# PICES Working Group 28:
# *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*

http://pices.int/members/working_groups/wg28.aspx

# What is PICES?

- PICES: North Pacific Marine Science Organization
- PICES is an intergovernmental scientific organization that was established and held its first meetings in 1992
- PICES members: Canada, Japan, the People's Republic of China, the Republic of Korea, the Russian Federation, and the United States of America
- PICES mission:
  - *To promote and coordinate marine scientific research in the North Pacific Ocean in order to advance scientific knowledge of the area concerned and of its living resources*

# PICES Mission Themes

- The PICES Mission has 5 central themes:
  1. *Advancing scientific knowledge*
  2. *Applying scientific knowledge*
  3. *Fostering partnerships*
  4. *Ensuring a modern organization in support of PICES activities*
  5. *Distributing PICES scientific knowledge*
- **www.pices.int**

# PICES FUTURE Program


**Objective 1: Understanding Critical Processes in the North Pacific**

(1) What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?

(2) How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?

(3) How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

**Objective 2: Status Reports, Outlooks, Forecasts, and Engagement**

# PICES Collaborations

**Some Scientific Topic Areas**

- **Climate Change**
- **Ecosystem Assessment**
- **Biological Invasions**
- **Ocean Acidification**
- **Marine Spatial Planning**

**HOW?**
**Joint Working Groups**
**Joint Workshops and Symposia**
**Joint Theme Sessions**

**Some Operational Areas**

- **Training/Capacity Building**
- **Knowledge Exchange/Communication**

**HOW?**
**Summer Schools**
**Workshops**
**PICES Press**

# Some PICES Products

**PICES Special Publications**

- **Marine Ecosystems of the North Pacific Ocean 2003-2008**
- **Marine Ecosystems of the North Pacific**

**Annual Reports**

**PICES Technical Reports (e.g., WG Reports)**

**PICES Journals**

**PICES Atlas of Non-indigenous Marine Species in the North Pacific**

# PICES Working Group 28

## *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*

Terms of Reference

1. Identify and characterize the spatial (and temporal) extent of critical stressors in North Pacific ecosystems both coastal and offshore and identify locations where multiple stressors interact. Identify trends in these stressors
2. Review and identify categories of indicators needed to document status and trends of ecosystem change at the most appropriate spatial scale
3. Using criteria agreed to at the 2011 PICES FUTURE Inter-sessional Workshop in Honolulu, determine the most appropriate weighting for indicators used for:
   a. documenting status and trends
   b. documenting extent of critical stressors
   c. assessing ecosystem impacts/change
4. Review existing frameworks to link stressors to impacts/change, assessing their applicability to North Pacific ecosystems and identify the most appropriate for application to North Pacific ecosystems.
5. Determine if ecosystem indicators provide a mechanistic understanding of how ecosystems respond to multiple stressors and evaluate the potential to identify vulnerable ecosystem components.

# PICES Working Group 28

## *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*

Terms of Reference (Cont)

6. For 1-2 case studies, identify and characterize how ecosystems respond to multiple stressors using indicators identified above. Are responses to stressors simply linear or are changes non-linear such that small additional stressors result in much larger ecosystem responses? Do different parts of the ecosystem respond differently (e.g., trophic level responses)? How do stressors interact?
7. Publish a final report summarizing results with special attention to FUTURE needs. This WG will focus primarily on delivery of FUTURE Questions 3 and 1 (outlined below).

Linkages to the FUTURE Science Plan:

1. What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
2. How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
3. How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

# PICES Working Group 28: First year activities

## Identifying critical multiple stressors of marine ecosystems

- Convened two scientific sessions at PICES Annual Meeting in Hiroshima, October 2012

- 3 ‘types’ of approaches are used to identify multiple stressors on marine systems, and their potential impacts; each have various pros and cons:
  - Expert elicitation
  - Model-based
  - Empirical-based

- Developed tables for the availability of data in 4 categories as to whether data exist, whether time series exist, and spatial extent of coverage:
  - Environmental, biological, human activities, social-economic-political

- Potential for Korean and Chinese members of NOWPAP to help complete these tables for their marine regions?

