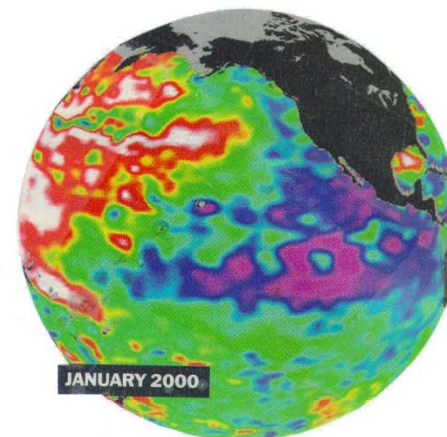
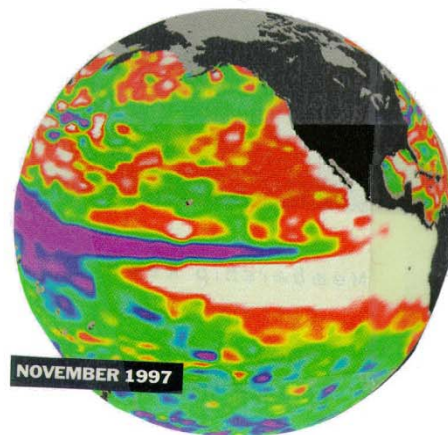


A Sample of Climate Change Impact & Adaptation Response Issues for B.C. Fish & Fisheries

Kim D. Hyatt

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Pacific Biological Station, Nanaimo, British Columbia.**



Outline for this talk

1. “Thumbnail sketch” of signature effects of climate variation and change on fish and fisheries through the lens of my own research on Pacific salmon.
2. Identify some key areas of vulnerability of fish and fisheries to climate change effects.
3. Brief comments on approaches to climate & fisheries science.
4. A suggestion for a shift in the emphasis of current research.

Freshwater and Marine Resources:

Constitute fundamental components of communities of place in all regions of North America:

Annual Economic Value

- Ocean Resources Sector: greater than \$200 billion
- Recreational Fisheries in Freshwater and Marine Contribute: \$70 billion
- Commercial Fisheries Processing Exports: \$41 billion
- Rapidly Growing Aquaculture Sector Contributes : \$6 billion

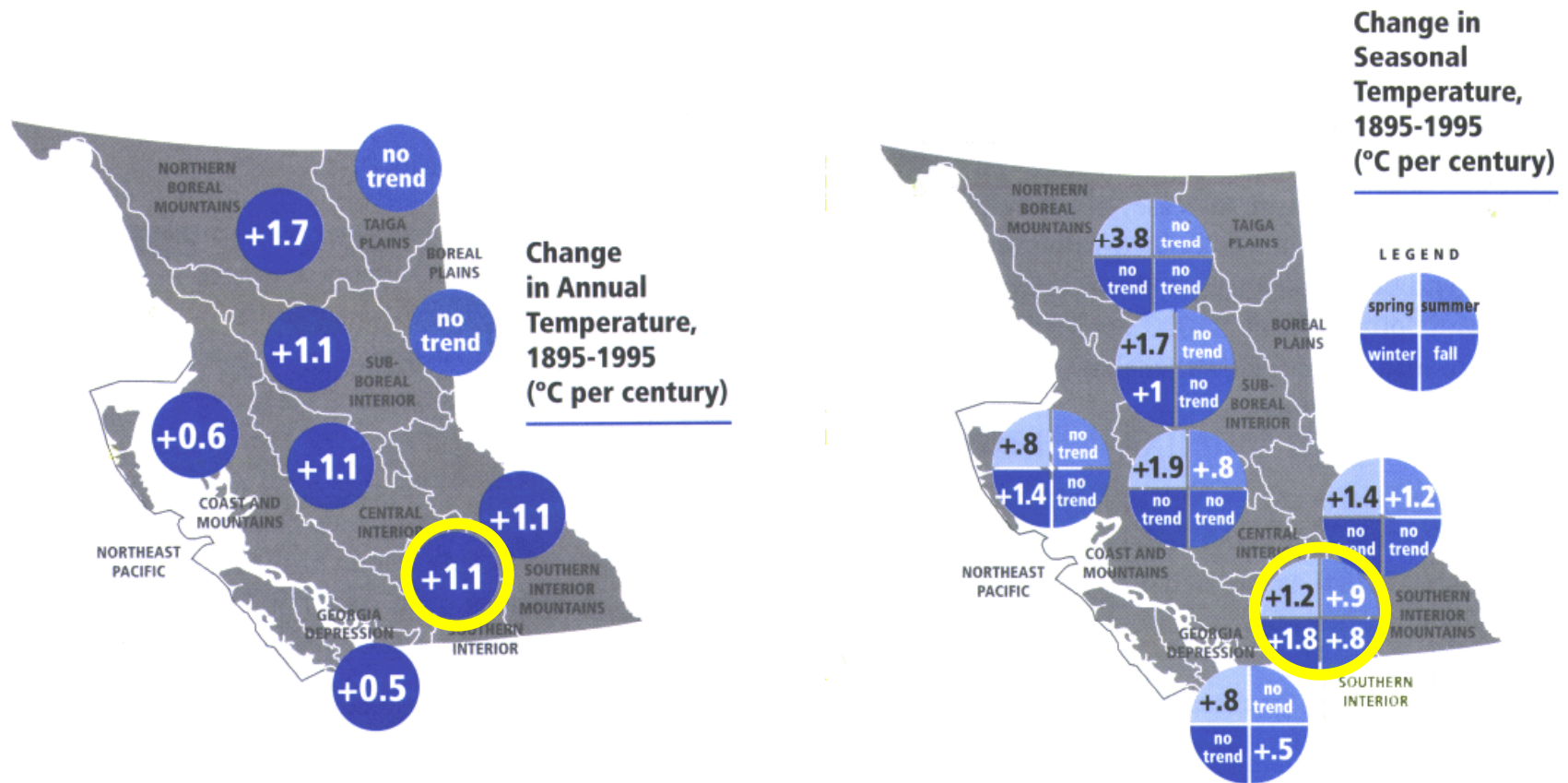
Community

- 90-100 million North Americans live in coastal areas but fisheries of one type or another are important to all.
- Fish and fisheries are integral components of the lives and cultures of both Indigenous peoples' and many non-indigenous local communities in rural areas.

Climate change impacts on Freshwater and Marine Ecosystems

- **CVC events:** have a dramatic impact on freshwater and marine ecosystems.
- **Climate Change Impacts include:** rising sea levels, changes in temperature, reduced permanent ice, increased coastal erosion, changes in ocean circulation, increased frequency of extreme weather events, changes in river flow and lake levels.
- **Climatic factors strongly influence:** habitats in freshwater and marine ecosystems along with the health, distribution, and abundance of the fish in them.
- **Signature Effects of CVC:** should be common and will have dramatic impacts on fisheries resource productivity.

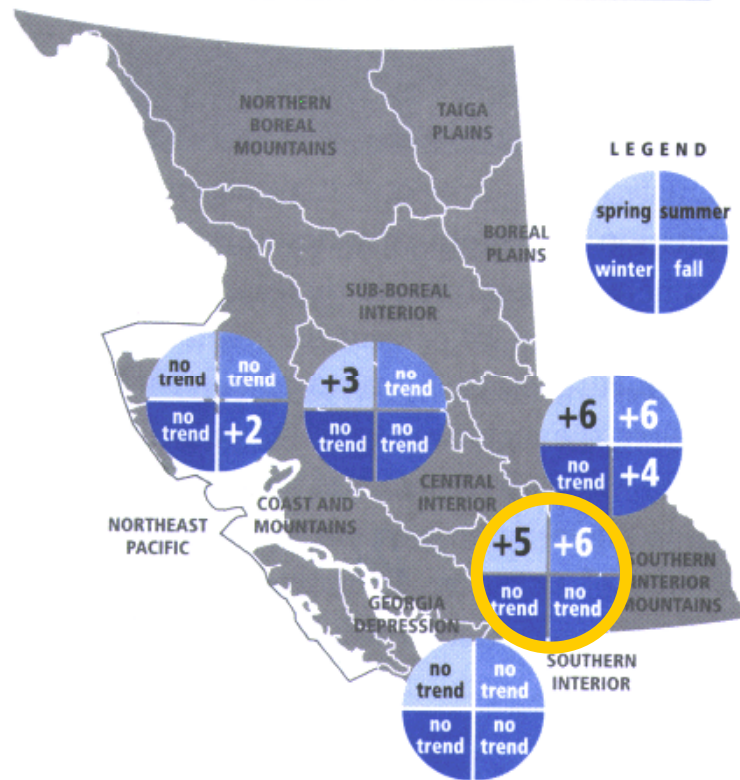
Signature Effects of Climate Change in the Pacific are Readily Detectable



Air, freshwater and sea surface temperatures have all exhibited trends to increase in the Pacific over the past 100 years.

