Coastal Ocean Sciences

Climate Systems
physics & chemical dynamics

Coastal Ocean Dynamics

Human Systems
individuals, groups, institutions

Marine Ecosystems
structure & function
Social-Ecological-Environmental System (SEES)

- Climate Systems
  - physics & chemical dynamics
- Marine Ecosystems
  - structure & function
- Human Systems
  - individuals, groups, institutions

Berkes and Folke 1998
Ostrom 2009
Perry et al 2010
Di Lorenzo et al., 2008
The North Pacific Gyre Oscillation (NPGO)
Climate Index (NPGO)

Di Lorenzo et al., 2008
The North Pacific Gyre Oscillation (NPGO)
Climate Systems

physics & chemical dynamics

Marine Ecosystems
structure & function

Social-Ecological-Environmental System

Individuals, groups, institutions
structure & function

Marine Ecosystems

Climate Index (NPGO)

Fish Populations in SF Bay

Jim Cloern, USGS
QUESTION:
Can we do better than this?

Fish Populations in SF Bay

Climate Index (NPGO)

Jim Cloern, USGS
QUESTION:
Can we do better than this?

Simple Process Model

Climate Systems
physics & chemical dynamics

Marine Ecosystems
structure & function

Social-Ecological-Environmental System

Fish Populations in SF Bay
Climate Index (NPGO)

QUESTION:
Can we do better than this?

Simple Process Model

Fish Populations in SF Bay

Process Model

Climate Systems
physics & chemical dynamics

Marine Ecosystems
structure & function
Ecosystem response to perturbation
how they integrate the forcing functions

Fish Populations in SF Bay

Process Model
Ecosystem response to perturbation
how they integrate the forcing functions

Di Lorenzo & Ohman, 2013
the double integration hypothesis

Social-Ecological-Environmental System

Climate Systems
physics & chemical dynamics

Marine Ecosystems
structure & function
Ecosystem response to perturbation
how they integrate the forcing functions

Di Lorenzo & Ohman, 2013
the double integration hypothesis

regime-like behavior in marine population
Ecosystem response to perturbation
how they integrate the forcing functions

Di Lorenzo & Ohman, 2013
the double integration hypothesis

Di Lorenzo et al. 2015
response to multiple-stressor filtering hypothesis

regime-like behavior in marine population
Ecosystem response to perturbation
how they integrate the forcing functions

Di Lorenzo & Ohman, 2013
the double integration hypothesis

Di Lorenzo et al. 2015
response to multiple-stressor filtering hypothesis

regime-like behavior in marine population

tendency for climate synchrony in fish populations

Climate Systems
physics & chemical dynamics

Social-Ecological-Environmental System
Ecosystem response to perturbation
how they integrate the forcing functions

Di Lorenzo et al. 2014
response to multiple-stressor filtering model

Di Lorenzo & Ohman, 2013
the double integration hypothesis

Emerging Properties
of climate & marine ecosystem

regime-like behavior in marine population

tendency for climate synchrony in fish populations
**EXAMPLES:** move beyond science at the interface between systems to true *integrative science* across the interface.

**Ecosystem response to perturbation**
how they integrate the forcing functions

**Di Lorenzo & Ohman, 2013**
the double integration hypothesis

**Di Lorenzo et al. 2014**
response to multiple-stressor filtering model

**Emerging Properties**
of climate & marine ecosystem

- regime-like behavior in marine population
- tendency for climate synchrony in fish populations
**EXAMPLES:** move beyond science at the interface between systems to true *integrative science* across the interface.

**APPROACH:** use *team of experts* and *observations* to develop ecological-environmental *quantitative models*

---

**Di Lorenzo & Ohman, 2013**
the double integration hypothesis

**Di Lorenzo et al. 2014**
response to multiple-stressor filtering model

**Emerging Properties**
of climate & marine ecosystem

- regime-like behavior in marine population
- tendency for climate synchrony in fish populations
**EXAMPLES:** move beyond science at the interface between systems to true *integrative science* across the interface.

**APPROACH:** use *team of experts* and *observations* to develop ecological-environmental *quantitative models*

**Emerging Properties**
*of climate & marine ecosystem*

- regime-like behavior in marine population
- tendency for climate synchrony in fish populations
**EXAMPLES**: move beyond science at the interface between systems to true *integrative science* across the interface.

