Aquatic Plants in Christchurch River Systems

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Contents

Executive Summary

- Although studied intensely between 1980 and 1994, there has been no detailed record of the aquatic plant species in Christchurch since.
- A detailed quantitative sampling of the vegetation of the Avon, Heathcote and Styx Rivers and tributaries was carried out using as many of the same sampling points of the previous studies as possible (Avon Catchment. 225 sites, Heathcote Catchment. 208 sites, Styx Catchment 129 sites).
- Species presence and abundance of the various zones of aquatics was recorded and a total site cover index calculated.
- For each catchment a separate multivariate classification was carried out to determine the main plant communities (12 at each excluding outliers).
- Each catchment was characterised by many sites having very low cover of aquatic species. Many of these were in heavily-shaded areas with river margin trees
- Some communities were characterised by the submerged aquatic macrophytes and others by floating or emergent marginal species and others by a combination of both.
- Although difficult because of the many changes since the 1994 sampling and the difference between quantitative and qualitative data, comparisons were made with the previous studies on a catchment basis.
- The Avon River has changed least. the largest change being the replacement of ephemeral cryptogams with aquatic macrophytes, especially *Potamogeton crispus* and *Callitriche stagnalis*.
- In the Heathcote River, the changes have been major, including the replacement of ephemeral cryptogams with aquatic macrophytes, a massive increase in margin species and a two-fold increase in species per plot.
- The Styx River has undergone similar changes to the Heathcote River. In particular, there has been a major increase in cover of aquatic macrophytes.
- Factors implicated in these changes include increased sedimentation and less 'grooming' of the river banks.
- Biodiversity values were calculated for the various communities. This revealed a general dominance by exotic species with only a few communities where native plants still dominate.
- The only well-dominated native community occurs on the Avon River in the central city between Salisbury Street and Antigua Boatsheds. This area is dominated by the otherwise rare native species *Ruppia polycarpa* and *Potamogeton pectinatus* on a fast-flowing gravel based bed.
- Other communities with predominantly native species also mostly occur on the Avon River, with little on the Heathcote and Styx.
- Controlling environmental factors determining composition are shade and sediment loads. The impacts of these are described.
- A list of pest plants and possible priorities is presented.
- Issues of management and maintenance are discussed and some new directions and options presented.
- Seven recommendations have been made.

1.0 Introduction

In a detailed survey of natural areas of Christchurch by Meurk et al. (1993), the remnant indigenous vegetation of the city was described and rated according to botanical values. This survey was used as the basis for the creation of the Ecological Heritage Sites listed in the Christchurch City Plan, these comprising 51 sites with ‘A’ rankings in that report. However, one habitat appears to have not been covered in the survey, this being the aquatic vegetation of the city’s streams and rivers. As a result there is no indication whether there are areas of botanical value for that type of vegetation.

There are however surveys of aquatic plants in Christchurch that vary in their detail. The earliest is that of Connor (1953) who described a small number of sites on the Avon and Heathcote Rivers. The earliest detailed survey was that carried out by Christchurch Drainage Board (Robb et. al. 1980). That survey described physical and biotic components of the Styx, Avon and Heathcote Rivers from re-locatable sampling points. As far as plants are concerned, the study was confined to aquatic components and the data was in the form of presence and absence of species at the site. Parts of that study were followed up by site repeat sampling in 1986 (Carroll & Robb 1986), and 1989 (Robb 1989). These and other studies were summarised by Baird (1992). A major repeat of the sampling was then undertaken in 1994 (Robb et al. 1994) after which this work ceased. The only comparative analysis of aquatic macrophyte changes was that of Taylor et al (2000) who compared those earlier studies but did not update them.

Following those studies, there has been little interest in aquatic plants as communities. There have been a number of reports focussing on problem aquatic species, including much effort undertaken to eradicate *Egeria densa* from the lower Avon River. This and the desire to control other weeds such as *Lagarosiphon major* resulted in the preparation of an identification manual by McCombs (2003). The only published scientific study has been an experimental examination of options to re-establish aquatic plants in a Christchurch river by Larned et al (2006). A study (known as the CREAS survey) is currently being undertaken of the upper reaches of the Christchurch rivers to characterise the stream and bank features into a “stream health score”. This is being undertaken at a very intensive sampling frequency along these reaches, but it does not include the lower reaches of the rivers. It includes some aquatic plant data, but not of the type that is used in this study.

There is therefore a major gap in understanding the aquatic vegetation of the main rivers of Christchurch at the larger scale. The previous work that provided such data between 1980 and 1994 has been made less useful by the many changes within the urban environment since it was undertaken, but it does provide a good baseline for comparison. This study was therefore undertaken to update that information. This information will be used for a range of purposes, including aquatic plant management, biodiversity preservation, weed management and river maintenance. It should also provide the basic information needed for future comparative studies, although it is hoped that these will occur at greater frequency than the long gap between the earlier reports and this.

2.0 Methods

2.1 Coverage

The study area covers the three major river systems of the plains of Christchurch City: the Avon, Heathcote and Styx and their tributaries. Therefore it excludes the tributaries of the Heathcote River that have their origins on the Port Hills such as in the Heathcote and Bowenvale Valleys, but does include Cashmere Stream. Also excluded are the Halswall River and its major tributary Knights Stream, which constitute the boundary of the City with Selwyn District for much of their length and the Otakaikino River (also known as the South Branch, Waimakariri River) as these were not covered in the original reports by Robb et al (1980, 1994). Two areas that were included in this survey despite not being covered by Robb et al (1980) are Horseshoe Lake (which was included in the 1994 survey), and Estuary Stream which flows directly into the Avon/Heathcote Estuary. Also, wetlands are not included. The study was restricted to stream macrophytes and thus to the places with flowing waters. Wetlands and ponds often carry completely different assemblages of aquatic and wetland species that would only complicate the stream patterns. Thus sites like Travis Wetland and Styx Mill Basin Wetland are not covered.

The sample points are based upon those used by Robb et al (1980, 1994) as closely as possible. There are however some problems with these. In the years since Robb's surveys, many sites have changed so much that the exact location was difficult to determine. Access to some sites has become problematic due to changing ownership, and some site descriptions were based on structures and buildings that no longer exist or were too general to enable exact locations to be determined. There were some tributaries and waterways that Robb did not survey and others that have been piped, daylighted (which involves exposing formerly piped sections) or re-aligned. Where appropriate, such new waterways and new sites on re-aligned sections have been added for this survey. For these reasons, GPS co-ordinates have been obtained for all sites so that in the future, sites can be located exactly.

Overall, the study involved visiting over 600 sites on the three rivers, collecting data on the aquatic plant species present and their abundance. Aquatic species included in the sampling are limited to macrophytes (plants that can be identified without microscopic examination). This comprises vascular plants, cryptogams (mosses and liverworts) along with macro-algae in the Characeae (stoneworts) and seaweeds of the estuarine zones because of their size. Some smaller algae were included (filamentous green algae and brown periphyton) if their presence was significant, but no attempt was made to identify these to species or any other taxonomic level.

2.2 Site sampling

At each site, the following sampling technique was used to determine the composition and abundance of the aquatic macrophytes present.

Each sample site comprises a bank length of 20m. A description of each site was made including details e.g 0-20m from a described point or a described point ± 10m (10m in each direction) so that the exact sampling method can be accurately re-determined for each site.

The sample site was divided into 3 sections running the length of the site as shown in Fig. 1:

True Left bank zone (TLB)
In-stream zone (IN)
True Right bank zone (TRB).

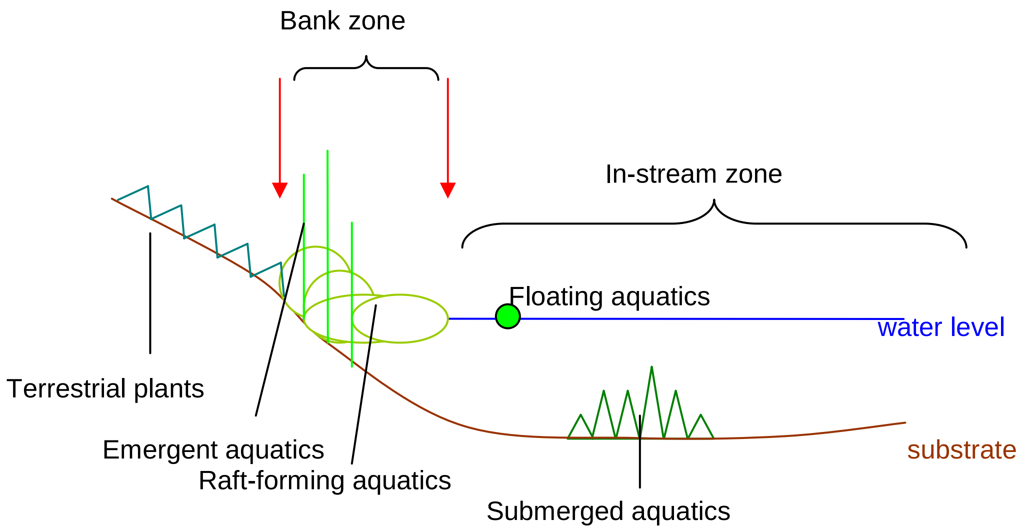
It was important to be able to delineate the boundary between the zones, especially with the terrestrial or riparian margins (which were not sampled). For free-flowing streams this was not especially difficult, although some streams did demonstrate fluctuations in water level. Where it became a problem was within the tidal parts of the rivers. All three rivers have extensive tidal sections (although this is highly modified on the Styx River by tidal gates), so there are long lengths that have fluctuating levels comprising both saline water exchange and backed-up river water fluctuations.

