# Border control for potential aquatic weeds

## Stage 1. Weed risk model

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A B S T R A C T

This report is the first stage in a three-stage development of a Border Control Programme for aquatic plants that have the potential to become ecological weeds in New Zealand.

A large number of freshwater aquatic plants have already been introduced and are naturalised in New Zealand, impacting on most waterbodies within this country. There are many additional potential weed species reported as present in New Zealand, but not naturalised, and an even greater number not recorded as introduced here. Some of these species could pose an even greater threat to our aquatic environment than those weeds currently naturalised. A range of tables is presented to illustrate the array of new aquatic species that are already believed to be in New Zealand or that could enter and become established.

Possible entry pathways identified in this report include natural spread from wind- and bird-dispersed seed, introduction of ornamental, culinary and medicinal herbs, contaminants in other plants and produce, mislabelled plants, and various types of illegal imports.

Existing weed risk assessment models fail to adequately separate aquatic plants with different levels of impact. A new model is presented, tailored to the impacts of aquatic species. Tables are presented to demonstrate the improved system of ranking risks for aquatic plant species.

A combination of assessments for weediness and the risk of entry into New Zealand will determine the potential threat of each species, allowing a comparison with existing weed species and other species not yet naturalised or introduced here. The greatest risk is perceived to be posed by some species reported to be present, but not yet naturalised in New Zealand, followed by species not reported here, but traded overseas with the potential to be brought here illegally.

***Keywords:*** border control, New Zealand, aquatic plants, weed species, introduced species, seed dispersal, seed contaminants, illegal imports.

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# 1. Introduction

This report is the first stage in a three-stage development of a Border Control Programme for aquatic plants that have the potential to become ecological weeds in New Zealand. For the purpose of this project the term 'aquatic plants' is used to denote freshwater species only. The emphasis in this first stage has been the development of a revised Weed Risk Model suitable for the assessment of risk from aquatic plants. An assessment is also provided of the potential impacts from new plant species, including further displacement of native species, deterioration of natural habitats, and adverse impacts on genetic diversity. Possible entry pathways for aquatic species have also been identified and discussed. This preliminary report has been limited in its scope to using readily accessible data, and presenting information as it is known to date.

The second stage (Weed Risk Assessment) will be based on investigative reporting and determination of the correct identity of aquatic species that have already entered the New Zealand border. Completion of the second stage will enable an accurate risk assessment to be undertaken for aquatic species, using both the model developed in Stage one and verifiable information on the present status of the aquatic species in New Zealand. Investigations from Stage two will also facilitate measures made of the likelihood of entry of any new species. This information (species identities and probability of entry), when combined with the new model for predicting weediness, will then enable a final risk assessment for new species to be prepared.

A third and final stage in the completion of a Border Control Programme for aquatic species (Weed Risk Management) will assess existing management systems (including determination of unwanted organisms, development of import health standards, and assessment of new organisms) and make recommendations on the need for new or enhanced management measures.

The overall aim of these investigations and reports is to assist the Department of Conservation to provide policy advice to the Minister for Biosecurity on the risks to indigenous flora and natural habitats from new aquatic plant species and new genetic varieties of established species. This risk assessment will also help develop a justifiable rationale for MAF entry restrictions on weed pests which are already established in New Zealand, and will help to establish criteria for the Environmental Risk Management Authority (ERMA) to assess new organisms under the Hazardous Substances and New Organisms (HSNO) Act 1996. ERMA is the key agency implementing the HSNO Act, which came into force on 1 July 1998 for new organisms and on 1 October 1998 for hazardous substances. This new legislation has significant implications for government and non-government agencies in New Zealand, including importers and distributors, researchers, and manufacturers in agriculture, horticulture and forestry.

A significant constraint in undertaking this assessment has been the uncertainty over the exact identity of aquatic plant species already present, but not naturalised in New Zealand. This issue was recognised prior to the commencement of this report, but was found to be even more significant than initially expected. The magnitude of this problem was confirmed when all of

the major aquarium and ornamental plant importers, growers and distributors within New Zealand (Appendix 1) were contacted by telephone. Incorrectly named aquatic plants have been shipped into the country from overseas suppliers, with errors perpetuated by dealers and even added to by some New Zealand distributors. Misnaming of plants would appear to be both deliberate and accidental. To improve the accuracy of the proposed Weed Risk Assessment report it will be necessary to undertake a comprehensive determination of the exact identity of all aquatic plant species within New Zealand, particularly plants from within the ornamental pond and aquarium trade. This will enable the status and risk of each species to be reassessed in the context of the confirmed presence and distribution within New Zealand.

In contrast to the problem of misnamed aquatic plants in the ornamental pond and aquarium trade, aquatic plants that have become naturalised in New Zealand are well known both in terms of their distribution and identity. The accuracy of this latter information arises from both the neutral and professional position of persons identifying and describing natural populations of aquatic plants. Verification of the correct identity of naturalised species is readily achieved through the various herbarium facilities and professional botanists that are available throughout New Zealand. Furthermore, the watchful eye of Plant Pest Officers (formerly known as Noxious Plant Officers) employed by Regional Councils and a variety of research personnel also help to provide an accurate account of the distribution of these naturalised species.

# 2. Characterisation of potential adverse impacts

To understand the potential for new species to further impact on indigenous freshwater biodiversity, a summary of the magnitude of current impacts is presented. During the 19th century, widespread colonisation resulted in extensive European plant introductions. Acclimatisation Societies were established to facilitate establishment of foreign species. New Zealand is now noted as having one of the highest records for the percentage (50%) of introduced flora in the world (Williamson 1996). At least 50 aquatic plant species are now naturalised in New Zealand, with most (75%) of these introduced as ornamental plants (Champion 1998). Deliberate introductions of aquatic plant species began in the mid 19th century, including *Elodea canadensis,* brought in with trout around 1868 and extensively distributed along with trout releases into natural waterbodies. From the 1940s in particular, the ornamental pond and aquarium trade contributed to the influx of new species, and it was not until 1950s that legislation was introduced to attempt to regulate their importation. Effective enforcement and the production of a prohibited list of aquatic plants for importation only began during the 1970s, under the Introduction and Quarantine of Plants Regulations 1973 pursuant to the Plants Act 1970. In 1982, six aquatic plants were gazetted as Class B Noxious Plants and banned from sale, propagation and distribution under the Noxious Plants Act 1978.

Legislation has now been redefined under the Biosecurity Act 1993 for pest management, while any new or unclassified species will now be required to be evaluated under the HSNO Act before entering the country, provided that it is not already here. Ironically, further introductions of any potential weed species already in the country (e.g. not yet naturalised or of limited distribution), cannot be refused entry to the country under the current GATT trade agreement, unless the species is subjected to an official control programme. Although the rationale is to prevent trade barriers, this situation could naturally increase the risk from undesirable species already in the country but not yet naturalised, and may also constitute an entry pathway for different genetic stock of naturalised species.

Despite the progressive increase in legislation regulating the importation of aquatic plants, records for new species have progressively increased over the last 150 years, with the highest between 1960 and1990 (Champion 1998).

## 2.1 LIFE-FORMS OF AQUATIC PLANTS

Because about 100 years of unregulated entry of aquatic plants has been permitted, it is hardly surprising that all of the major life-forms of aquatic plants are now well established within New Zealand. These life-forms can be conveniently classified as erect marginal, sprawling marginal, free-floating, attached-floating, and submerged. The following brief discussion, with illustrated examples, on each of these life-forms demonstrates the extent of adverse impact already recorded within the New Zealand aquatic vegetation, as well as the limited scope for any significantly different form of adverse impact to be introduced by new species.

### 2.1.1 Erect marginal emergents

New Zealand native erect marginal species could be regarded as the most successful of the various life-forms. The variety and vigour of native species occupying the interface between water and land has helped native species such as *Typha orientalis* maintain a prominent presence along the margin of many waterbodies. In fact this New Zealand native is regarded as an invasive species in several countries including Australia. Despite the vigour of this native life-form, competitive adventive species, such as *Zizania latifolia*, *Iris pseudacorus,* and *Phragmites australis*, can effectively displace all native erect marginal species, often resulting in an extension of occupied margins on to dry land and into deeper water. *Salix cinerea* (grey willow) has had a significant impact on wetland vegetation on account of its tall canopy and shade-inducing growth habit. In the absence of tall native erect species within the sheltered estuarine mud flats of New Zealand harbours, this vacant habitat has been extensively invaded by *Spartina* spp. This was deliberately introduced and planted primarily for land reclamation purposes and alleged habitat enhancement, but now it is actively controlled in most areas to prevent further spread following increased awareness of the value of open mud flats and of the ecological and wildlife impacts arising from plant invasion.

### 2.1.2 Sprawling marginal emergents

New Zealand native sprawling marginal species were historically poorly represented, with only *Persicaria decipiens* (swamp willow weed) fitting within this category. This habitat has subsequently become extensively colonised by introduced species of this life-form. One readily visible example was *Nasturtium officinale* (watercress), which was the first aquatic weed to come to public prominence over 150 years ago. Many more problematic examples now occur, including *Alternanthera philoxeroides* (alligator weed), *Myriophyllum aquaticum* (parrot's feather), *Glyceria maxima* (reed sweet-grass) and *Paspalum distichum* (Mercer grass).

### 2.1.3 Free-floating species

New Zealand native free-floating species are small plants often recognised and referred to by the public as water fern (*Azolla rubra*) and duckweed (*Lemna minor*). Both species remain common and provide the characteristic red or green surfaces seen on many sheltered ponds and small waterbodies around the country. The native *A. rubra* has now mostly been displaced by the introduced *A. pinnata* over much of the northern North Island. The small size of these species can result in and has resulted in rapid displacement by larger exotic free-floating species, such as *Salvinia molesta* (salvinia) and *Eichhornia crassipes* (water hyacinth). However, both of these exotic floating plants remain as Plant Pests of National Importance, with active eradication programmes in place wherever they are found in natural waterbodies. One other recent invasive plant that may occur either as a free-floating weed or throughout the water column is *Hydrodictyon reticulatum* (water net). This rose to prominence in New Zealand during the early 1990s, but it appears to have now abated as quickly as it appeared. This net-forming alga was unusual in its prolific growth, its habit of smothering submerged plants and open bottom sediment, and its ability to form surface floating mats, which gave it a competitive advantage over many aquatic species. *Utricularia gibba* is an introduced bladderwort with a similar growth habit to *H. reticulatum,* and it is now threatening the endangered native *U. protrusa*. The adventive species is a prolific seeder and has only recently started to expand and become problematic north of Auckland.

### 2.1.4 Attached-floating species

New Zealand is poorly represented with native species of this life-form, with only the small-leaved *Potamogeton cheesemanii* worthy of mention. A large variety of introduced species of this life-form have been imported into New Zealand. Many take prominence within the outdoor ornamental pond trade on account of their large colourful flowers. A variety of species of this life-form have become naturalised following accidental escape and, more commonly, deliberate planting. Notable examples include the water lily group of plants (*Nymphaea* species and many varieties), *Nuphar lutea* (yellow waterlily), *Nyphoides geminata* (marshwort), and *Hydrocleys nymphoides* (water poppy). Water lilies in particular have become widespread throughout New Zealand and are still actively planted in artificial ponds for their aesthetic appeal.

### 2.1.5 Submerged species

New Zealand's indigenous submerged species have proven susceptible to invasion on account of their low stature and density. Shallow-water turf-forming species found on exposed shorelines of lakes (such as *Isoetes kirkii*, *Glossostigma* spp., *Elatine gratioloides*) have remained relatively unscathed from invasive impact on account of the inhospitable habitat they occupy. On the other hand, native pondweeds (*Potamogeton* spp.) and milfoils (*Myriophyllum* spp.), which occupy less exposed mid-depth habitats, have been extensively replaced by invasive members of the Hydrocharitaceae family (e.g. *Elodea canadensis*, *Lagarosiphon major*, *Egeria densa*) and Ceratophyllaceae (*Ceratophyllum demersum* or hornwort). These introduced species have a growth habit unknown amongst indigenous species, with tall growing, canopy forming, dense weed beds that quickly over-grow submerged native species by light exclusion.

## 2.2 PRESENT STATUS OF INTRODUCED AQUATIC PLANTS

At present there are 26 aquatic species considered as pest plants within the legislation (Biosecurity Act 1993), out of a total of 52 naturalised aquatic plants (excluding wetland species that are normally only flooded for part of their life-cycle). There are an estimated 139 non-naturalised aquatic plants recorded in New Zealand. Therefore 27% of aquatic plants introduced to this country have become naturalised, and of those species 50% have become weedy. This is a departure from the 'tens rule' of Williamson (1996), which predicts that around 10% (5–20%) of species introduced into a country will naturalise and that around 10% of naturalised species will become problematic. This departure from the 'tens rule' probably reflects the paucity of the New Zealand native aquatic flora life-forms discussed above, and the competitive growth habits of many invasive species.

## 2.3 POTENTIAL FOR FUTURE IMPACTS FROM NEW SPECIES

The potential for new species to further impact on indigenous freshwater biodiversity is limited in comparison to that which has already arisen from historical introductions of weed species. Furthermore, the spread of already naturalised weed species represents the most immediate threat to the ecological values and biodiversity of the remaining non-impacted or minimally impacted habitats. Nevertheless, there is still further potential for new species to modify the nature and extent of existing impacts. Evidence for this can be taken from other countries, which demonstrate a progressive influx of weed species not recorded in New Zealand, some of which may present previously unexpected impacts or magnify already known impacts.

All potential aquatic life-forms are now present in New Zealand, although there is potential for more successful or competitive species within each life-form. For example, there are wetland trees such as *Melaleuca quinquenervia*

(paperbark tree) which are having a major impact on the wetlands in Florida and, given their tall dense growth habit, they may well be able to replace and even extend the willow impacts already experienced in New Zealand. Although there are already native and introduced species of the erect marginal life-form in New Zealand that are known for their competitiveness (e.g. *Typha orientalis*, *Zizania latifolia*, *Phragmites australis*), further problematic species of *Typha*, *Sagittaria* and *Butomus* could still have a marked impact if they were to be allowed entry to the country. The range of sprawling marginal species could well be extended by various grass species (e.g. *Brachiaria mutica* or para grass (already present on the Kermadec Islands); *Panicum repens* or torpedo grass) and *Ludwigia* species (e.g. *L. octovalvis*, *L. peruviana*), which are known to be problematic in other countries. With respect to free-floating species, those most likely to pose a risk to New Zealand (*Salvinia molesta* and *Eichhornia crassipes*) are already established. Cool temperate climatic conditions within New Zealand seem to present an obstacle to further invasion by some species of this life-form, including *Pistia stratiotes*, on account of sensitivity to winter frosting; however, several plants including *Stratiotes aloides*, and various species of *Utricularia*, *Lemna* and *Azolla* could all establish and become problematic. There are a number of attached-floating species that have the potential to be added to those representatives of this life-form already established in New Zealand, including *Trapa natans*, *Brasenia* and *Nymphoides* spp. The diversity of submerged species could also be extended by the introduction of further well known problematic species, such as *Myriophyllum spicatum*, *Najas* spp., and other exotic species of *Potamogeton* and *Myriophyllum*. Another known problematic species of this life-form is *Cabomba caroliniana*, which is already present in New Zealand but has not yet naturalised.

