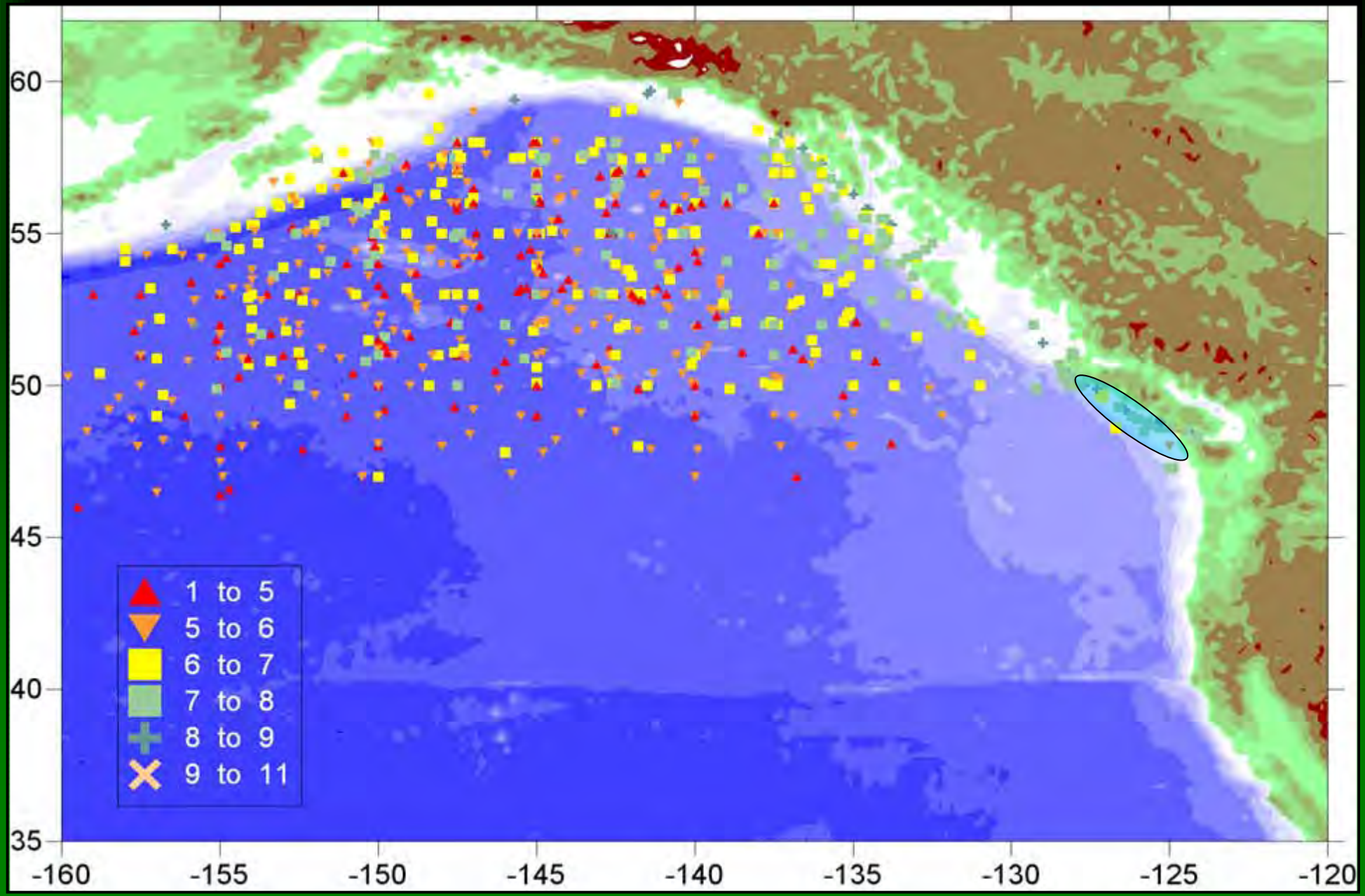
Evolution’s challenge to modeling sockeye salmon spawning migration

