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Control of *Hydrilla verticillata* in a New Zealand Lake Using Triploid Grass Carp

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Hydrilla verticillata, a submerged aquatic plant causing major weed problems overseas, presently has a restricted distribution in New Zealand. *Hydrilla is* established in 4 lakes in the Hawkes Bay Region of the North Island. Physical and chemical control measures, including use of the herbicide fluridone (which is an effective and commonly used method of control in the USA), have met with little success in New Zealand. Diploid grass carp have previously been used in New Zealand to remove a similar weed species, *Egeria densa.* This paper presents the first results of a trial using sterile triploid grass carp in New Zealand to remove *Hydrilla* from a Hawkes Bay lake. Grass carp were stocked at 100 fish ha^{-1} in Elands Lake (30°20'S, 176°45'E), a 4 ha, 7-m-deep lake. A total of 400 fish approximately 210-340 mm LONG were released on 3 November 1988. By April 1989 no measurable impact was recorded on the vegetation. The following autumn In April 1990, >99% of the *Hydrilla* biomass within the lake had been removed, an estimated 1.5 tonnes dry weight. By April 1991, no trace of *Hydrilla* was found In the lake and grass carp feeding had begun on marginal emergent plants such as *Typha orientalis.* By November 1991 occasional spring regrowth of *Hydrilla* shoots were noted from shallow water substrata arising from buried tubers and stem fragments. In the southern USA *Hydrilla* produces turions and tubers, with tubers viable for up to 4 yrs. Maintenance of fish browsing pressure Is recommended for a further 5 yrs before removing grass carp from the lake at the end of the trial to minimise any risk of tuber regrowth. Water quality showed no discernible changes during the trial.

Introduction

Hydrilla verticillata (Linn. f.) Royle (Hydrocharitaceae) is a submerged "oxygen weed" similar in appearance to *Elodea canadensis* Michx. (Hydrocharitaceae) (Canadian pondweed). *Hydrilla* is widespread throughout the world with records from Eastern and Southern Asia, Europe, parts of Africa, USA, Australia and New Zealand. Within 15 yrs of introduction to Florida the plant became the most troublesome aquatic weed on record (Haller *et al. 1976). Hydrilla* is presently undergoing adventive spread in many countries around the world and throughout the USA. *Hydrilla* displaces native flora by the dense canopy it produces near the water surface (which reduces 95% of light available to other species within 0.3 m; Haller and Sutton 1975), by its adaptation to low light environments (Bowes *et al.* 1977), and by its prolific asexual reproduction (Haller and Sutton 1975). The highly competitive growth characteristics and tolerance to a wide range of habitat conditions also enables *Hydrilla* to displace other adventive weed species such as *Egeria densa* Planch. (Hydrocharitaceae) (de Kozlowski 1991).

Hydrilla was first reported in New Zealand from Lake Tutira in Hawkes Bay in 1963 (Grant 1965) with identification confirmed by DSIR Botany Division. Both *Elodea* and *Hydrilla* were considered to have entered the lake since 1925, with *Hydrilla* being only a more recent introduction, since in 1963 it was observed at only a few points in the lake. *Hydrilla* has subsequently spread to become the dominant species in the lake. It has since spread to Lake Waikapiro (11 ha) which is attached by culverts to Lake Tutira, and to 2 other water bodies nearby: Lake Opouahi (6 ha); and Elands Lake (4 ha), the latter presumably from accidental introduction such as transfer within eel fishing nets. Confinement to the Hawkes Bay District is likely to have been facilitated by the distance of these infested lakes from the main North Island lake district, as recreational boat traffic is likely to be the major vector for interlake transfer (Johnstone *et al.* 1985). Furthermore, the prohibition of motorised boats on Lake Tutira, the most publicly accessible of the infested lakes, has undoubtedly reduced the risk of spread. Spread of *Hydrilla* to other waterbodies outside of the Hawkes Bay District not only poses a serious threat to their recreational and management uses but would also circumvent any possibility of eradication of this weed from New Zealand.

