

# Diffusion of the Chemical contaminants and quality of fish products

Mauro Marini  
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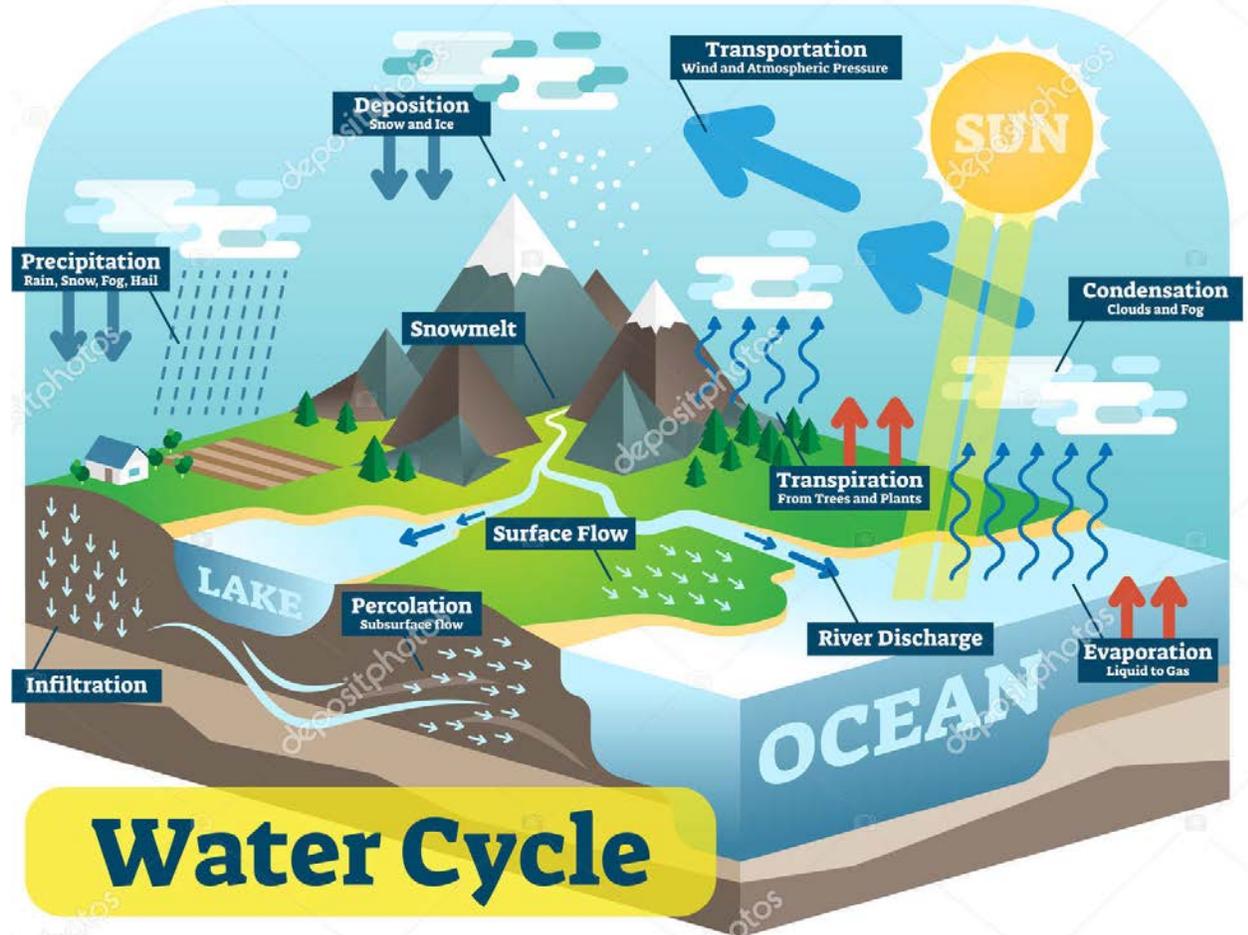
FISHMED-PhD  
Fano, 24-02-2026



FishMed-PhD



ALMA MATER STUDIORUM  
UNIVERSITÀ DI BOLOGNA



## Water Cycle

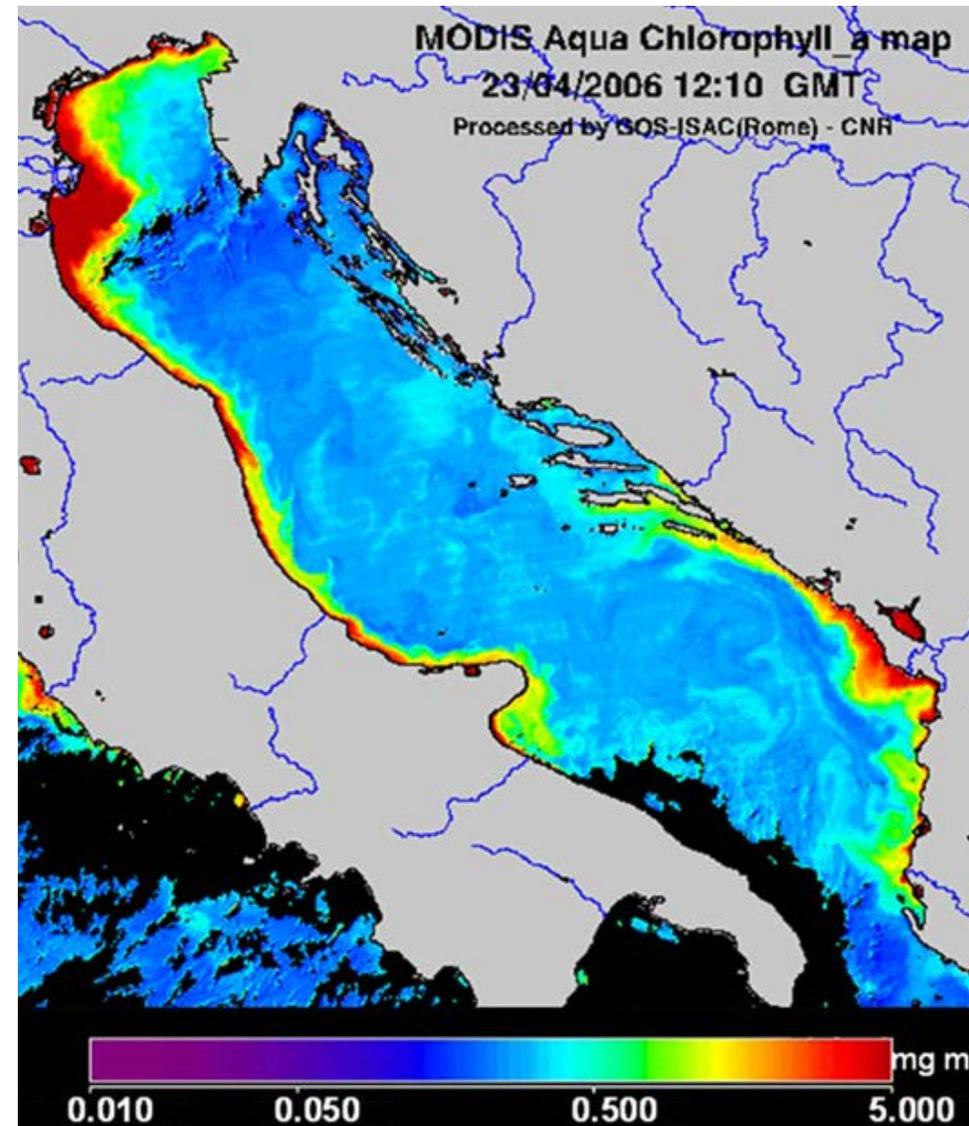
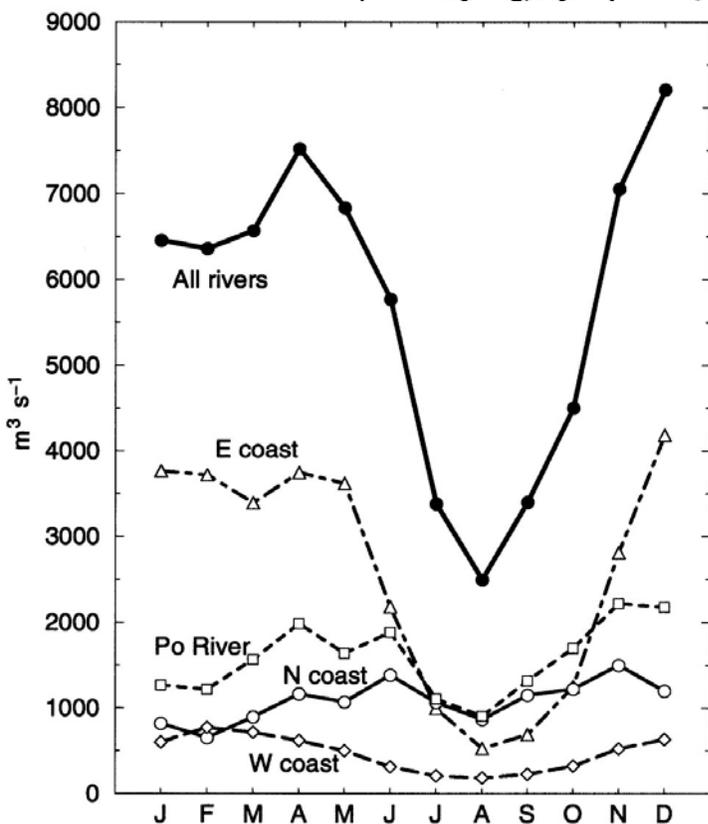
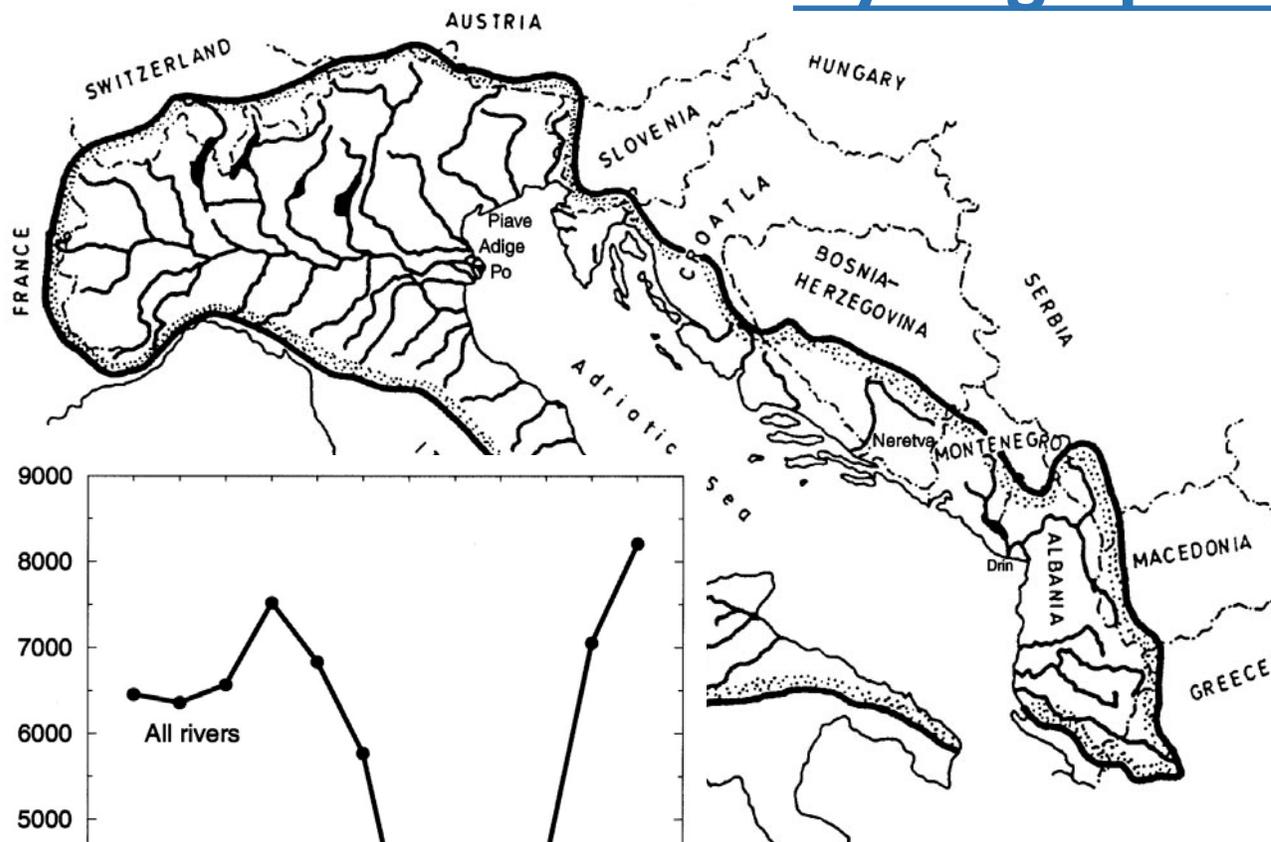
## **The exam to assess students' qualifications: one take-home essay.**

