SG-SEES Final Report

Study Group on
Social-Ecological-Environmental Systems (SEES)
http://pices.int/members/study_groups/SG-SEES.aspx

September 15, 2016

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Report on Terms of Reference

TOR 1. Establish a SEES transdisciplinary expert dialogue in PICES

Assemble a team of experts for all the components that make up a Social-Ecological-Environmental System (SEES) and initiate a tighter communication among the experts to understand the challenges of conducting integrated science that include the climate, marine ecosystem and human dimensions explicitly.

GOAL 1: Develop the dialog, understand the different views, agree on language and terminology. In the first year, the SG-SEES recruited expertise beyond the official members to incorporate additional key expertise on social-ecological systems and their modeling (*see list of non-member participants at end of the report*). This was a necessary step as it became clear that SG-SEES did not possess, within its membership, sufficient expertise for SEES modeling. During the period November 2013- October 2014, SG-SEES conducted several web-conference calls with different subsets of official and unofficial members. These conference calls enabled the group to formalize the dominant components and interaction pathways of the sub-systems that make up a SEES (e.g. humans, climate and marine ecosystem). The results of these conversations led to the development of a generalized model for a coastal hypoxia SEES (see Figure 1 below). The diagram is very articulated and we do not provide in this report a detailed description beyond the figure legend. This diagram served mostly as a starting point for the discussions that followed.

TOR 2. Develop a SEES modeling framework

Develop an integrated conceptual model of a SEES case study for hypoxia in the coastal ocean with the goal of developing a fully integrated quantitative model.

The development of a general framework for a coastal hypoxia SEES (**Figure 1**) was an important exercise for the group. It allowed the group to establish (**1**) trust among the members, and (**2**) a dialog among the different scientists with a common terminology (e.g. social, climate and marine ecosystem scientists). This activity led to the next goal of SG-SEES.