Although there is little if any potential for new life-forms to impose further new adverse impacts on New Zealand aquatic habitats or biodiversity, there is scope for alternative habitat modification or enhancement of already familiar detrimental impacts. An example using weed species already naturalised in New Zealand can be seen by considering species of the Hydrocharitaceae family, which were not previously represented in this country. The first recorded arrival of *Elodea canadensis* posed notable problems in a variety of waterbodies throughout the country. However, the subsequent introduction and establishment of *Lagarosiphon major*, followed by *Egeria densa*, resulted in equivalent life-forms but more competitive species each displacing previously established weed beds of the other species. Although this may not have been initially thought to be of any great consequence, this example illustrates how slight variations in growth habits of equivalent life-forms, even of species from the same family, can result in new environmental and management problems. In this particular example, *Lagarosiphon major* was able to grow taller and denser than *Elodea canadensis*, with the result that biodiversity was further reduced and surface-reaching weed beds posed even greater interference to waterbody usage. Similarly, *Egeria densa* was able to grow deeper and denser than either of the other two species, resulting in even greater species displacement. *Egeria densa* has also been associated with greater modification of sediments, which in turn has been implicated in contributing to the collapse and decline of vegetation in many Waikato shallow lakes. This clearly illustrates the importance of taking in to account not only the life-form of a potential new weed, but also its growth habits, environmental limitations, and the ecological niche it is likely to occupy.

## 2.4 ASSESSING IMPACT POTENTIAL

With respect to the potential for additional adverse impacts from new species or new genetic varieties it is therefore important to consider a number of perspectives:

1. What is the track record of a given species as an adventive in other countries?
2. Could species biodiversity be further degraded?
3. Are there vulnerable community or ecosystem types?
4. Are there endangered species that would have a greater risk of extinction?
5. Could new introductions allow pollination or hybridisation to modify the vigour or impact from existing species?
6. What is the potential for detrimental impact on water quality?
7. Are there particular waterbody types vulnerable to a given new species?
8. Could food chain relationships or stability be altered?
9. Would the management of a new species prove difficult or costly?
10. Will any new species add to existing hazards for waterbody users?

The above factors serve to illustrate the type of issues that need to be taken into account when performing a risk assessment. For example, the following two species which are not yet present in New Zealand would be regarded as high risk species for quite different reasons. *Trapa natans* produces spiny seeds, the liberation of which would pose a hazard to recreational users of waterfront properties and beaches; while *Myriophyllum spicatum* would pose a management problem, its resistance to herbicidal control necessitating more frequent control and higher costs incurred by waterbody managers.

Another example of how a new genetic variety of a species already established in New Zealand could exacerbate existing impacts and management problems is the genetically diverse *Hydrilla verticillata*. At present all *H. verticillata* plants in New Zealand are of the male sex, with all reproduction by vegetative means. If female plants of *H. verticillata* were to be introduced, the potential would then exist for sexual reproduction and seed formation. Extensive research on cultured *H. verticillata* samples collected from around the world has shown that male plants from New Zealand produce the most fertile crosses and abundant seed (Steward 1993). If *H. verticillata* were to sexually reproduce within New Zealand, it would predictably result in considerable greater spread, habitat adaptation and increasingly problematic control. Unfortunately this type of genetic information is rarely available, and as a consequence there must be considerable speculation on genetic risks or increased hazard from new varieties. For example, *Crassula helmsii* is an uncommon indigenous plant found on damp coastal cliffs of the South Island and on damp margins of a small number of waterbodies. Surprisingly, this New Zealand native is seen as an aggressive invasive species in the UK, where it dominates littoral margins of small waterbodies, forming monospecific, surface-reaching growths that are difficult to control. Genetic studies have not yet established whether these are in fact the same genotype or whether the UK plant represents a genetic

variation that could pose the same risks and impacts if it were to be reintroduced into New Zealand.

Another basic issue is that of the taxonomic accuracy of aquatic plants in the ornamental and aquarium trade internationally. For example, the New Zealand native *Lilaeopsis novae-zealandiae* is widely marketed in the aquarium trade overseas as a vigorous mat forming ground cover for use in aquariums. On examination of the diagnostic characteristics that distinguish the various species of *Lilaeopsis*, it is apparent that they are different species and that the so-called New Zealand native plant is in fact *L. caroliniana*, a native of the Americas. Another consideration is the potential for hybridisation by the introduction of new species of both native and naturalised genera within the country. For example, hybridisation may have already taken place between the native *Potamogeton ochreatus* and the now widespread adventive *P. crispus*, as indicated by limited isozyme analyses to date, although this still requires confirmation (NIWA unpublished data). A particular concern over hybridisation is the potential for 'hybrid vigour', in which the progeny can combine the successful attributes of both species to enable more successful exploitation of habitats than was possible by either of the parent species. Well known examples of hybrid vigour amongst aquatic plants include *Salvinia molesta* (*S. auriculata* × *Salvinia* spp.) and *Spartina anglica* (*S. alterniflora* × *S. marina*). Crosses (*Salix* × *rubens*) between single-sex introductions of the willows *S. fragilis* (male) and *S. alba* var. *vitellina* (female) commonly occur where the two parents are found, and these may be of either sex and have features intermediate between parent trees. Members of the families Potamogetonaceae, Nyphaeaceae, Salicaceae, and Typhaceae are renowned for their hybridisation potential, and species of these families not yet present in New Zealand should be viewed with considerable caution for this reason.

It is clear from these examples that there are two approaches to the undertaking of a risk assessment. Firstly, each potential adverse impact factor, such as those listed above, could be considered in isolation to identify whether there are any new species that might qualify as a risk for that factor. The alternative approach, which is emphasised in this report, is to focus on each new species and to consider what combination of cumulative adverse impacts might be based on all possible factors, so that the species itself can be ranked for risk. Such adverse impacts need to be assessed for their potential scale or extent. They also need to be placed in the context of the range of positive and negative potential impacts posed by each species, so that their final risk ranking will be based on a cumulative index of all factors. The nature and degree of potential adverse impact from new species has been incorporated in the Champion & Clayton model (see Section 6) in order to assess and rank the risk of each species, including species already within the country but not yet naturalised, as well as for those species not yet known to be in New Zealand.

# 3. Entry pathways

There are a variety of existing well known and potential entry pathways for aquatic plants into New Zealand. The following discussion considers known methods of entry with examples of particular species. This information has been based on historical accounts as well as common and not so common knowledge on plant movement practices.

## 3.1 NATURAL SPREAD

Wind-blown seed and migratory birds represent the two most common or likely entry pathways that are independent of anthropomorphic influences. Considering that only 29% of New Zealand aquatic flora are endemic, with much of the remainder also found in Australia, this would infer a well-established natural pathway has existed between these two countries. Wind-blown seed is known for its dust-like, airborne properties and continues to contribute to the flow of species across the Tasman Sea, with several recent introductions of orchid in Northland. Of the Australian aquatic species not already recorded in New Zealand, there are likely to be few potential new arrivals, although additional *Typha* species may well have the potential to enter as wind-blown seed.

Many species of aquatic plants set seed that subsequently resides in the sediment of waterbodies. Migratory birds that visit, feed and wade within such waterbodies are likely to come in contact with the seed from a range of aquatic plant species. Once again, the pathway between Australia and New Zealand is evident, with vagrant birds from Australia including the white-necked heron (*Areda pacifica*), white ibis (*Threkiornis molucca*), yellow-billed spoonbill (*Platalea flavipes*), and white-eyed duck (*Aythya australis*), along with various native species such as grey teal (*Anas gracilis*). Migratory birds may feed directly on the seed capsules of aquatic plants such as *Potamogeton* spp. and *Myriophyllum* spp., or they may simply have seeds attached to mud lodged or dried on their legs and feet. In the latter case, charophyte oospores are the most likely 'hitchhiker', and the presence of *Tolypella nidifica* in Lake Forsyth in Christchurch is likely to be an example of introduction by this means. *T. nidifica* is known from no other site within New Zealand, and the shores of Lake Forsyth are utilised by many migratory birds. A recent example of natural introduction includes *Gratiola pedunculata* (de Lange 1997).

## 3.2 SHIP BALLAST

Cumberland (1966) reported the likely introduction of *Zizania latifolia* in the soil ballast of ships. The release of ballast near Dargaville may have resulted in the first introduction of this weed to the Northern Wairoa River, from were it has continued to spread. *Alternanthera philoxeroides* (alligator weed) may have also arrived at the same destination by this means. De Lange et al. (1998)

proposed that *Schoenoplectus californicus* was probably introduced by ship ballast to the Port Waikato and Dargaville areas, where it has probably been established for many years. Ballast shipping is more carefully regulated now that the threat of pest transfer by this means has been well documented. Provided that ballast is taken on board and subsequently discharged in an appropriate manner, the current risk of new weed species arriving by this means would appear to be minimal.

## 3.3 FORAGE PLANTS

A limited number of marginal aquatic plants have been considered as useful pasture supplements for animal grazing. The best known example is *Glyceria maxima*, which was imported primarily as a coarse grass that would provide feed for cattle in wet areas. Another forage species that has proven problematic in wet areas is *Paspalum distichum* (Mercer grass). Stringent checks for weediness in new imports of forage species should prevent further imports of new weeds by this means.

## 3.4 INDUSTRIAL PURPOSES

Treatment of wastewater using robust emergent reeds has been practised overseas for many years, and the use of *Phragmites australis* has been commonly accepted for these purposes. Although Pest Management Strategies have been developed for this species under the Biosecurity Act 1993 within the few regions where it occurs, the use of this same species was permitted for evaluation purposes in the treatment of industrial wastewater. Certainly such use of aquatic plants under quarantine conditions could provide a reasonable potential for containment. Nevertheless, industrial use of aquatic plants should be considered a potential risk for the entry of new species and any application for importation for this purpose should be considered carefully.

## 3.5 ACCLIMATISATION SOCIETY

The first known submerged aquatic weed to be introduced into New Zealand was the common oxygen weed (*Elodea canadensis*), which was imported in 1868 with trout ova and subsequently with shipments of perch, tench and goldfish species (Thomson 1922). Although the 'colonialisation' syndrome has abated somewhat since the 1800s, the legacy from indiscriminate importation and deliberate release of foreign species remains. The further risk from new imports by this organisation is unlikely, but continued internal spread of many introduced plant and fish species is still practised, leading to the degradation of many waterbodies, especially within the Auckland and Waikato Regions.

## 3.6 PRE-LEGISLATIVE 'COLONIALISATION'

In the rush to create a mirror image of the mother country, numerous plants were brought into colonial New Zealand. Aquatic plants featuring showy and colourful flowers included lilies, irises and other similar plants that were highly prized for use in ornamental ponds. The flow of adventives was unabated until the late 1970s, when legislation was introduced to prohibit the entry of undesirable species. The destination of some of the earliest imported aquatic species is interesting. For example, the Hawkes Bay represents the only known location for three aquatic species. *Nuphar lutea* is a yellow flowering pond plant that has established in a large natural lake (Horseshoe Lake 42.5 ha) and it has had a limited appearance on the property of some lily growers. *Hydrilla verticillata* is known from only four lakes, with the original infestation almost certainly Lake Waikapiro or the interconnected Lake Tutira. It is quite possible that *Hydrilla* was a contaminant within bulbs or rhizomes of water lilies originally imported to the Hawkes Bay region, and subsequently planted in the sheltered bays of natural lakes. Finally, *Chara vulgaris* is likely to have had a similar history, with its first and last records dating back to Colenso (pre 1851, in Wood & Mason 1977). However, it was rediscovered by one of the authors (JC) in 1986 and remained confined to the ponds of a private resident, known to have had a historic association with the importation and culture of water lilies, until the ponds were left to dry out around 1996.

## 3.7 RESEARCH PURPOSES

Water net (*Hydrodictyon reticulatum*) is believed to have entered the country around 1980 as an unwanted import with a consignment of ornamental fish from Singapore, but it was present in the country for over 40 years prior to that date. Live material had been imported on several occasions from the UK and USA for teaching purposes at Auckland, Victoria, Canterbury, and Otago Universities. Phytosanitory precautions against possible escape ranged from strict quarantine to apparently no precautions, and it is perhaps fortuitous that there were no escapees from this source leading to naturalised populations at that time (Hawes et al. 1991). Research organisations and teaching institutes within New Zealand can exchange specimens for research and teaching purposes. For example, specimens of *Hydrilla verticillata* have been dispatched to Florida on a number of occasions to assist with a study on the genetics of internationally sourced populations. Similarly, specimens of this plant have been brought into New Zealand from the USA and Australia for comparative research (Hofstra 1997). *Marsilea hirsuta* is an aquatic fern that has also been imported and cultured by New Zealand universities for laboratory demonstration purposes, where fertilisation of megasporangia can be readily illustrated. Live and pressed specimens of aquatic species not known to be in this country have been allowed direct entry, following inspection and confirmation on the bona fide purpose for possession. Nevertheless, there remains a degree of risk that specimens may contain viable seed that could escape or that inappropriate practices are implemented with respect to the culture, containment and subsequent disposal of material on completion of

research. Despite the potential scientific value or justification for importing foreign specimens, research personnel are certainly recognised by Border Control Authorities as a high-risk profession for facilitating the entry of unwanted organisms.

