Rinderpest Eradication Strategy in the West and East Nile Ecosystems

Community-based Animal Health and Epidemiology (CAPE) Unit of the Pan African Programme for the Control of Epizootics (PACE)

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Abbreviations

CAHW	Community Animal Health Worker
CAPE	Community-based Animal Health and Participatory Epidemiology Unit
CBPP	contagious bovine pleuropneumonia
CCS	critical community size
ECF	East Coast fever
FAO	Food and Agriculture Organisation
FMD	Foot and mouth disease
GOS	Government of Sudan
IBAR	Interafrican Bureau for Animal Resources
OAU	Organisation of African Unity
OLS	Operation Lifeline Sudan
PACE	Programme for the Pan African Control of Epizootics
PDS	participatory disease searching
PE	participatory epidemiology
PRA	participatory rural appraisal
RP	rinderpest
RPV	rinderpest virus
SCF	Save the Children Fund
SE	stomatitis-enteritis
SRRA	Sudan Relief and Rehabilitation Association

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Disclaimer

The views and recommendations expressed in this report are solely the responsibility of the author.

Modelling Symbols

α	alpha: rate of recovery/removal (=1/infectious period)
β	beta: rate of transmission per infective (=cp)
γ	gamma: transition rate from exposed to infectious state (=1/latent period)
μ	mu: non-specific mortality rate
σ	sigma: rinderpest specific mortality rate
b	birth rate
c	number of physical contacts per day
d	duration of infectiousness
f	proportion immunized
h	proportion protected
v	proportion vaccinated
p	probability of transmission per contact
x	proportion susceptible
C	number of new cases
E	number exposed
I	number infectious
IP	incidence proportion
N	total number in population at risk (=S+E+I+R)
R	number removed/recovered
R_o	basic reproductive number (=cpd or βd)
R_e	effective reproductive number
R_h	between herd reproductive number
S	number susceptible

1. Executive Summary, Conclusions and Recommendations

Throughout most of the life of the OLS Livestock Programme, conventional wisdom held that rinderpest eradication from southern Sudan was not possible without peace. It was not until 1998, that the extent of the impact of the OLS Livestock Programme and the true potential of community-based vaccination using heat-stable vaccine was widely appreciated. As a result, the eradication of rinderpest from southern Sudan has not been a stated objective until relatively recently.

There is now an emerging consensus among non-governmental organizations, international agencies and the cattle owners of southern Sudan that the OLS Livestock Programme has been highly successful in controlling rinderpest in the south Sudan. There is also a realisation that the time for institutionalised vaccination has now passed. Eradication, although not certain under the prevailing security conditions, is a realistic aspiration.

The eradication phase of the programme should be implemented in a consultative manner to insure that organisations and communities involved continue to share in the ownership of the undertaking. Ownership of the eradication strategy by all partners is essential to its success. Dialogue is required between the stakeholders to design and adopt a disease surveillance strategy and identify time-bound vaccination targets.

Information from livestock owners and organisations on the ground suggest that the cessation of vaccination and intensification of surveillance in areas West of the Nile is an appropriate and prudent next step. The situation East of the Nile is less clear. Historically, this area has not benefited from the same levels of activity as the West and community-based infrastructure is much less developed. This has primarily resulted from problems of intermittent access and a consequent decision to focus resources West of the Nile as part of a phased programme.

At the present time, the Sobat Basin is difficult to access for either vaccination or surveillance. At the time of writing, OLS has indefinitely suspended all NGO activities in large areas of the Sobat Basin.

Further to the south, the largest communities in the region, the Murle and Toposa, have only recently been accessed to any significant degree. A shortage of information is not equivalent to the absence of disease. Building disease surveillance capacity, and conducting participatory disease searches should be the main priorities. Time-bound vaccination should continue within the Murle and surrounding communities, when and where it can be properly applied. In this manner, at the end of the 2001-02 dry season, sufficient data will be in hand to support an informed decision regarding the cessation of vaccination East of the Nile.

Conclusions and Recommendations:

1. The mission did not find direct evidence supporting the reports of a recent major epidemic of rinderpest in the Kengen River system. There was considerable evidence that rinderpest has been circulating in the southern portion of the East Nile Ecosystem within the last two years. Further, there is considerable indirect evidence that rinderpest is still present East of the Nile. This evidence includes wide spread-rumours, descriptions of endemic disease patterns, and the priority that the Murle and Karamojong cluster communities place on rinderpest.
2. The professionals of the OLS livestock programme have considerable skill in the use of participatory techniques to collect data on the epidemiology of disease. They have had insufficient experience in data analysis and in deriving best-bet scenarios from the information they collect. Training was provided to counterparts on the interpretation of results during the course of the mission. Data analysis should be a stated component of surveillance officer's duties.
3. Field data indicated that rinderpest in southern Sudan was moderately virulent with mortality ranging between 26 and 62%. The length of the inter-epidemic period was the primary determinant of the severity of outbreaks.
4. Based on serological information in the literature and small sample sets collected by OLS from unvaccinated populations, it was possible to estimate the basic reproductive number for rinderpest (R_o). The estimated values ranged between 3.5 and 5.3. The most likely value was taken to be 4.4.
5. The threshold level of herd immunity required for interrupting the transmission of rinderpest in large populations lies between 71 and 81% for the estimated range of R_o. In small populations, stochastic (chance) effects result in fade-outs at lower herd immunity levels.
6. In large populations, partial vaccination coverage can contribute to the establishment or maintenance of endemism. This concept was explored and demonstrated through the development of a stochastic SEIR model for rinderpest during the course of the consultancy.
7. The cattle population of southern Sudan is highly structured and should not be considered as having a homogeneous contact rate. The tribes and clans of southern Sudan should be considered as a series of interlinked subpopulations with attenuated contact rates between groups. It is not necessary to achieve uniform herd immunity rates in all communities to eradicate disease and global interpretations of vaccination coverage are misleading.
8. In terms of husbandry systems and internal contact rates, the major cattle populations of southern Sudan share many similarities. It is suggested that the main risk factor that distinguishes communities in regard to rinderpest risk is lack of access to services due to security concerns. The OLS Livestock Programme has always operated within the context of windows of opportunity.
9. Vaccination coverage in southern Sudan is reaching less than 10% of the estimated cattle population. However, were vaccination is being practiced it is highly focused. Seromonitoring has consistently shown herd immunity rates of over 70% in communities where vaccination is practiced. This approach removes

sub-populations from the overall pool of susceptible sub-populations and has contributed positively to the eradication of rinderpest.

10. The East Nile Ecosystem should be divided into two sub-systems: the Sobat Basin and the South East Nile Ecosystem centred on the Kengen River area. The Sobat Basin should be defined as the Nuer and Dinka communities on both banks of the Sobat. The South East Nile Ecosystem should include all communities in southern Sudan east of the Nile and to the south of the Nuer.
11. Emphasis must now shift from vaccination to surveillance. Remaining vaccination efforts should be highly targeted and time-bound. Vaccination should only be practiced where good access is available and 80 to 90% coverage is feasible. The need to continue vaccination should be critically reassessed at the end of the 2001-02 dry season (April 2002) in light of the results of surveillance activities. Dialogue on the cessation of vaccination should be carried out with the NGOs and communities. Ownership and the reality of a time-bound eradication strategy must be brought home.
12. As part of the eradication strategy, communities should be identified and categorized according to risk factors such size, contact structure, interaction with neighbouring communities and degree of accessibility. Three categories are proposed: vaccination and surveillance, surveillance, and limited access communities. As a point of departure for dialogue, the following classification is suggested for communities East of the Nile:

Vaccination and Surveillance Communities:	Toposa, Jie, Murle and Bor Dinka
Surveillance Communities:	Anuak, Kachipo, Lotuko, Lopit, Boya and Didinga
Limited access Communities:	Nuer and Dinka of the Sobat Basin and the Pibor Murle

13. Where vaccination occurs, it must be intensive and focused. In areas where vaccination is practiced, a resident programme should be established. The practice of staff managing several sites through intermittent visits has not been effective.
14. In southern Sudan, rapid response strategies are problematic. The OLS Livestock Programme exploits windows of opportunity. A rapid response capability implies that access is flexible and at the discretion of campaign managers. Aggressive eradication strategies that rely heavily on rapid response capability are not adapted to the reality of southern Sudan.
15. Considerable activity with the Murle, Jie and Kachipo is now feasible from Boma as a result of the construction of the bridge over the Kurun River. Security and access are good. It is an important centre for rinderpest surveillance and vaccination activities. This window of opportunity should be utilized.
16. Cattle raiding has been a constraint to service delivery in the southern part of the East Nile Ecosystem. Although it does not normally place OLS Livestock

Programme staff in danger, it hampers access to cattle across community lines by restricting the movement of counterpart staff and frequently causes cattle camps to seek out more remote locations. In the past, raiding has all but eliminated access to the Murle from towns such as Paluer, Pochalla and Akobo. It is strongly recommended the OLS Livestock Programme consider introducing conflict resolution activities. It is suggested that peace meetings are held between the Anuak, Jie, Kachipo, Murle, Niagatom and Toposa. Increased access to livestock service delivery, among other services, should be presented as one of the benefits of peace.

17. As new communities are accessed, purposive serosampling to detect the circulation of rinderpest should be carried out as a matter of priority. It is recommended that at least 5 to 10 herds be sampled with a total sample of at least 200 animals. In the Murle, this should be done before any vaccination is carried out.
18. The general disease reporting system is functioning well and reports of stomatitis-enteritis are being received and investigated. The primary source of reports is the community-based animal health network.
19. Comprehensive participatory disease searches to identify the date of the last rinderpest outbreak should be carried out in all of the principal communities east of the Nile during the 2001-02 dry season. Between 30 and 50 interviews should be conducted per community. The results should be tabulated and examined for patterns by qualitative methods.

The combination of participatory epidemiology and quantitative disease modelling used in this consultancy has contributed to rinderpest strategy development by clarifying the dynamics of rinderpest in the region. The use of existing veterinary knowledge as expert opinion combined with epidemiological parameter estimates from more conventional sources has allowed the construction of mathematical and conceptual models that illustrate the impact of control activities.

This approach can be further developed through model experimentation with the present models and the continued development of a structured population model. The collection of more data on community structure and contact rates would contribute to this effort.

The approach developed through this consultancy also has application to other infectious disease such as CBPP. It is proposed that participatory epidemiology and disease modelling be used as a means of studying the dynamics of CBPP in endemic, pastoral settings and developing more practical control strategies.

2. Participatory Disease Search in the East Nile Ecosystem

Introduction, Objectives and Methods

The immediate objective of the field mission was to investigate reports of the occurrence of rinderpest during November and December 2000 in the Kengen River area near Pibor. These reports described outbreaks of clinical disease consistent with the appearance of rinderpest in cattle and migratory white-eared kob. Secondly, the consultant provided training on participatory disease searching methods to project and counterpart staff.

In a more general context, the mission sought to collect information on the history of rinderpest circulation in the East Nile ecosystem through the process of participatory disease searching in order to inform the development of rinderpest eradication strategy. Several characteristic of the area are conducive to rinderpest endemism:

- Remoteness
- Marginalization
- Raiding
- Highly mobility
- Extensive, heterogeneous contact structure
- Numerous sub-populations with partial contact
- Absence of services

The Kengen River runs south to north from Kassegnor to Pibor and is used by Murle, Jie and Toposa pastoralists (Figure 1). The Jie have contact with Murle, Kachipo and Toposa groups. The Murle have contact with Jie, Bor Dinka and share borders with the Nuer and Anuak. The Toposa have contact with Jie and Murle to the North as well as a variety of peoples to the South, East and West. The Toposa are key to the containment of any residual RP in the East Nile ecosystem. The estimated cattle population for the communities east of the Nile are presented in Table 1.

The primary approach used throughout the mission was participatory epidemiology and participatory disease searching based on PRA techniques (Mariner, 2001). The PE or PDS approach relies primarily on semi-structured interviews, mapping and other participatory information gathering exercises to construct a best bet scenario on the dynamics of disease circulation in an ecosystem. This approach allows the systematic identification of high-risk sub-populations and the tracing of field reports to foci of active disease.

Reports of current and historic disease events are collected from multiple informants and evaluated using the process of triangulation. The following categories were used to the access the significance of individual reports:

1. A first hand report from a herder regarding morbidity/mortality due to rinderpest in his own herd.
2. A report of cases directly observed by a cattle owner.
3. Rural hearsay received from herders or elders in cattle camps who did not actually see the disease.
4. Town hearsay received from any source.

Table 1: East Nile Cattle Population Estimates by Community

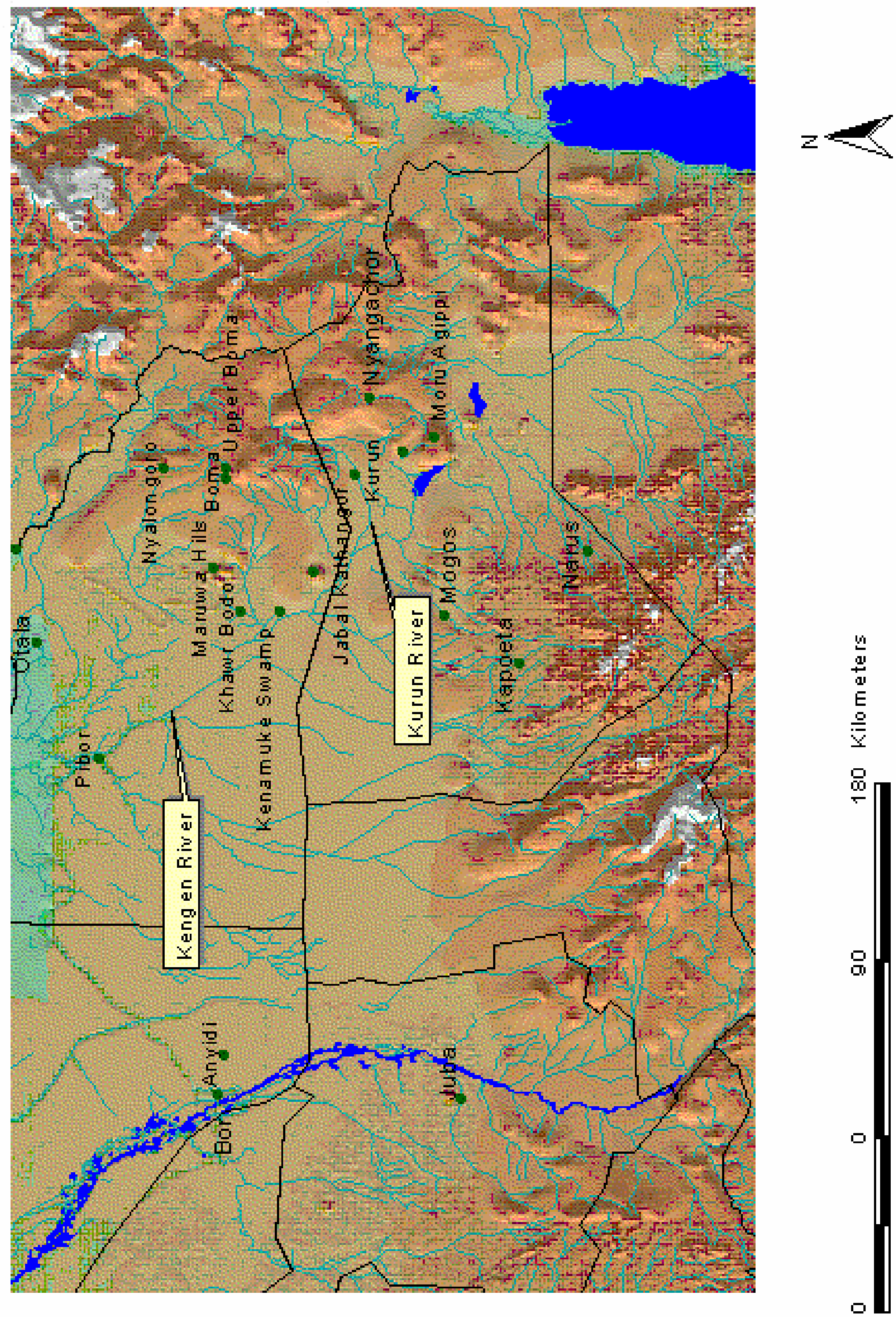
Community	**Head of Cattle**
Southern East Nile	
Anuak	5,000
Boya/Didinga	60,000
Lotuko/Lopit	80,000
Dinka (Bor)	90,000
Jie	40,000
Kachipo	5,000
Murle	800,000
Toposa	300,000
South East Nile Total	**1,380,000**
Sobat Basin	
Dinka	250,000
Gawere Nuer (Phou State)	135,000
Jikany Nuer (N. Latjor)	420,000
Jikany Nuer (S. Latjor)	24,000
Laak Nuer	55,000
Lou Nuer (Bieh State)	105,000
Lou Nuer (Akobo area)	100,000
Sobat Basin Total	**1,089,000**
East Nile Total	**2,469,000**

The population estimates presented above are derived from the working estimates obtained from key informants with direct experience in delivery of services to the respective communities and aerial surveys.

Reports that meet the criteria of categories 1 and 2 were used to directly construct the best bet epidemiologic scenario. Information that falls within categories 3 and 4 was used as leads during the investigation, but was not treated as data in the final analysis.

Information was also collected on the age structure of cattle herds, herd size and the severity of rinderpest disease in order to assist with the estimate of R_o, the basic reproductive number, for rinderpest. A proportional piling exercise was developed to estimate the herd age structure and mortality due to rinderpest by age group. Four categories were designated as sucklers, weaners, heifers and steers, and adult cattle. These categories were estimated to corresponded to less than 1 year-old, 1 to 2 years, 2 to 4 years, and older than 4 years. Respondents were asked to divide 50 seeds between the four categories to indicate the relative size of the different categories in a normal herd. Respondents were then asked to illustrate the relative mortality due to rinderpest (and other diseases) by removing seeds from each category. Where feasible, respondents were also asked to list the ages of all cattle in their herds.

Figure1: Kengen River Area



Boma

On the arrival of the first mission to Boma, the team assessed the available intelligence regarding herder movements and the accessibility of the Kengen River. The information suggested that the road from Kassengor travelling North along the Kengen was mined. Further, reports suggested that Murle cattle concentrations had moved away from the Kengen to locations to the North and Northwest of Boma. The Jie were concentrated due East of Boma at a swampy area called Kanamuge by the Jie (Bodo by the Murle) just to the East of the Moruwo Hills near the Kengen River. It was also apparent that vaccination coverage was low in these populations (Table 2). In order to obtain first hand intelligence, the team decided to visit these concentration points.

