

stramonium var. *tatula*) with distinct purple stems. We returned to the cars around 3pm after a very pleasant day and well satisfied with the fact that we

had observed six species on the Auckland Regional Threatened & Uncommon Vascular Plants List (Stanley et al. 2005).

Acknowledgments

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References

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Flora of eight southern Awhitu dune lakes, southwest Auckland

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Introduction

All the high coastal land of the Awhitu Peninsula down to the Waikato River mouth was formed by the gradual build up of a series of coastal sand dunes – each set of dunes, stabilised by forest, was subsequently buried by later dune advance and so the process continued over the last 2 million years or so (Hayward 2008). Most of the forest is long gone as shown by the Waipipi Block Survey map (Smith 1864), and the Whiriwhiri and Maioro Survey map (Reay & Clayton 1864) which show only rough open fern, scrubland-flax (*Phormium tenax*), toetoe (*Cortaderia splendens*), and coastal shrubs on the unconsolidated sand dunes. This dune land at southern Awhitu is now mainly farmed with exotic forestry at the southern tip. However, a number of small lakes and wetlands still exist filling the hollows of the old sand dunes.

The first published botanical account of this general southern Awhitu area was by Carse (1901), followed over a century later by Aspin (2008). Five southern Awhitu lakes (Otamatearoa, Kokahuake, Puketi, Rotoiti and Whatihua) were included as part of a wider lake health survey by NIWA of the Waikato and Auckland Regions during 2004-09 (Edwards et al. 2005, de Winton & Edwards 2009).

From 2006 to March 2011 we surveyed the best eight dune lakes in the southern Awhitu area: Whatihua, Puketi, Rotoiti, unnamed, Otamatearoa, Kokahuake (Parkinsons), Rotopopo, and Pongahurahura Lakes. They are spread over 6 km on old sand dunes, 1-2 km in from the coast, at 70-110 m asl (Fig. 1). Most lakes were visited at least twice (see Appendix 1) and our most recent visit to Lakes Puketi, Rotoiti and unnamed was with the Auckland Bot Soc (see Aspin 2011). Our survey was carried out by walking around the lake margins recording the flora, wading out in places but no underwater survey was carried out by us. However, washed up material was included and charophyte presence/cover was estimated by wading out from the margins. Although the emphasis of our survey was on the vascular flora, where observed,

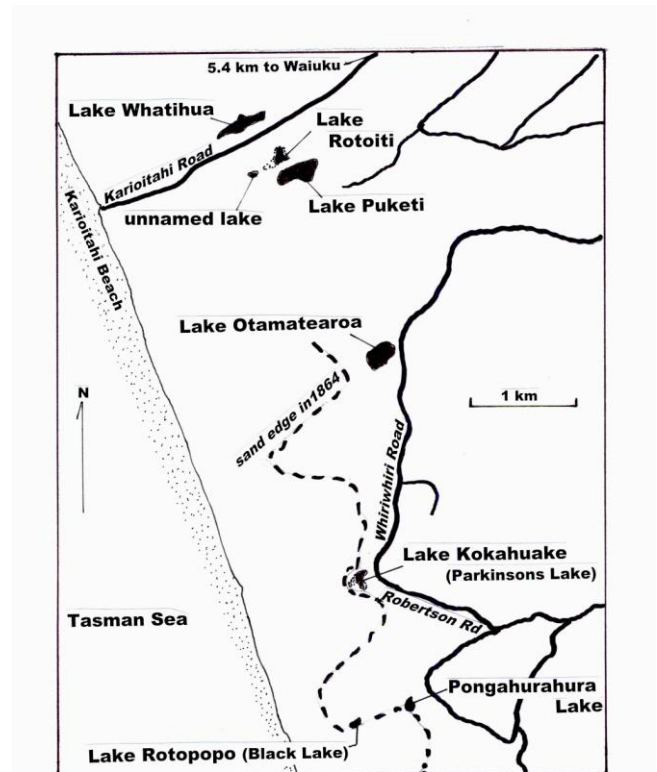


Fig. 1. Location of eight dune lakes surveyed in the southern Awhitu Ecological District (drawn by EKC).

algae (charophytes) and bryophytes were collected, later identified and were included in Appendix 1. Most of the lakes contained a large area of open water fringed by a usually narrow margin of emergent vegetation. The smaller lakes of this area not included in the survey are much more highly modified (PAA pers. ob.).

Apart from the Crown-owned Lake Kokahuake, all the lakes surveyed are on private land; Lakes Puketi and Rotoiti are both covenanted to DoC (Department of Conservation). Except for parts of Lakes Kokahuake and Whatihua all lakes are unfenced from stock (Fig. 2). The degree of grazing varies on stocking densities and cattle rotation. Except for one, none of the lakes have a natural outflow and therefore the levels

fluctuate depending on rainfall and season. The exception is Lake Puketi which has a channel c.300 m long from the northeast corner and then a 80m-long tunnel dug in 1900-10 from the east side using pick, shovel and wheelbarrow (Geoff Muir pers. comm. to PAA). All eight lakes lie within the southern part of the Awhitu Ecological District. However, only Lake Whatihua lies within the Auckland Council boundary; all the others are in Environment Waikato (EW).



Fig. 2. Lake Whatihua looking SW – at 500 m long this is the longest of the lakes in southern Awhitu. Foreground: cattle-grazed pasture and emergent lake-edge vegetation of *Eleocharis sphacelata* and raupo. Photo: 14 Mar 2006 (unless otherwise stated all photos by EKC).

