Turfs in turmoil:
an evaluation of stock exclusion as a tool for restoring threatened coastal turf communities.

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Abstract: Coastal turf communities are a nationally rare ecosystem in New Zealand, and are under threat from a combination of factors including increased soil fertility, stock trampling and browsing, and outcompetition by introduced pasture species. This study surveyed vegetation both inside and outside a stock-proof fence established around an area of turf at Stent Rd, Taranaki in 2002. The diversity and frequency of native turf species was higher within the exclosure; however, invasive weeds such as *Trifolium repens* and *Leontodon taraxicoides* were also more common and in better condition within the exclosure. Stock exclusion is a valuable tool for the restoration of turf communities but needs to be used in conjunction with weed control techniques to ensure that turf saved from trampling is not smothered beneath weeds.

Keywords: turf communities, weed control, stock exclusion, threatened plants

1. Introduction

New Zealand's coastal turf communities are a naturally rare ecosystem limited in distribution to several distinct areas around the coast of mainland New Zealand. Coastal turf communities are restricted to Fiordland, Southland, Otago, and north-west Nelson in the South Island and the Taranaki/Wanganui region in the North Island, although some floristic elements are found in other coastal (e.g. Wellington, Wairarapa) and inland (e.g. Lake Whangape, Moawhango) areas. Rogers (1999, p.6) defines coastal turfs as

> plant communities of halophytic (salt tolerant), low-growing herbs, sedges and grasses, seldom more than three centimetres tall, usually tightly interlaced and ground-smothering, and occupying coastal promontories exposed to the maritime influences of persistent wind and heavy salt deposition.

Because of their natural scarcity, coastal turf ecosystems (as defined in Williams et al., 2006) are considered as a priority for protection under Priority Three of the National Biodiversity Strategy's Statement of National Priorities (Ministry for the Environment, 2007).

Geologically, the Taranaki region west of the Taranaki fault consists of volcanic material (lahar debris and volcanic ejecta) unconformably overlaying marine mud- and sandstones (Suggate et al. 1978). Tectonic uplift and coastal erosion have subsequently caused the formation of flat coastal terraces and cliff-tops with shallow soils composed chiefly of raw volcanic gravels and magnetite sands (for a more in-depth geographic description see Roger, 1999). These flat terraces support fragmented turf communities discontinuously for approximately 120km of coast between the Stony River and Waverley.

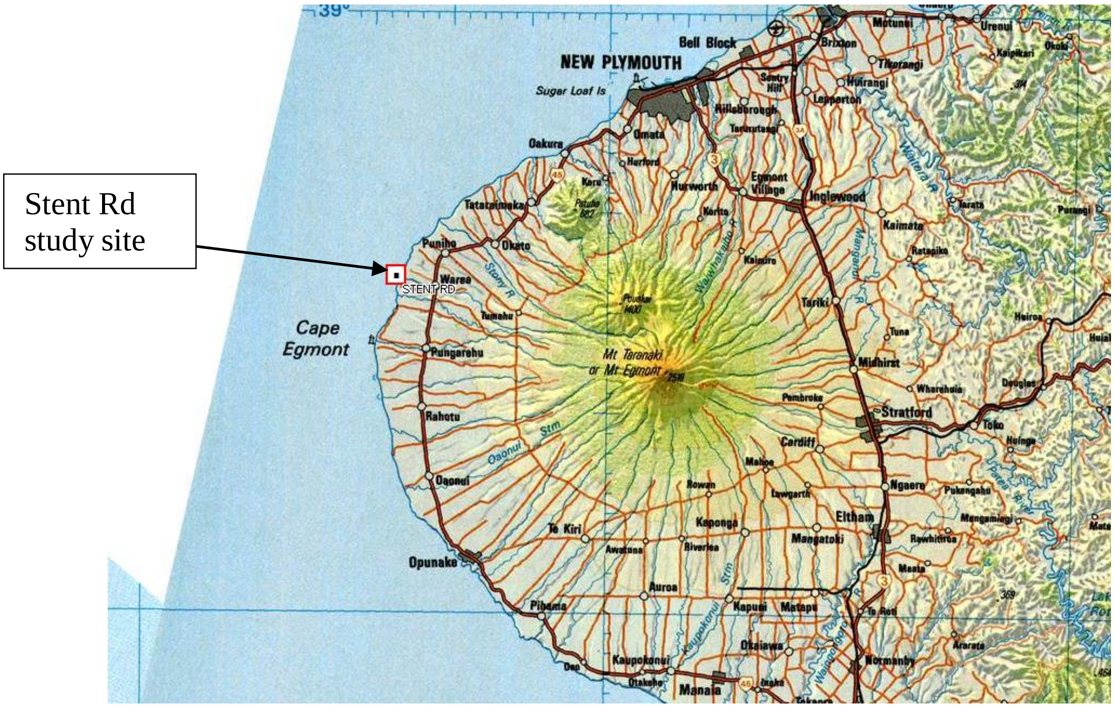
Turf communities in coastal Taranaki would once have occupied a narrow band between coastal scrub and the sea, a zone of high mechanical disturbance (wind and wave), solar radiation and salt deposition. Indeed, turf communities show common adaptations which allow them to survive in this extreme environment. Species are almost uniformly small and prostrate, and many are either succulent or else possess small, thick leaves to minimise water loss.

