

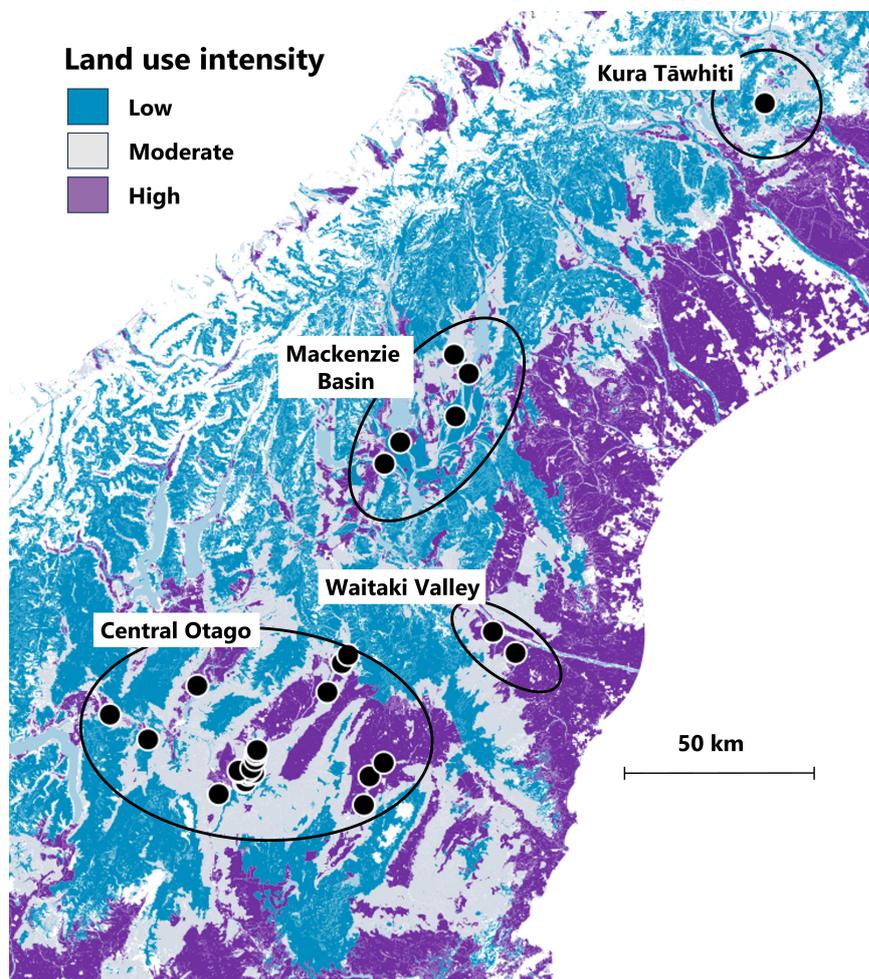
Supplementary Material

1. Data and derived attributes

Appendix S1. Land-use intensity levels ascribed to LCDB v5.0 (Landcare Research Informatics Team 2019) land-cover classes within 2 km radii of our *Lepidium* locations. Criteria were informed by our field observations at the locations in our study and are not necessarily applicable beyond those locations. Land-use intensity estimates should also be treated with caution because vegetation variations in our study regions are captured only coarsely in the land-cover classes in LCDB v5.0, and in some instances those data did not show recent changes in land cover near *Lepidium* locations.

Ascribed land-use intensity	Criteria	Cover class (% of all 2 km radii)
Intensive	Soils have been physically disturbed, planted, cultivated, irrigated, or built on, and land cover (whether vegetation, bare soil, or infrastructure such as roading) is wholly non-indigenous.	Exotic Forest (0.2%) Forest – Harvested (0.1%) High Producing Exotic Grassland (29.3%) Orchard Vineyard and Other Perennial Crops (0.5%) Surface Mines and Dumps (0.4%)
Intermediate	Soils have not been deliberately disturbed for intensive use, but exotic components of vegetation and stocking rates by sheep and/or other livestock (e.g. deer) have been enhanced by fertiliser (aerially applied or via runoff) and/or exotic seed.	Deciduous Hardwoods (2.1%) Herbaceous Freshwater Vegetation (2.2%) Herbaceous Saline Vegetation (0.2%) Low Producing Grassland (42.2%) Matagouri or Grey Scrub (0.1%) Mixed Exotic Shrubland (4.4%)
Low	No soil disturbance, no or little evidence of recent oversowing and topdressing, extensive sheep grazing or no present grazing use.	Depleted Grassland (12.2%) Gravel and Rock (1.5%) Lake and Pond (1.5%) Mānuka and/or Kānuka (<0.1%) River (0.9%) Tall-Tussock Grassland (2.2%)

Appendix S2. Land use intensity (coded as low, moderate or high) across the four geographical areas where inland *Lepidium* species occur (Kura Tāwhiti, the Mackenzie Basin, Central Otago and the Waitaki Valley).



