CANADA'S CHANGING PACIFIC MARINE ECOSYSTEMS:

FORECASTS, UNCERTAINTIES, POTENTIAL CONSEQUENCES, AND COMMUNICATION

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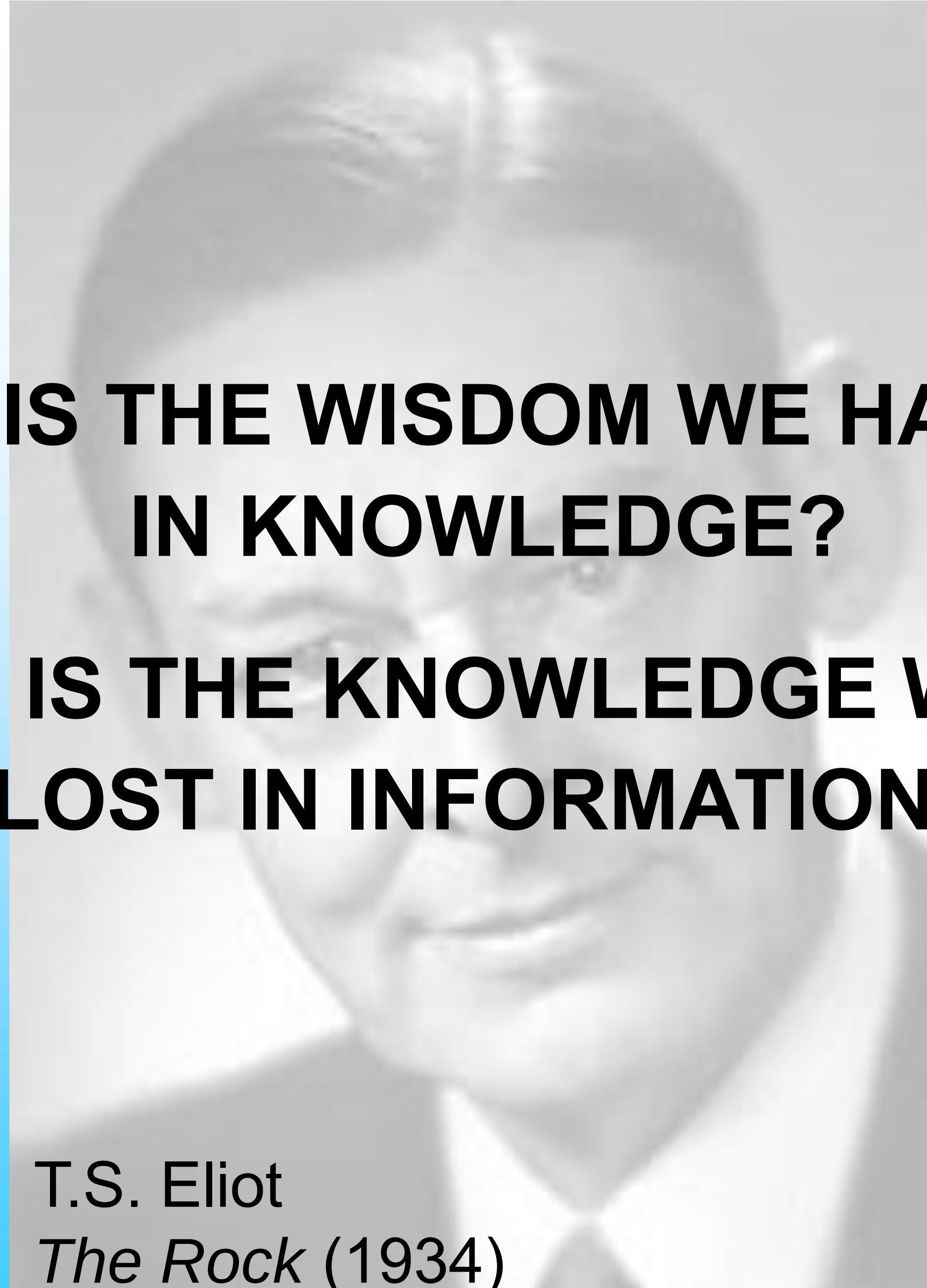
PICES FUTURE PROGRAM:

Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems

2013 MEETING THEME:

Communicating forecasts, uncertainty and consequences of ecosystem change

Products Tools Uncertainty Human dimensions



WHERE IS THE WISDOM WE HAVE LOST IN KNOWLEDGE?

WHERE IS THE KNOWLEDGE WE HAVE LOST IN INFORMATION?

T.S. Eliot
The Rock (1934)

2013 MEETING THEME:

Communicating forecasts, uncertainty and consequences of ecosystem change

Products Tools Uncertainty Human dimensions

Facts — **(Information)**

Application of facts — **(Knowledge)**

Wise use — **(Wisdom)**

Goal of this presentation

To describe what success might look like for FUTURE, using examples from a Canadian and NE Pacific perspective

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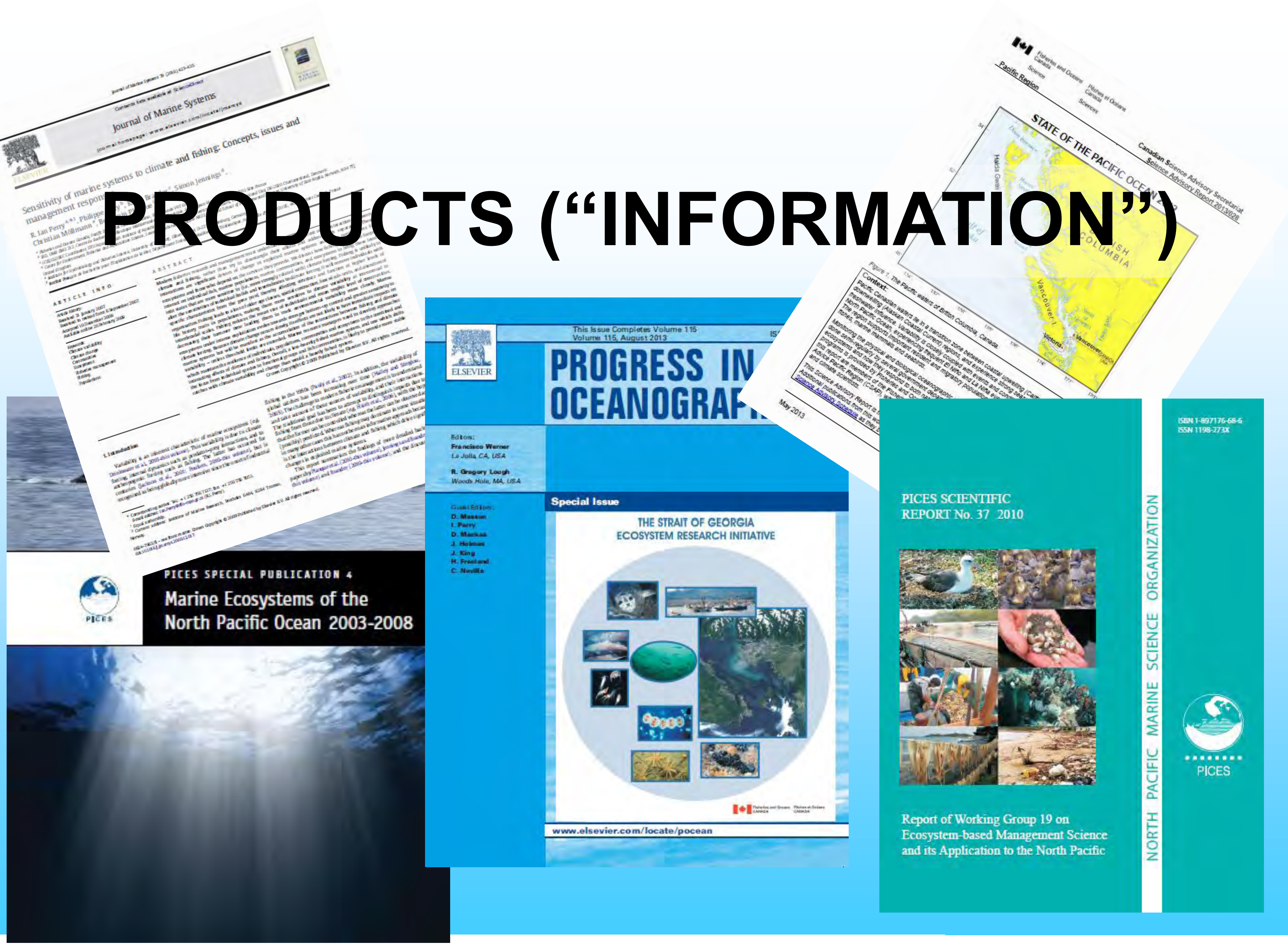
To describe what success might look like for FUTURE, using examples from a Canadian and NE Pacific perspective

- **What are current and expected conditions and pressures; and**
- **What are possible futures for Canada's Pacific waters?**

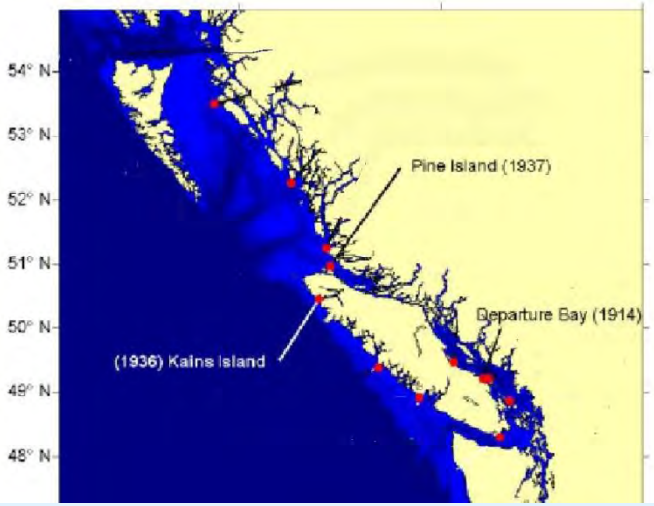
PRODUCTS ("INFORMATION")



PRODUCTS (“INFORMATION”)

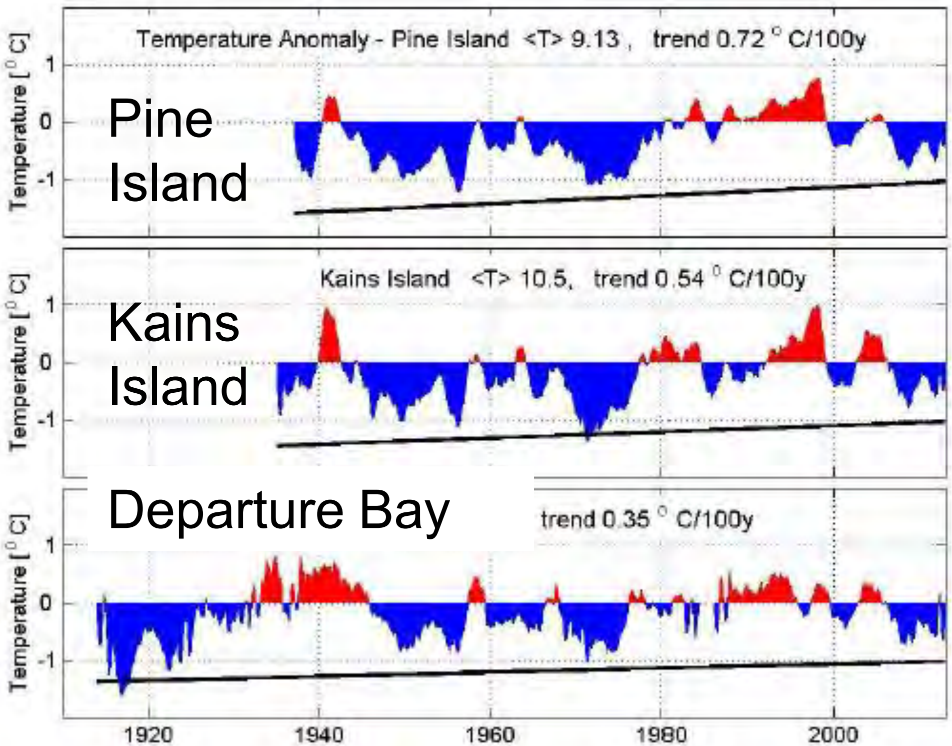
HOW ARE CANADIAN PACIFIC MARINE SYSTEMS CHANGING?

BC coastal waters have been getting warmer and fresher, but with interannual variability

