Dominant zooplankton shift in the Strait of Georgia: An educated guess on the trophic implications and the probable biophysical context

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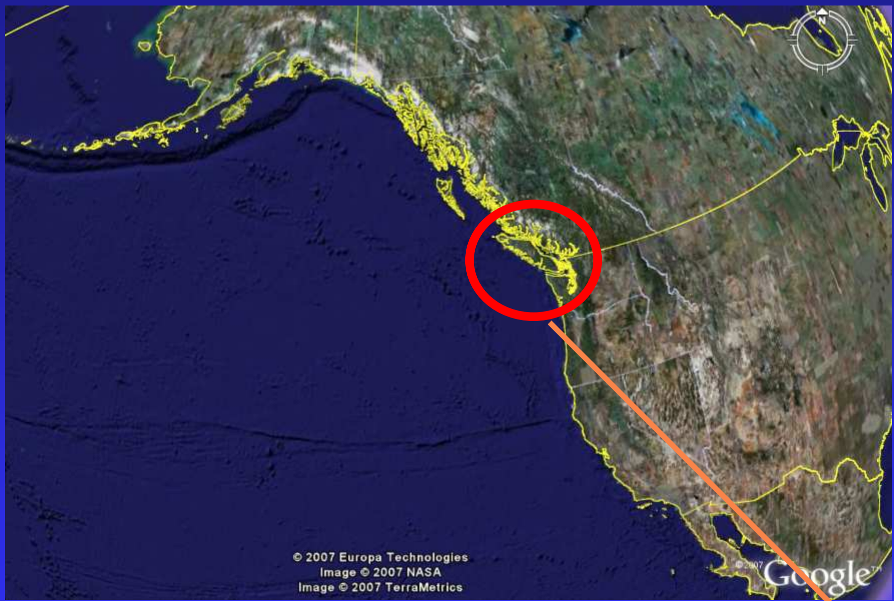
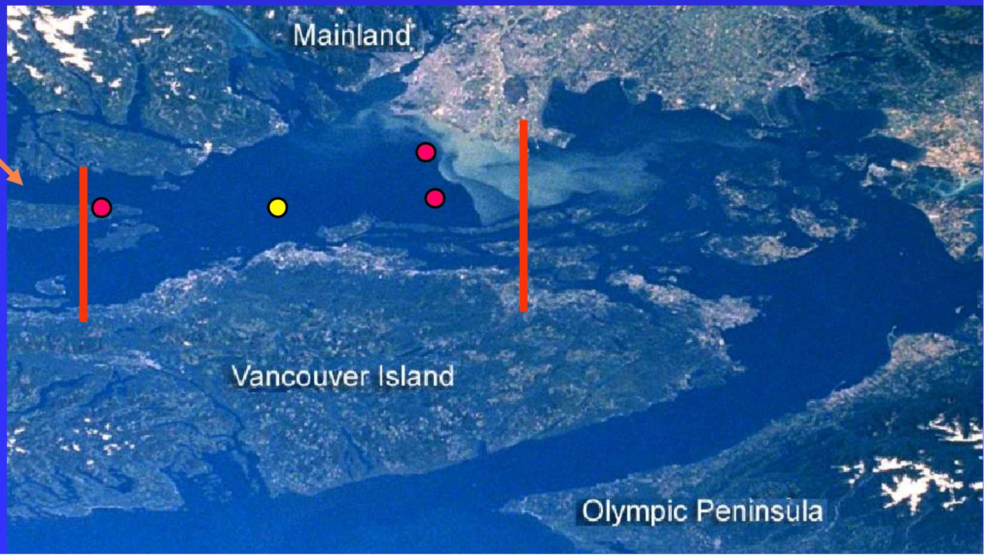
Study area: Strait of Georgia

