Monitoring changes in shoreline vegetation communities at Waituna Lagoon, Southland

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Contents

1.0 Executive summary

Waituna Lagoon is a shallow coastal lake in Southland which is rich in biodiversity, recreational and cultural values. This naturally dynamic lagoon has been subjected to artificial openings as well as increased sediment load and nutrient delivery since the advent of European farming in the catchment. These changes have impacted upon its condition and ecological values.

This project attempted to remeasure nine transects established by Peter Johnson in 1995 in order to determine any changes in zonation patterns of shoreline communities at Waituna Lagoon. Unfortunately, due to limitations in the data available for the 1995 measurements few comparisons are possible. However, it does appear that several species at the lagoon have extended their elevation range down slope, which is consistent with effects that can be expected by the increased regularity at which the lagoon is opened artificially.

The data collected in 2012-13 provide a valuable benchmark for repeated monitoring in future. It is recommended that these transects are remeasured in 3-5 years to determine if any changes in vegetation can be confirmed.

If downward trend in species elevation range can be proven then lagoon levels should not be managed any lower than current levels. If the lagoon is continually lowered and simultaneously filled with sediment it could functionally disappear.

2.0 Introduction

Waituna Lagoon is a shallow coastal lake in Southland which is rich in biodiversity, recreational and cultural values (DOC 1998). The lagoon is a naturally dynamic environment which in pre-European times would have intermittently broken through the gravel bar which separates it from the sea. However, land use intensification and lower than natural water levels due to artificial opening of the lagoon are driving changes in water quality and are likely to be affecting shoreline vegetation communities. This report covers the results of monitoring carried out between May 2012 and April 2013 to remeasure transects established along these shoreline communities in an effort to detect changes in these communities.

2.1 Background

Waituna Lagoon (c. 1,350ha) is included within the Waituna Wetlands Scientific Reserve and is the focal point of the Awarua Wetlands wetland of international impotance recognised under the Ramsar Convention (1983). Waituna is one of the best examples of a shallow coastal lake in New Zealand (Kirk and Lauder, 2000). This type of lagoon is characterised by: naturally small sediment yields; natural openings to the sea are rare and brief; fresh-brackish waters influenced by salt spray; wind and seiches influence the variation in the water-covered low-lying areas, particularly downwind (*ibid.*). Waituna Lagoon had higher than current day average water levels and a wider range in water levels under pre-European conditions (Johnson and Partridge, 1998). Naturally the lagoon maintained a higher water level for longer periods until the lowest point of the gravel bar dividing it from the sea gave way, partially draining the lagoon (*ibid.*). Seawater would then enter the lagoon and it would enter an estuarine phase. In due course longshore drift from the west would deliver material and rebuild the bar and close the lagoon (*ibid.*).

Three nationally threatened species and one naturally uncommon species of plant occur on the shoreline of Waituna Lagoon. These species are: *Isolepis basilaris* (nationally endangered), *Deschampsia caespitosa* (declining), *Urtica linearifolia* (declining) and *Mimulus repens* (naturally uncommon) (de Lange, et al., 2009).

Since the early 1900s artificial opening of the lagoon to the sea has significantly lowered the water levels of the lagoon, effectively reducing its volume and diminishing the force of wind-driven processes within the lagoon (Johnson and Partridge, 1998). The intensification of land use in the relatively small (19,955 ha) Waituna catchment has increased the delivery of sediment and nutrients into this naturally low-nutrient and low-sediment yield lagoon (*ibid.*). Aerial photography analysis demonstrates that increased sediment delivery has already caused an increase in the density of oioi (*Apodasmia similis*) around the lagoon's shoreline since 1951 (Johnson and Partridge, 1998). One of the potential effects of increased sediment delivery into the lagoon is the raising of the lagoon bed at a faster rate than predicted rises in sea level caused by climate change (Clayton, 2011). This, coupled with decreased water levels due to the artificial opening regime could see vegetation advance downhill along the retreating shoreline and lead to the eventual disappearance of the lagoon (*ibid.*).

Changes in salinity, sediment load, increased nutrients and reduced water levels are likely to have affected the composition and abundance of shoreline vegetation. Some of these changes may have been developing since the artificial opening regime began, however recent intensification of land use and the practice of opening the lagoon at lower levels to encourage ‘flushing’ of nutrients and sediment are likely to have accelerated any changes in shoreline vegetation communities.

3.0 Objectives

The intention of this monitoring project was to remeasure nine transects established by Peter Johnson in 1995 in order to determine any changes in zonation patterns of shoreline communities at Waituna Lagoon. Unfortunately quantitative comparisons between data collected in 1995 and 2012 are not possible for several reasons and any differences detected between the two sets of data may not be due to any real change in vegetation. The primary reasons these two data sets cannot be compared are: the original data have been misplaced (Rance 2012, pers. comm.) and summary data in Johnson and Partridge (1998) are not sufficiently detailed; and there is lack of certainty whether the 1995 and 2012 transects are in the same location (Johnson returned in 2005 to mark transect locations but due to high lagoon conditions the markers were only able to be placed at approximate locations).

However, data collected during this study can provide a basis for future, repeatable measures of these shoreline communities. All transects have been carefully marked and GPS coordinates recorded to ensure future measurements can be made with confidence. Analysis of future measurements can provide indications of changes in species richness, changes in the elevation range of species and changes in percentage cover/volume of species occupancy and changes in vegetation height.

4.0 Methods

The methodology was developed following suggestions in Clayton (2011) and in consultation with Dr Hugh Robertson (Scientific Advisor – Freshwater (Wetlands)), Brian Rance (Technical Advisor - Ecology) and Polly Bulling (Acting Project Manager - Awarua Wetlands). Where practical, the method aimed to duplicate the methods used by Johnson and Partridge (1998) in order that the two data sets could be compared.

4.1 Transects

A total of fifteen transects were measured, including remeasuring eight original transects and the establishing seven new transects. The locations for the new transects were selected to gain an even geographic spread and to ensure that a representative range of plant communities and shoreline types were included. All transects began at the first terrestrial vegetation at the water’s edge[1] and continued perpendicular to the shoreline until reaching dryland communities (i.e. those which are not substantially influenced by changes in water level). Transect lengths varied according to how gradually the elevation changed and how soon dry communities were reached. Transects ranged in length from 22 – 292 m. Transects did not extend into the lagoon to include aquatic plants as per Johnson and Partridge (1998) because other monitoring projects are undertaken to these measure these communities.

The start and end of transects were permanently marked with a warratah and warratahs were also placed at 50 m intervals along the transect to assist in remeasuring the transects with 50 m tapes. Sometimes it was not appropriate to place warratahs at the exact start or end points of transects because they could become

[1] Due to most of the transects being measured when the lagoon was relatively high (≥1.25 m), in practice the transect start was usually determined by the presence of taller vegetation such as oioi.

navigational hazards to boaters or they would be in places frequented by the public. In these cases short wooden stakes were used or warratahs were set at different points along the transects and notes were made to ensure that transects can be re-established correctly in future. GPS coordinates were recorded for all transects start and end points as well as all subplots along the transects and internal warratah positions. All coordinates were recorded in New Zealand Transverse Mercator Projection using a Garmin 60CSx with typical accuracy of 3 m. The compass bearing for each transect were recorded. Any additional species found within two metres either side of the transect which did not occur in the subplots were noted, with particular effort being made to find any threatened or rare species.

The transition between different vegetation communities along each transect was also recorded. In many cases community boundaries were not discrete and ecotone ('mix') communities were recorded too.

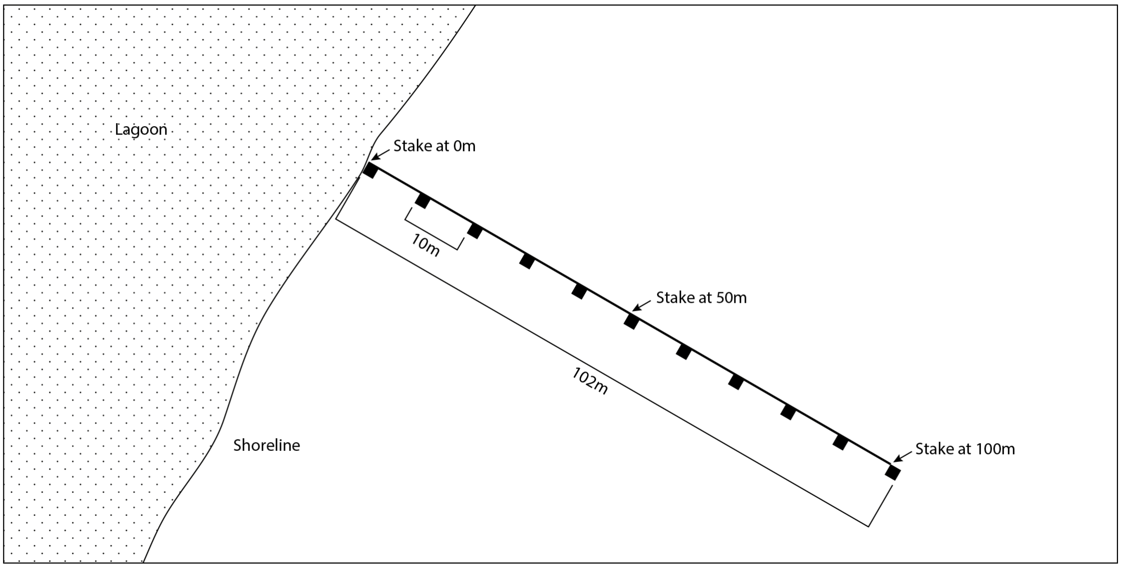

Figure 1: Example of transect layout

4.2 Subplots

Subplots measuring 2x2m were placed along the true right side of the transect allowing for movement along the true left of the transects without trampling vegetation within subplots. Subplots were established using four bamboo stakes and a 20m tape as illustrated in Photo 1 below.

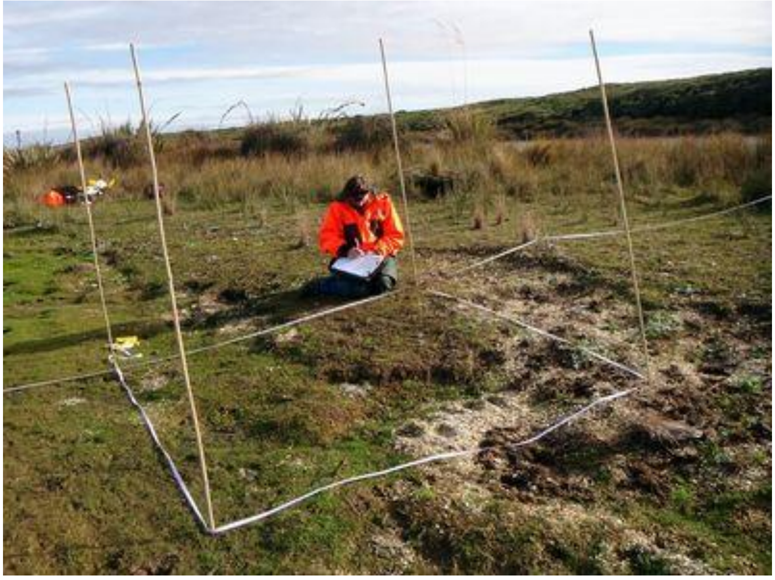

Photo 1: Subplot established on turf community along T3_2012 (Bythell, 2012)

The percentage of cover and the mean and tallest height for each species was recorded for all subplots (excluding flowering parts of plants). No height was recorded for species that are naturally shorter than 5 cm (e.g. *Selliera radicans*). Water depth was also measured at the centre of each subplot where necessary. Species were not recorded in separate strata as this proved too difficult in practise. Most plant communities consisted of one stratum, however in the manuka shrubland more than one stratum was present in a subplot and the percentage cover for many of these subplots totals more than 100%.

It would have been too time consuming to measure subplots along the entire length of each transect as per Johnson and Partridge (1998) so subplots were spaced at intervals along transects. The intervals between subplots were based on the length of the transect, see Table 1 below:

Table 1: Transect length and subplot intervals

Transect length	Subplot intervals	Number of transects
20 – 29 m	every 2 m (i.e. contiguous)	3
30 – 39 m	every 3 m	none
40 – 49 m	every 4 m	2
50 – 59 m	every 5 m	2
60 – 69 m	every 6 m	1
70 – 79 m	every 7 m	none
80 – 89 m	every 8 m	none
90 – 99 m	every 9 m	none
≥100 m	every 10 m	7

Additional subplots could be added if necessary to capture any plant communities occurring along a transect that were not already covered by the regularly spaced subplots. Additional subplots were added to capture turf communities in to two transects (T8_2012 and T12_2012).

Elevation measurements were taken for subplots using a tripod mounted surveyor's level (or 'dumpy level') and a graduated staff (see Photo 2 below). The datum for the elevation measurements for each transect was the mean water level on the gauge at Curran Creek on the day which the transect was measured.

