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Comparative analysis of Canadian Pacific North Coast and Strait of Georgia marine ecosystems

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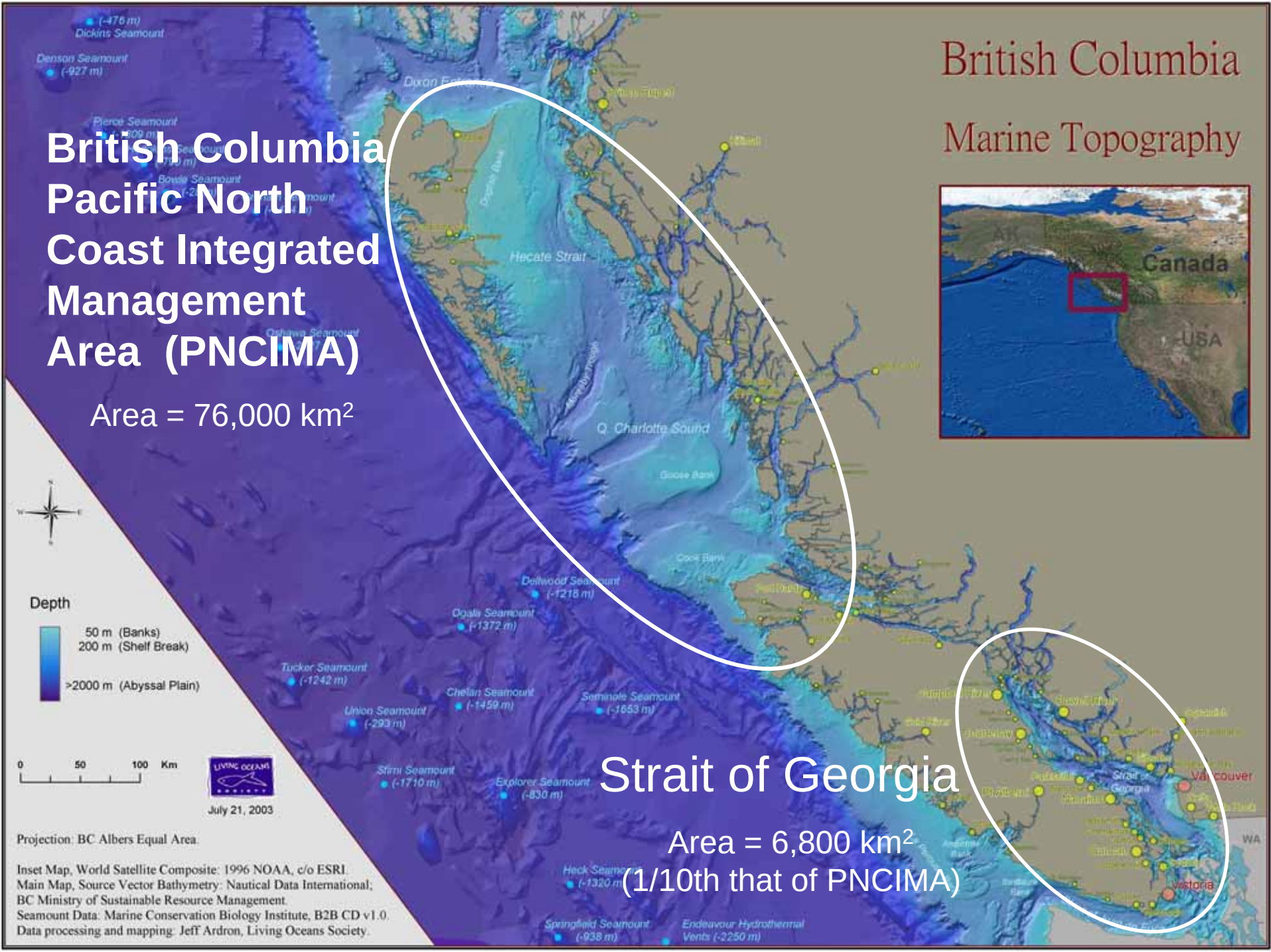
What information is needed for Ecosystem-based approaches to management of marine resources?

How are marine ecosystems structured?

How do marine ecosystems function?

What disrupts or changes structure and function?

A comparative approach to ecosystem description should achieve more than single system examinations.


British Columbia
Marine Topography
British Columbia Pacific North Coast Integrated Management Area (PNCIMA)
Area = 76,000 km²
Canada
USA
Hecate Strait
Q. Charlotte Sound
Strait of Georgia
Area = 6,800 km²
(1/10th that of PNCIMA)
Depth
50 m (Banks)
200 m (Shelf Break)
>2000 m (Abyssal Plain)
0 50 100 Km
July 21, 2003
Projection: BC Albers Equal Area.
Inset Map, World Satellite Composite: 1996 NOAA, c/o ESRI.
Main Map, Source Vector Bathymetry: Nautical Data International; BC Ministry of Sustainable Resource Management.
Seamount Data: Marine Conservation Biology Institute, B2B CD v1.0.
Data processing and mapping: Jeff Ardron, Living Oceans Society.

