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DEPARTMENT OF WATER AFFAIRS

REPUBLIC OF NAMIBIA

BIOLOGICAL CONTROL OF *SALVINIA MOLESTA* IN THE EASTERN CAPRIVI

PROGRESS REPORT : 1980 - 1995

THE PERMANENT SECRETARY
DEPARTMENT OF WATER AFFAIRS
PRIVATE BAG 13193
WINDHOEK

Report by:
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DEFINITIONS

Introduced species:	a species which has been distributed intentionally or unintentionally by man to areas beyond its native range or distribution.
Alien species:	an introduced species from outside the boundaries of Namibia.
Naturalised or established species:	an introduced species which has established self-sustaining populations in areas of natural or semi-natural vegetation or habitat.
Indigenous species:	a species which naturally occurs in Namibia as well as in other part of Africa.
Endemic species:	a native species restricted to a particular lake, drainage system or bio-geographical region.
Pest species:	a species which has major negative impact on the environment and does not have any desirable attributes.
Nuisance species:	a species for which the negative impacts generally outweighs the positive attributes which the species may have.
Invasive species:	an alien or translocated indigenous species which, after introduction, has spread unaided into untransformed ecosystems and may be responsible for causing an imbalance there.
Translocated indigenous species:	a species naturally found within southern Africa but which has been translocated either intentionally or unintentionally by man into catchments in which it was not naturally distributed.
Host specific:	a species which is dependent on one particular other plant or animal species for its livelihood.

(Definitions from de Moor and Bruton 1988).

BIOLOGICAL CONTROL OF *SALVINIA MOLESTA* IN THE EASTERN CAPRIVI
FINAL PROGRESS REPORT 1980 - 1995

ABSTRACT

Salvinia molesta Mitchell, or Kariba Weed, has caused an infestation in the Eastern Caprivi wetlands since the early 1970's. Several attempts to control the weed followed during the 1970's. Aerial spraying of herbicides proved too expensive and the introduction of *Paulinia acuminata* and *Cyrtobagous singularis* was of limited success.

The Department of Water Affairs took on the task of controlling the weed in 1980. This report deals with studies on the extent of the problem, local growth rates of the plant, the different control methods considered, the biological control programme, the financial implications and the present situation.

Chemical control, although effective, was rejected as environmentally unsound and a biological control programme was initiated. Host-specific natural enemies were sought and in 1983, 500 snout weevils, *Cyrtobagous salviniae* Calder and Sands, native to South America, were imported from Australia. These bred successfully in Katima Mulilo and by March 1985 over 10 000 had been released at 14 selected sites in the Eastern Caprivi. Within 14 months the first site was clear, i.e. 97% of the weed at Ngoma on the Chobe River had disappeared. Since then, *Cyrtobagous salviniae* beetles, bred at the research laboratory in Katima Mulilo, have been released at over 100 additional sites which are regularly monitored. The present low weed intensities indicate that the *Salvinia molesta* infestation is being successfully controlled by *Cyrtobagous salviniae*.

To date, the *Salvinia molesta* control programme has cost the Department of Water Affairs N$ 954 000 Considering the marked decline in the *Salvinia* infestation during the last decade and the socio-economic and ecological advantages this had for aquatic ecosystems in the eastern Caprivi, as well as controlling the spread of the infestation within the region and preventing its spread to vulnerable wetlands systems elsewhere in Namibia and in those shared by Angola, Botswana, Namibia and Zambia, this has been money well spent. The average cost of the insect breeding and monitoring programme is N$ 60 000 per annum and the project is handled by three staff members.

The biological control of aquatic weeds is a continuous task and present work is aimed at keeping up a good supply of *Cyrotobagous salviniae* weevils, ongoing monitoring of all release sites and surveillance work to release insects at any new infestations timeously. As a result of excellent co-operation between Botswana and Namibia on the control of aquatic weeds, Namibia, at the request of Botswana, introduced boat control measures at all border checkpoints in the Caprivi and Okavango regions in September 1993. In May 1994, the first regional meeting between scientists from Botswana and Namibia on "The Biological Control of Aquatic Weeds" was held at Balelwa in the Eastern Caprivi, Namibia, and the first joint survey of the Chobe River was undertaken by scientists from both the Departments of Water Affairs of Botswana and Namibia.

The future establishment of large scale irrigation schemes in the area and the possible impact which agro-chemicals i.e. both fertilisers and pesticides may have on the growth rates of the *Salvinia molesta* weeds and on the effectivity of the control agent *Cyrtobagous salviniae* is of particular concern. The biological control insects are also vulnerable to insecticides used in the region. These include locust control sprays used in the 1993/94 season, endosulphan used by Botswana on border rivers to control Tsetse fly and DDT used by the Ministry of Health and Social Services in their ongoing malaria control programme.

The analysis of field data collected during the monitoring programme since 1989 needs urgent attention as does the laboratory analysis of *Cyrtobagous salviniae* and *Cyrtobagous singularis* to determine the ratio of these two similar weevils in the field and their efficiency as control agents. The analysis of data collected for the period prior to 1989 will form part of the thesis of Mr C H G Schlettwein on the project.

In view of the need to continue with the project, an aquatic ecologist has been appointed to assist the Departemental research staff with the biological control programme for the next two years. He will commence work in July 1996 and his tasks will include dealing with the data backlog, placing the study on a sound scientific footing, evaluating the current monitoring project and assessing future research and monitoring needs. He will also provide essential on-site supervision of the project team.

1. INTRODUCTION

1.1 BACKGROUND

The *Salvinia molesta* research and control programme has been run by the Research Division of the Department of Water Affairs since 1980. During this time the once heavy infestation of this aquatic weed has been reduced greatly and the wetlands of East Caprivi are now largely clear of the weed. This success has been achieved using a weevil *Cyrtobagous salvinae* which is a natural enemy of the *Salvinia* in its natural habitat in South America. The weevil controls plant growth by damaging the growing tips of the plant, whilst its larvae damage the stems by burrowing into them. Success depends on a constant supply of control insects and vigilance. To insure this, insects are continuously bred in ponds at the Research laboratory in Katima Mulilo and research staff based in the Eastern Caprivi undertake regular patrols to spot new infestations, release insects and monitor sites where insects have been released. Throughout the project, co-operation with neighbouring countries which share these wetlands, particularly Botswana, has been a priority, as has collaboration with the world-experts on biological control of aquatic weeds, Dr Ken Harley and Dr Wendy Forno of the CSIRO in Australia.

1.2 PURPOSE

The purpose of this report is to review all departmental reports, steering committee reports, publications and presentations on the scientific investigation of the control of *Salvinia molesta* from 1980 to 1995. For more detailed results of the research work, the relevant reports as reflected in the list of references and submitted at the Annual Steering Committee Meetings should be consulted.

1.3 THE EASTERN CAPRIVI WETLANDS

The Caprivi region covers an area of 19 532 km^2 of which 12 600 km^2 was formerly called the Eastern Caprivi i.e. the area east of the Kwando River. The Eastern Caprivi wetlands consist of four perennial rivers, the Kwando, Linyanti, Chobe and Zambezi rivers and their floodplains. The minimum area of these wetlands, according to estimates from landsat images during the dry season in 1985, indicate that 6 480 km^2 i.e. about 50 % of the surface area of Eastern Caprivi can be classified as wetland of which 1 425 km^2 was open water. (Crerar 1987, Schlettwein *et al.* 1991). Soon after these estimates were made Lake Liambezi dried up and with the exception of an inflow in March 1989, which inundated a small area for a short time, the lake basin remains dry.

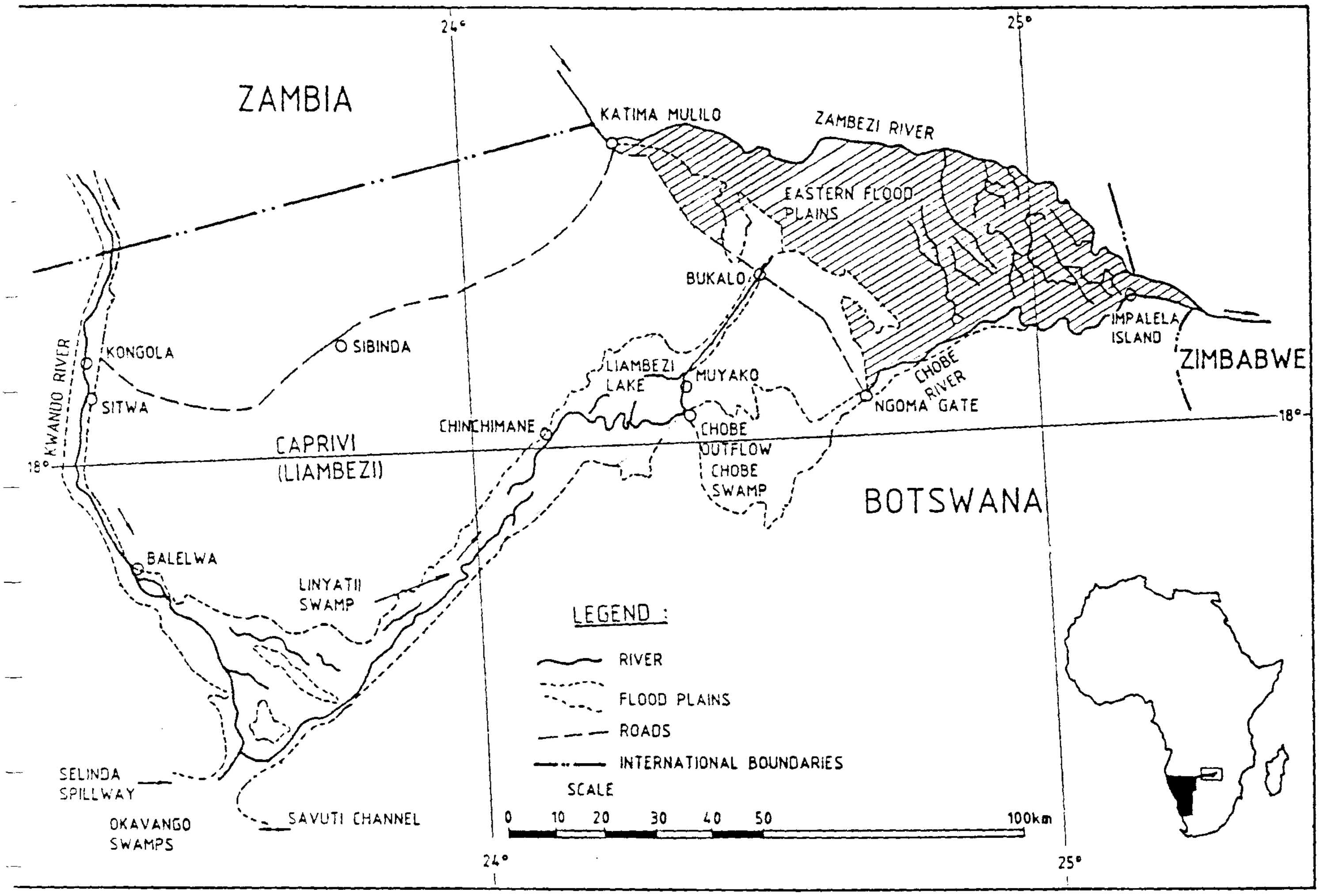


Figure 1. Map of the Eastern Caprivi.

1.3.1 WATER QUALITY

The perennial rivers of the Caprivi region and their associated wetlands are characterised by good water quality. The water is typically clear and soft with a fairly low conductivity and low nutrient concentrations (Schlettwein and Koch 1982, Schlettwein 84a, 85c). This is primarily due to the biological and chemical cycles that operate naturally in these rivers. The river processes depend on the annual floods to replenish the system.

1.3.2 HYDROLOGY

The hydrology of the Eastern Caprivi is well described by Rawlins (1983) and Crerar (1984, 1985, 1987). Suffice to mention that the hydrology of the region is interesting and complex. The region is extremely flat having an average elevation of 930 m above sea level. Consequently floodwater from the Zambezi and Kwando rivers produce large areas of permanent marsh as well as vast seasonally inundated wetlands. The floodplains of these two large rivers are connected in part in the south forming the Linyanti-Chobe system. The Zambezi River annually floods the eastern 30% of Eastern Caprivi to a depth of 1 - 3 m and floods usually peak in April. Floodplain inundation varies widely depending on the height and duration of the flood and the distance from the rivers. During these floods water may even reach Lake Liambezi as it did in 1989 either via the Kwando/Linyanti system, or via the Bukalo channel a backwater of the Zambezi or via the Chobe River which during high floods in the Zambezi acts as a backwater too. The Chobe River can flow in either direction depending on the relative water levels in the wetlands supported by the Zambezi and Kwando rivers. Prior to 1985 when Lake Liambezi dried up (Grobler and Ferreira 1990, Schlettwein *et al.* 1991), the Kwando River acted as a tributary to the Zambezi, flowing through the Linyanti swamps to Lake Liambezi which in turn drained via the Chobe River to the Zambezi River (Schlettwein *et al.* 1991). Water levels in the Linyanti River have been steadily declining and by April 1994 the river was dry from Chinchimani eastwards.

Mean annual flow in the Kwando River at Kongola, is almost 1 200 Mm^3 per annum and that of the Zambezi River at Katima Mulilo, almost thirty times more at 38 000 Mm^3 (Sivertsen and Eggers 1992). Since the 1981/82 season the seasonal flow volumes in both these rivers has been below these annual means with the exceptions of the 1988/89, and 1992/93 flows in the Zambezi River. **Figure 2** shows the seasonal flow volumes for the Zambezi River since 1980. (Seasonal refers to the annual hydrological seasons which are measured from October in one year to September the following year.)

