SYMPOSIUM on URBANIZATION and STREAM ECOLOGY

Monday 8 to Wednesday 10 December, 2003

University of Melbourne, Melbourne, Australia

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and

STREAM ECOLOGY

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Preface

Welcome to the Symposium on Urbanization and Stream Ecology, part of the International Year of Freshwater. We meet at a critical time as urban land use sprawls out from cities around the globe, with resulting impacts on greater and greater lengths of rivers and streams. Our meeting place, Melbourne, is no exception.

Over the next three days, this meeting will bring together stream ecologists and urban water managers to:

- discuss and synthesize current knowledge of the effects of urban land use on stream ecosystems
- examine priorities and potential for stream restoration in urban catchments
- identify knowledge gaps to direct future ecological research in urban catchments.

In addition to the diverse presentations, and the times for informal discussions, we will be holding two workshops to draw out key knowledge and knowledge gaps. The deliberations of these workshops will be synthesized into a report by Peter Cottingham, a knowledge broker with the Cooperative Research Centre for Freshwater Ecology.

Judy Meyer and Nancy Grimm will lead the first workshop on Tuesday afternoon to discuss commonalities and differences in approach to the study of urban impacts, and the possibilities and limitations to inter-city comparisons and collaborations. Derek Booth and Cathy Tate will lead the second workshop on Wednesday afternoon on our current understanding of restoration priorities for addressing urban impacts in streams and where our uncertainties lie. I encourage you all to participate vigorously in these discussions.

In addition to the benefits of us meeting and talking, the symposium will have three printed outputs:

- this book of abstracts
- A synthesis report to be published by the CRC for Freshwater Ecology
- A special issue of the *Journal of the North American Benthological Society*, containing about a dozen invited papers from the meeting.

I hope that you all find the meeting an enjoyable, illuminating and rewarding experience.

I acknowledge the generosity of our primary sponsors, Melbourne Water and the CRC for Freshwater Ecology. I thank my fellow members of the organizing committee, Peter Cottingham, Graham Rooney and Tim Fletcher for their enthusiasm and support. I also thank the conference secretariat, Bronwen Hewitt, Fiona Mallon and Jen Westphal, who have made the whole process remarkably easy.

Finally, I would like to dedicate this meeting to the memory of Professor W. D. Williams, a powerhouse in Australian and international Limnology. The last time I spoke to Bill, he strongly encouraged me to organize a meeting such as this. It has been a long time coming, but here we are, Bill.

Chris Walsh
Chair, Organizing Committee.

We gratefully acknowledge the generous support of our sponsors

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CRC for Freshwater Ecology

CRC Catchment Hydrology

Water Year 2003

LEGEND

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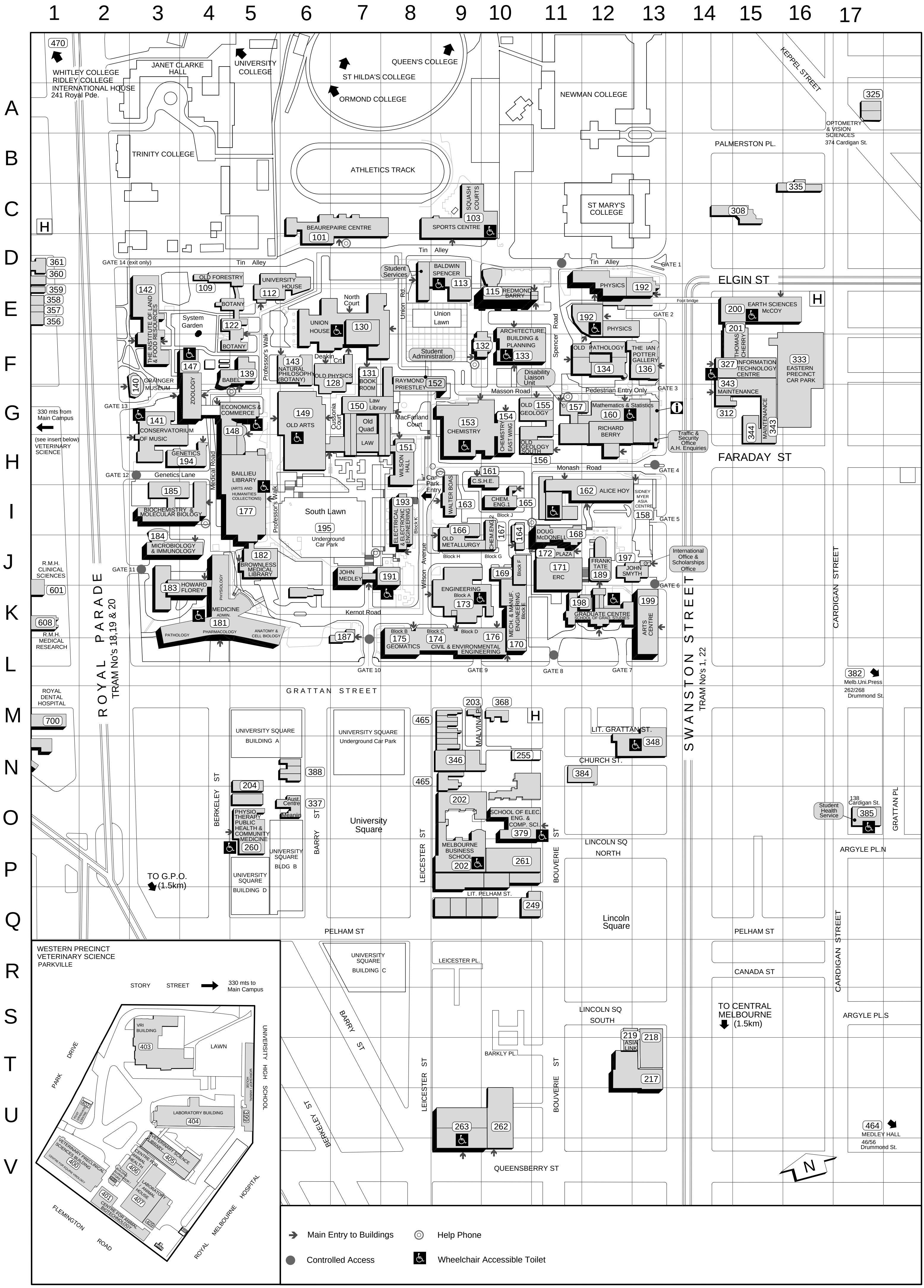

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Monday 8 December

8.00 Registration
Theme: the nature of urban impacts on streams
Chair: *C.Walsh*

9:00 Opening Address
Gary Jones, CEO Cooperative Research Centre for Freshwater Ecology

9:15 Keynote Address
J.Meyer, M.Paul, W.Taulbee
Ecosystem function in urban streams ***Page 1***

10:00 Contributed Paper
A.Roy, M.Freeman, B.Freeman, S.Wenger, W.Ensign, J.Meyer
Investigating hydrologic alteration as a mechanism for fish species loss in urbanising streams ***Page 9***

10:20 MORNING TEA

Concurrent Session 1
Chair: *J. Stribling*
1A: Catchment effects and assessment

10:50 Contributed Paper
I.Boothroyd
Upper catchment urbanisation effects on streams in the Wellington region, New Zealand ***Page 10***

11:10 Contributed Paper
C.Sellens, R.Norris, B.Chessman
River protection using good management practices: defining a reference condition for the biological assessment of urban streams ***Page 11***

11:30 Contributed Paper
D.Conrick, S.Choy
Long-term changes in water quality and macroinvertebrate communities in Southeast Queensland urban streams ***Page 12***

1B: Urban Lakes and wetlands

Chair: *V. Pettigrove*

10:50 Contributed Paper
P.Leahy
The development of hypereutrophic conditions in an urban floodplain wetland: palaeolimnological evidence ***Page 13***

11:10 Contributed Paper
J Burgess
Bacterial pollution in Lake Burley Griffin, ACT ***Page 14***

11:30 Contributed Paper
T.Weber, M.Barry, B. Lovell, K.Travis
Sustainability of shallow urban lakes in Melbourne ***Page 15***

11:50 Contributed Paper
T.Asaeda, J.Matatunge, D.Hai, N.Sahara
Effects of harvesting on the removable nutrient amount and sustainable management of Phragmites australis ***Page 16***

12:10 LUNCH

Chair: *N. Grimm*

13:15 Keynote Address
C.Tate, T.Cuffney, M.Meador, T.Short, M.Potapova
Stream ecological responses to urbanisation in three contrasting metropolitan regions of the United States ***Page 2***

14:00 Contributed Paper
J.Feminella, B.Helms, B.Lockaby, J.Schoonover
Land use change and stream signatures: effects of urbanisation on stream biogeochemistry and biodiversity in catchments of western Georgia, USA ***Page 17***

14:20 Contributed Paper
R.Morgan, S.Cushman
Urbanization effects on Maryland fish communities ***Page 18***

14:40 Contributed Paper
M.Barbour, J.Stribling
Challenges for establishing reference conditions in urban and agricultural landscapes ***Page 19***

15:00 Contributed Paper
J.Kennen, M.Chang, C.Roberts, B.Tracy
Effects of urban growth on fish assemblages in a North Carolina metropolitan area ***Page 20***

15:20 AFTERNOON TEA

Concurrent session 2

2A: Assessment using algae
Chair: *R. Coleman*

15:45 Contributed Paper
C.Parent, J.Boisson
The use of periphyton for assessing impacts of urban wet weather flows: assays in artificial streams and in microcosms ***Page 21***

16:05 Contributed Paper
J.John
The impact of land use on water quality of urban streams in Perth, Western Australia ***Page 22***

16:25 Contributed Paper
S. Komulaynen
Phytoperiphyton communities monitoring in urban rivers ***Page 23***

2B: Physical impacts on streams
Chair: *I.Boothroyd*

15:45 Contributed Paper
W.Symmans, J.Hodges
Understanding north shore streams - Streamwalk ***Page 24***

16:05 Contributed Paper
M.Williamson
Herbicide contamination of urban streams following remobilisation from hard surfaces ***Page 25***

16:25 Contributed Paper
M.Drury, I.Boothroyd, G.Mills
A pressure-state-response model for urban streams in Auckland, New Zealand ***Page 26***

16:45 HAPPY HOUR

Tuesday 9 December

Theme: Ecological processes in urban streams and watersheds
Session 1 **Chair: *J.Meyer***

9:00 Keynote Address
P.Groffman, L.Band, K.Belt, G.Fisher, S.Pickett, R.Pouyat
Natural ecosystem processes are important in urban watersheds and streams ***Page 3***

9:45 Contributed Paper
E.Harbott, B.Hart, M.Grace
Extracellular enzyme response to dissolved organic carbon in urban streams ***Page 27***

10:05 Contributed Paper
K.Aldridge, G.Ganf, J.Brookes
Structure and function of Mediterranean streams along a rural-urban gradient; influence on phosphorus dynamics ***Page 28***

10:25 MORNING TEA

Session 2
Chair ***Mike Grace***

10:55 Contributed Paper
J.Catford, C.Walsh, J.Beardall
The effect of light on benthic microalgae in streamsof different catchment urbanization ***Page 29***

11:15 Contributed Paper
W.Miller, A.Boulton
When the shredders leave town: impacts of exotic leaf litter on aquatic macroinvertebrates in an urban stream ***Page 30***

11:35 Contributed Paper
J.Simpson, L.Busse, S.Cooper
Urban sprawl in the Los Angeles area promotes nuisance algal blooms ***Page 31***

11:55 Contributed Paper
S.Perryman, G.Rees, C.Walsh
Variation in the denitrifying community structure from streams in an urban and non-urban catchment ***Page 32***

12:15 LUNCH

Session 3

Chair: ***Peter Groffman***

13:15 Keynote Address
N.Grimm, C.Crenshaw, C.Dahm, R.Sheibley, L.Zeglin
Nutrient retention and transformation in urban streams ***Page 4***

14:00 Contributed Paper
M.Grace, S.Taylor, C.Walsh
Urbanization effects on the metabolism of small streams ***Page 33***

14:20 Contributed Paper
T.Wallace, G.Ganf, J.Brookes
Bioavailability of dissolved organic carbon in rural and urban streams of the Torrens River catchment ***Page 34***

14:40 POSTER SESSION and AFTERNOON TEA

16:00 Workshop 1
Assessment of urban impacts: global comparisons and future possibilities
Facilitators:
TBA and Meyer

SYMPOSIUM DINNER

19:00 Guest speaker:
Ian Rutherfurd

Wednesday 10 December

Theme: Priorities for Restoration (and impacts on vertebrates
Chair: *Tim Fletcher*

9:00 Keynote Address
C.Walsh
Stormwater drainage infrastructure: the key to conserving and restoring streams in urban catchments ***Page 5***

