Report of the Study Group on *Common Ecosystem Reference Points*

The Study Group on *Common Ecosystem Reference Points* (SG-CERP) met on November 3, 2016, in San Diego, USA, under the Chairmanship of Dr. Elliott Hazen. Participants introduced themselves. Four members of the Study Group were in attendance as well as other PICES members (***SG-CERP Endnote 1***). SG-CERP reviewed and accepted the agenda (***SG-CERP Endnote 2***). While a number of the Study Group members were unable to attend the meeting, some of them were able to provide feedback electronically prior to the meeting. The Study Group was extremely productive, with constructive discussions and sharing of information.

SG-CERP was supported by FUTURE, MONITOR, and Section on *Human Dimensions of Marine Systems* (S-HD) in its attempt to address 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 in order to facilitate resilient ecosystems for ecological and societal goals. For example, high fishing rates under poor climatic conditions and high predation pressures are less likely to produce favorable management outcomes than the same fishing rates under good climatic conditions. This kind of observation motivated the need for dynamic reference points that reflect a dynamic marine environment and a coupled social-ecological system.

SG-CERP meeting participants. From left: Steven Bograd, Robert Blasiak, Jennifer Boldt, Elliott Hazen, Mary Hunsicker, Sukyung Kang.

Dr. Elliott Hazen presented the history of SG-CERP and why it was proposed, as a logical follow-up to WG 28 (Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*), with the opportunity to build collaborations with other PICES expert groups such S-HD, PICES/ICES Section on *Climate Change Effects on Marine Ecosystems* (S-CCME), and proposed Working Group on *Climate and Ecosystem Predictability* (WG-CEP).

AGENDA ITEM 3
Results of previous PICES expert groups

Dr. Jennifer Boldt followed with a presentation summarizing the results of previous PICES expert groups, including Working Group (WG 19) on *Ecosystem-based Management Science and its Application to the North Pacific* and WG 28, on developing indicators of responses to multiple stressors. She provided a good overview of previous work leading up to this Study Group, including:

2003 SG-EBM – *Ecosystem-based Management Science and its Application to the North Pacific*
2004–2009 WG 19 – *Ecosystem-based Management Science and its Application to the North Pacific*
2011–2015 WG 28 – *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*
2014 FUTURE OSM – Sessions on indicators, and development of a proposal for WG 28
2015–2016 SG-CERP

Members also discussed a number of frameworks including a framework to distinguish driving forces, pressures, states, impacts and responses (DPSIR) that can be used to place indicators into context.

Members then discussed SG-CERP Terms of Reference (***SG-CERP Endnote 5***, Appendices), and the information available to address them. Members identified the need for further work on ecosystem reference points and began brainstorming ideas for developing proposals for:

1. A Working Group to advance this work through the lifetime of the FUTURE program, including terms of references and deliverables;
2. A workshop on "*Identifying ecosystem indicators for reference point selection methods*" in conjunction with the 2017 Inter-sessional Science Board Meeting to address TORs 1, 2 and 6 (***SG-CERP Endnote 3***);
3. A Topic Session for PICES-2017 (***SG-CERP Endnote 4***).

AGENDA ITEM 4
Country reports

Dr. Mary Hunsicker gave a presentation on U.S. efforts towards establishing reference points, including her work in calculating non-linear responses in driver-pressure relationships (as part of California Current Integrated Ecosystem Assessment efforts) and providing leading indicators of ecosystem state with tipping point working groups at the National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara, California.

Dr. Robert Blasiak gave a presentation on his work in assessing cultural and economic roles in participation in conservation efforts, and on the climate vulnerability of social-ecological systems. This research highlighted the importance of S-HD endeavors being directly incorporated in the working group proposal.

Dr. Boldt presented information about Canadian efforts towards reference point development. Specifically, biological reference point examples were more common than for other categories, such as economic, ecological, environmental, and social. Also Canadian policies, *Acts*, and frameworks point to the need for reference points.

