Coastal turfs of mainland New Zealand—their composition, environmental character, and conservation needs

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CONTENTS

Abstract

Coastal turfs of prostrate herbs, sedges, and grasses were recorded from six coastal zones in mainland New Zealand: Taranaki-Wanganui, the Te Taitapu coast of Nelson, north Westland, the Waitutu coast of Fiordland, Foveaux Strait coast of Southland, and much of the east coast of Otago. The predominant bedrock underlying turfs is sedimentary strata, with strike more or less perpendicular to the coast and at gentle angles of dip. This landform alignment produces discordant coastlines of near horizontal, cliffed headlands and bays. Prevailing northwest to southwest winds and wave action strike these coasts at oblique or acute angles, delivering apparently high salt loads and mechanical buffeting to exposed and leeward parts of promontories and beaches. These physical factors select for halophytic communities away from their more traditional estuarine habitats. *Selliera radicans*, *Leptinella dioica*, *Plantago triandra*, *Centella uniflora*, *Colobanthus muelleri*, *Zoysia minima*, *Hydrocotyle novae-zeelandiae* var. *montana*, and *Agrostis stolonifera* are turf dominants throughout. Despite these widespread generalists, many geographically restricted species impart provincial distinctiveness to communities. Eleven nationally threatened and local plants occur in turfs.

Most turfs have apparently expanded beyond and along their originally narrow coastal fringe with the clearance of bordering scrub and forest, and the majority are now interspersed with pasture and grazed by farm stock. Turfs expand into pasture which is competitively weakened by farm stock. Conversely, monitoring experiments record turf retreat under expanding pasture with the removal of farm stock. Sheep grazing seems compatible with turf maintenance, although compositional instability from nutrient boost from their faeces may occur. Turfs of dry substrates have some resilience to surface fracture from cattle trampling, whereas wet substrates render them vulnerable to pugging.

The physiographic and community distinctiveness of turfs warrants their recognition as a separate coastal ecological unit, if not ecosystem. Seven natural area criteria were rated to produce conservation priorities for each zone, with 35 priority sites identified in the five conservancies. The uncertainty of maintaining indigenous species and community diversity in the face of competing pasture deems it prudent to recommend carefully monitored grazing as a maintenance tool in many situations. Additionally, reconstitution of intact sequences of coastal vegetation involving turfs should also be a priority in each conservancy in what is universally a highly modified environment.

1. Introduction

Turf is a term of convenience applied to a compositionally diverse range of vascular plant communities showing similar physiognomy. However, Atkinson's (1985) scheme is used here for formal vegetation classification. **Coastal turfs** are defined here 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. Apparently compositionally diverse, they may be dominated by grasses of the genera *Zoysia*, *Poa*, and *Puccinellia*, and many herbs such as *Selliera radicans*, *Leptinella* spp., *Myosotis* spp. *Eryngium vesiculosum*, *Colobanthus muelleri*, *Crassula* spp., and *Plantago triandra*[1]. Several rare species have also been noted, for instance *Ranunculus recens* and *Myosotis pygmaea* var. *minutiflora*. This ecosystem is in critical need of review because the majority of recorded sites are in private tenure, weed invasion is conspicuous, and wholesale or incremental conversion to improved pasture is a common threat.

Turfs are recognised as a separate ecological unit (*sensu* Myers et al. 1987: 16-17)[2] from other coastal communities of low-growing plants, such as those on dune slacks, by virtue of the consolidated substrates on exposed landforms which they occupy and their exposure to airborne salt from spume and spray-drift (Johnson 1993). Partridge (1992) and Johnson (1992) surveyed sand dune and beach vegetation of North, South, and Stewart Islands, but, given the substrate instability of sand, turfs were not a recognised feature of these landforms or inventories.

Southland (Rance & Rance 1995), Nelson/Marlborough, and Wanganui Conservancies are compiling inventories of coastal turfs and, in addition, much information exists in uncollated form in Otago Conservancy. These initiatives target community composition, some environmental parameters, and threats. From this foundation a national perspective was required to:

- Categorise the landform, edaphic, and plant community variability of coastal turfs in New Zealand.
- Analyse the physiographic and biogeographic patterns of these communities.
- Establish conservation and further survey priorities.
- Identify common threats to the conservation of turfs and initial priorities for management.
- Report on the monitoring of weed invasion of turfs in Wanganui Conservancy.

Science & Research Unit of the Department of Conservation undertook this research during the 1997/98 year.

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[1] *Plantago triandra* ssp. *masoniae* is footnoted in Webb *et al.* (1988: 954) as a separate subspecies of coastal habitats, quite distinct from *P.triandra* sp. *triandra*, which is predominantly an inland entity. The former is conspicuous in turfs throughout both main islands.

[2] In the strict sense coastal turfs diverge from the definition of 'ecological unit' of Myers *et al.* (1987) by being unmappable at a 1:50 000 scale. Nonetheless, their physiognomic and compositional distinctiveness on definable landform units argues for this classification.

2. Study area

Field inventory targeted the six geographical zones where turfs are a recognised feature of coastal vegetation: Taranaki/Wanganui (in the North Island), and the Te Taitapu coast of Nelson, north Westland, the Waitutu coast of Fiordland, Southland, and Otago (in the South Island). Although some floristic elements of turfs occur around exposed parts of the Wellington and Wairarapa coastlines, turf communities are curiously absent (A.P. Druce pers. comm. 1997). Coastal turfs are recorded from major off-shore island groups, such as Stewart Island (J. Barkla pers. comm. 1998), Antipodes Islands (S. Courtney pers. comm. 1998), and other sub-Antarctic Islands (C. West pers. comm. 1997), but only those of the two main islands are covered in the present study. There are also coastal herbfields on exposed, salt-inundated headlands of some Cook Strait islands (e.g., south end of Stephens Island) that experience much seabird activity (S. Courtney pers. comm. 1998). Prominent in these communities are *Suaeda novae-zelandiae*, *Spergularia media*, *Scleranthus biflorus*, *Atriplex buchananii*, *Samolus repens*, *Selliera radicans* and *Sarcocornia quinqueflora*.

3. Methods

3.1 DATA COLLECTION

Helicopters were used to reconnoitre the Catlins and southern Fiordland coastlines, followed by field inspection of individual sites. Elsewhere, coastlines were systematically searched on foot along landforms known to support, or to have the potential to support turfs. Field inventory and sampling were comprehensive, but not exhaustive, in the six zones. Sampling design initially identified each distinct geographical sector of turfs, and final plot placement selected a representative example from each sector. Sectors of usually discontinuous turf could cover up to 200 m or more of coastline on relatively uniform landforms. Consequently, in the course of sampling, limits were sometimes arbitrarily conferred. Vegetation composition and structure and site factors were described on 94 variable area plots in six zones following the RECCE method of Allen (1992), with additional variables included (see below).

At each plot the following environmental and site characteristics were recorded: altitude (a.s.l.), slope, aspect, direction and dip of bedrock, topographic position, distance from mean high water, depth of mineral soil, drainage, soil parent material, percentage ground cover in rock, soil, litter, non-vascular plant, and vascular plant classes, and canopy height of the vegetation. Topographic position was described using the nine-unit landsurface model of Dalrymple et al. (1968). Drainage was described using the 7 unit classification of Taylor & Pohlen (1970).

Composite variables were calculated for:

1. The difference between the direction of the primary landform and the aspect of the turf site itself. The 'offset angle' exists as a surrogate for the oblique angle at which the prevailing, on-shore, salt-laden wind strikes the coast.
2. The hypotenuse of a right angle triangle formed by the horizontal distance between mean high water and the centroid of the turf on the one hand, and the altitude (a.s.l.) of the turf on the other. In the absence of a direct measure of salt deposition, this distance measure reflects the transport distance for spume and air-borne salt from the breaker zone.

In describing parent material, distinction often had to be drawn between the uppermost parent material and the basement rock of the primary landform. For instance, thick marine mudstones form the coastal cliff sequence of the Waitutu coast in Fiordland, but a veneer of fluvioglacial outwash gravels forms the true soil parent material. Likewise, in south Taranaki and north Wanganui, 2–3 m of airfall andesitic tephra, along with thinner lahars in the Pihama to Opunake sector, overlie the basement marine sandstones. For the purposes of analysis, the following broad soil parent material classes were used:

cc = Cretaceous sandstones and conglomerates principally of the Te Taitapu coast.

mu = Tertiary calcareous sandstone, mudstone, and siltstone.

sa = Tertiary, mostly non-calcareous breccias, sandstones and gravels of Otago, Southland, and Fiordland.

gr = granites, gabbro, and other intrusives of Southland.

li = richly calcareous limestones and dolomites of Te Taitapu and north Westland coasts.

at = tephras, lahars, and magnetite sands of Taranaki and Wanganui.

ba = basalt of the Otago Peninsula.

pe = peat.

Representative soil samples (17) were collected from turfs developed on the zonally dominant lithologies. Soil samples consisted of at least 15 soil plugs of 1.5 cm diameter to 10 cm depth using a Hoffer tube and aggregation. Samples were analysed for soil pH, Olsen P, CEC, base saturation, exchangeable Ca, Mg, K, and Na, and soluble salts (Blakemore et al. 1987).

Plot data were entered onto and are available from Manaaki Whenua, Landcare Research's NIVS database at Lincoln.

3.2 DATA ANALYSIS

Plant composition data were classified using two-way indicator species analysis (TWINSPAN: Hill et al. 1975). Detrended correspondence analysis (DCA) (ter Braak 1987a) and detrended canonical correspondence analysis (DCCA) (ter Braak 1987b) were used to examine broad-scale relationships between species cover, the clustered plot groups, and environmental variables. Continuously distributed environmental variables are plotted as axes on ordination diagrams and categorical variables as centroids.

4. Results

4.1 GEOGRAPHY OF THE SIX COASTAL ZONES

Turfs are found along comparatively short sections of the central-west coast of the North Island and the northwest, south, and southeast coasts of the South Island (Fig. 1; Appendix 1). They mostly occur on promontories and exposed straighter coastlines, where coastal wind is deflected over headland crests or through slump depressions and chutes in cliffed topography. Their concentration leeward of cliff-tops and on crests of headlands suggests adaptation to the zone of greatest salt deposition, either directly opposing the wind or immediately behind a topographical barrier.

Geologically, turfs are concentrated on sedimentary strata of low metamorphism. Strike is more or less perpendicular to the coast and dip at gentle angles. These produce discordant coastlines (French 1997: 38), where landform structure lies perpendicular to the coast, and cliffed headlands and bays result. Prevailing westerly wind and wave action strikes these coasts at oblique or acute angles, delivering apparently high salt loads and mechanical buffeting to promontories. Rare exceptions to this bedrock model are two granite sites in Westland and several sites about Bluff on intrusive gabbro, ultramafic, and granite.

Detailed zonal physiographies follow.

Taranaki/Wanganui

Turfs discontinuously span 112 km of coast of the south Taranaki ringplain and the northern Wanganui terrace country bordering the Taranaki Bight from approximately Cape Egmont in the north to Waverley in the south (Fig. 1; Appendix 1). A small exception is a turf at Pukearuhe in north Taranaki (C. Ogle pers. comm. 1997), which was not sampled.

There is a broad uniformity in the soil parent material, the topographic position, and the prevailing wind direction of turf sites along this coast. Two distinct geological substrates produce similar terrace landforms. Taranaki's ringplain proper is composed of coalesced lahar debris fans and interbedded airfall tephra (Fig. 2), whereas, south of Opunake these volcanic ejecta unconformably overlie uplifted marine sandstones of the Wanganui terrace unit (Neall 1982) (Fig. 3). Marine benches have formed in both substrates and, following tectonic uplift, produced turf-supporting cliff tops and bordering terraces. About Cape Egmont, coastal terraces on lahar debris and airfall tephra are <5 m a.s.l. whereas south of this the marine sandstone cliffs range up to 40 m in altitude toward Patea, then decline again toward Wanganui. Irrespective of elevation, Holocene volcanic ejecta form the dominant soil parent material throughout. On the Taranaki ringplain proper, coarse sub-rounded gravels and magnetite sands of lahar and flow fans are the main soil parent materials. On the elevated marine sandstones south of Opunake, 3–4 m of sandy airfall tephra unconformably overlies the marine sediments, providing similar coarse magnetite sand pavements for turf formation (Fig. 4). Soils therefore range from raw gravels and

Figures 2 to 23 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

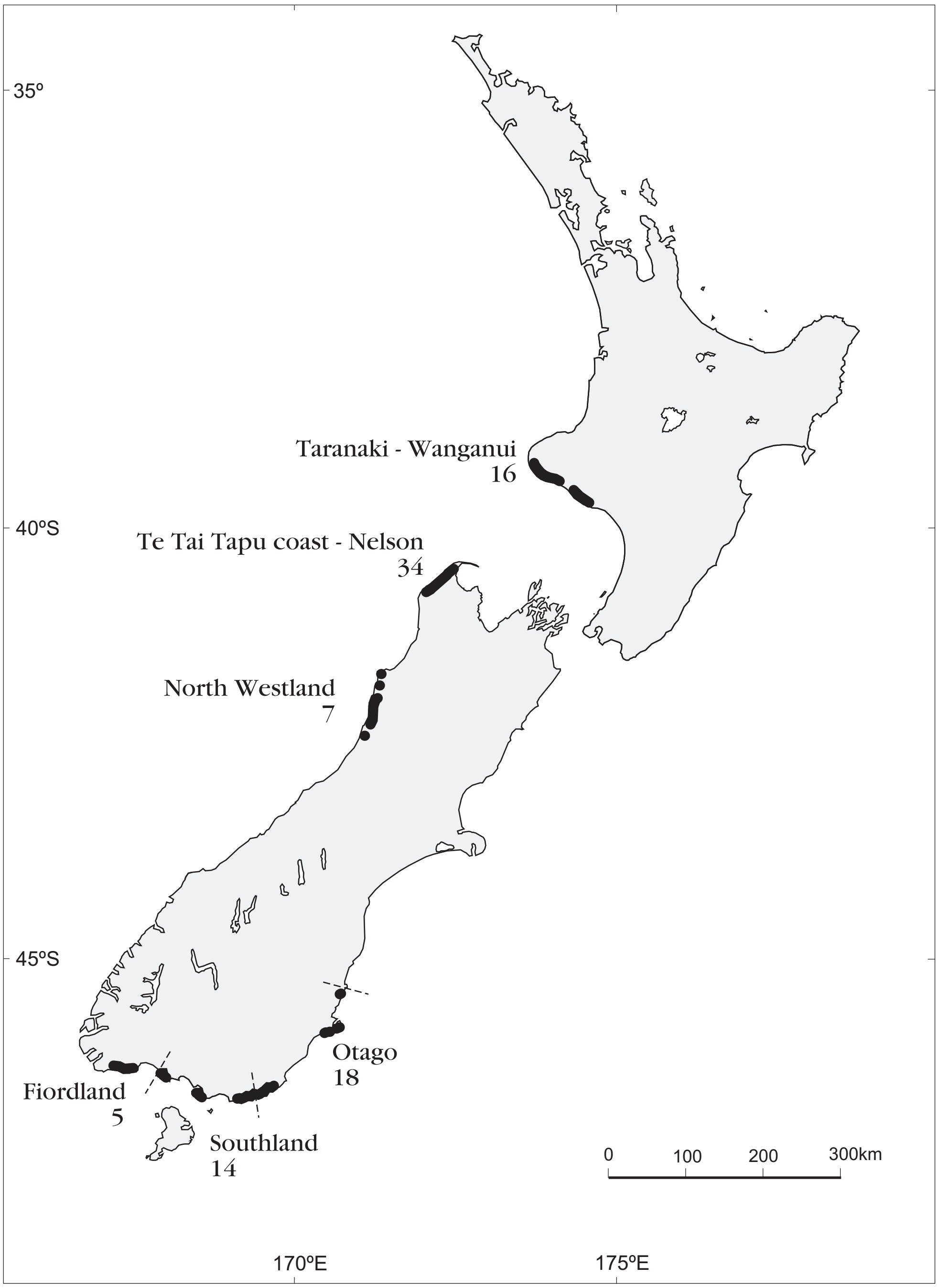


Figure 1. Coastal zones of mainland New Zealand supporting coastal turfs as ecological units. The numbers following the geographic labels are numbers of plots used to sample each zone.

sands to sandy loams. Mineral soil depth mostly ranges from 20–45 cm, but the exception is a mere 1–5 cm on welded podzol pans now exposed by ablation of overlying coverbeds. Deep, unstable dune or drift sands have accumulated along some cliff tops of the Wanganui sandstone sequence and, as expected, turfs are largely absent because the sand instability is incompatible with a prostrate and intertwined herbaceous growth form.

Topographically, most turfs occupy terraces bordering marine cliffs, although some occupy the convex creep slopes along cliff tops. An exception is a mosaic of turf and prostrate shrubland (the latter of *Pimelea* cf. *urvilleana* and *Coprosma acerosa*) on an upper cliff face at Sutherland Road, Manaia. Turfs south of Cape Egmont are commonly associated with headland promontories or coastal indentations, the latter effectively channelling or concentrating the intercepted wind.

