Distribution and biological activity of anthropogenic litter in freshwater ecosystems

Timothy Hoellein, Ph.D.
Loyola University Chicago
September 25, 2012

Joseph Gasior, Adam Pink, Owen McKenna
Marine litter accumulation is a growing concern, recognition in popular in scientific press

Fate of litter:

- **Accumulation**
  - aquatic and terrestrial environments, including pelagic gyres

- **Decomposition**
  - Microplastics
  - Release of toxic organic compounds

- **Ingestion**
Research is increasing and has global scale.
Studies of anthropogenic litter distribution should expand to other habitats

- Few assessments in non-marine ecosystems
  - Seco Pon and Becherucci (2012); city blocks
  - Armitage and Rooseboom (2000); stormwater drains
  - Zbyszewski and Corcoran (2011); plastic pellets on L. Huron beaches

- Reason
  - Litter problems less visible, widespread elsewhere? (restricted to urban environments)
  - Terminology is marine oriented? (e.g., “marine debris”)

- Anthropogenic litter, rather than “marine debris”
  - Differentiate from marine locations
  - Include a broader understanding of ‘marine debris’ life cycle
Current conceptual representations of marine debris do not include terrestrial or freshwater dynamics.
Research question 1

What is the composition and density of anthropogenic litter in urban freshwaters?
Research question 2

What is the biological activity of biofilms which colonize anthropogenic litter in urban freshwaters?
Research objectives

**Question 1:**

a) Measure pools of anthropogenic litter in
   1. Chicago River benthic and riparian zones
   2. Lake Michigan Beaches

b) Compare litter density and relative abundance across ecosystem types

**Question 2:**

Measure biofilm activity on anthropogenic litter
   - photosynthesis
   - respiration

**Student researchers**

- Joseph Gasior
- Adam Pink
- Owen McKenna
Litter abundance: methods

• In 2011, we sampled
  – 3, 70-100 m reaches of the N. Br. Chicago River streambed and riparian zone (within 10 m bank)
  – 3, 400 m reaches of Lake Michigan Beaches adjacent to LUC

• Removed all the anthropogenic litter

• Noted items location and marked with ID tag
Litter abundance: methods

- In lab, dried litter, removed dirt, sorted by category
- Number, mass, and surface area
- Compared total litter and litter categories
Biofilm activity: methods

- Same sized pieces of litter and natural surfaces

- Substrata:
  - Inorganic
    - unglazed tiles (‘rocks’)
    - plastic bottles
    - aluminum cans
    - glass
  - Organic
    - Red maple leaves
    - cardboard

- Sites:
  - Natural ecosystems (4-6 weeks)
    - Lake Michigan shoreline
    - Pond at LUC Retreat and Ecology Center
    - N. Branch Chicago River
  - Artificial stream facility (every 2 weeks for 8 weeks total)
Biofilm activity: methods

- Photosynthesis and respiration
- Hand-held dissolved oxygen meter
- Incubations in light and dark
Litter abundance in freshwaters

A) Abundance
ANOVA p=0.003

B) Mass
ANOVA p=0.005

C) Area
ANOVA p=0.001

Abundance (No m⁻¹)

Mass (g m⁻¹)

Surface area (cm² m⁻²)

River  Riparian  Beach
Marine debris abundance - beaches

How do our data compare?

Synthesis in Abu-Hilal and Al-Najjar (2009)
Freshwater and marine litter abundance

![Bar chart showing the amount (No. m\(^{-1}\)) of different types of litter at Brazil Beach (Costa dos Coqueiros, Brazil), River (Chicago River, USA), Riparian, and Lake MI Beach. The chart includes categories for Plastic, Paper, Glass, Metal, Fishing, Styrofoam, and Other.]

Ivar do Sul (2005)
Proportion of litter categories across ecosystems

city blocks (Seco Pon and Becherucci 2012; Argentina), developed marine beach (Ivar do Sul et al. 2011; Brazil), coral and sand marine benthos (Abu-Hilal and Al-Najjar 2009; Red Sea) and offshore marine benthos (Lee et al. 2006; Korea)
Proportion of litter categories across ecosystems

city blocks (Seco Pon and Becherucci 2012; Argentina), developed marine beach (Ivar do Sul et al. 2011; Brazil), coral and sand marine benthos (Abu-Hilal and Al-Najjar 2009; Red Sea) and offshore marine benthos (Lee et al. 2006; Korea)
Proportion of litter categories across ecosystems

city blocks (Seco Pon and Becherucci 2012; Argentina), developed marine beach (Ivar do Sul et al. 2011; Brazil), coral and sand marine benthos (Abu-Hilal and Al-Najjar 2009; Red Sea) and offshore marine benthos (Lee et al. 2006; Korea)
Proportion of litter categories across ecosystems