Appendix S3. *Lepidium kirkii* locations visited or investigated and material collected in Central Otago, showing the location name, region, month visited, the people who searched and collected *Lepidium* material, and notes on observations and seed. Asterisks highlight local extinctions. GL = Graeme Loh, MH = Michael Harding, MS = Mathew Sole, RW = Rob Wardle, SW = Susan Walker.

Location	Month visited	People	Notes
Upper Galloway	12/2020	SW, GL	Present but population very small (< 30 plants found). Seed collected and germinated.
*Galloway South 1	12/2020	SW, GL, MH	Evidently locally extinct.
Galloway South 2	12/2020	SW, GL, MH	Present, but only 3 plants seen. Plants were tiny, therefore not sampled for material, and not flowering.
Springvale DOC	12/2020	SW, GL, MH	Present (estimated > 50 plants), Seed collected and germinated.
*Springvale Private Land	12/2020	SW, GL, MH	Evidently locally extinct.
Lower Galloway	12/2020	SW, GL, MH	Present but < 20 plants found. Seed collected and germinated.
*Galloway airstrip	12/2020	SW, GL, MH	Evidently locally extinct.
Chapman Road	12/2020	SW, GL, MH	Present, but only 1 flowering plant seen on the Scientific Reserve, and about 6 non-flowering individuals (juveniles?) on the neighbouring property immediately north. Seed collected and germinated.
*Chatto Creek 2 (large saline patch north of saltbush plantation)	12/2020	SW, GL, MH, MS	Evidently locally extinct.
Chatto Creek 5	12/2020	SW, MH	Present. Two flowering <i>L. kirkii</i> plants seen in December 2020 on a saline patch at a location not previously recorded (<i>L. solandri</i> and not <i>L. kirkii</i> previously recorded nearby). Seed collected and germinated. More <i>L. kirkii</i> plants (< 20) found by KW & SW in the vicinity in January 2023, along with <i>L. solandri</i> .
*Olig 1 (saltbush)	12/2020	SW, MH	Evidently locally extinct: no <i>L. kirkii</i> plants found.
*Olig 2 (water race)	12/2020	SW, MH	Evidently locally extinct: no <i>L. kirkii</i> plants found.
Rockdale (Manuherikia, north of Chatto Creek)	Not accessed	-	Aerial imagery suggests location has been converted to pasture.
*Wilson Road (Maniototo)	12/2020	SW, MH	Evidently locally extinct: no <i>L. kirkii</i> plants found.
*Beatties Covenant (Maniototo)	12/2020	SW, GL, MH, RW	Evidently locally extinct: no <i>L. kirkii</i> plants found.
*Beatties Sluicing (Maniototo)	12/2020	SW, GL, MH, RW	Evidently locally extinct: no <i>L. kirkii</i> plants found.
Dovedale (Ida Valley)	Not accessed	-	Aerial imagery suggests location has been converted to pasture.

Appendix S4. *L. solandri* locations visited in Central Otago and the Waitaki Valley, showing the location name, region, month visited, the people who searched and collected *Lepidium* material, and notes on observations and seed. Asterisks highlight local extinctions. GL = Graeme Loh, KW = Kate Wardle, MH = Michael Harding, MS = Mathew Sole, RW = Rob Wardle, SG = Samantha Gale, SW = Susan Walker, SY = Sandy Yong, TH = Tayla Hooker.