9:45 Keynote Address
D.Booth
Short- and long-term rehabilitation of urban streams ***Page 6***

10:30 MORNING TEA

Concurrent Session 3

3A: Theme: Riparian and in-stream habitat restoration
Chair: *Nigel Ainsworth*

11:00 Contributed Paper
R.Jones, G.Leonard
Waitakere's urban streams - monitoring and restoration ***Page 35***

11:20 Contributed Paper
C.Pitts
Assessing the effectiveness of controlling point source pollution to a stream in an urban catchment: a case study of Spen Beck, West Yorkshire, UK ***Page 36***

11:40 Contributed Paper
M.Watson, I.Reinfields, F.Torpy
Urbanisation - effects on riparian woody vegetation ***Page 37***

12:00 Contributed Paper
A.Suren, S.McMurtrie, R.Barker
Stream enhancement activities in Christchurch: an overview and cautionary tale ***Page 38***

3B: Urban impacts on stream vertebrates
Chair: *Graham Rooney*

11:00 Contributed Paper
M.Serena, V. Pettigrove
Relationship of sediment toxicants and water quality to the distribution of urban platypus populations ***Page 39***

11:20 Contributed Paper
C.Browne, M.Thompson, R.Jeffree
Metal accumulation, reproductive effects, and biomonitoring in Australian freshwater turtles ***Page 40***

11:40 Contributed Paper
M.Walton, D.Salling, J.Wolin
Assessing biological integrity within substantially urbanised catchments ***Page 41***

12:00 Contributed Paper
J.Kearns, D.Nugegoda, V.Pettigrove
Biomonitoring of trace metals in Melbourne's streams and wetlands using the mosquito fish (Gambusia holbrooki) ***Page 42***

12:20 LUNCH

Restoration and management
Chair: *Alastair Suren*

13:20 Contributed Paper
E.O'Brien, E.Taylor-Wood
Suitability-priority decision model for selecting sustainable projects ***Page 43***

13:40 Contributed Paper
C.Teixeira, A.Roberto, R.Porto
AcquaNet: a model for quantity and quality integrated management of water ***Page 44***

14:00 Contributed Paper
A.Bryant
A planning tool to facilitate earlier consideration of stream ecology issues in planning and management processes ***Page 45***

14:20 Contributed Paper
T.Ladson
Improving stream health by retrofitting suburbs to decrease the connection between impervious surfaces and waterways ***Page 46***

14:40 Contributed Paper
P.Chowdhury
Urbanization and stream ecology: Bangladesh perspective ***Page 47***

15:00 AFTERNOON TEA

15:45 Workshop 2
Towards restoration priorities
Facilitators: Derek Booth and Cathy Tate

17:00 SYMPOSIUM CLOSE

POSTERS

Invited Speakers

Ecosystem function in urban streams

Judy L. Meyer

Michael J. Paul

W. Keith Taulbee
River Basin Science and Policy Center, Institute of Ecology,
University of Georgia, Athens, Georgia USA

Cities were built where water was available or could be made available, and flowing water provides valuable ecosystem services to human societies. Ecologists have described an urban stream syndrome with attributes such as elevated nutrients and contaminants, increased flashiness, and altered biotic assemblages. Yet streams in metropolitan areas exhibit a range of ecological conditions which can be related to indicators of urbanization such as road or stream density, impervious surface cover, human population density, and percent urban land use. Ecosystem function probably also varies along this axis of urbanization, although there are few stream networks in which this has been studied. We have examined functional characteristics of six tributaries of the Chattahoochee River near Atlanta, Georgia USA that differ in degree of urbanization. Elevated nutrient concentrations associated with urbanization are usually attributed to increased inputs from point and non-point sources. However, observed concentrations are a function of both elevated inputs as well as altered nutrient removal rates. We used short-term ammonium and phosphate addition experiments to measure nutrient uptake velocity, which is the rate at which a nutrient moves through the water column toward the benthos. This measure is useful for comparisons of nutrient removal among streams because it accounts for discharge-related differences that dominate comparisons of nutrient uptake length. Both ammonium and phosphate uptake velocities decreased as indicators of urbanization increased. Standing stock of fine benthic organic matter (FBOM) also decreased with increasing urbanization, and uptake velocities were directly related to FBOM. Uptake velocities were not related to ecosystem metabolism (gross primary production, community respiration, or net ecosystem production) as measured with diel oxygen curves. Measures of ecosystem function in a diversity of urban streams are needed to determine the extent to which urbanization is associated with a degradation of the ecosystem services provided by streams.

Stream ecological responses to urbanization in three contrasting metropolitan regions of the United States

Cathy M. Tate
U.S. Geological Survey, National Water-Quality Assessment Program,
Denver, Colorado, 80225 USA

T. F. Cuffney[1], M.R. Meador[2], T.M. Short[3]
U.S. Geological Survey,
[1]Raleigh, North Carolina, [2]Reston, Virginia, [3]Menlo Park, California USA

M. G. Potapova
The Academy of Natural Sciences of Philadelphia, Pennsylvania, USA

Responses of physical characteristics; water chemistry; and fish, invertebrate, and algal communities to urbanization were examined in three metropolitan regions of the United States: (1) the humid Northeast (Boston, Massachusetts), (2) the humid Southeast (Birmingham, Alabama), and (3) the semiarid West (Salt Lake City, Utah), as a part of the U.S. Geological Survey, National Water-Quality Assessment Program. Responses were measured along a gradient of urban intensity derived from land cover, infrastructure (e.g., road density), and socioeconomic variables. In each region, 30 sites were selected to limit the variability of natural landscape characteristics while representing the gradient of urbanization. This design allows for comparisons of ecological responses of streams to urbanization across multiple spatial scales in regions of contrasting climate, geology, hydrology, biogeography, and water use.

Alterations of the landscape and hydrologic regimes associated with urban land-use development affect ecological responses directly and/or indirectly. In urban streams having a low degree of hydrologic connectivity within and among drainage networks (e.g., semiarid West), spatial variation in physical characteristics such as water temperature, channel morphology, and substrate heterogeneity appeared to be independent of larger-scale land-use patterns. In urban streams having a high degree of hydrologic connectivity to the drainage network, spatial variation in physical characteristics along the urban gradient was more indicative of broader scale land-use effects. In general, water chemistry responded directly to urbanization. Specific conductance and pesticide concentrations increased with increasing urban intensity in all regions, whereas, nutrients increased in semiarid West and humid Northeast regions with increasing urban intensity but not in the humid Southeast region. Fish-community response to increasing urban intensity varied among regions. In humid regions, species diversity decreased in relation to increased urban intensity; however, fish-assemblage response differed between the Southeast and Northeast. In contrast, fish assemblages in the semiarid West were more related to stream size and food resources than to urbanization. Increasing invertebrate community degradation was related to increasing urban intensity in all regions, and responses occurred at the lower end of urban intensity. Algal communities generally responded more closely to indirect measures of urbanization such as ambient nutrient and light conditions.

Natural ecosystem processes are important in urban watersheds and streams

Peter M. Groffman
Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545, USA

Lawrence E. Band
Department of Geography, University of North Carolina, Chapel Hill, NC 27599, USA

Kenneth T. Belt
Urban Forestry Ecological Research Unit, NE/USDA Forest Service, Room 134 TRC Bldg, University of Maryland at Baltimore Co., 5200 Westland Blvd., Baltimore, MD 21227, USA

Gary T. Fisher
US Geological Survey, 8987 Yellow Brick Road, Baltimore, MD 21237, USA

Steward T.A. Pickett
Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545, USA

Richard V. Pouyat
US Geological Survey, 8987 Yellow Brick Road, Baltimore, MD 21237, USA

In this paper we use data on natural and anthropogenic pools and fluxes of nitrogen (N) in watersheds and streams in the metropolitan area of Baltimore, MD USA to test the hypothesis that natural internal N cycle processes such as mineralization, nitrification and denitrification are insignificant compared to anthropogenic processes such as atmospheric deposition, food consumption, sewage and fertilization in urban watersheds. The work is a product of the Baltimore Ecosystem Study (BES), a component of the U.S. National Science Foundation's long term ecological research (LTER) network. Data were taken from long-term monitoring of stream exports and terrestrial processes, studies of instream retention processes and nitrogen input/output budget analyses conducted as part of BES. In contrast to our expectations, natural processes appear to be quite important in the urban and suburban watersheds of Baltimore. For example, the magnitude and variability of mineralization and nitrification are much greater than atmospheric deposition (50 versus 8 – 20 kg N ha-1 y-1), more than 70% of atmospheric and fertilizer inputs are "retained" in watershed soils and vegetation, and organic debris dams in urban streams function as a negative feedback on nitrate levels, with denitrification increasing in response to stream nitrate concentrations. These results suggest that natural processes are important, and manageable, controllers of stream ecology and water quality in urban and suburban watersheds.

Nitrogen retention and transformation in urban streams

Nancy B. Grimm
Arizona State University, USA

Chelsea L. Crenshaw
University of New Mexico, USA

Clifford N. Dahm
University of New Mexico, USA

Richard W. Sheibley III
Arizona State University, USA

Lydia H. Zeglin
University of New Mexico, USA

Stream ecosystems are heterogeneous landscapes of interacting subsystems that are strongly connected to surrounding terrestrial ecosystems and to recipient aquatic ecosystems (groundwaters, lakes, large rivers, and coastal ecosystems). Because of this multidirectional connectivity, streams integrate processes of their uplands and contribute to the character of their recipient ecosystems. Streams are like arteries, but unlike arteries, they have significant capacity to transform and retain materials. These retention and transformation processes are important ecosystem services that are as yet not fully understood for the full suite of stream ecosystems. Moreover, nutrient retention by streams that have been modified by urbanization and other land-use changes is largely unexplored.

Nutrient spiraling in theory and application provides a framework for comparing nutrient retention efficiency of urban streams to relatively unmanipulated streams. We have found that native streams of the southwestern USA deserts are highly retentive of nitrogen (N) owing to N limitation, high productivity, and high channel complexity (in particular, extensive transient storage associated with the hyporheic zone). Most urban streams of the region have highly modified channel morphology and experience N loading from urban runoff and inputs of nitrate-contaminated groundwater. Therefore, we predict these streams are neither N limited nor as retentive, compared with native streams. For some urban streams, however, restoration efforts attempt to re-establish flow in long-dry channels, create non-structural flood management solutions, and design riparian areas as a public recreation amenity. These human modifications may, in part, restore N retention functions if channel complexity and heterogeneity are important factors contributing to N retention efficiency. We are conducting experimental additions of ^{15}N-nitrate to evaluate N retention in urban streams of the American Southwest. In this paper, we will present preliminary results of those experiments and test our predictions by comparing the results to similar experiments in native streams. Results also will allow us to evaluate the use of nutrient spiraling metrics as a tool for assessing the status of stream ecosystem services in urban restoration projects.

Stormwater drainage infrastructure: the key to conserving and restoring streams in urban catchments

Christopher J. Walsh
Cooperative Research Centre for Freshwater Ecology, Water Studies Centre, Monash University, Vic 3800, Australia

As the world rapidly urbanizes, the number of streams degraded or threatened by urban land use rises alarmingly. Yet stream ecologists have not agreed on the most appropriate priorities for protection of stream ecosystems from urban impacts, if the same approaches are applicable across regions, or indeed if protection of ecological health is possible in urbanized catchments. Urbanization can cause many impacts to receiving streams (including a range of hydrological disturbances, many pollutants, loss of habitat). While those impacts to the streams are usually difficult or impossible to separate, they ultimately stem from a smaller number of larger-scale impacts, which are potentially manageable

A brief review of in-stream habitat restoration experiments in urban catchments demonstrates that restoration of in-stream or riparian habitat is unlikely to have significant effects on in-stream ecosystems, if the structure and function of those systems is determined by dispersed, catchment-scale impacts of urban land use. I therefore argue that the catchment is the most appropriate primary scale for conservation and restoration of streams in urbanized catchments.

I report on an inter-disciplinary study of small streams to the east of Melbourne, Australia, which tested the hypothesis that a large proportion of variance in ecological structure and function in streams of varying catchment urbanization was explained by variation in the extent to which urban areas of each catchment were drained by stormwater pipes. Electrical conductivity, concentrations of filterable reactive phosphorus and dissolved organic carbon, benthic algal biomass and assemblage composition, production:respiration ratio and macroinvertebrate assemblage composition were all correlated with the gradient of urban density. Independently of this correlation, drainage connection (the proportion of impervious surfaces connected to streams directly by pipes) explained more variation in each of these indicators than could be explained by chance

The importance of drainage connection points to low-impact urban design approaches, most of which reduce hydraulic connection between impervious areas and downstream receiving waters, as the most appropriate primary means of protecting stream ecosystems from urban impacts. I use a conceptual model of the mechanisms by which piped stormwater drainage degrades stream ecosystems to classify stormwater disturbances by frequency and intensity. This model provides a framework for adaptively testing the effects of stormwater management measures that differ in the manner in which they disconnect impervious surfaces from streams.

