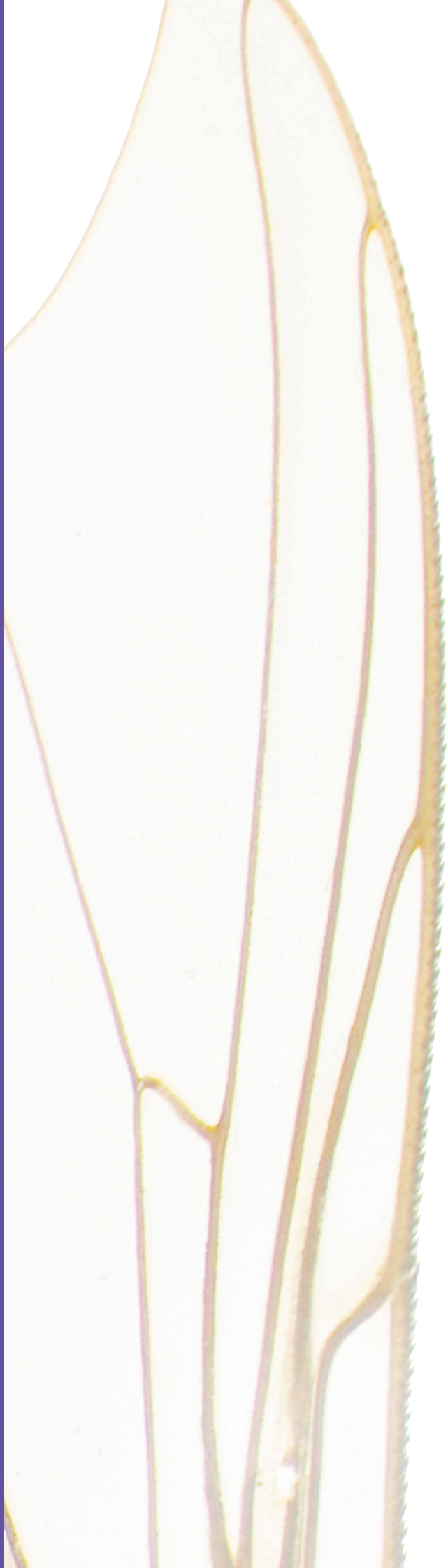

Middle Harbour and Lane Cove Macrobiological Monitoring Program

June 2005

Prepared for
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Executive Summary

Seven Local Government Authorities; Willoughby, North Sydney, Lane Cove, Hunters Hill, Ryde, Ku-ring-gai and Hornsby conducted biological monitoring of environmental quality in the tributaries of Lane Cove River and Middle Harbour Catchments using macroinvertebrates in spring 2004 and autumn 2005.

Biotrack Australia was engaged in spring 2004 to coordinate sampling, identify macroinvertebrates and report on stream condition. This report is a summary of results for the spring 2004 and autumn 2005 survey period.

Both catchments' streams are dominated by bedrock substrates, steep declines and small riparian vegetation strips. They are significantly modified by urban development, with the majority of tributaries containing segments of channelisation or storm water piping in the upstream reaches.

SIGNAL2, AUSRIVAS and macroinvertebrate richness measures reflect the highly disturbed nature of urban streams, recording low scores. AUSRIVAS scores generally indicated severely impaired sites. While a number of sensitive taxa were recorded with SIGNAL2 scores equal to or above six, the majority of fauna collected were tolerant to disturbance and poor water quality.

Both catchments reported similar results, indicative of similar environmental condition. While the Lane Cove Catchment collected a higher number of macroinvertebrates, this was not reflected in significantly higher SIGNAL2 or AUSRIVAS scores.

A review of current site selection, number of samples collected and data analysis is proposed to increase the level of precision in which changes to current conditions can be monitored.

1. Background

Willoughby, North Sydney, Lane Cove, Hunters Hill, Ryde, Ku-ring-gai and Hornsby Councils, with the assistance of a consultant, have been conducting a biological monitoring program to assess environmental quality in the Middle Harbour and Lane Cove River Catchments since 2001.

This program arose from a desire to establish a catchment-wide, long-term approach to better understand the health of local aquatic ecosystems. By monitoring the macroinvertebrate communities in aquatic ecosystems, the quality of water entering the harbour and catchment influences can be assessed, and the value of management interventions measured.

Present day Lane Cove and Middle Harbour Catchments are dominated by urban development. Most natural waterways in the upper catchments (first and second order streams) have been replaced by storm water channels and pipes, which are fed by an extensive storm water drainage network. These drains generally flow into open creeks lower down in the catchment before entering the Lane Cove River and Middle Harbour.

Many of the remaining creeks still exist because steep banks prohibit development or because they hold aesthetic value and are located in local or National Parks. The high proportion of impervious surfaces in the upper catchment result in significant modification to stream flow into the creeks and impact upon instream and riparian habitat. Runoff from urban and industrial centres also affects water quality.

At the local level, streams are dominated by bedrock and boulder substrates, small riparian vegetation strips and sewerage and storm water outlets.