Location	Region	Month visited	People	Notes
*Eden Creek	Central Otago	12/2020	SW, GL	Evidently locally extinct. No <i>L. solandri</i> plants found. Fenced and now under tall and dense exotic grass cover beside cultivated pasture. Full vascular flora not recorded.
Beatties Covenant	Central Otago	12/2020	SW, GL, MH, RW	Present. Total population estimated 30–40 plants. Most occurred on the brow of the curving terrace at the north end of the covenant. A few more occur north of the covenant (towards the woolshed) and on roadside scarp south of the covenant fence. Seed collected and germinated.
Beatties Sluicing	Central Otago	12/2020	SW, GL, MH, RW	Present. Two female <i>L. solandri</i> plants found on lip of scarp above sluicing pit. Seed collected did not germinate.
*Lower Galloway	Central Otago	12/2020	SW, GL, MH	Evidently locally extinct. Location invaded by <i>Austrostipa nodosa</i> .
Springvale private land	Central Otago	12/2020	SW, GL, MH	Present. Three <i>L. solandri</i> plants found remaining, all caged. Seed collected from the one female plant germinated.
Blackstone Hill Conservation Area	Central Otago	12/2020	SW, GL, MH	Present. A number of <i>L. solandri</i> plants scattered sparsely along scarp face. Seed collected and germinated. This is the location of herbarium specimen CHR 573584 dated 2003 from Michael Peak, which records plants “scattered across the rocky/stony ridge near salt pan”. Barkla and Thorsen (2007) also recorded the plant’s presence from this general area, along with the halophyte <i>Atriplex buchananii</i> .
Blackstone Hill private land	Central Otago	12/2020	SW, GL, MH	Present. <i>L. solandri</i> scattered in groups of up to 20 along scarp face. Plants in larger numbers and groups than on the adjacent public land. Seed collected and germinated.
*Chatto Creek 1 (saltbush and pipeline)	Central Otago	12/2020	SW, GL, MH, MS	Evidently locally extinct. No <i>L. solandri</i> plants found.
*Chatto Creek 3	Central Otago	12/2020	SW, MH	Evidently locally extinct. No <i>L. solandri</i> plants found.
*Chatto Creek 4	Central Otago	12/2020	SW, MH	Evidently locally extinct. No <i>L. solandri</i> plants found.
Chatto Creek 5	Central Otago	12/2020	SW, MH	Present. Although no <i>L. solandri</i> plants were found on December 2020 visit to this location (when <i>L. kirkii</i> was found, see Table 2), two <i>L. solandri</i> plants found on a subsequent visit (January 2023). One plant was male (only the inflorescence remained above ground), and the other was without flowers.
Mahaka Katia Scientific Reserve	Central Otago	12/2020	SW, MH, DP	Present. Tagged and caged plants at the three locations. Plants were very small and distorted and siliques held little viable seed, but some did germinate. Estimated total number about 20 plants.
Taieri Lake	Central Otago	-	-	Unknown. Not visited as unable to arrange access. It is probably worth determining whether plants still survive here.
*Wardles	Central Otago	12/2020	KW	Evidently locally extinct. No <i>L. solandri</i> plants now present at the back of these subdivided blocks at Galloway. Full vascular flora not recorded.
Lance McCaskill Nature Reserve	Kura Tāwhiti	01/2021	SY, MH, SW	Present inside the Lance McCaskill Nature Reserve, and a few plants remaining nearby outside the nature reserve fence. Flora recorded January 2021.
Tekapo Military Reserve	Mackenzie Basin	12/2020	SG, TH, MH, SW	Present. Seed collected and germinated. Flora recorded February 2021.
Maryburn	Mackenzie Basin	12/2020	SG, TH, SW	Present. Seed collected and germinated. Flora recorded February 2021.
Lake Tekapo Scientific Reserve	Mackenzie Basin	12/2020	SG, TH, MH, SW	Present. Seed collected and germinated. Flora recorded February 2021.
Pukaki	Mackenzie Basin	12/2020	SG, TH, SW	Present. Seed collected and germinated. Flora recorded February 2021.
Ruataniwha	Mackenzie Basin	12/2020	SG, TH, SW	Present. Seed collected and germinated. Flora recorded February 2021.

Appendix S5. *Lepidium sisymbrioides* locations visited or investigated in Central Otago and the Waitaki Valley, showing the location name, region, month visited, the people who searched and collected *Lepidium* material, and notes on observations and seed. Asterisks highlight local extinctions. DP = Dhana Pillai, GL = Graeme Loh, MH = Michael Harding, SW = Susan Walker, TW = Tom Waterhouse.

Location	Region	Month visited	People	Notes
Falls Dam	Central Otago	12/2020	SW, MH	Present. Estimated total number in this location about 20 plants. A number of robust plants on the rocky spur on true right of a creek entering Falls Dam, but none found on the true left. Morphology of plants in exposed positions was very <i>L. solandri</i> -like. Seed collected and germinated.
Fiddlers Flat	Central Otago	12/2020	SW, MH	Present. Two large male plants seen: one on terrace surface and one between terrace and bluffs above the river. Did not search bluffs as access is difficult (steep terrain).
Slapjack Creek Conservation Area	Central Otago	12/2020	SW, MH, DP	Present. Three plants at four historically tagged locations relocated. The location is difficult (sweet briar) and potentially dangerous to search (loose schist slabs).
Long Gully Conservation Area	Central Otago	12/2020	SW, MH, DP	Unknown. No plants seen. The location is difficult (sweet briar) and potentially dangerous to search (loose schist slabs).
Chard Road road cutting	Central Otago	12/2020	SW, MH, DP	Present. Two plants within the road cutting, neither flowering. Other Chard Road locations on private land recorded by Allen (2000) (NZTM 1276533E 5007336N) were not visited.
Fault scarps, north side Slapjack Creek (private land)	Central Otago	Not accessed	-	Locations recorded by Allen (2000) at NZTM 1288750E 5000841N and 1289151E 5000542N.
Swift Burn, Kawarau Gorge (private land)	Central Otago	Not accessed	-	Unknown. Location recorded by Allen (2000) at NZTM 1275330E 5008336N.
Gards Rd	Waitaki Valley	12/2020	TW, SW, MH	Present. Numerous <i>Lepidium</i> plants inside the Gards Road Conservation Area. Seed collected and germinated. Flora recorded February 2021.
Earthquakes	Waitaki Valley	02/2021	TW, SW, MH	Present. Two female adult plants found at Earthquakes in December 2020, and four juvenile plants were found beside one of these plants in February 2021. Seed present on the female plant in February. Adequate survey of this dissected location is difficult (steep terrain). Seed collected did not germinate. Flora recorded February 2021.
Hakataramea Highway (private land)	Waitaki Valley	Not accessed		Unknown. Herbarium record CHR 501036 indicates plants occurred on bluffs beside the road.