AGENDA ITEM 5
Draft Working Group proposal

The rest of the meeting was productive and dealt largely with editing the WG proposal. This included developing:

- A table of methods for detecting non-linearities in time series relationships (see ***SG-CERP Endnote 5***, Table 1);
- A table of previous indicator work, including sources for ecosystem indicators, indicator recommendations, and data availability (***SG-CERP Endnote 5***, Table 2);
- A schematic of where the proposed WG fits in with other PICES expert groups and with FUTURE (***SG-CERP Endnote 5***, Figure 1);
- A timeline for activities and deliverables for the WG (***SG-CERP Endnote 5***, Figure 2).

SG-CERP Endnote 1

SG-CERP participation list

Members

Robert Blasiak (Japan)
Jennifer Boldt (Canada)
Elliott Lee Hazen (USA, Chair)
Mary Hunsicker (USA)

Observers

Steven Bograd (USA, FUTURE SSC Co-Chair)
Sukyung Kang (Korea, FUTURE SSC)
Thomas Therriault (Science Board Chair)
Ian Perry (Canada, WG 28 Co-Chair)

Members unable to attend

China: Qing Yang
Japan: Kazumi Wakita
Korea: Jung Hee Cho, Jung Hwa Choi, Chung Il Lee

SG-CERP Endnote 2

SG-CERP meeting agenda

1. Welcome, introduction to SG and WG goals by Chair
2. Self introductions
3. Summary of WG 28 findings and results (Boldt)
4. Country reports
   Wakita/Blasiak (Japan)
   Yang (China)
   Hunsicker/Hazen (USA)
   Boldt (Canada)
5. Draft WG proposal, including membership

SG-CERP Endnote 3

Proposal for a 2-day inter-sessional Workshop on
"*Identifying ecosystem indicators for reference point selection methods*"
in conjunction with ISB-2017

Convenors: Mary Hunsicker (USA), Robert Blasiak (Japan), Jennifer Boldt (Canada), Elliot Hazen (USA)

Dates and location: TBD

SG-CERP Endnote 4

Proposal for a 1-day Topic Session on
"*Below and beyond maximum sustainable yield: Ecosystem reference points*" at PICES-2017

Convenors: Elliott L. Hazen (USA), Jennifer Boldt (Canada), Robert Blasiak (Japan), Mary Hunsicker (USA)

Potential Co-sponsors: ICES / INDISEAS

Suggested Invited Speakers: Mitsutaku Makino (Japan), William Sydeman (USA), Kirstin Holsman (ACLIM)

PICES SG/WG-CERP has been chartered with identifying ecosystem reference points that would integrate across committees to achieve FUTURE goals and missions. Specifically, we suggest a topic review session that would examine both a) examples of ecosystem reference points that have been established, and b) methodologies for calculating ecosystem reference points from driver-pressure relationships across PICES ecosystems. The goal would be for this topic session to bring together experts from physical, biological, and human dimensions to explore past and future approaches to understand how ecosystem management have and can best set reference points that deal with ecological and societal goals. Reference points for fisheries management are generally determined under a single set of environmental conditions with a single species focus. Almost all forms of resource management rely on reference points in order to manage a species (*e.g.*, BMSY, Potential Biological Removal, Yield per Recruit). However, ecosystem reference points that have been developed have largely focused on additive relationships but more attention is needed on setting reference points in relation to ecosystem functioning such as climatic forcing and predator-prey relationships. One such example, maximum ecosystem yield (MEY) in the Gulf of Alaska and Bering Sea provides an umbrella on total catch, but still does not account for intraspecific dynamics or climate forcing. We propose a topic session that will involve participation from multiple PICES committees and will focus on reviewing examples of ecosystem reference points and methods for defining reference points that have been used internationally. Anticipated Outcomes are a report to be distributed to PICES on the summary of the presentations and discussion and a Special Issue on "Ecosystem reference points" including a manuscript from WG participants in collaboration with a journal TBD. We anticipate a 1-day topic session with talks focusing on (a) examples of ecosystem reference points, (b) modeling studies examining mechanistic linkages between pressure – driver relationships, (c) methodological approaches towards identifying reference points.

