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Short- and long-term control of water lettuce (*Pistia stratiotes*) on seasonal water bodies and on a river system in the Kruger National Park, South Africa

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Abstract

Water lettuce (*Pistia stratiotes* L. (Araceae)) is alien to Africa and a declared weed in South Africa. In large perennial rivers it is effectively controlled by its biological control agent, *Neohydronomus affinis* (Coleoptera: Curculionidae). On those shallow isolated water bodies which are regularly subjected to alternate wet and dry regimes that become infested with water lettuce, chemical control is necessary to prevent further spread of the weed and to facilitate access to water. This paper discusses the short-term chemical control and the long-term biological control of water lettuce. The need for further research is outlined.

Introduction

Pistia stratiotes L. (water lettuce) is an alien plant to South Africa, the country of origin being South America and it is a declared weed in South Africa (Henderson et al., 1987). Water lettuce is one of three significant aquatic weeds in the Kruger National Park (KNP). It occurs in a number of areas within the KNP including shallow seasonal water bodies (pans) in the northern Pafuri area, on the Limpopo flood plain and in the southern area on a perennial river, the Sabie River. This river is known to have the highest species diversity for aquatic plants in South Africa.

An objective of the KNP is to manage and control alien plant invasions so as to prevent the disruption of the natural ecosystems. The term control encompasses actions aimed at eradication, limiting, maintaining or reducing infestations. (Zeller, 1993).

The pans in which water lettuce is a problem are Nhlangaluwe (22 °33′S 31 °16′E) and, in the same vicinity, Dakamila, Makwadsi and Mapimbi. These pans are seasonal but may contain water for several seasons depending on rainfall, then be dry for one or more seasons. The Sabie River runs through the southern part of the KNP where originally 12 km of the river were infested with water lettuce: a sparse infestation further downstream was followed by a dense infestation at Lower Sabie over approximately three kilometers (16–20 hectare). The control of alien plant invasions are of particular concern in these pans. When not controlled, further spread of the weed, because of its rapid uncontrolled growth, is possible and access to water is limited. The water becomes deoxygenated under dense infestations of the weed, evapotranspiration is increased, the indigenous fauna and flora are threatened and the whole ecological balance upset, contrary to the objectives of the KNP (Chikwenhere & Forno 1991; Deacon & Gagiano, 1992; Zeller, 1993).

Control measures for water lettuce are thus important and have to be ecologically acceptable. Biological control was successful in Australia (Harley et al., 1984) and was first used in 1985/86 with great success in Africa on seasonal pans in Nhlangaluwe and later Dakamila in the northern part of the KNP (Cilliers 1987, 1991). When water lettuce control programmes were started in the KNP in 1987/88 on the Sabie River, two options, chemical and biological control were followed. The study area of biological control on the

Sabie River was at Lower Sabie (25 °07′S 31 °53′E). Downstream of Lower Sabie there is a dam wall and water flow was not as rapid in this area as elsewhere on the river but usually there was a continuous overflow at the dam wall. The progress of the biological control agent *Neohydronommus affinis* (Hustache) (Coleptera: Curculionidae) was monitored to ascertain whether the eventual degree of control obtained would fall within ecologically acceptable levels, as biological control does not eradicate the target plant.

Chemical control on the Sabie river and later on the seasonal pans in the Pafuri area was undertaken to keep water lettuce levels as low as possible, to prevent further spread of the weed, and to provide access for wild animals to and in water.

For the purpose of this paper chemical and biological control on the Sabie River and chemical control of water lettuce on seasonal pans are described.