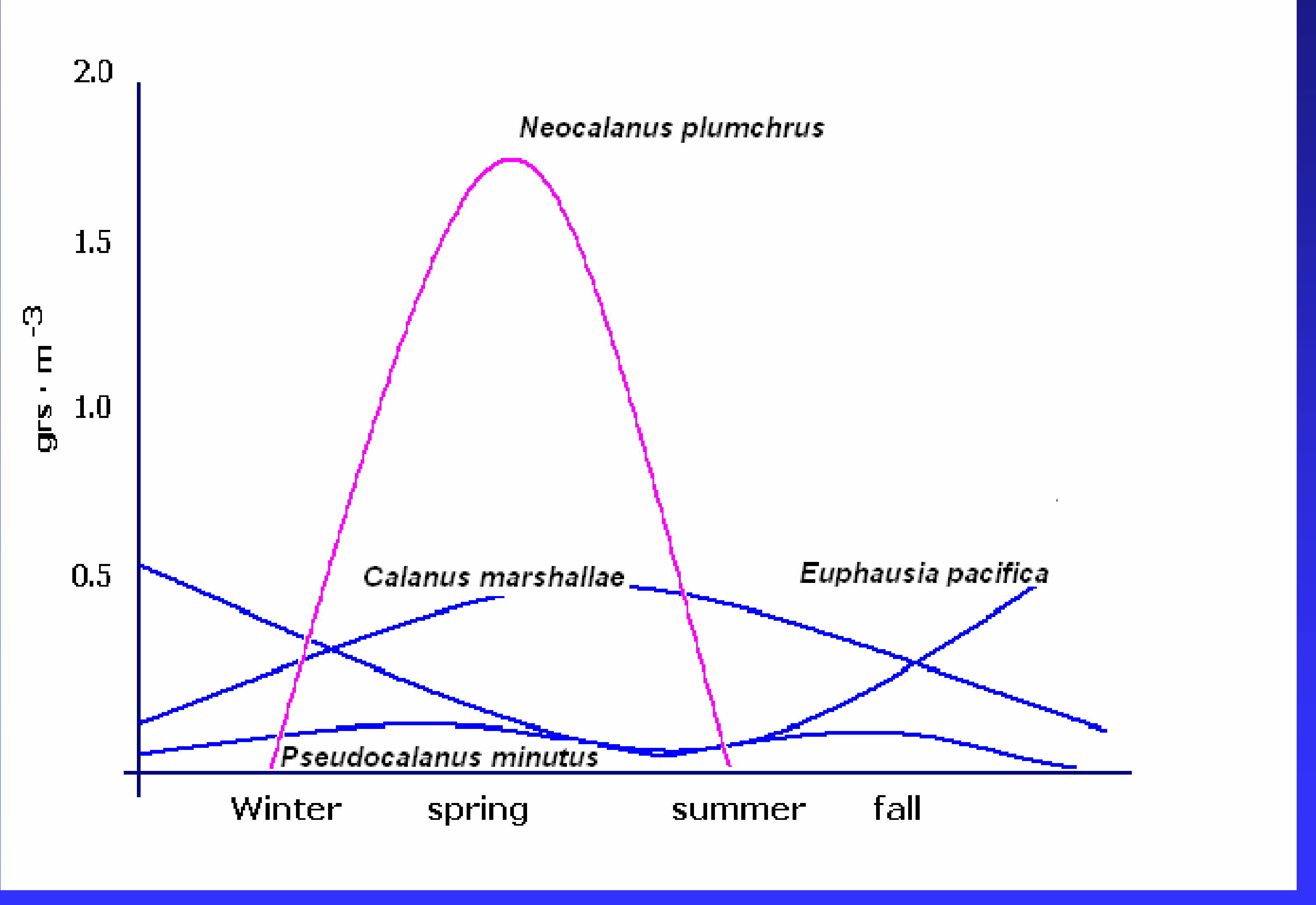


Sampling locations

- **Spring/summer, 1990 & 1991**
- Monthly , 1997



Dominant species



(Redrawn from Harrison et al., 1983)

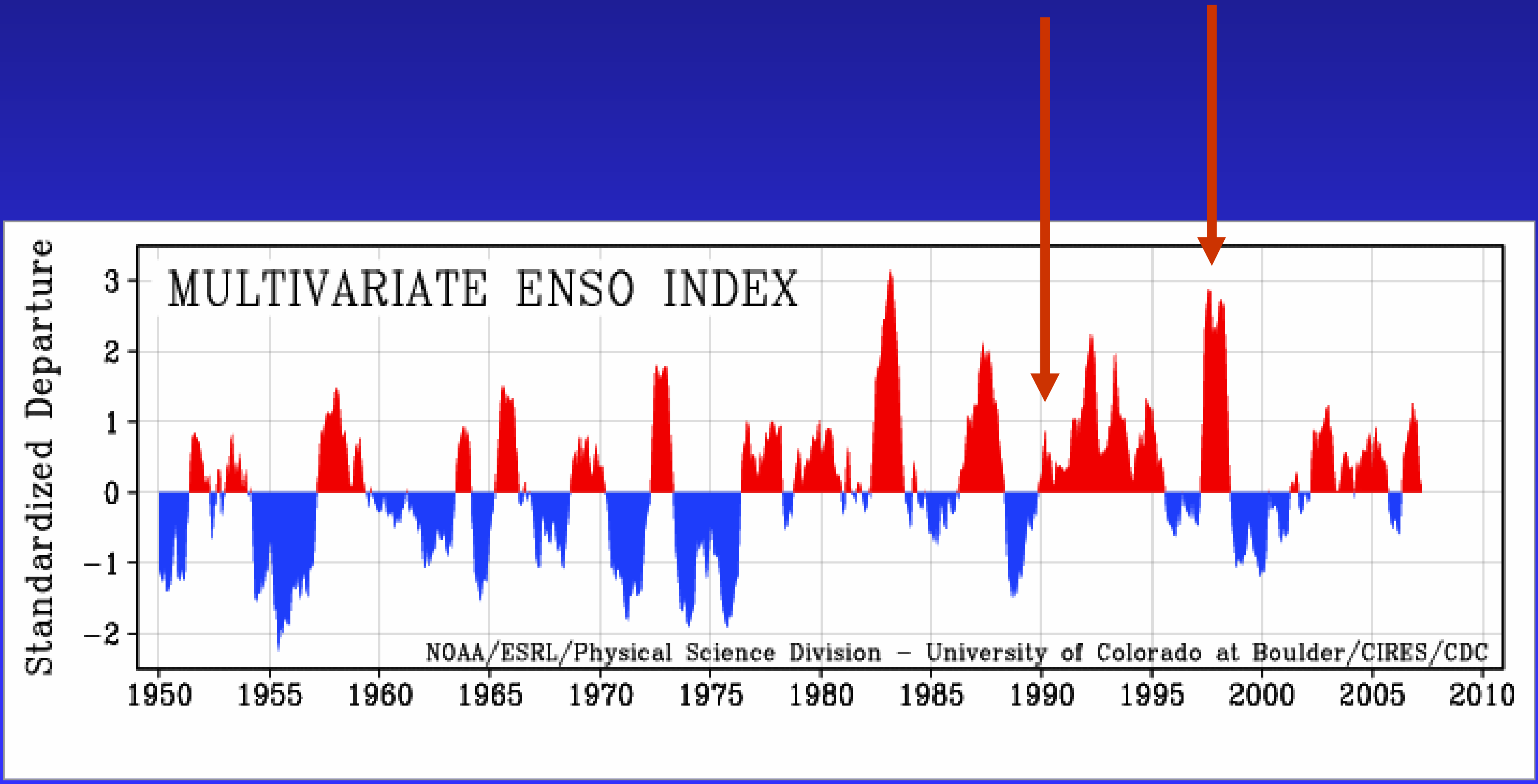
Objectives

- Trophic ecology of dominant zooplankton
  - Stomach contents
- Zooplankton community structure
  - Potential food - prey

