PROJECT TWIN STREAMS - 12 YEARS OF COMMUNITY RIPARIAN PLANTING AND STREAM HEALTH REPORTING

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ABSTRACT

This paper summarizes water and sediment quality data from PTS streams collated during four "snapshot surveys" conducted over a 12 year period and provides a summary of any trends and compliance of this data with environmental guidelines for aquatic ecosystem health and contact recreation. The reporting has been framed according to stream type using the river environment classification (REC) and land cover database (LCDB) version 4 to ensure that nonhuman induced effects on water quality (e.g. climate, source of flow, geology, land cover etc.) are factored out, thereby comparing like with like stream types.

Unlike previous reporting, this paper includes comparisons of the PTS sites with other sites from Auckland Council's State of the Environment (SOE) monitoring program. In making these comparisons it provides context as to how PTS catchments compare to other parts of the Auckland Region.

Keywords

Temporal and spatial analyses, river environment classification, habitat quality water quality, sediment quality, fresh water, ecology, riparian planting

PRESENTER PROFILE

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1 INTRODUCTION

Project Twin Streams (PTS) was initiated as a partnership between Waitakere City Council and the local community aimed at improving flood management (by increasing the flood plain via house removal, and increased stormwater detention), water quality and ecological health of waterways in and around Waitakere City. Since, 2016 this relationship now exists between community groups and the Auckland Council Parks department.

The project initially comprised planning changes to reduce flooding, followed by improving the treatment of stormwater, restoring native plantings along stream banks, clearing stream channels and developing wetlands to reduce land use pressures and enhance environmental values.

To gain maximum value for community engagement and flood mitigation, the restoration of most streams within the Project Twin Streams area focused efforts where population densities were highest. This means that much of the restoration work occurred within the mid to lower reaches of these stream catchments.

Project Twin streams covers the stream catchments draining to Henderson Creek. This includes the lower Oratia Stream and Lower Opanuku stream, Waikumete, and lower Swanson (Figure 1). These streams run through a mixture of native bush, rural and urban areas.

Environmental Impact Assessments Limited (EIA) were requested to repeat the Pressure-State-Response investigative stream reporting for PTS previously carried out by other consultancies (Eco Water Solutions 2004, Kingett & Mitchell 2006, Golders 2010).

The monitoring program for PTS comprised:

- Pressure monitoring using urban infrastructural indicators, including percent land use, and community response measures such as riparian planting;
- Aquatic ecology and habitat quality assessments
- Stream water quality monitoring
- Stream sediment quality monitoring

Historical snap shot monthly water quality surveys have been undertaken over the summer / autumn periods of 2003/04 (November – April), 2005/06 (December – May), a winter / spring period in 2010 (May – August) and recently an autumn period (April/May) in 2016. In addition to this, ecological surveys were undertaken in 2003, 2006, 2010 and 2016. Stream sediment quality surveys have previously been done in 2003, 2006, 2010 and repeated in 2016.

Unlike previous reports, the 2016 reporting included comparisons of the PTS sites with other sites from Auckland Council's State of the Environment (SOE) monitoring program. In making these comparisons it provided context as to how PTS catchments compared to other parts of the Auckland Region.

The Auckland Council's SOE program sites were selected based on river environment classification (REC) and land cover database (LCDB4) characteristics similar to those of the PTS stream sites.

1.1 CAUTIONARY NOTE

Several notes of caution are appropriate when reading this paper, as a means of providing suitable context for the reporting presented here. Most notable is in the comparisons of data and monitoring results between years. Where every attempt has been made to make sure that all field sampling and laboratory protocols were consistent for each period of data collection, as different personnel have been involved over the thirteen year period of data collection, some individual variation may have occurred. This will be most notable amongst the measures requiring human judgement or visual assessment (e.g. habitat assessments) in contrast to empirical laboratory measurements.

For the most part sampling for PTS has been over the spring and summer period (2003/04 and 2005/06 sampling). However in 2010 sampling was undertaken during the autumn and winter months, a period when stream conditions can be very different from the summer conditions (typically lower water temperatures, greater runoff and higher flows) while the 2016 sampling occurred during the autumn months of April and May. Deseasonalising of data has been made for time series analysis to remove any bias of season in the entire data set, however, it cannot be ruled out that some seasonal influence still exists within the data.

Water quality data is also affected by stream flow, however, most of the selected Auckland Council SOE monitoring programme sites are not monitored for flow, therefore flow adjustment has not been possible for this long-term water quality data.

Detailed methods of previous PTS reports were not available for some variables. In these instances, we have had to make an assumption of what was previously done. This is particularly so for the stream habitat assessments component.

No 2016 data was available for the SOE monitoring sites at the time of this reports compilation. Therefore comparisons of PTS site data measured in 2016 were compared against the SOE historical median values from previous data. There is likely to be error in making this comparison particularly in light of climate change. For example March 2016 was the warmest March on historical record, this could have resulted in an increase of stress to aquatic ecosystems not previously experienced.