SG-CERP Endnote 5

Appendix 1
Study Group on *Common Ecosystem Reference Points across PICES Member Countries*
Terms of Reference

Parent: Science Board

Term: October 2015–October 2016

Statement of Purpose

Managing ecosystems under a changing climate requires flexibility in order to facilitate resilient ecosystems that satisfy desired ecological and societal goals. For example, the combination of high fishing rates, poor climatic conditions and high predation pressures are likely to produce less favorable management outcomes than the same fishing rates and predation pressures under good climatic conditions. This type of observation motivates the need for an approach to management that includes dynamic reference points that reflect the variable marine environment and a coupled social-ecological system. Identifying such ecosystem reference points in relation to climatic variables or key ecological species is a primary goal, but a critical gap, at this time in many PICES member countries. To move forward on this front, we need 1) methodologies for determining how ecological (*e.g.*, trophic) interactions can be directly included in establishing reference points, 2) an examination of how climate variability and change might (should?) be incorporated into the determination of biological reference points, and 3) a methodological framework for identifying non-linearities, that might lead to surprises, in common ecosystem indicators.

Terms of Reference

1. Describe the societal needs and goals that underlie the establishment of reference points across PICES member nations, and determine those that are comparable.
2. Examine data availability for geographic areas and time periods of particularly strong climate influence and fisheries dependence within specific North Pacific ecosystems, fish stocks, and fishing communities.
3. Develop a heuristic model to examine climate forcing, ecosystem, and fishery responses to selected reference points.
4. Together these elements will contribute to Objective 1.1 of the FUTURE Science Plan to understand what determines "an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing".
5. Assess the efficacy of and refine the terms of reference for a potential future working group supporting FUTURE goals on "Common Ecosystem reference points as a common currency across PICES member countries".
6. SG will begin discussions on this subject inter-sessionally by correspondence, and will meet for a full day to discuss these issues at PICES-2016.

Appendix 2
Study Group on *Common Ecosystem Reference Points across PICES Member Countries* membership

Canada

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Appendix 3
Proposal for a Working Group on *Ecosystem Reference Points as a Common Currency across PICES Member Countries*

Parent: FUTURE SSC

Proposed Co-Chairs: Robert Blasiak (Japan), Mary Hunsicker (USA)

Proposed members: Jennifer Boldt (Canada), Ian Perry (Canada), Qing Yang (China), Kazumi Wakita (Japan), Jung Hee Cho (Korea), Jung Hwa Choi (Korea), Chung Il Lee (Korea), Vladimir Kulik (Russia), Elliott Hazen (USA), Scott Large (USA)

Reference points for fisheries management are generally determined under a single set of environmental conditions with a single species focus. All forms of fisheries management rely on specific reference points in order to manage a species (e.g. BMSY, Potential Biological Removal, Yield per Recruit) or ecosystem (e.g. Maximum Ecosystem Yield in Gulf of Alaska and Bering Sea, 1/3rd forage fish for the birds). However, more attention is needed on setting reference points in relation to ecosystem functioning such as climatic forcing and predator-prey relationships. Maximum ecosystem yield (MEY) is one example of an ecosystem reference point, and provides an umbrella on total catch but still does not account for intraspecific dynamics or climate forcing.

North Pacific ecosystems are influenced by dynamic atmospheric and oceanographic drivers, and most marine species have shown both cyclical and unidirectional trends over time. Broad scale forcing and fine-scale ecological interactions together result in ecosystem responses. An open question is whether biological responses within the ecosystems are linear or nonlinear in relation to the level of alternative climatic forcing variables or the abundance of other species (especially in the context of predator-prey relationships). Recent research indicates that the relationships between ecosystem states and biophysical drivers are often strongly nonlinear (Large *et al*., 2013, Fay *et al*., 2013, Large *et al*., 2015, Hunsicker *et al*., 2016). Strong nonlinearities suggest the existence of thresholds beyond which small changes in a climatic variable or species abundance cause large responses in another ecosystem component (Samhouri *et al*., 2011).

