# Nutrient and vegetation changes in a retired pasture stream

## Recent monitoring in the context of a long-term dataset

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# Abstract

This report records water quality and vegetation changes in the Whangamata Stream, Lake Taupo catchment from 1995 to 1998. The data represent the latest three years of a 24-year study on changes to this pasture stream since riparian strips were established in 1976, to retire the margins of the stream from pastoral farming. This data set is unique in New Zealand for its continuity and allows a quantitative assessment of the extent and time scales of change in rehabilitation programmes of this nature. The process of rehabilitation of the stream was assisted by some plantings of native species among the pasture-grassed banks. During this three-year study period, the number of vascular plant species recorded in the stream and along the banks has increased from 119 to 148. Native plants made up 41% of the total. Woody species are invading the flax-dominated stream banks. The reaches of the stream which had the original plantings (c. 1976) have the highest number of species. The old pasture has proved very resistant to invasion and in many areas where assisted plantings have not occurred, extensive areas of rank grass comprising the original pasture species are still intact.

The ability of the stream bank and channel flora to remove nutrients from the stream has been reduced over this three-year monitoring period, with nitrate and dissolved reactive phosphorus uptake in mid-summer now less than 15% of the mass flow of these nutrients. This compares with c. 90% removal in the mid-1980s.

Total suspended solids show a strongly seasonal pattern with values increasing in winter and decreasing to low values ($<5$ g m$^{-3}$) in summer. A similar pattern was recorded in the late 1970s and early 1980s. The winter maximum TSS concentration in 1996 was very high (c. 70 g m$^{-3}$) coinciding with the Ruapehu eruption which blanketed much of the catchment in ash.

The stream channel was essentially clear of the plant blockages which were a feature of the 1980s and early 1990s. The water flowed unimpeded below a dense cover of flax and toetoe, allowing easy access for spawning trout to the upper reaches of the stream. Fernbird, fantails, bellbird, pukeko were observed. The stream is now an increasingly important wildlife area. The role of the protected riparian strips has therefore changed over the years from a sediment and nutrient trapping mechanism to sediment control, with greatly enhanced wildlife values.

# 1. Introduction

Our three-year study provides a continuation of recording in the Whangamata Stream which has a 24-year history of data collection since the original riparian strips were established in the 1970s. This data set is now unique in New Zealand. Although the primary aim of the original stream protection was, as a part of the 'Lake Taupo Catchment Control Scheme', to minimise the impacts of soil erosion (Waikato Valley Authority 1966), mitigation of the effects of nutrient runoff from farmland was also seen as an important objective. The emphasis in monitoring this stream over the years has been on dissolved nutrients because the then DSIR, under which the programme began, was concerned at the time with the impact of nutrient runoff into Lake Taupo.

The last report on this project to the Department of Conservation (DOC) was in 1994 (Howard-Williams & Pickmere 1994a), and the data were also presented at, and published in, the DOC-sponsored proceedings of the Conference on Restoration of Aquatic Habitats (Howard-Williams & Pickmere 1994b). A further analysis was provided in Downes et al. (1997). These reports showed that the vegetation had undergone extensive changes since the riparian strips were established. The original pasture-dominated stream banks had been replaced with a 'wetland'. The process was accelerated by deliberate plantings of some native wetland species along the stream such as flax, toetoe and cabbage tree.

Nutrients were effectively stripped out from the stream waters by aquatic and semi-aquatic vegetation along the stream throughout the 1980s, but data in the early 1990s suggested that this process was reducing as the stream banks became more shaded and the high-light-requiring species which are able to strip nutrients directly from stream water became less common in the developing 'wetland'.

The Whangamata Stream has long been a significant trout spawning stream on the northern side of Lake Taupo. During the first few years after retirement of the stream from farm activity, the number of spawning trout increased dramatically (Young 1980). During the following decade, trout access up the stream was blocked by the dense growths of stream channel plants, and vegetation control measures were needed each year to allow trout access to the upper reaches of the stream (Taupo Times 1989, Target Taupo 1994). However, the situation improved (Howard-Williams & Pickmere 1994a,b) in the early 1990s when control of the vegetation became less necessary as the channel was increasingly shaded by tall-growing wetland species such as flax.

This 1995–98 three-year study was established to continue the monitoring work and, in particular, to report on the status of the changing vegetation and its nutrient stripping ability. The report was funded on an equal-share basis by the Department of Conservation (DOC Investigation Number 356) and Environment Waikato. We are grateful to Dr Harry Keys and John Gibbs of DOC and to Mark Davenport and Dr Nick Edgar of Environment Waikato for support.

# 2. Aims

The aims of this project for the period 1 May 1995 to 30 June 1998 were to:

- Sample the stream at two sites 2 km apart at about two-monthly intervals for water quality (Total Suspended Solids, Nitrate-N, Ammonium-N, Dissolved Reactive Phosphorus and Dissolved Organic-N and -P).
- On each sampling occasion gauge the stream flow and calculate nutrient and sediment flux rates.
- Maintain a database on concentrations and flux rates and a photographic archive of the stream.
- Compile a botanical species list of the stream and streambank habitats in 1998 and map the major botanical zonations.
- Produce a report including photographs which places this three-year programme in the context of the long-term data set for the stream.

# 3. Methods

## 3.1 SITE DESCRIPTION

The stream study section was a 2.0 km long second-order, spring-fed stream flowing through improved pasture into Whangamata Bay, Lake Taupo (Fig. 1). Two springs (Right Hand Spring and Left Hand Spring) provided the source of the water. The study section had a base flow discharge which varied between 0.04 and 0.11 $m^{-3}s^{-1}$ over long time scales (years). Flood flows accounted for only 5% of the total flow over a year. The low variance in discharge means that the stream is ideal for the study of nutrient dynamics and water quality (Howard-Williams et al. 1982 and Hearne & Howard-Williams 1988).