Water quality issues in the Lane Cove and Middle Harbour Catchments are those typically associated with an urban catchment dominated by first and second order streams. Storm water pollution sources are a key challenge and include:

- litter from general sources
- sediment and suspended solids from construction sites and poorly landscaped areas
- oils and surfactants from road based pollutants
- organic matter; leaves, twigs, etc carried by storm water
- nutrients from fertilisers, detergents and animal faeces
- toxic materials from accidental spills to deliberate dumping
- sewerage discharges

The seven councils involved in the monitoring program acknowledge the influences of highly modified landscape on aquatic ecosystem health and have combined resources to provide a greater insight into the current health of the Lane Cove and Middle Harbour Catchments. By combining resources and sharing information, each council can compare sites, located within their local council boundaries, to their neighbours and to those in similar sub catchments. This will provide significant insight into the value of different management strategies practiced by different councils, whilst sharing the responsibility of monitoring, maintaining and improving the aquatic ecosystem health for the two catchments.

This report presents the findings from sampling aquatic macroinvertebrates from 24 sites from the Middle Harbour and Lane Cove River Catchments in spring 2004 and autumn 2005.

2. Biological Water Quality Monitoring

Biological water quality monitoring involves measurements of the aquatic animals present in a waterway. The most commonly recorded aquatic animals are the many macroinvertebrate organisms, predominantly adult insects and their larvae (invertebrates), which live in streams and water bodies. These insects are generally large enough to be seen by the naked eye (macro). Biological monitoring is based on the premise that the particular combination of aquatic macroinvertebrates present in a waterway is a reliable indicator of the overall stream condition. Macroinvertebrates are exposed and respond to a full range of water qualities, including impacts from pollution events and nutrient pulses. Poor water quality will be reflected by an impoverished macroinvertebrate community. Conversely, a diverse macroinvertebrate community is indicative of good water quality.

Macroinvertebrates also react to structural changes in stream condition. Higher Orders, Families and species may appear or disappear according to the availability of structures in which they inhabit. Different macroinvertebrates will occupy different habitats (e.g. aquatic macrophytes, overhanging banks, presence of woody debris, different substrates) according to their particular body structure, feeding habitats and lifecycles. Removal or changes in habitat condition as a result of human intervention (e.g. increase in sedimentation or gross pollutants, increased frequency and intensity of flushing, scouring of creek substrate, and alteration of riparian vegetation) will subsequently result in a loss or change in macroinvertebrate composition.

Composition changes can be measured for some time after a pollution or disturbance event occurs unlike chemical measurements, which need to be taken on a regular basis at, or shortly after, the time of the event. Water quality and habitat improvements result in a steady succession of macroinvertebrates tolerant of the better conditions. That is, there is a general increase in the proportion of groups of macroinvertebrates that are sensitive to disturbance as habitat and water quality improves. This does not necessarily mean that diversity or abundance increases but that the combination of groups of macroinvertebrates change.

One key strength of using macroinvertebrates is that they show a wide range of sensitivities to water quality and/or habitat disturbance. Each group possesses different sensitivities based on their tolerance to organic pollution. Particular macroinvertebrates will thrive in areas of higher organic enrichment where others will disappear. In some groups, the level of organic pollution may not have a notable effect, however disturbances to habitat will. **For most macroinvertebrates, it is the combination of both water and habitat quality which determine if it will be present in a particular stream.** This means that there will always be a combination of species with differing tolerance levels even when conditions are severely degraded.

The specific combination of macroinvertebrates in a stream reflects the current status of the stream and provides a unique biological signature of the local aquatic environment. Repeated measurements of composition over time provide an accurate and sensitive monitoring tool to detect change in the health of the stream system. As a result, biological measures of water quality complement and extend chemical methods because the macroinvertebrates that live in these habitats fully integrate environmental conditions over the short, medium and long term.

Macroinvertebrates are also ubiquitous and conspicuous in almost all aquatic habitats. There are many different types and most of these are relatively easy to catch, observe, identify and count and many samples can be taken without disturbing the system. Accordingly, the abundance and composition of macroinvertebrates are now used extensively as a reliable method of biological water quality assessment.

3. Sampling

Aquatic macroinvertebrates were sampled by Council staff on two occasions, once in spring 2004 and once in autumn 2005, from 24 sites located within the Middle Harbour and Lane Cove River Catchments (Tables 1 & 2). There were 15 sites in the Lane Cove River Catchment and nine sites in Middle Harbour.

Biotrack Australia staff reviewed Council staff's sampling procedures in spring 2004 and took the chemical measures needed at each site to calculate AUSRIVAS scores.

Avondale, Blackbutt and Quarry Creeks (Ku-Ring-Gai Council) were sampled in spring only and Gordon Creek (Ku-Ring-Gai Council) was sampled in autumn only. All other sites were sampled in both seasons.

Two replicate samples were collected for Brickmakers Creek (Hunters Hill Council) in both spring and autumn seasons and for Tarban Creek (Hunters Hill Council) for the spring season only.

A single sample was collected at all other sites consistent with AUSRIVAS protocols (Turak & Waddell, 2001), where one site was demarcated as a river reach with a length of 100 metres.

To generate one sample, a sampling net of 0.25mm mesh size was used to collect macroinvertebrates from a total of 10 metres of all habitats in the edge sampling areas. Invertebrates were collected by using the net to disturb and dislodge animals from rocks, macrophytes and trailing vegetation and then swept through the water column to collect any floating specimens. Once completed, each sample was transferred to a bucket containing water.

