Observations and implications of unusual environmental conditions in 2014-2016 for salmon and associated fisheries in the eastern Pacific rim

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Freshwater and Marine Ecosystems Status & Trends in 2014-2016

- Intent: review what we saw in 2015, compare and contrast this with observations of returns in 2016, provide outlook on nature of returns in 2017-19.
- Observation: anomalous environmental conditions in both freshwater and marine ecosystems expected to induce increasingly variable survival and altered biological traits such as age, body size and time of returns for several salmon species and populations in Canada's Pacific region in the 2015-2018 interval.

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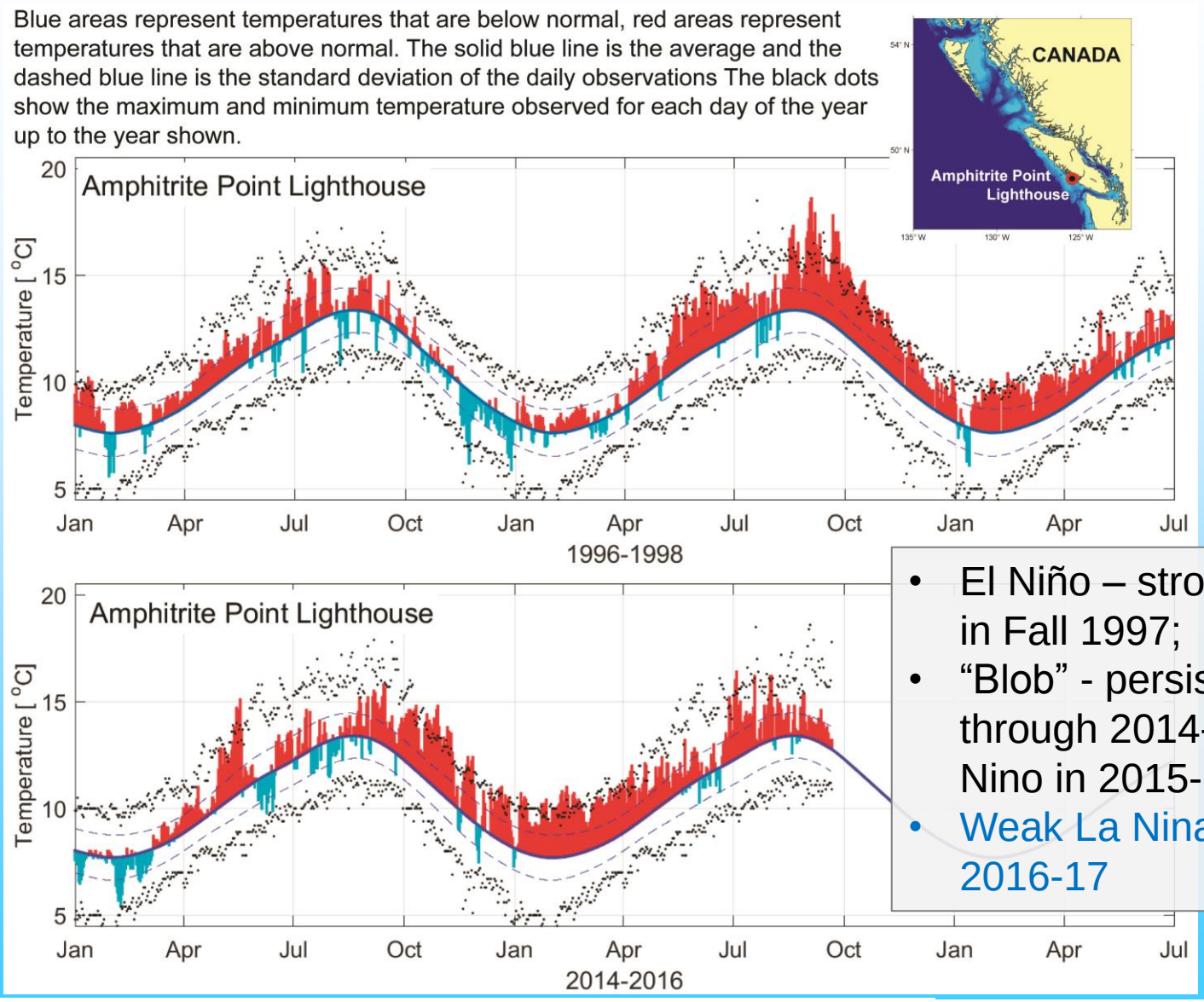
Coastal BC: very high SSTs October 2014-2015

ENSO, 1996 - 1998

The “Blob”, 2014 - 2016



- El Niño – strongest in Fall 1997;
- “Blob” - persistent through 2014-15. El Nino in 2015-16.
- Weak La Nina 2016-17

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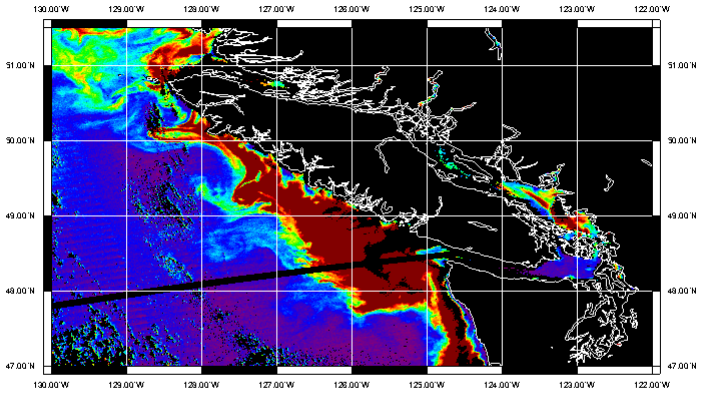
Exceptional phytoplankton bloom occurred along North American coast from May-Sept 2015

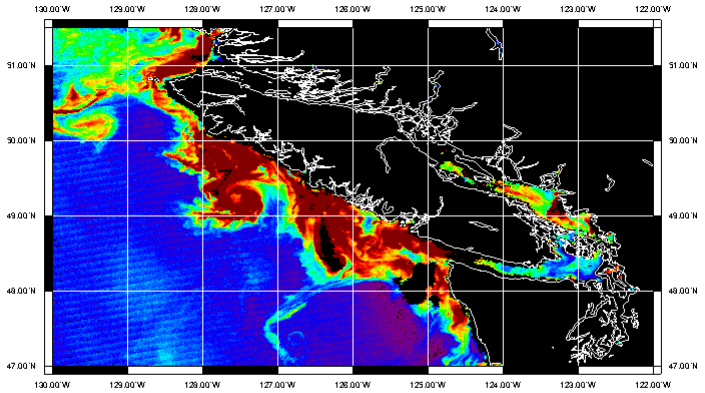
MODIS NFLH satellite images

Unusual in terms of:

- spatial extent of bloom (California to Alaska)
- duration of bloom (May to Sept)
- presence of toxic phytoplankton species (domoic acid producers)

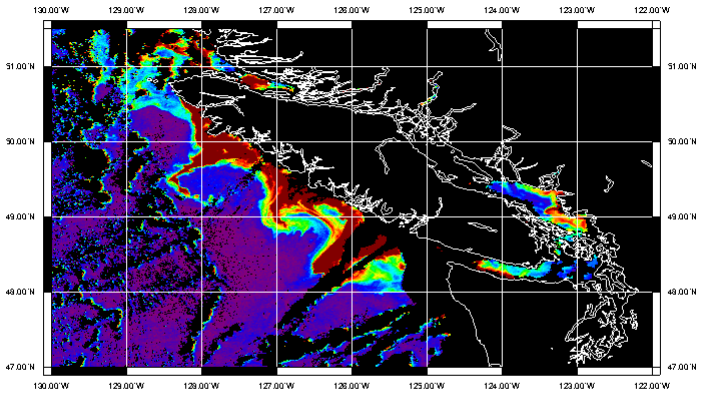
9 June 2015

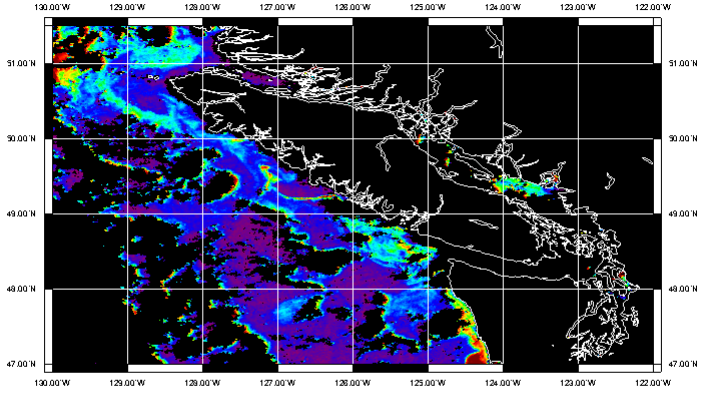




4 July 2015

6 Aug 2015





3 Sept 2015

A2015215214000.L2_LAC.Vancouver_Island.nflh

Fluorescence Line Height (normalized)

0 0.01 0.02 0.03 0.04 0.05

A2015246205500.L2_LAC.Vancouver_Island.nflh

Fluorescence Line Height (normalized)