## 3.2 SAMPLING

Two sampling sites were established for regular measurements: the Top site was 2.0 km upstream of Lake Taupo at the Whangamata Road bridge, and just below the junction of the two spring outflows (38°39'20" S, 175°56'20" E). The Bottom site was c. 250 m from the lake (Fig. 1). There were no inflows between the sites.

Occasional samples were also collected at the Right Hand Spring (Fig. 1). Flows were estimated using a Pygmy current meter at both Top and Bottom sites from velocities measured at 0.3 times water depth at 10 cm intervals across the stream channel. Usually 10 velocity measurements were made at each site. Discharge was calculated as velocity times area for each 10 cm segment and then added across the stream.

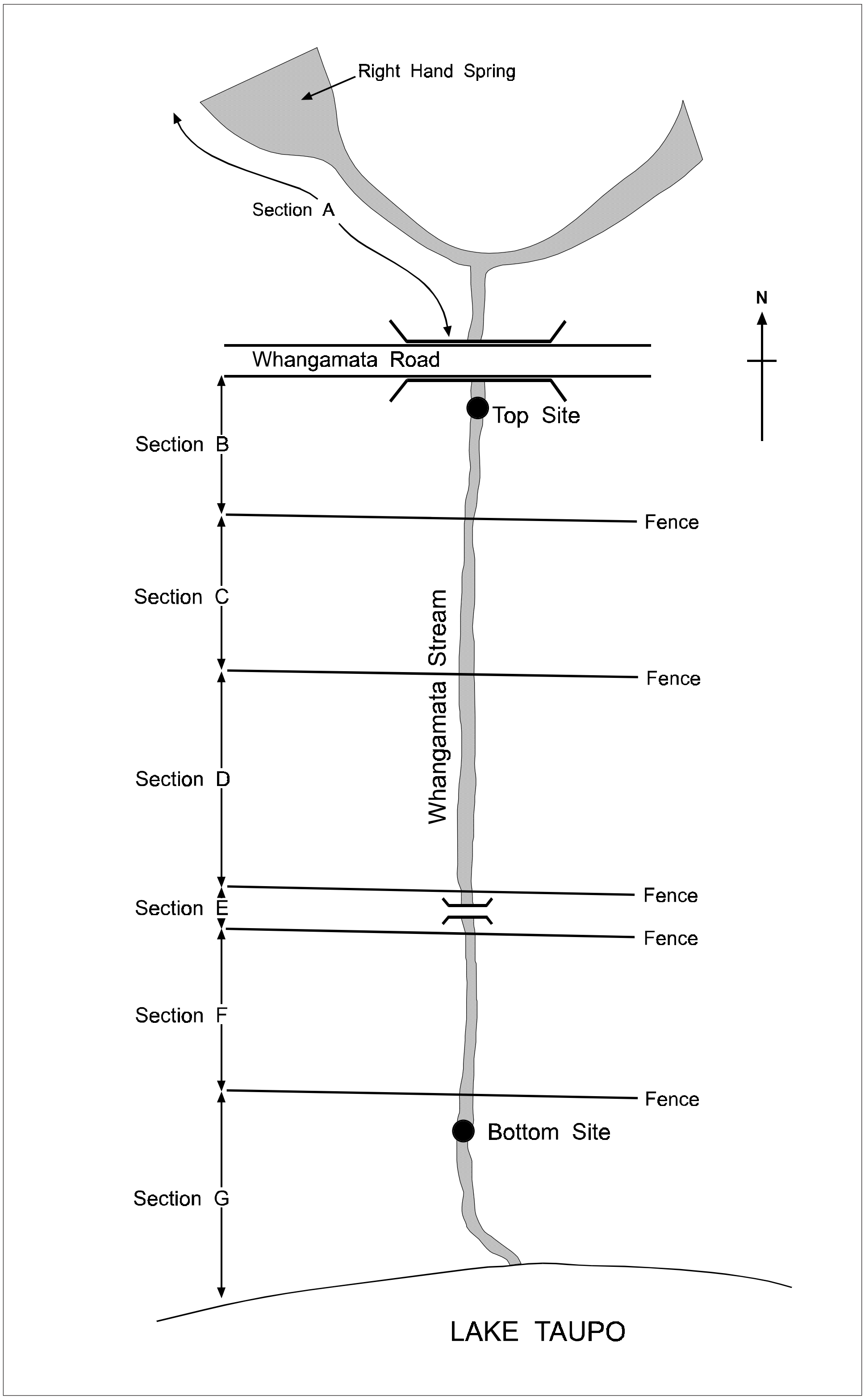


Figure 1. Schematic diagram of the Whangamata Stream, showing sampling sites and sections.

Duplicate water samples were collected at each site at approximately two-monthly intervals from May 1995 to June 1998. Analyses for dissolved nutrients were carried out with a Technicon II autoanalyser system using the methods detailed in Downes (1998). Only two nutrient compounds are discussed in detail in this report—Nitrate-Nitrogen ($NO_3$-N) and Dissolved Reactive Phosphorus (DRP). Ammonium Nitrogen was in low concentration throughout the study (<10 mg $m^{-3}$) and Dissolved Organic Nitrogen and Dissolved Organic Phosphorus were also in low concentrations and did not make significant contributions to the dissolved nitrogen and phosphorus budgets.

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 full 1998 species list and distribution pattern for 1998 is provided in Appendix 2.

In addition, one 250 m section of the stream at the Top site was demarcated for mapping of the stream bank vegetation.

