


# Vegetation changes at Tumurau Wetland, Bay of Plenty, after grey willow control





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Manaaki Whenua

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## Summary

### Project and Client

- This report presents the results of the 2014 measurement of vegetation monitoring plots following willow control at Tumurau Wetland, and an assessment of vegetation change since earlier (2011) measurements undertaken by Landcare Research for the Bay of Plenty Regional Council (BOPRC).

### Objectives

- To identify changes in vegetation composition at Tumurau Wetland after herbicide (glyphosate) application for the control of exotic grey willow.
- To attempt to identify if and how different methods of willow control (aerial or ground-based application of herbicide) affect subsequent indigenous wetland vegetation recovery.

### Methods

- Sixteen 10×10 m permanently marked vegetation plots and seventeen 2×2 m plots, established and measured in 2011 when willow control was underway, were remeasured in autumn 2014, 3 years after willow control.
- Ten plots had been aerially treated and 6 ground-treated for willow control in the 2010/2011 summer. One plot was left as a control.
- To identify the main vegetation gradients in the plot data, maximum cover scores estimated for each species in any tier in the 10×10 m plots for both surveys (2011 and 2014) were ordinated by DCA.
- To test for an overall directional shift in species composition between measurements, paired t-tests were performed on changes in plot ordination scores on the first two DCA axes. Paired t-tests were also performed for changes in total indigenous and total exotic cover between measurements. To test whether grey willow control affected indigenous vegetation recovery, ANOVA was performed on change in axes scores between measurements, using treatment type as a factor. We also used ANOVA to test whether changes in total indigenous and total exotic cover between measurements differed significantly between treatments.
- To test if either of the treatments (aerial versus ground) had a significant effect on indigenous vegetation recovery, we performed single-sample t-tests on changes in axis scores and indigenous and exotic cover between measurements for each treatment separately.
- To investigate changes in soil physical and chemical properties that may influence vegetation succession, and for comparison with other wetlands, two 7.5 cm soil samples and foliage samples from the dominant canopy species were collected from each 2×2 m plot. Paired t-tests were performed to test for differences in mean nutrient concentrations between 2011 and 2014 samples.

## Results

- The first DCA ordination axis separated indigenous-dominated from exotic-dominated communities. The second axis separated willow communities from open herbaceous communities.
- Between 2011 and 2014, plots shifted significantly along the first axis, indicating an increase in exotic species relative to indigenous species cover. Paired t-tests of exotic and indigenous cover confirmed that indigenous species cover declined significantly but exotic cover remained constant.
- Plots also shifted significantly over time on the second axis, indicating an increase in the abundance of herbaceous wetland species. For the first axis, overall significant differences appear to be driven by relatively minor changes in most plots and for the second, by major changes in a few plots.
- Although there was no change in overall exotic cover, there was a change in the vertical distribution of this cover, from upper to lower tiers.
- There was no significant difference between aerial and ground willow control treatments in the magnitude of change on either axis in response to the death of the willows. Indigenous species cover declined significantly after both ground control and aerial control, while exotic species cover did not change.
- There was a small but significant reduction in soil bulk density and an increase in soil carbon after willow control.

## Conclusions

Control of willow by aerial or ground spraying has led to reduced indigenous cover in Tumurau Wetland, at least in the short term (3 years after treatment). This appears to have resulted from reduced cover of indigenous species rather than from increased cover of exotic species. Possible mechanisms are (1) differential susceptibility of indigenous and exotic herbaceous species to the herbicide (glyphosate) used, and (2 increased light levels after removal of the tree canopy and enhanced exposure disadvantaged associated indigenous species. The similarity of changes in vegetation after aerial and ground control suggest that the second mechanism is more likely to be responsible for the reduction in indigenous cover. The increase in relative exotic cover may be transitory and a normal part of the recovery process, however, as populations of some indigenous species may recover over time, as has happened in some other wetlands subject to willow control.

## Recommendations

- Plots should be remeasured in 5 years' time to determine whether the short-term reduction in indigenous cover persists.
- A more gradual, staged removal of willow using ground-based control of coupes could be trialled in another wetland, to see if the microclimatic shock on indigenous plants can be moderated. Surviving indigenous species may more quickly recolonise coupes than after widespread willow control. Consideration could also be given to initially targeting female grey willow trees to minimise seed dispersal.

# 1 Introduction

Landcare Research was contracted by Bay of Plenty Regional Council to remeasure permanent plots established in 2011 in Tumurau wetland, Bay of Plenty, to assess the effect of grey willow control on residual and recovering vegetation.

# 2 Background

Open plant communities in New Zealand, including wetlands, have been particularly susceptible to invasion by exotic plant species (Healy 1969), including a suite of willows (*Salix* spp.). Willow forest (carr) is now a common vegetation type of fens of many parts of lowland New Zealand (Johnson & Gerbeaux 2004). An important recent advance in willow control is the use of aerial herbiciding with glyphosate (Bodmin 2012), which results in high rates of tree mortality but leaves an uncertain legacy in terms of the existing and future associated vegetation in wetlands.

Tumurau (Braemar) Lagoon Wetland (Figure 1) is a Regionally Significant wetland of approximately 119 hectares in the eastern Bay of Plenty (Fitzgerald et al. 2013). It had a major grey willow (*Salix cinerea*) infestation which was controlled by aerial spraying of herbicide and by ground-based application of herbicide to holes drilled in tree trunks in the summer of 2010/2011. Permanent plots established shortly after willow control (early 2011) provided the opportunity to assess how different methods of willow control affects subsequent indigenous dominance. The 2011 measurement is assumed to have been done before there were significant visible effects from the herbicide application.

The monitoring plots were randomly located throughout the wetland, and were intended initially to reflect equally areas of either ground or aerial control. However, aerial control was inadvertently carried out over a larger area of the wetland, making it difficult to compare between the treatments either in 2011 or 2014.

