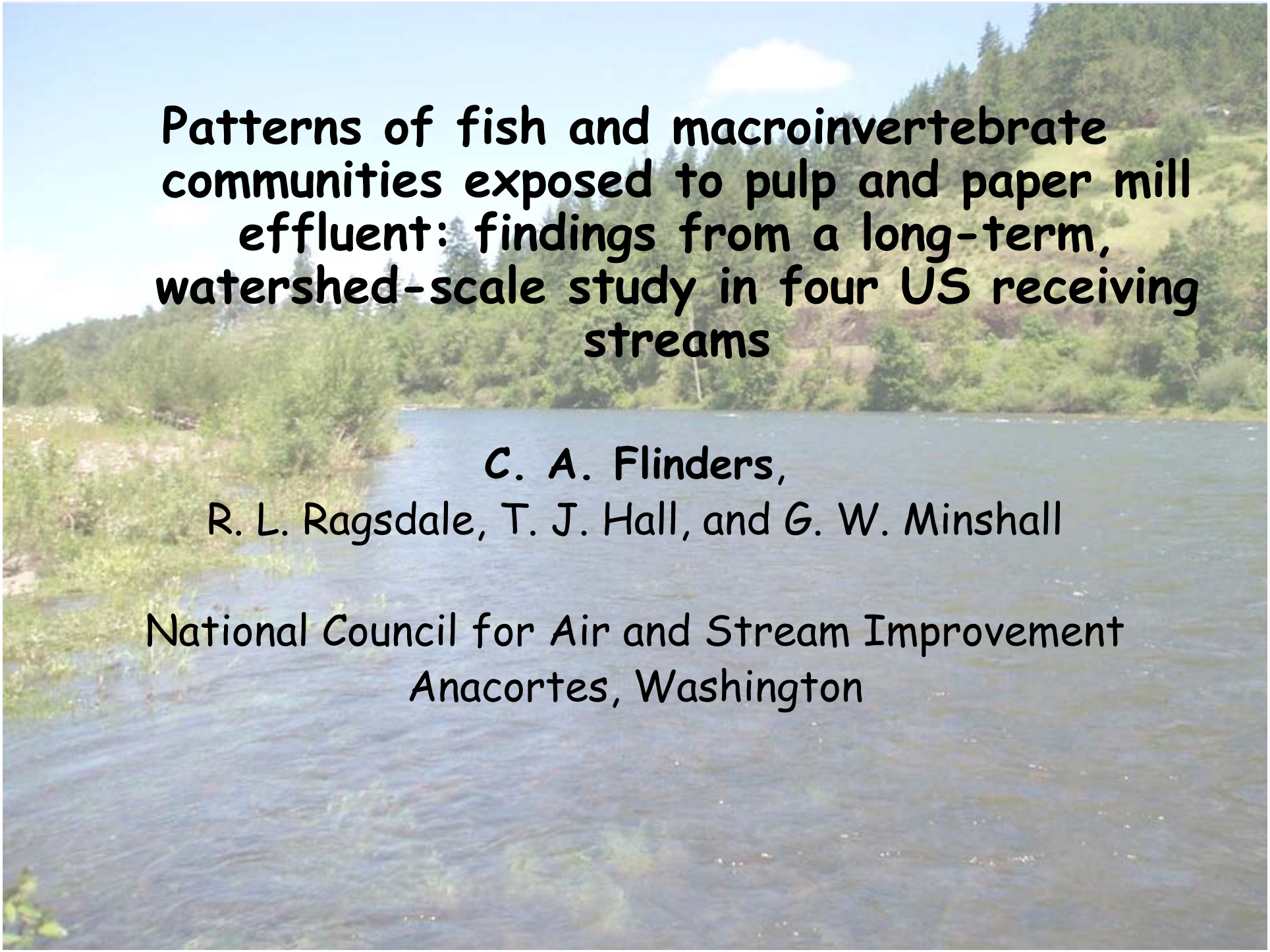

# Patterns of fish and macroinvertebrate communities exposed to pulp and paper mill effluent: findings from a long-term, watershed-scale study in four US receiving streams

