GLOBEC CANADA

Global Ocean Ecosystems Dynamics

Results & Follow-on Activities

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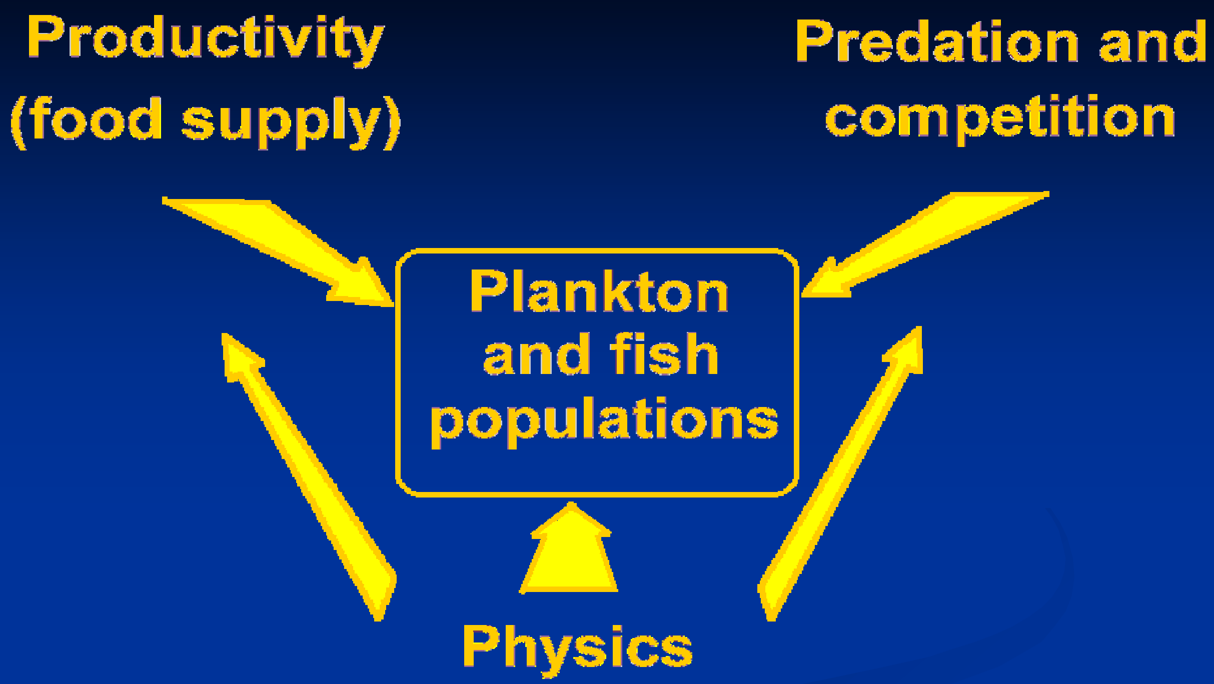


What and Why (basic scientific questions):

•How are target populations (plankton and fish) affected by variability in ocean physics?

•What is the relative importance of bottom-up vs. top-down vs. direct physical controls?

Specific scientific foci:

- Importance of seasonality and timing match between physical and biological events
- Amount and timing of freshwater inputs, and effects on physical mixing and transport
- Advective connections:
  Open ocean ↔ Continental margins
  Continental shelf banks ↔ basins
- Interaction between zooplankton and fish

How? (Scientific Strategy)

- **Collaboration between biologists and physicists**
- **Interaction and feedback between:**
  - **Retrospective analyses of long time series,**
  - **Focused process studies, and**
  - **Numerical models.**
- **Comparisons among different species and regions.**

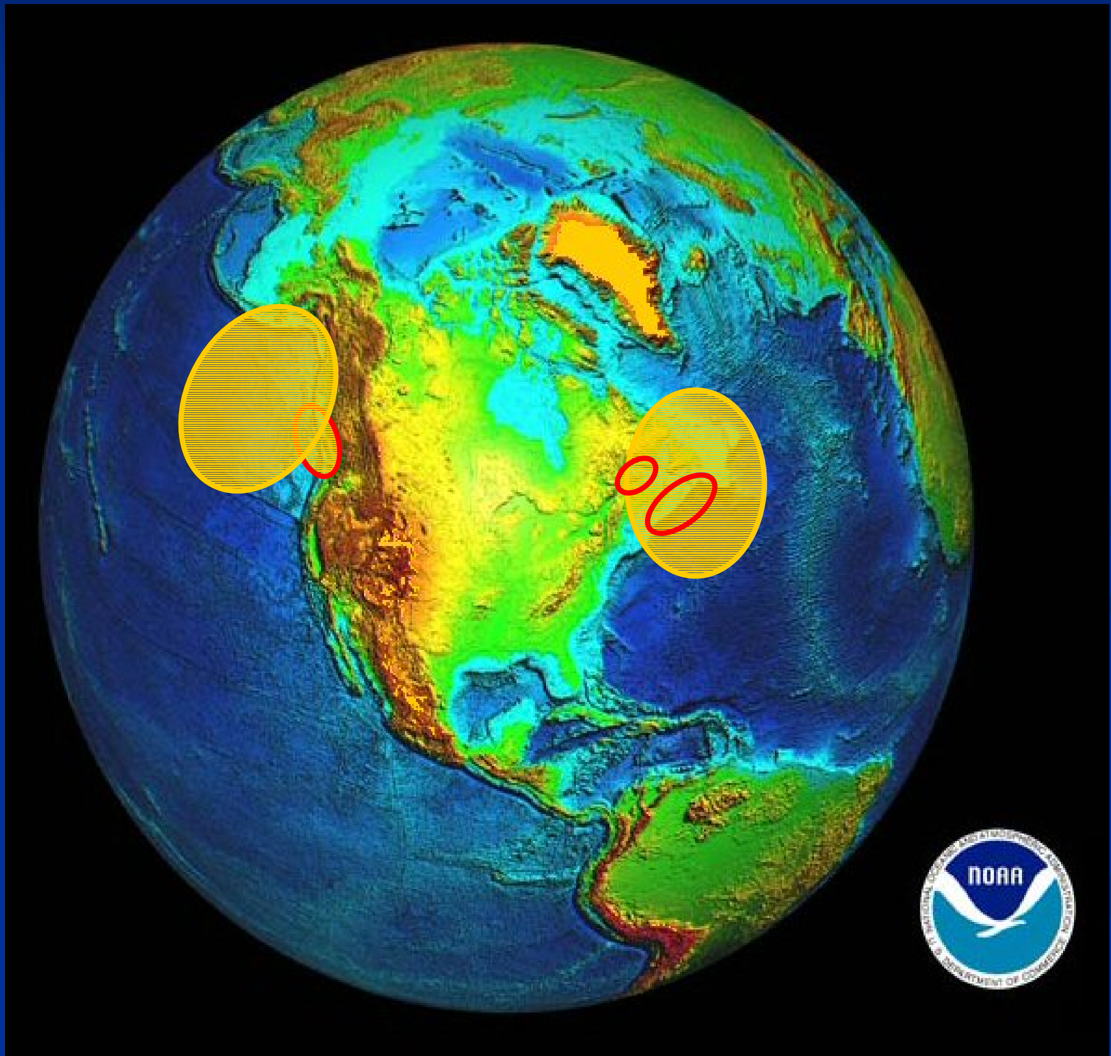
When?

