Productivity responses of Barkley Sound sockeye salmon to climate variation and change impacts in the Pacific Ocean.

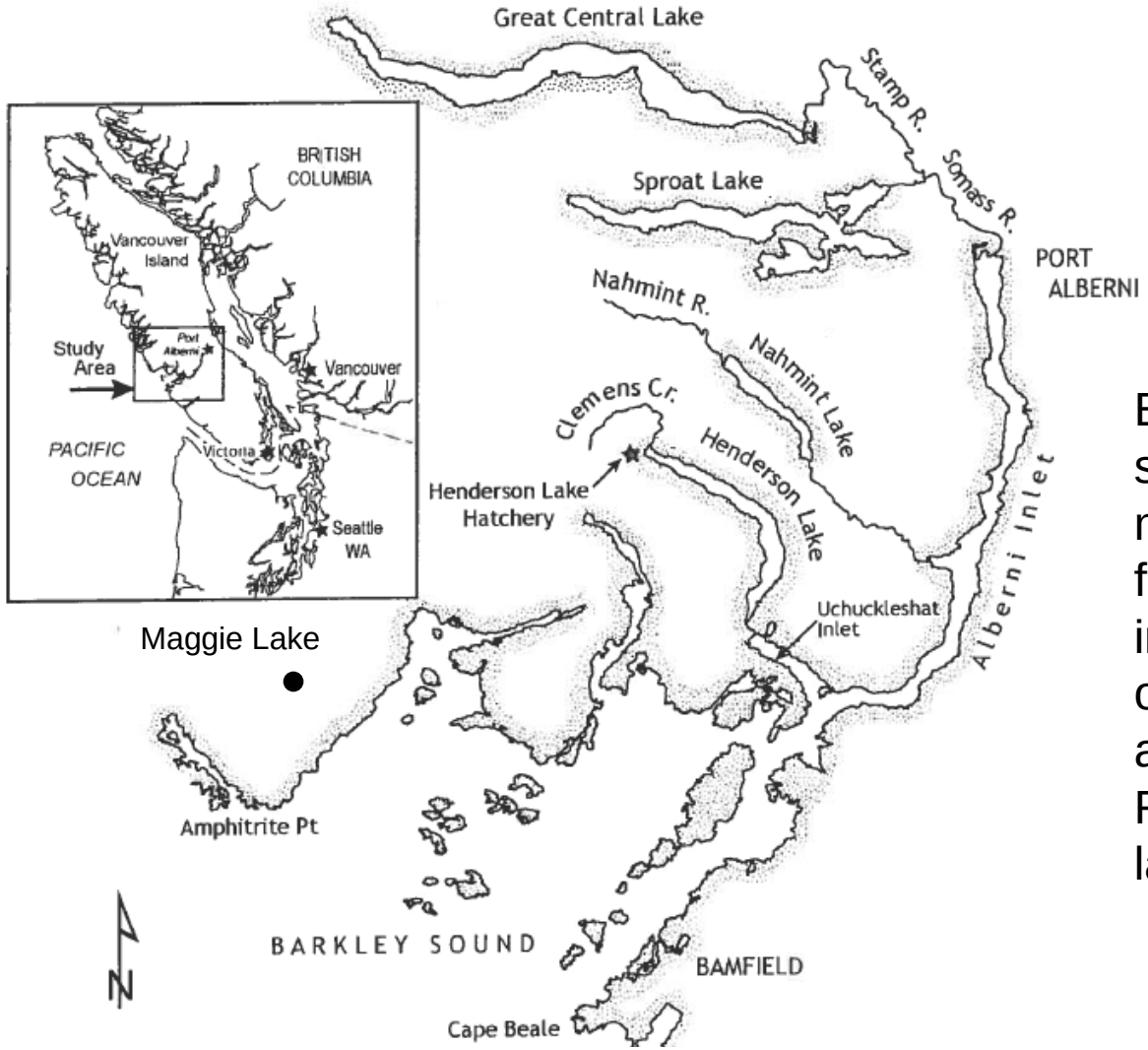
Kim D. Hyatt*, Howard Stiff, Diana Dobson and Wilf Luedke.

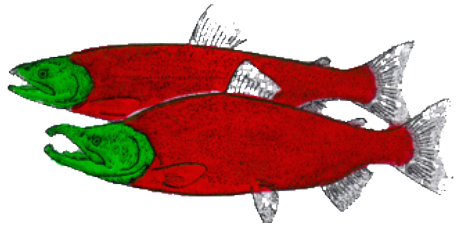
Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7 (kim.hyatt@dfo-mpo.gc.ca).

Presentation Outline

- **Briefly describe the environmental context and relative importance of the Barkley Sound sockeye salmon fishery.**
- **Review evidence for marine climate variation and change (CVC) impacts on Barkley Sound salmon recruitment variations and identify causal mechanisms**
- **Describe use of a simple, two-state, pathway of effects model to explain and then predict salmon recruitment variations due to CVC impacts.**
- **Provide projections and alternate scenarios for Barkley Sound salmon returns and the sustainability of fisheries there from 2000-2050s and then from the 2050s-2100.**

Barkley Sound Sockeye originate from three nursery lakes (Great Central, Sproat, Henderson) on the west coast of Vancouver Island



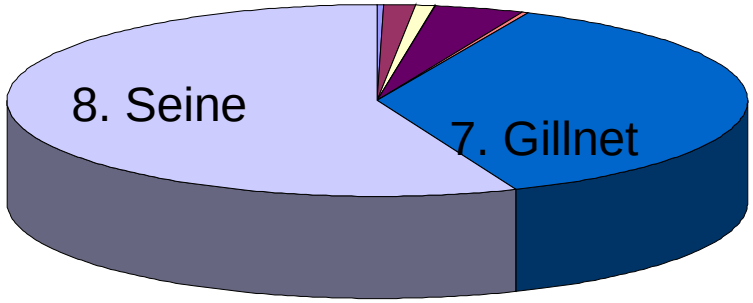


Barkley Sound sockeye support the 3rd to 4th most important set of fisheries for this species in British Columbia (i.e. only the Fraser, Skeena and, occasionally, Nass River fisheries are larger).

Hyatt et al, AFS Meeting, Kelowna, March 21,2018..

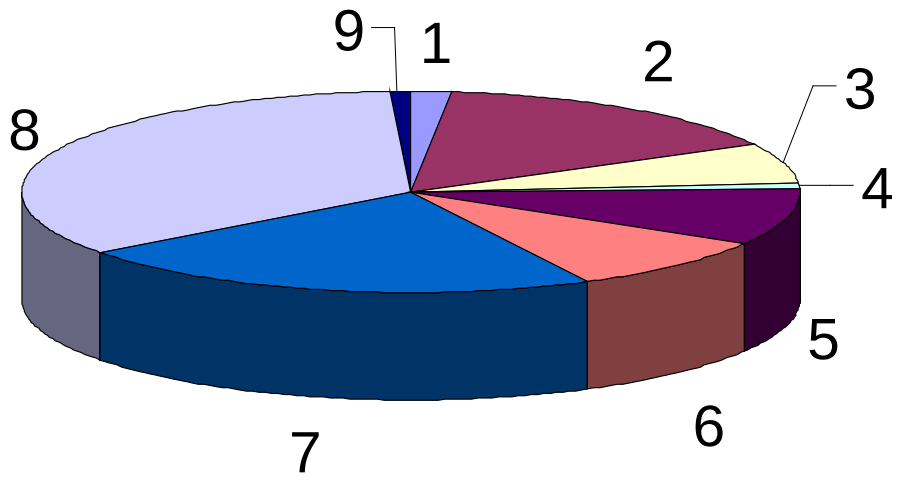
Barkley Sound sockeye have been successfully managed to support sustainable First Nations, recreational and commercial fisheries for more than a century (Hyatt and Steer, 1987) despite dramatic fluctuations in management policies and fish abundance

1980s Fishery



1980s – 2 fisheries (commercial seine & gillnet) accounted for 90 % of a 850,000 fish annual harvest.

