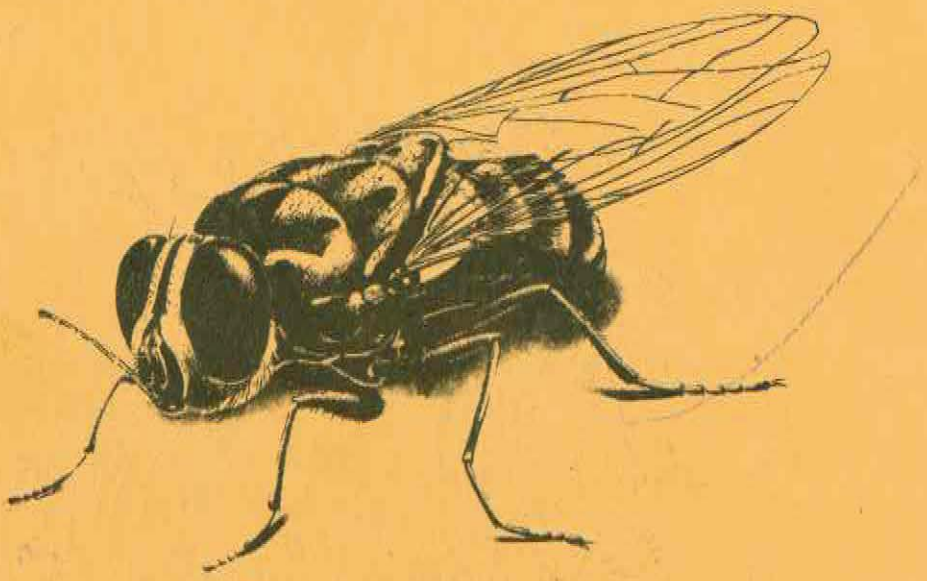
ABSTRACTS



INTERNATIONAL STUDY WORKSHOP ON tsetse population and behaviour

DUDUVILLE
Nairobi, Kenya
6–11 August 1989

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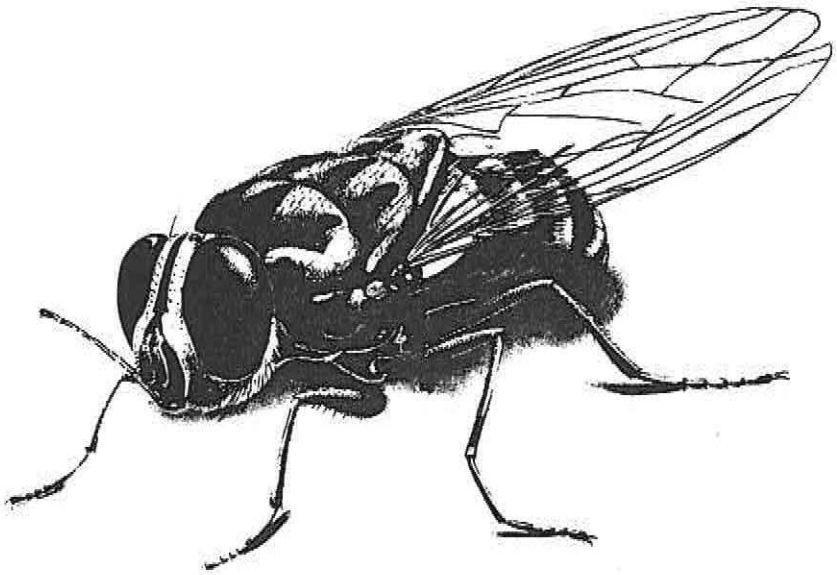

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Disease Transmission

SPECIATION AND SUBSPECIATION IN NANNOMONAS AND ITS EPIDEMIOLOGICAL SIGNIFICANCE

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Trypanosoma congolense and T. simiae have been the two recognized species within the subgenus Nannomonas. T. congolense is pathogenic to cattle and the small ruminants but not to pigs, while T. simiae causes disease only in pigs. The two species are difficult to distinguish from each other because both share the same developmental cycle in the tsetse fly and are broadly similar morphologically. However, their isoenzyme and DNA characteristics are quite different. Even more confusing is the fact that T. congolense itself is composed of a number of "strains", or types; historically the different types of T. congolense were often considered as separate species by different workers.

Now isoenzyme and DNA characterization show that T. congolense is composed of at least three different types, which are probably equivalent to subspecies. Furthermore, evidence for another species within the subgenus Nannomonas has come recently from isolates from tsetse fly midguts in The Gambia.

Specific DNA probes have now been produced for the different kinds of Nannomonas. With these, it is now possible to identify the different infections from midgut dissections of wild tsetse flies. This should now facilitate an elaborate study to determine the distribution and prevalence of the different types across Africa, their association with the different species of tsetse fly, and the significance of each in the causation of disease in domestic stock. The information gained will also help clarify the taxonomic status of each type within the subgenus.

IDENTIFICATION OF THE AFRICAN TRYPANOSOMES BY DNA PROBE TECHNIQUE

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The application of nucleic acid hybridization techniques in the identification of the African trypanosomes, using species specific probes have been described by many workers. Here we employed species-specific recombinant DNA probes in the characterization of natural trypanosome infections in cattle and tsetse flies from Uganda. Stabilates obtained from the International Centre of Insect Physiology and Ecology (ICIPE) and Uganda Trypanosomiasis Research Organization (UTRO) were also examined using this technique. Simultaneous infection involving T. brucei, T. vivax and both T. congolense, Savannah and Kilifi genotypes was revealed in one cow. This multiple infection could not be detected by the normal parasitological techniques. Field isolates from natural infection which have been passaged in laboratory animals tended to be mono-specific as evidenced by the 47 stabilates which were all either T. congolense, Savannah type or T. brucei.

