Proc. VI Int. Symp. Biol. Contr. Weeds, 19–25 August 1984,
Vancouver, Canada. Delfosse, E.S. (ed.). Agric. Can., pp. 557–65 (1985)

Use of the Chinese Grass Carp, *Ctenopharyngodon idella*, in the Control of the Submerged Water Weed *Potamogeton pectinatus* in an Inland Lake in the Transvaal, South Africa

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Abstract

As a result of nutrient loads trapped in sediments of Germiston Lake, Transvaal, which was rehabilitated from acid pollution from gold mine dumps, the submerged aquatic weed *Potamogeton pectinatus* invaded the littoral zone of the lake, seriously threatening recreational use of the water body. Attempts at mechanical removal of the weed proved ineffective. Chemical control was not considered because of costs involved and the possible health hazard it might pose.

An indigenous warm-water weed-eating cichlid *Tilapia rendalli* introduced experimentally into the lake did not survive prevailing winter water temperatures below 10°C. The Chinese grass carp was then introduced which not only grew well but also succeeded in controlling the excessive growths of *P. pectinatus* in the lake within 18 months.

Utilisation de la Carpe Herbivore *Ctenopharyngodon idella* pour la Lutte Contre la Mauvaise Herbe Aquatique Submergée *Potamogeton pectinatus* dans un Lac de la Province de Transvaal, en Afrique du Sud

La libération des charges alimentaires enfouies dans les sédiments du lac Germiston de la province de Transvaal au cours de sa dépollution (il avait été acidifié par l'infiltration des résidus de mine d'or) a provoqué la prolifération de la plante nuisible aquatique submergée *Potamogeton pectinatus* qui a envahi les rives du lac et a ainsi gravement nui à l'utilisation récréative de la nappe d'eau. Les tentatives d'élimination mécanique de la plante nuisible ont été inefficaces. La lutte chimique n'a pas été prise en considération compte tenu des coûts élevés et des dangers qu'elle risquait de poser pour la santé.

Un cichlidé herbivore indigène des eaux chaudes, *Tilapia rendalli*, a fait l'objet d'essais d'ensemencement, mais il n'a pu résister aux températures dominantes inférieures à 10°C de l'eau pendant l'hiver. La carpe herbivore *Ctenopharyngodon idella* a ensuite été introduite; ce poisson s'est non seulement bien développé dans le lac, mais y a également réduit la croissance excessive de *P. pectinatus* en 18 mois. Le rapport traite des possibilités de l'utilisation de ce poisson dans la lutte contre les mauvais herbes aquatiques en Afrique du Sud.

Introduction

Shifts in population densities in South Africa towards the more industrialized regions, largely confined to the Transvaal, where many gold mines are concentrated, has led to increased dependence there of man on impoundments for domestic, industrial and recreational needs. Germiston Lake near Johannesburg, *c.* 58 ha in size, with a relatively small catchment area of just over 1100 ha receives much of its water through stormwater drains. Apart from occasional minor pollution which occurred in the lake from effluents of metal industries, the quality of the lake water prior to 1969 was largely affected by seepage of highly mineralized acid water from nearby worked-out mine and ash dumps. Pollution of the lake water by mine and industrial effluents, which prohibited fish life for more than eighty years, dates back to the turn of the century when the lake was originally used to receive water and mineral-rich sludge pumped from the then-active working, but now defunct, Simmer and Jack gold mine.

In 1969 the first steps were taken by the Department of Zoology of the Rand Afrikaans University in collaboration with the municipal authorities of Germiston to rehabilitate the lake from pollution (Vermaak 1972). At that time, prior to remedial measures being taken to rid the lake from pollution, the pH of the lake water (largely affected by concentrations of sulphuric acid in seepage water from mine dumps), fluctuated mainly between 3.5 and 4.5. Mineral loads in the water contributed much to high conductivities recorded which exceeded 2500 μS/cm on occasions (Table 1).

Table 1. Some physico-chemical parameters of the water in Germiston Lake based on mean values obtained at 8 sampling localities during the various seasons of 1969-1970, 1978 and 1983. All values except pH and conductivity, in mg/l; analyses done according to Apha (1977).