• **1993-1995: Planning and proposal preparation (close collaboration with US GLOBEC)**

• **1996-early 2001: National program, jointly funded by Canada's DFO and NSERC (early-in and early-out compared to many other CCCCs programs)**

• **Since 2001: Numerous follow-on projects and synthesis activities, plus ongoing time series**

Where: both Pacific and Atlantic coasts of Canada



- Intensive programs on continental margins off British Columbia, Nova Scotia and in Gulf of St. Lawrence (red ovals)
- Retrospective and modeling studies linking continental margins to oceanic NE Pacific and NW Atlantic (orange ovals)

Who (Cast of Characters):

(National): 50 scientists + 60 students & postdocs
7 universities & 5 government labs

In the Pacific: 8 sub-projects, 20 lead investigators

Project title (abbreviated)	*Investigators*	*Type of research*
Biophysical modeling, Vancouver Island continental margin	M. Foreman, D. Ware, R. Thomson, P. Harrison	Model
Effects of currents on primary productivity, zooplankton, and feeding by fish	S. Allen, M. Foreman, P. Harrison, D. Mackas, I. Perry, R. Thomson, M. Whiticar	Process study
State-of-the-ocean time series	R. Thomson, B. Hargreaves, P. Harrison, K. Hyatt, D. Mackas, S. McFarlane, I. Perry, R. Stull, D. Ware	Retrospective + Ongoing Time Series
Hindcast models: continental margin currents, winds & water properties	W. Crawford, P. Cummins, M. Faucher	Retrospective + Model
Gulf of Alaska zooplankton	S. McKinnell, D. Mackas	Retrospective + Intercal.
Salmon growth	D. Welch, I. Perry	Retrospective + Time Ser.
Coupled general circ. & foodweb model	W. Hsieh, K. Denman	Model
Sonic tagging, migratory salmon	C. Hawryshyn	Instrument development

What we learned: Some examples of results from the Pacific

BC continental margin:

- **Decadal variability**
- **Aggregation at bathymetric edges**
- **IBM models of transport and aggregation**
- **Food-web tracers**

Alaska Gyre

- **Zooplankton biomass and life cycle timing**
- **Spatial coherence of salmon growth**

Decadal variability in the NE Pacific

The 1990s saw strong variability in ocean conditions along the NE Margin of the Pacific:

- 2 El Niño events (1991-92, 1997-98)

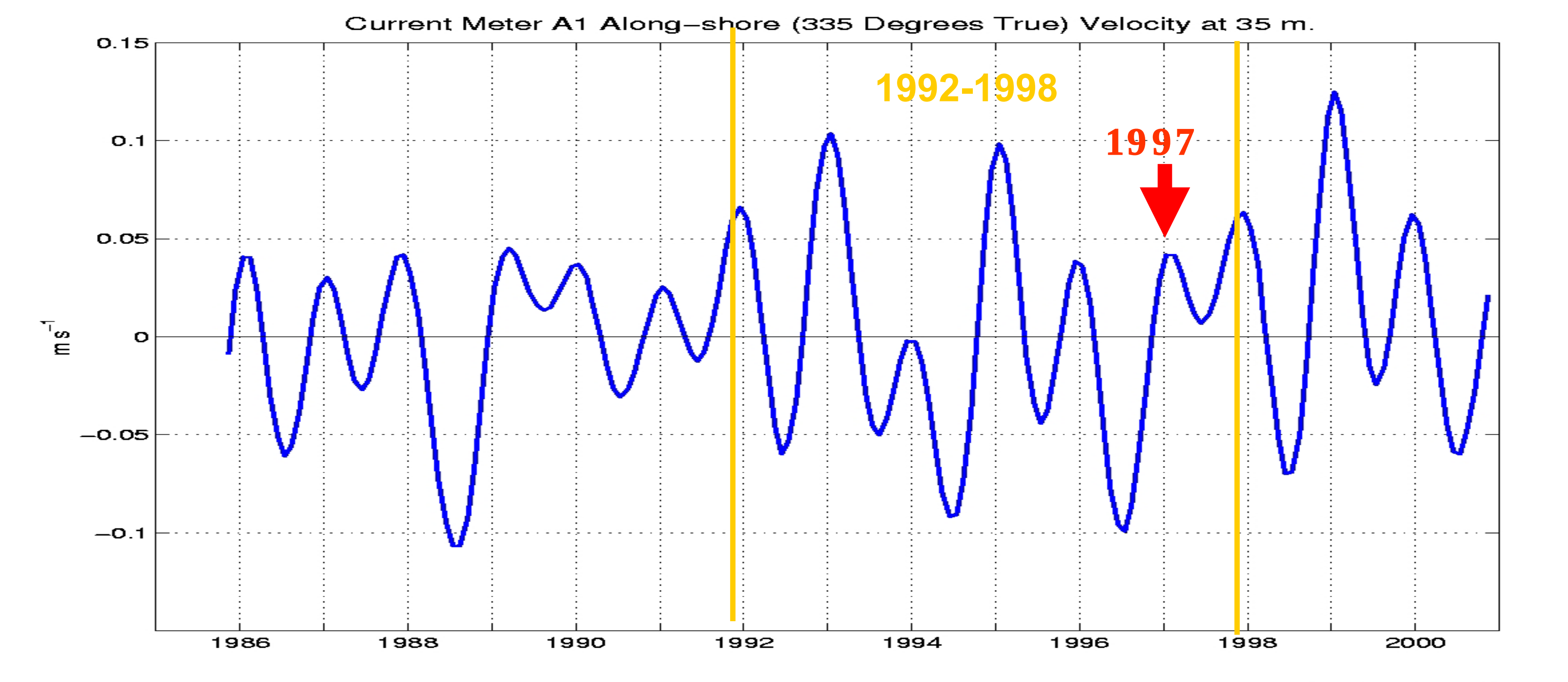
During the intervening period (1990-1998)

- Progressive warming, both coastal and offshore
- Changes in plankton productivity and community composition (less plankton, more “southerly” composition)
- Changes in fish distribution, reduced growth and survival of salmon

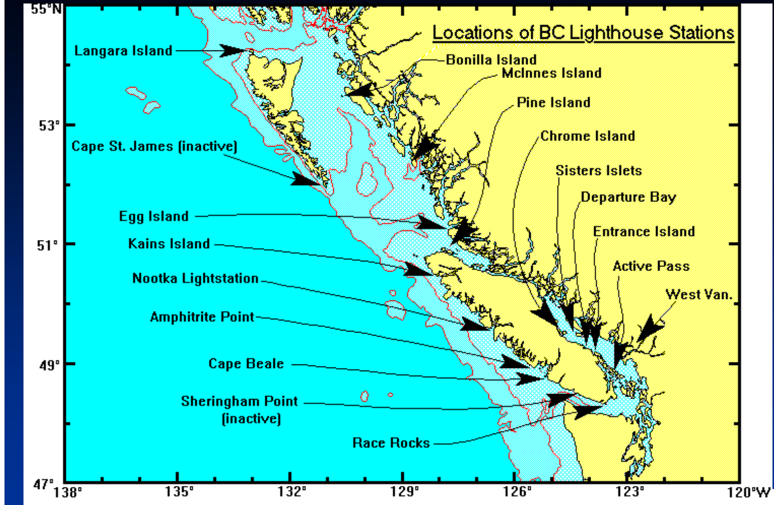
Abrupt reversal of these changes in 1999

Decadal Variability (alongshore currents):

