Effects of Oil Exposure on Submerged Aquatic Vegetation Growth, Reproduction, and Herbivory

Charles W. Martin
University of Florida/IFAS
Nature Coast Biological Station
Estuaries in the Gulf of Mexico provide much of the nation’s supply of **fisheries**, **wetlands**, & numerous desirable **natural resources**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Mexico</td>
<td>7,964,226,642</td>
<td>38%</td>
</tr>
<tr>
<td>Alaska</td>
<td>3,758,219,974</td>
<td>18%</td>
</tr>
<tr>
<td>North Atlantic</td>
<td>3,200,386,320</td>
<td>15%</td>
</tr>
<tr>
<td>Chesapeake</td>
<td>2,579,111,548</td>
<td>12%</td>
</tr>
<tr>
<td>Pacific Northwest</td>
<td>1,537,169,333</td>
<td>7%</td>
</tr>
<tr>
<td>California</td>
<td>935,943,498</td>
<td>4%</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>897,741,014</td>
<td>4%</td>
</tr>
<tr>
<td>Hawaii</td>
<td>2,279,240</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Nationwide</td>
<td>20,875,077,569</td>
<td>100%</td>
</tr>
</tbody>
</table>

From Lellis-Dibble et al. 2008
Deepwater Horizon Oil Spill

http://gomex.erna.noaa.gov/
Talk Outline

• Effects of Oil on Submerged Aquatic Vegetation
  • Growth
  • Reproduction
  • Root Morphology

• Food Web Effects of Plant Oiling
  • Herbivory of oil-affected plant tissue
  • Future food web work
Coastal Vegetation

• Coastal vegetation provides numerous ecosystem services
  • Refuge for nekton
  • Forage base for organisms
  • Buffer from storms
  • Water filtration

Widgeon grass, *Ruppia maritima*

Lacombe, LA

Cocodrie, LA

Port Sulphur, LA
Studies have focused on oil effects to emergent vegetation, while much less is known about submerged vegetation.

<table>
<thead>
<tr>
<th>Species</th>
<th>Effects</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spartina alterniflora</td>
<td>Little damage to existing stocks and new colonizers</td>
<td>de la Cruz et al., 1981</td>
</tr>
<tr>
<td>S. alterniflora and S. patens</td>
<td>64% decrease in cover in mixed species assemblage</td>
<td>Mendelsohn et al., 1990</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>No significant difference in above-ground biomass</td>
<td>DeLaune et al., 1979</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>No significant difference in above-ground biomass CO₂ fixation decreased at 6 days and recovered at 13 days</td>
<td>Smith et al., 1984</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>100% oil cover: no photosynthesis; Partial oil: photosynthesis decreased 50-80%</td>
<td>Pezeshki and DeLaune, 1993</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>No significant difference in above-ground biomass</td>
<td>Crow et al., 1976</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>Decreased production early, but no long-term effects</td>
<td>Lytle, 1975</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>No significant difference in above-ground biomass</td>
<td>DeLaune et al., 1979</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>No regrowth in the year following oil application</td>
<td>Lin and Mendelsohn, 1996</td>
</tr>
<tr>
<td>S. patens</td>
<td>Significant reduction in photosynthetic rate, above-ground biomass and no regrowth in the year following oil application</td>
<td>Lin and Mendelsohn, 1996</td>
</tr>
<tr>
<td>Sagittaria lancifolia</td>
<td>Significant increase in biomass and stem density</td>
<td>Lin and Mendelsohn, 1996</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>Non-linear response; stimulated plant growth and microbial activity at low level, but inhibited at higher levels</td>
<td>Li et al., 1990</td>
</tr>
<tr>
<td>S. patens</td>
<td>Significant reduction in photosynthesis, proportion dead above-ground tissue, and regrowth</td>
<td>Hester et al., 1998</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>Significant intraspecific variation in these responses</td>
<td></td>
</tr>
</tbody>
</table>

From Pezeshki et al. 2000
Objectives – *Ruppia maritima*

1. What are the effects of oil on *Ruppia maritima*?

2. Are there food web implications from this oil exposure?
1. What are the effects of oil on *R. maritima*?

- *Ruppia* grown in 19L tanks at 10 psi for 31-33 days
- 4 randomized treatments:
  - **No oil** (0mL)
  - **Low** (5mL)
  - **Medium** (10mL)
  - **High** (20mL)
- Tanks contained 2L of sediment and n=12/treatment
- In tanks containing oil, a layer was buried ~3cm deep before planting
1. What are the effects of oil on *R. maritima*?