Research on control of *Hydrilla* has shown the plant to be resistant to most traditional herbicides (Blackburn & Weldon 1970), particularly due to annual regrowth from over-wintering vegetative turions formed in leaf axils and tubers on underground rhizomes following any removal or die-back of vegetation. Fluridone, a new aquatic herbicide, has been used extensively in the USA since gaining an Environmental Protection Agency (EPA) experimental use permit in 1981, and full EPA registration in 1986 (Tarver 1986), where its systemic action at low dosages enables effective control of *Hydrilla* plants and partial control of regrowth from tubers and turions (Haller *et al.* 1990). Trials in New Zealand using a variety of cultured plant species (including *Hydrilla)* and in field plots proved fluridone was ineffective (Wells *et al.* 1986). This is possibly due to lower water temperatures in this country, or high iron content in aquatic plants which has been recently shown to reduce fluridone activity (Spencer and Ksander 1989).

Given the difficulties achieving adequate chemical control of *Hydrilla* and the increasing opposition to the use of chemicals in natural waterbodies, it is unlikely that *Hydrilla* can be adequately controlled and certainly not eradicated by chemical methods. Mechanical methods have been used for control, but high costs and short duration of control have limited the suitability of the method compared to alternatives. Research into biological control shows potential options of using fungi (Charudattan 1973, Charudattan and Lin 1974) and insects (Balciunas and Minno 1985, Buckingham 1988) and are presently undergoing further development. These methods would require additional evaluation (e.g., temperature tolerance and host-specificity) before being useable in New Zealand. These biological control agents are not presently available for practical application to management of *Hydrilla* in this country. Even if such agents received import approval, were accepted for field release and were to become established, it is unlikely that *Hydrilla* could be eradicated by them.

Diploid grass carp, *Ctenopharyngodon idella* Valenciennes (Cyprinidae), have been proven effective in controlling submerged weeds and have been used successfully against *Hydrilla* overseas. Considerable controversy surrounds the use of grass carp overseas (Sutton 1985) and in this country (Rowe and Schipper 1985); however the advent of individually certified sterile triploid grass carp (McCarter 1988) has helped to make their use more acceptable by removing the potential for sexual reproduction. Fertile diploid grass carp have been used in New Zealand to eliminate *Egeria* from a small lake (Mitchell 1980, Tanner *et al.* 1990), but opposition to the use of fertile grass carp in public waterbodies has resulted in their discontinuation as a management option.

While the distribution of *Hydrilla* remains confined to the Hawkes Bay District of New Zealand, the potential exists to completely eliminate this species from each of the 4 infestation sites, thereby eradicating this weed from the country. This paper reports the results of a trial which was established to test the feasibility of eliminating *Hydrilla* from one of these infested waterbodies using triploid grass carp.

Methods and Materials

Trial Site

Elands Lake (176°45' & 39°20') (Fig. 1) was selected for the trial site since it was the most isolated site and had no outlet. Elands Lake is 4 ha in size, 7-m-deep, with a temperature range of 8-24°C, and is located on private property 4.5 km off the Napier-Taupo highway, The lake is land-locked with a spring-fed water supply. The lake has no fish of particular recreational or intrinsic value (Mitchell, C., MAF Fisheries, Rotorua, personal communication, 1987). A trout fishery *(Salmo gardnerii* L.; Salmonidae*)* was established from *ca.* 1920-60, but has not been maintained. Coarse fish and eels do not appear to be present (Mitchell, K., farm owner, personal communication, 1991). The native common bully *(Gobiomorphus cotidianus),* introduced as a food source for trout from Lake Tutira (Caruthers, A., MAF Fisheries, Napier, personal communication, 1987), maintains a self-supporting population.