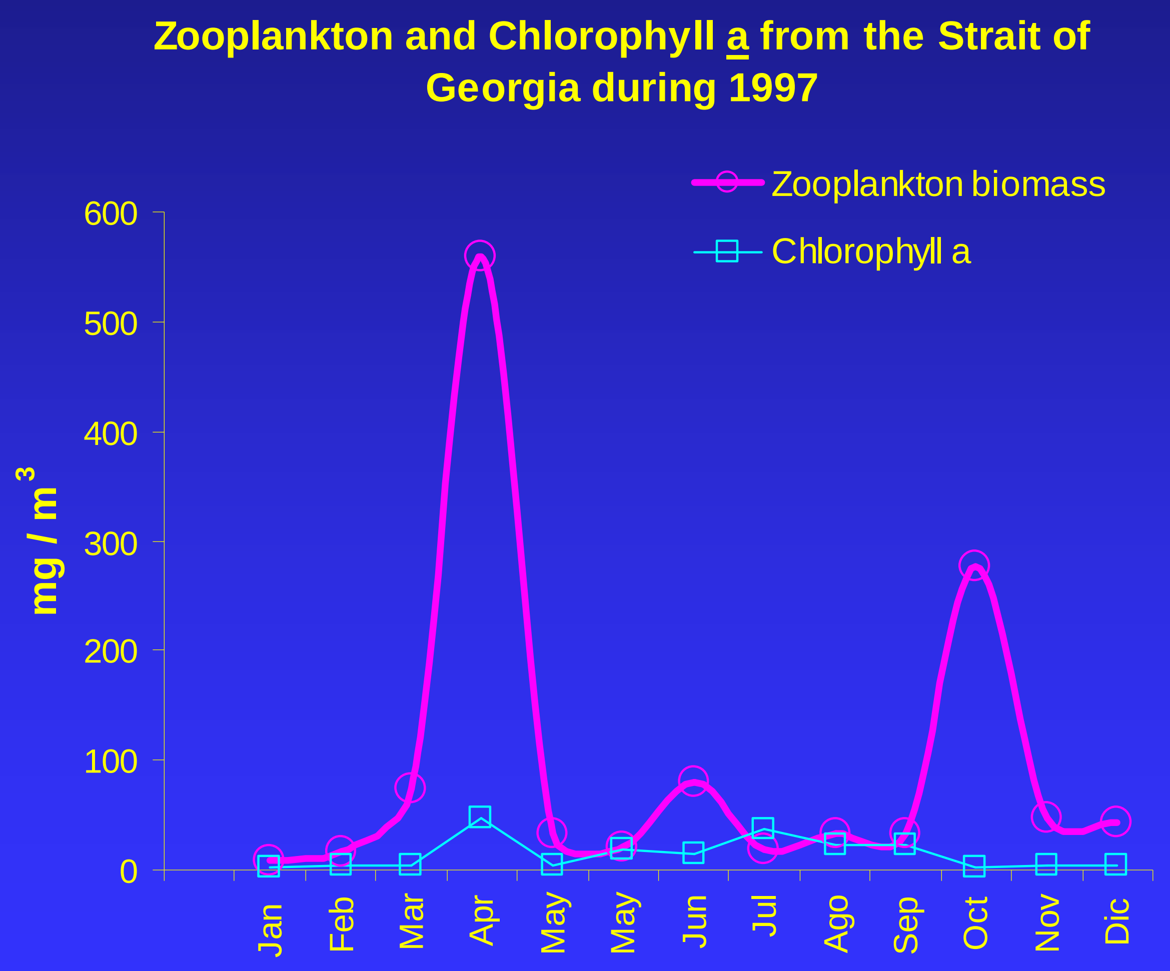
Material & Methods

- Bongo net 202-µm mesh
- Chlorophyll a, and zooplankton biomass
- Daylight sampling 10 AM – 14 PM; 0 – 400 M depth
- Zooplankton taxonomy to lowest possible level
- Community composition and dominance analyzed by principal component analysis (PCA)
- Similarity analysis between stomach contents and prey

Sampling dates: 1990, 1991 & 1997 in relation to ENSO



RESULTS


Zooplankton and Chlorophyll a from the Strait of Georgia during 1997
Zooplankton biomass
Chlorophyll a
mg / m3
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
May
Jun
Jul
Ago
Sep
Oct
Nov
Dic

PCA Results: Dominant species in 1990 & 1991

MAY 29 – JUNE 6 1990 (Estuarine plume 34%)

Oithona spinirostris, Cyphocaris challengeri , Parathemisto pacifica, Metridia okhotensis, Pseudocalanus minutus, Oithona similis, Metridia pacifica, Oncaea borealis

APRIL 7 - 16 1991 (Estuarine plume 37%)

Pseudocalanus minutus, Euphausia pacifica, Neocalanus plumchrus, Calanus marshallae, Cyphocaris challengeri, Metridia pacifica, Eucalanus bungii, Oithona spinirostris

JUNE 11 – 14 1991 (Estuarine plume and Central Strait 39%)

Pseudocalanus minutus, Euphausia pacifica, Parathemisto pacifica, Cyphocaris challengeri, Metridia pacifica, Paracalanus parvus, Oithona similis, Acartia longiremis

PCA Results: Dominant species during 1997

Late spring – summer (54%)

Cyphocaris challengeri, Parathemisto pacifica, Metridia pacifica, Pseudocalanus minutus, Oithona similis, Conchoecia alata minor

Fall – winter (9%)

Parathemisto pacifica, Oncaea borealis, Oithona similis, Pseudocalanus minututs, Conchoecia spinirostris, Cyphocaris challengeri

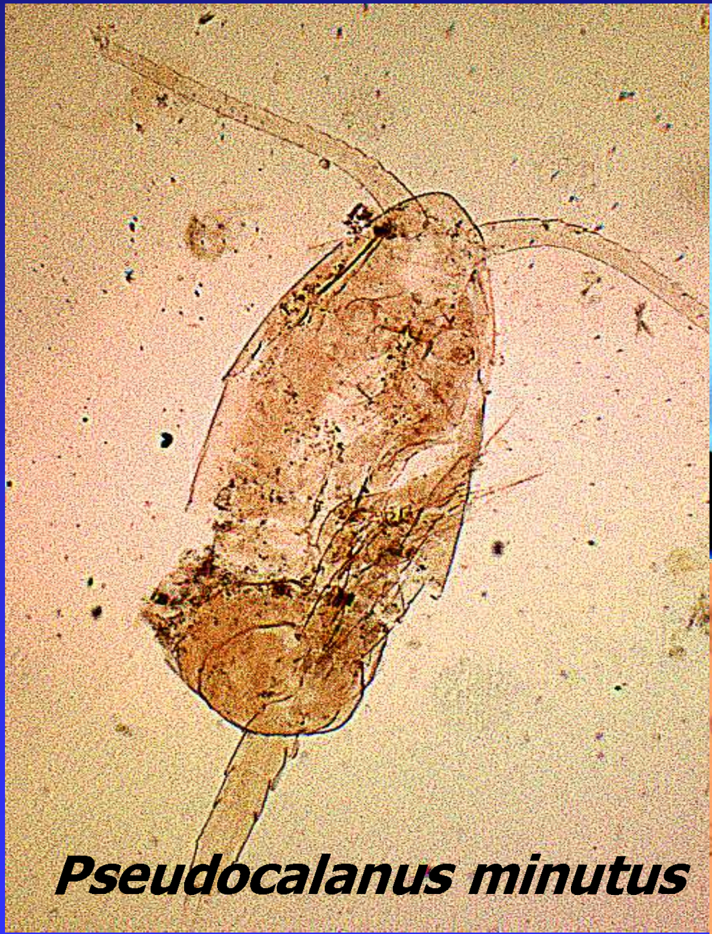
Late winter – spring (5%)