2004 Fishery

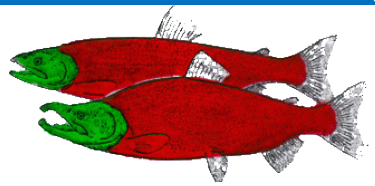


2004 – Seine & gillnet account for < 55 % of a 560,000 fish annual harvest with priority allocation to several First Nations & recreational fisheries

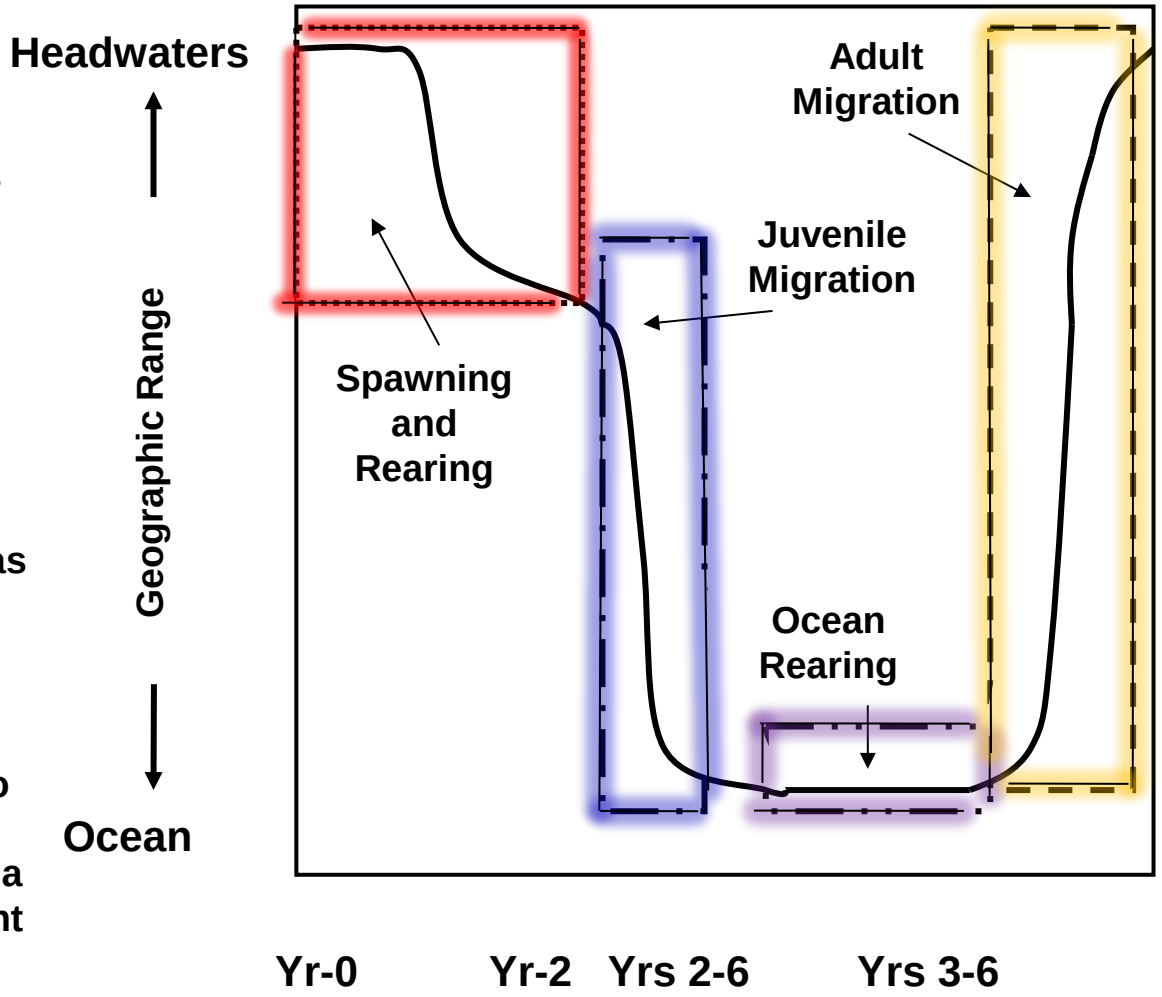
1. Test Fishery, 2. FN-Somass River, 3. FN-Inlet, 4. Sport River 5. Sport Inlet 6. Troll Inlet, 7. Comm. Gillnet, 8. Comm. Seine, 9. FN-Uchuck Inlet

Fisheries and Oceans Canada | Pêches et Océans Canada

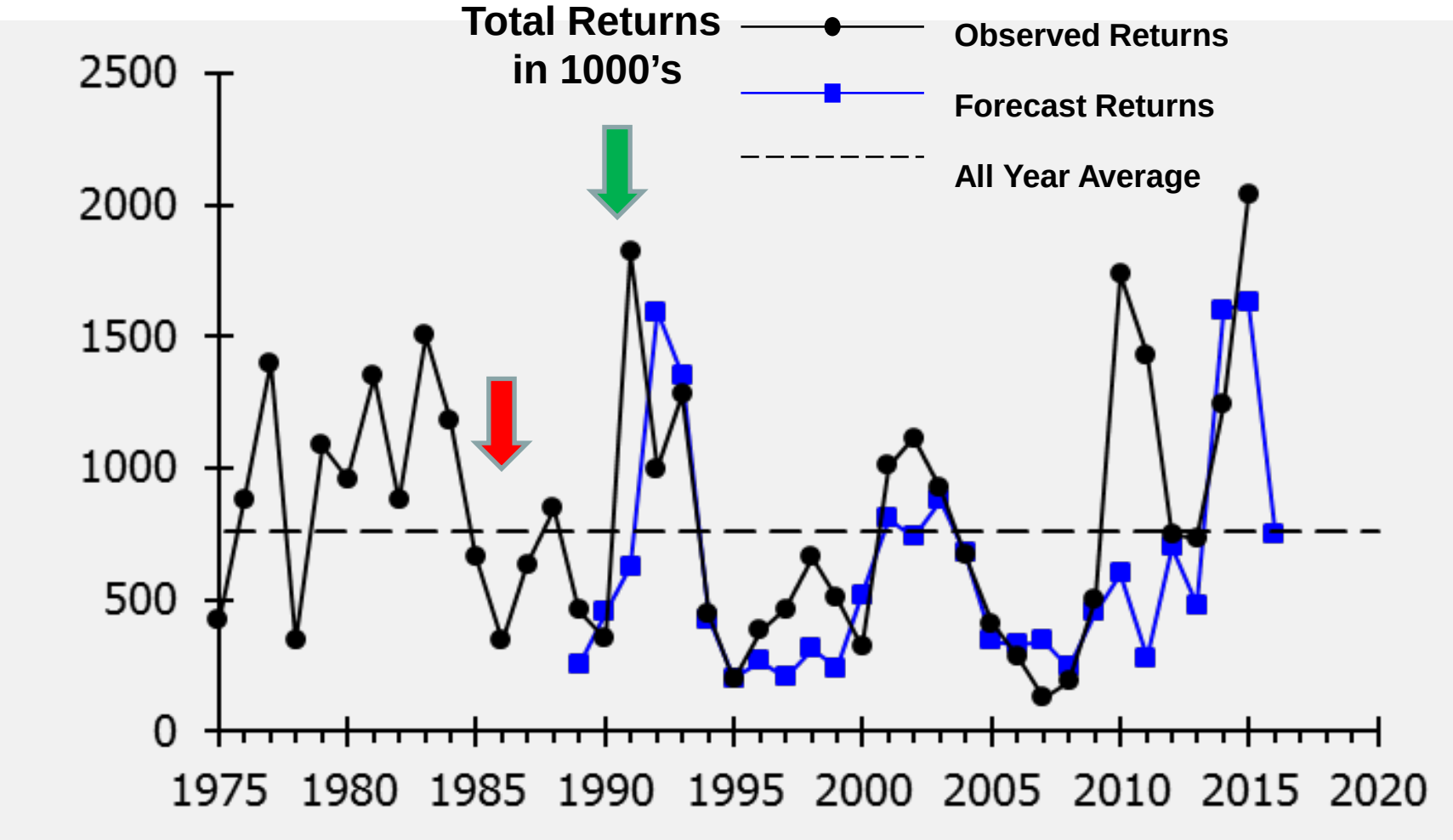
Given their life history variations and spatial distribution, sustainable management of many wild salmon populations in the face of climate change impacts poses a major challenge?



- Thousands of salmon populations (100s of CUs) inhabit west coast freshwater and marine systems.
- Production variations emerge through multi-scalar spatial & temporal processes operating at one or more life history stages completed in hours to years from headwater streams to the high seas and back.
- Given the cultural, economic and social values surrounding Pacific salmon, managing and adapting to the pervasive influence of climate change impacts on salmon poses a major challenge for the Department of Fisheries and Oceans on Canada's west coast.