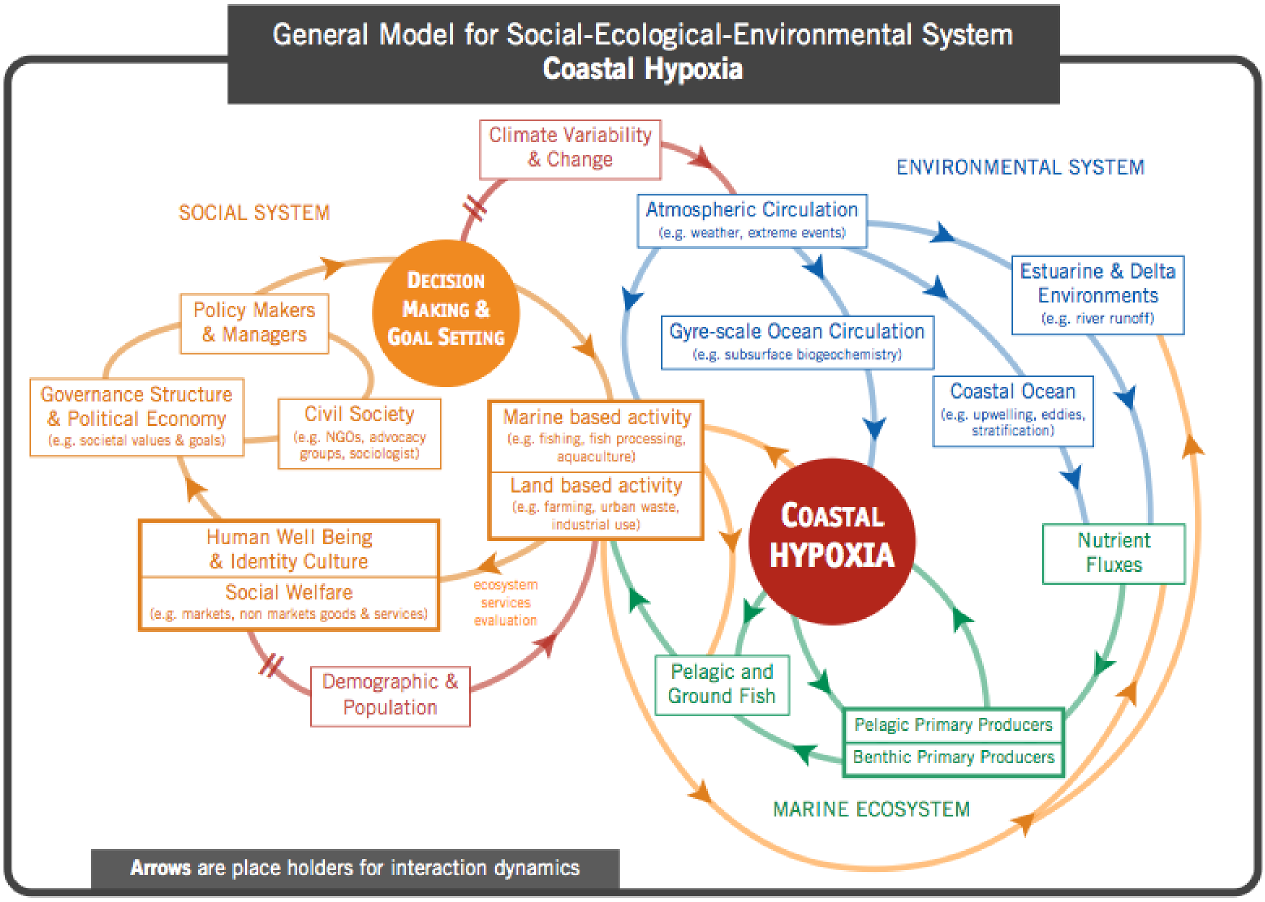


Figure 1: A generalized framework of a Coastal Hypoxia SEES. The dominant components for each sub-system are color coded. Each interaction dynamics is explicit in the direction of interaction. Red pathways are considered external forcing on the timescales considered in the study group.

GOAL 2: Identify the path for implementing an integrated SEES modeling framework. This step is necessary to conduct a comparative analysis of the hypoxia SEES case studies, and led to the following **3 activities**:

(1) ***Selecting a coastal hypoxia SEES on the eastern and western boundaries of the North Pacific.*** To be successful, the site selection for the case studies had to leverage existing efforts on studying coastal hypoxia in both the eastern and western boundaries. The choice of a site in the east and one in the west was dictated by the fact that these SEES have different SEES dynamics and drivers. In the eastern side, the area of Puget Sound (Washington, USA) was identified as an adequate site. In this region the problem of hypoxia and acidification are well-studied and some of the non-official members have conducted research on social science networks that focus on this issue. The group could also leverage existing datasets. On the western side, however, the site selection was more problematic. While there was consensus that hypoxia was also an historically important issue (Lee et al., 2018), we were unable to identify partners that had hypoxia as a research priority. Unfortunately, without leveraging existing activities the study group and PICES did not have the resources to initiate this research from scratch. This led to discussions within the group about revising the central theme for the SEES **from *coastal hypoxia* to *shifts in biogeography and impacts on fisheries.*** This latter topic seems to capture a larger group of researchers in both the eastern and western side of the Pacific. This shift in focus did not halt the **learning process of the SG-SEES** (see next paragraph). In 2018 an overview paper of the impacts of hypoxia in Korean coastal waters was published (Lee et al., 2018), but this publication appeared after the disbandment of the SEES Study Group.

(2) *Adapting the SEES general model to the specifics of the selected coastal sites.* The group reviewed previous examples of SEES modeling in **terrestrial ecology** conducted within the Harvard Forest Long-Term Ecological Research Site (LTER, http://harvardforest.fas.harvard.edu) in Massachusetts (USA) and in **marine ecology** along the Ningaloo Coral Reef on the west coast of Australia (https://www.dropbox.com/s/xtw24s7el52se53/Ningaloo_Report_MSE_Report-finalv3.pdf?dl=0). It became clear that while a substantial amount of work exists for terrestrial systems, examples of SEES integrated modeling for specific case studies of coastal marine ecosystems are very few—the Ningaloo Reef being probably the most advanced. Both examples highlight that the process of identifying the specifics of the model need to involve the Public and Stakeholders in the early process of the SEES model development. The approach of developing a specific SEES modeling framework is fundamentally different from the methodologies commonly used in physical and biological modeling. The main issue is that SEES are complex systems and considered to represent "wicked problems" (http://en.wikipedia.org/wiki/Wicked_problem; Balint et al., 2011). To develop models that allow studying "wicked problems" the strategy is to use an iterative approach. Based on previous studies and examples, the SG-SEES identified in (**Figure 2**) below illustrate three important iteration steps:

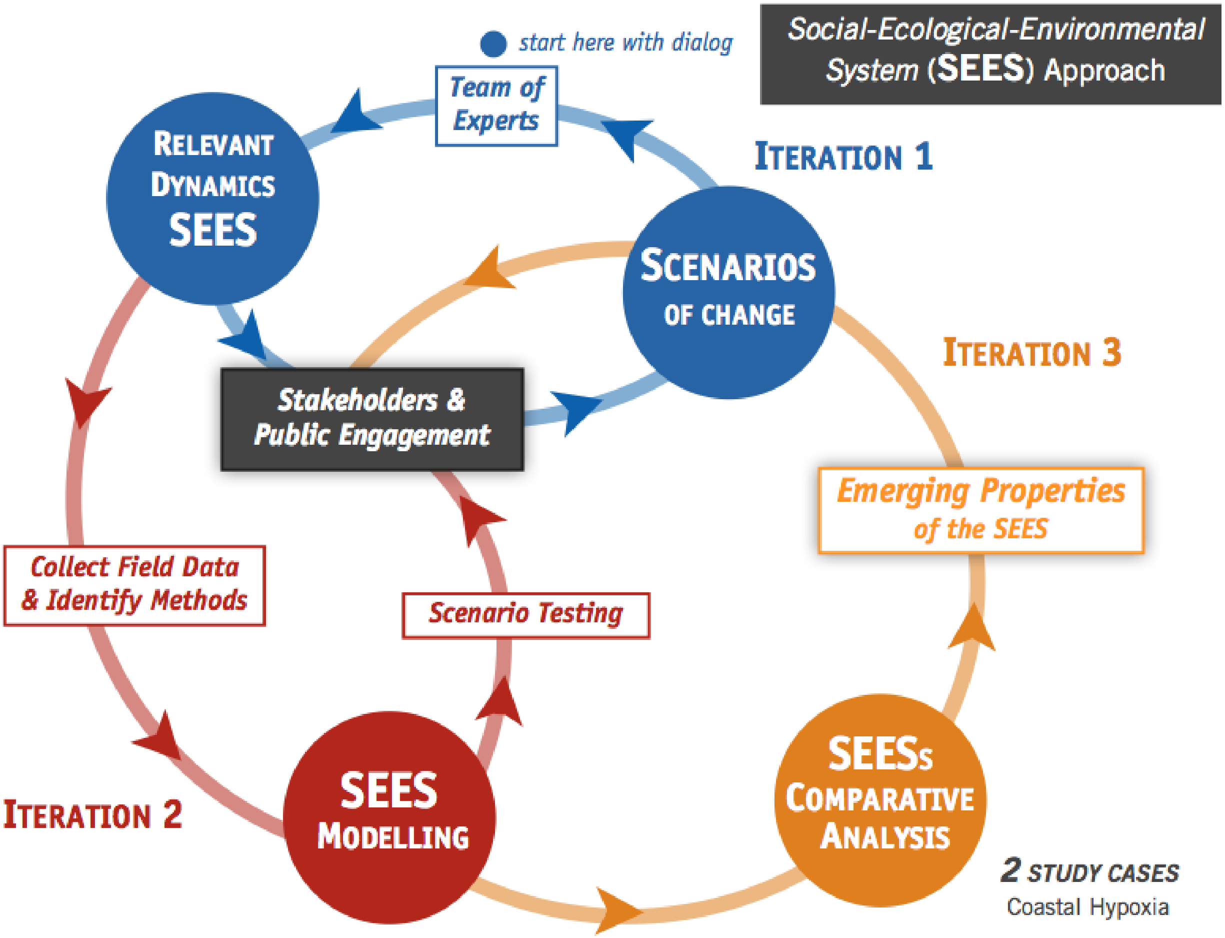


Figure 2: Iterative approach to SEES modeling

Iteration #1: The initial team of experts (e.g. including scientists and some key stakeholders) identifies what they consider to be the relevant social-ecological-environmental dynamics of the system under study. They communicate their findings to the Stakeholders and Public (typically through an open workshop, a method that is well understood in the social sciences). The Stakeholders provide feedback on what they perceive as being the important dynamics of the system. They also outline scenarios of change that are relevant to the SEES. These scenarios of change outline the type of sensitivity that the model should be able to resolve and that makes sense for the human system, which is the ultimate driver through "Decision Making & Goal Setting" (see **Figure 1**).

Iteration #2: After collecting this input from the Stakeholders and Public, the team of experts identifies the observational data and modeling methods that are required to test the different scenarios of change. At this stage a first version of the quantitative SEES model is developed and scenario testing begins. After the testing, a new phase of engagement with the Stakeholders and Public is necessary to report on the findings and collect new input for further improvement of the SEES model.

Iteration #3: After further revision of the SEES model the comparative analysis between the SEES case studies is conducted. The goal of the comparative analysis is to identify emerging properties of the SEES that are more general than the specifics of the site. These findings are then reported again to the Stakeholders and Public. An example of a comparative analysis and scenario evaluation is provided in the section titled "***Example of a comparative analysis of two SEES***" below. This iterative process involving the stakeholders, public and scientists is referred to as "social learning" and is considered to be a critical step towards collaborative sustainable development of SEES (e.g. *Kristjanson et al., 2014*).