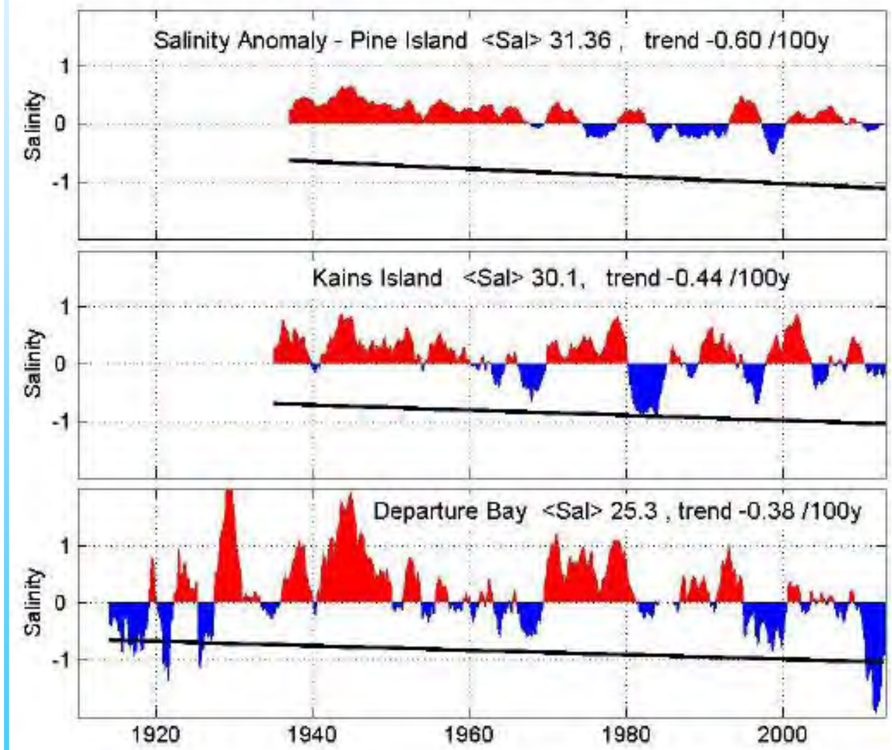


Chandler and Gower 2013

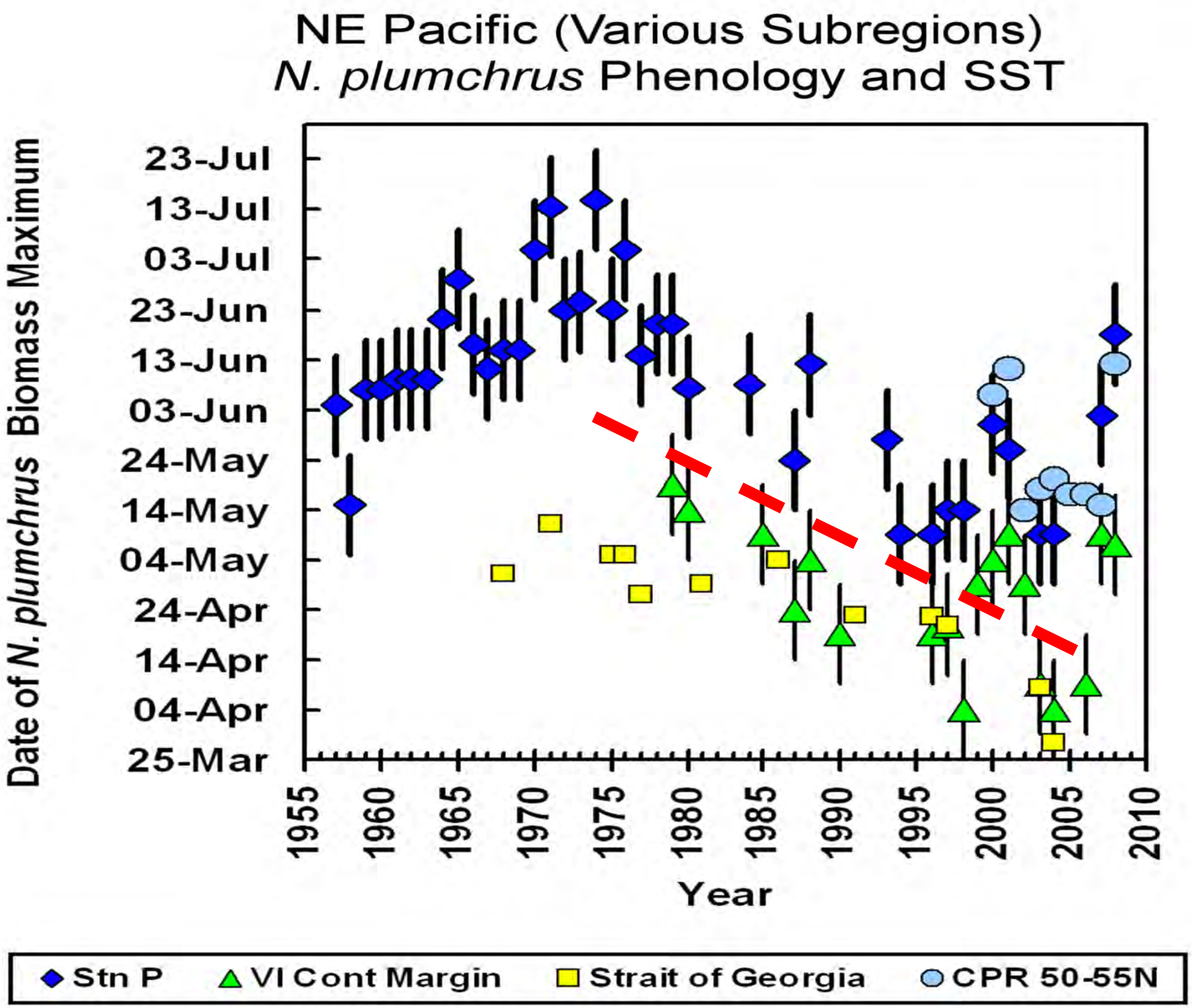
Temperature



Salinity



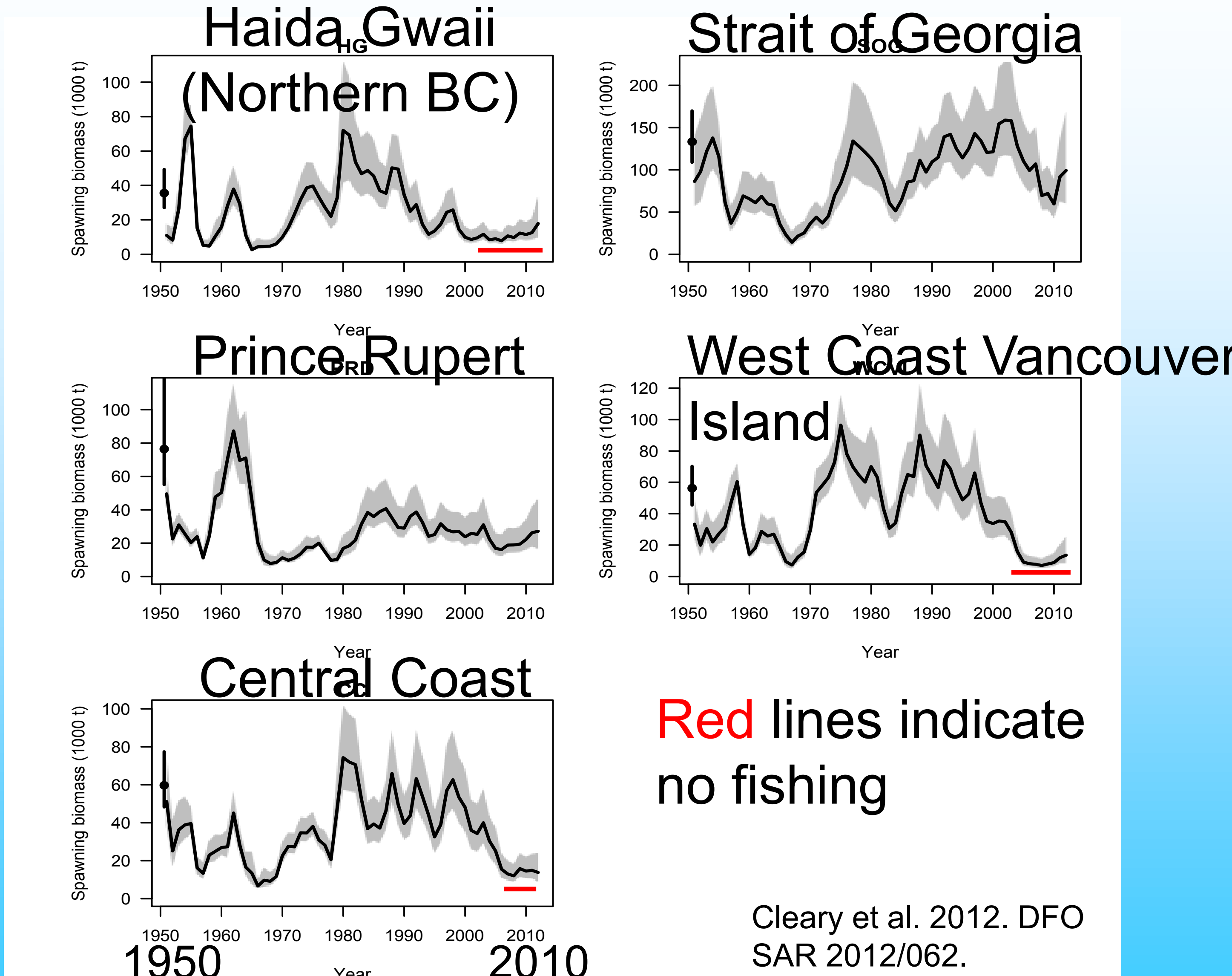
Zooplankton seasonality has been shifting earlier



Trend towards earlier date of maximum biomass of key food web copepods, associated with warming ocean climate

Courtesy D. Mackas

Pacific herring population abundance in BC



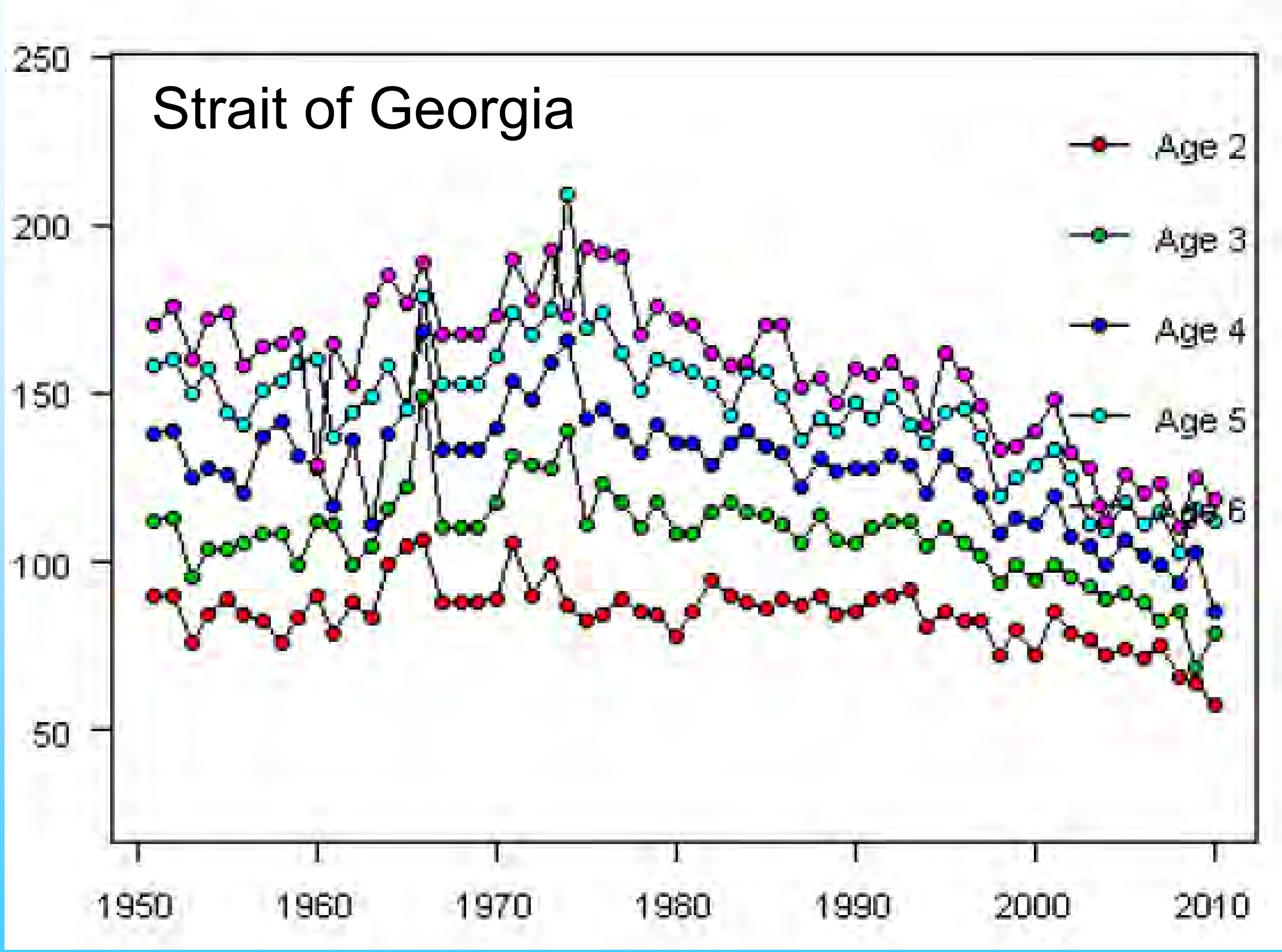
Red lines indicate no fishing

Cleary et al. 2012. DFO SAR 2012/062.

Fisheries and Oceans Canada Pêches et Océans Canada

Perry, 2013 PICES Annual Meeting, Session S1, Nanaimo, 14 October 2013

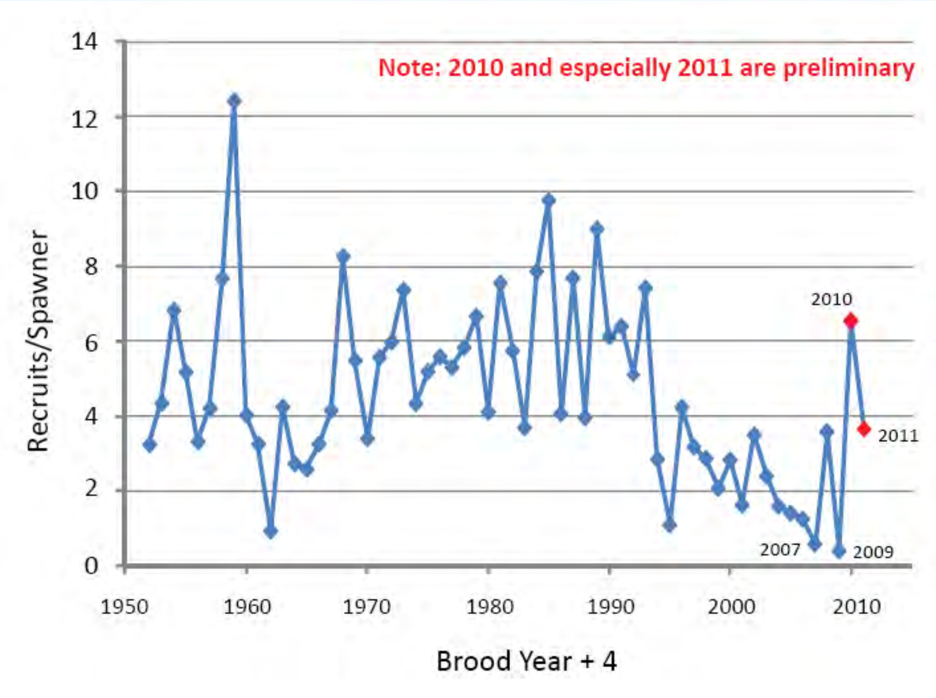
Pacific herring size-at-age has been declining along the BC coast since the 1990's



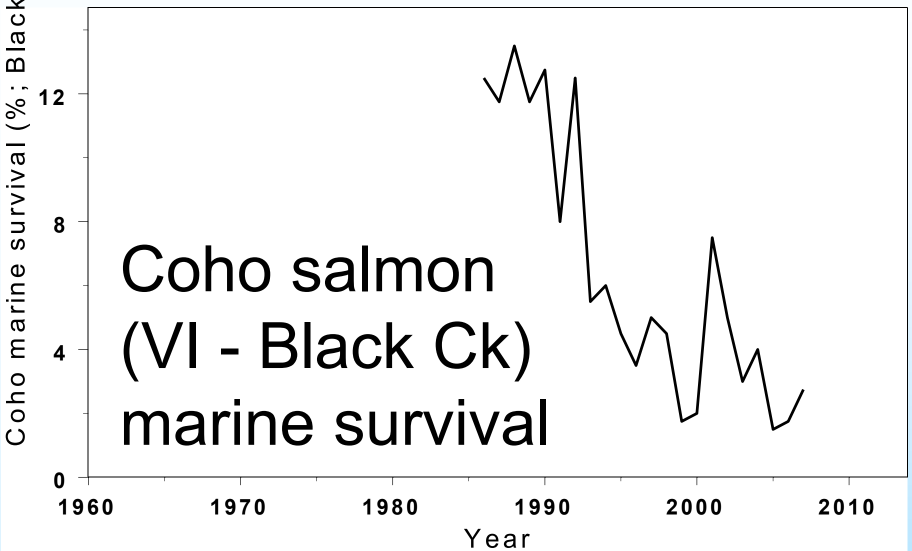
Boldt et al. 2013. DFO State of the Ocean Rept.

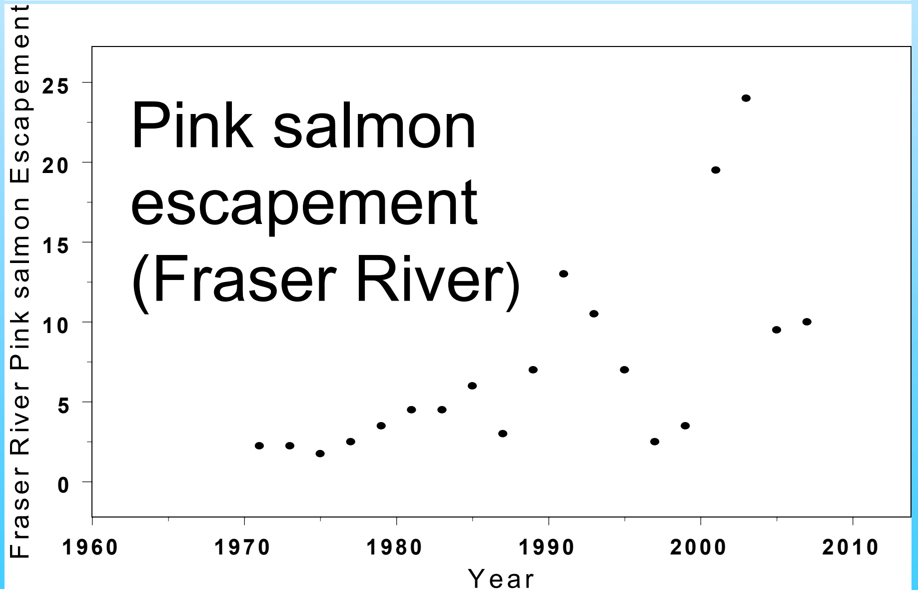
Some salmon species have declined; others have increased

Fraser River Sockeye salmon annual productivity

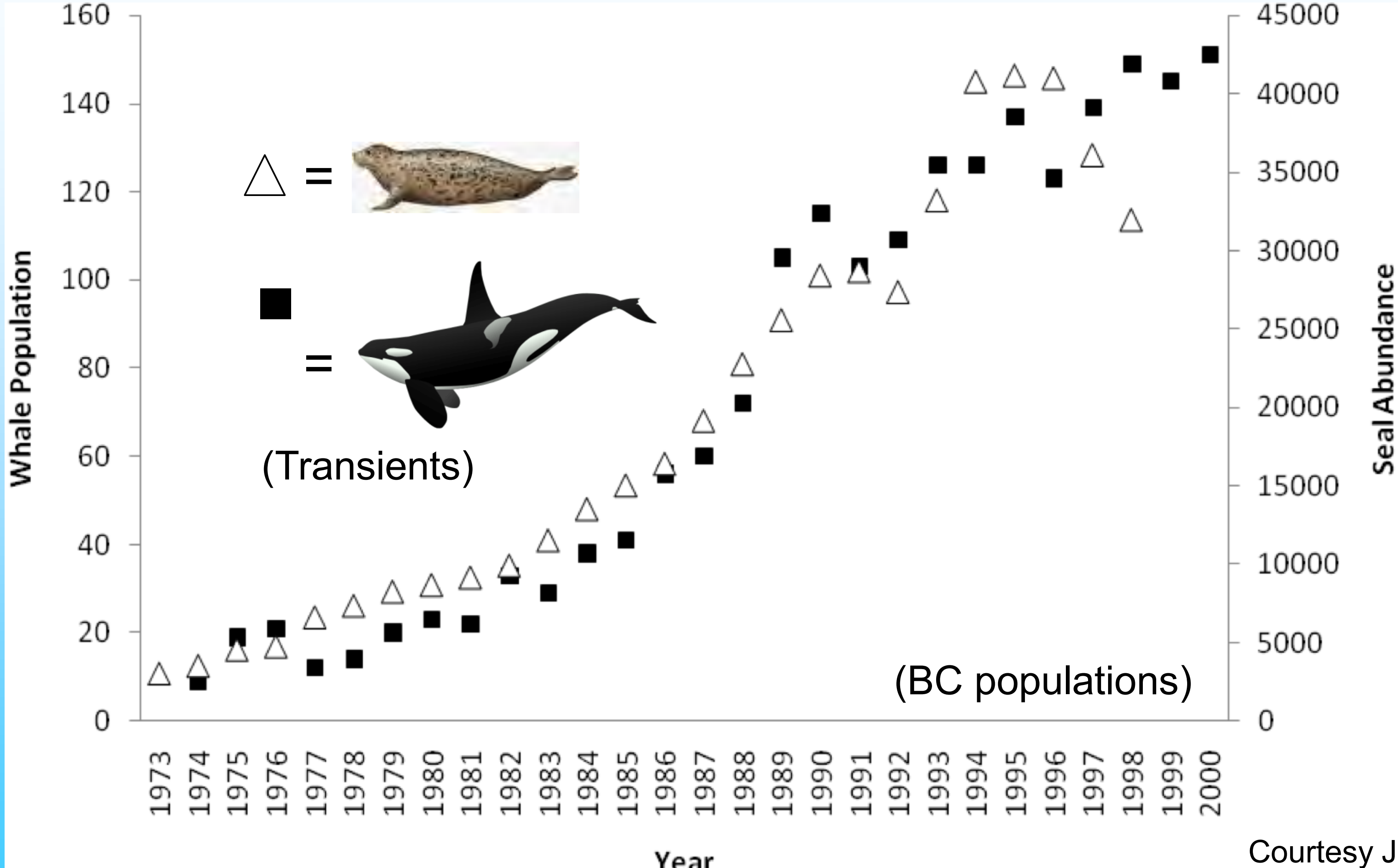


'Cohen Commission' Final Report 2012.





