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

The Working Group met from 9:00 to 17:00 on October 13, 2012 at the International Conference Center, Hiroshima, Japan. The main objective of the meeting was to review activities during the first year of WG-28 and discuss the methodologies and outcomes for characterizing critical stressors and indentifying locations where multiple stressors interact in North Pacific ecosystems. Participants at this meeting are identified in *WG 28 Endnote 1* and the agenda for the meeting can be found in *WG 28 Endnote 2*.

AGENDA ITEM 2
Review of activities during the first year

Terms of Reference

The Terms of Reference (*WG 28 Endnote 3*) were reviewed and discussed. It was recognized that they are very ambitious, each of which could be an entire research project on their own. However, the WG felt that progress made on any of the Terms of Reference would be an important contribution to PICES and its FUTURE program.

Report on PICES-2012 Workshop W1

Co-convenors, Drs. Jennifer Boldt and Jameal Samhouri, of PICES Workshop W1 on "*Identifying critical multiple stressors of North Pacific marine ecosystems and indicators to assess their impacts*" presented their report (see Session Summaries elsewhere in the PICES-2012 annual report). Seven papers were presented. Three types of approaches were proposed: (1) expert-based surveys, (2) model-based analyses, and (3) empirical/data based analyses, although it was recognized that the boundaries between the approaches are fuzzy and often more than one approach is used. High level advantages and disadvantages of each of these approaches were identified. Tables were developed to assess the general availability of data in four categories to develop indices of multiple stressors on marine system. These categories were environmental, biological, human activities and stressors, and social-political-economic indicators. The purpose was to identify information gaps, and which categories have similar or different levels of information available in each of the PICES member countries (Do they data exist? Are time series available? and What is the extent of spatial coverage?). The concept for these tables is similar to that used by WG 19 on *Ecosystem-based management science and its Application to the North Pacific* which developed a table to assess the information potentially available in each PICES member country for ecosystem indicators (*PICES Scientific Report 37, Chapter 3, Table 3.1.3*).

WG 28 expressed its appreciation to the Convenors for an excellent session.

Action: Korean and Chinese members of the Working Group are asked to complete the tables for their countries.

Report on PICES-2012 Topic Session S10

Co-convenors, Drs. Vladimir Kulik, Ian Perry, and Motomitsu Takahashi, gave a short presentation on the general contents and expected outcomes from Topic Session S10, "*Ecosystem responses to multiple stressors in the North Pacific*", which was held later in the week, on Friday 19, October. This session was co-sponsored by SOLAS (Surface Ocean – Lower Atmosphere Study), a core program of the International Geosphere-Biosphere Program (IGBP). See the Session Summaries section of the PICES-2012 annual report for a complete description of the Topic Session.

National Reports on related activities

WG 28 members provided brief reports on additional activities in their countries relevant to the work of WG 28.

Canada: Dr. Perry made a short presentation on the work by DFO Pacific Region to develop a risk-based assessment framework to identify priorities for ecosystem-based oceans management in the Pacific Region. The work is based on a recent report (DFO 2012. Risk-based Assessment Framework to Identify Priorities for Ecosystem-based Oceans Management in the Pacific Region. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/044. Available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2012/2012_044-eng.html). It develops an ecological risk assessment framework (ERAF) to support the identification of risks and threats to Valued Ecosystem Components (VECs). It is suitable for identifying and assessing relative risks of harm to VECs from human activities and their associated stressors, and for ranking the significance of activities and stressors based on the relative risks to VECs in support of ecosystem-based management. In addition, a Driver-Pressure-State-Impact-Response (DPSIR) model can be used to identify priority drivers and pressures.

Korea: Dr. Ik Kyo Chung presented a brief overview of the IFRAME concept as developed by Dr. Zhang (Zhang *et al.* 2010, *Fisheries Research*; Zhang *et al.* 2011, *ICES J. Mar Sci.*).

USA: Dr. Samhouri suggested that NOAA's Integrated Ecosystem Assessment activities for the California Current could be leveraged for WG 28 purposes. These activities include recent efforts to compile time series for drivers and pressures (which are good for characterizing the temporal extents of stressors) and a paper which integrates expert opinion with empirical data to evaluate risk to habitats. In collaboration with Stanford University and NCEAS at UC Santa Barbara, Dr. Samhouri is also part of a new project, focused on identifying thresholds for marine spatial planning (http://thresholds.nceas.ucsb.edu/static/Welcome.html), which may bear some relevance to WG 28 activities.

