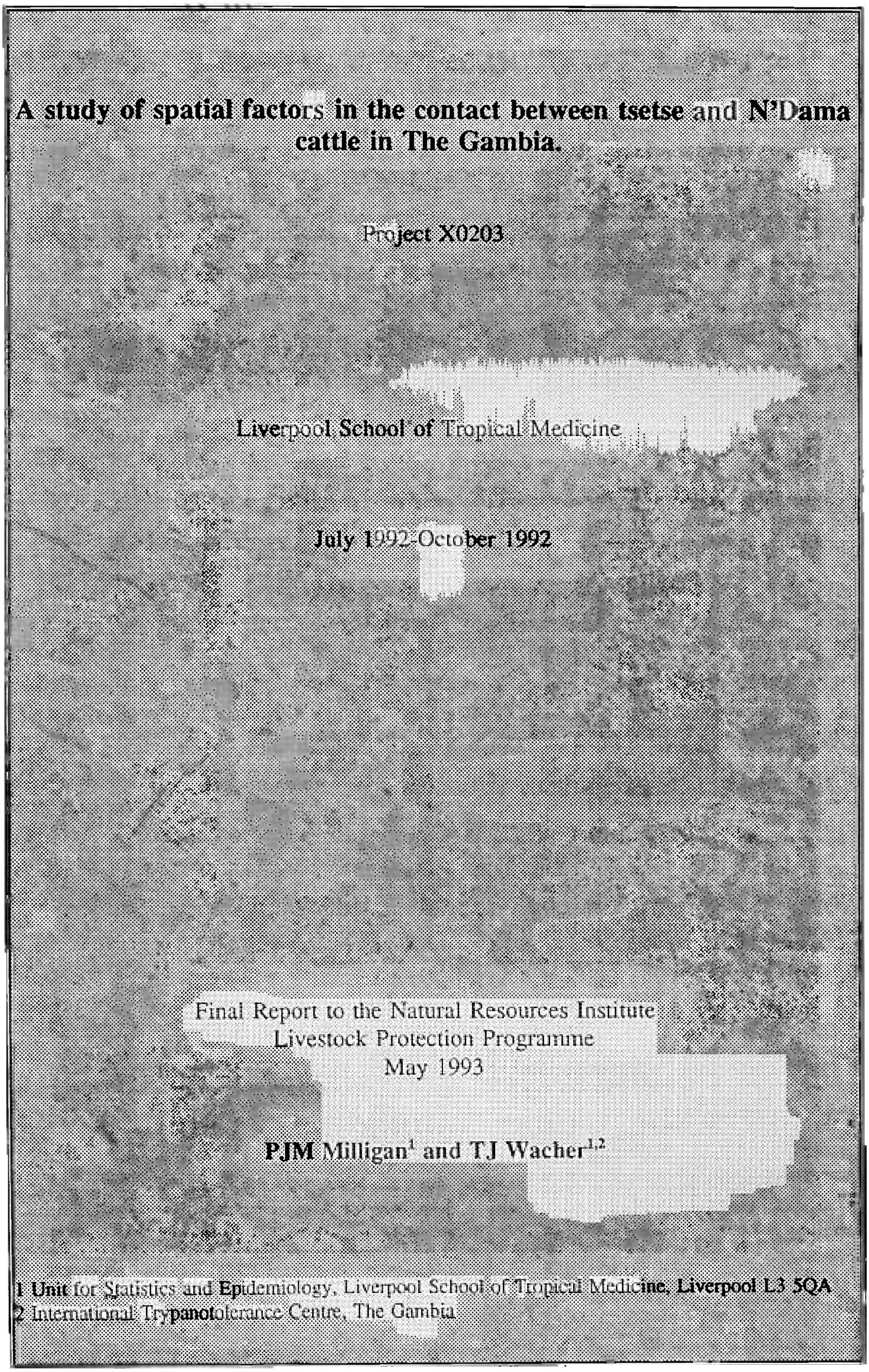

A study of spatial factors in the contact between tsetse and N'Dama cattle in The Gambia.

Project X0203

Liverpool School of Tropical Medicine

July 1992-October 1992

Final Report to the Natural Resources Institute
Livestock Protection Programme
May 1993

PJM Milligan[1] and TJ Wacher[1,2]

1 Unit for Statistics and Epidemiology, Liverpool School of Tropical Medicine, Liverpool L3 5QA
2 International Trypanotolerance Centre, The Gambia

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Contents:

1. *Objectives of the project.*

The ODA Entomology Programme of the International Trypanotolerance Centre had as its major objective the development of methods of measuring trypanosomiasis challenge to trypanotolerant N'Dama cattle under village management in The Gambia; the programme collected detailed data on tsetse distribution and cattle movements over 5-6 years in several study sites (Snow, Rawlings & Wacher, Annual Reports of the Entomology Programme, ITC). A key component of the Programme's work was Tim Wacher's study (March 1987-September 1991) of the spatial distribution of N'Dama cattle in relation to tsetse. Preliminary analysis of data from this study was done during a consultancy visit by PM to ITC in August 1991. The aim of the present short project (4 months, July-October 1992) was to allow the analysis to be completed and the work prepared for publication.

2. *Work completed during the period of the project.*

We have used the data to investigate the way in which spatial distribution tsetse and their hosts can influence the transmission of trypanosomiasis. We have considered two indices: the challenge rate or force of infection (the number of potentially infective bites per animal per day); and the basic reproduction rate, R_0 (a measure of the potential rate of transmission, and of the stability of the disease). These indices can be resolved into spatial and non-spatial components; we have used ITC data to estimate the spatial component. We have assessed the epidemiological significance of the variation in contact between cattle and tsetse using a mathematical model. An important implication of our results is that conventional measures of challenge can be misleading, despite the fact that they appear to be correlated with prevalence on a continental scale; they do not give a give a good indication of the risk of trypanosomiasis unless both spatial factors and host densities are taken into account. We have also been able to obtain quantitative estimates of the degree to which spatial heterogeneity in the contact between tsetse and cattle increases the basic reproduction rate of trypanosomiasis infections.

We visited ITC at the beginning of the project in order to check and clean datasets relating to the cattle herding study and from the tsetse monitoring program; our presence at ITC was essential as it was only by talking to ITC field assistants and computer staff that anomalies in data codings and format could be resolved; it would not have been possible to do this by post. This revealed a number of gaps in the data and it was possible to fill these during our visit; in particular we were able to conduct a census of small ruminant populations at the Keneba, Misira and Bansang study sites.

On returning to ITC at the end of the project in November we were able to finalize drafts of papers with collaborating scientists.

Three manuscripts have been submitted for publication and two others are being prepared. Copies of manuscripts have been forwarded to R. Allsopp. Practical implications of the work are incorporated in the training materials used in the FAO training courses held at ITC.

Our results were presented in an invited paper to the Workshop on the Modelling of Vector-Borne and Other Parasitic Diseases at ILRAD, November 23-27 1992.

3. *Results and findings obtained during the period of the project.*

a) Our results show that there can be great variation in the challenge rate to different herds at the same village; this variation, which would not be detected by traditional methods of estimating challenge, can be typically up to a factor of 10 between herds. Some results are summarized in Figures 1 and 2; Figure 1 shows maps of the study sites with surfaces representing the distribution of cattle grazing time superimposed. Figure 2 shows the distribution of 4 cattle herds at Keneba study site, in relation to contours of tsetse density. The details can be found in the MSS prepared for publication, copies of which have been forwarded, and are not repeated here.

b) The traditional estimate of challenge, the product of some measure of tsetse abundance and infection rate, is proportional to the force of infection only if the relative abundance of hosts, and the exposure of cattle to tsetse, are constant. If these vary, estimates of the index will not be comparable between locations. Re-analysing data from experiments of J Claxton, who recorded the incidence of infection in small groups of drug-treated zebu in each of our study sites, we have been able to obtain direct estimates of the force of infection. The same animals had been followed and their spatial distribution mapped; the direct estimate of the force of infection could therefore be compared with entomological estimates of challenge. The two measures are correlated only after the estimate of tsetse density in the entomological estimate has been divided by the abundance of hosts.