**APPROACH**: use *team of experts* and *observations* to develop *social-ecological-environmental quantitative models*.
**EXAMPLES**: move beyond science at the interface between systems to true *integrative science* across the interface.

**APPROACH**: use team of experts and observations to develop social-ecological-environmental quantitative models.

Emerging Properties
of complex SEES

- guiding principles?
- guiding principles?
APPROACH: use team of experts and observations to develop social-ecological-environmental quantitative models
Study group in **PICES** on **Social-Ecological-Environmental Systems (SG-SEES)**

*proposed and formally established in 2013*
Prof. Rosemary E. Ommer,
Depts. of History and Geography
University of Victoria, Canada

Dr. Naesun Park
International Affairs Section
KIOST, Korea

Prof. Derek Kellenberg
Chair, Department of Economics
University of Montana, USA

Dr. Juri Hori
Department of Psychology
Rikkyo University, Japan

Dr. Ian Perry
Head of Ecosystem Approaches Program
Fisheries and Oceans, Canada

Dr. Jeffrey M. Dambacher
Computational Informatics
CSIRO, Australia

Dr. Alida Bundy (SG-SEES)
Chair IMBER Human Dimension
Fisheries and Oceans, Canada

Dr. Mitsutaku Makino (S-HD)
Head of the Fisheries Management Group
Fisheries Research Agency, Japan

Prof. Patrick Christie
School of Marine & Environmental Affairs &
Jackson School of International Studies
University of Washington, USA

Dr. Beth Fulton
Head of Social-Ecological Modeling Group
CSIRO, Australia

Prof. Sara Cobb
School for Conflict Analysis and Resolution
George Mason University, USA

Dr. Sinjae Yoo (SG-SEES)
Marine Living Resources
KIOST, Korea

Dr. Mike Fogarty
Northeast Fisheries Science Center
WHOI, USA

Dr. Elena N. Anferova
Department of Math. Methods in Economy
Far Eastern Federal University, Russia

Dr. Frank Schwing
Ecosystem Management
Office of Management and Budget, NOAA, USA

Dr. Nathan Mantua (SG-SEES)
Southwest Fisheries Science Center
NOAA, USA
International study group in PICES on Social-Ecological-Environmental Systems (SG-SEES) proposed and formally established in 2013
International study group in PICES on Social-Ecological-Environmental Systems (SG-SEES) proposed and formally established in 2013

Identify a SEES of interest
Identify a SEES of interest

Human Systems
individuals, groups, institutions

Climate Systems
physics & chemical dynamics

Marine Ecosystems
structure & function

COASTAL HYPOXIA
Identify a SEES of interest
Model and Compare 2 CASE STUDIES (locations)

Identify a SEES of interest

COASTAL HYPOXIA

Human footprint
- 0 - 1
- 1 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 60
- 60 - 80
- 80 - 100

Figure from Diaz and Rosenberg, 2008
Formalize the interaction dynamics
Formalize the interaction dynamics
Climate Variability & Change

Coastal Ocean (e.g. upwelling, eddies, stratification)

Gyre-scale Ocean Circulation (e.g. subsurface biogeochemistry)

Atmospheric Circulation (e.g. weather, extreme events)

Estuarine & Delta Environments (e.g. river runoff)

Coastal Ocean (e.g. upwelling, eddies, stratification)

Nutrient Fluxes

Pelagic Primary Producers
Benthic Primary Producers

Pelagic and Ground Fish

Coastal Hypoxia

Decision Making & Goal Setting

Social System

Demographic & Population

Policy Makers & Managers

Governance Structure & Political Economy (e.g. societal values & goals)

Civil Society (e.g. NGOs, advocacy groups, sociologist)

Human Well Being & Identity Culture

Social Welfare (e.g. markets, non markets goods & services)

Decision Making & Goal Setting

Arrows are place holders for interaction dynamics.
General Model for Social-Ecological-Environmental System

Coastal Hypoxia VILLAGE SCALE

**SOCIAL SYSTEM**
- Policy Makers & Managers
- Civil Society (e.g. NGOs, advocacy groups, sociologist)
- Human Well Being & Identity Culture (e.g. societal values & goals)
- Demographic & Population
- Governance Structure & Political Economy (e.g. societal values & goals)

