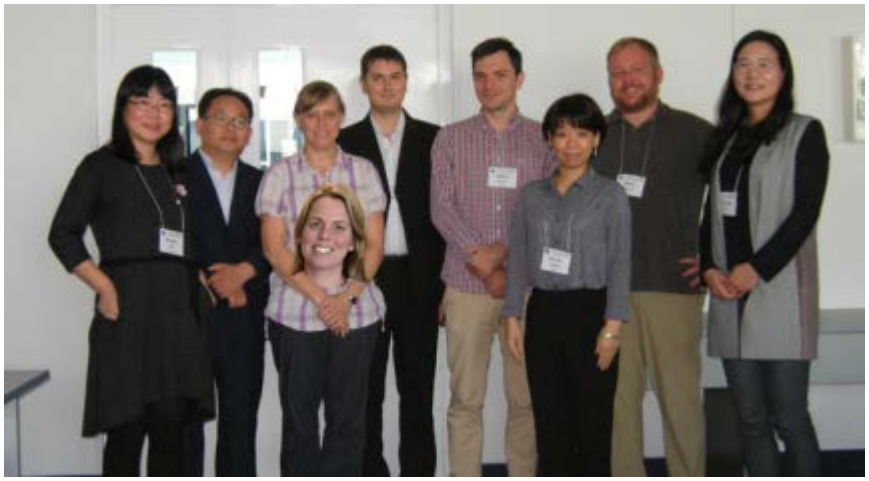
Report of Working Group
Common Ecosystem Reference Points across PICES Member Countries

The Working Group on *Common Ecosystem Reference Points across PICES Member Countries* (WG 36) met from 9:00 to 17:30 h on September 22, 2017 in Vladivostok, Russia under the chairmanship of Drs. Mary Hunsicker (USA) and Xiujuan Shan (China). The meeting objectives of this first were to review WG 36 TORS (WG deliverables), discuss and summarize WG 36 contributions to FUTURE, discuss indicators and reference points that are important to respective countries and ecosystems, identify action items, develop a work plan and timeline, and discuss cooperation with the other WGs and organizations.

The participants at this meeting are listed in ***WG 36 Endnote 1***. The agenda for this meeting is presented in ***WG 36 Endnote 2***.



Participants of the first meeting of WG 36 at PICES-2017, Vladivostok, Russia. Left to right: Xiujuan Shan, Sangchoul Yi, Mary Hunsicker, Jennifer Boldt, Vladimir Kulik, Robert Blasiak, Kazumi Wakita, Elliott Hazen, Sukyung Kang.

AGENDA ITEM 1
Welcome and WG member introductions

The WG 36 Co-Chairs welcomed members and working group members introduced themselves. Dr. Hunsicker participated via phone.

AGENDA ITEM 2
Review SG-CERP's report

Dr. Hunsicker provided an overview of the report from the Study Group on *Common Ecosystem Reference Points across PICES Member Countries* (SG-CERP). SG-CERP was supported by FUTURE, MONITOR, and S-HD and addressed Objective 1.1 of the FUTURE Science Plan to understand what determines "an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing." Managing ecosystems under a changing climate requires flexibility to facilitate resilient ecosystems for ecological and societal goals. This creates a need for dynamic reference points that reflect a dynamic marine environment and a coupled social-ecological system. Can we develop common ecosystem

reference points that incorporate both societal need and climatic variability? How do ecosystem reference points compare among PICES member nations?

SG-CERP members discussed the need for ecosystem reference points and drafted:

1. A Working Group proposal to advance this work through the lifetime of the FUTURE program, including terms of references and deliverables,
2. A Workshop proposal for the 2017 Inter-sessional Science Board meeting (did not occur because membership was still being determined for the WG),
3. Topic Session proposal for PICES-2017 in Vladivostok (S3: *Below and beyond maximum sustainable yield: Ecosystem reference points*),
4. A schematic of where the proposed WG fits in with other PICES expert groups and with FUTURE,
5. A timeline for activities and deliverables for the WG,
6. A table of methods for detecting non-linearities in time series relationships,
7. A table of previous indicator work, including sources for ecosystem indicators, indicator recommendations, and data availability.

AGENDA ITEM 3

Review of WG 36 Terms of Reference

WG 36 members reviewed the TORs for the WG (***WG 36 Endnote 3***).