Seventy percent of sampled turfs have SW quadrant aspects and the remaining 30% SE, effectively aligned perpendicular to or obliquely opposing the prevailing northwest winds. On the other hand, these aspects directly oppose the less common south winds. There is an average offset angle between aspect of the turf and landform direction of 29°. Turfs have an average elevation of 23 m a.s.l. and a nationally high salt deposition distance of 33 m, reflecting the high sandstone cliff profile south of Opunake.

Most turfs occupy free-draining sandy profiles. One exception is where surface water in shallow depressions allows moisture-tolerant herbs to consolidate previously unstable sand. Another exception is where stratigraphically older units of lahar, airfall tephra, and dune sands have been welded by podsolisation processes into iron-rich pans suitable for turf formation when exposed by aolian erosion of paleosol cover beds (Fig. 4). A Patea headland has examples of both (TW12 and TW13). Furthermore, many turfs occupy apparently truncated soil profiles, the loss of the upper horizons resulting from destruction and removal of previous coastal forest and scrub. With ablation of A and B soil horizons turfs occupy exposed, unweathered C or raw sand horizons of low colloidal content.

Half of the sites have human foot and vehicle traffic and cattle grazing as major disturbances (Fig. 2). These disturbances contribute to a comparatively low average plant cover of 64%. Notable undisturbed sites are those on the cliff-face at Sutherland Road, and where stock has been removed at Waipaepaenui Stream, a portion of the Kaikura Stream turfs, and at Puketapu Road where Wanganui Conservancy are monitoring vegetation responses to removal of stock grazing.

Nelson

Turfs are confined to 30 km of the Te Taitapu coast from Cape Farewell to Kahurangi Point (Fig. 1; Appendix 1). They are concentrated north of the Paturau River. An outlier turf at Wekakura Point just south of Kahurangi Point (S. Courtney pers. comm. 1997) was not visited. Although the Te Taitapu coast has a uniform northeast trend, it has a wide variety of landforms, lithologies, indentations and promontories. In the north from Cape Farewell to Nguroa and Kaihoka Lakes, Cretaceous non-calcareous conglomerates and massive sandstones dominate (Fig. 5, 6). From there south to Kahurangi Point, younger upper Tertiary calcareous sandstones, mudstones, and limestones outcrop (Fig. 7). All five lithologies support turfs on a wide variety of topographical units. Tectonic uplift and folding along the entire coast has produced steep shoreward relief and fault escarpment faces so that approximately half the turfs occupy steep topography. On the massive conglomerates and sandstones in the north, turfs often occupy chutes or clefts in the fragmented landforms into which the wind is channelled (Fig. 5, 6). South of Nguroa, large limestone blocks have cascaded downslope from escarpment outcrops above and now have small turfs around their bases within the spume zone. Another landform variation on the

Figures 2 to 23 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

calcareous sediments is small uplifted marine benches that project out over the tidal zone as turf-capped, cantilevered platforms (Fig. 8). Other turfs occupy steep rubbly talus debris. The average elevation is 17 m a.s.l.

The prevailing west to southwest wind strikes this northeast-trending coast obliquely and the average offset angle between aspect of the turf and landform direction is 41°. Perhaps predictably, 90% of turfs occupy west aspects and the remainder southwest on promontories directly intercepting this wind. If not on promontories, turfs occur in chutes and embayments that effectively concentrate the wind. In contrast to Taranaki–Wanganui turfs on interfluves, the majority here occupies the steeper topographical units of fallface and transportational midslope (53%). The rest occur on moderately steep convex creep slopes, seepage slopes, and colluvial toeslopes.

Soils throughout are predominantly sand and silt loams, although skeletal limestone gravels support turfs around limestone blocks. Most turfs are fronted by wave-wash platforms of rock. However, some low headlands supporting turfs, immediately north of sandy beaches, have periodic sand inundation from long-shore drift. For instance, wind-drift sand is deposited as a veneer at Kahurangi Point from sand derived from the south. Soils of the non-calcareous sandstones and conglomerates in the north are strongly leached and gleyed and conspicuous ironpans occur at depth. Te Taitapu turfs occur an average 20 m back from mean high water, whereas in other zones 10–12 m is the average inshore distance. In addition, the average salt deposition distance is 48 m, whereas elsewhere it is less than half that.

Seventy percent of sites are disturbed by stock grazing, yet mean plant cover is high at 89%. Nevertheless, there are sharp contrasts in the comparative intactness of sheep-impacted systems and the heavily fragmented surfaces subjected to cattle.

Westland

Turfs occur on seven promontories along 71 km of coast on a diverse range of basement lithologies (Fig. 1; Appendix 1). These exposed headlands are separated by long stretches of platformed coast either supporting or potentially supporting forest and scrub to the high tide mark. Southernmost Point Elizabeth and, further north, Truman Track (Fig. 9) have erodable calcareous mudstone basements. Turfs are scattered around large blocks of talus on a coastal escarpment at Point Elizabeth, whereas at Truman Track turfs cover a low-elevation terrace. Dolomite Point at Punakaiki has turfs scattered through wider chutes, narrower crevices (Fig. 10), and along pedestrian thoroughfares throughout the fluted and fractured limestone headland. Further north at Perpendicular Point and Kaipakati on calcareous sandstone, turfs occupy elevated terraces and escarpment slopes, respectively. A minor variation at Kaipakati Point is small turfs on a raised gravel beach. High granite headlands at Charleston have turfs along their shoreward crests and pedestrian nature trails (Fig. 11, 12). Finally, at Cape Foulwind, turfs occur along low-lying terraces above boulder beaches. Razorback Point was not included because it has small inconsequential turfs only. Similarly, despite apparently suitable physiography on the northern promontory of Tauranga Bay just south of Cape Foulwind, inconsequential patches only were evident amongst dominant *Phormium tenax*, along this prominent fur-seal haulout site.

Westland turfs straddle three topographical classes, interfluves, colluvial footslopes, and transportational midslopes. All turfs have west aspects opposing the prevailing southwest wind. Pedestrian traffic is the main disturbance factor on turfs at Dolomite Point, Truman Track, Kaipakati, Charleston, and Cape Foulwind, yet at levels apparently undamaging on dry substrates. Further, rock-climber activity at Charleston has apparently fostered turf expansion onto tops of headlands from their previous escarpment refugia. Westland turfs have a comparatively low 67% vegetation cover, principally reflecting the bouldery surface topography of mudstone and granite landforms and few are grazed.

The most likely explanation for an absence of turfs in central and southern Westland is a combination of incompatible landforms, few promontories, and competing forest and scrub to the strand zone.

Additional survey is required for completeness along the 'Tiropahi' coast, 12 Mile, and Seal Island.

Fiordland

Helicopter reconnaissance of the Foveaux Strait coast of Fiordland revealed turfs restricted to 15 km of the Waitutu marine terrace mudstones, with their overlay of fluvioglacial outwash gravels (Ward 1988), between easternmost Wairaurahiri River and westernmost Grant Burn (Fig. 1; Appendix 1). Turfs straddle a mid Holocene-aged marine bench or terrace at 3 m a.s.l. (Mark et al. 1988) (Fig. 13) and a c. 40 m high marine terrace with headland promontories of Last Interglacial age (80 000–120 000 years) (Ward 1988) (Fig. 14).

Turfs occur discontinuously along five coastal sectors, Crombie Stream, Angus Burn (Fig. 13), Long Point (Fig. 14), Waitutu Point, and Grant Burn (Appendix 1). Marine terraces provide uniform interfluve topography for turf formation, although this coast is in a state of retrogradation. Although no data exist for Waitutu, retreat rates for mudstone cliffs at Kaikoura are as high as 24–33 cm/yr (Healy & Kirk 1982).

Fiordland turfs have south aspects, opposing or aligned obliquely to the prevailing west to southwest wind.

Uppermost convex creep slopes atop coastal cliffs were the pre-human sites for Fiordland's turf flora. Apparently intact coastal vegetation sequences, including outermost turf on cliff tops, are rare or absent along the entire coastal sequence of Waitutu mudstone because of the ubiquitous effects of concentrated browsing by deer (e.g., Crombie Stream, Fig. 15; also see Mark et al. 1988). Indeed, all turfs are heavily impacted by deer and appear to have expanded considerably (Fig. 15) through this agent at the expense of previously taller vegetation of first sedgeland of *Carex appressa*, *C. virgata*, *C. flagellifera, and Hypolepis millefolium*, then scrub of *Leptospermum scoparium*, *Brachyglottis rotundifolia*, and *Phormium tenax* and, finally, low forest. Dead-standing and fallen stem wood of trees litter most non-headland turfs and bordering sedgeland and shrubland (Figs. 13, 15). Furthermore, innermost *Nothofagus solandri* var. *cliffortioides* forest may also suffer a saltatory retreat following collapse of buffering scrub. However, the relative influence of natural stand dynamics or deer-browsing on this phenomenon is problematic (Fig. 13).

Figures 2 to 23 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

Fluvioglacial outwash gravels form the main soil parent material. These gravels are poorly drained, and incipient ironpans occur at depth. Soils are mostly humic sandy loams, the high organic content resulting from impeded drainage through the gravels and, perhaps, high salt concentrations inhibiting litter decomposition (A. Mark pers. comm. 1998). However, there was a marked absence from Fiordland turfs of *Isolepis cernua* and *Crassula moschata*, which are indicators elsewhere, along with *Lilaeopsis novae-zelandiae*, of damp or wet soils. Also absent from sampled sites was *Selliera radicans*, a dominant of turfs elsewhere. The capping gravels are absent on a promontory at Long Point, where a large turf has developed on a mudstone-derived clay-loam soil (Fig. 14). This turf also supports high species diversity and few adventives. Fiordland turfs have a comparatively high salt deposition distance of 21.23 m, reflecting the high mean elevation of 15.8 m. Their mean offset angle is a comparatively low 7°.

The irregular and jagged granite landforms west of Green Islets and Big River are devoid of the pre-requisite marine benches or terraces that turfs occupy along this most exposed of coastlines. Turfs are also absent along the seacoast west of Puysegur Point in the fiord coastline, again because of inappropriate landforms (B. Rance pers. comm. 1997). Although outside the environmental envelope of this study, turfs infrequently develop on tidal-wash platforms in the more protected reaches of Fiordland's sounds. For instance a turf in Wet Jacket Arm (NZMS 260 B44 398944) (Fig. 16) contained *Samolus repens*, *Selliera radicans*, *Lilaeopsis novae-zelandiae*, *Leptinella squalida*, *Neopaxia australasica*, *Rumex neglectus*, *R. flexuosus*, *Isolepis cernua*, *Plantago triandra*, and *Myosotis tenericaulis*, compositionally quite different from elevated turfs along the Foveaux Strait coast. Most of these are common turf constituents outside Fiordland. These tidal systems are more akin to estuarine mat communities such as *Sarcocornia* saltmarsh in the manner in which salt is delivered.

Southland

Turfs are a conspicuous feature of solid rock and exposed landforms along 70 km of the Foveaux Strait coast from Oraka Point in the west to Curio Bay in the east (Fig. 1; Appendix 1). Landform lithologies can be divided into massive sandstones and conglomerates in the east from Curio Bay to Waipapa Point, intrusive ultramafics and granites around the Omaui and Bluff Peninsula (Fig. 17), and gabbro at Oraka Point (Fig. 18). All these lithologies have uplifted marine benches now preserved as low coastal terraces less than 10 m a.s.l. (Fig. 18). Higher sandstone headlands between Slope Point and Waipapa Inlet also have turfs atop cliffs and in embayments, across which the prevailing west to southwest wind is channelled. Turfs also transition from the low-level terraces down onto the rearward margins of gravel beaches, particularly on the ultramafic and gabbro landforms (Fig. 19).

All turfs have south to west aspects, a range somewhat wider than those along Fiordland's Waitutu coast because of the more deeply indented coastal profile. There is a large 89° offset angle between aspect and landform direction emphasising the influence of the oblique west wind on turf formation. Turfs have a comparatively low average elevation of 8 m a.s.l. Soils are mostly moderately well drained sandy loams. Those of the upper margins of beaches are on fine gravels and coarse sands (Fig. 19). Most are within the spume zone in close proximity to the wave wash platform. Those on the elevated headlands in the east are still within 20 m of the breakers, but at higher elevations. Nevertheless, persistent strong winds must deliver high salt loading. Wet soils predominate on the granites of Bluff Peninsula because drainage is impeded on the massive substrate (Fig. 17). These turfs are consequently vulnerable to pugging by cattle especially where lateral subsoil seepage emerges on escarpment slopes (Fig. 17). In contrast, soils developed behind the strand line on the gravel and sand beaches at Omaui and Oraka Point (Fig. 19) are free-draining and support a distinctive flora, including *Lepidium tenuicaule*.

There are no intact coastal vegetation sequences bordering turfs in Southland (e.g., Fig. 17). All turfs grade into surrounding or rearward pasture. The dynamic interplay between these two competing communities is difficult to gauge without monitoring experiments. Inferential evidence suggests that turfs more than 'hold their own' against competing pasture on sites grazed by sheep. Reconstruction of prehuman vegetation zonation is best attempted at Omaui, although even there indigenous vegetation is highly fragmented and mostly secondary. Patterns point to bordering sedgeland transitioning to coastal scrub and low forest in a pattern reminiscent of Fiordland's sequences (see above). The narrow turf zone at Omaui compressed between the gravel beach and rearward flaxland and shrubland point to its competitive extent with a reconstitution of the coastal scrub and forest belts. Stock graze almost all sites. Cattle, as opposed to sheep, are more destructive of turfs where soils are damp. The extensive turfs along 2.5 km of shore platform from the Three Sisters to Barracouta Point and from Slope Point to Black Point are now mostly deeply pugged, with disrupted hydrology and enhanced opportunities for weed invasion. Turfs appear to have a competitive advantage over pasture grasses when exposed to compaction under vehicular traffic on the Curio Bay headland.

Otago

Turfs are concentrated on headlands along the deeply indented Catlins coastline, about headlands of Otago Peninsula (Fig. 20, 21), and from there north only on the most exposed headlands to Shag Point (Fig. 1; Appendix 1). Otago has the only turfs in mainland New Zealand on an eastern shoreline, a reflection of the influence of southwesterly winds channelled around its southeast coast from Foveaux Strait. There is an average 76° offset between aspect of the turf and strata direction demonstrating the influence of oblique shoreline winds (Fig. 22). There also appears to be a reduction northward in the height of coastal cliffs upon which turfs have developed as the salt-depositing capacity and the strength of the southwesterly wind diminishes.

A large proportion of Otago turfs occur on headlands of the Catlins coast, from where forest has been comprehensively cleared (Fig. 23). The headland south of Frances Pillars is an encouraging exception. Disjunct examples of turfs north from the Catlins include Watsons Road, Tunnel Beach (and an unsampled example just south), Otago Peninsula (Cape Saunders and Sandymount (Fig. 20), and Shag Point, the latter the most northern record. Sandstones of the Southland syncline dominate the basement lithology of the Catlins coast (Fig. 23), with interbedded conglomerate seams failing to provide stable uplifted terraces for turf formation. Watsons Road has turfs on unconsolidated sand and gravel just above the strand line, an equivalent landform to Omaui and Oraka Point in Southland. The Otago Peninsula with two turf sites is composed of old basaltic

Figures 2 to 23 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

and andesitic flows (Fig. 21), while further north Shag Point is composed of Miocene breccia. Small turfs occur within a fur seal haul-out zone on a low coastal platform at Long Point providing the only clear-cut mainland association between turfs and marine mammals. Again turfs mostly occur on southwest aspects, although a small proportion point north and east.

The most extensive turfs occur along the margins and throughout seaward aspects of exposed coastal paddocks on The Brothers Point, Tautuku Peninsula, and Long Point headlands (Fig. 23). Judging from the helicopter-based survey, Chaslands Mistake peninsula supports only small turfs on one headland, but access permission to confirm this was denied. In heavily grazed systems, turfs are apparently expanding at the expense of bordering pasture (Fig. 23). A rare example of a turf developed on coastal peat occurs on the southern side of Long Point around an isolated crib.

Virtually all Otago turfs are subjected to stock grazing. The one at Shag Point is still influenced by pedestrian traffic, whereas vehicular traffic has been recently excluded. Partly intact coastal vegetation sequences at Frances Pillars on the Catlins coast again indicate that turfs were previously confined to cliff tops because of competing belts extending inland of first *Phormium tenax* flaxland, then scrub of *Coprosma propinqua* and *Pseudowintera colorata*, and finally forest of *Weinmannia racemosa*, *Podocarpus totara*, *Dacrydium cupressinum*, and *Metrosideros umbellata*.

4.2 COMMUNITY CLUSTERING

Eight vegetation associations were recognised at level 3 from the TWINSPAN classification of the 94 plots (Fig. 24). The first dendrogram split divides the *Zoysia minima* and *Centella uniflora* plots of Taranaki-Wanganui, Nelson, Westland, and Fiordland from the Otago and Southland plots with *Crassula moschata* and *Apium prostratum*. At level 2 the former group is divided into Groups C and D where the fleshy leaved herbs *Plantago triandra*, *Leptinella dioica*, and *Centella uniflora* distinguish these plots from those of Groups A and B with *Zoysia minima*. The latter group of plots at division 1 is divided at level 2 into those with *Samolus repens* and *Apium prostratum* from those with *Plantago triandra*, *Leptinella dioica*, and *Plantago raoulii*. At level 3, the Taranaki–Wanganui plots of Groups A and B are divided into those with dominant *Z. minima* and those with co-dominant fleshy herbs. Groups C and D distinguish the distinctive Fiordland plots with *Poa pusilla* and *Gunnera monoica* from that large group dominated by the three generalists, *Selliera radicans*, *L. dioica* and *C. uniflora*. The Otago-Southland-Fiordland plots of Groups E and F are divided on the dominance of *L. dioica*. Plot FD 5 is a distinct outlier of Association F, and at the next cluster division separates out as a single plot group. Finally, Group H of Otago is distinguished at level 3 from Group G by the presence of the southern endemic grass *Poa astonii*.

