Assessment of long-term field observations of invasive ctenophores interactions in the Black Sea

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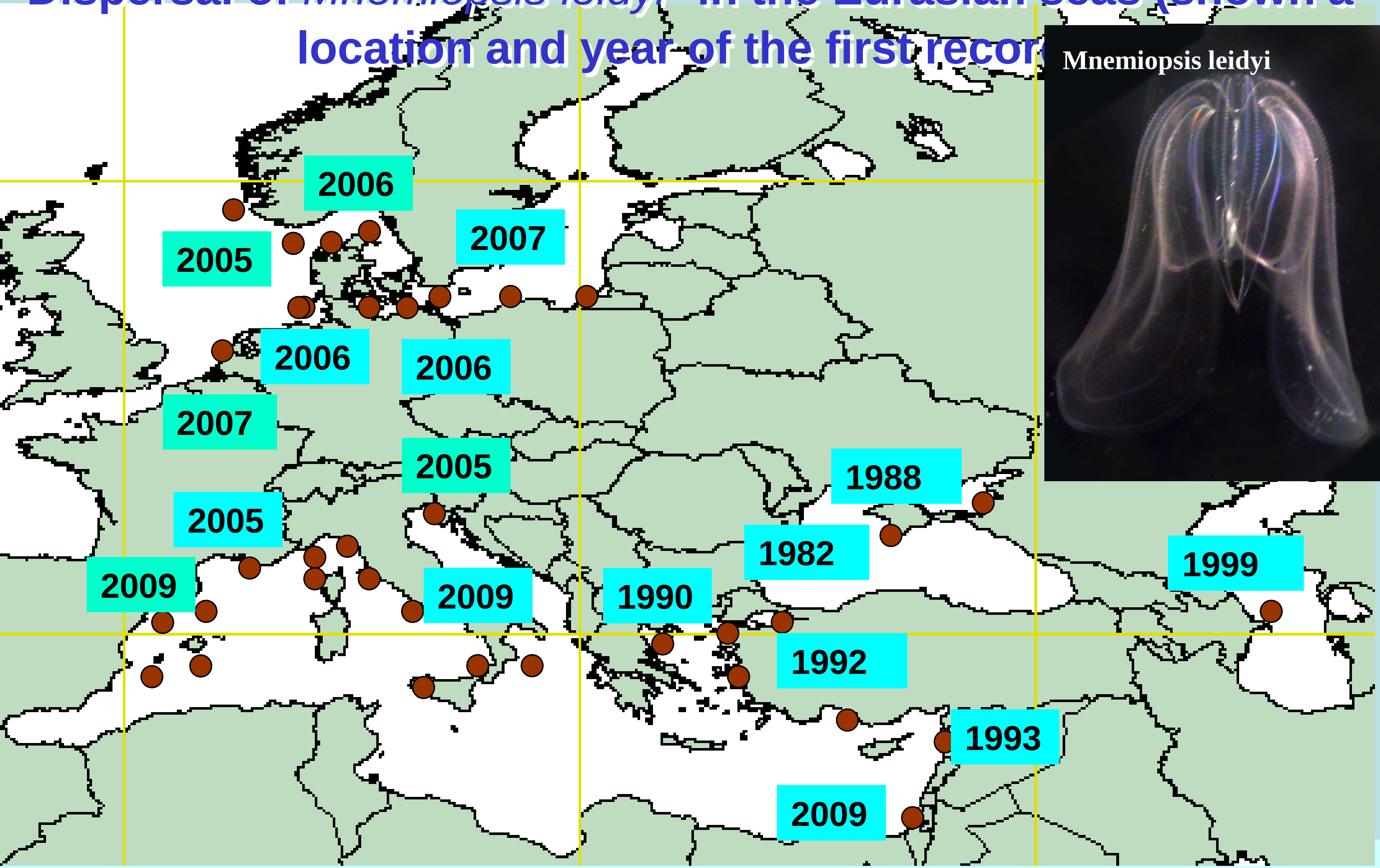
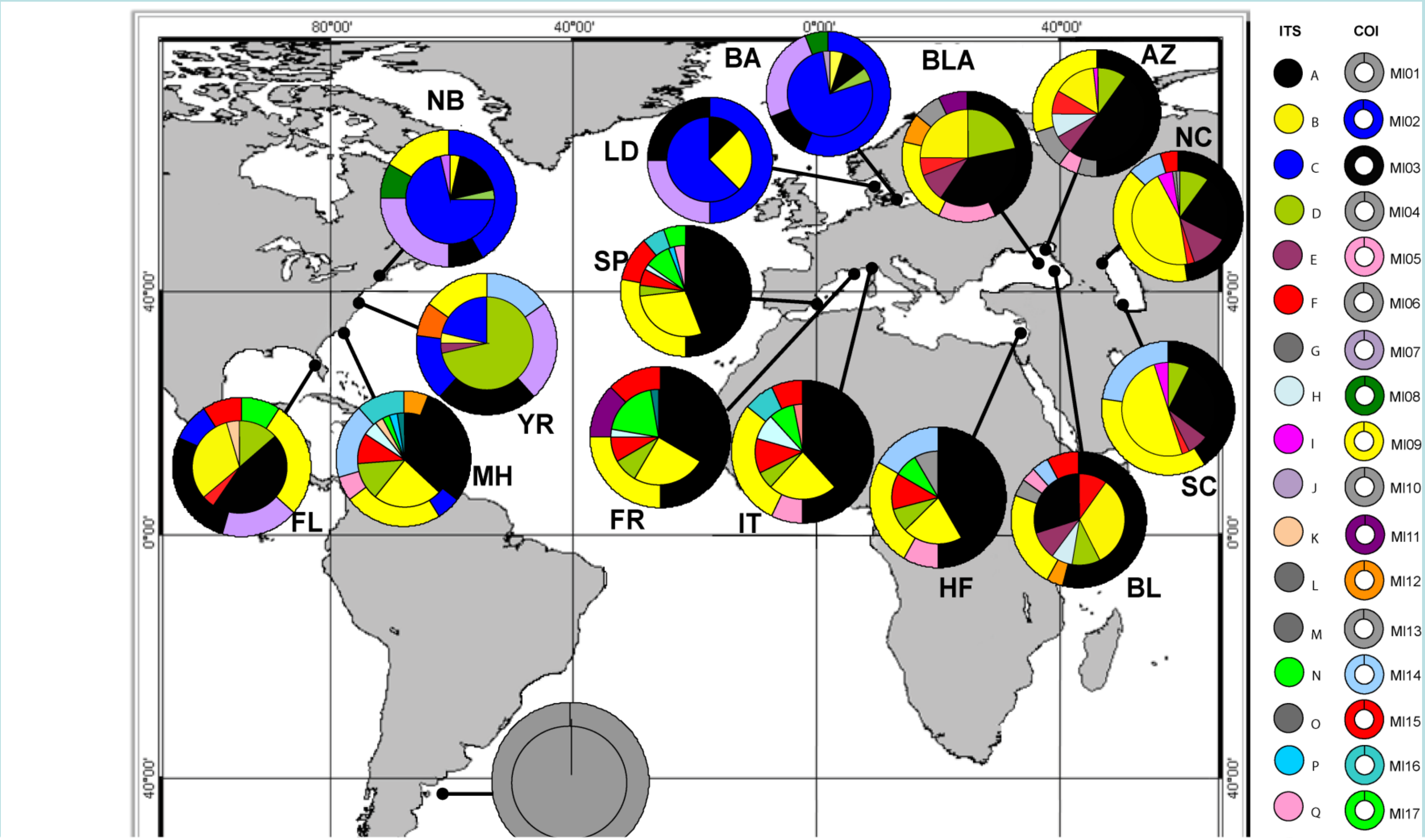
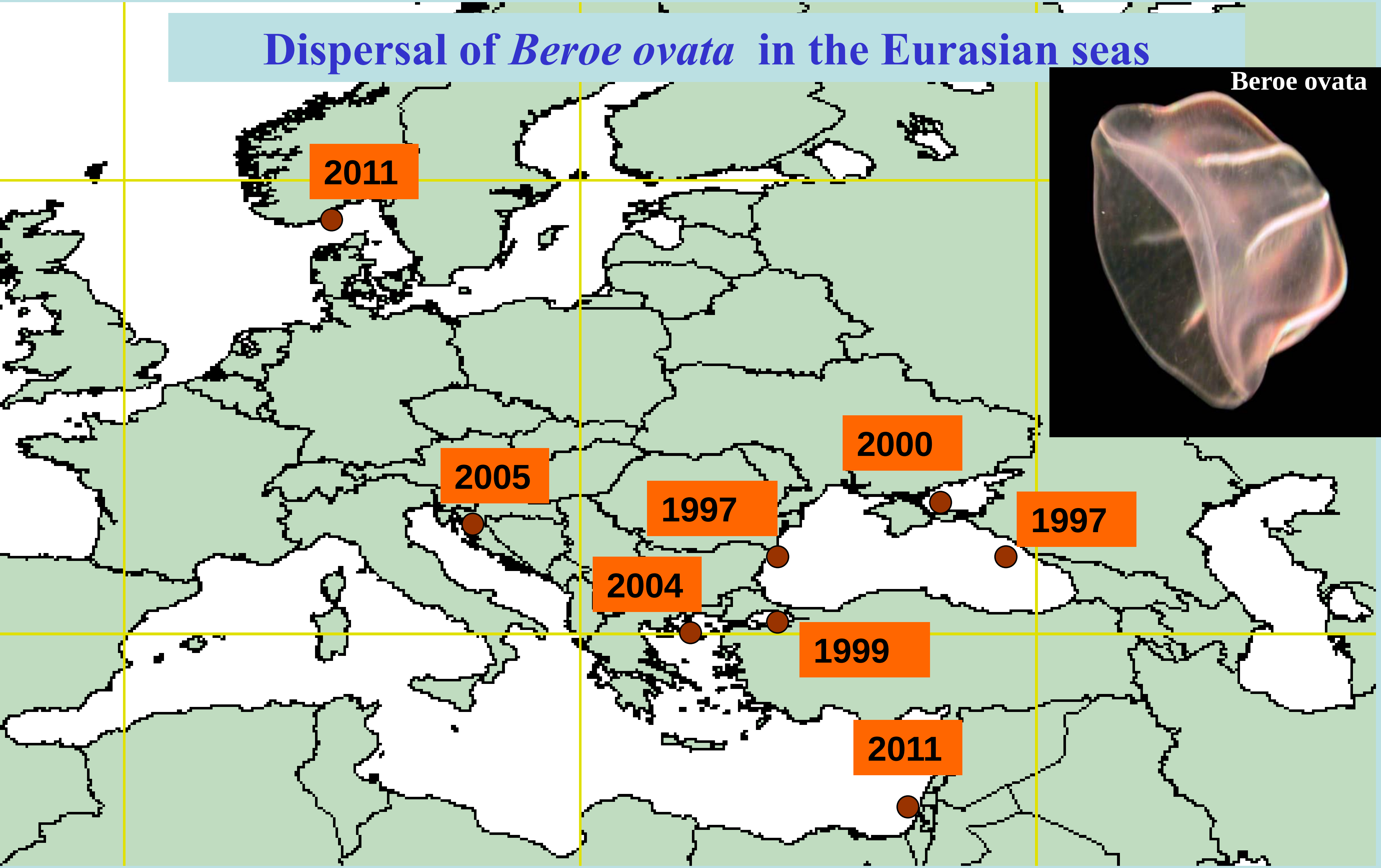
Dispersal of *Mnemiopsis leidyi* in the Eurasian seas (shown a location and year of the first recor