# 4. Results

## 4.1 FLOW RATES

Stream discharge values at base flow are shown in Fig. 2. Flow rates in the stream over this time were the highest since regular records began in 1976. Note, however, that for the period 1976–79 the average discharge was 0.11 $m^3 s^{-1}$ (Schouten et al. 1981), similar to that recorded over the last three years. In general, flows at the Bottom site were slightly higher than at the Top (average 6.1% increase, range 0–25%). There was no seasonal or annual pattern to the flow. At the beginning of this study period, flows were of the order of 0.04 $m^3 s^{-1}$, a typical flow rate for the period from the mid 1980s to early 1990s. From May 1995 discharge increased steadily to a maximum of 0.19 $m^3 s^{-1}$ in November 1996 and has been decreasing since then. Discharge values on 20 May 1998 were 0.12 $m^3 s^{-1}$ at the Top and at the Bottom sites. The reason for this rise and fall in flow rates is not known, but as the Whangamata is a strongly spring-fed stream these changes are due to changes in the flow from the source springs. The residence time of water in the underground reservoir is unknown.

## 4.2 TOTAL SUSPENDED SOLIDS (TSS)

At the Top site TSS values varied between 1.13 g $m^{-3}$ at the end of summer 1995 and the peak values of 58 g $m^{-3}$ (Top) and 75 g $m^{-3}$ (Bottom) recorded in September 1996 (Fig. 3). These high values are consistent with the timing of the June 1996 eruption of Mount Ruapehu which deposited some 10 million $m^3$ of ash over the Lake Taupo catchment (Cronin 1996).

TSS concentrations did not follow base flow discharges, but exhibited a strongly seasonal pattern, being lowest in the summer months and increasing to a peak in late

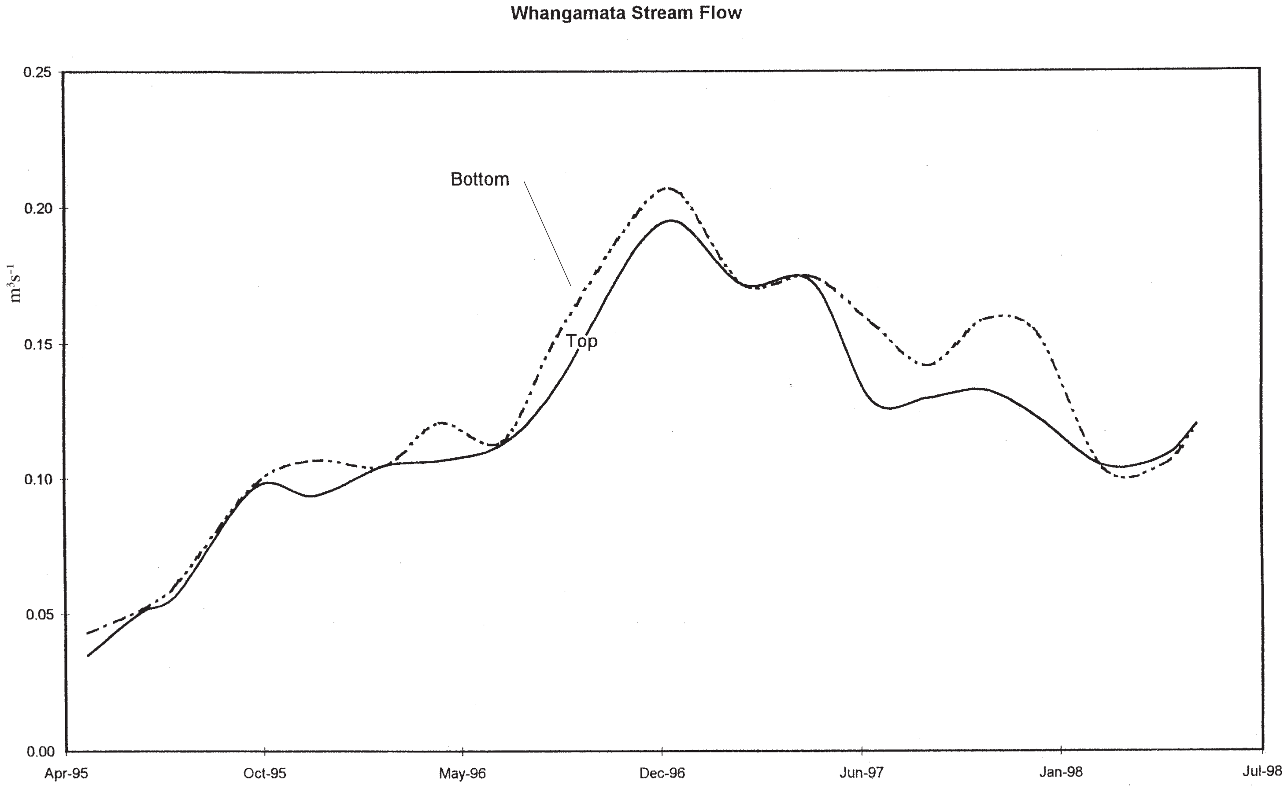


Figure 2. Whangamata Stream flow. Discharge ($m^3s^{-1}$) over the study period at the Top (solid line) and Bottom (hatched line) sites. No flood flows were measured.