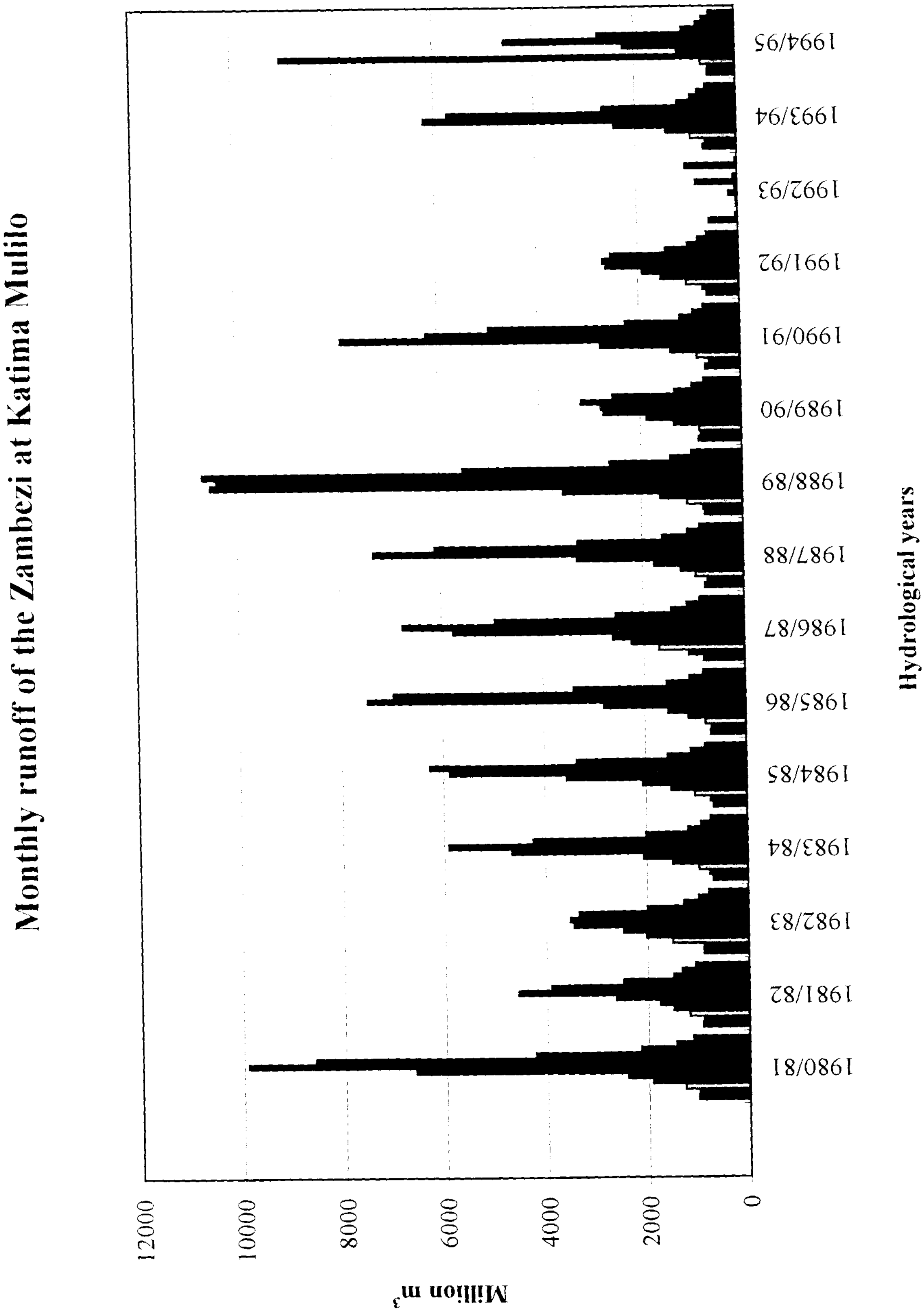


Figure 2: Seasonal flow volumes for the Zambezi River at Katima Mulilo.

1.3.3 PEOPLE

According to the National Population Census figure, the Caprivi region supports approximately 92 000 people i.e. 6% of the total population of Namibia. Most of these people live near the rivers or on the floodplains and are dependent, on a daily basis, on the natural resources provided by the wetlands.

Several wild aquatic plants are eaten by people in the Caprivi region. These include tubers of water lilies, and water chestnuts. Fruits of the sour plums, *Ximenia caffra* and *X. americana*, the monkey orange, *Strychnos cocculoides*, *S. pungens* and *S. spinosa* and a variety of nuts e.g. manketti nuts, *Ricinodendron rauteneii*. Reeds, sedges, grasses and trees are extensively used for building materials especially for houses, fences both bordering fields and as walls circling villages and individual houses, fishing equipment, boats, sledges and tools. Although many of the materials are obtained from the floodplains and are annually renewable, there is an accelerating trend towards over exploitation of these resources because of population pressure.

Many wetland animals are eaten, these include fish, snails, crabs, frogs, reptiles, birds as well as the larger mammals. Fish is very important in the daily diets for most people living near the rivers. There are several diseases of man and livestock caused by parasites that have intermediate invertebrate hosts living in freshwater. Examples are schistosomiasis (bilharzia), fascioliasis (liver fluke) and paramphistomiasis (conical fluke) whose parasitic nematodes use a freshwater snail as intermediate host. Although they do not feed on *Salvinia molesta*, snails are often found sheltering on the undersides of the weeds. The malaria and sleeping sickness parasites use mosquitoes and tsetse flies as intermediate hosts and the measures taken by Health Ministry to eradicate these diseases, by the application of biocides, including DDT and endosulphan, are detrimental to other wetland fauna, including the biological control agent of *Salvinia molesta*.

1.3.4 WETLAND STATUS

Two national parks, the Mamili and Mudumu parks protect important wetland areas alongside the Kwando River and the Linyanti Swamp region. The Zambezi floodplain in the east however has no conservation status. The Chobe River is protected in Botswana. .

Existing degradation of the wetland habitats in Caprivi is evident, especially along the river banks where riverine forest and reed fringes have been cleared. Most of this habitat loss is due to the human population pressure along these banks. Apart from direct habitat loss, such clearing and agriculture close to and in the floodplain leads to soil erosion and consequently to increased water turbidity. Other human related impacts include local pollution and enrichment of the river water as well as ever-increasing pressure on natural resources from direct use of wetland associated plants and animals. The *Salvinia molesta* infestation discussed in this report was also introduced, albeit inadvertently, by man.

1.4 INVASIVE ALIEN AQUATIC PLANTS

Unlike indigenous plants, alien plants are not in equilibrium with their environment. The absence of their natural enemies and new nutrient-rich habitats contribute to rapid, uncontrolled plant growth. In this way, *Salvinia molesta* Mitchell, commonly called Kariba weed, took full advantage of the enriched waters of the newly-impounded Zambezi River in 1960 and within a year covered 400 km^2 or 21% of the water surface of Lake Kariba (Mitchell 1969, 1972). This decreased naturally as the available nutrients were used up and has subsequently stabilised at 3 - 6% with the remaining plants restricted mainly to sheltered bays and river inflow regions (Jacot Guillarmod 1979).

The uncontrolled growth of aquatic weeds can interfere with navigation, hydro-electric schemes, domestic or irrigation water abstraction points, disease control, fish production and harvesting, water quality, aquatic crops and recreation. It hampers stream flow and creates blockages that affect flood levels and may increase water loss due to evapo-transpiration by the weeds. These problems are intensified in a tropical climate where plant growth continues throughout the year, complicating eradication measures.

An invasive alien species is a species from outside the country, which has been distributed intentionally or unintentionally by man into the country and which has subsequently spread unaided into natural ecosystems where it may cause an imbalance.

Invasive alien aquatic plants which cause problems in southern Africa are: *Salvinia molesta*, *Eichhornia crassipes* (Mart.) Solms (water hyacinth), *Myriophyllum aquaticum* (Vell.) Verdc. (parrot's feather), *Pistia stratiotes* L. (Nile cabbage, water lettuce) and *Azolla filiculiodes* Lam. (water fern). These can be spread by natural extension, water currents, wind, human activities (boats and fishing) and birds. At present, only *Salvinia molesta* and *Pistia stratiotes* occur in Namibian wetlands.

1.4.1 *SALVINIA MOLESTA*

Salvinia molesta, is a free-floating aquatic fern which occurs naturally in south-west Brazil. This extremely reduced fern has a horizontal floating stem with a pair of buoyant aerial leaves and a submerged "root" at each node. Buoyancy is maintained by a layer of air-trapping water repellent hairs on the upper surface of the aerial leaves. Being a sterile hybrid, *Salvinia molesta* propagates vegetatively. Attempts at germinating spores have been unsuccessful (Jacot Guillarmod, 1979).

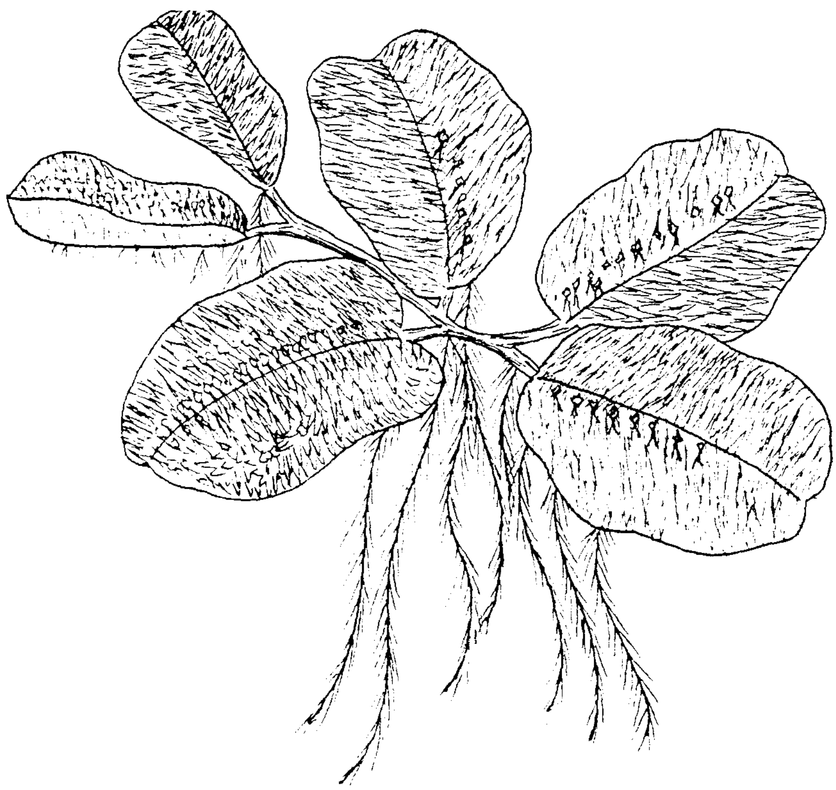


Figure 3: *Salvinia molesta*

Salvinia molesta has two distinct growth forms: the pioneer, invasive form, found in open waters which has flat, open leaves and; the mat form with larger folded, V-shaped leaves. Mats form when plants blown together intertwine as they grow. These can be half a metre thick, often support secondary colonisation and eventually form permanent "Sudd" islands which can block waterways, particularly in the more sheltered floodplain areas. This can cause rapid terrestrialisation of shallow water bodies.

The first specimens of *Salvinia molesta* in southern Africa were collected in 1948 at Katombara, fifty-five kilometres upstream of the Victoria Falls (Mitchell 1967). At present the heaviest infestations occur along the Zambezi and its tributaries and includes the wetlands in the Caprivi region.

1.4.2 *PISTIA STRATIOTES*

The only other alien floating macrophyte found in Eastern Caprivi is *Pistia stratiotes*, water lettuce or Nile cabbage. It is well named having close overlapping leaves. It occurs in the Chobe River and the Linyanti swamps near Nkasa Island as well as in northern Botswana (Hines *et al.* 1988, Schlettwein *et al.* 1991, Smith 1989). In the Manyame River in Zimbabwe it is successfully controlled by the weevil, *Neohydonous affinis* Hustache (Chikwenhere and Forno, in press).

1.4.3 *EICHHORNIA CRASSIPES*

An unconfirmed report of *Eichhornia crassipes,* commonly known as water hyacinth, was received from the Chobe River near Kasane in October 1991, but subsequent investigations of the area by both the Research Division and the Department of Water Affairs of Botswana, in December 1991, May 1992 and May 1994 failed to find any water hyacinth. Water hyacinths are free-floating plants, the leaves have a swollen spongy leaf-stalk and the most striking characteristic is the lilac flowers.

