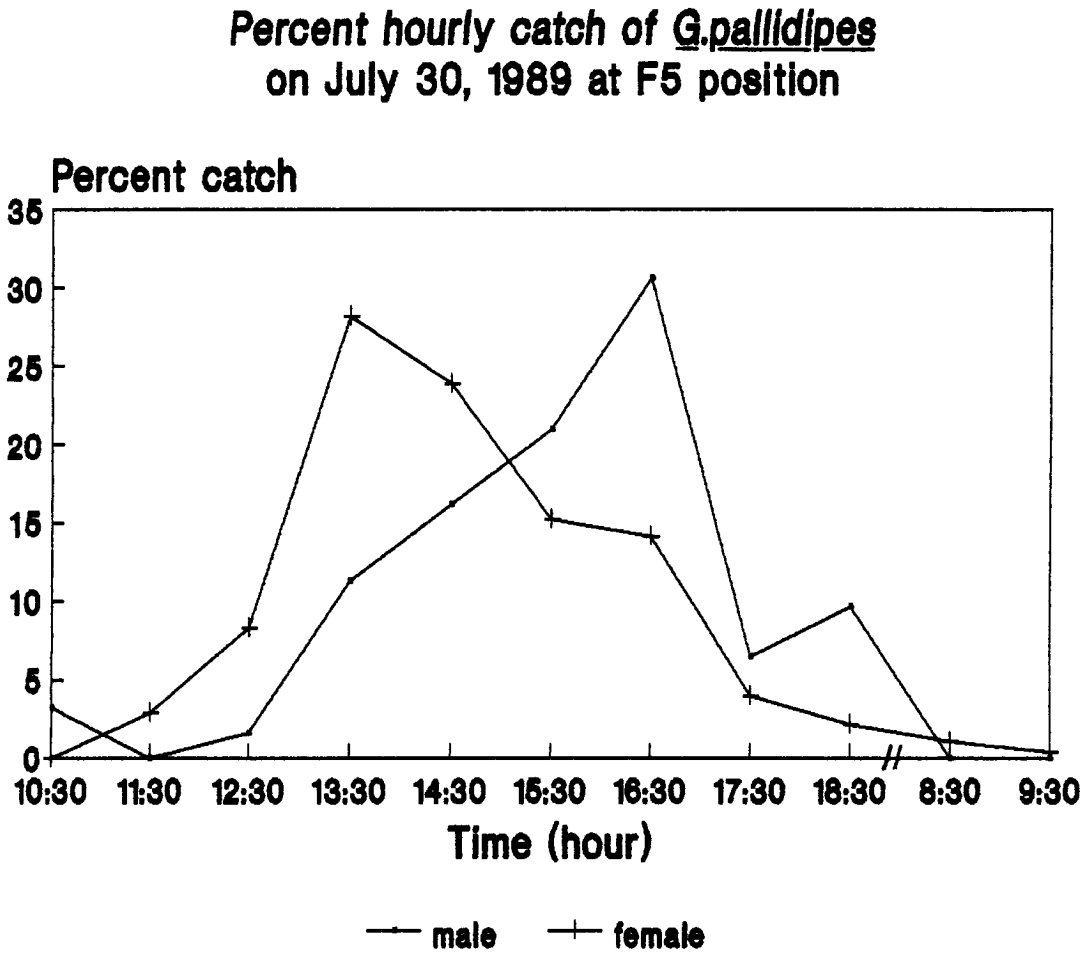

Percent hourly catch of G.pallidipes
on July 30, 1989 at F5 position
Percent catch
35
30
25
20
15
10
5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
8:30
9:30
Time (hour)
male
female

FIGURE 10.4a

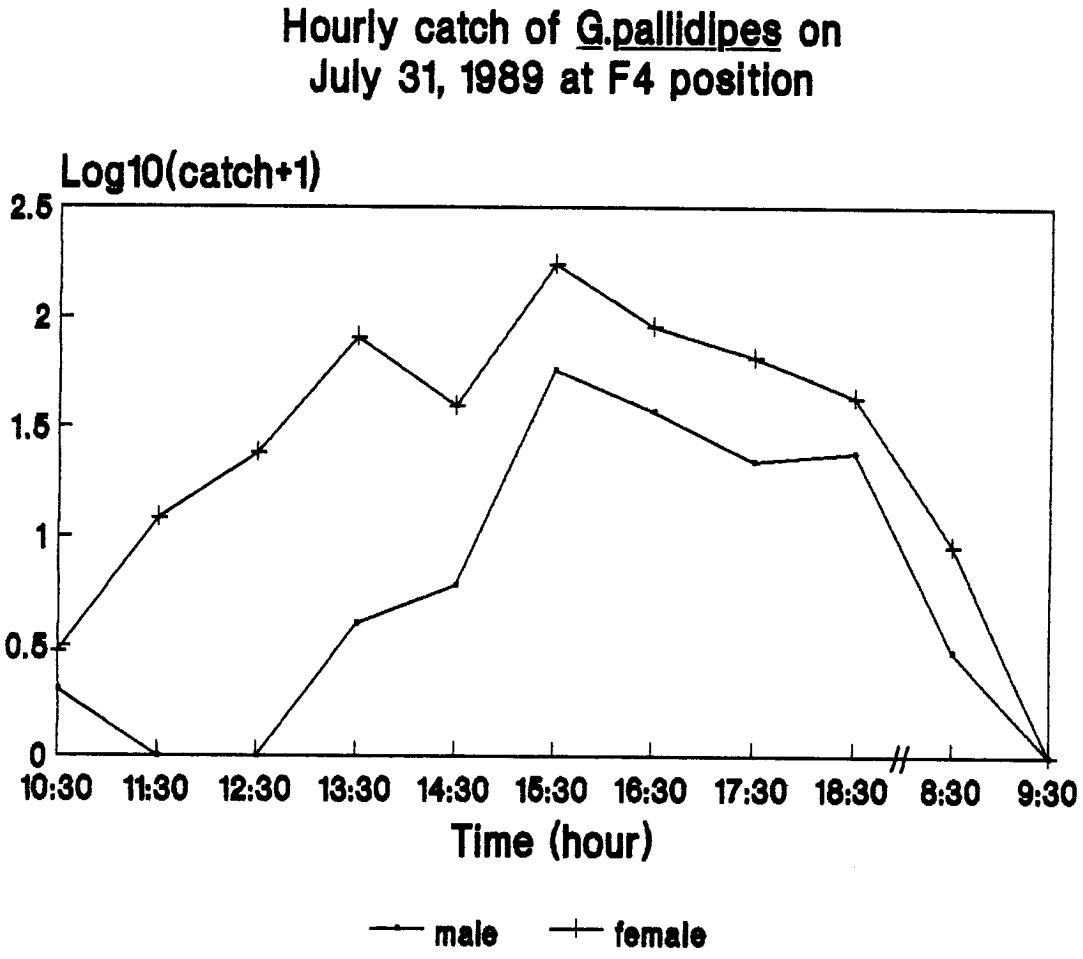

Hourly catch of G.pallidipes on
July 31, 1989 at F4 position
Log10(catch+1)
2.5
2
1.5
1
0.5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
8:30
9:30
Time (hour)
male
female

FIGURE 10.4b

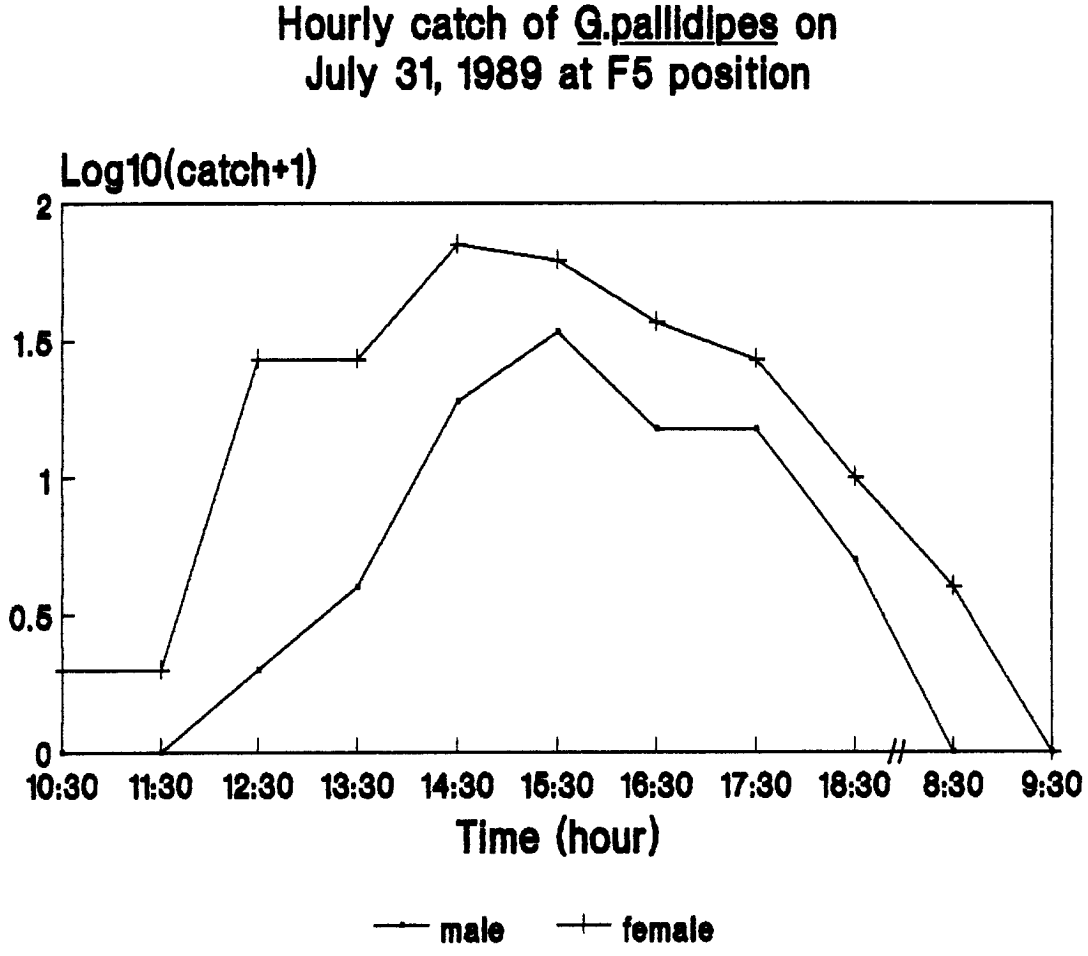

Hourly catch of G.pallidipes on
July 31, 1989 at F5 position
Log10(catch+1)
2
1.5
1
0.5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
8:30
9:30
Time (hour)
male
female

FIGURE 10.5a

Percent hourly catch of G.pallidipes on July 31, 1989 at F4 position

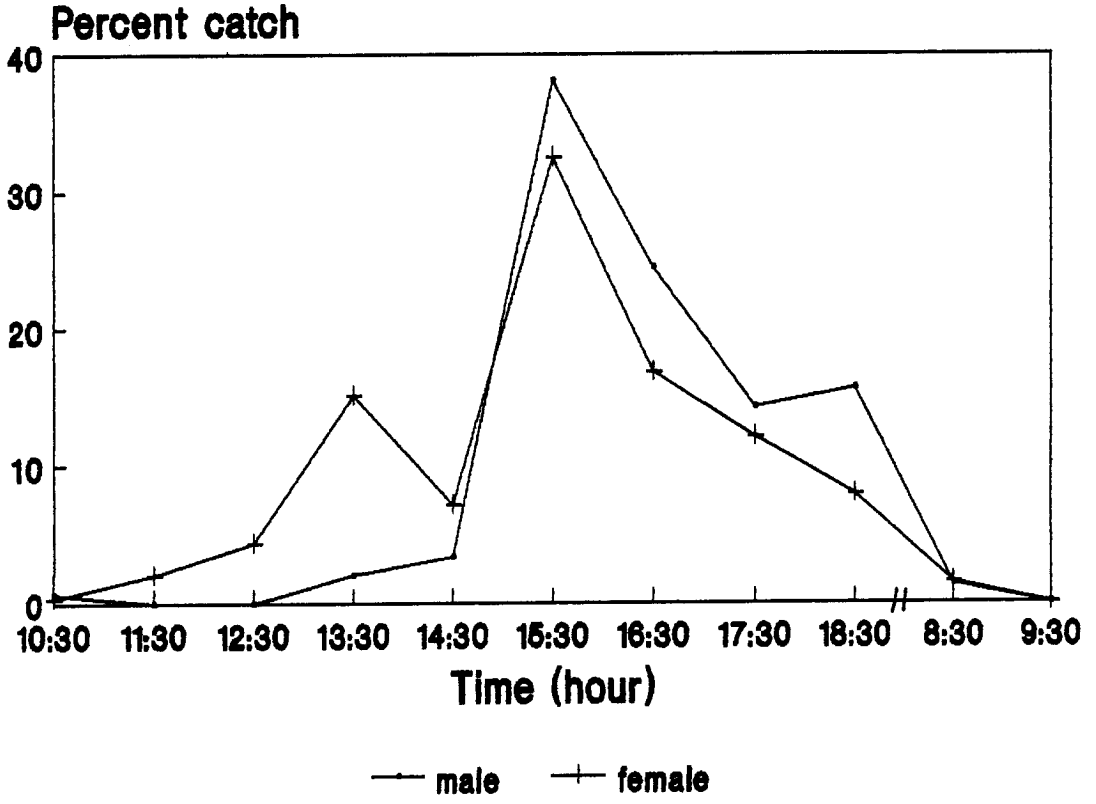
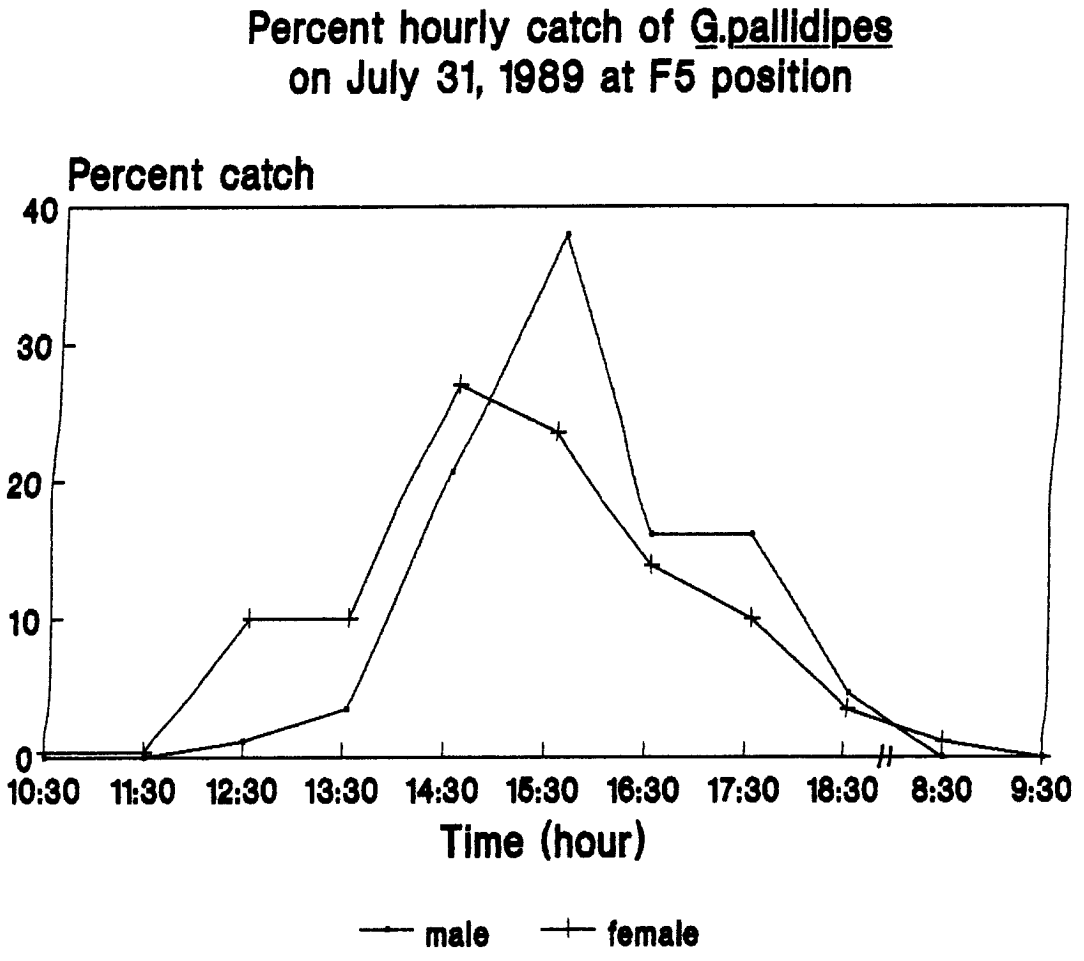


FIGURE 10.5b


Percent hourly catch of G.pallidipes
on July 31, 1989 at F5 position
Percent catch
40
30
20
10
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
8:30
9:30
Time (hour)
male
female

and 10:30h which may have rendered the flies virtually inactive. Fly activity was highest in the middle of the afternoon when the temperature was about 30°C.

SEPTEMBER

In Trap F5, more female G. pallidipes *were* trapped than male G. pallidipes before 17:00h; while in Trap F4, fewer female than male G. pallidipes were trapped at around 13:30h (Figures 10.6a,b and 10.8a,b). The activity patterns observed on September 6 and 7 in Traps F4 and F5 (Figures 10.7a,b and 10.9a,b) were generally bimodal and unimodal, respectively. In the case of a bimodal activity pattern for female G. pallidipes, the second peak which occurred at around 16:00h was higher than the one which occurred at around 12:00 and 11:00h on September 6 and 7, respectively. The second peak for male G. pallidipes occurred at around 16:00 and 18:00h on September 6 and 7, respectively; and a lower peak occurred at around 10:00h on both September 6 and 7.

An observed bimodal activity pattern in September in Trap F4 was probably due to the position on which Trap F4 was erected being in the shade in

FIGURE 10.6a

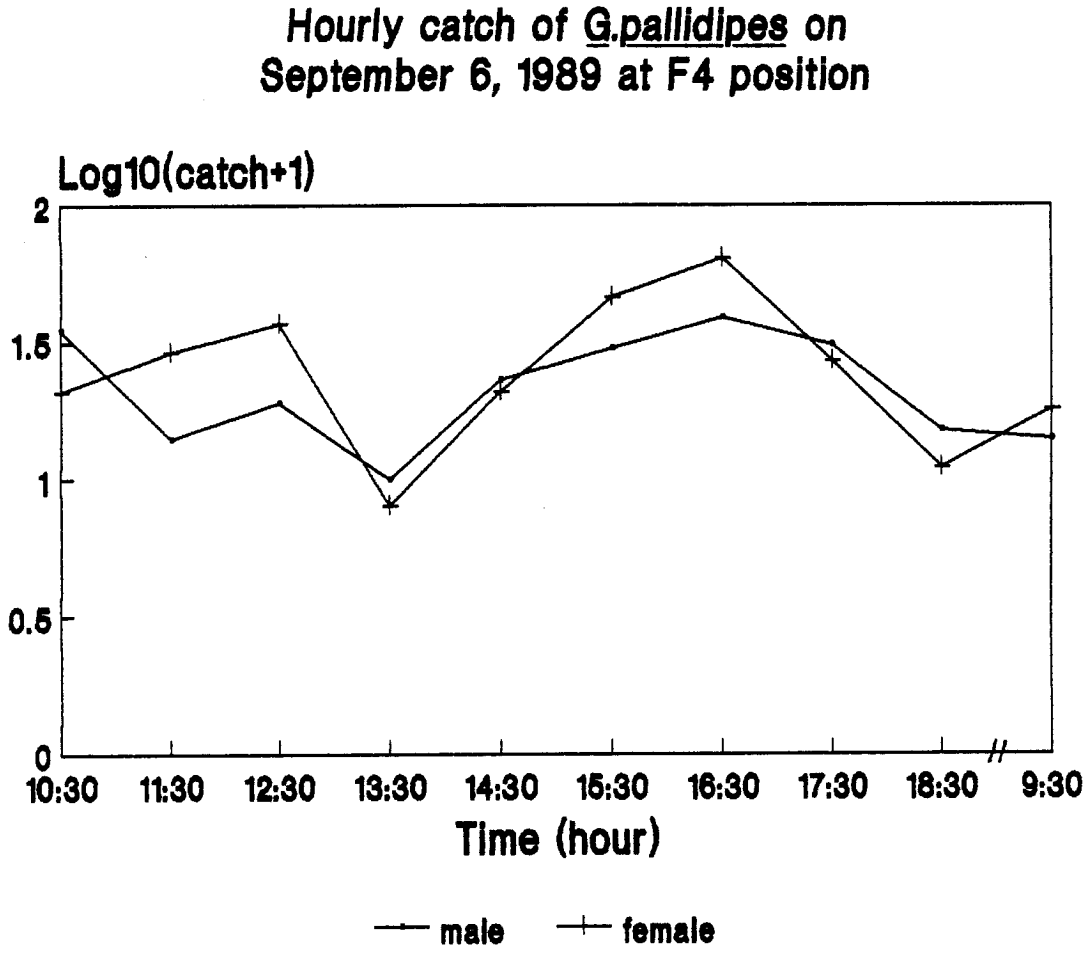

Hourly catch of G.pallidipes on
September 6, 1989 at F4 position
Log10(catch+1)
2
1.5
1
0.5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
9:30
Time (hour)
male
female

FIGURE 10.6b

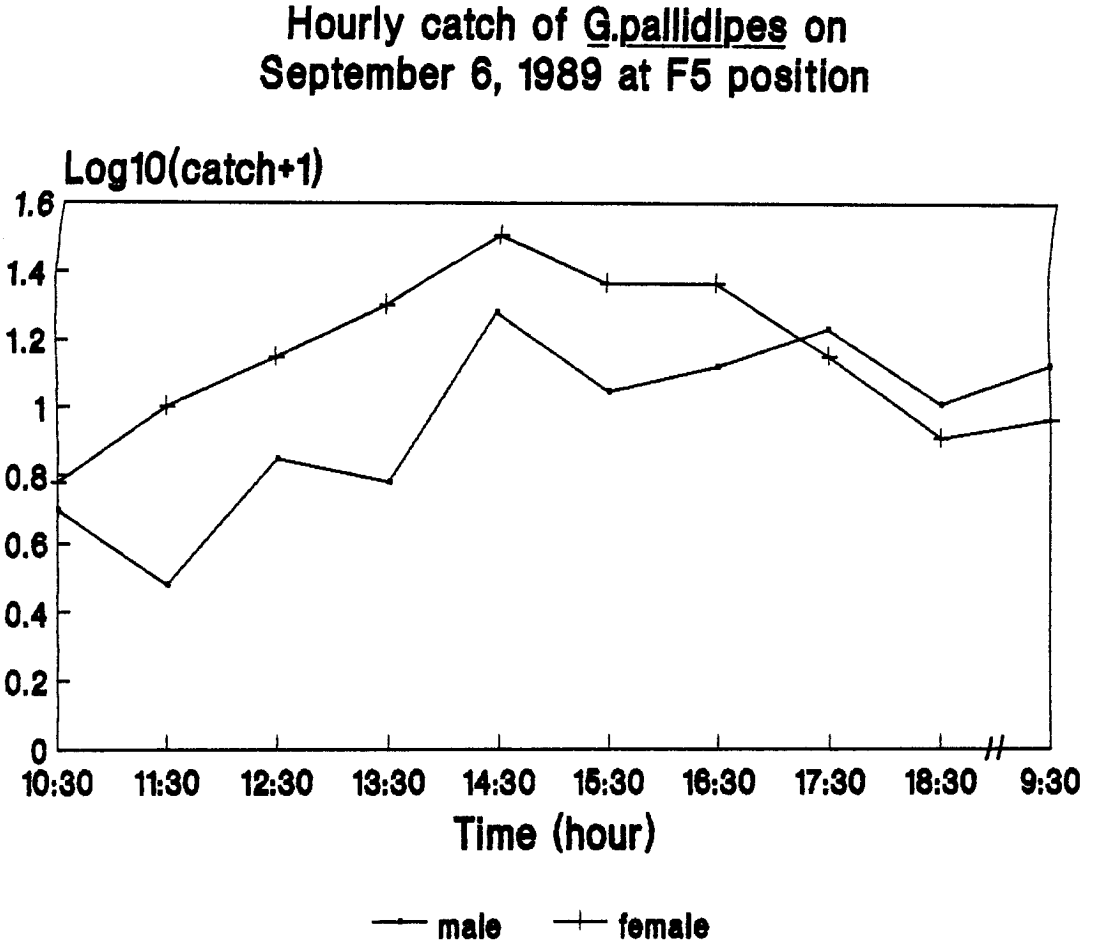

Hourly catch of G.pallidipes on
September 6, 1989 at F5 position
Log10(catch+1)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
9:30
Time (hour)
male
female

