Fish assemblages in the Powder River Basin in relation to coalbed natural gas development

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Outline

What are the concerns for fisheries?
Objectives
Study design
Methods
Results
Challenges
Discussion
Fish of the Powder River Basin

- Unique assemblage of 52 fish species
  - predominately suckers and minnows
- Includes 9 species of concern
Potential effects to fish

• Changes in water quality

• Changes in water quantity
Water quality

Surface vs. product

![Bar chart showing concentration of Sodium, Chloride, and Bicarbonate in Powder River and CBNG Product.](Clark et al. 2001)
Water quantity

- Groundwater pumping $\rightarrow$ reduced flow
Water quantity

• Groundwater pumping $\rightarrow$ reduced flow

• Direct discharge $\rightarrow$ increased flow
Determine if CBNG development has affected fish assemblages in tributary streams of the Tongue and Powder rivers.
Field study objectives

Has CBNG affected fish assemblages ...
Field study objectives

Has CBNG affected fish assemblages ...

1. In streams with and without CBNG?
Field study objectives

Has CBNG affected fish assemblages …

1. In streams with and without CBNG?
2. Compared to historical surveys conducted before CBNG?
Field study design

1. Treatment vs. control
2. Historical comparisons
Treatment vs. control

With CBNG

Without CBNG
Treatment vs. control

With CBNG

Without CBNG

Sample reaches
Treatment vs. control

- With CBNG
- Without CBNG

- Abundance
- Species richness
- IBI scores
Historical comparisons

1994
Before CBNG

2006
After CBNG

Sample reaches

- Species presence/absence
- IBI scores
Historical comparisons

1994 Before CBNG
2006 No CBNG

Sample reaches

- Species presence/absence
- IBI scores
Concept of biological integrity

- Clean Water Act 1972
  - “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters”
Concept of biological integrity

“a … community of organisms … comparable to that found in natural habitats of the region”
Index of Biotic Integrity (IBI)

Began in 1981
- Karr (1981) used fish assemblages to evaluate the biotic integrity of Midwestern streams
Index of Biotic Integrity (IBI)

Analogous to index of leading economic indicators

– Combines many measures to assess the “health” of the economy
Index of Biotic Integrity (IBI)

A metric is essentially a hypothesis predicting how a biological attribute will change with increasing anthropogenic stress

- The number of native fish species will decline
- The proportion of tolerant species (e.g. common carp, fathead minnow) will increase
- The proportion of invertivorous species will decrease
IBIs have been applied in many environments:

- Streams, rivers
- Lakes, reservoirs
- Wetlands, estuaries
- Terrestrial environments
### IBI scoring example

#### “good stream”

<table>
<thead>
<tr>
<th>Metric</th>
<th>Raw metric value</th>
<th>Metric score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. native spp.</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>No. native families</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>No. sucker and catfish spp.</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>% tolerant</td>
<td>53.4</td>
<td>4</td>
</tr>
<tr>
<td>% invert. minnows</td>
<td>43.1</td>
<td>6</td>
</tr>
<tr>
<td>No. benthic invert.</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>% rock spawners</td>
<td>82.9</td>
<td>10</td>
</tr>
<tr>
<td>% tolerant repro.</td>
<td>0.7</td>
<td>10</td>
</tr>
<tr>
<td>% native</td>
<td>100.0</td>
<td>10</td>
</tr>
<tr>
<td>No. long-lived</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Total IBI score</td>
<td></td>
<td>89</td>
</tr>
</tbody>
</table>

- **white sucker**: 241
- **longnose dace**: 122
- **flathead chub**: 55
- **lake chub**: 20
- **shorthead redhorse**: 7
- **stonecat**: 6
- **fathead minnow**: 3
- **longnose sucker**: 2
- **mountain sucker**: 1

**IBI scoring example**

A “good stream” is characterized by a high Total IBI score of 89, indicating a healthy aquatic ecosystem with a diverse and tolerant fish community.
## IBI scoring example

**“poor stream”**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Raw metric value</th>
<th>Metric score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. native spp.</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>No. native families</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>No. sucker and catfish spp.</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>% tolerant</td>
<td>100.0</td>
<td>0</td>
</tr>
<tr>
<td>% invert. minnows</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>No. benthic invert.</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>% rock spawners</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>% tolerant repro.</td>
<td>2.9</td>
<td>10</td>
</tr>
<tr>
<td>% native</td>
<td>2.9</td>
<td>0</td>
</tr>
<tr>
<td>No. long-lived</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

