The gulf of Trieste: a changing ecosystem

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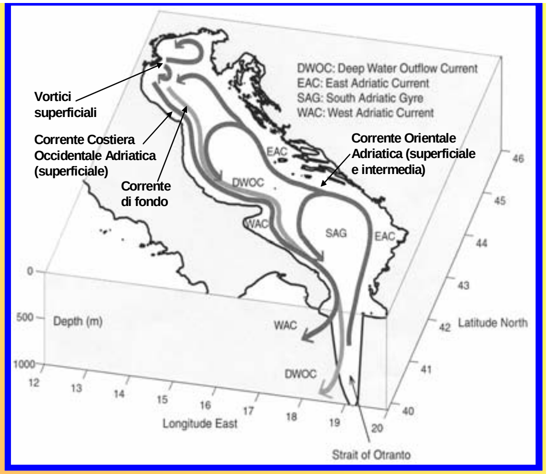
The study area: the Gulf of Trieste

- One of the few regions of high permanent production in the Mediterranean Sea
- The longest mesozooplankton time series in Italy, since 1970
- Semienclosed, shallow area (depth = 23 m in the southern part), with reduced hydrodinamism
- Large riverine input (Isonzo; Po); strong wind events



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C1: zoo t-s - S1: SST t-s

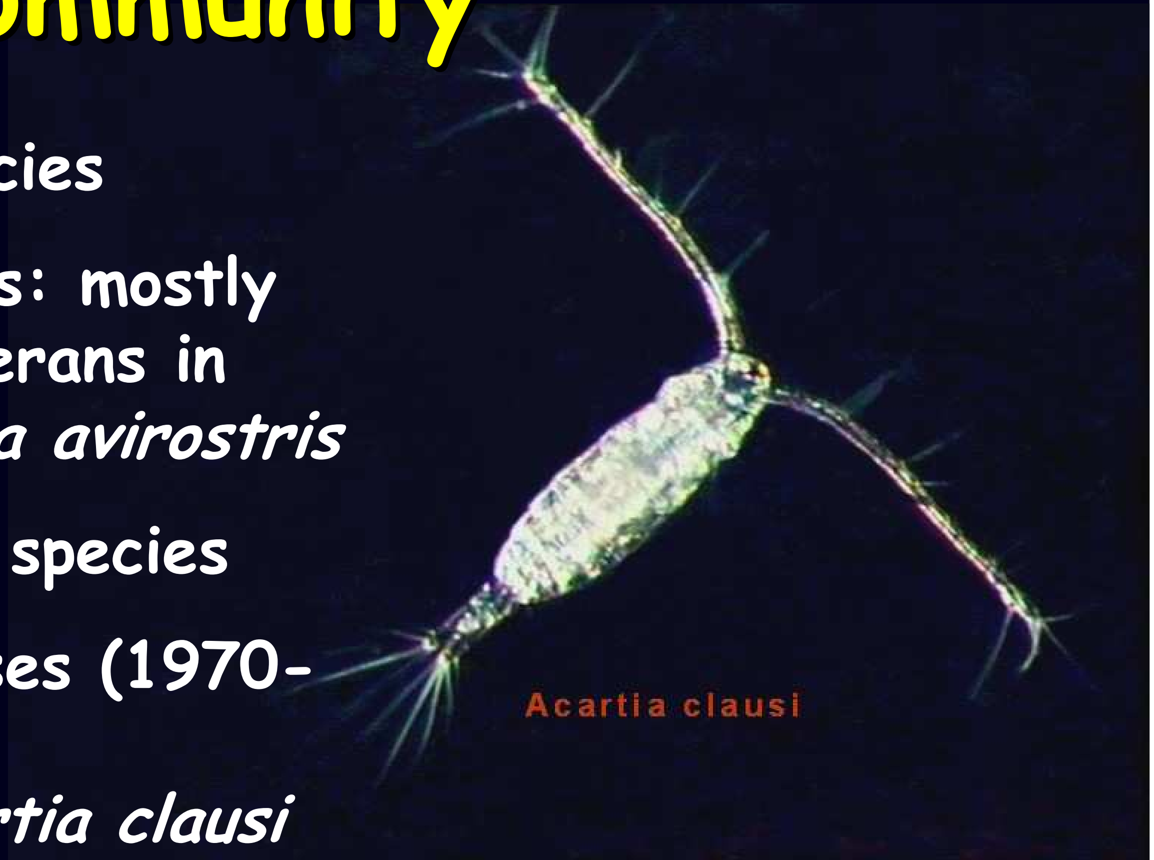
The mesozooplankton community

Not very diverse: ~30 mesozooplanktonic species

Dominated by copepods: mostly *Acartia clausi*. Cladocerans in Jul-Aug: mostly *Penilia avirostris*

