Distribution of these species was mostly within discrete zones, although parrot's feather and lagarosiphon were restricted to single sites (all in the Drury to Pukekohe waterways) and yellow flag was found at two sites, near Drury and Waimauku. Alligator weed (Figure 12) was restricted to the Parkhurst to Waimauku waterways, present in all waterways between Parakai and Rewiti (except saline influenced streams near Helensville) but absent outside of that area. Reed sweet grass was scattered at five sites within that zone, also present at one site north of Dairy Flat and two sites on the Oira and Whangapouri Creeks between Drury and Paerata. Egeria was present in the Whangapouri Creek and two upper tributaries of the Kaipara River. The most widespread species was water celery (Figure 13), dominant in all the Drury to Pukekohe waterways, but also present in the other two areas. Mercer grass was restricted to three sites near Waimauku.

Auckland urban pond surveys

One hundred properties were surveyed in Pukekohe (Birch Road and Upper Queen Street areas) on 17th March 2005, Blockhouse Bay (Peter Buck/Blockhouse Bay Road area) on 27th April 2005 and Howick (Sale Street and Evelyn Road area) on 3rd November 2005.

Results of these surveys are presented below in Table 3:

Table 3:

Results of urban pond surveys in Auckland Region.

Suburb/Town	No. of properties with ponds	Pest species (and frequency)
Pukekohe	14	Egeria (1), lagarosiphon (1), yellow flag (1), gypsywort (1), Mercer grass (2)
Blockhouse Bay	6	Eelgrass (Meola Creek variety – 1)
Howick	13	Myriophyllum variifolium (1), yellow flag (1+ 4 creek sites), water celery (1+1 creek site)

Of the 33 properties containing ponds, nine contained no plants (usually with goldfish) and the following ornamental plants were noted with frequency in parentheses and native species are indicated with an asterisk.; water lilies (*Nymphaea* hybrids – 14), **Myriophyllum propinquum* (native milfoil – 5), spearwort (*Ranunculus flammula* – 3), *Rotala indica* (3), *Acorus japonicus* (3), pickerelweed (*Pontederia cordata* – 3), *purei (*Carex secta* – 3), *Hydrocotyle leucocephala* (2), *Cyperus haspan* (2), *Bacopa monniera* (2), *Gunnera tinctoria* (2), purple taro (*Colocasia esculenta* – 2), arum (*Zantedeschia aethiopica* – 2), giant reed (*Arundo donax* – 2), * *Isolepis cernuus* (1), *Ludwigia natans* (1), *swamp sedge (*Carex virgata* – 1), *spike sedge (*Eleocharis acuta* – 1), elephant's ear (*Alocasia brisbanensis* – 1), marsh marigold (*Caltha palustris* – 1) and elodea (*Elodea canadensis* –1).

Gunnera tinctoria and giant reed are included in the ARC RPMS. *Myriophyllum variifolium* is an Australian species, possibly native to New Zealand (field site on Acheson Stream near the Hunua Reservoirs), but is regarded as weedy in much of its New Zealand range (Webb et al. 1995). It is currently sold under the misleading name of *Hippuris vulgaris*, a superficially similar plant unknown in New Zealand.

Distribution maps of freshwater pests within Auckland Region

The following Total Control plant pests managed under the Auckland RPMS are actively targeted for eradication at all sites within the region; arrowhead, Fringed waterlily (eradicated), marshwort, purple loosestrife, sagittaria, Senegal tea and water poppy. MAF (Biosecurity New Zealand) continue their eradication programme for known sites of salvinia and water hyacinth. No additional sites of lizard's tail, Manchurian wild rice or nardoo were discovered during this project. Distribution maps for the above species are not included in this report, but can be generated from the ARC GIS system or NIWA FBIS (fbis.niwa.co.nz).

The remaining species distributions are mapped below (Figures 14 to 29). Triangles denote current FBIS data, with new records from this study shown as orange squares. Note, distribution map includes some records from adjacent regions, Northland and Waikato.

Figure 14:
Distribution map of alligator weed.

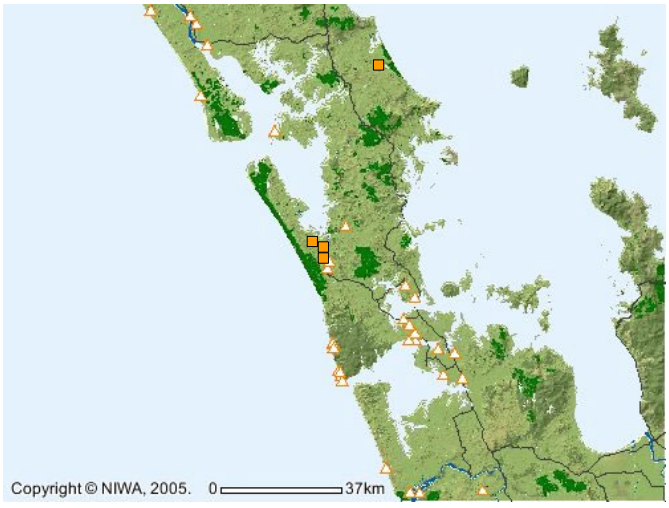


Figure 15:
Distribution map of bladderwort.

Figure 16:
Distribution map of eelgrass.

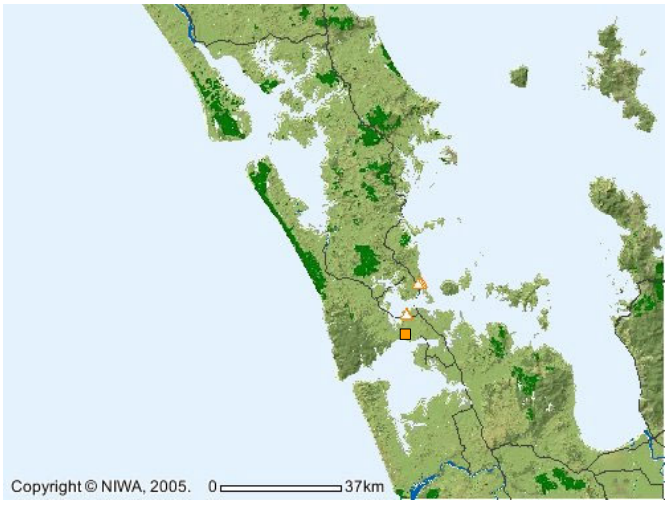


Figure 17:
Distribution map of egeria.

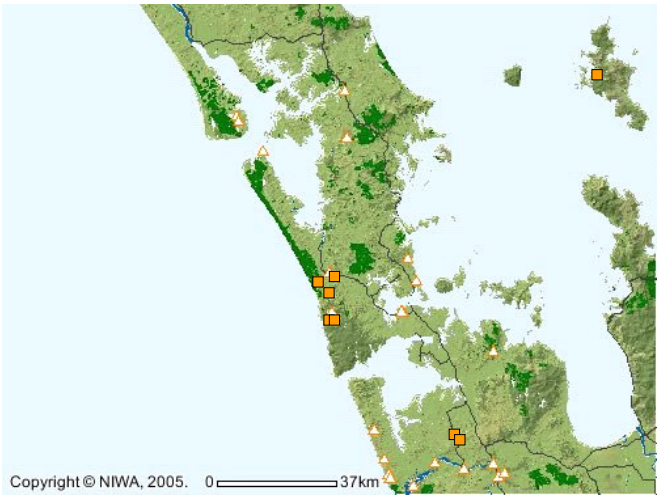


Figure 18:
Distribution map of hornwort.

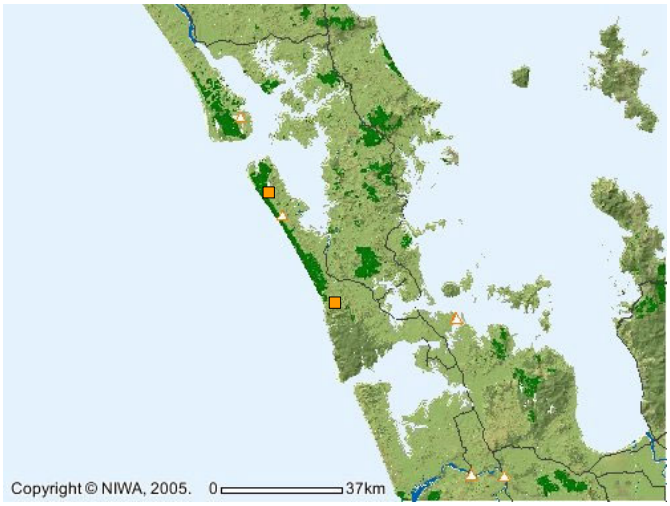


Figure 19:
Distribution map of lagarosiphon.