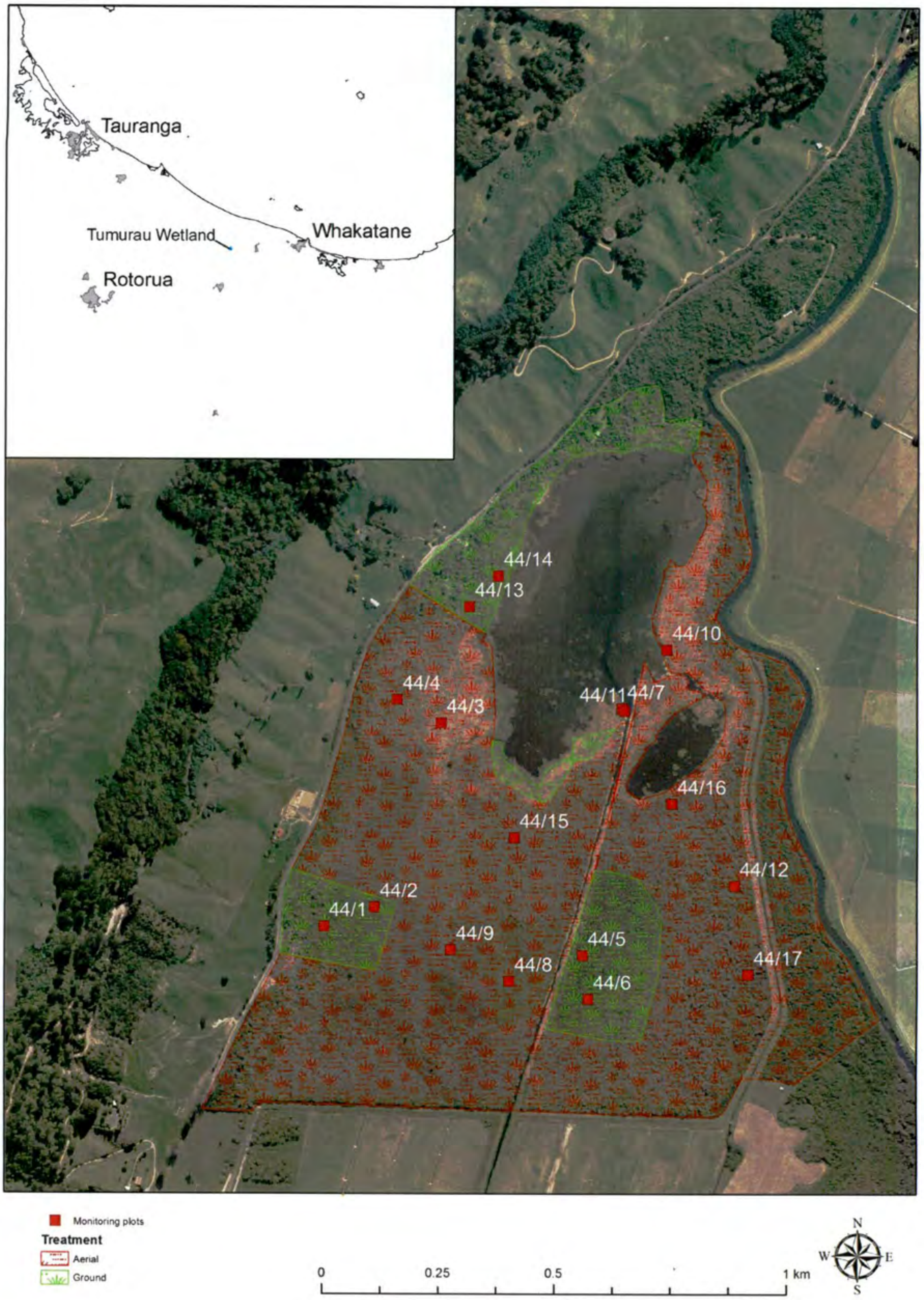


**Figure 1** Willow control areas and vegetation monitoring plots at Tumurau Wetland, Bay of Plenty.

## 3 Objectives

- To identify changes in indigenous and exotic vegetation cover at Tumurau Wetland after herbicide (glyphosate) application for the control of exotic grey willow.
- To attempt to identify if and how different methods of willow control (aerial or ground-based application of herbicide) affect subsequent patterns of wetland vegetation recovery.

## 4 Methods

Fourteen 2×2 m vegetation monitoring plots were established and measured in 2003 following the methods of Clarkson et al. (2004). These and three additional plots were measured in 2011. Sixteen 10×10 m plots were also established and measured in 2011 following the methods of Hurst and Allen (2007). The 10×10 m plots extend south and east from the north-western corner of each of the 2×2 m plots, except for one (plot 44/11) which is encompassed by another 10×10 m plot (plot 44/7).

During the summer of 2010/11, grey willow control was undertaken across most of the wetland, involving aerial and ground-based application of herbicide and some localised felling of trees (Figure 1).

The sixteen 10×10 m plots and seventeen nested 2×2 m plots were remeasured in autumn 2014. Soil cores and foliage samples were taken for chemical analyses.

The canopy cover of each species was assigned to one of 6 classes (<1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%) for each height tier in which they were present (<0.3 m, 0.3–2 m, 2–5 m, 5–12 m). The maximum cover scores of each species in any tier in the 10×10 m plots were used as our measure of species abundance. For example, if a species was assigned to cover class 1 in one tier and class 3 in another, we gave it cover class 3 for that plot. Since we were interested not only in testing whether plots changed in composition in response to treatment but also in the overall compositional direction of change, we used ordination to locate plots in species composition space. We applied a detrended correspondence analysis (DCA) to the data. DCA attempts to find gradients in species composition by fitting axes that capture as much of the variation as possible. Plot positions along axes tell us where they sit along the vegetation gradients within our data. Plots that occur close together in the ordination will have similar species composition, while those that are far apart will be very different. Plotting species in ordination space tells us what the axes mean in terms of species turnover between plots. We included data from both surveys (2011 and 2014) in the DCA ordination, since this allows us to make direct comparisons of plot positions in ordination space across measurements.

To test whether there was a consistent directional change in species composition between years, we ran paired t-tests for the plot ordination scores on the first two DCA axes for all species, indigenous species only, and exotic species only. To test if treatments differed in the direction and magnitude of compositional change between years, we ran an ANOVA on change in axes scores between years, using treatment type as a factor, indigenous species only, and exotic species only.

To investigate changes in soil physical and chemical properties that may influence vegetation recovery, and for comparison with other wetlands, two 7.5 cm soil samples and foliage samples from the dominant canopy species were collected from each 2×2 m plot. Soil samples were analysed for bulk density, pH, conductivity, organic carbon, total nitrogen, total (Kjeldahl) potassium, and total (Kjeldahl) phosphorus. Foliage samples were analysed for carbon, nitrogen, phosphorus, and potassium content. All samples were processed by the Landcare Research Environmental Chemistry Laboratory, Palmerston North.

Paired t-tests were used to test for differences in mean nutrient concentrations between 2011 and 2014 samples.

## 5 Results

One or more of the original wooden pegs marking the plots were relocated for all but three of the plots. New, taller plot markers (fibreglass and/or aluminium rods) were placed at each corner of the 2×2 m plots. Our inability to find some marker pegs is likely to be due to the collapse of the willow canopy and subsequent growth of dense ground vegetation (Figure 2). For plots where we could find no original markers, we recreated the plots as close as possible to previous coordinates and photographs.