AGENDA ITEM 4

WG 36 contributions to FUTURE

Dr. Hunsicker reported on WG 36 contributions to FUTURE, and potential collaborations with other WGs. Products from WG 36 will help address some of the goals of FUTURE, such as understanding how marine ecosystems in the North Pacific respond to climate change and human activities. In particular, WG 36 will help address FUTURE's research theme question: "How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?" WG 36 will help address FUTURE linkages from ecosystem processes to marine ecosystems and between marine ecosystems and human systems (Figure 1).

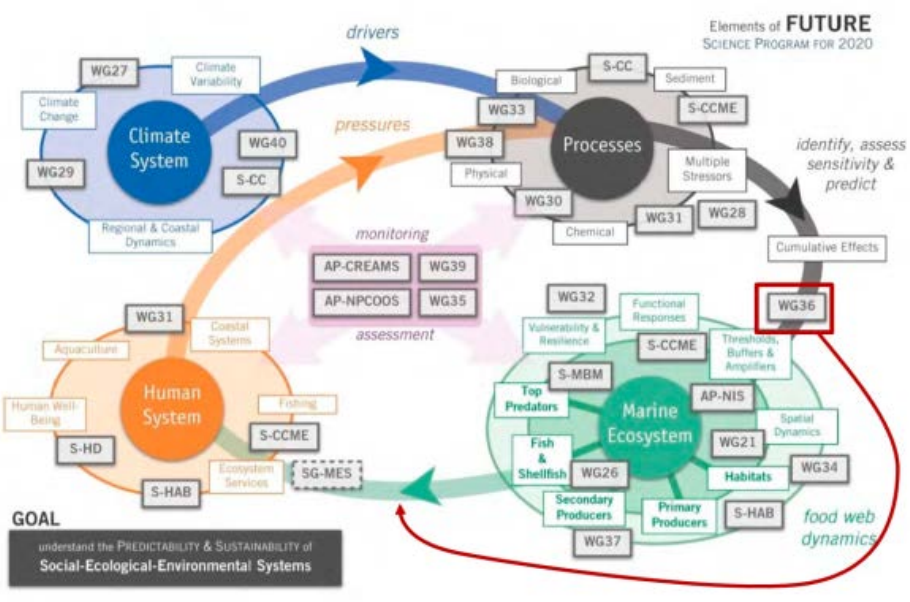


Figure 1 Schematic showing where WG 36 products fit into the FUTURE Science Program.

AGENDA ITEM 5

Presentations on indicators, reference points, and topics important to respective countries/study ecosystems and relevant to the WG activities

WG members provided brief, informal presentations on indicators, reference points, and topics that are important to their respective countries/study ecosystems and relevant to the WG activities.

Some of the main points arising from these presentations and follow-up discussions are the following.

- Some important references were identified, including:
  - Monnereau, I., Mahon, R., McConney, P., Nurse, L., Turner, R., Valles, H. 2017. The impact of methodological choices on the outcome of national-level climate change vulnerability assessments: An example from the global fisheries sector. *Fish and Fisheries* 1–15. DOI: 10.1111/faf.12199. Monnerau *et al*. (2017) identified shortcomings in methodological decisions behind vulnerability work such as inconsistent representation among countries belonging to each group, use of socio-economic indicators not scaled to population size, use of a small number of indicators, and lack of accounting for potential redundancy among indicators.
  - Cheung, W.W.L., Pitcher, T.J., Pauly, D. 2005. A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. *Biological Conservation* 124: 97–111. Cheung *et al*. (2005) and Cheung and Jones (in press) used fuzzy logic to deal with data gaps and differences in data quality (using a series of "if/then" statements).
  - Wakita *et al*. 2014. Human utility of marine ecosystem services and behavioural intentions for marine conservation in Japan. *Marine Policy* 46: 53–60. This study showed that peoples' perception of marine ecosystem services would be diverse based on their way of living and it would affect behavioral intentions for marine conservation.

- Participants discussed what indicators should be examined. Members suggested that the WG could start with some of the indicators recommended by WG 28 (*Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*) and WG 19 (*Ecosystem-based Management Science and its Application to the North Pacific*), such as, biomass of fish by group or community. Discussion points included:
  - Species richness would be difficult to calculate across surveys.
  - Access to some data is limited in different member countries. Publically available data will sometimes provide a different understanding than data that is used in decision making.
  - WG 36 could coordinate with WG 35 (WG-NPESR3) to get data time series or at least metadata for indicators.
  - One option could be to select one indicator per objective.
  - Indicator selection varies by ecosystem, major pressures, experts involved.
  - Do we need to select a species/objective that is important to all countries?
  - We could examine a couple common indicators across all ecosystems and also include additional indicators that are important for individual ecosystems.
  - Perhaps consider including migratory species shared among countries.

