Thirty years of stream protection

Long-term nutrient and vegetation changes in a retired pasture stream

Clive Howard-Williams and Stuart Pickmere

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Cover: Whangamata Stream upper section looking downstream from Whangamata Road Bridge in 2008—32 years after retirement from pasture. *Photo: Authors' collection*.

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ABSTRACT

Whangamata Stream, which flows into Lake Taupo (Taupomoana), New Zealand, was protected by the establishment of riparian strips in 1976. The stream has been monitored since 1978, and the findings from this monitoring programme are analysed in this report. The vegetation in the riparian zone developed from a ryegrass-clover (*Lolium-Lotus*) pasture to a mixture of exotic woodland and native scrub communities, with dense flax (*Phormium tenax*), sedges (*Carex* spp.) and toetoe (*Cortaderia fulvida*) overhanging the stream channel. With the help of conservation plantings, the number of species increased at an average rate of 5.2 species per year (6.6% per year). There has been a 7.2% annual turnover in species and a continuing increase in the proportion of woody species over time. Over the 32-year period, base-flow stream discharge has varied from 0.03 m^3/s to c. 0.166 m^3/s, with some long-term cycles apparent. In the source springs, nitrate concentrations have increased by 50% since 1984, while dissolved reactive phosphorus concentrations have only increased slightly. In the stream channel, there was marked seasonality in both the concentration and mass flow of total suspended solids and nutrients, with lowest values in summer at the time of maximum vegetation growth and therefore nutrient uptake. Active management of stream bank vegetation that minimises shade over the stream channel and maximises fast-growing stream plants is required if the management objective for the riparian strip is to enhance in-stream nutrient uptake (attenuation). If, however, the long-term objective is to restore the stream banks to a 'natural state'—in this case a manuka (*Leptospermum scoparium*) woodland—then dissolved nutrient attenuation will decrease with time. Riparian protection and managed enhancement of in-stream vegetation for nutrient removal needs to be considered as one of a range of nutrient control methods in farming catchments.

Keywords: riparian strips, restoration, nitrogen, phosphorus, wetland, stream rehabilitation, succession, biodiversity, nutrient attenuation

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1. Introduction

Changing land uses in rural New Zealand have been associated with changing water quality (MfE 2007). In the face of intensified land use, riparian management has been the most commonly used mitigation measure for protecting water quality, and stream restoration efforts in New Zealand's agricultural landscapes have largely focused on management of riparian areas that typically involves excluding livestock and planting with native trees and shrubs (MfE 2001). However, there are few long-term studies of streams that document in detail the time scales over which changes occur following such protection.

This report records the findings from the long-term study of the Whangamata Stream, a second-order spring-fed stream that flows into the northern side of Lake Taupo (Taupomoana). This stream was retired from pastoral agriculture in 1976 as part of the Lake Taupo Catchment Control Scheme, by the establishment of riparian strips along the stream margins (Fig. 1). Although the primary aim of the stream protection was originally to minimise the impacts of soil erosion (Waikato Valley Authority 1973), reduction of the effects of nutrient runoff from farmland was also seen as an important objective. Since then, the emphasis on nutrients has grown, owing to concern over the increasing nutrient loads entering Lake Taupo (Taupomoana) (MfE 2002). Since 1976, land use in the Whangamata Stream catchment has changed markedly from purely pastoral agriculture to forestry and life-style block development, and more recently has included urban development.

Discussions with the former owner of the land (Mr R. Holyoake, pers. comm.) indicated that before conversion to sheep pasture, the stream edges were originally occupied by manuka (*Leptospermum scoparium*). This matched the description of the vegetation of much of the area surrounding Lake Taupo (Taupomoana) as manuka and fern scrubland (Ward 1956). Ward's 'Taupo Country' land use map of 1954 shows the Whangamata Stream catchment as a mix of pasture, newly-turned land and burnt-over land (Ward 1956). After conversion to pastoral farming, the banks were grazed as ryegrass-clover (*Lolium-Lotus*) pasture from the 1950s to 1976. Following the riparian fencing of most of the stream banks in 1976, the process of rehabilitation of the stream margins was assisted by some plantings of native species, including the stream-bank wetland species flax (*Phormium tenax*) and toetoe (*Cortaderia fulvida*) on the pasture-grassed banks. These plantings were initiated in a few areas by the then Waikato Valley Authority (now Environment Waikato), the New Zealand Wildlife Service and in later years by its successor, the Department of Conservation (Howard-Williams & Pickmere 1999).