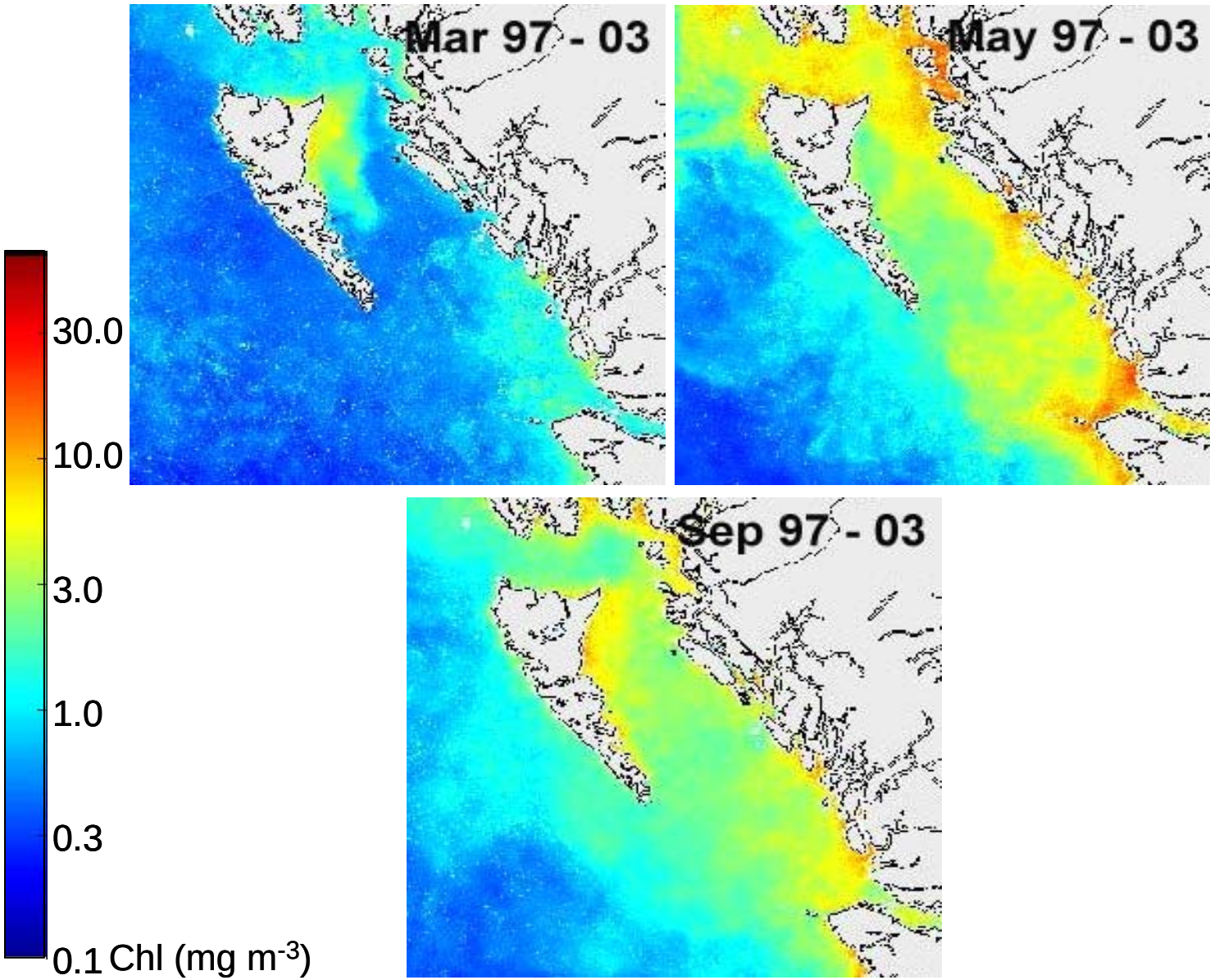
Physically, PNCIMA and Strait of Georgia structured by geological & topographical environments, and Aleutian Low (winter) and North Pacific High (summer) pressure systems

- steep coastal mountains influence winds, rainfall, runoff
- PNCIMA:
  - glacial-formed troughs and shallow banks influence circulation
  - Queen Charlotte Islands and meso-scale eddies reduce exchanges with open ocean
- Strait of Georgia:
  - Vancouver Island and islands at north and south entrances reduce exchanges with open ocean
  - freshwater from Fraser River is a dominant feature of southern half of the strait
    - drives strong estuarine circulation that brings deep nutrient-rich water into the Strait
    - strong tidal-driven vertical circulations at entrances to Strait
  - much of the Strait is deep (>100 m)

Controls on ecosystem structure – “Bakun’s Triad Plus”

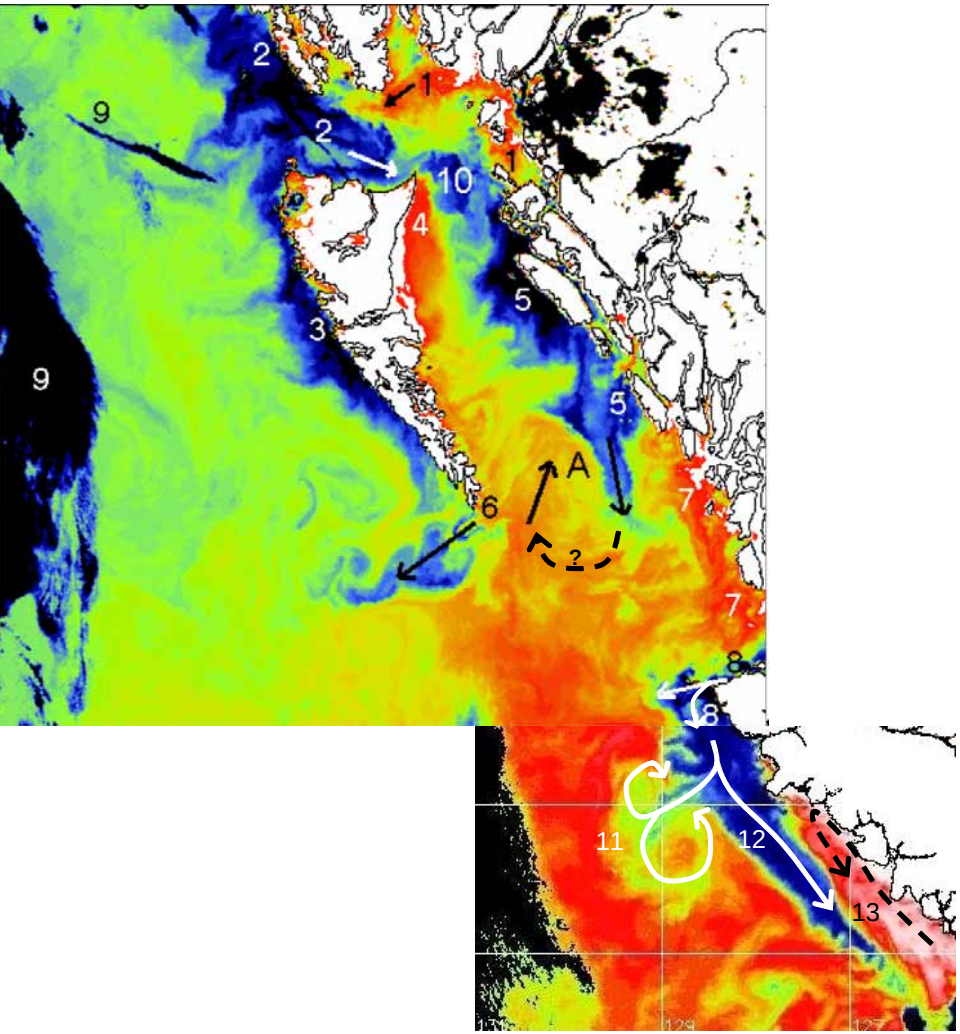
	PNCIMA	**Strait of Georgia**
Enrichment	- wind-driven upwelling; - tidal & wind mixing; - estuarine flow of freshwater (local effects)	- tidal & wind mixing; - estuarine flow of freshwater
Initiation (of plankton blooms)	- shallow banks limit depth of mixing (localised effect)	- interaction of wind mixing and freshwater stratification (broad effect)
Concentration	- bank edges and eddies; - river plume fronts	- smaller spatial scale of region; - river plume fronts
Retention	- meso-scale eddies; - recirculaton by topography	- estuarine circulation; - intense vertical mixing at entrances