Historically the pressure indicators for urban land use have been applied to all stream types. Some of these indicators e.g. stormwater infrastructure indicators, have little relevance to pastoral or forested streams as they are often not located in these types of streams. No relevant pressure indicator data for the pastoral or forested streams had been provided to date, therefore the pressure-state-response reporting of these stream types is less comprehensive.

In some instances water quality statistical analysis has not been conducted owing to sample sizes of data sets for particular sites being too small for comprehensive reporting. In each case a statement had been made where sites were not analysed.

All sampling for 2016 was undertaken by Thomas Civil and Environmental Consultancy Limited during the months of April and May following methods identified in previous reports.

The Site locations for the PTS monitoring project are provided in Table 1 and displayed spatially in Figure 1. These 19 sites were sampled for water quality on 6th and 7th April and 4th and 5th May 2016, providing 2 sets of water quality data per site. Aquatic macroinvertebrates were sampled on 6th and 7th April 2016, sediment sampling was undertaken on 4th and 5th May 2016 while stream habitat assessments were undertaken on 2nd, 3rd and 4th May 2016.

Land Cover (REC)	Programme	Site ID	Site Name	Data Available	Stream Order	REC Class	Distance to Sea (km)	Catchment Area (Ha)	Land Cover Database Category
Urban	SOE	8219	Otaki Creek	Water Quality	2	WD/L/M/U/LO/LG	0.8	159.4	Urban Parkland/Open Space
Urban	SOE	7830	Lucas Creek	Water Quality/ Ecology	3	WD/L/SS/U/MO/LG	2.3	628.3	Indigenous Forest
Urban	SOE	7811	Oteha Stream	Water Quality/ Ecology	3	WD/L/SS/U/MO/LG	3.0	1197.5	High Producing Exotic Grassland
Urban	SOE	8110	Oakley Creek	Water Quality/ Ecology	3	WW/L/M/U/MO/LG	0.4	1257.4	Indigenous Forest
Urban	PTS	J	Hibernia Stream	Water Quality/ Ecology	1	WW/L/SS/U/LO/MG	10.2	13.0	Urban Parkland/Open Space
Urban	PTS	L	Whakarino Stream	Water Quality/ Ecology	1	WW/L/M/U/LO/LG	9.2	38.9	Manuka and/or Kanuka
Urban	PTS	E	Potters Stream	Water Quality/ Ecology	1	WW/L/SS/U/LO/HG	11.3	78.7	Manuka and/or Kanuka
Urban	PTS	K	Hibernia Stream	Water Quality /Ecology	2	WW/L/SS/U/LO/LG	8.8	176.0	Built-up Area (settlement)
Urban	PTS	M	Waikumete Stream	Water Quality /Ecology	2	WW/L/SS/U/LO/LG	8.8	392.5	Built-up Area (settlement)
Urban	PTS	O	Waikumete Stream	Water Quality /Ecology	3	WW/L/SS/U/MO/LG	5.8	880.1	Urban Parkland/Open Space
Urban	PTS	N	Waikumete	Water Quality	3	WW/L/SS/U/MO/LG	7.2	556.4	Built-up Area (settlement)

Land Cover (REC)	Programme	Site ID	Site Name	Data Available	Stream Order	REC Class	Distance to Sea (km)	Catchment Area (Ha)	Land Cover Database Category
			Stream	/Ecology					
Urban	PTS	D	Opanuku Stream	Water Quality /Ecology	4	WW/L/SS/U/MO/LG	4.3	2570.0	Built-up Area (settlement)
Urban	PTS	I	Oratia Stream	Water Quality /Ecology	4	WW/L/SS/U/MO/LG	4.3	2857.4	Built-up Area (settlement)

Table 1: Continued…

Land Cover (REC)	Programme	Site ID	Site Name	Data Available	Stream Order	REC Class	Distance to Sea (km)	Catchment Area (Ha)	Land Cover Database Category
Forest	PTS	P	Swanson Stream	Water Quality /Ecology	2	WW/L/SS/IF/LO/MG	8.0	365.9	Manuka and/or Kanuka
Forest	PTS	A	Opanuku Stream	Water Quality /Ecology	3	WW/L/SS/IF/MO/MG	12.0	372.5	Manuka and/or Kanuka
Forest	SOE	6850	Mahurangi LTB	Ecology	2	WW/L/SS/EF/LO/HG	13.4	495.9	Indigenous Forest
Forest	SOE	6811	Mahurangi River (HQ)	Water Quality	2	WW/L/SS/EF/LO/HG	13.4	495.9	High Producing Exotic Grassland
Forest	PTS	F	Oratia Stream	Water Quality /Ecology	3	WW/L/SS/IF/MO/LG	8.6	692.6	Exotic Forest
Pastoral	PTS	Q	Swanson Stream	Water Quality /Ecology	3	WW/L/SS/P/MO/LG	6.1	671.1	High Producing Exotic Grassland
Pastoral	PTS	R	Swanson Stream	Water Quality /Ecology	4	WW/L/SS/P/MO/LG	3.2	962.9	Manuka and/or Kanuka
Pastoral	PTS	G	Oratia Stream	Water Quality /Ecology	3	WW/L/SS/P/MO/LG	6.3	1610.4	High Producing Exotic Grassland
Land Cover (REC)	**Programme**	**Site ID**	**Site Name**	**Data Available**	**Stream Order**	**REC Class**	**Distance to Sea (km)**	**Catchment Area (Ha)**	**Land Cover Database Category**