## 3.8 CULINARY AND MEDICINAL PURPOSES

The first known aquatic plant to be introduced to New Zealand also became a recognised weed problem. This was watercress or *Rorippa nasturtium-aquaticum,* which was introduced for culinary purposes by the French in 1840, and within a few years it had become a major weed problem on the Avon River in Christchurch (Howard-Williams et al. 1987). By 1857 a £2,000 reward was offered by the council for its successful eradication, which has never been claimed. A similar plant to watercress is the Japanese wasabi (*Wasabi japonica*) which has been allowed entry for the culture of its stems which are used as a condiment in food and exported back to Japan. *Ipomoea aquatica* is another marginal aquatic plant species where the leaves are eaten. The seed for this plant has been available in standard packets through the nursery and garden trade for many years. Another aquatic plant provides a valued corm at the base of its stem (*Eleocharis dulcis*) and approval to import this plant for culture purposes was granted following an assessment of its perceived risk, which was regarded to be minimal. In contrast, a request for the importation of water chestnut (*Trapa natans*) for its culinary value was declined on account of the known hazard posed by its spiny seeds if the plant were to become naturalised. Alligator weed (*Alternanthera philoxeroides*) has recently been found cultivated as a culinary crop by some members of the Sri Lankan and Somalian communities in Auckland and Hamilton, mistaking this species for a traditional vegetable mukuna-wenna (*A. sessilis*). Alligator weed can grow on land and around waterbody margins, and it is a significant weed problem in the northern half of the North Island in pasture, amongst crops, along drains and around lakes.

At present no other aquatic plants of notable culinary value are known to pose a risk upon entry in to New Zealand. However, with the progressive diversification of cultures within New Zealand there has been an associated increase in the diversity of foods and the demand for traditional ingredients. In particular, medicinal plants are becoming increasingly important as the quest for alternative medicine gains momentum. Historically recognised aquatic plants of medicinal value reported by Sculthorpe (1967), which are also weedy in some parts of their geographical range, include *Acorus calamus, Bacopa monnieri, Pistia stratiotes, Ottelia alismoides, Limnophila aromatica* and *Hygrophila spinosa.* Only the first two species have been known to be present in New Zealand since the apparent eradication of *P. stratiotes* in the early 1980s.

## 3.9 APPROVED IMPORTATION

A list of both Prohibited and Approved aquatic plants for importation was established in 1976. It has been modified on various occasions thereafter, as new information became available, or following investigations into non-classified species resulting from requests for entry. There are very few importers of aquatic plants into New Zealand, although over the last 20 years many have been involved to varying degrees. The most commonly cited reasons for the paucity of new introductions by this means has been what the industry regards as excessive restrictions and unreasonable quarantine requirements. Until recently, any plants entering the country were treated with alum to kill any unwanted attached organisms. This practice was known to kill many of the plants, on account of the difficulty in achieving pesticidal action without damage to foliage. This problem may have also been partly attributable to inconsistent treatment standards, such as from the use of different alum compounds by various authorities. Although treatment problems have been largely overcome and imported plants are now mostly sourced from hygienic hydroponically grown suppliers, permitted importation still presents a significant pathway for potential entry of new species. Legislation in the form of the Biosecurity Act 1993 and the HSNO Act 1996 will now require any organism or new genetic variety not already within New Zealand to undergo a risk assessment to determine the safety and suitability for entry. These measures should help to significantly reduce the risk of entry of further undesirable aquatic species by means of legal importation.

## 3.10 INCORRECTLY IDENTIFIED IMPORT

Lack of taxonomic expertise by Border Control authorities with respect to aquatic plants presents a tangible risk of new species entering the country. Immature plants are particularly difficult to identify, and this fact could be utilised by an unscrupulous importer. The difficulty in correctly identifying live specimens is further compounded by the often impossible task of confirming the identity of seed, which can be imported separately. One importer noted that all of his stock was imported from seeds and bulbs that had been declared to the appropriate authorities and permitted entry. Lack of expertise to differentiate species based on the seed and bulb characteristics of various aquatic species is seen as an obvious avenue for legitimate but unintentional entry of new species. No provisions or requirements exist for importers to grow a sample of seed (or vegetative propagules like bulbs and corms) to maturity to enable confirmation on the correct identity of species. This can be further compounded by any supplier who deliberately or accidentally provides the name of a 'Permitted Entry' species on documents accompanying prohibited plants, thereby increasing the chances of safe passage.

Examples of incorrectly identified plants present within the aquarium and pond plant trade in New Zealand are the now declared plant pest Senegal tea (*Gymnocoronis spilanthoides*) which was distributed as costata (*Hygrophila costata*) and *Hydrocotyle leucocephala*, which is still sold as *Cardamine lyrata*. In neither case are these plants taxonomically related.

## 3.11 CONTAMINANTS WITH LEGAL IMPORT

A variety of unwanted 'hitchhikers' are likely to have entered New Zealand attached to legally imported consignments. Some probable examples have already been noted above, such as water net (*Hydrodictyon reticulatum*) and *Hydrilla verticillata*. Hydroponically grown plants and plants raised from tissue culture present no obvious risk of unwanted contaminants. A small risk exists for shoot cuttings. The greatest risk of unwanted contaminants would be from pond plants grown in outdoor facilities or collected from natural waterbodies. In this respect, rhizomes, bulbs and stems with attached roots represent the greatest source of potential contaminants. Water lilies and other similar flowering pond plants clearly pose the greatest risk. One recent example identified by the authors of this report was *Nymphoides peltata*, which was found in a Hamilton nursery that cultivated and sold a range of water lily species. The seed or rhizome of this weed species had allegedly arrived as a contaminant on imported water lily rhizomes.

## 3.12 CONTAMINATED PRODUCTS

Drainage machinery imported from overseas can contain unwanted seeds, particularly where second-hand machinery is involved. For example, seed of one weedy grass species was believed to have been imported from Australia into the Bay of Plenty. Contaminated crates and other packaging have also been implicated in the transfer of seed in mud, although the risk of aquatic species being transported by this means is low.

## 3.13 MAIL ORDER PLANTS

Aquatic plants are known to be dispatched around the world by mail order. Although many transactions represent legal trade discussed under 'approved importation', there are likely to be a significant amount of species traded without approval. This applies to the research, business and private sectors. Requests for aquatic specimens from New Zealand for research purposes have been made, with instructions to dispatch under a 'for destructive analysis only' label, which illustrates how specimens could bypass normal quarantine channels. Aquatic plant researchers in New Zealand also received an unexpected thermos flask full of millions of *Chara vulgaris* oospores, when an overseas donor thought they might be helpful for field restoration trials. More discrete entry pathways include incorporation of seed into private letters. Csurhes & Edwards (1998) also reported on the ease by which people can smuggle seed of new plant species into Australia via the mail system. Some traders deal exclusively in mail order supplies and advertise a wide range of ornamental species in magazines that circulate in New Zealand. The internet provides yet another avenue for accessing mail order companies from around the world.

## 3.14 POCKET PLANTS

'Alternative' methods of entry of aquatic plants to New Zealand appear to be as diverse as the imagination and determination of interested persons. Although 'accidental' (deliberate or genuine) contamination of baggage (e.g. sports equipment used in water) may occur, inevitably there is no way of proving intent. The probability of interception is remote, with the result that such entry methods would have to be seen as high-risk options. Equally effective is the less subtle inclusion of seeds or propagules hidden within items of clothing. The practice is well known and sufficiently common to be referred to as the trade in 'pocket plants', but it is not possible to obtain reliable information of the extent of the practice. Although Border Authorities request overseas passengers to disclose whether any animal farms have been visited while abroad, with a view to preventing entry of potential agricultural disease, there is no equivalent check on visitations to foreign waterbodies or aquatic plant farms.

## 3.15 SUMMARY

Overall, it would appear that the importation of aquatic plants has had a history of prohibitive quarantine procedures, inconsistent application of regulations and insufficient taxonomic expertise by Border Authorities. When combined with the small size of the aquatic plant trade in New Zealand, the costs of importing plants through legal channels and the unfavourable experiences of a range of importers, it is not surprising that there are so few importers operating at any one time. Based on inquiries to date of all known growers and traders it would appear that there are only two importers operating at present, with live plants imported from Denmark, Singapore and South America. During the last five years, other importers have also brought in seeds, bulbs and rhizomes from the USA and Europe. There would appear to be a genuine concern on the part of those persons importing plants, that the industry must be self-regulating to prevent problematic plants becoming established within the country, as well as to help avoid the prospect of further potentially prohibitive restrictions being imposed by regulatory authorities. In this regard, the likelihood of new species entering the country by responsible traders would appear to be limited. On the other hand, it was argued that import restrictions were already prohibitive and that this was encouraging the use of illegal entry pathways. This suggestion implies that the likelihood of entry is inversely proportional to the severity of entry restrictions. Certainly, complaints over the use of perceived draconian quarantine measures, excessive charges and lack of taxonomic expertise by MAF officials have been seen as encouraging illegal trade and the incorrect disclosure of identity of an undetermined number of plants, which are believed to be cultured and covertly traded within New Zealand.

Contrary to the low risk posed by legal importation of correctly identified and approved species, probably the greatest risk of new species entering the country would appear to be through the 'pocket trade' in aquatic plants. In view of the very nature of this practice it is not possible to estimate the scale of activity or the degree of risk posed. Some sources of information indicated that this practice was not restricted to individual plants, with one unconfirmed

report of an undeclared species being bought in by their hundreds. Inevitably there would also have been undeclared aquatic plant passage through the border as 'extras' within legitimate plant shipments. One retired trader suggested they could name 20 people that had at one time or another participated in this practice. Although hearsay such as this cannot be substantiated, it does suggest the practice may be common, and this is further evidenced by the fact that there are more aquatic species found within the trade than were previously thought to exist. The trade in 'pocket plants' may also periodically operate on a semi-professional scale in conjunction with imported aquarium fish and pets. Illegal practices within this much larger and more profitable animal trade have led to a number of prosecutions for smuggling and breach of quarantine regulations.

# 4. Identification of priority species

A list of aquatic species not naturalised in New Zealand was compiled from most plant families with representative aquatic species (Cook et al. 1974). Species were selected on the following information:

- presence (unconfirmed for a number of species) in New Zealand based on the Landcare database, aquarium society survey (Parsons et al. 1997) and plant lists from nurseries and aquarium suppliers (e.g. Wai Mara, Redwood Aquatics);
- availability overseas in the plant trade (Tropica catalogue of species, Stodola 1967, Spencer-Jones & Wade 1986, Muehlberg 1982, Stapeley Water Gardens 1989, Slocum et al. 1996);
- history as a weed in other countries (Häfliger & Scholz 1980, 1981, Häfliger 1988, Parsons & Cuthbertson 1992, Pieterse & Murphy 1993, Holm et al. 1997, Aquatics 1978–1998);
- prohibited entry from the USA (USDA APHIS national prohibited list and Florida State prohibited list), Australia (AQIS 1998), or New Zealand (MAF NASS prohibited and permitted lists for importation of seed and nursery stock; Nichol 1997; and species evaluated by the MAF Weed Risk Assessment Model).

A total of 280 entities are listed (all recorded as species apart from two tropical genera: *Echinodorus* with 14 species reported in New Zealand and *Cryptocoryne* with 12–16 species reported from New Zealand, and the Iris 'Louisiana' complex composed of several species and their hybrids). These are shown in alphabetical order of families, with genera and species selected on the basis of life-form (obligate submerged, amphibious submerged, free-floating, attached floating (waterlily type), sprawling emergent (marginal) and erect emergent) in Tables 1–6.

TABLE 1. LIST OF OBLIGATE SUBMERGED AQUATIC SPECIES NOT NATURALISED IN NEW ZEALAND.

| Family | Genus | Species |
|---|---|---|
| Aponogetonaceae | *Aponogeton* | *crispus* |
| Aponogetonaceae | *Aponogeton* | *rigidifolius* |
| Aponogetonaceae | *Aponogeton* | *ulvaceus* |
| Cabombaceae | *Cabomba* | *aquatica* |
| Cabombaceae | *Cabomba* | *australis* |
| Cabombaceae | *Cabomba* | *caroliniana* |
| Campanulaceae | *Lobelia* | *dortmanna* |
| Ceratophyllaceae | *Ceratophyllum* | *echinatum* |
| Ceratophyllaceae | *Ceratophyllum* | *muricatum* |
| Ceratophyllaceae | *Ceratophyllum* | *submersum* |
| Eriocaulaceae | *Eriocaulon* | *melanocephalatum* |
| Haloragaceae | *Myriophyllum* | *exalbescens* |
| Haloragaceae | *Myriophyllum* | *filiforme* |
| Haloragaceae | *Myriophyllum* | *heterophyllum* |
| Haloragaceae | *Myriophyllum* | *hippuroides* |
| Haloragaceae | *Myriophyllum* | *laxum* |
| Haloragaceae | *Myriophyllum* | *pinnatum* |
| Haloragaceae | *Myriophyllum* | *salsugineum* |
| Haloragaceae | *Myriophyllum* | *spicatum* |
| Haloragaceae | *Myriophyllum* | *verticillatum* |
| Hydrocharitaceae | *Blyxa* | *aubertii* |
| Hydrocharitaceae | *Blyxa* | *japonica* |
| Hydrocharitaceae | *Elodea* | *nuttallii* |
| Hydrocharitaceae | *Elodea* | *potamogeton* |
| Hydrocharitaceae | *Lagarosiphon* | *roxburghii* |
| Hydrocharitaceae | *Nechamandra* | *alternifolia* |
| Hydrocharitaceae | *Ottelia* | *alismoides* |
| Hydrocharitaceae | *Ottelia* | *japonica* |
| Isoetaceae | *Isoetes* | *lacustris* |
| Najadaceae | *Najas* | *ancistrocarpa* |
| Najadaceae | *Najas* | *graminea* |
| Najadaceae | *Najas* | *guadalupensis* |
| Najadaceae | *Najas* | *indica* |
| Najadaceae | *Najas* | *marina* |
| Najadaceae | *Najas* | *minor* |
| Nymphaeaceae | *Barclaya* | *longifolia* |
| Pontederiaceae | *Heteranthera* | *dubia* |
| Pontederiaceae | *Heteranthera* | *limosa* |
| Pontederiaceae | *Heteranthera* | *zosterifolia* |
| Potamogetonaceae | *Potamogeton* | *foliosus* |
| Potamogetonaceae | *Potamogeton* | *gayii* |
| Potamogetonaceae | *Potamogeton* | *linguatus* ? |
| Potamogetonaceae | *Potamogeton* | *lucens* |
| Potamogetonaceae | *Potamogeton* | *malaianus* |
| Potamogetonaceae | *Potamogeton* | *perfoliatus* |
| Potamogetonaceae | *Potamogeton* | *praelongus* |
| Potamogetonaceae | *Potamogeton* | *pusillus* |
| Potamogetonaceae | *Potamogeton* | *richardsonii* |
| Potamogetonaceae | *Potamogeton* | *striatus* ? |
| Potamogetonaceae | *Potamogeton* | *vaginatus* |
| Potamogetonaceae | *Potamogeton* | *zosteriformis* |
| Primulaceae | *Hottonia* | *inflata* |
| Primulaceae | *Hottonia* | *palustris* |
| Ranunculaceae | *Ranunculus* | *aquatilis* |
| Ranunculaceae | *Ranunculus* | *circinatus* |
| Ranunculaceae | *Ranunculus* | *fluitans* |
| Ranunculaceae | *Ranunculus* | *penicillatus* |
| Scrophulariaceae | *Limnophila* | *conferta* |
| Scrophulariaceae | *Limnophila* | *sessiliflora* |