Population genetic analyses supported its invasion from the Gulf of Mexico (e.g., Tampa Bay) into the Black Sea, then secondary into the Azov, Caspian seas and the eastern and western Mediterranean (Ghaboolii, Shiganova et al., 2011; in press PLOS ONE)

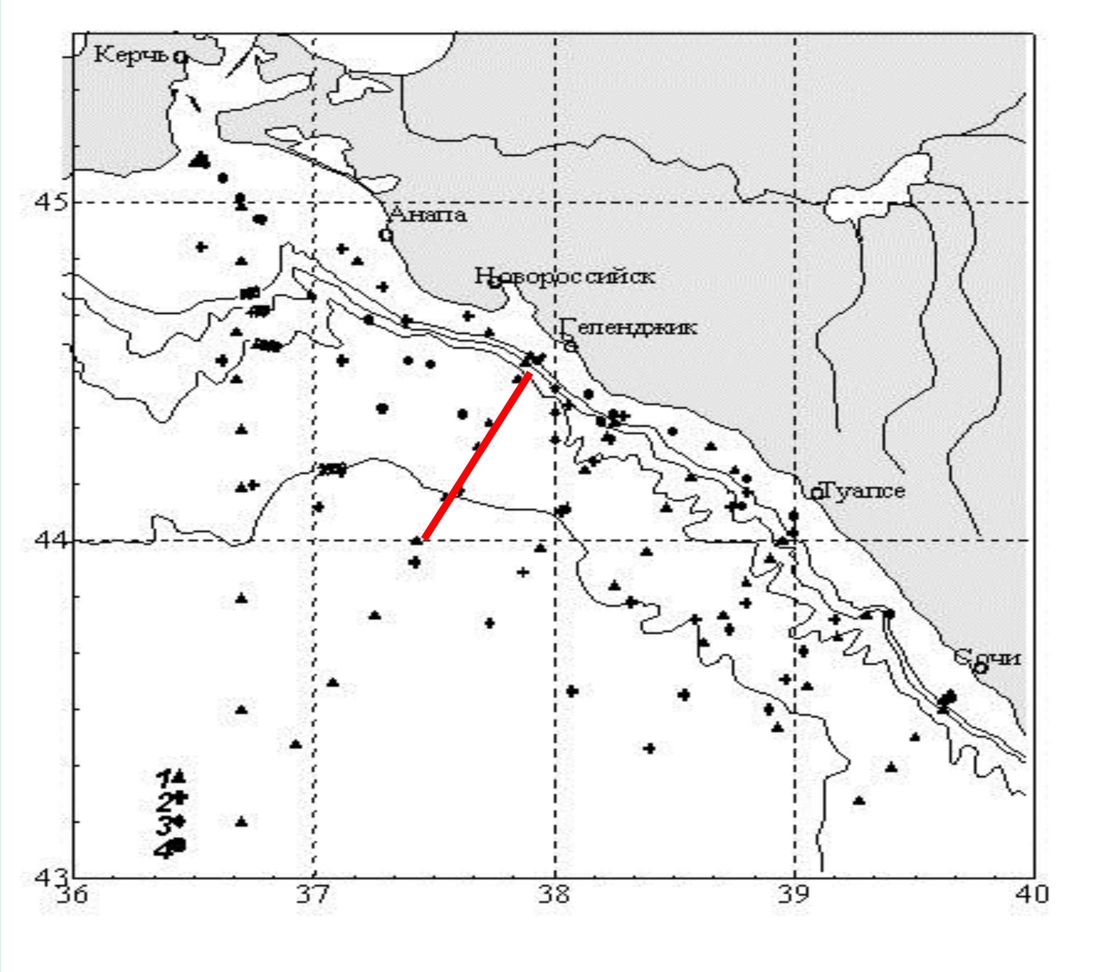
Dispersal of *Beroe ovata* in the Eurasian seas