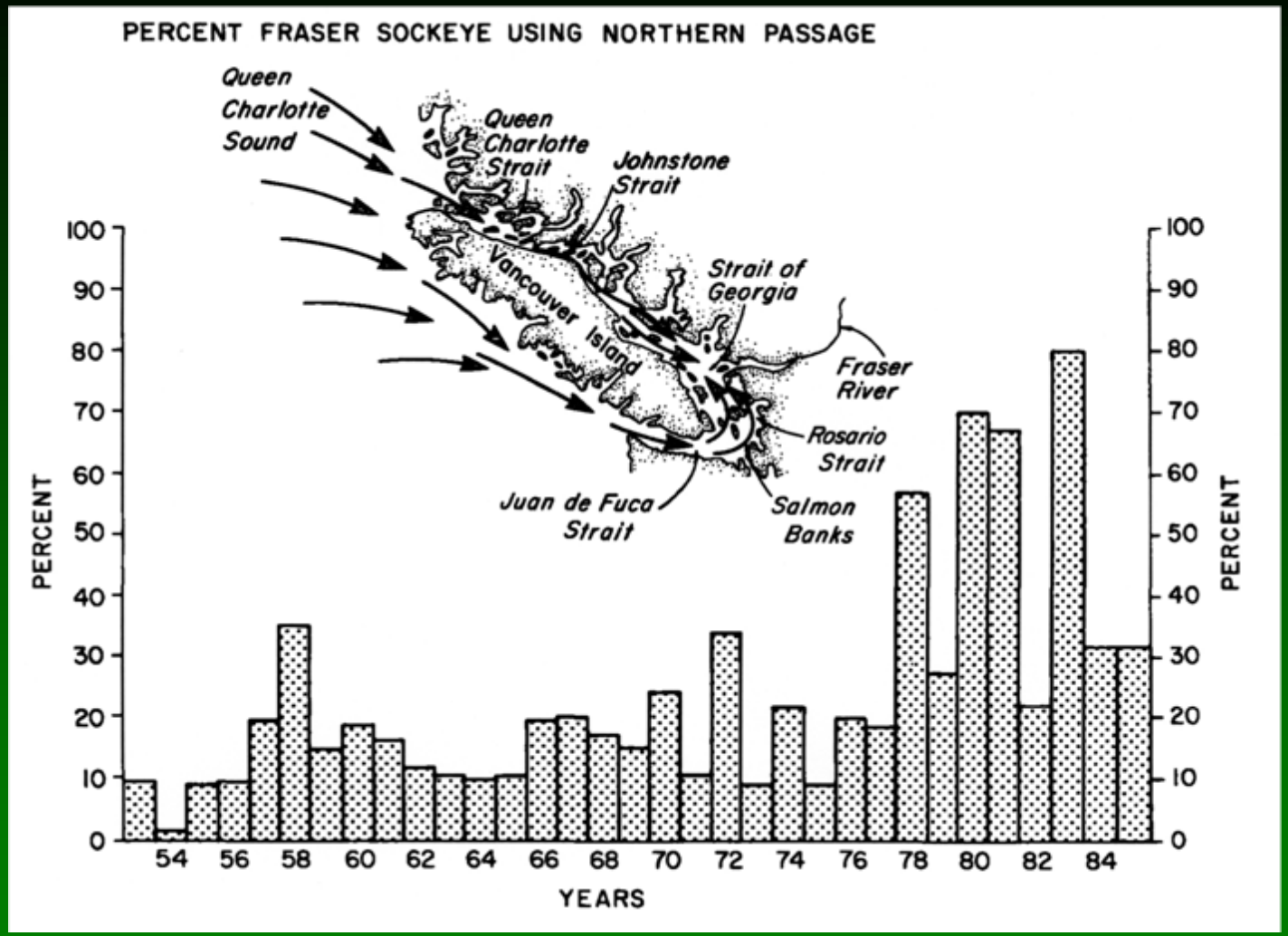
Sockeye salmon life history

- Fall spawners
- Egg
- Alevin (in gravel)
- Fry (1-4 y in lake)
- Smolt (physiological)
- Postsmolt
- Immature (1-4 y at sea)
- Adult

I.N.P.F.C. High Seas Tagging



Oceanic phase of Fraser River spawning migration

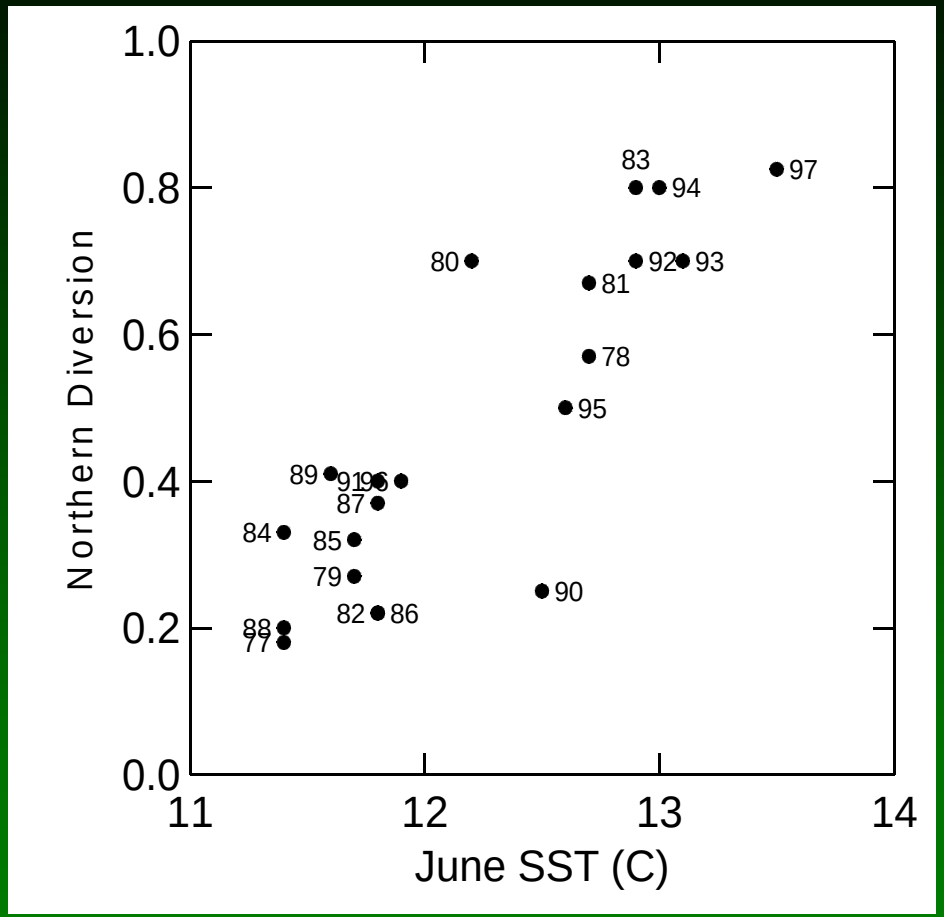


Groot & Quinn 1987

Wilbert A. Clemens, 1937

The small catch in 1936
in the Strait of Juan de Fuca
and the large catch in the Johnstone
Strait area was puzzling.