The exam will be limited to a maximum of two pages of text, plus figures (e.g., graphical abstract or specific figures with caption and title) and references

## Topics in this lesson:

1. Description of the Adriatic basin, main oceanographic processes.
2. Nutrients that reach the sea via rivers.
3. Organic contaminants that are dispersed in the sea, for example: polycyclic aromatic hydrocarbons, pesticides .....
4. Fate and accumulation of chemical contaminants in marine organisms.

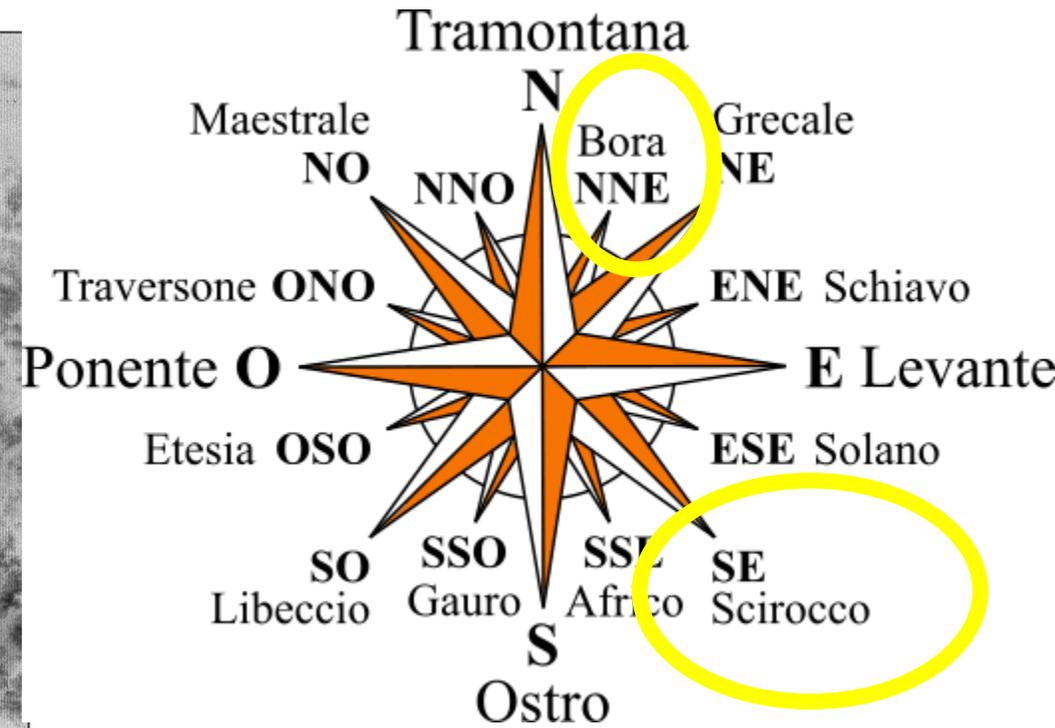
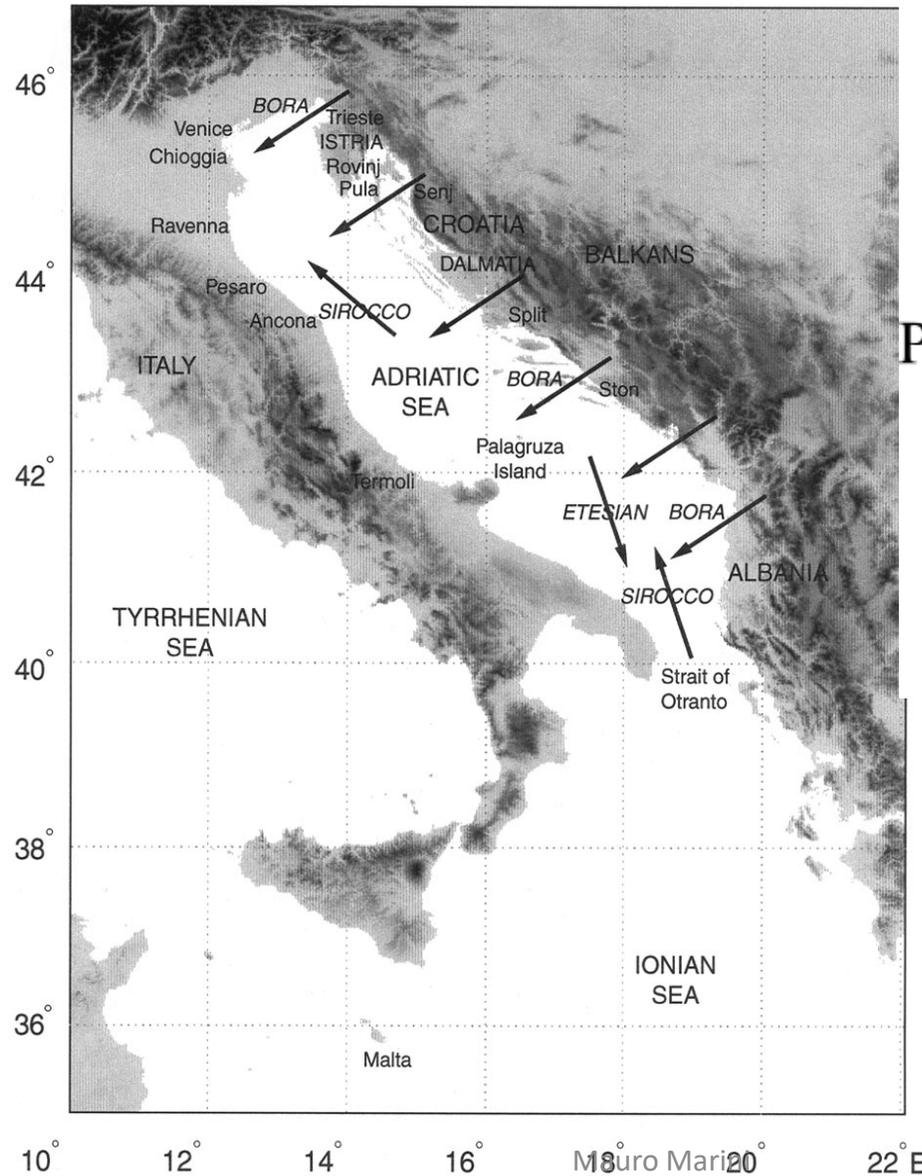
# Hydrographic basin of the Adriatic



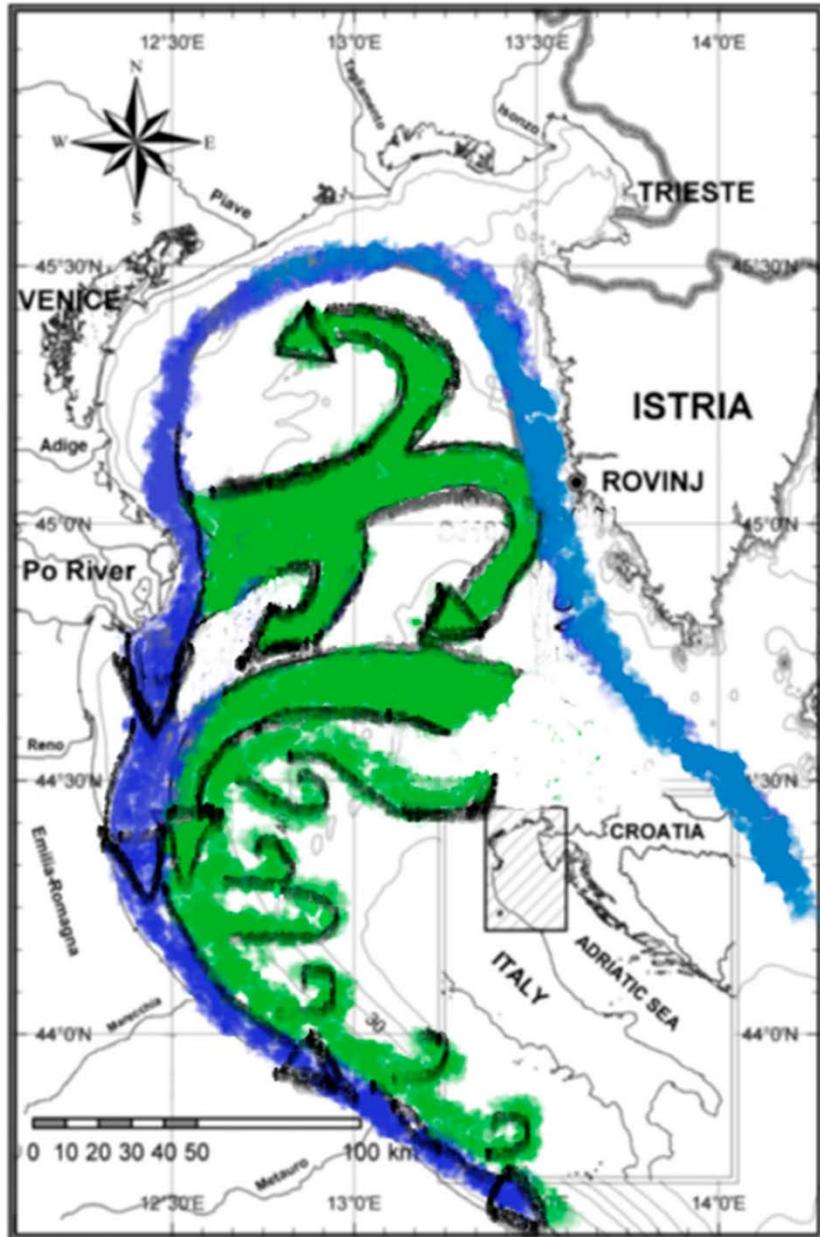
Cushman-Roisin, et al., Physical Oceanography of the Adriatic Sea: Past, Present and Future, 2001