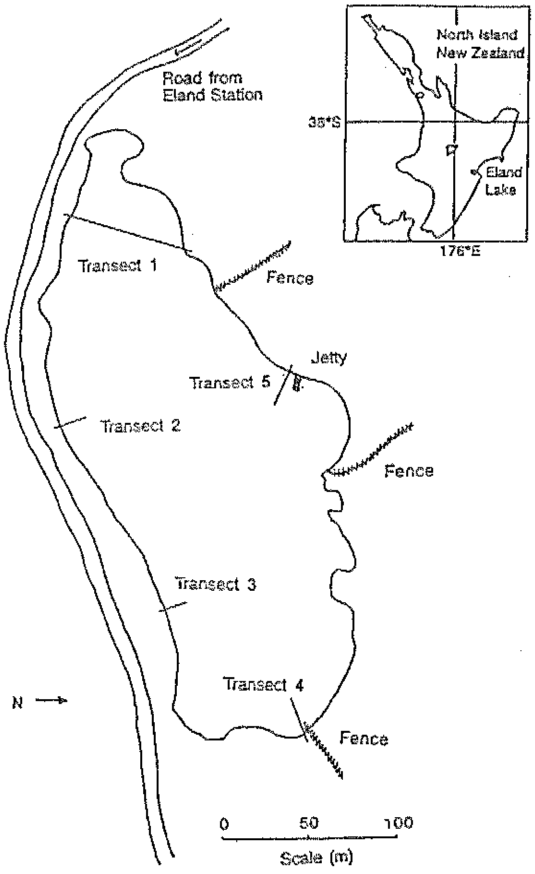

Figure 1. Locality of Elands Lake and position of transects.

Introduction of Triploid Grass Carp

On 27 September 1988, 5 wks prior to the introduction of grass carp, 30-L of gel formulation of the herbicide diquat was applied by boat on to an estimated 1 ha of *Hydrilla* weed beds in Elands Lake with the objective of reducing submerged vegetation biomass.

Triploid grass carp were produced by MAF Freshwater Fisheries at Rotorua (McCarter 1988) and 400 fish (mean length 275 ± *ca.* 65 mm) were transported to the release site on 3 November 1988. Eight fish died in transit and the remainder were liberated into Elands Lake.

Monitoring Programme

The following parameters were monitored prior to and during the grass carp trial.

Vegetation. Submerged and marginal vegetation was monitored (27 September 1988, 2 November 1988, 7 February 1989, 4 April 1989, 17 October 1989, 2 April 1990, 24 May 1990, 27 May 1991, 19 November 1991) using photographic and scuba methods (Clayton 1983) with all depth records for aquatic plants adjusted relative to the water level on the first sample date. Qualitative sampling was based on recording species present, species depth range, height and estimate of cover. Quantitative sampling involved setting up 5 permanent line transects through the vegetated zones of the lake, recording at metre intervals species present, mean, and maximum height, mean and maximum cover, and water depth. Triplicate 1 m^2 quadrates were laid in areas of maximum *Hydrilla* cover and height on 27 September 1988 and 2 April 1990. All plants within the quadrats were collected and dry weights measured. Surface sediment from a depth of 2-3 m was collected and sieved using a fine mesh bag to assess the presence and numbers of *Hydrilla* tubers and turions.

Water Quality. Secchi disc, temperature and dissolved oxygen readings were taken and water samples collected from 5 open-water sites at regular intervals prior to and during the grass carp trial. Water samples were bulked to give composite measurements of Chlorophyll *a*, turbidity, suspended solids, total phosphorus, soluble reactive phosphorus, total soluble phosphorus, Kjeldahl nitrogen, nitrate, ammonia and conductivity. The data set was analysed for any trends in water quality over the sample period using WQStat 11 (Phillips *et al.* 1988).

Wildlife. Wildfowl counts were made by Department of Conservation staff and macro-invertebrate and fish life were sampled qualitatively by Hawkes Bay Regional Council staff before and after the liberation of grass carp.

Results and Discussion

Vegetation Before the Introduction of Grass Carp

Emergent vegetation, dominated by *Typha orientalis* C.B. Presl.(Typhaceae) growing to a depth of 2 m with occasional *Schoeneoplectus validus* (Vahl.) Love et Love, occupied approximately 25% of the shoreline (Table 1). Low-growing, mat-forming species, dominated by *Glossostigma elatinoides* Benth. with locally common growths of *Lilaeopsis ruthiana* Affolt. *or Myriophyllum propinquum* Cunn., formed a dense turf from the lake edge up to 2 m depth for approximately 30% of the shoreline. The remaining 45% of the shoreline marginal vegetation was dominated by *Juncus gregiflorus* L. Johnson or pasture species extending to *ca.* 0.5 m depth with muddy substrata to *ca.* 1.5 m often covered by a layer of cyanobacteria dominated by *Oscillatoria limosa* Ag. ex Gormont and *O. subbrevis* Schmidle (Oscillatoriaceae).