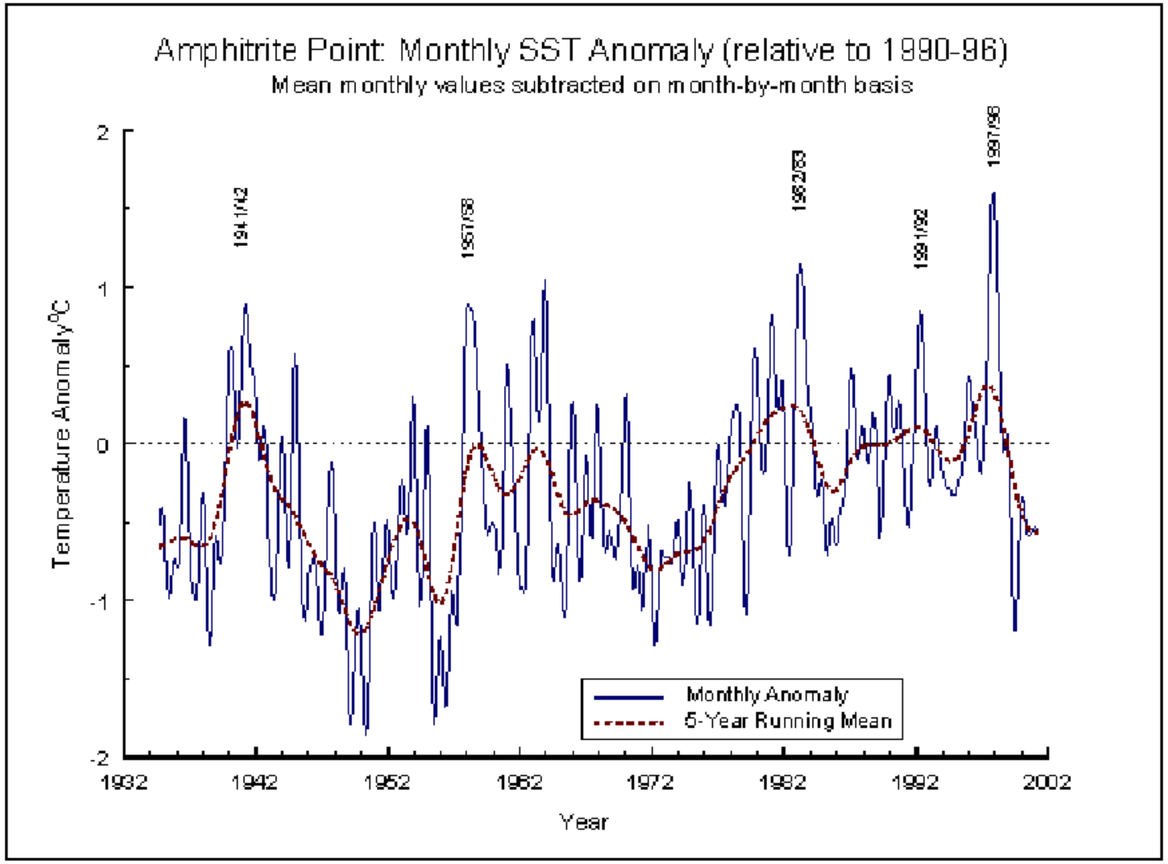
1990s had strong poleward flow in winter,
weak equatorward flow in summer

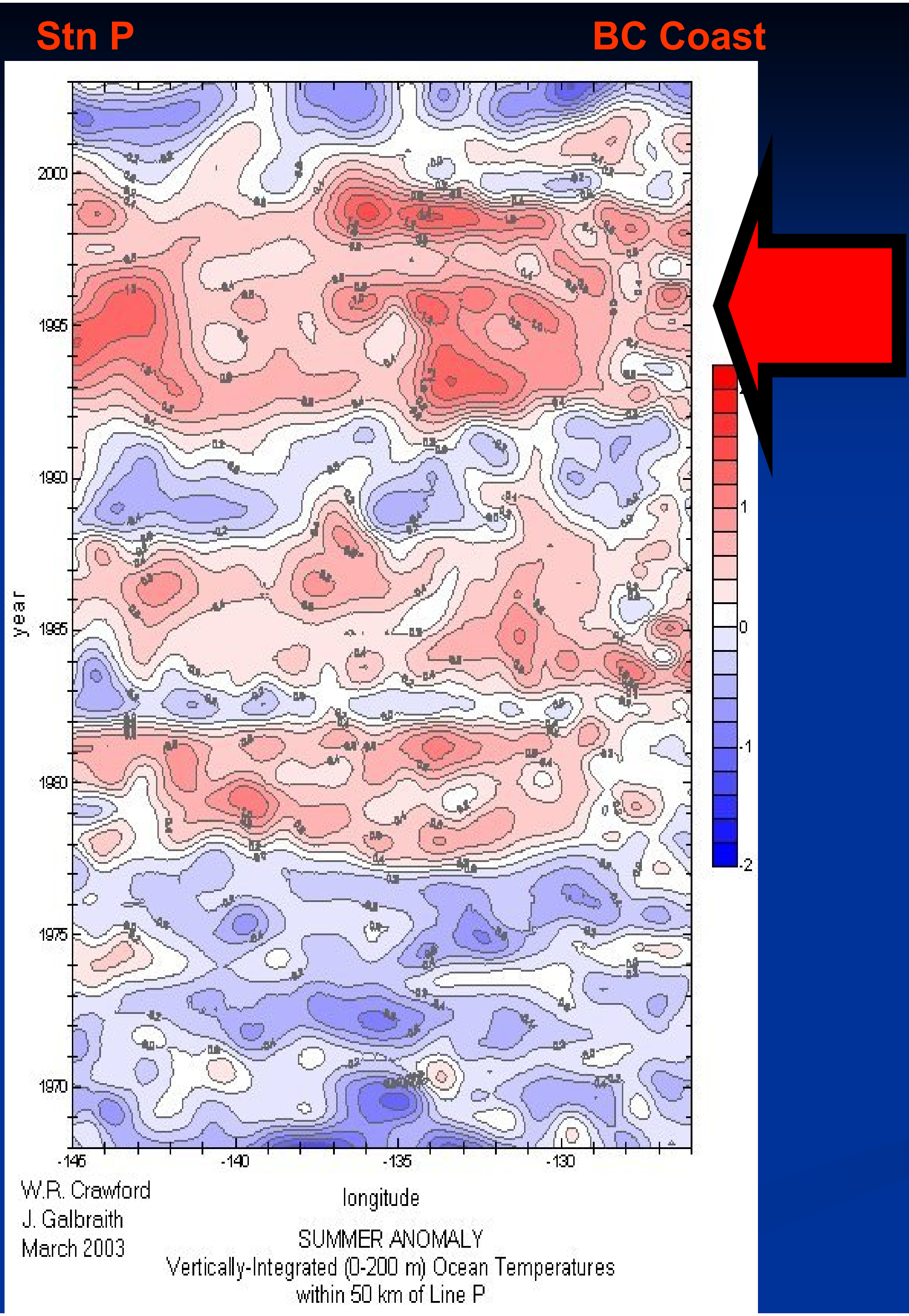


Courtesy R. Thomson



Monthly anomalies of sea surface temperature measured along the west coast of Vancouver Island since 1932. Horizontal dashed line is the 1990-1996 mean.

