What’s a Duck Worth?

REA Modeling of Bird Injuries at Copper Mines in AZ & NM

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NM Ecological Services Field Office
Albuquerque, NM

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Site Overview

- Operating open-pit copper mines, mills, and smelters
- Acidic, metal-rich surface waters impounded at waste-rock, tailings, and storm-water facilities
- Numerous metal contaminated terrestrial habitats & ephemeral streams
Hanover Creek
Arizona
New Mexico
Site Overview

- Operating open-pit copper mines, mills, and smelters
- Acidic, metal-rich surface waters impounded at waste-rock, tailings, and storm-water facilities
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Site Overview

- Operating open-pit copper mines, mills, and smelters
- Acidic, metal-rich surface waters impounded at waste-rock, tailings, and storm-water facilities
- Numerous metal contaminated terrestrial habitats & ephemeral streams
<table>
<thead>
<tr>
<th>Full Smelter Name</th>
<th>Years of Operation</th>
<th>Total Years Operation</th>
<th>Stack Height (ft)</th>
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</thead>
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<tr>
<td>Arizona Copper Co. #1</td>
<td>1882 - 1913</td>
<td>31</td>
<td>300</td>
</tr>
<tr>
<td>Clifton</td>
<td>1913 - 1942</td>
<td>29</td>
<td>200</td>
</tr>
<tr>
<td>Shannon Hill</td>
<td>1902 - 1918</td>
<td>16</td>
<td>200</td>
</tr>
<tr>
<td>Morenci Reduction Works Reverb</td>
<td>1942 - 1984</td>
<td>42</td>
<td>600</td>
</tr>
<tr>
<td>Morenci Redicton Works Converter</td>
<td>1967 - 1984</td>
<td>17</td>
<td>600</td>
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<tr>
<td>Morenci Pit (Detroit Copper Company)</td>
<td>1884 - 1920</td>
<td>34</td>
<td>200</td>
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<tr>
<td>Chino Mine Hurley Smelter</td>
<td>1939 - 2002</td>
<td>63</td>
<td>600</td>
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</tbody>
</table>

Shannon Hill Smelter

Chino-Hurley Smelters

Clifton Smelter
Why REA for Bird Losses?

A resource was injured (birds), and this resource could not be linked to lost habitat.

Similar to situation where birds are injured due to an oil-spill.

Active facilities with continued disturbances- an industrial moonscape.
Two Debit Modeling Approaches Considered

- Extrapolate from number of birds killed
  - Compensate for undercounting due to scavenging, decomposition, searcher inefficiency
  - Predict yearly losses based on migratory trends in region and precipitation

- Predict from number of birds visiting site and known facility characteristics
Total Number of Birds Landing on Mine Ponds in Year X

Adjust Bird Number Downward for Natural Mortality

Adjust Bird Number Downward for Observer Error

Total Number of Birds Exposed to Acidic, Metal-Rich Water
  - Exposed <1 Hour
  - % Birds Killed
  - % Birds Otherwise Injured
  - % Injured Birds Recovering
  - Exposed 1-6 Hours
  - Exposed >6 Hours

Total Number of Birds Exposed to Neutral, Low-Metals Water

Total Number of Birds Killed in Year X
### Input Values for Debit Calculations for Each Pond Type

- **%** = Hazings Year Cells requiring an input value
- **#** = Pre-Hazings Data Cells requiring an input value

- 35% = Natural mortality rate of birds (percentage)
- 2.3 = Average lifespan of birds in years
- 2005 = Base year for discounting
- 3% = Real discount rate

### Multiple Counting Adjustment by Pond Type (Percentage)

<table>
<thead>
<tr>
<th>Year</th>
<th>Pond Type</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before 2001</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
</tr>
<tr>
<td>2001</td>
<td>84%</td>
<td>68%</td>
<td>71%</td>
<td>93%</td>
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<tr>
<td>2002</td>
<td>84%</td>
<td>68%</td>
<td>71%</td>
<td>93%</td>
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<tr>
<td>2003</td>
<td>84%</td>
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<td>71%</td>
<td>93%</td>
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<td>2005</td>
<td>84%</td>
<td>68%</td>
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### Bird Exposure Durations by Pond Type

#### Pre-Hazing Years

<table>
<thead>
<tr>
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<th>&quot;A&quot; Ponds</th>
<th>&quot;B&quot; Ponds</th>
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<th>&quot;D&quot; Ponds</th>
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<tr>
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<td>&lt;1 Hour</td>
<td>1 - 6 Hours</td>
<td>&gt;6 Hours</td>
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<tr>
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### Allocation of Birds by Pond Type (Percentage)

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### Estimate of Total Birds at All Ponds (Number)