Methods

Biological control

A starter colony of the host specific beetle *N. affinis* was obtained and imported into South Africa from CSIRO, Brisbane, Australia in 1985. The beetle was first introduced onto a water lettuce infestation on Nhlangaluwe pan in December 1985 and the progress and effect on the plants was monitored (Cilliers, 1987). A population of 500 adult *N. affinis* was first released on the Sabie River at Lower Sabie in September 1987. Four further releases of between 100 and 1000 adults and larvae, totalling approximately 5000 beetles, took place over the next five years. The most important of these later releases were those beetles introduced at the source of the infestation in the Salitje River, upstream of Lower Sabie in July 1990 and again in January 1991. Various parameters were monitored every six weeks from August to May of each year in order to assess the progress and effect of *N. affinis* on water lettuce in this flowing river. The methods used were the same as described by Cilliers (1987). More parameters were included for the Lower Sabie monitoring than previously. For the purpose of this paper only the number of plants per m^2 and the number of those plants that were damaged by *N. affinis* as an index of beetle activity were analyzed. The samples were taken along two fixed transects, across the river and following the northern bank. The samples were taken from the left and right side of a boat where plants were present. Reference is made to the percentage of the total area covered by water lettuce, and stream flow was used to explain plant population fluctuations. The area covered by water lettuce at Lower Sabie was estimated from colour slides and photos taken from fixed points whenever sampling was undertaken and twice daily over the period September to October 1992. The total area at Lower Sabie where the water lettuce occured was 40 ha. The programme, Statgraphics Plus, Version 6, 1992, Manugistics Inc., USA was used to analyze the data.

Chemical control

The herbicide terbutryn was used for the chemical control of water lettuce, applied at a 3% mix with water either from a boat or from the river banks using CP15 backpack spray units. Aerial application of herbicide was by means of a helicopter using a micronair system giving 6 liters ha^{-1} at a 30% mix with water. Repeated follow-up operations were carried out. Chemical control was applied towards the end of the dry season when water levels were low, the plants more concentrated and access easiest. Areas under control were visually monitored for the presence of plants.

Results

Biological control

On Nhlangaluwe pan, in the Pafuri area, biological control was achieved within ten months (Cilliers, 1987). This pan then dried up and no water lettuce remained. Similar results were obtained at a nearby pan, Dakamila (Cilliers, 1991). When these two pans and two others, in the vicinity, Makwadsi and Mapimbi, again had water they became covered with water lettuce. Meanwhile it had been established that water lettuce produced viable seed in South Africa (Henderson & Cilliers, 1991). This provided an explanation as to why these isolated pans again became infested after a dry period. Although beetles were reintroduced onto the water lettuce these pans were also sprayed with herbicide. This decision was taken in order to try to deplete the seed reserve by preventing new seed reserves forming through continuous short term control.

At Lower Sabie the beetle population remained low and it was only a year after the initial release of beetles, in September 1987, that the beetle population and