Short and Long-Term Rehabilitation of Urban Streams

Derek B. Booth
Center for Water and Watershed Studies, Box 352700, University of Washington
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Ecological changes in urban streams have multiple causes and are difficult to correct. In the USA's Pacific Northwest, one such cause is hydrologic alteration, noteworthy in its pervasiveness and severity. Yet traditional hydrologic metrics do not describe ecologically significant alterations, and data to generate any metric are commonly unavailable. This motivates substitution of difficult-to-obtain hydrologic parameters with easy-to-measure ones (e.g., physical stream conditions), but results can be easily misunderstood. This approach also encourages misguided manipulation of physical habitat to address problems with other underlying causes.

Social attention to degraded urban streams is commonly greater than to healthier (but more remote) undisturbed counterparts. Because these degraded systems cannot sustain full biological integrity, however, successful short- and long-term rehabilitation techniques and goals must differ substantially from those in less disturbed environments. In the Pacific Northwest, coho and chinook salmon were historical salmonid species of lowland streams but their life histories are not tolerant of flashy discharges, disrupted food webs, and a host of other problems. Other fish, notably cutthroat trout, have found these same conditions more to their liking. This shift in species may be socially acceptable, but it also is symptomatic of underlying changes in biological health that have low visibility but potential long-term human and ecological consequences. Moving urban streams in the direction of improved biological health is therefore a defensible and worthwhile goal. Long-term rehabilitation actions must target the watershed processes that once sustained the parts of the system that constituted its integrity--most prominently, hydrologic rehabilitation of uplands, recreation of floodplain and floodplain connectivity, and vegetation succession in the riparian zone. Short-term rehabilitation should strive to make these systems better environments for the species that still can thrive there, and for engaging support from the society that surrounds them. Enhancement activities also should not preclude ultimately regaining biological integrity. Common actions that typically meet these (limited) short-term objectives are fish-passage improvements, local hydraulic modifications, chemical pollutant reduction, and buffer-strip plantings. For many urban systems, desired long-term goals are unattainable in our lifetimes. Incremental improvements within a coherent long-term framework, however, should lead to both short- and long-term gains.

Contributed Speakers

Symposium on Urbanization and Stream Ecology

8th to 10th December 2003

Investigating hydrologic alteration as a mechanism for fish species loss in urbanizing streams

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The pervasive influence of urban development in the landscape has altered stream biotic assemblages, often leading to species extirpation and suggesting a loss of ecosystem functioning. Hydrologic alterations such as flashy stormflows and reduced baseflows associated with impervious surfaces and rapid delivery of stormwater to streams are potential mechanisms by which urbanization is altering stream biotic assemblages. We are studying causes of faunal loss in an urbanizing, southeastern U.S. river system that supports an exceptional diversity of native stream fishes. Thirty streams in the Etowah River basin lying north of the rapidly sprawling metropolis of Atlanta, Georgia (population ~4 million) have been selected for this study. Study sites (9-18 km^2 catchments) were stratified by three classes of percent impervious cover in the sub-catchment (<10%, 10-20%, >20%) and by estimated degree of hydrologic alteration (using synoptic measurements of baseflow yield). We are quantifying storm flows using AquaRod© sensors with internal dataloggers that continuously monitor water level. Fish assemblages were sampled in summer 2002, and we have calculated various measures of assemblage integrity.

For the initial four months of data collection, sites with high impervious cover were characterized by greater increases in water level during small storms (r^2 = 0.54) and greater slope of the ascending limb of the storm (r^2 = 0.49). Percent impervious cover and percent forest cover could explain a combined 73% of the variation of abundance of sensitive fish species across the sites; however, few indicators of hydrologic alteration were related to the fish assemblages. Counterintuitively, there was a positive relationship between fish assemblage integrity and the slope of the descending limb of the storm, which was unrelated to impervious cover. Hydrologic alteration associated with urbanization and its relation to fishes must be quantified in order to understand the conditions under which urban streams can support relatively intact fish assemblages. Ultimately, these data can be used to make recommendations of how to manage storm flows to maintain fish assemblage integrity in small, suburban streams.

Upper catchment urbanisation effects on streams in the Wellington region, New Zealand

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Most urban centres have developed on the valley floors and catchment flood plains with suburban areas in the foothills of surrounding ranges. The influence of urbanisation on stream ecosystems from headwaters to the floodplains has been well documented. Wellington is the capital city of New Zealand, with a population of some 500,000 people. Wellington is characterised by its steep incised catchments, and the nature of development has often resulted in intensive urban development in the headwater catchments of streams, while the lower reaches of some catchments have been subject to much less modification. In places, headwater streams have been heavily modified and subject to the channelisation, piping, flood management and stormwater influences normally associated with urbanised floodplains. Biotic indicators of water quality and ecological condition, especially macroinvertebrate community indicators, from these modified headwater streams were more similar to highly modified lowland catchments. In some instances however, the lower catchment areas retained more natural landuse characteristics and recovery of the biotic communities was evident. This paper examines the ecological condition of a variety of urban streams in the Wellington region, and examines some of the factors influencing the macroinvertebrate communities, with a particular emphasis on the modified headwater streams and their recovery downstream.

River protection using good management practices: defining a reference condition for the biological assessment of urban streams

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Urban streams with good management practices (GMPs) can provide a reference against which to assess river condition. A GMP reference condition is particularly relevant in urban environments where a pristine or minimally disturbed reference condition can not be established. Protocols for selecting reference sites based on GMPs have been developed, and used in Canberra, Australia. A predictive model for the assessment of aquatic macroinvertebrate assemblages was developed from macroinvertebrate and habitat data collected at these sites. Urban test sites were assessed with both the predictive model based on GMPs, and a standard AUSRIVAS (Australian River Assessment System) predictive model for the ACT based on sites with perceived low levels of human disturbance. The GMP predictive model rated urban test sites as being in better condition than did assessment with the AUSRIVAS model for the ACT. This suggests that a reference condition based on GMPs may need to be used cautiously if ecological values are to be protected in urban environments.

Long-term changes in water quality and macroinvertebrate communities in Southeast Queensland urban streams.

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This paper describes the historical changes in water quality and aquatic macroinvertebrates in some of Brisbane's urban streams based on studies carried out by various investigators between 1972 and 1996. One catchment (Moggill Creek) used to be a relatively rural catchment whereas now it is more urban, with housing estates being a common feature. Another catchment (Bulimba Creek) has undergone rapid urban expansion. In both catchments, sewage treatment plants ceased operation in the early 1980s, resulting in the improvement of water quality and the recovery of the macroinvertebrate fauna. However, there are also indications of other sources of impact. Medium to high flood events act to 'reset' the water quality and faunal diversity and it is important that such natural flushing flows be maintained for the sustainability of such urban streams.

The development of hypereutrophic conditions in an urban floodplain wetland: palaeolimnological evidence

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Notions about the biological diversity, variability, water clarity and trophic status of pre-disturbance floodplain wetlands in south eastern Australia have been based on assumptions and scant historical data about these systems. Whilst pre-contact conditions may be neither achievable, nor desirable given the existence of highly altered urbanised river systems, their understanding and subsequent transformation may aid in setting realistic targets and in developing a better understanding of the inherent trajectory, rate of change and variability of floodplain wetlands. No guidelines for total phosphorus (TP) in wetlands exist for south-eastern Australia. Qualitative and quantitative palaeoecological reconstructions of TP can contribute to the development of appropriate guidelines.

Willsmere Billabong is a shallow wetland on the urbanised lower Yarra River floodplain. Concerns about aquatic plant blooms (*Nymphaea capensis* and *Lemna disperma*) have led to concerns that the billabong is rapidly degrading. A limnological and palaeolimnological investigation has aimed to better understand the development of the present-day condition of the billabong given the alterations to the site over the last 160 years. High-resolution sediment analysis has been possible because of an independently verifiable ^{210}Pb chronology. A diatom based TP transfer function model, developed for Yarra River billabongs is presented and appears to perform well. Diatom inferred TP (DI-TP) suggests that the greatest amount of change at the site was attributable to local landscape changes associated with freeway construction and the diversion of urban stormwater into the billabong. The DI-TP suggests that peak TP was experienced in the mid 1980's and that TP has since declined to present day concentrations. Diatom inferred TP compares well with measurements of TP in the mid 1980's. Recommendations for the future management of the wetland have focused on the need to use a wetland filter to decrease pollutant input into the wetland and on the need to manipulate inflows from the river.

Bacterial Pollution in Lake Burley Griffin, A.C.T.

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Recreational use of Lake Burley Griffin has been intermittently interrupted ever since the lake was formed in 1962 because of elevated bacterial levels that exceed the commonly accepted standards for primary contact recreation. Many causes have been advanced including leakage of sewage from the Canberra system, overflow of sewage from nearby Queanbeyan, wildfowl, input from rural catchments, rotting vegetation and stormwater. Data have been collected during 2002-2003 at six sample locations (close to points where data were collected in 1974) around the lake. It will be argued in this paper that the major sources for bacterial pollution are stormwater discharge at times of heavy rainfall and concentration of wildfowl populations in some parts of the lake. It will be further argued that bacterial levels in Lake Burley Griffin are not greatly different (for similar reasons) to those reported three decades ago.

Sustainability of Shallow Urban Lakes In Melbourne

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The sustainability of shallow urban lakes, and the minimisation of the severity and occurrence of algal blooms in constructed lake systems, has been identified as key issues for Melbourne Water. A clear management direction is required to minimise the risk of algal blooms through appropriate design of new lakes systems in the urban environment. As a consequence, preliminary guidelines for developers for the sustainability of shallow urban lakes have been developed. This paper presents guidelines that define the characteristics of typical sustainable shallow urban lake systems in Melbourne, and describes the approach taken to develop these guidelines.

The paper discusses results of the analysis of the historical evolution of water quality for some representative Victorian shallow lakes. Modelling techniques to assess the sustainability of future shallow lake developments are proposed. Results presented include recommended concentration limits for various in-lake water quality parameters; definition and discussion of resilient lake systems; discussion of modelling requirements; recommendations for lake management practices; and identification of required monitoring programs and existing research gaps. A modelled case study of a typical shallow urban lake, and the analysis of likely bloom risk using the guideline values developed; provide an example of their application. The paper contains a number of outcomes targeted at assisting future decision-making regarding the assessment of constructed shallow urban lake systems in Melbourne.

Effects of harvesting on the removable nutrient amount and sustainable management of *Phragmites australis*

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Constructing wetlands is a cheap, ecologically friendly method to treat wastewater. Although harvesting of plants effectively removes nutrients from water, the efficiency is not significant if timing is not appropriate. Moreover, it affects plant re-growth during the subsequent year. In this study, effects of harvesting the aboveground biomass on re-growth of *Phragmites australis* in the subsequent growing season was investigated following cutting in June or July. Seasonal changes in rhizome biomass and total nonstructural carbohydrate (TNC) in seven age categories, from newly formed to six years old, were monitored for two treatment stands and a control. The growth of the stands, as indicated by the aboveground biomass, showed a significant decline due to cutting in June but did not show a significant difference due to cutting in July, compared to that of the control. Timing of harvesting of aboveground biomass affected the annual rhizome resource allocation. A similar trend was observed for the pattern of resource allocation, as described by biomass variation of different rhizome-age categories for July-cut and control stands. However, the biomass of June-harvested rhizome categories tended to be smaller than the other two stands, indicating substantially reduced resource storage as a direct result of harvesting the biomass during the previous growing season. This implies that cutting of aboveground biomass in June is a better option for control of *P. australis* stands than cutting later in summer.

Further, a mathematical model was developed to simulate the harvesting process and nutrient removal rate by harvesting. In the model, the biomass of age-specific rhizomes, roots, shoots and panicles are evaluated through phenologically evaluated terms, such as production, respiration, mortality and translocation between organs. Validation of the model with previously reported datasets and the above observational results indicated that the model provides the sufficient agreement for all cases. Then, the model was applied to the evaluation of different harvesting time on the removable nutrient amount and the effect on the rhizomes and the aboveground growth in the following years. The simulated results indicated that August harvesting removes the highest amount of nutrients in spite of small damages on the community.