General characteristics, including the vegetation, of the eight lakes

Lake Whatihua (Map Topo50 BC31 481733 c.95 m asl, 3.8 ha) Fig. 2.

This narrow lake was the longest that we surveyed at c.500 m by up to 120 m across. The water was very clear with excellent charophyte cover. The main emergent species was *Eleocharis sphacelata* with beds up to 100 m long and usually <10 m across. Locally the tallest reeds were *Schoenoplectus tabernaemontani* and raupo (*Typha orientalis*); and grey willow (*Salix cinerea*) ≤4 m tall was the tallest vegetation with the largest thicket at the eastern end c.30 × 10 m. The floating liverwort, *Ricciocarpos natans* (Fig. 3), was common around the lake edge.

As the lake level recedes in the summer-autumn narrow beaches are exposed on the southern margin where native herbs, especially *Limosella lineata* and *Glossostigma elatinoides*, occur (Fig. 4). No natural flax was present. Part of the lake margin had been fairly recently fenced-out and planted with native trees and shrubs, including flax. Two water pumps and a mai mai were present.

Lake Puketi (Topo50 BC31 487728 c.95 m asl, 5.9 ha) see fig. 1 in Aspin (2011).

The lake was a rounded-rhomboidal shape measuring about 400 × 200 m. A reasonable charophyte cover was present. There was a good emergent fringe of

vegetation, 15-30 m wide, right around the lake edge dominated by: raupo >2 m tall in the deeper water out of reach from the cattle; grey willow thickets were locally common to >3 m tall; tall sedges *Eleocharis sphacelata* and *Baumea articulata* were mainly in the deeper water; and around the cattle-grazed fringe *Isolepis prolifera*, *Persicaria decipiens*, *Ludwigia palustris*, *Myriophyllum propinquum* and swards of Mercer grass dominated. The interesting small native herbs were restricted to local beaches and a stranded log (see Aspin 2011: fig. 2). A lone healthy Norfolk Is. pine (*Araucaria heterophylla*) c. 18 m tall near the lake edge in 2006 was nearly dead five years later – presumably from high water levels during the 2010-11 summer. Two mai mai were present amongst the raupo.



Fig. 3. The Nationally Endangered floating liverwort, *Ricciocarpos natans*, pictured here stranded by naturally lowering lake levels on Lake Whatihua. Photo: 14 Mar 2006.



Fig. 4. The lower lake level in the summer-autumn at Lake Whatihua exposes narrow beaches where native herbs, especially *Limosella lineata* and *Glossostigma elatinoides*, grow rapidly to flower and set seed before the water level rises in the winter. This habitat is reduced by aggressive grasses on the landward margin such as Mercer and kikuyu grass. Photo: 14 Mar 2006.



Fig. 5. Lake Rotoiti viewed from SE. Much of the lake-margin vegetation is quaking sudd. Photo: 14 Mar 2006. Compare with fig. 5 of Aspin (2011) where fence is shown at a higher water level.

Lake Rotoiti (Topo50 BC31 485730 c.95 m asl, 0.8 ha) Fig. 5.

The shape was roughly triangular with pinched-in sides, measuring c.90 m along the sides. There was a narrow tongue extending from the south-west corner nearly joining the unnamed lake when water levels were at their maximum (winter-spring). Rotoiti had quite a raft of floating sudd vegetation around much of the margins (e.g. see Aspin 2001: fig. 6) making up much of fringe vegetation measuring 5-25 m across.



Fig. 6. The small unnamed lake near Lake Rotoiti viewed from east. Note the tall-browsed raupo in the foreground (the shallow end), extending around the right-hand side. Photo: 14 Mar 2006.

Out of reach of the grazing cattle was abundant raupo along with swamp millet (*Isachne globosa*) with beds of *Baumea articulata* and more locally *Eleocharis sphacelata*, *Epilobium pallidiflorum* and *Hydrocotyle pterocarpa*. The grazed zone was dominated by *Eleocharis acuta*, *Persicaria decipiens*, *Myriophyllum propinquum*, *Galium palustre*, *Ludwigia palustris* and Mercer grass. Grey willow was local (c.2 m tall) and flax was absent. The shallow tongue was locally dominated by *Persicaria decipiens* (with a showy display of pink flowers in March 2011) and *Ludwigia*

palustris was closer to the edge. One mai mai was present.

Unnamed lake (Topo50 BC31 483728 c.95 m asl, c.0.4 ha) Fig. 6.

The smallest lake that we surveyed, with a long axis of c.95 m. Nearly half of the lake was dominated by tall raupo 3-4 m tall at the shallower eastern end. Tall-stemmed tussocks of both *Carex secta* (Fig. 7) and *C. virgata* were present amongst the raupo. At the deeper western end where there is open water was a large population of submerged *Potamogeton ochreatus*, and during the March 2011 visit (see Aspin 2011) we added the floating species of: *Ricciocarpos natans* (liverwort), the tiny water-meal (*Wolffia australiana*) and the exotic *Landoltia punctata*. A mai mai was present amongst the raupo.



Fig. 7. A fine-trunked specimen of *Carex secta* amongst raupo, at the shallower east side of unnamed lake. Scale: Tricia Aspin. Photo: 14 Mar 2006.

Lake Otamatearoa (Topo50 BC31 495711 c.70 m asl, 6.3 ha) Fig. 8.