FIGURE 10.7a

Percent hourly catch of G.pallidipes on September 6, 1989 at F4 position

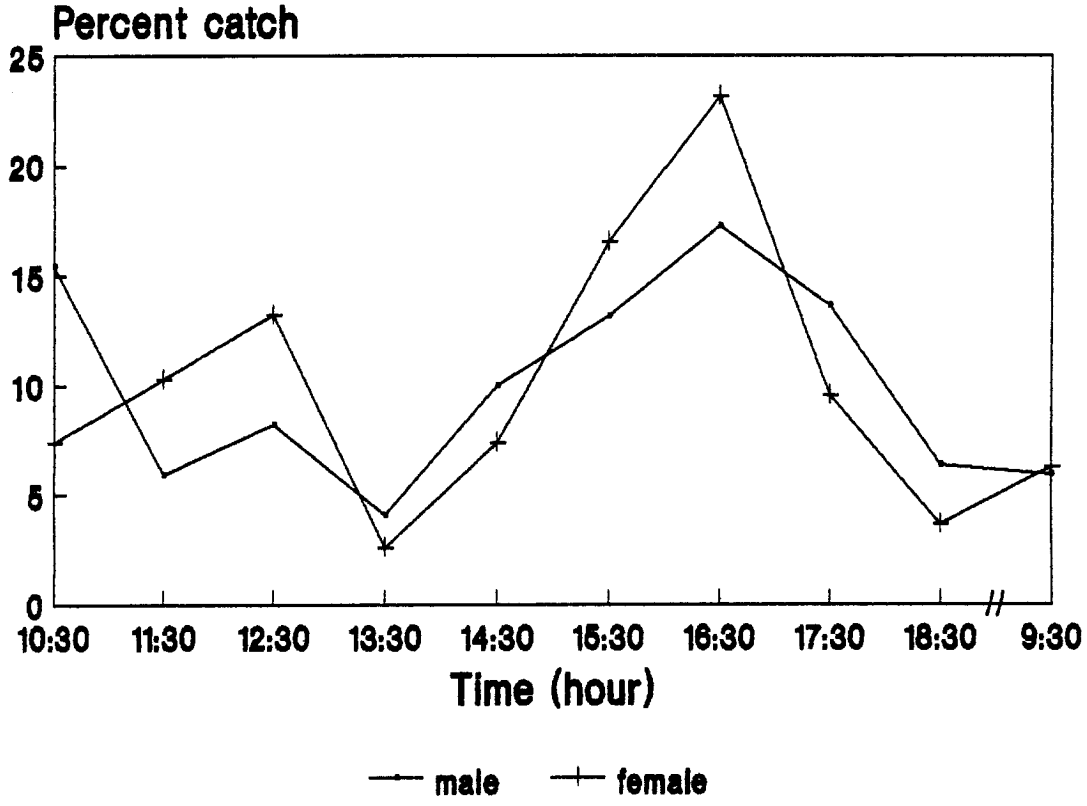


FIGURE 10.7b

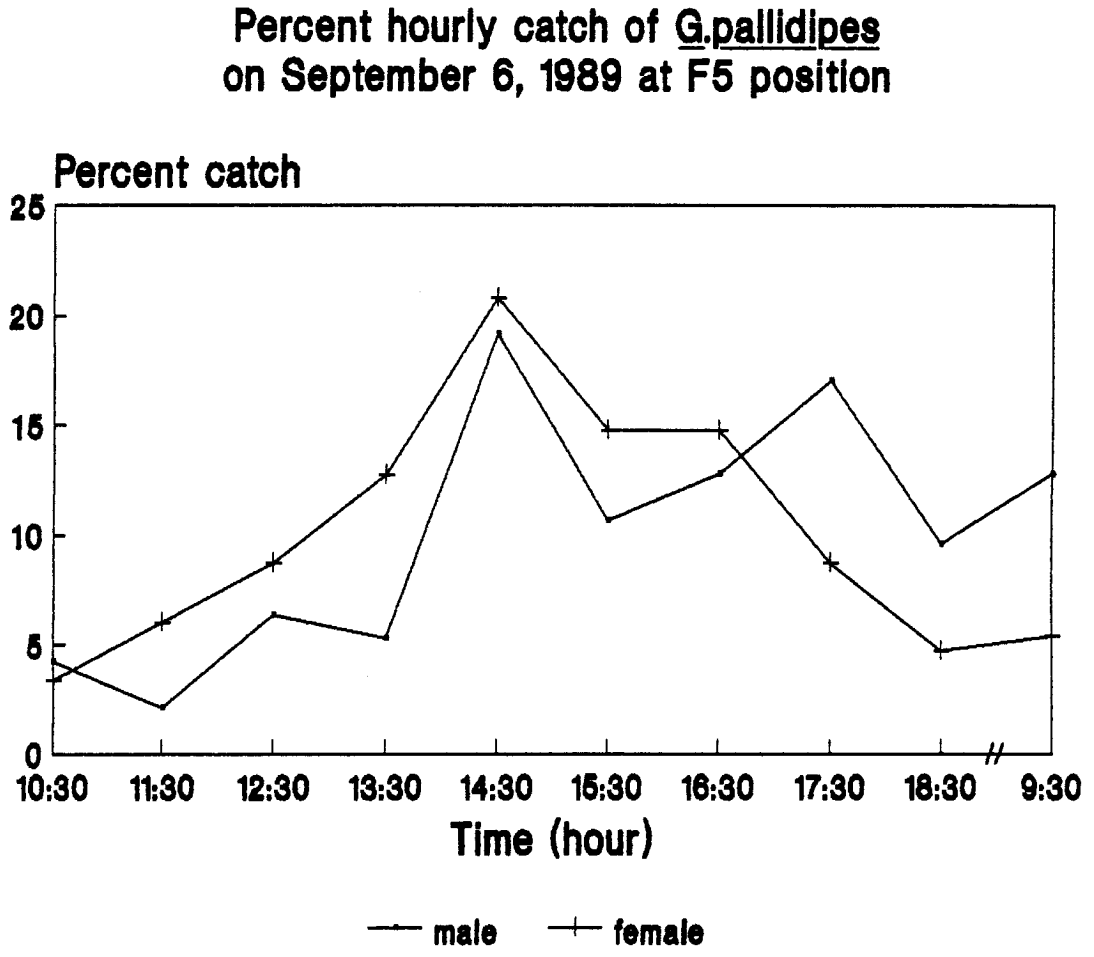

Percent hourly catch of G.pallidipes
on September 6, 1989 at F5 position
Percent catch
25
20
15
10
5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
9:30
Time (hour)
male
female

FIGURE 10.8a

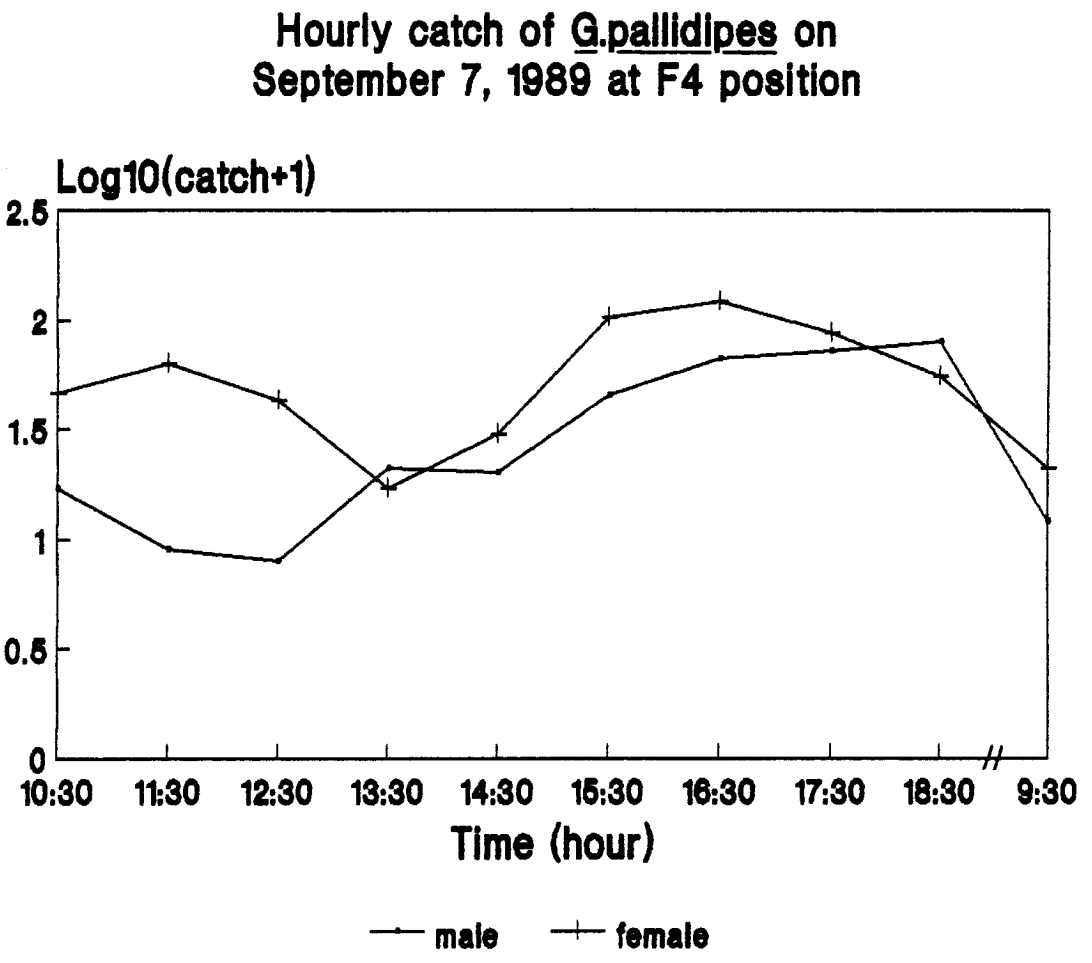

Hourly catch of G.pallidipes on
September 7, 1989 at F4 position
Log10(catch+1)
2.5
2
1.5
1
0.5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
9:30
Time (hour)
male
female

FIGURE 10.8b

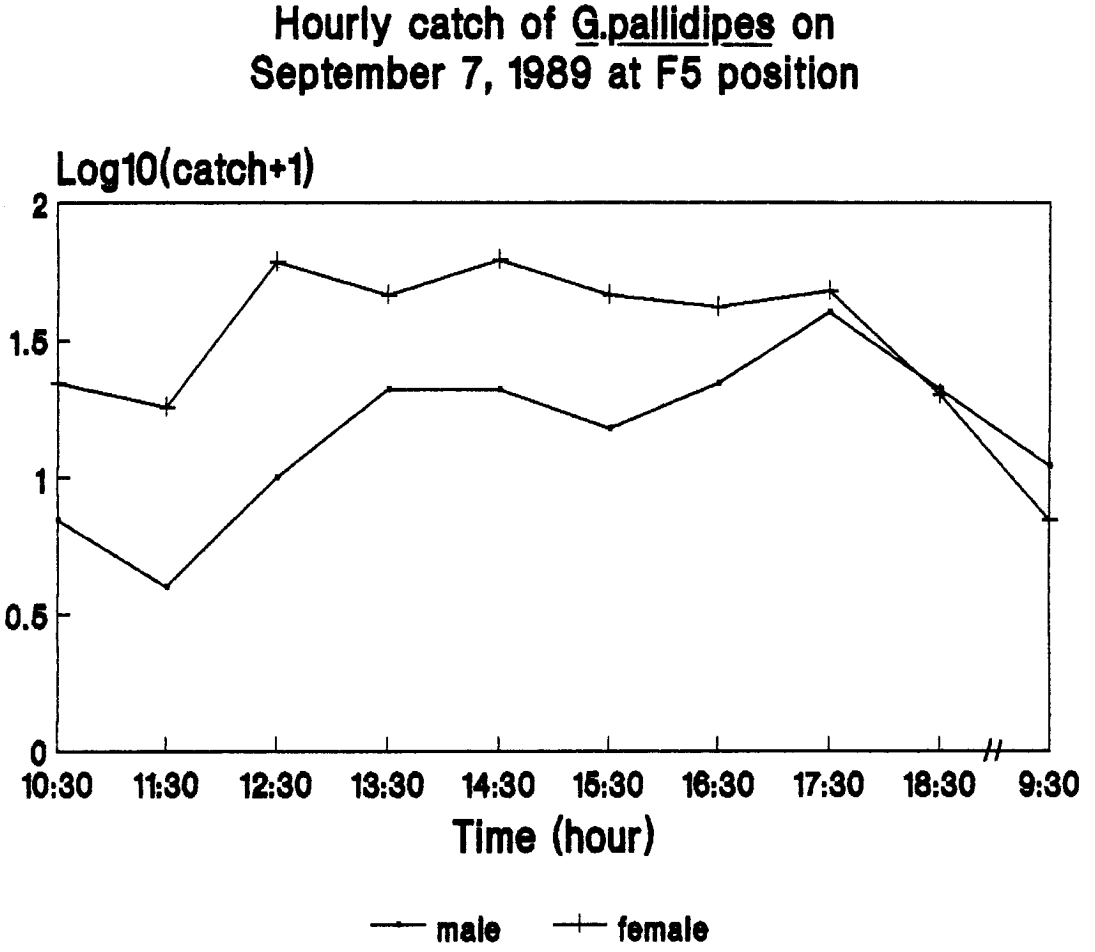

Hourly catch of G.pallidipes on
September 7, 1989 at F5 position
Log10(catch+1)
2
1.5
1
0.5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
9:30
Time (hour)
male
female

FIGURE 10.9a

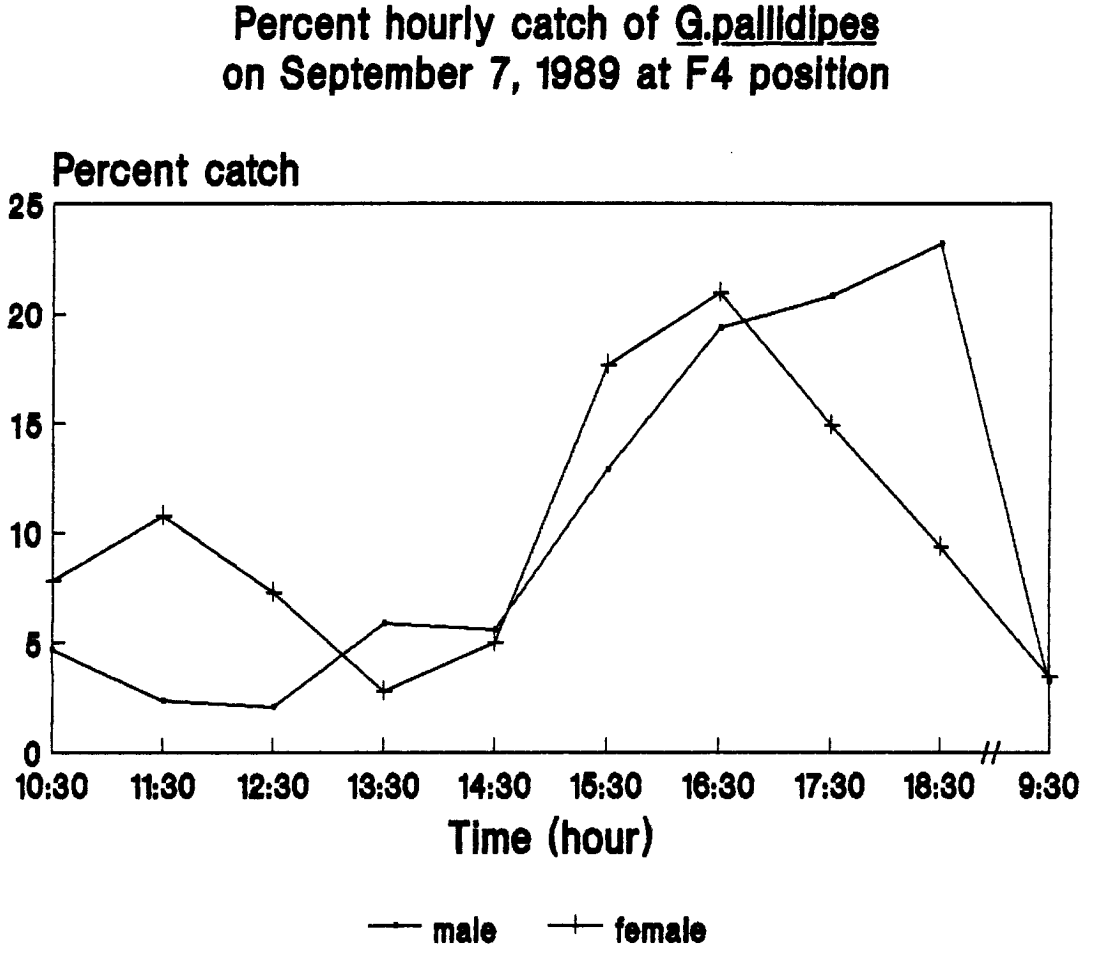
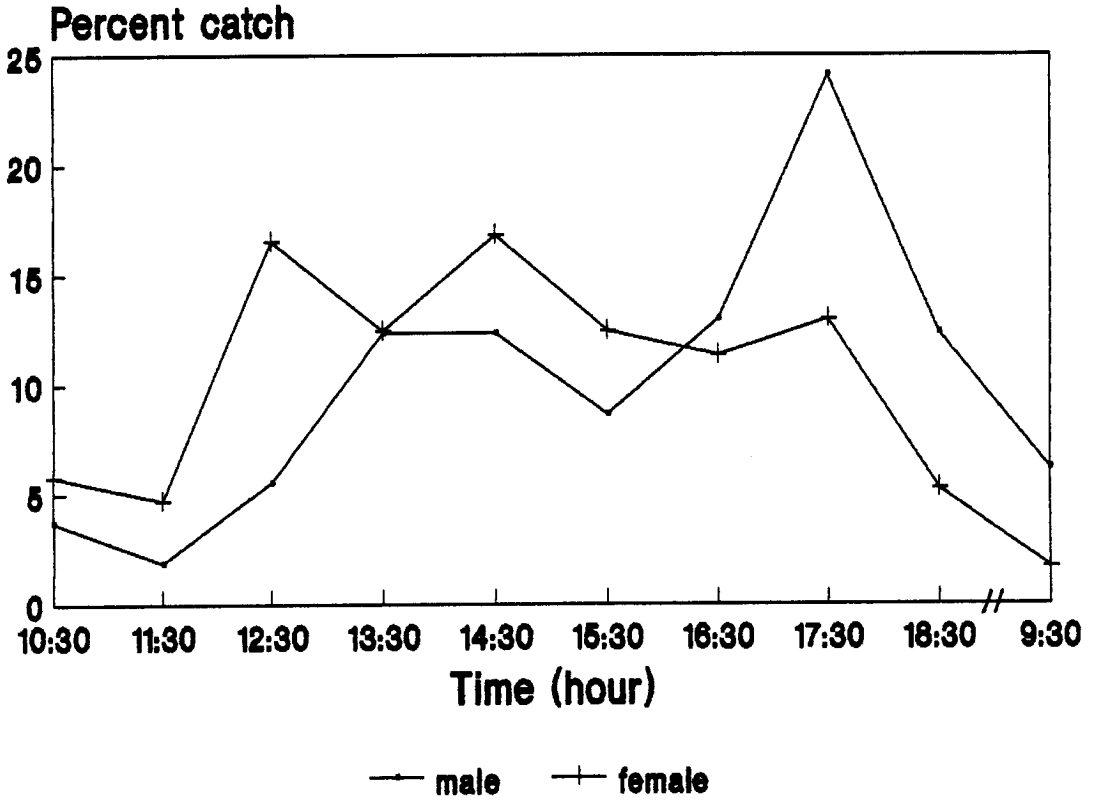

Percent hourly catch of G.pallidipes
on September 7, 1989 at F4 position
Percent catch
25
20
15
10
5
0
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
18:30
9:30
Time (hour)
male
female

FIGURE 10.9b

Percent hourly catch of G.pallidipes on September 7, 1989 at F5 position



the morning: offering refuge for the flies in the 33°C heat, suggesting that flies were photonegative at this temperature, and immediately the trap was in the sun around 13:00h, fewer flies were trapped in Trap F4. Starvation, over-riding any other activity cue, could be the explanation for the evening peak because at this time game begin to move.

NOVEMBER

More female than male G. pallidipes were trapped at a midday peak and more male than female G. pallidipes were trapped at an evening peak (Figure 10.10a,b). Both sexes had their bimodal peaks of activities occurring at about the same time at around noon and at about sunset (Figure 10.11a,b) probably due to high temperature of about 32°C and both traps being in the shade.

