# " Invasive *Mnemiopsis leidyi* in the northeastern Adriatic Sea
# effects on the ecosystem and possible solutions"


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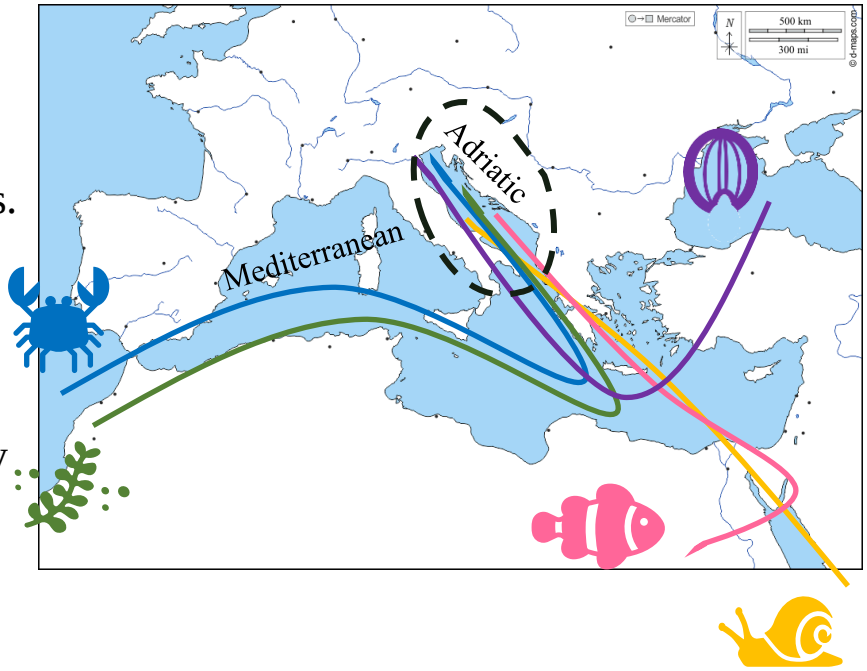
# Invasive species - a growing concern in the Adriatic

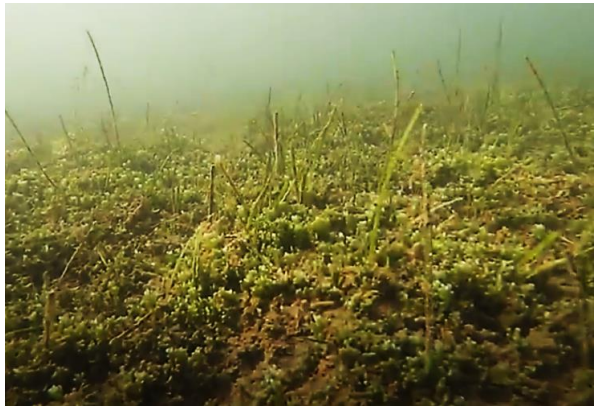
The Northern Adriatic Sea is one of the most productive marine areas of the Mediterranean.

It has around 440 species of fish and around 150 commercially valuable species of marine organisms.

Bluefish (sardines and anchovies) represent the majority of the catch in the Adriatic.

In the last decades, the Adriatic has experienced a growing number of **biological invasions**, especially of thermophilic organisms such as algae *Caulerpa* spp., various fish and snails from the Red Sea, the blue crab (*Callinectes sapidus*) from the coasts of Florida and Ctenophora such as *Mnemiopsis leidyi*.



