FACTORS AFFECTING VEGETATION OF THE HAWDON RIVER ALLUVIAL OUTWASH FAN, ARTHUR'S PASS, NEW ZEALAND

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INTRODUCTION

An alluvial fan is an area of gravel and sediment deposited by a river. As it washes out of a confining valley on to a plain, the river slows and becomes less able to support its sediment load, forming a spreading, delta-shaped fan. In many ways similar to a scree slope, a fan is a dynamic environment with a mobile substrate, subject to disturbances. Natural disturbances include floods and debris flows, which move substrate, scour out vegetation, and deposit gravel (Burrows 1977). Unnatural disturbances are caused by exotic organisms, including humans. Each disturbance regime has its own effect on vegetation.

The Hawdon River is located in Arthur's Pass National Park, South Island, New Zealand, with its catchment in the Polar and Savannah Ranges of the Main Divide (NZMS 260 K33 075010). The river has

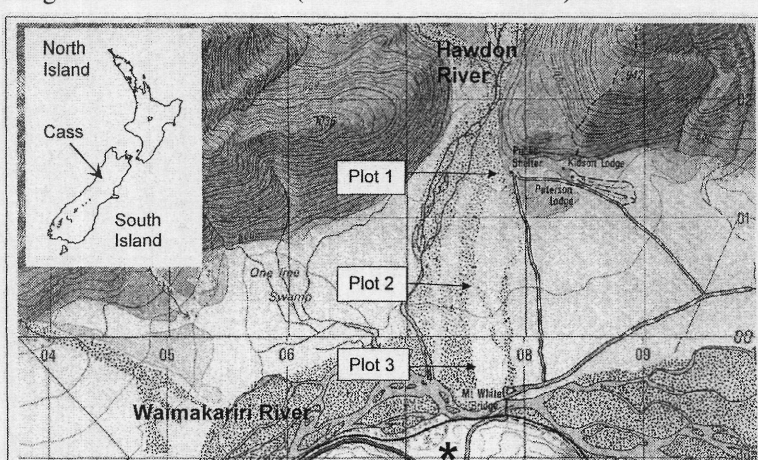

Fig. 1. Location of Hawdon River, and study site, showing sampling plots used on the Hawdon River fan. Source: NZMS 260 K33; 1km grid squares. The photographic point of Fig. 2 is marked by an asterisk. Inset of New Zealand showing site location.

formed an extensive alluvial fan, 2 by 2 km, where it exits the Hawdon Valley at about 750m altitude and joins the Waimakariri River (Figs. 1, 2). This study aims to determine if plant communities of the Hawdon River fan are affected by spatial position on the fan or by disturbance by river course changes, exotic animal browsing, or exotic plant invasion.

METHOD

Three areas were subjectively selected for study, reflecting diminishing likelihood of river disturbance: the top of the outwash fan (i.e. where the river leaves the valley), the middle, and the bottom (i.e. where the Hawdon River meets the Waimakariri River; Fig. 2). The area abuts the National Park, but is open to stock which graze the Waimakariri River flats.

At each area a 100m x 100m sampling plot was randomly sited across the riverbed/vegetation interface, and within each, fifteen 4m x 4m quadrats were placed at random. At each quadrat a range of data was gathered: estimated surface percentage cover for vascular vegetation, mosses,