Functional relations

Model II regressions were fitted to data sets which appeared to have linear profiles. There were no apparent differences in the activity profiles of female G. pallidipes caught in Trap F4 against relative humidity on July 30 and 31 and the data was, therefore, combined. Figure 10.12 shows the linear relationship between the catches and the relative

FIGURE 10.10a

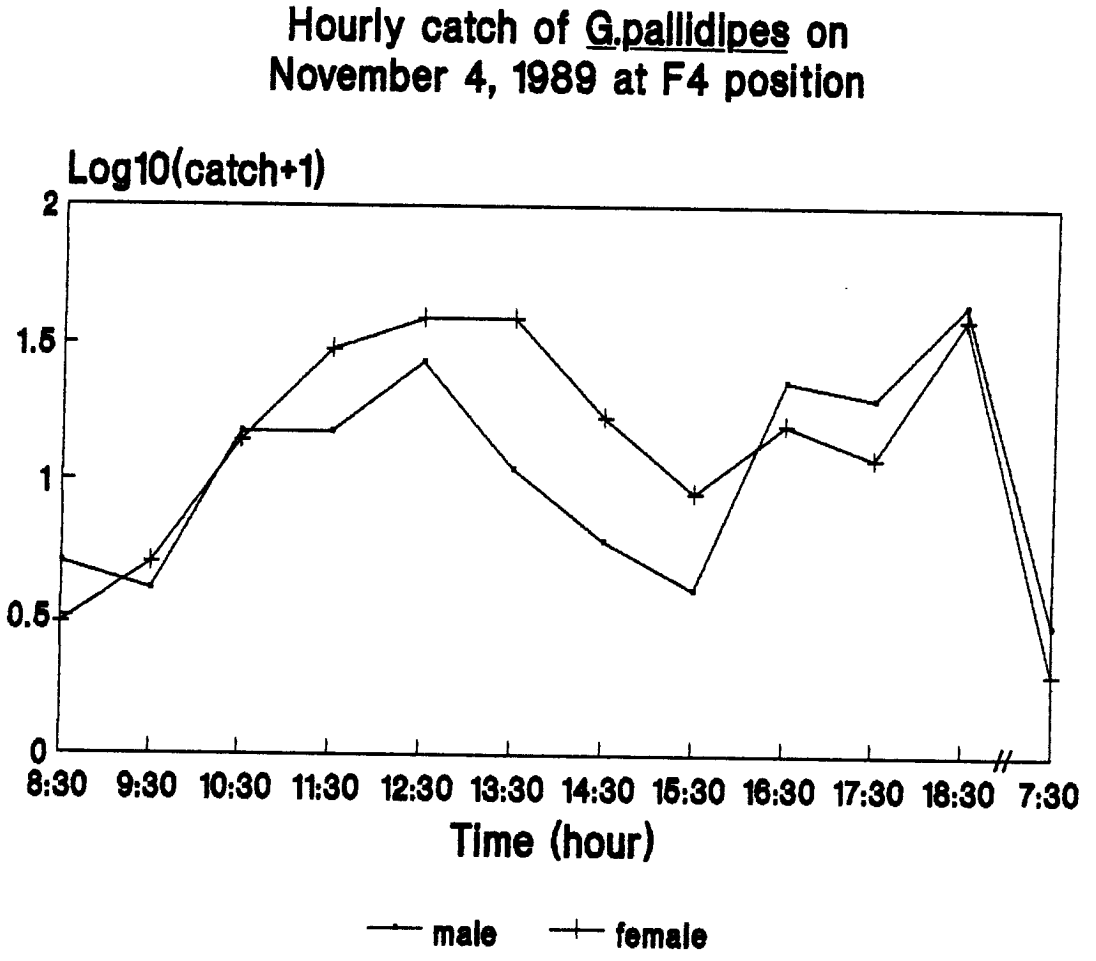


FIGURE 10.10b

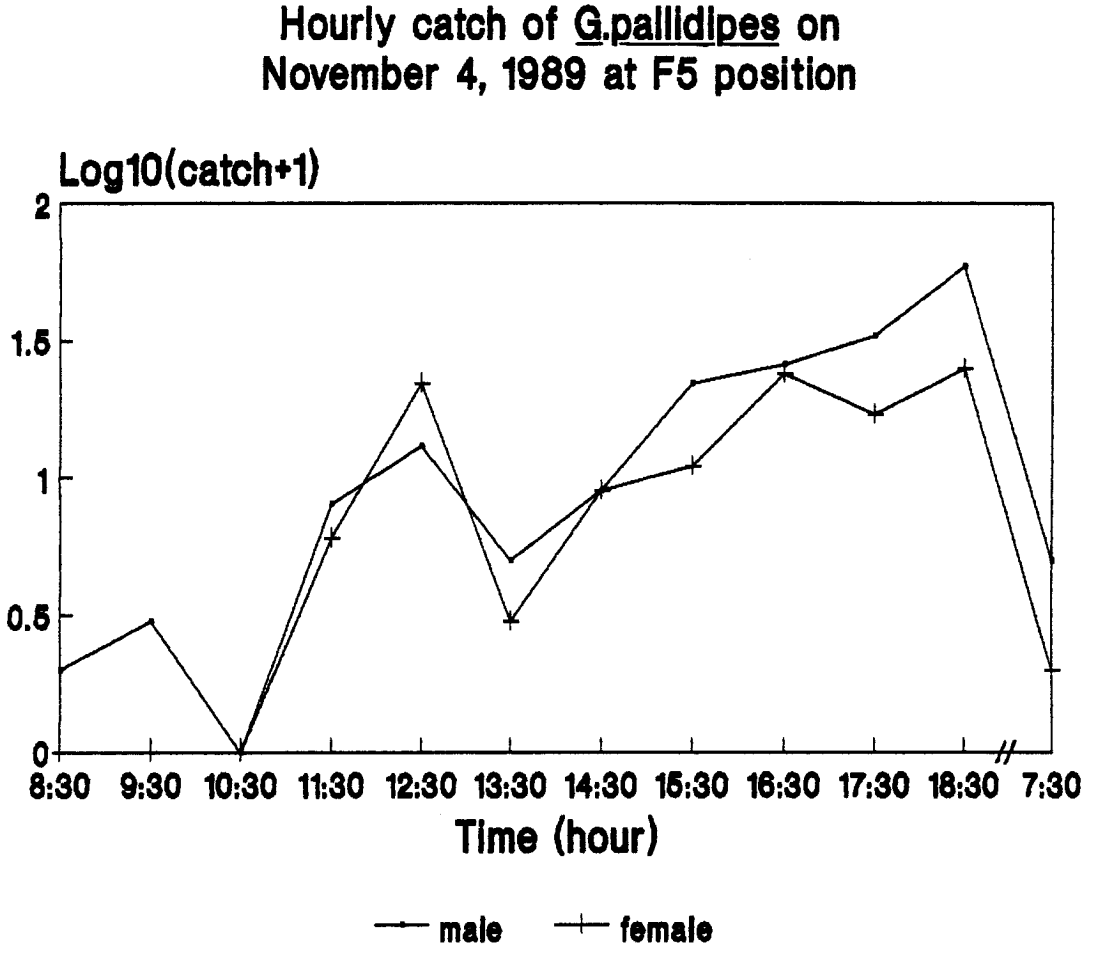


FIGURE 10.11a

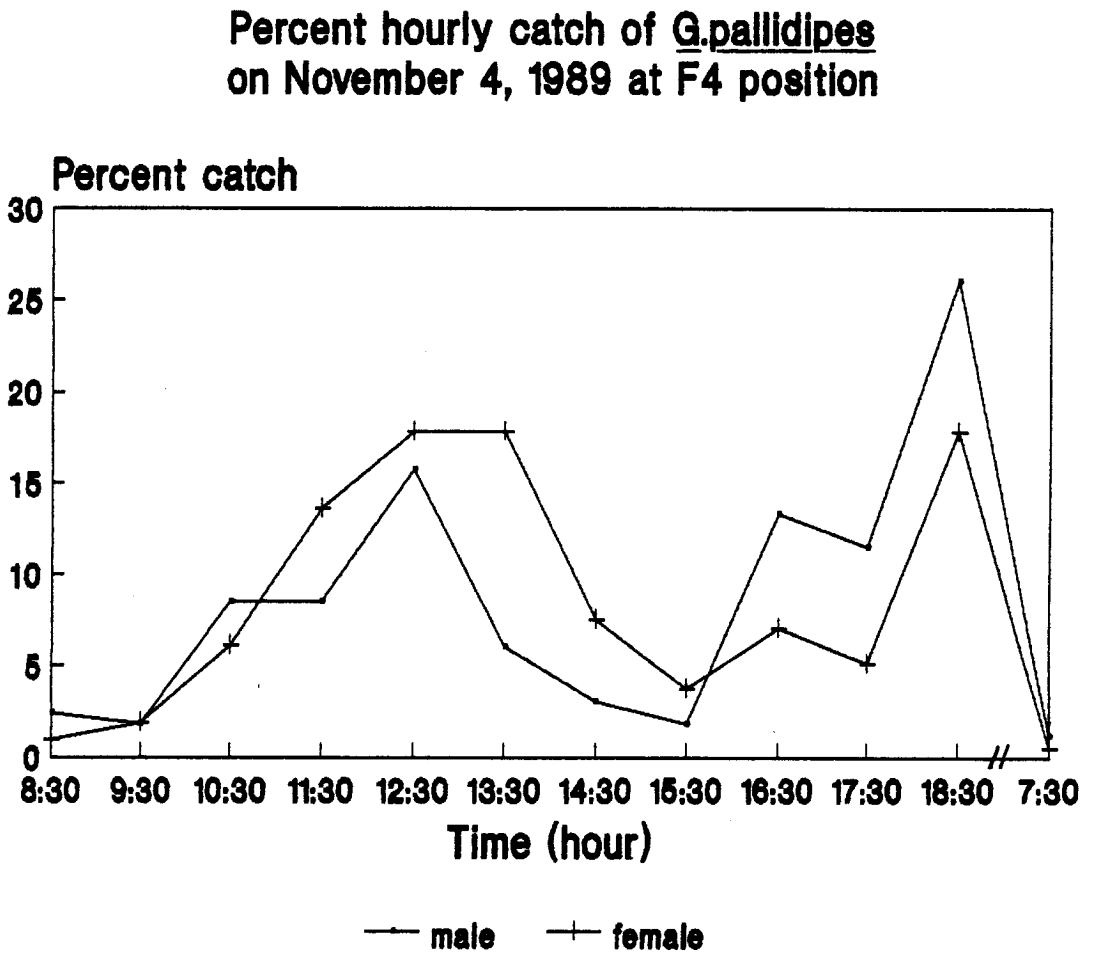


FIGURE 10.11b

Percent hourly catch of G.pallidipes on November 4, 1989 at F5 position

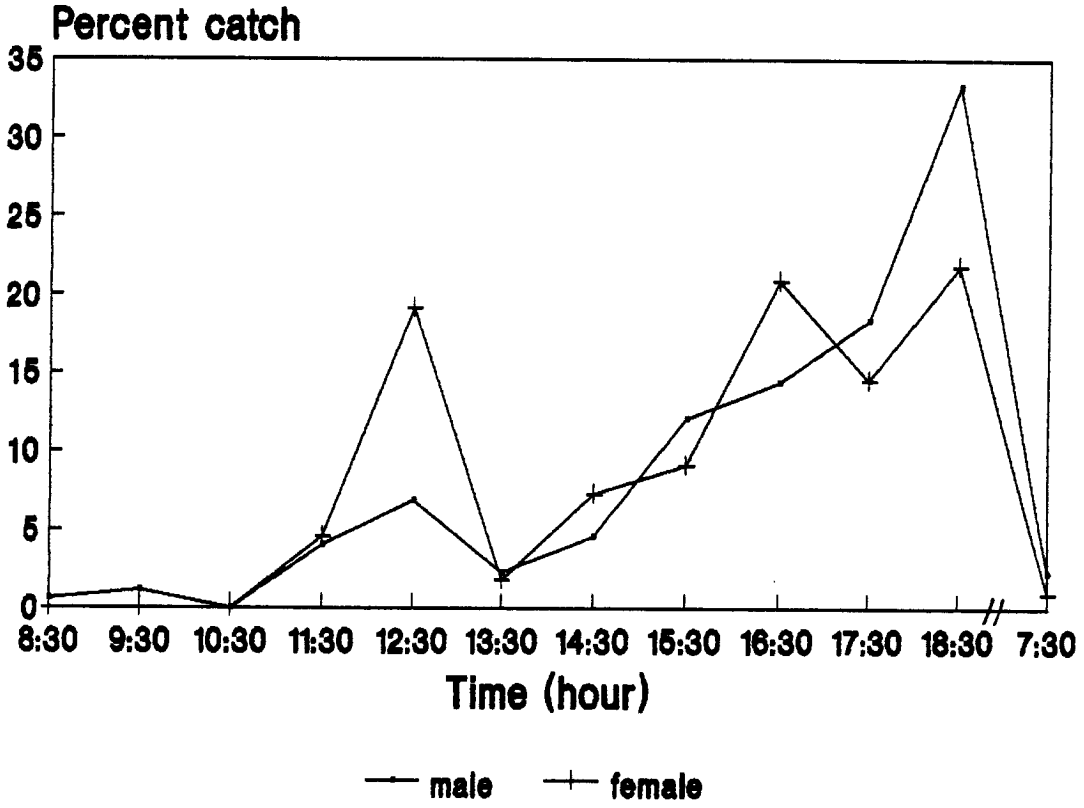
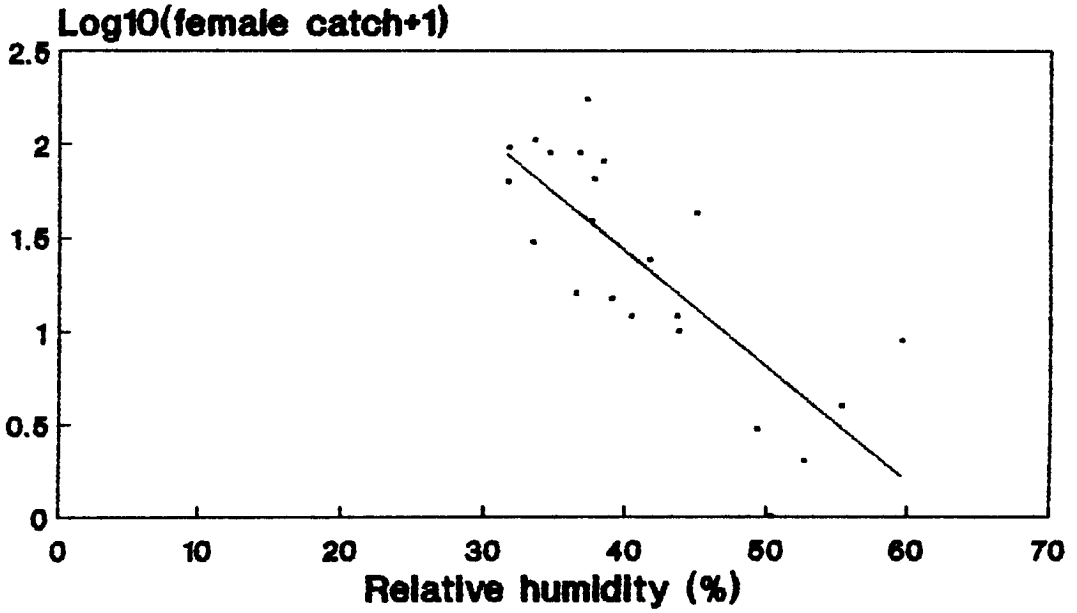


FIGURE 10.12

A linear function of female G.pallidipes against relative humidity



Y1 = 3.89 - 0.062 * Y2
95% CI for slope (-0.085,-0.039)
Y1: Log10(female catch+1); Y2: r.h.

humidity. The number of female G. pallidipes caught proportionally reduced with an increase in the relative humidity. In particular, a 95% decrease in female G. pallidipes catches was observed when the relative humidity increased from 32 to 52% r.h..

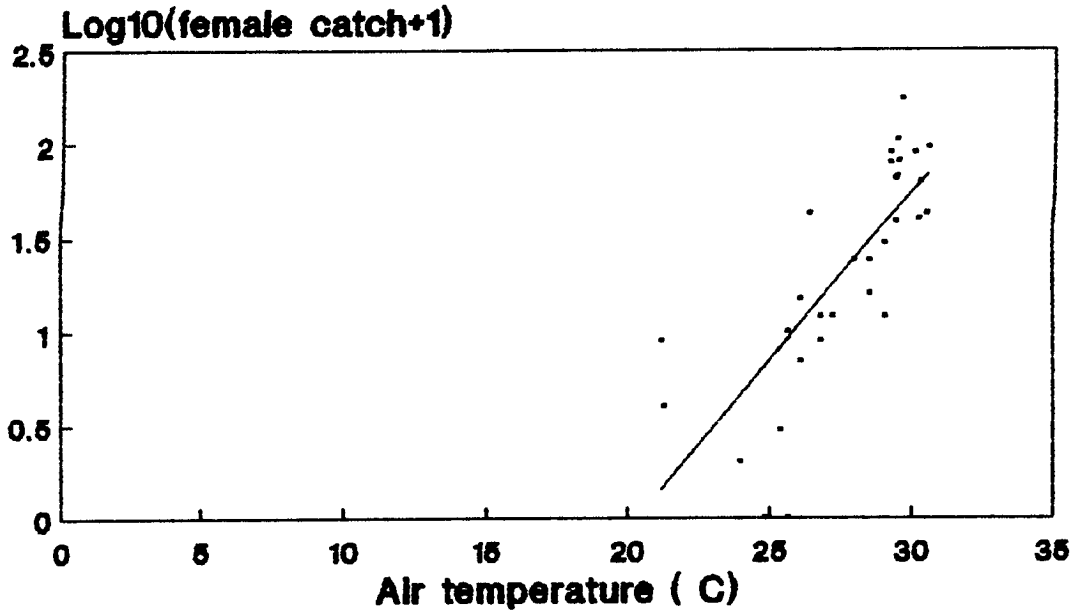
Apparently there were no differences among the profiles of female G. pallidipes caught against air temperature on July 30 and 31 in Trap F4 and on July 31 in Trap F5. A combined profile depicting a linear relationship between the catches of female G. pallidipes and the air temperature is shown in Figure 10.13. The catches proportionally increased with a rise in the air temperature. A threshold of 20.4^{o}C above which female G. pallidipes was active and below which it was inactive was computed using a model II regression equation.

In November, a temperature of 32^{o}C (range 30-34^{o}C) and a relative humidity of 32% (range 28-38%) appeared to be optimum for the G. pallidipes' activity (Figures 10.14 and 10.15).

Generally, female G. pallidipes' activity was better correlated with climatic factors than male's activity. In July, while female G. pallidipes'

FIGURE 10.13

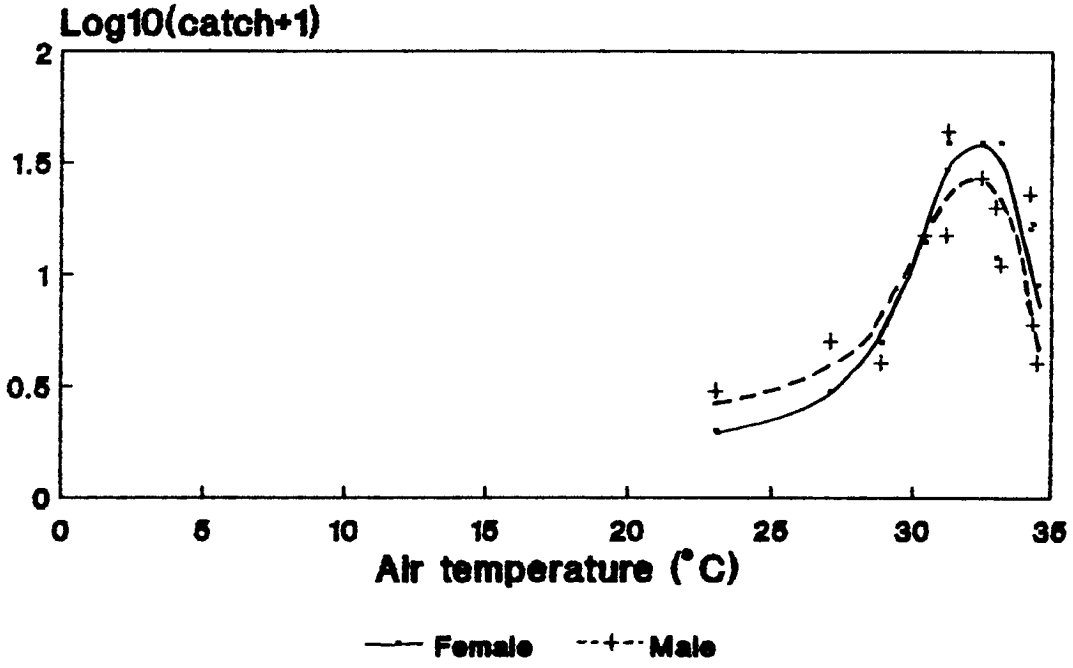
A linear function of female G.pallidipes against air temperature



Y1 = -3.68 + 0.18 * Y2
95% CI for slope (0.13,0.23)
Y1:Log10(female catch+1); Y2:Temperature

FIGURE 10.14

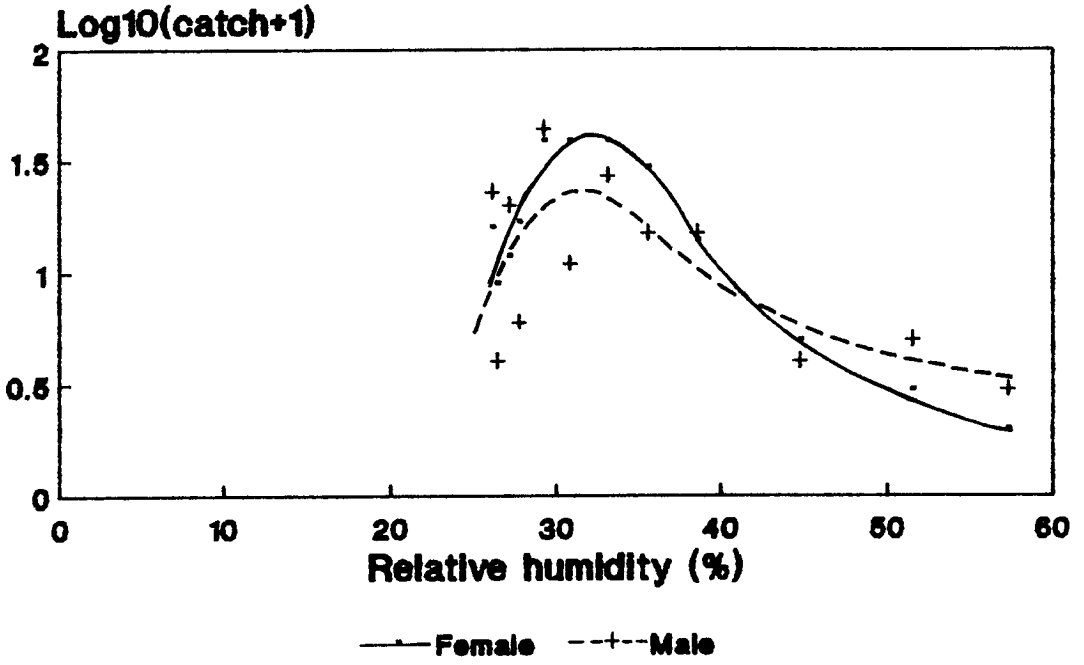
A *non*-linear function of G. pallidipes against air temperature



Optimum air temperature range 30-34°C

FIGURE 10.15

A non-linear function of G. pallidipes against relative humidity



Optimum relative humidity range 28-38%

activity was correlated with the air temperature and relative humidity, none of the climatic variables was correlated with male G. pallidipes' activity; and in November, female's profiles were much clearer than male's.

Experiment B

In Experiment B, the wind speed (Table 10.1) and the air temperature (Table 10.2) were found to be positively correlated to catches of G. pallidipes, while the radiation (Table 10.1) and the relative humidity (Table 10.2) were negatively correlated to the catches of the tsetse flies. An overall increase in catches of the tsetse flies of about 5 times was observed in the afternoon when the temperatures increased to about 30^{o} from about $26^{o}C$ in the morning and when the relative humidity reduced from about 60% in the morning to about 45% r.h. in the afternoon (Table 10.2). The mean wind speed increased from about 0.7 m/s in the morning to about 0.9 m/s in the afternoon, while there was a reduction in the mean radiation from about 0.6 kW/m^2 in the morning to about 0.4 kW/m^2 in the afternoon (Table 10.1).

Table 10.3 is a partial correlation matrix for any two climatic variables while the other two were

TABLE 10.1

Associations of wind speed, radiation and G. pallidipes' activity between January 8 and 11, 1990.

Time (hours)	No of readings	Wind speed (m/s) mean*±1s.e.	Radiation (kw/m^2) mean**±1s.e.	Total catch per trap Male	Female
08:00-12:00	96	0.68±0.031	0.61±0.028	363	397
12:00-16:00	96	0.87±0.028	0.45±0.033	1538	2259
Index of increase				4.2	5.7

* mean wind speeds significantly different between 08:00-12:00 and 12:00-16:00h

** mean radiations significantly different between 08:00-12:00 and 12:00-16:00h

TABLE 10.2

Associations of relative humidity, temperature and *G. pallidipes*' activity between January 8 and 11, 1990.

Date Time (h)	No of readings	Range %r.h.	Range oC	Catch per period Male (II)	Catch per period Female (II)
8.i					
08:00-12:00	24	55-78	20-27	173	109
12:00-16:00	24	28-55	27-31	499 (2.9)	698 (6.4)
9.i					
08:00-12:00	24	49-77	20-28	87	144
12:00-16:00	24	35-52	27-31	455 (5.2)	680 (4.7)
10.i					
08:00-12:00	24	48-75	21-28	77	109
12:00-16:00	24	38-54	28-32	407 (5.3)	580 (5.3)
11.i					
08:00-12:00	24	52-84	21-29	26	35
12:00-16:00	24	42-57	29-32	177 (6.8)	301 (8.6)

II Index of increase

comparison of catch at 12:00-16:00 to 08:00-12:00h

TABLE 10.3

Partial correlation coefficients between climatic variables.

	Wind speed (WS)	Air temperature (AT)	Relative humidity (RH)	Radiation (R)
WS	-			
AT	0.54***	-		
RH	-0.08	-0.43***	-	
R	0.05	0.40***	0.25***	-

Sample size = 295

held constant. The relative humidity was negatively partially correlated to both the air temperature and wind speed. A positive partial correlation was observed between the air temperature and wind speed. No significant partial correlation was observed between the wind speed and radiation nor the relative humidity. A positive partial correlation was observed between the radiation and air temperature or the relative humidity.

Despite the fact that the radiation was positively partially correlated with the relative humidity, a model II regression line relating these two variables was not significant (95% CI for slope -0.00060, 0.00022). Figure 10.16 is a scattergram for the radiation and relative humidity.

Figures 10.17 and 10.18 relate the air temperature to the radiation and wind speed, respectively. In both cases a simple model II linear regression appears to adequately explain the variation in the air temperature in relation to the variation in the radiation or wind speed.

The relationship between the air temperature and relative humidity was rather complex (Figure 10.19).

