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LONG-TERM VEGETATION AND WATER QUALITY CHANGES ASSOCIATED WITH THE RESTORATION OF A PASTURE STREAM

Clive Howard-Williams[1] and Stuart Pickmere[2]

[1]NIWA, P.O. Box 8602, Riccarton, Christchurch
[2]NIWA, P.O. Box 11-115, Hamilton

ABSTRACT

This paper records vegetation and water quality changes in a New Zealand pasture stream over a seventeen year period following stream protection (by fencing off riparian strips). It allows for an assessment of the time scales of change needed for rehabilitation of pasture streams. Following protection, the stream channel and margins have undergone a continuous successional change in the vegetation. The early stages of succession (2-6 years) were characterised by rapid growth of stream bank herbaceous flora, which stabilised banks and improved trout spawning. Water quality improved. Between seven and 12 years channel vegetation changes caused blockages to fish movement but acted as a nutrient filter, further improving water quality. Development of a diverse bank flora improved wildlife habitat. The most recent stages – 13-17 years – have been characterised by shading of the channel, better fish passage but decreasing nutrient filtration ability. Implications for stream management are discussed. It is anticipated that a stable vegetation type of predominantly woody stream bank species will have established after 30 years of protection.

INTRODUCTION

Forest clearance in New Zealand has proceeded very rapidly over the 150 years following the first European arrivals. Development of pastoral agriculture has created extensive networks of sunlit streams, to which the native stream flora was not adapted (Howard-Williams *et al.* 1987). Stream banks in pastoral country are almost entirely colonised by adventive species, many of which are highly palatable to stock. Thus, grazing to the water's edge and trampling and erosion of stream banks are very common occurrences (Fig. 1).

Increased use of fertilisers has meant addition of nutrients to stream waters, with consequent eutrophication problems in some areas (White 1982). Progress in the improvement of water quality in many of New Zealand's lakes and rivers will occur only if we can minimise nutrient losses from land, and thus reduce the amount of nutrients reaching larger water bodies.

There is an increasing awareness of the value of stream bank protection for water quality control, and the importance of riparian zones and wetlands along streams in the retention of nutrients and sediment from diffuse sources has been stressed in several New Zealand studies (McColl 1978, 1982, Wilcock 1986, Smith 1989, Rutherford *et al.* 1987, Quinn *et al.* 1993). In two nationally important lake catchments in New Zealand, riparian protection has been afforded to all streams in the catchment. This involved the establishment of buffer strips (by land retirement from grazing) to eliminate stock access to stream edges.

These so-called "Catchment Control Schemes" for Lakes Rotorua and Taupo were established with the aid of government subsidies in the 1960s and 1970s. The primary aim was to protect the catchments from soil erosion, but mitigation of the effects of nutrient runoff from farmland was also seen as an important objective (Waikato Valley Authority 1966).

The largest of these was the Lake Taupo Catchment Control scheme (Waikato Valley Authority 1966). A 20 year study of the Whangamata Stream in this scheme has provided an opportunity to examine vegetation development and associated water quality changes over a long time period. Details of nutrient transformations and some ecosystem processes for individual years are given in Vincent and Downes (1980), Howard-Williams *et al.* (1982, 1986), and some modelling of land use practises on stream water quality was carried out by Hearne and Howard-Williams (1988).

AIM

The aims of this paper are to:

1. Record the vegetation changes which have taken place in a New Zealand pastoral stream ecosystem over the first 17 years of riparian protection.

2. Record the associated trends in water quality over the same period.

3. Provide an assessment of the time scales of change needed for rehabilitation of New Zealand pasture streams.

METHODS

Detailed descriptions of the stream and the field and laboratory methods used are given in Howard-Williams *et al.* (1982) and Hearne and Howard-Williams (1988). A brief description will suffice here.

The stream study section was a 2.0 km long second order, spring-fed stream flowing into Lake Taupo. Two springs provide the source of the water, which has a base flow discharge between 0.04 and 0.1 m^3s^{-1}. Flood flows account for only 5% of total flow over a year. The low variance in the discharge means that the stream is ideal for the study of nutrient dynamics and water quality.

Three sampling sites were established for regular measurements; the TOP site was 2.0 km from the lake at the junction of the two spring outflows, the BOTTOM site was near the lake, and a MID site was ca. 1.0 km from the lake. There were no inflows between the sites.