Many marine mammal populations have been increasing



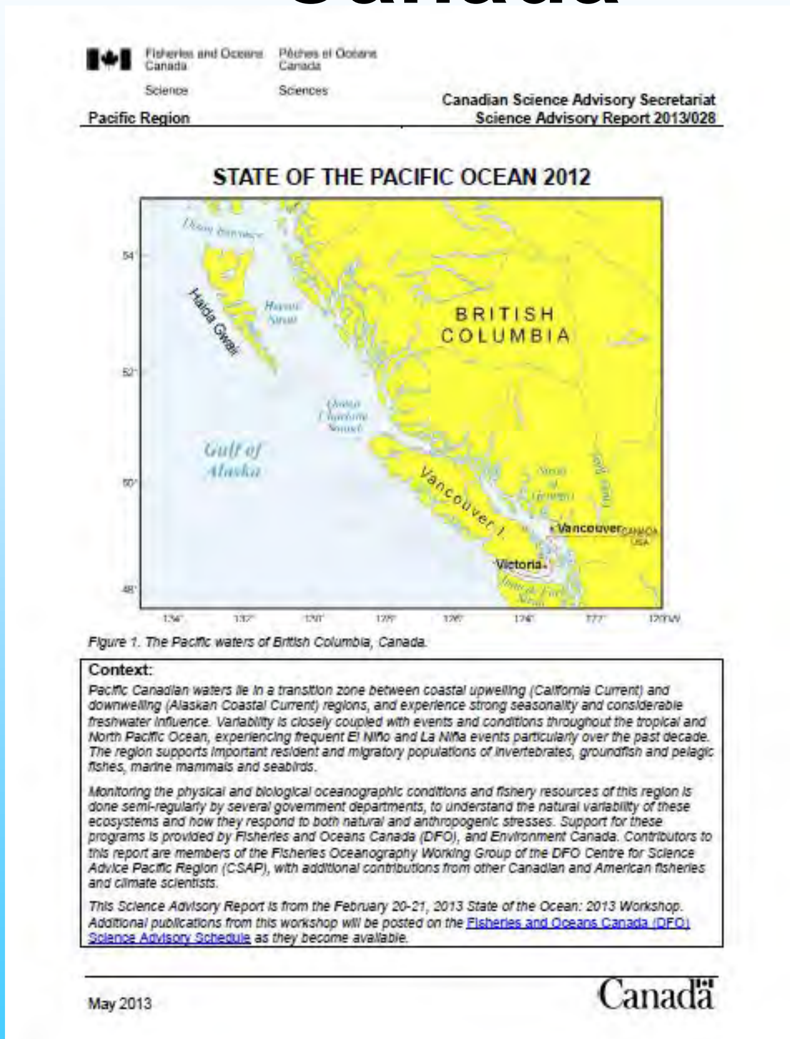
Courtesy J. Ford

Summary (so far) - Products

- Long-term warming and freshening, but with year-to-year variability
- Seasonal cycles of major zooplankton species are shifting earlier
- Abundances of key forage fish species such as herring are low in many areas of BC coast, even with no fishing
- Salmon which feed lower in the food web have generally been doing well; those feeding higher in the food web have been doing less well

Regular status and trends reports

Canada



Fisheries and Oceans Canada Pêches et Océans Canada

Science Sciences

Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2013/028

STATE OF THE PACIFIC OCEAN 2012

Figure 1. The Pacific waters of British Columbia, Canada.

Context:

Pacific Canadian waters lie in a transition zone between coastal upwelling (California Current) and downwelling (Alaskan Coastal Current) regions, and experience strong seasonality and considerable freshwater influence. Variability is closely coupled with events and conditions throughout the tropical and North Pacific Ocean, experiencing frequent El Niño and La Niña events particularly over the past decade. The region supports important resident and migratory populations of invertebrates, groundfish and pelagic fishes, marine mammals and seabirds.

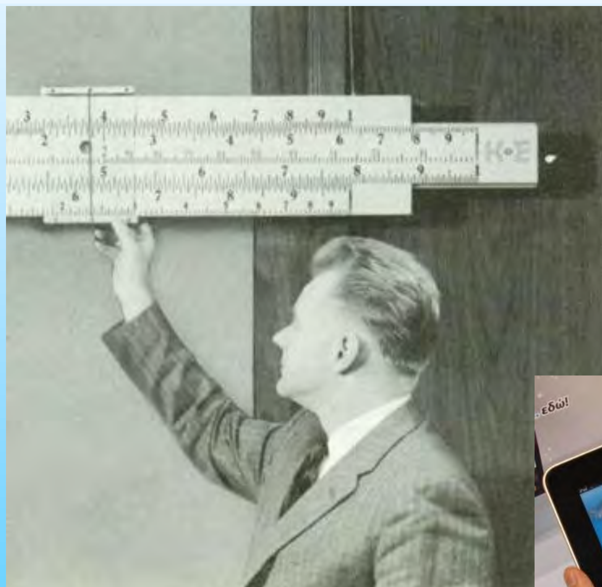
Monitoring the physical and biological oceanographic conditions and fishery resources of this region is done semi-regularly by several government departments, to understand the natural variability of these ecosystems and how they respond to both natural and anthropogenic stresses. Support for these programs is provided by Fisheries and Oceans Canada (DFO), and Environment Canada. Contributors to this report are members of the Fisheries Oceanography Working Group of the DFO Centre for Science Advice Pacific Region (CSAP), with additional contributions from other Canadian and American fisheries and climate scientists.

This Science Advisory Report is from the February 20-21, 2013 State of the Ocean: 2013 Workshop. Additional publications from this workshop will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

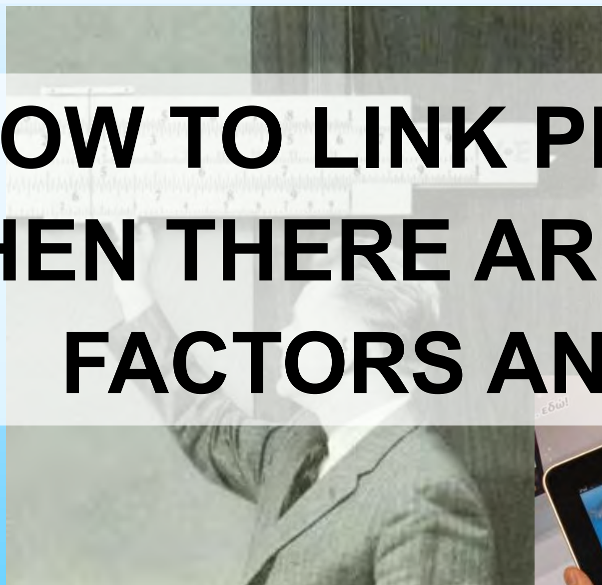
May 2013 Canada

PICES

TOOLS
("INFORMATION / KNOWLEDGE")

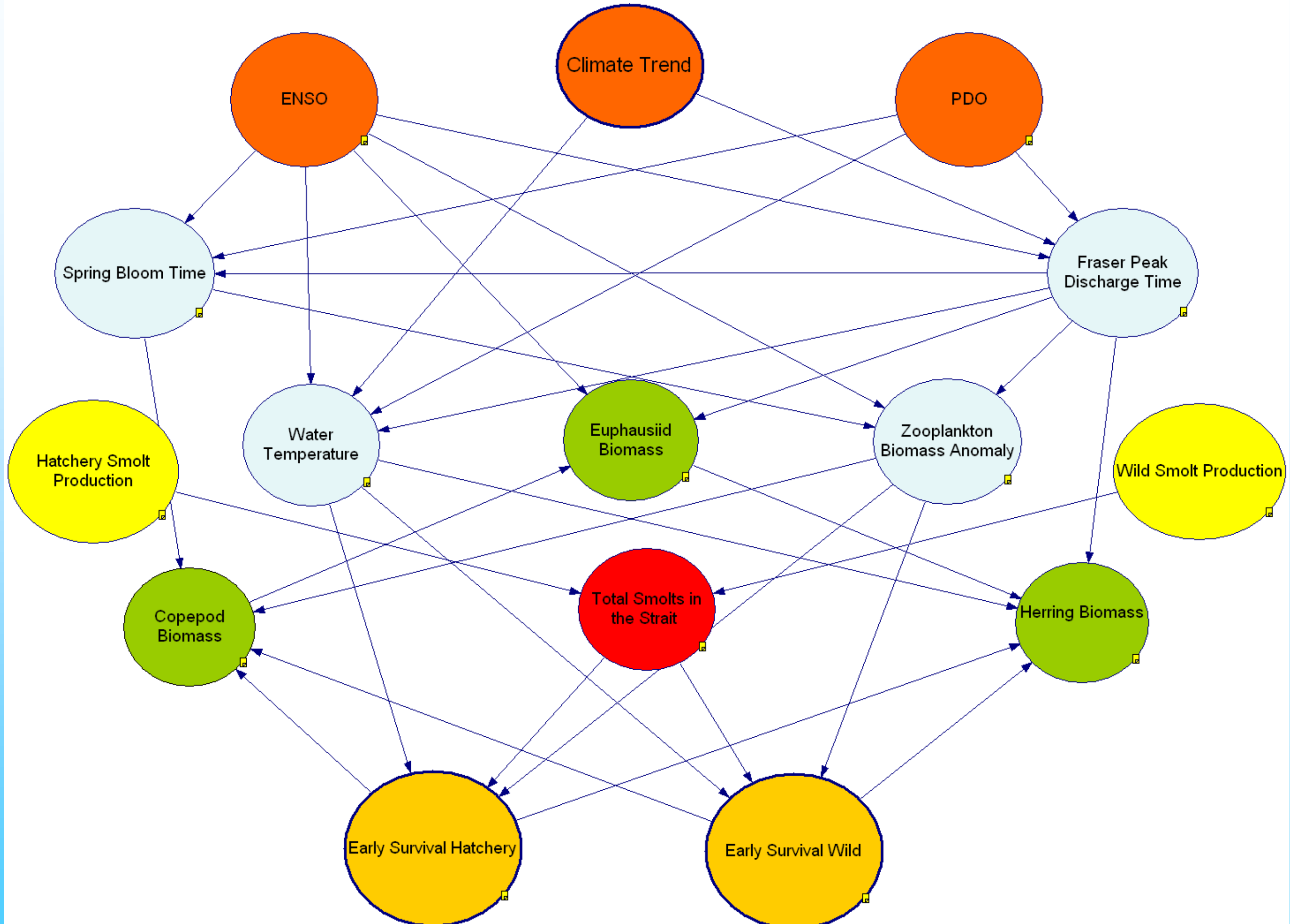


TOOLS
("INFORMATION / KNOWLEDGE")



HOW TO LINK PRESSURES TO CHANGES WHEN THERE ARE MULTIPLE INTERACTING FACTORS AND DATA LIMITATIONS?

Network models to identify indicators for Coho salmon early marine survival



Probabilistic causal (Bayesian) Network model to identify indicators for early marine survival of coho salmon in Strait of Georgia

Araujo et al. 2013
Prog. Oceanogr

Network models to identify indicators for Coho salmon early marine survival

Indicator	Diagnostic value
Zooplankton biomass anomaly	0.212
Calanoid copepod biomass	0.083
Herring biomass (pre-fishery)	0.073
Water temperature	0.056
Fraser peak discharge time	0.043
Euphausiid biomass	0.032
ENSO	0.029
PDO	0.021
Log spring bloom time	0.006

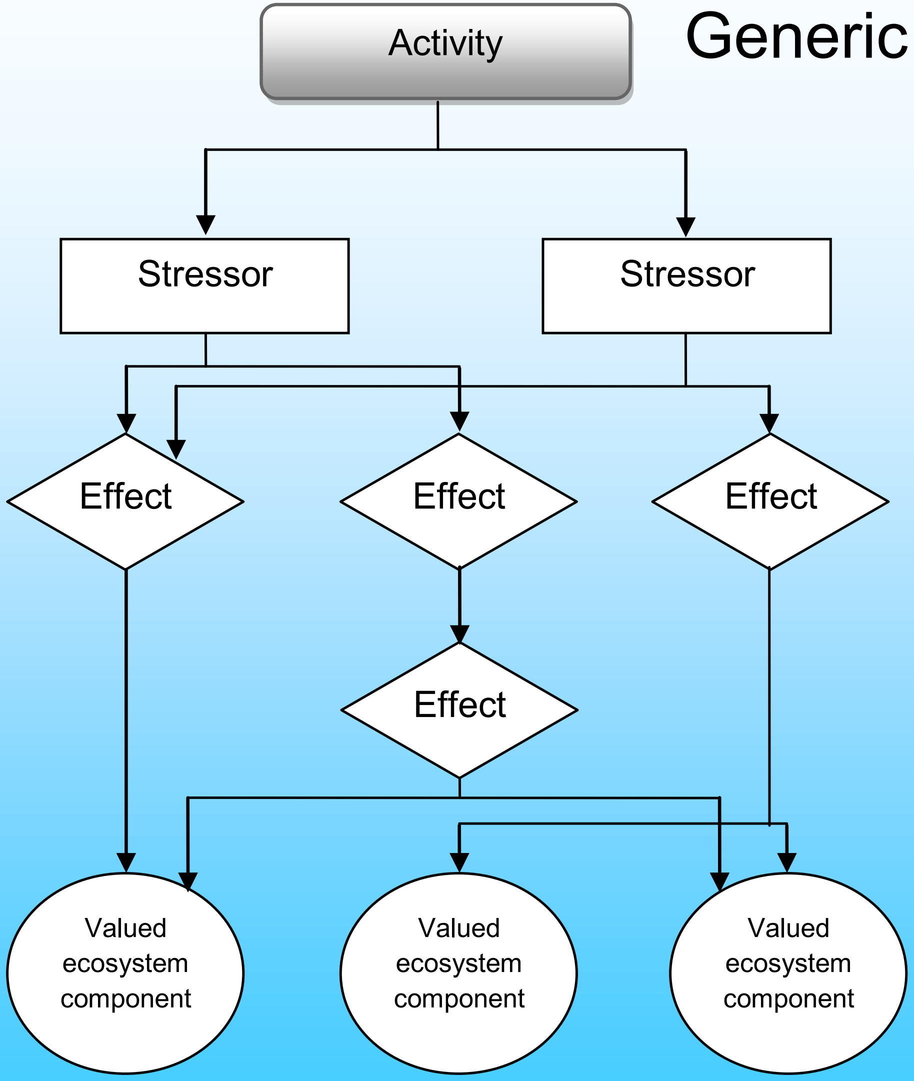
Bayesian network model

The 3 best indicators of coho early marine survival:

