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AN OVERVIEW OF BLACK FLY (DIPTERA: SIMULIIDAE) CONTROL IN THE ORANGE RIVER, SOUTH AFRICA

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ABSTRACT

Simulium chutteri Lewis has been a major pest of livestock along the arid middle and lower reaches of the Orange River ever since the construction of impoundments in the 1970s. A programme to control outbreaks, using helicopter applications of *Bti* and temephos, was started in 1991. An overview of the programme is presented, with emphasis on organisation and logistics. For most of the time the programme was successful in reducing the abundance of adult black flies to within acceptable levels. The success of the programme hinged on accuracy of applications, continued evaluation of larval and adult numbers, long-term monitoring of river conditions, the use of appropriate larvicides, and good communication between interested and affected parties. Future research should aim at reducing costs of the programme.

KEYWORDS: Black fly, *Simulium*, Orange River, *Bacillus thuringiensis* subsp. *israelensis*.

INTRODUCTION

The Orange River is the largest river in South Africa, with a length of 1,950 km and a median discharge of 100 m^3/sec. In the 1970's two large impoundments (van der Kloof and Gariep) were constructed in the mid-reaches. These impoundments reduced downstream seasonal flow-fluctuations, converting the river downstream from seasonal to perennial. Furthermore, planktonic algae developed within the impoundments, and this changed water quality downstream. These changes provided ideal conditions for the filter-feeding larvae of the pest black fly, *Simulium chutteri* Lewis, for a distance of over 1,000 km downstream. Under favourable conditions (fast-flowing, turbid water), *S. chutteri* larval numbers often exceeded 500,000/m^2. At such high densities, flow in irrigation pipes and canals was significantly reduced, and gauging weirs gave faulty readings. Adult female *S. chutteri* feed on the blood of livestock, and are particularly troublesome to sheep, horses and ostriches. In 1996 the Northern Cape Agricultural Union estimated that black flies along the Orange River annually accounted for R 88 million (US$ 20 million) in lost production of sheep alone. The flies occasionally feed on people, and the bites sometimes cause severe swelling and itching. High numbers of black fly adults make life outdoors intolerable. They are particularly troublesome to farm labourers and tourists. Black flies along the middle and lower Orange River were therefore of major social and economic concern.

The first attempt to control black fly outbreaks along the Orange River was in 1978, when discharge from van der Kloof Dam was stopped for 66 hrs (Howell et al., 1981). The lower water level reduced black fly populations for 370 km downstream of the dam (Howell et al., 1981). However, the method was not a practical solution for black fly control in the Orange River, and was never applied on a regular basis. The Onderstepoort Veterinary Institute then conducted a survey on the seasonal and spatial occurrence of *S. chutteri* adults along the Orange River (Jordaan and van Ark, 1990). Data collected during the survey, together with several studies on the biology and ecology of *S. chutteri* (e.g., Chutter, 1968; de Moor, 1982a,b; Car, 1983; de Moor and Car, 1986), and on black fly control programmes worldwide (e.g., Walsh, 1985; Fredeen, 1987; Kurtak et al., 1987) formed the basis for a large-scale control programme, which started in 1991.

The present paper provides an overview of the Black Fly Control Programme along the Orange River, with emphasis on organisation and logistics. A detailed account of the Control Programme is presented in Palmer (1997). Other publications arising from the programme include a rapid method of estimating immature black fly populations (Palmer, 1994), a study of the downstream carry of larvicides (Palmer et al., 1996a), the appropriate timing between successive applications (Palmer et al., 1996b), and environmental considerations (Palmer, 1993; Palmer and Palmer, 1995).