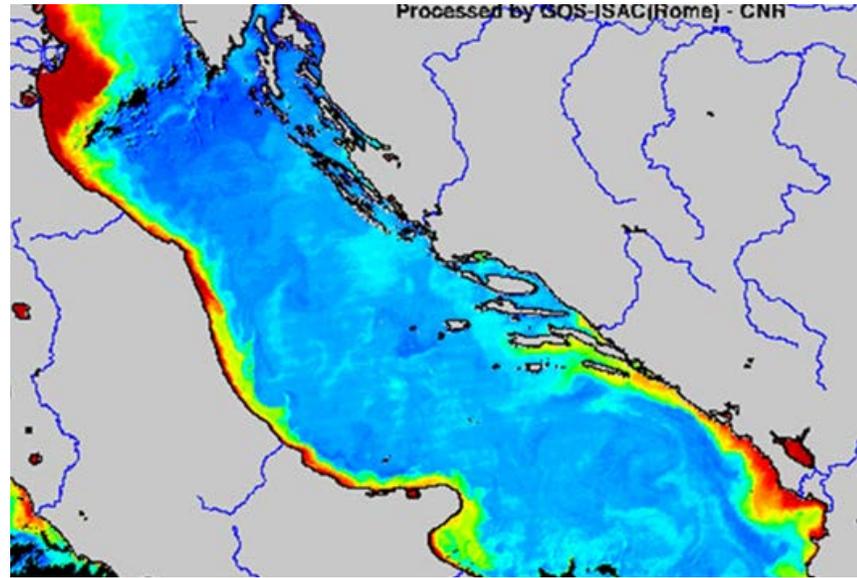
Mauro Marini

# Effect of winds on the catchment area

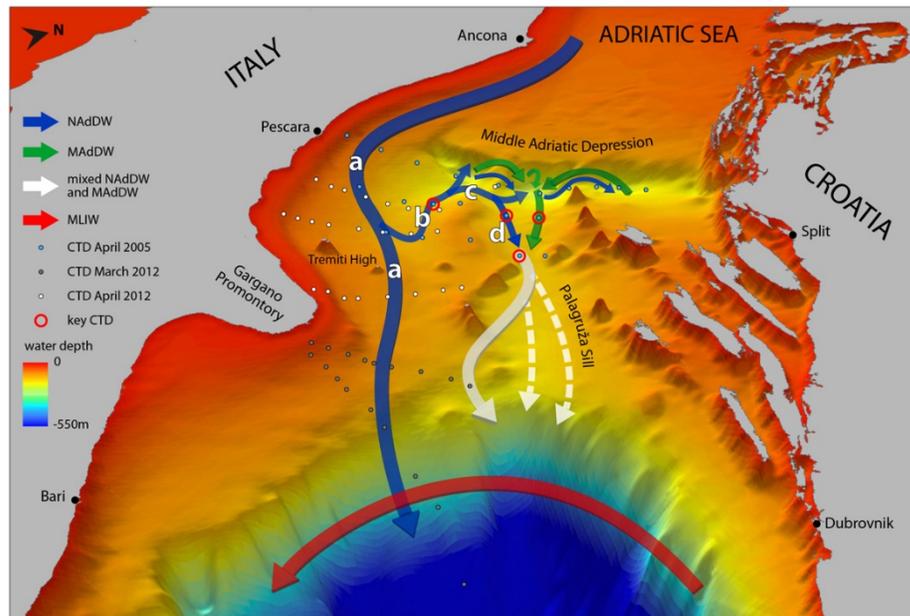
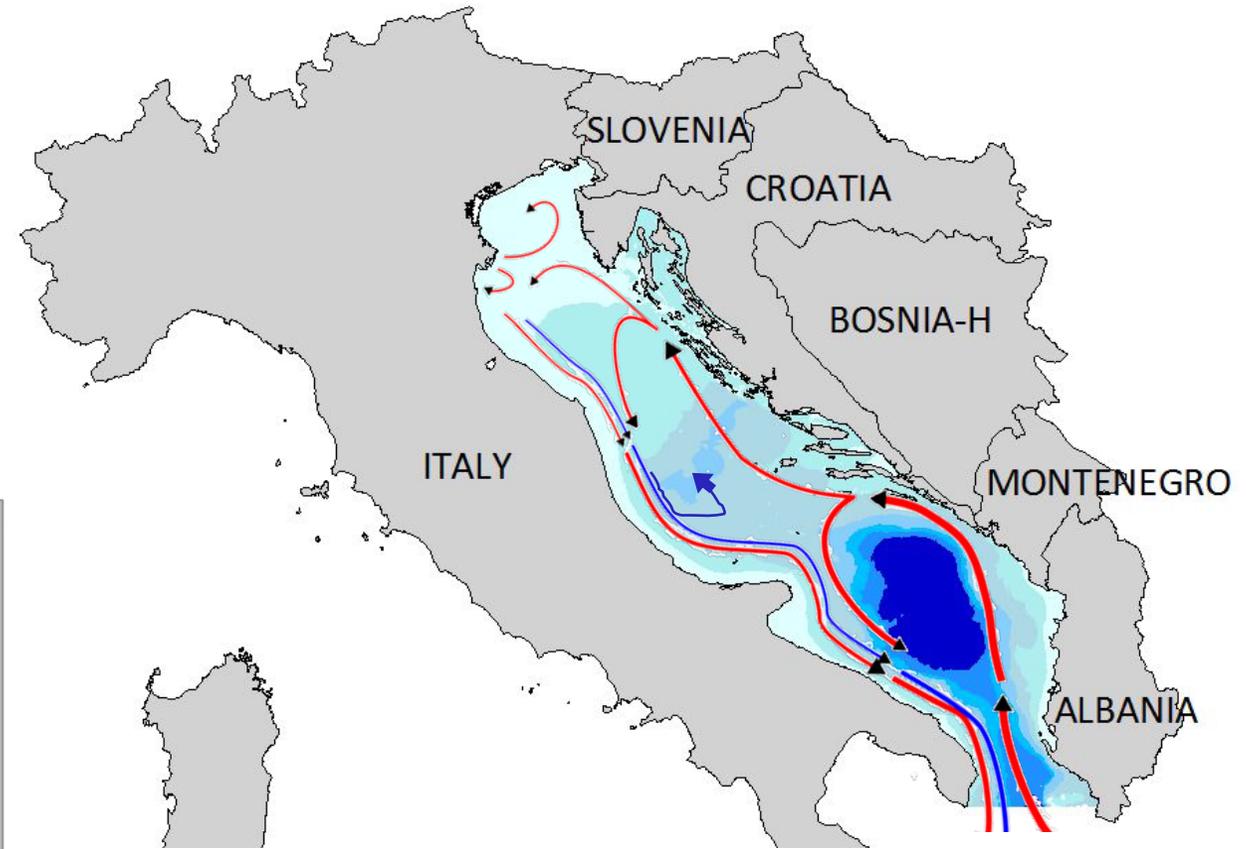