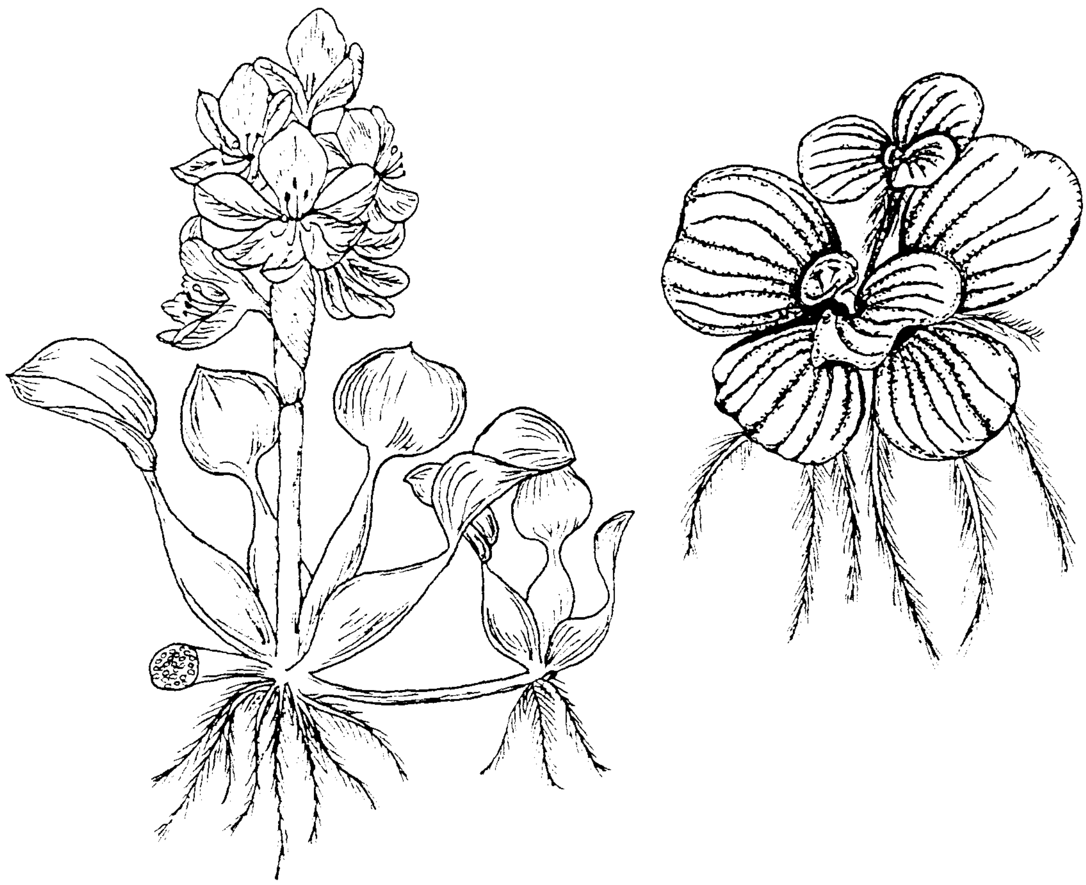


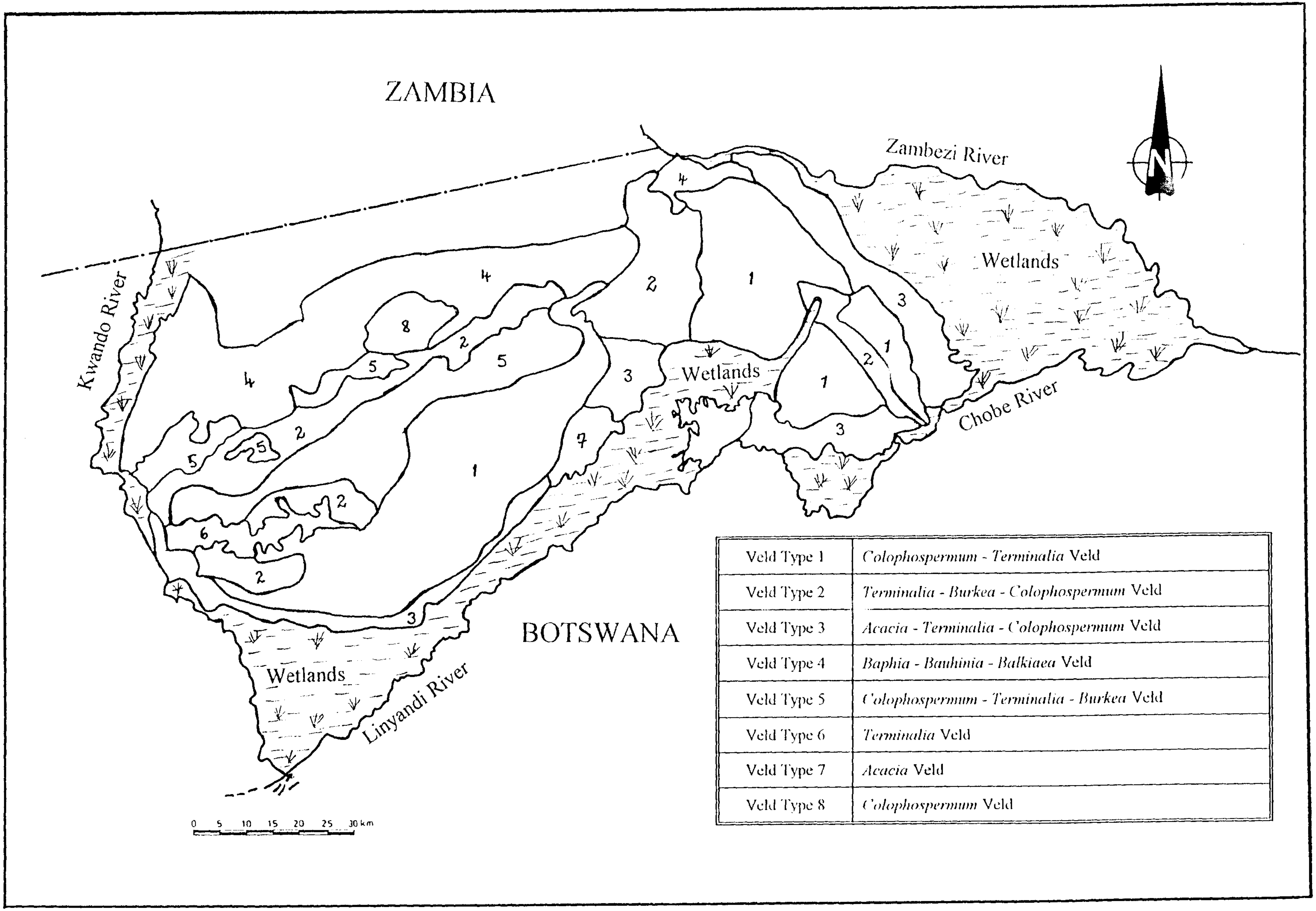
Figure 4: *Pistia stratiotes* and *Eichhornia crassipes*

1.4.4 FLORA AND FAUNA

An annotated checklist of the aquatic and wetland plants of Eastern Caprivi was compiled by Schlettwein (Schlettwein *et al* 1991) as part of the *Salvinia molesta* study and some more detailed work was conducted by the State Herbarium on Nkasa and Lupala islands but has not yet been published (G Maggs *pers. comm.*). A general vegetation map showing the major plant communities for the region is given in **Figure 5** on the opposite page.

The Eastern Caprivi is home to the greatest diversity of animals in Namibia. A checklist of freshwater macro-invertebrates found in the Eastern Caprivi wetlands list 123 species (Curtis, 1991). Although this is fewer than the species recorded from the Okavango River this is likely to be due to less extensive sampling and it is expected that the species diversity in the Eastern Caprivi is far higher, since the variety of wetland habitats is greater. There is a need for more intensive collecting of aquatic plant and animal specimens from the region to support the National Biodiversity Project.

Twenty-six species of frogs and toads including 8 new species occur in the Eastern Caprivi (Channing 1989). The region has the richest diversity of birdlife in Namibia accounting for 430 of the 620 (70%) species found in Namibia (Brown 1990). The greatest variety of freshwater fishes (72 species) have been collected from these wetlands (Van der Waal and Skelton 1984, Bethune and Roberts 1991). The wetland associated reptiles and mammals are dealt with in Griffin and Channing (1991) and Griffin and Grobler (1991) respectively.



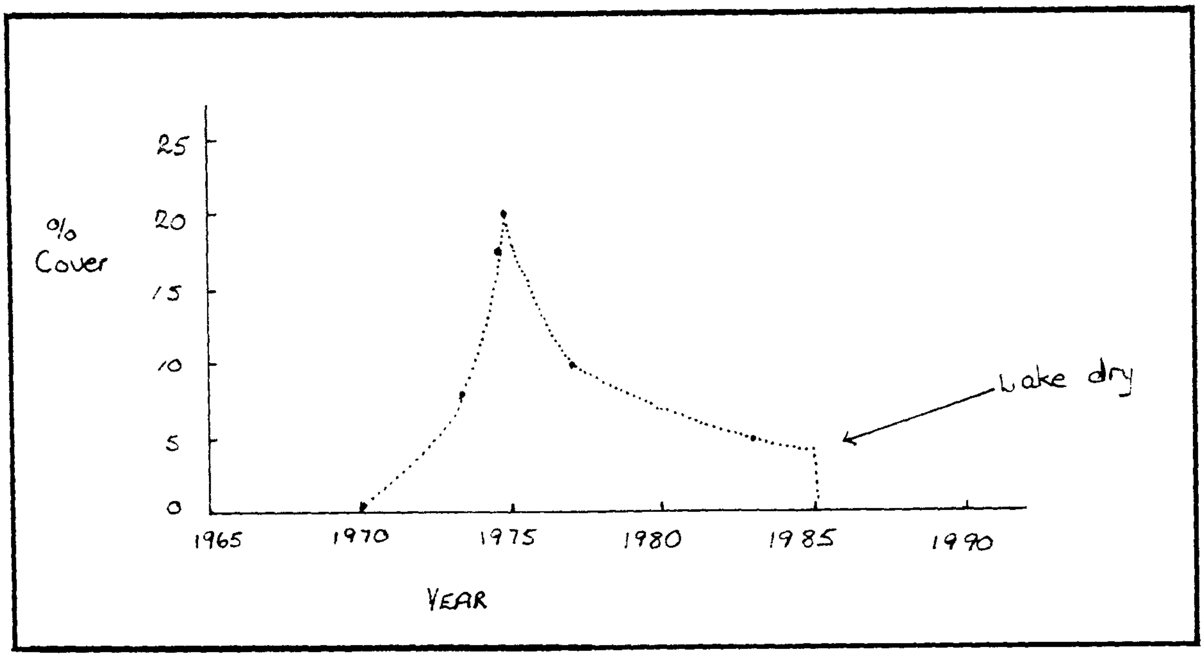
Veld Type 1	*Colophospermum - Terminalia* Veld
Veld Type 2	*Terminalia - Burkea - Colophospermum* Veld
Veld Type 3	*Acacia - Terminalia - Colophospermum* Veld
Veld Type 4	*Baphia - Bauhinia - Balkiaea* Veld
Veld Type 5	*Colophospermum - Terminalia - Burkea* Veld
Veld Type 6	*Terminalia* Veld
Veld Type 7	*Acacia* Veld
Veld Type 8	*Colophospermum* Veld

Figure 5. Vegetation map of the Eastern Caprivi.
Redrawn from VKE (1992) Feasibility study of the trans-Caprivi Highway.

1.5 *SALVINIA MOLESTA* CONTROL IN THE EASTERN CAPRIVI

1.5.1 EARLY ATTEMPTS AT *SALVINIA MOLESTA* CONTROL

Salvinia molesta was first noted in the Eastern Caprivi by W Waugh in 1965, but the exact locality is not known (Edwards *et al.* 1972) and by 1972 covered large areas of Lake Liambezi (Edwards and Thomas 1977). The graph in **Figure 6** below shows the increase and decline of *Salvinia molesta* on Lake Liambezi from 1970 when Vahrmeijer reported no weeds, until the lake dried up in 1985 (Van der Waal 1978, 1979, Malan and Koch 1985).



Based on Schlettwein, *et al*, 1991.

Figure 6. Percentage Of Lake Liambezi Covered By *Salvinia Molesta*.

To protect the wetlands in Eastern Caprivi and those in neighbouring Botswana it was essential to check the growth and spread of *Salvinia molesta*. Between 1969 and 1979 several attempts were made by Namibian and Botswana authorities to control *Salvinia molesta* in the wetlands between Namibia and Botswana by chemical and biological means (Smith 1969, Edwards and Thomas 1977, Hines *et al.* 1985), but did not achieve long-term success.

In April and June 1975 aerial spraying of *Salvinia molesta* using the herbicide "Paraquat" was tried at Kamantando in Botswana. This involved two applications, eight weeks apart and reduced plant cover at Kamantando from 100% to 5% within 16 months, but did not prevent regrowth from the margins.

Biological control is based on the fact that in its natural habitat in South America, *Salvinia molesta* growth is kept in check by several species of insects which feed on it. Early attempts to find a suitable control agent for *Salvinia molesta* were largely unsuccessful because of a taxonomic error. They concentrated on the natural enemies of *Salvinia auriculata* Aubl., a closely related species instead of *Salvinia molesta.*

Bennet (1976) collected insects associated with *Salvinia* plants in South America and tested them for host specificity using crops likely to be grown near Lake Kariba. The aquatic grasshopper, *Paulinia acuminata* De Geer, was subsequently released on both the Zambian and Zimbabwean sides of Lake Kariba. Between 1972 and 1974, the South African Plant Protection Research Institute released 2700 *Paulinia acuminata* grasshoppers, and 1300 *Cyrtobagous singularis* weevils, field collected in Trinidad, onto *Salvinia molesta* in the Linyanti and Chobe rivers (Bennet 1976, Edwards and Thomas 1977). In 1975, a further 250 *Cyrtobagous singularis* weevils were released at Pon Pon, about 10 km west of Shaile in Caprivi. Attempts at recapture were unsuccessful (Edwards and Thomas 1977), until 1981 when *Cyrtobagous singularis* was found on *Salvinia molesta* in Lake Liambezi.

During 1984 an investigation was undertaken by the Department of Water Affairs to establish the distribution, densities and effectiveness of *Cyrtobagous singularis* as control organisms in the Eastern Caprivi (Schlettwein 1985 b). Low densities of *Cyrtobagous singularis* weevils were found throughout the Eastern Caprivi wetlands with the exception of the Kwando River north of Balelwa. In Australia, insect densities as high as 101 adults per kilogram wet mass of plant material were recorded in the field (Thomas and Room 1986), this is much higher than the maximum density of 8 - 9 adults per kilogram wet mass found in Caprivi.

The low densities were attributed to the weevil's preference for *Salvinia auriculata* rather than the available *Salvinia molesta.* Although established and breeding in the Eastern Caprivi, *Cyrtobagous singularis* is not an effective control agent for *Salvinia molesta* (Schlettwein 1985 b). Compared to their more effective relative *Cyrtobagous salviniae* they do less damage to the target plants. *Cyrtobagous singularis* feeds randomly on the outside of the plants, whilst *Cyrtobagous salviniae* feeds selectively on growing tips and damages the plant by tunnelling inside the rhizomes. Further *Cyrtobagous singularis* populations decline as food supplies become scarce whereas *Cyrtobagous salviniae* populations increase until the food runs out (de Moor and Bruton 1988).

1.5.2 THE CONTROL AGENT *CYRTOBAGOUS SALVINIAE*

Australian scientists returned to South America to search for more specific natural control organisms for *Salvinia molesta*. Likely control organisms were collected in south eastern Brazil and taken to Australia for stringent testing. Results showed that the weevil *Cyrtobagous salvinae* (**Figure 7**) is an effective and highly specific control agent, feeding and breeding exclusively on the host plant *Salvinia molesta* (Forno 1987, Forno and Harley 1978, Forno *et al.* 1983, Room *et al.* 1981, 1984, Sands *et al.* 1983).

All four life stages of the weevil are dependent on the host plant. The eggs and pupae are inactive and harmless whilst the larval and adult stages can cause severe damage to the plant. The larvae tunnel into the floating stem and so cause the plant to disintegrate whilst the adults feed selectively on the leaves and apical buds, destroying them and effectively preventing vegetative propagation (Sands *et al.* 1983).

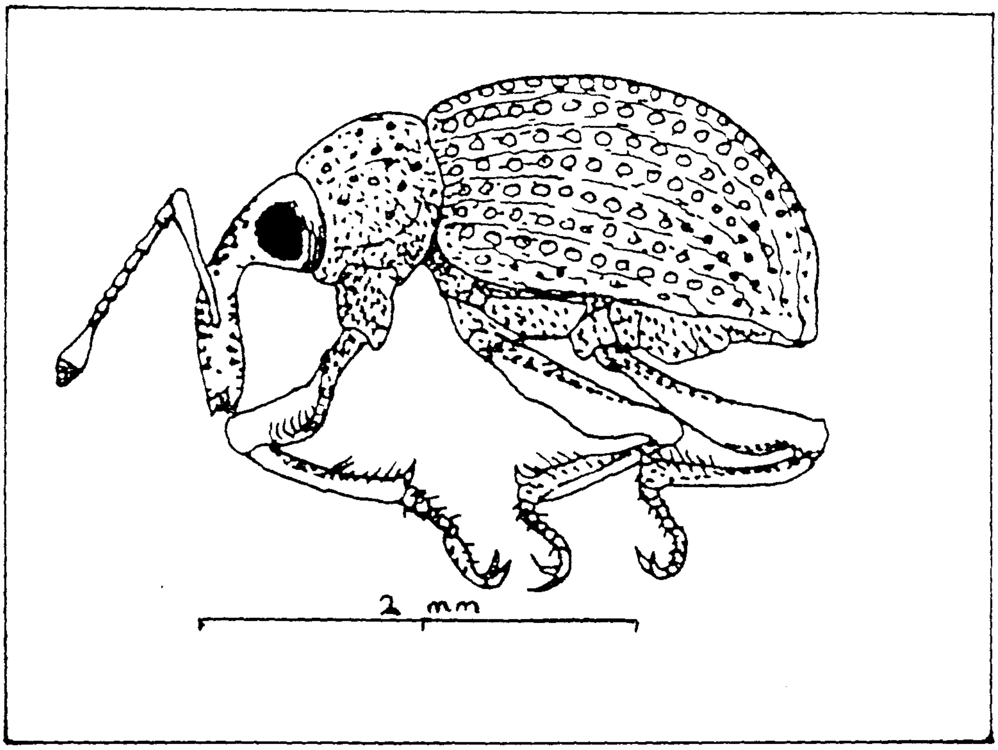


Figure 7: ***Cyrtobagous salviniae***

Cyrtobagous salviniae is a curculionid beetle (weevil) with a typical globular head with a slender elongated rostrum for feeding on plant tissues. The larvae are white, C-shaped legless grubs. Feeding and living exclusively on *Salvinia molesta* it is highly unlikely to cause any significant environmental damage to other plant species. Experiments in Australia showed that the eggs do not hatch at temperatures below 19^0C and that if nitrogen levels in the plant are too low the insects will not survive (Thomas and Room 1986).

1.5.3 THE DEPARTMENT OF WATER AFFAIRS RESEARCH PROJECT

In 1980, the control of *Salvinia molesta* in the Eastern Caprivi was taken over from the Department of Nature Conservation by the Namibian Department of Water Affairs and a Steering Committee was set up to guide the research. Two researchers in the Department of Water Affairs, messers Charlie Schlettwein and Harald Koch were appointed to conduct the research on the *Salvinia molesta* infestation and its control. The objectives of the Water Affairs research project were to:

- assess the extent of the infection and evaluate different control techniques,
- determine the growth potential and ecological requirements of *Salvinia molesta*,
- apply and monitor the most suitable form of control,
- investigate the effects of pesticides and herbicides on the control organisms,
- create public awareness, encourage international co-operation and lobby for legislation prohibiting the sale and transport of aquatic weeds.