This was the largest dune lake in the southern Awhitu Ecological District; it was roundish-rectangular in outline with the longest length c.320 m. It was surrounded by low-lying grazed pasture (it used to be a horse-racing track) with a ring of emergent wetland vegetation around the lake margin, mainly 15-60 m across, dominated by native sedges. The only woody vegetation first noted was a few small trees of grey willow mostly 2 m tall, but in the south-west corner they reached 6 m tall. The landowner, Geoff Muir, cut

down these willows when lake levels were low in the summer 2007-08, buried the cut vegetation and treated the stumps with *Tordon brushkiller* – the few new sprouts have been treated and it looks like willow may soon be eradicated from this lake.

Tall native sedges, *Eleocharis sphacelata* (Fig. 8) and *Baumea articulata*, dominated much of the lake fringe and raupo was locally common. Closer to the land edge the smaller *Eleocharis acuta* dominated. A total of 69 vascular plants were recorded, 58% being native species (Table 1). Although 42% were exotic species the vegetation was dominated by the indigenous species. Eight National and Regional threatened and uncommon native vascular plants were recorded for this lake (see Table 2, Appendix 1).



Fig. 8. Lake Otamatearoa looking ESE, with emergent stems of *Eleocharis sphacelata* in the foreground. Photo: 10 Apr 2006.



Fig. 9. Lake Kokahuake (Parkinsons) looking SE – with Tricia standing on a quaking sudd of Mercer grass and *Eleocharis sphacelata*. Mercer grass has smothered much of the native marginal vegetation in this cattle-excluded area. Photo: 10 Apr 2006.

Lake Kokahuake (Parkinsons Lake) (Topo50 BC31 493689 c.110 m asl, 1.9 ha) Fig. 9, 10.

The open water was a crescent-shaped lake, measuring c.160m on the longest length. There were also two in-filled arms. The south-west arm (c.120 ×

45 m) was quaking sudd vegetation with only small areas of open water; it was dominated by Mercer grass (*Paspalum distichum*) and *Eleocharis sphacelata* (Fig. 9). This arm is also shown as in-filled in 1864 (Reay & Clayton 1864). The south-east arm (c.45 × 20 m) was in-filled with the same two dominant species. However, it is shown as mainly open water in 1864 (Reay & Clayton 1864). The northern lake boundary (c.150 m long) is cattle-browsed with no emergent vegetation. The partial exclusion of cattle before 1995 around the much larger southern part of the lake has led to the development of a thick sward of Mercer grass and in places sudd vegetation. Along



Fig. 10. Lake Kokahuake (Parkinsons) 60 years ago from the N side looking back towards pump sheds by road. Water levels were higher in those days – present winter levels are about the same as this 1951 summer level. Note – PAA in the middle between her boy cousins. Photo: 1951, Aspin collection.



Fig. 11. Lake Rotopopo (Black Lake) looking WNW. This lake lacked emergent wetland vegetation around its margin. Photo: 10 Apr 2006.

the open lake margin where the cattle are excluded were abundant reed beds of *Eleocharis sphacelata* with *Persicaria decipiens* and *Ludwigia palustris*; *Baumea articulata* was local and raupo was limited to a single stand (c.20 × 20 m²) in the south-west arm. The exotic floating fern, *Azolla pinnata*, was abundant around the lake margin. Locally native trees and

shrubs have been planted in the fenced-off areas, especially cabbage trees (*Cordyline australis*) and flax.

Lake Rotopopo (Black Lake) (Topo50 BC31 493674 c.90 m asl, c.1.6ha) Fig. 11.

This lake was long and narrow reaching c.130 m by 45 m across. It is exposed to strong winds coming up the valley straight off the Tasman Sea. It lacked a fringe of emergent native wetland species, with a totally grazed margin. Kikuyu grass (*Pennisetum clandestinum*) was abundant on the southern side. We saw no charophytes.

Pongahurahura Lake (Topo50 BC31 498676 c.110 m asl, c.2.2 ha) Fig. 12.

It is longer than wide and has a maximum length of 120 m and lacks a fringe of emergent native wetland species. Sand drift has in-filled the lake to give it a maximum depth of 3 m, and at times it completely dries up (Chum Thomson pers. comm., and PAA pers. ob.). The vegetation was dominated by emergent exotic species like *Ludwigia peploides* (Fig. 12), *L. palustris*, *Bidens frondosa*, along with the native *Myriophyllum propinquum*. The floating fern, *Azolla pinnata*, and the tiny water-meal were also present. The lake's shallowness and dominance of emergent weeds resulted in this lake having the least amount of open water of the eight lakes, and at the time of our visit it was eutrophic. The Maori name Pongahurahura evidently arises because it used to be surrounded by ponga (*Cyathea dealbata*) (Chum Thomson pers. comm. to PAA). Chum personally can't remember ponga present there (he is now in his 80s) but evidently ponga still comes up in the adjacent side gullies among gorse (*Ulex europeaus*).



Fig. 12. The shallow Pongahurahura Lake with little open water - the main cover in the foreground is the yellow-flowering *Ludwigia peploides* dominant over a 50 m × 50 m area, with *L. palustris*, *Myriophyllum propinquum*, *Bidens frondosa* and *Azolla pinnata*. Photo: 10 Apr 2006.

Vascular Flora

Unless otherwise stated all records are based on our own observations from visits made 2006 - March 2011. A full species list for each lake is presented in

Appendix 1, and summarised totals are presented in Table 1. The four largest vascular floras are also the ones with the highest native percentage (Table 1). Threatened species (Table 2) and aggressive weed species are discussed below.

Many of the small native herbs survive in precarious niches mainly on ephemeral surfaces such as narrow beaches exposed as the lake water recedes in the summer (Fig. 4), only to be inundated by the higher lake levels in the winter. They also can occur on unusual habitats like logs on the lake margin. Such logs probably float and roll around in the winter, then become stranded in the summer-autumn, providing new surfaces to grow on.