**Figure 2** An original plot marker (permolat on wooden peg) found buried beneath a fallen willow trunk and dense regeneration of ground layer species.

## 5.1 Species ordination of both datasets

The first axis of the DCA ordination of the complete vegetation sampling dataset (2011 and 2014 data) contrasts indigenous-dominated wetland communities (including wetland coprosmas, *Machaerina* species and *Empodisma robustum*) on the right-hand side and drier exotic-dominated communities (including *Tradescantia fluminensis* and *Persicaria* species) on the left (Figure 3). The second axis is a contrast between willow-dominant communities at the bottom and open herbaceous communities at the top. Thus we can interpret increases in scores for the first axis as an increase in exotic cover, and for the second axis as a shift away from previously willow-dominated communities.

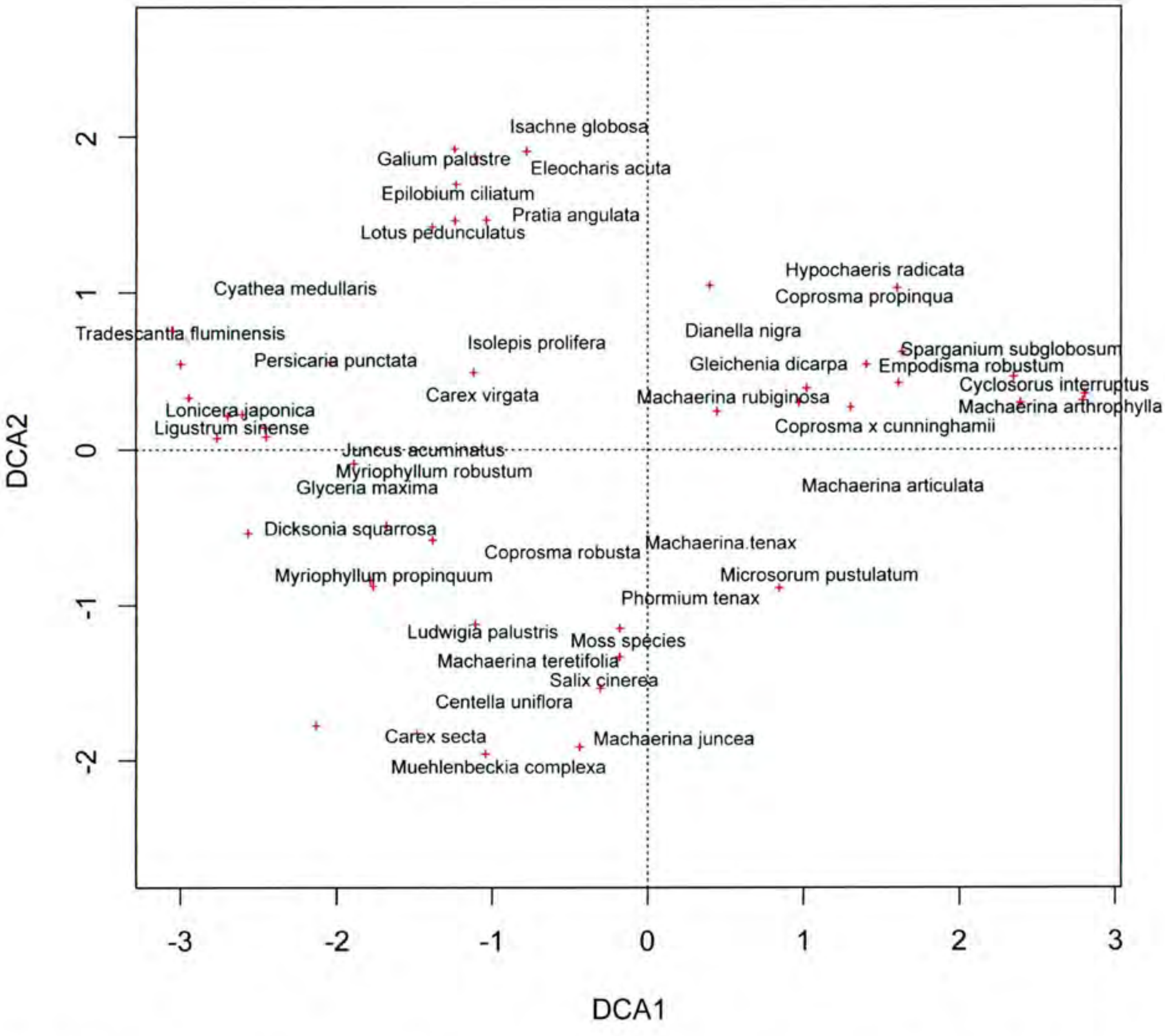


**Figure 3** Species ordination of the 2011 and 2014 vegetation plot data from Tumurau Wetland, Bay of Plenty.

## 5.2 Change in indigenous and exotic cover between 2011 and 2014

Between 2011 and 2014, there was an overall decline in indigenous cover and no overall change in exotic cover across all plots. This can be illustrated by plotting the total cover in 2014, minus the total cover in 2011 (Figure 4), which shows that the change in total cover of native species is strongly negatively skewed, but the change in exotic cover is fairly evenly distributed around no change. Although there was no change in overall exotic cover, there was a change in the vertical distribution of this cover, from upper to lower tiers (Figure 5) caused by the removal of exotic canopy species such as grey willow and small-leaf privet (*Ligustrum sinense*) and an increase in exotic herbs.