Parameters	1969-1970		1978		1983	
	Mean	Range	Mean	Range	Mean	Range
pH	–	3.5-6.9	–	7.8-9.2	–	7.8-8.8
Conductivity (μS cm^{-1})	2009	1644-2580	982	922-1061	793	700-880
DO	6.9	6.5-7.6	9.8	6.1-12.4	–	–
BOD	1.7	1.1-2.4	2.4	1.1-4.4	–	–
Total Alkalinity	20	11-31	73	65-82	–	–
Total Hardness ($CaCO_3$)	1074	890-1290	429	403-460	329	300-347
Mg-Hardness ($CaCO_3$)	395	310-505	165	144-190	–	–
Ca-Hardness ($CaCO_3$)	678	580-785	264	247-785	–	–
Cl^-	122	100-153	87	80-98	72	62-85
$SO_4^=$	978	886-1094	297	280-320	272	240-320
SRP ($PO_4^=$)	0.05	0-0.30	0.09	0.05-0.20	0.11	0.003-0.30
NO_3–N	2.76	2.2-3.6	1.59	1.45-1.75	0.90	1.50-1.00

Similarly, values obtained for total Mg and Ca hardness as well as those for chlorides and sulphates were all exceptionally high (1969–70 results, Table 1). First steps in recovery of the lake from pollution were taken in 1969–70. The various sources of mineral and organic pollution were first located (Vermaak 1972) and where possible, immediately eliminated by the City Engineer's, Parks and Recreation and Health Departments of the municipality. Seepage water emanating from the mentioned mine and ash dumps were diverted into a canal around the lake. To render the lake water more alkaline, more than 10^6 *l* NaOH was added, followed by the dispersal into the lake of *c.* 59 t of agricultural lime. Largely as a result of investigations by Vermaak (1972) and subsequent monitoring of conditions in the lake, no further serious pollution occurred. Due to strict control measures by municipal authorities (which followed elimination of major sources of pollution) but also as a result of periodic influx of rainwater into the lake, mineral loads in the lake water, as reflected by conductivity and related parameters (Table 1), rapidly declined by almost 40% within the first year of recovery. Since 1970 a progressive decrease in the mineral loads of the lake took place accompanied by dramatic increases in pH-values, which in 1978 and 1983 constantly fluctuated above 7 (Table 1).

Values for dissolved oxygen recorded in the lake, which ranged between 6.5 and 7.6 in 1969, began to fluctuate more during the subsequent years when water quality conditions began to improve. This was accompanied by increased algal blooms, especially during winter and the rapid development of submerged aquatic weeds.

Introduction of Fish into Lake

With the recovery of the lake water from pollution in 1970 certain fish species were introduced which could utilize the benthic macro-invertebrate fauna as well as the filamentous algal growths which covered the lake substrate. As a result of the occurrence of large numbers of chironomid larvae (Diptera: Chironomidae) and their flying adult stages which became a nuisance to people dwelling nearby, the benthic-feeding common carp *Cyprinus carpio* and Vaal river yellowfish *Barbus holubi* were released into the lake during 1971 followed by the largely algal feeding cichlid *Tilapia sparramanii*. With the exception of the yellowfish, which requires running water and a gravelly substrate to spawn, both the other two species reproduced so successfully after one year that two predators (namely the African sharptooth catfish, *Clarias gariepinus*, and the largemouth black bass, *Micropterus salmoides*) had to be introduced to control their numbers. Of the latter two species, *C. gariepinus* also spawned successfully in the lake. Since 1973 the lake developed into a popular angling resort.