Unfortunately, it was not always possible to measure elevation along the full length of all transects due to obscuring vegetation and therefore no elevation readings were taken for 72 of the 221 subplots. Typically elevation measurements were not possible for subplots at the upper end of transects, however vegetation was too tall along the entire length of T5_2012 for any elevation measurements to be taken.

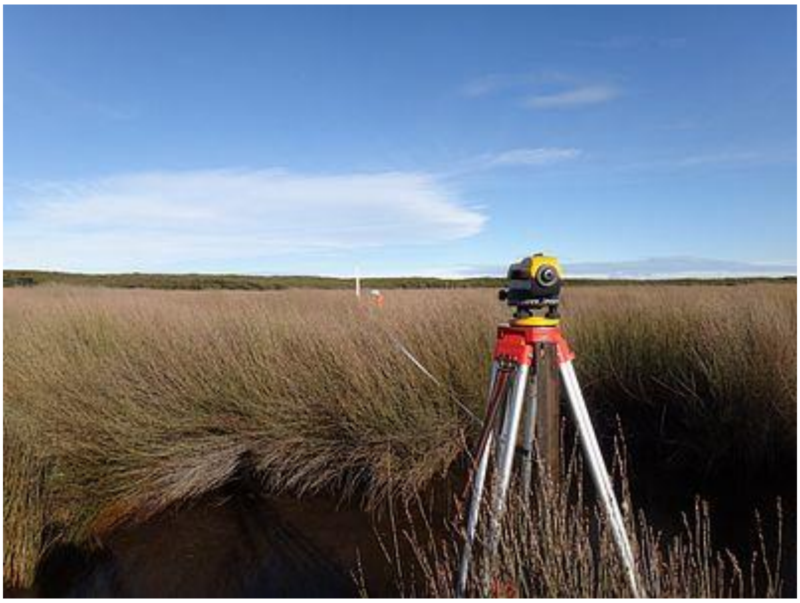

Photo 2: Using the builder's level to measure changes in elevation along T11_2012 (Bythell, 2012)

4.3 Soil samples

Soil samples were collected from within subplots at the start, centre and end of each transect. Core samples were taken using a piece of plastic pipe measuring 6.5x10cm, labelled and double bagged in zip lock bags and kept cool. Samples were sent to Landcare Research's Environmental Chemistry Laboratory in Palmerston North within one week of collection. Paired soil samples were taken at each site; one to measure bulk density and the other to analyse soil salinity, nutrient status, pH and organic content.

4.4 Photopoints

Photopoints were established at the start, centre and end of each transect. Four photos were taken at each photopoint: i) facing the lagoon, ii) at right angles with the lagoon to the left, (iii) facing along the transect, (iv) at right angles from transect line with the lagoon to the right. The bearing for each photo was recorded. All photos were taken with no zoom, at head height (approximately 165cm) using a Sony digital camera

i) facing the lagoon

ii) at right angles with lagoon on left

(iii) facing along the transect

(iv) at right angles with lagoon on right

Photos 3-6: Photos from the start of T9_2012 showing examples of photo point images (Bythell, 2012)

(Cybershot DSC-TX10 16.2 mega pixels). Unfortunately several photos are of mediocre quality due to the low position of the sun when most of this work was undertaken.

5.0 Results

5.1 Summary of transects

Fifteen shoreline transects were measured during this project (see Table 2 below for a summary of the transects).

Thirteen transects were measured (seven original and six new ones) over 15 days between 19 May and 15 July 2012. Limitations imposed by the weather, short daylight hours and tides reduced the available hours when fieldwork was possible and high lagoon levels have affected the measurement of the lower portions of some transects. T1_2012 and the lower portion of T12_2012 were measured after the lagoon was opened to the sea on 2 July.

Two additional transects were established in April 2013 to provide a dataset of fifteen transects, and the lower portions of transects T7_2012, T10_2012, T11_2012 and T13_2012 were remeasured because it was suspected that turf communities were likely to be present under the water when the initial measurements were made in winter 2012. Transect T11_2012 was burned by the November 2012 fire which spread from Awarua Bay. Some new shoots had developed from the burnt oioi stumps and a range of small native and exotic herbs were flourishing in the intervening space.

Table 2: Summary of transects (2012-2013)

Transect name	Length (m)	Number of subplots	Lowest elevation (cm)	Highest elevation (cm)	Community types[2]	Native species	Number of exotic species	Additional species in transect but not in subplots	At risk/ threatened species	Total species	Notes
T1_2012	42	11	107	176	WL10, WL10(m), NN2	4	4	RANgla	none	8	
T2_2012	26	13	137	271	WL10, DN5, F13	20	14	PTEesc, DRAlon	DESces	34	
T3_2012	26	13	115	171.5	WL15, NN1	21	20	None	ISObas	41	
T4_2012	142	15	122	245	WL10, WL10(m), NN1, NN2	20	13	CARdip, CARsec, PHOten, COPrig	none	31	
T5_2012	92	10	unable to measure		WL10, WL10-WL20, WL12, F19	13	2	PLAdiv, LEPjun	none	15	Only transect where WL12- manuka-tangle fern scrub occurs; very few weeds
T6_2012	102	11	88	500	WL10, NN1	18	11	AUSric, SELrad, SEDacr	URTlin	29	
T7_2012	112	12	75	>80	WL10, WL15, WL10-WL20, F13	23	11	MACten, CERfon, EMPmin, LEPjun, CHIrub	MIMrep	34	2 subplots remeasured in Mach 2013 and 5 extra native spp. and 6 extra exotic spp. found.

[2] See section 5.4 for descriptions of these community types based on Rogers and Singers (in press).

T8_2012	50	11	72	431	WL15, SA4, NN1, NN2	13	11	SAMrep, PLAdiv	MIMrep	24	The only transect with SA4 - shore bindweed, knobby clubrush gravelfield-stonefield community
T9_2012	22	10	125	>340	WL10, WL15, WL18(m), F19, F13	24	17	COPtay, HISinc, SCHaru	URTlin	41	The only transect containing WL18(m) - modified flaxland
T10_2012	292	30	106	>146	WL10, WL15, WL10-WL20, F13	43	19	CHEamb, MONfon, JUNpal, CHIrub, EPIcil	ISObas, MIMrep	62	3 subplots remeasured in Mach 2013 and 10 extra native spp and 7 extra exotic spp. found.
T11_2012	240	25	88	>118	WL10, WL15, F13	25	5	DESces	DESces, URTlin, ISObas	30	5 subplots remeasured in 2013 and 11 extra native spp. and 2 extra eoxtic species found. Entire transect burnt in 2011
T12_2012	274	29	122	290	WL10-WL20, WL10, F13, NN1	34	8	URTlin, COPrig, ELAgra, CARbre, CIRarv, SENvul	URTlin	42	Only transect where CARbre occcurred
T13_2012	40	10	124	>150	WL10, WL15, F13	29	19	RANgla, ELAgra	URTlin	48	2 subplots remeasured in Mach 2013 and 8 extra native spp. and 6 extra exotic spp. found.
T14_2013	52	11	56	>80	WL10, WL15, F13	21	8	PSElut, PHOten, PLAdiv	ISObas		
T15_2013	56	10	72	130	WL10, WL15, WL22, NN1	23	20	CARpro	ISObas, MIMrep	43	New record for Waituna, Spergularia bonnei found

Transects ranged in length from 22 - 292 m and yielded a total of 221 subplots. Subplots ranged in elevation from 56 - 500cm above the estimated bed of the lagoon.

5.2 Species summary

A total of 140 vascular plant species were recorded within the shoreline transects.

Table 3: Number of vascular species recorded in transects

	Native	Exotic	Total
Trees and shrubs	9	1	10
Herbs	38	30	68
Grasses, rushes, sedges	38	13	51
Other monocots	2	none	2
Lianes	2	none	2
Ferns	7	none	7
Total			140

The following eight species occurred within transects but not within subplots: toetoe (*Austroderia richardii*[3]), red tussock (*Chionochloa rubra* subps. *cuprea*), *Eleocharis gracile*, *Epilobium ciliatum*, tall fescue (*Schedonorus arundinaceus*), *Machaerina tenax*[4], *Montia fontana*, *Nertera scapanioides,* and stonecrop (*Sedum acre*).

5.3 At risk and threatened species

One Threatened and three At Risk plant species were recorded during the monitoring. At least one of the at risk or threatened plant species known from the area were recorded in thirteen of the fifteen transects. None of theses species were abundant and did not account for much of the cover of any of the subplots in which they occurred.

5.3.1 *Isolepis basilaris* (pygmy clubrush)

Isolepis basilaris (nationally critical) was initially only found in one subplot of T3_2012. However, remeasuring the drowned portions of transects T10_2012 and T11_2012 revealed more of this species and it was recorded in three additional subplots. This plant is very small and inconspicuous, preferring silty WL15 - Herbfield (Lakeshore turf) communities with an elevation range of 88 – 141 cm above the lagoon bed. Competition from taller exotic herbs is likely the most common threat to this species at Waituna Lagoon.

[3] Syn. *Cortaderia richardii*
[4] Syn. *Baumea tenax*

Photo 7: *Isolepis basilaris* in transect T10_2012 four months after the fire (Bythell, 2013)

5.3.2 *Deschampsia cespitosa* (tufted hair grass)

Deschampsia cespitosa (declining) was only recorded in two transects (five subplots within T2_2012 and outside of any subplots but within T11_2012). *Deschampsia cespitosa* was found in two community types, WL10 - Oioi restiad-rushland/reedland and DN5 - oioi, knobby clubrush sedgeland. Based on these occurrences, the elevation range for this species is 174 – 202 cm above the lagoon bed.

Johnson and Partridge note (1998) *Deschampsia caespitosa* as a common element in grassland communities on gravel bars. *Deschampsia caespitosa* is abundant in WL10(m) – modified oioi restiad-rushland/reedland on the western side of Moffat Creek, although few seedlings have been observed recruiting into the dense sward of *Agrostis stolonifera* which characterises this community. *Deschampsia cespitosa* observed in dense oioi rushland were typically small and appeared be struggling to compete with the much taller oioi. Competition with exotic grasses and taller species such as oioi appear to be the main threats to this species.

5.3.3 *Urtica linearifolia* (swamp nettle)

Urtica linearifolia (declining) occurred within six different subplots in five different transects (T6_2012, T9_2012, T10_2012, T13_2012 and T14_2013) and also in T12_2012 but not within a subplot. This species was found within the following communities: WL10 - Oioi restiad-rushland/reedland, WL10(m) – modified oioi restiad-rushland/reedland and WL15 - Herbfield (Lakeshore turf). Based on theses occurrences the elevation range for *Urtica linearifolia* is 120 – 149 cm above the lagoon bed.

Typically *Urtica linearifolia* grows from the silt trapped at the base of oioi clumps to scramble over oioi and adjacent vegetation such as *Plagianthus divaricatus*. In WL10(m) communities *Agrostis stolonifera* is likely to compete with young *Urtica linearifolia* plants.

5.3.4 *Mimulus repens* (native musk)

Mimulus repens (naturally uncommon) occurred in six subplots in four different transects (T7_2012, T8_2012, T10_2012 and T12_2012). This species is difficult to find when lagoon levels are high. Revisiting transects under lower water conditions proved important in determining whether *Mimulus repens* was present as four of the five observations for this species were made when lagoon levels were 75 cm (T12_2012 in July 2012 after the lagoon was opened to the sea, T7_2012 and T10_2012 when they were revisited in March 2012). Based on theses occurrences the elevation range for *Mimulus repens* is 75 - 122 cm above the lagoon bed.

Mimulus repens appeared to have been grazed by waterfowl when it was recorded in transect T12_2012 in July, making it very difficult to spot. This species appears widespread across the exposed lower portion of the shoreline which as sheltered with silty substrate and a relatively gentle slope (e.g. western ends of the lagoon) and was observed frequently en route to transects T11_2012 and T10_2012 while remeasuring their lower subplots in March 2012. *Mimulus repens* is also common on the lower shore of Little Waituna Lagoon. Because most transects were established when lagoon levels were high their starting points were usually determined by taller vegetation such as oioi. If these transects had been established under lower lagoon levels they are likely to have begun further down slope to include populations of short statured turf species such as *Mimulus repens*.

5.4 Vegetation community types

This report describes community types according to the Rogers and Singers (in press) ecosystem classification system. Where plant communities are substantially modified by exotic species (or in a few cases burnt by fire) they have been described as modified (m), e.g. WL10(m). This convention is helpful for discussing changes at Waituna Lagoon but is not part of the classification system developed by Rogers and Singers (in press). See Appendix 3 for a comparison of different names used by various authors for the community types found at Waituna.