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<td>= Cells requiring an input value</td>
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<tr>
<td>-------------------------------------------------------</td>
<td>---------------------------------</td>
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<tr>
<td>35% = Natural mortality rate of birds (percentage)</td>
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<tr>
<td>2.3 = Average lifespan of birds in years</td>
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<td>2005 = Base year for discounting</td>
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<td>3% = Real discount rate</td>
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</table>
### Input Values for Debit Calculations for Each Pond Type

- **Hazing Year Cells requiring an input value**
- **Pre-Hazing Data Cells requiring an input value**

#### Multiple Counting Adjustment by Pond Type (Percentage)

<table>
<thead>
<tr>
<th>Year</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2001</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
<td>72%</td>
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<tr>
<td>2001</td>
<td>84%</td>
<td>68%</td>
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<td>2005</td>
<td>84%</td>
<td>68%</td>
<td>71%</td>
<td>93%</td>
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</table>

#### Bird Exposure Durations by Pond Type

<table>
<thead>
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<th>Year</th>
<th>&lt;1 Hour</th>
<th>1 - 6 Hours</th>
<th>&gt;6 Hours</th>
<th>Sum % 100%?</th>
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<td>20%</td>
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<td>2003</td>
<td>6%</td>
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<tr>
<td>2005</td>
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<td>68%</td>
<td>71%</td>
<td>93%</td>
</tr>
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</table>

#### Allocation of Birds by Pond Type (Percentage)

<table>
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<tr>
<th>Year</th>
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<th>B</th>
<th>C</th>
<th>D</th>
<th>TOTAL</th>
<th>Un-adjusted/Pond</th>
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Input Values for Debit Calculations for Each Pond Type

- Hazing Year Cells requiring an input value
- Pre-Hazing Data Cells requiring an input value

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Bird Exposure Durations by Pond Type

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Allocation of Birds by Pond Type (Percentage)

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### Multiple Counting Adjustment by Pond Type (Percentage)

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Total Number of Birds Landing on Mine Ponds in Year X

Adjust Bird Number Downward for Natural Mortality

Adjust Bird Number Downward for Observer Error

Total Number of Birds Exposed to Acidic, Metal-Rich Water

Exposed <1 Hour

% Birds Killed

% Birds Otherwise Injured

% Injured Birds Recovering

Exposed 1-6 Hours

Exposed >6 Hours

Total Number of Birds Exposed to Neutral, Low-Metals Water

Total Number of Birds Killed in Year X
### Input Values for Debit Calculations for Each Pond Type

- 35% = Natural mortality rate of birds (percentage)
- 2.3 = Average lifespan of birds in years
- 2005 = Base year for discounting
- 3% = Real discount rate

### Multiple Counting Adjustment by Pond Type (Percentage)

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<thead>
<tr>
<th>Year</th>
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<th>C</th>
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### Bird Exposure Durations by Pond Type

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### Allocation of Birds by Pond Type (Percentage)
Based on SK's Allocation Table

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Total Number of Birds Landing on Mine Ponds in Year X

Adjust Bird Number Downward for Natural Mortality

Adjust Bird Number Downward for Observer Error

Total Number of Birds Exposed to Acidic, Metal-Rich Water

Exposed <1 Hour

Exposed 1-6 Hours

Exposed >6 Hours

% Birds Killed

% Birds Otherwise Injured

% Injured Birds Recovering

Total Number of Birds Exposed to Neutral, Low-Metals Water

Total Number of Birds Killed in Year X
### Input Values for Debit Calculations for Each Pond Type

- **Hazing Year Cells requiring an input value**
- **Pre-Hazing Data Cells requiring an input value**

#### Multiple Counting Adjustment by Pond Type (Percentage)

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#### Bird Exposure Durations by Pond Type

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#### Allocation of Birds by Pond Type (Percentage)

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<td>94.9</td>
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<td>Pre-Hazing Years</td>
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<td></td>
<td>Sum = 100%?</td>
<td>&quot;B&quot; Ponds</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>----------</td>
<td>----------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td>&lt;1 Hour</td>
<td>1 - 6 Hours</td>
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<td>42%</td>
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<td>6%</td>
<td>80%</td>
<td>14%</td>
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<td>17%</td>
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</tbody>
</table>
Total Number of Birds Landing on Mine Ponds in Year X