Table 2: Vaccination Coverage from Boma

Year	Total
1998	12,821
1999	500
2000	1,130
2001	2,579

Table 3: Summary of First Hand Reports of Rinderpest Received during the Boma Field Trip

Source	Most Recent Outbreak	Second Most Recent Outbreak	Comments on Periodicity
Toposa (Namurpus)	NA	NA	NA
Toposa (Kirun Bridge)	1994	NA	NA
Murle (Bea)	1995-96	1990	5 yrs
Murle (Itti)	1989	1984	2 yrs (minor), 10 yrs (major)
Murle (Garawurth)	1990	NA	NA
Jie (Khor Ardep)	1998	NA	NA
Jie (Lelimay)	1/2000	NA	NA
Jie (Lelimay)	2000	1999	2 yrs
Jie (Kanamuge)	11/1999	1990	2 yrs (minor)
Jie (Kanamuge)	3/1999	1990	NA
Jie (Taragabon)	1998	1995	2 yrs
Jie (Lelimay)	1999	1995	2 yrs
Murle (Pelizeya)	1998	1996	2 yrs, 'after two calvings'

Table 3: Respondents observations on the occurrence of rinderpest in their own cattle. Where NA is entered, the respondents were not asked to provide the information appropriate to the column. The Toposa at Namurpus did not identify rinderpest as a problem.

Comments suggested that the second most recent outbreaks mentioned where more memorable major outbreaks and that minor outbreaks occurred in many cases between the most recent and second most recent reports.

Murle (Nyalongoro and Garawurth)

The team had the impression that the Murle appeared less open or willing to share information than the Jie. This combined with the limited number of interviews indicates that the information obtained should be interpreted with caution.

In the first three Murle interviews, respondents clearly expressed that rinderpest (*bataboi*) had not been present in their cattle for at least 5 years. In the fourth interview, the respondent described rinderpest as a biennial event that occurred after every two calvings. By his watch, the community was just about due for the next outbreak.

All Murle groups stressed that they were very concerned about rinderpest. They stated that if the disease has been absent five years or more, a reintroduction would be very severe.

Approximately 66 sera were collected from Murle cattle at Nyalongoro and Garawurth. The majority were unvaccinated. Age data was collected to allow the calculation of the average age of seroconversion.

One report of direct observation of white-eared kob dying with tearing and diarrhoea was received, but no one reported having observed sick cattle. The wildlife deaths were reported from Teltelle near Kengen. Teltelle was described as two days walk south of Pibor, three days walk north of Bodo and 2 days walk west of Lazach. Teltelle was mentioned in the report of Dr. Aluma Araba as a place where the kob passed. Dr. Araba's report was based on information obtained from the SRRA vet officer, John Dodo and two vaccinators.

Lazach was described as a major grazing centre for the Murle from all directions. It was reported to be accessible by vehicle either from Bodo or Nyat travelling cross-country. An old road exists from Boma that passes through Lazach, but it is mined. Had the first mission continued in Boma, Lazach would have been visited. A second mission to Boma was undertaken in April with the objective of reaching Lazach. Unfortunately heavy rains occurred just as the mission reached Boma and off road travel became impossible. After waiting three days for the rivers to go down, the mission was able to return to Loki, but required three days to cover 300 km.

During the second mission, three interviews were conducted with groups that had recently come from Lazach. The first was with two respected elders that were also active in civil and political affairs (a former commissioner and a policeman). The second two interviews were with two men in their late 20's.

The elders who had returned from Lazach were bona fide cattle owners who spoke knowledgeably about disease and rinderpest. They identified three important diseases (*maam, kapunech, and bataboi*). They volunteered that trypanosomosis (*maam*) and CBPP (*kapunech*) where present, but made no statement on whether or not rinderpest was on going. When asked, they said that rinderpest was occurring in unvaccinated herds in Lazach. They estimated that less than 25% of the cattle were vaccinated. They stated that the disease occurred every 1 to 2 years. Their description was consistent with the expected behaviour of rinderpest in an endemic population with poor vaccination coverage.

Of the two young men interviewed one had originated from Thobor, 2 hours walk from Pibor, and had passed Duren on the Kengen River and then Lazach. The second young man was from Labarab village in Lazach and was a member of the Turain cattle camp (*kuthur*). Both young men described *maam* and *kapunech* in detail. They stated that these were the main problems of the cattle in Lazach and elsewhere. When asked, they could describe rinderpest well, but stated very clearly that it was not occurring at the present time in Lazach. The young man (26 years-old) who resided in Lazach stated that he had never seen the disease. The man from Thobor stated that he had last seen the disease in 1987-88.

It is of interest to note that the more politically active elders gave internally consistent reports of rinderpest while less complicated livestock owners gave opposite information. The consultant is concerned that the original reports from Pibor, which came from urbanized community leaders, may form a pattern of rumours to draw attention to a neglected area.

The missions did not find significant direct evidence of active RP among the Murle. However, it is difficult to support a negative conclusion in light of the extensive indirect evidence of rinderpest. This included widely disseminated rinderpest rumours, detailed existing veterinary knowledge about rinderpest and the priority the communities placed on rinderpest. Ruling out rinderpest requires more data *directly from the cattle camps* than has been collected among the Murle. Given the remoteness of the terrain, a tractor and wagon would be the most appropriate means of accessing these communities in any season. The Murle community should be an objective of further investigations in the next dry season.

Jie (Khor Ardep, Lelimay and Kanamuge) and Toposa

The Jie provided detailed descriptions of rinderpest outbreaks between late 1998 and January 2000. They used two terms for rinderpest, *achoke* and *acheke.* The term *achoke* appeared to be a loan word from the Toposa. *Acheke* was a term that referred to the standing of hair during the febrile phase. The Jie reported that the standing of hair was the first sign of rinderpest. No first hand reports of active rinderpest were received during the mission. The Jie had heard of disease outbreaks in kob and were concerned that the disease would come with the return of the kob to the area in March.

Vaccination coverage was moderate in Khor Ardep and Lelimay, and occasional in Kanamuge.

Kanamuge was a major dry season centre for the Jie. The mission estimated that 20,000 cattle were in the area at the time of the visit. The majority of families used the Lopet area as their wet season home and cultivation area. Some used the Moruwo Hills just next to Kanamuge and others used Longlebai Mountain extending to the south of Boma Mountain. It was reported that only cows in milk and calves normally travelled to these wet season areas.

Special efforts were made to seek out the Taragabon Jie at Kanamuge (Bodo) as a report from Pibor (George Were) indicated that this clan was currently suffering from RP. The report said that the Taragabon had travelled to the Kurun River area. The Makadol Jie also mentioned that they had heard that the Taragabon had rinderpest when they were crossing the Lodet area of the Kengen. The mission was unable to locate any Taragabon who had been a Lodet and was told that only about five families had crossed that way from Lopet by the way of Lodet. The Taragabon also pointed out Toposa groups in the Bodo area and stated that *Tabazak* was the Murle term for the Toposa people. They reported good relations with the Toposa in the area and no rumours of rinderpest.

Six sera were collected from a group of young Taragabon cattle reported to have been affected by RP in 1999.

The Kurun River and Kurun delta (Nagelmakol) are Toposaland areas to the south of Kassengor. This area was visit by Dr. Rafael Lotira Arasio on foot in mid-January 2001. The Toposa did not report active rinderpest and stated that they did not remember the last outbreak. In fact, they indicated that vaccination was no longer necessary. Dr. Lotira also travelled from Mogus in the direction of Lopet in early January 2001 interviewing Toposa in route. No reports of rinderpest were received. Jie were not encountered in either mission and it is believed to be problematic for Jie to enter these areas. This information complemented the findings of the limited interviews conducted by the consultant around Kurun in route to Boma.

The Jie consistently described a pattern of minor outbreaks with a two-year cycle. It was their opinion that RP was due to return in 2001. They indicated that the wet season was the traditional period of disease activity.

The conclusion of the mission was that there was sufficient evidence that rinderpest had been circulating in the Jie herds up until January 2000. The disease pattern and size of the community suggested that the Jie community were an important sub-population of an endemic system. The community is probably not large enough to maintain RPV in isolation from other communities. The absence of disease over the past 12 months is entirely consistent with the cyclic nature of rinderpest endemism.

Paluer: the Bor Dinka and the Murle

Bor Dinka

Rinderpest

ACROSS has estimated that the Bor Dinka are currently keeping about 96,000 cattle based on information from CAHWs, local chiefs and veterinary personnel. Almost all cattle were lost in 1992 during a period severe inter-factional conflict . At the present time, the Dinka are actively restocking. Cattle are being purchased from Murle, Nuer, Mandari and Dinka sources. Traditional loans and exchanges with other Dinka groups is also a major source of cattle. At the present time herd sizes are reported to be much smaller than in the past. Examples were encountered of herds with 10 to 30 cattle at present. Prior to 1992, an average cattle owner was reported to have kept over 100 head.

Rinderpest (*nyanatech*) was very well known and feared, but had not been seen in over a decade. As an example, elders at Akot cattle camp gave the most detailed description of rinderpest received since the beginning of the consultants mission to South Sudan. However, they had not experienced the disease in their cattle since 1976. This matter was probed in detail.

Table 4: Proportional Mortality at Akot Cattle Camp

Age Class	<1 year	1– 2 yrs	2-4 yrs	>4 yrs	Overall
Herd Structure (% of Herd)	20	20	20	40	
Severe RP Mortality (%)	100	100	30	15	54%
Annual CBBP Mortality (%)	0	30	30	15	18%

The Bor Dinka community has had limited contact with the Murle in recent years. In the past they used to share grazing in *Penyko* or *Aying* wilderness to the East of Bor. The name *Penyko* refers to whistling thorn that predominates in the wilderness. This wilderness was reported to run from the North to South and span the area from Waat to Lafon. The Murle were reported to be under the influence of the GOS at Pibor and the raiding of cattle and children was reported to be a major concern. The *Penyko* has functioned as a no-mans-land and probably as a natural and social barrier to rinderpest.

Since August of 2000, Murle peace deputations have sought the Dinka. Reconciliation was advancing at the time of the mission and Murle cattle camps were reported to be at Gam in the *Penyko*. Gam was described as being 4 hours walk from Anyidi and 3 days walk from Pibor. Abraham Alier Jocoyi, the Dinka CAHW Team Leader at Anyidi, had spent several days with the Murle. He was interviewed privately and reported that the Murle cattle were healthy without any rumours of rinderpest.

The Dinka are very concerned that the Murle will bring rinderpest. They state the reason for their concern is that the Murle cattle are unvaccinated. There are no rumours of rinderpest in the area. The white-eared kob (*juil*) were reported to be healthy. Elders did state that the kob could suffer from rinderpest with symptoms of tearing and diarrhoea. They were clear that the kob were healthy this year. The investigation team was concerned that extension messages may have already sensitised the community about the rumours of disease in kob.

Contagious Bovine Pleuropneumonia

The mission made inquiries into the importance of CBPP (*abutpio*) in the area and the methods and efficacy of treatment. It seems that *abutpio* and *luach* (trypanosomosis) are the major current animal health problems. The ACROSS veterinarian expressed concern that the prevalence of CBPP seemed to be rising despite treatment.

Proportional mortality ranking suggested that mortality was highest in the age groups between 1 and 4 years. Zessin et al. (1985)found that Dinka cattle in Bahr el Ghazal between 3 months and 3 years of age had a significantly higher risk of CBPP infection than other age groups. These same authors found a very low prevalence of clinical CBPP disease in all age groups.

Herders and CAHWs were interviewed as to the dosages and number of treatments applied as well as the response to treatment. It was apparent that oxytetracyclines were being applied at the correct dosage rate and that a single treatment could result in remarkable clinical improvement. It was reported, however, that new cases frequently continued to appear in the herd and that the original animals often fell sick within a few days to weeks of the first treatment. Respondents believed that their herd mates were reinfecting the treated animals. However, the time intervals suggested that recrudescence of clinical disease was more likely than reinfection. On the other hand, it was reported that treatment could clear the infection from a herd. Thus, the role of treatment from both an epidemiologic and economic perspective is unclear.

Murle

During the first two days of the mission, the team was informed that it was not possible to have direct contact with the Murle for security reasons. On the third day, ACROSS suspended its activities briefly while discussions were held with the SRRA regarding general security procedures. These were promptly resolved by a visit from county level authorities on the morning of the fourth day (and last full day) of the mission. The SRRA authorized and requested that the mission make contact with the Murle at the end of that same meeting.

The team travelled to Anyidi were a Dinka chief known to the Murle was contacted and interviewed. The chief reported that he had last experienced RP in 1986 at Aramjam cattle camp. The chief expressed the opinion that RP was hiding with the Nuer and Murle since they do not vaccinate. He also expressed the view that wildlife brought the disease, but stated that he was unaware of any disease in the white-eared kob (*juil*) this year.

Unfortunately, time did not allow the team to continue to the Murle community at Gam, but three Murle visitors from Gam were interviewed at Anyidi.

The three Murle respondents were two young adults and an adolescent. They stated that their home was at Macabol and that they did not cultivate. When asked about animal health, they spoke knowledgeably about a number of diseases but did not mention rinderpest (*bataboi*). When asked about rinderpest directly they described the disease roughly as bloody diarrhoea and reported that they had experienced this disease in 1987 as boys. When directly asked about rumours they stated that they had heard a rumour about current rinderpest at Yuot near Gumuruk. The interview suggested that RP has not been a major problem for the western Murle in the recent past. The rumour of rinderpest at Gumuruk was consistent with the rumours from Pibor town.

Shortly after the team left Paluer, a peace meeting was held between the Murle and local authorities. The ACROSS veterinarian, Micheal Otto, had the opportunity to meet with Jiji Ajak, the Murle Chief. The chief confirmed that the Macabol Murle had not experienced rinderpest since the 1980s.

As a result of the Murle's reconciliation with the Dinka, it is now possible for services to be delivered to the Murle community from Paluer. Previously, the Murle community was only accessible to the southern sector from Boma. This second point of entry to the Murle community is a major development.

The team conducted three separate group interviews in the Anyidi area on the frontier between Dinka and Murleland, two with Dinka and one with Murle. All three interviews stated their last direct experience with rinderpest as 1986-87.

Keichkon and the Sobat Basin

As only two days were spent at Kiechkon, interviews could be conducted at four locations. These were mainly with Nuer in the area of Paidouch (N 8 52 19, E 33 06 33). However, recently displaced Dinka from the Malakal area were also encountered. As these Dinka were not accessible to service delivery in the past, considerable effort was made to interview them and sample their cattle.

The rinderpest reports presented in Table 5 show some evidence of temporal clustering (3 reports) in 1998 in the Nuer and Dinka cattle along the Sobat from Malakal to Uleng. Two first hand reports of the sighting of rinderpest in 2000 by CAHWs were also received. From 1989 to 1995, OLS was active in cattle vaccination from Nasir and along the Sobat.

Table 5: First Hand Rinderpest Reports received through NGOs and Most Recent Outbreak Reports Received at Interviews

Location	Community	Date	Source
Baliet (Malakal)	Ngok Dinka	1977	Dinka Beny wut from Baliet
Paidouch	Nuer	Before 1980	Paidouch Chief and Elders
Homcor (Kohr Wako area)	Nuer	1986	CAHW's family herd
Homcor (Kohr Wako area)	Nuer	1986	CAHW's family herd
Doma	Nuer	1989	Seen by Paidouch CAHWs
Tuel	Nuer	1989	Elders in Tuel
Tuel	Nuer	1995	Elders in Tuel
Doma	Nuer	1998	Seen by Paidouch by CAHWs
Baliet (Malakal)	Ngok Dinka	1998	Two Dinka Cattle Owners in Tuel
Uleng	Nuer	1998	VSF-Belgium
Guelguk	Nuer/Brun	July-August, 2000	Seen by Paidouch CAHWs
Dhoreding (Nasir)	Nuer	Oct, 2000	ADRA CAHW

In general, it was noted that both Dinka and Nuer did not list rinderpest when asked to describe the problems or diseases in their cattle. With one exception, the respondents only mentioned *nyapec* after they were asked to describe the major disease of cattle from a historical perspective. This was very different from other groups interviewed at Bor and Boma. The amount detail of the descriptions of rinderpest varied. Some descriptions from elders and chiefs did not go beyond bloody diarrhoea, while others included tearing and oral lesions. Finally, it was difficult for the respondents in the Kiechkon area, especially Nuer, to date outbreaks. In order to date outbreaks, the respondents were asked to name major events that happened concurrently with the outbreak.

The Nuer communities occupy the southern bank of the Sobat and extend as far south as Waat and southeast as Akobo. The Murle inhabit regions further to the south. Due to cattle raiding and kidnapping of children, a large no-mans-land exists between the Nuer and Murle communities. It was concluded that the Sobat Basin should be treated as a separate system distinct from the Murle and Karamojong cluster peoples of Kengen River area.

Although some slight clustering was evident in 1998 it would be premature to conclude that RP had been present (or has been absent) in the area. What is needed is a more complete disease search focused on the Sobat Basin in its own right. This should include areas South of the River and would allow a more complete understanding of any linkages between the Sobat Basin and the Kengen River area.

Nuer

Two respondents at the village of Nuer provided very detailed accounts of rinderpest outbreaks. They reported that the severity of outbreaks was variable and described a severe outbreak in 1989 and a mild outbreak in 1995. The results of a proportional piling exercise on herd structure and rinderpest mortality are presented in Table 6.

Table 6: Rinderpest Mortality Described by the Nuer at Tuel

Age Class	<1 year	1– 2 yrs	2-4 yrs	>4 yrs	Overall
Herd Structure (% Of Herd)	21.1%	15.8%	26.3%	36.8%	
Severe RP Mortality ('89)(% of Age Class)	63.6%	72.7%	58.3%	56.3%	62.0%
Mild RP Mortality ('95) (% of Age Class)	36.4%	36.4%	25.0%	12.5%	26.0%

Dinka

Two interviews were completed with displaced Dinka from Baliet. One interview was with two cattle owners at Tuel who reported that they had last experienced rinderpest in 1998. The next morning the main Dinka cattle camp was visited and here the cattle camp leader (*beny wut*) reported that they had not experienced rinderpest since 1977. They reported that they had received limited vaccination from the northern sector operating out of Malakal. Very few animals were earmarked. Sixty-six samples were collected from unmarked/unvaccinated cattle. The ages of the cattle sampled were recorded for the calculation of the average age of infection if evidence of exposure to rinderpest is encountered.

