Zooplankton in Warming and more Oligotrophic Coastal Sea: the Northern Adriatic Case

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Northern Adriatic characteristics

- shallow (<60m) northernmost area of the Mediterranean Sea (**Fig. 1**),
- variable/extreme hydrographic conditions due to the geographic location and shallowness,
- high river inputs (Po river being the largest, 50km^{3}y^{-1}) from the western shore are the major external nutrient sources
- generally cyclonic circulation pattern brings oligotrophic waters of southern origin along the eastern part of the NA
- these hydrographic conditions create a marked east-west trophic gradient (**Fig. 1**)

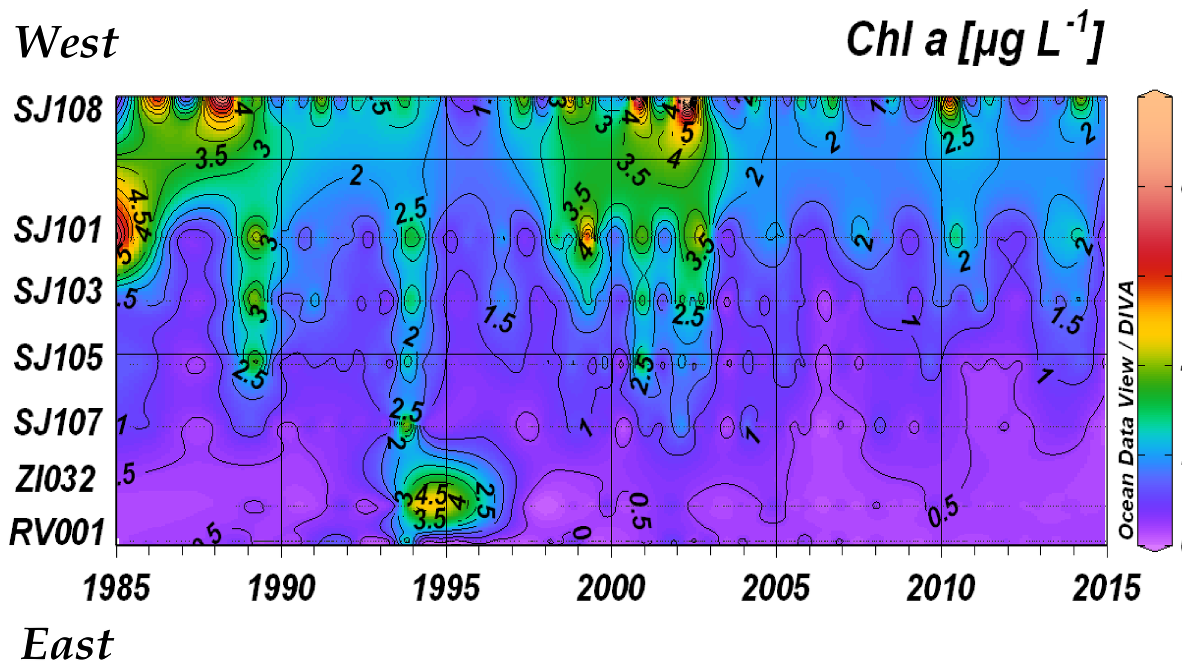


Fig. 1.Variations in Chlorophyll *a* biomass along northern Adriatic transect indicate an oligotrophication trend from west (top) to east (bottom) with decreasing biomass after 2000 (Brush et al. 2020)

Material and methods

- zooplankton sampled by vertical tows from near bottom to the surface using the WP2 net (200 µm mesh) at four stations (**Fig. 1**),
- dry mass (DM, 60 ^{0}C), ash-free DM (500 ^{0}C), the taxonomic composition from preserved samples,
- mean SST differences between 2006-2016 and 1991-2001 were computed using gap-filled gridded L4 satellite measurements (http://marine.copernicus.eu/) SST_MED_SST_L4_REP_OBSERVATIONS_010_021_a Dataset; SST difference arithmetic difference between time-averaged SST maps over the two periods
- MHW (MCS) events:
climatological SST distribution for each day of the year was assembled from Raicich & Colucci (2019) time series,

For each day of year maximum, mean, 10th percentile and 90th percentile values were computed,

A single MHW event was counted to occur for each consecutive 5-day period during which the minimum SST never dropped below the climatologically assessed 90th percentile for the days of year. A continuous 10-day period above the 90th percentile has thus been counted as two consecutive MHWs.