Figure 1.1 Typical turf community association: *Zoysia minima*, *Selliera radicans* and *Disphyma australe* alongside introduced *Plantago coronopus* and *Hypochaeris radicata*[1]

Farming activities in the last two centuries have had a significant and complex impact on coastal turf communities. Clearing of coastal scrub and forest for farming is thought to have allowed an expansion of coastal turfs back away from the coastal edge, attested to by the occasional sub-fossil remnants of *Podocarpus totara* now surrounded by turf (Rogers, 1999). However, farming has also had a deleterious effect on coastal turfs through grazing, increases in soil nutrients (via both animal waste and fertiliser drift), stock trampling, and, perhaps most importantly, the introduction of exoticspecies which can overtop and out-compete turf species (Figure 1.1) (Rogers, 1999; Rogers et al. 2002). There is significant interplay within these factors; grazing by stock reduces the density and size of highly-palatable pasture species (Pacala & Crawley, 1992), but increases in soil nutrients from animal droppings favour high-productivity invasive pasture species over low-productivity natives adapted to resource-poor

1 Genus often given as *Hypochoeris*; Allan Herbarium (2000) declare this name invalid and suggest *Hypochaeris* as the preferred genus name.

environments (Burke & Grime, 1996; Huenneke et al., 1990). Stock trampling damages turf plants and can lessen overall turf quality (Champion et al, 2001), but native turf species may be quicker to colonise disturbed ground (J Clarkson, pers. comm. See also unpublished data held in file NHS-10-02-04-04 at the Department of Conservation, Stratford Area Office), particularly if browsing pressure is being maintained.



<u>Figure 1.2</u> Map of Taranaki showing location of study site at Stent Rd.
Scale1:500 000 (Land Information New Zealand map, from Maptoaster v4.00.188 (2006), MetaMedia Ltd.)

This study focussed on the northern-most significant area of turf in Taranaki, located at the end of Stent Rd, Warea (Figure 1.2). The Stent Rd turf area was listed as a Priority Natural Area for protection under the Department of Lands and Survey's Protected Natural Areas programme (Bayfield & Benson, 1986). Rogers (1999) recommended Stent Rd as a high priority site for conservation due to its distinctiveness, species diversity, size, and the presence of threatened species such as *Myosotis pygmaea* var. *minutiflora*, *Oreomyrrhis* "minutiflora"[2], and *Crassula manaia*. Stent Rd is also the only known extant location of *Lepidium flexicaule* in the North Island.

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[2] De Lange et al. (1999) give the preferred name as "*Oreomyrrhis* (a) (CHR 364086 ; "minute flower")". For convenience this taxon will be referred to as *Oreomyrrhis* "minutiflora" throughout this paper.

Stent Rd is a highly popular recreational area with surfers, and is subjected to high levels of human impacts, particularly through trampling but also via the lighting of campfires, vehicles, and the erection of temporary structures for camping and events. The turf area backs onto an intensively farmed area and cattle are generally able to roam freely throughout the turf area.

In 2002 an area measuring roughly 10m x 70m was fenced off by the Department of Conservation to preclude livestock (Figures 1.3 and 1.4), with the goal of improving turf quality by reducing trampling and grazing. A signpost was also installed to discourage humans from entering the area. This has allowed evaluation of the effects of livestock removal on the turf community. This study investigated the diversity of both native and introduced species both within and without the fenced area, with the goal of determining the positive and/or negative impacts of livestock on the biodiversity and condition of the native turf community.

Figure 1.3 Fenced area at Stent Rd. This area has been ungrazed since 2002.

Figure 1.4 Unfenced area at Stent Rd. This area is still under grazing and trampling pressure.

2. Methods

2.1 Site description

The turf occupies a zone roughly 10m wide extending inland from the coastal margin along the top of a coastal terrace. The terrace borders a cobble-field beach on the seaward side with an eroding edge which gradually rises to form a 1.5m-high drop (Figures 1.3 and 1.4). On the landward side the site is contiguous with an area of paddock undergoing intensive dairy farming.

