

# INTEGRATED CONTROL MANAGEMENT AND MONITORING OF THE KARIBA WEED IN OKAVANGO DELTA, BOTSWANA

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## 1. Introduction

The Okavango River, supplemented by local rainfall, supplies on average 10,000 Mm<sup>3</sup> year<sup>-1</sup> to a wetland system known as the Okavango Delta. This wetland covers approximately 14,000 km<sup>2</sup> and comprises rivers, lakes and pools, perennial and seasonal swamps, floodplain grasslands, rain water seepage pans and pools (Smith 1989) providing habitat for a variety of plant species. Seasonal swamps and floodplains are heavily utilized by game and any disruption to these areas will limit the survival of Okavango Wild life (SMEC 1989). Other than drying up of these systems through natural or artificial processes, a major threat to the ecosystem is the invasion of alien aquatic weeds, especially, the Kariba weed (salvinia), *Salvinia molesta* Mitchell. *S. molesta* is a sterile floating fern native to south-eastern Brazil (Forno and Harley 1979).

In The Okavango Delta Management Plan (ODMP), the Ecosystem Approach was comprehensively adapted to devolve responsibility to all the levels of stake holders. Hydrology and Water Resources Division in the Department of Water Affairs envisages the issues of concern *viz.*, changes in the flood regime, drying up of the wetland and shifts in the flood distribution pattern. Stakeholders attributed these changes to vegetation blockages, flow interventions, demand for water supply and the spreading of salvinia weed. One of the perceived problems raised in the community and stakeholder consultations is the reinvasion and spread of the salvinia weed associated with the channel blockages, lack of effective control of boat movements, human impacts on water quality, e.g. sewage control from House Boats, villages and tourist lodges. This short review focuses on the salvinia current status, recent threats of infestations, progress made in the control of the weed and its ongoing monitoring in the Delta. The Aquatic Vegetation Control Unit in the Department of Water Affairs is the Nation's authorized centre directed to develop technology and monitor research for the control and management of invasive aquatic weeds in the surface water of Botswana.

## 2. Brief Historical Perspective of Salvinia

Salvinia invaded Botswana via the Zambezi at Kazungula in 1948 (Edwards and Thamos 1977). Subsequently, it became a serious weed in the Kwando/Linyanti/Chobe River systems on the border between Botswana and Namibia. Despite heavy use of herbicides, mainly paraquat, in the Kwando/Linyanti systems between 1972 and 1983 salvinia was not brought under control until a biological control weevil, *Cyrtobagous salviniae* Calder and Sands, was released on the Namibian side of the Kwando River in December 1983 (Forno and Smith 1999), following a spectacular biocontrol of salvinia in Australia (Room et al. 1981). The insect was discovered and collected by the Commonwealth Scientific Industrial Research Organization of Australia

(CSIRO Australia) in its native range in Brazil and confirmed as host-specific to *S. molesta* (Forno et al. 1983). Adults destroy leaf buds (Figure 1A and B)) and larvae tunnel in the rhizomes (Figure 1C) causing the plant to disintegrate and sink. By 1986 most of the salvinia in Kwando/Linyanti/Chobe river system was infested with the weevil and 12 months later the mats of salvinia were disintegrating and declining due to damage by the weevils. It is postulated that *Salvinia* was introduced into the Okavango Delta by animals or man, and was first sighted in Xini Lake and associated wetlands on 13 July 1986 (Forno and Smith 1999).