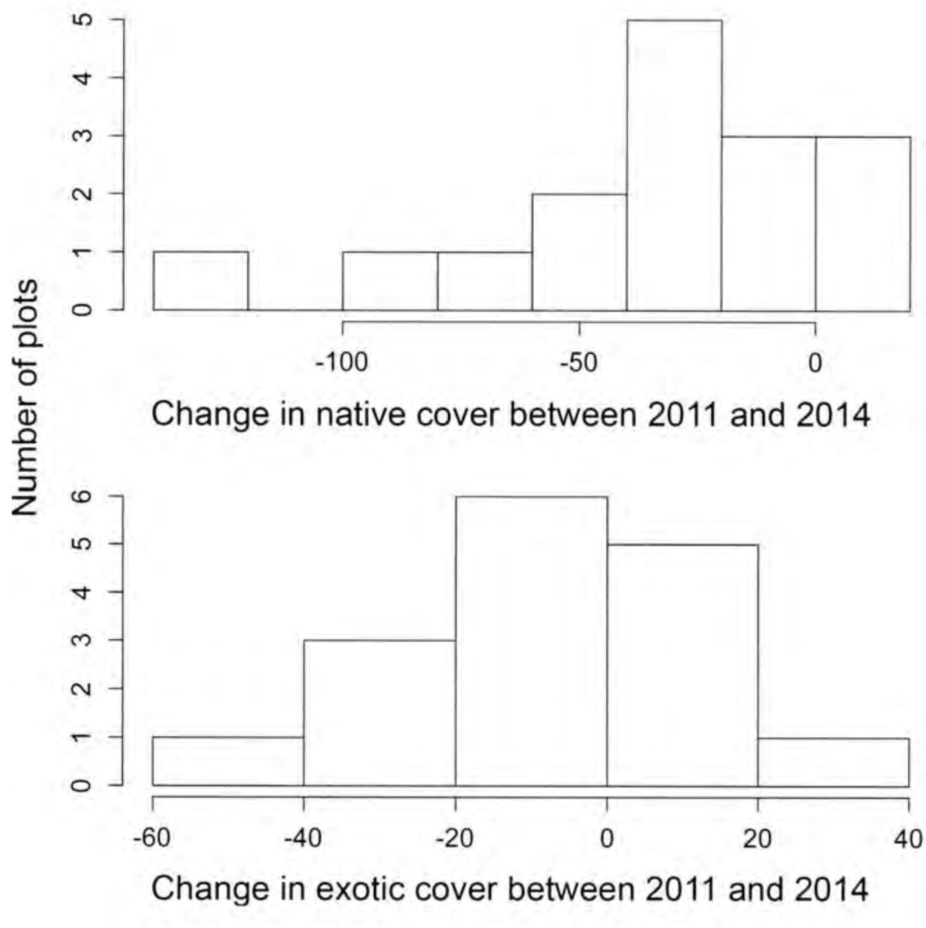


**Figure 4** Change in indigenous cover and exotic cover between 2011 and 2014. Plots where cover of native/exotic species declined have negative values, and plots where native/exotic cover increased have positive values.

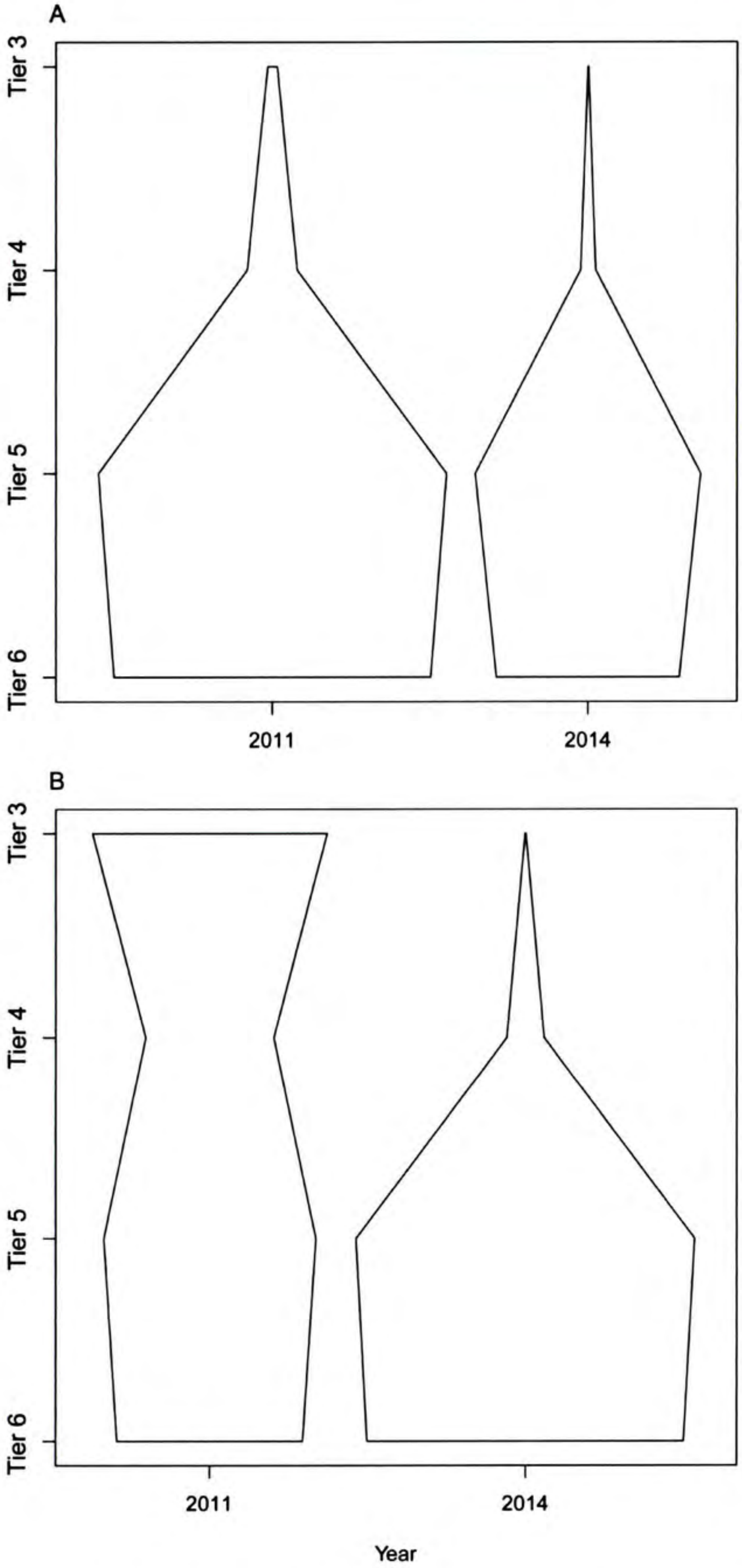


**Figure 5** Total cover (sum of the cover class median values as percent) of all native (A) and exotic (B) species by height tier in 2011 and 2014. Tier 6 is 0–0.3 m above ground, Tier 5 is 0.3–2 m, Tier 4 is 2–5 m, and Tier 3 is 5–12 m. The x-axis scale differs between A and B.

### 5.3 Change in plot ordination axis scores between 2011 and 2014

Paired t-tests revealed significant directional shifts for the first two DCA axes of the plot ordinations between measurements (Figure 6). Between 2011 and 2014, plots shifted from right to left along the first axis (t = -2.3995, df = 15, $p$ = 0.03), indicating a relative increase in exotic cover; indigenous species cover declined (t = -3.4786, df = 15, $p$ = 0.003) but exotic cover remained constant (t = -0.8973, df = 15, $p$ = 0.4).

