Donatia novae-zelandiae in the Awarua – Waituna wetland complex:

Current research, results and future management considerations

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Donatia cushion bog, Tiwai Spit

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SUMMARY OF FINDINGS AND RECCOMENDATIONS

1. *Donatia novae-zelandiae* is an iconic plant and a botanical highlight within the Awarua-Waituna wetland complex. The wetland complex is the only known locality where this sub alpine species occurs at near sea level.
2. Currently the plant is only found at a few localities within the wetland and its range is restricting within the wetlands. The common belief is that the encroachment of manuka shrub land is reducing its range and two field studies have been implemented to understand the reason for its decline.
3. At one study site, in an area of encroaching manuka shrub land, competing woody shrubs were removed by clipping in an attempt to aid *Donatia* growth. This manipulation was not successful in halting the decline in *Donatia* coverage, however decreased the rate of decline in comparison to adjacent sites not receiving shrub removal.
4. The second site underwent agricultural development in the early 1980's, however received no subsequent development. Here, *Donatia* recruitment and growth has occurred with the area occupied by numerous *Donatia* cushions which are increasing in size and number.
5. Our studies conclude that there is a complexity of factors surrounding *Donatia's* growth and recruitment in the wetland. It appears that woody shrub removal alone is not enough to halt the decline of *Donatia* at some sites and that disturbance, whether by fire or light agricultural disturbance, aids the plants recruitment and growth.
6. Restoring, or at least retaining, these *Donatia* remnants within the wetland is a priority for the community and a consideration for the Department of Conservation to undertake, however restoration techniques are unknown and some possible scenarios such as burning are not commensurate with the restoration and management goals for the wider wetland.
7. Discussion between the Department, community and other interested parties needs to take place in order to determine how we approach this issue and investigate possible restoration scenarios. Further research is also required to identify those factors which are critical to the successful growth and recruitment of *Donatia* within the wetlands.

INTRODUCTION

The cushion bog species *Donatia novae-zelandiae* is most typically found in the sub alpine and alpine bioclimatic zones in New Zealand and Tasmania, Australia. Within the Awarua-Waituna wetland complex, located on the Awarua Plains in the Waituna Ecological District, Southland, it is found in the lowland zone and adjacent to the coast at sea level. It is considered a highly distinctive component of the flora in the wetlands and is considered the "botanical highlight" of the Awarua-Waituna wetland complex (Johnson 1988). However there is evidence that the species is declining in frequency and distribution within the wetland and this is of concern to a number of people within the community.

Being a low stature cushion plant, reliant on disturbance and the absence of competition from woody plants for its survival, the viability of the *Donatia* population is being severely compromised by the encroachment of woody competitors and the lack of new recruitment sites within the wetland complex (Johnson 1996; Ward 2001). This decline in *Donatia* is clearly evident when reading historical accounts of its distribution within the wetlands which describe it as being common throughout the wetland (Department of Lands and Survey 1965). More recently photo points have documented the decline in cushion bog coverage within the wetland in the space of only a few decades (Ward 2001).

The Department of Conservation has not actively managed *Donatia* within the Awarua-Waituna wetland complex however it has undertaken research to understand the key drivers behind its decline and its associated cushion bog community. The realisation that, if not managed, *Donatia* may become functionally extinct in the wetland within the next few decades has prompted the Department to investigate these agents of decline and evaluate management options for *Donatia* and its associated cushion bog community.

This report reviews past and current studies surrounding two *Donatia* communities within the Awarua-Waituna wetland complex to try and evaluate the agents of decline and factors that influence the species growth and recruitment. This report also addresses future management considerations and research opportunities that should be considered if the Department is going to actively manage the species within the wetland.

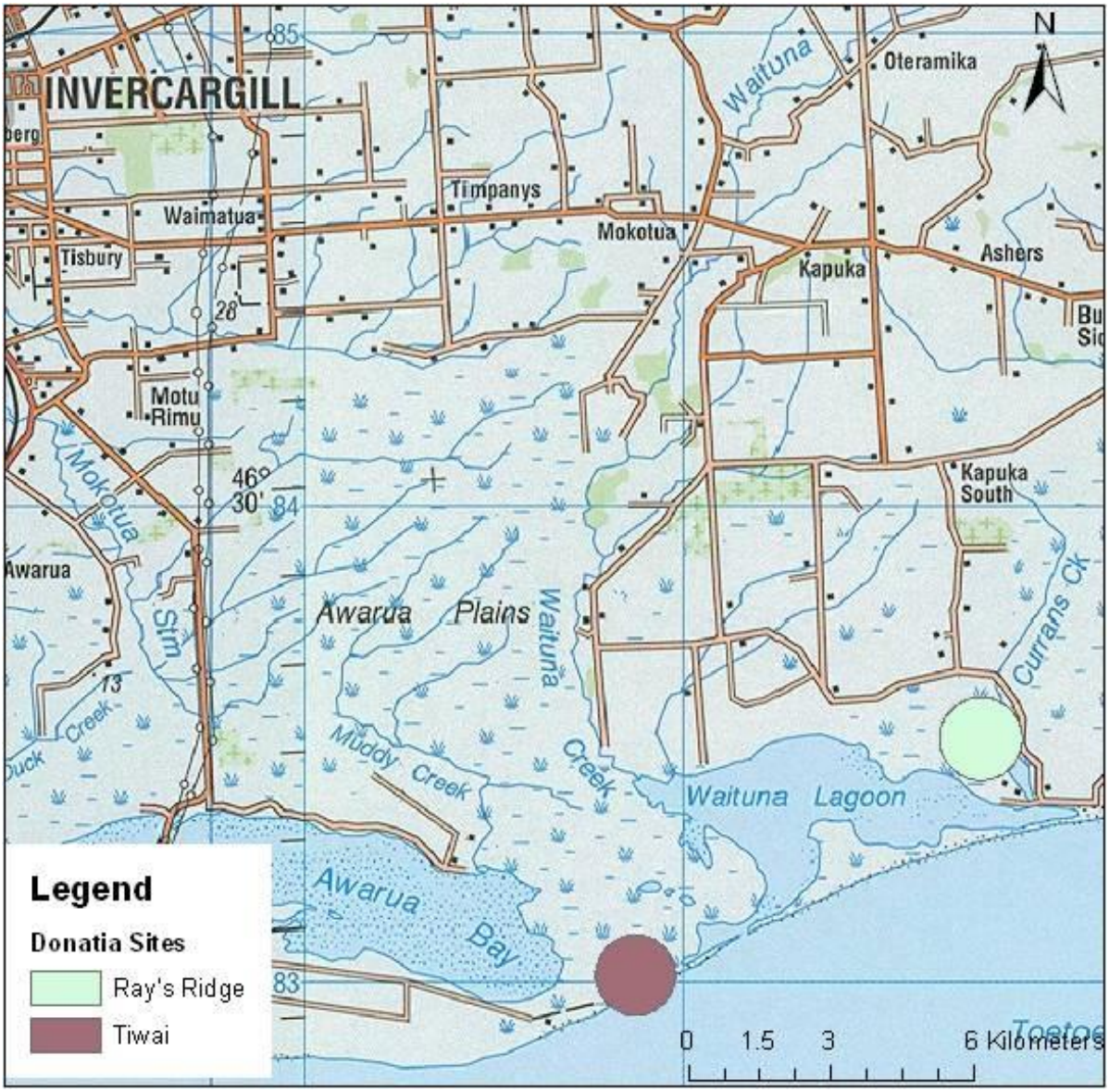

FIGURE 1: LOCATIONS OF THE TWO RESEARCH SITES WITHIN THE AWARUA-WAITUNA WETLAND COMPLEX

DONATIA'S HISTORY WITHIN THE AWARUA – WAITUNA WETLAND COMPLEX

The vegetation within the Awarua – Waituna complex has been subject to a long history of disturbance. The original vegetation consisted of a mosaic of wetland types interspersed by manuka (*Leptospermum scoparium*) scrubland and forest ecosystems. Following the arrival of Māori and latterly Pakehā, fires removed much of the forest cover, simplified the vegetation communities present, and provided more opportunities for *Donatia* to establish in modified areas of the wetland. Recent paeleoecolgy research from within the wetlands has highlighted that *Donatia* pollen counts were at their highest within the wetland after this period of high fire disturbance.