At each site the following aquatic macrophyte growth forms were used:

- **Floating**. (sometimes called 'floating unattached') These plants are not attached to the bank or the bottom of the waterway. Their leaves float on the water and their roots hang into it. They are generally found in slow-moving or still water or trapped amongst the stems of other larger plants along stream margins. Examples: *Lemna minor*, *Azolla filiculoides*.
- **Submerged**. These are rooted in the substrate at the bottom of the waterway or in some cases attached to other plants or surfaces (e.g. *Nitella*). They do not generally extend to the surface although some develop floating leaves. In some cases their flowers are borne on long stems that do reach the waters surface. Some submerged macrophytes become emergent or rafting plants as they increase in size. Examples: *Potamogeton ochreatus*, *Ruppia polycarpa*.
- **Emergent**. These are rooted at the bottom of the waterway and generally grow above it. They are usually found in shallow waters along the edges of rivers, backwaters or ponds. Examples: *Juncus subnodulosus*, *Carex secta*.
- **Raft-forming** (sometimes referred to as '**floating attached'**). These plants are rooted in the substrate on the bottom or in the bank itself and form a floating mass of vegetation that often extends from the bank into the waterway. Examples: *Nasturtium officinale*, *Glyceria fluitans*.

Some species can exhibit a mixture of growth forms often depending on the situation, and may be submerged, emergent and raft-forming.

Fig 1. Schematic diagram showing the vegetation zones and growth forms.



At each site, separate measurements were made for the three (TLB, IN, TRB) zones. In each zone, all aquatic macrophyte species present were recorded. Species abundance was subjectively estimated on the standard 'dafor' scale which represents the following cover classes:

5	75 – 100% cover	D = Dominant
4	50 - 75% cover	A = Abundant
3	25 - 50% cover	F = Frequent
2	5 - 25% cover	O = Occasional
1	less than 5% cover	R = Rare.

Sampling was often difficult because of various constraints, especially where the rivers were wide and could not be waded safely. To maximise data reliability, the following techniques were used:

- Use of vantage points above the river. Bridges are the obvious choice and many sites were situated near bridges. The Heathcote River in particular has many foot-bridges as well as road bridges. Large trees with overhanging branches were occasionally well placed and used.
- Choosing climatic conditions that allowed easier observation. These included, wind-less conditions, observations when the glare form the sun was minimal, use of polarised sunglasses, and visiting tidal areas at low tide.
- All three zones were examined from both sides. Observations were made from above the bank and from the opposite side using binoculars (this method proved to be most effective). In-stream data is similarly collected from both sides.
- For large rivers in some situations where in-stream data could not be collected by either direct observation and/or wading, a sample collection method was employed. Submerged aquatic macrophytes were retrieved using a 30 m long stout line with weights and attached treble fishing hooks. The barbs on the hooks were flattened and the points blunted for safety reasons. The line was thrown out into the river allowed to sink into the macrophytes (if they were present) and quickly retrieved. If the retrieval rate was too slow,

the hooks were dragged along the bottom and caught macrophytes all the way rather than just at the point of landing. At each site, 30 such 'retrieves' were used, 15 from each bank. This involves dividing the 20m bank length into 5 equally spaced sampling points and at each point the line was thrown in three times so that it landed approximately 10%, 25% and 40% of the distance across. This gave good coverage of the In-stream zone. Where macrophytes were not abundant, it was necessary to aim for any visible clumps and estimate their size in relation to the sample area.

To check on the sampling techniques, a selection of sample points were re-visited and re-sampled a few days later to ensure similar results. Also, some records were checked by using an independent observer to verify the measurements.

2.3 Analysis

The results were analysed using multivariate analysis to determine plant associations (classification). The method was Cluster Analysis with a flexible sorting strategy and a centroid distance measure. The analyses were performed using the SPSS software package V14.0. The three main catchments (Styx Avon, Heathcote) were analysed separately and the classifications compared. In each case some sites were excluded if they formed associations comprising fewer than four sites in the community. These are covered in the results.
For each site the three zones were combined to produce a single cover value used in the analyses. Combining the data recognised the varying relative sizes of the 3 sample zones. This was done using the ratios shown in Table 1.

Table 1. Ratios and formulae used to determine site cover values from the three sample zones at each site.

Size of stream	***Ratio***	***Formula***
Small (up to 2 m wide)	1:1:1	⅓ TLB + ⅓ IN + ⅓ TRB
Medium (2 to 5 m wide)	1:2:1	¼ TLB + ½ IN + ¼ TRB
Large (over 5 m wide)	1:3:1	$^{1}/_{5}$TLB + $^{3}/_{5}$ IN + $^{1}/_{5}$TRB

3.0 Results

3.1 Avon River

The community names are listed in Table 2 and the cover values for the 12 communities are shown in Table 3. The interpretations of the composition for each, along with the notable outliers are detailed in Appendix 1.

Table 2. The 12 Avon River communities.

Community	Description
A1	Waterways with varying but sparse plant cover
A2	*Glyceria fluitans* aquatic grassland in narrow streams
A3	*Juncus bufonis - Polygonium persicaria - Callitriche* herbfield in narrow streams
A4	*Nasturtium officinale – Callitriche stagnalis* emergent herbfield in narrow (& some wide) streams
A5	*Myriophyllum propinquum* submerged aquatic herbfield in wide streams & rivers
A6	*Elodea canadensis* submerged aquatic herbfield in rivers
A7	*Elytrigia repens - Polygoinum persicaria* / *Potamogeton crispus* aquatic herbfield in narrow streams
A8	*Ruppia polycarpa - Potamogeton ochreatus* - filamentous green algae submerged aquatic herbfield in rivers
A9	*Elodea canadensis - Potamogeton ochreatus - Nitella hookeri* submerged aquatic herbfield in rivers
A10	*Potamogeton ochreatus - P. crispus* submerged aquatic herbfield in tidal rivers
A11	*Iris pseudacorus / Potamogeton crispus - Myriophyllum triphyllum - P. pectinatus – P. ochreatus* submerged aquatic herbfield in rivers
A12	*Apodasmia similis* restiad saltmarsh in tidal rivers

Table 3. Avon River Community Types and species present. The values are mean percentage cover value for that community. A + is present but less than 0.1 cover value. Those with greater than 1.0 cover value are shown in bold. Minor species are excluded.

Community type No. of Sample Sites	A1 125	A2 8	A3 5	A4 7	A5 12	A6 14	A7 6	A8 11	A9 5	A10 13	A11 4	A12 6
Enteromorpha	+							0.3				+
Filamentous green algae - various	0.2	0.3	+	0.3	+		0.3	**1.1**		+	0.3	+
Periphyton	0.2				0.3	+						
Estuarine Brown algae	+							0.5				
Gracillaria sp.	+											0.8
Nitella hookeri	0.1	+			0.5	0.6	+	0.4	**1.2**	**1.2**	+	
Leptodictyum riparium	0.2	0.4	+	0.5	0.3	+						
Hypolepis ambigua	+	+			+				0.3	+		
Elodea canadensis	0.1				0.6	**1.1**	+	+	**1.9**	**1.2**	0.3	
Ruppia polycarpa	+					+		1.7			0.6	
Potamogeton cheesmanii	+	+									0.6	
Potamogeton ochreatus	+	+				+		**1.4**	**1.7**	**2.8**	**1.0**	
Potamogeton crispus	0.2	+		+	0.3	0.4	3.0	0.8	0.3	**1.7**	**2.2**	
Potamogeton pectinatus								+			**1.6**	
Juncus bufonius	+	+	0.8									
Juncus articulatus	+	0.4	+	0.3	+	+			+		+	
Juncus effusus	0.1	0.4	0.3	+	+	+			0.3	0.4		
Juncus krausii var. australiensis	+							+				0.6
Apodasmia similis	+										+	**2.4**
Iris pseudacorus	+			+		+		+	+	0.9	**1.5**	
Typha orientalis						0.3				+		
Cyperus eragrostis	0.1	+	0.4	0.5	+	+	+		+	0.3	+	
Schoenoplectus tabernaemontanii						+		+		+	0.5	
Carex secta	0.1	+	+	0.3	+	+	0.4	+	0.5	0.3	+	
Glyceria fluitans	0.1	**1.6**	+	0.5	0.6	+	0.5	+		+		
Elytrigia repens	+	+	0.6	+		+	**1.0**	0.3	+	+	+	+
Holcus lanatus	+	0.3		+	+	+	+		+	+	+	
Poa annua	+		0.5									
Agrostis stolonifera	0.1	0.9	+	0.5	+	+	+	+	0.3	0.4	+	
Schedonorus phoenix	0.1	+				+	+	0.3	0.3	+	0.4	0.4
Ranunculus repens	0.1	0.2	0.3	+		+	0.5	+	+	0.3	+	
Solanum dulcamara									0.5			
Nasturtium aquaticum	+	0.2	+	**1.5**	+	+	0.4	+	+	+	+	
Polygonum persicaria	0.1	0.2	0.7	+		0.3	1.0	+	0.3	+	+	
Rumex obtusifolius	0.1	0.2	+	+	+	+	0.3		+	+	+	
Myriophyllum triphyllum								0.3		+	**2.2**	+
Myriophyllum propinquum	+	+	+	0.3	**1.9**					+		
Callitriche stagnalis	0.2	0.6	0.7	**1.0**	0.3	0.4	+	+	0.3	+	0.6	
Urtica linearfolia		0.2							+	+		
Plagianthus divaricatus	+											0.7
Trifolium repens	+		0.3									
Salix cinerea	+			+					0.4	+		
Alnus glutinosa	+								0.4	+		
Coprosma lucida	+		+						0.3	+		
Plantago major	+	+	0.7			+	+			+		
Mimulus guttatus	+	+		0.5	+	0.9	+		+	+		

3.2 Heathcote River

The community names are listed in Table 4 and the cover values for the 12 communities are shown in Table 5. The interpretations of the composition for each along with the notable outliers are detailed in Appendix 1.