Signature Effects of Climate Change in the Pacific

Change in Seasonal Precipitation,
1929-1998 (% per decade)

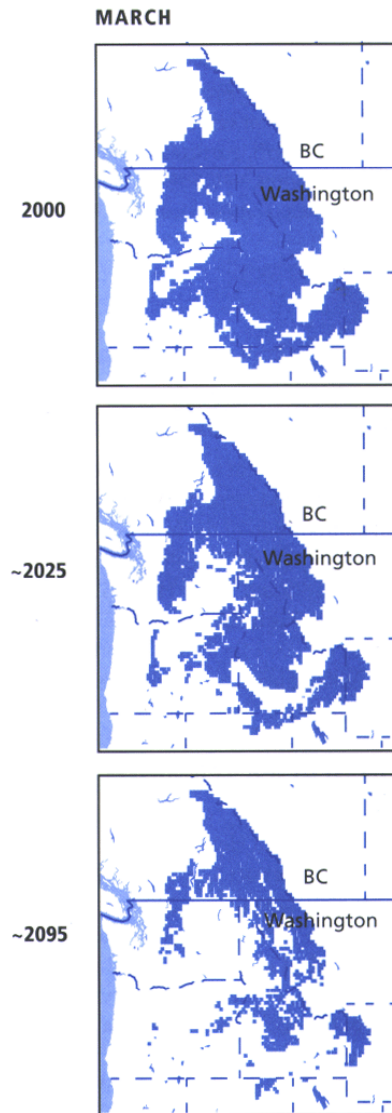


Average precipitation has increased by 3% per decade in the B. C. Southern Interior with most change occurring during spring and summer.

GCM and Regional Climate Models Project Many Changes for Watersheds & Freshwater Ecosystems:

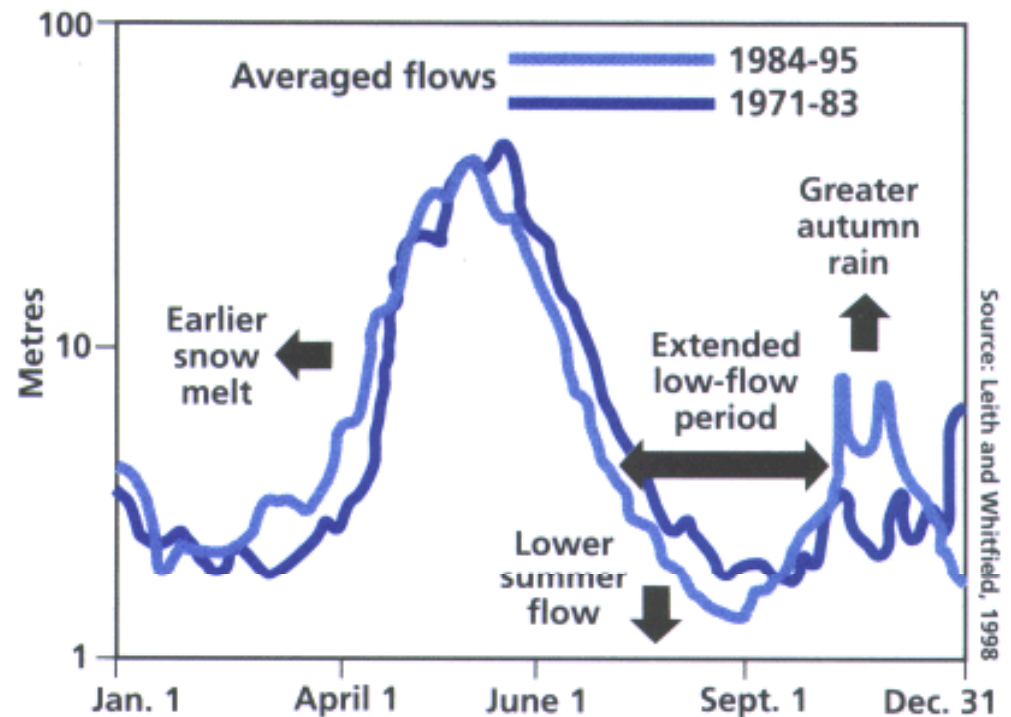
(1) Regional Snow pack

Joint Institute for the Study of Atmos. & Ocean, U of Washington



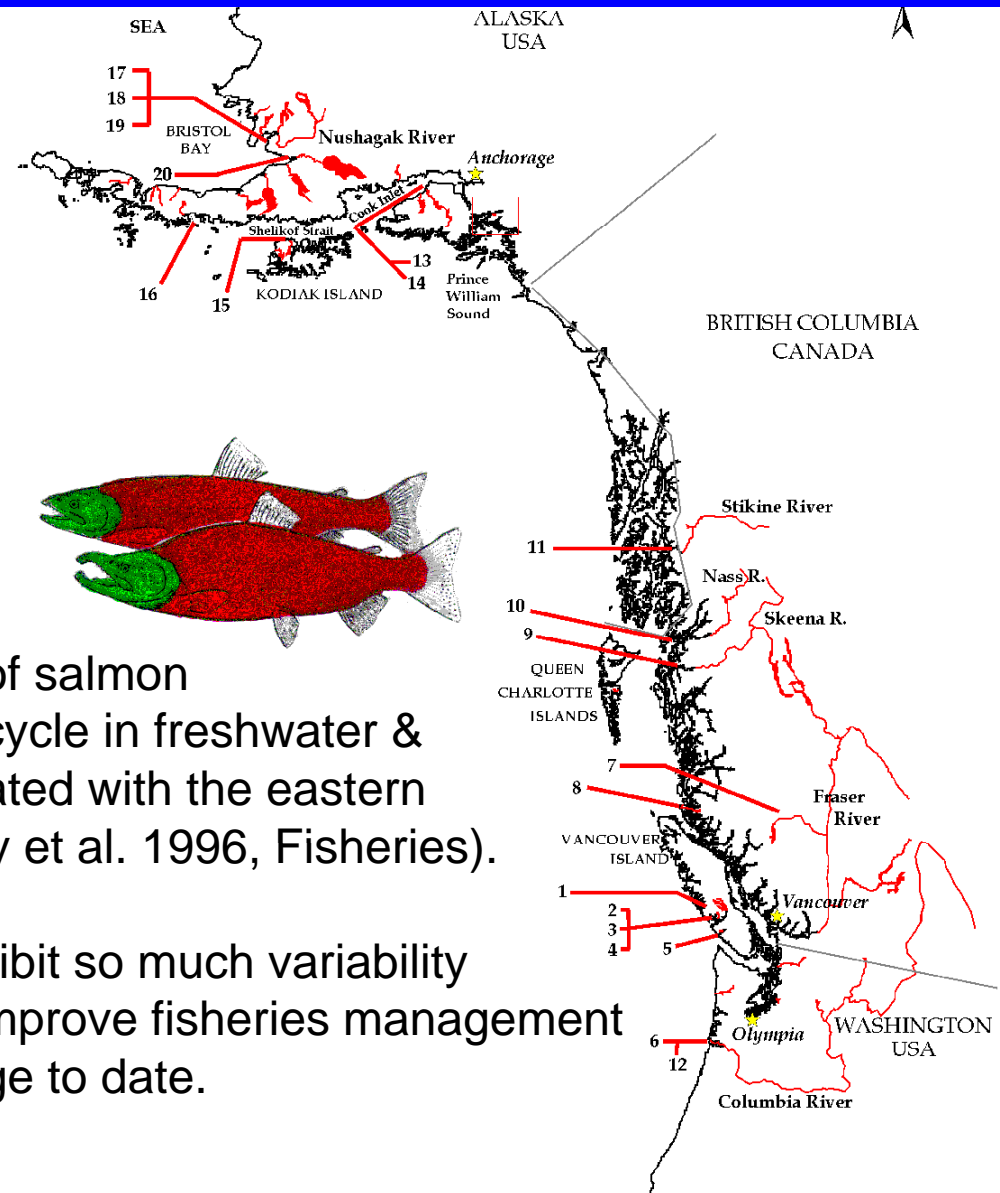
(2) Flow Timing and Variability in Snow-fed Rivers (*Leith and Whitfield, 1998*)

Upper Similkameen River



(3) Changes to Seasonal Thermal Regimes in Freshwater Lakes, Rivers and Streams

Pacific Rim Anadromous Salmon Stocks are Likely to be Especially Sensitive to Climate Change Effects due to Complex Life Histories

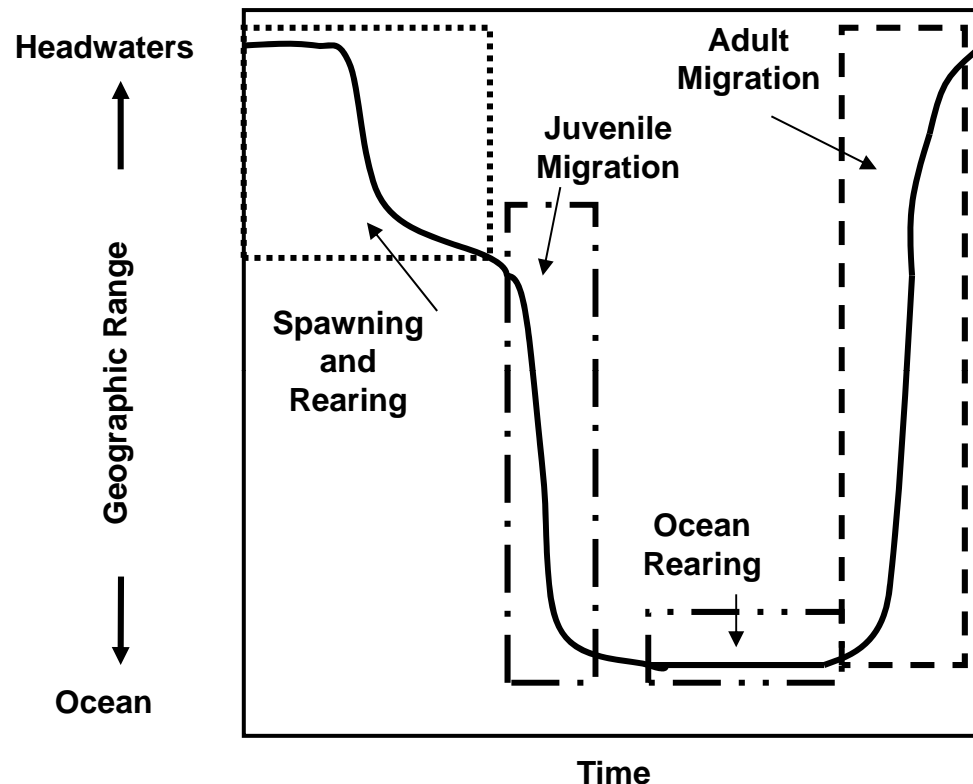


Thousands of populations of salmon spend portions of their life cycle in freshwater & marine ecosystems associated with the eastern rim of the N. Pacific (Slaney et al. 1996, Fisheries).