The Problem of *Potamogeton pectinatus* L. (Potamogetonaceae)

At the time of its recovery from pollution in 1971–72 only three species of aquatic macrophytes were observed to occur in appreciable densities in the lake; namely *Phragmitis communis* Trin. (Gramineae), which largely occurred around the southwestern perimeter of the lake, *Scirpus lacustris* L. (Cyperaceae) and *Lagarosiphon major* (Ridley) Moss (Hydrocharitaceae) (Vermaak 1972). In view of the improvement of water quality conditions, it was anticipated that a greater variety of aquatic organisms would appear and proliferate in the lake. It was also expected that the thick deposits of nutrient-rich sediments might facilitate increased growths and expansion in the lake of the already mentioned isolated stands of *Scirpus* and *Lagarosiphon*. In 1972 a small colony of *Potamogeton pectinatus* was observed in the lake. Since then and over a period of 3 yrs this species invaded the entire littoral zone of the lake, replacing almost completely *Scirpus* and *Lagarosiphon*. By 1978 the estimated wet biomass of *P. pectinatus*, based on seasonal quantitative transect studies on distribution of this weed in the lake (Fig. 1), amounted to 1329 t during summer with a winter maximum of 95 t (Vermaak *et al.* 1981). Seasonal biomass ratios of this weed was 1:2:4:8 for spring, winter, autumn and summer 1978, respectively. Due to clarity of the lake water column and active light penetration to the bottom of the lake at depths exceeding 3 m, densities in stands of *P. pectinatus* were still comparatively high at distances of 50 m and more from the shoreline (Fig. 2; data for 1978).

Steps to Control *P. pectinatus*

The progressive and rapid invasion of the lake by *P. pectinatus* seriously threatened effective management of the lake since 1973 and also made it virtually impossible for large portions of it to be used for water sport and recreation such as skiing, yachting and angling. Steps to combat the infestation of this weed were first taken by the Parks

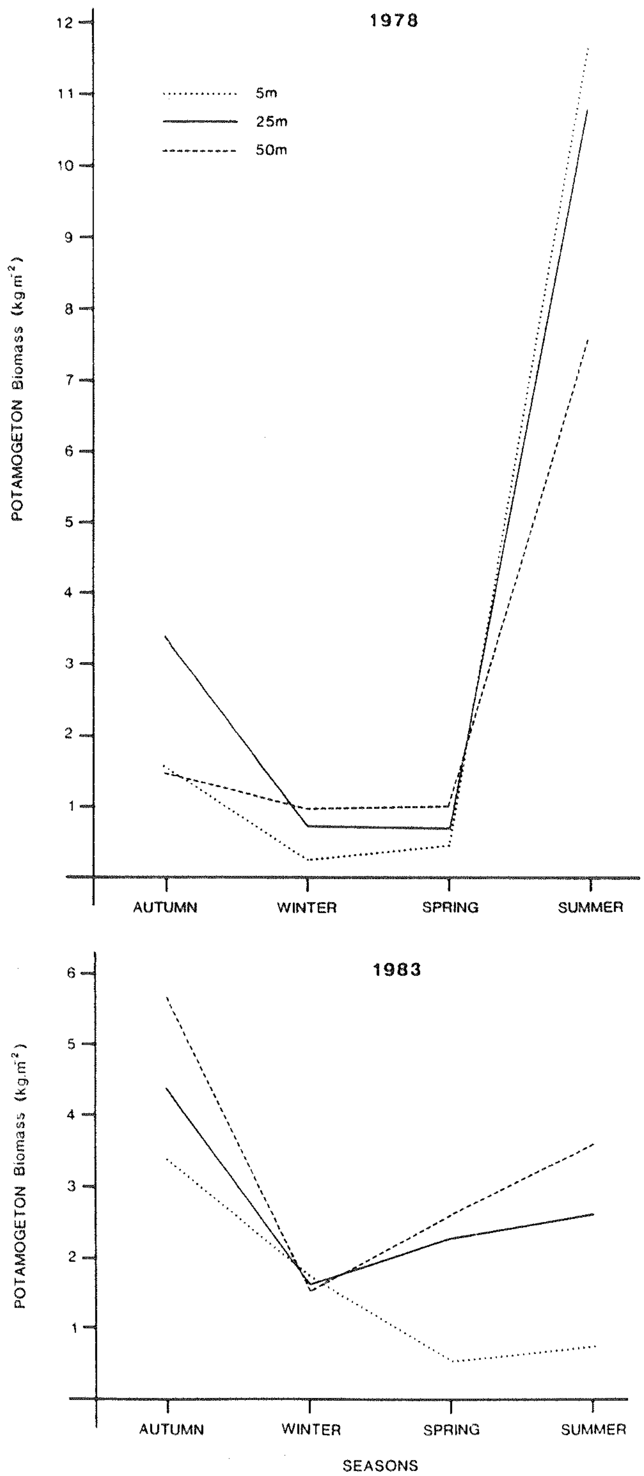

Fig. 1. Comparison of mean wet biomass values (kg/m^2) for *Potamogeton pectinatus* L. across transects at distances of 5, 25 and 50 m from the shore at eight localities in Germiston Lake for the various seasons of 1978 and 1983.