The dominant macrophyte in Elands Lake was *Hydrilla* which formed a continuous band of submerged vegetation around the lake between 1.5 and 4.5 m depth (Table 1). *Hydrilla* occupied an estimated 1 ha area, with dense sub-surface, canopy-forming beds up to 3 m tall. The mean dry weight for maximum biomass was 152.3 ± 25 g m^{-2}, with an estimated total lake dry weight biomass of *ca.* 1.5 tonnes. The dense sub-surface *Hydrilla* canopy effectively excluded light beneath and displaced almost all other species over the depth range of growth. Only occasional plants of *E. canadensis and Potamogeton ochreatus* Raoul (Potamogetonaceae) were recorded within this depth range. During winter the canopy of *Hydrilla* was typically covered with periphyton dominated by filamentous green algae and this was associated with an annual decline in overall vigour and height of the weed beds, similar to that reported by Berg 1978 (*in* Swarbrick *et al.* 1981).

Vegetation Following the Introduction of Grass Carp

Diquat application had no discernible affect on overall plant biomass and no difference was recorded in vegetation during the first 12 months following the release of grass carp.

The survey of 2 April 1990, 17 months after grass carp release, revealed a major reduction in the area and density of the *Hydrilla* beds (Figs. 2-4). Only 1 patch (100 m^2) was located in the western end of the lake (Fig. 2) with a mean maximum dry weight biomass of 54.4 ± 17.9 g m^{-2}. This equates to a lake dry weight biomass of *ca.* 5 kg in April 1990 compared to 1.5 tonnes in September 1988. Elsewhere, only occasional bare stalks were found (Fig. 3). No plants of *Elodea, Potamogeton* or *S. validus* were found on this or subsequent surveys. In contrast, at the time of this survey there was no visible reduction in area or deterioration in condition of *Typha or Glossostigma* dominated vegetation. *Glossostigma* even appeared to have increased its area by colonising some of the previously bare mud substrata (Fig. 4).

In April 1991, 2.5 yrs after grass carp release, there was no evidence of any of the original *Hydrilla* weed beds. Between 2-4.5 m depth, extensive areas of bare mud were noted, with a broken, patchy cover of cyanobacteria. Evidence of grass carp browsing on *Typha* was noted, with removal of plants from depths >1 m and a reduction in density of live plants from 0-1 m depth. Dense beds of *Glossostigma and Lilaeopsis* remained to a depth of 2 m, being particularly abundant between 0-1 m depth, the depth range favoured by these amphibious turf-forming species.

An extensive search at depths of 1-1.5 m in November 1991 revealed occasional plants of *Hydrilla* <10 cm tall growing from tubers or buried stems. Regrowth was predominantly from areas supporting a low-growing, turf-

Table 1. Vegetation of Elands Lake, depth ranges, mean and maximum height and cover before and after the introduction of grass carp.

Species			Height (m)		Cover Scale[a]	
		Depth (m)	Mean	Max.	Mean	Max.
Typha orientalis C.B. Presl.	Before	0.2-2.0	3.0	–	4	6
	After	0.2-1.0	3.0	–	3	5
Schoenoplectus vallidus (Vahl.) Love et Love	Before	0.5-1.0	1.5	–	2	4
	After	[c]	[c]	–	[c]	[c]
Juncus gregiflorus L. Johnson	Before	0-0.5	1.0	–	3	6
	After	0-0.5	1.0	–	3	6
Bolboschoenus fluviatilis (Torrey) Sojak	Before	0-0.2	1.0	–	1	2
	After	[c]	[c]	–	[c]	[c]
Eleocharis acuta R. Br.	Before	0-0.2	0.5	–	1	2
	After	0-0.2	0.5	–	1	2
Ludwigia palustris (L.) Elliot[b]	Before	0-0.2	–	–	1	1
	After	0-0.2	–	–	1	1
Callitriche stagnalis Scop.[b]	Before	0-0.2	–	–	1	2
	After	0-0.2	–	–	1	1
Ranunculus amphitrichus Col.	Before	0-0.2	–	–	1	1
	After	0-0.2	–	–	1	1
Polygonum salicifolium Willd.	Before	0-0.5	–	–	3	4
	After	0-0.5	–	–	2	3
Pratia perpusilla Hook. f.	Before	0-0.5	–	–	1	3
	After	0-0.5	–	–	1	3
Myriophyllum propinquum Cunn.	Before	0-1.5	0.2	0.1	1	5
	After	0-1.5	0.1	0.1	1	5
Lilaeopsis ruthiana Affolt.	Before	0-1.0	–	–	1	6
	After	0-1.0	–	–	1	6
Elatine gratioloides Cunn.	Before	–	–	–	–	–
	After	1.0	–	–	1	1
Glossostigma elatinoides Benth.	Before	0-2.0	–	–	4	6
	After	0-2.0	–	–	4	6
Potamogeton cheesemanii A. Bennett	Before	1.0	0.2		1	1
	After	[c]	[c]	–	[c]	[c]
P. crispus L.[b]	Before	1.0	0.2	–	1	1
	After	[c]	[c]	–	[c]	[c]
P. ochreatus Raoul[b]	Before	1.5-2.0	0.2	–	1	1
	After	[c]	[c]	–	[c]	[c]
Chara corallina Willd. Bennett	Before	1.0-1.5	0.1	–	1	1
	After	1.0-1.5	0.1	–	1	1
Nitella cristata A. Br.	Before	1.0	0.1	–	1	1
	After	1.0	0.1	–	1	1
Elodea canadensis Michx. Bennett[b]	Before	1.5-3.0	0.2	1.0	1	1
	After	[c]	[c]	–	[c]	[c]