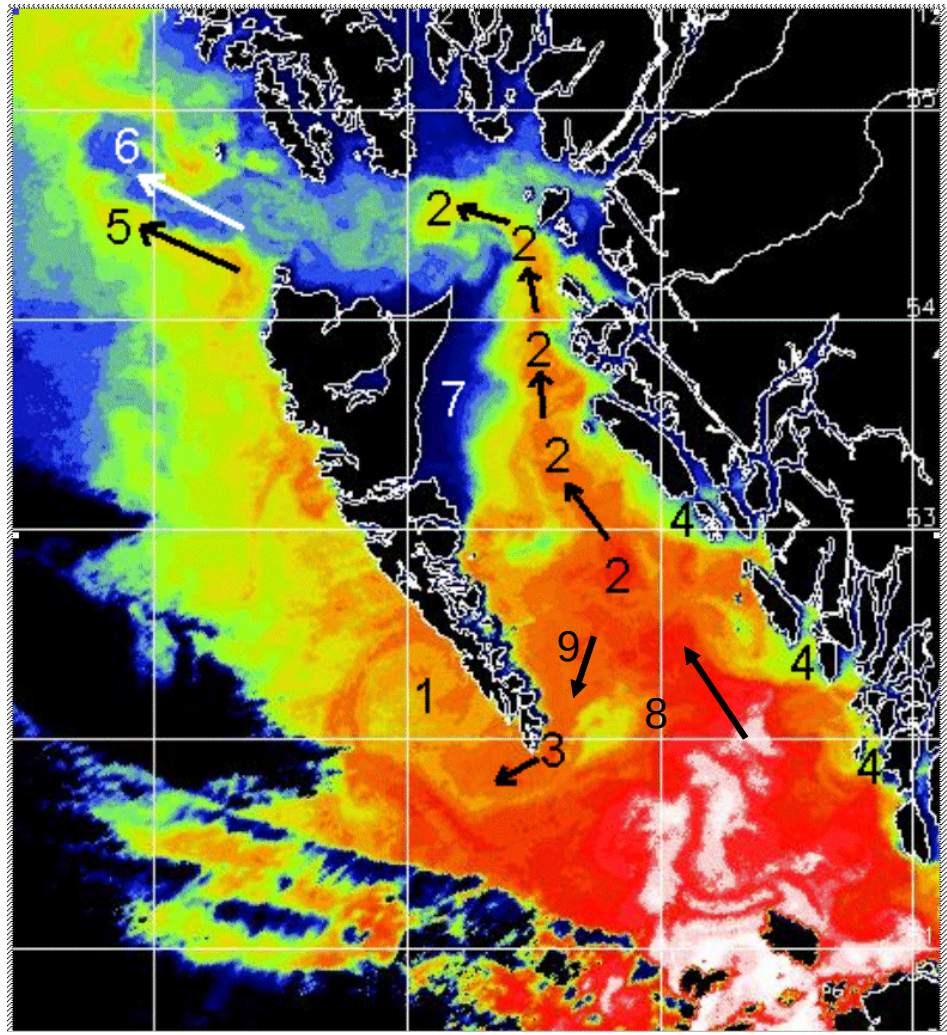
Seasonal patterns of chlorophyll biomass