2.2 Survey methods

Vegetation surveys were carried out at Stent Rd on the 9th and 10th of April 2008. Two transect lines were run out using a 100m tape, one inside the fenced area and one outside. Both transects started at the same point (E2577252 N6220391). The first transect ("ungrazed") ran inside the fence for 70 metres, running roughly parallel to the coast along a bearing of 220^{o} magnetic. The second transect ("grazed") ran for 70m outside the fenced area in the opposite direction (40^{o} magnetic), again roughly parallel to the coast. As the coastline was broken and indented, distance from the coastline varied along both transects. Minimum distance from the coastal edge was 0m and maximum was 10m

A 0.04m^2 (20 cm x 20cm) square quadrat was placed on the ground at every metre-mark along each transect. The start and end points were excluded, making a total of 68 quadrats measured for each transect. All species within each transect were identified in the field using Johnson (1998), Roy et al. (2004) and Sinclair et al. (1998). Samples of unidentifiable species were taken for identification and compared to the New Zealand Plant Conservation Network database (www.nzpcn.org.nz; accessed 10/04/08). Identification was verified from samples and photographs by Jim Clarkson (Department of Conservation), Graeme Lacock (Department of Conservation) and Colin Ogle. A series of voucher specimens were collected; these are listed in appendix two. All plant material was collected with permission from the Department of Conservation, Stratford Area Office (appendix three)

2.3 Statistical methods

The proportion of quadrats with each species present was calculated. Confidence intervals were calculated at the 95% level.

A two-tailed unpaired *t*-test was used to compare the mean native diversity per quadrat and mean exotic diversity per quadrat between the grazed and ungrazed area. The *t*-test was performed using the online *t*-test calculator available at www.graphpad.com (accessed 27/04/08).

3. Results

In total 30 species were recorded in the study area, of which 14 were native and 16 introduced species. A complete list of species found in this study is attached to the end of this report (appendix one). For more exhaustive listings of species present in this area see Druce (1972; but note latest update by Colin Ogle 2004 held on file by Department of Conservation, Wanganui Conservancy), Rogers (1999) and Bridge (2004). Simplified scientific names are used throughout the text for convenience; preferred full scientific names, as per the New Zealand Plant Names Database (Allan Herbarium, 2000), are given in appendix one.

Within the quadrats themselves, 12 native and 12 introduced species were recorded. As the potential area of the grazed site was many times greater than the spatially limited ungrazed site, only the species recorded in the transects will be discussed in terms of relative biodiversity between the two areas

Three threatened species were found in the study area (following de Lange et al., 2004): *Crassula manaia* (Gradual Decline), *Lepidium flexicaule* (Nationally Vulnerable), and *Oreomyrrhis* “minutiflora” (Sparse).

Previous studies have found the related (and more uncommon) *Crassula mataikona* at the Stent Rd site; the ability to differentiate between the two species is beyond the ability of the author, and so (it being better to err on the side of caution) all plants of the genus *Crassula* found were recorded as *C. manaia*. *Myosotis pygmaea* var. *minutiflora* is also known to be a component of the Stent Rd turf (Rogers, 1999; Bridge, 2004; I have also personally observed it in spring 2007), but as one of New Zealand's few “spring annuals” (Rogers et al., 2002) it had already flowered and disappeared by the time of this study.

Figure 3.1 shows the proportion of quadrats that each species was found in. The total number of species found was greater in the grazed site (20 species) than in the ungrazed site (16 species). The number of native species found was also higher in the grazed site (10 species) than in the ungrazed site (8 species). However, the distribution of threatened species was equal; *O.* "minutiflora" was found only in the ungrazed site, *L. flexicaule* was found only in the grazed site, and *C. manaia* was found in roughly equal quantities both inside and out.

Mean native diversity was 1.96 species per quadrat (S.D. = 1.28) in the ungrazed area and 1.53 species per quadrat (S.D. = 1.03) in the grazed area. This difference was found to be statistically significant (unpaired two-tailed t-test; *t*=2.0675, df=134, p=0.0406). Mean exotic diversity was 1.5 species per quadrat (S.D. = 1.03) in the ungrazed area and 1.68 species per quadrat (S.D. = 1.09) in the grazed area. There was no significant difference between the mean exotic biodiversity per quadrat (unpaired two-tailed t-test; *t*-test, *t*=0.9729, df=134, p=0.3323).