Table 4. The 12 Heathcote River communities

Community	Description
H1	*Potamogeton crispus – P. ochreatus* submerged aquatic herbfield and associated types
H2	*Glyceria fluitans – Agrostis stolonifera* aquatic herbfield and associated types
H3	Waterways with varying but very sparse plant cover
H4	*Glyceria fluitans* aquatic grassland in streams and rivers
H5	*Potamogeton crispus – P. ochreatus* submerged aquatic herbfield in rivers
H6	*Callitriche stagnalis* herbfield in narrow (& some wide) streams
H7	*Nasturtium officinale* emergent herbfield in springs and narrow streams
H8	*Glyceria fluitans – Nasturtium officinale / Elodea canadensis* submerged aquatic herbfield in wide streams
H9	*Agrostis stolonifera* aquatic grassland in narrow streams
H10	*Glyceria fluitans - Ranunculus repens* aquatic grassland in streams
H11	*Elytrigia repens / Callitriche stagnalis* aquatic grassland in narrow streams and rivers
H12	*Enteromorpha* aquatic algalfield in tidal narrow streams

Table 5. Heathcote Community Types and species present. The values are mean percentage cover value for that community. A + is present but less than 0.1 cover value. Those with greater than 1.0 cover value are shown in bold. Minor species are excluded.

Community type	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**	**H11**	**H12**
No. of Sample Sites	**38**	**64**	**25**	**12**	**9**	**13**	**5**	**9**	**6**	**7**	**4**	**4**
Enteromorpha	+											**3.0**
Ulva lactuca	0.2											0.3
Filamentous green algae - various spp	+	+	+	0.3	+	+	0.2		+	0.5		0.4
Estuarine brown algae	0.2										0.4	
Gracillaria sp.	+										0.5	
Nitella hookeri	+	0.1	+	0.2	+	+	+	0.6			+	
Leptodictyum riparium	+	0.2	0.3	+			+	+	0.2	0.6	0.3	
Azolla filiculoides		+					0.6	0.2				
Elodea canadensis	+	0.2	+	+	0.2			**2.6**		+	0.6	
Ruppia polycarpa	+	+		0.2								
Potamogeton ochreatus	0.6	0.1	+	0.3	**1.1**						0.6	
Potamogeton crispus	0.9	0.3	+	+	**1.9**	+	**1.2**	+		+	0.4	
Potamogeton pectinatus				0.2	0.2							
Lemna minor	0.3	0.1	0.2			0.2	**1.4**	0.6		+		
Juncus articulatus		+		0.3	+	0.2	0.2	+	+	+	+	
Juncus subnodulosus					0.3							
Juncus effusus	+	+		+	0.2	0.4	+		0.7	0.8	+	
Juncus krausii var. *australiensis*	0.2											
Apodasmia similis	0.2	0.1		+	+							
Phormium tenax	0.2	+	+	0.2	+				+	+	+	
Typha orientalis	+	+		0.2	+							
Cyperus eragrostis	+	0.1		0.3	0.3	+			+	+		
Carex maorica									0.2	0.2		
Carex secta	+	+	+	+	+	0.4			+	+		
Carex virgata	+	+	+	0.3		+				+		
Phalaris arundinacea	+	+		0.3	+	+					+	
Glyceria fluitans	0.2	0.4	+	**1.1**		0.3	0.6	**1.6**	+	**2.3**		
Elytrigia repens	0.4	+	+	+	+	+	+		+	0.4	**2.3**	
Agrostis stolonifera	+	0.4	0.3	0.3	0.4	0.9	**1.2**	0.8	2.8	0.8	+	
Schedonorus phoenix	0.4	+		0.4	0.8				0.3		+	
Ranunculus sceleratus		+	+	+		0.2	+	+				
Ranunculus repens	0.4	0.3	+	0.6	0.4	0.5	**1.3**	0.6	0.7	**1.3**	+	
Nasturtium aquaticum	+	0.2	+	0.7	0.5	0.2	**2.2**	**1.0**	+	+	+	+
Polygonum persicaria	+	0.1	+		0.5	0.4	+	+	**1.2**	0.3	0.3	
Rumex obtusifolius	0.2	0.2	+	0.2	0.2	0.2	+	+	0.4	0.3	0.3	
Rumex crispus	+	+	+	+	0.4	+	+	+	+	+	+	
Sarcocornia quinqueflora	0.3											
Myriophyllum triphyllum							**1.1**					
Myriophyllum propinquum	+			+		0.2		0.2	0.3			
Epilobium ciliatum	+	+	+	+							0.3	
Callitriche stagnalis	+	0.3	+	0.5	0.9	**2.0**	0.4		+	+	0.7	+
Plagianthus divaricatus	0.4	+		+	0.8							
Picris echiodes	+	+		+	0.2							
Cotula coronopifolia	+	+		+	+		0.2					+
Plantago major		+		+	0.2	+			+	+	+	
Plantago coronopus	0.3	+		+								
Plantago lanceolata	+	+			0.3		+		+		+	
Samolus repens	0.2	+										+
Myosotis laxa	+	0.1		0.2	+	+			+	0.2	+	
Limosella lineata		0.1									0.6	
Mimulus guttatus	0.2	0.1	+	+	0.5	0.3		+		+	0.4	

3.3 Styx River

The community names are listed in Table 6 and the cover values for the 12 communities are shown in Table 7. The interpretations of the composition for each along with the notable outliers are detailed in Appendix 1.

Table 6. The 12 Heathcote River communities

Community	Description
S1	*Nasturtium officinale* aquatic emergent herbfield in narrow streams
S2	*Glyceria fluitans* aquatic grassland in narrow streams
S3	Narrow streams with varying but sparse plant cover
S4	*Agrostis stolonifera / Potamogeton ochreatus* aquatic grassland in wide streams
S5	*Apodasmia similis* restiad rushland saltmarsh in tidal rivers
S6	*Nitella hookeri* aquatic algalfield narrow stream, in wide streams and rivers
S7	*Glyceria fluitans / Potamogeton crispus* aquatic grassland in wide streams
S8	*Veronica anagallis-aquatica / Agrostis stolonifera – Nasturtium officinale* emergent herbfield in wide streams
S9	*Glyceria fluitans – Nasturtium officinale – Elytrigia repens / Nitella hookeri* aquatic grassland in wide streams
S10	*Juncus effusus / Glyceria fluitans* rushland in narrow streams
S11	*Schedonorus phoenix* grassland in wide streams
S12	*Elodea canadensis – Potamogeton crispus* submerged aquatic herbfield in rivers

Table 7. Styx Community Types and species present. The values are mean percentage cover value for that community. A + is present but less than 0.1 cover value. Those with greater than 1.0 cover value are shown in bold. Minor species are excluded.

Community type No. of Sample Sites	S1 5	S2 8	S3 40	S4 2	S5 4	S6 20	S7 13	S8 2	S9 2	S10 5	S11 2	S12 22
Filamentous green algae - various	+	+	0.1			+				0.4		+
Nitella hookeri	+	0.3	0.1			0.9	0.2	+	**2.1**		+	0.4
Fissidens rigidulus	0.3		+									
Riccia sp.			0.1				+					0.2
Styx Liverwort	0.3											
Azolla filiculoides		+	0.1			+	+			**1.4**	0.5	0.3
Elodea canadensis		+	+			0.4	0.5		**1.0**	+	0.6	**2.8**
Zostera capricornii					0.9							
Potamogeton ochreatus			+	**1.0**		+						+
Potamogeton crispus	+	+	0.2			0.4	**1.7**		+	0.8	**1.0**	**1.1**
Lemna minor	+	0.5	0.1			0.8	0.2	0.5	+	0.9	0.6	0.3
Juncus articulatus	+	0.5	+				0.3					+
Juncus effusus	0.3	+	0.1	+		+	0.3		+	**2.6**	+	+
Juncus krausii var. *australiensis*					0.7							
Apodasmia similis					**1.6**							
Cyperus eragrostis			0.1			+	+			0.3		
Schoenoplectus pungens			+		0.6							
Glyceria fluitans	+	**1.6**	0.2	+		0.4	**2.2**	0.5	**2.5**	**2.6**	**1.0**	0.7
Elytrigia repens	+	+				+			**1.7**			
Holcus lanatus			+			+			0.5	+		
Agrostis stolonifera		+	0.1	**2.1**			+	**2.4**			+	0.2
Schedonorus phoenix			+		+	0.2	0.2		0.7	+	**3.5**	0.2
Ranunculus trichophyllus			+				0.2					
Ranunculus repens	+	0.3	+	0.3		0.2	0.2	**1.0**	0.6	+	+	0.3
Nasturtium officinale	**3.1**	0.5	0.1			0.4	0.8	**2.2**	**1.6**	0.8	0.7	0.7
Rumex obtusifolius		+	0.1	0.3			+	+		+		+
Rumex crispus		+	+			+	0.2	0.5	+	+	+	+
Epilobium ciliatum		+	+			+		0.6				
Ludwigia palustris											0.5	+
Callitriche stagnalis	+	+	0.1	0.8		+	0.2			+		+
Salix fragilis							0.2					
Myosotis laxa	0.3	+	+			+	+			0.3	+	
Mimulus guttatus		+	+			0.2	0.7		+		**1.0**	0.3
Veronica anagallis-aquatica			+				+	**1.2**	+			

3.4 Data Availability

The data produced during this survey or any part of it will be made available on request on CD from Christchurch City Council Botanist (Dr. Trevor Partridge) or the senior author (W. van den Ende).

4.0 Discussion

4.1 Identifications of Aquatic Species

In order to understand the results that follow, especially the comparisons with earlier studies, the following interpretations of earlier identifications have been made.

Potamogeton ochreatus
This native aquatic macrophyte has been recorded in some previous studies (e.g. Robb 1992, Robb et al. 1994) but was not listed at any sites in Robb et al (1980). Nor was it recorded by Connor (1953). Yet, as found in this study it is now very common. There are three possible interpretations:

- *P. ochreatus* has established and/or expanded considerably since those earlier studies. As a native species that is well within its natural range, this is considered unlikely
- *P. ochreatus* has been considerably under-recorded in the past. It can be quite cryptic and if mixed with *P. crispus*, difficult to separate from a distance.
- *P. crispus* has been recorded in error for *P. ochreatus*. This is likely as the two are similarly coloured. However, the strongly wavy margins of the latter are clear and distinguish the two.

