Long-term changes in zooplankton community size structure: a global comparison

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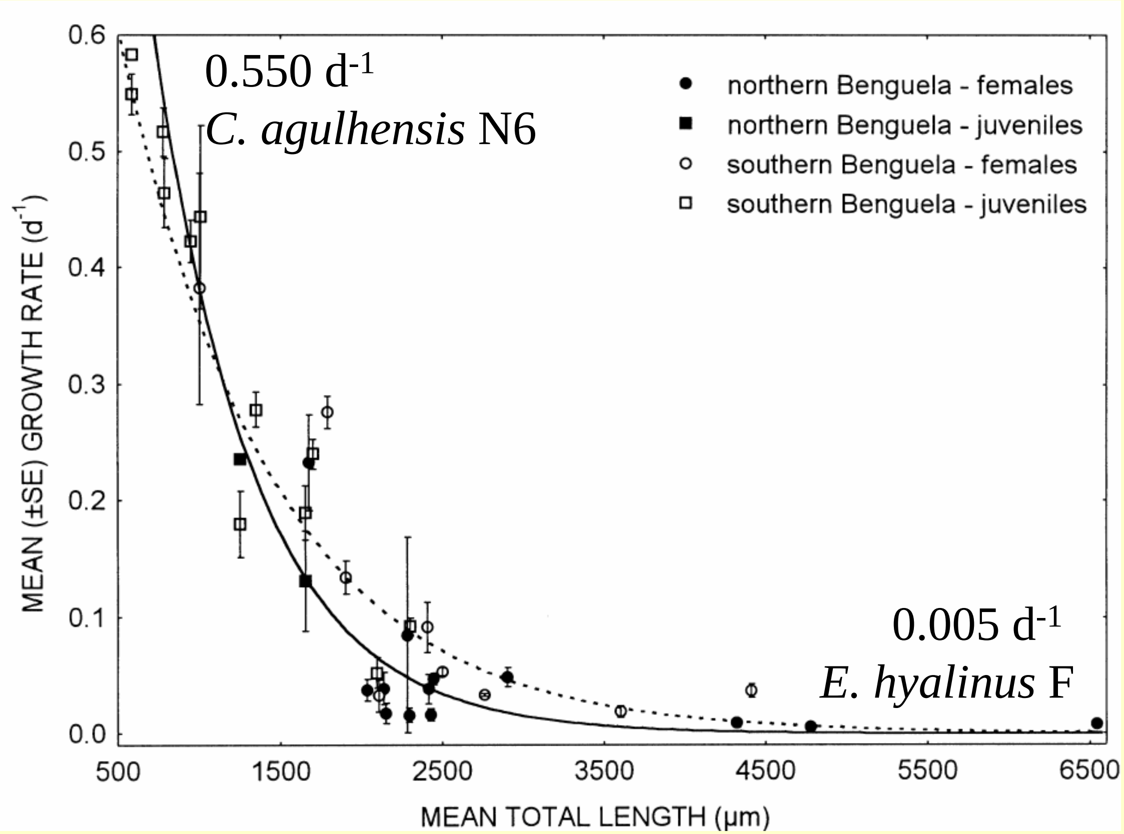
Importance of BODY SIZE in zooplankton:

Allometric relationships describe many biological rate processes in the ocean;
e.g.

- **Predation:**
  usually, large individuals eat smaller ones.

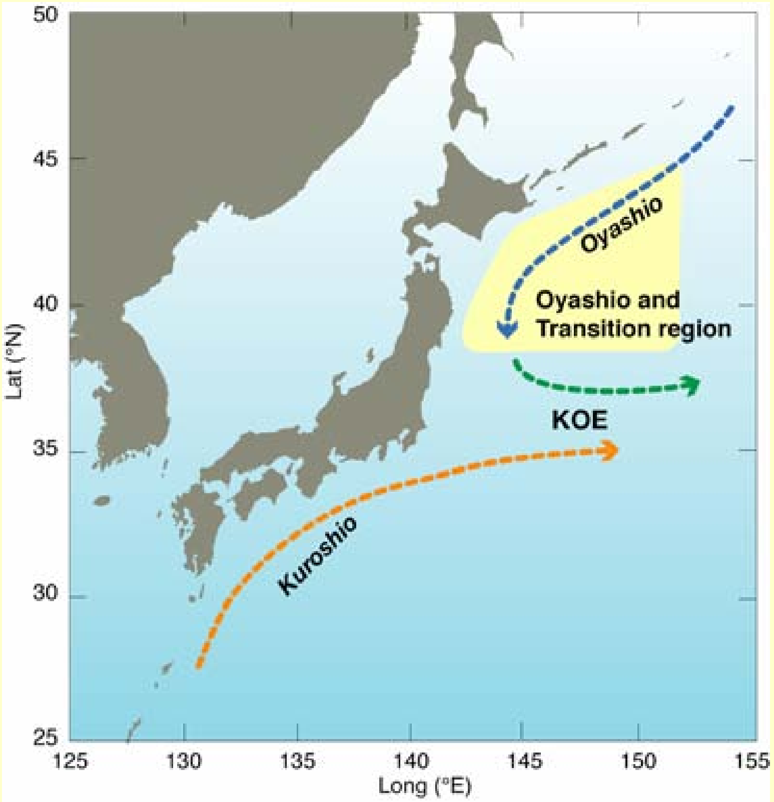
- **Growth:**
  progressive decrease of somatic & reproductive copepod growth rate with increasing body size;