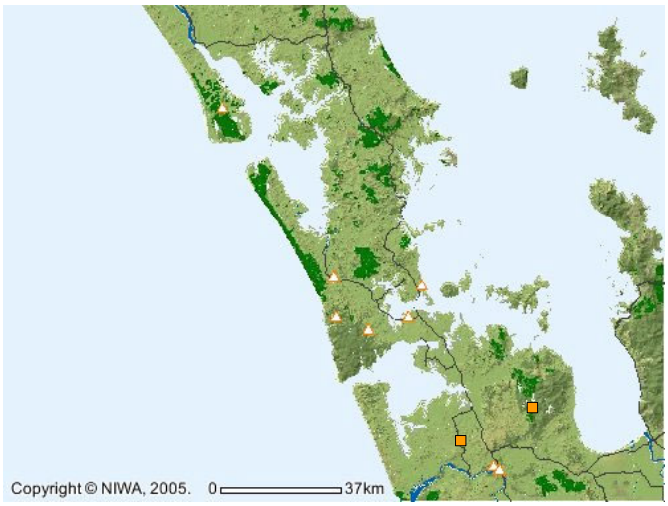


Figure 20:
Distribution map of parrot's feather.

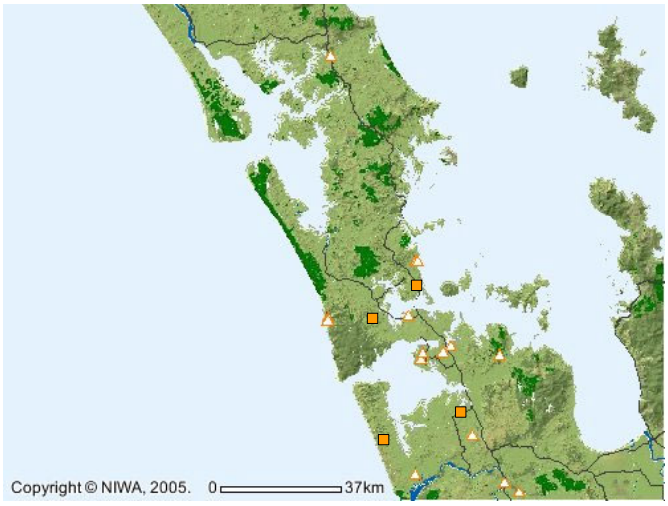


Figure 21:
Distribution map of primrose willow.

Figure 22:
Distribution map of reed sweet grass

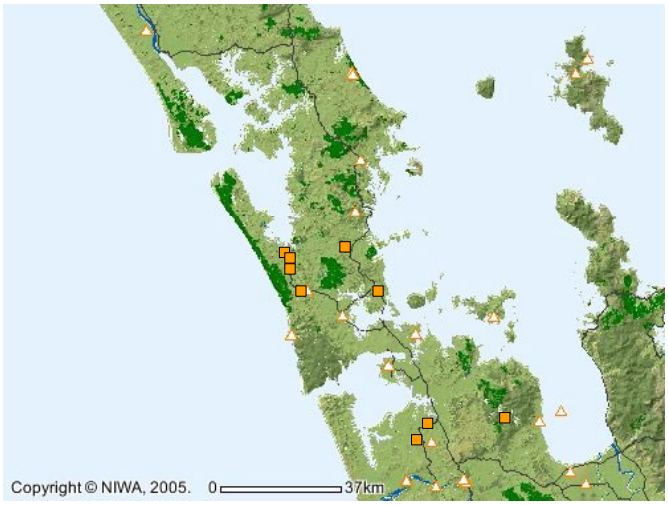


Figure 23:
Distribution map of yellow flag.

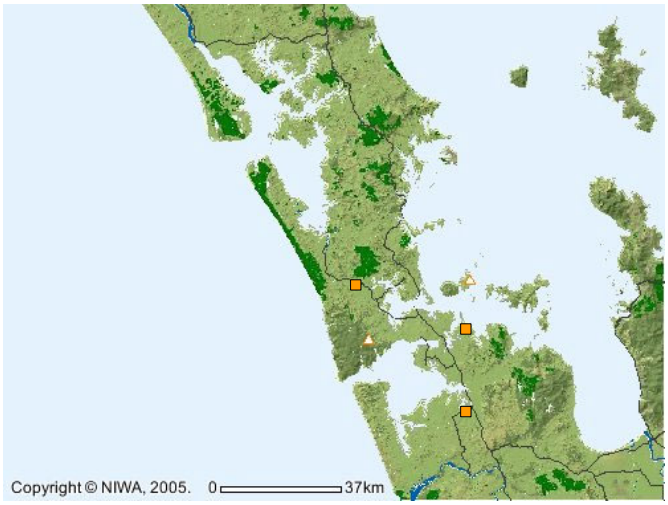


Figure 24:
Distribution map of catfish.

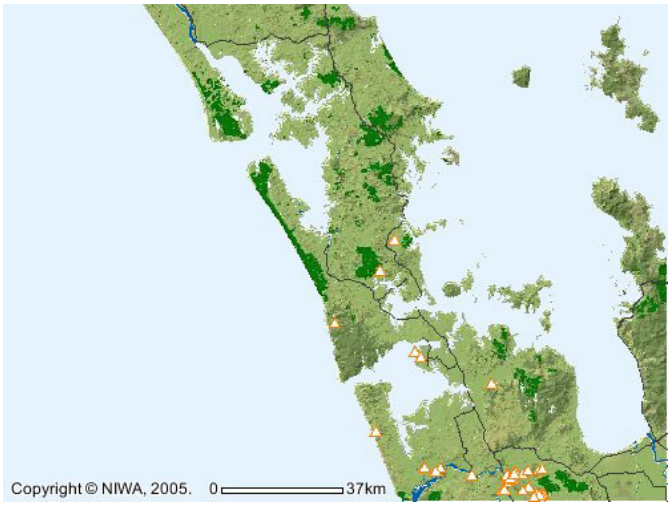


Figure 25:
Distribution map of gambusia.

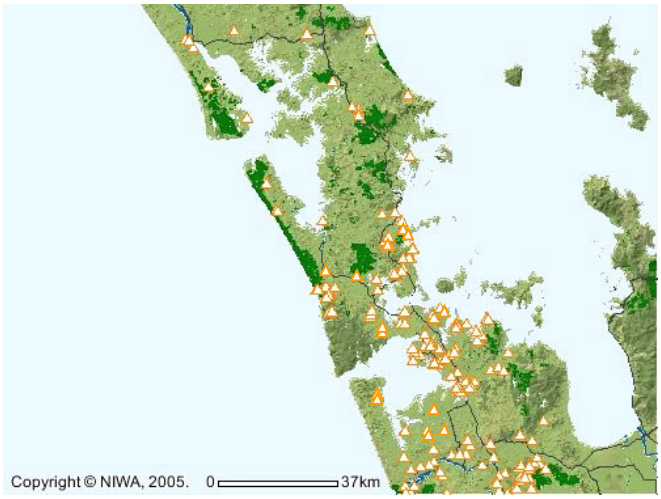


Figure 26:
Distribution map of koi carp.

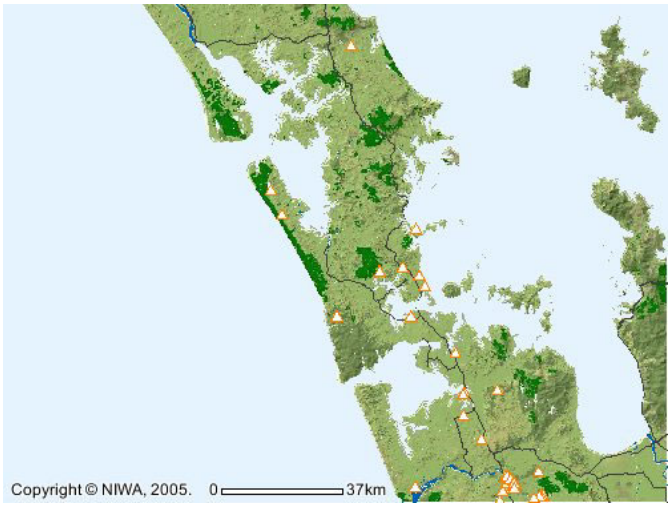


Figure 27:
Distribution map of perch.

