NTS Ecology Studies

- Laboratory Biofilter Study (Monash)
  - Effects of Plant Maintenance and Presence of Animals (earthworms) on biofilter performance (as judged by nutrient removal, GHG emissions (CH_4, N_2O,CO_2) , C-sequestration)
- Field Chronosequence Study (Perth, Melbourne, Sydney, Brisbane)
  - Evaluate changes in plant cover and diversity, microrrhizae, animal abundance and diversity, and heavy metal accumulation as biofilters age, in four regions with very different climates
- Southern California Biofilter Lab and Field Studies (UCLA)

NTS Ecology: Lab Biofilter Study

- How does plant harvesting and the presence of earthworms affect the structure and function of biofilters?

Andrew Mehring, UCSD/SIO

Brandon Winfrey, UCLA

Lisa Levin, UCSD-SIO

Richard Ambrose, UCLA

AUS Partners: Lab Biofilter Study

Belinda Hatt, Monash

Perran Cook, Monash

Monash Support Team:
- *Ana Deletic, Monash*
- *Richard Williamson, Monash*
- *Tony Brosinsky, Monash*
- *Emily Payne, Monash*
- *Gayani Chandrasena, Monash*
- *Mike Leach, Monash*
- *Christelle Schang, Monash*
- *Kerryn Roberts, Monash*
- *Tina Hines, Monash*
- *Mike Grace, Monash*
- *Kerrie Brown, Monash*
- *Tim Fletcher, Uni Melbourne*

CRC for Water Sensitive Cities

MONASH University

Monash Undergraduate Fellowship Winner
Daniel Guttman,

Lab Experiments: Key Questions

- Does <u>pruning</u> biofilter plants, a common practice, increase or decrease biofilter's ability to treat stormwater runoff? Do infiltration rates change? C-sequestration?
- Similarly, do <u>earthworms</u> play a large role in removing nutrients from stormwater runoff in biofilter columns (e.g., by enhancing redox heterogeneity)? Does infiltration increase when earthworms are present?

Approach: Lab Experiments

- 40 biofilters have been constructed
  - 10 unplanted, 15 planted with *Ficinia nodosa*, and 15 planted with *Carex appressa*
  - Earthworms added to 5 unplanted, 5 planted with *Ficinia nodosa*, and 5 planted with *Carex appressa*
  - Dosed with stormwater bi-weekly
  - All columns assessed relative to N-removal (^{15}N-labeled NO_3^- to determine fate of stormwater nitrate—denitrification, plant uptake), P-removal, C-sequestration, GHG emissions