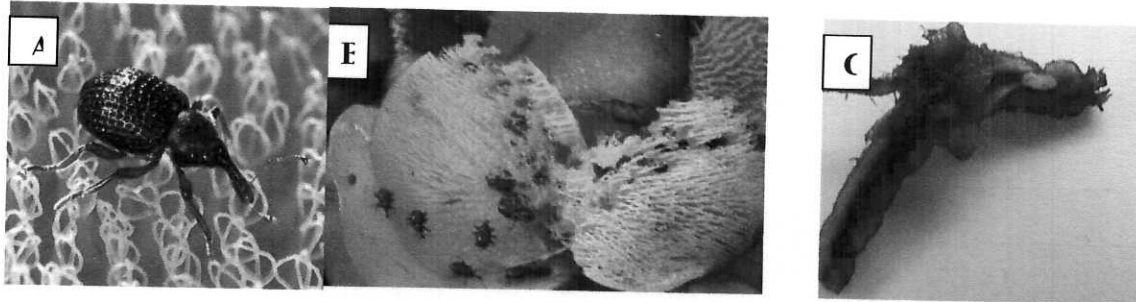


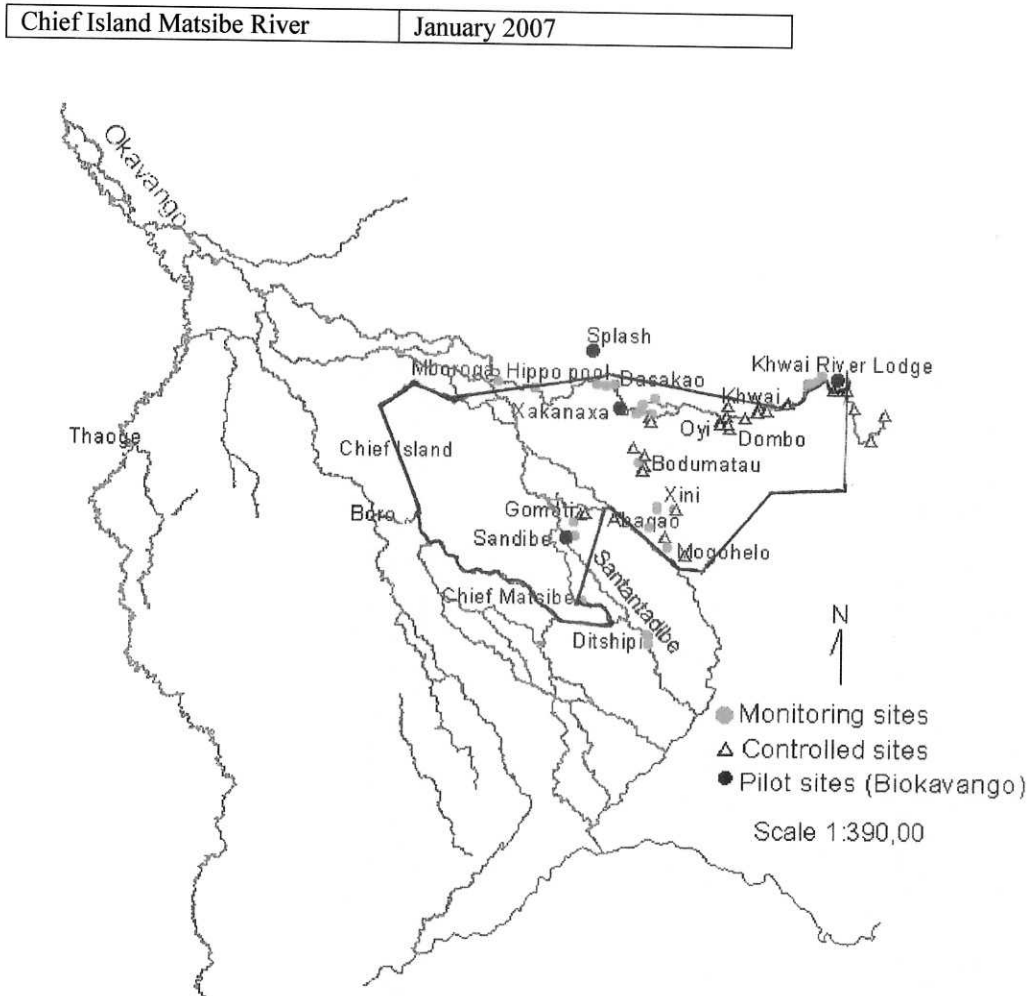
Figure 1 A and B. Adults' damage to young buds and leaves, C. Larva tunneling the rhizome