- zooplankton biomass anomaly,
- calanoid copepod biomass,
- biomass of herring

Araujo et al. 2013 Prog. Oceanogr

Ecological Risk Assessment Framework

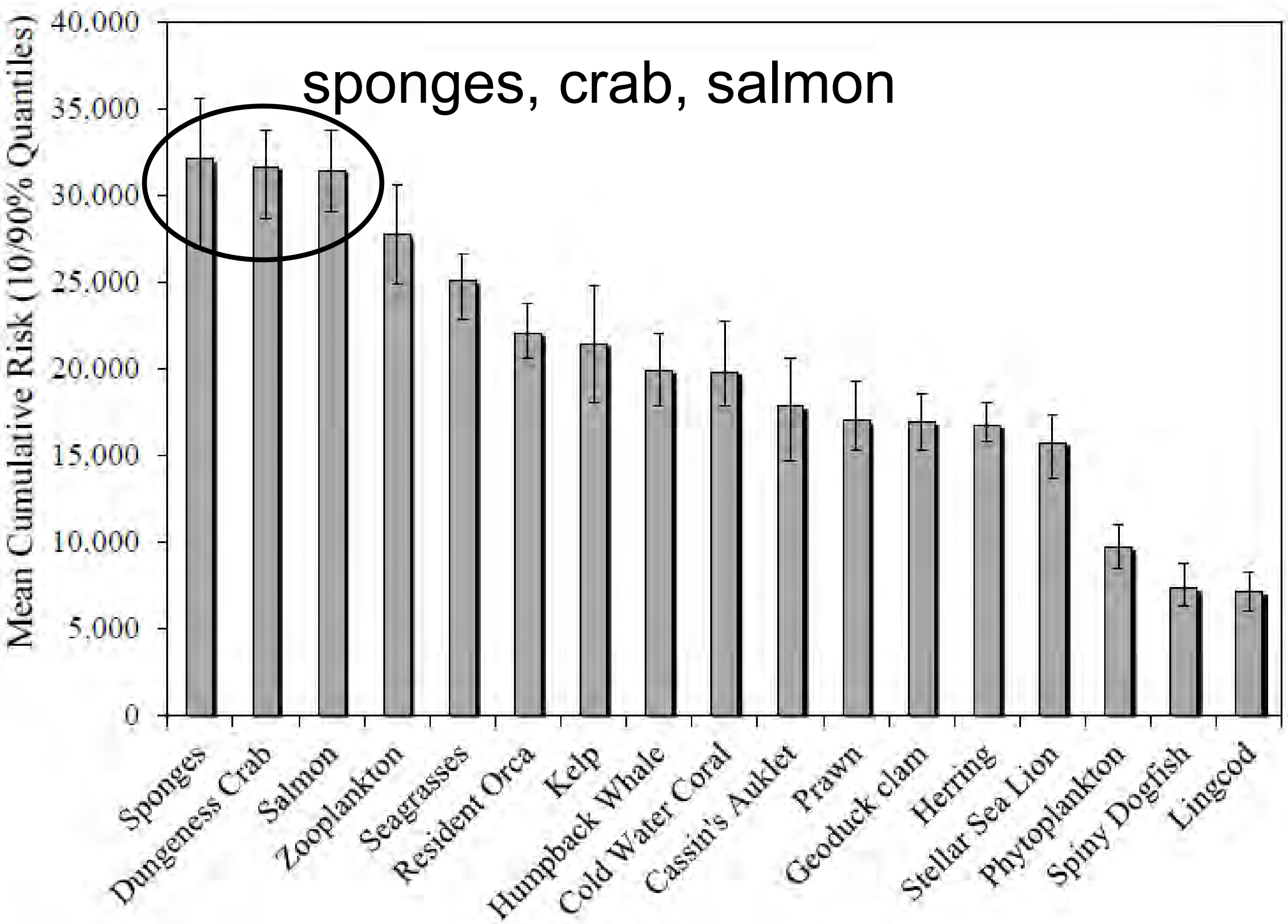


Generic Pathways of Effects model

1) Determine which activities and stressors interact with each important ecosystem component;
2) Develop area-specific Pathways of Effects models;
3) Score and rank the most significant stressors for each important ecosystem component

O et al. 2013. CSAS Res Doc.

Cumulative risk scores for impacts of human activities on selected ecosystem components [BC North Coast]

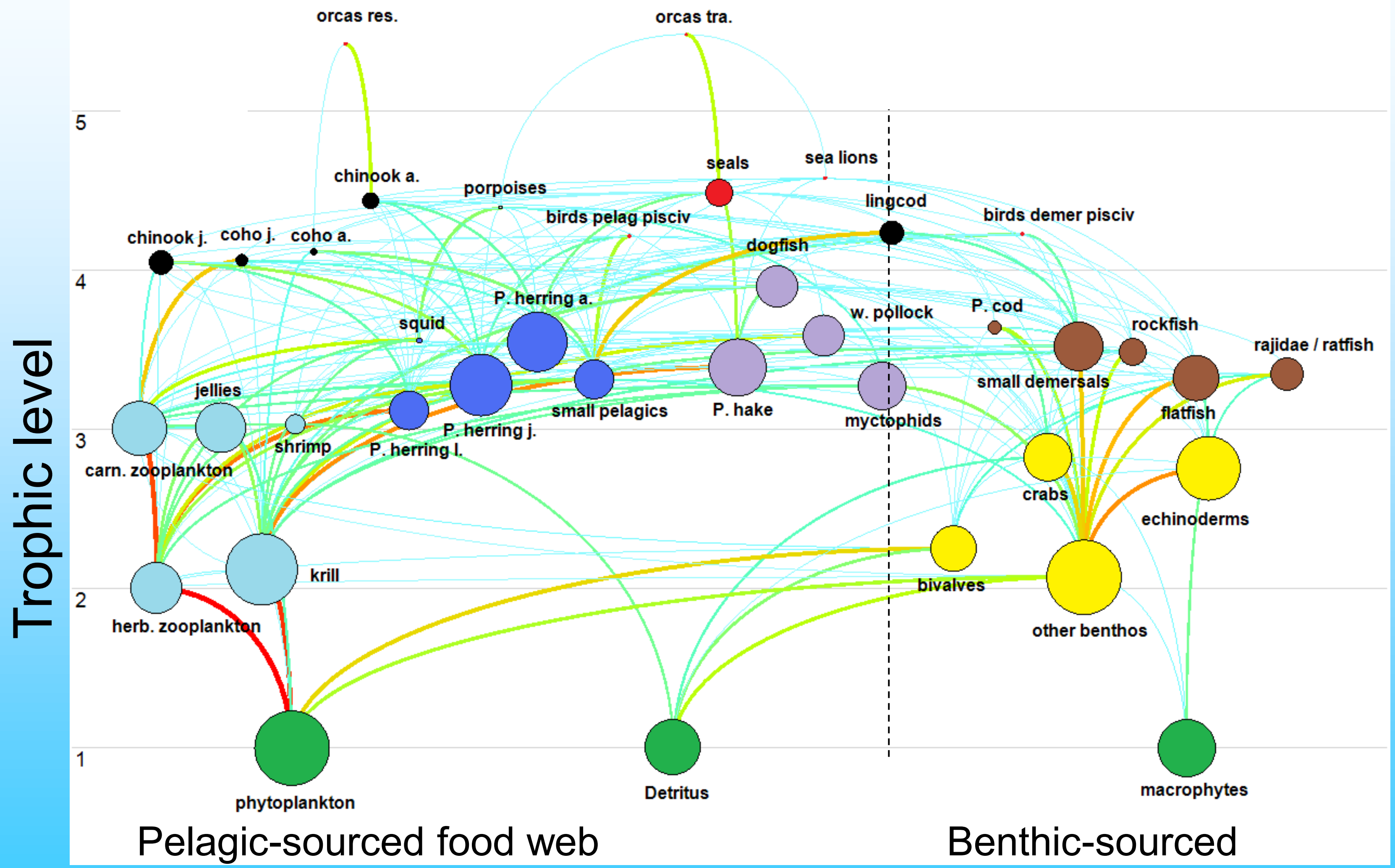


Human activities: aquaculture, settlements, harbours, ports, shipping, log dumps, fisheries (dive, sport, gillnet, seine, trap, trawl, troll, longline), tourism

Clarke-Murray et al. 2013. In revision

Fish-focussed food web models: Strait of Georgia

Ecopath with Ecosim (EwE) model food web for 2009

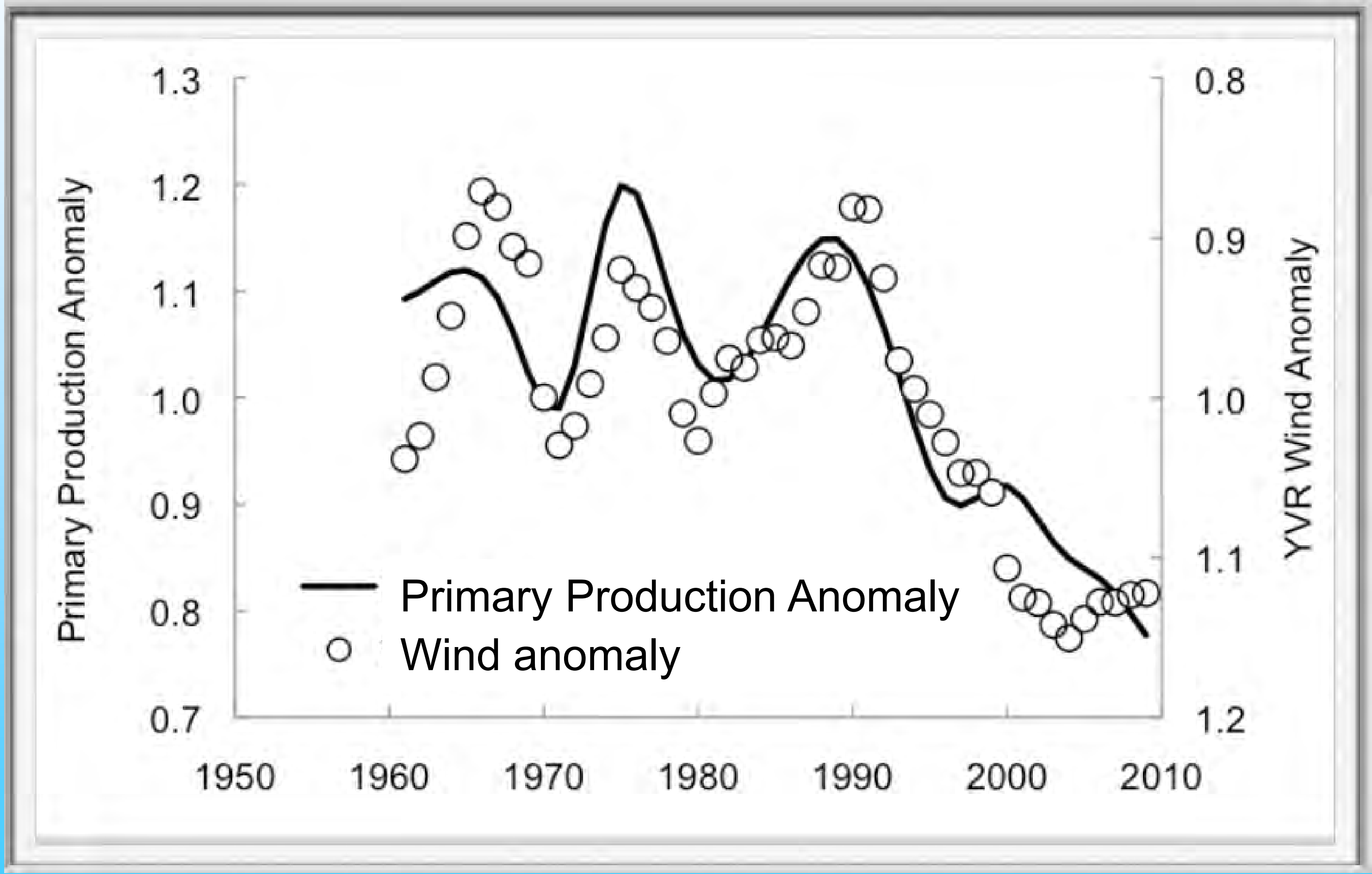


Preikshot et al. 2013 PiO

Fish-focussed food web models: Strait of Georgia

Primary production 'anomaly' back-calculated from the EwE model, and spring-summer winds at Vancouver airport

Declining productivity of the Strait of Georgia since 1990?

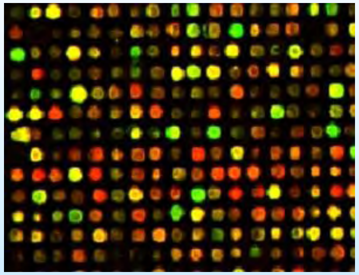


Preikshot et al. 2013 Prog. Oceanogr

Tools of the Future: Novel genomic technologies

DNA → RNA → PROTEIN

Microarrays scan the activity of 10's of 1000's of genes at once



Identify genomic signatures that describe the condition of individual fish

- Under physiological stress, responding to infections or disease
- Feeding or starving, growing fast or slow

Massively Parallel Sequencing

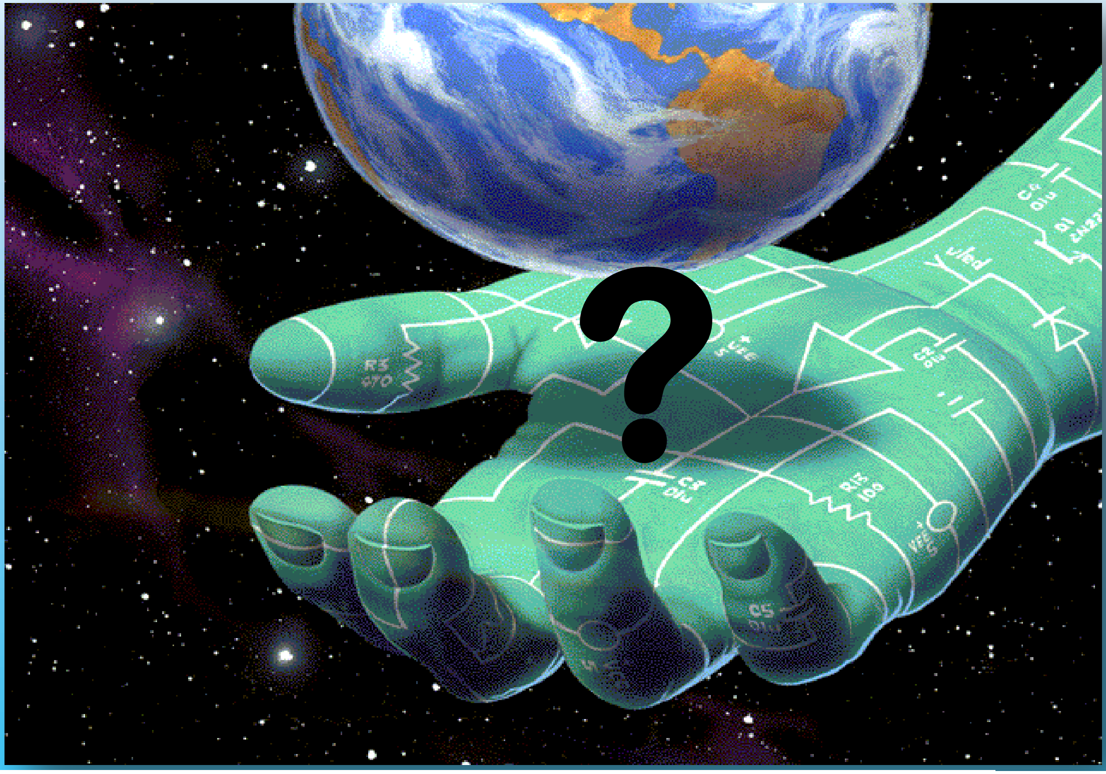
- Ecosystem monitoring: analyse individuals/samples to rapidly monitor all biological agents (e.g. plankton, microbes, pathogens, invasives)

Courtesy Kristi Miller

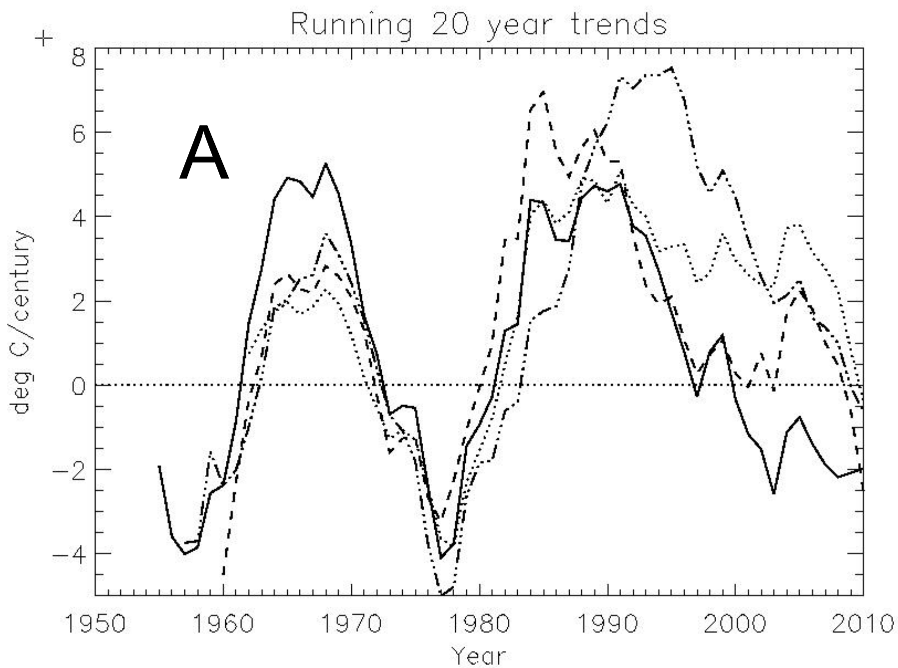
Summary (so far) - Tools

- When long data series are available, use statistical models to identify links between natural/human pressures and ecosystem changes, and develop indicators
- Use conceptual pathways-of-effects models based on data or local/expert knowledge to identify significant stressors on ecosystem features
- Simulation models can be used to explore our understanding of how ecosystems work and change, and identify gaps

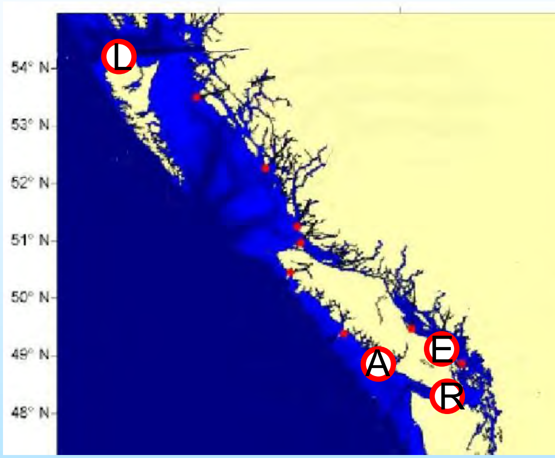
DEALING WITH UNCERTAINTY ("KNOWLEDGE")

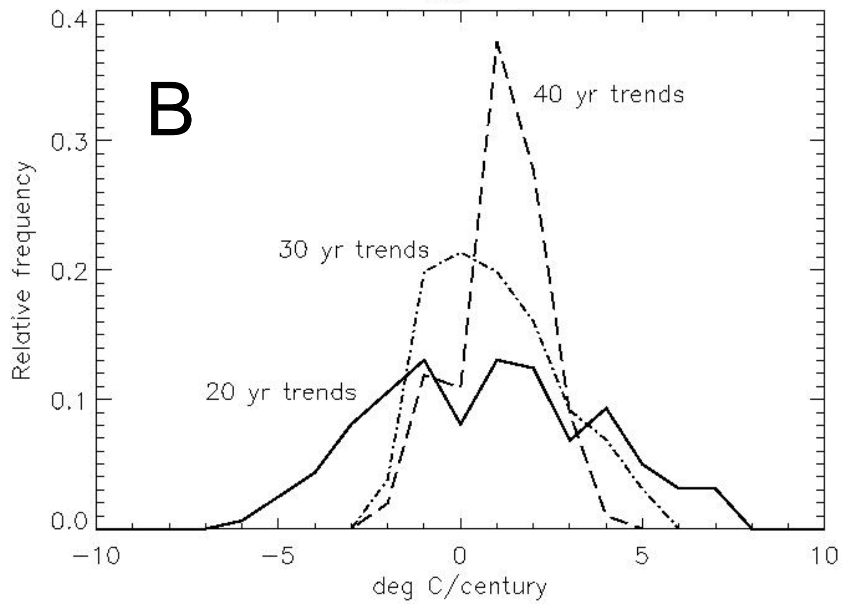


Statistical analyses of long-term sea temperature trends



Amphitrite Pt.
Race Rocks
Langara Is.
Entrance Is.





