Organism Consequence Assessment
Hydrilla verticillata

Hydrilla shoot (photo by R Wells)

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Organism Consequence Assessment: *Hydrilla verticillata*

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Prepared for

Biosecurity New Zealand

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1. Introduction

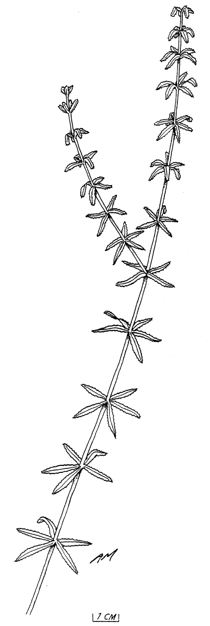
Biosecurity New Zealand (BNZ) are undertaking a review of nationally significant pests to identify those that should be managed by BNZ through a national pest management strategy.

The process for considering whether an organism is a nationally significant pest and should be managed by BNZ through a national pest management programme includes a rapid screen to exclude organisms which obviously do not meet the criteria for consideration for management on a national basis, an organism consequence assessment to determine the likelihood of spread and assess the consequences of such spread, and consideration of the consequence assessment together with information on factors such as feasibility, practicality, acceptability and cost and benefit of potential management options, to prioritise organisms for management by BNZ on a national basis.

Specifically, the purpose of the organism consequence assessment is to build on the information used in the rapid screening process to inform the priority setting decision making process.

BNZ have contracted NIWA to provide an Organism Consequence Assessment for hydrilla (*Hydrilla verticillata*), including a bibliography.

2. Organism description



Scientific name: *Hydrilla verticillata* (Lf) Royle

Family: Hydrocharitaceae

Common names: Hydrilla

Hydrilla is a submerged, rooted, monoecious or dioecious, annual or perennial aquatic macrophyte, which passes through unfavourable conditions as seed or turions or tubers. In New Zealand only the dioecious male hydrilla is present, which grows to water depths of ca 9 m and forms dense monospecific stands.

The stems of hydrilla vary in length from a few centimetres to several metres and are either creeping and stoloniferous or erect (see front cover). The leaves occur in opposite pairs, or typically in whorls of 4, although numbers may range from 3 to 8 (rarely up to 12) per whorl. Leaves are sessile and linear to lanceolate, terminating in a single spine cell at the apex, and up to 20 mm long and 4 mm wide (usually about 12 mm long and 2 mm wide). Leaves are generally green, but often have small reddish-brown spots and stripes. The midrib is distinct and occasionally bears unicellular spines on the abaxial surface. The margin is strongly serrulate with fine, translucent teeth that are visible to the naked eye (Cook and Luond 1982).

The male flowers are sessile and solitary, or in pairs in the axils of leaves. They have 3 broad sepals and 3 narrow petals and whitish in colour (Aston 1973). When the flower is released from the plant it floats to the water surface where it opens, with widely recurved sepals and petals, and explosively discharges the pollen grains into the air (Sculthorpe 1967). Hydrilla is highly gregarious and in flower populations the surface of the water can be white with floating pollen.

Reproduction of New Zealand's hydrilla is solely vegetative. Aside from reproduction via stem fragmentation, hydrilla also produces specialised vegetative structures called turions and tubers (Figure 1). Turions, also called axillary turions, are formed on erect stems in the water column. The mature turion is a green, ovate structure ca 10 mm in length (they can be smaller or larger), on a short stem, covered with numerous overlapping pointed leaf scales. Turions usually develop from axillary buds situated in the axils of leaves or branches, when mature the turion breaks off the plant and sinks to the sediment. However when newly formed and still attached to a plant fragment they may float for a time and be dispersed by water currents (Thullen 1990).

Tubers, also known as subterranean turions, are swollen, brown to white structures up to 15 mm long, which develop in the hydrosoil. The mature tuber becomes free from the parent plant when the attached stem decomposes or is ruptured (Yeo et al. 1984). Turions are viable for one to two years, while tubers have remained viable for four years (Van and Steward 1990) and probably in excess of 10 years in New Zealand conditions (Hofstra et al. 1999).

Figure 1: Hydrilla turions (top left) and tubers.