Table 1. Continued.

Species		Depth (m)	Height (m) Mean	Height (m) Max.	Cover Scale[a] Mean	Cover Scale[a] Max.
Elodea canadensis Michx. Bennett[b]	Before	1.5-3.0	0.2	1.0	1	1
	After	[c]	[c]	–	[c]	[c]
Hydrilla verticillata (Linn.f.) Royle[b]	Before	1.0-4.5	2.0	3.0	6	6
	After	1.0-1.5	0.1	0.1	1	1
Azolla filiculoides Lam.	Before	–	–	–	1	1
	After	–	–	–	1	1
Lemna minor L.	Before	–	–	–	2	2
	After	–	–	–	2	2

[a] Cover scale: 1= 1-5; 2= 6-25; 3= 26-50; 4= 51-75; 5= 76-95; and 6= 96-100%.
[b] Adventive species.
[c] Not recorded in subsequent surveys.

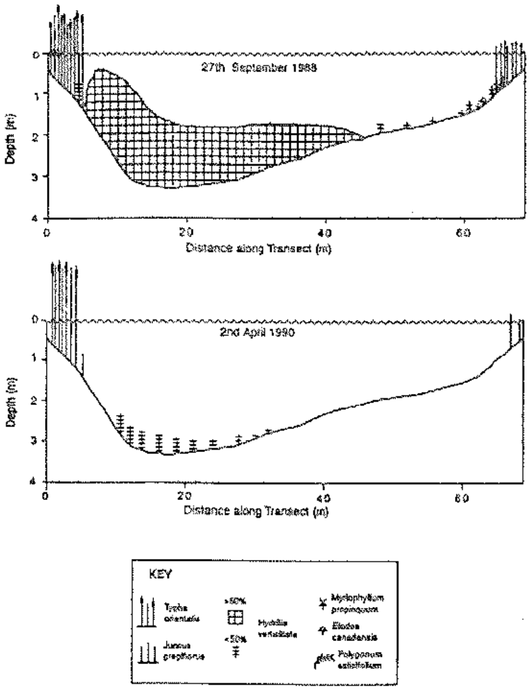

Figure 2. Changes in the vegetation of Elands Lake before and after grass carp introduction–Profile 1 (marginal emergents).

forming plant cover, particularly where substrata was firm or consolidated and presumably less readily disrupted or uprooted by grass carp feeding. Occasional *Hydrilla* plants were also found amongst fallen branches of trees, the maximum height of any shoots being <100 mm. All areas of the lake deeper than 1.5 m and up to 4.5 m, the primary depth range before the decline, were devoid of any plant shoots and there was no evidence found of tuber or turion regrowth from these soft unconsolidated sediments. Sediments from 2 and 3 m depths were sampled and sieved, and 5 viable turions were recovered from a volume of *ca.* 40-L of sediment.

Wildlife and Water Quality

No significant change in wildlife or trends in water quality have been detected during the trial. All water quality parameters monitored before and after grass carp release and subsequent to vegetation collapse appeared similar (Table 2). Richard and Small (1984) reported variable responses of different waterbodies to removal of lake vegetation using grass carp and noted that other studies had recorded either increases in algal blooms or no change in phytoplankton activity following grass carp stocking. The impact of grass carp on any waterbody will depend upon the complex interaction between the fish community, wildlife, water quality and weed beds (Rowe 1984, Rowe and Schipper 1985), and this will inevitably vary between waterbodies and will naturally account for the diversity of results reported in the literature.