A) 20-year running SST trends at four lighthouse stations.

B) Average histograms of lighthouse SST trends for 20-, 30- and 40-year running trends

<u>Probability of decreasing trend in temp:</u>

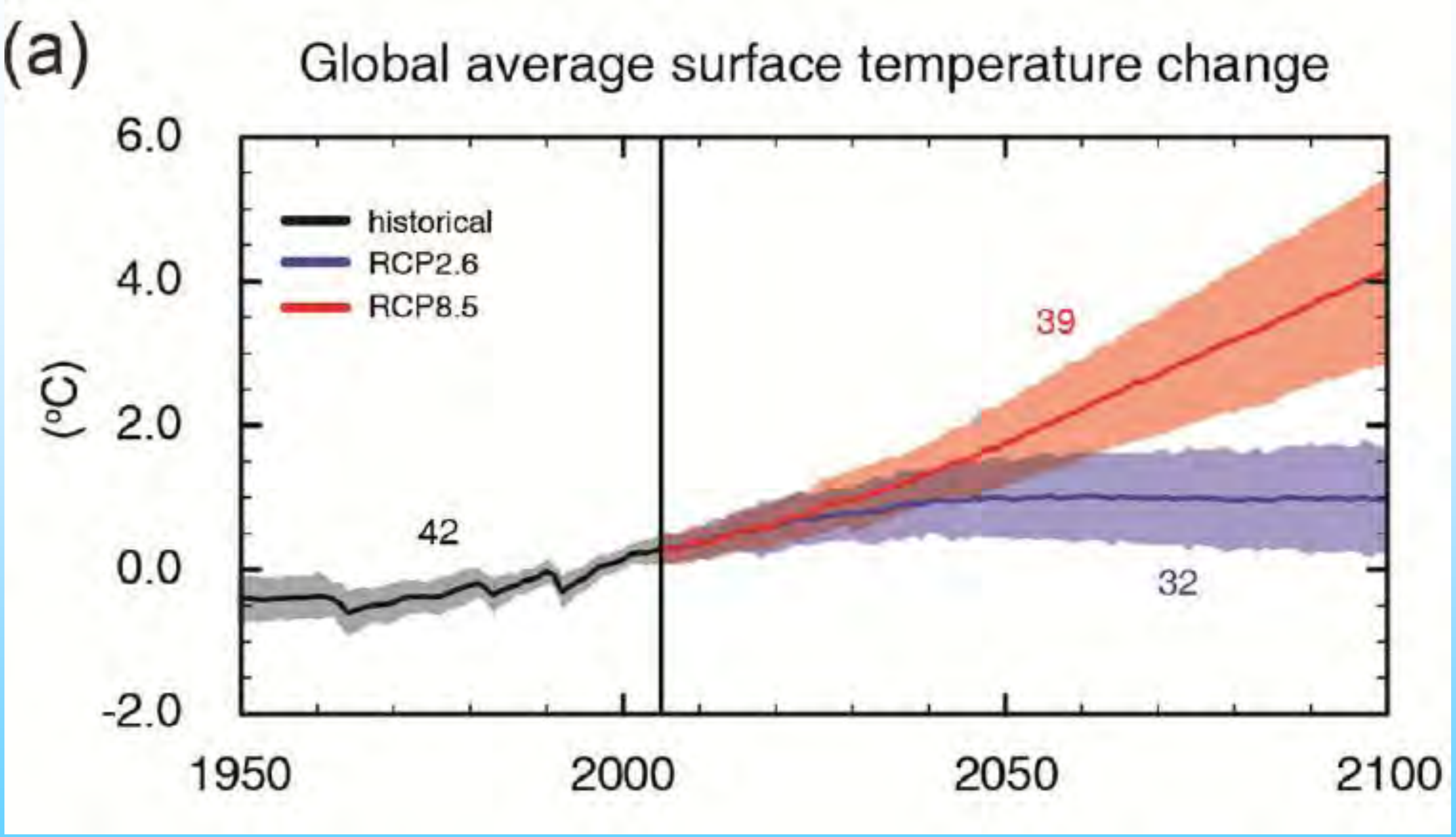
over 20 years: 39%

over 30 years: 34%

over 40 years: 17%

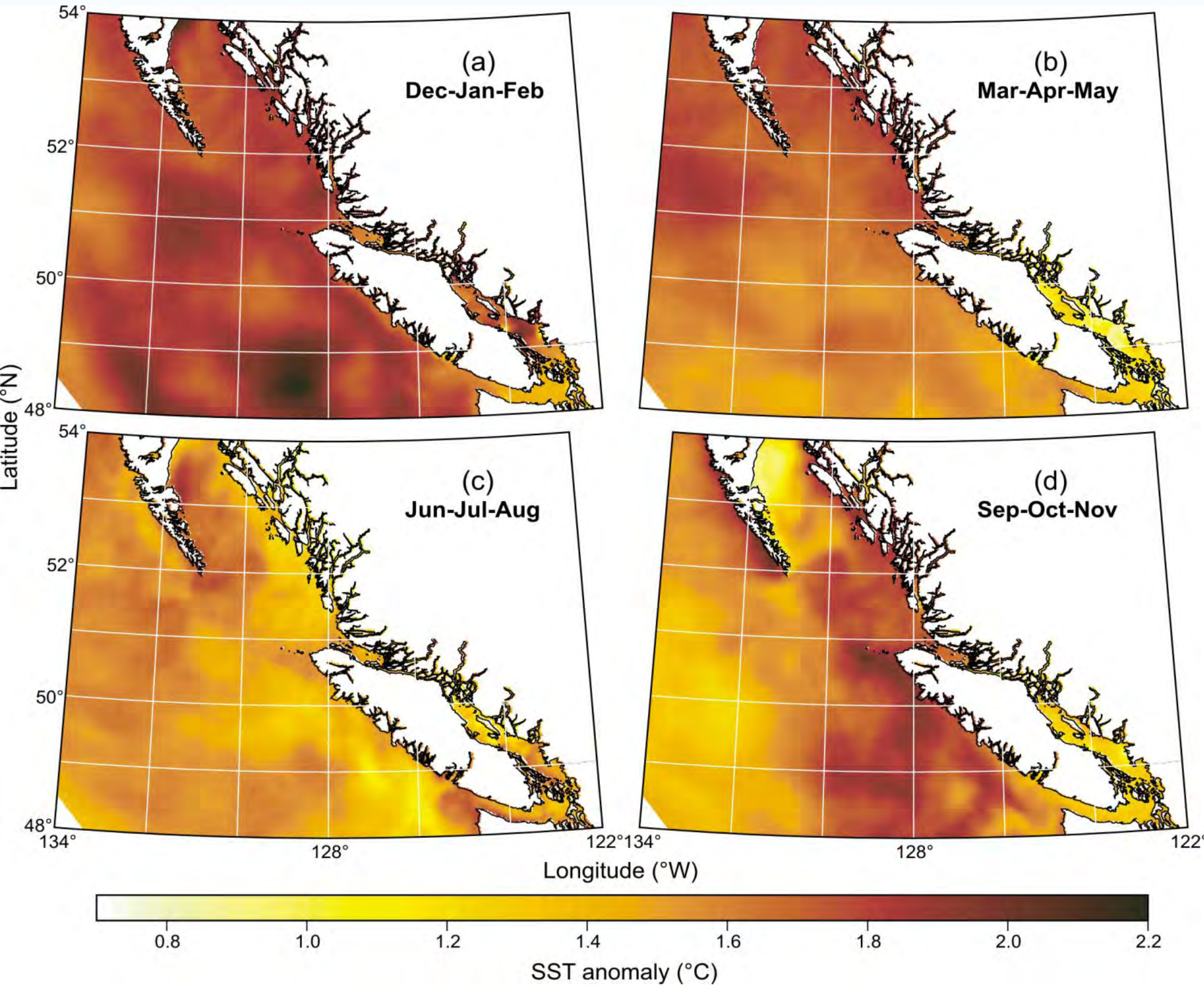
Cummins and Masson. Submitted

IPCC projections are for continued warming



Intergovernmental Panel on Climate Change, WG 1, 5th Assessment Report, 2013

Downscaling future projections from global climate models to regional (BC) waters



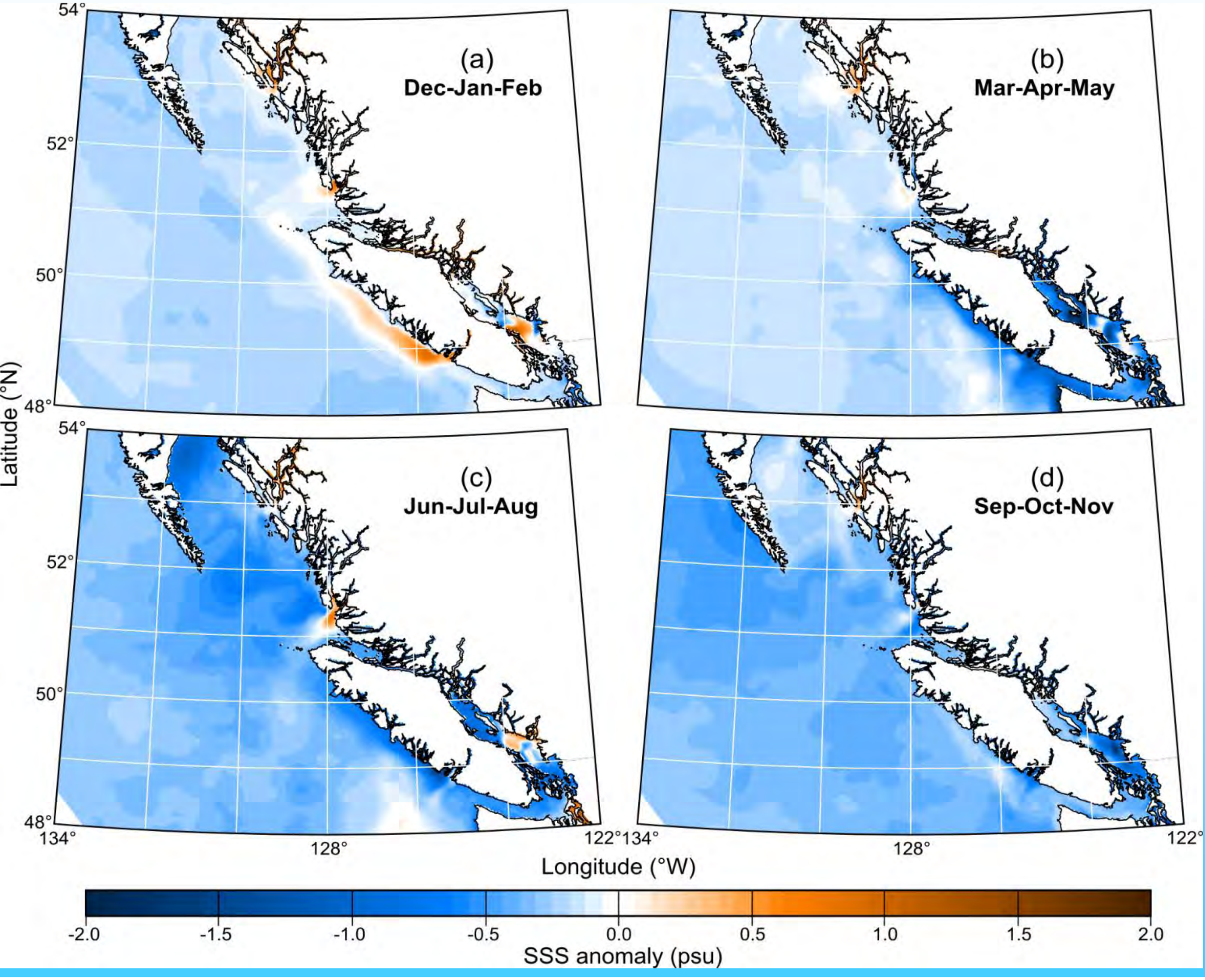
Sea surface temperature anomalies are monthly-averaged differences 2065-2078 minus 1995-2008

Warmer everywhere

Bigger differences (>1.5°) in winter

Foreman et al. In Press. Atmos-Ocean

Downscaling future projections from global climate models to regional (BC) waters



Sea surface temperature anomalies are monthly-averaged differences 2065-2078 minus 1995-2008