Summer

Winter

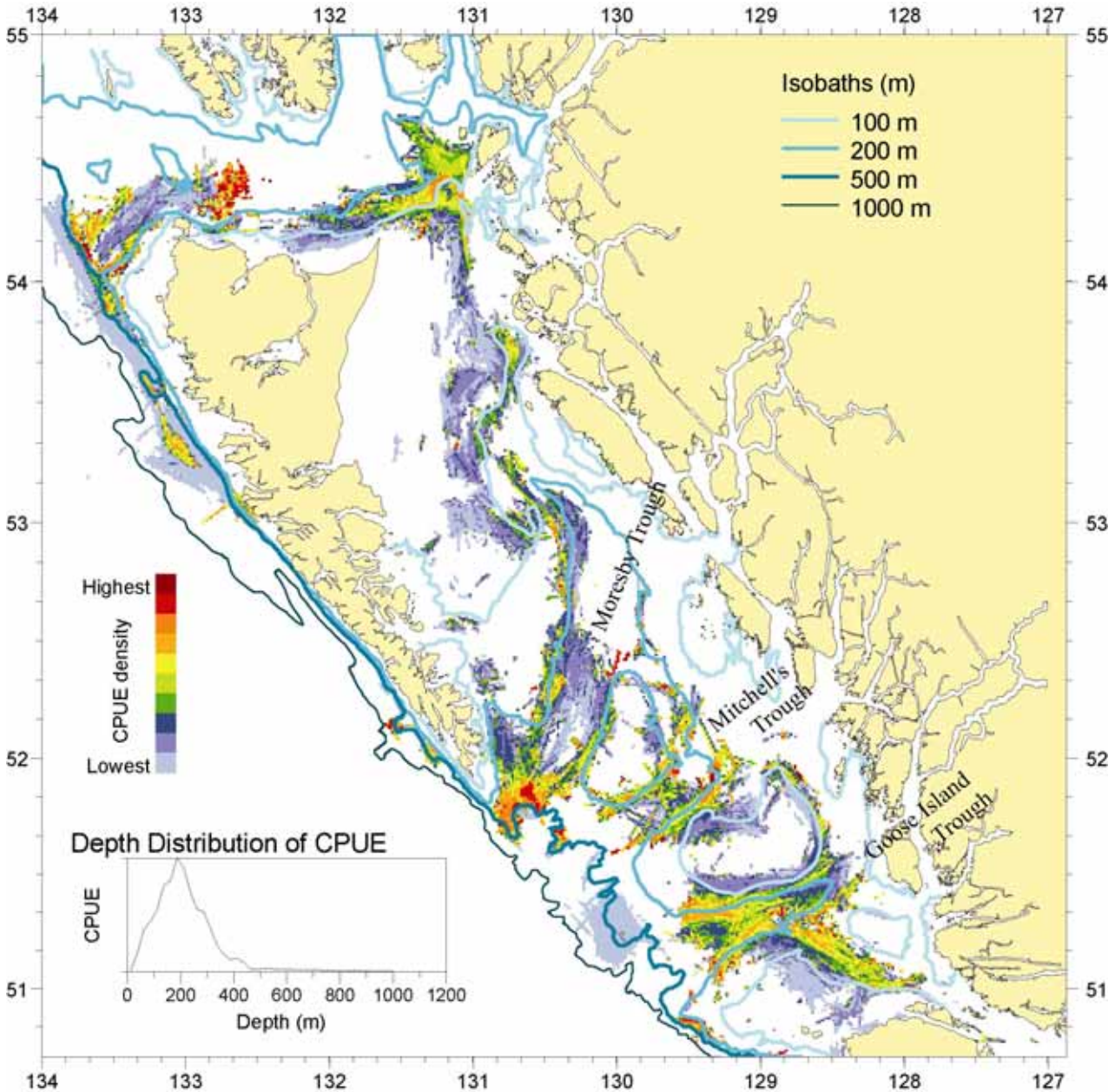


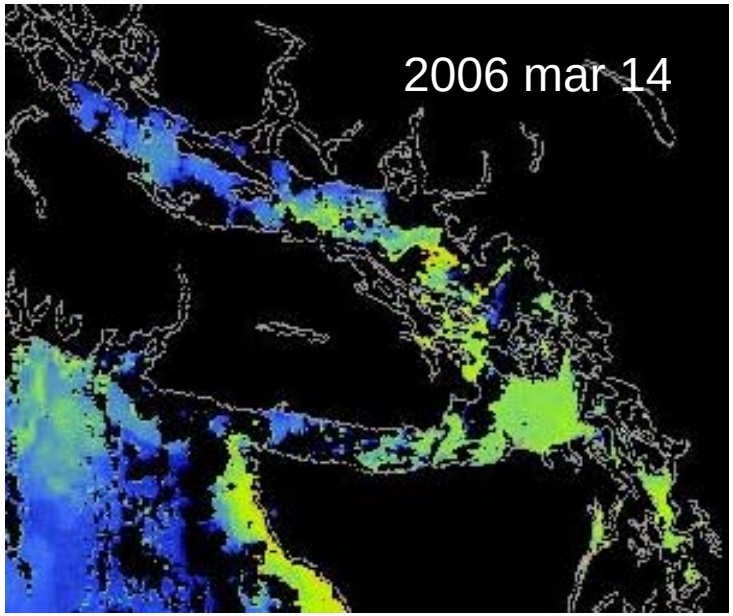


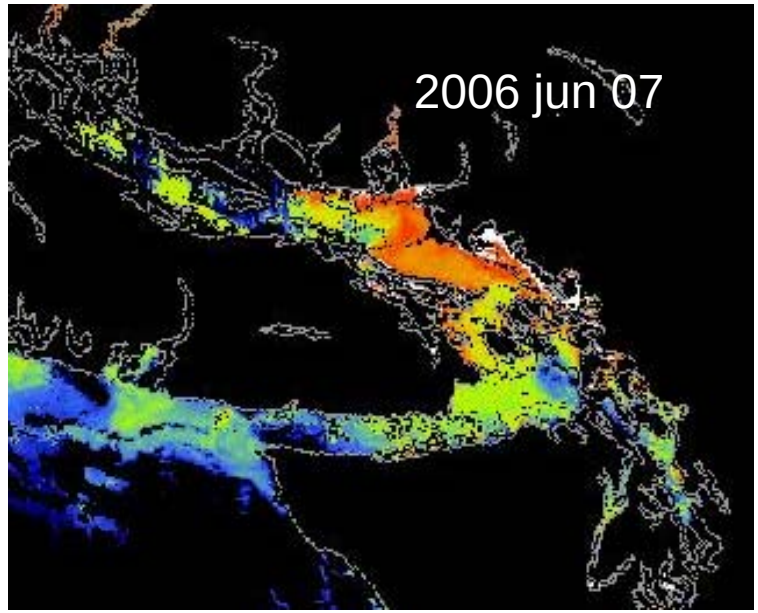
Satellite-derived sea surface temperatures, and assumed surface currents.

These currents are found during sunny days, which normally requires winds from the NE in summer, and outflow winds in winter.