Control of Hydrilla *using Triploid Grass Carp*

Aquatic weed control capabilities of triploid grass carp are essentially the same as diploids (Sutton and Vandiver 1986). Sutton (1985) considered *Hydrilla* was well-suited to management by grass carp. Grass carp eat a wide range of vegetation including marginal plants, overhanging terrestrial vegetation and flooded pasture; however, submerged plants are preferred and of these, *Hydrilla* is one of the more preferred species (Sutton and Vandiver 1986, Leslie *et at* 1987).

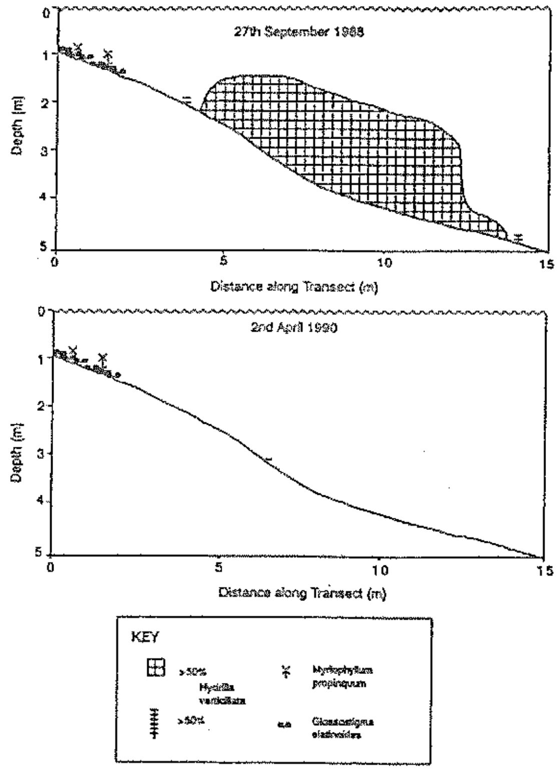

Figure 3. Changes in the vegetation of Elands Lake before and after grass carp introduction–Profile 2 (marginal turf-forming plants).

To be effective, grass carp stocking rates must be high enough to ensure fish consumption exceeds plant growth rate. A wide range of stocking rates from *ca.* 50-600 ha^{-1} have been reported to be effective in controlling *Hydrilla*. Recent approaches using serial stocking strategies to achieve regulated levels of weed control (Wiley *et al.* 1987), and the use of low stocking rates (3-8 fish ha^{-1})have been used successfully to control nuisance growths of *Hydrilla* in particular, while allowing coexistence of a variety of preferred native or less palatable plant species (Sutton 1985, Sutton and Vandiver 1986, Leslie *et al.* 1987). Use of low stocking rates is generally preceded by chemical or mechanical removal of the bulk of plant biomass to be controlled.

There is an extensive literature on effectiveness of grass carp controlling a variety of aquatic plant species. Control of *Hydrilla* has been undertaken in lakes ranging from small to very large such as Lake Conroe (270,000 grass carp in the 81 km^2 lake) and most recently Lake Marion (100,000 fish yr^{-1} for next 3 yrs in the 273 km^2 lake), which is the largest lake in the USA to be stocked. The Lake Conroe trial achieved removal of all weed species within 2 yrs of stocking at a rate of 74 fish/vegetated ha (Martyn *et al.* 1986), while Lake Marion stocking rate will be 25 fish/vegetated ha (de Kozlowski 1991).

Results of the Elands Lake trial and overseas research demonstrate that *Hydrilla* could be effectively controlled in all of the remaining *Hydrilla*-infested lakes in New Zealand (including the largest, the 147-ha Lake Tutira), by triploid grass carp. This would avoid any conceivable risk of *Hydrilla* escape or transfer to other waterbodies outside of its present distribution.