Crossing ecological thresholds can alter or redistribute ecosystem benefits to humans, with potentially negative outcomes for livelihoods, economic well-being and public health (Golden et al. 2016). In many decision-making contexts, such as fisheries and water quality, thresholds are used as target or limit reference points to prevent ecosystem components from tipping into undesirable states. Identifying such ecosystem reference points in relation to climatic variables or key ecological species is a primary goal, but a critical gap, at this time in many PICES member countries. To move forward on this front, we need 1) methodologies for determining how ecological (*e.g*., trophic) interactions can be directly included in establishing reference points, 2) an examination of how climate variability and change can be incorporated into the determination of biological reference points, and 3) a methodological framework for identifying non-linearities in common ecosystem indicators (Table 1).

Table 1 Methodologies for assessing non-linear driver-pressure relationships that will be evaluated as part of Working Group on *Ecosystem Reference Points as a Common Currency across PICES Member Countries*.

Methodology	Purpose	Citation
Specified functional forms	Identify nonlinearities in stressor-response relationships, sign and form of those relationships, and threshold values	Samhouri et al. 2011
Random gradient analysis	Detect threshold responses in stressor-response relationships	Large et al. 2015, Samhouri et al. *in prep*
Generalized Additive Models (incl. mixed effects GAMs and threshold GAMs)	Identify nonlinearities in stressor-response relationships, determine sign and form of those relationships	Large et al. 2013, Karr et al. 2015, Hunsicker et al. 2016, Samhouri et al. *in prep*
Nonlinear time series analysis	Test for nonlinear time series behavior	Deyle et al. 2013, Glaser et al. 2014, Liu et al. 2014, Hao et al. 2015
Second derivative analysis	Inflection point / threshold detection in stressor-response relationships	Large et al. 2013, Burthe et al. 2016, Samhouri et al. *in prep*
Changepoint analysis	Threshold detection in stressor-response relationships	Cury et al. 2011
Breakpoint analysis	Threshold detection in stressor-response relationships	Bestelmeyer et al. 2011
Sequential t-test analysis of regime shifts	Threshold detection in time series data	Rodinov et al. 2004 Vert-pre 2013
Structural equation modeling	Evaluation of heuristic model	Byrnes et al. 2011

Samhouri, J.F., P.S. Levin, C.A. James, J. Kershner, G. Williams. 2011. Using existing scientific capacity to set targets for ecosystem-based management: a Puget Sound case study. *Mar. Policy* **35**: 508-518. doi: 10.1016/j.marpol.2010.12.002.

Large, S.I., Fay, G., Friedland, K.D. and Link, J.S. 2015. Critical points in ecosystem responses to fishing and environmental pressures. *Mar. Ecol. Prog. Ser.* **521**: 1–17 doi: 10.3354/meps11165.

Large, S.I., Fay, G., Friedland. K.D., Link, J.S. 2013. Defining trends and thresholds in responses of ecological indicators to fishing and environmental pressures. *ICES J. Sci*. **70**: 755–767.

Karr, K.A., Fujita, R., Halpern, B.S., Kappel, C.V., Crowder, L., Selkoe, K.A., Alcolado, P.M. and Rader, D. 2015. Thresholds in Caribbean coral reefs: implications for ecosystem-based fishery management. *J. Appl. Ecol*. **52**: 402–412. doi: 10.1111/1365-2664.12388

Cury, P.M., Boyd, I.L., Bonhommeau, S., Anker-Nilssen, T., Crawford, R.J., Furness, R.W., Mills, J.A., Murphy, E.J., Osterblom, H., Paleczny, M., Piatt, J.F., Roux, J.P., Shannon, L., Sydeman, W.J. 2011. Global seabird response to forage fish depletion—one-third for the birds. *Science* **334**: 1703–1706. doi: 10.1126/science.1212928

Bestelmeyer, B.T., Ellison, A.M., Fraser, W.R., Gorman, K.B., Holbrook, S.J., Laney, C.M., Ohman, M.D., Peters, D.P.C., Pillsbury, F.C., Rassweiler, A., Schmitt, R.J., and Sharma, S. 2011. Analysis of abrupt transitions in ecological systems. *Ecosphere* **2**: art129. doi: 10.1890/ES11-00216.1

Rodionov, S.N. 2004. A sequential algorithm for testing climate regime shifts. *Geophys. Res. Lett*. **31**: L09204, doi:10.1029/2004GL019448

Fay, G., Large, S.I., Link, J.S., Gamble, R.J. 2013. Testing systemic fishing responses with ecosystem indicators. *Ecol. Model*. **265**: 45−55.