**DECISION MAKING & GOAL SETTING**
- Marine based activity (e.g. fishing, fish processing, aquaculture)
- Land based activity (e.g. farming, urban waste, industrial use)

**ENVIRONMENTAL SYSTEM**
- Climate Variability & Change
- Atmospheric Circulation (e.g. weather, extreme events)
- Gyre-scale Ocean Circulation (e.g. subsurface biogeochemistry)
- Estuarine & Delta Environments (e.g. river runoff)
- Coastal Ocean (e.g. upwelling, eddies, stratification)
- Nutrient Fluxes

**MARINE ECOSYSTEM**
- Pelagic and Ground Fish
- Pelagic Primary Producers
- Benthic Primary Producers

**COASTAL HYPOXIA**

Arrows are place holders for interaction dynamics.
QUESTION: How do we move forward?
QUESTION:

How do we move forward?

... an iterative process
QUESTION:

*How do we move forward?*

... *an iterative process*

... *a learning process*
Isolate specific dynamics of 2 case studies
Specify the scales of interaction

... an iterative process
SCENARIOS OF CHANGE

Team of Experts

Stakeholders & Public Engagement

Collect Field Data & Identify Methods

Scenario Testing

SEES Modelling

SEESs Comparative Analysis

2 STUDY CASES
Coastal Hypoxia
SCENARIOS OF CHANGE

Team of Experts

Stakeholders & Public Engagement

Collect Field Data & Identify Methods

Scenario Testing

SEES Modelling

SEES Comparative Analysis

Emerging Properties of the SEES

2 STUDY CASES
Coastal Hypoxia
**Iteration 1**

- **RELEVANT DYNAMICS SEES**
- **Team of Experts**
- **SCENARIOS OF CHANGE**
- **Stakeholders & Public Engagement**
- **Scenario Testing**
- **SEES Modelling**

**Iteration 2**

- **SEES Modelling**
- **Stakeholders & Public Engagement**
- **Scenario Testing**

**Iteration 3**

- **SEESs Comparative Analysis**
- **Emerging Properties of the SEES**
- **2 STUDY CASES**
  - Coastal Hypoxia

Social-Ecological-Environmental System (SEES) Approach

1. **Iteration 1**
   - **Relevant Dynamics SEES**
   - **Scenarios of Change**
   - **Stakeholders & Public Engagement**
   - **Scenario Testing**

2. **Iteration 2**
   - **SEES Modelling**
   - **Collect Field Data & Identify Methods**

3. **Iteration 3**
   - **SEES Comparative Analysis**
   - **Emerging Properties of the SEES**

**2 Study Cases**
- Coastal Hypoxia
- Other Study Case
What is the study group accomplishing?
GOAL (1)
Training step for the interdisciplinary dialogue

Social-Ecological-Environmental System (SEES) Approach

Team of Experts

Reduced Complexity SEES

Scenarios of Change

Iteration 3

Stakeholders & Public Engagement

Collect Field Data & Identify Methods

Scenario Testing

SEES Model

SEESs Comparative Analysis

Emerging Properties of the SEES

Iteration 2

GOAL (1)
Training step for the interdisciplinary dialogue

Coastal Hypoxia

2 Study Cases
GOAL (1)
Training step for the interdisciplinary dialogue

GOAL (2)
1st draft of Experimental & Model Design

Collect Field Data & Identify Methods
Scenario Testing
SEES Model
SEESs Comparative Analysis
Emerging Properties of the SEES

