DEVELOPMENT OF ECOSYSTEM INDICATORS WITHIN PICES

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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*

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PICES THEMES

The PICES Strategy has 5 central themes:

1. *Advancing scientific knowledge*
2. *Applying scientific knowledge*
3. *Fostering partnerships*
4. *Developing capacity for ocean observing, collaborating, and education/training*
5. *Ensuring a progressive organization in support of PICES activities*

www.pices.int

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PICES ECOSYSTEM INDICATOR-RELATED ACTIVITIES

North Pacific Marine Ecosystem Status Reports

2 have been produced to date: 2005, 2010. Available at http://www.pices.int/publications/special_publications/default.aspx

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

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

Section on *Human Dimensions of Marine Systems* http://www.pices.int/members/sections/S-HD.aspx

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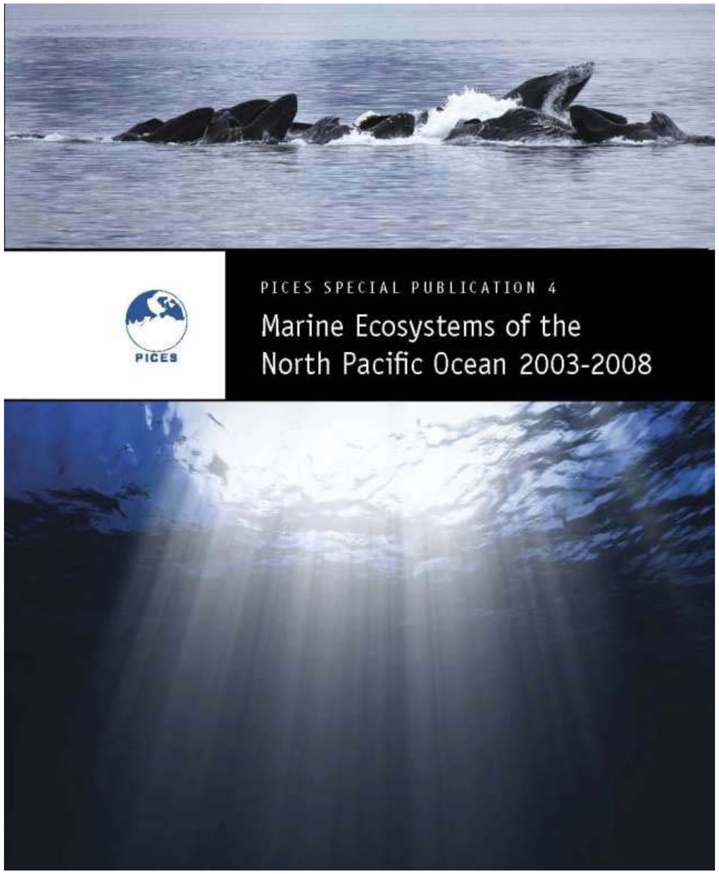
North Pacific Ecosystem Status Report, 2010



Chapters:

- Synthesis
- Oceanic
- California Current
- Alaska Current
- Bering Sea
- Sea of Okhotsk
- Oyashio
- Kuroshio
- Yellow and East China Seas

Chapter sub-headings

- Highlights
- Introduction
- Large-scale Indices
- Oceanography
- Phytoplankton
- Zooplankton
- Fishes and Invertebrates
- Marine Birds and Mammals
- References

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PICES ECOSYSTEM INDICATOR-RELATED ACTIVITIES

Terms of Reference for **Working Group 28** relevant to this workshop include:

- Identify and **characterise multiple pressures and activities** on North Pacific marine ecosystems
- Review **indicator-selection criteria**,
- **Identify categories of indicators** to document status and trends of ecosystem change at an appropriate spatial scale,
- Review potential **sources of data available**
- Review **approaches** for developing and evaluating indicators of responses to multiple stressors.