3. Likelihood of spread

3.1 Current distribution in New Zealand

Hydrilla is known from four lakes in the Hawkes Bay region (Figure 2). In three of these lakes, Tutira, Waikapiro and Opouahi, hydrilla forms significant weed beds. The fourth lake, Elands (on Elands farm) was historically (1980's) infested with hydrilla, however grass carp were introduced in 1988 and since 1990 only remnant plants were found. None were located during annual surveillance in 2005 and 2006 (Hofstra and Clayton 2006).

Figure 2: Hydrilla distribution map (Freshwater Biodata Information System 2006).

3.2 History of spread to current distribution – timescales and vectors

Hydrilla was first positively identified and recorded in Lake Tutira in 1963, at which time it had already spread to several sites of this 147 ha lake (Clayton et al. 1995). Currently hydrilla occupies an estimated 25 ha in Lake Tutira, where the weed beds extend from 1 to 9 m water depth (at some sites) and is on average 3 m in height, with 100% cover (i.e., dense monospecific stands) (Hofstra et al. 2003).

Lake Waikopiro is adjacent to Lake Tutira, and at times of high water levels may be joined by a culvert. Hydrilla is thought to have entered Lake Waikopiro (11 ha) some time after it had established in Lake Tutira. Currently hydrilla occupies an estimated 3.2 ha in Lake Waikopiro, where it forms a continuous dense band of vegetation from the ca 1 to 6 m water depth zone of the lake, with plants averaging 2 m in height and up to 100% vegetation cover (Hofstra et al. 2003).

Lake Opouahi is a 6 ha lake that was probably infested with hydrilla fragments from Lake Tutira (Clayton et al. 1995). The Lake Opouahi infestation was first noted in 1984, having established at some time between 1970 and its first record, because it was not reported in a full lake vegetation survey in 1970. A recent survey (Hofstra et al. 2003) has shown that hydrilla forms discrete clumps within the lake rather than broad bands of vegetation, with the exception of the jetty region. At the jetty hydrilla covers an estimated area of $300m^2$ with ca 90% cover between ca 1 to 4 m water depth, a maximum height of 2 m (Hofstra et al. 2003).

Elands Lake is a small lake (4 ha), situated on private farmland, which has in the past (1988) supported 1 ha of hydrilla that completely covered the 1.5-4 m water depth zone. These hydrilla beds were removed following the stocking of grass carp in the lake. In 1995 only a few stunted plants remained from the continued germination of hydrilla tubers (Clayton et al. 1995). More recently, 2005 and 2006, no hydrilla was found in the annual survey, however the water clarity was particularly poor and impeded a thorough investigation.

3.3 Environmental tolerances

Hydrilla is characterised by its prolific growth and vegetative reproduction over a wide range of ecological conditions (Miller et al. 1976). It occurs (overseas) in both still and slow flowing water (Mitchell 1977, Yeo et al. 1984, Van Dijk et al. 1986), and in water depths ranging from a few centimetres, where its photosynthesis is most efficient (Van et al. 1976, 1977) to 7 m and deeper (Yeo et al. 1984), where it does not reach the water surface. Water quality is rarely limiting, although high salinity does impede growth (Mitchell 1977, Carter et al. 1987). Hydrilla has been recorded in waters that are acid to alkaline, and oligotrophic to eutrophic (Cook and Luond 1982). It commonly forms dense stands of vegetation, especially in waterways that are characterised by high anthroprogenic disturbance (Pieterse 1981).

More specifically with regard to temperature, hydrilla occurs in both cold climes, for example, Beijing which has average winter (January) temperature of 0º -10ºC (Balciunas and Chen 1993), and warmer regions for example Florida. Hydrilla from the USA (monoecious and dioecious female plants) has been recorded with a thermal optimum temperature of 30ºC and growth retardation at 15ºC (McFarland and Barko 1987). New Zealand's hydrilla has been shown in cultivation to achieve maximum growth at 25ºC and 30ºC (Hofstra 1997). In New Zealand lake temperatures range between ca 0º - 10ºC in winter and ca 20º - 35 º C in summer (Green et al. 1987). The above records for hydrilla indicate that it would not be impeded by temperature in the majority of New Zealand's lakes and waterways.