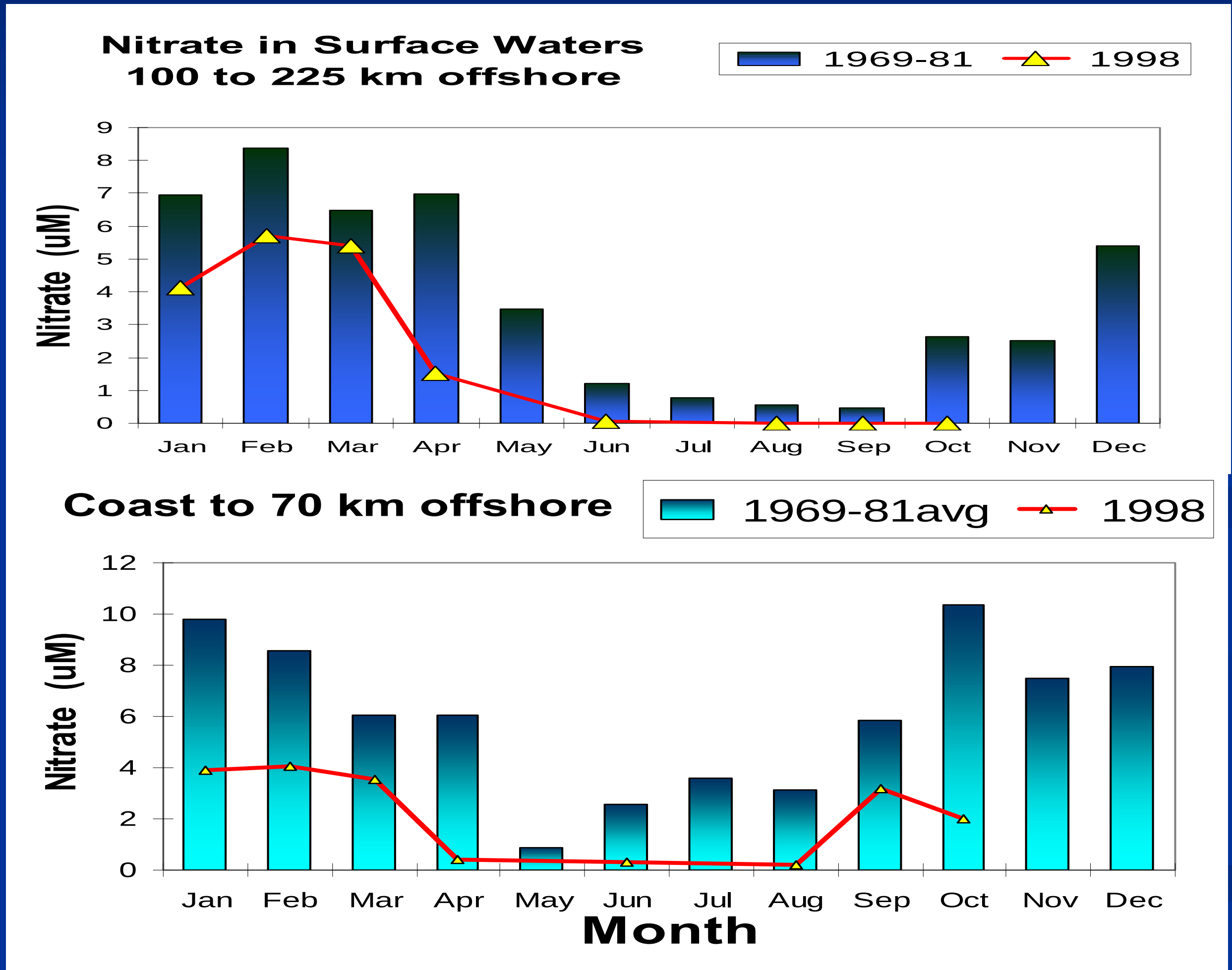




Consequences: Sustained warm water temperatures in the 1990s, both along the NE Pacific continental margin and in the Alaska Gyre (pink-red = positive anomaly)

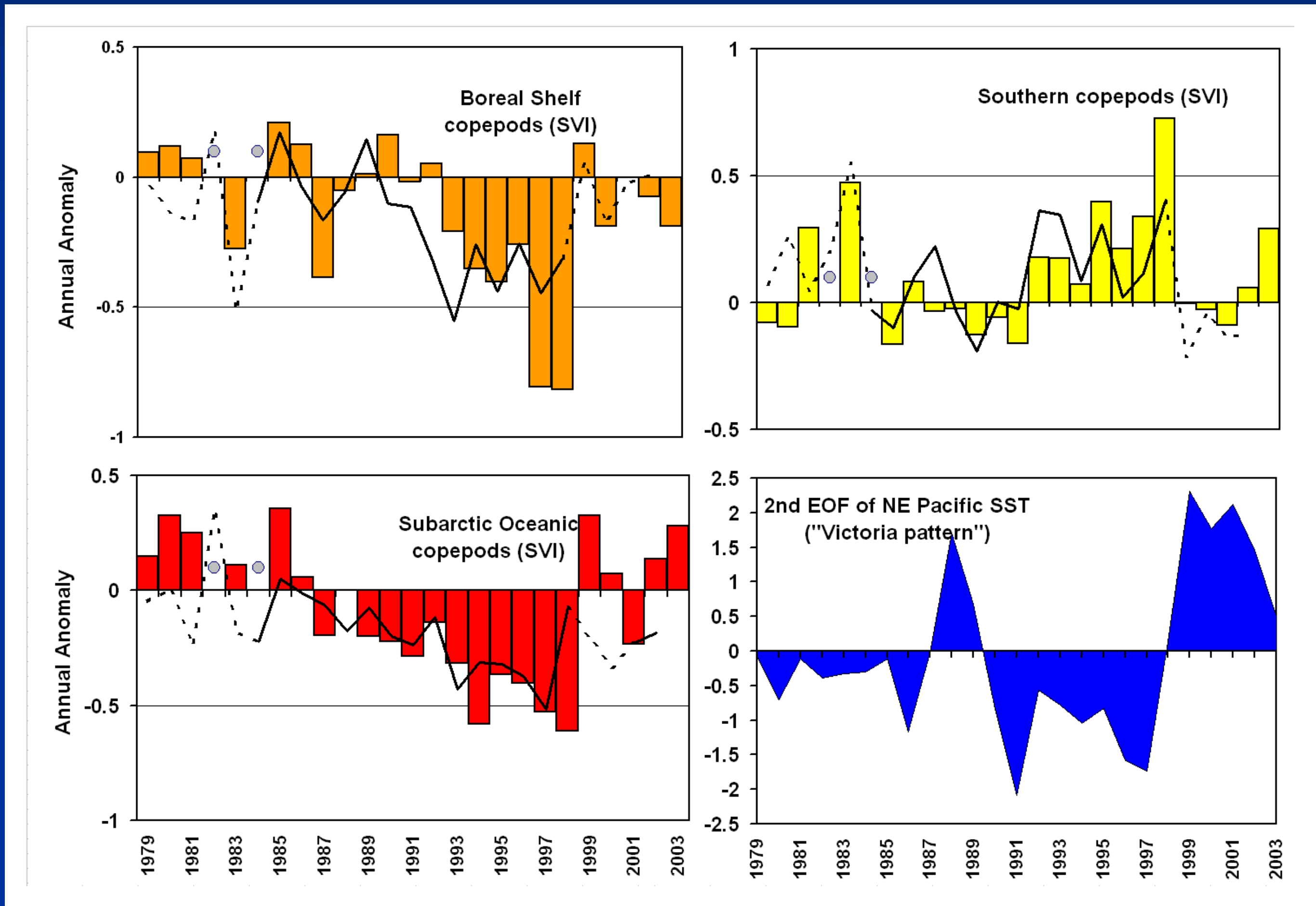
(Courtesy W. Crawford)

Consequences: Strong thermal stratification reduces nutrient re-supply by winter mixing – 1990-1998