Specimens were picked in the field into vials containing 70% ethanol and labelled with a unique barcode. Any vertebrates collected were returned to the creek.

Table 1. Creeks sampled and sampling times in the Lane Cove Catchment.

Council	Location	Site no.	Sampled in spring	Sampled in autumn
Hornsby	Devlins Creek	101	Y	Y
	Terrys Creek	102	Y	Y
Hunters Hill	Brickmakers Creek	103	Y	Y
	Tarban Creek	104	Y	Y
Ku-Ring-Gai	Avondale Creek	105	Y	N
	Blackbutt Creek	106	Y	N
	Coups Creek	107	Y	Y
	Quarry Creek	108	Y	N
Lane Cove	Gore Creek	109	Y	Y
	Stringybark Creek	110	Y	Y
North Sydney	Berrys Creek	111	Y	Y
Ryde	Buffalo Creek	112	Y	Y
	Porters Creek	113	Y	Y
Willoughby	Blue Gum Creek	114	Y	Y
	Swaines Creek	115	Y	Y

Table 2. Creeks sampled and sampling time in the Middle Harbour Catchment.

Council	Location	Site no.	Sampled in spring	Sampled in autumn
Ku-Ring-Gai	Gordon Creek	201	N	Y
	Moores Creek	202	Y	Y
	Rocky Creek	203	Y	Y
North Sydney	Tunks Park (Quarry Creek in previous studies)	204	Y	Y
Willoughby	Camp Creek	205	Y	Y
	Flat Rock Creek	206	Y	Y
	Sailors Bay Creek	207	Y	Y
	Scotts Creek	208	Y	Y
	Sugarloaf Creek	209	Y	Y

4. Specimen Processing

All samples were delivered to the Biotrack Australia laboratories at Macquarie University, Sydney, where specimens were identified using the bio**track**® system (Oliver et. al., 2000) by experienced biodiversity technicians to Family level with the exception of Chironomidae which was identified to subfamily and Oligochaeta (Class), Hydracarina (Order) and Ostracoda (Subclass). Once processing was complete, data were exported into Microsoft Excel in a sample by taxon matrix for subsequent analysis.

The bio**track**® system is a unique data management system designed to track and record large amounts of sampling and biodiversity information. Information is stored and analysed using Biota (Colwell, 1996), a biodiversity database manager. Individual specimens are linked to sample and site information by unique barcodes. Collection information (e.g. environmental, site location, operator names, weather conditions, etc) are linked to specimen information (e.g. taxonomic name, abundance) through relational databases. All of the above information can be instantly obtained through the scanning of a single barcode.

Biotrack Australia has an internal auditing system (for QA/QC) where 10% of all samples are re-identified by experienced staff to determine misidentification error rates. These rates are below the current standard of 5% (misidentification) as identified in AUSRIVAS protocols (Turak & Waddell, 2001). Biotrack also incorporates additional quality control mechanisms. Fields contain set criterion which lower the possibility of error in data entry. Unique barcodes also reduce the possibility of incorrectly entering sample/site names. Data are collected on a networked version of Biota which is backed up to separate hard drives daily, to tape weekly and to CD-ROM fortnightly.

5. Data Analysis

5.1. SIGNAL2

SIGNAL2 (Stream Invertebrate Grade Number-Average Level) scores (Chessman, 2003) are a simple index given to streams indicating water quality. These scores are based on the tolerance of macroinvertebrates to concentrations of nutrients (nitrogen and phosphorous), dissolved oxygen, salinity and turbidity. When combined with number of taxa present, these scores provide a general indication of water quality.

High SIGNAL2 scores indicate low levels of nutrients, salinity and turbidity with high levels of dissolved oxygen. SIGNAL scores are a relatively crude measure of water quality, yet provide important information on the tolerance of specific taxa that inhabit a stream. A low SIGNAL score generally indicates taxa that are tolerant to poor water quality and disturbance.

5.2. AUSRIVAS

AUSRIVAS mathematical models predict the combination of aquatic macroinvertebrates that should be present at a site in the absence of environmental stress. A measure of biological impairment is then created by comparing the macroinvertebrates predicted to occur at the field sites with those that were actually collected. For the AUSRIVAS models to work, the field sites are sampled in a season, or seasons, that correspond with the reference site used to construct the model. In NSW, AUSRIVAS models are available for spring and autumn (Turak & Waddell, 2001). Consistent with these models, data from samples taken in September, October and November were applied to the spring model and data for March, April and May for the autumn model. Data from both seasons are also combined and modelled.

The AUSRIVAS model produces an observed/expected ratios sheet that provides an indication of the overall biological condition of a sampling site. The classification of sites is determined using a combination of ratios based on the observed and expected taxa numbers at a site.

The final result, and reporting output, is a categorisation of the sites into bands representing different levels of biological impairment, including (following Turak & Waddell, 2001):

Band X: a richer invertebrate community than the reference sites, or contains excess nutrients
Band A: equivalent to the reference sites
Band B: a mildly impaired site
Band C: a moderately impaired site
Band D: a severely degraded site

6. Results

6.1. Catchment Assessments

A total of 3,415 specimens were sampled from 47 samples, generated from 24 sites over two sampling seasons. On average, there were 73 individuals and 11 Families per sample. Raw data is provided in a separate, electronic document.