TABLE 2. LIST OF AMPHIBIOUS AQUATIC SPECIES NOT NATURALISED IN NEW ZEALAND.

| Family | Genus | Species |
|---|---|---|
| Apiaceae | *Apium* | *inundatum* |
| Apiaceae | *Lilaeopsis* | *carolinense (n-z)* |
| Araceae | *Anubias* | *barteri* |
| Araceae | *Anubias* | *nana* |
| Araceae | *Cryptocoryne* | spp. |
| Callitrichaceae | *Callitriche* | *fallax* |
| Callitrichaceae | *Callitriche* | *verna* |
| Cyperaceae | *Eleocharis* | *acicularis* |
| Cyperaceae | *Eleocharis* | *vivipara* |
| Elatinaceae | *Elatine* | *triandra* |
| Lilaeaceae | *Lilaea* | *scilloides* |
| Lythraceae | *Ammania* | *coccinea* |
| Lythraceae | *Didiplis* | *diandra* |
| Lythraceae | *Rotala* | *indica* |
| Lythraceae | *Rotala* | *macrandra* |
| Lythraceae | *Rotala* | *rotundifolia* |
| Lythraceae | *Rotala* | *wallichii* |
| Mayacaceae | *Mayaca* | *fluviatilis* |
| Plantaginaceae | *Littorella* | *uniflora* |
| Polypodiaceae | *Microsorium* | *pteropus* |
| Scrophulariaceae | *Bacopa* | *caroliniana* |
| Scrophulariaceae | *Bacopa* | *lanigera* |
| Scrophulariaceae | *Bacopa* | *monniera* |
| Scrophulariaceae | *Bacopa* | *rotundifolia* |

TABLE 3. LIST OF FREE-FLOATING AQUATIC SPECIES NOT NATURALISED IN NEW ZEALAND.

| Family | Genus | Species |
|---|---|---|
| Droseraceae | *Aldrovanda* | *vesiculosa* |
| Euphorbiaceae | *Phyllanthus* | *fluitans* |
| Fabaceae | *Neptunia* | *plena* |
| Hydrocharitaceae | *Hydrocharis* | *morsus-ranae* |
| Hydrocharitaceae | *Limnobium* | *sinclairii* |
| Hydrocharitaceae | *Limnobium* | *spongia* |
| Hydrocharitaceae | *Limnobium* | *stoloniferum* |
| Hydrocharitaceae | *Stratiotes* | *aloides* |
| Lemnaceae | *Lemna* | *gibba* |
| Lemnaceae | *Lemna* | *minuscula* |
| Lemnaceae | *Lemna* | *trisulcata* |
| Lentibulariaceae | *Utricularia* | *biflora* |
| Lentibulariaceae | *Utricularia* | *flexuosa* |
| Lentibulariaceae | *Utricularia* | *floridana* |
| Lentibulariaceae | *Utricularia* | *foliosa* |
| Lentibulariaceae | *Utricularia* | *purpurea* |
| Lentibulariaceae | *Utricularia* | *vulgaris* |
| Limnocharitaceae | *Limnocharis* | *flava* |
| Onagraceae | *Ludwigia* | *helminthorrhiza* |
| Parkeriaceae | *Ceratopteris* | *pteroides* |
| Parkeriaceae | *Ceratopteris* | *thalictroides* |
| Pontederiaceae | *Eichhornia* | *azurea* |
| Salviniaceae | *Azolla* | *caroliniana* |

| | | |
|---|---|---|
| Salviniaceae | *Azolla* | *filiculoides* |
| Salviniaceae | *Salvinia* | *auriculata* |
| Salviniaceae | *Salvinia* | *cucullata* |
| Salviniaceae | *Salvinia* | *herzogii* |
| Salviniaceae | *Salvinia* | *natans* |
| Salviniaceae | *Salvinia* | *radula* |
| Salviniaceae | *Salvinia* | *rotundifolia* |
| Trapaceae | *Trapa* | *bispinosa* |
| Trapaceae | *Trapa* | *incisa* |
| Trapaceae | *Trapa* | *natans* |

TABLE 4. LIST OF ATTACHED-FLOATING AQUATIC SPECIES (WATER LILY TYPE) NOT NATURALISED IN NEW ZEALAND.

| Family | Genus | Species |
|---|---|---|
| Araceae | *Orontium* | *aquaticum* |
| Cabombaceae | *Brasenia* | *schreberi* |
| Limnocharitaceae | *Hydrocleys* | *bleheri* |
| Marsileaceae | *Marsilea* | *crenata* |
| Marsileaceae | *Marsilea* | *macropoda* |
| Marsileaceae | *Marsilea* | *quadrifolia* |
| Marsileaceae | *Marsilea* | *uncinata* |
| Marsileaceae | *Regnellidium* | *diphyllum* |
| Menyanthaceae | *Nymphoides* | *aquatica* |
| Menyanthaceae | *Nymphoides* | *cristata* |
| Menyanthaceae | *Nymphoides* | *indica* |
| Nelumbonaceae | *Nelumbo* | *lutea* |
| Nelumbonaceae | *Nelumbo* | *nucifera* |
| Nymphaeaceae | *Barclaya* | *motleyi* |
| Nymphaeaceae | *Euryale* | *ferox* |
| Nymphaeaceae | *Nuphar* | *advena* |
| Nymphaeaceae | *Nuphar* | *polysepala* |
| Nymphaeaceae | *Nuphar* | *pumila* |
| Nymphaeaceae | *Nuphar* | *variegata* |
| Nymphaeaceae | *Nymphaea* | *ampla* |
| Nymphaeaceae | *Nymphaea* | *caerulea* |
| Nymphaeaceae | *Nymphaea* | *lotus* |
| Nymphaeaceae | *Nymphaea* | *nouchali* |
| Nymphaeaceae | *Nymphaea* | *odorata* |
| Nymphaeaceae | *Ondinea* | *purpurea* |
| Nymphaeaceae | *Victoria* | *amazonica* |
| Nymphaeaceae | *Victoria* | *cruziana* |
| Potamogetonaceae | *Potamogeton* | *amplifolius* |
| Potamogetonaceae | *Potamogeton* | *distinctus* |
| Potamogetonaceae | *Potamogeton* | *illinoiensis* |
| Potamogetonaceae | *Potamogeton* | *javanicus* |
| Potamogetonaceae | *Potamogeton* | *natans* |
| Potamogetonaceae | *Potamogeton* | *nodosus* |
| Potamogetonaceae | *Potamogeton* | *tricarinatus* |
| Pontederiaceae | *Eichhornia* | *azurea* |
| Polygonaceae | *Persicaria* | *amphibia* |

TABLE 5. LIST OF SPRAWLING EMERGENT AQUATIC SPECIES NOT NATURALISED IN NEW ZEALAND.

| Family | Genus | Species |
|---|---|---|
| Amaranthaceae | *Alternanthera* | *ficoidea* |
| Amaranthaceae | *Alternanthera* | *reineckii* |
| Amaranthaceae | *Alternanthera* | *roseacefolia* |
| Apiaceae | *Hydrocotyle* | *leucocephala* |
| Apiaceae | *Hydrocotyle* | *ranunculoides* |
| Apiaceae | *Hydrocotyle* | *sibthorpioides* |
| Apiaceae | *Hydrocotyle* | *verticillata* |
| Brassicaceae | *Cardamine* | *lyrata* |
| Commelinaceae | *Murdannia* | *blumei* |
| Commelinaceae | *Murdannia* | *keisak* |
| Convolvulaceae | *Ipomoea* | *aquatica* |
| Convolvulaceae | *Ipomoea* | *fistulosa* |
| Fabaceae | *Neptunia* | *natans* |
| Juncaginaceae | *Triglochin* | *procera* |
| Lamiaceae | *Mentha* | *aquatica* |
| Onagraceae | *Ludwigia* | *adscendens* |
| Onagraceae | *Ludwigia* | *alternifolia* |
| Onagraceae | *Ludwigia* | *arcuata* |
| Onagraceae | *Ludwigia* | *hyssopifolia* |
| Onagraceae | *Ludwigia* | *inclinata* |
| Onagraceae | *Ludwigia* | *octovalvis* |
| Onagraceae | *Ludwigia* | *perennis* |
| Onagraceae | *Ludwigia* | *peruviana* |
| Onagraceae | *Ludwigia* | *repens* |
| Onagraceae | *Ludwigia* | *uruguayensis* |
| Poaceae | *Brachiaria* | *mutica* |
| Poaceae | *Hymenachne* | *amplexicaulis* |
| Poaceae | *Leersia* | *hexandra* |
| Poaceae | *Leptochloa* | *aquatica* |
| Poaceae | *Leptochloa* | *chinensis* |
| Poaceae | *Leptochloa* | *coerulescens* |
| Poaceae | *Oryza* | *rufipogon* |
| Poaceae | *Oryza* | spp. (except *sativa*) |
| Poaceae | *Panicum* | *elephantipes* |
| Poaceae | *Panicum* | *hemitomon* |
| Poaceae | *Panicum* | *purpurescens* |
| Poaceae | *Panicum* | *repens* |
| Poaceae | *Paspalidium* | *geminatum* |
| Poaceae | *Paspalum* | *fluitans* |
| Poaceae | *Pennisetum* | *purpureum* |
| Poaceae | *Sacciolepis* | spp. |
| Poaceae | *Vossia* | *cuspidata* |
| Polygonaceae | *Persicaria* | *amphibia* |
| Polygonaceae | *Persicaria* | *barbatum* |
| Polygonaceae | *Persicaria* | *coccinea* |
| Polygonaceae | *Persicaria* | *densiflora* |
| Pontederiaceae | *Heteranthera* | *reniformis* |
| Pontederiaceae | *Pontederia* | *rotundifolia* |
| Saururaceae | *Saururus* | *cernuus* |
| Scrophulariaceae | *Mimulus* | *orbicularis* |
| Scrophulariaceae | *Veronica* | *beccabunga* |

TABLE 6. LIST OF ERECT EMERGENT AQUATIC SPECIES NOT NATURALISED IN NEW ZEALAND.

| Family | Genus | Species |
|---|---|---|
| Acanthaceae | *Hygrophila* | *angustifolia* |
| Acanthaceae | *Hygrophila* | *auriculata* |
| Acanthaceae | *Hygrophila* | *corymbosa* |
| Acanthaceae | *Hygrophila* | *difformis* |
| Acanthaceae | *Hygrophila* | *polysperma* |
| Alismataceae | *Alisma* | *canaliculatum* |
| Alismataceae | *Alisma* | *gramineum* |
| Alismataceae | *Alisma* | *parviflorum* |
| Alismataceae | *Alisma* | *triviale* |
| Alismataceae | *Baldellia* | *ranunculoides* |
| Alismataceae | *Damasonium* | *minus* |
| Alismataceae | *Echinodorus* | *grandiflorus* |
| Alismataceae | *Echinodorus* | spp. |
| Alismataceae | *Sagittaria* | *calycina* |
| Alismataceae | *Sagittaria* | *kurziana* |
| Alismataceae | *Sagittaria* | *lancifolia* |
| Alismataceae | *Sagittaria* | *latifolia* |
| Alismataceae | *Sagittaria* | *pygmaea* |
| Alismataceae | *Sagittaria* | *sagittifolia* |
| Alismataceae | *Sagittaria* | *trifolia* |
| Amaryllidaceae | *Crinum* | *calamistratum* |
| Amaryllidaceae | *Crinum* | *natans* |
| Apiaceae | *Berula* | *erecta* |
| Apiaceae | *Cicuta* | *virosa* |
| Araceae | *Acorus* | *calamus* |
| Araceae | *Acorus* | *japonica* |
| Araceae | *Monotrichardia* | *linifolia* |
| Butomaceae | *Butomus* | *umbellatus* |
| Campanulaceae | *Lobelia* | *chinensis* |
| Cyperaceae | *Cyperus* | *difformis* |
| Cyperaceae | *Cyperus* | *papyrus* |
| Cyperaceae | *Cyperus* | *procerus* |
| Cyperaceae | *Cyperus* | *prolifer* |
| Cyperaceae | *Cyperus* | *serotinus* |
| Cyperaceae | *Eleocharis* | *acutangula* |
| Cyperaceae | *Eleocharis* | *dulcis* |
| Cyperaceae | *Eleocharis* | *kuroguwai* |
| Cyperaceae | *Eleocharis* | *palustris* |
| Cyperaceae | *Eleocharis* | *plantaginoidea* |
| Cyperaceae | *Schoenoplectus* | *tatora* |
| Cyperaceae | *Scirpus* | *confervoides* |
| Cyperaceae | *Scirpus* | *grossus* |
| Cyperaceae | *Scirpus* | *hotarui* |
| Cyperaceae | *Scirpus* | *mucronatus* |
| Eriocaulaceae | *Eriocaulon* | *luzulaefolium* |
| Haloragaceae | *Proserpinaca* | *palustris* |
| Hippuridaceae | *Hippuris* | *vulgaris* |
| Iridaceae | *Iris* | 'Louisiana (incl. ×)' |
| Iridaceae | *Iris* | *ensata* |
| Iridaceae | *Iris* | *laevigata* |

| | | |
|---|---|---|
| Iridaceae | *Iris* | *sibirica* |
| Iridaceae | *Iris* | *versicolor* |
| Iridaceae | *Iris* | *virginica* |
| Poaceae | *Phragmites* | *karka* |
| Poaceae | *Zizania* | *aquatica* |
| Poaceae | *Zizania* | *palustris* |
| Pontederiaceae | *Eichhornia* | *paniculata* |
| Pontederiaceae | *Monochoria* | *hastata* |
| Pontederiaceae | *Monochoria* | *korsakowii* |
| Pontederiaceae | *Monochoria* | *vaginalis* |
| Pontederiaceae | *Pontederia* | *cordata* |
| Pontederiaceae | *Pontederia* | *lanceolata* |
| Ranunculaceae | *Caltha* | *palustris* |
| Ranunculaceae | *Caltha* | *polypetala* |
| Ranunculaceae | *Caltha* | *sagittata* |
| Ranunculaceae | *Ranunculus* | *lingua* |
| Sparganiaceae | *Sparganium* | *erectum* |
| Sphenocleaceae | *Sphenoclea* | *zeylanica* |
| Sterculiaceae | *Pentapetes* | *phoenica* |
| Typhaceae | *Typha* | *angustifolia* |
| Typhaceae | *Typha* | *domingensis* |
| Typhaceae | *Typha* | *elephantina* |
| Typhaceae | *Typha* | *javanica* |
| Typhaceae | *Typha* | *latifolia* |
| Typhaceae | *Typha* | *laxmanii* |
| Typhaceae | *Typha* | *shuttleworthii* |

Tables 7–12 sort these species according to three variables:

- Whether the plant is present as a non-naturalised plant in New Zealand
- Whether the plant is distributed as an ornamental plant overseas
- Whether the plant is reported as a weed overseas

Within each table are further species sorted on their ranking by New Zealand, Australian and United States authorities, and life-form.