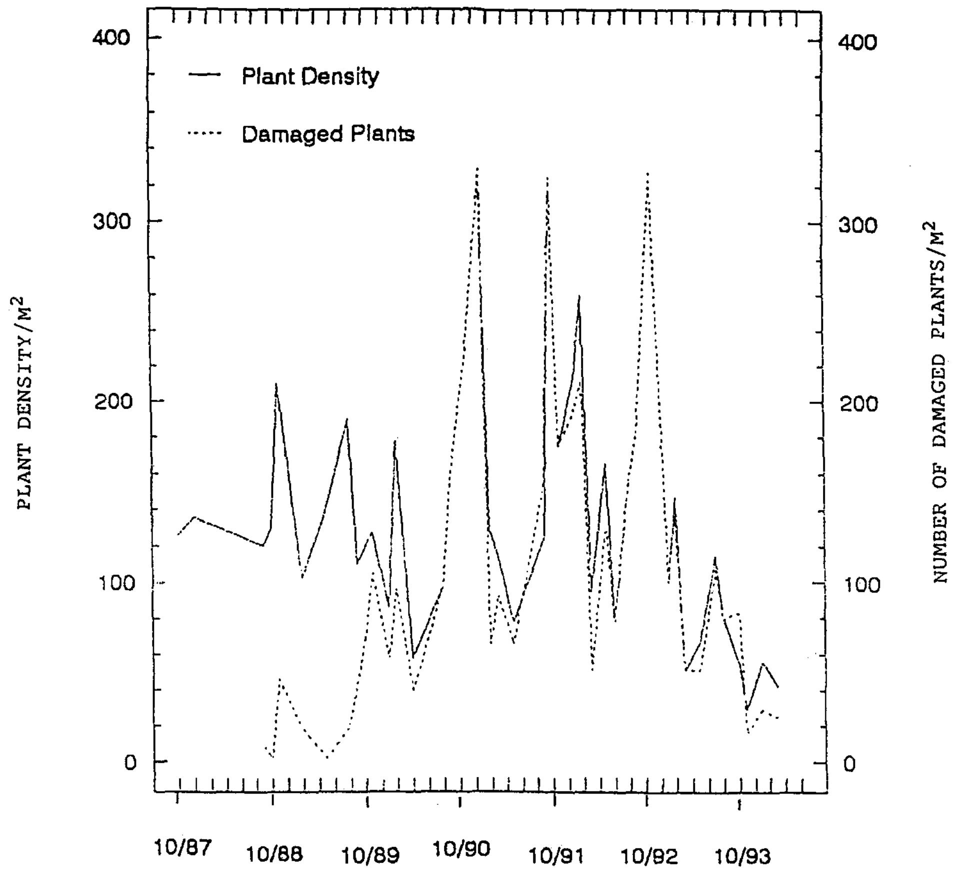

Figure 1. Time sequence plot of *Pistia stratiotes* (water lettuce) density per m^2 and the number of those plants damaged by the biological control agent *Neohydronomus affinis* at Lower Sabie. October 1987 to March 1994.

thus beetle damaged plants, could be readily observed during monitoring.

The density of plants in September 1988 was 120 m^{-2} of which only 8 plants showed insect damage (Figure 1). The total area covered by water lettuce was 60% (24 ha). Cyclical fluctuations occurred in the following years not only in plant population but also in number of beetle damaged plants. Plant populations peaked in November to February (summer) each year with a corresponding decline towards winter (Figure 1). By November 1990 and January 1991 all plants were damaged by *N. affinis*. However, large numbers of healthy plants were continually found at the top end of the study area where sampling was not done. In 1990 it was discovered that the Salitje river, a tributary of the Sabie River and upstream of Lower Sabie was a source of beetle free plants and beetles were therefore released on to plants in this river. In May and October 1991 and through to March 1992 those plants with insect damage were between 54–100%. In March 1992 not many plants were recorded per m^2 but the total area covered in water lettuce at Lower Sabie was 80% (32 ha) as opposed to between 10 to 15% (4 to 6 ha) cover in the previous year. In May 1992 the plant density again increased followed by a small decline in June 1992 and again a steady increase to November 1992. This was during a drought period in which temperatures were often above 40 °C and it was thought that more beetles were needed to curb the increase of plants. Booster colonies were released in April and May 1992. By September 1992 the surface covered by water lettuce had been reduced to less than 10% of the total area (less than 4 ha) with a continuous decline to 42 plants per m^2 in March 1994 (Figure 1). The positive correlation between plant density and number of damaged plants is illustrated by the high regression coefficient of $r^2 = 68.30\%$ (0.683), degrees of freedom = 37 (r^2 = the square of the correlation coefficient

