Are we facing a more gelatinous future for coastal waters – the Adriatic Sea case

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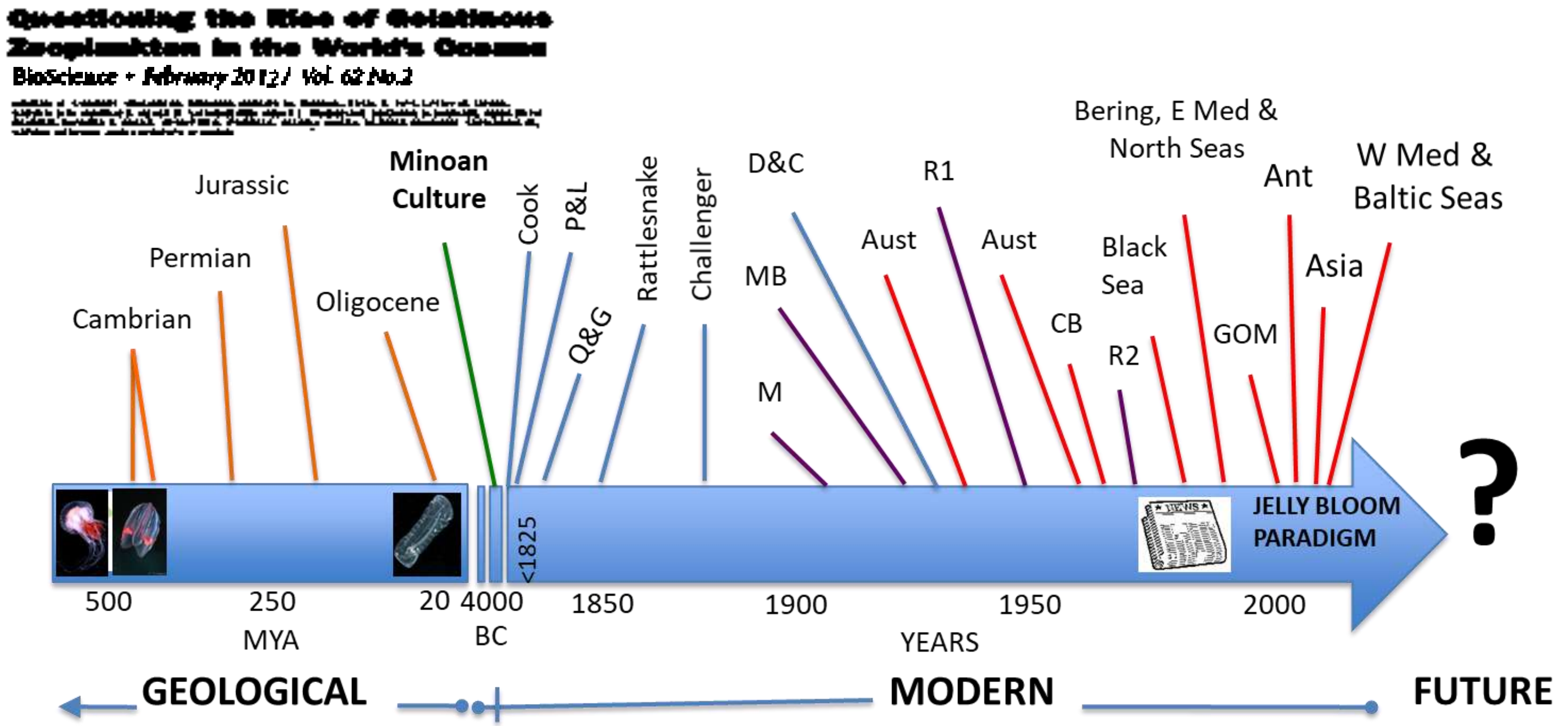
Are jellyfish blooms recent phenomena?

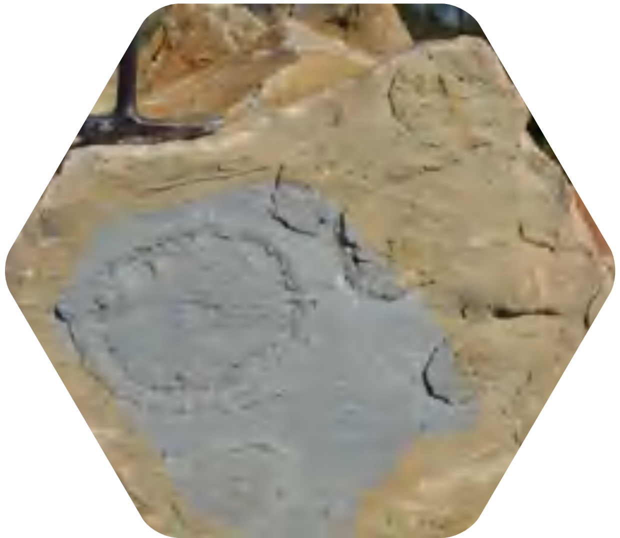
Jellyfish blooms on the geological time scale

Trieste, 17 May 2017



Solnhofen, Germany, upper Jurassic
Rhizostomites admirandus Haeckel 1866

Elerji, Slovenia
middle Eocene



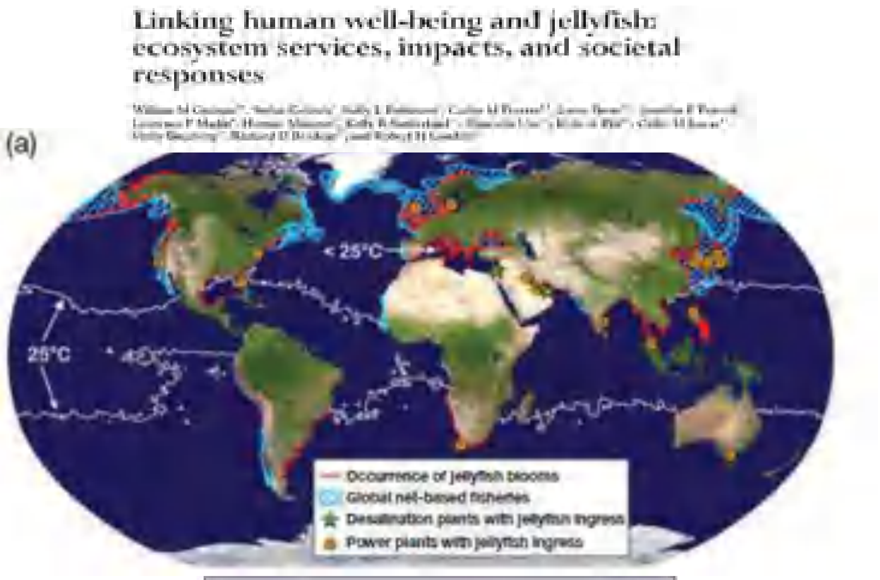
Jellyfish research: history

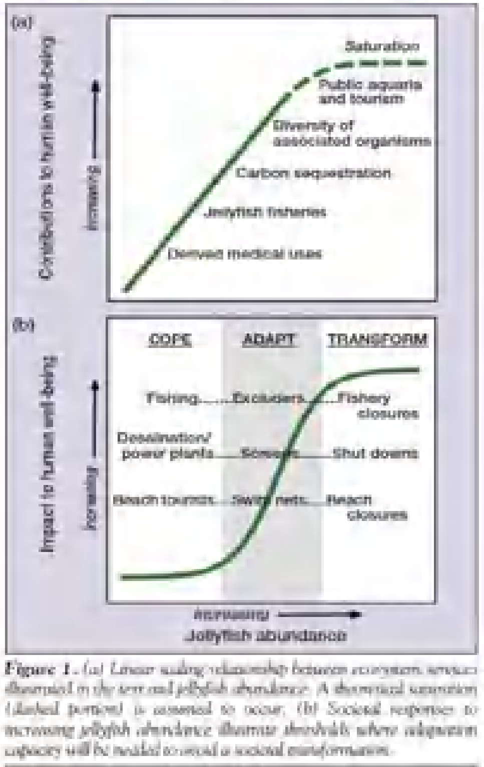
- Aristotle – ‘the founder of zoology’: Acalephae, cnide (name Cnidaria)

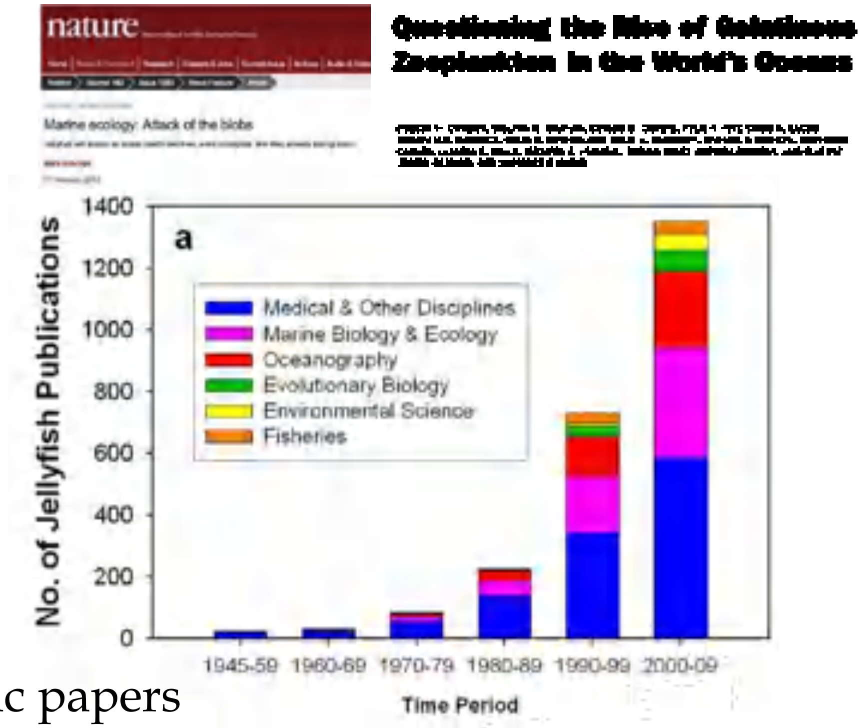
- second half of 19th century first golden “gelata“ era: Graeffe, Haeckel, Hadži, Leuckart, Agassiz, Mayer… described many gelatinous organisms