Courtesy F. Whitney

Changes in zooplankton biomass and community composition

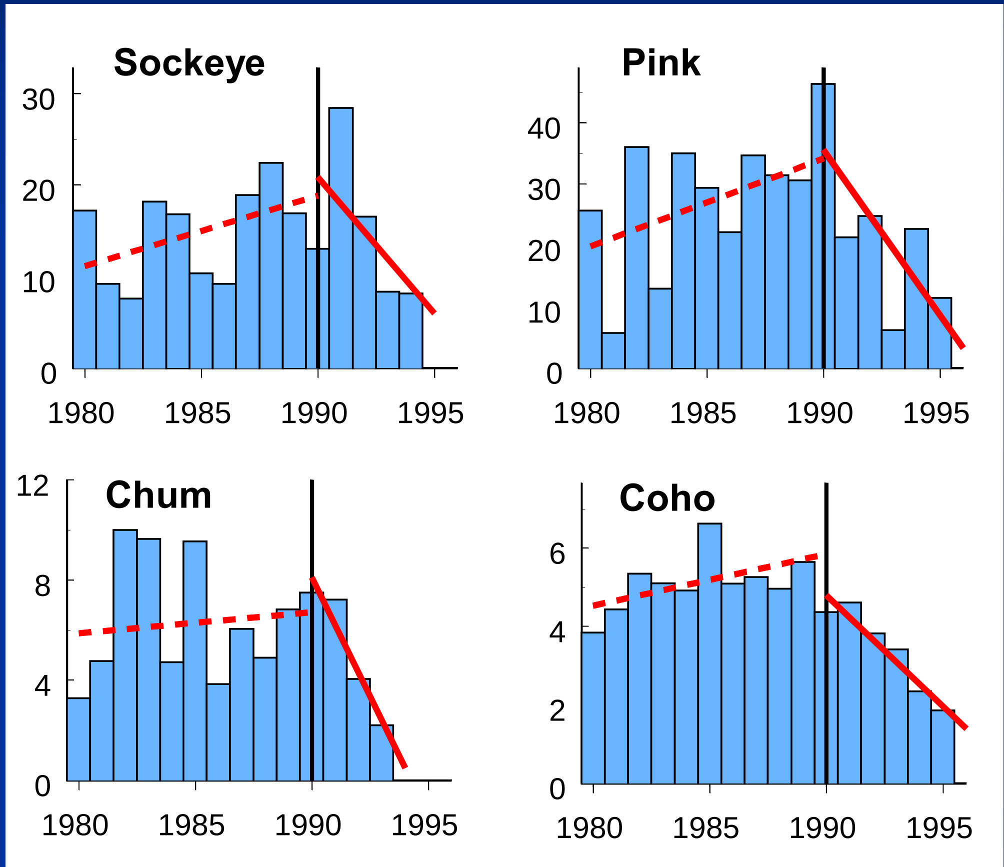


Updated from Mackas et al. 2001

Alongshore shifts in distributions of migratory fish stocks

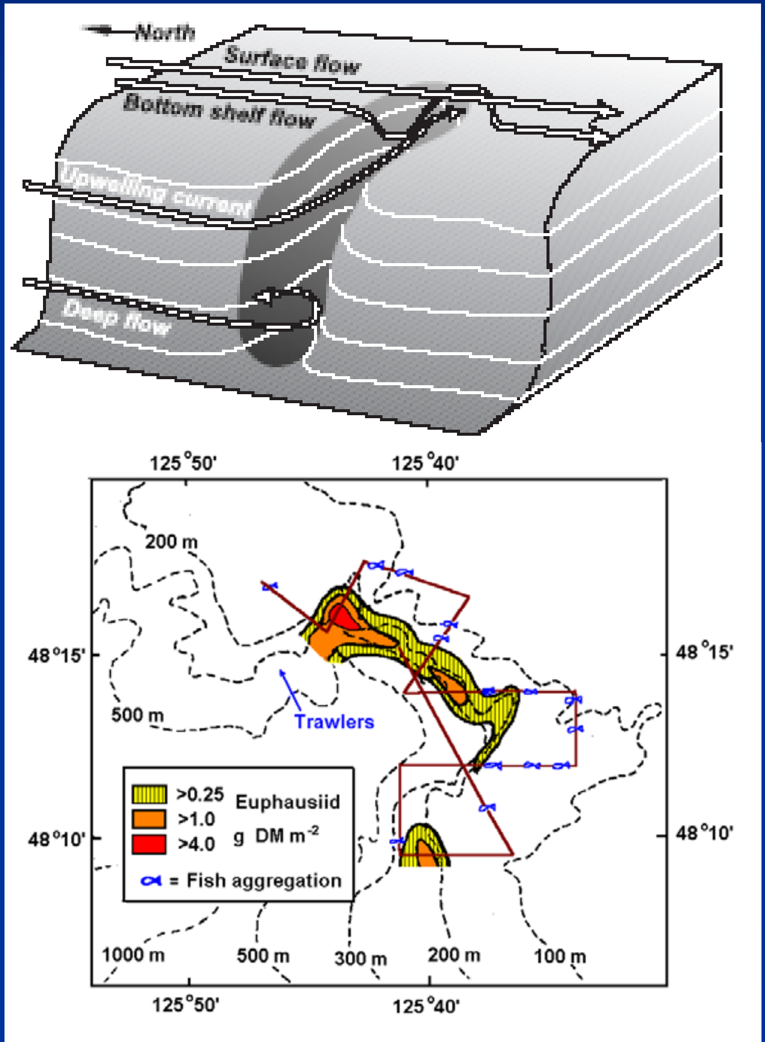
Courtesy S. McFarlane

Steep mid 1990s declines in salmon returns (and marine survival rate)



Population size, millions of fish
Courtesy D. Welch

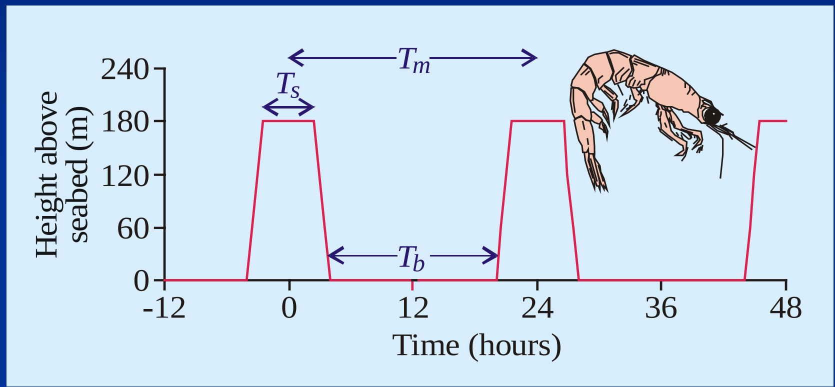
Spatial pattern: Field & model studies of transport and aggregation processes