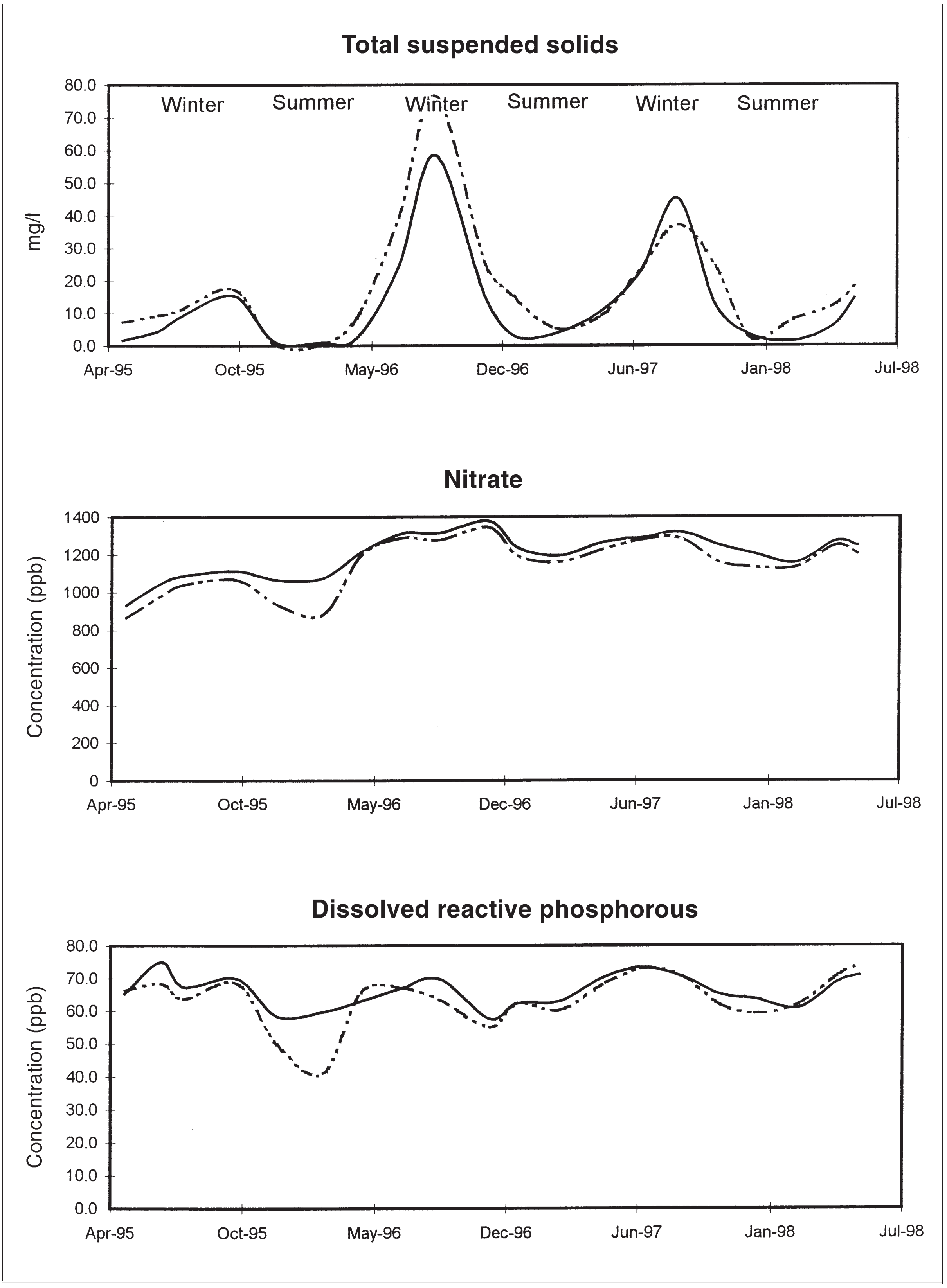
winter each year (Fig. 3). Values at the Bottom sampling site were consistently higher than at the Top, except for the winter peak of 1997. Mass flow of TSS (Fig. 4) follows the concentration pattern, with minimum values of <1 kg $hr^{-1}$ in the summer of 1995 and a peak at the bottom site of 42 kg $hr^{-1}$ in September 1996.

## 4.3 DISSOLVED NUTRIENTS

### 4.3.1 Nitrate-N

Nitrate-N concentrations were consistently lower at the Bottom site throughout the monitoring period (Fig. 3). At both sites a weak seasonal signal was apparent, increasing each winter and falling by c. 10% during the following summer. Maximum values occurred at the beginning of summer 1996 when concentrations of c. 1300 mg $m^{-3}$ were recorded. Nitrate concentrations during this study period were higher than at any time since the long-term monitoring began in 1979, and are now similar to the concentrations found at the source springs (Table 1). The maximum difference between Top and Bottom sites was in 1996 with a fall in concentration of 18% from 1075 mg $m^{-3}$ to 880 mg $m^{-3}$. In the following two summers the reduction was only 2%, indicating a very small summer removal of nitrate.