and Recreation Department of the municipality in July 1973 when a floating Wilder underwater weedcutter was purchased for mechanical removal of the plant at depths of up to 2 m below the water level. Despite acquisition of a second weedcutter in February 1975 it was still not possible to control this weed effectively. It was also found that annual operational costs to cut and remove the weed from the lake area became prohibitive, increasing to more than SA R100,000. From results obtained on mechanical removal of this weed it was clear that only limited success would be obtained controlling this weed in this way despite the high costs and efforts involved.

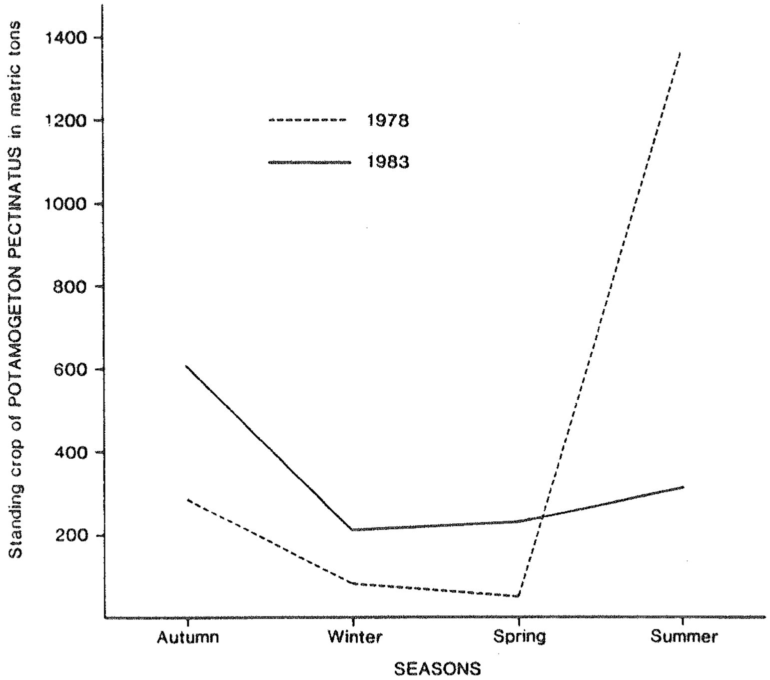

Fig. 2. Comparison of standing crop of *Potamogeton pectinatus* L. in Germiston Lake for the various seasons of 1978 and 1983.

Use of herbicides by research workers in South Africa and elsewhere for successful control of floating weeds such as water hyacinth, *Eichhornia crassipes* (Mart.) Solms. (Pontederiaceae) (Wild 1956; Robinson 1965; Van Donselaar 1968; Scott *et al.* 1979) was not considered, as even higher concentrations of weed killer would be needed for control of submerged weeds, and it was feared that levels of herbicide required to control *P. pectinatus* in Germiston Lake could be harmful to other aquatic organisms. Also, the danger existed that the levels of herbicide residues released into the water might exceed limits specified by the Department of Health of South Africa.

The possibility of using an indigenous weed-eating freshwater fish to control *P. pectinatus* was also considered as an alternative to mechanical removal, or use of herbicides, which was left as a last resort should all other attempts to control *P. pectinatus* fail. Apart from *T. sparrmanii,* which is omniverous but primarily an algal feeder (Crass 1964; Jubb 1967), none of the other already-mentioned fish species introduced into the lake were able to utilize *P. pectinatus* as food. The only indigenous South African freshwater fish known to actively feed on aquatic macrophytes is the red-chested tilapia, *T. rendalli* (Jubb 1967; Potgieter 1974; Bruton *et al.* 1982). This fish was released experimentally in the lake during 1973, in a cage enclosure at a density of 1 fish/m^2. At this density, *T. rendalli* was found to control *P. pectinatus* stands successfully during summer. Being a warm-water fish, however, it could not survive the colder, winter water temperatures which declined below 10°C in the lake. Mass mortalities occurred when the mean water temperatures declined below 14°C.

