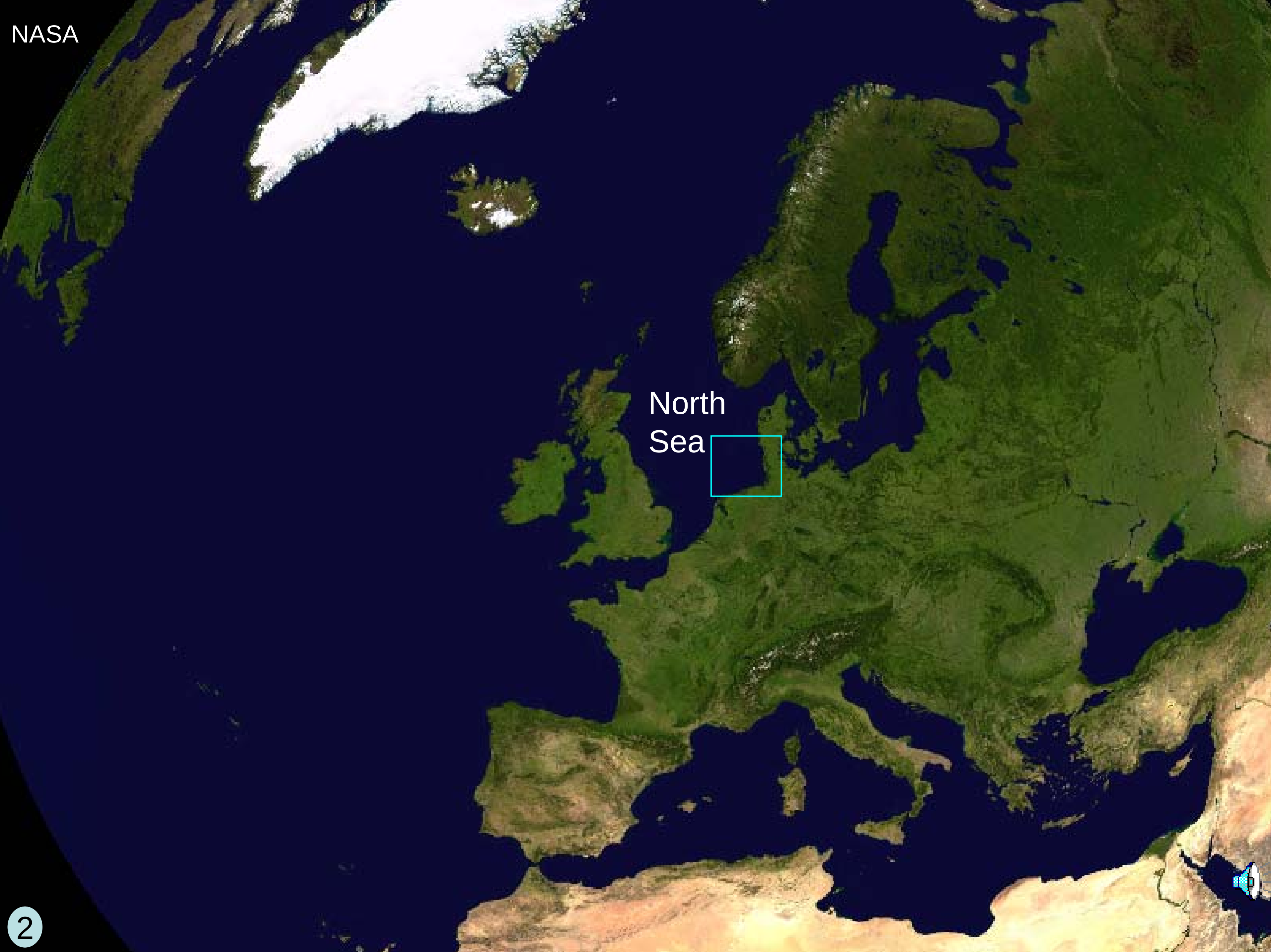
Climate effects on North Sea zooplankton

A: Introduction: Helgoland, a unique research site

B: Research objectives of marine biometeorology:

1. phenology: timing of phenophases
2. functional relationships of phenophases with preceding temperatures
3. phenological trends
4. seasonality of populations
5. trends in seasonality
6. inter-populative co-occurrence (match/mismatch)
7. climatic/latitudinal zoogeographic changes

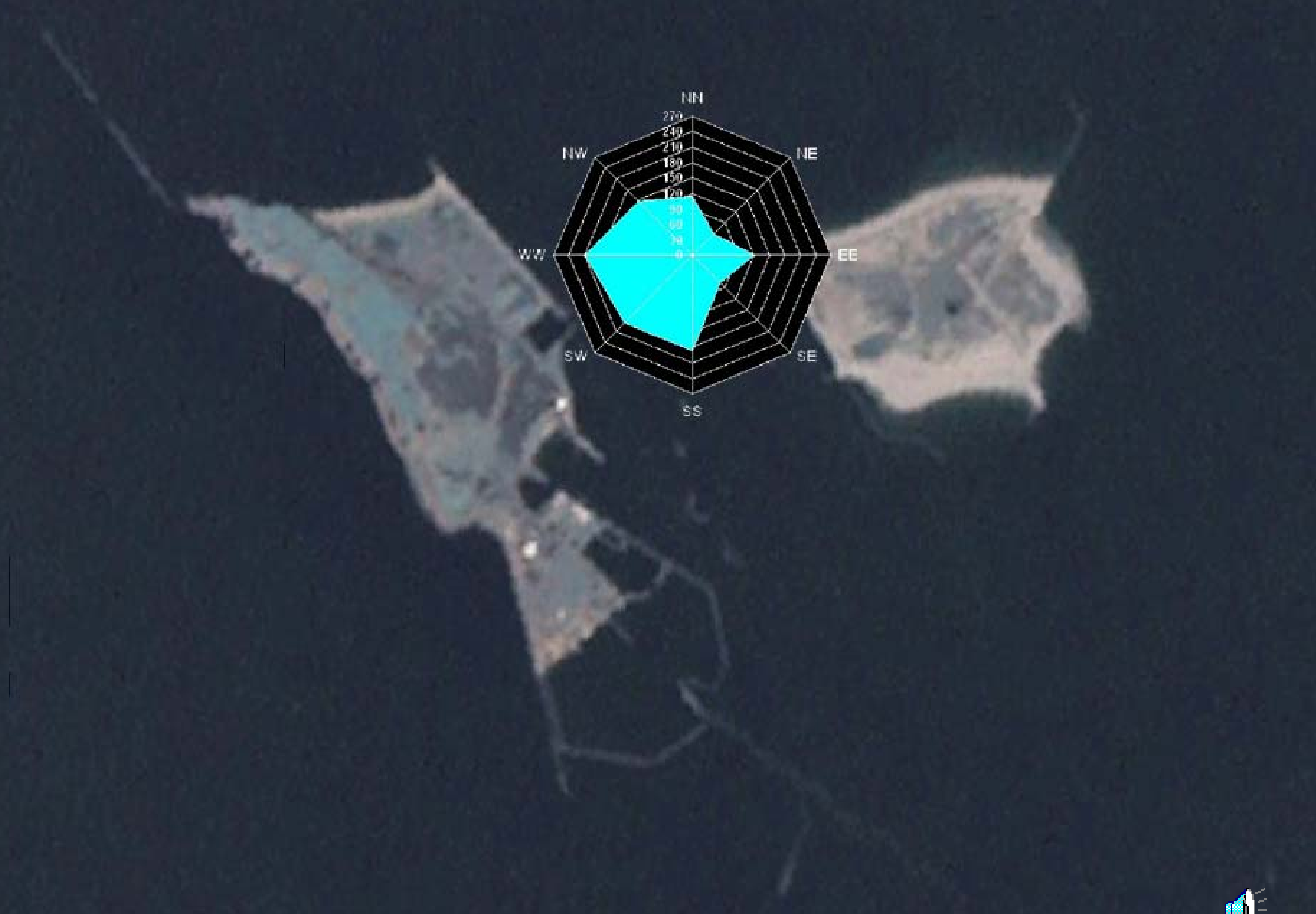
C: Consequences for marine research

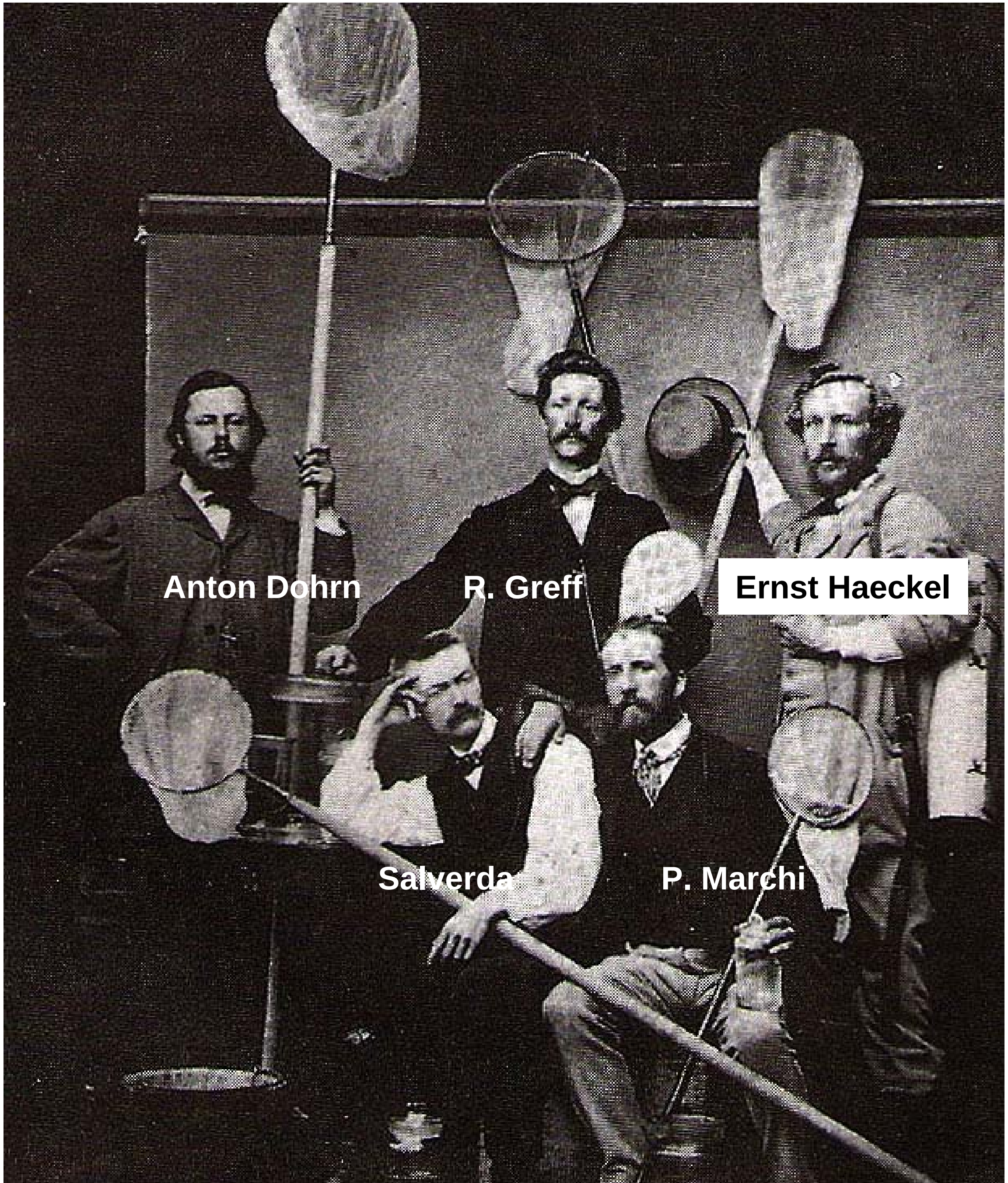

NASA
North
Sea


NASA
HELGOLAND
3


NASA
tidal current
residual current

Mean annual wind force distribution





After the detection of the „Auftrieb“ on Helgoland in 1845 by Johannes Müller and the publication in 1846 scientists swarmed to Helgoland to use butterfly nets for catching animals from the newly detected community of the water body which we now call zooplankton*.
In 1865 this photograph was taken of five of these Helgoland visitors some of which were or became famous scientists.