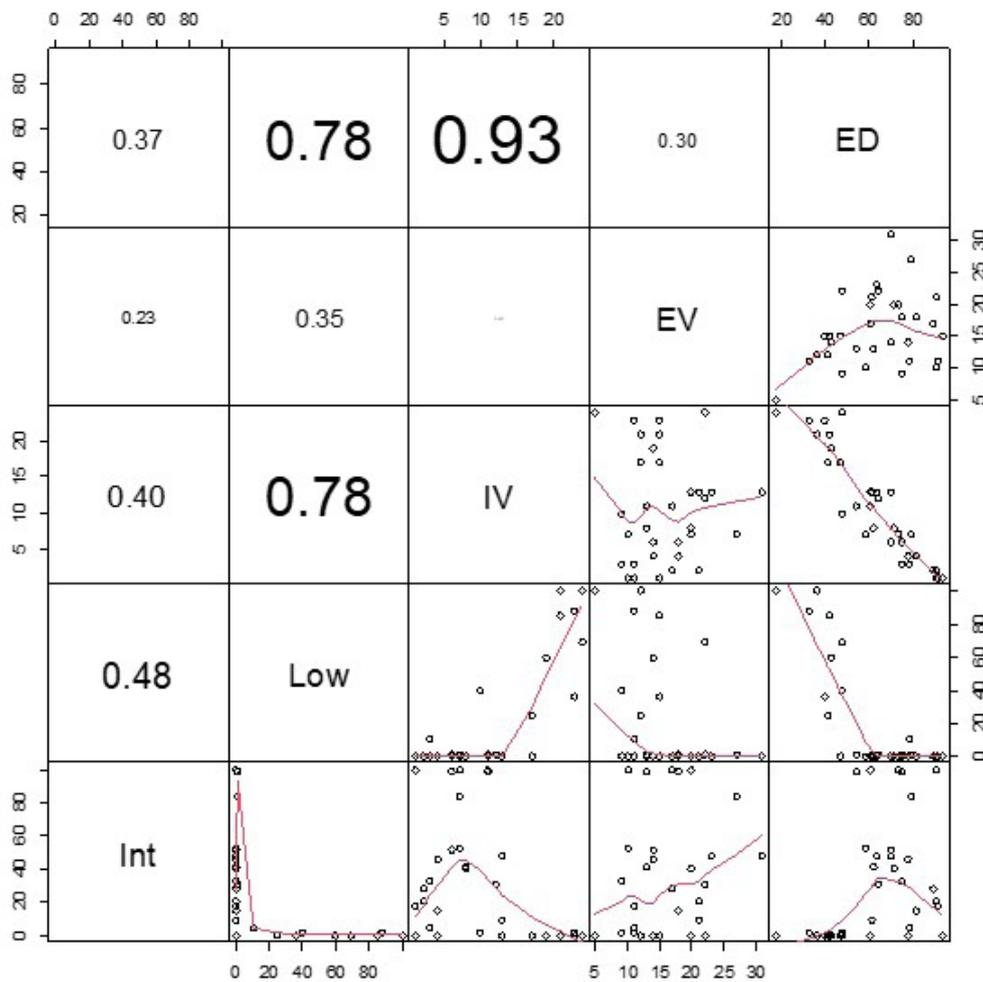
Appendix S6 (provided as a separate spreadsheet). Vascular plant species recorded at locations surveyed for inland *Lepidium* species between December 2020 and February 2021.

2. Comparisons of attributes between geographic regions and classification groups

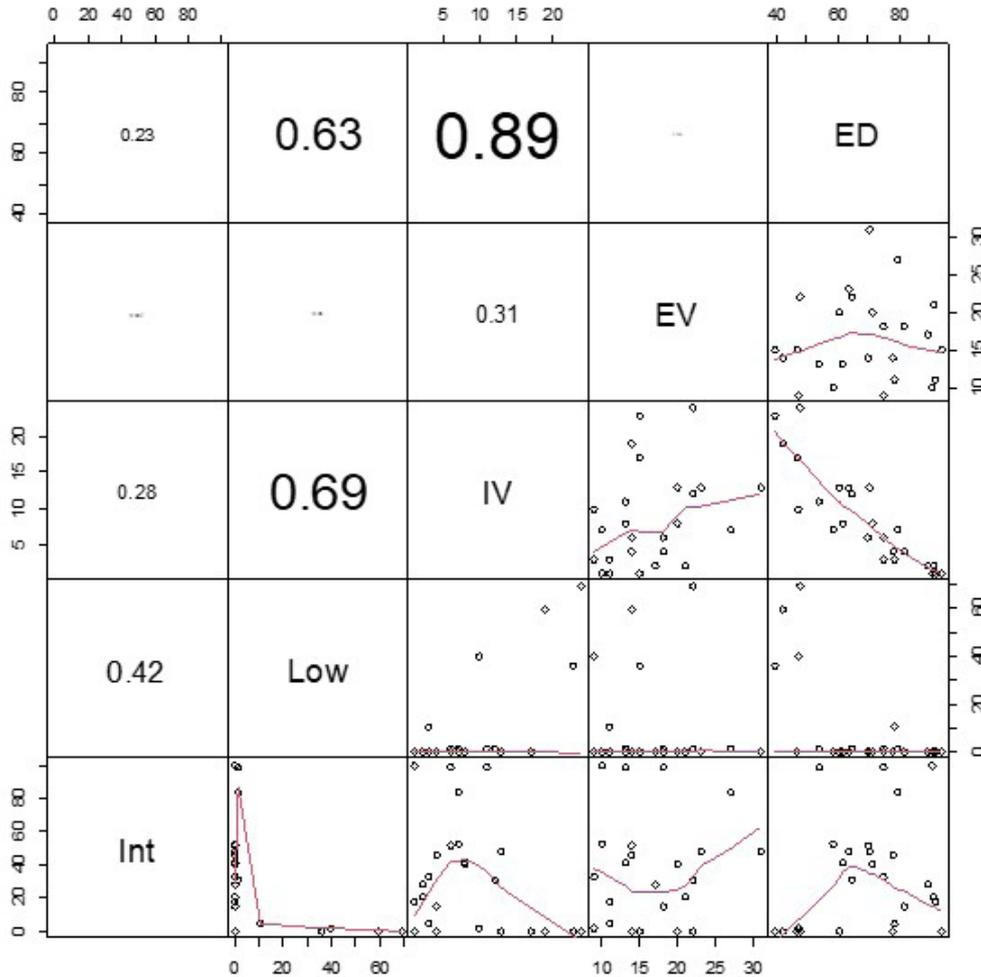
Correlations among landscape and vegetation attributes