We attempted to modify sample preparations for DNA probe analysis to suit field conditions. The results showed that samples which were spot blotted on nitrocellulose filters and either denatured or undenatured (but not baked) can be kept at room temperature for one month without significant loss of hybridization signals. This result is important in the field application of this technique. Samples are spot blotted on filters and kept in envelopes to be denatured and baked later in the laboratory. This eliminates the need for having liquid nitrogen and or an incubator in the field. The simplicity, sensitivity and specificity of this form of diagnosis using species specific DNA probes make it the future tool in the understanding of the epidemiology of the African trypanosomiasis.

ELECTROPHORETIC ANALYSIS OF TRYPANOSOMA BRUCEI ISOLATES FROM CATTLE, TSETSE AND HUMANS FROM THE LAMBWE VALLEY, WESTERN KENYA

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43 T. brucei stocks were isolated from humans, cattle and tsetse between 1985 and 1987 in the Lambwe Valley, Kenya. Isoenzyme analysis of 11 enzymes revealed considerable heterogeneity among all isolates, with tsetse isolates being the most diverse. Cluster analysis of relationships among the isolates indicated that the organisms could be grouped into three broad types corresponding to their origins in humans, cattle and tsetse. The human type was the least unique, being represented in all three groups. In contrast, most cattle and tsetse isolates were not represented in other groups. The predominant T. brucei zymodeme found during the 1980 outbreak of sleeping sickness was not observed. This zymodeme may have changed its isoenzyme pattern or it may have been eliminated during recent insecticide ground spraying operations against G. pallidipes. It is concluded that the heterogeneity observed among the fly isolates is an adaptive mechanism for this trypanosome's survival.

SELECTION AND EVOLUTION OF TRYPANOSOMA BRUCEI ZYMODEMES IN THE LAMBWE VALLEY, KENYA

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The Lambwe Valley in South Nyanza, Kenya is an endemic area of human sleeping sickness caused by Trypanosoma brucei rhodesiense. Tsetse flies (Glossina pallidipes) transmit disease to humans as a result of the close association between settlements and Ruma National Park. To understand the factors responsible for the maintenance of this disease focus, we analyzed taxonomic similarities among electrophoretic variants of the parasite in humans, cattle, wildlife and tsetse flies. Together with literature data, 321 isolates were available for analysis, consisting of 74 zymodemes. Cluster analyses of parasite stocks revealed complex relationships among zymodemes. In the 1970's, major

human zymodemes were associated with zymodemes found in cattle and tsetse flies. Nearly all wildlife isolates were associated with human zymodemes at that time. In the 1980's, major changes occurred in the types of parasites observed in the valley. In particular, most zymodemes isolated from tsetse flies were distinct from those found previously. Similarly, new zymodemes appeared to be circulating in different transmission cycles involving cattle and humans. These changes followed a severe decline in tsetse densities caused by aerial spraying of the valley in 1981. Altogether, these results suggest that the disease situation in the Lambwe Valley is still evolving, and has further potential for producing human epidemics.

APPROACHES TO MODELLING TRYPANOSOMIASIS TRANSMISSION DYNAMICS

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Some simple models are used to study some aspects of trypanosomiasis epidemiology: the role of reservoir hosts in maintenance of disease, recrudescence of infection, the effect of different control measures, acquisition of immunity, and interactions between different parasite species. If rough estimates of parameter values can be made, sensitivity analysis can be used to assess the relative importance of different parameters.

These models can aid understanding in as much as they are detail-free and simple enough to study analytically. But they describe changes in idealised quantities which are very difficult to measure. It is commonly supposed that it would not be feasible to measure all the parametres of more complicated models; but an alternative view is that only in such models can transmission dynamics be related to easily measurable quantities.

Thus more complex models may be constructed in which the predicted prevalence of infection is related to detectable prevalence by consideration of daily variation in the probability of detecting parasites and the decline in parasitaemia from patency to recovery.

For similar reasons, the proliferation of parameters (predictors) and consequent amplification of prediction error must be weighed against increased realism of models,

with the pay-off that if heterogeneities can be modelled explicitly, there are fewer fudge factors (parameters become more specific and less phenomenological).

EPIDEMIOLOGY OF AFRICAN TRYPANOSOMIASIS IN ETHIOPIA

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Studies on the epidemiology of African trypanosomiasis were conducted in Southwestern Ethiopia from 1980 - 1988. Flies were trapped and dissected for infection rate determination, aging and blood meal analysis. Fly infection rate was significantly correlted (r-0,87) with trypanosome prevalence in the area. Comparison of the frequency distribution of wild caught flies, during wet and dry season, using biconical traps, were made. The flies were analysed for wing fray, vein lengths, chloroform-extractable fat and haematin. There was a significant (P<001) difference in fat content between the wet and dry season catches. Prevalence of trypanosomiasis in cattle was recorded and correlated with the logarithm of tsetse challenge and a positive significant correlation (r-,67) was obtained. Trypanosome infections increased and decreased in a similar manner (Trends in trypanosome infection rates over time were similar for T. vivax, T. brucei and T. congolense). Packed cell volume (PCV) is a good predictor of infection. (PCV was correlated with trypanosome infection).

