National list of exotic pasture species

Draft report prepared for the Ministry for the Environment

April 27th, 2022

By

Gerald Cosgrove, Mike Dodd, AgResearch Grasslands, Palmerston North

Trevor James, AgResearch Ruakura, Hamilton

Project Brief

The project brief to the supplier was to undertake a brief literature review of the prevalence of exotic pasture species in NZ wetlands and wet pasture areas. The aim of the literature review is to inform the supplier's recommendations for which exotic pasture species should form a list used to assess the 'pasture exclusion.'

The literature review seeks to answer the queries below:

What exotic pasture species are commonly present in NZ wetlands? (including both nationally common species, and those common at a regional or local scale)?

The NZ Wetland Plant list has just been revised by Clarkson et al. (2021). This list identifies 363 exotic taxa, out of a total list of 1124 taxa. See also copy of Clarkson species list.

What exotic pasture plants are commercially available for sowing in New Zealand?

There are approximately 55 pasture species currently available for sowing in New Zealand. See Commercial category in the associated National list of exotic pasture species.

Are exotic pasture species that have historically been sown, but are no longer commercially available, commonly present in NZ wetlands?

Seeds of pasture species have been imported into New Zealand for more than 160 years and possibly, up to 200 years (McLintock, 1966). We have not been able to identify a cumulative list of species sown over that period of time. However, the number would likely be substantial, and the 363 exotic taxa identified by Clarkson et al. (2021) supports that.

Which exotic pasture species (both currently sown and historically sown, if applicable) can be used to differentiate between pasture-dominated wetlands and wet areas of pasture in pastureland, and wetlands elsewhere? These species should inform the supplier's recommendations for the list.

Given the regional variation (sub-tropical north to cool temperate south), seasonal variation, variation in altitude from low-lying coastal areas (e.g., lower western North Island sand dune wetlands and lakes) to upland wetlands in higher altitude South Island) the list of exotic species that can contribute to the differentiation of wetlands will be extensive. Furthermore, there will likely be year-to-year variation in the proportions of the exotic species existing in wetland areas, meaning that a narrowly-based list (in terms of species number) could result in different determinations when assessed under different conditions. For these reasons we consider a more inclusive approach is a better option: there is no cost or consequence associated with species included on the list not being found in wetland pasture areas, whereas exotic species found in wetland areas but not identified on the list could be disputed.

Brief Review of Literature

The brief review of literature consists of six component parts:

1. A formal literature search conducted to identify papers on pasture species surveys in New Zealand wetlands. The search was considered to be broad, but yielded 'few' results. In total 15 relevant items were identified. Below are brief, sample excerpts from the abstract of studies that identified exotic (and indigenous) species in wetland environments, to indicate the type of data and information available (for each source the inclusion of species lists, or not, is included in parenthesis):

In a survey of turf communities at Lake Whangape, Lower Waikato river, 91 out of 135 exotic species were identified (Champion et al. 2001). The survey considered the interactions of grazers (cattle, avian species) on wetland species composition and identified both negative (destructive to lake function) and positive effects (reducing the dominance of exotic, undesirable species) from the presence of grazers. (Species list included in Appendix 1).

In the Kaituna wetland, Bay of Plenty, exotic grasses were early colonisers in a 4-year period following fire and showed a relatively greater increase in species richness than did indigenous species (Christensen et al. 2019). (Species lists included).

Clarkson et al. 2004 (species lists included in Appendix 1).

In the Whangamata stream, north of Lake Taupo, 5 years of monitoring of the stream 1999-2003, 24 years following retiring in 1976, the biodiversity of the vegetation in the riparian strips continued to increase at a rate of 3% per year. Vascular plants totalled 172 species, of which 102 were exotic species. There was a 2% turnover in species every year and a continuing increase in the proportion of woody species as the vegetation matured (Howard-Williams and Pickmere, 2019). (Species list included in Appendix 2).

Korsten et al. (2013) investigated the role of grazing birds (introduced species, in light of extinction of indigenous) in the maintenance of local turf communities in a lacustrine environment in Otago, New Zealand. The results indicate that avian grazing decreased the proportion of dominant exotic plant species by biomass removal. Results from this site suggest that naturalised geese facilitate the maintenance of indigenous plant species in the face of exotic invasion, and have a conservation role in highly modified wetland systems. (Species lists included in Tables 1 and 2).

Classification of vegetation data identified 12 groups along a moisture gradient, from dry areas dominated by pastoral alien species, to wet communities dominated by native wetland sedges. Lower total species diversity and native representation in pastoral communities were related to the high proportion of alien competitor and competitor-disturbance species, compared with the stress tolerator-dominated flora of other groups. Comparison of root anatomy confirmed greater development of flood-tolerant traits in native species than in pastoral aliens, and vegetation N:P ratios indicated that most communities were probably nitrogen-limited (Sorrell et al. 2007) (Several Tables of species included).

In a study of wetland restoration strategy, conducted at three sites, one of which was at Bullock Creek (the other two were in the Netherlands) (van Bodegom et al. 2006), the responsiveness of traits to raised groundwater tables was related to soil type and vegetation presence and depended on actual groundwater levels. In the moist-wet zone, oligotrophic species, 'drier' species with higher seed longevity occupied gaps created by vegetation dieback on rewetting. The other rewetted zones still reflected trait values of the vegetation prevalent prior to rewetting with fewer adaptations to wet conditions, increased nutrient richness and higher seed longevity. Moreover, 'eutrophic' and 'drier' species increased at rewetted sites, so that these restored sites became dissimilar to control wetlands (No species list included). Long-term observations in restored and control wetlands with different groundwater regimes are needed to determine whether target plant species eventually revegetate restored wetlands. (No species lists included).