Land use change and stream signatures: effects of urbanization on stream biogeochemistry and biodiversity in catchments of western Georgia, USA

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In 2002 we began a multi-year study designed to examine linkages between land use change associated with urbanization and stream biodiversity and water quality, in response to rapid human population expansion in the southeastern USA. Twenty small catchments were selected along an urbanization gradient north of the city of Columbus, Georgia. Study catchments included largely urban, developing (suburban), agricultural (pasture), and managed pine and unmanaged mixed-forest land uses. Representative study streams are being sampled seasonally for biogeochemistry, periphyton, benthic macroinvertebrates, and fish. Preliminary data indicated that urban and developing catchments showed elevated streamwater fecal coliform, TDS, and DOC concentrations, and lower dissolved O_2 levels, compared with agricultural and forested catchments. Algal biomass (as chlorophyll *a*), and numbers and % abundance of macroinvertebrate species in the aquatic insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) were higher in forested than in urban catchments, possibly resulting from higher streambed stability in these less-disturbed catchments. In addition, abundance of pollution-tolerant fish (*Lepomis cyanellus*, *Gambusia affinis*, *Semotilus atromaculatus, Ameirus* spp.) was higher in urban and/or developing catchments than in forested catchments. Collectively, these data suggest that stream abiotic/biotic signatures are reliable ecological indicators of human-induced landscape change, measurable at the whole-catchment scale. This information is being integrated with other data collected in these catchments (avian biodiversity, socioeconomic factors) into a predictive model used to forecast the magnitude of whole-system changes in stream structure and function, associated with the conversion of forestland to urban/suburban land uses in the Southeast.

Urbanization Effects on Maryland Fish Communities

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Using 1995-1997 and 2000-2002 data from the Maryland Biological Stream Survey (MBSS), we examined changes in fish communities associated with urbanization, specifically in the Piedmont and Coastal Plain Provinces of Maryland. Major urbanization effects are already present in these provinces, and increasing stress will occur over the next 25 years, as Maryland adds almost another million residents to this rapidly growing area. The MBSS assesses first through third order non-tidal streams, which totals ~14,900 stream km statewide. These lower-order streams currently receive significant urbanization effects, as well as other historical stresses. The MBSS incorporates a hierarchical probability-based sampling design that allows for discrete quantification of biological, chemical and physical characteristics of Maryland streams. In addition, the MBSS program developed indices (benthic macroinvertebrate, fish, and physical habitat) to evaluate stream health, delineated the predominant fish communities and fish tolerance levels throughout Maryland physiographic provinces, and determined watershed land use characteristics upstream of each sample site using a GIS.

Each MBSS unit (~1,600 sites) was assigned to a class based on the degree of urbanization (0-10, 10-25, 25-50, 50-75, and over 75%) within its upstream watershed. Once classified, each site was examined for non-urbanization stresses, and the site was eliminated if other factors predominated (e.g. acid deposition, agriculture, etc.). Each fish community was then compared to the expected fish community within that physiographic province for that MBSS site. This set of analyses indicated that there are significant changes in fish communities in Maryland associated with urbanization effects. The amount of impervious area within a watershed appeared to be a key factor for brook trout populations, as well as for other species. Overall, urbanization tends to eliminate intolerant fishes, resulting in fish communities heavily dominated by tolerant fishes. Conservation practices to minimize the impact of urbanization on fish communities may be inadequate to protect non-tolerant fishes, due primarily to the invasive nature of urbanization and loss of fish refugia within a watershed.

Challenges for Establishing Reference Conditions in Urban and Agricultural Landscapes.

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Reference conditions are ideally established from undisturbed aquatic resources that provide a quantifiable target for impaired systems. However, many areas have undergone substantial land cover conversions resulting in conditions beyond reasonable restoration goals. Two land uses that prevail throughout the United States are agriculture and urban. The question is how to best characterize reference conditions that are appropriate for protection, restoration, and overall management of the human activities influencing the watershed. Case examples are provided for urban systems in the Baltimore, MD, and Washington, DC, corridor, and for the broad agricultural landscape in North-Central Mississippi. In both of these cases, reference conditions were based on existing stream reaches as a definition of regional expectations. For urban centers, identifying regional undisturbed or minimal disturbance is possible. For agricultural landscapes that predominate in specific geological landforms, the least disturbed conditions often function for reference conditions. Technical and socioeconomic considerations are closely linked for evaluating the appropriateness of reference conditions to serve as an adequate framework for assessing health and restoration potential in either predominant land use. In a pilot study on US urban watersheds, we find that the benchmark for assessment of health or restoration potential also depend on climatological drivers, e.g., the temperate Atlantic seaboard (Baltimore, MD), the inland Midwest (Cleveland, OH), or the arid Mediterranean-like area of the Pacific coast (San Jose, CA).

Effects of Urban Growth on Fish Assemblages in a North Carolina Metropolitan Area, USA, 1970-2000

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Landscape modification associated with urban development is occurring rapidly, yet its effects on aquatic communities are poorly understood. In this study, relations among aquatic indicators, land use, and water quality in the Raleigh-Durham, North Carolina, USA, study area from the 1970s to 2000 were examined. The study area consists of the contiguous metropolitan area plus a surrounding 20-mile buffer area that was chosen to incorporate projected urban growth and to evaluate the effects of urban development on aquatic communities. The Analytical Tool Investigating Land Assessment (ATtILA) computer program, was used to classify land use by calculating landscape metrics and indices at the hydrologic-unit scale using geospatial data. Complementary data were compiled from existing U.S. Geological Survey water-quality monitoring sites and from 39 overlapping North Carolina Department of Environmental and Natural Resourcess fish sampling sites for 1991 to 2000. Indirect ordination analysis using non-metric multidimensional scaling was used to evaluate which environmental variables were important in accounting for differences in fish assemblages across an urban disturbance gradient. Variables accounting for the greatest variability in the fish assemblage included percent urban area and its surrogates. Patch forest area and the number of forested patches were significantly related to urban development, indicating that an increase in forest fragmentation negatively affects fish assemblages.

The use of periphyton for assessing impacts of urban wet weather flows: assays in artificial streams and microcosms

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Repeated discharges of untreated wastewater due to urban Wet Weather Flows led to concern over the impacts of such complex effluents on the aquatic environment. These overflows, either from combined or separated sewer overflows, are typically composed of wastewaters and surface runoff from urbanized areas and occur after storm events, mostly during short periods of time. The purpose of this study is to evaluate the relevance of the use of periphyton as an indicator of these urban Wet Weather Flows impacts on running waters. Colonized substrata are collected in a natural stream and are submitted to a 4h combined sewer overflow exposure in two laboratory systems: artificial streams (dynamic conditions of flow) and microcosms (static conditions). Sampling times ranges from 4h to 4 days after the exposure. Both structural and functional parameters are studied: ash-free dry weight, algal biomass (chlorophyll-a and pheopigments), bacterial abundance (with discrimination of bacteria with intact cell membrane and bacteria with damaged cell membrane), and two extra-cellular enzyme activities: leucine aminopeptidase and β-glucosidase.

Observed effects vary among parameters, time responses, and systems. Concerning structural parameters, responses are the same in both systems. The discharge has no effect on ash-free dry weight and pheopigments, but it significantly increases chlorophyll-a concentrations (after 72h in artificial streams, and 4h in microcosms). It has positive then negative effects on bacterial abundance, indicating firstly a stimulating effect maybe due to organic matter supply, and secondly an inhibiting effect, some metallic compounds being possibly more bio-available by desorption. Functional parameters bring various results among systems. The effects of the discharge on community enzyme activities are significant in dynamic conditions, but not in a static state, which reveals for this parameter a 48h minimum time response of the periphyton community. Lastly, in both systems, specific enzyme activities (*i.e.* related to bacterial abundance) show a negative effect of the discharge 8h after the exposure.

The Impact of Land Use on Water Quality of Urban Streams in Perth, Western Australia

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The Swan-Canning estuarine system, around which the city of Perth was founded, has been displaying severe symptoms of eutrophication in recent years. Toxic dinoflagellate and cyanobacterial blooms within the last 20 years have highlighted the impact of excessive nutrient input from both the urban and rural catchment areas. The urban wetlands around the Swan River estuary have been displaying symptoms of degradation due to salinisation and eutrophication. Urbanisation of Perth which commenced in 1829 with the establishment of the Swan River Colony, has followed drastic alterations to the natural drainage system of the city. An investigation into the impact of urbanization on the urban streams and their nutrient status conducted between 1995–2000, has resulted in characterization and classification of the streams.

As many as 30 environmental factors including nutrient concentrations were used in characterising the streams and drains discharging into the Swan River. Multivariate analyses revealed that seven environmental variables (alkalinity, total phosphorus, total nitrogen, total organic nitrogen, ammonia and soluble reactive phosphate) had the highest correlation coefficient with stream –sites covering an area of 5 000 km^2. The urban stream sites were classified into three groups based upon the environmental factors – i.e. (a) severely impacted; (b) least impacted; (c) intermediate. The least impacted sites were positively correlated with the highest native vegetation coverage and deepest water table and the impacted sites with increasing alkalinity, ground water salinity, Riparian damage, catchment land use and colour of water. Landfill waste disposal sites, sewerage and farming were all identified as factors which have contributed to the deterioration of urban streams. Land use in the broad sense emerged as the overriding factor affecting water quality and habitat changes in the urban streams. Examples of mitigation and rehabilitation of impacted streams and subsequent improvement in water quality are also presented in the paper.

Phytoperiphyton communities monitoring in urban rivers

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The spatial distribution of the attached algae community was studied in some of rivers in Republic of Karelia (NW Russia). The purpose of this paper is to assess how informative phytoperiphyton structural parameters are, and to assess the feasibility of using them for biological monitoring of the river status. The periphyton communities influenced by anthropogenic impacts were analyzed in terms of species richness, species diversity, species ecological values, biomass and chlorophyll concentration. All rivers were subject to different kind of anthropogenic impacts in addition to natural disturbance. With regards to the taxonomy structure the differences between the urban and natural stretches of rivers are obvious. The data obtained demonstrate that the phytoperiphyton communities in urban streams enriched by broadvalent, pollution-tolerant and even saprophilic taxa. Substantial changes in periphyton structure were often caused by an enhanced mechanical impact by storm off, which retarded colonization, rather than any chemical influence. The burial of algae by sand and silt resulted in the loss of species or entire algal assemblages were observed. As a result the communities are dominated by a few species with high recolonization potential.

Understanding North Shore Streams

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North Shore City Council is currently applying for resource consents to operate, maintain and upgrade our stormwater and wastewater networks. To lodge our application we need to have a clear understanding of our freshwater resources and the impacts of the wastewater and stormwater networks on these streams.

The streamwalk project is a project to walk all major urban streams within the city. It was decided that the entire length of each stream needed to be walked to gain a complete picture of where and why impacts were occurring. It was also required to gain a full understanding of how barriers to fish passage were affecting fish distribution. This paper will discuss how traditional stream assessment methods were altered to allow the rapid collection of a data over the entire length of each stream.

A palmtop and GPS were also used to collect data, which in turn allowed data to be directly uploaded into a council system.

With such large volumes of data it was important that information was brought together in such a way that it was useful to both managers and yet in a form that could also be communicated to the stakeholders. A system was developed that allowed the ecological information collected on during the streamwalk to be summarized and streams to be grouped according to their ecological quality.

This paper will discuss the methodology used during the stream walk, along with the issues that arose from the collection and management of such large quantities of information. It will also present the results from a number of case studies.

Herbicide contamination of urban streams following remobilisation from hard surfaces

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A variety of herbicides is widely used in the urban environment for reasons including control of undesirable plants in amenity areas and reserves, maintaining visibility adjacent to roads, removing vegetation from fence lines, paths, gutters and stormwater drains and total vegetation control on commercial and industrial sites. Such use often results in herbicide being applied to concrete, asphalt or other synthetic hard surfaces which unwanted plants are growing over or adjacent to. Remobilisation of herbicide from such surfaces may lead to herbicide contamination of urban streams and this could be especially important during the first rainfall following a prolonged dry spell. Assessing the potential for such contamination to occur is difficult because of very limited information on the extent of remobilisation for different herbicides and under different conditions.

Potential remobilisation is being assessed by applying controlled amounts of herbicides to replicate standard pieces of different surfaces and then measuring herbicide runoff during simulated rainfall events. Factors such as drying time between spray application and rainfall and possibly inclusion of surfactants in the herbicide spray will be investigated. Results to date show greater remobilisation of 2,4-D from weathered concrete after longer drying times than when simulated rainfall is applied shortly after the herbicide spray. One possible explanation is that herbicide moves out of pores in the test surface as it drys and thus becomes more easily taken up in runoff when rain falls.