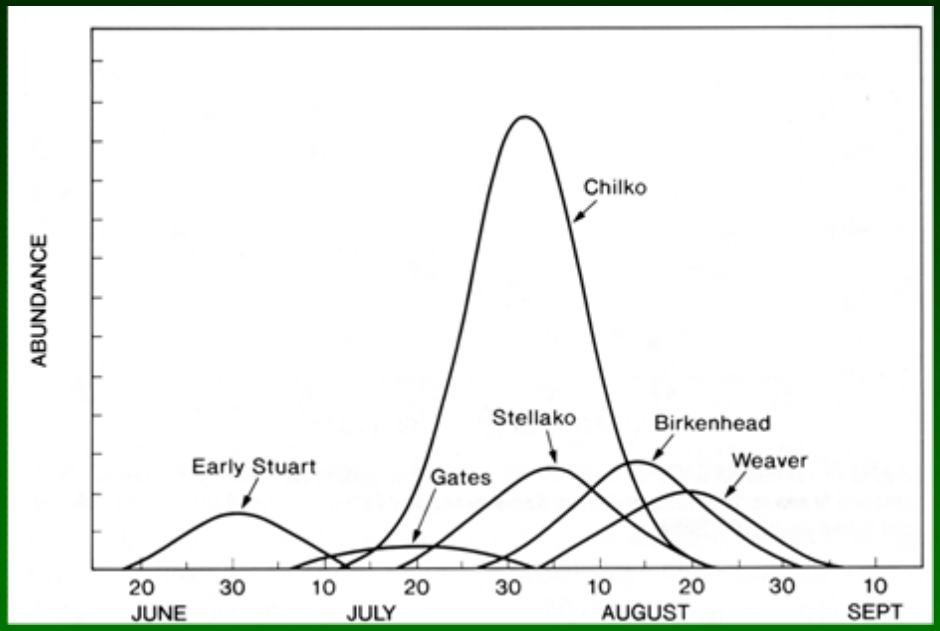
Migration route and SST



- Migration route around Vancouver Is. is determined annually by the oceanic environment.
- Either affects the route directly, or is a strong proxy for what is determining the route (e.g. oxygen conc. and SST are confounded)
- Prior to 1978, migration route was uncorrelated with SST!

McKinnell et al. 1999

Fraser River run timing



- Many spawning populations
- Order of annual arrival is predictable
  - e.g. those with furthest migration enter first
- Run timing has a strong genetic basis
- Reproductive isolation allows genetic selection to favour traits that confer higher fitness.

Figure from Roos (1991)