Calanus helgolandicus, Oithona helgolandica, Tomopteris helgolandica and almost 50 other species carry Helgoland in their names.

*Victor Hensen coined the word plankton in 1887.

From BAH 1992, modified

Time-series Helgoland Roads zooplankton

Since April 1974 every Monday, Wednesday and Friday two oblique net-hauls with mesh sizes 150µm (mesozooplankton) and 500µm (makrozooplankton) have been taken at Helgoland Roads. The abundance distribution of zooplankton populations permitted the definition of specific weekly, annual, inter-annual and decadal changes and variance.

These measurements were the basis to marine phenology Greve et al. 1995, Heyen et al. Greve et al. Greve which has been extended to the North Atlantic wide investigations of SAHfOS.

They also permitted the detection of neozoa to the area.

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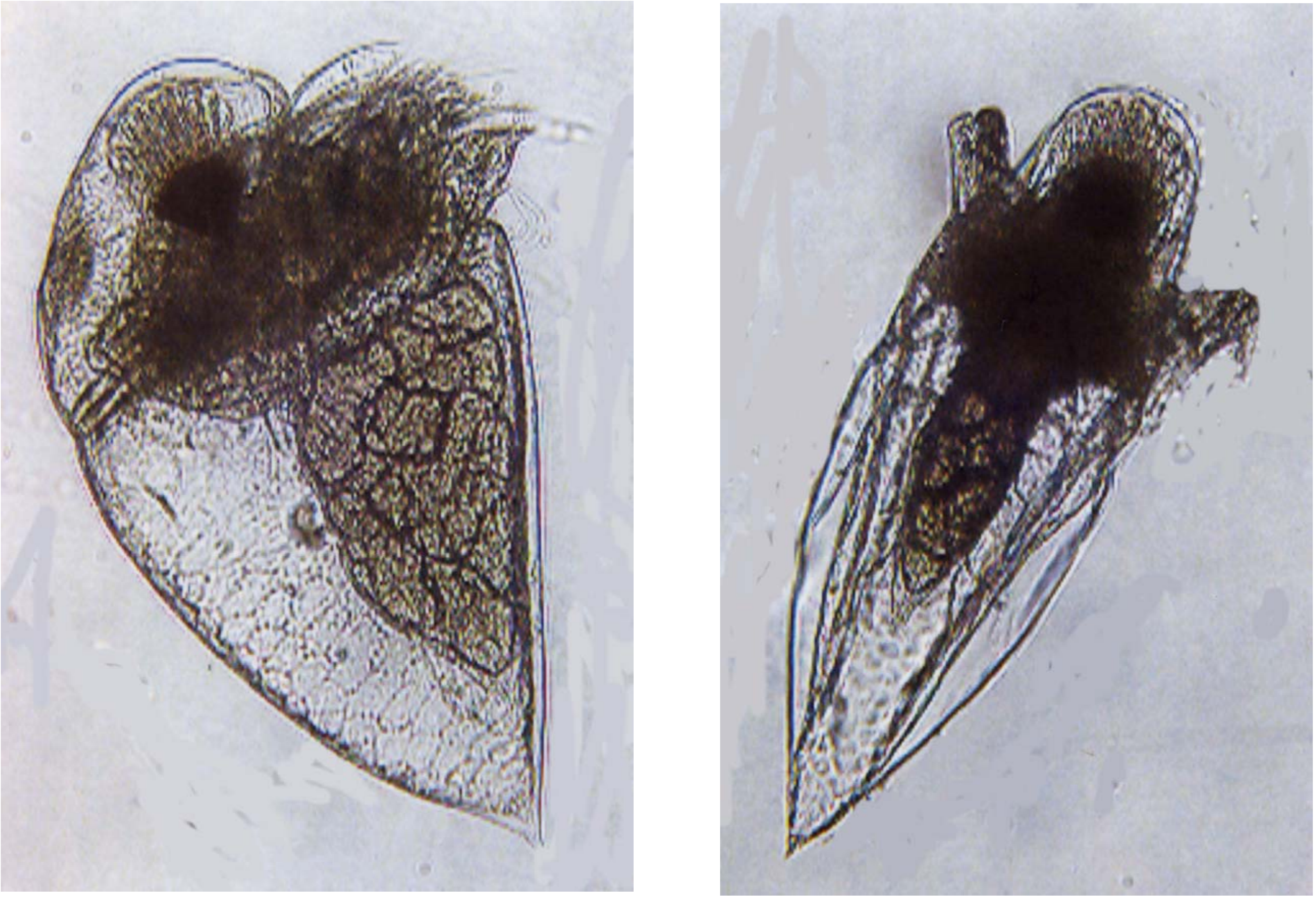
1. phenology: timing of phenophases

1. “Japan has records of the peak cherry blooms for the past 1.200 years”
2. “Plankton populations are seasonal”

Definition (EPN): *the study of the timing of recurring biological phases, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species*

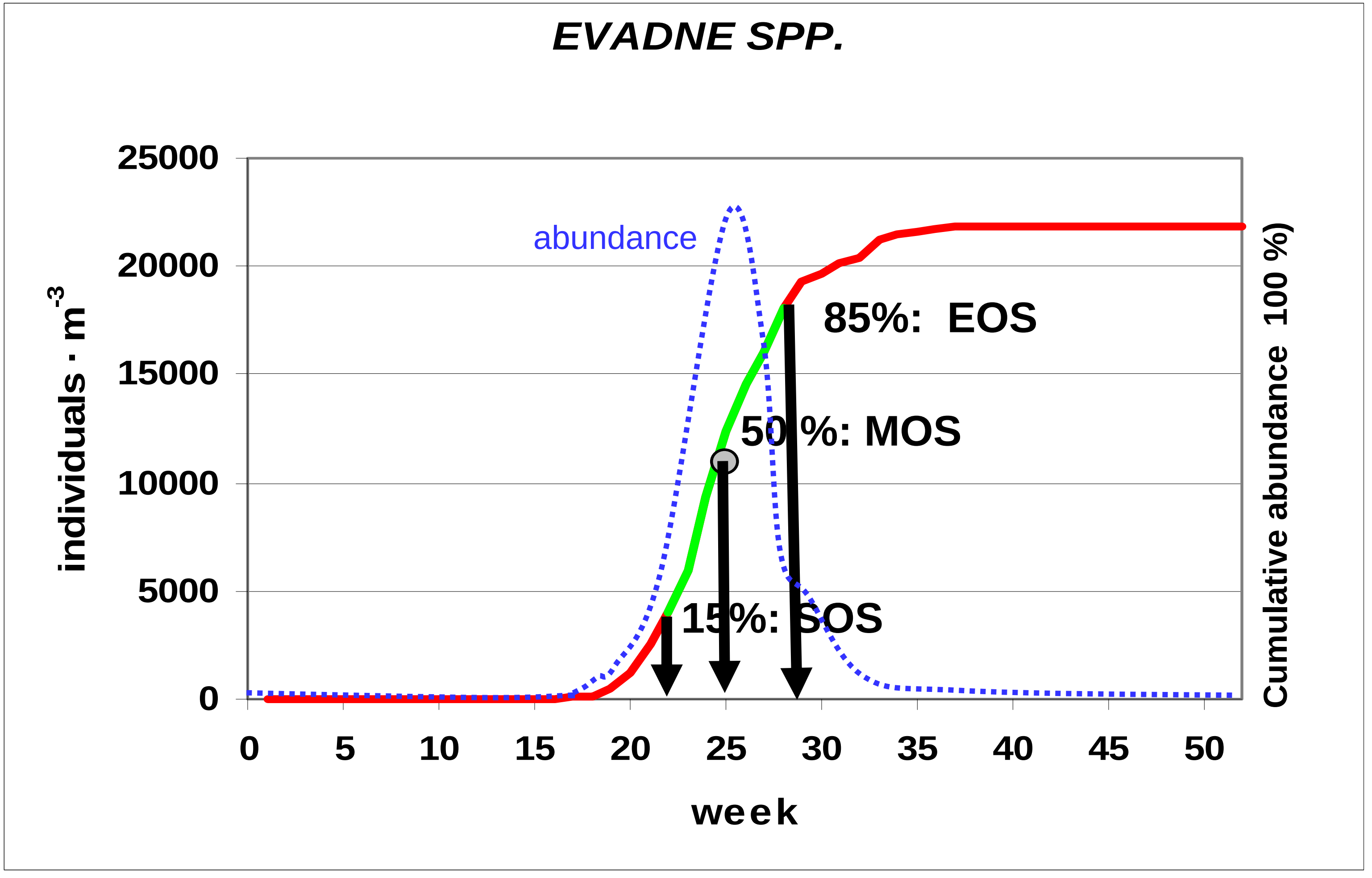
Methods: to determine the phenophases of populations e.g.:
-as threshold passage of the relational cumulative sum (Greve et al. 2001)
-as the centre of gravity below graphs of monthly means (Edwards and Richardson 2004)

Results:
phenophase determination converts abundance information into temporal information and thus adds another measure of performance