FIGURE 10.16

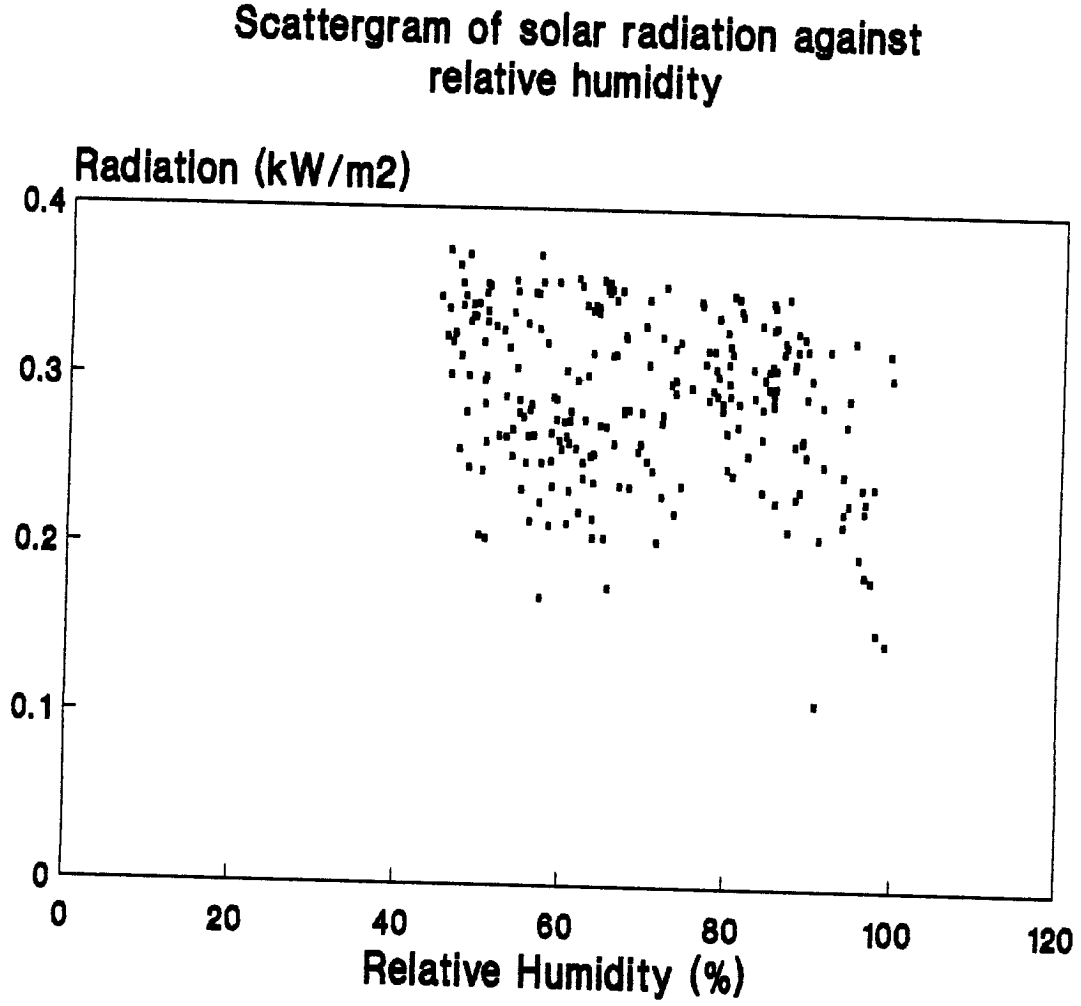
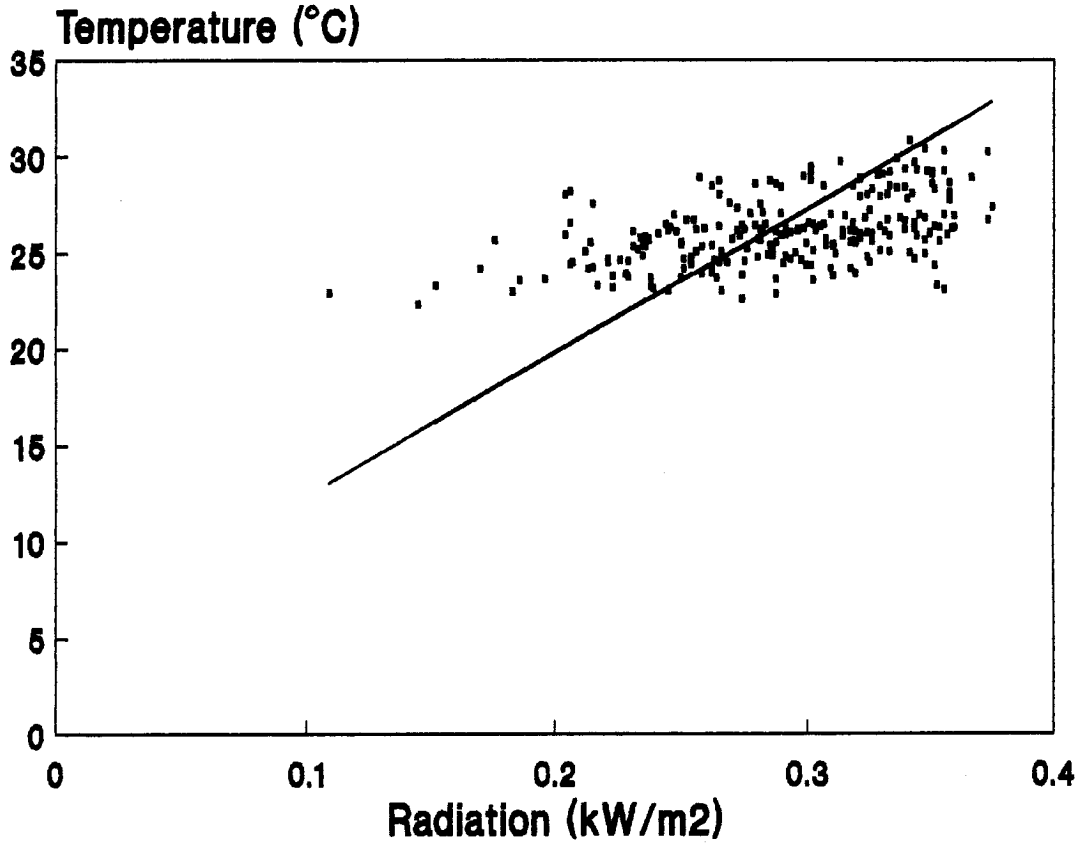

Scattergram of solar radiation against relative humidity
Radiation (kW/m2)
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
Relative Humidity (%)

FIGURE 10.17

Scattergram of air temperature against radiation with fitted line

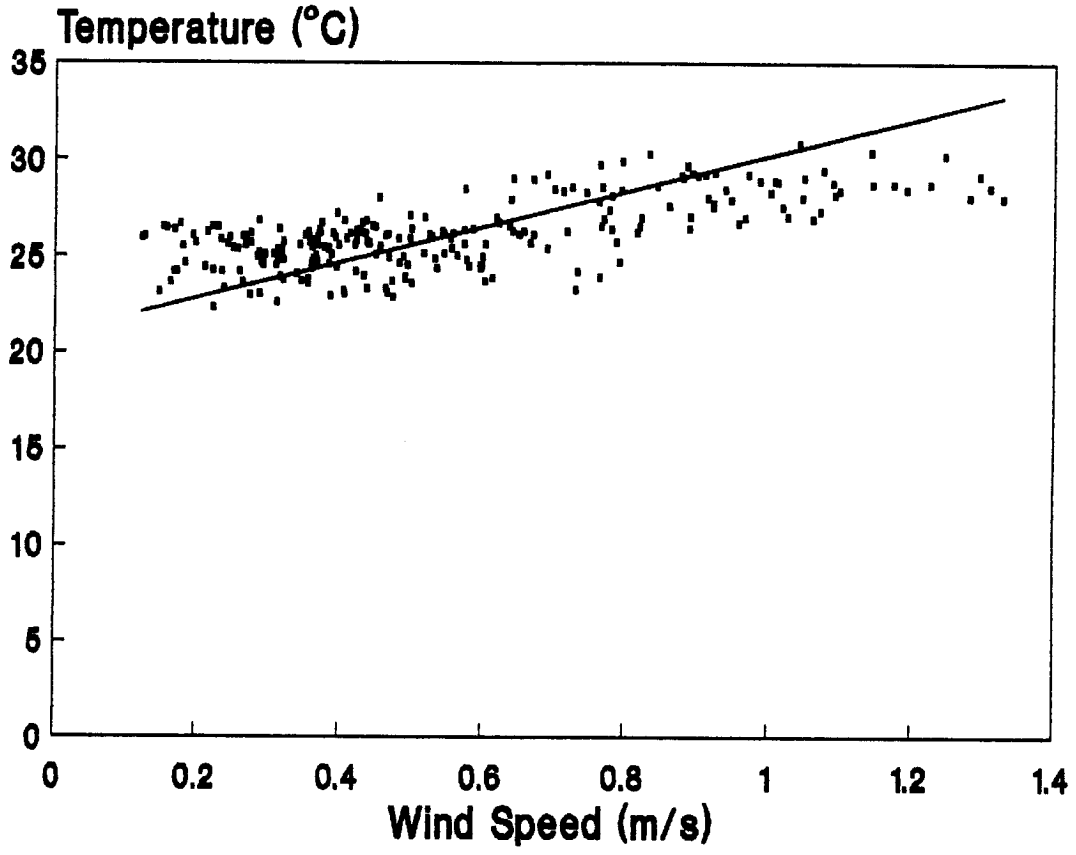


Temperature = 4.9 + 74.6 * Radiation

95% CI for slope (59.6, 99.5)

FIGURE 10.18

Scattergram of air temperature against wind speed with fitted line

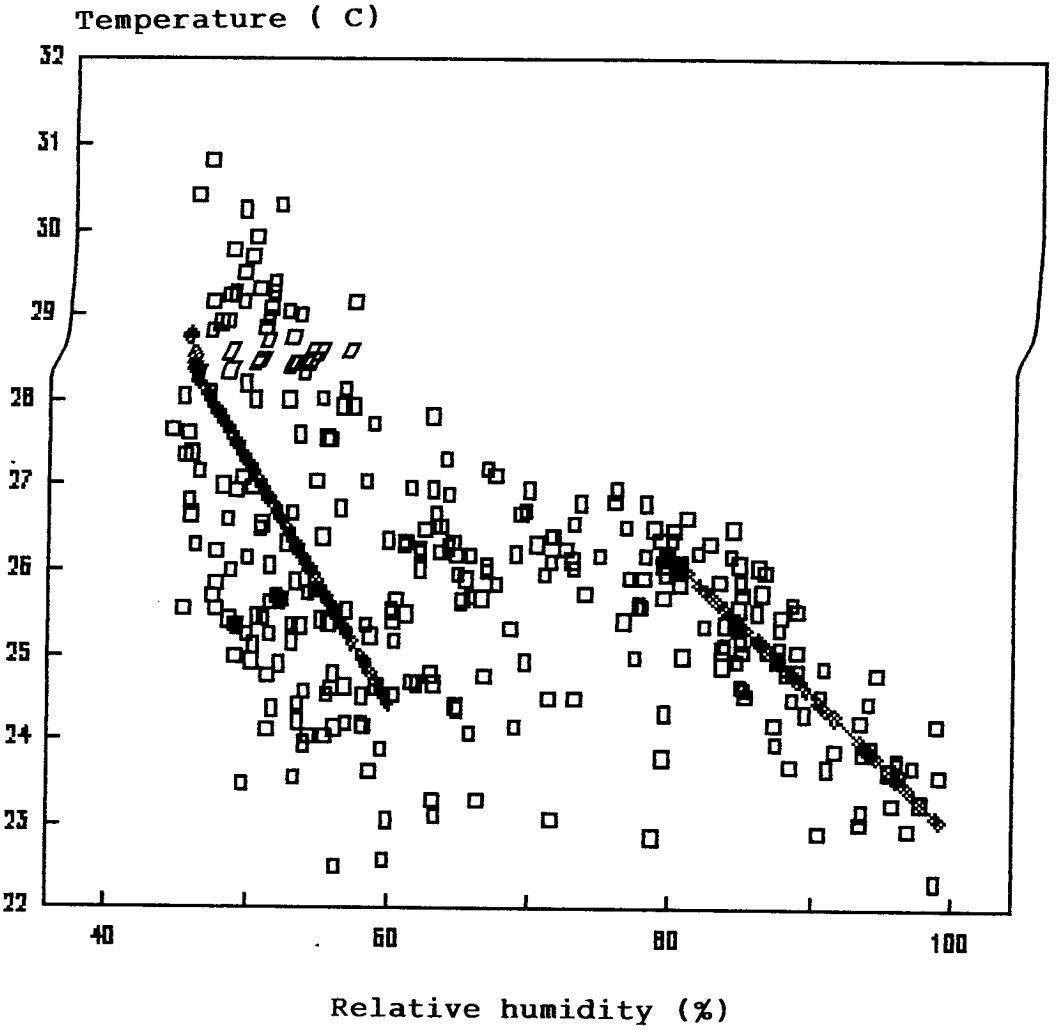


Temperature = 21.0 + 9.25 * Wind speed

95% CI for slope (8.15, 10.69)

FIGURE 10.19

Scattergram of temperature against relative humidity with fitted lines



Below 60% r.h.

Temperature = 41.2 - 0.28 * Relative humidity

95% CI for slope (-0.37, -0.19)

Above 80% r.h.

Temperature = 39.1 - 0.16 * Relative humidity

95% CI for slope (-0.19, -0.14)

The air temperature was better correlated (in terms of the narrowness of the width of the confidence interval) with the relative humidity at above 80% r.h. (Slope -0.16, 95% CI -0.19 to -0.14) than below 60% r.h. (Slope -0.28, 95% CI -0.37 to -0.19), and there was no correlation between the air temperature and relative humidity between 60 and 80% r.h. (Slope 0.004, 95% CI -0.03 to 0.04).

11.4 DISCUSSION

It has been clearly observed that some climatic factors are inter-correlated, such as the air temperature was better correlated with the wind speed than radiation. A relationship between some climatic factors may not be a simple linear relationship as the case was found between the air temperature and relative humidity. And this supports the notion that a graph should always accompany a statement on a linear relationship between two variables so that a linear relationship may clearly be seen.

Activity patterns of female G. pallidipes recorded in Nguruman on July 30 and 31 compare fairly well (with regard to peaks of activities) with previous observations at Nguruman (van Etten, 1982) and in the Lambwe valley (Turner, 1987). G.

pallidipes populations in Lambwe, Lugala in Uganda (Harley, 1965) and in Nguruman on July 30 and 31 all showed unimodal activity patterns.

On November 4, G. pallidipes in Nguruman showed a bimodal activity pattern with a lower peak occurring at noon and a higher peak at sunset, probably because November 4 was a hot day. This agrees with the bimodal activity pattern of G. pallidipes Jaensen (1981) found at Kibwezi, Kenya, though periods of peak activity in Nguruman occurred about an hour later than at Kibwezi.

The finding that G. pallidipes is about 5 times more active in the afternoon than in the morning in January implies that in an infested area, one may avoid contact with tsetse flies by travelling through the infected area during the morning. Maasai pastoralists who take their cows to graze in relatively heavily infested areas during the dry seasons should take their cows for grazing early in the morning and leave the areas by noon to minimize their cows' exposure to tsetse.

Fly activity may depend on temperature only to a small extent while starvation is known to have an

enormous effect on activity (Barrass, 1970b; Brady, 1972a, 1973, 1975b; Crump and Brady, 1979). The observed higher catches in the afternoon may be because during the late afternoon the game begin to move and the flies start to feed. But there may also be threshold temperatures, below and above which the flies are inactive.

A model II regression function relating catches of female G. pallidipes to the relative humidity on July 30 and 31 suggests that a rise of 20% in the relative humidity from 32 to 52% r.h. corresponded to about 95% decrease in female G. pallidipes' activity.

A threshold of 20.4°C above which female G. pallidipes was active and below which it was inactive compares well with results from several other studies. Turner (1980b) observed that G. tachinoides was inactive when temperatures were below 20°C and thereafter the activity of this fly was positively correlated with temperature until 16:30h. Power (1964) observed G. longipennis to be active when temperatures also exceeded 20°C. In his literature review, Challier (1982) concluded that generally tsetse flies become active when temperatures exceeded 16 to 18°C at sunrise.

There is overwhelming evidence from he current and previous studies that a temperature threshold above which tsetse flies become active and below which they become inactive is about 20°C.

Evidence is scanty on the optimum air temperature and relative humidity conditions in nature for the tsetse fly's activity. Gruvel (1975e) observed the activity of G. tachinoides to be optimum at 30.5°C. From the current study, figures of air temperature of 32°C (range 30-34°C) and relative humidity of 32% (range 28-38%) appear to be optimum for the fly's activity. The above finding of Gruvel is within the optimum air temperature range observed in the current study.

Differences in physiological states of the sexes may explain why female G. pallidipes' activity was better correlated with climatic factors than male's. It is less clear which precise physiological factors are responsible for this difference.

In the next chapter we discuss the barrier efficiency of a line of traps in relation to the radius of attraction of a baited Nguruman trap, and

relate this discussion to the problem of reinvasion of tsetse flies into an area in which the flies are being suppressed.

CHAPTER 11

REINVASION AND BARRIER EFFICIENCY OF A LINE OF TRAPS

11.1 INTRODUCTION

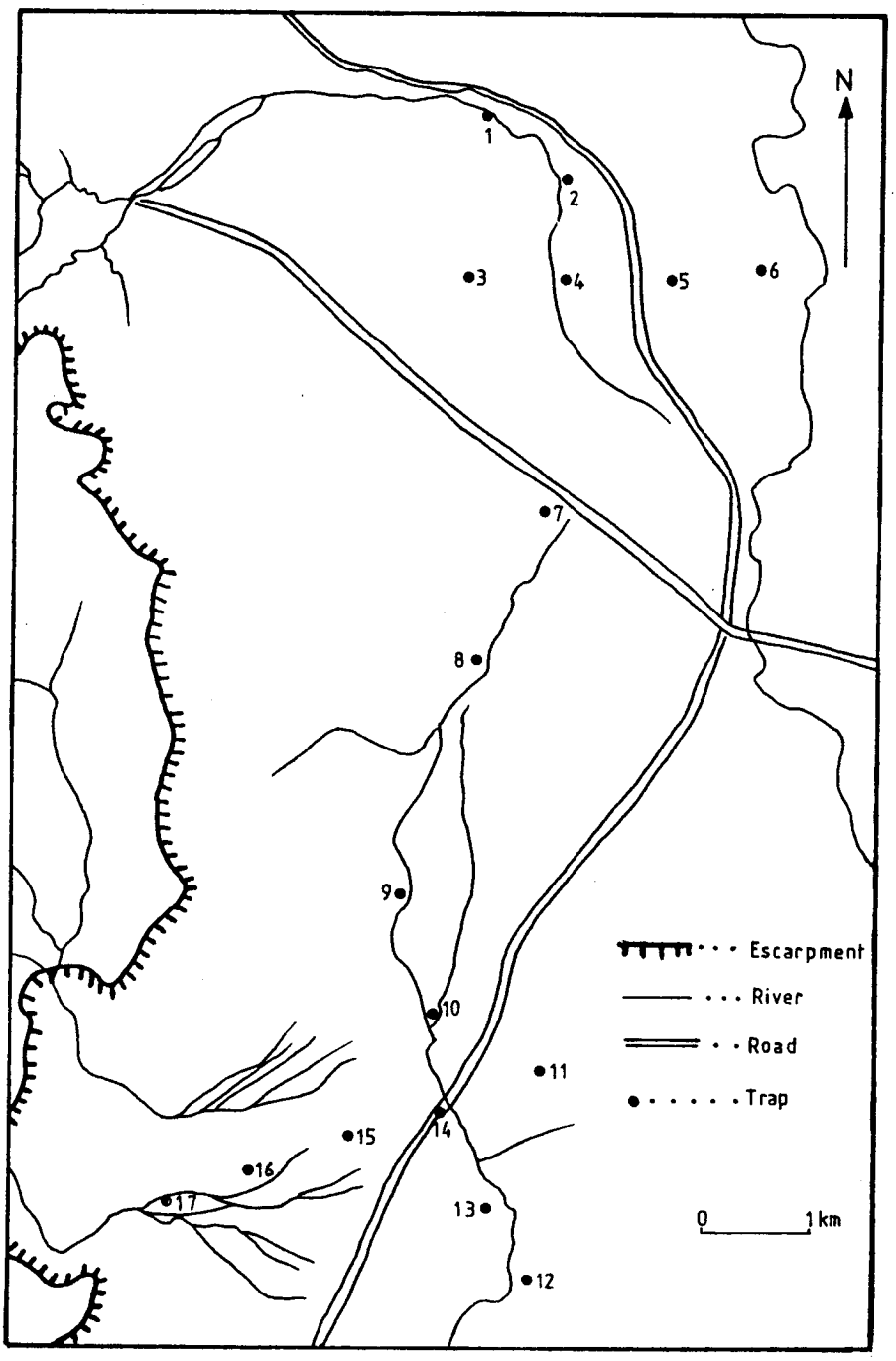
A line of baited Nguruman traps spaced about 100m apart has been used by an ICIPE Tsetse Research Team as a barrier against G. pallidipes and G. longipennis at Nguruman to control the reinvasion of tsetse flies into the area in which the flies are being suppressed (DITH, 1986). A line of `barrier traps' was erected along the pipeline road (Figure 4.1) and has been in place since 1987. This has proved to be ineffective especially during the rains (Dransfield et al., 1990). Here we discuss the results of experiments carried out to evaluate the efficiency of a barrier of a line of traps.

11.2 MATERIALS AND METHODS

Apparent changes in population size were monitored every 3 to 4 days in February and April 1989 by using 17 baited biconical traps (see for example Challier et al., 1977). Figure 11.1 shows the distribution of these 17 biconical traps and the position of the release site RS3. This study covered both dry and wet periods at Nguruman. In this study,

FIGURE 11.1

Distribution of the 17 biconical traps for spatial models



the data collected were used to produce spatial distribution maps. The maps were produced using CRIES (Schultink et al., 1987), a geographical information system's software.

In another study of the number of tsetse flies crossing the barrier from the northern area into the suppression zone, flies were marked and released at site RS3 on July 29 to 31, September 6 to 8 and on November 4 and 5, 1989. The movement of marked tsetse flies was monitored for about one month from the time of release by checking for marked flies in the 22 X-traps (see Figure 7.3 in chapter 7).

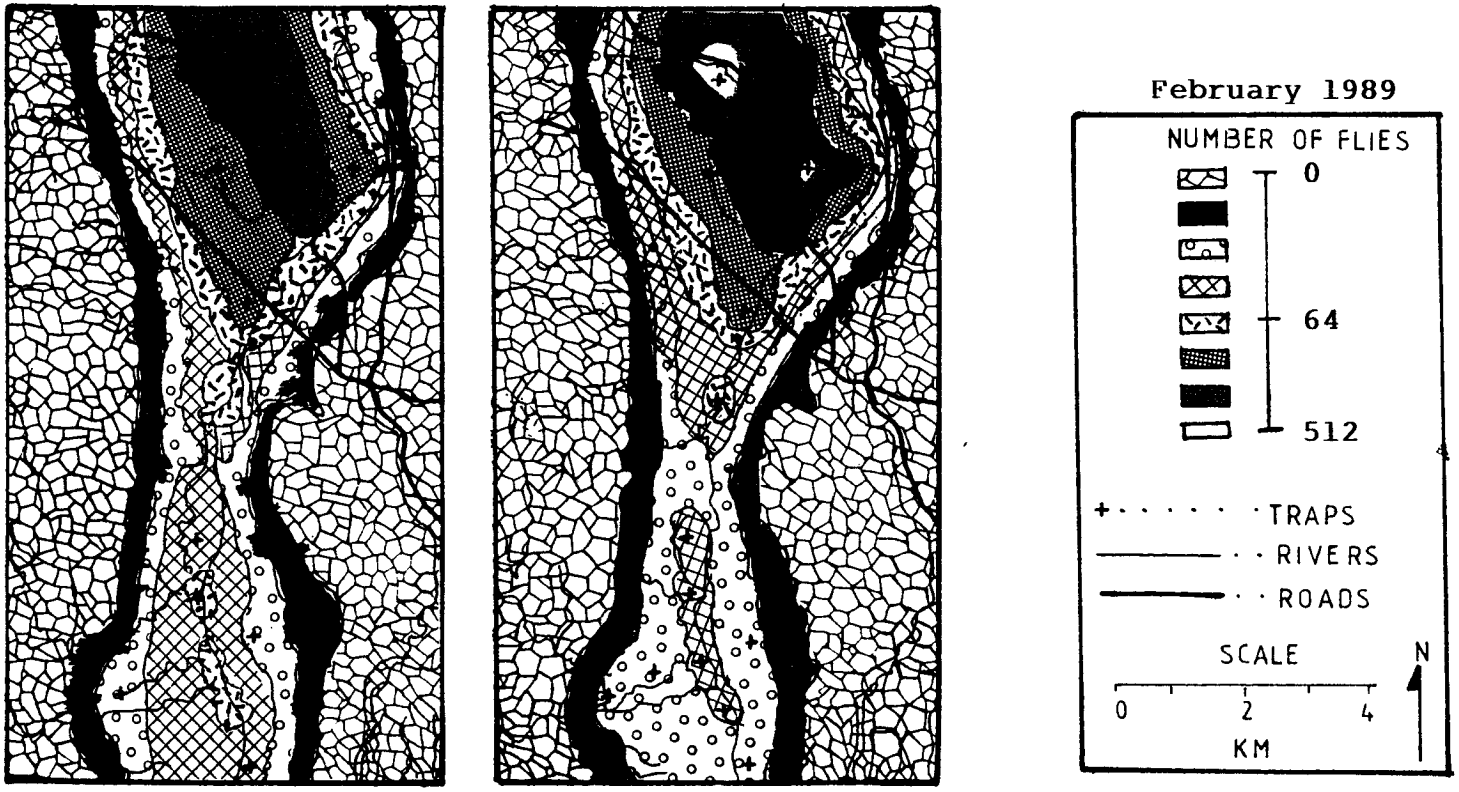
The penetrability of the barrier line of traps during the dry season was estimated from the rate at which marked flies released in the northern area were recaptured in the suppression zone.