CVC effects on salmon exhibit so much variability that general guidelines to improve fisheries management have largely failed to emerge to date.

Salmon are Keystone Species as Cultural Icons, Economic Drivers, Indicators of Ecosystem Integrity, and Ecosystem Drivers

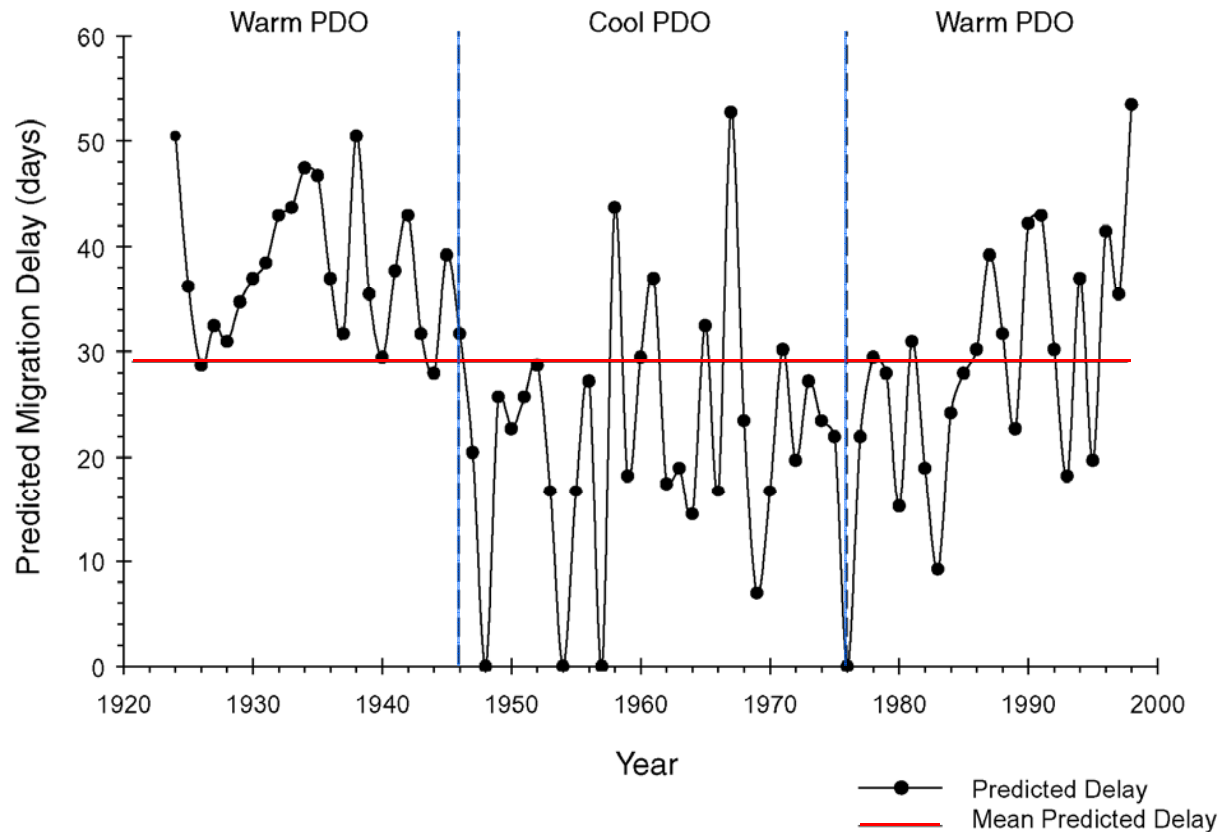
- Salmon life histories and the ecosystems they occupy are complex (rivers, lakes, estuaries, oceans).
- Climate change is expected to affect outcomes in each life-stage and ecosystem salmon occupy.



- Current knowledge is sufficient to identify some production trends & consequences For fish and fisheries on both spatial & temporal scales.

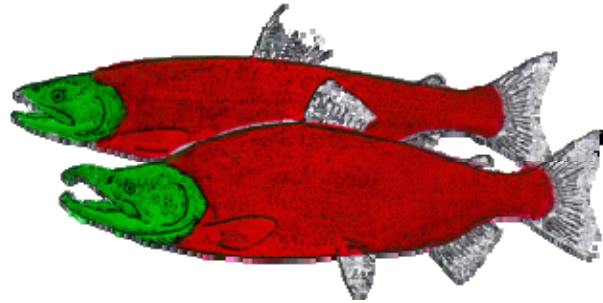
Temperature-based estimates of adult sockeye migration delays 1924-1998 (Hyatt et al. 2003)

Adult sockeye migration delay based on seasonal changes in water temperature of the Okanagan River



The magnitude of migration delays (0-72 days) alternate with PDO cycles & have been increasing steadily in association with climate warming during 1985 - 2000 compared with lesser delays in the “cool” 1947-1985 interval.

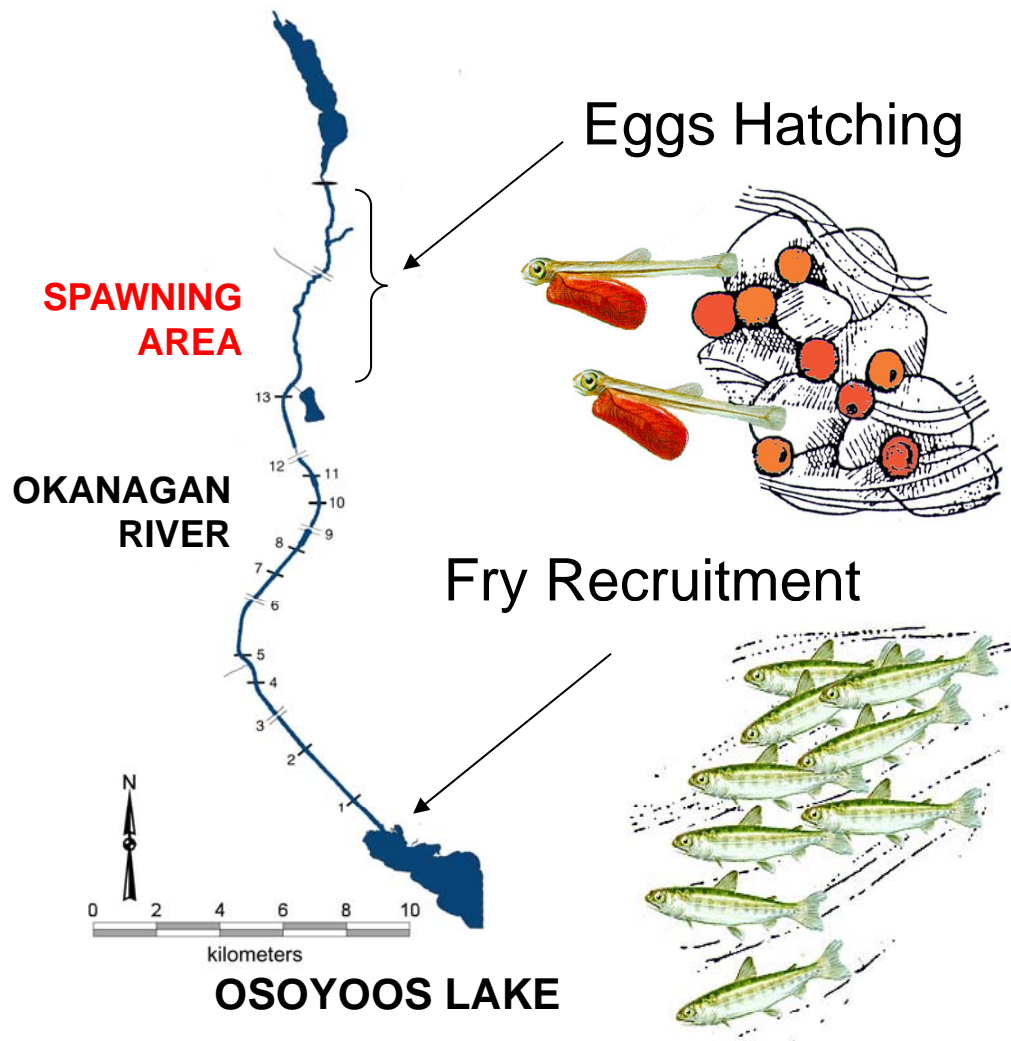
Okanagan Adult Sockeye Average Peak Spawn Date