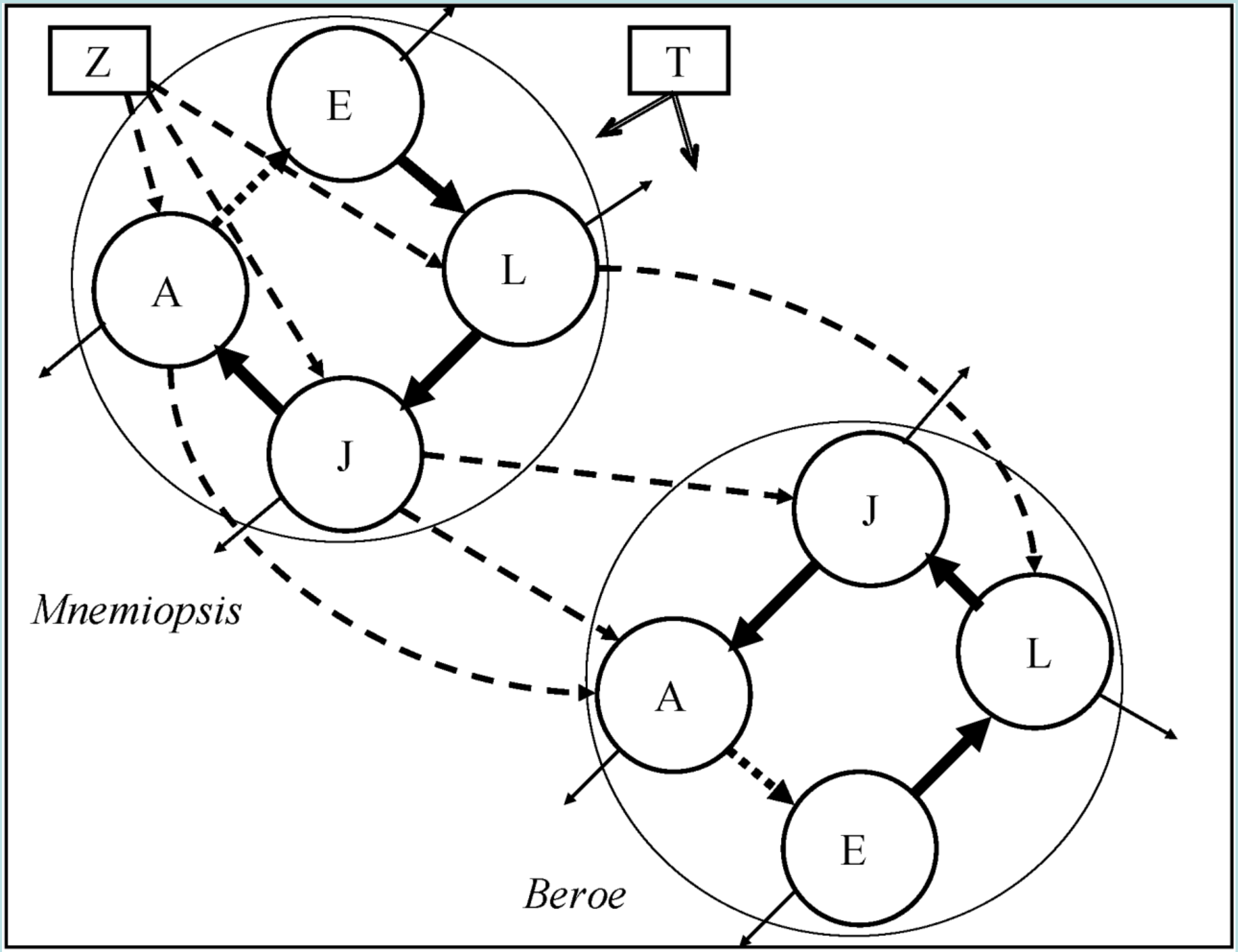


❖Data:

Long term field data on mesozooplankton and ctenophores in the northeastern Black Sea for >25 years

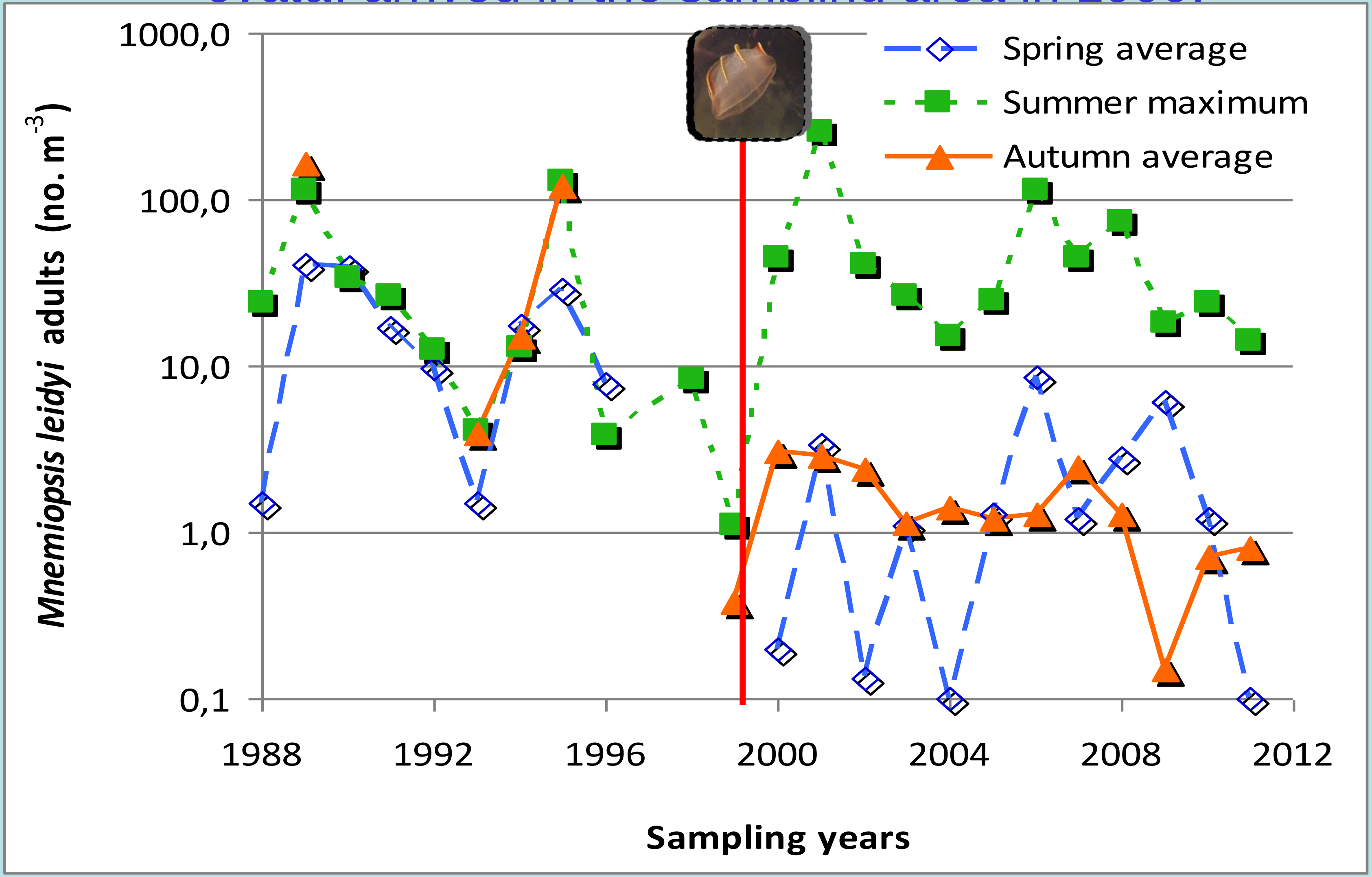
Experimental data on ecophysiology on *M.leidyi* and *B.ovata*