Neritic and eurivalent species

Previous cluster analyses (1970-80): late spring group characterized by *Acartia clausi* and *Temora longicornis* and autumn-winter group characterized by *Temora stylifera* and *Oncaea spp*



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The data

1970 – 2005 (36 yr), monthly

Gap in copepod series: 1981-85

- 20 copepod taxa
- total copepod abundance
- copepod diversity
- SST

Vertical hauls from bottom (18 m) to surface, 200 m offshore, WP2 net (200 µ)

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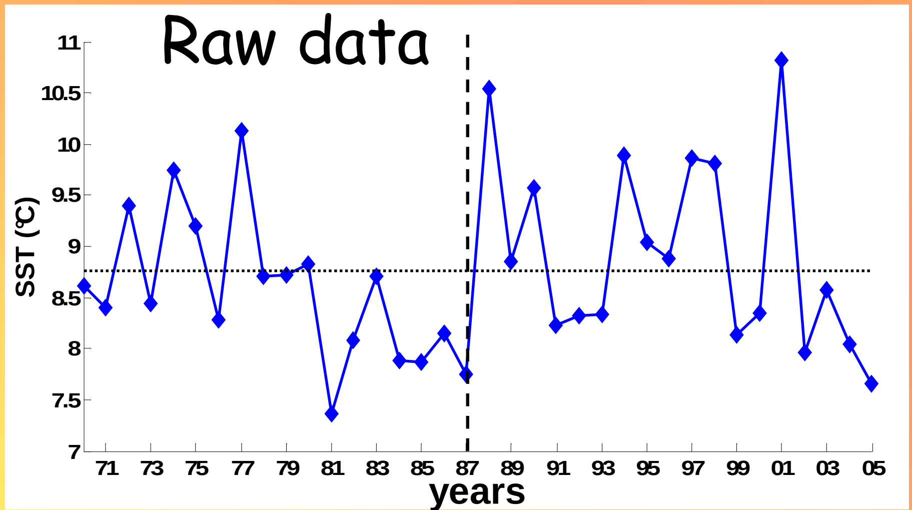
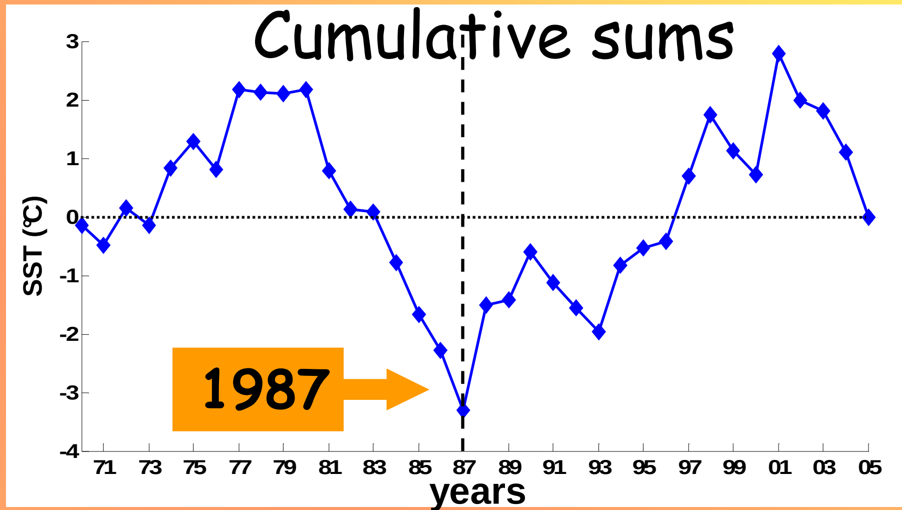
1) Acartia clausi
2) Calanus helgolandicus
3) Calanus spp.
4) Centropages kroyeri
5) Centropages spp.
6) Centropages typicus
7) Clausocalanus spp.
8) Corycaeus spp.
9) Ctenocalanus vanus
10) Diaixis pygmoea
11) Euterpina acutifrons
12) Harpacticoida
13) Oithona spp.
14) Oncaea spp.
15) Paracalanus parvus
16) Pseudocalanus elongatus
17) Temora longicornis
18) Temora spp.
19) Temora stylifera
20) Other copepods
21) Total copepods
22) Copepod diversity

i) Changes in the physical system

Winter SST patterns





The choice: 1970-87 (T1) *vs* 1988-2005 (T2)