The availability of light is of unique importance in aquatic systems because of the marked attenuation with increase in depth and turbidity. Studies on hydrilla (USA) in the 1980's demonstrated that hydrilla was very effective at growth under low light. For example shoot elongation at light levels that were too low for a net photosynthetic gain were achieved, which the authors considered may confer a competitive advantage for the hydrilla (Barko and Smart 1981). Similar results have been obtained with New Zealand's hydrilla (Hofstra 1997), supporting field observations that hydrilla is capable of prolific growth under high light and low light (shaded, or deep water) habitats.

3.4 Distribution potential

As mentioned above (3.3) the potential distribution of hydrilla in New Zealand is almost unlimited based on its environmental tolerance, with the exception of waterways with saline input.

3.5 Biological factors influencing rate of spread – reproductive strategy

The sole means of reproduction for hydrilla in New Zealand is asexual, with three different propagule types, stem fragments, turions and tubers. Tubers are long lived propagules that ensure survival of the plant once it has established in a particular waterbody, rather than playing a significant role in the accidental spread of hydrilla, as they are buried in the sediment (Hofstra et al. 1999).

Plant fragmentation is the reproductive strategy that has the greatest influence on hydrilla spread both between waterbodies and within (Hofstra et al. 2003), (where fragments may be readily moved with water currents), whereas stolons are the predominant mechanism for localised expansion of hydrilla in undisturbed areas (Madsen and Smith 1999). Turions, like plant fragments may be readily spread within a waterbody due to currents. Additionally turions may also be readily spread, just as fragments, between waterbodies and provide a longer-lived propagule (ca 2 years)

(Hofstra et al. 1999) more resilient than a plant fragment that will readily desiccate (Johnstone et al. 1985).

3.6 Dispersal mechanisms

The historical association of people in the dispersal of hydrilla is evident in its spread between Hawkes Bay lakes (see 3.2). Research in the 1980s using lake user surveys illustrated that submerged aquatic weed distribution between lakes was significantly associated with boating and fishing activities, rather than to any natural vectors such as birds and wind (Johnstone et al. 1985). Recently, the ease with which this type of inadvertent dispersal could occur was highlighted when hydrilla fragments were observed in the bottom of a kayak lying on the shore of Lake Waikopiro (Figure 3).

Figure 3: Hydrilla fragments in a kayak at Lake Waikopiro.

3.7 Natural population control mechanisms – natural enemies and competition

Hydrilla has no naturally occurring enemies in New Zealand. However grass carp (*Ctenopharyngodon idella*) can provide a natural (non-chemical or physical) means of reducing hydrilla biomass. For example, in an effort to determine whether hydrilla could be controlled and/or eradicated by grass carp, Elands Lake became the site of a trial in 1988 (Clayton et al. 1995). At that time there was a reported 1 ha of hydrilla covering the 1.5 - 4.5 m water depth zone, and 400 triploid grass carp were released. By April 1990, 99% of hydrilla biomass was gone, with remnant stands at the south end of the lake. Two and a half years after the original release of the grass carp (April 1991) there was no trace of hydrilla weed beds in the lake other than occasional growth from turions, tubers and stem fragments. In subsequent years up to April 2002, remnant hydrilla plants and viable tubers have still been found during annual lake surveys. No plants or propagules of hydrilla were found during the last two annual surveys. Grass carp have sustained a low hydrilla biomass (near zero density) and are currently the most effective option for minimising the further spread of hydrilla (Hofstra et al. 2000).

Black swans (*Cygnus atratus*) also feed on hydrilla. On Lakes Tutira and Waikopiro swans can be seen browsing on the hydrilla weed beds, which they effectively crop and prevent from becoming surface reaching. By cropping the weed beds to a depth approaching 1 m, the likelihood of entanglement with small water craft is significantly decreased.

Hydrilla has demonstrated (section 3.2) that it can readily displace the native submerged aquatic flora. However overseas experience, and contained studies in New Zealand also illustrate hydrilla is highly competitive amongst other submerged weeds (Spencer and Ksander 2000, Hofstra et al. 1999, Van Dijk et al. 1986). The ability of hydrilla in many situations to replace other submersed plants and eventually grow as a monoculture (Sutton, 1986) has been reported in a number of lakes overseas (DiTomaso and Healy 2003). For example, in the USA there is evidence that hydrilla can compete effectively with *Egeria densa* and *Ceratophyllum demersum*. In Lake Marion (South Carolina), *E. densa* was the dominant aquatic plant in 1980, infesting 6000 ha of open water, but once hydrilla had established in 1982, it rapidly replaced *E. densa* and spread into previously uninfested water (De Kozlowski 1991). Hydrilla has also been reported to displace *C. demersum* in the USA (Chambers et al. 1993).