0 0.01 0.02 0.03 0.04 0.05

Fish Can

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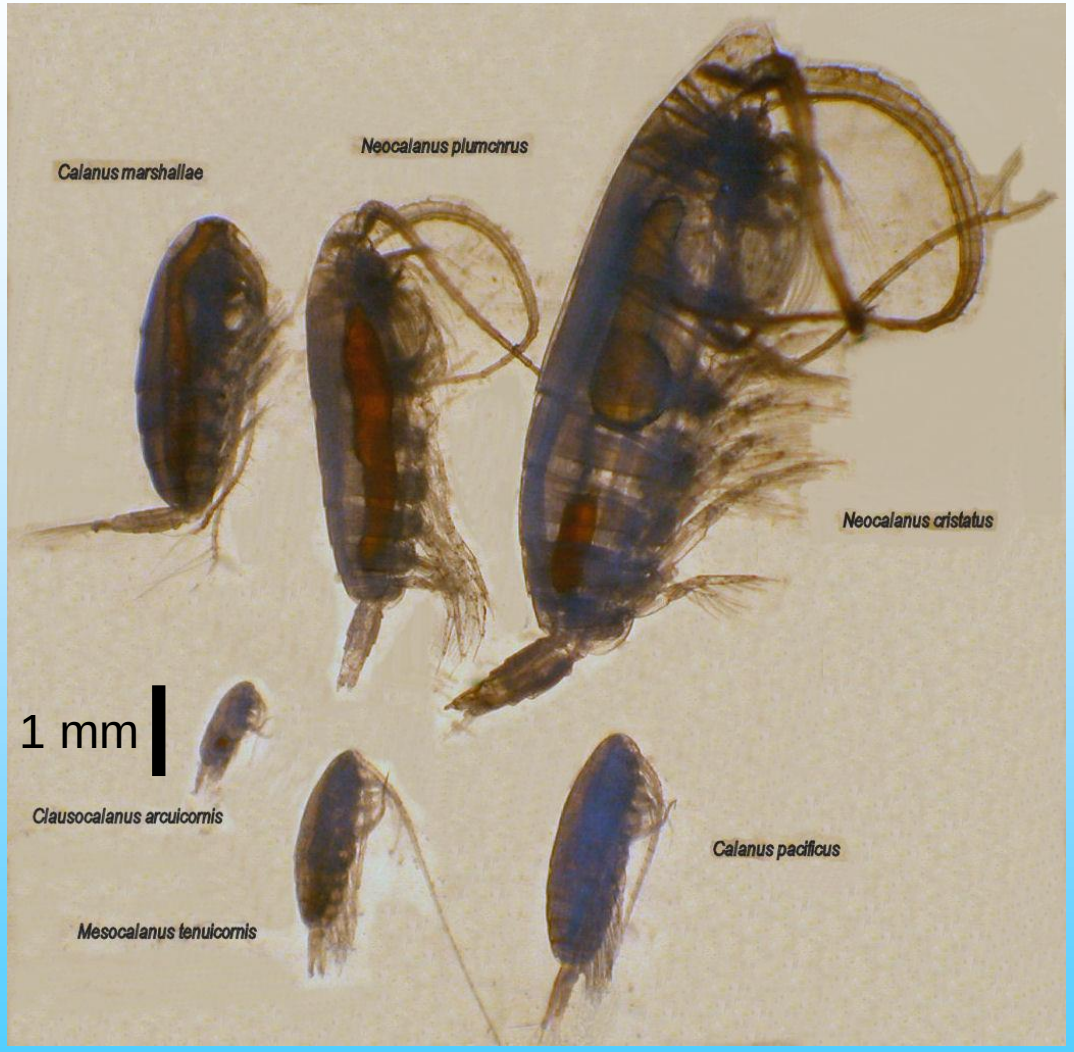
Changes in water temperature are reflected in changes in coastal marine zooplankton species composition



- northern-type zooplankton occurred along Vancouver Island in 1st half of 2014 when water was cool (large nutritious species, good for fish)

- but, southern-type zooplankton in 2nd half of 2014 and in 2015 when water was warm (small poor quality species)

Implications for fish – “exotic” warm water migrants appear in greater numbers in Canadian waters in 2014-2015

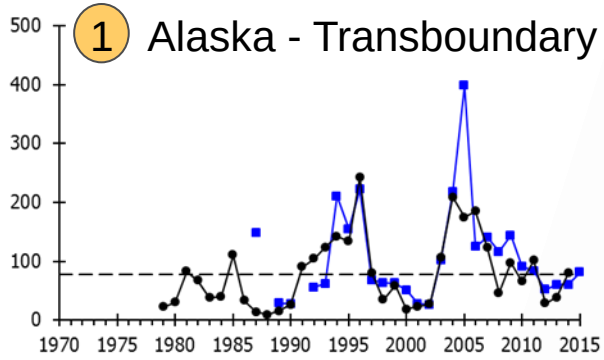
Finescale Triggerfish, *Balistes polylepis*,
26.3 cm Standard length (Courtesy RBCM)

Pacific Pompano (butterfish)

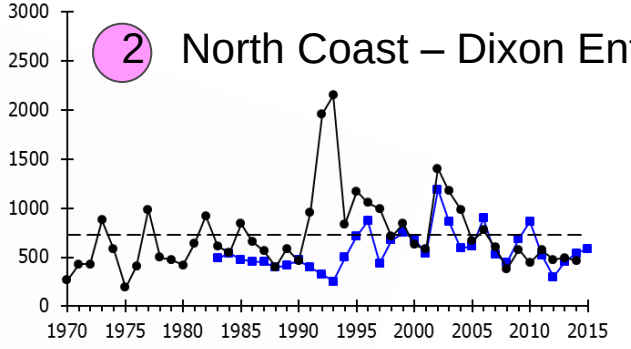
Louvar, *Louvaris imperialis*,
72.0 cm SL (Courtesy RBCM)

Coast-wide Sockeye in 2015 (returns at or above forecast except Fraser)

1 Alaska - Transboundary

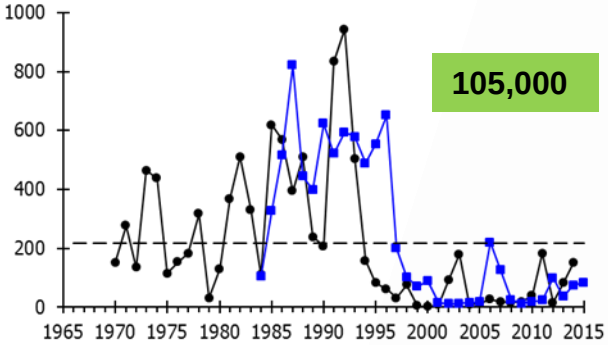


2 North Coast – Dixon Entrance



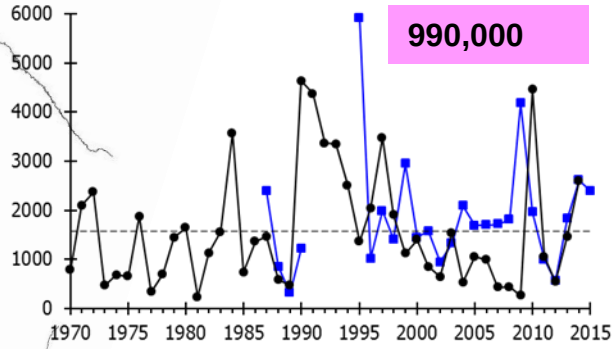
3 Central Coast – Hecate St.