The members of the Steering Committee were, Mr J H J Jordaan, Secretary for the Department of Water Affairs, Mr W Ravenscroft, Director of Investigations and Research, Mr P F Hamman, Chief: Water Quality, and Mr S Crerar, Ms S Bethune and Mr C H G Schlettwein from the Directorate of Investigations and Research, Dr D F Toerien from the Institute for Environmental Studies in Bloemfontein, Dr D E Edwards of the Plant Protection Unit in Pretoria, Dr S Neser, from Stellenbosch University, Mr C Le Roux, and from the former Administration for Caprivians and Dr E Joubert, Head of Research, of the former Department of Nature Conservation.

The Steering Committee met annually at Balelwa in the Eastern Caprivi for four years from 1982 until 1985. Annual reports on all aspects of the research project were submitted for discussion and comment and the programme for the next year was discussed and approved.

The Research project can be divided into four phases:

1. Phase I: The preliminary control assessments (1980/81 -1982/83).
2. Phase II: The application and testing of biological control (1983/84 - 1986/87)
   This included:
   - The growth rate studies (1982/83; 1983/84; 1984/85).
   - The biological control research programme (1983 - 1987)
   - Pesticide and herbicide tests (1987)
   - Ongoing public awareness.

3. Phase III: The expansion of the control programme and distribution of control insects (1987/88 - 1989/90)
4. Phase IV: The ongoing control and monitoring and assistance with hydrological, water quality and geohydrological monitoring (1990/91 - 1995/96).

2. METHODS AND MATERIALS

2.1 PHASE I: THE PRELIMINARY CONTROL ASSESSMENTS (1980/81 - 1982/83)

A literature survey was done and some preliminary investigations were carried out to assess the various control options.

2.1.1 MECHANICAL CONTROL:

A physical barrier was erected across the Kwando River at Kongola Bridge to trap any *Salvinia molesta* drifting downstream from Angola, as this was thought to be a possible source of infestation into the Eastern Caprivi. Chicken mesh wire 1 m wide was suspended vertically across the River. It was held by a nylon rope across the top and a steel cable underneath, about 40 cm protruded above the water surface. The barrier was checked and cleared weekly and remained in place for a year during the 1982/83 season.

2.1.2 CHEMICAL CONTROL:

Six herbicides (Roundup, Paraquat, Diquat, 2-4 D, Diuron and Gramaxzone) were tested for their suitability to control *Salvinia molesta*. These tests were conducted in experimental ponds at the laboratory in Katima Mulilo. One field test was conducted in an isolated backwater at Balelwa on the Kwando River. An area of approximately 1000m^2 was hand sprayed during 1983 using " Roundup".

2.1.3 BIOLOGICAL CONTROL:

From the literature it soon became evident that biological control using a suitable host specific control agent was the best control option for *Salvinia molesta* and would be a viable option for the Eastern Caprivi.

2.2 PHASE II: THE APPLICATION AND TESTING OF BIOLOGICAL CONTROL (1982/83 - 1986/87)

2.2.1 THE GROWTH RATE STUDIES (1982/83 - 1984/85)

While negotiations were underway to secure the most suitable control organisms, the seasonal growth and habitat requirements of *Salvinia molesta* in the Eastern Caprivi were examined in relation to nutrient levels in the water.

Growth rates were calculated using the formula:

$$RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$ (Mitchell and Tur 1975)

Where RGR is the Relative Growth Rate and W_1 and W_2 are plant weights at times t_1 and t_2. The same formula was used to calculate the growth rates by means of the number of leaf pairs. RGR x 100 = % Growth per time interval. Netto growth rates were derived by subtracting mortality rate from growth rate.

2.2.1.1 Field Growth Rates (1982/83):

During the 1982/83 season, field observations were carried out at five sites: an open water site, an existing *Salvinia molesta* mat and a reed bed in Lake Liambezi, in flowing water in the Chobe River and at the end of the Bukalo Channel.

At two monthly intervals, five plants each with five pairs of leaves were collected at each site and placed in floating squares (0,75 x 0,75m) fitted with wire mesh bases to prevent intrusion by nearby plants. The total wet biomass, total number of leaf pairs and the number of dead leaves per square as well as water temperatures were recorded regularly. Monthly water analyses were done to determine nutrient concentrations and general water quality.

2.2.1.2 Comparison Of Field Growth Rates In Natural And Enriched Waters (1983/84):

During the 1983/1984 season field trials were conducted to compare growth rates in natural waters and artificially enriched water at six different localities: the Bukalo channel and Chobe outflow in Lake Liambezi, Lisikili, Kalembeza, Sitwa and Balelwa.

Square floating boxes which were divided into three sections, two of which were lined with plastic bags each filled with 80 litres of water, the third section served as a control were used. Four boxes were placed in the Bukalo channel and two at each of the other sites. Each week the bags were filled with nitrogen and phosphorus enriched water and three plants, each with five pairs of leaves, were collected nearby and placed in each section.

In the Bukalo channel seven concentrations of 11% N, 22% P fertiliser were used (0,16g/ℓ 0,32g/ℓ, 0,64g/ℓ, 1,28g/ℓ, 2,56g/ℓ, 5,08g/ℓ and 10,16g/ℓ), and at the other sites three concentrations were used (0,64g/ℓ, 1,28g/ℓ and 5,08g/ℓ). Relative growth rates were calculated and monthly water analyses continued.

2.2.1.3 Comparison Of Growth Rates In The Field And Laboratory (1984/85):

During the 1984/1985 season growth rates were measured under both natural field and controlled laboratory conditions. Two floating quadrants were placed in a permanent pool at Ngoma Bridge from August 1984 to January 1985 to determine natural field growth rates.

A simultaneous laboratory experiment was conducted in 44 open plastic containers (0,4m x 0,4m x 0,7m). Four contained natural river water from the Zambezi, twenty contained nutrient enriched water (2g 46% N/100 litres) and twenty contained a balanced nutrient solution (1,5g $Ca(NO_3)_2$, 2gKNO_3, 10g $MgSO_4$, 0,75g $NH_4H_2PO_4$, 0,75g $(NH_4)_2$ HPO_4, 0,076g $FeSO_4$ $7H_2O$ and 0,1g Na EDTA per 100 litres).

Five plants, each with five pairs of leaves, were placed into each quadrant and container, each week the leaf pairs were counted and the fresh mass of each plant recorded. The plants and culture solutions were replaced every three weeks.

2.2.1.4 Nutrient Analysis

To determine the influence of water quality, particularly dissolved nutrient concentrations, on *Salvinia molesta* growth rates, water samples from 5 sites: Katima Mulilo (Zambezi River), Kongola and Sitwa (Kwando River), Ngoma (Chobe River), and Muyako (Lake Liambezi) were analysed each month from August 1981 to November 1984. In August 1983, monitoring was expanded to 11 sites grouped into these four wetland "systems":

A. The Kwando River system - Kongola (mainstream), Sitwa and Balelwa (backwaters)

B. The Linyanti/Chobe system - Ngoma and Chinchimane (both mainstream)

C. The Lake Liambezi system - Muyako (inflow) and Chobe outflow

D. The Zambezi system - Katima Mulilo (mainstream), Kalimbeza (side stream), and Lisikili (backwater).

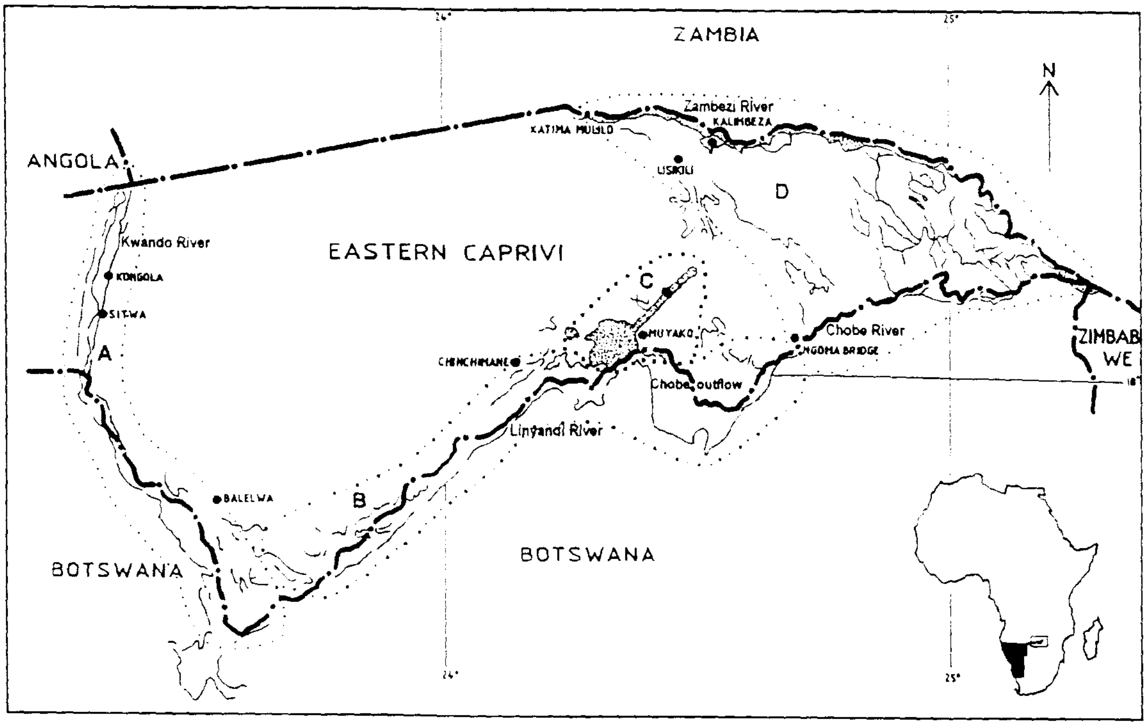


Figure 8: The four wetland systems of Eastern Caprivi.

All samples were analysed by the Water Quality laboratory at the Aigams Centre of the Department of Water Affairs in Windhoek. Chemical analysis of the plant material (*Salvinia molesta*) was done to correlate nutrient levels to growth rates. During April and May 1982 and again in September 1984 plant material collected from Sitwa, Balelwa, Muyako, Ngoma and Lisikili were analysed for nitrogen. Three plants each with five healthy pairs of leaves were collected from each site, dried at 100 °C, milled and analysed using the Kjeldahl method (Toerien *et al.* 1974, Schlettwein 1985). Regular chemical analysis of water samples from monitored insect release sites continue.

2.2.2 THE BIOLOGICAL CONTROL RESEARCH PROGRAMME (1983/84 - 1986/87).

2.2.2.1 The Breeding Programme:

Two consignments of adult *Cyrtobagous salviniae* beetles were obtained from the Entomology Division of the C.S.I.R.O. in Australia. The first 144 insects imported in 1982 failed to breed. A second batch of 500 arrived in September 1983 and bred successfully. Of the 473 which survived transport, 150 were released into each of 3 ponds (3 x 1 x 0,35m) containing *Salvinia molesta* plants with approximately 600 buds.

The plants were grown in nutrient solution to ensure maximum growth rates and optimal food quality for the weevils. Each week the adults, larvae and pupae on each of 20 plants were counted and the ratio of damaged to undamaged buds determined. Early in November, 397 beetles were harvested and used to start four new colonies.

2.2.2.2 The Release And Monitoring Programme:

As soon as the *Cyrtobagous salviniae* reached a density of 35 adults per 20 plants and bud damage was as high as 75%, half of the infested plant material was removed for use at the release sites and the ponds were restocked with uninfested plants.

In December 1983, the first 450 adult *Cyrtobagous salviniae* beetles were harvested and released at Sitwa in a side channel of the Kwando River, a site chosen because of the absence of the closely related, *Cyrtobagous singularis* weevils (Schlettwein 1985 b).

By March 1985, over 10 000 insects had been released at 15 selected sites: Sitwa, Bukalo channel, Mayako on Lake Liambezi Ngoma bridge, Lisikili, two sites at Ihaha, Lianshulu, Balelwa, Nkasa island, Kasaya channel, Kasika, two sites in the Mutwalwizi channel, and at the first blockage on the Kwando). These localities are shown in **Figure 9** below.

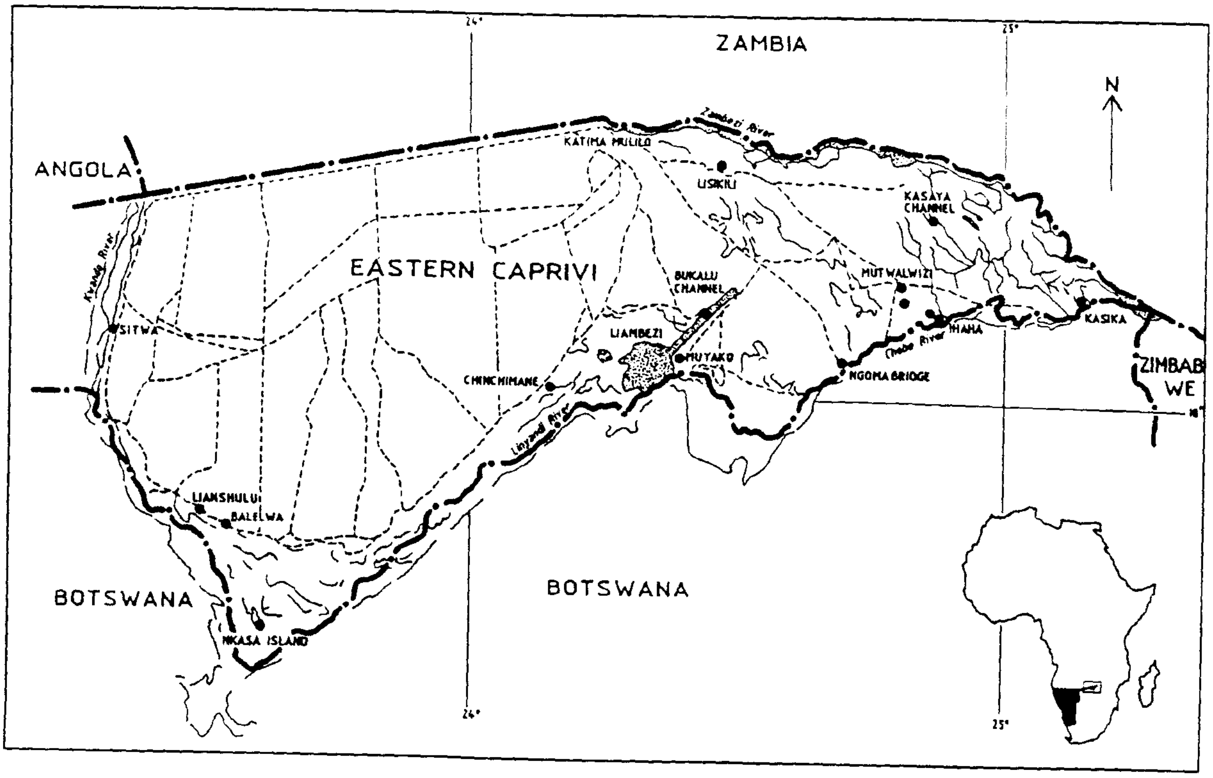


Figure 9: Map of the Eastern Caprivi indicating 15 original insect release sites.