# *Mnemiopsis leidyi*

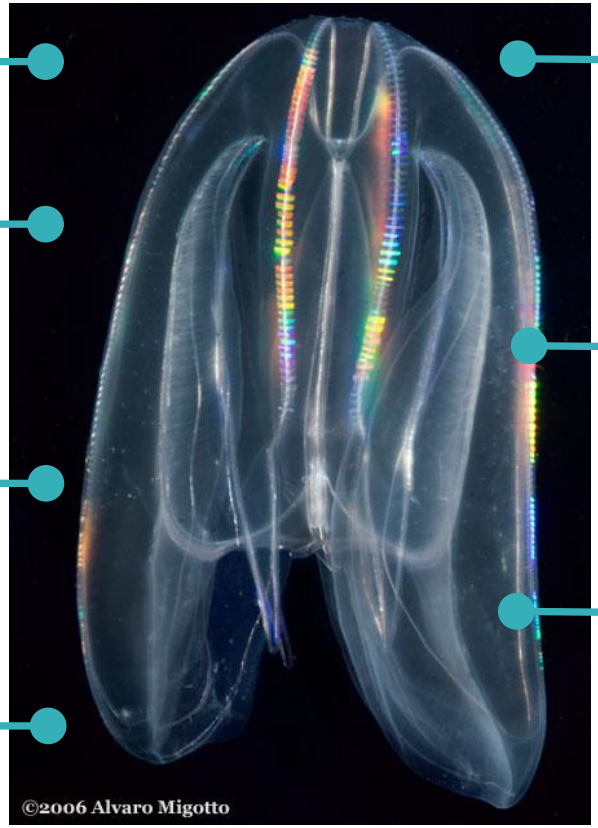
Sea walnut | Noce di mare | Morski orah

Eurivalent species

- Temp. 4-31 ºC
- Salinity 3-39

Consumes prevalently zooplankton

Bioluminescent

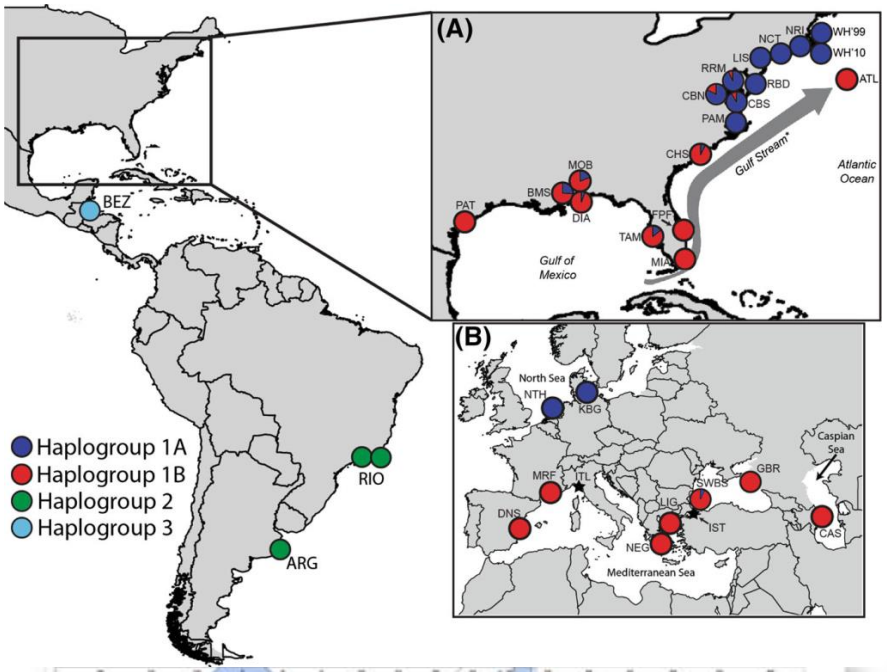



Self fertilizating hermaphrodites

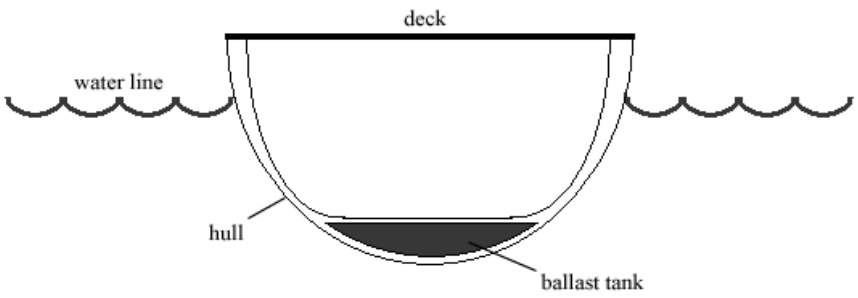
Can produce up to 12 000 eggs daily.

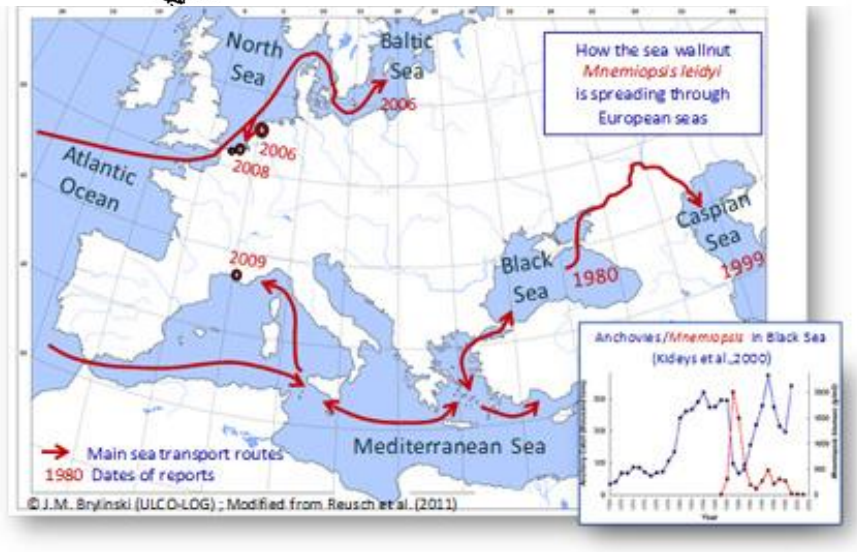
Substantial regeneration of damaged/lost body parts.

# Invasive species - a growing concern in the Adriatic




- *M .leidyi* arrived from the west Atlantic by **ballast waters** causing deleterious effects on fisheries and ecosystems.

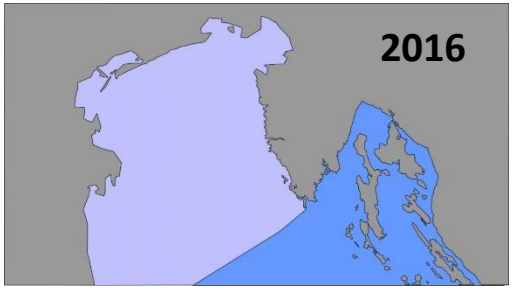


# Invasive species - a growing concern in the Adriatic

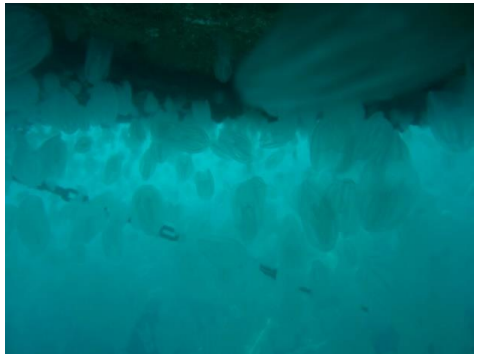
- The first occurrence was documented in the autumn of **2005** in the **Gulf of Trieste** and was **unsuccessful** (Shiganova & Malej, 2009).

- The second invasion began in the summer of **2016** (Malej et al. 2017), and since then, every year, by the end of Summer and beginning of Autumn, large swarms are detected across the **whole northern Adriatic**.