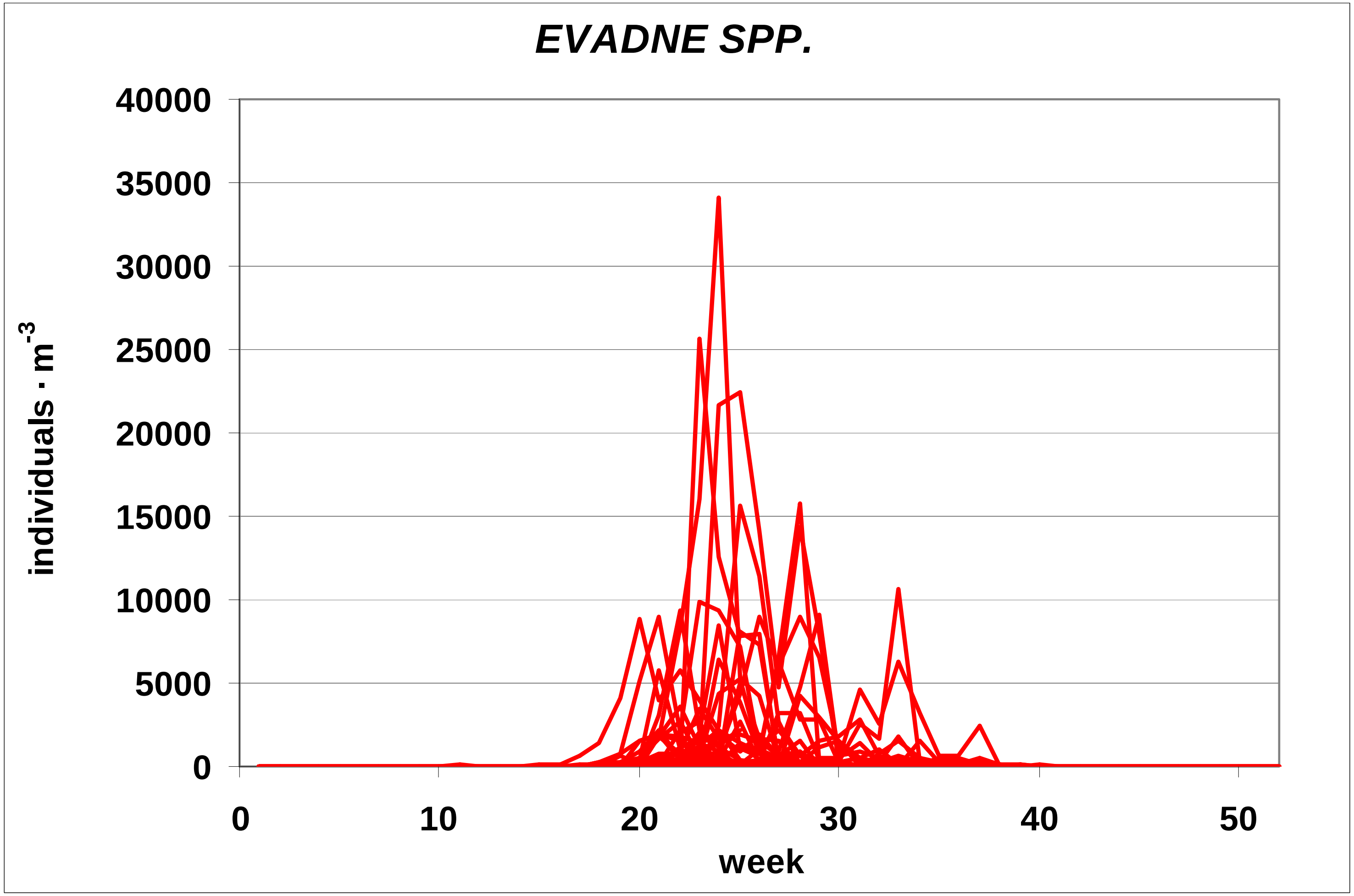


Evadne spp.

phenological conversion of abundance into temporal information
SOS = start of season, MOS = middle of season, EOS = end of season
defined as as passages of the abundance thresholds 15%, 50% and 85%



30 years population dynamics overlay of *Evadne spp.* Indicating how inter-annual variance may exceed the annual length of season



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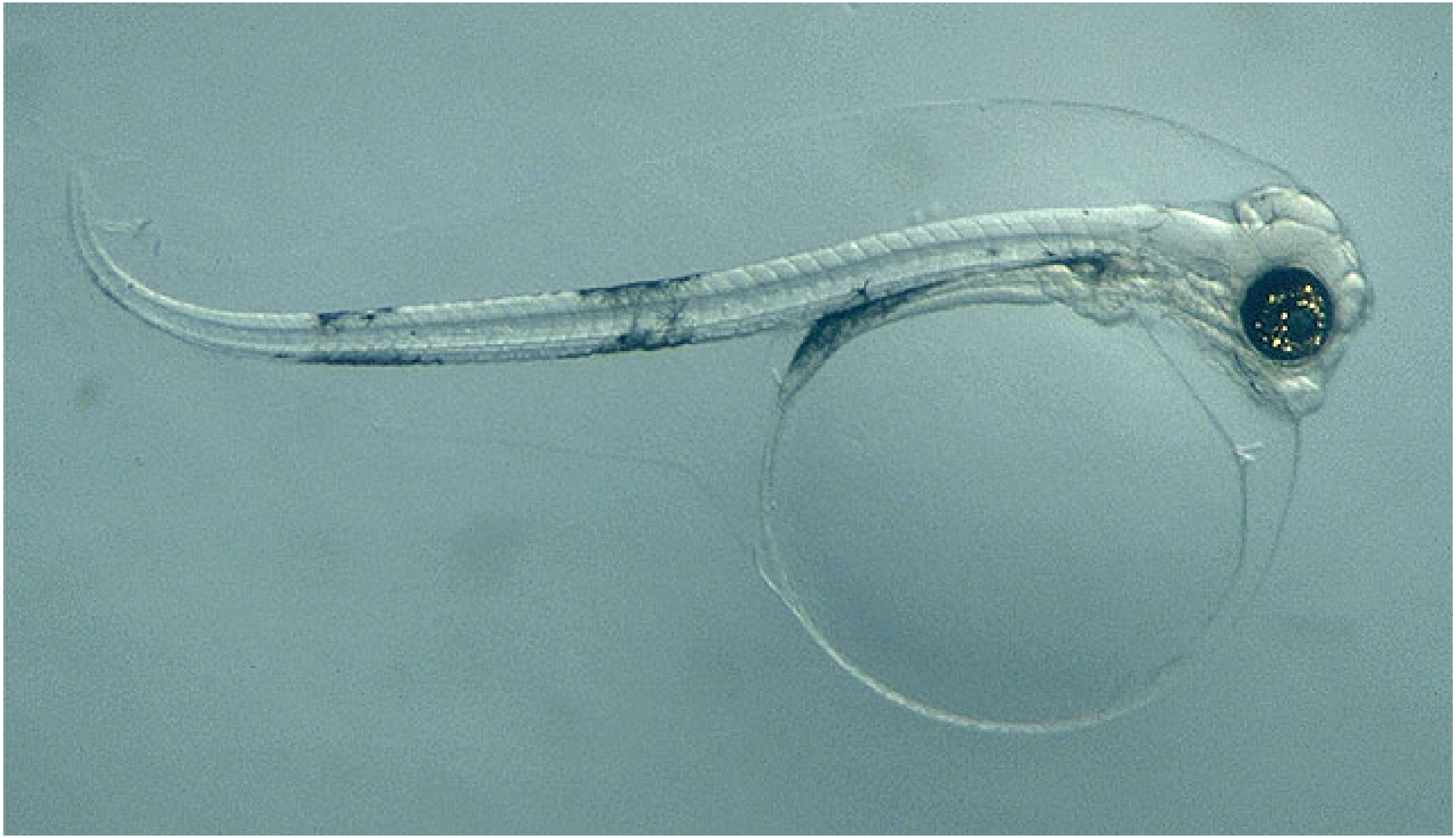
2. functional relationships of phenophases with preceding temperatures

Definition: determination of the best regression/determination coefficient
of phenophase timing with varied preceding temperatures

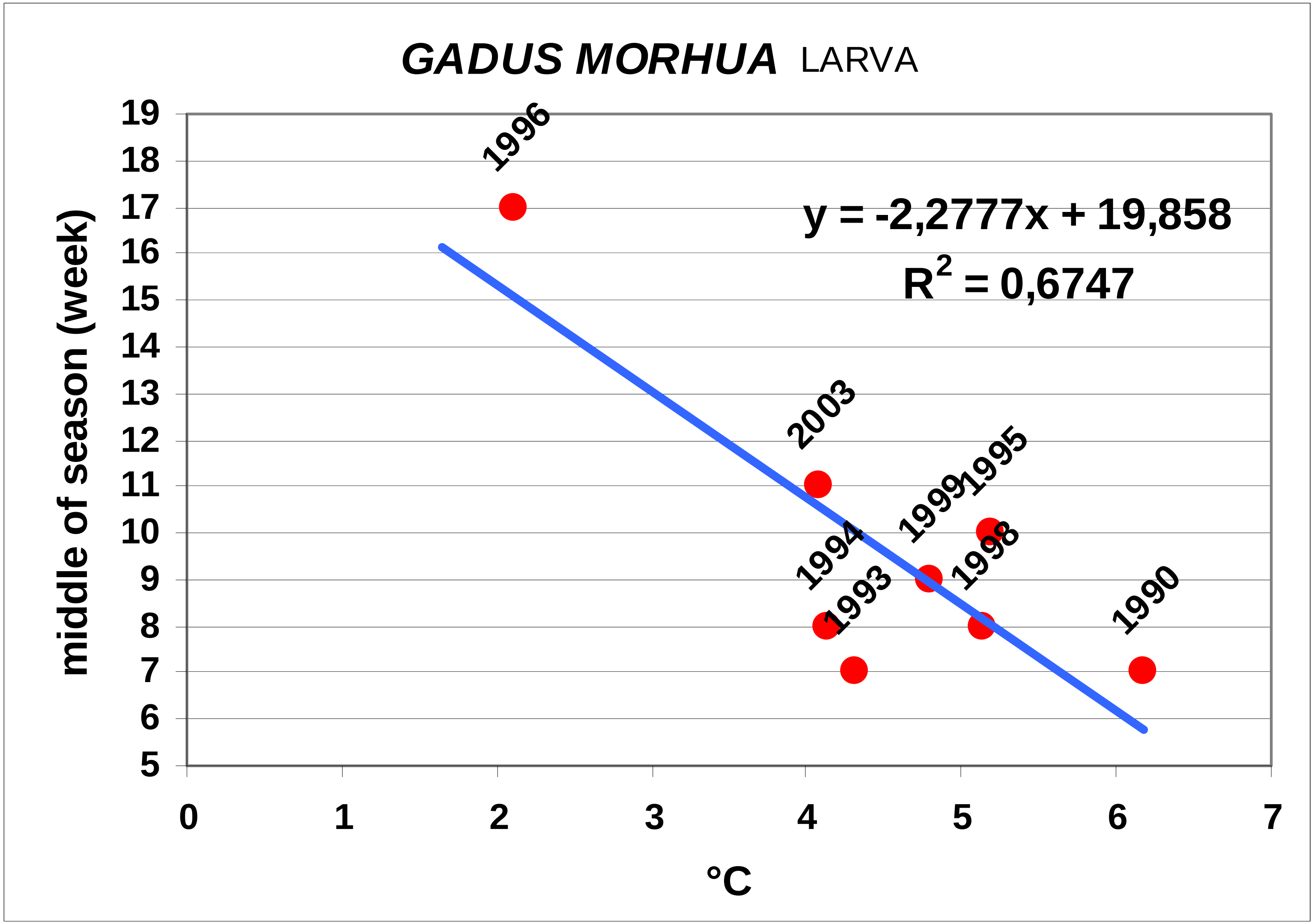
Methods: Utilizing the inter-annual variance of temperature and
phenophases to calculate their functional relationship prior to
phenological trend determination