105,000



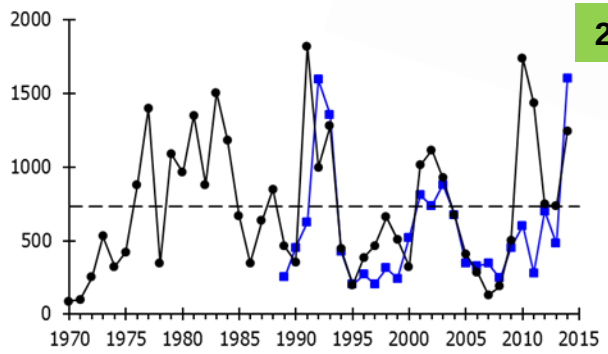
4 Fraser R. – Georgia Basin

990,000



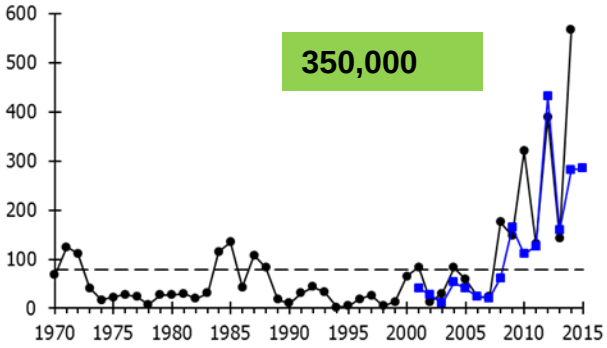
5 West Coast Vancouver Island

2,000,000

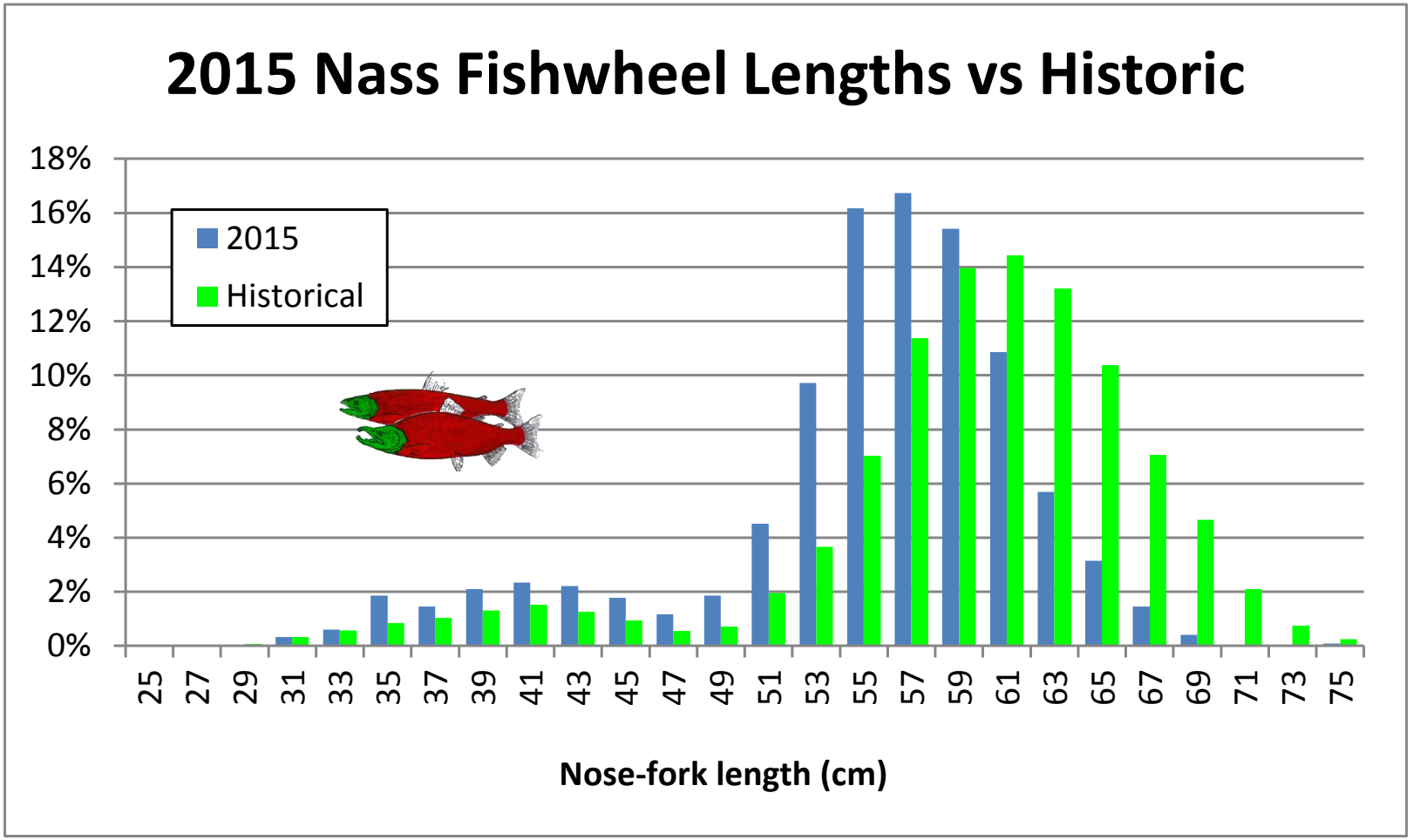


6 Columbia - Okanagan

350,000



Sockeye, coho salmon were 2-4 cm smaller than average in 2015 (e.g. Nass, Barkley sockeye, WCVI and OPI coho; Nass sockeye were about 4cm shorter in 2015 than historic average; Bristol Bay-& Copper R-Ak sockeye were smallest in 20 years)



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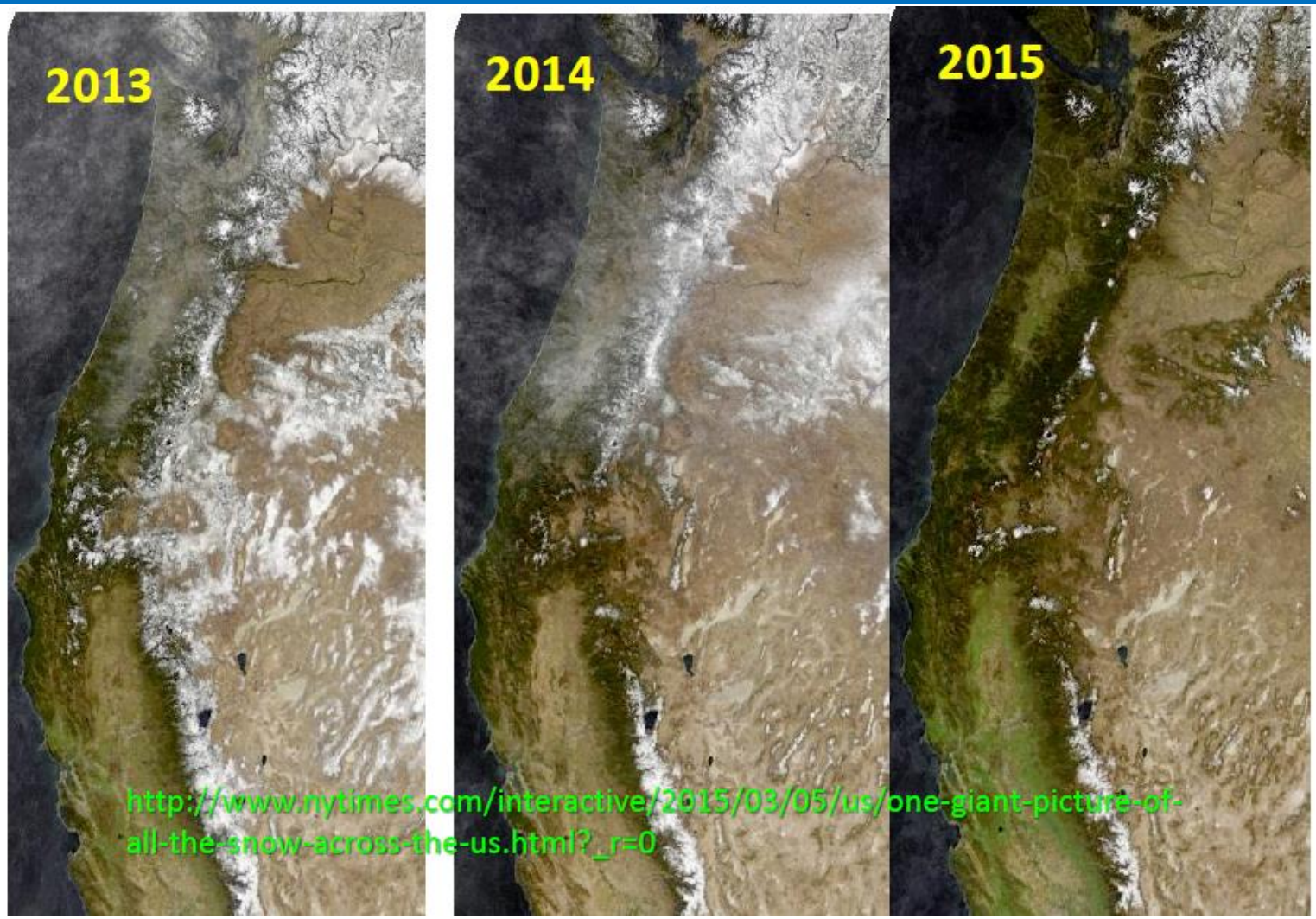
Freshwater Ecosystems Status & Trends in 2014-15

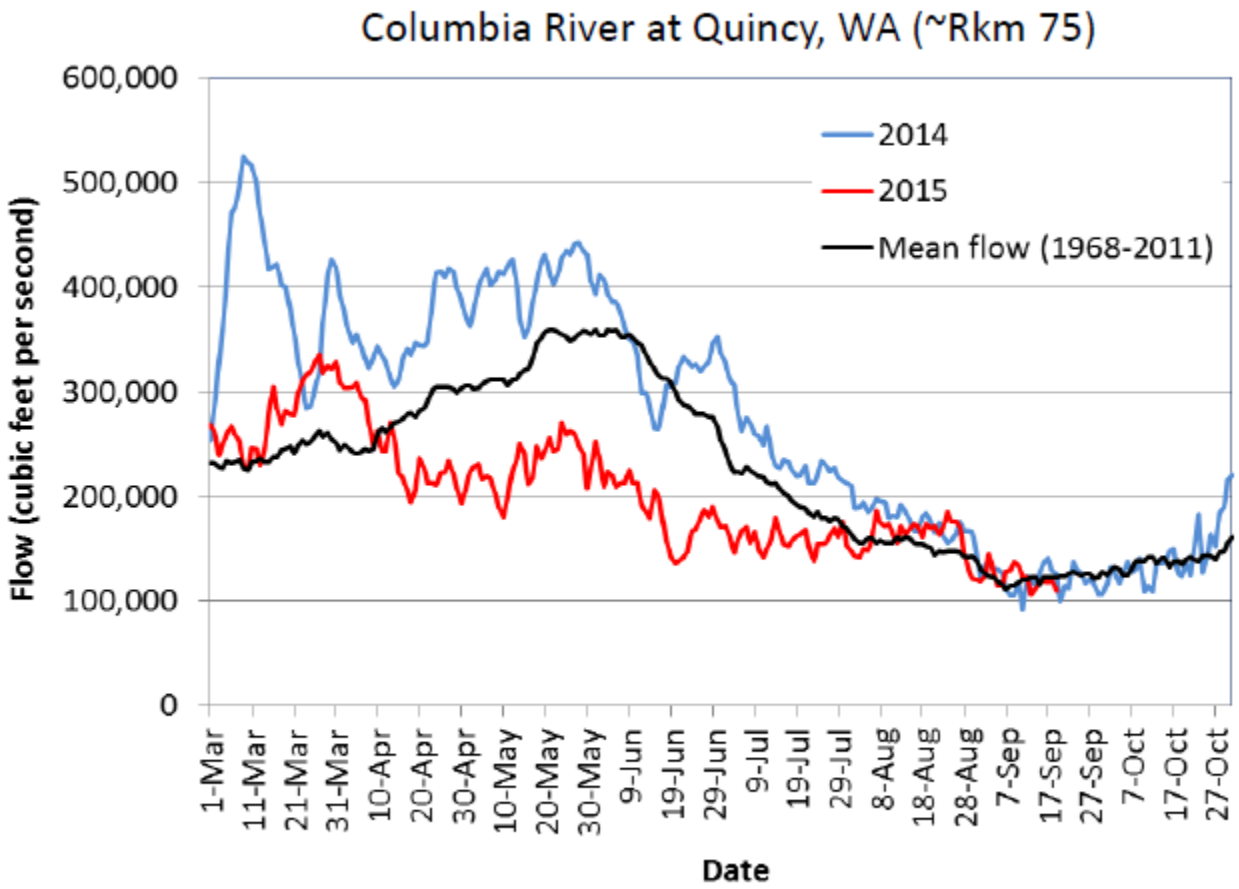
- above average air & water temps all winter
- normal precipitation but far above average winter runoff
- low snow-packs throughout PNW-Southern BC
- summer drought and low discharges throughout the south
- record breaking spring-summer temperatures in rivers
- implications for freshwater fish including salmon

Winter snowpack declined in the PNW and Southern BC from 2013-15



K. Hyatt, Salmon & Environment, Fraser Forum, Jan 2017.

Timing and magnitude of spring-summer flows in major rivers (Columbia, Fraser) and streams (Cowichan, WCVI) were very high in winter and very low in summer-fall e.g. Columbia R. peak flows in March 2014 & 2015, instead of late May.