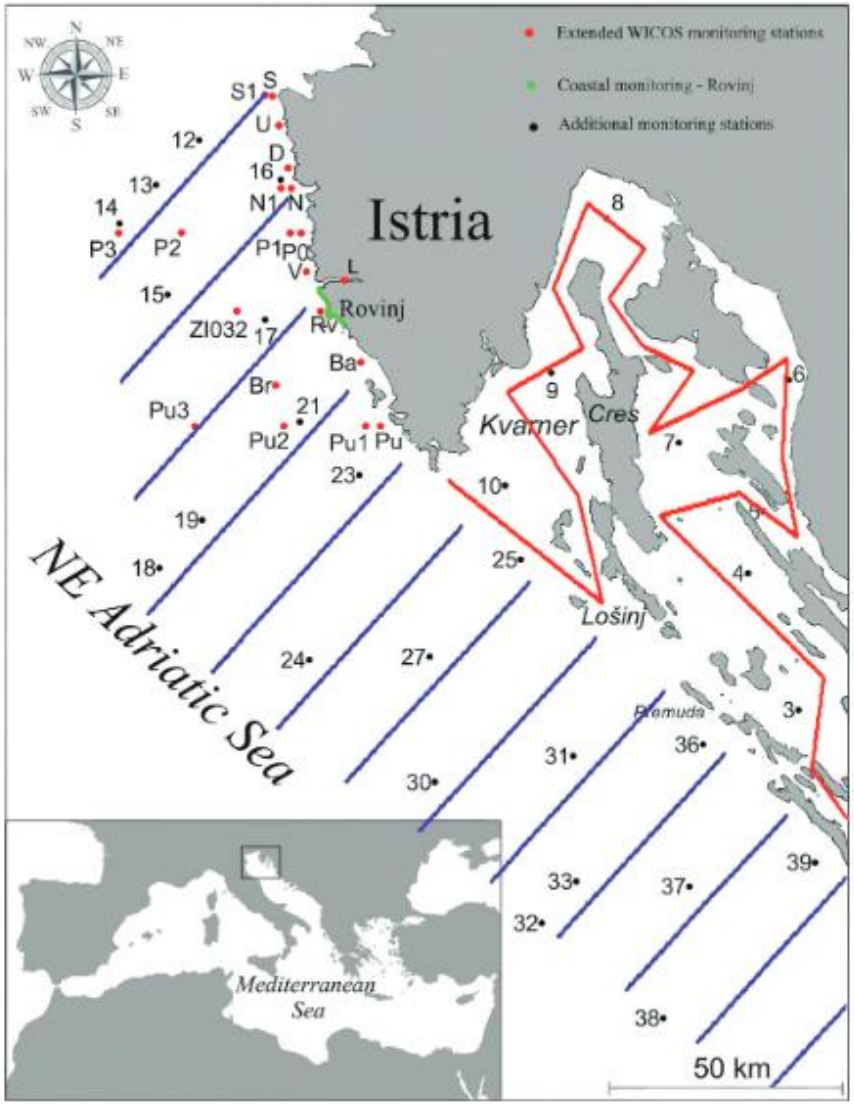




- Our monitoring started in the summer of 2016 with the 1st appearance of *M. leidyi* by the eastern coast of the northern Adriatic.

- We have studied the appearances, variability in abundance, distribution, diet, and various other effects on the ecosystem and even proposed methods for preventing the further spread of this alien species.



# *M. leidyi* monitoring




Period:

- From 2016 (2015)
- From 1st records to nowadays
- Frequency: variable, depending on a subproject and sampling scope

Parameters:

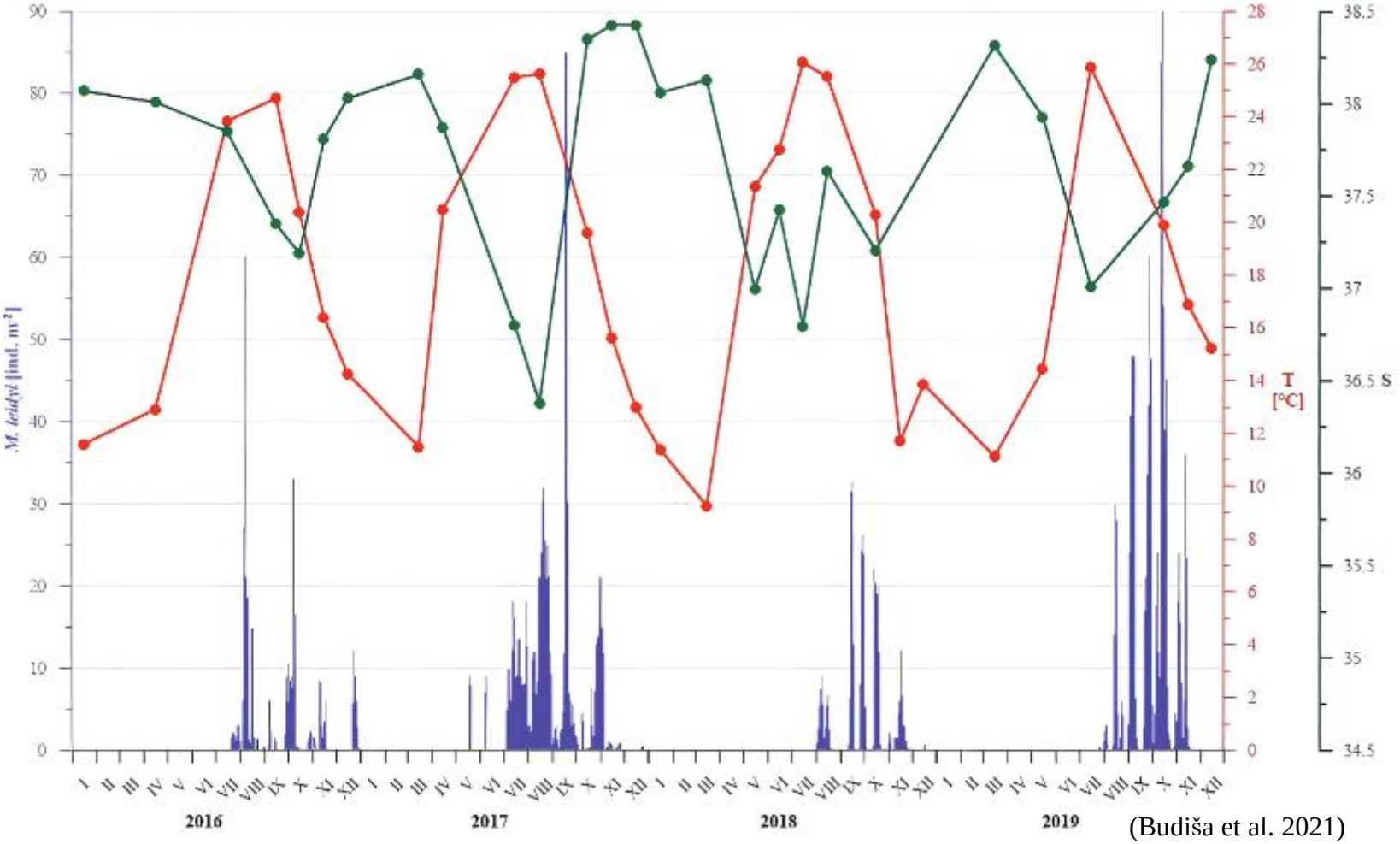
- Physico-chemical: CTD, sonar, nutrients, dissolved organic matter (DOM)
- Biological: pico-macro plankton fractions, fish

Study locations:

- Transects
- Trajectories
- Stations

# Seasonality of *M. leidyi* appearances

- On the east side of the northern Adriatic, *M. leidyi* appears first in spring, reaching its maxima in summer and disappearing in winter.