Similarly, a single MCS event was counted to occur for each consecutive 5-day period during which the maximum SST never rose above the climatologically assessed 10th percentile for the days of year in question.

Warming of the northern Adriatic

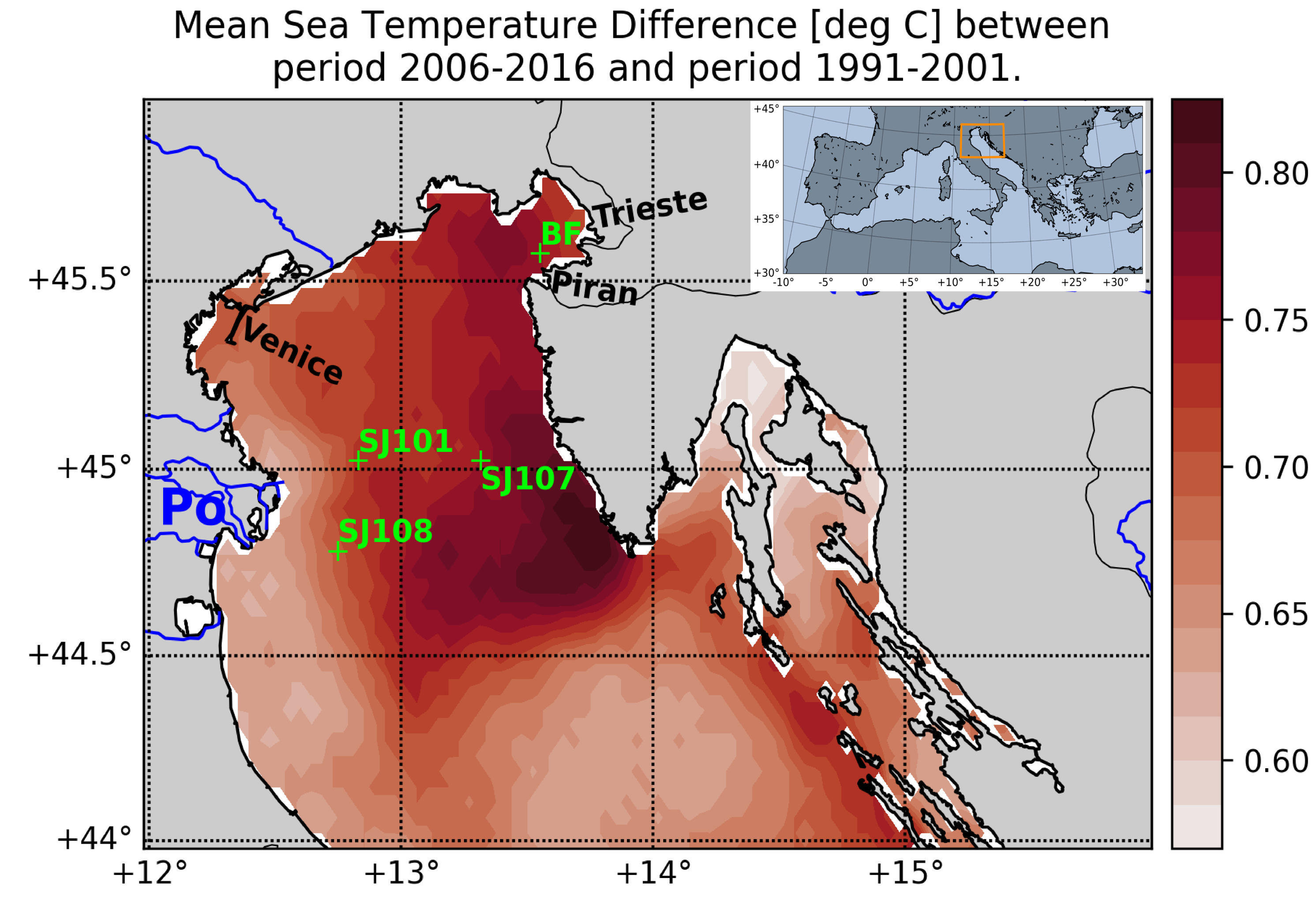
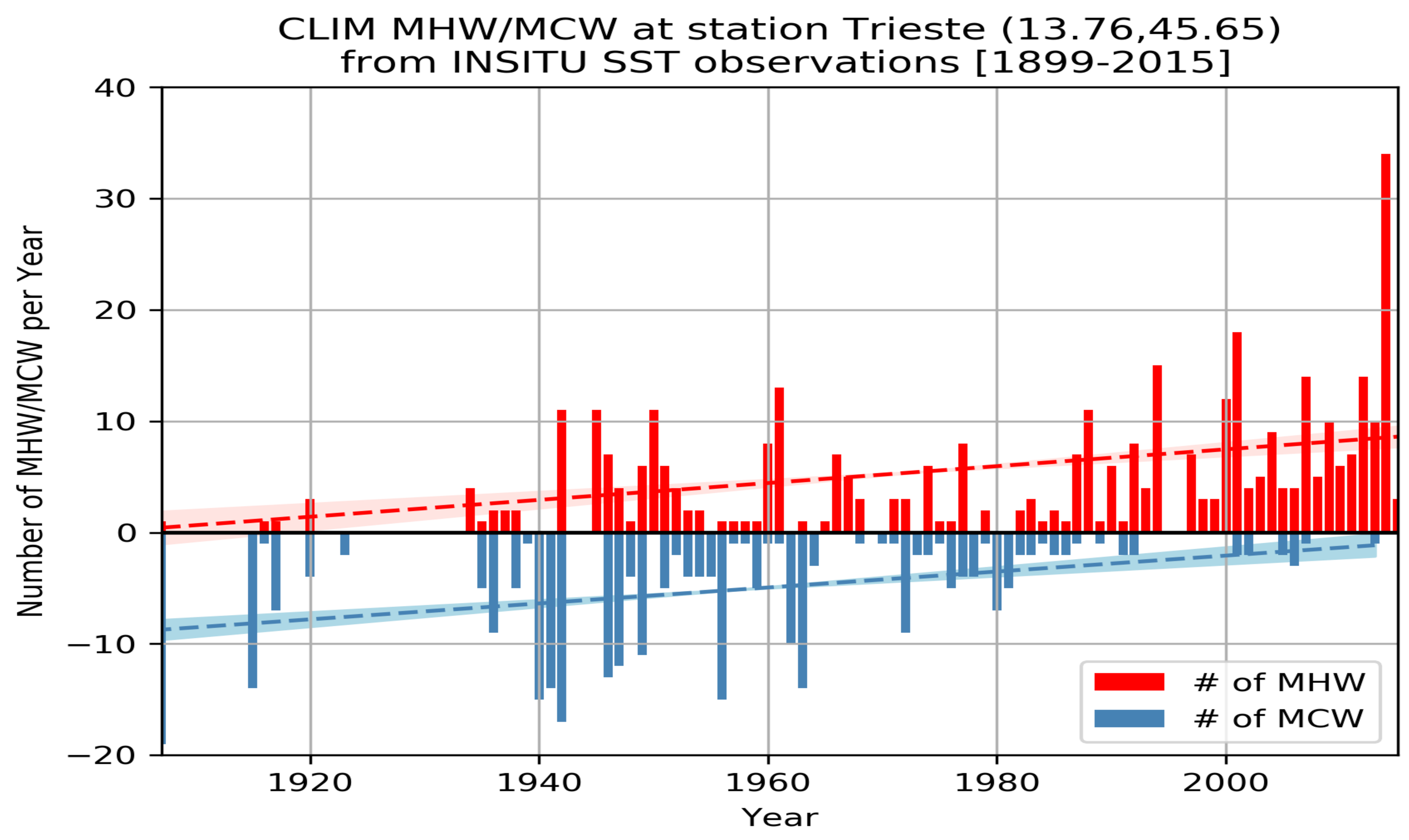