Independent studies: Demirov and Pinardi, 2002

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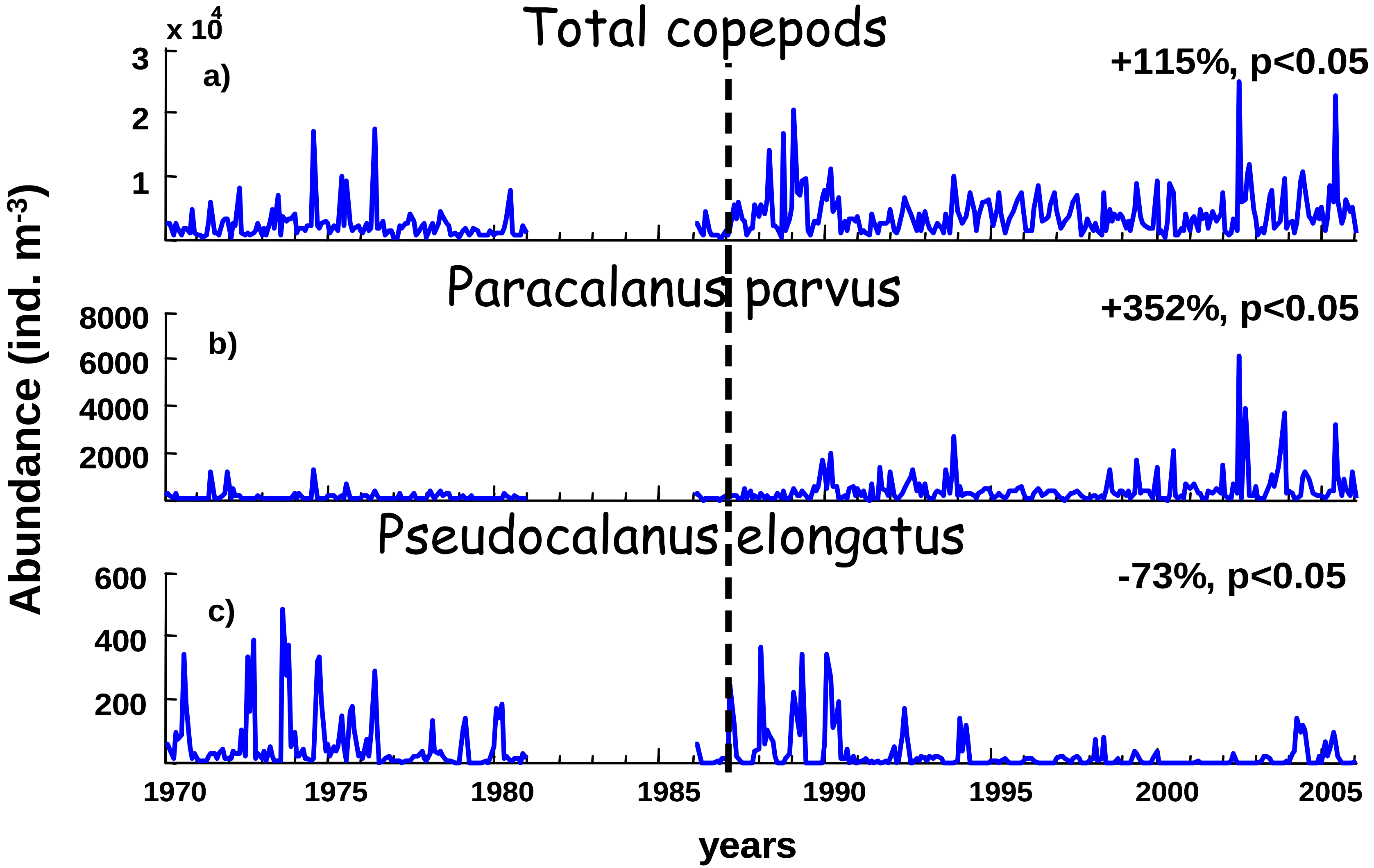
Changes in abundance - 1