Weeds - submerged

The most invasive submerged aquatic weed in New Zealand, hornwort (*Ceratophyllum demersum*) (Edwards et al. 2005), was only seen at Lake Otamatea where evidently it appeared after 1996 (Edwards et al. 2009). Geoff Muir asked EW for advice in how to manage it, which has led to a test spraying of a herbicide (*Endothall* = *Aquathall*TM) over the lake, funded by NIWA and EW, to calculate the minimum amount of herbicide required for total control. The initial low dose had a 95% effect and a second treatment has been approved for funding by NIWA and Biosecurity NZ (Geoff Muir & Rohan Wells pers. comm. to PAA).

Two oxygen weed species are also present: *Egeria densa* (in 5/8 lakes) and *Elodea canadensis* (2/8). We recorded both species at Lake Whatihua. A fourth aquatic species that also has the potential to shade out the charophyte beds is the yellow-flowering exotic bladderwort (*Utricularia gibba*) which was first found in Lake Puketi in December 2009 and has increased quickly at the lake since then (Aspin 2011). Although *U. gibba* smothers it has not been found yet to displace the charophytes or other native aquatic plants (Rohan Wells pers. comm. to PAA).

Weeds - emergent

By far the most widespread, aggressive and mat-forming weed on the lake margins is Mercer grass (*Paspalum distichum*) (present in 7/8 lakes). Only grazing appears to control this sward-forming species. Other dominant emergent wetland weeds recorded included: *Azolla pinnata* (7/8), *Osmunda regalis* (1/8), *Apium nodiflorum* (4/8), *Callitriche stagnalis* (2/8), *Galium palustre* (5/8), *Ludwigia palustris* (7/8), *L. peploides* (1/8) (Fig. 12), *Lycopus europaeus* (2/8), *Nasturtium officinale* (4/8), *Nymphaea alba* (2/8), *Ranunculus flammula* (4/8), *Ranunculus repens* (5/8), grey willow (5/8), *Glyceria* spp. (3/8) and kikuyu grass (7/8). *Nymphaea alba* was intentionally planted at Otamatea in the 1950s and Kokahuake in the 1980s (PAA pers. ob.)

Table 1. Wild vascular flora totals for eight dune lakes for each plant group, percentage native and number of Nationally and Regionally threatened species.

Plant Group	Wha*	Puk	Iti	unn	Ota	Kok	Pop	Pon	Totals
Native ferns	5	3	4	-	5	1	-	-	6
Native dicots	15	20	12	3	14	8	3	3	31
Native monocots	19	17	15	7	21	13	2	1	27
<i>Native sub totals</i>	39	40	31	10	40	22	5	4	64
Naturalised ferns	2	1	1	1	1	1	-	1	2
Naturalised dicots	19	14	13	10	17	12	7	7	36
Naturalised monocots	10	14	10	7	11	11	10	3	22
<i>Naturalised sub totals</i>	31	29	24	18	29	24	17	11	60
Overall totals	70	69	55	28	69	46	22	15	124
<i>% native</i>	56	58	56	36	58	48	23	27	52
No. of threatened & uncommon species	6	6	5	2	8	5	-	-	15
Lake area (ha)	3.9 ²	5.9 ¹	0.8 ¹	0.4	6.3 ¹	1.9 ¹	1.6	2.2	
Max. lake depth (m)	11 ²	7 ¹	7 ¹	-	5 ¹	8 ¹	-	3	

*Wha = Whatihua, Puk = Puketi, Iti = Rotoiti, unn = unnamed, Ota = Otamateara, Kok = Kokahuake, Pop = Rotopopo, Pon = Pongahurua Lakes.

¹ = from Edwards et al. (2005)

² = from de Winton & Edwards (2009)

Table 2. Threatened and uncommon plants present in the Awhitu dune lakes.

Nationally threatened and uncommon native vascular plants and a liverwort (vascular rankings from de Lange et al. 2009, liverwort ranking from Glenney et al. 2011)

Nationally Endangered: *Amphibromus fluitans* (see below), *Utricularia australis*, *Ricciocarpos natans* (liverwort);

Nationally Declining: *Myriophyllum robustum* (see below);

Nationally Uncommon: *Myriophyllum votschii*, *Ranunculus macropus*;

Vagrant: *Gratiola pubescens*.

Regionally threatened and uncommon native vascular plants (rankings from Stanley et al. 2005)

Regionally Critical: *Galium trilobum*, *Gratiola sexdentata*;

Regionally Endangered: *Sparganium subglobosum*;

Sparse: *Baumea arthropphylla*, *Glossostigma elatinooides*, *Potamogeton ochreatus*;

Data Deficient: *Hydrocotyle pterocarpa*, *Isolepis distigmatosa*, *Ranunculus glabrifolius*, *Ruppia polycarpa*.

Notes:

Amphibromus fluitans – has not been recorded in any of the eight dune lakes surveyed by us. However, it was recorded by Carse (1901: p. 370) from a small pond, that is dry in the summer, at the roadside of the Karioitahi Road about 2 miles (3.2km) from Waiuku just before reaching the first of the sand hills. This is quite close to the two larger lakes of Whatihua and Rotoiti (which do not dry up). However, most of these southern Awhitu dune lakes are potentially still reasonable habitat for this cryptic aquatic grass, which we believe could still occur in the better quality lakes. The Carse literature record is supported by herbarium specimens: CHR 5924 & 333119, *H. Carse*, Dec 1900, Karioitahi, west coast, Manukau Co., on margin of small pond among sand dunes; WELT 68460, *H. Carse*, 25 Nov 1899, Karioitahi, near Waiuku, Manukau Harbour, in dry pond; WELT 68456, *D. Petrie*, Jan 1914, west of Waiuku, near sea coast (see Ogle 1987); and AK 1600, *H. Carse*, undated, nr Waiuku (T.F. Cheeseman Herbarium).