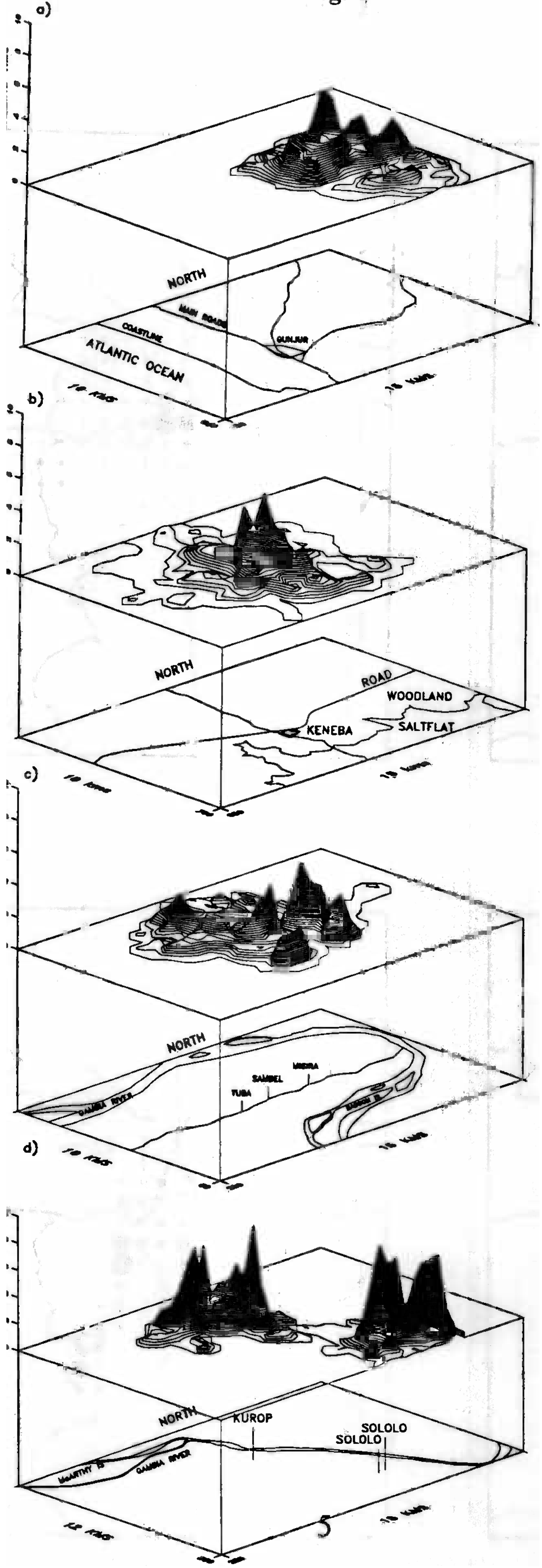
c) We have assessed the epidemiological significance of the variation in contact between cattle and tsetse using a mathematical model.

In order for disease transmission to persist, vector/parasite interactions must be efficient enough, and tsetse/host contact must be close enough, that at least one of the flies feeding on an infected host is able to transmit the infection to another animal before the infected host dies or becomes aparasitaemic. An overall measure of the rate of transmission is the basic reproduction rate, R_0, which is simply the average number of secondary cases of infection that each infected host could potentially give rise to through transmission by tsetse.

It is a well-known principle that this average number is smallest when all hosts are evenly exposed to vectors, and is increased if some are more exposed than others. But the magnitude of this effect in practice is unknown for most disease systems. Using the data on spatial distribution of tsetse and livestock and a model of tsetse movement, we can estimate the magnitude of the effect for trypanosomiasis in ITC study sites in The Gambia. The model needs some explanation:

1-3 weeks after tsetse flies acquire trypanosome infection, the infection can be transmitted to another host animal when the fly feeds again, if it survives long enough to do so. The usual approach has been to assume all flies are equally likely to take a bloodmeal in any part of their habitat; in this homogeneous model, we just have to consider whether a the fly is still alive after the incubation period, and then estimate the number of infective bloodmeals it is likely to take before it dies; in the spatially heterogeneous model, we also have to consider where the fly is. The more mobile flies are, the more likely it is that infection can be transmitted to another herd in a different location.

Fig. 1


a)
NORTH
MAIN ROADS
COASTLINE
ATLANTIC OCEAN
GUNJUR
b)
NORTH
ROAD
WOODLAND
KENEBA
SALTFLAT
c)
NORTH
GAMBIA RIVER
TUBA
SAMBEL
MISIRA
d)
NORTH
KUROP
SOLOLO
SOLOLO
GAMBIA RIVER

We have modelled tsetse dispersal using information about fly movement from a recapture experiment (Milligan & Rawlings, in prep.), habitat maps, and information on spatial distribution of tsetse density. This is based on a random walk model in which bias towards favourable habitat has been incorporated. The model tracks the movement of flies after they have fed at a particular x,y location. We use the model to calculate the probability of a fly being found in different parts of the grid after a certain time, conditional on it having most recently fed at x,y. This conditional probability distribution spreads out as time goes on; results of some simulations, assuming a daily step length of 500m, are illustrated in Figure 3; this shows dispersal of flies in Keneba study site; the first plot shows the location of a fly taking a bloodmeal on day 0. Subsequent plots show the probability distribution of the fly's location at various times after this, assuming the fly is still alive.

We can now assess the epidemiological importance of spatial heterogeneity in terms of age-dependent changes in location of individual flies, and hence in the probability of them biting hosts in different parts of the habitat. The basic reproduction rate now becomes a function of the rate of movement of tsetse and the spatial distribution of hosts.

The results show that spatial heterogeneity increases the basic reproduction rate by a factor of as much as 2-50 (with most of our simulations giving values near the upper limit), compared with the homogeneous value, depending on the assumptions made about the rate of tsetse dispersal and the amount of habitat-bias in the random walk model. This is a much larger effect than might have been anticipated; the practical implication is that control measures targetted to the most exposed groups of hosts are likely to be much more effective than blanket measures.

The results emphasize the epidemiological importance of studies of tsetse movement in relation to feeding behaviour, and of the space utilisation of livestock and wild hosts in relation to tsetse. This approach can complement other approaches (such as use of sattelite imaging data) in determining the severity of the trypanosomiasis problem in different areas, the likely resistance of the disease to control measures, and the persistence of trypanosomiasis under changes in the distribution and abundance of the vectors caused by possible climatic changes. However, before this is possible, basic information about the wild host reservoir needs to be obtained. The situation is clearly illustrated in Figure 4, which shows the spatial distribution of tsetse density (upper plot) and host numbers (lower plot) at Keneba: tsetse are most abundant in areas where livestock are absent; indeed over 90% of *G.m.submorsitans* bloodmeals derive from warthog. Yet surprisingly little is known about the epidemiology of cattle-infective parasites in wild hosts. The basic information that is needed relates to the prevalence of parasites infective to livestock and other basic parasitological data, and the ecology of the interaction between wild hosts and tsetse.

Fig.