### 3. *Salvinia* status in Moremi Game Reserve

The first observations of salvinia in the various wetlands in Moremi Game Reserve are presented in Table 1. After its discovery in 1986 in Xini, salvinia started spreading to other rivers, lakes, ponds and pools. Notable infestations between 1986 and 1996 were Bodumatau, Xakanaka lagoon and Dasakao wetlands in Maunachira River; Oyi and Dombo Lediba in Khwai river; Mogohelo and Abaqao streams (Figure 2). Infestations in Santantadibe River appeared in 2003. *Salvinia* was sighted in Mboroga and Maunachira Hippo pool in 2006 and Chief Island Matsibe River in 2007 (Figure 2). The spread of the weed severely impeded the normal flows and affected the navigation in Dasakao channels, upstream and downstream of Khwai River while Mogohelo, Xini and Bodumatau pools were completely covered with salvinia causing an eye sore to the tourists. Wild life was threatened and the animals were found moving away from the infested wetlands of salvinia. The back water pools were found choking and complaints of tourist establishments were pouring into the office of Aquatic Vegetation Control Unit (AVC Unit) in Maun.

Table 1 Chronology of *salvinia* infestations first observed in various wetland and riverine systems in Okavango Delta

Name of associated wetlands	Month - Infestation sighted
Xini	July 1986
Bodumatau	July 1988
Abaqao/Mogohelo	August 1992
Xakanaxa	July 1992
Khwai	1992
Gomoti	1987
Santantadibe River at Sandibe and Ditshipi	November 2003
Maunachira Hippo pool	October 2006



**Figure 2** Current status of salvinia weed in target areas (the monitoring sites) in Moremi Game Reserve, Okavango Delta

#### 4. Integrated Control of Salvinia

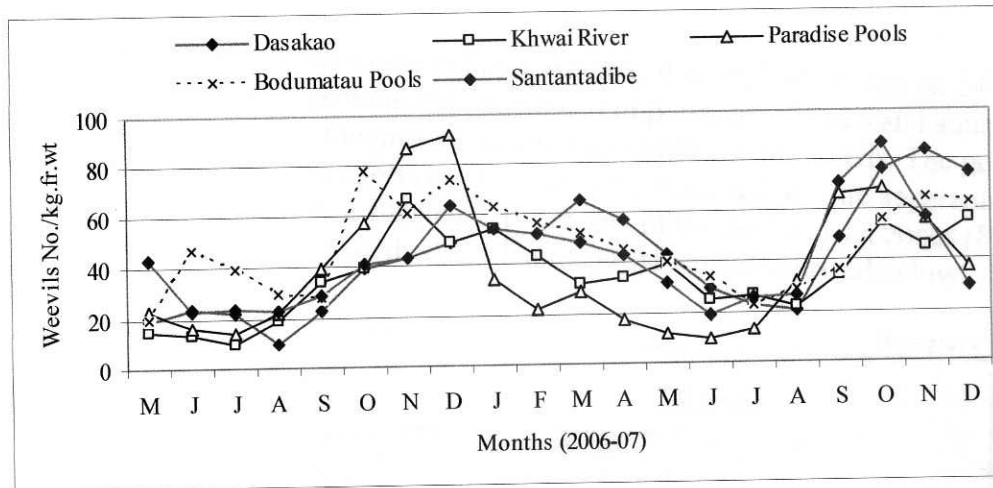
As soon as the salvinia was found in Lake Xini, the immediate concern was to prevent the weed from being spread by animals, tourists or water. As a pre-emptive measure, the infested Xini Lake and associated areas were fenced to prevent the animal movement. Subsequently the Lake and its wetlands were dried by pumping water using diesel-powered pumps and as a result, the dried salvinia mat was raked and burnt. As a back up measure, salvinia infested with weevils were collected from the Kwando River and introduced amongst the salvinia in Lake Xini. Similar operations were implemented to eradicate salvinia in Bodumatau hippo pools when the salvinia was found in July 1988. Physical control integrated with biological measures yielded substantial control of salvinia in these areas (Forno and Smith 1999). The dense weed mat in