12.3 RESULTS

The spatial distribution of G. pallidipes and G. longipennis in February and April 1989 is shown in Figures 11.2a,b and 11.3a,b. The density of these flies was higher in February when it was dry than in April when it was wet.

FIGURE 11.2a

Distribution of G.pallidipes in Nguruman in February 1989

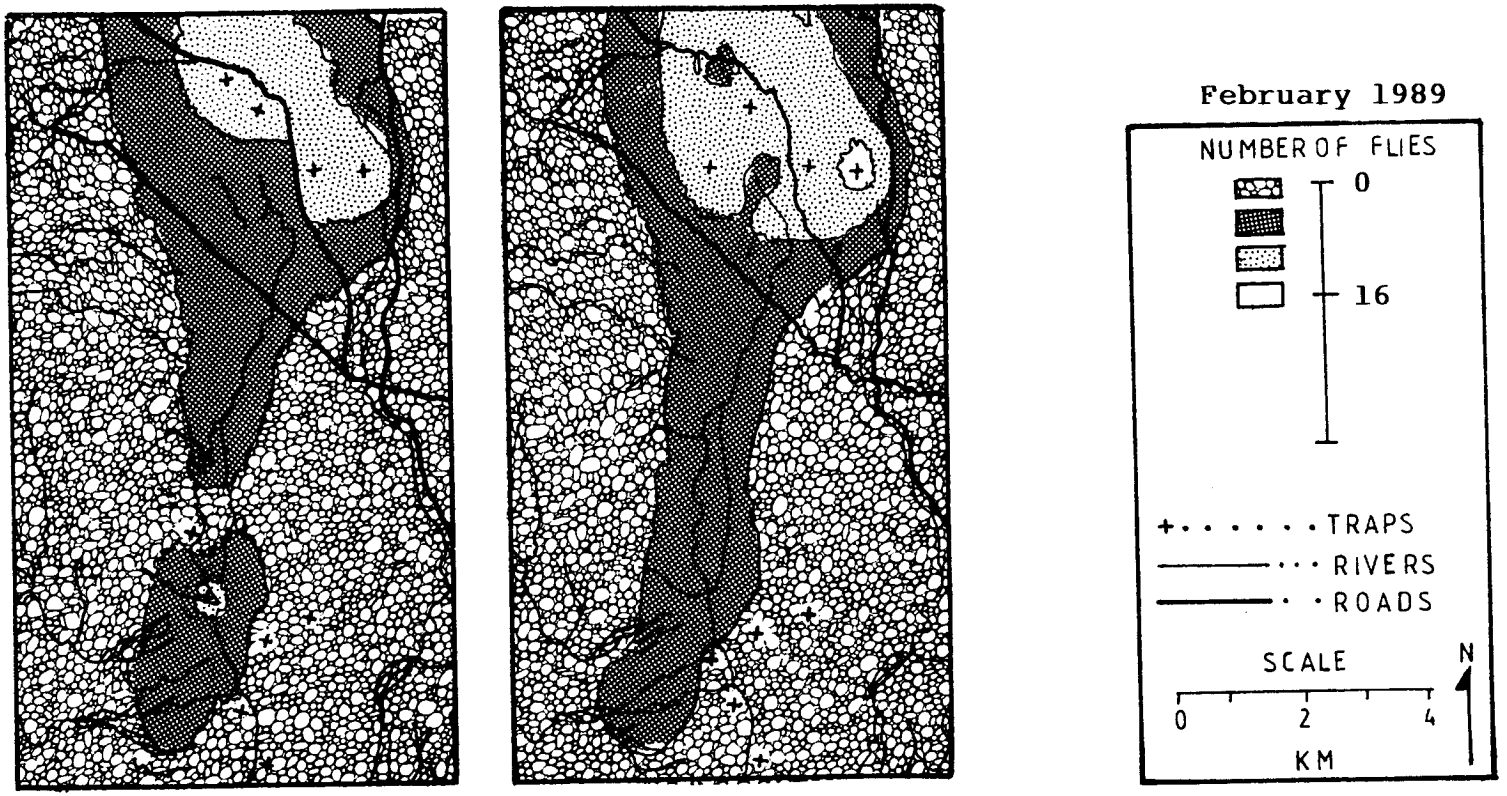


Female

Male

FIGURE 11.2b

DISTRIBUTION OF G.longipennis in Nguruman in February 1989



Female

Male

FIGURE 11.3a

Distribution of G.pallidipes in Nguruman in April 1989

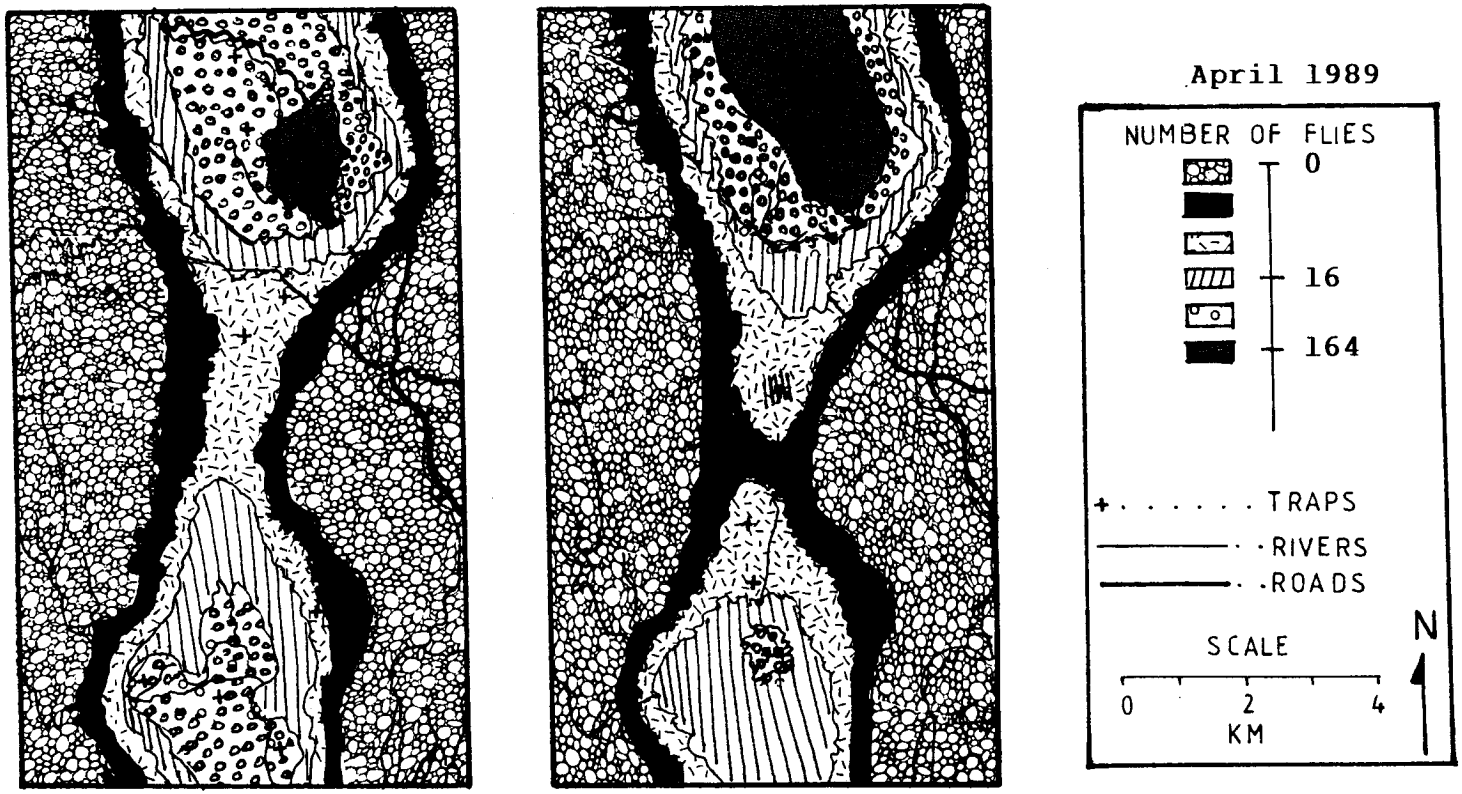


FIGURE 11.3b

Distribution of G.longipennis in Nguruman in April 1989

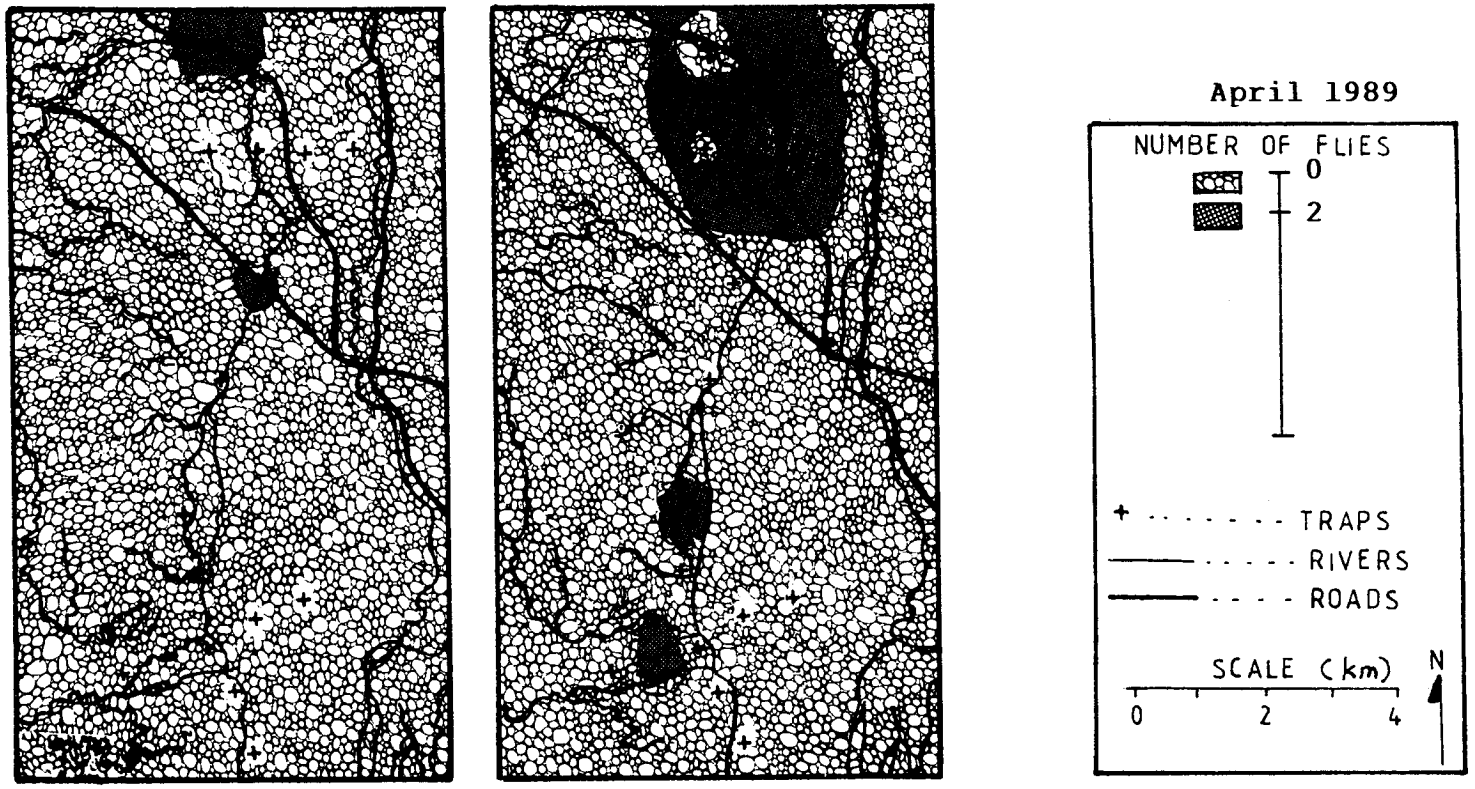


Table 11.1 shows recapture rates of marked G. pallidipes in August, September and November 1989. In all the three months about 9 in 1000 marked female G. pallidipes crossed the barrier to be recaptured in the suppression zone. About 4 in 1000 marked male G. pallidipes passed through the barrier in September, while no male G. pallidipes crossed the barrier in August and November. The overall number of females that crossed the barrier during the dry season, August to November 1989, was about 4 times that of males. An average of 4 male and 6 female G. longipennis was marked per day throughout the experiment, out of which none were recaptured in the suppression zone.

More male than female G. pallidipes were trapped in the northern area while more females than males were trapped in the suppression zone (Figures 11.2a and 11.3a), suggesting that female G. pallidipes were immigrating into the suppression zone and consequently reducing their numbers in the northern area while male G. pallidipes tended to stay in the northern zone.

The number of trapped G. longipennis is insufficient to suggest movement of this species

TABLE 11.1

Recapture rates of marked G. pallidipes during the dry season, August to November 1989.

Marking date	Sex	Number marked	Number recaptured per 1000
29-31.vii	Male	203	0
	Female	1135	9
6-8.ix	Male	795	4
	Female	1654	9
4-5.xi	Male	276	0
	Female	336	9
Combined	Male	1274	2
	Female	3125	9

immigrating into the suppression zone confirms observations made by Dransfield et al. (1990) in the same area in 1987 that at the onset of the short rains in November 1987, immigrant females constituted the great majority of the population in the suppression zone.

The barrier of a line of traps spaced about 100m apart in Nguruman does not eliminate the immigration of mainly female flies (Dransfield et al., 1990) but targets spaced about 30m apart in Zimbabwe have been used successfully to prevent re-establishment of tsetse flies (Vale et al., 1988). We need to look at the range of attraction of the baited Nguruman trap in order to enhance the efficiency of the barrier traps. In the following chapter we, therefore, examine the range of attraction and spacing of the baited Nguruman trap for use in control programs for tsetse flies.

CHAPTER 12

TSETSE FLIGHT AND THE RANGE OF ATTRACTION OF THE BAITED NGURUMAN TRAP

12.1 INTRODUCTION

It is generally assumed that tsetse flies move randomly in the absence of specific host stimuli (Vale, 1974a); and that in the presence of an odour plume, they tend to fly upwind (Gibson and Brady, 1988b; Bursell, 1984; 1987; Colvin, Brady and Gibson, 1889). Molyneux, Baldry and Fairhurst (1979) have presented both entomological and epidemiological evidence which supports the hypothesis that Glossina can be dispersed by wind. They noted that the effect of wind on tsetse dispersal was ignored by Bursell (1970a) and Glasgow (1970) in their reviews on dispersal. In view of these contrasting hypotheses and the inconclusive evidence on random dispersal of tsetse flies in chapter 8, a study was conducted in the Nguruman woodland to determine the effect of wind on the dispersal of G. pallidipes in this woodland.

Evidence in the previous chapter and from Dransfield et al. (1990) suggest that a line of baited Nguruman traps spaced about 100m apart does

not provide an effective barrier for tsetse flies. Hence, a series of experiments was initiated to determine the range of attraction of the baited Nguruman trap and to suggest an effective barrier for use in control campaigns for tsetse flies.

12.2 MATERIALS AND METHODS

Tsetse flight

The layout of the experiment is shown in Figure 12.1. Four Nguruman traps baited with acetone, octenol and cow urine were set at 100 and 50m from the central release point on each alternate day for 4 days from May 7 to 10, 1990. These traps were used to capture tsetse flies for marking and monitoring the direction the flies flew. The wind direction was monitored every 10 minutes using an automated Delta-T weather station set at the release point. In order to minimize stress on the flies a piece of damp cotton wool was placed inside the collection cage and traps were emptied every 45 minutes. Captured flies were marked with different patterns corresponding to release times with artist's oil paint and put in a marking cage. Recaptured marked flies were given an extra mark to identify them to a latest release time. A different colour was used on each experimental day. The marking cage was covered with a damp black cloth

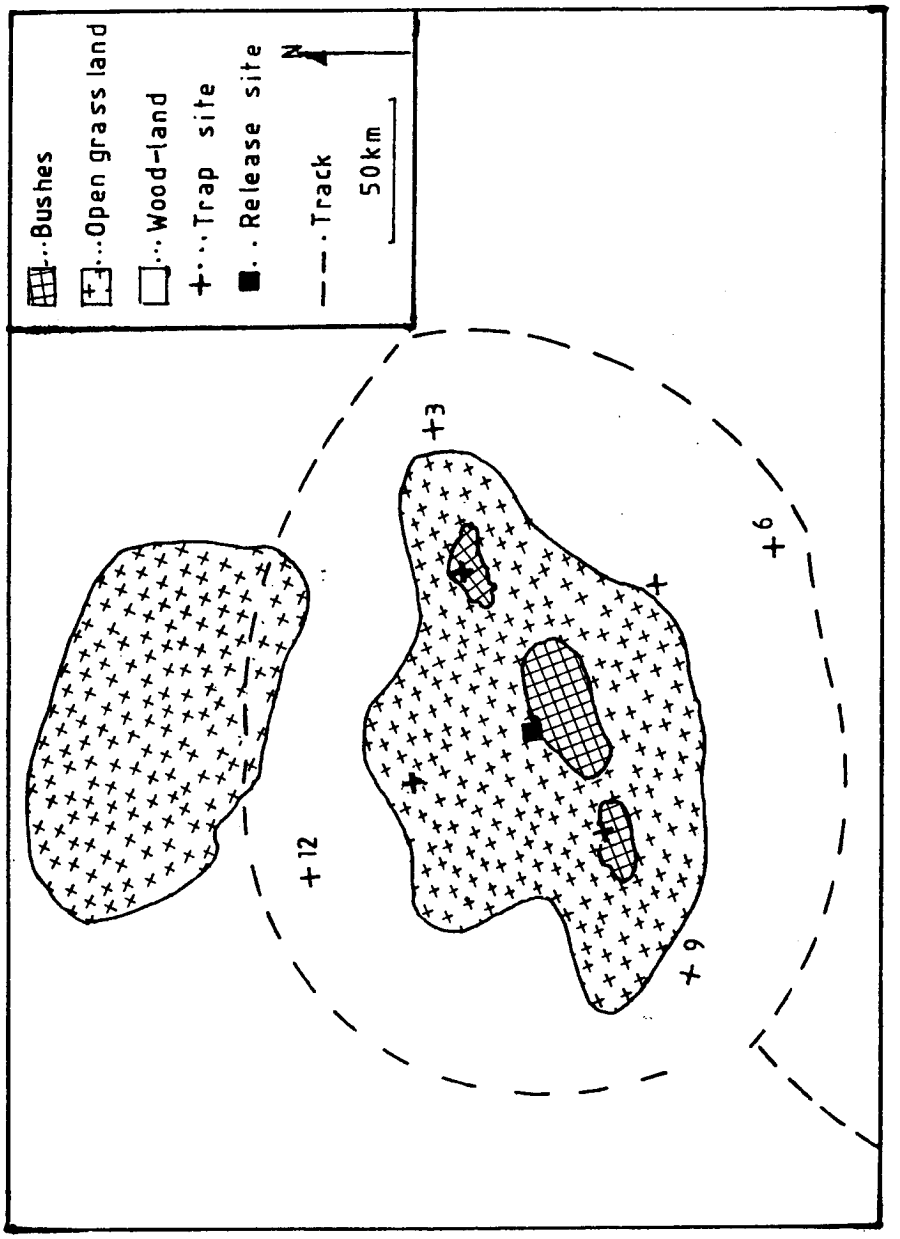


FIGURE 12.1

Map showing trap positions for tsetse flight experiment

to reduce stress and activity of the flies in order to prevent the marks rubbing off. The marked flies were released from the centre of the array of traps at 12:15, 13:45, 15:15 and 16:45h. The direction in which the released flies flew was checked every 45 minutes from the time of release by emptying the cages and checking for the marked flies; the captured flies were used for later release. Cages were emptied just before releasing the marked flies when both of these events occurred at about the same time.

Range of attraction

Biconical and Nguruman traps were used in the experiments to determine the range of attraction of the baited Nguruman trap. The bait used was a mixture of acetone, octenol and cow urine dispensed from separate containers placed close together.

The methods used for determining the range of attraction of a baited Nguruman trap are variations on the methods used by Vale (1977) and Dransfield (1984) in which interception traps are set at varying distances from an odour source. Another method used to determine the range of attraction of the baited Nguruman trap involves determining the flight direction of tsetse flies. In the absence of host

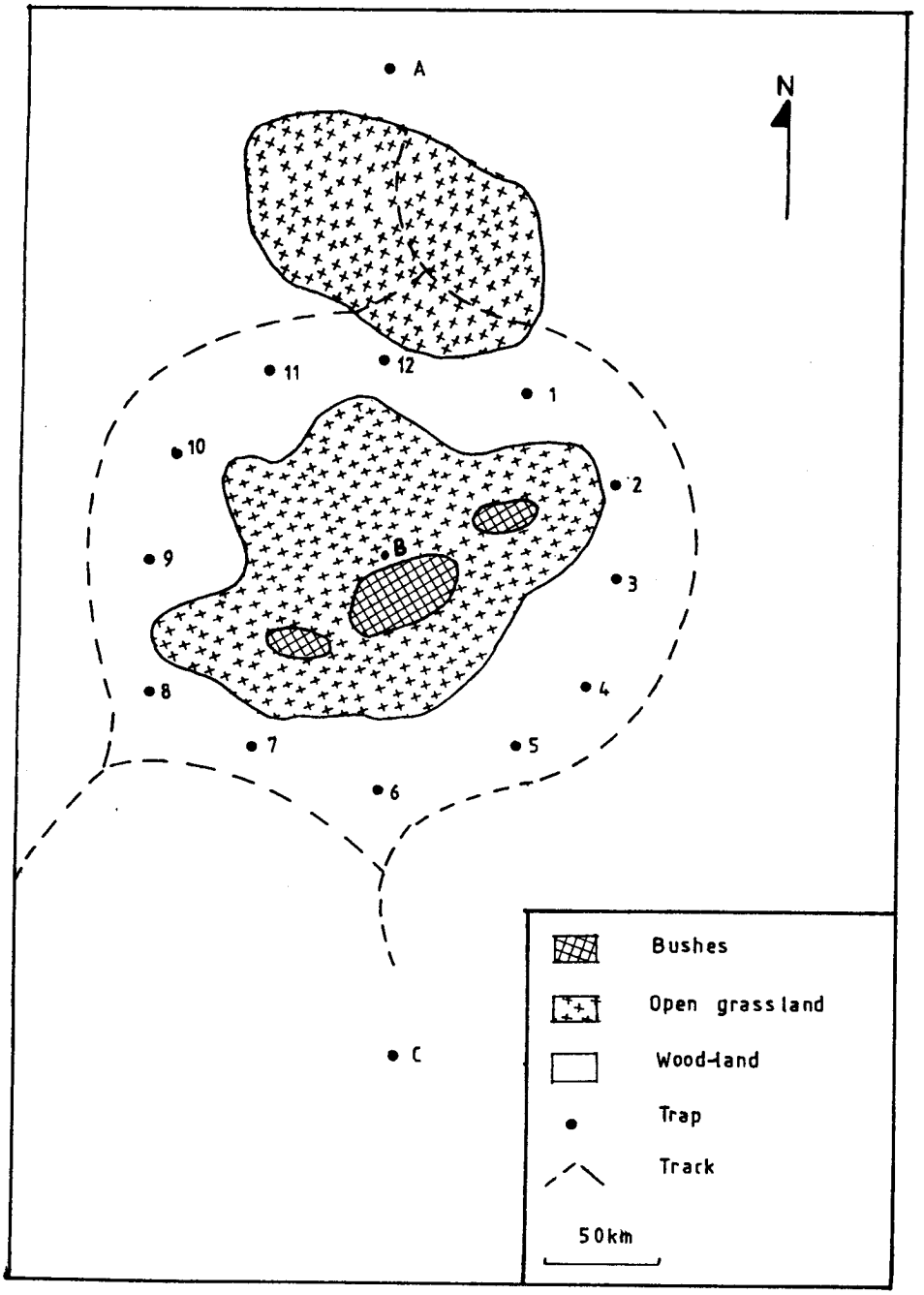
odour, flies tend to navigate down-wind; and in the presence of host odour, they tend to fly upwind (see for example Brady and Gibson, 1989).