Figure 2 suggests that *Donatia* presence within the wetland was at its peak during early European colonisation and this is supported by accounts like that of Crosby–Smith who's 1927 description of the Awarua plains clearly accounts for cushion bog communities containing *Donatia* being not uncommon within the landscape. A Department of Lands and Survey report from the area indeed shows that in 1865 the extent of the cushion bogs was far more extensive than today.

It is clear that fire, or at least the disturbance it brings, is likely to be a critical factor behind the species persistence within the wetland. The removal of competing vegetation and the creation of suitable habitat brought about by fire leads us to believe that it is a key driver behind the elevated populations of *Donatia* that we have seen over the past century.

Considering the historical distribution of *Donatia* it is prudent to suggest that *Donatia's* current extent within the wetland complex is over represented and its perceived decline is just a natural retraction to its original range within the wetland. However there is a push from some members of the community to retain the current level of *Donatia*. In order to preserve its current distribution in the wetland complex it is evident that active management is required to maintain these communities and create conditions which facilitate the growth and recruitment of *Donatia*. Just what sort of management is required has been a pressing question and two key research projects have been established to look at this.

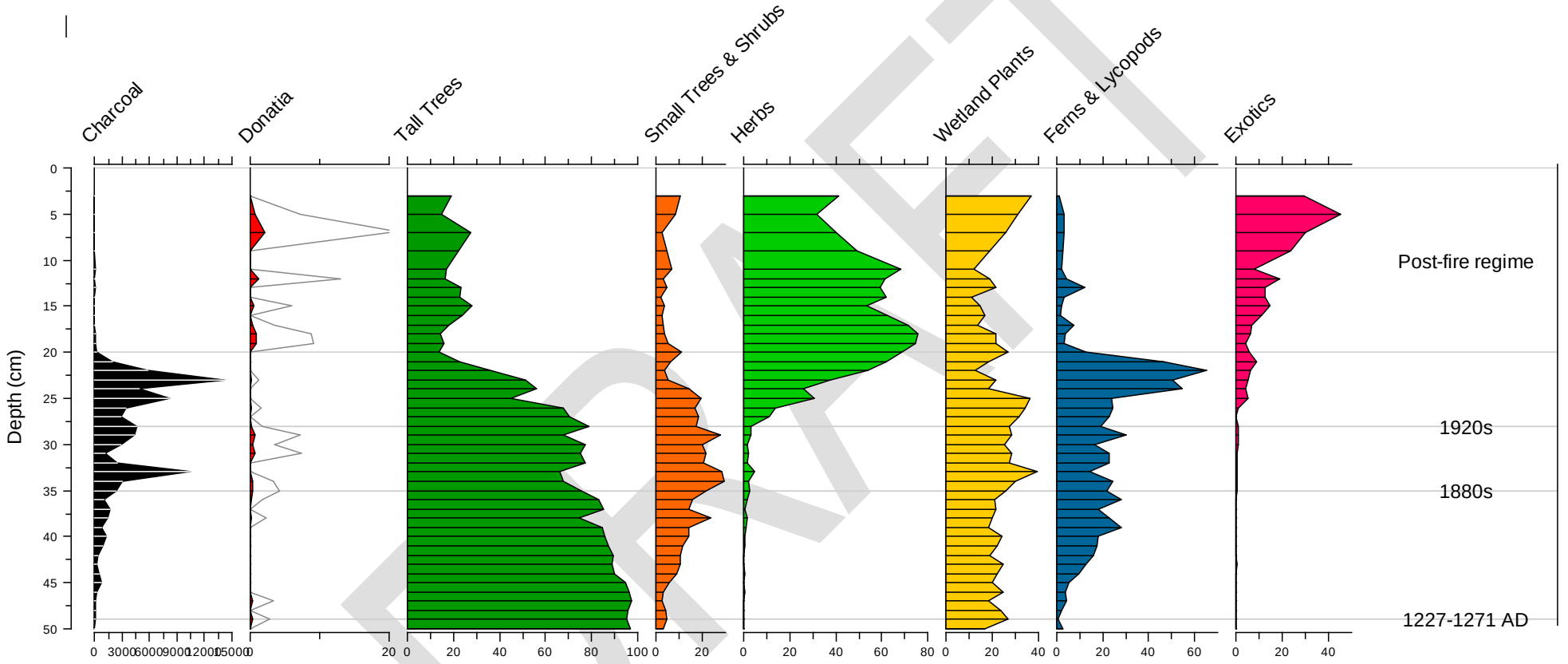

FIGURE 2: SUMMARY POLLEN DIAGRAM OF THE WAITUNA *DONATIA* CORE SITE WITH POLLEN COUNTS REPRESENTED ON EACH GRAPHS X AXIS. GREY LINES ON THE DONATIA GRAPH ARE A 5 X EXAGGERATION TO EMPHASISE DONATIA POLLEN COUNTS. THE WAITUNA CORE (LAB I.D. X06/3, GRID REFERENCE NZMS MAP SHEET F47: 2175214E, 5398296N) WAS COLLECTED FROM A 600 X 300M AREA OF RAISED BOG, APPROXIMATELY 3M HIGHER THAN THE SURROUNDING BOG LEVEL, IN A DONATIA CUSHIONFIELD. VEGETATION IMMEDIATELY SURROUNDING THE CORE SITE CONSISTED OF SHORT WIRE RUSH AND SPHAGNUM (80%) WITH SCATTERED SHORT MANUKA (15 - 20%), GLEICHENIA, CUSHION DONATIA AND DROSERA. DATES PROVIDED ON Y AXIS ARE APPROXIMATES.

CURRENT RESEARCH

There are currently two research sites in operation within the wetland complex. At the eastern end of Tiwai Peninsula there is a small cushion bog community remaining, probably part of a previously more extensive community, which has slowly been reduced in size by the encroachment of manuka and inaka (*Dracophyllum longifolium*). At this site there are photo points along with a split plot trial looking at the response of *Donatia* and other cushion bog species to the physical removal of competing woody vegetation (by clipping).

On Ray Waghorn's property, beside Curran's Creek, there is another cushion bog community. This site has been grazed, drained, burnt and fertilised over the years and is under private ownership. With the consent of the land owner *Donatia* within a 50x100m plot has been mapped out and measured for structural integrity and recruitment. The primary focus is to look at the health and recruitment of the *Donatia* at this site under a human induced disturbance regime. There were intentions to burn half of the plot to assess the response of *Donatia* to fire however this has not eventuated yet. Research at this site has been progressed with the site being used by Otago University doctorate student Britt Cranston for her research into the ecology of *Donatia*.

Other research on cushion communities within the wetland has been limited to a series of trials in the 1980's looking at the effectiveness of poisoning black backed gull (*Larus dominicanus*) colonies in preserving cushion bog communities on Tiwai Spit. Within this operation a series of photo points were established and these have been subsequently remeasured with the last occurring in January 2011. The photos conclusively show that at this site manuka and Dracophyllum are invading the cushion communities vigorously (Johnson 1988; Ward 2001). These photos can be seen in Appendix 1.

RESEARCH SITE 1: TIWAI

Introduction

At 0m altitude this site has the lowest elevation of any known population of *Donatia* in New Zealand. It is believed that cushion plant communities were extensive along this part of the peninsula however in recent times the encroachment of native woody species has led to the regression of these areas to the point where there is only a small 10x20m site left with an intact cushion bog community.

Photo points in the area, established in 1984 by the Department of Lands and Survey, and a subsequent study of the site by post graduate student Molly Ward highlighted that this vegetation encroachment was severely restricting the cushion bog community and one of the recommendations was to initiate vegetation removal by clipping to halt the encroachment of woody vegetation at the site (Ward 2001).

Subsequently in 2002 Department of Conservation botanists, Carol West and Brian Rance, led the establishment of four vegetation plots at the site, two being in an open cushion bog, *Donatia* dominated community, while two were in a shrub (manuka/inaka) dominated community containing remnants of *Donatia* and other cushion bog species.

At each of these sites one plot was cleared of all woody vegetation while the other was left intact.

The goal of the study was to see if the physical clearance of the competing woody vegetation halted the decline of *Donatia* and its other associated cushion bog community species.

Study design and methods

Four plots were established in 2002, these were remeasured in 2008. Two were located in open cushion bog and two in closed/woody dominated cushion bog. The two open plots were called the open – cleared plot and the open – uncleared plot. Each plot was 5x5m in size and gridded into 25 1x1m subplots when measured. The open – cleared plot had all woody plants removed by way of clipping to ground level after it had been remeasured.