Galium trilobum – recorded only at Lake Otamateara, this locally rare plant has possibly only been collected three times in the Auckland region in the last 120 years.

Myriophyllum robustum (Fig. 13) – it appears that the first collection of this species at Lake Otamateara was by *Chris Tanner* on 27 May 1988 (WAIK 9316) which is the first Auckland region record for over 100 years. In 2006 it was locally common on the south-east side for nearly 100 m in sudd vegetation of *Baumea arthropphylla*, *Eleocharis sphacelata*, *E. acuta* and some raupo.

Ranunculus macropus – present in four of the lakes (Appendix 1) – there appears to have been few definite collections of this species in the Auckland region over the last 100 years, with only one outside of these southern Awhitu dune lakes.

Ricciocarpos natans (Fig. 3) – common in two of the lakes – no other recent records from the Auckland region. However, there was a collection from the “Helensville lakes” [Woodhill dune lakes] by F.M. Warren in the 1960s which was donated to AKU in the 1980s but appears to be lost (EKC pers. ob.).

Utricularia australis – recorded only at Lake Otamateara, this species appears to be currently limited to only three sites in the Auckland region.

These dune lakes also appear to be the Auckland stronghold of other regionally threatened species, e.g. *Sparganium subglobosum* (Fig. 14), *Baumea arthropphylla*, *Hydrocotyle pterocarpa* and *Isolepis distigmatosa*.



Fig. 13. The Nationally Declining *Myriophyllum robustum* growing among floating-type vegetation of *Baumea arthropylla*, *Eleocharis acuta*, *E. sphacelata* and some raupo at Lake Otamatearoa – the only known current occurrence of this plant in the Auckland Region. Photo: 10 Apr 2006.

Conservation rankings by the flora

Above the lake surface

Based on the number of threatened and uncommon plant species present, and the percentage of the native component of the vascular flora, the lakes can be ranked in terms of relative native plant conservation value. Lake Otamatearoa came out on top (Table 3).

Below the lake surface from NIWA (Edwards et al. 2005, 2009; de Winton & Edwards 2009)

This is limited to the five Awhitu dune lakes surveyed by NIWA who used submerged aquatic plants as indicators of lake condition and ranked all five at the lower end of their "Satisfactory" (the middle category of: "excellent", "satisfactory" and "unsatisfactory"). Lake Whatihua scored highest on all three characters and Otamatearoa scored last on its LakeSPI index mainly because of the presence of hornwort; however, on its 2009 Native Index it did rank third (see Table 4).

Table 3. Relative conservation ranking of the eight lakes based on threatened (mainly emergent) species and percentage of native vascular plants.

Lake	Threatened species (from Table 2)	% native vascular species (from Table 1)	Relative conservation ranking
Otamatearoa	8	58	1 st
Puketi	6	58	2 nd
Rotoiti	6	56	3 rd =
Whatihua	6	56	3 rd =
Kokahuake	5	48	5 th
unnamed	2	36	6 th
Rotopopo	0	27	7 th
Pongahurahura	0	23	8 th

Table 4. Submerged vegetation indices (2004) from NIWA (Edwards et al. 2005), plus an updated ranking for Otamatearoa (Edwards et al. 2009), and a 2005 ranking for Whatihua (de Winton & Edwards 2009).

Lake	Native Index (%) ¹	Invasive Index (%) ²	LakeSPI index (%) ³
Whatihua	43	81	33
Kokahuake	35	82	28
Rotoiti	25	84	23
Puketi	18	85	21
Otamatearoa	43, 29	90, 96	23, 18

¹ = Native Index captures the native character of the submerged vegetation – a higher score means healthier, deeper, diverse beds;

² = Invasive Index captures the invasive submerged weed character – a higher score means a higher impact from weeds;

³ = LakeSPI index is a synthesis of both the native and invasive condition of the submerged aquatic vegetation – the higher the score the better the condition.

Fauna (observed in passing – not searched for)

Birds

Birds we observed on all the larger lakes included: black swan (≤30 birds), Paradise shelduck (≤20 birds), pukeko, mallard/grey duck (≤30 birds), welcome swallow; and occasional harrier, little and black shag. Dabchicks were seen in Lakes Puketi (with chicks), Kokahuake and Whatihua; a bittern at Lake Kokahuake; white-faced heron at Whatihua; spur-wing plover (≤5) at Whatihua and Rotopopo; kingfishers at several lakes with nest holes in the banks on the north side of Lake Puketi; goldfinch at

Puketi; tui, Indian myna and magpie by Whatihua, and eastern rosella by Whatihua and Pongahurahura.