Potamogeton pectinatus
This native aquatic macrophyte was never recorded in earlier studies. It may have been confused with *Ruppia polycarpa*.

Ruppia megacarpa
The 1980 study recorded both *Ruppia megacarpa* and *R. polycarpa*, and the 1994 study only *R. megacarpa*. However, during this study, no plants were seen that match *R. megacarpa*, so we are uncertain as to what was recorded earlier. If *R. megacarpa* has disappeared it is an unfortunate loss. It is however plentiful nearby in Te Waihora/L. Ellesmere. It is assumed in this study that all previous records of *R. megacarpa* are *R. polycarpa*.

Myriophyllum
Some earlier studies list both species (*M. propinquum*, *M. triphyllum*) as present, but they are not separated in the site data. In this study, the two have been recorded separately. Although recorded from the lower Waimakariri River (Webb et al. 1995), no specimens of the exotic *M. simulans* were found. It differs little from *M. propinquum*, and specimens need to be in flower for full confirmation.

Glyceria maxima
Robb (1992) refers to *G. maxima* as being ‘floating sweetgrass’. It should be referred to as being reed sweetgrass. Floating sweetgrass is usually *G. fluitans*. Hence the earlier records of *G. maxima* need to be treated with a degree of uncertainty. The 1994 records (Robb et al. 1994) do seem to be correct. *G. maxima* is becoming a problem in the Heathcote River and is also found in the Avon River. Its expansion has been very recent and knowing how long it has been in Christchurch is important.

Aquatic bryophytes
This study identified individual species of which *Leptodictyum riparium* (formerly *Amblystegium riparium*) is the most common. A species of *Fissidens* was also occasionally found. In the earlier studies, this group was referred to as 'aquatic mosses' but *Riccia* sp. and an unidentified "Styx liverwort" is included in this study. The term 'aquatic bryophytes' is used in this report for comparisons between the studies.

There are of course the usual taxonomic name changes as well.

4.2 Changes since 1980

It became clear during the visits to the sampling sites, that the intended comparisons with the results of Robb et al (1980, 1994) were not as straightforward as was originally expected. This was mainly because this many years' gap in this kind of habitat in an urban environment was simply too long a period between records. Christchurch City Council has during this time, undertaken a great many projects on the rivers, including riparian plantings, tree removal (especially willows), the ongoing process of macrophyte cutting, stream re-alignment, naturalizing previously boxed drains, and construction of banks including gabion baskets and walls to halt erosion. All these have had major impacts upon the aquatic vegetation, especially that closer to the banks such as the emergent plants. Many such changes have occurred as a result of subdivision and urbanization of previously rural land. Only the Styx River and the upper reaches of Cashmere Stream on the Heathcote River have streams still flowing through a rural landscape, and those areas are themselves likely to be subject to future subdivision.

Many of the sites used by Robb et al (1980) could not be relocated accurately. In those pre-GPS times, they were described using local features. Some, such as bridges still exist, but others based on trees and buildings had changed so much that it was not possible to know exactly where the site was. In some extreme cases the stream itself had been re-located. The sample points used in this study are all re-locatable from GPS points.

The nature of the data also differs from the previous studies. The 1980 to 1994 studies used presence/absence data for points, whereas in this study, the data is quantitative. Quantitative data is not easy to obtain in these habitats and the 'three habitat' division of the site, combined with the width ratio multipliers (Table 1) give a fair representation of the cover classes across the river, be that a narrow headwater stream or a wide flowing river. The aims of this project were such that it was felt important to have quantitative data, as it was hoped to be able to use the data to make management decisions regarding biodiversity issues or aquatic plant removal.

However, despite these limitations, some broad comparisons can be made by reducing the data from this study to presence/absence and comparing it on a catchment basis with that of the four previous studies from 1980 to 1994.

The changes in species frequency of the main species in the Avon River is shown in Table 8. Some of the patterns within the previous studies are highly erratic (e.g. *Glyceria* spp.) while others show clear and interpretable trends. Species to show major decline since the original four samplings include filamentous green algae and water bryophytes. Other species have remained fairly consistent, such as *Nitella hookeri*, *Ruppia* spp., *Callitriche stagnalis* (which is the most frequent species in 2007) and *Mimulus guttatus*. A few species have shown a steady increase since 1980, most notably *Potamogeton crispus*. Others that appeared to be in decline, have instead reversed that process since 1994 including *Elodea canadensis*, *Myriophyllum* spp. and *Agrostis stolonifera*.

Table 8. Percentage frequency of key plant species in the Avon River and tributaries at the five different sampling times. nr = not recorded.

	1980	**1986**	**1989**	**1994**	**2007**
filamentous green algae	62	73	47	71	30
water bryophytes	36	51	73	51	27
Nitella hookeri	29	34	26	32	28
Elodea canadensis	23	12	11	8	26
Potamogeton cheesemanii	10	2	9	13	5
Potamogeton ochreatus	nr	2	nr	10	20
Potamogeton crispus	6	16	18	23	36
Myriophyllum spp.	27	11	7	5	17
Ruppia spp.	10	9	9	8	10
Callitriche stagnalis	17	50	36	47	47
Agrostis stolonifera	30	30	15	5	31
Glyceria spp.	47	8	8	20	33
Nasturtium officinale	12	18	14	17	20
Ranunculus repens	5	36	29	36	24
Ranunculus sceleratus	nr	1	2	13	4
Mimulus guttatus	nr	11	17	17	21

In the Avon River, the greatest change in the truly aquatic (mostly submerged) species has been the replacement of filamentous green algae and the water bryophytes with the aquatic macrophytes *Callitriche stagnalis* and *Potamogeton crispus*. The other aquatic species have shown signs of recovery following periods of decline between 1980 and 1994 or remained stable, and of these the stability in the native *Myriophyllum* spp. is of special significance, as it was feared that it might disappear altogether (Robb et al 1994). The emergent species growing along the margins appear to have changed considerably, but caution needs to be exercised here, as the exact boundary of the aquatic to riparian zone may be very different. This is especially so in regard to the 1980 sampling in which the margin species are very under-represented.

Table 9. Percentage frequency of key plant species in the Heathcote River and tributaries at the five different sampling times. nr = not recorded.

	1980	**1986**	**1989**	**1994 ***	**2007**
filamentous green algae	55	48	62	61	21
water bryophytes	5	25	32	39	20
Nitella hookeri	38	32	30	24	19
Elodea canadensis	5	1	nr	1	17
Potamogeton cheesemanii	3	6	14	7	2
Potamogeton ochreatus	nr	11	7	12	17
Potamogeton crispus	8	16	20	35	32
Myriophyllum spp.	8	10	10	7	7
Ruppia spp.	6	nr	1	9	5
Callitriche stagnalis	9	59	24	40	42
Agrostis stolonifera	10	27	39	13	52
Glyceria spp.	31	35	34	41	45
Nasturtium officinale	9	29	19	33	34
Ranunculus repens	1	54	42	50	53
Ranunculus sceleratus	nr	23	nr	20	10
Mimulus guttatus	5	31	45	32	25

* This sampling covered only 3/4 of the sites

The changes in species frequency in the Heathcote River have been so great that it is difficult to imagine what the vegetation would have looked like in 1980 (Table 9). At that time, its aquatic component was mostly filamentous algae and the macro-algae *Nitella hookeri*, with patches of *Gylceria fluitans* along the margin. By the time of the 1986 sampling, the situation was beginning to change with an increase in cover of margin species in particular, but also many of the aquatic components. In 2007, the Heathcote River comprised a considerable diversity of submerged and rafting plants both in the water (e.g. *Potamogeton crispus*, *Callitriche stagnalis*) and along the margins (e.g. *Agrostis stolonifera*, *Ranunculus repens*). Indeed, the number of species per sampling site has virtually doubled, from 1.22 in 1980 to 2.22 in 2007. Quantitative data from the earlier sampling times would have been of considerable value in determining the scale of aquatic plant increase.

The Heathcote River catchment has undergone some spectacular changes during this period, that may have been the cause of these changes in composition. Firstly, there has been major urbanisation of the Port Hills, with consequent increases in sediment runoff into the river. Second, the construction of the Woolston Cut, and the change in hydrology and salinity regimes had major impacts on the Lower Heathcote River. Third, the construction of flood retention basins in the upper reaches has resulted in an amelioration of flood peaks. Those floods no longer scour the sediment from the river downstream, and now that the aquatic macrophytes such as *Potamogeton crispus* hold this sediment, scouring becomes even less likely.

The changes in species frequency in the Styx River (Table 10) are much greater than might be expected from a catchment that has retained much of its rural character, but apart from the remarkable stability of *Elodea canadensis*, and *Nasturtium officinale*, this is not the case. The filamentous green algae and water bryophytes have declined considerably, the latter to very low frequency. They have been replaced by a large number of aquatic macrophytes, floating and raft-forming species of which *Potamogeton crispus* and

Glyceria fluitans have increased most. Indeed, many of these plants were not at all common in 1980. As with the other rivers, there has been a major increase in marginal emergents but this may be partly a product of the sampling. There have also been some remarkable fluctuations in species such as *Callitriche stagnalis*, *Agrostis stolonifera*, and *Ranunculus repens*.

Table 10. . Percentage frequency of key plant species in the Styx River and tributaries at the five different sampling times. nr = not recorded.