The average SIGNAL2 scores and AUSRIVAS scores for all sites in both seasons are displayed in Table 3. Both catchments registered relatively similar results for richness, SIGNAL2 and AUSRIVAS, which were suggestive of degraded stream conditions. This is indicative of the urban nature and environmental features of both catchments.

Overall both catchments contain mostly tolerant taxa, and only a few taxa were collected that are considered sensitive to pollution and disturbance (Table 4, Plate 1).

Table 3. Average Richness, SIGNAL2 and AUSRIVAS scores for all sites divided by season and catchment. Average AUSRIVAS scores are from the combined seasons model.

	Lane Cove Catchment			Middle Harbour Catchment		
Season	**Richness**	**SIGNAL2 score**	**AUSRIVAS score (O/E50)**	**Richness**	**SIGNAL2 score**	**AUSRIVAS score (O/E50)**
Spring	12	2.98	C (0.36)	10	3.34	C (0.28)
Autumn	10	3.06	C (0.34)	7	3.51	C (0.30)

Table 4. Sensitive taxa collected in each catchment displayed by site. Taxa are considered sensitive if SIGNAL2 scores are equal to or greater than six.

Taxon	SIGNAL2 score	Site no.	Catchments found
Hydracarina	6	102,103, 106, 107, 109, 110, 112, 202, 207	Lane Cove/Middle Harbour
Leptoceridae	6	103, 113	Lane Cove
Psephenidae	6	103, 105, 107, 109, 110, 114, 115, 203, 207, 209	Lane Cove/Middle Harbour
Scirtidae	6	205	Middle Harbour
Corydalidae	7	205, 207	Middle Harbour
Elmidae	7	101, 102, 202	Lane Cove/Middle Harbour
Synlestidae	7	203	Middle Harbour
Antipodeciidae	8	209	Middle Harbour

Considering the general degree of disturbance to urban streams, and the unlikeliness that urban streams can be restored to an undisturbed or reference condition, comparisons of SIGNAL2 scores to scores of pristine reference sites is limited value.

A benchmark of condition that is realistic in an urban setting is a SIGNAL2 score above four and with sample richness greater than 15 Families. In Biotrack's experience, this is generally considered to represent a creek of fairly good condition in an urban environment. No sites or samples in either season or catchment fit these criteria (Figure 2).

The Lane Cove Catchment generally contains greater richness than the Middle Harbour Catchment, but not necessarily higher SIGNAL2 scores. The spring sampling season generally collected greater numbers of Families (Figure 1).

The SIGNAL2 scores and seasonal variation for both catchments overlap significantly, indicating that both catchments are in a similar environmental condition (Figure 1).

It is important to note the limitations of SIGNAL2 scores, which do not take into account the numbers of Families collected. Those sites that have high SIGNAL2 scores but low numbers of Families collected are sites that are in poor condition. Sites in good condition have both high SIGNAL2 scores and high numbers of Families collected.

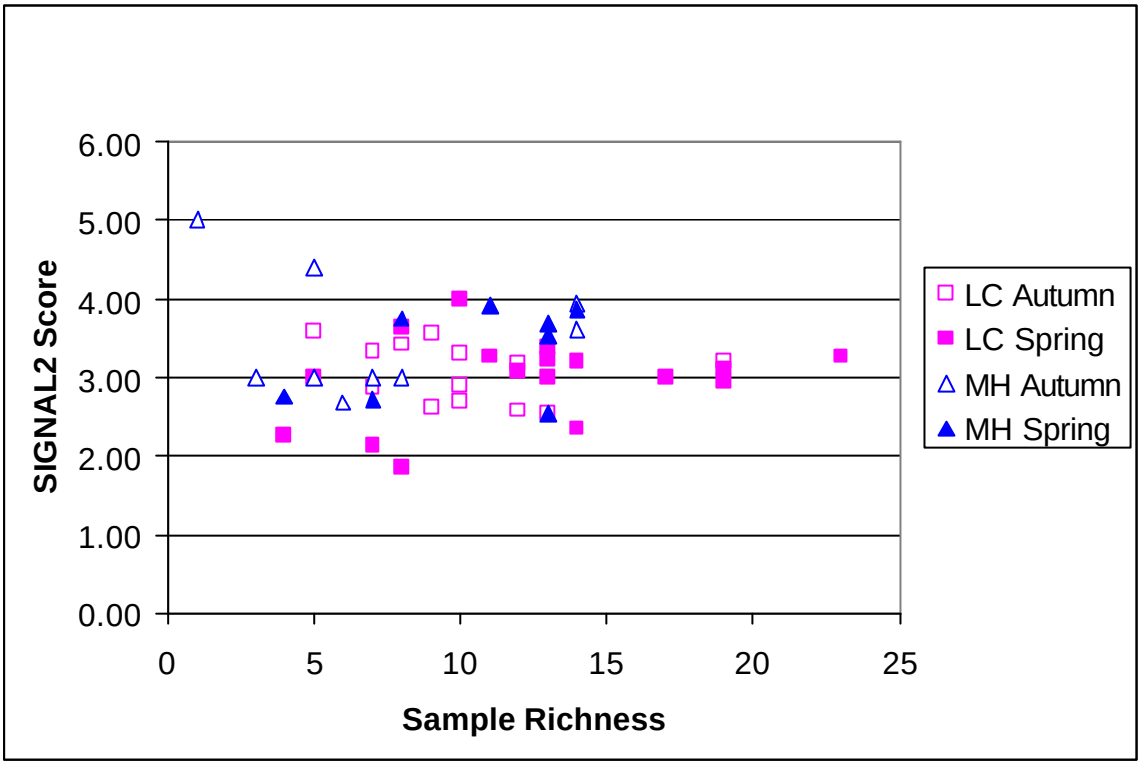

Figure 1. SIGNAL2 scores plotted against sample richness. LC = Lane Cove Catchment, MH = Middle Harbour Catchment. Sites in good condition have both high SIGNAL2 scores (>4) and high numbers of Families collected (>15).