The **Section on the Human Dimensions of Marine Systems** is doing similar work, but with a focus on indicators of human activities relevant to marine ecosystems in the North Pacific

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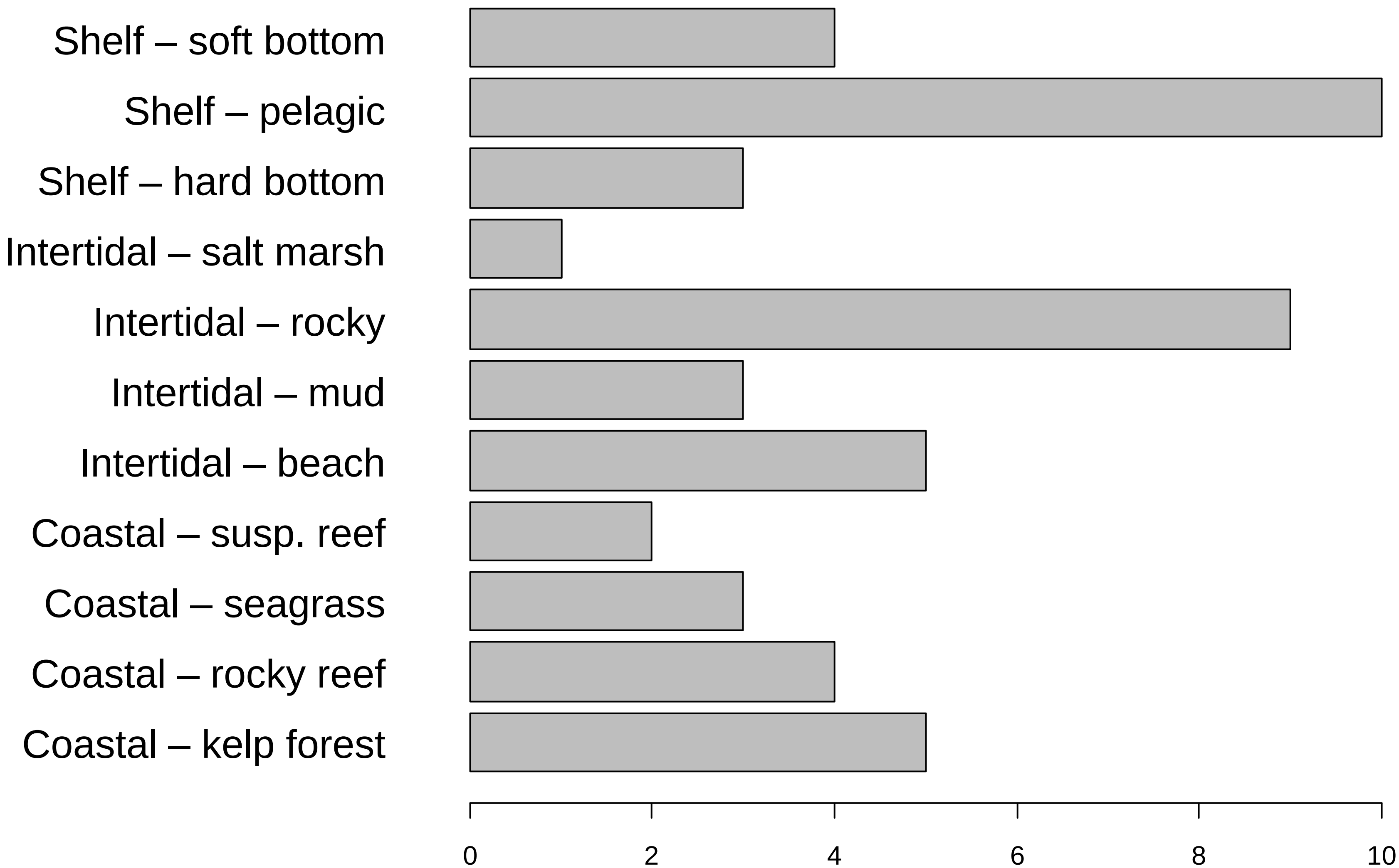
Multiple stressors in the North Pacific (20 stressors x 22 habitats)

Number of stressors identified per habitat type Strait of Georgia – expert opinion survey



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Indicator categories

- Status and trend
- Leading (early warning) or tipping points
- Climate, biodiversity, fishing, habitat, eutrophication, hazardous substances, water quality or quantity, air quality, human health and quality of life, and socio-economic-political
- Organism, species, population, ecosystem, landscape
- Contextual/audit/descriptive and management

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Suites of indicators - comparison

- Primary pressures
- Ecosystem type (e.g., semi-enclosed vs. open)
- Number and background of experts involved
- Data availability
- Incorporation of multiple stressors
- Multi-ecosystem comparison vs. ecosystem-specific suite

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IndiSeas (Indicators for the Seas)