	1980	**1986**	**1989**	**1994***	**2007**
filamentous green algae	26	54	51	78	18
water bryophytes	26	27	51	41	5
Nitella hookeri	46	51	68	54	33
Elodea canadensis	32	21	35	27	32
Potamogeton cheesemanii	1	5	4	6	4
Potamogeton ochreatus	nr	nr	nr	nr	5
Potamogeton crispus	2	34	30	29	40
Myriophyllum spp.	10	1	nr	1	4
Ruppia spp.	2	2	nr	3	nr
Callitriche stagnalis	16	54	10	46	24
Agrostis stolonifera	10	8	24	3	21
Glyceria spp.	12	39	17	62	61
Nasturtium officinale	27	47	43	43	42
Ranunculus repens	1	58	5	57	46
Ranunculus sceleratus	nr	41	nr	29	5
Mimulus guttatus	nr	21	31	25	29

* The Styx River drains were not sampled so the data only covers the main rivers

The predominantly rural environment has therefore not spared the Styx River from the changes similar to those seen in the Avon and Heathcote Rivers. It too has gone from being an algae-dominated system to one in which aquatic macrophytes predominate. This change may be related to the increased urbanization in the upper reaches of both the Styx River and its main tributary, Kaputone Stream. Large silt loads now characterize the river and provide habitat for *Potamogeton crispus* in particular. Changing agricultural practices along the rural riverbanks have probably allowed for the increase in raft-forming species such as *Gylceria fluitans* and *Nasturtium officinale*.

Setting aside the effects that may be explained as differences in sampling techniques for species such as *Mimulus guttatus*, *Ranunculus repens* and *Agrostis stolonifera*, the major difference recorded in the rivers of Christchurch, has been the replacement of the algae and bryophytes by vascular aquatic macrophytes, especially *Potamogeton crispus* and *Callitriche stagnalis* (Table 11). There have been increases in the mat-forming marginal aquatics as well, especially *Nasturtium officinale* and *Glyceria fluitans*. This indicates that the rivers are now far more vegetated, both in-stream and on the margins than they were in 1980. It is interesting to note however, that the greatest changes have occurred in the Heathcote and Styx River catchments, while the Avon River catchment has changed far less.

There are two likely generalised explanations, which are probably linked. The first involves management of the waterways. During the time of the surveys between 1980 and 1984, the rivers of Christchurch were managed for drainage purposes and the priority was to keep the river bed and its margins clear of vegetation so that water, especially that which fell during heavy rainfall events, would drain away as rapidly as possible. In the intervening 27 years, there have been many changes to that philosophy, resulting in rivers that are very different today. The construction of stormwater retention basins and swales in subdivisions and the ‘daylighting’ of drains, result in there no longer being such a need for the rivers to act as conduits for large flows, meaning that their bases and margins need no longer be kept so very clear of vegetation. Coupled with this is an increasing appreciation of the ecological values of waterways, resulting in extensive riparian plantings and a desire to ‘naturalise’ the city’s rivers and streams.

The second reason is that the ecology of the rivers have changed. There are strong indications that there has been major ecological change in the rivers, mainly as a result of increased sedimentation in the waterways. This seems to have been greatest in rivers downstream of major subdivisions such as on the Port Hills for the Heathcote River and Northwood in the Kaputone Stream tributary of the Styx River. In the Heathcote, this coupled with increased sedimentation down Bowenvale Valley as the result of ongoing land instability, has resulted in large amounts of sediment being deposited in the lower Heathcote. This sediment drops out in the tidal sections of the river downstream of Beckford Road, the very sections where *Potamogeton crispus* has come to dominate. Further downstream, in the estuarine parts of the Lower Heathcote River, increased sedimentation have been implicated in the death of the stands of sea rush salt marsh (*Juncus krausii*) (Partridge 2005).

In the Styx River, the sedimentation problems have become accentuated by the disappearance of headwater springs, thus reducing the capacity of the river to flush sediments. So the implicated subdivisions not only add the sediment, but also reduce the flows are compounding the problem. This has probably also occurred in the past on the Avon River, but its earlier urbanisation suggests that even by the time of the survey of Robb et al (1980) the changes had already occurred. The upper reaches of the many branches of the Avon River no longer carry water as they once did through suburbs such as Avonhead. As to the outcome of this process for both the Styx and Heathcote Rivers, especially considering the changing management regimes, the Avon River may be an example of what might happen in the future.

These changes have resulted in less demand for cutting back ‘weeds’ both in the rivers and along their margins. This would clearly result in the replacement of the highly ephemeral freshwater algae, *Nitella* and aquatic bryophytes, by larger, longer-lived plants such as *Potamogeton crispus* in the riverbed, and the development of raft-forming plants and emergents at the margins. The one river for which such changes have been least is the Avon River, and indeed, much of its margins, especially close to the central city, are still maintained in the highly manicured manner of earlier times, except for the characteristic plantings of *Carex secta* along the margin.

Table 11 summarises the changes in frequency using just the 1980 and 2007 samplings, in a way that emphasises the changes and allows for comparisons between the three rivers.

Table 11. Summary of species frequency changes in the three catchments. Only those species covered in both surveys are included.

Species	Avon	Heathcote	Styx	Total	Explanation
Filamentous green algae	-31	-39	-16	-86	Declined in all catchments, esp. Avon & Heathcote
Nitella hookeri	-9	-21	-13	-43	Declined in all catchments, esp. Heathcote
water bryophytes	-14	8	-27	-33	Declined in Styx and Avon, small increase in Heathcote
Ruppia megacarpa	-8		-3	-11	Not recorded in this study. Identification uncertain
Myriophyllum spp.	-3	-2	-6	-11	Slow decline everywhere. Two taxa – Robb treats as one
Potamogeton cheesemanii	-7	-1	3	-5	Fairly stable. Slight decline in Avon
Spartina anglica		-2		-2	Subject of major control programme
Lagarosiphon major			-1	-1	Pest plant not seen in 2007
Ruppia polycarpa	8	-2	-3	3	Increase in Avon only. Confused with *R. megacarpa*?
Glyceria maxima	1	2		3	Slow increase
Bolboschoenus caldwellii	1	3	1	5	Salt marsh – sampling method difference?
Schoenoplectus pungens	2	1	2	5	Salt marsh – sampling method difference?
Isolepis cernuus	4	1	1	6	Salt marsh – sampling method difference?
Typha orientalis	2	3	2	7	Increased by plantings
Iris pseudacorus	8	0	2	10	Recent increases in Avon. Some control
Mentha X*piperita*	2	1	9	12	Becoming more common in Styx especially
Elodea canadensis	4	12	-1	15	Remarkably stable. Some increase in Heathcote
Azolla filiculoides		4	19	23	Increasing in Styx
Juncus articulatus	8	13	5	26	Increase due to sampling differences?
Myosotis laxa	8	13	15	36	Even increase in all catchments
Nasturtium officinale	1	25	16	42	Big increases in Heathcote and Styx
Lemna minor	4	24	23	51	Big increases in Heathcote and Styx
Agrostis stolonifera	1	42	14	57	Increase due to sampling differences?
Glyceria fluitans	-7	14	51	58	Variable behaviour. Massive increase in Styx
Juncus effusus + *J. edgariae*	25	11	26	62	Increase due to sampling differences? Planting?
Callitriche stagnalis	30	32	7	69	Major increases in Avon and Heathcote
Potamogeton crispus	30	22	38	90	Major increases in all catchments.
Ranunculus repens	24	52	45	121	Increase due to sampling differences?

The comparative stability of the Avon River is again clear. The changes there have been matched or exceeded by both the Heathcote and Styx Rivers in terms of both increases and declines in species frequency. Some of the less frequent species do differ, for instance the increase in *Iris pseudacorus* and the decline in *Potamogeton cheesemanii* are greatest in the Avon River. Also, there has been a decline in *Glyceria fluitans*, while the other rivers have shown increases. The situation regarding the Ruppia species is probably the result of different identification determinations.

The sizes and directions of change in the Heathcote and Styx Rivers are similar, although there are differences between the two. *Callitriche stagnalis* and *Agrostis stolonifera* have increased more in the Heathcote River, and *Glyceria fluitans*, *Azolla filiculoides* and *Mentha Xpiperita* in the Styx River. The decline in filamentous green algae and *Nitella hookeri* have been greater in the Heathcote River, and *Myriophyllum* spp. in the Styx River. The only major difference in direction has been in the water bryophytes which have increased in the Heathcote River, but declined considerably in the Styx River.

It is unfortunate that such a long gap has occurred since the samplings of 1994, especially considering that prior to that, repeat recordings were frequent. It is therefore important that some form of follow-up sampling occurs on a regular basis. This should occur every 5 years. That need not constitute such a detailed study, but can concentrate on covering critical sites and communities, especially those of greatest biodiversity value.

4.3 Biodiversity

The protection of indigenous flora and fauna (i.e. biodiversity) is principally achieved in the Christchurch City Plan through the designation of 50 Ecological Heritage Sites and the rules associated with these. Those sites were determined from a detailed survey of remnant indigenous vegetation undertaken by Meurk et al (1993). This covers the City before amalgamation with Banks Peninsula District. In that report, they divided the city by broad geographical and habitat criteria and by vegetation type. However, the aquatic vegetation of the city's rivers were not covered in that report, and so there were no freshwater river or stream sites either recommended or designated as Ecological Heritage Sites.

The communities with high biodiversity values are listed in Table 12. To be included, the community needed to have a total vegetative cover of >1.5, so excludes those which are characterised by low vegetative cover and therefore only covers well-vegetated communities.

The saltmarsh communities are excluded from further discussion as they form part of the vegetation of the estuaries associated with the mouths of the rivers and are typically dominated by native halophytes (McCombs & Partridge 1992). These sites are also protected as Ecological Heritage Sites as part of those estuaries.

Of the 31 remaining vegetation/catchment communities, only 3 have more native cover than exotic. All three occur in the Avon River and comprise only 27 sites. Community A8 stands out as it has both a high native cover and a low exotic component. The two dominant species are native submerged aquatics, *Ruppia polycarpa* and *Potamogeton ochreatus*. Other native species (e.g. *Nitella hookeri*, *Myriophyllum triphyllum*) are minor components. The only exotic species of any note is *Potamogeton crispus*. All sites are on the main part of the Avon River, but comprise two groups, an upstream and an estuarine group. The species they have in common is *Ruppia polycarpa* a plant not found in any equivalent abundance elsewhere.