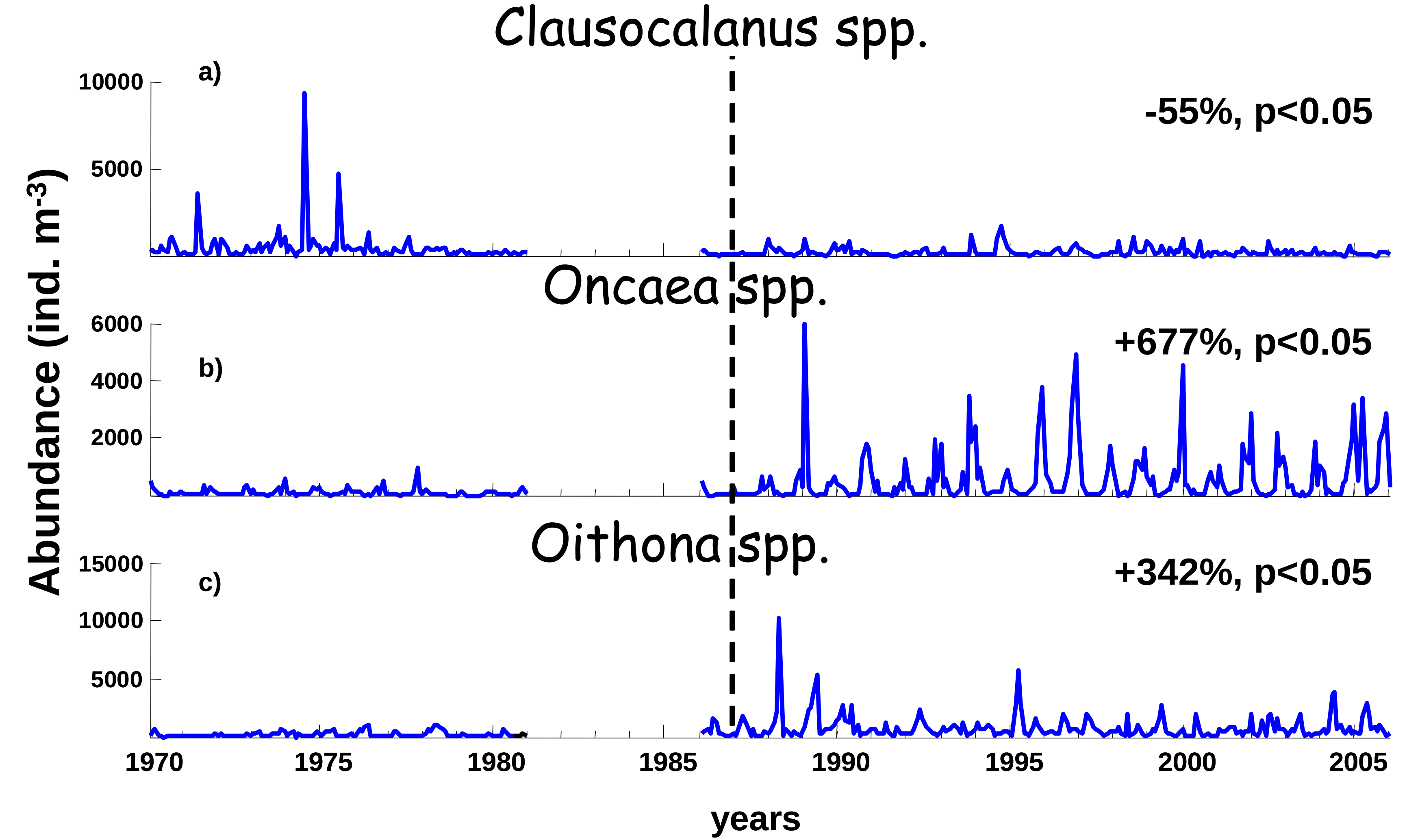
Ho: no change T2 vs. T1



p values following Wilcoxon Mann Withney test

Changes in abundance - 2

Ho: no change T2 vs. T1



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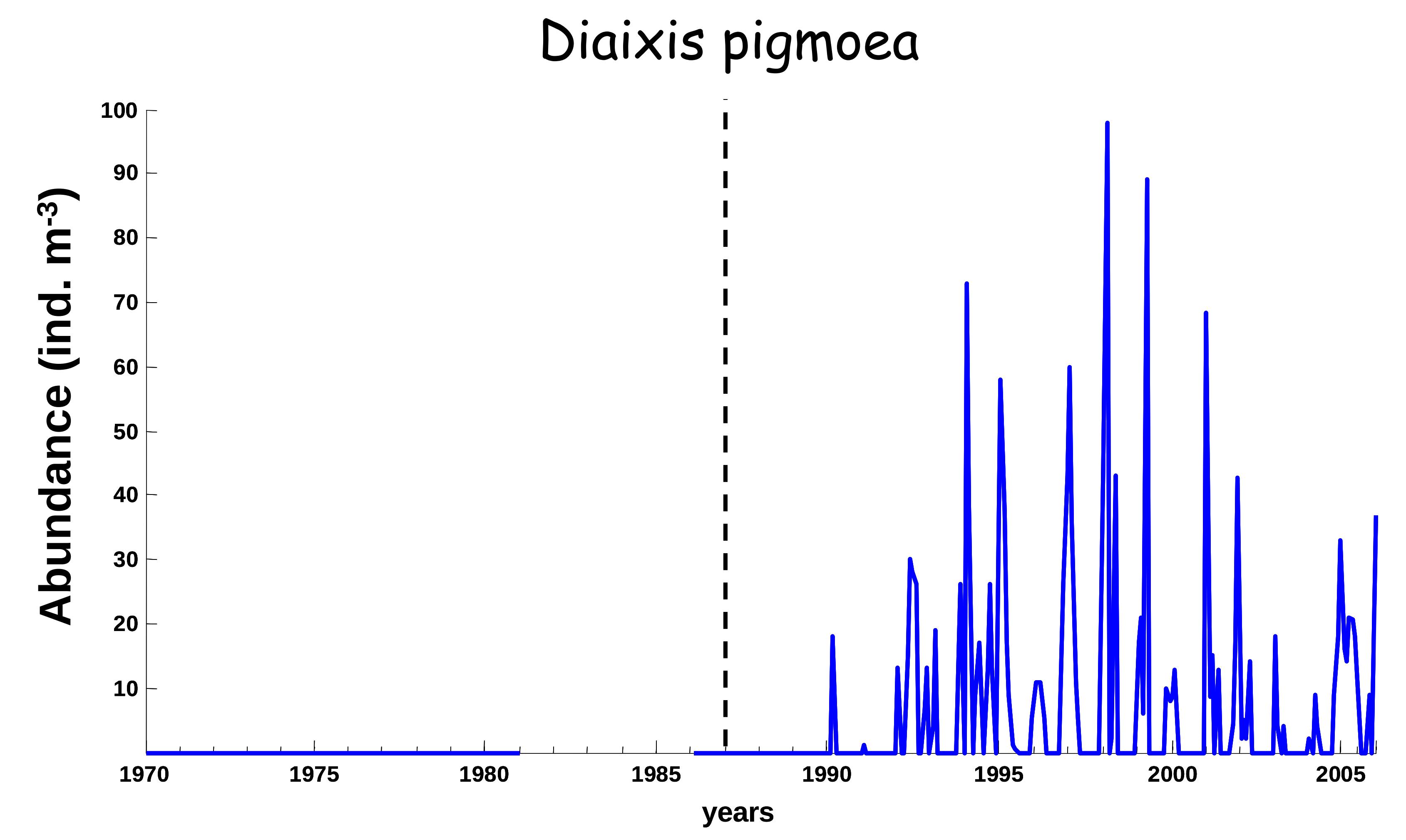
p values following Wilcoxon Mann Withney test