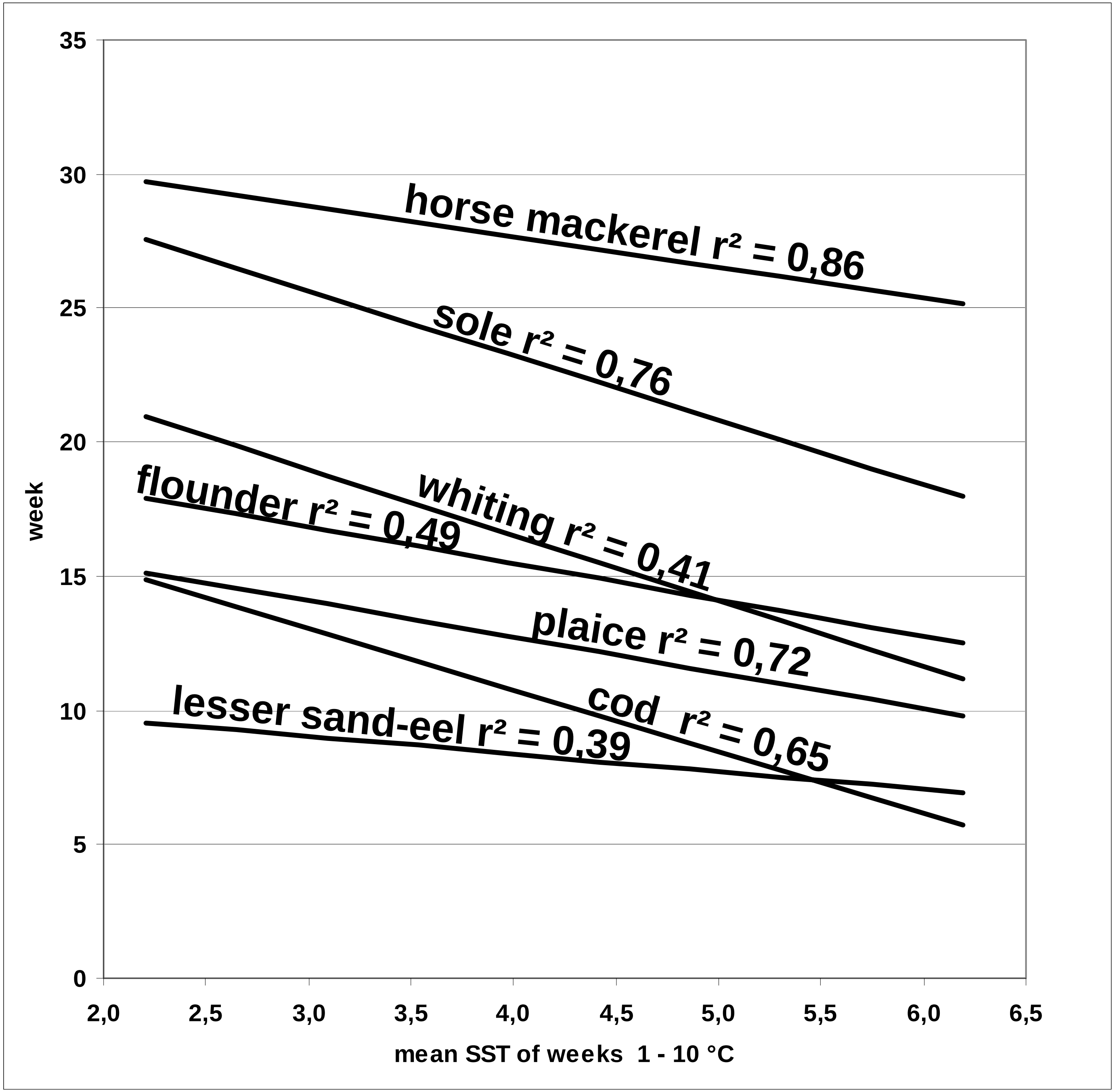
Results: regression or determination coefficients of each phenophase and
each species population has a unique value
defining the functional relationships of phenophases with preceding
temperatures
values differ in prefix and magnitude



Larva von *Gadus morhua* (cod) foto: fishweb

Functional relationship of the phenophase MOS with winter (week 1 – 10) mean temperatures





Phenophase MOS functional relationship with winter SST of commerciaL North Sea fish .larvae

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C: Consequences for marine research

3. phenological trends

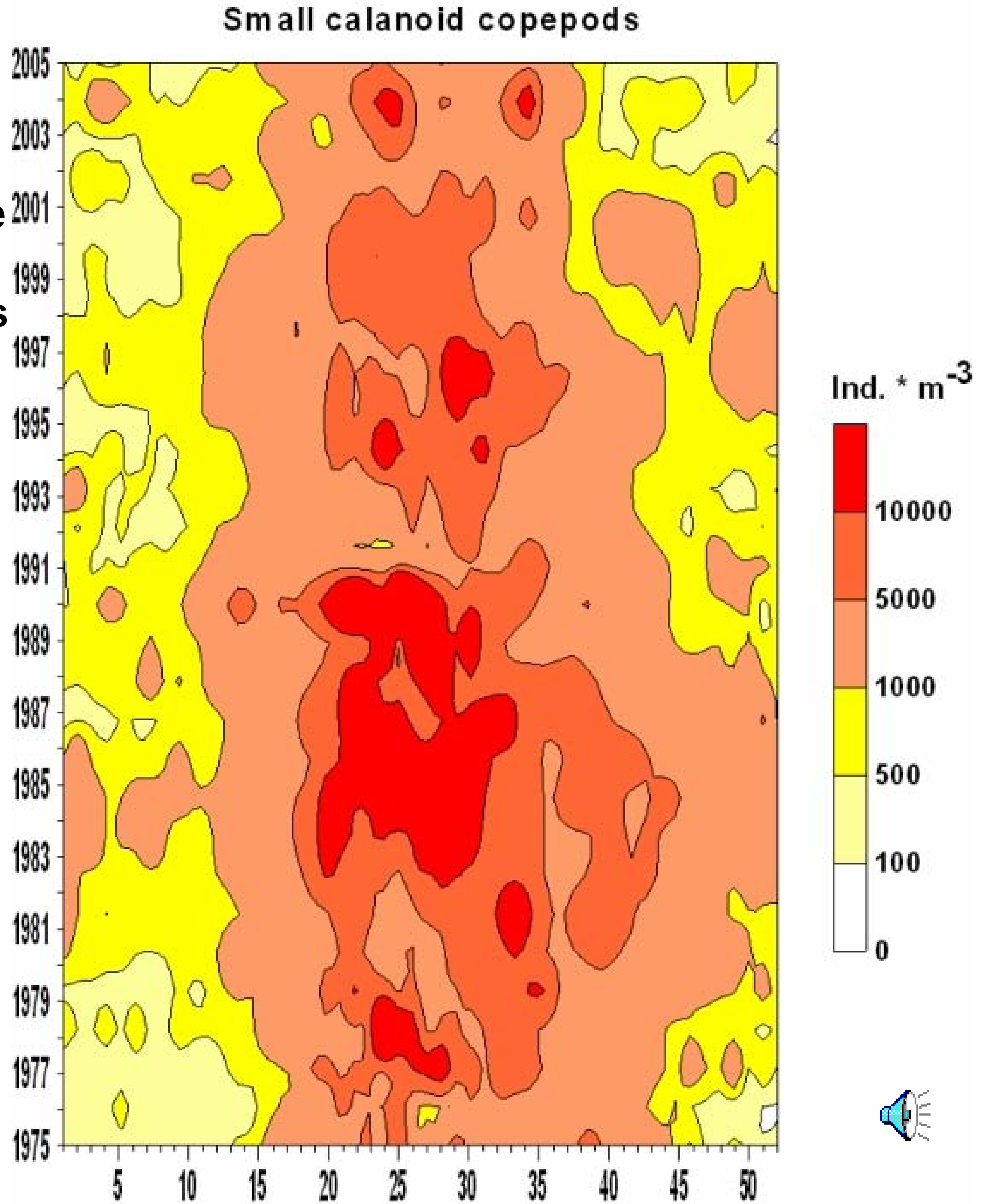
Definition: statistical tendency of phenophase variance

Methods: to calculate the regression of the annual phenophase values against time

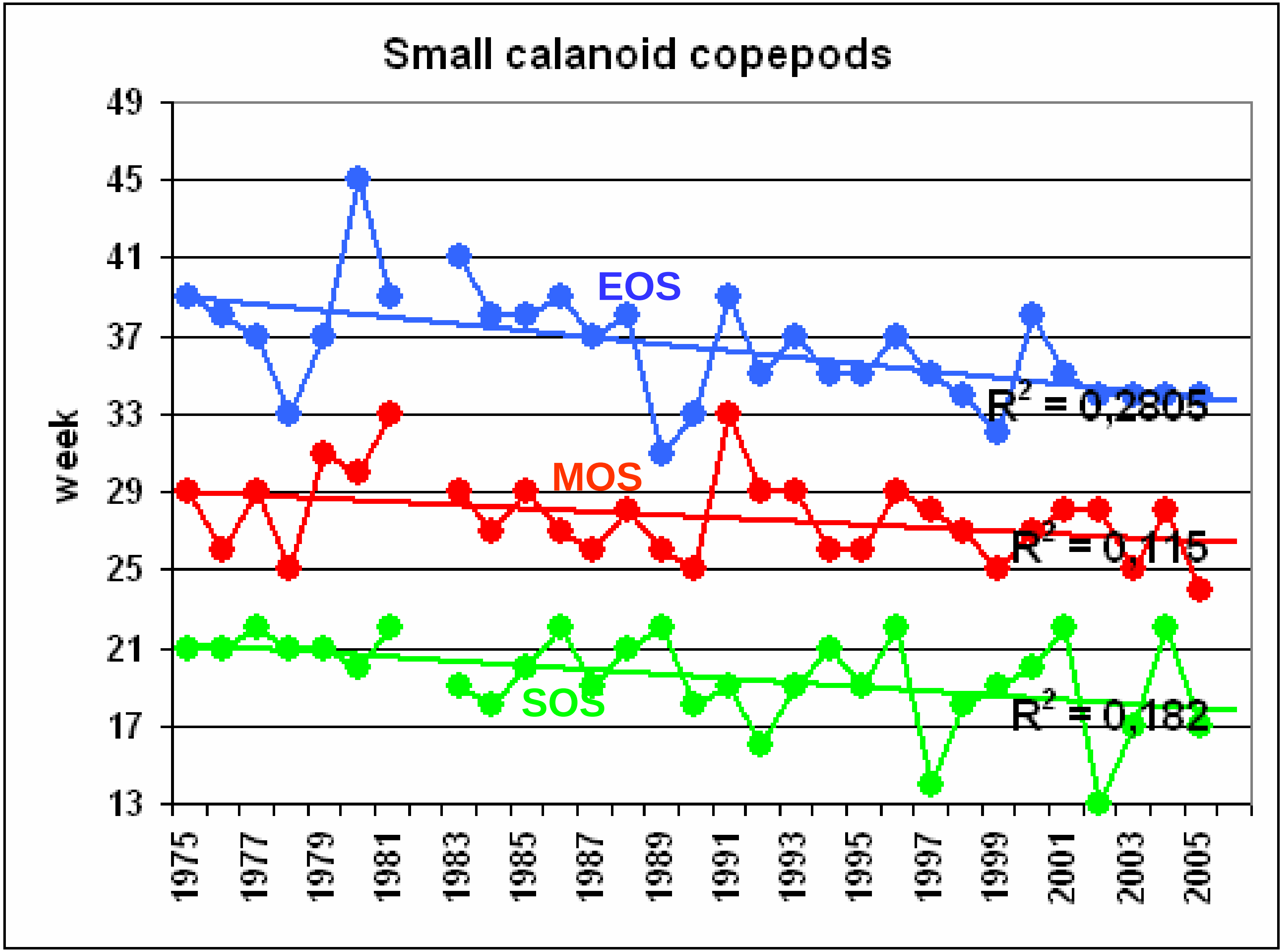
Results: phenophases of species populations vary with time values and differ in prefix and magnitude