RELATIONSHIPS BETWEEN TSETSE CHALLENGE AND TRYPANOSOME PREVALENCE IN TRYPANOTOLERANT AND SUSCEPTIBLE CATTLE

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The relationships between estimates of tsetse challenge and trypanosome prevalence in trypanotolerant and susceptible cattle were examined at sites of the African Trypanotolerant Livestock Network. Estimates of tsetse challenge were determined as the product of tsetse relative densities, their trypanosome infection rates and the

proportions of feeds taken by them from cattle. Trypanosome prevalence in both trypanotolerant and susceptible breeds of cattle was estimated from monthly examination of groups of ear-tagged cattle. Regression equations were fitted to a log10 transformation of tsetse challenge estimates and an arcsin transformation of trypanosome prevalence. Highly significant relationships between estimates of tsetse challenge and trypanosome prevalence were found for sites with trypanotolerant cattle ($p<0.0001$) and sites with susceptible cattle ($p<0.01$). Mean trypanosome prevalence at a given level of tsetse challenge was at least twice as high in susceptible as in trypanotolerant cattle. The slopes of the regression lines for the two groups of cattle were significantly different ($p<0.05$). The results indicate superior ability of trypanotolerant cattle to withstand tsetse challenge in the field. The curves obtained for both groups of cattle illustrate the necessity in tsetse control campaigns for a major reduction of tsetse populations before significant decreases in trypanosome incidence in livestock can be achieved.

Tsetse Population Dynamics

ECOLOGICAL STUDIES OF GLOSSINA AUSTENI IN ZANZIBAR, UNITED REPUBLIC OF TANZANIA

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In an attempt to overcome the problem of catching Glossina austeni Newstead in reasonable numbers and enable quantitative studies of its ecology in Zanzibar, a new tsetse trap (the Chuka trap) was developed. Its design and an assessment of its G. austeni catching ability and limitations are described. The Chuka trap helped to establish that G. austeni is a very low flyer. In Jozani Forest (Unguja Island, Zanzibar) G. austeni was most abundant in the "forest floor" biotope in which also bushpig tracks were most numerous and their wallows were apparently restricted. Acetone vapour together with that of a phenol mixture failed to increase Epsilon trap catches of G. austeni.

THE POPULATION DYNAMICS OF GLOSSINA LONGIPENNIS CORTI AT NGURUMAN, SOUTH-WESTERN KENYA

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Studies were carried out at Nguruman, south-western Kenya, on the population dynamics of Glossina longipennis Corti, a little known member of the fusca group of Glossina.

Changes in the apparent densities of G. lonipennis were monitored simultaneously using biconical and the newly developed NG2B traps. Apparent densities of both sexes were regularly observed to increase during the rainy seasons and decrease during dry seasons.

Mortality rates estimated from ovarian age structure and from Moran curves were observed to be highest during the hot dry seasons and lowest during the cool wet seasons. Adult mortality rates showed a significant positive correlation with maximum temperature and a negative correlation with minimum relative humidity.

All non-teneral but nulliparous females and over 80% teneral females were inseminated. A significant negative correlation was observed between abortion rate and minimum relative humidity.

The absolute population size of G. longipennis was estimated through mark-release-recapture experiments at different times of the year. The trend of changes in the absolute estimates corresponded with those in apparent estimates from trap catches. The feeding cycle of G. longipennis was found to be 2-3 days for males whilst for females the 9-10 day pregnancy cycle was the main factor affecting the recapture rate. There was a considerable amount of movement of marked flies in and out of the study area but the movement was shown to be greater in one direction than the other.

POPULATION ECOLOGY OF GLOSSINA FUSCIPES FUSCIPES ON RUSINGA ISLAND AND MAINLAND IN SOUTH NYANZA, KENYA

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A study of population ecology of Glossina fuscipes fuscipes was initiated on Rusinga Island and the mainland of Mbita Division, South Nyanza District, Kenya. Investigations into fly distribution, activity pattern, adult population density, age composition, reproductive abnormalities and fly movement were carried out using biconical traps. The distribution of flies was found to be confined to a strip of thick vegetation along the lake shore. The adult population was remarkably stable during the period of study although heavy rainfall appeared to influence changes in apparent density. There was no significant difference in age composition of flies caught from the island and mainland but mortality rates of the two populations were not correlated. Reproductive abnormalities were in general rare. G. f. fuscipes was found to have restricted mobility, hardly covering a distance of 1.5 km in a month. The implications of these findings in terms of tsetse fly control are discussed.

MARK-RELEASE-RECAPTURE STUDIES ON GLOSSINA PALLIDIPES AT NGURUMAN, KENYA

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Mark-release-recapture (MRR) studies have formed an important component of detailed studies on the population dynamics of Glossina pallidipes carried out at Nguruman, south-western Kenya. Two factors complicate MRR studies on tsetse, namely abnormal dispersive behaviour after marking and cyclic availability to the sampling device, and data on these two aspects are presented. Despite these complications, it is still possible to obtain absolute population estimates and these are compared with relative estimates obtained before and after tsetse population suppression. As well as providing data on population size and loss and gain rates, MRR can also provide data on tsetse movement and this is examined in relation to interchange between two subpopulations.