Community types recorded within the shoreline transects fall into three broad categories: wetland communities, non-wetland communities and non-native communities. These community types are summarised in Table 4 below:

Table 4: Summary of different community types recorded in shoreline transects (2012-2013)

	Number of subplots	% of subplots	Elevation range (cm above estimated lagoon bed)	Native species	Exotic species	Total species	At risk/threatened species	Notes
Wetland community types								
WL10 - oioi restiad-rushland/reedland	106	48	70 – 190	43	25	68	DESces, URTlin, MIMrep	
WL10(m) - modified oioi restiad-rushland/reedland	18	8.1	80 – 160	14	9	23	URTlin	AGRsto suppresses small species which add to diversity
WL10-WL20 mix	7	3.2	130 - 190 (est.)	11	4	15	None	Oioi with some shrubs
WL10 - F13 mix	6	2.7	unable to measure	11	2	13	None	Oioi with some manuka
WL10-WL15 mix	3	1.5	100 - 130	20	20	40	URTlin, ISObas	
WL10(m)-WL15 mix (burnt)	2	2.7	90 - 100	11	4	15	ISObas	
WL12 - Manuka-tangle fern scrub/fernland	1	0.45	Not measured	8	none	8	None	
WL15 - Herbfield (Lakeshore turf)	14	6.3	50 - 130	26	18	44	ISObas, URTlin, MIMrep	
WL18(m) - modified flaxland	2	0.9	150 – 180	15	8	23	URTlin	
WL22 Carex Schoenus sedgeland	3	1.5	100 – 150	11	8	19	None	
DN5 - Oioi, knobby clubrush sedgeland	4	1.8	190 – 250	8	17	25	DESces	Higher elevation supports exotic spp.
Non-wetland community types								
SA4 - Shore bindweed, knobby clubrush gravelfield-stonefield	5	2.2	120 –390	5	3	8	None	Mostly gravel, supports few species
F13 - Manuka scrub	11	4.9	≥270	15	2	17	None	Too shady for weeds

	Number of subplots	% of subplots	Elevation range (cm above estimated lagoon bed)	Native species	Exotic species	Total species	At risk/threatened species	Notes
F19 - Bracken fernland	7	3.2	≥270	16	10	26	None	
Non-native community types								
NN1 - Exotic grassland	27	12.2	80 - 500	38	30	68	MIMrep	Weeds dominate % cover
NN2 - Exotic ruderal gravel beach community	5	2.2	130 - 210	6	16	22	None	
Total	221							

5.4.1 Wetland community types

There are five different community types at Waituna which can be classified as wetland communities within the Rogers and Singers (in press) ecosystem classification system.

- **WL10 - Oioi restiad-rushland/reedland**

  Oioi rushland was the most abundant community type recorded, representing in 142 of the 221 subplots. Of these, 106 subplots included an intact community of oioi rushland (WL10) while 18 subplots included modified oioi rushland (WL10(m)). Only two of the fifteen transects did not include instances of oioi rushland (T3_2012 and T8_2012).

  Oioi rushland ranges from 70 – 190 cm above the lagoon bed. Below 150 cm individual oioi plants grow in clumps, often with turf communities nested between them, but above 160 cm it forms dense swards in which very few other species occur. Other native species in this community include coastal ribbonwood (*Plagianthus divaricatus*) and sedges such as *Carex appressa*, *C. dipsacea*, *C. secta* and *C. virgata* occur in small amounts.

  Modified oioi rushland (WL10(m)) refers to subplots where the space between oioi clumps has been invaded by a dense sward of creeping bent (*Agrostis stolonifera*) with some native species intermingled, including *Eleocharis acuta*, *Galium propinquum*, *Myriophyllum propinquum* and silverweed (*Potentilla anserinoides*). The diversity of native species is much lower in the modified oioi rushland than it is in the intact version of this community, in large part due to the *Agrostis stolonifera* inhibiting the presence of small native turf species. The elevation range for this modified community is 80 – 160 cm above the lagoon bed. This modified community type occurs where oioi grows in clumps and represents <75% of the overall cover. The substrate for this community type is almost always silt. Some of the largest populations of *Deschampsia cespitosa* at Waituna Lagoon have been observed in this open oioi rushland, although not in any of the transects established for this project. It is likely the prevalence of creeping bent in the open oioi rushland areas will reduce recruitment opportunities for Deschampsia cespitosa.

  Sixteen subplots were composed of mixed communities where oioi rushland blended with another community type (i.e. WL10-WL15 mix, WL10-WL20 mix and WL10-F13 mix). The WL10-Wl20 - Coprosma Olearia scrub mix community occurred in 7 subplots across three different transects. It typically occurred at the upper limits of WL10 - Oioi restiad-rushland/reedland before the elevation became sufficiently high and dry for manuka scrub (F13) to become the dominant vegetation. The WL20 community always occurs as a mix with oioi rushland and typically contains mingimingi (*Coprosma propinqua*), *C. rigida* and a small amount of manuka. Tall vegetation prevented elevation readings from being made for most instances of this community. Very few exotic species were recorded in this community.

  These the WL10-WL15 mix and WL10-F13 mix communities are described below.

- **WL12 - Manuka-tangle fern scrub/fernland**

Only one subplot exhibited this community type, at the end of transect T5_2012. This community was part of a sequence preceded by oioi rushland-Coprosma Olearia scrub mix (WL10-WL20 mix) followed by bracken fernland which then ended at Waghorn Road. The elevation range for this community type could not be measured as vegetation was too dense along the length of the transect to facilitate the use of the builder's level. No exotic species were recorded within this community.

- **WL15 - Herbfield (Lakeshore turf)**

Lakeshore turf communities occurred in 19 different subplots across nine of the fifteen transects. This includes 14 subplots which are occupied entirely by turf communities (WL15), three subplots which are a mix of both turf communities and oioi rushland (WL10-WL15) and two subplots which are occupied by a mix of burnt oioi rushland turf communities (WL10(m)-WL15). The elevation range for turf communities is 50 – 160 (431) cm above the lagoon bed.

Turf communities occur on silty substrates at elevations ranging from 50 – 120 cm above the estimated bed of Waituna Lagoon often around the base of oioi pedestals. Typically these silty turf communities include: *Isolepis cernua*, *I. basilaris* (nationally critical), *Hydrocotyle hydrophila*, *Samolus repens*, *Lilaeopsis novae-zelandiae*, *Limosella lineata*, *Mimulus repens* and *Myriophyllum triphyllum*. *Urtica linearifolia* (declining) seedlings often occur at the base of oioi pedestals mixed oioi-turf communities. Exotic species found within these lower elevation creeping bent, toad rush (*Juncus bufonius*) and herbs such as *Cotula coronopifolia*,hairy plantain (*Plantago australis*),curled dock (*Rumex crispus*) and *Atriplex prostrata*. These exotic species and are capable of enduring drowning and exposure (e.g. creeping bent) or can rapidly colonise exposed ground when the water level is low (e.g. *Atriplex prostrata*).

Turf communities on gravel substrates occur at shore elevations ranging from 110 – 160cm[5]. Typically these gravelly turf communities include: *Chenopodium ambiguum*, *Selliera radicans, Pseudognaphalium luteoalbum, Samolus repens*, *Limosella lineata*, *Lilaeopsis novae-zelandiae*, *Crassula moschata*, *Leptinella dioica*, silverweed and very small amounts of *Myriophyllum triphyllum* in subplots partially covered in water at the time of measurement. Exotic species in gravelly turf communities include: creeping bent, annual poa (*Poa annua*), hawkbit (*Leontondon taraxacoides*), scarlet pimpernel (*Anagallis arvensis*), *Cotula coronopifolia*, smooth sow thistle (*Sonchus asper*), birdsfoot trefoil (*Lotus pedunculatus*), hairy plantain and Atriplex prostrata.

All the exotic species found within turf communities are taller than the turf species and threaten them by competing for light and space. Versatile species such as *Atriplex prostrata* may displace native turf species by rapidly colonising newly available habitat before native species can occupy this space.

[5] Subplot T8_2012_S11 occurred on the edge of a pond part way up the gravel bar which separates the lagoon from the sea, hence the relatively high elevation of 431cm above the estimated lagoon bed. This turf community was comprised almost entirely of *Leptinella dioica* and its proximity to the coast means it might rightly be classed as SA5 – Herbfield (coastal turf).

- **WL18(m) – Modified flaxland**

  This community type was only found in two subplots along a single transect and only a modified variant of it was observed. The elevation range for these two subplots is 150 – 180 cm above the lagoon bed.

  This community type would normally be dominated by flax but in these two subplots it appears that gorse had invaded the area and displaced the flax. Subsequent weed control work had removed the gorse leaving bare ground which has been colonised by creeping bent and gorse seedlings. This community type occurred within the elevation range 150 – 180 cm above the lagoon bed level. This flaxland community occurred between oioi rushland-lakeshore turf mix (WL10-WL15 mix) and bracken fernland (F19).

- **WL22 Carex Schoenus sedgeland**

  This community type occurred in three subplots along two different transects (T13_2012 and T15_2013). The elevation range for the sedgeland community is 100 – 150 cm above the lagoon bed.

  This community is usually dominated by cutty grass (*Carex coriacea*) and *C. gaudichaudiana*, with some *C. appressa*, *C. sinclairii* and *C. dissita*. Exotic species present in the sedgeland community include: creeping bent, cocksfoot (*Dactylis glomerata*) and small herbs such as birdfoot trefoil.

- **DN5 – Oioi, knobby clubrush sedgeland**

  This community occurred in three subplots across two different transects. The elevation range for this community type is 190 – 250 cm above the lagoon bed.

  Knobby clubrush (*Ficinia nodosa*) is typically the dominant species within this community, with some oioi, flax, cutty grass and small amounts of *Deschampsia cespitosa*. Exotic species present in this community type include: creeping bent, cocksfoot, Yorkshire fog (*Holcus lanatus*), Californian thistle (*Cirsium arvense*) and gorse.

5.4.2 Non-wetland community types

Three non-wetland native community types were recorded, all falling within the upper ends of the shoreline transects where they occurred. These communities include shore bindweed-knobby clubrush stonefield (SA4) and two seral communities, manuka scrub (F13) and bracken fernland (F19).

- **SA4 – Shore bindweed, knobby clubrush gravelfield-stonefield**

  This community type occurred in five subplots along a single transect (T8_2012) on the gravel bar which separates the lagoon from the sea. This community type is comprised of sparse vegetation cover over a quartz gravel substrate, with an elevation range of 120 –390 cm above the lagoon bed.

  Knobby clubrush and shore bindweed (*Calystegia soldanella*) are the dominant species with occasional *Muehlenbeckia axilaris* and *Haloragis erecta*. Exotic species in this community only make up a small amount of cover and include *tall fescue*, Californian thistle and curled dock. Pieces of driftwood were recorded as far up slope as 254 cm above the lagoon bed, indicating that wave action partly influences this community.

- **F13 - Manuka scrub**

This community occurred in nine different transects. There were eleven subplots containing an intact manuka scrub community as well six subplots containing a mix of manuka scrub and oioi rushland (WL10-F13 mix). Elevation measurements for this community were difficult to make because the height of the vegetation prevented us from using the builder's level. An estimated elevation range for intact manuka scrub is ≥ 270 cm above the lagoon bed, while a mix of manuka scrub and oioi rushland has an estimated elevation range of 80 – 150 cm above the lagoon bed.

The manuka scrub included both dense manuka and semi-open manuka communities. The dense manuka was younger and included very few other species, whereas the semi-open manuka was older and contained species such as mingimingi, prickly mingimingi (*Leptecophylla juniperina*), and ferns such as bracken and *Blechnum minus*, with occasional occurrences of inaka/turpentine shrub (*Dracophyllum longifolium*) and *Coprosma dumosa*. Gorse was the only common exotic species in this community, but was limited to open manuka scrub where there was sufficient light.

- **F19 bracken fernland**

This community occurred in seven subplots within three different transects. The elevation range for this community is ≥ 270 cm above the lagoon bed.

Bracken fernland is typically dominated by bracken with some manuka, flax and small amounts of prickly mingimingi and mingimingi. Few exotic species occur in this community, but there were some instances of gorse and exotic herbs and grasses such as creeping bent and birdfoot trefoil open areas with sufficient light.

5.4.3 Exotic plant communities

Two exotic plant communities were encountered while measuring the shoreline transects: NN1 – exotic grassland and NN2 – exotic ruderal beach community. The communities are not covered by the Rogers and Singers (in press) classification system which is concerned with native ecosystems.

- **NN1 – exotic grassland**

This community is widespread was found in 26 subplots from eight different transects. The elevation range for this community type is 70 – 500 cm above the lagoon bed.

This community may contain some native species and many instances of it likely represent native communities which are so modified by the presence of exotic grasses that is would now be difficult to confidently assign a native community type. Typically the low elevation exotic grassland (70 – 150 cm) is dominated by creeping bent with some jointed rush (*Juncus articulates*) present. Mid-elevation exotic grassland (150 – 300 cm) is dominated by creeping bent with other pasture species such as Yorkshire fog, tall fescus, sweet vernal (*Anthoxanthum odoratum*), *Poa pratensis*, cocksfoot and herbs such as hawkbit. On dunes (at elevations above 300 cm) creeping bent is replaced by marram grass (*Amophila arenaria*) as the dominant exotic grass species.

