Ecosystem Services in the Context of Natural Resource Damage Assessment – An Oil Spill Case Study

Greg Baker – National Ocean Service
Natalie Cosentino-Manning – National Marine Fisheries Service

Damage Assessment Remediation and Restoration Program
Topics

- Characteristics of oil spill NRDAs
- Evidence gathering
- Assessment approaches
  - How ecosystem services are assessed
- Case study
  - *M/V Cosco Busan* allision, Nov 7, 2007 in San Francisco Bay
  - Assessing lost services in eelgrass habitat
Potential Components of Pollution Cases

• Response costs
• Penalties
• Natural resource damages
• Other claims
  • Public entities (lost tax revenue, lost parking fees, extra staff time, etc.)
  • Private claims (lost income, property damage, etc.)
Special considerations for oil spills

• Important data are ephemeral
  – Little time to plan and execute data gathering
    • Triage focus areas for assessment
  – Need for coordination / potential interference with emergency response activities

• Lost human use may be large component of the overall damages
  – Human use data also ephemeral
  – Increased public awareness

• Emergency restoration

• Duration of reduced ecosystem services may be shorter than at chronic contamination sites
Initial Data Collection

• Documentation of baseline conditions
  – Historical monitoring
  – On scene prior to arrival of oil (if possible)
  – Post-recovery
• Documentation of impacted conditions
  – Field surveys, sample collection, photographs
  – Novel sources of injury evidence, public involvement

Subsequent Data Collection

• Service loss duration and recovery curves
• Other studies
Federal Oil Pollution Act of 1990 (OPA) and Natural Resource Services

Loss of natural resource services is included in the definition of “injury” under the OPA regulations.

Natural resource services means, “The functions performed by a natural resource for the benefit of another natural resource and/or the public”

– Ecological services
– Human services
Cases and Ecosystem Services in California

Over 30 cases

- Wetlands
- Rocky intertidal
- Sandy beaches
- Mudflats
- Riparian
- Stream
- Eelgrass
- Birds
- Fish
- Marine mammals
- Human uses
The NRDA process for oil spills

1) Oil Spill
2) Initial Data Collection
   3) Coordination with Response / Public Information
4) Further Data Collection and Analysis
   5) Injury and Damage Quantification
6) Public Scoping Meeting
   7) Draft Restoration Plan – public comment
8) Final Restoration Plan
   9) Implement Restoration Projects

WE ARE HERE
Assessment of Human Use Services

Studies

• Documentation of closures (beaches, piers, fishing, special events, etc.)
• Surveys - during the spill – after the spill
• Estimation of lost user-days by activity (post spill visitor counts)
• Valuation of lost user-days by activity (literature or site-specific)

Basic Calculation

Lost Use Value =

(# of lost user-days) X ($ per lost user-day)

More than 50 beaches, piers, and coastal access points closed during Cosco Busan spill
Ecological Services – Habitat Equivalency Analysis

To assess equivalency, resource injuries and restoration benefits are quantified in terms of services

- Services may entail one or several functional or structural attributes of an ecosystem

- Challenge: express ecological service losses in a way that integrates available information about multiple toxicity end points into a single measure of ecological services (Cacela et al 2005)
Habitat/Resource Equivalency Analysis

Service Acre-Years Of Loss Due to Spill = Service Acre-Years Gained from Restoration Project

- **Value of Habitat**
- **Initial Level**
- **Spill** (Baseline)
- **Injury** (Recovery)
- **Primary Restoration**
- **Compensatory Restoration**
- **Project Benefits**
- **Time**
Case-Specific Injury Studies or Scientific Literature?