Reduced Complexity SEES
Scenarios of change
Iteration 3
Iteration 2

Team of Experts

Social-Ecological-Environmental System (SEES) Approach

Stakeholders & Public Engagement

Start here with dialog

2 Study Cases
Coastal Hypoxia
REDUCED COMPLEXITY SEES

Scenearios of change

GOAL (1)
Training step for the interdisciplinary dialogue

GOAL (2)
1st draft of Experimental & Model Design

GOAL (3)
Emerging Properties of the SEES

Start here with dialog

Team of Experts

Collect Field Data & Identify Methods

Scenario Testing

SEES Model

SEES Comparative Analysis

Iteration 3

Iteration 2

2 Study cases
Coastal Hypoxia
QUESTION: What are some expected outcomes?
QUESTION:

What are some expected outcomes?
COASTAL OCEAN SEES
Ningaloo Coral Reef

DR. BETH FULTON
CSIRO, AUSTRALIA

TERRESTRIAL SEES
Massachusetts Forest

DR. KATHY FALLON LAMBERT
HARVARD, USA
COASTAL OCEAN SEES
Ningaloo Coral Reef

TERRESTRIAL SEES
Massachusetts Forest

Stakeholders & Public Engagement

SEES MODEL & SCENARIOS

Stakeholders & Public Engagement

SEES MODEL & SCENARIOS
SCENARIO #1
“business as usual”
SCENARIO #2
“ecosystem conservation”
**SEES Model & Scenarios**

**SCENARIO #3**
“better human integration”
“humans become integral part of the biodiversity”
“humans become integral part of the biodiversity”
Towards Social-Ecological-Environmental System Approach & Modeling

Human Systems
individuals, groups, institutions

Climate Systems
physics & chemical dynamics

Marine Ecosystems
structure & function

SEES
QUESTION:

How is the this important for PICES FUTURE?
Elements of FUTURE SCIENCE PROGRAM FOR 2020
Elements of FUTURE SCIENCE PROGRAM FOR 2020

.... spheres of interest for FUTURE
Processes

Climate System

Human System

Marine Ecosystem

.... spheres of interest for FUTURE
Processes

Climate System

Human System

Processes

Marine Ecosystem

Top Predators
Fish & Shellfish
Secondary Producers

identify, assess sensitivity & predict

food web dynamics

drivers

Elements of FUTURE SCIENCE PROGRAM FOR 2020
Processes

Climate System

Human System

Marine Ecosystem

Top Predators
Fish & Shellfish
Secondary Producers

drivers
pressures

identify, assess sensitivity & predict

food web dynamics

Elements of FUTURE SCIENCE PROGRAM FOR 2020
Processes

Climate System
- Climate Change
- Climate Variability
- Regional & Coastal Dynamics

Human System

Marine Ecosystem
- Secondary Producers
- Fish & Shellfish
- Top Predators

Processes
- Biological Primary Producers
- Physical
- Chemical
- Fishing

Elements of FUTURE SCIENCE PROGRAM FOR 2020

Identify, assess sensitivity & predict

Food web dynamics

Drivers

Pressures

Processes

Climate System

identify, assess sensitivity & predict

Climate Variability

pressures

Regional & Coastal Dynamics

Human System

Human Well-Being

Ecosystem Services

Multiple Stressors

Physical

Chemical

Cumulative Effects

Marine Ecosystem

Ecosystem Services

Fish & Shellfish

Secondary Producers

Top Predators

Food web dynamics

Marine Ecosystem

Processes

Biological Primary Producers

Fishing

FUTURE SCIENCE PROGRAM FOR 2020
Climate System

Climate Variability

Regional & Coastal Dynamics

Climate Change

Drivers:

Processes

Biological Primary Producers

Physical Stressors

Multiple Stressors

Chemical

Fishing

Cumulative Effects

Human System

Coastal Systems

Ecosystem Services

Human Well-Being

Marine Ecosystem

Functional Responses

Thresholds, Buffers & Amplifiers

Top Predators

Fish & Shellfish

Secondary Producers

Food Web Dynamics

Elements of FUTURE SCIENCE PROGRAM FOR 2020

Identify, assess sensitivity & predict

Pressures:

Processes

Food web dynamics
Processes

Climate System

Climate Variability

Regional & Coastal Dynamics

Human System

Climate Change

Ecosystem Services

Human Well-Being

Processes

Biological Primary Producers

Physical

Multiple Stressors

Chemical

Fishing

Cumulative Effects

Element of FUTURE SCIENCE PROGRAM FOR 2020

Marine Ecosystem

Top Predators

Fish & Shellfish

Vulnerability & Resilience

Functional Responses

Secondary Producers

Thresholds, Buffers & Amplifiers

Spatial Dynamics

Marine Ecosystem Services

Drivers

pressures

Food web dynamics

Elements of FUTURE SCIENCE PROGRAM FOR 2020
GOAL
understand the PREDICTABILITY & SUSTAINABILITY of Social-Ecological-Environmental Systems
QUESTION:
Where is PICES FUTURE today?
QUESTION:
Where is PICES FUTURE today?

