Tidal creeks as sentinel habitats: a conceptual model for describing the effects of land use change on coastal ecosystems

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Problem

Area of urban land is projected to triple between 2000 and 2030

Charleston SC area

Allen and Lu (2003)
Primary Research Question

• How do coastal development practices impact the ecological character of coastal habitats?

• In the southeastern US, we ask how coastal development practices impact tidal creeks. Why?
Tidal creeks have ecological and economic value

- Refuge and nursery habitat for fisheries
- Primary hydrologic link to uplands
- Preferred sites for development
Tidal creek networks

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Development of tidal creek watersheds
Coastal development and impervious surface

Impervious cover can be used to represent the degree of development

Forested

Suburban

Urban

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Conceptual model

People are moving to the coasts! People=pavement?

Stressor

Coastal Development Activities

Increased Population Density

Altered Land Cover

Increased Impervious Cover
Understanding the stressor

Population increase relates to development level

![Graph showing the relationship between 2000 Population Density (#/ha) and 2001 Impervious Cover (%). The graph includes data points for NC, SC, and GA, with a linear trend line indicating a significant correlation (P<0.001, r²=0.81).]
Understanding the stressor

Growth of urban areas and loss of forests in SE watersheds

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Coastal development impacts the creek environment

**Stressor**

- Coastal Development Activities
- Increased Population Density
- Altered Land Cover
- Increased Impervious Cover

**Exposure**

- Physical-Chemical Changes
  - Impaired Water Quality & Hydrography
  - Microbial and Pathogen Contamination
  - Chemical Contamination

Conceptual model
Physical-chemical changes

Nutrients increase with development

$\Delta$ 1st order  $\square$ 2nd order  $\Diamond$ 3rd order

$r^2 = 0.47$

$r^2 = 0.29$
Microbial indicators increase with development

Physical-chemical changes

Fecal Coliforms (log(cfu/100ml)) vs. Impervious Cover (%)

1st order
2nd order
3rd order

$r^2 = 0.63$
Physical-chemical changes

Chemical contamination increases with development

\[ r^2 = 0.81 \]

Impervious Cover (%) vs. ERMQ (log)

- 1st order
- 2nd order
- 3rd order

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Physical-chemical changes

Flame retardant contamination is found in developed creeks

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Conceptual model

Coastal development impacts creek ecology

**Stressor**
- Coastal Development Activities
  - Increased Population Density
  - Altered Land Cover
  - Increased Impervious Cover

**Exposure**
- Physical-Chemical Changes
  - Impaired Water Quality & Hydrography
  - Microbial and Pathogen Contamination
  - Chemical Contamination

**Ecological Response**
- Living Resources
  - Impaired Animal Health
  - Reduced Biological Productivity
  - Altered Food Webs

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Ecological response

Headwater benthic assemblage changes with development

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Ecological response

Shrimp in headwaters decrease with development

Penaeid Shrimp (Log abund.)

Impervious Cover (%)

$r^2 = 0.36 \quad p = 0.0023$
Conceptual model

Research has identified impervious cover cutpoints

Stressor

Coastal Development Activities

Increased Population Density

Altered Land Cover

Increased Impervious Cover

Exposure

Physical-Chemical Changes

Impaired Water Quality & Hydrography

Microbial and Pathogen Contamination

Chemical Contamination

Ecological Response

Living Resources

Impaired Animal Health

Reduced Biological Productivity

Altered Food Webs

10-20%

20-30%

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Conceptual model

What about people?

Stressor

Coastal Development Activities

Increased Population Density

Altered Land Cover

Increased Impervious Cover

Exposure

Physical-Chemical Changes

Impaired Water Quality & Hydrography

Microbial and Pathogen Contamination

Chemical Contamination

Ecological Response

Living Resources

Impaired Animal Health

Reduced Biological Productivity

Altered Food Webs

Societal Response

Health and Welfare

Beach and Shellfish Bed Closures

Vulnerability to Flooding

Public Health Risk & Economic Impact

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Development alters the water distribution of watersheds
Stormwater runoff increases with development

Photos
Post & Courier
Charleston SC
13 June 2007

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Other impacts on people and their lives?