AGENDA ITEM 3
Methodologies to address the Terms of Reference (*WG 28 Endnote 3*)

Framework for identifying multiple interacting stressors and their trends

WG 28 developed an applied web-based questionnaire regarding expert opinions on habitats which may be vulnerable to multiple stressors. For each question, respondents were 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%).

- *Spatial Extent*: spatial scale at which a single event of the activity/stressor impacts this habitat. Values were scored as 1 = <10 km^2; 2 = 10–100 km^2; 3 = 100–1000 km^2; 4 = >1000 km^2.

- *Frequency*: average annual frequency at which the activity/stressor occurs at a particular location in this habitat. Values were scored as 1 = rare, *e.g.* once every >5 yrs; 2 = occasional, *e.g.* once every >1–5 yrs; 3 = seasonal, *e.g.* every season to once a year; 4 = persistent, *e.g.* daily or continual.

- *Trophic impact*: primary level affected by the activity/stressor within the habitat. Values were scored as 1 = species (single or multiple); 2 = single trophic level; 3 = >1 trophic level; 4 = entire community.

- *Resistance to change*: degree to which the species, trophic level(s), or entire habitat's "natural" state is impacted by the activity/stressor, *i.e.*, how good is the resistance of this habitat to change caused by this activity/stressor. Values were scored as 1 = activity/stressor has a positive impact; 2 = high resistance to change (*i.e.* little significant negative change in biomass); 3 = moderate resistance to negative change; 4 = low resistance to negative change (*i.e.* significant negative biomass changes result from small stresses).

- *Recovery time*: average time required for the affected species, trophic level(s), or entire community to return to its "natural" state following disturbance by this activity/stressor. Values were scored as: 1 = <1 year; 2 = 1–10 years; 3 = 10–100 years; 4 = >100 years.

This survey of experts to identify habitats, stressors, and the vulnerability of habitats to each stressor was discussed:

Canada: The survey was distributed to over 50 experts; the geographic focus was the Strait of Georgia. The response rate was rather low, with some respondents replying that the survey was too difficult and they felt they did not have the expertise to respond to habitats and stressors beyond the research areas. Other respondents replied that the survey was too simplistic and could not possibly capture what is really going on. Dr. Perry presented the results in Topic Session S10.

China: no information was obtained from China yet, but Dr. Takahashi received some responses from some Chinese experts and will follow up on this.

Japan: Dr. Takahashi provided a brief overview of his presentation for Topic Session S10, reviewing the survey results for Japanese waters. He focused on the survey results from the Seto Inland Sea, in which coastal development has reduced the natural shore lines (majority of effects are artificial and semi-natural) and decreased tidal flat and sea grass beds due to coastal development. Problems for scoring encountered in survey: evaluation of impacts could be different among experts with different expertise; certainty of impacts are different among ecosystems due to quality and quantity of information. For the East China Sea, more information on intertidal and coastal waters along China are needed.

Korea: Dr. Chung did the survey with his students, and they found it difficult. He suggested conducting a preliminary review of information and then reducing the list and sending it out to survey participants. He commented that there is a lot of activity in member countries, and it was important to collate that information and not re-invent the wheel.

Russia: Dr. Kulik described that Dr. Olga Lukyanova does research on small spatial scales and human activities/stressors on ecosystems, which is regulated by government standards. Dr. Kulik's research is on a broader spatial scale. Ecosystem status; surveys sampled all the fish caught by trawl with 1 cm mesh, targeting mainly to estimate commercially important species, and the project to estimate energy flows in ecosystems through carbon (C/N) and nutrients among species moved to a new stage this year. Geographic and temporal (seasonal) variation will be taken into account. He noted that environmental information including water property profiles (T, S and sometimes acidity, pH, alkalinity, phosphate, silicate, nitrite, nitrate and DO), zooplankton composition and stomach contents almost at every trawling station are available, but at the first stage of extracting environmental pattern fluctuations, more frequent and regular time series such as SST and sea ice were chosen. Human information has been estimated through ship tracks taking into account maximum power of each vessel and type of trawling (is it bottom trawling or not?) through the area since 2003.

USA (Washington): Dr. Samhouri made a presentation at Workshop W1 on his results from the survey sent to experts on Puget Sound. He is restricted to sending the survey to federal employees only, but distributed the survey to ~45 of them.

USA (Alaska): Dr. Patricia Livingston attended the WG meeting on behalf of Dr. Stephani Zador. She described the Ecosystem Considerations document that is developed each year to accompany their stock assessment advice reports. They developed a team-based approach to derive a focused set of indicators and to provide ecosystem-specific assessments with state information. The main conclusions are: 1. the physiological and biological nature of the ecosystem, the extent of scientific knowledge about the ecosystem, and the particular expertise of team members will influence the final assessment product; 2. team discussion of assessment structuring themes should occur before indicator selection, and 3. developing assessments should be an iterative process with frequent review by fisheries managers. Some experts have expertise in only some areas; could target expert opinion in particular habitats.