Pastoral	PTS	H	Oratia Stream	Water Quality /Ecology	3	WW/L/SS/P/MO/LG	6.0	1686.9	Urban Parkland/Open Space
Pastoral	PTS	B	Opanuku Stream	Water Quality /Ecology	2	WW/L/SS/P/LO/LG	8.3	1687.1	Manuka and/or Kanuka
Pastoral	SOE	6607	Matakana LTB	Ecology	4	WW/L/SS/P/MO/LG	2.0	1418.6	Indigenous Forest
Pastoral	SOE	6604	Matakana River	Water Quality	4	WW/L/SS/P/MO/LG	2.0	1418.6	Indigenous Forest
Pastoral	PTS	S	Swanson Stream	Water Quality /Ecology	4	WW/L/SS/P/MO/LG	1.8	2418.0	Indigenous Forest
Pastoral	PTS	C	Opanuku Stream	Water Quality /Ecology	4	WW/L/SS/P/MO/LG	6.2	2190.1	Broadleaved Indigenous Hardwoods
Pastoral	SOE	7173	Waiwera River	Water Quality	4	WW/L/SS/P/MO/LG	3.5	3032.4	Broadleaved Indigenous Hardwoods

Table 1: ***Monitoring Sites of the PTS and SOE Programs***

Key: PTS = Project Twin Streams Sites

SOE =State of the Environment Monitoring Sites

REC Descriptors: WW = Warm Wet Climate – Warm = mean annual temperature > 12 °C, wet = 500-1500 mm/yr mean annual rainfall

WD = Warm Dry Climate – Warm = mean annual temperature > 12 °C, dry = < 500 mm/yr mean annual rainfall

L = Low Elevation Stream - < 400 m elevation

SS = Soft Sedimentary Geology

P = Pastoral - > 25% of catchment in pasture land cover

U = Urban - > 15% of catchment in urban land cover

IF = Indigenous Forest – the spatially dominant land cover category

EF = Exotic Forest – the spatially dominant land cover category

MO = Medium Stream Order (3-4)

LO = Low Stream Order (1-2)

LG = Low Gradient – catchment valley slope based on Euclidian length < 0.02

MG = Medium Gradient – catchment valley slope based on Euclidian length 0.02 – 0.04