Ficinia nodosa

Carex appressa

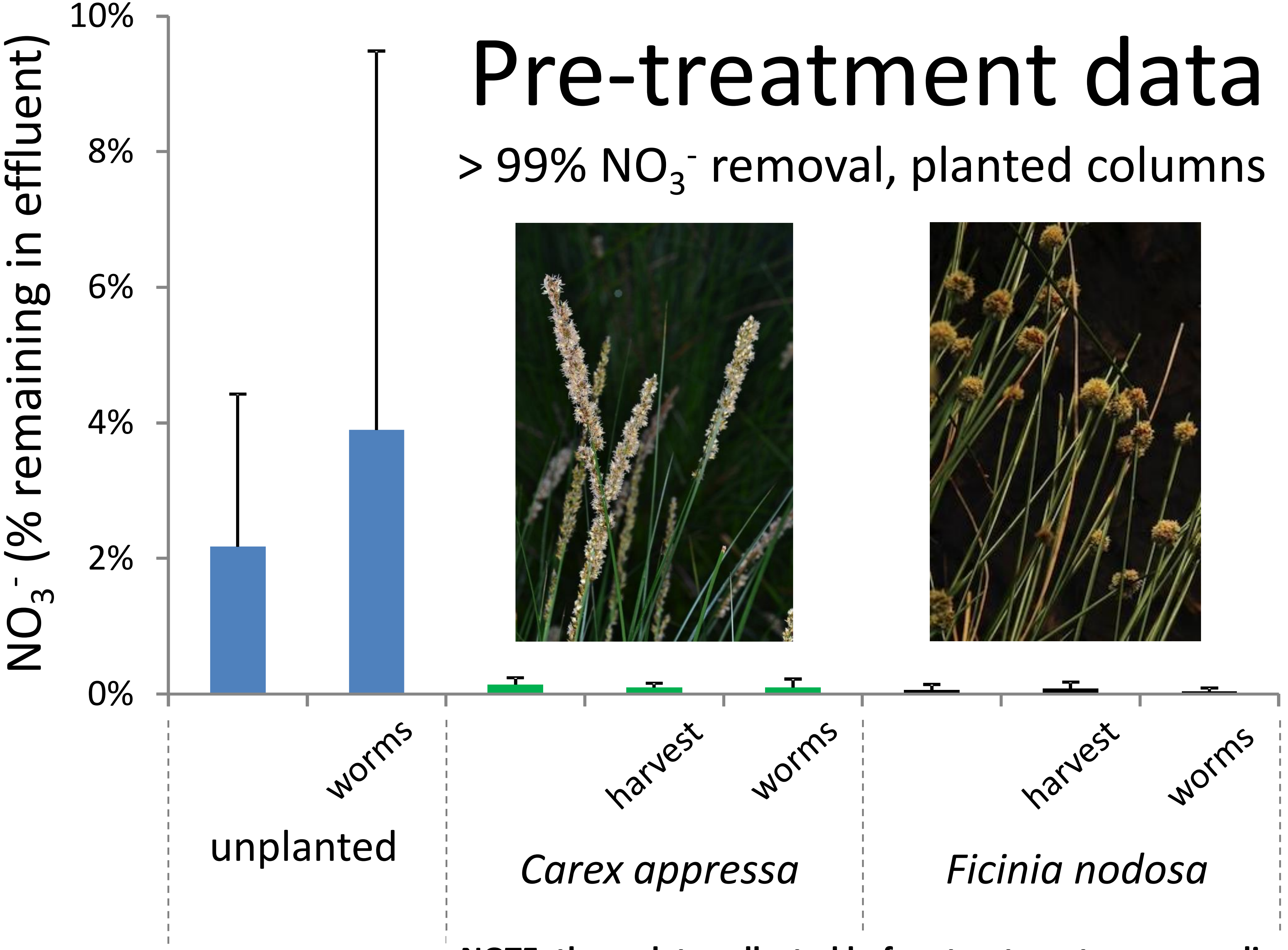
+ earthworm

Experiment Timeline (5 mo. project):

9/1/14: Columns constructed and planted
10/20/14: Added synthetic stormwater runoff (cont. bi-weekly)
11/18/14: Sampled greenhouse gases and water quality
11/21/14: Added earthworms
12/8/14: Sample GHG and WQ
12/16/14: Test Infiltration Rates
1/26/15: Sample GHG and WQ
1/30/15: Harvest plant biomass
2/9/15: Sample GHG and WQ
3/16/15: Sample GHG and WQ
3/23/15-4/3/15: Disassemble columns and evaluate final biomass/plant tissue N and P