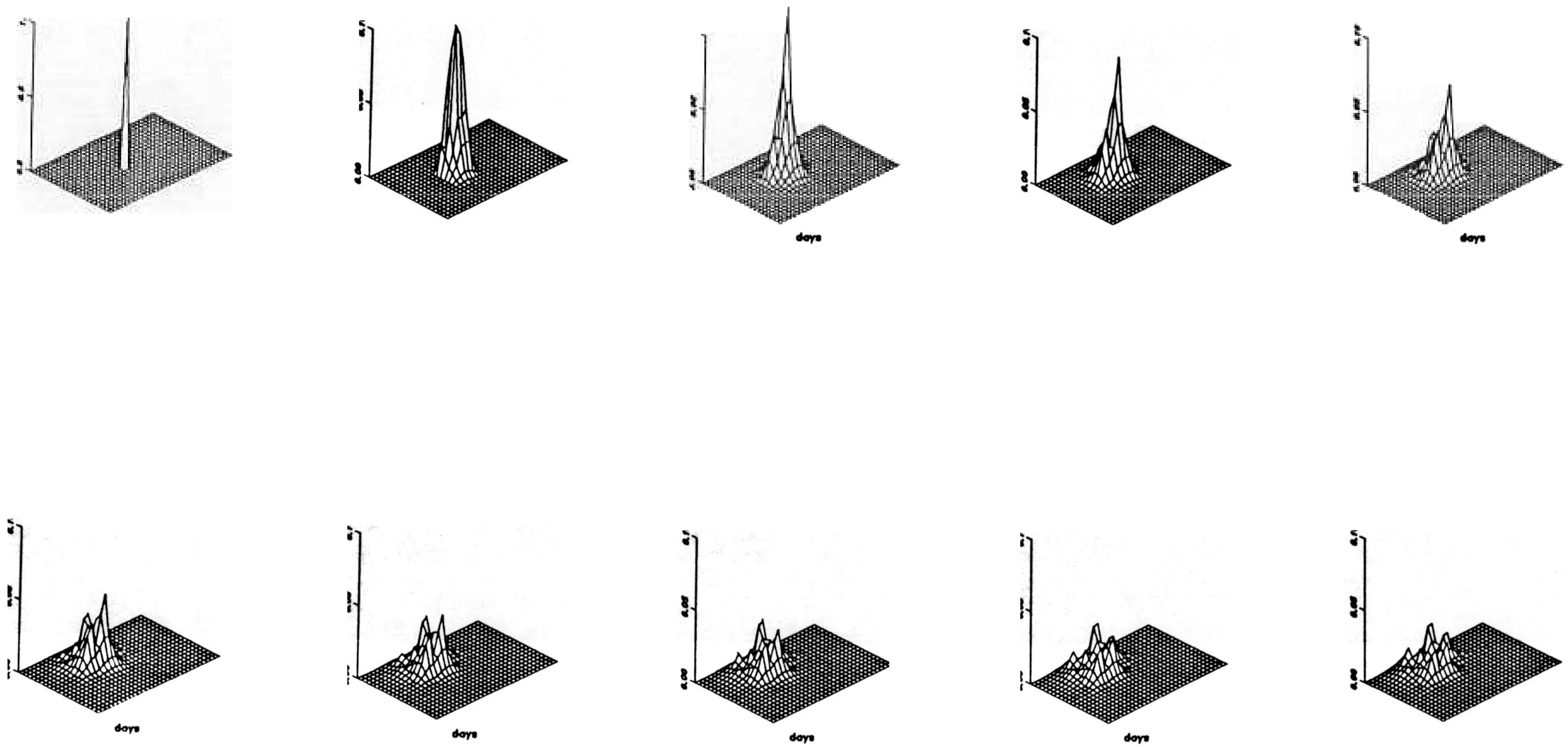
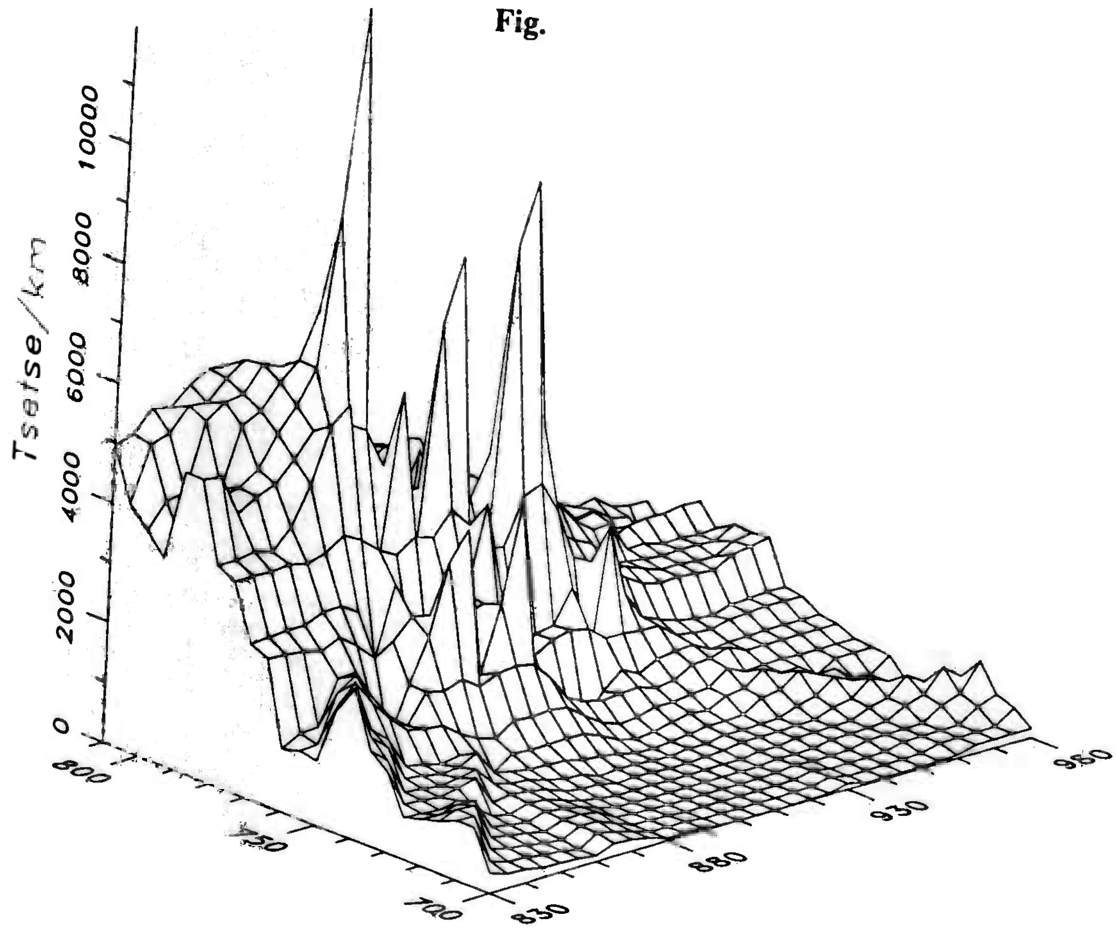
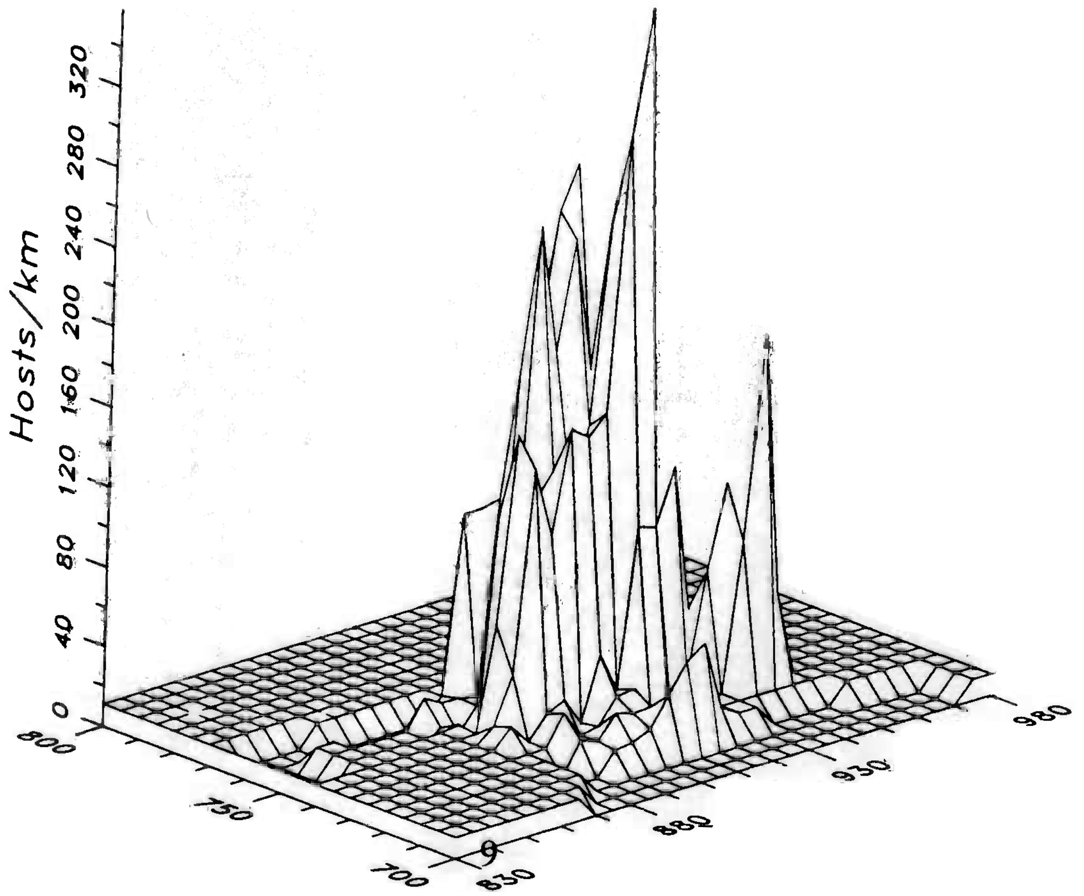