Organisations and funding

The Orange River Black Fly Control Programme is entirely state-funded. A helicopter, larvicides and most of the personnel involved with black fly control were provided by the Directorate of Agricultural Resource Conservation, a branch of the Department of Agriculture. Funds were allocated on an annual basis only. The management of the programme was contracted by the Directorate to the Onderstepoort Veterinary Institute (OVI), a member of the Agricultural Research Council. The responsibilities of the OVI were to advise on the timing and spacing of applications, keep stock of larvicides, monitor the success of the programme, inform interested and affected parties of results, and assist with applications. The OVI was also responsible for research on improving the programme, with funds provided by the Water Research Commission. The commission established a steering committee to assist with the research, and ensure that funds were used appropriately. The steering committee consisted of members from various government departments (OVI, Agriculture, Animal Health, Nature Conservation, Environment and Tourism), non-government agencies (Wildlife Society), academic institutions and farming representatives. The Department of Water Affairs and Forestry, Upington, provided an on-site research facility, with access to daily flow data. Industry assisted with the testing of new formulations, and provided expert advice on various aspects of the programme. Farmers co-operatives assisted with the storage of larvicides, and interested farmers monitored the abundance of adult black flies. Their complaints and praises formed the basis for continuing the programme. An information newsletter, produced by the OVI and distributed by the Orange River Farmer's Cooperative, kept farmers informed of developments within the programme.

Mapping the breeding sites

After funding was approved, the next step was to map black fly breeding sites. During an aerial survey in 1991, breeding sites (riffles, rapids and waterfalls) between Buchuberg Dam and Augrabies Falls were marked onto 1:50,000 scale maps. However, in the following year river levels dropped, and additional breeding sites appeared. The entire problem area, between van der Kloof Dam and Sendelingsdrift — near the Orange River mouth, was then surveyed (Fig. 1). The section upstream of Hopetown was omitted from the Control Programme because of problems with daily generation of hydroelectricity, which made dosage calculations impossible. Likewise, the stretch downstream of Onseepkans was omitted from consideration, partly because of the inaccessibility and remoteness of the area, partly because breeding sites were almost continuous (making control difficult), and partly because half the flies were Namibian (therefore requiring international collaboration). Therefore, the stretch which was finally treated on a regular basis lay between Hopetown and Onseepkans, a river distance of over 800

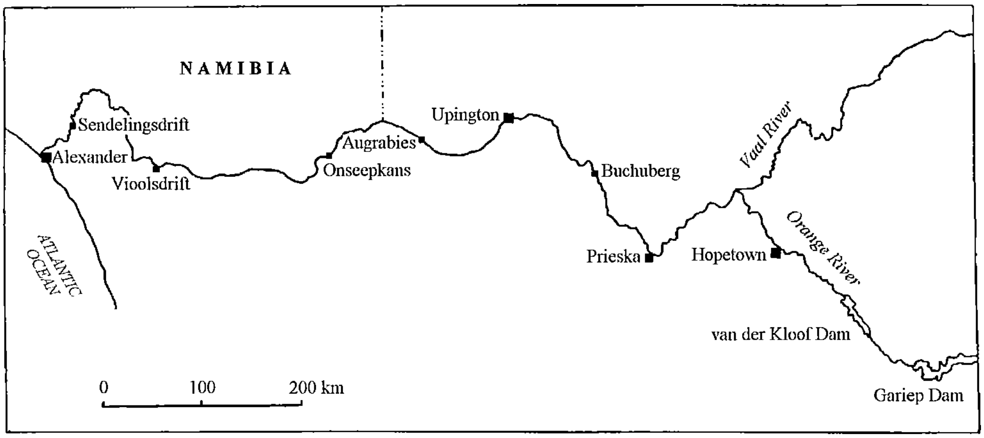

Fig. 1. Map of the black fly problem area along the middle and lower reaches of the Orange River, showing major towns, impoundments and sites mentioned in the text.

km. Within this area over 150 breeding sites were located. A small (10 km) stretch in the vicinity of Upington was left untreated as a control area. All breeding sites within the treatment area were numbered, and located using a Global Positioning System (GPS).

