# Developing indicators for ecosystem responses to multiple pressures: case studies between the eastern and western North Pacific

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## Objective of Presentation

Use a comparative approach on entire ecosystems to attempt to identify general ecosystem responses to multiple pressures, and appropriate system-level indicators.

Focus at this stage is:

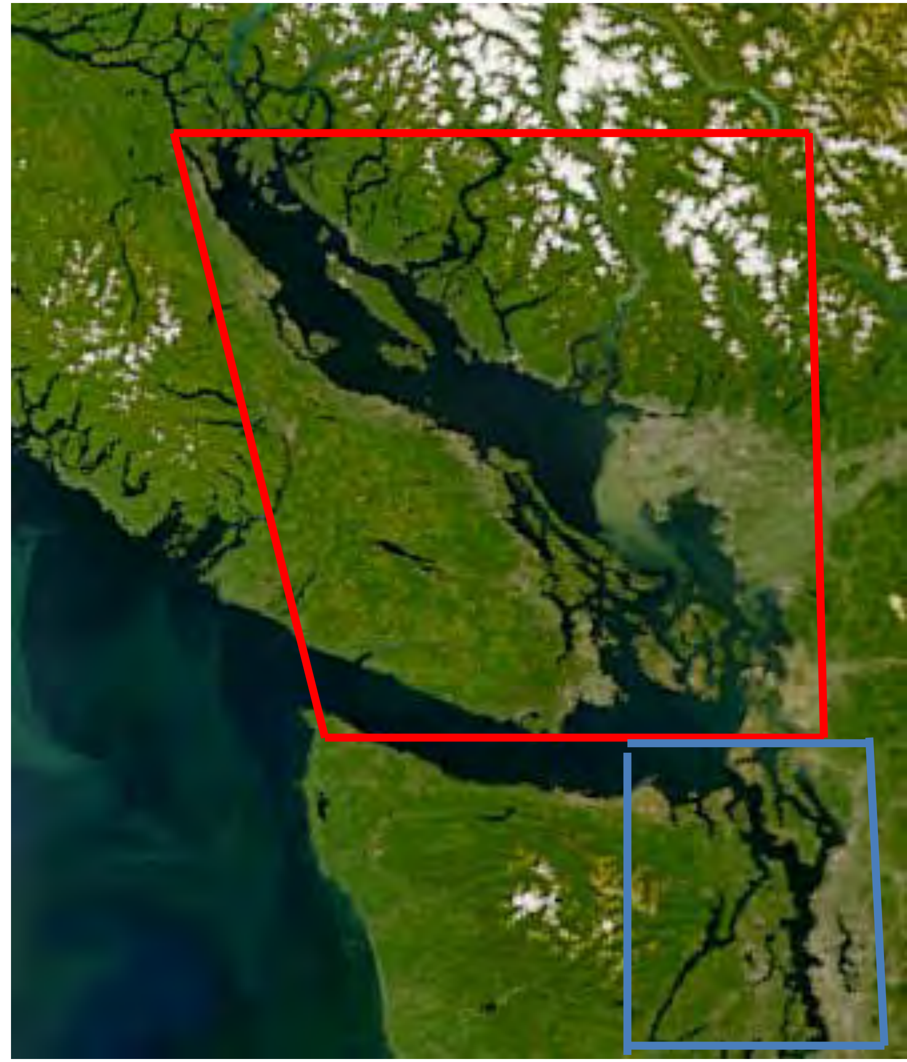
- development of a practical approach to link pressures with ecosystem responses and indicators, and
- compare these among different geographic systems, as a contribution to the work of PICES WG28.

Three coastal ecosystems as case studies:

- Seto Inland Sea, Japan;
- Strait of Georgia, Canada;
- Puget Sound, U.S.

Seto Inland Sea, Japan


Strait of Georgia, Canada



Puget Sound, USA

# Potential impacts of human activities and natural stressors on specific habitats were evaluated using an expert-based screening method

Human activities

Natural stressors

| Activities/Stressors | **Intertidal** | **Coastal** | **Shelf** | **Oceanic** |
|---|---|---|---|---|
| 1. Polution from land<br>2. Coastal engineering<br>3. Coastal development<br>4. Direct human impact<br>5. Ecotourism<br>6. Commertial activity<br>7. Aquaculture<br>8. Fishing - demersal<br>9. Fishing - pelagic<br>10. Fishing - illegal<br>11. Offshore development<br>12. Polution from ocean<br>13. Freshwater input<br>14. Sediment input<br>15. Nutrient input<br>16. HABs<br>17. Hypoxia<br>18. Species invasion<br>19. Climate Chg - Sea level<br>20. Climate Chg – Temp. | 1. Rocky<br>2. Beach<br>3. Mud<br>4. Salt marsh | 1. Seagrass<br>2. Kelp forest<br>3. Rocky reef<br>4. Suspension feeder reef<br>5. Sub-tidal soft bottom | 1. Soft bottom<br>2. Hard bottom<br>3. Ice<br>4. Pelagic water column | 1. Soft bottom slope<br>2. Hard bottom slope<br>3. Soft bottom benthic<br>4. Seamount<br>5. Vents<br>6. Soft bottom canyon<br>7. Hard bottom canyon<br>8. Deep pelagic water column<br>9. Upper pelagic water column |

Each stressor – habitat combination was rated on estimates of:

- **spatial scale of interaction,**
- **frequency of disturbance,**
- **trophic levels impacted,**
- **resistance to change,**
- **recovery time**

Weak ⟷ Strong

| Feature | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| Spatial scale | < 10 $km^2$ | 10-100 $km^2$ | 100-1000 $km^2$ | > 1000 $km^2$ |
| Frequency | > 5 yrs | 1-5 yrs | Seasonal | Continuous |
| Trophic level | Species | Single trophic | Multitrophic | Community |
| Resistance | Positive impact | High | Moderate | Low |
| Recovery time | < 1 yr | 1-10 yrs | 10-100 yrs | > 100 yrs |

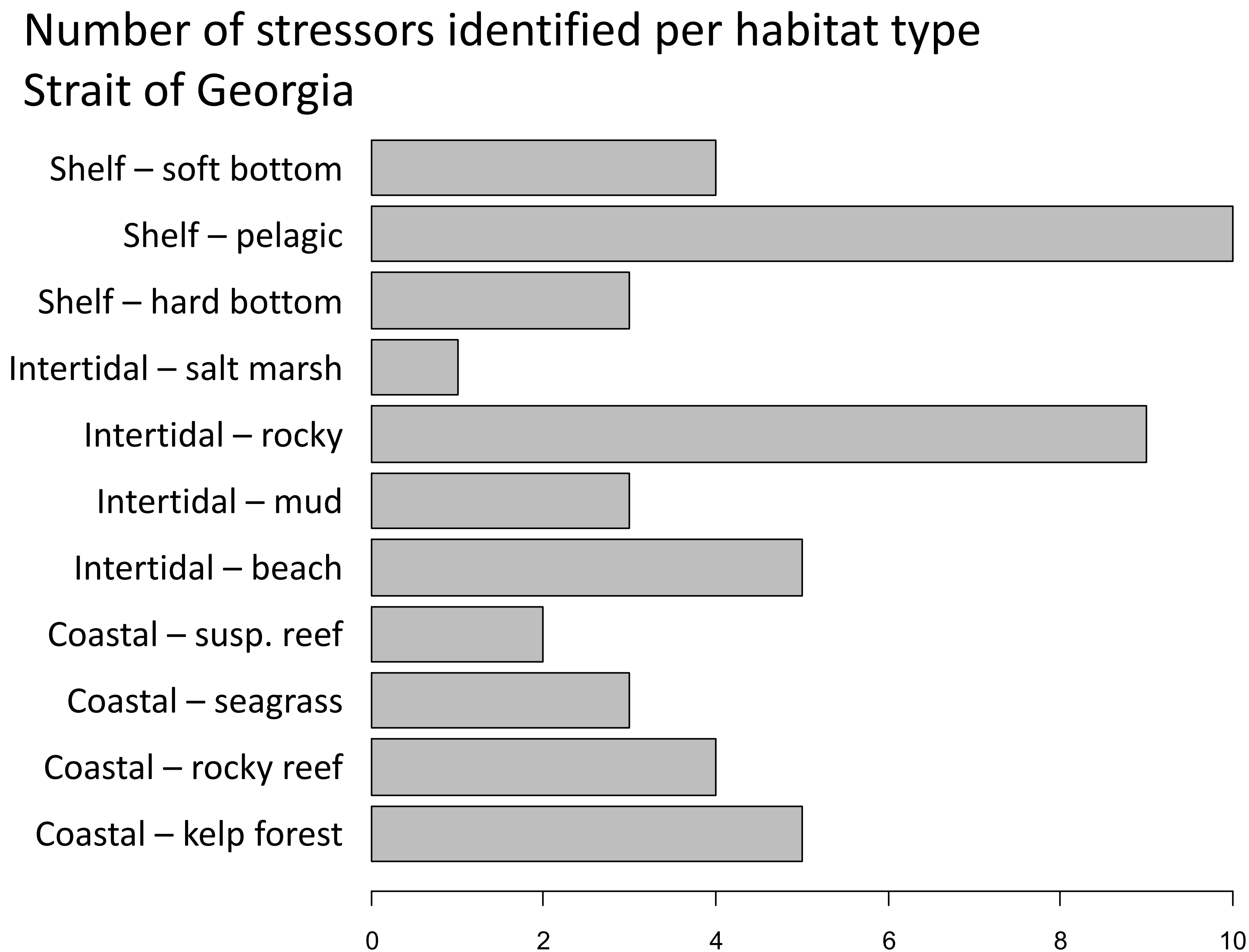
# Survey response rate:

Strait of Georgia survey was sent to 56 people:

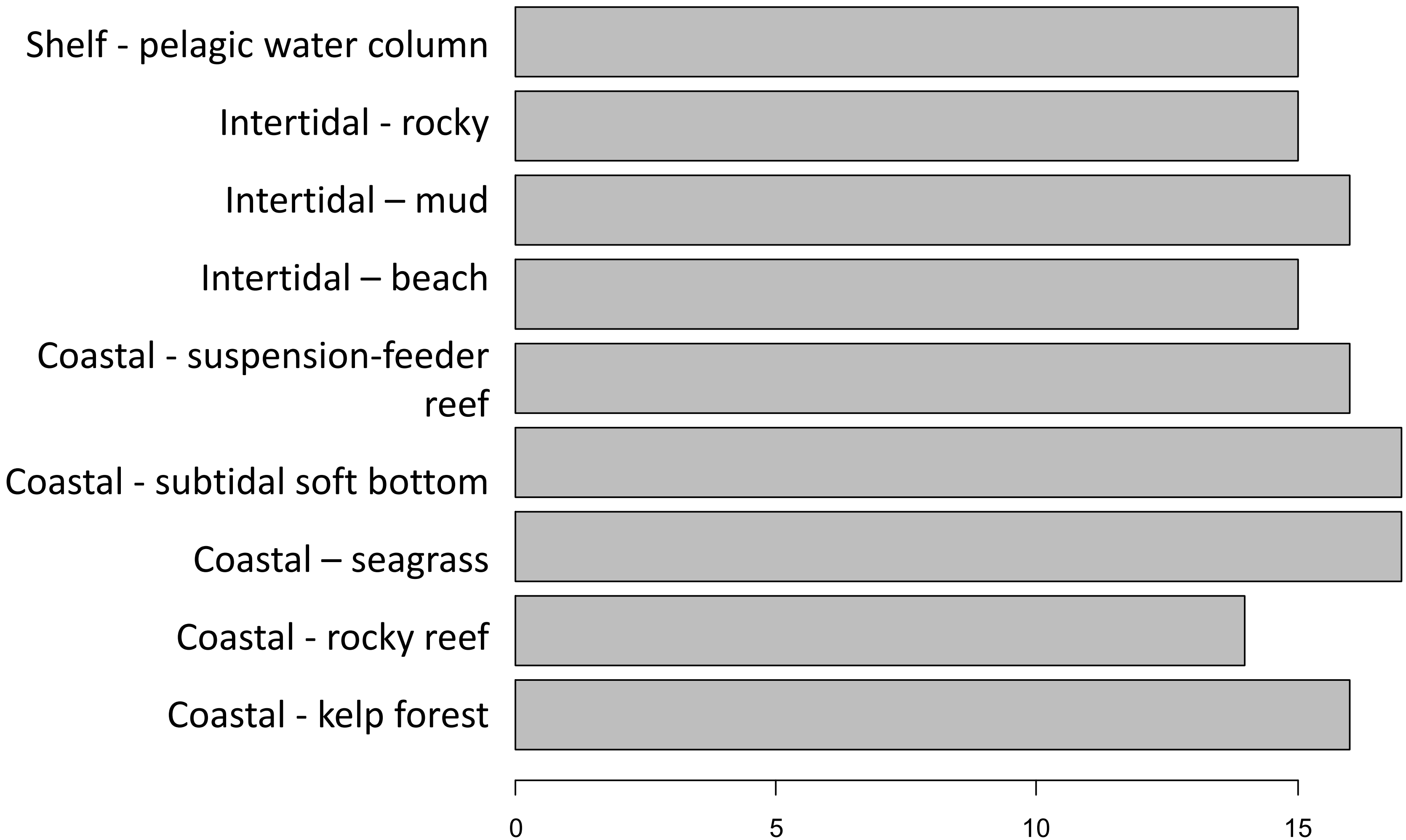
| | Sent: | Returned to date: |
|---|---|---|
| Government: | 34 | 12 |
| University: | 14 | 6 |
| NGO: | 8 | 0 |

Seto Inland Sea was sent to 9 people:

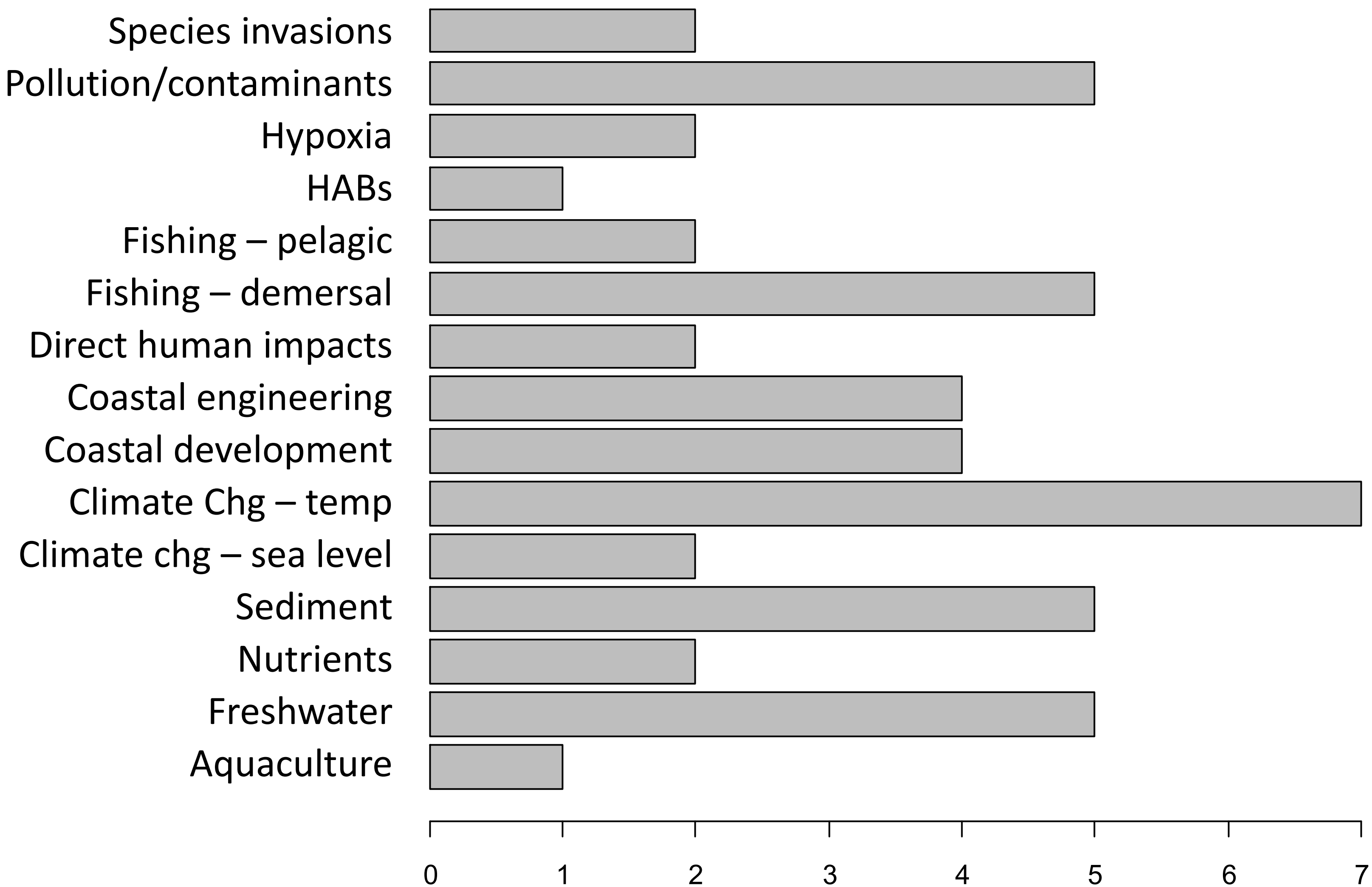
| | Sent: | Returned to date: |
|---|---|---|
| Government: | 6 | 4 |
| University: | 3 | 1 |
| NGO: | 0 | 0 |


Number of stressors identified per habitat type
Strait of Georgia
Shelf – soft bottom
Shelf – pelagic
Shelf – hard bottom
Intertidal – salt marsh
Intertidal – rocky
Intertidal – mud
Intertidal – beach
Coastal – susp. reef
Coastal – seagrass
Coastal – rocky reef
Coastal – kelp forest
0
2
4
6
8
10

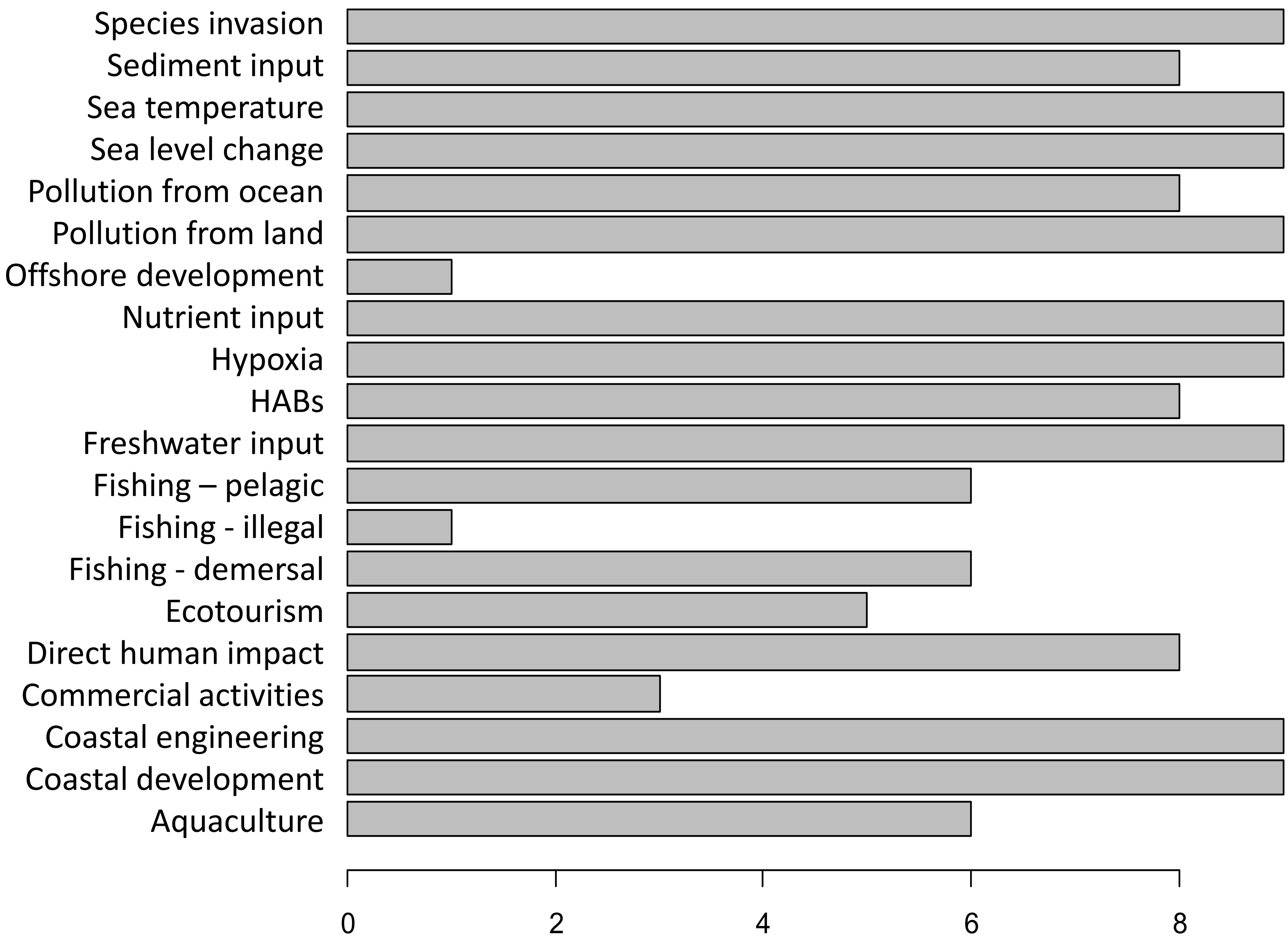
# Number of stressors identified per habitat type
Seto Inland Sea



# Number of habitats per stressor: Strait of Georgia



# Number of habitats per stressor: Seto Inland Sea



Following Samhouri and Levin (2012) [and others], define "Risk" or "Vulnerability" as a function of 'Sensitivity' and 'Exposure':