GOAL
understand the PREDICTABILITY & SUSTAINABILITY of Social-Ecological-Environmental Systems
GOAL
understand the PREDICTABILITY & SUSTAINABILITY of Social-Ecological-Environmental Systems

Climate System
- Climate Variability
- Climate Change
- Regional & Coastal Dynamics

Human System
- Human Well-Being
- Ecosystem Services

Drivers

Pressures

Elements of FUTURE SCIENCE PROGRAM FOR 2020

WG27 Climate Variability & Change
WG28 Ecosystem Indicators & Multiple Stressors
WG29 Regional Climate Modeling
WG30 Marine Radiation
WG31 Marine Pollution
WG32 Biodiversity Biogenic Habitats

S-CC Carbon and Climate
S-HAB Harmful Algal Blooms
S-HD Human Dimensions
S-CCME Climate Change & Marine Ecosystems
**GOAL**
understand the PREDICTABILITY & SUSTAINABILITY of Social-Ecological-Environmental Systems

**Processes**
- Human System
- Marine Ecosystem
- Climate System

**Climate System**
- Climate Variability
- Regional & Coastal Dynamics
- Climate Change

**Human System**
- Ecosystem Services
- Human Well-Being

**Marine Ecosystem**
- Fish & Shellfish
- Secondary Producers
- Top Predators

**Processes**
- Fishing
- Multiple Stressors
- Biological Primary Producers
- Physical
- Chemical

**Cumulative Effects**
- Vulnerability & Resilience
- Functional Responses
- Thresholds, Buffers & Amplifiers
- Spatial Dynamics

**Food Web Dynamics**

**Elements of FUTURE SCIENCE PROGRAM FOR 2020**

**WG27**
- S-CCME

**WG28**
- S-HD

**WG29**
- S-CC

**WG30**
- S-HAB

**WG31**
- S-CC

**WG32**
- S-HAB

**WG29**
- S-CC

**WG32**
- S-HAB

**WG30**
- S-HAB
understand the PREDICTABILITY & SUSTAINABILITY of Social-Ecological-Environmental Systems
PICES next steps ...

Social-Ecological-Environmental Systems (SEES) Approach & Modeling:

GOAL
understand the PREDICTABILITY & SUSTAINABILITY of Social-Ecological-Environmental Systems
**Social-Ecological-Environmental Systems (SEES) Approach & Modeling:**

- Create a culture of awareness to SEES dynamics
Social-Ecological-Environmental Systems (SEES) Approach & Modeling:

- Create a culture of awareness to SEES dynamics
- Train scientist in the practice of a trans-disciplinary SEES dialogue
Social-Ecological-Environmental Systems (SEES) Approach & Modeling:

• Create a culture of awareness to SEES dynamics

• Train scientist in the practice of a trans-disciplinary SEES dialogue

• no a priori questions and model

• questions and model are developed from the exchange

• requires a substantial level of interaction
**Social-Ecological-Environmental Systems (SEES) Approach & Modeling:**

- Create a culture of awareness to SEES dynamics
- Train scientist in the practice of a trans-disciplinary SEES dialogue
- Engage multiple “non-science” actors
Social-Ecological-Environmental Systems (SEES) Approach & Modeling:

- Create a culture of awareness to SEES dynamics
- Train scientist in the practice of a trans-disciplinary SEES dialogue
- Engage multiple “non-science” actors
- Identify issues that are prime for implementing a SEES approach
**Social-Ecological-Environmental Systems (SEES) Approach & Modeling:**

- *Create a culture of awareness to SEES dynamics*
- *Train scientist in the practice of a trans-disciplinary SEES dialogue*
- *Engage multiple “non-science” actors*
- *Identify issues that are prime for implementing a SEES approach*
- *Find proper sources of funding and coordination*
GOAL
understand the PREDICTABILITY & SUSTAINABILITY of Social-Ecological-Environmental Systems