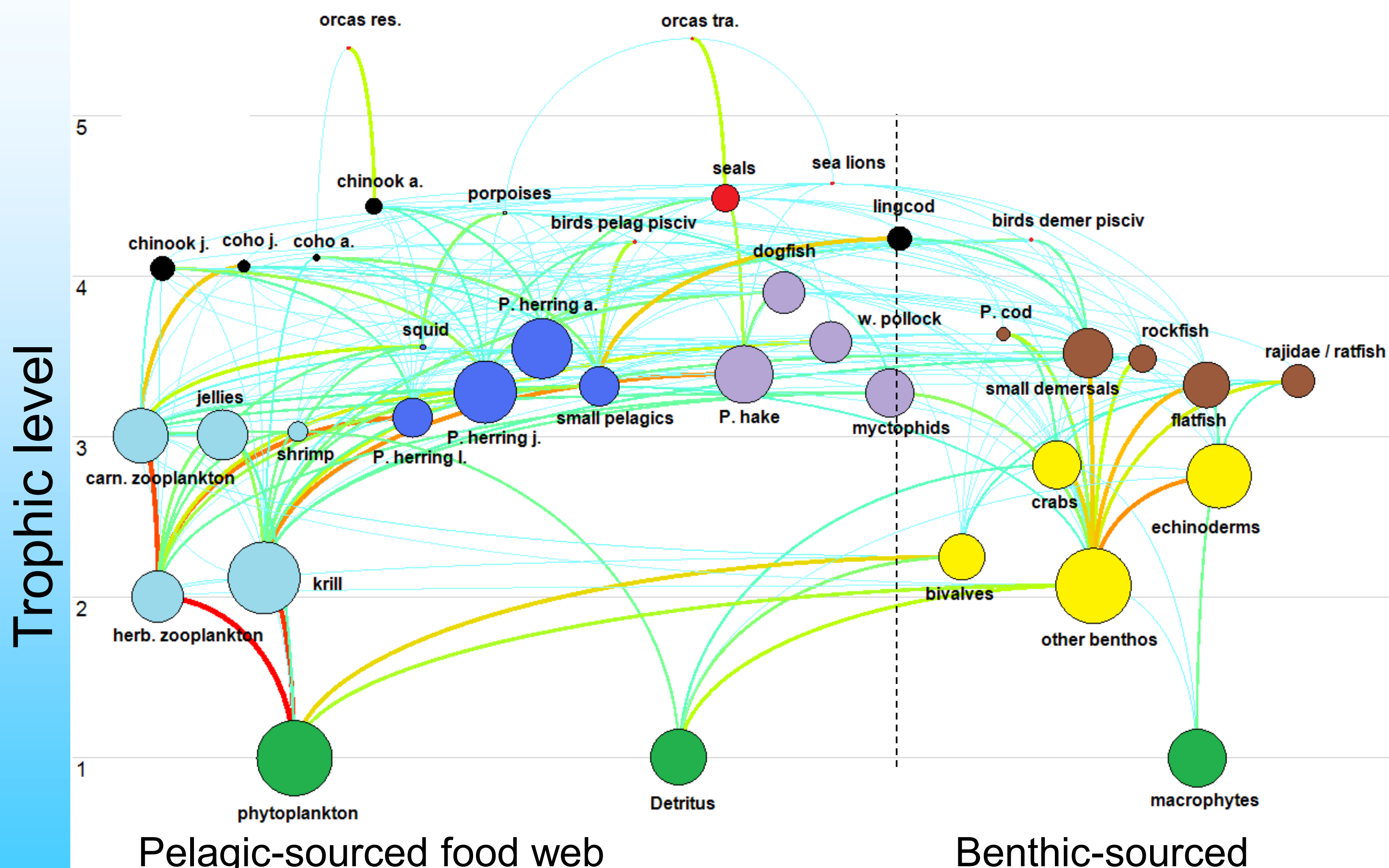
Generally fresher

Some timing changes produce saltier regions

Foreman et al. In Press. Atmos-Ocean

Fish-focussed food web models: Strait of Georgia

Ecopath with Ecosim (EwE) model food web for 2009



Preikshot et al. 2013 PiO

Projecting climate impacts on fish-focussed food webs

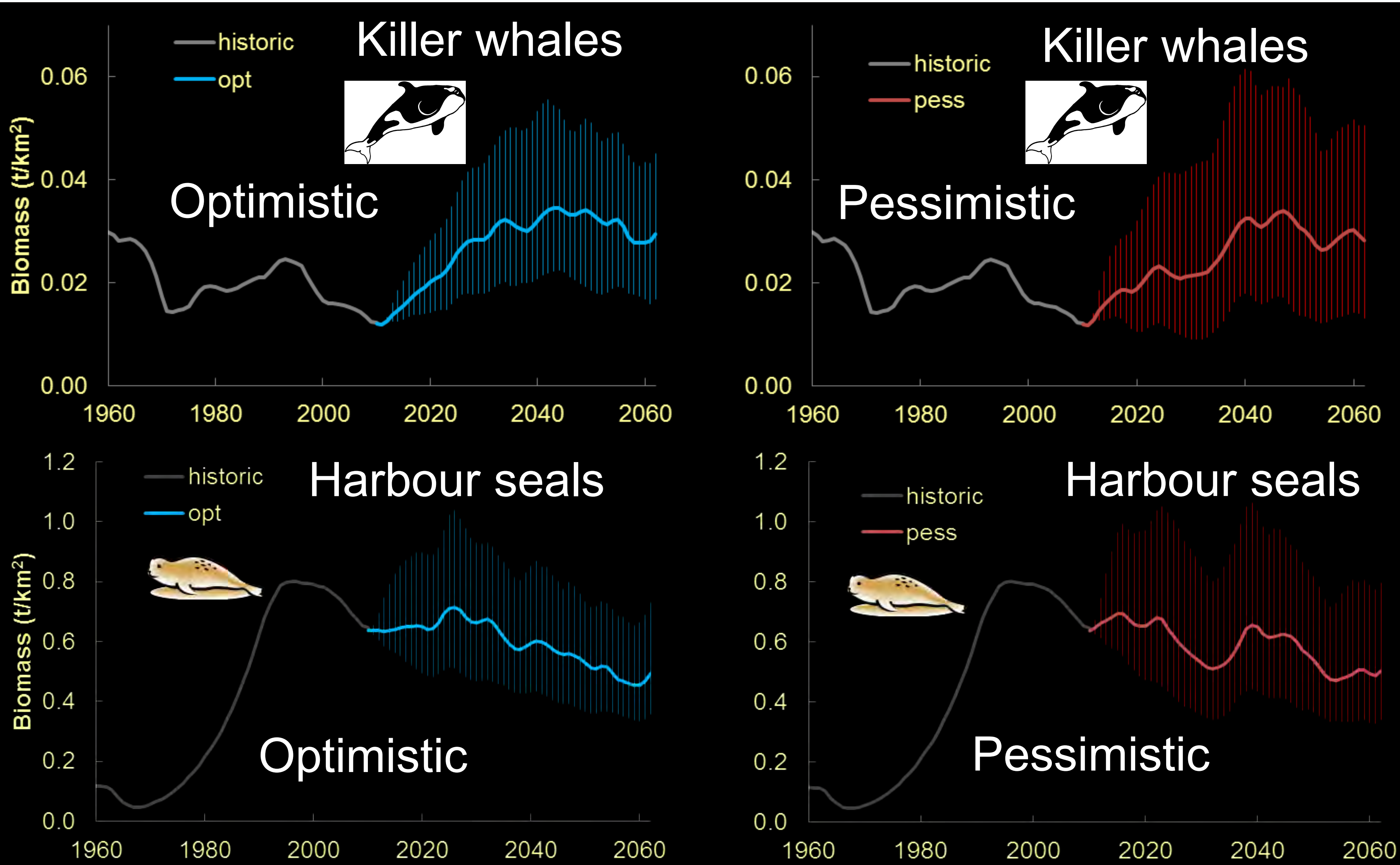
Optimistic assumption (Earth System Model 2M, rcp26):
- CO_2 emissions under control in next two decades.
- Increase in SST of 0.5-1ºC by 2060.

Pessimistic assumption (Earth System Model 2M, rcp85):
- CO_2 emissions continue to increase linearly.
- Increase in SST of 1-1.5ºC by 2060.

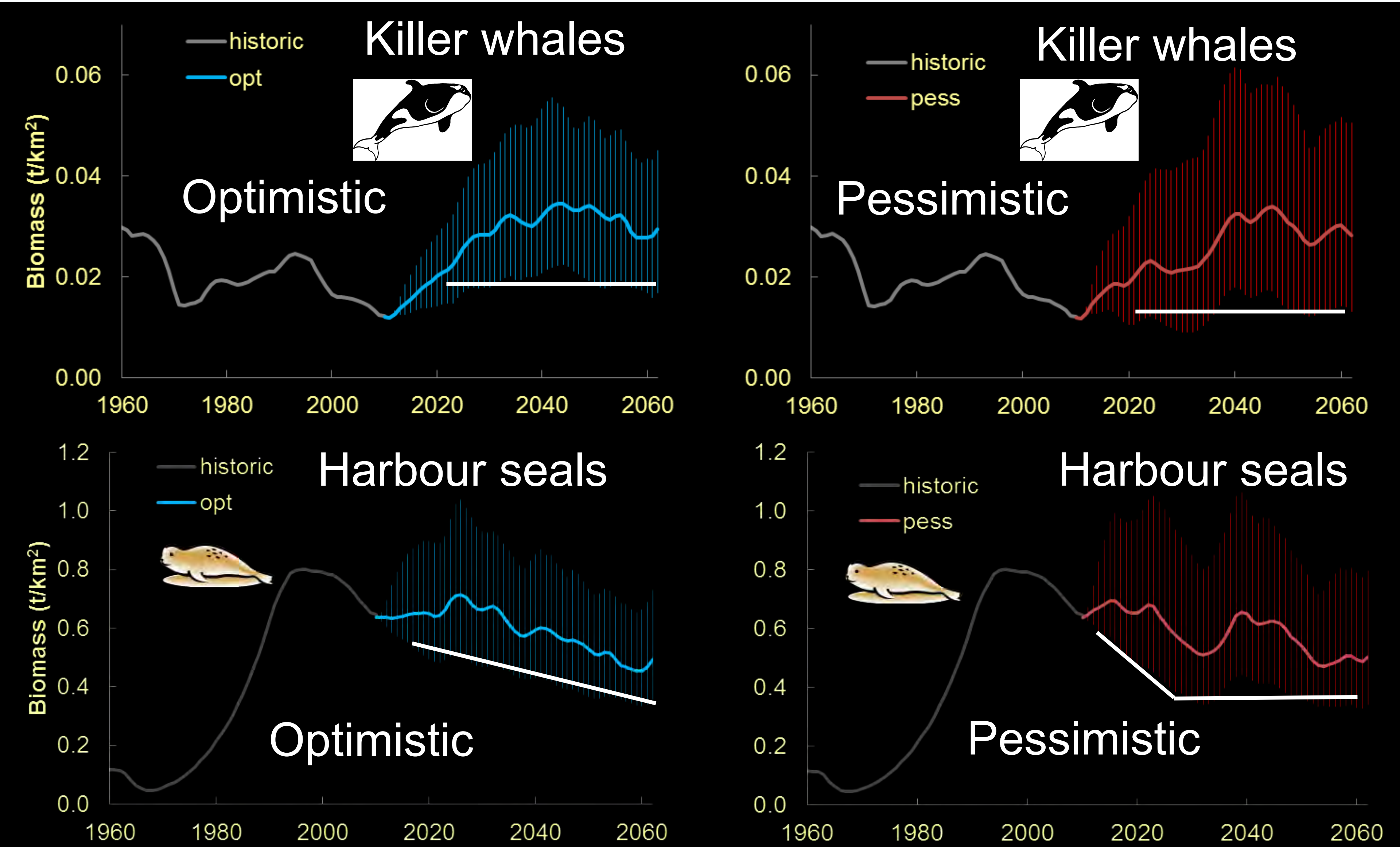
Climate Drivers: Temperature, Chl a, Dissolved Oxygen, pH
- Resample primary production (Chl a) many times under optimistic and pessimistic assumptions to produce a probabilistic distribution of potential future ecosystem states

Courtesy: Dave Preikshot et al.

Projecting climate impacts on food webs



Projecting climate impacts on food webs



Summary (so far) – uncertainty and future projections

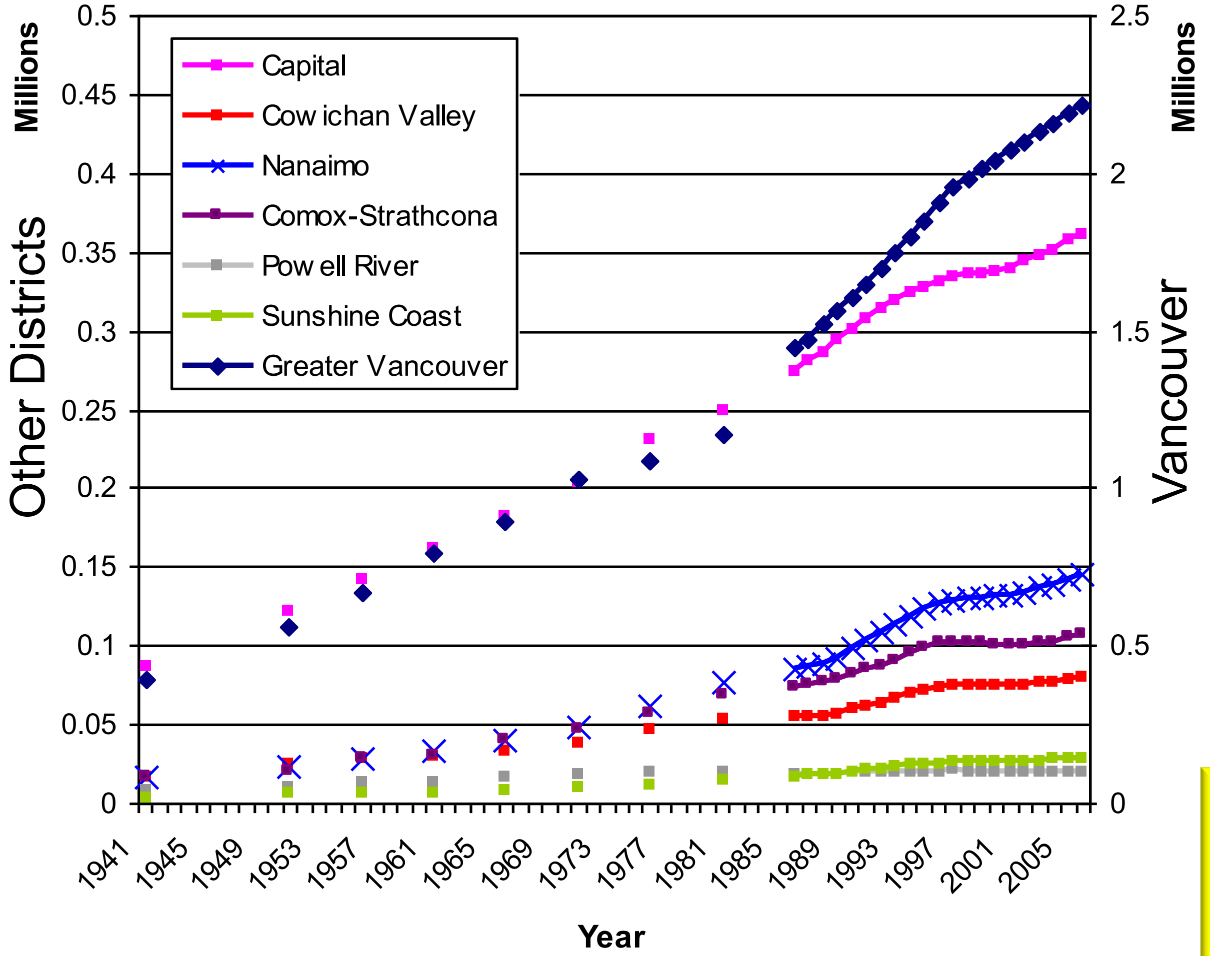
- Warming trend is predicted overall, but on time scales <20 years cooling trends are almost as likely
- 40 years from now, predict warmer and fresher everywhere, especially in winter
- Outcomes for species at top of food web are uncertain: could be better, or worse, than now
    - worst situation would be several consecutive years with low abundances – ratchet effect

HUMAN DIMENSIONS OF MARINE ECOSYSTEM CHANGE (“WISDOM”)

Fisheries and Oceans Canada Pêches et Océans Canada

Perry, 2013 PICES Annual Meeting, Session S1, Nanaimo, 14 October 2013

People as drivers of change: Human population around the Strait of Georgia



Population increases from 1986 to 2006:

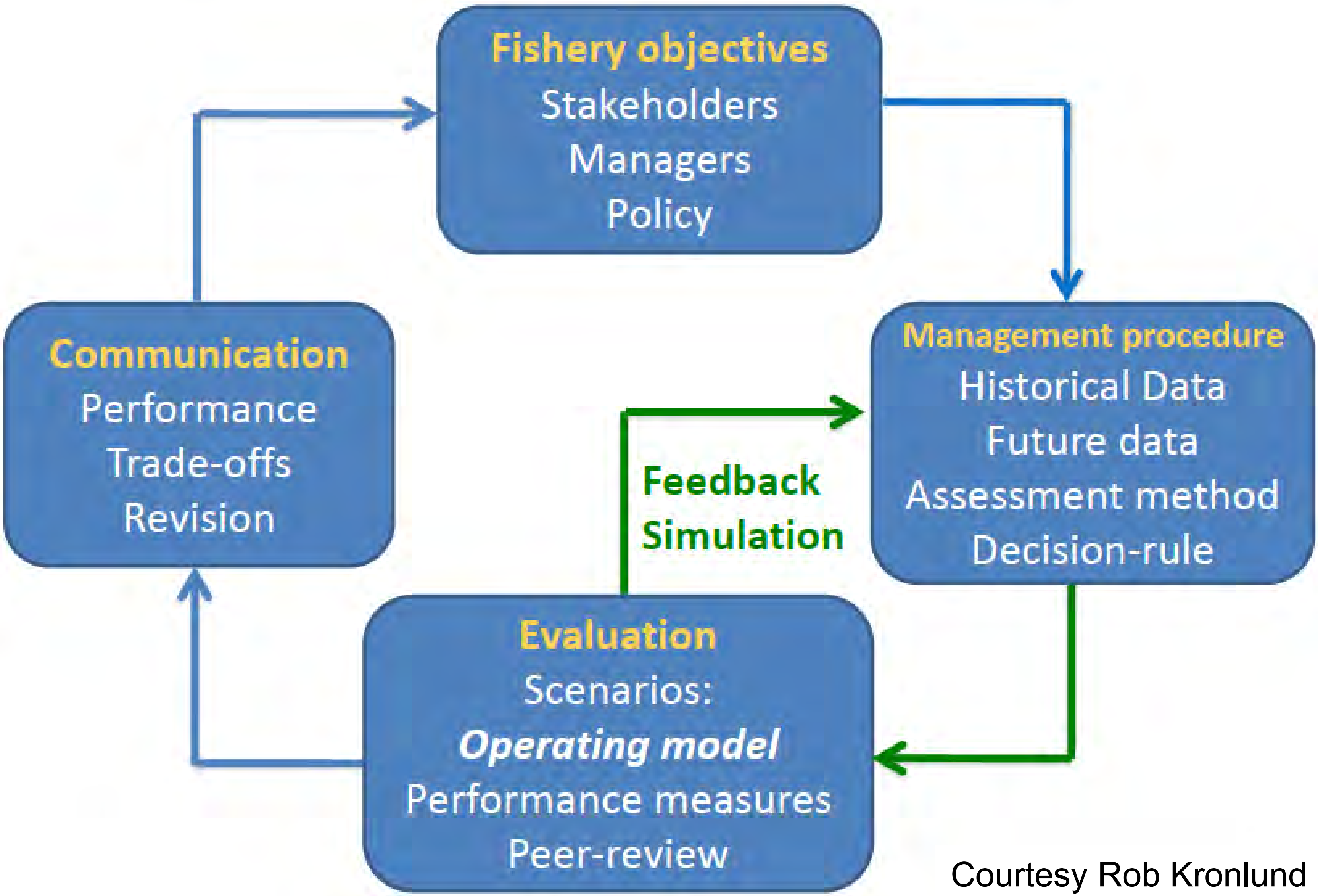
Vancouver 54%

Nanaimo 71%

Powell River 9%

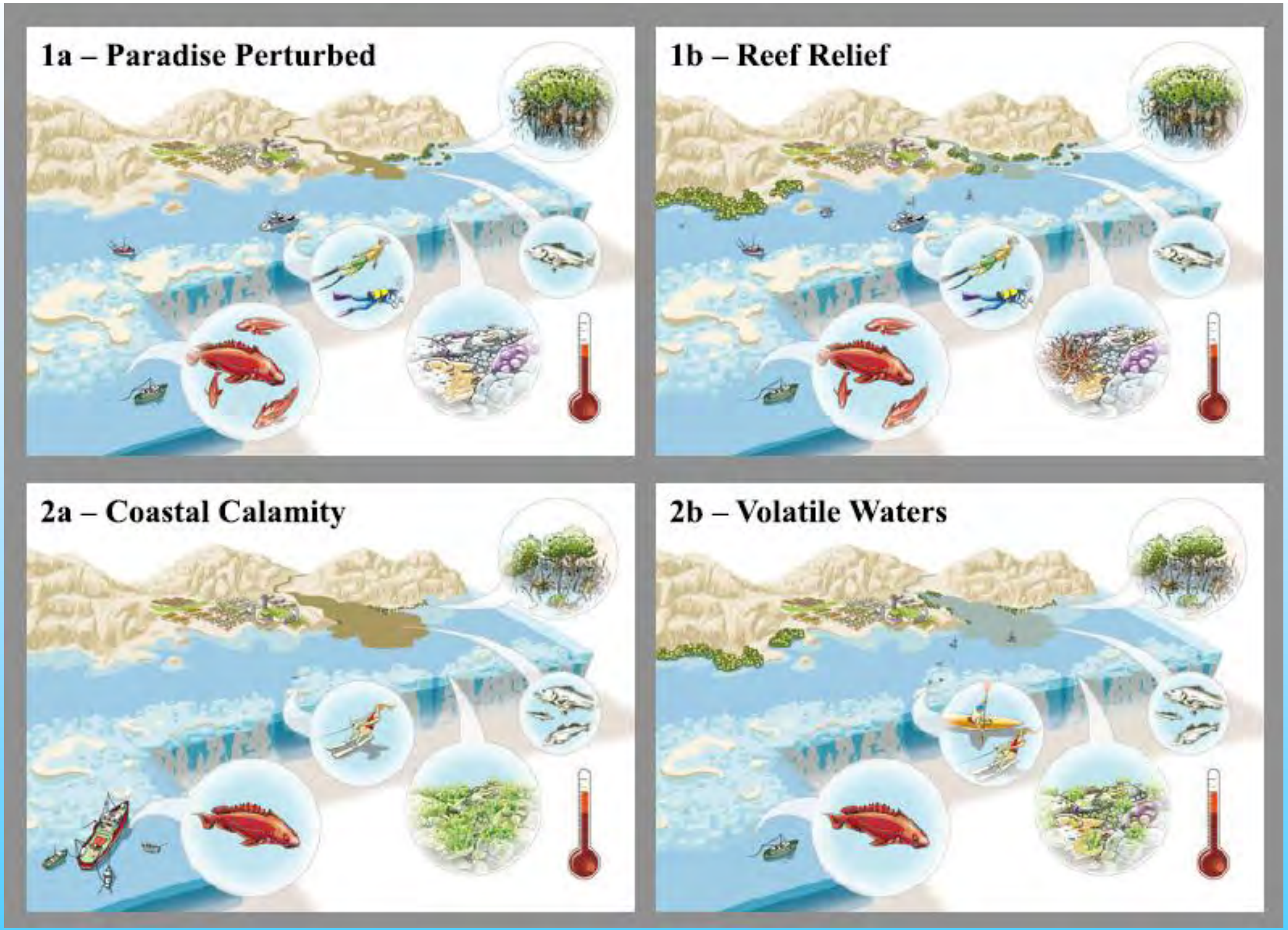
Populations double every 36 years

Testing Scenarios: Management Strategy Evaluation



Courtesy Rob Kronlund

Scenarios as tools to project possible futures and model alternative management actions

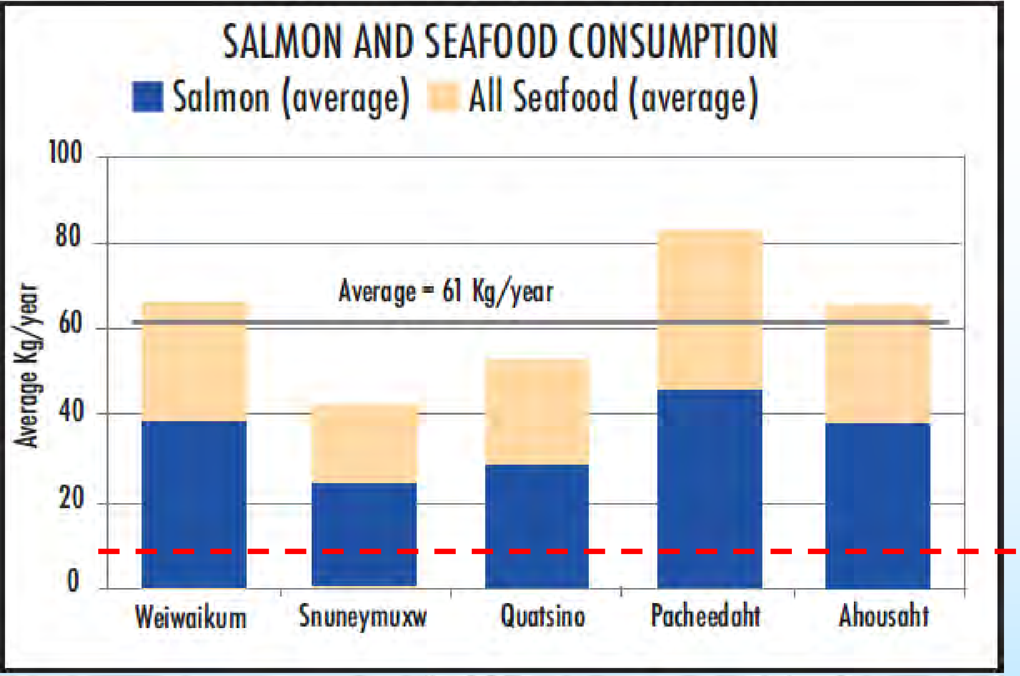


Climate Change: Moderate / Extreme

Adaptation: Limited / Ideal

Great Barrier Reef

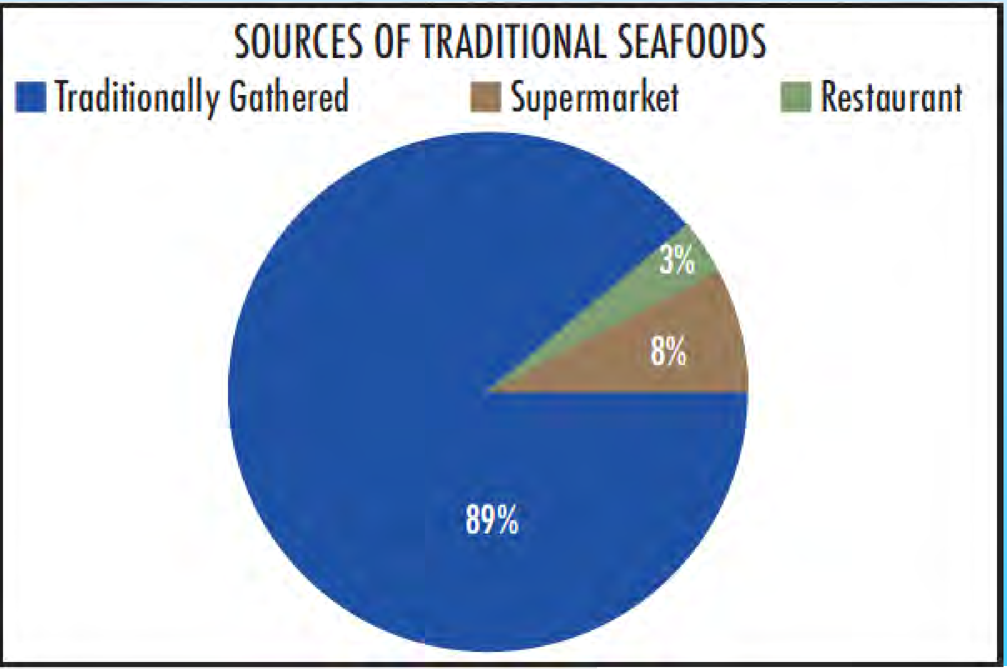
Evans et al. 2013 Human Ecology



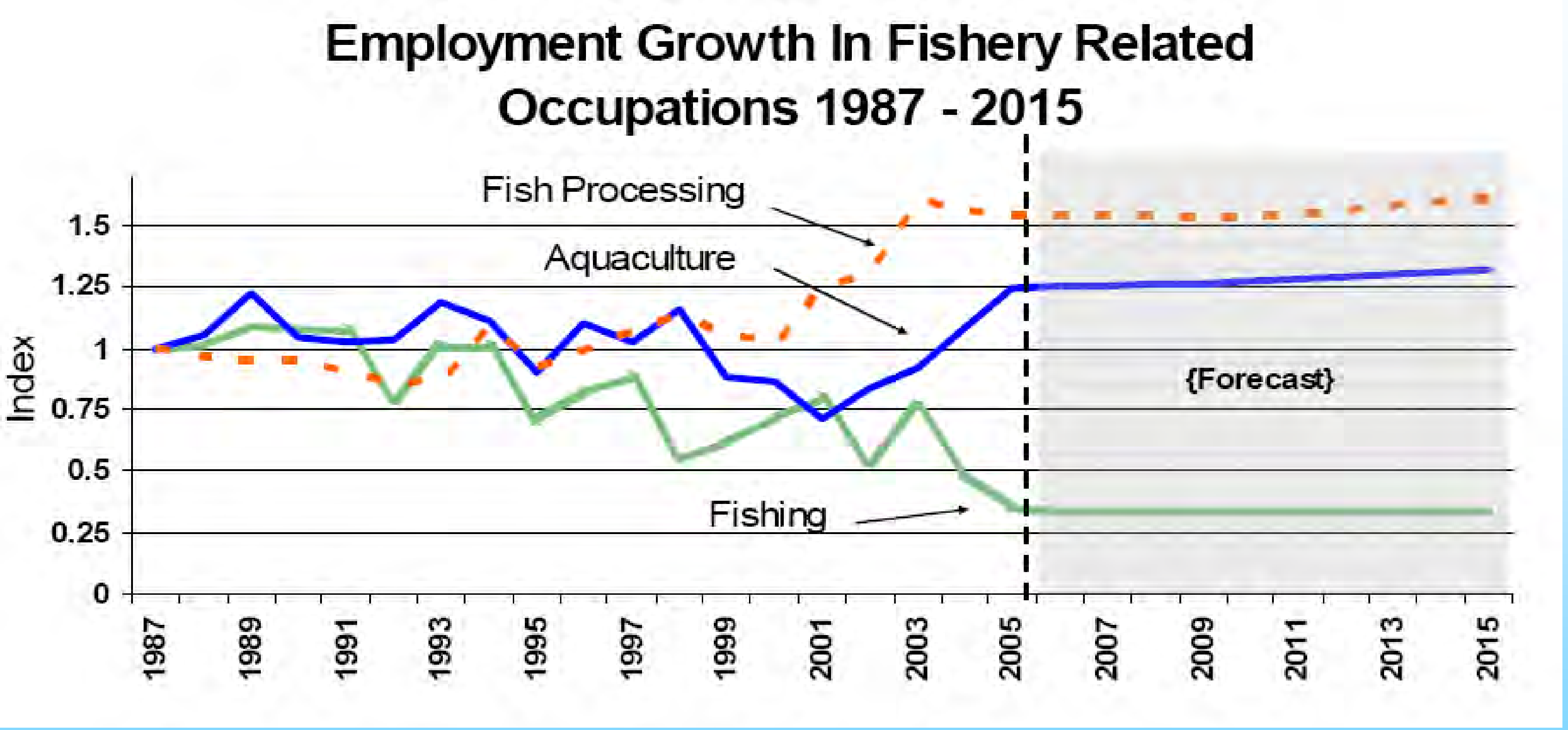
Seafood security of First Nations peoples on Vancouver Island

8 kg/yr - Canadian average

Source: Tom Child. 2008. In: Ross and Child. VIU Workshop Rept., 2008



Livelihood security in BC fishing industry



Employment in fish processing has been supported by imports of raw products for processing, diversification into different species, and processing of aquaculture products

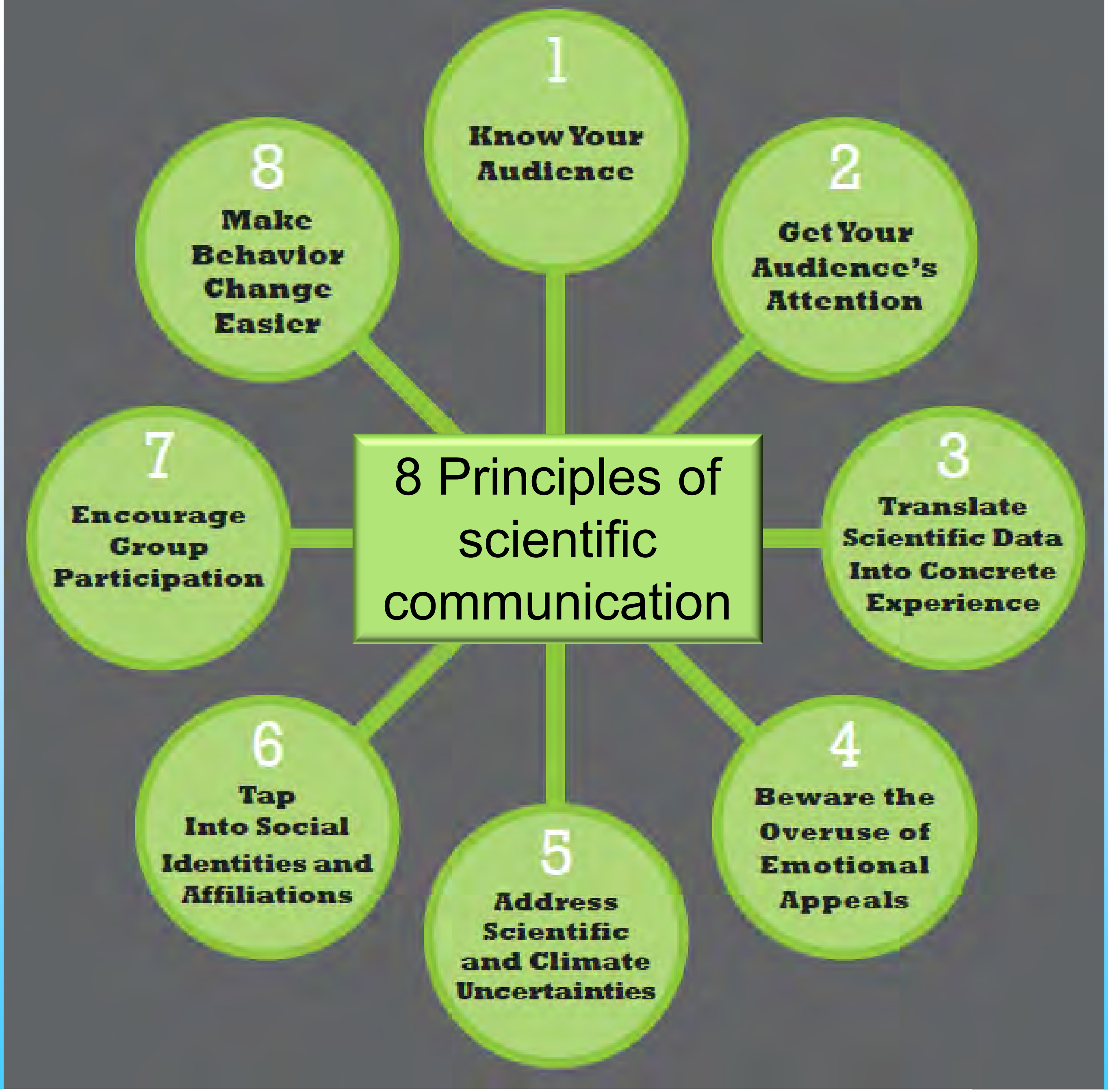
Responses of fishing-dependent human communities to changes in marine ecosystems