A Pressure-State-Response Model for Urban Streams in Auckland, New Zealand

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Understanding the relationships between land use pressures, the state of the environment and the effectiveness of the management responses lies at the core of sustainable land and water management. Despite this, little research has been done to uncover these relationships, and to develop the pressure-state-response (PSR) framework for practical use by management agencies. Pressure, state and response indicators were developed and applied to urban streams in the Auckland region of New Zealand. Pressures on the Auckland region were synonymous with increasing urbanisation, e.g., impervious area, population, vehicle numbers and wastewater infrastructure to service the growth. Although there was a considerable amount of information on the quality of Auckland's urban streams and estuarine receiving environments, much of it has not been collated into a form that can be used for further analysis. Nevertheless PSR patterns were clearest where pressures were high and water quality was poor, but ecological health was more variable. These patterns occurred as response initiatives have been implemented, such as habitat improvements in the lower catchments of urban streams. In some instances, good water quality occurred where pressures were low but ecological health remained very poor. The nature and age of the wastewater infrastructure influenced pressures in some cases. An environmentally based framework for pressure, state and response environmental reporting will be presented. The environmental reporting framework results in an alignment of pressures and state for urban streams, and allows an explanation of patterns and the reporting of trends for state of the environment reporting.

Extracellular Enzyme Response to Dissolved Organic Carbon in Urban Streams

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Concentrations of organic carbon, the major driver of riverine food webs, vary seasonally, due to flushing associated with high discharge events. Most of the detrital organic matter residing in streams and rivers originates from allochthonous sources. Flushing from soils, groundwater, leachates from leaf litter, precipitation filtering through vegetation, living and decaying plant and animal matter all deliver dissolved organic carbon (DOC) into the stream .Urban streams have additional stressors: channel alterations, catchment imperviousness, increased drainage connection and receiving of stormwaters containing additional nutrients. Dissolved organic carbon (DOC) concentrations are routinely measured for stream samples, yet provide no information about carbon bioavailability. An enzyme activity technique measuring the rates of bacterial enzymatic activity with artificial substrates was used to explore how urbanisation affects bioavailability of DOC compounds in stream ecosystems. The activities of six extracellular enzymes were measured by incubating water samples with 4-methylumbelliferyl substrates to investigate streams across a gradient of urbanization east of Melbourne, Australia.

In a PCA ordination of the six activity measurements, sites separated according to their relative urbanisation. Interestingly, the activities of leucine aminopeptidase and esterase dominated in the more urbanized streams compared to the less impacted streams which were distinguished by moderate activities from a diverse range of enzymes. The contribution of leucine aminopeptidase to overall enzyme activity stressed the increased importance of peptides as a carbon source for heterotrophic bacteria in urban environments. The contributions of ß-N-acetyl glucosaminidase and ß-xylosidase highlighted the significance of microbial detrital material as a carbon source and the processing of plant-derived xylooligosaccharide substrates in less disturbed environments. Results clearly demonstrated the techniques potential to discriminate between carbon bioavailability in streams spanning a range of urbanisation, despite similar bulk dissolved organic carbon concentrations, which do not provide information about the biological importance of the classes of carbon compounds present.

Structure and function of mediterranean streams along a rural-urban gradient; influence on phosphorus dynamics

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Streams with complex physical structures and diverse biological communities have the potential to buffer the impacts of eutrophication on downstream ecosystems by providing multiple pathways for nutrient interception and transformation. However, in urbanized catchments, streams are often engineered to mitigate flooding and so streams experience simplification of their physical structure and a reduction in their biological diversity. This may alter the functioning of stream ecosystems and reduce the number of pathways for nutrient interception and transformation, increasing the potential for eutrophication of downstream ecosystems.

The relationship between stream structure, function and phosphorus dynamics along a rural-urban gradient was assessed within the Torrens River Catchment, South Australia. The ability of reaches with varying levels of in-stream development to retain phosphorus was assessed on a seasonal basis through a series of soluble reactive phosphorus (SRP)-sodium chloride injection experiments, whereby expected phosphorus concentrations were traced by conductivity. Results indicate that natural stream reaches (complex physical structure) within the Torrens River Catchment, have a high affinity for SRP, retaining approximately 70% of the added SRP. In contrast, highly engineered reaches (simplified physical structure) retained approximately 8% of the added SRP. Community metabolism (gross primary production and respiration) was used to measure ecosystem function by monitoring dissolved oxygen levels within Perspex benthic chambers over 24 hours within stream reaches with varying levels of in-stream development. Results indicate that in-stream benthic communities within the Torrens Catchment are highly productive ecosystems, with net primary production rates (NPP) up to 400 mg C m^{-2} day^{-1} and respiration rates (R) up to 200 mg C m^{-2} day^{-1}. In general, more natural stream reaches had higher NPP:R, due to lower R in more natural sites. Results obtained provide important information for the management of the functional integrity of streams and the treatment of urban stormwater through the rehabilitation of stream structure and function.

The effect of light on benthic microalgae in streams of different catchment urbanization, Melbourne, Australia.

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Algae are well-established indicators of stream health and are known to respond to changes in ecosystem condition. Urban land use degrades aquatic ecosystems in numerous ways, most importantly in many cities through the impact of stormwater runoff. Nutrient concentrations, light climate and flow regime are key influences on the development of benthic microalgae (MPB), and all are affected by urban stormwater. This study aimed to determine the effect of different levels of irradiance and stream urbanization, and their interaction, on the development of MPB assemblages. The level of urbanization of the study streams, located to the east of Melbourne, was gauged by the proportion of catchment imperviousness and drainage connection.

Three light levels were achieved in four streams of different catchment urbanization by shading with neutral density filters (12.5 %, 50 % and 100 % light transmission), and two of the levels were comparable between all four streams. MPB assemblages were sampled fortnightly from each stream over 79 days in winter. Biomass (chlorophyll *a,* pheophytin and cell density) and assemblage composition were determined. Algal biomass increased with level of catchment urbanization. Most of the variation in algal biomass was attributable to the urban gradient between streams. Each stream had distinct assemblages. Time and light had no apparent effect on assemblage composition, and light only affected biomass in streams with high nutrient concentrations. Although it was postulated that algal populations were light-limited in all four streams, light limitation was overridden by nutrient limitation in the least urbanized streams. The greater energy reserves of MPB under high light enabled alleviation of nutrient limitation in the second most urbanized stream. Top-down pressure from scour may have affected MPB in the most urban stream. MPB in these streams at this time of the year were chiefly controlled by nutrient enrichment, with light level having a relatively minor effect. Reduction in catchment-derived nutrient loads would be the most effective means for controlling MPB (in the long-term and at a broad-scale), although the maintenance of riparian shade would also help to inhibit algal blooms in these streams.

When the shredders leave town: impacts of exotic leaf litter on aquatic macroinvertebrates in an urban stream

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Urban centres in much of cool-temperate Australia have exotic, deciduous trees planted along their streets. Massive volumes of leaf fall from these trees during autumn are transported directly to urban streams via stormwater drains, but their effects on ecosystem processes are poorly known. Organic matter and macroinvertebrate community composition in an urban stream running through Armidale, NSW, were compared with those in nearby rural and reference streams to determine the effects of this 'flush' of exotic leaf litter. Coarse particulate organic matter (CPOM) and associated macroinvertebrates were sampled monthly commencing in March 2002 at four sites on each stream.

The amount of CPOM differed among streams (R ANOVA $P=0.0006$) and time ($P<0.0001$). As expected, CPOM was highest in the urban stream, peaking during winter/spring in the drought of 2002. CPOM was lower in 2003, probably due to higher rainfall providing a flushing effect. The macroinvertebrate community in the urban stream was less variable in composition than the rural and reference streams. Community composition differed significantly among all streams (2-way crossed ANOSIM $P<0.0001$) and seasonally ($P<0.0001$) for most seasons. There were higher densities of macroinvertebrates in the urban stream ($P = 0.0033$), mostly tolerant taxa such as midge larvae (*Chironomus*, Chironomidae) and tubificid oligochaete worms, and these two groups contributed the most to the dissimilarity among the urban, reference and rural streams. Species richness was lowest in the urban stream and highest in the reference stream. Collector-gatherers were the dominant feeding group in the urban stream but there were few shredders, implying that although allochthonous organic matter is important to stream ecosystems, the large amount of leaf litter entering this urban stream may not be broken down by invertebrates. Consequently, these exotic leaf accumulations may be detrimental to the health of the stream, reducing dissolved oxygen concentrations and perhaps contributing secondary organic compounds.

Urban sprawl in the Los Angeles area promotes nuisance algal blooms

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Urban development can impact streams through increased nutrient loading, channelization, and removal of riparian vegetation, and these changes can have profound effects on the structural and functional attributes of the impacted streams. The Malibu Creek watershed, located approximately 55 km west of Los Angeles, California, USA, has been subject to rapid development in recent decades. Concurrent with this development, several streams within the watershed have become impaired by nuisance algal growth. In 2001 and 2002 we conducted a study in the Malibu Creek watershed to quantify algal community composition and biomass, and to determine the principal factors promoting excessive algal growth. We sampled multiple sites representing a gradient of land use types, including undisturbed, rural, residential, and commercial. At each site we surveyed algae (biomass, percent cover, and species composition), nitrogen and phosphorous concentrations, and light availability. We also performed an experiment with nutrient diffusing substrata at a subset of these sites to determine whether N or P limited algal growth.

Algal biomass and macroalgal cover increased across a gradient of anthropogenic influence. Algal biomass (as chlorophyll *a*) increased by three orders of magnitude from the reference (0.5 ±0.2 mg m^{-2} chlorophyll *a*) to the more heavily impacted sites (up to 969.2 ±482.5 mg m^{-2}). Nutrient concentrations also varied by orders of magnitude, and were generally higher at the more impacted sites. Algal community composition changed dramatically with changes in resource abundance, with large floating mats of the macroalga *Enteromorpha intestinalis* forming at sites with both high light and high nutrient levels. Multiple regression analysis demonstrated that biomass of benthic algae was positively correlated with nutrient concentrations, while biomass of floating algae was positively correlated with both nutrient concentrations and light availability. The nutrient diffuser experiment showed N limitation at the reference site, but we observed no positive biomass response to nutrient enrichment at most impacted sites, suggesting that algal biomass at those sites was not nutrient limited. Drastic reductions in N or P loading at these sites may be required to bring nutrient concentrations down to levels which limit algal growth.

Variation in the denitrifying community structure from streams on an urbanization gradient

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Analysis of the denitrifying community structure, using PCR amplification of the nitrous oxide reductase (*nosZ*) gene from sediment-extracted DNA and terminal restriction fragment length polymorphism (T-RFLP) analysis, demonstrated that the community structure varied in response to the degree of urbanization. These changes in community structure were examined in relation to the underlying environmental variables altered by the process of urbanization. Changes to the catchment (impervious surface area, catchment-stream connectivity, channelization) which alter the concentrations, speciation and delivery of compounds have a selective pressure on the bacteria responsible for the important ecological function of denitrification.

Urbanization Effects on the Metabolism of Small Streams

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Whole stream metabolism methods measure the gross primary production (GPP) and community respiration (CR) occurring within a stream by using the diel change in dissolved oxygen concentration in the water column. Whole stream metabolism integrates all the individual processes contributing to GPP and CR and therefore provides information about the net trophic status of the stream (autotrophic vs heterotrophic). Such information can be directly related to the processing of carbon and the ecological functioning of the stream. Stream metabolism measurements have recently been proposed as indicators of stream health in Australia, as it is hypothesized that GPP and CR (and their ratio) will be sensitive to disturbance of the stream environment. However, this hypothesis has yet to be examined across a disturbance gradient.

There is only one published study measuring stream metabolism in an urban environment – a comparison of an urban stream and an agricultural stream in Indiana, which showed higher metabolic rates in the stream in the agricultural catchment. The paper presented here examines the effects of urbanization on streams in a systematic manner. Hence the purpose of the described work is two-fold: an investigation of urbanization effects and a test of the hypothesis that stream metabolism will be sensitive to disturbance. To achieve these aims, whole stream metabolism has been measured across an urbanization gradient in 7 streams ranging from closed catchment forest to heavily urbanized. The results showed that although all streams were heterotrophic (P/R < 1), there was a strong positive relationship between the P/R ratio and the extent of urbanization as estimated by effective catchment imperviousness. This relationship was driven by the much greater gross primary production in the urban streams. Community respiration rates displayed little variation across the urbanization gradient. The paper will discuss the reasons for this behaviour.