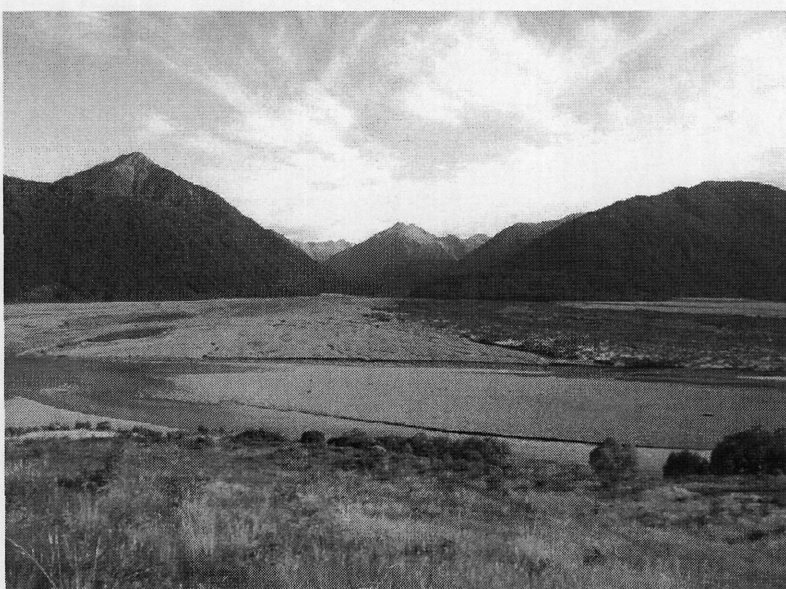

Fig. 2. The Hawdon River alluvial fan, with the Waimakariri River in the foreground, the sampled riverbed / vegetation junction in mid-picture, and the Hawdon River flowing on the left side of the fan.

Table 1. Mean environmental data for each community, and cover (%) of dominant or interesting species; 0.5 = trace amount of cover. Topography is measured with respect to the lowest point in the gravelly communities (A and B) in each plot. * indicates exotic species. (Continued next page)

Community	A	B	C	D	E	F	G
	Riverbed	*Epilobium* gravel	*Muehlen-beckia* gravel	Matagouri grassland	Mature matagouri	Tutu-matagouri grassland	*Racomitrium* -matagouri
Animal presence (% of quadrats)	67	75	80	100	100	100	100
Average substrate depth (cm)	0.6	2.0	9.2	8.9	6.4	10.4	6.2
Average topography height (cm)	40	60	41	70	83	86	77
Gravel cover (%)	92	77	54	24	23	37	10
Sand / soil cover (%)	1	16	12	4	3	3	0
Vascular vegetation cover (%)	5	10	32	74	80	59	95
Moss cover (%)	2	1	3	5	5	4	46
Epiphytic lichen (%)	0	0	0	3	3	5	6
Maximum *Discaria* height (cm)	61	13	76	107	123	185	120
Species diversity	30	37	31	45	45	25	39
Exotics (% species diversity)	42	44	46	39	39	49	41
Exotics (% cover of vegetation)	30	22	41	45	17	28	18

Table 1: (continued)

Community	A Riverbed	B *Epilobium* gravel	C *Muehlen-beckia* gravel	D Matagouri grassland	E Mature matagouri	F Tutu-matagouri grassland	G *Racomitrium* -matagouri
Acaena glabra (%)	0.5	0	4	0.5	2	0.5	0
*Agrostis capillaris** (%)	1	0.5	1	13	3	0.5	5
*Anthoxanthum odoratum** (%)	0.5	1	1	17	7	2	10
Coriaria sarmentosa (%)	0	0	0	0	0	23	0
Discaria toumatou (%)	0.5	0.5	1	27	52	21	32
Epilobium melanocaulon (%)	0.5	6	0.5	0.5	0.5	0.5	0
Festuca novae-zelandiae (%)	0	0	0	0.5	0.5	0	0.5
*Hieracium pilosella** (%)	0	0	1	4	1	18	3
*Holcus lanatus** (%)	0.5	0.5	0.5	0.5	1	0.5	0.5
*Hypochaeris radicata** (%)	0.5	0.5	0.5	1	0.5	0.5	1
Leucopogon fraseri (%)	0.5	0.5	0.5	2	2	0.5	2
Melicytus alpinus (%)	0	0	0	0	0	0	0.5
Muehlenbeckia axillaris (%)	0.5	0.5	5	4	3	0.5	4
Poa sp. (%)	0	0	0	5	3	8	1
Racomitrium pruinosum (%)	0.5	0.5	0.5	4	2	1	42
Raoulia australis (%)	2	1	0	0.5	0.5	0	0.5
Raoulia tenuicaulis (%)	0.5	1	0.5	1	0.5	1	1
*Trifolium arvense** (%)	0.5	0.5	1	2	1	0.5	0.5
*Trifolium repens** (%)	0.5	0.5	3	0.5	0.5	0.5	0.5
Wahlenbergia albomarginata (%)	0.5	0.5	0	0.5	0.5	0.5	0.5

