How to manage oil spill risks (in the Baltic Sea)?

ECGS-501 Management of environmental problems in aquatic ecosystems

Inari Helle
Fisheries and Environmental Management group (FEM)
Department of Environmental Sciences
University of Helsinki
inari.helle@helsinki.fi
1. Introduction
   - **D**: Oil demand, maritime traffic
   - **P**: Maritime accidents
   - **S**: Oil in aquatic environment
   - **I**: Impacts of oil spills
   - **R**: Management measures

2. Oil spill risks in the Gulf of Finland: a cost-benefit approach
Oil transportation in the Gulf of Finland

OIL TRANSPORTATION IN THE GULF OF FINLAND 1995-2015

Source: SYKE

2.5.2015

Others = Inkoo + Helsinki + Kotka/Hamina + Sillamäki + Vene-Balti
Estimated capacity in year 2015 is 235 million tonnes

Source: SYKE
Global oil demand

Maritime transportation

- The most cost-effective way to carry goods/people
- > 90% of the world's trade is carried by sea

Maritime traffic

Maritime traffic in the Baltic Sea

• "On average 2 000 ships at sea each day"

• Environmental effects
  – Exhaust gas emissions: eutrophication and air quality
  – Sewage: eutrophication
  – Alien species
  – Noise, toxic anti-fouling paints...
  – Oil accidents and illegal oil discharges

Source: HELCOM
Maritime accidents

Number of reported accidents in the Baltic Sea

- No information
- No pollution
- Pollution

P

Collision 18%
Contact 20%
Other type 29%
Grounding 29%
Pollution 4%

Source: HELCOM (2014); Annual report on shipping accidents in the Baltic Sea in 2013

HELCOM
Accidents involving tankers in the Baltic Sea in 2004-2013

Year: SH1_Categ, SH2_Categ
- 2013 (18)
- 2012 (21)
- 2011 (25)
- 2010 (17)
- 2009 (22)
- 2008 (16)
- 2007 (18)
- 2008 (14)
- 2005 (22)
- 2004 (15)

Total number of tanker accidents: 188
Data by: DE, DK, EE, FI, LT, LV, PL, RU, SE
Oil discharges from ships

- In 2016, 53 detected discharges, decreasing trend

Source: HELCOM (2017): Annual report on Discharges observed during aerial surveillance in the Baltic Sea 2016
Behaviour of oil and weathering
Possible impacts of oil accidents

• Personal injuries
• Loss of ship and/or cargo
• Impacts of oil on
  – the environment
  – livelihoods: fisheries and tourism industries
  – recreational use
  – real estate prices
  – etc.
• Oil spill combating and clean-up costs
Ecological impacts

- Oil type
- Weather
- Season
- Spill volume
- Location

Fate of oil
Areal extent of oil spill

Spatial distribution of species
Exposed population
Sensitivity

Behaviour

Acute impact
ACUTE IMPACTS

- Intoxication
- Smothering
- Immunosupression
- Growth impairment
- Developmental disorders

Acute death
Sublethal effects

LONG-TERM IMPACTS

Reproduction
Habitats
Foodwebs
Interactions
Prediction is difficult...

- Amoco Cadiz
- Exxon Valdez
- Unknown vessel

- Spill size (tons)
- Dead birds (ind.)
Possible impacts of oil accidents

• Personal injuries (€)
• Loss of ship and/or cargo €
• Impacts of oil on
  – the environment (€)
  – livelihoods: fisheries and tourism industries €
  – recreational use €
  – real estate prices €
  – etc.
• Oil spill combating and clean-up costs €
Example: *Prestige*

- The tanker split in half and sunk in the coast of Galicia in November 2002
- > 60 000 t of heavy oil was spilled
- > 1300 km of coastline were polluted
- 115 000–230 000 birds died etc.