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# Background

- Pulp and paper mill effluent (PPME) is one of the most studied industrial effluents

- Laboratory studies are more common than in-stream or mesocosm studies, with fish being the primary study organism

- A variety of effluent-related effects have been noted with alterations in fish reproductive indicators receiving the most attention

**Short-term in-stream and mesocosm studies have shown:**

**Macroinvertebrates:**

- Increased or inhibited growth rates
- Higher density and biomass
- Shifts in community structure
- No change

**Fish:**

- Deterioration of community integrity
- Shift in species composition & diversity
- No change

**Study Objectives:**

i. identify community structure and metric response patterns relative to PPME,

ii. determine the temporal stability of endpoints, and

iii. examine the relationship between biota and water quality and a restricted set of habitat variables


McKenzie
River, OR


Codorus Creek, PA


Willamette
River, OR


Leaf River, MS

**Design accounts for naturally-occurring spatial (US-DS) and temporal variation (season, year)**

## Macroinvertebrates

·Replicate Hess (Codorus Cr., Oregon rivers) and Hester-Dendy samples (Leaf River)

## Fish

·Boat electrofishing in Leaf and Oregon rivers (large-bodied fish)

·Backpack electrofishing in Codorus Cr. and for small-bodied fish in Oregon rivers

## Periphyton

·Replicate rock samples (n=5/site) in rock-bottom streams

·Replicate artificial samplers (n=3/site) in Leaf River (sand-bottom)

## Habitat/Water Quality

·Water samples collected 6 times/year and analyzed for nutrients, conductivity, pH, color

·Depth, temperature, substrate, flow measured in conjunction with biological sampling

## In-stream biological data examined in terms of:

- Community structure (species type and relative abundance)
- Biological structure and function metrics

| Parameter | Endpoint | Study Stream | | | | Totals |
|---|---|---|---|---|---|---|
| | | Codorus Cr. | Leaf R. | McKenzie R. | Willm. R. | |
| Sample # | Fish | 162 | 58 | 204 | 255 | **679** |
| | Invertebrates | 129 | 74 | 84 | 108 | **395** |
| | Periphyton | 104 | 28 | 72 | 92 | **296** |
| Specimen # | Fish | 13,766 | 9,934 | 11,080 | 16,701 | **51,481** |
| | Invertebrates | 767,524 | 232,880 | 509,406 | 559,451 | **2,069,261** |
| Parameter # | Community | 3 | 3 | 4 | 4 | **14** |
| | Metric | 16 | 17 | 23 | 23 | **79** |
| | Biota-Env | 3 | 3 | 4 | 4 | **14** |

Robust dataset from multi-site, multi-season, multi-year sampling

| Metrics Examined | | |
|---|---|---|
| **Fish** | **Invertebrates** | **Algae** |
| Fish abundance | Density | Chl *a* |
| Richness | Richness | |
| Simpson's Index | Simpson's Index | |
| %Dominant Taxa | % Dominant Taxa | |
| %Intolerant species | HBI | |
| Biomass | Biomass (AFDM) | |
| %DELT | | |
| %Omnivore | | |
| %Piscivore | | |

# Data Analyses

1. Differences in fish (small- & large-bodied) & macroinvertebrate community structure with site, season, and year—**Bray-Curtis similarity, ANOSIM, & non-metric multidimensional scaling (MDS) (Primer)**

2. Spatial and temporal variation in fish (small- & large-bodied) & macroinvertebrate metric response—**General Linear Models (SYSTAT)**