Pairs plots show strong overall correlations (> 0.7) between percentage high intensity land use within a 2 km radius, number of indigenous plant species at a location, and the percentage of vascular plant species at the location that are exotic. These relationships were evident across the four regions (Central Otago, the Waitaki Valley, the Mackenzie Basin, and Kura Tāwhiti; Appendix S7) and in Central Otago alone (Appendix S8).

Appendix S7. Pairs plot showing the correlations and correlation coefficients between variables used in our analysis across our four geographical regions (Central Otago, the Waitaki Valley, the Mackenzie Basin, and Kura Tāwhiti). Int = percentage high intensity land use within a 2 km radius; Low = percentage low intensity land use within a 2 km radius; IV = number of indigenous vascular plant species at the location; EV = number of exotic vascular plant species at the location; ED = percentage of vascular plant species at the location that are exotic.



Appendix S8. Pairs plot showing the correlations and correlation coefficients between variables used in our analysis within our Central Otago region. Int = percentage high intensity land use within a 2 km radius; Low = percentage low intensity land use within a 2-km radius; IV = number of indigenous vascular plant species at the location; EV = number of exotic vascular plant species at the location; ED = percentage of vascular plant species at the location that are exotic.



Appendix S9. Statistical tests and software

For our descriptive statistics we adopted a simple hypothesis testing approach to determine whether differences between regions and classification groups were statistically significant at $P < 0.05$ (Castilho & Prado 2021). All analyses exclude the Eden Creek and Wardles locations in Central Otago, where we did not record complete floristic data in December 2020.

We compared proportions of high- and low-intensity land use within 2 km of locations with analysis of variance (function `aov` in the `stats` library for R; R Core Team 2022) followed by Tukey’s honest significant difference (HSD) test (function `HSD.test` in the R package *agricolae*; de Mendiburu 2023). Proportions of high and intermediate land use were logit-transformed for these analyses to meet linearity assumptions.

To compare numbers of indigenous and exotic species we fitted three models for each response variable: (1) a generalised linear model assuming a poisson distribution (`glm` function in the package *stats* for R; R Core Team 2022); (2) a generalised linear mixed model with an observation-level random effect (OLRE) (`glmer` function in *lme4*; Bates et al. 2015), assuming a poisson distribution; and (3) a negative binomial model (`glm.nb` function in *MASS*; Venables & Ripley 2002). We selected

the best model using Akaike’s information criterion corrected for small sample size (AICc; Hurvich & Tsai 1989), tabulated using the `aictab` function in *AICcmodavg* (Mazerolle MJ 2020). If the negative binomial (3) was the best model, chi-squared tests were then applied to assess whether differences between pairwise contrasts between regions and classification were statistically significant (using the `glht` function in *multcomp*; Hothorn et al. 2008). For generalised linear and generalised linear mixed models, we used Tukey’s HSD tests to assess pairwise differences.

To compare proportions of vascular species that were exotic (representing local exotic dominance of vascular flora) we fitted binomial generalised linear models, in which successes and failures in the dependent variable were numbers of plant species that were exotic and indigenous, respectively, and performed chi-squared tests to assess pairwise differences between regions and classification groups (using the `glht` function in *multcomp*).

We inspected residual plots to check that all models met the assumptions of linearity and homoscedasticity (for plotting residuals we used the `plot` function in the base library for R).