HG= High Gradient – catchment valley slope based on Euclidian length > 0.04

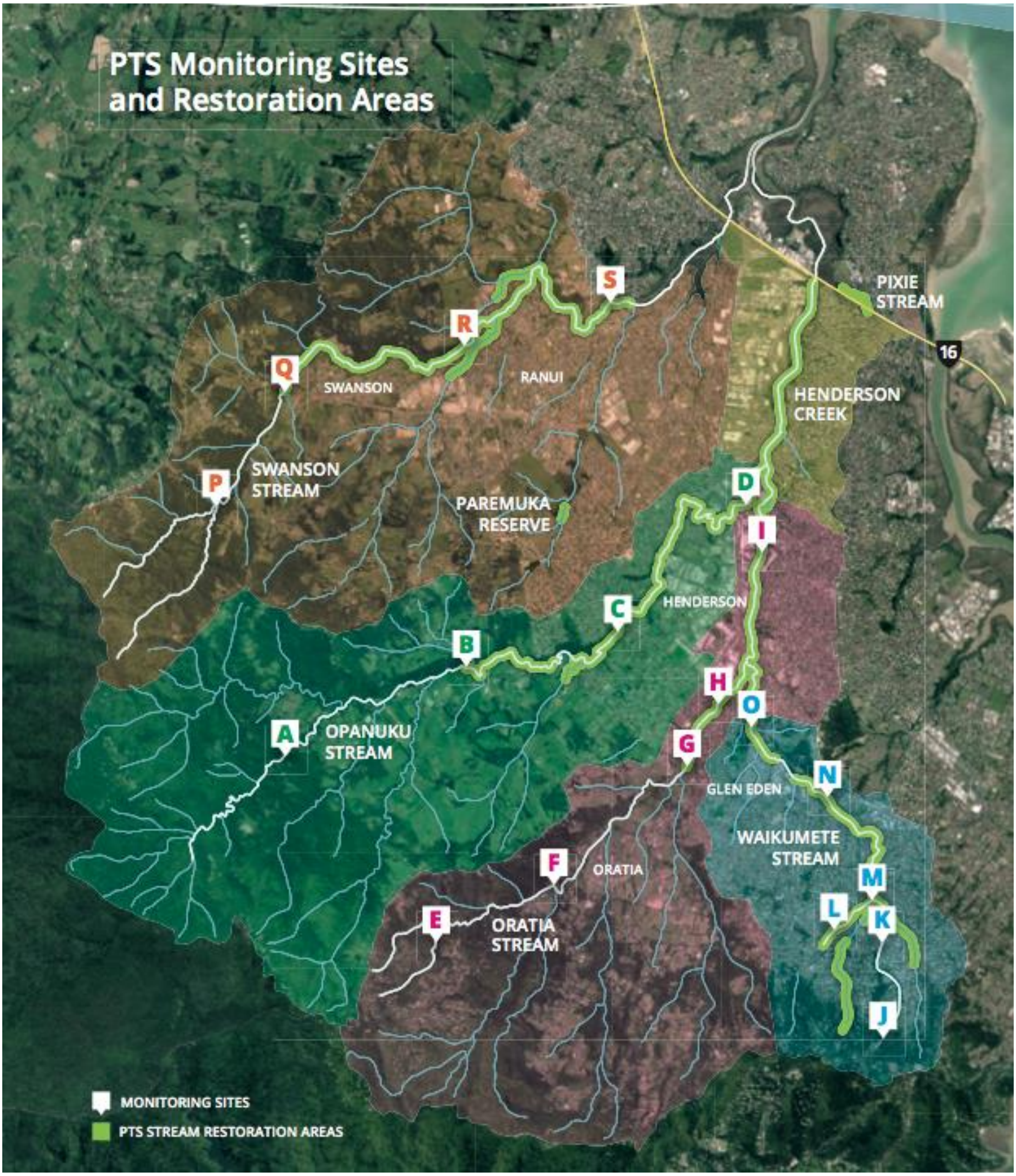

Figure 1: Monitoring Sites and Restoration Areas of the Project Twin Streams Program.

2 METHODS

2.1 SITE SELECTION AND RIVER TYPING

The comparative Auckland Council's SOE program sites were selected based on river environment classification (REC) and land cover database (LCDB4) characteristics similar to those of the PTS stream sites. This ensured that similar streams of the two programs were being compared.

Data from the PTS and SOE monitoring programs were matched for the same time periods to ensure consistent seasonal variation of water quality data.

2.2 PRESSURE STATE RESPONSE VARIABLES

In keeping with previous reports, the current report focused on the same pressure, state and response variables.

The major pressure indicators analysed in previous PTS reports have included:

1. Impervious area upstream

2. Total pipe length – this indicator estimates the total length of piping that may be discharging from a stream catchment.

3. Land cover- Using the land cover database (version 4) the percentage of various land cover types (cropland, grassland, shrubland, native forest, plantation forest, urban settlement, and urban park land).

4. Number of stormwater outlets and inlets-

5. Total number of stormwater outlets > 375 mm

While response indicators previously examined as a desktop exercise, have included:

6. Riparian planting within each catchment

As with previous reports all pressure and response monitoring was conducted as a GIS desktop exercise using ArcView GIS version 10.3.

Unfortunately no PSR data was available for the SOE monitoring program so this analysis could not be conducted on this data set for comparison with the PTS program.

2.3 ECOLOGICAL MONITORING

Stream habitat assessments were conducted on 2nd, 3rd and 4th May 2016 during baseflow conditions (previous fresh of 3 X median flow occurred on 18/02/2016) at each site. Details of the habitat assessments can be viewed in Stansfield 2016.

Macroinvertebrates were sampled at all sites using protocol C1 for hard bottom streams or C2 for soft bottomed streams (Stark et al 2000) during April 6th and 7th 2016. The macroinvertebrate samples were processed, according to the P200 protocol method (Stark et al 2000) and taxonomically analysed to MCI level precision (Stark 1998) using an Olympus SZ30 or Meiji EMZ-13 dissecting microscope.

Invertebrate data was entered into an excel macro for calculation of the biotic indices (taxa richness, EPT, %EPT taxa, %EPT individuals and MCI).

Comparisons of macroinvertebrate biotic indices of PTS sites for 2016 have been compared to the median value of data generated from the SOE monitoring programme. This was done because 2016 ecological data was not available for the SOE monitoring programme at the time of report writing furthermore many of Council's ecology monitoring sites are sampled less frequently (3 yearly).

2.4 WATER QUALITY SAMPLING

Stream water from each site was sampled for the analytes listed in Table 2. Water samples were collected on the 6th and 7th of April and the 4th and 5th of May during baseflow conditions.

Onsite measurements of water temperature, dissolved oxygen concentration, % dissolved oxygen, pH, electrical conductivity and specific conductivity, were conducted using a hand held YSI Pro Plus meter. Prior to each sampling day, the hand held meter was calibrated using standard buffer solutions for electrical conductivity, and pH.