- Participants discussed methodologies for assessing non-linear responses of indicators. The main points were:
  - When comparing different methodologies to detecting nonlinear responses of indicators, General Additive Model (GAM) results are more easily interpreted compared to gradient forest approach.
  - One limitation of GAMs is that they do not work well if there are missing data, and the data time series has to be fairly long.
  - Not many indicators examined so far have a clear threshold.
  - One con of specified functional forms is that you have to know form beforehand
  - GAMs and Gradient forest don't rely on knowing functional form.

- Nonlinear time series analysis needs a lot of data
- Change-point analysis is easy to run
- Rodionov's STARs analysis may be better than other change point analyses because it provides a test of significance and behaves better at the end of the time series. STARS has an excel add-on; we could look for R code.
- Structural equation modeling, which doesn't require a known functional form, is being explored for the California Current's Integrated Ecosystem Assessments (IEA), for use after thresholds have been detected. How the model is structured is important.
- Second derivative and GAM methodologies are very similar.
- Gradient forest is used to look for changes in variance – which is somewhat similar to change point analysis.
- R code is available for GAMs and second derivatives.
- Gradient forest could be examined for a couple of time series.
- A GitHub repository could be used to share code.

AGENDA ITEMS 6 TO 11

Action items, work plan/timeline, and meetings for 2017/2018

WG 36 members discussed action items and developed a work plan, and a schedule for meetings during 2017/2018.

- Participants discussed and identified tasks for WG members for TORs 1–3.
  TOR 1: Outline each member country's mission, goals, government science plans and write a summary for the first TOR.
  - Summarize government science plans
    Action item: Each country can likely pull together information for this TOR; the focus would be on fisheries; a variety of ministries in each country would have to be consulted.
    Action item: Dr. Hunsicker to write a template or write the U.S. description so others can follow.
  - Afterwards, WG members could compare among descriptions to identify comparable areas.

  TOR 2: Previous PICES WG 28 and WG 19 tables of data availability provide information for this TOR.
  - The WG will re-visit these tables once we identify/update list of indicators.
  - Determine a subset of indicators: discuss the best method to do this; review objectives or indicators in the excel spreadsheet.
  - Members to review these indicators and determine which are most important for their systems and identify which ones have data that would be easily accessible within the next 6 months and are long enough so that the WG can do analyses on these.
  - Can we do this within the next couple months so that the WG can do analyses on them at the inter-sessional workshop?
  - Members discussed which ecosystems should be examined. There are the NPESR identified ecosystems that could be used (region numbers); there are individuals that are responsible for each LME. The WG could use data from the NPESR if it matches what was contributed to NPESR.
  - NPFC/PICES group – can WG 36 link to them? Regions 18 and 23 – there are data for Pacific saury with the NPFC. NPFC would be a useful source of data for a couple of species. A WG on jack mackerel will meet in Vladivostok this year.
    Action item: Dr. Kulik to look into data availability from the NPFC.
  - There is no representation from Alaska in WG 36, but the WG could invite someone for the inter-sessional workshop, since they have long time series.
    Action item: members to think about other ideas in terms of how we decide on focal ecosystems.
  - Difficult for some members to identify which indicators are important for their region, perhaps a step-wise approach would be best. For example, the Bering Sea has good biological data

coverage. We may have some ecosystems with multiple indicators (*e.g*., Bering Sea) and others will have fewer indicators, but perhaps indicators in common with the Bering Sea, so comparisons could be made across multiple ecosystems.

Action: Dr. Hunsicker to send an example and develop this over the next couple of months.

Action: Dr. Hazen to ask S-MBM for top predators data.

TOR 3: Potential methods the WG could use.

Action item: Dr. Hunsicker to add pros and cons (including time series length requirements, if method can handle data gaps; interpretability, *etc*.) to the methodology table and add other methods (*e.g*., papers that Dr. Blasiak introduced), include references in the table.

- WG to continue to think about this, but TORs 1 and 2 are a higher priority.

Action item: Elliot to set up a GitHub repository to share code for methods.

Action item: Dr. Hazen to assemble data sets before the inter-sessional workshop.

