MALARIA CONTROL IN THE LUBOMBO SPATIAL DEVELOPMENT AREA

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Contents

1. **Project Overview** 2
2. **Funding** 4
3. **Impact of Intervention to date** 5
    - **3.1 Malaria Infection Rates** 5
    - **3.2 Hut Exiting Malaria Vector Mosquitoes** 9
    - **3.3 Insecticides** 11
        - **House Spraying** 10
        - **Bioassays** 10
    - **3.4 Malaria Information Systems** 13
    - **3.5 Tourism** 13
4. **Management** 17
5. **Training** 17
6. **Developing a GIS Based Decision Support System** 18
7. **Regional Population Movement** 19
8. **Future Sustainability** 19
9. **Regional Malaria Control Commission** 20

1. Project Overview

The Lubombo Spatial Development Initiative (LSDI) is a programme by the governments of Mozambique, Swaziland and South Africa to develop the Lubombo region into a globally competitive economic zone. The geographic region targeted by this initiative is broadly defined as eastern Swaziland, southern Mozambique and north-eastern KwaZulu Natal, an area linked by the Lubombo Mountains. It also aims to create sustainable employment and equity in access to economic opportunity in the region.

In July 1999, President Mbeki, President Chissano and His Majesty, King Mswati III signed the General Protocol which put in place a platform for regional cooperation and delivery. In October 1999, the Lubombo Malaria Protocol and tri-national malaria programme was launched. It is managed by the Regional Malaria Control Commission (RMCC), comprised of malaria control programme managers, public health specialists and scientists from the three countries. In December 1999, the World Heritage Convention Act was promulgated and the Greater St Lucia Wetlands Park inscribed on the World Heritage Convention list. In June 2000, the three countries signed the Lubombo Transfrontier Conservation and Resource Area Protocols.

Although the malaria control project addresses a number of aspects central to increasing the effectiveness of malaria control in the two highest risk malaria provinces in South Africa, and in Swaziland, the primary emphasis was to extend malaria control to southern Mozambique. There is increasing consensus that, if malaria control measures are optimal in South Africa and Swaziland (i.e. effective drugs and insecticides are in place), disease incidence can only be further reduced by a regional approach to control.

There is also increasing evidence that malaria control is a positive precursor to development. The situation prior to malaria control in South Africa provides well documented evidence of the negative effects of the disease on tourism and agricultural development in the 1930's. The LSDI malaria programme aims to create a platform for development, the beneficiaries being tourism, business, governments and communities in areas with some of the lowest socio-economic development in the region.

The effectiveness of the malaria control programme in the long-term will be assessed by the incidence of malaria over time in Mozambique as well as in the neighbouring malarious areas of South Africa and Swaziland. The success will not only be measured using process (e.g. spraying coverage) and biological markers (e.g. parasite prevalence rates, health facility patient numbers and mosquito vector reductions), but by assessing the effects on tourism using tourist facility occupancy rates, job creation and malaria risk perceptions, in all three countries over the course of the period 2000 to 2005.

The malaria control component in Mozambique has been implemented in phases (Figure 1) starting with Zone 1 which is the area extending from the border with KwaZulu-Natal to Maputo City. Zone 1A covers the area surrounding the MOZAL plant that has been sprayed as part of their social responsibility campaign. Zone 2A comprises part of the Boane District, and Zone 2 extends northward of Zone 1 to approximately ¼ of the length

of the Kruger National Park. Zone 3 lies north of Zone 2. The control programme covers an area of approximately 20 500 km^2. The regional malaria situation prior to and post intervention in Mozambique is broadly evident in Figures 1, 2 and 3.

Funding for the project for the first five years (1999-2003) was by The Business Trust, MOZAL, the Department of Health in South Africa, and the Ministry of Health in Mozambique (Table 1). To date, 70% of the funding for the project has come from the private sector. Programme funding was wholly from the private sector in the first two years, decreasing to 50% with an increase in public financial support (Figure 4).