“Cool” Period 1947 - 1985	“Warm” Period 1985 - 2000
October 11th (Oct. 3 - Oct. 19) n = 11	October 19th (Oct. 10 - Oct. 24) n = 12

- peak spawning by adult sockeye has been delayed, on average, by 9 days during recent “warm” interval

ATU Model “Rules” Used to Estimate Hatch & Emergence Dates for Okanagan Sockeye Eggs and Fry

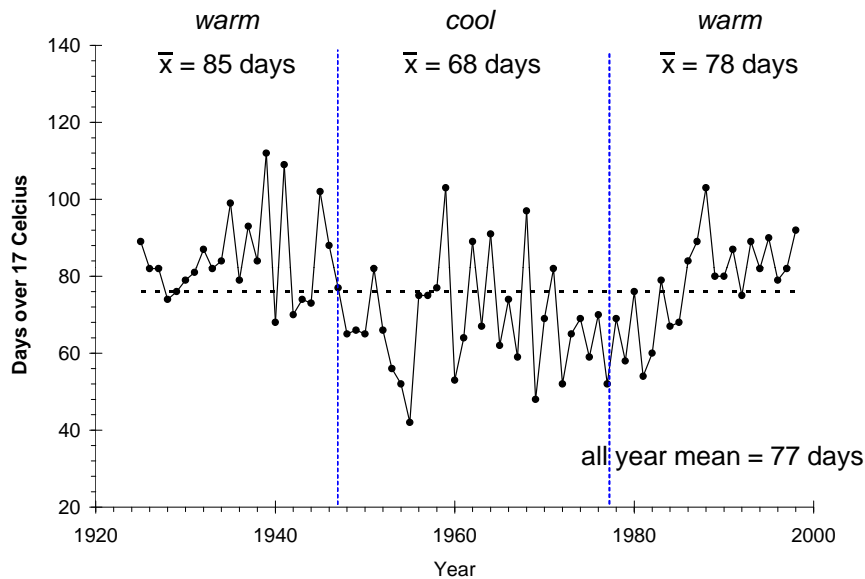


“Cool Period” 1947-1985	“Warm” Period 1985-2001
Peak Hatching Dates	
Feb. 16 Dec. 03 – Apr. 09 n = 10*	Mar. 03 Feb. 05 – Mar. 26 n = 11*

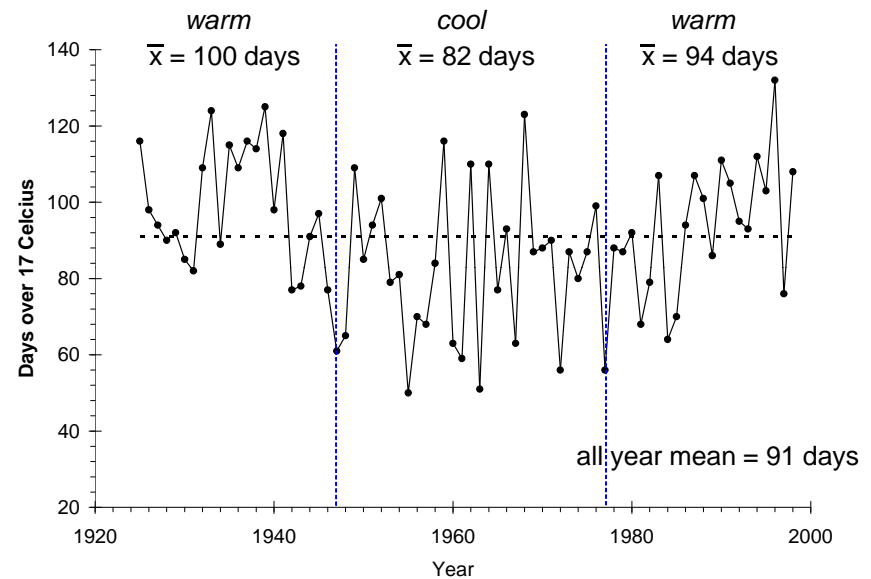
On average, 100% hatch date is delayed by 15 days during warm intervals (i.e. 1985-2001) relative to cooler intervals (i.e. 1947-1985).

17 °C “Rule” Predictions of Number of Days Juvenile Sockeye are Excluded from Surface Waters of Osoyoos (B.C. Interior) and Great Central (Vancouver Island) Lakes (1924 - 1998)

(a) Osoyoos



(a) Great Central

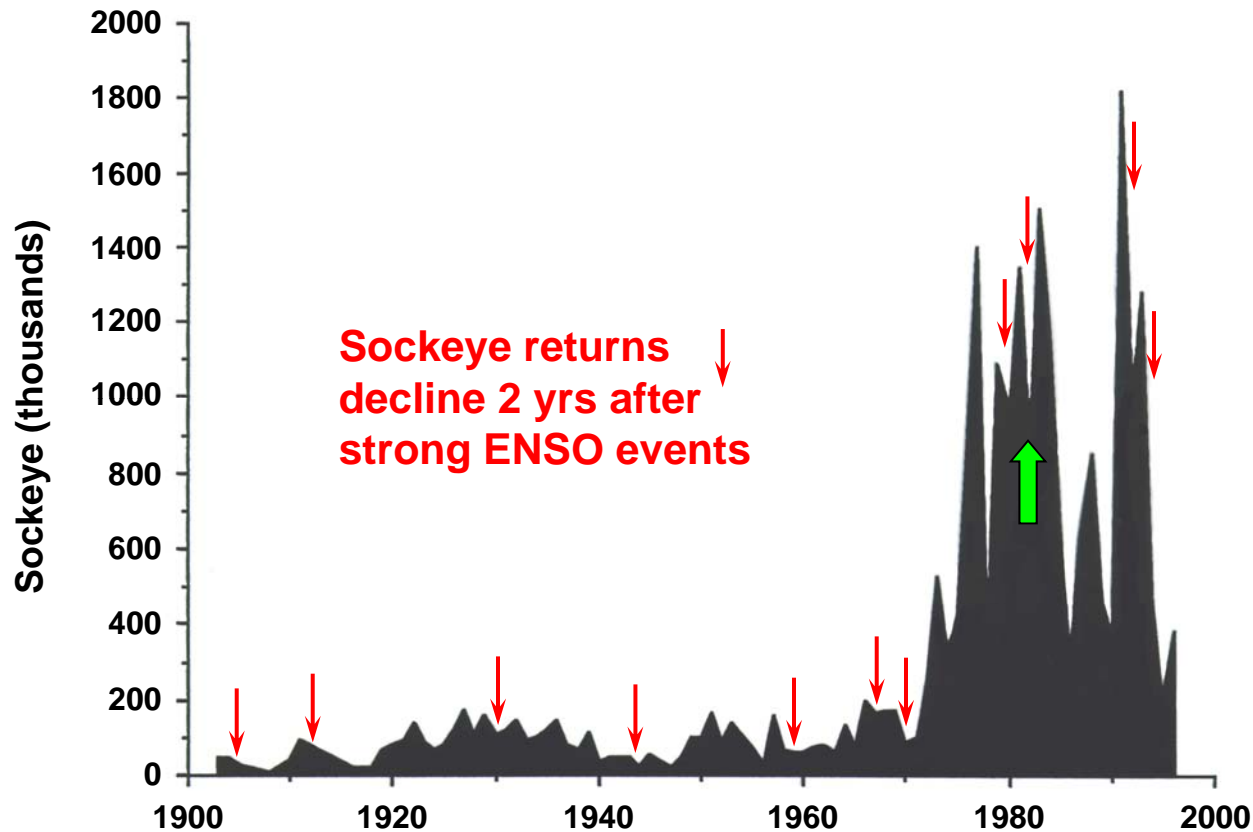


- temperature induced exclusions of juvenile sockeye from surface waters of two southern lakes range from 40 - 120 days per year & average 78 days per year.
- these effects are especially clear in Osoyoos Lake but are similar in distant locations suggesting a regional climate “driver” associated with PDO cycles.

Climate-induced Migration Delays of Salmon in Freshwater Alone Create Serious Biological, Social and Economic Impacts.

