Proactive management of aquatic weeds to protect the nationally important Northland dune lakes, New Zealand

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Summary Northland dune lakes are of national significance, with many having good water quality. Perhaps the most outstanding character of these lakes is the current limited impact of invasive species on their native biota. However, invasive aquatic weeds are steadily invading and having major impacts on their ecology. This paper presents a proactive lake management strategy that involves the identification and protection of lakes with highest ecological value. Key components of this strategy include targeted weed surveillance of high use areas, weed spread prevention and targeted weed eradication of the worst weed species in order to protect adjacent high value lakes. Progress to date includes 1) the detection of weeds during surveillance activities while in the very early stages of invasion, thus allowing successful eradication and 2) three lake-wide eradication programmes resulting in the expected eradication of target weeds, with restoration of indigenous vegetation resulting from selective herbicide use.

Keywords Aquatic weeds, surveillance, eradication, lake management strategy.

INTRODUCTION

Northland region has the greatest number of dune lakes nationally and represents a large proportion of warm, lowland New Zealand lakes still with relatively good water quality. Dune lakes in other, more heavily populated, western parts of the North Island have been severely impacted by eutrophication from agricultural land use and pest fish and plants. Northland dune lakes and their surrounding wetland margins support a range of endemic endangered species providing the only known habitat, or the national strongholds for a range of biota. An outstanding character of these lakes is the current limited impact of invasive species on their native biota, which is unparalleled in any other region of mainland New Zealand.

Ecological values of 76 lakes were assessed, including habitat size, buffering, water quality, aquatic vegetation diversity and integrity, presence of endangered and key species and connectivity (Champion and de Winton 2012). Based on this work, a strategy for the management of Northland Lakes has recently been developed (Champion and de Winton 2012, Champion 2014). The twelve highest value lakes have been adopted by Northland Regional Council (NRC) on Northland's list of Regionally Outstanding Water Bodies (Champion 2014).

This paper documents the spread of aquatic and wetland weeds in these lakes and management activities undertaken to protect the regionally outstanding waterbodies.

WEED SPECIES AND THEIR DISTRIBUTION

Cunningham *et al*. (1953) described the vegetation of six Northland lakes as being entirely indigenous. Five of these lakes are now dominated by invasive species. Tanner *et al*. (1986) examined 25 lakes in this region and reported five with invasive species, with a further report (in 1970) of the weed *Lagarosiphon major* (Ridl.) Moss in Lake Waiparera, but not found during their survey. Since that time, a further five lakes have been invaded by either *L. major*, *Egeria densa* Planch. or *Ceratophyllum demersum* L. and only one of the 25 lakes is not impacted by *Utricularia gibba* L. (Wells and Champion 2013).

An annual monitoring programme of 76 lakes (with each lake visited at least every five years) revealed that seven lakes were invaded by *C. demersum*, 12 by *E. densa*, three by *L. major* and 41 by *U. gibba*. Dates of first records and cumulative numbers of lakes impacted are plotted in Figure 1.

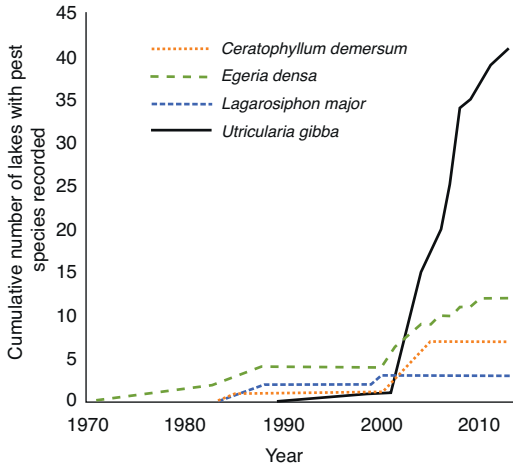

Figure 1. Cumulative number of Northland lakes with populations of aquatic weeds from 1970 to 2014.