The closed plots were established as 5x5m plots however in the initial measure, due to a lack of time, only a 3x5m part of these plots were measured. The full 5x5m plot was remeasured in 2008. They were called the closed – cleared and closed - uncleared plots. The closed cleared plot had all woody material removed by way of clipping after its first measure.

At each 1x1m subplot percent cover of each species was recorded. If a species was less than 1% it was recorded as present (P). In the first measure the height of all inaka and manuka plants was recorded for each subplot. This was changed in the second remeasure (2008) - manuka and inaka were given a top height and an average height as recruitment was so high it was not feasible to record every plants height as done at the establishment.

Data was entered into Microsoft Excel and analysis was undertaken using Microsoft Excel and R2.9.2 (R Development Core Team 2008).

Results

Donatia Coverage – open cushion bog

The open cushion field communities have changed in their *Donatia* coverage markedly since the first measurement. On the cleared plot, *Donatia* coverage was initially at 42% however declined by 33% over the six years between measurements to 28%. The uncleared plot declined in coverage by 37% from 60% cover in 2002 to 38% cover in 2008 showing both plots, although containing differing amounts of *Donatia*, declined at approximately the same rates as each other. Paired T Tests assuming unequal variances were performed between years for plots using *Donatia* cover within the subplots as the base unit. The results showed that the decline in *Donatia* coverage between the measurements in the open plots was highly significant in both plots.

Donatia Coverage – closed cushion bog

In the closed plots initial *Donatia* coverage was already low – 3.8% and 9.2% in the cleared and uncleared plots respectively and declines in the coverage was correspondingly small. These declines were not significant when paired T Tests were performed.

Table 1 below shows the average percentage coverage of *Donatia* in 2002 and 2008, the % change and associated p values from paired T Tests assuming unequal variances.

TABLE 1: PERCENTAGE COVER AVERAGES FOR *DONATIA* WITHIN CLEARED AND UNCLEARED PLOTS IN OPEN AND CLOSED DONATIA COMMUNITIES. P VALUES ARE CALCULATED FROM PAIRED T TESTS ASSUMING UNEQUAL VARIANCES.

	OPEN CUSHION BOG			
	2002	2009	% CHANGE	P VALUE
CLEARED	42.0	28.2	33	<0.05
NOT CLEARED	60.1	37.64	37	<0.001
	CLOSED CUSHION BOG			
	2002	2009	% CHANGE	P VALUE
CLEARED	3.5	2.2	37	0.2 - ns
NOT CLEARED	9.2	4.6	50	0.1 - ns

Subplots within each plot were also ranked binomially, with plots containing *Donatia* receiving a 1 and plots without *Donatia* receiving a 0. This was conducted to help us assess whether *Donatia* was establishing in plots that previously had no *Donatia* recorded or conversely, was previously recorded and now not present.

TABLE 2: COUNT OF NUMBER OF SUBPLOTS PER PLOT WITH *DONATIA* PRESENT IN 2002 AND 2008

		2002	2009
OPEN	CLEARED	25	24
OPEN	NOT CLEARED	25	25
CLOSED	CLEARED	9	7
CLOSED	NOT CLEARED	12	9

Table 2 indicates that for the open *Donatia* plots the distribution within the plots has remained largely unchanged despite overall cover declining. The closed plots have declined in the number of subplots containing *Donatia* suggesting the fractured remnant *Donatia* population is still reducing in its dispersion.

There were no instances of *Donatia* being recorded in subplots in 2008 when it was not present within the subplot in 2002. This loosely suggests that recruitment is not occurring, or very limited, within the subplots where *Donatia* was previously unrecorded.

Cushion bog community cover

The following species are considered true alpine cushion bog community species*: Actinotus novae-zelandiae, Donatia novae-zelandiae, Isolepis aucklandica* and *Oreobolus pectinatus.* During the analysis these species have been classed as 'cushion' while all other vascular and non vascular species have been classed as 'non cushion'. The percentage covers of these community classes were compared within plots between years to see whether they reflected the trends seen in *Donatia*.

TABLE 3: MEAN CUSHION SPECIES COVERAGE PER PLOT UNDER THE DIFFERENT TREATMENTS WITH *DONATIA* INCLUDED AS A CUSHION SPECIES (A) AND WITHOUT *DONATIA* INCLUDED AS A SPECIES (B).

A: MEAN CUSHION BOG COVERAGE INCLUDING *DONATIA*					
SITE	TREATMENT	2002	2009	% CHANGE IN COVER	P VALUE
OPEN	CLEARED	17.7	15.2	- 2.5	<0.05
OPEN	NOT CLEARED	23.7	19.1	- 4.6	<0.05
CLOSED	CLEARED	7.7	4.9	- 2.8	ns
CLOSED	NOT CLEARED	10.0	7.9	- 2.1	ns
B: MEAN CUSHION BOG COVERAGE EXCLUDING *DONATIA*					
SITE	TREATMENT	2002	2009	% CHANGE IN COVER	P VALUE
OPEN	CLEARED	5.4	8.5	+ 3.1	ns
OPEN	NOT CLEARED	5.5	9.7	+ 4.2	<0.05
CLOSED	CLEARED	6.3	2.7	- 3.6	ns
CLOSED	NOT CLEARED	5.0	7.9	+ 3.0	ns

The results from Table 3 show that although declining in their coverage in each of the plots this percentage decline in cushion coverage was much smaller than that of *Donatia* alone. When *Donatia* is removed from the cushion class a mean increase in cushion species coverage between the two measurements occurs for all but one plot. This highlights that the decline in *Donatia* coverage is principally responsible for the declines in the coverage of the cushion bog community as a whole.

Changes in individual species composition

To assess changes in individual species composition we focussed on species which exhibited a mean change in percentage cover within each plot of greater than 3% between the two measurements. A change greater than 3% was chosen because we deemed any changes less than this had a high risk of being a product of observer variability in estimating species coverage, as opposed a product of real, biological change.

As shown in Table 1, *Donatia* has declined in all the plots particularly the open plots. The percentage decrease for *Donatia* is higher in the not cleared plots. There were few other species that declined more than three percent however those that did were low stature plants located at the closed sites. Results are summarised in Table 4 below.

Increases in coverage were seen for a number of species. It is important to note that the cleared plots were measured after all woody vegetation was cleared from the plot. This created a vacant niche for plants to fill and this is reflected in the higher number of plants that increased their coverage between the two measurements for the cleared plots. It is interesting to note that it was not always the woody plants that took advantage of this to dominate the community.

In the open, cleared plot bryophyte coverage increased by 19% with wire rush (EMP min) increasing by 7%. Woody species manuka and inaka (LEP sco, DRA lon) did not recruit back into the plot at the expected high rates with only a 3-4% increase.

In the open, uncleared plot manuka increased the most by 6.6% along with the cushion species *Oreobolus pectinatus* (ORE pec) (6.3%). Inaka had a small increase (3%) but overall there were fewer species with >3% improvements most likely due to the lack of recruitment opportunities than in the open cleared plot which was provided by the disturbance and space created from the vegetation removal.

Once again, more species increased in the closed cleared plot which is likely due to the reasons given above. Manuka increased the most (17%). Water coverage increased significantly (15.6%) and it is interesting to note that this increase coincides with an increase in three other wetland bog species within the plot; wire brush, oioi (LEP sim) and sphagnum moss (SPH cri).

In the closed, uncleared plot manuka was still the dominant species (44%) and this had not changed between measurements. Species to decrease were low stature species which prefer more open sites. There were small increases seen in a limited range of wetland species with litter increasing, most likely as a function of this plots succession towards a woody shrub community that is encroaching around the site.

TABLE 4: CHANGES IN MEAN COVER (>3%) BETWEEN 2002 AND 2008

	INCREASE IN COVERAGE		DECREASE IN COVERAGE	
PLOT	SPECIES*	% INCREASE	SPECIES*	% DECREASE
OPEN - CLEARED	Bryo	19.4	DON nov	12.6
	EMP min	7.5		
	ORE pec	4		
	Water	4		
	PER mac	3.7		
	LEP sco	3.7		
	DRA lon	3.3		
OPEN – NOT CLEARED	LEP sco	6.6	DON nov	22.5
	ORE pec	6.3		
	DRA lon	3		
CLOSED - CLEARED	Water	18.5	ORE pec	6.2
	EMPmin	15.6		
	LEP sim	12		
	SPHcri	9.3		
	GLE dic	4.2		
	LEP sco	16.8		
CLOSED – NOT CLEARED	EMP min	6.8	GUN pro	15.3
	Litter	4.4	DON nov	6.4
	SPH cri	4	ISO auc	3.2
	DRA lon	3.9		
	ORE pec	3.3		

* Species nomenclature follows that described in Hurst and Allen (2007). The species code consists of the first three letters of the plant genus in upper case followed by the first three letters of the plant species in lower case. For a full up-to-date reference list of codes and associated Latin and common names go to http://nvs.landcareresearch.co.nz.