Flows were estimated from an acoustic stage recorder set in a calibrated square section flume at MID site. Considerable difficulties were encountered in the flume calibration due to seasonal water level changes in the stream caused primarily by seasonal changes in vegetation density, rather than changes in flow rate. As the biomass of the aquatic vegetation increased in summer, the water level also increased, due to stream blockage. Thus, a large number of calibration gaugings were necessary to define the flood peaks and the base flow. Details are given in Hearne and Howard-Williams (1988).

Duplicate water samples were collected at each site at weekly intervals from 1979 to 1981, and at fortnightly intervals from 1982 to 1993. Analyses for dissolved nutrients were carried out with a Technicon II autoanalyser system using the methods detailed in Downes (1988). Only two nutrient compounds are discussed in this paper – Nitrate-Nitrogen (NO_3-N) and Dissolved Reactive Phosphorus (DRP). Ammonium nitrogen concentrations were low throughout the study (<10 mg m^{-3}). Dissolved organic nitrogen and dissolved organic phosphorus concentrations were also low and did not make significant contributions to the dissolved nitrogen and phosphorus budgets.

Analyses of nutrient changes during flood flows are available only for the 1979 to 1981 period. The data presented in this paper deals with base flow conditions which, in any case, account for over 95% of the total mass flow of NO_3-N and DRP.

Vegetation surveys were carried out by walking the length of the stream and constructing species lists for all plants growing in the stream channel, on the banks and on wet soil on either side of the banks, where this occurred. The survey data are available for 1974, 1982, 1986 and 1993 (Howard-Williams 1987, Howard-Williams *et al.* 1987, and unpublished data).

In addition, three 250 m sections of the stream (one at each sample site), were marked out for detailed mapping of the stream bank vegetation areas. These were mapped to a scale of 1:200 from transect lines stretched across the stream every 5 m and gave an indication of changes in abundances of the dominant species.

Figure 2 Detailed changes over a mapped reach of the stream at TOP site over a 12 year period.

Figure 1 A-C: Changes in the riparian vegetation of the Whangamata stream at the TOP site. A: 1974 Pre-retirement, B: 1981, C: 1986.D-E: Contrasting views of the stream in 1983. D: Stream channel in a retired reach blocked by musk with young toetoe and flax on the stream banks, E: Stock damage and heavy grazing on the stream banks in the lower reach exempt from protection in 1983.

Figure 3 Time course of species changes (number of species) following protection of the Whangamata stream. Data are given for Total Number of Species, Native Species, and Species Lost (formerly recorded but no longer present).

RESULTS

General Physiographic Changes

The sequence of changes in the stream between 1974 – prior to fencing – and 1980 – thirteen years following fencing – is shown in Figure 1.

Prior to fencing of the riparian strips (retirement) in 1976 the stream was wide, shallow, and carried a high load of shifting pumice from the unstable bed. The banks were heavily grazed and trampled (Fig. 1A). However, some aquatic vegetation persisted in the lower reaches of the stream as it ran through a lightly grazed paddock.

By 1979 the banks had become colonised by a vegetation community made up mostly of watercress (*Rorippa nasturtium-aquaticum*) and floating sweetgrass (*Glyceria declinata*) which grew out over the water surface each summer. The banks had stabilised and were covered with herbaceous vegetation. In the early 1980s, aquatic and semi-aquatic vegetation such as watercress and monkey musk (*Mimulus guttatus*) choked the channel in summer and autumn, impeding the migrations of spawning trout (Fig. 1D).

Some assisted plantings, together with natural growth of toetoe (*Cortaderia toetoe* and *C. fulvida*) and flax (*Phormium tenax*), began to appear along the stream banks by 1979, and between 1981 and 1984 the channel edges became significantly shaded (Fig. 1B), so that the low growing streambank plants began to disappear in patches. However, there were still some reaches of the stream where the vegetation remained dense enough to impede trout movements, so that manual clearing of the channel was necessary in the months of April-May. This has continued on a reduced scale until 1993.

Table 1 Selected list of species gains, declines in abundance and losses from the Whangamata Stream from 1986-1993. * = adventives; # = recent plantings.