Over the 32 years of protection (1976–2008), there have been a significant number of research papers and popular articles on this stream, documenting changes throughout the period. Since 1994, an annual monitoring report has been produced for the Department of Conservation and Environment Waikato. In 1999 and 2005, the Department of Conservation produced two publications in their *Science for Conservation* series that compiled and reported on monitoring reports for the previous 5 and 7 years (Beadel 1993, 1998; Howard-Williams & Pickmere 1999, 2005; Wildland Consultants Ltd 2003). These described

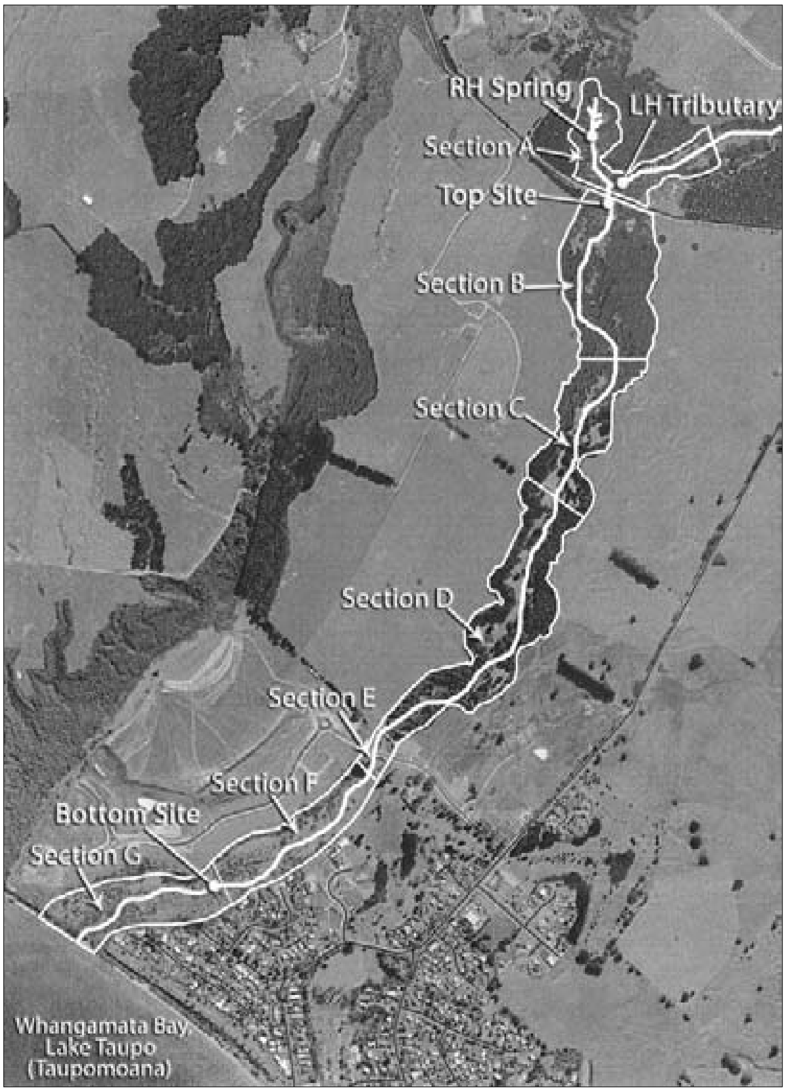

Figure 1. The study section of the Whangamata Stream showing the riparian strip (thin white outline), the sampling sites and the seven sections (A–G) for the vegetation descriptions outlined in section 4.1. Stream channel (thick white line) location is approximate. Distance between Top Site and Bottom Site is c. 2 km. Modified from original diagram in Wildland Consultants 2008 (with permission).

vegetation changes, flow rates and water quality in the stream at an upper ('Top Site') and lower ('Bottom Site') sampling point, and in the spring waters feeding the stream. Steps in the stream restoration process between 1976 and 1993 were identified (Young 1980; Howard-Williams & Pickmere 1994) and were recorded in the book 'Restoration of aquatic habitats' (Collier 1994); these were then added to in 1999 (Howard-Williams & Pickmere 1999).