WG 28 participants went over the scoring for the survey. Did the metrics work well? It can be difficult for experts to simplify things to fill out the survey. Some people did not want to do the survey because they did not have expertise on all things; others who know a lot about the ecosystem had difficulty because they know too much – *i.e.*, it can be difficult for experts to think generally. However, the value of this type of survey is having many people respond to the survey (provides an idea of consensus). In addition, the conclusions drawn from the responses can be verified in situations where empirical data exist. For the survey, respondents were asked to provide an estimate of their certainty for each question. These results can be used to identify components of vulnerability of habitats to stressors where information and understanding is lacking. For example, in the Canadian survey it appears that resistance to change and recovery time was usually scored with lower certainty than the other three components.

There was a long discussion on how to combine scores, and in particular how to include the certainty estimates for each component. For example, add them up or weight the responses based on their certainties estimates? In general, the goal is to produce a scaling in which a larger number represents a stronger impact. Dr. Perry proposed re-scaling the certainty scores, for example:

		Low certainty	High certainty
		Certainty scores 1 or 2	Certainty scores 3 or 4
Low impact	Certainty scores 1 or 2	2	1
High impact	Certainty scores 3 or 4	1	2

These weightings would then be multiplied by the scores for each vulnerability component, and then summed to derive the overall vulnerability score for that habitat to that stressor.

Dr. Samhouri proposed weighting the certainty values and multiplying them by the impact score. Alternatively, responses for which uncertainty >50% (*i.e.*, certainty <50%), could be deleted. In Alaska, Dr. Zador asked for uncertainties for each entry, which were then entered as a decimal. For example: enter 1–4 according to the definition (column B) for each vulnerability (x) AND include the decimal value in each cell corresponding to how certain you are of this value:
(x.1) best guess,
(x.2) some evidence of interaction from other systems,
(x.3) some evidence of interaction from this system,
(x.4) evidence of interaction from this specific habitat in this system (*e.g.*, published paper).
If there is no interaction, just leave the cell blank. For example: a value of 3.2 would represent moderate certainty seasonal changes in freshwater flow affect intertidal mud habitats based on studies from other systems.

Another suggestion was to use a certainty score of 0 and 1; however, it was pointed out that a score of 0 would eliminate too much information and having more than 2 scores provides more information.

In conclusion to this agenda item, it was suggested to examine different methods for this, and consider performing a sensitivity analysis on different weighting scenarios. The goal would be to recommend a common method for all members of WG 28 to use. It was also noted that the Teck *et al.* paper (*Ecological Applications* 20(5): 1402–1416, 2010) suggests that vulnerability is better represented by the resistance to change and the trophic level components.

Action: Drs. Samhouri and Perry to explore options for dealing with the certainty values.

Potential indicators for these stressors and interactions, and how they relate to ecosystem responses and identification of vulnerable ecosystem components

The Working Group discussed whether ecosystem indicators for multiple and interacting stressors would be any different from those developed for single stressors, such as fishing.

It was noted that the 'management class' of ecosystem indicators perhaps depends on the objectives constructed for those indicators more so than the type of stressor that is present. For example, say that indicators are relevant to objectives and the indicators will change for the objectives. However, knowing which stressors are causing ecosystems to respond is important for understanding how and why the ecosystem is changing. The indicators developed from the IndiSeas (www.indiseas.org) and the Alaska Ecosystems Considerations chapter may provide good starting points for baseline indicator sets that could be examined to determine if they need to be expanded to address issues of multiple stressors. Another suggestion was to develop indicators of ecosystem responses, followed by how stressors are changing, and then conduct correlative type analyses to relate the two sets of time series.

It was recommended that this topic be given further thought and be a main item for discussion at the Working Group meeting next year.

AGENDA ITEM 4
Discussion on draft Table of Contents and outline for the WG 28 final report

A draft Table of Contents (*WG 28 Endnote 4*) for the final report of WG 28 was reviewed and modified, and proposed chapter leads were identified. It was recommended to consider the use of a web-based platform (*e.g.*, Google docs) to access and track edits and version changes to the evolving chapters. Alternatively, a private page on the PICES website could be requested for the Working Group. The Group chose to leave it to the discretion of each set of chapter authors as to how they wish to handle their writing process. In addition, it was agreed that the delivery date for the Working Group could be no earlier than 2014 (which is the expected due date to the parent BIO and MEQ committees), but could possibly need to be extended to 2015.