Appendix S10. Comparison of attributes between regions**Attribute: High-intensity land use within 2 km**

Region	Mean (logit scale)	std	<i>n</i>	se	Min	Max	Q25	Q50	Q75	Superscripts from Tukey's HSD test
Central Otago	-2.41	4.76	26	0.87	-9.21	7.01	-7.89	-0.88	-0.11	b
Waitaki Valley	7.01	0.00	2	3.12	7.01	7.01	7.01	7.01	7.01	a
Mackenzie Basin	-8.23	2.19	5	1.98	-9.21	-4.32	-9.21	-9.21	-9.21	b
Kura Tāwhiti	-2.29	NA	1	4.42	-2.29	-2.29	-2.29	-2.29	-2.29	ab

Attribute: Low-intensity land use within 2 km

Region	Mean (logit scale)	std	<i>n</i>	se	Min	Max	Q25	Q50	Q75	Superscripts from Tukey's HSD test
Central Otago	-6.76	3.66	26	0.70	-9.21	0.81	-9.21	-9.21	-4.32	b
Waitaki Valley	-9.21	0.00	2	2.53	-9.21	-9.21	-9.21	-9.21	-9.21	b
Mackenzie Basin	3.34	3.57	5	1.60	-1.12	7.01	1.77	2.03	7.01	a
Kura Tāwhiti	-9.21	NA	1	3.58	-9.21	-9.21	-9.21	-9.21	-9.21	b

Attribute: Number of indigenous vascular plant species (Raw count data)

Region	Mean	std	<i>n</i>	se	Min	Max	Q25	Q50	Q75	Superscripts from Tukey's HSD test, raw data
Central Otago	8.54	6.65	26	1.21	1.00	24.00	3.25	7.00	12.75	b
Waitaki Valley	9.00	2.83	2	4.37	7.00	11.00	8.00	9.00	10.00	ab
Mackenzie Basin	21.20	2.68	5	2.76	17.00	24.00	21.00	21.00	23.00	a
Kura Tāwhiti	13.00	NA	1	6.17	13.00	13.00	13.00	13.00	13.00	ab

Model comparisons

In model comparison tables, AICc is Akaike's information criterion corrected for small sample size

Model number	Distribution	Model	K	AICc
M1	Poisson	Null	1	317.12
M2	Poisson	Region	5	271.24
M3	Poisson	Region + (1 Location)	6	229.02
M4	Negative binomial	Region	5	228.42 (best model)

Summary of best (negative binomial) model: Mackenzie Basin as reference Region

Parameter	Estimate (log scale)	Std. Error	Z value	Pr(> z)
(Intercept)	3.054	0.2762	11.059	0.000***
Central Otago	-0.9094	0.306	-2.972	0.003**
Kura Tawhiti	-0.4891	0.6981	-0.701	0.483
Waitaki Valley	-0.8568	0.5467	-1.567	0.117

Pairwise contrasts

Best model	vs	Estimate (log scale)	Chisq	Pr(>Chisq)
Kura Tawhiti	Central Otago	0.42	0.41	0.521
Kura Tawhiti	Waitaki Valley	0.37	0.21	0.644
Waitaki Valley	Central Otago	0.05	0.01	0.914
Mackenzie Basin	Kura Tawhiti	0.49	0.49	0.484
Mackenzie Basin	Waitaki Valley	0.86	2.46	0.117
Mackenzie Basin	Central Otago	0.91	8.83	0.003**

Superscripts from pairwise contrasts

Region	Superscripts
Central Otago	b
Waitaki Valley	b
Mackenzie Basin	a
Kura Tāwhiti	b

Attribute: Number of exotic vascular plant species (Raw count data)

Region	Mean	std	n	se	Min	Max	Q25	Q50	Q75	Superscripts from Tukey's HSD test, raw data
Central Otago	16.38	5.61	26	1.04	9.00	31.00	13.00	15.00	20.00	a
Waitaki Valley	18.50	2.12	2	3.75	17.00	20.00	17.75	18.50	19.25	a
Mackenzie Basin	11.00	3.67	5	2.37	5.00	15.00	11.00	12.00	12.00	a
Kura Tāwhiti	21.00	NA	1	5.31	21.00	21.00	21.00	21.00	21.00	a

Model comparison

Model number	Response error distribution	Model	K	AICc
M1	Poisson	Null	1	219.86
M2	Poisson	Region	5	215.97
M3	Poisson	Region + (1 Location) ¹	6	214.85
M4	Negative binomial	Region	5	215.01 (best model)

¹Random intercept*Summary of best (negative binomial) model: Mackenzie Basin as reference Region*

Parameter	Estimate (log scale)	Std. Error	z	Pr(> z)
(Intercept)	2.3979	0.1577	15.207	< 2e-16***
Central Otago	0.3984	0.1688	2.36	0.018*
Kura Tāwhiti	0.6466	0.3254	1.987	0.047*
Waitaki Valley	0.5199	0.2619	1.985	0.047*

Pairwise contrasts

Contrast	vs	Estimate (log scale)	Chisq	Pr(>Chisq)
Kura Tāwhiti	Central Otago	0.25	0.73	0.394
Kura Tāwhiti	Waitaki Valley	0.13	0.13	0.720
Waitaki Valley	Central Otago	0.12	0.31	0.577
Mackenzie Basin	Kura Tāwhiti	-0.65	3.95	0.047*
Mackenzie Basin	Waitaki Valley	-0.52	3.94	0.047*
Mackenzie Basin	Central Otago	-0.40	5.57	0.0189