Hunsicker, M.E., Kappel, C.V., Selkoe, K.A., Halpern, B.S., Scarborough, C., Mease, L. and Amrhein, A. 2016. Characterizing driver-response relationships in marine ecosystems for improved ocean management. *Ecol. Appl*. **26(3)**: 651–663.

Glaser, S.M., Fogarty, M.J., Liu, H., Altman, I., Hsieh, C.H., Kaufman, L., MacCall, A.D., Rosenberg, A., Ye, H. and Sugihara. G. 2014. Complex dynamics may limit prediction in marine fisheries. *Fish and Fisheries* **15**: 616–633, doi: 10.1111/faf.12037

Deyle, E.R., Fogarty, M., Hsieh, C.H., MacCall, A.D., Munch, S.B., Perretti, C.T., Ye, H. and Sugihara, G. 2013. *Proc. Natl. Acad. Sci. USA* **110(16)**: 6430–6435, doi: 10.1073/pnas.1215506110

Liu, H., Fogarty, M.J., Hare, J.A., Hsieh, C.H., Glaser, S.M., Ye, H., Deyle, E., Sugihara, G. 2014. Modeling dynamic interactions and coherence between marine zooplankton and fishes linked to environmental variability. *J. Mar. Syst*. **131**: 120−129

Hao, Y., Beamish, R.J., Glaser, S.M., Grant, S.C.H., Hsieh, C.H., Richards, L.J., Schnute, J.T. and Sugihara, G. 2015. *Proc. Natl. Acad. Sci. USA* **112(13)**: E1569–E1576, doi: 10.1073/pnas.1417063112

Burthe, S.J., Henrys, P.A., Mackay, E.B., Spears, B.M., Campbell, R., Carvalho, L., Dudley, B., Gunn, I.D.M., Johns, D.G., Maberly, S.C., May, L., Newell, M.A., Wanless, S. Winfield, I.J., Thackeray, S.J. and Daunt, F. 2016. Do early warning indicators consistently predict nonlinear change in long-term ecological data? *J. Appl. Ecol*. **53**: 666–676.

Vert-pre, K.A., Amoroso, R.O., Jensen, O.P. and Hilborn, R. 2013. Frequency and intensity of productivity regime shifts in marine fish stocks. *Proc. Natl. Acad. Sci. USA* **110(5)**: 1779–1784, doi/10.1073/pnas.1214879110

Byrnes, J.E., Reed, D.C., Cardinale, B.J., Cavanaugh, K.C., Holbrook, S.J. & Schmitt, R.J. (2011) Climate-driven increases in storm frequency simplify kelp forest food webs. *Global Change Biol*. **17**: 2513–2524.

Golden, C.D., Allison, E.H., Cheung, W.W.L., Dey, M.M., Halpern, B.S., McCauley D.J., Smith, M., Vaitla, B., Zeller, and Myers, S.S. 2016. Nutrition: Fall in fish catch threatens human health. *Nature* **534**: 317–320, doi:10.1038/534317a.

The proposed WG would contribute to 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 in order to facilitate resilient ecosystems for ecological and societal goals. For example, high fishing rates under poor climatic conditions and high predation pressures are less likely to produce favorable management outcomes than the same fishing rates under good climatic conditions. This kind of observation motivates the need for dynamic reference points that reflect a dynamic marine environment and a coupled social-ecological system. This WG would build on previous key indicator work (Table 2) and on the findings of PICES Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors* (WG 28) and WG-NPESR3 on identifying indicators, and will seek to work closely on reference points under future climate scenarios developed by WG-CEP (proposed, see below) and Section on *Climate Change Effects on Marine Ecosystems* (S-CCME) (Figure 1). A timeline of planned activities are outlined below (Figure 2).

Table 2 Review of previous key indicator work, including sources for ecosystem indicators, indicator recommendations, and data availability.