Action:
- Chapter leads and contributing authors (see *WG 28 Endnote 4*) are to develop outlines for their chapters and detailed contents (for those chapters where this is possible) over the next year, and have ready for discussion at the next meeting.
- Working Group Chairs to notify the parent Committees about the anticipated delivery dates for the WG 28 final report.

AGENDA ITEM 5
Discussion of interactions with other PICES groups

Working Group members anticipate interactions with the following PICES groups:
- Section on *Climate Change Effects on Marine Ecosystems*
- MAFF-funded project on marine ecosystems and human well-being
- Section on *Human Dimensions of Marine Systems*
- Any expert groups working on harmful algal blooms or invasive species
- MONITOR Committee, re: environmental indicators

Interactions with other PICES groups are also welcome.

AGENDA ITEM 6
Topic Session at PICES-2013

A proposal for a Topic Session at the next PICES Annual Meeting was submitted through a new on-line submission system to the PICES website (*WG 28 Endnote 5*). The Working Group felt this was a very ambitious topic, but appropriate for this Working Group to begin to address. Suggestions for possible invited speakers include: Marten Scheffer (The Netherlands), Steve Carpenter (USA), an expert from the IndiSeas program, Shinsuke Tanabe (CMES, Ehime University, Japan) – eco-toxicologist, and Isabel Coté (Canada) or her student Emily Darling.

The next meeting of the Working Group is expected at PICES-2013 to be held in Nanaimo, Canada.

AGENDA ITEM 7
Adjourn

The meeting adjourned at 1700 h, followed by a sake sampling and yakitori dinner party.

WG 28 Endnote 1

WG 28 meeting participation list

Members	Observers
Jennifer L. Boldt (Canada)	Christopher Aura (Japan)
Ik Kyo Chung (Korea)	Karin Baba (Japan)
Sachihiko Itoh (Japan)	Natalie Ban (Australia)
Vladimir V. Kulik (Russia)	Yoichiro Ishibashi (Japan)
Ian Perry (Canada, Co-Chairman)	Patricia Livingston (USA)
Jameal Samhouri (USA)	Kazuhito Mochida (Japan)
Motomitsu Takahashi (Japan, Co-Chairman)	Masakatsu Ohyama (Japan)
Naoki Yoshie (Japan)	Takafumi Yoshida (Japan)
Stephani Zador (by WebEx for the first half of the meeting)	Hiroaki Saito (Japan)

WG 28 meeting participants at PICES-2012 in Hiroshima, Japan. Left to right: Motomitsu Takahashi, Hiroaki Saito, Sachihiko Itoh, Takafumi Yoshida, Christopher Aura, Naoki Yoshie, Jameal Samhouri, Natalie Ban, Yoichiro Ishibashi, Patricia Livingston, Karin Baba, Jennifer Boldt, Ik Kyo Chung, Vladimir Kulik, Ian Perry.

WG 28 Endnote 2

WG 28 meeting agenda

1. Welcome, Introduction and sign-in (all)
2. Review of activities during the 1st year of WG-28
   a) General review of Terms of Reference
   b) Report on outcomes of Workshop W1
   c) Report on Topic Session S10
   d) Report on additional related activities from each PICES country
3. Discuss methodologies to address the Terms of Reference
   a) Framework for identify multiple interacting stressors and their trends (e.g. session S10)
   b) Potential indicators for these stressors and interactions, and how they relate to ecosystem responses and identification of vulnerable ecosystem components (e.g. W1)
4. Discussion on draft Table of Contents, outline for the WG28 final report, and assignment of tasks: begin developing the outline for the final report, discuss the general contents of each chapter, and who will take the lead on each chapter.
5. Discussion of interactions with other PICES groups
   a) Relationships between WG28 and other Working Groups and Committees
   b) Contributions to FUTURE
6. Discussion on Topic Session at PICES-2013
   a) Review of a topic session proposal
   b) Other related issues
7. Adjourn

WG 28 Endnote 3

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 if possible.
2. Review and identify categories of indicators needed to document status and trends of ecosystem change at the most appropriate spatial scale (e.g., coastal, regional, basin).
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.
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?

WG 28 Endnote 4

DRAFT Final Report Table of Contents

(Note: all WG members are expected to contribute to each main chapter; names listed are those who will likely take the leads for each chapter)

1. Introduction (Co-Chairs)
   – background to WG 28
   – Terms of Reference / Objectives
   – brief overview of the issue of multiple activities/stressors on marine ecosystems:
     - *e.g.*, use of the phrase "activities/stressors (or "pressures") to indicate both natural and anthropogenic pressures, and that not all of these are always "bad" for the ecosystem,
     - include definitions for "stressors", issue that information to construct indicators is often available at multiple but different time and space scales, *etc*.