- WG members wrote a proposal for an inter-sessional workshop (see ***WG 36 Endnote 4***):
  - Options include:
    - 4th international climate change symposium in Washington, DC, June 4–8, 2018,
    - Transitional areas conference in La Paz, Mexico, April 24–26, 2018.
  - The climate change symposium is a priority because we could get input from Scott Large, IndiSeas people.

- Members discussed PICES-2018:
  - No Topic Session was proposed,
  - 1 business day meeting was requested,
  - The Co-Chairs prepared a proposal for a workshop (see ***WG 36 Endnote 5***). This would be a continuation of the Intersessional workshop, where we could potentially start analyses for leading indicators (TOR 5). "Identify ecosystem components that respond earliest to changes in biophysical drivers and could potentially serve as leading indicators of loss of resilience and ecosystem change."
  - It was suggested that the WG request another member from Canada.
  - WG 36 should coordinate with S-MBM, WG-NPESR3, and look to better coordinate with HD, and, in year 2 or 3, with WG 40.

- Members developed a PowerPoint presentation report to FUTURE SSC

Action: Dr. Boldt to draft meeting report and send to the Co-Chairs for edits.

WG 36 Endnote 1

WG 36 participation list

Members	Members unable to attend
Xiujuan Shan (China, Co-Chair)	China: Yanbin Gu, Yan Jin
Sangchoul Yi (Korea)	Japan: Mitsutaku Makino
Mary Hunsicker (USA, Co-Chair)*	
Jennifer Boldt (Canada)	Observer
Vladimir Kulik (Russia)	
Robert Blasiak (Japan)	Steven Bograd (USA, FUTURE SSC, SB, POC)
Kazumi Wakita (Japan)	
Elliott Hazen (USA)	
Sukyung Kang (Korea)	

*Participated remotely

WG 36 Endnote 2

WG 36 meeting agenda

1. Welcome and WG member introductions
2. Review SG-CERP's report
3. Review WG 36 TORS (WG deliverables)
4. Discuss and summarize WG 36 contributions to FUTURE
5. Brief, informal presentations on indicators, reference points, and topics that are important to respective countries/study ecosystems and relevant to the WG activities
6. Identify action items, develop work plan/timeline, and schedule meetings for 2017/2018
7. Discuss cooperation with the other WGs and organizations, for example, ICES
8. Draft proposal for an inter-sessional workshop in 2018
9. Draft proposals for a workshop and a topic session at PICES-2018
10. Discuss other potential proposal ideas for priority projects and activities with financial and policy implications
11. Review main highlights for the Co-Chairs' report to the FUTURE SSC

WG 36 Endnote 3

WG 36 Terms of Reference

1. Outline each country's mission, goals, and governmental science plans that point to the establishment of reference points across PICES member nations, and identify those that are comparable. (Intersessional / Yr1);
2. Summarize previous efforts identifying data availability for geographic areas and time periods of particularly strong climate influence and dependence on marine systems within specific North Pacific ecosystems, fish stocks, and fishing communities. This will build upon indicators identified via WG-19, WG-28, S-HD and WG-35 (NPESR-3). Determine a subset (or not) of ecosystems and indicators that will be the focus of WG activities. (Intersessional / Yr 1);
3. Summarize and select previous methods for determining thresholds (both non-linear and societal limits) in ecosystem indicators. This would include statistical and objective-based approaches (Intersessional / Yr 1);
4. Determine shapes or functional forms of driver - response relationships from available datasets, and quantify thresholds to identify potential ecosystem reference points. (Yr 2);
5. Identify ecosystem components that respond earliest to changes in biophysical drivers and could potentially serve as leading indicators of loss of resilience and ecosystem change. (Yr 3);
6. Develop a "heuristic model" to examine drivers (climate forcing, fishing) and ecosystem response using selected ecosystem reference points for member nations. (Yr 3);
7. Publish final report.