Plots also shifted from bottom to top on the second axis (t = -2.3235, df = 15, $p$ = 0.04), indicating an increase in the abundance of herbaceous wetland species. For the first axis, overall significant differences appear to be driven by relatively minor changes in most plots and for the second, major changes in a few plots (Figure 6).

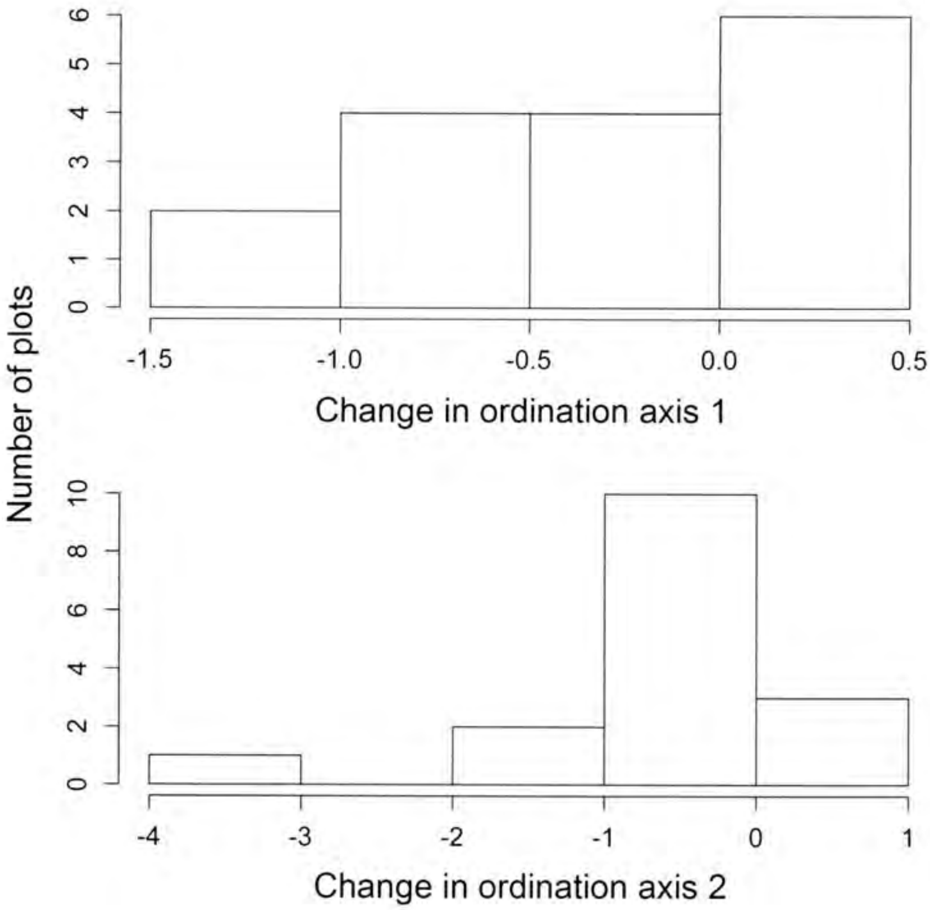


**Figure 6** Change in plot DCA ordination axis scores between 2011 and 2014. Negative values represent a shift to the left (for axis 1) and down (for axis 2).

### 5.4 Effect of aerial vs. ground-based willow control

There was no significant difference (Axis 1: F = 0.3, $p$ >0.6; Axis 2: F = 0.7, $p$> 0.4) between aerial and ground willow control treatments in the magnitude of change in either axis

(Figure 7). Neither change in indigenous species cover (F = 0.018, $p = 0.9$) nor exotic cover (F = 1.673, $p = 0.2$) was related to treatment type (Figure 8). Indigenous species cover reduced significantly after both ground control (t = 2.7008, df = 5, $p = 0.04$) and aerial control (t = 2.3883, df = 8, $p = 0.04$). Exotic species cover did not change significantly after either ground control (t = 1.3281, df = 5, $p = 0.2$) or aerial control (t = –0.3285, df = 8, $p$ = 0.8).

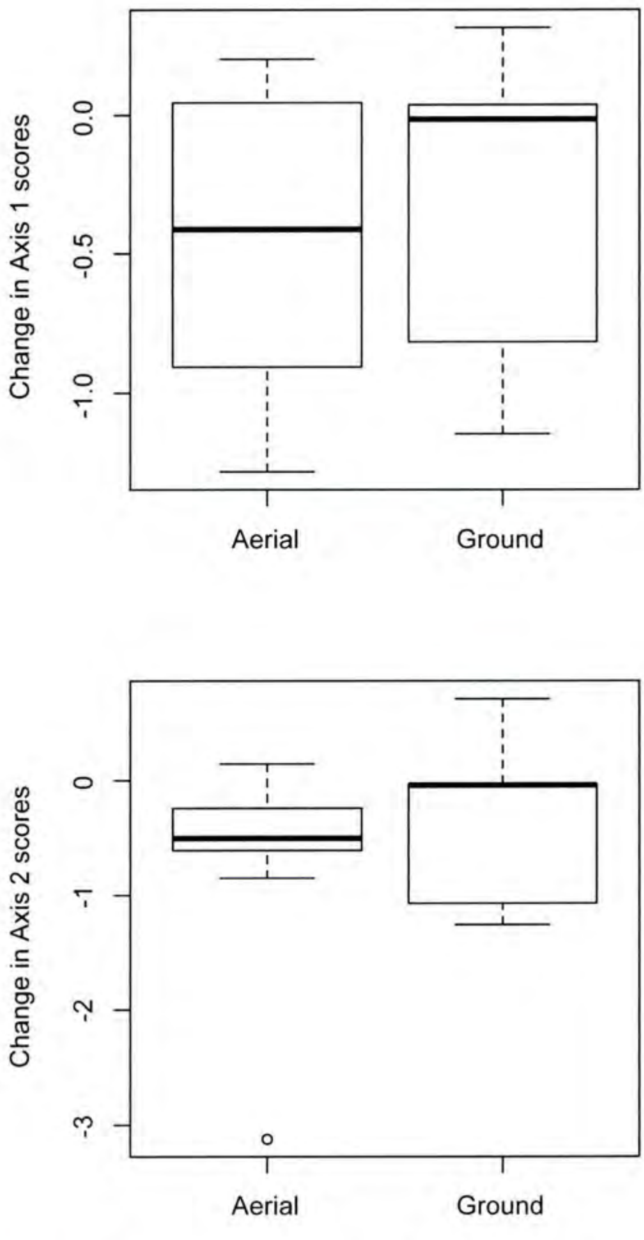


**Figure 7** Box plot of change in ordination axis scores between 2011 and 2014 after aerial and ground-based willow control. Horizontal bars represent median change; the top and bottom of the boxes represent the 75th and 25th quartile respectively; the dashed vertical lines show the maximum and minimum values.