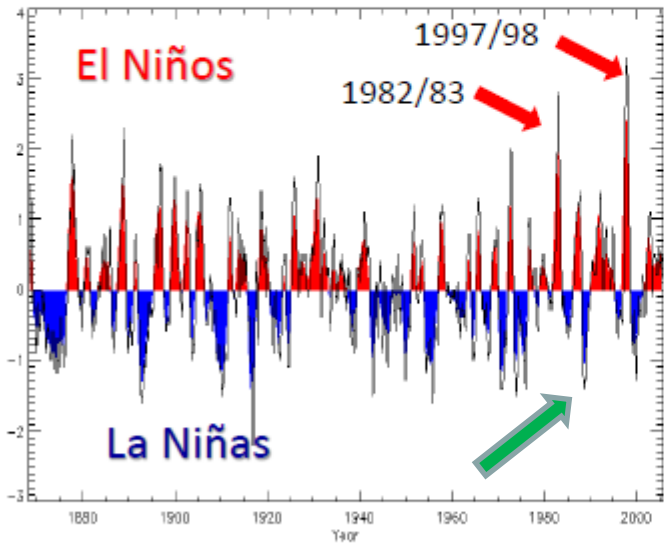
Barkley Sound sockeye salmon, predictably exhibit "stanzas" of above to below average returns ranging from <250,000 *(in 2008)* to > 2,000,000 *(in 2015)* fish.



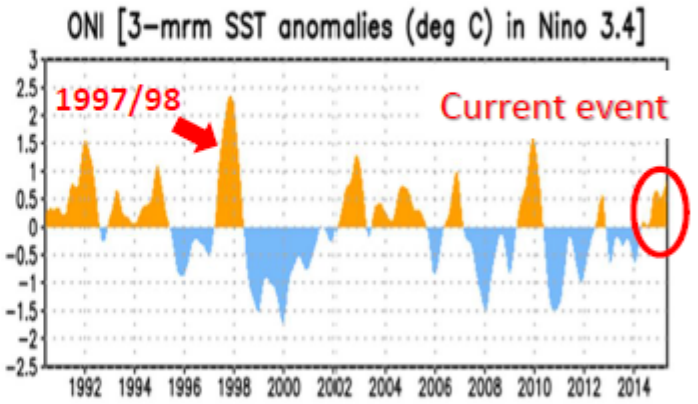
Hyatt et al, AFS Meeting, Kelowna, March 21,2018..

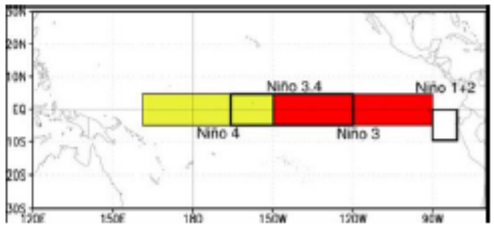
El Niños are tropical phenomena that occur every few years. Big events in 1982/83 & 1997/98

SOI, 1870-2005

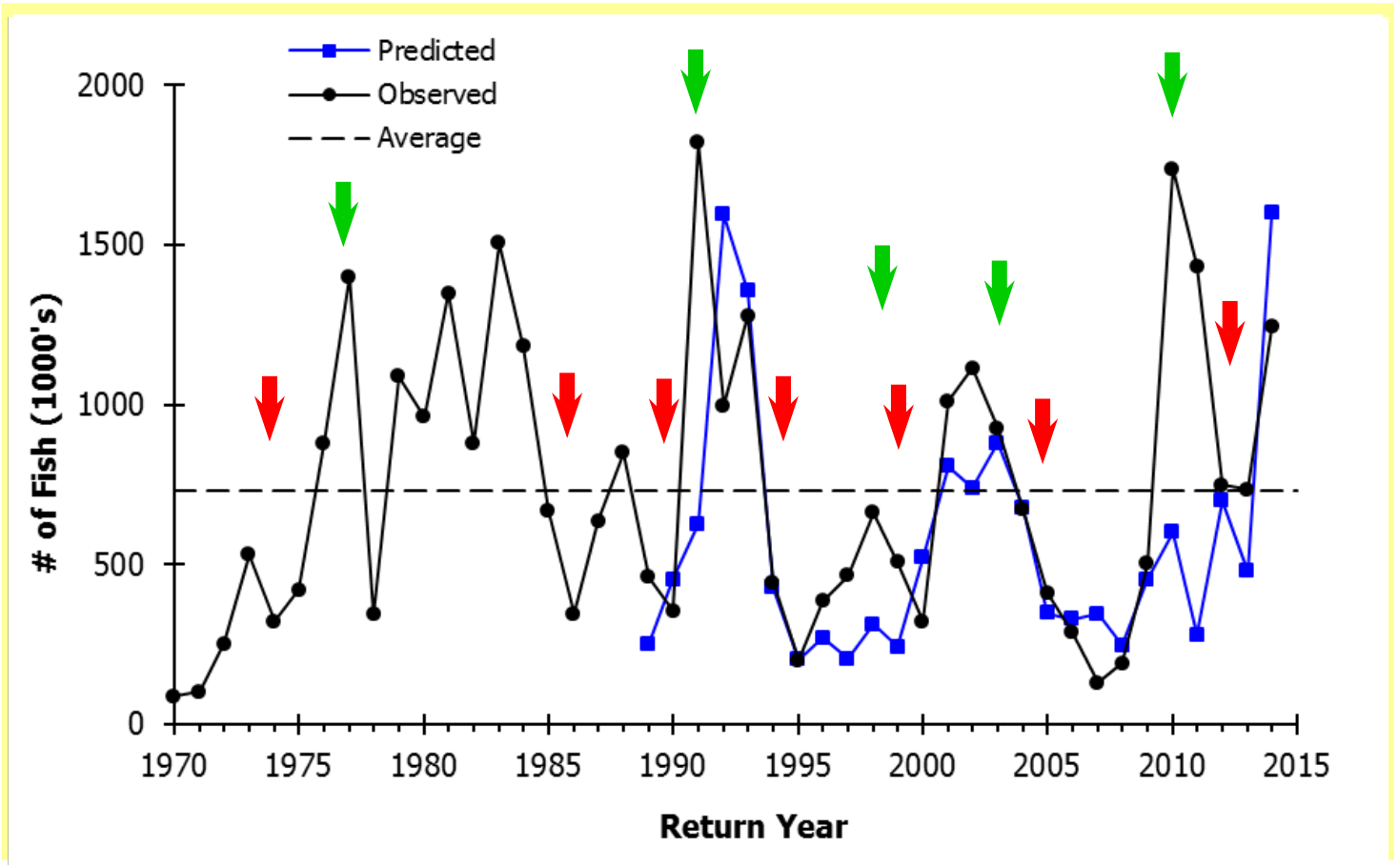


ONI, 1990-2015





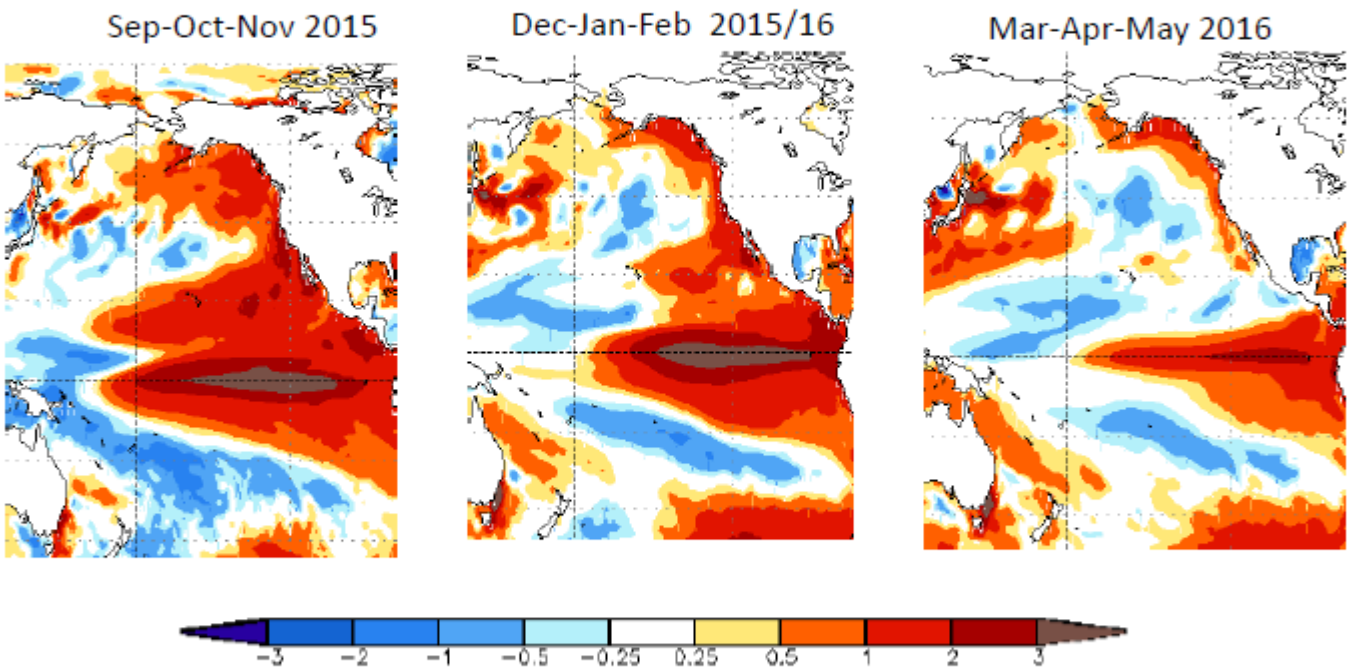
Lagged El Niño (red) and La Niña (green) events increase forecasting skill for Barkley Sound sockeye returns (1970-2014, Hyatt & Steer 1989, Hyatt et al 2016)



Mechanisms: Ecosystem reorganization in the Northern California Current System influences early marine survival of juvenile sockeye salmon where survival is high in a “cold-ocean” and much lower in a “warm-ocean”.