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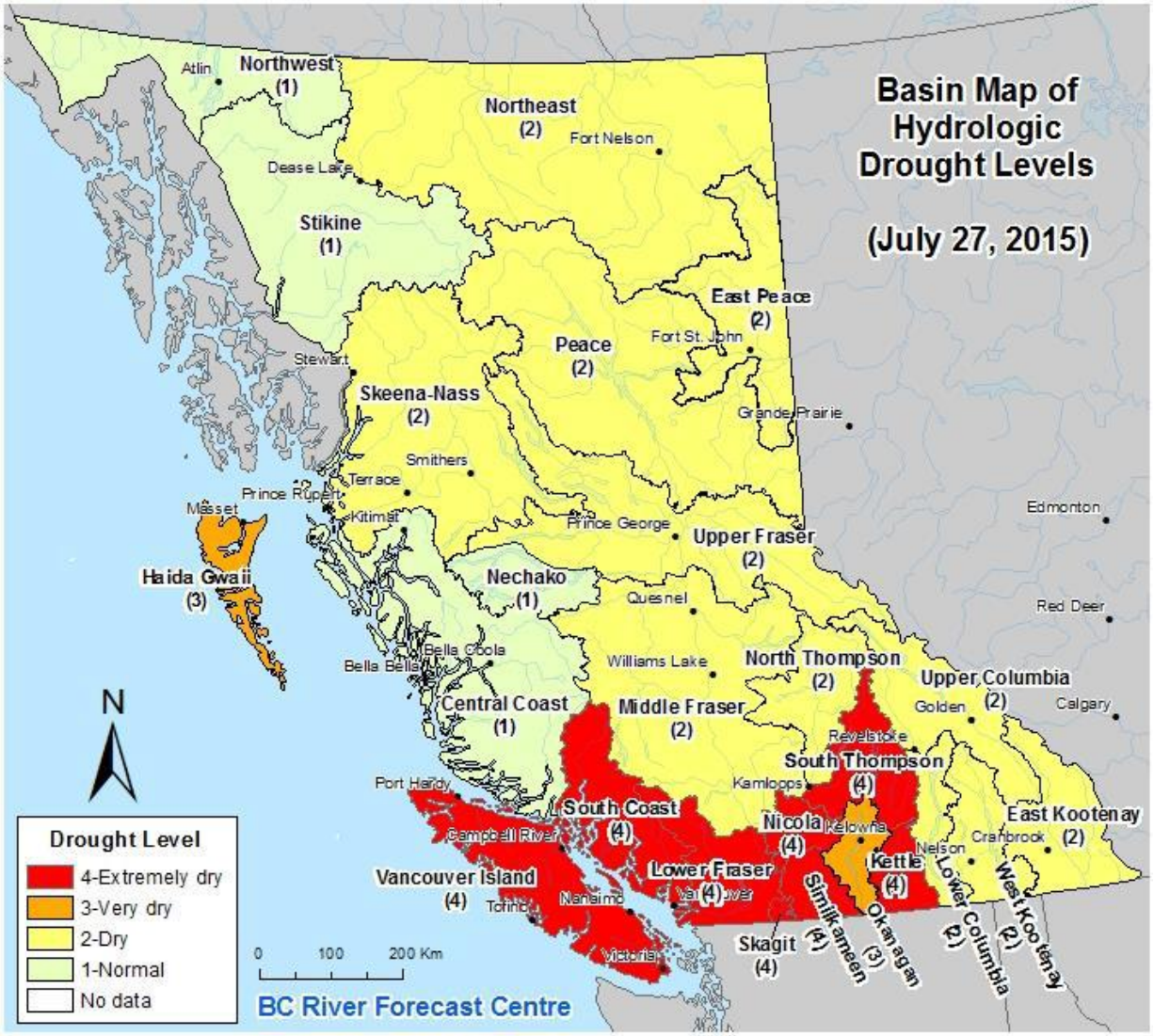
Low winter snow-packs & limited spring rains produced a large "footprint", summer drought in the PNW and Southern BC in 2015



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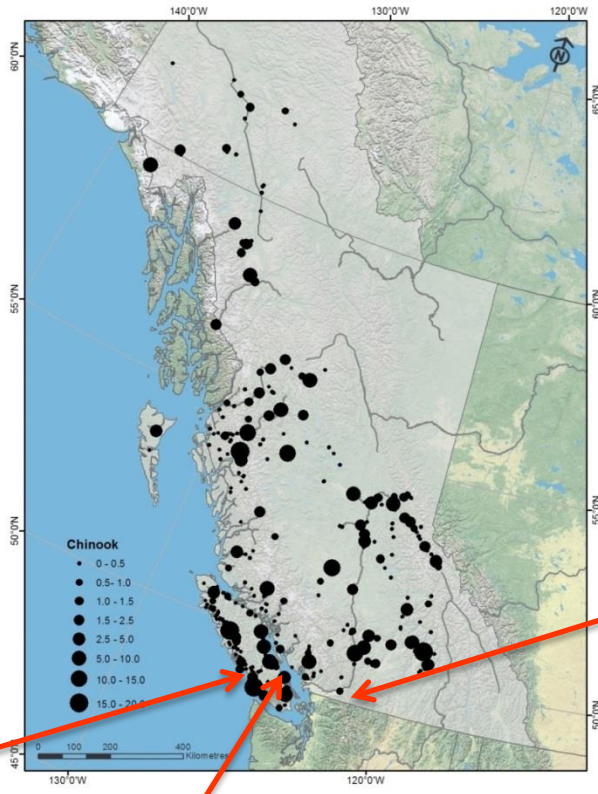
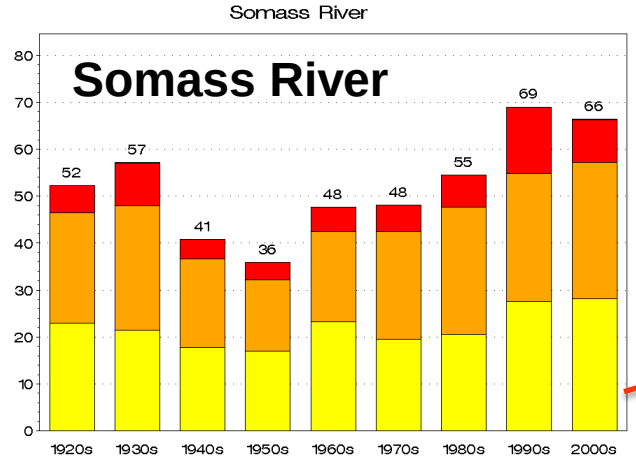
Record breaking intervals in 2015 of high stress temperatures for migrating summer Sockeye and Chinook salmon (Hyatt and Stiff, DFO-ACCASP, 2016).

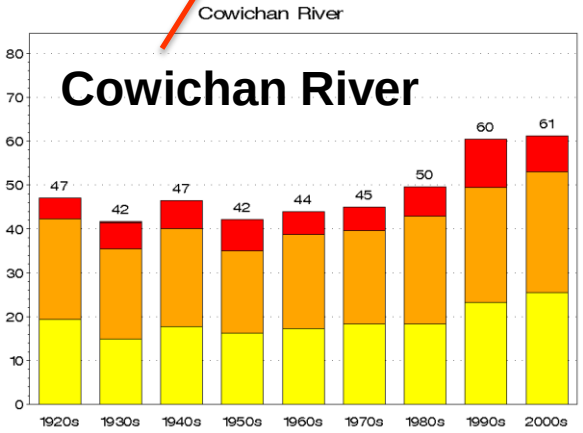
Summer migrations of Chinook and Sockeye



POT $_{>18}{}^{o}$c event analysis: Assumes Chinook migration interval of July-Oct in BC rivers by decade from 1920s-2010 (Hyatt and Stiff, DFO-2013).