3. Community-environment relationships—**BIOENV algorithm (Primer)**

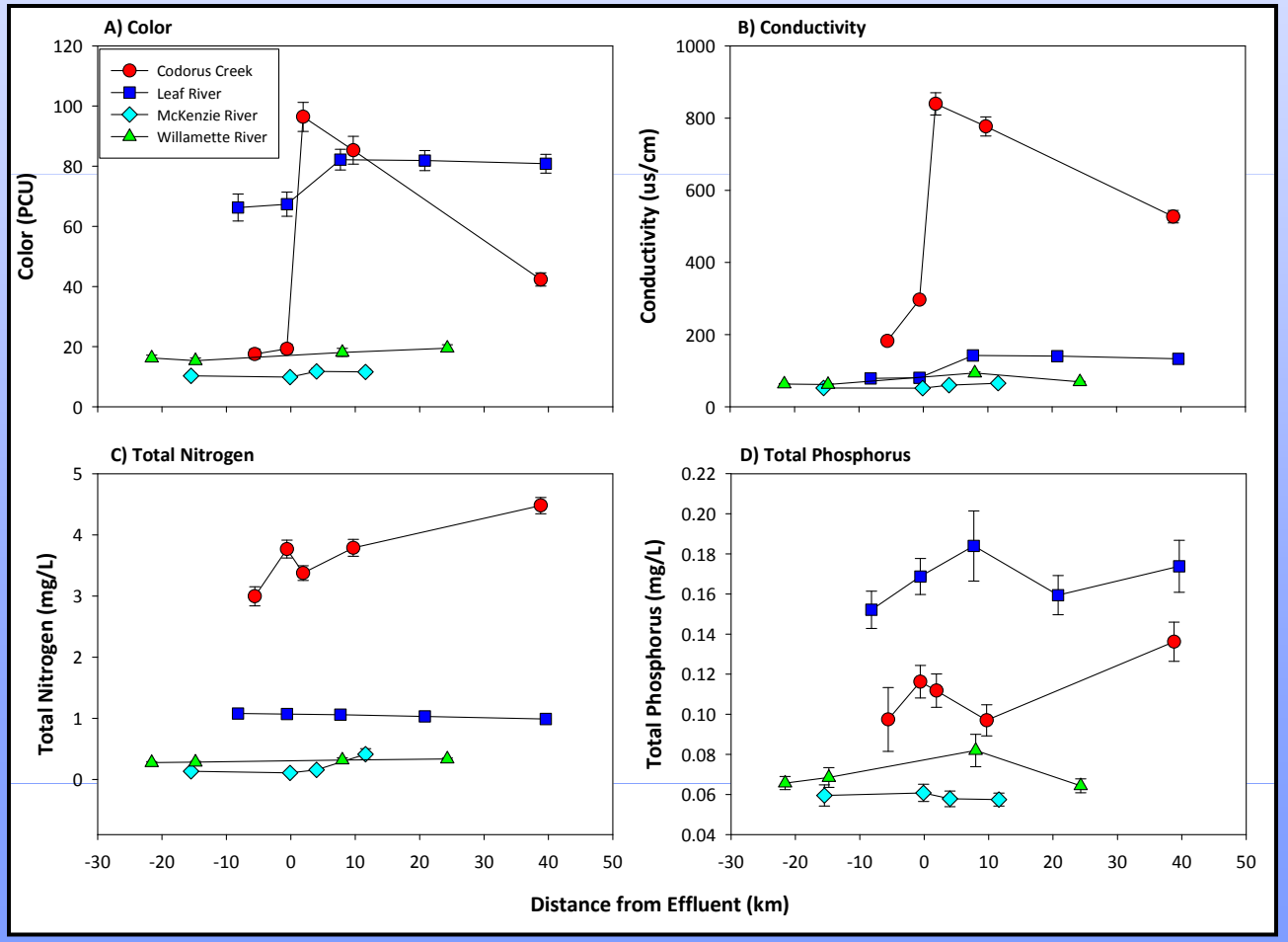
# Results

## Habitat and water quality

·No effluent-related changes in habitat measures (substrate, depth, flow)