Pochalla

Pochalla is the main town of the Anuak, a primarily agricultural people who keep cattle. The town borders Ethiopia and the Anuak community straddles the frontier. Cattle from the area are marketed in Ethiopia at Panadur.

The white-eared kob were present in large numbers in the area at the time of the team's visit. The consultant was able to sample 5 kob killed by hunters along the road from Pochalla to Ajwara and Otala. The communities reported that the kob were present in especially large numbers and that they were not experiencing disease. They did report that hunger was a problem and it was noted that kob carcasses were lean. Hunting was very extensively practised and drying meat was observed at almost every homestead. It was stated by hunters that kob were difficult to bring down and that as many as two-thirds of the animals shot were not recovered. As a result, decaying kob carcasses were plentiful throughout the bush.

Because of raiding and child theft, the Anuak and Murle were not in contact. It was not possible to access Murle areas from Pochalla. The local community had received a peace delegation from the Murle, however they did not have confidence that the peace initiative was genuine. It was the team's conclusion that the local cattle population had almost no contact with other communities in southern Sudan.

Anuak

The Anuak did not have a term for rinderpest. As agriculturalists, the Anuak's existing veterinary knowledge was not very extensive. The Anuak at Otala did recognise the Murle term *bataboi* but translated the term as diarrhoea. The team concluded that the Anuak were probably not familiar with rinderpest.

In mapping exercises, the team inquired about the location of Jum. This was one of the sites identified by community leaders at Pibor as an area where the white-eared kob were dying of rinderpest. The Anuak indicated that Jum was a swampy area to the North of Otala. Formerly, Jum was an important grazing area. However, due to insecurity, the Anuak mainly used Jum as a hunting area. The Anuak reported that the kob were not dying of disease.

The mission investigated a chronic disease problem in Otala that had caused significant mortality over a period of months. The Anuak had no name for the disease and actually gave very contradictory descriptions of the clinical history. Numerous carcasses were present at the outskirts of the village in various stages of decay. The primary clinical signs in the village herd were weight loss and anaemia. Lymph nodes were normal. The areas where the community was willing to graze the village herd were exhausted. The situation was not characteristic of rinderpest.

The World Relief veterinarian had previously conducted a post mortem examination on one severe case and observed liver flukes. Animals were grazed in swampy areas throughout much of the year. Blood smears from affected animals were submitted to the Save the Children laboratory at Lokichokio at that time and as part of the present mission. Theileria parva were promptly observed in both sets of blood smears. However, the absence of swollen lymph nodes suggested that ECF was not the primary problem.

The World Vision veterinarian and the OLS team concurred that the mortality at Otala was probably multi-factorial with starvation, liver flukes and ECF all contributing. The veterinarian developed a response plan consisting of information on management and treatment of the entire village herd with flukicide.

The diagnostic challenge at Otala is representative of chronic health situations in southern Sudan and demonstrates the value of the laboratory at Lokichokio. As the Anuak are primarily agriculturalists, the situation was further complicated by the their limited disease knowledge and a reluctance to take action on husbandry issues.

Dinka

There were two cattle camps owned by displaced Bor Dinka at Pochalla. They had come to Pochalla without cattle in the early 1990s by various routes. The Dinka were able to provide very precise descriptions of rinderpest. When directly asked one Dinka group indicated that they had experienced rinderpest in 1999 just prior to the training of CAHWs and vaccination at Pochalla. The second cattle camp clearly stated that they had not seen rinderpest since they left Bor in 1991. At the time of the CAHW training in 1999, Dr. Were did not note any reports of rinderpest.

Overall Findings of the Rinderpest Investigations

The mission covered 4 major locations and a total of 7 distinct communities in a period of 5 weeks. In April, a second mission was made to Boma. After allowing for travel time and interruptions due to cancelled flights, etc. this allowed on average 2 days of contact per community during the first mission. As a result only 4 to 8 interviews could be completed per community. With such a limited number of interviews, only very dramatic disease patterns would be detected with confidence.

The Bor Dinka, Murle, Jie and Toposa communities were very knowledgeable in regard to rinderpest and without fail could provide a full and accurate description of the disease. All of the communities volunteered rinderpest when asked to describe the disease problems in their cattle.

The Nuer and Dinka communities of the Sobat Basin were aware of rinderpest as a disease but with a few exceptions, they could not describe rinderpest with the same degree of confidence as the communities surrounding the Murle.

The pattern of first hand reports indicated that the Jie had experienced rinderpest throughout 1999 up until January 2000. The Jie descriptions of the patterns of infection, together with the one Murle report of 1998, were very consistent with endemic infection with a two-year inter-epidemic period. The absence of disease reports over the last 12 months is consistent with an inter-epidemic trough and may not represent the absence of disease. The consultant concluded that the Jie community is a component of an endemic system that may still be active.

The reports from the Sobat Basin, although less convincing than the information obtained in Jie, are of concern. Access to the Sobat Basin has been poor in recent years and appears to be continuing to deteriorate. The consultant's visit to Pagak was cancelled due to security concerns and Kiechkon was evacuated one week after the team visited there. At the time of writing OLS has suspended NGO activities throughout most of the Sobat basin. This raises questions as to feasibility of rinderpest vaccination, surveillance or rapid response in the Sobat Basin. It also highlights the importance of taking advantage of windows of opportunity where they occur.

Table 7: Herd Structure and Rinderpest Mortality

Age Class	N	1 year	1–2 yrs	2-4 yrs	>4 yrs	Overall
Percent of Herd	15	17.2%	16.8%	23.8%	42.3%	
Percent RP Mortality in Major Outbreaks	10	69.9%	67.0%	54.4%	47.6%	57.3%
Percent RP Mortality in Minor Outbreaks	6	38.3%	33.4%	34.3%	26.1%	32.3%

Major outbreaks were described as occurrence of the disease after an inter-epidemic period of five or more years. Minor outbreaks were annual or biennial events. Overall RP mortality was estimated as 57.3% for major outbreaks.

Table 7 provides the overall data on the proportional piling exercises for herd age structure and rinderpest mortality. The exercise proved to be highly repeatable and provided data that matched the conventional wisdom regarding lineage 1 rinderpest.

Although the consultant did not encounter active rinderpest, he is far from confident that rinderpest was absent from the East Nile Ecosystem. Traditionally, the cessation of vaccination has been regarded as a final test of the eradication of rinderpest. The decision suggests that there is a high level of confidence that RP has been eradicated. One might say a confidence level of 90% or more. This level of confidence in the eradication of rinderpest does not exist East of the Nile.

Vaccination

A separate concern is the impact of vaccination as it is now being practised in south Sudan on rinderpest. There is no doubt that vaccination has suppressed rinderpest in southern Sudan. The absence of reports from areas West of the Nile combined with the relatively good access enjoyed by the veterinary programme on the Western side provide some confidence that rinderpest is no longer present west of the Nile.

East of the Nile, it is doubtful that the current levels of vaccination have been sufficient to interrupt the transmission of rinderpest in the ecosystem. An epidemiologic discussion of this point relative to transmission dynamics and the structure of the cattle population in south Sudan will follow.

3. Estimation of The Basic Reproduction Number R_O

The basic reproductive number is defined as the number of secondary cases that arise from one infectious index case in a totally susceptible population. It is a key concept in measuring the transmissibility of an infectious agent in a population and has important consequences in regard to the dynamics of epidemics and endemism.

The basic reproductive number also has important consequences for control strategy, as it is the major determinant of the level of herd immunity necessary to interrupt disease transmission and is a determinant of the critical community size (threshold size) necessary to maintain an agent in nature.

In the case of rinderpest, R_o is a function of:

- The transmissibility of virus strain and
- The contact structure of the population in question.

In regard to transmissibility of a strain of rinderpest, the following characteristics of the virus have an impact:

- Amount of virus shedding
- Infectivity of the strain (minimum infectious dose or animal ID_{50})
- Duration of shedding (d)

Features of the population that have an impact are:

- Density
- Movement
- Heterogeneity
    - Herd size
    - Community size
    - Within herd and between herd interactions

As a result, a general statement about R_o for all strains of rinderpest in all animal husbandry systems cannot be made. The same strain of virus may have a very different R_o in a pastoral setting as opposed to a cut and carry smallholder dairy system. Physical contact rates are usually high in the pastoral systems and may be essential zero in the dairy setting.

Alternately the conventional wisdom on the transmissibility of lineage 1 RPV versus lineage 2 viruses suggests that the R_o values for these strains are different. This thinking predicts a higher reproductive number for lineage 1 RPV than for lineage 2 RPV in the same population.

This relationship has been stated mathematically as:

R_o	=	Number of physical contacts per day (c)	•	Probability of transmission per contact (p)	•	Days infective (d)

Or:

$R_o = cpd$ (equation 1)

The two terms, c and p, are sometimes expressed as one term, β, the effective contact rate. The effective contact rate can be defined as the number of contacts an infected animal has per day that result in transmission in a totally susceptible population. In models using a β term:

$R_o = \beta d$ (equation 2)

Methods for Estimating R_O

Proportion susceptible in endemic areas

In endemic populations with low or no vaccination cover, the value of R_o can be calculated from the proportion of the population that is susceptible to infection (Anderson, 1992).

If the proportion susceptible is termed x than:

$R_o = 1/x$ (equation 3)

For example, if the proportion susceptible is 0.29 (71% seropositive) than

$R_o = 1/0.29 = 3.45$

If the proportion susceptible is 0.226 as Majok et al. (1991) reported for the southern Sudan then:

$R_o = 1/0.226 = 4.42$

This method assumes random mixing and more or less continuous transmission. In situations where endemism is characterized by a cyclic wave of transmission (most situations) the proportion susceptible must be measured in a manner that averages the peaks and troughs. True random sampling throughout the population accomplishes this. Poor or moderate vaccination coverage should not distort this measure in the case of a disease with a high R_o as wild virus circulation will continue until the proportion of susceptibles falls to the levels determined by R_o. This has been demonstrated with field data on measles in England and Wales (Fine and Clarkson, 1982).

Average age of infection in endemic areas

The basic reproductive number can also be estimated from the average life expectancy (L) and the average age of infection (A) (Fine, 1993). The relationship is:

$R_o = L/A$ (equation 4)

Average life expectancy can be estimated rather easily from demographic studies. For a disease with low mortality, average age of infection can be estimated from serologic studies were age data is collected. For a disease with significant mortality, data on age-specific mortality rates are also needed.

Incorporation of the average age of loss of maternal immunity (M) gives a more precise estimate.

$R_o = (L-M) / (A-M)$ (equation 5)

In this method, pulses of vaccination have the potential to significantly distort the calculation and would tend to lower the average age of infection. For a highly transmissible strain of lineage 1 RP virus, the effect of vaccination campaigns more than 3 years in the past would probably not affect the calculations significantly. The effect of intermittent vaccination would be more severe for calculations on lineage 2 viruses, if indeed they are less transmissible.

Incidence proportion and proportion susceptible after epidemics

Incidence proportion (IP) is the number of animals affected during a time period divided by the total number of animals at risk. After an epidemic, the proportion dead or recovered divided by the number at risk is the incidence proportion for the period of the epidemic. The proportion of the population that is susceptible (x) after an epidemic is:

$x = 1 – IP$

(equation 6)

and the proportion susceptible after an epidemic is proportional to R_o

$x < 1/R_o$ (equation 7)

Thus, if the number of susceptible and total population, or the proportion susceptible after an epidemic is known, R_o can be estimated.

In the case of classic rinderpest, if the descriptions of greater than 90% mortality are accepted, then R_o:

$(1-.9) < 1/R_o$

$10 \cong R_o$

However, at these high mortality rates the value of R_o is very sensitive to small changes in the mortality rate. If 95% mortality was experienced then R_o was on the order of

$(1-.95) < 1/R_o$

$20 \cong R_o$

An estimate of R_o in the range of 10 to 20 is consistent with conventional wisdom on severe or classical rinderpest and corresponds to the information available on measles (Anderson, 1982).

Estimates from case rates

Where detailed outbreak data is available, β and R_o can be estimated from population data (N), the number of new cases (C), the number susceptible (S) and the number infectious (I). The following basic relationship for calculating the number of new cases is used:

$$C = \beta \bullet SI/N \qquad \text{(equation 8)}$$

This method has been used in the developed world where very accurate and extensive investigations are undertaken as part of emergency responses to exotic disease introductions (Stegeman et al., 1999) and longitudinal studies (van Roermund et al., 1998). Unfortunately, this method is not very appropriate for the analysis of rinderpest epidemiology in the developing world due to the vast amounts of very detailed monitoring data required.

Estimates from laboratory transmission experiments

Methods are now available for determining R_o in controlled transmission experiments. This approach has been used to evaluate vaccine efficacy and offers considerable advantage over more traditional methods of vaccine evaluation (de Jong, 1995; de Jong and Kimman, 1994).

It should be born in mind that R_o is a feature of an agent in the context of a population. R_o is determined by the combined effect of the contact structure of the population (c) and the probability that a contact results in transmission (p) and the duration of infectivity (d). The last two parameters are, in part, features of the strain of agent involved whereas contact is a feature of the population and the husbandry system. Thus, a measurement of R_o in a laboratory setting, although of virologic interest, may not have direct epidemiologic relevance to disease control strategies in the African pastoral setting.

Expert opinion: Values of R_o implicit in the rinderpest modelling literature

For the most part the rinderpest modelling literature has not stated explicit values for R_o and has assumed values for transmission parameters related to contact. In general, the assumptions regarding effective contact were based upon expert opinion on transmissibility and the characteristic behaviour of rinderpest epidemics. However, the values of R_o implicit to the models can be calculated from the information provided.

Rossiter and James (1989)

The most detailed and complete model of rinderpest transmission is based on a state transition approach and uses Monte Carlo methods to introduce stochastic effects where small numbers of transitions occur (James and Rossiter, 1989; Rossiter and James, 1989). There is a considerable body of literature describing the clinical course and excretion of rinderpest virus for various strains representing different pathotypes of the virus (mild to severe). Rossiter and James (1989) relied on this data to make fixed-point estimates for most parameter values in the model.

Rossiter and James (1989) made use of an effective contact rate parameter, C_r, that is equivalent to β or cp. They noted ‘There are no data which can be used to estimate the value of C_r’ and ‘Changes in the C_r, produced greater degrees of change in epidemic curves than any other parameter, indicating that the model is especially sensitive to it and that may be the most important single factor in determining the spread of virus.’

Through experimentation with the model, contact rates were determined that allowed the model to perform in a manner consistent with field observations of outbreaks and the basic assumptions of the model. Using equation 2, the contact rate and virus excretion period parameters provided allow the calculation of the values of R_o implicit to the model.

Table 8 Values of R_o Used in the Rossiter and James (1989) Model

Pathotype (virulence)	**High**	**Moderate**	**Low**	**Mild**
Virus Excretion Period (days)	6	5	4	3
Contact rate	2.0	1.0	0.5	0.25
Basic Reproductive Number	12	5	2	0.75

Note that R_o values in the range of 2 to12 are consistent with theory and the conventional wisdom regarding the behaviour of the various types of outbreaks. An R_o value of less than one, as suggested in this paper for mild strains, is not consistent with the spread of virus, and in theory an infectious agent with a R_o of less than one would not be able to survive in nature.

Tille et al. (1991)

Tille et al. (1991) described both a deterministic and stochastic approach to discrete-time modelling of infection caused by mild to severe strains of rinderpest. Rather than fixed parameter values for incubation and infectious periods, these authors used ranges for parameter values to mimic biologic variability. The model input parameter values are shown in Table 9.

Table 9: Model Parameters and R_o Values Used in the Tille et al. (1991) Model

Virulence	High	Moderate	Low
Latent Period (Max, Min (days))	3,8	5,10	6,12
Infectious Period (Max, Min (days))	4,6	5,7	6,8
RP Mortality Rate (%)	90	50	10
Physical Contact Rate	20	20	20
Probability of Infection per contact	0.04	0.02	0.01
R_o (Max, Min)	3.2, 4.8	2.0, 2.8	1.2,1.6

The basic reproductive number was calculated using equation 1 by multiplying the physical contact rate (c) times the probability of infection per contact (p) and the maximum and minimum values for the infectious period (d). Cumulative infection of the population reached 100% in model runs based on virulent parameters in both the deterministic and stochastic models. Ninety-five percent cumulative infection was achieved with moderate strains. To the consultant's knowledge, field outbreaks of virulent RP have never been shown to infect 100% of the population. Ninety to 95% would appear to be the practical maximum for the most virulent outbreaks on record. This suggests the model is not fully valid.

From their deterministic model, the authors derive expressions for the minimum herd immunity rate required to prohibit establishment of persistence. These equations correspond to the classic expression $1/R_o = x$ or the proportion susceptible. The herd immunity threshold for the median of the range of the infectious periods is presented below in Table 10.

Table 10: Herd Immunity Threshold for the Interruption of Transmission as Determined by Tille et al. (1991)

Virulence	High	Moderate	Low
Median R_o	4	2.4	1.4
Herd Immunity Threshold (R=1) (%)	75	58.3	28.6

This model finds that persistence of less virulent and therefore less transmissible strains (lower R_o values) can be prohibited by relatively lower herd immunity rates. This agrees with textbook formulations such as those presented by Halloran (1998), Anderson (1992) and Ferguson et al. (1999). This suggests that lower herd immunity levels can interrupt the transmission of mild rinderpest strains than required for more virulent strains.

Dobson (1995)

Dobson (1995) has published on the modelling of dynamics of rinderpest in the cattle and wildlife populations of the Serengeti ecosystem. Unfortunately, the assumptions on transmission implicit to the model are not clearly stated and units are not specified were values are given.

Estimates of R_o for Rinderpest in Southern Sudan Livestock Populations

Given the available data, three methods can be used for estimation of R_o in southern Sudan. These are:

- Proportion of the population susceptible
- Average age of infection in endemic populations
- Expert opinion

In endemic populations where only modest levels of vaccination has taken place, the percent susceptible is still a function of the transmissibility of wild virus. Wild virus circulation will continue despite vaccination until the percent susceptible falls to a level consistent with R_o (Anderson, 1992). The data of Majok et al (1991) provide the most extensive and reliable estimate of the proportion susceptible. They estimated that vaccination coverage was only 15%, which could not account for the high levels of herd immunity found in their survey.

Operation Lifeline Sudan mainly collected sera from vaccinated populations. Estimation of vaccination cover is very difficult as the overall population estimates are very imprecise. Vaccination and serum collection tended to be focalised. As a result only two groups of sera were identified that seemed appropriate for the estimation of R_o. These groups were unvaccinated cattle collected by OLS in Ayod in 1991 and Naita in 1997. A third group of sera collected in 1999 from Murle cattle at Kavula have yet to be tested.