Xaxanaka lagoon was removed with the assistance of the Department of Wild life in 1992. *Salvinia* was sighted in Gomoti River in 1985 and the weevils were released in the infested areas. The confidence in biological control increased through these operations and subsequent control has been carried out primarily using the approach, which is considered a biodiversity-friendly long-term alternate measure to chemical control measures. At times (where necessary), Physical control measures are integrated with the biocontrol.

### **5. Progress in Bio-control of *Salvinia***

Systematic and regular monitoring of *Salvinia* was discontinued after 1990 and there was a complete lack of scientific approach in the management of *salvinia* until 1996. With the result, thick re-infestations developed in several areas of Moremi Game Reserve. The Aquatic Vegetation Control Unit (AVCU) undertook systematic monitoring in 1998 in Paradise Pools, Khwai River and Dombo Lagoon and showed that biocontrol could be faster in closed systems like pools and lagoons than in the dynamic flowing rivers (Naidu et al. 2000), where control could be achieved in two to three years.

Systematic sites for *salvinia* monitoring were demarcated between January and March 1999 (Figure 2) in all the areas of infestations in the Okavango Delta. The exercise involved identifying acute problem areas of *salvinia* and areas with established biological control agent of the weed in the Delta. Biological control agent, *C. salviniae* with adults, larvae and eggs were collected in the areas of high density weevil populations and seeded them in the fresh infestations. These continuous releases of *C. salviniae* from April 1999 to December 2000 are one of the biggest releases ever undertaken in Botswana (Kurugundla 2003). *C. salviniae* populations were steadily built up in the released areas and by 2002 the *salvinia* infestations in Paradise Pools, Xini, Bodumatau, Oyi, Dombo Lagoon in Khwai River, Xakanaxa Lagoon in Maunachira River, Abaqao and Mogohelo were brought under control. The data obtained from May 2006 to December 2007 indicate that the weevils have established in several monitoring sites of the systems (Figure 3). The abundance of weevils in the infestations is temperature dependent and the breeding increases between 20-32<sup>0</sup>C in summer and declines in winter at or below 20<sup>0</sup>C (Naidu et al. 2000, Schlettwein 1985). The integrated control of *salvinia* is a continuous process and its responsibility lies with the Department of Water Affairs. However, efforts have been initiated to enhance the control and monitoring of the *salvinia* through Biokavango Pilot Project in the four problem areas of Moremi Game reserve (Figure 2).



**Figure 3 Successful areas of salvinia control in river channels, pools and lagoons in Moremi Game Reserve, Okavango Delta, data obtained between May 2006 and December 2007**