Fig.


Tsetse/km
10000
8000
6000
4000
2000
0
800
750
700
830
880
930
980


Hosts/km
320
280
240
200
160
120
80
40
0
800
750
700
830
880
930
980

4. *Acknowledgements*.

We are grateful to the Acting Director of ITC, Dr Bakary Touray, for providing accommodation and working facilities during our visits; to Dr Snow for advice and for provision of transport during our stay; to ITC computer staff; and of course to the field assistants who helped collect the original data.

5. *Summary of financial expenditure.*

NRI Extra Mural Contract X0203
Project budget: £28944.00

Salaries	16511.20
Travel & subsistence	5584.50
Insurance	164.80
Consumables	79.10
Overheads	6603.40

Paul Milligan
Unit for Statistics and Epidemiology
Liverpool School of Tropical Medicine
Pembroke Place
Liverpool L3 5QA.

Annex 1: Papers presented at conferences or submitted for publication:

1. Spatial factors in the assessment of trypanosomiasis challenge to livestock. TJ Wacher, PJM Milligan, P Rawlings and WF Snow. Invited paper presented to the Workshop for Modelling Vector-Borne and other Parasitic Diseases, ILRAD, November 23-27 1992.

2. Tsetse-Trypanosomiasis challenge to village N'Dama cattle in The Gambia I: Field assessments of spatial and temporal patterns of tsetse-cattle contact and the risk of trypanosomiasis infection. TJ Wacher, PJM Milligan, P Rawlings and WF Snow.

3. Cattle migration and stocking densities in relation to tsetse-trypanosomiasis challenge in The Gambia. TJ Wacher, P Rawlings and WF Snow.

4. Ranging behaviour of N'Dama cattle in The Gambia. TJ Wacher and WF Snow.

In preparation:

5. Estimating the effect of spatial heterogeneity on the transmission of animal trypanosomiasis. PJM Milligan, TJ Wacher, P Rawlings and WF Snow.

6. A mark-release experiment to study a population of *Glossina morsitans submorsitans* in The Gambia. PJM Milligan and P Rawlings.

Annex 2: Abstract of the paper presented at the Workshop for Modelling Vector-Borne and other Parasitic Diseases, ILRAD, November 23-27 1992:

Spatial factors in the assessment of trypanosomiasis challenge to livestock. T Wacher, P Milligan, P Rawlings, W Snow.

The severity of the trypanosomiasis problem in a particular location is traditionally assessed in terms of the challenge index - Apparent density of tsetse, or trap catch per day, times infection rate - which is assumed to be proportional to the force of infection. However, this index masks variation in the force of infection among herds and among individuals within herds. It is also not comparable between sites since the relative abundance of tsetse hosts may vary. We have studied spatial distribution of herds of livestock in relation to tsetse and calculated an index of challenge based on the ratio of vectors to hosts. This index is strongly correlated with estimates of the force of infection calculated from the incidence of infection in susceptible zebu; and it provides information on heterogeneity in exposure of different herds to tsetse. We argue that study of spatial distribution of vectors and hosts is a prerequisite for the application of epidemiological models of vector-borne diseases to real-life field situations.

Annex 3: Figures illustrating the data used in the study.

Fig.A1 Map of The Gambia, on the Atlantic Coast of West Africa, showing the locations of Keneba and Niamina East study sites, with expanded sections showing details of local geography and habitats at each.

Fig.A2 Keneba and Niamina East study sites, The Gambia, showing details of local geography and habitats, with the locations of Blue Box trap arrays set out for three days of sampling in each month of the study period indicated by square blocks. Note that at Keneba, solid squares indicate initial trap array used until Sept.1987, while hollow squares indicate additional traps added for extended sampling from November 1987 on.

Fig.A3 Mean catch/trap/day of *Glossina morsitans submorsitans*, over full trap arrays from Wet Season 1987 (WS87) to Late Dry Season 1990 (LD90), at Keneba and Niamina East, The Gambia. Note that *G.palpalis gambiensis* is also present at Niamina East in low numbers, but not represented.

Fig.A4 Detail of Keneba study site showing tsetse distribution (top layer) and grazing distribution of village herds combined (middle layer) over the site map in a) early dry season, b)late dry season and c) wet season 1988. Note that in analysis the grazing distribution is further broken down to the range of each herd separately for comparison with the tsetse map.

Fig.A5 Detail of Niamina East study site showing tsetse distribution (top layer) and grazing distribution of village herds combined (middle layer) over the site map in a) early dry season, b)late dry season and c) wet season 1988. Note that in analysis the grazing distribution is further broken down to the range of each herd separately for comparison with the tsetse map.

Fig.A6 Stock census results at Keneba and Niamina East study sites for the period Late Dry Season 1987 to ED90 at Keneba and Early Dry Season 1988 (ED88) to ED90 at Niamina East, The Gambia.