- the last decades of the 20th century - a revival of the jellyfish research - mainly due to problems with blooms

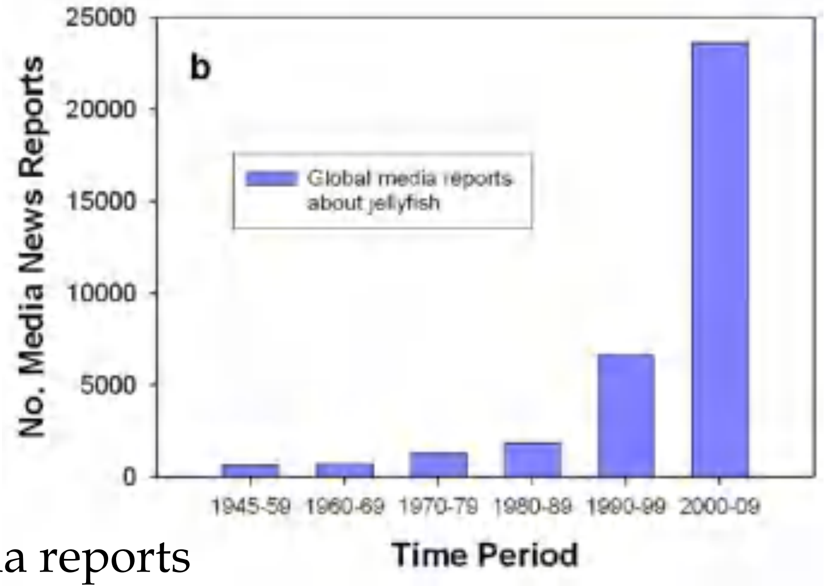
Jellyfish perception – global problem?



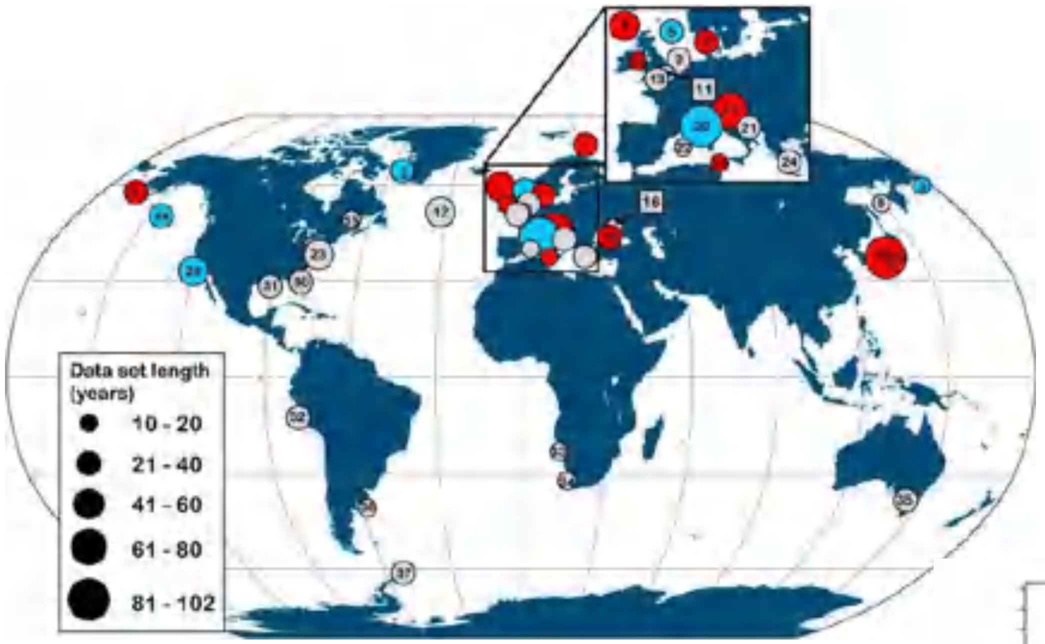




Scientific papers



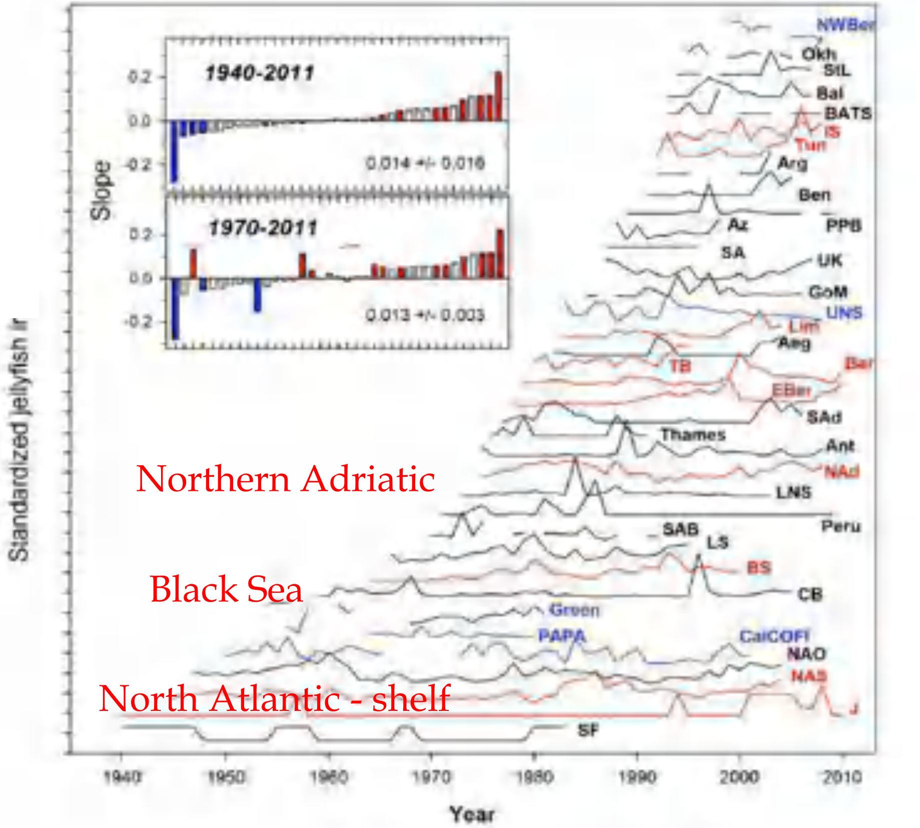
Media reports



www.pnas.org/cgi/doi/10.1073/pnas.1210920110

Recurrent jellyfish blooms are a consequence of global oscillations

Analysis included available published and unpublished long-term datasets till 2011 (datasets > 10 years)



Colours indicate trends in jellyfish abundance over time (linear regressions, P < 0.05):

significant increase (**red**),
significant decrease (**blue**),
no trend (**gray**)

Adriatic Sea

- an elongated semi-enclosed sea basin with a southeast-northwest orientation

- major freshwater inputs on north-western shore (Po) – most productive part

- generally cyclonic circulation pattern

- Three distinct basins:

NEA – with depths < 50 m (TB < 30 m)

CEA – transition area between shallow northern part and deep southern and characterized by many island on east

SEA – deep (> 1000 m), communicating through Otranto Staits with Ionian Sea

BK – Boka Kotorska is large bay often called fjord due to steep mountain coast

Scyphozoa (no. of species)

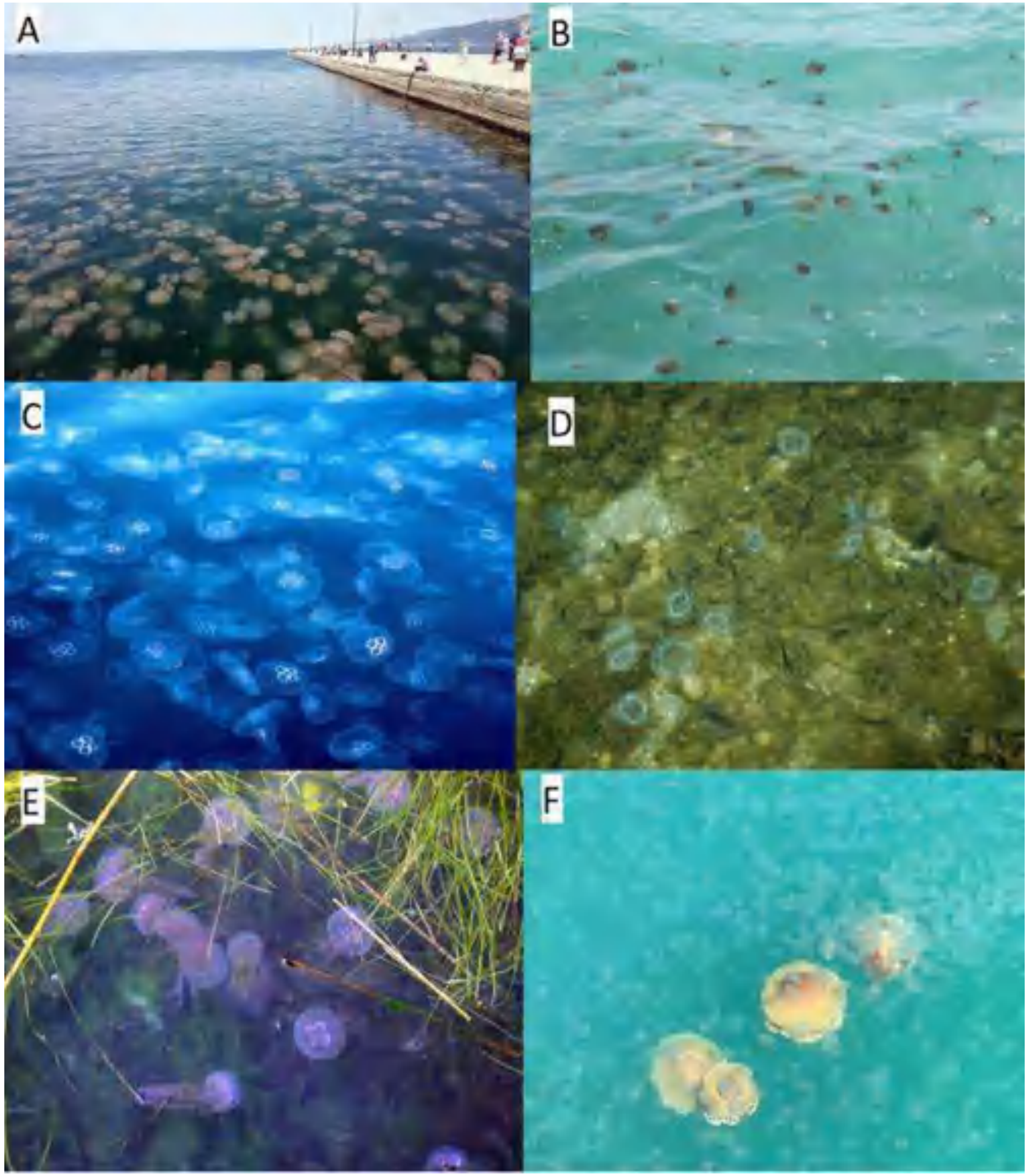
Adriatic:	9 native + 4 NIS
Mediterranean:	10 native + 13 NIS