This segregation of categories should assist in the screening of priority species for further evaluation using a suitable risk assessment model (see Section 6).

KEY TO SYMBOLS USED IN TABLES 7–12:

***Present in New Zealand***

| | |
|---|---|
| y | on Landcare list of species present in New Zealand |
| t | listed as present within the nursery/aquarium trade |
| e | eradicated from New Zealand |
| ? | doubtful record |

***Weed overseas***

| | |
|---|---|
| AF | weed in Africa |
| AS | weed in Asia |
| AU | weed in Australia |
| EU | weed in Europe |
| NA | weed in North America |
| SA | weed in South/Central America |
| WWW | recorded as one of world's worst weeds in Holm et al. (1997) |

***Ranking***

| | |
|---|---|
| An | species, or genus rejected by AQIS pre-entry weed risk assessment model |
| Aa | species, or genus accepted by AQIS pre-entry weed risk assessment model |
| USn | species banned from import by USDA, or Florida State |
| NZn | species, or genus rejected by MAF pre-entry weed risk assessment, or Nichol (1997) |
| Nza | species, or genus accepted by MAF pre-entry weed risk assessment |
| Nze | species, or genus requiring further evaluation by MAF pre-entry weed risk assessment |
| NASSn | species, or genus banned from import according to MAF NASS Standards for importation of seed, or nursery stock (1976–94) |
| NASSa | species, or genus accepted for import according to MAF NASS Standards for importation of seed, or nursery stock (1976–94) |

***Life-form***

| | |
|---|---|
| as | amphibious submerged |
| ee | erect emergent |
| ff | free-floating |
| os | obligate submerged |
| se | sprawling emergent |
| wl | water lily type (attached-floating) |

TABLE 7. AQUATIC SPECIES PRESENT IN NEW ZEALAND, DISTRIBUTED AS AN ORNAMENTAL PLANT, AND A WEED OVERSEAS.

| Family | Genus | Species | Present in NZ | Weed overseas | Sold overseas | Ranking | Life-form |
|---|---|---|---|---|---|---|---|
| Hydrocharitaceae | *Hydrocharis* | *morsus-ranae* | t | NA,EU | y | NASSn | ff |
| Pontederiaceae | *Eichhornia* | *azurea* | t | SA | y | USn, NZn, NASSn | wl, ff |
| Salviniaceae | *Azolla* | *caroliniana* | t? | EU,NA,SA | y | NASSn | ff |
| Salviniaceae | *Salvinia* | *auriculata* | t | SA | y | Usn, NASSn | ff |
| Salviniaceae | *Salvinia* | *rotundifolia* | t | NA,SA | y | An, NASSn | ff |
| Cabombaceae | *Cabomba* | *caroliniana* | y,t | NA,AU,AS | y | An, NZn, NASSn | os |
| Najadaceae | *Najas* | *guadalupensis* | y | NA | y | An | os |
| Potamogetonaceae | *Potamogeton* | *perfoliatus* | y | EU,AU | y | NASSn | os |
| Apiaceae | *Hydrocotyle* | *verticillata* | y,t | SA, NA | y | An, NASSn | se |
| Convolvulaceae | *Ipomoea* | *aquatica* | y | NA,AS | y | USn, Aa | se |
| Onagraceae | *Ludwigia* | *repens* | y,t | NA | y | NASSn | se |
| Marsileaceae | *Marsilea* | *quadrifolia* | y,t | WWW | y | An, NASSn | wl |
| Menyanthaceae | *Nymphoides* | *aquatica* | y | NA | y | NASSn | wl |
| Nymphaeaceae | *Nuphar* | *advena* | y | NA | y | An, NASSn | wl |
| Nymphaeaceae | *Nuphar* | *variegata* | y | NA | y | An, NASSn | wl |
| Nymphaeaceae | *Nymphaea* | *nouchali* | y,t | AS | y | An, NASSa | wl |
| Acanthaceae | *Hygrophila* | *polysperma* | y,t | NA | y | USn, NASSa | ee |
| Alismataceae | *Sagittaria* | *sagittifolia* | y?,t | EU | y | USn, NZn, Aa, NASSn | ee |
| Butomaceae | *Butomus* | *umbellatus* | y | NA | y | NASSn | ee |
| Cyperaceae | *Eleocharis* | *palustris* | t | WWW | y | An | ee |
| Sparganiaceae | *Sparganium* | *erectum* | y | EU | y | USn, An, NASSn | ee |
| Typhaceae | *Typha* | *angustifolia* | y,t | WWW | y | An | ee |
| Typhaceae | *Typha* | *latifolia* | y,t | WWW | y | NZn, An | ee |
| Cyperaceae | *Eleocharis* | *acicularis* | y,t | WWW | y | NASSn | as |
| Cyperaceae | *Eleocharis* | *vivipara* | y,t | NA | y | NASSn | as |
| Lythraceae | *Rotala* | *indica* | y,t | AS | y | An, NASSn | as |
| | | | | | | | |
| Marsileaceae | *Marsilea* | *crenata* | y | AS | y | | wl |
| Cyperaceae | *Cyperus* | *prolifer* | t? | NA | y | | ee |
| Cyperaceae | *Scirpus* | *mucronatus* | t | AS | y | | ee |
| | | | | | | | |
| Parkeriaceae | *Ceratopteris* | *thalictroides* | y,t | NA,AS | y | Aa, NASSn | ff |
| Parkeriaceae | *Ceratopteris* | *pteroides* | t | NA | y | Aa, NASSn | ff |
| Nelumbonaceae | *Nelumbo* | *nucifera* | y | AS | y | Aa, NASSn | wl |
| Cyperaceae | *Eleocharis* | *dulcis* | y | WWW | y | Aa, NASSn | ee |
| Lamiaceae | *Mentha* | *aquatica* | y,t | EU | y | Aa | se |
| Nymphaeaceae | *Nymphaea* | *odorata* | t | NA | y | Aa, NASSa | wl |
| Alismataceae | *Echinodorus* | *grandiflorus* | y,t | SA | y | NASSa | ee |
| Cyperaceae | *Cyperus* | *papyrus* | y,t | AF | y | Aa | ee |
| Scrophulariaceae | *Bacopa* | *caroliniana* | y,t | NA | y | NASSa | as |
| Scrophulariaceae | *Bacopa* | *monniera* | y,t | NA | y | Aa, NASSa | as |

TABLE 8. AQUATIC SPECIES ABSENT FROM NEW ZEALAND, DISTRIBUTED AS AN ORNAMENTAL, AND A WEED OVERSEAS.

| Family | Genus | Species | Weed overseas | Sold overseas | Ranking | Life-form |
|---|---|---|---|---|---|---|
| Hydrocharitaceae | *Limnobium* | *spongia* | NA | y | NASSn | ff |
| Lemnaceae | *Lemna* | *gibba* | EU,SA | y | NZn, NASSn | ff |
| Lemnaceae | *Lemna* | *trisulcata* | NA | y | NASSn | ff |
| Lentibulariaceae | *Utricularia* | *vulgaris* | NA | y | NASSn | ff |
| Menyanthaceae | *Nymphoides* | *indica* | AS,SA | y | An, NASSn | ff |
| Salviniaceae | *Azolla* | *filiculoides* | EU,NA,SA | y | NASSn | ff |
| Salviniaceae | *Salvinia* | *cucullata* | AS | y | Usn, An, NASSn | ff |
| Salviniaceae | *Salvinia* | *natans* | EU,AS | y | Usn, An, NASSn | ff |
| Trapaceae | *Trapa* | *bispinosa* | NA | y | USn, An, NASSn | ff |
| Trapaceae | *Trapa* | *natans* | NA | y | USn, An, NASSn | ff |
| Haloragaceae | *Myriophyllum* | *exalbescens* | NA | y | NASSn | os |
| Haloragaceae | *Myriophyllum* | *heterophyllum* | NA | y | NASSn | os |
| Haloragaceae | *Myriophyllum* | *spicatum* | WWW | y | USn, An, NASSn | os |
| Haloragaceae | *Myriophyllum* | *verticillatum* | EU | y | NASSn | os |
| Hydrocharitaceae | *Elodea* | *nuttallii* | EU,NA,AS | y | NZn, NASSn | os |
| Hydrocharitaceae | *Ottelia* | *alismoides* | AS | y | An, NASSn | os |
| Najadaceae | *Najas* | *minor* | NA | y | An | os |
| Potamogetonaceae | *Potamogeton* | *lucens* | EU | y | NASSn | os |
| Potamogetonaceae | *Potamogeton* | *malaianus* | AS | y | NASSn | os |
| Potamogetonaceae | *Potamogeton* | *zosteriformis* | NA | y | NASSn | os |
| Scrophulariaceae | *Limnophila* | *sessiliflora* | NA | y | USn, An, NASSa | os |
| Apiaceae | *Hydrocotyle* | *ranunculoides* | AU, SA | y | An | se |
| Onagraceae | *Ludwigia* | *peruviana* | AU,NA | y | NZn, An, NASSn | se |
| Pontederiaceae | *Heteranthera* | *dubia* | NA | y | An, NASSn | se |
| Cabombaceae | *Brasenia* | *schreberi* | NA | y | NASSn | wl |
| Marsileaceae | *Marsilea* | *macropoda* | NA | y | NASSn | wl |
| Marsileaceae | *Marsilea* | *uncinata* | NA | y | NASSn | wl |
| Nelumbonaceae | *Nelumbo* | *lutea* | NA | y | An, NASSn | wl |
| Nymphaeaceae | *Nuphar* | *polysepala* | NA | y | An, NASSn | wl |
| Potamogetonaceae | *Potamogeton* | *natans* | EU,NA | y | An, NASSn | wl |
| Alismataceae | *Sagittaria* | *calycina* | NA | y | An, NASSn | ee |
| Alismataceae | *Sagittaria* | *kurziana* | NA | y | NASSn | ee |
| Alismataceae | *Sagittaria* | *lancifolia* | NA | y | NASSn | ee |
| Pontederiaceae | *Pontederia* | *lanceolata* | NA | y | NASSn | ee |
| Najadaceae | *Najas* | *indica* | AS | y | | os |
| Najadaceae | *Najas* | *marina* | WW | y | | os |
| Ranunculaceae | *Ranunculus* | *aquatilis* | EU,SA,NA | y | | os |
| Ranunculaceae | *Ranunculus* | *circinatus* | NA | y | | os |
| Polygonaceae | *Persicaria* | *amphibia* | NA | y | | se |
| Polygonaceae | *Persicaria* | *barbatum* | AS | y | | se |
| Menyanthaceae | *Nymphoides* | *cristata* | AS | y | | wl |
| Alismataceae | *Alisma* | *gramineum* | NA | y | | ee |
| Callitrichaceae | *Callitriche* | *verna* | AS | y? | | as |

TABLE 9. AQUATIC SPECIES ABSENT FROM NEW ZEALAND, NOT DISTRIBUTED AS AN ORNAMENTAL PLANT, AND A WEED OVERSEAS.

| Family | Genus | Species | Weed overseas | Ranking | Life-form |
|---|---|---|---|---|---|
| Lemnaceae | *Lemna* | *minuscula* | EU | NASSn | ff |
| Lentibulariaceae | *Utricularia* | *biflora* | NA | NASSn | ff |
| Lentibulariaceae | *Utricularia* | *flexuosa* | AS | NASSn | ff |
| Lentibulariaceae | *Utricularia* | *floridana* | NA | NASSn | ff |
| Lentibulariaceae | *Utricularia* | *foliosa* | NA | NASSn | ff |
| Lentibulariaceae | *Utricularia* | *purpurea* | NA | NASSn | ff |
| Salviniaceae | *Salvinia* | *herzogii* | SA | USn, NASSn | ff |
| Salviniaceae | *Salvinia* | *radula* | SA | USn, NASSn | ff |
| Trapaceae | *Trapa* | *incisa* | NA | USn | ff |
| Ceratophyllaceae | *Ceratophyllum* | *muricatum* | AS | An | os |
| Haloragaceae | *Myriophyllum* | *laxum* | NA | NASSn | os |
| Haloragaceae | *Myriophyllum* | *pinnatum* | NA | NASSn | os |
| Haloragaceae | *Myriophyllum* | *salsugineum* | AU | NASSn | os |
| Hydrocharitaceae | *Blyxa* | *japonica* | AS | NASSn | os |
| Hydrocharitaceae | *Ottelia* | *japonica* | AS | An | os |
| Pontederiaceae | *Heteranthera* | *limosa* | SA,NA | An | os |
| Potamogetonaceae | *Potamogeton* | *foliosus* | NA | An, NASSn | os |
| Potamogetonaceae | *Potamogeton* | *linguatus* | SA | NASSn | os? |
| Potamogetonaceae | *Potamogeton* | *praelongus* | NA | NASSn | os |
| Potamogetonaceae | *Potamogeton* | *pusillus* | NA | NASSn | os |
| Potamogetonaceae | *Potamogeton* | *richardsonii* | NA | NASSn | os |
| Potamogetonaceae | *Potamogeton* | *striatus* | SA | NASSn | os? |
| Potamogetonaceae | *Potamogeton* | *vaginatus* | NA | NASSn | os |
| Scrophulariaceae | *Limnophila* | *conferta* | AS | An | os |
| Onagraceae | *Ludwigia* | *hyssopifolia* | WWW | NASSn | se |
| Onagraceae | *Ludwigia* | *octovalvis* | WWW | NASSn | se |
| Onagraceae | *Ludwigia* | *uruguayensis* | SA,NA | An, NASSn | se |
| Poaceae | *Brachiaria* | *mutica* | AU,SA, | Aa,NZn | se |
| Poaceae | *Hymenachne* | *amplexicaulis* | NA | An | se |
| Poaceae | *Oryza* | *rufipogon* | WWW | An | se |
| Poaceae | *Oryza* | spp. (except *sativa*) | WWW | An | se |
| Poaceae | *Panicum* | *repens* | AS,NA | NZn | se |
| Poaceae | *Paspalidium* | *geminatum* | CG | An | se |
| Poaceae | *Pennisetum* | *purpureum* | NA | NZn | se |
| Poaceae | *Vossia* | *cuspidata* | AF | USn | se |
| Pontederiaceae | *Heteranthera* | *reniformis* | EU,SA | An, NASSn | se |
| Scrophulariaceae | *Mimulus* | *orbicularis* | AS | An | se |
| Potamogetonaceae | *Potamogeton* | *amplifolius* | NA | NASSn | wl |
| Potamogetonaceae | *Potamogeton* | *distinctus* | AS | An, NASSn | wl |
| Potamogetonaceae | *Potamogeton* | *illinoiensis* | NA | NASSn | wl |
| Potamogetonaceae | *Potamogeton* | *javanicus* | AU | NASSn | wl |
| Potamogetonaceae | *Potamogeton* | *nodosus* | NA | An, NASSn | wl |
| Potamogetonaceae | *Potamogeton* | *tricarinatus* | AU | An, NASSn | wl |
| Alismataceae | *Sagittaria* | *pygmaea* | AS | An, NASSn | ee |
| Alismataceae | *Sagittaria* | *trifolia* | AS | An, Nza, NASSn | ee |
| Apiaceae | *Cicuta* | *virosa* | EU | An | ee |
| Campanulaceae | *Lobelia* | *chinensis* | AS | An | ee |
| Cyperaceae | *Eleocharis* | *kuroguwai* | AS | An | ee |
| Cyperaceae | *Eleocharis* | *plantaginoidea* | AS | An, NASSn | ee |
| Cyperaceae | *Schoenoplectus* | *tatora* | SA | An | ee |
| Pontederiaceae | *Monochoria* | *hastata* | AS | USn, NZn | ee |