terrestrial lichen, and various types of substrate; the presence and type of animal faeces; topsoil depth (average of 5 probes at corners and centre); and cover of each vascular species, epiphytic lichen, and the common white woolly moss *Racomitrium pruinosum*. The height of each quadrat was recorded above an arbitrary origin defined as the lowest quadrat in a river braid community (i.e., with >75% cover of gravel). A profile was constructed along the plot's central axis at right angles to the flow of the Hawdon River. As a measure of plot age, the maximum height of the tallest woody shrub of *Discaria toumatou* was recorded, and for the two lower plots the shrub's age was calculated from a count of growth rings at a height of 20 cm, assuming annual formation.

The species data per quadrat were allocated to "communities" by a cluster analysis using Pearson similarity coefficient and Ward linkage (SYSTAT, 1996). Communities were named after dominant species, and distributions in each plot mapped using field observations. The percentage cover of important or interesting species in each community was tabulated, along with environmental data (Table 1). A Canonical Correspondence Analysis investigated species or quadrat relationships in ordination space, when constrained by the environmental vectors (ter Braak & Smilauer 2002).

RESULTS

Environmental changes with position on the fan

No standing water was found on any plot. Rabbit sign was almost ubiquitous, while sheep sign occurred in half the quadrats, and cattle sign infrequently and in only the upper two plots (data in Adamson et al. 2004). Two sheep were seen on the river shingle adjacent to the study area. Moving from top to bottom of the fan, moss and lichen cover declined (data not presented), while average substrate depth increased (3.85 cm in the top plot, to 7.15 cm, and 8.08 cm). Distance to the nearest active river braid increased down the fan (240, 411, >1000 m). Maximum *Discaria* height was lowest in the top plot (185 cm), and increased with distance down the fan (202 cm, where the largest stem was aged at 44 years for the middle plot, and 260 cm and 152 yrs for the bottom plot).

The topography along the centre-line transects of the three plots all showed the low-lying, gravelly zone closest to the current river course. This has its greatest scouring (lowest ground) closest to the higher, uneroded surfaces (Fig. 4), and for the lower two plots created an erosion scarp. The top plot was characterised by a relatively even, but low, topography (with respect to the adjacent river flow). In the middle plot most of the vegetation was on a raised area between two river braids. The bottom plot had a mostly vegetated raised surface, but with uneven topography reflecting the position of ancient river braids.

Plant community characteristics

The vegetation analysis separated into seven communities, in two groups strongly
related to the extent of cover of matagouri (*Discaria toumatou*; Fig. 3). The first group incorporates the Riverbed community (present only in the top plot), and two other communities found in all plots, i.e. the: *Epilobium* gravel and *Muehlenbeckia* gravel communities, which are on or near river braids. Of the communities with substantial cover of *Discaria toumatou* (matagouri), and located in less disturbed areas, Mature matagouri and Matagouri grassland are found in all plots, while Tutu-matagouri grassland is mainly found in the middle plot, and *Racomitrium*-matagouri mainly in the bottom plot.

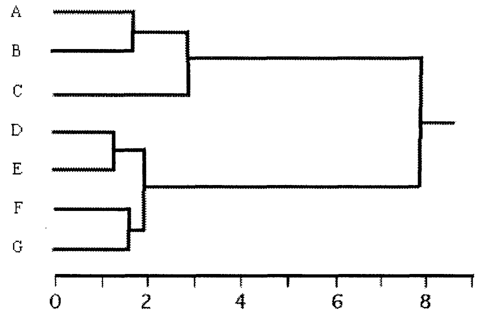

Fig. 3. Dendrogram of relationships of vegetation communities.