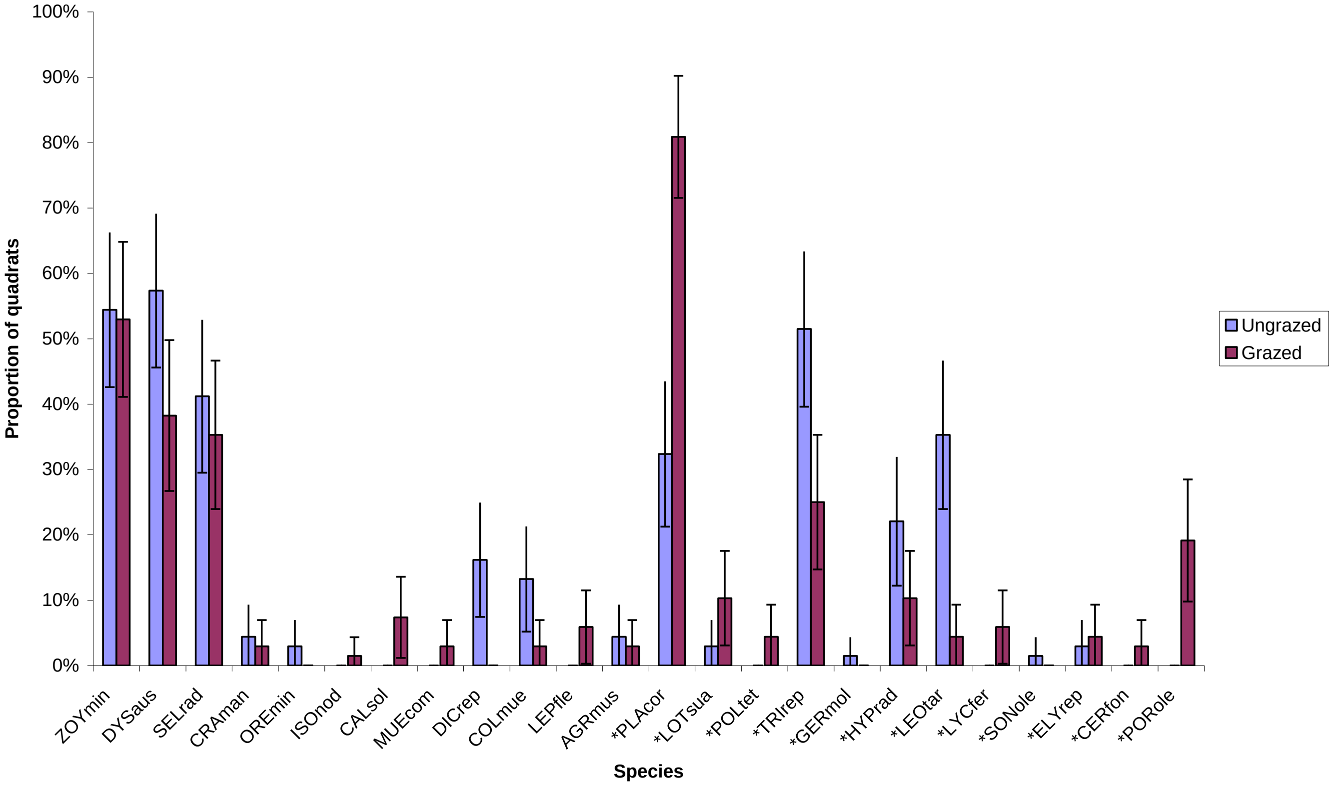

Figure 3.1 Proportion of quadrats with each species present. Error bars represent 95% confidence intervals.

Plantago coronopus was significantly more common in the grazed area. There were significantly higher frequencies of *Trifolium repens* and *Leontodon taraxicoides* in the ungrazed area. *Disphyma australe, Hypochaeris radicata* and *Colobanthus muelleri* were also noticeably more frequent in the ungrazed area, but the difference was not significant at the 95% confidence level. *Dichondra repens, O.* "minutiflora", *Sonchus oleraceus* and *Geranium molle* were found only in the ungrazed area. *Isolepis nodosa,* *Calystegia soldanella, Muehlenbeckia complexa, L. flexicaule, Polycarpon tetraphyllum, Lycium ferocissimum, Cerastium fontanum* and *Portulaca oleracea* were found only in the grazed area.

Areas of intact turf were generally dominated by dense mats of *Zoysia minima* and *Selliera radicans*, with *S.radicans* increasing in dominance in broken areas and towards the coastal edge. Areas dominated by *Z. minima*/*S. radicans* were typically extremely prostrate, with canopy height never exceeding 3cm. A number of native turf species (*O.* “minutiflora”, *C.muelleri, C. manaia, Agrostis muscosa*) were found only in areas dominated by *Z. minima* and *S. radicans*, while other native species associated with turf communities (*Z. minima, D. repens, D. australe, S.radicans* and *L. flexicaule*) were also found in areas dominated by exotic species.