<table>
<thead>
<tr>
<th>Commercial and environmental</th>
<th>M €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>112.66</td>
</tr>
<tr>
<td>Mussel sector</td>
<td>12.83</td>
</tr>
<tr>
<td>Canning and fish processing</td>
<td>26.77</td>
</tr>
<tr>
<td>Tourism sector</td>
<td>110.55</td>
</tr>
<tr>
<td>Recreation</td>
<td>NA</td>
</tr>
<tr>
<td>Birds and mammals</td>
<td>25.12</td>
</tr>
</tbody>
</table>

**Total** 287.93

**Clean-up**

- Cleaning and recovery 351.52
- Extraction of fuel inside tanker 100
- Recycling of residuals 32
- Volunteers 4
- Other 21.9

**Total** Yhteensä 509.42

**Other expenditures**

- Transfers due to fishing bans 134.3
- Other compensations 94

**Total** 228.3

**TOTAL** 1025.65 M €

Who pays?

• PPP, but...
  – Finnish Oil Pollution Compensation Fund
  – Tankers: IOPC Funds (1992 Fund and Supplementary Fund)

• Compensation limit
• Only certain types of damages

More information: www.iopcfunds.org
How to reduce risks?

Decrease the probability of accidents and oil spills (pre-spill)

**Ships:** structure, condition etc.

**Mariners:** education, working conditions...

**Navigation:**
- VTS
- GOFREP
- ENSI
- Traffic separation schemes, routing
- Piloting
- Ice breaking assistance
- Waterways, navigation charts etc.

Minimize the impacts of oil spills (post-spill)

**Offshore oil combating:**
- Mechanical recovery

**Shoreline combating:**
- Booms, skimmers, sorbents
- Manual and mechanical clean-up
Prevention

- Construction/equipment of ship: IMO (EU)
- Ship condition: IMO, EU, firms
- Mariners: IMO, ILO
- Navigation
  - VTS: IMO
  - GOFREP: Regional (IMO)
  - Traffic separation schemes: IMO (reg. + states)
  - Piloting: States
  - Ice class, ice breaking services: States

Prevention

• VTS – Vessel Traffic Services
  – VTS centers provide information, navigational assistance and traffic organization for vessels in VTS areas (territorial waters)
  – Monitor vessel movements in real time based on information transmitted by AIS, radars, cameras and VHF radio

• GOFREP – Gulf of Finland is a Mandatory Ship Reporting System
  – VTS centers in Tallinn, Helsinki and St. Petersburg monitor shipping movements and provide advice and information (e.g. about weather conditions) in the international waters of the GoF
  – Further, Estonia and Finland have implemented mandatory ship reporting systems in their territorial waters outside their VTS areas

• Traffic Separation Schemes
  – Idea is to guide ships to the lanes so that ships can anticipate the movements of other ships

• Piloting
  – In Finland, ships with a length of over 60 m, a breadth of over 10 m, or which carry dangerous cargo
General guidance and monitoring concerning prevention of and response to oil spills

- Ministry of the Environment
  - SYKE
    - Advisory board Authorities + volunteers
    - Response commander
      - RC’s staff
        - Surveillance, situation picture, special transports and forecasts etc
      - Rescue Services Coastal areas and shore
      - SYKE Oilied animals
      - ELY centres
        - Prevention of and response to land-based oil spills and oil spills from ships within their area
          - Volunteers
            - Municipality / Rescue Services
              - Post spill restoration

Advice and supervise the local municipalities in arranging the pollution preparedness and response.

Source: SYKE
Offshore oil combating

• In the Baltic, oil combating is based on mechanical recovery (HELCOM recommendation 22/2)
• Finland has 19+1 oil recovery vessels capable of recovering oil independently in offshore conditions
• Encirclement by booms (if possible) + oil recovery with mechanical recovery devices
• Outcome highly dependent e.g. on wave height, currents and oil type
Shoreline combating and clean-up

- If/when oil approaches shoreline: regional rescue services
- Oil still afloat: deflection booms and recovery with skimmers etc.
- Oil washed ashore: mechanical and manual clean-up
- Always slow and expensive!
Where to invest?

Should we invest in preventive measures or post-spill measures or neither or both...

... given that we do not know whether there actually will be a spill...