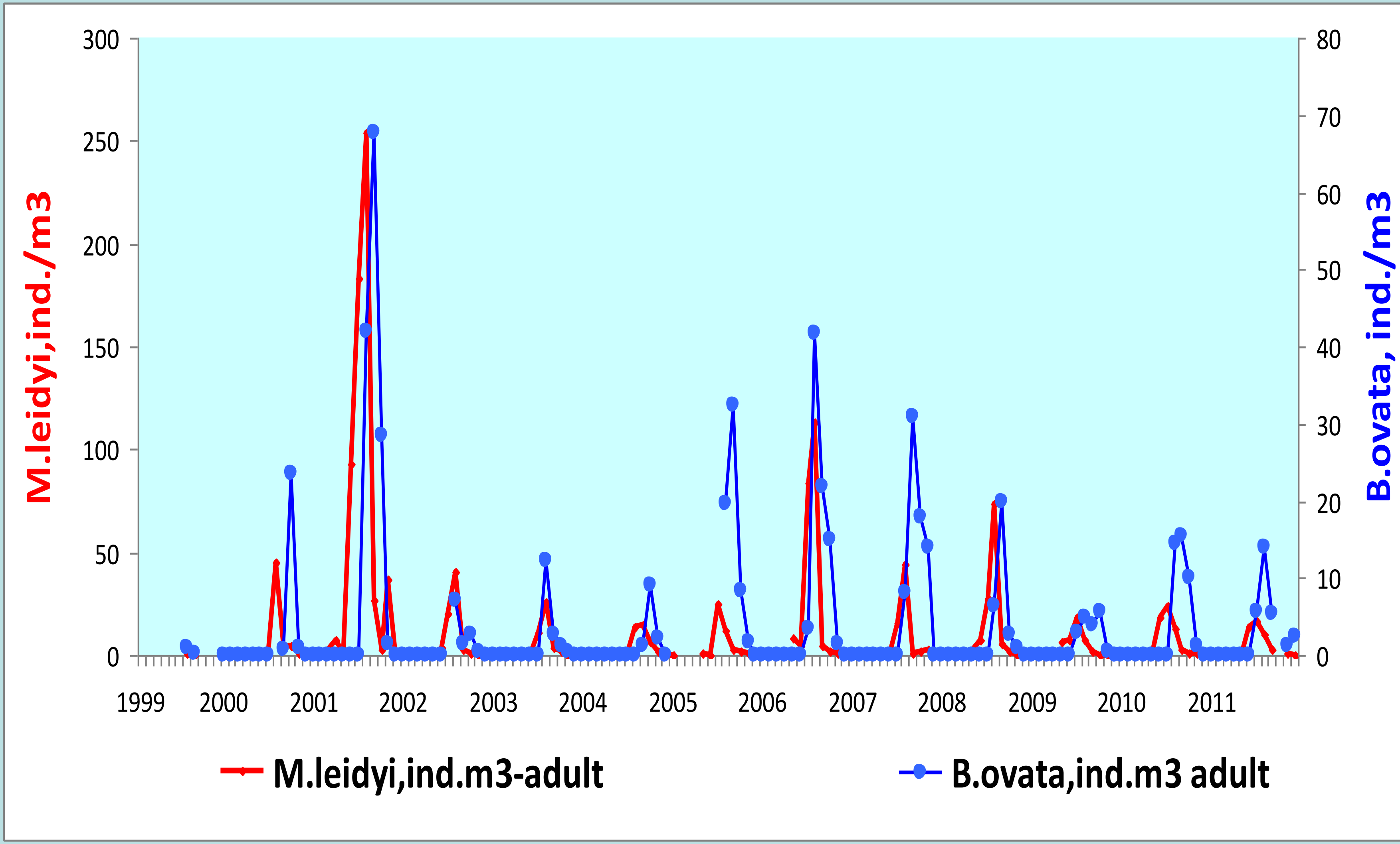


The *B. ovata-M. leidyi* predator-prey system. Stages of *M. leidyi* feed on zooplankton (dashed arrows from Z to *M. leidyi*), and stages of *B. ovata* feed on *M. leidyi* (dashed arrows from *M. leidyi* to *B. ovata*). Feeding largely determines the number of individuals transferred from one stage to the next (thick solid arrows), and also egg production (dotted arrows). In each stage, mortality (thin solid arrows) causes a decrease in number of individuals. T: temperature.

Abundances of *M. leidyi* in northeastern Black Sea in three seasons. Spring: average of values from March and April; summer: annual peak value; autumn: average of values from September to November. The predator of *M. leidyi*, *B. ovata*, arrived in the sampling area in 1999.



Interannual variation of *M.leidyi* and *B.ovata* in the Black Sea



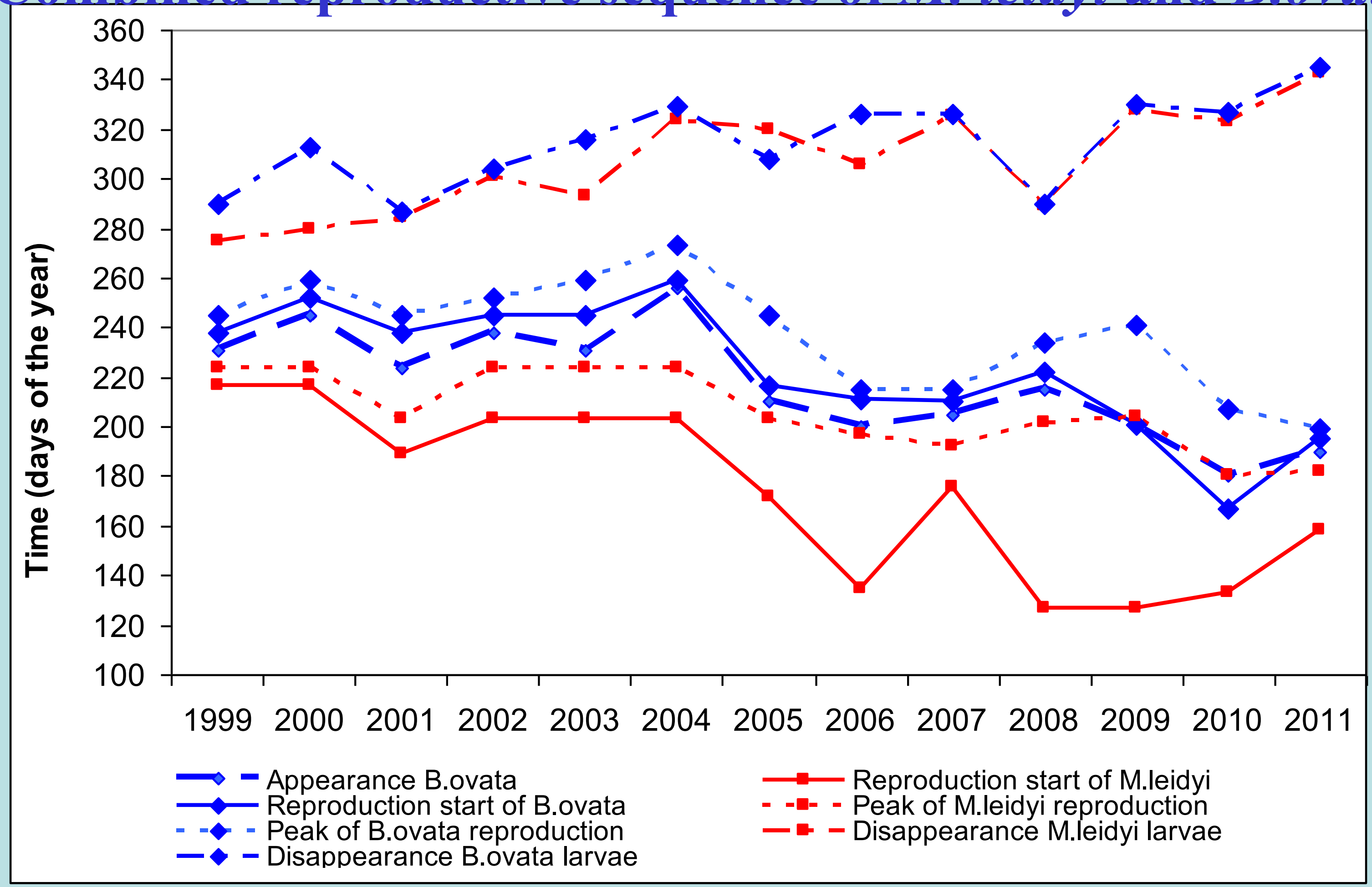
ASSUMPTIONS:

1. Since *B. ovata* arrived in the Black Sea, its population dynamics has controlled, year after year, by *M. leidyi* population since it is present in sizable numbers. However, *B. ovata* and *M. leidyi* continue to co-exist year round, the latter in small numbers until the spring increase in water temperature, and showing some years high reproductive populations until the seasonal development of *B. ovata.*

2. The same sequence of predator-prey mechanisms led *B. ovata* to take control of *M. leidyi* year after year, irrespective of interannual environmental variability.