Invasive exotic species were observed to be colonising in two distinct ways: either as a wave (*T. repens-Lotus suaveolens* complex) or as individual pioneers (*P. coronopus, H. radicata, L.taraxicoides*). With the exception of *P. coronopus*, which was prostrate, exotic species were taller than native turfs, with canopy height generally varying from 3cm to approximately 10cm (and higher, in the quadrats dominated *by L. ferocissimum*). The canopy was noticeably higher in the ungrazed area than in the grazed area (Figure 3.2).

Figure 3.2 Differing canopy heights in ungrazed (left, background) and grazed (right, foreground) pasture at Stent Rd.

4. Discussion

4.1 Notable species

Oreomyrrhis (a) (CHR 364086 ; "minute flower"), commonly referred to as *O.* “minutiflora”, is a tiny, taxonomically indeterminant member of the Apiaceae found in coastal turfs throughout New Zealand (Figure 4.1). Within Taranaki *O.* “minutiflora” is uncommon, although it is found in greater numbers in the turfs of the South Island, particularly those of north-west Nelson, Southland and Otago (Rogers, 1999). *O.* “minutuflora” is sufficiently restricted in range to warrant a conservation status of “Sparse” (de Lange et al., 2004).

O. “minutiflora” was only ever observed in areas dominated by *Z. minima* and *S. radicans*, suggesting that it is incapable of competing against the (relatively) much taller introduced species. This study found *O.* “minutiflora” only within the fenced area, in the turf community that is untrampled by stock. Bridge (2004) surveyed Stent Rd over three years (2002-2004) and never recorded *O.* “minutiflora” outside the fenced area; however, the cover of *O.* “minutiflora” within the fenced area showed an almost ten-fold increase over the same period, improving from 0.13% to 1.22% cover (Bridge, 2004). Stock may be having a major suppressive impact on *O.* “minutiflora”, most likely by trampling the diminuitive and fragile plants. If true, this is particularly worrying for the long-term viability of the Taranaki populations of *O.* “minutiflora”, as stock have historically been able to roam freely through the majority of the other turfs containing populations of *O.* “minutiflora” on the Taranaki coast. The Department of Conservation is actively communicating with landowners with the goal of restricting stock access to coastal turfs.

Figure 4.1 *Oreomyrrhis "*minutiflora"

Although not strictly speaking a turf plant (following the definition given in Rogers, 1999), *L. flexicaule* is nonetheless an important component of native turf communities. Once relatively common throughout New Zealand, it is now restricted to a few isolated patches of the coastal South Island (Norton & de Lange, 1999). Until recently, *L. flexicaule* was thought to be extinct from the North Island, and the Stent Rd community represents its only known extant population in the North Island. *L. flexicaule* at was first reported at Stent Rd by Bridge (2004), who recorded it growing both inside and outside the fenced area. It is curious that the presence of *L. flexicaule* was previously overlooked during surveys by A.P. Druce (1972), Bayfield and Benson (1986), Rogers (1999) and Colin Ogle (pers.comm). As it is unlikely that such eminent botanists as Druce and Ogle would have overlooked as conspicuous a plant as *L. flexicaule*, it is likely that this plant is a recent arrival to the area, within the last decade at most (Colin Ogle, pers. comm.). There are several possible ways in which *L. flexicaule* could have established itself. There is a high amount of human traffic to the area (particularly surfers, who are presumably highly mobile and coastally-oriented), and it is possible that travellers from the South Island carried seed over attached to footwear or clothing. Alternatively, as the site is of high botanical interest, seed may have been unwittingly transported by a visiting botanist. Seals and seabirds are also capable of transporting *Lepidium* seed (Norton et al., 1999), and may potentially have brought seed of *L. flexicaule* over from South Island sources.

It was interesting to note that *L. flexicaule* was found only outside the fenced exclosure. *L. flexicaule* is a highly-palatable species (Norton & de Lange, 1999) and it is surprising that it has not suffered from grazing by stock. Norton & De Lange (1999) state that native *Lepidium* species are typically associated with high-fertility sites, and it is possible that the additional nutrients added to the soil via animal droppings have increased its competitiveness outside the grazed area; however, nutrient input from fertiliser drift, guano and nitrogen-fixing plants is likely to greatly overshadow the input from animal waste, and a soil analysis undertaken by Agricultural Research Limited in 2002 found no appreciable differences in soil nutrients between the grazed and ungrazed areas (unpublished data held by Department of Conservation, Stratford Area Office in file PLA-012).

