Towards end-to-end modeling for investigating the effects of climate and fishing in the Strait of Georgia ecosystem, Canada

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Work in progress

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**OSMOSE** (Object-oriented Simulator of Marine ecOSystems Exploitation)

-----Individual-based model (IBM), multi-species, structured by size.

- Class **SYSTEM**
  - abundance, biomass
  - species richness $S$
  - carrying capacity
  - size spectrum
  - $S$ species

- Class **SPECIES**
  - abundance, biomass
  - growth parameters
  - reproduction parameters
  - distribution area/age
  - fishing mortality/age
  - (longevity+1) cohorts

- Class **COHORT**
  - species
  - abund., biomass
  - n schools

- Class **SCHOOL**
  - species, age
  - abundance, biomass
  - spatial coordinates
  - length, weight
  - predation efficiency

Size-based predation

1- Thresholds for predator/prey size ratio
2- Maximum ingestion rate
3- Spatial-temporal co-occurrence

Modelled food webs are variable in structure
Opportunistic predation
Predation efficiency ξ
**Fish life cycle**

Spatial distribution ➔ Natural mortality ➔ Piscivores ➔ Predation ➔ Starvation ➔ Growth

\[ \xi = \text{Predation efficiency} \]

\[ \xi_{\text{crit}} = \frac{\text{ration for maintenance}}{\text{maximal ration}} \]
Water temperature changes in the Strait of Georgia

Sea surface temperature (°C)

Jan    Feb    Mar    Apr    May    Jun    Jul    Aug    Sep    Oct    Nov    Dec

1948-1977

1978-2007
Changes in fish community in the Strait of Georgia

- Pacific hake dominates the resident fish biomass.
- Pacific herring are at high abundance.
- Harbour seal biomass has tripled.
- Groundfish species such as Pacific cod are nearly absent.

Research questions

- What has driven these changes in the strait, climate change? fishing?...
- What will the strait be like in the future?
- How can we manage marine resources under changing environment?
Application of OSMOSE to the Strait of Georgia

Selecting 14 key species in the model

Criteria:

✓ commercial interest (>90%)
✓ importance in biomass (>70%)
✓ perceived ecological significance
Key species from the Strait of Georgia

- Euphausiid
- Pacific herring
- Spotted ratfish
- Walleye pollock
- Pacific hake
- Chinook salmon
- Harbour seal
- Spiny dogfish
- Pacific cod
- Lingcod
- Yelloweye rockfish
- English sole
- Dover sole
- Pandalid shrimp
- Harbour seal

Changes due to fishing? Climate changes?

Biomass (1000 t)

- 1978-88
- 2000-07
**Inputs for OSMOSE model**

1. Habitat maps
2. Water temperature over time and optimal level for larval survival and growth
3. Migration patterns
4. Fishing and reproduction seasonality
5. Spatial distributions of OSMOSE species (grids of 4km x 4km)
6. Biological parameters