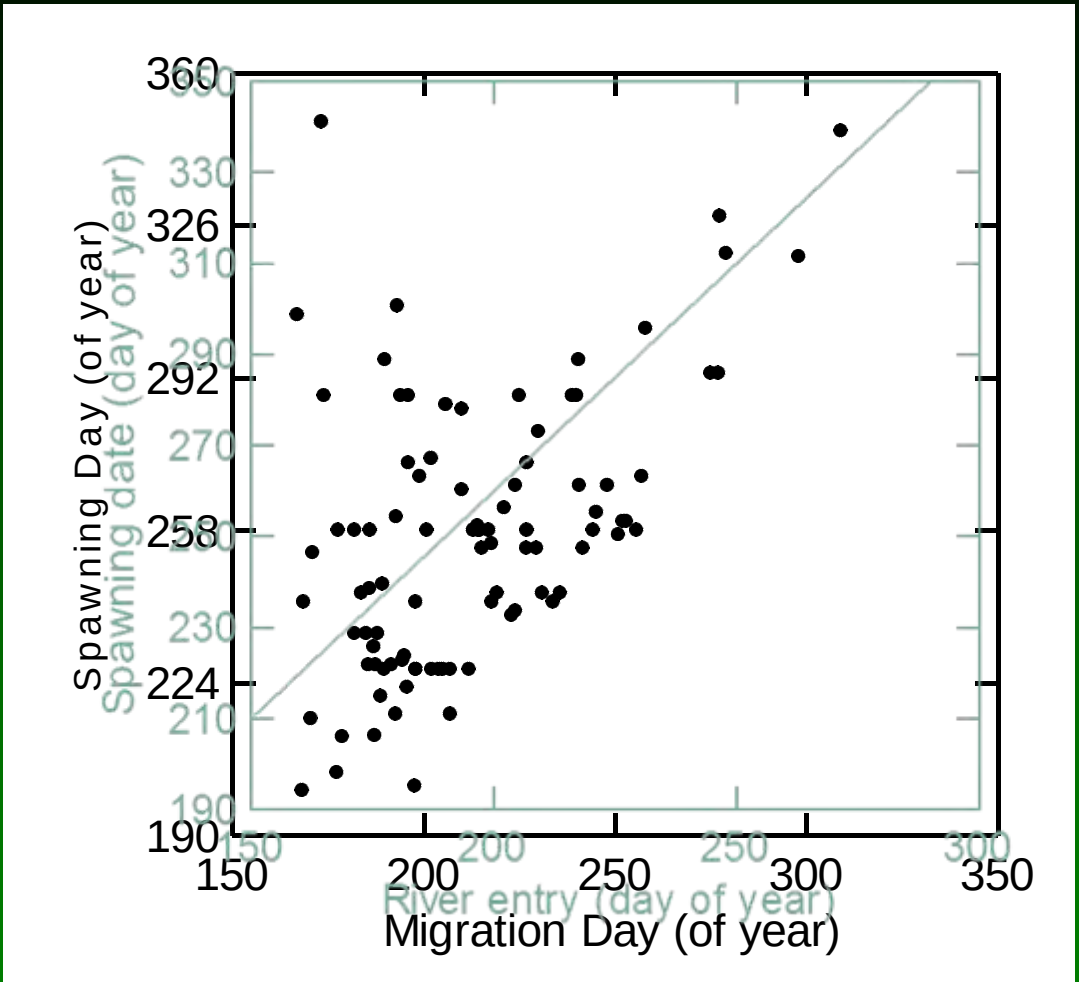
Evolution of run timing

The timing of adult sockeye salmon migration into fresh water: adaptations by populations to prevailing thermal regimes.

Sayre Hodgson and Thomas P. Quinn, 2002

Abstract: Selective pressures on sockeye salmon run timing operate in freshwater to avoid high river temperatures.

Spawning and migration dates

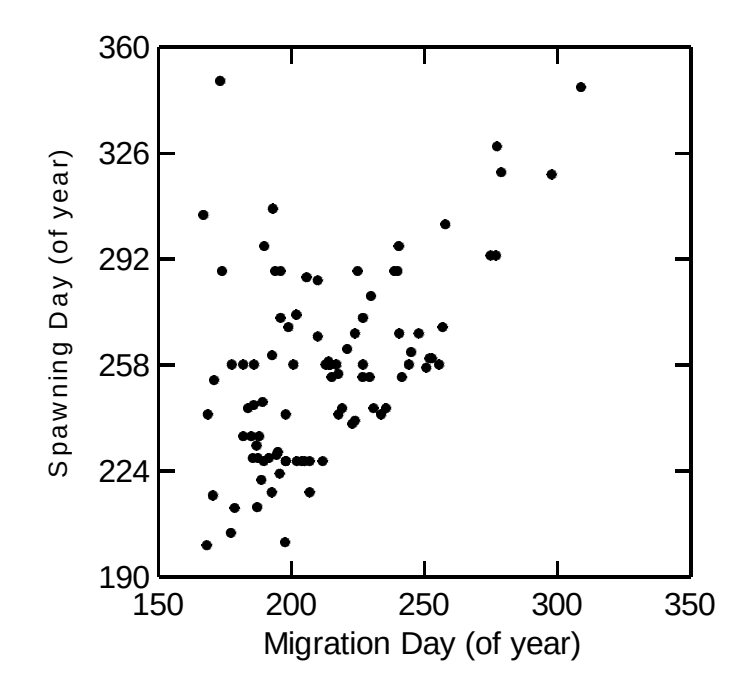


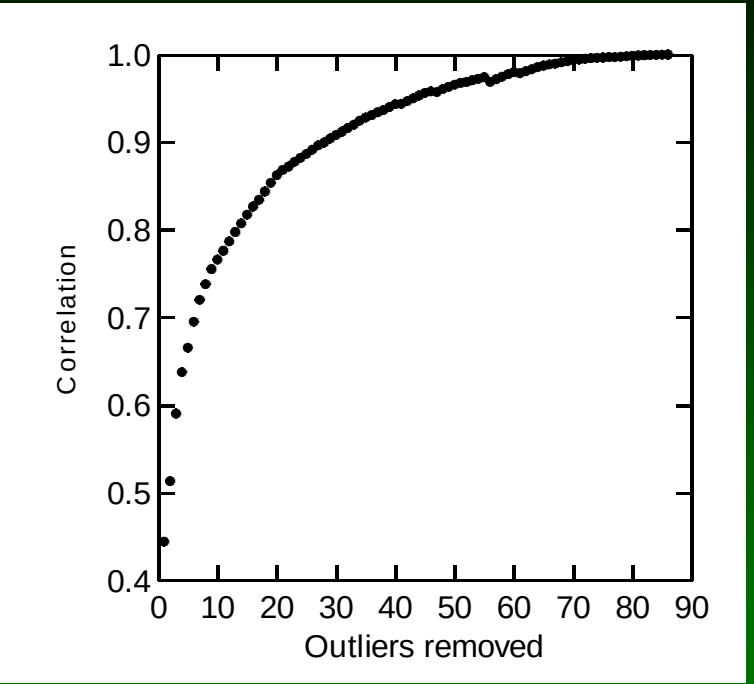
(Data from: Hodson and Quinn 2002)