The full list of papers identified including authors, title, reference and abstract are included in Appendix 1.

2. Identification of various publications on species composition in grazed pastures. This includes surveys such as those conducted in 1935 in the South Island (Hilgendorf, 1935) and in the North Island (Madden, 1940) of New Zealand; a localised survey conducted across four distinct land types of the Manawatu region by Brougham and co-workers in summer 1967/68 (Brougham et al. 1974); and a New Zealand wide survey by Field in 1987/88 (Field, 1989; Field and Forde, 1990; Field and Roux, 1993). It also included other publications relevant to specific regions of New Zealand, e.g., that by Scott et al. (1995) on pastures and pasture species for the New Zealand high country, or for specific purposes such as species for promoting soil conservation in erosion-prone areas (e.g., Plant materials for soil conservation, Volume 2, Introduced plants, Van Kraayenoord and Hathaway, 1986).

3. Various reference texts such as Levy (1951, 1970), Healey (1982), Langer (1984), Lambrechtsen (1986), Edgar and Connor (2000), which include species lists in the context of grazed pastures and species identification keys. Of particular relevance is the occasional publication Pasture and Forage Plants for New Zealand, 4th Edition, 2014, published by the New Zealand Grassland Association. The species listed in this book cover virtually all of those available commercially (and was used by Greater Wellington Regional Council as their reference for wetland determination guidance). A 5th Edition, slightly expanded, is due to be published shortly. Two, illustrated guides to common weeds of New Zealand (Popay et al. 2010) and common grasses, sedges and rushes of New Zealand (Champion et al. 2012), provide useful reference material on photographic, identification and regional distribution.

4. In addition to the lists noted in point 3 above, two data bases held by New Zealand Government Departments, the Ministry for Primary Industries, Plants Biosecurity Index (Version: 02.01.00), and the Environment Protection Agency, List of Plant Species in New Zealand. These are very broad lists, of which pasture species are numerically minor components.

5. The recent growth of interest in 'Regenerative Agriculture' and specifically in pasture diversity, has resulted in preparation of list of species for use in that context. This includes a section on Regenerative Agriculture in PGG Wrightson Seeds, Forage Options 7th Edition, 2012. This list comprises approximately 45 species, many of which have not been widely used (if at all) in recent decades, but may have been in earlier times. A second example is a list of approximately 30 species, prepared for a similar purpose by Specialty Seeds.

6. There is considerable expertise held by current and former staff members of AgResearch and its predecessor organisations, the Department of Scientific and Industrial Research, and the Research Division of the Ministry of Agriculture and Fisheries. This includes Dr David Hume (Senior Scientist) and Zane Webber of the Margot Forde Germplasm Centre, Dr John Caradus (CEO) and Bruce Belgrave (Business Development Manager) of Grasslanz Technology (a subsidiary entity of AgResearch), Dr Alan Stewart (Chief Scientific Officer) and Wayne Nichol (Extension Agronomist and Nutritionist) PGG Wrightson Seeds. The personal expertise and knowledge of this group (in addition to that of co-authors Drs Mike Dodd and Trevor James) has been invaluable for compiling this report.

Approach and Methodology

The requirements for the national list were provided by MfE as follows:

Species that should be included:

- Exotic pasture species that are currently or were historically deliberately sown to form pasture areas. The list developed by the New Zealand Grassland Association1 and currently used by GWRC2 should be used as a baseline for development.

AND

- Any other exotic species with wetland indicator status ratings of FAC (Facultative), FACU (Facultative Upland) or UPL (Upland) that are known to be common within pasture areas AND palatable to livestock/ contributing to productive pasture, including when not deliberately sown.

Species that should be excluded:

- Any exotic species that have ratings of OBL (Obligate Wetland) or FACW (Facultative Wetland), for example, swamp buttercup.
- Any exotic species, regardless of their indicator rating, which are common within pasture or wetland areas but are non-productive (unpalatable or toxic to livestock), and therefore not encouraged in well-managed pasture.
- Any exotic species not found in pasture or wetland areas.

<u>Included on the pasture exclusion list:</u>

1. *Commercial*. Non-native herbaceous species which are or have historically been commonly established for the purpose of livestock production and which have been the subject of cultivar development.

In most cases these cultivars have been developed in New Zealand, but we have also included some species where the cultivars have been developed overseas (e.g., *Trifolium subterraneum*). Given the global connectedness of the pasture seed industry it seems likely that cultivars of these species will have been available to New Zealand farmers to sow at some point.

An additional consideration for inclusion is potentially useful species present in New Zealand forage seedbanks and having an overseas cultivar, but not yet in use. An example might be Kenya white clover (*T. semipilosum*/*T. burchellianum*, cv. Safari). This group of species is only relevant if it is considered appropriate to “future-proof” the exclusion list, or may be deferred to a future review of the exclusion list.

While many of these commercial species are unsuitable for wet soil habitats and thus unlikely to be found in wetlands (i.e., UPL or FACU habitat ratings), they are included on the basis that they may form a component of mixed species pastures established on sites where soil moisture status varies spatially and temporally.

For the most part this list is sourced from Stewart et al. (2014), 4th edition. A 5th edition is in preparation and those additional species identified in the 5th edition are included here where relevant. Additional entries are sourced from Scott et al. (1995) relevant to high country environments.

2. *Non-Commercial.* Non-native herbaceous species commonly found in pastures and considered palatable to livestock but without known cultivars. These were typically established historically as sown mixtures (e.g., "bush burn") and have subsequently spread as adventives. In recent times they have not deliberately been sown but are certainly managed as productive pastures via grazing and the application of fertiliser and lime. Hence, they make a substantive contribution to livestock productivity in some environments.

Sourced from pasture surveys (e.g., Field 1989).