Superscripts from pairwise contrasts

Region	Superscripts
Central Otago	a
Waitaki Valley	a
Mackenzie Basin	b
Kura Tāwhiti	a

Attribute: Proportion of vascular plant species exotic*Summary of binomial generalised linear model: Mackenzie Basin as reference group*

Parameter	Estimate (logit scale)	Std. Error	z value	Pr(> z)
(Intercept)	-0.66	0.17	-3.95	0.000***
Central Otago	1.31	0.19	7.05	0.000***
Kura Tāwhiti	1.14	0.39	2.91	0.004**
Waitaki Valley	1.38	0.33	4.15	0.000***

Chi-squared tests, binomial model

Contrast	vs	Estimate (logit scale)	Chisq	Pr(>Chisq)
Kura Tāwhiti	Central Otago	-0.17	0.23	0.635
Kura Tāwhiti	Waitaki Valley	-0.24	0.28	0.597
Waitaki Valley	Central Otago	0.07	0.05	0.818
Mackenzie Basin	Kura Tawhiti	-1.14	8.48	0.004**
Mackenzie Basin	Waitaki Valley	-1.38	17.20	0.000***
Mackenzie Basin	Central Otago	-1.31	49.63	0.000***

Superscripts from pairwise contrasts

Region	Superscripts
Central Otago	a
Waitaki Valley	a
Mackenzie Basin	b
Kura Tāwhiti	a

Appendix S11. Comparison of attributes between classification groups identified by agglomerative clustering.**Attribute: High-intensity land use within 2 km (logit)**

Classification group	Mean (logit scale)	std	n	se	Min	Max	Q25	Q50	Q75	Superscripts from Tukey's HSD test
A	-1.00	4.06	15	1.14	-9.21	7.01	-1.44	-0.71	-0.04	ab
B	-8.23	2.19	5	1.97	-9.21	-4.32	-9.21	-9.21	-9.21	c
C	-2.13	5.71	6	1.80	-9.21	4.26	-6.93	-0.11	1.17	abc
D	1.73	6.11	4	2.20	-3.91	7.01	-3.38	1.90	7.01	a
E	-7.48	3.46	4	2.20	-9.21	-2.29	-9.21	-9.21	-7.48	bc

Attribute: Low-intensity land use within 2 km (logit)

Classification group	Mean (logit scale)	std	n	se	Min	Max	Q25	Q50	Q75	Superscripts from Tukey's HSD test
A	-8.56	1.72	15	0.77	-9.21	-4.32	-9.21	-9.21	-9.21	c
B	3.34	3.57	5	1.33	-1.12	7.01	1.77	2.03	7.01	a
C	-7.58	2.52	6	1.21	-9.21	-4.32	-9.21	-9.21	-5.54	bc
D	-5.24	4.63	4	1.49	-9.21	-0.41	-9.21	-5.68	-1.71	bc
E	-2.14	4.75	4	1.49	-9.21	0.81	-2.72	-0.08	0.50	ab

Attribute: Number of indigenous vascular plant species (Raw count data)

Classification group	Mean (logit scale)	std	n	se	Min	Max	Q25	Q50	Q75	Superscripts from Tukey's HSD test, raw data
A	4.60	3.20	15	0.88	1.00	12.00	2.00	4.00	6.50	c
B	21.20	2.68	5	1.53	17.00	24.00	21.00	21.00	23.00	a
C	12.33	3.27	6	1.40	7.00	17.00	11.50	13.00	13.00	b
D	7.75	3.59	4	1.71	3.00	11.00	6.00	8.50	10.25	bc
E	19.75	4.99	4	1.71	13.00	24.00	17.50	21.00	23.25	a

Model comparison

Model number	Distribution	Model	K	AICc
M1	Poisson	Null	1	317.12
M2	Poisson	Region	5	191.27 (best model)
M3	Poisson	Region + (1 Location)	6	194.24
M4	Negative binomial	Region	6	194.24

Attribute: Number of exotic vascular plant species (Raw count data)

Classification group	Mean	std	<i>n</i>	se	Min	Max	Q25	Q50	Q75	Superscripts from Tukey's HSD test, raw data
A	15.07	4.15	15	1.23	9.00	22.00	12.00	14.00	18.00	ab
B	11.00	3.67	5	2.14	5.00	15.00	11.00	12.00	12.00	b
C	21.50	6.92	6	1.95	13.00	31.00	16.25	21.50	26.00	a
D	14.25	5.12	4	2.39	9.00	20.00	10.50	14.00	17.75	ab
E	18.00	4.08	4	2.39	14.00	22.00	14.75	18.00	21.25	ab

Model comparison

Model number	Response error distribution	Model	K	AICc
M1	Poisson	Null	1	317.12
M2	Poisson	Region	5	208.32 (best model)
M3	Poisson	Region + (1 Location) ¹	6	210.57
M4	Negative binomial	Region	6	210.55

¹Random intercept**Attribute: Proportion of vascular plant species exotic***Summary of binomial generalised linear model: Mackenzie Basin as reference group*