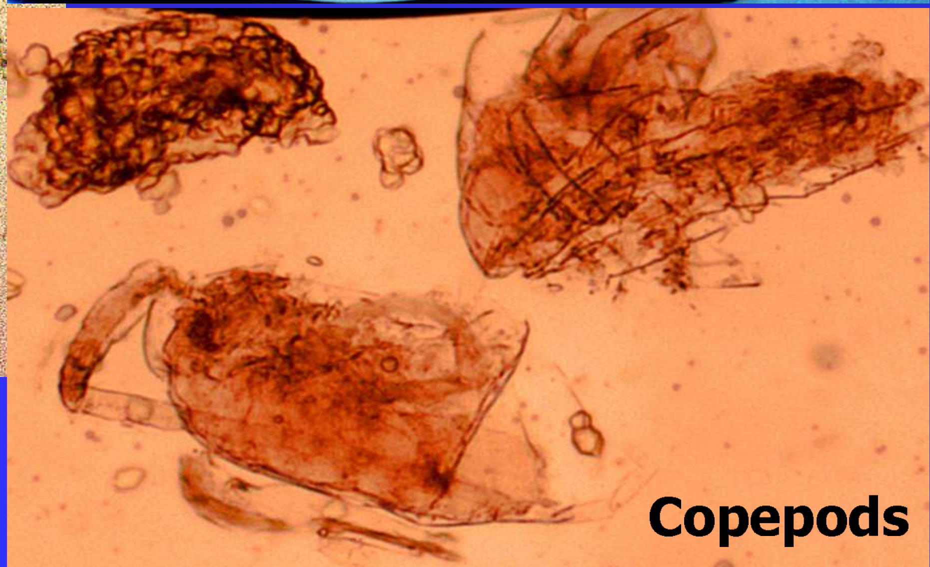
Oithona similis, Pseudocalanus minutus, Metridia pacifica, Conchoecia spinirostris, Limacina helicina, Parathemisto pacifica, Cyphocaris challengeri.

Peak abundance of main species in the Strait of Georgia

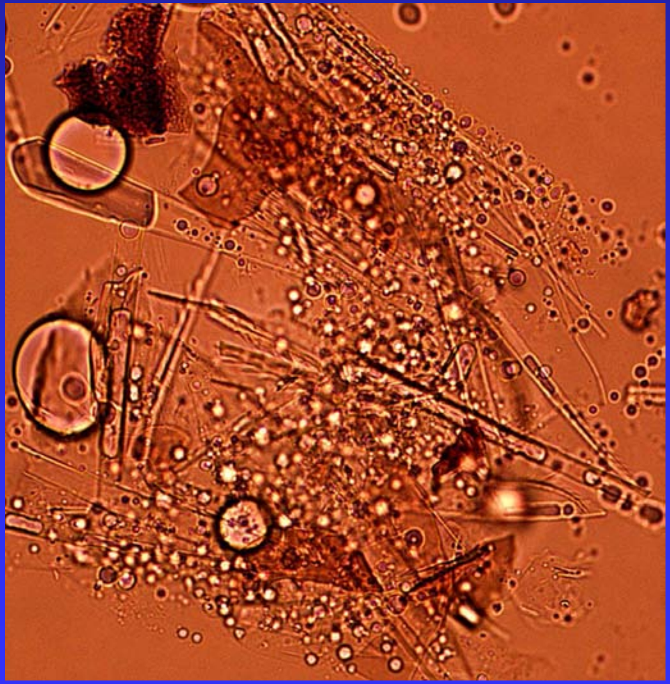
Species and size in mm	season	author
Neocalanus plumchrus, 5 *Calanus marsallae, 4* *Calanus pacificus, 3* *Metridia pacifica, 3* *Pseudocalanus minutus, 1* *Oithona similis, 0.7* *Oithona spinirostris, 1.4* *Oncaea boralis, 0.7*	Spring Summer Summer Fall Spring & fall Late fall & winter Fall Spring & fall	Fulton, 1973 Stephens et al., 1969 Stephens et al., 1969 Stephens et al., 1969 Harrison et al., 1983 (LeBrasseur, 1965) Haro, 2001 Haro, 2001
Euphausia pacifica, 25	Fall & winter	Harrison et al., 1983
Parathemisto pacifica,16	Summer & Fall	Haro 2001

Stomach contents
Parathemisto pacifica





Stomach contents
Cyphocaris challengeri



Oithona sp. male

Number of prey items (numerator) identified per number of stomachs analyzed (denominator) for samples collected during three years from the Strait of Georgia.