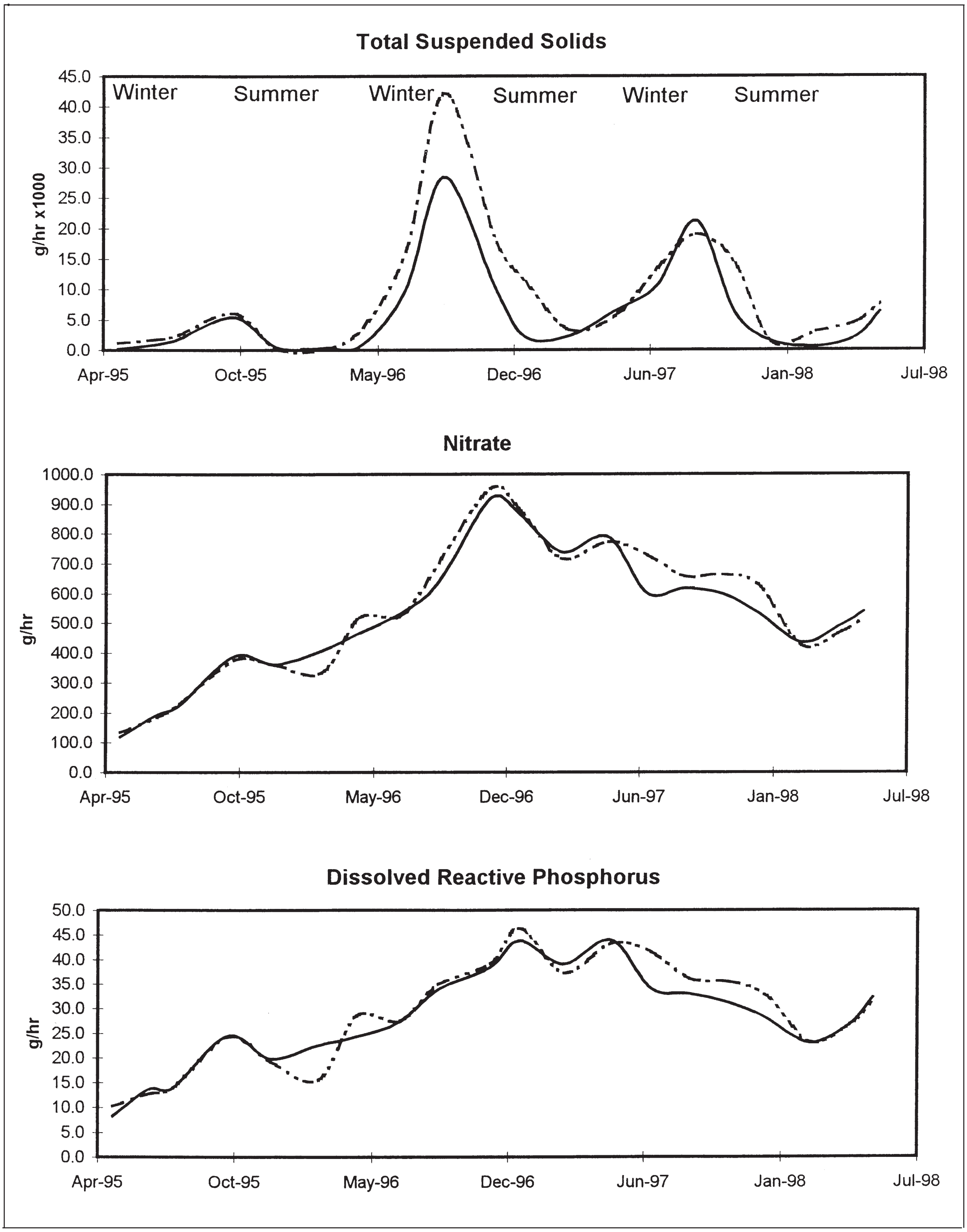
The mass flow of Nitrate-N followed the same pattern as discharge (Fig. 4) with a peak nitrate flux rate of 916 g $hr^{-1}$ (22 kg $day^{-1}$) in November 1996, the highest export rate since records began. By May 1998 this was reduced at the bottom site to 416 g $hr^{-1}$ (10 kg $day^{-1}$) due to the decrease in discharge between November 1996 and May 1998. The


Total suspended solids

Nitrate

Dissolved reactive phosphorous

Figure 3. Concentrations over time of Total Suspended Solids (mg/l or g $m^{-3}$)—top panel; Nitrate-Nitrogen (mg $m^{-3}$ or ppb)—middle panel; Dissolved Reactive Phosphorus (mg $m^{-3}$ or ppb)—lower panel. Top site = solid line, Bottom site = hatched line.


Total Suspended Solids

Nitrate

Dissolved Reactive Phosphorus

Figure 4. Mass flows over time of Total Suspended Solids (kg hr$^{-1}$)—top panel; Nitrate-Nitrogen (g hr$^{-1}$)—middle panel; Dissolved Reactive Phosphorus (g hr$^{-1}$)—lower panel. Top site = solid line, Bottom site = hatched line.

TABLE 1. NUTRIENT AND TSS CONCENTRATIONS JUST BELOW THE RIGHT HAND SPRING. DATA AS ppb = mg $m^{-3}$ EXCEPT TSS WHICH WAS g $m^{-3}$.

| DATE COLLECTED | DRP ppb | TDP ppb | DOP ppb | $NH_4$-N ppb | $NO_3$-N ppb | TDN ppb | DON ppb | TSS g $m^{-3}$ |
|---|---|---|---|---|---|---|---|---|
| 03.05.95 | 78.1 | 76.0 | -2.0 | 0.5 | 1053 | 1106 | 53 | * |
| 27.06.95 | 81.5 | 88.0 | 6.0 | 3.7 | 1114 | 1215 | 97 | * |
| 31.07.95 | 78.8 | 81.4 | 3.0 | 4.1 | 1129 | 1221 | 88 | * |
| 18.10.91 | 81.0 | 82.3 | 1.0 | 5.9 | 1017 | 1121 | 99 | 3.30 |
| 22.04.92 | 80.0 | 81.0 | 1.0 | 7.0 | 1103 | 1274 | 164 | 2.04 |
| 01.05.93 | 66.2 | 67.0 | 0.8 | 10.9 | 1346 | 1505 | 148 | 2.60 |
| 24.08.93 | 78.8 | 80.4 | 1.6 | 6.9 | 1094 | 1142 | 41 | 4.24 |
| 19.05.94 | 88.3 | 88.5 | 0.5 | 6.2 | 1106 | 1078 | 22 | 3.98 |

annual removal of Nitrate-N for the three-year period was 73 kg for 1995/6 and negligible for 1996/7 and 1997/8 (Table 2).

### 4.3.2 Dissolved Reactive Phosphorus (DRP)

DRP concentrations showed a seasonal signal with maximum concentrations in winter and minimum in summer (Fig. 3). However, as with $NO_3$-N the signal is relatively weak (c. 20% fall in the ambient concentration each summer). In general, concentrations at the Bottom site were lower than at the Top, consistent with DRP removal down the stream. The largest downstream difference occurred in February 1996 (42 mg $m^{-3}$, a fall of 30%). There was no reduction in February 1998.

DRP concentrations in the stream were close to those reported at the springs (Table 1). Spring concentrations varied between 66 and 81 mg $m^{-3}$ (mean = 78 mg $m^{-3}$ ) with no distinct seasonal or interannual pattern.