A proposal to the Global Fund requesting five years of funding was submitted in 2002, signed by the three participating countries, and awarded in principle in February 2003 for an amount of approximately US $22 million over 5 years. The contract was signed in June 2003 and the initial disbursement came through on the 22 July 2003.

Source	**Amount**
1. Business Trust	R 6,247,202.00
2. NRF / DACST	R 1,715,896.00
3. MOZAL	R 4,800,000.00
4. Mozambique Government	R 4,350,000.00
5. South African Government	R 5,000,000.00
TOTAL	R 22,113,098.00

Table 1: Funding for the LSDI project for 2002/2003

Figure 4. Ratio of public private sector funding to the LSDI.

3. Impact of Intervention to Date

3.1 Malaria Infection Rates

Base line surveys have been carried out at a number of sentinel localities in the LSDI zones of Mozambique (Table 2), in three localities in South Africa and four in Swaziland (December 1999 and June 2000). This was done to document the extent of the malaria problem prior to programme implementation and to allow comparison post intervention. These included surveys on parasite prevalence, indoor mosquito numbers, and Knowledge, Attitudes and Perceptions (KAP) regarding malaria. Sentinal malaria surveys have been undertaken each year thereafter in June to evaluate the effectiveness of the intervention.

The baseline malaria survey (pre-spraying) conducted at 7 sentinel sites in southern Mozambique in December 1999 showed average malaria infection rates of 64% in children aged 2 to 14 years of age, based on the HRP-2 antigen. Infection rates of 90% were found in Catuane, on the Mozambique side across the border from Ndumu Game Reserve in northern KwaZulu-Natal, the highest risk area in South Africa. Pre-spraying infection rates measured at 5 sentinel sites in the area surrounding the MOZAL Industrial Park (Zone 1A) were also high (>85%) prior to vector control as was the situation at 8 sentinel sites in Zone 2 in 2002 (>69%) and at 5 sentinel sites in Zone 3 in 2003 (>75%) (Figure 5).

By June 2003, combined control efforts had resulted in a 86% reduction in malaria prevalence in children in Zone 1 and a 79% decrease in Zone 1A. After one spray round in Zone 2, the prevalence was reduced by 51% (Figure 5). The reductions in prevalence in Zones 1, 1A and 2 are statistically significant (Table 3).

Zone	No. of sentinel sites	Area Km^2	Number of structures
1	7	7 592	79 799
1A	5	408	123 104
2	8	5 202	109 018
2A	1	522	65 395
3	5	6 894	No data

Table 2. Malaria control Zones in Mozambique indicating number of sentinel sites, area in Km^2, number of structures (2003).