Pre-treatment data

> 99% NO_3^- removal, planted columns

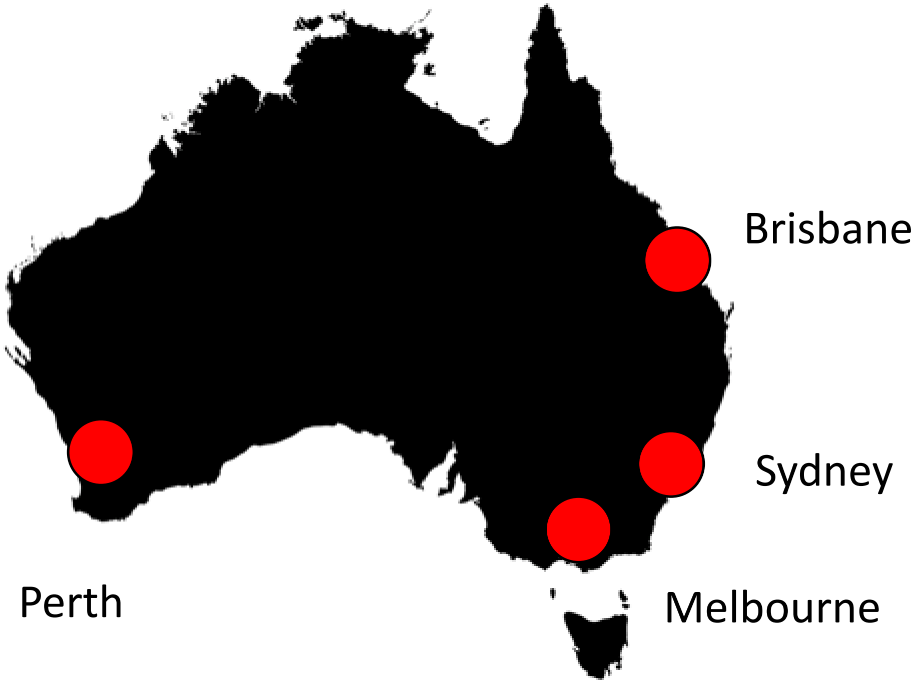


NOTE: these data collected before treatments were applied

Conclusions and Products

NTS Ecology: Field Chronosequence Study

- Does biofilter age affect plant richness and diversity? Total root length and mass, and mycorrhizae? Invertebrate communities? Heavy metals?



Andrew Mehring, UCSD/SIO

Brandon Winfrey, UCLA

Lisa Levin, UCSD-SIO

Richard Ambrose, UCLA

AUS Collaborators: Heavy metal and invertebrate biofilter chronosequence site selection

Belinda Hatt
Monash University

David Beharrell
Hornsby Shire Council

Paul Tatham
City of Sydney

(Olaf) Jay Jonasson
Ku-ring-gai Council

Caroline Carvalho
Knox City Council

Michael Godfrey
Melbourne Water

Tim Fletcher
U of Melbourne

Darren Bos
U of Melbourne

Anne Simi
Brisbane City Council

Tony Weber
Australian Nat. University

<u>AUS Collaborators</u>: Plant richness and biodiversity, root length, mass, mycorrhizae

Richard Williamson, Monash Uni

Bonnie Glaister, Monash Uni

Emily Payne, Monash Uni

Stephanie Watts Williams, Monash Uni

Ben Witten, UWA

Tim Fletcher, Melbourne Uni

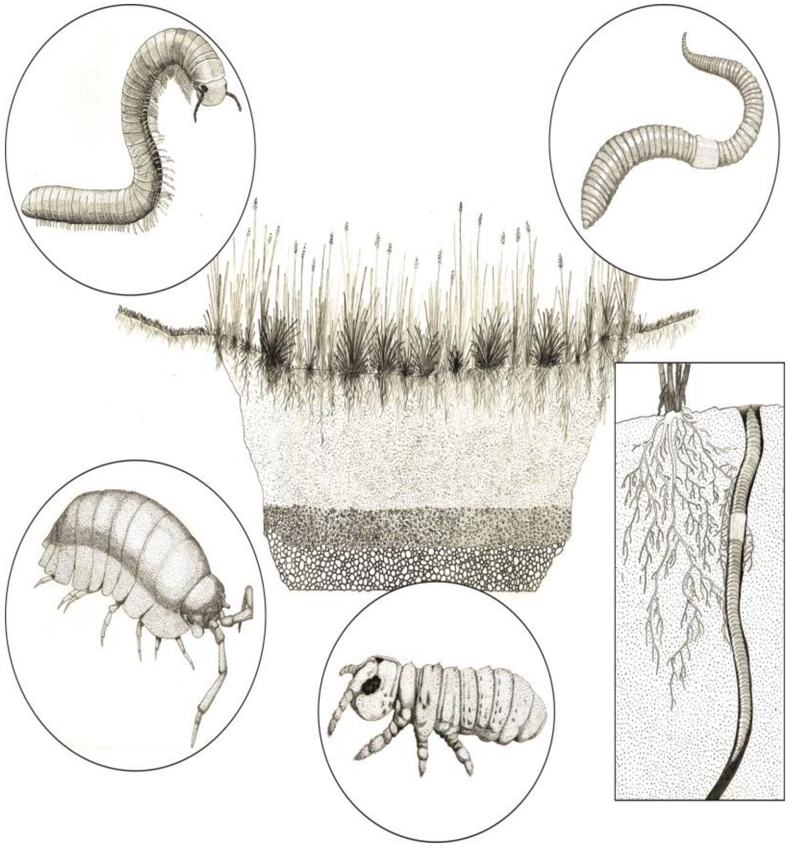
Antonietta Torre, Western Australia Dept. of Water