| | | | | | |
|---|---|---|---|---|---|
| Pontederiaceae | *Monochoria* | *vaginalis* | AS | USn, NZn, Aa | ee |
| Typhaceae | *Typha* | *domingensis* | NA,AU | NZn, An | ee |
| Typhaceae | *Typha* | *elephantina* | AS | An | ee |
| Typhaceae | *Typha* | *javanica* | AS | An | ee |
| Elatinaceae | *Elatine* | *triandra* | AS | An | as |
| | | | | | |
| Ranunculaceae | *Ranunculus* | *fluitans* | EU | | os |
| Ranunculaceae | *Ranunculus* | *penicillatus* | EU | | os |
| Commelinaceae | *Murdannia* | *blumei* | AS | | se |
| Commelinaceae | *Murdannia* | *keisak* | AS | | se |
| Convolvulaceae | *Ipomoea* | *fistulosa* | NA | | se |
| Lythraceae | *Ammania* | *coccinea* | NA | | se |
| Najadaceae | *Najas* | *ancistrocarpa* | NA | | se |
| Poaceae | *Leersia* | *hexandra* | AS,AU | | se |
| Poaceae | *Leptochloa* | *chinensis* | AS | | se |
| Poaceae | *Panicum* | *elephantipes* | SA | | se |
| Poaceae | *Panicum* | *hemitomon* | NA | | se |
| Poaceae | *Panicum* | *purpurescens* | NA | | se |
| Poaceae | *Paspalum* | *fluitans* | NA | | se |
| Poaceae | *Sacciolepis* | spp. | AS | | se |
| Polygonaceae | *Persicaria* | *coccinea* | NA | | se |
| Polygonaceae | *Persicaria* | *densiflora* | NA | | se |
| Alismataceae | *Alisma* | *canaliculatum* | AS | | ee |
| Apiaceae | *Berula* | *erecta* | EU | | ee |
| Araceae | *Monotrichardia* | *linifolia* | SA | | ee |
| Cyperaceae | *Cyperus* | *difformis* | AS,AU | | ee |
| Cyperaceae | *Cyperus* | *procerus* | AS | | ee |
| Cyperaceae | *Cyperus* | *serotinus* | AS | | ee |
| Cyperaceae | *Eleocharis* | *acutangula* | AS | | ee |
| Cyperaceae | *Scirpus* | *confervoides* | NA | | ee |
| Cyperaceae | *Scirpus* | *grossus* | AS | | ee |
| Cyperaceae | *Scirpus* | *hotarui* | AS | | ee |
| Poaceae | *Phragmites* | *karka* | AS | | ee |
| Pontederiaceae | *Monochoria* | *korsakowii* | EU | | ee |
| Sphenocleaceae | *Sphenoclea* | *zeylanica* | AS | | ee |
| Sterculiaceae | *Pentapetes* | *phoenica* | AS | | ee |
| Acanthaceae | *Hygrophila* | *auriculata* | SA | | as |
| Scrophulariaceae | *Bacopa* | *rotundifolia* | NA | | as |
| | | | | | |
| Alismataceae | *Damasonium* | *minus* | AU | Aa | ee |
| Apiaceae | *Apium* | *inundatum* | EU | Aa | as |
| Ranunculaceae | *Caltha* | *sagittata* | SA | NASSa | ee |

TABLE 10. AQUATIC SPECIES PRESENT IN NEW ZEALAND, DISTRIBUTED AS AN ORNAMENTAL, AND NOT RECORDED AS A WEED OVERSEAS.

| Family | Genus | Species | Present in NZ | In trade | Ranking | Life-form |
|---|---|---|---|---|---|---|
| Onagraceae | *Ludwigia* | *belminthorrhiza* | y,t | y | NASSn | ff |
| Aponogetonaceae | *Aponogeton* | *rigidifolius* | y,t | y | An, NASSn | os |
| Aponogetonaceae | *Aponogeton* | *ulvaceus* | y,t | y | NASSn | os |
| Pontederiaceae | *Heteranthera* | *zosterifolia* | y,t | y | An, NASSn | os |
| Potamogetonaceae | *Potamogeton* | *gayii* | t | y | An, NASSn | os |

| | | | | | | |
|---|---|---|---|---|---|---|
| Primulaceae | *Hottonia* | *palustris* | y | y | NASSn | os |
| Brassicaceae | *Cardamine* | *lyrata* | y,t? | y | NASSn | se |
| Onagraceae | *Ludwigia* | *alternifolia* | y,t | y | NASSn | se |
| Onagraceae | *Ludwigia* | *arcuata* | y,t | y | NASSn | se |
| Onagraceae | *Ludwigia* | *inclinata* | y,t | y | NASSn | se |
| Onagraceae | *Ludwigia* | *perennis* | y,t | y | NASSn | se |
| Saururaceae | *Saururus* | *cernuus* | y,t | y | NASSn | se |
| Nymphaeaceae | *Barclaya* | *motleyi* | y | y | An, NASSa | wl |
| Nymphaeaceae | *Nuphar* | *pumila* | y,t | y | An, NASSa | wl |
| Nymphaeaceae | *Nymphaea* | *caerulea* | y,t | y | An, NASSa | wl |
| Poaceae | *Zizania* | *aquatica* | e? | y | NZn, Aa | ee |
| Poaceae | *Zizania* | *palustris* | e? | y | NZn | ee |
| Ranunculaceae | *Ranunculus* | *lingua* | y,t | y | NASSn | ee |
| Typhaceae | *Typha* | *shuttleworthii* | y | y | An | ee |
| Lythraceae | *Rotala* | *rotundifolia* | y,t | y | An | as |
| Fabaceae | *Neptunia* | *plena* | y | y | | ff |
| Isoetaceae | *Isoetes* | *lacustris* | y | y | | os |
| Amaranthaceae | *Alternanthera* | *ficoidea* | y | y | | se |
| Amaranthaceae | *Alternanthera* | *reineckii* | t | y | | se |
| Amaranthaceae | *Alternanthera* | *roseacefolia* | y,t | y | | se |
| Apiaceae | *Hydrocotyle* | *leucocephala* | y,t | y | | se |
| Apiaceae | *Hydrocotyle* | *sibthorpioides* | y,t | y | | se |
| Acanthaceae | *Hygrophila* | *difformis* | y,t | y | | ee |
| Alismataceae | *Alisma* | *parviflorum* | y,t | y | | ee |
| Alismataceae | *Alisma* | *triviale* | y | y | | ee |
| Alismataceae | *Baldellia* | *ranunculoides* | y,t | y | | ee |
| Iridaceae | *Iris* | *ensata* | y,t | y | | ee |
| Iridaceae | *Iris* | *laevigata* | y,t | y | | ee |
| Iridaceae | *Iris* | *sibirica* | y,t | y | | ee |
| Iridaceae | *Iris* | *versicolor* | y,t | y | | ee |
| Iridaceae | *Iris* | *virginica* | y,t | y | | ee |
| Typhaceae | *Typha* | *laxmanii* | t | y | | ee |
| Apiaceae | *Lilaeopsis* | *carolinense (n-z)* | t | y | | as |
| Lythraceae | *Didiplis* | *diandra* | y,t | y | | as |
| Lythraceae | *Rotala* | *macrandra* | y,t | y | | as |
| Lythraceae | *Rotala* | *wallichii* | y,t | y | | as |
| Mayacaceae | *Mayaca* | *fluviatilis* | y,t | y | | as |
| Scrophulariaceae | *Bacopa* | *lanigera* | y,t | y | | as |
| Aponogetonaceae | *Aponogeton* | *crispus* | y,t | y | Aa, NASSn | os |
| Campanulaceae | *Lobelia* | *dortmanna* | y,t | y | Aa, NASSa | os |
| Nymphaeaceae | *Barclaya* | *longifolia* | y,t | y | Aa, NASSa | os |
| Scrophulariaceae | *Veronica* | *beccabunga* | y | y | Aa | se |
| Nymphaeaceae | *Nymphaea* | *lotus* | y,t | y | NASSa | wl |
| Nymphaeaceae | *Victoria* | *amazonica* | y | y | Aa | wl |
| Acanthaceae | *Hygrophila* | *angustifolia* | y,t | y | NASSa | ee |
| Acanthaceae | *Hygrophila* | *corymbosa* | y,t | y | NASSa | ee |
| Alismataceae | *Echinodorus* | spp. | y (14) t (9) | y | NASSa | ee |
| Amaryllidaceae | *Crinum* | *calamistratum* | y,t | y | Aa | ee |
| Amaryllidaceae | *Crinum* | *natans* | y,t | y | Aa | ee |
| Araceae | *Acorus* | *calamus* | y,t | y | Aa, NASSn | ee |
| Araceae | *Acorus* | *japonica* | y,t | y | Aa, NASSn | ee |
| Iridaceae | *Iris* | 'Louisiana (incl. ×)' | y,t | y | Aa | ee |
| Pontederiaceae | *Pontederia* | *cordata* | y,t | y | Aa, NASSn | ee |
| Ranunculaceae | *Caltha* | *polypetala* | t | y | Aa, NASSn | ee |
| Ranunculaceae | *Caltha* | *palustris* | y,t | y | Aa, NASSa | ee |
| Araceae | *Anubias* | *barteri* | Y,t | y | NASSa | as |
| Araceae | *Anubias* | *nana* | y,t | y | NASSa | as |
| Araceae | *Cryptocoryne* | spp. | y (12)t (16) | y | NASSa | as |
| Polypodiaceae | *Microsorium* | *pteropus* | y,t | y | Aa, NASSn | as |

TABLE 11. AQUATIC SPECIES ABSENT FROM NEW ZEALAND, DISTRIBUTED AS AN ORNAMENTAL, AND NOT RECORDED AS A WEED OVERSEAS.

| Family | Genus | Species | In trade | Ranking | Life-form |
|---|---|---|---|---|---|
| Hydrocharitaceae | *Stratiotes* | *aloides* | y | USn, An, NASSn | ff |
| Cabombaceae | *Cabomba* | *aquatica* | y | USn, NASSn | os |
| Cabombaceae | *Cabomba* | *australis* | y | An, NASSn | os |
| Ceratophyllaceae | *Ceratophyllum* | *echinatum* | y | An | os |
| Ceratophyllaceae | *Ceratophyllum* | *submersum* | y | An | os |
| Pontederiaceae | *Eichhornia* | *paniculata* | y | NASSn | se |
| Pontederiaceae | *Pontederia* | *rotundifolia* | y | USn, An | se |
| Araceae | *Orontium* | *aquaticum* | y | NASSn | wl |
| Marsileaceae | *Regnellidium* | *diphyllum* | y | An, Nze, NASSn | wl |
| Acanthaceae | *Hygrophila* | *spinosa* | y | An | ee |
| Alismataceae | *Sagittaria* | *latifolia* | y | NASSn | ee |
| Hippuridaceae | *Hippuris* | *vulgaris* | y | NASSn | ee |
| Euphorbiaceae | *Phyllanthus* | *fluitans* | y | | ff |
| Hydrocharitaceae | *Limnobium* | *sinclairii* | y | | ff |
| Hydrocharitaceae | *Limnobium* | *stoloniferum* | y | | ff |
| Eriocaulaceae | *Eriocaulon* | *melanocephalatum* | y | | os |
| Haloragaceae | *Myriophyllum* | *filiforme* | y | | os |
| Haloragaceae | *Myriophyllum* | *hippuroides* | y | | os |
| Primulaceae | *Hottonia* | *inflata* | y | | os |
| Juncaginaceae | *Triglochin* | *procera* | y | | se |
| Nymphaeaceae | *Euryale* | *ferox* | y | | wl |
| Nymphaeaceae | *Ondinea* | *purpurea* | y | | wl |
| Nymphaeaceae | *Victoria* | *cruziana* | y | | wl |
| Haloragaceae | *Proserpinaca* | *palustris* | y | | ee |
| Plantaginaceae | *Littorella* | *uniflora* | y | | as |
| Droseraceae | *Aldrovanda* | *vesiculosa* | y | NASSa | ff |

TABLE 12. AQUATIC SPECIES ABSENT FROM NEW ZEALAND, NOT DISTRIBUTED AS AN ORNAMENTAL, NOT RECORDED AS A WEED OVERSEAS.

| Family | Genus | Species | Ranking | Life-form |
|---|---|---|---|---|
| Hydrocharitaceae | *Lagarosiphon* | *roxburghii* | An | os |
| Hydrocharitaceae | *Nechamandra* | *alternifolia* | USn | os |
| Fabaceae | *Neptunia* | *natans* | An | se |
| Poaceae | *Leptochloa* | *coerulescens* | An | se |
| Limnocharitaceae | *Hydrocleys* | *bleheri* | An | wl |
| Eriocaulaceae | *Eriocaulon* | *luzulaefolium* | An | ee |
| Callitrichaceae | *Callitriche* | *fallax* | An | as |
| Poaceae | *Leptochloa* | *aquatica* | | se |
| Lilaeaceae | *Lilaea* | *scilloides* | | as |

# 5. A weed risk model for aquatic species

Aquatic plants are a relatively small group of species within a wide number of families, but most have a similar range of adaptive characteristics to enable them to survive in the aquatic environment. These include an ability to rapidly spread through a waterbody, often by asexual means, and a general lack of lignified structural tissue, with support being provided by the surrounding water. The spread of introduced aquatic species is often constrained by a lack of natural dispersal vectors from one waterbody to another. They are reliant on human activities for distribution, either accidental or deliberate. Impacts of aquatic weeds are well known, with obstruction of waterbodies and displacement of desirable species often the most cited impacts arising from these plants. Within the context of risk management, water plants have a number of notable differences from their terrestrial counterparts, and in this respect they need to be addressed separately (Champion 1994).