Table 11: Values of R_o Calculated from the Proportion of the Population Susceptible

Location	Date	No. Positive/Sample Size	R_o	Source
Bahr el Ghazal	1980	3152/4074	4.42	Majok et al , 1991
Ayod	1991	29/100	3.45	OLS
Naita	1997	15/80	5.33	OLS

Majok et al. (1991) also found a mean age of 5.68 yrs and provided age stratified serological data for Bahr el Ghazal Province. This data is present in Table 12.

Table 12: Age Stratified Prevalence of RP Antibody as Reported by Majok et al. (1991).

Age (yrs)	Prevalence (%)
0-1	59.59
2-4	68.17
5-7	87.25
8-10	85.99

Using equation 7 and estimating M as 3 months, A as 18 months and L as 5.68 yrs, on can calculate R_o:

R_o = (L-M) / (A-M) = ((5.68 yrs * 12 m – 3 m) / (18 m – 3 m) = 4.34

This is in very close agreement with the estimate derived from the proportion susceptible in Bahr el Ghazal as described in Table 11.

Based on the results of the proportional piling exercises (Table 7), rinderpest outbreaks in southern Sudan could best be described as moderately virulent. If one examines previous rinderpest models as a source of expert opinion, Rossiter and James (1989) found parameters equivalent to a R_o value of 5 resulted in simulations that best fit for rinderpest dynamics for moderately virulent viruses. Tille et al. (1991) on the other hand chose values in the range 2.0 to 2.8 for moderately virulent virus.

The consultant recommends that a relatively conservative approach be utilized. Agents with higher R_o values require higher levels of herd immunity to interrupt transmission. For the purposes of subsequent analysis, the value of R_o for southern Sudan will be estimated to lie in the range of 3.5 to 5.3 with the most likely value being 4.4.

4. Determining the Role of Vaccination and Herd Immunity in southern Sudan

The Basic Reproductive Number and Herd Immunity in Southern Sudan

Once the value of R_o has been estimated, the level of herd immunity required to interrupt transmission (h) can be estimated by the relationship shown below.

$$h = 1 - 1/R_o \qquad \text{(equation 9)}$$

This relationship for a range of values of R_o is illustrated in Figure 2. Note that for values of R_o greater than 10, more than 90% of the cattle must be immune to interrupt transmission. This simple deterministic model assumes homogeneous mixing and does not allow for chance effects. In real life, disease can be expected to 'fade out' at lower herd immunity levels due to chance effects where infected animals do not have contact with susceptibles. Further, heterogeneous contact structures can also contribute to lowering the global herd immunity rate required to interrupt transmission.

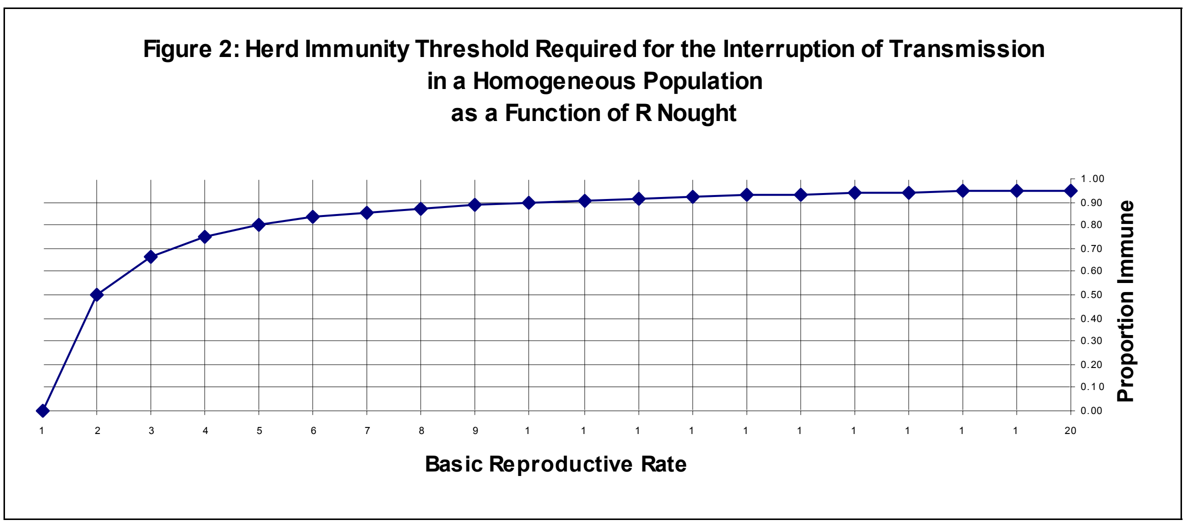


Figure 2: A graphic representation of the herd immunity threshold required to interrupt disease transmission as a function of the basic reproductive number, R_o. Note that a value of R_o between 4 and 5 requires a herd immunity of 75 to 80% to interrupt transmission. Classic virulent rinderpest and measles viruses require herd immunity rates of over 90%. This analytical model does not incorporate chance effects and assumes homogeneous mixing. As will be explained later, eradication is possible in heterogeneous populations at much lower global immunity rates.

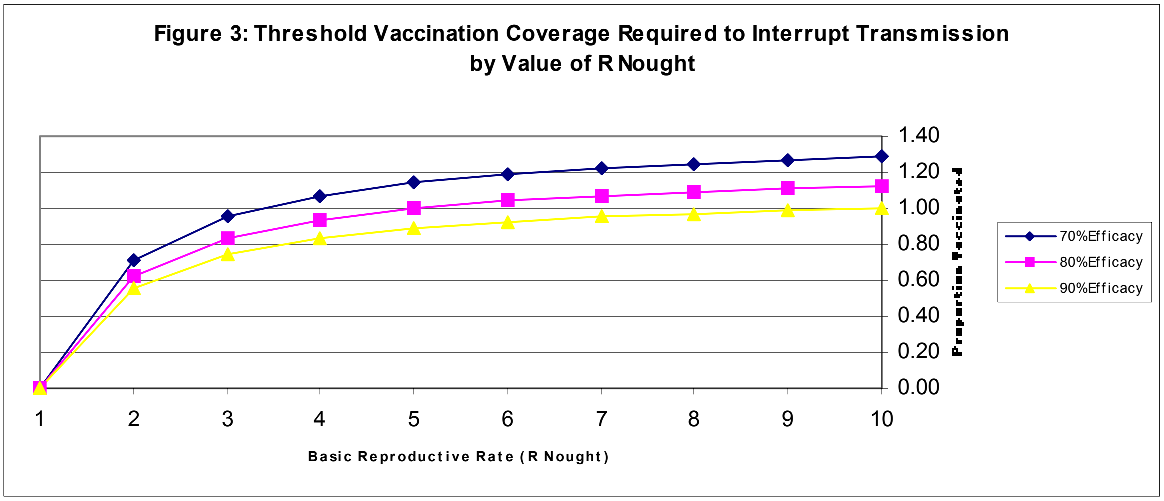


Figure 3: Vaccination levels required to achieve the interruption of transmission as a function of the basic reproductive number R_o and vaccination efficiency. Vaccination efficiency is defined as that proportion of vaccinations that actually generate protective immunity under field conditions. Note that for R_o in the range of 4 to 5 and 90% vaccination efficiency, the deterministic model predicts that 83 to 89% vaccination coverage is required to interrupt transmission. This suggests that one round of vaccination in an extremely well executed campaign could interrupt transmission in a defined homogeneous population. At lower vaccination efficiencies, more than one round of vaccination coverage is required to achieve the required herd immunity thresholds given the transmission dynamics of rinderpest in southern Sudan.

Table 13 presents the levels of population herd immunity required to interrupt transmission for the values of R_o estimated for southern Sudan in the previous section.

Table 13: Herd Immunity and R_o in southern Sudan

	R_o	Herd Immunity
Min R_o	3.5	71.4
Peak R_o	4.4	77.3
Max R_o	5.3	81.1

Not all vaccinations work. In large campaigns, 80 to 90% vaccination efficiency is usually a practical goal. If the proportion of vaccinations that actually immunize the recipient (f) is added to equation 9, one can calculate the required proportion of the population that must be immunized to interrupt transmission as function of R_o. Once again, the model is deterministic and assumes homogeneous mixing. Fade outs will occur at lower vaccination levels.

$v = (1 - 1/R_o) / f$ (equation 10)

In terms of infectious disease epidemiology, a population can be defined as a group that shares contact. One can talk about the population of cattle in southern Sudan and consider communities as inter-linked sub-populations within the global population of southern Sudan. In this light, the cattle population of southern Sudan is a heterogeneous population with a complex contact structure. The importance of this conceptual model will be developed in the next section.

Vaccination Coverage, Herd Immunity and Heterogeneous Populations in Southern Sudan

Due to the fact that access to many locations within southern Sudan is restricted by security concerns, OLS Livestock Programme activities are concentrated in a subset of communities and locations. As a result, it has never been possible to implement blanket vaccination. It has not and probably will not be possible to conduct randomised sampling to estimate herd immunity or to conduct serology-based disease surveillance based on Cannon and Roe's sampling designs (Anonymous1982) as required by the OIE Pathway (Office International des Epizooties, 1998). It has been possible to carry out purposive sampling to answer specific epidemiologic questions regarding virus circulation or the local effectiveness of vaccination for defined sub-populations.

The structure of populations varies between pastoral ethnic groups in southern Sudan. In order to assess the impact of vaccination some simplifying generalizations can be made. The units of structure are the individually owned herd, the cattle or grazing camp, clan and tribe. This gives at least four levels of structure. Although cattle are moving between groups through exchange, dowry, loan and raiding, the four levels of structure loosely define the structure of contact.

The community-based approach of OLS targets specific identifiable community groups and works through the social structure to deliver services. As a result, vaccination is focused in particular sub-groups of the population. For the most part, the OLS Livestock Programme works at the level of cattle camps and clans. Given the size and extent of tribal communities in the south, it is rare for one NGO to cover an entire tribe, although it has occurred in some of the smaller communities.

Globally, the number of vaccinations achieved is provided in Table 14. Cattle population estimates vary considerable. As estimated by the OLS Livestock Programme, the population of cattle accessible from the southern sector is 5,849,150 head of cattle. This figure has been used to calculate the global coverage rates.

Table 14: Global RP Vaccination Coverage in Southern Sudan

Year	Vaccination	Percent Global Coverage
1999	541,578	9.3%
2000	473,582	8.1%

Source: Bryony Jones, Review of Rinderpest Control Activities and Impact in Southern Sudan Since the Start of the OLS Livestock Programme (1989-2000), 2001

However, analysis at the global level that treats southern Sudan as one homogeneous population is misleading. Vaccination coverage in southern Sudan is not dispersed homogeneously throughout the entire population. It is highly focused in accessible communities. Seromonitoring has shown that these communities generally have herd immunity rates of 70 to 80%. As summarized in Table 15, eight years of seromonitoring found an average herd immunity rate of 73.2% East of the Nile and 70.3% West of the Nile in the populations served by the OLS community-based animal health programme.

Table 15: Summary of OLS Seromonitoring Results: 1991 to 1999

	Sample Size	Number Vaccinated	Prevalence of Antibody Vaccinates	Prevalence of Antibody Non-Vaccinates	Prevalence of Antibody Overall
East of Nile	1172	579	80.5	60.8	73.2
West of Nile	1203	597	77.9	51.6	70.3
Total	2447	1176	79.2	56.7	71.7

Source: Bryony Jones, Review of Rinderpest Control Activities and Impact in Southern Sudan Since the Start of the OLS Livestock Programme (1989-2000), 2001

With only two exceptions, the data presented in Table 15 is from serum samples collected from vaccinated populations. Animals listed as unvaccinated are from vaccinated areas and are either un-marked or reported as unvaccinated by the owner. Conventional wisdom holds that many of these animals are in fact vaccinated. The results show that the prevalence of antibody is higher among vaccinates (80.5% East of the Nile and 77.9% West of the Nile) than among non-vaccinates (60.8% East of the Nile and 51.6% West of the Nile). Sub-optimal vaccination does not normally raise herd immunity levels above the level determined by R_o in endemic populations (Fine and Clarkson, 1982). The fact that antibody levels among vaccinated animals are higher than non-vaccinates suggests that the high levels are indicative of effective vaccination rather than disease circulation. *Where vaccination is being practiced in southern Sudan, it is being applied correctly and at levels that are sufficient to interrupt transmission in the immediate communities served.*

The seromonitoring results indicate the OLS cattle program has been effective in removing specific sub-populations from the pool of susceptible sub-populations that contribute to the maintenance of rinderpest in southern Sudan. Whether they are the right populations or enough populations to eradicate the disease is not clear.

> *"In an effort to describe just the most superficial level of such complexity, Anderson and May formulated a set of general equations describing populations broken into several groups with two different within and between group (high and low) transmission characteristics. They found that eradication could be achieved with fewer overall vaccinations if they were distributed primarily to high contact*

> *rate groups … than if they were distributed uniformly to the overall population. Beyond this intuitively sensible qualitative result, that it may be advantageous to target interventions at high risk groups we are left with the conclusion … social structure can have a profound effects on the likelihood and patterns of infection transmission and, hence, upon herd immunity thresholds."* Fine, 1993, pg. 282

Herd Immunity and Population Age Structure

The understanding that older animals are immune to rinderpest is a part of the existing veterinary knowledge of many communities in southern Sudan. This is attributed to previous exposure to disease or vaccine. The serologic survey conducted by Majok (1991) and basic epidemiologic concepts regarding endemic disease clearly support this concept. The results of the proportional piling exercises on mortality by age group are a very good illustration of this traditional knowledge.

Work with measles modelling has shown that adequate consideration of the age structure of herd immunity is important to predicting the impact of vaccination and the likelihood of disease fade outs in communities (Anderson and May, 1984). Although the construction of an age-structured model is beyond the scope of the present consultancy, the approach is important to understanding the impact of rinderpest vaccination in endemic communities.

The fact that most vaccination in southern Sudan is concentrated on young stock increases the impact of the limited number of vaccinations performed. When vaccination is spread out over all age groups in populations already exposed to antigenic stimuli, the major part of vaccinations have no impact on the overall herd immunity because the recipients were already immune.

A life expectancy of 5.68 years is equivalent to a herd replacement rate of 17.6% per year if the population is to remain stable. Thus, at the global level the OLS Livestock Programme is only vaccinating at about half the rate of birth of susceptible animals into the population. However when the impact of vaccination focused on young stock *and* specific communities are considered together, it suggests a very efficient strategy for the interruption of virus circulation.

Quantitative Modelling

Model building

Modelling can be used as a tool assist in disease control strategy formulation and to assess the impact of interventions. For example, disease modelling has been used to:

- Identify optimal vaccination strategies for the interruption of transmission,

- Demonstrate the impact of sub-optimal vaccination strategies on disease transmission,
- Identify conditions that contribute to endemism,
- Estimate the critical community size required to sustain endemism,
- Prioritise data collection efforts to better understand disease dynamics

With an estimate of the basic reproduction number from the field data and expert opinion as well as estimates of other model parameters such as the latent period and infectious period from the laboratory experiments, modelling can provide insight into the dynamics of rinderpest in southern Sudan.

During the course of the consultancy three stochastic, discrete-time SEIR rinderpest models were constructed in @Risk. The mathematical formulations are presented in Annex 3. This is the first rinderpest model to incorporate actual estimates of R_o from serological data. The models differ from previous RP models in that they incorporated probability distributions for key input parameters rather than fixed values and they used the mass action formulations of the stochastic SIR model as developed by de Jong (1995). These probability distributions reflect both biological variation and the uncertainty in parameter estimates.

A stochastic element was used for fractional transitions between the SEIR states rather than rounding to a whole number. Where probability calculations predicted less than one transition per time step the model was fully stochastic. Outputs are presented as probability distributions. The outputs include R_o, the duration of the epidemic, the total number of cases and the number susceptible remaining.

The first model was a closed population model where the basic relationship between the course of an epidemic in relation to the input parameters. In the closed model, birth and mortality parameters are not incorporated and the population has a fixed size. The R state represents recovered animals and no animals are removed (die) from the population. Parameter inputs include:

α	Alpha: rate of recovery/removal (=1/infectious period)
γ	Gamma: transition rate from exposed to infectious state (=1/latent period)
C	Number of physical contacts per day
p	Probability that one contact results in transmission
ΔT	Time step

The following initial values are entered:

E	Initial number exposed
I	Initial number infectious
N	Initial population size
R	Number removed/recovered (or vaccinated)

The second model was an open population model where new susceptibles are born at each time step. Open population models allow experimentation with both epidemic and endemic patterns of disease transmission. The model added the following input parameters:

b	Birth rate
μ	Mu: non-specific mortality rate
σ	Sigma: rinderpest specific mortality rate

In this model, the R state represents recovered animals. A fifth state of removed (or dead) animals is implicit to the model. The mass action term incorporates the population size at each time step as the sum of the four states (S+E+I+R) rather than a fixed value of N.

The third model introduced a heterogeneous population structure by replicating the open population model to simulate a series of interlinked sub-populations, each analogous to a pastoral community. The model incorporated a sub-population contact matrix where the physical contact parameter, C, could be entered to vary the degree of contact between populations. The structured population SEIR model runs slowly and work remains to be completed to streamline its operation. Experimentation with this model was not begun.

Potential future work includes:

- Increase the stochastic element by raising the cut off level for stochastic determination of state transition from susceptible to exposed.
- Systematic experimentation with the open population model
- Development of the structured population model
- Development of an age-structured model
- Application of the model to CBPP

The next section details some preliminary experimentation with the model. Systematic experimentation will be completed in the future. During the course of the mission, the model was used to demonstrate basic concepts of rinderpest epidemiology.

Preliminary insights from the models

The following discussion develops a selection of concepts explored in the models. It is important to note that the models are still under development. The relative effects illustrated by the models are valid, however the reader is cautioned not to draw conclusions about estimates or the absolute values required to generate certain scenarios.

As an example, the open population model easily generates endemic scenarios with relatively modest population sizes. By increasing the stochastic element in the model, the chance of fade-outs is greatly increased. This would raise the critical community size (CCS) for the maintenance of rinderpest.