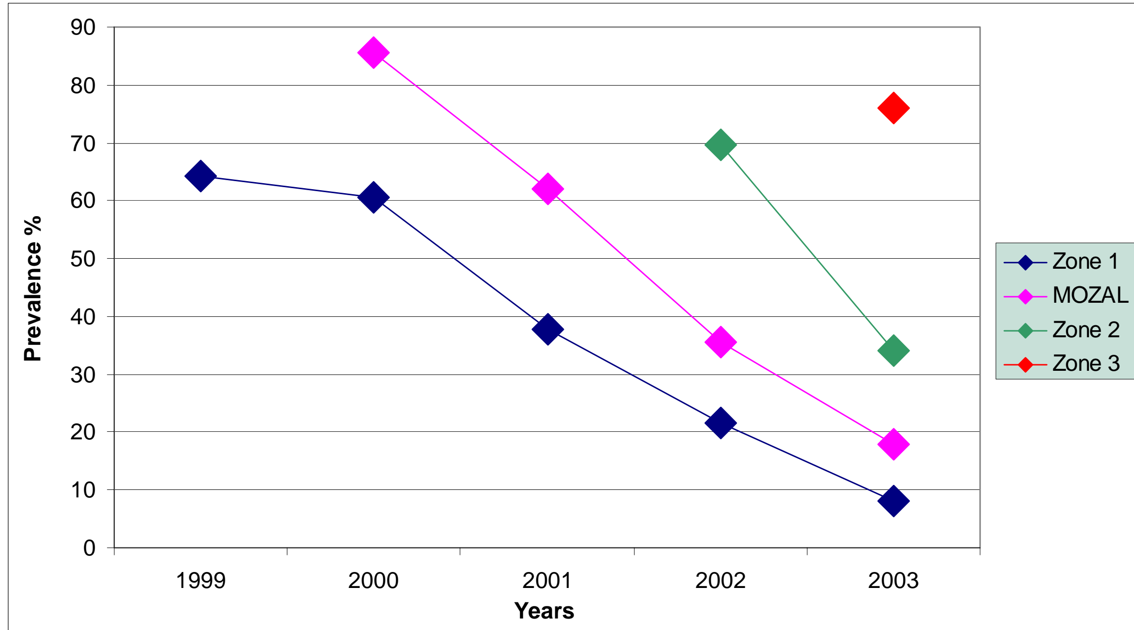

Figure 5: Average Parasite Prevalence in children aged 2-<15 years of age in Zones 1 and 1A of Mozambique, 1999 – 2002

2000-2001	Odds Ratio	CI	P<
Zone 1	0.26	0.2-0.32	0.001
Zone 1A	0.33	0.23-0.47	0.001
2000-2002			
Zone 1	0.09	0.07-0.11	0.001
Zone 1A	0.1	0.07-0.15	0.001
2000-2003			
Zone 1	0.054	0.041-0.072	0.0001
Zone 1A	0.036	0.026-0.050	0.0001

Table 3. Annual statistical comparisons of parasite prevalence rates in Zones 1 and 1A against the pre-spraying baseline.

Following three years of sustained effort of implementing malaria vector control in the LSDI area, the overall prevalence of the disease has dramatically decreased. At all seven sentinel sites in Zone 1 in Mozambique, the prevalence of the disease has been reduced to less than 20%, attaining the 5 year objective after only three years. Four of the seven sites have parasiteamia of < 10%.

In the MOZAL area (Zone 1A) significant reductions in parasite prevalence have also been recorded with the average prevalence having reduced from 85% to 17.7%.

Malaria incidence has steadily decreased in Swaziland and reached 91% by 2002/2003 in comparison to the baseline year of 1999/2000 despite no changes in insecticide or drug

policy during this period (Figure 6). The reduction in malaria cases in South Africa since 2000 are partly attributed to the introduction of combination therapy (Artemether-lumefatrine) in KwaZulu-Natal in 2001 and in Mpumalanga in 2002 (SP-artesunate), and a change in insecticide policy to DDT in Mpumalanga and KwaZulu-Natal Provinces and the malaria control measures introduced in Mozambique. KwaZulu-Natal had recorded a 96% decrease in malaria incidence by the 2002/2003 malaria season in comparison to the 1999/2000 season. Mpumalanga Province has shown a 75% decrease in malaria incidence over the same time period.

Figure 6. Regional reductions in malaria in the 2000/2001, 2001/2002 and 2002/2003 seasons in comparison to baseline indicators in 1999/2000

3.2 Hut exiting malaria vector mosquitoes

Traps to catch mosquitoes exiting from houses were fitted to homes at each of the sentinel sites. These are cleared daily by the homeowners, and the mosquitoes preserved in labeled and dated containers for analysis. Table 4 shows the number of window traps in place in each zone in 2003. Figures 7 and 8 show the average number of mosquitoes caught per trapping day in Zones 1 and 1A. Two vector species have been identified i.e. *An. arabiensis* and *An. funestus*. The vector populations showed seasonal peaks in summer prior to house spraying. Numbers began increasing in both areas in late 2000 and early 2001, but decreased dramatically after the first spraying round, further decreasing after the second spray round, and remained low thereafter. Figure 9 shows the mosquito reductions after a single spray round in Zone 2. The numbers decreased initially with *An. gambiae* showing an increase in May and *An funestus* in April. In general however, the number of mosquitoes captured per trapping day in Zone 2 were considerably lower than those in Zones 1 and 1A and are expected to decrease following the annual respraying of the area.