Outliers

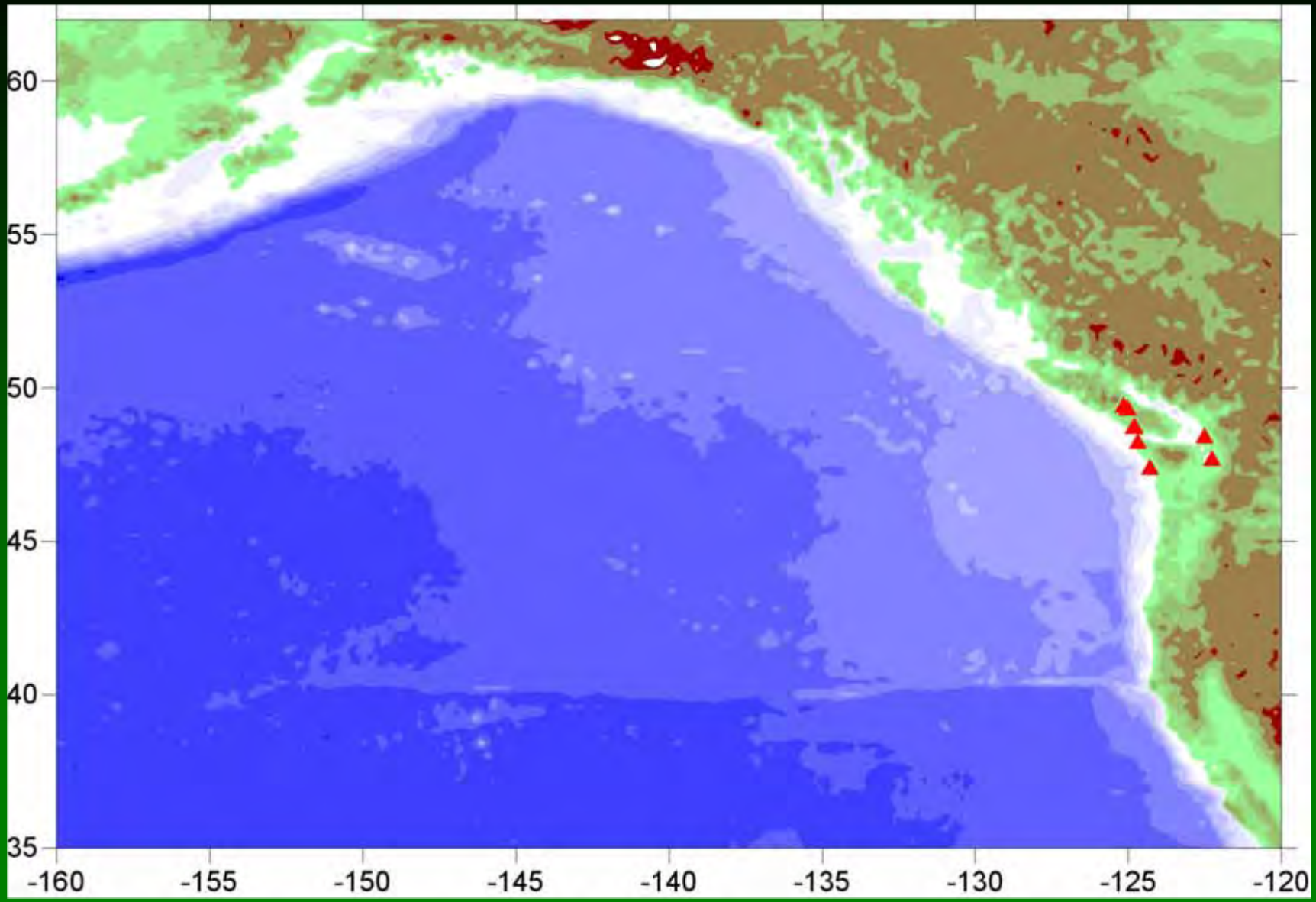
- In the Columbia R., early arrival by 3 populations is an effective way to avoid high river temperatures during a lengthy migration [doesn't happen in the Fraser River].
- [WA west coast] Lake Ozette, Lake Quinault, [Puget Sound] Baker Lake populations could migrate after the summer temperature peak, but they don't for some reason.
- High flow conditions may make late migration less viable in Lake Quinault (west coast).
- In others there is no apparent benefit to early return with a long delay (Lake Ozette, Baker Lake).