Fig. A

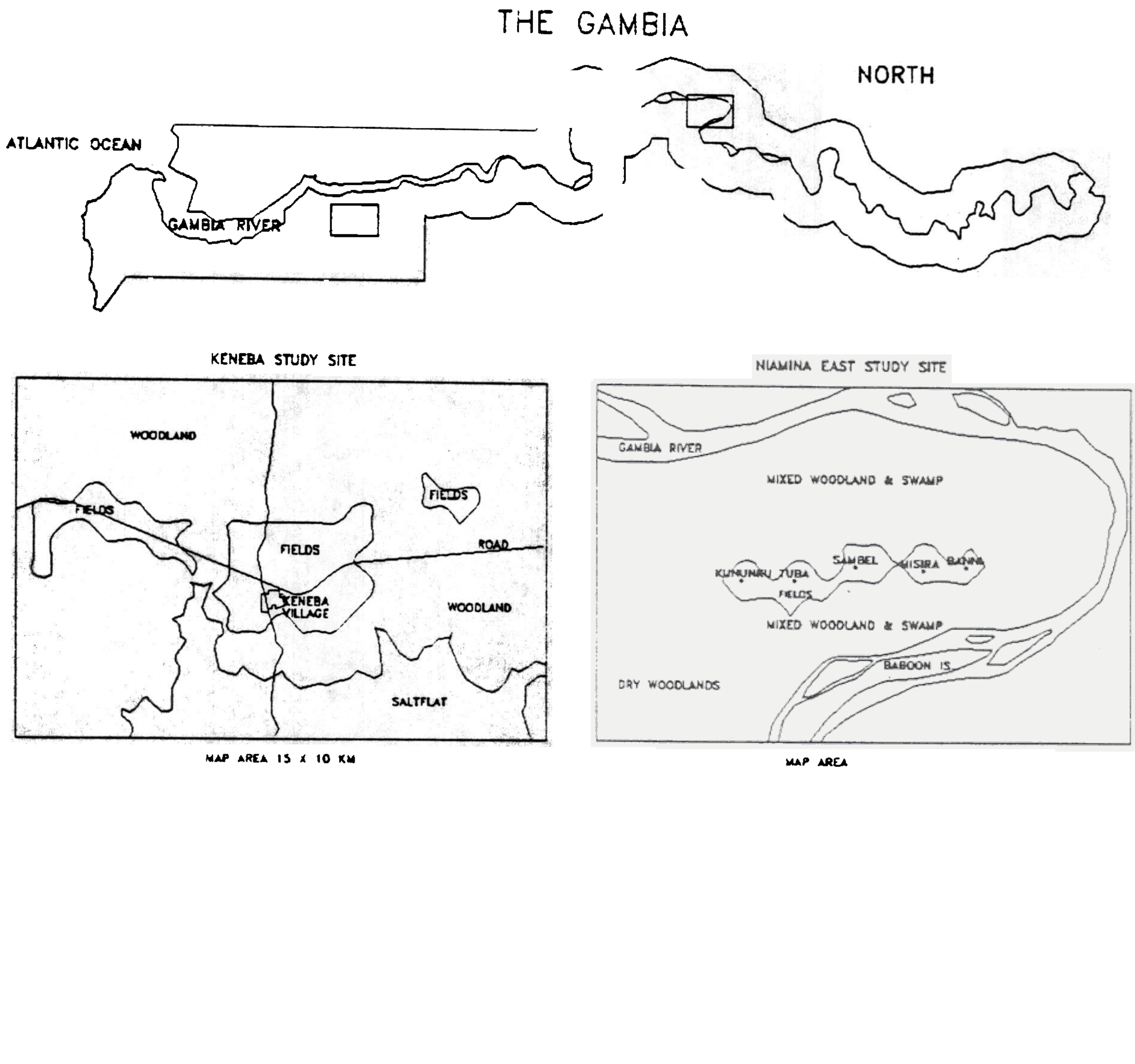
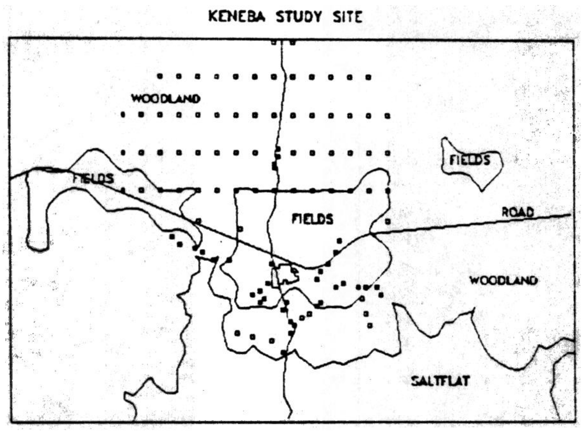
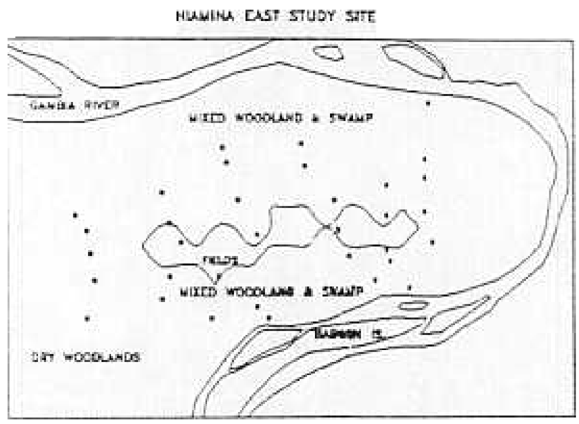

THE GAMBIA
NORTH
ATLANTIC OCEAN
GAMBIA RIVER
KENEBA STUDY SITE
WOODLAND
FIELDS
FIELDS
FIELDS
ROAD
KENEBA VILLAGE
WOODLAND
SALTFLAT
MAP AREA 15 X 10 KM
NIAMINA EAST STUDY SITE
GAMBIA RIVER
MIXED WOODLAND & SWAMP
SAMBEL
MISIRA
TUBA
FIELDS
MIXED WOODLAND & SWAMP
BABOON IS.
DRY WOODLANDS
MAP AREA