C. manaia was found at similar frequencies in both the grazed and ungrazed areas; however, it was only ever found in areas dominated by *Z. minima*/*S. radicans*, and never in areas dominated by introduced pasture species. *C. manaia* is a tiny succulent (figure 4.2) and, like *O.* "minutiflora", is likely to suffer heavily from competition for light with taller introduced species.

Figure 4.2 *Crassula manaia*. The metal square shown in the picture has sides of 5cm.

While *D. repens* was found outside the fence, its absence from any of the quadrats illustrates the relative scarcity of *D. repens* in the grazed turf compared to the ungrazed, where it was relatively common. *D. repens* is a low, stoloniferous, fleshy-leaved herb, and it is likely that the disturbance associated with cattle trampling is to blame for its absence in the grazed area.

4.2 Biodiversity

Although the total number of native species in the grazed area was slightly higher than in the ungrazed area, several of the native species found only in the grazed area (specifically *I. nodosa, C. soldanella* and *M. complexa*), although typically associated with turf communites, cannot be considered to be part of the coastal turf *sensu stricto (*Rogers, 1999).The mean biodiversity per quadrat was higher in the ungrazed area, with higher frequencies of typical turf plants *A. muscosa, C. muelleri, C. manaia*, and *O. "*minutiflora". Turf communities within the ungrazed area were more intact and diverse, suggesting a higher turf quality in the absence of stock. Champion et al (2001) found a similar increase in turf quality when cattle were excluded from lakeshore turfs at Lake Whangape. Stock trampling may disrupt the normal turf community by breaking up the soil and destroying plants; less common turf species such as *C. manaia* and *O.* "minutiflora" are more likely to become locally extinct and less likely to recolonise rapidy than more common dominant species such as *Z. minima* and *S. radicans.*

4.3 Weed invasion

Previous studies on the invasion of turf communities by invasive weeds have highlighted the shared role played by both disturbance and increased nutrients in encouraging weed invasion (Burke & Grime, 1996; Huenneke et al., 1990; Huston, 2004). The Stent Rd turf occupies a hard terrace, covered in a thin soil with a high sand content (Bridge, 2004); this, coupled with high salt deposition rates from the predominantly westerly winds, would have made for an extremely harsh low-fertility environment. It is impossible to measure the impact that past farming practices have had on the soil fertility, but it is safe to assume that soil nutrient levels are higher now than before human occupation, due to the combined effects of fertiliser drift and nitrogen fixation from species such as *L. suavelons* and *T. repens.*

Two distinct weed colonisation patterns are evident at Stent Rd: "island" and "wave". In the island pattern, seeds of pioneer species such as *P. coronopus, L. taraxicoides* and *H. radicata* are able to establish in the shelter provided by the low mat of native species. These pioneer invasive species all possess prostrate, rosette growth forms, allowing them to avoid the worst of the wind. *P. coronopus,* with its thick, coriaceous leaves, is particularly welladapted to survive in the harsh coastal turf environment. Once these pioneer species are established, less hardy species such as *T. repens* are able to grow in the increased shelter provided. These species in turn increase the level of soil nutrients, creating a more equitable habitat for further weed invasion. In the wave pattern, stoloniferous weeds such as *L. suaveolens*, *Elytrigia repens* and *T. repens* growing in pasture along the margins of the turf gradually colonise the turf community, moving inwards from the edge in a rolling wave. Both patterns of colonisation greatly reduce the amount of turf area, as turf plants are smothered and out-shaded by the taller weed species.

An equilibrium between hardy native turf species and less tolerant weed species appears to exist towards the extreme coastal edge, where increased salt deposition, solar radiation and the mechanical processes of wind and wave action create an environment too hostile for the most weed species. However, even this zone of extreme environmental stress is at risk, as the spread of the hardy shelterbelt species *L. ferocissimum* threatens to create a sheltered microclimate in which introduced species can thrive to the detriment of native turfs.

4.4 Potential tools for increasing native turf habitat

Pacala & Crawley (1992) showed a positive correlation between browsing intensity and diversity, provided that there is also a correlation between palatability and competitiveness; that is, if the most competetive and dominant species are also the species most preferred by herbivores, then higher levels of herbivory will increase the relative competitiveness of other species. Evidence of this is provided at Stent Rd., where *P. coronopus* was far more common in the grazed area of turf, while the more palatable *T. repens* and *L. taraxicoides* were more common in the ungrazed area. Heavy cattle browse on the highly palatable species *T. repens* and *L. taraxicoides* may have increased the relative competitiveness, and therefore the frequency, of the less palatable *P. coronopus.* Provided that desirable native species are less palatable than introduced weeds (as seems to be the case with the majority of turf species), controlled grazing may be an effective tool for suppressing weed species and increasing the comptetitiveness of natives.