<u>Excluded from the pasture exclusion list:</u>

3. *Neutrals.* There are many herbaceous species that might be considered common pasture species, in that they are found in mixed species pastures and are consumed by livestock. However, they are generally of little forage value and depending on context may even be considered weeds. They are noted in the spreadsheet for the purpose of consideration by reviewers.

Sourced from pasture surveys.

<u>Other groupings not listed in the spreadsheet:</u>

4. *Crops.* Included in the lists in Stewart et al. (2014) are a number are annual crops, i.e., wheat, oats, brassicas, ryecorn, Tritcale, fodder beet. They can be considered pastures (*sensu* ley pastures established for grazing or as catch crops following forage crops for the purpose of reducing nitrate leaching losses) but all generally need to be established by cultivation and so should not be on the pasture exclusion list as we would not want to encourage sowing them in wetland environments.

Sourced from Stewart et al. (2014).

5. Exotic herbaceous species considered a threat to native-dominated wetland ecosystems, e.g., *Glyceria fluitans.* This has a rating of OBL, so is out of scope for this project.

6. Exotic non-herbaceous species (woody browse) established for the purpose of livestock forage but not fitting the definition of pasture, e.g., tagasaste.

7. Exotic non-herbaceous species established as adventives and opportunistically browsed by livestock but considered weedy, e.g., gorse.

8. Indigenous herbaceous pasture species commonly found in pastures and considered palatable to livestock but without cultivars. These have likely never been deliberately sown (unless as part of self-harvested mixed pasture seed crops) and so have only established adventively. In some situations, they can contribute substantively to livestock diet and in that sense are considered productive species. One in particular can be purchased for pasture seed in Australia, where it is a *relatively* palatable forage (*Microlaena stipoides*). They are generally upland dry habitat species, so unlikely to be found in wet soil habitats and may be excluded from the exclusion list on that basis, in addition to their indigenous status.

Sourced from Scott et al. (1995). As indigenous species they are out of scope for this project, but are noted here as a record of their indigenous status, and thereby reason for exclusion.

Concluding comments

The list of Commercial species identified in the accompanying spreadsheet largely update that available in the current 4th Edition of Pasture and Forage Plants for New Zealand. The revised 5th Edition contains some additional entries (Stewart, *pers comm*.) and these have been included here.

There is a possibility of other species being added to the various lists we have used as sources of information. For example, climate change predictions of higher rainfall in western regions of New Zealand requiring wet-adapted pasture species, or trends such as regenerative agriculture resulting in greater diversity in pasture species usage, may broaden the range of species used in pastoral farming. For these reasons we suggest the list compiled here should be reviewed after 5 years.

References and Sources of Information

Bodmin, K. 2012. Wetland Restoration. A Handbook for New Zealand Freshwater Systems. Edited by Monica Peters and Beverley Clarkson. Chapter 9, Weeds. P 122 – 153. Published by Manaaki Whenua Press, Lincoln, New Zealand. Accessed 22 April 2022. https://www.landcareresearch.co.nz/uploads/public/Publications/Wetland-restoration-handbook/Chp_9_Weeds_2012.pdf

Brougham, R.W.; Grant, D.A.; Goodall, V.C. 1974. The occurrence of browntop in the Manawatu. Proceedings of the New Zealand Grassland Association 35:86-94.

Clarkson, B.R.; Fitzgerald, N.B.; Champion, P.D.; Lisa Forester, B.D. Rance. 2021. New Zealand Wetland Plant List 2021. Envirolink Grant: 2123-HBRC259. Prepared for Hawke's Bay Regional Council by Manaaki Whenua Landcare Research.

Cosgrove, G.P.; Field, T.R.O. 2016. Hill country pastures, botanical composition and productive capacity. Pp 281 – 288. Hill Country Symposium. Grasslands Research and Practice Series No. 16. New Zealand Grassland Association, Dunedin, New Zealand.

Champion, P.; James, T.; Popay, I.; Ford, K. 2012. An illustrated guide to Common Grasses, Sedges and Rushes of New Zealand. New Zealand Plant Protection Society (Inc.).

Edgar, E,; Connor, H.E. 2000. Flora of New Zealand Vol V Gramineae. Manaaki Whenua Press, Lincoln, New Zealand.

Environmental Protection Authority. 2021. List of plants present in New Zealand. New Zealand Government.

Field, T.R.O. 1989. Vegetational survey of managed pastures in New Zealand. Proceedings of the XVI International Grasslands Congress, Nice, France. p. 1407.

Field, T.R.O.; Forde, M.B. 1990. Effects of climate warming on the distribution of C4 grasses in New Zealand. Proceedings of the New Zealand Grassland Association. 51: 47-50.

Field, T.R.O.; Roux, M. 1993. Pasture types and farming enterprise in New Zealand. Proceedings of the XVI International Grasslands Congress, Palmerston North, New Zealand. Pp. 341-342

Healy, A.J. 1982. Identification of weeds and clovers. A New Zealand Weed and Pest Control Society Publication. 299 pp.

Hilgendorf, F.W. 1935. The grasslands of the South Island of New Zealand. Bulletin No. 47. Department of Scientific and Industrial Research, Wellington, New Zealand. 22 pp.

Howell, C. 2008 Consolidated list of environmental weeds in New Zealand. DOC Research & Development Series 292. Department of Conservation, Wellington. 42p. https://www.doc.govt.nz/globalassets/documents/science-and-technical/drds292.pdf

Johnson, Peter; Brooke, Pat. 1989. Wetland Plants in New Zealand. DSIR Field Guide. Department of Scientific and Industrial Research Publishing, Wellington 1989. 319 pp.