Exposure (E) = average scores of

**Spatial scale**,
**Frequency of occurrence**,
**Trophic level**

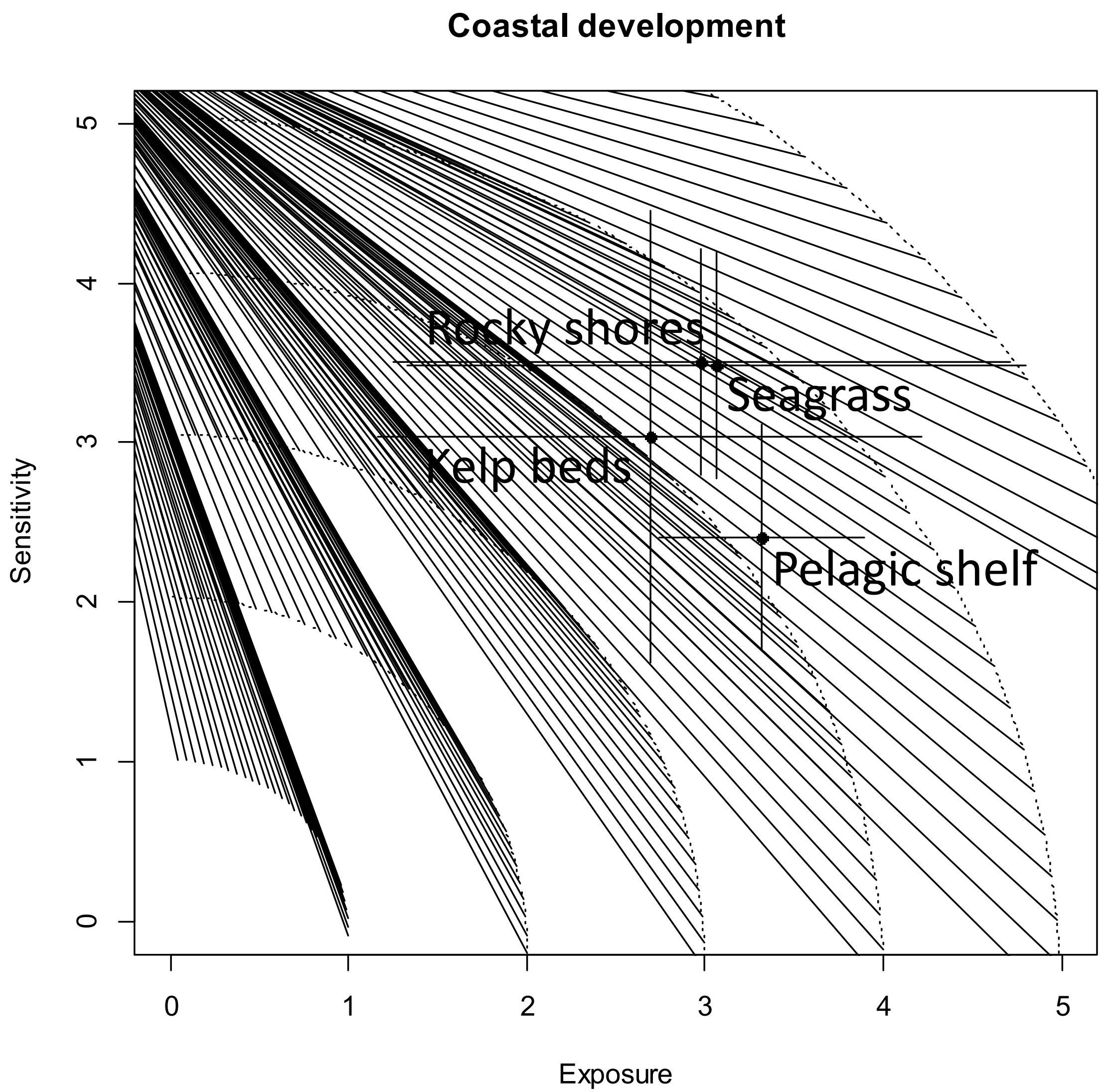
Sensitivity (S) = average scores of

**Resistance to change**
**Recovery time**

Risk score (for Stressor *i* on Habitat *j*) $= \sqrt{(E-1)^2 + (S-1)^2}$

(Note: rated Uncertainties not included)

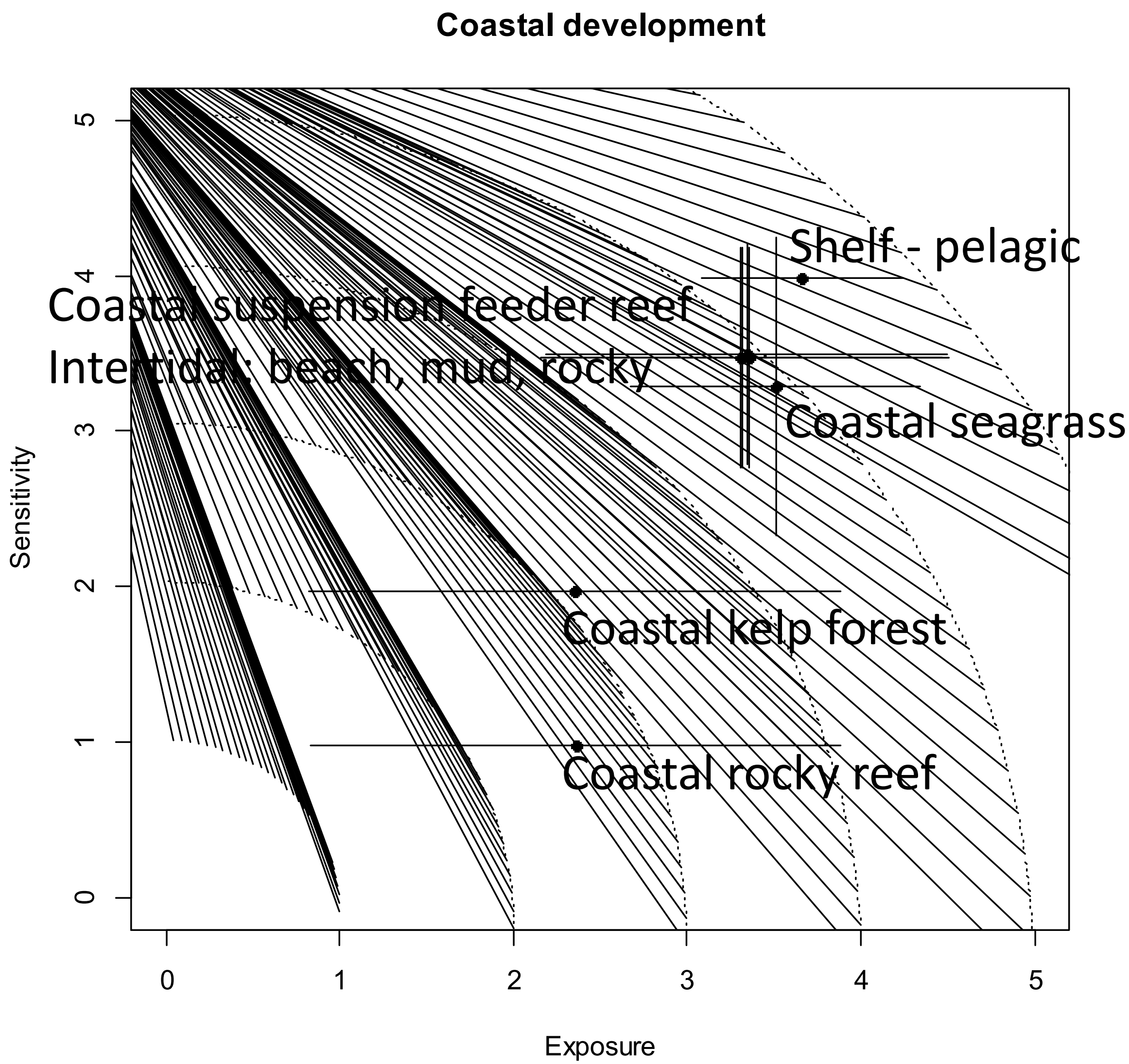
# Example: Exposure and Sensitivity of Habitats in **Strait of Georgia** to Coastal Development




Error bars represent variability of responses among experts (1 std dev)