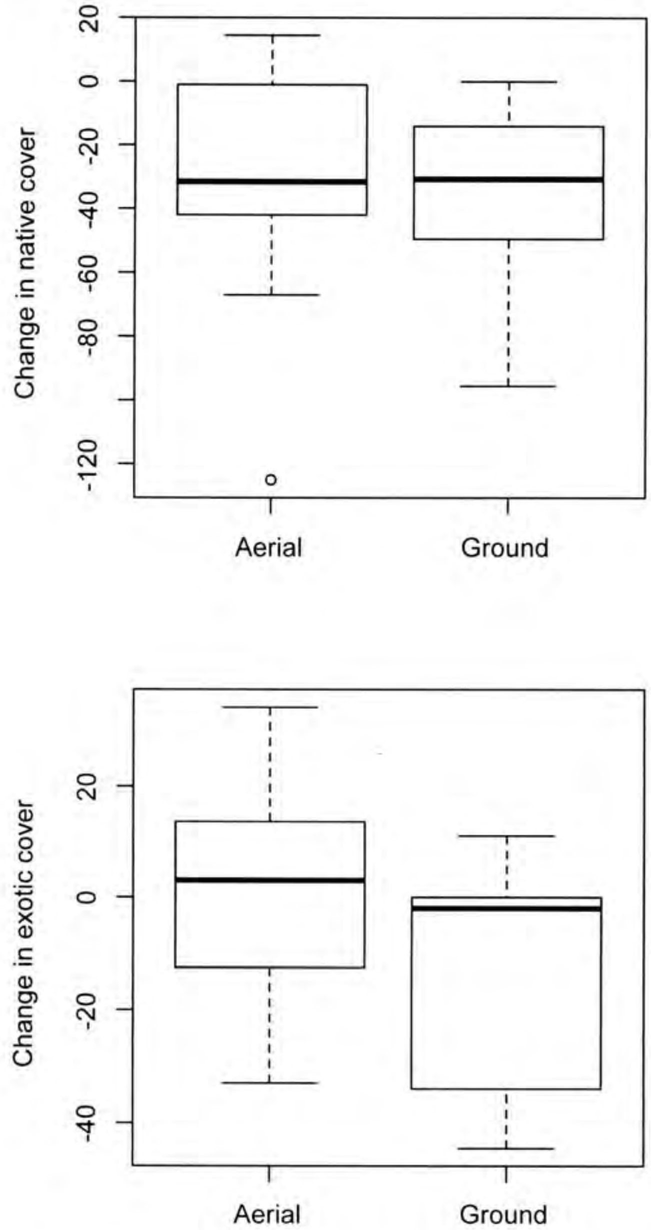


**Figure 8** Box plot of change in indigenous cover and exotic cover between 2011 and 2014 after aerial and ground-based willow control. Horizontal bars represent median change; the top and bottom of the boxes represent the 75th and 25th quartile respectively; the dashed vertical lines show the maximum and minimum values.

## 5.5 Soil and foliar analyses

Soil collected in 2014 had significantly lower bulk density and higher total carbon than in 2011 (t = 2.411, df = 15, $p = 0.03$, t = -2.931, df = 15, $p = 0.01$ respectively). Total nitrogen, phosphorus, and pH were not significantly different ($p > 0.05$; Table 1).

**Table 1** Soil chemistry of monitoring plots at Tumurau Wetland in 2011 and 2014

| | Bulk density ($T/m^3$) | | pH | | Conductivity (µS) | | Total Carbon (%) | | Total Nitrogen (%) | | Phosphorus (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plot** | **2011** | **2014** | **2011** | **2014** | **2011** | **2014** | **2011** | **2014** | **2011** | **2014** | **2011** | **2014** |
| 44/1 | 0.08 | 0.06 | 5.4 | 5.38 | 0.65 | 1.34 | 36.5 | 45.6 | 1.9 | 1.24 | 0.082 | 0.054 |
| 44/2 | 0.09 | 0.08 | 5.4 | 5.06 | 0.5 | 0.88 | 35.4 | 39.6 | 2.4 | 2.21 | 0.113 | 0.099 |
| 44/3 | 0.07 | 0.06 | 5.6 | 5.83 | 1.27 | 1.68 | 41.9 | 37.7 | 2.2 | 2.33 | 0.129 | 0.175 |
| 44/4 | 0.1 | 0.08 | 5.4 | 5.64 | 0.72 | 0.83 | 40.4 | 43.8 | 2.2 | 2.11 | 0.134 | 0.124 |
| 44/5 | 0.09 | 0.1 | 4.4 | 4.24 | 0.21 | 1.08 | 34.3 | 47.9 | 2.1 | 2.22 | 0.143 | 0.114 |
| 44/6 | 0.14 | 0.1 | 4.3 | 4.18 | 0.18 | 46.4 | 29.5 | 46.4 | 1.8 | 2.09 | 0.117 | 0.092 |
| 44/8 | 0.05 | 0.04 | 5.1 | 5.14 | 0.18 | 1.55 | 31 | 38.9 | 2 | 1.98 | 0.0935 | 0.131 |
| 44/9 | 0.1 | 0.08 | 5.5 | 5.17 | 0.29 | 0.65 | 37.4 | 38.5 | 2.5 | 2.48 | 0.106 | 0.126 |
| 44/10 | 0.07 | 0.06 | 5.4 | 5.8 | 2.21 | 1.57 | 40.6 | 41 | 2.3 | 2.19 | 0.125 | 0.108 |
| 44/11 | 0.14 | 0.08 | 5.5 | 5.88 | 0.43 | 1.13 | 19.3 | 34.3 | 1.3 | 2.19 | 0.109 | 0.119 |
| 44/12 | 0.46 | 0.48 | 4.8 | 5.17 | 0.09 | 0.2 | 12.1 | 12 | 0.81 | 0.83 | 0.098 | 0.100 |
| 44/13 | 0.32 | 0.34 | 5.5 | 5.53 | 0.12 | 0.11 | 10.3 | 7.5 | 0.63 | 0.48 | 0.056 | 0.050 |
| 44/14 | 0.24 | 0.12 | 5.6 | 5.57 | 0.14 | 0.19 | 12.4 | 15.9 | 0.67 | 0.9 | 0.071 | 0.067 |
| 44/15 | 0.07 | 0.08 | 5.2 | 5.32 | 0.52 | 0.42 | 40.4 | 41 | 2.5 | 2.73 | 0.149 | 0.164 |
| 44/16 | 0.14 | 0.06 | 4.9 | 5.26 | 0.2 | 0.31 | 24.7 | 45.7 | 1.3 | 2.29 | 0.093 | 0.114 |
| 44/17 | 0.52 | 0.5 | 5.2 | 4.97 | 0.15 | 0.34 | 9.6 | 8.7 | 0.74 | 0.72 | 0.115 | 0.111 |
| *Mean* | *0.17* | *0.15* | *5.2* | *5.3* | *0.49* | *3.67* | *28.5* | *34.0* | *1.7* | *1.81* | *0.108* | *0.109* |

Not all plant species sampled for chemical analysis in 2011 could be collected from the same plots in 2014 due to the loss of some species through willow control. Statistical comparison of foliar chemistry was not carried out in these instances, but results are given in Appendix 1.