Lambrechtsen, N.C. 1986. What grass is that? A guide to identification of some introduced grasses in New Zealand by vegetative characters. Grasslands Division, Department of Scientific and Industrial Research. Information Series No.87. Government Printing Office Publishing, Wellington, New Zealand. 151 pp.

Langer, R.H.M. 1984. Pastures and Pasture Plants. Published by Lincoln College, with permission of A.H. and A.W. Reed. 430 pp.

Madden, E.A. 1940. The grasslands of the North Island of New Zealand. Bulletin No. 79. Department of Scientific and Industrial Research, Wellington, New Zealand. 45 pp.

Levy, E.B. 1951. Grasslands of New Zealand. Printed by R.W. Stiles & Co, under the authority of R.E. Owen, Government Printer. 344 pp.

Levy, E.B. (Sir). 1970. Grasslands of New Zealand. 3rd Edition. A.R. Shearer, Government Printer, Wellington, New Zealand. 374 pp.

McLintock, A.H. 1966. An Encyclopedia of New Zealand. Accessed 26 April; 2022. https://www.TeAra.govt.nz/en/1966/pastures/page-2

Ministry for Primary Industries Plants Biosecurity Index Version: 02.01.00. Accessed 22 April 2022. https://www1.maf.govt.nz/cgi-bin/bioindex/bioindex.pl/query

PGG Wrightson Seeds Forage Options. 2021. Seventh Edition. Regenerative Agriculture p 188 – 203. Accessed 22 April 2022.
https://www.pggwrightsonseeds.com/?gclid=CjwKCAjwsJ6TBhAIEiwAfl4TWA2dycbZ9i7aDR5mxRFo58rL-lXuwnxr6JM_Sv-rJglWdjDic_c3vhoCtuwQAvD_BwE

Plant Materials Handbook for Soil Conservation. 1986. Volume 2 Introduced Plants. Water and Soil Miscellaneous Publication No. 94. Edited by C.W.S. Van Kraaenyoord and R.L. Hathaway. Soil Conservation Centre, Ministry of Works and Development, Palmerston North.

Plants of the World Online (Kew). Accessed May 2, 2022. https://powo.science.kew.org/

Popay, I.; Champion, P.; James, T. 2010. An illustrated guide to Common Weeds of New Zealand. Third Edition. New Zealand Plant Protection Society (Inc.).

Scott, D.; Maunsell, L.A.; Keoghan, J.M.; Allan, B.E.; Lowther W.L.; Cossens, G.G. 1995. A guide to pastures and pasture species for the New Zealand high country. Edited by Nick Round-Turner and

David Ryde. Grasslands Research and Practice Series No. 4. New Zealand Grassland Association Incorporated, Palmerston North.

Specialty Seeds. 2021. https://www.specseed.co.nz/regenerative-pasture/ Accessed 22 April 2022.

Stewart, A.; Kerr, G.; Lissaman, W.; Rowarth, J. 2014. Pasture and Forage Plants for New Zealand. Grassland Research and Practice Series No. 8. 4th Edition. New Zealand Grassland Association.

USDA Plants Database. United States Department of Agriculture, Natural Resources Conservation Service. https://plants.usda.gov/home Accessed 27 May 2022.

Wardle, P. 1991. Vegetation of NZ. Cambridge, Cambridge University Press.

Personal Communications and Acknowledgements

John Caradus, CEO, Grasslanz Technology, Palmerston North

Bruce Belgrave, Business Development Manager, Southern Hemisphere, Grasslanz Technology, Palmerston North

Alan Stewart, Chief Scientific Officer, PGG Wrightson Seeds, Christchurch

Wayne Nichol, Extension Agronomist and Nutritionist, PGG Wrightson Seeds, Dunedin

David Hume, Senior Scientist, AgResearch Grasslands, Palmerston North

Zane Webber, Research Associate, Margot Forde Germplasm Centre, AgResearch Grasslands, Palmerston North

Roseanne Jatania, Knowledge Advisor, AgResearch Ruakura, Hamilton

Darion Embling, Team Leader, Pest Plants, Waikato Regional Council, Hamilton

Kerry Bodmin - Freshwater Biosecurity Coordinator, Kairuruku Haumaru Koiora – Waimāori, Department of Conservation, Waikato District Office, Te Rapa, Hamilton

Peer Review

Peer review of the proposed approach and the resulting species list and the brief literature review has been undertaken by Paul Champion. We would like to thank Mr Champion for his expertise.

Appendix 1

Literature Research Report

Search brief:

The presence of exotic pasture species could be a way to classify wetlands in NZ. What plant species surveys have been done of wetlands in NZ? Looking at freshwater not estuarine areas.

Resources searched & search strategy:

BIOSIS, CAB Abstracts and SCOPUS, the scholarly journal databases, were searched using a variety of keywords. The best search string was:

(TITLE-ABS-KEY ((plant OR botan*) W/5 species) AND TITLE-ABS-KEY (wetland*) AND TITLE-ABS-KEY (zealand))

Search Comments:

The search was broad but has yielded few results. Hopefully there may be one or two articles (see Richardson et al.) that provide useful insights or references to take the search further. Please let me know how the search can be refined and re-run.

Note: Including the keyword “survey” resulted in zero results.

Champion, P. D., S. M. Beadel, et al. (2001). **Turf communities of Lake Whangape and some potential management techniques**. Science for Conservation; 2001. (186): 54 pp. 25 ref. Wellington, Department of Conservation.