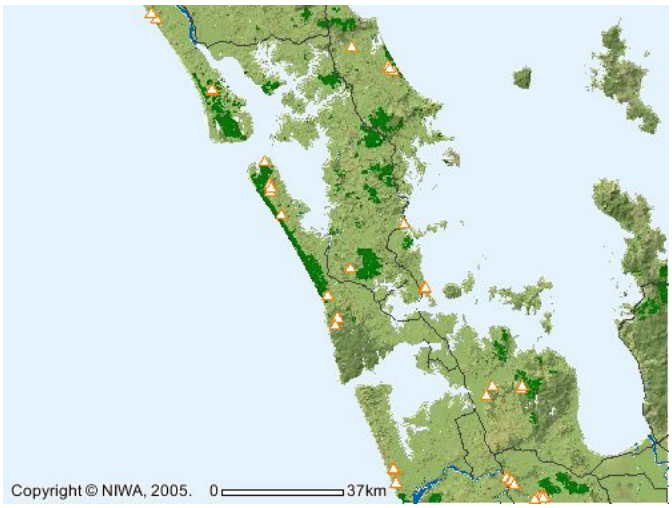


Figure 28:
Distribution map of rudd.

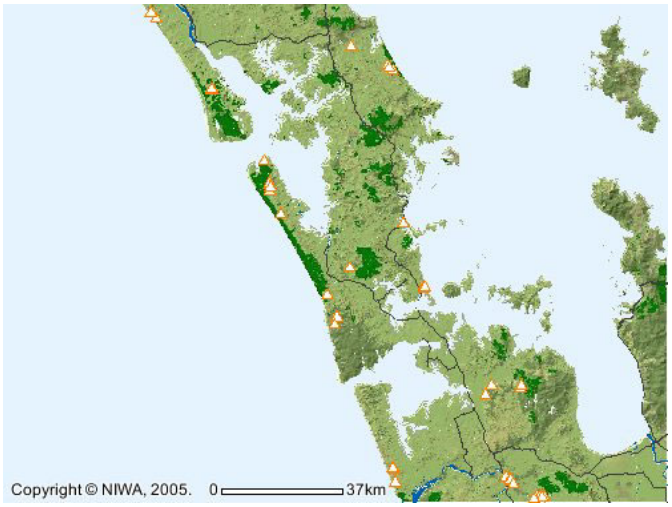
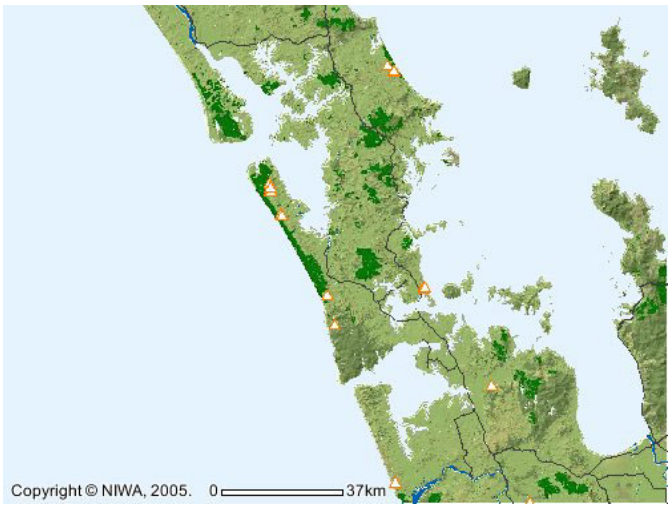


Figure 29:
Distribution map of tench.



Discussion

Risk posed by pest plant species

1.1.21 Weed Risk Assessment Model

The Aquatic Weed Risk Assessment Model (AWRAM) scores freshwater plants according to their weediness and biological success so that the threat posed can be compared (Champion and Clayton 2000). Table 4 shows the scores assigned to the aquatic weed species included in the Auckland RPMS. The model scores from 0 to 100; the highest ranking aquatic plant in New Zealand is the erect emergent *Phragmites australis* (75) followed by *Hydrilla verticillata* (74) which is the highest of the submerged species. The current distribution, potential impact and mechanisms and likelihood of spread of these species are discussed in the next sections.

Table 4:

Aquatic weed species present in the Auckland Region and potential invaders ranked according to Champion and Clayton (2000).

Key to symbols: * - absent from region, ψ - total control/MAF controlled, α- surveillance, β - research, χ- not in RPMS.

Life - form	Species	AWRAM score
Erect emergent	* Phragmites australis	75
Submerged	* Hydrilla verticillata	74
Erect emergent	α Zizania latifolia	68
Submerged	α Ceratophyllum demersum	67
Free-floating	ψ Eichhornia crassipes	67
Submerged	α Egeria densa	64
Sprawling emergent	α Alternanthera philoxeroides	63
Submerged	α Lagarosiphon major	60
Water lily-like	ψ Nymphoides peltata	58
Free-floating	ψ Salvinia molesta	57
Sprawling emergent	ψ Gymnocoronis spilanthoides	57
Sprawling emergent	α Myriophyllum aquaticum	56
Submerged	α Utricularia gibba	54
Erect emergent	ψ Lythrum salicaria	54
Erect emergent	β Lycopus europaeus	53
Erect emergent	α Iris pseudacorus	52
Sprawling emergent	ψ Sagittaria platyphylla	52
Sprawling emergent	α Ludwigia peploides	52
Submerged	α Vallisneria spp.	51
Sprawling emergent	α Glyceria maxima	51
Sprawling emergent	χ Apium nodiflorum	50
Erect emergent	ψ Sagittaria montevidensis	46
Water lily-like	ψ Nymphoides geminata	46
Water lily-like	ψ Hydrocleys nymphoides	45
Sprawling emergent	χ Paspalum distichum	45
Water lily-like	* Nuphar lutea	43
Sprawling emergent	χ Myriophyllum variifolium	43
Erect emergent	β Saururus cernuus	37
Water lily-like	α Marsilea mutica	37

1.1.22 Current and potential weed impacts

Species are discussed within life-form groups and then in order of weed risk as scored by AWRAM.

1.1.22.1 Submerged species

Hydrilla

Hydrilla verticillata (hydrilla) is not known from Auckland Region. It is only found in three northern Hawke's Bay lakes. Hydrilla is ranked as New Zealand's worse potential submerged weed due to its production of perennating organs (tubers and turions) making eradication a very difficult proposition. This species can displace native vegetation to depths of 9 m (with an extremely dense branched canopy layer) also disrupting water body use. Only male plants are present in New Zealand. Potential impacts on Auckland lakes could be severe, however risk of introduction is very low (see Section 5.4).

Hornwort

Ceratophyllum demersum (hornwort) was only recorded from three sites in Auckland prior to this survey, first recorded from the Tahuna-Torea Reserve, Glendowie in 1975. The remaining three sites are Lakes Kuwakatai, Kereta and Okaihau. Hornwort does not appear to be common within the region, although more sites are likely especially in southern areas. Hornwort has a widespread distribution in much of the North Island, being especially abundant in the Waikato River system.

It is currently the worst submerged weed in New Zealand, with major impacts on power generation, irrigation, flood control and recreational activities in addition to severe impacts on aquatic ecosystems (Hofstra 2002). Its potential to displace all submerged vegetation (including other introduced species) is illustrated in several central North Island lakes where it grows from the waters edge in sheltered bays to depths exceeding 15 m. The species completely dominated Lake Kereta and was the only submerged species present in Lake Kuwakatai. In Lake Okaihau hornwort formed a monoculture to 3.9 m water depth in some areas and formed the deepest vegetation zone. This species is likely to displace all submerged vegetation from sheltered sites of other lakes and would have the greatest impact on deep-water charophyte meadows, unlike all other submerged species which do not have the ability to grow to those deeper depths. Therefore lakes Ototoa and Pupuke could be severely impacted by an incursion of this species. This species is also a major drain weed, often dominating turbid slow flowing water bodies, impeding drainage and irrigation activities.