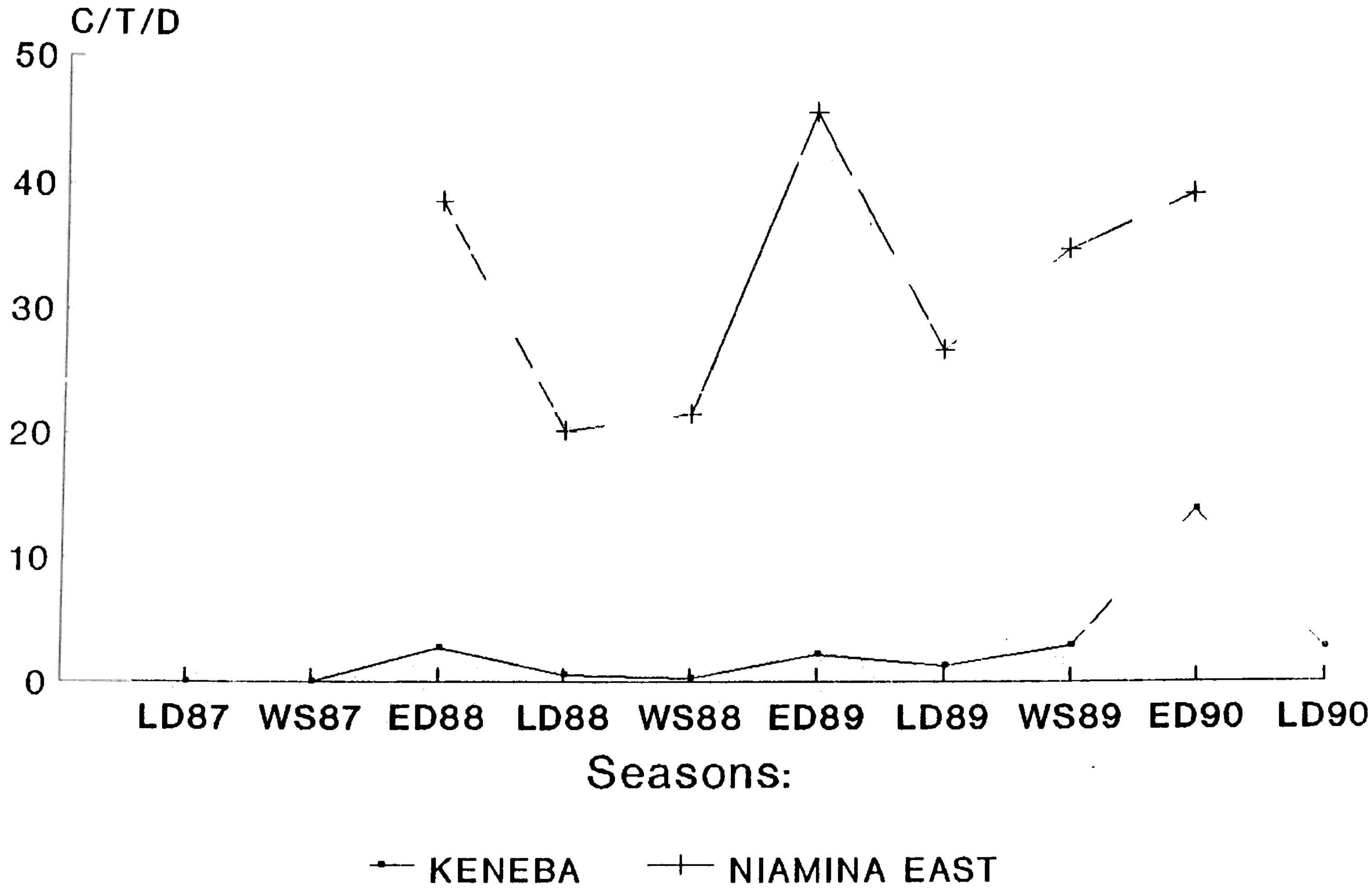
Fig. A2





MAP AREA 15 X 10 KM

Fig. A3



C/T/D
50
40
30
20
10
0
LD87
WS87
ED88
LD88
WS88
ED89
LD89
WS89
ED90
LD90
Seasons:
KENEBA
NIAMINA EAST

Fig. A4

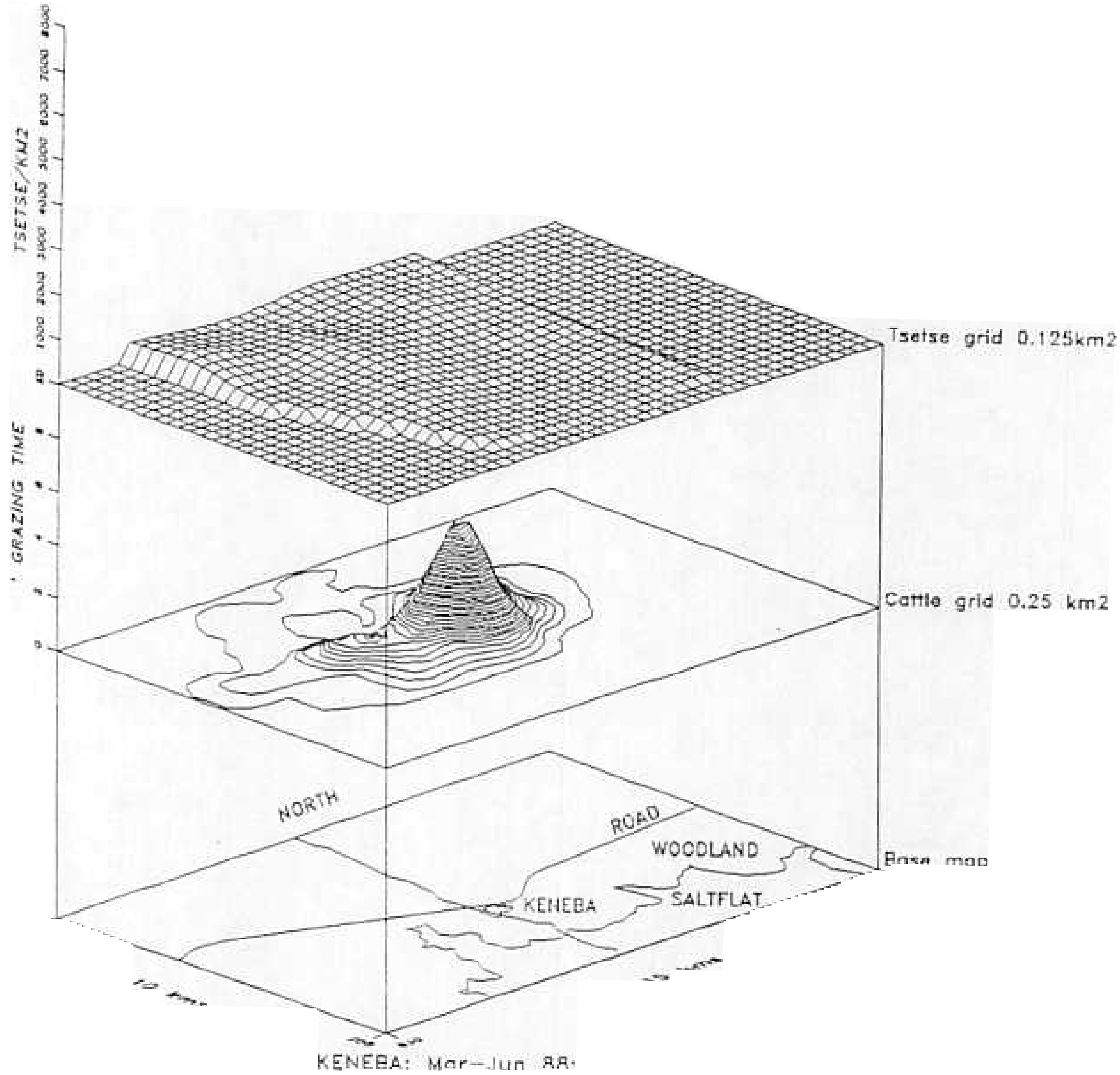

TSETSE/KM2
GRAZING TIME
Tsetse grid 0.125km2
Cattle grid 0.25 km2
NORTH
ROAD
WOODLAND
Base map
KENEBA
SALTFLAT
KENEBA: Mar–Jun 88

Fig. A4 (contd.)