At Lake Whangape, Lower Waikato River, New Zealand, almost 14 km of the 29 km shoreline supports turf communities during late summer/early autumn. A 1997 survey discerned 21 community types of turfs, comprising both indigenous and alien species. Most turfs were highly diverse - 44 indigenous and 91 alien plant species were reported from an area of 800 m^2 of shoreline. Many species were ephemeral, either facultative or obligate annuals, colonizing exposed sediments and dying once submerged. The critically endangered grass Amphibromus fluitans, found during 1990, now appears to be extinct here. The lake supports the largest known population of the indigenous annual sedge Fimbristylis velata. Regionally important populations of Pratia perpusilla and Carex gaudichaudiana are present. Cattle grazing and grass-selective herbicides were investigated by constructing cattle exclosures and monitoring vegetation changes inside and outside, over three years. Dominant species were usually perennials, with the alien Mercer grass (Paspalum distichum) and the indigenous emergent spike sedge (Eleocharis acuta) most common. There was no change in the abundance of turf species. The grass-specific herbicide Gallant successfully controlled Mercer grass for at least one year. Factors controlling the distribution and composition of the turfs were minimum lake level and timing of drawdown, wave exposure, and the grazing impacts of cattle, waterfowl, and coarse fish. Weedy alien plants were not considered current threats. Cattle access to the lake is detrimental to the whole lake system, reducing plant cover, and preventing establishment of a nutrient buffer of marginal/emergent vegetation. Actions for managing the turf communities include: lowering the existing outlet structure (sill) giving more exposed surface for summer turf development; fencing larger areas of turf against cattle access, or attempting to prevent cattle access to the entire shoreline; monitor impact of waterfowl grazing; control expansion of willows and other weeds; trial fish exclosures for the impact on turfs; attempt restoration of amphibious communities around Plot 4.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=caba5&AN=20023002486
https://www.doc.govt.nz/globalassets/documents/science-and-technical/sfc186.pdf

Christensen, B., P. Cashmore, et al. (2019). "**Fire disturbance favours exotic species at Kaituna Wetland, Bay of Plenty**." *New Zealand Journal of Ecology 43(2): 3369*.

Fires regularly occur in New Zealand wetlands, affecting ecological indicators and conservation values such as native plant species richness. Following a small fire at the Kaituna Wetland, Bay of Plenty, foliage cover was measured and biodiversity indices determined on eight occasions over 48 months. Visual percentage estimation of species cover in six height classes showed that grasses (especially naturalised exotic species) were early colonists, although plots were subsequently dominated by the exotic Japanese honeysuckle (Lonicera japonica) and the native common twig rush (Machaerina rubiginosa). At 48 months, there were 14 exotic vascular species in burnt plots compared to 10 in unburnt plots; conversely 10 native species were found in burnt plots, compared to 18 in unburnt plots. Mean species richness, Shannon-Weiner diversity, and total vegetation cover increased in the burnt quadrats over time, with exotic plant species having a greater relative

increase in these measures than native species. Without proactive management, fire does not confer conservation benefits to the Kaituna Wetland. Disturbance events such as fires can be used as natural experiments to measure restoration and rehabilitation initiatives post-perturbation.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=biop45&AN=PREV201900835517
http://dx.doi.org/10.20417/nzjecol.43.23

Clarkson, B. R., L. A. Schipper, et al. (2004). "**Vegetation and peat characteristics in the development of lowland restiad peat bogs, North Island, New Zealand**." *Wetlands 24(1): 133-151*.
A chronosequence of restiad peat bogs (dominated by Restionaceae) in the lowland warm temperate zone of the Waikato region, North Island, New Zealand, was sampled to identify the major environmental determinants of vegetation pattern and dynamics. Agglomerative hierarchical classification of vegetation data from 69 plots in nine different-aged bogs, initiated from c. 600 to c. 15000 cal yr BP, identified eight groups. Six of these groups formed a sequence from sedges through Empodisma minus, the main peat-forming restiad species, to phases dominated by a second restiad species, Sporadanthus ferrugineus. The sequence reflected bog age and paralleled patterns of temporal succession over the last 15000 years (from early successional sedges through mid-successional Empodisma to late successional Sporadanthus) derived from previous studies of plant macrofossils and microfossils in peat cores. This indicated that different-aged bogs in the Waikato region could be used to interpret temporal succession. The remaining two classificatory groups comprised plots from sites modified by drainage, fire, or weed invasion and currently dominated by non-restiad species. The relationships between environmental variables and the six groups representing restiad bog succession indicated that, as succession proceeds, von Post decomposition index and nutrients in the top 7.5 cm peat zone decrease. The most useful indicators of successional stage were von Post, total P, total N, and % ash. Environmental response curves of the dominant plant species separated the species along nutrient and peat decompositional gradients, with early successional species having wider potential environmental ranges than late successional species. Empodisma minus, a mid-successional species, also had a relatively wide environmental range, which probably contributes to its key role in restiad bog development.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=caba5&AN=20043065761
http://dx.doi.org/10.1672/0277-5212(2004)024[0133:VAPCIT]2.0.CO;2
https://link.springer.com/content/pdf/10.1672/0277-5212(2004)024[0133:VAPCIT]2.0.CO;2.pdf