The objective of complete eradication of a weed species (as opposed to control) is less often pursued as a management goal since: it may not be feasible (e.g., seed-producing weed species with a long viability); it may result in unacceptable environmental impacts (e.g., total removal of all vegetation, including desirable species such as marginal emergents); or the management benefits may be short-lived (e.g., re-introduction from nearby infested waterbody). Although vegetatively reproducing adventive weed species have been eradicated from waterbodies using grass carp with subsequent re-establishment of a desirable native flora (Tanner *et al.* 1990), the ability of triploid grass carp to eradicate *Hydrilla* remains unclear. Van Dyke *et al.* (1984) reported *Hydrilla* had been "possibly eradicated" from 3 Florida lakes since no records had been made for 6 yrs following the removal of weed beds; however continued presence of grass carp may have masked regrowth potential.

The difficulty in eradicating *Hydrilla* from a waterbody arises from the plants' overwintering strategy of producing tubers and turions.

Turions are dormant compact shoot apices which store food reserves and detach from the parent plant and serve as propagules for new growth. Tubers are similar to turions but are produced on rhizomes beneath the sediment. Tubers make *Hydrilla* eradication particularly difficult since burial removes them from any physical, chemical or biological control agents. Stewart (1984) reported up to 4,240 tubers m^{-1} and Sutton and Fortier (1985) reported highly variable numbers of turions from different waterbodies in Florida. Our limited sampling of sediments beneath *Hydrilla* beds in this country have revealed only a low incidence of tubers and turions, which is consistent with Swarbrick *et al.* (1981) who reported turions were not common in *Hydrilla* found in Australia.

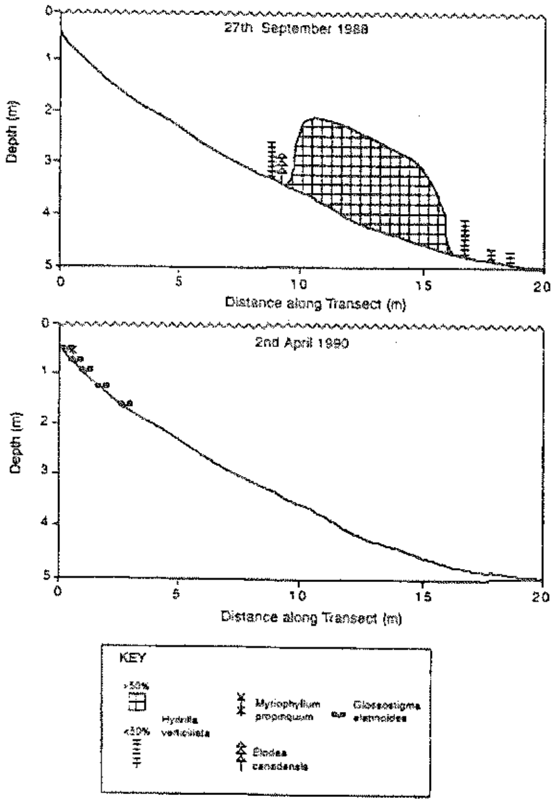

Figure 4. Changes in the vegetation of Elands Lake before and after grass carp introduction–Profile 5 (no marginal vegetation).

Based on geographic proximity and plant morphology, Australia is likely to be the source of origin for *Hydrilla* in New Zealand. Bruner and Batterson (1984) reported that apart from temperature, daylength and soil fertility, tuber production rate was an intrinsic property of the plant. This was supported by Stewart and Van (1987), who also noted that tuber production was greater in monoecious than dioecious *Hydrilla* plants. Although *Hydrilla* in New Zealand was thought to be dioecious male plants only, crosses with overseas dioecious females subsequently generated dioecious males and females as well as monoecious progeny (Stewart, K., USA, personal communication, 1991), which suggests that New Zealand *Hydrilla* may in fact be monoecious, although this is yet to be confirmed. The literature on *Hydrilla* indicates that there are numerous biotypes of this plant throughout the world (Stewart and Van 1987), and this has led to unproductive debate in this country over the potential weediness of the New Zealand biotype. Verkleij *et al.* (1983) reported there was no correlation between isozyme pattern, chromosome number and plant morphology from a wide variety of *Hydrilla* populations from around the world. Based on these studies there appears to be no reasonable evidence to predict nuisance potential based on biotype or morphology. The objective of *Hydrilla* eradication in New Zealand is therefore recommended while there is still a potential to succeed.