The existing MAF Weed Assessment Model (developed by P.A. Williams based on Pheloung 1996), as with other general weed evaluation models, fails to adequately separate aquatic plants with different levels of impact (Table 13). The MAF model assigns a score to each weedy, or non-weedy attribute (from –3 to 2), with a final ranking given by the sum of these scores. It recognises the predominance of introduced aquatic species becoming weedy by giving those plants a score of 5. However, many of the attributes scored by this model are not relevant to the assessment of aquatic plants, e.g. fire risk and several dispersal characteristics. Aquatic habitats are less likely to suffer the extremes of temperature found in terrestrial habitats, and many so-called tropical species, e.g. water hyacinth, salvinia and water poppy, are able to tolerate most lowland climatic conditions experienced in New Zealand.

A new weed risk assessment model has been developed by the authors. It provides a useful basis to compare the success of one aquatic species with another. This model is based on adaptations of the systems used in Esler et al. (1993) and Champion (1995). Attributes of the plants' ecology, biology and weediness are assessed based on observations of their behaviour in New Zealand, and/or information from other countries. The attributes of greatest importance are ranked on a scale of 0–10, of intermediate importance 0–5 and 0–3 and of minor importance 0–1. These attributes are briefly discussed below and are fully outlined in Appendix 2.

### *Versatility (2–10)*

This relates to the tolerance of plant species to a range of environmental variables such as low temperature, salinity, water depth/exposure, trophic status and water clarity.

### *Competitive ability (0–10)*

This compares the competitive ability of the plant to displace other species within the same life-class (e.g. submerged, floating, emergent) and between life

classes. This competitiveness is determined from field observations and/or inter-species competitive trials, e.g. Hofstra et al. (1999).

### *Propagule dispersal (0–10)*

This relates to the range and effectiveness of dispersal mechanisms into new catchments including natural agents (birds, or wind), human activity (accidental or deliberate), and the ability to spread within a catchment via seed or plant fragments.

### *Degree of obstruction (0–10)*

This relates to potential obstruction problems caused by the plant affecting recreational water use, access to waterbodies, hydro-electric power generation, irrigation, flood control and aesthetic qualities (visual and olfactory).

### *Damage to natural ecosystems (0–10)*

This relates to ecosystem values such as reduction in biodiversity (Adair & Groves 1998), reduction in water quality (especially deoxygenation) and negative impacts on physical processes (e.g. substrate stability, increased/ decreased flooding)

### *Extent of suitable habitat not occupied within New Zealand (0–10)*

This evaluates the current distribution of the plant in New Zealand and its potential distribution. The score relates to available habitat not presently occupied by the plant.

### *Resistance to management (0–10)*

This combines various aspects of weed control, including ease of recognising a weed problem, accessibility, scope of control methods, suitability of control methods, and the effectiveness and duration of control.

### *Weed history in different habitats (1–9)*

This combines the potential degree of weediness of the species in lentic (flowing), lotic (static) waters, and wetland habitats.

### *Seeding ability (0–5)*

This evaluates the potential maximum seed (or other perennating structures) production, its viability and persistence.

### *Cloning ability (0–5)*

This relates to the ability of the plant to spread by fragmentation, rhizome, or stolon extension.

### *Behaviour in other countries (0–5)*

This evaluates the weediness of the plant in other temperate or tropical countries and its history of naturalisation into other countries.

### *Maturation rate (1–3)*

This evaluates the time taken to produce dispersive propagules.

### *Other undesirable traits (0–3)*

This relates to other features not accounted for under the other attributes and includes aspects of health impairment (drowning risk, toxicity, wounding and mosquito breeding habitat) and weediness in terrestrial systems.

## Use of the model

Tables 13–15 compare the ranking of six obligate submerged, three free-floating, two water lily type and six emergent species already present in New Zealand, and four species evaluated for import into New Zealand using the MAF and the Champion & Clayton models.

The MAF weed assessment model evaluated all species apart from *Regnellium diphyllum* as species that would not be accepted for import. That species was rated a score of four, requiring further evaluation. As a model for acceptance, further evaluation, or rejection of taxa for importation, this would be a satisfactory outcome. However, as a means of determining relative risk of new species to those already present, this model is not suitable. Obligate submerged species were ranked in almost reverse order to their observed competitive behaviour in New Zealand, with only two points dividing the six species.

TABLE 13. AQUATIC PLANTS RANKED USING THE MAF AND THE CHAMPION & CLAYTON MODELS, SORTED ON THE MAF SCORE.

| Species | MAF Weed Risk Assessment score | Champion & Clayton score |
|---|---|---|
| *Elodea canadensis* | 24 | 46 |
| *Egeria densa* | 23 | 64 |
| *Lagarosiphon major* | 23 | 60 |
| *Vallisneria* spp. | 23 | 51 |
| *Ceratophyllum demersum* | 22 | 67 |
| *Hydrilla verticillata* | 22 | 74 |
| *Eichhornia crassipes* | 22 | 67 |
| *Pistia stratiotes* | 20 | 42 |
| *Salvinia molesta* | 17.5 | 57 |
| *Nymphoides geminata* | 18 | 46 |
| *Nymphoides peltata* | 17 | 58 |
| *Sagittaria graminea* | 26 | 52 |
| *Sagittaria montevidensis* | 25 | 46 |
| *Alternanthera philoxeroides* | 22 | 63 |
| *Myriophyllum aquaticum* | 17 | 56.5 |
| *Phragmites australis* | 15 | 74.5 |
| *Zizania latifolia* | 14 | 68 |
| *Cabomba caroliniana* | 16 | 58 |
| *Ludwigia peruviana* | 13 | 65 |
| *Panicum repens* | 9 | 66 |
| *Regnellidium diphyllum* | 4 | 20 |

TABLE 14. AQUATIC PLANTS RANKED USING THE MAF AND THE CHAMPION & CLAYTON MODELS, SORTED ON THE CHAMPION & CLAYTON SCORE.

| Species | MAF Weed Risk Assessment score | Champion & Clayton score |
|---|---|---|
| *Hydrilla verticillata* | 22 | 74 |
| *Ceratophyllum demersum* | 22 | 67 |
| *Egeria densa* | 23 | 64 |
| *Lagarosiphon major* | 23 | 60 |
| *Vallisneria* spp. | 23 | 51 |
| *Elodea canadensis* | 24 | 46 |
| *Eichhornia crassipes* | 22 | 67 |
| *Salvinia molesta* | 17.5 | 57 |
| *Pistia stratiotes* | 20 | 42 |
| *Nymphoides peltata* | 17 | 58 |
| *Nymphoides geminata* | 18 | 46 |
| *Phragmites australis* | 15 | 74.5 |
| *Zizania latifolia* | 14 | 68 |
| *Alternanthera philoxeroides* | 22 | 63 |
| *Myriophyllum aquaticum* | 17 | 56.5 |
| *Sagittaria graminea* | 26 | 52 |
| *Sagittaria montevidensis* | 25 | 46 |
| *Panicum repens* | 9 | 66 |
| *Ludwigia peruviana* | 13 | 65 |
| *Cabomba caroliniana* | 16 | 58 |
| *Regnellidium diphyllum* | 4 | 20 |

TABLE 15. COMPARISON OF AQUATIC SPECIES RANKED BY THE MAF AND THE CHAMPION & CLAYTON MODELS.

| Species ranked by MAF score | Species ranked by Champion & Clayton score |
|---|---|
| *Sagittaria graminea* | *Phragmites australis* |
| *Sagittaria montevidensis* | *Hydrilla verticillata* |
| *Elodea canadensis* | *Zizania latifolia* |
| *Egeria densa* | *Ceratophyllum demersum* |
| *Lagarosiphon major* | *Eichhornia crassipes* |
| *Vallisneria* spp. | *Panicum repens* |
| *Alternanthera philoxeroides* | *Ludwigia peruviana* |
| *Ceratophyllum demersum* | *Egeria densa* |
| *Eichhornia crassipes* | *Alternanthera philoxeroides* |
| *Hydrilla verticillata* | *Lagarosiphon major* |
| *Pistia stratiotes* | *Cabomba caroliniana* |
| *Nymphoides geminata* | *Nymphoides peltata* |
| *Salvinia molesta* | *Salvinia molesta* |
| *Myriophyllum aquaticum* | *Myriophyllum aquaticum* |
| *Nymphoides peltata* | *Sagittaria graminea* |
| *Cabomba caroliniana* | *Vallisneria* spp. |
| *Phragmites australis* | *Elodea canadensis* |
| *Zizania latifolia* | *Nymphoides geminata* |
| *Ludwigia peruviana* | *Sagittaria montevidensis* |
| *Panicum repens* | *Pistia stratiotes* |
| *Regnellidium diphyllum* | *Regnellidium diphyllum* |

Anomalies were also noted with the ranking of the other life-forms already in New Zealand, compared to observed performance. The species not naturalised in New Zealand all ranked poorly compared to those already here. The performance of all but *R. diphyllum* in either, or both the USA and Australia (e.g. Mackey & Swarbrick 1997) would rank them all as potentially serious weeds, at least in northern areas.

The Champion & Clayton model appears to provide a more realistic assessment of comparative weediness and success of aquatic species already naturalised in New Zealand. This model also rates *Panicum repens, Ludwigia peruviana* and *Cabomba caroliniana* as plants with comparable weedy tendencies to many of those problem species already naturalised in New Zealand (Tables 13–15).

# 6. Preliminary risk assessment

The potential risk of an aquatic species becoming a weed in New Zealand can be assessed by the evaluation of two factors:

- predicted success and weediness in New Zealand conditions
- chance of gaining entry into New Zealand

Indicators of weediness in a species include being:

- recorded as a weed overseas (Tables 7–9)
- rejected for importation in the USA, Australia, or New Zealand (Tables 7–12)
- a member of a life-form poorly represented in New Zealand (Tables 1, 3, 4 and 5)

The prediction of weed potential of each new species may be obtained from the Champion & Clayton model (see Appendix 2). A selected range of species evaluated by this model is presented in Table 16.

A number of species which fit the weediness criteria listed above are reported as present, but not naturalised within New Zealand. Examples include *Eichhornia azurea, Cabomba caroliniana, Ipomoea aquatica, Butomus umbellatus, Typha latifolia* and *Rotala rotundifolia* and other species listed in Tables 7 and 10. These species obviously do not have any barrier to their entry into this country and future spread will be dependent on their ability to establish and compete with existing vegetation.

Species sold as ornamental, culinary, or medicinal plants overseas, but not yet present within New Zealand would be the next highest threat for spread to this country. Species in this category are listed in Tables 8 and 11. Examples of weedy ornamental species not present in New Zealand include *Myriophyllum spicatum, Utricularia vulgaris, Najas marina, Ludwigia peruviana, Stratiotes aloides* and *Hydrocotyle ranunculoides*. The edible *Trapa* species and medicinal plants *Otellia alismoides* and *Hygrophila spinosa* are also potential weeds. The most likely method of entry would be as illegal importations (see Section 3).

Much lower risks are presented by overseas weeds that are not distributed within the plant trade. These include the species listed in Table 9 and 12 (e.g. the grasses *Panicum repens, Phragmites karka,* and *Vossia cuspidata*). Introduction into New Zealand would have to be either by natural means (wind- or bird-dispersed seed), or as contaminants of other plants or produce (e.g. contaminated soil).