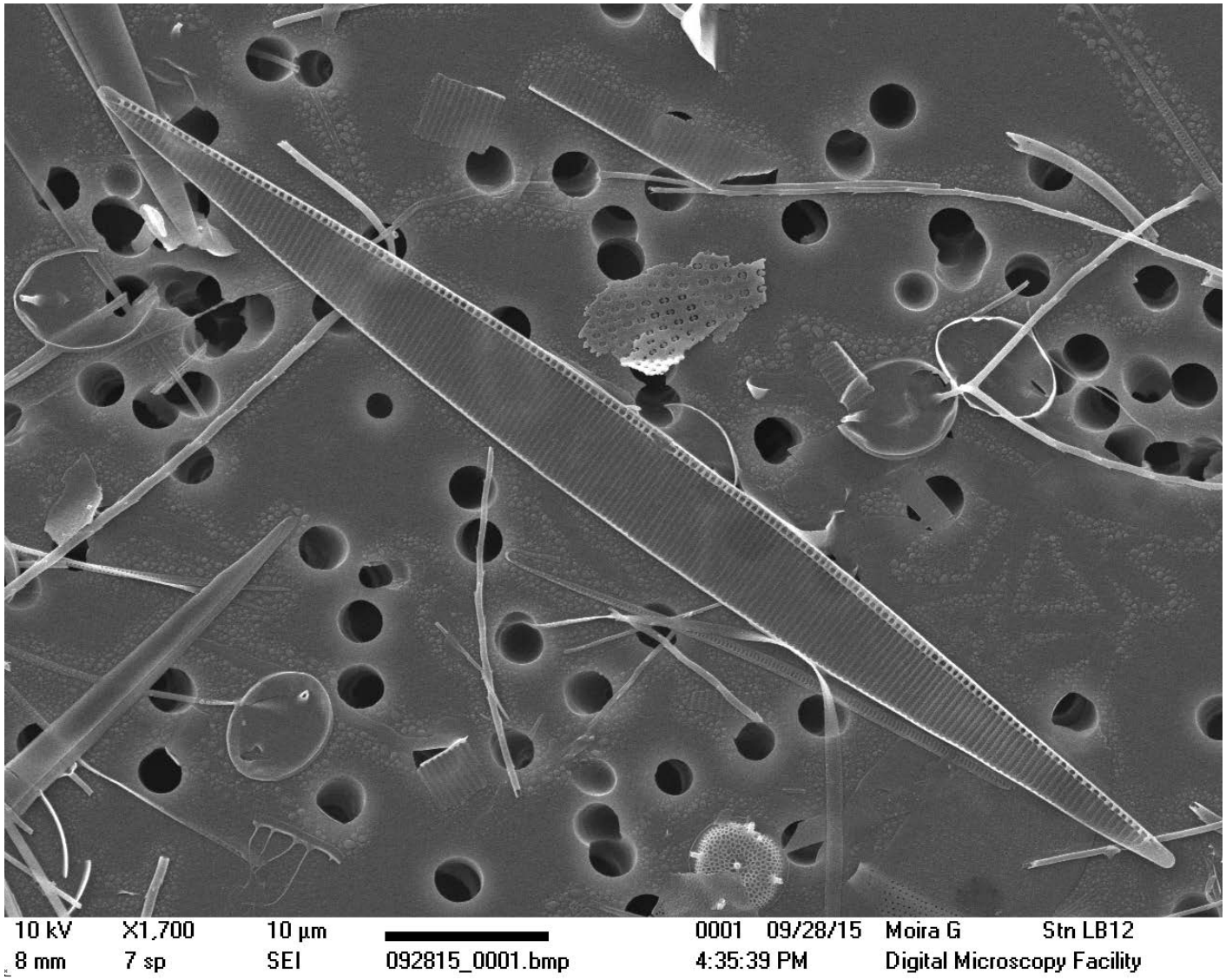
Powerful El Nino's influence temperature, circulation patterns and ecosystem "structure" along the coastal migration routes of Barkley Sound sockeye (e.g. 2015 El Nino).

NOAA Climate prediction Center coupled forecast model 2



http://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

Example Changes: exceptional phytoplankton bloom along North American coast accompanied the 2015 El Nino from May-Sept .



Pseudo-nitzschia fraudulenta

In early July 2015 at the shelf break, *Pseudo-nitzschia fraudulenta* comprised 32% of all diatoms, and 19% of all microplankton sampled

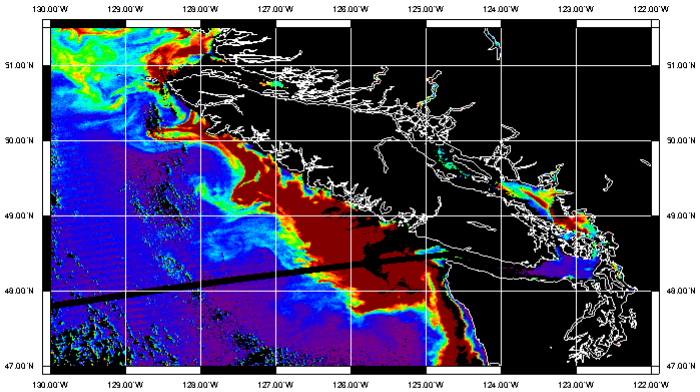
James Ehrman
Digital Microscopy Facility
Mount Allison University
Sackville, NB

Exceptional phytoplankton bloom occurred along North American coast from May-Sept 2015

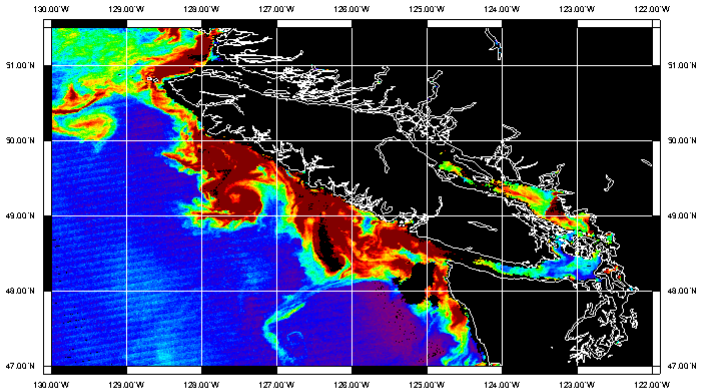
Phytoplankton bloom in 2015 extended from California to Alaska and lasted from May to Sept (Gower et al, DFO-IOS).