Ctenophora (no. of species)

Adriatic:	14 native + 2 NIS
Mediterranean	30 native + 2 NIS

Examples of jellyfish blooms in the Adriatic:

A) *Rhizostoma pulmo*
B) *Chrysaora hysoscella*
C) *Aurelia solida*
D) *Discomedusa lobata*
E) *Pelagia noctiluca*
F) *Mnemiopsis leidyi* & *Cotylorhiza tuberculata*



Scyphomedusae and Ctenophora of the Eastern Adriatic: Historical Overview and New Data

Branka Pestorić [1], Davor Lučić, Natalia Bojanić [2], Martin Vodopivec, Tjaša Kogovšek [1], Ivana Violić, Paolo Paliaga and Alenka Malej

diversity 2021

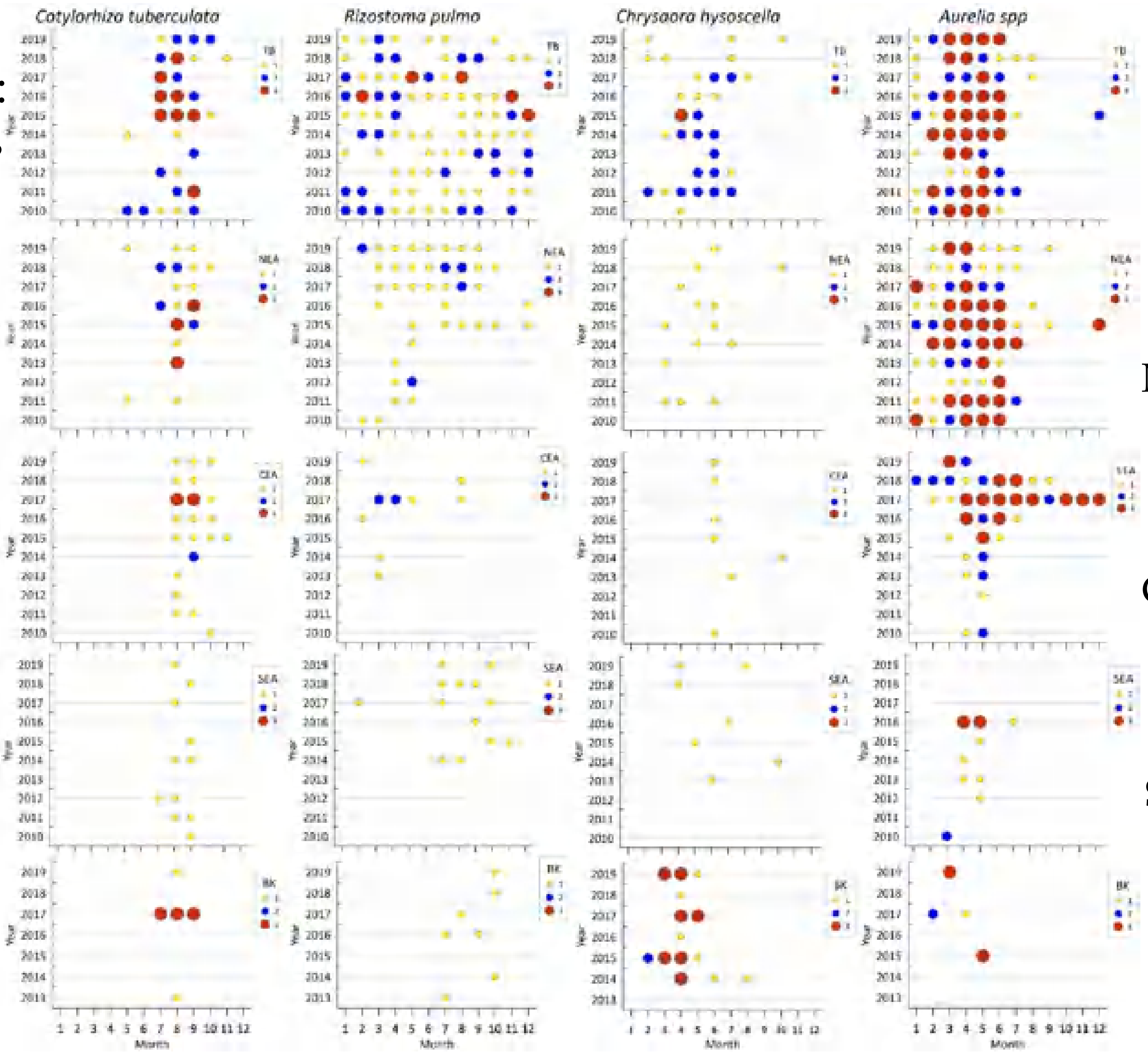
Spatial and temporal variability: four dominant Scyphozoa species (monthly data, 2010 – 2019)

blank – jellyfish not observed

yellow dot – sporadic occurrence of individual organisms

blue dot – frequent occurrence of individual organisms

red dot – frequent occurrence of large aggregations



TB

NEA

CEA

SEA

BK

Scyphomedusae and Ctenophora of the Eastern Adriatic: Historical Overview and New Data

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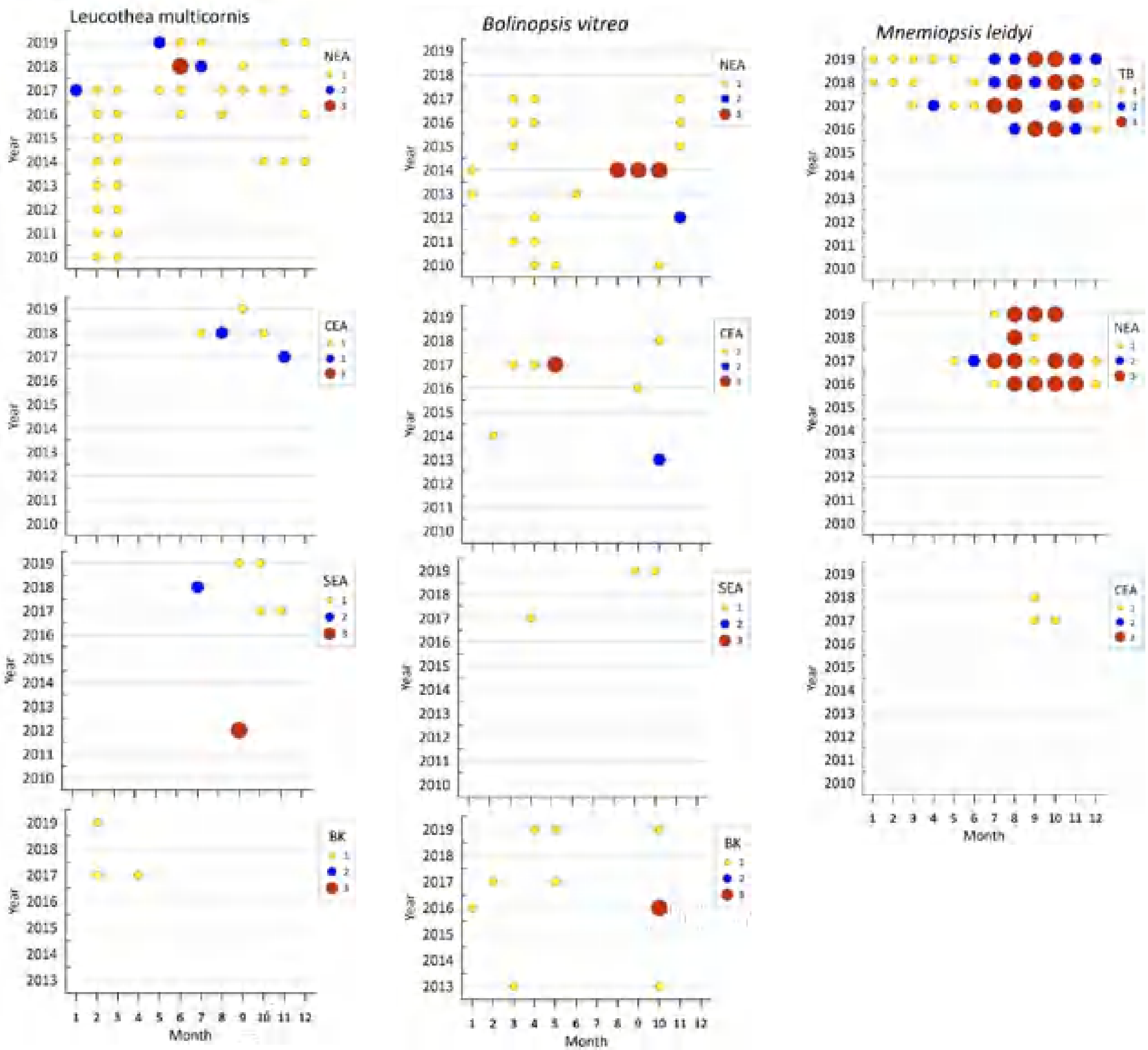
diversity 2021

Spatial and temporal variability: three dominant Ctenophora species (monthly data, 2010 – 2019)