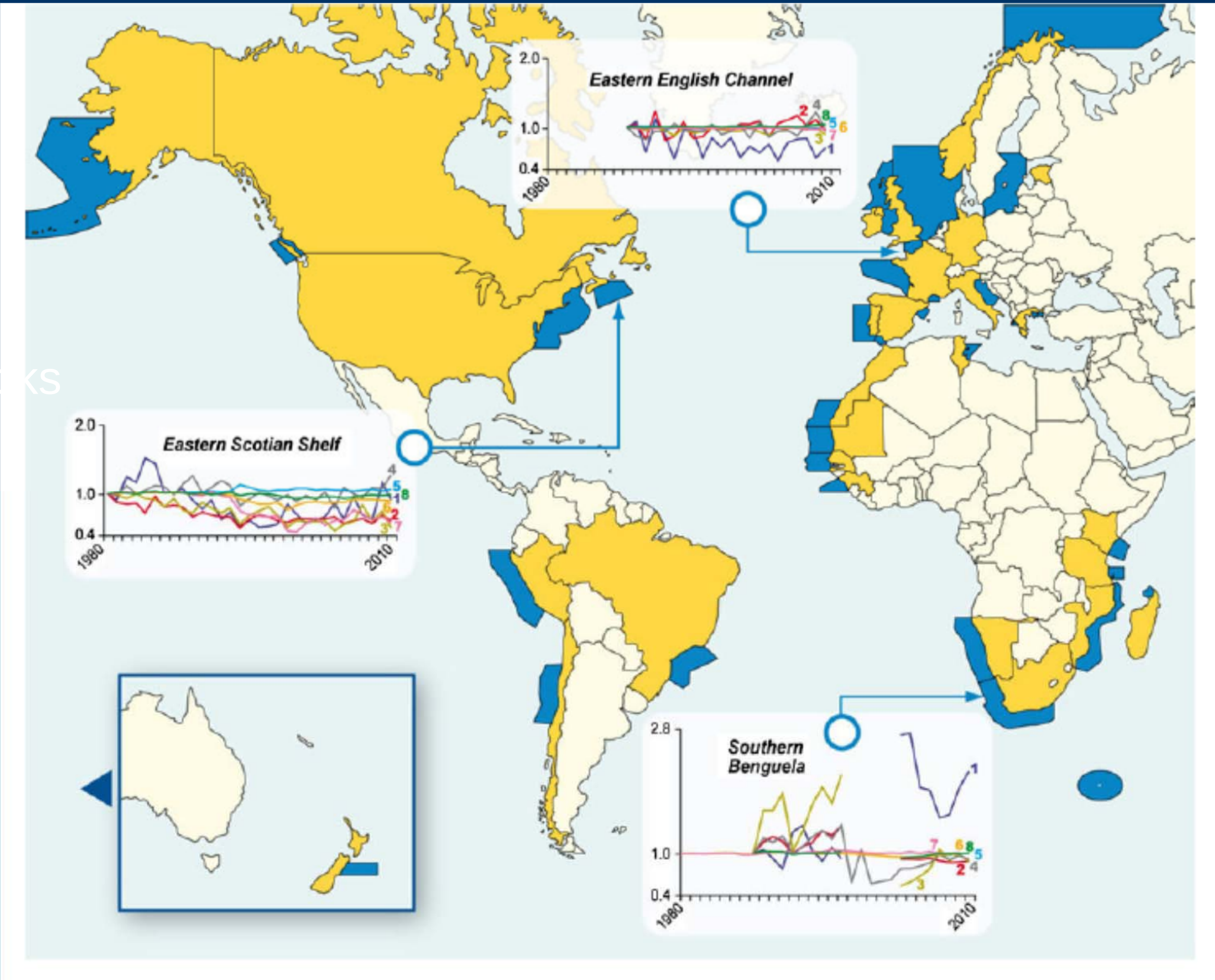
Evaluating the status of marine ecosystems in a changing world

Co-Leads: Yunne Shin (IRD), Lynne Shannon (UCT), Alida Bundy (DFO)

Biodiversity
- Fish size
- Trophic level
- %Predators
- Life span
- Biomass stability
- % sustainable stocks
- Biomass
- Inverse F
- Vulnerability

Climate
- SST
- Chl a

Human
- Management
- Governance
- Contribution
- Well-being



Tested and recommended indicators - EBFM

Conserve biodiversity	Reference
Hill's species evenness	4
Large fish indicator	4
Mean age at maturity	4
Mean individual fish weight	4
Mean length at maturity	2, 4
Mean von Bertalanffy growth parameter	4
Proportion of non-fully exploited stocks	5
Proportion of predatory fish	5
Species richness (number of species)	1, 2, 3, 4
Total abundance	4
Slope of size spectrum, all species	1, 2, 3