Mapping of the breeding sites was fairly straightforward because tributary streams were almost always dry, and were therefore excluded. However, certain sections of the river, particularly downstream of Upington, were highly braided (Fig. 2). Breeding sites in braided areas changed from time to time, depending on flow, and this complicated planning and logistics.

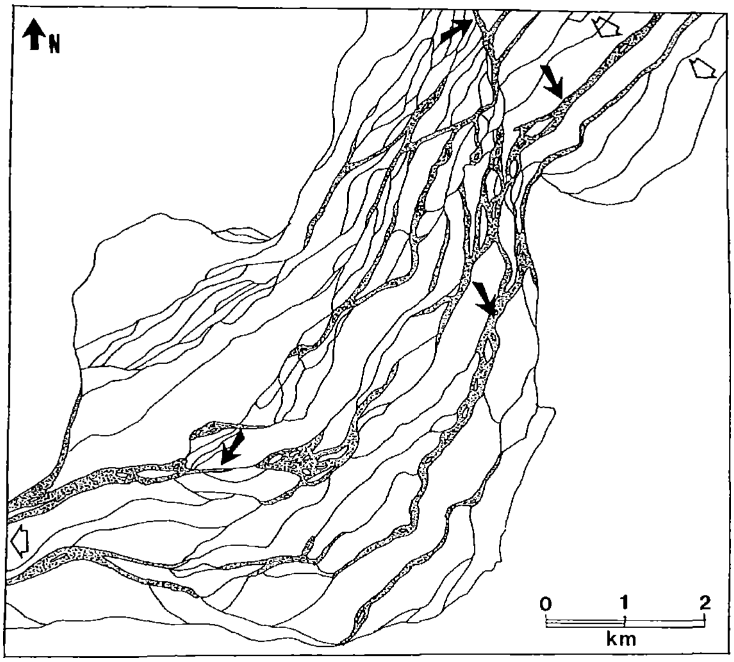

Fig. 2. Map of the Orange River downstream of Upington, showing multiple channels, with the main channels shaded. Solid arrows indicate application points.

Defining the annoyance level

The Orange River Black Fly Control Programme did not set out to eradicate black flies. Therefore, it was accepted that adult black flies would be present at times. This raised the question of what was an acceptable "Annoyance Level". The question seemed simple enough, but there was no simple answer. Female black flies have preferences for feeding on certain species, so what may be acceptable for a goat farmer may not be acceptable for a cattle farmer. Furthermore, black flies are attracted to certain individuals more than to others. A flock of sheep may be 95% unaffected and 5% severely affected. The stage at which this ratio becomes "unacceptable" is arbitrary. Furthermore, black fly bites may be painful, and may elicit severe allergic responses. Consequently, a single black fly can prevent an animal from feeding. When this happens, the animal loses condition, and this may be considered unacceptable. However, to run a control programme for the sake of one or two black flies per sheep would be absurd.

Because the Black Fly Research was run concurrently with the Black Fly Control Programme, the opportunity for studying adult black flies in pest proportions was small. Therefore, there was little opportunity for obtaining data which linked larval abundance with adult annoyance. However, even if such data were available, such a link would be tenuous because adult survival (longevity) is strongly dependant on weather conditions; a large larval population in mid-summer does not pose the same threat as it would in spring or autumn. Furthermore, field evidence suggested that the larvae of *S. chutteri* did not pupate at water temperatures below 10°C. Treatments were generally considered necessary when larval abundance exceeded about 60 per 16 cm^2. This value is similar to the threshold value used in the Saskatchewan River (Fredeen, 1987). However, bookings for the departmental helicopter were usually made well in advance. Planning of treatments was therefore based on past experience, rather than larval numbers at a particular time. However, larval numbers were always checked prior to treatment, and treatments were cancelled if necessary. Therefore, the decision of whether or not to apply larvicides at any particular time was not straightforward, and a computer model is being developed to assist in making this decision.