·Some effluent-related changes

·no significant increase in [TN] and [TP] downstream of effluent discharges

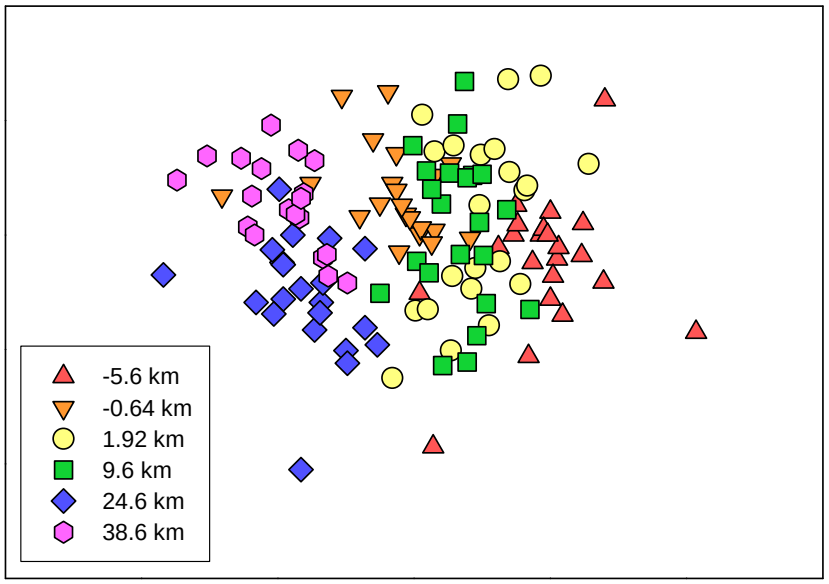


| Taxa Group | Endpoint | | Metric | Study Stream | | | |
|---|---|---|---|---|---|---|---|
| | | | | Codorus Cr. | Leaf R. | McKenzie R. | Willamette R. |
| Fish | Community | Sm-bodied | | × | × | × | × |
| | | Lg-bodied | | × | × | × | × |
| | Structure and Function Metrics | Lg-bodied | Fish abundance | × | × | × | × |
| | | | Richness | × | × | × | × |
| | | | Simpson's Index | × | × | × | × |
| | | | %Dominant Taxa | × | × | × | × |
| | | | %Intolerant species | × | × | × | × |
| | | | Biomass | × | × | × | × |
| | | | %DELT | × | × | × | × |
| | | | %Omnivore | × | × | × | × |
| | | | %Piscivore | × | × | ✓ | × |
| | | Sm-bodied | Fish abundance | . | . | × | × |
| | | | Richness | . | . | × | × |
| | | | Simpson's Index | . | . | × | × |
| | | | %Dominant Taxa | . | . | ✓ | × |
| | | | %Intolerant species | . | . | × | × |
| | | | Biomass | . | . | × | × |
| | | | %DELT | . | . | × | × |
| Inverts | Community | | | × | × | × | × |
| | Structure and Function Metrics | | Density | × | × | × | × |
| | | | Richness | × | × | × | × |
| | | | Simpson's Index | × | × | × | × |
| | | | % Dominant Taxa | × | × | × | × |
| | | | HBI | × | × | ✓ | × |
| | | | Biomass (AFDM) | × | × | × | × |
| Periphyton | | | Chlorophyll a | ✓ | × | ✓ | × |