## 6 Conclusions

Control of grey willow by aerial or ground means has led to an increase in the proportion of exotic cover in Tumurau Wetland, at least in the short term (3 years after treatments applied), and especially in lower tiers. This increase in relative exotic cover has resulted from reduced cover of indigenous species rather than from increased cover of exotic species, and removal of the willow canopy. Possible mechanisms are (1) differential susceptibility of indigenous and exotic herbaceous species to the herbicide (glyphosate) used; and (2) greatly increased sub-canopy light levels after death of the tree canopy causing stress from a suddenly altered microclimate for indigenous species sensitive to exposure. The similarity of changes in vegetation after aerial and ground control suggest that the second mechanism is more likely to be responsible for the reduction in indigenous cover.

Although willow control has reduced indigenous dominance, a measure of ecological integrity (Lee et al. 2005) in the short term, more time is needed to ascertain whether this is a transitory effect and a normal part of the recovery process in wetlands where willows have been long dominant. In other wetlands, populations of some indigenous species (e.g. *Carex secta*, *C. virgata*, and *Machaerina* spp.) also present at Tumurau have recovered several years after similar willow control operations (BR Clarkson, Landcare Research, pers. comm.). Stable exotic cover implies that the loss of almost all willow cover has been partly compensated for by an increase in the cover of herbaceous exotic species.

The increase in soil carbon and lower bulk density after willow control is likely to be due to incorporation of plant material into the soil from the dead foliage and stems. These changes are not likely to significantly affect vegetation composition, at least in the short-term.

## 7 Recommendations

- Plots should be remeasured in 5 years' time to see if the decline in indigenous cover persists.
- A more gradual, staged removal of willow using ground-based control of coupes could be trialled in another wetland, to see if the microclimatic shock on indigenous plants can be moderated. Surviving indigenous species may more quickly recolonize coupes than after wholesale willow control. Consideration could also be given to initially targeting female grey willow trees to minimise seed dispersal.

## 8 Acknowledgements

We thank Bay of Plenty Regional Council for funding this project and Nancy Willems for supporting the work and organising access permission with the wetland owners, and the managers of Tumurau Farm. Scott Bartlam (Landcare Research, Hamilton) assisted with fieldwork.

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## Appendix 1 – Foliar chemical analysis

Foliage nutrient composition of species collected in monitoring plots at Tumurau Wetland in 2011 and 2014. * denotes exotic

| Plot | Year | Plant species | Carbon (%) | Nitrogen (%) | Phosphorus (%) | Potassium (%) |
|---|---|---|---|---|---|---|
| 44/1 | 2011 | *Empodisma robustum* | | 0.79 | 0.03 | |
| 44/2 | 2011 | **Salix cinerea* | | 1.18 | 0.07 | |
| 44/2 | 2011 | *Empodisma robustum* | | 1.07 | 0.04 | |
| 44/3 | 2011 | *Isachne globosa* | | 1.57 | 0.14 | |
| 44/4 | 2011 | *Machaerina rubiginosa* | | 1.14 | 0.06 | |
| 44/4 | 2011 | **Salix cinerea* | | 1.35 | 0.64 | |
| 44/5 | 2011 | *Leptospermum scoparium* | | 1.29 | 0.07 | |
| 44/6 | 2011 | *Machaerina rubiginosa* | | 1.12 | 0.05 | |
| 44/7 | 2011 | **Polygonum punctatum* | | 1.4 | 0.22 | |
| 44/8 | 2011 | *Isachne globosa* | | 1.96 | 0.19 | |
| 44/9 | 2011 | *Machaerina rubiginosa* | | 1.07 | 0.06 | |
| 44/10 | 2011 | **Glyceria maxima* | | 2.73 | 0.22 | |
| 44/10 | 2011 | *Typha orientalis* | | 1.43 | 0.13 | |
| 44/11 | 2011 | **Glyceria maxima* | | 1.98 | 0.12 | |
| 44/12 | 2011 | **Salix cinerea* | | 2.21 | 0.18 | |
| 44/13 | 2011 | *Coprosma tenuicaulis* | | 1.47 | 0.11 | |
| 44/14 | 2011 | *Machaerina juncea* | | 0.77 | 0.03 | |
| 44/14 | 2011 | *Phormium tenax* | | 1.39 | 0.16 | |
| 44/15 | 2011 | *Machaerina rubiginosa* | | 1.19 | 0.07 | |
| 44/16 | 2011 | *Machaerina rubiginosa* | | 1.01 | 0.06 | |
| 44/17 | 2011 | **Ligustrum sinense* | | 2.35 | 0.15 | |
| 44/1 | 2014 | *Leptospermum scoparium* | 53.6 | 1.05 | 0.06 | 0.43 |
| 44/1 | 2014 | *Empodisma robustum* | 48.8 | 1.21 | 0.05 | 0.62 |
| 44/2 | 2014 | *Leptospermum scoparium* | 52.6 | 1.69 | 0.08 | 0.75 |
| 44/2 | 2014 | *Empodisma robustum* | 48.5 | 1.16 | 0.02 | 0.34 |
| 44/3 | 2014 | *Isachne globosa* | 39.8 | 1.85 | 0.14 | 0.64 |
| 44/4 | 2014 | *Coprosma tenuicaulis* | 47 | 2.1 | 0.16 | 0.77 |
| 44/4 | 2014 | **Lotus pedunculatus* | 47.5 | 4.65 | 0.28 | 1.73 |
| 44/5 | 2014 | *Leptospermum scoparium* | 54.6 | 1.31 | 0.06 | 0.46 |
| 44/6 | 2014 | *Phormium tenax* | 53 | 1.77 | 0.09 | 1.16 |
| 44/6 | 2014 | *Coprosma tenuicaulis* | 49.2 | 1.45 | 0.1 | 0.6 |
| 44/8 | 2014 | *Isachne globosa* | 43.5 | 1.64 | 0.14 | 0.97 |
| 44/8 | 2014 | *Phormium tenax* | 51.6 | 1.13 | 0.08 | 0.88 |