Matthias Leopold, UWA

Jeffrey Shragge, UWA

Approach: Animal and Metal Chronosequence

- Sediment cores were collected from 35 biofilters:
  - Brisbane, Sydney, Melbourne
  - <1 to 15 years old
  - Sediment cores collected from three locations in each biofilter and analyzed for 26 metals, C, N, P, and soil invertebrates



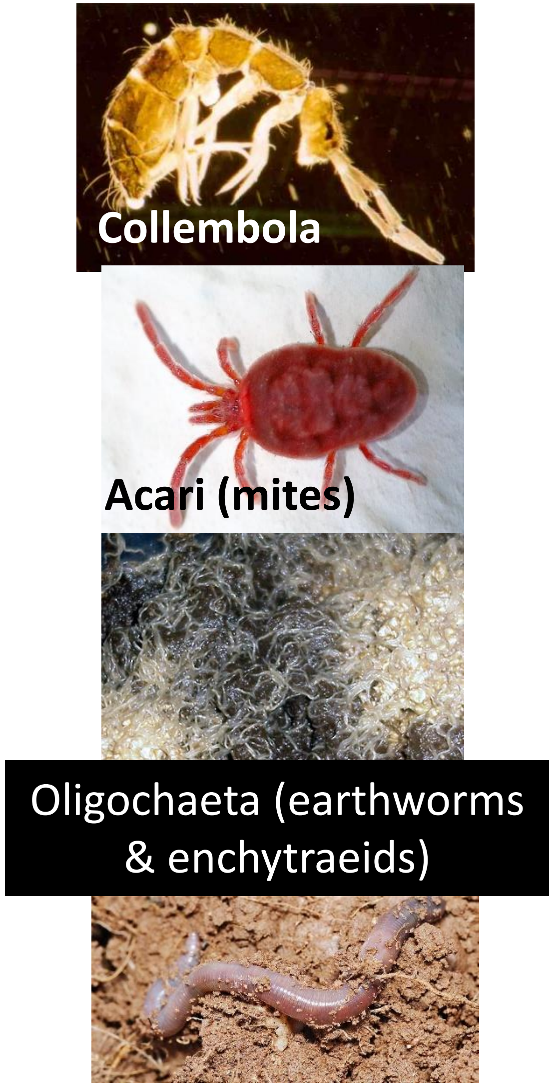
Mehring & Levin – in review at *Journal of Applied Ecology*

Approach: Plant Chronosequence

- Plant surveys conducted and roots collected from 36 biofilters
  - 13 Melbourne, 11 Sydney, 12 Perth
  - Native status of plants assesed
  - WinRhizo system (at Monash) used to determine root length, surface area, average diameter, percent <0.5 mm
  - Mycorrhizae identified by clearing and staining roots prior to investigation under dissecting microscope.