The computer model

A computer model, developed by Biological Application Software, South Africa, is being developed to assist in deciding when larvicides should be applied. In doing so, the computer program was intended to minimise the number of applications, and therefore the costs of control. The computer program was based on historical data of the important driving variables. Variables included in the model were water temperature, water flow, evaporation, and the abundance of black fly larvae, black fly predators, and the blue green alga *Microcystis* sp., which was suspected of being toxic to *S. chutteri* larvae. The computer program used two methods to determine the timing of applications. The first was based on the probability of an outbreak occurring, based on variables selected. The second was based on threshold rules concerning larval abundance, evaporation and water temperature. Both methods were able to simulate larvicide applications, and estimate the theoretical impact of applications on adult annoyance.

The model allows the user to set the relationship between flow and habitat availability for black fly larvae. This relationship depends on the species of black fly involved, and the structure of the river. In an attempt to define this relationship for *S. chutteri* in the Orange River, aerial photographs were taken of rapids between Buchuberg Dam and Upington at different flow levels. A typical example of the results is presented in Fig. 3. The results indicated that the inflection point for major black fly problems lay at a flow somewhere between 600 and 1500 m^3/s. However, the rationale for doing this for the Orange River was tempered by the fact that unacceptably high levels of black flies occurred at flows as low as 50 m^3/s.

One of the problems with the model was the inherent discrepancy between the driving variables in the field, which are continuous, and the variables chosen to "drive" the model, which are discrete. For example, evaporation was thought to play an important role in adult mortality, but a hot day which culminates in an afternoon thunderstorm may register an overall low evaporation for the day. The critical factor (a hot day) is therefore not registered. Furthermore, evaporation data from the Upington area was both incomplete and unreliable (McKenzie and Roth, 1994). A further problem inherent in the model was that many of the variables were recorded weekly. The maximum level of resolution of the model was therefore 7 days. Variables which were recorded more frequently, such as the flow, had to be summarised, which left one having to select an appropriate summary value — the minimum, maximum and average values all give a different picture. Despite the problems, the model did provide a logical framework for approaching the black fly problem.