| Plot | Year | Plant species | Carbon (%) | Nitrogen (%) | Phosphorus (%) | Potassium (%) |
|---|---|---|---|---|---|---|
| 44/8 | 2014 | *Coprosma tenuicaulis* | 48.2 | 2.09 | 0.14 | 0.82 |
| 44/9 | 2014 | *Leptospermum scoparium* | 53.8 | 1.61 | 0.09 | 0.62 |
| 44/10 | 2014 | *Typha orientalis* | 48.9 | 1.77 | 0.13 | 1 |
| 44/10 | 2014 | **Glyceria maxima* | 40.9 | 2.12 | 0.15 | 1.46 |
| 44/11 | 2014 | **Glyceria maxima* | 45.2 | 2.79 | 0.16 | 1.31 |
| 44/12 | 2014 | *Carex secta* | 44.1 | 2.21 | 0.13 | 1.56 |
| 44/12 | 2014 | **Salix cinerea* | 49.6 | 3.24 | 0.2 | 1.53 |
| 44/13 | 2014 | *Coprosma tenuicaulis* | 49 | 1.54 | 0.09 | 1.04 |
| 44/14 | 2014 | *Phormium tenax* | 50.4 | 1.38 | 0.14 | 1.46 |
| 44/14 | 2014 | *Machaerina juncea* | 43.1 | 1.06 | 0.05 | 1.53 |
| 44/15 | 2014 | *Leptospermum scoparium* | 52.3 | 1.51 | 0.09 | 0.73 |
| 44/16 | 2014 | *Leptospermum scoparium* | 52.7 | 1.13 | 0.07 | 0.48 |
| 44/16 | 2014 | *Coprosma tenuicaulis* | 49.4 | 1.57 | 0.09 | 0.63 |
| 44/17 | 2014 | *Persicaria decipiens* | 47.2 | 2.99 | 0.16 | 1.55 |
| 44/17 | 2014 | **Ligustrum sinense* | 48.9 | 2.18 | 0.13 | 0.92 |

## Appendix 2 – Plot photos: 2011 and 2014

**Figure 9** Plot 44/1, 20014. There is no photo for this plot in 2011.

**Figure 10** Plot 44/2, 2014. There is no photo for this plot in 2011.

**Figure 11** Plot 44/3, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 12** Plot 44/3, 2014.

**Figure 13** Plot 44/4, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 14** Plot 44/4, 2014.

**Figure 15** Plot 44/5, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 16** Plot 44/5, 2014.

**Figure 17** Plot 44/6, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 18** Plot 44/6, 2014.

**Figure 19** Plot 44/7, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 20** Plot 44/7, 2014.

**Figure 21** Plot 44/8, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 22** Plot 44/8, 2014.

**Figure 23** Plot 44/9, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 24** Plot 44/9, 2014.

**Figure 25** Plot 44/10, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 26** Plot 44/10, 2014.

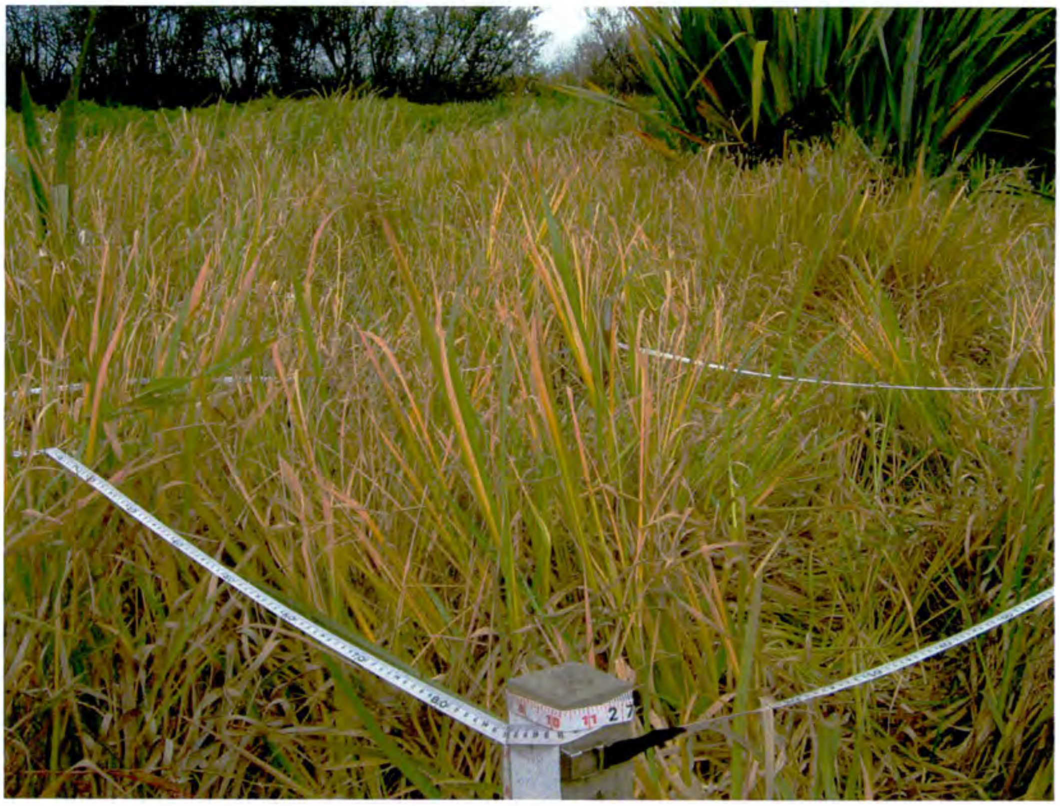

**Figure 27** Plot 44/11, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 28** Plot 44/11, 2014.

**Figure 29** Plot 44/12, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 30** Plot 44/12, 2014.

**Figure 31** Plot 44/13, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 32** Plot 44/13, 2014.

**Figure 33** Plot 44/14, 2014. There is no photo for this plot in 2011.

**Figure 34** Plot 44/15, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 35** Plot 44/15, 2014.

**Figure 36** Plot 44/16, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 37** Plot 44/16, 2014.

**Figure 38** Plot 44/17, 2011 (Photo by H Dean, courtesy N Willems).

**Figure 39** Plot 44/17, 2014.