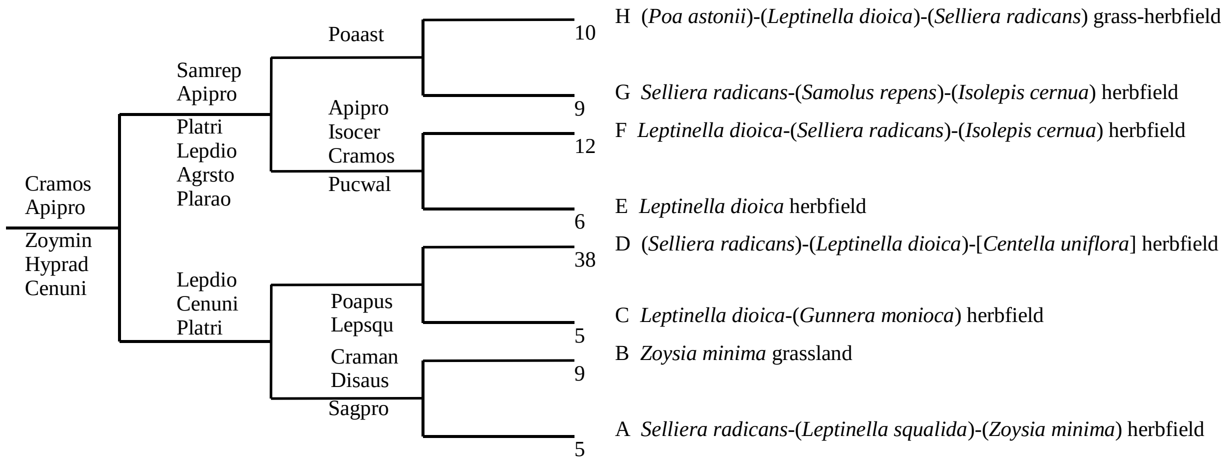


Figure 24. TWINSPAN dendrogram of 94 plots of turf vegetation on mainland New Zealand. Indicator species names at each division abbreviated to first three letters of genus and species names. Names of associations based on Atkinson (1985). Numbers beside last divisions indicate numbers of plots classified in each association (for plot membership see Table 1, below).

TABLE 1. PLOT COMPOSITION OF TWINSPAN GROUPS SHOWN IN FIGURE 25.

A	B	C	D		E	F	G	H
TW 3	TW1	FD1	TT1	TT23	OT3	FD5	TW12	SD5
TW4	TW2	FD2	TT2	TT24	OT6	SD1	TW14	SD14
TW5	TW8	FD3	TT3	TT25	OT9	SD6	TT7	OT4
TW6	TW9	FD4	TT4	TT26	OT14	SD7	TT10	OT7
TW7	TW10	WD6	TT5	TT27	OT16	SD8	TT19	OT8
	TW11		TT6	TT29	OT17	SD9	TT28	OT10
	TW13		TT8	TT30		SD10	WD1	OT11
	TW15		TT9	TT31		SD11	WD2	OT12
	TW16		TT11	TT32		SD13	WD5	OT15
			TT12	TT33		OT1		OT18
			TT13	TT34		OT5		
			TT14	WD3		OT13		
			TT15	WD4				
			TT16	WD7				
			TT17	SD2				
			TT18	SD3				
			TT20	SD4				
			TT21	SD12				
			TT22	OT2				

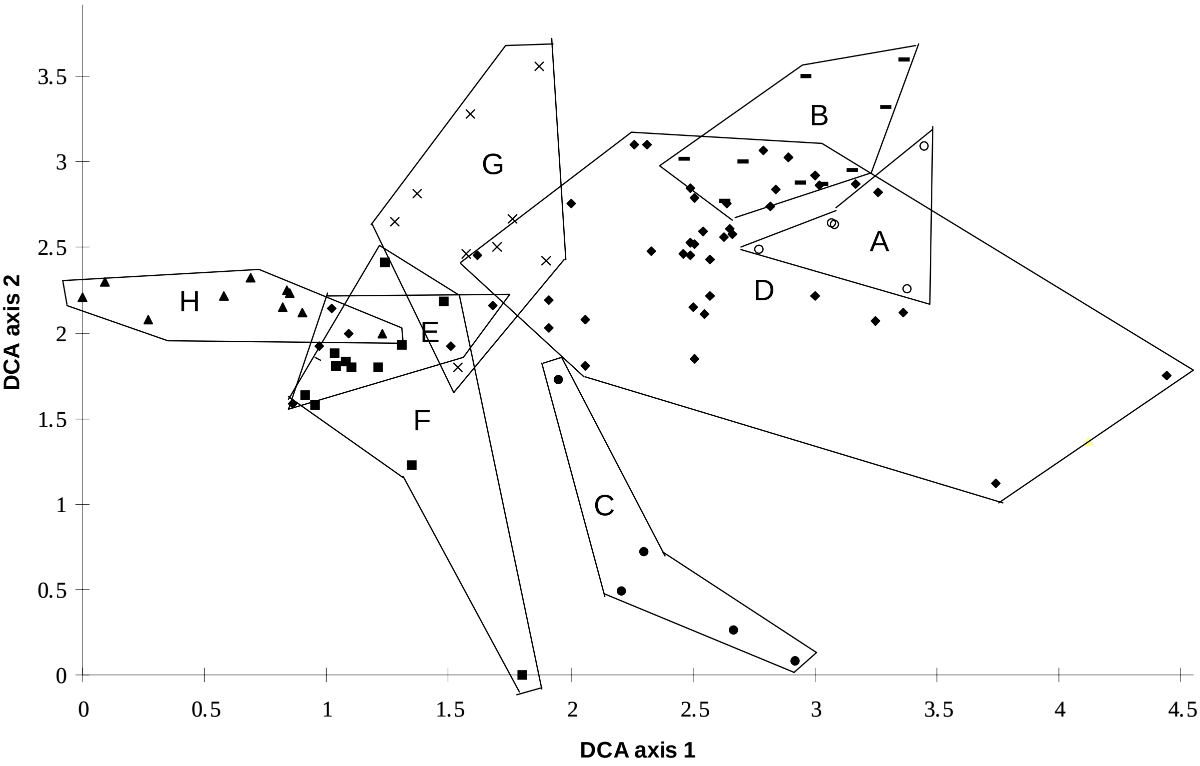
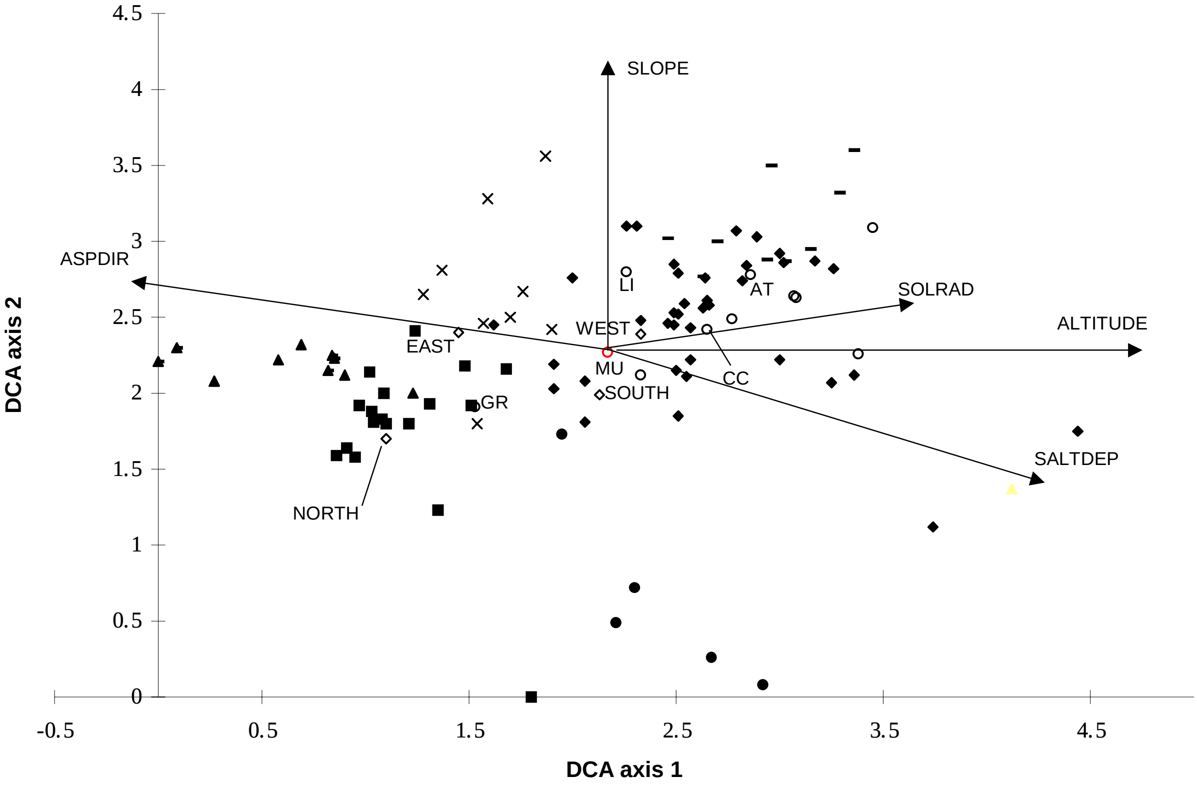


Figure 25. DCA ordination of plots based on species, with TWINSPAN associations superimposed.



SALTDEP = distance from breaker zone; ASPDIR = offset angle between landform direction and aspect;
AT = volcanic tephras; CC = Cretaceous sandstones and conglomerates; GR = granites, gabbros, and other intrusives;
LI = limestone/dolomite; MU = calacareous mudstones, siltstones, and sandstones; SOLRAD = solar radiation.

Figure 26. DCA ordination of plots, with axes and centroids for continuous and categorical variables, respectively.

4.3 ORDINATIONS

The DCA ordination resulted in separation of the plots along both the first and second axes (Fig. 25) (eigenvalues were 0.49 and 0.41, respectively). When overlaid, the eight vegetation associations partitioned much of the ordination space, although there is considerable overlap of Groups A and B with the multi-zonal Group D and between Groups E and F. Groups C, D, and F by virtue of small numbers of outliers suggest high compositional variation.

Ordination correlations between vegetation composition and environmental variables suggest that the physical factors of altitude, the distance from the breakers, and substrate type are the most influential factors on turf composition (Fig. 26; Table 2). Solar radiation although correlated with other physical factors was much less influential. At a second level, DCA axis 2 seems to relate to variables reflecting the ground surface, for instance, soil parent material, soil moisture or drainage, soil depth, and % cover of rock, soil, and vegetation. Associations E, F, G, and H, composed mainly of Otago and Southland plots, occur at shorter distances and lower altitudes from the breakers, have larger offset angles (in other words acute angles between shoreline direction and prevailing wind), and lower solar radiation. Most of the Taranaki-Wanganui, Nelson, and Fiordland plots occur at greater elevations and distances from the breakers.

TABLE 2. SPEARMAN'S RANK ORDER CORRELATIONS OF ENVIRONMENTAL VARIABLES WITH DCA ORDINATION AXES.

ENVIRONMENTAL VARIABLE	DCA1	DCA2
Altitude	0.33**	0.09
Distance	0.18	−0.1
Salt distance	0.23*	−0.06
Aspect offset	−0.18	−0.1
Landform dip	−0.04	0.15
Landform direction	0.56**	0.47**
Mean top height	−0.09	−0.04
% cover rock	−0.05	0.24*
% cover soil	0.13	0.24*
% cover vascular plants	−0.03	−0.31**
Slope	−0.03	0.19
Soil depth	−0.15	−0.2*
Drainage	−0.1	0.29**
North aspect	−0.11	−0.13
East aspect	−0.13	0.03
South aspect	−0.02	−0.22*
West aspect	0.14	0.26*
Solar radiation	0.32	0.23*
Tephra	0.42	0.39**
Basalt	−0.23	−0.04
Cretaceous sandstones/conglomerates	0.28	0.05
Intrusives	−0.23	−0.32**
Limestone/dolomite	0.02	0.34**
Mudstone/siltstone	0.04	0.03
Massive sandstones	−0.42	−0.43**

* significant at $P<0.05$, ** significant at $P<0.01$.

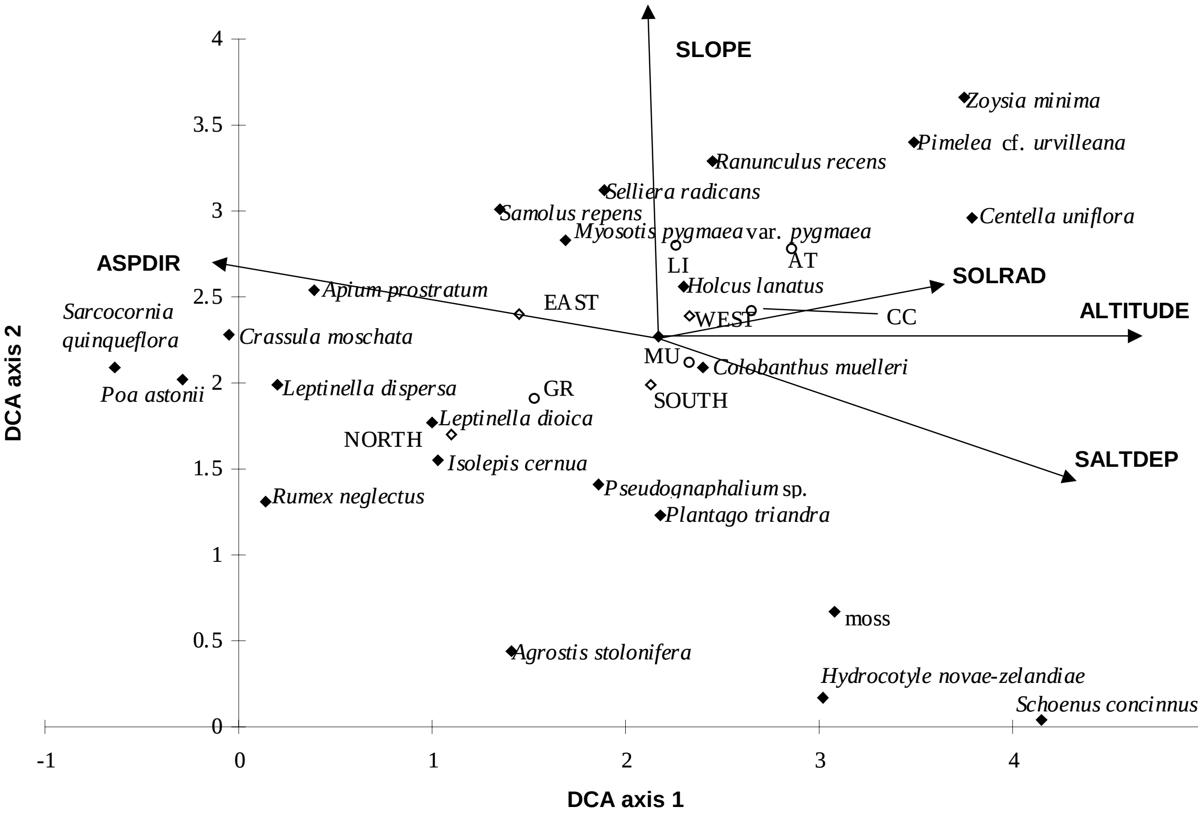


Figure 27. DCA ordination of species, with axes and centroids of continuous and categorical variable, respectively. For abbreviations see caption to Figure 26.

Sarcocornia quinqueflora, *Poa astonii*, *Apium prostratum*, *Crassula moschata*, *Leptinella dispersa*, and *Rumex neglectus* are correlated with short distances from the breakers and at large offset angles between landform direction and aspect (Fig. 27). Alternatively, *Schoenus concinnus*, *Zoysia minima*, *Pimelea* cf. *urvilleana*, *Centella uniflora* and moss occur at greater distances from the breakers. A group of widely distributed and mostly structural dominants, *Selliera radicans*, *Samolus repens*, *Holcus lanatus*, *Leptinella dioica*, *Isolepis cernua*, *Colobanthus muelleri*, and *Plantago triandra*, have weak correlation with most physical factors. The rare plants *Ranunculus recens*

TABLE 3. EIGENVALUES AND GRADIENT LENGTHS FOR FIRST AND SECOND AXES OF DCA AND DCCA ORDINATIONS FOR THE DATA FROM TURF COMMUNITIES.

	EIGENVALUES		GRADIENT LENGTH		
AXIS	DCA	DCCA	DCA	DCCA	r_s
1	0.485	0.406	4.439	3.182	0.773
2	0.412	0.308	3.598	4.065	0.497

r_s is Spearman's rank correlation of first and second DCA axis plot scores with first and second DCCA axis plot scores.

and *Myosotis pygmaea* var. *pygmaea* also have weak relationships with the recorded environmental variables.