Affirmation of a new species



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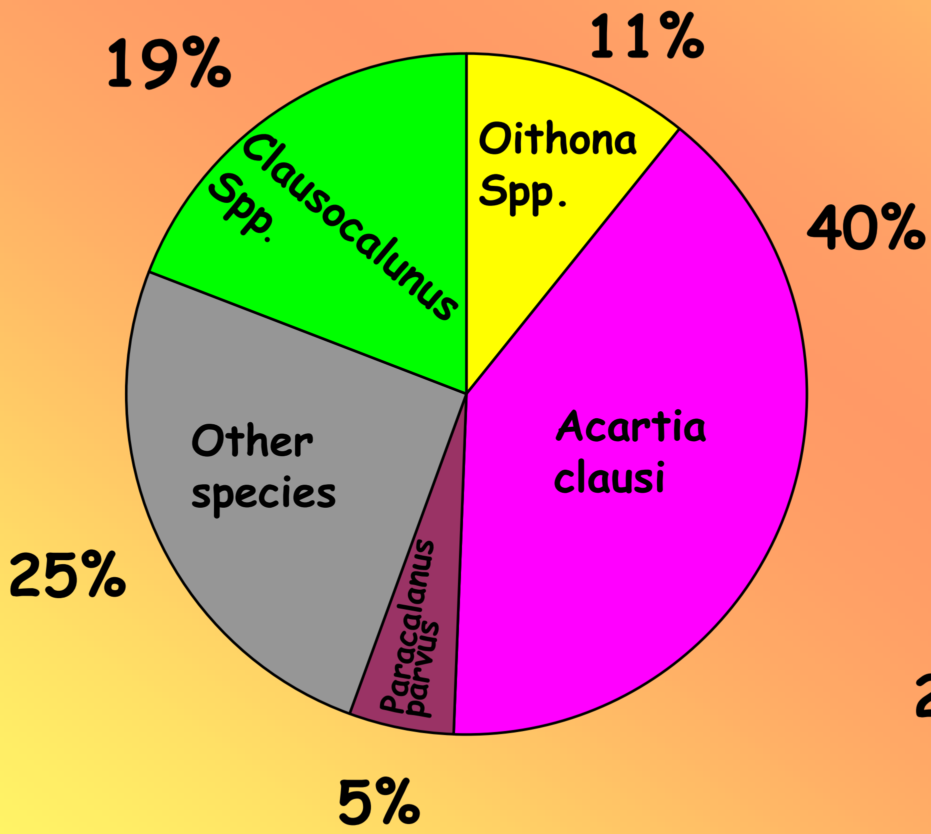
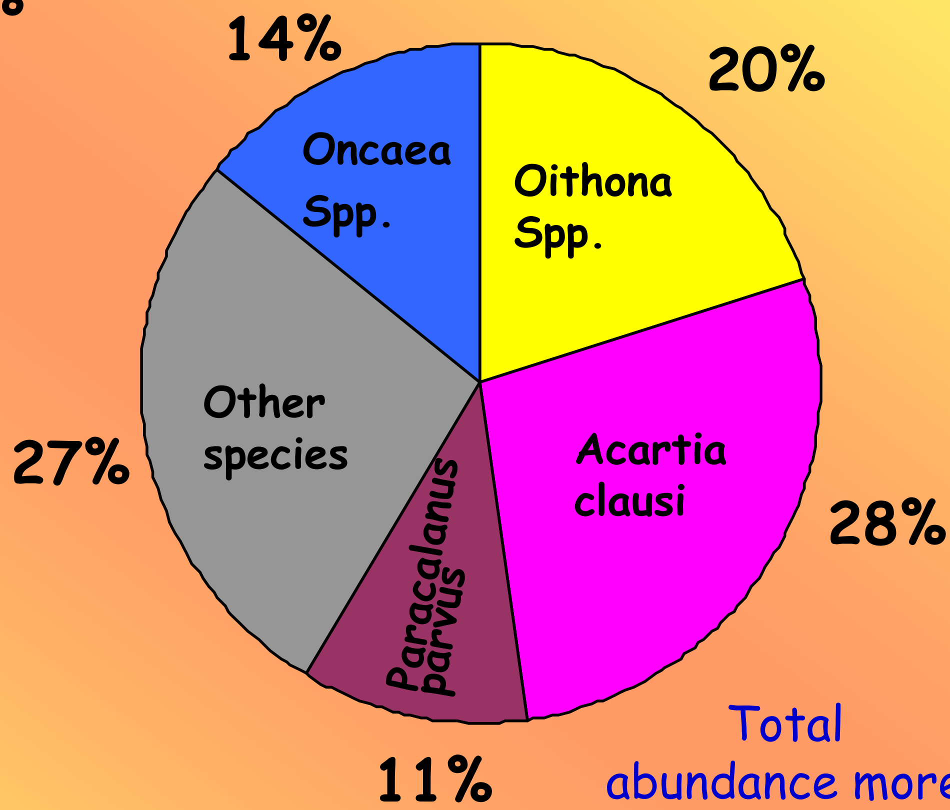
Changes in relative proportions T1 vs T2