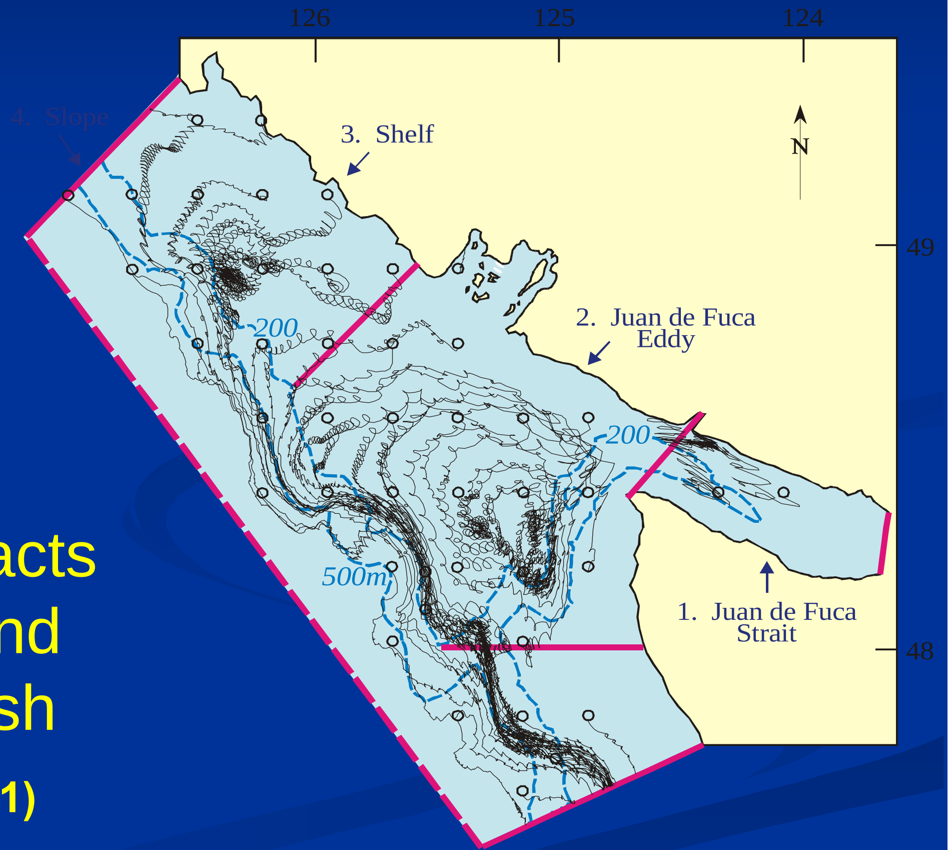


Convergent flow in submarine canyons (and at other bathymetric edges) produces dense aggregations of euphausiids and their predators

(Allen et al. 2001; Mackas et al. 1997)

Spatial pattern: Field & model studies of transport and aggregation processes





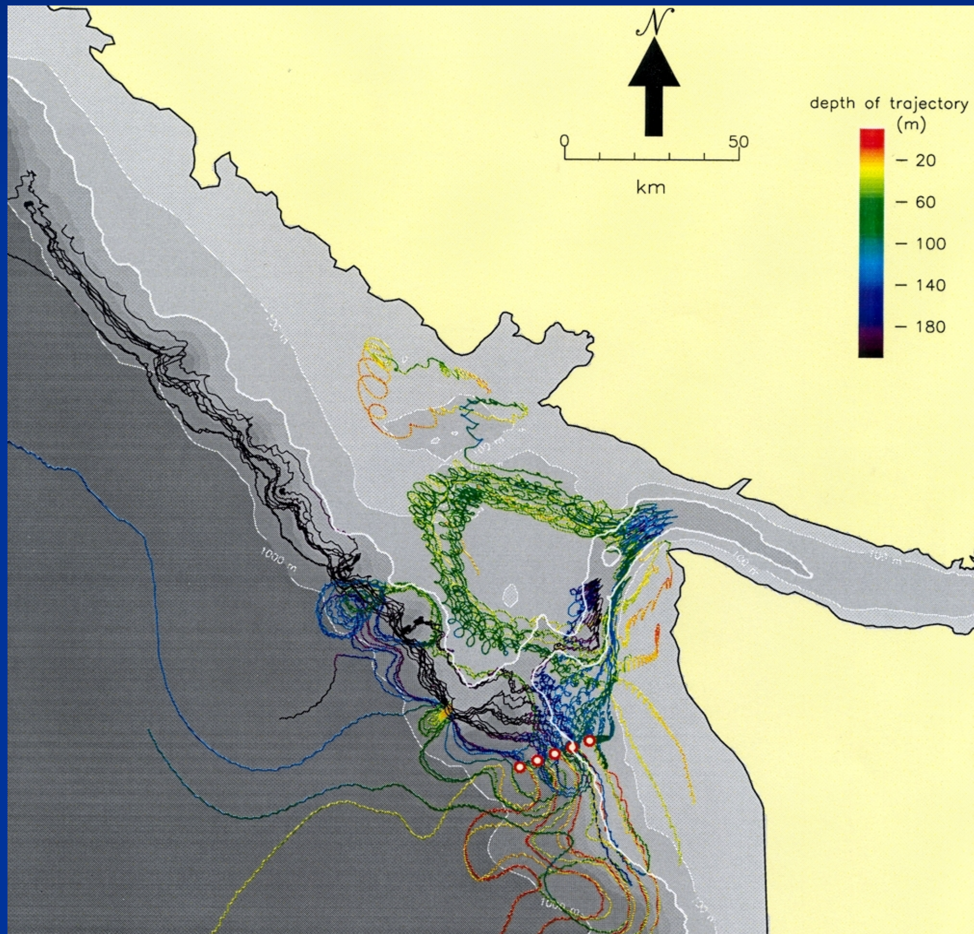
Diel vertical migration interacts with diurnal tides to trap and aggregate plankton and fish

(Smith, Hill, Foreman and Pena 2001)

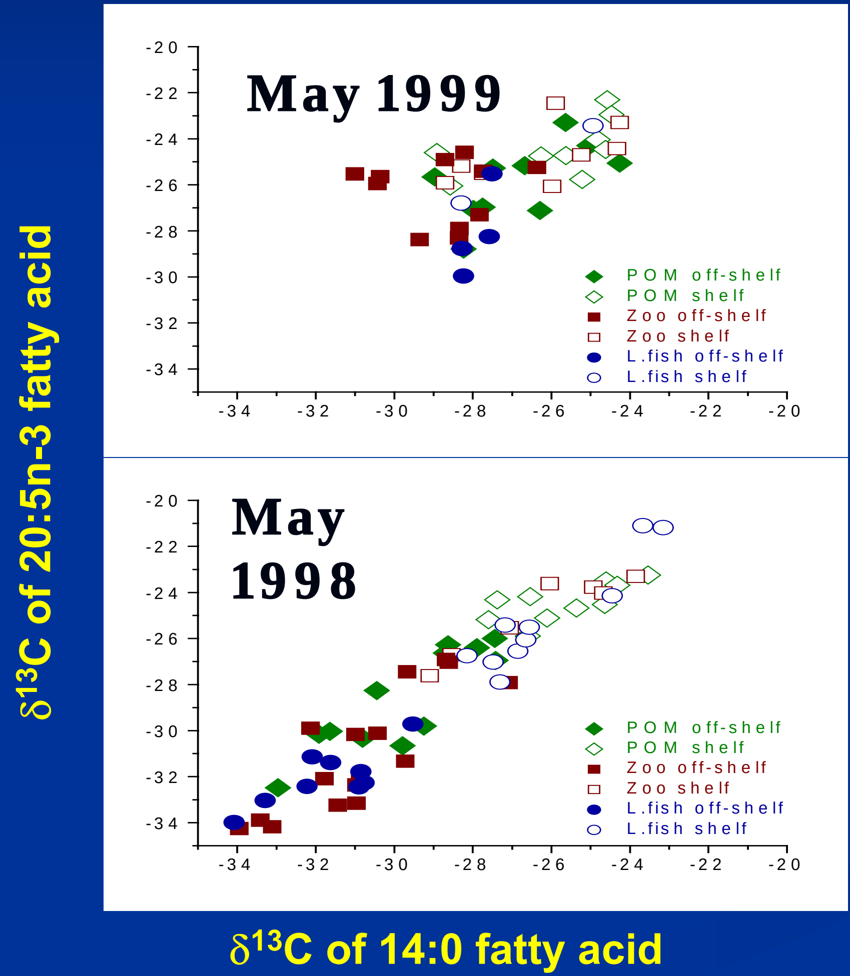
Spatial pattern: Field & model studies of transport and aggregation processes

Estuarine circulation and tides enhance nutrient supply to the shelf from California Undercurrent source

(courtesy M. Foreman)



Food-web tracers:
Compound-specific isotopic signature varies with source (shelf vs. offshore), productivity (99 vs 98), and trophic level



Fatty Acids in:

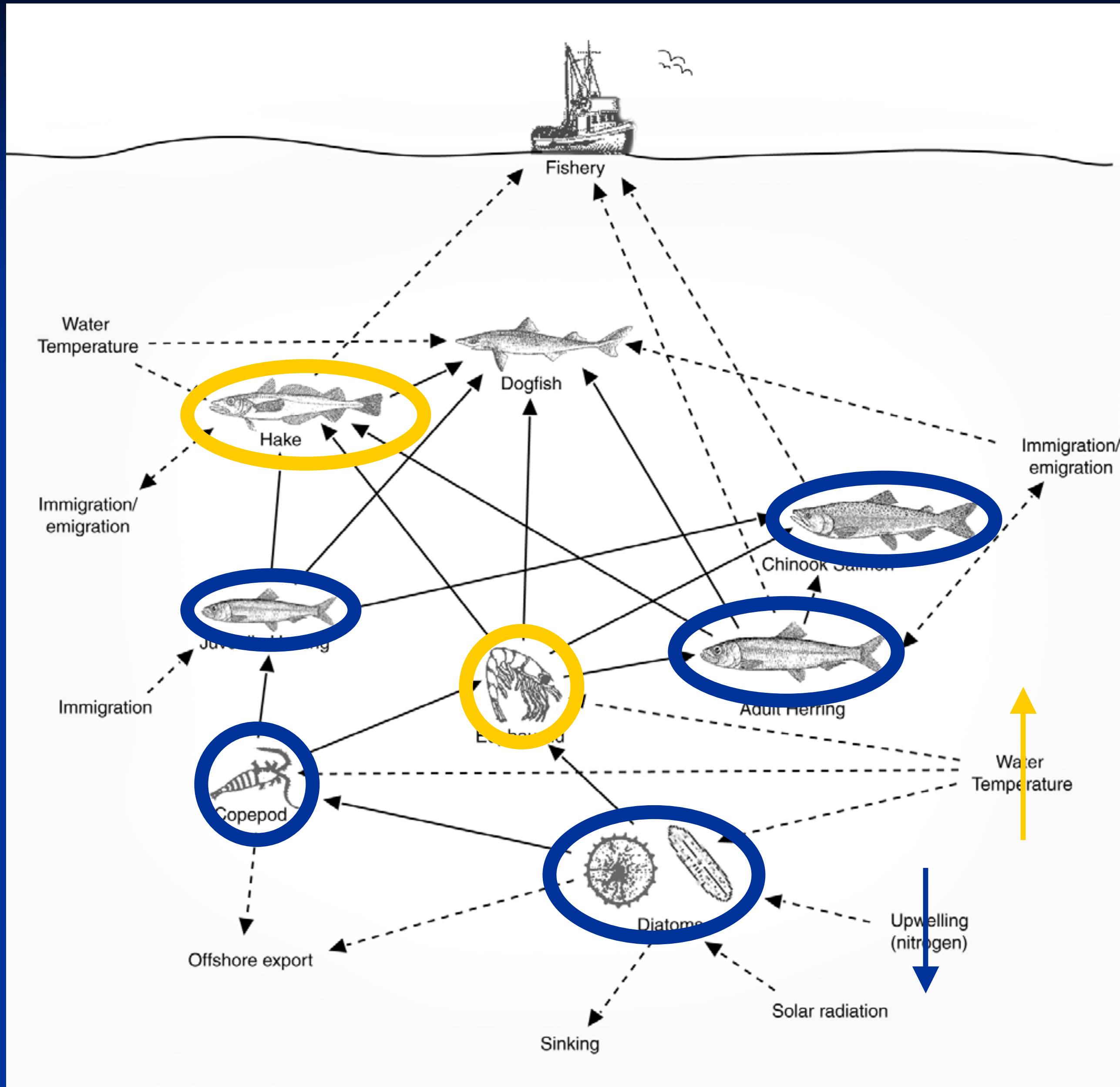
- **particulate material (green diamond)**
- **zooplankton (red square)**
- **larval fish (blue circle)**

Open symbols - on-shelf

Closed symbols - off-shelf

Courtesy R. Veefkind and M. Whiticar

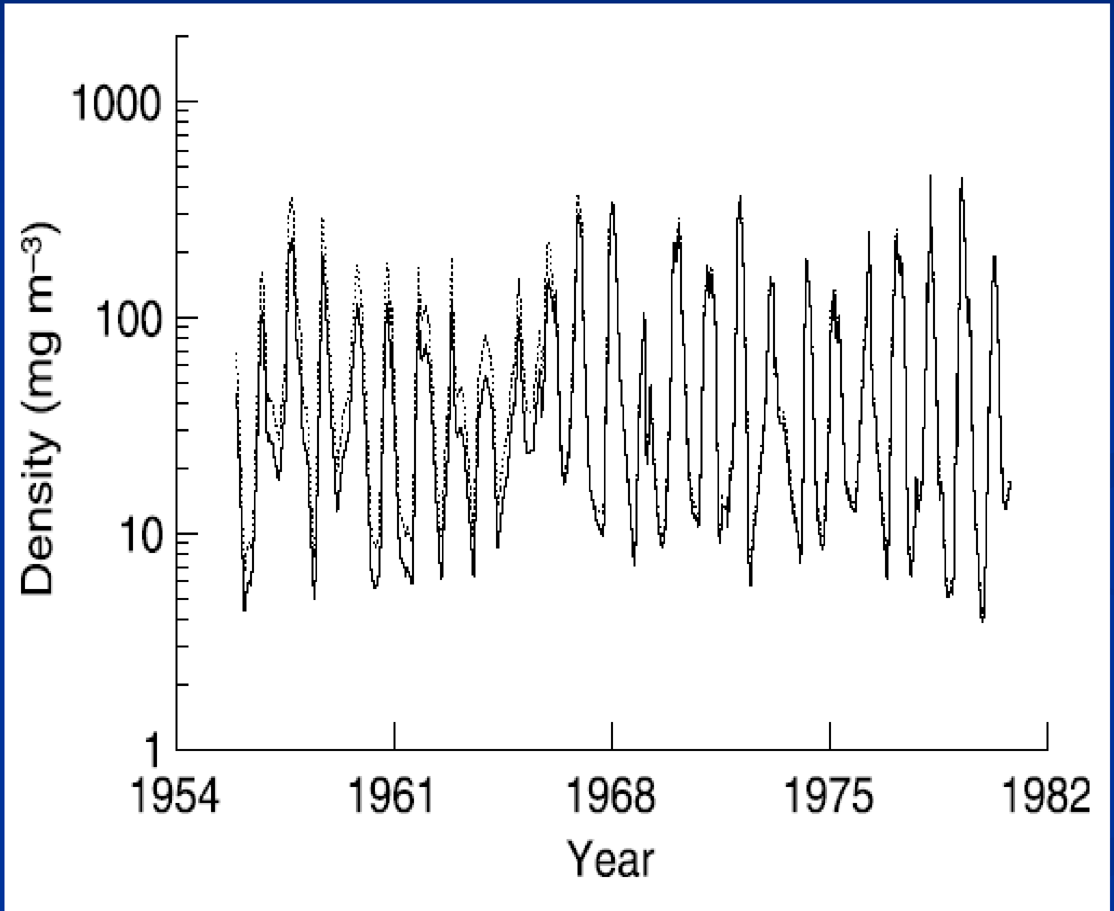
Trophodynamic Modelling



Source: Robinson and Ware. 1999. Can. J. Fish. Aquat. Sci. 56: 2433-2443

Alaska Gyre:

Re-calibration of the Station P zooplankton zooplankton time series

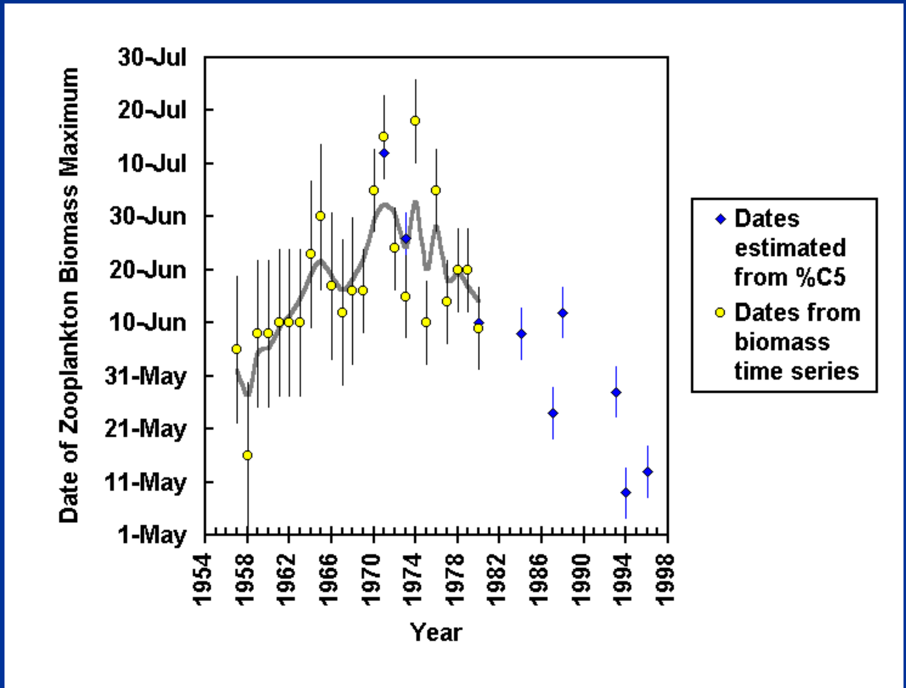


- **Little difference in capture efficiency between SCOR, NORPAC, and bongo nets**
- **Main effect is variation in volume filtered per unit mouth area (wire angle and tilting of net)**
- **Re-calibrated time series (solid line) has slightly larger post-1976 increase in biomass**

(McKinnell and Mackas 2003)

Alaska Gyre:

Changes in seasonal timing of *Neocalanus*

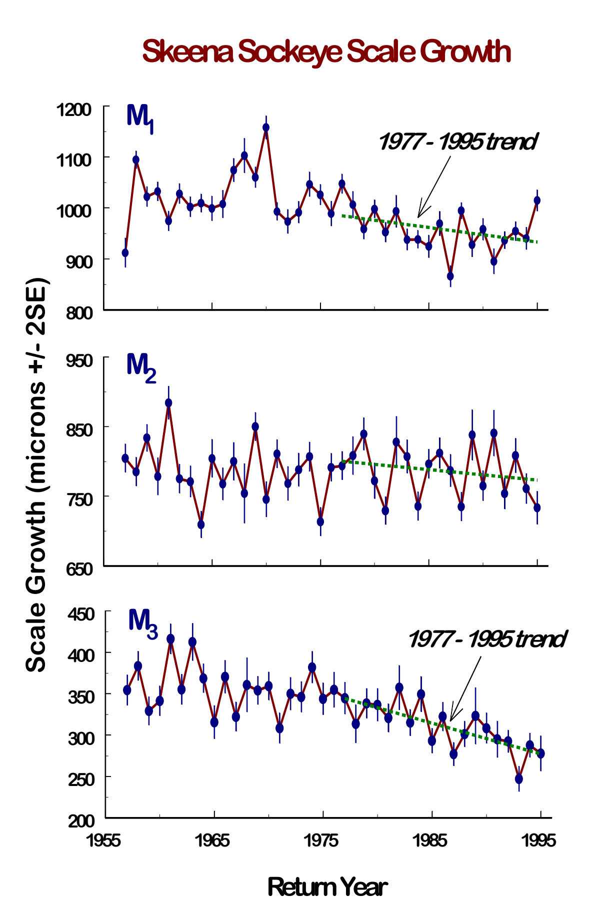


- Annual biomass maximum about 1 month duration
- Timing of maximum has changed by 1.5-2 months
- Earlier maximum when surface layer warmer and more stratified

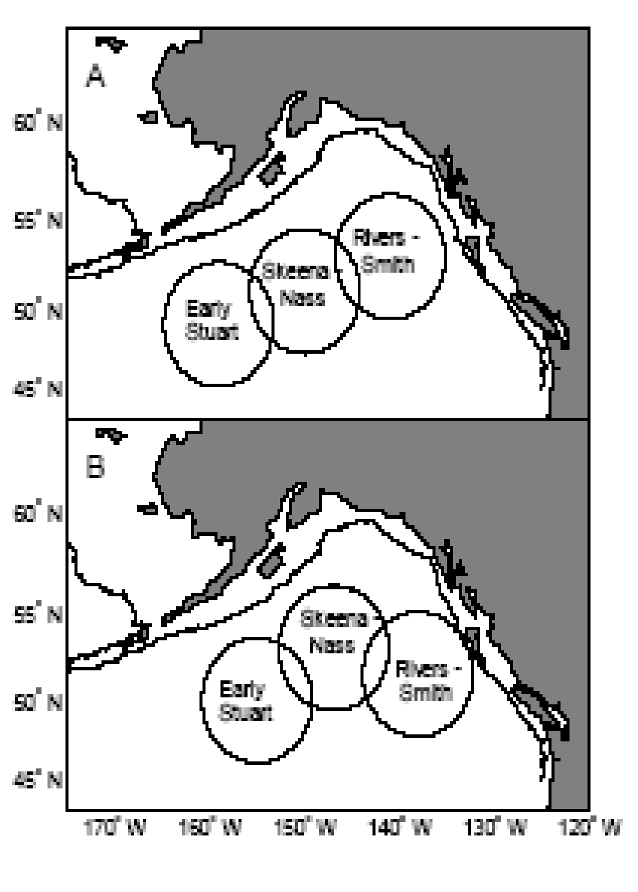
(Mackas et al. 1998)

Alaska Gyre: Trends and spatial patterns of salmon growth rate

Declines in salmon growth rate (estimated from scale annuli)



Correlations among stocks suggest differing patterns of ocean habitat



(Welch, Eveson & Perry, submitted)

The Big Picture

- SST's along the BC Coast were unusually warm during the 1990's - due to 2 El Nino's but also to sustained warming offshelf deep waters in the NE Pacific experienced warm periods in the 1990's that seem associated more with the 2 El Ninos
- there was a strong response of the marine ecosystem off BC to these anomalous conditions in the 1990's, associated with
    - changes in the normal distribution patterns, and
    - changes in the productivity of the system (declines).

GLOBEC Canada ended as a funded program in early 2001 (most of us think prematurely)

However, CGLOBEC has left some active (and hopefully viable) successors

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Continental margin (Canadian PACOOS) and Line P time series sampling programs

NSERC STRATOGEM (physics, plankton and juvenile fish in the Strait of Georgia)

“Haida Eddies” (large coastal origin eddies that enter the Alaska Gyre from the eastern margin)

ECOHAB (distribution and causation of harmful algal blooms off Washington, Oregon and BC)

Census of Marine Life POST program (acoustic tagging/tracking of migrating salmon)

Synthesis and Comparisons with other regions

What we learned: Some examples of results from the Pacific

BC continental margin:

- Decadal variability
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- IBM models of transport and aggregation
- Food-web tracers

Alaska Gyre

- Zooplankton biomass and life cycle timing
- Spatial coherence of salmon growth
- Models of basin-scale response to El Niño and to the 1976 regime shift

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Global Ocean Ecosystems Dynamics

Alaska Gyre: Basin-scale model of 1976 regime shift changes in nutrient supply and plankton biomass

Nutrient – N

Phytoplankton

Microzooplankton

(Haigh, Denman & Hsieh 2001)