The DCCA axes 1 and 2 account for somewhat less of the variation in the species data than the DCA axes 1 and 2 (Table 3). What this implies is that there may be other factors of the environment that are influencing the compositional variation that were not (or could not) be measured.

4.4 SPECIES RICHNESS

A total of 150 taxa (Appendix 2) were recorded from the 94 plots (Appendix 1), comprising 122 native and 28 exotic taxa. Mosses and lichens were not identified to species level, but aggregated into two categories. There was an average taxon richness per site of 13.2±3.42 and an average native taxon richness of 8.8±2.59.

Average taxon richness per plot ranged from c. 9 for Taranaki–Wanganui and Otago to c. 17 for Fiordland (Table 4). Nelson, Westland, and Southland shared similar degrees of intermediate richness. Variation in the number of exotics accounted for some of this range (Table 4), but natives accounted for most. Otago showed the lowest average diversity of exotics, nearly one third that of Taranaki–Wanganui and Nelson. Some of the low average richness of Taranaki-Wanganui turfs relates to the species depauperate communities formed by *Zoysia minima* (pers. obs.). Taxon richness of the TWINSPAN Groups (Table 5) predictably reflected their zonal complexions, with the Fiordland-dominated Group C substantially higher than the rest. Overall, species richness was not correlated with latitude.

TABLE 4. AVERAGE SPECIES RICHNESS OF SAMPLED TURFS IN SIX COASTAL ZONES.

ZONE	TARANAKI/ WANGANUI	NELSON	WESTLAND	FIORDLAND	SOUTHLAND	OTAGO
Total richness	11.44±3.67	15±6.12	12.86±5.87	18.8±3.7	13.71±4.98	9.72±2.49
Exotic richness	2.75±1.73	2.56±1.74	1.86±2.34	2.2±1.79	1.78±1.37	1.06±1.26
Native richness	8.69±2.52	12.41±5.45	11±5.54	16.6±4.62	11.93±4.03	8.67±2.11

TABLE 5. AVERAGE SPECIES RICHNESS IN EIGHT TWINSPAN VEGETATION ASSOCIATIONS.

TWINSPAN GROUP	A	B	C	D	E	F	G	H
Total richness	13.2±3.42	10.22±3.87	19±3.32	15.32±5.91	9.67±2.25	14.08±4.98	9.67±2.69	9.5±2.42
Exotic richness	4.4±1.67	2±1.22	3±2.45	2.5±1.77	1.83±0.98	1.83±1.11	1.22±1.2	0.5±1.27
Native richness	8.8±2.59	8.22±2.73	16±5.61	12.79±5.27	7.83±1.83	12.25±4.25	8.44±2.51	9±1.76

Three zones had plots with unusually rich native floras:

- Nelson—Sandhills Creek (27); Wylie No. 1 (22); and Kaihoka No. 2, Sharkshead No. 2, and Kahurangi Point (20).
- Westland—Charleston (Doctor Bay) (23).
- Fiordland—Long Point (22); Angus Burn (20).

4.5 NATIONALLY THREATENED AND LOCAL TAXA

Twelve taxa from the New Zealand Threatened and Local Plant lists (Cameron et al. 1995) appear as turf constituents (Table 6). Ten of these were restricted to one or two zones, and the remaining two were more widely distributed. More detailed notes on individual taxa appear in the provincial summaries (4.6 Zonal summaries).

TABLE 6. PLANT TAXA OF THE NEW ZEALAND BOTANICAL SOCIETY THREATENED AND LOCAL PLANT LIST (CAMERON ET AL. 1995) THAT APPEAR IN TURFS OF THE SIX COASTAL ZONES.

STATUS	TAXA	COASTAL ZONE
Endangered	*Lepidium flexicaule*	Nelson, Westland
	Ranunculus recens "Manaia"	Taranaki–Wanganui
	Crassula peduncularis	Taranaki–Wanganui
Vulnerable	*Lepidium tenuicaule*	Southland, Otago
	Mazus novaezeelandiae	Nelson
	Ranunculus recens s.s.	Nelson, Southland, Otago
	Oreomyrrhis "minutiflora"*	Taranaki–Wanganui, Nelson, Southland, Otago
Rare	*Mazus arenarius* ("False Islet")	Southland
	Poranthera microphylla	Nelson
Taxonomically Indeterminate–Rare	*Limosella* "Manutahi"	Taranaki–Wanganui
Local	*Crassula manaia*	Taranaki–Wanganui
	Leptinella calcarea	Nelson

* *Oreomyrrhis* "minutiflora" Druce (1993) is an unnamed taxon found predominantly in coastal habitats. Its sessile umbels at the flowering stage and minute flowers of c. 1 mm diameter (Druce 1992) distinguished it from *O. colensoi* var. *delicatula*, which typically occurs on inland sites subjected to periodic inundation by water.

4.6 ZONAL SUMMARIES

4.6.1 Taranaki–Wanganui

Communities

There were two principal and one minor community highlighted in the classification:

- Association A—*Selliera radicans*-(*Leptinella squalida*)-(*Zoysia minima*) herbfield.
- Association B—*Zoysia minima* grassland.
- Association G—*Selliera radicans*-(*Samolus repens*)-(*Isolepis cernua*) herbfield.

S. radicans and *Z. minima* dominate most turfs, but mostly in a spatial pattern that suggests antagonistic interactions. *Z. minima* prospers on dry pavements of free-draining sand whereas *Selliera* and other herbs prefer loam soils. *Leptinella squalida* var. *squalida* was also frequent, along with *Plantago triandra*, *Colobanthus muelleri*, *Agrostis muscosa*, *Pseudognaphalium* sp. unnamed, *Disphyma australe*, *Oreomyrrhis* "minutiflora", *Pimelea* cf. *urvilleana*, *Lobelia anceps*, and *Crassula manaia*. *Leptinella dioica* was dominant in turfs of all provinces except Taranaki-Wanganui, from where it was curiously absent.

Weeds infiltrated turfs either as smothering waves or as isolated individuals. The most frequent species were *Holcus lanatus*, *Plantago coronopus*, *Hypochoeris radicata*, *Trifolium dubium*, *Cerastium fontanum*, *Sagina procumbens*, and *Lotus suaveolens*, although their combined cover seldom exceeded 15% (for an exception see stock exclusion experiment details below). Other less frequent weeds were *Arctotheca calendula* (Cape weed), *Coronopus didymus* and *Plantago lanceolata*. Only on the outermost convex creep slope are turfs somewhat immune from invasion by exotics, and it is postulated that in prehuman times turfs were compressed to these most exposed sites by taller-statured coastal scrub or low forest. The presence of subfossil stumps and logs of *Podocarpus totara* within 2 m of a Patea cliff edge and surrounded by present day turfs (Fig. 28) testify to the tolerance of trees on cliff margins along this heavily salt-inundated coastline.

Disturbance

The most extensive turfs are all subjected to stock grazing and/or human traffic, pointing to expansion at the expense of potentially taller competing vegetation such as pasture grasses, *Ammophila arenaria* (marram) and *Lycium ferocissimum* (boxthorn). Examples are Stent Road (Fig. 2), Waipaepaenui Stream, Kaikura Stream (Fig. 4), and Waverley. However, turfs are not immune to fragmentation from heavy impact by vehicles, cattle (Fig. 29), other farming activities, and earthworks (Fig. 30).

Figures 28 to 48 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

No turfs on this coast are an integral component of an intact sequence of native vegetation, although a cliff site at Sutherland Rd, Manaia has considerable cover of native flax, shrubs, and herbs (Fig. 31). Several have grazing excluded and concomitant expansion of boxthorn and marram (Fig. 4).

Trends following removal of stock at Puketapu Rd

Monitoring experiments at two headlands at Puketapu Rd, Pihama are gauging the responses of turfs to the removal of stock grazing (Fig. 32) (G. La Cock pers. comm. 1997). Since November 1992, exotic weeds have substantially smothered native turf communities on five of the six transects. This conversion process operates along a migrational wave front, rather than from a coalescing of outlier nuclei, although the latter is evident to some extent on Transect 3. Bare areas resulting from turf fragmentation are sites readily colonised by exotics. Conversion to weeds accelerates in a gradient inland, with only one turf exposed to maximum salt deposition and wind exposure on the southernmost headland (Transect 1, Fig. 32) showing little change and therefore offering the best prospects of long-term survival of a turf community.

Notable rare plants

An upper cliff face of consolidated andesitic ash at Sutherland Rd, Manaia (Fig. 31) supports the only provincial population of *Ranunculus recens*. Annual population monitoring since November 1994 indicates declining numbers, partly in response to competition from taller plants such as *Coprosma acerosa*, *Hypochoeris radicata*, *Leontodon taraxacoides*, *Leptinella squalida* var. *squalida*, and *L. dispersa* var. *rupestris* (G. La Cock pers. comm. 1997). An earlier Thomas Kirk record from near Hawera, possibly from Waihi Beach has not been subsequently confirmed. *R. recens* was recorded in turfs from three other zones, Nelson (8), Southland (3), and Otago (5), although it occurs in other coastal habitat in Southland and Stewart Island (B. Rance pers. comm. 1997) and Otago. There appears to be no consistent regional variation in its leaf morphology despite variations in the proportion of brown pigmentation concentrated around the petiole and lamina base, the petiole length, the degree of terminal lobation or partitioning, and the density of adaxial and marginal hairs, the former with tuberculate bases. Further, although plants of *R. recens* s.s. from the only known inland population in the Ngawakaakauae catchment, southern Kaimanawa Mountains are predominantly brown, they appear to differ little from coastal populations in leaf morphology. Small differences in the petal width were noted between Kaimanawa and Otago–Southland plants, but its consistency is unknown. The species' conservative seed dispersal capacity (Fig. 31) and absence from recently expanded turfs suggests that it prefers long established and extremely prostrate communities.

A spring annual, *Myosotis pygmaea* var. *minutiflora*, is currently known from Stent Rd and Puketapu Rd in Taranaki–Wanganui only (Fig. 33), although A.P. Druce recorded it from turf near Taungatara Stream in 1964 (CHR 131005) and Paora Road in 1970 (CHR 210679). Other, reasonably recent coastal records are from the edge of a brackish rockpool on the north end of Kapiti Island and also on fine shingle at Ngawhi Point near Cape Palliser (C. Ogle pers. comm. 1998). Fig. 33 also provides comparisons with related taxa in this species complex, that possibly constitute separate species in their own right.

A Normanby Rd turf supports one of these varieties in the one presently known provincial population of *Myosotis pygmaea* var. *pygmaea* (C.C. Ogle pers. comm. 1997) (Fig. 33), although A. P. Druce recorded it from Puketapu Road in the early 1970s. It was also recorded from Arawhata on Auckland's west coast in 1932 by L. B. Moore; from Castlepoint, from Hiemama Stream, and Round Rock New Plymouth in 1964 by A. P. Druce; and from the Hawera coast by Mackie (1935). This taxon is also presently known from turfs in Nelson, Southland, and Otago.

Crassula spp.: The upward spiky growth form of *Zoysia minima* (Fig. 34) hosts three crassulas found in turfs of Taranaki–Wanganui only: the very restricted *Crassula peduncularis* (Fig. 34), the slightly more widespread *C. mataikona*, and the more widespread *C. manaia* (Fig. 35). These minute plants appear more vigorous in *Zoysia* mats subject to periodic, but light, sand inundation. *C. peduncularis* appeared in one provincial turf only on the rua pit headland at Puketapu Rd. *C. mataikona* was recorded from the same headland and a dry sand turf on a Patea headland (TW13).

Zoysia minima is a structural dominant of turfs on dry, sandy, skeletal soils, from which overlying organic horizons have possibly vanished. As a dominant mat, it appears antagonistic to many other turf constituents and, consequently, it promotes low species diversity (crassulas, *Colobanthus muelleri*, *Agrostis muscosa*, and *Myosotis pygmaea* var. *minutiflora* are exceptions). It has greatest dominance in Taranaki turfs, but also features on low-fertility Nelson sites (non-calcareous conglomerate and sandstone) and in a turf on granite at Charleston, north Westland.

Limosella sp. unnamed (*L*. '"Manutahi") and *Selliera rotundifolia* are two other rare species recorded from turfs atop a Patea headland. Both occur on a wet, but unconsolidated, sand depression. The former species is under taxonomic investigation (P. Heenan pers. comm. 1997) and the latter is at its northern limit on its Horowhenua–Wanganui sand plain habitat (Heenan 1997).

Oreomyrrhis "minutiflora" is a conspicuous, yet, comparatively rare component of herbaceous turfs in this zone. However, it is frequent in turfs of Nelson, Southland, and Otago.

Coprosma acerosa: Populations of a compact form of this taxon are confined to Wanganui Conservancy coast. It occurs as far south as Wai-inu (Waitotara River) on limestone outcrops on the coast (C. Ogle pers. comm. 1998).

Pimelea sp. unnamed (*P*. cf. *urvilleana*, incl. *P. prostrata* var. *quadrifaria*) (Druce 1992) is one of the few shrubs sufficiently prostrate for inclusion in a turf classification. Prominent along the Taranaki–Wanganui and known from the Te Taitapu coast at Cape Farewell only, its hosting of the moth *Notoreas* 'foxi' in the former province is the subject of detailed investigation (L. Sinclair pers. comm. 1997). This plant appears to replace colonising herbs such as *Selliera radicans* and *Leptinella dioica* as turfs undergo successional change. *P. prostrata* replaces the above *Pimelea* in turfs of Southland.

Selliera rotundifolia (Heenan 1997) was found in both wet and dry sand habitats at Patea (Fig. 28) on the Taranaki coast. The evolutionary specialisation of this species to sand plains points to a long history for this habitat on the Taranaki–Wanganui–Manawatu coast.

Although not recorded from turfs, *Leptinella dispersa* sp. *rupestris* is a noteworthy species in sand pockets on wet sea cliffs of this coast. It has scattered, mostly single-sexed populations from Waihi Beach, Hawera to Wanganui (C.C. Ogle 1997, from D. Lloyd pers. comm.). (See further note under Southland.)

Figures 28 to 48 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

4.6.2 Nelson

Communities

Despite a large number of plots on diverse substrates and landforms, there was just one major and one minor community identified in the classification:

- Association D—(*Selliera radicans*)-(*Leptinella dioica*)-[*Centella uniflora*] herbfield.
- Association G—*Selliera radicans*-(*Samolus repens*)-(*Isolepis cernua*) herbfield.

This reflects the overwhelming dominance of *S. radicans* (Fig. 36), *L. dioica*, and *C. uniflora*. Association G, with *S. repens*, *I. cernua* and, frequently, *Lilaeopsis novae-zelandiae* occurs close to strand lines on wetter pavements, with assumed greater salt deposition. *Schoenus concinnus–C. uniflora* turfs with prostrate shrubs of *Leptospermum scoparium*, *Coprosma rhamnoides*, and *Cassinia leptophylla* are important on the northern sandstones and conglomerates at Curious Cliff south of Nguroa. These turfs have developed on impoverished, gleyed clay soils with deeper iron pans.

Wider community variation, however, was imparted by the less abundant species. *Zoysia minima* was conspicuous in turfs of headland crests with compact, often, sandy soils (e.g., TT22). *Crassula helmsii*, was abundant in one wet substrate turf (TT10). *Leptostigma setulosum* [*Nertera setulosa*] (TT11, TT12), *Eryngium vesiculosum* (TT13, TT14, TT34), *Pimelea* cf. *urvilleana* (TT15, TT17, TT19, TT32), and *Leptinella calcarea* (TT5) were conspicuous in or dominated others. *Lepidium flexicaule* populations were associated with seven turfs around limestone blocks and talus on steep slopes above the strand line from Kaihoka Lakes south to West Whanganui Inlet (Appendix 3).

Notable rare plants

A cliff ledge and chute on the coast west of Kaihoka Lakes (TT3) supports the only turf record of *Mazus novaezeelandiae* ssp. *impolitus* in New Zealand (Fig. 37).

Ranunculus recens was recorded from the above site (Fig. 37) along with five others, TT4 and TT5, TT13, TT16, TT26, and TT30. A previous record exists from Kahurangi Point (TT31), but it was not re-confirmed in the present study, despite considerable searching. (See also notes under Wanganui, Southland, and Otago).

Myosotis pygmaea var. *pygmaea* was recorded from six sites, TT16, TT20, TT23, TT26, TT30, and TT31. This species, along with *Ranunculus recens*, appeared to prefer stable or long-established turfs.

Mazus radicans featured in one turf, Sandhills Creek (TT30) (Fig. 38).

Eryngium vesiculosum was recorded in turfs of the Te Taitapu coast only, where it forms striking green-glaucous rosettes with spinously-toothed leaves (Fig. 38). More a species of coastal sands, gravels, and rock clefts (Allan 1961), as a tap-rooted species in stable, well drained turfs it was highly competitive.