Bioavailability of dissolved organic carbon in rural and urban streams of the Torrens River catchment

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The Torrens River is the largest catchment within the Adelaide region, flowing through the Mount Lofty ranges and metropolitan Adelaide before discharging into St.Vincents Gulf. Water quality in the urbanised sections of the Torrens River and its tributaries is heavily degraded by urban stormwater inputs. The high load of organic matter transported by the stormwater generates a substantial oxygen debt and anoxic conditions in the urbanized streams. Rain event sampling indicates that the average biochemical oxygen demand ($B.O.D._5$) is much lower in the rural streams (3.1 mgL^{-1}) than in the urbanized streams (15.3 mgL^{-1}), and that the majority (>80%) of the $BO.D._5$ is driven by dissolved organic carbon (<0.45 μm). Fractionation of the dissolved organic carbon using ion exchange resins into five classes: aquatic humic substances (AHS), hydrophobic neutrals (HoN), hydrophilic neutrals (HiN), bases (BaS), and hydrophilic acids (HiA), reveals a relative increase in HoN and decrease in AHS in the urban streams compared to the rural streams. No difference was observed in HiN, HiA and BaS between the urban and rural streams. The relative increase in HoN and decrease in AHS in the urban streams is associated with an increase in $B.O.D._5$:DOC ratios between the rural ($B.O.D._5$:DOC ratio = 0.39) and urban ($B.O.D._5$:DOC ratio = 1.01) streams, and this observation forms the basis of ongoing research.

Waitakere's Urban Streams – monitoring and restoration

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Waitakere City, located in the West of Auckland has a large number of natural catchments. Many of the urban catchments originate in the Waitakere Ranges, and flow eastwards to the Waitemata Harbour. Protection and restoration of streams including the urban area is an important goal of Waitakere City Council. This is recognized in its plans and policies, as well as programmes to improve stream ecological health. To ensure the adverse effects on aquatic environments are being avoided or mitigated requires a certain level of monitoring of the environmental state of the City's streams. In 2000 a standardised comprehensive monitoring programme was developed to cover all the urban catchments within Waitakere City to provide a wide range of information the ecology, water quality and habitat on of the stream health. The USHA (Urban Stream Habitat Assessment) model developed by NIWA (National Institute of Water and Atmosphere) was used to determine limiting factors of the stream health. The reports have been written in a way that is useful to a range of audiences, such as managers, scientists and the public. The sites are included on a GIS layer with links to a full report and a summary sheet. This allows the information to be readily accessible throughout the Council and available to the public on request.

This Stream Monitoring Programme is the beginning of an extensive and ambitious city-wide stream restoration project. While some actions to improve waterway condition need to occur on a citywide scale, such as environmental-friendly urban design and reduction of impervious surfaces, there are many small-scale actions that can be done within individual waterways or in sections of waterways. The results from the monitoring have been used to establish priorities for action and develop "demonstration" stream restoration projects around the city. Community action is a key determinant of establishing priorities for waterway restoration. Waitakere City has many community environmental groups that are active in protecting urban streams. It is envisaged that these demonstration projects will be a good way to show community groups the possibilities, and inspire community-driven action.

Assessing the effectiveness of controlling point source pollution to a stream in an urban catchment: A case study of Spen Beck, West Yorkshire, UK

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Spen Beck is a tributary of the River Calder in the North of England. The catchment is urbanised and it has a long history of pollution resulting from a legacy of industrial land-use. A major cause of organic pollution is from two point source inputs of treated sewage effluent. During dry weather these effluents contribute up to 70% of the total volume of flow. Recently (1999), there has been an investment of £3.9m to re-route these effluents through an underground pipeline directly into the River Calder to enable sufficient dilution of the effluents. The paper aims to (1) identify post-remediation changes in benthic invertebrate community structure, (2) relate any changes in benthic invertebrate communities to water quality improvements, and (3) use these findings to assess the overall effectiveness of the remediation scheme.

Water chemistry data were collected throughout the catchment over the study period (1998-2002) and invertebrate samples were taken annually at a number of sites. These were assessed using abundance, family richness, Shannon scores, EPT family richness, BMWP and ASPT scores. Water chemistry data indicates that levels of organic pollution have reduced significantly since the remediation. However, there have been only limited improvements in invertebrate communities during the same period. It is suggested that there may be a number of factors inhibiting the effectiveness of the scheme in delivering ecological recovery and these include:

- episodes of non point source toxic pollution washed from industrial sites during periods of storm runoff;
- ineffective catchment stewardship by the statutory planning authorities responsible for the catchment area;
- poor natural habitat due to the existence of modified stream banks; and
- inputs from combined stormwater overflows.

The discussion also suggests simple practical and planning framework modifications that may result in a more substantial ecological recovery in the future.

Urbanisation – effects on riparian woody vegetation

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The woody vegetation of riparian zones and wetland habitats depends to varying degrees on periodic inundation. There is a range of factors - both catchment scale changes and direct impacts - associated with urbanisation that have the potential to impact upon this vegetation. Factors include physical disturbance, increased nutrient loading, exotic species invasion, hydrological change and edge effects. The combined effects may typically result in increasing degradation of riparian plant habitat following catchment urbanisation. In response to such degradation, there has been growing interest in approaches to management that aim to optimise existing - and enhance potential - ecological values of stream corridors within urban areas. The broad focus of this presentation is on management of native vegetation within catchments that have been subjected to urbanisation. More particularly, the reported research is designed to quantify hydrological and hydraulic design criteria for vegetation conservation projects concerned with woody plant habitats in areas subject to periodic inundation.

While this is only one component of the more comprehensive research effort that is needed to effectively inform riparian vegetation management projects, it remains a necessary undertaking. Post-urbanisation catchment hydrology may, for example, be so altered that previous plant distributions no longer provide an adequate model; either for longer term conservation of significant existing vegetation remnants, or for rehabilitation planting design. Similarly, the hydraulics of modified channels – either natural or constructed - is liable to present novel soil wetting regimes in all parts of the channel above base flow level. It is hoped that the research will assist matching information about the hydrological tolerance of suites of riparian plant species to the observed and statistically predictable behaviour of streams subjected to urbanisation. Furthermore, by focussing on the woody vegetation zones it is hoped that the project may resonate with an increasingly inclusive concept of riparian buffer zones and with an approach to urban stream management that recognises ecological connection between floodplain and stream.

Stream enhancement activities in Christchurch: an overview and cautionary tale

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Christchurch city covers an area of 290 km^2, and drains four catchments. Since European settlement in 1845, there have been enormous changes to waterways within these catchments to drain the once swampy land. Since 1875 many streams that meandered across Christchurch have been straightened, and riparian and instream vegetation cleared to maximise drainage efficiency. Repercussions of these activities on streams have been dramatic, with reductions in habitat quality and a species-poor biological community. Analyses of historic invertebrate data with contemporary surveys have documented the disappearance of sensitive mayfly taxa (*Deleatidium* and *Coloburiscus*) from the Avon River mainstem within Christchurch. During the 1990s, the city council altered their philosophy to focus on ecological as well as drainage functions of streams, and have undertaken a variety of enhancement programmes to replace lost riparian vegetation, and naturalise channels. We examined responses of 5 streams to enhancement projects, involving either riparian planting alone (3 streams), or a combination of channel "naturalization" and riparian planting (2 streams). Sites were surveyed prior to enhancement in 1995, and 5 years after, and changes in riparian, instream habitat, and hydraulic conditions quantified. Benthic invertebrates were also collected before enhancement, and 5-6 years after.

Enhanced sites had greatly altered physical habitats, with dramatic changes to riparian vegetation, bank conditions, substrate composition, and instream organic matter. Invertebrate communities prior to enhancement were species poor, and dominated by snails, amphipods, hydroptilid caddisflies, oligochaetes and chironomids. Invertebrate communities changed little after enhancement. Lack of a strong response by aquatic insects may reflect colonisation bottlenecks for their adult stages, or poor sediment quality. Analysis of epilithon in 8 urban streams showed high levels of heavy metals, and very high levels of PAH. These contaminants may be limiting invertebrate communities. To test this, 100 mayflies (*Deleatidium*) were placed into replicate cages containing contaminated sediments in urban streams. Uncontaminated sediments were also transplanted into the urban environment to see whether water quality was lacking. The results of this experiment suggest that metal contamination and sedimentation may be adversely affecting instream communities, and could limit the success of reintroducing some aquatic insects to restored urban waterways.

Relationship of Sediment Toxicants and Water Quality to the Distribution of Urban Platypus Populations

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Platypus have declined or disappeared along many waterways in eastern Australia, yet little is known about how physico-chemical factors may affect population survival. Live-trapping surveys undertaken since 1995 by the Australian Platypus Conservancy and Melbourne Water have recorded platypus in 77% of the 57 waterways investigated in the Greater Melbourne Area (GMA), though many populations are disjunct or occur at very low density. We report here on the first study to investigate how the distribution of urban platypus populations is related to spatial variation in water quality and sediment toxicants.

Selected surface water variables (summer concentrations of dissolved oxygen, total Kjeldahl nitrogen and total phosphorus; percent of impervious surface in catchment; 50th, 75th and 90th percentiles of suspended solids), concentrations of sediment toxicants (zinc, lead, cadmium, arsenic, chromium, copper, mercury, nickel), and the status of platypus were assessed along 28 reaches in the GMA. Platypus occupied 17 areas, with no animals captured in 11 reaches. Habitats supporting breeding platypus populations had significantly lower concentrations of nitrogen, phosphorus and suspended solids (90th percentile) in water and significantly less cadmium, lead and zinc in sediment as compared to habitats without resident platypus. As well, both nitrogen and phosphorus showed a significant negative linear relationship with the number of platypus captured per unit trapping effort (a reliable indicator of population density). In absolute terms, the median and maximum concentrations of heavy metals associated with urban breeding populations were respectively 0.1 and 0.25 mg/kg (cadmium), 15.25 and 55.0 mg/kg (lead) and 53.0 and 150.0 mg/kg (zinc). The corresponding values for water quality variables were 0.55 and 1.27 mg/l (nitrogen), 0.048 and 0.106 mg/l (phosphorus) and 39.2 and 57.0 mg/l (90th percentile of suspended solids). As homeotherms, platypus need to consume the equivalent of 20% of their body mass (or more) each day, mainly in the form of benthic macro-invertebrates. Accordingly, the negative relationship between platypus abundance and elevated levels of nutrients, sediment, and heavy metals plausibly reflects the adverse effects of pollution on aquatic invertebrate populations. As well, one or more of the metals may be directly toxic to platypus themselves.

Metal Accumulation, Reproductive Effects, and Biomonitoring in Australian Freshwater Turtles

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Turtles are the largest vertebrate biomass in some freshwaters, including many polluted urban waterways, yet nothing is known of contaminant effects on Australian freshwater turtles, some of which are endangered. Metals are common and persistent pollutants in urban areas, entering waterways via road runoff, atmospheric deposition, sewage outfall and industrial dumping. Results will be presented of a study conducted in Sydney establishing which metals are present in environmental samples, which are accumulating in turtles (*Chelodina longicollis*, *Emydura macquarii*), how they distribute over the body tissues, how concentrations in carapacial bone vary with age, sex and species, and how they affect reproductive outcome. Non-lethal sampling and metal analysis of carapacial bone, blood, and egg were also tested for biomonitoring efficacy.

Assessing Biological Integrity within Substantially Urbanized Catchments

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Indices based upon biological communities have been useful for demonstrating impairments in urban streams in comparison to undisturbed stream ecosystems. However, the utility of biological indicators for distinguishing impacts among stream sites or for monitoring restoration progress *within* already urbanized catchments remains largely unexplored. We examined covariation of a standard multimetric index of biological integrity (IBI) based upon fish communities with multiple features of land cover, human demography, and stream habitat quality for small stream catchments in a region characterized by substantial urban and suburban development in northeast Ohio, USA. A digital elevation model was used to define sub-catchments for 167 stream sites at which the Ohio Environmental Protection Agency (OEPA) had quantified fish communities between 1991 and 2000. For each "sample-point catchment", we characterized land cover using satellite imagery (Landsat), human population and household density from U.S. Census data, and in-stream habitat quality from data provided by OEPA. Multiple linear regression and principal components analyses were used to test predictive value of these variables for IBI. The analyses also included quadratic and cubic transformations of variables to test for non-linear relationships. In addition, the variables were quantified at two spatial scales, total sample-point catchment and a 500-m “neighbourhood” upstream of the sample point.

Our analyses indicated that urban impacts on streams are complex, non-linear, and dependent upon scale. Impervious cover showed a non-linear, cubic relationship with IBI at the 500 m scale, but was not predictive at the whole sample-point catchment scale. Woodland cover in the catchment was negatively related to IBI. Some sites classified as wooded were within inner-ring suburban residential neighborhoods with dense street tree cover. Wetlands were positively related to IBI at the sample-point catchment scale, pointing to the value of preserving, restoring, or creating wetlands for stream restoration in urban settings. Our analyses also indicated that most variation in the IBI was attributable to a few sub-metrics, e.g., species richness and proportions of pollution-sensitive and headwater species. Continuing work focuses on the value of other biological indicators, e.g., algae, macrophytes, and stream invertebrates, for distinguishing among urban stressors in this region.