Dotted lines represent equivalent risk (vulnerability) profiles

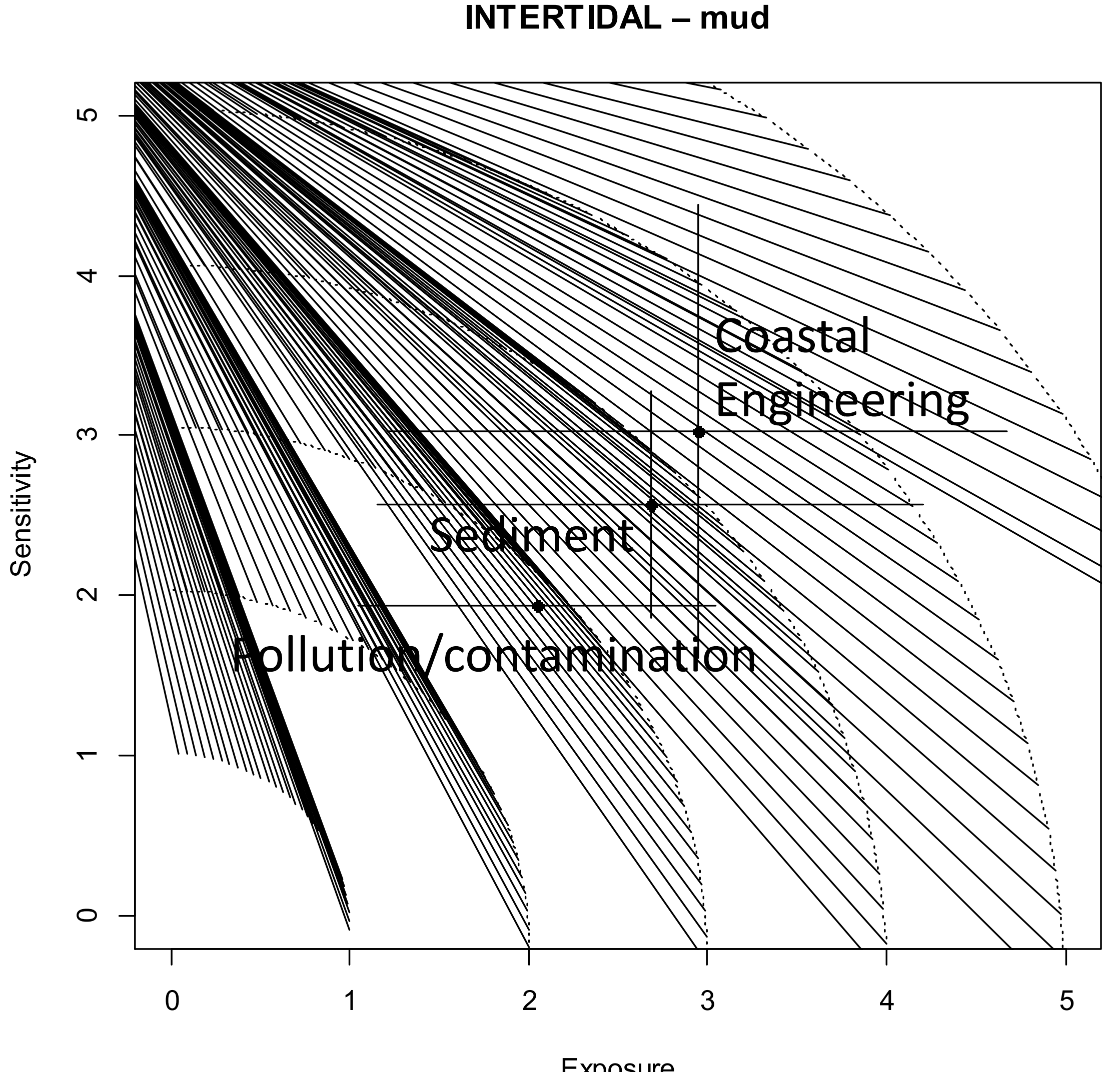
# Example: Exposure and Sensitivity of Habitats in **Seto Inland Sea** to Coastal Development




Error bars represent variability of responses among experts (1 std dev)

Dotted lines represent equivalent risk (vulnerability) profiles

# Also use to represent Exposure and Sensitivity imposed by Stressors on Habitats in **Strait of Georgia**

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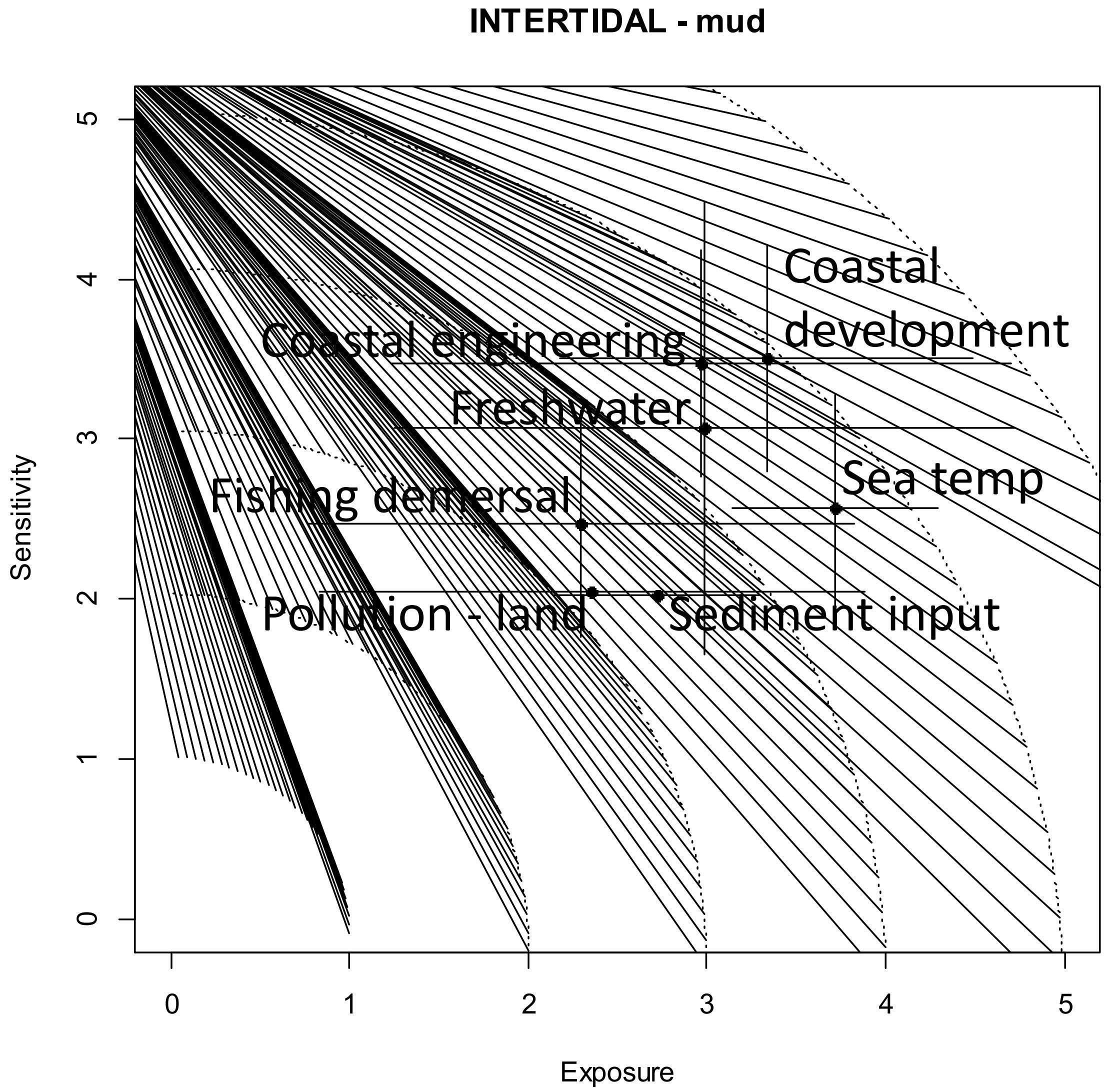
# Also use to represent Exposure and Sensitivity imposed by Stressors on Habitats in **Seto Inland Sea**