Lepidium flexicaule was recorded from seven turfs and four non-turf sites along the Te Taitapu coast and from two turfs in north Westland (Appendix 3). All occupied base-rich substrates (Fig. 39). Soil chemical analysis, from one site

(TT7) confirmed above average readings for pH, exchangeable cations of Ca, K, P, Mg, and S and CEC (Appendix 4)[4]. Some of the Te Taitapu coastal records are new and vouchered (CHR), and an estimated 410 plants were recorded. Other vouchered records are provided by Garnock-Jones & Norton (1995). Norton et al. (1997) suggest that seabirds and seals are 'critical for the survival of *Lepidium* species by keeping sites open through disturbance, dispersing seed, and providing nutrient enrichment'. Recognising that current seabird populations are probably highly depleted, they (red-billed gulls) appeared to play only a minor disturbance role in one *L. flexicaule* population (TT30—Sandhills Creek) (Fig. 8, and 38) along the Te Taitapu coast. Alternatively, in most of the sites, sheep disturbed the habitat (Fig. 39) by creating bare ground (possibly for seedling establishment), by apparently concentrating faeces and therefore possibly nutrient enrichment, and by suppressing competitive weeds by grazing. In all this, sheep disturbance appears to play a beneficial role in the 'openness' of habitat. Plants' vegetative vigour benefited from exposure of the weathered rendzina soils associated with limestone blocks, and virtually all regeneration was on exposed mineral soil. In some habitats, the plants tolerated raw, skeletal limestone talus accumulating from exfoliation of limestone blocks above, with little or no competition from other plant species, although some disturbance from stock was evident.

Oreomyrrhris "minutiflora" requires taxonomic reappraisal and probably elevation to species rank. A distinctive species, it occurred in numerous turfs of Nelson. It appears to have low colonisation or migration capacity and is, again, a species probably indicative of stable or long-established turfs.

Wahlenbergia congesta var. *congesta* was encountered in several Te Taitapu coastal turfs. It also occurs on the Westland and Southland coasts, but not from turfs sampled in the present study.

Leptinella calcarea is a Nelson endemic and a striking component of turfs along the Te Taitapu coast (Fig. 36). It demonstrates vigorous migrational and colonisation behaviour on free-draining and moderately fertile substrates.

Poranthera microphylla, a nationally rare species, occurred in only one sampled turf on impoverished, non-calcareous sandstone and conglomerate in the north of Wylie's property just south of Curious Cliff.

Dichondra brevifolia, and *Crassula helmsii* were other noteworthy species.

Influence of stock grazing

All but eight sites are grazed by stock, with pasture swards replacing the original border to turfs provided by shrublands of *Metrosideros perforata*, *Muehlenbeckia complexa*, *Coprosma propinqua*, *Coprosma rhamnoides*, *Phormium tenax*, and *Cassinia leptophylla*. Important examples of the spatial relationship between turfs and bordering, but sometimes secondary, shrublands occur at Stone Bridge Beach (TT11), Green Hills Stream (TT13, TT14), Nguroa (TT15), Greycliff (TT18), Bar Point (TT22), and Sandhills Creek (TT30). A turf

Figures 28 to 48 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

[4] This analysis of an unweathered skeletal limestone soil can be compared with that of unweathered, granite gravels beneath *Lepidium banksii* from Totaranui (Appendix 4). Remarkably low comparative values for all indices characterise the latter.

adjacent to an inland dune lake on Puponga Farm Park 500 m from the coast demonstrated the positive benefits to species richness from stock grazing (cf. TT1, TT12). Sixteen native species featured in turf on the grazed side of a divisional fence (Fig. 40), whereas four survived after 10 years of stock removal in the resulting grass sward of 20 cm mean canopy height on the other side.

An unusual turf of *Schoenus concinnus* on the Cretaceous sandstones and conglomerates in the north also had prostrate *Leptospermum scoparium*, *Cassinia leptophylla*, and *Muehlenbeckia complexa* (Fig. 41).

4.6.3 Westland

Communities

The seven north Westland sites showed wide community diversity associated with the wide geological differences (Table 1; Fig. 24; Appendix 1):

- Association C—*Leptinella dioica*-(*Gunnera monoica*) herbfield.
- Association D—(*Selliera radicans*)-(*Leptinella dioica*)-[*Centella uniflora*] herbfield.
- Association G—*Selliera radicans*-(*Samolus repens*)-(*Isolepis cernua*) herbfield.

Although one plot was included in Association C, *G. monoica* was not recorded in Westland turfs. Other frequent species contributing to community diversity were *Crassula moschata*, *Schoenus concinnus* (on granite), *Zoysia minima*, *Pimelea* cf. *urvilleana*, and *Leptinella squalida*. Further compositional differences were from either rare species (*Lepidium flexicaule*) or those with aberrant habitats, e.g., *Celmisia monroi* and *Brachyglottis bellidioides*.

Although recovering from past disturbance, a natural sequence of coastal vegetation on calcareous landforms can be inferred from patterns at Point Elizabeth, and at Truman Track. Turfs were sandwiched between wave- and spume-washed platforms and coastal scrub-low forest of *Hebe elliptica*, *Phormium tenax*, *Melicytus ramiflorus*, *Macropiper excelsa*, *Coprosma lucida*, *C. repens*, and *Olearia avicenniifolia*. Finally, a *Dacrydium cupressinum* and *Metrosideros robusta* forest extended inland. Human pedestrian traffic contributes to maintaining turf-covered walkways at Dolomite Point, Truman Track, Charleston (Fig. 12), and Cape Foulwind. Well-drained and consolidated soils buffer turfs against fragmentation under this pressure, but wet profiles are vulnerable to fracturing and erosion.

Notable rare species

Lepidium flexicaule was recorded from calcareous mudstone at Point Elizabeth and from limestone at Dolomite Point (Appendix 3). Neither population is threatened, although the former is a small population indeed. The importance of disturbance-induced fresh pavements in seedling establishment is evident around unstable mudstone talus at Point Elizabeth and along pedestrian thoroughfares at Dolomite Point.

Charleston was the northernmost and only Westland turf record for *Gentiana saxosa*, a more frequent species in Southland and, to a lesser extent, Otago turfs.

Crassula helmsii occurred at Cape Foulwind, its only Westland turf record.

Lepidium naufragorum (Garnock-Jones & Norton 1995) was a possible constituent of north Westland turfs in the past, with its preference for base-rich soils, decumbent habit, and association with seabird roosts, but it was not recorded in this study.

Brachyglottis bellidioides and *Celmisia monroi* are noteworthy turf components on granite at Charleston, disjunct from their normal, inland alpine habitats.

4.6.4 Fiordland

Communities

Four of the five Fiordland turfs were classified as Association C, *Leptinella dioica*-(*Gunnera monoica*) herbfield (Table 1; Fig. 24). The remaining site was included in Association F, *Leptinella dioica*-(*Selliera radicans*)-(*Isolepis cernua*) herbfield. To some extent, these labels belie their rich and, relatively unusual, composition, with prominent species such as *Schoenus nitens*, *Ranunculus multiscapus*, *Pratia angulata*, *Eleocharis acuta*, *Schoenus maschalinus*, *Gunnera dentata*, *Poa pusilla*, *Sonchus kirkii*, *Rytidosperma setifolium*, *Ophioglossum coriaceum*, *Lagenifera petiolata*, *Marchantia berteroana*, and *Viola cunninghamii*. Curiously, *Selliera radicans* was absent from turfs along this coast. Long Point (FD3) displayed a wide mix of unusual turf constituents such as *Rytidosperma setifolium*, *Senecio lautus*, and *Sonchus kirkii*.

Given the high pellet densities, deer exert heavy impact upon the Waitutu coastal fringe, with circumstantial evidence that considerable rearward and longitudinal expansion of turfs has resulted (Fig. 19). Despite this pervasive influence, Fiordland turfs offer the most reliable insights nationally into their spatial relationship with bordering coastal scrub and forest. Headlands probably supported the only substantial areas of turfs, with very narrow and discontinuous fringes along straighter coastlines. That most constituents of turfs survive on upper cliff faces was obvious. From there they colonised adjoining tops vacated by deer-weakened scrub. Abandoned deer-traps over several turfs offer an opportunity to investigate the regulatory role of deer in Fiordland's turfs if they can be resurrected.

Notable rare species

Fiordland turfs had no nationally threatened or local species or few provincially significant entities. *Gunnera dentata* was found only in Fiordland turfs. They did, however, support numerous nationally unusual entities (see above).

4.6.5 Southland

Communities

Three communities are represented that demonstrate the ubiquitous dominance of *Selliera radicans* and *Leptinella dioica* in this zone (Fig. 24):

- Association D—(*Selliera radicans*)-(*Leptinella dioica*)-[*Centella uniflora*] herbfield.
- Association F—*Leptinella dioica*-(*Selliera radicans*)-(*Isolepis cernua*) herbfield.

Figures 28 to 48 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

- Association H—(*Poa astonii*)-(*Leptinella dioica*)-(*Selliera radicans*) grass-herbfield.

Association D occurs in all five South Island zones, whereas Associations F and H have a southern South Island identity (Table 1). Association F covers most of the plots on intrusive substrates.

Additional frequent species in Southland turfs are *Plantago triandra*, *Agrostis muscosa*, *Gentiana saxosa*, *Apium prostratum*, *Plantago raoulii*, *Crassula moschata*, *Myosotis pygmaea* var. *pygmaea*, *Poa astonii*, and *Oreomyrrhis* "minutiflora". Minor variation in community composition was imparted by *Pratia angulata*, *Schoenus concinnus*, *Nertera depressa*, *Rumex neglectus*, *Puccinellia walkeri*, *Lepidium tenuicaule*, *Leptinella traillii*, *Euphrasia repens*.

Farm stock grazed all sampled turfs and the nature of pre-human vegetation transitions inland can only, at best, be reconstructed from highly modified remnants and more intact examples along the Catlins coast, Otago. Likely dominants were *Phormium tenax*, *Hebe elliptica*, *Carex flagellifera*, *Carex appressa*, *Pseudowintera colorata*, *Cortaderia richardii*, and *Coprosma propinqua*. Black Point offers insights into the differential effects of cattle and sheep on Southland turfs. Sites west of the Black Point boundary fence are grazed by sheep and are comparatively intact, whereas cattle grazing east of the fence has severely fragmented and pugged equivalent turfs. Unfortunately, no Southland turf sites offer encouraging prospects for a reconstitution of a natural sequence of coastal vegetation.

Notable rare species

Acaena microphylla var. *pauciglochidiata* (Fig. 42) featured in turfs of Southland only. It is also recorded from dune slacks of Otago, rocky coastal cliffs at Cape Saunders, Otago Peninsula, along with other coastal and inland habitats in Southland. The species is disjunct from southern South Island to central North Island.

Lepidium tenuicaule (Fig. 43) is restricted to poorly-consolidated gravels and sands and to coastal margins of turfs just beyond strand-lines and on low elevation marine terraces within the spume zone in turfs of Otago and Southland (Fig. 19, 43). Southland turf sites are Omaui Point and Beach (SD 7 and SD 8), Oraka Point (SD 11), and Waipapa Point (SD 14). (See note under Otago).

Ranunculus recens occurred at three turf sites in this survey, Blue Cod Bay (SD2), Black Point 1 (SD3), and Oraka Beach (SD 12) (Fig. 38).

Myosotis pygmaea var. *pygmaea* occurred at Blue Cod Bay (SD2), Black Point 1 (SD3), Black Point-Slope Point (SD 6), Omaui Point (SD8), Bluff pipeline 2 (SD10), Oraka beach (SD 12) (Fig. 42), Barracouta Point bay (SD 13), and Waipapa Point (SD 14).

Oreomyrrhis "minutiflora" is frequent in most turfs (Fig. 44).

L. dispersa ssp. *dispersa* occurred in turfs of Southland (Fig. 45), but not Otago (records also from coast of Westland, see Lloyd 1972). Indeed, Southland turfs had the highest diversity of *Leptinella* with four species, *L. squalida* ssp. *mediana*, *L. traillii* ssp. *pulchella*, *L. dispersa* ssp. *dispersa*, and *L. dioica*. (See also note on other subspecies *L. dispersa* ssp. *rupestris* in Taranaki–Wanganui.

The two subspecies are considered by some to be separate species (C. Ogle pers. comm. 1998)).

A particularly large-leaved form of *Atriplex buchananii* featured in a turf at Barracouta Point.

Mazus arenarius (Fig. 45) was recorded from a Barracouta Point turf only.

Euphrasia repens (2 sites) and *Tetrachondra hamiltonii* (1 site) were recorded in Southland turfs only.

Finally, there is a group of species now largely endemic to southern New Zealand coastal environments that appear in turfs of Southland and Otago (Table 7).

TABLE 7. A GROUP OF TAXA LARGELY ENDEMIC TO SOUTHERN NEW ZEALAND COASTAL ENVIRONMENTS APPEARING IN TURFS OF FIORDLAND, SOUTHLAND, AND OTAGO.

Acaena microphylla var. *pauciglochidiata*	*Leptinella traillii*
Anisotome lyallii	*Mazus arenarius*
Euphrasia repens	*Myosotis rakiura*
Gentiana saxosa (also in a Westland turf)	*Poa astonii*
Lepidium tenuicaule (historical records from Wellington province)	*Puccinellia walkeri*
	Senecio carnosula

4.6.6 Otago

Communities

Otago turfs share three associations with those of Southland (Table 1), Association E is an addition to these:

- Association D—(*Selliera radicans*)-(*Leptinella dioica*)-[*Centella uniflora*] herbfield.
- Association E—*Leptinella dioica* herbfield
- Association F—*Leptinella dioica*-(*Selliera radicans*)-(*Isolepis cernua*) herbfield.
- Association H—(*Poa astonii*)-(*Leptinella dioica*)-(*Selliera radicans*) grass-herbfield.

Again, the ubiquitous presence and abundant cover of *Selliera radicans* and *Leptinella dioica* is emphasised in the classification. Association H with 50% of plots was dominant. *Crassula moschata*, *Rumex neglectus*, *Plantago triandra*, *Holcus lanatus*, *Puccinellia walkeri*, *Poa astonii*, *Crassula moschata*, *Samolus repens*, *Isolepis cernua*, *Apium prostratum*, were other frequent species. *Anisotome lyallii*, *Senecio carnosula*, *Myosotis rakiura*, *Atriplex buchananii*, and *Puccinellia walkeri* imparted some zonal distinctiveness. Most of these are normally dwellers of coastal cliffs.

Figures 28 to 48 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

Extensive turfs of comparatively homogeneous composition appear to be competing aggressively with pasture where salt-deposition and stock grazing are heavy. Examples occur on the Tautuku, Long Point, and Brothers Peninsulas (Fig. 46). For the most part, the peninsulas of the Catlins coast have been comprehensively cleared of forest (Fig. 23) and offer few opportunities to manage sectors for a reconstitution of uninterrupted patterns of coastal vegetation to inland forest. Frances Pillar headland, although lightly grazed, has considerable coastal flaxland, scrub and forest in close proximity to turfs. It probably offers the best Catlins prospects for turf protection and reconstitution of native vegetation patterns. Overall, the most natural turfs on the Catlins coast are likely to be the cliff face systems at False Islet (not in database) and Long Point, both under no threat of modification. Chaslands Mistake was not surveyed on foot (access denied), but aerial survey from a helicopter revealed no turfs of note.

There are three turfs in the vicinity of Dunedin. The sparse and fragmented system amongst a gravelfield at Cape Saunders has both *Ranunculus recens* and *Myosotis pygmaea* var. *pygmaea*, and probably offers reasonable prospects for long-term survival if grazing is removed. Sandymount has a valuable and comparatively unmodified cliff face system. Vegetation patterns at Tunnel Beach are highly modified, although isolated shrublands and flaxlands occur on adjoining hillslopes. Cape Wanbrow at Oamaru revealed no turfs, although there is an early record of *Lepidium tenuicaule*. Katiki Point was not surveyed.

Notable rare species

Large populations of *Ranunculus recens* occur at Sandymount on a stony spur and patchily at Long Point Peninsula, while smaller populations within turf occur at Tautuku Peninsula and at Watsons Road (Fig. 47).

Atriplex buchananii featured in turfs at Tautuku Peninsula, Brothers Point, and Tunnel Beach.

Lepidium tenuicaule was recorded from strand line gravels at Shag Point (OT 6), both within and immediately beyond a car park, at Watsons Road (OT 14) (Fig. 47), and around Lighthouse buildings at Cape Saunders. The latter site replicates the plant's habitat at Waipapa Point, Southland, suggesting deliberately created gravelfield could aid its survival where disruption of natural, geomorphic disturbance has been curtailed. One site at 140 m on a rocky knoll 2 km inland from Shag Point supported several plants in turf being smothered by pasture grasses.

Puccinellia walkeri is a turf dominant of several Catlins coastal sites (Fig. 48).

4.7 OTHER BIOGEOGRAPHICAL NOTES

In general, grass turfs of *Poa astonii*, *Puccinellia walkeri*, and *Zoysia minima* do not foster high species diversity, possibly reflecting their adaptation to impoverished parent materials and their tightly interlaced and competitive root masses.

The most frequent and cover-dominant turf constituents are *Leptinella dioica*, *Selliera radicans*, and *Plantago triandra*. The first two are vigorous colonisers of disturbed sites, bare pavements or unthrifty pasture (Fig. 46). Other frequent species are *Zoysia minima*, *Centella uniflora*, *Colobanthus muelleri*, *Hydrocotyle novae-zeelandiae* var. *montana*, *Isolepis cernua*, *Samolus repens*, *Agrostis stolonifera*, and *Trifolium dubium*.