Water Clarity was also measured using the black disc technique specified by Davies-Colley (1988).

Table 2: Water Quality Analytes Measured

Analyte	Concentration Unit	Laboratory
Turbidity	NTU	Hill Laboratories
Total Suspended Solids	g/m^3	Hill Laboratories
Dissolved Copper	g/m^3	Hill Laboratories
Total Copper	g/m^3	Hill Laboratories
Dissolved Zinc	g/m^3	Hill Laboratories
Total Zinc	g/m^3	Hill Laboratories
Ammoniacal Nitrogen	g/m^3	Hill Laboratories
Nitrite Nitrogen	g/m^3	Hill Laboratories
Nitrate Nitrogen	g/m^3	Hill Laboratories
Total Oxidised Nitrogen		Calculated Field
Soluble Inorganic Nitrogen		Calculated Field
Dissolved Reactive Phosphorus	g/m^3	Hill Laboratories
E. coli	MPN/100ml	Watercare Laboratories
pH		YSI Pro Plus Meter
Temperature	**° C**	YSI Pro Plus Meter
Dissolved Oxygen	mg/l	YSI Pro Plus Meter
Dissolved Oxygen	%	YSI Pro Plus Meter
Electrical Conductivity	uS/cm	YSI Pro Plus Meter
Specific Conductivity	uS/cm @ 25 °C	YSI Pro Plus Meter

Water Clarity	m	Black Disc Technique

2.5 SEDIMENT QUALITY SAMPLING

Three stream bed sediment samples were collected at each site using a perspex tube of 100mm diameter and were composited into one sample which was transferred to plastic containers provided by Hill Laboratories. The top 2 cm of the stream bed was sampled from depositional areas of each stream reach. Run habitat was most ideal for collecting these samples and as this is where stream depths are not too deep and sediments often deposit.

Each sediment sample was analysed for total recoverable and acid soluble copper, lead and zinc. Sediment size fractions were also analysed for each sample. All analyses were conducted by Hill Laboratories. All sediment quality analytes were assessed for compliance against the ANZECC 2000 interim sediment quality ISQG High and ISQG Low guidelines.

2.6 DATA FORMATTING AND STATISTICAL ANALYSES

Prior to any analysis of laboratory data, all less than detection limit data was converted to half its value while any greater than detection limit data was converted to its value. This is a standard data formatting procedure recommended prior to data analysis (Ward et al1990).

Spatial site comparisons of water and sediment quality was undertaken using Trend and Equivalence Analysis version 5 using box and whisker plots. The box plots were created using all available information for both the PTS and SOE sites. This made the PTS data set slightly larger (inclusion of April and May 2016) than the SOE data set (2016 water quality data not available). The data sets were matched for the same time periods to remove any possibility of seasonal bias influencing the comparative results.

All water quality analytes were assessed for compliance against relevant guidelines (ANZECC 2000) or standards (National Policy Statement for Freshwater Management (NPS-FM), 2014).

All sites were subject to temporal trend analysis using the Mann Kendall Trend test or the Seasonal Kendall Trend Test provided in Trend and Equivalence Analysis version 5. Prior to trend analysis site analyte data was tested for seasonality. If seasonality was demonstrated then the Seasonal Kendall Trend Test was used to remove this influence, otherwise the Mann Kendall Trend test was used. Seasonality testing requires that at least three years of a particular season be in the data set to determine whether a seasonal influence is occurring within the time series data set. Therefore any data sets that had less than three seasons (e.g. macroinvertebrate, turbidity, clarity or sediment data) were subject to trend analysis without seasonal adjustment.

To confirm that a trend was significant and meaningful, three criteria were needed:

- The trend must have statistical significance ($p<0.05$) – this ensures that the trend is not simply due to chance.
- The magnitude of the trend must be greater than laboratory detection limits – this means the trend must be measurable. If the trend is less than the laboratory detection it is not considered a significant trend as it is likely a laboratory could not measure the difference between the beginning and the end of the time series.
- The trend must have environmental significance – as a general rule of thumb, water quality or sediment quality trends > 1% per annum are considered environmentally significant. For sediment analyses I also adopted some descriptive criteria recommended by Auckland Council (Mills et al. 2012). I also adopted the criteria recommended by Collier & Hamer (2012) for

which an overall change of 15% or greater in MCI and the trend slope exceeding 1% per annum over the time period is considered ecologically significant.

Because the SOE sites are not monitored for flow no flow adjustment was undertaken in determining the water quality temporal trends. This means that any trends when comparing SoE sites to PTS sites detected in this report could be due to the influences of flow rather than any differences in catchment restoration initiatives.

2.7 RESULTS AND DISCUSSION

2.7.1 SITE SELECTION AND RIVER TYPING

GIS and LCDB4 analysis of the PTS and SOE monitoring programs revealed that most comparable sites of the two programs were warm wet low elevation streams of soft sedimentary geology. The next hierarchical driver of water quality that distinguished the sites into groups was land cover of which the sites were grouped according to indigenous forest, pastoral, or urban. A description of these groupings follows.