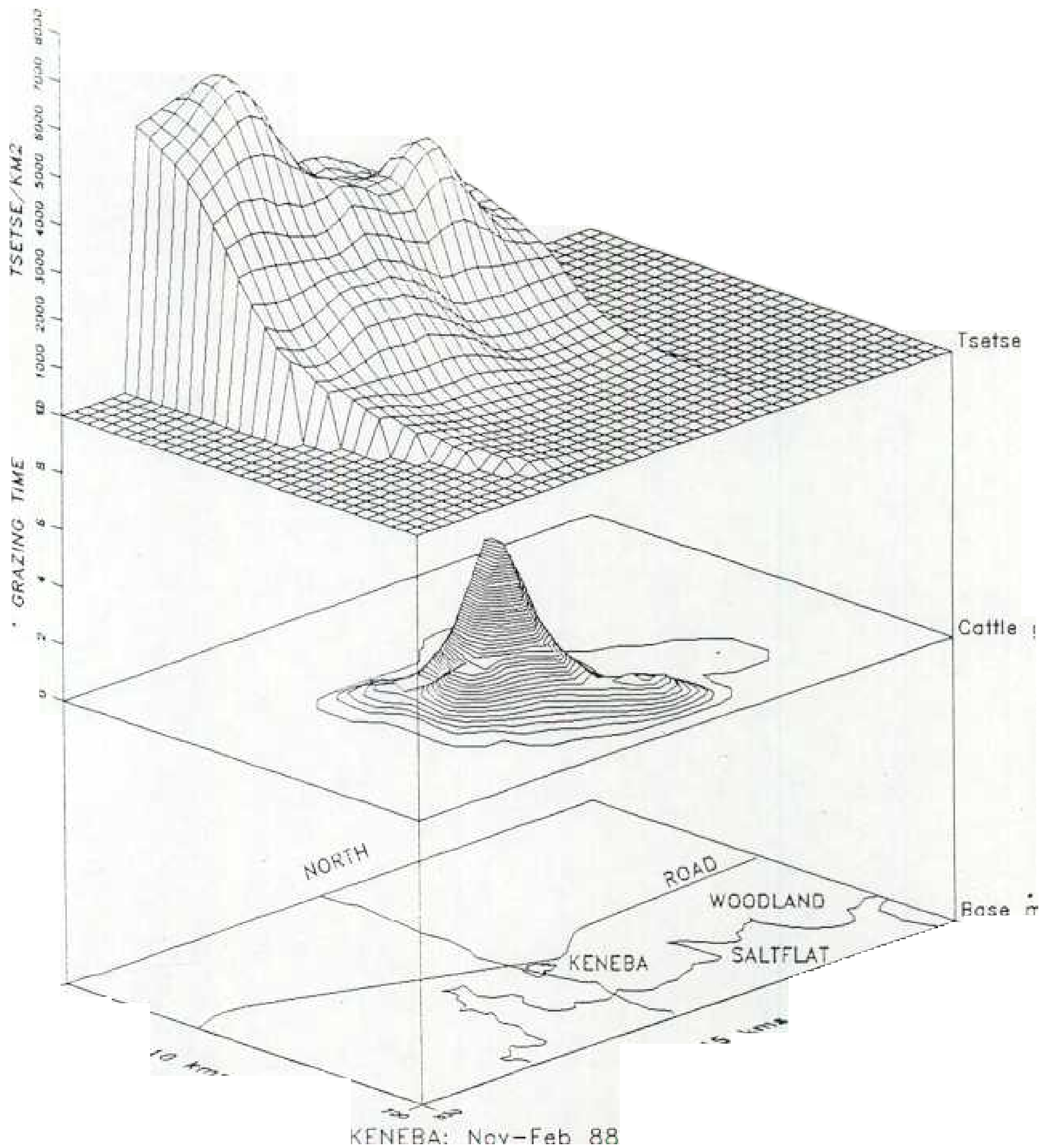
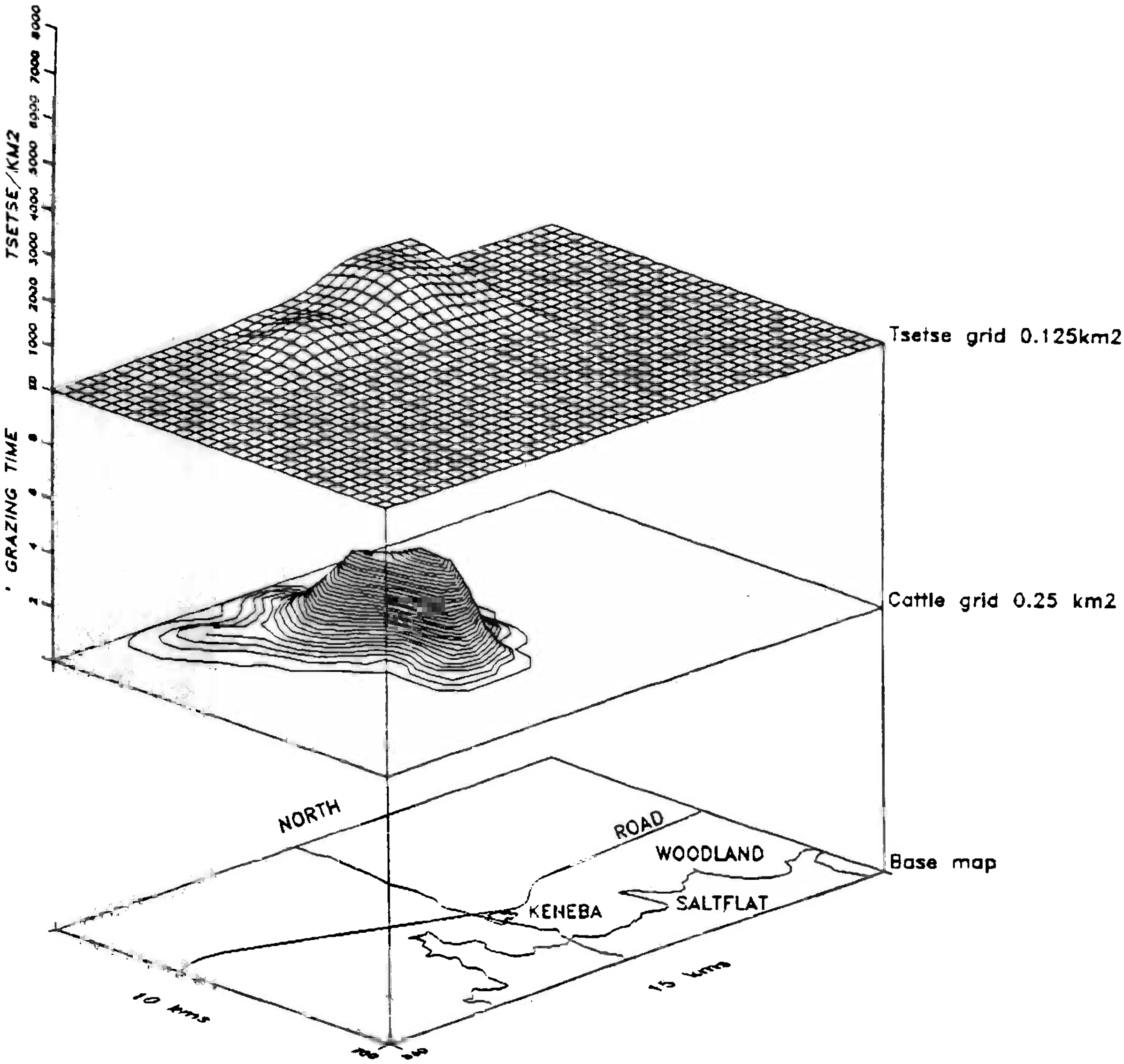

TSETSE/KM2
GRAZING TIME
Tsetse
Cattle
Base
NORTH
ROAD
WOODLAND
KENEBA
SALTFLAT
10 km
KENEBA: Nov-Feb 88

Fig. A4 (contd.)