- at short time scales (coping strategies):
  - intensification of fishing
  - diversification to other species and gears
  - migration to follow the fish
  - hibernation (family and social assistance)
- at longer time scales (adapting strategies):
  - education and skills upgrading
  - diversification to other industries
  - political action
  - abandonment of the community

Perry et al. 2011 Fish & Fisheries

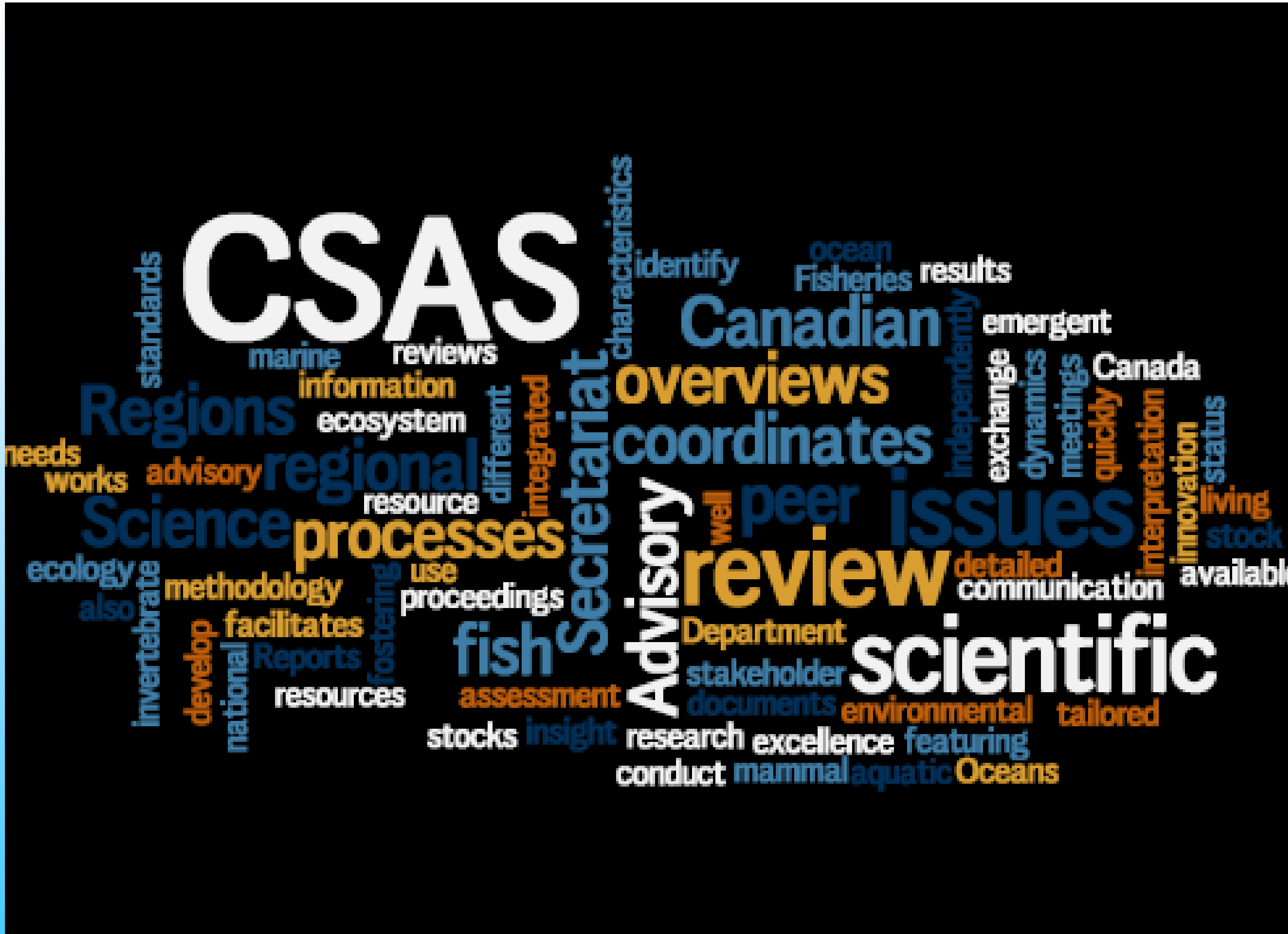
Communications: transforming information to knowledge to wisdom

- Communicating What?
- Communicating Why?
- Communicating to Whom?
- Communicating How?



cred.columbia.edu/guide

Canadian Science Advisory Secretariat (CSAS)



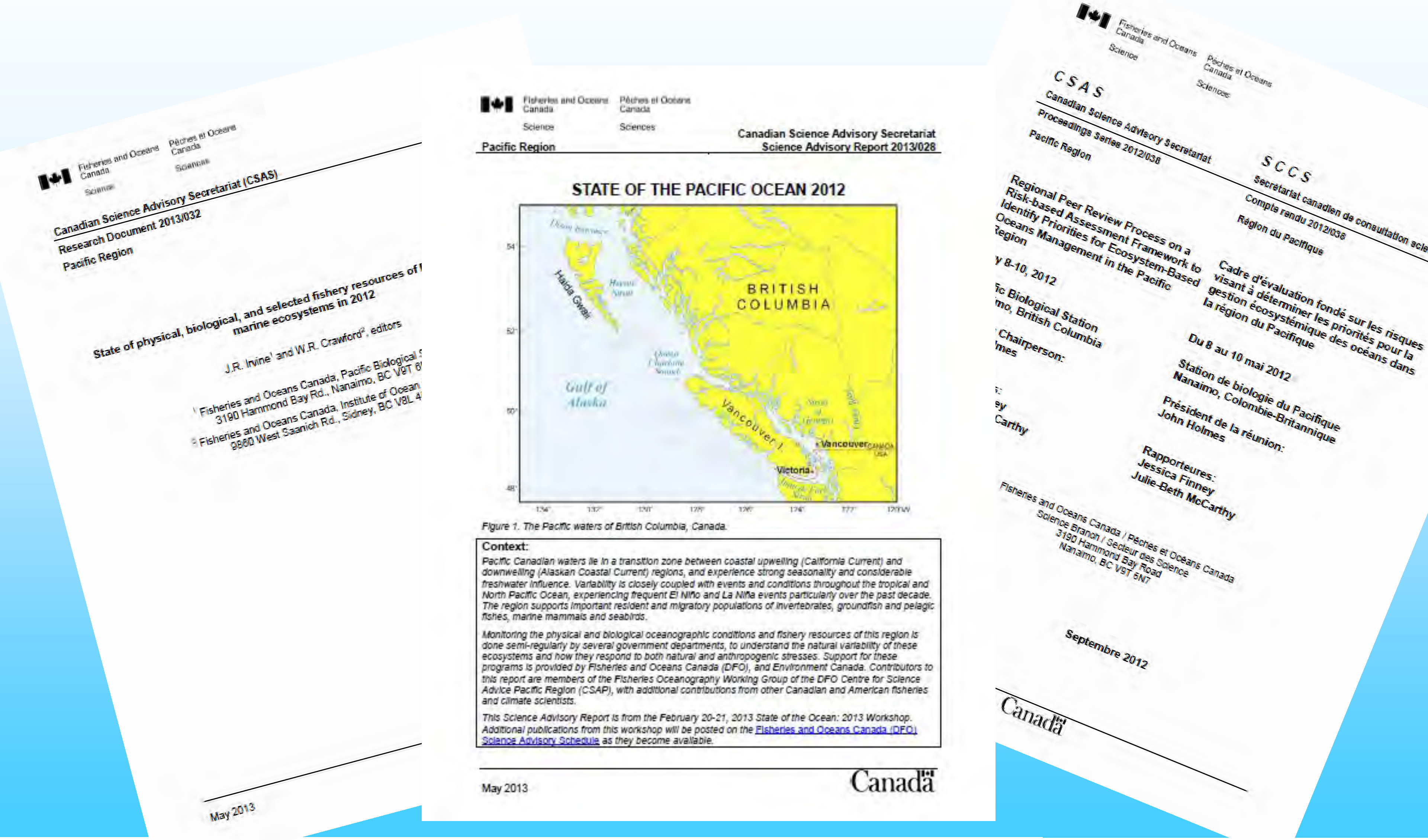
DFO’s Science Peer Review and Advisory Process

CSAS approach is based on the SAGE (Scientific Advice for Government Effectiveness) Principles and Guidelines:

- Early Issue Identification
- Inclusiveness
- Transparency
- Sound Science and Sound Advice
- Communication of Uncertainty and Risk
- Review (the process and as science advances)

To provide sound, objective, impartial science advice

DFO's Science Peer Review and Advisory Process - Products



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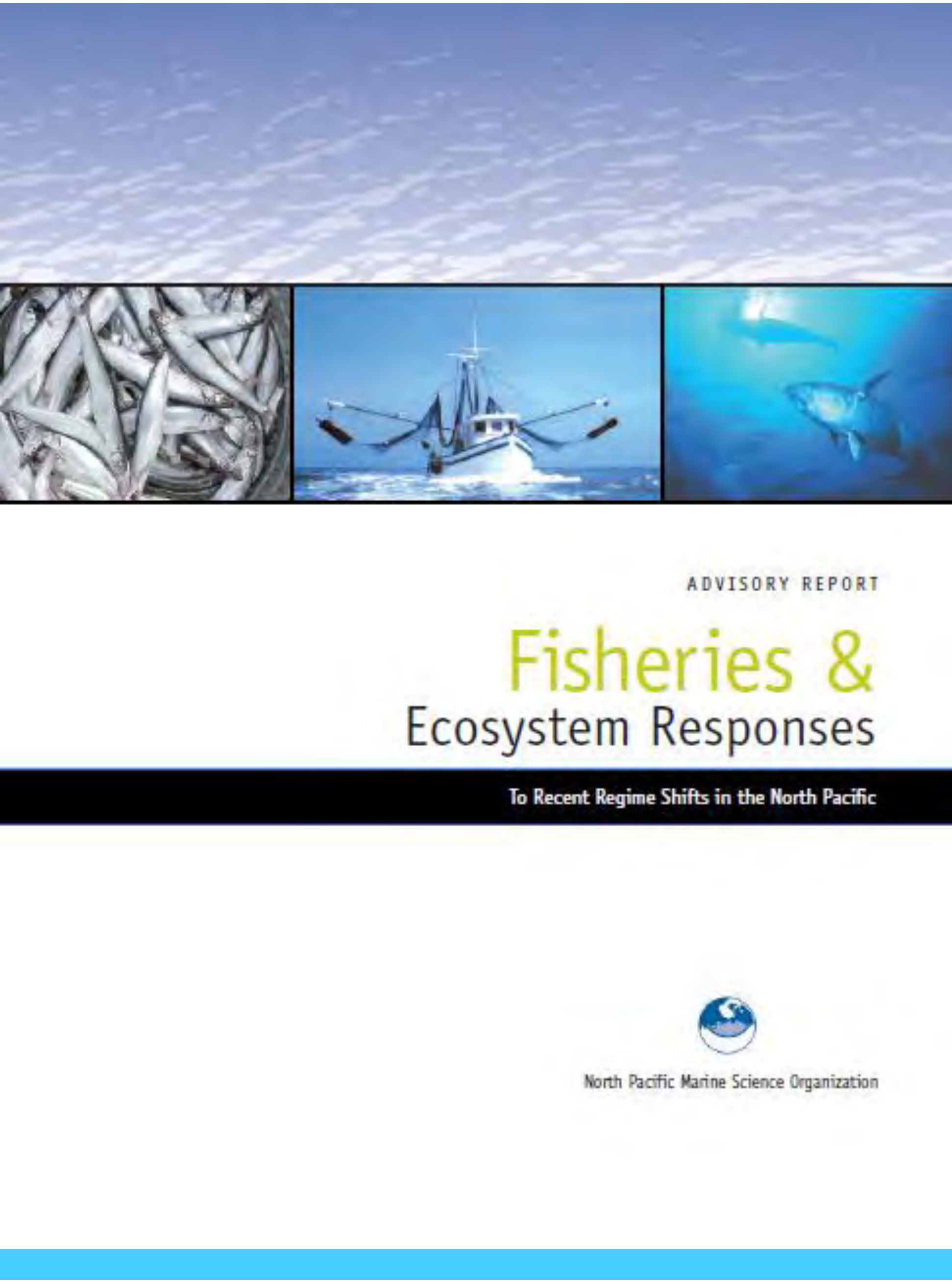
Perry, 2013 PICES Annual Meeting, Session S1, Nanaimo, 14 October 2013



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AVISO

AN INFORMATION BULLETIN ON GLOBAL ENVIRONMENTAL CHANGE AN

ISSUE NO. 6

The Index of Human Insecurity

Introduction

Traditional perspectives on security have been conceived of primarily in terms of neutralizing military threats to the territorial integrity and political independence of the state. However, in recent years, there has been increased emphasis placed on expanding the traditional conception of security to include so-called non-conventional threats. These include: resource scarcity, rapid population growth, human rights abuses, outbreaks of infectious disease, environmental degradation caused by toxic contamination, ozone depletion, global warming, water pollution, soil degradation and the loss of biodiversity (*cf.* Ullman, 1983; Renner, 1989; Westing, 1989). It is now accepted that *environmental stress, often the result of global environmental change, coupled with increasingly vulnerable societies, may contribute to insecurity and even conflict.*

As our perspective on security changes, it is important to adapt our policy framework to meet this change. One alternative is to focus on *human security*, recognizing the inter-linkages of environment and society, and acknowledging that our perceptions of our environment and the way we interact

AVISO

AN INFORMATION BULLETIN ON GLOBAL ENVIRONMENTAL CHANGE AND HUMAN

ISSUE NO. 1

Environmental Change, Vulnerability and Security in the Pacific

INTRODUCTION

Intuitively at least, we have a sense that environmental change has the potential to undermine human security. The degradation of resources can negatively affect the capacity of people to sustain their livelihoods. Accessibility to basic necessities such as food can be reduced by environmental change and there are widespread effects upon human health that can be linked directly to changes in the quality of the environment. Peoples' sense of security can be influenced also when resource exploitation and environmental change have impacts upon local communities, cultural norms and traditions, and socio-political structures. In some acute cases, the insecurities that arise from environmental change may lead to violent conflict.

It is much more difficult to establish precisely what the connections are between environmental change and human security. Land degradation, for example, threatens the economic and food security of people around the world, but the underlying causes often can be traced to complex processes of economic and political transformation that extend across regional, national and international territories.

AVISO

AN INFORMATION BULLETIN ON GLOBAL ENVIRONMENTAL CHANGE AND HUMAN SECURITY

ISSUE NO. 4 September 1999

Food Security in a Changing World

"Despite massive increases in world food production, food insecurity persists."

What is Food Security?

"Food Security" is easily discussed in general terms, but it embodies a complex set of intertwined concerns and issues. The concept continues to evolve, with almost 200 definitions proposed since 1975. A universally accepted definition remains elusive, but most contemporary conceptions present food security as *people having access to sufficient stocks and supplies of food to provide a nutritionally adequate diet.*

Accurate and timely measures of food insecurity are difficult to obtain. Malnutrition and hunger are often employed as surrogate measures, but actually represent the most advanced and chronic forms of food insecurity. Food insecurity occurs long before malnutrition and hunger set in, therefore using these indicators greatly underestimates the number of individuals suffering food insecurity.

One indicator regularly used to establish a standard or threshold for separating undernourished persons from others is minimum recommended dietary allowances (RDAs). Nutritionists continue to debate what the minimum value ought to be and whether the complex relationship between diet and human development is represented adequately by a single indicator such as caloric intake. Methods for estimating RDAs, as well as designation of minimum thresholds, vary amongst agencies and countries, and sometimes result in diverging estimates of food insecurity.

Malnutrition estimates derived from macro-scale national studies provide little insight into the distribution of hunger within a region or country. For example, national average per capita caloric intake in Sri Lanka and India are similar – both are above 2000 cal/day – but a smaller portion of Sri Lankans suffer from hunger. Elsewhere, a recent FAO report estimates that even in countries with a food supply in the 2700 cal/day range, which is well above recognized minimum RDAs, at least 10% of the population is undernourished.

Data availability and quality also impede the establishment of reliable and precise measures of food insecurity. Inadequate public infrastructure makes obtaining

Global Environmental Change and Human Security Program

WHERE IS THE WISDOM WE HAVE LOST IN KNOWLEDGE?

WHERE IS THE KNOWLEDGE WE HAVE LOST IN INFORMATION?

T.S. Eliot
The Rock (1934)

Conclusions: Canada as a Case Study for FUTURE

"**Information**"

- Canadian marine ecosystems are changing in important ways
  - we are observing and reporting these changes

"**Knowledge**"

- Tools to identify and integrate multiple stressors and their effects on Canadian marine ecosystems
- Projections of future conditions including uncertainty

"**Wisdom**"

- "Human Dimensions" as drivers of change and support of food and livelihood security
- Tools to test management actions in uncertain futures
- Communication is key

What can we do – individually, and as members of PICES?

Marine environmental change matters to people

As individuals:

- Integrate People as drivers, and recipients, of ecosystem change, and effects on human well-being, into our research
- Seek opportunities to communicate our results to a wide range of audiences using plain language

As PICES:

- Provide accessible summaries of ocean conditions
- Develop community tools for understanding stressors and impacts
- Prepare Science Advisory Reports on important topics

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