Fish

Grass carp were successfully introduced to Kokahuake as a bio-control for oxygen weed, *Egeria densa*, in 1976 and then the carp were removed in 1981. Unfortunately since 1996 *E. densa* has re-invaded (Edwards et al. 2005). We saw a large carp (grass/koi?) in this lake in 2006. We have seen: abundant mosquito fish and a galaxid sp. in Whatihua; eels and bullies in Otamatearoa; and schools of possibly rudd or juvenile trout (or both?) many with red-coloured fins in both Puketi and Rotoiti. A NIWA freshwater fish database

(<http://www.niwa.co.nz/our-services/databases/freshwater-fish-database>) records: common bully and abundant rudd in Rotoiti in 1978; abundant rudd in Puketi in 1978; and bullies, short-finned eels, rudd and rainbow trout in 1980. A Fish and Game report for August 2008 records that they released trout in: Whatihua – 200 rainbow and 20 brown yearlings; Otamatearoa – 200 rainbow and 20 brown yearlings (access for fishing to this lake is now denied by landowners); and Kokahuake – 50 rainbow and 10 brown yearlings. Unless the lakes are continually stocked with trout they will die out (Graham Surrey pers. comm.).

Frogs

The Australian golden bell frogs (*Litoria auria*) were seen at both Puketi and the unnamed lake.

Invertebrates

We observed the native freshwater mussel (*Hydriddella menziesi*) at Lakes Whatihua and Puketi. Dragonfly and damselfly species were common at most lakes.

Discussion

The long-term health of the dune lakes depends on two major factors:

Controlling invasive weeds

Invasive submerged weeds have the potential to displace the native submerged species and form monospecific weed beds (Edwards et al. 2005). Six of the eight surveyed lakes already contain four of these species: *Elodea canadensis* (in 2 lakes); *Egeria densa* (5), hornwort (1) and *Utricularia gibba* (1). Grass carp and the specific herbicides offer hope as management tools controlling/eradicating these weed species. The only two lakes that appeared to be free of these submerged aquatic weeds were: the small unnamed lake (with the threatened submerged native monocot – *Potamogeton ochreatus*); and Lake Pongahurahura which was shallow, eutrophic and weedy. To limit the dispersal of aquatic weed species it would be best to ban any form of boating that requires boats being transferred from lake to lake (already implemented for Lake Otamatearoa).

Cattle grazing helps to control some of the most aggressive emergent weed species around the margins of the wetland, especially the two sward-forming exotic grasses: Mercer and kikuyu grass. Such grazing allows the smaller native lakeside vegetation from being overwhelmed by these grasses. Controlled grazing (not too intense) appears better for the health of the emergent wetland vegetation than fencing the stock out, preferably with a separate water trough available to the stock to discourage them from trying to drink from the lake itself. Some other form of management would also be required to protect the palatable native species, e.g. *Sparganium subglobosum*. The presence of wild flax at only 2/8 lakes is most likely a result of over-grazing by cattle.



Fig. 14. The Regionally Endangered *Sparganium subglobosum* amongst *Baumea* and *Eleocharis* species at Lake Otamatearoa – a stronghold for the species within the Auckland Ecological Region. Upper 'balls' are of male flowers, lower balls of young fruit. Photo: 14 Mar 2006.

Interestingly the ranking order of the five lakes in common that are ranked for conservation values on their emergent (Table 3) and submergent (Table 4) floras are reversed by the two different ranking systems. It would be ideal to improve both the emergent and submergent flora rankings.

Retaining the water quality

The water quality started to decline when the lake catchments were converted to agriculture. This has often been in association with drainage (e.g. Lake Pupuke), reduction of lake-margin emergent vegetation by over-grazing (totally lost for Rotopopo, Pongahurahura), fertiliser runoff, nutrient enrichment and siltation from farming activities (Edwards et al. 2005, pers. ob.).

Overseas researchers have suggested that bands of tall, emergent plants around the margins of small lakes, as is present around many of the eight surveyed lakes, is effective in reducing algal blooms, because the emergent plant tissues decompose more slowly and retain nutrients more strongly than other plants (Anon. 2006). This is a good reason to maintain the marginal vegetation not only for its own botanical importance, but to maintain good water quality of the lake itself. The ultimate restoration

would be to establish native wetland forest around the lake margins and this would also assist to shade out the exotic grass swards and therefore possibly eliminate the need for light grazing.

Exotic pest fish appear to have been widely released in these lakes. They uproot plants, stir up bottom sediments and must heavily impact on the native aquatic invertebrate fauna. It would be good to remove all exotic fish.

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Geoff and Terri Muir for access to Lakes Otamateara, Puketi, Rotoiti and the adjacent unnamed lake; Alastair and Jennifer Thomson for access to Whatihua; Alan and Mary Thomson for access to Rotopopo and Pongahurahura; John Braggins and Jessica Beever for bryophyte identifications; Paul Champion for comments on the draft article; Paul Champion and Peter de Lange for assistance with some identifications and plant records; Rohan Wells for information on the hornwort eradication at Lake Otamateara and comments on *Utricularia gibba*; Graham Surrey for fish information; and Toni Cornes (WAIK) and Ines Schönberger (CHR) for specific herbarium label data.

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Conclusions

Six of the eight lakes (excl. Lakes Rotopopo and Pongahurahura) although highly modified still have very high botanical conservation values and we are fortunate that most of the southern Awhitu lakes are managed by conservation-sympathetic farmers. These lakes are so important in conservation terms that the various territorial authorities need to do more to control the aggressive exotic biota (flora and fauna) that has so far established before these lakes are reduced to exotic monocultures.

Appendix 1. Flora of eight southern Awhitu dune lakes and supporting herbarium vouchers.

Symbols

a = abundant, c = common, o = occasional, l = local, lc = locally common, s = scarce X = present

* = naturalised species

[] = adjacent to the wetland (< 10 m distant) – omitted from all totals

AK = Auckland Museum herbarium voucher number

Ed'09 = from Edwards et al. 2009 (species not seen by us)

PA = used to occur here c.1995 (PAA pers. ob.)