Egeria

Egeria densa is more widespread than hornwort occurring in 10 sites within the region, first recorded at Western Springs in 1963. This survey reports several new sites including lakes Okaihau, Kawaupaku and Wainamu (re-established since a vegetation collapse in 1990's) and stream sites near Waimauku and Pukekohe. At these sites it dominated the vegetation, apart from Lake Okaihau where shoots were found

amongst hornwort at some sites. Coffey and Clayton (1987) report its rapid colonisation of Lake Pupuke from 1980 to 1985. Egeria is now widespread throughout much of the North Island.

It is a major concern in eutrophic water bodies and has displaced native and introduced species like *Elodea canadensis* and *Potamogeton crispus* from many sites. In clear lakes it can grow to depths of around 8 m forming tall dense beds, but unlike *C. demersum* it is unable to grow to depths where it would threaten charophyte beds growing deeper than 5 m. In shallow nutrient-rich lakes this species is implicated in the collapse of submerged vegetation and consequent toxic algal blooms as has occurred in Lake Omapere (Northland), Lake Wainamu and many lower Waikato lakes (Champion and Burns 1999).

Lagarosiphon

Lagarosiphon major is apparently sparsely distributed in Auckland with five FBIS sites prior to this study. The first herbarium record (location unspecified) in Auckland was 1953. Additional sites in the Acheson Stream in the Hunuas and an ornamental pond and stream site near Pukekohe are recorded.

It has similar impacts to *E. densa* although it is more tolerant of wave exposure and grows successfully in oligotrophic waters, but is unlikely to grow to depths greater than 6.5 m. Wells et al. (1999) document its displacement of *E. canadensis* in Lake Tarawera from depths between 2 and 4 m, and following the subsequent invasion of that lake by *C. demersum, L. major* was still able to occupy this zone in moderately exposed sites.

Bladderwort

The alien bladderwort (*Utricularia gibba*) was first collected from Bethells Beach in 1978 and has since spread to become fairly widespread in Waitakere and Rodney Districts.

It is the sprawling nature of *U. gibba,* which grows over the top of other submerged species, which differs from the impacts of other submerged weeds. The other weeds, discussed above, are attached to bottom sediments and competitively displace other species. Recent surveys in shallow sheltered clear water Northland dune lakes have seen severe impacts, especially where associated epiphyton (attached algae) formed a dense mat which would reduce light to plants growing below these.

The current and potential impacts of bladderwort, seasonality and mechanisms of spread require further investigation.

Eelgrass

Vallisneria spiralis (eelgrass) is commonly available in the aquarium trade, but is only naturalised in a few sites in the North Island, the first recorded site being Meola Creek in Western Springs (1982), it's only known Auckland site. A pond site was discovered in Blockhouse Bay as part of this project. A second species of eelgrass (*V. gigantea*) is present in Lake Pupuke and the adjacent quarry, known to have been introduced there in 1885 (Coffey and Clayton 1987). It has not been recorded elsewhere in New

Zealand.

Eelgrass appears to be displaced by both hornwort (based on monitoring of Lake Wiritoa near Wanganui) and egeria, but is likely to persist and dominate areas with fast flows and exposed lake zones, it's rhizomatous habit and thick strap-like leaves providing more tolerance to wave/water velocity than the leafy stemmed species discussed in early parts of this section.

1.1.22.2 Water lily-like and free-floating species

There are few field sites of the problem water lily-like fringed waterlily (first record 1987), marshwort (first record 1987) and water poppy (first record 1971) in Auckland Region. These and all known garden pond sites are all actively managed under the Auckland RPMS and many have been eradicated.

A site of yellow water lily (probably *Nuphar variegata*) was noted at Wrights Water lily Gardens, Patamahoe, with the owners advised to remove all plant material. The only known field site of *Nuphar* water lilies in New Zealand is in southern Hawkes Bay (*N. lutea*).

Two sites of nardoo (*Marsilea mutica*), in Hunua (first record 1986) and Waitakere, have been controlled in the past by ARC, but impacts of this species appear to be limited based on field observations.

MAF (Biosecurity New Zealand) continue their eradication programme for known sites of the free-floating salvinia (first New Zealand record from Western Springs in 1963) and water hyacinth (first Auckland collection in 1951).

1.1.22.3 Emergent and wetland species

The emergent pest plants arrowhead (*Sagittaria montevidensis* collected first in 1996), sagittaria (first record 1989) and Senegal tea (first record 1989) are reported from a few field sites, with additional ornamental pond sites of these species and also purple loosestrife (collected first in 1997) occurring within Auckland Region. All are targeted for eradication under the Auckland RPMS and many have been eradicated.

Additional species ranked in Section 5.1.1 are discussed as follows:

Phragmites

Phragmites australis is of very limited distribution in New Zealand, with the closest populations to Auckland occurring in the vicinity of Napier. These are now under a Hawkes Bay Regional Council eradication programme.

Phragmites is a tall rhizomatous grass which could invade and dominate the emergent vegetation of any small lake or sheltered bays of larger lakes as well as swamp and fen vegetation. Fortunately this plant has not yet established within natural wetland vegetation in New Zealand and risks of introduction to Auckland Region are very low.

Manchurian wild rice

Zizania latifolia (Manchurian wild rice) is of limited distribution in Auckland and has been targeted for eradication in the vicinity of Helensville, Laingholm and Mangere. It is locally abundant on the shores of Lakes Kereta and Karaka, first recorded at Kereta in 1950. Elsewhere in New Zealand it is only abundant in the vicinity of Dargaville, being introduced there around 100 years ago. Joynt and Newby (1998) estimate a total infested area there of 338 ha, mostly in drains, river margins and flood-prone pasture.

Manchurian wild rice is taller (up to 4 m) and grows more densely than native emergent species and spreads mainly by rhizome extension and could invade and dominate the emergent vegetation of any small lake or sheltered bays of larger lakes as well as swamp vegetation, displacing other species to deeper water. Impacts on indigenous biota were reported by Champion et al. (2001).

Alligator weed

Alternanthera philoxeroides (alligator weed) is locally abundant in some parts of Auckland Region, but significant areas remain free of this weed. It is currently abundant on the Waitakere coastal zone (Whatipu to Bethells - first record at Piha in 1945) and the Kaipara River, with scattered occurrences through urban Auckland. Alligator weed - free zones include central Rodney, South Head and all areas south of Papakura. Alligator weed is actively controlled at the Waikato Heads and Aka Aka drainage district by Environment Waikato, but this plant is widespread and mostly uncontrolled in Northland.

It could be a major drain weed throughout Auckland, also spreading into cropping land and wet pastures, the species being toxic to cattle. It is likely to invade and displace other herbaceous plants in nutrient rich swamps and form dense floating mats which raft over and shade out submerged vegetation and displace other emergent species including other alien weeds.

Parrot's feather

Myriophyllum aquaticum (parrot's feather) is widespread throughout the North Island but surprisingly few records of this plant have been made within Auckland Region (first record at Western Springs in 1969).

Parrot's feather could be a major drain weed throughout Auckland, but would have minimal impact on vegetation in large exposed lakes. It also has major impact on shallow aquatic areas within sheltered, nutrient-rich lakes and swamps, with floating mats displacing shallow water vegetation, as is the case in open water in the Waikatere Wetland (Champion 2003).

Gypsywort

Lycopus europaeus (gypsywort) is apparently of restricted distribution in Auckland Region with collections made from Oratia (first record 1982), Whatipu, Chelsea Bay and Kakamatua Bay on the North Shore. Gypsywort was noted at Lakes Whatihua and Pokorua and in the pond survey of Pukekohe. Gypsywort is abundant throughout the Lower Waikato Basin.

Gypsywort tends to invade lake margins and disturbance prone wetlands. It can colonise emergent vegetation smothering beds of sedges and raupo at several sites in the Waikato. Recent research (Burnett 2005) has shown the weediness of this species to be greater than previously thought, with the AWRAM score increasing from 40 to 53, based on saline tolerance, seed viability/buoyancy and cloning ability. Burnett (2005) predicted gypsywort could be at least as invasive in Auckland Region compared with its behaviour in the Waikato.