Colour code the same as for Scyphozoa

No *Mnemiopsis leidyi* before 2016, in CEA 2017

No *Mnemiopsis leidyi* in SEA and BK



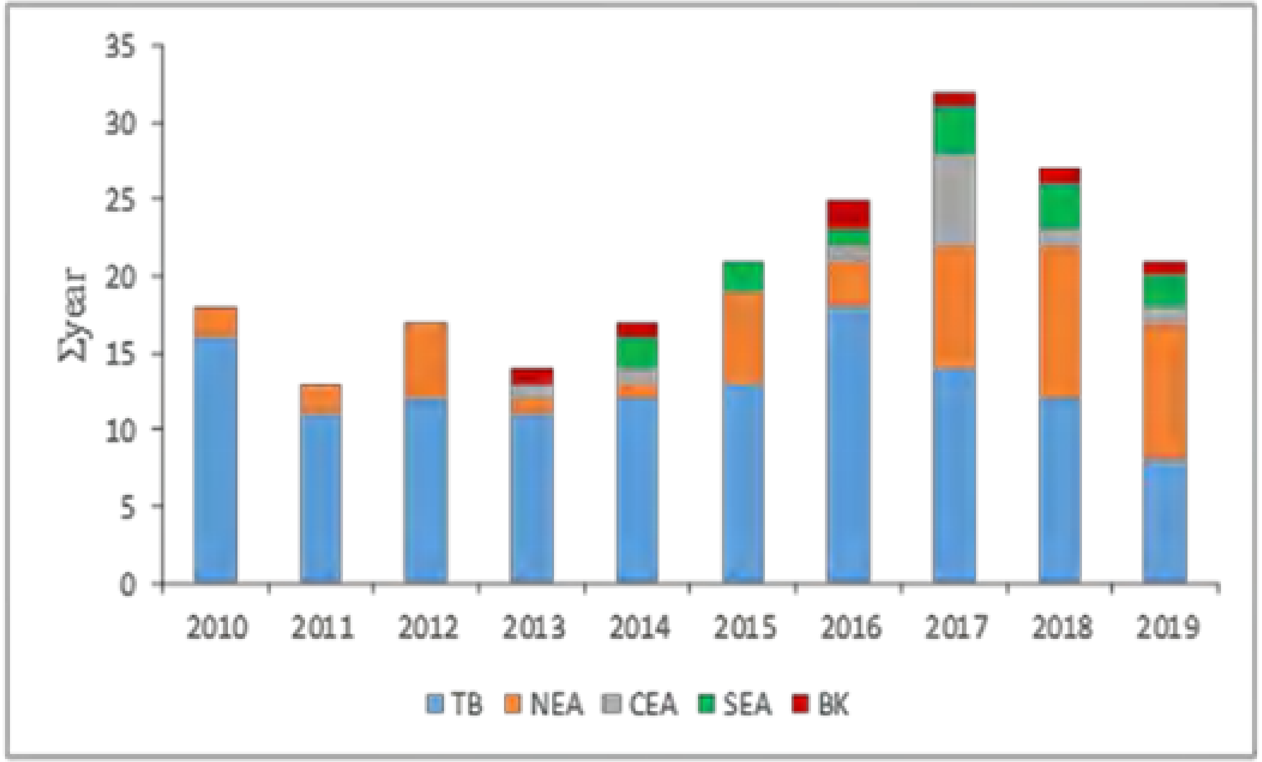
Spatial distribution of dominant scyphomedusae in the Adriatic (2010 - 2019)

SIMPER test:

- the greatest similarity between TB and NEA

- the greatest differences among TB, NEA vs. SEA, BK (average dissimilarity ~ 80 %)

- *Rhizostoma pulmo* made the largest contribution to observed differences among areas

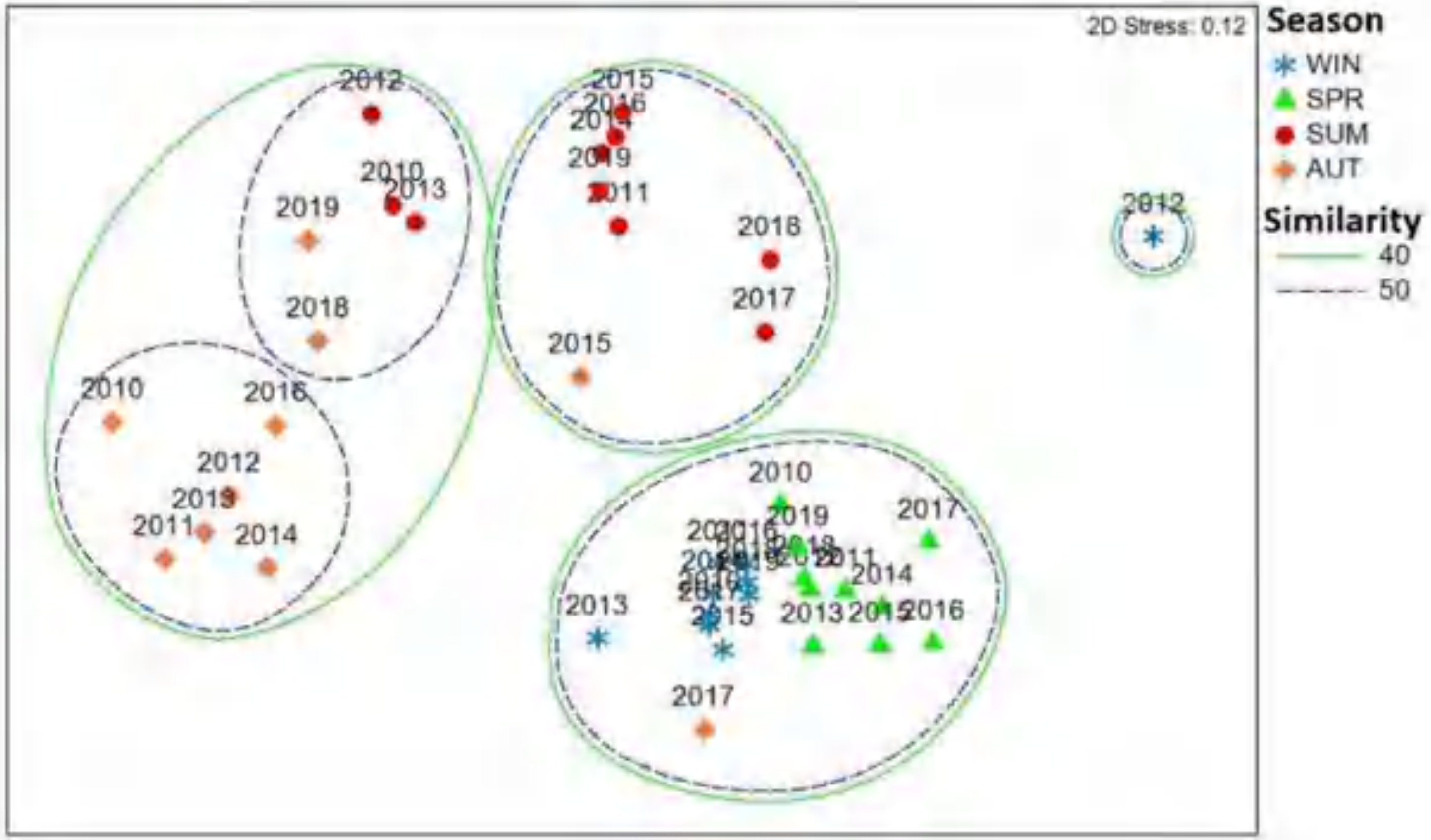


Annual cumulative abundance:
TB – Gulf of Trieste (blue), NEA – northern Adriatic (ochre)
CEA – middle Adriatic (grey), SEA – southern Adriatic (green)
BK – Boka Kotorska Bay (red)

Similarity levels on the temporal scales (year/month 2010-2019) – all areas included

Hierarchical clustering and MDS ordination
(Bray-Curtis similarities from semi-quantitative abundance data) :

- no grouping for investigated years
- clearly visible seasonal grouping
- winter 2012 singled out (extremely low winter temperatures; very low jellyfish abundances



Long-term fluctuations of scyphomedusae in the Gulf of Trieste
(reconstructured time series of presence/absence since 1790)

Wavelet analysis - four meroplanktonic species:

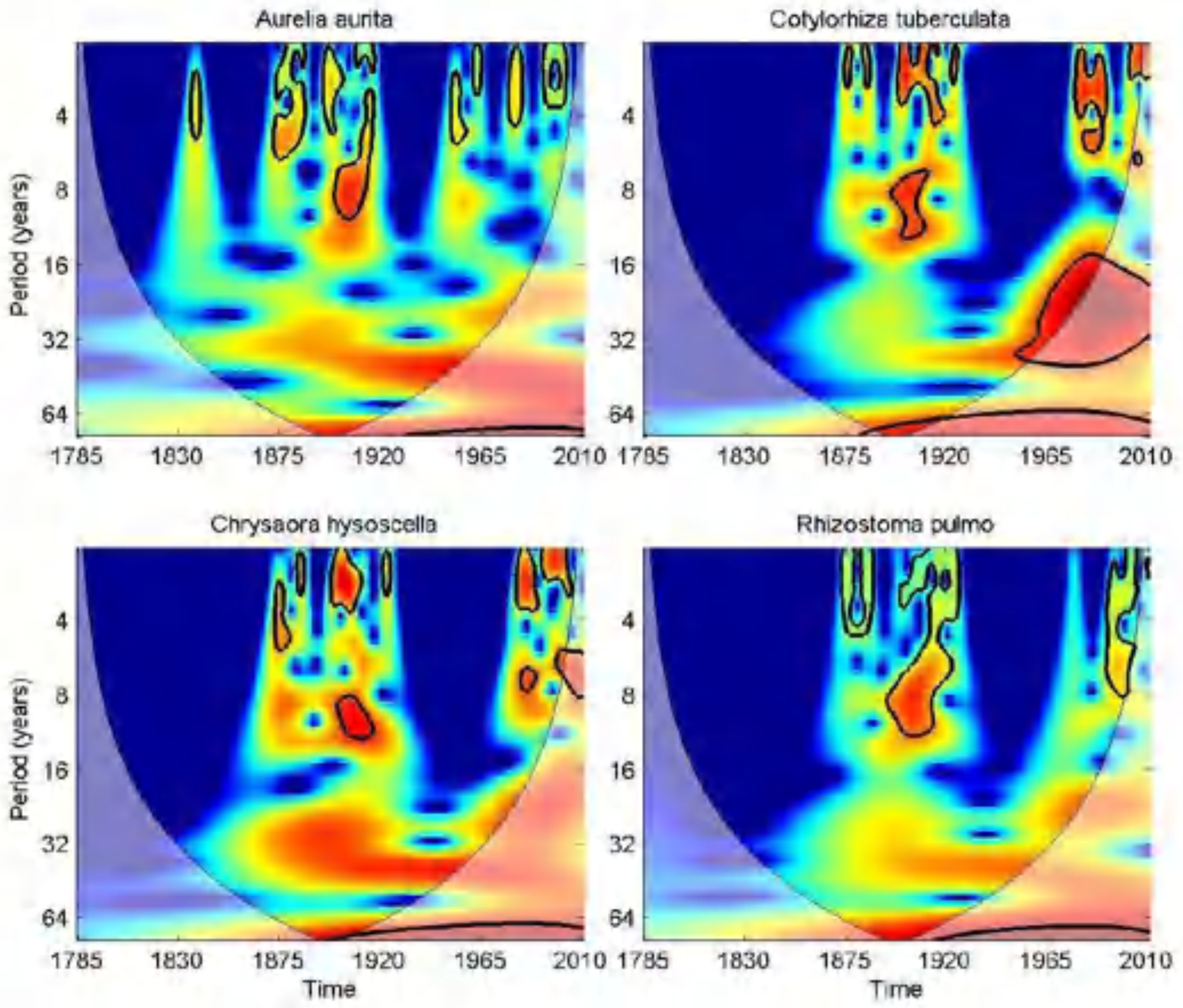
Aurelia aurita,
Cotylorhiza tuberculata
Chrysaora hysoscella
Rhizostoma pulmo

Two main periods of jellyfish outbreaks:

~1875-1920 and since 1970 on

Similar periodicity for all four species:

8 – 12 years during first period
< 8 years from 1970 on

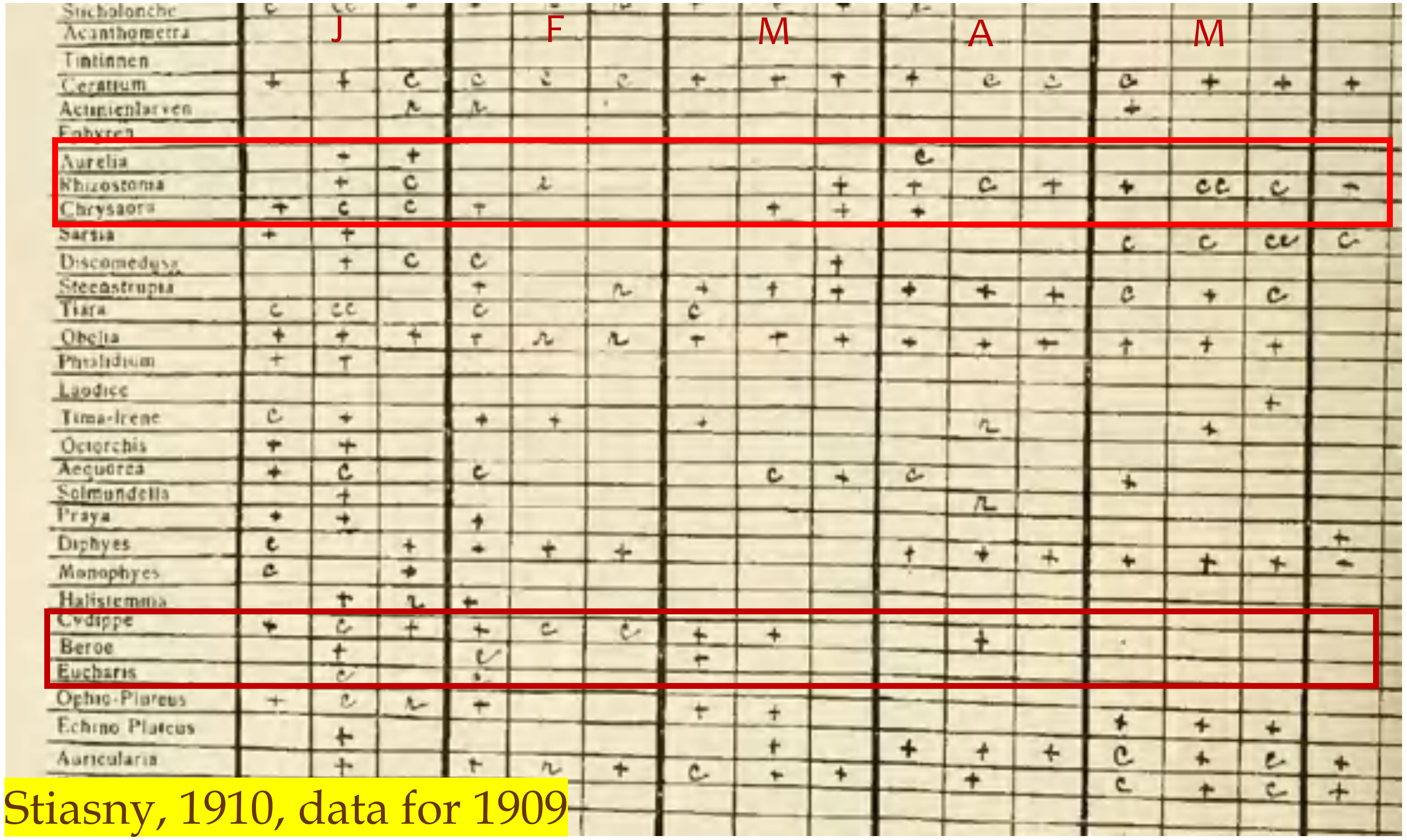


Hydrobiologia (2010) 645:81–96
DOI 10.1007/s10750-010-0217-8

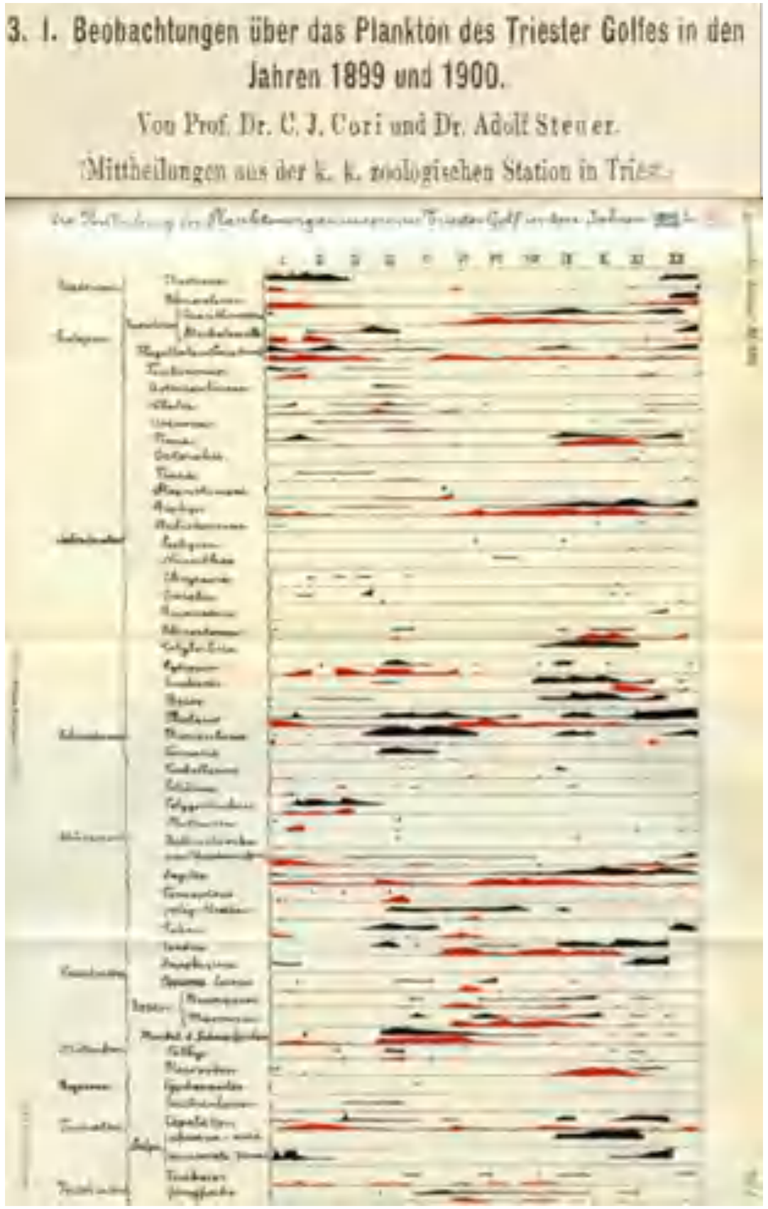
Recurrence of bloom-forming scyphomedusae: wavelet analysis of a 200-year time series

Tjaša Kogovšek · Branko Bogunović · Alenka Malej

Gulf of Trieste: long-term plankton and jellyfish semi-quantitative data



Stiasny, 1910, data for 1909



Our observations (semi-quantitative data)

Each month of the year is assigned a value between 0 and 3:

0 – jellyfish are not seen at all;

1 – sporadic occurrence of individuals;