## Bathymetry of the Adriatic Sea





## Circulation of the Adriatic Sea



Marini et al., Marine Geology, 2016

Vol. 31: 227-237, 2006

CLIMATE RESEARCH  
Clim Res

Published July 27

### Short-term physical and chemical variations in the bottom water of middle Adriatic depressions

M. Marini<sup>1\*</sup>, A. Russo<sup>2</sup>, E. Paschini<sup>1</sup>, F. Grilli<sup>1</sup>, A. Campanelli<sup>1</sup>



# Dense water evolution in Mid Adriatic depression

Marine Geology 375 (2016) 5–14

Contents lists available at ScienceDirect

Marine Geology

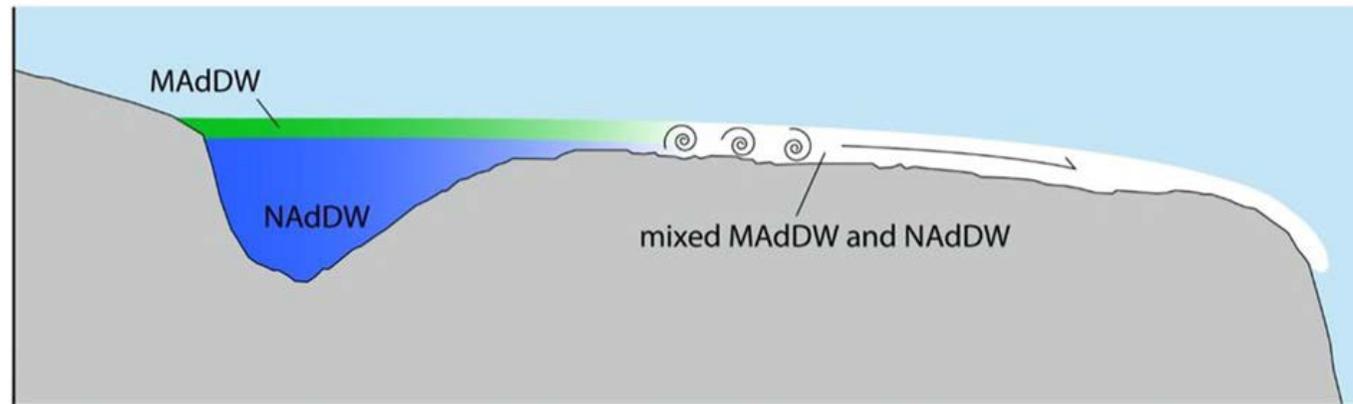
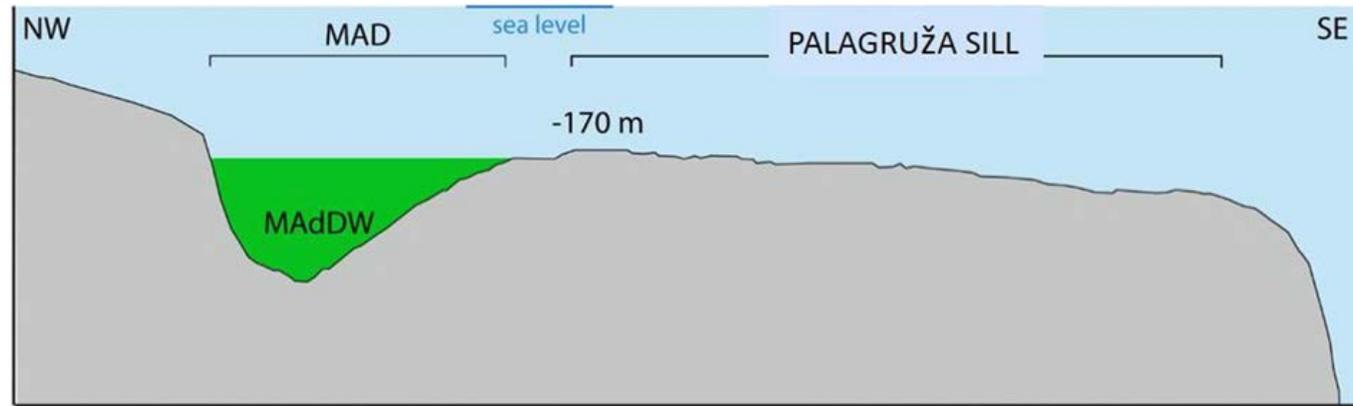
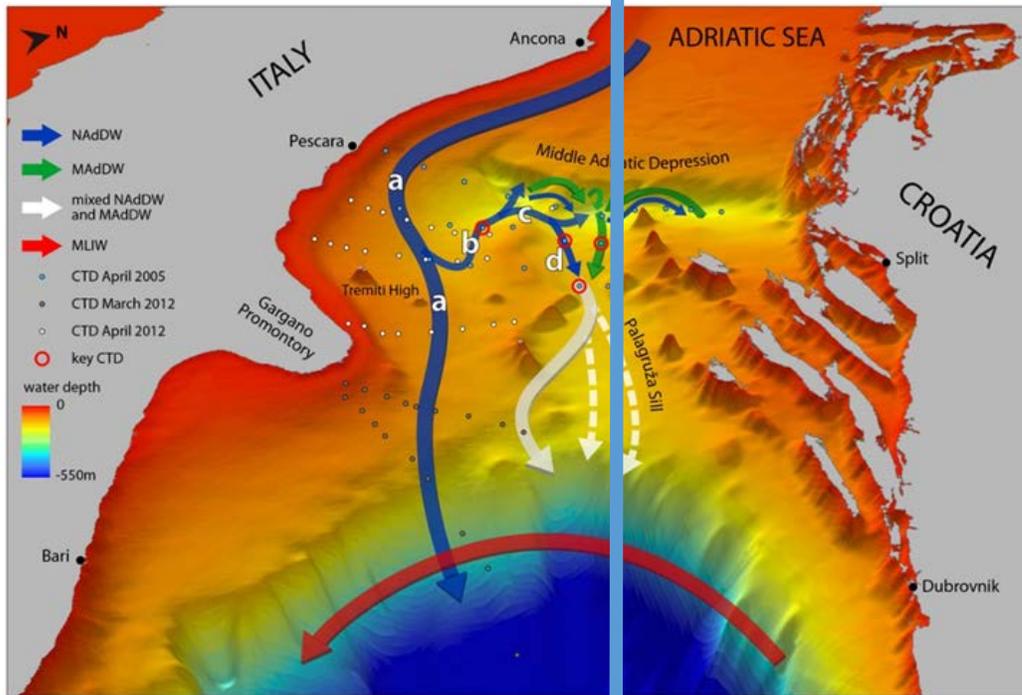
journal homepage: [www.elsevier.com/locate/margo](http://www.elsevier.com/locate/margo)



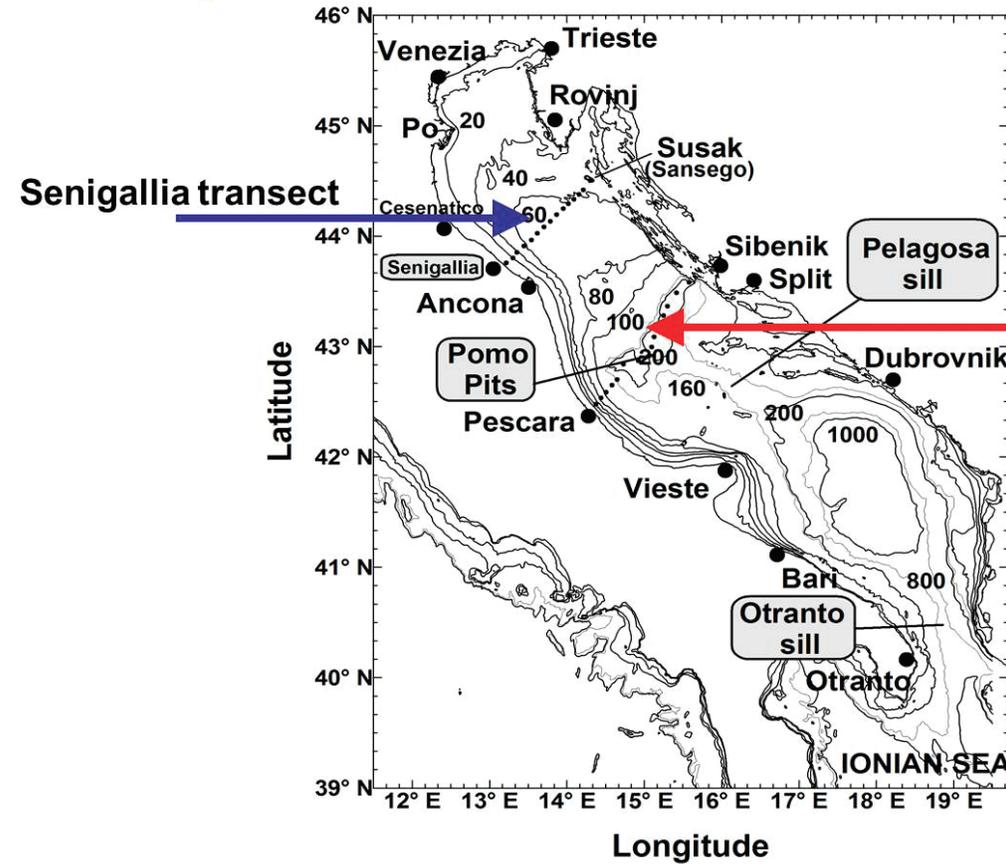
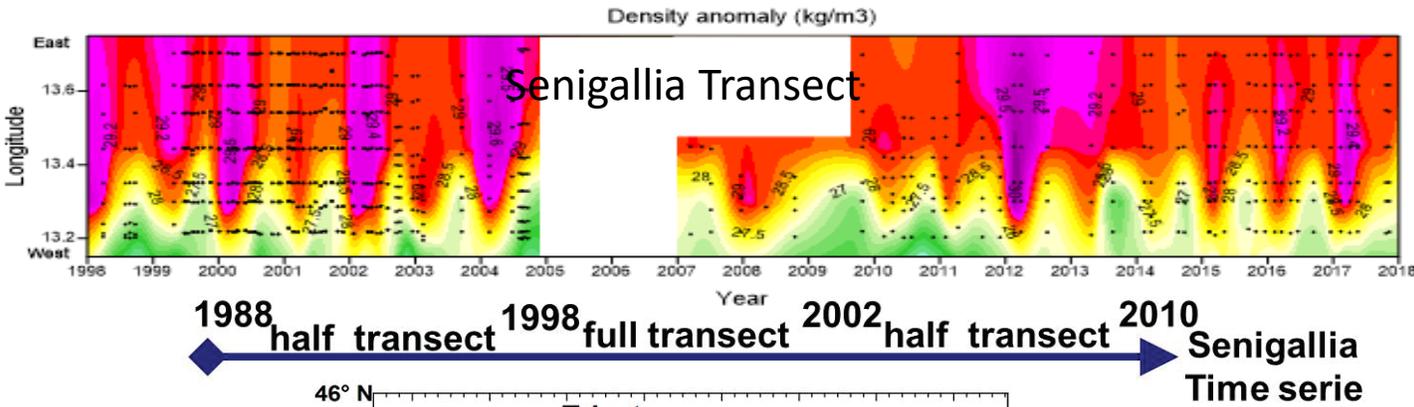
Role of the Mid-Adriatic deep in dense water interception and modification



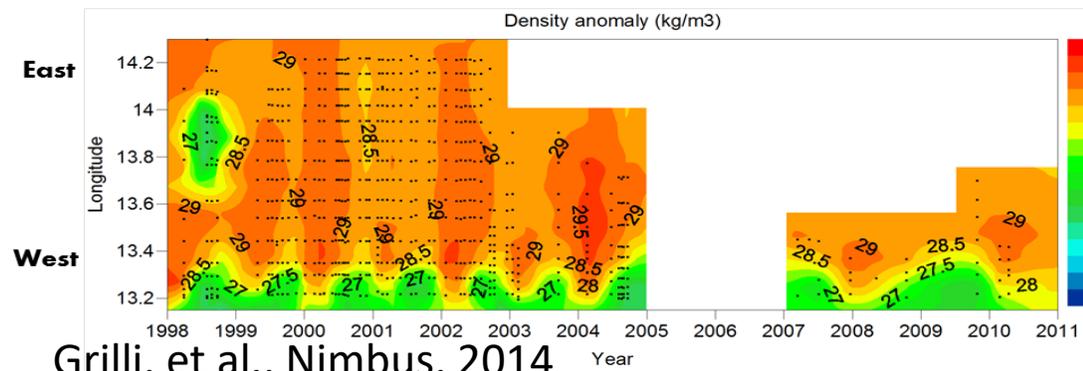
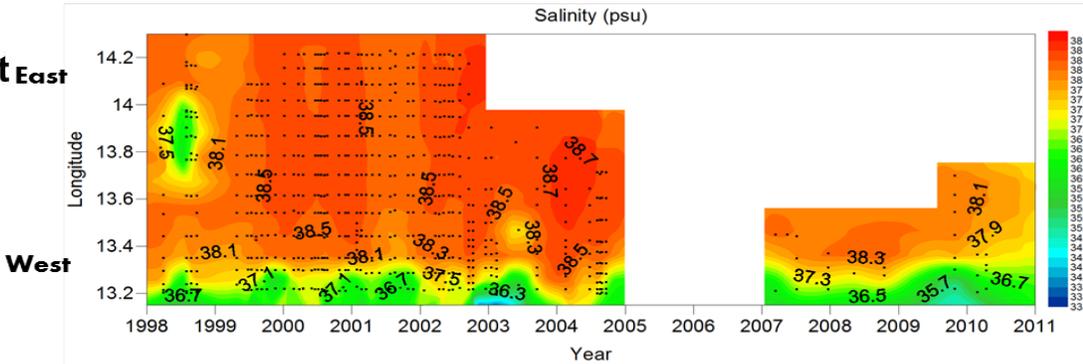
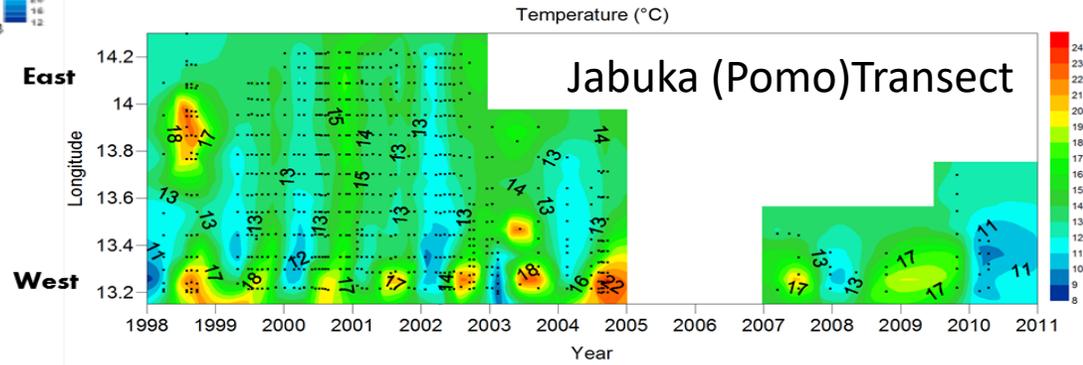
Mauro Marini <sup>a,\*</sup>, Vittorio Maselli <sup>b</sup>, Alessandra Campanelli <sup>a</sup>, Federica Foglini <sup>b</sup>, Federica Grilli <sup>a</sup>