Zone	Number	No. of sites
Zone 1	28	5
Zone 1A	30	5
Zone 2	30	5
Boane (2A)	12	3
Zone 3	34	6
Total	134	24

Table 4: Window traps in place in the respective Zones in Mozambique, 2003.

Figure 7: Average number of Anopheline mosquitoes captured per trapping day in Zone 1: 1999-2003

Average A.funestus group and A.gambiae s l per hut per day
Zone 1A

Figure 9: Average number of Anopheline mosquitoes captured per trapping day in Zone 1A: 2000- 2003

Average A.funestus group and A.gambiae s l per hut per day
Zone 2

Figure 10: Average number of Anopheline mosquitoes captured per trapping day in Zone 2: 2002- 2003

3.3. Insecticides

The initial technical proposals identified pyrethroids as the insecticide to be used in the spraying component of the LSDI. However, with the discovery of high levels of pyrethroid resistance in *An. funestus*, meetings were held with the RMCC, as well as national and international experts, to recommend an alternative to the use of this insecticide.

Resistance by *An. funestus* to synthetic pyrethroids was first detected in December 1999 in the southern area of Maputo Province within the LSDI programme, Zone 1. Since then, extensive collections have been made at different sites in the country to ascertain the distribution of resistance of malaria vectors to different insecticides used in malaria control activities. F_1 generation *An. funestus* were subjected to standard WHO susceptibility tests using all major insecticide families, e.g., pyrethroids, organophosphates, carbamates and DDT. To date, 20 locations have been sampled, and the susceptibility tests on these F_1 generations showed that resistance of *An. funestus* to synthetic pyrethroids is concentrated in the southern region of Mozambique, in particular, the localities of Moamba, Catuane, Catembe, Bela Vista and Boane in Maputo Province. In Gaza Province, resistance of adult *An. funestus* to synthetic pyrethroids was also found. Carbamate insecticide has been used in the IRS programme and resistance is anally monitored.

North of Gaza Province, susceptibility of *An. funestus* (F_1) was found to be greater than 96% in all areas. Data collections are still in progress with a focus on areas of agricultural importance. The above data have been analysed and have provided an informed basis for insecticide choice for the LSDI malaria vector house spraying program.

Increasing levels of insecticide resistance as well as a limited number of available insecticides restrict the options with respect to the residual house spraying programme in southern Mozambique. Discussions emanating from the discovery of pyrethroid and carbamate resistance have emphasized the need to consider rotational insecticide use as the only way forward, and to avoid fixing resistant genes in the vector population. These findings have implications for the future of malaria control in the region and funding from NIH will allow the evaluation of rotational spraying during the next three years.

House Spraying:

Table 5 outlines the house spraying activities that have been carried out in the different zones in Mozambique. Both Zones 1 and 1A have had 4 spray rounds since 2000. Zone 2A was first sprayed in 2001 and the first spray round was completed in Zone 3.

Zones	No. of Round	Total No. of structures
1	4	246456
1A	4	377 608

2	1	202006
2A	2	130649
TOTAL		**956719**

Table 5 : Number of spray rounds and structures sprayed by September 2003 in the respective Zones in southern Mozambique.

Bioassays :
Bioassays were conducted in four localities to investigate the residual effect of Bendiocarb in order to determine when re-spraying is required. Ten houses in each of the four localities, Bela Vista, Catuane, Namaacha and Ponto du Ouro, were bioassayed at monthly intervals. Following one hour of exposure to the insecicide, the 24 hour mortality decreased from 100% one month after spraying to 80% at 5 months and 19.26% at 7 months post spraying. These results indicate that re-spraying should optimally take place five months after the first round of spraying. This data has assisted in planning control activities in southern Mozambique to ensure that successive rounds of spraying overlap this time period.