Maintain resource potential	Reference
1/(landings /biomass)	5
Biomass by group or community	1, 2, 3, 5

Maintain stability and resistance	Reference
1/CV of total biomass	5
Mean life span	5

Maintain structure and function	Reference
Maximum or mean length	2, 3, 5
Trophic level or trophic spectrum of catch	1, 2, 3, 5
# groups representing 80% of biomass	1
Abundance of scavengers	3
Biomass ratios	1, 2
Consumption	1
Fishery removals	2, 3
Habitat-forming taxa	1, 2, 3
Landings of target species	3
Mapping biomass indicators	1
Mean number of interactions per species	1, 3
Number of cycles	3
Nutrient cycling	1
Production; total primary production	1
Respiration or total production	1
Throughput	1
Volume of gelatinous zooplankton	3
Biophysical characteristics	2

1. Fulton et al. (2005)
2. Perry et al. (2010)
3. Link (2005)
4. Greenstreet et al. (2012)
5. IndiSeas (2012)

Biological Indicators		Canada	China	Japan	Korea	Russia	U.S.
Relative biomass	gelatinous zooplankton	N,N	Y,N	N,N	Y,Y	Y,Y	Y,Y
	cephalopods	N,N	Y,N	Y,Y	Y,Y	Y,Y	N,N
	small pelagic fishes	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y
	scavengers	N,S	N,N	N,N	S,S	Y,Y	N,Y
	demersals	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	N,Y
	piscivores	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	N,Y
	top predators	Y,Y	Y,Y	Y,Y	S,S	Y,Y	Y,Y
Biomass ratios	piscivore:planktivore	N,Y	Y,Y	Y,Y	Y,Y	S,Y	N,Y
	pelagic:demersal	N,Y	Y,Y	Y,Y	Y,Y	N,Y	N,Y
	infauna:epifauna	N,N	N,N	N,N	N,S	N,Y	N,N
Habitat-forming taxa	nearshore	Y,Y	S,N	S,S	S,S	Y,Y	N,N
	offshore	N,N	S,N	N,N	S,S	Y,Y	Y,Y
Size spectra		N,N	Y,Y	N,N	Y,Y	Y,Y	Y,Y
Taxonomic diversity		S,S	Y,Y	S,S	Y,Y	S,S	N,Y
Total fishery removals		Y,Y	S,Y	Y,Y	S,S	Y,Y	Y,Y
Max. (or mean) length		N,Y	Y,N	Y,Y	Y,Y	Y,Y	N,Y
Size-at-maturity	target species	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	Y,S
	bycatch	N,N	N,N	N,N	Y,Y	Y,Y	N,S
	top predators	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y
Trophic level or spectrum of catch		Y,Y	Y,Y	Y,Y	Y,Y	S,Y	Y,Y
Biophysical		S,S	Y,Y	Y,Y	Y,Y	S,S	S,S

PICES (2010) 1,2=> regularly calculated, availability of time series data

Broad Indicators of Pressures

Indicators, Activities, Stressors	Canada	China	High Seas	Japan	Korea	Russia	USA
Environmental stressors/indicators							
Temperature	Y,Y,Y			Y,Y,Y			
Sea Ice				Y,Y,Y			
Chla	Y,Y,Y			Y,Y,Y			
Nutrients	Y,Y,N	N		Y,Y,S	Y,Y,Y	Y,Y,N	Y,Y,N
River discharge	Y,Y,Y	N	N/A	Y,Y,Y	Y,Y,N	S,Y,N	Y,Y,Y
Toxic contaminants	Y,N,N	N	S,N,N	Y,S,S	Y,Y,N	Y,N,N	Y,N,N
Large scale climate index	Y,Y,Y			Y,Y,N			
pH	Y,N,N	S,Y	Y,N,N	Y,Y,S	Y,Y,N	Y,N,N	Y,N,N
Oxygen	Y,Y,N	S,Y		Y,Y,S	Y,Y,Y	Y,Y,N	Y,Y,N
Human activities & stressors							
Fishing	Y,Y,Y	N,N,N	S,S,S	Y,Y,Y	Y,Y,Y	Y,Y,Y	Y,Y,Y
Oil and Gas				Y,Y,S			
Military Activity	N,N,N	N,N,N	N,N,N	N,N,N	N,N,N	N,N,N	N,N,N
Wave/Wind/Tidal				Y,Y,Y			
Shipping				S,?,?			
Coastal engineering	Y,S,S	Y,N,N	N/A	Y,S,S	Y,S,N	Y,N,S	Y,N,S
Aquaculture				Y,S,S			
Ecotourism				N,N,N			
Land-based pollution				Y,S,S			