(Budiša et al. 2021)

***Fig. 2:*** Daily average abundance of *M. leidyi* (ind. $m^{-2}$) along the coast of Rovinj in the period from the summer of 2016 until the end of 2019 regarding the monthly sea surface temperatures (T) and salinities (S) at Rv station in the same period.

# Invasive species - a growing concern in the Adriatic

- The amount of prey that was found in the digestive tract was relatively small, between 1.2 and 2.5 zooplankton organisms per ctenophore.

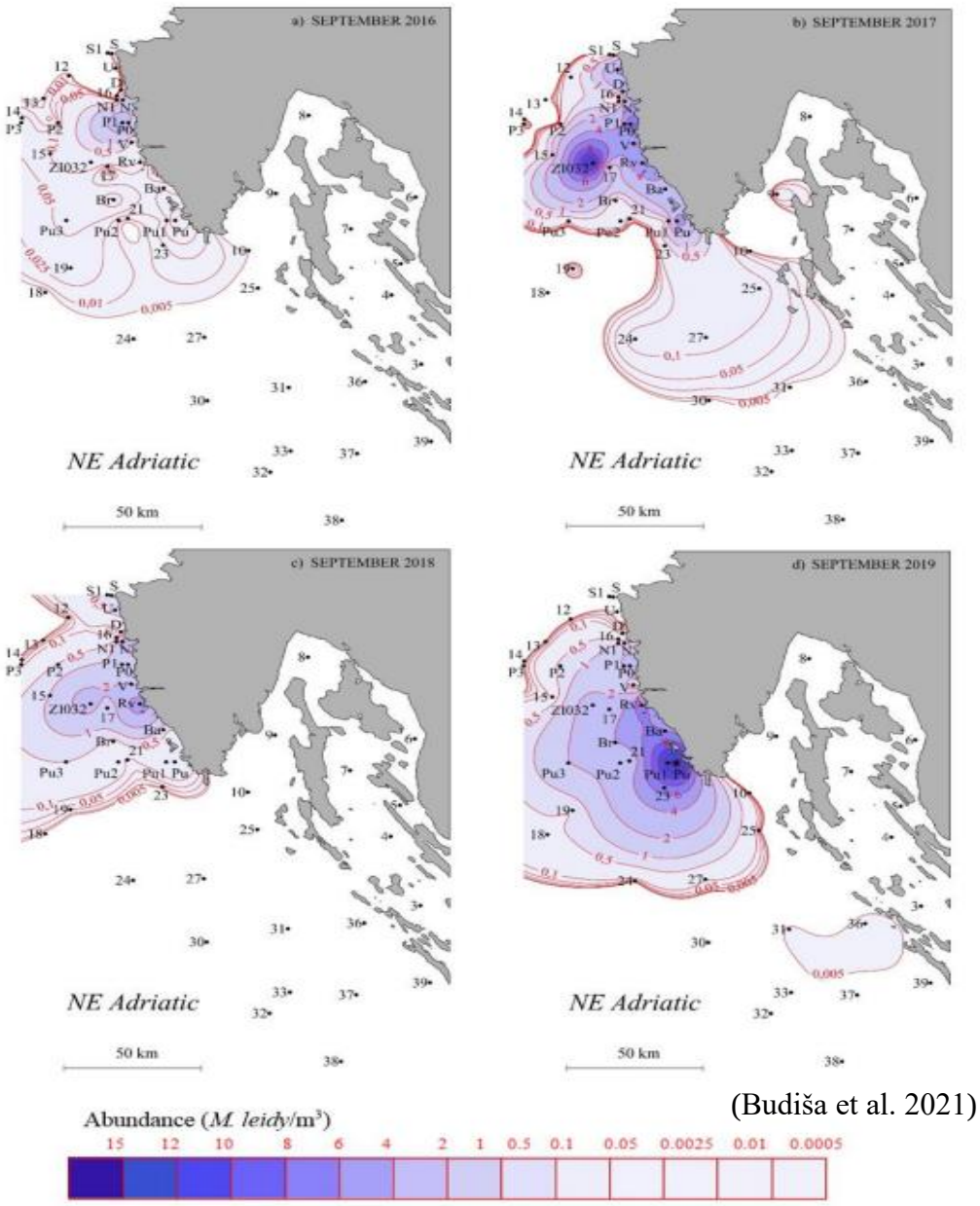
- A total of 39 zooplankton taxa ranging from protists to fish eggs have been found in the digestive tract of *M. leidyi.*

- 10 taxa accounted for about 90% of *M. leidy*i's prey :

  Copepoda, Cladocera, Ctenophora, Pteropoda, Appendicularia, Chetognata, Bivalvia larvae, Hidrozoa, Protista, fish eggs.

- In general, the dimensions of zooplankton in *M. leidyi'*s digestive system were bigger than those in the environmental net samples.

# *M. lediyi* swarms cover hundreds km$^2$




(Budiša et al. 2021)