A. Riverbed community:
 This community has 92% gravel cover with very shallow substrate and very little vegetation; it is topographically the lowest of the communities. 58% of species are native; the exotics are mainly pasture species.
B. *Epilobium* gravel community:
 Also with little vegetation cover (7%), high gravel and sand cover (93%), and shallow substrate (2cm). 56% of species are native (mostly alpine herbs) with mats of *Epilobium melanocaulon*; exotics are mainly grasses.
C. *Muehlenbeckia* gravel community:
 High proportion of gravel cover (54%); low proportion of vegetation cover (32%); 9cm deep sandy substrate. Mat forming

plants dominate the vegetation.

D. Matagouri-grassland community:
Significant matagouri cover (27%), with exotic pastoral species important in the diverse understorey vegetation (45% of vegetative cover). Matagouri reaches over 100 cm. Substrate depth also 9cm, but of soil.

E. Mature matagouri community:
Vegetation cover is 80%, with matagouri dominant at 52% and up to 1.2 m high above a range of native and exotic herbs. The soil is relatively well developed (6 cm deep). Species diversity is high.

F. Tutu-matagouri grassland community:
51% of species native. Tallest of all communities (185 cm), the shrubs tutu (*Coriaria sarmentosa*) and matagouri having a combined cover of 43%. Exotics are dominated by *Hieracium pilosella* (18%).

G. *Racomitrium*-matagouri community:
Occupies well-stabilised riverbed (substrate depth 6 cm). Dominated by *Racomitrium* (42% of cover) and tall matagouri (32%), while exotic grasses provide 15% cover.

Community patterns on the fan

In the top plot (Fig. 4A) the Mature matagouri (E) and other matagouri communities are scattered over the plot, between recent river braids which map as the Riverbed community (A). In the middle plot (Fig. 4B) the *Epilobium* gravel community (B) and two quadrats with no plants at all are closest to the current bed of the Hawdon River or in a major braid, while other communities are on higher surfaces. A large patch of tutu (*Coriaria sarmentosa*) abuts a river braid. In the bottom plot (Fig. 4C), the braided river community *Epilobium* gravel (B) dominates closest to the river, while the Matagouri-grassland (D), Mature matagouri (E) and *Racomitrium*-matagouri (G) communities occur in various old channels further from the river.

Successional relationships

The first axis of the CANOCO analysis of the species constrained by the environmental vectors (data not presented) reflects a successional gradient from disturbed to more mature sites. Gravel cover has a strong influence on many small herb species of open ground, while epiphytic lichen cover is associated with the height of matagouri shrubs, as is substrate depth. Native species are associated with gravelly, open areas, while the exotics tend to be located in the more developed, grassy sites