- **NN2 – exotic ruderal beach community**

  This community type occurred in five suplots along three different transects. The elevation range for this community is 130 – 210 cm above the lagoon bed. Species in this community type include twincress (*Lepidium didymium*), scarlet pimpernel, sheeps dock (*Rumex acetosella*), and *Atriplex prostrata*. These communities are quick to appear when conditions are favourable and their distribution at different elevations along the relatively bare shore can often indicate previous lagoon levels. Native species such as *Pseudognaphalium luteoalbum* occur in small amounts.

5.5 Vertical elevation range of species

Some comparison of the vertical elevation range of some species is possible using the list of 39 species with elevation ranges in Johnson and Partridge (1998) (see Appendix 4 for a full list of these species and their elevation ranges). The majority of these species (35 out of 39) appear to have extended their range down slope. However, nineteen are versatile species which can adapt quickly to take advantage of new habitat and their range extension may be recent (primarily herbs and short some monocotyledons). Nine of these versatile species are exotic and ten are native.

However, twelve of the species which have moved down slope are not short-lived species and this possible extension in their elevation range implies that reduced water levels in the lagoon have affected their distribution.

5.6 Soils

Thirty-seven soils samples were collected from thirteen transects (no samples were collected for the new transects established in 2013). Samples were taken from the start, centre and end of transects, although unfortunately due some samples being mislabelled there is no end sample for transect T1_2012 and due to water levels being too high at the time, there is no start sample for transect T9_2012.

Soil samples were taken from the three main substrates at Waituna: silt, gravel and peat. The elevation range for the soil samples is 70 – 500 cm above the lagoon level. Samples were collected from most community types, with the exception of WL12 - Manuka-tangle fern scrub/fernland. The majority of samples were collected within WL10 - oioi restiad-rushland/reedland.

Interpreting the results of the soil sample analysis is beyond the capability of this author. The full results have been submitted with this report and for other more qualified people to review.

5.7 Limitations of comparison between 1995 and 2012 measurements

There are limitations to comparing data collected in 1995 to those collected in 2012. Firstly, the original 1995 data have been misplaced and these data are only summarised in Johnson and Partridge's 1998 report. Secondly, because the 1995 transects were not intended to be remeasured they were not permanently marked at the time. Johnson returned in 2004 to record GPS coordinates and mark transects with aluminium stakes based on his notes and memory of the sites. However, due to high lagoon levels at that time not all transects were marked and none were marked at their start to indicate where the shoreline had been in 1995 when the transects were measured. Table 5 below summarises the difficulties associated with relocating and re-measuring the original transects:

Table 5: Summary of the re-establishment of Johnson's transects

Transect name in Johson and Partridge (1998)	**Transect established and renamed in 2012**	**Comparison between 1995 and 2012-2013 measurements possible**	**Notes on re-establishment of transect**
Transect 1	T1_2012	Yes	The aluminium stake erected by Johnson in 2004 near the start of Transect 1 appears to have been lost to erosion and the 2012 transect was re-established based on notes and the transect description
Transect 2	N/A	No	Transect not marked with a stake in 2004 and notes indicate GPS coordinates are only an approximate. Analysis of coordinates revealed a possible scribing error. A new transect was placed in the area (T2_2012) but because of uncertainty about where the original transect comparison between these two transects is not possible.
Transect 3	T2_2012	Yes	Transect 3 was re-established along stakes placed by Johnson in 2004 and superficially the sequence of vegetation has not changed much between 1995 and 2012. However, the exact start point of the transect could not be determined because the stakes placed by Johnson were 11.2 m inland from where the shore was deemed to be when the 2012 measurements were taken.
Transect 4	T3_2012	Yes	Transect 4 was re-established based on the notes in Johnson (2004) and by reference to the aluminium stake placed approximately 10m from the transect (not placed in exact location due to high lagoon levels). Superficially the 1995 and 2012 transects are very similar (turf community grading into exotic grass-rushland and back to a turf community).
Transect 5	T4_2012	Yes (partially)	Area near Curran Creek frequently visited by the public so no stake positioned in 2004. Re-established in 2012 based on bearings and landmarks in Johnson's 2004 field notes but one landmark had been removed and the alignment of the creek mouth appears to have shifted. Transect now marked with warratahs and short wooden stakes.
Transect 6	T5_2012	No	No stake located, quite likely it has been removed by nearby drain cleaning. Transect re-positioned approximately 15m to the west between two drains avoid future loss of stakes.
Transect 7	T6_2012	Yes	This transect was re-established based on the sketch and coordinates in Johnson (2004) and the stake placed in 2004.

Transect 8	N/A	No	Not revisited in 2004 and unable to relocate in 2012 because vegetation appears to have changed substantially compared to that described in Johnson and Partridge (1998). New transect (T8_2012) established nearby to capture a different diverse community.
Transect 9	T9_2012	Yes (partially)	Unable to relocate stakes and transect re-established based on Johnson's 2004 field notes and information in Johnson and Partridge (1998).

Some qualitative comparisons are possible between previous and recent measurements of Transects 1 (T1_2012), 3 (T2_2012), 4 (T3_2012) and 7 (T7_2012 by looking at the width of plant communities and the relative abundance of the dominant species (see Appendix 6 for an attempt to compare the 1995 and 2012 data). However, without having a clear indication of where Johnson's transects began, direct comparison between subplots is not possible. For this same reason comparison is not possible between the 1995 and 2012-13 'distance from shore data' summarised in Johnson and Partridge (1998). The species cover is represented in a simplified manner in the elevation sketches in Johnson and Partridge (1998) making comparison between 2012 and 1995 measurements impossible.

Comparing the mean height for each species is not possible because these data are not available for 1995 and the plants in the elevation sketches are not drawn to scale.

Comparing species richness between previous and current measurements is problematic because the elevation sketches in Johnson and Partridge (1998) only include species amounting to ≤2% cover. Small-stature species, such as those found in turf communities, are often only minor components of overall cover and therefore may not be included by Johnson in elevation sketches of all transects where they did occur.

6.0 Discussion

Differences between the data sets and uncertainty around the exact positioning of the earlier transects have limited the amount of comparison possible between the measurements taken in 1995 and 2012-13. This is unfortunate, and has resulted in an inability to confirm changes in species richness or abundance which appear to have been occurring over the intervening years. However, the data collected in 2012-13 provide a valuable benchmark for repeated monitoring in future. It will be interesting to see how quickly any changes in vegetation can be confirmed after remeasuring these transects.

Some qualitative comparisons are possible between the observations noted in Johnson and Partridge (1998) and the 2012-13 measurements. These comparisons reveal several differences, although some of these may be attributable to natural change (e.g. succession or lagoon processes) and it is not clear how much change may have been caused by lower water levels or increases in nutrients and sediment.

It is clear that undertaking this type of work while the lagoon is high (i.e. over 1 m) reduces the ability to measure turf communities. Remeasuring portions of some transects illustrated how many species were present beneath the water.

A selection of 1995 elevation ranges for some species has provided insight into a downward shift in elevation range for most of these species.

7.0 Recommendations

- All transects should be remeasured in 3-5 years following the same method outlined in this report. Ideally this work will be undertaken in late summer and should occur under lower lagoon levels than when the 2012 monitoring was undertaken (shortly after the lagoon is opened to the sea is optimal).
- Investigation into a better method of measuring fine changes in elevation may prove helpful if elevation data for the full length of each transect is required.
- The height of each warratah projecting above the level of the ground should be recorded in future to provide some understanding of whether sediment is accreting at different elevations along the transects.
- Lagoon levels should not be managed any lower than current levels to halt any continual downward creep of shoreline communities. If the lagoon is continually lowered and simultaneously filled with sediment it could functionally disappear.

8.0 Acknowledgements

I would like to thank Liz Gunning (Department of Conservation) for her diligence and determination in often frustrating field conditions, and Alex Fergus for his botanical insights and field assistance, as well as Polly Bulling, Lee Boyde, Karen Maw and Darren May for their assistance in the field. Thanks are due to Murray Waghorn for allowing access through his property and providing advice on how to successfully cross the pea gravel in a 4x4 vehicle. This work would have been much more difficult to undertake without Chris Owen and his expert boat skills and his with Waituna Lagoon. Brian Rance (Department of Conservation) has been invaluable in identifying some shockingly poor specimens collected at a less than optimal time of the year and provided some helpful insight into how this report might be structured. Gratitude is also owed to Hugh Robertson and Polly Bulling (Department of Conservation) for their advice and support during this project.

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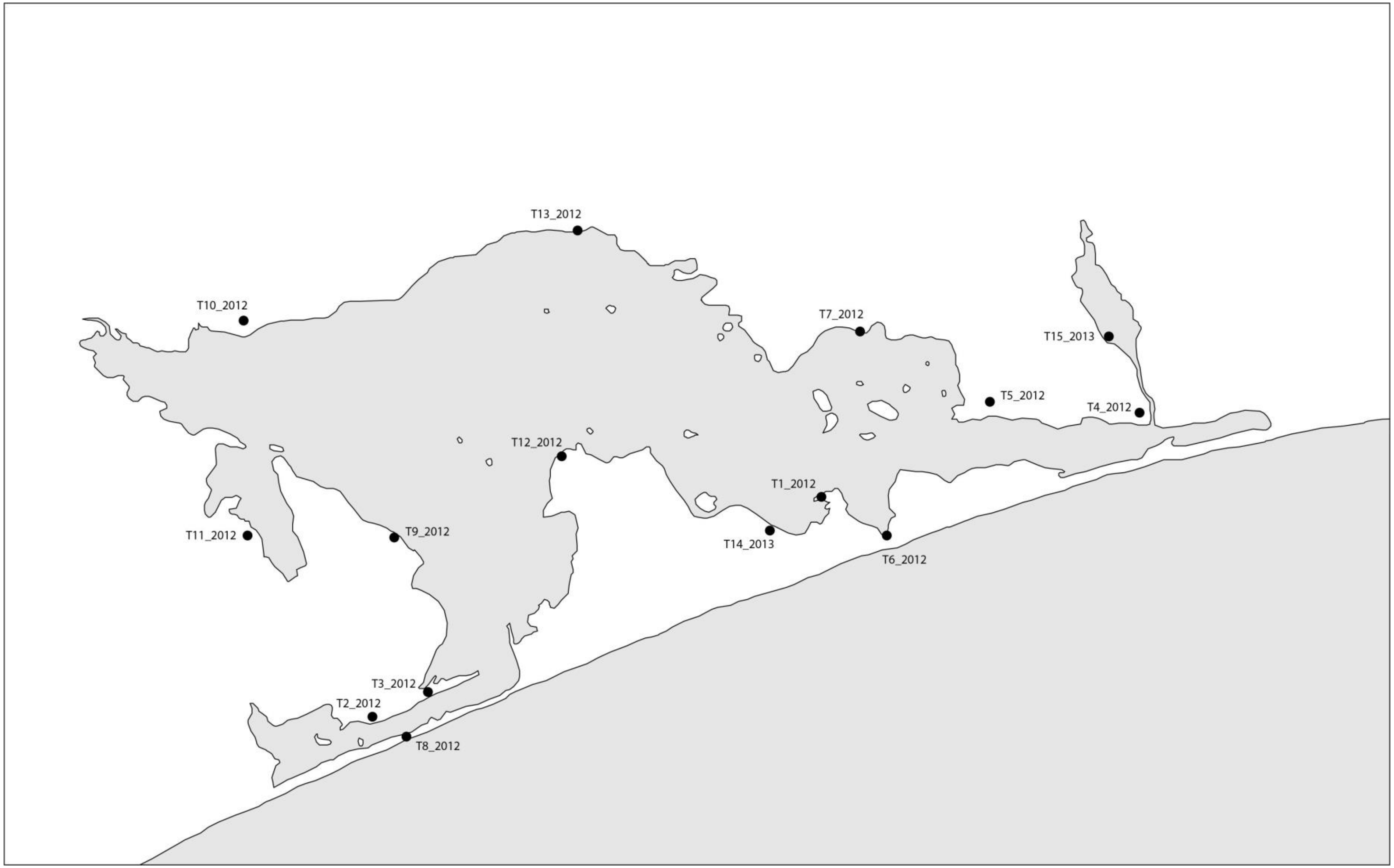
Appendix 1 - Map indicating position of shoreline transects around the margins of Waituna Lagoon