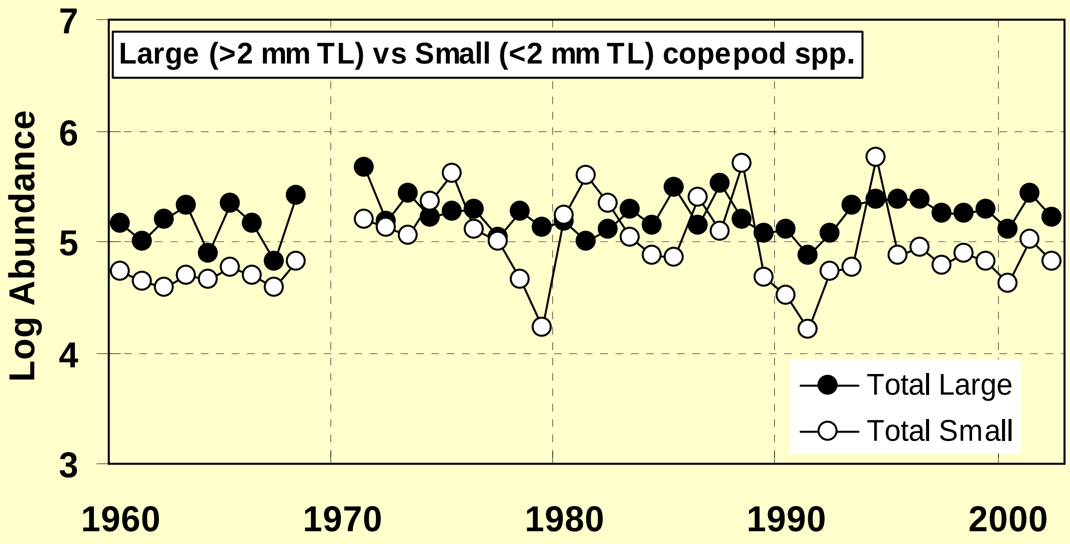


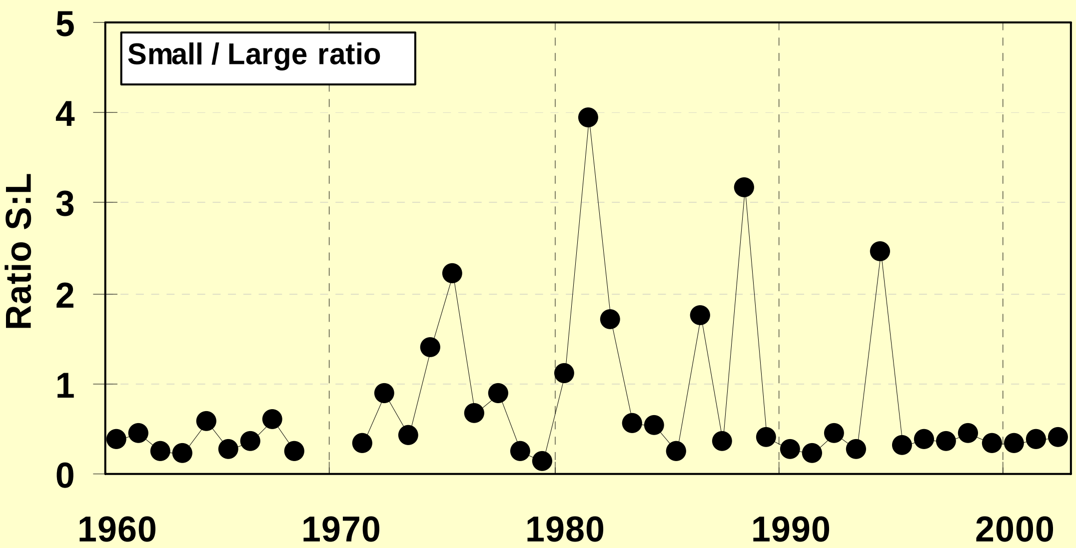
Richardson & Verheye 2001

Oyashio, Japan

1960-2002





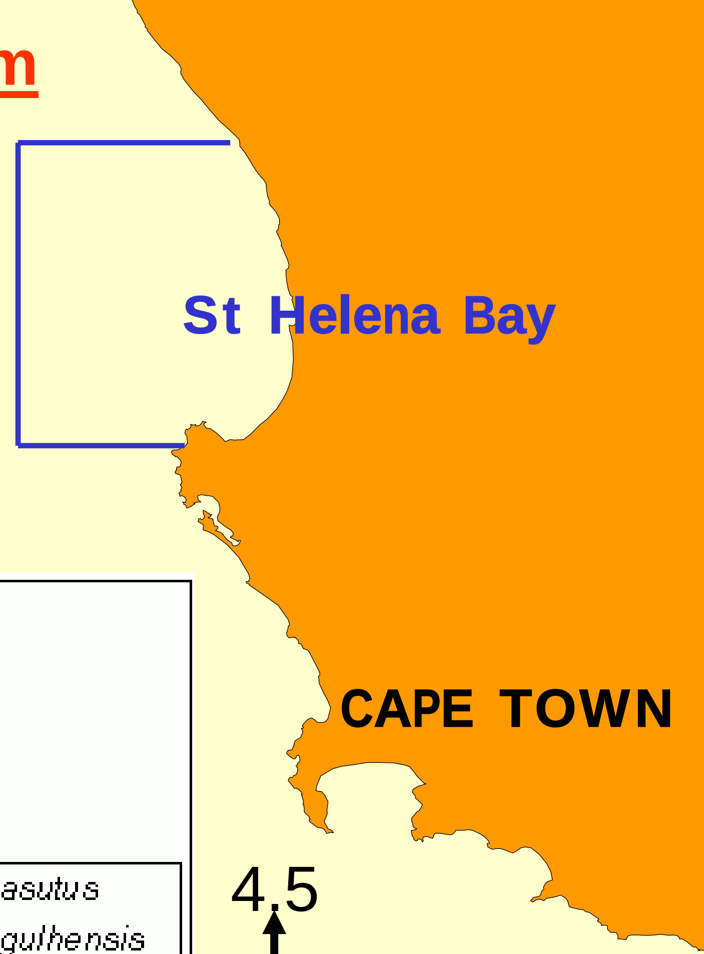


59 dominant copepod spp.