Mauro Marini

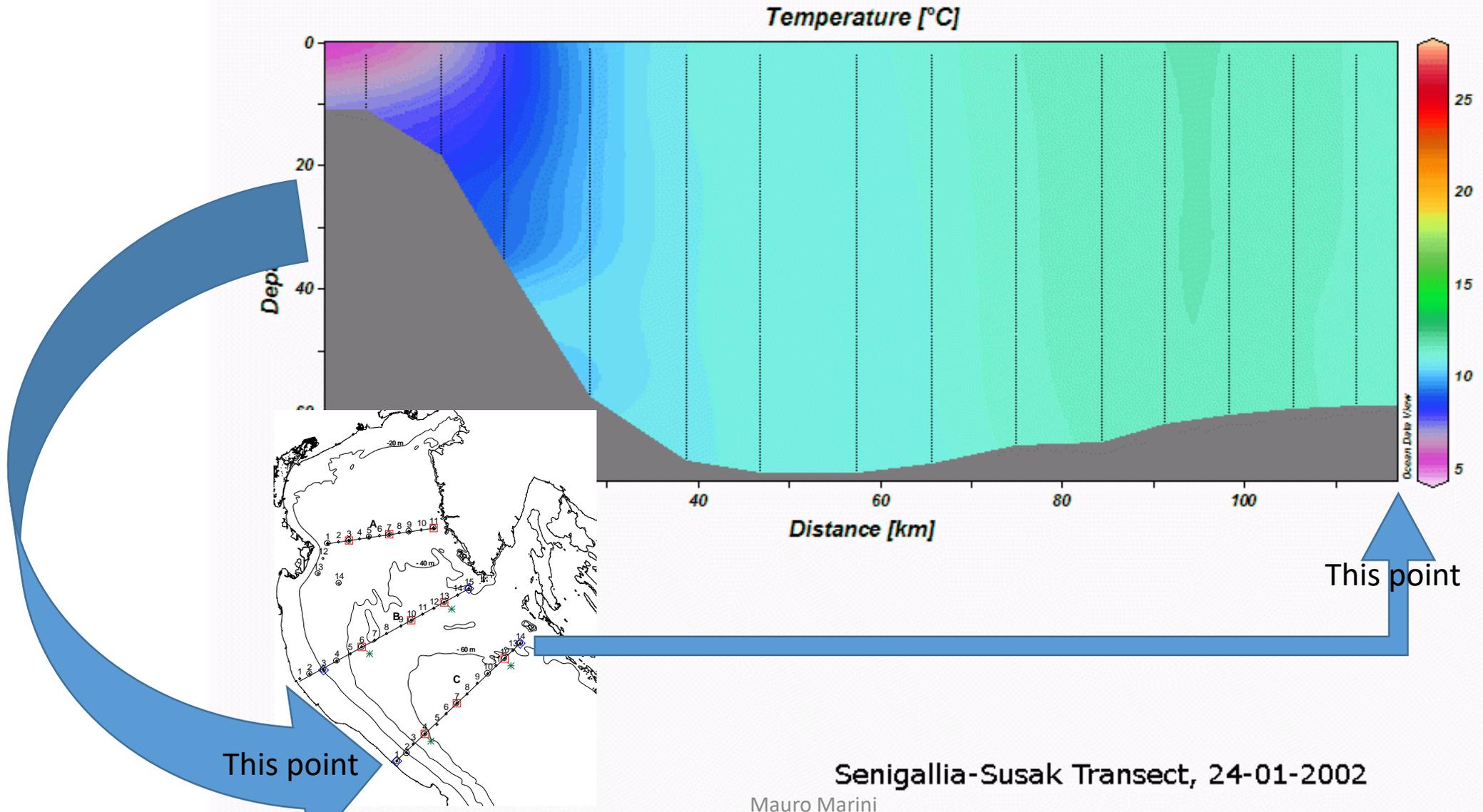


## Example of the time series





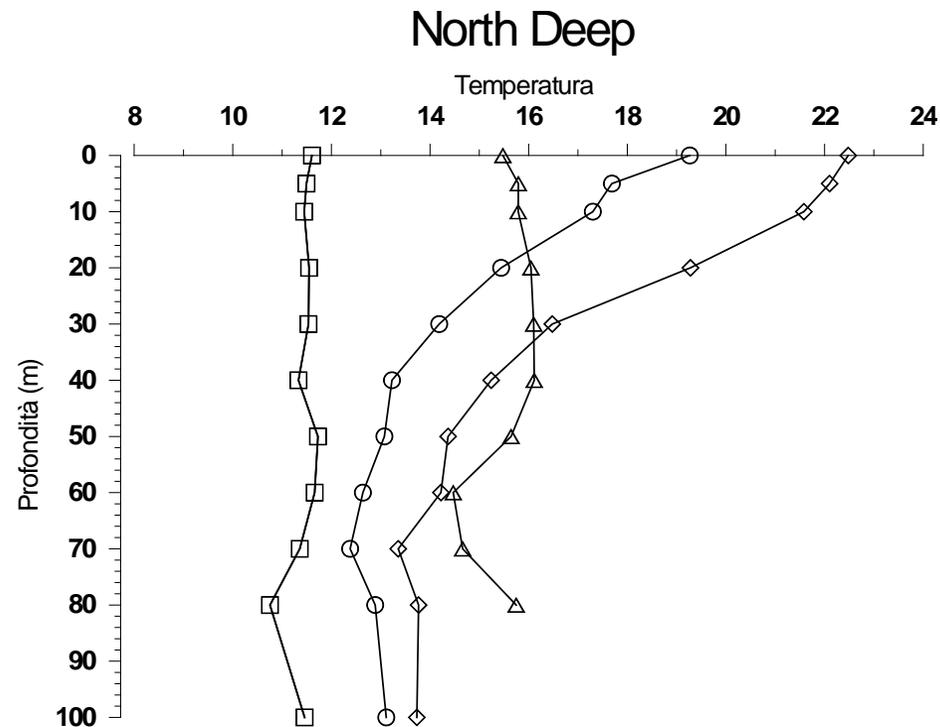
# Thermocline or double thermal layer in the transect of Senigallia



# Oceanographic seasons

Two databases were used to describe the thermal, saline and dynamic characteristics. For the Northern and Central basin, the [data base ATOS](#) (Adriatic Temperature, Oxygen and Salinity) made up of 5543 stations performed throughout the year from 1911 to 1983, while for the southern basin the [data base MATER](#) (Mass Transfer and Ecosystem Response) consisting of oceanographic data (from 1996 to 1999) relating to the measurements of physical and biochemical parameters in the water column. Spatial and seasonal averages were made for both.

- Artegiani *et al.*, 1997 [https://doi.org/10.1175/1520-0485\(1997\)027%3C1492:TASGCP%3E2.0.CO;2](https://doi.org/10.1175/1520-0485(1997)027%3C1492:TASGCP%3E2.0.CO;2)

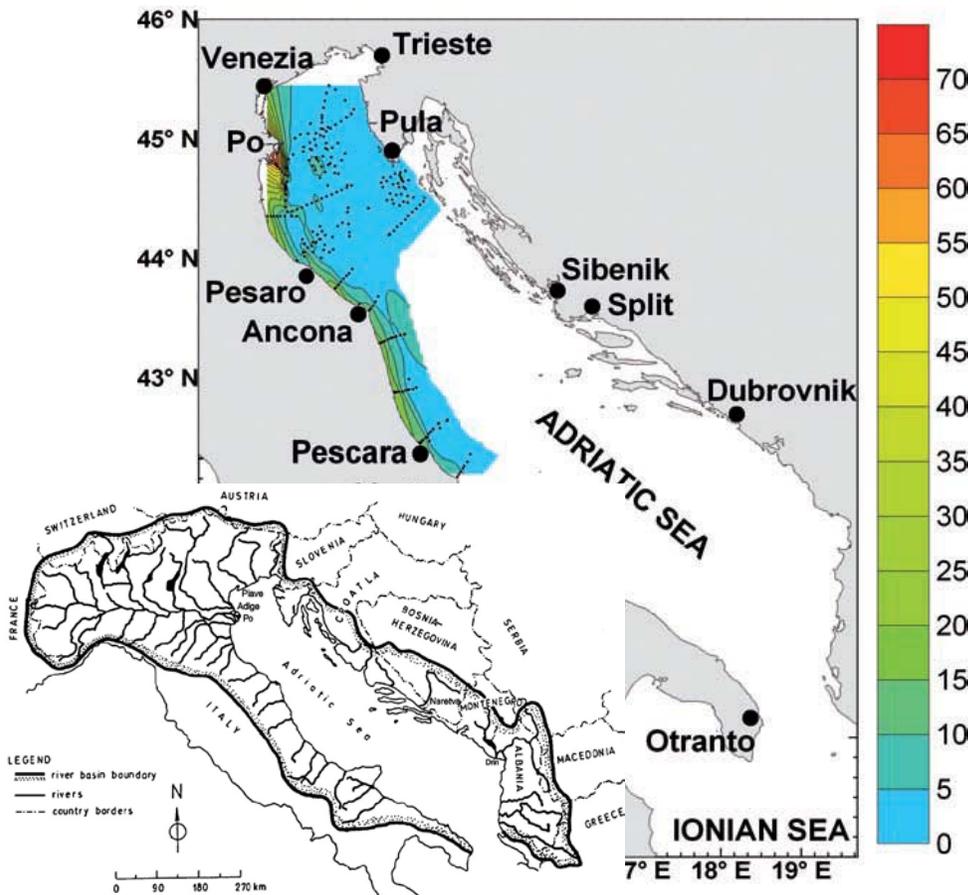


To define the [oceanographic seasons](#), we based ourselves on the trend of the average monthly heat flux at the sea surface. It turned out that the period during which **the sea loses heat**, i.e. [winter](#), runs from **January to April**, while the period during which **the sea receives heat**, i.e. the [summer period](#), runs from **July to October**. The transition period between winter and summer, i.e. [spring](#), are the **months of May and June** the transition period between summer and winter, i.e. [autumn](#), are the **months of November and December**.