Appendix 2 – Complete species list for 2012-2013 transects

Six letter code (non-NVS codes in bold)	Species (* indicates exotic species)
Trees and shrubs	
COPdmo	Coprosma dumosa
COPpro	Coprosma propinqua
COPrig	Coprosma rigida
DRAlon	Dracophyllum longifolium
GAUmac	Gaultheria macrostigma
HALere	Haloragis erecta
LEPsco	Leptospermum scoparium
LEPjun	Leptecophylla juniperina (syn. Cyathodes juniperina)
PLAdiv	Plagianthus divaricatus
ULEeur	* Ulex europaeus
Herbs	
ACAnov	Acaena novae-zelandiae
ANAarv	* Anagalis arvensis
APIpro	Apium prostratum
ATRpro	*Atriplex prostrata
CALsol	Calystegia soldanella
CALsta	* Callitriche stagnalis
CALpet	Callitriche petriei
CAPbur	* Capsella bursa-pastoris
CARdeb	Cardamine debilis agg.
CENery	* Centaurium erythraea
CENuni	Centella uniflora
CERfon	* Cerastium fontanum
CHEamb	Chenopodium ambiguum
CIRarv	* Cirsium arvense
CIRvul	* Cirsium vulgare
COTcor	*Cotula coronopifolia
CRAmos	Crassula moschata
EPIcil	*Epilobium ciliatum
GALpal	* Galium palustre
GALLIU	Galium aff. perpusillum
GALpro	Galium propinquum
GENgri	Gentianella grisebachii
HYDdis	Hydrocotyle dissecta
HYDhyd	Hydrocotyle hydrophila
HYDnzm	Hydrocotyle novae-zelandiae var. montana
HYDsul	Hydrocotyle sulcata
HYPrad	* Hypochaeris radicata
LEOtar	*Leontodon taraxacoides
LEPdid	* Lepidium didymum
LEPdio	Leptinella dioica
LILnov	Lilaeopsis novae-zelandiae
LIMlin	Limosella lineata
LOTped	* Lotus pedunculata
MIMrep	Mimulus repens
MONfon	Montia fontanum

MYRIOP	Myriophyllum sp.
MYOlax	Myosotis laxa
NERbal	Nertera balfouriana
NERdep	Nertera depressa
NERsca	Nertera scapanioides
PARvis	* Parentucellia viscosa
PERmac	Persicaria maculosa
PLAaus	*Plantago australis
POTans	Potentilla anserinoides
PSElut	Pseudognaphalium luteoalbum
RANaca	Ranunculus acaulis
RANfol	Ranunculus foliosus
RANgla	Ranunculus glabrifolius
RANrep	* Ranunculus repens
RANscl	Ranunculus sceleratus
RUMace	* Rumex acetosella
RUMcri	* Rumex crispus
SAGpro	* Sagina procumbens
SAMrep	Samolus repens
SEDacr	* Sedum acre
SELrad	Selliera radicans
SENvul	* Senecio vulgaris
SENmin	Senecio minimus
SONasp	*Sonchus asper
SPEarv	*Spergula arvensis
SPEBoc	*Spergularia bocconei
STEmed	* Stellaria media
STEals	Stellaria alsine
TRIdub	* Trifolium dubium
TRIrep	* Trifolium repens
URTlin	Urtica linearifolia
VICsat	* Vicia sativa
VIOcun	Viola cunninghamii

Grasses, rushes and sedges

AGRsto	* Agrostis stolonifera
ALOgen	Alopecurus geniculatus
AMMare	* Ammophila arenaria
ANTodo	* Anthoxanthum odoratum
APOsim	Apodasmia similis (syn. Leptocarpus similis)
CORric	Austroderia richardii (syn. Cortaderia richardii)
BAUten	Baumea tenax
CARapp	Carex appressa
Carbuc	Carex buchananii
CARbre	Carex breviculmis
CARcor	Carex coriacea
CARdip	Carex dipsacea
CARdis	Carex dissita
CARfgl	Carex flagillifera
CARfla	Carex flaviformis
CARgau	Carex gaudichaudiana
CARova	*Carex ovalis
CARsec	Carex secta
CARsin	Carex sinclairii

CARvir	Carex virgata
CHIrsc	Chionochloa rubra subsp. cuprea
DACglo	* Dactylis glomerata
DESces	Deschampsia cespitosa
ELEacu	Eleocharis acuta
ELEgra	Eleocharis gracilis
EMPmin	Empodisma minus
FICnod	Ficinia nodosa (syn. Isolepis nodosa)
HOLlan	* Holcus lanatus
ISObas	Isolepis basilaris
ISOcer	Isolepis cernua var. cernua
ISOhab	Isolepis habra
ISOret	Isolepis reticulatus
JUNart	* Juncus articulatus
JUNbuf	* Juncus bufonius
JUNedg	Juncus edgariae (syn. Juncus gregiflorus)
JUNeff	* Juncus effusus
JUNpro	* Juncus procerus
JUNpal	Juncus pallidus
LACstr	Lachnagrostis striata
LEPaus	Lepidosperma australe
LOLper	Lollium perenne
LUZcon	*Luzula congesta
LUZpic	Luzula picta
POAann	Poa annua
POAcit	Poa cita
POApra	* Poa pratense
POApus	Poa pusilla
SCHaru	* Schedonorus arundinacea
SCHpun	Schoenoplectus pungens
SCHmas	Schoenus mascholinus
TRIstr	Triglochin striata

Other monocots

CORaus	Cordyline australis
PHOten	Phormium tenax

Lianes

MUEaxi	Muehlenbeckia axillaris
MUEcom	Muehlenbeckia complexa

Ferns

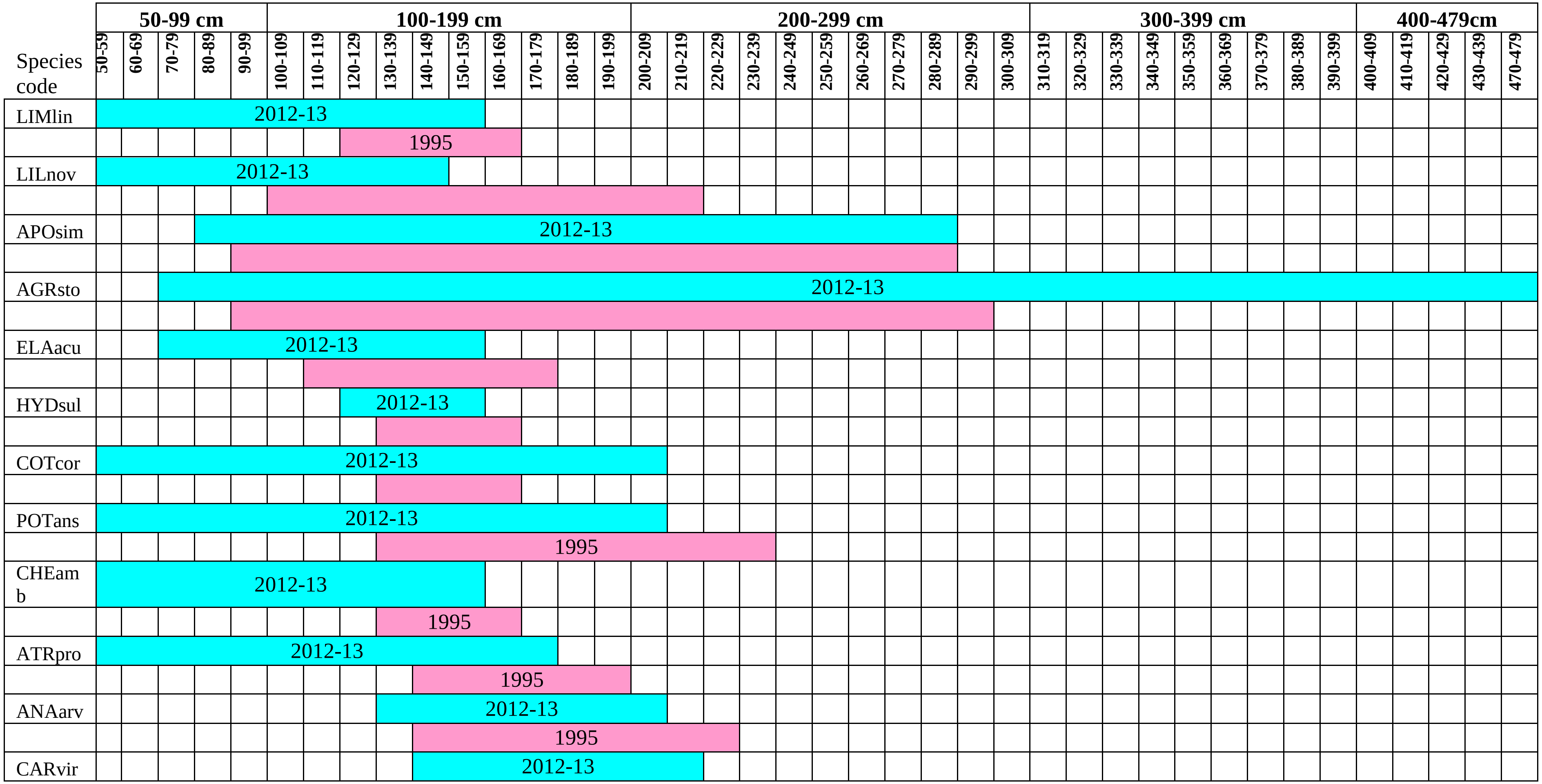
BLEmin	Blechnum minus
BLEpen	Blechnum penna-marina
GLEdic	Gleichenia dicarpa
HISinc	Histiopteris incisa
PAEsca	Paesia scaberula
POLves	Polystichum vestitum
PTEesc	Pteridium esculentum

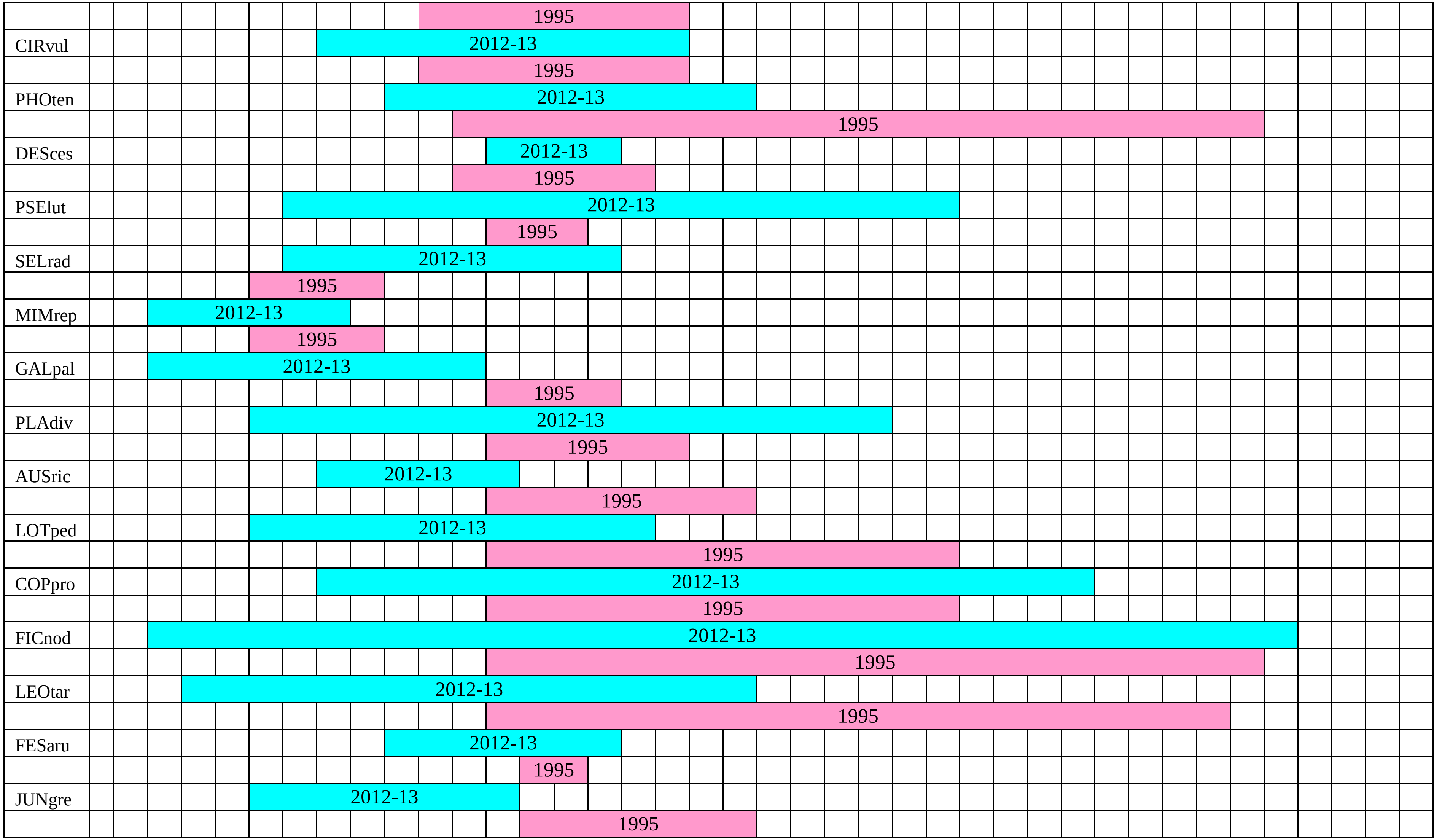
Appendix 3 – Summary of different vegetation community classifications relevant to shoreline transects at Waituna Lagoon