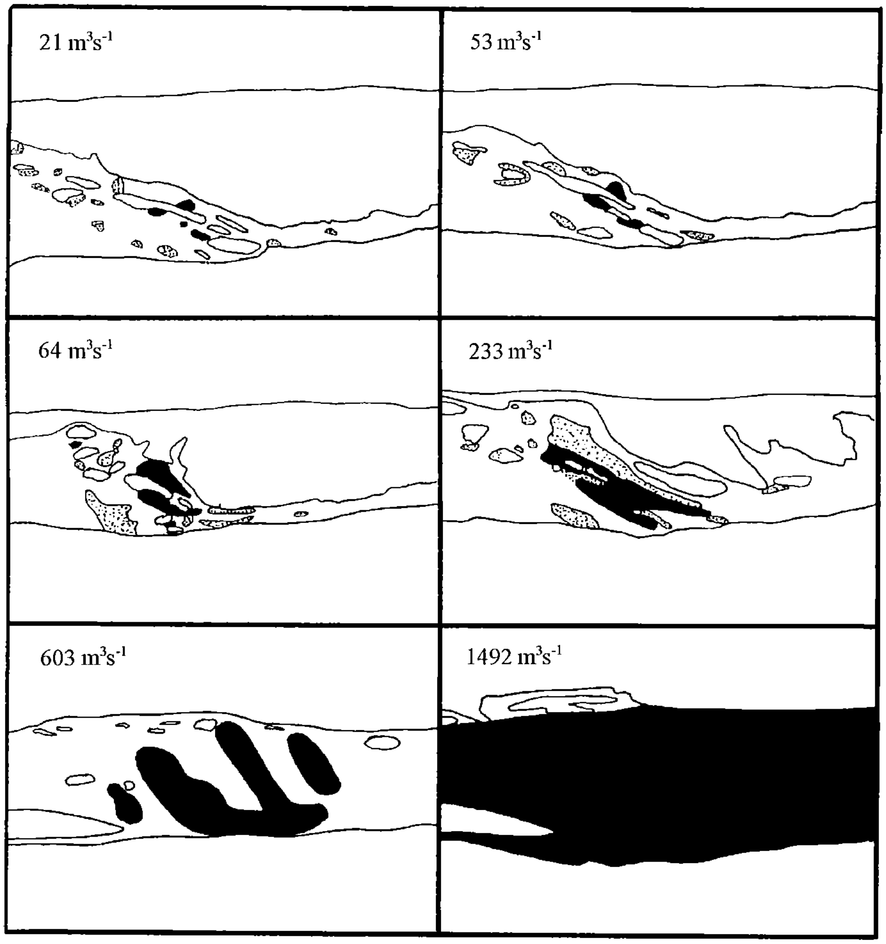

Fig. 3. Changes in habitat availability for *Simulium chutteri* larvae (in black) at rapid 147 at various flows.

Planning and logistics

Having decided to treat a certain stretch of river at a particular time, the next step involved the planning and logistics of a treatment. The helicopter and most of the people involved with the Control Programme were stationed in Gauteng Province, some 900 km from the river. Problems inherent with travelling long distances were therefore the order of the day. Larvicides and jet fuel were stored at various depots alongside the river. The long distances between rapids, and poor condition of some of the access roads, meant that the helicopter moved faster than its ground support. For this reason, three pick-up vehicles were used to supply the helicopter with larvicide and fuel. The vehicles were each equipped with 600-L larvicide containers, 200-L fuel drums, and 2-way radios. Dosage calculations and the distance between applications were based on daily flow data, obtained from gauging weirs managed by the Department of Water Affairs and Forestry. Each vehicle then loaded sufficient larvicide to treat a particular stretch, and drove to a predestined meeting place.

The helicopter was fitted with a 600-L glass fibre Simplex® spray tank, equipped with a short (1.5 m) aluminium boom with 8 large (1 cm diam) nozzles. Flow volumes were determined using a Micronair® flowmetre, calibrated with Vectobac® 12AS (produced by Abbott Laboratories), and operated by the co-pilot. The pilot was given a list of numbers which indicated the breeding sites which needed treatment, and the volume of larvicide to be applied at each site. In braided sections of the river, where exact localities of breeding sites changed from time to time, treatment sites were left to the discretion of the pilot.

Treatments always started downstream and worked upstream so as to avoid overdosing. Treatments started early each morning, when air temperatures were lowest, so as to maximise helicopter buoyancy and the amount of larvicide the helicopter could carry. The remainder of the day was used to clean equipment, and to load larvicides and fuel for the next day's treatment. Treatment of the 800 km problem area usually took 2.5 days. Attaching the spray tank to the helicopter and preparing for treatment usually took half a day. Travel time to and from Gauteng Province took 2 days. An entire treatment therefore took most of a working week. Problems involved with working over weekends (closed stores etc.) meant that treatments almost always started on a Monday. This meant that the timing between successive treatments was seldom ideal.

Monitoring

An important aspect of the control programme concerned monitoring of larval and adult abundance. Since 1990 adult black fly abundance was ranked daily by local farmers on a 4-point scale (Fig. 4). Although there were problems with this method concerning standardisation and reliability (some forms were completed in advance!), it did provide a useful index of the overall success of the Control Programme (Fig. 4). However, these data took time to be analysed, and did not provide information on the success of individual treatments. For this reason, larval numbers were examined at selected sites before and after each treatment. This enabled quick detection of any failure of control, and corrections could be made speedily. Problems with monitoring larval numbers included the long distances between sites, accessibility and unsuitable substrates. For these reasons, monitoring of larvae was usually conducted at the same few sites (about 10), and often relied on post-counts only. Nevertheless, monitoring of larval numbers was an essential and integral part of the Control Programme.