3. Experimental and field results identified temperature and food as the key environmental factors influencing *M. leidyi*, and model analysis indicated that interannual environmental variations that affect *M. leidyi* abundance cascade to proportional changes in *B. ovata* abundance (i.e. environmental conditions determined the joint abundances of the two species)

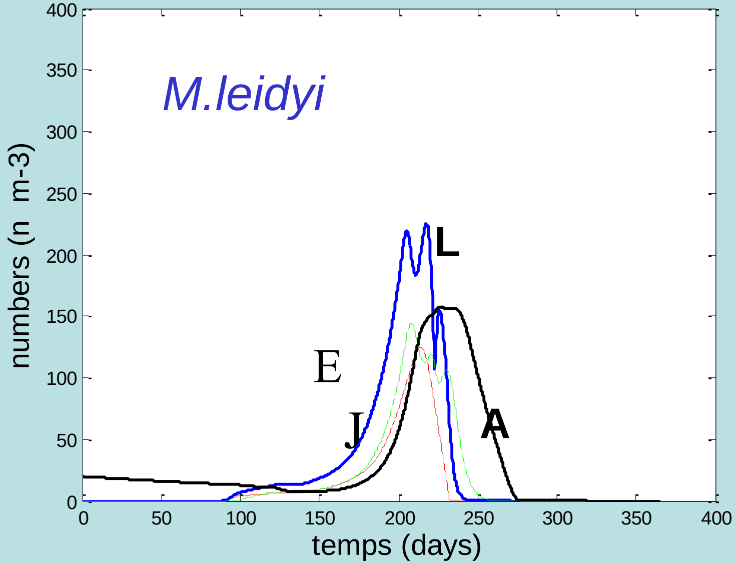
Combined reproductive sequence of *M. leidyi* and *B.ovata*

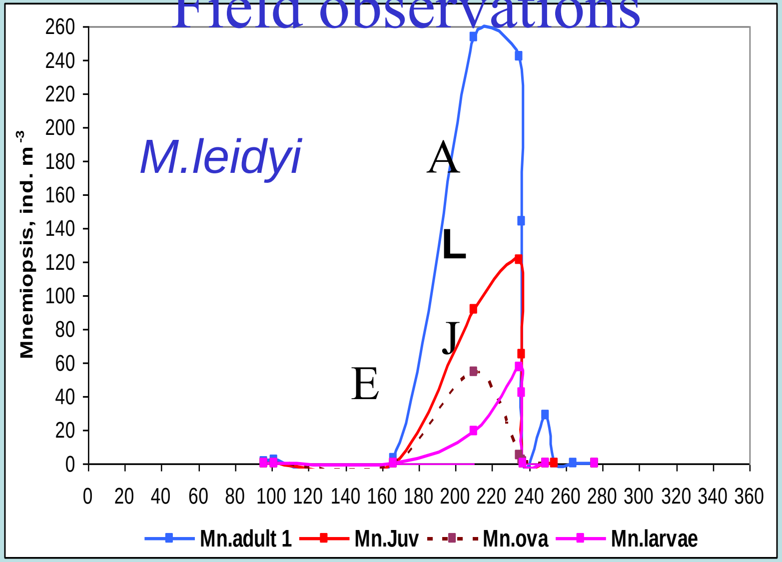


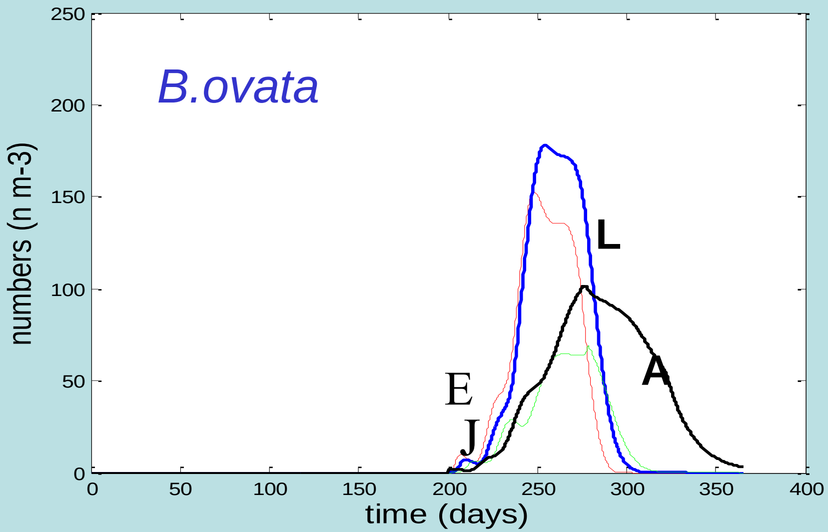
The reproductive sequence comprised 7 steps: (i) adult *M. leidyi* started to reproduce, (ii) reproduction of *M. leidyi* reached its annual peak value, (iii) adult *B. ovata* appeared in the sampling area, (iv) adult *B. ovata* started to reproduce, (v) reproduction of *B. ovata* reached its annual peak value, (vi) *M. leidyi* larvae disappeared from the sampling area, (vii) *B. ovata* larvae disappeared from the sampling area