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C. The Lake Liambezi system - Muyako (inflow) and Chobe outflow

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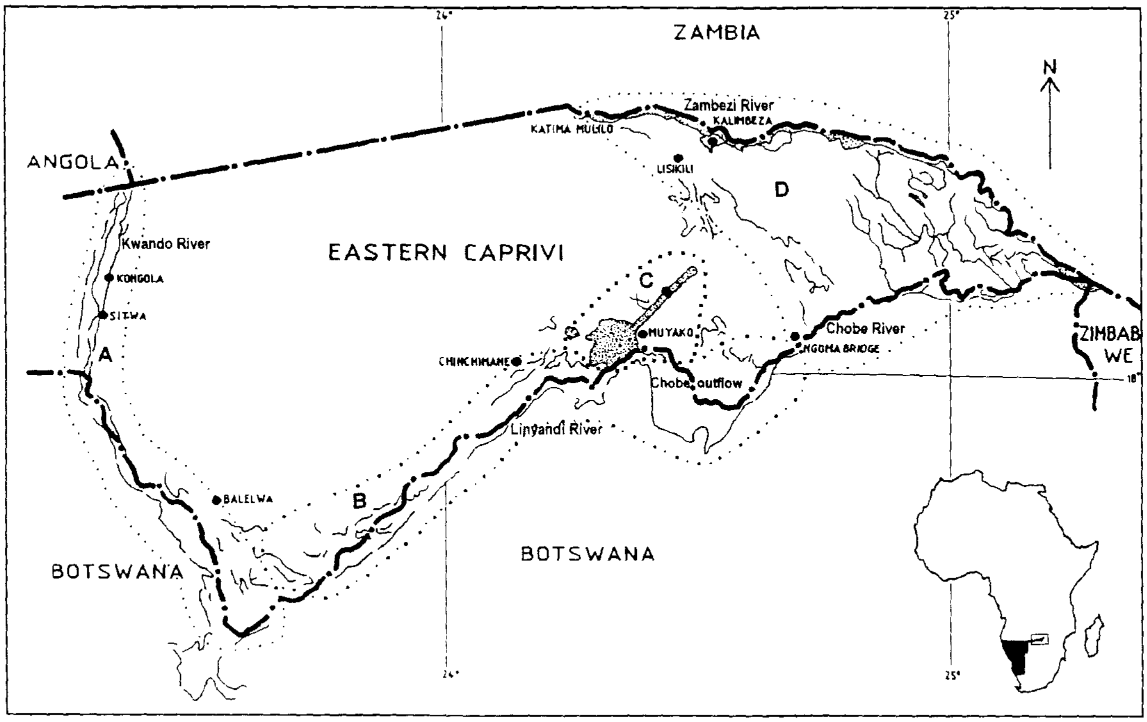

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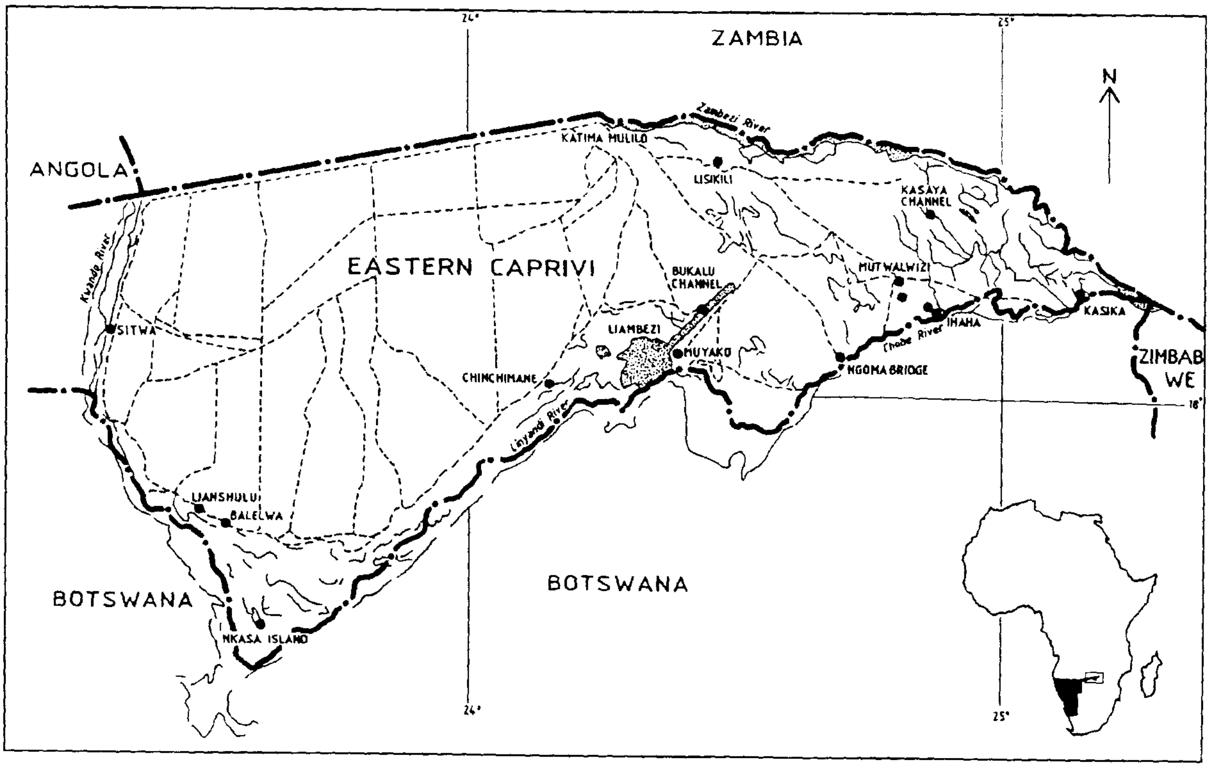


Figure 9: Map of the Eastern Caprivi indicating 15 original insect release sites.

Four of the sites, Ngoma, Muyako, Lisikili and Ihaha were photographed regularly to obtain a visual record of the progressive deterioration of the mats. At each site 2 - 5 kg wet mass *Salvinia molesta* was collected each month and weighed.

The insects were extracted using a Berlese funnel (Boland and Room 1983), then counted to determine insect densities and the percentage of damaged buds was calculated.

2.2.2.3 Pesticide And Herbicide Tests (1987)

The effects of the insecticides used for tsetse fly (*Glossina moritans centralis* Machado) and mosquito (*Anopholes* sp.) control on the biological control agents of *Salvinia molesta* were investigated. In preliminary tests, the same concentrations of DDT and Dieldrin and the herbicide Paraquat that are routinely used in field pest control programmes were used. Five repetitions were done for each poison. These were applied to isolated *Salvinia molesta* cultures each with 30 beetles. A detailed investigation into the effect of Endosulfan and alphamethrin, used to control tsetse fly in the Okavango Delta, was carried out in 1987 at Mpacha airport (Schlettwein and Giliomee 1990).

2.2.2.4 Ongoing Promotion Of Public Awareness, International Co-Operation And Measures To Prevent The Spread Of Aquatic Weeds:

Throughout the study every opportunity was used to create public awareness, encourage international co-operation and prevent the sale and transport of aquatic weeds. Radio and newspaper interviews were granted, a television documentary made, popular and scientific articles on the research published, presentations and posters presented at conferences, a show display organised, and annual Steering Committee meetings were held. International co-operation was facilitated by participation in the SARRCUS subcommittee for Aquatic Weeds.

2.3 PHASE III: THE REGIONAL EXPANSION OF THE CONTROL PROGRAMME AND DISTRIBUTION OF CONTROL INSECTS (1987/88 - 1989/90)

From 1987 - 1990, millions of insects were successfully bred and released. Releases were made wherever infestations were found and these were regularly monitored. To maintain a wide distribution of control organisms, fresh *Salvinia molesta* plants with *Cyrtobagous salviniae* weevils were re-introduced where *Salvinia* mats and the insects on them had sunk.

2.4 PHASE IV: THE ONGOING CONTROL AND MONITORING (1990/91 - 1995/96)

Since 1990, *Cyrtobagous salviniae* insects continued to breed successfully in the insect breeding ponds at the Research Laboratory in Katima Mulilo and were released as required. Monitoring of release sites continued although access to flooded sites in the Zambezi floodplains was often difficult. During this period the field station at Balelwa was damaged by elephants three times necessitating repair. The accommodation facilities had to be rebuilt in 1993.

3. RESULTS AND DISCUSSION

3.1 PHASE I: THE PRELIMINARY CONTROL ASSESSMENTS (1980/81 - 1982/83).

3.1.1 MECHANICAL CONTROL:

Weed removal by means of barriers, rakes, nets or mechanised harvesters are labour-intensive, time-consuming and must be repeated regularly. It was considered impractical in the extensive wetlands of Eastern Caprivi due to access problems.

The barrier at Kongola bridge caught all floating debris coming downstream but not a single *Salvinia molesta* plant, indicating that the Kwando River was not a source of new infestations.

3.1.2 CHEMICAL CONTROL:

Herbicide tests showed that a selective dipyridyl herbicide could be used to combat *Salvinia molesta* effectively in the short-term. In 1992, chemical control for a *Salvinia molesta* infestation in Letaba River between Tzaneen Dam and Merenshy island, cost the South African authorities R100 per hectare (Charel Bruwer *pers. comm.*) or R 20 000 per year (Dr Karina Celliers *pers. comm.*) for the chemicals. Given a 15 % annual inflation rate, the equivalent 1996 cost would be R 700 per hectare and R 125 000 per year.

Given that the minimum total wetland area in Eastern Caprivi is estimated as 6 480 km^2 (Crerar 1987); subtracting the open water area of 1 425 km^2 to allow for the lake drying up and clear water channels, we can estimate that at least half of the remaining 5 055 km^2 i.e. approximately 2 500 km^2 is 25 000 ha^2 was infested with *Salvinia molesta*. Based on the South African experience, this would have cost the Department of Water Affairs N$ 2 500 000 at N$ 100 per hectare in 1982 and by 1996 the annual cost would be the region of N$ 17 500 000.

The nature of the infestation in Namibia would have made it difficult to control chemically, as access to these wetlands is a problem and the dense emergent and floating vegetation in many of the river channels and backwaters and floodplains would have made it impossible to eradicate the plant, as some plants would always "hide" in the fringe vegetation and regrow. Continuous inputs via the Zambezi river floods would make it necessary to repeat spraying each year. Given an annual inflation rate of 12 - 15 %, chemical control would have cost the Namibian Government in the region of 100 million dollars for the 14 year period since 1982.

Because herbicide treatments are expensive and detrimental to the environment in the long-term they are not considered suitable. In 1986 a decision was taken to switch to biological control using the *Cyrtobagous salviniae* beetles.

3.1.3 BIOLOGICAL CONTROL:

Biological control using *Cyrtobagous salviniae* was chosen as the most effective and ecologically sound, long-term solution to control the *Salvinia molesta* infestation in the Eastern Caprivi. *Cyrtobagous salviniae* meets all three requirements for a successful biological control agent:

- it shows a definite preference for the target plant,
- it inflicts damage severe enough to significantly retard growth and prevent propagation,
- it poses no threat to the local ecology.

Cyrtobagous salviniae weevils had been successfully reared in Australian laboratories, stringently screened, and had been used successfully to control *Salvinia molesta* on Lake Moondarra in Australia (Room *et al.* 1981, Forno *et al.* 1983, Finlayson 1984).

3.2 PHASE II: THE APPLICATION AND TESTING OF BIOLOGICAL CONTROL (1982/83 - 1986/87)

3.2.1 THE GROWTH RATE STUDIES (1982/83 - 1984/85)

Detailed tables of results are given in the respective annual reports submitted at the Steering Committee meetings from 1982 to 1985 (Schlettwein and Koch 1982, 1983, Schlettwein 1984a, 1985c). Only the main findings are discussed here.

3.2.1.1 Field Growth Rates (1982/83):

Growth rates of *Salvinia molesta* measured during the 1982/83 season under natural conditions ranged from 0,3% per day in the open water in Lake Liambezi to 8,5% per day at Ngoma in the Chobe River. Strong seasonal fluctuations were evident in Lake Liambezi where growth rates increased with increasing water temperatures. Growth rates were highest in autumn at water temperatures of 27°C and lowest in July at temperatures of 15°C. In Kariba, growth is best in the autumn (Sculthorpe 1967). *Salvinia molesta* can survive temperatures as low as 10°C and even light frosts (de Moor and Bruton 1988).

No seasonal pattern was detected in the Chobe River, perhaps because the river had stopped flowing and the resultant increase in nutrient concentrations enhanced growth rates. Compared to relative growth rates measured on Lake Kariba which ranged from 4,85% per day to 8,61% per day (Mitchell and Tur 1974), *Salvinia molesta* growth rates on Lake Liambezi of 0,3% per day to 5,9% per day were low, whilst those measured at Ngoma in the Chobe River of 4,4% per day - 8,5% per day were similar.

3.2.1.2 Comparison Of Field Growth Rates In Natural And Enriched Waters (1983/84):

The 1983/84 comparison of field growth rates in natural and enriched waters showed that in summer, growth rates varied from 3,8% to 6,1 % per day on Lake Liambezi and from 14% - 15% per day on enriched water. The results confirmed the positive correlation between nutrient concentrations and relative growth rates.

3.2.1.3 Comparison Of Growth Rates In The Field And Laboratory (1984/85):

The 1984/85 results showed that field growth rates for *Salvinia molesta* at Ngoma (4,3 - 8,5% per day) remained similar to those determined in 1982/83 i.e. similar to Lake Kariba rates but were far lower than the maximum relative growth rate of 19% measured in Lake Moondarra in Australia (Finlayson 1984).

Salvinia molesta grown in the laboratory on natural water from the Zambezi River were lower at 3.1% to 5.3% per day. Much higher growth rates of 16% to 24% per day were observed in plants grown on artificially enriched water in the laboratory. These rates are similar to other laboratory determined optimal growth rates of 15% to 30% per day (Gaudet 1973).

These growth experiments showed that natural or field growth rates of *Salvinia molesta* in the Eastern Caprivi were low compared to rates recorded in Lake Kariba and Lake Moondarra, the only exception was in the Chobe River where rates were comparable to Kariba Lake. Under natural conditions in the Eastern Caprivi the plants could double their mass in 8 to 20 days, whilst under optimum laboratory conditions the plants could double their mass in 3 days.

3.2.1.4 Nutrient Analysis

Chemical concentrations in Eastern Caprivi waters remained low and fairly constant throughout the study. Slight increases could be attributed to evaporation and decreases to dilution following flood inputs. Concentrations were generally lower in flowing waters than in backwaters and nutrient levels remained low and were often difficult to detect. Most of the nutrients essential for *Salvinia molesta* growth occurred in levels high enough not to limit growth. The important exception is nitrogen particularly in the Kwando and Zambezi Rivers.

Chemical analysis of *Salvinia molesta* plant material collected in the Eastern Caprivi confirmed that low nitrogen or phosphorus levels could be limiting growth (Toerien *et al.* 1984).

3.2.2 THE BIOLOGICAL CONTROL RESEARCH PROGRAMME

Detailed results of the study are given in the reports prepared for the annual Steering Committee Meetings in 1984 and 1985 and an Limnological Society of Southern Africa Congress paper (Schlettwein 1984b, 1985a, 1986a). A complete record of results will appear in Mr Schlettwein's thesis.