The impact of these species vary, with greatest impact resulting from the invasion by *C. demersum*, followed by *E. densa*, *L. major* and *U. gibba* as evaluated with the aquatic weed risk assessment model (Champion and Clayton 2001). The submerged vegetation of all Northland lakes invaded by *C. demersum* was essentially displaced by this species from 1 m to the bottom limit of vegetation. *Egeria densa* had similar impacts in lakes of eutrophic or more nutrient enriched status (e.g. Lake Omapere) but has not significantly impacted the mesotrophic Lake Rotokawau (Pouto Peninsula; i.e. it does not form dense, tall weed beds). It was mostly displaced by *C. demersum* in Lake Heather and Rotootuauru. *Lagarosiphon major* had a more limited impact in the three lakes it occupied, with some displacement of native species, often in the zone between 1.5 and 3 m, with indigenous plants dominating deeper waters. None of these species sexually reproduce in New Zealand and spread is exclusively human-mediated. *Utricularia gibba* is a recent coloniser of Northland. Before 1999, the species was restricted to north-western Auckland where limited seed set was observed. Plants discovered on the Aupouri Peninsula in 1999 were morphologically different from Auckland material, and produced viable waterfowl-dispersed seed (Salmon 2001). Salmon (2001) suggested Northland plants were naturally dispersed from Eastern Australia by waterfowl, whereas Auckland plants originated from aquarium escapes. The Northland form of *U. gibba* can be considered to be a native invasive species. It has rapidly colonised aquatic habitats throughout Northland and has spread to sites further south of this region. Unlike *C. demersum*, *E. densa* and *L. major*, this species does not displace other vegetation, being mostly unattached to bottom sediments and forming a smothering canopy over existing vegetation (both indigenous and introduced), much like the impacts of an invasive terrestrial climbing weed. There is no evidence of significant collapse or displacement of vegetation beneath *U. gibba* mats, but the larger native *Utricularia australis* R.Br. has virtually disappeared from its former national stronghold in the Aupouri lakes over the same time period and is now ranked as Nationally Critically Endangered (de Lange *et al*. 2013). The relatively rapid rate of spread of *U. gibba* shown in Figure 1, reflects the spread by natural agents compared with human-mediated spread of the other species. de Winton *et al*. (2009) discuss the same trends on a New Zealand-wide basis. Most introductions of human-mediated spread are found in lakes close to population centres with easy boat access, or those fished for eels, with spread via contaminated watercraft or nets.

Additionally, emergent weeds such as *Zizania latifolia* (Griseb.) Stapf, *Alternanthera philoxeroides* (Mart.) Griseb., *Iris pseudacorus* L., *Ludwigia peploides* (Kunth) Raven and *Glyceria maxima* (Hartm.) Holmb. (listed in order of invasiveness assessed by Champion and Clayton 2001) were found on the margins of one, 16, one, two and four lakes respectively. *Alternanthera philoxeroides* is the most widespread, but the only exclusively clonal, species of this group. It has been naturalised in Northland for over 100 years and widely spread via contaminated drainage machinery and likely deliberate spread by duck hunters (Wells and Champion 2013).

PROACTIVE AQUATIC WEED MANAGEMENT

Surveillance, weed spread prevention and targeted weed eradication are three proactive management approaches undertaken to protect those 12 Northland dune lakes identified as having outstanding ecological value.

Surveillance Wells and Champion (2013) undertook annual surveillance of six of the high-value lakes (Lakes Ngatu, Waiporohita, Waikare, Taharoa, Kai-Iwi and Humuhumu) where risk of weed invasion was assessed as high. The remaining six regionally outstanding waterbodies were deemed to be of lower risk of invasion due to very restricted public access, and these are only inspected every five years.

Likely sites of introduction were intensively searched. In the case of watercraft, boat entry points (e.g., boat ramps and commonly used beach access points) and anchorage areas (such as favoured fishing areas and sheltered bays), where plant fragments in an anchor well could be unwittingly liberated, were searched. Lakes were inspected using a combination of shoreline inspection for submerged plant fragments and establishment of emergent weeds, snorkelling in water shallower than 2 m allowing detection of submerged weeds in this zone and scuba divers either on boat tows, or underwater scooters searching submerged vegetation to the bottom limit of existing plants. These divers must be trained to enable detection of target weed species amongst existing vegetation. Techniques for surveillance are detailed by Wells and Bodmin (2008). For example, Lake Waikare is a popular water skiing lake with access via a concrete boat ramp at the western end and beach access at the south-eastern end. The shoreline 200 m either side of the boat ramp is searched from the shore and also by one snorkeler and two scuba divers to a depth of 10 m. Divers also check the area immediately adjacent to the boat ramp to the bottom of existing vegetation (currently 19 m). The south-eastern bay is also checked

by snorkel and scuba divers over a 400 m area (Wells and Bodmin 2008).

To date, no new submerged plant incursions have been detected at the six surveillance lakes, although viable fragments of the weed *Elodea canadensis* Michx. were found on the shore of Lake Taharoa at a popular boat launching area in 2007. Surveillance at Lake Ngatu led to the detection and successful eradication of the emergent *I. pseudacorus* by hand weeding in 2007 and eradication of *A. philoxeroides* detected at Lake Ngatu in 2012 using the herbicide metsulfuron methyl is well advanced. Thus, three weed invasions have been detected and eradicated as part of this programme.