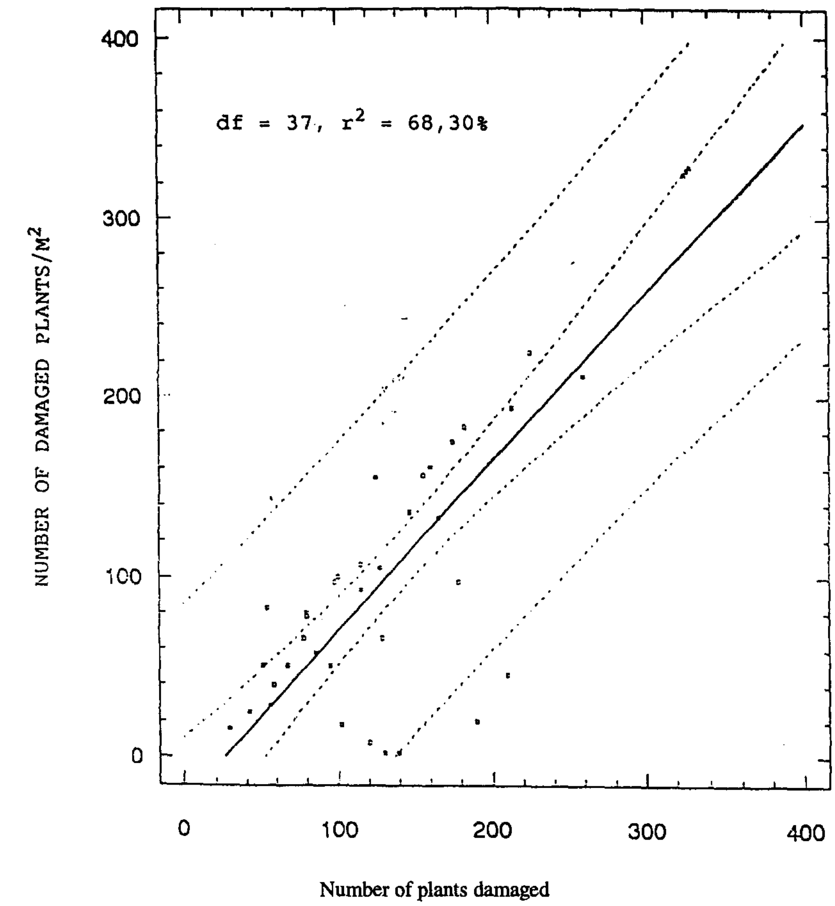

Figure 2. Regression of *Pistia stratiotes* (water lettuce) density per m^2 and the number of those plants damaged by the biological control agent *Neohydronomus affinis* at Lower Sabie, October 1987 to March 1994. $r^2 = 68.3\%$, df=37. The solid line is the regression line. The pair of hatched lines closest to the regression line represent the 95% confidence limits. The pair of hatched lines furthest from the regression line represent the 95% confidence limits for future predictions.

as a percentage or 68.30% of 1 = 0.683) (Figure 2). A time series analysis of mean monthly river flow and the plant density showed an increase in plant numbers when there was a reduction in flow (Figure 3) and partly explained the increase in total area covered by water lettuce. If we restrict the prediction to the period after January 1990 when most of the plants were insect damaged the regression ($r^2 = 92.9\%$ (0.929) with degrees of freedom = 31) is further strengthened by restricting the regression to periods of low flow of less than 15 m^3 s^{-1} to give $r^2 = 95.88\%$ (0.9588) with degrees freedom = 21 (Figure 4).

By 1991 and the beginning of 1992 it was clear that *N. affinis* could control *P. stratiotes* on a flowing river.

Chemical control

Twelve kilometers of the Sabie River from Skukuza downstream were heavily infested with water lettuce and it was decided to chemically control this infestation. By the end of 1988 six kilometers of river below Skukuza were under control. During 1989 chemical control was continued and a further 6 km were brought under control and three follow-up operations were carried out on the total of 12 kilometers that year and again in 1990. At this time it was thought that water lettuce had been eradicated from this stretch of river and no controls were carried out during 1991. This proved to be wishful thinking as 49 man days, 11.5 litres herbicide, and a fortunate flooding of the river, were required to again clear this infestation during