MODIS NFLH satellite images

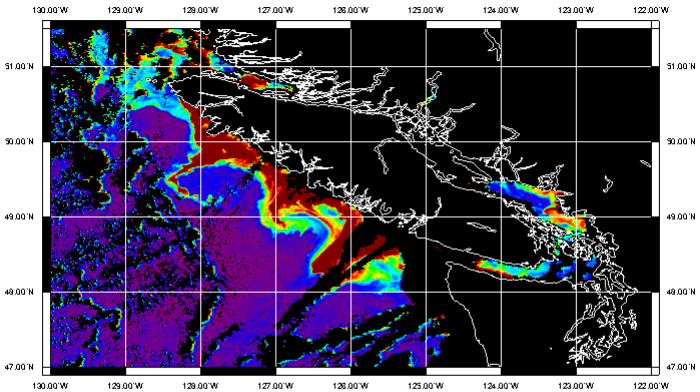
9 June 2015



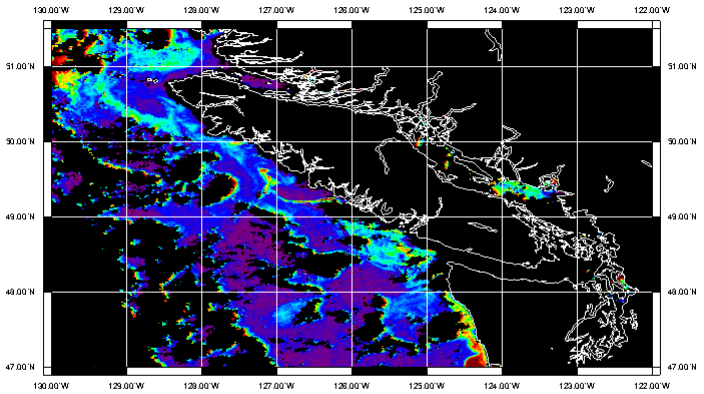
4 July 2015

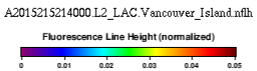


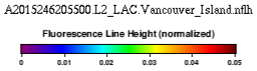
6 Aug 2015



3 Sept 2015



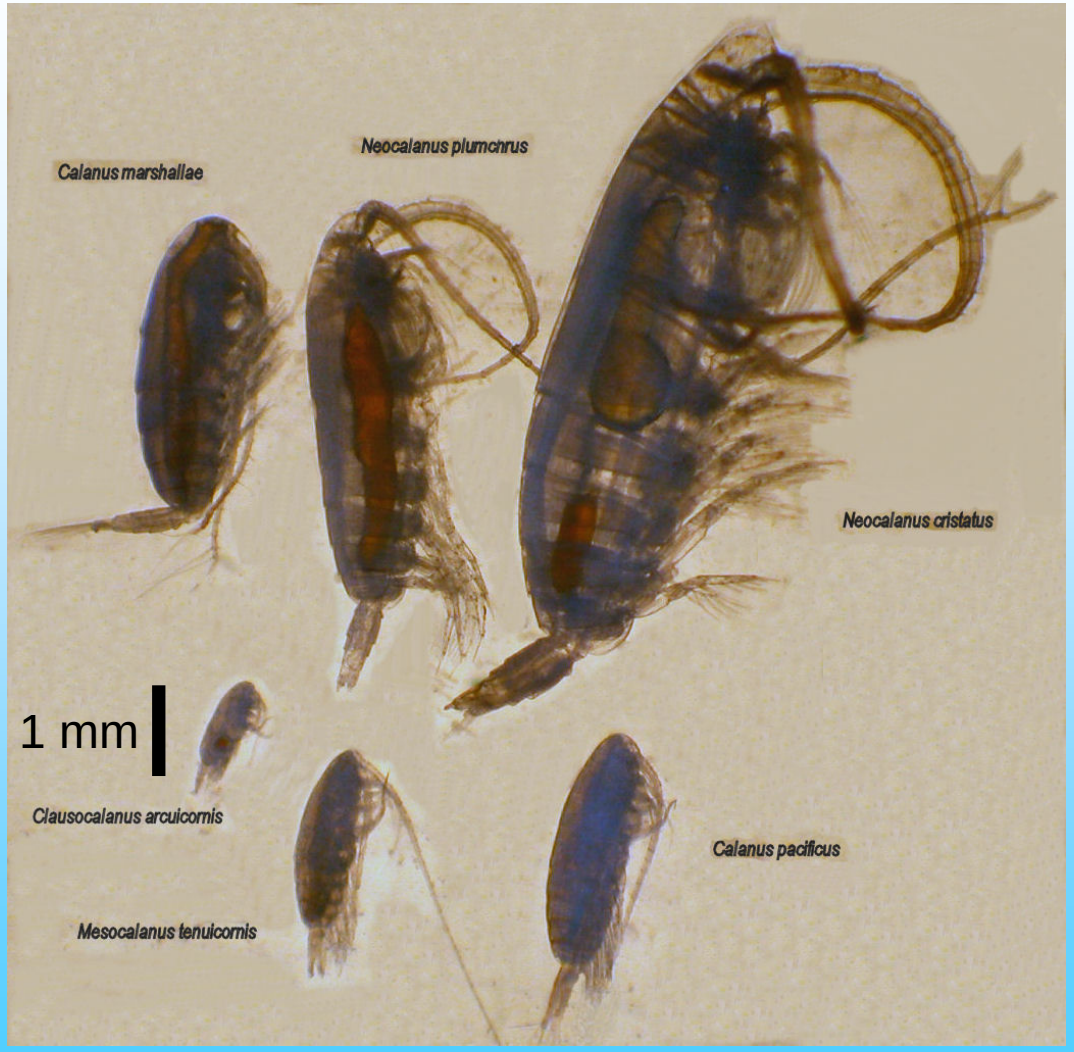




Fisheries and Oceans Canada | Pêches et Océans Canada

Hyatt et al, AFS Meeting, Kelowna, March 21,2018..

Changes in water temperature are reflected in changes in zooplankton species composition



- Subarctic zooplankton dominate in the Northern California Current system under “cool-ocean” conditions (large nutritious species, good for fish)
- Subtropical zooplankton species dominate in the Northern California Current under “warm-ocean” conditions (small poor quality species)

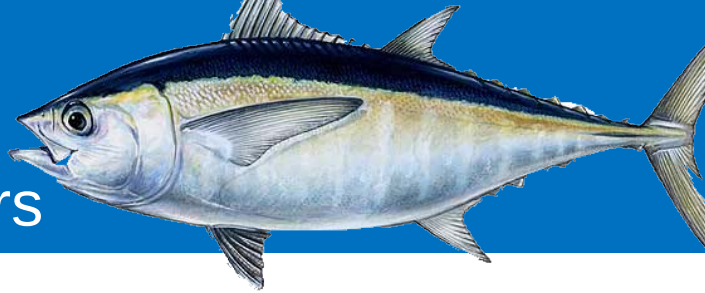
Implications for fish – warm water migrants enter Canadian waters

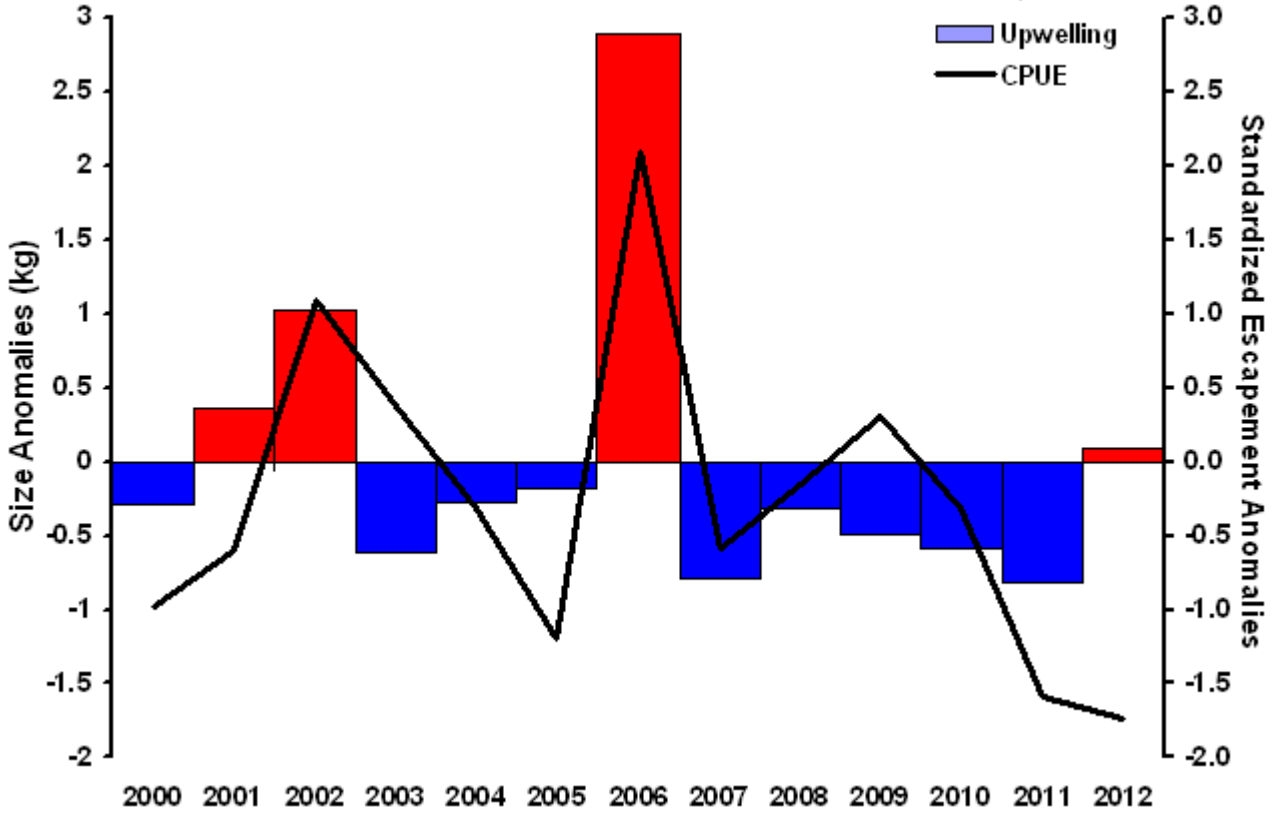
Finescale Triggerfish, *Balistes polylepis*,
26.3 cm Standard length (Courtesy RBCM)