(3) *Identifying the modeling approaches to implement a quantitative SEES model.* When modeling physical and ecosystem dynamics we are often able to identify governing equations that allow us to track quantitatively the evolution of the system. In social systems it is not always possible to quantify the state and fluxes of a system. However, qualitative modeling techniques still allow us to model the sensitivity of the SEES dynamics in response to different scenarios of change and to external perturbations. This implies that SEES modeling requires interfacing models with different currencies and that use different approaches. The Ningaloo Reef SEES modeling provides an example and roadmap for interfacing different models of the subsystems (e.g. the Atlantis model; Audzijonyte_et al. 2017a, 2017b; Fulton et al. 2011a, 2011b, 2011c). Although time consuming, these types of models can be developed through the iterative process outlined above.

General Recommendation: The findings outlined under TOR 2 poses important challenges on conducting SEES modeling research in PICES, but also creates important opportunities. These are discussed in the "Challenges" and "Recommendation" sections (below).

TOR 3. FUTURE Open Science Meeting Session 2014

Conduct a meeting at the FUTURE Open Science Meeting (April 2014) to discuss the conceptual SEES model and isolate the steps needed to initiate the development of the quantitative integrated model.

The SG-SEES had a very productive meeting in Hawaii with presentations from Beth Fulton (Head of Social-Ecological Modeling Group, CSIRO, Australia) and Patrick

Christie (School of Marine & Environmental Affairs & Jackson School of International Studies, University of Washington, USA). Dr. Fulton led the study on the SEES modeling in the Ningaloo Reef and her input was very important in shaping the strategy for developing coastal hypoxia SEES outlined above. Dr. Christie reported on differences that exist between social and natural science networks. During the meeting we also discussed the selection of the coastal hypoxia case studies reported under TOR 2 (see above).

TOR 4. PICES Annual Meeting Session 2014

Conduct a meeting at the PICES Annual Meeting (October 2014) to finalize a report with recommendations for how the Organization can advance in this field of coupled SEES approach to meet the goals of FUTURE.

The SG-SEES had their final meeting during the PICES annual meeting in Korea. The meeting was attended by 5 members of the group: Criddle (USA), King (Canada), Yoo (Korea), Di Lorenzo (USA), Hori (Japan). The central goal of the meeting was to review the progress of the study group and formalize the recommendations from the SG-SEES, which are outlined below.