AGE DEPENDENT CHANGES IN THE PROBABILITIES OF SURVIVAL AND CAPTURE OF AN ISLAND POPULATION OF TSETSE FLIES: IMPLICATIONS FOR THE DETERMINATION OF THE POPULATION DYNAMICS OF GLOSSINA SPP.

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In April-May 1986, 180 male and 218 female Glossina morsitans morsitans Westwood were marked uniquely and released unfed within 18h of emergence on Redcliff Island, Lake Kariba, Zimbabwe. Flies were recaptured on ox fly-rounds carried out twice daily for 6 months; marks were recorded and the flies released unharmed. For both sexes 56% of the flies released were recaptured at least once. For females, the change in capture probability with age t was calculated using 23 flies caught at least once for $t >$ 90 days. The probability of being captured at least once in a 9 day period was 0.35 - 0.40 for $t <$ 30 days, 0.17 - 0.27 for $30 < t <$ 70 and > 0.50 for $70 < t$ 90 days old. The capture probabilities and flyround catches for all females were used to estimate the function relating age and survival probability. The average daily mortalities were 5.0%, 0.6%

and 3.5% for weeks 1-2, 3-8 and 9-18 respectively and 2.3% for the whole 18 week period. For males, similar calculations produced daily mortality estimates of 10.9%, 2.8% and 9.6% for days 0-7, 8-17 and 18-40 respectively and 9.1% over the whole 40 days. These mortality patterns are qualitatively similar to those found for laboratory reared tsetse. The results are discussed in terms of the estimation of mortality rates from samples of tsetse flies.

MODELLING TSETSE MOVEMENT

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A diffusion model is being developed to investigate patterns of tsetse fly movement in the field. The movement is based on a diffusion equation and a logistic function is used to describe the density dependent mortality. Implications for tsetse sampling and trap deployment will be discussed.

THE USE OF GEOGRAPHIC INFORMATION SYSTEMS AND REMOTE SENSING FOR ANALYZING TSETSE FLY DISTRIBUTION AND MOVEMENT

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Tsetse population distributions over time and space have been prepared using a geographic information system. Mean monthly trap data for two separate trap designs has been interpolated by using two different approaches: a straight point interpolation and one weighted by vegetation type. Results illustrate the change in tsetse distribution over time and space. Tsetse distribution maps for G pallidipes have been created for both males and females for comparative distribution analysis.

RECENT ADVANCES IN TSETSE POPULATION MODELLING

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The talk presents the case for a `top-down' approach to tsetse population modelling, for several reasons. The assumptions of such models are easier to test in the field, their predictions more transparently related to the input parameters and variables, their use in designing efficient pest control strategies more straightforward than is the case for complex simulation models. In addition simple population models are more easily incorporated into more general models for disease transmission.

We then identify the `minimal set' of input variables and parameters for such tsetse population modelling, some experimental results of recent field-work aimed at quantifying life-history mortalities, and some recent attempts at analyzing and modelling past data sets from West and East Africa. Extremely simple simulation models incorporating no more than single density independent (environmentally determined) mortalities and classical density dependent relationships give fits to field data that are remarkably convincing.

The apparent accuracy of such simple models suggests that in certain cases, analytical solutions of algebraic models for tsetse populations may be possible. An example is given to illustrate the relative effectiveness of killing or sterilizing flies during control programmes.

The talk ends with a plea that all modellers should have, sitting on their shoulders, a parrot trained to repeat the phrase "what about density dependence then?" at regular intervals of no more than one tsetse generation.

Tsetse Behaviour and Physiology

REPRODUCTIVE AND NUTRITIONAL DETERMINANTS OF THE AVAILABILITY TO TRAPS OF GLOSSINA PALLIDIPES FEMALES

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Female Glossina pallidipes, sampled with baited Ngu2B traps at Nguruman, Kenya, were ovarian dissected, and then analysed for fat and haematin. The measured reproductive products were calibrated against those of wild-caught, lab-held females dissected on known days of their pregnancy cycle, thus providing for the first time data on the nutritional characteristics of field flies on each day of their pregnancy cycle.

Ngu2B traps catch approximately twice as many females on day 6 of their 9-day pregnancy cycle as on any previous day, rather fewer day-7-8 flies than day-1-5 flies and very few day-9 flies. During pregnancy the fat content of females increases at a diminishing rate, culminating in a 2mg loss of fat on the final day, while the corrected reduced dry weight increases at an accelerating rate. The frequency distributions of hematin levels indicates that as pregnancy proceeds flies feed earlier during the haematin excretion cycle. The majority of females were trapped towards the end of their feeding cycle, about 72 hours after their last blood meal. The daily regressions of fat against haematin show that, despite provisioning a larva in utero, females consistently use up fat at twice the rate of males. The significantly greater regression slope on day 6, indicating greater activity, may account for the females' greater trappability on this day.

MATING EFFICIENCY IN GLOSSINA PALLIDIPES

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Female sexual receptivity and male sexual aggressiveness and their control were studied in G. pallidipes with reference to the Nguruman population in the Rift Valley of Kenya. The flies were trapped and reared in the laboratory and the F1 generation used in all mating

experiments. The readiness of females to mate was highest at days 10 - 13.