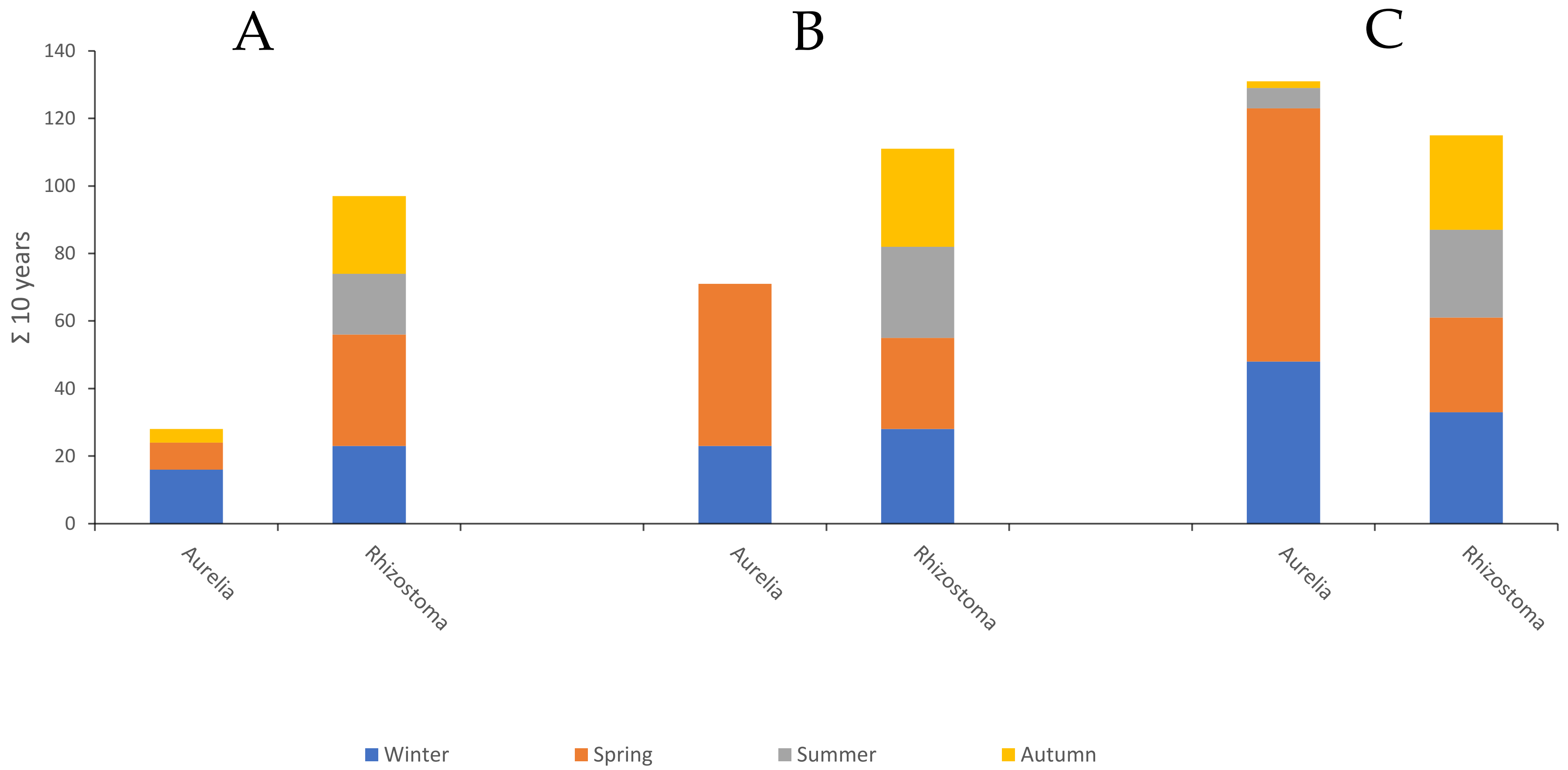
2 – occurrences of individuals and/or small aggregations;

3 – occurrences of large aggregations

Gulf of Trieste - comparison of three 10-year periods (*Aurelia, Rhizostoma*): A) 1900-1909; B) 2000-2009; C) 2010-2019

$\Sigma year_{10}$ = [(t.o. x rel. ab. 1) + (t.o. x rel.ab. 2) + (t.o. x rel.ab. 3)]

t.o. = times observed; rel. ab. 0, 1, 2, 3 = relative abundance / 10 years



Mass occurrences/increases of jellyfish – contributing factors

- metagenic life history (exchange of attached polyp and free-swimming medusa)

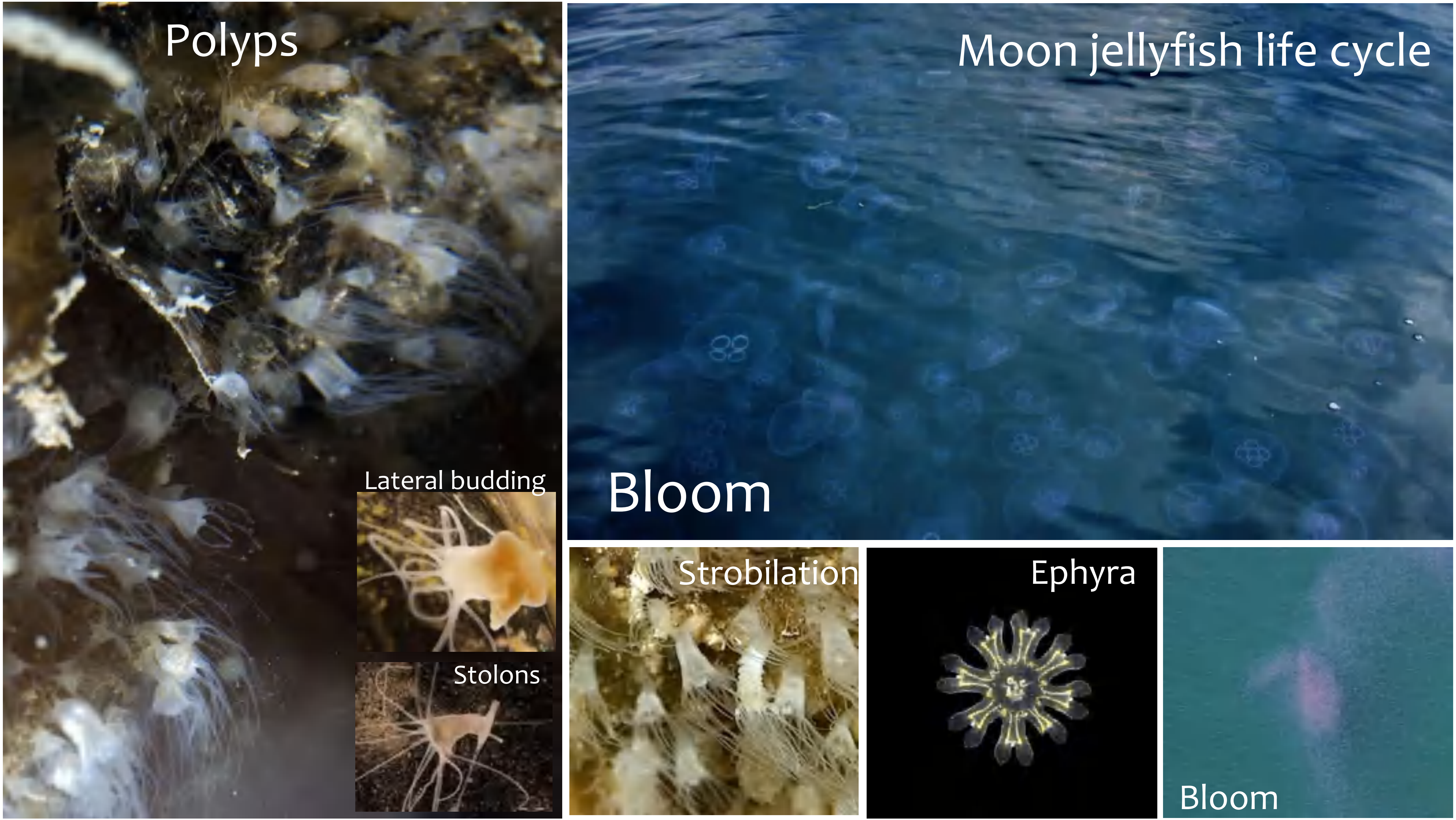
- different asexual modes of polyp reproduction

- high fecundity of medusae

- high feeding capacity and high growth rate

- live in habitats that create favourable conditions for aggregation (shallow water, enclosed or semi-enclosed systems, specific local hydrodynamics…)

- anthropogenic factors (artificial substrates and enhanced connectivity, removal of predators/competitors, eutrophication, introduction of NIS, warming)


Moon jellyfish life cycle
Polyps
Lateral budding
Stolons
Bloom
Strobilation
Ephyra
Bloom

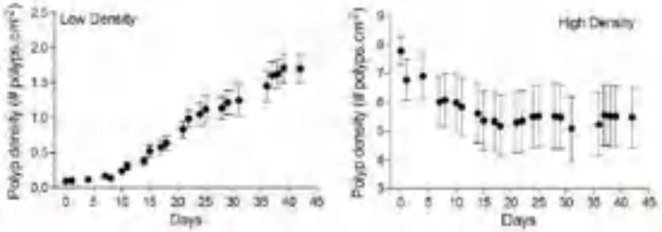
Unmasking *Aurelia* species in the Mediterranean Sea: an integrative morphometric and molecular approach

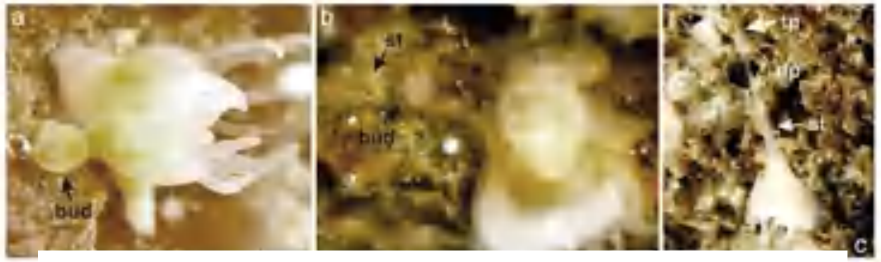
SIMONETTA SCORRANO[1,2], GIORGIO AGLIERI[1,2], FERDINANDO BOERO[1,2,3], MICHAEL N. DAWSON[4] and STEFANO PIRAINO[1,2]

Figure 5. Interspecific morphological differences in the anastomoses and bell indentations: A, *Aurelia coerulea* (= *Aurelia* sp. 1), female, bell diameter (BD) = 125 mm; B, ***Aurelia relicta* sp. nov.** (= *Aurelia* sp. 5), immature specimen, BD = 65 mm; C, *Aurelia solida* (= *Aurelia* sp. 8), male; BD = 160 mm.