3.2.2.1 Breeding Programme:

The first *Cyrtobagous salviniae* eggs were noted six days after the insects were released into the breeding ponds. After a month the first larvae appeared and within two weeks pupae were found. A week later an increase in the number of adult weevils was recorded.

Breeding continued throughout the year but slowed down in autumn and winter when the water surface temperatures dropped below 20°C. Experiments conducted in Australia showed that no eggs were laid at temperatures below 21°C and that most eggs failed to hatch at temperatures below 19°C (Forno *et al.* 1983).

In summer, temperatures above 39°C retarded breeding but this problem was overcome by covering the ponds with 40% shade cloth. Temperatures decreased to 33°C and breeding rates recovered. Since 1983 *Cyrtobagous salviniae* have been reared successfully at the laboratory in Katima Mulilo.

3.2.2.2 Release And Monitoring Programme:

The earliest success was achieved in the Chobe River at Ngoma bridge. A total of 1 500 insects were released at Ngoma Bridge. Releases were made in February, October and November 1984. Once established, population densities of the weevil increased steadily and peaked in January 1985 at 2,26 ±0,48 adults per plant. Bud damage decreased in autumn and winter and again slightly just before peaking in January. The mat started to sink in December 1984 when bud damage was 73,8%. By the end of February 1985, 50% of the mat had sunk and 15 months after the insects had first been released on the mat, the area was clear with only a few plants visible at the edges. These were all in the primary invading form.

Similar trends were observed at the other release sites. Insect numbers gradually increased on the mats with a slight decrease in winter when surface water temperatures were below 20°C and a mid-summer peak when water temperatures were above 30°C. Low population densities and resultant low bud damage can also be correlated to low nitrogen concentrations in the host plants (Schlettwein 1986 a). The periods between releases and visible damage ranged from 8 - 12 months, and the time taken for a mat to sink varied from 15 months to just over three years.

Laboratory experiments showed that an estimated population density of 300 adults and 900 larvae of *Cyrtobagous salviniae* per square metre are needed to control *Salvinia molesta* effectively (Room 1988). At Ngoma densities of 89 adults per kilogram wet mass were sufficient to cause the mat to deteriorate and eventually sink. Soon afterwards a maximum density of 750 adults per kilogram was recorded on the few remaining plants.

By the end of 1989, *Salvinia molesta* in the Eastern Caprivi had decreased dramatically and that which remained was firmly under control. On the Kwando River plants were limited to a fringe along the bank and the remaining mats in the Linyanti swamp area supported high densities of control organisms. Lake

Liambezi had dried up in 1985. The Chobe was almost weed-free and many dense mats had disappeared in the Zambezi floodplains leaving only a fringe of *Salvinia* along the river banks. Mats were still found in the Masida backwater and a new infestation was found in Chinchimani channel (Schlettwein *et al.* 1991).

3.2.2.3 Pesticide And Herbicide Tests: (1987)

In the preliminary tests using DDT and Dieldrin, all the *Cyrtobagous salviniae* insects died within 48 hours of being exposed to these poisons at the concentrations used in disease control programmes. In the herbicide test all the insects died within 3 days but it is not clear if this was on account of the poison or starvation after their food source had been eradicated.

In the aerial spraying simulations, adult *Cyrtobagous salviniae* beetles were susceptible even at low dosages of 6g/ha endosulfan, whilst the weevils exposed to 6 - 12g/ha showed a remarkable recovery after 3 weeks but were killed at the higher dosages (Schlettwein and Giliomee 1990).

Recommendations based on these results are that aerial spraying of endosulfan to control tsetse fly be applied when water temperatures are above 21°C and that 21 days or more be allowed between repetitions to give the weevils a chance to recover. (Schlettwein and Giliomee 1990)

Large-scale agricultural projects could threaten the success of the control programme. Pesticides used to protect agricultural crops are often non-specific and can harm non-target species. It is essential that all pesticides must be carefully tested and screened prior to use to avoid the possibility of it harming the *Cyrtobagous salviniae* weevils so vital to the control of *Salvinia molesta* in the region. Similarly fertilisers applied to such large-scale irrigation projects will increase nutrient concentrations in the rivers and wetlands. *Salvinia molesta* growth is nutrient limited and any increase in nutrient concentrations will increase growth rates and can intensify the aquatic weed problem. Ironically a slight increase in nitrogen levels could be beneficial to biological control as the control agent requires a certain minimum nitrogen concentration in its food. At present the very low nitrogen concentrations in the Kwando and Zambezi rivers may account for the relatively low densities of *Cyrtobagous salviniae* in the field.

3.2.2.4 Ongoing Promotion Of Public Awareness, International Co-Operation And Measures To Prevent The Spread Of Aquatic Weeds.

The following scientific articles based on this research work have been published:

Hines, C.J.H., C.H.G. Schlettwein. and W. Kruger. 1985.*
Invasive alien plants in Bushmanland, Owambo, Kavango and Caprivi. Pages 6-12. In: Invasive alien organisms in South West Africa/Namibia. (Eds. C.J. Brown, I.A.W. Macdonald and S.E. Brown) South African National Scientific Programmes 119. CSIR.

Schlettwein, C.H.G. 1985.
Distribution and densities of *Cyrtobagous singularis* Hustache on *Salvinia molesta* Mitchell in the Eastern Caprivi Zipfel. *Madoqua.* 14 (3): 291-293.

Schlettwein C.H.G. & S Bethune. 1992. *
Aquatic Weeds and their management in Southern Africa: Biological Control of *Salvinia molesta* in the Eastern Caprivi (173 - 178). T Matiza and H N Chabwela (EDS), 1992. Wetlands Conservation Conference for Southern Africa. Proceedings of the SADCC "Wetlands Conservation Conference" held in Gaborone, Botswana, 3 - 5 June 1991. IUCN, Gland, Switzerland.

Schlettwein, C.H.G., and J. H. Giliomee. 1990.
The effects of different dosages of the insecticide mixtures endosulfan/ alphamethrin on adults of the biological control agent *Cyrtobagous salviniae* (Coleoptera: Curculionidae) against *Salvinia molesta. Madoqua.* 17 (1): 37-39.

Schlettwein, C.H.G., and P.F. Hamman. 1984.
The control of *Salvinia molesta* in the Eastern Caprivi Zipfel. *SWA Annual*, S.W.A. Publications.

Schlettwein, C.H.G., R.E. Simmons. I.A.W. Macdonald, and H.J.W. Grobler. 1991. *
Flora, fauna and conservation of the East Caprivi wetlands. In: Status and Conservation of wetlands in Namibia (Eds R.E. Simmons, C J Brown and M Griffin) *Madoqua* 17(2) : 67 - 76.

Toerien, D.F., C.H. Wiltshire, C.H.G. Schlettwein, and H.W.R. Koch. 1984.
Chemical composition of *Salvinia molesta* from the Eastern Caprivi Strip. *Madoqua.* 14 (1): 91-93.

Water Quality Division, 1985.
Biological control of *Salvinia molesta* in the Eastern Caprivi. Show pamphlet compiled by S Bethune and issued by the Department of Water Affairs, Namibia.

* also presented at conferences

The following papers were presented at scientific conferences:

Schlettwein, C.H.G. and H.W.R. Koch. 1983.
Seasonal relative growth rates of *Salvinia molesta* in the Eastern Caprivi Strip. 20th Annual Congress and workshop of the Limnological Society of southern Africa, "Wetlands in perspective " 4 July, Durban.

Schlettwein, C.H.G. 1984. (Poster)
Aspects of Biological control of *Salvinia molesta* in the Eastern Caprivi Zipfel. Symposium on Perspectives in southern Hemisphere Limnology - 2 - 7 July Wilderness

Schlettwein, C.H.G. 1986.
Successful biological control of Kariba weed, *Salvinia molesta* Mitchell in the Eastern Caprivi Zipfel. Limnological Society of Southern Africa Congress 30 June - 4 July, Windhoek.

An exhibition on the Biological control of *Salvinia molesta* was held at the annual agricultural show in Windhoek during October 1985. Pamphlets were distributed to the public and a video on the research work complimented the model and photographs.

A SATV documentary for the programme 50/50 was made on the research project in the Caprivi and shown on South African television during 1985. Numerous radio and press interviews were granted, a presentation given to members of the Wildlife Society of Namibia during 1987 and a popular article published in the Wildlife Society Newsletter *Roan News.*

As a member of the subcommittee for Aquatic Weeds of the Standing Committee for Hydrology of SARCCUS, annual meetings have been attended since 1981 and progress reports submitted each year. Close co-operation with Research Institutes in South Africa and the Entomology Division of the CSIRO, in Australia has been maintained throughout the project. Dr Ken Harley and Dr Wendy Forno world-authorities on biological control of aquatic weeds visited the Caprivi in 1986 to advise on the project. In 1995 and February 1996, Namibian research staff travelled to Botswana to attend meetings with the Botswana *Salvinia* control team and Dr Wendy Forno.

Both South Africa and Botswana has sought advice on *Salvinia molesta* control. Insects bred at Katima Mulilo have been released on the Letaba River in South Africa and in the Moremi Game Reserve in Botswana. Following the advice of Charlie Schlettwein, effective control was achieved on the Xini lagoon in Botswana by a combination of insect releases, isolation of the lagoons and extensive pumping to dry out the lagoons in 1986. Two further infestations in the Okavango Swamps were discovered in Moremi in 1988 at Bodumatau and Abaqao. Insect releases have been made at both sites and good control was achieved.

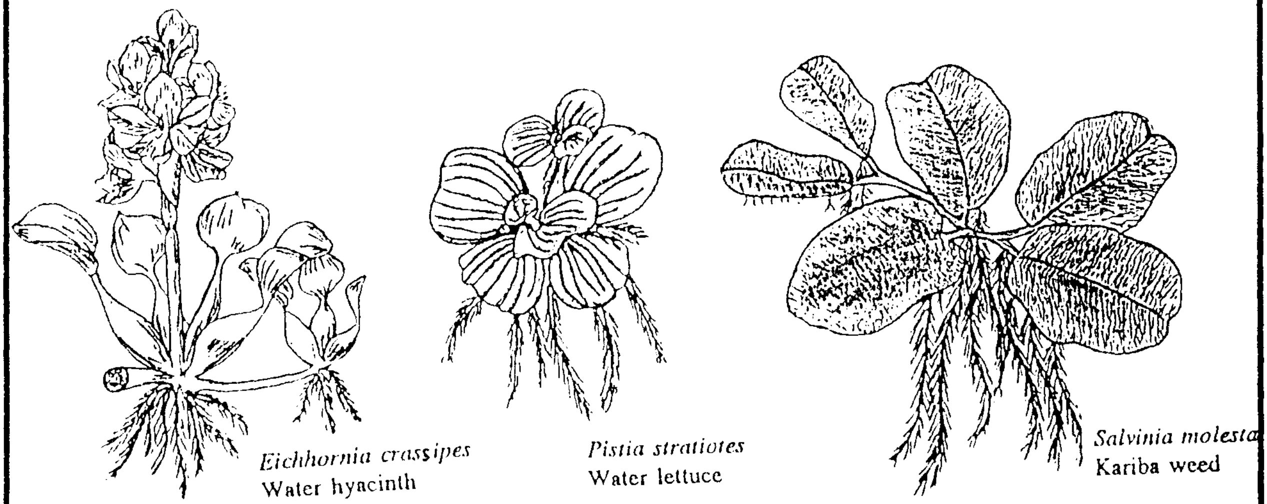
To prevent the spread of aquatic weeds, all plant nurseries in Windhoek are inspected annually for aquatic weeds. Nursery owners are informed about the dangers associated with the spreading of these weeds. Weeds has been found, confiscated and destroyed during these exercises. In 1992, three aquatic weed species, *Salvinia molesta*, *Eichhornia crassipes* (water hyacinth) and *Pistia stratiotes* (water lettuce) were found and confiscated from several of the nurseries and pet shops in Windhoek. Since then none have been found.

To prevent boats spreading aquatic weeds, legislation was passed in Botswana in 1986 strictly regulating the importation of boats and fishing equipment. To help with this effort, Namibia introduced boat control measures, similar to those in Botswana, at border check points in the Caprivi and Okavango regions. An information package which included posters and pamphlets on aquatic weeds in Botswana and Namibia together with a short report (Bethune 1993) were prepared and distributed to veterinary offices, tourist camps and lodges, checkpoints and border crossings in both the Okavango and Caprivi regions. **Figure 10** is a copy of the poster prepared by the Research Division to promote public awareness and solicit co-operation.

HELP COMBAT AQUATIC WEEDS

Namibia, together with other Southern African states, is trying to prevent the spread of aquatic weeds in our waterways.

These three aquatic weeds are of concern:



Boats are a major means of spreading these weeds, so please if you have a boat in the Okavango or Caprivi Regions or plan to take your boat in or out of the regions, call at the Veterinary offices in either Rundu or Katima Mulilo to have your boat inspected and sprayed.

Katima Mulilo
Dr EA Mbise
Tel: 067352-142

Rundu
Dr T Tolmay
Tel: 067372-16

THANK YOU FOR HELPING US TO STOP THE SPREAD OF AQUATIC WEEDS.

PERMANENT SECRETARY FOR WATER AFFAIRS, NAMIBIA

Figure 10: Poster designed to inform the public about aquatic weeds and solicit co-operation at boat control check points.

3.3 PHASE III: THE EXPANSION OF THE CONTROL PROGRAMME AND DISTRIBUTION OF CONTROL INSECTS (1987/88 - 1989/90)

During the period 1987 to 1990 insects were bred and released at all infested sites in the Eastern Caprivi. As the work concentrated on finding new infestations and releasing insects at each, monitoring was rather irregular during this period. By the beginning of 1991, *Cyrtobagous salviniae* insects had been released at over a hundred sites mainly in the Eastern floodplain region. The map below (**Figure 11**) indicates these sites in the Eastern Caprivi.