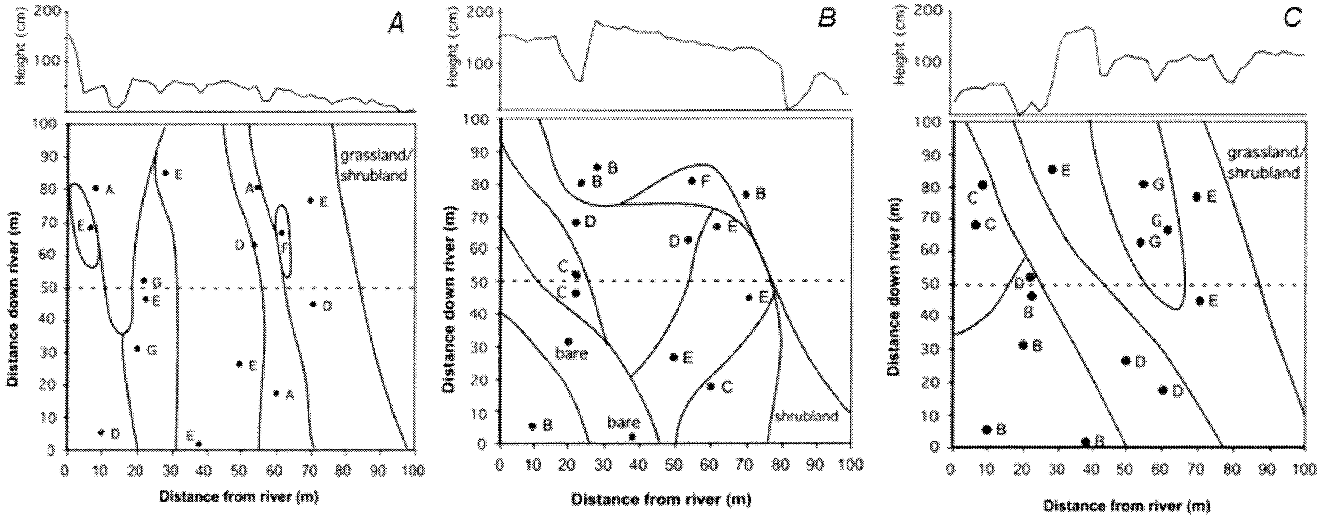

Fig. 4: Plots showing quadrat locations and community assignments with boundaries interpolated from field observations. The topography is or the centre-line (dotted line) of each plot A—top, B—Middle, C—Bottom.

with deeper substrate, which are north facing and relatively high above the river.

Discussion

The successional sequence

When an area is left undisturbed for a reasonable period of time a succession of vegetation occurs. In a braided riverbed this involves the appearance via wind-borne seed of *Epilobium brunnescens*, *E. melanocaulon*, and *Raoulia tenuicaulis* over about a year (Wardle 1972; Burrows 1977; Dawson 1988). Then wind blown silt accumulates in *Raoulia* mats, which are important in the build-up of humus. After three years, these mats are colonised by species such as *Anthoxanthum odoratum*, *Agrostis capillaris*, and *Trifolium repens*, and scattered small shrubs then appear. On the Hawdon River fan, conditions are comparable, and a similar succession can be inferred, probably over a similar time-line. Here the sequence is from bare gravels through pioneering communities containing *Epilobium melanocaulon*, and secondly *Muehlenbeckia axillaris* and *Acaena* mats (communities A-C).

The later stages of succession involve the advent of native herbs and shrubs, especially matagouri (*Discaria toumatou*), the commoner nitrogen fixing species present, the other being *Coriaria sarmentosa* (Community F), a species of stable sands (Burrows 1977). The divaricating shrub *Melicytus alpinus* is occasional on the bottom plot. Of the matagouri dominated communities, Matagouri grassland and Mature matagouri (D and E) are probably the oldest, being tall and diverse, with much vegetation cover and deep soils. Though the facilitative effects of *Racomitrium pruinosum* cushions are widely recognised, the *Racomitrium*-matagouri community (G) is only conspicuous in the bottom plot. Matagouri is likely to be the final vegetation on the site (c.f. Calder 1961; Wardle 1972), as it appears to be a fan specialist (Cockayne 1911), and because ongoing disturbance clearly limits native tussock invasion.

Despite broad similarities, there are some differences between the succession recorded here, and that described in the literature. With a well-drainded fan surface, *Raoulia tenuicaulis* cushions are not important here, as they are in the subalpine zone of the nearby Broken River (Wardle 1972). Instead the summer-green *Epilobium melanocaulon*, with its long tap roots, is the commonest early successional plant (Calder 1961; Wardle 1972), though its cover declines over time. (Cockayne 1911) attributes this species differentiation to riverbed stability in the upper Rakaia River (rainfall >250 cm/yr), where *Epilobium* occured on unstable beds, subject to occasional flooding, and *Raoulia* on more stable areas. But at Hawdon the vertical moisture gradient may be more important, with moisture not limiting deeply rooting plants, though it may be too dry for the more shallow-rooted *Raoulia* (Wardle 1972). The mat-forming *Muehlenbeckia axillaris*, which has deep roots, is more common at Hawdon than in higher altitude, wetter, sites (Calder 1961; Wardle, 1972). Water must be supplied by subsurface seepage (Cockayne 1911) or rainfall: Cass receives >130 cm/yr, and the Hawdon catchment is probably slightly wetter, due to its proximity to the Main Divide (Greenland 1977).