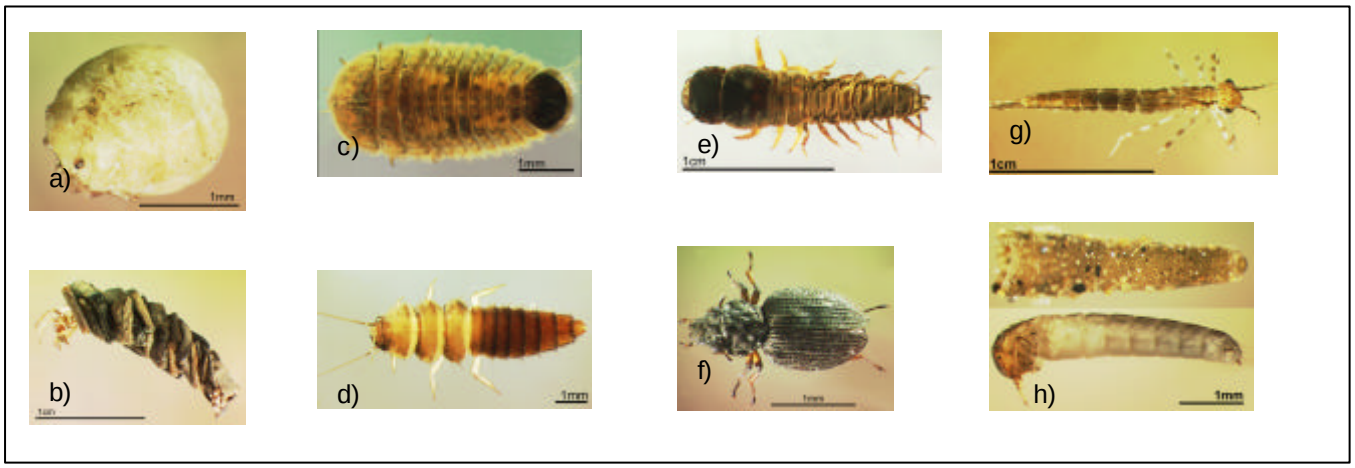

Plate 1. Sensitive taxa collected during Spring and/or Autumn sampling, common names are provided in brackets. a)Hydracarina (water mite), b)Leptoceridae (caddis fly larvae), c)Psephenidae (water penny beetle), d)Scirtidae (marsh beetle), e)Corydalidae (alderfly larvae), f)Elmidae (riffle beetle), g) Synlestidae (damselfly larvae), h)Antipodeciidae (caddis fly larvae).

6.2. Individual Site Assessments

The sample richness, SIGNAL2 and AUSRIVAS scores for each site are displayed in Table 5 for sites located in the Middle Harbour Catchment and Table 6 for the Lane Cove River Catchment.

Sites are ranked from those scoring highest to lowest based on AUSRIVAS scores for combined seasons (single season where indicated), average macroinvertebrate richness (over two seasons) and average SIGNAL2 scores (over two seasons) in that order, for each catchment. Raw data is given in a separate electronic document.

*Table 5. Individual site results for the Middle Harbour Catchment. Sites are ranked by average AUSRIVAS combined seasons, average macroinvertebrate richness and average SIGNAL2 scores, in that order, for each catchment. * denotes single season data used only.*

Rank	Location	Average richness	AUSRIVAS OE/50	AUSRIVAS band	Average SIGNAL2
1	Moores Creek	13.5	0.55	B	3.08
2	Sailors Bay Creek	14	0.45	C	3.89
3	Sugarloaf Creek	10	0.43	C	3.35
4	Camp Creek	8	0.32	C	4.15
5	Rocky Creek	7	0.31	C	4.27
6	Gordon Creek*	8	0.28	C	3.00
7	Scotts Creek	5.5	0.24	C	3.38
8	Flat Rock Creek	6.5	0.19	C	2.69
9	Tunks Creek	4.5	0.13	D	2.88

*Table 6. Individual site results for the Lane Cove River Catchment. Sites are ranked by average AUSRIVAS combined seasons, average macroinvertebrate richness and average SIGNAL2 scores in that order, for each catchment. * denote single season data used only.*