3.4 Malaria Information Systems

Malaria Information Systems (MIS) were developed and implemented for each of the partner-sectors with modifications being made on an ongoing basis. This computerised system allows the input, management and output of malaria case data which is used for both management and research purposes. It includes a spatial component using a geographic information system (GIS) which is being customised to minimise end-user skill requirements and optimise access to the different data sets. The data collected during routine operations and entered into the MIS consists of both in- and out-patient data of confirmed and clinically diagnosed malaria cases. In South Africa and Swaziland all cases are definitively diagnosed and definitive diagnosis will be implemented in Mozambique. The input screens mirror the data collection forms and the automatic-linking and drop-down list minimising data entry errors. Pre-designed outputs are provided in the form of maps, graphs or tables (i.e. number of can refills per week per person). This allows problems to be identified and addressed on an ongoing basis. Spatial data has been collected for the region and includes administrative boundaries, population, health facility locations, towns and other relevant information. New sources are continually sought to ensure that current data at appropriate scales are provided.

Information officers have been employed in Mozambique and Swaziland to assist the control programmes with the collection, management and distribution of malaria-related information and to provide technical support. The successful completion of their three-month probation periods has resulted in their contracts being extended for a further two years. They have developed new databases, taught programme staff to use various computer packages, and ensured that the data, which is core to monitoring the efficacy of the programme, is managed and distributed as required. Information officers will be hired and placed in each of the three malarious provinces in South Africa in 2004.

3.5 Tourism

A tourism survey (86 tourist facilities) conducted in the LSDI area during 2000/2001, found that malaria was perceived as the principle negative determinant on bed occupancy. Cancellations were recorded from tourist facilities in all the districts of the LSDI during the 2000 malaria season, with an average cancellation figure of 44% being recorded in southern Mozambique. This was largely due to the floods early in 2000 resulting in tourists being concerned about a possible malaria epidemic which was widely reported on in the press.

All tourist facilities visited in the 2000/2001 study were revisited in January/February 2003 to assess changes in attitude that might have taken place. Local (82) and international (58) tourists were interviewed in July in KwaZulu-Natal as part of the second round data collection.

A similar study to determine the influence of malaria on tourism and to assess the risk perception of facility owners and managers was carried out in January and July 2003 in Mpumalanga Province, sampling 86 facilities. Local (82) and international (58) tourists were interviewed in July in Mpumalanga to assess their risk perception in regard to malaria.

The study will be expanded to the Limpopo province in 2004 and the same sample sizes for tourist facilities (86) and local (82) and international tourists (58) will be captured. Data collections in Swaziland and southern Mozambique will be increased in the same period to include the whole of eastern Swaziland and Xai-Xai in southern Mozambique, which is approximately 250 km north of Maputo city.

A booklet providing appropriate information for tourists regarding malaria prophylaxis, treatment and risk was produced in 2001and was made available to tourism facilities. The booklet is currently being updated and will be distributed early in 2004. A malaria update including risk maps was made available to all facility owners in KwaZulu-Natal during 2003 and at the Tourism Indaba, and these were also made available to tourists following interviews.

Malaria cases in KwaZulu-Natal decreased dramatically from 41077 during the 1999/2000 season, to 1688 in the 2002/2003 season (Figure 10). It is anticipated that the malaria case reductions in Swaziland, South Africa and southern Mozambique will have a positive influence on tourism in the Lubombo corridor.