| Approach | Pros | Cons |
|---|---|---|
| | | |
| **Expert elicitation** | Solution to the no data problem | Difficult to validate responses |
| | Appropriate for global and regional visualization | |
| | | |
| **Empirical analysis** | Track emerging stressors where expert input is untested or models are unavailable | Difficult to find data at appropriate scales |
| | Appropriate indicators can be tailored to the physical and biological nature of ecosystem | Least common denominator issue (shortest time series, smallest common spatial domain) |
| | Remotely sensed data available for many physical variables | |
| | | |
| **Model based analyses** | Can generate as much data as you need | Must have a model |
| | Can create an ensemble of models using different frameworks | Outputs are only as good as the data that go into the model |

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| Indicators, Activities, and Stressors | Canada | Japan | Russia | U.S.A. | High Seas |
|---|---|---|---|---|---|
| **Environmental stressors/indicators** | | | | | |
| Temperature | | | | | |
| Sea Ice | | | | | |
| Chla | | | | | |
| Nutrients | Y,Y,N | Y,Y,S | Y,Y,N | Y,Y,N | |
| River discharge | Y,Y,Y | Y,Y,Y | S,Y,N | Y,Y,Y | N/A |
| Toxic contaminants | Y,N,N | Y,N,N | Y,N,N | Y,N,N | S,N,N |
| Large scale climate index (e.g., PDO, ENSO) | | | | | |
| pH | Y,N,N | Y,N,N | Y,N,N | Y,N,N | Y,N,N |
| Oxygen | Y,Y,N | Y,Y,S | Y,Y,N | Y,Y,N | |
| | | | | | |

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| Indicators, Activities, and Stressors | Canada | Japan | Russia | U.S.A. | High Seas |
|---|---|---|---|---|---|
| **Human activities & stressors** | | | | | |
| Fishing | Y,Y,Y | Y,Y,Y | Y,Y,Y | Y,Y,Y | S,S,S |
| Oil and Gas | | | | | |
| Military Activity | N,N,N | N,N,N | N,N,N | N,N,N | N,N,N |
| Wave/Wind/Tidal | | | | | |
| Shipping | | | | | |
| Coastal engineering | Y,S,S | Y,S,S | Y,N,S | Y,N,S | N/A |
| Aquaculture | | | | | |
| Ecotourism | | | | | |
| Land-based pollution | | | | | |

| Indicators, Activities, and Stressors | Canada | Japan | Russia | U.S.A. | High Seas |
|---|---|---|---|---|---|
| **Socio-economic-political** | | | | | |
| Seafood demand | | | | | |
| Coastal population trends | Y,Y,Y | Y,Y,Y | ?,?,? | Y,Y,Y | N/A |
| Marine Employment | S,Y,Y | Y,Y,Y | N?,N?,N? | S,Y,Y | S,S,S |
| Marine Revenue | | | | | |
| Marine exports/domestic consumption | | | | | |
| Participation/stakeholder involvement | | | | | |
| Governance | | | | | |
| Happiness | | | | | |
| Satisfaction with ocean status | | | | | |
| Community vulnerability | | | | | |
| Coastal infrastructure | | | | | |

# PICES Working Group 28: First year activities

## Identifying critical multiple stressors of marine ecosystems

**Recommendations:**

Use multiple approaches (expert elicitation, model-based simulation, and empirical analysis) to identify and evaluate critical multiple stressors of North Pacific marine ecosystems and indicators to assess their impacts.

Finish filling out the tables with help from other PICES working groups, sections, and committees. For example, the human dimensions section could provide expertise on socio-economic indicators. The FIS and BIO committees could provide help on the biological indicators and the MONITOR committee could provide expertise environmental indicators and stressors.

A next step might be to identify the gaps in the tables and those that are important for which to get information.