Discussion

Donatia is a long lived species and has been present within the wetland complex for centuries, with accounts of it being commonplace within the wetland dating back to the early 19th century (Crosby-Smith 1927; Department of Lands and Survey 1865). The retraction in its coverage over recent decades has highlighted a need to understand the processes behind its decline if we are to preserve its status within the wetland.

The encroachment of early successional woody species such as manuka and inaka has largely been considered as the leading cause of decline in *Donatia* and its associated cushion bog community. Photo points have clearly illustrated this (Department of Lands and Survey 1985). However no management trials were initiated to test this theory until the late 20th century. The removal of competing woody vegetation was thought to be the principal method behind restoring *Donatia* (Ward 2001) however this trial has highlighted that, although this is a large factor in its decline, it is likely to only be part of the equation.

Although this trial is a small one and by no means gives us solutions to addressing this decline it does give us a much better insight into the possible factors surrounding *Donatia's* decline and highlights that further, detailed studies need to be conducted for us to be able to understand fully the processes affecting *Donatia's* persistence within the wetland.

There is no doubt that manuka and inaka are out-competing *Donatia*. The fact that the plant cannot survive the low light conditions under a shrub canopy is clear to be seen at the site and past photo points of previous sites lost through woody succession have highlighted this (Department of Lands and Survey 1985). The interesting question is why is *Donatia* still declining in the open cushion bog communities when other cushion bog species are persisting if not increasing in their coverage? The cushion bog community provides an intact continuum of vegetation cover and the trial has illustrated that woody species encroachment is relatively slow. At intact cushion bog sites the threat appears to be from other cushion species such as *Oreobolus pectinata* and low growth forms of wetland species such as wire rush. This raises several questions – is the increase in these species due to the lack of recruitment of *Donatia* or altered physical characteristics of the site making it more suitable for these other species?

Donatia recruitment has not been studied to any great extent however the few studies that have been conducted on *Donatia* or other similar cushion bog species show that recruitment is slow (Forbis Doak 2004; Mark & Wilson 2005) so the probability of this study illustrating recruitment over the space of four years is low. Nevertheless *Donatia* coverage is significantly declining in the absence of woody competitors so other factors have to be looked at as agents of decline. The conditions that facilitate *Donatia* recruitment and growth are likely to be influenced by below ground physical factors such as hydrology, soil fertility and temperature and above ground factors such as competition, disturbance and seed supply.

For example, permanent water ponding was evident in the 2008 remeasure which was not recorded in any significance in 2002. *Donatia,* although a bog species, does not tolerate permanent inundation by water (Pers comm. Brian Rance). Changes in the hydrological regime of the site may have resulted in the raised water table observed and this may be restricting *Donatia* growth and providing opportunities for species that tolerate inundation or water logging. Obviously this cannot be directly proven with the current information from the site but it highlights that there are factors that we have not measured that may be resulting in this change.

The lands and survey trial initiated gull control at the site in an attempt to halt weed invasion and the threats the colony brought to the *Donatia* community it was located upon. Although soiling of the site by gulls and subsequent weed invasion was a threat to the plants the removal of the gulls facilitated the encroachment of woody plants into this fertile area. Prior to this, gulls were most likely keeping woody plants at bay through the disturbance they created and although damaging the larger *Donatia* (Johnson 1988), they may have actually been maintaining a habitat for the wider cushion community. Mammalian herbivores and bird species are known to maintain turf communities along lakeshores (Johnson and Rogers 2000) and it may have been the historical use of this site by gulls that allowed for these communities to exist through the disturbance they brought. With vigorous exotic weeds that we see today, leaving the gulls may well have led to the sites demise as well but this does raise questions over the conditions that *Donatia* and cushion bogs prefer. Do gulls create a habitat that encourages turf community development? Does the raised fertility of gull colonies aid *Donatia*? Although remote it may be plausible that there was some historical sympatric relationship between *Donatia* and gull colonies at this site.

Previous reviews looking at *Donatia* within the wetland have suggested the control of woody species through pruning will maintain these communities (Ward 2001) but our data shows that plants are still declining in coverage despite these attempts and there appears to be little or no recruitment at the site. Disturbance from fire events has been thought to have restricted manuka from encroaching into cushion bogs and possibly facilitated the spread of *Donatia* through the wetland. This is commensurate with peleocology data from the site (pers comm. Janet Wilmshurst) however there are studies which show that frequent fire is detrimental to the plants survival (Kirkpatrick & Dickinson 1984; Johnson 1998) so there is likely to be an optimal fire frequency or intensity which facilitates *Donatia's* maintenance within the wetland while keeping its woody competitors at bay (Calder 1992; Ward 2001).

There are other research sites within the wetland and these will be discussed in the following pages but this study highlights that the factors influencing *Donatia* growth and recruitment are complex and there are large knowledge gaps that need to be addressed if the Department is to manage this species successfully within the wetland.

RESEARCH SITE 2: RAY'S RIDGE, WAGHORNS DONATIA BLOCK

Introduction

Ray's ridge, located on Ray Waghorn's property on the border of Waituna Lagoon and Curran's Creek, has moderate to low densities of *Donatia*. The site is on an exposed, low peat ridge with scattered low manuka present with some gorse. After a fire at the site in 1980, drainage ditches were dug around the periphery which lowered the water table. Subsequently the area was fertilised and rotary hoed. Since this, the site has been lightly grazed by sheep. The landowner, Ray Waghorn, noted that the *Donatia* flourished post fire and believes now the species is being outcompeted by invasive species such as wire rush and manuka. He has surmised that *Donatia* requires frequent fire/disturbance to maintain its dominance and has advocated burning the site to promote this.

In response to Mr Waghorns interest and the significance of the site as one of the best examples of *Donatia* within the wetland complex the Department offered to establish monitoring at the site to assess the *Donatia* population and the factors influencing its growth and recruitment. The monitoring proposed was a combination of individually mapping each *Donatia* within a 100x50m plot and recording plant size and health; and establishing random vegetation plots and assessing the composition and structure of the plots through time. This monitoring was established in 2004 and it was envisaged that a fire would occur over the site post the establishment of this monitoring. To date (June 2010) the site has not yet been burnt however Ray Waghorn still has the intention of doing so.

Methods

Donatia size, health and distribution

A plot of 100m x 50m (5000m2) was established in 2004. The plot was systematically surveyed on a grid system and every *Donatia* plant was located with the size and condition of the plant recorded. The following details of each *Donatia* plant were recorded:

- Location using X and Y coordinates within the plot
- Maximum height (cm), maximum length (cm) and width (cm, taken at right angles to maximum length).
- Condition of plant, scored from 0 – 4 as follows:

  5 = structure destroyed

  4 = severe decay, some structure remaining

  3 = moderate decay, some damage to structure

  2 = good, minor damage to structure\

  1 = perfect, no visible damage to structure

- Percentage of plant covered by other species, grouped as follows:

  1 = none

  2 = < 1%

  3 = 1 – 5%

  4 = 6 – 25%

  5 = 26 – 50%

  6 = 51 – 75%

  7 = 76 – 100%

- Species list of all other species growing on each *Donatia novae-zelandiae* plant.

Vegetation composition

Sixteen vegetation plots were established to record changes in vegetation composition. These were located randomly within the 100 x 50m plot. The percentage of cover for each species within the plots was recorded. Plots were located at least 5m within the plot boundaries to minimise edge effects. In the 2008 remeasure subplot 16 could not be located and therefore was unable to be measured.

Donatia recruitment subplot

A new subplot was established to measure the significant recruitment observed around one of the larger *Donatia* plants. Aluminium pegs were used to permanently mark a 150 x 130cm plot. *Donatia* plants were measured with the method described for individual *Donatia* measurements.