Rank	Location	Average richness	AUSRIVAS OE/50	AUSRIVAS band	Average SIGNAL2
1	Porters Creek	16.5	0.7	B	2.78
2	Blackbutt Creek*	23	0.67	B	3.27
3	Devlins Creek	16	0.64	B	2.82
4	Brickmakers Creek Rep1	12	0.51	B	3.17
5	Quarry Creek*	12	0.48	C	3.08
6	Brickmakers Creek Rep2	13.5	0.45	C	3.19
7	Coups Creek	9.5	0.45	C	3.78
8	Swaines Creek	12.5	0.38	C	3.28
9	Gore Creek	10.5	0.38	C	3.09
10	Terrys Creek	13	0.32	C	2.90
11	Buffalo Creek	11.5	0.32	C	2.85
12	Stringybark Creek	7	0.32	C	2.78
13	Avondale Creek*	13	0.29	C	3.23
14	Tarban Creek Rep1	8	0.26	C	2.38
15	Blue Gum Creek	6.5	0.26	C	3.61
16	Berrys Creek	6	0.26	C	2.93
17	Tarban Creek Rep2*	8	0.1	D	1.86

Sites in Band B are considered mildly impaired, Band C are considered to be severely impaired and Band D severely degraded.

In both catchments, most sites fall into Band C, as duplicated in the overall catchment assessments (Table 3), however a number of sites within each catchment are considered to be in good condition (receiving Band B scores). This is a particularly good result considering the urban nature of each catchment. These sites are Moores Creek for the Middle Harbour Catchment and Porters, Blackbutt, Devlins and Brickmakers Creeks for the Lane Cove River Catchment.

7. Key Messages

This study has continued to provide a meaningful assessment of stream condition within Lane Cove and Middle Harbour Catchments, where condition is reported as Family richness, SIGNAL2 and AUSRIVAS scores.

SIGNAL2 and AUSRIVAS scores were both low, indicating poor water quality and habitat condition. This is not surprising given the significant amounts of storm water input resulting in stream scouring and flush events. The composition of macroinvertebrates was reflective of the urban nature of both catchments.

Both catchments are in similar condition, with neither catchment displaying significantly different results for richness, AUSRIVAS or SIGNAL2.

While most sites show significantly impaired macroinvertebrate communities, indicative of the urban nature of both catchments, a number of sites are in fairly good condition with reasonable results for richness, AUSRIVAS and SIGNAL2 scores. These sites are Moores Creek for the Middle Harbour Catchment and Porters, Blackbutt, Devlins and Brickmakers Creeks for the Lane Cove River Catchment (Tables 5 & 6).

8. Recommendations

Sampling should continue to build monitoring capacity onto the good baseline data already established. Some modifications to the current design would increase the information return for effort.

Whilst there is a considerable amount of data available from the five years of macroinvertebrate sampling in the Lane Cove River and Middle Harbour Catchments, these data are not fully utilised.

The idea of sampling once at a site (and usually in each creek) limits possible interpretations because there is no internal measure of variability within a creek against which to compare differences between creeks.

Each site will have a unique set of characteristics and, consequently, a different combination of macroinvertebrates. At any given point in time, there is large natural variation in composition within a site as a result of habitat variability, sampling and weather conditions, flow regimes, cumulative effects of past flows and opportunism by the organisms in the creeks, all interacting with a myriad of physical conditions. In order to effectively capture this variability, and still be able to confidently characterise the condition of a site, it is recommended that ***three*** samples be taken at any site during one sampling event. This will also allow analyses to detect any local trends in individual creeks by listening to the natural noise in the data.

In addition, concentrating data analyses solely on AUSRIVAS and SIGNAL measures provides a limited view of local site condition. These measures provide a useful comparison for broader regional comparisons of health, but are often not subtle enough to detect differences in site condition at the local scale particularly in urban environments.

AUSRIVAS and SIGNAL2 are ***site assessment*** tools as opposed to ***monitoring*** tools. This distinction is recognised by the coordinators of the AUSRIVAS program. The coarseness of these measures do not provide enough detail to reasonably monitor change within sites or make accurate comparisons across sites.

One option is to consider extending the data analysis to include the calculation of ***biological signatures***. Biological signatures is based on the premise that any site at any given point in time a unique combination of invertebrates may be found. This combination is a signature of local site conditions, such as habitat and water quality; and importantly, the impact of any land use or management intervention that may have occurred.

Unique combinations of organisms happen because some invertebrates are sensitive to disturbance, while others are more tolerant. So the specific combination reflects the immediate, past and long-term history of the environmental conditions at the site, through the responses of the animals that live there.

Biological signatures can be compared between sites and over time. They provide a more detailed picture of the condition of a creek, as well as the macroinvertebrates that play a key role in determining this condition. Comparing the biological signature of a site over time is a very powerful way to track the status of a particular location. More detail on the calculation of biological signatures can be found in Appendix 2.

Biotrack also recommends a review of site locations, sampling practices and knowledge gaps of sampling personnel. A significant number of samples contained unusually low numbers of individuals and Family richness. Although urban sites generally contain lower numbers of individuals and Family richness than non-urban sites, urban sites should still contain a reasonable number of individuals and families. The richness of a sample can be maximised by selecting appropriate sampling points along a creek, along with the use of appropriate sampling equipment and techniques.

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Appendix 1A: Spring Water Quality

Water quality measurements for spring season collected on 17th and 18th November, 2004. All parameters were collected using a Yeokal® 611 water quality meter, with the exception of Alkalinity which was analysed using CHEMetrics Titrets® hand held titration cells.