Impacts of position on the fan

Vegetation on the Hawdon River outwash fan also follows an approximate developmental sequence from the top to the bottom plot. Though different braids can be at different stages of succession depending on when they were last disturbed, there is a general trend down the plots of decreasing gravel cover, increasing soil depth and matagouri height and age, as well as increasing importance of exotic species of grasses and flatweeds. Although the two lower plots have marked erosion scarps between the riverbed and more mature communities, indistinguishable mature communities are present on all three plots. This suggests the same processes operate in each plot. The top plot has much flatter topography (except for a new riverside gravel stopbank, which shows at the beginning of the centre-line profile; Fig 4A), with a shallow substrate, so the succession there is probably primary. The top of the fan obviously experiences ongoing erosion caused by floods exiting from the relatively confined Hawdon valley. At least 60 major floods occurred at nearby Cass between 1865 and 1975 (Burrows 1977), and probably many of these also occurred at Hawdon. The more developed soils on the terraces of the lower plots suggest the current vegetation is secondary. The aged matagouri stem implies that it is at least 150 years since a major non-erosive disturbance, such as a fire, affected this area, and the community probably dates back to scrub clearance by the earliest settlers in the area. Currently sheltered by old braids, the lower portions of the fan have not experienced a flood or fire sufficiently severe to eliminate shrubs for more than a century. The higher, more stable surfaces can only be affected by flood events severe enough to swing the current flow channel of the Hawdon River to the east side of the fan. The bottom plot is probably equally prone to flooding by the Waimakariri River.

Impacts of exotic species

A stable environment normally allows native plants such as tussocks, *Hebe*, *Parahebe* and *Discaria* to enter Canterbury riverbed successions after about ten years (Burrows 1977). However, the mature communities of the Hawdon fan contain many exotic species. To eliminate competition exotics require disturbances (Jesson et al. 2000), such as grazing animals which defoliate established plants, mobilise nutrients, and act as seed vectors. Selective grazing on palatable species aids in preventing a single species from dominating the riverbed (Gibb 1994), but the increased diversity can also incorporate invading exotics. Though Gibb & Fitzgerald (1998) reported rabbits declining as shrub cover increased in the bed of the Orongorongo River, rabbit sign was almost ubiquitous at Hawdon. Cattle and sheep impacts are unclear, but all three herbivores probably facilitate exotic invasion, as well as grazing on the relatively palatable native herb flora, already rendered depauperate as locally available seed sources are depleted by adjacent farming activities.

CONCLUSION

Successional processes in the vegetation on the Hawdon River alluvial outwash fan are affected by disturbance regimes characterised by alluvial processes, invasion of exotic plant species, and herbivory. Hydrological disturbance as a result of flood events initiates succession by providing new areas of gravel for native plants to colonise and establish. As environmental conditions ameliorate, exotic species increase in prominence, underneath native shrubs of matagouri. Location on the alluvial fan does not appear to affect vegetation directly but is correlated with disturbance regime. The relatively wet conditions of the Hawdon fan, near the Main Divide, allow a number of relatively infrequent riverbed species to become more important in the early stages of succession.

ACKNOWLEDGEMENTS

This paper is abbreviated from a project report completed by students of the third year course, *Vegetation Studies in New Zealand.* Thanks to Peter van Essen and Scott Carver for their assistance and for the superb food, the University of Canterbury for the use of the Cass field station, Steve Gurney for providing the entertainment, and the Department of Conservation for the necessary permits.

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