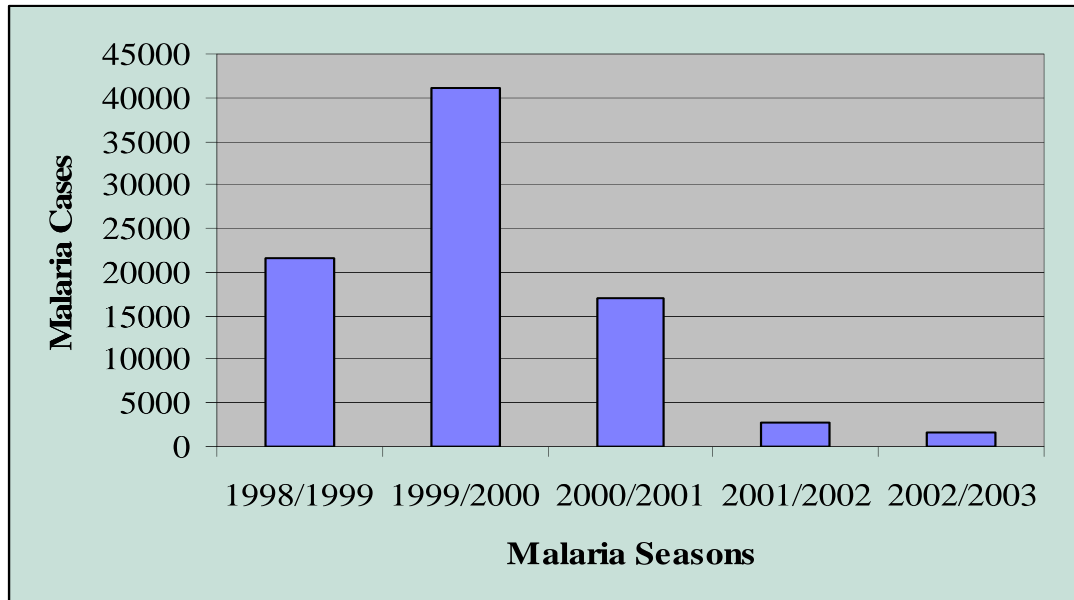

Figure 10. Seasonal KwaZulu-Natal malaria case totals from 1998/1999 to 2002/2003.

Figures 13 and 14 indicate the location of the tourist facilities with regard to small scale variations in malaria incidence in KwaZulu-Natal Province, and show the decrease in case incidence from 1999/2000 to 2002/2003. In the 1999/2000 malaria season, 33% of tourist facilities were in areas of > 25 malaria cases per 1000 people, and 67% were in areas where less than 25 malaria cases per 1000 people were recorded (Figure 11).

A major reduction in malaria cases in the 2002/2003 malaria season was achieved. In the 2002/2003 malaria season none of the tourist facilities were in areas of > 25 malaria case per 1000 people, and 98% were in areas where the malaria incidence was very low, with 0.001-5 cases per 1000 people being recorded (Figure 12). The reductions in the 2002/2003 malaria season indicate the positive effect of the regional approach to malaria control in the Lubombo corridor. It is essential that this information is made available through all media to encourage tourists to visit the area.

Figure 11. Tourist facilities with respect to malaria incidence per 1000 population :: July 1999 to June 2000

Figure 12 : Tourist facilities with respect to malaria incidence per 1000 population : July 2002to June 2003

4. Management

Management of the programme consists of five tiers:

- i. Tri-Lateral Ministers meeting
- ii. LSDI management
- iii. RMCC management
- iv. Management structures in Mozambique
- **v.** Research and control management

Management structures were set up at a Provincial and District level in Zone 1 in Mozambique that permitted the implementation of the programme with the help of external experts (RMCC and scientists) and built capacity at both levels. In 2003 further integration of the programme into the Provincial health structure of Maputo Province, Mozambique was undertaken.

5. Training

The foundation of a successful, efficient and effective spraying programme is optimally trained staff at every level. Experience in this regard was lacking in Mozambique, and training was therefore a key priority before a spraying programme could be introduced. It was also conducted on an ongoing process once spraying started. Table 6 indicates the number of spray operators who have been trained during the course of the initiative to undertake the indoor residual house spraying for vector control.

Zone	Year	Male Spray Operators	Female Spray Operators	Total
1	2000	48		48
	2001	48		48
	2002	90	5	95
	2003	74	6	80
1A	2000	24	1	25
	2001	81	17	98
	2002	52	18	70
	2003	51	19	70
2	2002	76	17	93
	2003	95	23	118
2A	2001	23	13	35
	2002	37	13	50
	2003	40	14	54
3 anticipated	2003			60
TOTAL		**799**	**145**	**944**

Table 6. Number of spray operators trained from January 2000 to December 2002 per LSDI Zone.

Training of field staff, whether spray operators or supervisors, followed a similar pattern i.e. 85% practical and 15% theory. However, supervisors received more in-depth training on environmental hazards, toxicity, first aid and safe handling/disposal of insecticides. Training of supervisors and spray persons has taken place each year. The Mozambican programme mangers assisted Mpumalanga in training their spray operators in 2002.