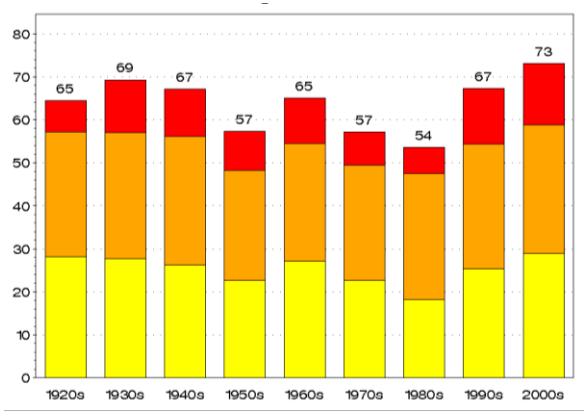


2015 - **106** days
2000's - **66** days



2015 - **99** days
2000's - **61** days

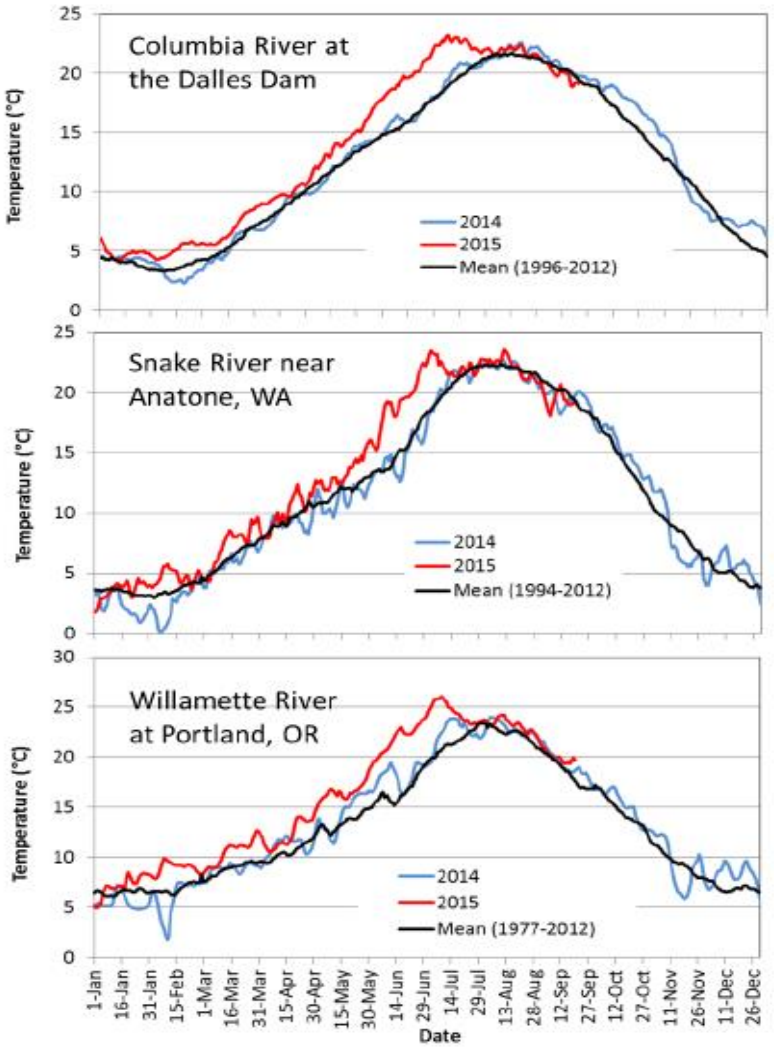
Okanagan River



2015 - **121** days
2000's - **73** days

High temperatures in Columbia River accompanied by *en route* mortality of >95% of adult Sockeye (>200,000) returning to the Okanagan River in 2015 !

Low river flow+
hot spring
= high river
temperatures &
fish kills



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Freshwater & Marine Ecosystem States in 2014-2015

- Warm “blob” (2014-2015)
- ‘Toxic’ phytoplankton bloom (2015)
- Powerful El Nino (2015-16)
- Unusual zooplankton (2015-16)
- Warm water fish species (2015-16)
- Unusually warm lake and river temps in 2014-2015
- Anomalous environmental conditions in marine and freshwater ecosystems accompanied by highly variable returns in 2015 and altered biological traits such as age, body size, time of returns, migration and spawning success for several salmon species & populations.

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2016 Environment and Fraser Sockeye Issues ?

- In-season estimates indicate 2016 returns of Fraser River Sockeye as the lowest on record.
- In the post-Cohen era, there is a growing interest both inside and external to the Department in understanding the reason for the low returns and implications for the future.

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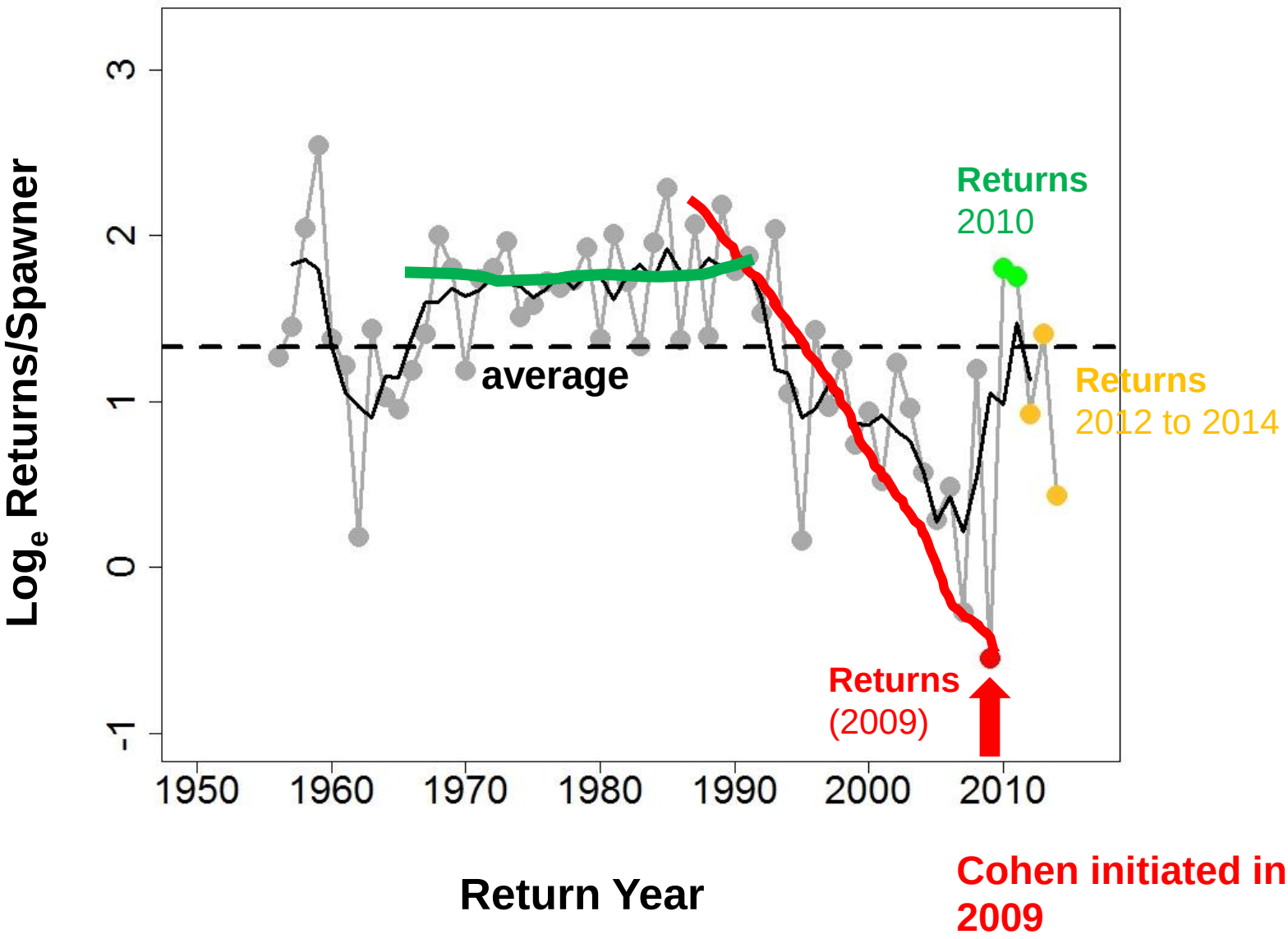
What did we know going into 2016?

- In the **State of the Pacific Ocean Technical report**, the British Columbia sockeye salmon outlooks suggested an expectation of increasingly variable survivals for all sockeye salmon stocks returning to BC waters due to increasingly variable environmental conditions (**Hyatt et al. 2016. State of the Pacific Ocean Report**).

- **Fraser Sockeye Forecasts: CSAS Supplement** (DFO. 2016 (in press)) concluded that survival signals for the 2016 return were mixed based on a synthesis of recent DFO research and monitoring activities in the freshwater and marine ecosystems.