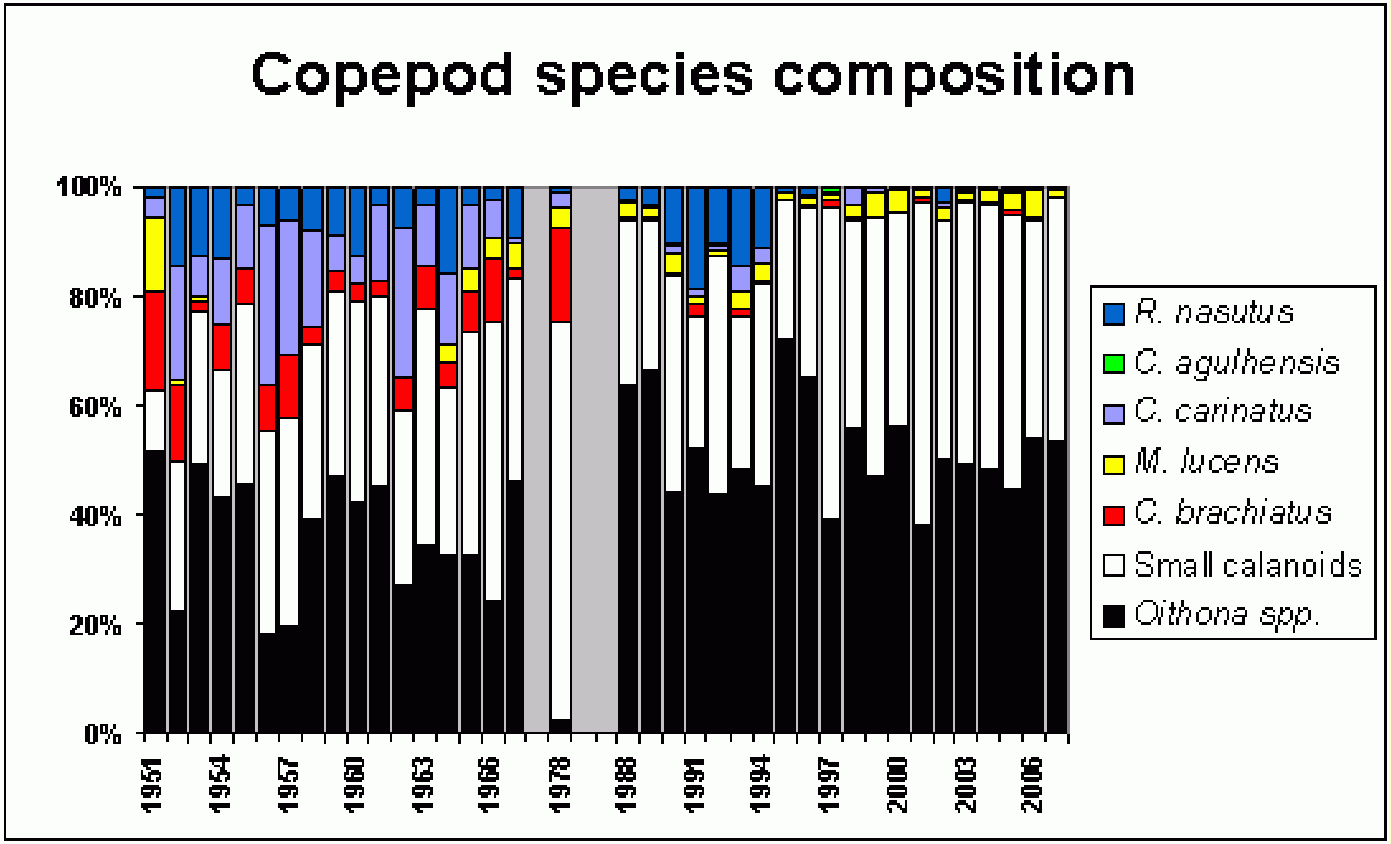
data: Sanae Chiba

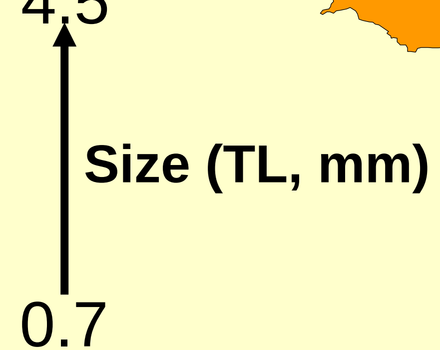
Southern Benguela upwelling system

(St Helena Bay, South Africa)
1951-2007



Substantial changes through time in species = size composition

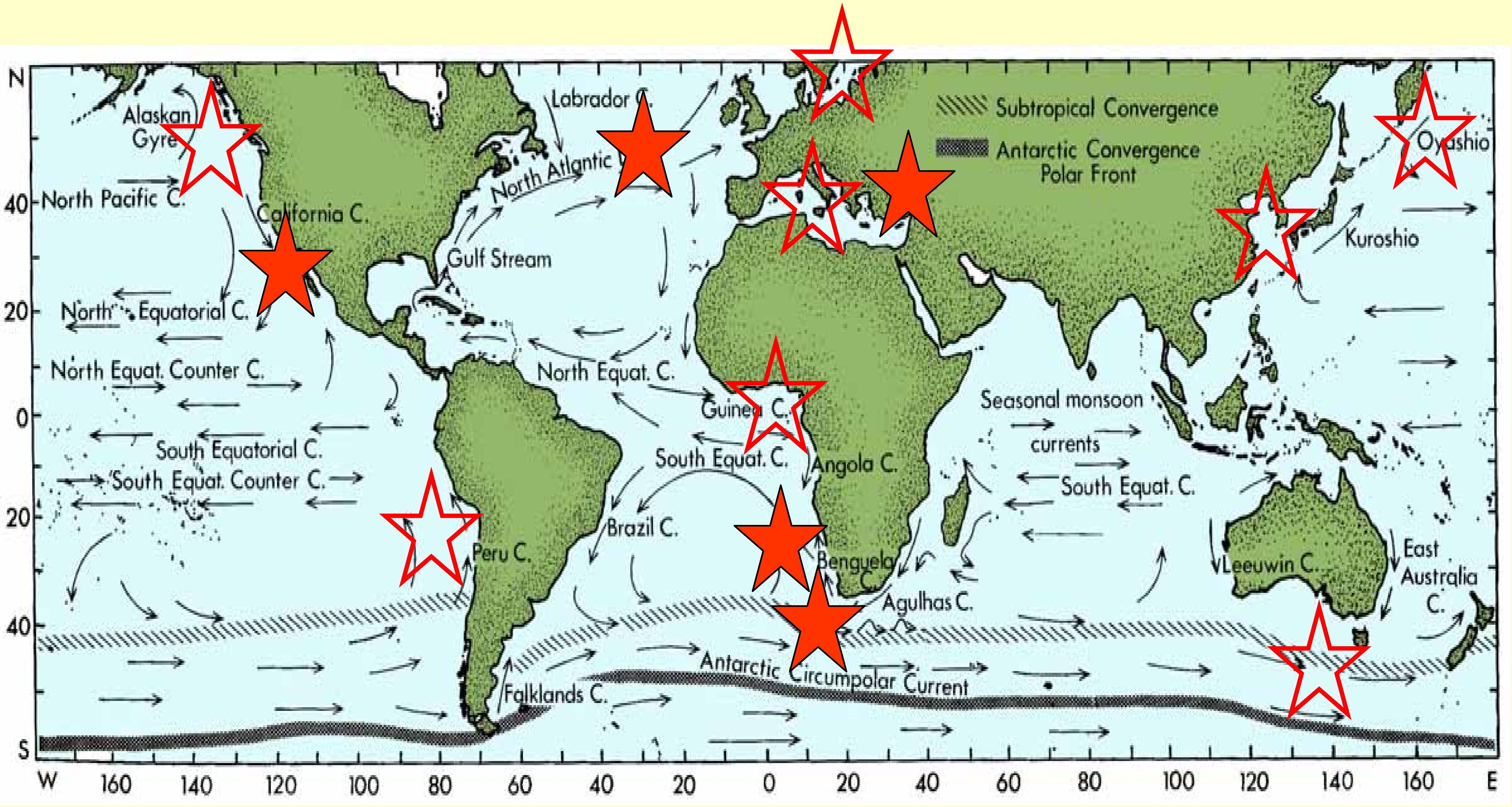




Verheye 2007

Objectives:

To examine and compare long-term changes in the size structure of zooplankton communities from different regions of the world's oceans



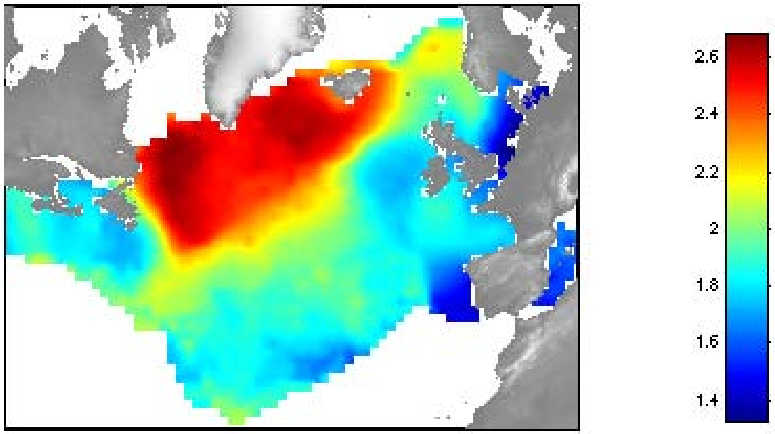
Hypothesis:

Warm-water zooplankton communities are often dominated by species of a smaller size (and more diverse) than their cold-water counterparts,

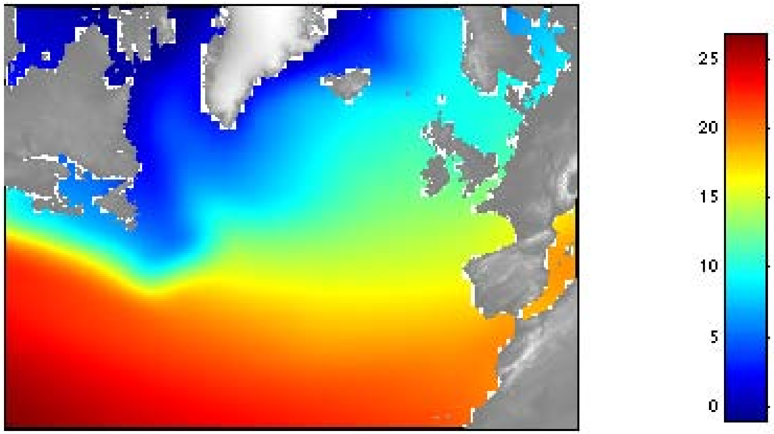
so that

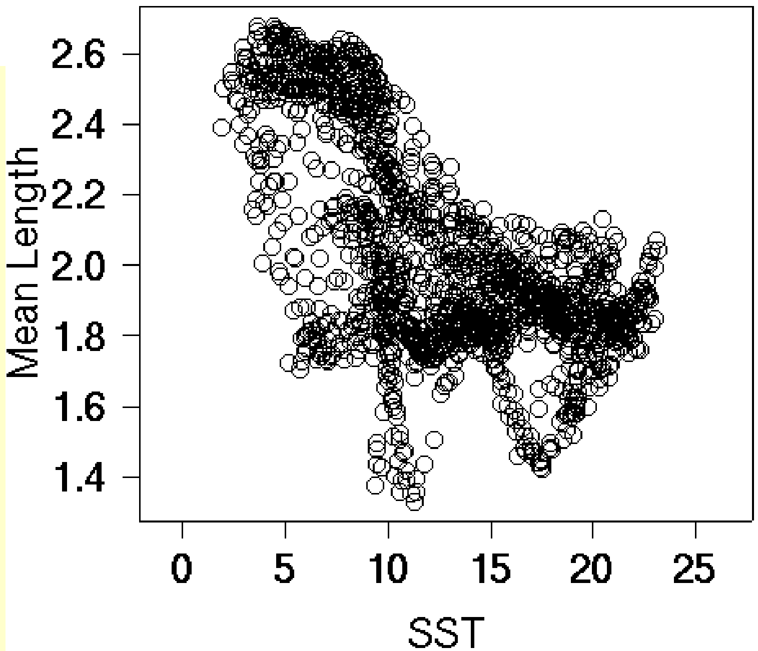
a shift to a smaller average community size over time is indicative of warming of the ecosystem, while a shift to a larger average size indicates cooling.

Mean Calanoid Length



SST





CPR surveys

North Atlantic

1948-present

Ángel López-Urrutia,
Anthony Richardson

Approach:

To derive a size-based index of community structure and track its change over time.

- **Focus on substantial changes in average community size based on changes in species composition.**

- **Focus on copepod community (most abundant; best resolved taxonomically in most sample analyses).**