- Presence of oil documented
- Exposure data (chemistry)
- Injury evidence – linked to source oil
- Data on degree and duration of injury
- Reliance on previous cases and literature

- Tiered approach
Synthesizing data to scale lost ecosystem services for habitats

**Example: Ecological services / functions attributed to salt marsh habitats**

<table>
<thead>
<tr>
<th>Ecological Services</th>
<th>Function</th>
<th>Examples of Metrics</th>
<th>Consideration given for Injury Quantification</th>
</tr>
</thead>
</table>
| Primary production  | Production of plant material that forms the base of the primary food web and the detrital food web. | Above-ground biomass  
Below-ground biomass  
Stem density  
Species composition, diversity | Medium: a key service that is related to other services; good literature on oil-spill effects |
| Habitat for biota   | Marshes serve as physical habitat for a variety of organisms including birds, mammals, reptiles, insects, fish and a suite of invertebrates. | Canopy architecture of vegetation  
Above-ground biomass  
Degree of usage by birds, mammals, etc. | High: a key service that is related to other services; good literature on oil-spill effects |
| Food web support    | Related to primary productivity but encompasses the entire system including invertebrates that are food for higher trophic levels that may only spend minor amounts of time in the wetland. | Density and biomass of living vegetation, infauna and epifauna  
Macrophyte and benthic algae detritus  
Degree of use by higher trophic levels | High: a key service; direct oiling of marsh vegetation and sediment surface; good literature on oil-spill effects |
Synthesizing data to scale lost ecosystem services for habitats

<table>
<thead>
<tr>
<th>Author</th>
<th>Key Taxa</th>
<th>Spill/Location/Amount</th>
<th>Stage/Phase</th>
<th>Noted Recovery</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chan 1975</td>
<td>Barnacles, Mytilus californianus, limpets, Tegula, Pachygrapsus crassipes, Pollicipes</td>
<td>Arizona/Standard/Golden Gate/800,000</td>
<td>Pachygrapsus/Hemigrapsus/Sausalito approx 1 yr</td>
<td>Most algae recovered to prespill densities CA mussels @ higher densities post-spill P. crassipes at Duxbury still below pre-spill levels at 3 yrs post</td>
<td>Noted mortality to key taxa listed. Study site on open coast, high exposure</td>
</tr>
<tr>
<td>Duncan &amp; Hooten 1996</td>
<td>Fucus germlings, limpets, periwinkles (littorines)</td>
<td>Valdez/AK/lots</td>
<td>Fucus recruitment</td>
<td>50-100% reduction in recruitment of Fucus germlings. Similar range for grazers</td>
<td>Categorize as Light-Moderate Oiling? Tests done on 50% stained substrates</td>
</tr>
<tr>
<td>Kinnetics Lab 1992</td>
<td>Fucus/Endocladia/Mastocarpus papillatus</td>
<td>Barge NESTUCCA, Washington and Vancouver Island; 231,000 gal Bunker C fuel</td>
<td>&gt;3 yrs</td>
<td>Rocky intertidal assemblages of 2 out of 5 oiled sites studied recovered. No oiled and cleared sites recovered. (Oiled had &gt;30%)</td>
<td>Categorize as Moderate Oiling?</td>
</tr>
<tr>
<td>Foster et al. 1988 [synthesis]</td>
<td>Mytilus californianus</td>
<td>NA/Oregon NA/ Montery CA NA/WA NA/Bodega, CA</td>
<td>&gt; 8 yrs 2.5 yrs 5-7 yrs &gt;&gt;3 yrs</td>
<td>Most algal recovery to prespill densities CA mussels @ higher densities post-spill P. crassipes at Duxbury still below pre-spill levels at 3 yrs post</td>
<td>Synthesis of studies, Clearings.</td>
</tr>
<tr>
<td>Foster et al. 1988 [synthesis ]</td>
<td>Prionitis</td>
<td>NA/Montery, CA</td>
<td>&gt;7 yrs</td>
<td>Most algal recovery to prespill densities CA mussels @ higher densities post-spill P. crassipes at Duxbury still below pre-spill levels at 3 yrs post</td>
<td>Synthesis of studies, Clearings.</td>
</tr>
</tbody>
</table>
# Service Losses from Previous Cases