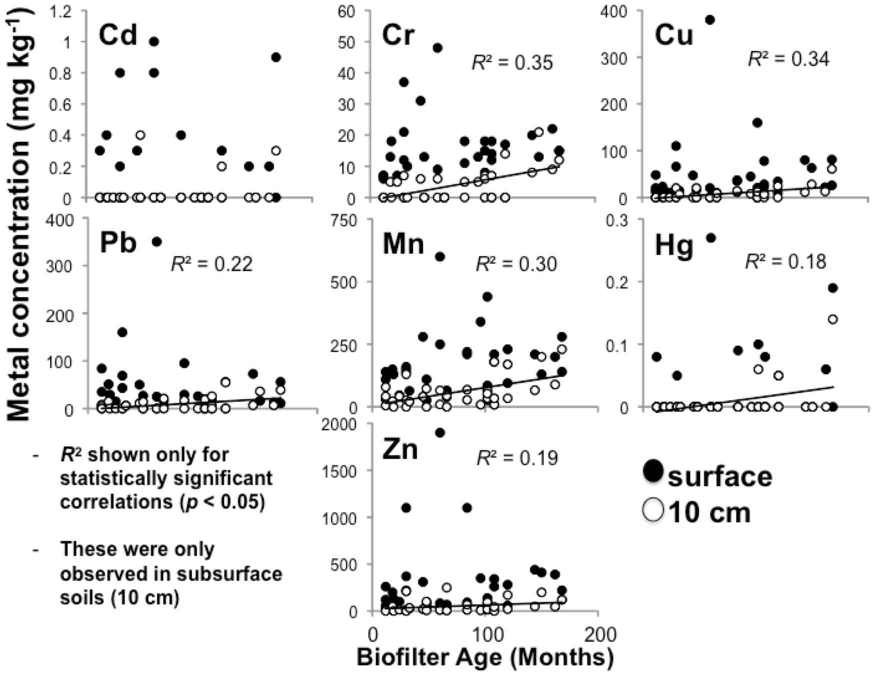
Results: Animal Chronosequence

- Invertebrate abundance and diversity did not change substantially with biofilter age. Biofilters are colonized rapidly, and/or invertebrates are introduced with initial planting.
- Invertebrate communities dominated by oligochaetes (some large earthworms, but primarily tiny enchytraeids), fungivorous Collembola (springtails), and Acari (mites)
- Most invertebrates concentrated toward the inlet of the biofilter (due to moisture, OC content,..)
- (in a separate study with UPP Invertebrate abundance correlated with OC content)



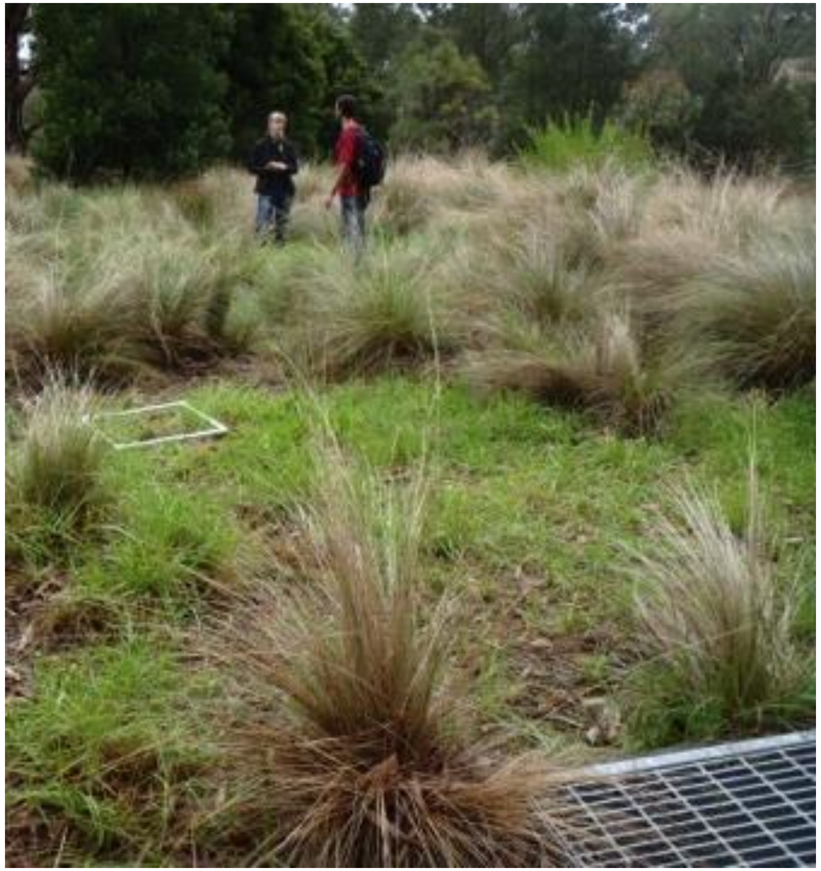
Results: Metal Chronosequence

- Initial results for Cd, Cr, Cu, Pb, Mn, Hg:
  - Higher concentrations at biofilter surface, compared to 10 cm depth
  - All but Cd show a positive correlation with biofilter age
  - Implications for biofilter maintenance schedules, and survival of “bio” component