**Total IBI score**

36
Field methods
Treatment vs. control

- Control
- Treatment

0 100 Km
## Water quality

<table>
<thead>
<tr>
<th>Response</th>
<th>Control Mean</th>
<th>Treatment Mean</th>
<th>SE</th>
<th>Treatment SE</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>22</td>
<td>23</td>
<td>0.5</td>
<td>0.9</td>
<td>0.160</td>
</tr>
<tr>
<td>pH</td>
<td>8.6</td>
<td>8.6</td>
<td>0.07</td>
<td>0.09</td>
<td>0.520</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>35</td>
<td>28</td>
<td>9.5</td>
<td>10.1</td>
<td>0.637</td>
</tr>
<tr>
<td>Conductivity (µmhos/cm)</td>
<td>3133</td>
<td>4565</td>
<td>462</td>
<td>778</td>
<td>0.829</td>
</tr>
</tbody>
</table>
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<th>Control SE</th>
<th>Treatment Mean</th>
<th>Treatment SE</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkalinity</td>
<td>305</td>
<td>24.7</td>
<td>636</td>
<td>89.7</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>319</td>
<td>128</td>
<td>17</td>
<td>3.15</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Sulfate</td>
<td>836</td>
<td>103</td>
<td>2028</td>
<td>495</td>
<td>0.158</td>
</tr>
<tr>
<td>Bicarbonate (mg/L)</td>
<td>362</td>
<td>28</td>
<td>621</td>
<td>61</td>
<td>0.033</td>
</tr>
</tbody>
</table>
Product water streams

8 species observed...

- Green sunfish
- Black bullhead
- Plains killifish
- River carpsucker
- White sucker
- Fathead minnow
- Sand shiner
- Flathead chub
Species Richness

![Graph showing species richness comparison between control and treatment groups. The graph indicates that species richness is higher in the treatment group compared to the control group. The vertical bars represent the confidence interval.](image-url)
Biotic Integrity

IBI score

Control Treatment Low Medium High

AA B B BB
Biotic Integrity

$r^2 = 0.025$
$P = 0.431$
Biotic Integrity

The scatter plot shows the relationship between CBNG Wells per km² and IBI Score. The equation for the line of best fit is given by $r^2 = 0.045$ and $P = 0.2878$. The scatter of points suggests a weak negative correlation between the two variables.
Biotic Integrity vs. Water Management

\[ r^2 = 0.00 \]
\[ P = 0.997 \]

\[ r^2 = 0.029 \]
\[ P = 0.789 \]
Biotic Integrity vs. Water Management

- CBNG Product Water Outfalls to On Channel Reservoirs
  - $r^2 = 0.000$
  - $P = 0.985$

- CBNG Product Water Outfalls to Off Channel Reservoirs
  - $r^2 = 0.003$
  - $P = 0.778$

- CBNG Product Water Outfalls that Directly Discharge to Streams
  - $r^2 = 0.001$
  - $P = 0.907$
Biotic Integrity vs. Water Quality

$r^2 = 0.019$
$P = 0.401$
Biotic Integrity vs. Water Quality

$r^2 = 0.047$

$P = 0.196$
Historical treatment

Historical control

Historical treatment
Changes

<table>
<thead>
<tr>
<th>Lost</th>
<th>Gained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake chub</td>
<td>Black bullhead</td>
</tr>
<tr>
<td>Plains minnow</td>
<td>Brown trout</td>
</tr>
<tr>
<td>Sturgeon chub</td>
<td>Spottail shiner</td>
</tr>
<tr>
<td>Western silvery minnow</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>Lost</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------</td>
</tr>
<tr>
<td></td>
<td>Lake chub</td>
</tr>
<tr>
<td></td>
<td>Plains minnow</td>
</tr>
<tr>
<td></td>
<td>Sturgeon chub</td>
</tr>
<tr>
<td></td>
<td>Western silvery minnow</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>
<tr>
<td>Treatment</td>
<td>Lost</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>Treatment</td>
<td>Lake chub (2)</td>
</tr>
<tr>
<td></td>
<td>Plains minnow (4)</td>
</tr>
<tr>
<td></td>
<td>Sturgeon chub (1)</td>
</tr>
<tr>
<td></td>
<td>Western silvery minnow (1)</td>
</tr>
<tr>
<td>Control</td>
<td>Brassy minnow (2)</td>
</tr>
<tr>
<td></td>
<td>Goldeye (2)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Biotic Integrity

The graph shows the comparison between Treatment and Control in 1994 and 2006. The data points are scattered, indicating variability in Biotic Integrity over the years.
Conclusions

• Treatment streams have higher levels of alkalinity and bicarbonate; however, there was no significant relationship between these water quality variables and biotic integrity.
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Research Challenges

• No pre-CBNG fish surveys on small tributaries
• Water management constantly changing
• WYPDES permits difficult to access or interpret
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• Water management constantly changing
• WYPDES permits difficult to access or interpret

  No clear designation of the type of product water outfalls

  Difficult to assess quantity of product water entering the system at a given time
Research Limitations

• Most conservative model
• Short term data set
• Drought (2005-2006)
Acknowledgments:
BLM: Joe Platz, Larry Gerard
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