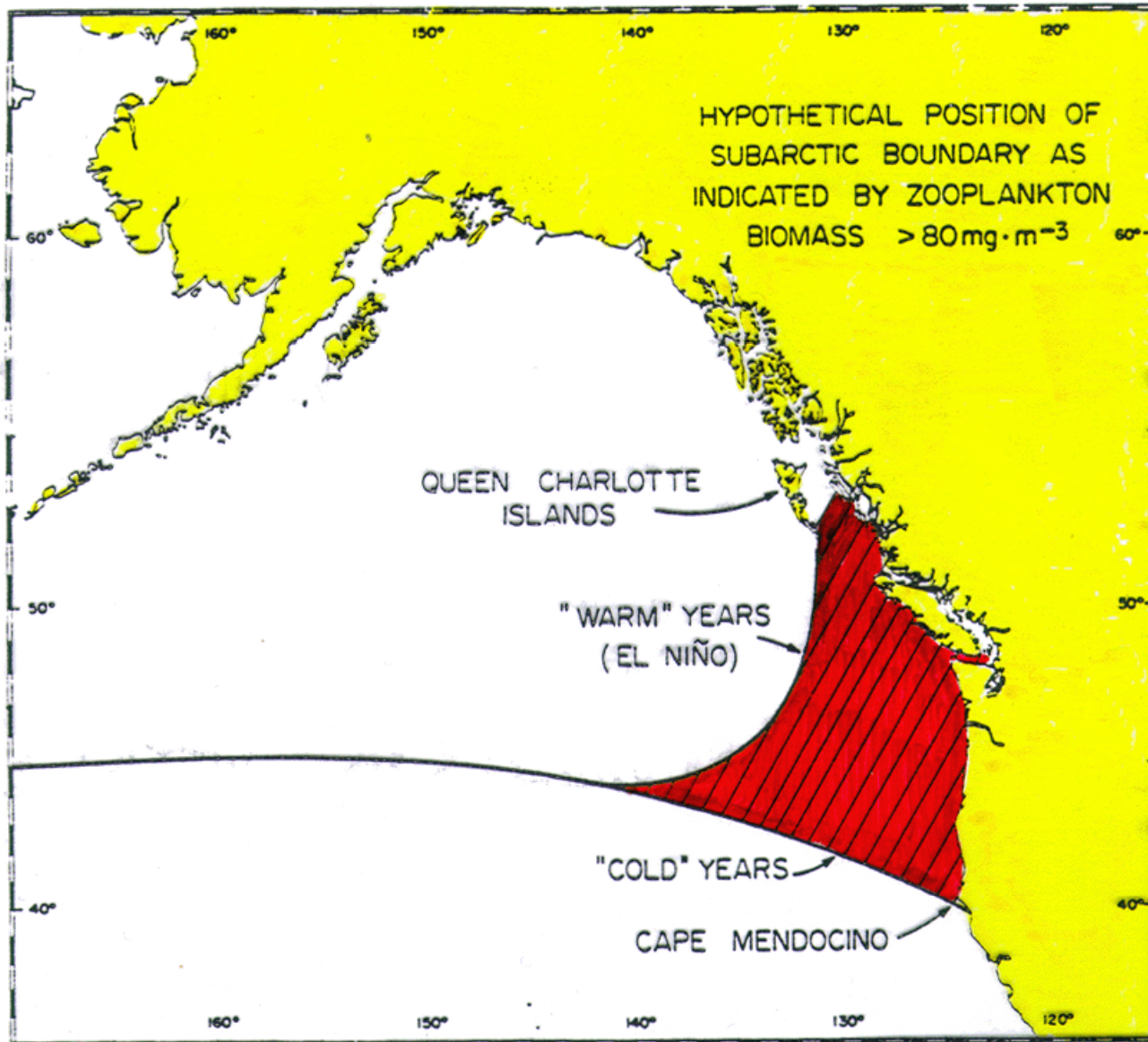
- 30 day delay given “warm” PDO equals time to migrate the entire 1000 km from the coast to upriver spawning areas for Okanagan sockeye. Migration delays reduce salmon “fitness” (MacDonald et al 2001).
- Migration delays alter access to early return fish by First Nation’s subsistence and ceremonial fisheries (Hyatt et al 2003).
- Migration deviations of between 28-42 days by major stocks of Fraser R. sockeye salmon were associated with mortalities representing losses of up to **\$72 million CDN in fishing industry losses during 2002 alone (Cooke et al. 2004, Fisheries 29: 22-33). 2004 & 2005 were probably worse.**

Pacific Marine CVC Events & Barkley Sound Sockeye Return Variations (Hyatt et al 1996)



- returns exhibit two multi-decadal, production “regimes” (i.e. low & high average production)
- lots of within decade variation to complicate harvest management

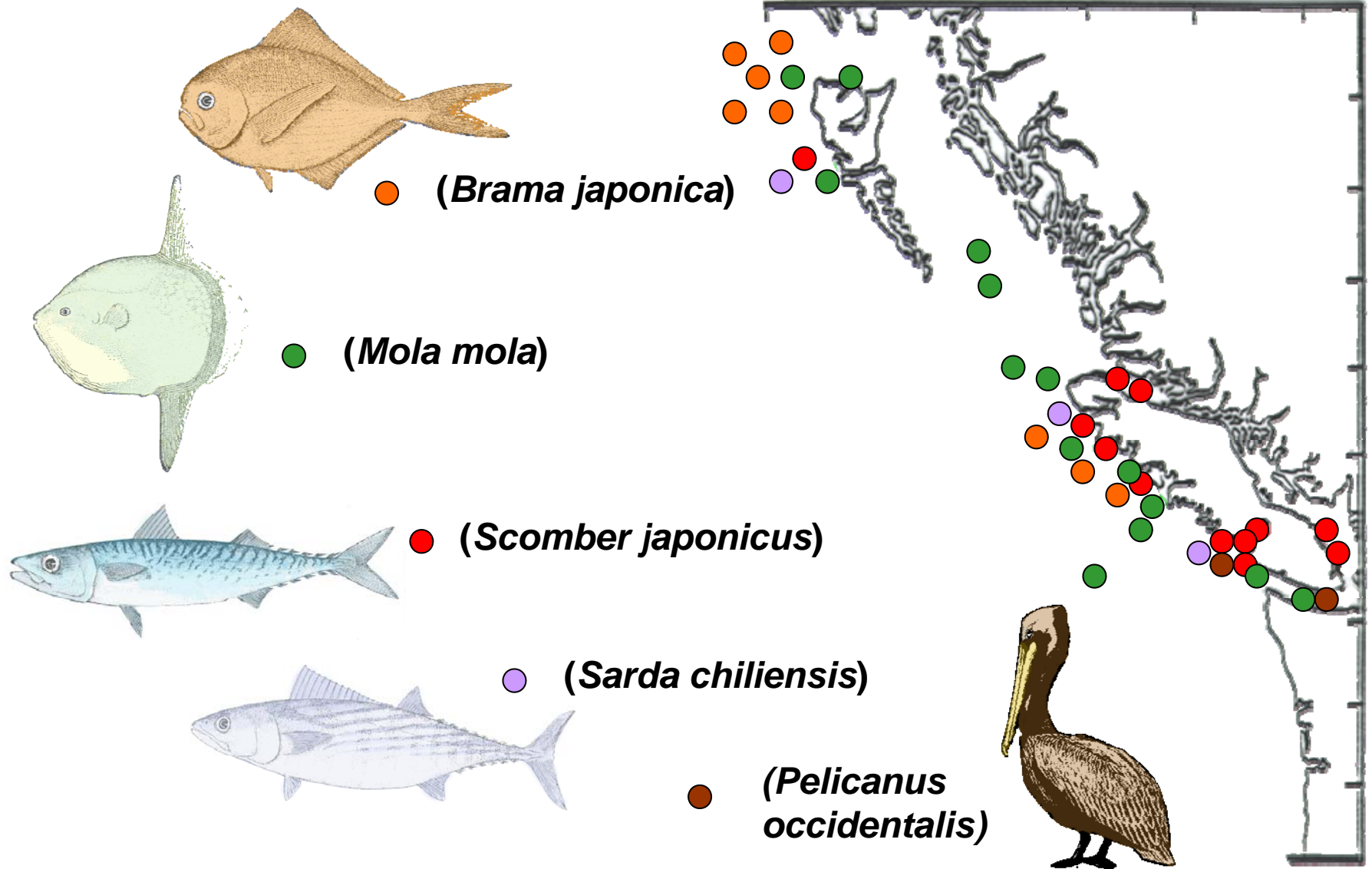
Barkley Sound sockeye are especially sensitive because of their transitional zone location over which the subarctic domain has a varying influence (Fulton and LeBrasseur 1985)



Strong El Niño-La Nina events induce major changes in continental shelf ecosystems.

Some of these changes alter ecosystem capacity to support "robust" salmon populations.

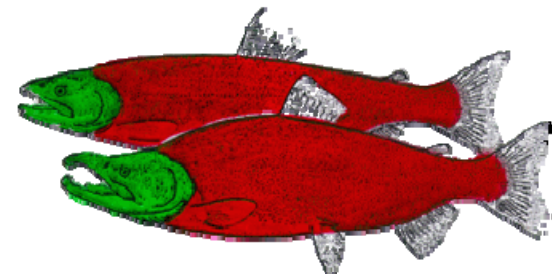
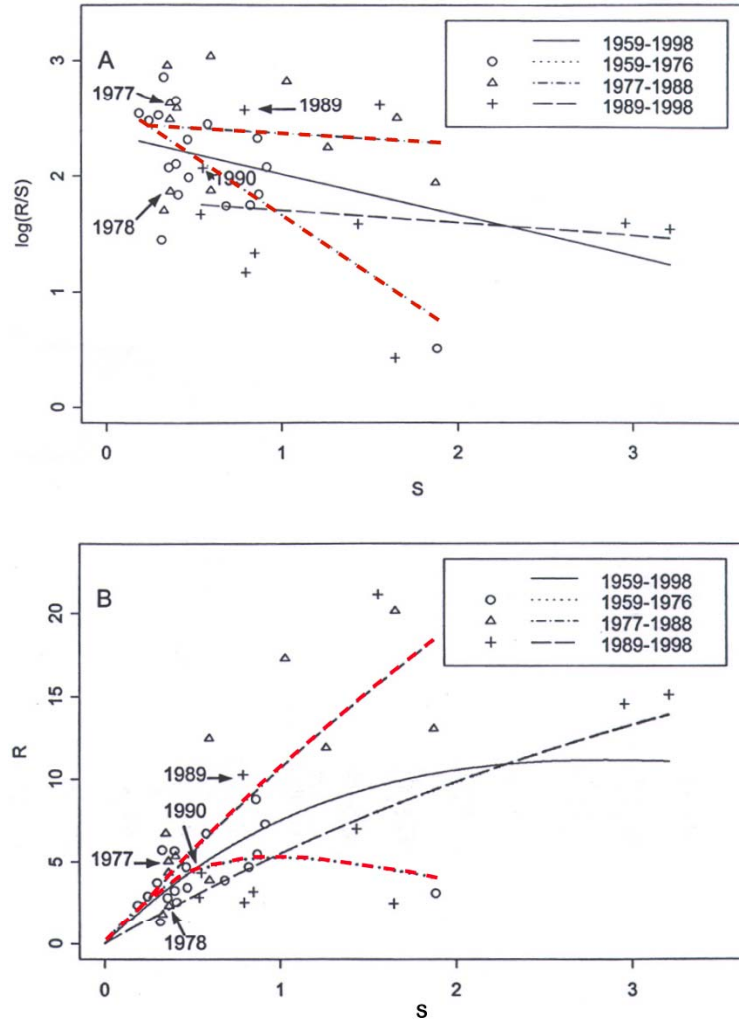
Exotic Species on the BC Coast in 1983 & 2005 Suggest Ecosystem Reorganization (J. Fulton-83 & M. Trudel-05 P.B.S.)