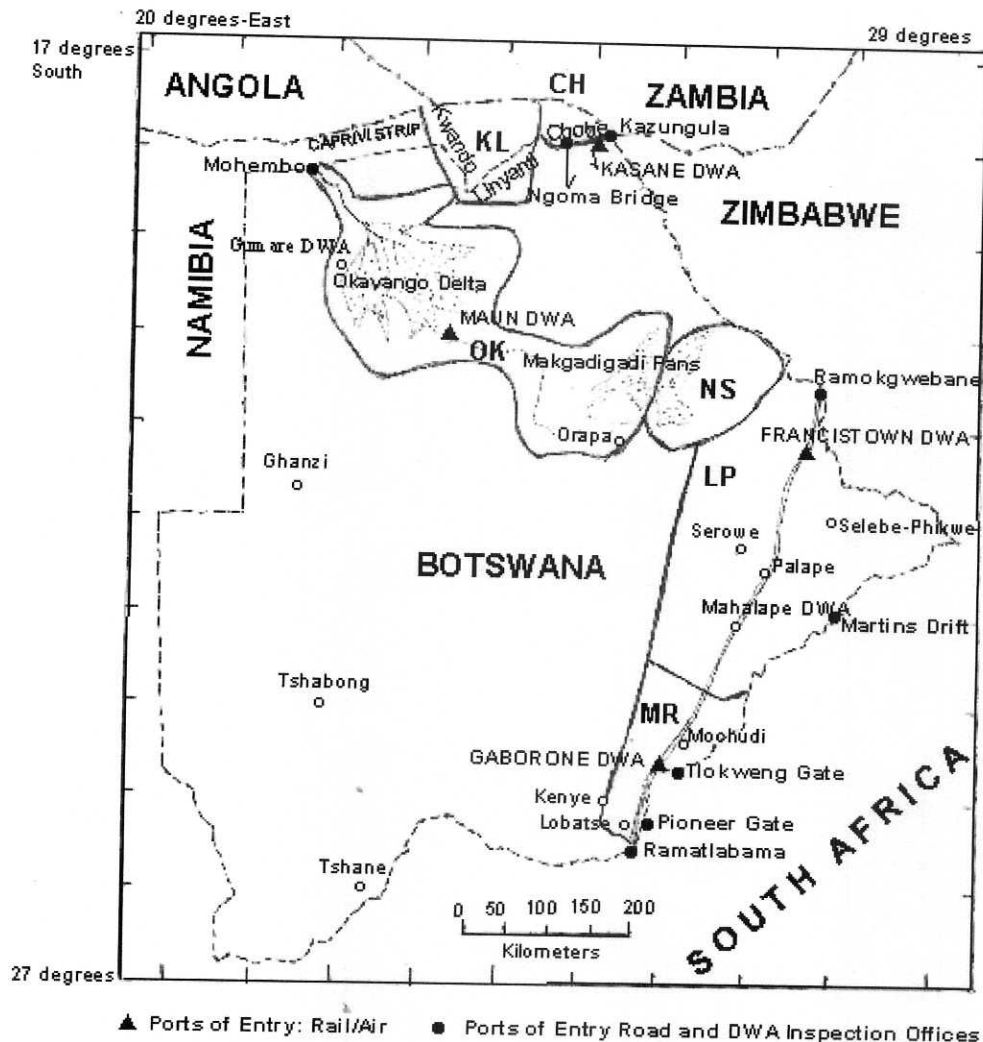
## 6. Collaborative Efforts in Building Local Capacity in the Bio-monitoring of Salvinia

DWA (through the AVCU) has been managing the weed by physical and bio-control programs in the Delta for the past 25 years. Despite the significant progress made in the last ten years, the DWA has experienced several constraints such as lack of funds, transport, man power, and complaints of staff sickness in implementing the program. The Biokavango Project (HOORC) is aimed at lifting barriers to mainstreaming biodiversity conservation objectives into three production sectors: water, tourism and fisheries. In the water sector, *S. molesta* is a potential threat to the Okavango Delta's biodiversity. The species has the potential to adversely affect Delta water systems by covering the surface water, blocking the channels, disturbing the biodiversity, deprive the livelihoods of rural communities and operations of private entrepreneurs. There is therefore a need to strengthen the integrated control and monitoring program for the weed.

As a result, both the Biokavango Project and DWA identified Tour Operators as key stakeholders whose capacity need to be built in the control and monitoring of the spread of the salvinia weed. Five companies viz., Camp Moremi, Moremi Safaris, Splash Camp, Sandebi Camp and Khwai River Lodge are engaged in implementing the intervention. In order to run the project, the Biokavango and DWA provided the infrastructure that includes the erection of salvinia weevil breeding pools and weevil extraction equipment in the Pilot sites. Two guides from each Safari Camp were trained to implement the monthly salvinia monitoring and data collection to determine the impact of weevils on salvinia infestation. Thus, the biocontrol techniques on salvinia control was transferred to the tour operators, who are actively engaged in the protection of biodiversity within their concession areas. The pilot intervention may be replicated in other infested wetlands of Botswana after considering the success of the pilot project.