Yellow flag

Iris pseudacorus (yellow flag) has a widespread naturalised distribution in New Zealand, but is apparently rare north of the Waikato, with only two known Northland sites, Motutapu Island and Oratia (first record 1980). Further sites were discovered during this project at Waimauku, Drury and Howick. It was propagated and distributed for sale until relatively recently and it is likely to be widely cultivated, possibly present in gardens anywhere within the region.

Yellow flag has a major impact on the emergent vegetation of sheltered lakes, as it may form dense floating mats of rhizomes that raft over other vegetation which is rooted in bottom sediments, thus displacing it. It is also a weed of salt marshes and has spread into saline influenced sites on the Avon River, Christchurch. It is extremely toxic to livestock and will invade wet pasture.

Primrose willow

Ludwigia peploides subsp. *montevidensis* (primrose willow) has a limited naturalised distribution, predominantly restricted to the Lower Waikato Basin where it is abundant, with significant populations in West Auckland, with the earliest collection from Bethell's Beach in 1934. It was also recorded in scattered locations elsewhere in the Auckland Region, with new records from the lakes south of Lake Kereta and also from Lake Pokorua.

It is unlikely to impact on most larger lakes within Auckland, but can form large sprawling mats over shallow, sheltered, nutrient-rich lakes extending into adjacent nutrient-rich swamps. It does not appear to be problematic in drain situations.

Reed sweet grass

Glyceria maxima (reed sweet grass) is widespread in much of Auckland (first record from Bethell's Beach in 1971) and the rest of New Zealand, being a common weed of drains. New records include some of the drains within the three areas surveyed, with this species also recorded from the Upper Mangatawhiri Dam in the Hunuas.

This highly productive and competitive species has come to dominate riparian areas along many nutrient rich lowland waterways, also forming floating mats which can block pumps and promote flooding. In nutrient rich sites, it could exclude other emergent species, but impacts on Auckland lakes are not likely to be significant. It is toxic to livestock although cattle readily eat it and deaths have been reported as a result of feeding on this species (Connor 1977).

Water celery and Mercer grass

Apium nodiflorum (water celery) and *Paspalum distichum* (Mercer grass) are common drain weeds, but are likely to be too widespread within Auckland Region to be considered further as candidates for management at a regional scale, with seed dispersed by natural means (water fowl and water movement) in addition to contaminated machinery.

Lizard's tail and *Myriophyllum variifolium*

Saururus cernuus (Lizard's tail) is not known to be naturalised in New Zealand, but was found in garden sites in Auckland, with a fragment establishing downstream from a streamside site at Puhoi (Champion 2001). Its weed potential has recently been evaluated using competition trials (Champion et al. 2004a). It did not displace or reduce the biomass of a range of native and introduced emergent species, but had reduced biomass when grown with *Eleocharis acuta* and *Typha orientalis*. It was not considered to be a serious threat to indigenous wetlands and aquatic habitats and is not considered further.

Myriophyllum variifolium was first found in the Acheson Stream adjacent to the Upper Mangatawhiri Dam and may have been naturally introduced from Australia (Champion et al. 2004b). It has also been distributed as an ornamental pond plant, with a pond site found at Howick. Its ability to dominate the vegetation of the Acheson Stream and further downstream sites on the Mangatawhiri Stream and also in the Opawa Loop in Blenheim indicate some weed potential.

Ranking of Auckland lakes

In order to rank the lakes within Auckland Region, their biota, water quality and catchment use were considered. The shallow lakes north of Whatipu and the water supply reservoirs of Waikatere and Hunua were not considered in this exercise.

1.1.23 Submerged vegetation

The lakes within the Auckland Region can divided into three groups based on submerged vegetation characteristics:

- Native vegetation;
- Introduced weed dominated vegetation;
- De-vegetated.

1.1.23.1 Native vegetated lakes

Lake Ototoa was the only natural lake within Auckland Region with unmodified native submerged vegetation extending to depths of 10 m.

The only other water bodies with native vegetation are the Hunua and Waitakere water

supply dams, with maximum vegetation depths of 8 and 4 m respectively.

1.1.23.2 Introduced weed dominated lakes

Lakes Kuwakatai, Kereta and parts of Lake Okaihau were dominated by the worst submerged weed hornwort. Maximum vegetation depths are ~3 m, 2 m (maximum lake depth) and 3.9 m respectively. Hornwort dominated the two South Head lakes, with egeria and limited native vegetation in shallow water also present in Lake Okaihau.

Egeria was the dominant submerged species in lakes Wainamu, Kawaupaku, Pupuke, Pehiakura and Whatihua. Egeria was present in Lake Pokorua, but it was not the dominant vegetation.

Egeria dominated vegetation had collapsed in Lake Wainamu in the late 1990's (de Winton et al. 2005), but improving water clarity has led to its re-colonisation. Egeria is expected to increase and dominate over the next few years. A future collapse of egeria in this lake threatens this system, which may return the lake to a more highly turbid state as it was in the late 1990's to 2004.

Lake Kawaupaku has only recently been invaded by egeria (first recorded in 2004), but it had already dominated the lake vegetation at that time (J. Clayton pers. comm.).

A mosaic of species occurred in Lake Pupuke, with 10 species (5 native and 5 introduced) present and vegetation to a depth of 10 m. Eelgrass, lagarosiphon, the native milfoil (*Myriophyllum triphyllum*) and deep-zone charophytes were all locally dominant.

A collapse of egeria-dominated vegetation has occurred in Lake Pokorua, where egeria dominated the vegetation in 1988, but was of very limited distribution in 2005, with native pondweeds and charophytes being more abundant.

The submerged vegetation of Lake Whatihua was diverse; even though egeria beds dominated much of the area native species were dominant in shallower and deeper water (to 7 m) than the egeria zone.

1.1.23.3 Devegetated lakes

Lakes Slipper, Spectacle, Tomarata, Karaka, Poutoa, Ngakaru / Piripoua and Paekawau were essentially devegetated. In 1988 Lake Tomarata supported native charophyte dominated vegetation, but in 1999 submerged vegetation was lacking, even though clarity was still sufficient for submerged plant growth (1.4 m Secchi depth - Gibbs et al. 1999). Lakes Slipper and Spectacle had tannin-stained waters and were surrounded by floating rafts of emergent vegetation so habitat for submerged species is lacking. The remaining lakes (all south of Lake Kereta) were shallow and apparently prone to drying out (Bendall 2005, G. Hoskins pers. comm.), however all contained only native submerged species, albeit at low covers. Despite its limited submerged vegetation, Lake Karaka has a valuable marginal plant assemblage and provides excellent bird habitat. Prior to the introduction of hornwort, Lake Kuwakatai was devegetated (NIWA unpublished data, 1988).

1.1.24 Pest fish

The coarse fish koi carp, perch, rudd and tench have been introduced to and established in many of the Auckland Region lakes, with FBIS records of those species from Lakes Spectacle, Tomarata, Ototoa, Kuwakatai, Kereta, Pupuke, Okaihau, Wainamu and Cossey's Dam in the Hunuas. Catfish have also been collected from Lakes Wainamu and Pekiahura. Gambusia are only recorded from Lakes Ototoa and Kereta. Rudd, koi carp and tench are implicated in increasing water turbidity (Rowe in Champion et al. 2002) and coarse fish may have contributed to water quality and submerged vegetation declines in Lakes Tomarata and Wainamu. Vegetation in the other lakes was apparently not impacted to the same extent. Other impacts would be the predation of other fauna by perch and probably gambusia and catfish. For example dwarf inanga and koura are now scarce in Lake Ototoa since a large population of perch established in that lake.

1.1.25 Water quality

Gibbs et al. (1999) ranked seven of the Auckland Region lakes in order of water quality (reducing) as follows:

Ototoa > Pupuke > Tomarata > Wainamu > Kereta > Kuwakatai > Spectacle

Using the most recent records of submerged vegetation bottom limit of as an indicator of water clarity the following ranking can be obtained:

Ototoa > Pupuke > Whatihua > Pehiakura > Wainamu > Pokorua > Okaihau > Kereta > Kuwakatai

Other lakes had negligible submerged vegetation.