- **Use female length (TL or PL) to represent the size of a species.**

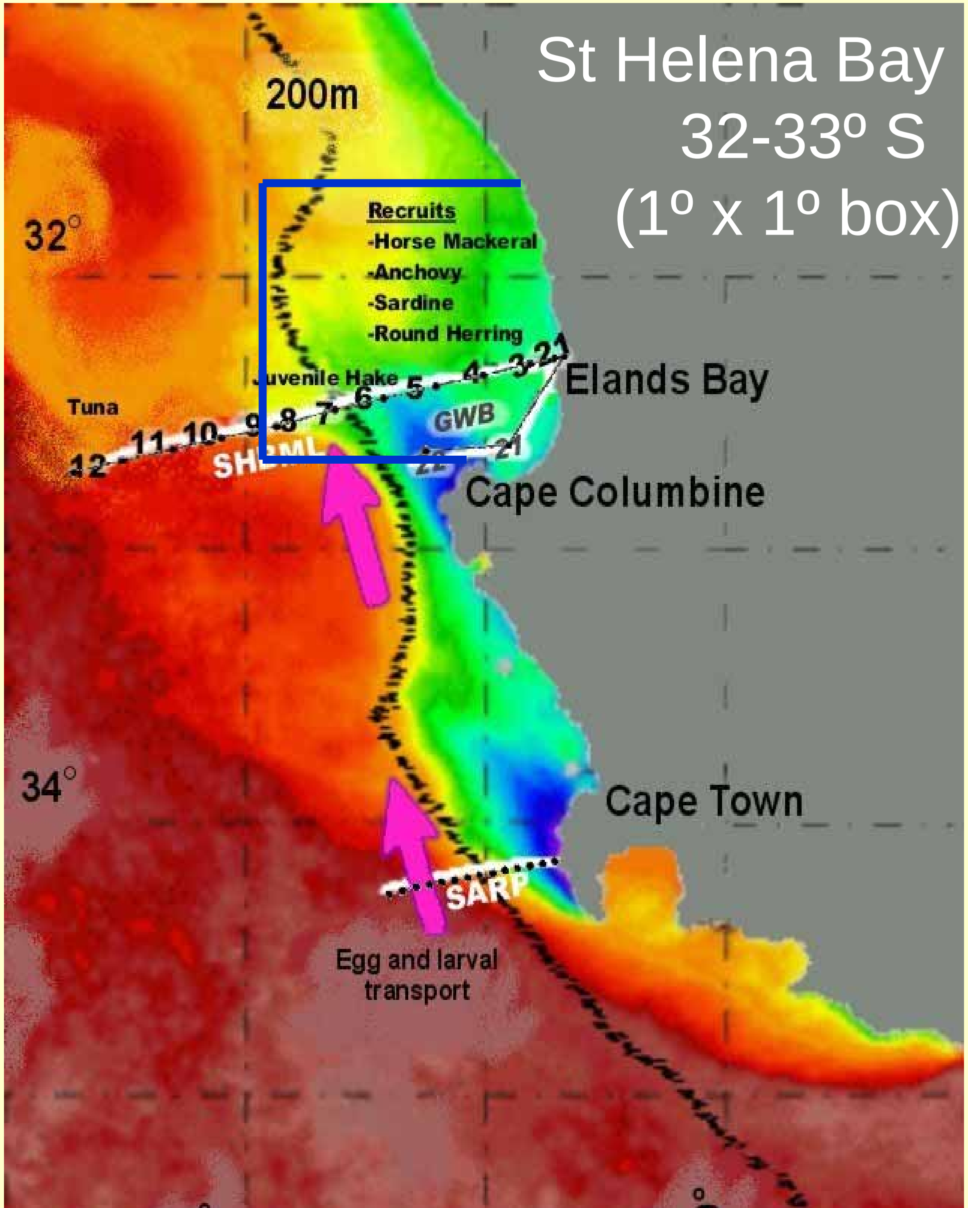
Calculation of average copepod community size $\overline{S}$

$$\overline{S} = \frac{\sum_{i=1}^{N}(L_i \times X_i)}{\sum_{i=1}^{N} X_i}$$

For each sample, multiply total length (*L*) of each species *i* (adult female) by its abundance (X_i), sum over all species (*N*), and divide by total abundance.

Assumptions:

- no change in mean body size of species over long time period
- no seasonal variations in mean body size



Southern Benguela Current

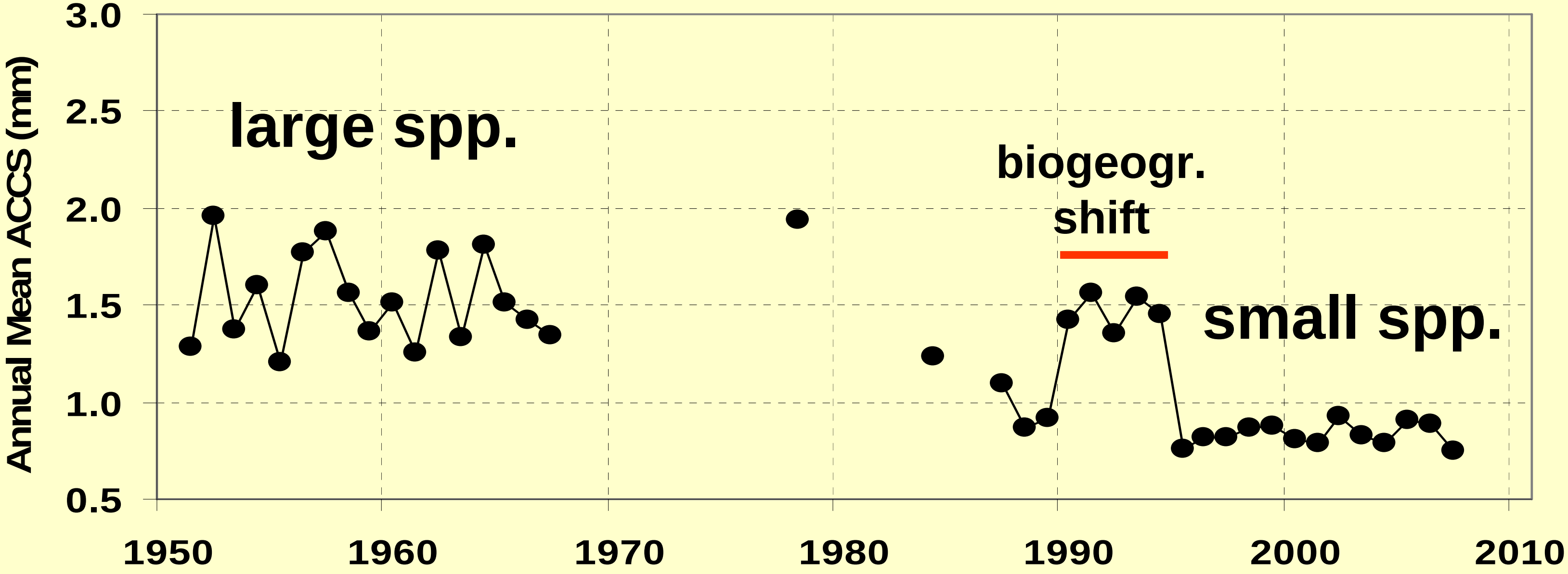
South Africa

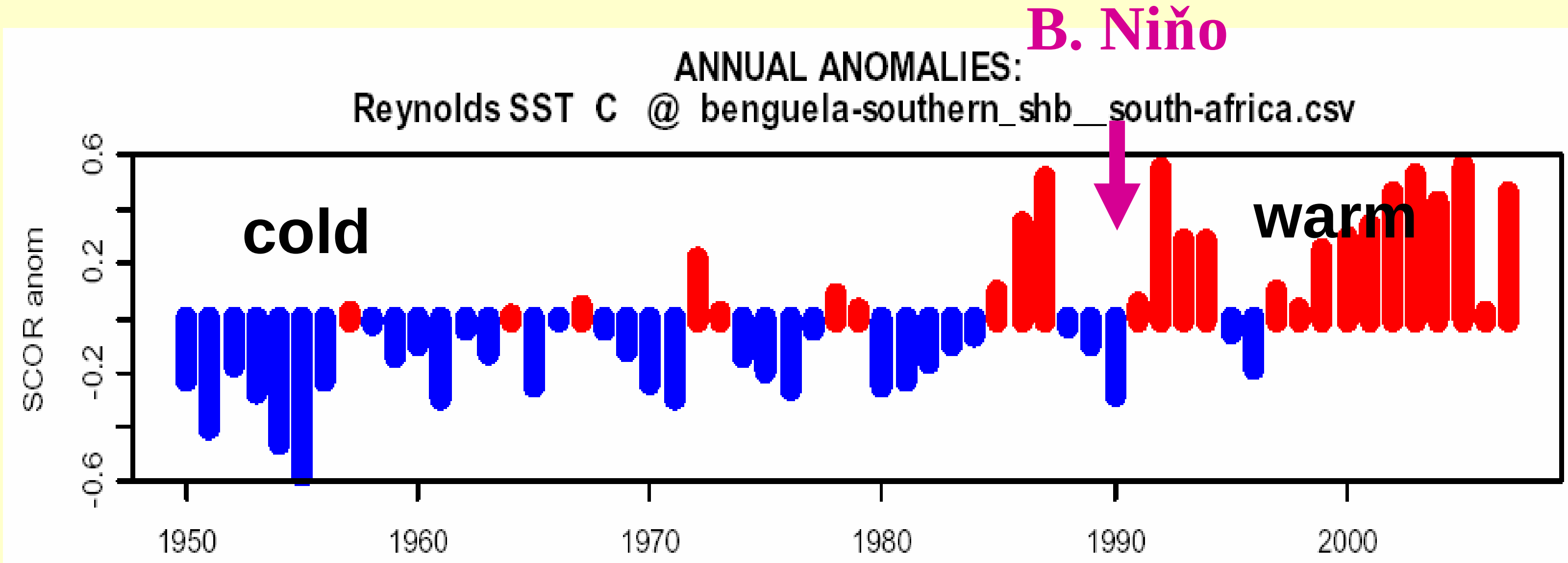
1951-2007
(austral autumn)