In addition to the monitoring of larval black fly abundance before and after each treatment, river conditions in an untreated section of the river in the vicinity of Upington were monitored weekly. Variables monitored included water temperature, water transparency, the abundance and composition of planktonic algae, benthic algae, black fly predators and the species composition and abundance of black fly larvae and pupae. Benthic invertebrates were sampled monthly. These data were used in planning treatments, and to evaluate the impact of the Control Programme on the aquatic environment. Although Upington is situated almost mid-way along the treatment area, spatial changes were significant. For example, in the colder, upper reaches of the control area, outbreaks could be expected in all months except winter. By contrast, in the warmer and more arid lower section, outbreaks could be expected in all months except summer. Because of the great distance between the river and where the helicopter was based, timing of treatments was a compromise between these areas. Consequently, control in the middle (Upington) area was usually better than in other parts of the river (Fig. 5). This was true except in 1996, when a major outbreak of flies occurred, despite repeated applications.

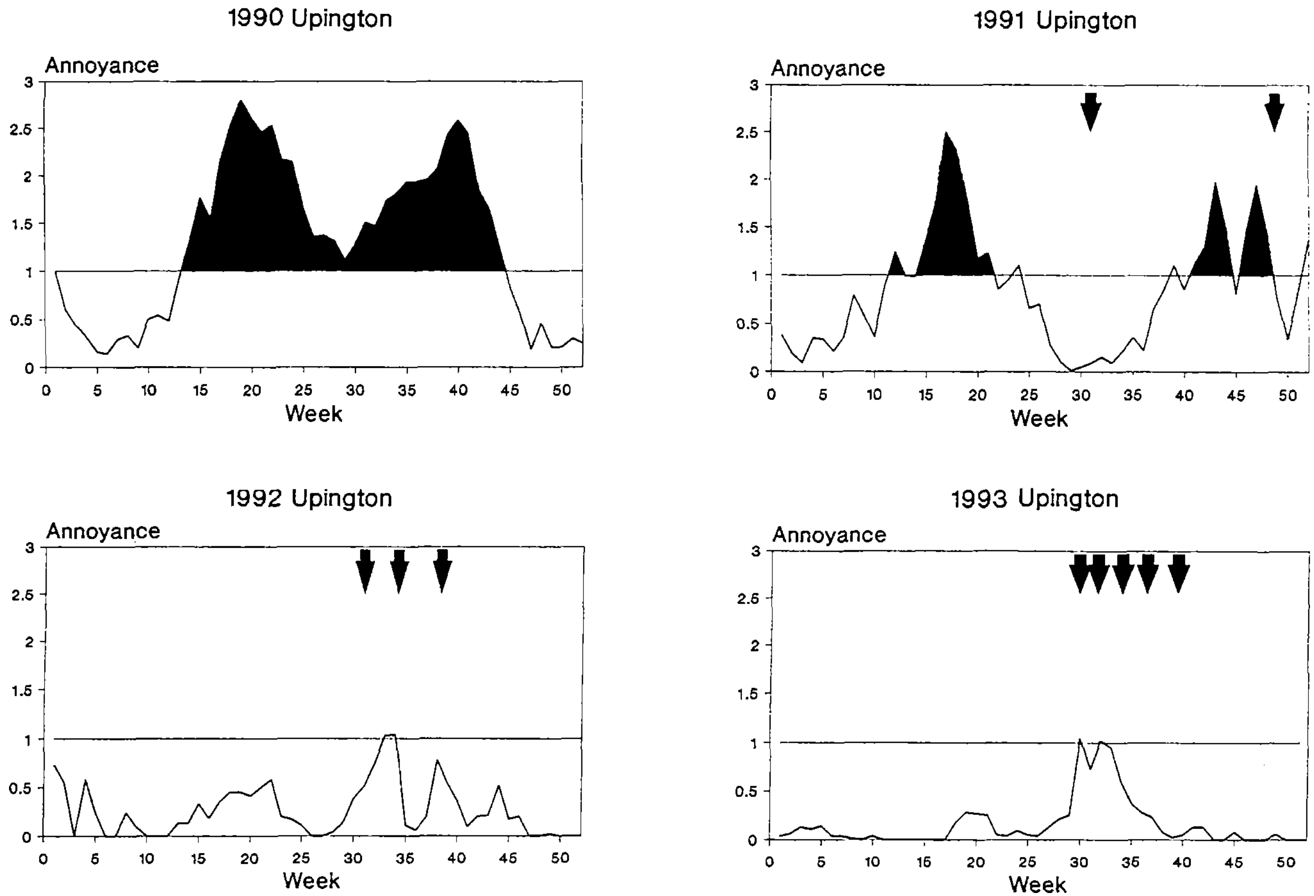

Fig. 4. Weekly average annoyance of adult female black flies in the vicinity of livestock in the Upington area between 1990 and 1993. Annoyance was based on daily reports submitted by stock-farmers, ranked as 0 = no black flies; 1 = present but not a nuisance; 2 = common and troublesome; 3 = abundant and causing severe nuisance. Arrows indicate timing of application. The black indicates levels which were considered unacceptably high (average value 1).