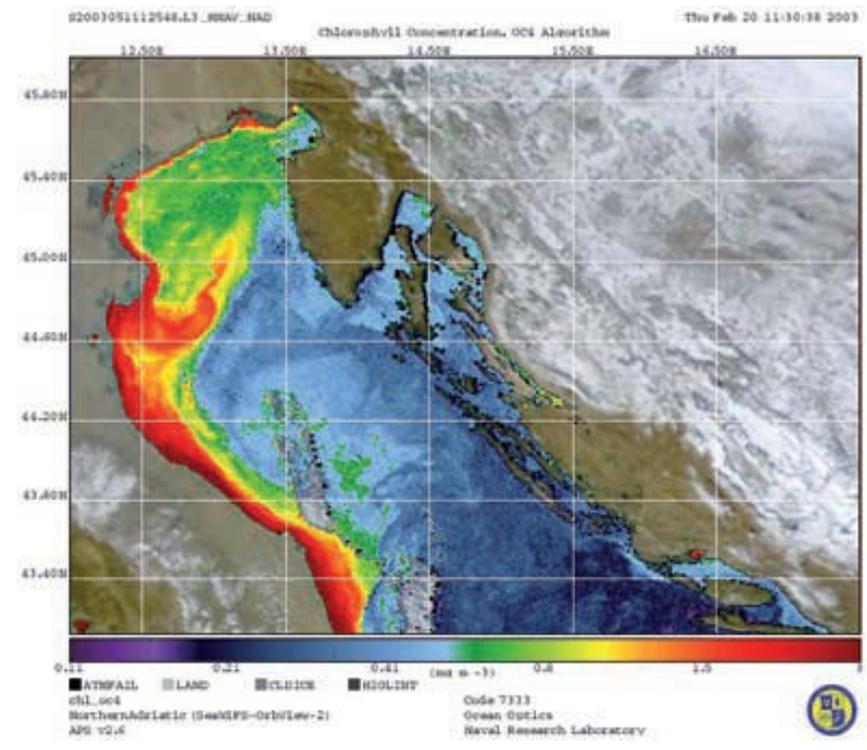
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# Winter surface distribution of dissolved inorganic nitrogen



*Spatial distribution of the concentration of dissolved inorganic nitrogen ( $\mu\text{M}$ ) on the surface in **February** 2003, the black dots represent the location of the measuring stations*



*Satellite image of surface distribution of chlorophyll concentration ( $\text{mg}/\text{m}^2$ ) dated **February** 20, 2003*

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, C05S90, doi:10.1029/2007JC004370, 2008

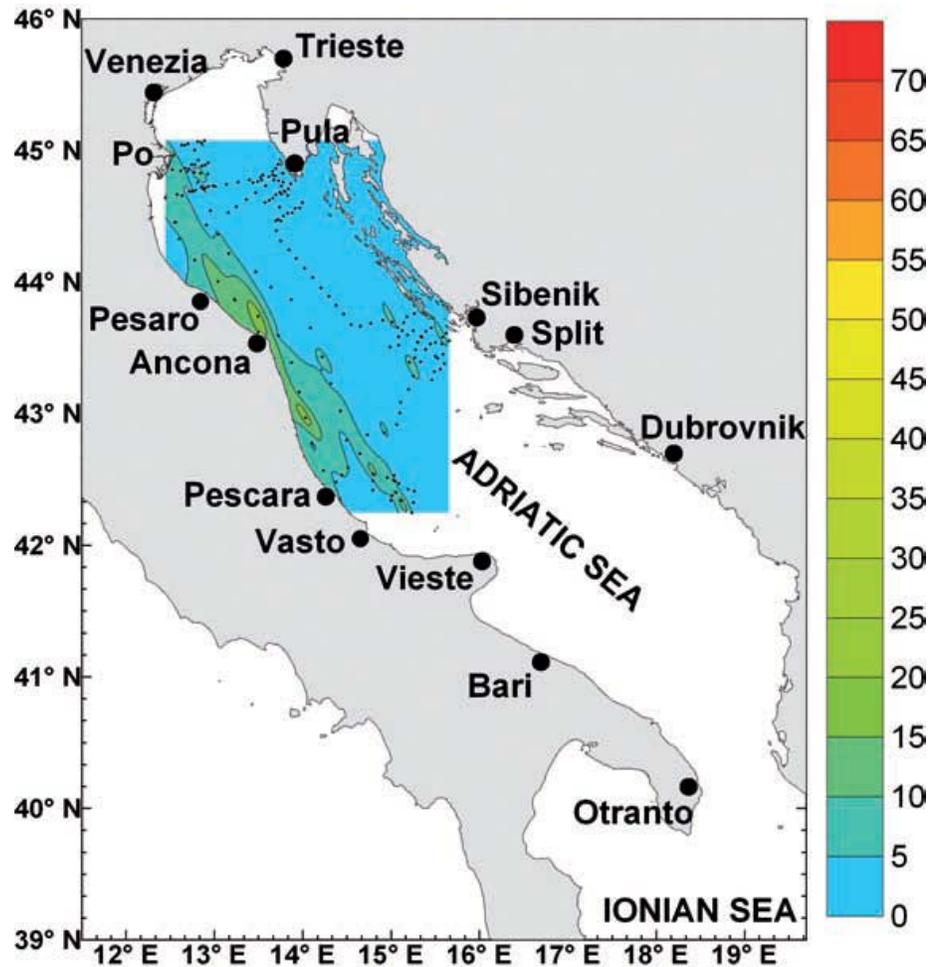
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## Seasonal variability and Po River plume influence on biochemical properties along western Adriatic coast

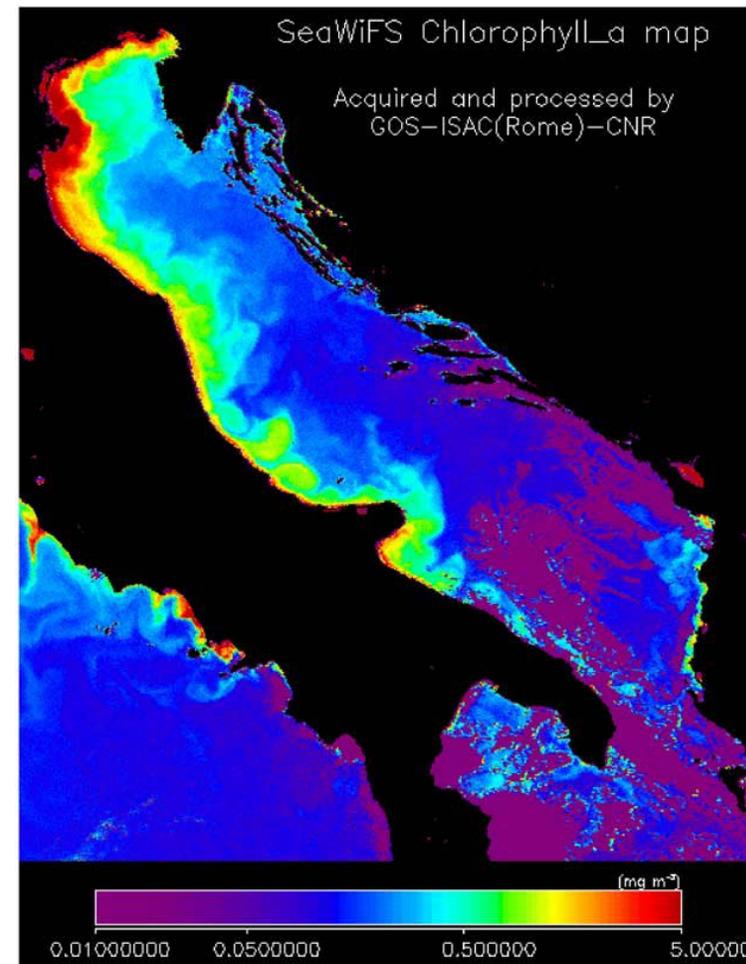
Mauro Marini,<sup>1</sup> Burt H. Jones,<sup>2</sup> Alessandra Campanelli,<sup>1</sup> Federica Grilli,<sup>1</sup> and Craig M. Lee<sup>3</sup>

Mauro Marini

# Summer surface distribution of dissolved inorganic nitrogen

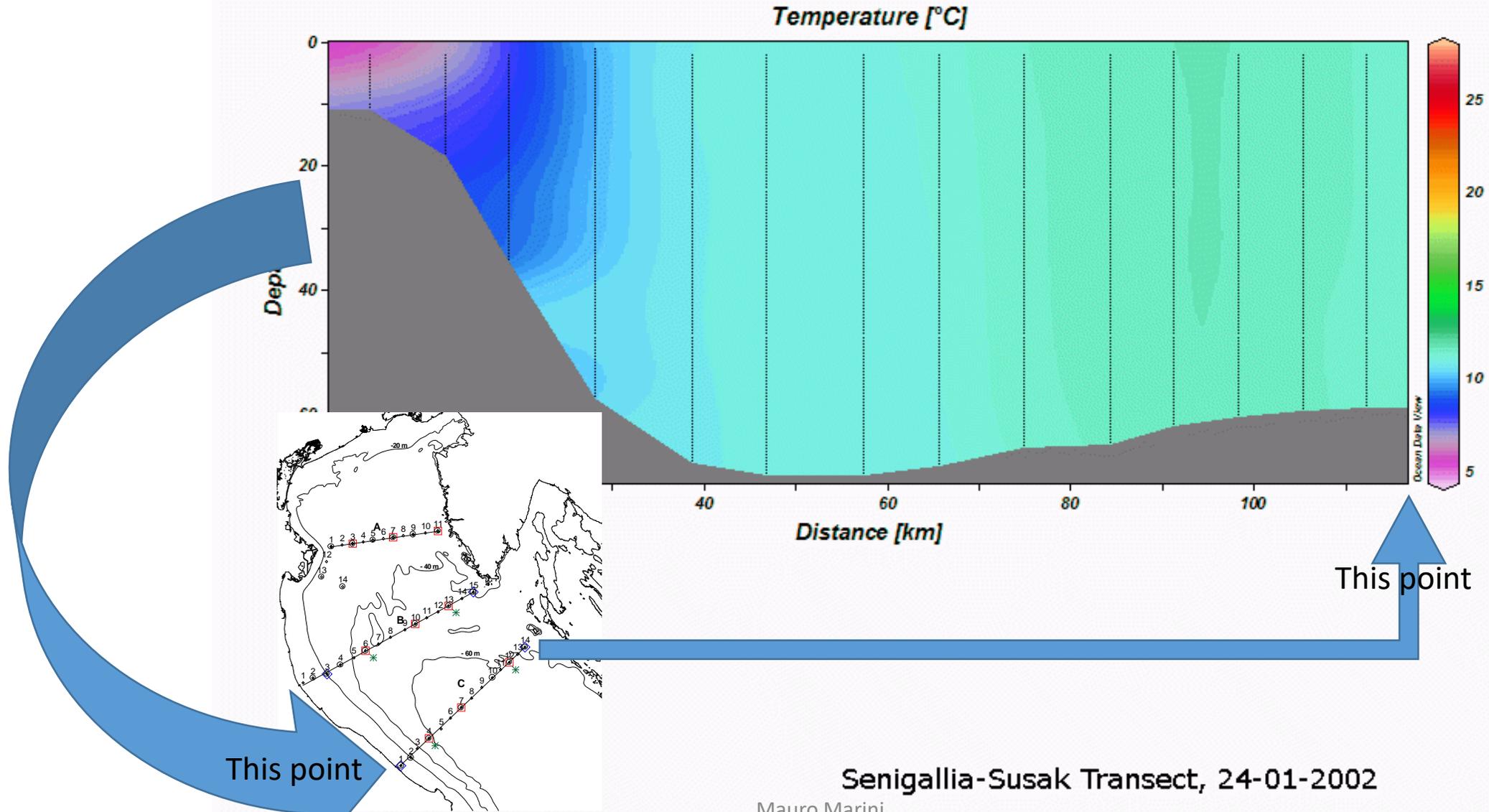


*Spatial distribution of **dissolved inorganic nitrogen** concentration ( $\mu\text{M}$ ) on the surface in the month of **May-June** 2003, the black dots represent the location of measuring stations.*