city blocks (Seco Pon and Becherucci 2012; Argentina), developed marine beach (Ivar do Sul et al. 2011; Brazil), coral and sand marine benthos (Abu-Hilal and Al-Najjar 2009; Red Sea) and offshore marine benthos (Lee et al. 2006; Korea)
Proportion of litter categories across ecosystems

city blocks (Seco Pon and Becherucci 2012; Argentina), developed marine beach (Ivar do Sul et al. 2011; Brazil), coral and sand marine benthos (Abu-Hilal and Al-Najjar 2009; Red Sea) and offshore marine benthos (Lee et al. 2006; Korea)
Anthropogenic litter types (%)

Plastic  Paper  Cigarette butts  Glass  Metal  Fishing gear  Polystyrene  other

City Blocks  Dev. marine beach  Dev. lake beach  Riparian zone  Marine benthos (nearshore, coral)  River benthos  Marine benthos (offshore)

Terrestrial  Transitional  Shallow aquatic  Deep aquatic

city blocks (Seco Pon and Becherucci 2012; Argentina), developed marine beach (Ivar do Sul et al. 2011; Brazil), coral and sand marine benthos (Abu-Hilal and Al-Najjar 2009; Red Sea) and offshore marine benthos (Lee et al. 2006; Korea)
Question 2: Biofilm metabolism on litter surfaces in freshwaters
River: Lower biofilm metabolism on glass, aluminum

**Gross Primary Product (GPP)**

- Tile: µg cm⁻² h⁻¹
- Glass: µg cm⁻² h⁻¹
- Plastic: µg cm⁻² h⁻¹
- Aluminum: µg cm⁻² h⁻¹

**Community Respiration (CR)**

- Tile: µg cm⁻² h⁻¹
- Glass: µg cm⁻² h⁻¹
- Plastic: µg cm⁻² h⁻¹
- Aluminum: µg cm⁻² h⁻¹

ANOVA, p=0.024

ANOVA, p=0.006

Leaves, cardboard
Totally decomposed
**Pond: Biofilm metabolism on anthropogenic litter**

A) Inorganic substrata

- **ANNOVA, p=0.507**

B) Organic substrata

- **T-test p=0.344**
Artificial streams: biofilm activity through time (inorganic)
Community Respiration and Gross Primary Production (µg O₂ cm⁻² h⁻¹)

Artificial streams: biofilm activity through time (organic)
Summary and interpretation: abundance

• Freshwaters:
  – Litter is abundant (0.2-1 piece per m), but lower than some marine sites
  – L. Michigan beach lowest
  – Reason
    • regular grooming in summer?
    • These are first data reported, more needed

• Across all ecosystems
  – Terrestrial: more paper, including smoking-related
  – River: much more glass
  – Marine: more fishing related items

• Reasons
  – Rapid paper decomposition in aquatic environments
  – Low export of glass
  – Less fishing near Chicago?

Implications: Littering rate not only important factor. Human export (i.e., clean-up), land/water–use, natural retention (glass), and decomposition rates also control abundance
Summary and interpretation: metabolism

• Trend: lower rates of ecosystem function (respiration) on litter surfaces
  – Especially in river, and within 4-8 weeks incubation
  – Due to lower number of microbes/algae on litter?
  – Due to change in community composition during coloniziation?
  – Not previously measured in any ecosystem

Implications: Abundant litter could affect ecosystem function (i.e., C and N transformation rates) at reach scale. Effects on biological communities (microbes -> fish) are unknown
Beaches
Coastal waters
Pelagic

Terrestrial, city blocks
River
Riparian
Inland lake
Non-beach littoral zone
Beach
Shallow littoral
Epipelagic
Benthic
Food webs
Grant submission and continued work

1) Document anthropogenic litter pools:
   Rivers, inland lakes, and Great Lakes
   Correlate landscape drivers with GIS.

2) Measure fluxes of anthropogenic litter
   - Inputs
   - Retention
   - Outputs

3) Quantify ecosystem effects
   - Biofilm activity
   - Microbial communities
   - Decomposition rates
   - Habitat for macroinvertebrates

4) Calculate litter budgets

Partners
LUC undergraduates and graduate students
   (including student teachers)
Biology faculty
Institute for Sustainability
Alliance for the Great Lakes
Field, lab, technical assistance
- Students: Thomas Manghi, Michael Hassett, Steven Polaskey, Kayla Turek, Melaney Dunne, Ricardo Magallon, Simon Morgan, Angeline David.

- Alliance for the Great lakes, Adopt a Beach: Jamie Cross,
- Friends of the Chicago River
- Institutional support and funding: Loyola University Chicago