# PICES Working Group 28: First year activities

## Framework for identifying multiple interacting stressors and their trends

WG 28 developed a web-based questionnaire to obtain expert opinions on habitats which may be vulnerable to multiple stressors:

**Spatial Extent**: spatial scale of impact of a single event of the activity/stressor

**Frequency**: average annual frequency of the activity/stressor at any location

**Trophic impact**: primary level affected by the activity/stressor

**Resistance to change**: degree to which the species, trophic level(s), or entire habitat's "natural" state is impacted by the activity/stressor

**Recovery time**: average time required for the affected species, trophic level(s), or entire community to return to its 'natural' state following disturbance

For each, respondents also asked to identify how certain they are of their estimates: 1: very low (<15%); 2: low (15-50%); 3: high (50-85%); 4: very high (>85%)

# PICES Working Group 28: First year activities

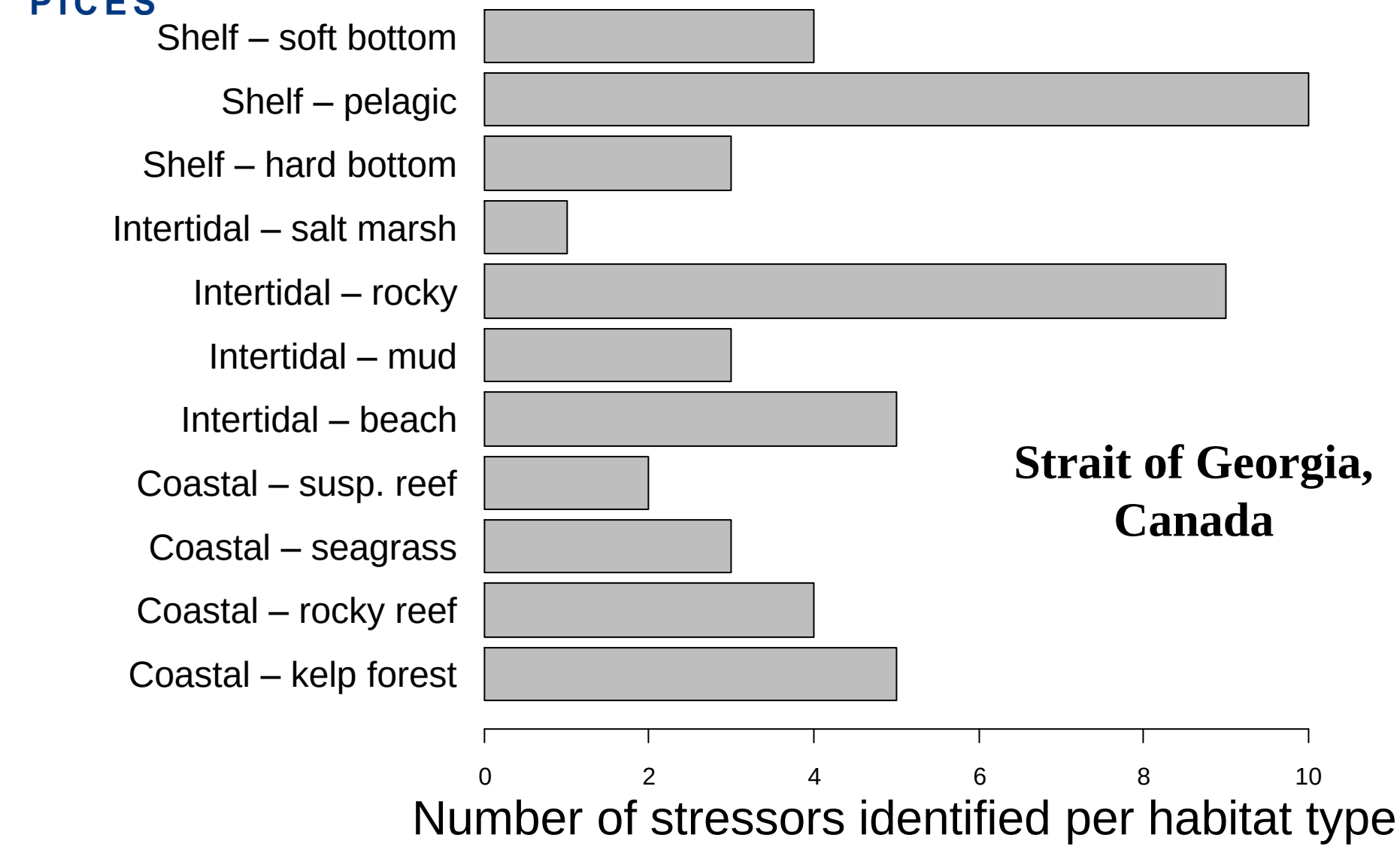
## Framework for identifying multiple interacting stressors and their trends

The analyses to date include marine ecosystems in Canada, Japan, Russia, and the United States.