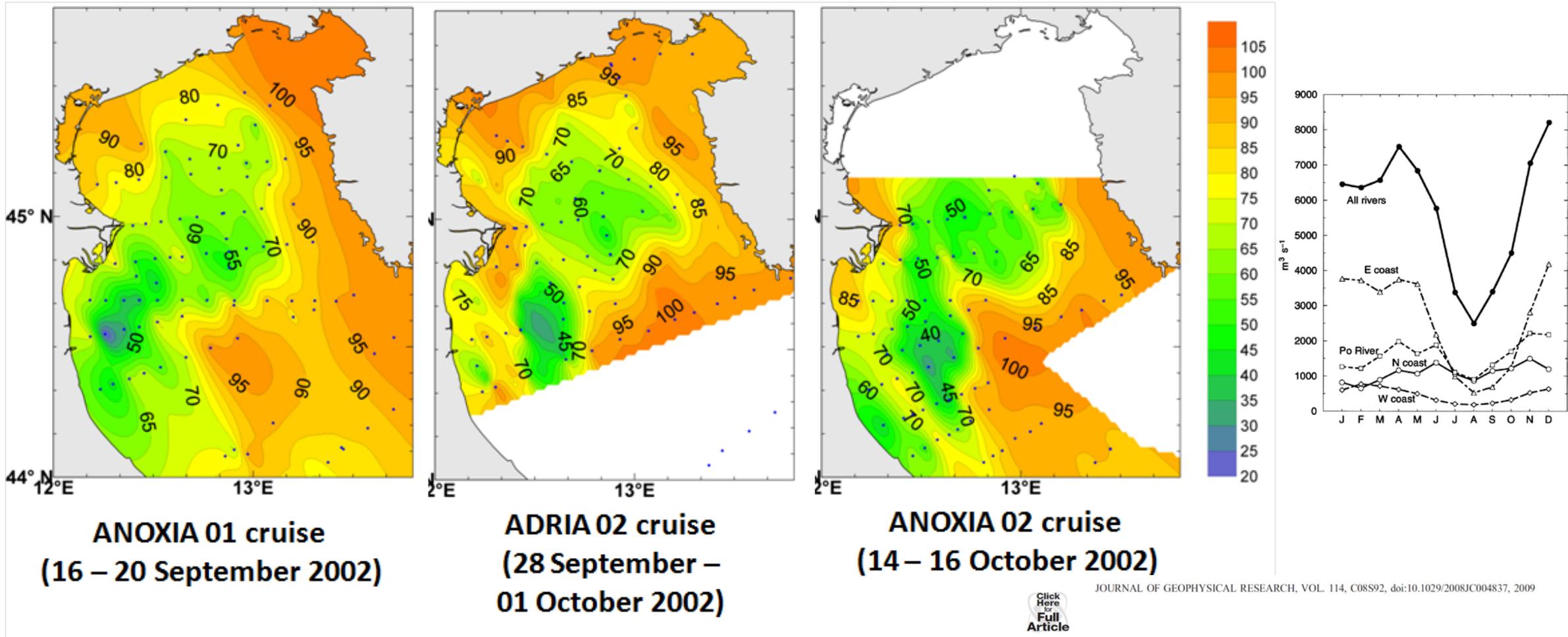


*Satellite image of the surface distribution of **chlorophyll** concentration ( $\text{mg}/\text{m}^2$ ) from **June** 4, 2003*

# Thermocline or double thermal layer in the transect of Senigallia



# Effect of the thermocline on coastal inputs. Hypoxia (% of oxygen saturation) on the waters of the bottom layer of the northern Adriatic.



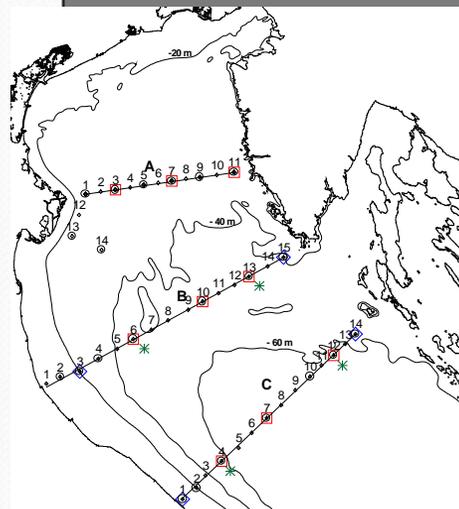
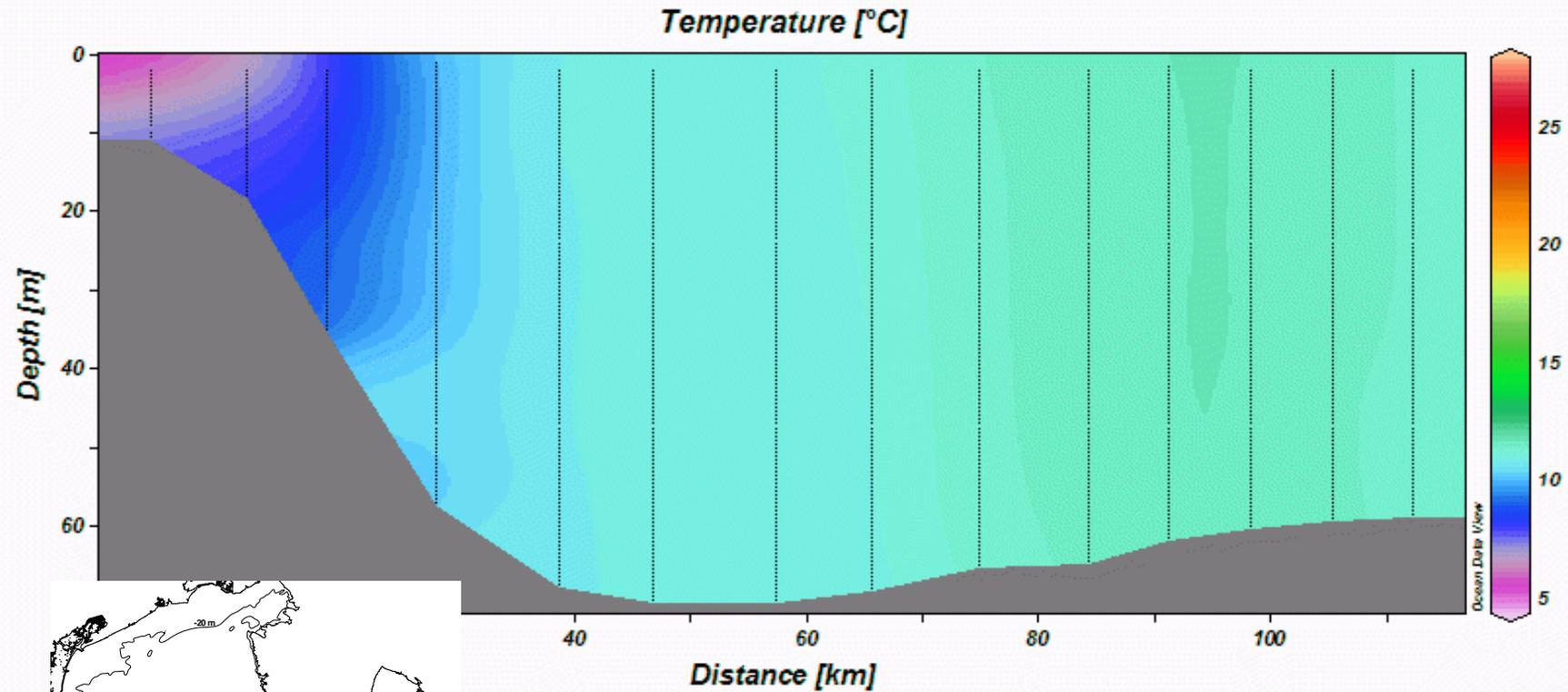
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 114, C08S92, doi:10.1029/2008JC004837, 2009

[Click Here for Full Article](#)

Effects of bora wind on physical and biogeochemical properties of stratified waters in the northern Adriatic

A. Boldrin,<sup>1</sup> S. Camiel,<sup>1</sup> M. Gianì,<sup>2</sup> M. Marini,<sup>3</sup> F. Bernardi Aubry,<sup>1</sup> A. Campanelli,<sup>3</sup> F. Grilli,<sup>3</sup> and A. Russo<sup>4</sup>