Biomonitoring of trace metals in Melbourne's streams and wetlands using the mosquito fish (*Gambusia holbrooki*)

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Trace metals in freshwater ecosystems have received notable attention due to their toxicity and accumulation in biota. Many wetlands and streams throughout the Greater Melbourne Area (GMA) have elevated concentrations of trace metals and other toxicants in sediments that may affect the health of aquatic ecosystems. Fish maybe affected by bioaccumulation of trace metals and maybe good indicators of trace metal pollution in urban wetlands. Currently, no information exists regarding metal bioaccumulation rates, or the effects of sediment pollution on fish populations in the GMA.

The exotic mosquito-fish *Gambusia holbrooki* was investigated to determine whether it is a good bioindicator of trace metal pollution in Melbourne's streams and wetlands. *G. holbrooki* were sampled from 10 wetlands within the GMA that display a gradient in trace metal pollution. Fish were freeze dried, acid digested and metal concentrations analysed by atomic absorption spectrophotometry (AAS). Pb, Cu and Zn were all detectable in female fish from all sampling locations. The accumulation and depuration of Zn and Pb in *G. holbrooki* via water was also studied in the laboratory in separate exposures. *G. holbrooki* were exposed to a range of dissolved metals concentrations in the water for a period of four weeks to study accumulation and then placed in clean water for two further weeks to study elimination. Fish were sacrificed at weekly intervals to determine body burdens of Zn and Pb. At higher concentrations of dissolved Zn, fish were shown to have the mechanisms to regulate Zn within the body for two weeks, after which they actively accumulated Zn within the body. *G. holbrooki* exposed to dissolved Pb concentrations showed no evidence of the capacity to regulate Pb. Net accumulation of Pb in fish exposed to all concentrations was observed after only one week.

Suitability-Priority Decision Model for Selecting Sustainable Projects

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A decision-making tool has been developed to assist land managers and community groups to select urban stream rehabilitation projects by ranking their suitability and priority in relation to a suite of sustainability criteria. The complexities of site selection, resource availability, community and social considerations as well as the ecological outcomes have been factored into the decision tree. The project was initiated by the Total Environment Centre in Sydney and funded by Sydney Water Corporation. The first stage of the project was a review of best practice and the development of environmental, social/cultural and economic criteria to be used to assess the need for and practical application of rehabilitation proposals. Rigorous testing to verify the model was not within the scope of the first stage. A second stage for the project was developed to test the model on a range of stormwater channels located throughout Sydney and owned by Sydney Water.

Within each group of criteria (environmental, social/cultural and economic), the criteria used to develop the suitability and priority ranking includes both general criteria, which can be applied to all assessments (e.g. condition of riparian vegetation, current recreational use) and those which are project specific (e.g. impact on stormwater drainage). Maintaining a degree of flexibility in the model was important so that the model can be adapted to suit the required outcomes of the project. For example, different criteria may be chosen if the outcomes of the project are to provide improved riparian and instream habitat compared to desired outcomes that are to improve the recreational amenity of the site through restoration of the site. When applying the model, a numerical score is assigned for each criterion, with the sum for each group expressed as a percentage and plotted on a three dimensional graph, providing a simple graphical method of identifying priority. The suitability/priority ranking system provides: discrimination between likely success factors; a mechanism to include interaction between criteria; and, an indication of overall project feasibility. Thus, providing land managers and other stakeholders with a guide with which to select the most appropriate restoration option based on the relative merits of each potential option.

AcquaNet: A Model for Quantity and Quality Integrated Management of Water

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Nowadays, one of the most important problems concerning the shortage of water is water quality deterioration, because of the pollution associated with the different water uses: urban, industrial, irrigation and recreation. AcquaNet is a model capable of determining the impact of industry and urban waste sources in rivers, considering dry and wet periods, given by the flow time series. In this context, AcquaNet model represents a useful and versatile tool. The more recent version of the model is able to determine the optimized flow in function of several demands and also the concentrations of BOD, DO, total coliforms, total phosphorus, algae, organic nitrogen, ammonia, nitrite and nitrate in several points in the river and for the different flow scenarios.

This paper has the objective of presenting the AcquaNet model methodology. It is a network flow model; in which the basin can be configured with points of reservoirs, passage points, demands and links (pieces of a river). AcquaNet model works associated with AlocaLS model, which models optimized management of water quantity in a basin. The determination of the water quality parameters is done for each value of optimized flow, through the QualidadeCLS model. Both models (AlocaLS and QualidadeCLS) are connected with AcquaNet, they share the same data base and can analyze quantity and quality of water integrally.

A planning tool to facilitate earlier consideration of stream ecology issues in planning and management processes

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The cumulative impact of numerous individual impacts is the primary concern for management of most natural systems, and is especially true for urban streams. Whilst stream management is simplified by the linear nature of the cumulating impacts (tidal areas aside) the mix of impacts over a range of temporal and geographic scales creates a complex management scenario in most urban areas. The reduction of cumulative effects on stream ecosystems (and generally) requires processes: for the early recognition and avoidance of potential incremental impacts; for targeted restoration and mitigation to reduce existing impacting factors; and, to manage the negotiation of offsetting actions to compensate (at least in part) unavoidable and unmanageable impacts.

Poor management of urban streams is compounded by the fact that planning systems are usually too generalised to provide an effective framework for the consistent, rigorous application of policy in testing of the adequacy of proposals for development and management action. Many of the deficiencies in these frameworks fall into four broad classes: incomplete, poorly integrated policies; insufficient guidance in tailoring and applying framework elements; a lack of appropriate specialist expertise during the assessment process; and, inadequate process-monitoring to provide feedback on framework implementation. It is proposed that the delivery of clearer, consistent policy requirements and more targeted guidance on the nature of factors that might potentially impact on stream ecology for non-specialists would provide a basis for improvements in the quality of both lodged proposals and assessment processes, and facilitate improved stream management outcomes. The apparent complexity of this task can be simplified through interactive, on-line applications that respond to user needs by digesting a range of information to provide targeted guidance on the management outcomes that should be expected of acceptable and high quality proposals; of the signs that indicate poor quality management solutions; and of the processes that might be followed to revisit poor proposals. There are also substantial benefits in terms of automated monitoring as a basis for policy improvements, the preparation of additional guiding material and reporting processes.

Improving Stream Health by Retrofitting Suburbs to Decrease the Connection Between Impervious Surfaces and Waterways

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Many urban streams are unhealthy; the challenge is to determine the cause and implement a solution. Recent work has shown that stream health is strongly influenced by the proportion of a catchment that consists of impervious surfaces *directly connected to waterways*. The direct delivery of water and pollutants from impervious surfaces to streams has a major detrimental effect on stream health. Where there is opportunity for attenuation of these inputs, that is, where the link between impervious surfaces and streams is less direct, the damage to stream health seems to be mitigated. This suggests that improving stream health, in areas subject to urbanisation, in part, involves finding ways to decrease the efficiency of water delivery from impervious surfaces.

We have undertaken a feasibility study of approaches that could be used to retro-fit an existing suburb to improve stream health by decreasing the connection between impervious surfaces and waterways. Possible approaches include: rainwater tanks to capture roof runoff rather than disposal into the stormwater system; swale drains along roads rather than piped drainage direct to streams; and porus pavements for roads and driveways. One promising approach is the use of rainwater tanks where the captured water is used to replace a portion of the mains supply and where some of the tank volume is reserved to hold stormwater inputs. We are now proposing a field trial of the feasible retro-fit options and are identifying candidate streams. Some urban streams in Melbourne are in poor ecological condition even though development is concentrated in a small part of their catchment and proportion of imperviousness is quite low. Typically these are areas where the proportion of connected impervious surface is high. It is in these areas that we expect stream health to improve if works were undertaken. We are currently modelling the effect of a range of measures to decrease connection and are aiming to predict their effect on stream health as measured by indicators based on macroinvertebrate populations. The next step is to develop a strategy, in consultation with local government and the community, to implement the most promising measures and monitor their effect.

Urbanization and Stream Ecology: Bangladesh Perspective

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The rapid pace of urbanization and the rather haphazard or uncontrolled pattern of urban growth and expansion in Bangladesh are manifest in the various sectors of the urban environment such as sewerage, sanitation, drainage, garbage disposal, drinking water supply, electricity and cooking fuel, education and community services.

The pressure of rising numbers of people on finite amounts of land, water and other natural resources has already meant mounting deforestation (a reduction from 10 to 6 percent in forest cover) that may become irreversible within 20 years, rising salinity and water logging of cultivated land, declining water tables and soil fertility and high levels of erosion in the hills. The fisheries resources of floodplains and wetlands are also being seriously depleted both by natural forces and human interventions. At the same time, grave new ecological threats – water and air pollution and the build-up of solid waste – accompany rapid urbanization in Bangladesh's large and medium-sized cities.

The environment, economic growth and development of Bangladesh are all highly influenced by water - its regional and seasonal availability, and the quality of surface and groundwater. Spatial and seasonal availability of surface and groundwater is highly responsive to the monsoon climate and physiography of the country. Availability also depends on upstream withdrawal for consumptive and non-consumptive uses. In terms of quality, the surface water of the country is unprotected from untreated industrial effluents and municipal wastewater, runoff pollution including fertilizers, pesticides and oil. Bioaccumulation of harmful substances in the water-dependent food chain can occur. Inland surface water quality varies due to seasonal variation of river flow, operation of industrial units, and use of agrochemicals. Overall, inland surface water quality in the monsoon season is within tolerable limit with respect to the standard set by the Department of Environment. However, quality degrades in the dry season.

Salinity intrusion in the southern region and pollution problems in industrial areas are significant. In particular, water quality around the capital Dhaka is so poor that water from the surrounding rivers can no longer be considered as a supply source for human consumption. Among the polluted areas, the worst problems are in the River Buriganga, where the most significant source of pollution appears to be from tanneries in the Hazaribagh area. In the dry season the Dissolved Oxygen (DO) level in the river becomes very low or zero. The seasonal variation of water quality in the Buriganga is linked with seasonal variation of water flow and the operation of tanneries. The second most polluted river is the Sitalakhya, flowing on the east of Dhaka. The major polluters of this river are Ghorashal Urea Fertilizer Factory, and oil terminals situated on the bank

of the river. Industrial units at Narayanganj and Demra are also the sources of pollution.

Notwithstanding the large number of rules and regulations to protect water and stream ecology from industrial effluents and other pollution, and the policies for enabling the environment through dry season augmentation of water, concerns for the future still prevail. These are regarding proper implementation of national policies, due to the lack of institutional capability and awareness to properly address the policy objectives and goals.

Posters

Symposium on Urbanization and Stream Ecology

8th to 10th December 2003

Urban stream management framework: classification of urban streams of North Shore City, Auckland, New Zealand

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Increasing pressure on existing urban and rural waterways within the North Shore City, Auckland is expected through growth and economic development. In order to provide appropriate management for North Shore streams a management framework is being developed based partly on the habitat and ecological characteristics as well as other factors of the waterways. An investigation of the ecological characteristics of North Shore streams, and an understanding of the habitat and catchment urbanisation development factors that influence aquatic biotic communities was undertaken. Four stream types were originally identified based on aquatic macroinvertebrate communities: semi-natural or forested, urban semi-modified, urban modified and concrete-lined channels. As this work has progressed we have added a further category (piped sections). Key ecological (habitat, riparian vegetation and bank erosion) characteristics were described for each stream type. The sites surveyed had a wide range of benthic invertebrates present. Landuse, channel modifications, bank erosion and instream cover have been used to classify sections of catchments and ecosystem objectives have been applied to each stream type.

Willow influences on aquatic habitat in the Yarrowee River, Ballarat

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The present study is part of a group of projects at the University of Ballarat focusing on willows along the Yarrowee stream continuum. The Yarrowee River is highly modified and its gold mining history, engineering works and urbanisation have altered riparian zone structure and vegetation. A pervasive effect of urbanisation is an increase in impervious surface cover, which has ultimately altered the hydrology and geomorphology of the stream. Willows are recognised for their high resistance to erosion and high sediment retention rates under erosive conditions, yet the consequences of these attributes for habitat formation in urban streams is not well understood. The association between riparian vegetation and in-stream habitats was mapped along 11 km of the Yarrowee River, Ballarat including reaches with high densities of native riparian species such as *Eucalyptus viminalis*, *E. rubida*, *E. obliqua* and *Acacia melanoxylon* and reaches dominated by willows (*Salix fragilis var fragilis)*. Distinct geomorphologic features such as pool and riffle sequences and bedrock outcrops were found in association with native and exotic species. Almost all pools were associated with willows. In an attempt to establish a causal mechanism for the observed association, sediment profiles were mapped along random reaches. Willows captured greater amounts of sediment when compared with native species and willow root mats bound the sediment into erosion resistant 'weirs', which defined the downstream edge of pools. The restoration of pool-riffle sequences is generally seen as a desirable attribute of river restoration. Willows are a Weed of National Significance (WON) yet appear to create potentially desirable in-stream habitat, thus willow management becomes complex. Desirable riparian vegetation outcomes such as the replacement of willows with native seedlings may have undesirable stream geomorphology outcomes. The assessment and identification of key individual trees or stands of trees may aid overall ecosystem health objectives.