Over time, there have been significant improvements to wildlife, rainbow trout (*Oncorhynchus mykiss*) spawning and biodiversity values in the stream (Young 1980; Howard-Williams & Pickmere 1999, 2005), and a series of changes in water quality parameters associated with changing riparian vegetation and changing discharges from the two springs feeding the stream. Recent interest in the long-term protection of Lake Taupo (Taupomoana) (MfE 2002) has focused on nutrients entering and then travelling in the groundwater towards the lake. Groundwater ages of the catchment have been estimated at between 35 and 80 years (Vant & Smith 2002), with the water emerging at the Whangamata Stream springs being amongst the oldest. Focus has also been on the role of riparian vegetation in stream nutrient attenuation, which places a special interest in this long-term dataset because it provides a continuous record of nutrient concentrations and mass flows during the period of stream bank vegetation change.

This report documents and summarises information collected over the monitoring period 1979–2008, and also includes information from earlier studies in 1973–1974 (Vincent & Downes 1980) and 1977–1978 (Schouten et al. 1981).

2. Aims

This monitoring programme for Whanagamata Stream was formally established in 1994, but built on a near-continuous record of information on the same parameters that had been collected as a long-term research project by the then Department of Scientific and Industrial Research from 1977 to 1991.

The aims of the 1994–2008 monitoring programme were to:

- Carry out flow gaugings and conduct water quality sampling at two sites on the stream on a series of sampling occasions each year.
- Sample the tributary spring waters at least once each year.
- Photograph the stream from standard sites and other sites of interest, and maintain a photo archive.
- Analyse the water samples for total suspended solids, nitrate-N, ammonium-N, dissolved organic nitrogen, dissolved reactive phosphorus and dissolved organic phosphorus. Since 2003, particulate nitrogen and particulate phosphorus have also been monitored, so that total nitrogen and total phosphorus could be calculated.
- Update the stream water quality archive database.
- Carry out a vegetation survey of the stream margins in 1998, 2003 and 2008, compile a species list, and analyse vegetation changes.
- Produce interim annual reports.
- Produce 5-year summary discussion papers in 1999 and 2005.

This report comprises a final overview that summarises the findings from the whole monitoring period and attempts to put them in a broader context of the implications of riparian restoration in a stream in a pasture catchment that should be of wide interest.

3. Methods

3.1 SITE DESCRIPTION

The Whangamata Stream is a 2-km-long second-order, spring-fed stream that flows into Whangamata Bay, Lake Taupo (Taupomoana) (Fig. 1). Two springs ('Right Hand Spring' and 'Left Hand Spring') provide the source of water. Water from the Left Hand Spring travels over 1 km to its confluence with the Right Hand Spring (Fig. 1). The stream has been described in detail in several previous publications referenced in Howard-Williams & Pickmere (1999, 2005).

3.2 SAMPLING

Two sampling sites, Top Site and Bottom Site, are shown on Fig. 1. Occasional sampling was also undertaken just below Right Hand Spring and in the tributary from Left Hand Spring just above Top Site. While the water quality of Right Hand Spring is likely to reflect the spring water itself, the tributary from Left Hand Spring is over 1 km in length, so water quality is likely to have been modified during downstream passage from the spring to the sampling site; therefore, this sampling site is referred to as 'Left Hand Tributary' (Fig. 1).

Stream flows were estimated from average velocities (ten readings) measured at 30% of the water depth at 10-cm intervals across the channel. For each 10-cm segment, discharge was calculated as velocity multiplied by area; these were then summed across the stream.

Duplicate water samples were collected from each site at approximately quarterly intervals from June 1992 to June 2008. From 1976 to 2001, analyses for dissolved nutrients were carried out with a Technicon II autoanalyser system using the methods detailed in Downes (1988), and since 2002 by FIA using a Lachat QuikChem FIA+ 8000 series using QuikChem Method 31-107-04-01 for nitrate, Method 31-107-06-1-1-B for ammonia and Method 31-115-01-1-I for dissolved reactive phosphorus. Only two nutrient compounds are discussed in detail in this report—nitrate-nitrogen (NO_3-N) and dissolved reactive phosphorus (DRP). Ammonium-nitrogen (NH_4-N), dissolved organic nitrogen and dissolved organic phosphorus were in low concentrations and did not make significant contributions to the total dissolved nitrogen and phosphorus budgets (see Appendix 1 for data).

A measure of the change in nutrient concentration per unit of downstream distance in a stream is known as the nutrient attenuation coefficient, Kw (Newbold et al. 1981; Howard-Williams 1985; Rutherford et al. 1987). This coefficient (unit = m^{-1}) was estimated for mid-summer periods from the stream nitrate concentrations by:

$$Kw = \ln(Cz/Co)/z \qquad \text{Equation 1}$$

where z is the distance between two points in a stream, Co is the nutrient concentration upstream and Cz is the nutrient concentration downstream.