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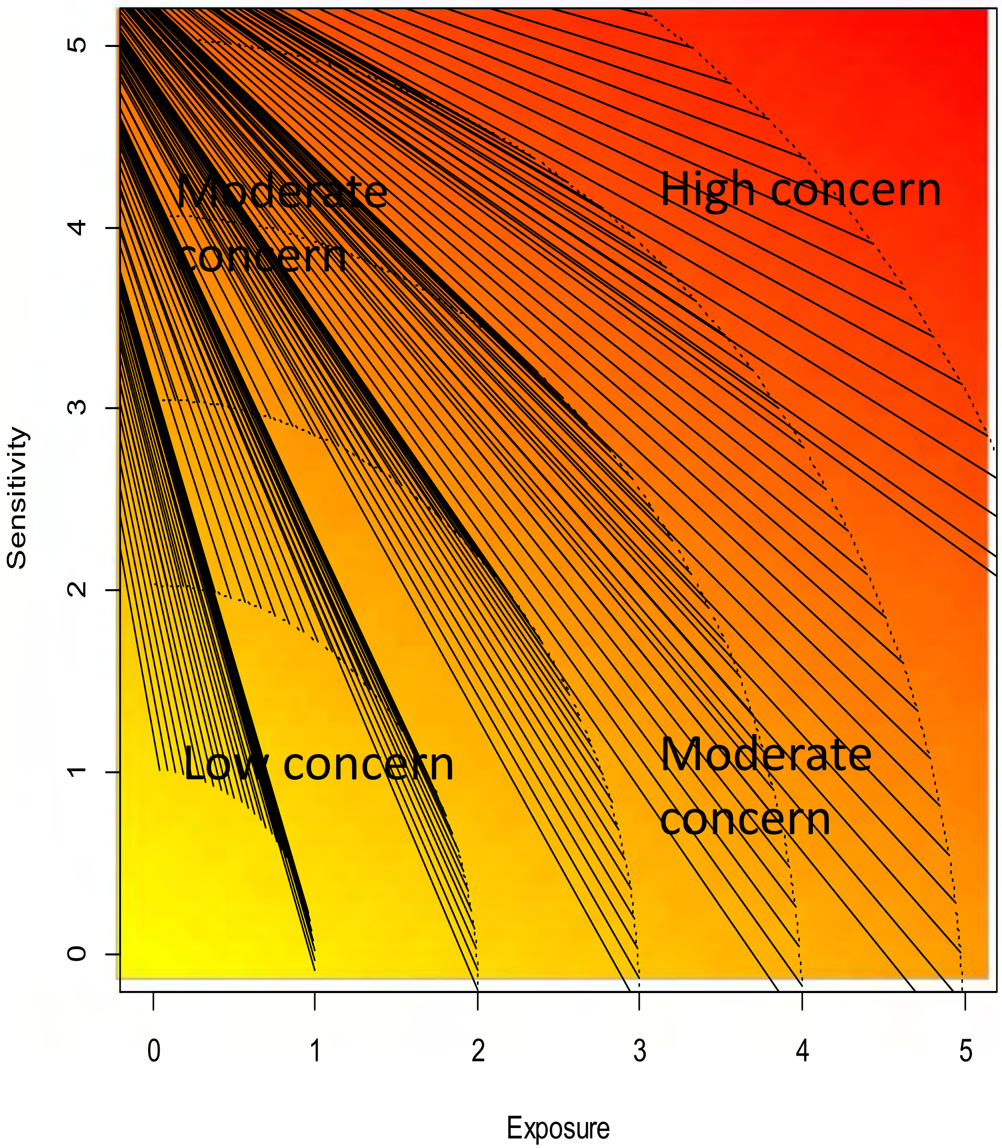
Dotted lines represent equivalent risk (vulnerability) profiles

# Perception of 'risk'



Suggests that habitat/ecosystem characteristics relating to higher sensitivity may be of greater interest (with ‘Sensitivity defined as a function of {resistance to change, recovery time} )

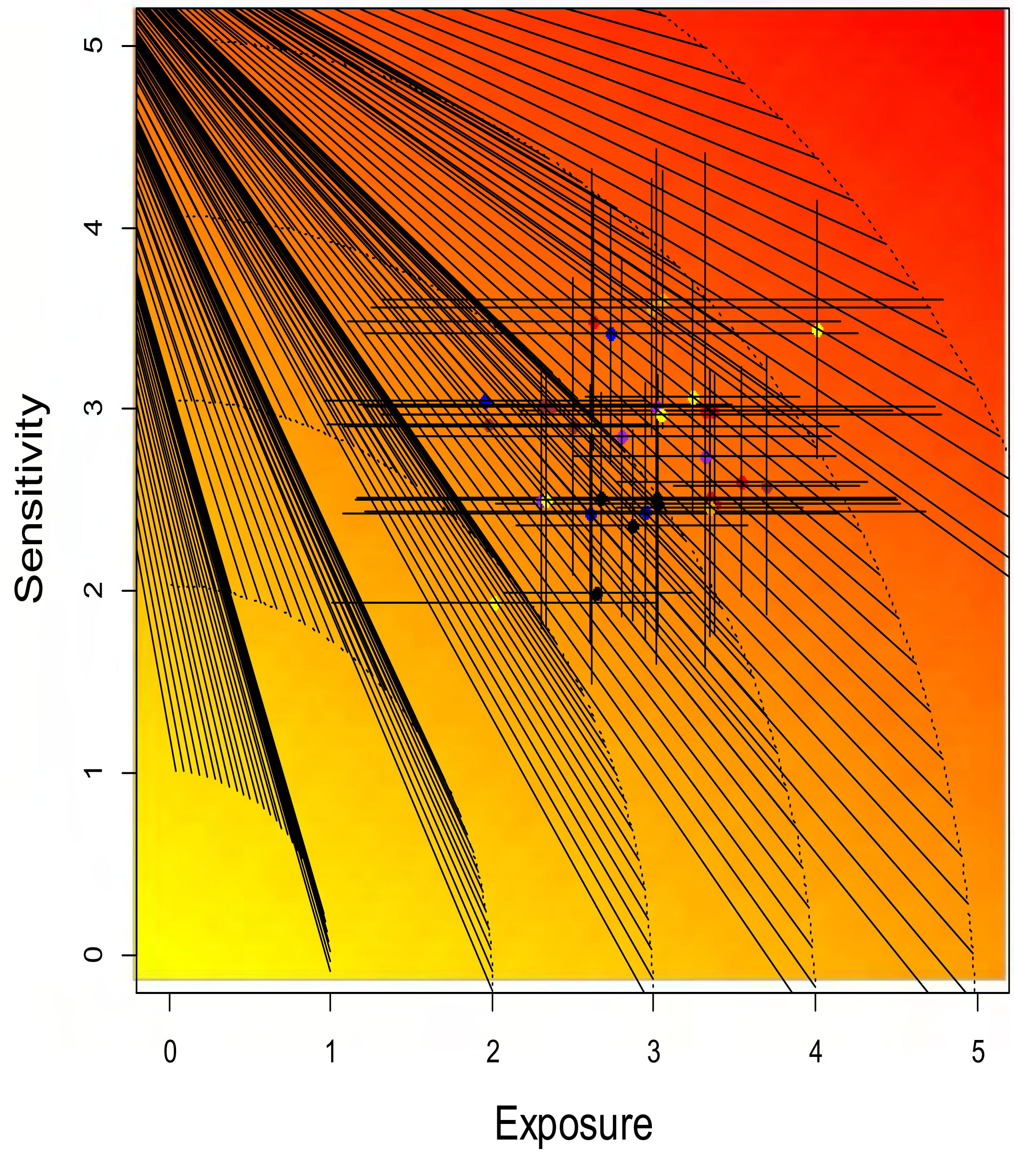
For potential indicators of ecosystem responses to multiple and cumulative stressors, consider focusing on:

- habitat and stressor combinations which result in higher sensitivity, and
- features and characteristics of **resistance to change** and **recovery time** which lead to high sensitivity