1.1.26 Catchment use and marginal vegetation

Lake Pupuke is the only lake in Auckland Region that is situated within an urban catchment, although much of the lake surrounds are in mown grass parkland. Lake Kawaupaku and much of Lakes Ototoa, Kuwakatai and Wainamu are surrounded by native scrub/forest. Pine plantation forestry is present in the catchments of Lakes Spectacle, Tomarata, Ototoa, Kereta and the lakes to the south of this. The following lakes have a predominantly pasture catchment: Spectacle, Slipper, Tomarata, Kereta and the lakes to the south, Paekawau, Okaihau, Pehiakura, Pokorua and Whatihua. Lakes Slipper, Spectacle, Tomarata, Kereta, Karaka, Wainamu and Kawaupaku were surrounded by a dense fringe of emergent vegetation providing buffering for nutrient run-off from adjacent land. Lakes Kuwakatai, Ototoa, Pehiakura and Pokorua were fenced to exclude livestock access, with differing degrees of emergent vegetation developed. Lakes Poutoa, Ngakaru, Piripoua, Paekawau, Okaihau and Whatihua were predominantly unfenced.

1.1.27 Synthesis

Table 5 summarises the information discussed above and presents a preliminary ranking of Auckland Region lakes.

Lakes were ranked for:

- Presence of native submerged vegetation (1=wholly native vegetation; 2=areas dominated by native species; 3=native species present; 4=wholly introduced vegetation, 5=no submerged vegetation).
- Presence of submerged pest plants (1=no pest plants; 2= pest plants present but not dominating vegetation; 3=egeria dominant; 4=hornwort dominant).
- Presence of pest fish (1=no pest fish; 2=gambusia or goldfish only; 3=other pest fish present but not implicated in vegetation loss; 4=other pest fish present and implicated in vegetation loss).
- Water quality/clarity (1=Secchi>5 m, vegetation□10 m deep; 2=Secchi<5 m, vegetation□10 m deep; 3=vegetation> 5 m deep, <10 m deep; 4=vegetation> 2 m deep, <5 m deep; 5=vegetation<2 m deep).
- Catchment (1=indigenous vegetation; 2=mostly indigenous/pine forestry; 3=partially pasture; 4=wholly pasture).
- Buffering effect of marginal/emergent vegetation (1=entire buffer; 2=fenced but limited emergent vegetation; 3=grazing access to lake margin).

Much of this information is based on historical information (1980's onwards). The methodology recommended to assess lake condition prioritisation is LakeSPI. A Native Condition Index provides a measure (score) of the diversity, quality and abundance of indigenous submerged vegetation. The Invasive Condition Index scores the impact by any of ten invasive alien plant species that may be present. A high Invasive Condition score indicates large impacts by invasive alien plants. The LakeSPI Index integrates components of these indices, together with additional ecological information. The specific features that are assessed to generate each score are detailed on the web-reporting pages (lakespi.niwa.co.nz). The LakeSPI Index provides a measure of how close a water body is to its potential or unimpacted pristine state, and can be used to detect changes in lake condition over time and make comparisons between lakes. However, this method has only been used for Lakes Ototoa and Wainamu to date and is recommended for all other lakes in the future.

Another important criterion is the presence of endangered biota including birds, fish and plants. Due to lack of data these were not considered in the present evaluation.

Table 5:

Lakes ranked in order of importance; based on presence of native submerged plants, pest species, water quality and catchment/nutrient buffering (see Section 5.2.5 text for derivation of the numbers used).

Lake (highest to lowest rank)	Native submerged vegetation	Pest plants	Pest fish	Water quality	Catchment	Buffering of emergent/wetland margin
Ototoa	1	1	3	1	2	2
Pupuke	2	3	3	2	3	2
Wainamu	3	2	3	3	2	1
Whatihua	2	3	1	3	4	3
Karaka	3	1	1	5	3	1
Tomarata	5	1	4	3	3	1
Kawaupaku	4	3	3	4	1	1
Pokorua	2	2	1	4	4	3
Pehiakura	3	3	3	3	4	3
Poutoa	3	1	1	5	4	3
Ngakaru and Piripoua	3	1	1	5	4	3
Paekawau	3	1	1	5	4	3
Kereta	4	4	3	4	3	1
Slipper and Spectacle	5	1	3	5	4	1
Okaihau	3	4	3	4	4	3
Kuwakatai	4	4	3	5	3	3

Introduction pathways and risks

Aquatic and wetland weeds may be spread to new sites by a range of natural and human induced mechanisms:

Natural spread includes the movement of propagules by:

- Water (e.g., flood waters dispersing contents of ornamental ponds).
- Wind (e.g., seed with parachute-type hair attachments like *Typha orientalis*); or
- Waterfowl (e.g., seed palatable to ducks or attached to their legs etc.).

Human induced spread can be divided into deliberate and accidental means as follows:

- Deliberate spread:
  - Liberation of aquarium contents and dumping of garden waste.
  - Ornamental plantings in natural water bodies.
  - Introduction of aquatic plants with coarse fish.
- Accidental spread:
  - Contaminated water craft.
  - Contaminated fishing nets.
  - Contaminated drainage machinery.
  - Contaminated clothing, footwear etc.

The risk of transfer of these propagules to unimpacted water bodies or wetlands is essentially the probability that one or more of the mechanisms noted above will move plant material (seeds and vegetative fragments) from a weed source to that unimpacted area.

These distribution pathways and their relevance to spread of aquatic and wetland weeds into and within Auckland Region are discussed in the following sections.

1.1.28 Natural spread

The six submerged aquatic weeds discussed in Section 5.1.2.1, with the possible exception of bladderwort, do not set seed in New Zealand, either because only one sex is present or, in the case of hornwort, due to unfavorable environmental conditions and/or self-incompatibility. Therefore natural spread, through water movement, is only important within a catchment for these species. Flood events could feasibly transfer those species to downstream sites should an outdoor pond containing one of those species be inundated.

Bladderwort may be distributed by waterfowl. Recent surveys in Northland have found this species in areas inaccessible to drainage machinery and boat traffic. Seed are possibly set, or alternatively the fine filamentous stems of this species may be transferred via waterfowl feet.

Of the remaining aquatic weeds, phragmites, alligator weed, parrot's feather, lizard's tail and the *Myriophyllum variifolium* do not produce viable seed in New Zealand, and Manchurian wild rice only rarely appears to set viable seed. The seed of the other six aquatic species are adapted for water dispersal and while this is an effective means of spread within a catchment, dispersal to other catchments would need to occur through some other mechanism (e.g., contamination of drainage machinery). The limited and patchy distribution of these plants within Auckland Region, even though some have been present within the region for at least 50 years (e.g., yellow flag) illustrates this point.

Thus only plants adapted for dispersal by birds have the potential to be effectively dispersed naturally between catchments and their spread would be impossible to prevent should a species establish as a naturalised plant within the region. None of the species discussed are spread by wind movement, although *Phragmites australis* could be dispersed in this way should compatible strains be grown in close proximity to each other. Other species require human assistance to spread between catchments.

1.1.29 Deliberate human spread

The majority of alien aquatic and wetland weeds present in New Zealand were intentionally introduced either for ornamental gardens, ponds or aquaria, as fodder species (e.g., reed sweet grass and Mercer grass), or possibly for medicinal/homeopathic purposes (gypsywort) (Champion and Clayton 2000).

As the majority of weeds discussed in this report do not reproduce sexually or are not effectively dispersed outside of catchment boundaries (Section 5.3.1), deliberate or unintentional transfer by human activities would provide the main mechanisms of spread. Legislation has prevented sale, distribution and propagation (Sections 52 and 53 of the Biosecurity Act 1993) of a number of species with high weed potential as a mechanism to circumvent their dispersal around New Zealand, with their declaration as Unwanted Organisms and their inclusion on the National Pest Plant Accord NPPA (Biosecurity New Zealand, Ministry of Agriculture and Forestry 2002). In 1983, seven aquatic weed species (salvinia, lagarosiphon, hydrilla, hornwort, egeria and both eelgrass species) were banned from sale and distribution under the Noxious Plant Act (1978) and this has limited their deliberate movement and reduced the number of potential sources for new weed incursions into natural water bodies.