Introduction of the Chinese Grass Carp, Ctenopharyngodon idella *Val. (Cyprinidae)*

Since none of the local indigenous fish species were able to control effectively excessive growths of submerged aquatic weeds under low temperature water conditions (Kruger and Brandt 1975), the Chinese, phytophagous, cold temperature tolerant, grass carp *C. idella* was first imported into South Africa from Malaysia by the Natal Parks and Fish Preservation Board for the purpose of investigating this fish in aquatic weed control programs. These fish, kept at the Umgeni Fish Hatchery in Natal, were spawned artificially with limited success in 1974. Some of these fish so produced were used in some experimental control of aquatic weeds in Natal. In 1975 a second group of 330 grass carp juveniles were imported from Mindelaltheim, West Germany, by the Marble Hall Fish Research Station of the Division of Nature Conservation of the Transvaal Provincial Administration (DNC). These fish were grown to maturity and successfully spawned with the aid of carp pituitary gland extract (*PGE*) and human chorionic gonadotropin (*HCG*) in 1977 (Schoonbee *et al.* 1978). Since then, methods for large-scale artificial spawning of this fish species were perfected under local conditions at various fish hatcheries in southern Africa (Brandt and Schoonbee 1980; Schoonbee and Prinsloo 1984).

After obtaining permission from and in co-operation with the DNC, grass carp juveniles, spawned in 1981 at the Umtata Fish Hatchery of Transkei and grown to an average size of 26.9 g, were transported in oxygen-filled plastic bags to the lake. A total of 7000 juveniles were released on 27 November 1982 in an open cage, 50 $\times$ 20 m, sunk into the lake substrate and isolated from the rest of the lake by 10 mm nylon mesh screen as enclosure. After 6 wks acclimation, the fish were released into the lake. A set of fine mesh steel screens prevented the fish from leaving the lake at its point of outflow. An anticipated 30% mortality was allowed for as the fish were of large enough size not to be caught so easily by fish-eating birds such as cormorants which frequent the lake in large numbers.

Observations on Growth of Grass Carp in Germiston Lake

Gill nets were used to sample the fish on two occasions after their release, namely after 298 days (21 September 1983) and again after 436 days (11 February 1984) towards the end of the 1983–84 summer period. No serious mortalities of grass carp released into the lake were observed. Results obtained on growth performance of the fish based on number caught are represented in Table 2 and Fig. 2.

During the first 298 days after release of grass carp in the lake (which included winter 1983), fish (mass 1187 g) were found to grow at an average rate of 3.9 g/day. In a further 138 days and at a mean mass of 4023 g the growth rate of the grass carp over the 1983–84 summer season amounted to 10.18 g/day (Table 2; Fig. 1).

Comparison of P. pectinatus *Biomass in 1983 with that of 1978*

To determine possible effects of grass carp on biomass of *P. pectinatus* in 1983, procedures followed in collection and processing of the weed were the same and at the identical localities, as well as along the same transects, as those for the 1978 surveys