Salmon Stock-Recruit Relationships are Not Stationary Under the Influence of Climate Change

Barkley Sound studies suggest reasons salmon stock-recruit relationships are unlikely to be stationary.

Beamish et al (TAFS 2004) recently showed that stock-recruitment relationships of Fraser River pink and sockeye salmon improve when data are partitioned by climate and ocean regimes.



Some Impact Predictions for Pacific Salmon are Nothing Short of Apocryphal !

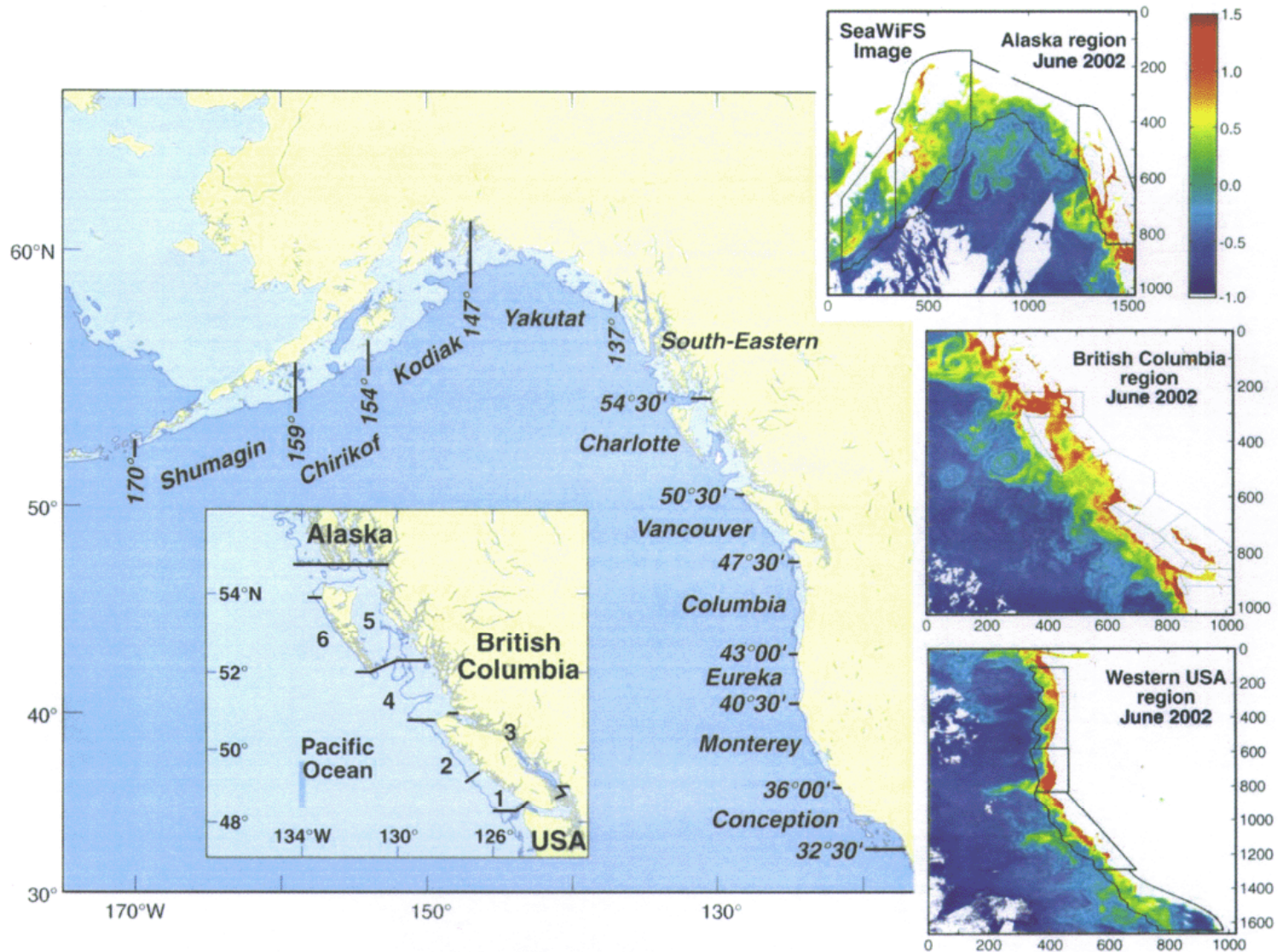
Welch et. al., (1998) have suggested sockeye might be forced from the North Pacific and Alaska Gyre into the Bering Sea in summer given a doubling of atmospheric CO₂ and accompanying warming.

***Projected southern limit
of sockeye salmon
under a doubling of
impact climate change
scenario***

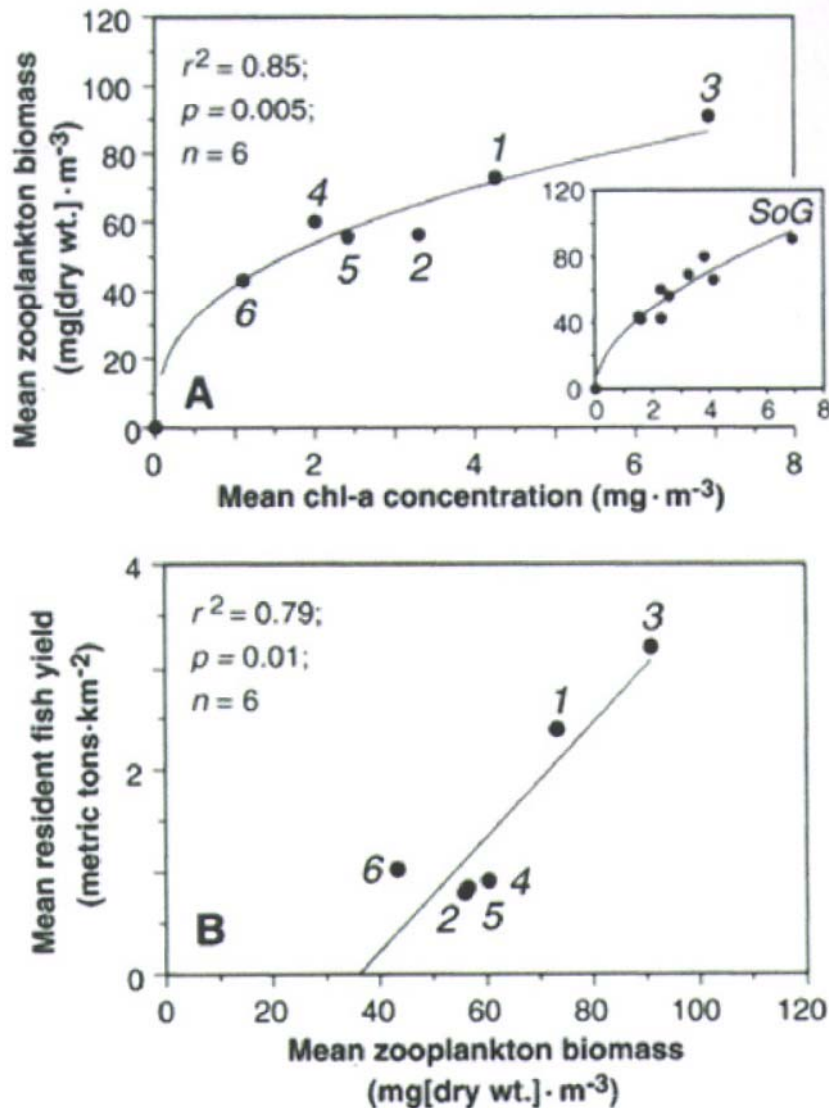
***1995 southern limit of
sockeye salmon
distribution***



Ware & Thomson (Science 2005) recently examined “production” variations at successive trophic levels from plankton through to resident fish on the continental shelf in the eastern Pacific



Indices of production from phytoplankton to zooplankton & resident fish appeared to be dominated by “bottom-up” processes along the continental shelf in the eastern Pacific (i.e. no “trophic cascade”).