Sequential removal of outliers

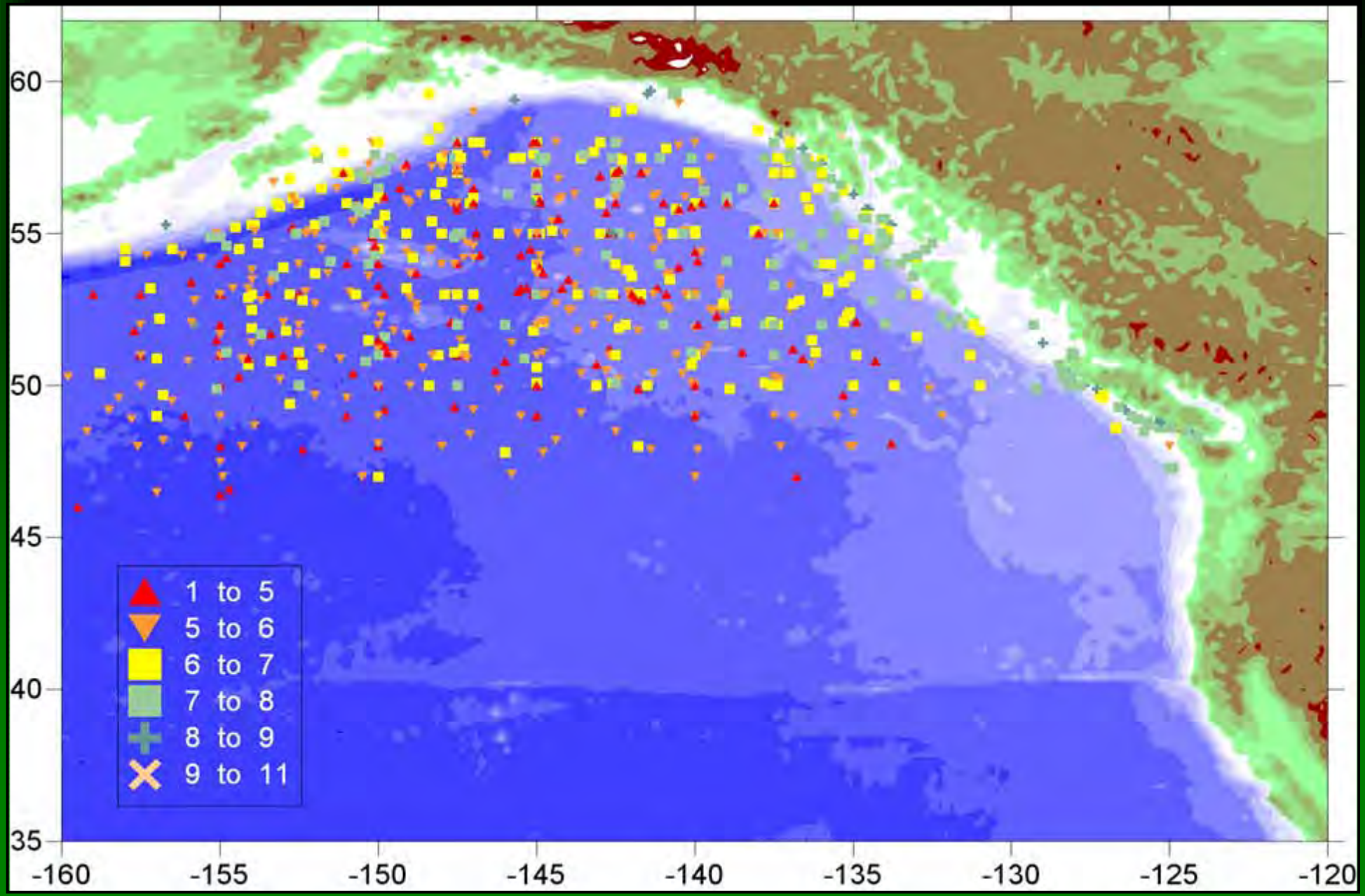




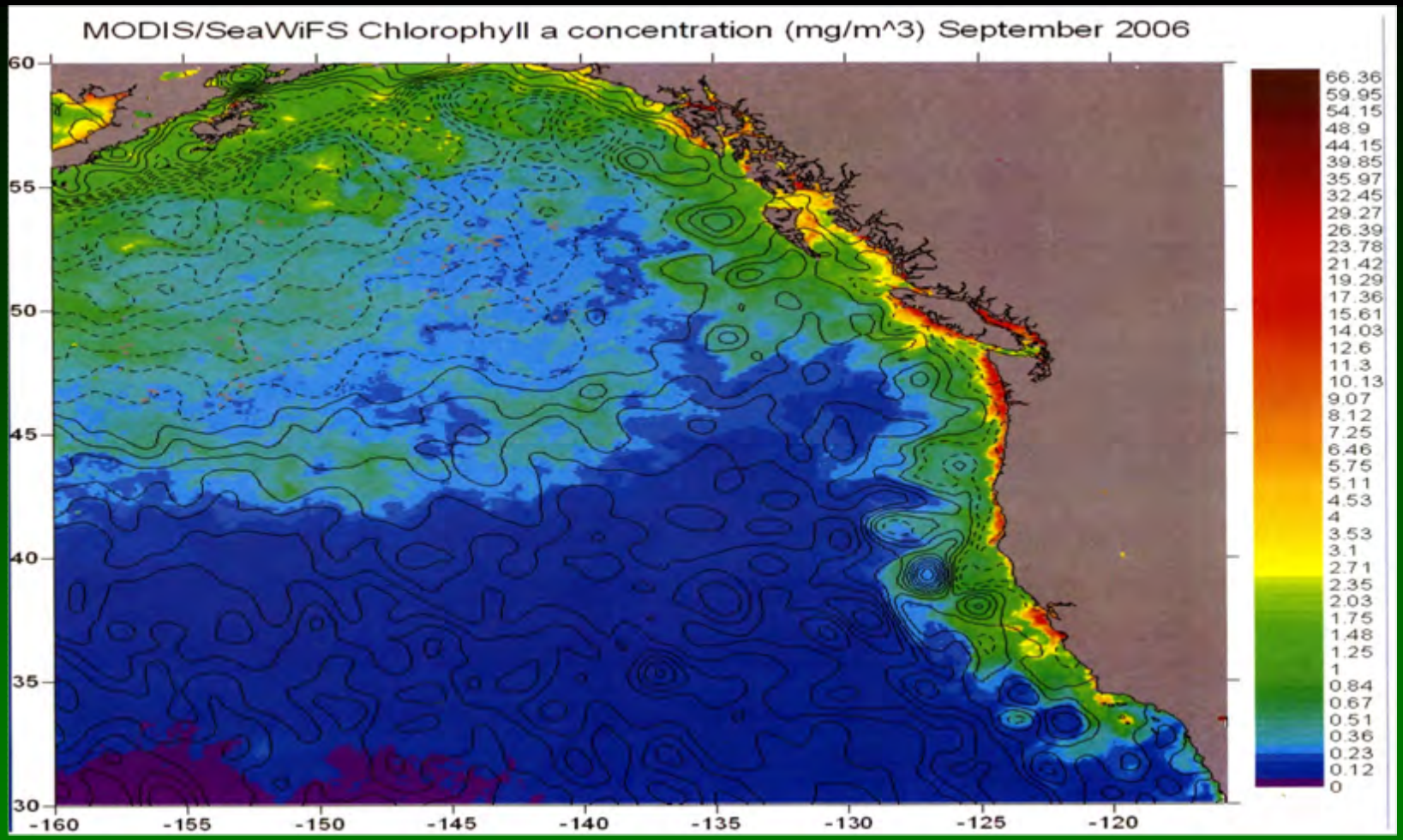
Rivermouths of top 10% residuals



I.N.P.F.C. High Seas Tagging

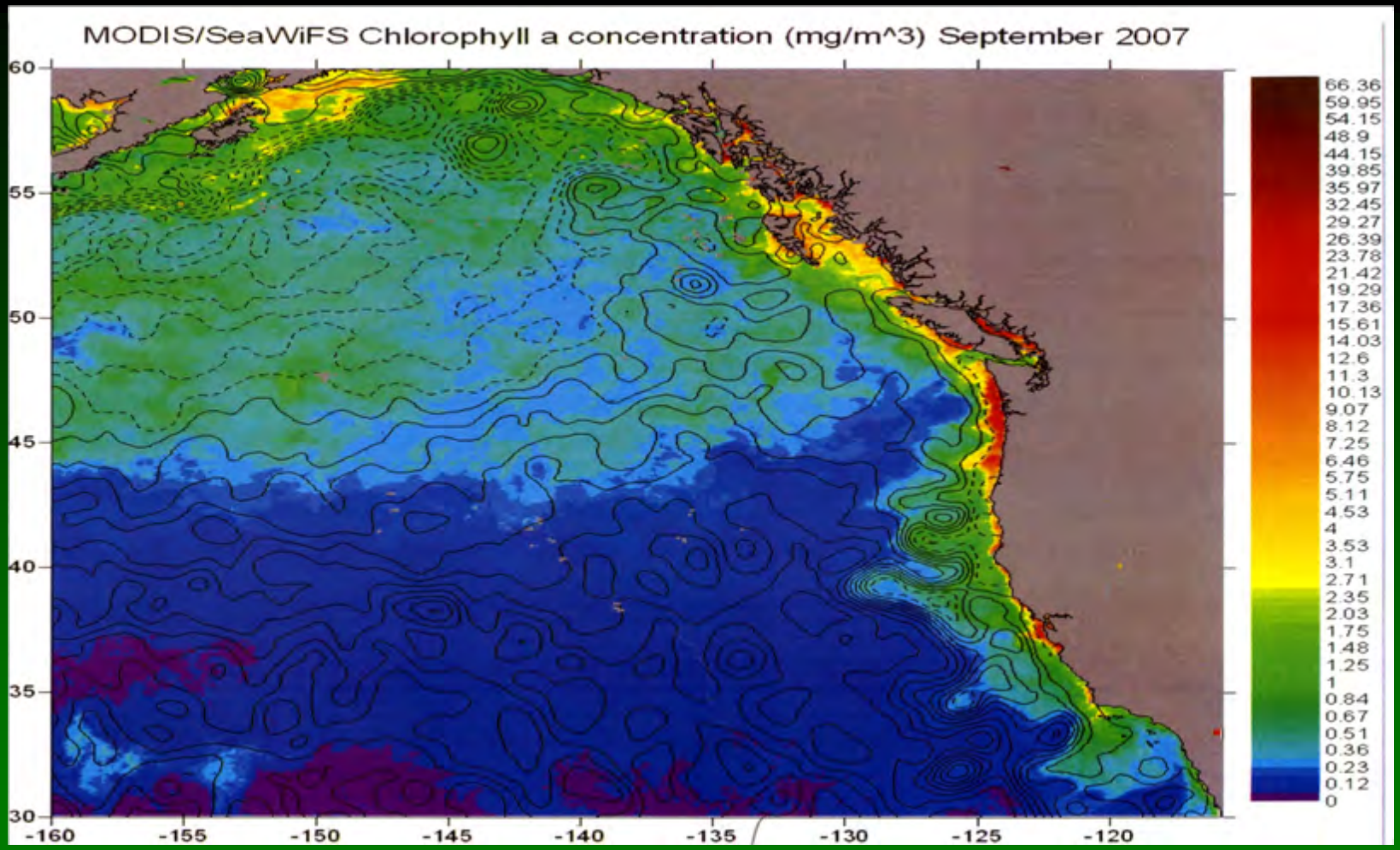


Chlorophyll and sea level



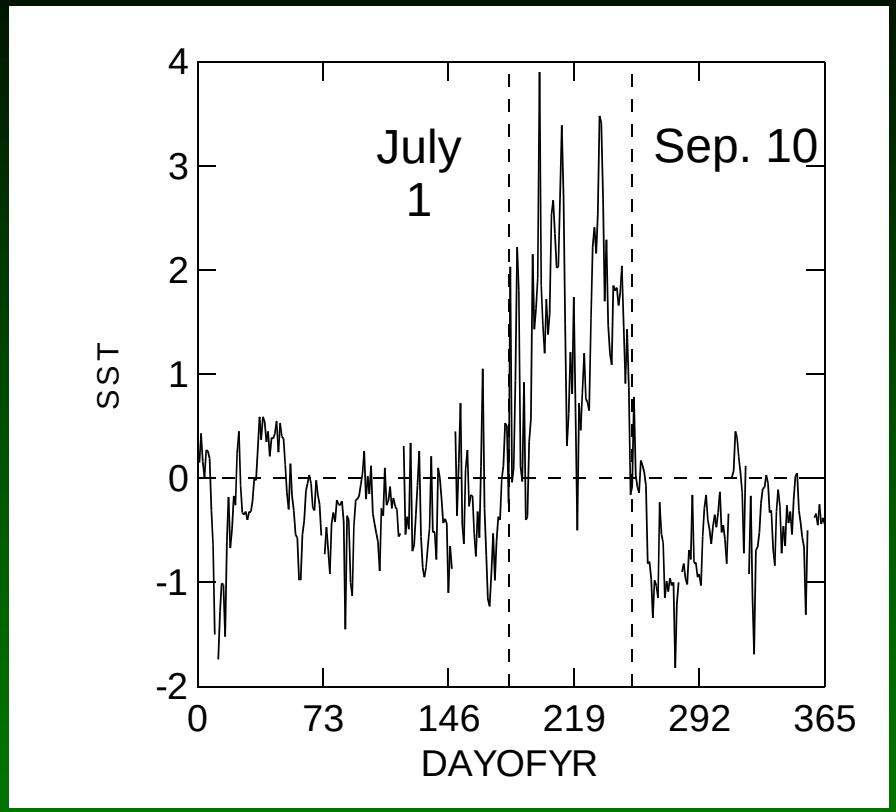
Courtesy of Bill Crawford, IOS

Chlorophyll and sea level

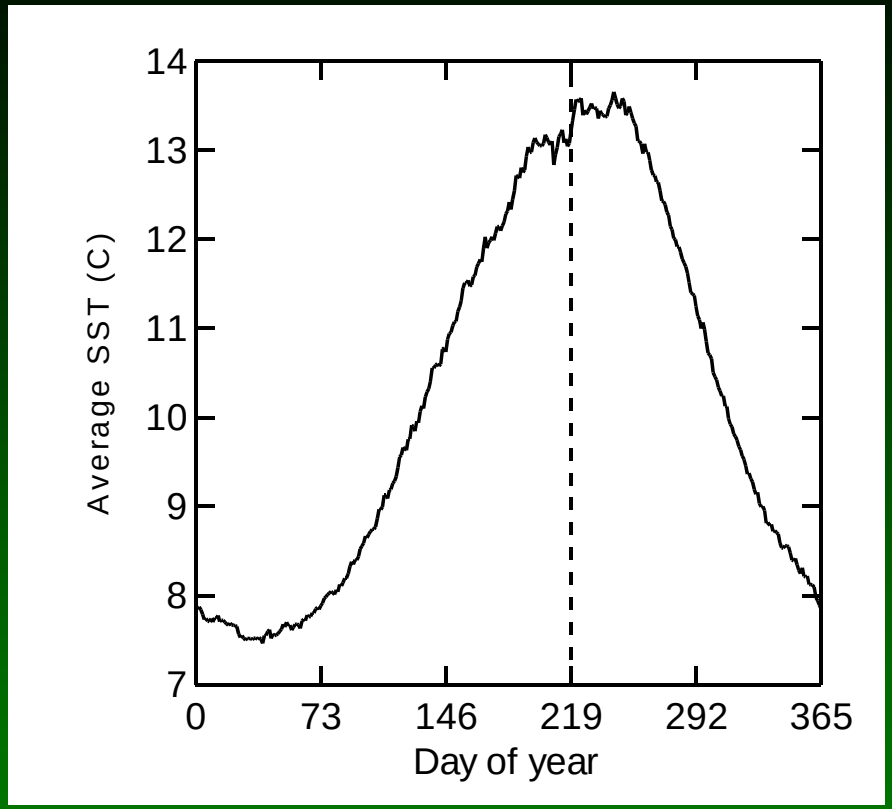


Courtesy of Bill Crawford, IOS

Kains Island SST



2007 anomalies



Climatology (75 y)

Summary

- Contemporary migratory behaviour is highly correlated (caused by) oceanic influences.
- Average SST since 1978 has been warmer during the migration, causing Fraser River sockeye salmon to avoid the West coast.
- Fraser River sockeye salmon were not found west of Vancouver Island (beyond the slope).
- Perhaps because it is not very “Subarctic”

Summary

- Southern populations that lack the Johnstone St. “escape route”, migrate early to avoid a “sockeye-unfriendly” oceanic state
- No sockeye salmon populations in the south/western range have a “typical” migration timing.
- Changes in large-scale gyre circulation is the probable cause of current (post-1977) oceanic environment.
- Migration timing of southwestern populations suggests that evolution has selected against “normal” run timing behaviour.