In experiment A carried out between January 6 and 13, 1990 three baited Nguruman traps were set about 250m apart (A, B and C in Figure 12.2). The central trap B was surrounded by a circle of radius about 100m on which 0, 3, 6 and 12 baited Nguruman traps were set on day 1, 2, 3 and 4, respectively. The traps around the circle were presumed to act as a barrier to the central trap. A sketch map showing trap positions is depicted in Figure 12.2.

The next experiment B was carried out between March 3 and 10, 1990. The design of this experiment was similar to that of experiment A except that odours were set along the circle at about the 12 hour clock positions at the very first day. The following day, 12 Nguruman traps were set alongside the 12 odour dispensers: giving an intertrap spacing of about 50m along the circular barrier. On the third and subsequent days, four traps on hour positions 12, 3, 6 and 9 were kept in the same positions together with their odours. The adjacent traps to each of these four traps together with their odours were

FIGURE 12.2

Map showing trap positions for range of attraction experiment



brought closer by about 10m to each of the four traps each day: giving a within group of intertrap spacing of about 40, 30, 20 and 10m and an intergroup spacing of traps of about 70, 90, 110 and 130m for the 3rd, 4th, 5th and 6th day, respectively.

Experiment C was run for 5 days between April 8 and 15, 1990 in a woodland 100m west of RS4 (see Figure 4.1). A line of 15 traps with the central trap being a Nguruman trap and the rest being biconical traps were set on day 1 with no baits. On the second and subsequent days, the Nguruman trap was baited while the biconical traps remained unbaited. The traps were erected 10m apart along the north-south direction.

The site effect was presumed to be the main confounding factor in the treatment (intertrap spacing) comparison in experiments A and B. Hence, experiment D which was carried out between July 18 and 25, 1990 was designed to remove the effect of this confounding factor from the treatment effect. Experiment D was carried out on the same site on which experiments A and B were conducted. The within group trap spacings were 0, 5, 10, 15 and 20m with a different spacing being used each day in each group

of traps giving a Latin square design. The effects of trap spacing, site and day can then be separated, assuming that there is no Site*Day interaction (Winer, 1971). Throughout this experiment the central trap in each group of traps remained baited while the two adjacent traps were unbaited.

Analysis

Binomial distribution

Consider a situation in which we release n tsetse flies from the same point and suppose that each fly flies either up- or down-wind. Let p be the probability of flying upwind, q the probability of not flying upwind. If we assume that p is constant each time a fly takes off and that the direction one fly takes is not affected by the direction taken by any other fly; we have a Bernoulli process, and the distribution of flies caught upwind will be binomial. The probability of catching x flies upwind out of n released tsetse flies, is then (Sokal and Rohlf, 1981)

$$p(x) = (n!/((n-x)! * x!)) * q^{(n-x)} * p^{x}$$

The data in experiment C were adjusted for site effect by expressing catches as proportions of the

first day catch. Data in experiments A and B were expressed as ratios of catches in trap B to total catches in traps A and C, total catches in traps around the circle to total catches in traps A and C, catches in trap B to total catches in traps around the circle, and catches in the central trap to total catches in the two adjacent traps around the circle. Data in experiment D were subjected to a logarithmic transformation to the base 10 before analyzing variability of catches using the analysis of variance method.

12.3 RESULTS

Tsetse flight

The distribution of recaptures in traps set on 50 and 100m radii from the central release point is shown in Table 12.1. A two-fold increase in the recaptures was observed when the traps were set on a 50m radius as compared to recaptures when traps were set on a 100m radius.

Figure 12.3 shows the distribution of wind speeds between 15:00 and 18:30h. The most frequent wind speed was about 0.6 m/s. During this time, the prevailing winds were south-westerly as shown in Figures 12.4a,b,c,d. About 79% of female and 63% of

TABLE 12.1

Distribution of recaptures in traps along 50 and 100m radius from the release point from May 7 to 10, 1990.

	100m		50m	
	Male	Female	Male	Female
Marked	267	692	320	914
Recaptured	17	27	38	56
% recaptured	6.4	3.9	11.9	6.1

FIGURE 12.3

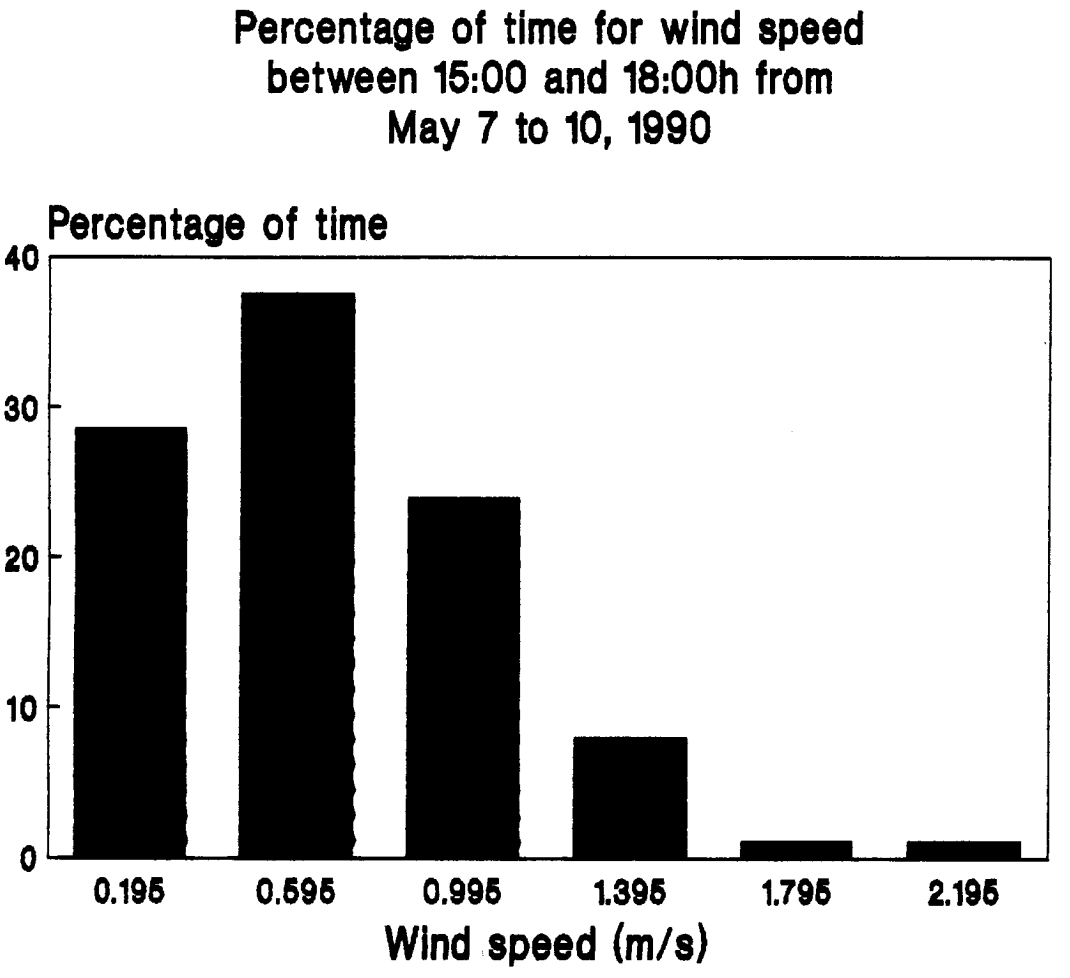

Percentage of time for wind speed
between 15:00 and 18:00h from
May 7 to 10, 1990
Percentage of time
40
30
20
10
0
0.195
0.595
0.995
1.395
1.795
2.195
Wind speed (m/s)

FIGURE 12.4a

Wind runs for wind speeds of more than 0.5 m/s from 12:00 to 18:30h (May 7, 1990)

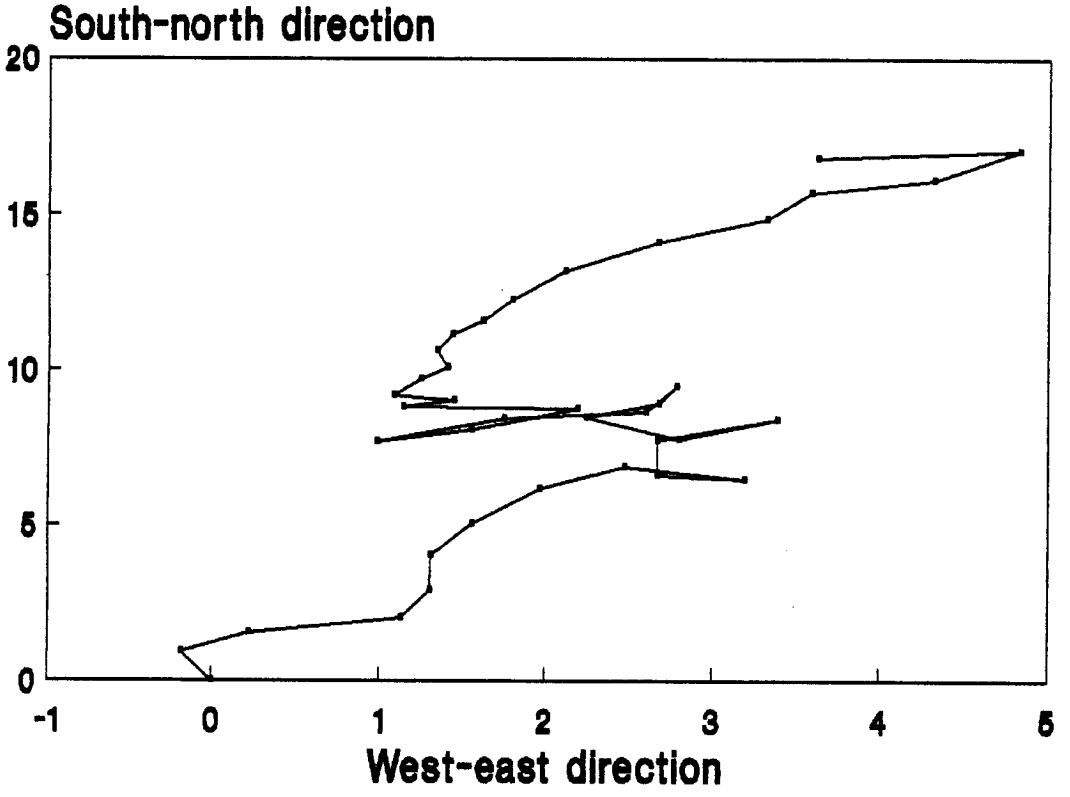


FIGURE 12.4b

Wind runs for wind speeds of more than
0.5 m/s from 12:00 to 18:30h
(May 8, 1990)

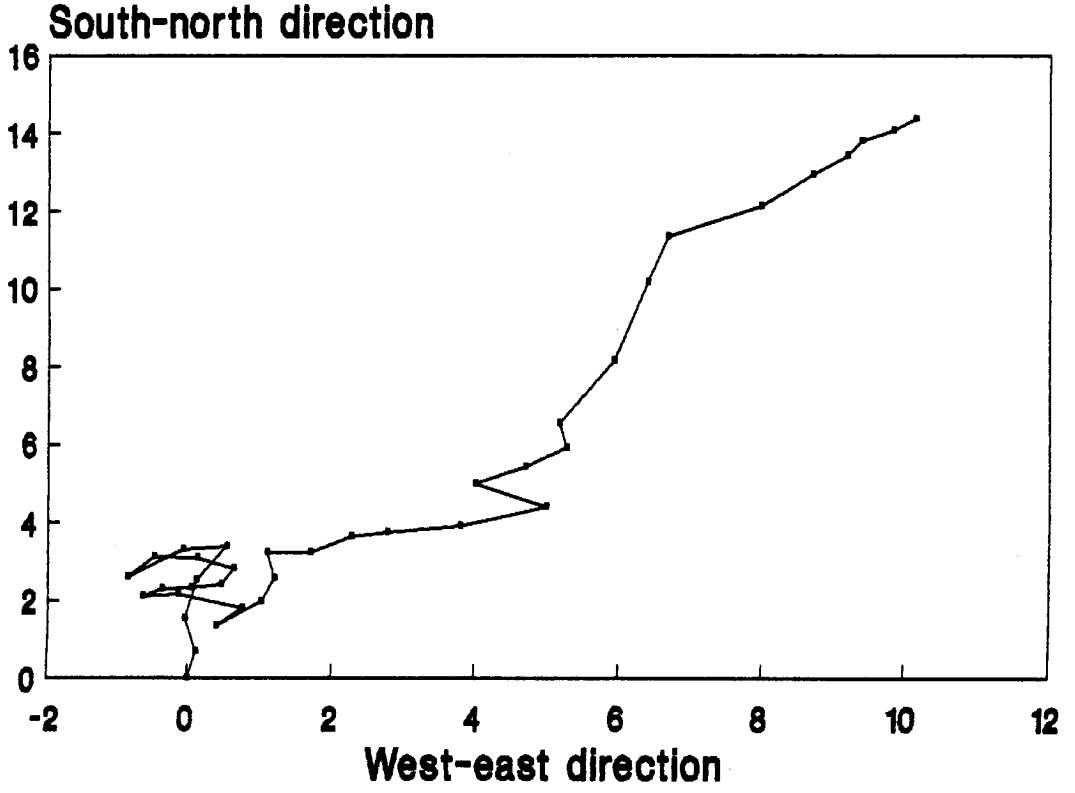


FIGURE 12.4c

Wind runs for wind speeds of more than
0.5 m/s from 12:00 to 18:30h
(May 9, 1990)

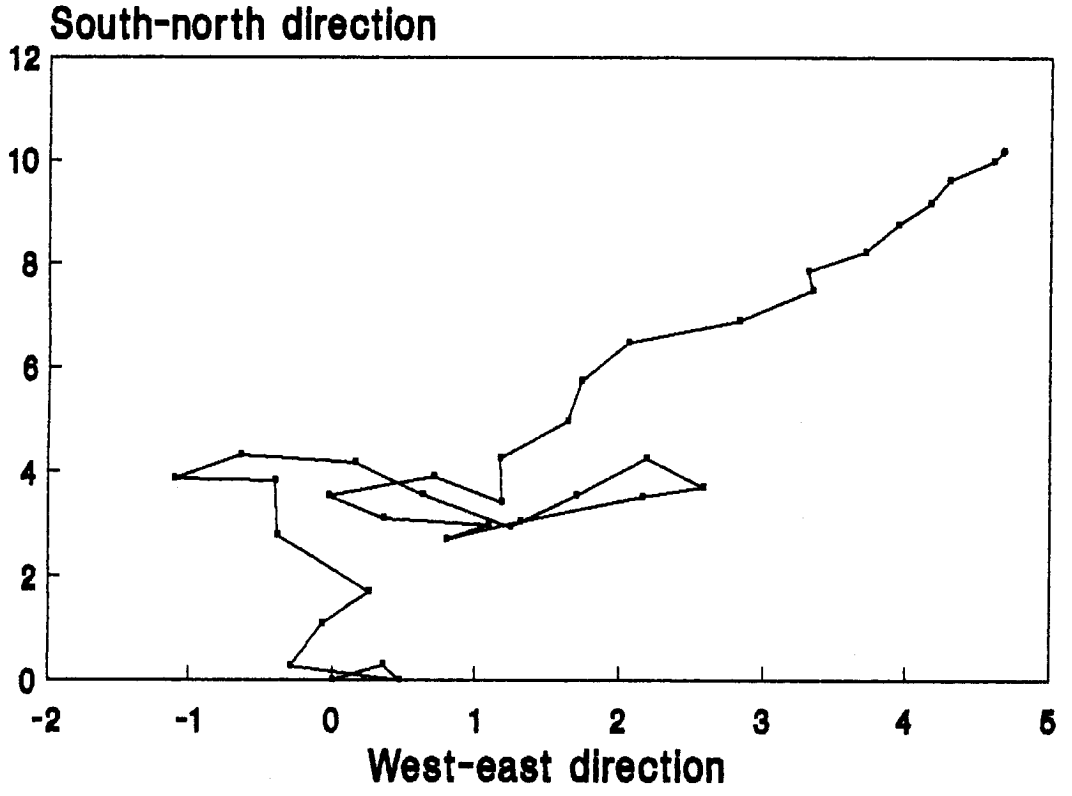
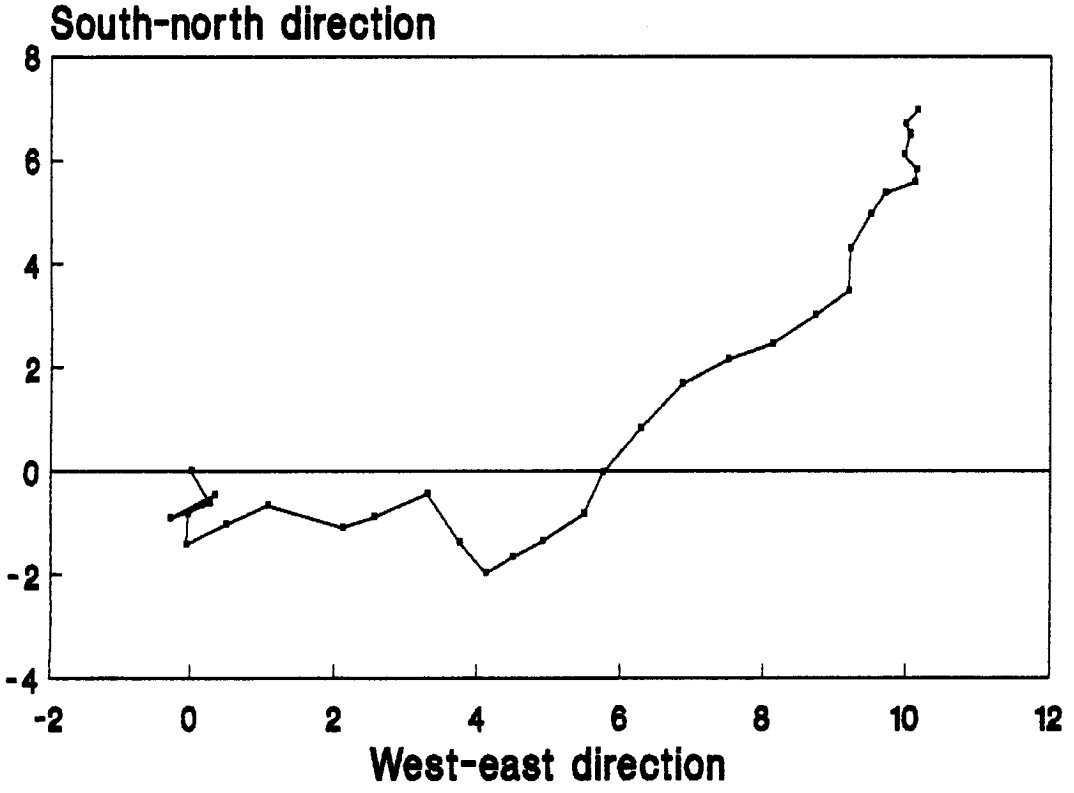


FIGURE 12.4d

Wind runs for wind speeds of more than 0.5 m/s from 12:00 to 18:30h (May 10, 1990)



male G. pallidipes flew downwind to be recaptured in traps at positions 3 and 12 (Table 12.2). A Binomial distribution was used to determine the statistical significance of downwind flight. The evidence of a bias for males flying downwind was not statistically significant ($p>0.05$). It is evident that a statistically significant greater number of females flew downwind than upwind ($p<0.001$).

Range of attraction

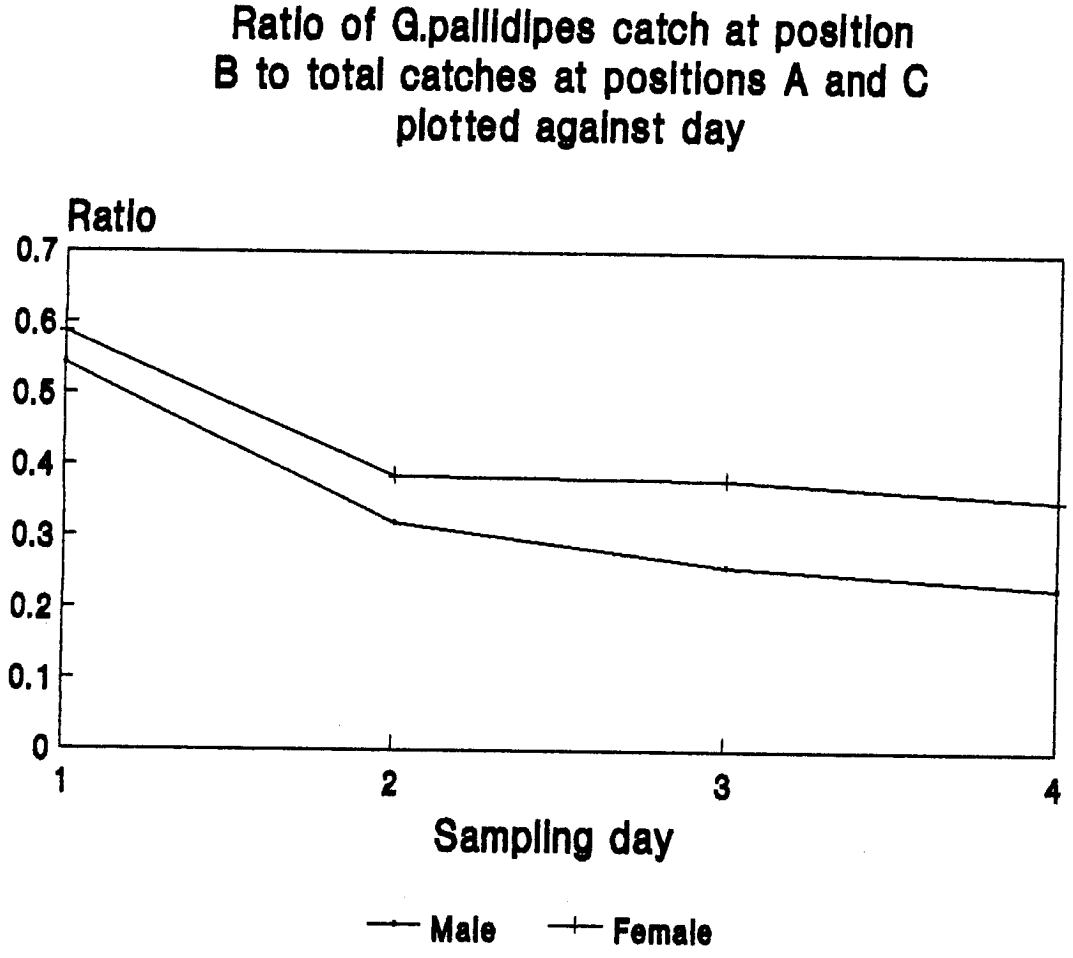
In the analysis of the data of experiment A (Figure 12.5a.3), in which we have plotted the ratio of catches in trap B (central trap) to the total catches in traps around the circle (<1-12>, barrier traps), the observed decline in the catches of female G. pallidipes in trap B was not as expected (we expected a sharper decline than observed when we increased the number of barrier traps from 3 to 6 and then to 12) as we may have been drawing in more female flies each day along the circular barrier by increasing the number of traps and the odour plume (Figure 12.5a.2), while the catches of female G. pallidipes at the central trap remained almost constant when the number of barrier traps was increased from 3 to 6 and then to 12 on sampling days 2 to 4 (Figure 12.5a.1). A reduction in the numbers

TABLE 12.2

Distribution of recaptures between 15:00 and 18:30h from May 7 to 10, 1990 when winds were predominantly south-westerly (Percentages in brackets).