Questions arising from these analyses:

- How can the impacts of multiple stressors on habitats be examined when more than two stressors are occurring? For example, a study of the Strait of Georgia, Canada, found that the modal number of stressors on any 4 $km^2$ region in the Strait was between 20 and 25.
- When developing indices for multiple stressors, they need to be “simple” but at the same time allow for users to ‘drill down’ to obtain more details about how particular sets of stressors might be driving particular responses in habitats.
- An important shortcoming in these approached was noted regarding temporal changes, and how to update the analyses. A stepwise process was recommended, involving identification of habitats, stressors, and their vulnerabilities, noting that these vulnerabilities of specific habitats to different stressors likely do not need to be updated on a regular basis.

# PICES Working Group 28: First year activities




**Strait of Georgia, Canada**

# PICES Working Group 28: Second year activities

Identification of ecosystem multiple indicators of ecosystem responses to multiple stressors

This is the main topic for activities during 2013 and 2014.

A scientific session will be held as part of the 2013 PICES Annual Meeting in Nanaimo, Canada (October 2013)

Among other approaches, we will be exploring the application of the ecosystem indicators developed by the IndiSeas project.

# IndiSeas Working Group Background

1. Established in 2005 as an international collaborative program
   - endorsed by IOC/UNESCO
   - co-funded by the NoE EUROCEANS , FP7 MEECE project, IRD, UCT

2. IndiSeas aims to perform comparative analyses of ecosystem indicators from the world's marine ecosystems to quantify the impact of fishing and to provide decision support for fisheries management in a context of climate variability and change.

3. IndiSeas1 (2005–2009) focused on ecological indicators.

4. IndiSeas2 (2010-2014) aims to address issues raised during phase 1 analyses, based on extensive sets of indicators including climate, biodiversity and human dimension indicators.

IOC=International Oceanographic Commission; UNESCO=United Nations Educational, Scientific and Cultural Organization; NoE=European Network of Excellence; EUROCEANS=EURopean research on OCean Ecosystems under Anthropogenic and Natural forcingS; FP7 MEECE=Marine Ecosystem Evolution in a Changing Environment; Institut de Recherche pour le Développement; UCT=University of Cape Town

# *INDISEAS 1 (2005-2009)*

OBJECTIVE: Evaluate ecological status of marine ecosystems:

- with respect to fishing activity
- using a set of ecological indicators
- using a comparative approach across marine ecosystems

STRATEGY: Select common list of indicators, with constraints:

- the set of indicators must remain tractable and measurable for an extended range of ecosystems
- must be meaningful to the public at large, and to managers

*ecosystem experts must participate in the diagnosis and comparison across ecosystems to take into account local specifics in the interpretation of indicators –to avoid biases sometimes found in global meta-analysis

# *Deliverables Indiseas 1*

–Special Series of papers for *ICES Journal of Marine Science*

- Online: February 2010
- Published: May 2010

–Website: www.indiseas.org

# IndiSeas1 Indicators

Indicators selected from a list of candidates on the basis of:

1. Ecological significance,
2. Sensitivity,
3. Measurability,
4. General public awareness.

**Table 3.** Summary of ecological indicators selected by the IndiSeas WG and the corresponding management objectives.

| Indicators | Headline label | Used for State or Trend | Management objective[a] |
|---|---|---|---|
| Mean length | Fish size | S, T | EF |
| TL of landings | TL | S, T | EF |
| Proportion of under- and moderately exploited stocks | % healthy stocks | S | CB |
| Proportion of predatory fish | % predators | S, T | CB |
| Mean lifespan | Lifespan | S, T | SR |
| 1/*CV* of total biomass | Biomass stability | S | SR |
| Total biomass of surveyed species | Biomass | T | RP |
| 1/(landings/biomass) | Inverse fishing pressure | T | RP |

[a]CB, conservation of biodiversity; SR, maintaining ecosystem stability and resistance to perturbation; EF, maintaining ecosystem structure and functioning; RP, maintaining resource potential.

**Image Source:** www.indiSeas.org

**Table Source:** Shin et al. (2010a)

# PICES Working Group 28: First year activities

Interactions and collaborations with similar activities in NOWPAP are welcome!