<table>
<thead>
<tr>
<th>SPILL</th>
<th>SAND</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VL</td>
</tr>
<tr>
<td></td>
<td>Yrs after spill/services present</td>
</tr>
<tr>
<td>Bouchard No. 120</td>
<td>0/90%</td>
</tr>
<tr>
<td></td>
<td>0.5/90%</td>
</tr>
<tr>
<td>Athos (sand/mud)</td>
<td>0/50%</td>
</tr>
<tr>
<td></td>
<td>2/95%</td>
</tr>
<tr>
<td>Kure (sand/gravel)</td>
<td>0/90%</td>
</tr>
<tr>
<td></td>
<td>30 days/100%</td>
</tr>
<tr>
<td>Kure (mudflats)</td>
<td>0/90%</td>
</tr>
<tr>
<td></td>
<td>10 days/0%</td>
</tr>
<tr>
<td>Stuyvesant *</td>
<td>0.25/90%</td>
</tr>
<tr>
<td>Cape Mohican (beaches)**</td>
<td>0.25/90%</td>
</tr>
<tr>
<td>Cape Mohican (mudflats)***</td>
<td>1/90%</td>
</tr>
</tbody>
</table>
Case Study – M/V Cosco Busan
7 November 2007, San Francisco Bay

- Early morning fog
- Allision with bridge
- Human error
- 53,000 gallons of bunker fuel
- Central bay and outer coast
NOAA Spill Trajectory Simulation

M/V Cosco Busan Nov. 7, 2007 08:30
Spill Hour 0 – 32
11/07/2007 08:30

NOAA Spill Trajectory Simulation

Release Track Line
Cosco Busan NRDA to Date

- Divided into seven teams according to injured resource category:
  - birds
  - mammals
  - fish
  - marsh and beach habitat
  - rocky intertidal habitat
  - eelgrass habitat
  - human uses
Shoreline oiling

- Shoreline Cleanup and Assessment Team (SCAT)
- Response and clean-up
- Not designed for NRDA
- Agreed upon method
- Additional data needed for NRDA
Angel Island, Marin County

Before

After
<table>
<thead>
<tr>
<th>Degree of oiling</th>
<th>Length of shoreline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy</td>
<td>1.9 miles</td>
</tr>
<tr>
<td>Moderate</td>
<td>6.0 miles</td>
</tr>
<tr>
<td>Light</td>
<td>23 miles</td>
</tr>
<tr>
<td>Very Light</td>
<td>68 miles</td>
</tr>
<tr>
<td>No Observed Oil</td>
<td>272 miles</td>
</tr>
<tr>
<td>Total shoreline</td>
<td>371 miles</td>
</tr>
</tbody>
</table>
EELGRASS (Zostera marina)

• Angiosperm – expands rhizomes and seeds
• Not a weed
• 3,000 acres in SF Bay (2002) (<1%)
• Most beds Central and North Bay
  • Intertidal and subtidal
• Provides refuge, food and spawning habitat (EFH)
• Erosion control
• Many efforts to restore ($ NOAA, SCC, OPC)
• Total acreage within impacted area: Pending
• Total acreage affected: Pending
EELGRASS – Site Selection for NRDA

- Moderate to heavy oiling
- Previous data
- Intertidal sites
- Control sites
Documenting injury to eelgrass

**Exposure**
- PAH analysis
- Plants: smothering
- Sediments: uptake

**Response**
- death, reduced growth and reproduction

**Documentation**
- Photosynthesis
- Stress - Phenolics
- Seed viability*
- Rhizomes
- Shoot density
- Percent cover

**Base-line data, natural variability**

*Photo by UW*
Documenting injury to eelgrass community

Invertebrates

Exposure
PAH analysis
Invertebrates
(Tissue)

Response
smothering
uptake
dearth

Documentation
Abundance
Species diversity

Base-line data,
natural variability

Photos by SFSU
### SUMMARY (Eel Grass)