- Urban streams – Nine sites from PTS belong to this grouping (sites L, E, M, K, J, N, O, I, D) have been compared to 4 sites from Auckland Council's state of the environment monitoring programme (i.e. Lucas Creek, Oteha Stream, Oakley Creek and Otaki Creek). The state of the environment monitoring programme (SOE) only has one warm wet low elevation urban stream site (Oakley Creek) and it was felt that this was too few sites for comparison. Therefore the additional 3 sites were brought in for more robust comparison, however these sites (Lucas Creek, Oteha Stream and Otaki Creek) are of a warm dry climate.

- Forestry streams – this grouping comprises three sites from PTS (sites A, F and P) and two sites from the SOE programme (Mahurangi LTB and Mahurangi River).The PTS sites are located in indigenous forest, while the SOE sites are located in exotic forest catchments. These sites have a stream order of either 2 or 3 and have a catchment area between 365 to 693 Ha.

- Pastoral streams – This group comprises 7 PTS sites (B, Q, R, G, H, S, C) and 4 SOE sites (Okura Creek, Matakana Long Term Baseline (LTB), Matakana River & Waiwera River). The land cover database shows that sites Q, and G are surrounded by high producing exotic grasslands while site H is surrounded by open park land. The remaining pastoral sites are surrounded by native vegetation. These stream sites are between 2^{nd} to 4^{th} order and have a catchment area varying between 671 to 3032 Ha.

The reader is advised to view Stansfield 2016 and Stansfield 2016a for any graphical outputs discussed in the following section.

2.7.2 URBAN STREAMS

The urban streams display the poorest water quality and ecology of all stream types. This is an expected result as urban streams are likely to be under the greatest amount and variety of land use pressure compared to the other land uses. Within the urban stream group some interesting spatial trends have emerged.

Site J (Hibernia Stream) shows particularly good ecosystem health and biodiversity value as measured by the biotic indices (taxa richness, EPT, % EPT and MCI). Site J is quite unique from the remaining sites in that it has the second lowest proportion of impervious cover and pipe length, its catchment has the highest proportion of shrubland, and it has the smallest catchment area. These unique properties are expected to result in the higher value biotic indices observed. However, this site also shows the second poorest habitat quality score which is surprising. This indicates that despite the poor habitat quality, the reduced urban pressure (as measured by the urban pressure indicators) may be driving the better macroinvertebrate community health of this stream.

The EPT indices tend to show that the Waikumete Stream has the poorest quality of the urban stream group. Unique features of these sites (M & O) is that they have the highest and 2^{nd} highest amount of piping / Ha of catchment area and amongst the highest catchment imperviousness (30 & 34% respectively). Site M does show the poorest habitat quality of the group so poor habitat in addition to the high degree of piping and catchment imperviousness could be contributing to the lower EPT scores at this site.

The range of MCI values for the PTS sites are not considered to be significantly different to those MCI values of the SOE monitoring programme. This would indicate that despite the riparian restoration and other efforts to reduce the effects of urban land use pressure on receiving waters, the PTS project has not resulted in any significant ecological improvement of its streams compared to other areas of the Auckland Region

Dissolved copper and specific conductivity are the only two water quality variables that show clear differences in concentrations when comparing the PTS to the SOE group of sites. The soluble concentrations of the SOE sites regularly exceed the total copper concentration guideline of 0.025 g/m^3 indicating that metal speciation is warranted to determine the risk to the aquatic biota of these streams. The differences in dissolved copper concentrations of the PTS and SOE sites could be the result of varying urban influences within their respective catchments. Unfortunately no urban pressure indicator data has been provided for the SOE sites, however further research into this area is warranted.

The dissolved copper differences could also be due to urban pressures not previously monitored e.g. traffic volumes, or could be the result of streambed substrate differences. Again further reporting into this area would also be of benefit to helping explain the differences in dissolved copper concentrations in these streams.

Water and sediment quality is particularly good at site J (Hibernia Stream) and site E (Potters Stream). These two sites have had no community riparian planting efforts undertaken along their length since the commencement of Project Twin Streams so the good water and sediment quality at these sites cannot be attributed to any PTS riparian planting measures. Unique features of sites J and E is that they have the lowest proportions of piping in their catchments and site E has the lowest amount of imperviousness in its catchment (7%). Whether these urban pressure indicators are driving this pattern in water quality would require further investigations.

Two PTS sites demonstrated a decline in sediment metal concentrations. A decreasing trend of extractable lead over time was observed at Site N (Waikumete Stream). The slope equates to a percent annual change of -4.2 % / yr. If this trend continues into the future it is likely to bring Site N (Waikumete Stream) into compliance with the ANZECC ISQG low guideline for extractable lead (50 mg/kg).