- **Reproduction**
  - Flowers
  - Fruiting Bodies

- **Root Characteristics**

- **Growth**
1. What are the effects of oil on *R. maritima*?

1. Growth (proportional change in weight, number of shoots)
1. What are the effects of oil on *R. maritima*?

## 1. Growth

**Wet Weight**

- None
- Low
- Medium
- High

- *p* = 0.494

**Number of Shoots**

- None
- Low
- Medium
- High

- *p* = 0.737
1. What are the effects of oil on *R. maritima*?

2. Reproduction (proportional change in number of flowers, fruits)
1. What are the effects of oil on *R. maritima*?

2. Reproduction

- **Flowers**
  - p = 0.008

- **Fruit**
  - p = 0.015
1. What are the effects of oil on *R. maritima*?

3. Root Characteristics (mass, length, diameter, area, uprooting strength)
1. What are the effects of oil on *R. maritima*?

**NO OIL**

**HIGH OIL**

**Root Mass**  
\[ p = 0.686 \]

**Root Area**  
\[ p = 0.015 \]

**Root Diameter**  
\[ p = 0.021 \]
1. What are the effects of oil on *R. maritima*?

Silliman et al. 2012

Turner et al. 2016
2. Are there food web implications?

The link between C:N and Herbivory

<table>
<thead>
<tr>
<th>Citation</th>
<th>Plant</th>
<th>Herbivore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kraft &amp; Denno 1982</td>
<td>Shrub</td>
<td>Insects</td>
</tr>
<tr>
<td>Coley 1983</td>
<td>Terrestrial trees</td>
<td>Insects</td>
</tr>
<tr>
<td>Schroeder 1983</td>
<td>Terrestrial tree</td>
<td>Insects</td>
</tr>
<tr>
<td>Onuf et al. 1977</td>
<td>Mangroves</td>
<td>Insects</td>
</tr>
<tr>
<td>Lilly 1975</td>
<td>Terrestrial plants</td>
<td>Insects</td>
</tr>
<tr>
<td>Bjorn 1975</td>
<td>Seagrass</td>
<td>Green turtle</td>
</tr>
<tr>
<td>Zieman et al. 1984</td>
<td>Seagrass</td>
<td>Green turtle</td>
</tr>
<tr>
<td>Williams 1988</td>
<td>Seagrass</td>
<td>Green turtle</td>
</tr>
<tr>
<td>McGlathery 1995</td>
<td>Seagrass</td>
<td>Fishes</td>
</tr>
<tr>
<td>Preen 1995</td>
<td>Seagrass</td>
<td>Dugong</td>
</tr>
<tr>
<td>Valentine &amp; Heck 2001</td>
<td>Seagrass</td>
<td>Urchins</td>
</tr>
<tr>
<td>Goecker et al. 2005</td>
<td>Seagrass</td>
<td>Fishes</td>
</tr>
</tbody>
</table>

Herbivores prefer plants with high nitrogen content.

Oil Exposure = Lower C:N!
2. Are there food web implications?

• Laboratory herbivory assays


• Herbivores:
  • Grass shrimp (x5) (*Paleomonetes pugio*)
  • Amphipods (x10) (*Gammarus mucronatus*)
2. Are there food web implications?

**Experiment 1**

- None vs Low
- Low vs Medium
- Medium vs High

**Experiment 2**

- A
- B

**Proportion Loss**

- p=0.19
- p=0.49
- p=0.04
- p<0.01
- p<0.01
- p<0.01

*All Comparisons n=12*
2. Are there food web implications?