1970-1987



1988-2005



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Total abundance more than doubled here

Phenological changes

shifts in the timing of the seasonal peak

Ho: the observed changes in abundance entail changes in the timing of the peak of the maximum abundance

T Index
(Edwards and Richardson 2004)

$$T = \frac{\sum_{m=1}^{12} m x_m}{\sum_{m=1}^{12} x_m}$$

m = month 1,..,12
Xm = abundance in m

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Shifts in the timing of the seasonal peak

Bimodal species	ΔT (m) Winter/Spring	ΔT (m) Summer/Fall	major peak	Trend p-value	
Calanus helgolandicus	0.7	1.7	spring (may)	0.17	0.09
Calanus spp.	0.03	1.3	irregular	0.76	0.14
Clausocalanus spp.	-0.4	1.1	fall (july)	0.58	0.19
Ctenocalanus vanus	-1.2	1.6	fall (july)	0.09	0.07
Paracalanus parvus	1.6	0.2	jun-aug(irr)	0.0005	0.88
Pseudocalanus elongat.	0	2.8	irregular	0.81	0.001

Unimodal species	ΔT (m)	month of major peak:	Trend p-value
Centropages typicus	-1	Spring (June)	0.97
Corycaeus spp.	4.6	Fall (Oct)	0.0001
Euterpina acutifrons	1.2	Winter (Nov-Dec)	0.37
Harpacticoida	1.7	-	0.22
Oncaea spp.	1.5	Winter (Oct-Dec)	0.40
Other copepods	2.2	-	0.10
Temora longicornis	-1.6	Spring (May)	0.01

T Winter/Spring = months 1-6
T Summer/Fall = months 7-12

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System – wide changes T2 *vs* T1

- Total copepod abundance almost doubles
- The copepod community shifts toward smaller species (*Oncaea, Oithona, Euterpina*)
- Presence of southern species: *Diaixis, Paracalanus parvus*
- Reduction in cold species: *Pseudocalanus elongatus, Ctenocalanus vanus*
- Shifts in the timing of the seasonal peak > 1 month in 65% of species, of which 35% are significant at $\alpha=0.10$