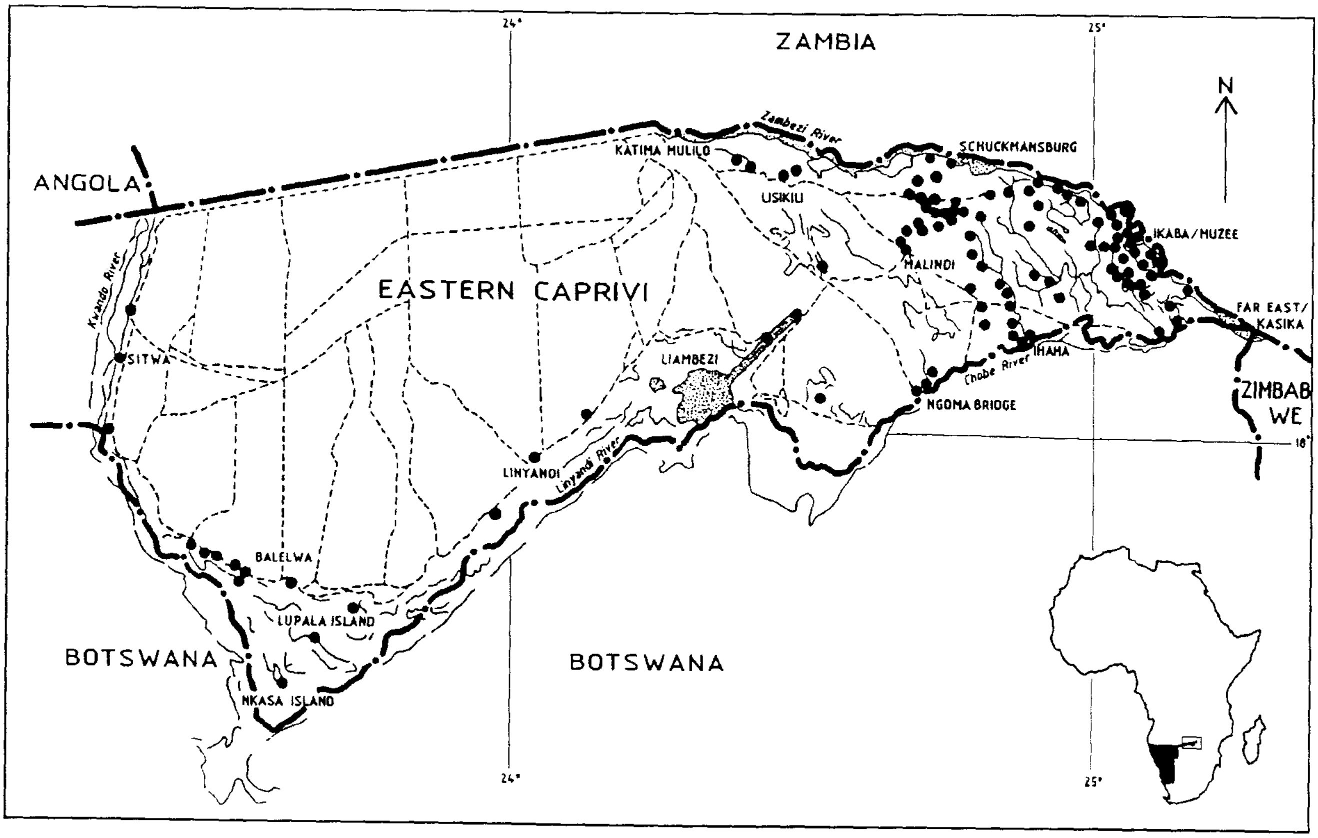


Figure 11. Map of the Eastern Caprivi indicating the insect release sites at the end of the expansion phase i.e. 1990

3.4 ONGOING CONTROL AND MONITORING (1990/91 - 1995/96)

Although some progress has been made with the assessment of the data collected since 1988, a concerted effort is needed to deal with this backlog. This information is vital to assess the ongoing effectiveness of the control programme and the possible impacts of developments, particularly large agricultural projects, on the control programme. The impacts of fertilisers and pesticides are of concern. Although the technician and workhand based in Caprivi managed to deal with the day to day running of the project, it has become apparent that the more scientific aspects of the project requires more timeous inputs and supervision.

During 1991 steps were taken to place the monitoring programme on a more scientific footing. All the release sites were listed and marked on a large 1:100 000 map. The area was divided up into regions and a monitoring programme drawn-up to ensure that each site is visited at regular intervals 2 - 3 times each year.

As shown in the map below, by August 1992, almost 90% of the 109 sites being monitored were largely clear of the weed with only a few small plants around the margins of the water bodies. Only 11 sites; Sisanta, Ihaha II, Nasisangani, Mutwalwizi, Bulyankala, Isale, Isuzu, Kashelana, Nanchinga, Namasimanwe and Namalweza were still covered by *Salvinia molesta* (Bethune 1992).

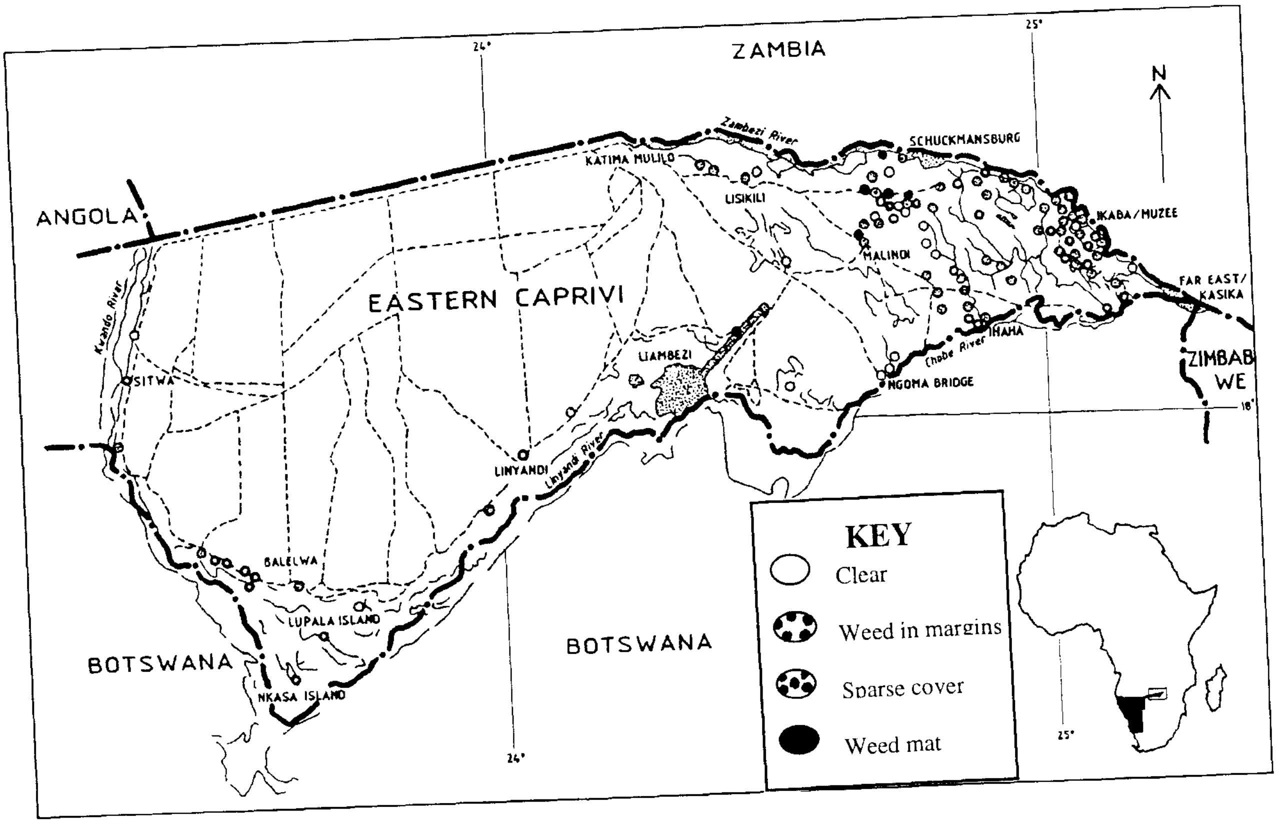


Figure 12: Map of the Eastern Caprivi showing the level of control achieved by August 1992 at the 109 insect release sites monitored.

During 1993, the rising flood waters of the Zambezi River brought in a fresh influx of *Salvinia molesta* plants. These were first noted at Katima Mulilo in mid-February and by early March it was estimated that 15 plants per second were drifting down from Zambia. These new plants are annually spread throughout the floodplain region and a concerted effort is needed to bring these new infestation under control. Nutrients brought in by the floodwaters and with runoff from agricultural fields are expected to boost weed growth and complicate control. Field monitoring of all release sites continues, but access is often difficult, because the area east of the Katima Mulilo - Ngoma road, is flooded for 6 - 8 months each year. As the project is supervised from Windhoek, 1 200 km away, lack of on site supervision, at times, further hampered progress.

Throughout the project, scientist from Namibia and Botswana co-operated to control aquatic weeds in both countries. In December 1991, May 1992 and May 1994, Namibian researchers assisted Botswana by conducting in looking for water hyacinths on the Chobe River and in September 1993, a boat control programme was initiated in Namibia at the request of Botswana. Boat control checkpoints were set up at Mohemba on the border between the Okavango region and Botswana south of the Popa rapids, at Ngoma gate on the border with Botswana and at the Wenela ferry crossing into Zambia. Further it was agreed that at times of dense boat traffic, for example, when angling competitions are held, additional checkpoints at Bagani bridge and Kongola bridge could be set up. The map below shows these checkpoints (Bethune 1993)

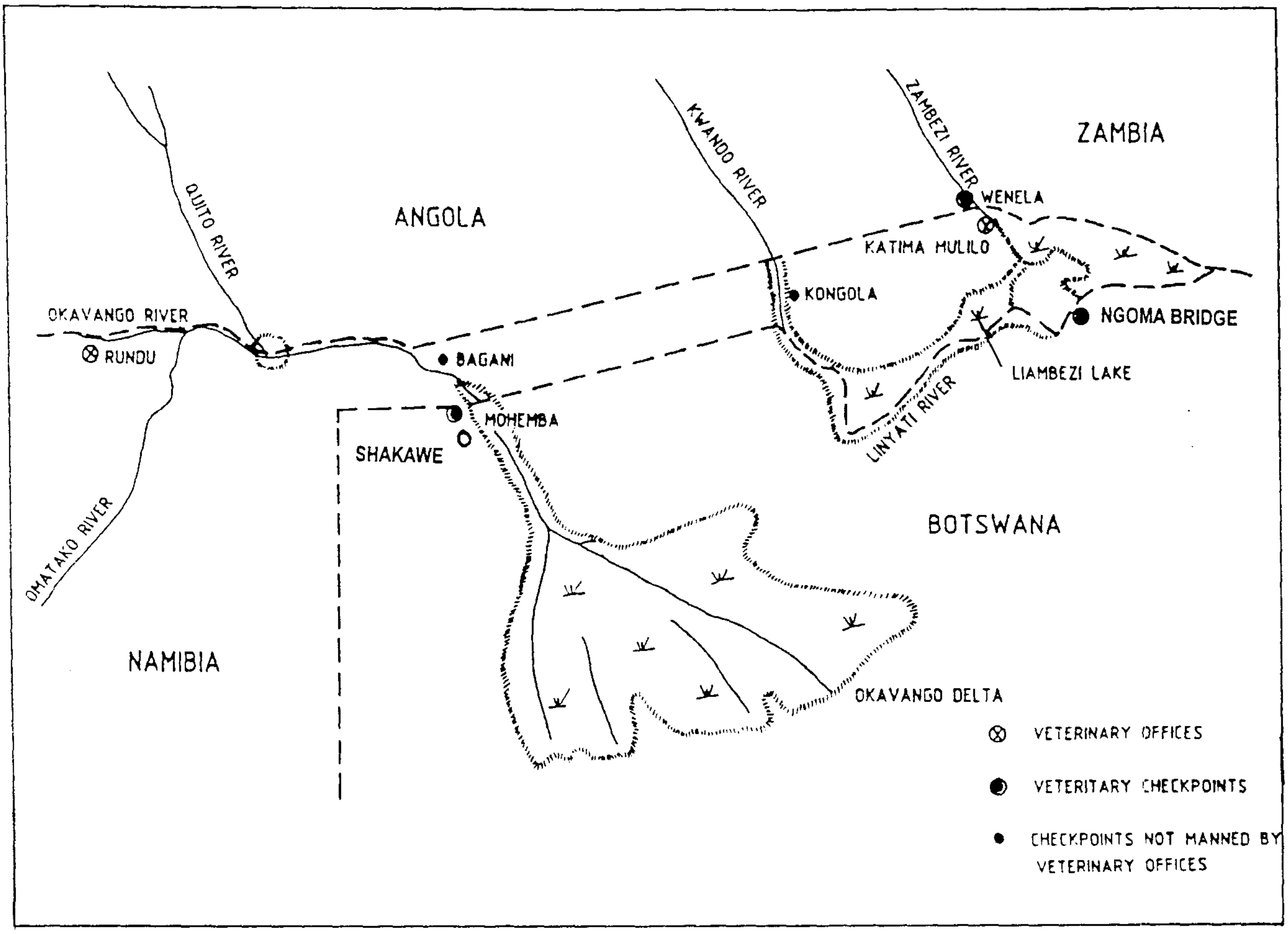


Figure 13: Map of the Aquatic Weed Control points in the Okavango and Caprivi regions in Namibia.

An hydrologist from the Department of Water Affairs of Namibia, Shirley Bethune, visited the Kenyan Agricultural Research Institute (KARI) near Nairobi in October 1993, to exchange information with Kenyan scientists working on the biological control of *Salvinia molesta* in Lake Naivasha. The scientists reported more rapid success rates with mats sinking within 8 -12 months. This could be attributed to higher nutrient levels in Lake Naivasha compared to the Caprivian wetlands, which improves the nutritional aquality of the *Salvinia*, hence the weevils are healthier and more effective. Also being tropical, the area is not subject to low temperatures i.e. temperatures below 19^{0}C, which would inhibit insect breeding and growth.

Scientists from Botswana, Zambia and Kenya working on biological control of *Salvinia molesta* were invited to attend the first regional meeting on "The Biological control of Aquatic Weeds" held at Balelwa on 22 and 23 May 1994. Unfortunately due to lack on funding, neither Zambia nor Kenya could attend. However the meeting served to place the excellent co-operation between Namibian and Botswana scientists on a firm footing and enabled a joint weed survey on the Chobe River to be undertaken. A second meeting between Namibia and Botswana scientists and a joint survey was held at Kasane in Botswana from 9 - 10 February 1996 to coincide with a visit from Dr Wendy Forno, the international expert on *Salvinia* control.

At present, the *Salvinia* project is run by a senior technical assistant, Mr Vincent Simana, and a workhand, Mr Alfred Makumbi, who are stationed in Katima Mulilo and is supervised by Ms Shirley Bethune, a Chief Hydrologist from the Research Division in Windhoek. Since May 1996, an aquatic ecologist volunteer from Britain, Dr Nicolas Clarke, has been based in Katima Mulilo to supervise the programme until a second volunteer, Dr Eliot Taylor, takes up his appointment to direct the project form July 1996 until June 1998.

4. FINANCES

4.1 INTRODUCTION

In 1980, the control of *Salvinia molesta* in the Eastern Caprivi was taken over by the Namibian Department of Water Affairs. Because of the extent of the *Salvinia molesta* infestation and the unsuccessful previous attempts to control *Salvinia molesta*, the Department of Water Affairs realised that a proper research project had to be set up and the necessary infrastructure established. The Committee for Research Priorities (CRP) in Namibia, was approached for funding and N$ 180 000 was requested for the first 3 years.

The aquatic weed research project was funded in 4 phases as shown in Table 1:

TABLE 1: FOUR PHASES OF THE PROJECT

PHASE	PERIOD	YEARS	OBJECTIVES
I	1980/81 - 1982/83	3	The preliminary control assessments
II	1983/84 - 1986/87	4	The application and testing of biological control
III	1987/88 - 1989/90	3	The expansion of the control programme and distribution of control insects
IV	1990/91 - 1995/96	6	The ongoing control and monitoring

4.2 COSTS

4.2.1 PHASE I: THE PRELIMINARY CONTROL ASSESSMENTS (1980/81 - 1982/83)

In the first phase (1980/81 - 1982/83) a fully equipped laboratory at Katima Mulilo, quarantine facilities and a field station at Balelwa were built. Different control techniques were assessed and emphasis was placed on different chemical control methods. **Table 2** gives an indication of the money spent. During the first year, a senior hydrologist, Mr Harald Koch was appointed. He was joined by a hydrologist, Mr Charlie Schlettwein, a technical assistant and a workhand the next year. A camp attendant for Balelwa joined the staff in1982. Mr Koch was recalled to Windhoek at the end of Phase I.