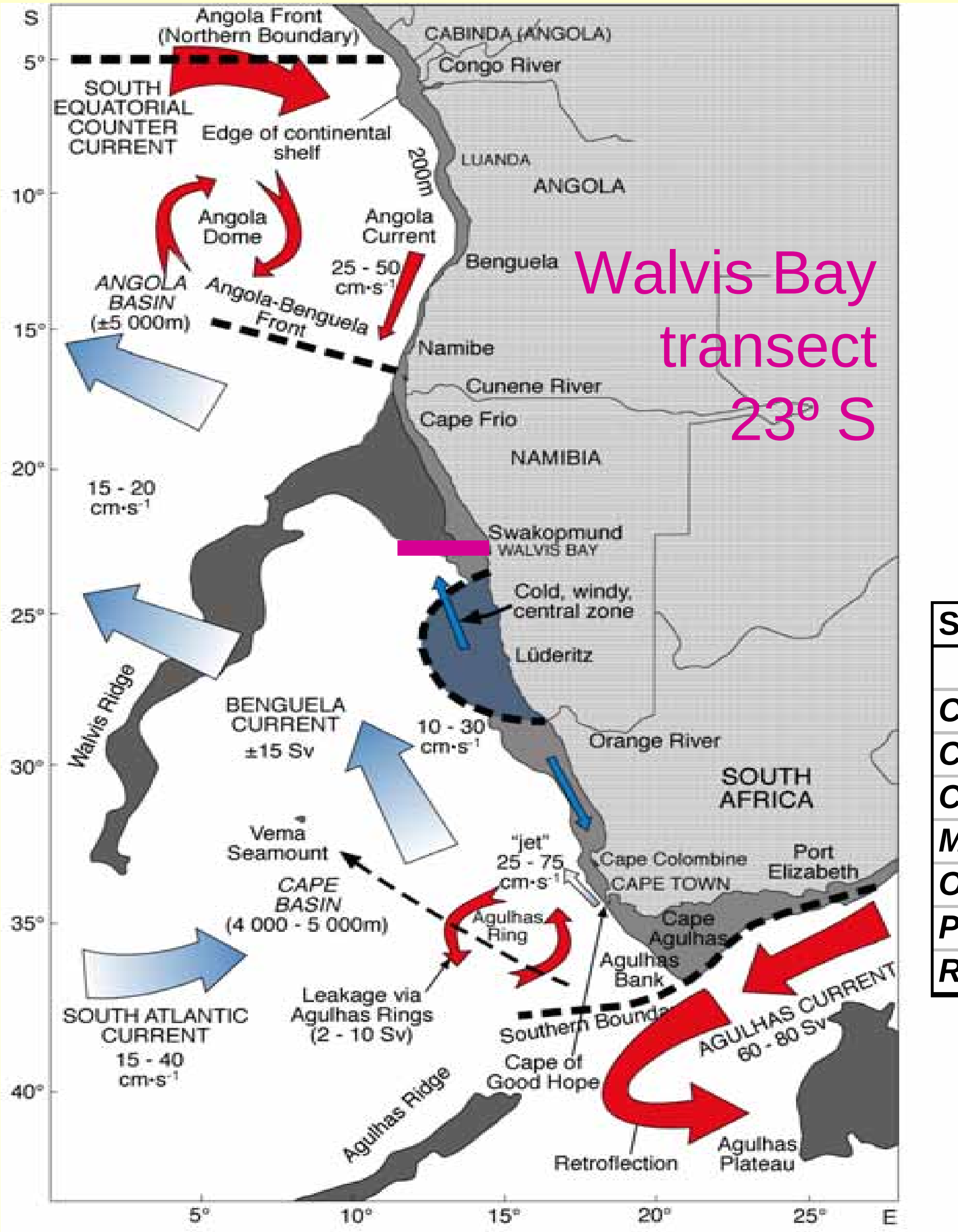
Species	Fem min.TL (mm)
Calanoides carinatus	2.25
Calanus agulahensis	2.45
Centropages brachiatus	1.73
Metridia lucens	2.39
Oithona spp.	0.68
Rhincalanus nasutus	3.90

data: Hans Verheye

St Helena Bay transects (33°S), South Africa
austral autumn (March-June)







Northern Benguela Current

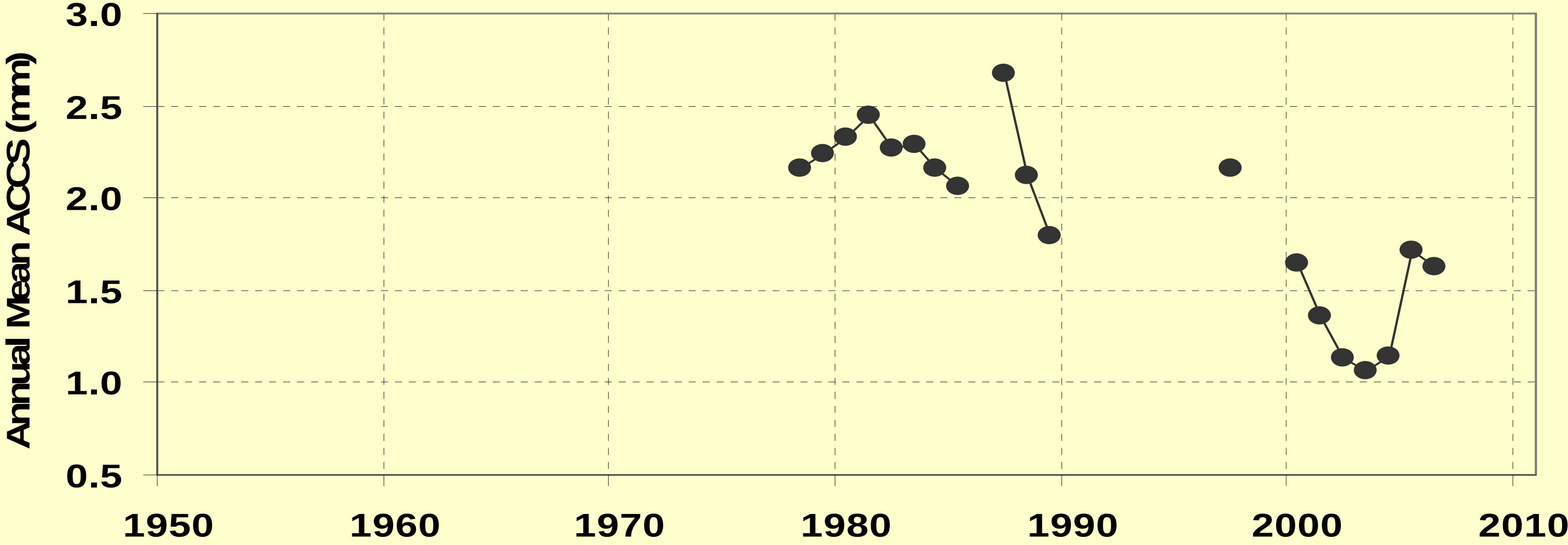
Namibia

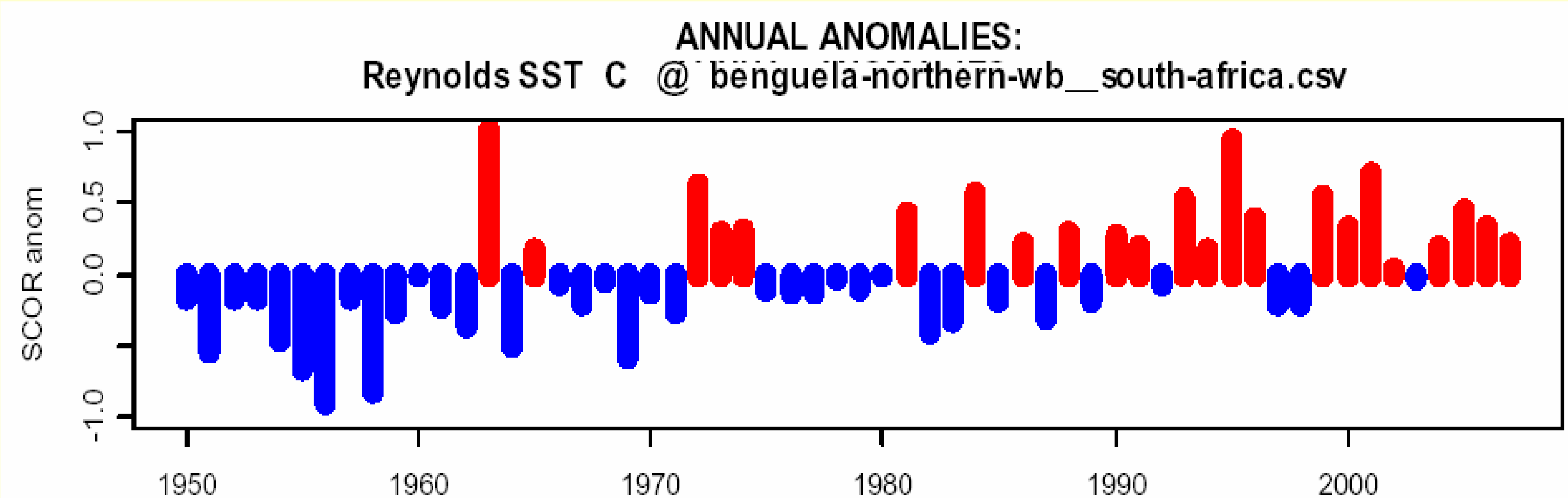
1978-2006 (quasi-monthly

Species	Fem TL (mm)
Calanoides carinatus	2.445
Calanus sp.	2.760
Centropages brachiatus	1.677
Metridia lucens	2.294
Oithona spp.	0.850
Pleuromamma sp.	2.137
Rhincalanus nasutus	4.319