FRASER SOCKEYE TOTAL SURVIVAL



Cohen initiated in 2009

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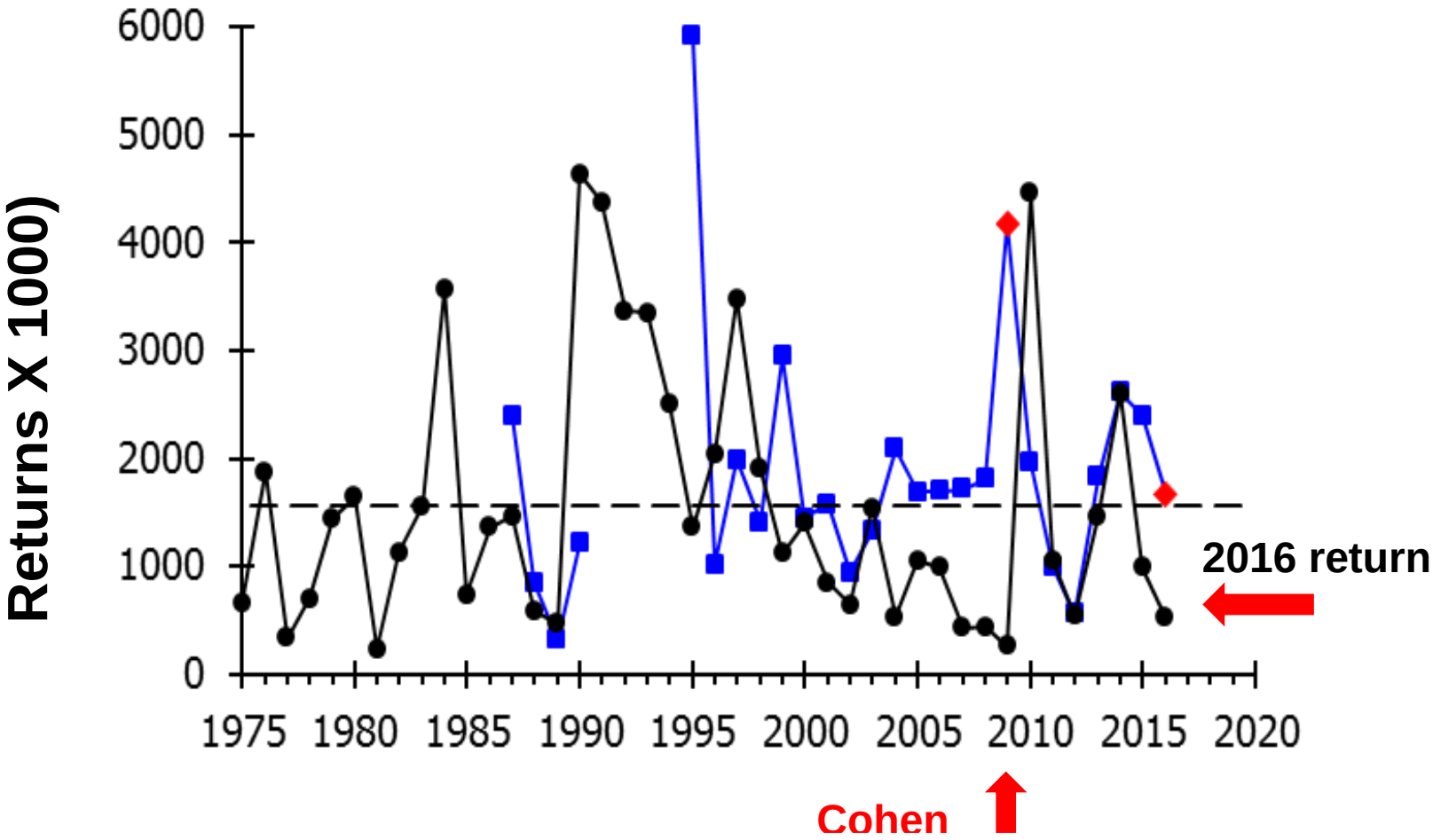
CHILKO SOCKEYE RETURNS

Difference of forecast to observed for 2016 Fraser returns was not exceptional in contrast to the 2009 and 2010 “Cohen” years !



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Was 2016 the same as 2009?

- The short answer is **no**! The 2016 return did not repeat 2009.
- The 2016 returns were approximately 1/3 of the expected return.
- The 2009 returns were only 1/15 of the expected return.
- In 2009, lower than average survival was reported for all Fraser River sockeye salmon stocks; for many stocks the 2009 survival was the lowest on record.
- In 2016, in-season information suggests that not all Fraser River sockeye salmon stocks exhibited below average survival.

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Associations Between Unusual Environmental Conditions and Returns

- Given the complex life-history of salmon, unusual conditions in either freshwater or marine ecosystems may have major impacts on productivity.
- Unusual ocean conditions: exceptionally warm offshore and then onshore ocean conditions 2013-2016 (the “Blob” and EL Niño); warm water alters ecosystem structure having effects on the types and availability of foods and the types and abundance of predators.
- Broad scale climate variability may also influence conditions in freshwater spawning and rearing habitats (as in winter-summer 2014-2015) so both need to be considered.

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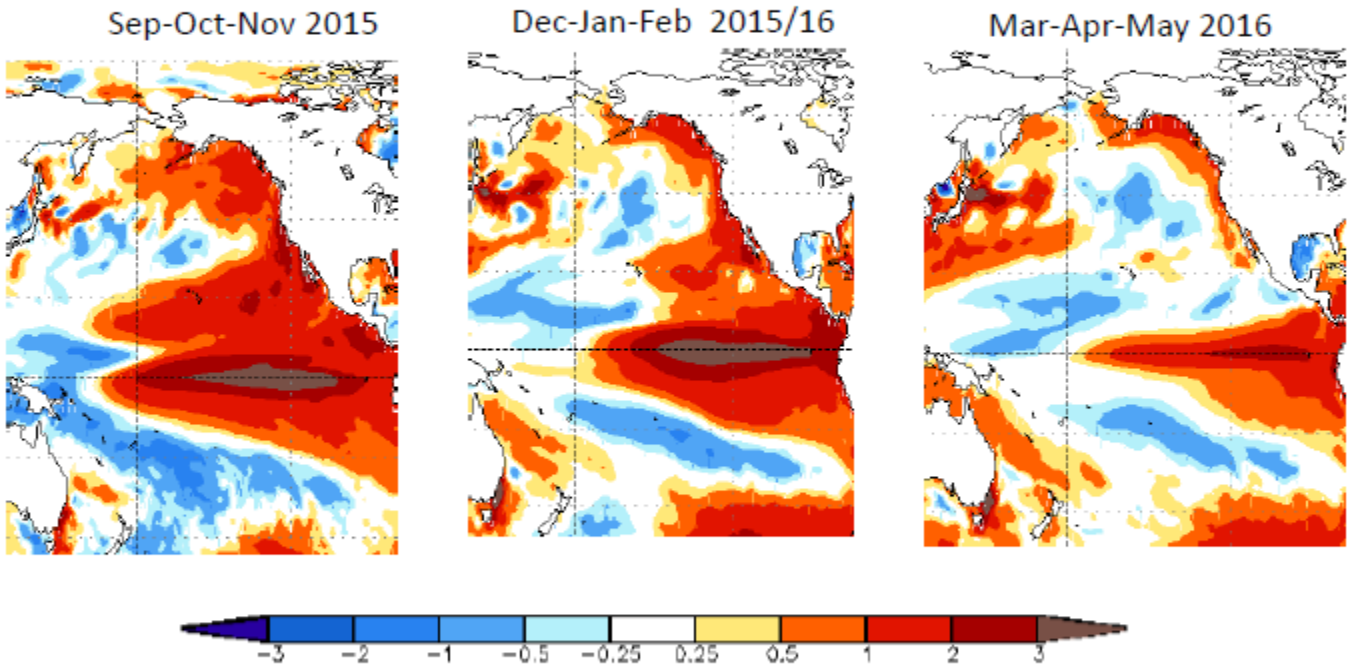
A broader perspective on ecosystems and salmon in the eastern Pacific in 2016?