Preliminary attempt at quantifying quality

• Attempt to fold together environmental and ecological aspects of our understanding of coastal development on creeks
• Tie them to what people perceive as important elements of a place—what makes a place have a high quality?

Can we eat the seafood? Can we swim in the water?
Can we enjoy the aesthetics? Are we safe? Is it sustainable?
Readily Available Data

National Land Cover Database
- Tree Canopy % = TREE_CAN
- Impervious cover % = IC

Tidal Creeks Research
12 S.C. Creeks
- ERMQ = ERMQ
- Precipitation/Runoff ratio = PRECIP_R

U.S. Census 2000
- Population density per acrea for watershed = POP_DEN
- Parcel Density per acre for watershed = PARC_DEN
- Median Parcel Value = MEDIAN_P
- Log10 median income = l_m_in
- Log10 median parcel value = l_m_par
- Median Income = MEDIAN_I
- Less than 25K(%) = LT_25K
- Greater than or equal to 25K(%) = GT_EQ_25
# Quality of Place—Preliminary Results

<table>
<thead>
<tr>
<th>Creek</th>
<th>Quality of Place ranking</th>
<th>Creek Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okatie</td>
<td>0.5822</td>
<td>suburban</td>
</tr>
<tr>
<td>Guerin</td>
<td>0.5819</td>
<td>forested</td>
</tr>
<tr>
<td>Village</td>
<td>0.5473</td>
<td>forested</td>
</tr>
<tr>
<td>Albergottie</td>
<td>0.4537</td>
<td>suburban</td>
</tr>
<tr>
<td>Parrot</td>
<td>0.4021</td>
<td>suburban</td>
</tr>
<tr>
<td>Orange Gr</td>
<td>0.1688</td>
<td>suburban</td>
</tr>
<tr>
<td>North Inl</td>
<td>-0.0462</td>
<td>forested</td>
</tr>
<tr>
<td>Bull</td>
<td>-0.0930</td>
<td>urban</td>
</tr>
<tr>
<td>James Isl</td>
<td>-0.1736</td>
<td>suburban</td>
</tr>
<tr>
<td>Shem</td>
<td>-0.3410</td>
<td>urban</td>
</tr>
<tr>
<td>Murrells</td>
<td>-0.4025</td>
<td>urban</td>
</tr>
<tr>
<td>New Market</td>
<td>-1.6797</td>
<td>urban</td>
</tr>
</tbody>
</table>
Quality of Place may help integrate across model boxes

Conceptual model

Coastal Development Activities → Physical-Chemical Aspects of Creeks → Altered Living Resources in Creeks

QoP

Human Health and Well Being

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Conclusions

• In southeastern US, tidal creeks are an important habitat
  • refuge and nursery
  • pollution & materials processing
  • part of the unique character of this place

• Coastal development has a unmistakable and negative impact on the ecological character of these creeks.

• Conceptual model provides useful tool for understanding AND relating the relationship(s) between stressor(s) and impact(s).
Conclusions, cont.

- What about the impact on human health and welfare? Development may impact the ecological services provided by these habitats, diminishing sustainability.

- Results shown are place-specific, but the sentinel habitat approach used here can generalized. Conceptual approach can be moved to other coastal areas or inland.

- Provides a platform from which to integrate disparate information and inject it into the decision-making process.
Thank you! Questions?
An ecological index may provide a measurement of “Quality of Place”

**An Index includes:**

- Key indicators of health
- Sentinel habitats and organisms
- Flexibility to region, data, issues
- Useful for decision-makers to determine multiple effects brought about by changes in land use. Environmental status.
- Promotes sustainable economics
Quality of Place

Index classifications suggest a reasonable beginning...