Howard-Williams, C. and S. Pickmere (2019). **Long-term nutrient and vegetation changes in a retired pasture stream: Monitoring programme and vegetation survey 1999–2003, updating data from 1976.** *Science for Conservation 257*. Department of Conservation. 2019-December.
This report is part of an on-going long-term study on the Whangamata Stream, north of Lake Taupo, New Zealand, since the stream margins were protected from pastoral farming by the establishment of riparian strips in 1976. The dataset is unique in New Zealand for its continuity and allows a quantitative assessment of the extent and time scales of change in stream restoration programmes. The five years covered here include data from the 2-to 3-monthly samples of flow rate and water quality at two stream sites, a continuation of the

photographic record, and a vegetation survey of the stream margins. The biodiversity of the vegetation in the riparian strips continued to increase at a rate of 3% per year. Vascular plants totalled 172 species, of which 70 were indigenous. There was a 2% turnover in species every year and a continuing increase in the proportion of woody species as the vegetation matured. Stream discharge decreased from 0.15 m3 /s to 0.03 m3 /s, the lowest since 1995. There was a trend for the discharge at the bottom end of the stream to be lower than at the top, which needs further investigation as it implied water loss between the upstream and downstream sampling sites. Both concentration and mass flow of suspended solids declined in the monitoring period, with lowest values recorded in summer at the time of maximum vegetation growth. Marked differences in nutrient concentrations between the top and bottom sampling sites in mid-summer reappeared, and proportionately more nutrient was stripped from the through-flowing water. Intensification of catchment use from pasture to forestry and recent extensive urban development indicate that further changes to this highly valued stream are inevitable. © October 2005, Department of Conservation.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85118832945&partnerID=40&md5=70085dc4d9a438fd3a0c4939853e6f99
https://www.doc.govt.nz/globalassets/documents/science-and-technical/sfc257.pdf
https://www.doc.govt.nz/globalassets/documents/science-and-technical/sfc257a.pdf

Korsten, A. C., W. G. Lee, et al. (2013). "**Understanding the role of birds in sustaining indigenous turf communities in a lacustrine wetland in New Zealand**." *New Zealand Journal of Ecology 37(2): 206-213*.

Since human settlement, wetland ecosystems in New Zealand have been severely modified by fire and reduced by drainage for agricultural development. Those remaining are problematic to manage, with modified water regimes, invasive weeds and grazing by livestock. Before settlement, wetland habitats supported diverse avian herbivores, the majority of which are now extinct. However, introduced birds are increasing in wetlands. We sought to understand the role of grazing birds in the maintenance of local turf communities in a lacustrine environment in Otago, New Zealand. To determine the causes of the vegetation patterns, we investigated the influence of abiotic (water table and soil nutrients) and biotic (direct via grazing and indirect via faeces deposition) effects of the birds on the vegetation. Four plant communities were distinguished, two dominated by Leptinella and two by Carex species. The occurrence of the communities was correlated with the distance from the nearest permanent water, soil phosphorus levels, and amount of faecal deposition. The results indicate that avian grazing decreased the proportion of dominant exotic plant species by biomass removal, but not through enhanced nutrient inputs via faecal deposition. Results from this site suggest that naturalised geese facilitate the maintenance of indigenous plant species in the face of exotic invasion, and have a conservation role in highly modified wetland systems, perhaps restoring a herbivore function lost with the extinction of native avian grazers. The long-term conservation management of wetlands in New Zealand may require the utilisation of both native and introduced avian grazers to facilitate the dominance of indigenous plants.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=biop39&AN=PREV201300792454
https://www.jstor.org/stable/24060783

McAlpine, K. G. and D. M. Wotton (2009). **Conservation and the delivery of ecosystem services: a literature review**. Science for Conservation; 2009. (295): 81 pp. many ref. Wellington, Department of Conservation.

Ecosystem services are the benefits people obtain from ecosystems, such as clean air, fresh water, and the pollination of crops. The aim of this literature review was to find empirical data illustrating the ways in which conservation land and conservation management activities affect ecosystem services. The widely-held belief that natural ecosystems - such as those found on conservation land in New Zealand - provide a range of ecosystem services is generally supported by the literature. International studies show that natural vegetation can decrease air pollution, regulate local air temperatures, improve water quality, reduce shallow soil erosion, and retain natural nutrient cycles. It can also be beneficial for pest control and pollination on agricultural land. Wetlands can improve water quality and can play a role in drought and flood mitigation. Seagrasses, saltmarsh vegetation, and mangroves can reduce the height and force of waves and play a role in flood protection. In addition, maintaining biodiversity preserves genetic libraries and future options for discoveries of valuable biological compounds. The few studies investigating the effects of conservation management activities on ecosystem services indicate that restoring vegetation can improve water quality and water storage functions, can reverse soil degradation on a local scale, and can restore plant-insect interactions. Additionally, removing some invasive plant species can increase water yield. Unfortunately, very few studies of ecosystem services have been conducted in New Zealand to date, and only some of the international results are likely to be applicable under New Zealand conditions. Accordingly, while conservation is probably beneficial for a range of ecosystem services in New Zealand, the scarcity of local data makes it difficult to ascertain where and when, and to what extent, the majority of those benefits transpire.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=caba6&AN=20093222548
https://www.doc.govt.nz/documents/science-and-technical/sfc295entire.pdf

Miller, C. J. (2006). "**Vegetation on the edge: a gradient analysis of the riparian zone, Poerua River, New Zealand**." *New Zealand Journal of Ecology 30(3): 357-370*.

Forest vegetation patterns alongside the Poerua River, south Westland, were studied to determine whether a distinct riparian community could be defined either immediately adjacent to the river, or out to the limit of overbank flooding. Ten randomly located 100 m transects were established perpendicular to the river at each of two sites. Ground cover of alluvial sediment indicated that annual overbank flooding occurred up to 20 m into the forest (the flood zone). No significant difference in vascular plant species richness was found between the flood zone and non-flood zone at either site, however a significant difference in species richness was found between sites, and this was attributed to recent disturbance at the edge of one site. Detrended correspondence analysis separated plots by site and indicated a gradient of species change from the river's edge to the ends of the transects. There were inconsistent differences in the densities and/or basal areas of trees and shrubs between sites and zones. No distinct band of vegetation was recognizable as a riparian zone alongside the Poerua River. Instead, there was evidence that edge processes had influenced vegetation patterns on a gradient away from the river, fluvial processes had eroded into, and influenced the vegetated edge, and historical disturbance events had had strong effects

on vascular plant community composition. The riparian zone incorporates the whole floodplain and environmental management needs to take this into consideration.
https://newzealandecology.org/nzje/2331
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=caba6&AN=20073026954

Perry, G. L. W., J. M. Wilmshurst, et al. (2014). "**Ecology and long-term history of fire in New Zealand.**" *New Zealand Journal of Ecology* 38(2): 157-176.