Fig. 2. Studied area within the Mediterranean Sea, zooplankton sampling stations and the mean SST anomalies (^{0}C) for the 2006-2016 relative to 1991-2001 assessed from satellite data



- a mean temperature rise of 1.1±0.3 ^{0}C per century was estimated from a time series (1899 – 2015) of sea surface temperature (SST) in measured in Trieste harbour (Raicich & Colucci, 2019)
- superimposed onto long-term warming trend are increasing number of marine heatwaves (MHW – short-term extreme warming events) and a reduced number of marine cold spells (MCS), **Fig. 3**

Phytoplankton and zooplankton biomass

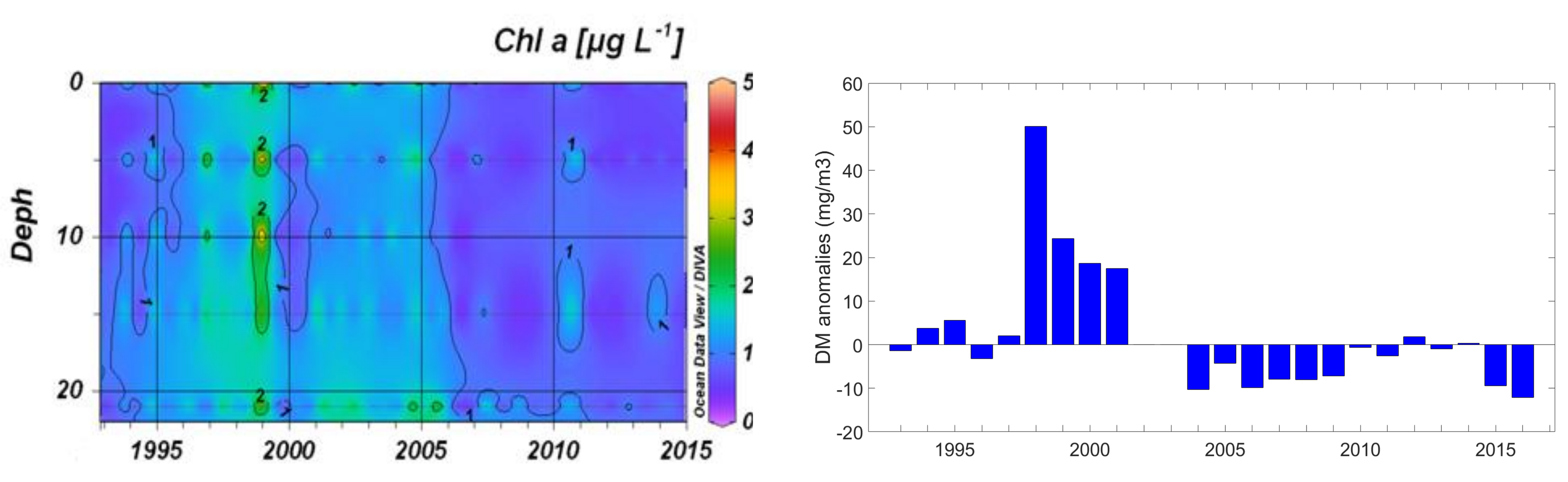


Fig. 4. Interannual variations in Chlorophyll *a* (left) and zooplankton dry mass anomalies (right): Decrease in phytoplankton biomass after 2000s propagated up food-web