Aurelia solida – non-native species

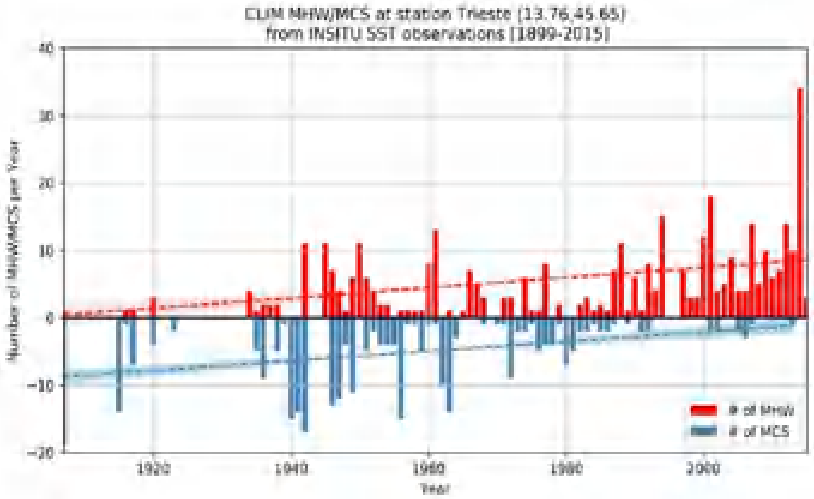
Fig. 1 Effects of polyp density on the population growth of *Aurelia aurita* s.l. polyps (mean ± SD)





Density-dependent effects control the reproductive strategy and population growth of *Aurelia aurita* s.l. scyphistomae

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



- a mean temperature rise of 1.1 ± 0.3 ^{0}C per century was estimated from the time series (1899 – 2015) of sea surface temperature (SST) measured in Trieste harbour (Raicich & Colucci, 2019)

- superimposed onto long-term warming trend are increasing number of marine heatwaves (MHW) and a reduced number of marine cold spells (MCS)

Warming, artificial structures

Offshore marine constructions as propagators of moon jellyfish dispersal

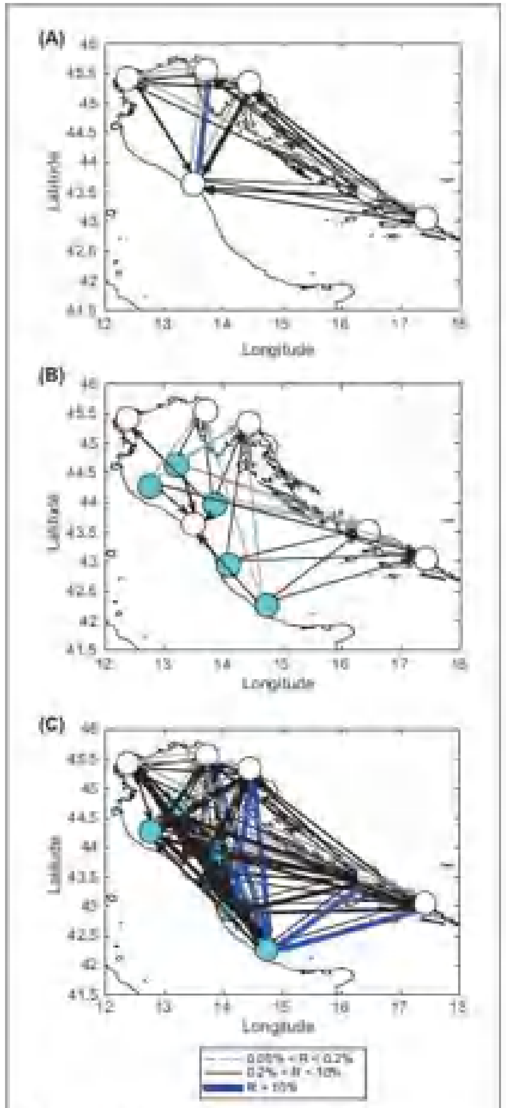
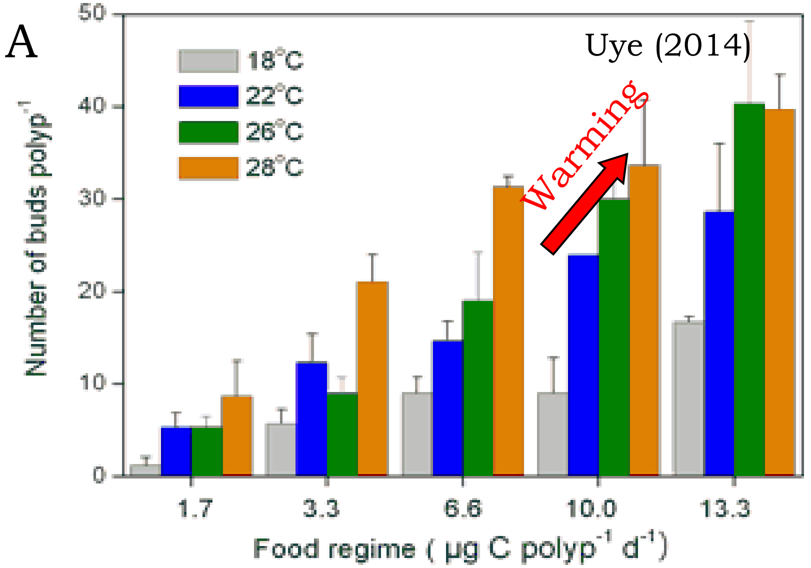


Figure 6. (a) Connectivity (estimate of recruitment—R) between shore-based polyp subpopulations. (b) Connectivity of platforms originating jellyfish with shore-based locations. (c) Connectivity between all locations considered (including platforms). Trieste and Koper have been merged together in order to make the image easier to read.

Temperature effects on asexual reproduction and mortality

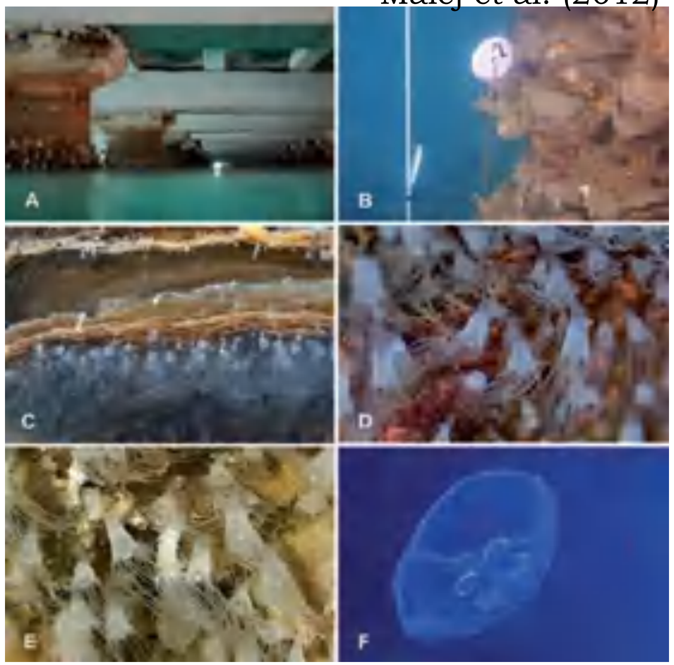
A) laboratory experiments
B) Field evidence
C) Impact of cold spells

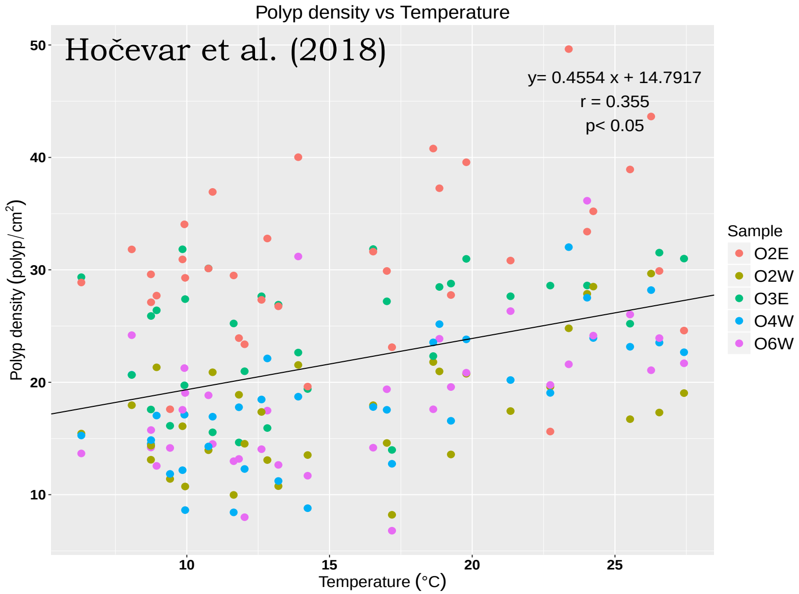
A



B

Malej et al. (2012)