Direction		Male (%)	Female (%)
Downwind	Trap 3	14	25
	Trap 12	8	8
	Combined	22 (63)	33 (79)
Upwind	Trap 6	10	9
	Trap 9	3	0
	Combined	13 (37)	9 (21)

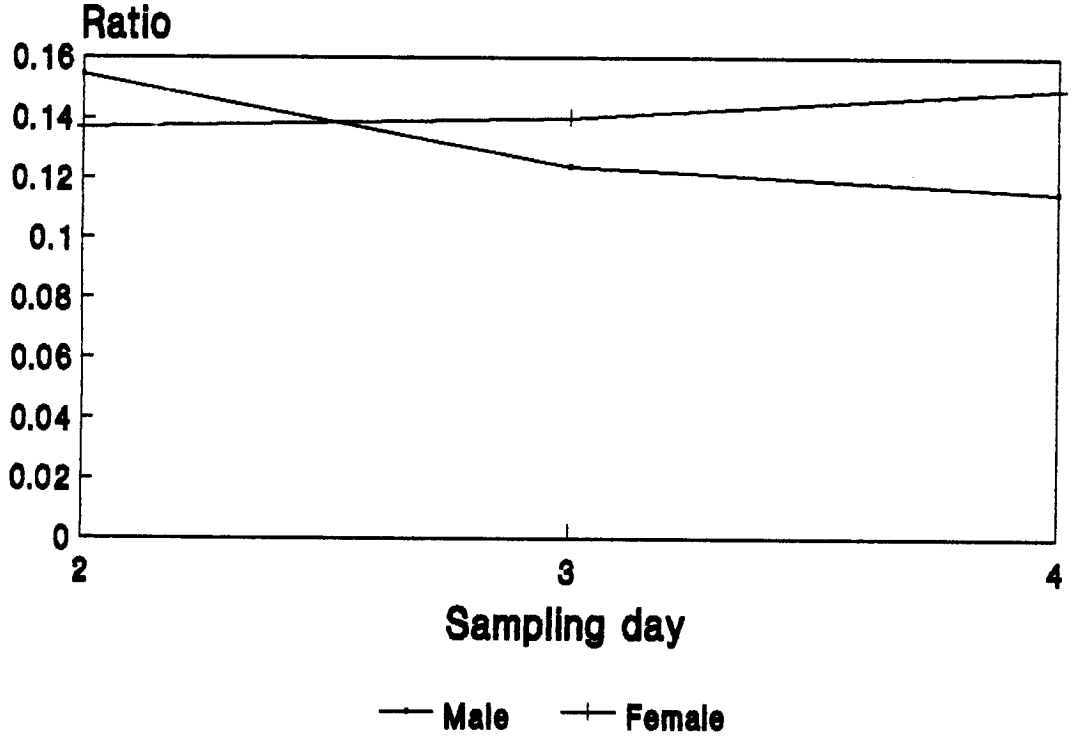
FIGURE 12.5a.1



Analysis of catches in Experiment A

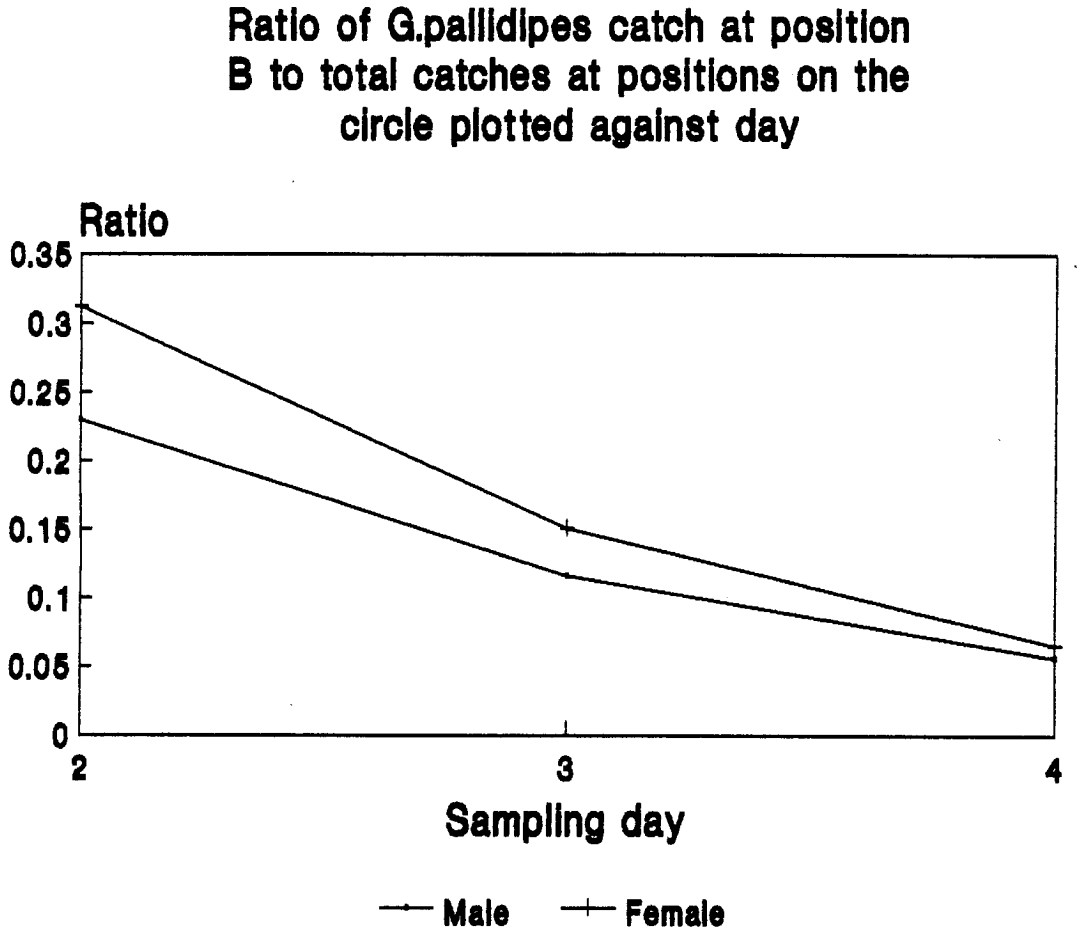
FIGURE 12.5a.2

Ratio of G.pallidipes total catches at positions on the circle to total catches at positions A and C plotted against day



Analysis of catches in Experiment A

FIGURE 12.5a.3

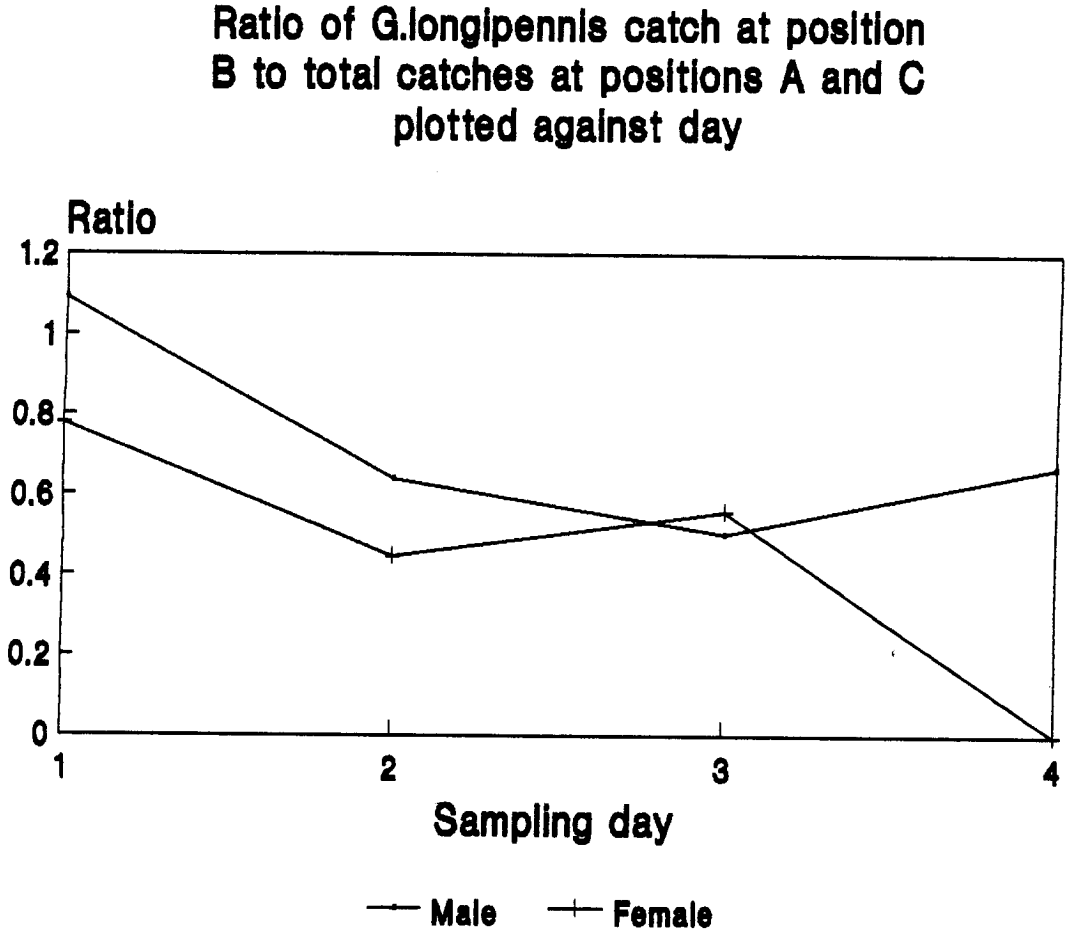


Analysis of catches in Experiment A

of male G. pallidipes captured at the barrier (Figure 12.5a.2) was slower than a reduction at the central trap (Figure 12.5a.1), hence the observed reduction in males in Figure 12.5a.3. The data for G. longipennis is shown in Figures 12.5b.1,2,3. It appears that the 12 traps surrounding the central trap formed an effective barrier for female G. longipennis. But this was partly because catches of G. longipennis were very small (maximum of 24/trap per day) in number. More importantly, no single female G. longipennis was captured at the central trap when the barrier was composed of 12 traps. Given that the catches were small in number, it is not possible to draw conclusions about the efficacy of barriers for G. longipennis.

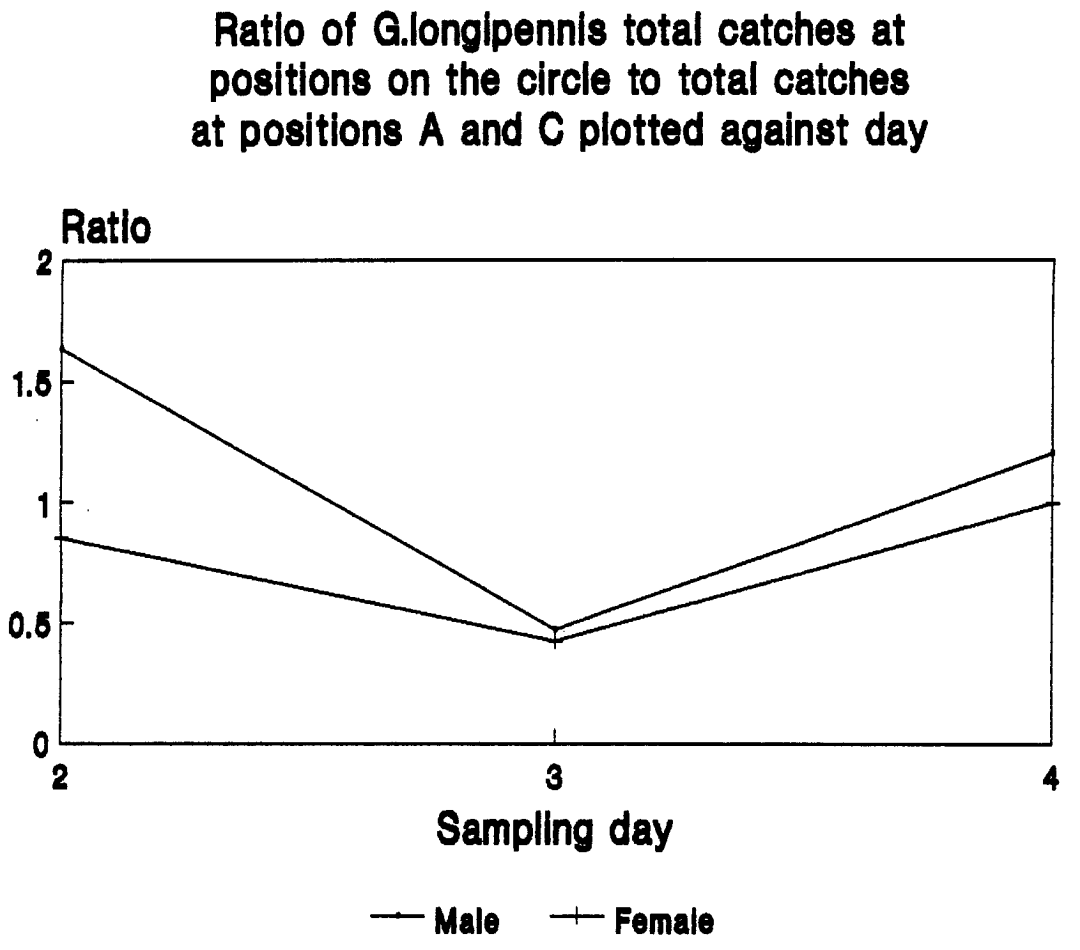
In the analysis of data of experiment B, no trend emerged from the catches of G. pallidipes at the central trap (Figure 12.6a.1). A downward trend for male G. pallidipes captured at the barrier was observed (Figure 12.6a.2), while no clear trend emerged for the number of female G. pallidipes captured at the barrier. With a within group intertrap spacing of about 30m and an intergroup spacing of traps of about 90m, the central trap captured fewer flies than the traps in the barrier

FIGURE 12.5b.1



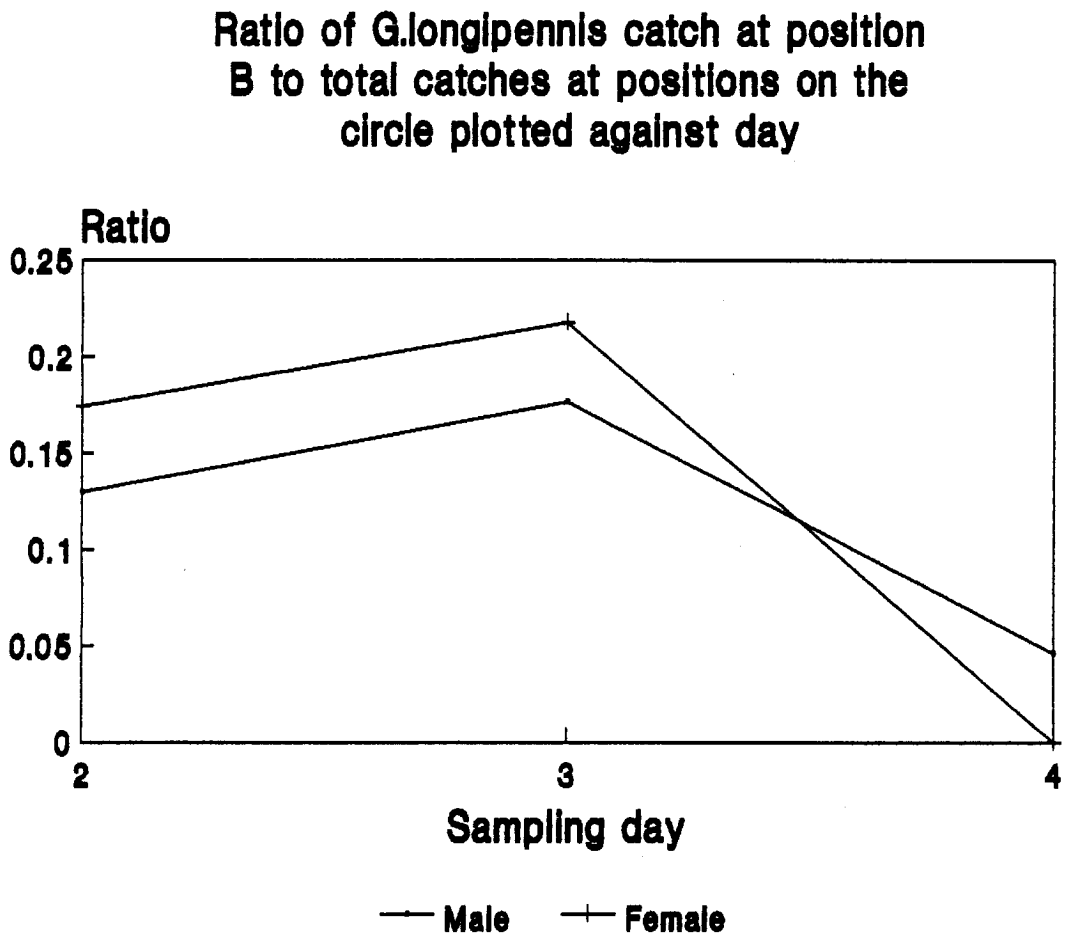
Analysis of catches in Experiment A

FIGURE 12.5b.2



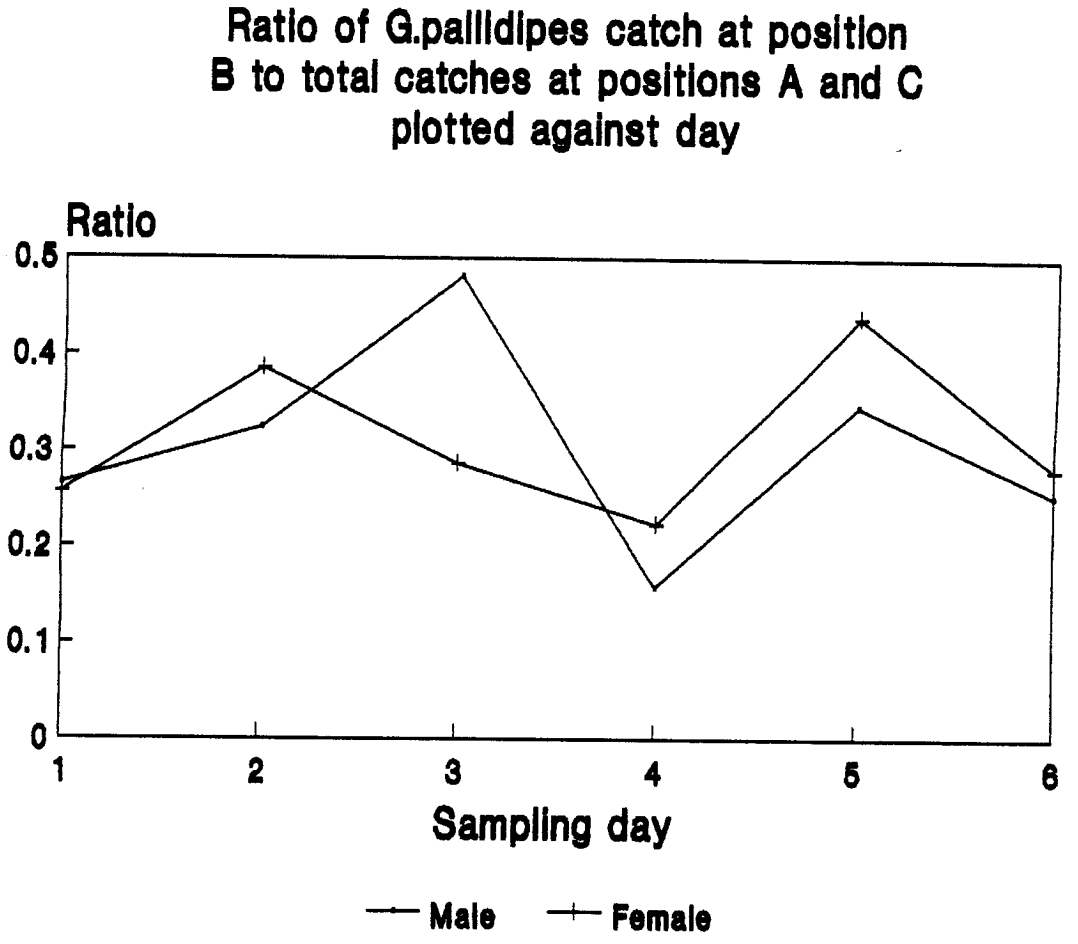
Analysis of catches in Experiment A

FIGURE 12.5b.3



Analysis of catches in Experiment A

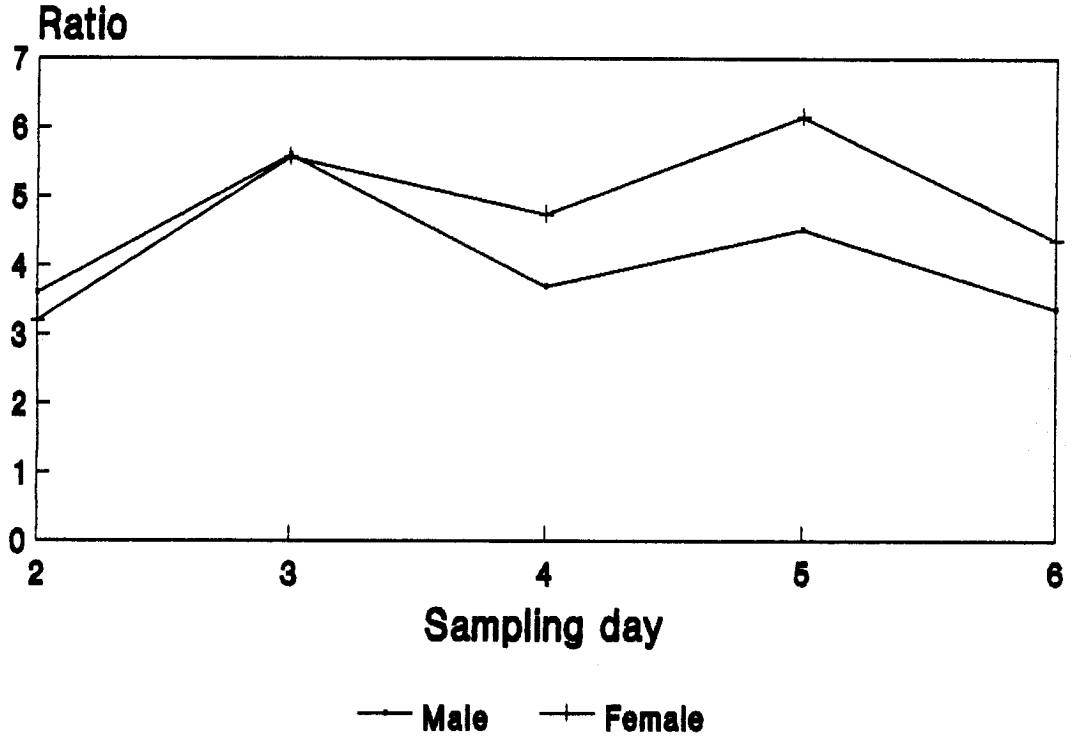
FIGURE 12.6a.1



Analysis of catches in Experiment B

FIGURE 12.6a.2

Ratio of G.pallidipes total catches at positions on the circle to total catches at positions A and C plotted against day



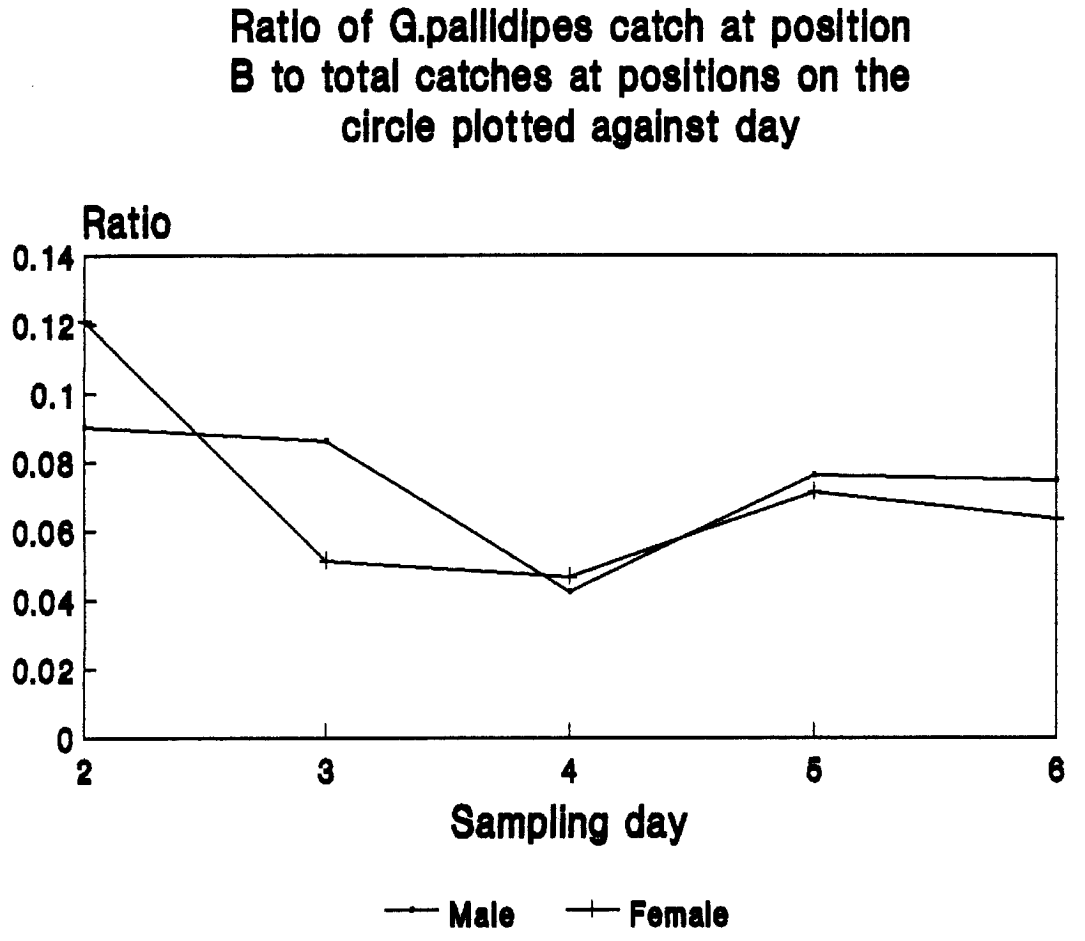
Analysis of catches in Experiment B

(Figure 12.6a.3), suggesting that this intertrap and intergroup spacing may make an effective trap barrier.