Example of a comparative analysis of two SEES

To illustrate how the comparative analysis of two SEES models can lead to important guiding principles, we perform a comparison between the Harvard Forest Long-Term Ecological Research Site SEES modeling output (Finzi et al. 2011; Ollinger et al., 2008) and the Ningaloo Coral Reef SEES (Fulton et al., 2011a, 2011b, 2011c). While the focus of these SEES was on different natural systems, one terrestrial (Harvard) and one marine (Ningaloo), both modeling activities followed the iterative path shown in **Figure 2** (iterations 1 and 2). In both cases the SEES models were used to evaluate different scenario in the context of social-ecological norms (see **Figure 3**). Among the tested scenarios, there were usual scenarios such as a business as usual or a very ecologically conservative scenario. However, in both cases, there was also a scenario that was characterize as a “better human integration” scenario where the humans were considered part of the ecosystem rather than external. Although the details of these scenarios varied between the marine and terrestrial example, in both cases the scenario testing led to the conclusion that better integration of the human in the natural system was the optimal pathway towards maximizing the majority of the norms of interest (e.g. human use, ecosystem services, biodiversity). This result has been identified in the social-ecological community as a new and improved guiding principle for marine conservation. It is important that such principles can be recovered through the SEES modeling as emerging properties of the SEES. Ideally, experiments like this can lead to identifying new guiding principles when different set of norms are defined.