## 7. Legislative Control

The Government of Botswana gazetted the Aquatic Weed (Control) Act on 24<sup>th</sup> October 1986. The Act regulates the inspection, movement and importation of boats and aquatic apparatus, such as fishing gear, to prevent the importation and spread of aquatic weeds. The government specifies inspection and disinfection procedures for boats and aquatic apparatus and they are checked and/or treated before passing between any of the declared six zones (Figure 4). The salient features of the Act described in Chapter 34:04 are summarized below.



**Figure 4 Six zones in Botswana showing port of entries by road, rail and air with DWA Inspection offices for boat registration and inspection**

1. Based on the surface waters and the presence of dams, the country has been divided into six zones viz., Okavango Zone-OK, Kwando-Linyanti Zone -KL, Chobe Zone-CH, Nata-Sua Zone-NS, Limpopo Zone -LP and Marico Zone-MR (Figure 4)
2. The inter zonal movement permits for the boats and aquatic apparatus must be obtained from the Department of Water Affairs situated in their respective zones

3. Import permits for the boats outside the country should carry import permits, which may be obtained from the Department of Water Affairs, Gaborone and Maun.
4. Traditional Mokoros are exempted from the registration
5. Any person found with boat without import permit, registration number, inter-zonal movement permit and herbicide treatment shall be guilty and upon conviction be liable to a fine of P1000.00 and/or imprisonment for 12 months or to both.
6. No person shall import into Botswana, or move within Botswana in possession of any aquatic weed, if found, shall be guilty of an offense and liable to a fine not exceeding P2000.00 or to a imprisonment for a term exceeding two years or to both.

## 8. Blockage Clearances

The Department of Water Affairs continuously monitors the blockages in the channels that impede the boat movement and reduce the downstream flows to the potentially productive areas (Figure 5). The blockage clearances are normally undertaken in the flood season as the dead and live vegetation such as papyrus and reeds move fast along with the high water currents blocking the channels. DWA faces a herculian task on the issue of channel blockages with the communities.



Figure 5 Clearance of vegetation blockage in Santantadibe River, Okavango Delta.

## 9. Public Awareness Program

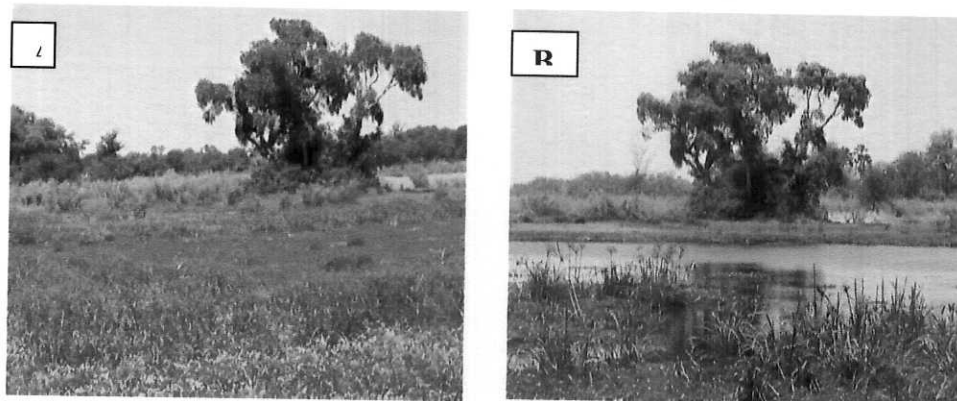
The Aquatic Vegetation Control Unit undertakes public awareness programs on annual basis. The program includes distribution of posters depicting the weeds and their impacts to water systems. Notices about the weed plants and danger of their importation are issued at the border posts and National Park entry points. Safari operators are consulted to disseminate information to the tourists. Regular Kgotla meetings are held to sensitize the communities about the danger of alien invasive species to the aquatic ecosystem. Sign boards for boat regulations and movements are erected at the port of entry points of international borders and road entry points to avoid conflicts between the stakeholders and the Aquatic Weed Control Act.