Trend	Type	Species examples
Species gains	woody trees and shrubs	*Coprosma robusta* *Cordyline australis* *Coriaria arborea* *Dicksonia squarrosa* *Griselinia littoralis* *Hebe stricta* *Leptospermum scoparium* *Melicytus ramiflorus* **Salix cinerea* **S. fragilis* #*Dacrycarpus dacridioides* #*Nothofagus fusca* #*Sophora tetraptera*
Species declines	free-floating aquatic	*Lemna minor*
	floating emergent	*Glyceria declinata*
	floating aquatic	**Rorippa nasturtium-aquaticum*
	emergent aquatic	**Polygonum persicaria*
Species losses	free-floating aquatic	*Azolla filiculoides*
	floating emergent	**Ludwigia peploides*
	aquatic	**L. palustris*
	submerged aquatic	*Myriophyllum triphyllum* *M. propinquum*
	emergent aquatic	*Typha orientalis*

Figure 4 1979-1980 data showing seasonal changes in nitrate concentrations at the TOP and BOTTOM sites and the mean biomass of aquatic plants (watercress) (Data from Howard-Williams *et al* 1982).

By 1985 the bank vegetation had developed to the extent that the first fernbird (*Bowdleria punctata*) was recorded. By 1986 the stream had a distinctly natural wetland appearance (Fig. 1C), with the stream channel hidden beneath flax and toetoe. The channel banks at this stage were lined with the root masses of the wetland plants.

Maps of the upper section of the stream for selected years from 1979 show the loss of the scrambling semi-aquatic vegetation of the channel surface (watercress and monkey musk), as the flax, toetoe and other large species expanded (Fig. 2).

Changes in the Vegetation

Changes in the number of species over the years are shown for total species and native species (Fig. 3). Over the first 6 years following riparian protection (1976-1982), the total number of species almost doubled from 24 to 40, with a slight increase in the number of natives. A rapid rise in diversity took place between 1982 and 1986, with the total number of species recorded increasing 2.5 fold to just over 100. This was made up to a large extent by an increase in invading native species which, by 1986, comprised almost 50% of the flora. A further increase of 17 species occurred between 1986 and 1992 (Fig. 3, Appendix 1). Many of these, including the windborne seeds of the Compositae and Onagraceae (e.g. *Epilobium* spp.), and bird dispersed seeds (Cyperaceae), will have invaded from the Otakitaki Scenic Reserve area ca. 1 km west of the stream.

The increase in the number of recorded species over time has been accompanied by a loss in some conspicuous aquatic plants. For instance, between 1982 and 1986, five species disappeared, and between 1986 and 1993 a further seven species disappeared. If these are added to the total compliment of species that has occurred in the stream since riparian protection, the number is 130.

The type of plants which have been displaced is of significance. The losses in species were in the aquatic category (Table 1). For instance, the species submerged in the channel such as the *Myriophyllum* spp., free-floating aquatics (*Azolla filiculoides*), and some of the floating emergent species such as *Ludwigia* spp. are no longer recorded. In addition to these losses, detailed mapping of streambank vegetation indicated some significant declines in abundance. Duckweed (*Lemna minor*), a free-floating species commonly associated with *Azolla* in the period 1979-1982, is now rarely seen. Watercress and floating sweetgrass were the dominant stream edge plants in 1980, when they occurred along the entire length of the stream and frequently colonised the entire stream channel. In 1993 they were found in a few isolated clumps at the upper section of the stream and formed only thin (<0.5 m wide) fringes in the lower sections.

A significant number of large plants have invaded the stream banks. An increase in the abundance of flax and toetoe and the cabbage tree (*Cordyline australis*) has had the most obvious visual impact. However, the number of woody tree and shrub species has also increased markedly (Table 1). Many of these plants are still small but the future trend for a woody streambank vegetation can already be identified. Rapidly growing plants such as *Coprosma robusta* and tutu (*Coriaria arborea*) are colonising in patches. Young tree fern, wheki (*Dicksonia squarrosa*), now occur along the length of the stream in the shade of the flax and toetoe, while clumps of manuka (*Leptospermum scoparium*) and young whiteywood (*Melicitus ramiflorus*) are also increasing in abundance. Several species have been planted by the Department of Conservation to hasten the restoration process. Between 1990 and 1992, the lower reaches of the stream were planted with kahikatea (*Dacrycarpus dacrydioides*) red beech (*Nothofagus fusca*) and kowhai (*Sophora tetraptera*).

Of concern has been the recent arrival (between 1986 and 1993) of willows – grey willow (*Salix cinerea*) and crack willow (*S. fragilis*). These have the potential to dominate the flora along the stream and arrest the current trend towards a native woody vegetation cover for the stream banks. The replacement of native wetland vegetation by willows has been particularly marked in the Whangamarino swamp (Ogle and Bartlett 1981). The likely source of willow propagules in the Whangamata Stream is the widespread willow planting programme carried out by the former Waikato Valley Authority to arrest gully erosion in many small catchments in the Taupo area.