Training was extended to include intervention assessment and in this regard, window-trap caught mosquitoes were morphologically identified in Mozambique, and residual efficacy bio-assays carried out. The latter required the maintenance of an insectary and the ability to undertake both susceptibility and biochemical resistance testing which are increasingly being done in the country and will lead to a postgraduate degree. Training has been undertaken to equip field entomologists with the necessary research techniques, field staff to use global positioning system (GPS) receiver hand-held units, office staff in the use of the MIS and insectary staff in Maputo. Sonia Casimiro obtained her MSc degree through the University of Natal in 2003 on insecticide resistance in Mozambique.

An important factor identified prior to the implementation of the spraying programme was the necessity to adequately supervise the spray operations. Due to the vast area to be sprayed, supervision of spray operators' activities on a daily basis was virtually impossible. A fourth generation relational database (Microsoft access) was therefore designed as an information repository for all spraying activities, and the data generated from computerized reports made it possible to evaluate productivity and spraying performance on an ongoing basis. Quality control was undertaken by the malaria control programme managers of Swaziland, KwaZulu-Natal and Mpumalanga during each spraying round.

6. Developing a GIS based Decision Support Systems

The Department of Arts Culture Science and Technology (DACST) recently funded a project entitled "Developing a GIS based Decision Support Systems (DSS) for the Lubombo Spatial Development Initiative (LSDI)". The project takes cognisance of the fact that malaria control, and development in general, have a spatial component which is ideally suited to be supported by a GIS based Decision Support System (DSS).

The project aims to 1) develop and implement a GIS based DSS and 2) develop malarial prediction models for the region to be used as health management tools within the LSDI.

The spatial DSS will consist of an expanded Malaria Information System (MIS), a repository for spatially referenced data, and a web-based spatial and statistical query and analysis tool for information dissemination. This will support:

- the extension of malaria control to southern Mozambique,
- the assessment of the intervention effects on tourism,
- decision-making regarding broader development issues in the region.

7. Regional Population Movement

Population movement has long been recognized as a possible factor in the spread of malaria in the LSDI area. Cross-border movements between Mozambique (where malaria was not controlled for many years) and South Africa and Swaziland has been seen as a reason for the persistence of malaria in the border areas of Kwazulu-Natal, Mpumalanga and Swaziland. However, the relationship between population movement and malaria transmission has never been formally investigated in order to establish the implications of such movements for malaria control. A study has therefore been conducted on the movement of people within the region to better understand its role on the dynamics of malaria transmission from a regional perspective, and is under final analysis.

8. Future Sustainability

From an operational perspective, starting a malaria control programme in a largely underdeveloped rural area as well as in an area designated for industrial development, was successful, and the necessary skills to run and evaluate the control programme are in place. The future sustainability of the programme, the first regional project of this nature in Africa that aims to create a platform for development, is reliant on appropriately skilled personnel, funding, and access to effective insecticides and anti-malarial drugs. As outlined, training has been ongoing, and an appropriate skills base exists in the region to effectively implement a vector control programme based on house spraying. An application to the Global Fund towards financially sustaining the programme has been successful. Effective anti-malarial treatment in all the LSDI areas is being phased in as a result of this funding through the SEACAT project which is now fully part of the LSDI.

9. Regional Malaria Control Commission

At a recent meeting held by the RMCC it was decided that absent members no longer employed in their RMCC capacity would be replaced.

Mozambique

Ministry of Health

Avertino Barreto
Abdul Mussa
Samuel Mabunda
Elizabeth Streat
Sonia Casimiro
Manual Dinis

Swaziland

Ministry of Health

Simon Kunene
Quinton Dlamini

South Africa

South African Medical Research Council

Brian Sharp
Rajendra Maharaj
Carrin Martin
Francois Maartens
Mano Konar

University of CapeTown, Department of Pharmacology

Karen Barnes

Department of Health, KwaZulu-Natal Province:

Joatham Mthembu
Isaac Hatting

Department of Health, Mpumalanga Province:

Kobus la Grange
Marlize Booman

Department of Health, Communicable Disease Control Directorate:

Devanand Moonasar