Information on the viability of *Hydrilla* tubers and turions is essential when considering potential eradication of *Hydrilla from* a waterbody. Van and Stewart (1990) report turions germinate readily and are expired within 1 yr, whereas monoecious *Hydrilla* tubers may survive for up to 4 yrs in undisturbed sediment. These authors suggested there was an environmentally imposed dormancy which prevented rapid depletion of tubers through excessive germination.

With regard to eradication of *Hydrilla* from Elands Lake in New Zealand, germination from tubers has been observed and viable turions have been sieved from sediment >1 yr following the removal of *Hydrilla* weed beds by grass carp. To ensure eradication of *Hydrilla* from this lake it is suggested that grass carp will need to be retained for a further 4-5 yrs, until viability of tubers is exhausted. This raises some potential problems such as the retention of an active grass carp population in the near absence of a food source and their ability to retain sufficient browsing pressure over all areas of the lake to prevent further opportunity for shoots to generate new tubers.

Another possible difficulty concerns the potential for *Hydrilla* plants to remain protected from browsing while beneath fallen trees or amongst shallow-water, turf-forming species growing on consolidated substrata where uprooting or direct feeding by grass carp may be less effective. Finally, the longevity of tubers in the New Zealand *Hydrilla* is untested and it is possible that cool water temperatures (*ca.* 8-24°C) in New Zealand lakes *with Hydrilla* may result in tuber viability exceeding the 4-yr longevity reported by Van and Stewart (1990) based on studies in Florida.

Table 2. Water quality data for Elands Lake (December 1984-September 1991).

Date	Secchi (m)	Conductivity (μmho cm^{-1})	NO_3 (g m^{-3})	NH_3 (g m^{-3})	Total P (g m^{-3})	Soluble Reactive P (g m^{-3})	Chlorophyll *a* (μg m^{-3})	Turbidity (NTU)
19.xii.84	0.51	70	0.02	0.03	0.05	0.01	33.0	20.0
15.i.85	1.17	80	0.02	0.03	0.05	0.01	16.0	1.0
20.ii.85	1.02	73	0.01	<0.02	<0.01	<0.01	30.0	–
20.iii.85	1.42	65	0.04	0.03	0.06	0.01	34.0	4.3
24.iv.85	1.04	57	0.02	<0.02	0.10	<0.01	76.0	3.0
28.iv.87	–	100	–	–	–	–	–	9.8
09.xi.87	1.41	70	–	–	–	–	–	9.8
26.ix.88	1.77	65	0.68	0.03	0.04	0.01	7.5	2.5
30.xi.88	0.78	65	0.01	0.02	0.09	0.03	37.0	10.0
20.xii.88	0.86	65	0.01	<0.02	0.06	0.02	25.0	4.0
17.i.89	1.40	55	0.02		0.09	0.02	–	3.0
17.ii.89	1.13	60	<0.01	0.03	0.06	0.02	–	8.0
17.iii.89	1.19	50	<0.01	<0.02	0.06	0.01	–	5.0
12.iv.89	0.78	65	<0.01	0.45	0.07	0.02	–	10.0
12.v.89	1.38	60	0.21	0.07	0.08	–	–	4.0
10.xi.89	1.01	50	0.09	0.02	0.07	0.01	9.6	3.0
12.xii.89	1.20	70	0.01	0.02	0.06	0.01	4.4	–
31.i.90	1.00	60	0.02	<0.02	0.01	0.03	3.9	–
21.ii.90	1.20	55	0.01	0.04	0.02	0.02	10.0	–
27.iii.90	1.50	60	0.01	<0.02		0.01	1.0	2.0
27.iv.90	0.60	60	0.04	0.20	0.08	0.02	10.2	–
14.vi.90	1.00	100	0.09	0.28	0.12	0.01	55.8	5.0
16.vii.90	1.60	80	<0.02	0.54	0.06	0.01	3.4	3.0
18.ix.90	1.20	65	0.12	0.30		0.01	13.3	–
07.xi.90	1.00	80	0.03	<0.02	0.08	0.01	18.2	–
27.xi.90	0.90	60	0.04	<0.02	0.07	0.01	9.9	–
09.ix.91	1.00	60	–	<0.02	0.05	–	–	4.0

In conclusion, effective *Hydrilla* ***control*** can be achieved in all remaining infested waterbodies in New Zealand, with containment of the plant and avoidance of any risk of spread, by using sterile triploid grass carp; but the feasibility of achieving *Hydrilla* ***eradication*** has yet to be demonstrated.

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