Other entry pathways of invasive plants are through deliberate planting of ornamental species e.g. water lily rhizomes contaminated by submerged weeds and liberation of aquaria or pond contents either through deliberate release or the result of a flood event. As part of the Northland lake strategy, surveillance of ponds on private properties adjacent to the Kai-Iwi lakes (Waikare, Taharoa and Kai-Iwi) in 2013/14 led to the detection of the weed *L. peploides* and also goldfish (*Carassius auratus* Linnaeus) that may have a deleterious impact on water clarity (Rowe 2014). The threat of invasion of these two species from ornamental ponds has been averted.

Incursion response readiness measures for submerged weeds identified by Wells and Bodmin (2008) included delimitation of the entire water body should a weed species be detected by surveillance, netting of infested areas to restrict further spread and eradication techniques including hand weeding, bottom lining with opaque material, suction dredging, use of aquatic herbicides or grass carp dependent on the level of infestation.

Weed spread prevention NRC have deployed signage at boat access points to warn lake users of the risks posed by invasive pest animals and plants.

NRC propose to deploy weed cordons (Lass 2012) at boat access points at Lake Taharoa to intercept any plant fragments that may be introduced by water craft. These have been successfully trialled in the Rotorua lakes, showing a greater than 70% recovery of plant fragments, with the recent apparently successful interception of *C. demersum* and *E. densa* fragments in Lake Rotoma, a lake currently free of these species (Hamish Lass, Bay of Plenty Regional Council, pers. comm.).

Eradication In addition to the incursion responses for *I. pseudacorus* and *A. philoxeroides,* there have been several whole of lake eradication programmes initiated by NRC in response to recommendations resulting from annual ecological monitoring.

The vegetation of two lakes, Lake Rotootuauru and Lake Heather were completely dominated by the weeds *C. demersum* and *E. densa.* Lake Rotootuauru is situated on the Pouto Peninsula amongst a group of other lakes that are relatively unimpacted by introduced weeds, with lakes Humuhumu, Rotokawau and Kanono all classified as regionally outstanding waterbodies. For example, Lake Humuhumu is located only 300 m away from Lake Rotootuauru. Lake Heather is situated within a group of lakes on the southern Aupouri Peninsula including the regionally outstanding Lake Ngatu. In order to protect these high-value lakes, the eradication of *C. demersum* and *E. densa* was proposed and grass carp (*Ctenopharyngodon idella* (Valenciennes)) were introduced to the lakes in 2009 and 2010 respectively. Annual monitoring of submerged vegetation transects across these lakes were undertaken. In Lake Rotootuauru, no plants of either species found in 2012 to 2014, so removal of the grass carp will be recommended. In Lake Heather, occasional isolated fragments of *C. demersum* were found in 2014.

A third eradication programme was initiated in Lake Phoebe, a small lake on the Pouto Peninsula. This lake supported the only known Northland population of *L. major* south of the Aupouri Peninsula (over 150 km away) and although it was 4 km from the nearest outstanding value lake (Humuhumu) and relatively isolated, an eradication programme was advocated. As grass carp were likely to be non-selective and also remove these native species, it was decided to attempt eradication of *L. major* using the dipotassium salt of endothall, an aquatic herbicide. This herbicide had been used to selectively eradicate *L. major* from shallow gravel ponds in Southland, with no damage to indigenous charophyte vegetation and rapid recovery of the milfoil *Myriophyllum triphyllum* Orch. ten months after treatment (Wells and Champion 2012). The liquid formulation of endothall (Aquathol® K) was applied at a rate of 5 ppm to 25% of the area of Lake Phoebe in 2012. The lake was inspected by scuba divers in May 2014, with no plants of *L. major* detected. The vegetation was dominated by *Potamogeton ochreatus* Raoul and *Nitella* sp. aff. *cristata*.

CONCLUSIONS

The Northland lake strategy provides direction for management agencies to identify the ecological values of lakes within this region and enable a region-wide prioritisation of lakes for protection. On-going monitoring has detected a decline in condition of many of these lakes, with the spread of invasive aquatic weeds a major driver of these changes.

Proactive management measures undertaken to date appear to be effective and have successfully protected those lakes classified as regionally outstanding waterbodies from further weed incursions, with further measures likely to increase their effective biosecurity. Targeted eradication of the problem species *C. demersum* and *E. densa* from two strategically important lakes is well advanced. Selective herbicidal control of *L. major* has been achieved from Lake Phoebe with completely indigenous submerged vegetation now present in this lake after two years.

While these responses have been successful there are some invasions detected by annual monitoring that cannot be managed by currently available techniques, such as the unchecked natural spread of *U. gibba* by waterfowl throughout Northland waterbodies. This species has severely impacted some waterbodies and threatens many populations of the critically endangered *U. australis*. Research into the protection of lake populations of *U. australis* through exclusion of *U. gibba* is advocated.

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