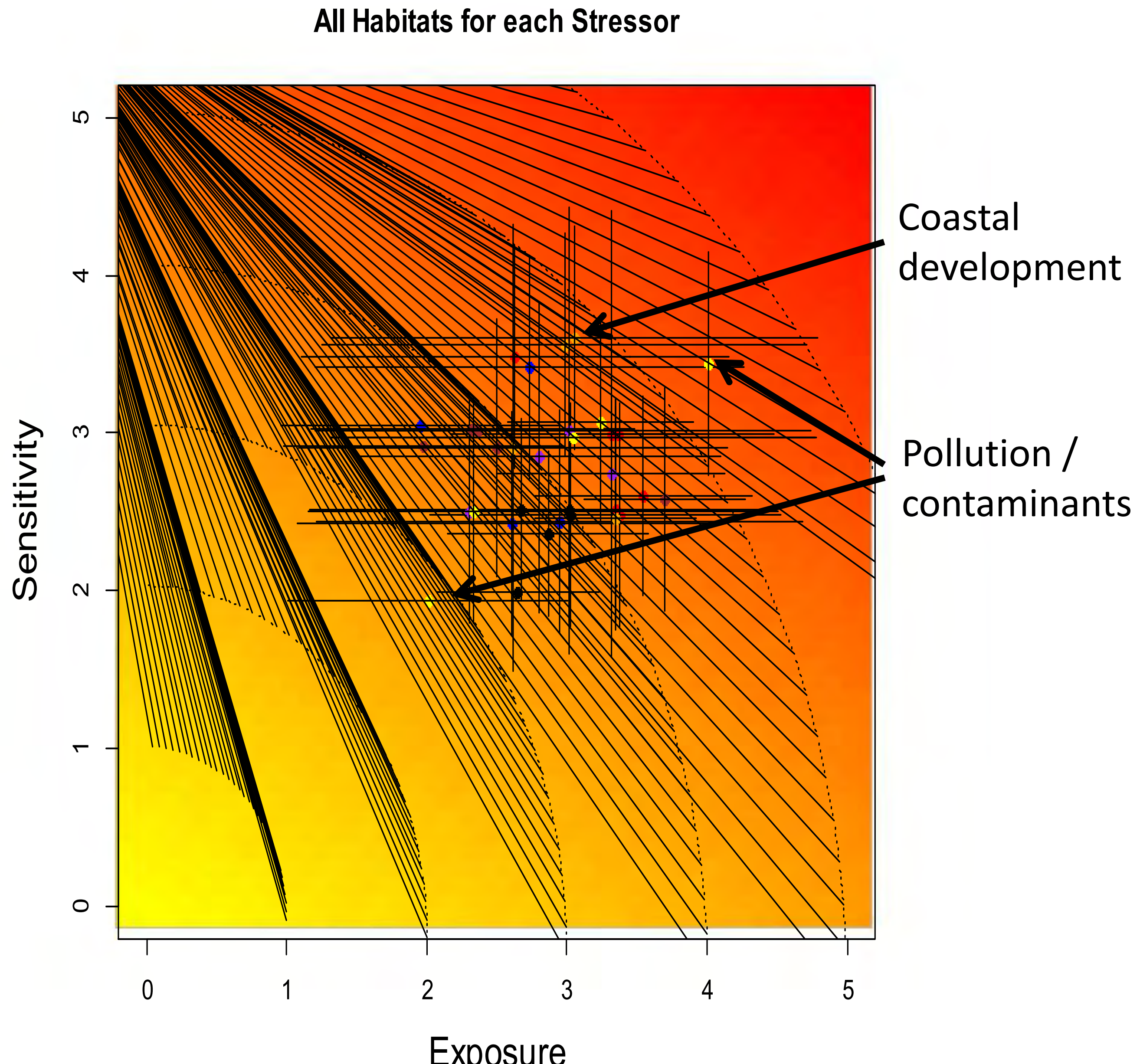
(these are also likely to be among the more uncertain and poorly defined characteristics of habitats and ecosystems)