Of the species evaluated in Table 16, two species (*C. caroliniana* and *T. latifolia*) are reported as already introduced into New Zealand. Of the remainder, all but *P. repens* are distributed in the overseas plant trade. Of those species only *L. peruviana* is naturalised in Australia and could also spread here by bird-ingested seed, or seed-contaminated products. *M. spicatum* only reproduces asexually outside of its native range. *Panicum repens* is most likely to enter on contaminated machinery, or packaging. The risk of entry

TABLE 16. ASSESSMENT OF SPECIES USING THE CHAMPION & CLAYTON WEED RISK ASSESSMENT MODEL.

| | *Cabomba caroliniana* | *Ludwigia peruviana* | *Panicum repens* | *Regnellidium diphyllum* | *Typha latifolia* | *Myriophyllum spicatum* |
|---|---|---|---|---|---|---|
| **Versatility** | **7** | **5** | **7** | **4** | **7** | **7** |
| Temperature | 2 | 1 | 1 | 1 | 1 | 3 |
| Salinity | 0 | 0 | 1 | 0 | 1 | 0 |
| Habitat | 2 | 2 | 3 | 1 | 2 | 2 |
| Water/substrate | 2 | 1 | 1 | 1 | 2 | 2 |
| Clarity | 1 | 1 | 1 | 1 | 1 | 0 |
| **Habitat** | **5** | **5** | **6** | **2** | **4** | **5** |
| Lentic | 2 | 0 | 1 | 0 | 0 | 2 |
| Lotic | 3 | 3 | 2 | 1 | 3 | 3 |
| Wetland | 0 | 2 | 3 | 1 | 1 | 0 |
| **Competition** | **6** | **10** | **10** | **4** | **5** | **7** |
| Within | 6 | 8 | 8 | 4 | 5 | 7 |
| Between | 0 | 2 | 2 | 0 | 0 | 0 |
| **Dispersal** | **4** | **9** | **3** | **2** | **7** | **4** |
| Bird/wind | 0 | 5 | 0 | 0 | 5 | 0 |
| Accidental | 2 | 2 | 2 | 0 | 1 | 2 |
| Deliberate | 1 | 1 | 0 | 1 | 0 | 1 |
| Within | 1 | 1 | 1 | 1 | 1 | 1 |
| **Maturation** | **3** | **3** | **3** | **1** | **1** | **3** |
| **Seeding** | **3** | **5** | **3** | **2** | **4** | **0** |
| Quantity | 1 | 3 | 2 | 1 | 3 | 0 |
| Viability | 2 | 2 | 1 | 1 | 1 | 0 |
| **Cloning** | **5** | **5** | **5** | **3** | **3** | **5** |
| **BIOLOGICAL SUCCESS** | **33** | **42** | **37** | **18** | **31** | **31** |
| **Obstruction** | **8** | **5** | **8** | **0** | **4** | **9** |
| Water use | 2 | 1 | 1 | 0 | 1 | 2 |
| Access | 0 | 1 | 2 | 0 | 1 | 1 |
| Flow | 2 | 0 | 2 | 0 | 0 | 2 |
| Irrigation | 2 | 2 | 2 | 0 | 1 | 2 |
| Aesthetic | 2 | 1 | 1 | 0 | 1 | 2 |
| **Natural areas** | **6** | **6** | **7** | **1** | **6** | **9** |
| Biodiversity | 5 | 5 | 5 | 1 | 5 | 5 |
| Water quality | 0 | 0 | 1 | 0 | 1 | 3 |
| Physical | 1 | 1 | 1 | 0 | 0 | 1 |
| **Other** | **0** | **0** | **0** | **0** | **0** | **1** |
| Health | 0 | 0 | 0 | 0 | 0 | 1 |
| Weed | 0 | 0 | 1 | 0 | 0 | 0 |
| **Habitat** | **8\8** | **5\5** | **4\4** | **1\1** | **10\10** | **10\10** |
| **Resistance to management** | **6** | **2** | **4** | **0** | **2** | **5** |
| Implementation | 1 | 1 | 1 | 0 | 1 | 1 |
| Recognition | 1 | 0 | 0 | 0 | 0 | 1 |
| Scope | 1 | 0 | 0 | 0 | 0 | 0 |
| Suitability | 1 | 0 | 1 | 0 | 0 | 1 |
| Effectiveness | 1 | 0 | 1 | 0 | 0 | 1 |
| Duration | 1 | 1 | 1 | 0 | 1 | 1 |
| **Other countries** | **5** | **5** | **5** | **0** | **5** | **4** |
| **WEEDINESS** | **25** | **23** | **29** | **2** | **27** | **38** |
| **TOTAL SCORE** | **58** | **65** | **66** | **20** | **58** | **69** |

into New Zealand would be, in order of highest probability, *C. caroliniana* and *T. latifolia/R. diphyllum/L. peruviana/M. spicatum/P. repens*. *R. diphyllum* is the only species of this group that is likely to be permitted entry into this country after evaluation through the MAF weed assessment model, and is therefore ranked higher than the other species not known to present in New Zealand.

# 7. Overview and recommendations

The development of a Weed Risk Assessment report for aquatic plants must consider potential impacts and possible entry pathways for potential ecological weeds. A basic concept is that 'risk' is a function of the potential for adverse impacts as well as the probability of entry for any species. A risk assessment based on this approach would be quite meaningful, provided that there was an assurance that the potential species under consideration was not already present in the country, and that the criteria used for determining potential adverse impacts and probability of entry were reliable.

A number of obstacles to the development of a meaningful Weed Risk Assessment based on these criteria were apparent prior to commencement of this report. Given the time frame and constraints placed on this initial report, it was recognised that any risk assessment would be of a preliminary nature, based largely on presently known or readily available information. The expected requirements for the completion of a final Weed Risk Assessment were previously suggested, but subject to amendment following the outcome from this preliminary report.

In order to appreciate the limitations on the scope of this preliminary report it is necessary to understand certain shortcomings that need to be resolved before a meaningful Weed Risk Assessment can be promulgated.

Firstly, there is an absence of reliable information on the presence or the correct identity of many potential aquatic weed species already in New Zealand, which means that any risk assessment would be compromised by unreliable data. Although the issue of border control still needs to be addressed, any meaningful border control measures will be compromised by not knowing the correct identity, distribution and establishment status of a range of potential aquatic weed species that are not yet naturalised. This type of evaluation has never been previously carried out and it would enable the species priorities identified in the preliminary Risk Assessment of this report to be revised as well as testing of entry pathways by historical association to be done. During the preparation of this report, all known importers and traders of aquatic plants in New Zealand were identified and contacted for initial information. However, the final Weed Risk Assessment report will require site visits, specimen collections, and in some cases further culture, in order to obtain accurate information on the identity and status of aquatic species already within the

aquarium and ornamental pond trade. Clearly the greatest risk from potential ecological weeds comes from aquatic species that have already slipped through the New Zealand border. Although such species could be regarded as no longer a border issue, they do represent a more immediate ecological risk, while repeated entry could further extend any risk unnecessarily.

The second shortcoming to the preparation of an accurate Weed Risk Assessment has been the inadequacy of current risk assessment models when applied to aquatic plants. The existing MAF weed risk assessment model, along with that prepared by Esler et al. (1993) have been designed primarily for ranking terrestrial plants and have provided poor delineation between aquatic species. Rectification of this problem has been a primary focus of this report, along with the compilation of tables that establish relevant groupings of aquatic species by their currently known presence in New Zealand and by their status in the New Zealand and overseas trade in species. This report presents a new model developed specifically for aquatic species. It ranks species based on their potential weediness and thereby provides the basis for an accurate preliminary risk assessment. Although entry pathways for aquatic species have been identified, the risk posed by probability of entry for each species can be only meaningfully assessed following clarification of what species are already present in the country. Nevertheless, examples are given that illustrate both the application of the revised model for defining potential weediness, as well as how a final risk assessment can be achieved by combining this factor with the probability of entry.

Another related problem is the absence of accurate data with respect to the risk posed by certain of the entry pathways. Although the entry pathways have been described, there is at present no way of establishing the volume of traffic likely to enter by these means, particularly with respect to 'pocket plants' (including culinary, medicinal and ornamental) which are suspecting of potentially contributing the highest traffic in new species. The proposed visits to all New Zealand importers (historical and current) and growers of aquarium and pond plants to gather accurate identifications of aquatic species in the country will also provide an opportunity to better estimate the volume of new species by historical association. Without accurate estimates on the volume of species likely to enter by each of the various pathways, it is not possible to combine the potential weediness of a species with its likelihood of entry in order to determine a meaningful risk assessment for entry.

In summary, the two major difficulties in developing a meaningful Weed Risk Assessment for aquatic plants have been ***inadequate tools*** (i.e. models for determining potential weediness) and ***unreliable data*** (i.e. identity of potential ecological weeds already in New Zealand and volume of traffic entering the border by illegal means). This stage of the report (Weed Risk Model) has focused on resolving the first problem by developing a specific risk assessment model for aquatic plants, while Stage two of the Border Control Programme (Weed Risk Assessment) will correct the data on aquatic species in this country and volume of traffic entering by the various pathways. The first priority will be to apply the Risk Assessment Model to all aquatic species identified as weeds in other countries, or listed for exclusion from importation and combine this with an estimation of risk of entry to New Zealand.

Following completion of Stage two of the Border Control Programme, the third and final phase (Weed Risk Management) in the implementation of a management strategy to minimise further risk from new aquatic species in New Zealand, will be to review and revise existing management systems. Information is available from other countries on their initiatives in addressing similar issues. For example, the Aquatic Nuisance Species Task Force of the USA has reported to Congress on their review of issues surrounding Border Control of aquatic species. They have recognised the importance of making ecologically meaningful decisions as well as achieving a balance between greater risk reduction and accommodating current activities that depend on the use of non-indigenous species. Many of their recommendations could be appropriately modified for New Zealand, including the need for promoting education, cooperation and accountability. Because prevention is recognised as key to risk reduction, most of their recommendations centre around decision-making processes, with effective implementation dependent on achieving the involvement and cooperation of the private sector, public organisations and the aquatic plant industry. Once procedures for Border Control and Risk Management have been established in New Zealand it will be important to monitor the effectiveness of prevention, surveillance and control measures, with provision for review and adjustment as required.

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# Appendix 1

## LIST OF AQUATIC PLANT GROWERS AND IMPORTERS CONTACTED

| | |
|---|---|
| Barker, Murray | Braeside Aquaria, Te Aroha |
| Garrett, Dave | Brooklands Aquaria, New Plymouth |
| Gear, Ian | Hamilton |
| Henderson, Ian | Wai Mara Nurseries, Warkworth |
| Himsell, Eddie | Petworld, Christchurch |
| Holley, George | Biological Supplies, Wellington |
| Jansen, Ralph | Jansens Pets, Auckland |
| van Oorshot, Franz | Amazon Aquatics, Whakamaru |
| O'Reagan, Tim | O'Reagan Aquatics, Auckland |
| Parson, Paul | Palmerston North |
| Price, John | King Fisheries, Tauranga |
| Thackwray, Lou | Kumeu Waterlilies, Kumeu |
| Ward, Bob | Redwood Aquatics, Christchurch |
| Whorley, Richard | Highway Fisheries, Te Puke |
| Wilson, Ian | Wirihana Nurseries, Whatawhata |

# Appendix 2

## A WEED RISK ASSESSMENT MODEL FOR AQUATIC WEEDS IN NEW ZEALAND

| ATTRIBUTE | SUB-GROUP | NOTES |
|---|---|---|
| **Versatility 2–10** | **temperature tolerance** | 0–3 Maximum if frost tolerant, 2 if growth checked by winter temps, 1 if dies off over winter, 0 if killed over winter. |
| | **salinity** | 0–1 Can tolerate saline conditions, or not. |
| | **range of habitat** | 1–3 Maximum if able to grow from water to dry land, 2 if water to wetland, or from shallow to deep (>5 m) water, 1 narrow range. |
| | **water/substrate type** | 1–2 Maximum if tolerant of sandy to muddy (or peaty) substrate, or oligotrophic to eutrophic waters, 1 if restricted by either. |
| | **water clarity** | 0–1 Maximum if unaffected by water clarity, i.e. floating, or emergent. |
| **Habitat 1–9** | **lentic** - rivers, streams, drains, irrigation channels | 0–3 Maximum if major weed, 2 if minor weed, 1 if present but not weedy, 0 absent. |
| | **lotic** - ponds, shallow and deep lakes | 0–3 Maximum if major weed, 2 if minor weed, 1 if present but not weedy, 0 absent. |
| | **wetland** - water margin, swamp, marsh, bog | 0–3 Maximum if major weed, 2 if minor weed, 1 if present but not weedy, 0 absent. |
| **Competitive ability 0–10** | **within growth form,** i.e. submerged, floating, emergent | 0–8 e.g. maximum *Hydrilla:Ceratophyllum:Egeria/Lagarosiphon/ Elodea/P. crispus*/native species. |
| | **between growth form** | 0–2 Maximum if able to completely displace another growth form, 1 if some suppression, 0 no interaction. |
| **Propagule dispersal 0–10** | dispersal **outside catchment** by **natural** agents, e.g. birds, wind | 0–5 Maximum if propagule well adapted for bird/wind distribution, 1 if propagule could be spread in bird crop. |
| | dispersal **outside catchment** by **accidental** human activity, e.g. drainage machinery, boat trailers, eel nets | 0–3 Maximum if spread by 3 methods, etc. |
| | dispersal **outside catchment** by **deliberate** introduction | 0–1 Maximum if attractive to humans (ornamental fishpond or aquarium). |
| | effective spread **within waterbody/ catchment** | 0–1 Maximum if effective spread within waterbody by seed, or plant fragments. |
| **Maturation rate 1–3** | | Includes growth rate and time to maturity under ideal conditions. |
| **Seeding ability 0–5** | **quantity** | 0–3 Maximum if >1000 seed/plant, 2 100-1000, 1 <100, 0 nil. |
| | **viability/persistence** | 0–2 Maximum if high viability for several years, 1 low viability. |
| **Cloning ability 0–5** | | Maximum for far-reaching rhizomes/stolons/fragmentation capable of forming new colonies, 3 for rhizome/stolons, 1 for clump forming, 0 no vegetative spread. |

| | | |
|---|---|---|
| **Obstruction 0–10** | **physical - water use (recreation)** | 0–2 Maximum for major nuisance, 1 minor nuisance. |
| | **physical - access** | 0–2 Maximum for major nuisance, 1 minor nuisance. |
| | **physical - water flow, power generation** | 0–2 Maximum for major nuisance, 1 minor nuisance. |
| | **physical - irrigation, flood control** | 0–2 Maximum for major nuisance, 1 minor nuisance. |
| | **aesthetic** - visual, olfactory | 0–2 Maximum for both visual and smell problems, 1 either. |
| **Damage to natural areas 0–10** | reduce **biodiversity** | 0–5 Maximum for forming monospecific stands, reducing score for lessening impact. |
| | reduce **water quality** | 0–3 Maximum for major impacts especially deoxygenation. |
| | negatively affect **physical processes** | 0–2 Maximum for major effects on substrate stability, hydrology (flooding). |
| **Other undesirable traits 0–3** | **health impairment,** e.g. drowning, poisonous, sharp leaf edges, mosquito breeding habitat | 0–2 Maximum for 2 or more effects. |
| | **weed of agriculture** | 0–1 Maximum if a problem land weed. |
| **Extent of suitable habitat 0–9** | | Available habitat present in NZ scored out of 10, amount of available habitat not occupied scored as a fraction, e.g. alligator weed 4/6 (scores 4), raupo 0/10 (scores 0), hydrilla 9/10 (scores 9). |
| **Resistance to management 0—10** | ease of **implementation** | 0–2 Maximum if accessibility to weed is difficult, e.g. dense tall impenetrable growths. |
| | **recognition** of problem | 0–1 Maximum if difficult to assess weed, e.g. submerged. |
| | **scope** of control methods | 0–2 Maximum if no control method, 1 if only one control option. |
| | **suitability** | 0–1 Maximum if control method not always acceptible, e.g. grass carp, unregistered herbicide. |
| | **effectiveness** | 0–2 Maximum if ineffective, 1 if partial control. |
| | **duration** of control | 0–2 Maximum if no control, 1 if control for 3+ months. |
| **Problem in other countries 0–5** | | Maximum if widespread problem weed in other temperate countries, 4 only problem in some temperate countries, 3 if adventive, not weedy in other temperate countries, 2 if tropical weed, 1 if adventive, but not weedy in tropics, 0 not adventive elsewhere. |