Year	1990	1991	1997	Total
Parathemisto pacifica	48 / 116	47 / 114	45 / 77	140/ 307
Cyphocaris challengeri	40 / 99	38 / 79	38 / 80	116/ 258
Total	88 / 215	85 / 193	83 / 157	256/ 565

Stomach contents

Parathemisto Pacifica

Copepods 44%	Amphipods 31%	Cladocerans 7%
Corycaeus anglicus	*Parathemisto pacifica*	cladocerans
Metridia pacifica	*Cyphocaris challengeri*	
Oncaea borealis		
Paracalanus parvus		
Pseudocalanus minutus		

Cyphocaris challengeri

Copepods 32%	Amphipods 32%	Bryozoans 8%
Corycaeus anglicus	*Parathemisto pacifica*	*Cyphonautes larva*
Oithona similis	*Cyphocaris challengeri*	
Paracalanus parvus		
Pseudocalanus minutus		

Diet of main zooplankton species

Species and size in mm	Food	Author
Neocalanus plumchrus, 5 *Calanus marsallae, 4* *Calanus pacificus, 3* *Metridia pacifica, 3* *Pseudocalanus minutus, 1* *Oithona similis, 0.7* *Oithona spinirostris, 1.4* *Oncaea boralis, 0.7*	Centric diatoms Hervibore Omnivore Omnivore-fac.pred Nannoplankton Nannoplankton Nannoplankton Nannoplankton	Harrison et al., 1983 (Marshall and Orr, 1972). Parsons et al, 1969 Raymont 1983 Corkett & McLaren´s 1978 Parsons & Lalli 1988 Parsons & Lalli 1988 Parsons & Lalli 1988
Euphausia pacifica, 25	Omnivore	Lasker 1966
Parathemisto pacifica,15 *Cyphocaris challengeri,16*	Microphage-carnivore Carnivore	Haro, 2004 Haro, 2004

Herring and juvenile salmon diet in the Strait

	Food	Author
Pink	*Neocalanus plumchrus, Parathemisto pacifica*	LeBrasseur et al., 1969
Sockeye	*Parathemisto pacifica*	Beacham, 1986
Chinook, Coho	Herring	Parker and Kask, 1972a,b
Steelhead	Herring	Parker and Kask, 1972a,b
	Herring	Parker and Kask, 1972a,b
Herring, juv	*Pseudocalanus minutus*	Raymont, 1983
Herring, adult	Copepods and *Parathemisto pacifica*	Raymont, 1983

Discussion

- ✓ Typical dominant species were scarce during 1997, therefore a change in functional groups occurred
- ✓ Change in food web structure and trophic pathways
- ✓ Different nutritional value and size of zooplankton available as food for consumers