Council	Location	pH	Conductivity (µs)	Temp (°C)	Diss. O_2 (%)	Diss. O_2 (mg/l)	Turbidity (ntu)	Alkalinity (ppm)
Ku-ring-gai	Coups Creek	7.82	509	19.09	91.20	8.90	0.70	32
	Avondale Creek	6.85	450	17.72	29.30	2.80	3.00	40
	Blackbut Creek	7.14	464	18.00	76.10	7.20	1.80	32
	Quarry Creek	7.09	949	19.37	39.40	3.60	4.00	105
	Gordon Creek	7.53	314	18.26	92.50	8.70	1.00	28
	Moores Creek	6.77	141	18.80	66.00	6.10	12.10	35
	Rocky Creek	7.18	476	18.42	82.00	7.70	0.00	30
Willoughby	Flat Rock Creek	7.64	56	18.55	62.60	5.90	4.10	110
	Scotts Creek	7.34	24	19.20	78.20	7.20	0.30	35
	Sugarloaf Creek	7.00	240	21.46	79.50	7.00	1.40	27
	Sailors Bay creek	7.18	383	20.34	68.40	6.20	0.20	45
	Camp Creek	6.21	12	19.00	21.90	1.90	33.00	15
	Swaines Creek	7.14	30	21.15	74.90	6.60	0.10	50
	Blue Gum Creek	7.10	405	19.14	74.00	6.80	1.80	42
Lane Cove	Gore Creek	7.62	399	19.50	120.00	11.20	0.70	45
	Stringybark Creek	7.18	406	19.04	65.90	6.10	4.30	70
North Sydney	Tunks Park	7.45	505	19.88	69.30	6.30	2.20	80
	Barrys Creek	7.51	29	22.45	73.70	6.40	0.70	70
Ryde	Buffalo Creek	7.00	61	21.13	57.70	5.10	10.70	70
	Porters Creek	7.33	93	22.50	81.75	7.10	1.00	27
Hunters Hill	Brickmakers Creek	6.85	465	20.75	6.00	0.60	5.40	100
	Tarbon Creek	6.76	448	24.90	36.70	3.10	0.00	60
Hornsby	Devlins Creek	7.40	573	18.80	73.50	6.80	2.50	48
	Terrys Creek	7.24	583	17.30	60.70	5.80	2.80	40

Appendix 1B: Autumn Water Quality

Water quality measurements for autumn season collected on 11th and 12th April, 2005. All parameters were collected using a Yeokal® 611 water quality meter, with the exception of Alkalinity which was analysed using CHEMetrics Titrets® hand held titration cells. *na* refers measurements that were unavailable due to a faulty probe.

Council	Location	pH	Conductivity (µs)	Temp (°C)	Diss. O_2 (%)	Diss. O_2 (mg/l)	Turbidity (ntu)	Alkalinity (ppm)
Ku-ring-gai	Coups Creek	7.60	107	18.38	11.10	10.90	1.80	40
	Avondale Creek	7.26	599	17.67	21.10	2.30	12.00	80
	Blackbut Creek	6.88	166	16.74	6.50	66.00	2.60	30
	Quarry Creek	7.08	1391	18.51	42.30	3.90	7.20	100
	Gordon Creek	7.93	264	19.13	128.00	11.90	1.40	50
	Moores Creek	7.13	110	17.10	91.10	8.60	2.90	42
	Rocky Creek	7.10	496	17.07	96.00	9.20	1.50	45
Willoughby	Flat Rock Creek	7.70	422	19.11	94.20	8.80	10.60	70
	Scotts Creek	7.34	53	18.14	100.00	9.50	15.20	23
	Sugarloaf Creek	6.97	na	19.14	97.10	8.90	10.00	20
	Sailors Bay Creek	7.35	160	18.49	97.40	9.10	3.70	35
	Camp Creek	6.33	165	17.24	69.50	6.60	3.10	16
	Swaines Creek	7.46	106	18.60	99.20	9.30	5.10	30
	Blue Gum Creek	7.25	108	17.68	100.00	9.60	10.00	26
Lane Cove	Gore Creek	7.40	na	17.40	85.00	8.10	10.00	60
	Stringybark Creek	6.75	na	17.80	72.80	6.90	4.80	32
North Sydney	Tunks Park	7.52	105	19.07	103.00	9.60	4.20	35
	Barrys Creek	7.64	471	19.47	78.00	7.10	8.90	45
Ryde	Buffalo Creek	7.48	442	19.20	59.00	5.40	5.00	100
	Porters Creek	7.46	1932	18.20	90.40	8.95	6.00	45
Hunters Hill	Brickmakers Creek	6.76	na	17.45	49.50	4.70	29.00	36
	Tarbon Creek	6.63	na	18.20	24.60	2.30	7.70	90
Hornsby	Devlins Creek	7.25	na	16.90	65.00	6.30	2.10	55
	Terrys Creek	7.22	na	16.36	72.50	7.10	1.50	55

Appendix 2: Biological Signatures

The nature of biodiversity data is such that richness (number of taxa) and abundance is highly variable. Consequently, the best way to assess differences in biodiversity is to use statistical tools that can group multivariate data based on predetermined categories. This is especially powerful if data are transformed in various ways to reflect the importance of abundance (no transformation), intermediate abundances (logN+1) or composition (presence/absence).