PA¹ = used to occur here c.1960 (PAA pers. ob.)

PdL = a collection by Peter de Lange in Jan 1999 (species not seen since)

PI = only planted?

WE'09 = from de Winton & Edwards 2009 (species not seen by us)

Species	Wha	Puk	Iti	unn	Ota	Kok	Pop	Pon	AK voucher
Ferns (6 + 2)									
<i>Azolla pinnata</i> *	l	lc	lc	o	l	a		a	232949
<i>Blechnum novae-zelandiae</i>	lc	o	l		X	X			295471
<i>Dicksonia squarrosa</i>	X	o	l		X				
[<i>Doodia australis</i>]	[!]								
<i>Histiopteris incisa</i>	X	s	s		X				
<i>Hypolepis ambigua</i>	l		s						295572
<i>Microsorium pustulatum</i>					X				

<i>Osmunda regalis*</i>	s								295309
<i>Paesia scaberula</i>	X					X			

Conifers (0 + 0)

[*Pinus radiata**] [s]

Dicots (28 + 36)

<i>Alternanthera nahui</i>								I	301751
<i>Apium nodiflorum*</i>	X			o	X		X		
<i>Bidens frondosa*</i>	lc	lc	X	X	X	X		X	323067
<i>Callitriche stagnalis*</i>				lc				PA ¹	
<i>Calystegia sepium</i> ssp. <i>roseata</i> × <i>C. silvatica*</i>						lc			301710
<i>Centella uniflora</i>	X	X	X		X				
<i>Centipeda cunninghamii</i>							I		301744
<i>Ceratophyllum demersum*</i>						lc			295580
[<i>Cirsium arvense*</i>]	[I]								
[<i>Cirsium vulgare*</i>]	[O]								
<i>Conyza sumatrensis*</i>	X	I	X	X	X				
<i>Coprosma propinqua</i> × <i>C. robusta</i>		X							
[<i>Corynocarpus laevigatus</i>]						[s]			
<i>Cotula coronopifolia</i>	X			o		X		lc	
<i>Crepis capillaris*</i>			o					X	
<i>Epilobium ciliatum*</i>			X						
<i>Epilobium pallidiflorum</i>	X	X	lc		X				295556
<i>Euchiton collinus</i>		o							
<i>Euchiton involucratum</i>					o				301677
<i>Galium palustre*</i>	lc	o	lc	o	X				
<i>Galium trilobum</i>					I				298013
<i>Glossostigma ? diandrum</i> (<i>G. submersum</i> of NIWA)	WE'09	Ed'09							
<i>Glossostigma elatinoides</i>	lc	lc	I			lc			294952
<i>Gratiola pubescens</i>						PdL			247105
<i>Gratiola sexdentata</i>		I	I			lc			301621-22
[<i>Hebe stricta</i>]		[s]							
<i>Hydrocotyle pterocarpa</i>	lc	lc	lc		lc				295468
<i>Hypochaeris radicata*</i>	X		X		X	X			
<i>Leontodon taraxacoides*</i>					X				
<i>Leptospermum scoparium</i>		X							
<i>Lilaeopsis novae-zelandiae</i> (incl. <i>L. ruthiana</i>)	lc	I	I						295571
<i>Limosella lineata</i>	lc	lc							295562
<i>Lobelia anceps</i>	o	I			X				
<i>Lotus pedunculatus*</i>	X		lc		X				
<i>Ludwigia palustris*</i>	lc	a	a	lc	X	X		lc	
<i>Ludwigia peploides*</i>								a	301752
<i>Lupinus arboreus*</i>							X		
[<i>Lycium ferocissimum*</i>]						[I]			
<i>Lycopus europaeus*</i>					o	lc			295500
<i>Lythrum hyssopifolia*</i>				o		X			
[<i>Melicytus ramiflorus</i>]		[s]							
<i>Mentha pulegium*</i>		lc							
<i>Muehlenbeckia complexa</i>	X	X	X		lc		X		
<i>Myosotis laxa*</i>	X	lc	o		lc				298014
<i>Myriophyllum pedunculatum</i>		Ed'09							
<i>Myriophyllum propinquum</i>	la	a	c	X	X	a		lc	
<i>Myriophyllum robustum</i>					lc				298008
<i>Myriophyllum triphyllum</i>	WE'09	o			lc	Ed'09			295596
<i>Myriophyllum votschii</i>		I							294951
<i>Nasturtium officinale*</i>	lc	I			X		X		
<i>Nymphaea alba*</i>					lc	I			295447
[<i>Olearia furfuracea</i>]		[s]							
<i>Parentucellia viscosa*</i>			X						
<i>Persicaria decipiens</i>	lc	a	la	lc	X		X	X	

<i>Persicaria hydropiper</i> *	lc	lc	o						323065
<i>Persicaria maculosa</i> *	l	s				lc		X	301746
<i>Persicaria punctata</i> *	o							l	301757
<i>Plantago australis</i> *	X							X	
<i>Prunella vulgaris</i> *	o				X				
<i>Pseudognaphalium luteoalbum</i>		s	l			s			295481
<i>Ranunculus amphitrichus</i>						lc			298012
<i>Ranunculus flammula</i> *	X	o				o	o		301675
<i>Ranunculus glabrifolius</i>				Ed'09					
<i>Ranunculus macropus</i>	lc	l	l			la			294972
<i>Ranunculus repens</i> *	lc	lc				X	X	X	
<i>Ranunculus scleratus</i> *					lc				o
<i>Rumex conglomeratus</i> *	X		o	o				X	
<i>Sagina procumbens</i> *		l					l		
<i>Salix cinerea</i> *	l	lc	l	l	X				
<i>Salix fragilis</i> *	X								
<i>Senecio minimus</i>	s								
[<i>Solanum chenopodioides</i> *]				[l]			[l]		301742
[<i>Solanum mauritianum</i> *]	[l]								
<i>Sonchus oleraceus</i> *							X		
<i>Utricularia australis</i>						o			306743
<i>Utricularia gibba</i> *		lc							310183
[<i>Xanthium spinosum</i> *]	[s]								