TABLE 2. BIOLOGICAL REMOVAL (kg $year^{-1}$) OF NITRATE NITROGEN AND DISSOLVED REACTIVE PHOSPHORUS IN THE WHANGAMATA STREAM BETWEEN 1986 AND 1997.
negl = NEGLIGIBLE, – = NO DATA.

| YEAR | MASS REMOVED (kg $year^{-1}$)<br>$NO_3$-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 |
| 1993–94 | – | – |
| 1994–95 | – | – |
| 1995–96 | 73 | 5.5 |
| 1996–97 | negl | negl |
| 1997–98 | negl | negl |

The mass flow of DRP (Fig. 4) also followed that of discharge with the peak DRP flux over the study period occurring in December 1996 (46 g $hr^{-1}$ or 1.9 kg $day^{-1}$). The annual removal of DRP from the stream water was 5.5 kg for 1995–96 and negligible after that (Table 2).

### 4.3.3 Ammonium-N ($NH_4$-N)

Ammonium values were very low, ranging from 3 to 20 mg $m^{-3}$ at the Top site and 7–19 mg $m^{-3}$ at the Bottom (Appendix 1). There was no consistent difference in concentration between the two sites, and no distinct seasonal pattern. $NH_4$-N comprised only 1% of the total inorganic nitrogen in the stream.

### 4.3.4 Dissolved Organic Nutrients (DON, DOP)

Dissolved Organic Nitrogen concentrations (DON, Appendix 1) varied from not detectable (April 1998) to 170 mg $m^{-3}$ (June 1998). No seasonal pattern was evident but there was a consistent downstream increase in DON from May 1995 to May 1997 and then a reversal of this pattern. Values after September 1997 were always low, below 50 mg $m^{-3}$. Dissolved Organic Phosphorus (DOP) was a negligible constituent in the stream with values below 10 mg $m^{-3}$ throughout the period.

# 5. Vegetation

## 5.1 CHANGES TO THE FLORA (BIODIVERSITY)

The total list of vascular plants for the stream and streambanks in 1998 comprised 148 species, of which 60 (41%) were natives. This is an increase in total of 23% since 1993. However, a total of 38 species (13 natives and 25 adventives) were recorded in 1998 that were not present in 1993, but 16 of the species which were recorded in 1993 were not found in 1998. Nine of these 'lost' species were natives (Table 3). Figure 5 shows the trend in the number of the vascular plant species with time. A cumulative 28 species in total have been 'lost' from the stream since 1982. All the plants listed as present in 1993 but absent in 1998 were recorded in 1993 as being 'rare' and most were found only at the Bottom end of the stream. It is worth noting that it is at this lower reach that the Department of Conservation has carried out extensive plantings since the early 1990s, and a significant cover (Photos 1–5, p. 19) of flax and toetoe has developed.

Table 4 provides a breakdown of the total number of species and the portion are as 'woody trees and shrubs' at each of seven sections down the stream from the Right Hand Spring to the lake. Highest total biodiversity and highest number of woody trees and shrubs were found in Section A and Section B (Fig. 6). The stream sections that have the longest planting history (Sections A and B) also had the highest number of native species (Fig. 6). In these sections flax, toetoe, hebe, some red beech and cabbage trees were planted in the late 1970s. Zones D, E and F had limited bank plantings (mostly flax) in the 1980s and the number of native species found here was relatively low (Fig. 6).

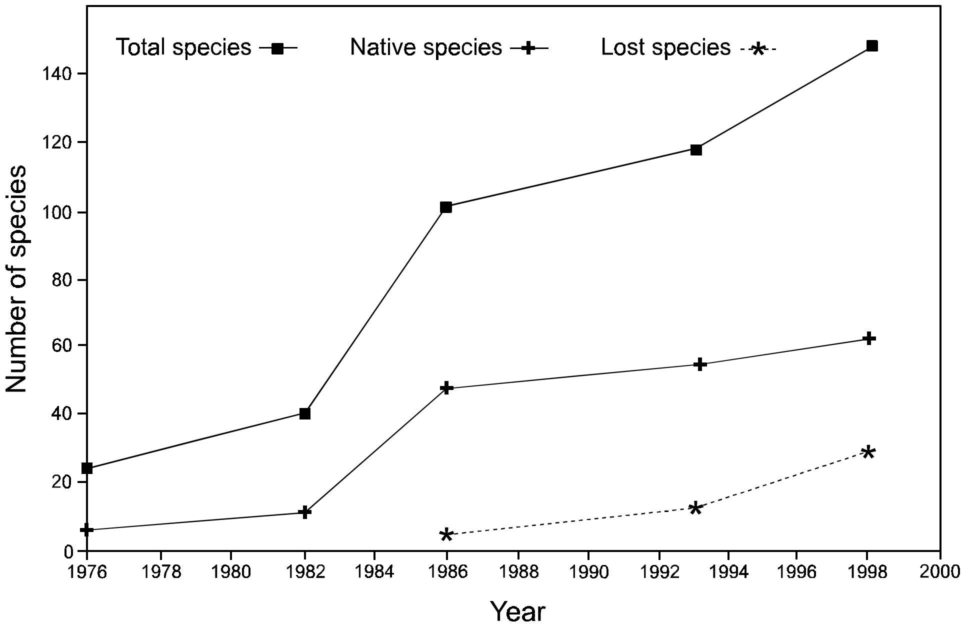


Figure 5. Time course of vascular plant biodiversity (number of species) following protection of the Whangamata Stream. Data are given for total number of species, native species and species lost (formerly recorded but no longer present).

Plantings in the lower section (Section G) by the Department of Conservation in the last 5–8 years have resulted in the formation of a wide ‘wetland’ with flax, toetoe, hebe and kanuka (Photos 1–5, p. 19). A total of 64 native and adventive species was found in this reach, illustrating the impact of planting as a catalyst to the development of species diversity.