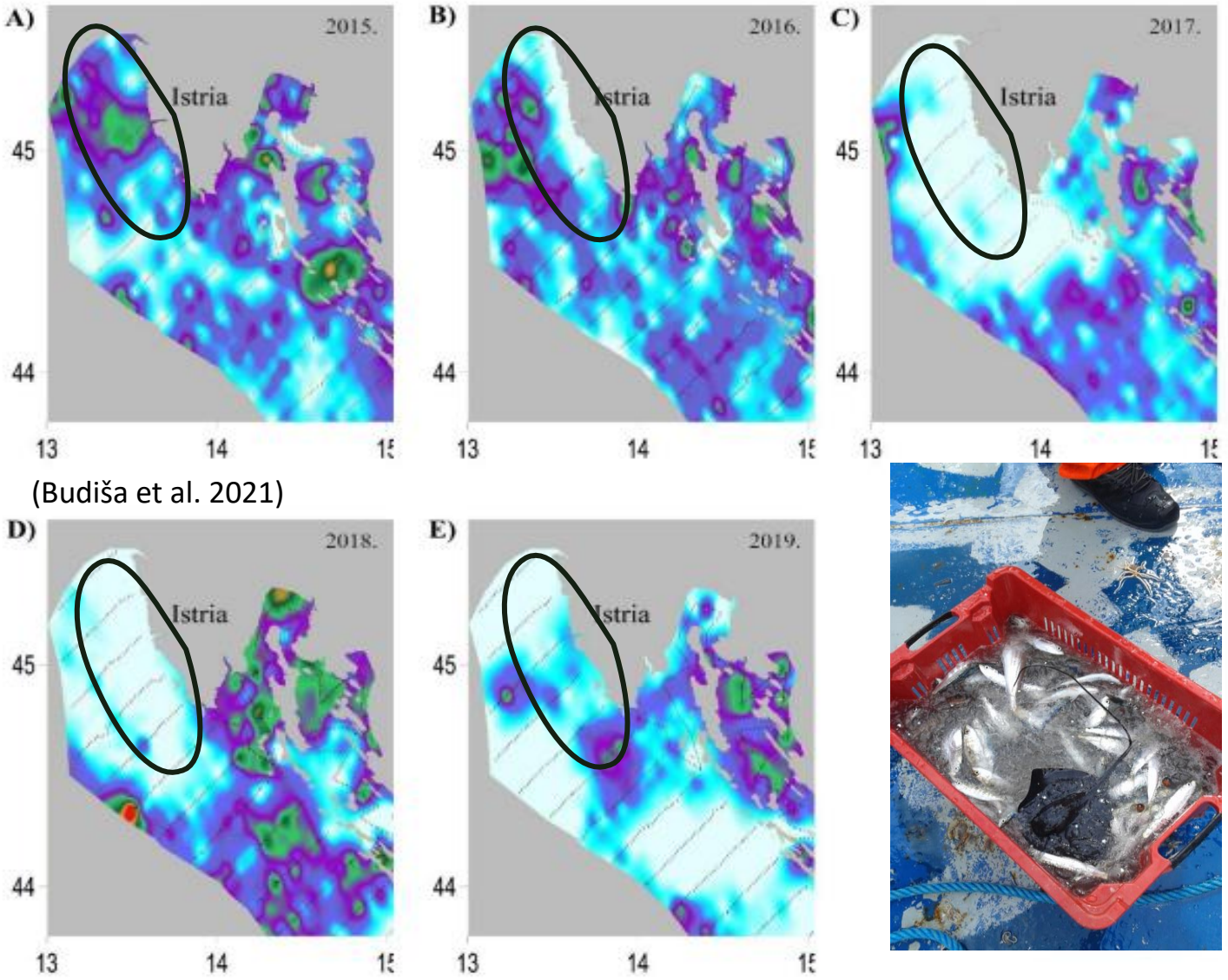
Around **70%** of *M. leidyi* is concentrated in the surface layer 0-5 m

About **27%** is present between 5-15 m (thermocline)

Bottom layer, only **1-3%**

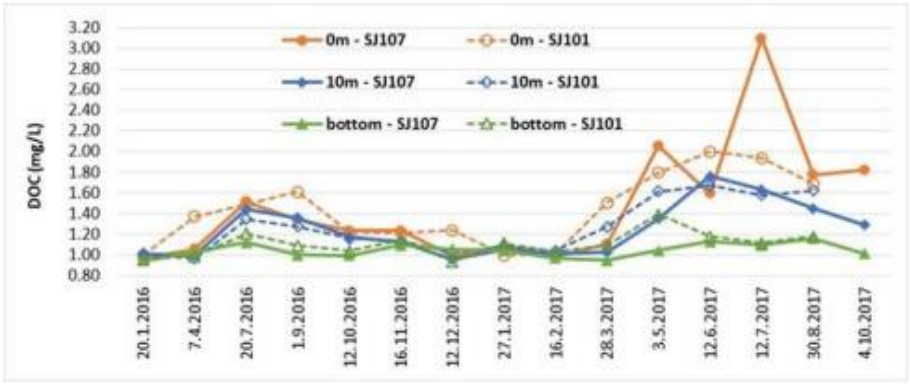
# *M. leidyi* negatively affects anchovy stocks

- Competition for resources with fish.

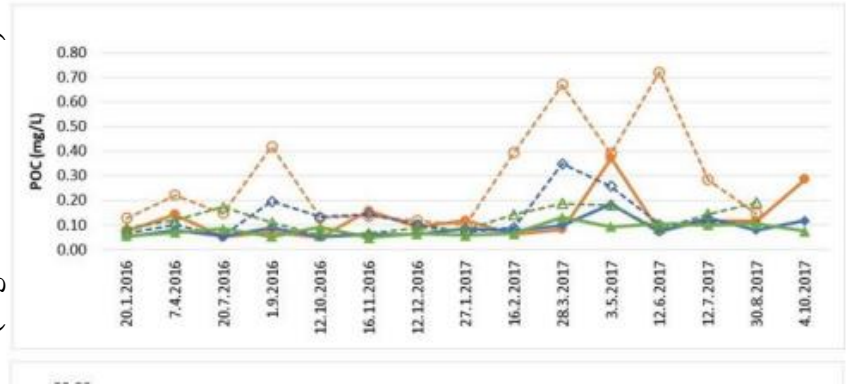



(Budiša et al. 2021)

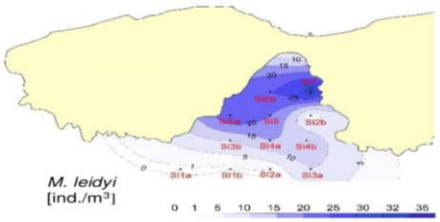
# Swarms affect DOM & microbial community

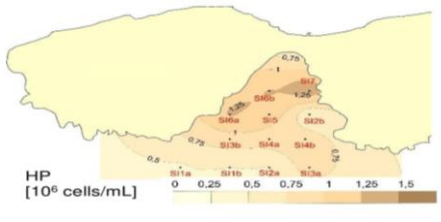


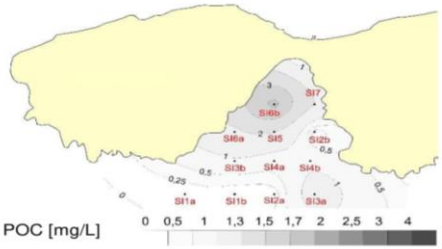

(Ciglenečki et al. 2021)