Figures 28 to 48 are coloured photographs. They are presented as Plates following the References and preceding the Appendices.

Saltmarsh-adapted *Sarcocornia quinqueflora*, *Disphyma australe, Samolus repens*, *Crassula moschata*, and *Isolepis cernua* appeared the most salt-tolerant by virtue of their seaward locations. Turf dominants on wet substrates are *Selliera radicans*, *Isolepis cernua*, *Lilaeopsis novae-zelandiae*, *Crassula moschata*, and *Triglochin striatum*.

Six ferns and fern allies appeared in turfs, demonstrating their high tolerance to salt inundation, namely *Blechnum blechnoides*, *Asplenium obtusatum*, *Azolla filiculoides*, *Lindsaea linearis*, *Ophioglossum coriaceum*, and *Sticherus cunninghamii*.

Adventive species were comparatively unimportant and only one—*Agrostis stolonifera*—featured in the TWINSPAN classification. The dynamic interplay between exotic and native species occurred in two spatial patterns. First, several species such as catsear (*Hypochoeris radicata*) and clovers, occur as isolated, but generally small, patches showing few features of aggressive expansion. Where grazing pressure is relaxed, smothering of native turfs is more common along a more or less continuous migrational fronts rather than a coalescing of expanding patches. Alternatively, numerous examples in Nelson, Southland and Otago demonstrate aggressive expansion of turfs at the expense of heavily grazed pasture.

4.8 Soils

Turfs occupy a wide range of soil types from raw sand to deeply weathered clays, with associated variations in drainage, cohesion, and colloid content. Predictably, the 17 soil samples from divergent parent materials and pedogenic histories displayed wide variation in chemistry (Appendix 4). Soil characteristics of plots were grouped according to the vegetation associations derived from cluster analysis (Table 8). Between and within group variation was high. Further, lack of replication in the data prevented strict statistical comparison, however, some qualitative comparisons are possible. Comparison of OT1, a strand-line site with inputs from fur seal excreta, with OT2 and OT3 receiving farm stock inputs reveals substantially greater values of exchangeable cations for the fur seal-influenced site. Soluble salts for most turfs are

TABLE 8. MEANS OF SOIL ANALYSIS PER VEGETATION ASSOCIATION.

Assn.*	n	pH	Ca	K	P	Mg	Na	S	SS	TEB	%BS	CEC
B	3	6.23	7	12.33	36.67	90	284.33	112.33	0.32	393.67	15.24	22.67
D	4	5.9	7.75	15.75	25.5	108	261.25	189.25	0.53	392.75	14.49	24.5
E	1	5.8	6	20	30	95	109	66	0.14	230	12.78	18
F	4	5.9	11.75	24.75	111	167.5	337.5	258.25	0.93	541.5	14.69	36
G	2	7.95	35.5	31.5	73.5	225	457.5	720	2.26	749.5	9.44	75.5
H	3	6.67	12.33	38.33	44	183.3	498.33	276	1.21	732.33	17.23	42.67

* Vegetation associations (Assn.) as per Table 1 and Fig. 24.

Ca = exchangeable Ca^{2+} (g/40^4ml extract). K = exchangeable K^+ (g/25x10^4ml extract). P = Olsen P (ug/ml). Mg = exchangeable Mg^{2+} (g/10^6ml extract). Na = exchangeable Na^+ (g/10^6ml extract). S = potassium phosphate extractable S (ppm). SS = calcium sulphate extractable soluble salts (%). TEB = sum of exchangeable bases (g/10^6ml extract). BS = base saturation (%). CEC = cation exchange capacity (me%).

comparable to or exceed those of saline soils of Central Otago basins (New Zealand Soil Bureau 1968). As expected, exchangeable Na is particularly high in all turf soils compared to a suite of inland soils from brown-grey earths to upland yellow-brown earths. Predictably, the limestone-derived soil (TT7) is comparatively high in all chemical properties.

Soil chemistry values for a granite-derived, skeletal talus beneath *Lepidium banksii* (Totaranui) are sharply less than those for limestone talus beneath *Lepidium tenuicaule* (TT7) (Appendix 4). The former is a nationally critical species, the latter a nationally endangered species. Soil analysis was not undertaken beneath *Lepidium tenuicaule* at its Southland and Otago sites, but, judging from its gravel substrates low values of at least exchangeable cations, if not P and N, are anticipated.

5. Discussion

5.1 PHYSICAL GEOGRAPHY

New Zealand is well endowed with a variety of coastal landforms and lithologies (Healy & Kirk 1982) and, in combination with high wave energy and salt deposition on the south and west coasts, conducive conditions for turf formation on headlands. Nevertheless, turfs occur in widely disjunct zones and in areal extent occupy a small fraction of total coastline. This suggests that a comparatively rare mix of physical factors leads to their formation. Substantial offset angles between landform strike and aspect direction of turfs points to the importance of oblique wind shear and salt deposition in turf formation. Cliffed topography also generates turbulence and greater chance of salt deposition in the lee of topographical barriers. High wind energy, accelerated around promontories, delivers spray-splash and spume in abundance and mechanical damage to plants of erect architecture.

Prevailing winds of south Taranaki–Wanganui are northwest to west, those of the Te Taitapu coast, Nelson and north Westland are southwest, those of Foveaux Strait, Fiordland and Southland are west, and those of Otago southwest. Turfs occur on eastern shorelines in Otago only. Salt delivered in crystalline form or in dry atmospheric conditions probably produces the greatest osmotic stress to leaf cuticles. In contrast, forest vegetation probably survives to the strand line in much of Westland, possibly because salt is delivered mostly in solution because of the regular precipitation. Central and south Westland and north Taranaki both receive predominantly perpendicular on-shore winds, deviating from the model of oblique wind shear.

Abundant circumstantial evidence suggests that the majority of turfs have considerably expanded their prehuman ranges, both rearward and parallel with the coast as farming activity suppressed competing, taller native vegetation. Further, the prostrate intertwined growth form of halophytic herbs competes effectively in capturing resources (solar radiation and soil nutrients) with grazed and salt-exposed pasture.

Surprisingly, there are no turfs proper along the exposed Wellington and Wairarapa coastlines of Cook Strait although constituents of the flora are present (A.P. Druce pers. comm. 1998). Indeed, 31 taxa recorded elsewhere from mainland turfs in this survey are recorded from the Cape Palliser coastal platform by A. P. Druce in his local species list (S. Courtney pers. comm. 1998). Although wave energy, wind, and salt delivery all appear comparable to say the Te Taitapu and Foveaux Strait coasts, more or less stable and horizontal coastal platforms are either absent, have unconsolidated gravels or are too bouldery for turf formation. Perhaps the predominant greywacke substrate fragments into erodable and unstable detritus inimical to turf formation. Certainly, greywacke does not feature as a substrate in the six coastal zones of this study. The absence of turfs from central Westland to Foveaux Strait is possibly explicable in terms of incompatible landforms and forest extending close to beach strand lines, effectively excluding halophytic herbs. Most salt is delivered in solution with the frequent precipitation, allowing tall woody species to be competitive even in this high salt-deposition environment. Along Fiordland's southwest coast, the coarsely crystalline granite and gneiss lacks regular orientation to jointing, so no 'grain' influences the formation of erosional landforms on this coastline. North Taranaki is another zone where turfs are curiously missing or very restricted.

5.2 MARINE MAMMALS AND SEABIRDS

Marine mammals apparently use turfs of the sub-Antarctic Islands as haul-out habitat (C. West pers. comm. 1997), but their regulatory role is unknown. At the same time, there are many turfs on steep southwest facing slopes with no marine mammals. The prostrate stature of halophytic herbs may pre-adapt them to survive wallowing sea mammals. Alternatively, the extensive turfs atop cliffs on the exposed western shore of Enderby Island in the Auckland Islands are uninfluenced by marine mammals. In addition, few mainland turfs hosted marine mammals. Low density fur seal populations were observed resting on a turf at Kaihoka Point, Nelson and on a strand line turf at Long Point, Otago. Their access to many turfs atop cliffed topography is impossible. There is, however, circumstantial evidence from Long Point, Otago that fur seals promote a boost in soil nutrients beneath turfs.

Penguins (little blue and yellow-eyed), may traverse turfs in some zones, but apparently impart little influence. Possums commonly inhabit coastal turfs judging by the frequency of their faeces in many sites in all six zones, but their browsing influence is unknown. Red-billed gulls were the only seabirds recorded on turfs, as judged from guano deposits and observation. A solitary example occurred on the seaward margin of the Sandhills Creek promontory of the Te Taitapu coast, Nelson. Interestingly, *Lepidium flexicaule* was associated with the site. The much greater numbers of seabirds in prehistoric times may have impacted turfs, although present day nesting colonies of gulls, terns, cormorants, and petrels commonly devegetate coastal sites under nesting colonies. Elevated levels of K in soils is a residual effect of seabirds, but the edaphic effect of this on coastal vegetation in general, and turfs in particular, is unknown.

5.3 SUCCESSIONAL PATTERNS

The successional evolution of turfs is largely unknown, but species of rosette, cushion, or clumped growth forms appear less adapted to turf expansion than species with creeping and interlaced growth forms. Low species diversity and dominance by *Selliera radicans*, *Leptinella dioica*, and *Zoysia minima* appear to be bio-indicators of disturbance-induced or recently formed turfs.

5.4 GRAZING IMPACTS

There is abundant observational evidence that many, if not most, turfs have expanded beyond their original convex creep slope positions on cliff tops onto adjoining interfluves. Forest clearance and, latterly, pastoral farming fostered this expansion. Cattle are largely incompatible with the maintenance of intact turfs on wetter substrates, but, sheep appear complementary, even advantageous, principally by competitively weakening pasture grasses. Where grazing is removed, invasion of weeds commonly unfolds along a wave-front, and much less so by a coalescing of expanding outlier nuclei. Much of the ecological diversity of turfs throughout New Zealand are presently grazed by farm stock. Without a full understanding of these impacts, a pre-cautionary approach suggests that some sheep-mediated systems be included within our conservation priorities. Above all however, self regulating turfs should be our long-term conservation priority.

5.5 CONSERVATION GUIDELINES

Turfs have such a divergent physiographic and compositional character from other coastal communities that they warrant individual conservation recognition as habitats for our low-growing halophytic flora beyond that available for them in estuaries. The physiographic distinctiveness within and between each zone's landforms, soil parent materials, and climate argues for setting conservation priorities for each zone. Furthermore, physiography strongly influences community composition (see 4.3 Ordinations) and plays a critical role in ecosystem processes. However, the cluster analysis of communities does show some inter-zonal homogeneity in composition, particularly the widespread (*Selliera radicans*)-(*Leptinella dioica*)-(*Centella uniflora*) association representing 40% of plots. Despite several widespread dominants, there are profound regional differences in the rarer species and the zonal endemics that argue for plant biogeography as an important criterion for zonal conservation priorities.

Important criteria for assessing the ecological worth of sites include those listed by Myers et al. (1987: 58–65):

- Representativeness—the primary criterion
- Diversity
- Rarity and special features

- Naturalness
- Long-term viability
- Size and shape
- Buffering and surrounding landscape

Ecological health also is central to this exercise. It has numerous facets (Simpson 1997), not least of which are:

- An ability for species and their communities to adapt to new circumstances (evolve), to reproduce and migrate to new habitats.
- Resilience, that capacity of species and communities to recover from perturbations in regulatory factors.
- Adequate representation of a full range of species and their communities in protected areas.

The presence of exotic plants does not necessarily imply ill-health (Simpson 1997), for as isolated individuals of low canopy cover, their influence on key ecological processes is assumed to be small.

A primary zonal division was adopted for setting conservation priorities. Identifying places for recognition and protection used the procedural steps of the rating system of Myers et al. (1987: 66–73) with one exception—representativeness was rated under 'representative quality of site' only, making a total of 13 rated parameters (Myers et al. 1987: 69) and, perhaps, inadvertently reducing the arithmetic prominence of 'representativeness'. Combined site scores over 30 were arbitrarily categorised as high priority.

5.5.1 High priority sites

High priority sites are listed by zone, along with criteria that rated highly. No priority order is implied for each zone.

Taranaki–Wanganui

- Stent Road (TW1)—representativeness, species rarity, species diversity, size.
- Sutherland Road (TW3)—representativeness, species rarity, species diversity.
- Puketapu Road (quarry and rua pit headlands) (TW8, 9, 10)—representativeness, high community and species diversity, size, viability seaward margins, and species rarity.
- Patea headland (TW12)—representativeness, species rarity, community diversity.
- Kaikura Stream (TW14)—high microhabitat, community, and species diversity, moderate viability, size.
- Normanby Road (TW4)—a subjective addition because of its species rarity and species diversity ratings.

Nelson

- Sandhills Creek (TT30)—representativeness, buffering, size and shape, species and community diversity, species rarity, naturalness, long-term viability.

- Wylie cliff (TT2)—species diversity, representativeness, buffering, naturalness, viability.
- Wylie headland (TT4, 5, 6)—size, community diversity.
- Wylie limestone (TT7)—rare species.
- Wylie conglomerate (TT8, 9)—representativeness, buffering, naturalness.
- Kaihoka No. 2 (TT17)—species and community diversity, rare species.
- Green Hills Stream 1 (TT13)—representativeness, species diversity, size, naturalness, buffering, viability.
- Greycliff 3 (TT20)—rare species, size, viability.
- Sharkshead No. 2 (TT26)—representativeness, species diversity, size, viability.
- Kahurangi Point (TT20)—species diversity, size, viability.

Westland

- Point Elizabeth (WD1)—representativeness, rare species, naturalness, buffering.
- Dolomite Point (WD2)—representativeness, rare species, naturalness (in chutes), community diversity, viability (in chutes).
- Truman Track (WD3)—representativeness, naturalness, size, buffering, viability.
- Charleston (Doctor Bay) (WD7)—representativeness, species diversity.

Fiordland

- Crombie Stream (FD1)—buffering.
- Angus Burn (FD2)—representativeness, naturalness, buffering, species diversity.
- Long Point (FD3)—representativeness, naturalness, size, buffering, species diversity.
- Waitutu Point (FD4)—size, buffering.

Southland

- Blue Cod Bay (SD2)—representativeness, community diversity, species rarity.
- Black Point 1 (SD3)—community diversity, species rarity, viability.
- Black Point to Slope Point (SD4, 5, 6)—size, community diversity.
- Omaui (SD 7, 8)—representativeness, species rarity, naturalness, viability.
- Oraka Point (SD11)—species rarity, naturalness, viability.
- Oraka Beach (SD12)—representativeness, species rarity, naturalness, viability.
- Barracouta Point bay (SD13)—size, community diversity, species rarity.

Otago

- Long Point (OT2, 3, 4)—representativeness, size, community diversity, species rarity.
- Shag Point (OT6)—representativeness, species rarity.
- Sandymount (OT7)—naturalness, buffering, viability.

- Frances Pillars (OT11, 12, 13)—buffering, size, community diversity.
- Watson Road (OT14)—representativeness, species rarity.

The central plank of conservation management for turfs is the role of grazing in community composition, size, naturalness, and vulnerability to fragmentation. That many turfs occupy greatly expanded ranges through stock suppressing competing pasture grasses seems indisputable. The Puketapu Road experiment and the across-the-fence differences at the dune lake site in Nelson suggest that geographic contraction and/or loss of species richness accompanies removal of stock (and deer). In some instances rare plants may be threatened by the likely seaward contraction of turfs to narrower coastal strips, e.g., *Mazus arenarius* at Barracouta Point (Southland). Although a large proportion of turfs are surrounded by pasture, there are rare examples, such as Point Elizabeth (Westland) and Sandhills Creek (Nelson), that demonstrate their narrow natural range in relation to taller competing coastal scrub and forest on even the most exposed coasts. Nevertheless, excluding grazing and allowing natural or aided reconstitution of coastal woody transitions through scrub to forest must be the main management objective for this habitat or ecosystem.

6. Recommendations and future research

The major goal of this study was to make an inventory of turfs on the two main islands. Insights into habitat processes and turf dynamics have also emerged and, in combination, are sufficient to provide extra recommendations to those in section 5.5 Conservation guidelines.

- Priorities for turf protection should not only target zonally representative sites of current eco- and biodiversity, but reformation opportunities of coastal sequences of native vegetation so rarely encountered in this study.
- Light grazing by sheep may not be incompatible with a gradual reconstitution of coastal sequences of native vegetation involving turfs, while maintaining species and community diversity of attendant turf.
- Presence of cattle is detrimental to all management objectives for turfs.

Additional work is now desirable to:

- Compile comprehensive zonal databases using Appendix 1 as a substantial foundation. Small additional survey work is required in Southland, Westland, and Otago.
- Examine the critical role of grazing by farm stock and deer, habitat use by marine mammals, and impacts of human trampling in the maintenance of turfs and their threatened species under exposure, soil moisture, and salt deposition gradients.
- Examine the self-regulating extent of turfs with a reconstitution of intact coastal sequences of native vegetation.

- Investigate offshore turfs. Extensive coastal turfs are known from off-shore islands such as Cook Strait (S. Courtney pers. comm. 1998) and the sub-Antarctic Islands where some are associated with marine mammal loafing areas (C. West pers. comm. 1997). Their incorporation into a national database for this habitat is highly desirable.
- Continue monitoring at Puketapu Road, Taranaki to assess the full extent of shoreward contraction of turfs as they approach dynamic equilibria with competing vegetation.