### 5.1.1 The Upper Reach (Section B)

The upper 250 m of Section B has been mapped since 1979 and a photographic series extends back to 1974. A pictorial sequence of the Top Reach (Section B, Appendix 2) since the stream was a sheep pasture with heavily grazed banks in 1976 is shown in Photos 6–10 (p. 21). Schematic maps of the top 250 m reach in Section B are shown in Fig. 7.

TABLE 3. SPECIES RECORDED IN 1993 AND 1996 BUT NOT IN 1998.

*Carex fascicularis*
*Digitalis purpurea*
*Elymus rectisetus*
*Epilobium nummulariifolium*
*Epilobium obscurum*
*Geranium potentilloides*
*Gnaphalium involucratum*
*Gnaphalium limosum*
*Juncus acuminatus*
*Juncus dichotomus*
*Microtis unifolia*
*Orobanche minor*
*Paspalum distichum*
*Polystichum richardii*
*Senecio bipinnatisectus*
*Verbascum virgatum*

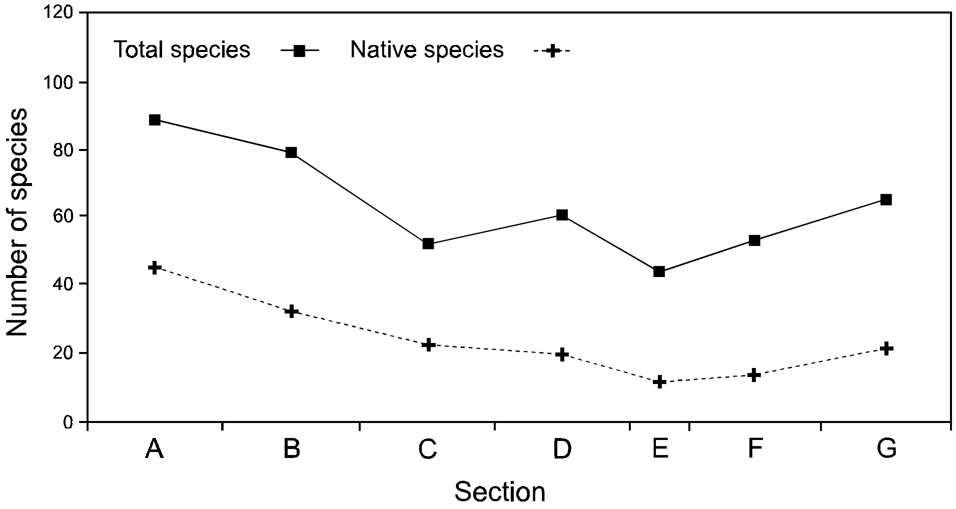


Figure 6. Total number of species and number of native species of vascular plants in each section of the stream (see Fig. 1 for section map).

In 1998 there were 79 species in this reach, of which 35% were classed as trees and shrubs. Half of these woody species were natives (Table 4, Appendix 2). Within the total species assemblage for the reach there were 32 natives and 47 adventives. The following native species were recorded with cover classes of 3 or greater (see Appendix 2): *Phormium tenax, Hebe stricta, Cortaderia fulvida*. These provide the bulk of the stream channel shade. In addition, the adventive tree *Acacia melanoxylon* was also common, with a cover class of 3. The entire length of the channel in Section B of the stream was covered over by flax and toetoe (Fig. 7, Photos 1–5, p. 19). One or two single plants of watercress and musk were found on the shaded banks under these taller plants. Five-finger, coprosma and tree fern were common throughout this reach, growing up amongst the flax (Photos 1–5, p. 19). Some of these species were projecting above the flax. Ten-metre high groves of cabbage trees have become established (Photos 1–5, p. 19).

### 5.1.2 The Middle and Lower Reaches (Sections C–G)

Sections C–E had the lowest number of species and assisted plantings have not been as comprehensive as in Sections A, B and G. The stream channel itself between Sections C and E is shaded for almost the entire length by a band of *P. tenax, C. fulvida* and *C. toetoe*. However, in the lower reaches (Sections F and G), *Carex spp*. (particularly *Carex geminata)* was the dominant plant overhanging the stream channel (Photos 1–5, p. 19). Adventive grasses with a cover class of 3 were *Agrostis capillaris, Dactylus*

TABLE 4. TOTAL SPECIES AND DISTRIBUTION OF WOODY PLANTS IN THE FLORA AT SEVEN SECTIONS OF THE STREAM FROM RIGHT HAND SPRING TO THE LAKE. SEE FIG. 1 FOR MAP OF THE STREAM SECTIONS.

| STREAM SECTION | TOTAL SPECIES (NUMBER) | NUMBER OF WOODY TREES AND SHRUBS | % TREES AND SHRUBS | % OF NATIVES IN TREES AND SHRUBS CATEGORY |
|---|---|---|---|---|
| A | 93 | 33 | 35 | 61 |
| B | 79 | 26 | 33 | 54 |
| C | 53 | 18 | 33 | 56 |
| D | 62 | 20 | 32 | 45 |
| E | 45 | 10 | 22 | 50 |
| F | 51 | 17 | 33 | 41 |
| G | 64 | 23 | 36 | 47 |