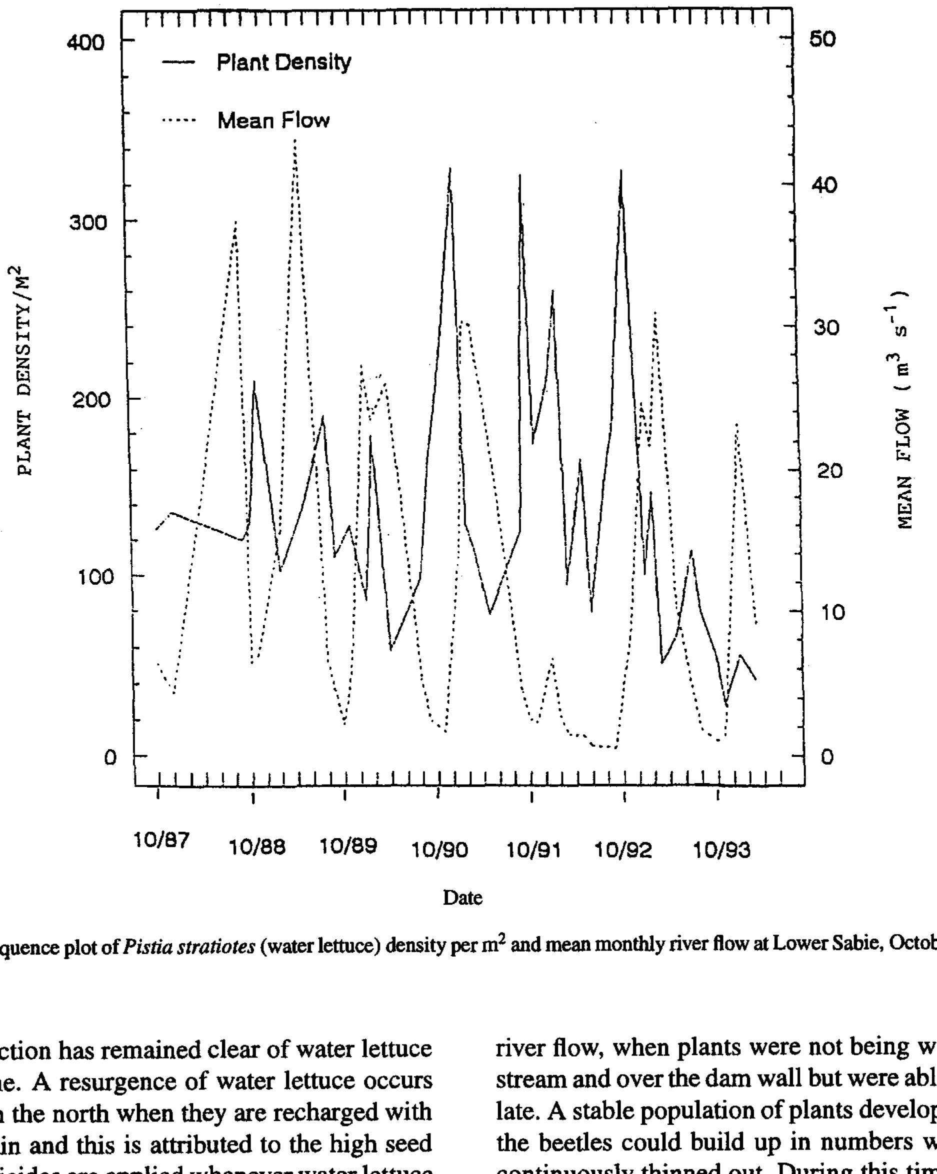

Figure 3. Time sequence plot of *Pistia stratiotes* (water lettuce) density per m^2 and mean monthly river flow at Lower Sabie, October 1987–March 1994.

1993. This section has remained clear of water lettuce since that time. A resurgence of water lettuce occurs on the pans in the north when they are recharged with water after rain and this is attributed to the high seed reserve. Herbicides are applied whenever water lettuce starts appearing, and before the plants are able to seed, in an attempt to reduce the seed reserve.

Discussion and conclusion

In biological weed control there is no eradication of the target plant but the aim is to bring the weed population down to an environmentally/ecologically acceptable level through the use of one or more natural enemies. The dramatic increase in the surface area of the study site covered in water lettuce during March to September 1992 was attributed to the extremely low river flow, when plants were not being washed downstream and over the dam wall but were able to accumulate. A stable population of plants developed on which the beetles could build up in numbers without being continuously thinned out. During this time plants that were beetle damaged varied between 80–100% (Figure 1). It was thus wrong to assume that the beetles may have succumbed to heat experienced during the excessive drought and booster colonies were unnecessary. A series of photographs taken in September and October 1992 showed that the water lettuce was being moved either towards the study area or away from it depending on the wind direction. Based on these facts it is concluded that *N. affinis* was able to control water lettuce on a flowing river and other natural enemies of water lettuce need not be considered further. Without the fixed point photography a wrong impression might have been formed of the area covered with water let-