Despite the gazettal of submerged species which banned them from sale and distribution in 1983, they are still being distributed around New Zealand as pond and aquarium plants through garden plant exchanges, rather than sale. Additionally species may be unwittingly transferred as a contaminant of other pond plants, such as the rhizomes of water lilies, or even transported with fish. The incidence is probably low

based on the ornamental pond survey, where only one pond containing egeria, lagarosiphon and eelgrass (Meola Creek variety) were found on the 300 properties and 33 ponds.

The deliberate distribution of all of the species listed on the Auckland RPMS and/or the NPPA (all species included in this report with exception of water celery, Mercer grass, lizard's tail and *Myriophyllum variifolium*) should have been prevented since 2002.

Many of the species discussed in Section 5.1.2 are only likely to spread within the Auckland Region through deliberate ornamental plantings, as they are unlikely to be moved accidentally (see next section). These species include the submerged *Vallisneria* species that need to be planted into bottom sediments to establish, all of the water lily-like and free-floating plants, the emergent phragmites, arrowhead, sagittaria, Senegal tea, purple loosestrife, yellow flag and lizard's tail.

Subsequent spread within the catchment of the species discussed in the above paragraph is dependant on the ability of the species to spread either sexually or by fragmentation of stems and rhizomes.

The deliberate transfer of coarse fish is often accompanied by release of aquatic plants, which may be used to transport fish or ova from site to site. Hornwort and egeria are likely to have been introduced into several lakes accompanying the liberation of pest fish species.

1.1.30 Accidental human spread

The submerged plants discussed in Section 5.1.2.1 are all dispersed via stem fragmentation and their main mode of spread to new water bodies appears to be via contamination of watercraft (lakes), drainage machinery (flowing waters and drains) and fishing nets (all water bodies) with these fragments (Johnstone et al.1987) rather than by natural dispersal (Section 5.3.1). In a similar way the sprawling emergent species alligator weed, parrot's feather, primrose willow and potentially *Myriophyllum variifolium* which all predominantly reproduce by stem fragmentation could also be spread by contamination, with drainage machinery the most likely vector. Similarly stem/rhizome fragments of the rhizomatous grasses Manchurian wild rice, reed sweet grass and Mercer grass and also yellow flag could be dispersed by contaminated drainage machinery. Seed produced by gypsywort, water celery, the grasses and yellow flag could also be spread by drainage machinery, vehicle tyres or even footwear.

The risk of accidental spread of these weeds is dependant on a number of factors:

- Adaptations of weed species to enable their spread to new sites (e.g., tolerance to desiccation, ease of attachment to a vector, regenerative capacity etc.).
- Proximity of weed source in relation to the unimpacted site. Generally the closer the distance, the greater the risk (e.g., Johnstone et al.1987).

- Abundance of weed sources (both in number and extent). The more sources the greater the risk of spread.
- Type of dispersal vector (e.g., fyke versus seine net; jet boat versus outboard versus inboard motor driven boat) and probability of propagule survival.
- Accessibility of the weed site(s) and unimpacted site to the potential vector (e.g., road access, boat ramps etc.).
- Frequency of vector movements between weed source and unimpacted sites.
- Desirability of the weed site(s) and unimpacted site to the potential vector (e.g., are both water bodies well stocked with eels that may be fished by commercial and recreational fishers).

Evaluation of threat posed by aquatic weed species and management implications

Although most of the current freshwater pest plants on the ARC Regional Pest Management Strategy (RPMS) were deliberately introduced into New Zealand, either as ornamental pond or aquarium plants (excepting alligator weed and Manchurian wild rice), the survey of ponds in three areas of urban Auckland showed that a very low frequency of homeowners now grow these species in their gardens. The current approach of investigating and managing new pest plant sites based on reports of potential problem species occurrence appears to be warranted, rather than a random survey of all properties.

Prohibition of sale and distribution of these species through the Auckland RPMS is an effective deterrent to the continued culture of most of these species.

The evaluation of vectors and associated risks discussed in sections 5.3, along with the risk posed by each species need to be quantified in order to target the management of aquatic weed spread. These are presented in Table 6:

Table 6:

Vectors, risk of spread and management implications for aquatic weed species (excluding total control and MAF controlled species) in the Auckland Region.

Species	Vectors	Risk of spread	Management requirements
Submerged			
Hydrilla	Accidental (predominantly nets)	Very low – no motorised boats on hydrilla lakes, requires transfer from Hawkes Bay	None
Hornwort, egeria and lagarosiphon	Ornamental ponds or aquaria	Low – uncommon, unlikely to be spread	None
	Accidental (nets)	High – requires transfer from Auckland or Waikato sources	Surveillance of high priority lakes. Monitor eel fishing patterns. Notify fishers of contaminated water bodies.
	Accidental (drainage equipment)	Moderate – most likely requires transfer Auckland or Waikato sources	Surveillance for Auckland sites and notify contractors of contaminated sites, clean/sterilise diggers before moving to new sites.
	Accidental (boats)	Moderate – requires transfer from boat-accessible lakes (Pupuke – egeria and lagarosiphon) or Waikato lakes	Surveillance of high priority lakes accessible by boats
Bladderwort	Natural (birds)	High – common in north west of region	Surveillance for Auckland sites.
	Accidental (boats, nets and drainage equipment)	High – easily entangled	Surveillance for Auckland sites.
Eelgrass	Ornamental ponds or aquaria	Low – uncommon, unlikely to be spread	None
	Deliberate (planting)	Low – inclusion of both eelgrass species on NPPA will remove incentive for planting/harvesting of plants in the wild	None

Species	Vectors	Risk of spread	Management implications
Emergent			
Phragmites	Deliberate	Low – promoted as a wetland treatment system for effluent treatment, but UO status and eradication programmes limit the risk	None
Manchurian wild rice	Accidental (drainage machinery)	Moderate/high - requires transfer from infested sites in Northland (plants would be obvious to operator)	Educate and notify contractors of risk, clean/sterilise diggers before moving to new sites.
	Deliberate	Low – planted as fodder/bank stabilizer	Educate
Alligator weed	Deliberate	Low – promoted as vegetable in some ethnic communities	Educate
	Accidental (drainage machinery)	High – requires transfer from infested sites (plants not obvious to operator – widespread in region)	Surveillance for Auckland sites and notify contractors of contaminated sites, clean/sterilise diggers before moving to new sites.
Parrot's feather	Ornamental ponds or aquaria	Low – possibly in a few pond sites	Educate
	Accidental (drainage machinery)	High – requires transfer from infested sites (plants not obvious to operator – widespread in parts of region)	Surveillance for Auckland sites and notify contractors of contaminated sites, clean/sterilise diggers before moving to new sites.
Gypsywort	Natural (waterfowl and water borne seed)	Low – apparently limited natural dispersal between catchments, but very effective within catchments (floating seeds)	Surveillance for Auckland sites. Investigate control/eradication where naturalised in high-risk sites
	Accidental (drainage machinery/contaminated clothing/footwear of hunters etc.)	High – small seed, long viability.	Surveillance for Auckland sites. Investigate control/eradication where naturalised in high-risk sites
Yellow flag	Deliberate	Low – probably scattered in gardens and ponds	Surveillance for Auckland sites

Species	Vectors	Risk of spread	Management implications
	Natural (water borne seed)	High – seed dispersed in infested catchments	Investigate control/eradication where naturalised in high-risk sites
	Accidental (drainage machinery)	Low – rhizomes and possible seed could be dispersed from infested catchments)	Notify contractors of contaminated sites.
Primrose willow	Natural (water borne seed)	Low – Apparently poor disperser between catchments	Surveillance for Auckland sites
	Accidental (drainage machinery)	Low – requires transfer of seeds or stem fragments from infested sites (plants limited in distribution)	None
Reed sweet grass	Natural (water borne seed)	High – seed dispersed in infested catchments	None
	Accidental (drainage machinery)	High – rhizomes and possible seed dispersed from infested catchments)	Educate and notify contractors of contaminated sites, clean/sterilise diggers before moving to unimpacted sites.
Water celery and Mercer grass	Natural (waterfowl and water borne seed)	High – well adapted to natural dispersal.	None
	Accidental (drainage machinery)	High – well adapted to dispersal.	None
Myriophyllum variifolium	Deliberate	Moderate/high – currently sold (Annies Aquatics)	Advocate removing from sale (if indigenous then not a candidate for NPPA)
Lizard's tail	Deliberate	Low – spread by gardeners, risk to natural habitats evaluated as low	Monitor behaviour at known sites

Surveillance programme

1.1.31 Regional surveillance

It is unlikely that the distribution of the submerged species hornwort, egeria, lagarosiphon and bladderwort and the emergent species alligator weed, parrot's feather, yellow flag, primrose willow, gypsywort and reed sweet grass are as limited as presented in this report. A surveillance programme investigating water bodies throughout the region (lakes, ponds, dams, rivers, streams and drains) would provide a much better baseline of distribution of these species and allow better-targeted management.