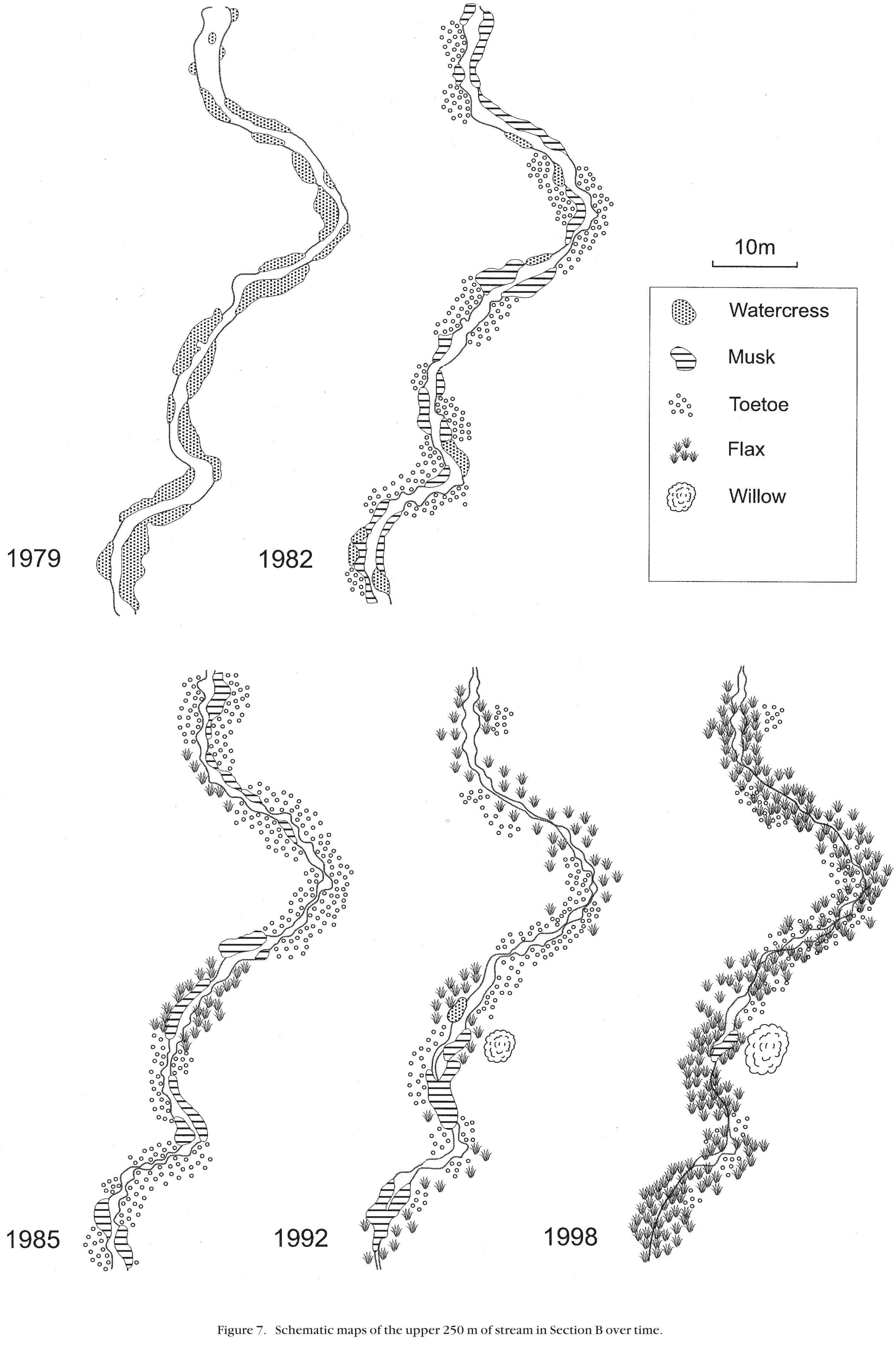


Figure 7. Schematic maps of the upper 250 m of stream in Section B over time.

*glomeratus* and *Holcus lanatus*. These grasses, together with *Anthoxanthum odoratum* (Cover Class 2), would have formed part of the original pasture over 20 years ago before riparian protection. They now frequently occur as very dense swards away from the river banks where shade is sparse. These swards were found to be up to 50 cm high, forming an extremely thick mat of live and decaying stems and leaves. This almost impenetrable mat was clearly very resistant to invasion by other species (Photos 1–5, p. 19). There were a few short 5–10 m stretches of the stream bank where flax and toetoe cover was sparse enough to allow this grass sward to exist on the banks.

# 6. Discussion on the long-term dataset

## 6.1 SIGNIFICANCE OF THE CHANGING FLORA TO ECOSYSTEM PROCESSES

Musk, watercress and floating sweetgrass (*Glyceria declinata* and *G. fluitans*) which dominated the stream banks along the entire length of stream in the late 1970s and 1980s (Photos 6–10, p. 21) were found in this study as occasional plants with cover values never exceeding 5% in any reach. Floating and submerged aquatic species were virtually absent. Thus the fast-growing species that colonised the stream channel during the 1980s were a minor part of the flora in 1995–98. In the 1980s, these stream channel species formed dense masses of vegetation, frequently blocking the channel in late summer and autumn when spawning rainbow trout were moving to upstream redds.

The loss of this vegetation has had two consequences:

1. Nutrient removal from stream water has been reduced.
2. Fish passage up the stream channel has been enhanced.

A summary of the processes illustrated by five dates over the last 24 years is provided in Table 5 and a pictorial summary is shown in Photos 6–10, p. 21.

### 6.1.1 Nutrient removal

The 24-year record of nutrient concentrations in the stream is shown in Fig. 8. The seasonal changes in nutrients, and particularly the differences between the Top and Bottom sampling sites, became more accentuated as the vegetation developed over the first decade and then has gradually decreased as tall (wetland) vegetation developed, assisted by plantings along the bank. This became particularly evident from 1990 onwards. The annual mass of inorganic nutrients removed from the stream each summer was obtained from integrating the difference in mass flow rates between the Top and Bottom sites each year. The data from 1986 are shown in Table 2 and for selected dates over the whole period in Table 5. The fate of the dissolved nutrients that were removed from the water was discussed in Hearne and Howard-Williams (1998). In general the nutrients are trapped by the growing vegetation and exported from the stream as particulate nitrogen and phosphorus during the winter months. Nitrogen is also lost by denitrification.

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