Analysis and data storage

Data was entered into Microsoft Excel and analysis was undertaken using Microsoft Excel and R2.9.2 (R Development Core Team 2008).

5.3 Results

Donatia mapping

Individual *Donatia* were mapped out within the 100x50m plot. We calculated surface area (A), in centimetres squared, for the *Donatia* plants using the below formulae used for calculating the surface area of a dome.

$$A = 2\pi r_c h,$$

Where h represents height and r_c represents the radius of curvature for a dome.

$$r_c = \frac{h^2 + (d/2)^2}{2h}$$

Figure 3 below shows the location of *Donatia* measured within the plot from both measurements. The site of the bubbles is only indicative of the size of the plant in relation to the others at the site. To see actual size classes of the plants refer to Table 2. There is one cluster of *Donatia* which has been left out of Figure 3 and measured as a separate unit. This is due to the close proximity of all the plants and the rapid recruitment occurring in this site. This is graphically displayed in Figure 4.

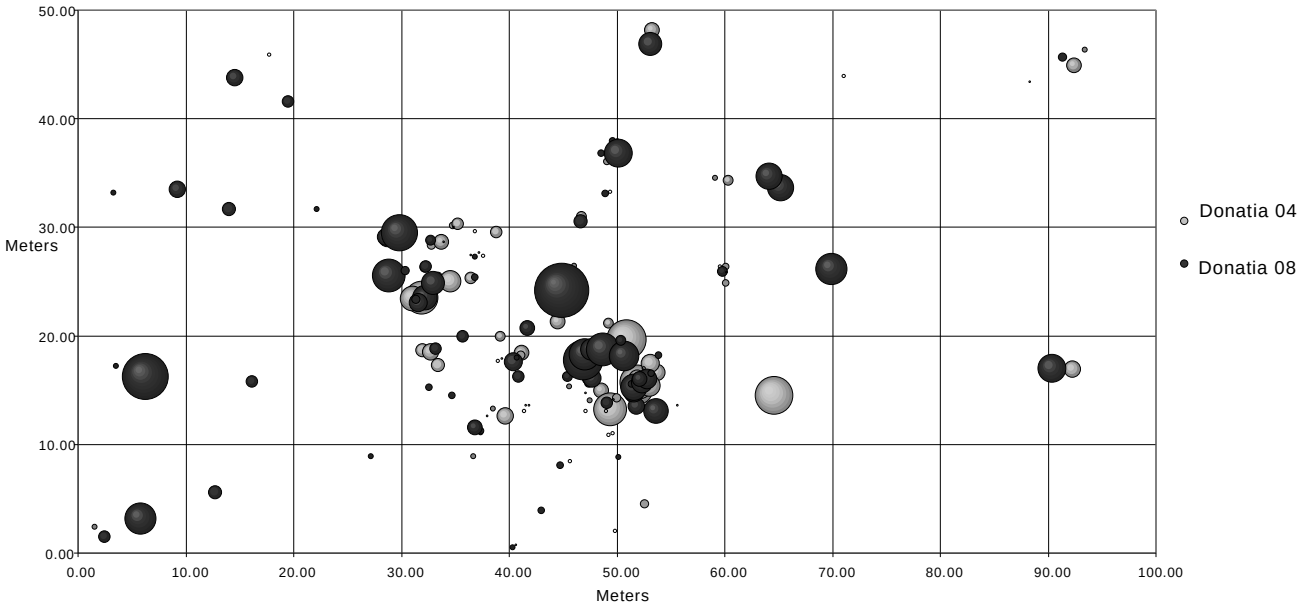

FIGURE 3: MAP OF PLOT (50X100M) WITH X-Y GRID LOCATIONS OF DONATIA PLANTS FROM THE 2004 AND 2008 MEASUREMENTS. BUBBLES ARE PROPORTIONATE TO THEIR SIZE (LENGTH X WIDTH X HEIGHT) IN RELATION TO EACH OTHER HOWEVER THEY ARE NOT PROPORTIONATE TO THE AREA THEY PHYSICALLY COVER AT THE SITE. SIZE DISPLAYED HAS BEEN INCREASED BY A MAGNITUDE OF 6 FOR GRAPHING PURPOSES. THEY ARE INDICITAVE ONLY.

Figure 3 shows that there are some *Donatia* in the 2008 remeasure that were not recorded in the 2004 measure. Rather than these being new recruits the majority of these are likely to have been missed in the previous measure as *Donatia* are slow growing and it is impossible for them to achieve this size over the space of four years, also some of these are likely to have been mapped inaccurately at the time of measurement. Although this figure graphically shows the distribution and proportionate size of the plants on the grid it does not provide accurate detail on growth and recruitment as it is hard to identify the same plant between measurements for all but the biggest. Nevertheless it is a useful tool in showing the approximate spread of the plants over the site and will highlight any large scale changes in the population in the future.

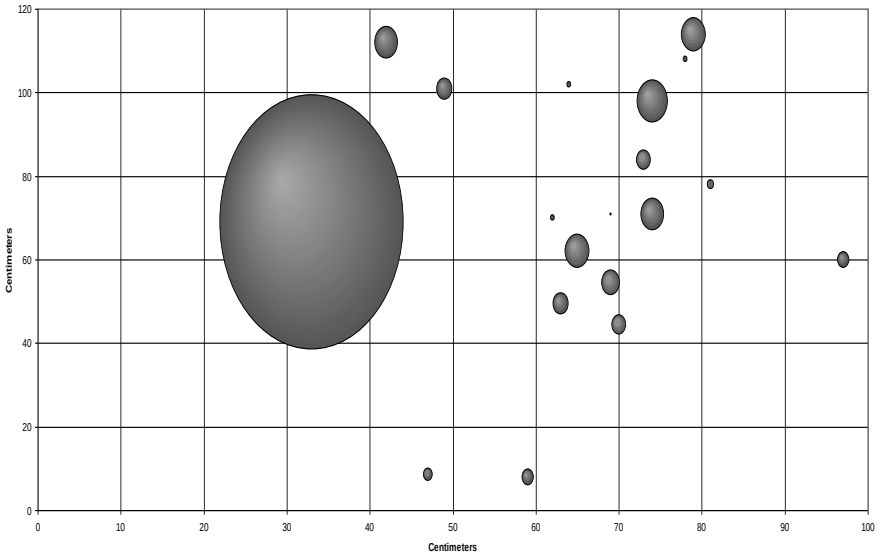

FIGURE 4: MAP OF RECRUITMENT PLOT (120X100CM) WITH X-Y GRID LOCATIONS OF DONATIA PLANTS FROM THE 2008 MEASUREMENT. BUBBLES ARE PROPORTIONATE TO THEIR SIZE (LENGTH X WIDTH X HEIGHT) IN RELATION TO EACH OTHER HOWEVER THEY ARE NOT PROPORTIONATE TO THE AREA THEY PHYSICALLY COVER AT THE SITE. SIZE DISPLAYED IS AT A MAGNITUDE OF 0.6 OF ACTUAL SIZE FOR GRAPHING PURPOSES.

Figure 4 depicts the *Donatia* population around one of the larger plants at the site. This separate grid was established when considerable recruitment was noted around the plant. All of the recruiting *Donatia* are located to the eastern, downwind side of the plant. They are scattered in a sheltered dell nestled between some small manuka shrubs. Interestingly, the same observation of recruitment occurring in sheltered hollows was made for *Donatia* recruitment at Peter Johnson's 1998 post fire study site.

Donatia coverage

All *Donatia* were summed for their coverage in each year and averaged. The summary statistics are presented in Table 5. Averages are very similar and a two tailed t test performed on the data showed that the difference between the two means was not significantly different.

TABLE 5: SUMMARY STATISTICS FOR *DONATIA* SURFACE AREA COVERAGE (CM^2) IN 2004 AND 2008

	2004	2008
MEAN	3010	3406
MEDIAN	2322	2331
SUM	367294	442880
COUNT	122	130

Donatia size class distributions

The data from the plants in the recruitment plot were incorporated into the larger data set to enable all plants to be analysed.

We considered size class for the plants to be most appropriately represented by the surface area of the plant as it is only the surface of the plant that holds live foliage.

Seven size classes were developed based on the size range of the plants and their distribution within this range. Size classes and the number of *Donatia* within these are shown in Table 6 below.