Johnson & Gerbeaux, 2004	**Rogers and Singers (in press)**	**Johnson and Partridge (1998)**	**Boffa MiskellLtd and Urtica Inc, 2010**
Wetland vegetation			
Marsh	WL10 - Oioi restiad-rushland/reedland	Leptocarpus rushland	AP - Oioi
Bog	WL12 - Manuka-tangle fern scrub/fernland	Manuka scrub	DM - Dense manuka
Fen	WL20 - *Coprosma Olearia* scrub	Scrub community	GS - Grey scrub
	WL22 - *Carex Schoenus* sedgeland	Sedge community	CA - Carex
Swamp	WL18 - Flaxland		PH - Flaxland
	(DN5 - Oioi, knobby clubrush sedgeland)	Rush community	N/A
Ephemeral wetland	WL15 - Herbfield (Lakeshore turf)	Turf comunities	N/A
Non-wetland vegetation			
	SA4 - Shore bindweed, knobby clubrush gravelfield-stonefield	Gravel beaches	PO - Silver tussockland
	F13 - manuka scrub	Manuka scrub	Manuka scrub
	F19 - Bracken fernland		Bracken fernland - not mapped

Appendix 4 - Vertical range of species in 1995 and 2012

1995 elevation range based on Figure 4 in Johnson and Partridge (1998)




1995
CIRvul
2012-13
1995
PHOten
2012-13
1995
DESces
2012-13
1995
PSElut
2012-13
1995
SELrad
2012-13
1995
MIMrep
2012-13
1995
GALpal
2012-13
1995
PLAdiv
2012-13
1995
AUSric
2012-13
1995
LOTped
2012-13
1995
COPpro
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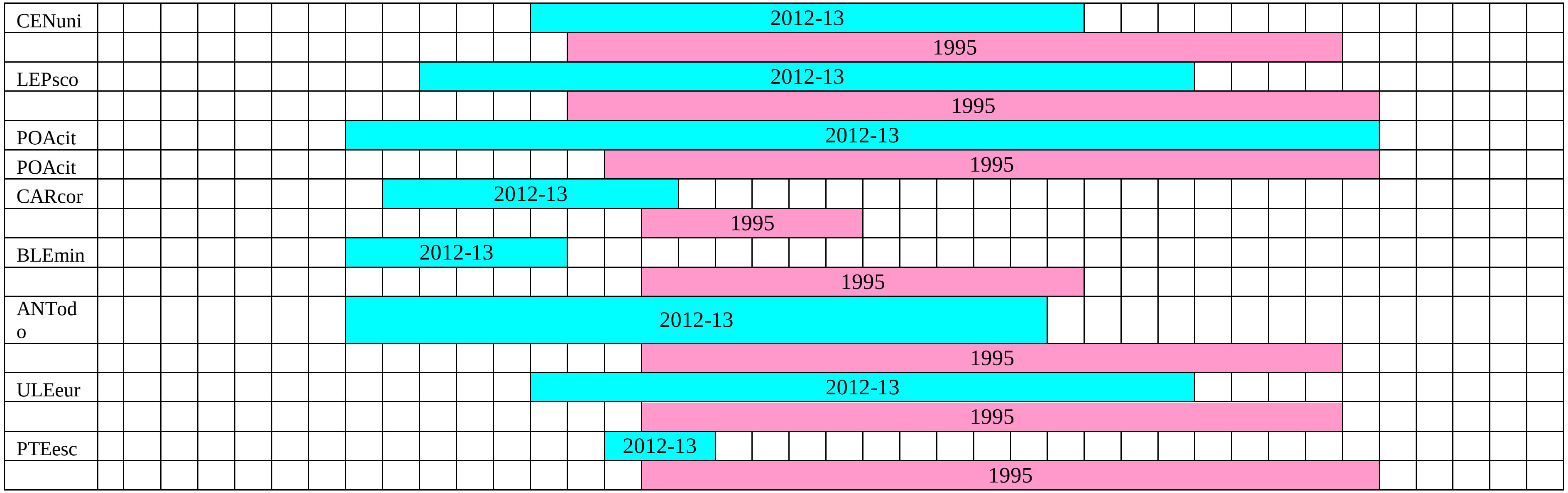
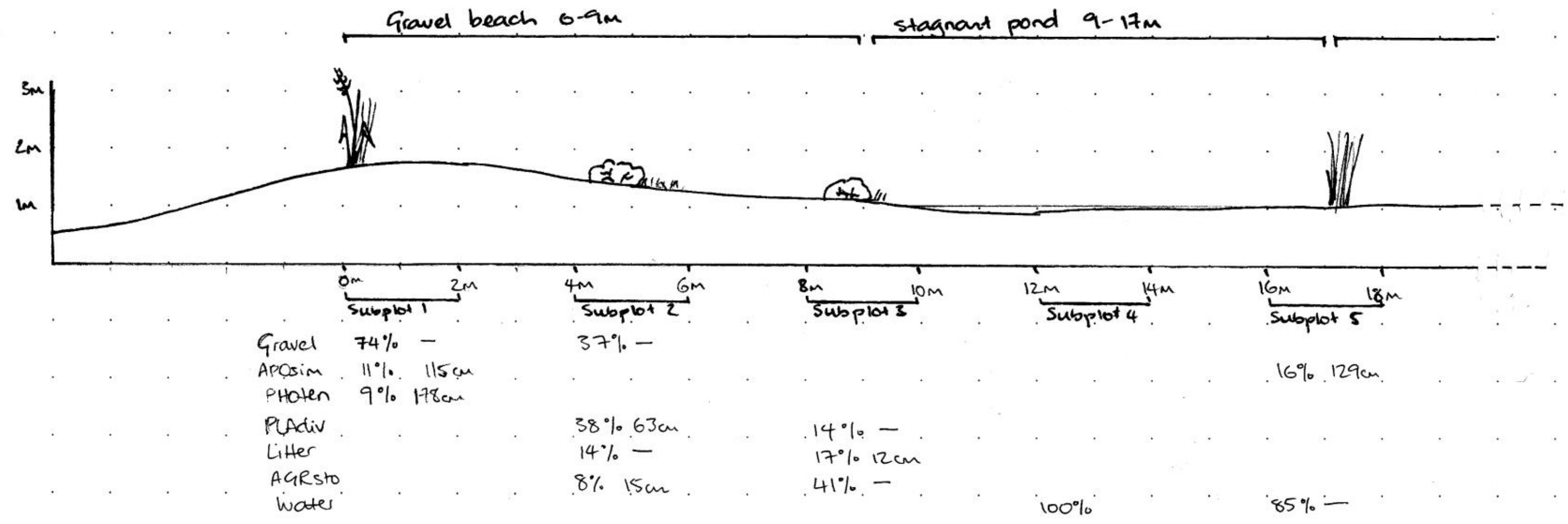
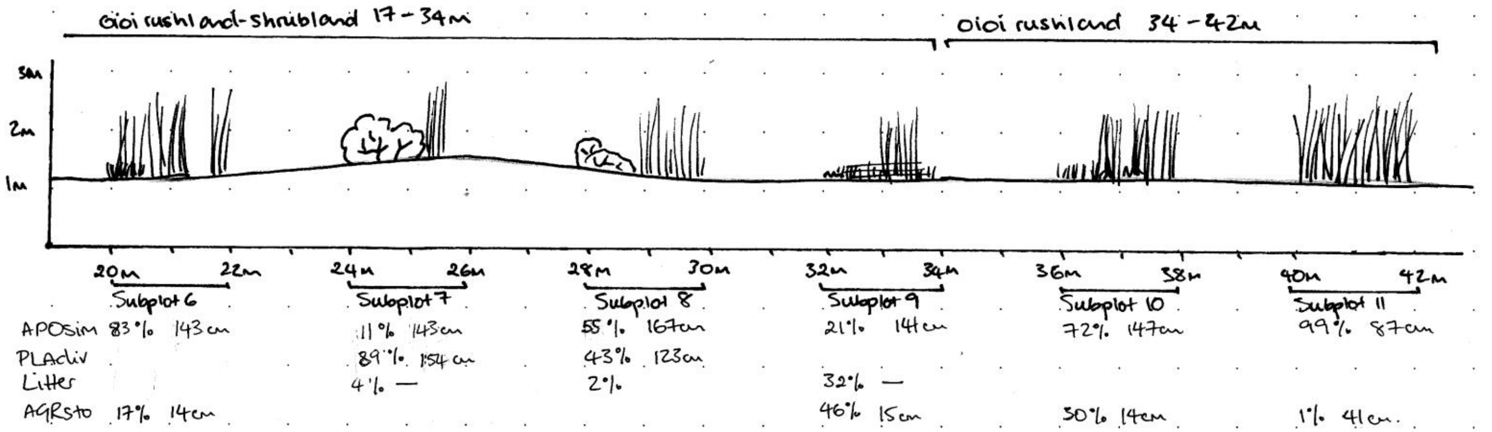
1995
JUNgre
2012-13
1995



CENuni
2012-13
1995
LEPsco
2012-13
1995
POAcit
2012-13
POAcit
1995
CARcor
2012-13
1995
BLEmin
2012-13
1995
ANTodo
2012-13
1995
ULEeur
2012-13
1995
PTEesc
2012-13
1995

Appendix 5 – Qualitative comparisons between 1995 transects remeasured in 2012
T1_2012





Vegetation communities redfined based on Rogers and Singers:

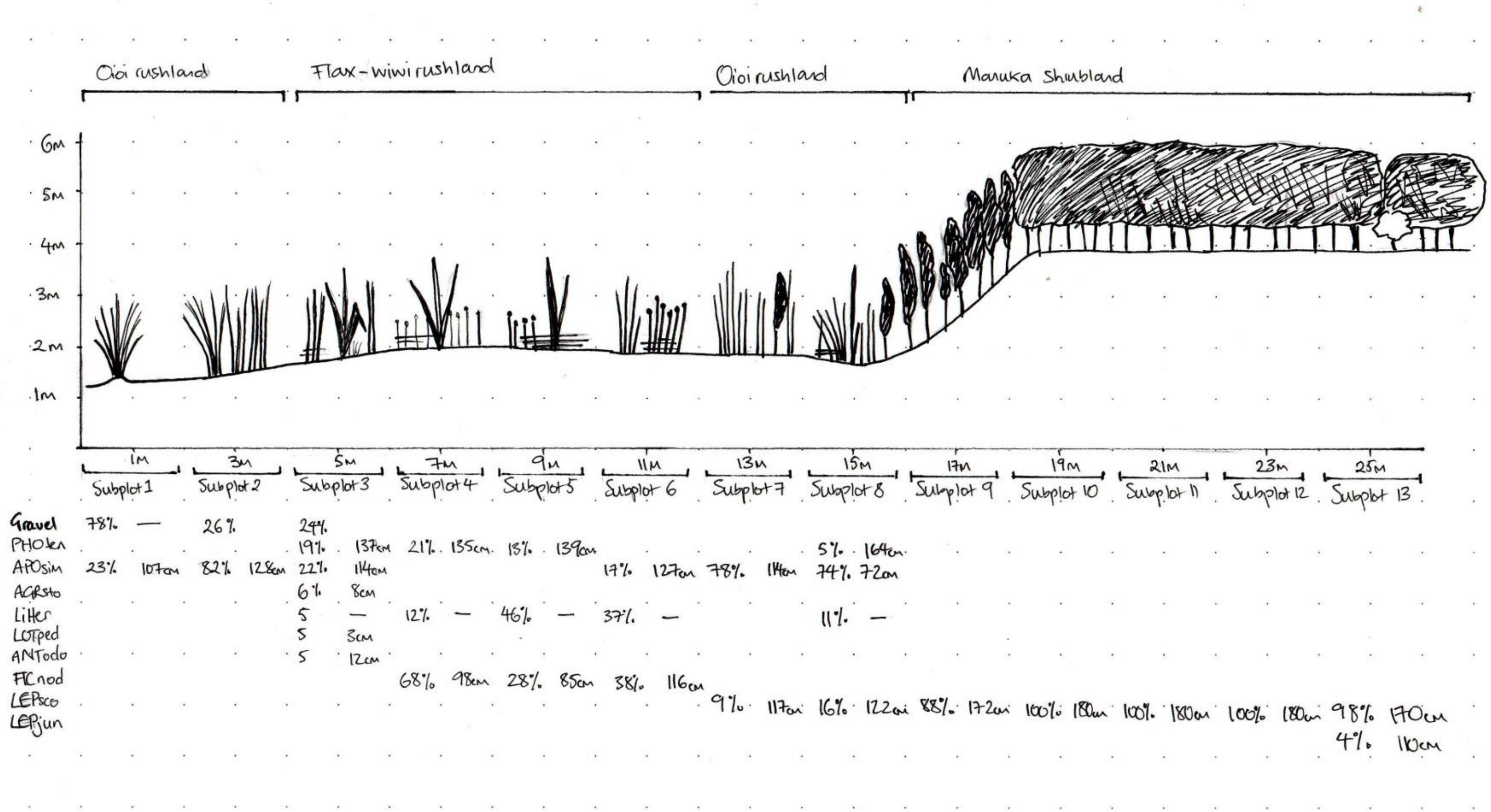
0-17 m WL10
17-34m WL-WL20 mix
34-42m WL10