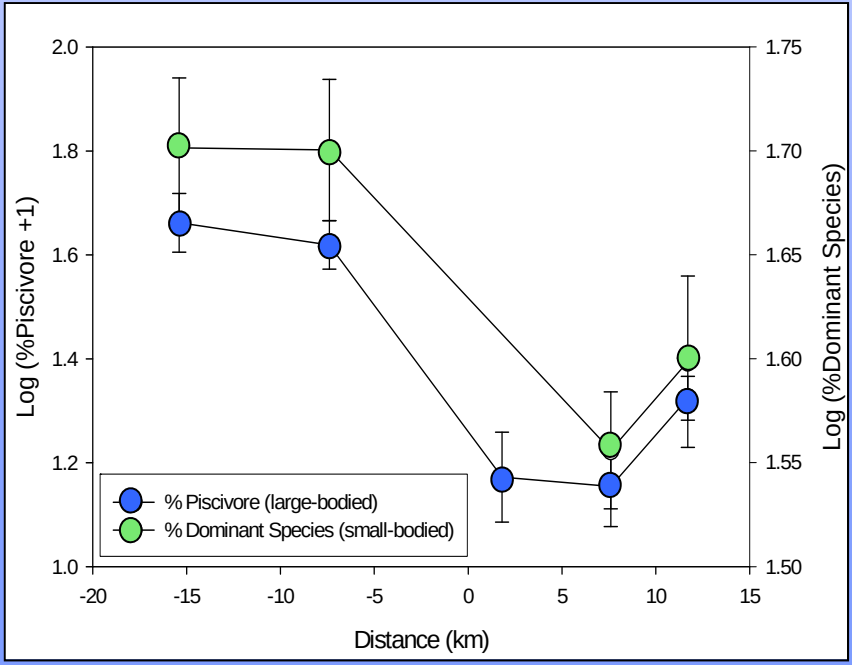
# Fish—Community Structure

·Community differences with site seen only in Codorus Creek, but not PME related

·No clear US-DS patterns, or temporal changes in any streams




# Fish—Structure/Function Metrics



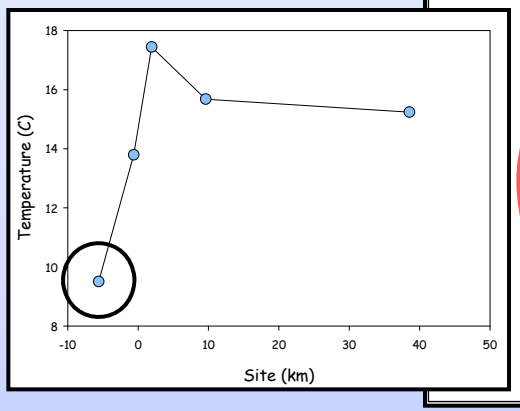

·Effluent-related site differences seen in only 2/16 metrics in McKenzie R.

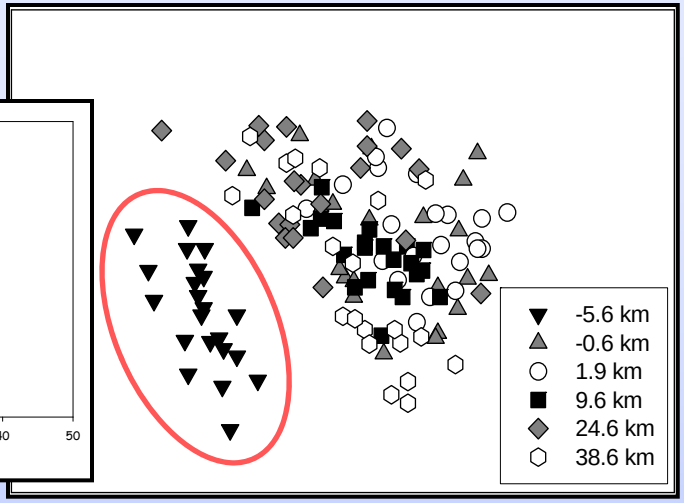
·US-DS %Piscivore pattern seen in nearby streams, possibly related to location of USFWS stocking activities

# Invertebrates—Community Structure

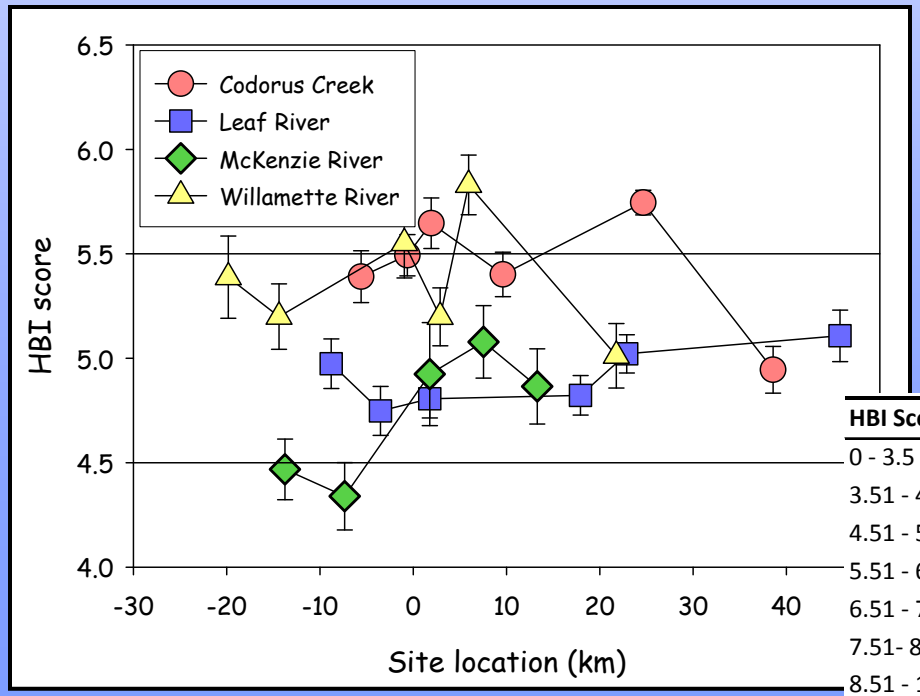
·Community differences in season & year in all but Codorus Cr.