(Vermaak *et al.* 1981). A comparison of the results obtained for 1983 with those of 1978 (Fig. 1) showed that for autumn, biomass values at all three distances from the lake shore, were in each corresponding case higher during 1983. These findings are in agreement with observed increases in densities of *P. pectinatus* during 1980–83 and substantiate the problems experienced by people using the lake for recreation. The results also indicated that the young grass carp still could not cope successfully at that stage in controlling the weed. A similar situation existed during winter with the biomass of *P. pectinatus* still being higher than that of 1978. A dramatic change occurred, however, during spring and summer of 1983, when not only a drastic increase in the size of the individual grass carp was observed, but the effective and spectacular control of otherwise luxurient growths of *P. pectinatus* of previous years, occurred. Where the mean summer biomass values for *P. pectinatus* fluctuated between 7.6 and almost 12 kg/m^2 during 1978, this was reduced to vary betwen 0.8 kg/m^2 (5 m from shore) and 3.6 kg/m^2 (50 m from shore) for 1983. The sharp reduction and eventual disappearance of *P. pectinatus* from the upper layers of the lake water since summer 1983 is further demonstrated by figures calculated for standing crop of this weed for the corresponding seasons of 1978 and 1983 (Fig. 2). Here again it can be observed that during the initial months after release of grass carp, the estimated *P. pectinatus* biomass for 1983 compared with 1978 were still higher by between 50 t and 150 t, respectively (autumn and winter, Fig. 2). However, between spring and summer 1983, when the estimated biomass of the grass carp ranged between 360–480 kg/ha, this fish was able to control the growth of *P. pectinatus* completely in Germiston Lake. Since release of grass carp in Germiston Lake in November 1982 it has not been necessary to use any other method of weed control.

Table 2. Biomass (g) and fork length (cm) measurements of grass carp, *Ctenopharyngodon idella* Val. at the time of introduction, after 298 and 436 days respectively, in Germiston Lake[1].

		Fish biomass (g)			Fork length (cm)		
Date	*n*	*x*	Range	S.D.	*x*	Range	S.D.
27-11-82	121	26.9	5.3-70.2	± 14.5	11.8	7.8-17.20	±2.2
21-09-83	10	1187.0	724-1836	±301.0	40.5	36.00-48.20	±3.5
06-02-84	10	4022.5	3351-4795	±440.0	58.6	55.00-60.90	±1.8

[1] First introduction of fish into cages in lake.

The Problem of *Bothriocephalus gowkongensis* (Bothriocephalidae)

Even though strict precautionary measures were taken to prevent importation of diseases with grass carp into South Africa, indications are that an outbreak of *B. gowkongensis* at the Transvaal Provincial Fisheries Research Station, at Marble Hall amongst the common carp *C. carpio* was due to an original infestation of grass carp brought in from West Germany (Brandt *et al.* 1981). This parasite which uses a cyclopoid copepod as intermediate host for part of its larval development was also recorded from other cyprinid fish at other localities in the Transvaal. An effective treatment against the parasite for pond fish was worked out using the cestocide Lintex (2′,5′-dichloro-4′-nitrosalicylamide) a Bayer niclosamide preparation (Brandt *et al.* 1981).

Concluding Remarks

The use of the Chinese grass carp, *C. idella*, to control the aquatic weed *P. pectinatus* in Germiston Lake, Transvaal, has been achieved within a period of 18 months and indications are that this fish will be able to stabilize growth of this weed to acceptably low levels providing a certain number of the fish can be maintained in the lake in the future. Further investigations will, however, have to be made on the possible impact of *C. idella* on the rest of the lake ecosystem. Such information will be valuable in any future use of this fish species if similar weed control programs in the Transvaal may be contemplated. The considerable impact of a relatively small number of grass carp on the density of *P. pectinatus* in the lake clearly points towards the care that must be taken not to overstock a water body with this fish in the event of a control program. A knowledge of the standing crop and the preference of the fish for a particular weed that needs to be controlled is of the utmost importance.

Acknowledgments

This paper is dedicated to our colleague, the late Dr. J.F. Vermaak, who was intimately involved in the rehabilitation of Germiston Lake and who died tragically during an accident on 22 October 1983. Our sincerest thanks are due to the Municipality of Germiston for their generous financial support which made this study possible and to the staff of the various Municipal Departments, who played an active role in the elimination of the various sources of pollution. The financial assistance of the Victoria Lake Yacht Club is also hereby gratefully acknowledged. The Division of Nature Conservation of the Transvaal Provincial Administration is thanked for allowing us to use the Chinese grass carp for the control of *P. pectinatus* in Germiston Lake. The Department of Zoology of the University of Transkei is thanked for the provision of grass carp juveniles which were spawned at the Umtata Fish Hatchery for the purpose of this investigation. Lastly this work was made possible by equipment and laboratory facilities provided through the Department of Zoology of the Rand Afrikaans University.

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