Pacific Pompano (butterfish)

Louvar, *Louvaris imperialis*,
72.0 cm SL (Courtesy RBCM)

Catch rates of salmon predators (e.g. tuna, mackerel) increase in coastal areas In El Nino years and diminish in La Nina yrs



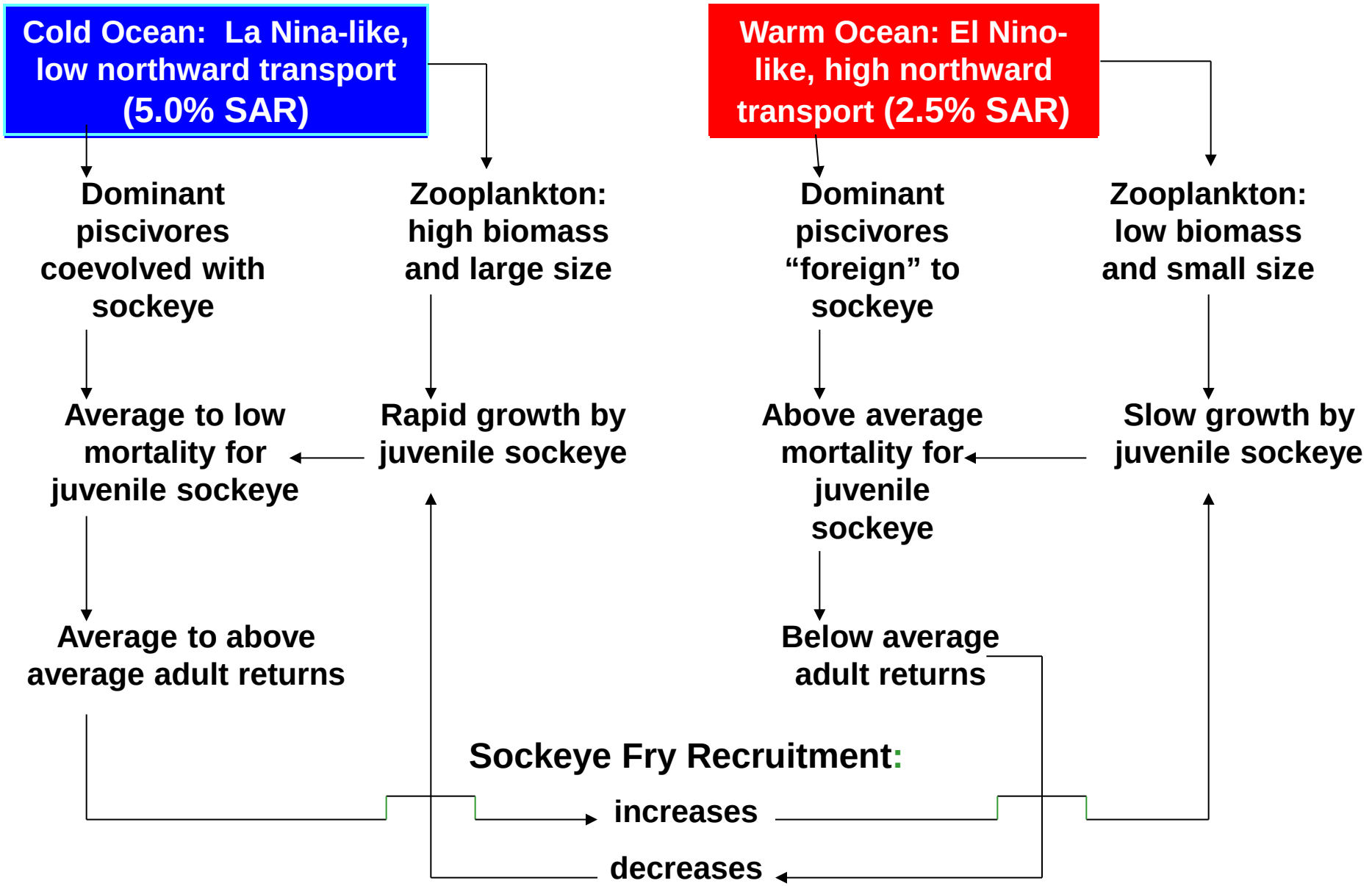


CPUE is highest in warm-water years with favourable upwelling conditions along the continental shelf.

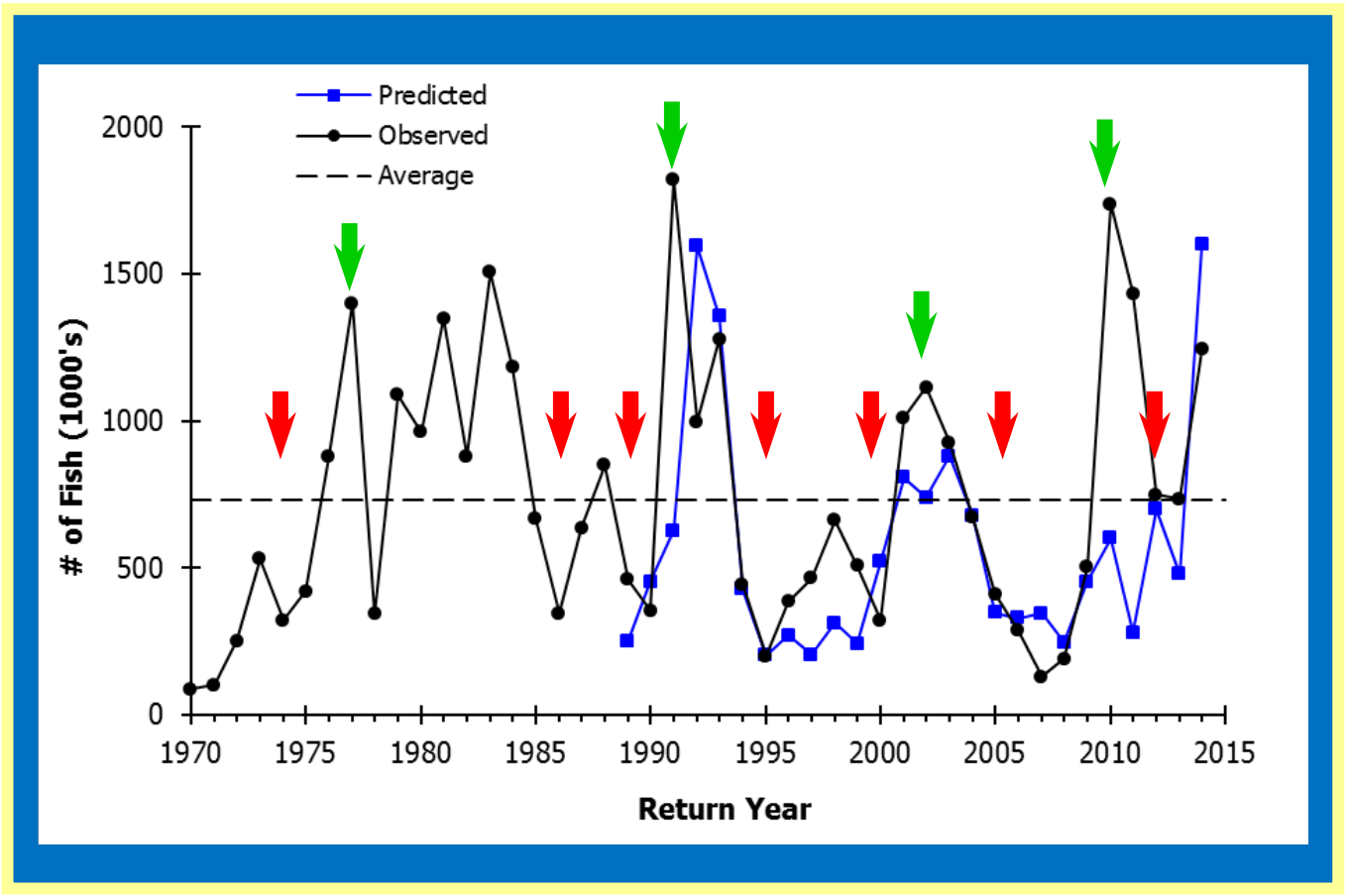
Source: John Holmes, SOPO, 2012.

Hyatt et al, AFS Meeting, Kelowna, March 21,2018..