How to improve your report card when monitoring water quality with invertebrates

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The many invertebrates which live in urban streams are often exposed to poor water quality from pollution events, litter and nutrient pulses. Invertebrate assemblages tend to be dominated by tolerant taxa, which reduces the effectiveness of current invertebrate based water quality indices. An urban stream that has been significantly rehabilitated may still be given a poor report card, yet such rehabilitation can be highly valuable locally. One solution is to identify specimens beyond Family to provide more sensitivity to detect change in assemblage composition. In 2002 a sampling program was undertaken in two streams within Ryde City Council, Sydney in which all the specimens were identified to Family and then to morphospecies using bio**track**® sorting protocols and digital images. Over 5,500 specimens were sampled and 45 Families and 69 morphospecies were recorded. The composition and relative abundance of organisms in each sample was analysed with multivariate methods to provide unique biological signature. It was possible to distinguish significant biological difference 1) between creeks, 2) between sites within a creek, 3) between samples at different times of the year and 4) between habitats within a site. The use of bio**track**® identification and database technologies provides a rapid solution to demonstrating improvement to local water quality, even when initial conditions are poor.

Urban Stream Improvement: Applications of Pressure-State-Response framework for management initiatives in the Twin Streams catchment, Waitakere City, Auckland

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Diffuse Sources

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Waitakere City Council

Waitakere City Council (WCC) has embarked upon a programme of works aimed at improving the water quality and ecological heath of the Oratia and Opanuku streams, and the Waitemata Harbour, known as Project Twin Streams. As part of this project WCC is planning to reduce floods and control pollution, restore native trees along stream banks, clearing stream channels and developing wetlands to reduce pressures and enhance environmental values. A pressure, state and response investigation (PSR) was undertaken into water quality and ecological health of the Oratia and Opanuku catchments. It aimed to measure the current status of the Twin Stream catchments and to monitor the effectiveness of management responses to the pressures of human activities.
Although limited by the availability of suitable data, it was apparent that where pressures were rated low to moderate ecological health was good, while where pressures were moderate-high, the ecological health varied from moderate-good. The use of the PSR model assisted the prioritisation of future management responses. We have suggested monitoring specific indicators to measure changes in pressures, state of the environment, and responses.

Age distribution of willows along urban and rural stream reaches

Lia Gray

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Superficially willows form similar stands along urban and rural streams in Victoria that appear to be monocultures of apparently even-aged trees. However, patterns of disturbance are likely to be different in intensively managed reaches of urban streams compared to unmanaged rural streams. It was predicted that urban streams would have a distinct recruitment pattern relative to rural streams because of these differences. To explore whether urban and rural willow stands were demographically different, age class distributions of Crack Willow (*Salix fragilis* var. *fragilis*) were obtained from riparian zones of the urban Yarrowee River that were subject to substantial disturbance pressures and outside of Ballarat at semi-rural sites with mid-level disturbance. Demographics at Spring Creek, Hepburn Springs, were also evaluated as an example of a rural low-level disturbance site that was within a protected area, Hepburn Regional Park. The relationship between size (diameter at breast height, DBH) and the age of individuals was investigated to determine whether DBH was an accurate estimate of individual age. Age of individuals was determined through dendrochronological analysis of tree growth rings obtained by core samples using a 5mm increment borer. The relationship between age and size was determined through correlation analysis.

Crossdating of ring chronologies was complicated due to the consistency of ring widths. The average growth rate for each year was calculated and where variations were observed, dates were checked alongside meteorological data for presence of abnormal weather patterns such as drought or flood, which indicate periods of suppression and release. The three urban sites had consistent recruitment through time. The Spring Creek site was found to have had no recruitment for the last 25 years. Higher recruitment rates and tree density were found at site two within Ballarat, which was the most frequently disturbed site. Willow age-class distributions observed in urban and rural reaches were consistent with the predicted pattern. Recurring disturbance events in urban reaches were likely to facilitate willow recruitment whereas in rural reaches, especially when in a protected area, more even aged stands with little new recruitment developed. Willow management under the two recruitment scenarios should be different.

The impact of urbanisation and dilapidated sanitary systems on the ecology of Chunga stream

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Chunga stream is found in the city of Lusaka and is polluted by discharge from dilapidated Waste treatment facilities. The overall objective of this paper is to promote ecological and sustainable management of sanitation systems in urban settlements of Lusaka, to healthy urban streams and environmental protection. This paper describes the status of sanitary conveyance systems and waste treatment facilities for both biological and conventional waste treatment plants. It highlights the impacts of urbanization and dilapidated sanitary systems on the urban environment, focusing on Chunga stream's ecology, which receives the discharge that impacted negatively on the stream ecosystem. It also shows how poor sanitation has contributed to outbreaks of most human infections. The paper points out how inadequate design and maintenance of sewer network causes environmental degradation in the urban areas. It further revealed how leakages, over loading and choked sanitary facilities have resulted into the production of offensive odours (air pollution), contamination of ground and surface water bodies by spilled un-treated (raw) sewage that poses a health hazard and degradation of the environment as well as the urban stream ecology.

The sewer network and sewage treatment plants for Lusaka were built in the late 1950-'s when the population of Lusaka was 195,700. Even though some improvement to the structure was made in 1980, this was not adequate to effectively cater for a population of Lusaka, which is estimated at 1.2 million. The Manchinchi and Chunga sewage works, are as a result, choked and requires further investigation if the negative impacts on the urban streams is to be addressed. In view of the given background and in order to achieve the overall aim of promoting ecological and sustainable management of wastewater treatment systems in the urban settlements, primary and secondary data on the operation of waste treatment plants, conveyances and the environmental health hazards impacted negatively on the stream was collected through review of existing literature; Interviews, focus group discussion and observation. Data was subjected to both quantitative and qualitative analysis and the variables to analyse include; socio-economic, policy regarding urban drift and environmental hazards to stream ecology.

An Ecological Management and Sustainable Development Model for Developing Countries

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Due to the rapid growth in physical infrastructure in the urbanization process in the developing countries, environmental degradation and hence ecological destruction is worsening. The focus in the developing countries should be on environmental management in parallel with the development of physical infrastructures, as the natural ecological cycle is often less exploited than is the case in developed countries.

The major factors for ecological destruction are degradation of natural environment for human use and hence water, air and soil pollution caused by them. The process is now rapid in the developing countries rather than developed one, therefore emphasis should be given for the use of construction material that may not affect on environment and sufficient awareness for the protection of natural habitat of fauna and flora should be emphasized. All the development activities should be planned and implemented in such a way that natural stream ecology must not be exploited and pollution should be minimized. In this light, An Ecological Management and Sustainable Development Model for developing countries for the urbanization process should be formulated for the preservation and stability of natural ecology in real sense.

The effects of stream morphology on composition and structure of macroinvertebrate assemblages along an urban gradient – the example of the Spree

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Investigations about the role of physical patterns for the diversity and distribution of benthic macroinvertebrates in brooks and some rivers are numerous, however this issue has been neglected for watercourses of urban landscapes. Therefore the impact of anthropogenic modification of substrate conditions and shoreline fixation is presently being investigated on an urbanization gradient on the stream Spree in the north-east lowlands of Germany. The aim of this study is to investigate the relationship between channel morphology/bottom substrate and the invertebrate assemblages along a gradient from the city-centre to the hinterland. The approach underlies the hypothesis, that the effects of physical habitat modification on the urban invertebrate fauna are detectable amongst other anthropogenic modification of living conditions within the urban River Spree. It is planned to run a multipart program comprising the analysis of physico-chemical quality of water and sediment (pollution by selected organic xenobiotica and heavy metals) and the amount of phytoplankton. Quantitative benthos samples were taken with at least three replicates per substrate type and bank fixation type at seven sites, differing in morphological specificity. Besides that, the stream morphology, physico-chemical parameters, bottom substrate type and particle size distribution are surveyed. Experimental studies via application of standardised artificial substrate samplers were conducted. They were used to separate the influences of substrate types from other living conditions and to gain an insight into the colonization potential of the sampling sites. *Dreissena polymorpha* (Pallas 1771) is used as an enzymatic biomarker for an impact classification of the benthos sampling sites. Data will be analysed with multivariate statistics like the Gifi-System and the Hassediagramm technique.

The first analysis of benthos data showed a gradient in longitudinal distribution of species richness of Trichoptera. Species richness decreased from 17 to 4-5 species by increasing urbanization impact. The inclusion of the experimental approach (artificial substrate) within the standard sampling methods yield a more comprehensive survey of macroinvertebrate diversity and an insight into the function of hard substrate for the benthic communities.

Grassroot participation and management for rural water-related environmental problems in Ebo Itumbonuso, ini local geverment area, Akwa Ibom State, Nigeria

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Grassroot participation in the management of rural water-related environmental problems aimed at providing sustainable and safe water for drinking, farming and other domestic and public uses is hereby discussed. The scheme integrates the rural water stakeholders comprising the association of women, men, youths, traditional rulers, religious leaders, peer groups and the parliamentarians (politicians) into a neatly-woven sphere for the containment and abatement of water-related environmental problems that includes flooding of river line communities, silting of rivers and water bodies from overlying farmlands, pollution of water bodies from refuse dumps and animal grazing activities, erosional hazards, and outbreaks of diseases such as Typhoid fever, Polio, Hepatitis, Diahorrhea, Dysentery and Cholera. It examines the participatory approach to include sustained public awareness and education programmess hinged on a values-based approach using TV, Radio, Newsletter, Magazines, and Illustrative Drama as well as the creation of a water sanitation agency, a training scheme to develop manpower as well as a knowledge enhancement programme with detailed drafting of a curriculum for the primary and secondary schools and the setting up of water use and rights groups in these schools. The direct participation of the CBO - the “Itu Mbonuso Youth Cooperative Multipurpose Society” and the NGO- the ”Ikono-Ini Youth Consultative Assembly”-IIYCA towards the successful execution of the “GRASSROOT PROJECT” within International, Federal and State Agencies outlines and standards is herein described.

Assessment of Riparian Vegetation Condition in an Urban Setting

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Riparian vegetation is known to be a key contributor to waterway health, acting as a buffer between the waterway and adjacent lands. A well-vegetated riparian zone regulates instream primary production through shading, and is a supplier of leaf litter and other organic debris. Riparian vegetation improves water quality by filtering overland flow, providing important structural habitat and bank stability. Furthermore, in an urban context, riparian vegetation may act as a corridor, linking fragmented habitats and offer aesthetic and recreational value. Given this background, any appraisal of waterway condition must incorporate an assessment of riparian vegetation.

There are very few ecosystem health monitoring programs or methodologies that provide a comprehensive assessment of riparian vegetation condition. In an attempt to address these limitations, Brisbane City Council has developed an easy and rapid assessment of riparian vegetation condition by adopting and modifying two well-recognised vegetation assessment methodologies. These methodologies are the Queensland Herbarium Corveg methodology for quaternary assessment (Neldner et al. 1999) and the Common Nature Conservation Classification System (CNCCS) (Chenoweth et al. 2001). Through modifying and applying a rating system to integrate a variety of data this new methodology provides both a quantitative and qualitative assessment of the condition of riparian vegetation.

This new riparian vegetation condition assessment tool enables key issues to be identified and is able to guide Council's future actions in managing riparian vegetation and waterway corridors in Brisbane City. This methodology has proven to be an extremely beneficial tool for developing an accurate ecological health assessment in a relatively short time period.

New Zealand progress in the implementation of water sensitive urban design

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New Zealand has an evolving programme of implementation of Water Sensitive (or Low Impact) Urban Design (WSUD) encompassing both greenfield and brownfield developments in major cities. Programmes are underway to unlock impediments faced by every category of stakeholder to mainstream implementation of WSUD. Stakeholders include, among others, policy and plan makers, and resource consent granting agencies such as Regional and District Councils, developers, construction personal, real estate agents and home buyers. Environmental education of all sectors is vital to achieve buy-in. Also, research is under-way to demonstrate the achievement of hydrological neutrality and the maintenance of receiving water ecological integrity as a result of implementation of WSUD.

The paper illustrates progress at greenfield sites in the Auckland Region including Long Bay in North Shore City, Dairy Flat in Rodney District and small scale pipeless subdivisions in Auckland and Waitakere Cities. Implementation in brownfield areas targets the naturalisation of streams (Christchurch City) and the incorporation of infiltration devices, swales and raingardens into established or redeveloping sites.

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Notes

Notes

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