Figure 5 Downstream transect in the Whangamata Stream showing mid-summer depletion of nitrate between 1975 (pre-retirement) and 1992.

Water Quality Changes

The record for dissolved nutrient concentrations in the stream is continuous for the last 14 years (1979-93), with some data extending back a further six years. As with most pasture streams in New Zealand, a marked seasonal pattern in dissolved nutrients occurred in the Whangamata Stream (Fig. 4). This is due to the seasonal growth of the aquatic and streambank vegetation (Fig. 4) which absorbs nutrients rapidly through the growing season causing a characteristic summer depletion of nutrients in the stream waters (Howard-Williams *et al.* 1986).

A transect down the stream in mid-summer shows a decline in concentration with distance downstream (Fig. 5) due to nutrient stripping by the streambank vegetation. The trend from 1979 to 1989 was for increasing amounts of nutrients to be removed from the stream, so that by the summer of 1989 there was a greater than 95% reduction, with <5 mg m^{-3} NO_3-N and <2 mg m^{-3} DRP remaining in the bottom 0.5 km of the stream. Since that time, the trend has slowed down with considerably less nutrient uptake in 1992 and 1993. For instance, in the summer of 1992, the nitrate decreased downstream by only 60% (Fig. 5), so that 350 mg.m^{-3} remained in the bottom 0.5 km of the stream.

The water quality record for NO_3-N and DRP since 1979 is shown in Figure 6. A set of earlier data for 1974 are shown in Vincent and Downes (1981). On the basis of these records, the trends in water quality changes can be divided into three phases:

Figure 6 Concentrations (mg m^{-3}) of (A) nitrate, (B) dissolved reactive phosphorus (DRP) at TOP and BOTTOM sites between 1979 and 1993.

1. 1979-1982: This was characterised by a 30-50% reduction in NO_3-N (Fig. 6A) and a 10-60% reduction in DRP (Fig. 6B) for 1-2 months in summer over the 2.0 km study reach.

2. 1983-1989: This was a period of large scale summer nutrient reduction. Over this period, NO_3-N and DRP were reduced to almost zero at the bottom end of the stream. The length of time that nutrients were continuously depleted from the stream water to concentrations of less than 10 mg m^{-3} of DRP or NO_3-N increased from 2.5-3 months in 1983-1984 to 4-5 months in 1986-1989.

3. 1990-present: This period was one of declining nutrient uptake from the stream waters. Since 1990 the amount of nutrient removed from the stream in summer has declined markedly, so that in 1992-1993 the nutrient concentrations upstream were reduced by 50-60% at the bottom site for only two months.

A drop in concentration between sites where there are no inflows indicates that nutrients have been stripped from the stream water. However, the most suitable measure of nutrient removal is that of mass flow (g s^{-1}) rather than concentration. Calculations of mass flow require stream discharge data. While the concentration data are continuous for the study period 1979-1993, the discharge records for the stream are not. However, records do exist for the periods 1979-1981 and from 1984-1993. Mass flow data for NO_3-N and DRP for the period 1984-1993 show the same trends as those of concentration with the last few years characterised by a reduction in the extent of nutrient removal (Figs. 7A and B). Calculations of the mass of nutrient removed from the stream are made by integrating the area between the curves for the TOP and BOTTOM sites each year. The data (Table 2) show that since 1989 the removal of DRP has fallen by 85% from 78 kg to 11 kg, and the removal of NO_3-N has fallen by 85% from 787 kg to 125 kg.

Figure 7 **Mass flow ($g\ s^{-1}$) of (A) nitrate, and (B) dissolved reactive phosphorus over time at TOP and BOTTOM sites.**

Table 2 **Biological removal ($kg\ year^{-1}$) of nitrate-nitrogen and dissolved reactive phosphorus from the Whangamata Stream water between 1986 and 1993.**

Year	**Mass removed ($kg\ year^{-1}$)**	
	NO_3-N	**DRP**
1986-87	475	47.4
1987-88	787	71.7
1988-89	558	48.0
1989-90	413	33.8
1990-91	239	14.6
1991-92	234	20.7
1992-93	125	10.7

DISCUSSION

Following stream protection by fencing riparian strips in 1976, the stream changed from an open ryegrass-clover pasture to a wetland suitable for fernbird within 9 years (Fig. 1). Fernbird is a secretive species with a restricted habitat range and has become localised and greatly reduced in numbers since pastoral development (Best 1979). The presence of fernbird in the Whangamata Stream is thus a good indicator of a rehabilitated natural wetland. The diversity of native plant species is still increasing after 17 years of protection, but the successional changes in vegetation associated with continued protection have had a series of consequences. Firstly, in the early 2-5 year period after protection a dense aquatic and semi-aquatic vegetation developed along the stream channel. The species which dominated this community were watercress and floating sweetgrass. This community grew out, covering the stream channel each summer, and died back in winter, leaving a clear channel for migrating fish during spawning. Trout spawning increased dramatically over this period as a result of bank protection, vegetation cover along the banks, and a clear central channel for movement (Young 1980). Uptake of nutrients from stream waters also increased over this period as the vegetation biomass increased (Howard-Williams *et al.* 1982, 1986).