Zooplankton abundance

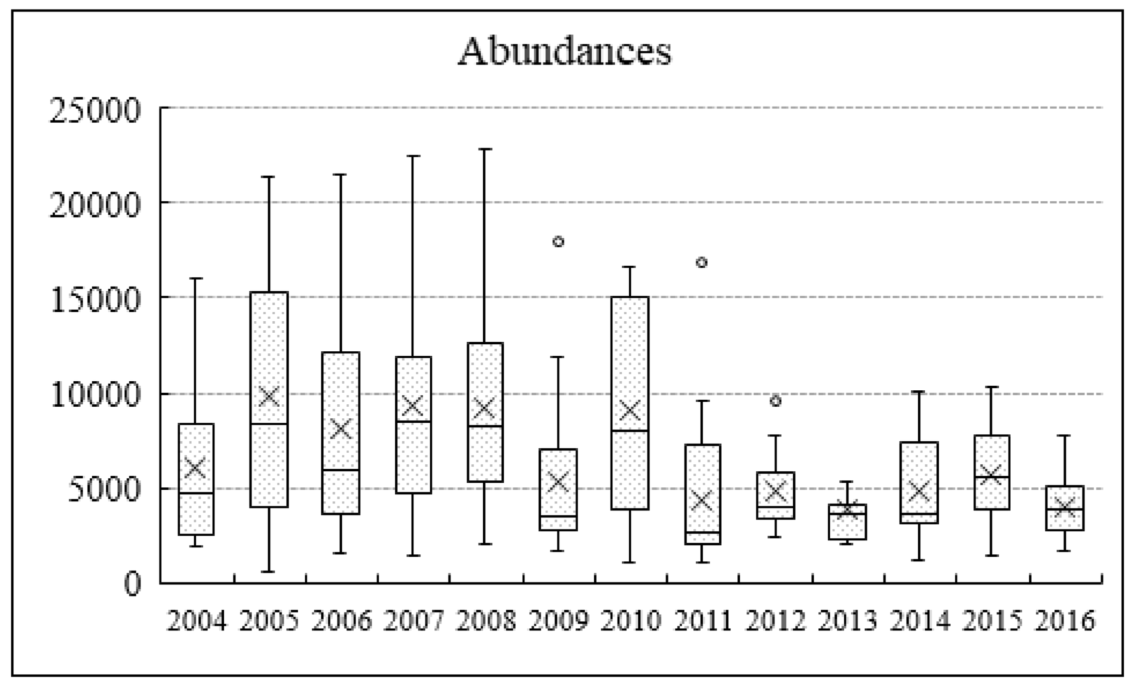


Fig. 5. Box plots of total mesozooplankton abundances (line within the box marks the median, x the mean value)

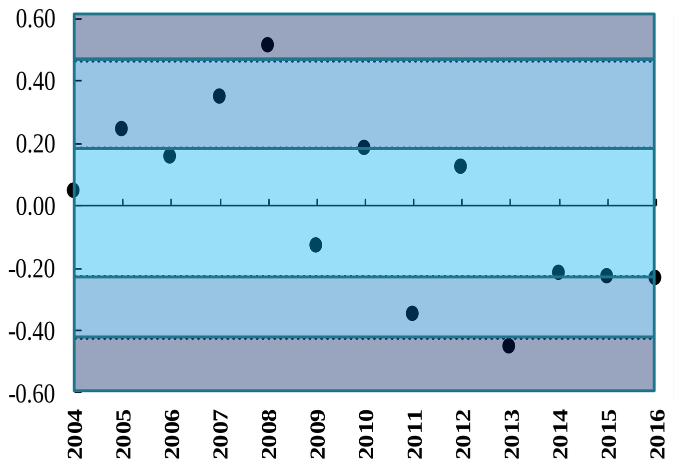


Fig. 6. el Annual anomalies in copepod abundance: 25-75 percentiles – small change, 75-97.5 – important change 2.5 percentile – extreme change