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Colour plates

Figures 2–23 and 28–48 are colour photographs. They are presented as Plates on the following pages.

Appendix 1

Characteristics of 94 plot sample sites from 6 zones for coastal turfs on mainland New Zealand

(The order of the plots is arranged north to south for each zone. See Fig.1 for map of the zones.)

PROVINCE/ PLOT NO.	ECOLOG. DISTRICT	LOCALITY	GRID REF. MZMS 260	ALTITUDE (m)	TENURE	AREA (ha)	LANDFORM LITHOLOGY	PHYSIO-GRAPHY
Taranaki–Wanganui/TW1	Egmont	Stent Rd	P20/772203	5	Maori Reserve	0.3	andesitic tephra	seepage slope
Taranaki–Wanganui/TW2	Egmont	Cape Egmont	P20/748137	4	Private	0.05	andesitic tephra	interfluve
Taranaki–Wanganui/TW7	Egmont	Arawhata Rd	P20/794980	7	Private	0.001	andesitic tephra	convex creep slope
Taranaki–Wanganui/TW10	Egmont	Puketapu Redoubt NW aspect	P21/883871	30	Maori lease	0.03	andesitic tephra	transportational midslope
Taranaki–Wanganui/TW9	Egmont	Puketapu Redoubt south aspect	P21/884870	30	Maori lease	0.01	andesitic tephra	seepage slope
Taranaki–Wanganui/TW8	Puketapu Rd Egmont	quarry	P21/887868	30	Maori lease	0.05	andesitic tephra	seepage slope
Taranaki–Wanganui/TW5	Egmont	Waipaepaenui Stm ablation pavement	P21/904862	30	Private	0.005	andesitic tephra	interfluve
Taranaki–Wanganui/TW6	Egmont	Waipaepaenui Stm hummock pavement	P21/903862	30	Private	0.3	andesitic tephra	interfluve
Taranaki–Wanganui/TW11	Egmont	Kaupokonui	P21/008817	10	Maori Reserve	0.03	andesitic tephra	interfluve
Taranaki–Wanganui/TW3	Egmont	Sutherland Road	P21/063802	30	Private	0.001	andesitic tephra	fallface
Taranaki–Wanganui/TW4	Egmont	Normanby Road	P21/048802	40	Private	0.015	andesitic tephra	interfluve
Taranaki–Wanganui/TW14	Foxton	Kaikura Stream 1	Q21/314631	22	Private	0.4	andesitic tephra	interfluve
Taranaki–Wanganui/TW15	Foxton	Kaikura Stream 2	Q21/316630	20	Private	0.006	andesitic tephra	convex creep slope
Taranaki–Wanganui/TW12	Foxton	Patea headland seasonal wetland	Q22/358592	35	Local Auth. Reserve	0.04	andesitic tephra	interfluve
Taranaki–Wanganui/TW13	Foxton	Patea headland ablation pavement	Q22/356592	35	Local Auth. Reserve	0.001	andesitic tephra	interfluve
Taranaki–Wanganui/TW16	Foxton	Waverley Beach	Q22/502512	8	Local Auth.	0.03	andesitic tephra	seepage slope
Nelson/ TT1	West Whanganui	Puponga dune lake–grazed	M24/823774	40	DOC Reserve	0.3	conglomerate	colluvial footslope
Nelson/ TT12	West Whanganui	Puponga dune lake 2	M24/823774	40	DOC Reserve	0.02	conglomerate	colluvial footslope
Nelson/ TT11	West Whanganui	Stone Bridge Beach	M24/817778	10	DOC Reserve	0.005	conglomerate	fallface
Nelson/ TT14	West Whanganui	Green Hills Stream 2	M24/796774	10	DOC Reserve	0.005	conglomerate	transportational midslope
Nelson/ TT13	West Whanganui	Green Hills Stream 1	M24/795772	35	DOC Reserve	0.038	conglomerate	convex creep slope
Nelson/ TT15	West Whanganui	Nguroa	M24/790767	4	Private	0.012	conglomerate	transportational midslope
Nelson/ TT8	West Whanganui	Wylie conglomerate 1	M24/769751	20	Private	0.05	conglomerate	seepage slope
Nelson/ TT9	West Whanganui	Wylie conglomerate 2	M24/769752	20	Private	0.05	conglomerate	seepage slope
Nelson/ TT7	West Whanganui	Wylie lime-stone block 1	M24/767750	15	Private	0.01	limestone	interfluve
Nelson/ TT10	West Whanganui	Wylie lime-stone block 2	M24/767749	15	Private	0.008	limestone	colluvial footslope
Nelson/ TT4	West Whanganui	Wylie headland 1	M24/762746	35	Private	0.5	quartzose sandstone	transportational midslope
Nelson/ TT5	West Whanganui	Wylie headland 2	M24/762746	35	Private	0.1	quartzose sandstone	transportational midslope

SOIL TYPE	HABITAT	VEGETATION CLASSIFICATION	BIOGEOGRAPHICALLY SPECIAL PLANT SPECIES	DISTURBANCES
sandy loam	terraced platform	*Zoysia minima-Selliera radicans* sedgeland	*Crassula manaia, Myosotis pygmaea* var. *minutiflora*	stock
sandy loam	terraced platform	*Zoysia minima-Selliera radicans* sedgeland		stock
clay loam	crest of lahar pedestal	*Selliera radicans-Leptinella squalida* herbfield		stock
sandy loam	crest of headland	*Zoysia minima* sedgeland	*Crassula manaia, Crassula mataikona*	human trampling
sandy loam	crest of headland	*Zoysia minima*-moss sedgeland	*Crassula manaia, Crassula pedunculatus, Crassula mataikona, Myosotis pygmaea* var. *minuitiflora*	human trampling
sandy loam	crest of headland	*Zoysia minima* sedgeland	*Crassula manaia, Crassula mataikona*	human trampling
sand	crest of headland	*Selliera radicans* herbfield		
sandy loam	crest of headland	*Zoysia minima-Leucopogon frazeri* sedgeland		
sand	crest of headland	*Zoysia minima-Crassula manaia* sedgeland	*Crassula manaia*	stock and human trampling
clay loam	cliff	*Coprosma acerosa-Leptinella squalida* shrubland	*Ranunculus recens*	human trampling
clay loam	crest of headland	*Selliera radicans-Leptinella squalida-* Lichen herbfield	*Pimelea urvilleana, Myosotis pygmaea* var. *pygmaea*	stock
sand	terraced headland	*Selliera radicans-Samolus repens* herbfield		
sand	terraced headland	*Zoysia minima-Selliera radicans* herb sedgeland		
sand	crest of headland	*Selliera radicans-Isolepis cernua* herbfield	*Limosella* "Manutahi"	
sand	crest of headland	*Zoysia minima* sedgeland	*Crassula manaia, Crassula mataikona*	
sandy loam	terraced headland	*Zoysia minima-Selliera radicans* herb sedgeland	*Crassula manaia*	human trampling
silty loam	dune lake shoreline	Adventive grass-*Centella uniflora-Hydrocotyle novae-zeelandiae* herbfield		stock
silty loam	dune lake shoreline	*Adventive grass-Nertera setulosa-Centella uniflora* grassland		waterfowl
sand and gravel	shute on headland	*Nertera setulosa-Leptinella calcarea* herbfield		
sandy loam	slope of headland	*Leptinella dioica-Eryngium vesiculosum-Zoysia minima* herbfield		
gravels	slope of headland	*Leptinella calcarea-Eryngium vesiculosum* herbfield	*Ranunculus recens*	
sandy loam	slope of headland	*Leptinella dioica-Selliera radicans* herbfield		
clay loam	crest of headland	*Centella uniflora-Schnoenus concinnus-Zoysia minima* herbfield		
clay loam	crest of headland	*Schnoeus concinnus-Centella uniflora-Leptospermum* shrub-sedgeland		
limestone talus	shaded ledge	*Isolepis cernua-Selliera radicans-* adventive grass herbfield	*Lepidium flexicaule*	stock
silty loam	seepage slope	*Selliera radicans-Crassula helmsii* herbfield		stock
silty loam	crest of headland	*Centella uniflora-Plantago masoniae-Liliaeopsis novae-zelandiae* herbfield	*Ranunculus recens*	stock
silty loam	crest of headland	*Leptinella calcarea-Pimelea urvilleana* herbfield		stock

PROVINCE/ PLOT NO.	ECOLOG. DISTRICT	LOCALITY	GRID REF. MZMS 260	ALTITUDE (m)	TENURE	AREA (ha)	LANDFORM LITHOLOGY	PHYSIO-GRAPHY
Nelson/ TT6	West Whanganui	Wylie headland 3	M24/762746	35	Private	0.05	quartzose sandstone	interfluve
Nelson/ TT3	West Whanganui	Wylie 2	M24/755736	22	Private	0.005	quartzose sandstone	fallface
Nelson/ TT2	West Whanganui	Wylie cliff	M24/754736	5	Private	0.03	quartzose sandstone	fallface
Nelson/ TT32	West Whanganui	Kaihoka Point 1	M24/750733	7	Private	0.03	limestone	convex creep slope
Nelson/ TT33	West Whanganui	Kaihoka Point 2	M24/748731	5	Private	0.025	limestone	convex creep slope
Nelson/ TT34	West Whanganui	Kaihoka Point 3	M24/744730	7	Private	0.053	limestone	convex creep slope
Nelson/ TT16	West Whanganui	Kaihoka 1	M24/744727	3	Private	0.02	conglomerate	seepage slope
Nelson/ TT17	West Whanganui	Kaihoka 2	M24/742726	6	Private	0.1	limestone	transportational midslope
Nelson/ TT18	West Whanganui	Greycliff 1	M24/736721	10	Private	0.015	conglomerate	transportational midslope
Nelson/ TT19	West Whanganui	Greycliff 2	M24/736721	8	Private	0.128	limestone	transportational midslope
Nelson/ TT20	West Whanganui	Greycliff 3	M24/727715	8	Private	0.465	limestone	transportational midslope
Nelson/ TT21	West Whanganui	Bar Point 1	M24/723709	15	Private	0.024	sandstone	transportational midslope
Nelson/ TT22	West Whanganui	Bar Point 2	M24/719705	20	Private	0.01	sandstone	transportational midslope
Nelson/ TT25	West Whanganui	Sharkshead 1	M25/665659	8	Private	0.025	calcareous siltstone	fallface
Nelson/ TT26	West Whanganui	Sharkshead 2	M25/667665	30	Private	0.48	calcareous siltstone	transportational midslope
Nelson/ TT27	West Whanganui	Sharkshead 3	M25/667665	30	Private	0.06	calcareous siltstone	convex creep slope
Nelson/ TT24	West Whanganui	Te Hapu	M25/651651	10	Private	0.5	limestone	transportational midslope
Nelson/ TT23	West Whanganui	Waikaki	M25/639641	12	Private	0.038	limestone	transportational midslope
Nelson/ TT28	West Whanganui	Paturau south	M25/607615	6	Private	0.015	limestone	transportational midslope
Nelson/ TT29	West Whanganui	Paturau 2	M25/600605	15	Private	0.15	calcareous siltstone	transportational midslope
Nelson/ TT30	West Whanganui	Sandhills Creek	M25/585592	3	Private	0.032	calcareous mudstone	colluvial footslope
Nelson/ TT31	West Whanganui	Kahurangi Point	L25/439477	20	Private	0.4	calcareous mudstone	convex creep slope
Westland WD1	Greymouth	Point Elizabeth	J31/633680	9	DOC Reserve	0.01	mudstone	transportational midslope
Westland WD2	Punakaiki	Dolomite Point	K30/716979	13	DOC Reserve	0.06	limestone	transportational midslope
Westland WD3	Punakaiki	Truman Track	K30/725004	3	DOC Reserve	0.25	mudstone	colluvial footslope
Westland WD4	Punakaiki	Perpendicular Point	K30/728012	13	Private	0.1	calcareous sandstone	colluvial footslope
Westland WD5	Punakaiki	Kaipakati Point	K30/747065	8	DOC Reserve	0.08	calcareous sandstone	transportational midslope
Westland WD7	Foulwind	Charlston–Doctor Bay	K29/797213	23	DOC Reserve	0.035	granite	interfluve

SOIL TYPE	HABITAT	VEGETATION CLASSIFICATION	BIOGEOGRAPHICALLY SPECIAL PLANT SPECIES	DISTURBANCES
silty loam	crest of headland	*Selliera radicans-Agrostis muscosa* herbfield		stock
silty loam	wet gully	*Leptinella monoica-Selliera radicans-Mazus novaezeelandiae* herbfield	*Mazus novae-zelandiae*	stock
silty loam	wet cliff	*Leptinella dentata-Selliera radicans-Centella uniflora* herbfield		
silty loam	crest of headland	*Pimelea urvilleana-Selliera radicans-Samolus repens* herbfield		stock
silty loam	coastal terrace	*Selliera radicans-Leptinella calcarea-Leptinella dioica* herbfield	*Lepidium flexicaule*	stock
silty loam	crest of headland	*Eryngium vesiculosum-Selliera radicans* herbfield	*Lepidium flexicaule*	stock
sandy loam	crest of headland	*Selliera radicans-Zoysia minima* herbfield	*Ranunculus recens, Myosotis pygmaea* var. *pygmaea*	stock
silty loam	limestone talus	*Selliera radicans-Leptinella dioica* herbfield	*Lepidium flexicaule*	stock
sandy loam	coastal cliff	*Selliera radicans-Samolus repens* herbfield		
silt loam	limestone talus	*Selliera radicans-Apium prostartum* herbfield	*Lepidium flexicaule*	stock
silt loam	slope of headland	*Pimelea urvilleana-Selliera radicans* shrubland	*Lepidium flexicaule*	stock
sandy loam	coastal cliff	*Selliera radicans* herbfield		stock
sandy loam	coastal cliff	*Zoysia minima* sedgeland		
silty loam	slope of headland	*Selliera radicans-Samolus repens* herbfield		stock
silty loam	crest of headland	*Selliera radicans-Pimelea urvilleana* herbfield	*Ranunculus recens, Myosotis pygmaea* var. *pygmaea*	stock
silty loam	crest of headland	*Leptinella dioica* herbfield		stock
silty loam	slope of headland	*Selliera radicans* herbfield		stock
silty loam	slope of headland	*Selliera radicans-Plantago-masoniae* herbfield		stock
silty loam	coastal cliff	*Selliera radicans* herbfield		stock
silty loam	embayment cliff	*Selliera radicans-Samolus repens-Pimelea urvilleana* herbfield		
silty loam	crest of headland	*Selliera radicans-Eryngium vesiculosum* herbfield	*Ranunculus recens, Myosotis pygmaea* var. *pygmaea*	stock
sandy loam	slope of headland	*Selliera radicans-Centella uniflora* herbfield	*Ranunculus recens, Myosotis pygmaea* var. *pygmaea*	stock
silty loam	coastal talus	*Samolus repens* herbfield	*Lepidium flexicaule*	
silty loam	shute on headland	*Samolus repens-Selliera radicans* herbfield	*Lepidium flexicaule*	human trampling
silty loam	coastal platform	*Samolus repens-Selliera radicans* herbfield		human trampling
sandy loam	crest of headland	*Samolus repens-Selliera radicans* herbfield		stock
sandy loam	shute in headland	*Selliera radicans-Isolepis cernua* herbfield		human trampling
sandy loam	crest of headland	*Schoenus concinnus-Selliera radicans* sedgeland		human trampling