·site difference only in Codorus Cr., but not effluent-related




# Invertebrates—Structure/Function Metrics




| HBI Score | WQ |
|---|---|
| 0 - 3.5 | Excellent |
| 3.51 - 4.5 | Very Good |
| 4.51 - 5.5 | Good |
| 5.51 - 6.5 | Fair |
| 6.51 - 7.5 | Fairly Poor |
| 7.51- 8.5 | Poor |
| 8.51 - 10 | Very Poor |

·Only PPME-related difference seen in McKenzie River HBI scores

·Shift in WQ from "very good" upstream of PPME to "good" downstream of PPME

# Community-Environment Patterns—Fish

| River | Community | *R* | p | Best Model Variables |
|---|---|---|---|---|
| Codorus Creek | All | 0.142 | * | Conductivity, Color |
| Leaf River | Large-bodied | 0.305 | * | pH |
| McKenzie River | Small-bodied | 0.089 | NS | Conductivity, TN |
| | Large-bodied | 0.029 | NS | TN |
| Willamette River | Small-bodied | 0.146 | NS | TP |
| | Large-bodied | 0.174 | * | Conductivity |

- Weak relationship to water chemistry variables in Codorus Creek, the Leaf River, and large-bodied fish in the Willamette River

- No community-environment relationship in the McKenzie River, or with small-bodied fish in the Willamette River.

Model Variables
- Conductivity
- Color
- pH
- TN
- TP
- Temperature

- Substrate
- Average depth

# Macroinvertebrates

| River | Season | *R* | Best Model Variables |
|---|---|---|---|
| Codorus Creek | -- | 0.288 | Velocity, pH, Conductivity, TN |
| Leaf River | Spring/Summer | 0.559 | pH, TN |
| | Fall | 0.554 | Color, Conductivity, TN |
| McKenzie River | Spring/Summer | 0.647 | %Boulder, pH, Conductivity |
| | Fall | 0.624 | Depth, pH, Conductivity, TN |
| Willamette River | Spring/Summer | 0.315 | TN |
| | Fall | 0.36 | Velocity, Depth |

Model Variables
- Conductivity
- Color
- pH
- TN
- TP
- Temperature

- Substrate
- Average depth
- Velocity

- Community structure related to water chemistry variables in Leaf R., and physical-chemical variables in McKenzie R.

- Seasonal differences in best-model variables

# Summary

- Fish and macroinvertebrate communities are spatially and temporally variable

- In most cases, spatial patterns in fish & invertebrate communities were unrelated to PPME in the 4 study rivers.
  Exception: McKenzie River
  - Small-bodied fish %Dominant Taxa
  - Macroinvertebrates Hilsenhoff Biotic Index

- Measured water quality & habitat variables were poor at explaining:
  - fish community structure patterns in all streams
  - macroinvertebrate patterns in Codorus Cr. & Willamette R.

- Absence of effluent effects indicates that:
  - PPME qualities were such that biotic communities were unaffected,
  - PPME concentrations were not sufficient to affect community structure, or
  - naturally-occurring community variation obscured possible effluent-related influences.

- Although other studies have shown PPME effects at lower levels of organization in fish (i.e. physiological, population), these are either not evident or do not translate to effects at the community level in the 4 streams of this study.

- Because of the spatial and temporal variation in biological communities, caution should be taken in interpreting results from studies with a limited spatial or temporal component