However, 10% mated when 6 days old reaching 60% at age 9 days. No fly less than 6 days old mated when left with males for 24 hours. Male sexual aggressiveness was high when 12 days old and appears to increase with increasing age. Females were generally reluctant to mate even at the optimum age of sexual receptivity. Female momogamy in tsetse flies appears to be well demonstrated in this species as no previously mated female was observed to mate again.

The duration of copulation of females at various ages was short and was not significantly different ($F=1.06$, $P>0.05$) irrespective of age of fly. Between 5 to 22% of virgin flies ovulated when 7 - 25 days old while over 70% of older virgins 40 days and over had ovulated. 60% of mated females ovulated 24 hours after mating although this depends on the age of the fly.

The length of ovariole A reaches maturity about age 7 days and the maximum size is reached at age 10 which corresponds with high receptivity in females. The accessory reproductive gland (ARG) reaches its highest diameter at ages 11 - 12 corresponding with high male aggressiveness.

EFFECTS OF NUTRITIONAL AND HORMONAL FACTORS ON MATING AND REPRODUCTION OF THE TSETSE FLY, GLOSSINA PALLIDIPES

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The purpose of the present study was to examine various nutritional and hormonal factors which influence sexual behaviour, inseminating capability, larval development and progeny production in Glossina pallidipes.

Young females of less than a week old and males of less than 10 days old usually do not mate under laboratory conditions. However, as they become older and take more blood meals, they show increased sexual activity and rate of insemination. There appears to be a direct correlation between insemination rate and the development of the first oocyte. In males, a change in feeding frequency causing reduction of total blood intake adversely affects the development of accessory reproductive glands (ARG) which in turn reduces their inseminating capability. In females, first oocyte maturation is only slightly affected due to

reduction in the blood meal resulting in a relatively smaller egg for the first cycle.

Administration of a juvenile hormone analog (JHA) in small repeated doses results in increase of ARG diameter of the younger males but the inseminating capability of the JHA-treated males remains un-altered. However, younger males receiving injection of brain extract from mature donors in addition to JHA show higher sexual activity and inseminating capability than those which receive only JHA. Results indicate that both juvenile hormone and a brain factor are required for male sexual maturation. Administration of 20 hydroxy ecdysterone to young non-receptive females increased their receptivity compared to the control of the same age group.

In utero larval development depends on availability of adequate nutrient from the milk gland of the female tsetse through the pregnancy. Absence of timely blood meal and adequate meal size results in poor lactogenesis which in turn causes abortion of developing larvae or production of low-weight pupae which are either non-viable or suffer post-emergence mortality.

STUDIES ON RESPONSES OF GLOSSINA AUSTENI TO BAITED AND UN-BAITED TRAPS AT THE KENYA COAST

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The distribution of Glossina austeni extends along the Eastern African coast from southern Somali down to Mozambique. Its preferred habitat is typical coastal forest or dense thicket with evergreen vegetation. Sampling of G. austeni was carried out in the past by the method of fly rounds. There appear to be no records of successful trapping in the past.

Studies were initiated at the beginning of 1989 to look into the responses of G. austeni to various trapping methods in the field in Muhaka forest along the Kenya South Coast. Both odour baited and non-baited traps were tested. In general traps captured very few G. austeni, and there was no significant difference between the various trap-types, baited or non-baited. However, catches fluctuated from season to season and the March-April period was the most productive with catches that were at least twenty fold

greater than those of other months. Effect of urine, and phenols on trap-catch is discussed.

THE ORIGIN OF PHENOLIC TSETSE ATTRACTANTS FROM BUFFALO URINE: STUDIES ON THE MICROBES AND PRECURSORS INVOLVED

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The attractive properties of buffalo urine to tsetse flies was previously shown to be largely due to a blend of seven phenols of which 4-cresol and 3-n-propylphenol were shown to be crucial for activity. The performance of samples of urine in the field and in the laboratory suggested that there was an in-built mechanism for the gradual formation of these phenols in urine. Further experiments showed that the formation of phenols was associated with the presence of microorganisms. The possibility of using such a system as a model for simple microbial methods of controlled-release of phenolic (and other) attractants prompted us to undertake a detailed study of the nature of the proattractants and the microbes responsible for their breakdown.

Eight bacteria have been isolated from buffalo urine and screened for their ability to degrade the proattractant(s) in the urine. Three of these organisms "A", "L" and "M" have demonstrated varying ability to form buffinol, the formation of which was confirmed by observing the build-up of 4-cresol by means of gas-chromatography.

Relatively pure samples of the major proattractants fractions were obtained by chromatographic procedures and examination of their 200MHz H-1 NMR spectra shows the presence of glucuronate of 4-cresol as the major product. Other derivatives of 4-cresol were also shown to be present in smaller amounts.

RESPONSES OF TSETSE FLIES TO HOST DERIVED KAIROMONES

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So far, two sets of kairomonal compounds derived from either the breath of host animals or their excretory products have been shown to mediate host-seeking behaviour of tsetse flies. Experiments undertaken in a wind tunnel show that additional kairomones are present on the body of host animals and that these at close-range elicit responses which include alighting and probing.