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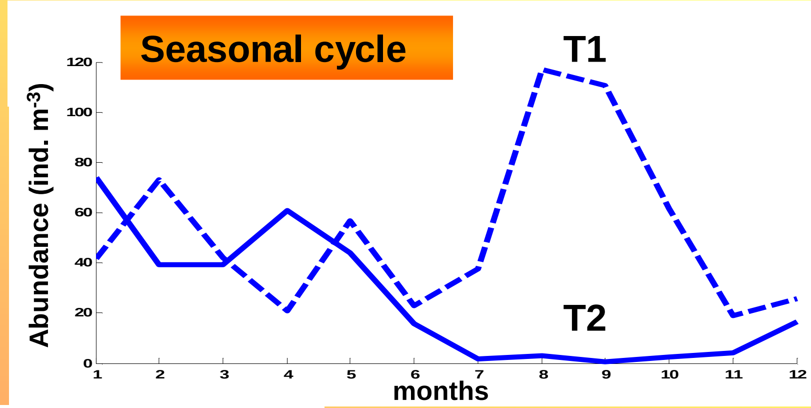
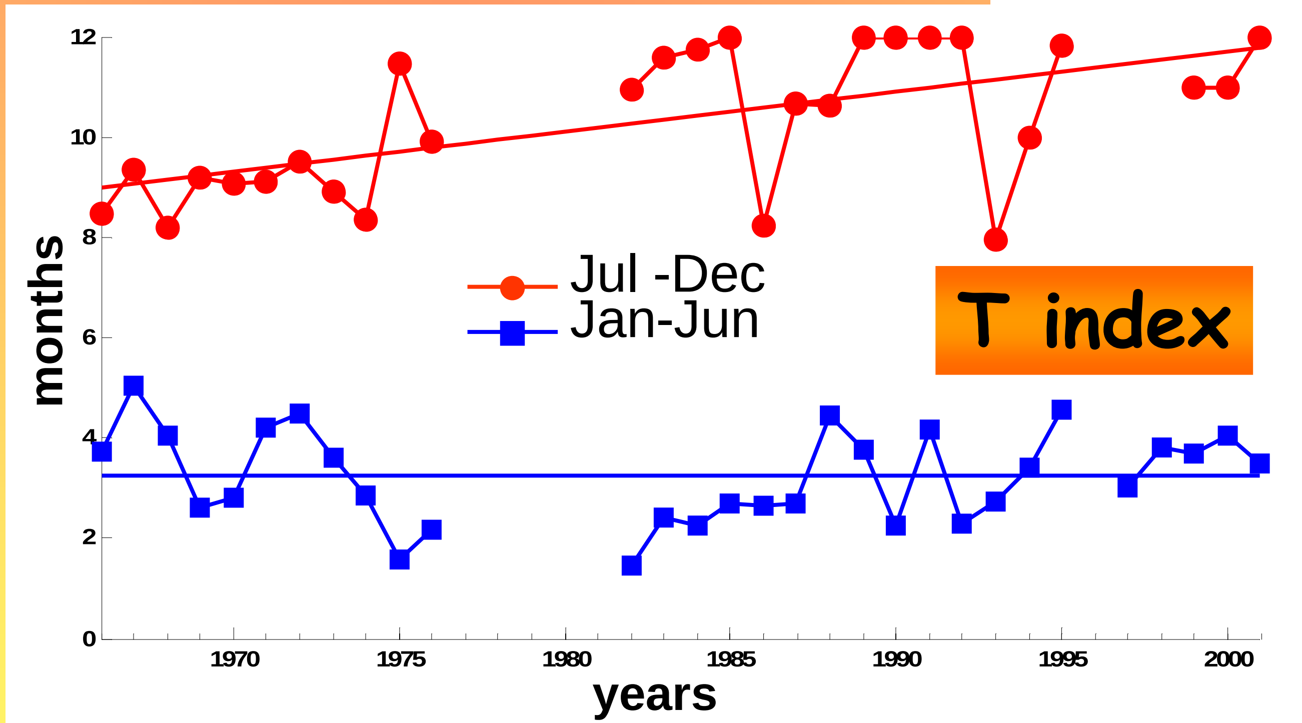
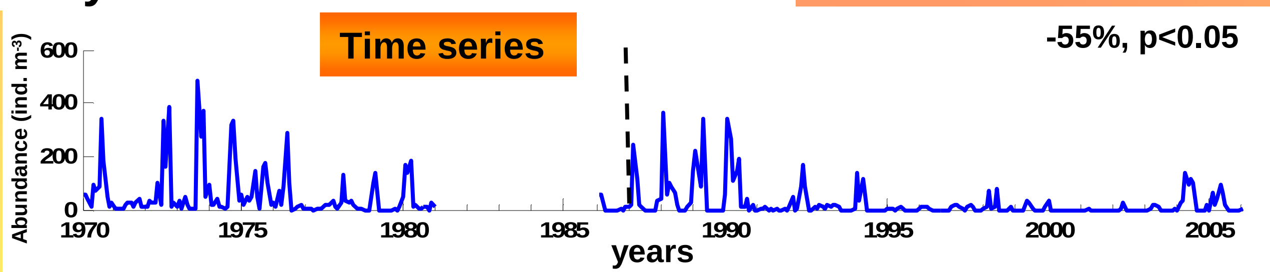
Pseudocalanus elongatus





+ 2.8 m



Hypotheses

1) response to the warming of the system
2) response to some other type of large scale physical forcing centered at the end of the 1980