<table>
<thead>
<tr>
<th>Species</th>
<th>$L_x (cm)$</th>
<th>$k$ (year$^{-1}$)</th>
<th>$t_0$ (year)</th>
<th>$a$ (g $\cdot$ cm$^{-3}$)</th>
<th>$b$</th>
<th>$\phi$ (eggs $\cdot$ g$^{-1}$)</th>
<th>$A_{max}$ (year)</th>
<th>$A_{rec}$ (year)</th>
<th>$M$ (year$^{-1}$)</th>
<th>$F$ (year$^{-1}$)</th>
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<tbody>
<tr>
<td>Euphausiids</td>
<td>1.84</td>
<td>1.680</td>
<td>-0.200</td>
<td>0.0091</td>
<td>2.920</td>
<td>24469</td>
<td>1</td>
<td>2</td>
<td>1.151</td>
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<td>15.50</td>
<td>0.924</td>
<td>0.232</td>
<td>0.0006</td>
<td>3.069</td>
<td>345</td>
<td>2</td>
<td>4</td>
<td>0.576</td>
<td>0.100</td>
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<tr>
<td>Pacific herring</td>
<td>26.30</td>
<td>0.360</td>
<td>-0.030</td>
<td>0.0070</td>
<td>3.000</td>
<td>200</td>
<td>3</td>
<td>10</td>
<td>0.230</td>
<td>0.200</td>
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<tr>
<td>Pacific hake</td>
<td>44.50</td>
<td>0.457</td>
<td>-0.173</td>
<td>0.0074</td>
<td>2.997</td>
<td>108</td>
<td>4</td>
<td>12</td>
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<tr>
<td>Walleye pollock</td>
<td>44.50</td>
<td>0.918</td>
<td>0.575</td>
<td>0.0053</td>
<td>2.441</td>
<td>938</td>
<td>4</td>
<td>8</td>
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<tr>
<td>Pacific cod</td>
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<td>0.387</td>
<td>-0.010</td>
<td>0.0074</td>
<td>3.096</td>
<td>564</td>
<td>3</td>
<td>8</td>
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<td>English Rock sole</td>
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<td>0.311</td>
<td>-0.279</td>
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<td>3.125</td>
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<td>Dover sole</td>
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<td>0.081</td>
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<td>Lingcod</td>
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<td>3.217</td>
<td>26</td>
<td>5</td>
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<tr>
<td>Yellow Quill rockfish</td>
<td>64.53</td>
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<td>0.0114</td>
<td>3.126</td>
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<td>16</td>
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<td>Spotted ratfish</td>
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<td>0.196</td>
<td>0.000</td>
<td>0.0067</td>
<td>3.013</td>
<td>2 (per ♀)</td>
<td>5</td>
<td>15</td>
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<td>Spiny dogfish</td>
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<td>25</td>
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<td>2</td>
<td>3</td>
<td>5</td>
<td>0.461</td>
<td>0.461</td>
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### Calibration targets

<table>
<thead>
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<tbody>
<tr>
<td>Euphausiids</td>
<td>227874.04</td>
<td>227874.04</td>
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<tr>
<td>Pandalid shrimp</td>
<td>21451.76</td>
<td>22803.11</td>
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<td>Pacific herring</td>
<td>116232.27</td>
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<tr>
<td>Pacific hake</td>
<td>64478.10</td>
<td>153034.49</td>
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<td>Walleye pollock</td>
<td>17011.65</td>
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<td>Pacific cod</td>
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<tr>
<td>English Rock sole</td>
<td>1094.27</td>
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<td>Dover sole</td>
<td>1935.35</td>
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<tr>
<td>Lingcod</td>
<td>881.92</td>
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<td>Yellow Quill rockfish</td>
<td>403.17</td>
<td>1397.84</td>
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<td>Spotted ratfish</td>
<td>16581.09</td>
<td>7620.18</td>
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<td>Spiny dogfish</td>
<td>75075.71</td>
<td>17188.48</td>
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<td>Harbour seal</td>
<td>637.25</td>
<td>2040.00</td>
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<tr>
<td>Chinook salmon</td>
<td>16425.17</td>
<td>653.26</td>
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</tbody>
</table>

- Tuning parameters include larval mortality for each species and accessibility coefficient for each plankton compartment.
- Calibration is done by using a genetic algorithm specifically developed for OSMOSE (Shin et al. in review)

### Questions to be addressed through OSMOSE simulations

- What if water temperature increased by another degree?
- What if herring were removed from the system?
- What if harbour seals were removed?
- What if Pacific cod were not fished but climate was not favorable?
- What if Pacific cod were not fished but climate was favorable?
Examples of Output

Population biomass

Time Step
Biomass loss due to each cause

- Predation
- Fishing
- Natural
Trophodynamic indicators

Mean TL, TL-at-age

TL distribution

Diets

Euphausiid

Copepod

Diatoms

> 10 cm

< 10 cm

Mean
Future Research

1. Tuning model using Genetic Algorithm and doing model sensitivity analyses
2. Coupling with ROMS-NPZD
3. Comparing OSMOSE and other models’ output, such as Atlantis.
4. Conducting management strategy evaluation
THANKS FOR YOUR ATTENTION