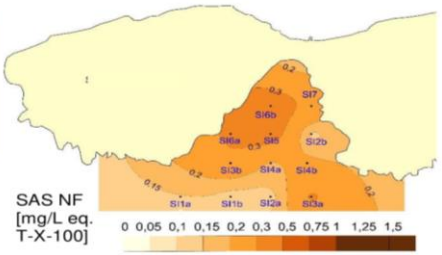


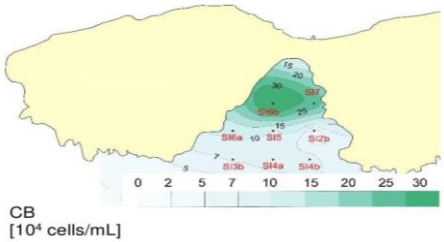

(Paliaga et al. 2021)

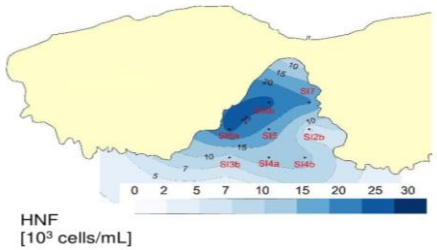


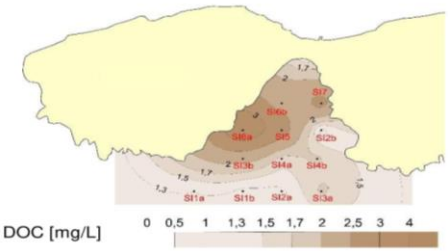



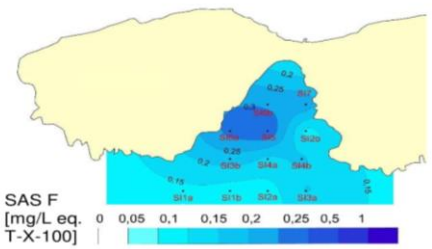



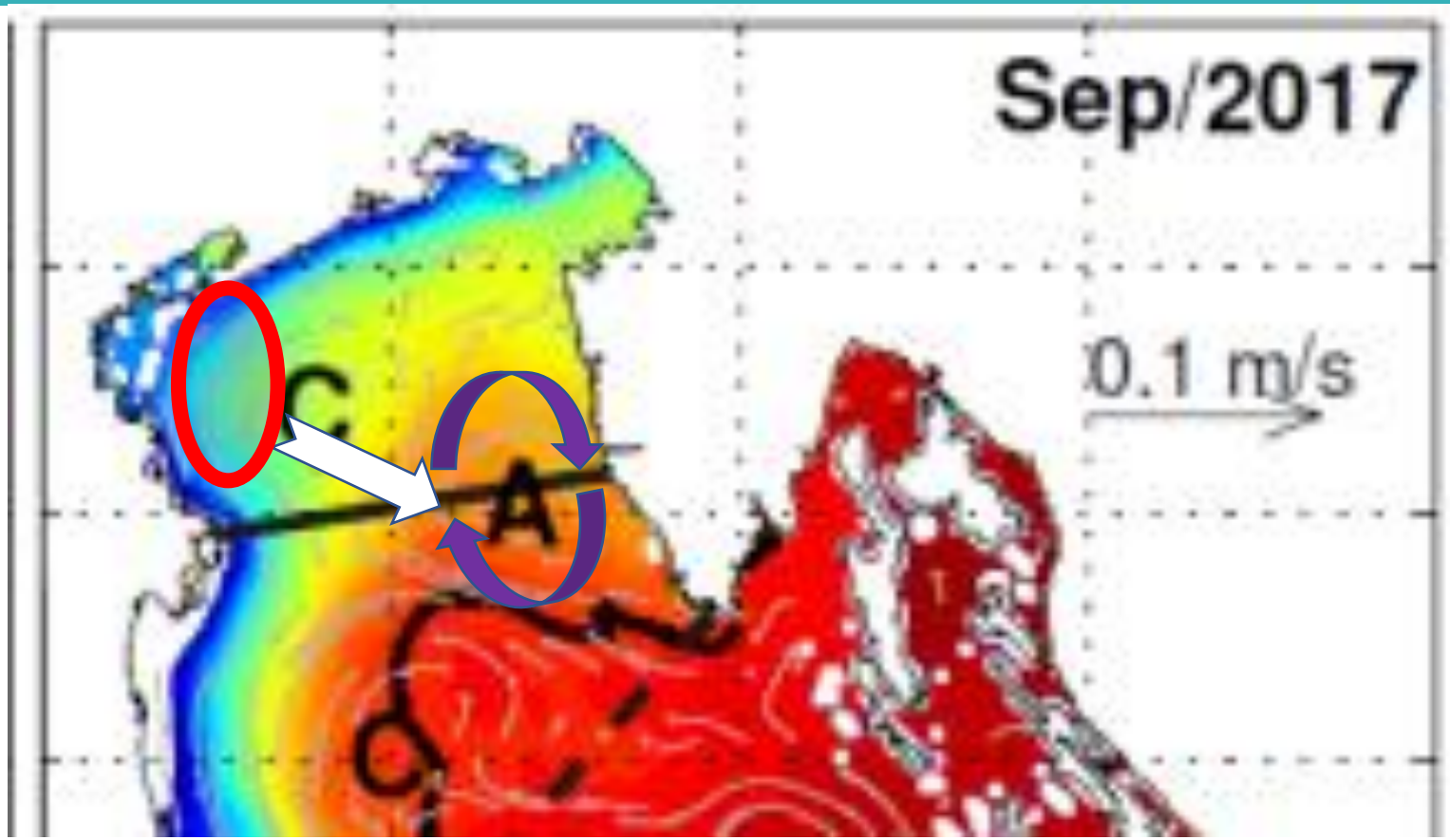



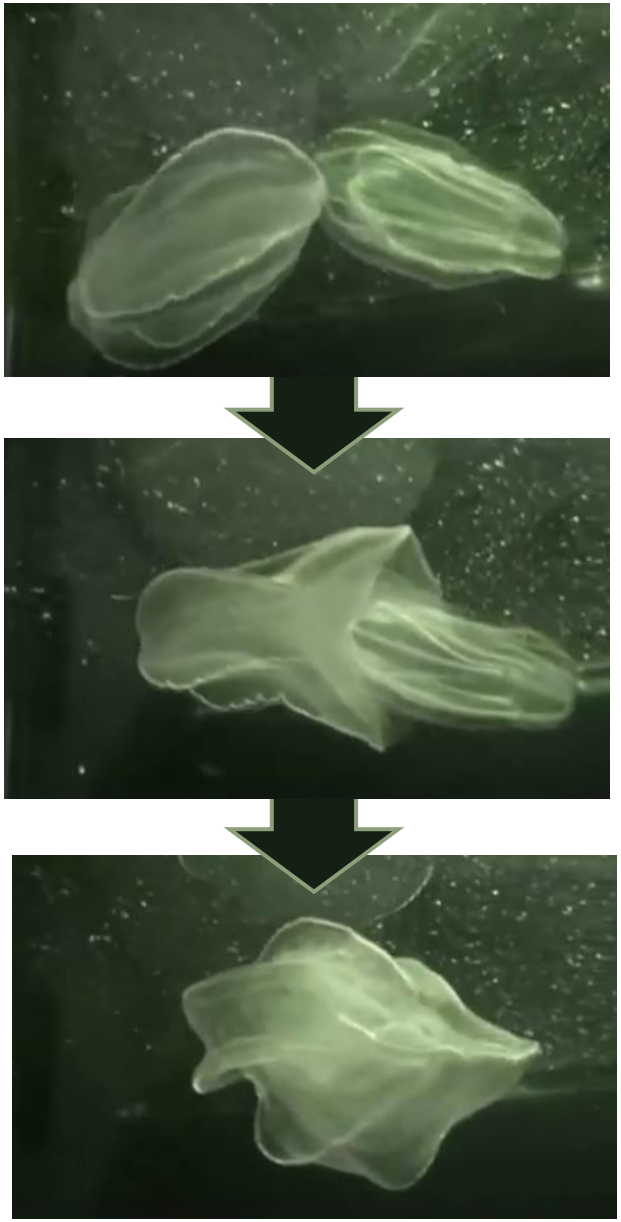
# Anticyclonic gyres forming in the northern Adriatic transport *M. leidyi* to the WIC.




There is a reservoir of *M. leidyi* in front of the Venetian Lagoon from which the northern Adriatic is recolonised every year.