Size of main functional groups

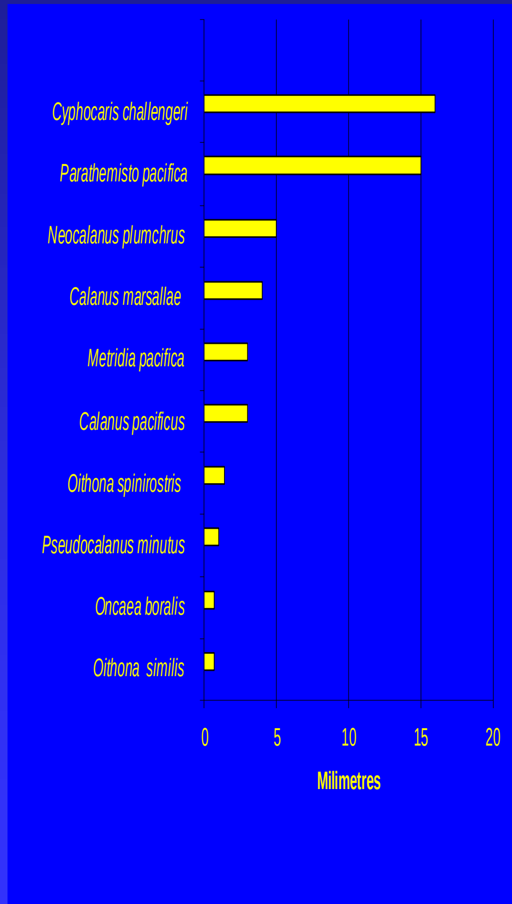
Neocalanus plumchrus 5 mm

Oncaea borealis

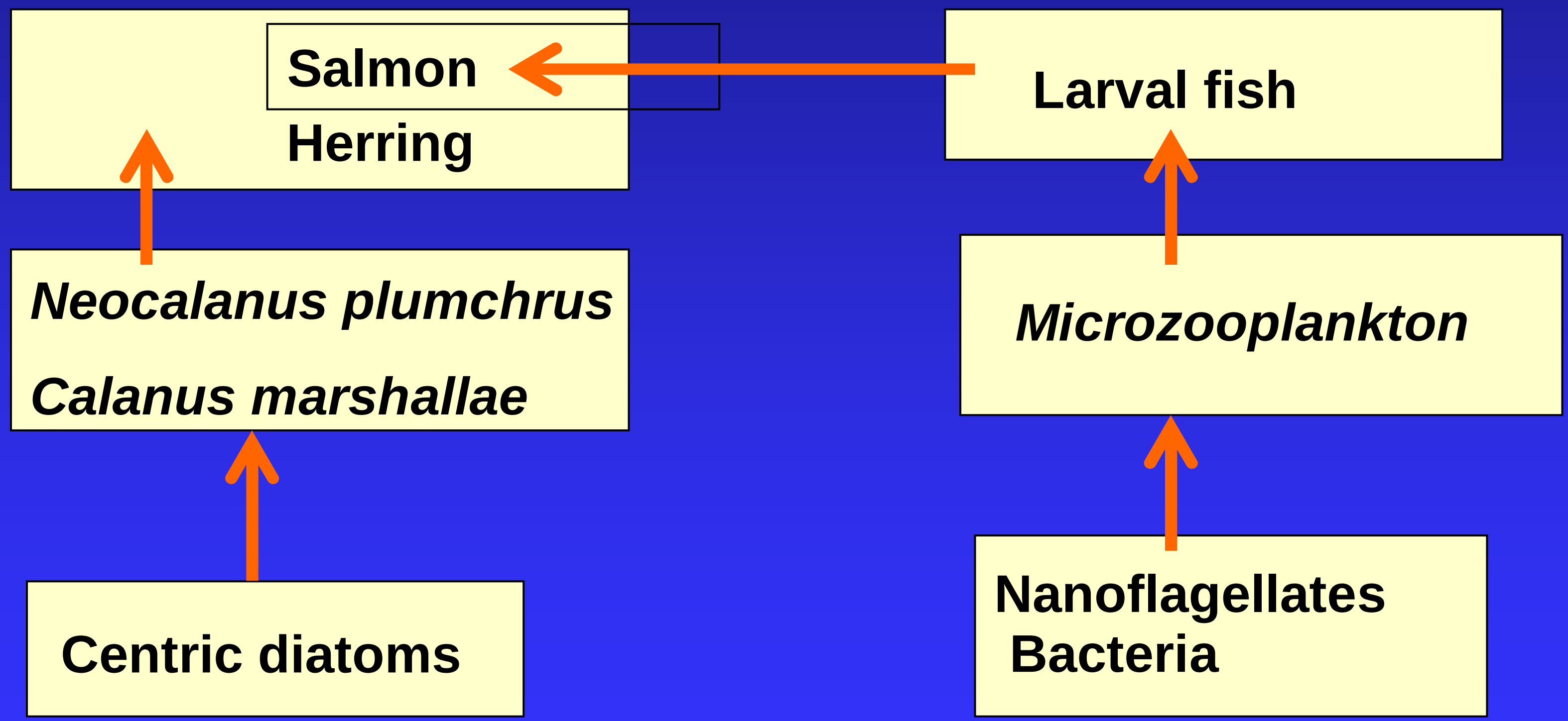
0.7 mm

Oithona similis 0.7 mm