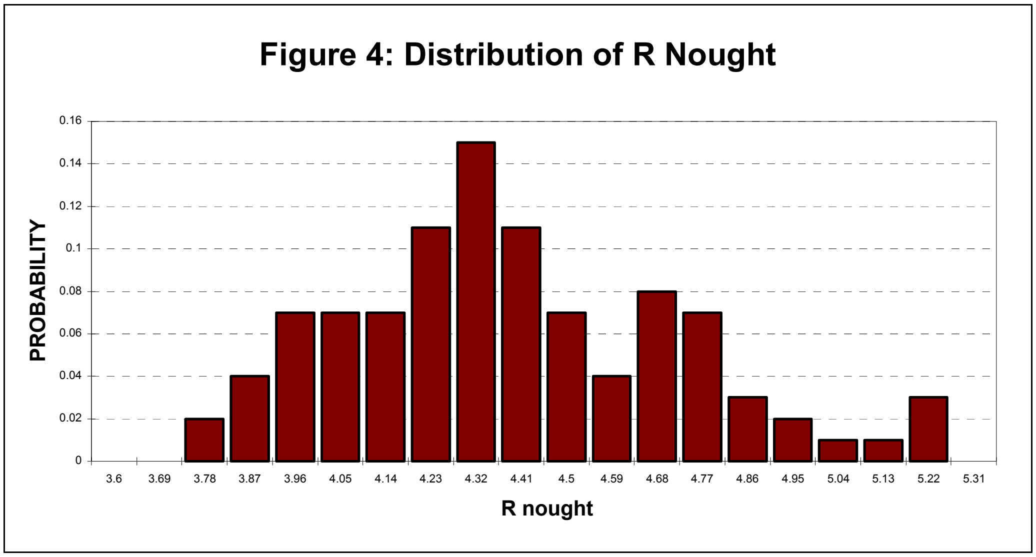


Figure 4: The distribution of R nought values used in the example modelling runs presented in this report.

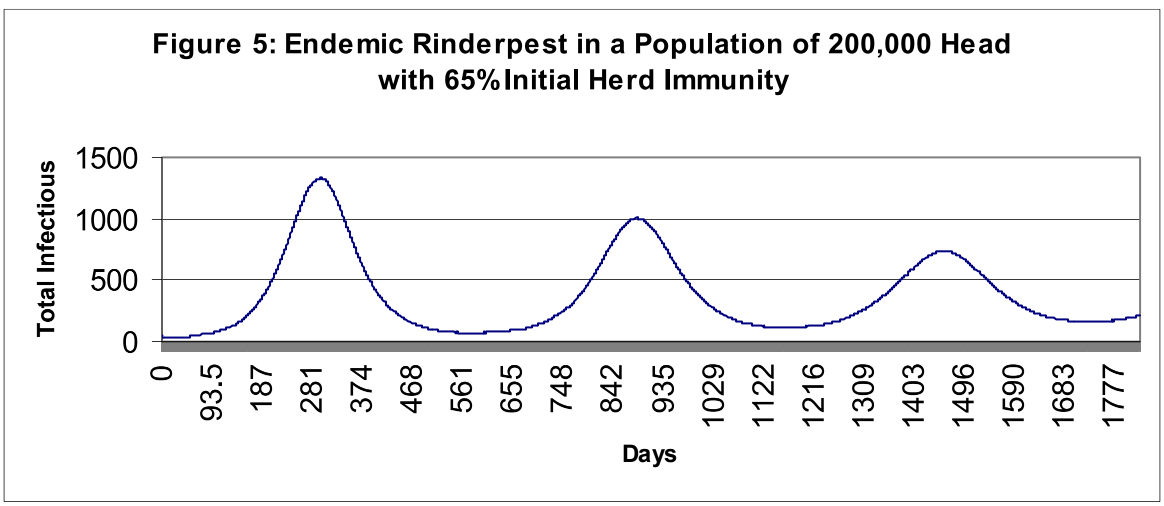


Figure 5: An example of endemic rinderpest in a homogeneous population of 200,000 head. Initial conditions included 130,000 recovered and 50 exposed. The source of the initial 130,000 recovered could be from previous disease exposure of vaccination. This curve is consistent with endemic rinderpest with or without sub-optimal vaccination at the outset and no vaccination thereafter. Note the inter-epidemic period of approximately 600 days.

Beyond expert opinion, there is no data available at this time upon which to base a decision regarding the appropriate level of stochasticity in the model. In the case of measles, model design greatly influences estimates of critical community size for viral persistence. These estimates range between 100,000 and 500,000 individuals.

Incorporating age-structure and heterogeneity in the contact structure influences estimates of CCS (Earn et al., 1998; Keeling, 1997; Keeling and Grenfell, 1997; Rohani et al., 1999).

The R_o input distribution used in preliminary experimentation is presented in Figure 4. Figures 5 presents an example of an endemic scenario in a population of 200,000 animals over 5 years. Note that the initial conditions included 50 exposed animals. Due to the high number of exposed animals present at the outset, the virus almost always persists.

Figure 6 is the distribution of the lengths of outbreaks one would expect if a single infected animal were introduced into the same population modelled in Figure 5. Modelling literature distinguishes between minor and major outbreaks. Minor outbreaks are an introduction where the infection fails to take hold and rapidly dies out without causing a classic epidemic. Major outbreaks are those introductions that lead to an epidemic that infects the majority of the population. As seen in Figure 6, when a single infectious animal is introduced into a 65% immune population, 87% of outbreaks are minor, and 7% are major. In 6% of the iterations the disease persists with fade-outs occurring in one third of these cases.

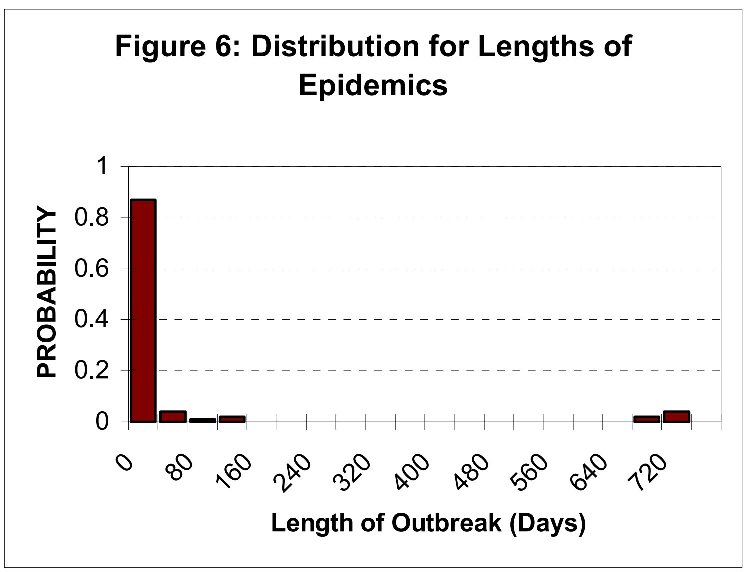


Figure 6: The distribution of 100 outcomes for the length of the epidemic after the introduction of a single exposed animal into a population that is otherwise identical to the example in the previous figure (65% immune). Note that in 87% of iterations a minor outbreak occurs. In 7% of the iterations a major outbreak lasting 40 to 160 days occurs. In 2% of the iterations the disease fades out between 680 and 720 days. In 4% of the iterations the disease is endemic at the end of two years.

Figures 5 and 6 suggest that a moderate level of herd immunity (65% in this example) may not be sufficient to eradicate endemic infection, but it sufficient in most cases to prevent introductions to a population.

The relationship between the number of immune animals present in a population of 200,000 and the length of an outbreak resulting from the introduction of 5 exposed animals is graphed in Figure 7. One could conceive of this experiment as the introduction of one or a few exposed herds into a large pastoral community with extensive mixing.

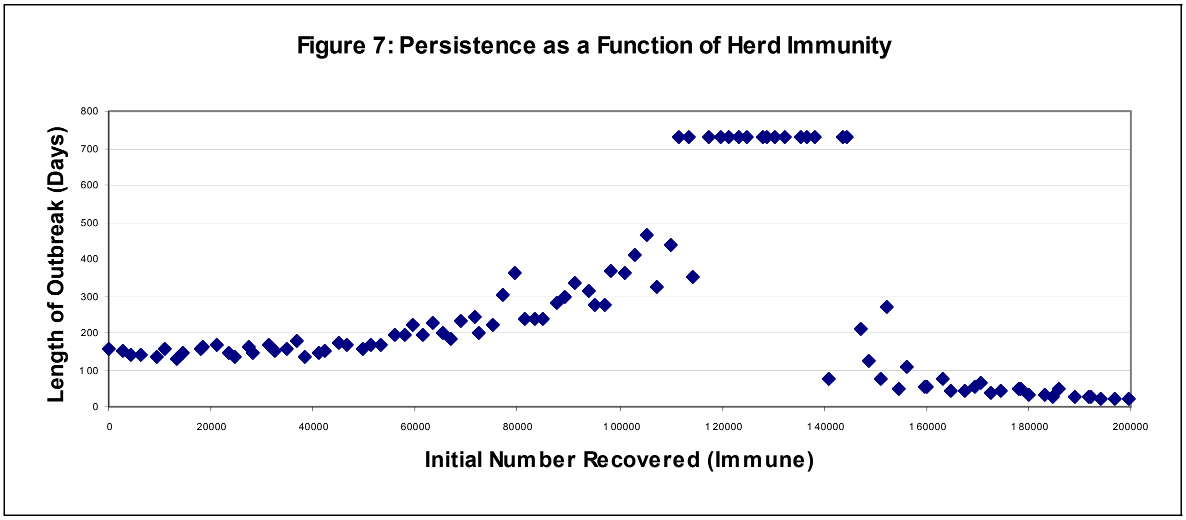


Figure 7: In this simulation the model was run over two years after the introduction of 5 exposed animals. The initial number of recovered (immune) animals present varied between 0 and 200,000 by sampling a uniform distribution for the initial number recovered. The length of the outbreak is plotted against the number initially immune. Note that at low levels of herd immunity outbreaks last about 150 days. As the herd immunity rises to about 50% (100,000 immune animals out of 200,000) the length of the outbreak increases to the range of 300 to 500 days. Between about 55 and 70% herd immunity, the introduction of 5 exposed animals resulted in persistent infection that was still on going at the end of 730 days. When herd immunity surpassed 80% (160,000 immune out of 200,000) only minor outbreaks occurred.

When herd immunity is:

- Less than 30%, an epidemic results that is over in about 150 days. The disease does not persist in this homogeneous population.
- Between 30 and 50%, the result is still an epidemic, but it is extended over a longer period. The epidemic curve is wider and flattened relative to an epidemic in a more susceptible population.
- Between 55 and 70%, the disease persists throughout the time period modelled. The virus becomes endemic.
- Greater than 80%, only minor outbreaks occur and the population is protected

Once again, it would *not* be advisable to draw specific quantitative conclusions from these preliminary experiments. However, the trends and concepts are valid.

5. Rinderpest Eradication Strategy for the East and West Nile Ecosystems

Throughout most of the life of the OLS Livestock Programme, international authorities have taken view that rinderpest eradication was not possible in southern Sudan without peace. It was not until 1998, that the international community developed an appreciation of the extent of the impact of the OLS Livestock Programme on rinderpest in southern Sudan and the true potential of community-based vaccination using heat-stable vaccine. As a result, eradication has not been a stated objective of the programme until relatively recently. Formulation and implementation of a comprehensive eradication strategy only began about two years ago.

It is a generally accepted principle in disease eradication that vaccination efforts should be focused on high-risk communities where transmission parameters (e.g. R_o) are highest (Anderson and May, 1984; May and Anderson, 1984; Fine, 1993). This approach has the greatest impact on disease transmission by removing the key populations that contribute the most to the maintenance and dissemination of infection.

The Pan African Rinderpest Campaign successfully applied this principle in Ethiopia where lowland pastoral groups were identified as the communities with the greatest potential for disease maintenance. Sedentary communities contributed much less to the maintenance of the disease as animal contact rates were very much lower. This resulted in a lower value of R_o. When blanket vaccination was discarded and vaccination was targeted to high-risk communities, rinderpest was eradicated from the country in three to four years with global vaccination coverage not exceeding 10 to 15% of the national population. The coverage was, however, concentrated in high-risk communities. It was a very successful and efficient strategy.

It has already been stated that the animal population in southern Sudan is structured and that vaccination coverage is focused. However, the dichotomy of pastoral and sedentary production systems is not present. Although the degree of mobility varies between communities, all major animal populations of southern Sudan are transhumant. Thus, it is not expected that R_o would vary drastically between major sub-populations.

It would be more appropriate to view southern Sudan as a series of interlinked sub-populations with similar 'within-population' transmission parameters (R_o). These sub-populations would be related by 'between-population' transmission parameters determined by the amount of shared grazing and watering locations, stock transfers and raiding. These relationships often vary year to year as communities make and break peace agreements. In this context, it is more difficult to identify specific high-risk communities that warrant priority in vaccination programmes. In fact, rinderpest may circulate between communities in a somewhat stochastic (chance) manner. Removing communities from the pool of susceptible communities through focused vaccination decreases the chance that rinderpest will survive in a region.

One can hypothesize that the following characteristics are criteria for prioritising the major pastoral communities in terms of their potential contribution to the risk of endemism:

- Community size
- Number of communities in contact
- Quality or degree of each intercommunity contact
- Internal mobility

For example, the Toposa and Murle are highly mobile and large communities. They are estimated to have approximately 300,000 and 800,000 cattle respectively. This is above any estimates of critical community size for rinderpest or related disease agents. Due to their size, these groups border a number of other communities, but they have had limited peaceful contact with most of their neighbours since the mid 1980s. The Murle probably could maintain rinderpest on their own, perhaps with only rare spill over of virus to other communities. It is also possible to conceive of the Murle clans as an interlinked system of sub-populations in their own right.

On the other hand, the Jie are a small community with only about 40,000 cattle. This number is probably less than the critical community size for rinderpest indicating that the Jie could not maintain rinderpest alone. Rinderpest in Jie is best understood as periodic spill over from other communities or part of a larger endemic system of sequential flow of infection through a series of communities. The most immediate links to the Jie are the Toposa and Murle. In a sense, the Jie may be functioning as an indicator population for disease endemism in one or more of these larger communities.

If the mechanism of endemism in the southern Sudan is the continuous flow of virus between interlinked sub-populations, vaccination of a sufficient number of key communities in the chain of transmission should be enough to break the chain. In this regard, the focal nature of the OLS vaccination has been highly appropriate.

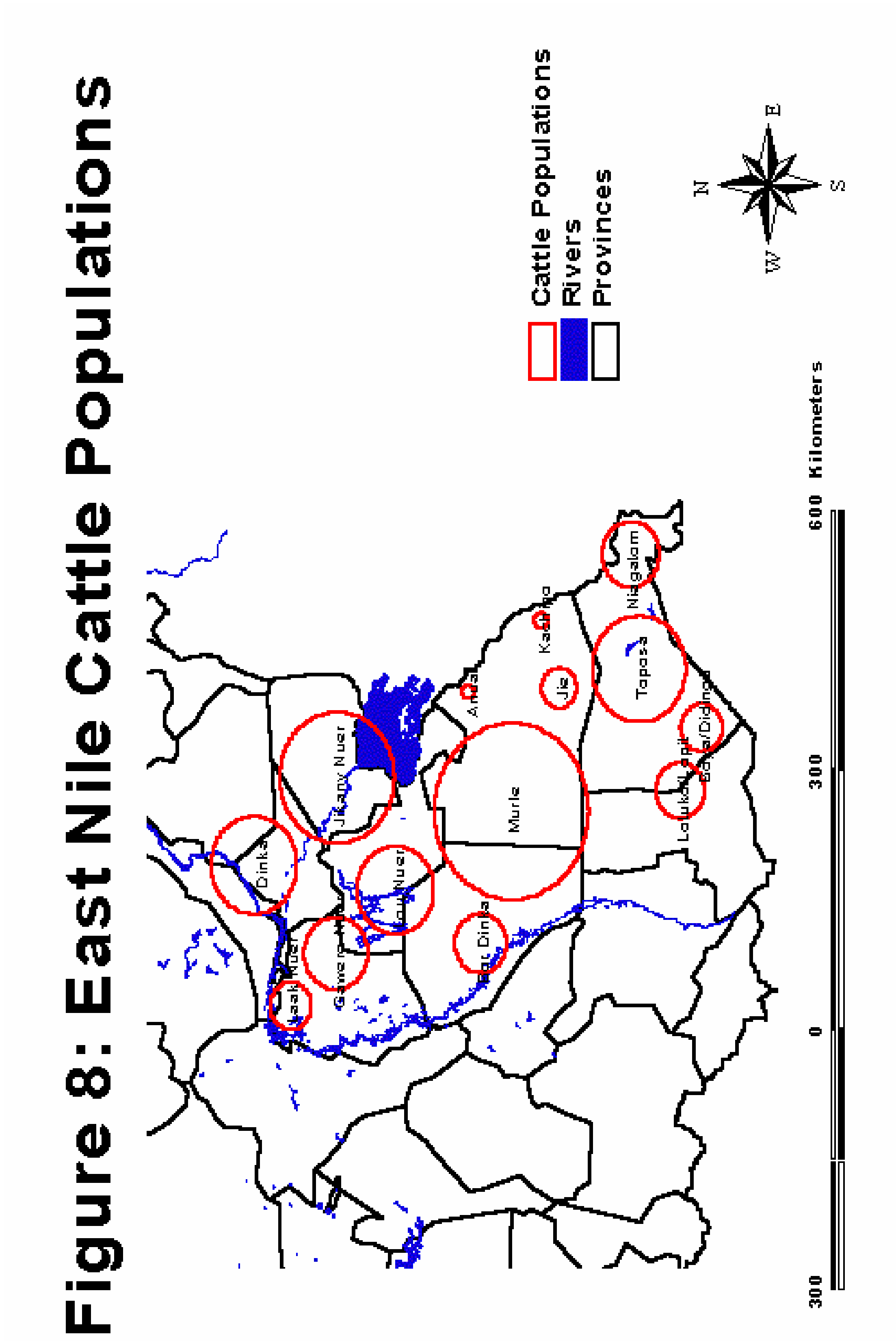
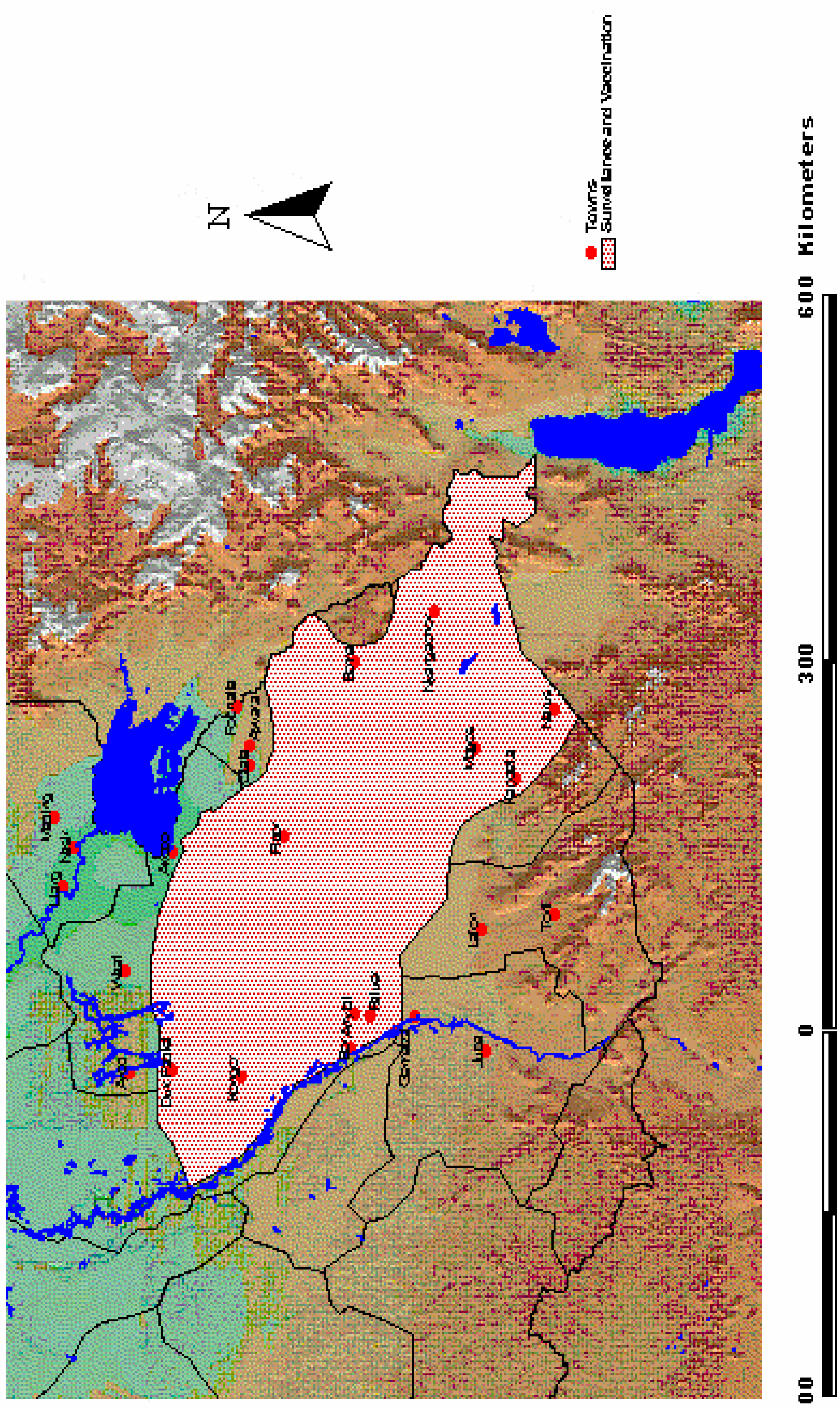