The next stage in the succession (1983-1989) was a change in the semi-aquatic plant community when watercress was replaced by monkey musk, which does not die back in winter. This plant caused blockages over long stretches of the stream and prevented trout spawning migrations. However, nutrient uptake rates were high, and in summer NO_3-N and DRP concentrations were effectively reduced to zero by the dense biological filter that these plants provided (Fig. 1D). Stream management by manual clearing of the central stream channel in the trout spawning season began. During this period, the large herbaceous wetland species such as flax and toetoe began to grow rapidly, with a consequent increase in the shading of the channel edges. This limited shading, combined with the very extensive year round cover of monkey musk, caused a loss of several of the aquatic species from the stream.

Further successional development of the vegetation, some 12 years after protection, tended towards larger species and greater shading over the channel with a consequent reduction of the high light requiring plants such as watercress and monkey musk. With the reduction in these species, the ability of the stream community to take up nutrients has diminished.

Monkey Musk is still a problem in the stream's lower reaches, recently retired, where control by limited spraying is currently practised by the Department of Conservation (Target Taupo 1994).

CONCLUSIONS

The dataset from the Whangamata Stream allows for the calculation of time scales of rehabilitation processes in pasture streams in New Zealand. Seventeen years after protection, the riparian vegetation is still undergoing successional change with the following patterns. The following time scales cover the major processes:

•**1-5 years** – rapid development of a stream channel flora and herbaceous streambank flora

•**5-17 years** – slower development of a flora dominated by large emergent wetland species and invasion of woody species.

The succession has had the following consequences for the stream ecosystem:

•**1-5 years** – bank and channel bed stabilisation and enhanced nutrient removal capacity

•**5-13 years** – very high nutrient removal capacity but stream blockages and fishery management problems

•**13-17 years** – decreasing nutrient removal capacity but improvements in channel conditions for the fishery, and enhanced wildlife habitat.

It is realistic to expect a further 10 years of change before a reasonably stable vegetation prevails. This may have a high proportion of woody species. In total, it appears that the rehabilitation of a pasture stream to a relatively stable condition dominated by native vegetation will take **30 years**.

The dataset also raised questions for the management of riparian strips of protected pasture streams. If maintenance or enhancement of streams for salmonid spawning is the management goal, then vegetation control – at least in the 5-13 year period – will be necessary to avoid stream blockages. In streams which are not strongly spring-fed, some nutrient reduction is likely to occur in the riparian zone before the water reaches the stream channel (McColl 1982; Quinn et al. 1993). This study clearly demonstrates that considerable reductions can take place in the stream channel itself. If nutrient reduction is the management goal, then maintenance of a high light environment on the stream banks and channel is needed to prevent shading of the species which are most effective at nutrient stripping.

FUTURE DIRECTIONS

Section 230 of the Resource Management Act (RMA) (1991) has placed a significant emphasis on stream bank protection through a policy of providing for the establishment of esplanade reserves. However, the requirements of the Act (demonstration of benefits, alternatives and costs, and monitoring of the effects of any policy) emphasise the need for research on the ecology of riparian strips and stream restoration processes. Future directions in these topics in New Zealand will be influenced by the RMA.

To date, research in riparian zones has generally centred on short-term (1-3 year) studies. Where riparian management involves management of human disturbed stream ecosystems (e.g. in pastures, exotic forest), successional changes in riparian vegetation are inevitable. This study has shown that these changes cause changes to the nutrient dynamics of a stream. Ecological theory predicts that food webs and energy flows will likewise change. There is a need for long term studies (decade(s)) to develop and test predictions of stream restoration by riparian management. A starting point could be a broadscale vegetation analysis of existing riparian strips and protected streams in varied catchments and topographies. The dates of "retirement" are in most cases documented.