Table 12. Communities at which the native vegetative components make the greatest contributions to vegetative cover. A is for Avon River, H for Heathcote River and S for Styx River sites. The number of sites is in brackets. * There is an ecological outlier that is most closely related to A8, making the number of sites there effectively 11.

Vegetation Type	Native	Exotic	Diff
Salt Marsh Types			
S5 *Apodasmia similis* restiad rushland saltmarsh in river (4)	3.8	0	3.8
A12 *Apodasmia similis* restiad saltmarsh in tidal river (6)	3.7	0.4	3.3
Freshwater – Native Dominated Types			
A8 *Ruppia polycarpa - Potamogeton ochreatus* - filamentous green algae submerged aquatic herbfield in river (10) *	3.8	1.4	2.4
A11 *Iris pseudacorus / Potamogeton crispus - Myriophyllum triphyllum - P. pectinatus – P. ochreatus* submerged aquatic herbfield in river (4)	6.5	5.0	1.5
A5 *Myriophyllum propinquum* submerged aquatic herbfield wide in stream & river (12)	2.7	1.8	0.9
Freshwater – Native and Exotic Mixture Types			
S6 *Nitella hookeri* aquatic algalfield in narrow stream, wide stream or river (20)	1.7	2.2	-0.5
H1 *Potamogeton crispus – P. ochreatus* submerged aquatic herbfield and associated types (38)	2.4	3.0	-0.6
A10 *Potamogeton ochreatus - P. crispus* submerged aquatic herbfield in tidal river (4)	4.3	5.2	-0.9
A9 *Elodea canadensis - Potamogeton ochreatus - Nitella hookeri* submerged aquatic herbfield in river (3)	4.1	5.0	-0.9
Freshwater – High Native Cover, Very High Exotic Cover			
H7 *Nasturtium officinale* emergent herbfield in springs and narrow stream (5)	3.3	7.1	-3.8
S10 *Juncus effusus / Glyceria fluitans* rushland in narrow stream (5)	2.3	7.4	-5.1
H5 *Potamogeton crispus – P. ochreatus* submerged aquatic herbfield in river (9)	2.1	8.2	-6.1
S9 *Glyceria fluitans – Nasturtium officinale – Elytrigia repens / Nitella hookeri* aquatic grassland in wide stream (2)	2.1	8.6	-6.5

The larger group of sites occurs upstream of Salisbury St where there is a significant and semi-continuous stand of *Ruppia polycarpa*, and extends through the central city as far as the Antigua Street boatsheds. This section of the river is non-tidal, has a relatively steep fall, water is shallow but swift, and the substrate is gravel and sand. Finer sediments are restricted to deeper and slower areas. The other sites are all in the lower Avon between the Wainoni Road Bridge and Evans Avenue. The river is tidal, wide and deep. Sea water enters the lower stretches during high tides. Water clarity is much lower and the stands of *Ruppia polycarpa* are much less dense than the upstream site. These sites also have considerable build-up of sediments.

The second community with more native than exotic cover (A11) comprises only four sites that have a high overall cover with a mixture of native and exotic species. The list of submerged aquatics is remarkable comprising 5 species. The sites are located on the lower Avon River from Corsers Stream / Briarmont Street to Culver Place. (sites all near Anzac Drive), which places them just upstream from the downstream sites of Community A8. The river here is tidal, wide and deep and is influenced by the backup of freshwater at high tides. There is however cause for alarm at the spread of the emergent *Iris pseudacorus* in this area as this plant has a major impact on the bank communities.

The third community dominated by native species cover (A5) is very different as it is dominated by *Myriophyllum propinquum*. There are suggestions that this plant and the related *M. triphyllum* may have declined considerably in recent times. Anecdotal reports suggest it has been mostly replaced by *Potamogeton crispus*. All 12 sites have formed or boxed wall and/or steep banks. This explains the relative lack of emergent species growing along the margins of the waterways. Walls were constructed of wood, concrete and rock or (in one case) gabions. At all sites water flow was rapid, due to the fall of the river at these sites. Substrates were gravel and sand with any silt and organic debris restricted to backwaters. The sites are scattered through the upper reaches of the Avon River and its tributaries.

There are 4 communities in which native and exotic species cover is fairly even (Table 12). Two (A9, A10) occur in the Avon River and, like those dominated by native species cover, are characterised by *Potamogeton ochreatus* but have only 7 sites between them. Likewise, the community on the Heathcote River (H1) has *P. ochreatus*, but it and A10 comprise approximately equal amounts of *Potamogeton crispus*. At such locations, the exotic species occurs closer to the margins, while the native species dominates the deeper water. It is quite a feature of the river, occurring at 38 sites, mostly located on the main branch of the river from the confluence with Cashmere Stream to the estuary. The fourth community (S6) is very different and occurs on the Styx River at 20 sites. They are dominated by the macro-algae *Nitella hookeri* and occur throughout the catchment on both wide and narrow streams. The only feature they seem to have in common is a fast water flow.

Four communities have been identified as having high native species cover that is greatly exceeded by exotic plant cover (Table 12). There are only 21 sites in total, and all the communities occur on the Heathcote and Styx Rivers. They comprise some of the most highly vegetated sites and have varying mixtures of submerged, raft-forming and emergent species. Community H7 occurs around springs in the upper reaches of the Heathcote River tributaries. Community H5 comprises a common combination of *Potamogeton ochreatus* and *P. crispus*, but in this case the latter dominates. The two communities on the Styx (S9, S10, with *Nasturtium officinale* and *Glyceria fluitans*, are very like rural rivers elsewhere on the Canterbury Plains and indeed occur where the Styx River flows through farmland.

The paucity of native-dominated aquatic communities shows how important these small remnants are, and how vulnerable they might be to future change. They therefore require greater recognition, and protection for their values.

There is also the need to protect some native species present in very small amounts. *Potamogeton pectinatus* for instance, is present at only a few sites in the Avon River, and *Montia fontana* subsp. *fontana* has only recently been discovered from a few locations in the Styx River. *Ruppia polycarpa*, which was probably once previously common, is now confined to a very few locations. There has been concern regarding the two native species of *Myriophyllum* being displaced by *Potamogeton crispus*. This study suggests that these are now fairly stable, although probably in much diminished abundance. The sites where these highly restricted native aquatic species are found require monitoring, and if under threat of extinction, the local populations will need to be rescued to preserve their genetic integrity.

4.4 Environmental Features

Environmental parameters were not measured as part of this study. However from the results and casual observations, it is possible to put forward a number of hypotheses as to what factors are causing the wide range of variation observed. These hypotheses along with the site records would provide a good baseline for determining actual relationships.

Salinity seems to play a major role at the mouths of the three rivers with a transition from freshwater aquatics to estuarine plants of the salt marsh. Plant communities such as A12, H12 and S5 are clearly estuarine and saline, but only in the Heathcote River is there a clear intermediate between river and estuary in the form of Community H1. The absence of this transition mixture of saltmarsh plants such as *Apodasmia similis* and freshwater species such as *Potamogeton crispus*, is obvious in the Styx River as the change occurs abruptly at the tidal gates. On the Avon River the transition is not well defined as this zone, essentially between Bexley Wetland and Cockayne Reserve, is marked by concrete walls and gabion baskets which are unsuitable habitats for plants. In contrast, the Heathcote River has an ever-changing mixture through the Woolston Loop. There are also occasional remnants of salt marsh species further upstream from the time of the Woolston Cut being opened to salt water.

Shade and its effect upon the light regime plays a major role in determining both the cover and composition of aquatics and margin vegetation. Dense shade, such as that provided by a willow canopy that closes over the stream, results in the disappearance of most of the aquatic species and many marginal plants. The characteristic ‘low-cover’ vegetation types such as A1, H2, H3 and S3, all with many sites but highly variable composition, appear in the main to be a result of dense shade. This shade occurs in the form of trees planted along the stream and street margins, especially weeping willow (*Salix babylonica*), and in wild stands of crack (*S. fragilis*) and grey (*S. cinerea*) willow in rural areas such as the Styx River.

There is no indication of deep shade-loving species being present in any abundance. Instead species found in abundance in other areas occur at much lower cover where there is abundant shade. However, it does appear that in partial shade, there are distinct communities that would possibly become overwhelmed by more vigorous species such as *Potamogeton crispus* or raft-forming plants that dominate open streams and rivers. In particular, the narrow-leaved aquatics such as *Potamogeton pectinatus*, *Ruppia polycarpa*, and *Myriophyllum* spp. seem to do best in partial shade. Indeed the vegetation types where these occur, especially Communities A8 and A11, which also have high biodiversity values, are characterised by partial shade, amongst other features. This is provided by riverbank trees that do not close in the centre either by their growth forms (e.g. *Populus nigra* cv. 'Italica') or by the river being wider. Through the central city for instance, Community A8 with its dominant *Ruppia polycarpa* and *Potamogeton ochreatus* seems to be too shaded to be taken over by *Potamogeton crispus*.

Excessive sedimentation also seems to play a role in determining the composition of the vegetation. In such situations, aquatic macrophytes find it very difficult to become rooted as the sediment is constantly shifting. Such situations instead are more likely to be characterised by raft-forming plants that have no such problem establishing on the banks, and poor cover of submerged aquatics. However, such situations may also occur where in open and unshaded streams with little bank clearance, rafting species cause a decline in submerged species by reducing light reaching the water surface. Situations in which ideal conditions for submerged aquatic plants to dominate are rare, being confined to the few reaches with stony stream beds. These mostly occur in the Avon River, while both the Heathcote and Styx (especially Kaputone Stream) have major sediment loads, thus some of the major differences between them.

The other major factor determining the vegetation is stream and bank management. Stream management mostly involves machine cutting and clearing of aquatic macrophytes to facilitate better stream flow. When rivers become choked with macrophytes, water backs up upstream and can cause flooding. Therefore macrophyte clearing involves removing this dense vegetation. *Potamogeton crispus* is the largest problem in this regard, although *P. ochreatus* and sometimes *Myriophyllum propinquum* cause similar situations. In narrower streams aquatic macrophytes such as *Callitriche stagnalis* and *Potamogeton cheesemanii* are cleared by hand.