... and given that in case of spill, there exist large uncertainties related to the spill size, oil type as well as e.g. the efficiency of oil combating?

PROBAPS: Protection of the Baltic Sea: Benefits, Costs and Policy Instruments

Methods: Bayesian networks

• Models, which describe variables and probabilistic dependencies between them
• Can integrate knowledge from different sources: modelling results, statistics, expert knowledge etc.
• Decision and utility variables → influence diagrams
  – How effective different management measures are?
  – How large are uncertainties?
  – What is the optimal combination of the decisions?
## Example

**Spill size (t)**

<table>
<thead>
<tr>
<th>Spill size (t)</th>
<th>0-500</th>
<th>500-1000</th>
<th>1000-5000</th>
<th>5000-15000</th>
<th>15000-30000</th>
<th>&gt; 30000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-500</td>
<td>0.87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000-5000</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5000-15000</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15000-30000</td>
<td>0.013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;30000</td>
<td>0.007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Spill size**

- μ = 1215, σ^2 = 1.56E7

<table>
<thead>
<tr>
<th>Spill size (t)</th>
<th>0-500</th>
<th>500-1000</th>
<th>1000-5000</th>
<th>5000-15000</th>
<th>15000-30000</th>
<th>&gt; 30000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000-5000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5000-15000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15000-30000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;30000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Spill size (t)**

<table>
<thead>
<tr>
<th>Spill size (t)</th>
<th>0-500</th>
<th>500-1000</th>
<th>1000-5000</th>
<th>5000-15000</th>
<th>15000-30000</th>
<th>&gt; 30000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000-5000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5000-15000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15000-30000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;30000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Oiled coastline (km)**

<table>
<thead>
<tr>
<th>Oiled coastline (km)</th>
<th>0-500</th>
<th>500-1000</th>
<th>1000-5000</th>
<th>5000-15000</th>
<th>15000-30000</th>
<th>&gt; 30000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-50</td>
<td>0.13</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50-100</td>
<td>0</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100-300</td>
<td>0</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>300-600</td>
<td>13.23</td>
<td>0.16</td>
<td>0.10</td>
<td>0.06</td>
<td>0.10</td>
<td>0.06</td>
</tr>
<tr>
<td>600-1000</td>
<td>0.25</td>
<td>0.10</td>
<td>0.06</td>
<td>0.03</td>
<td>0.14</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**Oiled coastline**

<table>
<thead>
<tr>
<th>Oiled coastline (km)</th>
<th>0-50</th>
<th>500-1000</th>
<th>1000-5000</th>
<th>5000-15000</th>
<th>15000-30000</th>
<th>&gt; 30000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-50</td>
<td>0.13</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50-100</td>
<td>0</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100-300</td>
<td>0</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>300-600</td>
<td>13.23</td>
<td>0.16</td>
<td>0.10</td>
<td>0.06</td>
<td>0.10</td>
<td>0.06</td>
</tr>
<tr>
<td>600-1000</td>
<td>0.25</td>
<td>0.10</td>
<td>0.06</td>
<td>0.03</td>
<td>0.14</td>
<td>0.42</td>
</tr>
</tbody>
</table>
The model

• Two management alternatives
  – Automatic alarm system in VTS centers
  – New oil combating vessel
• Includes tanker groundings and collisions with other vessels
• Calculates the expected yearly amount of spilled oil
  → expected yearly combating and clean-up costs and environmental damages

*How will the management measures affect these?*
Costs and benefits

Costs:
• Development cost of the AAS
• Purchase cost + maintenance costs of the new vessel

Benefits:
• Expected decrease in oil combating and clean-up costs and in environmental damages
  – Offshore: oil recovery by vessels, storage, transportation and final processing of oily waste, aerial surveillance
  – Shoreline: manual and mechanical clean-up, storage, transportation and final processing of oily waste, booms and boats
  – Environmental losses people experience due to the negative impacts spilled oil has on the environment
Contingent valuation survey