Changes observed between Transect 1 (1995) and Transect T1_2012

The aluminium stake erected by Johnson in 2004 near the start of Transect 1 appears to have been lost to erosionand the 2012 transects was re-established based on notes and the transect description in Johnson and Partridge (1998). Some changes are apparent:

- **The gravel beach at the transect start has eroded** – in 1995 the transect began at 150cm to include the oioi and creeping bent growing on the gravel beach. In 2012 vegetation begins at the beach crest at 176cm and dead flax and oioi clumps scattered nearby indicate the vegetation is being actively eroded from this gravel beach. This is likely to natural wind and wave action.
- **Turf species are absent -** There is no sign of the turf species *Selliera radicans, Lilaeopsis novae-zelandiae* and *Cotula coronopifolia* recorded in 1995. These turf plants could have scoured away when the other species were removed.
- **Species diversity is reduced –** prolonged ponding along this transect has caused underlying vegetation (probably creeping bent) to die and there is no sign of the *Cotula coronopifolia* and *Myriophyllum propinquum* previously recorded. This ponding is described as a natural process in Johnson and Partridge (1998). It will be interesting to note which species colonise these hollows/ponds.

T2_2012



Vegetation communities redefined based on Rogers and Singers:

0-4 m = WL10
4-124 m = DN5
34-42 m = WL10

Changes observed between Transect 3 (1995) and Transect T2_2012

Transect 3 was re-established along the stakes places by Johnson in 2004 and superficially the sequence of vegetation has not changed since 1995 and 2012. Both measurements captured a sequence of oioi- rushland followed by oioi, knobby clubrush sedgeland and then manuka scrub as the transect ascends a small scarp. However, several differences are apparent:

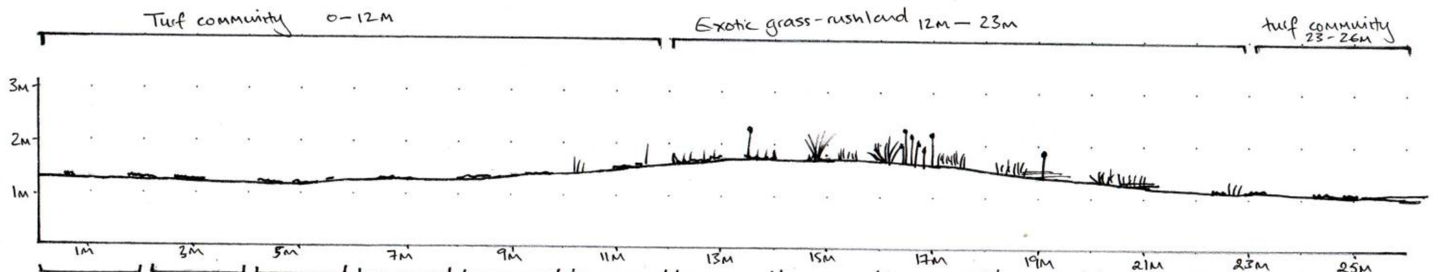
- **The elevation pattern has changed -** In 1995 the transect gradually ascended from 120cm to 200cm before climbing a steep scarp to approximately 380cm. In 2012 the transect began at approximately 135cm and climbed to 200cm before descending to 170cm and then climbing the scarp to approximately 370cm. The development of a small hollow behind the gravel beach at the beginning of this transect is likely due to natural processes because the shoreline here is exposed to the effects of southerly winds and wave action. Large pieces of driftwood and thick layers of litter were observed in and around the transect.
- **Turf species are less abundant and there is change in the species present** - In 1995 Johnson recorded five species with covers ranging from 5-25% (*Selliera radicans*, *Samolus repens*, *Lilaeopsis novae-zelandiae*, *Limosella lineata* and *Isolepis cernua*). In 2012 four species were recorded but each one comprised less than 1% of the cover in the 2x2m subplots where they occurred (*S. radicans*, *Potentilla anserinoides*, *Hydrocotyle novae-zelandiae var. montana* and *Apium prostatrum*). It is not clear whether changes in turf species are real or due to changes in the positioning of the transect. It is possible that turf species recorded by Johnson at 120cm are still present but were underwater during the 2012 monitoring.
- **Native grasses have been replaced by oioi in a newly developed hollow at 10-16m along the 2012 transect -** Previously Johnson recorded *Poa cita* (silver tussock) and *Austroderia richardii* (toetoe) along with *Agrostis stolonifera* growing between the oioi rushland and the manuka shrubland. A search approximately 15m either side of the transect in 2012 did not reveal any silver tussock, but one toetoe was seen nearby. *Deschampsia caespitosa* accounted for 5% cover in the 1995 transects but in 2012 it was only 2% or less in the subplots where it occurred. Reduction in *Deschamspia caespitosa* cover may be due to it being shaded by the taller oioi. *D. caespitosa* measured between 45 and 55cm tall and oioi around 120cm tall in subplots where they occurred together on this transect. The changes in species composition on this part of the transect may be due to the hollow and the wetter conditions favouring oioi.
- **Manuka shrubland has become denser and shaded out bracken and *Dracophyllum longifolium* -** Both bracken and *D. longifolium* were minor components within the 2012 transect but did not occur in any subplots. This transect is exposed to the south and strong wind may preclude the leading edge of the shrubland getting tall enough to support a diversity of understorey species. Outside the transect open patches containing bracken, flax and gorse occur within the manuka shrubland. This change in the manuka shrubland is a natural part of the maturation of this plant community.

T3_2012

Vegetation communities redefined based on Rogers and Singers:

0-12 m = WL15
12-23 m = NN1
23-26 m = WL15

Transect 4



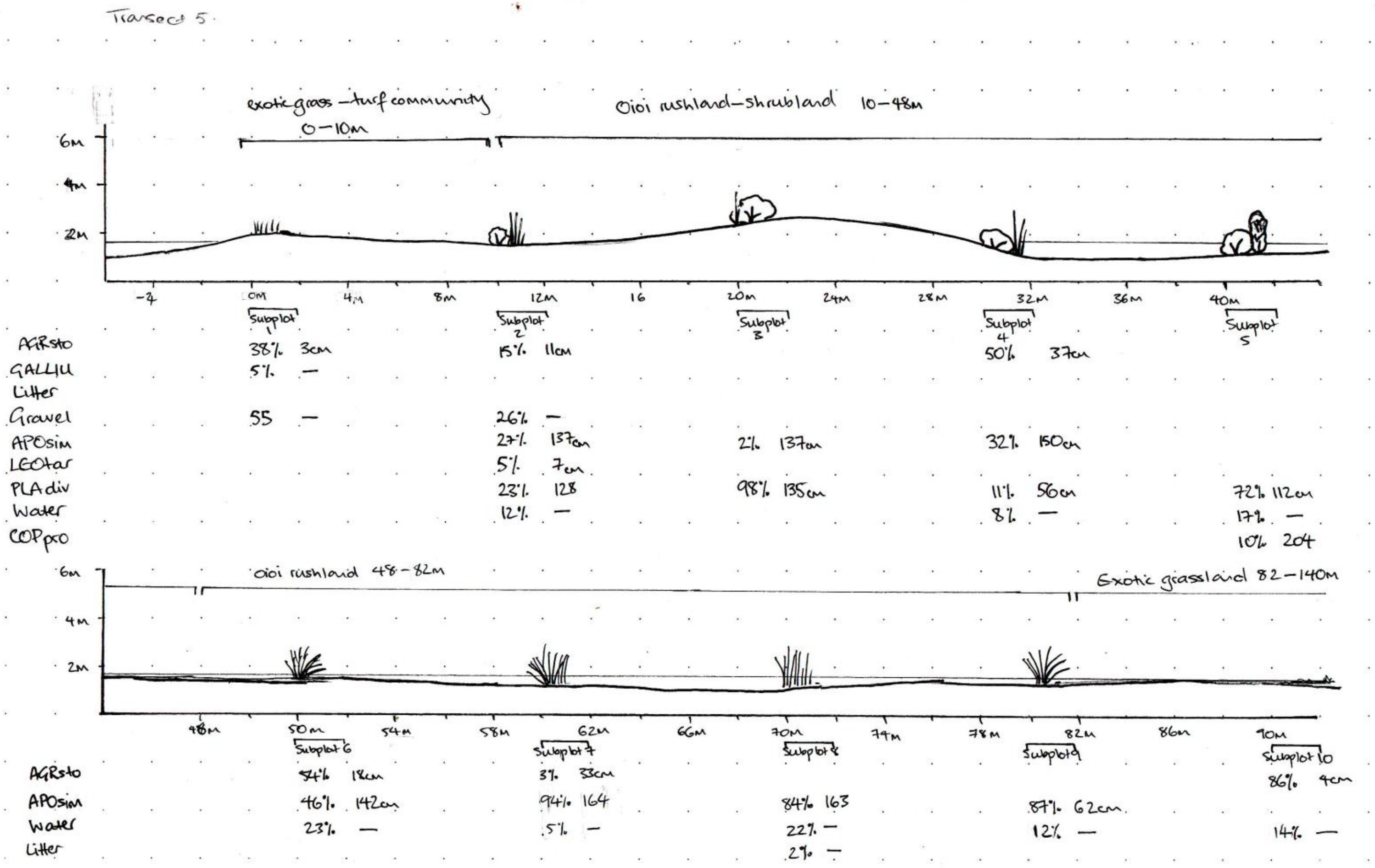
	Subplot 1		Subplot 2		Subplot 3		Subplot 4		Subplot 5		Subplot 6		Subplot 7		Subplot 8		Subplot 9		Subplot 10		Subplot 11		Subplot 12		Subplot 13	
Water	40%	—	74%	—	85%	—	1%	—	22%	—	38%	—	1%	—											28%	—
Gravel	58%	—																								
SAMnep	3%	—	23%	—	6%	—			15%	—													10%	—		
*POAann	2%	—	3%	—	1%	—			1%	—													1%	—		
PSElut			2%	—							1%	—									7%	—				
4Lnov			3%	—			4%	—	14%	—	4%	—													4%	
SELrad					1%	—			1%	—	28%	—	6%	—												
*COTcor					1%	—																				
LIMlin					2%	—	2%	—	12%	—	1%	—											14%	—	25%	—
litter					2%	—			3%	—	6%	—							37 (FICnod)		21%	—	5%	—		
Algae							94%	—	28%	—															8%	—
*AGRsto											26%	12cm	83%	11cm	45%	12cm	32%	11cm	45%	27cm	45%	17cm	3%	12cm	7%	5cm
Moss											2%	—	3%		4%				8%	—	3%					
LEPdio											1%	—					4%	—								
FICnod													2%	32cm	36%	51cm	45%	48cm	3%	44cm						
*LEOtar													1%				3%	—								
*ANTodo															8%	14cm	8%	10cm								
POAcit															7%	59cm	8%	42cm								
ACAnov															1%	—										
*TRIrep																										
APOsim																					28%	96cm	8%	72cm		
silt																							20%	—	22%	—
POTans																					1%	12cm				
HYDhyd																							2%	—		
CARdip																			1%	48cm						
MYRIOP																									3%	—

Changes observed between Transect 4 (1995) and Transect T3_2012

Transect 4 was re-established based on the notes in Johnson (2004) and by reference to the aluminium stake placed approximately 10m from the transect. Superficially the 1995 and 2012 transects are very similar (turf community grading into exotic grass-rushland and back to a turf community). However, comparison with Table 2 in Johnson and Partridge (1998, p. 19) shows there has been an increase of largely exotic species. In 1995 20 native species and 14 exotic species were recorded within Transect 4[6]. In 2012 the following mix of nine native and exotics species were absent: *Mimulus repens, Crassula sinclairii, Apodasmia similis, Acaena microphylla, Lachnagrstis striata, Juncus bufonius, Galium palustre, Holcus lanatus* and *Sedum acre*. These additional 12 species were recorded in 2012, most of which are exotic: Hydrocotyle sulcata, Leptinella dioica, Ranunculus acaulis, *Coprosma propinqua* (seedling), *Poa annua, Senecio vulgaris, Sonchus asper, SAgina procumbens, Capsella bursa-pastoris, Rumex acetosella, Parentucellia viscose* and *Trifolium dubium.*

[6] This figure excludes two species of moss because non-vascular species such as moss and algae were not indentified in 2012.