1,2,3=> data existence, availability, spatial extent

Broad Indicators of Pressures

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

1,2,3=> data existence, availability, spatial extent

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H. Batchelder, UNEP Workshop on indicators for regional seas, Geneva, July 2014

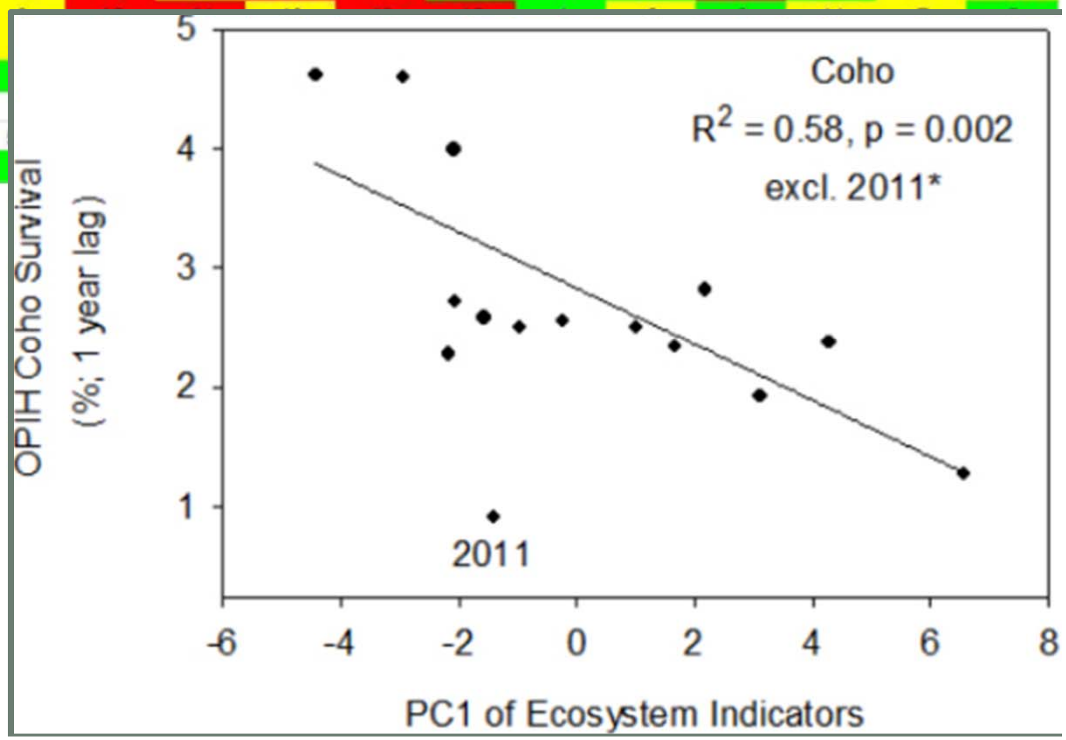
Approach	Pros	Cons
Empirical analysis	Track emerging stressors where expert input is untested or models are unavailable	Difficult to find data at appropriate scales
	Appropriate indicators can be tailored to the physical and biological nature of ecosystem	Least common denominator issue (shortest time series, smallest common spatial domain)
	Remotely sensed data available for many physical variables	
	Establish causal relationships between pressures and indicator responses	
Expert elicitation	Solution to the no data problem	Not enough info. for specific response variables
	Appropriate for global and regional visualization	
Model based analyses	Can generate as much data as needed	Must have a model (data and time intense)
	Can create an ensemble of models using different frameworks	Outputs are only as good as the data that go into the model