Name	**Description**	**Produced by**	**Key parts**
Report[1] on the PICES North Pacific Ecosystem Status Report and World Ocean Assessment 'Human Dimensions' Workshop, June 13-15, 2013, Honolulu, USA	1) Effort to compile and review socio-economic data from North Pacific for use in 3rd NPESR; 2) Identify data gaps; 3) Identify additional data sources for first WOA.	Criddle, K., Makino, M., Perry, R.I., Therriault, T.	Page 7, Table 1: Proposed list of Human Dimensions indicators
Report[2] from an Invitational Workshop on Evaluation and Synthesis of North Pacific Time Series Observations (2016), June 28–30, 2016, Sidney, Canada	Outcome of interim workshop on time series for NPSER	North Pacific Ecosystem Status Report (NPESR)	Tables 2 and 3: Summary statistics of ETSOs
Developing Ecosystem Indicators for Responses to Multiple Stressors[3] (2014)	Article in *Oceanography* aiming to "to identify a meaningful set of indicators that can be used to assist with the management of multiple types of human interactions with marine ecosystems."	Boldt *et al.* (2014)	Page 129, Table 3: with a compiled suite of indicators recommended for ecosystem-based fisheries management (drawing on (1) Fulton *et al.* (2005), (2) Perry *et al*. (2010a), (3) Link (2005), (4) Greenstreet *et al*. (2012), and (5) IndiSeas (Bundy *et al*., 2012))
Indicators that consider what defines resistance to change and recovery time of habitats when exposed to multiple stressors may have greater management utility,[4] PICES-2013, Nanaimo, Canada	Application of "a comparative approach on entire ecosystems to attempt to identify general ecosystem responses to multiple pressures, and appropriate system-level indicators."	Perry, R.I., Takahashi, M., Samhouri, J.	Framework (slides 4–5), and particularly, conclusions (slide 23)
Workshop (W1)[5] on "*Identifying critical multiple stressors of North Pacific marine ecosystems and indicators to assess their impacts*", PICES-2012, Hiroshima, Japan	Provides "in-depth examination and discussion of the spatial and temporal extents of critical marine ecosystem stressors and their potential indicators."	BIO Workshop	Table 2: broad-scale indicators identified in the workshop to address three main categories (environmental, human activities and stressors, and sociopolitical-economic).
Report of Working Group 19 on Ecosystem-based Management Science and its Application to the North Pacific (2010)[6]	Final report of PICES Working Group 19	WG 19	Page 87, Table 3.1.3: Current data available among PICES member countries to calculate indicators from core set of consensus indicators for ecosystem-based fisheries management (from Fulton *et al*. 2004; Link, 2005).

[1] http://meetings.pices.int/-publications/other/-2013_07_17_PICES_NPESR_and_-WOA_Workshop_report.pdf
[2] Currently not online (will be available through SG NPESR)
[3] http://tos.org/oceanography/article/-developing-ecosystem-indicators-for-responses-to-multiple-stressors
[4] http://pices.int/publications/presentations/PICES-2013/2013-S8/Day2-S8-1010-Perry.pdf
[5] http://meetings.pices.int/publications/other/members/W28-W1-Annual2012-Session-summaries.pdf
[6] http://meetings.pices.int/publications/scientific-reports/Report37/Rep37.pdf

IndiSeas[7]	IndiSeas is a scientific program which evaluates the effects of fishing on the health status of marine ecosystems.	IOC/UNESCO, the European Network of Excellence EUROCEANS, the FRB project EMIBIOS, IRD and the European MEECE project	A panel of indicators characterizing the ecological and biodiversity status of exploited resources, their environment, and the human dimension of fisheries.
Marine Strategy Framework Directive (MSFD)[8]	"The Commission Decision on criteria and methodological standards on good environmental status (GES) of marine waters, adopted on 1 September 2010, contains a number of criteria and associated indicators for assessing good environmental status, in relation to the 11 descriptors of good environmental status laid down in Annex I of the Marine Directive."	European Union	Alternate 'toolbox' of indicators

[7] http://www.indiseas.org/indicators
[8] http://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm

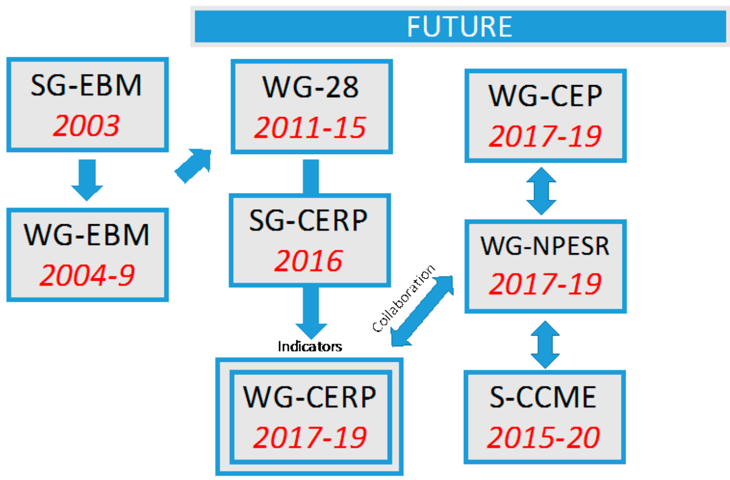

Figure 1 Alignment of WG-CERP within past and ongoing PICES expert groups.

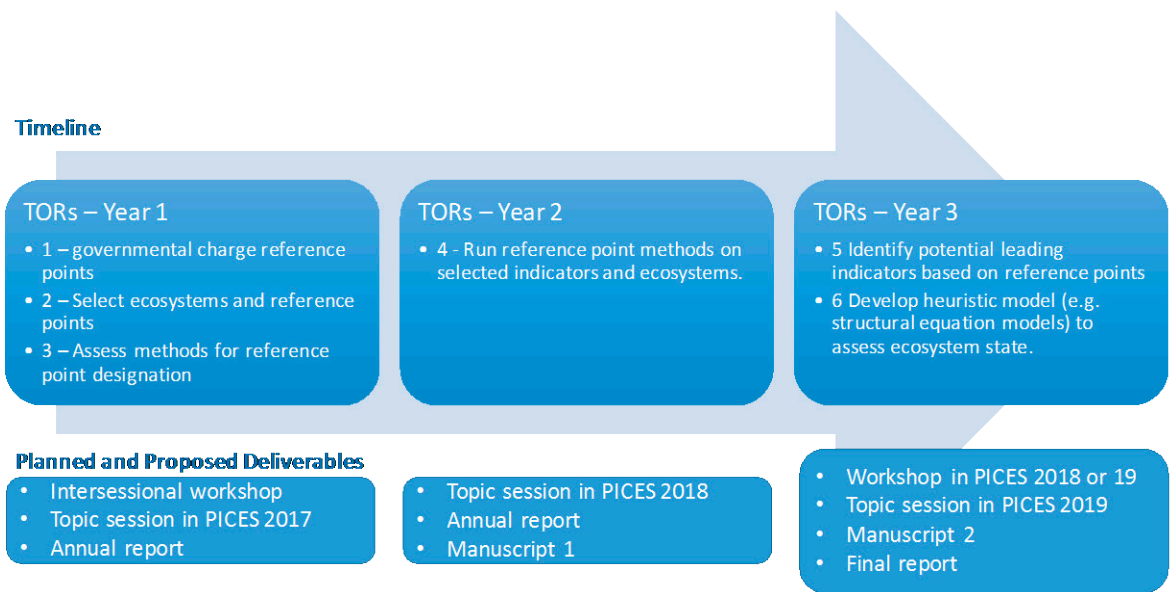

Figure 2 Proposed timeline and deliverables for the terms of reference of WG-CERP.

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 countries, 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 NPESR3. 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 countries. (Yr 3)
7. Publish final report.

Expected deliverables/Activities

1. Hold an inter-sessional workshop in 2017 on "*Identifying ecosystem indicators for reference point selection methods*"
2. Convene Topic Sessions at PICES Annual Meetings 2017–2019 on Ecosystem Reference Point relevant topics.
3. Hold a workshop in 2018 on methodological testing of reference point identification.
4. Write annual reports on WG progress.
5. Prepare two manuscripts on ecosystem reference points.
6. Submit a final report summarizing WG results and next steps, with special attention to FUTURE needs and goals.