Monocots (27 + 22)

<i>Agrostis stolonifera</i> *		o	X		lc	X			298010
<i>Baumea arthropphylla</i>					la				295499
<i>Baumea articulata</i>	l	lc	lc		a	l			
<i>Carex maorica</i>	o				lc				295477
<i>Carex secta</i>	X	o	o	o	X				
<i>Carex virgata</i>	X	o	X	o	X	o			
<i>Cordyline australis</i>	s	s				s			
<i>Cortaderia ?seloana</i> *			s						
<i>Cyperus brevifolius</i> *		X	lc					X	
<i>Cyperus congestis</i> *		o			lc			X	298009
<i>Cyperus eragrostis</i> *	l		X						
<i>Cyperus ustulatus</i>		X	X		X	l			
<i>Digitaria sanguinalis</i> *									X
<i>Egeria densa</i> *	X	c	a			la	c		295561
<i>Eleocharis acuta</i>	lc	c	a		a	Ed'09			301620
<i>Eleocharis sphacelata</i>	a	c	X	X	a	a			
<i>Elodea canadensis</i> *	X				Ed'09				295559
<i>Glyceria declinata</i> *							l		301747
<i>Glyceria fluitans</i> *		o			X				295501
<i>Holcus lanatus</i> *		o				X			
<i>Isachne globosa</i>	la	la	X		X	lc			
<i>Isolepis distigmata</i>					lc				295498
<i>Isolepis prolifera</i>	X	lc	X		lc				295569
<i>Isolepis reticularis</i>	l				X	l			295575
<i>Isolepis sepulcralis</i> *	X	X		o	X	X	lc		301749
<i>Juncus articulatus</i> *	X	o	o	X	lc		X		298011
<i>Juncus bufonius</i> *				o		l	la	X	301745
<i>Juncus effusus</i> *	X	X	X		X	X			
<i>Juncus microcephalus</i> *						l			301743
<i>Juncus planifolius</i>			X						
<i>Juncus prismatocarpus</i> *		s							295496
<i>Lachnagrostis filiformis</i>	X	lc	lc		l				301666
<i>Landoltia punctata</i> *	lc	X	X	c	X	X		X	295557
<i>Lemna minor</i>		Ed'09	Ed'09		X	Ed'09			
<i>Ottelia ovalifolia</i> *	WE'09	l		l		l			301741
<i>Paspalum distichum</i> *	a	a	a	a	X	a	a		301706

<i>Pennisetum clandestinum*</i>	c	a	a	a	a	c	la	
<i>Phormium tenax</i>	Pl	o			X			
<i>Poa anceps</i>							X	
<i>Potamogeton cheesemanii</i>	lc	lc	lc		X	X	lc`	295462
<i>Potamogeton crispus*</i>					Ed'09		la	301715
<i>Potamogeton ochreatus</i>	WE'09			c		l		295585
<i>Ruppia polycarpa</i>	lc							295565
<i>Schoenoplectus tabernaemontani</i>	X			X	l			
<i>Schoenus maschalinus</i>	lc	X	X		X			
<i>Sparganium subglobosum</i>		l	s		lc	PA		301673
<i>Triglochin striata</i>	l	X			X			295470
<i>Typha orientalis</i>	o-lc	a	a	a	a	l		323069
<i>Wolffia australiana</i>				c			X	323072

Bryophytes

<i>Bryum billardierei</i> var. <i>platyloma</i>	l							302130
<i>Bryum clavatum</i>	l							302126
<i>Chiloscyphus ? novae-zelandiae</i>	l							302009
<i>Chiloscyphus semiteres</i>	l				l			295307
? <i>Leptodictyum riparium</i>	l				la			294970
<i>Marchantia macropora</i>		l						323161
<i>Marchantia pileata</i>	l							302008
<i>Rhaphidorrhynchium amoenum</i>	l							302131
<i>Riccardia</i> sp.			lc					323162
<i>Ricciocarpos natans</i>	lc			lc				295308

Algae (Charophytes)

<i>Chara australis</i>		Ed'09			Ed'09	X		301750
<i>Chara fibrosa</i>	WE'09	c			Ed'09	X		295602
<i>Chara globularis</i>	a				l	X		295600-01
<i>Nitella</i> aff. <i>cristata</i>	WE'09	Ed'09			Ed'09	Ed'09		
<i>Nitella hyalina</i>	c				X			295599
<i>Nitella pseudoflabellata</i>		l	Ed'09		Ed'09			301839

Survey visits by EKC & PAA

11 Jan 2006 (PAA)		X	X	X	X			
14 Mar 2006 (EKC & PAA)	X	X	X	X	X			
10 Apr 2006 (EKC & PAA)					X	X	X	X
22 Jan 2008 (PAA & Steve Benham)		X	X	X	X	X		
8 Mar 2008 (EKC & PAA)	X							
27 Oct 2009 (PAA)					X			
10 Dec 2009 (PAA)		X	X	X				
19 Mar 2011 (EKC & PAA)		X	X	X				