It is difficult to ascertain what effect this clearing has on the composition. However, the rivers were cleared more frequently and more thoroughly at the time of the reports of Robb et al (1980, 1994). At that time there was far more filamentous green algae and charophyes such as *Nitella hookeri*. These are fast-growing species that rapidly re-establish following clearing. It therefore appears that their replacement by larger aquatic macrophytes (Table 8) may be a result of this changed management.

The species of the river banks are also affected by the frequency and intensity of marginal clearing. This varies from mowing and slashing of taller grass to occasional weed clearance with some areas, mostly on private land receiving no maintenance at all. This clearly influences the margin vegetation, especially the raft-forming species. This has been complicated by plantings along the river margins as this introduces a whole man-made component, but itself affects the maintenance regime.

4.5 Weeds

The following species are notable weeds found in the rivers. They vary from one-off occurrences to widespread problems.

- ***Potamogeton crispus*** **(curly-leaved pondweed)**. This plant has successfully invaded the three rivers to such an extent that it now dominates open sun-lit waters throughout. The data collected in this study suggests that it is continuing to increase. It is by far the most common species cut and removed from the rivers during macrophyte cutting operations. Curly-leaved pondweed is now so widespread and dominant that it is almost certainly too late to do anything to control it.
- ***Elodea canadensis*** **(Canadian pondweed).** This deeply-submerged species seems remarkably stable and under the current situation constitutes little threat.
- ***Lagarosiphon major*** **(lagarosiphon).** previously recorded from the Styx River catchment, this plant is no longer present. It is however, dominant at Lake Rotokahu and considering that this is used for boating, and the propensity for this plant to be dispersed by boats, vigilance needs to be strong to ensure it does not enter the other waterways of the city. Environment Canterbury have identified 11 waterways (lakes and rivers) that are free of lagarosiphon and which have been placed on a schedule (Appendix 5 of the RPMS) for special attention. None are within Christchurch City. It is also a prohibited species under the National Pest Plant Accord so registered nurseries should not be trading in lagarosiphon. It is however a common and popular aquarium and pond plant and the greatest risks come from these.
- ***Egeria densa*** **(egeria).** A major infestation of egeria at Kerrs Reach on the Avon River has been eliminated and this plant has not been seen there for 5 years. It is however still in a pond at Bottle Lake. Environment Canterbury have defined a containment zone in the Avon River from Gayhurst Road bridge to Avondale Road bridge including the Kerrs Reach Loop (Map 4 of Appendix 8 in the RPMS), but the plant is no longer there. The greatest risks from egeria come from boating (this is almost certainly how egeria reached the Avon River) and the disposal of plant material from fish tanks. Therefore, for these kinds of plants surveillance is of extreme importance.
- ***Aponogeton distachyus*** **(Cape pond weed).** This plant was discovered for the first time in Christchurch as part of this study, at two sites on the Avon River. All plants were removed and the sites are being checked on an annual basis. Cape pond weed is known to be present in Waimakariri District.
- ***Gymnocoronis spilanthoides*** **(Senegat tea).** Although not found on the survey, a small patch was recently discovered and removed from a pond adjacent to Smacks Creek, a tributary of the Styx River. It is a prohibited species under the National Pest Plant Accord.
- ***Iris pseudacorus*** **(yellow flag)** This river margin emergent has become a major nuisance on the lower Avon River and has appeared on the Heathcote and Styx Rivers in increasing amounts. Some control is underway but needs to be considered for expansion. It is a prohibited species under the National Pest Plant Accord.
- ***Lythrum salicaria*** **(purple loosestrife).** The subject of control by Christchurch City Council on the Avon River, this marginal species has shown a great ability to spread rapidly. It is a prohibited species under the National Pest Plant Accord.
- ***Phalaris arundinacea*** **(reed canary grass).** The impacts of this tall, raft-forming grass are considerable. It is becoming especially common in the Heathcote River, and if it performs as well there as it has elsewhere in Canterbury, could come to dominate the margins to the detriment of lower-growing species. Currently no control is being undertaken on this plant that was not recorded in previous studies.
- ***Glyceria maxima*** **(reed sweet grass).** Very similar in behaviour to reed canary grass, this reed was recorded in the previous studies but seems to have suddenly increased recently.

- ***Phragmites communis* (phragmites).** No longer found on the river systems, but does occur in two locations in Christchurch. This plant is a 'National Priority' pest and any records need to be reported to Biosecurity New Zealand through Environment Canterbury.
- ***Carex pendula* (giant sedge).** This large ornamental sedge has established on the Heathcote River, presumably from Otahuna, where it was first recorded wild in New Zealand. No control is currently being undertaken, but needs to be considered.

Other pest plants, especially aquatic macrophytes, that have not been recorded, may do so in the future. Vigilance needs to be maintained for species such as alligator weed (*Alternanthera philoxeroides*), hornwort (*Ceratophyllum demersum*), water hyacinth (*Eichornia crassipes*), hydrilla (*Hydrilla verticillata*), water poppy (*Hydrocleys nymphoides*) bogbean (*Menyanthes trifoliata*), parrot's feather (*Myriophyllum aquaticum*) water lettuce (*Pistia stratiotes*), clasped pondweed (*Potamogeton perfoliatus*), arrowhead (*Sagittaria* spp.), salvinia (*Salvinia molesta*), eelgrass (*Vallisneria spiralis*) and the wide range of water lilies. Also requiring clarification is the record of the exotic *Myriophyllum simulans* from near Christchurch, especially as it is so similar to the native species.

4.6 Management and Maintenance

This study was not designed to answer issues regarding management and maintenance of the city's waterways, but a number of findings are of relevance to such issues. The current vegetation is very much the product of past and present management practices and changes to those practices can have considerable impact on the aquatic and margin plants. If these practices can be changed to benefit the ecosystem functioning of the waterways, then there may be considerable ecological and biodiversity gains to be made.

The provision of shade in the form of river margin trees is critical for both the presence and composition of aquatic macrophytes and plants along the waterways margins. The native macrophytes seem to benefit most from partial shade. Under dense shade, for instance beneath a closed canopy of weeping willows on both banks, there is insufficient light for macrophytes and many of the marginal species. A large proportion of the sites characterised by poor cover occur under such shade. There seems to be no real shade-tolerant aquatic macrophytes, as light must penetrate both canopy and water surface. Under dense shade many of the marginal species are very sparse. The component most suited to such a situation is the shade-loving native ferns, and these are virtually absent. Species such as *Blechnum minus* and *B. fluviatile* would be ideally suited to such situations and their planting would enhance visual, functional and biodiversity values of shaded waterways.

Native aquatic species also seem to perform poorly in full light however. This is probably because this brings them into competition with *Potamogeton crispus*, an invasive exotic that can dominate such habitats. Some native species are sometimes able to avoid that invader, such as *Potamogeton ochreatus* in deep water and *Myriophyllum* spp. in backflows. Instead it is in the partly shaded habitats between the extremes where native plants such as *Ruppia polycarpa* and *Potamogeton pectinatus* have found a niche. The kinds of semi-opening plantings that occur along the Avon River in the central city seem ideal. Therefore the possibility of establishing such a shade regime may be the best way of creating habitat for these now highly restricted species.

The changes in maintenance of both banks and waterways from the time of the earlier studies (e.g. Robb et al 1981, 1994) have had major consequences for the composition and density of both aquatic and riparian species. These changes may have had gains for other aquatic components such as the invertebrate fauna, but such benefits have not so far accrued to the native species. The native aquatic plants have succumbed to the invasion of *Potamogeton crispus* and *Callitriche stagnalis* in large and small streams. These plants have found the sediment loads of these waterways ideal and the native species that would have occupied gravel beds with good flows have declined. This has been particularly evident in the Heathcote and Styx Rivers where sediment loads are now considerable. This suggests that before anything else can be done to restore the native to exotic balance, the issue of sediment load needs to be addressed. In particular, there is the suggestion that the alleviation of the flood flows through retention basins and swales may have had a detrimental effect by not clearing out the sediment load. This issue requires further investigation to determine the role of the sediment, and options for its possible removal need to be considered if it is found to be a problem.

The composition of the riparian banks from the earlier studies indicates a much more intensive level of maintenance than currently being undertaken. Where there were once intensely groomed banks, there is now a broad fringe of marginal plants, many of these rafting into the water. While there have been benefits for the stream fauna, it needs to be pointed out that with one rare exception (*Montia fontana* subsp. *fontana*) none of these are native. Studies elsewhere have shown that these rafting plants can also hinder growth of the submerged macrophytes (King 1996). Therefore, from a botanical point of view, the benefits of such practices themselves are minimal. Also, pest plants that would have once been minor components now thrive in the lower maintenance situation (e.g. *Iris pseudacorus*, *Glyceria maxima*, *Phalaris arundinacea*). This can only be overcome by riparian margin planting with suitable native species and concurrent management of exotic species. Unfortunately, some of the native species planted have themselves caused problems, especially in smaller streams which have become choked with plants such as *Typha orientalis* and *Schenoplectus tabernaemontanii*. On the banks the plantings have frequently been insufficiently maintained and have developed rafts of *Phalaris arundinacea* on the river interface and have been invaded by prairie grass (*Bromus unioloides*), tree of heaven (*Ailanthus altissima*) and willows. Also frequently seen are suckers of elms and poplars where such plantings have been placed near such riverbank trees.

Therefore the whole question of management (including plantings) and maintenance need to be examined in more detail to take into account all these factors, plus those not even covered here (e.g. fauna). There is therefore the need for such practices to be considered holistically and ecologically if benefits are to accrue to the whole functioning of the waterways. There may be conflicts however, not only the usual problem of drainage vs. ecology, but also between for instance different types of plants. Currently the Christchurch City Council's Streamside Planting Guide is the basis for streamside management. Clearly this is insufficient to ensure that the waterways are managed and maintained appropriately.