Pseudocalanus minutus 1.5 mm

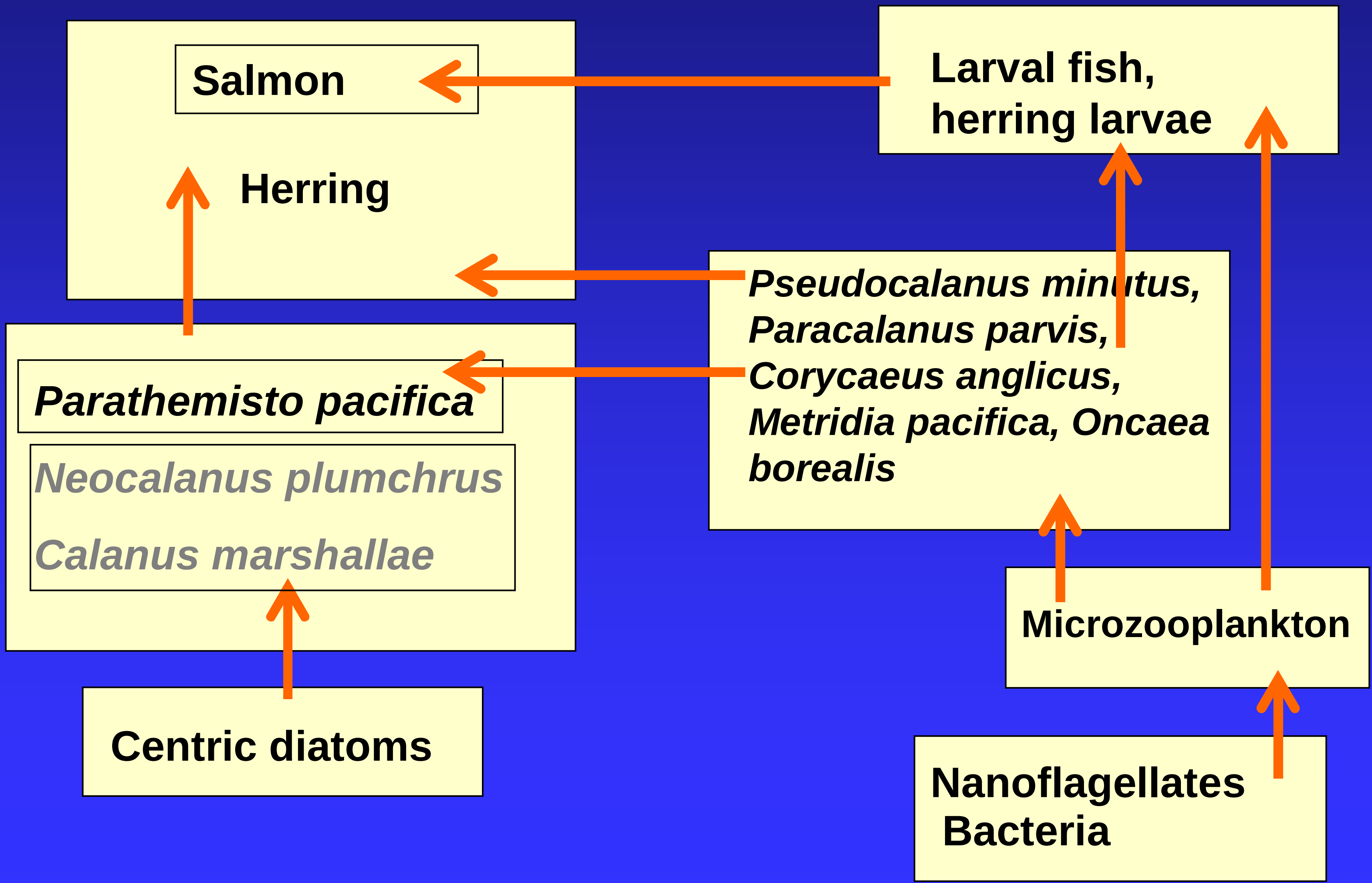


Established spring throphic pathway in the Strait of Georgia

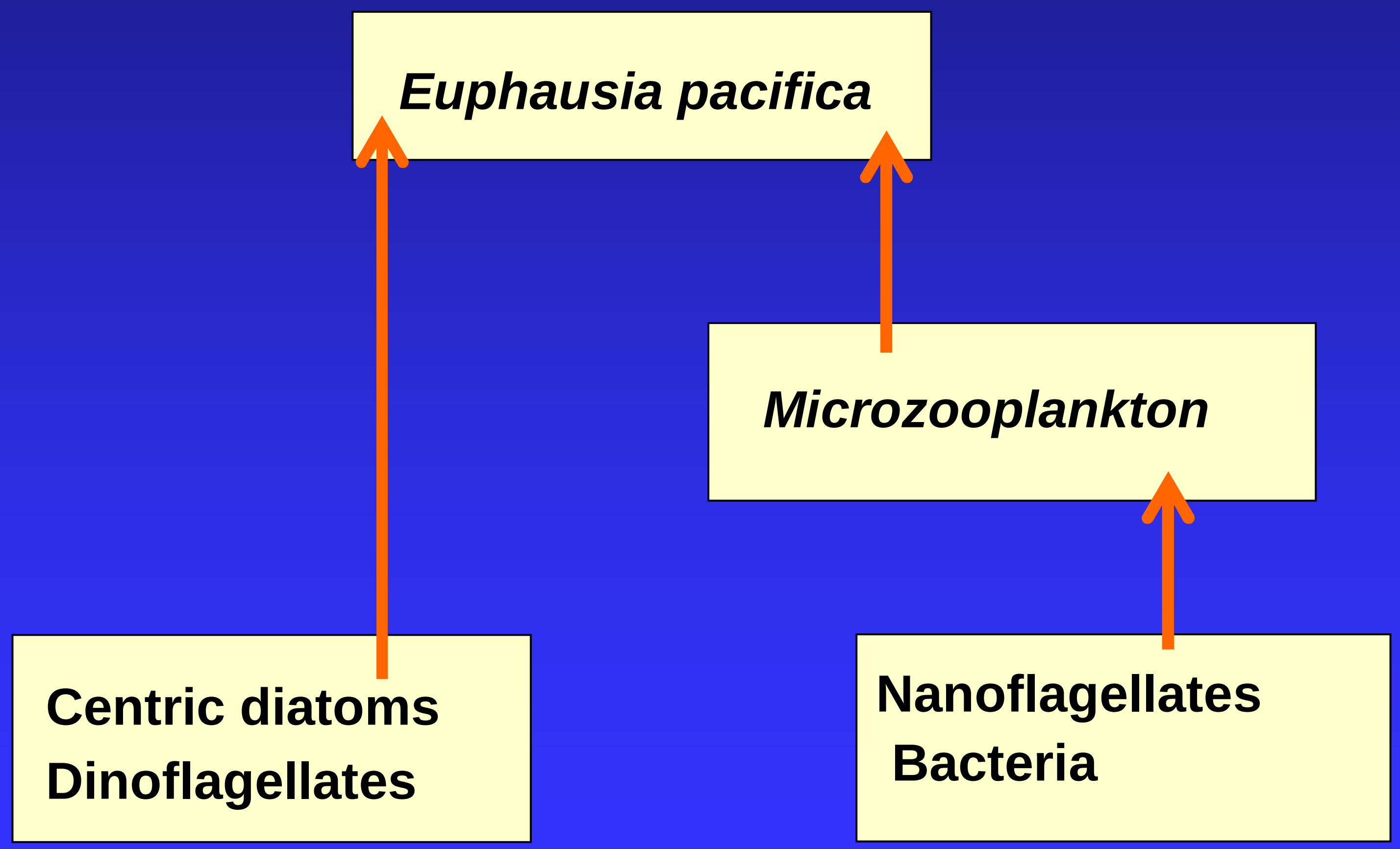


(Harrison et al., 1983)