Results of the behavioural and electrophysiological studies to determine the olfactory selectivity of the antennae of G. m. morsitans and G. pallidipes to various phenolic kairomones indicate that 4-cresol among the 4-alkylphenols and 3-n-propylphenol among the 3-alkylphenols were the most stimulatory. Responses of both species to 4-alkylphenols increased as the alkyl chain decreased from 3 carbon atoms to one, while an opposite trend was observed with 3-alkylphenols. Comparison of the responses indicate differences in the sensitivities of the chemoreceptor systems of the two species.

Wind tunnel experiments in order to investigate how these individual phenols and their combinations affect tsetse beaviour indicate that a blend of 4-cresol-3-n-propylphenol evoked the most activation behaviour, upwind flight and source contact behaviour. Results indicate that responses differ between species; with G. pallidipes flies exhibiting significantly more upwind flight and source contact behaviour with the above mixture.

OLFACTORY ATTRACTANTS OF RIVERINE TSETSE

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It was proved, several years ago, that some species of Glossina from the palpalis group, in the Soudano-Guinean Zone, Burkina Faso, find their host in part with olfactory factors. Experiments were carried out with Glossina

tachinoides, a man, a pig and a cow were shown to be attractants. Other experiments carried out in the forest in Ivory Coast gave no positive results with pigs and Glossina palpalis.

Some products have been identified (phenolic compounds derived from cattle urine). The most efficient was meta-cresol which, at the end of the 1988 dry season, increased the captures of Glossina tachinoides when it was associated with octenol; octenol alone had no attractant effect on Glossina tachinoides. The dispenser was a polythene tube and captures with biconical traps increased by 2.5 times (much less than the results obtained with Glossina from the morsitans group)

However, these results could not be repeated all along the year, neither in every site. There are important variations of the Glossina sensibility to olfactory attractants. Octenol does not potentialize meta-cresol during all the year; sometimes, the same day, the same product gives different results; in two different sites. The reasons for these differences (Genetic, Nutritive Conditions .....) must be studied.

DYNAMICS OF BLACK FLY (DIPTERA:SIMULIIDAE) HOST LOCATION WITH REFERENCE TO OLFACTORY ATTRACTRANTS

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Host location in black flies (Diptera: Simuliidae) appears to be an integrated behavioural "programme" that is activated, maintained and driven by host-originating olfactory and visual cues.

To investigate the nature of programme activation and de-activation, host-seeking flies were captured and held for various lengths of time prior to being given the opportunity to bite a warmed artificial membrane. Percent biting decreased asymptotically with holding time indicating a gradual de-activation of the host location programme at the population level. Flies held for longer periods took longer to bite the membrane for the first than did short period-held flies. This is thought to indicate that a small proportion of flies that had de-activated during the longer holding periods were re-activated by the warmth stimulus from the membrane.

The evidence for olfactory host attractants for black flies is also reviewed and the preliminary results of a project designed to identify the host attractants for cattle-biting siblings of Simulium arcticum in the Athabasca region of Canada are described.

WHERE DOTH THE WIND BLOW?

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Plotting the movement of air through typical tsetse habitats in Zimbabwe revealed that it does not - as has been thought - move in straight lines from any given starting point. In reality, it is liable to change direction by over 900 within a few metres. In winds of <1m s-1, there is a negative correlation between windspeed and the wind's tendency to meander, whether in thick bush or over short grass. And at the mean windspeed in wet season mopane woodland (0.3 m s-1) the wind changes direction by c. 200 s-1.

Accordingly, host odour cannot move downwind in simple trajectories that tsetse flies could easily follow. Even a mere 15 m from a source, odour (modelled with smoke) approached a tsetse fly (video camera) for only a third of the time directly from the source, whereas for 20% of the time it approached from 900 or more away from the source. Futhermore, both experiment and theory indicate that at common tsetse resting sites, air turbulence generates much nonsence information about the `true' direction of any odour-bearing wind. One of the many unanswered questions about how tsetse find their hosts is thus, how do they handle this confusing information from the wind about where their hosts lie?

STIMULATION AND CONTROL OF BLOOD FEEDING RESPONSES IN THE STABLE FLY (DIPTERA: MUSCIDAE)

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The physical an sensory bases of stable fly (Stomoxys calcitrans, Diptera: Muscidae) blood feeding have been studied using electron microscopy and behavioural and physiological experimentation.

Initial penetration of the skin during biting is accomplished by eversible labellar teeth and followed by protraction of the labral-hypopharyngeal complex into the wound. Labellar sensilla and previously undescribed labral (apical gustatory/tactlile complex, rows of long mechanosensory hairs along length of labrum) and cibarial sensilla (gustatory and mechanosensory elements) monitor sensory aspects of the biting and feeding process.

Gorging appears to be stimulated by two classes of phagostimulants in blood; one of these consists of molecules smaller than 5000D (probably adenine nucleotides) while the other appears to consist of very large molecules (>100,000D).

Evidence from pharmacological studies suggests that the gorging response is mediated by molecular receptors that closely resemble vertebrate P2x purinoceptors.