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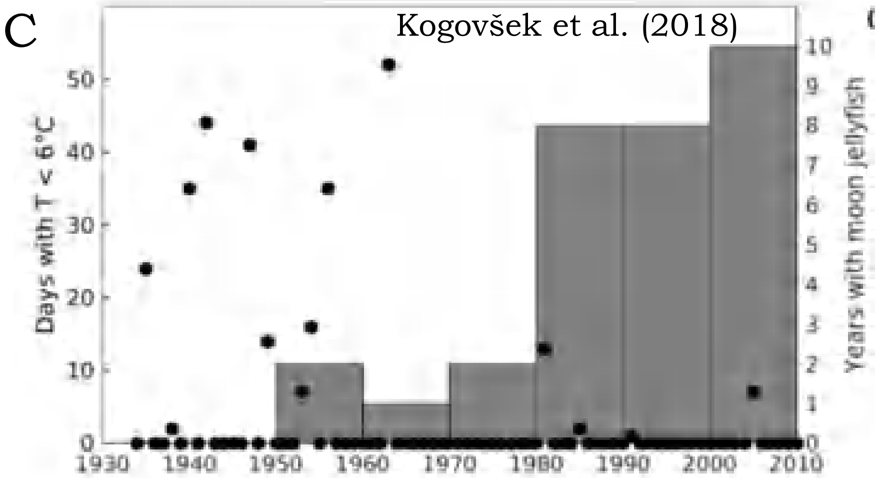
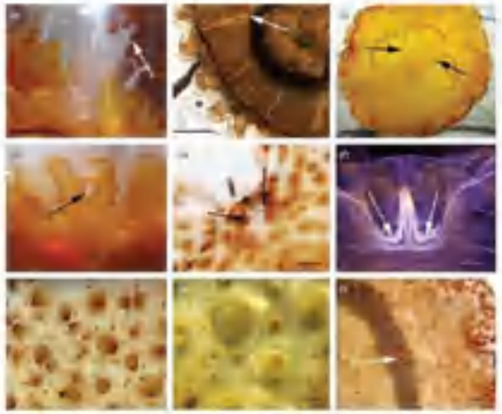


Redescription of *Pelagia benovici* into a new jellyfish genus, *Mawia*, gen. nov., and its phylogenetic position within Pelagiidae (Cnidaria : Scyphozoa : Semaeostomeae)

M. Avian[A,F,*], A. Ramšak[B,*], V. Tirelli[C], I. D'Ambra[C,D] and A. Malej[B,E]



Comparative phylogeography of meroplanktonic species, *Aurelia* spp. and *Rhizostoma pulmo* (Cnidaria: Scyphozoa) in European Seas

Andreja Ramšak · Katja Stopar · Alenka Malej

diversity MDPI

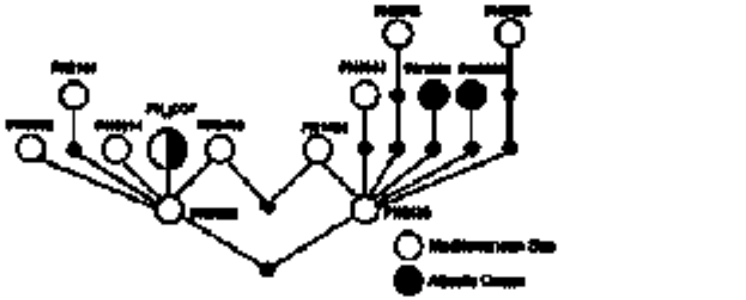
Interesting Images

Why Do Only Males of *Mawia benovici* (Pelagiidae: Semaeostomeae: Scyphozoa) Seem to Inhabit the Northern Adriatic Sea?

Valentina Tirelli [1,*], Tjaša Kogovšek [2], Manja Rogelja [3], Paolo Paliaga [1], Massimo Avian [3] and Alenka Malej [4]

Lack of genetic structure in the jellyfish *Pelagia noctiluca* (Cnidaria: Scyphozoa: Semaeostomeae) across European seas

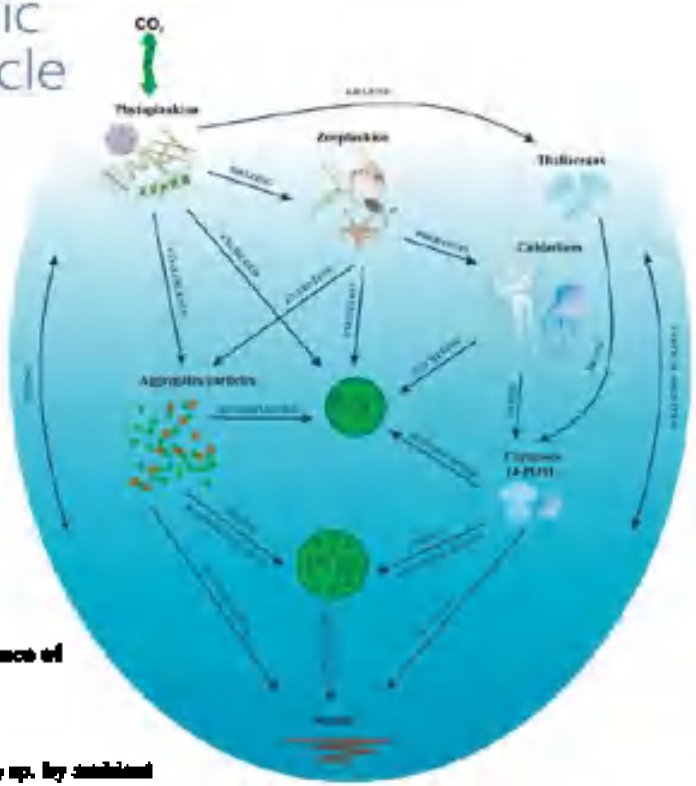
Katja Stopar[a], Andreja Ramšak[b,*], Peter Trontelj[b], Alenka Malej[a]



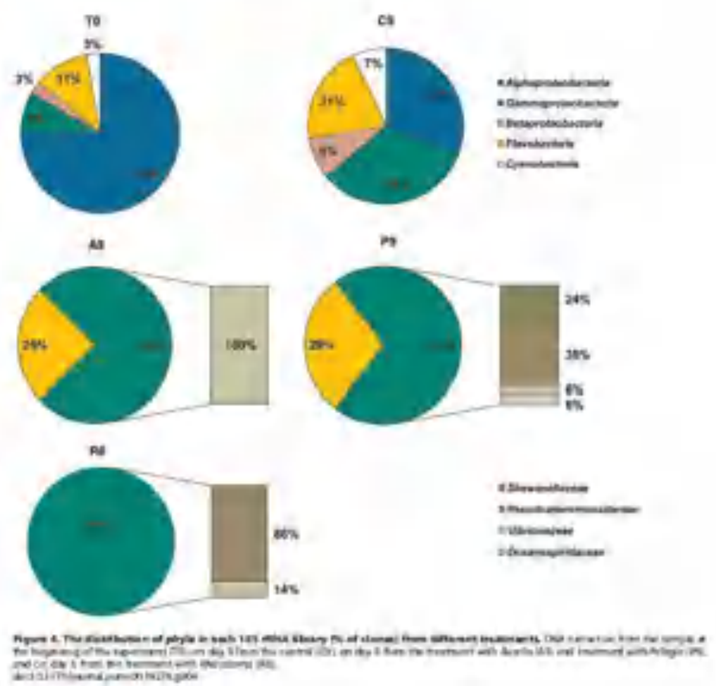
M. benovici – a non-native species introduced from the shore near Dakar (Senegal, Bayha et al. 2017); by ballast waters or hull fouling.

Our suggestion: polyps rather than medusae introduced

Mario Lebrato (Leibniz Institute of Marine Science, Germany) **and Daniel O.B. Jones** (National Oceanography Centre, UK)



Jellyfish Modulate Bacterial Dynamic and Community Structure



Bloom/end of bloom

- ❖ feeding
- ❖ jelly-falls
- ❖ biomass stoichiometry

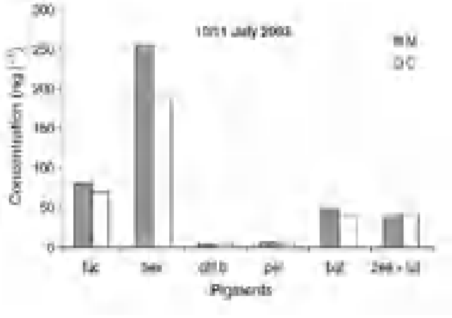
Jellyfish biochemical composition: importance of standardised sample processing

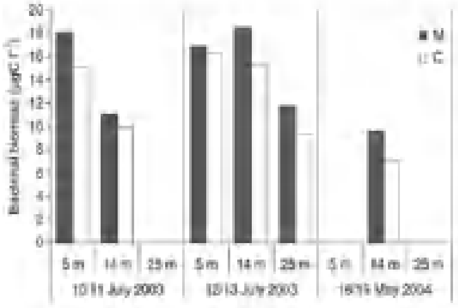
Degradation of the Adriatic medusa *Aurelia* sp. by ambient bacteria

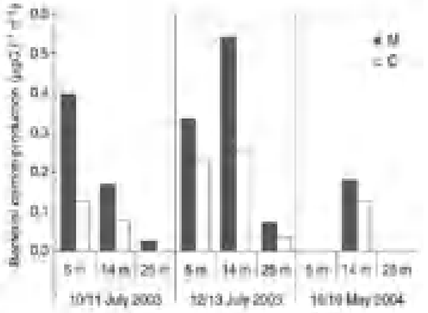
Aurelia aurita Ephyrae Reshape a Coastal Microbial Community

Feeding of *Aurelia* sp. (Scyphozoa) and links to the microbial food web

Valentina Turk[1], Davor Lučić[2], Vesna Flander-Putrle[1] & Alenka Malej[1]







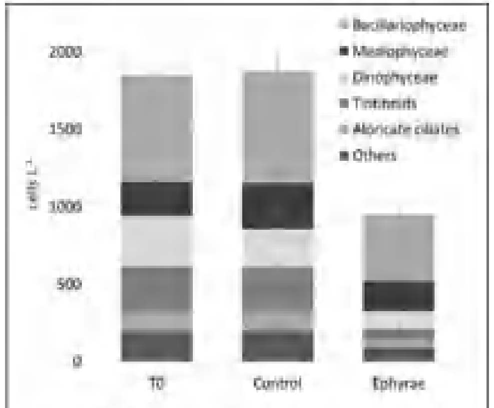


FIGURE 1 | Abundances (±SD) of major microplanktonic groups at T0 and T24 for the control and ephyra-treatment microcosms.

Summary

- jellyfish blooms are not a new phenomenon and finds of fossilized scyphomedusae show that dense accumulations already occurred in the Cambrian (> 500 myo years)

- *Aurelia* and *Rhizostoma* blooms were monitored in the northern Adriatic more than 120 years ago

- the frequency of blooms has increased in the last decades, their duration is longer

- anthropogenic disturbances (habitat changes, especially new artificial substrates, warming, introduction of new species, overfishing) have contributed to this development


Thank you for
your attention