Fire is a complex physical and ecological process and one that has dramatically affected New Zealand's landscapes and ecosystems in the post-settlement era. Prior to human settlement in the late 13th century, the Holocene palaeoenvironmental record suggests that fire frequencies were low across most of New Zealand, with the notable exception of some wetland systems. Because few of New Zealand's indigenous plant species show any real adaptation to fire, the greatly increased fire activity that accompanied human settlement resulted in widespread, and in some cases permanent, shifts in the composition, structure and function of many terrestrial ecosystems. The combined effects of Maori and European fire have left long-lasting legacies in New Zealand's landscapes with the most obvious being the reduction of forest cover from 85-90% to 25% of the land area. Here we review the long-term ecological history of fire in New Zealand's terrestrial ecosystems and describe what is known about the fire ecology of New Zealand's plant species and communities, highlighting key uncertainties and areas where future research is required. While considerable emphasis has been placed on describing and understanding the 'initial burning period' that accompanied Maori arrival, much less ecological emphasis has been placed on the shifts in fire regime that occurred during the European period, despite the significant effects these had. Post-fire successional trajectories have been described for a number of wetland and forest communities in New Zealand, but in contemporary landscapes are complicated by the effects of exotic mammalian species that act as seed and seedling predators and herbivores, reduced pollination and dispersal services due to declines in the avifauna, and the presence of pyrophyllic exotic plant species. Many invasive plant species (e.g. Pinus spp., Acacia spp., Hakea spp., Ulex europaeus) are favoured by fire and now co-occur with indigenous plant species in communities whose long-term composition and trajectory are unclear. On the other hand, some highly-valued ecosystems such as tussock grasslands may require recurrent fire for their long-term persistence. Combined, the direct and indirect effects of the introduction of anthropic fire to New Zealand may have shifted large areas into successional 'traps' from which, in the face of recurrent fire, escape is difficult. Developing appropriate management strategies in such a context requires a nuanced understanding of the place of fire in New Zealand's ecosystems. © New Zealand Ecological Society.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-84904472535&partnerID=40&md5=c61a4ac7d6baf78c458a98f539ffed7d
https://newzealandecology.org/nzje/3198

Reeves, R. R., M. Wilke, et al. (2018). "**Physical and ecological effects of rehabilitating the geothermally influenced Waikite Wetland, New Zealand**." *Journal of Environmental Management 228: 279-291*.

Pressure to optimise land use and to maximise the economic viability of land has had a detrimental impact on wetlands worldwide. Rehabilitating wetlands has been identified by resource managers as increasingly important to enhance environmental values and restore

ecosystem functions that may have been lost through developments effecting wetlands. This paper investigates rehabilitating a geothermally influenced wetland that had been drained and used for grazing stock. The Waikite Wetland (New Zealand) is a relatively unique wetland because the primary water source to the wetland has a significant geothermal water component. This results in the area hosting populations of rare flora and fauna that are significant to New Zealand. A range of management actions that included diverting a geothermal stream back into the wetland, blocking drains, pest control, weed control, native plantings, fencing and building a weir to increase water levels were used to rehabilitate the wetland. This was done to promote thermotolerant vegetation growth, restore wetland water levels and minimise pest plant species re-establishing while minimising the effects on geothermal surface features and allowing indigenous wetland vegetation to re-establish. Physical, chemical and vegetation monitoring show that management actions have increased thermotolerant vegetation growth in the wetland while having a small potential impact on geothermal discharges into the wetland. Increasing the water level in the wetland appears to be helping control plant pest species close to the weir, but has also made sensitive vegetation growing close to the waterways more susceptible to flooding caused by high-intensity rainfall events.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=biop45&AN=PREV201900012637
http://dx.doi.org/10.1016/j.jenvman.2018.09.027

Richardson, S. J., R. Clayton, et al. (2015). "**Small wetlands are critical for safeguarding rare and threatened plant species**." *Applied Vegetation Science 18(2): 230-241*.

Question: Rare and threatened species are a common focus of natural area protection, but selecting sites to protect them must be balanced against other conservation objectives. Using a series of wetlands as a case study, we ask: (i) will protecting sites based on species rarity capture all critical community types; (ii) do rare plant species occur in rare environments; and (iii) will safeguarding large wetlands protect taxonomic and functional richness of rare and threatened species? Location: Southern New Zealand.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=caba6&AN=20153104872
http://dx.doi.org/10.1111/avsc.12144

Secker, N. H., J. P. S. Chua, et al. (2016). "**Characterization of the cyanobacteria and associated bacterial community from an ephemeral wetland in New Zealand**." *Journal of Phycology 52(5): 761-773*.