Groundfish catch rates (CPUE) 1996-2003



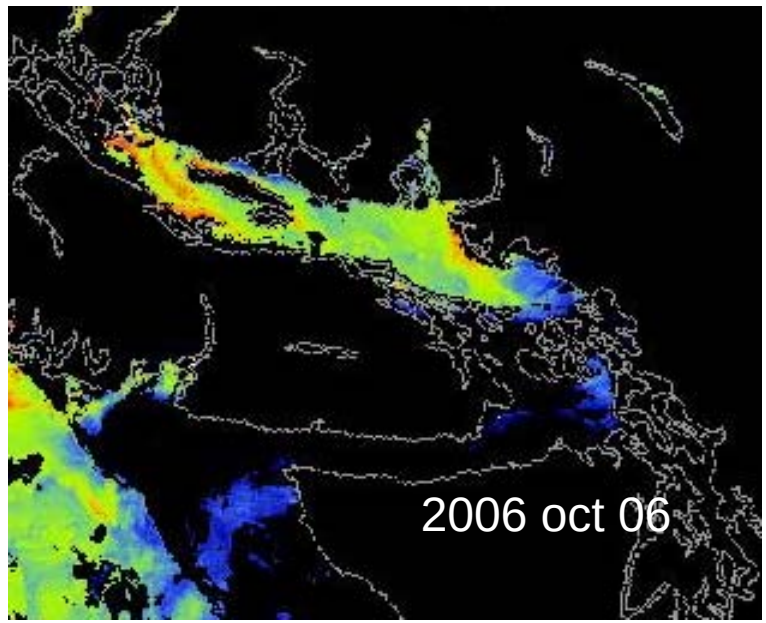


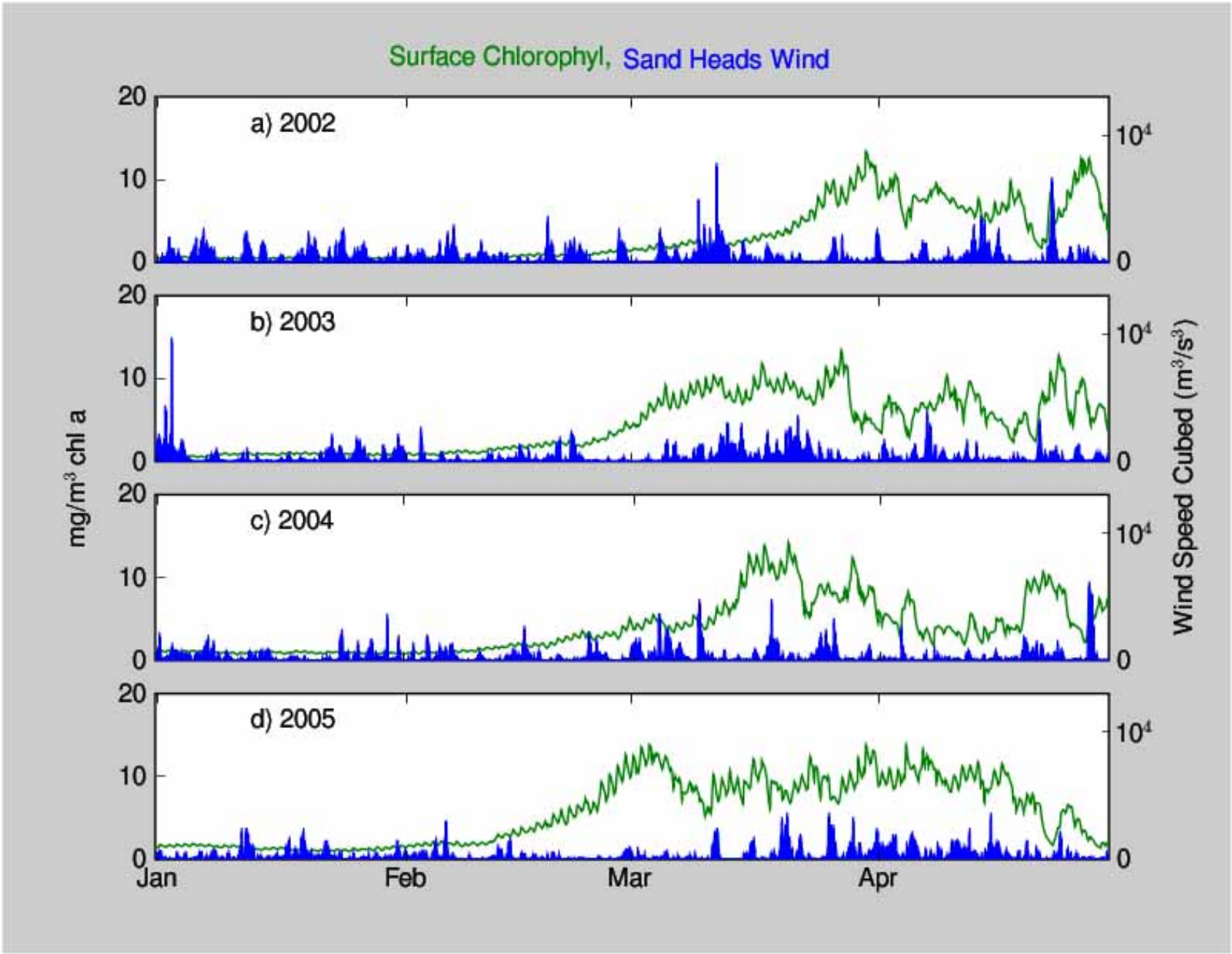


MERIS satellite

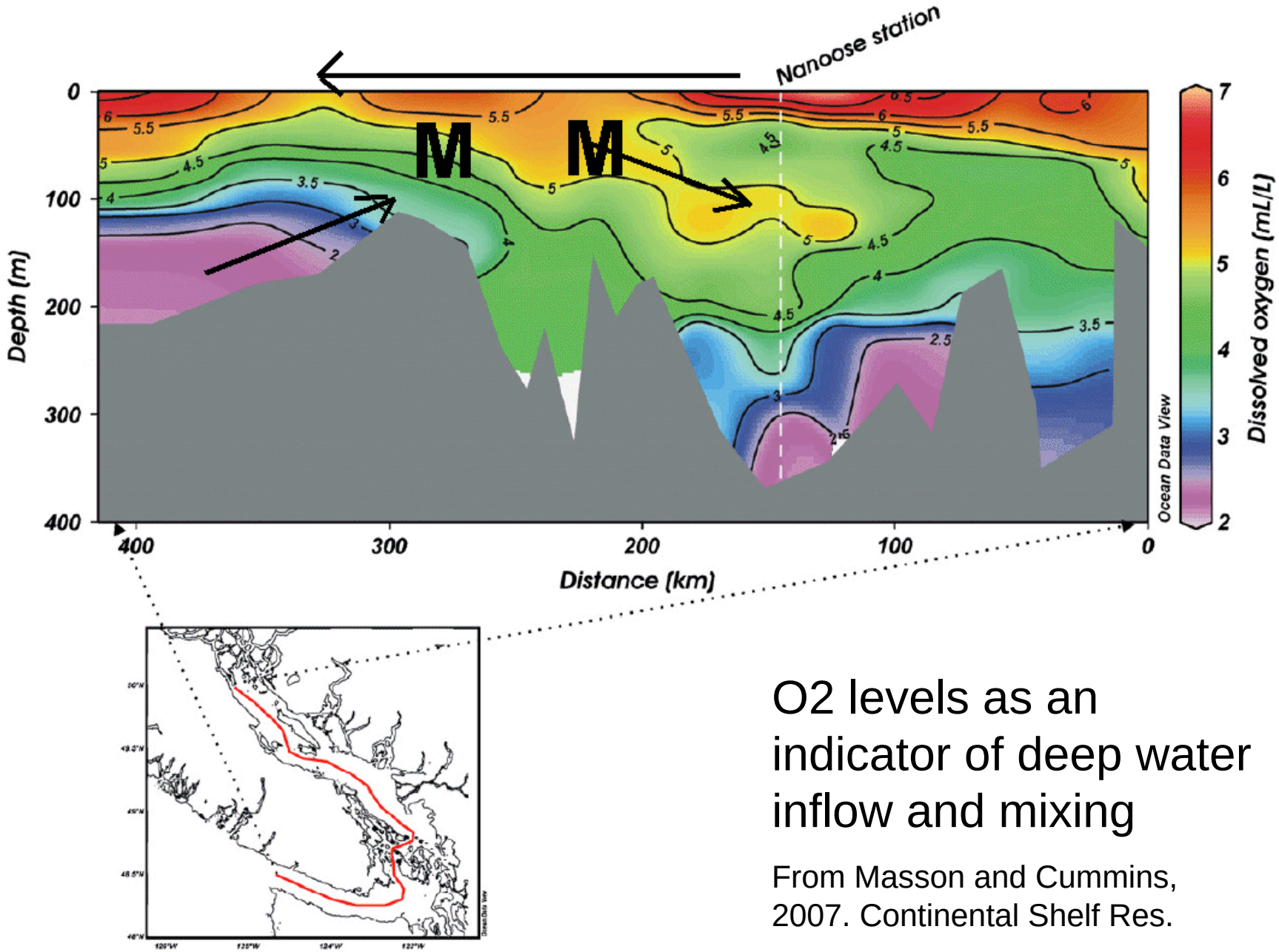
Chlorophyll (algal1) concentration

Strait of Georgia





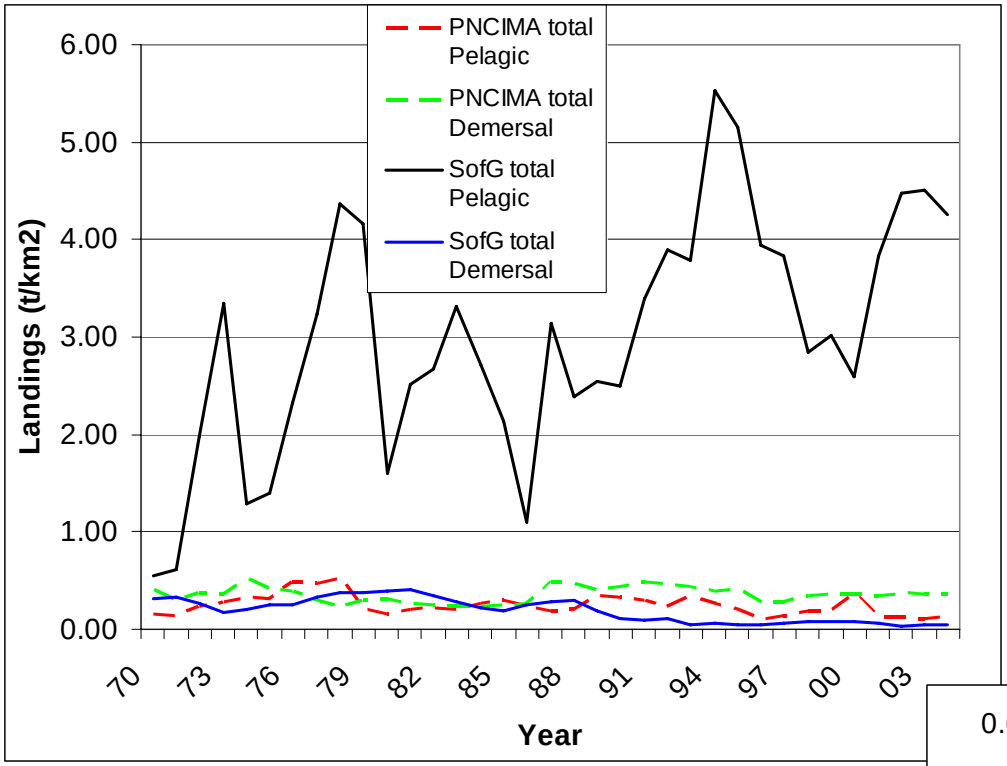
University of British Columbia, STRATOGEM Project – slide courtesy of Susan Allen



O2 levels as an indicator of deep water inflow and mixing