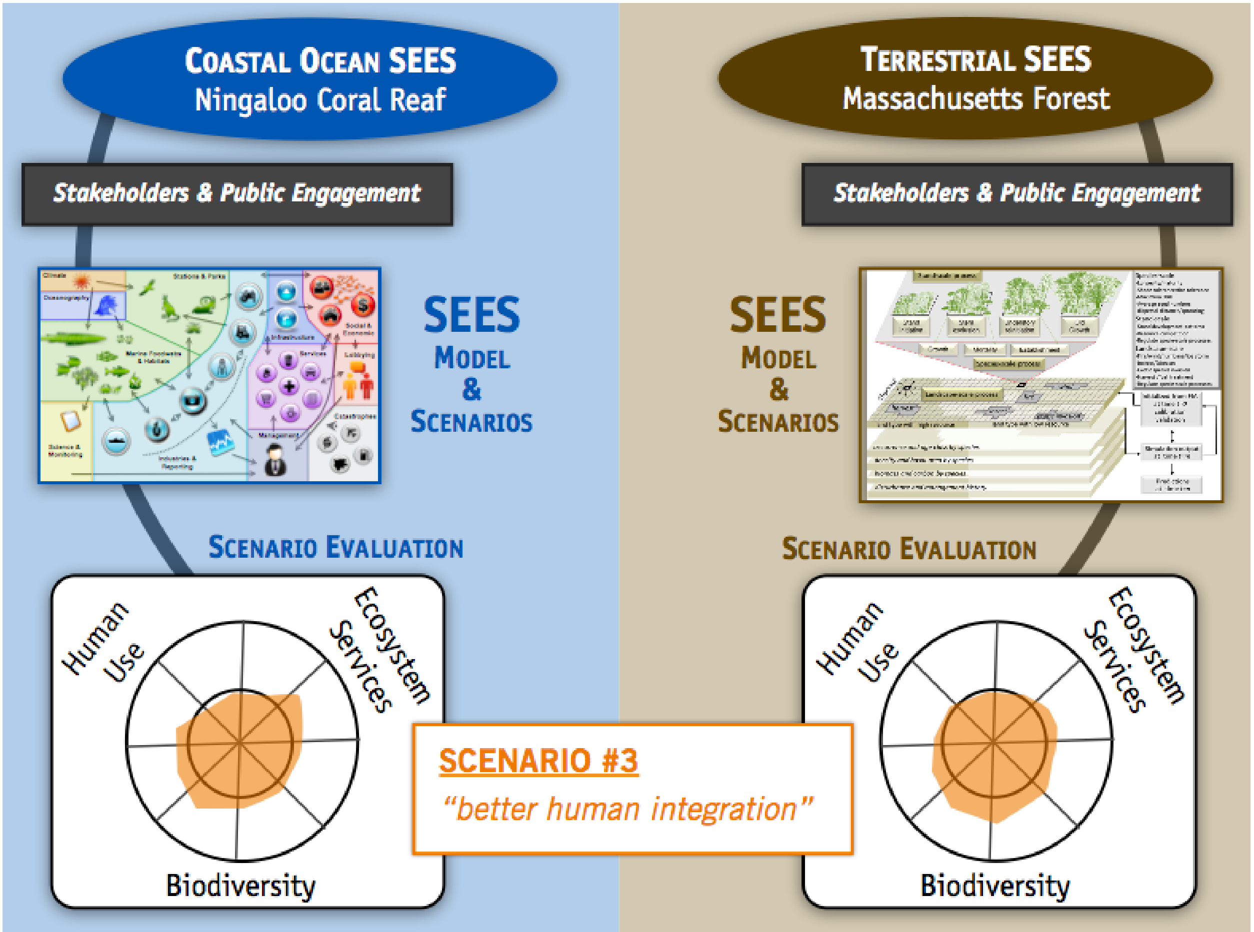


Figure 3: A comparative analysis of a marine and terrestrial SEES scenario testing

Challenges for conducting SEES activities in PICES

(1) Developing the SEES expertise in the PICES community.

The first challenge that the group encountered is the lack of expertise within the PICES community in the area of integrated SEES studies. While PICES has developed a strong science capacity in climate and marine ecosystem sciences, the social science dimension still lacks important spheres of expertise. While the S-HD has been making steady progress in encouraging social scientists to attend PICES and providing training opportunities for the PICES community, the integration and collaborative research between social and natural scientists needs to be further developed.

(2) Adopting the "Transdisciplinary Model" for SEES.

After developing the general framework on how to develop an integrated SEES modeling approach, it became clear that this level of integration requires time and resources that go beyond the scope of a study group. While the study group facilitated an important brainstorming activity and collected valuable expertise, continuing the SEES modeling activity will depend on group members having their own funding to conduct this research and to come together. The main issue is that while group activities in ecosystem and climate science can often patch together the research of several individuals into a coherent whole, SEES studies require an immediate and deeper level of integration with a **Transdisciplinary Approach (**see King et al., 2009, for the definition http://goo.gl/t3RQU7**)**. This approach goes beyond just interfacing the knowledge of the sub-disciplines.

The ***Transdisciplinary Approach*** *connotes a research strategy that crosses many disciplinary boundaries to create a more holistic understanding. It applies to research efforts focused on problems at the interface of two or more disciplines, and can refer to concepts or methods that were originally developed by one discipline, but are now used by several others. In the transdisciplinary approach the model of the integrated system is not posed a priori but is developed bottom up from the exchange among different disciplines, hence requiring a substantial level of interaction among the members of the science team.*

Recommendations from SG-SEES

Considering the growing recognition of the need for taking into account the human dimensions of climate and ecosystem sciences, it is recommended that PICES continues to **develop the science capacity to support a SEES approach to problems that intersect climate, marine ecosystem, and social sciences**. This expertise appears to be less common in the marine sciences and conducting SEES studies poses important challenges not only to PICES, but also for the wider community. Specifically, developing the conditions to implement a transdisciplinary approach to SEES studies relies heavily on enabling the proper transdisciplinary dialog between scientists with different expertise and on providing the funding resources that allow the dialog to develop into mature SEES studies. Although these are important challenges, which will likely not resolve in the short term, PICES still has an opportunity to take a leadership role.