2. Frameworks linking pressures to impacts and changes in North Pacific marine ecosystems (Perry, Takahashi, Samhouri, Zhang, Lee)
   – brief review of potential frameworks that could be used to link activities and stressors to ecosystem responses,
   – assessment of their applicability to North Pacific marine ecosystems,
   – recommendations for applications,
   – *e.g.*, Pathways of Effects and Driver-Pressure-States-Impact-Response models; simulation and other analytical modeling approaches, *e.g.* Ecopath with Ecosim, probabilistic (Bayesian) networks; Integrated Ecosystem Analyses; IFRAME, others?
   – addresses ToR 4.

Multiple pressures on North Pacific marine ecosystems
   – identification of the spatial (and temporal, if available) extent of important activities and stressors in North Pacific marine ecosystems,
   – identify habitats and general locations (if possible) where multiple stressors overlap,
   – identify trends in these activities/stressors if possible,
   – sub-sections of this chapter for each PICES country, preferably using a common approach, plus a synthesis section,
   – *e.g.*, PICES Topic Session S10 at 2012 Annual Meeting (Hiroshima),
   – addresses ToR 1.

3. Ecosystem indicators (Boldt, Ito?, Samhouri, Yoshie, Kulik, Chung – re filing W1 tables)
   – brief review of indicators proposed in the literature to document status and trends of ecosystem conditions,
   – present criteria proposed for the selection of indicators, *e.g.*, Rice and Rochet (2005. *ICES J. Mar. Sci.* 62: 516–527), PICES-2011 FUTURE Workshop,
   – focus in particular on indicators relevant for assessing multiple pressures,
   – addresses ToR 2 and 3.

Indicators for ecosystem responses to multiple pressures
- identify ecosystem indicators which might be used to provide an understanding of how ecosystems respond to multiple stressors
- (could use case studies to provide mechanistic understanding where these are known)
- evaluate their potential to identify vulnerable ecosystem components
- *e.g.*, PICES Workshop W1 at 2012 Annual Meeting (Hiroshima)
- Include tables produced in W1 regarding available data
- addresses ToR 5

4. Case study examples (or embed in above chapters??) (Samhouri, Perry, Boldt, Takahashi, Itakura?)
- which areas:
  - Salish Sea (Strait of Georgia; Puget Sound),
  - Seto Inland Sea,
  - Possibly: Sea of Okhotsk, Bering Sea (?Lukyanova, Kulik, Zador?)

5. Conclusions and recommendations (Co-Chairs)

Appendices
1. Terms of Reference
2. Membership
3. Reports of sessions held by WG28

etc.

WG 28 Endnote 5

Proposal for a 1-day Topic Session on "*Ecosystem indicators to characterize ecosystem responses to multiple stressors in North Pacific marine ecosystems*" at PICES-2013

Multiple natural and human stressors on marine ecosystems are common throughout the North Pacific, and may act synergistically to change ecosystem structure, function and dynamics in unexpected ways that can differ from responses to single stressors. Further, these stressors can be expected to vary by region, and over time. Understanding the impacts of multiple stressors, and developing indicators which capture their behaviours and changes, are major challenges for an ecosystem approach to the North Pacific and for the PICES FUTURE project. The objective of this session is to present potential indicators of ecosystem responses to multiple stressors in the North Pacific (with the focus on multiple, rather than single, stressors). One goal of the session is to determine if these proposed ecosystem indicators provide a mechanistic understanding of how ecosystems respond to multiple stressors and to evaluate their potential to identify vulnerable ecosystem components. For example, 1) are responses to stressors simply linear or are changes non-linear such that small additional stressors result in much larger ecosystem responses; 2) do different parts of the ecosystem respond differently (e.g., trophic level responses); 3) how do stressors interact and can these interactions be adequately captured by the proposed indicators? Both empirical and model-based analyses are welcome. This session will provide input to Working Group 28 on ecosystem indicators for multiple stressors on the North Pacific, and will feature progress and presentations from within and outside of this Working Group.

Sponsoring Committee/Program: BIO/FIS/MEQ/TCODE/FUTURE

Co-convenors: Ian Perry (Canada), Vladimir Kulik (Russia), Chaolun Li (China), Jameal Samhouri (USA), Motomitsu Takahashi (Japan) , Chang-Ik Zhang (Korea)