From Masson and Cummins, 2007. Continental Shelf Res.

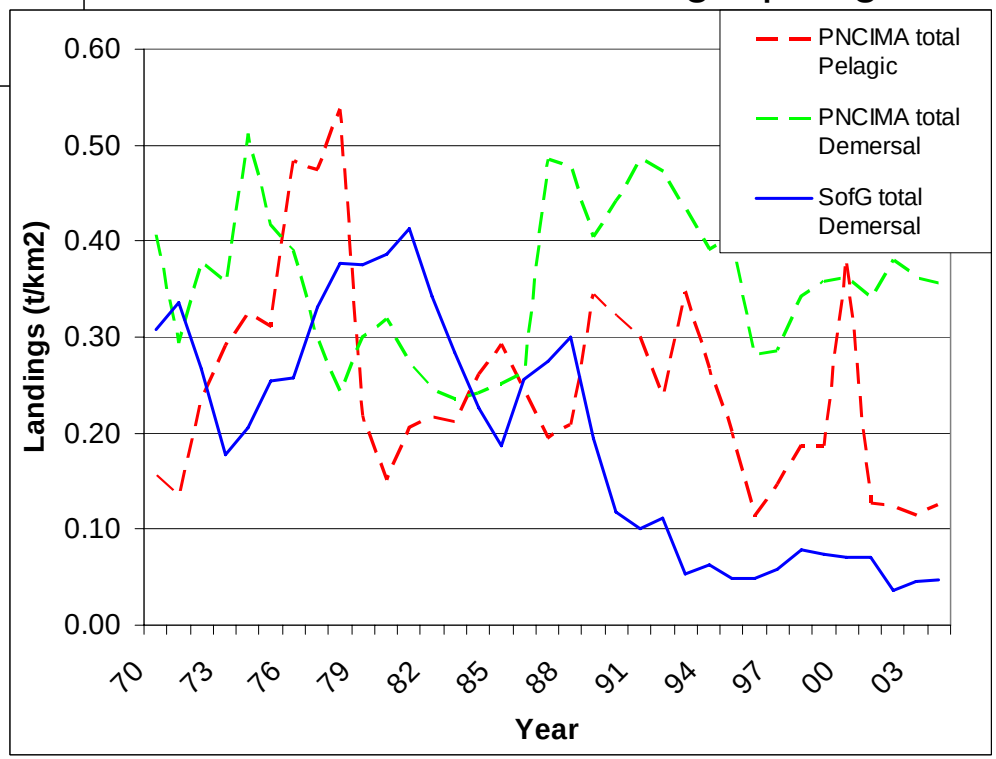
Fig. 3. Dissolved oxygen concentrations measured along the main axis of the coastal basin, during a seasonal survey in April, 2000. The position of the Nanoose station along the section is indicated.



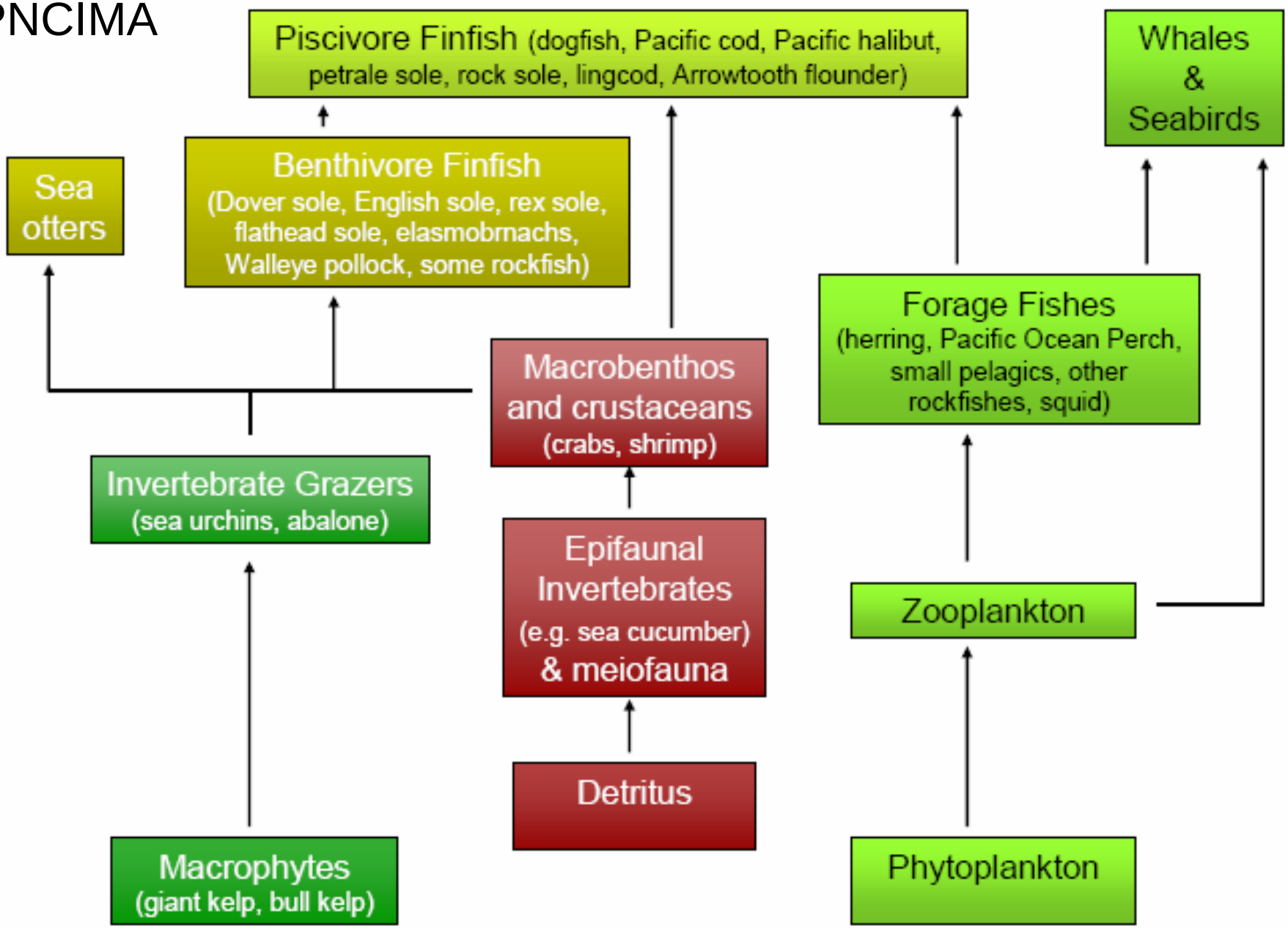
Pelagic and demersal fish landings (t/km^2) in Strait of Georgia (solid lines) and PNCIMA (dashed lines)