Results: Plant Survey Chronosequence

- Plant cover, diversity, and richness not correlated with biofilter age
- Instead, plant community may depend on
  - Management regime
  - Setting
  - Initial Planting
- **Driving forces for biofilter "succession" may be social-ecological, rather than strictly ecological**



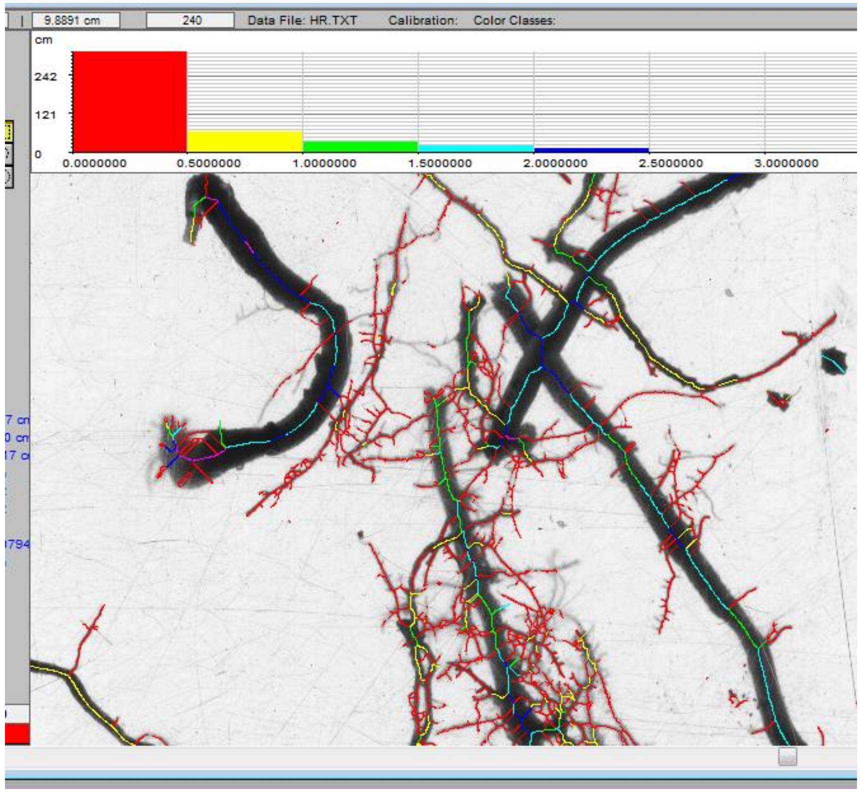
Potential Drivers of Plant Diversity: **Maintenance**

Potential Drivers of Plant Diversity: **Setting**

Biofilters in Sydney, NSW: above, system in forested conservation area contains >10 species; below and right, systems in urban areas contain 1–2 species.

Results: Root Chronosequence

- Root length and root mass increases with age of biofilter
- Root surface area does not increase with age
- **Roots are becoming "coarser" as biofilters age**
- Implications for treatment?



Summary: Preliminary Chronosequence findings

- Animal abundance and diversity not correlated with biofilter age
- Heavy metals accumulate with biofilter age, concentrated at surface
- Plant cover and diversity not correlated with biofilter age
- Biofilter structure and function may be less influenced by age and more by initial planting, maintenance, and setting

First year's UPP Down Under samples of biofilter invertebrates sorted by undergraduate student Diana Kraikittikun (on left, not sure who is on right)

NTS Ecology: UCLA Lab Biofilter Studies

- Do California native plant species perform as well as Australian analogues?
- How does antecedent dry period effect biofilter performance (+/- saturation zone)?
- How do the removal efficiencies of nutrients and metals compare in UCLA vs Monash biofilters?

UCLA mesocosm column design adapted from Melbourne mesocosms

NTS Ecology: UCLA Field Biofilter Studies

- How does the structure/function of biofilters in southern California and Australia compare?
- Are mycorrhizae present in southern California biofilters?