Forecast SST anomalies

NOAA Climate prediction Center coupled forecast model 2



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

"Godzilla" El Nino developing for fall-spring 2015-2016

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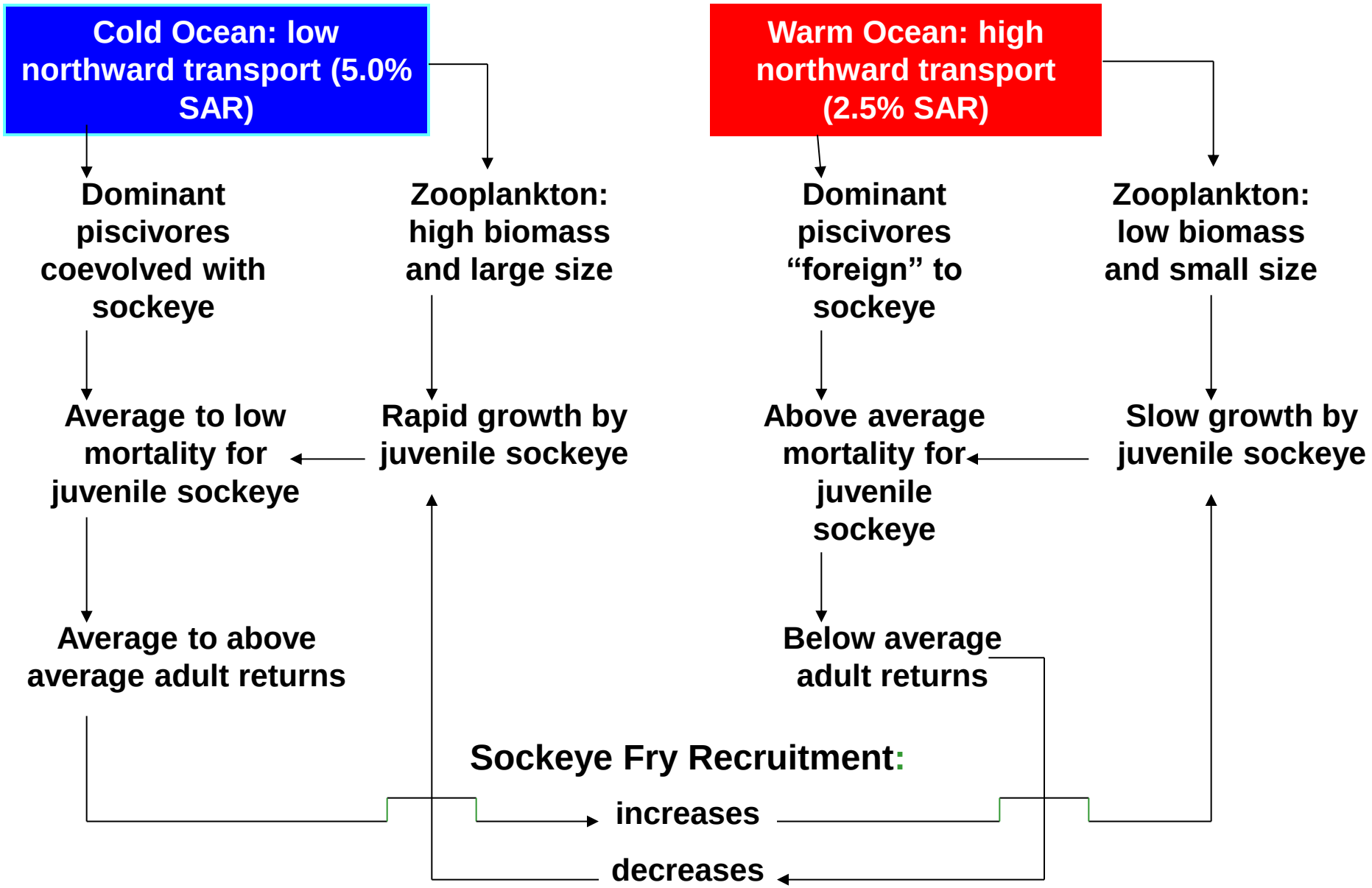
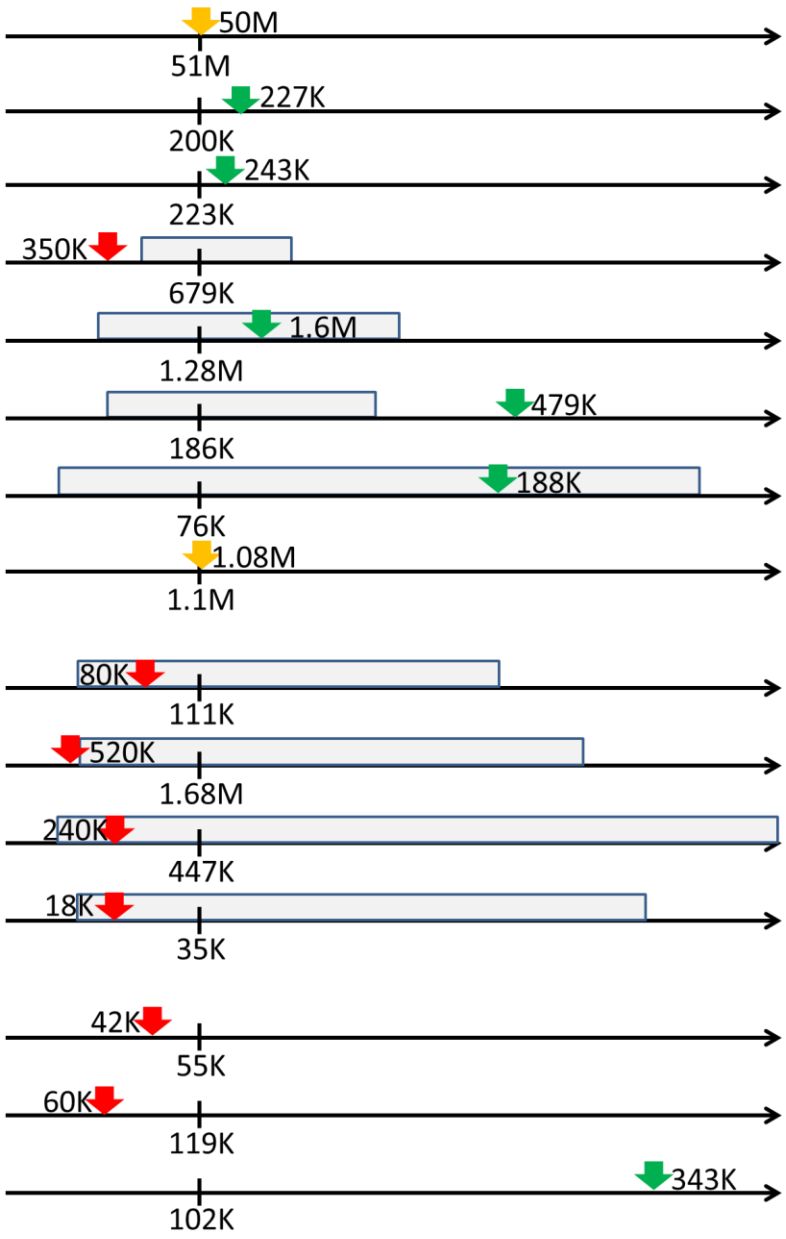
Two-state, ocean and salmon production-outcome model (Hyatt et al PSARC 1989) assumes a "cold" ocean favours HIGH survival & a "warm" ocean LOW survival of salmon due to reorganization of southern coastal ecosystems.



Pre-season forecast compared to observed returns in 2016 suggests inverse production regimes at play for southern vs northern sockeye populations

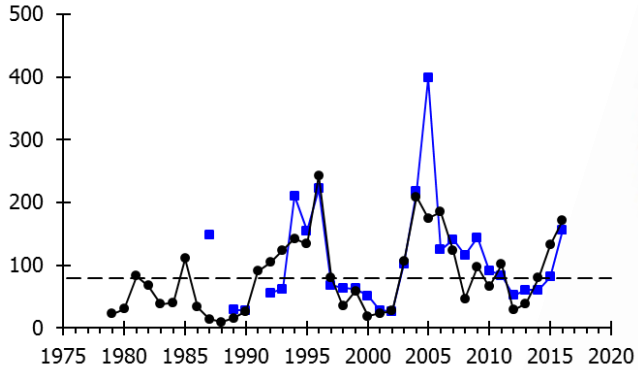


"**Northern**" - most (but not all) above average!

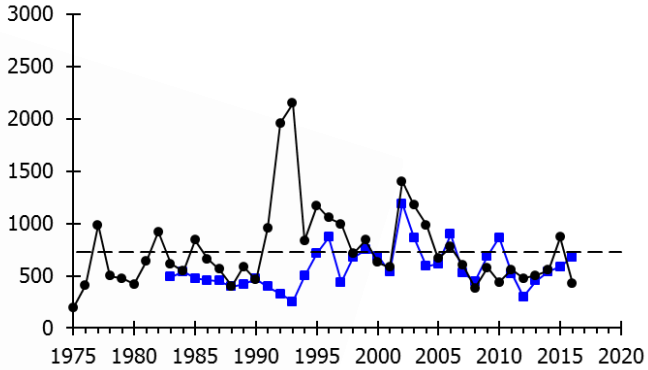
"**Southern**" - Mostly below average!

2016 update of BC index stocks

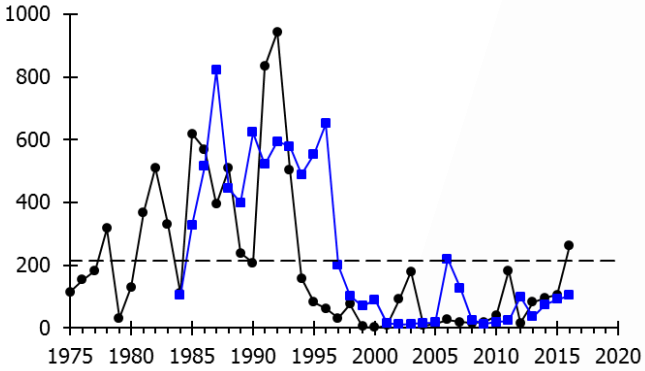
1 Tahltan (Ak – Transboundary)



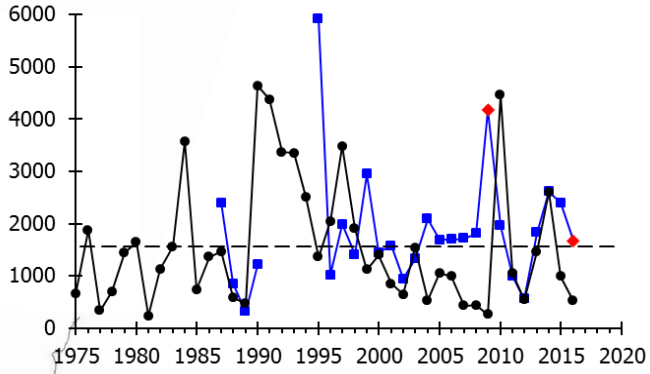
2 Nass (North Coast)



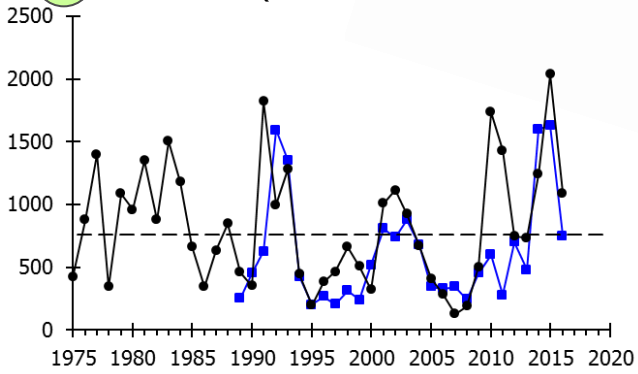
3 Smith Inlet (Central Coast)