TABLE 6: SIZE CLASS DEFINITION FOR INDIVIDUAL *DONATIA* PLANTS INCLUDING TOTAL NUMBERS WITHIN EACH SIZE CLASS IN 2004 AND 2008.

SIZE CLASS	SURFACE AREA (CM²)	N.2004	N.2008
0	0-1000	28	39
1	1000-2000	29	17
2	2000-4000	30	31
3	4000-6000	17	16
4	6000-8000	11	9
5	8000-10 000	6	11
6	10 000+	1	5
	TOTAL	**122**	**128**

Figure 5 below is a graphical representation of this size class distribution highlighting the comparatively minor changes in size class distributions and total *Donatia* numbers measured at the site.

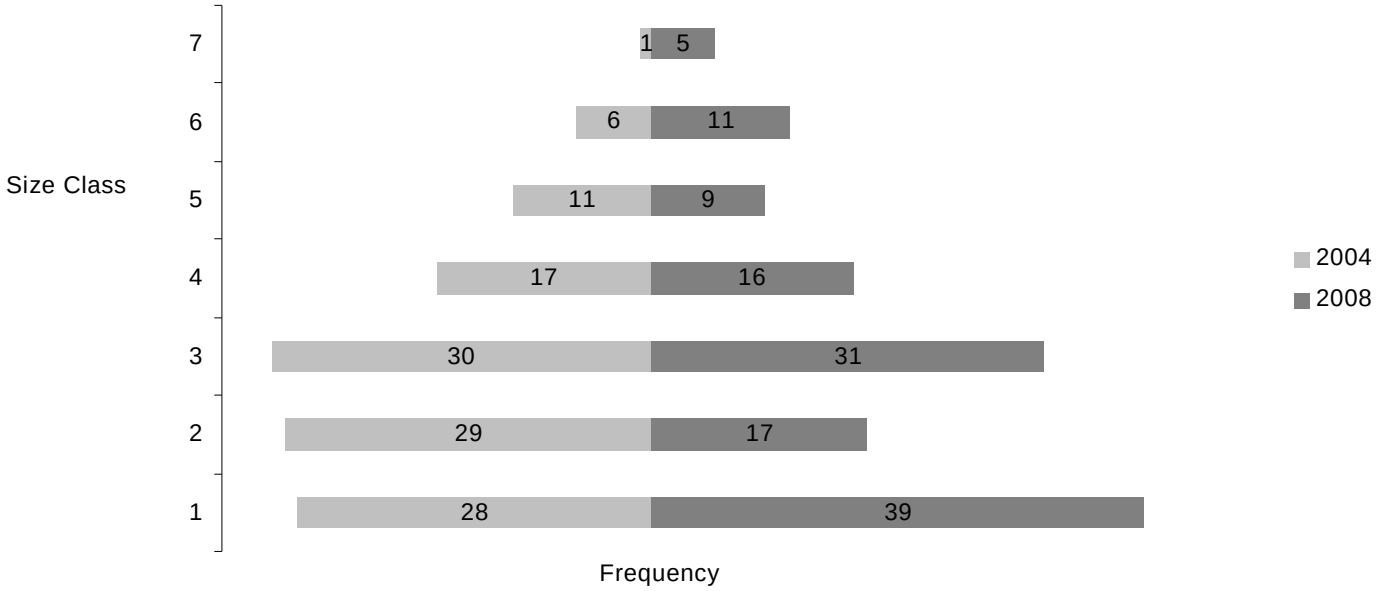

FIGURE 5: SIZE CLASS DISTRIBUTION OF *DONATIA* IN YEARS 2004 AND 2008. N 2004 = 121; N 2008 = 128.

There are some small differences in the numbers of *Donatia* in each size class between years however we consider these changes comparatively minor. For example, if we combine size classes one and two together this results in a total of 57 plants in 2004 and 56 plants in 2008. Our overall total has changed very little with only six additional plants measured in 2008. There were four more *Donatia* in size class 6 observed in 2008. These plants are all over a meter square in surface area. We consider the difference in numbers of plants in size class 6 a result of a better search effort for plants in 2008 as the growth rates required to get five additional plants into this class over only four years is highly improbable.

Donatia Condition and species coverage

Each *Donatia* was given a condition score of 1 to 5 with lower scores indicating poorer condition. Figure 4 illustrates a frequency distribution of the scores given for each of the measurements. Mean condition score increased from 2.5 to 3.0 however as this data is non parametric and outliers can skew the mean, median values should also be taken into account. The median did not change and remained at three over both measurements. For non parametric data with unequal sample sizes the most appropriate method of assessing if two distributions are significantly different is the use of the Mann-Whitney U test. Unfortunately we violate one of the assumptions that both samples are independent however this cannot be avoided. This test was performed using the **wilcox.test** function in R 2.8.2 The test result gave us a probability of $p<0.005$ that the distributions are not equal showing that the mean increase in condition scores is a true reflection of the increase in *Donatia* condition between the two measures.

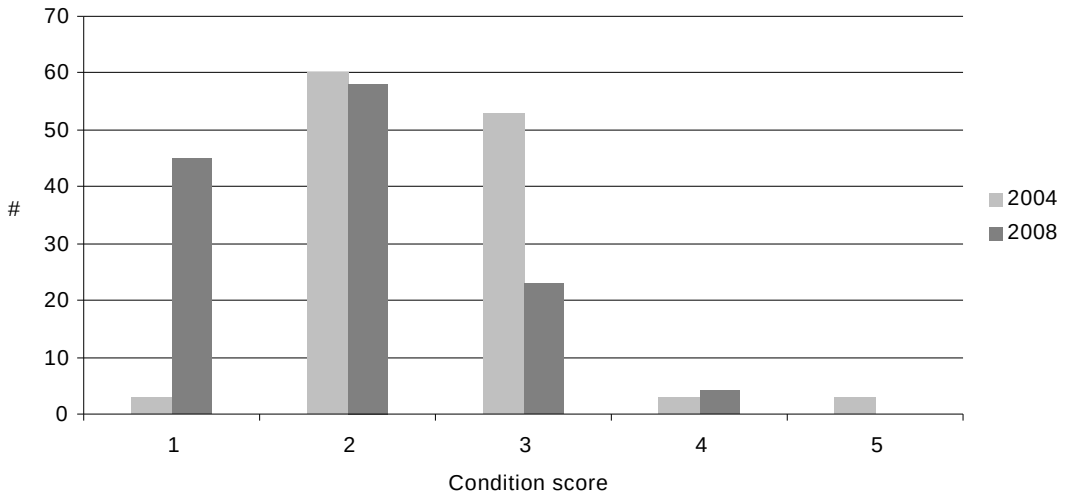

FIGURE 6: FREQUENCY DISTRIBUTION OF CONDITION SCORES IN 2004 (N=121) AND 2008 (N=130).

The coverage of the *Donatia* plants by other epiphytic plants was recorded and grouped into seven categories from 1 to 7 with a score of 1 representing no species present on the plant to a score of 7 indicating that over 75% of the plant is covered by other species. Once again the Mann-Whitney U test was used and means and medians were compared. The mean cover increased from 4.7 to 4.9 and both medians remained at five. The test score however indicated that this change was not significant with a probability of $p = 0.17$. Figure 7 illustrates that both measurements had very similar cover score distributions.

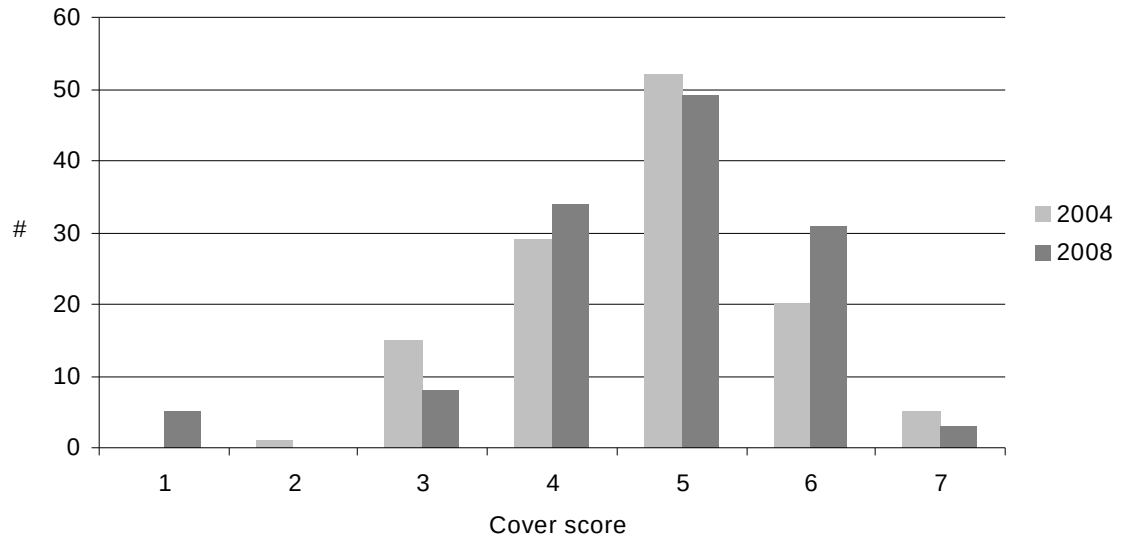

FIGURE 7: FREQUENCY DISTRIBUTION OF COVER SCORES IN 2004 (N=122) AND 2008 (N=130).