## 10. Challenges

DWA faces some challenges viz., monitoring salvinia in rainy season, inaccess to the infestations in high flood season and to the source of infestations in the blocked channels. Wild animals such as Hippos and elephants create a great concern in the continuous spread of salvinia in the wetlands of the Delta. Gillnets used by local fishermen causes a widespread of salvinia in the community dominated wetlands. The monitoring and inspection of boats has become a huge task for the AVC Unit due to lack of sufficient staff and transportation. Tour operators can play a key major role in controlling the infestations in their concession areas provided the managements undertake the salvinia monitoring as an important tool to protect the biodiversity in the Delta. Salvinia control being implemented by Biokavango and DWA can be a marketing tool for the Pilot Champions.

## 11. Conclusion

Botswana fight against alien invasive species had been initiated in 1972 by Agricultural Research and spearheaded by Water Affairs in the country. The assistance and services of safari operators, local communities and non-governmental organizations in the control of weeds and clearance of vegetation in the channels are invaluable. The department works with the other departments such as Environmental Affairs, Tourism, Wild Life and Okavango Research Center, University of Botswana to combat the weeds in the country



**Figure 6** How effective the biocontrol agent, the weevil of salvinia is! **A. April 2005 B. October 2005**

## References

- Edwards, D and P. A. Thomas. 1977. The *Salvinia molesta* problem in the northern Botswana and eastern Caprivi area. In: Proceedings of the Second National Weeds Conference of South Africa. Stellenbosch University, Stellenbosch, 2-4 February 1977, A.A Balkema, Cape Town, pp 221-237
- Forno, I. W. and K. L. S Harley. 1979. The occurrence of *Salvinia molesta* in Brazil. Aquatic Botany 6:185-187



Forno, I. W., D. P. A. Sands, and W. Sextone. 1983. Distribution, biology and host specificity of *Cyrtobagous singularis* Hustache (Coleoptera: Curculionidae) for the biological control of *Salvinia molesta*. Bulletin of Entomological Research 73: 85-95

Forno, I. W. and P. A. Smith. 1999. Management of the alien weed, *Salvinia molesta* in the wetlands of Okavango Delta, Botswana. In: Streever, W. (ed.). An International Perspective on Wetland Rehabilitation. P.159-166. Kluwer Academic Publishers, Netherlands

Kurugundla, C. N. 2003. Aquatic Vegetation Control Unit - Annual Report, September 1999 – March 2003. Department of Water Affairs. pp. 3-19

Naidu, K. C., I. Muzila, I. Tyolo and G. Katorah. 2000. Biological control of *Salvinia molesta* in some areas of Moremi Game Reserve, Botswana. African Journal of Aquatic Science 25:152-155

Room, P.M., K. L. S Harris, K.L.S. Forno, I.W. and D. P. A. Sands. 1981. Successful biological control of the floating weed *salvinia*, Nature, Lond. 294:78080

Schlettwein, C.H.G. 1985. The biological control of *Salvinia molesta*. Department of water Affairs, Namibia, Research Report W85/5. 10pp

SMEC. 1989. Ecological zoning. Okavango Delta. Final Report. Volume 1 – Main Report. SMEC, Cooma, New South Wales, Australia.

Smith, P. A. 1989. Vegetation. Pp.53-76 In: SMEC 1989. Ecological Zoning. Okavango Delta. Final Report. Volume 1 – Main Report. April 1989. SMEC, Cooma, New South Wales, Australia