Proposed spring throphic pathway in the Strait of Georgia during 1997

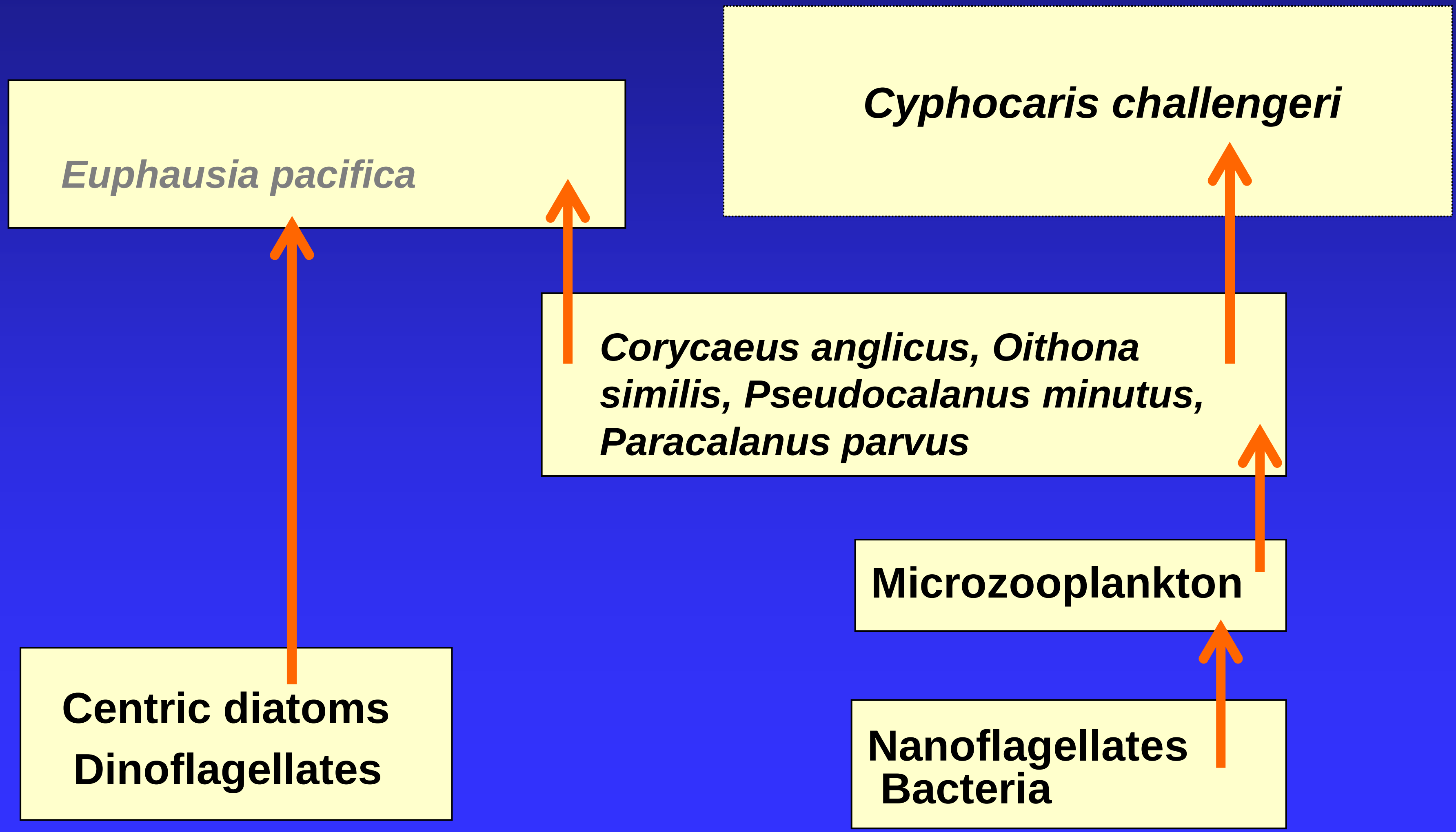


Established autumn throphic pathway in the Strait of Georgia

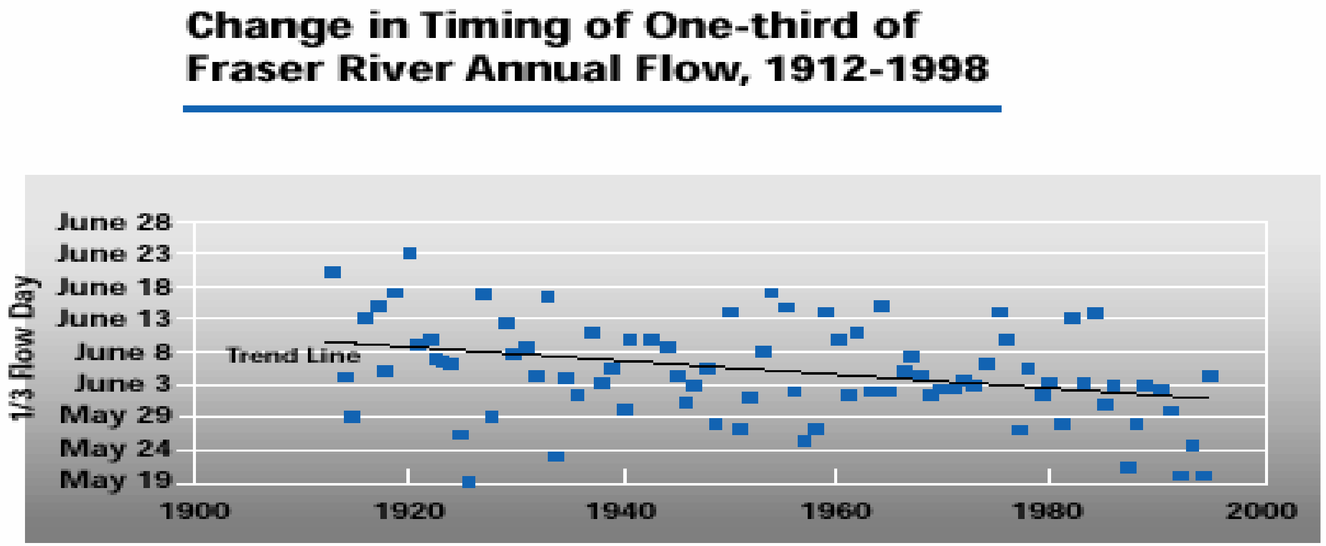


(Harrison et al., 1983)

Proposed autumn throphic pathway in the Strait of Georgia during 1997



✓Earlier phytoplankton bloom coincided with low Fraser River flow



SOURCE: Data from the Water Survey of Canada, Environment Canada. Analysis by John Morrison, Institute of Ocean Sciences, 2001, for Ministry of Water, Land and Air Protection. NOTES: All values are statistically significant. (R^2 = 0.1216, p = 0.001).

Properties of climate that have changed during the 20th century, affecting marine, freshwater, and terrestrial ecosystems in British Columbia.

- Average annual temperature increased by 0.6ºC on the coast, 1.1ºC in the interior, and 1.7ºC in northern BC
- Night-time temperatures higher across most of BC in spring and summer
- Precipitation increased in southern BC by 2 to 4% per decade.
- Lakes and rivers become free of ice earlier in the spring
- Sea surface temperatures increased by 0.9ºC to 1.8ºC along the BC coast
- Two large BC glaciers retreated by more than a kilometre each
- The Fraser River discharges more of its total annual flow earlier in the year.
- Water in the Fraser River is warmer in summer

http://www.gov.bc.ca/wlap.

Consequences of changes in climate in the estuarine environment

- Changes in freshwater inflow, air temperatures, and precipitation patterns affect water residence time, nutrient delivery, dilution, vertical stratification, which control phytoplankton growth rates

- Decreased freshwater runoff will increase estuarine water residence time.
- Whereas increased runoff will decrease residence time
- Increased air temperature may also lead to earlier snowmelt and the resulting peak in freshwater inflow.
  - Summer flows may be reduced as a result of greater evapotransporation.
  - Therefore increase in estuarine salinity modifyes stratification and mixing, thus influencing biotic distributions, life histories, and biogeochemistry

(Malone 1977, Cloern 1991, 1996, Buskey *et al*. 1998, Moore et al., 1997, Howarth *et al*. 2000)

Conclusions

- Earlier phytoplankton bloom observed most probably caused by combined effect of warm water, premature entrainment and / or wind events [River flow during 1997 was lower, earlier and warmer (www.gov.bc.ca/wlap)]
- Mismatch of *N. plumchrus* with spring bloom
- Altered feeding window for migrating juvenile salmon, and other fish
- Also change in zooplankton community structure, and different nutritional value of zooplankton for zooplanktivores
- Change in attributes of functional groups (number, size, schedule, biochemical composition) that link to upper levels as food, therefore:
- Trophic pathways not as previously reported

Therefore: consequences of trophic changes for consumer fish

- Smaller body size
- Lower survival
- Decreased adult fecundity
- Fishery and economics

Areas of research that need further studies or development

- Microozooplankton
- Bioenergetic and trophodynamic modelling of key species
- Field and modelling analysis combined to explore plankton dynamics and its propagating effects to upper trophic levels

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