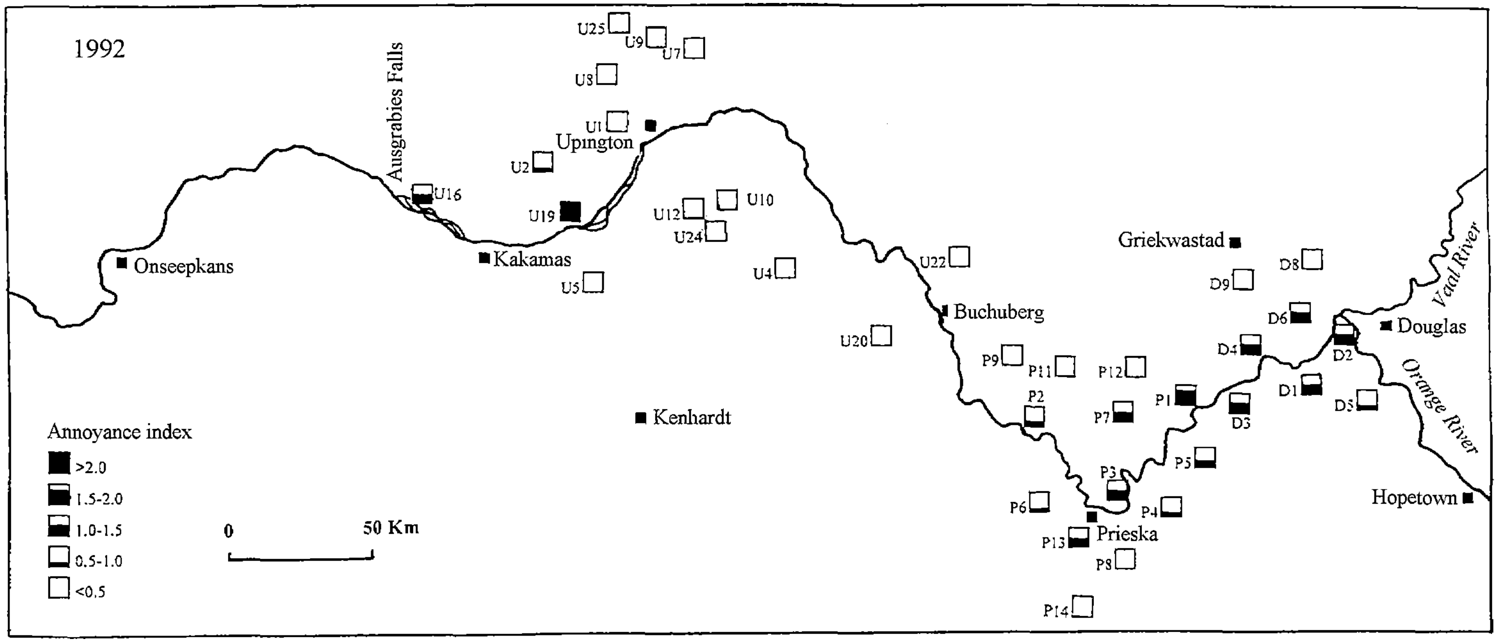

Fig. 5. Annual average annoyance of adult female black flies in the vicinity of livestock on various farms in 1992. Annoyance was based on daily reports submitted by stock-farmers, ranked as 0 = no black flies; 1 = present but not a nuisance; 2 = common and troublesome; 3 = abundant and causing severe nuisance.

Problems in 1996

Several factors are likely to have attributed to an outbreak of black flies in the lower reaches of the Orange River in 1996. Firstly, there was a flood in February/March. This made the applications which were planned for that time of the year impossible. Treatments were resumed as flood-waters receded in April. By that time, there was already a large adult black fly population present. High turbidity precluded the use of *Bti*, and temephos was used, with good results. In the lower reaches, water temperatures remained high (>10°C) throughout winter because of a late and mild winter. Consequently, larval development and pupation were not arrested, and adult black flies were unusually common during the first and most important application, in mid-winter (July). More importantly, both the first and second application (in August) coincided with strong wind (>60 km/hr). The wind affected the accuracy of application, particularly in braided sections of the river, and was perhaps the most important factor leading to a major outbreak of black flies in the lower reaches in spring. However, complaints of black flies were received, for the first time, from areas which had never been treated. This suggested that black fly populations were exceptionally high, as may be expected during a post-flood phase. Indeed, larval *S. chutteri* were found at high densities in flow conditions usually considered sub-optimal. Furthermore, monthly sampling of benthic invertebrates showed an almost complete disappearance of all filter-feeding invertebrates, except black fly larvae, for at least 5 months after the flood. This implied that black fly larvae had little competition from other filter-feeding invertebrates, and were therefore not food-limited. Furthermore, as water temperatures increased in