PROVINCE/ PLOT NO.	ECOLOG. DISTRICT	LOCALITY	GRID REF. MZMS 260	ALTITUDE (m)	TENURE	AREA (ha)	LANDFORM LITHOLOGY	PHYSIO-GRAPHY
Westland WD6	Foulwind	Cape Foulwind	K29/818382	5	Private	0.35	granite	interfluve
Fiordland FD1	Waitutu	Crombie Stream	C46/615229	40	DOC Reserve	0.15	glacial gravels	interfluve
Fiordland FD2	Waitutu	Angus Burn	C46/580235	3	DOC Reserve	0.24	glacial gravels	interfluve
Fiordland FD3	Waitutu	Long Point	C46/557225	15	DOC Reserve	0.3	mudstone	interfluve
Fiordland FD4	Waitutu	Waitutu Point	C46/538236	16	DOC Reserve	0.3	glacial gravels	interfluve
Fiordland FD5	Waitutu	Grant Burn	B46/459249	5	DOC Reserve	0.03	mudstone	colluvial footslope
Southland/ SD1	Tahakopa	Curio Bay headland	G47/119869	15	Local Auth. Reserve	0.05	sandstone	interfluve
Southland/ SD2	Tahakopa	Blue Cod Bay	F47/096864	15	Private	0.1	sandstone	transportational midslope
Southland/ SD6	Tahakopa	Black Point–Slope Point	F47/005859	8	Private	1.1	sandstone	convex creep slope
Southland/ SD5	Tahakopa	Black Point headland	F47/004859	12	Private	0.6	sandstone	convex creep slope
Southland/ SD4	Tahakopa	Black Point 2	F47/002861	8	Private	0.1	sandstone	transportational midslope
Southland/ SD3	Tahakopa	Black Point 1	F47/999863	10	Private	0.05	sandstone	convex creep slope
Southland/ SD14	Tahakopa	Waipapa Point	F47/919861	2	DOC Reserve	0.013	conglomerate	colluvial footslope
Southland/ SD10	Southland Plains	Bluff Hill, Ocean Beach	E47/509905	8	Private	0.15	ultramafic norite	transportational midslope
Southland/ SD9	Southland Plains	Bluff Hill, pipeline point	E47/506908	4	Private	0.1	ultramafic norite	colluvial footslope
Southland/ 13	Foveaux	Barracouta Point	E47/442959	10	Private	0.1	ultramafic norite	transportational midslope
Southland/ SD8	Foveaux	Omaui Point	E47/436995	4	Private	0.006	ultramafic norite	colluvial footslope
Southland/ SD7	Foveaux	Omaui Beach	E47/436995	5	Private	0.05	ultramafic norite	colluvial footslope
Southland/ SD11	Southland Plains	Oraka Point	D46/164118	7	Private	1	gabbro	colluvial footslope
Southland/ SD12	Longwood	Oraka Beach	D46/162119	4	Private	0.3	gabbro	alluvial toeslope
Otago/ OT6	Waianakarua	Shag Point	J43/400234	5	DOC Reserve	0.05	breccia	interfluve
Otago/ OT8	Dunedin	Cape Saunders	J44/334783	15	Private	0.05	basalt	seepage slope
Otago/ OT7	Dunedin	Sandymount	J44/302769	35	DOC Reserve	0.05	basalt	fallface
Otago/ OT15	Dunedin	Tunnel Beach	I44/127731	14	Private	0.36	sandstone	transportational midslope
Otago/ OT14	Tokomairiro	Watson Road	H45/903461	2	Private	0.05	mudstone	convex creep slope
Otago/ OT1	Tahakopa	Long Pt (Inihuka) seal cove	G47/480981	2	DOC Reserve	0.05	sandstone	alluvial toeslope
Otago/ OT2	Tahakopa	Long Pt (Inihuka) apex	G47/479979	35	DOC Reserve	0.1	sandstone	seepage slope
Otago/ OT3	Tahakopa	Long Pt (Inihuka) south embayment	G47/477981	30	DOC Reserve	0.2	sandstone	convex creep slope

SOIL TYPE	HABITAT	VEGETATION CLASSIFICATION	BIOGEOGRAPHICALLY SPECIAL PLANT SPECIES	DISTURBANCES
sand	coastal terrace	*Plantago masoniae–Leptinella dioica* herbfield		stock
sandy loam	coastal terrace	*Gunnera monoica–Hydrocotyle novae-zelandiae* herbfield		deer
sandy loam	coastal terrace	*Schoenus nitens–Isolepis cernua–Leptinella squalida* sedgeland		deer
clay loam	crest of headland	*Leptinella dioica–Gunnera monoica* herbfield		deer
sandy loam	coastal terrace	*Leptinella dioica* herbfield		deer
sandy loam	coastal terrace	*Gunnera monoica–Plantago masoniae* herbfield		deer
clay loam	crest of headland	Adventive grass–*Leptinella dioica* grassland		vehicles and stock
clay loam	valley slope	*Plantago masoniae–Leptinella dioica–Colobanthus muelleri* herbfield	*Myosotis pygmaea* var. *pygmaea*, *Ranunculus recens*	stock
sandy loam	terraced headland	*Leptinella dioica–Puccinellia walkeri–Selliera radicans* herbfield	*Myosotis pygmaea* var. *pygmaea*	stock
sandy loam	terraced headland	*Puccinellia* sp.–*Selliera radicans–Schoenus concinnus* herbfield		stock
clay loam	terraced headland	*Selliera radicans–Samolus repens–Leptinella dioica* herbfield		stock
clay loam	exposed ridge	*Leptinella dioica–adventive grass* herbfield	*Ranunculus recens*, *Euphrasia repens*, *Myosotis pygmaea* var. *pygmaea*	stock
gravel	beach and slope	*Selliera radicans–Samolus repens* herbfield	*Lepidium tenuicaule*, *Myosotis pygmaea* var. *pygmaea*	human traffic
sandy loam	coastal platform	*Selliera radicans–Leptinella dioica–Isolepis cernua* herbfield	*Myosotis pygmaea* var. *pygmaea*	stock
sandy loam	coastal platform	*Gentiana saxosa–Isolepis cernua–Leptinella dioica* herbfield		stock
sandy loam	beach and slope	*Leptinella dioica* herbfield	*Mazus arenarius*, *Myosotis pygmaea* var. *pygmaea*	stock
sandy loam	wave-washed platform	*Lepidium tenuicaule–Selliera radicans–Leptinella dispersa* herbfield	*Lepidium tenuicaule*, *Myosotis pygmaea* var. *pygmaea*	stock
gravel	wave-washed platform	*Selliera radicans–Isolepis cernua* herbfield	*Lepidium tenuicaule*	stock
sandy loam	coastal terrace	*Leptinella dioica* herbfield	*Lepidium tenuicaule*	stock
gravel	wave-cut platform	*Leptinella dioica* herbfield	*Ranunculus recens*, *Lepidium tenuicaule*, *Myosotis pygmaea* var. *pygmaea*	stock
gravel	coastal platform	*Lepidium tenuicaule–Leptinella dioica* herbfield	*Lepidium tenuicaule*	human trampling
clay loam	terraced headland	*Selliera radicans–Leptinella dioica* herbfield		stock
clay loam	cliff	*Sarcocornia quinqueflora–Puccinellia walkeri* herbfield	*Senecio carnosulus*	stock
sandy loam	crest of headland	*Leptinella dioica–Samolus repens–Selliera radicans* herbfield		stock, human traffic
sandy loam	coastal platform	*Leptinella dioica* herbfield	*Lepidium tenuicaule*, *Ranunculus recens*, *Myosotis pygmaea* var. *pygmaea*	stock
clay loam	bench	*Leptinella dioica–Selliera radicans* herbfield	*Gentiana saxosa*	fur seals
clay loam	crest of headland	*Leptinella dioica–Selliera radicans–Plantago masoniae* herbfield	*Myosotis rakiura*, *Gentiana saxosa*, *Myosotis pygmaea* var. *pygmaea*, *Ranunculus recens*	stock, human trampling
clay loam	gully slope	*Plantago masoniae–Leptinella dioica* herbfield	*Myosotis pygmaea* var. *pygmaea*, *Ranunculus recens*	stock

PROVINCE/ PLOT NO.	ECOLOG. DISTRICT	LOCALITY	GRID REF. MZMS 260	ALTITUDE (m)	TENURE	AREA (ha)	LANDFORM LITHOLOGY	PHYSIO-GRAPHY
Otago/ OT4	Tahakopa	Long Pt (Inihuka) chasm	G47/479978	5	DOC Reserve	0.05	sandstone	fallface
Otago/ OT5	Tahakopa	Long Pt (Inihuka) crib terrace	G47/477981	3	Private	0.05	sandstone	terrace platform
Otago/ OT9	Tahakopa	Tautuku Pen. –north head	G47/375941	5	Maori land	0.6	sandstone	convex creep slope
Otago/ OT10	Tahakopa	Tautuku Penninsula	G47/369936	25	Maori land	0.05	sandstone	interfluve
Otago/ OT11	Tahakopa	Frances Pillars –middle	G47/339934	20	Maori land	1.5	sandstone	seepage slope
Otago/ OT12	Tahakopa	Frances Pillars –south 2	G47/336938	12	Maori land	1	sandstone	seepage slope
Otago/ OT13	Tahakopa	Frances Pillars –south 1	G47/335938	3	Maori land	1	sandstone	transportational midslope
Otago/ OT16	Tahakopa	Shades Beach	G47/229899	22	Private	0.01	sandstone	interfluve
Otago/ OT17	Tahakopa	Brothers Pt 1	G47/190875	23	Private	0.75	conglomerate	transportational midslope
Otago/ OT18	Tahakopa	Brothers Pt 2	G47/190875	21	Private	0.06	conglomerate	convex creep slope

SOIL TYPE	HABITAT	VEGETATION CLASSIFICATION	BIOGEOGRAPHICALLY SPECIAL PLANT SPECIES	DISTURBANCES
silt loam	gully slope	*Sarcocornia quinqueflora-Atriplex buchananii* herbfield	*Myosotis rakiura, Senecio carnosulus*	stock
silt loam	seepage	*Isolepis cernua-Leptinella dioica-Rumex neglectus* sedgeland		stock
clay loam	terraced headland	*Leptinella dioica* herbfield	*Myosotis pygmaea* var. *pygmaea*	stock
clay loam	terraced headland	*Poa astonii-Leptinella dioica* grassland	*Gentiana saxosa*	stock
clay loam	crest of headland	*Poa astonii-Leptinella dioica* grassland		stock
clay loam	crest of headland	*Poa astonii-Selliera radicans* herbfield	*Myosotis rakiura-Myosotis pygmaea* var. *pygmaea*	stock
clay loam	coastal platform	*Leptinella dioica-Selliera radicans* herbfield		Maori
sandy loam	crest of headland	*Leptinella dioica* herbfield		stock
sandy loam	crest of headland	*Leptinella dioica-Selliera radicans* herbfield		stock
sandy loam	crest of headland	*Puccinellia walkeri-Selliera radicans* herbfield		stock

Appendix 2

Plant species recorded in 94 sample plots of turfs from 6 zones

Acaena anserinifolia
Acaena microphylla var. *pauciglochidiata*
Agrostis muscosa
*Agrostis stolonifera**
*Aira caryophyllea**
*Ammophila arenaria**
*Anagallis arvensis**
Anisotome lyallii
Apium prostratum
*Arctotheca calendula**
Asplenium obtusatum
Atriplex buchananii
Azolla filiculoides
*Bellis perennis**
Blechnum blechnoides
Brachyglottis bellidioides
Cardamine debilis
Carex comans
Carex flagellifera
Ozothamnus leptophylla
Celmisia "Pupu"
Celmisia monroi
Centella uniflora
*Cerastium fontanum**
Colobanthus apetalus
Colobanthus muelleri
Coprosma acerosa
Coprosma propinqua
Coprosma rhamnoides
Cotula coronopifolia
Craspedia minor
Craspedia uniflora
Crassula helmsii
Crassula manaia
Crassula mataikona
Crassula moschata
Crassula pedunculatus
Crassula sieberiana
*Creeps capillaris**
Dichondra brevifolia agg.
Disphyma australis
Eleocharis acuta
Elymus solandri
Epilobium komarovianum
Eryngium vesiculosum
Euphrasia repens
Gentiana saxosa
*Geranium molle**
Gnaphalium audax
Gonocarpus aggregatus
Gonocarpus micranthus
Gunnera dentata
Gunnera monoica
Hebe elliptica ssp. *elliptica*
Helichrysum filicaule
*Holcus lanatus**
Hydrocotyle novae-zeelandiae var. *montana*
*Hypochoeris radicata**
Isolepis cernua
Isolepis nodosa
*Isolepis marginata**
Juncus caespiticius
Lachnagrostis filiformis
Lagenifera petiolata
Lagenifera pumila
*Leontodon taraxacoides**
Lepidium flexicaule
Lepidium tenuicaule
Leptinella calcarea
Leptinella dioica ssp. *dioica*

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* adventive species

Leptinella dispersa ssp. *dispersa*
Leptinella squalida ssp. *mediana*
Leptinella squalida ssp. *squalida*
Leptinella traillii ssp. *pulchella*
Leptospermum scoparium
Leptostigma setulosum [*Nertera setulosa*]
Leucopogon fraseri
Lichen spp.
Lilaeopsis novae-zelandiae
Limosella "Manutahi"
Limosella lineata
Lindsaea linearis
Lobelia anceps
*Lotus pedunculatus**
*Lotus suaveolens**
Luzula banksiana ssp. *banksiana*
Marchantia berteroana
Mazus arenarius
Mazus novaezeelandiae ssp. *impolitus*
Mazus radicans
Mentha cunninghamii
Montia fontana
Moss spp.
Muehlenbeckia axillaris
Myosotis pygmaea var. *minutiflora*
Myosotis pygmaea var. *pygmaea*
Myosotis rakiura
Nertera depressa
Neopaxia australasica
Ophioglossum coriaceum
Oreomyrrhis "minutiflora"
Oxalis exilis
Pimelea prostrata
Pimelea cf. *urvilleana*
*Plantago coronopus**
*Plantago lanceolata**
*Plantago major**
Plantago triandra ssp. *masoniae*
Plantago raoulii
*Poa annua**
Poa astonii
*Poa pratensis**
Poa pusilla
*Polycarpon tetraphyllum**
Poranthera microphylla
Pratia angulata
Pseudognaphalium sp. unnamed (aff. *P. luteoalbum*)
Puccinellia walkeri
Ranunculus acaulis
Ranunculus flexuosus
Ranunculus multiscapus
Ranunculus recens
Ranunculus royi
Einadia triandra
Rumex neglectus
Rytidosperma gracile
*Rytidosperma racemosum**
Rytidosperma setifolium
*Sagina procumbens**
Samolus repens
Sarcocornia quinqueflora
Schoenus concinnus
Schoenus maschalinus
Schoenus nitens s.s.
Scleranthus biflorus
Selliera radicans
Selliera rotundifolia
Senecio carnosulus
*Senecio jacobaea**
Senecio lautus
Sonchus kirkii
*Sonchus oleraceus**
Sticherus cunninghamii
Suaeda novae-zelandiae
*Taraxacum officinale**
Tetrachondra hamiltonii
Thelymitra longifolia
*Trifolium dubium**
*Trifolium pratense**
*Trifolium repens**
Triglochin striatum
Wahlenbergia congesta
Zoysia minima

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* adventive species

Appendix 3

Site records of *Lepidium flexicaule* from a survey of coastal turfs along the Te Taitapu, Nelson, and north Westland coasts. Not all records are from coastal turf communities

ZONE	GRID REF. (NZMS 260)	HABITAT	APPROX. NO. OF PLANTS	DISTURBANCE FACTORS
Te Taitapu coast, Nelson, TT17	M24/741726	base of limestone blocks	c. 200	stock
Te Taitapu coast, Nelson, TT20	M24/727715	base of limestone blocks	34	stock
Te Taitapu coast, Nelson	M24/748732	base of limestone blocks	3	stock
Te Taitapu coast, Nelson	M24/746731	base of limestone blocks	c. 66	stock
Te Taitapu coast, Nelson	M24/744729	below limestone overhang	c. 22	limited stock
Te Taitapu coast, Nelson, TT7	M24/767750	base of limestone blocks	11	stock
Te Taitapu coast, Nelson	M24/754735	shelf below sandstone overhang	2	nil
Te Taitapu coast, Nelson, TT19	M24/736721	limestone talus	c. 30	stock
Te Taitapu coast, Nelson, TT33	M24/748731	limestone terrace	6	stock
Te Taitapu coast, Nelson, TT34	M24/744730	limestone terrace	c. 25	stock
Te Taitapu coast, Nelson, TT30*	M25/585592*	limestone terrace	12	seabirds
North Westland, Point Elizabeth, WD1	J31/633680	mudstone talus	5	nil
North Westland, Dolomite Point, WD2	K30/716979	limestone terrace and escarpment	not counted	pedestrian traffic

* Another limestone terrace 40 m south, upon which red-billed gulls nest, requires survey.

Appendix 4

Soil analysis of selected plots from turf associations

PLOT NO.	pH	Ca	K	P	Mg	Na	S	SS	TEB	%BS	CEC
TW1	5.9	3	5	89	30	58	37	0	96	12	8
TW9	6.4	7	10	7	95	145	31	0.03	257	13.53	19
TW16	6.4	11	22	14	145	650	269	0.93	828	20.2	41
TT7	7.6	50	40	145	295	750	1405	4.4	1135	10.61	107
TT8	6	4	12	5	59	170	145	0.12	245	17.5	14
WD1	8.3	21	23	2	155	165	35	0.12	364	8.27	44
WD7	5.4	4	8	22	48	55	34	0.07	115	11.5	10
SD5	6.4	10	32	46	150	450	279	1.29	642	17.83	36
SD7	6.2	11	25	96	150	240	193	0.65	426	13.31	32
SD9	5.6	14	18	97	195	590	381	1.56	817	17.76	46
SD12	6.3	17	27	54	230	750	558	1.88	1024	17.96	57
OT1	6.2	14	37	89	205	360	382	1.23	616	14.33	43
OT2	5.9	6	16	21	95	70	20	0.04	187	11	17
OT3	5.8	6	20	30	95	109	66	0.14	230	12.78	18
OT7	7.4	16	53	71	230	605	235	0.93	904	16.74	54
OT11	6.2	11	30	15	170	440	314	1.41	651	17.13	38
OT13	5.6	8	19	162	120	160	77	0.26	307	13.35	23
Totaranui	6.6	9	6	54	81	47	5	0	143	7.52	19

Ca = exchangeable Ca^{2+} (g/40^4ml extract). K = exchangeable K^+ (g/25x10^4ml extract). P = Olsen P (ug/ml). Mg = exchangeable Mg^{2+} (g/10^6ml extract). Na = exchangeable Na^+ (g/10^6ml extract). S = potassium phosphate extractable S (ppm). SS = calcium sulphate extractable soluble salts (%). TEB = sum of exchangeable bases (g/10^6ml extract). BS = base saturation (%). CEC = cation exchange capacity (me%).