- Finnish citizens' willingness to pay (WTP) for improvements in oil spill response capacity in the GoF (Ahtiainen 2007)
  - 360 respondents
- Probabilistic interpretation of the results of the original WTP survey (Juntunen et al., manuscript)
- Aggregated WTP was 122M euros [95–155]
- The estimated WTP was used to derive the marginal damage of a ton of spilled oil
## Results: Expected cost vs. benefits (/year)

<table>
<thead>
<tr>
<th>Decision</th>
<th>AAS</th>
<th>New vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State of the other decision</strong></td>
<td><strong>No</strong></td>
<td><strong>No</strong></td>
</tr>
<tr>
<td><strong>Costs/Benefits</strong></td>
<td><strong>C (€)</strong></td>
<td><strong>B (€)</strong></td>
</tr>
<tr>
<td>Development of AAS</td>
<td>-33 200</td>
<td></td>
</tr>
<tr>
<td>Purchase costs of new vessel</td>
<td>-2 720 000</td>
<td></td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>-264 000</td>
<td></td>
</tr>
<tr>
<td>Offshore oil combating</td>
<td>2 000</td>
<td>-17 200</td>
</tr>
<tr>
<td>Waste operations (offshore)</td>
<td>500</td>
<td>-1 000</td>
</tr>
<tr>
<td>Shoreline combating</td>
<td>6 800</td>
<td>7 700</td>
</tr>
<tr>
<td>Waste operations (shore)</td>
<td>8 200</td>
<td>23 600</td>
</tr>
<tr>
<td>Environmental damages</td>
<td>280 000</td>
<td>830 000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>-33 234</strong></td>
<td><strong>-3 002 200</strong></td>
</tr>
<tr>
<td><strong>NBV</strong></td>
<td><strong>264 000</strong></td>
<td><strong>-2 141 000</strong></td>
</tr>
</tbody>
</table>
Discussion

Why are not the benefits of the new vessel (even) larger?

• According to the model, the probability of large-scale accidents is low
  – Probability of oil leakages from tankers is 8%
  – However, e.g. the probability that the spill is over 15 000 m³ is 3% (collisions) and 0.6% (groundings)

• Probability that the weather conditions are suitable only for the new vessel is only 3.2 %
  – But in that case decreases the amount of stranding oil by 16%

• The whole purchase cost was allocated to oil combating, although the vessel is a multipurpose vessel
# Oil combating costs (€)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spill size (m³)</td>
<td>3000</td>
<td>30 000</td>
</tr>
<tr>
<td>Oil type</td>
<td>Heavy</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Combating operations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offshore</td>
<td>1 500 000</td>
<td>1 500 000</td>
</tr>
<tr>
<td>Shoreline</td>
<td>4 000 000</td>
<td>14 700 000</td>
</tr>
<tr>
<td><strong>Waste treatment operations</strong></td>
<td>3 200 000</td>
<td>32 800 000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>8 700 000</strong></td>
<td><strong>49 000 000</strong></td>
</tr>
</tbody>
</table>

If there is only one day to recover oil offshore, the costs exceed **115 000 000 €**...
Situation in Finland

• In the GoF, the target is to recover 30 000 tons of oil within three days

• People have different risk attitudes: one is more willing to pay for preparedness than other, if possible losses are high (cf. insurances)

• For how big accident should we be prepared?

• Societal discussion has an important role
Summary

- The Baltic Sea has high maritime traffic densities and intense oil transportation
- Oil accidents have various kinds of impacts, some of which can be expressed in monetary terms (and some of which cannot)
- Risks can be managed with preventive and post-spill measures
  - E.g. maritime safety is regulated at many levels; international level is typically slow and reactive instead of being proactive
- Risks can never be eliminated totally
More information

- HELCOM
  - [http://www.helcom.fi/action-areas/shipping](http://www.helcom.fi/action-areas/shipping)
- Finnish Environment Institute’s oil pages:
  - [http://www.environment.fi/oil](http://www.environment.fi/oil)
- International Maritime Organization (IMO)
  - [www.imo.org](http://www.imo.org)