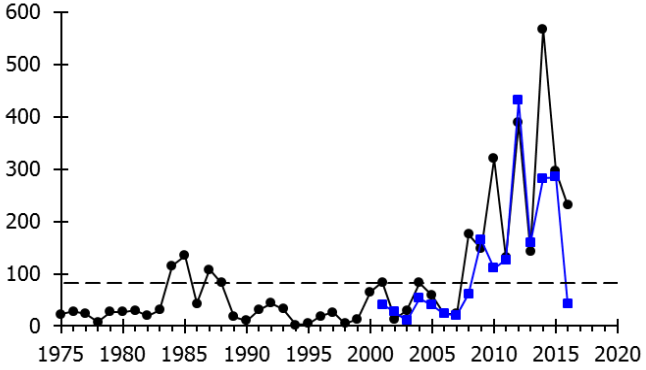
4 Chilko (South Coast Fraser)

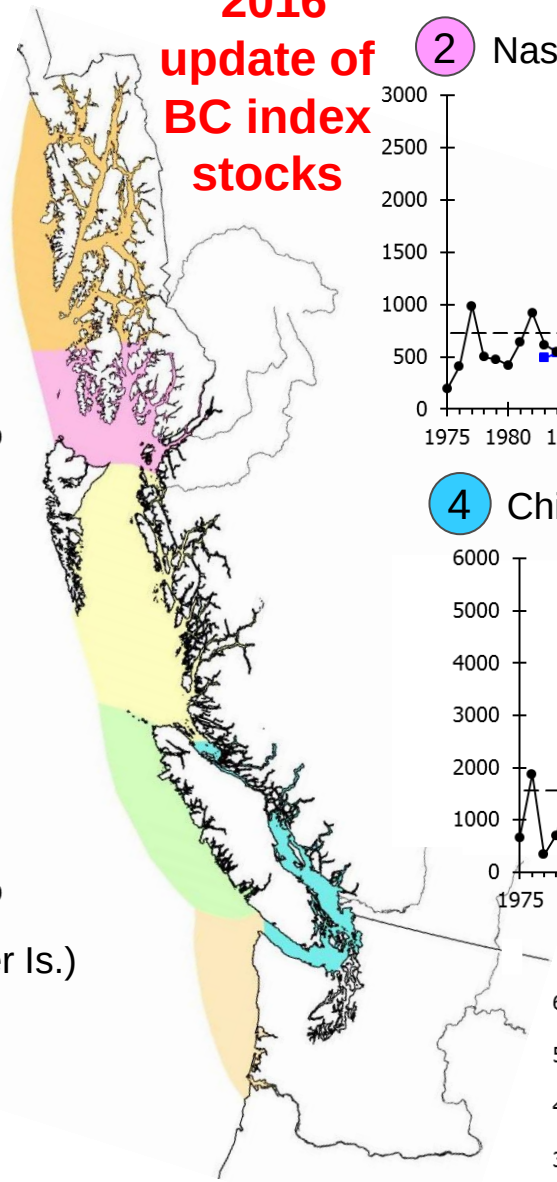


5 Somass (West Coast Vancouver Is.)



6 Okanagan (Columbia R.)





Total Returns in 1000's

Observed

Forecast

Average

Inferences from Coast-wide Sockeye Indicators, 2016

- Sub-average returns of Fraser sockeye in 2016 were not representative of a coast-wide pattern of decline.
- Central Coast sockeye returns in 2016 to Smith & Rivers Inlet rose above the all-year average for the 1st time in more than 20 years.
- Returns to Barkley Sound were above the all-year average and pre-season forecast. The forecast did anticipate the sharp drop in 2016 returns relative to 2015, and supported an orderly fishery .
- Okanagan and Columbia River sockeye continued their multiyear trend for above average returns and greatly exceeded the pre-season forecast, but not the fall 2015 "outlook".
- Northern stocks appear to have performed better than southern stocks on average for 2016 returns which is in-line with a reversion to a general inverse north-south pattern of production (Mantua et al, 1997) for salmon in the eastern Pacific.

Exceptional abundances of gelatinous zooplankton in 2014-2015 and exceptional returns of Chum in 2016?

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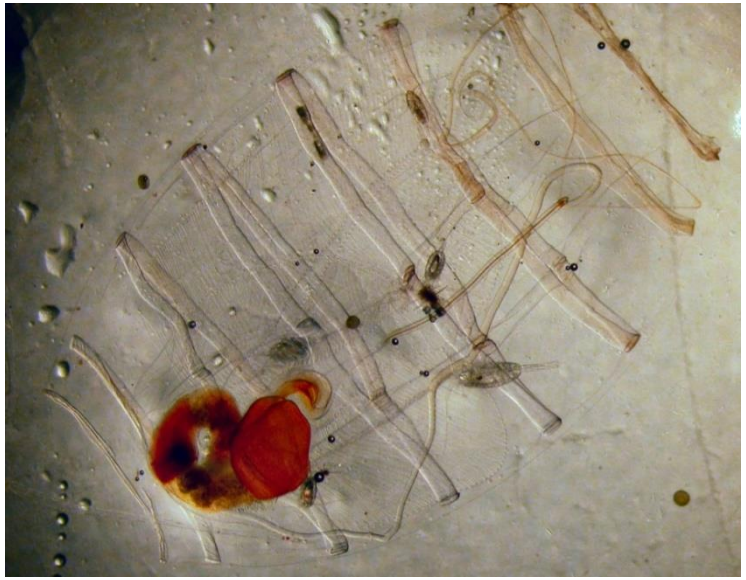

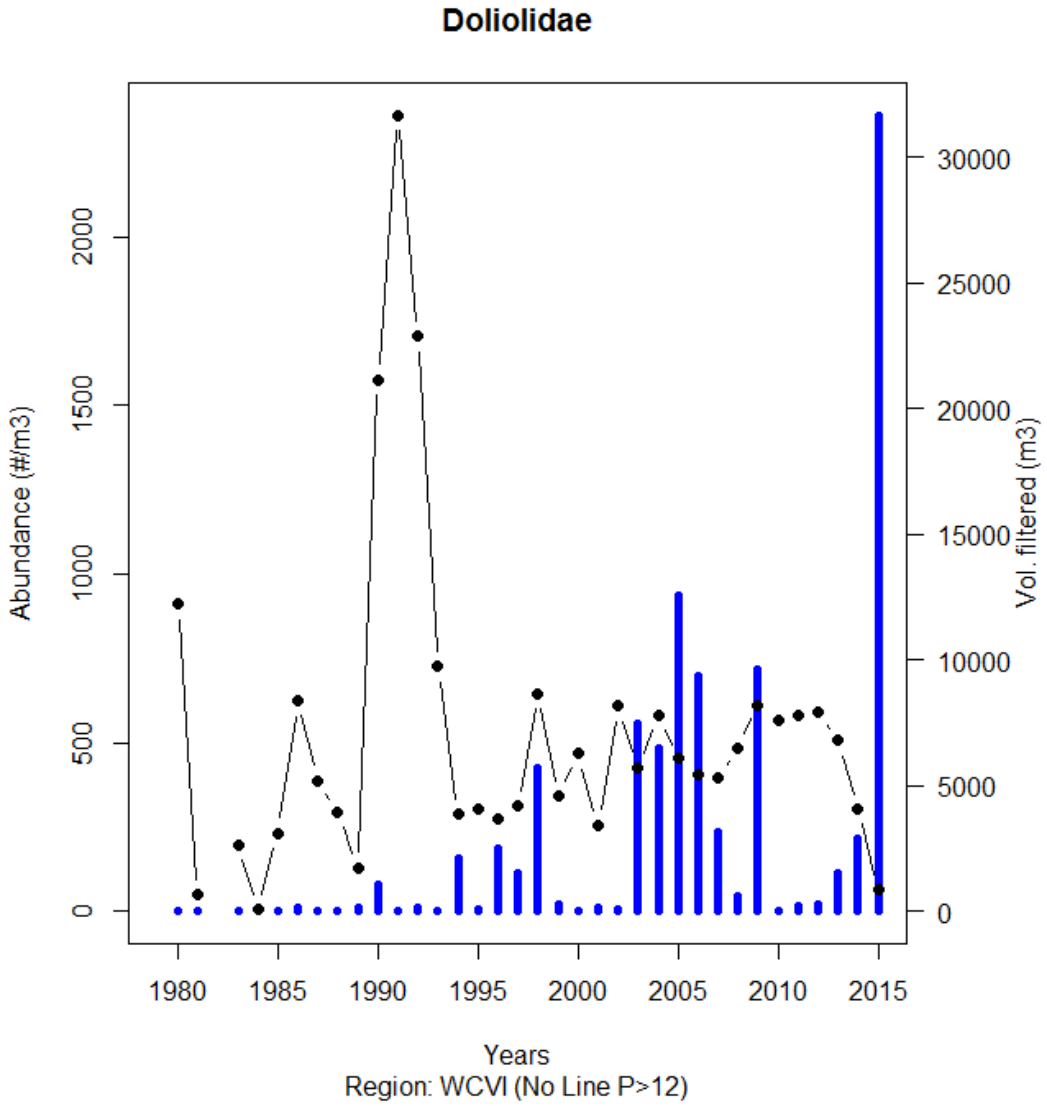

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Conclusions: Salmon & Environment Interactions in Marine & Freshwater Ecosystems 2014-16 & Effects on Returns 2017-19

- Multi-year (2014-16) warm conditions ("Blob", El Nino) induce ecosystem changes in the eastern rim of the Pacific.
- 2016 returns revert to north-south "reciprocal-production pattern" for major sockeye populations in eastern Pacific rim .
- Pacific food-web changes in 2014-2016 may have induced well above average chum salmon returns in southern BC.
- Impacts of warm ocean in 2015 and El Nino in 2016 suggest survival unfavourable conditions for central-to-south coast salmon in those years so expect continuation of below average adult returns in 2017 for southern sockeye populations.
- Impacts of winter freshets, summer drought in 2015 in southern watersheds may reduce salmon fry & smolt production in 2016-2017 and adult production in 2017-19.