Salaries did not form part of the CRP funding and were paid by Department of Water Affairs. Travel costs and salaries of Steering Committee members to attend annual meetings were met by their own institutions and not included in these budgets.

TABLE 2 COSTS OF FIRST PHASE (3 YEARS)

FINANCIAL YEAR	CRP FUNDING			D W A	
	Chemicals + consumables	Capital costs + Equipment	S & T + Transport	Salaries	Total
1980/81	20 000	105 000	10 000	12 000	147 000
1981/82	5 000	5 000	10 000	33 000	53 000
1982/83	3 000	2 000	20 000	35 000	60 000
TOTAL			**180 000**	**80 000**	**260 000**

The total amount of money spent in the first phase was N$ 260 000 i.e. N$ 180 000 provided by CRP and N$ 80 000 by Department of Water Affairs for salaries.

4.2.2 PHASE II: THE APPLICATION AND TESTING OF BIOLOGICAL CONTROL (1982/3 - 1986/87)

The second phase (1983/84 - 1986/87), commenced with the growth studies and nutrient analysis (1982/83 - 1984/85), tested the biological control programme (1983/84 - 1986/87) and included pesticide and herbicide tests (1987) as well as a concerted public awareness and international co-operation campaign. Funding for this phase was requested from the CRP and the money spent is indicated in **Table 3**.

TABLE 3 COSTS OF SECOND PHASE (4 YEARS)

FINANCIAL YEAR	CRP FUNDING				D W A	
	S & T	Consumables	Equipment	Transport	Salaries	Total
1983/84	5 000	7 000	5 000	3 000	20 000	40 000
1984/85	3 000	2 000	4 000	7 000	24 000	40 000
1985/86	2 000	2 000	1 000	7 000	28 000	40 000
1986/87	2 000	2 000	1 000	7 000	32 000	44 000
TOTAL				**60 000**	**104 000**	**164 000**

During the second phase a total of N$ 164 000 was spent on the research project of which N$ 60 000 was from CRP and N$ 104 000 from the Department of Water Affairs. At the end of this phase, the hydrologist in charge was also recalled to Windhoek and the biological monitoring was continued by a technical assistant and a workhand under supervision from Windhoek.

4.2.3 PHASE III: THE EXPANSION OF THE CONTROL PROGRAMME AND DISTRIBUTION OF CONTROL INSECTS (1987/88 - 1989/90)

The third phase (1987/88 - 1989/90) concentrated on biological monitoring, breeding of insects and active distribution of weevils to all infected sites particularly in the eastern floodplain area. Some funding was provided by the CRP and the amounts are shown in **Table 4**.

TABLE 4 COSTS OF THIRD PHASE (3 YEARS)

FINANCIAL	CRP FUNDING				D W A	
YEAR	S & T	Consumables	Equipment	Transport	Salaries	Total
1987/88	1 000	2 000	1 000	14 000	28 000	46 000
1988/89	1 000	1 000	2 000	12 000	29 000	45 000
1989/90	2 000	1 000	2 000	11 000	28 000	44 000
TOTAL				**40 000**	**85 000**	**135 000**

During the third phase a total of N$ 135 000 was spent. A large proportion of the money was spent on transport, because of the importance of locating new infestations and the distribution of the weevils to these newly infested areas.

4.2.4 PHASE IV: THE ONGOING CONTROL AND MONITORING (1990/91 - 1995/96)

During the fourth phase (1990/91 - 1995/96) monitoring of the activities in the Eastern Caprivi were expanded to include the monitoring of biological control work, water quality monitoring, surface water level recording and rainfall recordings for the Division Hydrology and ground water level recordings for Geohydrology Division.

During this period regional co-operation was formally established and the first joint surveys and formal meetings with scientists from Botswana were conducted.

After Independence, the CRP ceased to function and no external funding was received for the fourth phase. The emphasis shifted from purely biological monitoring of aquatic weeds to include general water monitoring in the Eastern Caprivi and co-operation with Botswana was strengthened. The cost of this phase is given in **Table 5**.

TABLE 5 COSTS OF FOURTH PHASE (6 YEARS)

FINANCIAL YEAR	D W A FUNDING					
	S & T	Consumables	Equipment	Transport	Salaries	Total
1990/91	2 000	1 000	4 000	10 000	33 000	50 000
1991/92	2 000	3 000	4 000	11 000	39 000	59 000
1992/93	5 000	3 000	3 000	13 000	35 000	59 000
1993/94	4 000	5 000	1 000	19 000	37 000	66 000
1994/95	4 500	* 12 000	4 500	25 000	37 000	83 000
1995/96	3 000	1 000	2 000	35 000	37 000	78 000
TOTAL					**218 000**	**395 000**

* This included the repairs of Balelwa and the laboratory.

After Independence in 1990, Mr Schlettwein was appointed Permanent Secretary and the task was continued by a technical assistant and a workhand based in the Caprivi region under supervision of a hydrologist, Mr Claudius Kaunjua in Windhoek. When he left for further studies in October 1991, Ms Shirley Bethune took over the task in addition to her duties as Chief of the Ecology Section.

4.3 SUMMARY

From 1980 until 1990, the CRP funded the capital and running costs of the Aquatic Weed Research project, while the salaries were paid by the Department of Water Affairs. **Table 6** gives a summary of the contribution from Department of Water Affairs and CRP for each phase.

TABLE 6 COST OF AQUATIC RESEARCH PROJECT

PHASE	YEARS	CRP FUNDS	DWA's COSTS	TOTAL	COST/YEAR
Phase I (1980-83)	3	180 000	80 000	260 000	87 000
Phase II (1983-87)	4	60 000	104 000	164 000	41 000
Phase III (1987-90)	3	50 000	85 000	135 000	45 000
Phase IV (1990-95)	6	-	395 000	395 000	66 000
TOTAL	**16**	**290 000**	**664 000**	**954 000**	**60 000**

To date the Aquatic Weed Research project in the Eastern Caprivi has cost a total of N$ 954 000.

5 FUTURE RESEARCH

More attention must be given in future to the assessment and evaluation of the field data collected during the monitoring phase (Phases 3 and 4) of the control programme. There is a backlog which goes back to 1988. During Phase II of the study, insects extracted using the Berlese funnels were kept with the intention of doing more detailed counts and distinguishing between the two *Cyrtobagous* species introduced to the Eastern Caprivi. This was started in May 1996.

Finlayson (1984) warns that even where *Salvinia molesta* growth is controlled, any increase in nutrient levels will cause an increase in growth rates in which case the control agent may not be able to successfully control the plant. This is a very real threat in the Eastern Caprivi where ever-increasing agricultural activity is expected to increase the nutrient levels. It is important that nutrient concentrations in the wetlands of Caprivi continue to be monitored.

There is also a need to re-assess the project as a whole, identify what work needs to continue and what the future research needs are. The monitoring programme, as implemented in 1992, should be evaluated and refined and an intensive 2 year period of fieldwork supervised by a qualified aquatic ecologist is necessary to place the project on a sound scientific footing.

There is a need to correlate the wealth of chemical water quality data collected during the study. In view of future development and environmental concerns in the Caprivi region, this task should be undertaken, a data base compiled and the results compared to earlier publications (Van der Waal, 1976, Seaman *et al.* 1978) This task will be dealt with by a competent technical assistant in the Research Division.

The next phase of the project will thus deal with the data evaluation backlog, re-evaluation of the monitoring, re-assessment of the project as a whole and include a two year period of intensive fieldwork and produce a detailed report of the findings. This is expected to take until June 1998 (1996/97 - 1997/98) and will cost the Department of Water Affairs approximately N$ 150 000, of which N$ 112 000 will be required for salaries. The salary of the volunteer aquatic scientist's time in Caprivi (May 1996 - June 1998) will be N$ 42 000 for the 2 years.

6. CONCLUSIONS

Salvinia molesta Mitchell, or Kariba Weed, has caused an infestation in the Eastern Caprivi wetlands since the early 1970's. Several attempts to control the weed followed during the 1970's. Aerial spraying of herbicides proved too expensive and the introduction of *Paulinia acuminata* and *Cyrtobagous singularis* was of limited success. The Department of Water Affairs took on the task of controlling the weed in1980.

The various control options were carefully assessed. Mechanical control was ruled out as *Salvinia molesta* exploitation is not commercially profitable and carries the serious risk of re-infestation. Chemical control was also decided against, although controlled herbicide applications have been used in the Okavango Swamps to check *Salvinia molesta* encroachment at a cost of approximately R 100 000 (R 1 = N$ 1) annually (Jacot Guillarmod, 1979) and in the Letaba River in South Africa at an initial cost of R 20 000 in 1982 (Dr Karin Cilliers *pers. comm.*). Based on an infested wetland area of approximately 2 500 km^2 in the Eastern Caprivi it is estimate that chemical control would have cost the Namibian Department of Water Affairs N$ 2 500 0000 in 1982 and by 1996, the annual cost would be N$ 17 500 000 and that the total cost since the project started would have been in the region of N$ 100 000 000. Thus both in terms of cost and the negative ecological impacts of herbicides on the wetland environment chemical control is not considered a suitable long-term solution to the infestation of the weed in Namibia. Biological control using the weevil *Cyrtobagous salviniae* was identified and selected as the best long-term solution to the *Salvinia molesta* problem in the Eastern Caprivi.

A series of growth rate studies revealed that *Salvinia molesta* growth rates in the Eastern Caprivi are relatively low and can be correlated to low nutrient concentrations. Laboratory and field studies using artificially enriched water proved that *Salvinia molesta* has the potential to grow much faster, it could double its mass every 3 days. *Cyrtobagous salviniae* weevils, native to south-eastern Brazil, were imported from Australia as a promising biological control agent. The insect rearing and breeding programme was successful. The beetles adapted well, have become firmly established in Namibia and have a major beneficial impact on the control of the alien aquatic weed *Salvinia molesta* in the Caprivi. Insects bred in Namibia have also been exported to South Africa and Botswana to combat *Salvinia molesta* problems there.

The first success in the biological control programme was achieved in 1985, five years after the start of the research project, when the mat at Ngoma bridge sank within 15 months. Under local conditions it takes from 15 months to 3 years for *Salvinia molesta* mats to sink after treatment. During the period 1987 to 1990, the project concentrated on locating weed infestations and releasing control insects throughout the eastern Caprivi. By August 1992, only eleven of the 109 sites where insects had been released were still covered by *Salvinia molesta*, the rest were either clear or small plants were limited to the margins. Unfortunately the 1993 flood brought in a new infestation via the Zambezi.

Currently, *Salvinia molesta* appears to be under control in Namibia. The intensity of the infestation has decreased drastically since *Cyrtobagous salviniae* was introduced. Insects continue to be bred and released in the Caprivi and more than 100 release sites are currently being regularly field monitored. Unfortunately the project has been hampered by access problems and vehicle trouble, the assessment and evaluation of information has been neglected and there have been problems with long-distance supervision. To overcome these problems, a well qualified, aquatic ecologist has been appointed to deal with the backlog, provide on site supervision and re-assess the project during the next two years.

Further, it is essential that the *Cyrtobagous salviniae* and the *Cyrtobagous singularis* populations in the area be carefully monitored in order assess the ongoing effectiveness of the control measures on *Salvinia molesta*, to update distribution records and to monitor any possible unforeseen harmful effects on the environment and possible impacts of development proposals on the control insects. Pesticide and herbicide tests confirmed the vulnerability of the control agents to these poisons. Agricultural developers must be made aware of the potential impact agro-chemical i.e. herbicides, pesticides and fertilisers in areas where the control organism is active.

Throughout the project, co-operation with Botswana has been an important factor in the success of the work. Authorities in Botswana are very aware of the potential threat of *Salvinia* infestations in the Okavango Swamp and have asked Namibia for assistance in preventing the spread of weeds, in dealing with isolated occurrences of the plant, and for the supply of *Cyrtobagous* weevils. Both countries are members of the SARCCUS subcommittee for Aquatic Weeds and have exchanged information at annual meetings since 1981. In May 1994, Namibia hosted the first regional meeting on "The biological control of Aquatic Weeds" at Balelwa, which included a joint survey with Botswana of the Chobe River. Representatives from Zambia and Kenya were also invited, but were unfortunately unable to attend. On 9 February 1996, the second joint meeting between Botswana and Namibia was held at Kasane in Botswana and a joint survey of the Chobe River was conducted the next day.

The biological control of *Salvinia molesta* in the Eastern Caprivi has been a success and has cost N$ 954 000 over a 16 year period. Of this N$ 290 000 was funded by CRP and the rest by the Department of Water Affairs. The average annual cost has been N$ 60 000.

Since 1990, the research staff in Katima Mulilo have assisted the Hydrology, Water Quality and Geohydrology divisions and the Weather Bureau with their routine data recording and fieldtrips were arranged to coincide with the needs of these divisions. This worked well initially, but vehicle and access problems as well as a lack of on site supervision have created problems in recent years.

The project has been a success, both in terms of bringing the *Salvinia molesta* infestation under control in the Eastern Caprivi without any detrimental environmental effects and in terms of the scientific approach taken. The N$ 954 000 spent on the project has been money well spent. In the next two years the project will be reassessed, the monitoring programme refined, the data evaluation backlog dealt with and an aquatic ecologist will be based in the Caprivi to undertake and supervise an intensive one year field programme aimed at providing information for the re-assessment and placing the project on a sound scientific footing. Regional co-operation remains an important component of the project's success and annual meetings will be held with Botswana and Zambia.

Shirley Bethune

Prepared by: Shirley Bethune

Date: 31. March 1996

7. ACKNOWLEDGEMENTS

This report is an updated version of a paper prepared in consultation with Mr C H G Schlettwein and presented at the SADCC Wetlands Conservation Conference held in Gaborone in June 1991 and published in the Proceedings of the Conference by IUCN in 1992 (Schlettwein and Bethune 1992).

This report was prepared by Shirley Bethune of the Ecology Section. The following people are acknowledged for their help: Dr J S de Wet, Mr K S Roberts, Mrs E Almirall, Mr R Roeis.

8. RECOMMENDATIONS

It is recommended that:

1. This be accepted as the complete progress report on the "Biological control of *Salvinia molesta* project" for the period 1980 - June 1996;

2. During the next two years, the backlog be dealt with, the breeding, release, field monitoring and training needs be scientifically reassessed; and a two year field monitoring programme be conducted; **RESEARCH**

3. The results of the reassessment and intensive monitoring be made available in a final report, by June 1998; **RESEARCH**

4. Co-operation with neighbouring countries, particularly Botswana and Zambia be continued and that regional meetings on "The Biological Control of Aquatic Weeds", joint surveys and boat control check points be continued. **RESEARCH**

9. APPROVAL OF RECOMMENDATIONS

This report is approved for submission to the Director: Investigations and Research.

CHIEF: RESEARCH

DATE: 25/4/96

I support the recommendations contained in this report and submit it to the Permanent Secretary for Water Affairs.

DIRECTOR: INVESTIGATIONS AND RESEARCH

DATE: 29/4/96

The recommendations in this report are approved / ~~not approved~~

PERMANENT SECRETARY FOR WATER AFFAIRS.

DATE: 10 7. 96

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