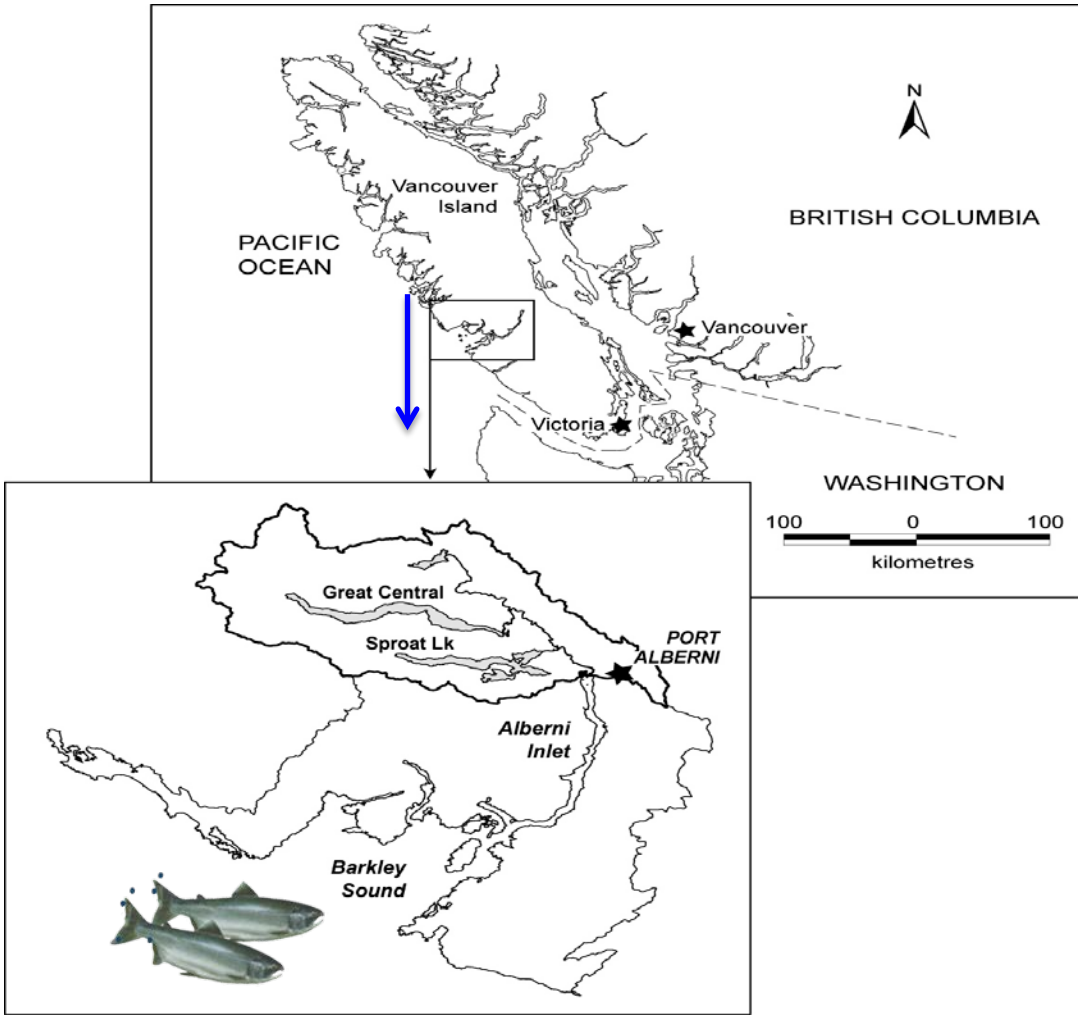
POE Model: Two-state, ocean and salmon production-outcomes model (Hyatt et al PSARC 1989) reflecting PDO-ENSO induced reorganization of the Northern California Current Ecosystem.



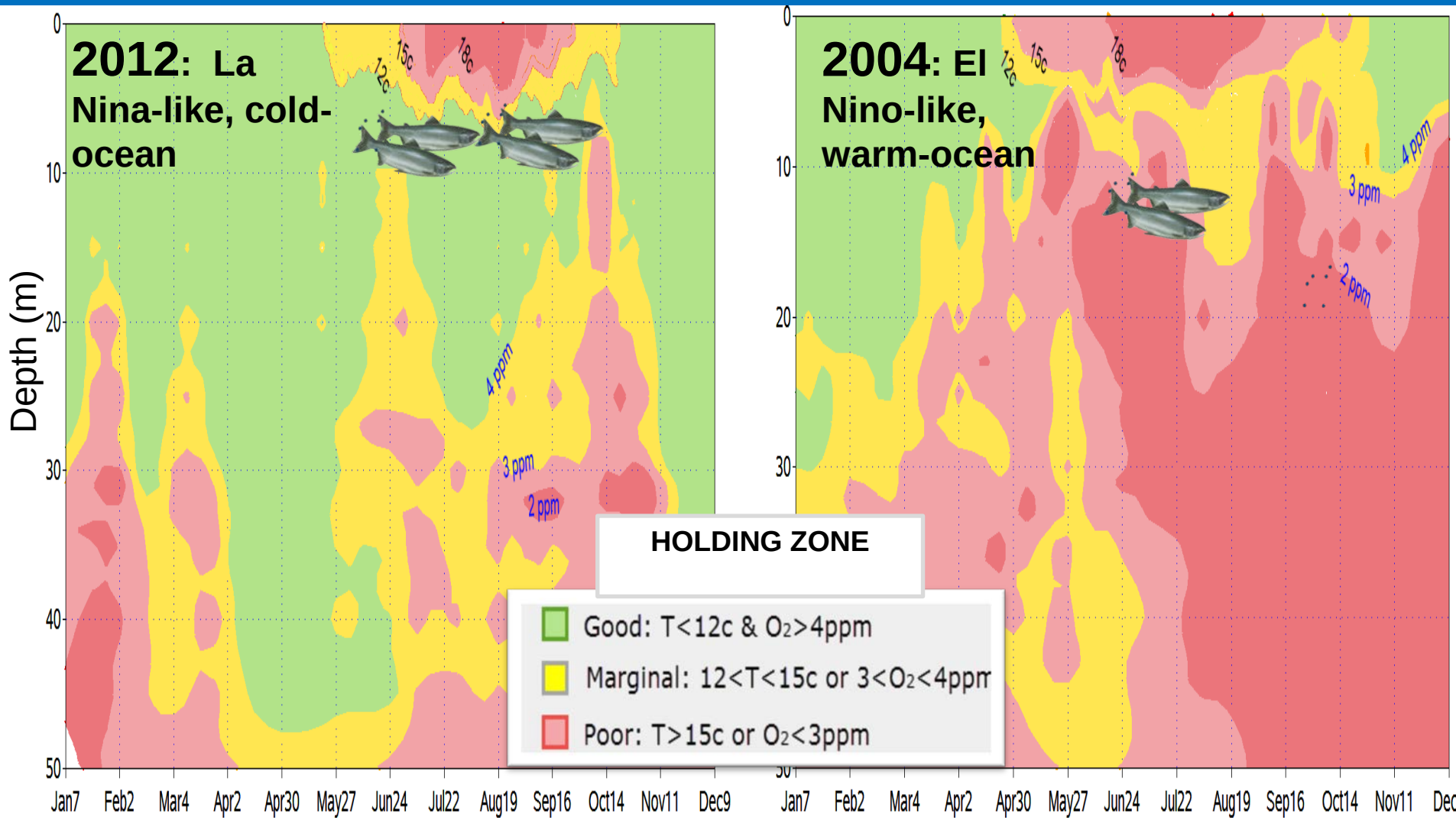
Lagged El Niño (red) and La Niña (green) events increase forecasting skill for Barkley Sound sockeye returns (1970-2014)



Recent work suggests losses of pre-spawning adult sockeye in terminal, holding areas of Alberni Inlet also follow a “cold-ocean, warm-ocean” set of rules (Stiff and Hyatt, 2015 DFO-State of the Pacific Ocean Report, 2015)