Adjust Bird Number Downward for Natural Mortality

Adjust Bird Number Downward for Observer Error

Total Number of Birds Exposed to Acidic, Metal-Rich Water

Exposed <1 Hour

% Birds Killed

% Birds Otherwise Injured

% Injured Birds Recovering

Exposed 1-6 Hours

Exposed >6 Hours

Total Number of Birds Exposed to Neutral, Low-Metals Water

Total Number of Birds Killed in Year X
### CONTAMINANTS IN PONDS

<table>
<thead>
<tr>
<th>Exposure Duration</th>
<th>Pond Category</th>
<th>&quot;A&quot; Ponds</th>
<th>&quot;B&quot; Ponds</th>
<th>&quot;C&quot; Ponds</th>
<th>&quot;D&quot; Ponds</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 hour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incur lethal exposure</td>
<td></td>
<td>20%</td>
<td>0%</td>
<td>25%</td>
<td>20%</td>
</tr>
<tr>
<td>Incur sub-lethal injuries from exposure</td>
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<td>10%</td>
<td>0%</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>Incur no effects</td>
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<td>70%</td>
<td>100%</td>
<td>70%</td>
<td>70%</td>
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<tr>
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<td>YES</td>
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<td>1 - 6 hours</td>
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<tr>
<td>Incur lethal exposure</td>
<td></td>
<td>30%</td>
<td>0%</td>
<td>35%</td>
<td>30%</td>
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<tr>
<td>Incur sub-lethal injuries from exposure</td>
<td></td>
<td>15%</td>
<td>0%</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Incur no effects</td>
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<td>55%</td>
<td>100%</td>
<td>55%</td>
<td>55%</td>
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<tr>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Recover from sub-lethal exposure</td>
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<td>50%</td>
<td>100%</td>
<td>40%</td>
<td>50%</td>
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<tr>
<td>&gt; 6 hours</td>
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<td>60%</td>
<td>45%</td>
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<td>25%</td>
<td>0%</td>
<td>20%</td>
<td>25%</td>
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<tr>
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<td>100%</td>
<td>20%</td>
<td>30%</td>
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<tr>
<td>SUBTOTAL = 100%?</td>
<td></td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Recover from sub-lethal exposure</td>
<td></td>
<td>35%</td>
<td>100%</td>
<td>20%</td>
<td>35%</td>
</tr>
</tbody>
</table>
So, you have “X” DLBY’s, now what??

- Avoid temptation to apply a “buck-a-duck” approach to offsetting service losses.

- Unless you’re captive breeding birds, you need to figure out how much habitat you need to generate “x” number of discounted lost bird years.

- Must determine service benefits of a particular restoration project, over and above baseline.

- If a cash-settlement is possible, you then have to determine the cost of the restoration projects.
<table>
<thead>
<tr>
<th><strong>RESTORED WETLAND/PONDED HABITAT</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acres of restored wetland/ponded habitat</td>
<td>40</td>
</tr>
</tbody>
</table>

**Maturity function parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipated start year for restoration project</td>
<td>2007</td>
</tr>
<tr>
<td>Anticipated year for project to reach maximum bird production</td>
<td>2017</td>
</tr>
<tr>
<td>Additional birds expected IN FIRST YEAR OF RESTORATION per acre of restored wetland/ponded habitat</td>
<td>10</td>
</tr>
<tr>
<td>Additional birds expected IN YEAR WHEN RESTORATION REALIZES MAXIMUM PRODUCTION per acre of restored wetland/ponded habitat</td>
<td>15</td>
</tr>
<tr>
<td>Additional years of project benefits at maximum bird production</td>
<td>20</td>
</tr>
<tr>
<td>Final year of credit for bird production in restored wetland/ponded habitat</td>
<td>2037</td>
</tr>
<tr>
<td>Number of days/yr additional wetland/ponded birds at site</td>
<td>90</td>
</tr>
</tbody>
</table>

**Total additional present value birds provided by restoration of wetland/ponded habitat**

2,638 DLBYYs
Additional Considerations for Restoration Project Crediting

Project X restoration crediting assumed service increases due to:
- Reduced chance of greater grazing pressure (2%)
- Reduced chance of development (16%)
- Elimination of grazing/grassland recovery (54%)
- A 2x multiplier for high value habitat benefits

Other crediting options
- High value species multiplier
- Benefits to species/habitats not injured
- Transfer ratio for restoration of habitats different than those injured
- Success probability
Converting Services to $$

- Restoration planning (including environmental compliance)
- Project implementation (including cost & success contingencies)
- Long-term operation and maintenance
- Trustee oversight and implementation monitoring
- Biological monitoring to evaluate success
The long-term mean of the ratio of an area’s mean annual precipitation to its mean annual potential evapotranspiration is the Aridity Index (AI).

Notes: The map is based on data from UNEP Geo Data Portal (http://geodata.grid.unep.ch/). Global area based on Digital Chart of the World data (147,573,196.6 square km); Data presented in the graph are from the MA core database for the year 2000.
• Put a nice habitat shot here, preferably one of SW AZ/SE NM habitat.