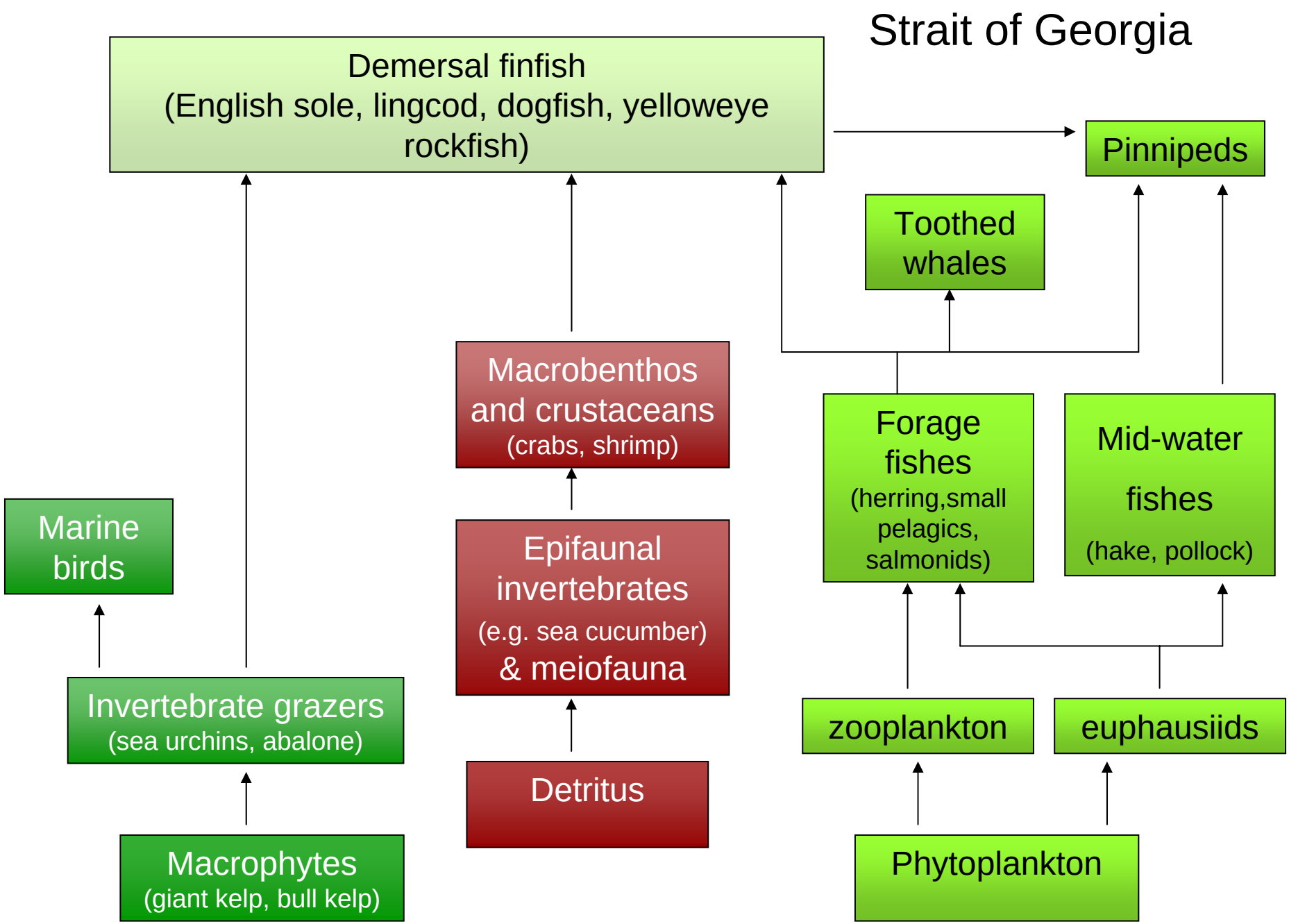
Pelagics and demersals for both areas

without Strait of Georgia pelagics



PNCIMA


Piscivore Finfish (dogfish, Pacific cod, Pacific halibut, petrale sole, rock sole, lingcod, Arrowtooth flounder)
Whales & Seabirds
Sea otters
Benthivore Finfish (Dover sole, English sole, rex sole, flathead sole, elasmobrnachs, Walleye pollock, some rockfish)
Forage Fishes (herring, Pacific Ocean Perch, small pelagics, other rockfishes, squid)
Macrobenthos and crustaceans (crabs, shrimp)
Invertebrate Grazers (sea urchins, abalone)
Epifaunal Invertebrates (e.g. sea cucumber) & meiofauna
Zooplankton
Detritus
Macrophytes (giant kelp, bull kelp)
Phytoplankton


Strait of Georgia
Demersal finfish
(English sole, lingcod, dogfish, yelloweye rockfish)
Pinnipeds
Toothed whales
Macrobenthos and crustaceans
(crabs, shrimp)
Forage fishes
(herring,small pelagics, salmonids)
Mid-water fishes
(hake, pollock)
Marine birds
Epifaunal invertebrates
(e.g. sea cucumber)
& meiofauna
Invertebrate grazers
(sea urchins, abalone)
Detritus
zooplankton
euphausiids
Macrophytes
(giant kelp, bull kelp)
Phytoplankton

Food web properties

		Strait of Georgia	PNCIMA
Number of "species"	S	32	45
Number of Links	L	299	354
Link density	L/S	**9.3**	**7.9**
Direct Connectance	$C_{dir} = L/S^2$	**0.29**	**0.17**
Connectivity	C = L/ [S(S-1)/2]	**60.3%**	**35.8%**
Stability proxy	SxC	19.2	16.1
Top nodes	T	9.4%	6.7%
Bottom nodes	B	9.4%	4.4%
Intermediate nodes	I	81.3%	88.9%