Data-based

Peterson et al. 2013

Ecosystem Indicators	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
PDO (December-March)	15	6	3	11	7	16	10	14	12	9	5	1	13	4	2	8
PDO (May-September)	10	4	6	5	11	15	14	16	12	13	2	9	7	3	1	8
ONI Jan-June	16	2	1	5	12	13	11	14	7	10	3	9	15	4	5	7
46050 SST (May-Sept)	14	8	3	4	1	7	16	13	5	15	2	9	6	10	11	12
NH 05 Upper 20 m T winter prior (Nov-Mar)	16	10	7	9	5	13	14	11	12	4	1	8	15	3	2	6
NH 05 Upper 20 m T (May-Sept)	13	10	12	4	1	3	16	15	7	8	2	5	11	9	6	14
NH 05 Deep Temperature	16	6	8	4	1	9	12	14	10	5	2	7	13	11	3	15
NH 05 Deep Salinity	16	3	7	4	5	13	14	8	6	1	2	11	15	10	9	12
Copepod Richness Anomaly	16	3	1	7	6	12	11	15	13	10	8	9	14	4	5	2
N. Copepod Biomass Anomaly	15	12	7	8	5	14	13	16	9	11	4	10	6	1	2	3
S. Copepod Biomass Anomaly	16	3	5	4	2	11	13	15	12	10	1	8	14	9	7	6
Biological Transition	16	11	7	3	8	12	10	15	14	4	1	2	13	5	9	6
Winter Ichthyoplankton	16	8	2	4												
Chinook Juv Catches (June)	15	4	5	13												
Coho Juv Catches (Sept)	11	2	1	4												
Mean of Ranks	14.7	6.1	5.0	5.9												
RANK of the Mean Rank	16	6	2	5												

Coho Salmon survival vs. PC of environmental indicators



Suites of North Pacific indicators in the literature

Program	Framework for indicator selection	Ecosystem(s)
Salish Sea EPA	DPSIR	Salish Sea (includes Puget Sound)
Puget Sound Partnership Vital Signs	DPSIR and IEA	Puget Sound (within Salish Sea)
AFSC Ecosystem Considerations	DPSIR and experts	Gulf of Alaska, Eastern Bering Sea, Aleutian Islands (3 regions), Arctic

HUMAN DIMENSIONS INDICATORS

Landings and catch (amount) in EEZ, outside EEZ
Landings and catch (value) in EEZ, outside EEZ
marine aquaculture production (value and amount)
Exvessel price
Sport fishing
other non-commercial fishing
Fishing costs
Fishing subsidies
IUU fishing

fishing vessels (number by gear type, size and tonnage)
fishing vessel power (HP)
fishing companies (number)
fishing effort(by gear type)
CPUE

commercial fishers (numbers)
commercial fishers (demographic characteristics, full-time or part-time)
mortality/injury rates (absolute and relative)
income of fishermen (absolute and relative to median)
~~net revenues from fishing~~

fish processing plants (number by scale and scope)
employment in fish processing
processed fish products (amounts)
first wholesale value
value added
value added multiplier

fishing households (number)
fishing villages/communities (number)
fishing ports (number)
~~Gini coefficient--egality?~~

health/contamination monitoring
per capita consumption
fish price to consumers

fish exports
fish imports
inventories of fish products

laws etc
international agreements

Value of ecosystem services
environmental acct/natural capital
valuation of non-marketed goods/services
replacement cost of ecosystem services

In development for next NPESR

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H. Batchelder, UNEP Workshop on indicators for regional seas, Geneva, July 2014

Conclusions

- The topic of Ecosystem Indicators, in particular in response to multiple ecosystem pressures, is an active topic of research for several PICES scientific groups.
- Existing approaches in the North Pacific and elsewhere are being reviewed
- A suite of indicators is expected to be refined by 2016 for use in the PICES 3rd Ecosystem Status Report
- The suite of integrative indicators are expected to cover key components and gradients at the appropriate spatial scales.
- The approach will include indicators of natural and human social conditions.

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Caution: The Devil is in the Details

- Indicators are used to inform decisions/actions
  - Need to be available (measurable; inexpensive)
  - Need context sensitivity (specificity and responsivity)
- Certainty is better than uncertainty
  - There are many sources contributing to uncertainty
    - Data: measurement error/observation uncertainty
    - Scope: spatial, temporal and compositional extent
    - Process: system connections and interactions (inclusivity)
    - Communication: ambiguity, semantics
    - Relevance: context sensitivity
  - Few of them are well quantified & often not disclosed
- Process-based indicators are (usually) better than statistical-based indicators (more likely to respond appropriately to novel situations)

Indicators: What do they indicate? How are they connected to things we care about (like marine resources, ocean health, etc.)?

"The absence of certainty is not an excuse to do nothing."

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H. Batchelder, UNEP Workshop on indicators for regional seas, Geneva, July 2014

Thanks & Questions??

Acknowledgements

- A large number of PICES scientists have provided significant expertise and time to indicators—what they measure, etc.
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- Jennifer Boldt (Chair of MONITOR Committee)
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