New Zealand ephemeral wetlands are ecologically important, containing up to 12% of threatened native plant species and frequently exhibiting conspicuous cyanobacterial growth. In such environments, cyanobacteria and associated heterotrophs can influence primary production and nutrient cycling. Wetland communities, including bacteria, can be altered by increased nitrate and phosphate due to agricultural practices. We have characterized cyanobacteria from the Wairepo Kettleholes Conservation Area and their associated bacteria. Use of 16S rRNA amplicon sequencing identified several operational taxonomic units (OTUs) representing filamentous heterocystous and non-heterocystous cyanobacterial taxa. One Nostoc OTU that formed macroscopic colonies dominated the cyanobacterial community. A diverse bacterial community was associated with the Nostoc colonies, including a core microbiome of 39 OTUs. Identity of the core microbiome

associated with macroscopic Nostoc colonies was not changed by the addition of nutrients. One OTU was highly represented in all Nostoc colonies (27.6%-42.6% of reads) and phylogenetic analyses identified this OTU as belonging to the genus Sphingomonas. Scanning electron microscopy showed the absence of heterotrophic bacteria within the Nostoc colony but revealed a diverse community associated with the colonies on the external surface.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=biop43&AN=PREV201700028335
http://dx.doi.org/10.1111/jpy.12434

Sorrell, B. K., T. R. Partridge, et al. (2007). "**Soil and vegetation responses to hydrological manipulation in a partially drained polje fen in New Zealand**." *Wetlands Ecology & Management 15(5): 361-383*.

Anthropogenic drainage causes loss of natural character in herbaceous wetlands due to increased soil oxygen penetration. We related vegetation gradients in a New Zealand polje fen to long-term effects of drains by using hydrological, edaphic and vegetation data, and a before-after-control-impact (BACI) design to test responses to experimental drain closure. Soil profiles and continuous water level records revealed a site subject to frequent disturbance by intense but brief floods, followed by long drying periods during which areas close to drains experienced lower water tables and more variable water levels. Classification of vegetation data identified 12 groups along a moisture gradient, from dry areas dominated by pastoral alien species, to wet communities dominated by native wetland sedges. Lower total species diversity and native representation in pastoral communities were related to the high proportion of alien competitor and competitor-disturbance species, compared with the stress tolerator-dominated flora of other groups. Species-environment relationships revealed highly significant correlations with soil water content and aeration as measured by redox potential (E-H) and steel rod oxidation depth, as well as soil nutrient content and bulk density. Comparison of root anatomy confirmed greater development of flood-tolerant traits in native species than in pastoral aliens, and vegetation N:P ratios indicated that most communities were probably nitrogen-limited. Flooding rapidly re-established wetland hydrology in dried sites in the impact area, and lowered E-H and soil oxidation depth, but had no effect on N and P availability. Presence and cover of pastoral alien species decreased in these areas. This study supports the use of hydrological manipulation as a tool for reducing soil oxidation and thus the impact of alien plant species at restoration sites with minimal intervention, but suggests the need for detailed information on species flooding tolerances and hydrological preferences to underpin this approach.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=biop33&AN=PREV200700518452
http://dx.doi.org/10.1007/s11273-007-9035-9

van Bodegom, P. M., A. P. Grootjans, et al. (2006). "**Plant traits in response to raising groundwater levels in wetland restoration: evidence from three case studies**." *Applied Vegetation Science 9(2): 251-260*.

Question: Is raising groundwater tables successful as a wetland restoration strategy?
Location: Kennemer dunes, The Netherlands; Moksloot dunes, The Netherlands and Bullock Creek fen, New Zealand.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=biop33&AN=PREV200700181705

https://doi.org/10.1111/j.1654-109X.2006.tb00674.x

Wardle, P. (1991). **Vegetation of New Zealand**. *Cambridge, Cambridge University Press, xx + 672*.
A comprehensive account of the origins, ecology, biogeography and community structure of New Zealand's vegetation with particular attention given to the unique indigenous flora. The 16 chapters describe: The physical and biological environment; Origins and history of the flora and vegetation; Plant form in relation to habitat; Reproductive aspects, seedling form and longevity; Description, nomenclature and classification of vegetation, environment and ecological processes; Botanical provinces; Chapters 7-13 contain expanded descriptions of plant communities (Forest; Bush, heath, scrub and fernland; Grassland and herbfield; Wetland vegetation; Open or patchy vegetation on primary surfaces and depleted lands; The alpine and nival belts; and Outlying islands); Biomass, growth, nutrition and tolerances; Succession, retrogression and invasion; and Disturbance, regeneration and trends in native forests. Indexes are given for plant genera and species, and general topics.
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=caba3&AN=19920657306

Weeks, E. S., R. G. Death, et al. (2016). "**Conservation Science Statement. The demise of New Zealand's freshwater flora and fauna: a forgotten treasure**." *Pacific Conservation Biology 22(2): 110-115*.
New Zealand's freshwater ecosystems support a diverse and unique array of endemic flora and fauna. However, the conservation of its freshwater biodiversity is often overlooked in comparison to terrestrial and marine environments, and is under increasing threat from agricultural intensification, urbanisation, climate change, invasive species, and water abstraction. New Zealand has some of the highest levels of threatened freshwater species in the world with, for example, up to 74% of native freshwater fish listed as endangered or at risk. Threatened species are often discounted in water policy and management that is predominantly focussed on balancing water quality and economic development rather than biodiversity. We identify six clear actions to redress the balance of protecting New Zealand's freshwater biodiversity: 1. change legislation to adequately protect native and endemic fish species and invertebrates, including those harvested commercially and recreationally; 2. protect habitat critical to the survival of New Zealand's rare and range-restricted fish, invertebrate and plant freshwater species; 3. include river habitat to protect ecosystem health in the National Objectives Framework for the National Policy Statement for freshwater; 4. establish monitoring and recovery plans for New Zealand's threatened freshwater invertebrate fauna; 5. develop policy and best management practices for freshwater catchments in addition to lakes and rivers to also include wetlands, estuaries, and groundwater ecosystems; and6. establish, improve, and maintain appropriately wide riparian zones that connect across entire water catchments. We have published these recommendations as a scientific statement prepared for the Oceania Section of the Society for Conservation Biology to facilitate communication of our thoughts to as wide an audience as possible
https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=biop42&AN=PREV201600679356
http://dx.doi.org/10.1071/PC15038