One would expect that an increase in species coverage on *Donatia* would influence the condition score of the plant. A cover score of 5 illustrates that 26-50% of the plant is covered by other species which appears high. Non parametric correlations using the Kendall Tau Rank Correlation Coefficient were performed to see if there were correlations between size classes and cover scores within each measurement. There were strong positive correlations between increases in species coverage and declines in plant condition in both years with 2004 having a stronger relationship ($p < 0.0001$; correlation -0.51) than 2008 ($p < 0.002$; correlation – 0.3). This correlation is much stronger than the Mark and Wilson (2004) study which only observed other species on *Donatia* cushions when the centres were in decline.

Species Richness

Mean species richness of plants found on *Donatia* has increased significantly ($p<0.05$, two tailed t test) between measurements from 7.7 plants per *Donatia* in 2004 to 8.5 plants in 2008. High species richness is often attributed to amelioration in climatic conditions (Badano et al. 2006). The high species richness and high numbers within these species observed at this site is likely to be a result of the comparatively mild conditions of the wetlands in relation to the plants natural alpine habitat where diversity is limited and climatic fluctuations are far more extreme. Other factors such as soil chemical parameters may also be facilitating this. Ward (2001) noted that in comparison to cushion bogs in the Blue Mountains, *Donatia* sites in the wetland had comparatively higher mean temperature, pH and soil conductivity - all likely facilitators of species richness and presence on the *Donatia* plants.

Vegetation composition plots

The main function of these plots was to illustrate changes in vegetation composition at the site. T tests were performed for each species to see if there was a significant change in their cover between the two measurements. Table 3 below contains those species which either A: compromise of more than 3% of the cover in any year or B: underwent a change in coverage of 3% or more over the measurement period.

TABLE 7: MEAN SPECIES COVERAGE IN 2004 AND 2008. ASTERIX INDICATE SIGNIFICANT CHANGES IN COVER UNDER A TWO SAMPLE T TEST. * = P<0.05; ** = P<0.005.

SPECIES	2004	2008	% CHANGE
MOSS	28.2	26.9	- 1.3
EMPODISMA MINUS	18.3	32.1	+13.8 *
GUNNERA PROREPENS	17.3	8.5	- 8.8 *
LEPTOSPERMUM SCOPARIUM	11.5	24.9	+13.3 **
LICHEN	10.5	1.0	- 9.5
ANTHOXANTHUM ODORATUM	6.5	3.0	- 3.4
SELLIERA RADICANS	6.3	0.0	- 6.3
ISOLEPIS AUCKLANDICA	6.0	5.4	- 0.6
LITTER	4.8	0.0	- 4.8
CAREX OVALIS	4.5	0.0	- 4.5
OREOSTYLIDIUM SUBULATUM	4.3	0.0	- 4.3
DONATIA NOVAEZELANDIAE	4.0	7.5	+3.5
HYPOCHOERIS RADICATA	3.8	1.2	-2.6
CENTELLA UNIFLORUM	3.8	1.1	-2.7
MARCHANTIA BERTERORANA	3.1	0.0	-3.1
GAUTHERIA MACROSTIGMA	2.6	4.9	2.4
JUNCUS GREGIFOLIUS	1.0	5.9	4.9
ULEX EUROPAEUS	1.0	12.0	11.0

Significant changes in cover between measurements were observed in very few species. Manuka and wire rush increased markedly and significantly in their coverage which is commensurate with results from the Tiwai Spit study. *Gunnera prorepens* was the only other species to significantly change over this time period. Moss, gorse (*Ulex europaeus*), wire rush and manuka were the dominant species within the plots, with gorse cover increasing markedly (but not statistically significant). *Donatia* coverage increased too but there were only two plants sampled in the plots so we cannot read too much into this.

5.4 Discussion

The results show that there have been relatively few changes within the *Donatia* population on Rays Ridge over the four years of the study. The population distribution remains similar with still a large number of smaller plants present within the population, with no major declines in numbers of plants nor any size category changing dramatically. This slow rate of change within the *Donatia* community is not unexpected. Mark and Wilson (2005) observed very slow rates of change in the order of decades at their cushion bog site on the Maungatua summit plateau. This slow rate of change has also been observed in other studies and is a common occurrence among long lived cushion species (Forbis and Doak 2004). Although the cushion bog studied here is at a lower altitude and could be expected to change at a faster rate, the measurement period of four years would preclude any large changes in the population from being observed with such a slow growing species.

The size class distribution is typical of a young age class population structure however without other *Donatia* populations to compare this distribution against it is not possible to tell if this is indeed a sign that recruitment has been prolific or the structure is just a product of similar aged *Donatia* having differing growth rates. Such a high numbers of plants in what could be considered juvenile plant categories is an unusual occurrence in long lived species where low recruitment rates are expected and countered by the high probability that adults will contribute to further generations (Forbis and Doak 2004). Mark and Wilson (2005) observed that growth rates in *Donatia* cushions were not uniform and that smaller cushions were not uniform in age. From this evidence, if recruitment is to be monitored in the future, smaller sized plants (e.g. size class 2) should not be precluded from monitoring as it is likely that the sexual maturity of a plant is not directly linked to its size.

Due to this apparent healthy population demographic it is evident that *Donatia* is doing well under the current conditions. Management at the site has included fire, fertiliser, grazing and drainage and these factors individually, or in combination, are likely to have resulted in this comparatively healthy population. It is clear that there needs to be more research into these and other management techniques if we are to develop an optimal management regime for *Donatia*. Nevertheless, what we have seen is a genuine and healthy response in recruitment and growth to these recent management practices.

Measuring the recruitment of smaller plants is always going to be difficult with the plant's cryptic habit making them hard to identify in the field. The small recruitment plot developed in 2008 will hopefully prove useful in measuring the growth and development of some of the smallest plants at the site. This plot may also aid us in developing an understanding of *Donatia's* recruitment requirements. Currently recruitment is downwind of the prevailing wind direction and localised in a shallow, sheltered cushion hollow within half a meter of the plant. Interestingly, Peter Johnson (1996) observed the same phenomenon with *Donatia* recruiting in sheltered hollows after a fire in the wetland in 1985. The results of new research from PhD student Britt Cranston's study at this site may shed more light on this phenomenon and other life traits of *Donatia*.

Gridding the individual plants does provide us with a useful indication of the spread and clustering of *Donatia* at the site however its use beyond this, comparing individuals through time for example, is limited by the method used. Tagging individual plants would be more useful and would allow us to trace individuals through time and track recruitment more accurately however for the purposes of this study the current method is providing sufficient information.

Our hypothesis is that *Donatia* is facilitated by the disturbance created by fire based on reviewed literature and the results presented here. *Donatia* under intense fire conditions has been severely burnt to the point of death (Kirkpatrick & Dickinson 1984; Johnson 1998) however at Ray's ridge it appears the level of fire experienced there facilitated the regeneration of *Donatia*. The lower intensity of the fire at the site is likely to have resulted in it going around the open cushion field but with enough disturbance to allow recruitment to occur. In addition to this the conditions created by the pastoral management of the site, including drainage, appear to have facilitated this process. The vegetation plots have showed that wire rush and manuka are increasing in their coverage on Ray's Ridge and from what we have seen at the Tiwai Spit research site they are likely to become a threat to *Donatia*. Once again fire would provide as a useful tool to keep these species at bay. If we are to manage *Donatia* at Ray's Ridge to inform us on best practices that could be used promote *Donatia* it would be prudent to replicate this style of disturbance again by burning the site. However as burning is a high risk management practice we need to explore other techniques that reduce or eliminate this risk and are more suitable for their use on Public Conservation Land. Such techniques could involve the use of herbicides to retard woody vegetation encroachment along with methods of disturbance to create recruitment sites such as harrowing of the soil. It is also important to note that there are likely to be many other factors that influence the growth and recruitment of the plant. If any manipulation of *Donatia* is going to take place it is important to recognise that factors other than fire are likely to be equally as important and should be considered when looking at treatments.