Paliaga et al., 2021

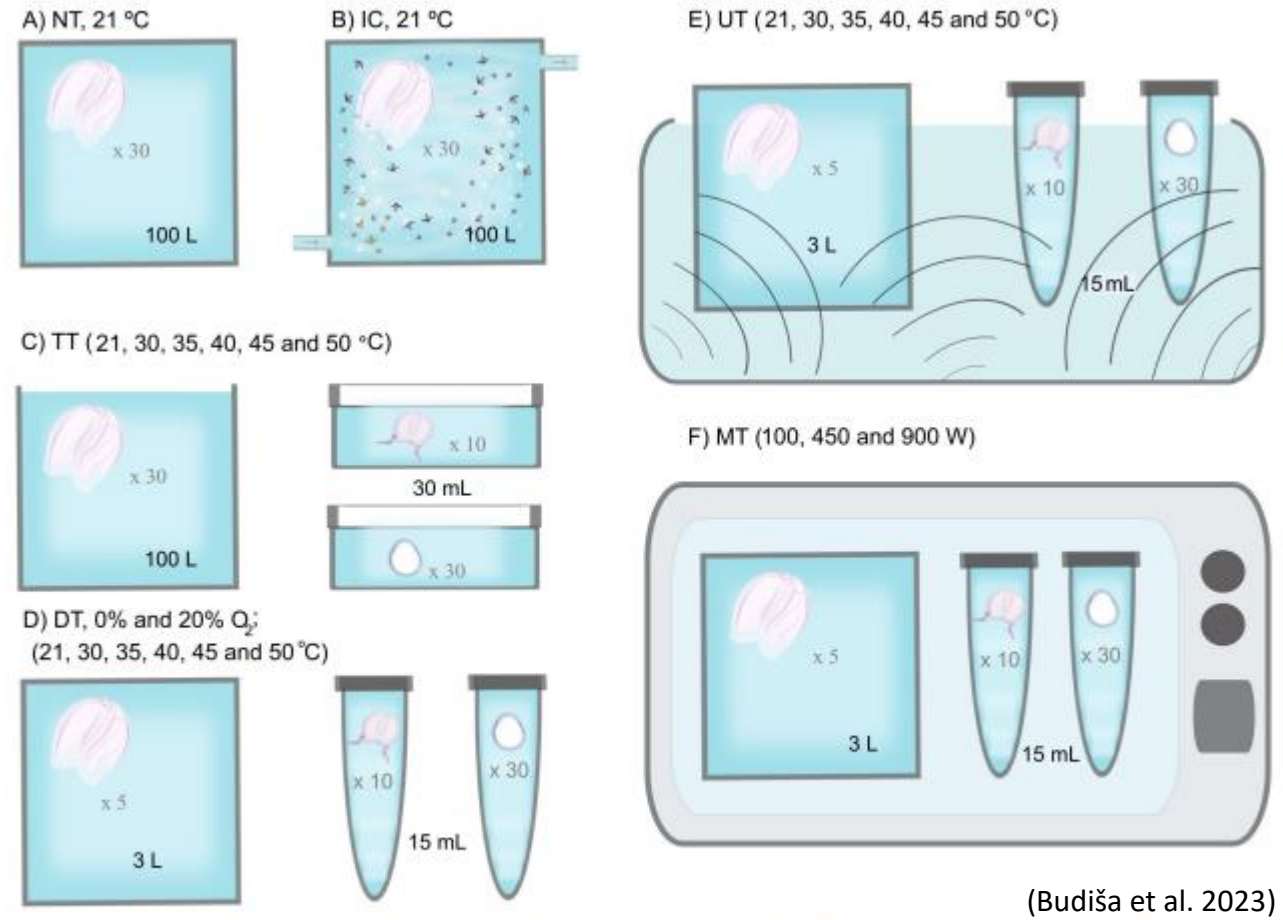
# *Beroe ovata* - a predator that could control *M. leidyi*



- Another ctenophora, autochthonous to the west Atlantic, has already established its population in the Black Sea.
- Physiological characteristics*:*
  dimensions 10-20 cm,
  brown-pink colour.
- Preys on zooplankton, especially other Ctenophorae.
- Back in 2005, it was found in the Gulf of Trieste, but it has not been encountered again until today.