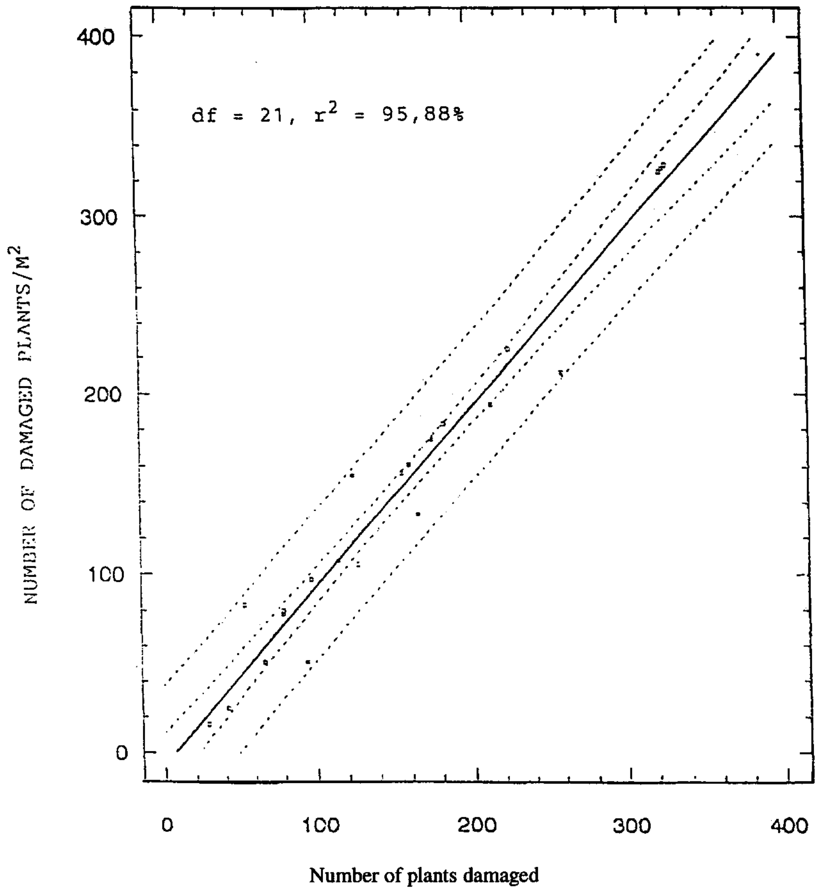

Figure 4. Regression of *Pistia stratiotes* (water lettuce) density per m^2 damaged by the biological control agent *Neohydronomus affinis* at Lower Sabie when mean river flow was below 15 m^3 s^{-1}, January 1990 to April 1994. r^2 = 95,88%, df = 21. The solid line is the regression line. The pair of hatched lines closest to the regression line represent the 95% confidence limits. The pair of hatched lines furthest from the regression line represent the 95% confidence limits for future predictions.

tuce at Lower Sabie as the samples were always taken where plants occurred along the transect lines. Future sampling needs to take this factor into consideration.

The Sabie River system, the pans in the Limpopo flood plains and elsewhere in the KNP are of priority concern in the control of water lettuce. Biological control is very successful on the pans and on the Sabie River. It will remain the main form of control of *P. stratiotes* in the KNP, but will be augmented by chemical control where necessary. On the Sabie River at Lower Sabie a cover of less than 10% of the water surface is presently regarded as the residual plant population that has to be tolerated. There is still further need for research on the influence of *P. stratiotes* on a sensitive section of the Sabie River in Sabie Poort 10 km downstream of Lower Sabie. In the Sabie Poort River braided channels in the dry season become isolated pools covered with water lettuce. Although the beetles also eventually control water lettuce here, the rotting plants cause eutrophication of the water. Herbicidal control would have the same effect. These pools are important habitats for many aquatic species, being home to more than 10 species of fish of which one species is endemic to the Sabie River. Two highly sensitive species have already become extinct in the Olifants River (Dr A. Deacon, personal communication, Kruger National Park, Skukuza, 1993). This problem needs further research.

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