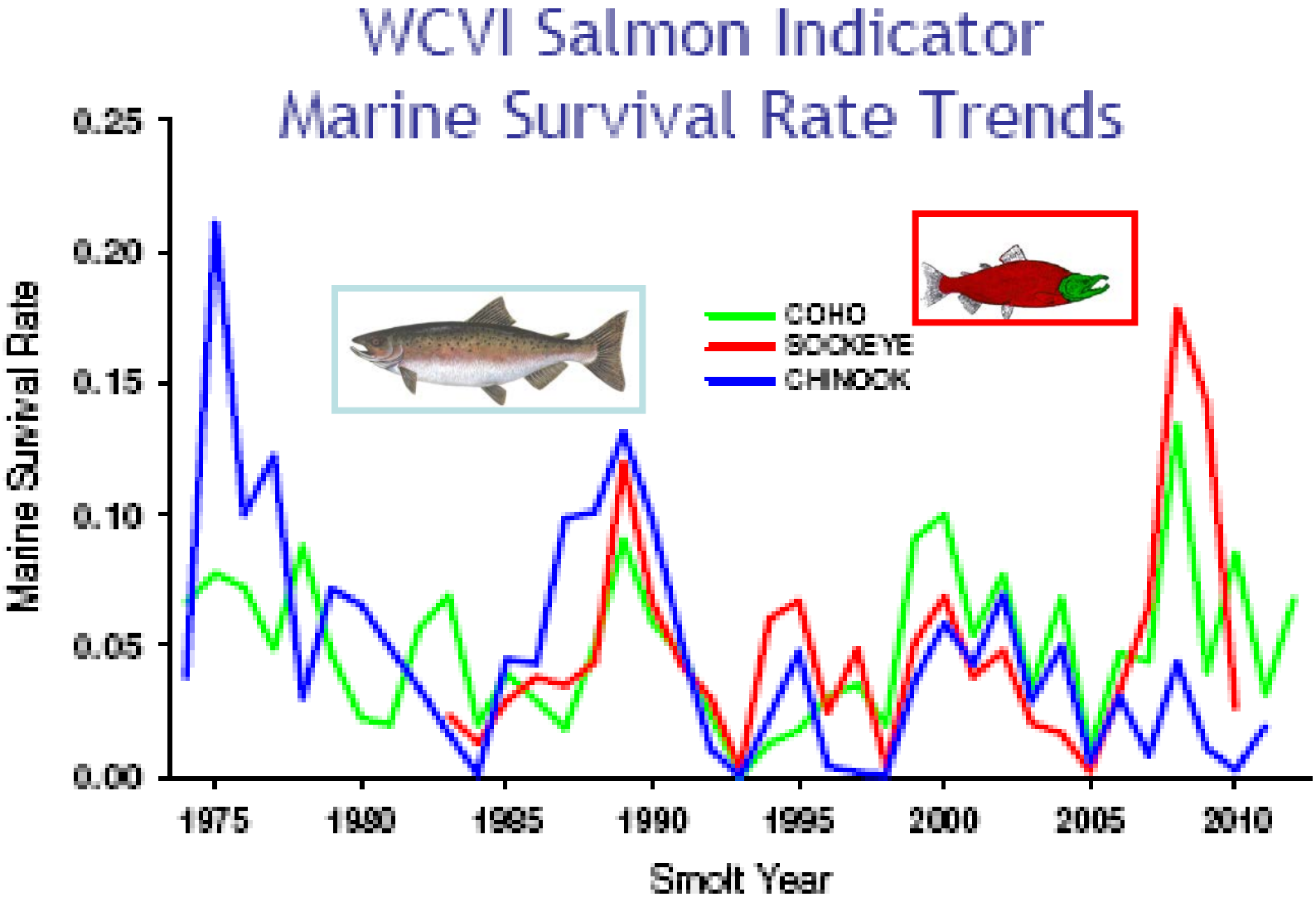
Temp-oxygen conditions in the Alberni Inlet holding area alternate from survival favorable (e.g. 2012) to unfavorable (e.g. 2004, 2015) given cold and warm ocean state changes



Fisheries and Oceans Canada | Pêches et Océans Canada

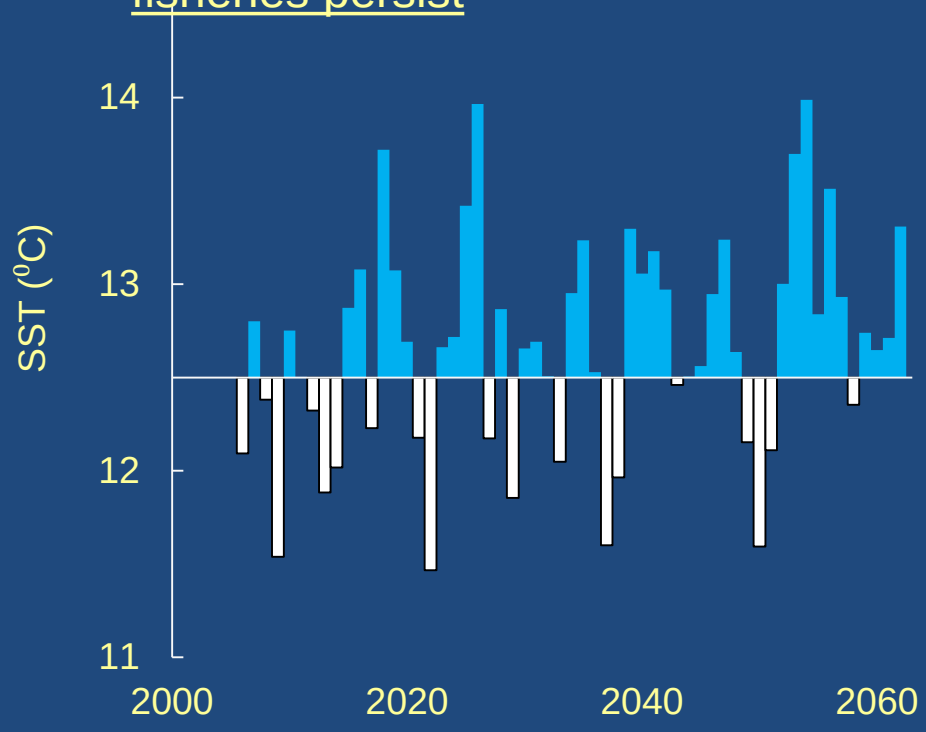
Hyatt et al, AFS Meeting, Kelowna, March 21,2018..

Marine survivals of WCVI salmon CUs co-vary suggesting POE-model applies to at least three salmon species & fisheries in the NCCS !

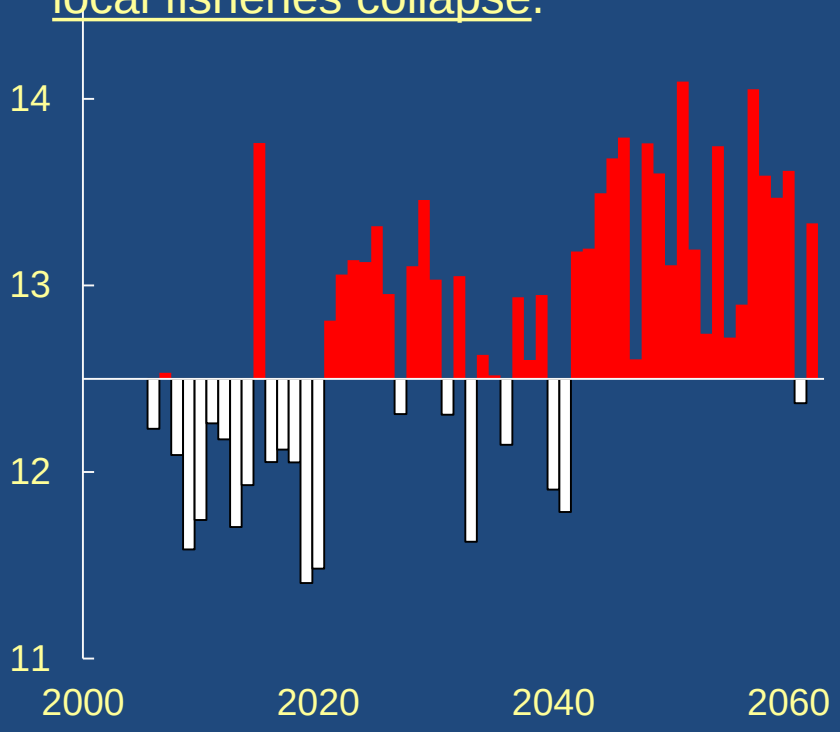


Projections of WCVI-SST 2000- 2060 relative to 2006-2011 mean from NOAA Earth-Simulator-2, Climate-model (results adapted from Preikshot and Perry 2013)

Optimistic* scenario: Moderate increase in "warm ocean" frequency i.e. WCVI salmon production declines likely similar to mid 80s & mid 90s so <u>local fisheries persist</u>



Pessimistic scenario**: Larger increase of "warm ocean" frequency i.e. WCVI salmon production declines likely more severe than mid-80s & 90s so <u>local fisheries collapse</u>.



*GHG emission rate decreases, ** GHG emission rate remains at current levels

Conclusions – Marine CVC Impacts on WCVI Salmon

- **Cumulative effects of climate variation and change induce large-magnitude recruitment variations in Barkley Sound and West Coast Vancouver Island salmon returns.**
- **“Cold La Nina-like” and “warm El Nino-like” alternations induce biophysical changes to the California Current System (and Alberni Inlet) that favour above-average and below-average sockeye salmon recruitment respectively.**
- **Climate change favours an increased frequency and possibly intensity of “warm El Nino-like” future ocean states in CCS.**
- **Given known climate change impacts and current, pessimistic, emissions scenarios, Barkley Sd sockeye returns are projected to exhibit increased variability (2000’s-2050’s) followed by decreased variability (by 2100) due to chronic recruitment failures and fisheries collapse.**