A decreasing trend of extractable lead over time was also observed at Site I (Oratia Stream). The slope equates to a percent annual change of -3.5 % / yr. If this trend continues into the future it is likely to bring Site I (Oratia Stream) into compliance with the ANZECC ISQG low guideline for extractable lead (50 mg/kg).

The reason for these time series trends is unclear.

2.7.3 PRESSURE AND RESPONSE INDICATOR TRENDS

Since 2010, the greatest increase in impervious cover and associated piping has occurred at sites L, M, N and O of the Waikumete Catchment. These sites also feature as having had the greatest increase in riparian planting. Unfortunately these stream restoration efforts have not resulted in any significant ecological improvement possibly because the urban pressures were already high in 2010. However none of these sites have demonstrated any significant decline in ecosystem health despite the increased land use pressure occurring within these catchments, which is a positive outcome.

Since 2010 the smallest increase in impervious cover and associated piping has occurred at sites D and E, however no riparian planting has occurred at site E while site D has had significant (14%)

riparian planting which has resulted in an improvement of habitat quality (33%) However this has not resulted in a corresponding improvement in ecological health of site D (Opanuku Stream). This result could be due to the fact that site D still has an impervious cover (10%) that is potentially unlikely to result in adverse effects on the aquatic biota (Walsh et al 2005, 12%).

2.8 PASTORAL STREAMS

The pastoral streams are of better quality than the urban streams and generally of an intermediate quality between the urban and forested streams.

Of the PTS sites, site B (Opanuku Stream) and G (Oratia Stream) show particularly good ecosystem health and biodiversity value as measured by the biotic indices (taxa richness, EPT, % EPT and MCI). No riparian community planting has been undertaken at these sites so the good ecological status of these streams cannot be attributed to any PTS riparian planting work.

With the exception of sites B and G, the SOE sites generally show better ecological health than the PTS pastoral stream sites. This would indicate that despite the riparian restoration and other efforts to reduce the effects of pastoral land use pressure on receiving waters, the PTS project has not resulted in any significant ecological improvement of its streams compared to other areas of the Auckland Region.

The Swanson Stream shows a marked downstream decline in MCI values moving from site Q to site S. This trend is considered ecologically significant as the change in MCI is greater than 20%. The habitat quality at these two sites is very similar, so the reason for the decline in MCI is unclear. While water quality does decline in a downstream direction for the Swanson Stream, the magnitude of change is not great, so the water quality determinants cannot be solely responsible for the change in ecosystem health experienced downstream.

Unfortunately no pastoral stream land use pressure indicators have been provided to help determine why certain patterns in water quality and ecology of the pastoral streams exist. In future a GIS desktop analysis of pastoral land use pressure indicators would be useful. Possible pressures to examine could include stocking units / Ha, proportion of catchment subject to tillage of topsoil, kg/Ha of nitrogen or phosphorus fertiliser applications, proportion of catchment subject to intensive agricultural land use practices etc.

In terms of water quality the PTS sites tend to display better water clarity, lower electrical conductivity and higher dissolved oxygen concentrations than the SOE sites, however the differences are not considered to be ecologically significant and cannot be attributed to any restorative catchment efforts of the PTS program as sites for which no riparian planting effort has been conducted (sites B and G) show no difference to the remaining PTS sites.

All sites of the pastoral group are compliant with the NPS-FM Total oxidised Nitrogen guidelines for class A waters. Three sites comply with the NPS-FM Ammoniacal median and 95th percentile standards for class A waters (≤ 0.03 and ≤ 0.05 g/m^3) namely site B, C (Opanuku Stream) and G (Oratia Stream). The remaining sites fall within the NPS-FM median and 95 percentile standard for class B waters (1-2.4 and 1.5 – 3.5 g/m^3). In general the PTS and SOE sites show similar levels of compliance with the NPS-FM for total oxidised nitrogen and ammoniacal nitrogen standards.

All of the pastoral streams fail to meet the NPS-FM *E. coli* median and 95th percentile standards for class A waters (< 260 E. coli / 100ml). Sites B (Opanuku Stream) and Q (Swanson Stream) meet the median standard of < 540 E.coli / 100 ml for wading class B waters, however the 95 percentile values of all sites indicates that while not ideal for bathing, all sites pose a significant health risk to bathing in these waters.

In general the PTS sites show similar dissolved copper concentrations to the Okura Creek SOE site. Compliance with the ANZECC 2000 Guidelines for dissolved zinc, is variable and dependent on each site however all sites show good compliance with the ANZECC 80% protection level for aquatic ecosystems.

The only pastoral stream site to show a significant change in surface water quality was the Waiwera Stream (SOE) for which ammoniacal nitrogen concentrations were in decline. The slope equates to a percent annual change of -15% / yr which exceeds the environmental significance criteria of 1% / yr.

2.9 FORESTED STREAMS

The forested streams display the best water quality and macroinvertebrate communities of the three land cover types. This pattern is expected given that forested streams are generally located away from intensive land uses and tend to have good riparian cover along their stream lengths.