data: Fabienne Cazassus & Anja Kreiner

Walvis Bay transect (23°S), Namibia
(quasi-)monthly sampling





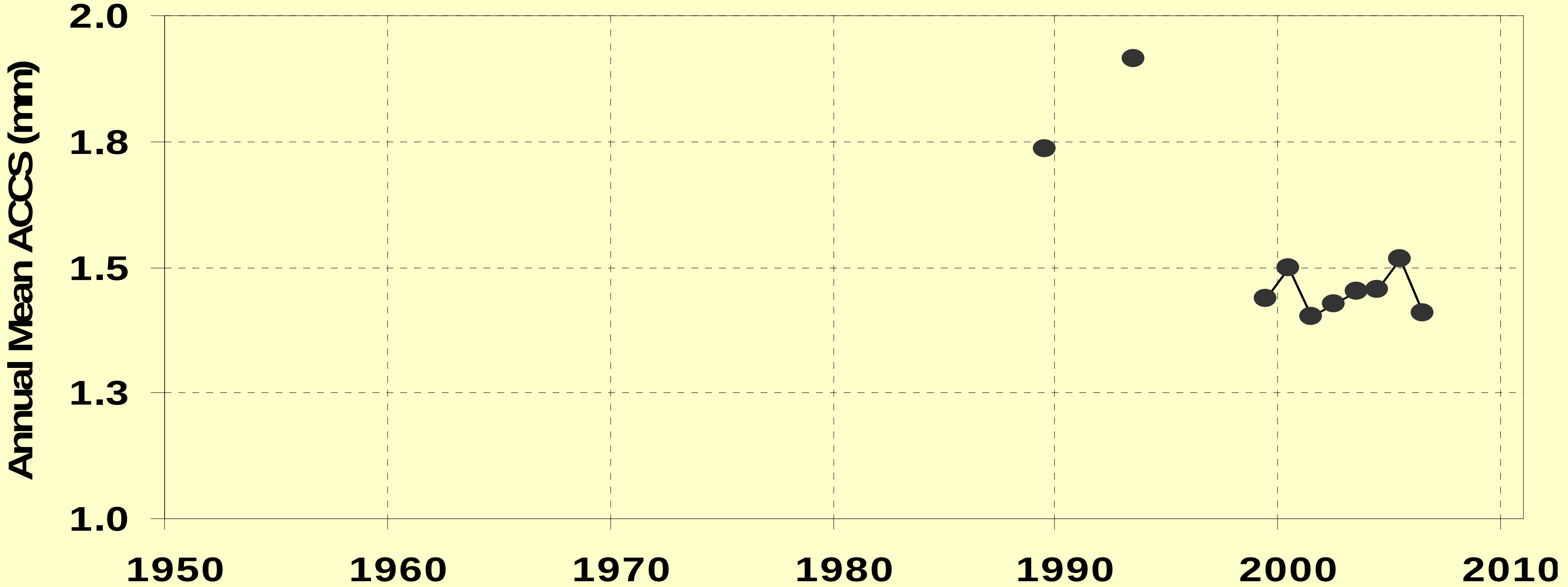
Black Sea:

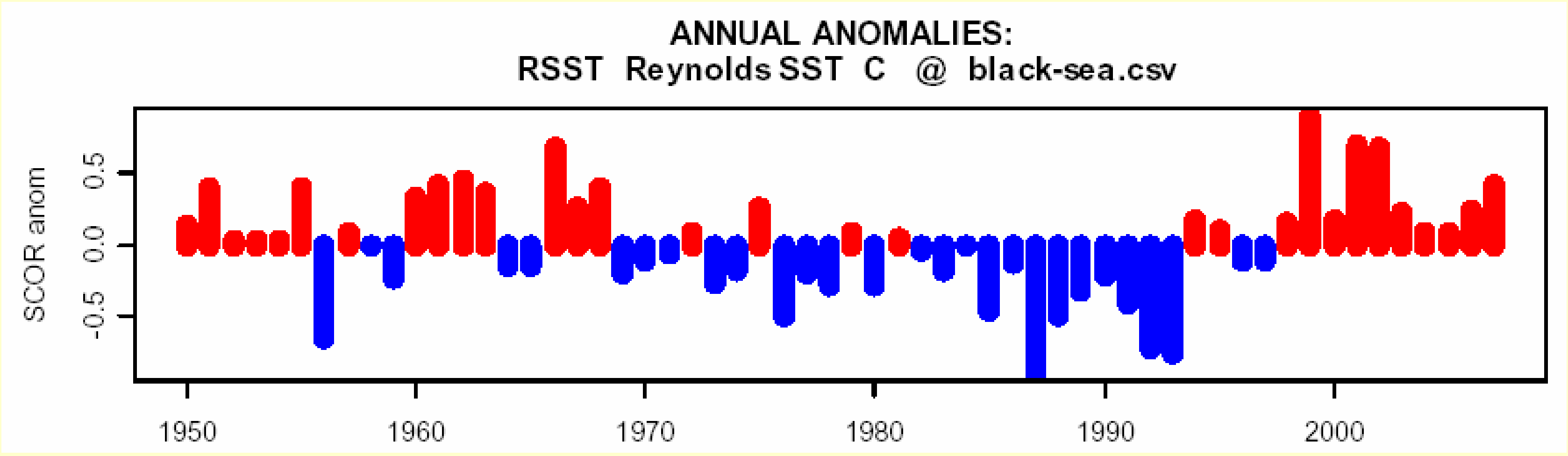
1989-2006
(late autumn)

Species	Fem TL (mm)
Acartia clausi	1.50
Calanus euxinus	3.10
Centropages ponticus	1.70
Oithona similis	0.90
Paracalanus parvus	1.20
Pseudocalanus elongatus	1.60

data: Elena Arashkevich

Black Sea - late autumn

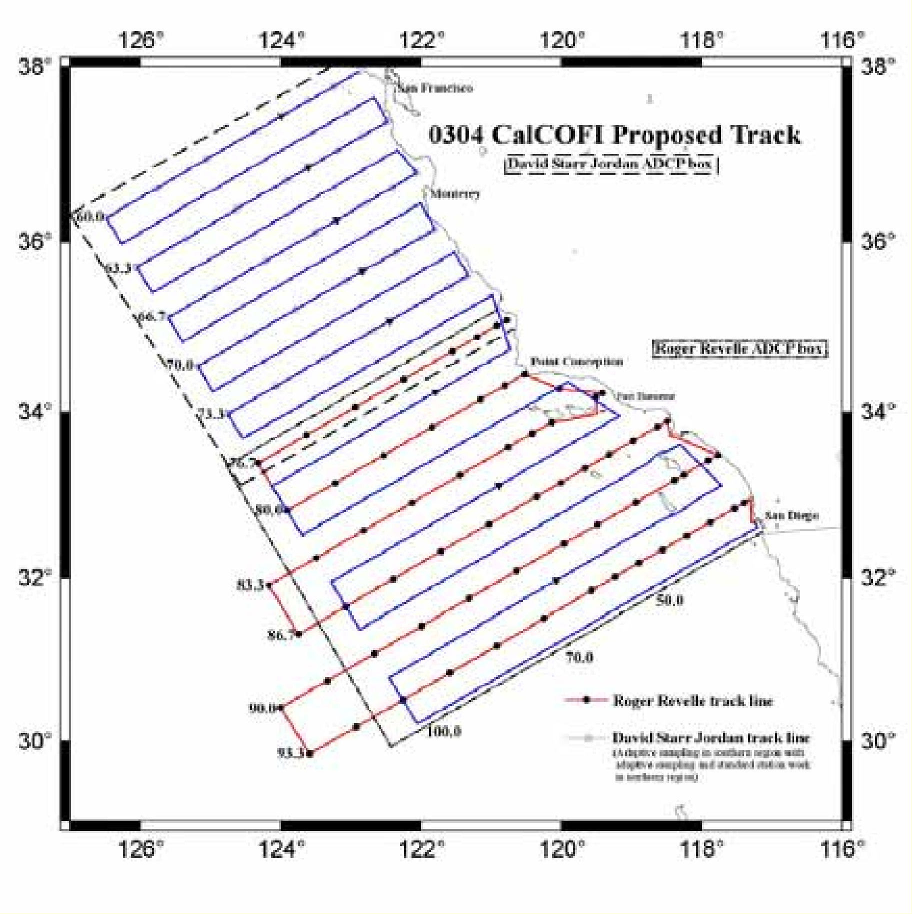




California Current:

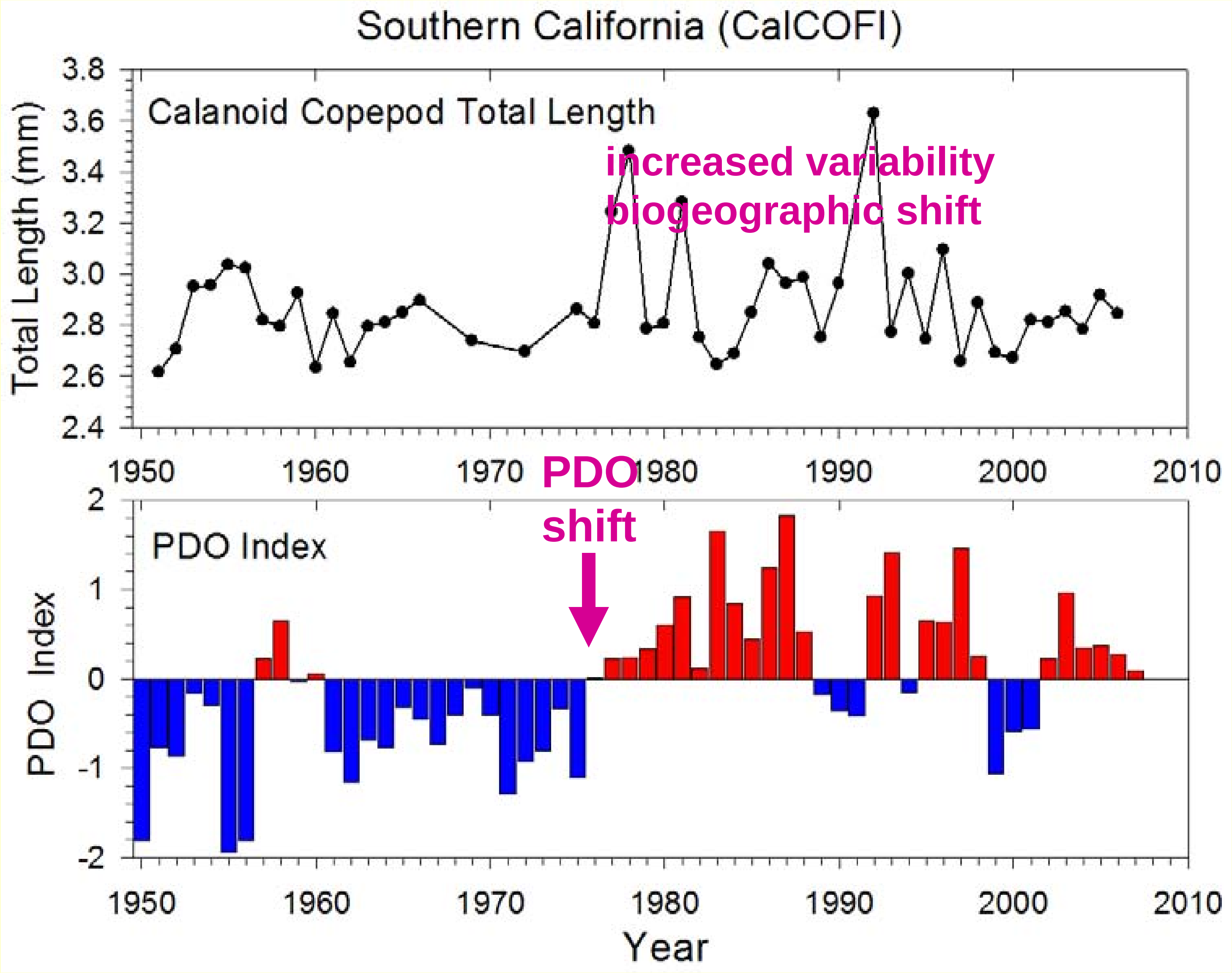
Southern California (CalCOFI)

1951-2006 (spring)



Dominant 20 species	TL (mm)
Aetideus bradyi	1.59
Calanus pacificus	3.15
Candacia bipinnata	2.35
Candacia curta	2.26
Eucalanus californicus	6.21
Euchaeta media	3.53
Euchirella pseudopulchra	3.95
Heterorhabdus papilliger	2.03
Labidocera trispinosa	2.81
Lucicutia flavicornis	1.56
Mesocalanus tenuicornis	1.80
Metridia pacifica	2.37
Nannocalanus minor	2.03
Pleuromamma abdominalis edentata	3.05
Pleuromamma abdominalis typica	3.38
Pleuromamma borealis	2.07
Pleuromamma gracilis	2.08
Pleuromamma piseki	1.73
Pleuromamma quadrungulata	4.16
Rhincalanus nasutus	4.24

data: Mark Ohman

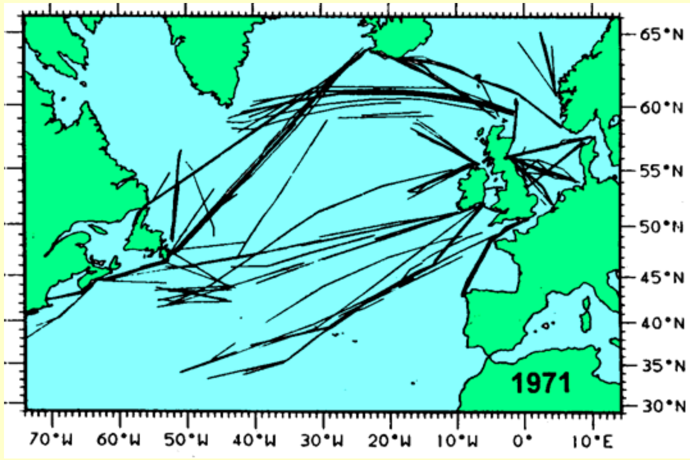

Southern California (CalCOFI)
Calanoid Copepod Total Length
Total Length (mm)
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
increased variability
biogeographic shift
1950
1960
1970
1980
1990
2000
2010
PDO
shift
PDO Index
PDO Index
2
1
0
-1
-2
1950
1960
1970
1980
1990
2000
2010
Year