The central trap captured fewer G. longipennis than did the traps in the barrier when the within group intertrap spacing in the barrier was about 20m and the intergroup spacing of traps was about 110m (Figure 12.6b.3). Apparently, no trend was observed for G. longipennis caught at the barrier when the within group intertrap distance in the barrier was decreased (Figure 12.6b.2). A downward trend was observed for female G. longipennis caught at the central trap when the within group intertrap distance was decreased in the barrier (Figure 12.6b.1). But these results must be interpreted with caution as catches of G. longipennis were not more than 12/trap per day.

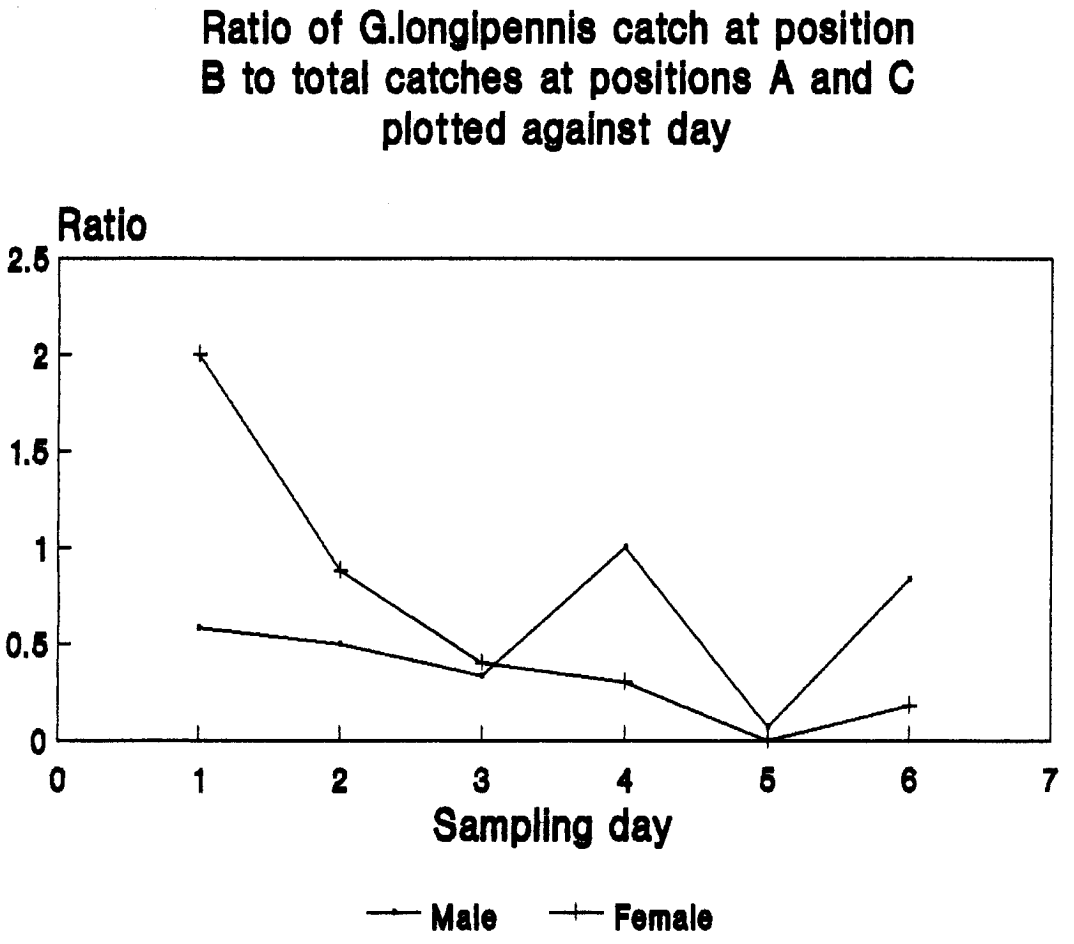
Comparison of catches in the central traps (12, 3, 6 and 9) with those in the adjacent traps (1, 2, 4, 5, 7, 8, 10 and 11) suggests that the threshold range of attraction for the baited Nguruman trap for G. pallidipes is about 20m (Figure 12.7a). Increasing or decreasing this intertrap spacing resulted in the central traps catching more G.

FIGURE 12.6a.3



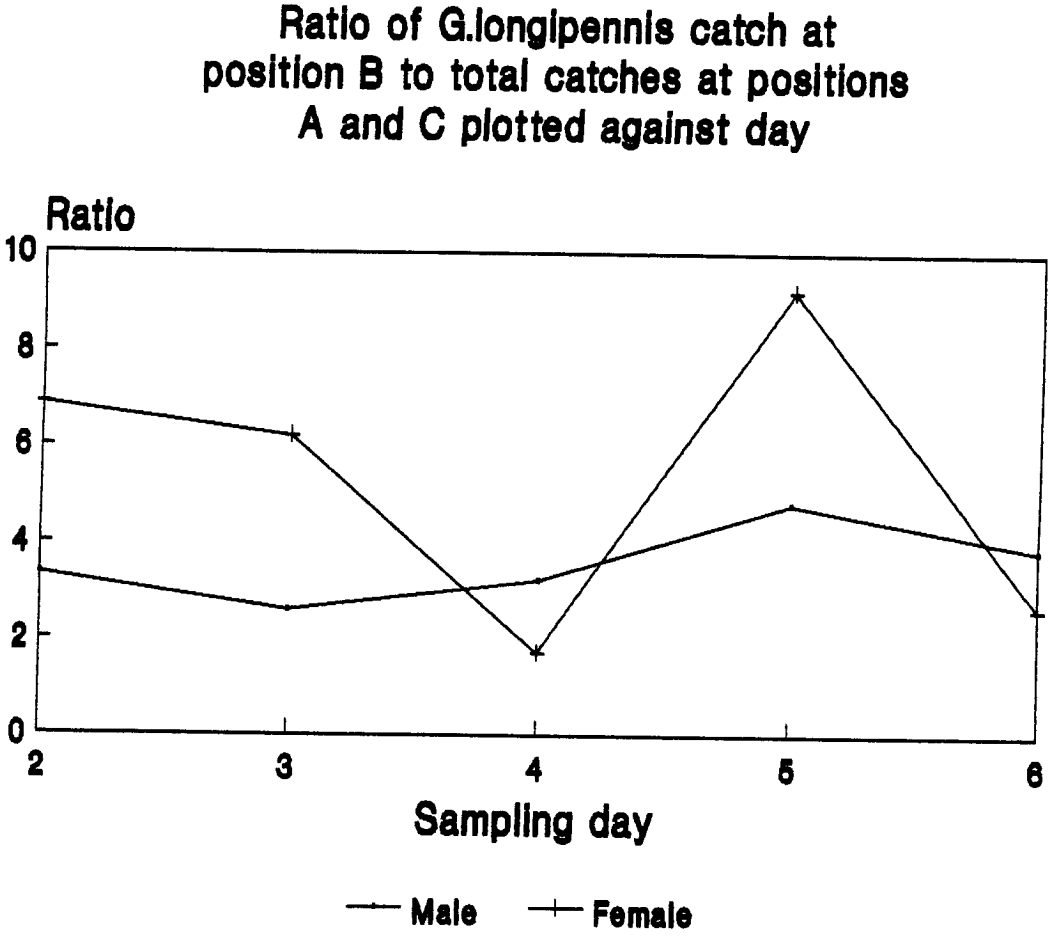
Analysis of catches in Experiment B

FIGURE 12.6b.1



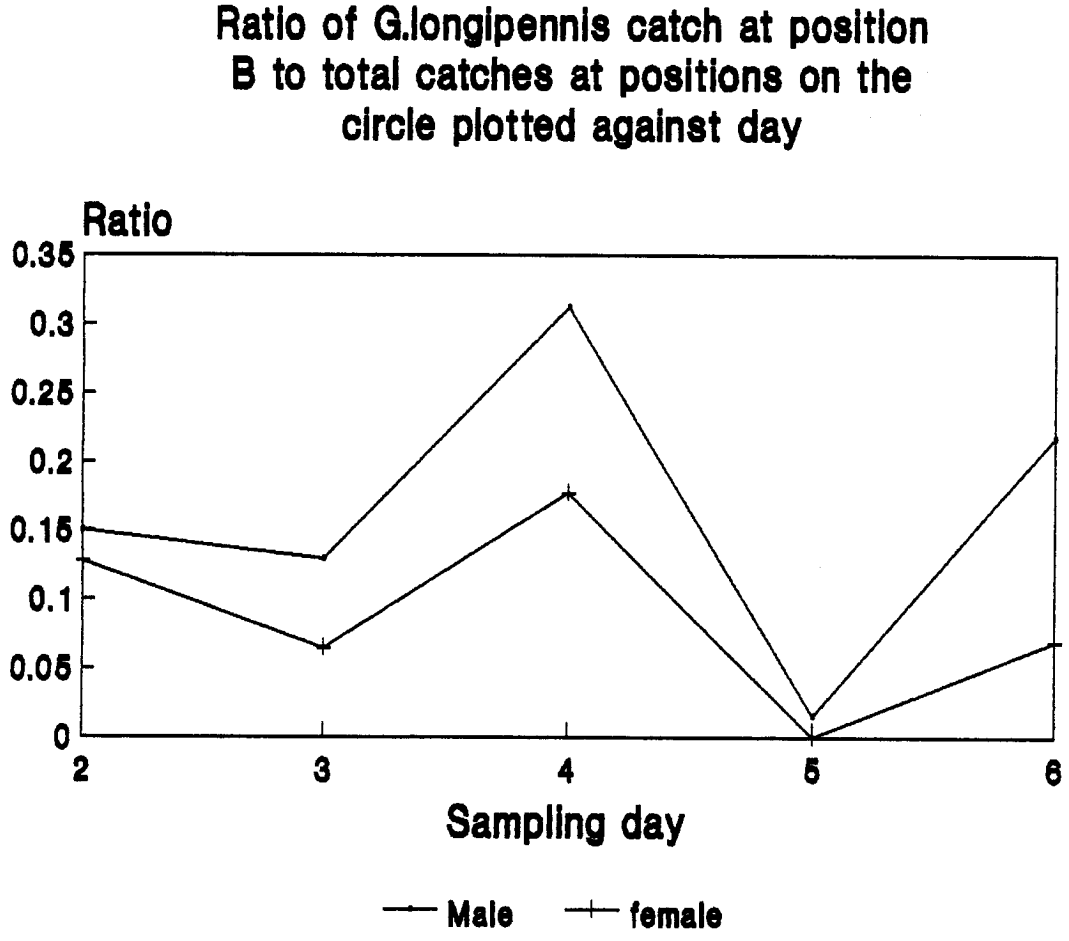
Analysis of catches in Experiment B

FIGURE 12.6b.2



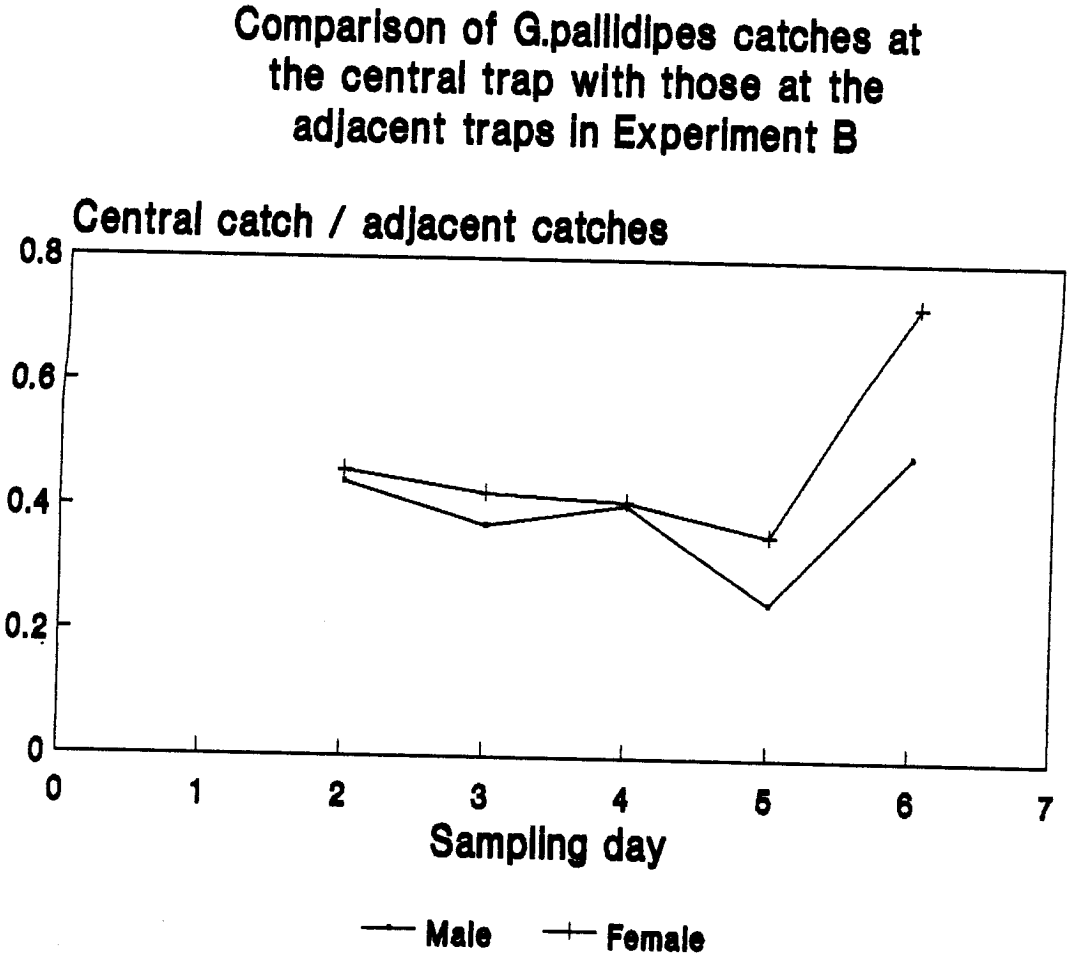
Analysis of catches in experiment B

FIGURE 12.6b.3



Analysis of catches in Experiment B

FIGURE 12.7a


Comparison of G.pallidipes catches at the central trap with those at the adjacent traps in Experiment B
Central catch / adjacent catches
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
Sampling day
Male
Female

pallidipes than the adjacent traps. This is in fact about the tsetse visual range. It seems that given the low wind speeds, we are unable to test the odour range of attraction. It appears visual attraction is more important than odour attraction in the Nguruman woodland. It is not possible to suggest the range of attraction of baited Nguruman traps for G. longipennis from our analysis (Figure 12.7b).

Analysis of experiment C data (Figure 12.8) suggests that the range of attraction of the baited Nguruman trap for male G. pallidipes extends to between 15 and 20m and that of females between 20 and 25m. Again, this is about the visual range of attraction.

Analysis of variance of log-transformed data of experiment D is shown in Tables 12.3a,b. The intertrap spacing was not a significant factor. Nevertheless, the decline and increase in catches at the central trap suggests that a baited Nguruman trap has an optimum range of attraction for both sexes of G. pallidipes of about 15m (Figure 12.9).

FIGURE 12.7b

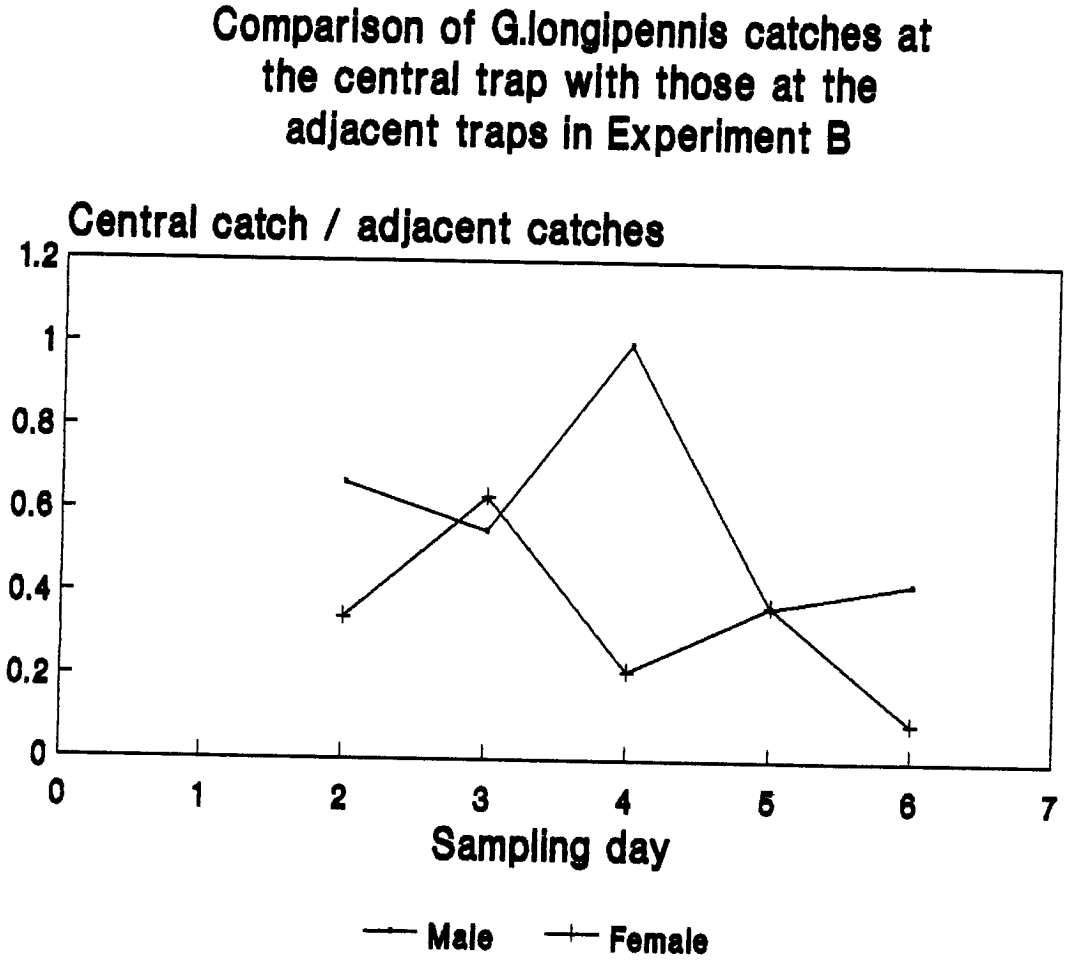
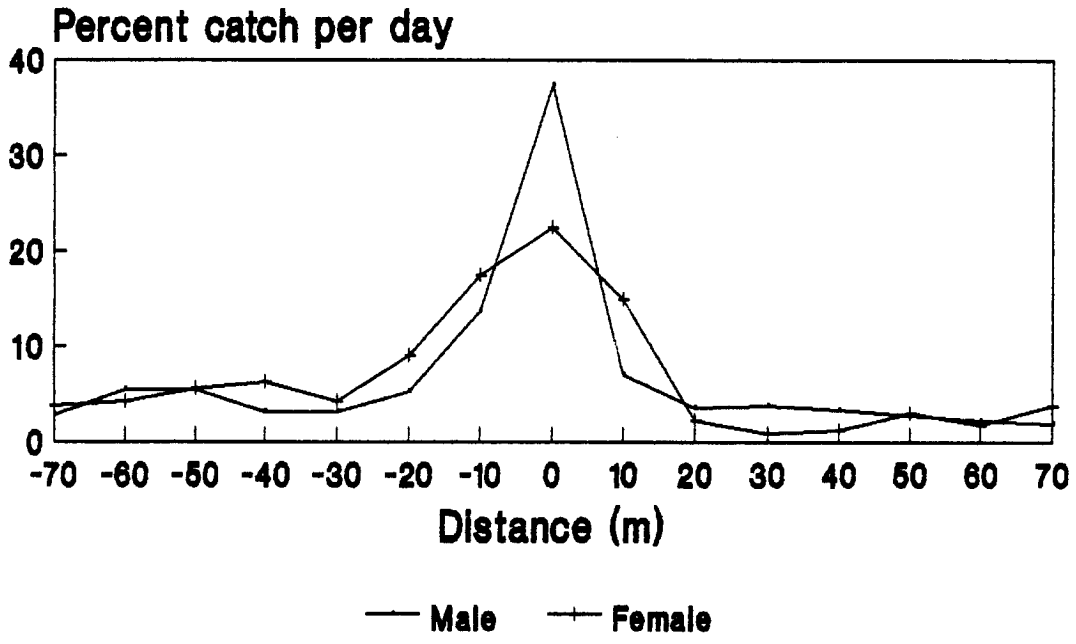

Comparison of G.longipennis catches at the central trap with those at the adjacent traps in Experiment B
Central catch / adjacent catches
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
Sampling day
Male
Female

FIGURE 12.8

Percent catch of G.pallidipes plotted against distance from the central trap (Experiment C)



Negative distance implies distance of a trap lying to the left of the central trap

TABLE 12.3a

Analysis of variance of G. pallidipes data from Experiment D.

Source of variance	d.f.	Male MS	Male F-ratio	Female MS	Female F-ratio
Day	4	0.090	<1	0.207	2.5
Site	4	0.296	3.1*	0.450	5.3**
Intertrap spacing	4	0.161	1.7	0.125	1.5
Residual	52	0.093		0.084	

TABLE 12.3b

Analysis of variance of G. longipennis data from Experiment D.

Source of variation	d.f.	Male MS	Male F-ratio	Female MS	Female F-ratio
Day	4	0.182	2.3	0.181	1.8
Site	4	0.093	1.2	0.077	<1
Intertrap spacing	4	0.087	1.1	0.081	<1
Residual	52	0.079		0.103	

FIGURE 12.9

Log-number of G.pallidipes caught in the central trap plotted against the within group intertrap spacing (Experiment D)