5.0 Recommendations

This study was not designed to make management recommendations, but rather to obtain both baseline data and to compare that with previous studies. A number of issues or aspects requiring further examination have presented themselves and are summarised below.

- The aquatic macrophyte vegetation of the Avon River in the central city between Salisbury Street and Antigua Boatsheds has considerable natural and conservation value as the last place on these three rivers where native species dominate. It is worthy of recognition and protection as an Ecological Heritage Site in the City Plan.
- Locations where native species that are otherwise rare in Christchurch are located (e.g. *Potamogeton pectinatus*) need to be monitored and plants rescued if threatened with extinction.
- An investigation on whether river management can be adjusted to favour native aquatic macrophytes such as *Myriophyllum* spp. and *Potamogeton cheesemanii* over aggressive aquatic species such as *Potamogeton crispus* needs to be initiated.
- The waterways need to be monitored for the introduction of new aquatic weeds. Currently egeria and lagarosiphon are absent, but are to be found elsewhere in the city. Considering the problem that curly-leaved pondweed has created, these and other weeds that have been controlled already (e.g. Cape pond weed) or which are so far absent, need to be checked for and actioned if they appear.
- A weed management strategy for aquatic and marginal plants needs to be developed and priorities set and actioned accordingly.
- In order to make best use of the data obtained in this study, repeat samplings should occur in 2011 and at 5-year intervals thereafter. The whole study need not be repeated (although it would be advantageous if it was), but critical sites and communities need to be covered, especially those with high biodiversity value.
- A holistic approach to waterway management and maintenance taking into account the ecology of aquatic macrophytes and margin species, especially biodiversity values needs to be developed using the Streamside Planting Guide as a starting point.

References

Baird, A. 1992. An overview of botanical information and recommendations for the management of the freshwater reaches of the Avon and Heathcote Rivers. Department of Conservation, Canterbury: Conservancy Technical Report Series No. 5.

Carroll, K.D., Robb, J.A. 1986. A botanical survey of rivers in the metropolitan Christchurch area and outlying districts: The Avon, Heathcote and Styx Rivers and their tributaries. Christchurch Drainage Board.

Christchurch City Council Streamside Planting Guide

Christchurch City Council City Plan

Connor, H.E. 1953. Report on waterweeds in rivers administered by the Christchurch Drainage Board. DSIR Botany Division Report.

King, J.J. 1996. The impact of drainage maintenance strategies on the flora of a low gradient, drained Irish salmonid river. Hydrobiologia 340: 197-203.

Larned, S.T., Suren, A.M., Biggs, B.J.F., Riis, T. 2006. Macrophytes in urban stream rehabilitation: establishment, ecological effects, and public preception. *Restoration Ecology 14:* 429-440.

McCombs, K. 1997. Changes in the riparian vegetation along the Styx River. Christchurch City Council Report.

McCombs, K.P.C., Partridge, T.R. 1992. Vegetation of the Avon-Heathcote Estuary, Christchurch. Christchurch City Council, Christchurch.

Meurk, C.D., Ward, J.C., O'Connor, K.F. 1993. Natural Areas of Christchurch: Evaluation and Recommendations for Management as Heritage. Centre for Resource Management Report to Christchurch City Council.

Partridge, T.R. 2004. Decline of sea rush saltmarshes in the Lower Heathcote Estuary. Canterbury Ecology Consultancy Services Contract Report CECS04/06.

Robb, J.A. 1980. A biological survey of the rivers in the metropolitan Christchurch area and outlying districts: The Avon, Heathcote and Styx Rivers and their tributaries. Christchurch Drainage Board.

Robb, J.A. 1989. A biological survey of the Styx River Catchment. Christchurch Drainage Board Report.

Robb, J.A. 1992. A biological re-evaluation of the Avon River Catchment 1989-90. Christchurch City Council Report.

Robb, J.A., Manning, M.J., Marshall, A.E., McGill, A. 1994. A botanical survey of the Avon, Heathcote and Styx rivers and their tributaries and the city outfall drain. Christchurch City Council Report.

Taylor, M.J., Suren, A.M., Sorrell, B.K. 2000. A consideration of aspects of the Styx River ecology, and its implications for whole-river management. NIWA Client Report: CHC00/34.

Webb, C. J., Sykes, W.R., Garnock-Jones, P.J., Brownsey, P.J. 1995. Checklist of dicotyledons, gymnosperms, and pteridophytes naturalised or casual in New Zealand: additional records 1988-1993. New Zealand Journal of Botany 33: 151-182.

Appendix 1. Species List.
An asterisk indicates a New Zealand native species, but some may not be native to these catchments.

Species	**Common name**
Agrostis stolonifera	creeping bent
Alisma plantago-aquatica	water plantain
Alnus glutinosa	alder
Apium prostratum *	shore parsley, native celery
Apodasmia similis *	jointed wire rush, oioi
Aponogeton distachyus	cape pondweed
Armoracia rusticana	horseradish
Aster novi-belgii X *A. lanceolatus*	Michaelmas daisy
Atriplex prostrata *	orache
*Azolla filiculoides**	azolla, karerarera
Bellis perrennis	bellis daisy
Blechnum minus *	kiokio
Bolboschoenus caldwellii *	leafy three-square
Callitriche stagnalis	starwort
Cardamine debilis	bittercress
Carex geminata *	
Carex maorica *	
Carex secta *	makura
Carex virgata *	
Coprosma lucida *	
Coprosma repens *	
Coprosma robusta *	
Cortaderia richardii *	toetoe
Coryline australis *	cabbage tree
Cotula coronopifolia *	batchelor's button
Crassula kirkii *	
Cyperus eragrostis	umbrella sedge
Cyperus ustulatus *	giant umbrella sedge
Eleocharis acuta *	sharp spike-rush
Elodea canadensis	canadian pond weed
Elytrigia repens	twitch / couch
Enteromorpha *	
Epilobium ciliatum	willow herb
estuarine brown algae	
Euchiton involucratus *	creeping cudweed
Filamentous green algae - various spp.	
Fissidens rigidulus *	
Glyceria fluitans	floating sweetgrass
Glyceria maxima	reed sweetgrass
Gracillaria sp.*	fine brown algae
Gunnera tinctoria	Chilean rhubarb
Hebe salicifolia *	
Holcus lanatus	Yorkshire fog
Hydrocotyle microphylla *	

Hypolepis ambigua *	rough pig fern.
Impatiens glandulifera	Himalayan balsam
Iris pseudocorus	yellow flag
Isolepis cernua *	slender clubrush
Isolepis prolifera *	
Juncus articulatus	jointed rush
Juncus bufonius	toad rush
Juncus caespiticius *	
Juncus distegus *	
Juncus effusus	soft rush
Juncus edgariae *	
Juncus krausii var. *australiensis* *	sea rush
Juncus pallidus	
Juncus subnodulosus	
Lemna minor *	duckweed, karearea
Lepidium africanum	peppercress
Leptinella dioica *	
Leptodictyum riparium *	water moss
Lilaeopsis novae-zeandiae *	
Limosella lineata *	mudwort
Lotus penunculatus	lotus
Ludwigia palustris	
Lycium ferocissimum	boxthorn
Lythrum salicaria	purple loosestrife
Melissa officinalis	lemon balm
Mentha pulegium	pennyroyal
Mentha X*piperita*	peppermint
Mentha X*piperita* var. *citrata*	bergamont mint
Mimulus guttatus	yellow (monkey) musk
Mimulus moschatus	musk
Mimulus repens *	sea musk, native musk
Montia fontana *	blinks
Myoporum laetum *	ngaio.
Myosotis laxa	water forget-me-not
Myriophyllum propinquum *	
Myriophyllum triphyllum *	
Nasturtium officinale	watercress
Nitella hookeri *	
Nitella hyalina *	
periphyton	periphyton brown algae
Phalaris arundinacea	red canary grass
Phormium tenax *	harakeke
Picris echiodes	oxtongue
Plagianthus divaricatus *	saltmarsh ribbonwood
Plantago coronopus	buck's horn plantain
Plantago lanceolata	narrow-leafed plantain
Plantago major	broad-leafed plantain
Poa annua	annual poa
Polygonum persicaria	willow weed
Polypogon monspeliensis	annual beard-grass

Potamogeton cheesmanii *	red pondweed
Potamogeton crispus	curly pondweed
Potamogeton ochreatus *	blunt pondweed
Potamogeton pectinatus *	
Potentilla reptans	creeping cinquefoil
Puccinellia stricta *	salt grass
Ranunculus repens	creeping buttercup
Ranunculus sceleratus	celery buttercup
Ranunculus trichophyllus	water buttercup
Riccia sp. *	water liverwort
Rorippa palustrus	marsh yellow cress
Rumex acetosella	sheep's sorrel
Rumex crispus	curled dock
Rumex obtusifolius	broad leafed dock
Ruppia polycarpa *	horse's mane weed
Sagina procumbens	pearlwort
Salix cinerea	grey willow
Salix fragilis	crack wllow
Samolus repens *	sea primrose
Sarcocornia quinqueflora *	glasswort
Schoenoplectus pungens *	three-square
Schoenoplectus tabernaemontani *	lake clubrush
Selliera radicans *	remuremu
Schedonorus arundinaceus	tall fescue
Solanum dulcamara	bittersweet
Solanum nigrum	black nightshade
Spartina anglica	cord grass
Spergularia media *	sea spurrey
Stellaria alsine	bog stitchwort
‘Styx liverwort’	
Suaeda novae-zealandiae *	sea blite
Tamarix chinensis	Chinese tamarix
Trifolium pratense	red clover
Trifolium repens	white clover
Triglochin striata *	arrow grass
Typha orientalis *	raupo
Ulva lactuca *	sea lettuce
Urtica linearifolia *	swamp nettle
Veronica anagallis-aquatica	water speedwell
Zannichella palustrus *	
Zantedeschia aethiopica	arum lily
Zostera capricornii *	eelgrass, seagrass