Figure 8: East Nile Cattle Populations
Cattle Populations
Rivers
Provinces
N
E
S
W
300
0
300
600
Kilometers
Dinka
Murle
Jie
Toposa

Figure 9: Surveillance and Vaccination Zone



Cessation of Vaccination

The final test in the eradication process is the cessation of vaccination. When surveillance indicators provide a reasonable level of confidence that the disease has not occurred for two years (Office International des Epizooties, 1998) and the capacity to respond rapidly to any flare-ups of occult rinderpest is in place, vaccination should cease. A period of intensive surveillance should follow. If one views the likelihood of rinderpest eradication as a probability, vaccination should cease when decision makers are 90 to 95% confident that the disease is eradicated. In situations where the capacity for rapid response is reduced, decision makers should require a greater degree of confidence.

In the case of southern Sudan, where access comes in the form of windows of opportunity, it is easy to imagine outbreak scenarios where rapid response is not feasible despite the best of preparations. This suggests that decision makers should require detailed surveillance data or a higher level of confidence resulting from a prolonged period of disease absence before ceasing vaccination.

On the other hand, the R_o estimates and modelling exercises clearly indicate that vaccination should not be practised where it cannot be applied properly. This means that vaccination should not be undertaken unless there is a reasonable expectation of achieving 80% herd immunity in a defined subpopulation. Rather than create the conditions conducive to the maintenance of occult endemism, it would be more appropriate to cease (or never start) vaccination in such areas and conduct surveillance.

West of the Nile, it has been more than five years since the last confirmed rinderpest outbreak. Participatory methods also indicate that livestock owners have not experienced rinderpest in over five years. The CAHW networks are well established and access is generally good. The potential for rapid response exists. Cessation of vaccination is the prudent and appropriate next step.

East of the Nile, the situation is much more complex. It is helpful to consider the East Nile Ecosystem as two sub-systems. The northern sub-system is essentially the Nuer and Dinka communities of the Sobat Basin (Figure 8). Both banks of the river should be included in this system as the communities cross the river freely. The logical northern boundary for the Sobat Basin subsystem is the extent of the Nuer and Dinka communities. Although contact exists with the highly transhumant Fellata and Beggara communities to the North, they have distinctly different contact, density and movement patterns.

The Southeast subsystem is centred on the Kengen River and begins North of Pibor at the boundary between the Nuer and Murle communities. There is a large no-mans-land between the Nuer and Murle, and cattle raiding appears to be the main contact between these two groups. The Southeast Nile ecosystem should be considered to include the Toposa community to the South and the communities in the Torit area. The Nile is the boundary to the West with the Bor Dinka included in the sub-system.

The situation in Sobat Basin (the northern East Nile Ecosystem) is less clear. First hand evidence of disease circulation was received during the mission that described outbreaks in 1998 and 2000. However, the sample size was small as only two days were spent in the field at Kiechkon. The OLS disease reporting system received passive reports throughout this same period, but all of these that could be investigated by the OLS network were concluded not to be rinderpest. Most importantly, the window of opportunity to conduct work in the Sobat Basin is decreasing. It is difficult to imagine effective vaccination or surveillance taking place in this region in the near future.

In the Southeast Nile Ecosystem, the last confirmed rinderpest occurred in 1998 in the Lopit Hills. However, participatory disease searching revealed a clear pattern of disease circulation in the Jie community in Jonglei throughout 1999 into early 2000. Given the constraints to disease surveillance in southern Sudan, this should be accepted as evidence that two years have not elapsed since the last occurrence of rinderpest. The window of opportunity to conduct work in the Kengen and Kurun River is expanding. Good access is available to the Toposa, Jie and large sections of the Murle community from Boma and Paluer. These opportunities should be utilized.

Rinderpest Eradication in the East Nile Ecosystem

Zonation and vaccination

Combining pragmatic, sociologic and epidemiologic considerations it is recommended that the rinderpest eradication strategy East of the Nile develop a time-bound strategy that targets vaccination and surveillance at the community level.

The first step is to inventory and assess communities according to risk factors and accessibility. It is proposed that three categories of communities are defined as follows:

- *Surveillance and vaccination communities*: accessible communities at risk for rinderpest where effective vaccination is feasible.
- *Surveillance communities*: partially accessible communities that are at risk for rinderpest but where effective vaccination is not feasible. Also, accessible communities that are at low risk or are unlikely to contribute to endemism.
- *Limited access communities*: neither effective surveillance nor vaccination is feasible. Where possible surveillance should be carried out. Interpretation of results should proceed with caution.

In light of the security situation, it seems unlikely that adequate access to the communities in the Sobat Basin will be possible in the short-term. Rather than designate this area as a surveillance zone, when adequate surveillance is not feasible, their status as limited access communities should be clearly indicated. This avoids false expectations. Surveillance should be carried out to the extent possible. Present information suggests that the surveillance system will need to depend on CAHWs and carefully selected Stockpersons.

The approximate geographic extent of the vaccination and surveillance zone is indicated in Figure 9. In the southern portion of the East Nile Ecosystem, good access is enjoyed to large sub-sections of the Murle community from Paluer, Boma and Akobo. Several clans of the Jie are also accessible from Boma. The Toposa are accessible from two locations, Niangachor and Narus. Based on the historical information from Boma and Kurun indicating that at least parts of these communities have been involved within the last two to three years in rinderpest outbreaks, it is recommended that the Toposa are considered a surveillance and vaccination community. Vaccination of Dinka cattle from Paluer will protect the areas to the West of the Nile from reintroductions while the status of the East Nile Ecosystem is more carefully defined. The portions of the Murle and Jie community near Pibor should be considered limited access communities.

Access to the Lotuko/Lopit and Boya/Didinga is variable. These communities are also small and isolated from the pastoral Murle and Karamojong cluster groups to the East. It is doubtful that these smaller communities could maintain rinderpest without the involvement of the larger populations to the East. The outbreak in 1998 in the Lopit hills was suggestive of an indicator population. These areas should be considered surveillance communities.

The Anuak and Kachipo communities are small and peripheral to any possible endemic focus. It is recommended that vaccination is not resumed in Pochalla and that vaccination is not begun for the Kachipo.

Table 16: Epidemiologic Categorization of Communities of the East Nile Ecosystem

Vaccination and Surveillance Communities:	Toposa, Jie, Murle and Bor Dinka (Figure 9)
Surveillance Communities:	Anuak, Kachipo, Lotuko, Lopit, Boya and Didinga
Limited access Communities:	Nuer and Dinka of the Sobat Basin and the Pibor Murle

Where vaccination is carried out, it should be intensive. The target should be 100% coverage. The serological studies indicate that, in general, the delivery strategy has been effective in achieving 70 to 80% herd immunity where it has been practiced. It was noted that in communities where CAHW programmes where implemented with intermittent support through short-term visits, vaccination coverage was not adequate. Examples are Pochalla and Boma. The key is to focus resources. The programme at Boma should be fully implemented with its own dedicated staff.

Conflict resolution

Cattle raiding has been a constraint to service delivery in the southern part of the East Nile Ecosystem. Although it does not normally place OLS Livestock Programme staff in danger, it hampers access to cattle across community lines by restricting the movement of counterpart staff and frequently causes cattle camps to seek out more remote locations. In the past, raiding has all but eliminated access to the Murle from towns such as Paluer, Pochalla and Akobo. It is strongly recommended the OLS Livestock Programme consider introducing conflict resolution activities. It is suggested that peace meetings are held between the Anuak, Jie, Kachipo, Murle, Niagatom and Toposa. Increased access to livestock service delivery, among other services, should be presented as one of the benefits of peace.

Epidemiologic assessment and surveillance

More important than vaccination, is a complete understanding of the epidemiology of rinderpest in the region to direct control efforts. This can only be accomplished by an appropriate combination of epidemiologic study and surveillance.

The accessible communities East of the Nile should be systematically searched over the next dry season by a dedicated team to determine community consensus regarding the date of the last outbreak(s) in each location. The methodology used in this consultancy should be applied in more depth. It is recommended that at least 30 interviews be carried out in each community (or sub-community for the larger groups).

The concept of surveillance is developed more fully in the next section. As requested by the terms of reference, general suggestions and recommendations for an effective surveillance system are presented. Thereafter, specific recommendations for surveillance in southern Sudan are provided.

6. Participatory and Quantitative Epidemiology in CAPE and PACE

Development and Promotion of Sustainable, National Epidemiology Units

Building in sustainability

National epidemiology projects often fail to thrive. In order to succeed, epidemiologic systems must be integrated into the overall animal health delivery system. Epidemiologic systems require partners to collect or provide data and to carry out the interventions indicated by the conclusions of epidemiologic analysis. If these partners do not perceive the need for and *experience* the benefits of an epidemiologic system, the system will not be sustainable.

The first step to establishing sustainable national epidemiology units is to identify the stakeholders or ‘customers.’ Potential customers include decision-makers, the livestock industry, public and private veterinary service providers, and most importantly the livestock owners. The next step is to conduct a needs assessment. One might think of this as market research – What do our stakeholders want for their time and money? The needs assessment has to identify feasible products that help the beneficiaries to reach their objectives. Participatory assessments and participatory epidemiology should be part of the design process of the national epidemiology units.

Surveillance systems and epidemiologic studies

One can distinguish between two types of epidemiological activities. The first is epidemiological studies that seek to collect baseline data on national livestock systems or detailed data on specific priority issues. The second major activity is disease surveillance. Surveillance seeks to detect and investigate animal health events as they occur. In this sense, surveillance is about current events whereas studies tend to have a longer time horizon. Surveillance and studies are complimentary activities. Studies often provide the contextual information required to correctly interpret surveillance data.

Surveillance has been defined as information for action. Surveillance systems must not only collect representative and timely information, they must process this information into useful products that have real world impact as events are occurring. Good surveillance data is essential to effective animal health decision-making and action.

Participatory epidemiology and national epidemiology systems

Data is expensive and in short supply. In order to be sustainable, national epidemiology units need to identify reliable and affordable data sources. Many conventional epidemiological methods are based on high cost approaches that are difficult to sustain, even in the developed world. In this regard, participatory epidemiology has an important contribution to make. It provides timely and cost-effective information. Although participatory epidemiology is most effective in combination with laboratory-based epidemiology, participatory epidemiology is not fully dependent on slow or non-functional laboratory facilities. It often provides key intelligence when and where it is needed.

Participatory epidemiologic approaches also assure that the epidemiologic system is in direct contact with the livestock owners. As a result, outputs of epidemiologic systems that involve participatory data collection have a much greater chance of providing information that is actually relevant to producers.

Participatory epidemiology has important contributions to make to both surveillance systems and epidemiological studies. The next section will define surveillance activities and describe a role for participation in surveillance. Thereafter, the role of participatory epidemiology in broader studies will be discussed.

A national role for community-based disease surveillance

Effective targeted surveillance programmes from the perspective of conventional systems have been described previously (Mariner et al., 1998; Mariner et al., 1998). In conventional veterinary service terms, ‘the first line of defence is the farmer.’ The source of most disease reports is the livestock owner. He either provides information or presents his animals for treatment. In order to have effective reporting, a positive interaction is required between the formal veterinary sector the livestock owning community. Community-based systems are a proven method for cultivating and maintaining a positive interaction and the community animal health worker is a major resource for surveillance systems.

The key components of surveillance systems and the potential role of community-based disease surveillance include:

- *General disease reporting*: General disease reporting systems are routine systems for collection of data on the range and frequency of disease occurring in the field. Information from the monthly monitoring and reporting by CAHWs should be summarized by supervisors and incorporated in formal disease reporting channels.
- *Targeted disease reporting*: In the case of diseases targeted for control, specialised systems for sensitive and rapid reporting of all reports or intelligence is required. These usually include specialised disease report

registers and predefined rapid communication channels. Livestock owners and CAHWs are the initial source of information. The CAHW monitoring process should be directly linked to targeted disease reporting.

- *Outbreak investigation*: The approaches of participatory epidemiology are essential to the tracing of reports to active outbreaks for investigation and sampling. In effect, PE is analogous to a systematic method of history taking and herd health evaluation adapted to traditional livestock keeping systems. Through appropriate technology, CAHWs can collect samples suitable for laboratory analysis by serologic and molecular techniques. Blood can be collected on filter paper or tissues can be collected in formalin or ethanol. The health worker must be interviewed to obtain the descriptive information to accompany samples.
- *Laboratory diagnosis*: Accurate descriptive clinical information is required to guide laboratory testing. Community-based approaches are key to obtaining valid and unbiased information on the history and context of the cases.
- *Serosurveillance*: Quantitative serosurveillance has been incorporated in the OIE Pathway as a final validation of disease eradication. Accurate data on community structure and contact is essential to developing valid sampling regimes that are representative.

  In the absence of a best-bet scenario on the history and dynamics of the disease in the community under study, serosurveillance data has often proved difficult to interpret, if not an outright enigma. Community-based disease surveillance has repeatedly provided a common sense check on the validity of laboratory-based studies on sample sets derived from the developing countries. In the case of lineage 2 rinderpest, participatory data was the first indication that available serologic tests were much less sensitive than assumed.

Integrating community-based disease surveillance into national surveillance systems

Regrettably, the interface between formal epidemiologic surveillance systems and community-based programmes has been the weak link in the surveillance chain. This seems to stem in part from a disdain on the part of many conventional veterinarians and quantitative epidemiologists to embrace the world of traditional knowledge and qualitative disease intelligence. A loss in confidence on the part of communities in the ability of veterinary services to respond has also contributed to the gap. If one views surveillance data as information for action, but the action never comes, it is understandable that the information stops flowing. Some approaches to minimizing the information gap are:

1. *Avoid raising expectations*. Be sure the means match the aspirations. Collect information that there is a reasonable capacity to act on.

2. *Involve disease-reporting personnel in community-based programme design and training.* The national epidemiology units need to share in the ownership of the programmes. Community-based disease reporting in southern Sudan is productive because all formally trained staff are involved in the community-based system.
3. *Promote dialogue and needs assessment.* Hold national or sub-national workshops that involve epidemiologists, community-based programmes staff, CAHW supervisors and CAHWs.
4. *Provide training on PE methods to professionals.* Expose professionals to the methods of PE and community-based programmes through training workshops that provide theory and practical experience. Break out into field groups with an assignment. Ask the groups to describe the dynamics of a disease in a community using PE data and compare the results of the break out groups in discussion.
5. *Include PE methods in veterinary curricula.* Role models and examples of successful programmes define the professional expectations and ethics of young veterinarians. In order to produce professionals with appropriate value systems and expectations, realistic models adapted to local needs must be taught in school.
6. *Provide feedback and take action.* CAHW supervisors, as with any data collectors, must see the results of their efforts. Communities need to see that their information results in access to the right interventions in a timely manner.

To be sure, participatory epidemiology has its limitations and is not a panacea. But the real output from statistical epidemiology in the developing world has been very limited. Even for important human diseases such as malaria, quantitative information is too expensive relative to the available investment in health. The most effective surveillance system will be based on appropriate combinations of qualitative and quantitative epidemiology using both conventional and community-based methods.

Epidemiologic Intelligence Gathering for Control/Eradication of Major Epizootic Disease (Rinderpest, CBPP, FMD).

Participatory disease searching and scenario building

Participatory disease searching is the process of using participatory rural appraisal techniques to derive a best bet epidemiologic scenario that describes the history and dynamics of a disease in a population or community. In essence it is targeted disease investigation using participatory epidemiologic techniques. It was the approach used in this consultancy in the field in southern Sudan. It is a sensitive, rapid and low cost method for locating active disease. The techniques were summarized in the introduction to the section of this report on the field investigation. A how to manual with detailed discussion on the use of PDS for rinderpest investigation has been published by FAO (Mariner, 2000).