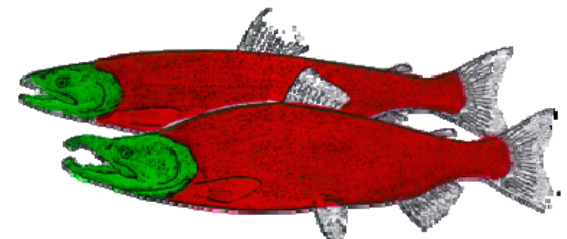


Strong associations between phytoplankton production (chl-a), zooplankton biomass and mean yield of resident fish suggest we should expect to see marine fish yield fluctuations as ocean “regimes” shift and primary producers respond under the influence of climate change.

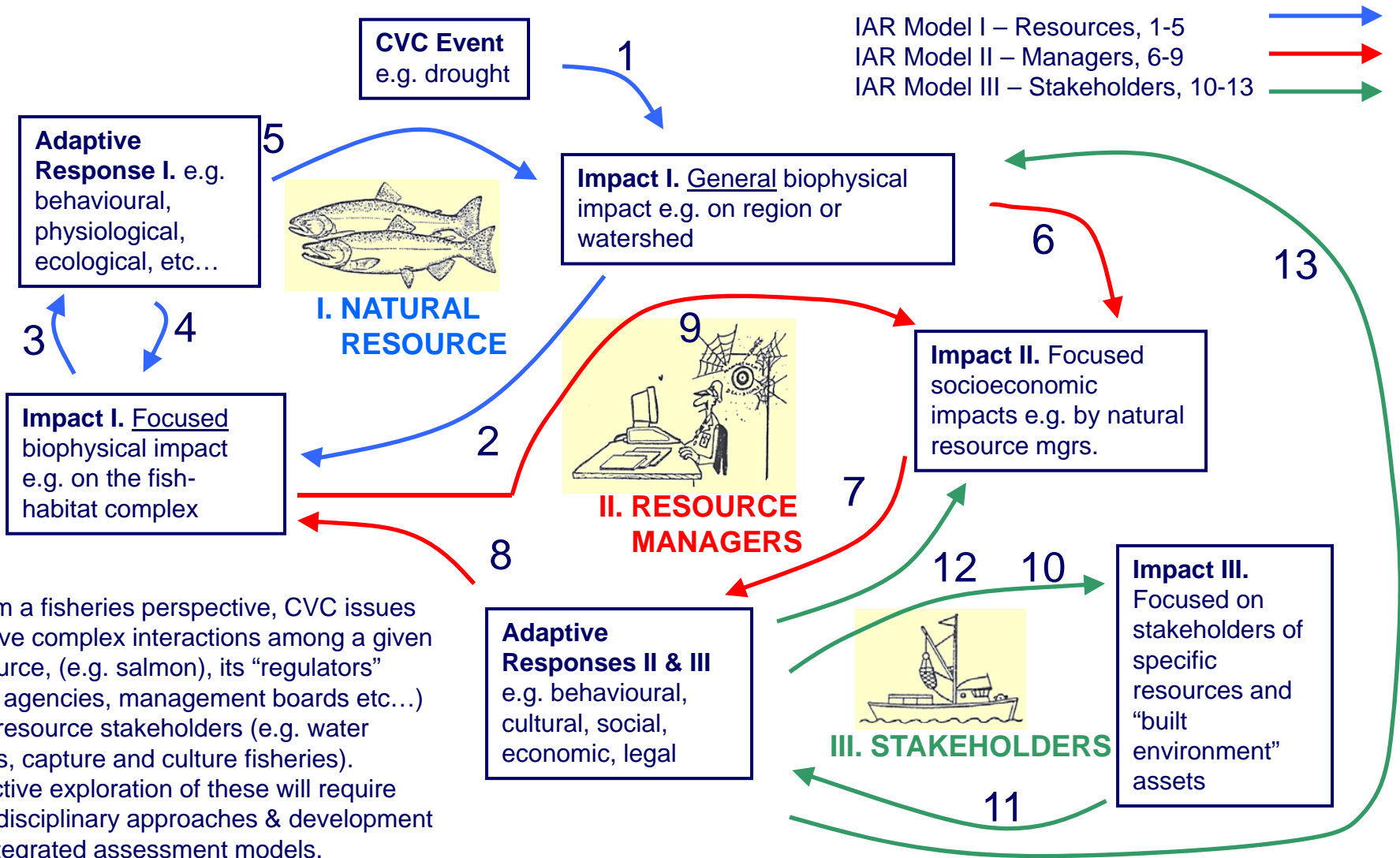
(Ware & Thomson, Science 2005)

Key Vulnerability Issues Will Force Us to Re-engineer Current Management Systems

- Conflicts provoked by ineffectual responses of highly vulnerable fisheries mgt. systems to climate-induced production trends outside of the historic (but not prehistoric) range of many species (e.g. Atlantic cod & Pacific salmon fisheries).
- Conflicts over water use in N. America to meet human needs versus ecosystem service needs (e.g. Klamath Valley-CA, Columbia Basin-PNW, Georgia Basin-BC).
- Conflicts over managing for biomass (of harvest) or biodiversity (e.g. species listings under US-ESA & CDN-SARA). Climate change effects may frustrate recovery efforts.
- Maintenance or establishment of “stable” food, ceremonial and societal (FCS) fisheries as part of treaty settlements with indigenous peoples may be difficult.
- Things that “go bump in the night” e.g. (i) disruption of thermo-haline circulation & massive ecosystem effects in Atlantic, (ii) elimination of nursery areas for salmon (Welch et al.), (iii.) reduced “venting” of deep waters in the NW-Pacific and consequences for E-Pacific shelf ecosystems, (iv) effects of invasive & exotic species on freshwater & marine ecosystems, and (v.) potential impacts of “acidification” of oceans on identity and functional properties of primary producers.

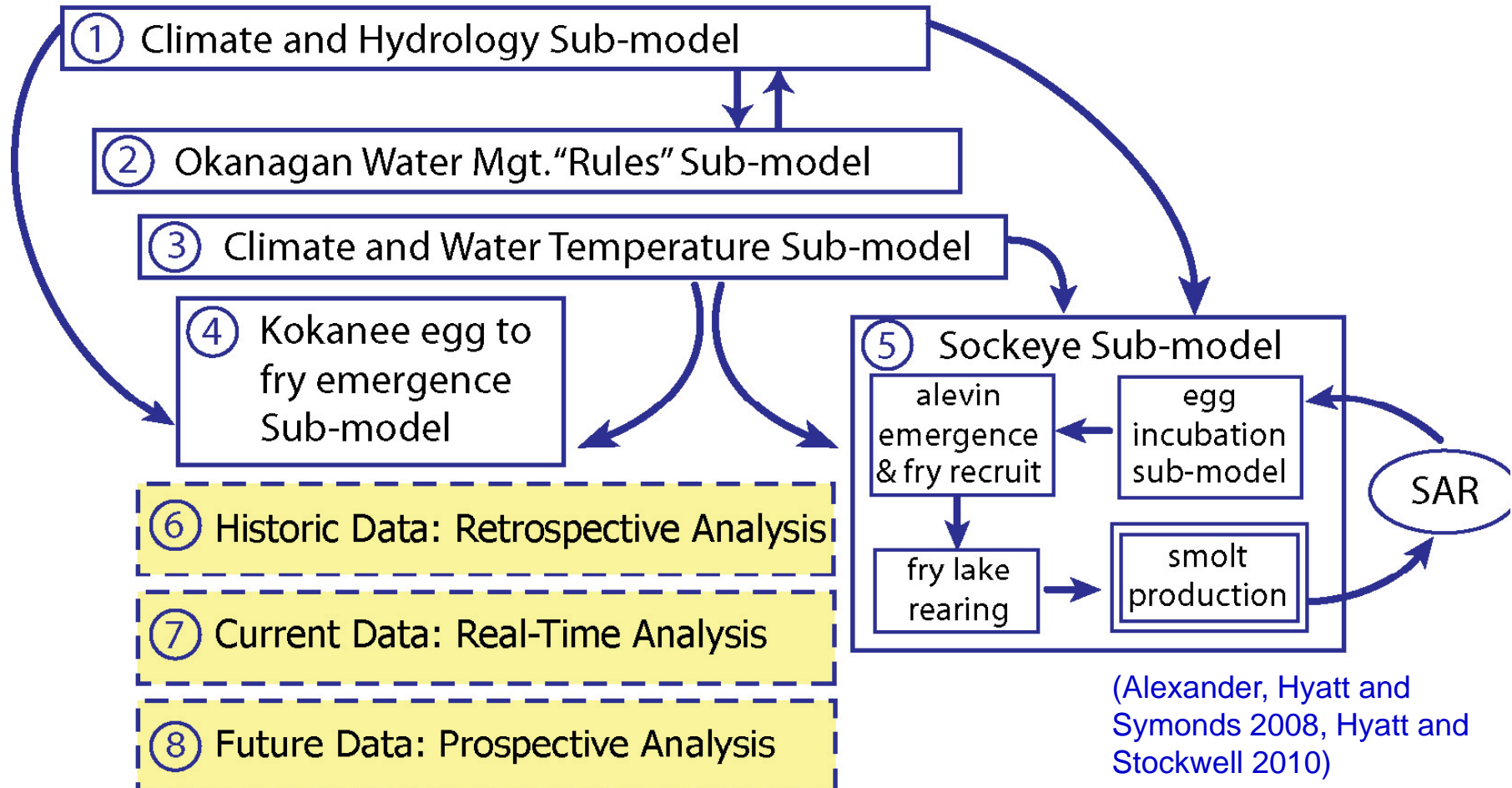


Integrated Assessment Models of Impact & Adaptation Responses (IAR) to Climate Variation & Change (CVC) Events Deal with More than just “Physics, Fish and Phytoplankton”



- from a fisheries perspective, CVC issues involve complex interactions among a given resource, (e.g. salmon), its “regulators” (e.g. agencies, management boards etc...) and resource stakeholders (e.g. water users, capture and culture fisheries). Effective exploration of these will require interdisciplinary approaches & development of integrated assessment models.