# Preventive measures as alternative solutions

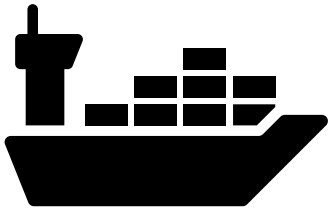
Laboratory experiments simulating different ballast water treatments.




(Budiša et al. 2023)

**Figure 1.** Experimental set-up for testing survival in A) stagnant closed tanks (NT), B) under ideal conditions with available food, air bubbles and water circulation (IC), C) thermic treatment in oxic, D) hypoxic and anoxic conditions (DT), E) thermal and ultrasound treatment (UT) and F) exposure to microwave radiation (MW). Treatments A-E were set in triplicates while F was repeated 6x.

# Ballast waters treatments



- A combination of heating and deoxygenation of ballast waters prevents the further spreading of *M. leidyi* by ships.

**Table 3.** Duration of ballast water treatment (TT and DT, anoxia) in variable conditions. (Budiša et al. 2023)

| Case scenario | Treatment | Seawater temperature (˚C) | Ambient air temperature (˚C) | Ballast water temperature (˚C) | Treatment duration (h) |
|---|---|---|---|---|---|
| 1.1 Worse | Temperature | 15 | 10 | 45 | 6.5 |
| 1.2 Worse | Temperature | 15 | 10 | 50 | 2.5 |
| 1.3 Worse | Temperature, $N_2$ | 15 | 10 | 35 | 6 |
| 1.4 Worse | Temperature, $N_2$ | 15 | 10 | 45 | 2.5 |
| 2.1 Most likely | Temperature | 20 | 15 | 45 | 6.5 |
| 2.2 Most likely | Temperature | 20 | 15 | 50 | 2.5 |
| 2.3 Most likely | Temperature, $N_2$ | 20 | 15 | 35 | 6 |
| 2.4 Most likely | Temperature, $N_2$ | 20 | 15 | 45 | 2.5 |
| 3.1 Best | Temperature | 25 | 25 | 45 | 6.5 |
| 3.2 Best | Temperature | 25 | 25 | 50 | 2.5 |
| 3.3 Best | Temperature, $N_2$ | 25 | 25 | 35 | 6 |
| 3.4 Best | Temperature, $N_2$ | 25 | 25 | 45 | 2.5 |

# Conclusions

The invasive ***M. leidyi*** affects numerous aspects of the northern Adriatic ecosystem on a seasonal scale because it is:

- is an **unselective and efficient predator** that feeds on **zooplankton**,
- **competes** with other consumers of zooplankton (such as **anchovies**) and can displace them from their natural habitats,
- **enriches** the surrounding **waters with organic matter and nutrients** which **fuel the microbial loop** and increase the abundance of prokaryotes and protists.
- **spreads** across the Adriatic by seasonal **gyres and geostrophic currents**.
- could be potentially controlled by introducing its natural predator *Beroe ovata*.

The **prevention** of *M. leidyi* spreading to other basins can be achieved by **thermal and deoxygenation treatments of ballast waters**.

# Scientific literature


Budiša A; Paliaga P; Juretić T, Lučić D; Supić N, Pasarić, Z, Djakovac T, Mladinić M, Dadić, V, Tičina V (2021) Distribution, diet and relationships of the invasive ctenophore *Mnemiopsis leidyi* with anchovies and zooplankton, in the northeastern Adriatic Sea 22(4):827-842. DOI: 10.12681/mms.23305.

Budiša A, Burić E, Blecich P, Matulja, T, Millotti G, Iveša, N Djakovac, T, Najdek M, Mičić M, Paliaga P (2023) Treating ballast waters to limit *Mnemiopsis leidyi* access to new habitats 14(2):E5JO0, 17.

Ciglenečki I, Paliaga P, Budiša A, Čanković M, Dautović J, Dutour-Sikirić M, Kraus R, Kužat N, Lučić D, Marić Pfannkuchen D et al. (2021) Dissolved organic carbon accumulation during a bloom of invasive gelatinous zooplankton *Mnemiopsis leidyi* in the northern Adriatic Sea; case of the anomalous summer in 2017. 222:103599, 19. DOI: 10.1016/j.jmarsys.2021.103599.

Malej A, Tirelli V, Lučić D, Paliaga P, Vodopivec M, Goruppi A, Ancona S, Benzi M, Bettoso N, Camatti E et al. (2017) *Mnemiopsis leidyi* in the northern Adriatic: here to stay? 124(6):10-16. DOI: 10.1016/j.seares.2017.04.010.

Pestorić, Branka ; Lučić, Davor ; Bojanić, Natalia ; Vodopivec, Martin ; Kogovšek, Tjaša ; Violić, Ivana ; Paliaga, Paolo ; Malej, Alenka (2021) Scyphomedusae and Ctenophora of the Eastern Adriatic: Historical Overview and New Data. 13(5)18: 28. DOI:10.3390/d13050186.

Paliaga, P Budiša, Andrea ; Dautović, Jelena ; Djakovac, Tamara ; Dutour-Sikirić M, Mihanović H, Supić N, Celić I, Iveša N, Buršić M et al. (2021) Microbial response to the presence of invasive ctenophore *Mnemiopsis leidyi* in the coastal waters of the northeastern Adriatic. 259:107459, 12. DOI: 10.1016/j.ecss.2021.107459.

Shiganova T, Alenka Malej A (2009) Native and non-native ctenophores in the Gulf of Trieste, Northern Adriatic Sea. Journal of Plankton Research, 31(1):61-71. DOI: 10.1093/plankt/fbn102.

# Thank you for your attention!

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