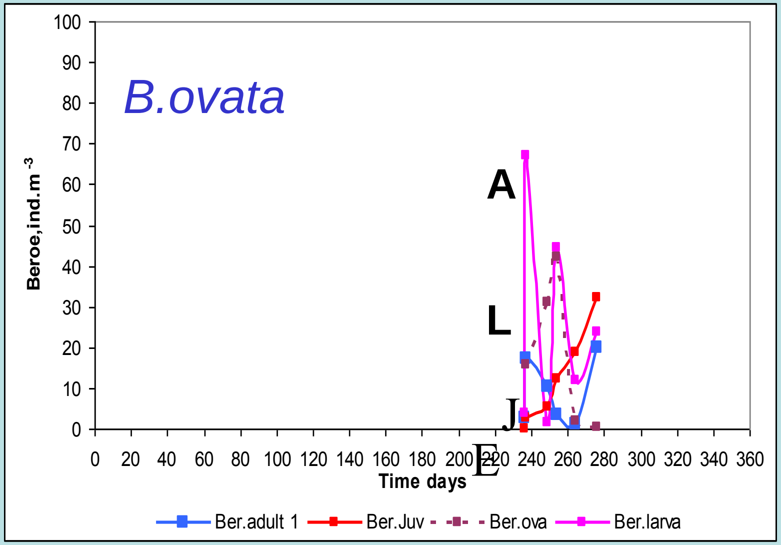
Model

Field observations



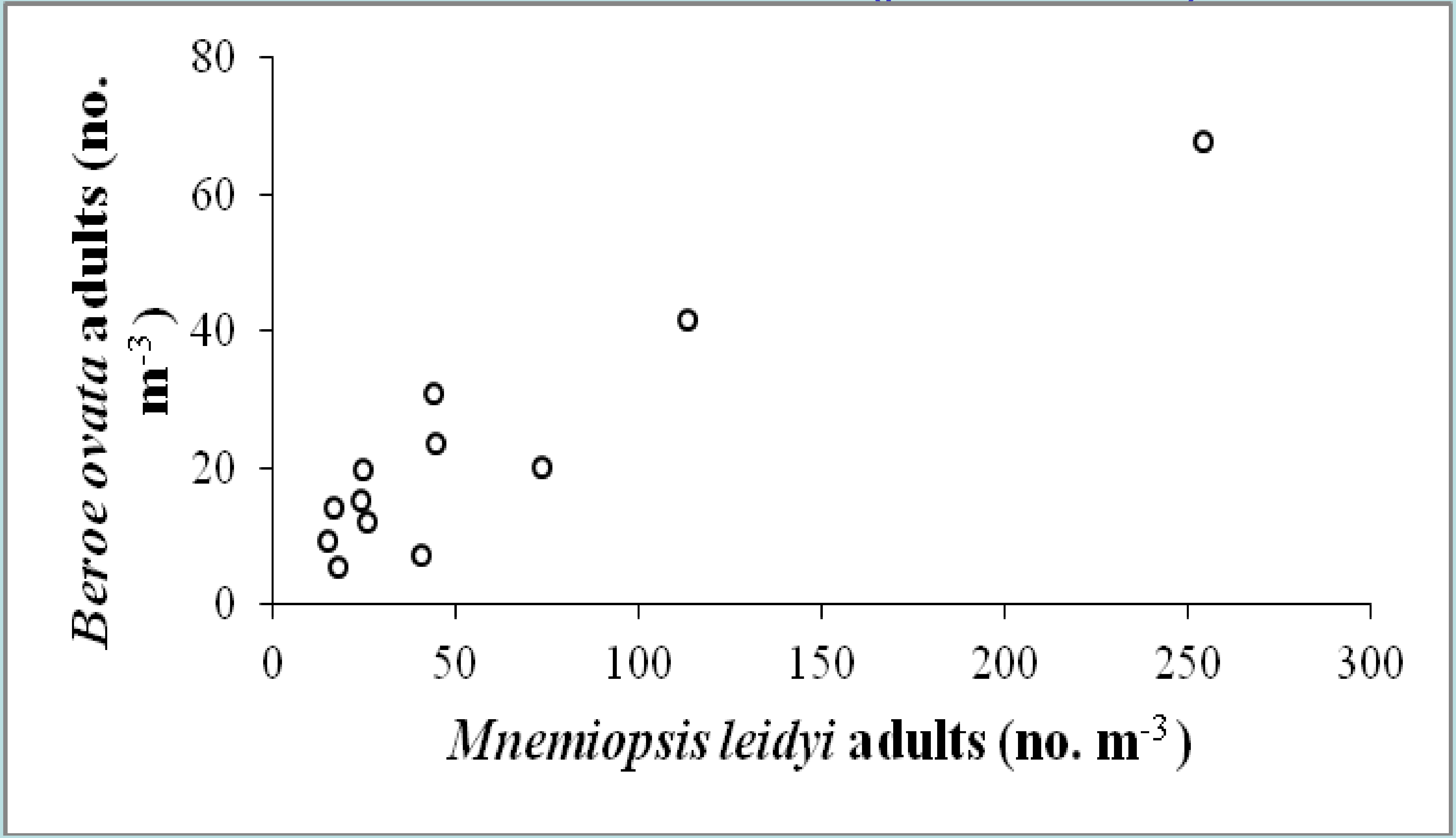




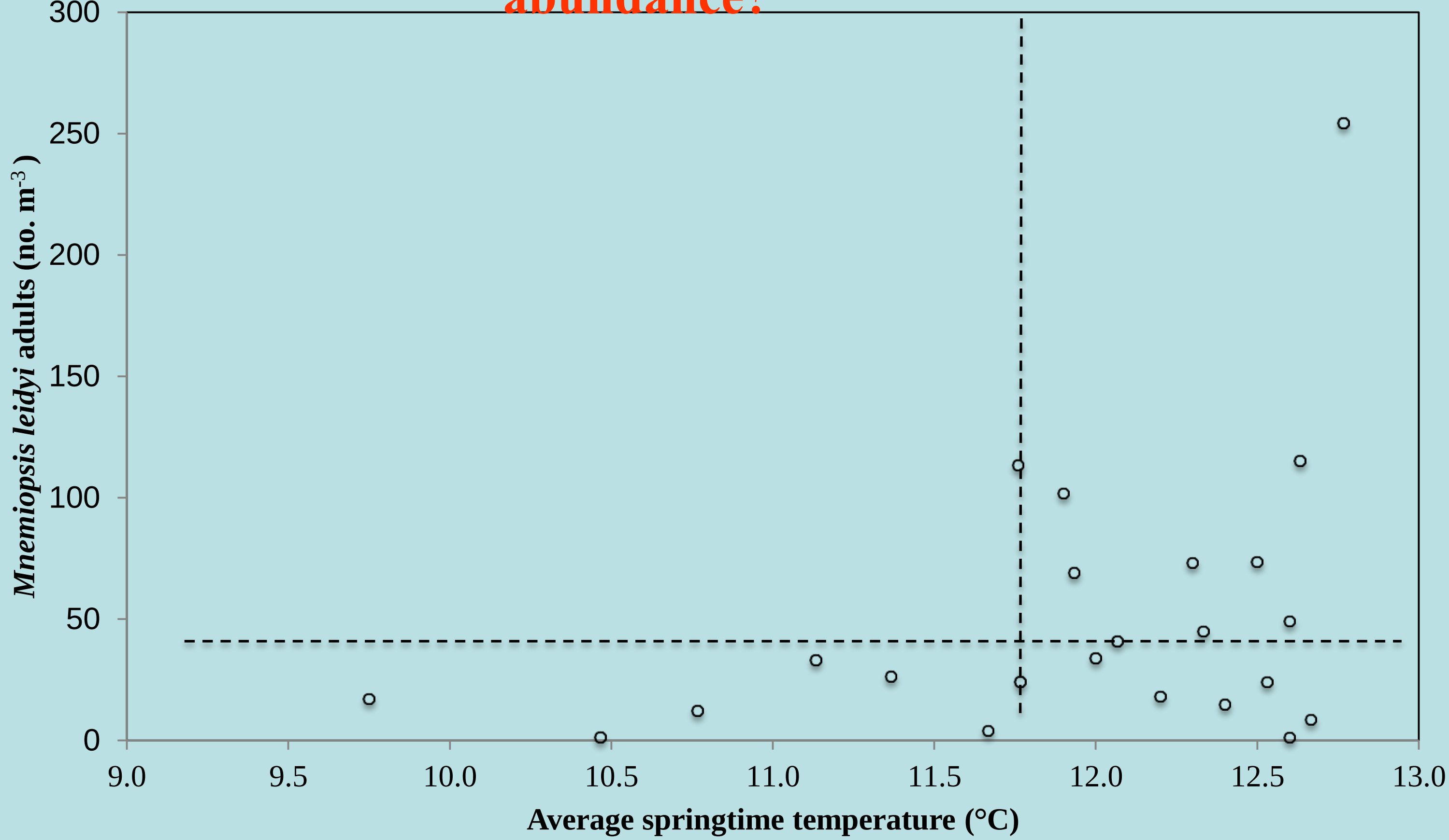


Phenology of two species

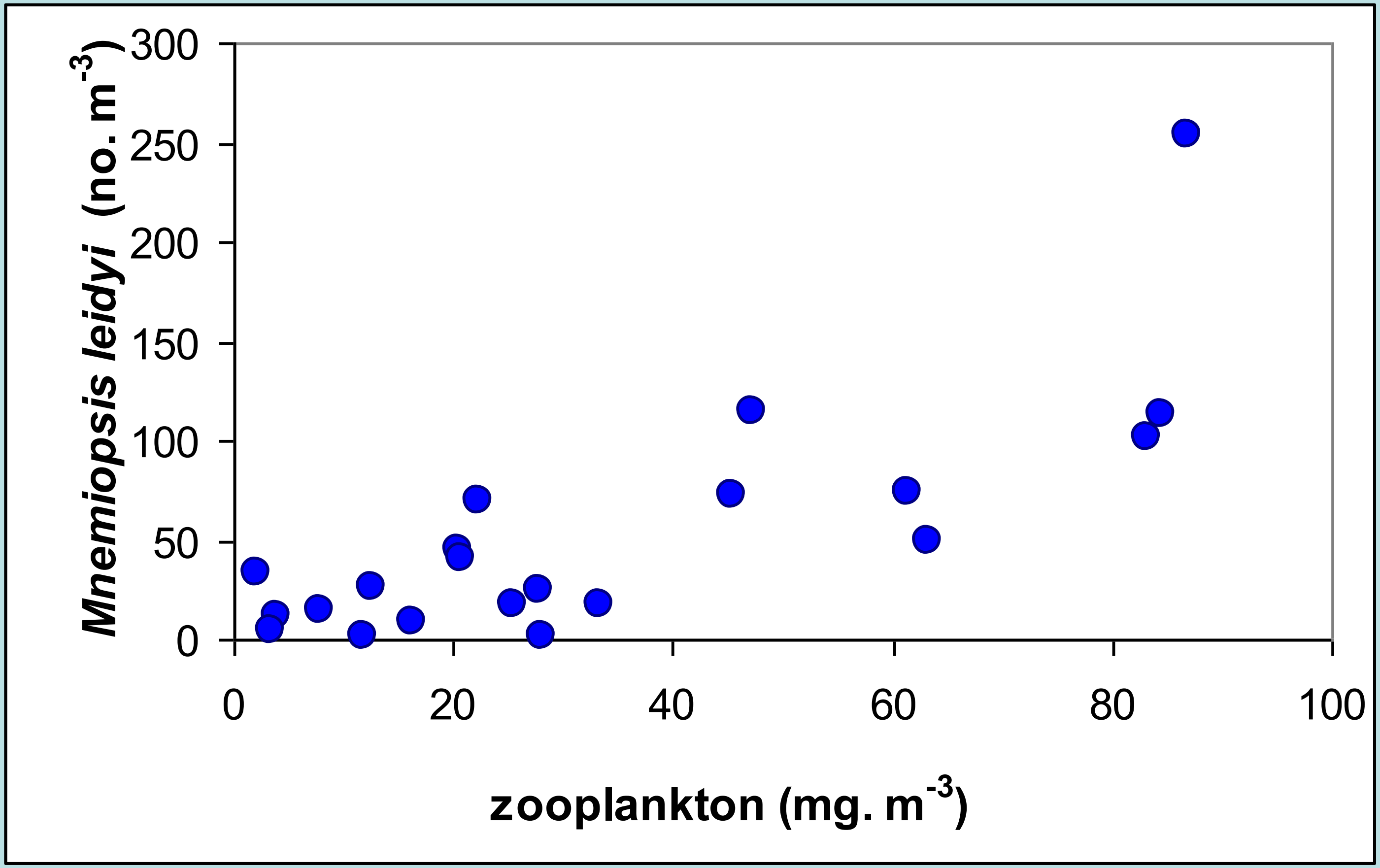
Maximum annual number of adult *B. ovata* plotted as a function of maximum annual number of adult *M. leidyi* from 1999 to 2011. The coefficient of linear correlation between the two variables is r = 0.93 (prob. < 0,001)