GENETIC ASPECTS OF QUALITY CONTROL IN TSETSE COLONIES

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Tsetse flies colonized either for laboratory studies or for release in S.I.T. programmes are assumed to be healthy and genetically similar to flies in natural populations. However, insect colonies are subjected to the same evolutionary forces that influence genetic changes in natural populations, namely "drift", "selection", "hitch-hiking", "mutations", "assortative mating", and "immigration". The influence of these on genetic structure of colonized tsetse flies is outlined, and examples are

presented from several species. There is little or no evidence for adaptation during the early phases of laboratory colonization of five species of tsetse. A model is presented indicating that with as little as a five percent fitness difference between males, some colonies have existed long enough to have undergone significant changes in the relative numbers of males having "standard" and "enhanced" fitness. Slight changes in heterozygosity of colonized flies is documented by comparisons of flies from several colonies with flies from field populations as well as comparisons within colonies over periods of several generations or years. An example of "hitch-hiking" is illustrated with the closely linked genes Sr (sex ratio) and Est-X in G. m. submorsitans. Possible interactions between alleles at these loci are discussed. A summary is presented of polyacrylamide gel electrophoretic methods for monitoring 14 polymorphic loci distributed among the X chromosome and autosomes of tsetse flies.

Control Technology Revisited

STRATEGIC AND TACTICAL DEVELOPMENTS IN TSETSE CONTROL IN ZIMBABWE, 1981 - 1989

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Tsetse flies have been eradicated from an area of 48 000 km2 in Zimbabwe since 1981. The main approach has been pesticidal control, involving ground spraying, aerial spraying, cattle dipping and artificial bait techniques, in some circumstances in combination.

This represents a change in tactic from the pre-independence period when control relied solely on ground spraying. Factors which have influenced choice of technique are discussed in the paper, including scale of trypanosomiasis problem, technical limitations of the technique, cost-effectiveness and environmental considerations.

Ground spraying, the mainstay of tsetse control operations in Zimbabwe prior to 1980, is becoming increasingly disfavoured because of high logistical requirements and environmental reasons, but remains an effective technique under a wide range of circumstances.

Aerial spraying has proved very effective for management of crisis situations but is comparatively expensive, capital intensive in hilly terrain and generally less effective against Glossina pallidipes than against G. morsitans.

Vector control by applying insecticide (deltamethrin) to cattle appears technically feasible at a very competitive cost. This is a most promising technique in areas where there are already cattle and few wild hosts.

Controls of tsetse using odour-baited and insecticide treated screens has proven technically feasible in a wide range of terrain and appears economically competitive with ground spraying. Both technical and financial performance of the technique are still being improved. Bait technology offers scope for the new approaches to control of the fly and defence of cleared areas from reinvasion.

THE USE OF ODOUR BAITED INSECTICIDE IMPREGNATED SCREENS AGAINST GLOSSINA MORSITANS CENTRALIS MACHADO (DIPTERA:GLOSSINIDAE) IN ZAMBIA

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Results are presented of a two year research project aimed at examining the effectiveness of odour baited insecticide impregnated screens as a means of control against Glossina morsitans centralis in a cattle grazing area in the west of Zambia. Altogether, 3000km2 were covered including area completely consisting of suitable habitat as well as areas with only patches of suitable habitat. The overall target density varied between 0.5 and 3.8 targets km2. Prior, during and after the deployment of screens the fly population in and outside (control area) the treated area was monitored directly by F3-traps, screen fly rounds as well as a motorcycle with an electric net fitted on the back. Besides, the fly population was monitored indirectly by determining the trypanosomiasis challenge in animals of sentinel herds. Depending on the deployment pattern and overall target density fly populations declined at rates of up to 3.0% Day-1. Targets used consisted of black cloth with or without netting panels at the sides. Field trials with electrified nets showed that for Glossina morsitans centralis the performance of the targets used can be significantly increased by adding a blue component.

SEASONAL DISPERSAL OF GLOSSINA PALLIDIPES IN RELATION TO REINVASION INTO CONTROL AREAS

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Since early 1987, populations of Glossina pallidipes have been suppressed over about 100 km2 at Nguruman, Kenya using odour baited traps made by the local community. Percentage reduction relative to areas outside the suppression zone reaches 99 - 99.9% in the dry season, but during the rains only a 90% suppression can be maintained. This partial reinvasion appears to result from a mass movement of flies during the rains both from the north of the area and from the top of the escarpment. Older females

constitute the majority of the dispersing flies. The factors affecting seasonal dispersal are examined in detail with reference to a long term study on the spread of G. pallidipes from thicket areas into Acacia woodland and open grassland.

USE OF IMPREGNATED TARGETS FOR CONTROL OF G. PALLIDIPES IN KENYA

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Trials using Deltamethrin impregnated odour-baited targets, for control of tsetse have been running in Galana Ranch on the coastal hitherland since 1986. In July 1988, a similar trial was started in Lambwe Valley, Western Kenya. G. pallidipes is the sole vector in the valley and is present in very high densities.

In Galana Ranch trial, octenol and acetone are used as odours while in Lambwe Valley, natural cow urine is used in addition to acetone and octenol. Tsetse population densities were assessed weekly for 3 weeks, before deployment of targets and thereafter at monthly intervals. A herd of cattle is used to monitor the effect of the control measures on disease incidence.

On Galana Ranch, the Block where the initial trial began has remained free of G. pallidipes for a period of 3 years. In a period of nine months in the second year of the trial, the berenil index in a herd of cattle was 0.07 in the controlled area compared to 2.5 in the uncontrolled area.

In Lambwe Valley a 99.9% reduction in trap catches has been observed in most parts of the park at the end of the first year. The berenil index in the cattle has dropped from 6.3 to 0 and there is a general improvement in the health of the animals. Observations are continuing at both sites.