Vegetation surveys were carried out by Wildland Consultants Ltd in 1993, 1998, 2003 and 2008 (Beadel 1993, 1998; Wildland Consultants Ltd 2003, 2008), and involved surveying the length of the stream and reporting on species present or absent in each of seven stream sections (sections A–G, Fig. 1). An estimate of percentage cover of each species in each section was also made. The full 2008 species list and distribution pattern is provided in Appendix 2. Information about the stream vegetation prior to these surveys was obtained by the Department of Scientific and Industrial Research in conjunction with the Rotorua Botanical Society.

4. Results

4.1 VEGETATION

A total of 189 vascular plant species were recorded for the study area in 2008 (see Appendix 2 for the full species list). This represented an increase of 17 species (10%) since the last survey in 2003. On average, the vascular plant biodiversity in the riparian strip increased at a rate of 5.2 species per year or 6.6% per year between 1976 and 2008. The most rapid rises in numbers occurred in the first decade (14% per year increase); over the last decade, the total species number has increased at a rate of 2.6% per year. With increasing maturity of the riparian area, the number of native species rose steadily to 2003 but has remained static since then, with 70 native species recorded in 2003 and 71 in 2008 (Figs 2 & 3). Native plants now represent 38% of the total flora. This is a slightly lower percentage than in 2003, when 42% of the flora comprised native species.

The vegetation is still in a dynamic successional stage, with new species arriving and some existing species disappearing from the stream margins. For instance, 33 new species (24 exotic and 9 native) were found in 2008 that were not recorded in previous surveys, while 20 species that were recorded in the 2003 survey (Wildland Consultants Ltd 2003) were not found in 2008. These comprised 'lost species' (Table 1). Thus, as the flora matures, there is a continual exchange of species invading and species disappearing. It is likely that many of the invaders move into the area but do not succeed in establishing themselves. This exchange (or species turnover) accounted for 8% over the last 5 years, compared with 6% in the previous 5 years (Howard-Williams & Pickmere 2005). The average turnover since 1982 has been 6.4%.

A cumulative total of 54 species have been 'lost' from the stream since 1982 (Table 1). All the species lost since the 2003 survey were listed as having a percentage cover of < 1% (see Table 1 for the list) and all were recorded in only one of the survey areas, with the exception of *Mimulus moschatus* (two survey areas), *Carduus nutans* (five areas), *Cyathea smithii* (two areas), *Epilobium pallidiflorum* (two areas), *Persicaria decipiens* (four areas) and *Senecio minimus* (two areas). It is likely that the other 'lost' species probably had occurred only as single specimens and may still be in the area. For instance, five species that

Figure 2. Number of species of vascular plants at Whangamata Stream, following its protection in 1976. Lost species are the cumulative totals of those species formerly recorded but no longer present.

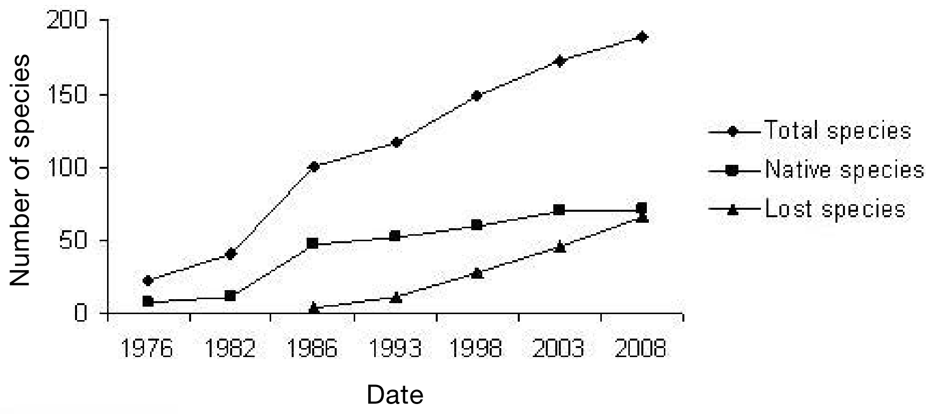

Figure 3. Time series of vegetation growth at Top Site, Whangamata Stream, looking downstream from Whangamata Road Bridge, from 1975 to 2006. (1974 photo: Dennis Crequer, Environment Waikato; other photos from authors' collection.)

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