Studies in New Zealand have demonstrated that, if hydrilla were to invade a lake in which other introduced submerged weeds dominate (ie *C. demersum*, *E. densa*, *Lagarosiphon major)*, hydrilla can also be expected to displace these species (Hofstra et al. 1999). This has far reaching implications because unlike hydrilla, these other weed species can be more readily controlled (Clayton 1996), and they do not produce long lived vegetative propagules (tubers and turions).

3.8 Other constraints on spread in New Zealand

The sale and distribution of hydrilla has been prevented since 1982 under the Noxious Plants Act (1978) and then the Biosecurity Act (1993). Current activity controls on the hydrilla infested Hawkes Bay lakes i.e., the prohibition of motorised boats and commercial eeling, have undoubtedly facilitated the containment of hydrilla to this region.

3.9 Predicted future spread

Given the wide tolerance range of environmental conditions, hydrilla is capable of prolific growth in a range of aquatic habitats from ornamental ponds, streams, rivers, ditches, channels and canals to shallow and deep lakes. The timescale of future invasion of a new lake or waterway is dependent on the effectiveness of current containment strategies.

3.10 Likelihood of re-establishment or re-invasion if eradicated

If eradicated from the Hawkes Bay the likelihood of re-establishment depends largely on border controls and the likelihood of hydrilla re-entering the country. If eradicated from any one of the infested waterbodies, the likelihood of re-establishment is dependent on the access/activity control surrounding the use of hydrilla infested lakes, ie the potential for hydrilla transfer (firstly) and secondly suitable habitat for establishment. For example, if appropriate access and activity controls are in place then the potential for hydrilla transfer and hence, re-infestation would remain low (Hofstra et al. 2003).

4. Likely consequences

4.1 Economic well being

In its current localities the economic impacts of hydrilla are localised (minimal) however should hydrilla escape from the Hawkes Bay region the potential for economic losses is considerable (e.g., dislodged submerged weeds of related species frequently block intakes and result in lost power generation (e.g., Hofstra and Champion 2006)).

If hydrilla established outside of the region, shallow waterways would also be at risk. In these hydrilla could form dense surface growth that would cause significant impediment to navigation of waterways, and impede water flow in irrigation and drainage channels, with subsequent economic impacts (Anderson 1990).

4.2 Biodiversity and water quality

In New Zealand hydrilla grows prolifically in the Hawkes Bay lakes. It is characterised by its extremely dense subsurface canopy that is monospecific and displaces and excludes native vegetation particularly through the 1 to 5 m water depth zone. In addition dense weed beds can also result in localised deoxygenation of the water, resulting in unfavourable conditions for associated fauna (AERF 2003).

4.3 Human health and recreation

Local problems for people are that weed beds can be a direct nuisance to bathers, divers, anglers and boaties. There is also a risk of accidental drowning through weed entanglement (Walls 1994). In addition plant material that drifts to shore, particularly after storm events may be smelly as it decomposes.

Recreational use of the hydrilla infested lakes is also impeded, because of the activity controls that are design to reduce the risk of hydrilla spread (section 3.8).

4.4 Relationship of Maori

The tradition of mahinga kai is pivotal to maori culture so the loss of this as can occur with the presence of invasive weed species and the introduction of weeds has particular significant implications for Maori (Biosecurity Council 2003).

Walls (1992) documents the concerns of local Maori with regard to issues and options surrounding hydrilla in the Hawkes Bay. Briefly, the Ngati Kahungunu hapu concerns included: being uncomfortable with the continued presence of hydrilla in the lakes; because is constitutes a threat to other waterways in New Zealand, it prevents eeling, and it prevents restoration of rongoa in the lake shallows (Walls 1994).

Currently, an assessment of Biosecurity Risks to Maori is being undertaken by BNZ. Findings should be incorporated into this consequence assessment.

5. Acknowledgements

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