The Mahurangi River SOE site shows the greatest taxa, EPT richness and MCI values of all the forested sites. The reason for this is unclear as no habitat quality data was available for the SOE sites. Site A (Opanuku Stream) displayed the greatest % EPT and the best habitat quality of the PTS sites. In general the PTS sites show an increasing MCI value with increased habitat quality.

Specific conductivity is generally low at all sites which is expected of forested streams. The good water quality of the forested streams is reflected in their excellent compliance with environmental guidelines and standards. Stream and sediment heavy metal concentrations are also generally low which is also expected of forested streams.

In general the aquatic ecology, habitat and water and sediment quality characteristics of the forested streams demonstrate what could be achieved for an urban or pastoral stream if land use effects in these latter stream types were extensively mitigated. The costs associated in mitigating these land use effects, and the cost benefit relationship needs to be further investigated alongside other environmental goals.

The only forested sites to show significant temporal trends were for site A (Opanuku) which demonstrated a decline in sediment extractable copper concentrations. The slope equates to a percent annual change of -1.07% / yr which just exceeds the environmental significance criteria of 1% / yr. This 1.07% /yr change borders on non-significant to small emerging trend status according to Auckland Council marine benthic sediment contaminant trend criteria (Mills et al. 2012). All copper concentrations of the time period are below the ANZECC ISQG low guideline of 65 mg/kg extractable copper.

Conversely site A (PTS) also displayed an increase in sediment extractable zinc concentrations. The slope equates to a percent annual change of 2.79% / yr which exceeds the environmental significance criteria of 1% / yr. This 2.79% /yr change equates to a stronger trend that is worthy of follow up according to Auckland Council criteria (Mills et al. 2012). The zinc concentrations of the time period are all below the ANZECC ISQG Low guideline of 200 mg/kg extractable zinc.

2.10 Land Cover Comparisons

The only urban and pastoral streams that have displayed similar or better water and ecology qualities compared to the forested streams include:

Site J (Hibernia Stream) – this urban stream displays similar ecology and water quality to the forested streams. The site is fully compliant with the NPS-FM standard for class A waters for total oxidised nitrogen and ammoniacal nitrogen.

Site E (Potters Stream) – this urban stream does not display as good ecology as the forested group, however it does show similar water and sediment quality to the forested streams

Site B (Opanuku Stream) this pastoral stream displays similar ecology and water quality to the forested streams. Compliance with environmental guidelines at this site is generally excellent.

These streams are all located towards the headwater reaches of their catchments and are therefore likely to have the least amount of land use pressure of their respective urban or pastoral grouping. These sites have not been subject to any PTS riparian restoration measures so they have not been influenced by any catchment community response efforts.

2.11 Comparisons of PTS with SOE

The PTS sites do show better water quality than the SOE sites in the following ways:

- Dissolved copper concentrations are lower at the urban stream sites
- Water clarity is higher at the pastoral sites
- Dissolved oxygen of the pastoral sites is higher
- Water temperatures are less variable at the pastoral Unfortunately these patterns of better water quality at the PTS sites have not resulted in significant improvements to the macroinvertebrate ecology of the streams compared to the SOE sites. Having said that the PTS sites generally have not shown a significant decline in ecosystem health which is a positive outcome.

2.11.1 LESSONS LEARNT

Using land cover as a defining group has weaknesses in that it does not distinguish the variability of land uses that can occcur for example intensive dairy farming vs extensive pastoral lifestyle blocks are likely to have very different effects on water quality and ecology.

Measuring other pressure indicators may help with understanding the benefits of PTS, particularly in the pastoral catchments for which few pastoral or agricultural pressure indicators have been monitored. Reporting of traffic volumes within the urban catchments could also be a useful urban pressure indicator to monitor to gain a better understanding of urban pressures on these stream catchments.

Temperature sondes were deployed in the initial stages of the monitoring regime (Ecowater Solutions 2003), however this was never repeated. Repeating the temperature sonde monitoirng would add value to this project to gain an understanding of declines in water temperature owing to riparian planting.

Storm event water quality sampling should have been a component of the survey design to capture peak contaminant loadings. This was a downfall of the monitoring that should be included in any future monitoring projects of this type.

3 CONCLUSIONS

The PTS monitoring program has provided some insight towards understanding the ecological benefits of stream restoration measures in urban, pastoral and forested stream catchments. While in stream ecological improvements have not yet been demonstrated, other monitoring (terrestrial biodiversity, community engagement, flood mitigation) has shown significant improvements (TCEC 2016, Stephenson 2016).

The data sets themselves are very small and statistical precision is low (n= 16 for most water quality variables, n= 4 for most ecological variables and n= 4 for sediment quality variables), so any findings discussed are preliminary. More confidence would be placed in the results if the data sets were larger.

New methods of measuring the success of stream restoration have evolved since the inception of the PTS program (Parkyn et al 2010) that would have improved the overall survey design, however they only became available in the latter stages of the PTS project.

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