# Strait of Georgia

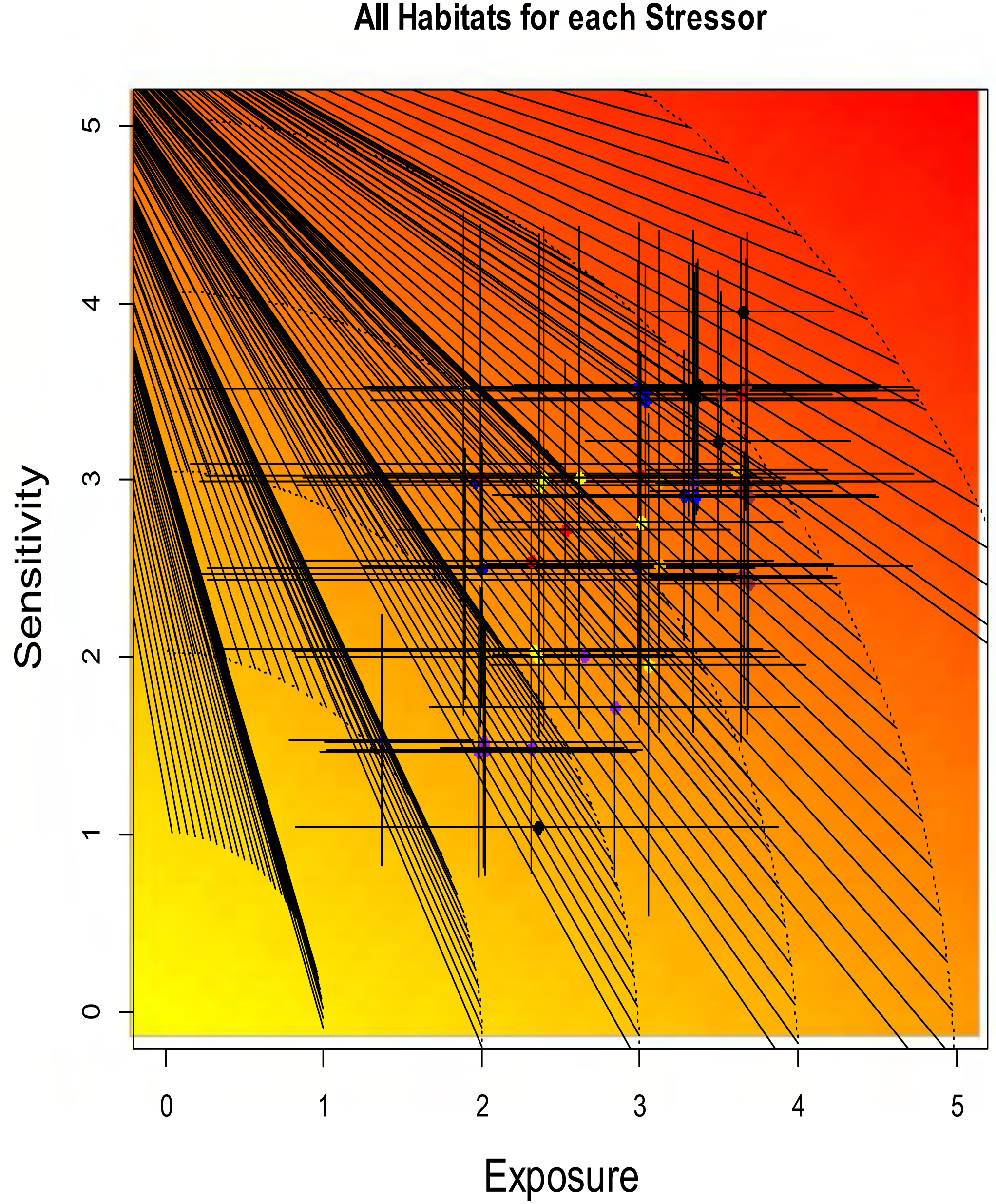
All Habitats for each Stressor



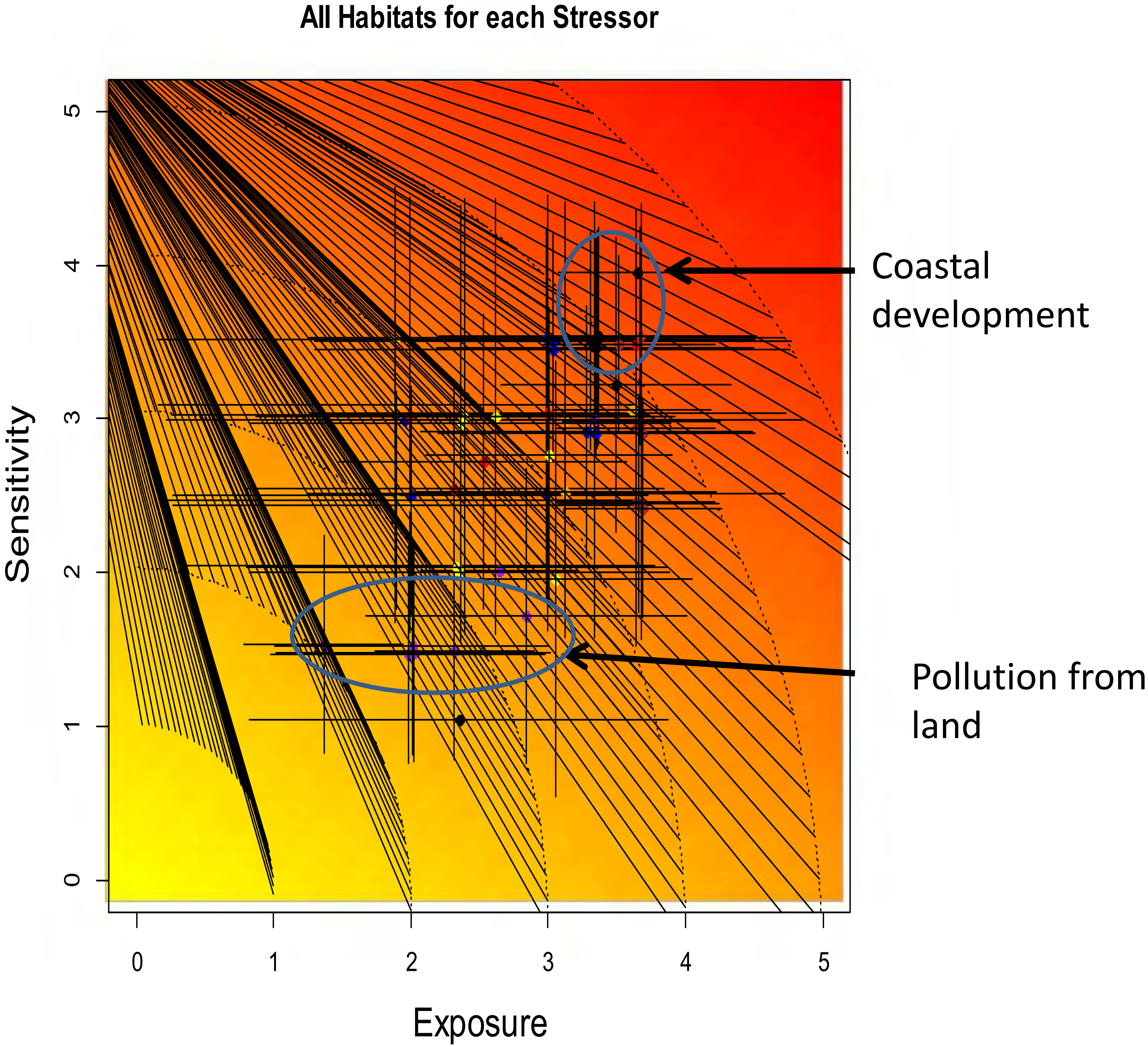
# Strait of Georgia



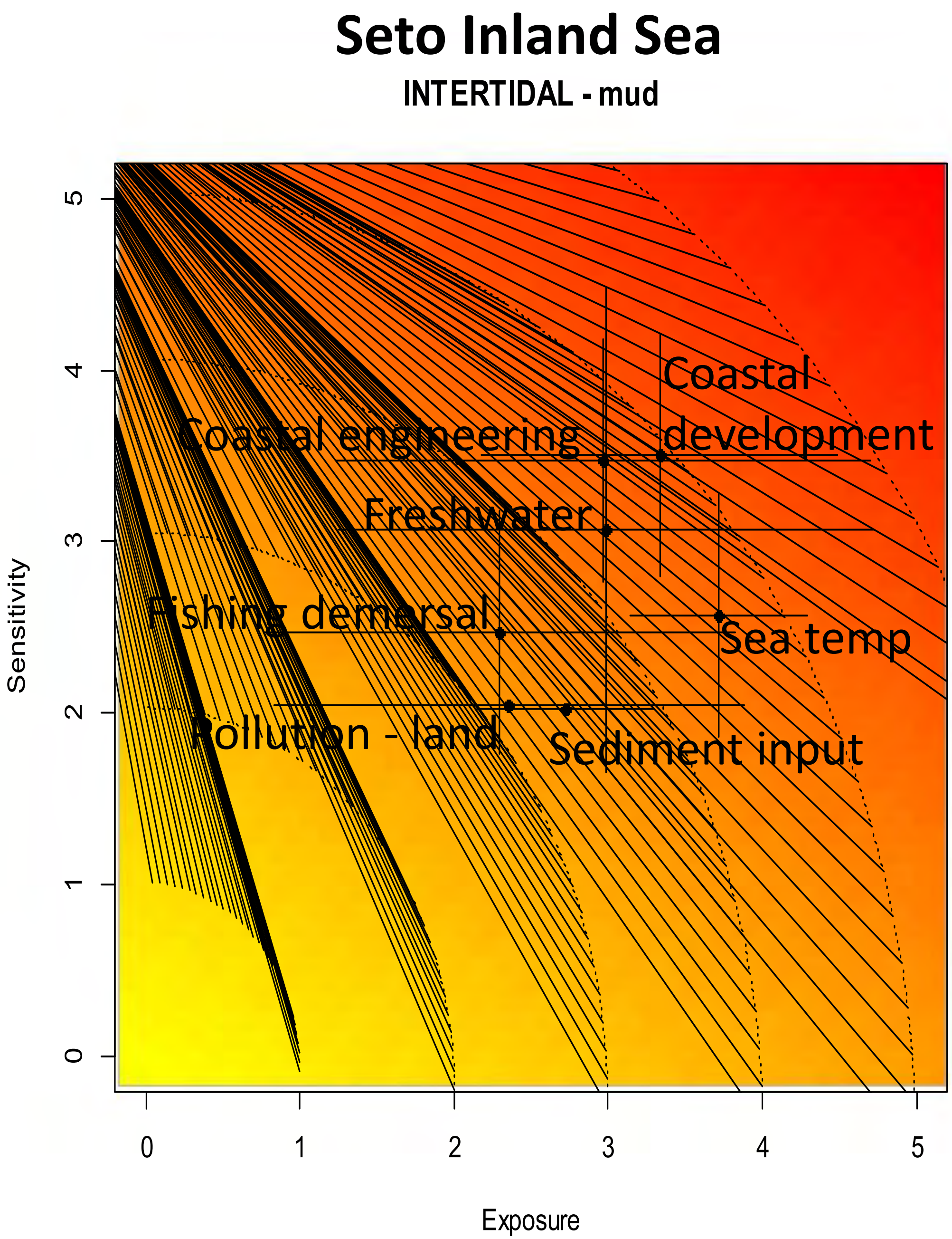
# Seto Inland Sea



# Seto Inland Sea



What determines the **recovery time** and **resistance to change** of intertidal mud habitats to coastal engineering that cause it to have similar sensitivity to coastal development with less exposure?



Conclusions (for now)

Working through methods to compare stressors and habitat risks/vulnerabilities among selected coastal ecosystems, as a case study for Working Group 28 on indicators for ecosystem responses to multiple stressors

Expert assessment of vulnerabilities of similar habitats to similar stressors compared between Strait of Georgia and Seto Inland Sea suggest higher sensitivity to coastal development in both but more variable responses to land-based pollution

Indicators which consider **what defines resistance to change and recovery time of habitats** when exposed to multiple stressors may have greater management utility