Species	TL (mm)
Acartia danae	1.08 [a,b,c]
Acartia longiremis	1.04 [a,c]
Acartia negligens	1.05 [b,c]
Acartia spp.	1.15 [c]
Aetideus armatus	1.73 [b,c,d]
Anomalocera patersoni	3.20 [c]
Calanoides carinatus	2.18 [b,c,e]
Calanus finmarchicus	2.70 [c,e]
Calanus glacialis	4.60 [t]
Calanus helgolandicus	2.68 [b,c]
Calanus hyperboreus	6.95 [c,e]
Calanus I-IV	1.65 [f]
Calanus tenuicornis	1.74 [b,c,e]
Calanus V-VI	2.48 [g]
Candacia armata	2.18 [c,h]
Candacia bipinnata	1.95 [b,c]
Candacia ethiopica	2.15 [c]
Candacia longimana	3.41 [b,c,h]
Candacia norvegica	2.75 [c,h]
Candacia pachydactyla	2.15 [c]
Candacia tenuimana	2.14 [b,c,h]
Candacia varicans	2.20 [b,c,h]
Centropages bradyi	1.87 [b,c,g]
Centropages hamatus	1.30 [c]
Centropages typicus	1.55 [c,g]
Centropages violaceus	1.80 [b,c,g]
Clausocalanus spp.	1.15 [i]
Copepod nauplii	0.48 [u]
Corycaeus spp.	1.57 [i]
Ctenocalanus vanus	0.94 [b,c,j]
Diaixis hibernica	1.20 [c]
Diaixis pygmoea	0.95 [c]
Euaetideus giesbrechti	2.04 [c]
Eucalanus attenuatus	3.94 [b,c,k]
Eucalanus crassus	2.85 [b,c,k]
Eucalanus elongatus	4.69 [b,c,k]
Eucalanus monachus	2.13 [c]
Euchaeta acuta	3.84 [b,c]
Euchaeta gracilis	6.60 [b,c]
Euchaeta hebes	2.80 [b,c]
Euchaeta marina	2.72 [b,c]
Euchaeta media	3.65 [b,c]
Euchaeta norvegica	7.00 [c]
Euchaeta pubera	3.94 [b,c]
Euchaeta spinosa	6.32 [b,c]
Euchaeta tonsa	6.50 [c]
Euchirella brevis	3.50 [l]
Euchirella curticauda	3.90 [b,c,l]
Euchirella messinensis	4.84 [b,c,l]
Euchirella pulchra	3.00 [l]
Euchirella rostrata	2.95 [c,l]
Euterpina acutifrons	0.50 [c]
Gaetanus minor	1.93 [c,m]
Gaidius tenuispinus	3.10 [b,c,n]
Halithalestris croni	2.30 [c]
Haloptilus acutifrons	2.86 [b,c]
Haloptilus longicornis	1.96 [b,c]
Haloptilus spiniceps	4.14 [b,c]
Heterorhabdus abyssalis	2.40 [c]
Heterorhabdus clausi	2.20 [c]
Heterorhabdus norvegicus	2.77 [b,c]
Heterorhabdus papilliger	1.76 [b,c]
Heterostylites longicornis	3.00 [c]
Isias clavipes	1.25 [c]
Labidocera acutifrons	3.00 [c]
Labidocera wollastoni	2.20 [c]
Macrosetella gracilis	1.40 [c]
Mecynocera clausi	0.84 [c,k]
Metridia I-IV	0.93 [f]
Metridia longa	4.10 [c,o]
Metridia lucens	2.27 [b,c,o]
Nannocalanus minor	1.71 [c,e]
Neocalanus gracilis	2.76 [b,c,e]
Neocalanus robustior	3.42 [b]
Oithona spp.	0.68 [i]
Paracandacia bispinosa	1.67 [b]
Paracandacia simplex	1.75 [b]
Parapontella brevicornis	1.37 [c]
Parapseudocalanus spp.	0.70 [i]
Phaenna spinifera	1.80 [c]
Pleuromamma abdominalis	2.67 [b,c,p]
Pleuromamma borealis	1.97 [b,c,p]
Pleuromamma gracilis	1.76 [b,c,p]
Pleuromamma piseki	1.73 [b,c]
Pleuromamma robusta	3.13 [b,c,p]
Pleuromamma xiphias	4.13 [b,c,p]
Pontellina plumata	1.69 [b,c]
Pontellopsis regalis	4.00 [c]
Pseudocalanus elongatus	1.20 [q]
Rhincalanus cornutus	3.21 [b,c]
Rhincalanus nasutus	3.99 [b,c,k]
Scaphocalanus echinatus	1.92 [c]
Scolecithricella spp.	1.40 [c]
Scolecithrix bradyi	1.16 [b,c]
Scolecithrix danae	2.05 [b,c]
Scottocalanus persecans	4.80 [c]
Scottocalanus securifrons	4.30 [b,c]
Temora longicornis	1.00 [c]
Temora stylifera	1.45 [b,c]
Tortanus discaudatus	2.00 [r]
Undeuchaeta major	4.55 [b,c,s]
Undeuchaeta plumosa	3.18 [b,c,s]
Unid. *Candacia* spp.	2.31
Unid. *Centropages* spp.	1.63
Unid. *Eucalanus* spp.	3.40
Unid. *Euchaeta* spp.	4.82
Unid. *Euchirella* spp.	4.24
Unid. *Heterorhabdus* spp.	2.49
Unid. *Labidocera* spp.	2.60
Unid. *Paracandacia* spp.	1.71
Unid. *Pleuromamma* spp.	2.56
Unid. *Scaphocalanus* spp.	1.92
Unid. *Undeuchaeta* spp.	3.86
Urocorycaeus spp.	1.76 [i]
Xanthocalanus spp.	5.80 [c]

NE Atlantic

CPR surveys

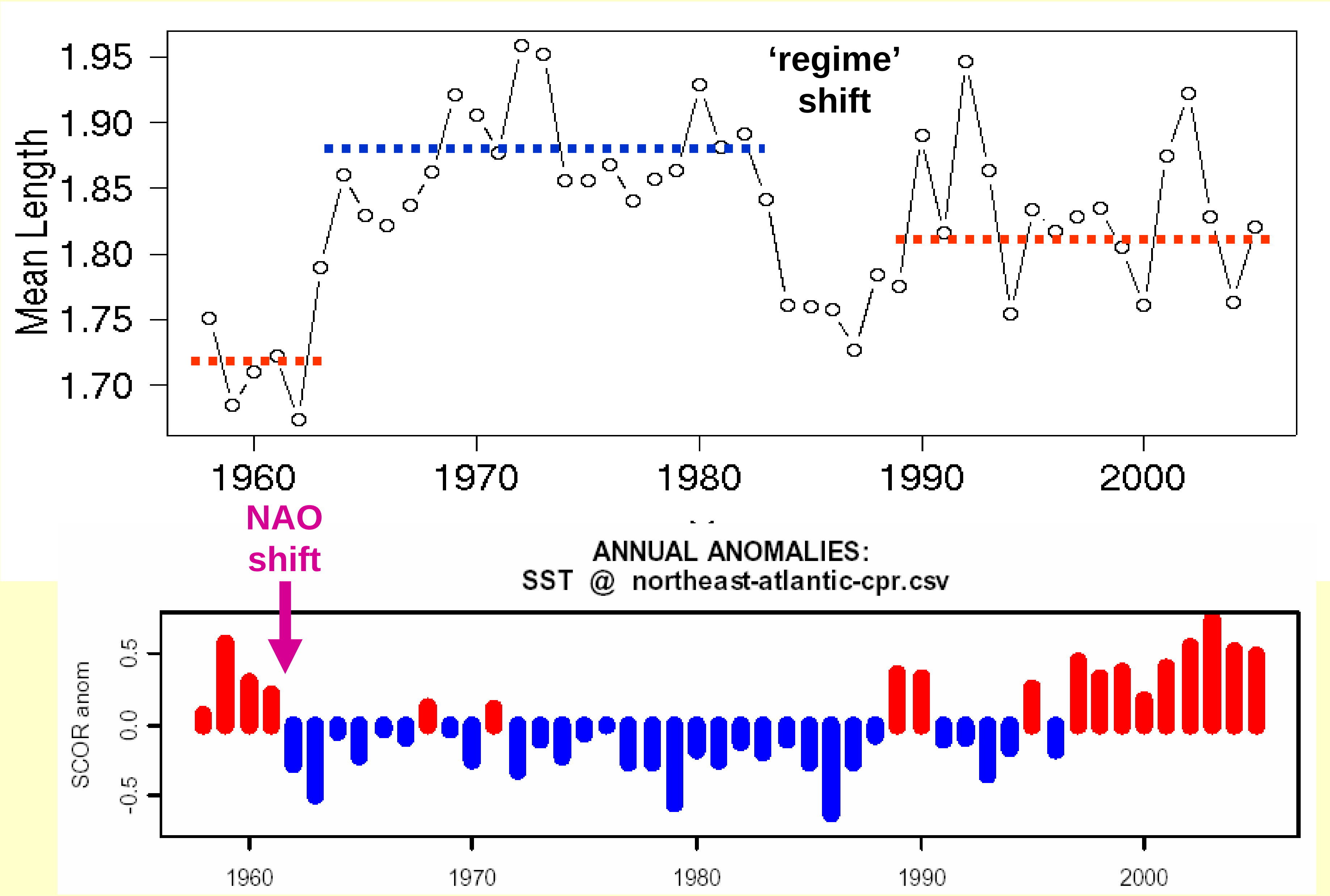
1958-2005



Calanoid copepods:
115 spp.
TL: 0.5 – 7.0 mm

data: Ángel López-Urrutia & Anthony Richardson

Northeast Atlantic (CPR)



Conclusions

- tracking changes over time of mean copepod communities enables detection of major changes in community structure as a consequence of hydro-climatic variability and shifts in biogeographical distribution

- correlation between large-species dominated communities and ocean cooling, & between small-species dominated communities and ocean warming, on regional and decadal scales

- shifts in zooplankton community size structure may have fundamental effects on biogeochemical processes and fisheries

- need access to other existing long-term datasets & application of appropriate statistical analysis techniques

Thank you…!

… and please, send your datasets (copepod female abundance + body size) to: hans.verheye@gmail.com

… or come visit me here…

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