Experiment 1
Paired Choice Experiment

Experiment 2
Foraging Rate Experiment

Proportion Loss

48 Hours

All Comparisons n=12
Food Web Resilience to Oil

Variable effects of DWH on populations

- No effect

Insects
- McCall & Pennings 2012

Small fish
- Able et al. 2015

Large fish
- Fodrie & Heck 2011

Food Web Resilience to Oil

Literature Synthesis

Oil Sensitivity
- No data (13)
- 0: none (16)
- 1: weak (10)
- 2: strong (12)

Extirpation of most sensitive nodes
Extirpation of most sensitive nodes

<table>
<thead>
<tr>
<th>Unoiled</th>
<th>Oiled</th>
</tr>
</thead>
<tbody>
<tr>
<td># Nodes</td>
<td>51</td>
</tr>
<tr>
<td># Links</td>
<td>343</td>
</tr>
<tr>
<td>Link density</td>
<td>6.72</td>
</tr>
<tr>
<td>Connectance</td>
<td>0.13</td>
</tr>
</tbody>
</table>
1. What are the effects of oil on *Ruppia maritima*?
   Reduced flowering, changes to root morphology, decreased uprooting force

2. Are there food web implications from this oil exposure?
   Because of changes to plant chemical composition, foraging trends were altered
Acknowledgements

• **Funding:**
  - This research was made possible in part by a grant from The Gulf of Mexico Research Initiative. Data are publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) at [https://data.gulfresearchinitiative.org](https://data.gulfresearchinitiative.org).
  - Northern Gulf Institute. The funders had no role in the design, execution, or analyses of this project.


• **Alabama:** J. Valentine, K. Heck, S. Powers, S. Alford, K. Blankenhorn, T. Kauffman, L. Steele, R. Puntila, S. Sklenar, S. Madsen, M. Dueker, L. Lee
Questions?
Email: charles.martin@ufl.edu
Alter food web structure & resilience
Critical for resilience

Critically sensitive species

Few indirect effects

Food web importance

Oil sensitivity

Literature Synthesis

- Critical for resilience
- Critically sensitive species
- Few indirect effects

Ecological Network Analysis

Diet Matrix

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Literature Synthesis

Diet Matrix

```
1 0 1 0 1 1 0 1
0 0 0 0 0 1 1 1
0 1 0 0 0 0 0 0
0 0 0 1 0 0 0 1
0 0 0 0 0 1 0 0
0 1 0 0 0 0 0 0
0 1 0 0 0 0 0 0
0 0 0 0 0 0 0 0
```

Ecological Network Analysis

- Critical for resilience
- Critically sensitive species
- Few indirect effects

Oil Sensitivity Data

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Oil Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

52 nodes
376 links
Phytoplankton
Spartina alterniflora
Omnivorous snails

*Littoraria irrorata*
Piscivorous fish

Dolphins
Carn. fish
Invert. fish
Benth. fish
Disc. fish
Zoop. fish
Pelg. omn. fish

Sea birds
Seabirds
Clapper rail
Perpendicular
Carr. insects
Harm. crabs
Omn. insects
Brines
Fish. crabs
Marsh det. fish
Marsh herb. fish
Art. insects
Det. insecte
Heli. insects
Iso. Amphs
Nursa
Meiofauna
Detr. snail

Diel
Macroalg
Phytoch.
Photo
Distichis
Juncus
Other plants
Salter
Sp. sponges
Oil Sensitivity

○ No data (13)
● 0: none (16)
● 1: weak (10)
● 2: strong (12)
Food web importance

- Critical for resilience
- Critically sensitive species
- Few indirect effects

Oil sensitivity

Food Web Resilience to Oil

- Biomarker approach to food web effects
  - Bulk Stable Isotopes
  - Fatty Acids
  - Compound specific isotopes
Food Web Resilience to Oil

- Biomarker approach to food web effects
  - Bulk Stable Isotopes
  - Fatty Acids
  - Compound specific isotopes

![Food Web Resilience to Oil Diagram]

Fish Stomach Contents

- Hardhead Catfish
  - May
    - n=7
    - 52% blue crab, 28% shrimp, 4% crustacean, 4% fish
  - October
    - n=10
    - 43% blue crab, 18% shrimp, 40% crustacean, 18% fish

- Red Drum
  - May
    - n=6
    - 37% blue crab, 24% shrimp, 36% crustacean, 3% fish
  - October
    - n=11
    - 51% blue crab, 35% shrimp, 11% crustacean, 3% fish
Food Web Resilience to Oil

- Biomarker approach to food web effects
  - Bulk Stable Isotopes
  - Fatty Acids
  - Compound specific isotopes

Terrestrial plants are the primary carbon source for most terrestrial arthropods.

Estuarine inverts mostly derive carbon from algae.