These hypotheses are not mutually exclusive

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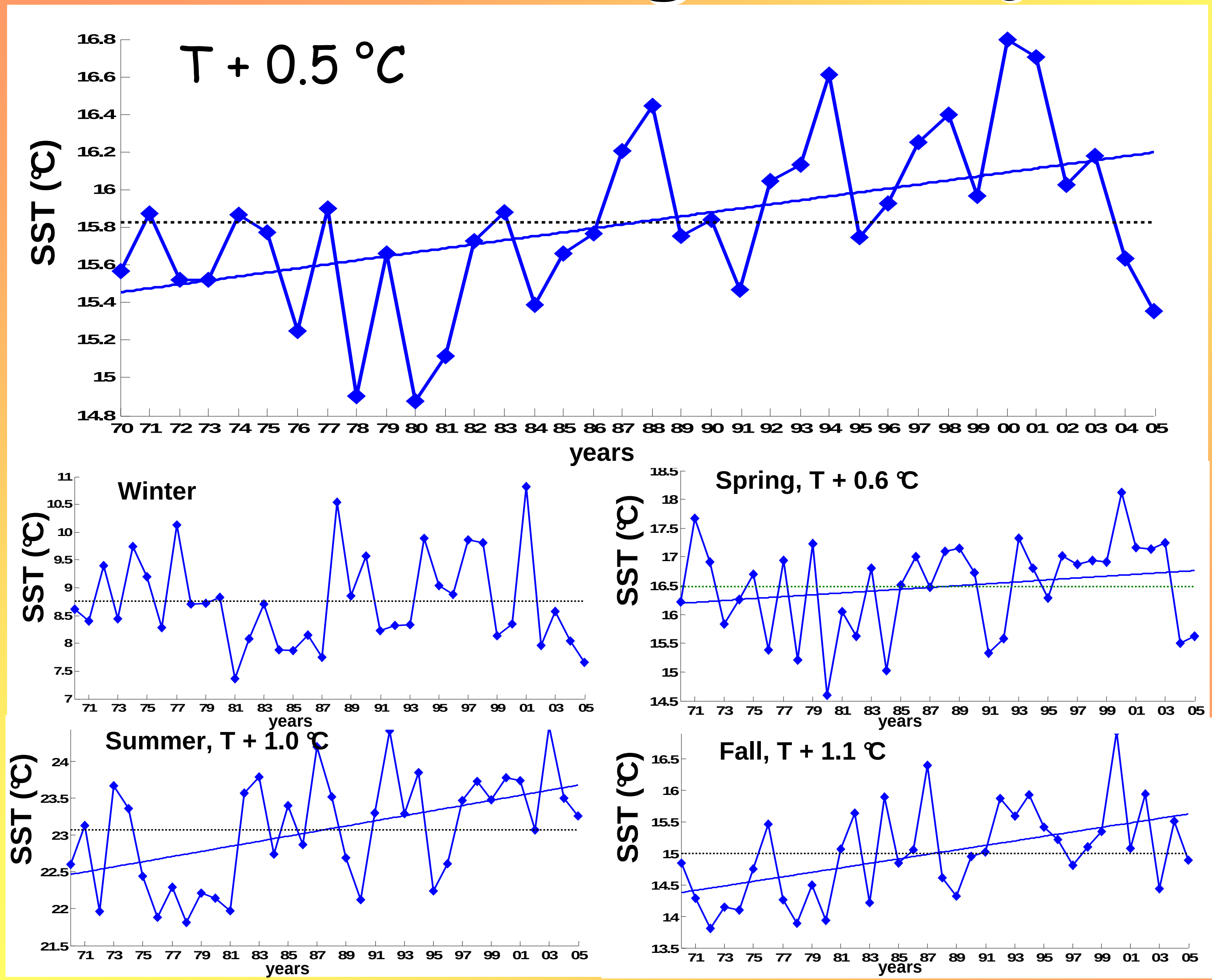
The warming (H_01)



Physical forcing, end of 1980 (H_02)

Peculiar physical conditions at the end of the 1980s in the Mediterranean:

- Pinardi and Demirov (02) distinguish two periods (81-**87**, 88-93) which differ in **precipitation** and **wind** regime
- Pinardi et al (97), Korres et al (00) show the dramatic changes that occur in the surface circulation in **87**, in particular the **Ionian gyre reversal**
- This reversal is considered one of the pre-conditions for the phenomenum called the East Mediterranean Transient

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Conclusions

There are extensive changes in the copepod community of the Gulf of Trieste, around the end of the 1980s. These include:

- Shift toward smaller species
- Appearance of a new species
- Southern species spread northward
- Cold species diminish
- Changes in the phenology of most species

HYPOTHESES-Above changes related to:

- The large scale change in the Mediterranean surface circulation at the end of the 1980s (non-linear)
- The 0.5 °C warming (1 °C in summer and fall) over the 36 years sampled

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