THE CONTROL OF RIVERINE TSETSE FLIES

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Riverine tsetse flies, which are vectors of human and animal vectors, are very difficult to control because of the specific nature of their habitat and behaviour. The problem, however, is not technical because nowadays entomologists have at their disposal a wide range of efficient methods to eradicate them. The problem is therefore practical, and its related to the way in which these methods are used.

In fact, the entomologist is faced with several intractable problems that reduce his scope of action. First of all, because he has to pay due regard to the environment, he is obliged to refrain from taking any action that may be fatal for the tsetse fly but harmful for the environment such as cutting down woody, scrub and shrub vegetation, setting bush fires, etc. Furthermore, he is not allowed to tamper with wildlife which is the nutritional source of the tsetse fly but which is also an important source of foreign exchange through tourism. He also must respect the non-target fauna, especially the aquatic fauna, with the result that this limits:1) the choice of pesticides that can be used, all of which, in one way or the other, affect the chain in the biological cycle, invertebrates, fish, birds, mammals; 2) the method of application of chemical because he can not use everywhere residual sprays or aerial aerosols.

The entomologist must also take into account economic considerations. The world economic crisis has considerably reduced the availability of potential sources of donor funds, and most African countries afflicted by sleeping sickness and animal trypanosomiasis cannot individually undertake large-scale eradication campaigns for lack of funds, adequate equipment and trained manpower. Using airplanes or hordes of workers is therefore out of question. Similarly, controlling the tsetse fly through the use of sterile male release technique, which is a complementary control method to attain the 0 density, seems now to be unachievable because of the huge investments that are required.

Finally, many scientists, economists and ecologists have recently begun to wonder if controlling the tsetse fly is after all a good solution since the disappearance of harm if one case and of vectors in the other would lead to the overexploitation of the land so freed from the attacks of

tsetse flies resulting in the destruction of the vegetation and in bio-climatic changes and finally total desertification. The challenge therefore is how to control the tsetse fly under these conditions.

The use of traps seems to be a good solution since experiments conducted here and there in Africa (and since the discovery of certain olfactory attractants) have showed that it is effective, safe for the environment, easy to use, and especially very cheap when it is used by the rural communities. But even with trapping a number of questions are being asked: Is it better to kill the tsetse fly than to sterilize it? Is impregnating it with an insecticide indispensable? Is there no risk of selecting a "trap resistant strain" of tsetse? Can the use of traps lead to eradication?

In fact, in most cases, eradication is wishful thinking and controlling the fly is the only realistic thing to do; the entomologist has to control but cheaply and with the less harmful technique. Besides, because of its numerous qualities, trapping is the only method that can be used nowadays as long as it is used wisely.

MORTALITIES AND LESIONS CAUSED BY BEAUVERIA BASSIANA AND METARHIZIUM ANISOPLIAE INFECTIONS IN ADULT TSETSE, GLOSSINA MORSITANS MORSITANS

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Adult male tsetse, Glossina morsitans morsitans exposed to spores of Beauveria bassiana and Metarhizium anisopliae exhibited high mortalities ranging from 71 - 95% by 18 days post-exposure. Some of the Metarhizium anisopliae-infected tsetse developed circular melanized abdominal lesions believed to correspond to the sites of penetration by the germ tubes. Similar lesions were not, however, observed in tsetse exposed to spores of Beauveria bassiana. Histological sections of tsetse fixed soon after death revealed fungal hyphae in the fat body, muscles and gut wall of the infected insects, but the numbers of hyphae were scanty and no cellular immune reactions were observed in the infected tissues. After death, the fungi invaded the tissues rapidly destroying most of the internal organs and penetrated the cuticle forming extensive surface mycelia. Scanning election microscopy revealed an intricate network of hyphae on the cuticle surface. The potentials of B.

bassiana and M. anisopliae as biological control agents for tsetse are briefly discussed.

A SPREADSHEET MODEL FOR THE ECONOMIC ANALYSIS OF TSETSE CONTROL OPERATIONS BENEFITTING CATTLE PRODUCTION

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A spreadsheet computer model of the benefits and costs of tsetse control has been developed. It aims to provide a sufficiently standardised framework for setting these out so that widely different situations can be compared. A series of runs of the model illustrates how it can be used to define the conditions under which tsetse control is likely to be economically viable. For this purpose, the main variables are grouped into four categories: cattle production system, disease impact on productivity, tsetse control costs and stocking density (represented by cattle in the area before control and those transferred into the area subsequently). The model covers direct benefit due to changes in productivity resulting from reduced mortality, morbidity and drug use and indirect benefits due to transfers of cattle into the area and the increased use of work oxen.

LIFE IN AFRICA WITH AND WITHOUT TSETSE

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The main reason for tsetse eradication is to remove the restraint of disease on cattle production: it is argued, however, that the main restraint is not disease but poor land made worse by overgrazing. An association between overgrazing and drought is recognized in South America, Central America and Australia: the Geography and Geology of Africa make the climate of Central Africa much more susceptible to overgrazing. Tsetse populations have, in the past, been a major restraint on overgrazing but it is now possible (at least in theory) to eradicate all tsetse populations. It is argued that tsetse populations should be

'managed' to protect vulnerable rangelands and as a means of pasture improvements.