Southern California Collaborations

- Orange County biofilters
  - Experimental, field-scale biofilters to be installed at Orange County Public Works Glassell Campus as part of a stormwater LID Retrofit.
  - Collaboration between UCI Water-PIRE scientists and Orange County to evaluate biofilter performance and ecology with field scale manipulations.
- Ventura County biofilters
  - Similar to OC project: working with VC to install field-scale biofilters with specifications that allow us to monitor water quality

Products: Biofilter Plant Studies

Accepted Manuscripts:

1. Ambrose, RF, Winfrey, BK. 2014. Comparison of Stormwater Biofiltration Systems in Southern California and Southeast Australia. *WIREs Water*.

Manuscripts in Preparation:

1. Winfrey, BK, Ambrose, RF. Role of Vegetation in Stormwater Biofilters.

Expected Manuscripts (Tentative Titles):

1. Winfrey, BK, Ambrose, RF, Hatt, BE. Mycorrhizae in Stormwater Biofilters.
2. Winfrey, BK, Ambrose, RF, Hatt, BE. Plant Community Development in Stormwater Biofilters- Social and Ecological Drivers
3. Winfrey, BK, Mehring, AS, Ambrose, RF, Levin, LA, Hatt, BE, Cook, PLM. Effects of Plant Pruning on Nutrient Removal in Stormwater Biofilters- A Column Study
4. Winfrey, BK, Mehring, AS, Guttman, DI, Ambrose, RF, Levin, LA, Hatt, BE. Effects of Plant Pruning on Metal Removal in Stormwater Biofilters- A Column Study.
5. Winfrey, BK, Mehring, AS, Ambrose, RF, Levin, LA, Hatt, BE. Functional Traits of Pruned Plants in Stormwater Biofilters- A Column Study.

Conference Presentations and Posters:

1. Winfrey, BK, Ambrose, RF. “Plant Ecology and Function in Stormwater Biofilters in Melbourne, AUS” Presented at American Ecological Engineering Society Annual Meeting, 2014.
2. Winfrey, BK, Ambrose, RF “Does Species Composition affect Water Quality Improvement in Stormwater Biofilters?” Poster presented at American Ecological Engineering Society Annual Meeting, 2014.

Products: Biofilter Animal Studies

Manuscripts in Review or Revision:

1. Mehring, A.S. & Levin, L.A. 2015. Can soil fauna improve the efficiency of rain gardens used as natural storm water treatment systems? In Review at *Journal of Applied Ecology*.
2. Levin, L.A. & Mehring, A.S. 2015. Optimization of bioretention systems through application of ecological theory. In Revision at *WIREs Water.*

Expected Manuscripts (Tentative Titles):

1. Mehring, A.S., Levin, L.A., Grant, S.B. & Cook, P.L.M. 2015. The contribution of aquatic invertebrates to benthic greenhouse gas flux in urban wetlands. To be submitted to *Proceedings of the National Academy of Sciences*.
2. Mehring, A.S., Levin, L.A. & Hatt, B.E. 2015. Land use and design specifications control rain garden heavy metal accumulation in the major urban centers of Australia. To be submitted to *Frontiers in Ecology and the Environment*.
3. Mehring, A.S., Levin, L.A., Orelo, B., Gonzalez, J. & Hatt, B.E. 2015. Factors affecting colonization, structure, and succession of soil invertebrate communities in a chronosequence of urban rain gardens in eastern Australia. To be submitted to *Ecology.*
4. Mehring, A.S., Winfrey, B.K., Levin, L.A., Ambrose, R.F., Cook, P.L.M., & Hatt, B.E. 2016. Earthworms enhance plant growth and nutrient uptake, and denitrification in upper soil layers of rain gardens – To be submitted to *Journal of Ecology*.
5. Mehring, A.S., Winfrey, B.K., Levin, L.A., Ambrose, R.F. & Hatt, B.E. 2016. Earthworms enhance heavy metal uptake by plants in rain gardens – To be submitted to *Ecological Applications*.
6. Mehring, A.S., Winfrey, B.K., Levin, L.A., Cook, P.L.M., Ambrose, R.F. & Hatt, B.E. 2016. Earthworms enhance infiltration, downward leaching of nitrate, and denitrification in submerged zones of rain gardens – *Soil Biology and Biochemistry*
7. Mehring, A.S., Kraikittikun, D. & Levin, L.A. 2016. The effects of millipedes on soil nitrogen and phosphorus retention in the presence of nanoparticulate iron – To be submitted to *Ecological Engineering.*