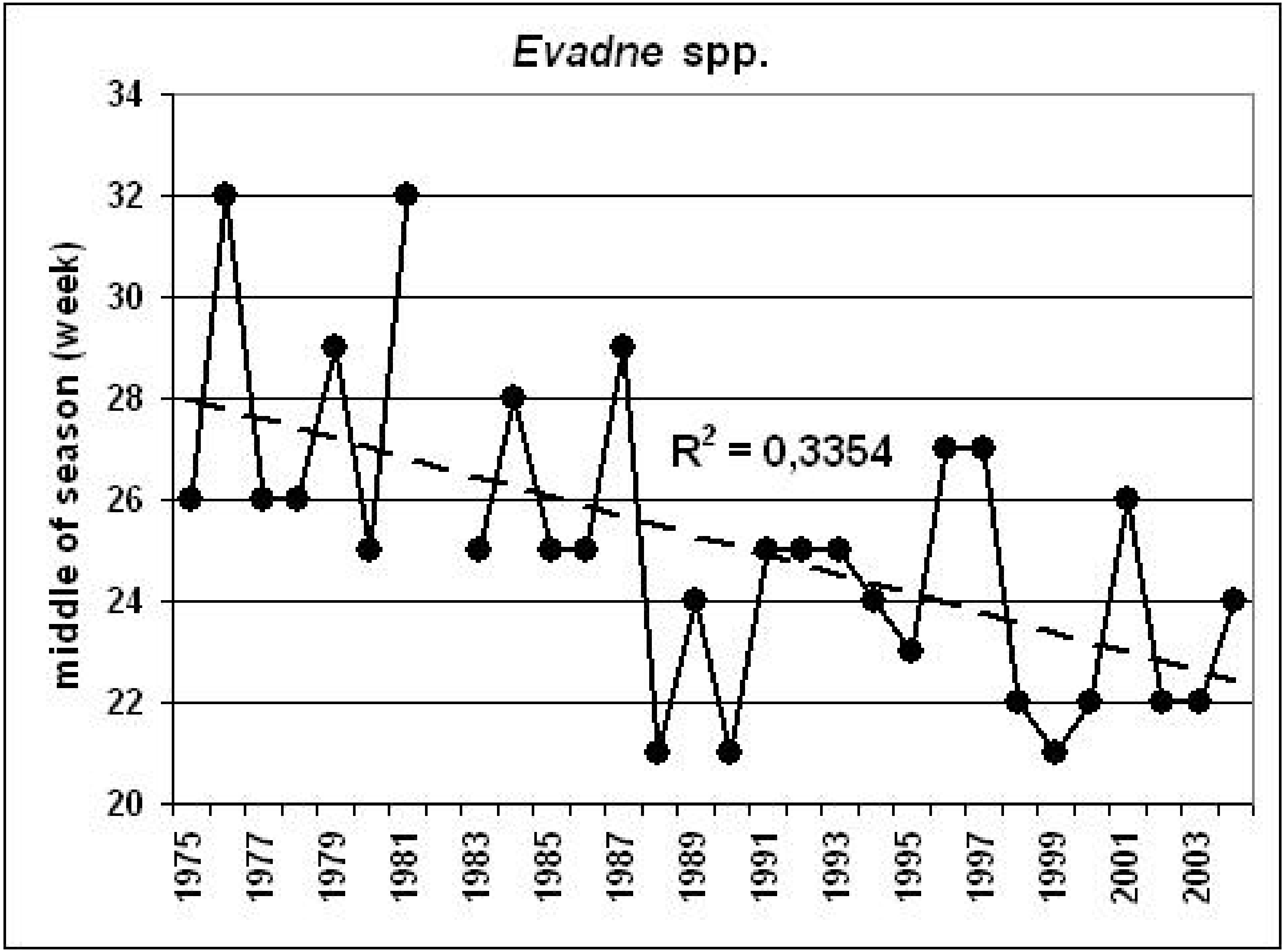
The distributional shift of populations is released from the abundance change information by the phenological calculations

Thus this information is converted into:



Phenological changes of the sum of *Acartia spp., Temora longicornis, Paracalanus parvus, Pseudocalanus elongatus* and *Centropages spp.*





Trend of the phenophase "middle of season" of *Evadne* spp. indicating a shift from week 28 in 1975 to week 23 in 2005

from Greve et al. 2005

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C: Consequences for marine research

Definition: period of main abundance (>15% and <85% of the cumulative abundance of populations

Methods: determining EOS, SOS and LOS length of season
LOS = EOS - SOS

Results: zooplankton populations are seasonal

the season of zooplankton populations varies in species specific timing and length

holoplankton responds in generation time and start of reproduction
meroplankton responds in gonad maturation, reproduction or budding of medusae

Podon spp.
Evadne spp.
Penilia avirostis
Calanus spp.
Pseudocalanus elongatus females
Para- und Pseudocalanus
Centropages typicus females
Centropages hamatus females
Centropages
Temora longicornis
Acartia spp.
Oithona spp.
Nauplius
Temora longicornis Nauplii
Cirripedia Nauplii
Euterpina acutifrons

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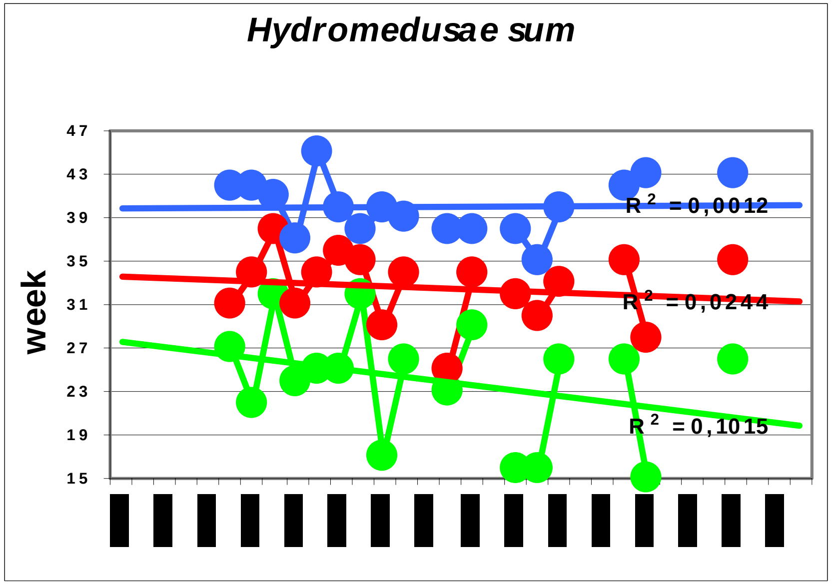
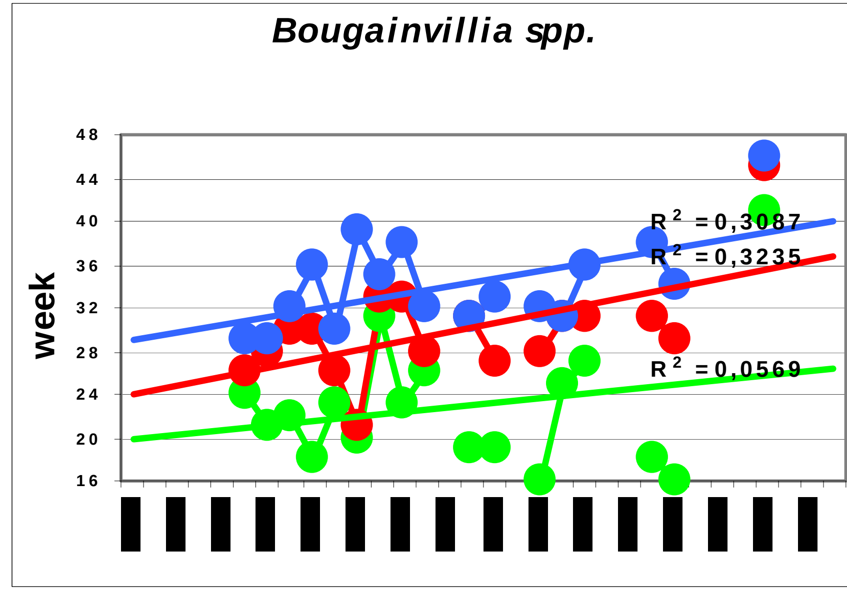
C: Consequences for marine research

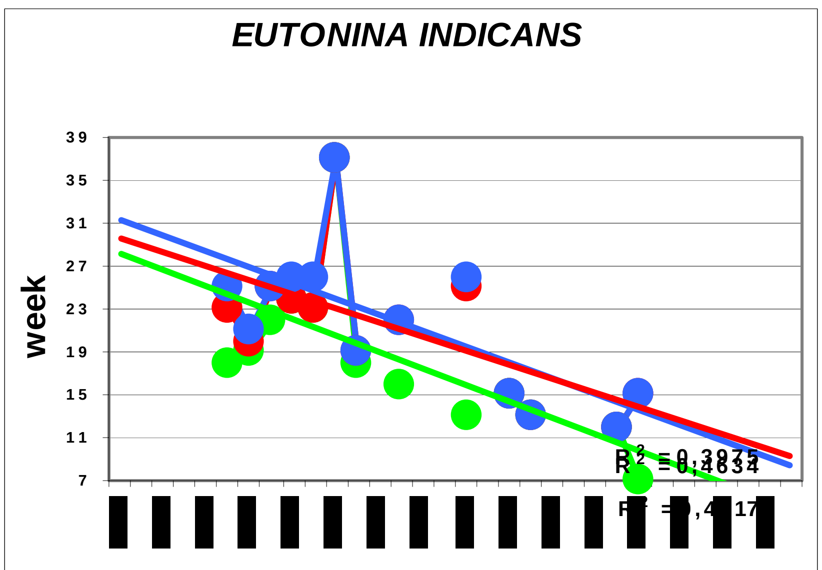
Definition: statistical tendency of SOS, EOS and resulting LOS with time