<table>
<thead>
<tr>
<th>Category</th>
<th>$A_i$</th>
<th>$\Sigma$</th>
<th>$A_i \Sigma$</th>
<th>$(A_i \Sigma)/\text{Total}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy</td>
<td>17.6</td>
<td>0.85</td>
<td>14.93</td>
<td>12.5%</td>
</tr>
<tr>
<td>Moderate</td>
<td>11.4</td>
<td>0.52</td>
<td>5.92</td>
<td>5.0%</td>
</tr>
<tr>
<td>Light</td>
<td>118.8</td>
<td>0.22</td>
<td>26.51</td>
<td>22.2%</td>
</tr>
<tr>
<td>Very Light</td>
<td>771.4</td>
<td>0.09</td>
<td>71.83</td>
<td>60.3%</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>919.2</strong></td>
<td><strong>1.68</strong></td>
<td><strong>119.19</strong></td>
<td><strong>100.0%</strong></td>
</tr>
<tr>
<td>$r$</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
- $A_i$: Area of category (acres)
- $\Sigma$: dSAY per acre of category (spill at t=0)
- $A_i \Sigma$: Total dSAY per category

### SERVICE TRAJECTORIES BY INJURY CATEGORY

<table>
<thead>
<tr>
<th>Heavy</th>
<th>Service Time</th>
<th>Service</th>
<th>Moderate</th>
<th>Service Time</th>
<th>Service</th>
<th>Light</th>
<th>Service Time</th>
<th>Service</th>
<th>Very Light</th>
<th>Service Time</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>5%</td>
<td>0.00</td>
<td>10%</td>
<td>0.00</td>
<td>50%</td>
<td>0.00</td>
<td>75%</td>
<td>0.00</td>
<td>75%</td>
<td>0.00</td>
<td>75%</td>
</tr>
<tr>
<td>0.25</td>
<td>5%</td>
<td>0.25</td>
<td>25%</td>
<td>0.25</td>
<td>60%</td>
<td>0.25</td>
<td>80%</td>
<td>0.25</td>
<td>80%</td>
<td>0.25</td>
<td>80%</td>
</tr>
<tr>
<td>0.50</td>
<td>10%</td>
<td>0.50</td>
<td>50%</td>
<td>0.50</td>
<td>75%</td>
<td>0.50</td>
<td>95%</td>
<td>0.50</td>
<td>95%</td>
<td>0.50</td>
<td>95%</td>
</tr>
<tr>
<td>0.75</td>
<td>50%</td>
<td>0.75</td>
<td>75%</td>
<td>0.75</td>
<td>100%</td>
<td>0.75</td>
<td>100%</td>
<td>0.75</td>
<td>100%</td>
<td>0.75</td>
<td>100%</td>
</tr>
<tr>
<td>1.00</td>
<td>75%</td>
<td>1.00</td>
<td>90%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>100%</td>
<td>1.50</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Graph:
- **Baseline**
- **Heavy**
- **Moderate**
- **Light**
- **Very Light**

<table>
<thead>
<tr>
<th>% Service</th>
<th>Time (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>20%</td>
<td>1</td>
</tr>
<tr>
<td>40%</td>
<td>2</td>
</tr>
<tr>
<td>60%</td>
<td>3</td>
</tr>
<tr>
<td>80%</td>
<td>4</td>
</tr>
<tr>
<td>100%</td>
<td>5</td>
</tr>
</tbody>
</table>
Keil Cove Scar

- Discovered in March after routine side scan
Potential Restoration Projects

• Select restoration projects
  – Creation of new bed (seed buoys, transplants)
  – Expansion of newly restored beds (seed buoys, transplants)
  – Replacement of anchor chains in Sausalito
  – Creosote piling removal
  – Acquisition/protection of subtidal property – eelgrass potential
ACKNOWLEDGEMENTS

NOAA doesn’t do this work alone. We rely on our State and Federal co-Trustees and other partners.

Special thanks to:

-- California Department of Fish and Game
   Office of Spill Prevention and Response (OSPR)

-- California State Lands Commission

-- U.S. Department of Interior
   Fish and Wildlife Service
   National Park Service
   Bureau of Land Management

-- Research Planning, Inc.
Questions/discussion?