The Science of Risk Modeling and Modeling Approaches

Modeling Team
JD Ross Leahy (Presenter), Adam Byrd, Alex Suchar, Melba Salazar-Gutiérrez
Discussion topics

- Feedback on the foundational model approach?
- Feedback on the schedule and sequence for model development?
- How can we best provide you information and opportunities for input?

Legislative background

- ESHB 1578 was passed in 2019 to reduce the risk of oil spills, and protect Southern Resident Killer Whales

- Ecology's Spills Program tasked to undertake or assist with multiple policy initiatives in the bill, including the development of an oil spill risk model
Our project team

- Adam Byrd, PhD
  Database administration, Geographic Information Systems

- Alex Suchar, PhD
  Statistical and mathematical modeling

- Melba Salazar-Gutierrez, PhD
  Statistical and mathematical modeling

- JD Ross Leahy, Licensed Master
  Maritime operations

Research philosophy

- Transparent
  - Open
  - Inclusive

- Reproducible
  - Well documented
  - Methodologically sound

- Credible
  - Peer reviewed
  - Validated
Model development project goals

- Produce **a tool** to quantitatively assess current and potential oil spills risks from covered vessels in Washington waters
- Provide **a framework** for future oil spill risk analyses

Defining risk

- “A hazard, a probability, a consequence, or a combination of probability and severity of consequence.”
- “Risk is the combination of the likelihood of an event and the consequence if the event occurs.”
  - Dept of Ecology in Columbia River Vessel Traffic Evaluation and Safety Assessment (CRVTSA)
**Likelihood and consequence**

- The chance that a vessel will be involved in an accident, e.g.
  - Days at sea
  - Waterway conditions where the vessel operates

- The severity of the consequences of a vessel accident, e.g.
  - Injury
  - Damage to vessel
  - Damage to other property
  - Damage to environment

**Describing oil spill risk**

\[ Risk = P \times C \]

\[ Risk = f(S, P, C) \]

- \( P \) = probability of a vessel accident
- \( C \) = consequence of the accident
- \( S \) = various scenarios of what can go wrong in the system
Describing oil spill risk

- Scenarios
  - Hazard identification: collision, allision, grounding, explosion, etc.

- Probability
  - How likely is each identified hazard?

- Consequences
  - If an accident happens, how likely is that an oil spill occurs, where it will occur, and what volume of oil will be released?

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Vessel Loss of Propulsion

**CAUSES**
- Equipment failure
- Human error

**INCIDENT**
- Loss of Propulsion

**ACCIDENT**
- Grounding

**CONSEQUENCE**
- Oil Spill

**Intervention**
- e.g. maintenance
- e.g. tug escort
- e.g. double hull
A step by step approach to building modules

- **Vessel Movement Module**
- **Vessel Encounter Module**
- **Vessel Accident Module**
- **Oil Outflow Module**

**Timeline:**
- **Introduction:** June – August 2020
- **Model Development:** September 2020 – May 2021
- **Model Validation:** June – January 2022
Objective

- Represent vessel volume and distribution
- Simulate random traffic configurations that are based on data

Approach

- Aggregate routes from AIS
- Populate vessels on routes
- Proceed at a given timestep.
- Organize by vessel type
**Inputs and Data**
- AIS and other sources
- Common vessel routes
- Vessel characteristics
- Geographic range
- Navigational rules
- Temporal resolution
- Other factors

**Challenges**
- Noisy AIS dataset
- AIS provided vessel types not sufficient
- Smaller vessels and barges don’t have AIS
Objective

• Detect situations that could lead to accidents

When the relationship of a vessel to shore or another vessel creates the possibility of grounding or a collision

Approach

• Encounter detection based on various criteria

Indicator

Spatiotemporal proximity of the vessels

Safe boundary

Area around a vessel clear of other vessels

Minimum Distance to Collision

Minimum distance between two vessels that allows for collision avoidance
**Inputs and Data**
- Vessel navigational data
- Vessel characteristics
- Waterway characteristics
- Other encounter details

**Indicator**
- Spatiotemporal proximity of the vessels
- Relative distance
- Distance and Time to Closest Point of Approach (CPA)
- Bearing / Speed
- Vessel characteristics
- Waterway conditions

**Safe boundary**
- Area around a vessel clear of other vessels
- Circular
- Compound
- Elliptical
- Polygonal
- Empirical
Challenges
• Vessel behavior limited to AIS inputs
• Many approaches