Increased distrubance has traditionally been linked with an increase in the rate of establishment and invasion of exotic weed species, especially when combined with increased soil fertility/productivity (Burke & Grime, 1996; Huston, 2004). However, traditional dogma generally assumes a full native canopy, with disturbance creating “light gaps” which allow the rapid growth of weeds which would otherwise be uncompetitive in the shade of mature natives. In coastal turfs, however, there is no such dominance of the canopy layer by native species; indeed, even relatively prostrate species such as *T. repens* or *L. taraxicoides* are capable of rapidly overtopping native turf species even from the seedling phase. Disturbance may, therefore, actually increase the competitiveness of native turf species, by removing weeds which would otherwise outshade and smother prostrate natives. Indeed, theories suggesting that weed establishment should be higher in disturbed communities (Huston 2004) also hold true for the re-establishment of native species in areas previously completely overgrown with weeds. This seems to be born out in practice; Champion et al. (2001) found that cattle browse (particularly of Mercer grass *Paspalum distichum*) and trampling around the edges of Lake Whangape significantly increased the area of turf communities, albeit at a cost of reduced quality. In an ongoing experiment at the Puketapu Rd turf in south Taranaki, the top layer of soil was scraped completely bare. In succeeding years, recolonisation by native species was much faster than by exotic species, suggesting that disturbance may favour the rehabilitation of native turfs, provided there is an appropriate seed source nearby (Unpublished data held in file NHS10-02-04-04 in the Department of Conservation, Stratford Area Office).

Disturbance may favour the re-establishment of dominant, widespread native turf species, for which seed sources are common. However, plants which are locally uncommon may be less able to recolonise, particularly if all of the individuals in an area are destroyed by the disturbace event. Disturbance as a tool for increasing turf communities on the coast must therefore be carefully directed, so that the amount of habitat available for rare species is increased without reducing the ability of rare species to recolonise.

5. Summary

The erection of a stock-proof fence at Stent Rd appears to have had both positive and negative outcomes for the turf community. Native biodiversity of key turf species is higher in the ungrazed area, as is the quality of the turf community. However,the reduction in browse and trampling may have increased the competitiveness of exotic weeds, allowing them to establish and dominate much of the area that would once have been turf.

The exclusion of heavy stock such as cattle is a useful tool for the restoration of native turf areas, but needs to considered as merely one tool in the ecological restorer's toolbox. In isolation, stock exclusion may increase the quality of turf but over time any gains made may be lost through weed invasion. Limited browsing by lighter herbivores such as sheep could be used to reduce the canopy height and competitiveness of pasture species.

Controlled disturbance through the scraping of soil, use of herbicides and even manual weeding could all contribute to the control of weed species and subsequent expansion of turf habitat. Careful monitoring needs to be undertaken as part of any ecological restoration, to ensure that fragile native species such as *L. flexicaule, M. pygmaea* var. *pygmaea* and *O.* “minutiflora” are able to flourish and spread.

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References

Allan Herbarium (2000) Ngā Tipu o Aotearoa - New Zealand Plant Names Database. Landcare Research, New Zealand. Available http://nzflora.landcareresearch.co.nz/ (Accessed 24 April 2008).

Bayfield, M.A. & Benson, M.A. (1986). Egmont Ecological Region: Survey report for the New Zealand Protected Natural Areas Programme. New Zealand Protected Natural Areas Programme No.2. Wellington; Department of Lands and Survey.

Bridge, D. (2004). Invasion of introduced species of short stature coastal turf communities of the Taranaki terrace. Unpublished report produced as part of doctoral research at the University of Waikato. Held in file NHS-10-02-04 at the Department of Conservation, Stratford Area Office.

Burke, M.J.W. & Grime J.P. (1996). An experimental study of plant community invasibility. Ecology **77**(3):776-790

Champion, P.D., Beadel, S.M. & Dugdale, T.M. (2001). Turf communities of Lake Whangape and some potential management techniques. Science for Conservation 186. Wellington; Department of Conservation.