Parameter	Estimate (logit scale)	Std. Error	z value	Pr(> z)
(Intercept)	1.19	0.14	8.63	0.000***
Group B	-1.84	0.22	-8.54	0.000***
Group C	-0.63	0.20	-3.15	0.002**
Group D	-0.58	0.26	-2.20	0.028*
Group E	-1.28	0.21	-6.00	0.000***

Chi-squared tests, binomial model

Contrast	vs	Estimate (log scale)	Chisq	Pr(>Chisq)
A	B	1.84	72.96	0.000***
A	C	0.63	9.90	0.002**
A	D	0.58	4.85	0.028*
A	E	1.28	35.99	0.000***
B	C	-1.21	30.04	0.000***
B	D	-1.27	20.68	0.000***
B	E	-0.56	5.86	0.016*
C	D	-0.05	0.04	0.842
C	E	0.65	8.80	0.003**
D	E	0.70	6.45	0.011*

Superscripts from pairwise contrasts

Classification group	Superscripts
A	a
B	d
C	b
D	b
E	c

3. Generalised linear models

Appendix S12. Correlations among landscape and vegetation attributes. Pairs plots showing correlations and correlation coefficients between variables used in our analysis across our four geographical regions are plotted in Part 2 of the Supplementary Material (Appendices S7 and S8). There are strong correlations (> 0.7) between percentage low intensity land use within a 2 km radius, number of indigenous plant species at a location, and the percentage of vascular plant species at the location that are exotic, both across our four regions and within Central Otago alone.

Appendix S13. Statistical tests and software

Effects of high intensity land use within 2 km of *Lepidium* locations

We used generalised linear models (function `glm` in the package *stats*; R Core Team 2022) to test whether local land use intensity had significant effects on numbers of indigenous species, and proportions of species that were exotic, across past and present inland *Lepidium* locations in the four regions.

We compared null models (no predictors) of each response variable to models with region, and region and proportion of land under intensive land use as predictors. We selected the best model using Akaike's information criterion corrected for small sample size (AICc; Hurvich & Tsai 1989) and the `aictab` function in *AICcmodavg* (Mazerolle 2020).

A poisson error distribution was assumed for the number of indigenous species, and proportion of species exotic was fitted as a binomial variable with successes and failures being numbers of exotic and indigenous plant species, respectively. Proportion of land under intensive land use was scaled and centred for analysis.

Effects of local vegetation attributes on local extinction of inland *Lepidium* in Central Otago

We asked whether local extinctions of inland *Lepidium* species at locations in Central Otago since the 1990s were predicted by the local numbers of indigenous species and proportions of species that were exotic.

For this test we fitted binomial generalised linear models of local extinction, where absence of one of more *Lepidium* species present in the 1990s was coded as one, and persistence as zero; null models (no predictors) were compared against models with numbers of indigenous species and proportions of species that were exotic as predictors.

Model checking

We inspected residual plots to check that all models met the assumptions of linearity and homoscedasticity (for plotting residuals we used the `plot` function in the base library for R).

Calculating and plotting effects

The `effects` and `allEffects` functions in *effects* package for R (Fox 2003) were used to calculate fitted effects of the best models, and the back-transformed effects were plotted (Fig. 4). To facilitate interpretation, predictors which were scaled for analyses (i.e. proportion of land under intensive land use, local numbers of indigenous species and proportions of species that were exotic) were back-converted to their original scale for the horizontal axes of these plots.

References

- Allen RB 2000. Inland *Lepidium* recovery plan, 2000-2010. Wellington, Department of Conservation. 25 p.
- Barkla J, Thorsen M 2007. Pt Michael Peak botanical values. Dunedin, Department of Conservation. 11 p.
- Bates D, Maechler M, Bolker B, Walker S 2015. Fitting linear mixed-effects models using `lme4`. *Journal of Statistical Software* 67: 1–48.
- Castilho LB, Prado PI 2021. Towards a pragmatic use of statistics in ecology. *PeerJ* 9: e12090.
- de Mendiburu F 2023. `agricolae`: Statistical procedures for agricultural research. R package version 1.3-6. <https://CRAN.R-project.org/package=agricolae>
- Fox J 2003. Effect displays in R for generalised linear models. *Journal of Statistical Software* 8(15): 1-27.
- Hurvich CM, Tsai CL 1989. Regression and time series model selection in small samples. *Biometrika* 76: 297–307.
- Hothorn T, Bretz F, Westfall P 2008. Simultaneous inference in general parametric models. *Biometrical Journal* 50: 346–363.
- Landcare Research Informatics Team 2019. LCDB v5.0 Land Cover Database version 5.0, Mainland, New Zealand. <https://iris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/> (Accessed 13 April 2023)
- Mazerolle MJ 2020. `AICcmodavg`: Model selection and multimodel inference based on (Q)AIC(c). R package version 2.3-1. <https://cran.r-project.org/package=AICcmodavg>
- R Core Team 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>
- Venables WN, Ripley BD 2002. Modern applied statistics with S. 4th edn. Springer, New York. 446 p.