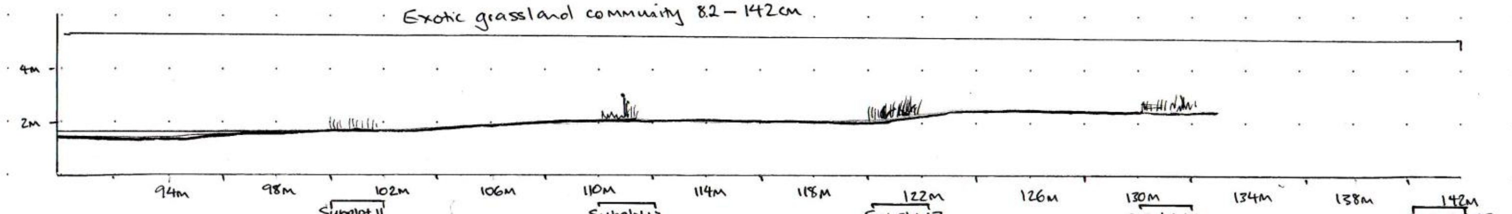
T4_2012



Vegetation communities redefined based on Rogers and Singers:

0-10 m = NN2
10-48 m = WL10-WL20 mix
48-82 m = WL10
82-142m = NN1

transect 5 cont.



	Subplot 11	Subplot 12	Subplot 13	Subplot 14	Subplot 15
AGRsto	62% 9cm	70% 8cm	77% 16cm	82% 9cm	12% 12cm
LEOtar	32% 1cm	18% 1cm			
Silt	14 —	5% —			
JUNbuf	1% —				
JUNart	1% 8cm				
FICnod		3% 62cm			81% 63cm
HOLlan			23% 15cm	2% 10cm	
Moss			1% —	3% —	
DACglo					3% 50cm
HYPrad				1% —	
litter				12	

Changes observed between Transect 5 (1995) and Transect T4_2012

Transect 5 was re-established using notes and sketches provided by Johnson in 2004. The lower two thirds of the transect appear to have changed since 1995 but the upper portion is similar. Most differences between the two measurements of Transect 5 can probably be accounted for by the likelihood that the 2012 transect is not in exactly the same places as the 1995 one and variation in the alignment of nearby Curran Creek. Notable changes in vegetation include:

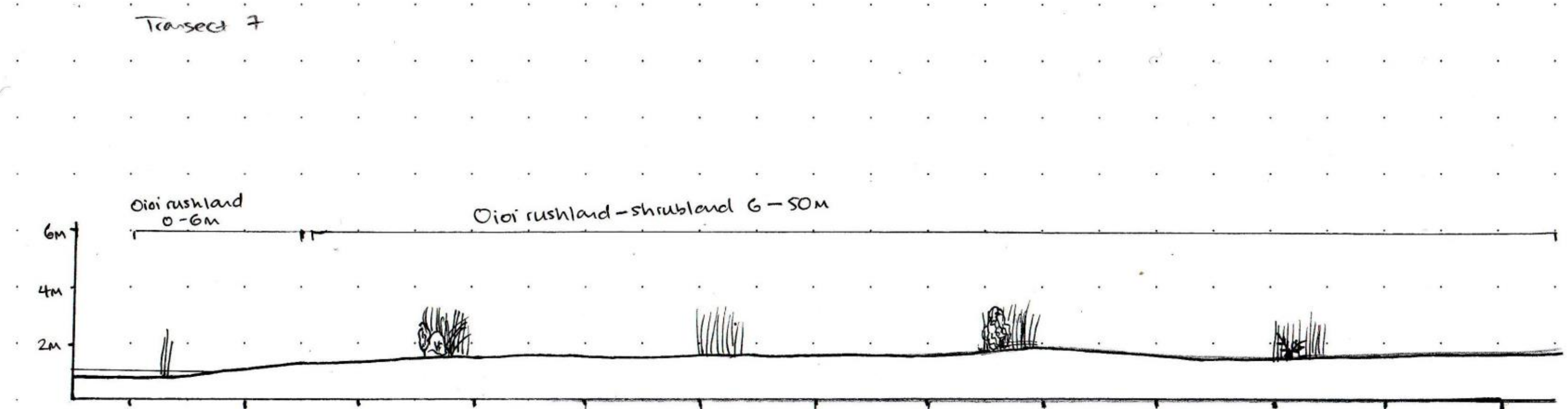
- **Turf community appears to have altered in composition -** Johnson recorded '*Muehlenbeckia axilaris* and other vegetation' at the start of 1995 transect but turf species recorded in 2012 included *Potentilla anserinoides, Selliera radicans* and *Gallium* aff. *perpusillum* and *Muehlenbeckia* was not present.
- ***Schoenoplectus pungens* no longer occurs within the transect -** When the transect was re-established in 2012 this species did not occur within the transect although it is growing nearby.
- **Shrubs species along the transect have changed -** *Plagianthus divaricatus* and *Coprosma propinqua* were recorded along the 2012 transect but did not comprise ≥2% cover to be included in the 1995 elevation sketch. Gorse and tree lupin no longer occur in the upper portion of the transect and this is probably due to weed control in the intervening time period.

Changes observed between Transect 6 (1995) and Transect T5_2012

Although Transect 6 was marked in 2004 the stake could not relocated in 2012 and it is likely it was removed during the cleaning of a nearby drain. Therefore Transect 6 was established approximately 15m to the west of where it is believed to have been to avoid future loss of markers through drain cleaning operations. No elevation sketch has been produced for this transect because the thick vegetation prevented the use of the builder's level. The 1995 and 2012 transects are not in the same location and cannot be directly compared. However, the broader vegetation patterns between the two transects are similar in that both recorded oioi rushland followed by an oioi-shrubland mix and then manuka shrubland. However, there is a noticeable reduction in the number of species recorded in 2012 compared with those recorded in 2012. Species now absent from the upper portion of the transect include: toetoe, *Chionochloa rubra* subsp. *cuprea*, *Coprosma elaterioides*[7], gorse, *Lepidosperma australe* and *Ficinia nodosa*[8] in the oioi-shrubland zone. These changes may be due to an increase in dominance of oioi in the oioi-rushland zone. Johnson recorded additional understorey species in the manuka shrubland including: *Viola cunninghamii*, *Nertera setulosa*, *Centella uniflora*, *Carex sinclairii*, *Gaultheria macrostigma*, *Gentianella grisebachii* and *Carex flaviformis*. The decreased diversity in the manuka shrubland may be due to grazing, road maintenance and drain cleaning.

[7] *Coprosma* aff. *intertexta* in Johnson and Partridge (1998).
[8] Syn. *Isolepis nodosa*

T6_2012

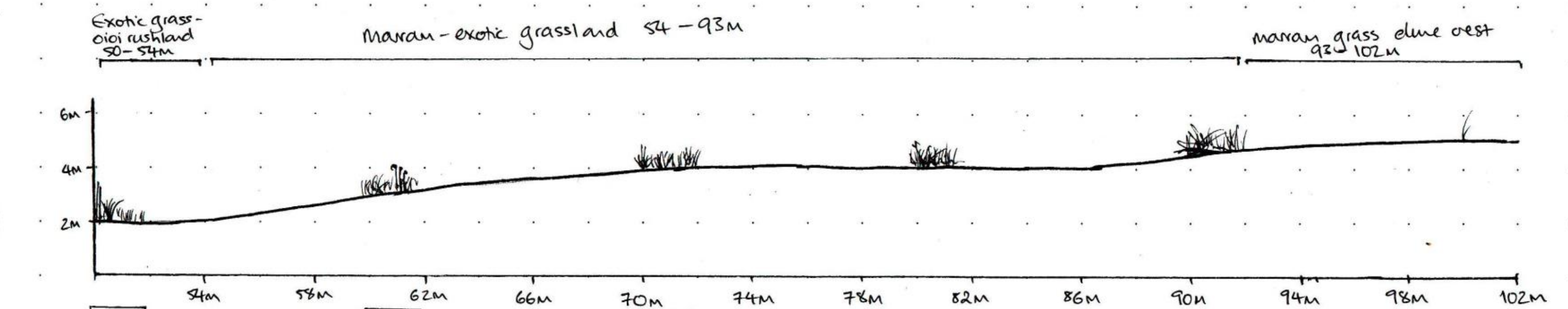


	Subplot1	Subplot2	Subplot3	Subplot4	Subplot5
Water	94% —				
APOsim	3% 138cm	77% 185cm	98% 180cm	82% 188cm	96% 136cm
Silt	3% —				
COPpro		24% 138cm	3% 116cm	21% 173cm	
PLAdiv		12%			
BLEmin					5% 83cm
Litter				7% —	2% —

Vegetation communities redefined based on Rogers and Singers:

0-6 m = Wl10
6-50 m = WL10-WL20 mix
50-54 m = WL10(m)
54-102m = NN1

transect 7 cont.



	Subplot 6	Subplot 7	Subplot 8	Subplot 9	Subplot 9	Subplot 10
APOsim	4% 110cm					
DACglo	25% 60cm	4% 24cm	28% 35cm			
FICnod	7% 53cm					
CARflv	7% 17cm					
AGRsto	25% 35cm	25% 18cm			16% 13cm	
AMOare		25% 70cm	62% 80cm	45% 62cm	43% 75cm	1% 28cm
POApra		30% 19cm		55% 23cm		
FICnod		8% 62cm	3% 70cm			
ANTodo		4% 22cm				
Litter			6% —	2 —	8%	
CALsol					4% 8cm	
Gravel					27% —	100 —
Driftwood					5% —	

Changes observed between Transect 7 (1995) and Transect T6_2012

This transect was re-established based on the sketch and coordinates in Johnson (2004) and the stake placed in 2004. Differences between the 2012 and 1995 transect descriptions include:

- **Species diversity is significantly reduced** – A diverse range of 68 species is listed by Johnson and Partridge (1998) in the table on pages 20-21. Of these, 43 were not recorded in 2012, although some are likely to have been missed due to the time of year (e.g. *Microtis unifolia*). Six additional species were recorded in 2012.
- **Turf species and Schoenoplectus punges are absent** – Schoenoplectus was not present anywhere near the start of this transect in 2012 despite being the dominant in the lower 15m of the transect in 1995. The shoreline appears to have eroded and large loose clumps of dead oioi root bases can be seen lying on a gravelly bed of the lagoon nearby. Previously the lagoon has been opened to the sea very near to Transect 7. Likewise, several turf species are absent which are listed in Johnson and Partridge (1998, p. 20)[9]. The disturbance created by the opening may be responsible for the loss of the *Schoenoplectus pungens* and erosion of the lower portion of this transect.
- **Gorse and broom have been removed from this transect**

[9] Note that there are two tables labelled 'Table 2' in this report. The table on page 19 refers to Transect 4 and the table on pages 20-21 refers to Transect 7.

T9_2012

Transect 9.

	Subplot 1	Subplot 2	Subplot 3	Subplot 4	Subplot 5	Subplot 6	Subplot 7	Subplot 8	Subplot 9	Subplot 10
Water	25% —									
Gravel	35% —	2% —	2% —							
APOsin	25% 125cm									
AGRsto	2% 12cm	40% 22cm	35% 21cm	21% 17cm						
Litter	5% —				22% —	42% —				98% (groundcover)
HYDhyd	3% —	2%								
JUNgre		30% 110cm								
PHOten		15% 183cm	46% 194cm			6% 260cm	4% 224cm			
GIRvul		2% —								
ELAacu		2% —								
Soil			3% —	5% —	14% —	9% —				
ULEeur				24% 8cm	15% 4cm		6% 112cm			
HOLlan				15% 13cm						
ANTodo			5% 13cm	5% 13cm						
PTEesc			3% 30cm	3% 30cm	25% 55cm	46% 75cm	52% 85cm	70% 110cm	50% 102cm	17% 90cm.
LOTped					2% —					
LEPsco					1% 8cm			35% 250cm		35% 300cm.
LEPjun							8% 65cm	4% 64cm	3% 100	5% 80cm.

Vegetation communities redefined based on Rogers and Singers:

0-2 m = Wl10-WL15 mix
2-9 m = WL18(m)
9-19 m = F19
19-20m = F13

Changes observed between Transect 9 (1995) and Transect T9_2012

The stake marking Transect 9 was not relocated in 2012 and therefore the transect was re-established using Johnson's 2004 notes and the elevation sketch in Johnson and Partridge (1998). A greater diversity of species were observed in 2012 but this could be due to the placement of the transect and the fact that the elevation sketch (Johnson and Partridge, 1998) is simplified and only shows a few dominant species.