WG 36 Endnote 4

Proposal for an inter-sessional workshop on
"Quantifying thresholds in driver-response relationships to identify reference points"
in conjunction with the 4th International Symposium on
***"The effects of climate change on the world's oceans"* in 2018**

Duration: 2 days

Convenors: Xiujuan Shan (China), Mary Hunsicker (USA) Jennifer Boldt (Canada), Elliott Hazen (USA)

Suggested Invited Speakers: Yunne-Jai Shin (France), Lynne Shannon (South Africa), Jameal Samhouri (USA), Scott Large (Denmark/ICES)

Marine ecosystems are influenced by dynamic atmospheric and oceanographic drivers and human activities. An open question is whether biological responses within the ecosystems are linear or nonlinear in relation to climatic forcing variables or the abundance of other species. Strong nonlinearities indicate the existence of thresholds beyond which small changes in a climatic variable or species abundance cause large responses in another ecosystem component. Crossing ecological thresholds can alter or redistribute ecosystem benefits to humans and thereby have important socioeconomic consequences. Thus, knowledge of where these thresholds exist is valuable for determining target or limit reference points to prevent ecosystem components from tipping into undesirable states. TOR 4 of WG 36 CERP is to 'determine shapes or functional forms of driver - response relationships from available datasets, and quantify thresholds to identify potential ecosystem reference points'. The proposed workshop is a key step for achieving this goal and for establishing a strong foundation for TOR 5, 'identifying ecosystem components that respond earliest to changes in biophysical drivers and could potentially serve as leading indicators of loss of resilience and ecosystem change'. In addition, having the proposed workshop at the joint ICES/PICES meeting provides an excellent opportunity to develop a cooperation or partnership between these two organizations to advance the science of thresholds and leading indicators of ecosystem change. The specific objectives of the workshop are to: 1) Review results from TORs 1-3, specifically the focal ecosystems and indicators identified for our WG (TOR 2), the available data sets (TOR 2), and the methods selected for identifying thresholds in the ecosystem indicators (TOR 3). 2) Develop or refine previous R code via GifHub that is generalizable for identifying nonlinearities and thresholds in driver-response relationships in the focal ecosystems. 3) Apply analyses to focal ecosystems and indicators and summarize/compare findings. 4) Review and summarize methods for identifying leading indicators of ecosystem change in marine ecosystems to lay the foundation for TOR 4. 5) Review similar efforts from ICES working groups and discuss potential strategies for facilitating a partnership between ICES and PICES, *e.g*. joint working group.

WG 36 Endnote 5

Proposal for a Workshop on
"Identifying common reference points and leading indicators of ecosystem change"
at PICES-2018

Convenors: Xiujuan Shan (China), Mary Hunsicker (USA), Vladimir Kulik (Russia)

Duration: 1 day

Suggested Invited Speakers: Gavin Fay (USA), Steve Munch (USA). Jin Gao (USA), Beth Fulton (Australia), Michael Litzow (USA)

Abrupt nonlinear change in ecosystem structure and function can dramatically alter human-derived benefits from the system and can have negative impacts on people's livelihoods and well-being. A growing number of driver-response relationships in marine ecosystems are being identified as strongly nonlinear, indicating that they are potentially prone to inflection points and threshold dynamics. Better knowledge of where such thresholds occur can advance our ability to anticipate future conditions and critically inform what management actions can maximize ecological, social or economic benefits. Moreover, thresholds common across analogous systems can be used to develop robust sets of reference points to prevent ecosystem components from tipping into undesirable states. A major goal of WG 36 CERP is to 'determine shapes or functional forms of driver - response relationships from available datasets, and quantify thresholds to identify potential ecosystem reference points' in North Pacific ecosystems (TOR 4). The proposed workshop is an important step for completing this goal and for making comparisons among the focal ecosystems selected for WG 36 activities. The workshop will also allow WG 36 to make progress in 'identifying ecosystem components that respond earliest to changes in biophysical drivers and could potentially serve as leading indicators of loss of resilience and ecosystem change' (TOR 5). In addition, the proposed workshop will give WG 36 members an opportunity to work together to ensure that the methods and R code generated for the WG activities can be easily used by PICES member nations as well as other nations to identify potential target or limit reference points and early warning signs of ecosystem change. The specific objectives of the workshop are to: 1) Conduct analyses for TOR 4 to 'determine shapes or functional forms of driver–response relationships from available datasets, and quantify thresholds to identify potential ecosystem reference points' in North Pacific ecosystems. 2) Identify differences and commonalities among thresholds / ecosystem reference points in the focal ecosystems of WG-36 activities. 3) Select common methods for system-wide comparisons to identify leading indicators of ecosystem 4) Develop, test and share R code via shared GitHub repository that is generalizable for other ecosystems. 5) If time allows, begin applying leading indicator analyses to focal ecosystems of PICES member nations (TOR 5).