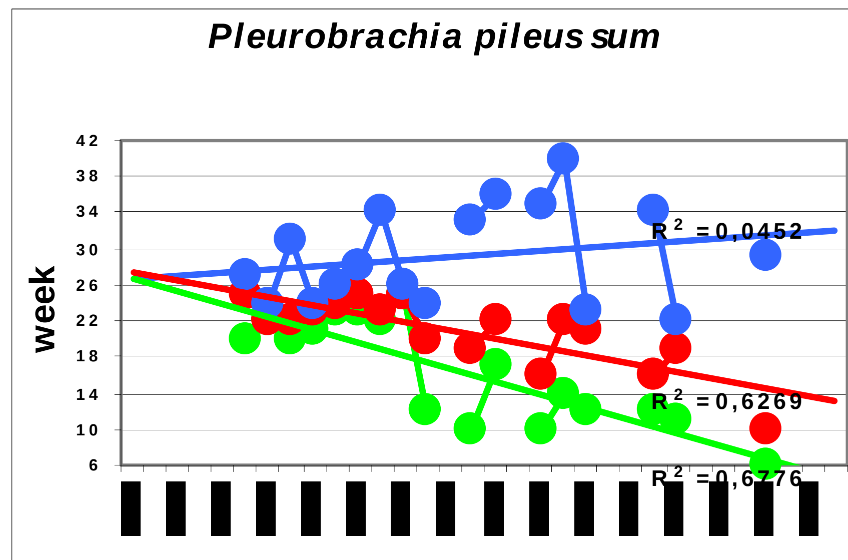
Methods: calculation of the linear regression of the phenophase timing and resulting LOS for the annual change in weeks

Results: seasonal timing of SOS and EOS varies independently in regression inclination. Populations thus alter in timing and length of season

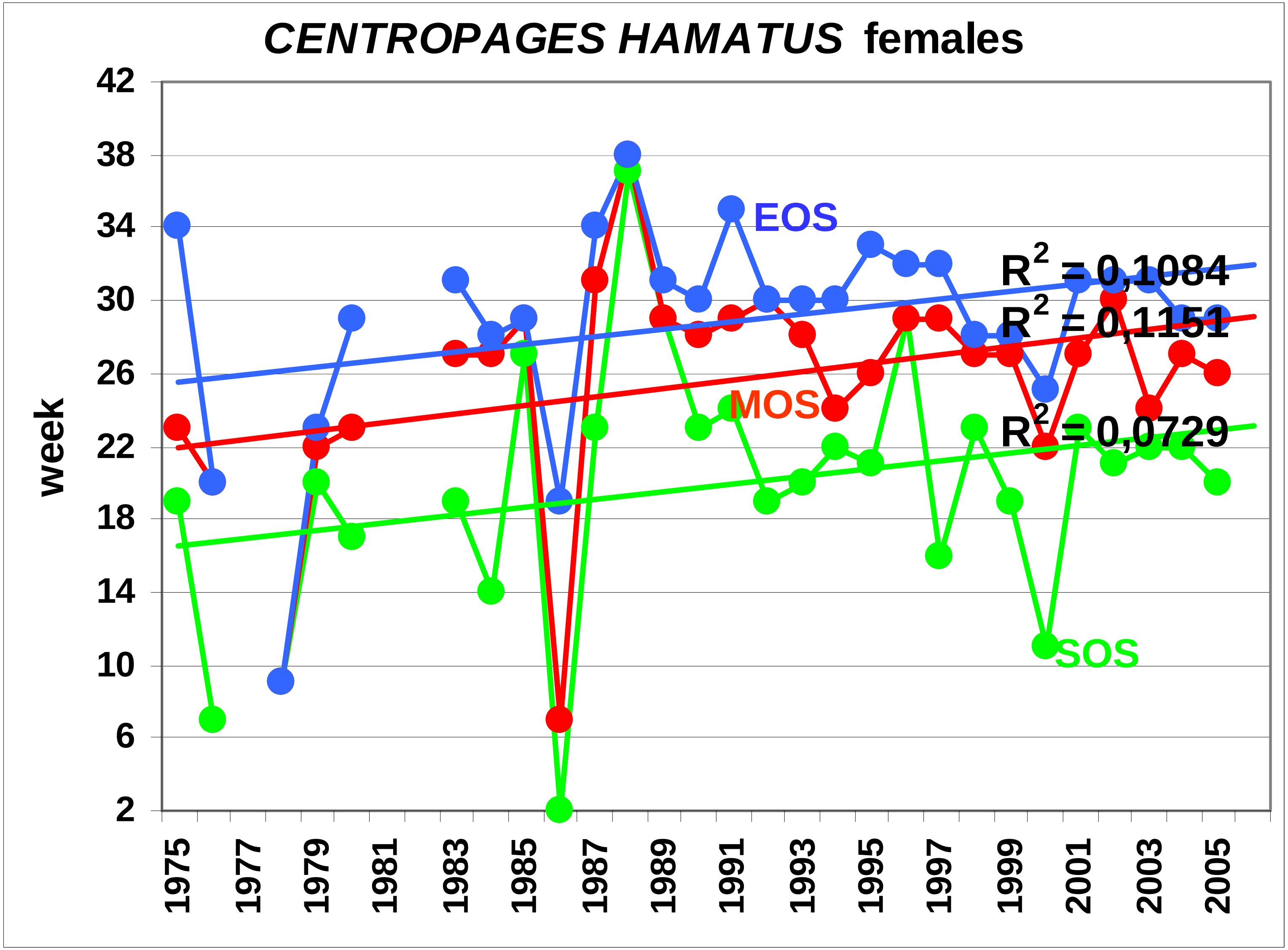

Hydromedusae sum
week
47
43
39
35
31
27
23
19
15
R² = 0,0012
R² = 0,0244
R² = 0,1015


Bougainvillia spp.
week
48
44
40
36
32
28
24
20
16
R² = 0,3087
R² = 0,3235
R² = 0,0569

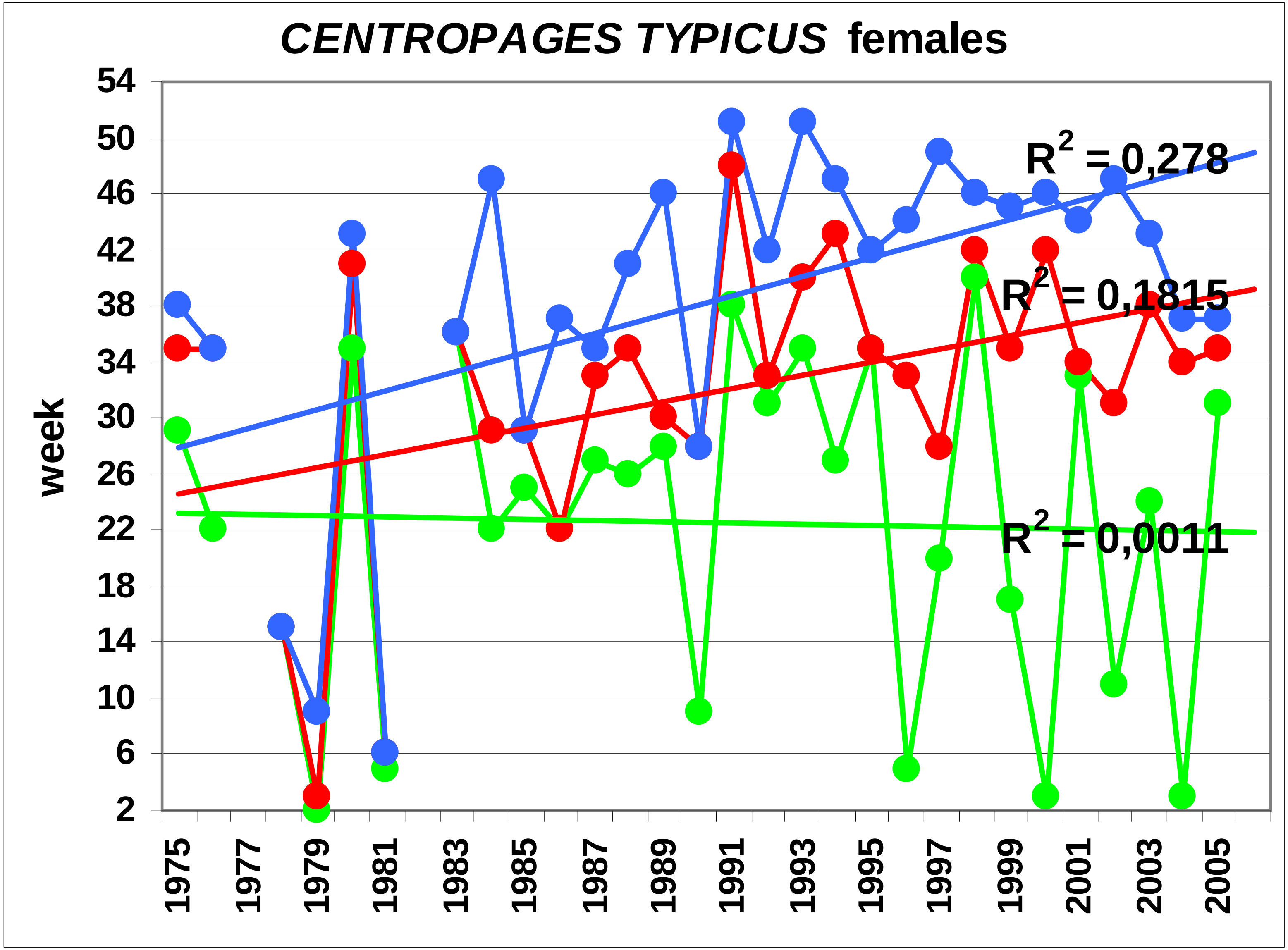

EUTONINA INDICANS
week
39
35
31
27
23
19
15
11
7
R² = 0,3975
R² = 0,4634


Pleurobrachia pileus sum
week
42
38
34
30
26
22
18
14
10
6
R² = 0,0452
R² = 0,6269
R² = 0,6776

Seasonal changes of *Centropages hamatus* females



Seasonal changes of *Centropages typicus* females



	SOS	MOS	EOS	LOS
Fish larvae	0,086	0,183	0,226	0,139
Harpacticoida	0,168	0,152	0,045	-0,123
Noctiluca scintillans	-0,012	0,033	0,048	0,060
Ctenophora	-0,080	0,017	-0,014	0,066
Copepoda	-0,088	0,012	-0,051	0,037
Lamellibranchia	-0,013	0,005	0,126	0,139
Chaetognatha	-0,011	-0,013	-0,020	-0,009
Hydrozoa	-0,060	-0,024	0,051	0,111
Appendicularia	-0,187	-0,049	-0,027	0,160
Calanoida	-0,117	-0,066	-0,162	-0,045
Gastropoda	0,002	-0,086	-0,120	-0,122
Cladocera	-0,097	-0,095	-0,035	0,062
Cyclopoida	-0,125	-0,151	-0,157	-0,032
Decapoda	-0,128	-0,155	-0,144	-0,016
Echinodermata	-0,105	-0,177	-0,163	-0,058
Polychaeta	-0,127	-0,222	-0,092	0,036