	1999-2002			2009-2014		
	max (ind m^{-3})	No. of species	F (%)	max (ind m^{-3})	No. of species	F (%)
Anthoathecata		4			14	
Lizzia blondina (Forbes 1848)	44		28	293		50
Thamnostoma dibalia (Busch 1851)				8		6
Podocorynoides minima (Trinci 1903)	17		31	279		44
Corymorpha nutans (Sars 1835)	1		4	9		7
Stauridiosarsia gemmifera (Forbes 1848)	12		3	8		6
Euphysa aurata (Forbes 1848)				5		16
Ectopleura dumortierii (Van Beneden 1844)				87		15
Leptothecata		6			9	
Aequorea forskalea (Péron & Lesueur 1810)				1		6
Eirene viridula (Péron & Lesueur 1809)	2		6	2		5
Helgicirrha shultzei (Hartlaub 1909)	2		10	5		24
Clytia spp. (Lamouroux 1812)	154		35	1024		66
Obelia spp. (Péron and Lesueur 1810)	32		18	55		32
Trachymedusae		3			4	
Aglaura hemistoma (Péron & Lesueur 1810)	20		18	73		56
Persa incolorata (McCrady 1857)				8		8
Rhopalonema velatum (Gegenbaur 1857)	18		21	37		19
Narcomedusae (*Solmaris* spp.)	157		14	622		47

Table 1. Hydromedusan fauna during two periods, their max. abundances, total no. of species per taxonomic group and frequency of occurrence (F for taxa withF>%%)

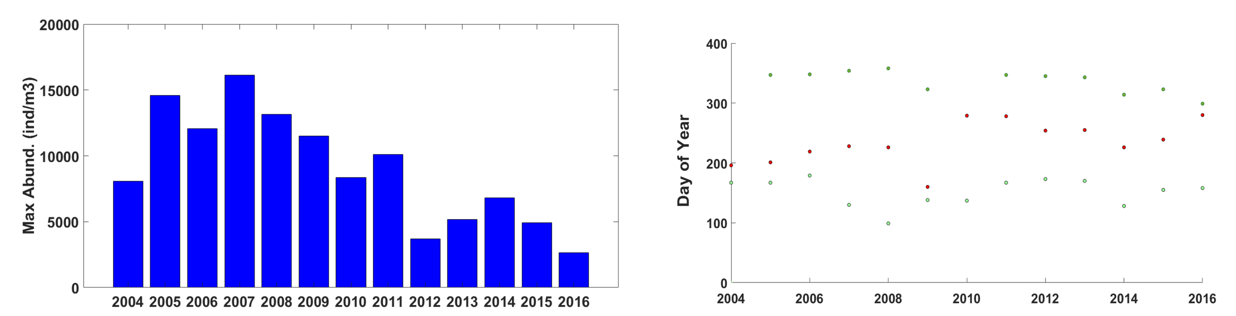


Fig. 7. *Penilia avirostris* maximal abundances (left), days in a year when they were noted for the first/last time, and maximal abundance (red dots), right

Conclusions

- period of high zooplankton dry mass in the late 1990s was followed by a decline (Fig. 4), the decreasing trend is clear also in total zooplankton abundances (Fig. 5)
- copepod abundances showed marked seasonality and significant interannual variability (Fig. 6)
- contrary to our expectations that pico- and nano-feeders would be favored in warmer and more oligotrophic conditions two representative taxa (Thaliacea and cladoceran *Penilia avirostris* did not increase
- Thaliacea did not exhibit a clear trend, while abundance of *Penilia* declined and its peak counts appeared later in a season (Fig. 7)
- jellyfish (Hydromedusae, Table 1, and Scyphomedusae) seem to be winners in warming and more oligotrohoc northern Adriatic.

References

Brush M. et al. 2020. Phytoplankton dynamics in a changing environment. In Malone et al (eds) Evolution and Comparative Analysis of Coastal Ecosystems.
Raicich F & R. Colucci. 2019. A near-surface sea temperature time series from Trieste, northern Adriatic Sea (1899–2015). Earth Syst. Sci. Data, 11, 761–768

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