Once this is undertaken then delimitation of impacted/unimpacted areas can be made and either local control, education of vectors and surveillance for incursions in unimpacted areas can proceed if appropriate.

1.1.32 Targeted lake surveillance

1.1.32.1 Submerged species

Of the lakes prioritised in Section 5.2 Lakes Ototoa, Pupuke, Whatihua, Wainamu and Tomarata are suitable candidates for incursion monitoring for submerged pest plants.

Lake Ototoa is the highest ranked lake within Auckland Region. No other Auckland lakes approach Ototoa regarding current water quality and biodiversity values. It is currently in a weed-free condition and the 2005 Scuba survey included a thorough examination of access points from shallow to mid-water depths (5 m). Observations at the two access points at Lake Ototoa suggest the public access from Donohue Road would be more conducive to the establishment of introduced aquatic weeds than the access way via forestry roads; the latter comprising a hard-packed sand beach and steep drop off. Proposed increased public access and use of Lake Ototoa would increase the likelihood of pest plant introduction. Restriction of boat use in this lake (e.g. no motorized boats, or only use of boats resident at the lake) would be an effective way of reducing the risk of boat-mediated weed introduction.

An annual survey of Lake Ototoa should be carried out, with an eradication programme instigated should any pest species be located. A full survey of vegetation in this lake is advocated every 2 or 3 years to allow detection of new weed incursions, should they occur away from entry points. Discussion with lake users to ascertain anchorage sites and high use areas would further improve the likelihood of early pest plant detection.

Hornwort introduction into Lake Pupuke would impact submerged vegetation and associated biota, but also is likely to cause greater disruption of recreational use than the current eelgrass and egeria impacts. The closest sources of hornwort would be the ponds at Tahuna-Torea Reserve and the Waikato River system. The restriction of

motorized boat use to safety craft for rowing regattas certainly reduces the risk of introduction, but it is recommended that annual surveillance of access points be carried out targeting incursion of this species.

Lake Whatihua was a clear lake, although a collapse of egeria beds could lead to a dramatic decline in water quality. Hornwort incursion may cause a decline in lake condition and the close proximity to the Waikato River and Muir's Lake (Otamatearoa) in Waikato District (both with abundant hornwort) increases introduction risk. Access is difficult and would require permission of the landowner, but potentially eel fishers and recreation boats could introduce this species. Discussion with local lake users would allow for targeted surveillance for hornwort at entry points and high use areas. Surveillance of access points and fishing positions is recommended on an annual basis.

Access to Lake Wainamu is difficult, either through the outlet stream or pathways over or around the dune at the lake outlet. Egeria was most likely introduced to the lake via contaminated water lily plants at the lake outlet (Champion 1995). Hornwort is a major threat to the lake and could displace egeria and other species should it be introduced. The greatest threat is posed by coarse fishers, with the possible transfer of hornwort from Lakes Okaihau or Kereta in fishing nets, or associated with future fish liberations in the lake. Surveillance in the narrow neck of Lake Wainamu near the outlet and fishing positions on the western lake shore are recommended annually.

Lake Tomarata is presumably still devoid of submerged vegetation (based on Gibbs 1999), but water clarity would be sufficient for establishment of aquatic plants, with pest fish browsing potentially a barrier to this occurring. Surveillance of entry points throughout the zone of light penetration is advocated on a 3 yearly basis.

In the case of Lake Karaka, the risk of hornwort introduction from neighboring Lake Kereta, while not substantial, would alter this water body by occupying open water. The turbid nature of this lake would preclude any surveillance activities for early detection of hornwort or incursion management should it be detected.

1.1.32.2 Emergent species

None of the six highest ranked lakes are impacted by alligator weed, although there are probably potential sources in close proximity (e.g., wetland vegetation near Lake Spectacle close to Lake Tomarata; drains north of Parakai close to Ototoa and Karaka, Waitakere Wetland adjacent to Lake Wainamu; North Shore sites near Lake Pupuke and Waikato River/Aka Aka drains near Whatihua). Transfer would most likely be through deliberate planting by duck hunters (apparently the cause of some Northland infestations – Champion et al. 2005) or transfer into the catchment from drainage machinery. Neither vector is assessed as being high risk, but surveillance of lake margins every 3 to 5 years should detect any new incursion. This frequency of inspection should be sufficient to intercept new infestations of the remaining emergent species. Of these parrot's feather is locally present in Lake Pupuke and more widespread in Lake Wainamu; primrose willow is abundant in Karaka, Wainamu and Pupuke and Manchurian wild rice is present in Lake Karaka and the adjacent Lake Kereta. There is little evidence to show rapid invasion of this species into new areas,

with Cunningham (1953) noting this grass dominating the southern third of Lake Kereta in 1950, not dissimilar to its current location.

Targeted control and management of pest plants

Based on the survey of Auckland RPMS Surveillance plants as discussed in Section 4.5.1 it may be decided to elevate the status of some species in the next RPMS where control is undertaken (e.g. Total Control). Yellow flag and gypsywort are the most likely species to warrant active control.

Hornwort, egeria, lagarosiphon, alligator weed, parrot's feather and reed sweet grass are all problem drainage weeds, with alligator weed also a potential pest in cropping land and wet pasture. Prevention of spread to unimpacted areas would involve educating users of drainage machinery and potentially landowners to both maintain good decontamination procedures and also report any new weed incursions.

New incursions of emergent pest plant species can be eradicated either by manual removal, or use of appropriate herbicides. In both cases regular surveillance of treated sites is required to ensure any regrowth is prevented.

Eradication of submerged pest plants is much more difficult, with very few eradication options. Early detection is critical to any successful control programme. Very small infestations can be controlled by careful hand weeding by divers and covering the area with an opaque material (e.g., black polythene or weed mat) with appropriate follow-up. This method was used to manage an incursion of lagarosiphon detected in Lake Waikaremoana. Larger sites (up to several metres diameter) can be eradicated using diver operated suction dredging. Larger sites (apart from eelgrass which has a basal growth pattern) are likely to have already dispersed within the water body.

Whole of water body treatment options are restricted to the use of Chinese grass carp. Appropriate stocking levels can effectively devegetate a water body and following carp removal re-colonisation of native species from the buried seed banks in bottom sediments can occur. This is especially useful in lakes with minimal inlets/outlets, so containment of fish is less of an issue. Lake Parkinson (Rowe and Champion 1995) is an example of a successful restoration programme using these fish. Currently there are no herbicides available capable of submerged plant eradication on a lake-scale, although local control of access points where contamination of boats/trailers may be attained using this method.

Lake Tomarata once supported native submerged vegetation and this may recover if pest fish are controlled and water clarity improves from the 1-1.5 m range recorded in the late 1990's (Gibbs et al. 1999). Alternatively exclosure cages could be used to allow re-establishment of native plants from the lake sediment seed bank as has been successfully trialed in Lake Rotomanuka, Waikato (NIWA unpublished). This would significantly improve the ecological value of this lake.

Acknowledgements

We would like to thank Jack Craw, Richard Gribble, Mike Harre, Don Austin, Graeme Wrightson, Chris Katterns, Greg Hoskins and Rod Smart (all members of the Biosecurity Section, ARC) for assistance in this project.

Rohan Wells, Aleki Taumoepeau and Fleur Matheson (NIWA, Hamilton) provided field assistance in the Kaipara drain and lake Scuba surveys. Rohan also provided a useful critique of the report.

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