MOS · a^{-1} ranking of the annual temporal shift of the sasonal trend of MOS

	SOS	MOS	EOS	LOS
Appendicularia	-0,187	-0,049	-0,027	0,160
Lamellibranchia	-0,013	0,005	0,126	0,139
Fish larvae	0,086	0,183	0,226	0,139
Hydrozoa	-0,060	-0,024	0,051	0,111
Ctenophora	-0,080	0,017	-0,014	0,066
Cladocera	-0,097	-0,095	-0,035	0,062
Noctiluca scintillans	-0,012	0,033	0,048	0,060
Copepoda	-0,088	0,012	-0,051	0,037
Polychaeta	-0,127	-0,222	-0,092	0,036
Chaetognatha	-0,011	-0,013	-0,020	-0,009
Decapoda	-0,128	-0,155	-0,144	-0,016
Cyclopoida	-0,125	-0,151	-0,157	-0,032
Calanoida	-0,117	-0,066	-0,162	-0,045
Echinodermata	-0,105	-0,177	-0,163	-0,058
Gastropoda	0,002	-0,086	-0,120	-0,122
Harpacticoida	0,168	0,152	0,045	-0,123

LOS · a^{-1} ranking of the annual temporal shift of the sasonal trend

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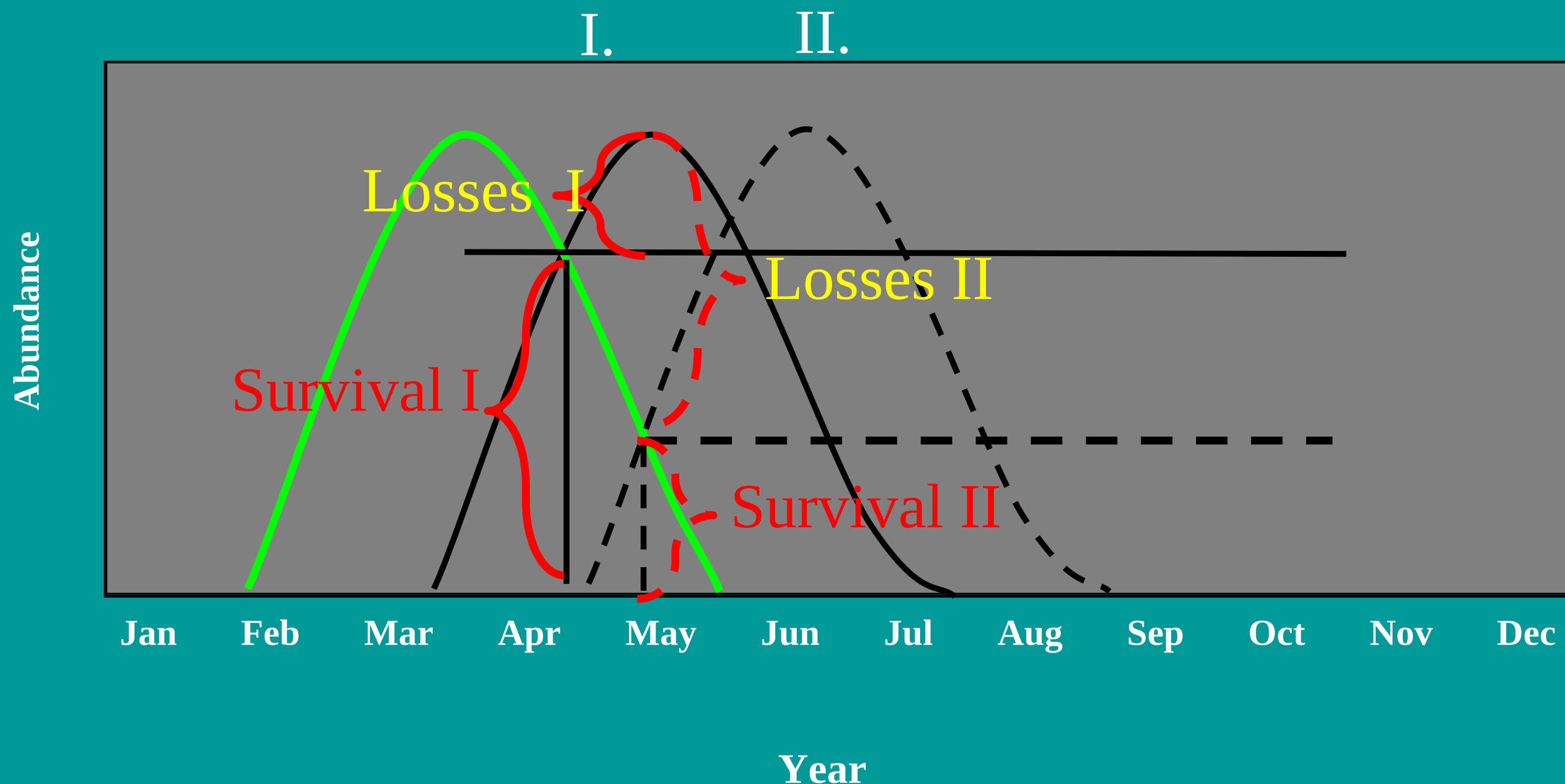
C: Consequences for marine research

Definition: calculation of the temporal population overlap

Methods: definition of the seasonal timing of potential interaction partners and calculation of co-occurrence

Results: preliminary investigations prove the potential power of this approach for the prediction of population performance

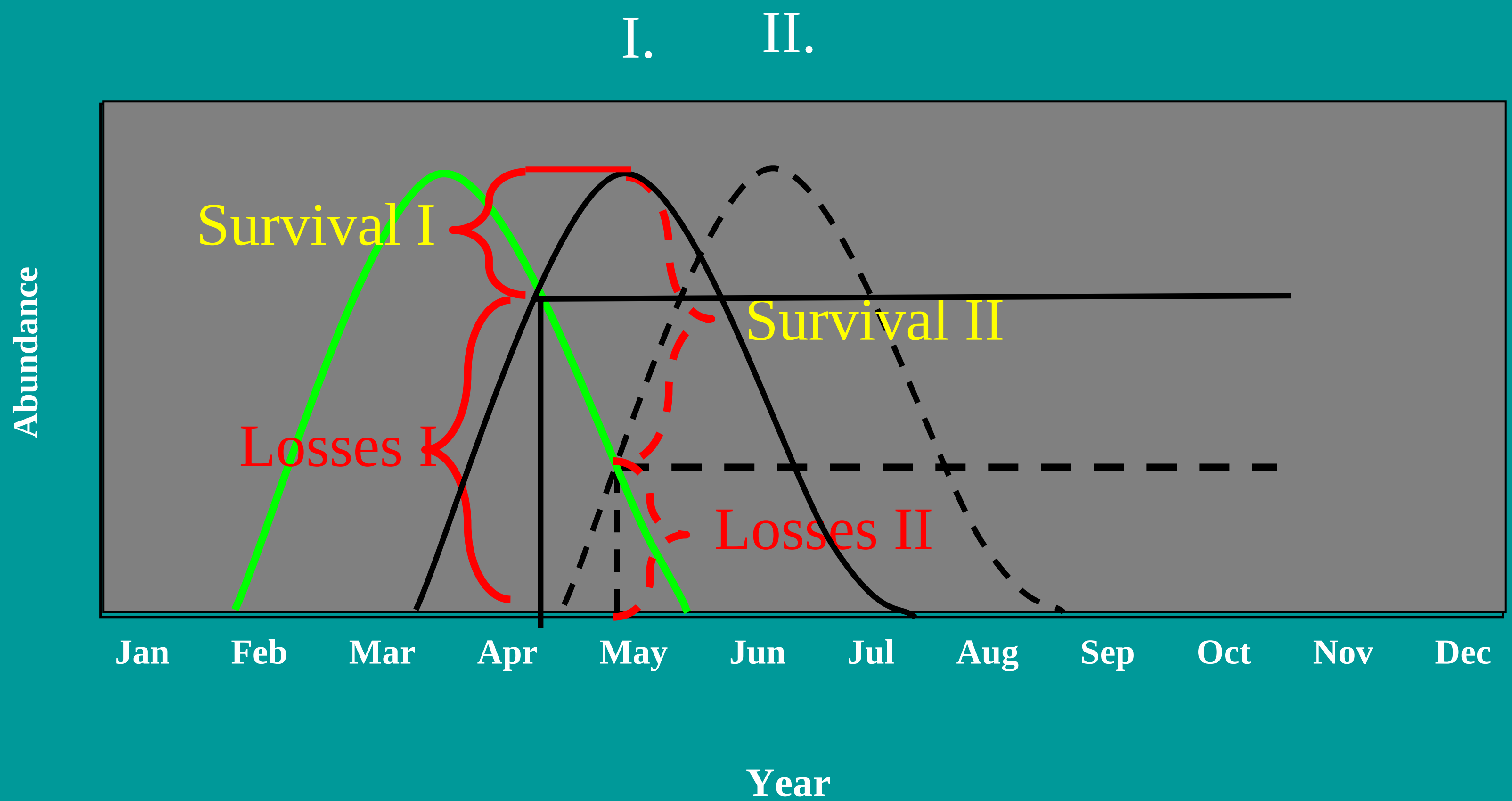
PREY-CONTROL:



Year-class formation as an optimisation process 1: nutrition

- prey
- predator case I: match
- predator case II: mismatch

PREDATOR-CONTROL:



Year-class formation as an optimisation process 2: predator avoidance

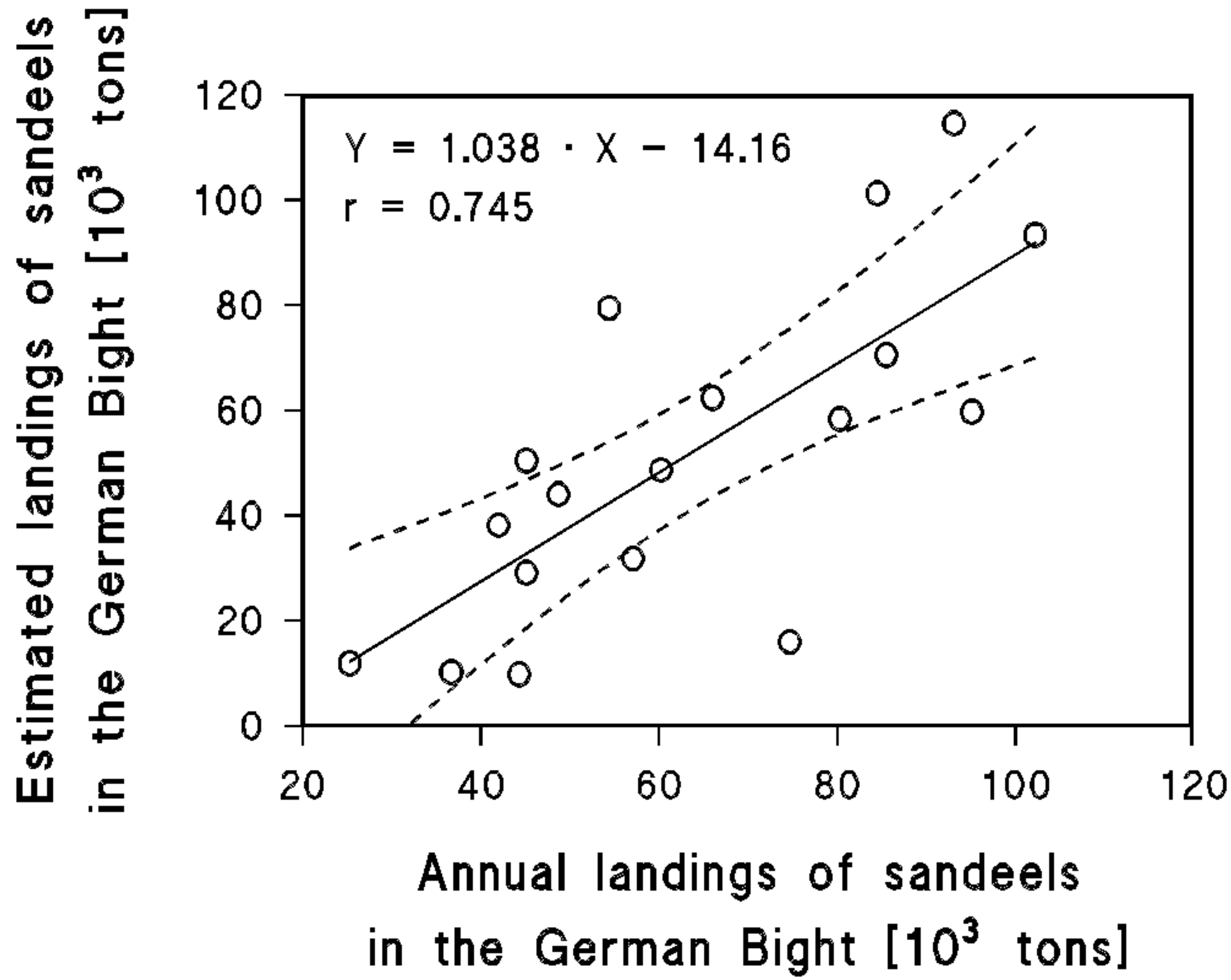
prey

predator case I: match

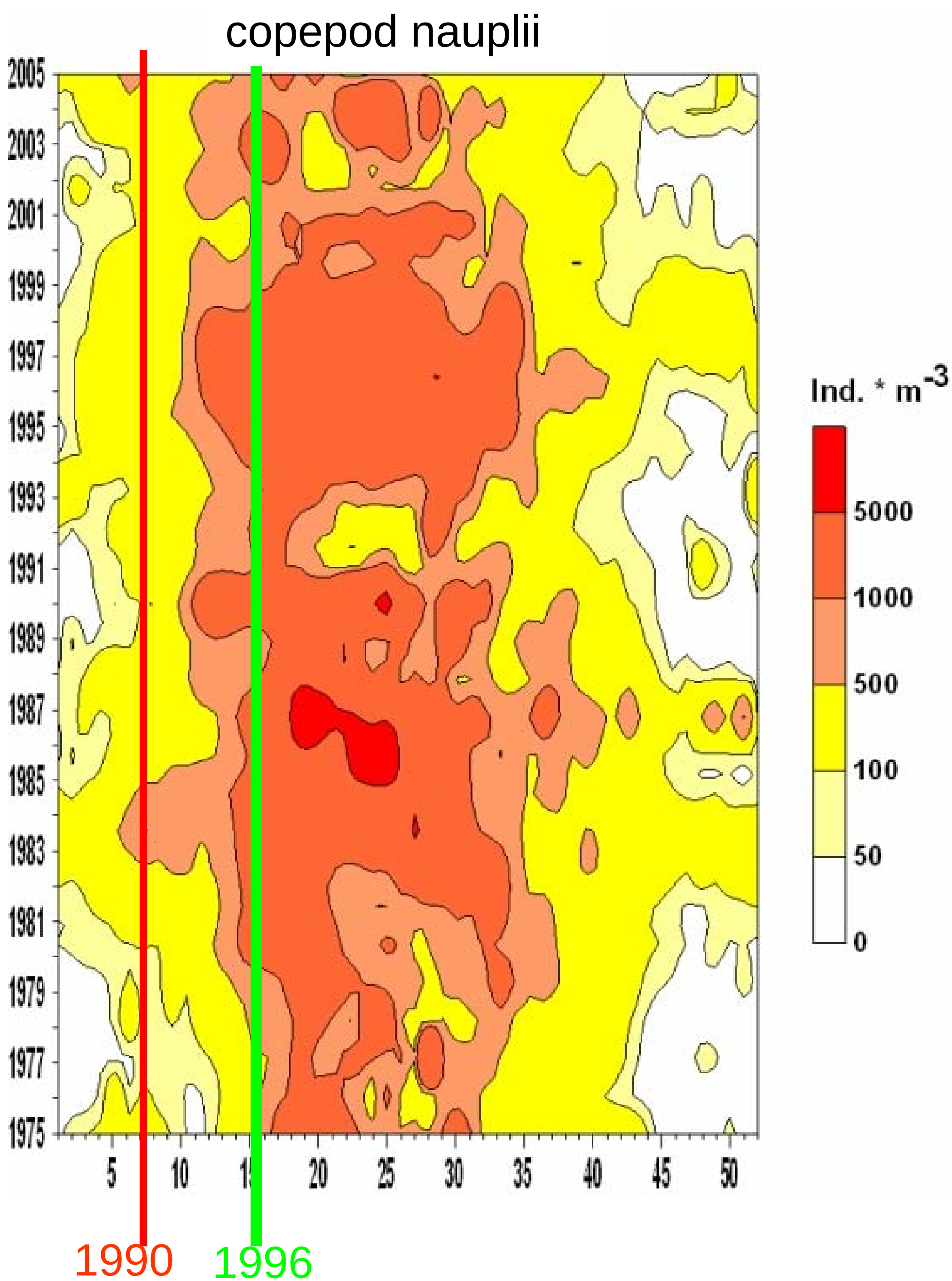
predator case II: mismatch

Ammodytes marinus

1 year prognoses of sand eel landings in the German Bight based on last year´s landings, predicted phenological time of hatching and abundance of copepod nauplii (measurements) 14 days after hatching



Mainik, Lange & Greve, ´99



Phenological timing
of cod spawning in
1990 and 1996 and
abundance dynamics
of copepod nauplii
1975 to 2005

standing for match
and mismatch conditions

as a possible cause for the
reduction of cod in the
North Sea

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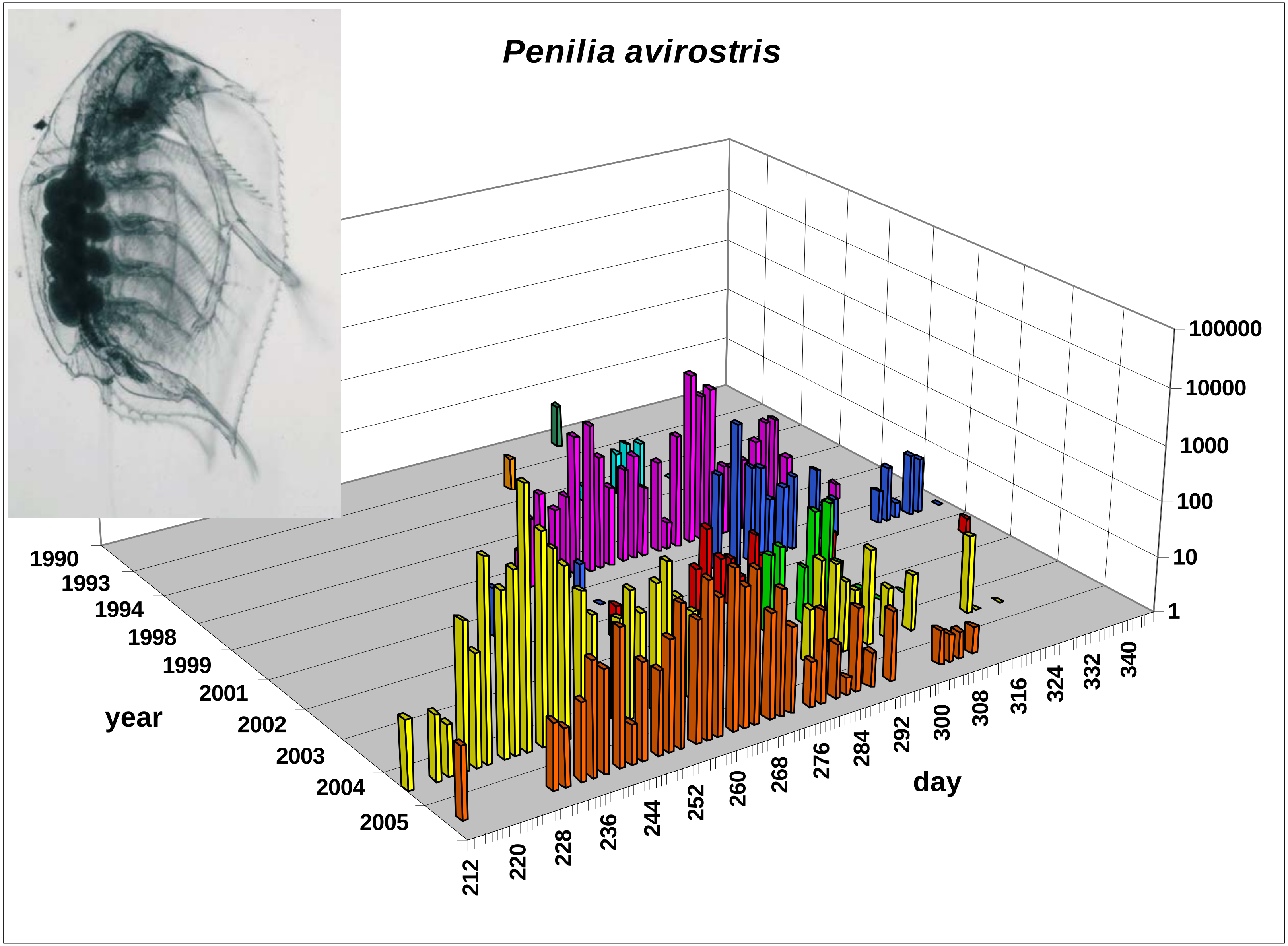
C: Consequences for marine research

Definition: determining the lateral displacement of zooplankton populations

Methods: observation of regional taxonomic biodiversity,
investigation of the origin of neozoa

Results: Besides populations which are imported by human activities (ballast water, aquaculture, aquarists) some populations immigrate such as *Doliolum nationalis, Muggiaea atlantica* and *Penilia avirostris* which were determined as neozoa of the North Sea. These species thus expanded their lateral distribution northwards.


Penilia avirostris
100000
10000
1000
100
10
1
1990
1993
1994
1998
1999
2001
2002
2003
2004
2005
year
212
220
228
236
244
252
260
268
276
284
292
300
308
316
324
332
340
day

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Summary of results and consequences

Zooplankton (holo- and merozooplankton) - dynamics are temperature controlled

Local abundance dynamics can be time-shifted inter-annually in the order of the length of the population's season

Climate change is confirmed by zooplankton dynamics

Zooplankton populations respond to temperature change species specific with regard to their:

- phenology
- seasonality
- distribution

Inter-annual comparisons have to take such responses into account

Global warming is a „natural experiment“ which can help to reveal the species specific Interactions in the marine ecosystem especially match/mismatch based secondary effects

Weekly observations are the baseline for measuring and understanding such changes

Thank you!

questions to wgreve@meeresforschung.de