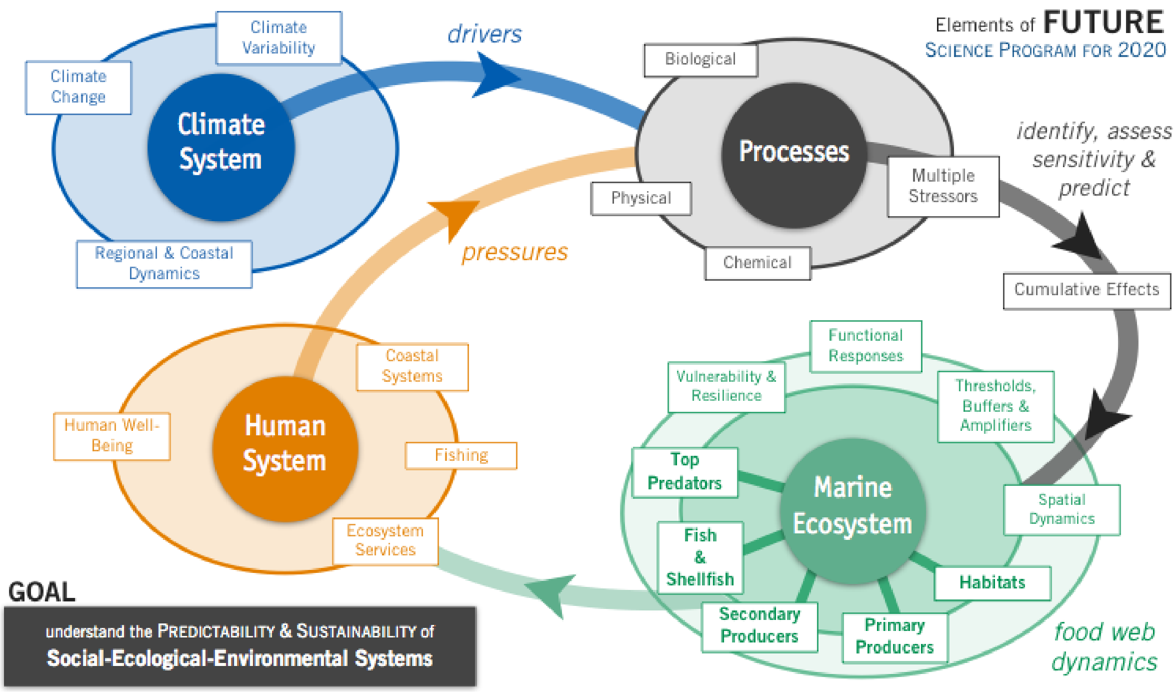
(1) Establishment of a SEES-Club Annual Meeting & Event

While it may be premature to develop organized expert groups to work on the SEES approach and modeling, PICES can still continue to develop and foster the SEES approach within its membership with more informal activities. In particular, we propose the establishment of a short SEES-Club gathering at the annual meetings where one or more stakeholders from the hosting country is invited to talk on a particular topic that identifies a SEES issue or theme (e.g. climate and fisheries, coastal toxins and aquaculture, sea level rise and coastal planning, etc.). The short talk is then followed by a discussion among the participants of the SEES-Club. This type of informal interaction may serve as a seed activity to foster the SEES thinking within PICES members who are interested in engaging in integrated science across the physical, biological, chemical and human dimension of ocean systems of the North Pacific.

For this activity to get started PICES would need to (1) identify two informal point of contacts for the SEES-Club to identify local speakers at the annual meeting, (2) setup a simple web page to advertise and keep track of the SEES-Club events, and (3) reserve a room for the meeting for a timeslot of 1-2 hours. Participation in the SEES-Club would be open to all PICES members and would be managed by the SEES-Club.

(2) Incorporate the SEES approach in the next PICES Science Plan

In the current FUTURE science plan PICES has outlined the structure of a large social-ecological-environmental system as evident from the recent diagram developed by the FUTURE SSC (see below). While in the current plan different expert groups are identifying and contributing to further articulate processes within one of the systems (e.g. climate, ecological or human) or at the interface between two systems, the next science plan may want to incorporate some goals that aim at developing SEES modeling activities that attempt to integrate multiple systems.



Elements of FUTURE
Science Program for 2020
Climate System
Climate Variability
Climate Change
Regional & Coastal Dynamics
drivers
Processes
Biological
Physical
Chemical
Multiple Stressors
identify, assess sensitivity & predict
Cumulative Effects
pressures
Human System
Coastal Systems
Human Well-Being
Fishing
Ecosystem Services
Marine Ecosystem
Functional Responses
Vulnerability & Resilience
Thresholds, Buffers & Amplifiers
Top Predators
Spatial Dynamics
Fish & Shellfish
Habitats
Secondary Producers
Primary Producers
food web dynamics
GOAL
understand the Predictability & Sustainability of
Social-Ecological-Environmental Systems

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