Strait of Georgia: ECOPATH diet matrix, Beamish et al. 2001. PICES Sci Rept 17
PNCIMA: ECOPATH diet matrix, Ainsworth et al. 2002 UBC Fisheries Centre Report 10(4)

Controls on ecosystem structure and function – "Bakun's Triad Plus"

	PNCIMA	**Strait of Georgia**
Enrichment	- wind-driven upwelling; - tidal & wind mixing; - estuarine flow of freshwater	- tidal & wind mixing; - estuarine flow of freshwater
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Concentration	-bank edges and eddies; - river plume fronts	- river plume fronts; - smaller spatial scale of region
Retention	- meso-scale eddies; - recirculaton by topography	- estuarine circulation; - intense vertical mixing at entrances
Trophic **Dynamics**	- demersal fisheries significant; -pelagic fisheries secondarily important; - lower connectivity	- pelagic fisheries very strongly dominant; - higher connectivity

Conclusions

Ecosystem structure and function set by features of “Bakun’s Triad Plus”:

enrichment, initiation, concentration, retention, trophic dynamics

but processes differ by Region:

PNCIMA:

- shallow banks enhance production but concentration at bank edges
- retention within Region by offshore island barriers and meso-scale eddies

Strait of Georgia:

- deep bottom depths
- high volume river outflow increases vertical stability over large area
- estuarine circulation and strong vertical mixing at entrances to Strait

leads to different trophic dynamics:

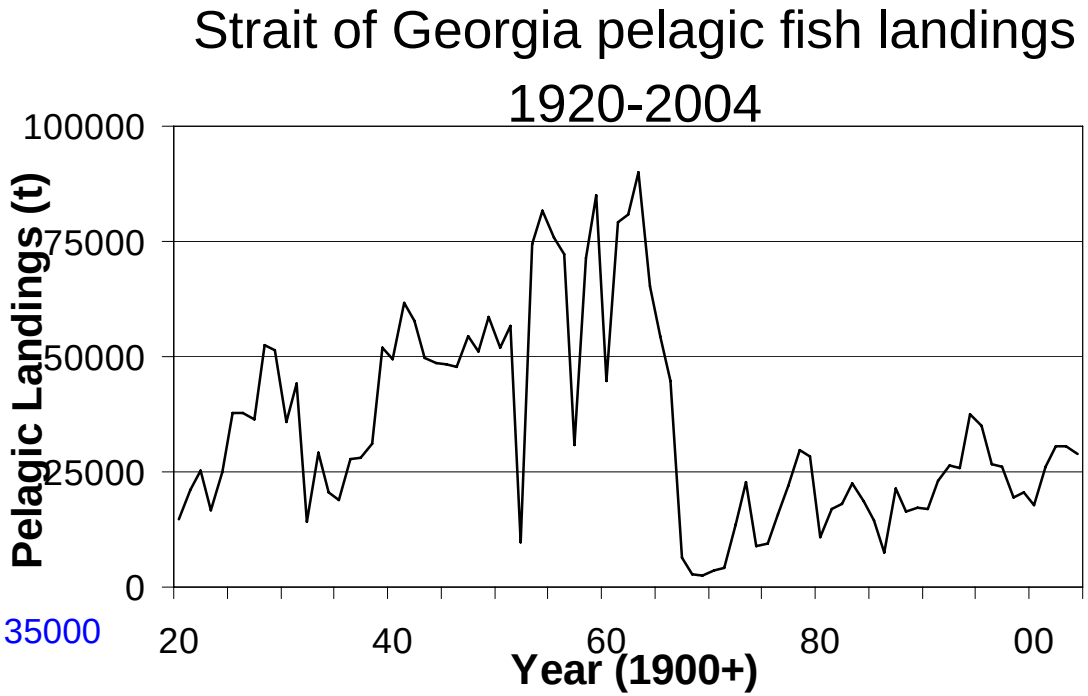
PNCIMA:

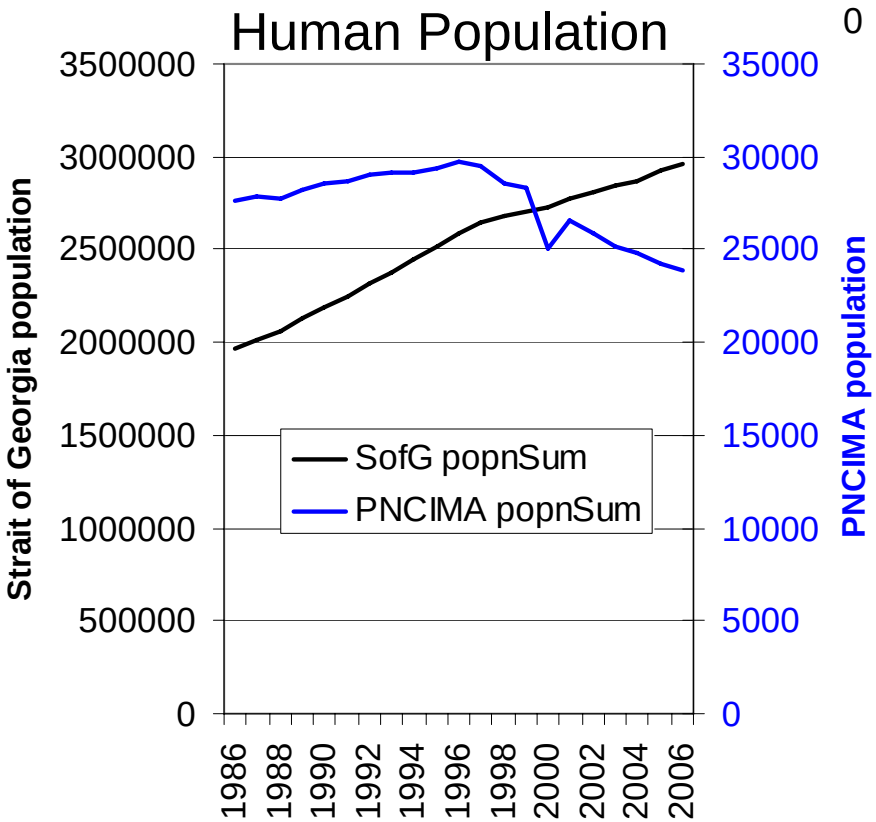
- demersal fishes dominate, but pelagics also significant

Strait of Georgia:

- pelagic fishes strongly dominate; higher connectivity (because of smaller area?; more robust?)

Vulnerabilities





Human pressures

PNCIMA and Strait of Georgia

Conclusions (2)

Both systems vulnerable to whatever disrupts production processes of “Bakun’s Triad Plus”:

Strait of Georgia:

- warming, and changes in stratification and wind mixing;
- intensive fishing;
- increasing human population

PNCIMA:

- intensive fishing