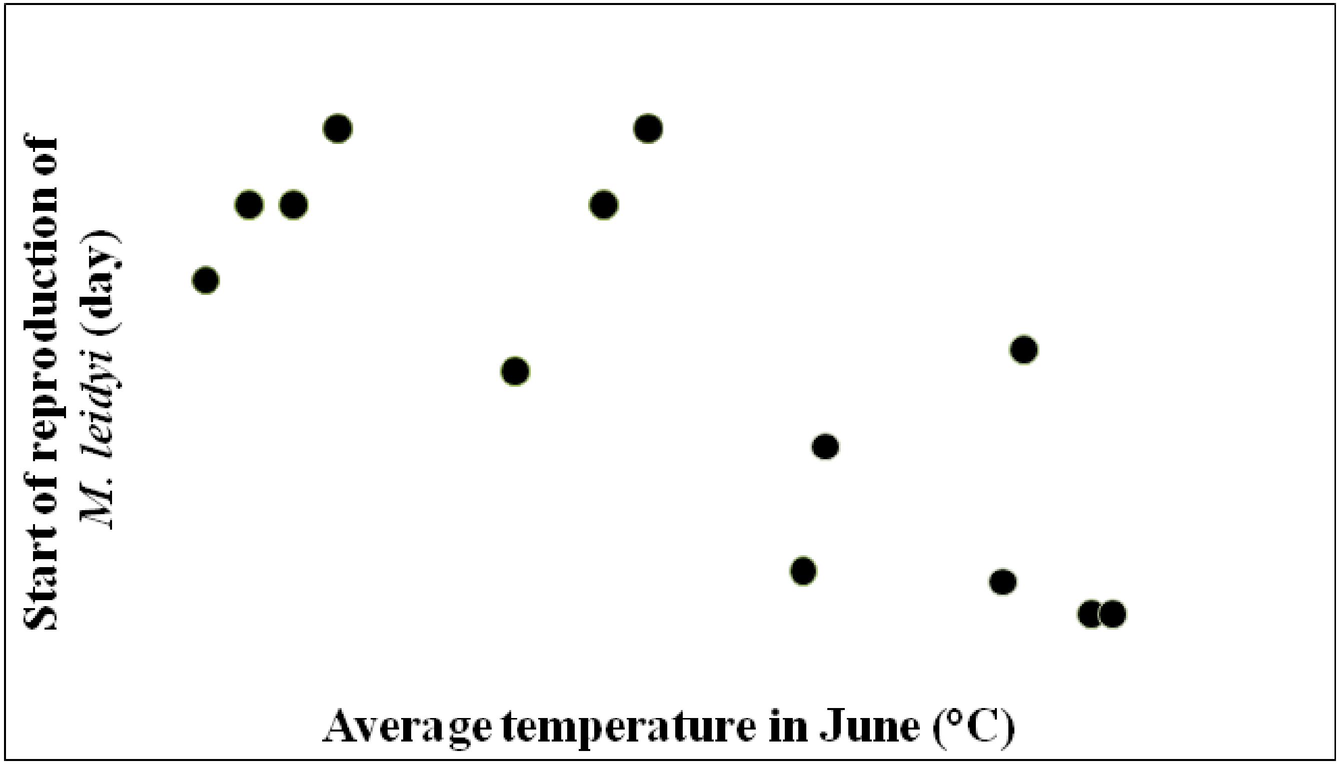
Which factors determine *M.leidyi* seasonal development and abundance?



Maximum annual abundance of *M. leidyi* plotted as a function of springtime temperature (average of March to May). The vertical dotted line delineates temperatures <11.8 and ≥11.8°C, and the horizontal dotted line, abundances ≤33 and >33 ind m^{-3}. The corresponding 2 x 2 contingency table has Wilks' $X2 = 9.77$ (prob < 0.01).