There are limits to the extent that riparian zones can mitigate sediment and nutrient runoff from pasture, and sediment loads from exotic forestry practices. Advances in stream restoration and riparian research will need closer interaction between aquatic and terrestrial sciences (agronomy, forestry) than has been the case to date. A greater emphasis is required on the holistic approach to landuse, where riparian and stream bank vegetation are seen as parts of a continuum of practices that embrace the economic and biological values of catchments.

The Danish experience (Iversen *et al.* 1990) is that the general improvement in Danish streams over the past decade is largely due to stream habitat maintenance rather than complete restoration. Maintenance measures include: leaving vegetation along stream banks, cutting weed only when strictly necessary, and cutting in a sinuous pattern, maintaining over-hanging banks, stones and roots, maintaining defined hydraulic capacity, undertaking essential mechanical works only in autumn.

Complete stream protection as a restoration measure will result in successional changes that may not be compatible with some instream uses. For instance, channel blockages by wetland vegetation and shading out of species useful for cover or nutrient uptake. The goals of the restoration (or maintenance) works must be clearly defined, as this study has shown that the endpoint in the restoration may be three or more decades from the time that any protection policy is implemented.

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APPENDIX 1. Species list of the vascular plants of the Whangamata Stream, Lake Taupo, including stream channel, banks and adjacent wet areas on 15 April 1993. * = not recorded in 1986.

Acacia melanoxylon
Aceana novae-zelandiae
Achillea millefolium
Agrostis capillaris
Anthoxanthum odoratum
Asplenium flaccidum subsp. *flaccidum**
Bidens frondosa
Blechnum "blackspot" (unnamed, common species)
B. minus
*Blechnum penna-marina**
Brachyglottis repanda var. *repanda**
Callitriche stagnalis
*Calystegia sepium**
Carex fascicularis
C. lessoniana
C. ovalis
C. secta
C. virgata
C. sp. (*C. geminata agg.*)
Cerastium fontanum subsp. *triviale*
*Chaemaecytisus palmensis**
Cirsium arvense
C. vulgare
Conyza albida
Coprosma robusta
Cordyline australis
Coriaria arborea
Cortaderia fulvida
C. toetoe
Crepis capillaris
Cytisus scoparius
*Dacrycarpus dacrydioides**
Dactylis glomeratus
Dicksonia squarrosa
*Digitalis purpurea**
Diplazium australe
Eleocharis acuta
*Elymus rectisetus**
Epilobium ciliatum
*E. nummulariifolium**
E. obscurum
*Erica lusitanica**
Fuschsia excorticata
Galium aparine
*Geranium potentillioides**
*Griselinia littoralis**
Glyceria declinata
Gnaphalium involucratum
G. limosum
*Hebe stricta**
Haloragis erecta subsp. *erecta*
Histiopteris incisa
Holcus lanatus
Hypericum sp.
Hypochaeris radicata
Hypolepis ambigua
*Juncus acuminatus**
J. articulatus
J. bufonius
*J. dichotomus**
J. effusus
J. gregiflorus
J. tenuis
Kunzea ericoides var. *ericoides**
*Lactuca serriola**
Lemna minor
Leptospermum scoparium
*Leucopogon fraseri**
Lolium perenne
Lotus pedunculatus
Lupinus arboreus
Melicytus ramiflorus sub sp. *ramiflorus**
Mentha spicata subsp. *spicata*
*Microtis unifolia**
Mimulus guttatus
M. moschatus
Muehlenbeckia australis
Mycelis muralis
Myosotis scorpioides
*Nothofagus fusca**
*Orobanche minor**
Paesia scaberula
*Paspalum dilatatum**
P. distichum
*Phleum pratense**

Phormium tenax
*Phymatosorus diversifolius**
*Pittosporum colensoi**
*P. tenuifolium**
*Plantago lanceolata**
Polygonum hydropiper
*Polystichum richardii**
P. vestitum
Populus nigra cv *Italica**
Prunella vulgaris
Pteridium esculentum
*Ranunculus acris**
R. repens
Rorippa nasturtium-aquaticum
Rosa rubiginosa
Rubus sp. (*R. fruticosus* agg.)
*Rumex acetosella**
Rumex conglomeratus
R. obtusifolius
Rytidosperma sp.*
*Salix cinerea**
*S. fragilis**
*Senecio bipinnatisectus**
S. jacobaea
*S. minimus**
*Solanum nigrum**
Sonchus oleraceus
*Sophora tetraptera**
Stellaria media
*Taraxacum offinale**
*Trifolium pratense**
T. repens
*Verbascum virgatum**