In order to use PDS, the target disease must be clinically recognizable and a priority for the beneficiaries. It should form a part of the existing veterinary knowledge.

Some uses of PDS are:

- *Outbreak investigation:* Disease outbreak reports can be rapidly and sensitively investigated by PDS. Once clinical cases are located, sampling for laboratory confirmation is appropriate.
- *Strategy formulation*: An epidemiologic scenario on the history and dynamics of a disease in a population is the essential basis for defining an effective and targeted strategy for disease control/eradication.
- *Eradication verification*: Participatory disease searching can be used as a sensitive method to verify the eradication of a disease from a community. In order to do this a sufficient number of interviews needs to be conducted relative to the size and diversity of the population under study.

It is recommended that PACE integrate a PDS approach into the suite of epidemiologic tools for the control and eradication of epizootics. The next section presents a brief concept on the integration of participatory disease searching and participatory epidemiology into the PACE strategy formulation process with particular reference to CBPP.

The dynamics of disease endemism and the development of effective control/eradication strategies

The PACE programme has a broad mandate to develop epidemiologic capacity, establish effective strategies for trans-boundary disease control, and internationally coordinate disease control efforts. Within the context of PACE, the CAPE Unit is to contribute to these goals through the development of effective service delivery to communities and the development of participatory surveillance and epidemiological data collection methods. The CAPE Unit seeks to integrate participatory epidemiology into conventional epidemiologic delivery systems. This includes both participatory disease surveillance and participatory epidemiologic study methods.

Because of the limitations of conventional epidemiology, strategies for disease treatment and control in the pastoral setting have largely been based on assumptions or adaptation of methods from more sedentary livestock keeping systems. An understanding of the dynamics of endemism of infectious and vector borne agents in pastoral systems is a prerequisite for the design of effective control and eradication strategies. The methods used in this consultancy to study rinderpest are a good example of how PACE and CAPE can meet this challenge and should be applied to other disease control initiatives.

To date, some progress has been made on the understanding of the dynamics of selected disease in the pastoral setting through participatory epidemiologic studies. Examples of such studies exist for rinderpest (Mariner and Flanagan, 1996), trypanosomosis (Catley and Irungu, 2001) and mixed parasitism (Catley et al, 2001). However, there is definite need to continue to develop data and intelligence on the ecology of rinderpest in the southern Sudan and Somali areas. Other diseases included in the PACE mandate such as CBPP, FMD and vector borne disease are actually of higher priority to livestock owners on a day-to-day basis. These diseases, especially CBPP, warrant study with methods appropriate to the realities of the pastoral setting.

Although participatory epidemiology is established as an approach, full development of the potential of participatory epidemiology has not yet been realized. The integration of participatory epidemiology and conventional quantitative epidemiologic analysis as a cost effective and pragmatic approach to providing epidemiologic services to livestock owners has only just begun. Many participatory techniques have yet to be adapted and evaluated as tools for epidemiologic data collection. The adaptation of statistical analysis to participatory epidemiologic data and the incorporation of participatory data into more conventional epidemiologic surveillance systems, studies and models is an activity of the CAPE Unit that should be emphasized.

The perceived importance of CBPP by both livestock owners and animal health experts make this disease a logical focal point for the epidemiological activities of PACE and CAPE. The existing strategies for the control of CBPP are costly and logistically demanding. A major source of difficulty is the short duration of immunity generated by available vaccines and variability in the immune response among vaccinated animals. The limits of available diagnostic tests compounded by the difficulty in detecting asymptomatic carriers further complicate the control of CBPP. The prominence of movement control in CBPP strategies suggests that the control of CBPP in pastoral situations will be extremely challenging.

Participatory epidemiologic approach in combination with the strategic use of laboratory testing can provide cost effective and timely insights into the dynamics and impact of endemic CBPP in pastoral societies. Techniques such as semi-structured interviews, mapping, progeny history analysis, proportional piling and seasonal calendars are available to collect information on morbidity, mortality, response to treatment, recurrence of disease, the temporal and spatial disease distribution, herd demographics, age structure and contact structure.

Many of the data collection exercises utilized in participatory epidemiology can generate quantitative data. One of the strengths of participatory epidemiology is the flexibility of the approach. This facilitates the discovery process where new unforeseen information can guide and shape the data collection process while it is already underway. The concept of key informants is central to participatory information collection. Key informants are people or groups of people who are likely to have special insight into the issues of interest. Information and intelligence derived from key informants is a form of expert opinion. Due to the high cost of data, disease modelling, economic modelling and risk analysis in the developed world rely heavily on expert opinion. It is appropriate that PACE and CAPE promote the use of existing veterinary knowledge provided by key informants as a source of expert opinion for epidemiologic analysis.

One of the criticisms of models is that they can become disconnected from the situation on the ground and reflect the opinion of technical experts rather than actual social and epidemiologic realities. The use of participatory epidemiology as a source of data and expert opinion is a logical and cost-effective solution. In the context of rinderpest dynamics in the pastoral setting, livestock owner's perceptions have repeatedly caused a reassessment of conventional wisdom among professionals. Participatory epidemiologic studies on CBPP will probably make similar discoveries.

The author proposes that PACE should focus a portion of their epidemiologic resources on the development of the interface between appropriate pastoral data collection methods and epidemiologic analysis relevant to disease control strategy. The focus of these efforts should be on CBPP, however further progress can be made on rinderpest simultaneously.

The first phase should be participatory data collection on key parameters regarding the dynamics and impact of CBPP. In order not to bias respondents and capture added value, information on rinderpest, FMD and vector borne disease can be collected concurrently. In addition, information of general epidemiologic value to multiple diseases on herd demographics and the contact structure of the community should be collected.

One to two communities should be identified. Candidate communities include the Murle and Jie communities accessible from Boma in the southern Sudan and the groups using the Kagera Valley in Tanzania. Selection of Boma as the study site offers an opportunity to better understand rinderpest epidemiology in the southern portion of the East Nile Ecosystem as an added benefit.

The following indicators or CBPP parameters should be accessed by participatory and/or serologic methods:

- Infection rates
- Existing veterinary terminology and case definitions
- Morbidity and mortality rates
- Herd size and age structure
- Herd mobility and movement patterns
- Community structure and contact levels between sub-groups
- Response to treatment

Conventional expert opinion should also be collected through consultation with CBPP experts. This could take the form of a brain storming session to develop and refine questions followed by individual interviews to collect responses.

Screening with the complement fixation test followed by confirmatory testing with competitive ELISA can give an objective estimate of active infections as antibody titres from both vaccination and infection are short lived. This information in combination with herd demographics can be used in deriving estimates of the basic reproduction number, $R_{o,}$ from simple modelling relationships under an assumption of endemic stability.

Once the field data is available, the analytical phase should begin with the estimation of the basic reproductive number, R_o, and other parameter as point values and probability distributions using quantitative methods and excepted approaches for modelling expert opinion. In this second phase, model development and experimentation can be used to test the impact of control options. The first step should a sensitivity analysis to establish the relative importance of model parameters in determining the course of CBPP in a population. This step may highlight further data needs that require a brief return to the field.

The effect of interventions on disease persistence, likelihood of disease fade-out and the effective reproductive number, R_e, should then be examined in the model. Combinations and schedules of vaccination, testing, reduction in contact rate (quarantine), removal of infectious animals and treatment can be considered. The objective would be to develop a more pragmatic strategy for CBPP control and eradication or identify the threshold of intervention efficacy or actions required for control.

Epidemiologic Surveillance in Southern Sudan

Current activities

At the time of the consultant's mission, several activities were underway to strengthen surveillance. A workshop was held to begin implementation of expanded activities and efforts were underway to collate data collected over the last decade or more on disease reporting, serosurveillance activities and population estimates. Draft data from these efforts has been provided to the consultant by Byrony Jones and was used as the basis for some of the summaries presented in this report. The reader is requested to consult the final report of Dr. Jones for the detailed data.

Disease reporting and investigation

The consultant noted that a robust disease reporting and investigation system was in place in southern Sudan. An officer was appointed to oversee disease reporting and support field investigations. Very complete disease investigation kits had been prepared and distributed to 35 field locations.

The disease reporting system in southern Sudan involved the community and outbreak reports for a number of diseases were received. The main source of reports was livestock owners and CAHWs. It was gratifying to see that reports of suspected rinderpest or stomatitis-enteritis were being forward and investigated wherever feasible. Table 17 presents annual statistics and performance analysis. The quantity of data suggest that disease reporting and investigation is being applied more diligently in southern Sudan than in many other regions participating in PACE.

Table 17: Disease Reporting Statistics for 1998-2000

Year	Disease Reports	Stomatitis-Enteritis Reports	Percent Investigated
1998	26	8	75%
1999	57	11	73%
2000	66	13	77%

Source: Gachengo Matindi

Receipt of reports of SE outbreaks does not indicate that rinderpest is present. It does confirm that the surveillance is ongoing. Where reports can be fully investigated, negative outcomes raise the level of confidence regarding the absence of disease. Of the 8 reports that could not be investigated on site, 7 were in the East Nile Ecosystem.

Serosurveillance

The OLS Livestock Programme has given significant attention to the collection of sera for seromonitoring purposes, but has place limited emphasis on serosurveillance for evidence of disease circulation. Most sample sets come from vaccinated populations. The serological data has been useful in confirming the efficacy of the focused vaccination programme.

The technique of collecting blood on filter papers for serology has been distributed to most OLS Livestock Programme sites. At the moment, the technique has not been implemented at the level of CAHWs, as they are unable to record the background information on the papers. Large numbers of sera have been collected and are awaiting testing.

Laboratory support

At present, most diagnostic and serologic samples are sent to Muguga. Turn around time on suspected rinderpest samples is reasonable, however there is a very large backlog on serologic samples that covers more than a years worth of samples.

The SCF laboratory at Lokichokio serves as a staging area for the processing and forwarding of samples to Nairobi. It also offers simple diagnostic services including the examination of blood smears, faecal samples and skin scrapings as well as brucellosis testing. Although the mission received prompt assistance with several requests to the laboratory, reports of delayed feedback or misplaced samples were also received. In the case of misplaced samples, the submitting agency left the samples in a vaccine carrier in the OLS veterinary office when all staff where in the field. These simple procedures provide feedback to field staff on sample submission and if completed in a timely manner greatly encourage disease reporting and field investigation.

Suggestions for strengthening surveillance

Due to the patchy nature of access to southern Sudan, surveillance based on randomised sampling is not possible. Several methods recommended in the OIE Pathway are based on randomised sampling designs to detect disease with predetermined confidence levels at a hypothetical prevalence (Anon,1982). Lack of random access means that it is not possible to estimate quantitative epidemiological parameters at levels above the local community.

Several of the measures required by the OIE Pathway lack biological coherence. They do not take into consideration the transmission dynamics of rinderpest. The requirement to conduct randomised serosurveillance to high confidence levels for the detection of disease at 1% prevalence levels is a prime example.

Bearing in mind concepts such as critical community size, the high levels of herd immunity consistent with circulation of an endemic disease with an R_o of 4 to5, and the heterogeneous population structure of southern Sudan, it should be possible to complete and verify the eradication of rinderpest in the absence of randomised sampling designs. This will require the formulation of specific surveillance plans for each community.

Surveillance should target communities and sampling should be purposive. That means that each surveillance exercise should explicitly state the hypothesis being tested. The most common question will be: Is rinderpest circulating in a particular circumscribed community? A definition of the community under evaluation is an integral part of the hypothesis. An example would be a list of clans or cattle camps included in the population and the range of movements and interactions with other communities.

Participatory disease search vs. random clinical surveillance

Clinical surveillance is the process of searching for clinical disease by examining cattle. This process has sometimes been recommended on a random basis as a surveillance method for rinderpest. Given the short duration of clinical signs, it is undoubtedly a very insensitive and inefficient method of searching for rinderpest.

Participatory disease searching is the most sensitive way to find clinical cases. It takes advantage of the tremendous reach of local knowledge and communication systems. Once suspect animals or herds are identified, clinical investigation is appropriate. The process of participatory disease searching was described in the section on the field investigations.

Organizationally, disease searching is a relatively specialised activity and is best implemented under the immediate guidance of a small team of trained individuals. It is recommended that at least two specialised officers are identified for this assignment for the duration of the 2001/02 dry season, one for the East and one for the West Nile Ecosystems. It is important that the method is applied consistently and that the group is small enough to communicate directly and freely on the interpretation of results. Only one individual from the team needs to travel to each community to carry out the PDS. The interview team on the ground should incorporate local NGO and counterpart staff to bring a variety of perspectives to the exercise and provide a sense of ownership of the results of search to the local stakeholders.

In the past, it seems that OLS veterinarians have largely been acting as data collectors. A large body of data covering several years' work is only now being analysed. Analysis should be an on going process that continually informs and updates the data collection process.

In limited access areas, it may be feasible to train counterpart staff in the PDS approach and for them to carry out rinderpest assessments independently. Trainees would need to be carefully selected. A pilot workshop could be organized to provide training on techniques. Sample data should be provided and participants will need to break out into groups to interpret it. Most importantly field exercises should be incorporated in the programme.

Market surveillance

The consultant was informed that market surveillance activities are now being implemented as part of the surveillance programme in south Sudan. This is a very sensitive method and should incorporate semi-structured interviews as well as clinical inspections. Market interviews could also be incorporated in PDS work.

Disease reporting and investigation

The system of community-based disease reporting could be further reinforced through the provision of rewards for information leading to the identification of SE cases for sampling. CAHW supervisors can be provided with disposable cameras and photographs of SE lesions should be considered as a means of verification. The incentive should be moderate but reward all levels of the reporting/investigation system.

Laboratory testing

The SCF laboratory should be supported and modestly expanded. The laboratory serves a very positive role in providing feedback on a proportion of submissions and disease reports. Timely feedback is essential to the continued participation of stakeholders and the success of the surveillance effort.

Efforts should be made to streamline sample submission and the reporting of results through the establishment of standard operating procedures and identification of points of contact. This information should be distributed to all agencies involved by E-mail and discussed as part of one of the routine coordination meetings. Some simple performance indicators can be established to monitor the laboratory.

Examples are:

- Percent of sample submissions received in good condition
- For samples received in good conditions for in-house testing, percent of submissions for which results were reported within 7 days

The value of serosurveillance data deteriorates with time. The current turn around time in serological studies is not compatible with the success of surveillance efforts. Comments from field staff reflected a demoralised atmosphere with regard to the collection of serum samples. Interest in the collection of filter papers has declined because counterparts are yet to hear the results of their efforts.

A sustainable method of supporting the regional diagnostic laboratory at Muguga must be found or alternative-testing facilities should be identified without delay.

The consultant recommends that routine ELISA testing on samples from areas such as south Sudan and Somalia be put out to tender for the current phase of PACE. The terms of the tender could include an advance payment that would allow for the procurement of equipment and reagents and a per test payment. Government-owned laboratories with independent accounting practices should be allowed to compete. Penalties similar to those stipulated in supply contracts should apply for the late reporting of results.

Purposive serosurveillance

As access is gained to non-vaccinated populations, every effort should be made to conduct purposive surveys to detect and date circulation of rinderpest virus. If it has been more than two years since the last vaccination, purposive sampling can detect the circulation of virus in young animals. If it has only been one year since vaccination, the age band of seronegative animals is narrow and results are difficult to interpret. The sample should be age structured using the standard approach and serum collection forms. Recording the best estimate of the age of animals would provide additional information, allow estimation of the basic reproductive number and assist the dating of historical rinderpest outbreaks.

It is suggested that at least 10 non-vaccinated herds are sampled and that at least 200 sera are collected. These numbers are arbitrarily selected and do not have statistical significance. Remember that the objective is not just to detect circulation, but to also estimate the date since the last outbreak.

Examples of opportunities to conduct extremely useful purposive surveys in East Nile Ecosystem are:

- Murle from
  - Boma
  - Paluer

    - Akobo
- Newly accessed Nuer and Dinka communities in the Sobat Basin

In order to be really valuable a brief (one page) narrative report should be attached to the sample logs. The report should describe:

- The reason for sampling – the hypothesis being tested
- A description of the community sampled
- A sketch map of the community's location and movements
- Information on contacts with other communities
- Area vaccination history
- Information on last reported outbreak

Annex 1: Terms of Reference

TERMS OF REFERENCE

Community-based Animal Health and Participatory Epidemiology Unit (CAPE)
Pan African Campaign for the Control of Epizootics (PACE)
Organisation of African Unity/Inter-Africa Bureau for Animal Resources (OAU/IBAR)

Consultancy to assist in the development of a rinderpest eradication strategy
In the West Nile and East Nile Ecosystems

Background

Within the Pan African Campaign for the Control of Epizootics (PACE), the Community-based Animal Health and Participatory Epidemiology (CAPE) Unit has the mandate to support community-based delivery systems for the control of epizootic and other diseases in marginalized pastoral ecosystems. This role includes the further development and testing of appropriate disease investigation and surveillance methods, particularly participatory methods, in resource-poor pastoral ecosystems. Due to long-term conflict in Sudan, the West Nile* and East Nile** Ecosystems present special challenges to disease control programmes and consequently, parts of these ecosystems are considered to be among the few remaining foci of rinderpest in Africa.

The UNICEF Operation lifeline Sudan (Southern Sector) Livestock Programme has been co-ordinating a community-based animal health worker (CAHW) programme in southern Sudan since 1989. A key feature of this programme was an innovative approach to rinderpest control using CAHWs to deliver heat-stable vaccine. Despite severe operational constraints, the approach resulted in a substantial reduction in rinderpest outbreaks in southern Sudan and this situation has been maintained up until the present day. This achievement was recognised by OVU/IBAR and the Global Rinderpest Eradication Programme as one of the key successes of the Pan African Rinderpest Campaign (PARC).

In 1998 and with support from PARC, the UNICEF-OLS programme began to consider options for assisting southern Sudan to follow the OIE pathway for rinderpest eradication. At this time, the preferred option was to use the natural barrier of the Nile to create the West and East Nile zone was considered suitable for the introduction of community-based active surveillance whereas the East Nile included some key inaccessible areas where little was known about the rinderpest situation and vaccination programmes had not been widely implemented. These areas included Pibor/Boma and the Sobat Basin. When applied correctly, methods such as participatory disease searching provide opportunities to improve understanding of rinderpest in these locations and use the information gained to inform a rinderpest eradication strategy for southern Sudan.