It is clear that there are a number of factors that influence *Donatia* growth and recruitment. If *Donatia* is to remain in the wetland we need to be able to understand these influences and develop manipulative techniques that allow it to persist. To do this requires the continuation of this project and further research into the plant and its physical, environmental and physiological drivers. The Ray's Ridge study site has the ability to show us how *Donatia* reacts under the current management regime, and give us an insight into its threats and proponents. However the current study cannot answer everything and if we are to pursue a quest for this knowledge, further investment is required in order to learn how this plant has maintained itself in the wetland.

DONATIA IN THE AWARUA WAITUNA WETLAND – MANAGEMENT DECISIONS AND CONSIDERATIONS

Donatia is declining in the wetland, this is clear. In order to manage a self maintaining population in the wetland the reasons for decline and its requirements for growth have to be established. This will require further research, which will take time and financial investment.

Prioritising the plant

If the Department is going to actively manage the plant within the wetland it needs to establish if *Donatia* is of high enough priority in relation to the Department's work programme and community expectations. Under the new NHMS (Natural Heritage Monitoring System) framework *Donatia* in the Waituna Wetland is likely to be classed as a 'local treasure'. A local treasure is a species or ecosystem that is not ranked nationally but is of local or regional significance. The national allowance for local treasure monitoring is being rationalised at present with a likely cut in funding at Conservancy level. This will restrict Conservancies and Areas on where they spend their money on such projects. However, where *Donatia* falls out in the priority rankings of locally treasured sites within Murihiku or Southland is unknown at this stage. There are four priority drivers that will influence the decision on whether we manage *Donatia* within the wetland.

1. NHMS monitoring framework: Realignment of monitoring priorities within the Murihiku Area in accordance with funding allocations and guidance across sites, species, research and local treasure projects
2. Area or Conservancy priority: Is the species a high enough Conservancy or Area project to receive funding?
3. Local values: Do the community value the site enough to implement their own management or lobby the Department to undertake management?
4. Scientific values: Is the scientific value of the site high enough to generate funding interest and support from the scientific community?

Until this decision has been made furthering the monitoring and research program beyond its current extent is not advised. The current sites are a commitment enough and extra capacity and funding needs to be generated if we are to move forward with further research.

Management scenarios

After this prioritisation and assessment of the project there are two options:

1. Do nothing: This will likely result in *Donatia*, a regionally and scientifically unique species – but not nationally uncommon or endangered, being lost from Public Conservation Land in the wetland, or at least becoming highly uncommon within the next few decades.
2. Do something: Within the do something approach there are three possibilities: 1. Manage one site with possible supplementation of plants from elsewhere. This would be a low cost option. 2. Manage all current populations to maintain the current extent and condition of *Donatia* within the wetland. 3. expand on option two above and create new communities.

If the decision is to actively maintain the species within the wetland all three scenarios in option two above require research to help us achieve them. Currently plants within the wetland are in decline and the agents of this decline are unresolved and complex. If we are to reverse this trend we need to take advantage of experimental research and adaptive management to identify agents of decline and promote recovery of the species.

6.3 Knowledge gaps and research themes

The research in this document and the literature reviewed highlight that there are many variables that affect *Donatia* recruitment and growth and our knowledge of these is limited. To understand factors that retard *Donatia* recruitment and growth the research themes we need to focus upon are:

1. Cost effective methods of restricting the encroachment of dominant woody and non woody wetland species such as manuka and wire rush.
2. Understanding the factors that are required to promote *Donatia* recruitment and growth.
3. Development of techniques that enable or promote *Donatia* recruitment and growth.

The three factors are intrinsically linked and some of the knowledge gaps we need to address are listed below.

- Substrate: Does the plant require mineral soil to regenerate?
- Micro sites: Are specific micro sites required for its recruitment?
- Hydrology: Do water table fluctuation or periodicity affect plant growth and recruitment?
- Chemical: Do the soil/peat nutrient statuses or pH levels affect growth and recruitment?
- Meteorological: Are climatic changes affecting the plants growth and recruitment?
- Plant physiology: are plant physiological processes e.g. flowering and seeding affecting its recruitment
- Successional pathways and influences: is competition from other plants retarding growth and affecting regeneration? Is there a community or a plant that *Donatia* is co dependent on for its survival? Does the grazing of competing plants aid *Donatia*?

What has the research shown us?

Donatia communities are visibly declining within the wetland through the encroachment of woody plants however it is likely that there are other factors influencing this.

The Tiwai Spit photo points clearly show that once established at a site, woody species such as manuka and inaka can overtake and displace the plant. At Rays Ridge however, manuka is present and has been there for a long time and the *Donatia* community is not changing rapidly. At Tiwai the manuka growth rates are more vigorous and have out-competed the cushion bog community. However, as we have seen at Tiwai, even the manual clearance of manuka and other woody species has not halted the decline in *Donatia* coverage. Other plants such as wire rush are encroaching and this raises questions – Is the successional encroachment of other plants displacing *Donatia* or is this a natural decline in size resulting from other processes such as soil hydrological or chemical changes, seed fall or substrate – or all of these?

The site at Rays Ridge underwent large scale disturbance with fire and rotary hoeing in the early eighties. Nutrients increased with fertiliser inputs, ash and animal effluent being added to the system, the water table was lowered and on top of this grazing was introduced. Could the combination of these factors have helped *Donatia* remain or indeed flourish? We hypothesise that *Donatia* was aided by the disturbance, higher nutrient status, lowered water table and the suppression of weed encroachment by the initial fire, and subsequent grazing. All these factors are likely to influence the growth and recruitment of *Donatia*, and appear to have positively influenced the plants at Ray's Ridge. A manipulative experiment is likely to tease out the benefits of each of these and is recommended if we are to understand the conditions *Donatia* require for successful growth and recruitment. Currently data shows that this induced regime is not causing a decline in the health of the *Donatia* population. As discussed in the previous section the burning of this site could confirm that low intensity burns do indeed facilitate *Donatia* growth and recruitment. Novel methods such as the use of herbicide and soil disturbance could also be used to see if they promote *Donatia*.

If we are to maintain and enhance the *Donatia* population in the wetland all these considerations have to be explored in order for us to successfully manage this species. Firstly however, we have to make the decision upon whether or not we are going to invest in the maintenance and management of *Donatia* within the wetland, for if we are more research will be needed.

Where to from here?

The research and management requirements for *Donatia* are potentially complex and will require funding to initiate and complete. Consequently decisions need to be made by managers as to whether we invest in assuring this species within the wetland remains or alternatively accept its relictual status and the consequences of leaving it unmanaged.

All key parties, both within the department and externally, need to discuss the priority of maintaining *Donatia* within the wetland. If we are to successfully manage *Donatia*, the complexities of its management and the requirement for further research needs to be acknowledged along with the need for financial and time commitments. With all these considerations taken into account the decision of if we manage it needs to be made. If management is to occur it is recommended that the literature in this document along with expert advice is consulted upon in the formation of a research and management plan. Levels of funding will dictate how we approach this management and research and the levels of investment in each. In any case, developments in the decision to manage *Donatia* should be consulted upon with relevant departmental staff, interested community members and associated research bodies.

ACKNOWLEDGEMENTS

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APPENDIX 1

Tiwai Donatia photo points

Photo point 5 - Gull colony: Tiwai Spit.

1984 1992 1999 2011

NZTM GPS Co ordinates: E 1259482 N 4830231 Photo bearing: 20° Magnetic

Photo point 4: North of photo point 5.

1984 1992 1999 2011

NZTM GPS Co ordinates: E 1259487 N 4830211 Photo bearing: 80° Magnetic

Photo point 1 – Cushion Bog: Tiwai Spit

1984 1992 1999 2011

NZTM GPS Co ordinates: E 1259517 N 4830171

Photo bearing: c.40° Magnetic (north east)