FWMT Decision Support System



FWMT is a coupled-set of 4 biophysical models of key relationships among climate, fish and water that interact with a 5th water-management rules model used to predict consequences of water management decisions for fish and other water users. FWMT software allows system users to explore water management decision impacts in near "real-time" (current-mode), historic intervals (retrospective-mode) or future intervals (prospective-mode) given data on water supplies, climate and fish population state(s) .

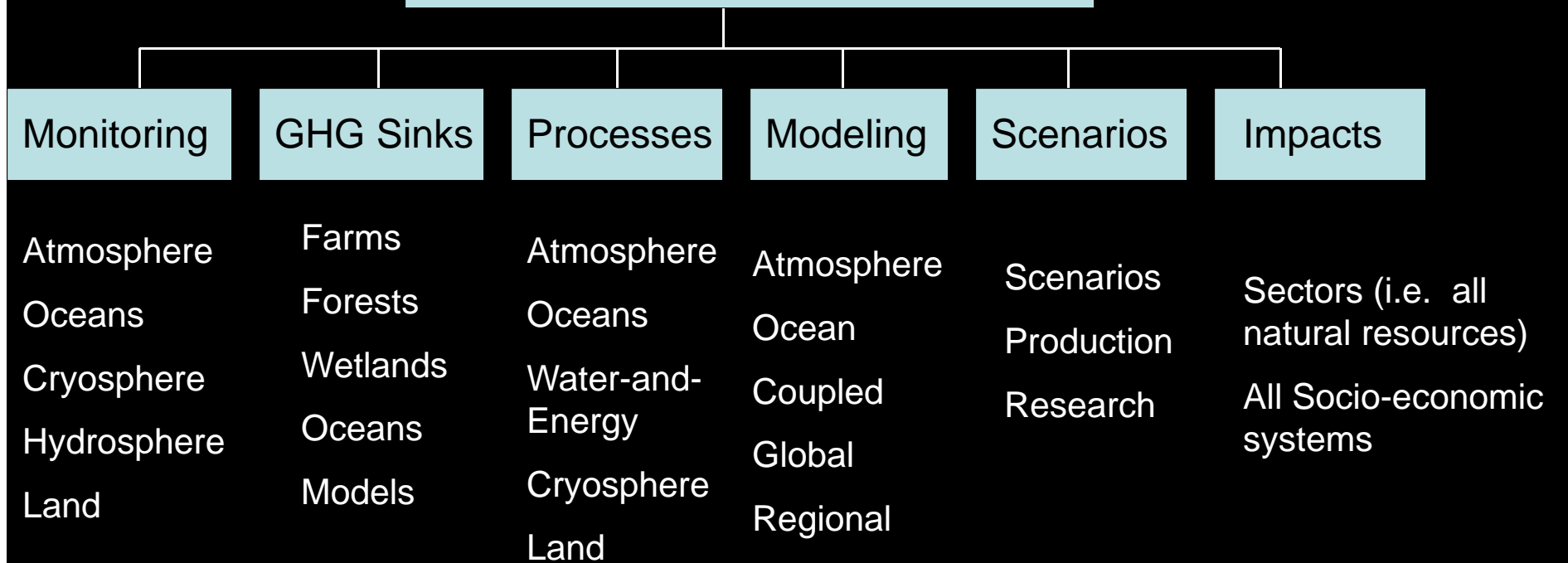
General Conclusion: The fisheries sector will survive but its makeup will depend on the magnitude of future climate impacts on the resource base and societal decisions about how to adapt to specific changes.

As climate induced effects on fisheries increase, societal pressure will build to implement various adaptations including:

- Reductions in harvest rates to provide stock conservation buffers to counter increased recruitment variations (already underway for west coast salmon fisheries).
- Reform regulatory and licensing systems to stabilize economic opportunities for licensees given increased fluctuations in the resource base (e.g. reverse century long trend of narrowing gear, species, space and time restrictions ?).
- Invest more heavily in hatchery production to maintain fisheries despite declining productive capacity of freshwater ecosystems (e.g. BC southern interior and Georgia Basin)
- Engineer and regulate water supply systems to meet water quality and flow requirements (e.g. southern BC including Fraser River)
- Promote even more rapid development of aquaculture to meet increasing market demands despite increased variability of wild product in capture fisheries.

Where have we been going with development of CVC Science to inform resource management ?

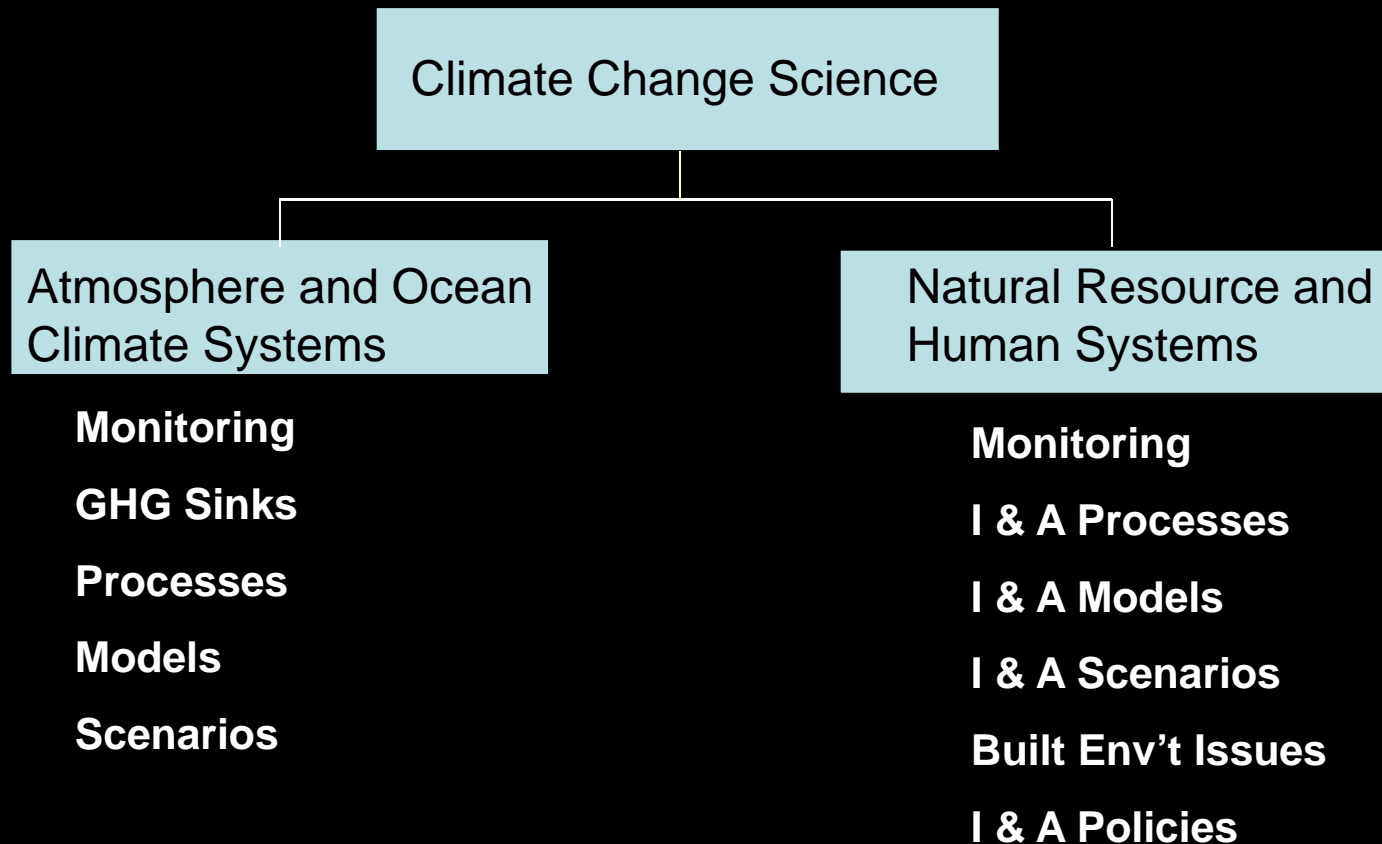
Draft Climate Change Science Plan



More “physics and phytoplankton” i.e. a cont’d emphasis on the physics & biophysics of atmosphere & ocean climate systems (i.e. 5 of 6 FCCSP thematic streams focus on this)

Short shrift to sectoral impacts & adaptation ?

Suggestion for a more balanced approach to “Fisheries” CVC Science (C-CIARN Fisheries NAC, May 1, 2004)



A shift in emphasis is required if we're to develop “fisheries” climate science to effectively explore impact and adaptation outcomes to solve problems in “large interactive natural resource and human systems” ! The current pace of climate change will impose greater penalties if we delay.

Thank You !

www.fishclimate.ca