September, a bloom of planktonic green algae developed, providing high-quality food for black fly larvae. It is well known that the efficacy of *Bti* is reduced by the presence of algae. Dosages were therefore increased by 25%, but the results were variable. The lessons learnt from the 1996 outbreak were firstly, to modify the spray system by increasing the nozzle size to reduce aerial drift. Secondly, effective control of black flies along the Orange River cannot rely on current formulations of *Bti* alone, but should include the use of temephos when necessary.

Costs

The major cost of the Orange River Black Fly Control Programme was the larvicide. The average volume of *Bti* used to treat 800 km of river once was 3,200 L, equivalent to 4 L/ km. However, volumes varied between 2,160 and 4,795 L, depending on river conditions. Likewise, the number of annual treatments necessary to curb an outbreak was highly variable, and ranged between 3 and 10. Although the total annual budget for the Control Programme was small (less than US$ 0.4 million) compared to the estimated costs of no control (US$ 20 million for sheep production alone), funding for the programme competes with other demands. Therefore, minimising the costs of the Control Programme is essential for its continued survival.

CONCLUSIONS

For most of the time, the Orange River Black Fly Control Programme was successful in reducing the abundance of adult black flies to within acceptable levels. However, the programme is expensive, and methods of reducing costs should be the focus of future research. The computer model will play a pivotal role in this regard, because it will be able to predict the outcomes of various scenarios before larvicides are actually applied. However, the strength of the model relies on the data on which it is fed, and this highlights the importance of long-term monitoring. Furthermore, the success of the programme is strongly dependant on accuracy of applications, the use of the appropriate larvicide at the appropriate times, and good co-operation and communication between all interested and affected parties.

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