De Lange, P.J., Heenan, P.B., Given, D.R., Norton, D.A., Ogle, C.C., Johnson, P.N. & Cameron, E.K. (1999). Threatened and uncommon plants of New Zealand. New Zealand Journal of Botany **37:**603-628

De Lange, P.J., Norton, D.A., Heenan, P.B., Courtney, S.P., Molloy, B.P.J., Ogle, C.C. & Rance, B.D., Johnson, P.N. & Hitchmough, R. (2004). Threatened and uncommon plants of New Zealand. New Zealand Journal of Botany **42**:45-76

Druce, A.P. (1972). Vascular plants on the western Taranaki coast between Waitara and Hawera. Unpublished list no. 78, Botany Division DSIR 1972. Last revised by Druce 1989. On file NHS-10-02-04 at the Department of Conservation, Stratford Area Office

Huenneke, L.F., Hamburg, S.P., Koide, R., Mooney, H.A. & Vitousek, P.M. (1990). Effects of soil resources on plant invasion and community structure in Californian serpentine grassland. Ecology **71**(2):478-491

Huston, M.A. (2004). Management strategies for plant invasions: manipulating productivity, disturbance and competition. Diversity and Distributions **10**(3):167-178

Johnson, P.N. (1998). Wetland plants in New Zealand. Lincoln, Canterbury, New Zealand; Manaaki Whenua Press.

Ministry for the Environment (2007). Protecting our places: Information about the statement of national priorities for protecting rare and threatened biodiversity on private land. [Author], Wellington. Available at www.biodiversity.govt.nz as of 16/04/08

Norton, D.A. & de Lange, P.J. (1999). Coastal cresses (Nau) recovery plan. Threatened Species Recovery Plan No.26. Wellington; Department of Conservation.

Norton, D.A., de Lange, P.J., Garnock-Jones, P.J. & Given, D.R. (1997). The role of seabirds and seals in the survival of coastal plants: lessons from New Zealand Lepidium (Brassicaceae). Biodiversity and Conservation **6**(6):765-785

Pacala, S.W., Crawley, M.J. (1992). Herbivores and plant diversity. The American Naturalist **140**(2):243-260

Rogers, G. (1999). Coastal turfs of mainland New Zealand – their composition, environmental character and conservation needs. Science for Conservation 107. Wellington; Department of Conservation.

Rogers, G. Walker, S., Tubbs, M. & Henderson, J. (2002). Ecology and conservation status of three"spring annual" herbs in dryland ecosystems of New Zealand. New Zealand Journal of Botany **40**:649-669

Roy, B., Popay, I., Champion, P., James, T. & Rahman, A. (2004). An illustrated guide to common weeds of New Zealand. Lincoln, Canterbury, New Zealand; New Zealand Plant Protection Society.

Sinclair, L., Ogle, C. & Clarkson, J. (1998). Coastal herbfield plants of South Taranaki: An identification guide. Wellington; Department of Conservation.

Suggate, R.P., Stevens, G.R. & Te Punga, M.T. (Eds.) (1978). The Geology of New Zealand. Wellington; Government Printer.

Williams, P.A., Wiser, S., Clarkson, B. & Stanley, M. (2006). A physical and physiognomic framework for defining and naming originally rare terrestrial ecosystems: First approximation. Landcare Research Internal Report: LC0506/185

List of Figures

Appendix One: Preferred names for all taxa referred to in text

Authorities follow Allan Herbarium (2000).

^ Denotes species found in the area but not recorded in the transects.

<u>Native</u>

Zoysia minima (Colenso) Zotov (1943):

Selliera radicans Cav.

Agrostis muscosa Kirk (1881)

Colobanthus muelleri Kirk (1895)

Dichondra repens J.R. Forst. & G. Forst.

Disphyma australe (W.T.Aiton) N.E.Br. (1930)

Oreomyrrhis (a) (CHR 364086 ; "minute flower") (1999) (nom. inv.)

Crassula manaia A.P. Druce & Sykes (1988)

Calystegia soldanella (L.) R.Br.

Muehlenbeckia complexa (A.Cunn.) Meisn. (1841)

Isolepis nodosa (Rottb.) R.Br. (1810)

Lepidium flexicaule Kirk (1882)

^*Coprosma repens* A.Rich (1832)

^*Sarcocornia quinquefolia* (Bunge ex Ung.-Sternb.) A.J.Scott (1978)

<u>Exotic</u>

Cerastium fontanum (Baumg.)

Geranium molle L. (1753)

Plantago coronopus L.

Trifolium repens L.

Lotus suaveolens Pers.

Polycarpon tetraphyllum (L.) L.

Lycium ferocissimum Miers

Leontodon taraxicoides (Vill.) Mérat

Hypochaeris radicata (L.)

Sonchus oleraceus L. (1753)

Portulaca oleracea L.

Elytrigia repens (L.) Nevski (1933)

^*Modiola caroliniana* (L.) G.Don

^*Paspalum distichum* L. (1759)

^*Arctotheca calendula* (L.) Levyns

^*Lotus pedunculatus* Cav. (1793)