Objective
• Determine likelihood of vessel accidents/spills for simulated scenarios

• Simulated scenarios include the following:
  • Groundings/Allisions
  • Collisions
  • Transfer Spills
  • Fire/explosion
  • Sinking
Approach
• Allow varying levels of complexity in accident probability estimation

Simple to complex
Probability of an accident, per encounter, per accident type
Probability of an accident, per encounter, per accident type & vessel characteristics
Probability of an accident, per encounter, per accident type, vessel characteristics & waterway conditions

Factors affecting probability
Probability of an accident given an encounter
Probability of LOP incident
Probability of other spills – transfer/fire
Drift model
Vessel Accident Module
Inputs and Data
- USCG MISLE database
- USCG accident reports
- IHS Markit (Lloyd’s)
- Transportation Safety Board (Canada)
- National Transportation Safety Board (US)
- Ecology incident data

Example accident data

Challenges
- Data availability
- Process uncertainty
**Objective**  
- Estimate the amount of oil that is spilled to water from a simulated accident

**Approach**  
- Estimate the amount of oil that is spilled to water from a simulated accident

- Simple to complex
- Statistical estimation of oil spill rates
- Mechanistic models of oil spills
- Combination of both approaches
Data and Inputs

- Vessel construction
- Tank location
- Amount of oil (cargo)
- Amount of oil (fuel)
- Oil type
- Accident details

Challenges

- Data availability for vessel characteristics
- Accurately simulating amount and type of onboard oil
A step by step approach to building modules

Running the model

- Integrated modeling approach
  - Both mathematical and statistical

- Stochastic simulation
  - Each model run will have unique outputs
Requirements for the model

- **Quantitative**
  - Measurable & numerical results
- **Covered vessels**
  - Vessel type specific
- **Tribe and stakeholder involvement**
  - Ongoing outreach and transparent approach
- **Account for changes in traffic**
  - Explicit modeling of vessel traffic
- **Evaluate risk reduction measures**
  - Explicit modeling of accident causes
- **Updatable**
  - Based on data

A flexible framework

- **Requests**
  - Consider USCG data on number and size of spills from oil barges
  - Deal with challenge of a lack of incidents to calibrate on
  - Use engineering analysis to consider force needed to cause oil outflow
- **Model Structure**
  - Uses historical data
  - Uses stochastic simulation
  - Includes oil outflow module
## A flexible framework

<table>
<thead>
<tr>
<th>Requests</th>
<th>Model Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consider the natural distribution of other tugs besides an ERTV</td>
<td>The simulator pulls from the historical distribution</td>
</tr>
<tr>
<td>Consider distribution of ships transiting in irregular patterns</td>
<td>The simulator pulls from the historical distribution</td>
</tr>
<tr>
<td>Differentiate between laden/unladen transits</td>
<td>Simulated vessels are uniquely represented</td>
</tr>
<tr>
<td>Include separate transit lines for tugs</td>
<td>Vessel typology allows for this</td>
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## A flexible framework

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<tr>
<td>Include fate, transport, and effects of a spill</td>
<td>Discrete model outputs</td>
</tr>
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<td>Compatibility with other models</td>
<td>Discrete model outputs</td>
</tr>
<tr>
<td>More robust treatment of spill consequence and impact</td>
<td>Initial description of consequence</td>
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</tbody>
</table>
Consequence

Model Outputs:
• Geographic location of spills
• Date and time of spills
• Type of oil spilled
• Amount of oil spilled
• Incident characteristics
• Accident characteristics

Cultural Damage
Ecological Damage
Economic Damage
Human Health Hazard

A step by step approach to building modules

Vessel Movement Module
Vessel Encounter Module
Vessel Accident Module
Oil Outflow Module
Opportunities for updates

<table>
<thead>
<tr>
<th>Monthly Division</th>
<th>Introduction</th>
<th>Model Development</th>
<th>Model Validation</th>
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### Progress Briefings

<table>
<thead>
<tr>
<th>Module</th>
<th>Briefing Date</th>
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<tbody>
<tr>
<td>Vessel Movement Module</td>
<td>October 2020</td>
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<tr>
<td>Vessel Encounter Module</td>
<td>March 2021</td>
</tr>
<tr>
<td>Vessel Accident Module</td>
<td>July 2021</td>
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<tr>
<td>Oil Outflow Module</td>
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**Upcoming event**

September 16th, 2020 – 1 pm to 3 pm

- Vessel Movement Module
Discussion logistics

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References