In addition to operational context and conditions, the design of a disease eradication programme depends on the epidemiology of the disease agent and the characteristics of the curative or preventive measures available. In the case of vaccines, important characteristics include the proportion of animals vaccinated that are protected, the duration of protection and the coverage achieved by the vaccination programme. The most important epidemiological parameter is the basic reproductive number R. epidemiological theory can use this information to guide the design of eradication programmes by assessing the feasibility of eradication, the proportion and age of animals to be vaccinated, the vaccination interval and the duration of vaccination programme required. To date, mathematical models have been used to describe viral diseases such as rabies, foot and mouth disease, and African horse sickness, but modelling of rinderpest has been limited. It seems likely that the development of models for rinderpest would assist PACE, CAPE and OLS to develop an appropriate eradication strategy for the West Nile and East Nile Ecosystems according to field conditions and the OIE pathway.

The epidemiological methods used during the consultancy can be regarded as extremes on a scale moving from qualitative, field-level data gathering (not assisted by computers) to quantitative, theoretical modelling (highly dependent on computers). Therefore, the consultancy is an opportunity to compare two very different epidemiological methods and provide guidance on the use and promotion of these methods by PACE and CAPE.

Specific Tasks

1. Train veterinarians in the participatory disease searching methodology.

2. With OLS, conduct a comprehensive participatory disease search for rinderpest in SPLM-controlled areas of Eastern Equatoria, Jonglei and Eastern Upper Nile (this work will complement similar searches in Government of Sudan controlled areas).

3. According to the quantity and quality of data available on rinderpest in southern Sudan, determine whether the basic reproductive number can be calculated for rinderpest in Sudanese areas of the West Nile and East Nile Ecosystems.

4. Based on the outcome of Specific Task 3. above, propose approaches for determining the role of mass vaccination in achieving sufficient levels of herd immunity for the termination and/or prevention of rinderpest outbreaks in southern Sudan.

5. If herd immunity is considered to vary widely between communities, advise how this situation will affect the epidemiology of rinderpest in southern Sudan in the long-term.

6. Based on the results of Specific Tasks 2 to 5 above plus an analysis of operational and logistical factors, and organisation capacities, design a protocol for rinderpest eradication in Sudanese areas of the East Nile and West Nile Ecosystems.

7. Assess the role of the methods used during the consultancy in relation to the outputs of CAPE and PACE viz. development of community-based disease surveillance in pastoral areas (CAPE) and development and promotion of sustainable, national epidemiology units (PACE). Issues to consider include the pros and cons of the methods in pastoral areas; role in national epidemiology units; relative value of the methods for control/eradication of major epizootic disease (rinderpest, CBPP, FMD).

Time input

56 days, being 28 days in southern Sudan and 28 days in Nairobi.

Qualifications and experience required

1 consultant is required with the following qualifications and experience:

- Degree in veterinary medicine with specialised knowledge of mathematical modelling.
- Field experience in pastoral areas affected by conflict, preferably in southern Sudan.
- Practical experience of participatory disease searching, preferably for rinderpest.
- Knowledge of community-based animal health systems in pastoral areas.
- Knowledge of community-based rinderpest control and active surveillance in relation to OIE pathway for rinderpest eradication.

Deliverables

. Detailed work plan, by Day 7;
. Preliminary report, by Day 28;
. Draft final report, by Day 52;
. Final report by Day 56 to Director, OAU/IBAR.

Reporting

The consultant shall report directly to the Epidemiology and Informatics Officer of CAPE will disseminate information and reports to the PACE Coordinator, PACE Main Epidemiologists and PACE Epidemiologist for East Africa.

Notes:

*Western Upper Nile, Bahr el Ghazal, Kordofan, Dafur, Nuban areas of Sudan plus Eastern Chad and eastern Central African Republic.

** Eastern Upper Nile, Jonglei, Blue Nile areas of Sudan plus Ilubabor (Gambela) and Welega region of Ethiopia.

Annex 2: PRA Checklist

Chiefs and elders or small groups of cattle owners were interviewed. Separate interviews were conducted with key informants such as official chiefs and veterinary authorities.

The interview team never mentioned rinderpest before the cattle owners introduced the subject.

1. Introductions: identify the respondents and establish if they own cattle owners.
2. Establish their main herding locations.
3. What are the current cattle disease problems in their herd?
   If tearing or diarrhoea is mentioned, explore these syndromes in detail.
4. What are the current cattle disease problems in the area?
5. Historically, what are the most important disease problems of cattle?
   Rinderpest is frequently mentioned as one response to this question.
6. Have they seen it in their lifetimes? What does it look like?
7. When was the last time their cattle where affected by rinderpest? Where? Where did it come from?
8. Were their cattle affected by rinderpest in any previous times? What years? Where?

As warranted, further probing questions can be added to cross check reports made in other interviews, further define cattle movements which may affect the epidemiology of the disease.

Mapping of herding movements was completed as part of most interviews. Proportional piling exercises on herd age structure and rinderpest mortality were completed as part of all interviews after the first day.

If the respondent mentions rinderpest, always request a description and validate the term.

Annex 3: Inventory of Serum Collected

Location Collected	Number and Species	Comments
Nyalongoro, Boma N 6 27 25, E 34 26 17	21 Cattle	Unvaccinated from largely unvaccinated Murle cattle. Last outbreak reported as 1995-96. Ages recorded.
Garaworth, Boma N 6 16 49, E 34 26 41	26 Cattle	All but two unvaccinated cattle from largely unvaccinated Murle cattle. Ages recorded.
Nyalongoro, Boma N 6 27 25, E 34 26 17	2 Reed buck	Hunter kills encountered along road.
Kanamuge, Kassengor N 6 07 46, E 33 51 34	6 Cattle	Reported to have survived a RP outbreak in 1998. Owner reported vaccinated but no earmarks. Both filter paper and sera collected.
Pulgoure, Kiechkon N 8 53 42, E 33 06 12	66 Cattle	Unvaccinated cattle from a largely unvaccinated Dinka herd. The cattle originated from Baliet/Adong in West Latjor State. The *beny wut* reported last outbreak as 1977. The previous day to cattle owners from the Baliet Dinka had stated they had RP in 1998. Ages recorded.
Ajwara, Pochalla	5 White-Eared Kob	Hunter kills along the road to and from Ajwara.

Annex 3: Rinderpest Model Structure

Closed Population Model

The SEIR model is a state transition model with 4 states:

Susceptible – Animals fully susceptible to infection,

Exposed – Animals latently infected and not yet shedding virus,

Infectious – Animals infected and shedding virus in sufficient quantity to transmit the disease,

Recovered – Animals that are no longer shedding virus and considered immune.

All animals in the model fall into one of the four states and members of each state transition between states according to rate equations.

The model uses a discrete time step of ΔT and expresses the transition rate equations as difference equations. The model tracks the population over 3650 time steps. If the time step is set to 0.1 days, this is equivalent to one-year. Initial values are entered for the total population size (N), initial number exposed to RP (E), the initial number infectious or shedding virus (I) and the initial number recovered or vaccinated (R). The initial number susceptible (S) is calculated by the model as:

$$S = N - (E+I+R)$$

For each time step the model calculates the change (Δ) in the number of animals in each of the four SEIR states.

The difference equations are:

$$\Delta S = -cp(IS/N)(\Delta T)$$

$$\Delta E = +cp(IS/N)(\Delta T) - \gamma E(\Delta T)$$

$$\Delta I = +\gamma E(\Delta T) - \alpha I(\Delta T)$$

$$\Delta R = +\alpha I(\Delta T)$$

Where the parameters are defined as:

α alpha: rate of recovery/removal (=1/infectious period)

γ	gamma: transition rate from exposed to infectious state (=1/latent period)
c	number of physical contacts per day
p	probability that one contact results in transmission

Once the change is calculated, the total numbers of animals in each SEIR state in the new time step are calculated by adding the change in number to previous total to obtain the new total.

$S_{t+1} = S_t + \Delta S$

$E_{t+1} = E_t + \Delta E$

$I_{t+1} = I_t + \Delta I$

$R_{t+1} = R_t + \Delta R$

Open Population Model

The open model has the same general structure as the closed model except that the transition rate equations incorporate terms for birth, non-specific mortality, and mortality from rinderpest.

As the total population size changes, it must be recalculated in each time step. For this reason, the mass action term (IS/N) is replaced by IS/(S+E+I+R) in the open population model.

The difference equations have the following form:

$\Delta S = -cp(IS/(S+E+I+R)(\Delta T) + b(S+E+I+R)(\Delta T) - \mu(S)(\Delta T)$

$\Delta E = +cp(IS/(S+E+I+R)(\Delta T) - \gamma E(\Delta T) - \mu(E)(\Delta T)$

$\Delta I = +\gamma E(\Delta T) - \alpha I(\Delta T) - \mu(I)(\Delta T) - \sigma(I)(\Delta T)$

$\Delta R = +\alpha I(\Delta T) - \mu R(\Delta T)$

Where ‘b’ is the birth rate, μ is the non-specific mortality rate and σ is the rinderpest specific mortality rate.

Annex 5: Stomatitis-Enteritis Sample Collection

In the event cases are observed that meet the SE Outbreak Definition, samples should be collected from all affected animals for laboratory diagnosis. Recent, acute cases are the best subjects for virus isolation, antigen detection, or RT-PCR.

Live affected animals:
- ocular and nasal swabs (essential)
- scrapings of oral lesions
- serum
- prescapular lymph node aspirates (optional)

If available, perform a Clearview tests on site. Be sure to conserve sufficient swab sample for confirmatory tests such as RT-PCR, immunocapture ELISA or AGID.

Herd or in contact animals:
- serum

Sacrificed or deceased animals:
- 10 gm samples of fresh spleen, mesenteric lymph node and tonsil
- eyelids in formalin
- 10 gm blocks of spleen, lymph node and tonsil in formalin and ethanol

Comments:
For most viral diseases, pathogens are most easily detected in the acute phase just at the onset of symptoms. This is particularly true for rinderpest and every effort should be made to sample animals in the phase after the onset of fever and before the onset of diarrhoea. Usually, tearing and oral erosions appear during this 48-hour period. Thus, the herder can be asked to point out animals that just started tearing within the last 24 hours but have not started to show signs diarrhoea, if diarrhoea is a feature of the outbreak.

If the SE outbreak is not associated with mortality, sampling will have to focus on ocular and nasal swabs, scrapings of oral lesions and serum. Lymph node aspirates can also be collected, but offer no particular advantage over good ocular swabs. If a high index of suspicion exists that the SE outbreak is rinderpest, the appraisal team can request the herders to sacrifice an animal or offer to buy a sick animal for post mortem. However, even full payment may be refused.

As a general rule, serum should be collected from the entire herd.

In the event that moribund cases or recently deceased cattle are present, an autopsy should be completed and tissue samples should be collected. Fresh and formalin fixed tissues should be collected. Definitive diagnosis can be made on tissue samples collected in formal using simple immunohistochemical techniques. Samples collected up to 24 or 48 hours post mortem are diagnostic. Eyelids have been shown to be the most useful sample for immunohistochemistry and are also easy to collect (Brown et al., 1996).

Annex 6: Itinerary

Date	Activities
28/1/01	7:45 Jeff Mariner (JM) departs Fort Collins
29/1/01	9:30 Arrive Netherlands
30/1/01	9:00 Discussion on estimation of R_o, Dr. Stegeman, Utrecht, Dr. Roermund, Lelystad.
31/1/01	8:30 Depart Amsterdam. 21:00 Arrive Nairobi.
1/2/01	7:30 Cape Project, Dr. Catley. Discussions on mission objectives and field schedule. Meetings with Drs. Bessin, Thomson, Kock, Conner and Leyland. Arranging logistics and supplies.
2/2/01	Discussions with Drs. Jones and Andy Catley (AC) on RP reports in South Sudan since 1998. Arranging logistics and supplies. 14:00 Depart by air for Lokichokio. Met by Drs. Aluma Araba (AA) and John Osman (JO). Departure to Sudan delayed until 3/2/01 due to lack of police escort to border (mandatory).
3/2/01	Arranging sampling equipment, cold chain, radios, GIS and cars. Only one car available for travel to Boma. Meeting on disease search methods with AA and JO. Report preparation.
4/2/01	Preparations in Loki
5/2/01	JM, AA and JO travel by road Loki to Boma (2 days), stopping at Kirun Bridge en route. Interviews at two Toposa cattle camps in route.
6/2/01	JM arrives Boma late afternoon evening;
7/2/01	Meetings in Boma with SRRA Secretary and vet staff as well as vaccinators. Travel by road Boma to Nyalongoro; interviews with Murle (Bea cattle camp - 6 27' 25" N 34 26' 17" E).
8/2/01	Interviews with Murle and serum collection. Return to Nyat and night at cattle camp at Garaworth.
9/2/01	Interviews with Murle herders Garaworth east of Nyat (6 16' 49" N 34 26' 41"). Return Boma: preparations for Kanamuge (Bodo).
10/2/01	Jieland. Travel Boma to Kanamuge (Bodo) swamp (6 07' 46" N 33 51'34"). Interviews in route at Khor Ardep (N 6 07' 33", E 34 19' 10") and Lelimay (N 6 08' 02", E 34 16' 28"). Interviews with chief of Makadol clan. Heavy rains at night.
11/2/01	Interviews and mapping with Makadol and Taragabon clan elders. Begin return to Boma. Night in bush.
12/2/01	More interviews at Lelimay and Khor Ardep. Arrive back in Boma; overnight in Boma.
13/2/01	Day trip to Nyalongoro. Interviews with Murle of Bea.
14/2/01	JM, AA JO discuss mission conclusions. JM and JO travel by road, Boma to Narus
15/2/01	Narus to Loki. Meeting with GM and telephone contact with AC.
16/2/01	Drafting notes and collecting reports; prepare for Paluar trip
17/2/01	JM & Gachengo Matindi (GM) fly Loki to Paluar, east of Bor. Field work at Anyidi, Dinka East of Bor
18/2/01	Field work at Akot cattle camp on the Nile, South of Bor (JM, JO and GM)

19/2/01	Paluar. Operations temporarily suspended due to security concern. Estimation of R nought and report preparation.
20/2/01	Fieldwork at Anyidi. Bor Dinka and Murle from Gam (JM, JO and GM)
21/2/01	JM, JO & GM fly to Paluar to Loki. Literature review.
22/2/01	Loki: RP Model building and preparation for Sobat. Pagak evacuated. Pochalla proposed as alternative destination.
23/2/01	Loki: RP Model building and preparation for Sobat.
24/2/01	Team flies Loki to Kiechkon (JM & GM plus EU team). Discussions with ADRA and RASS officials.
25/2/01	Kiechkon: Fieldwork with Nuer and Dinka.
26/2/01	Kiechkon: Fieldwork with Nuer and Dinka. Sera collected from Dinka cattle.
27/2/01	JM, GM and Dr. Kajume of EU Team fly Kiechkon to Loki.
28/2/01	Loki: Preparations for Pochalla.
1/3/01	Team flies Loki Pochalla. Discussions with World Relief and SRRA officials. Mapping of Pochalla area and Jom.
2/3/01	Pochalla: Investigation of disease outbreak at Otala, interview at Dinka cattle camp.
3/3/01	Pochalla: Interview with Dinka.
4/3/01	Pochalla: Collection of antelope sera.
5/3/01	Pochalla: Interview at Ajwara village, Meeting at Otala.
6/3/01	Pochalla: Preparations for flight to Boma, Flight delayed and later cancelled. Preliminary visit to second Dinka cattle camp in evening.
7/3/01	Pochalla: Interview with Dinka. Literature review. Flight scheduled for next day.
8/3/01	JM and GM fly from Pochalla to Loki. Stop on Boma. Flied work at Boma cancelled due to broken radio.
9/3/01	JM flies Lokichokio to Nairobi.
10/3/01	Calculation of Ro. Modelling and report preparation.
11/3/01	Modelling and report preparation. Preparation of presentation.
12/3/01	Debriefing presentation to PACE and CAPE staff. Modelling and report preparation.
13/3/01	CAPE Meeting. Handing over of serum samples to PACE Epidemiology Unit. Visit to Muguga Laboratory to discuss serologic testing.
14/3/01	Modelling and report preparation.
15/3/01	Modelling and report preparation. Kenya visa renewal.
16/3/01	Presentation to Sudan Delegation. Modelling and report preparation.
17/3/01	Modelling and report preparation.
18/3/01	Heterogeneous population modelling and report preparation.
19/3/01	US Embassy. Modelling and report preparation. Logistics for trip to Boma in April.
20/3/01	Meetings at OLS and ILRI. Modelling and report preparation.
21/3/01	Meetings with Bryony Jones, Russ Cruska and John McDermott. Arc View GIS base maps for Africa and southern Sudan. Heterogeneous population modelling and report preparation.
22/3/01	Modelling and report preparation. Travel arrangements and

	logistics for April trip to Boma.
23/3/01	Meetings with Russ Cruska, John McDermott and Paul Coleman. Collection of GIS data and modelling information. Modelling and report preparation.
24/3/01	Meeting with Tim Leyland. Modelling and report preparation.
2/4/01	Travel Nairobi to Loki. Trip Preparations. Meeting with Sally Crafter, VSF/Belgium.
3/4/01	Travel Loki to Kurun River. Interviews with Toposa at Kayapagain village (bore hole 45kms from Narus) in Nail and Takanchok 15kms east of Kurun Bridge.
4/4/01	Interviews at Kurun Bridge. Travel to Boma. Road condition dry. Eighteen hours of rain began afternoon of arrival to Boma.
5/4/01	Rain stopped mid-morning. Discussions with Luka Biong, SRRA Database Coordinator and Luka Ipoto Ojok of New Sudan Wildlife Society. History of Boma and the wildlife park. Movement by vehicle not possible.
6/4/01	Movement by vehicle not possible. Walked to Upper Boma. Interviews with Murle communities, women and female-headed households. Visit to DOT school.
7/4/01	Interviews with Murle elders and two young men from Lazach. Meeting with SRRA Women's Group Coordinator. Meeting with SRRA Commissioner and Secretary
8/4/01	Early morning rain. Began return. Reached Kurun Bridge at 4 PM.
9/4/01	Early morning rain. Crossed river out of Kurun with assistance of DOT Unimog. Ten hours to cover 16 km. Night at Kayapagain.
10/4/01	Kayapagain – Loki.
11/4/01	Report preparation. Meetings with VSF/Belgium vet and VSF/Germany vet
12/4/01	Report preparation. Mapping.
13/4/01	Travel Loki – Nairobi. Report preparation.
14/4/01	Report Preparation
15/4/01	Report preparation
16/4/01	Report preparation.
17/4/01	Presentation of draft report.

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