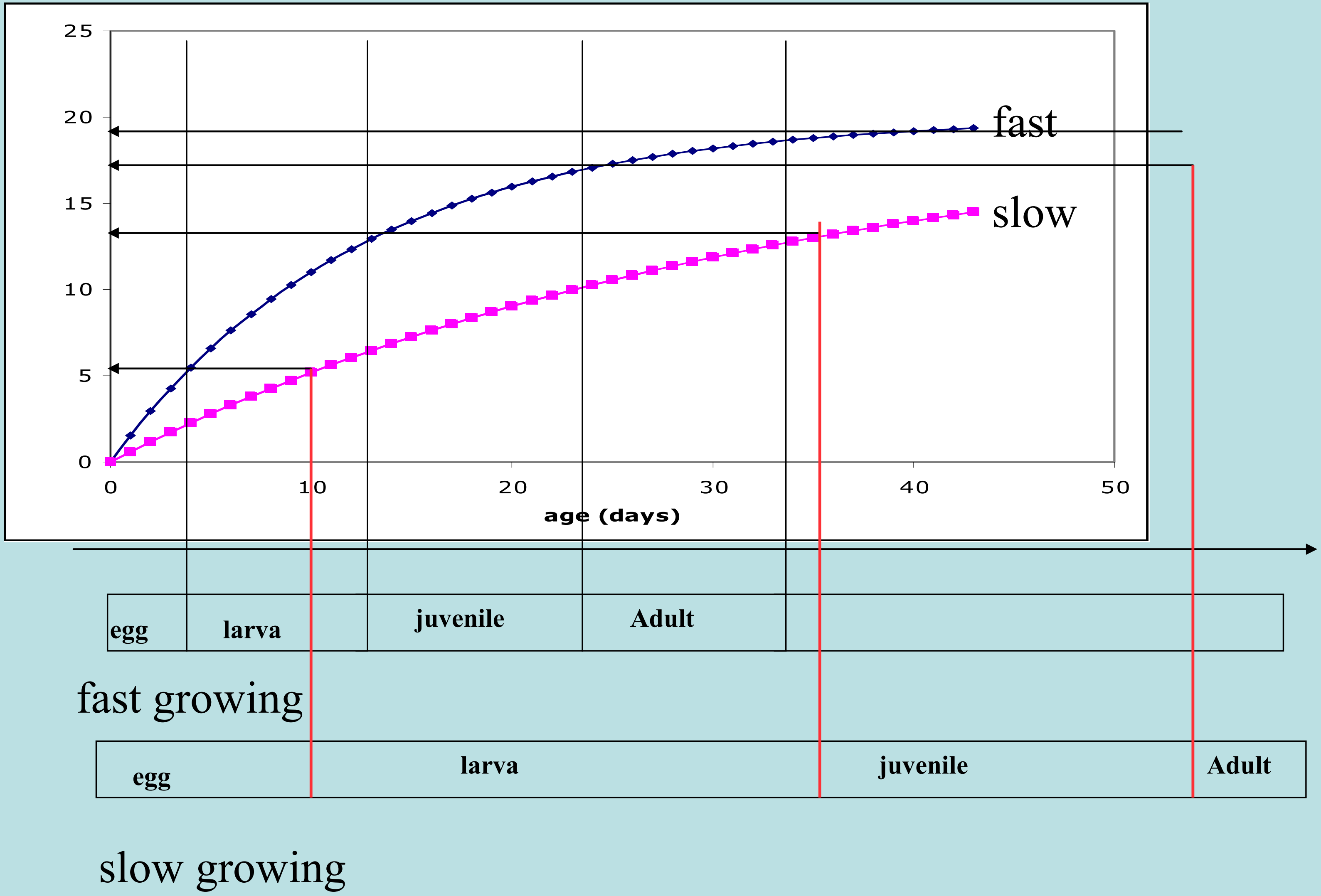


Maximum annual abundance of *M. leidyi* plotted as a function of summer zooplankton biomass (wet weight; average of values in June and July, i.e. before the seasonal development of *B. ovata*). The coefficient of linear correlation between the two variables is $r = 0.79$ (prob. < 0.001) with or without the inclusion of the point corresponding to the highest *M. leidyi* abundance in 2001

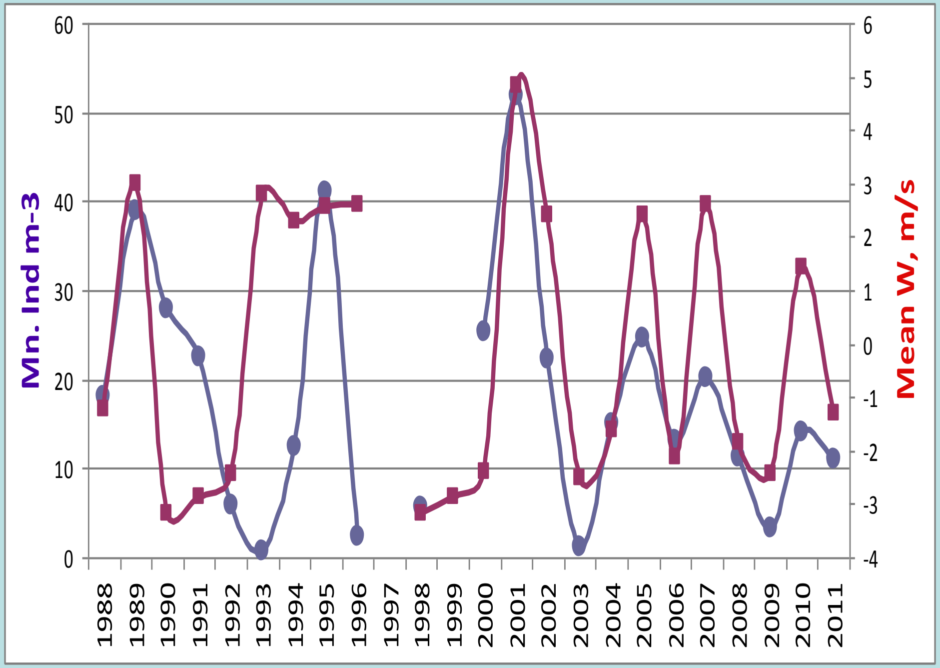


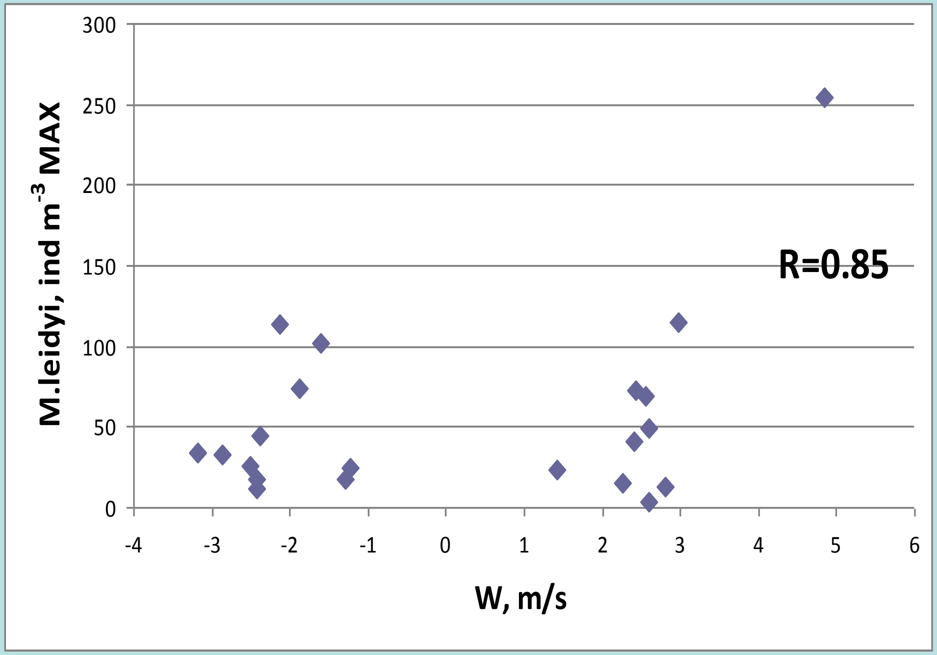
Starting date of reproduction of *M. leidyi* plotted as a function of average temperature in the surface layer in June from 1999 to 2011. The coefficient of linear correlation between the two variables is r = - 0.78 (prob. < 0.01).

Change in stage duration depending on physiology (food, temperature)



Co-variation between the mean concentration of *M. leidyi* during the month and the mean wind speed





Mean concentration of *M. leidyi* during the month when its maximum abundance >30 ind. m-3 was associated with high positive winds, that were favouring strong transport toward the coast. Finally, two opposite situations occurred on two extreme years, i.e. 2001 and 2003. In 2001 the highest *M. leidyi* concentration for the whole time series corresponded to the largest positive wind, i.e. favouring the strongest transport toward the coast, whereas in 2003, one of the lowest *M. leidyi* concentrations corresponded to one of the largest negative winds, i.e. favouring strong transport

Conclusion

- 1 Since the arrival of *B. ovata*, its population dynamics has controlled, year after year, when *M. leidyi* was present in sizable numbers.
- Before the arrival of *B. ovata*, the abundance of *M. leidyi* was generally >5 ind. m^{-3} from spring through autumn (and perhaps also winter), whereas after the arrival of *B.ovata*, occurrence of *M. leidyi* was generally restricted to two or three summer months depending on the starting time of *B. ovata* seasonal development.

2 *B. ovata* and *M. leidyi* continued to co-exist year round the same sequence of predator-prey mechanisms led *B. ovata* to take control of *M. leidyi* year after year, irrespective of the interannual environmental variability. field observations, year after year since 1999, have shown of the same combined reproductive sequence for *M. leidyi* and *B. ovata* that comprised 7 steps.

The minimum and maximum duration of the reproductive sequence varied from year to year, but the sequence itself (i.e. the order of events) remained unchanged over the 13-year period. Repetition of the same 7-step sequence over 13 years is a remarkable characteristic of the *B. ovata - M. leidyi* predator-prey relationship

3. Because there were strong interannual variations in the abundances of both *M. leidyi* and *B. ovata*, environmental conditions mainly wind direction and its velocity determine the joint abundances of the two species. Simultaneously there was strong covariability between the numbers of *M. leidyi* and *B. ovata* every year after the arrival with a significant positive relationship between the maximum yearly numbers of the two species during the period 2000-2011

Acknowledgement

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Thank you for attention