KENEBA: Jul-Oct 88:

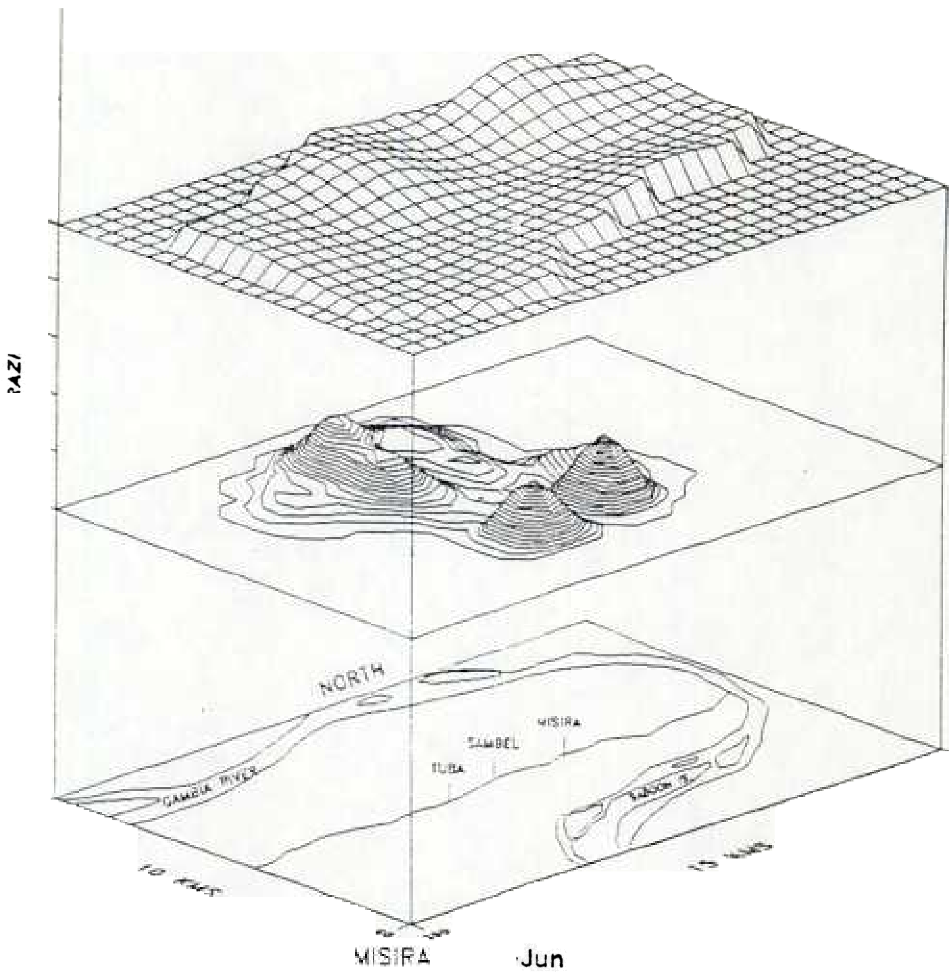
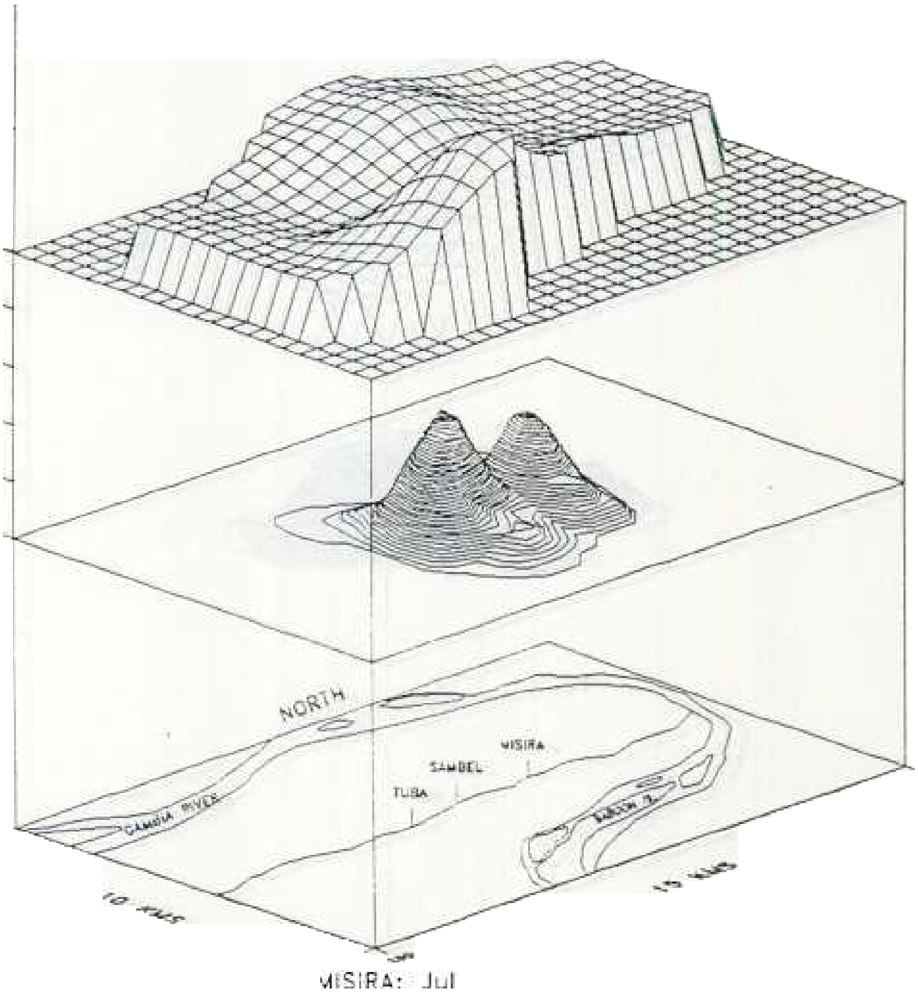

NORTH
SAMBEL
MISIRA
TUBA
MISIRA
Jun

Fig A5 (contd



MISIRA: Jul

PROJECT COMPLETION REPORT

A: BASIC DATA

COUNTRY:	UK/The Gambia
MIS CODE:	793 630 032 YK
PROGRAMME TITLE:	Livestock Production
PROJECT TITLE AND R NUMBER:	Analysis of interactions between tsetse and trypanotoloerant cattle - **R5211**
SECTOR:	Renewable Natural Resources
COMMODITY:	Livestock
BRIEF DESCRIPTION:	To analyse spatio-temporal interactions between tsetse flies and trypanotolerant cattle in The Gambia
APPROVED BY:	Dr R D Cooke
DATE APPROVED:	16 June 1992

B: OUTPUTS OF IMPLEMENTATION PHASE

1. INITIAL

Working with herds managed by local communities the Gambian International Trypanotolerance Centre's ODA funded entomology programme collected detailed data on cattle movements and tsetse distribution over a six year period in several study sites. This current project analysed these data to investigate ways in which the spatial distribution of tsetse and their hosts influenced trypanosomiasis transmission.

2. ACHIEVMENTS

Accurate knowledge of trypanosomiasis challenge or epidemiological risk is extremely valuable for targetting control activities. This study illustrates the importance of estimating spatial and temporal interactions between host and vector when assessing risk. Traditional methods, which tend to ignore spatial parameters, cannot give a true estimate. The basic reproduction rate of a disease is a measure of its stability and a model developed by this project can be used predictively to estimate how this stability and thus epidemiological risk might be affected by, for instance, climate change.

3. RATING

- ✓ Outputs all realised
- Outputs largely realised
- Significant drawback with realisation of outputs
- Major problems with realisation of outputs
- Outputs completely unrealised - project abandoned

C: FINANCIAL PROFILE

1. AMOUNT INITIALLY APPROVED: £28,944
2. SUBSEQUENT AMENDMENTS:
3. PROFILE:

	F/Y1	/Y2	F/Y3
PLANNED	28944		
ACTUAL	26727		

4: WERE ANY COST CHANGES IDENTIFIED IN A TIMELY WAY? YES/~~NO~~
5: WHEN SOUGHT, WERE THEY PROPERLY JUSTIFIED AND EXPLAINED YES/NO
6: ACTUAL CASH COST AS A PERCENTAGE OF INITIALLY PLANNED CASH COST

91.4%