Multivariate analyses are conducted using PRIMER v5 (Clarke & Gorley, 2001). Multi-dimensional scaling (MDS) can be used to display the relative differences in composition between samples. MDS has simplicity, provides the best use of sample information and has general applicability (Clarke & Warwick, 1994). MDS also makes fewer assumptions regarding the form of the data and the inter-relationships of the samples and more efficiently preserves distance relationships in low-dimensional ordination space (Clarke & Warwick, 1994). The graphical presentation of the MDS is prepared using similarity matrixes, based on similarity coefficients that measure the similarity (S) between sample pairs. Generally, the Bray-Curtis measure of association is used.

An advantage of ordination is that statistical comparisons of a priori sample groupings can be made using permutation procedures. These procedures, that use Monte Carlo approaches to generate significance levels, test questions about biological distance between samples of a given category. The specific procedure used is Analysis of Similarities (ANOSIM), which is a multivariate analogue of one-way analysis of variance. The null hypothesis tested is that samples are positioned at random in the ordination space irrespective of their a priori assignment to a group (category). So samples from the same group are not expected to cluster together in the ordination space and therefore show similar biological composition. The interpretation of a significant ANOSIM result is that differences in composition between samples within a group compared to those between groups is less than would be expected by chance. ANOSIM is a non-

parametric permutation procedure that makes minimal assumptions about the normality of the data and uses the assemblage relationships between samples as summarised in the ranks of the biotic similarity matrix (Clarke & Gorley, 2001).

The similarity percentages procedure (SIMPER) can be used to identify the taxa that contribute most to the biological difference between sites. SIMPER computes the average dissimilarity between all pairs of inter-group samples and then measures individual contributions of each taxon to this dissimilarity (Clarke & Warwick, 1994). If a taxon consistently contributes much to the site dissimilarity across all sample comparisons, then that taxon is a good discriminator of diversity differences.

Glossary and other words of interest

Abundance - the number of specimens from a particular taxon in a sample.

Arthropod - the largest phylum in the animal kingdom. Includes Classes Trilobita, Chelicerata, Crustacea and Uniramia. Characteristics include: hard exoskeleton, segmented bodies and jointed appendages. Most of the animals caught in pitfall traps are arthropods.

*bio**track**® system* - innovations for the collection, management and interpretation of biodiversity data to achieve objective environmental measurement and reporting.

Biodiversity - the variety of genes, organisms and ecosystems on Earth or at a particular place. The biodiversity of a site is often measured by the number of species. In Biotrack, we consider this term to encompass the number and kinds of plants and animals found in a habitat.

Biodiversity difference - various statistical measures of the difference in composition and relative abundance of species between samples from separate habitats or over time.

Biodiversity signature - the unique combination of (morpho)species recorded in a sample from a given habitat at a given time.

Biota© - a relational database for the storage and retrieval of information on samples and specimens from bio**track**® surveys.

Complementarity - the proportion of species shared between samples or habitats or a measure of biodiversity difference; sometimes referred to as turnover.

Composition - the species that occur in a habitat or sample.

Ecosystem processes - the range of processes that affect, and are affected by, the biodiversity in an environment. They include the water cycle, the dynamics of the gaseous composition of the atmosphere, soil fertility and pollination. The biodiversity of a place affects the rate or reliability of ecosystem processes.

Environmental management - the actions implemented to achieve specific environmental outcomes.

Family - a rank in the hierarchy of taxonomic classification lying between Genus and Order.

Genus - a rank in the hierarchy of taxonomic classification lying between Family and species.

Invertebrates - organisms without backbones. Insects, spiders, earth worms, crustaceans and the like are all invertebrates. These animals are found in every ecosystem in Earth. They constitute approximately 99% of all animal species.

Invertebrate (*bio*)*diversity* - the different numbers and kinds of invertebrates that inhabit a given environment or habitat.

Higher taxa - higher order taxa such as Family and Order.

Morphospecies - taxa based on external morphological differences obvious to a trained biodiversity technician. These morphological differences are character traits of taxonomic importance and are the same as those used in formal taxonomy. (See Species)

Order - a rank in the hierarchy of taxonomic classification lying between Class and Family.

Parataxonomist - a technician with taxonomic training able to rapidly identify specimens using a combination of formal taxonomy and biotrack® protocols.

Pitfall trap - 250ml plastic jar buried flush with the soil and left open for a week. During this time invertebrate animals fall in and are preserved in solution.

Rapid Biodiversity Assessment - the rapid counting and identification of very large numbers of specimens using a combination of information technology and parataxonomy.

Richness - the number of (morpho)species in a given sample or habitat.

Signature - (see *biodiversity signature*).

Species - a group of actually or potentially interbreeding populations that is reproductively isolated from all other kinds of organisms. The basic taxon of formal taxonomy, frequently, but not always, distinguished by morphological characters. (See Morphospecies)

Taxon (*taxa*) - a formal taxonomic group of any rank.

Taxonomic sufficiency - the identification of a specimen to that taxonomic level which provides sufficient information to meet the requirements of the project.

Turnover - the change in the composition of taxa from one place to the next.

Vertebrate - animal with a back bone. Includes birds, mammals, fish, amphibians and reptiles.

Virtual biodiversity assessment - involves the use of images of voucher specimens, delivered via the Internet, to identify an unknown specimen, rather than the traditional use of a physical voucher specimen.

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