# Thermocline or double thermal layer transect of Senigallia



Senigallia-Susak Transect, 24-01-2002

Mauro Marini

# Example of seasonal maps obtained from historical series

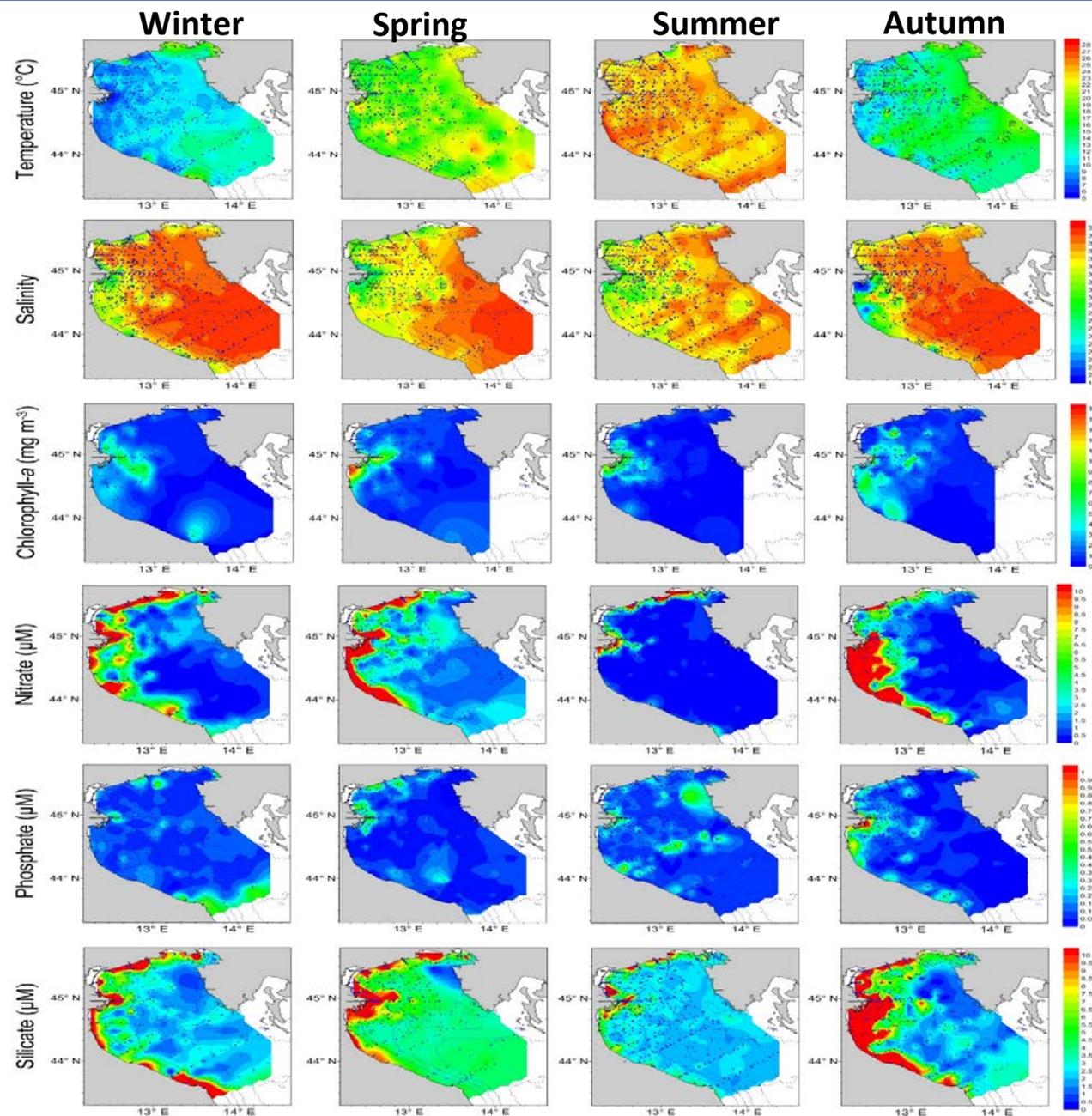
## Surface data



Article

### Seasonal and Interannual Trends of Oceanographic Parameters over 40 Years in the Northern Adriatic Sea in Relation to Nutrient Loadings Using the EMODnet Chemistry Data Portal

Federica Grilli <sup>1,\*</sup>, Stefano Accoroni <sup>2,3</sup>, Francesco Acri <sup>4</sup>, Fabrizio Bernardi Aubry <sup>4</sup>, Caterina Bergami <sup>5</sup>, Marina Cabrini <sup>6</sup>, Alessandra Campanelli <sup>1</sup>, Michele Gianì <sup>6</sup>, Stefano Guicciardi <sup>1</sup>, Mauro Marini <sup>1,3</sup>, Francesca Neri <sup>2</sup>, Antonella Penna <sup>3,7</sup>, Pierluigi Penna <sup>1</sup>, Alessandra Pugnetti <sup>4</sup>, Mariangela Ravaioli <sup>5</sup>, Francesco Riminucci <sup>5,8</sup>, Fabio Ricci <sup>3,7</sup>, Cecilia Totti <sup>2</sup>, Pierluigi Viaroli <sup>9</sup> and Stefano Cozzi <sup>10</sup>



# Italian oceanographic vessels used for these research



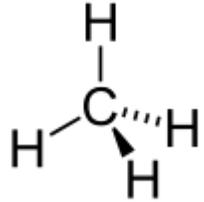
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# What are hydrocarbons?

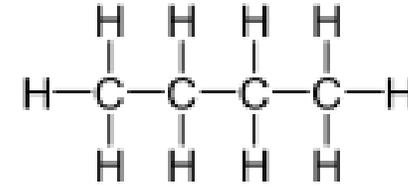
Wide range of organic compounds containing only C and H atoms.

They are divided into two main categories:



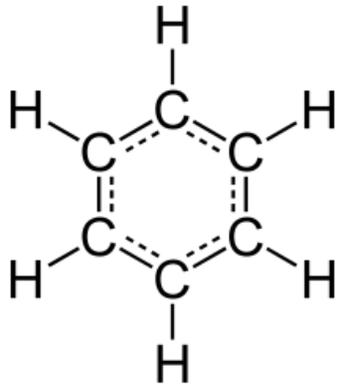
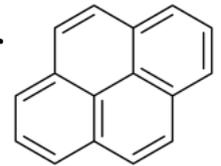
**Methane**

**Alifatic, linear chains e.g. Butane C<sub>4</sub>H<sub>10</sub>**



**Polycyclic Aromatic Hydrocarbons (PAH), multiple aromatic rings linked together**

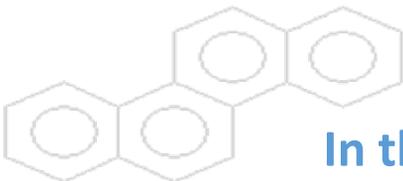
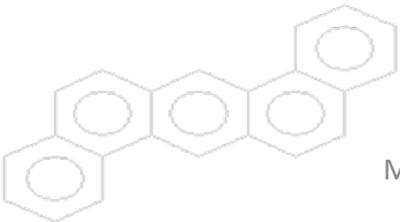
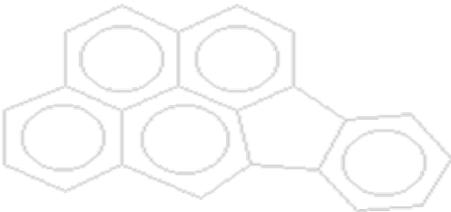
**e.g. Pirene C<sub>16</sub>H<sub>10</sub>**



**Benzene**

- Light low molecular weight PAHs (2-3 rings condensed)
- Medium Molecular Weight IPA (4 rings condensed)
- Heavy high molecular weight PAHs (5-6 rings condensed)

STRONGLY LIPOPHILIC

<i>Naftalene</i>	<i>Acenaftilene</i>	<i>Acenaftene</i>	<i>Fluorene</i>
			
<p><b><u>Polycyclic aromatic hydrocarbons are organic compounds (consisting of C and H atoms) belonging to a class of hydrocarbons characterized by the presence in their chemical structure of at least two condensed aromatic rings.</u></b></p>			
<i>Crisene</i>	<i>Benzo(a)antracene</i>	<i>Benzo(b)fluorantene</i>	<i>Benzo(k)fluorantene</i>
			
<p>In the background are examples of molecular structures.</p>			
<i>Benzo(a)pirene</i>	<i>Dibenzo(a,h)antracene</i>	<i>Benzo(g,h,i)perilene</i>	<i>Indeno(1,2,3,c,d)pirene</i>
			

## SOURCES OF HYDROCARBONS

### NATURAL

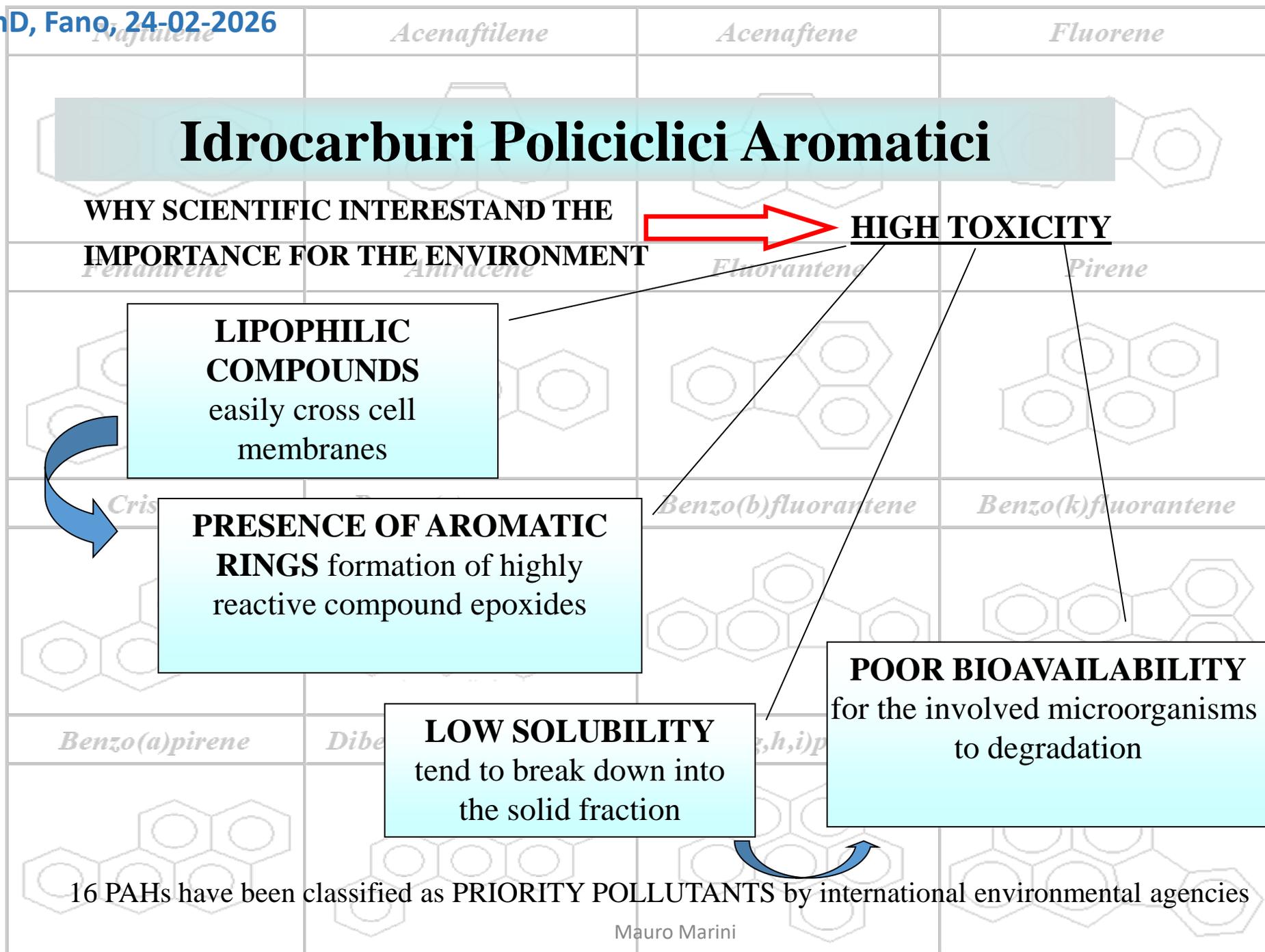


- Volcanic eruptions
- Forest fires
- Synthesized by plant organisms
- ...

### ANTROPOGENIC



- Industries
- Oil processing
- Motor vehicle emissions
- ...



16 PAHs have been classified as PRIORITY POLLUTANTS by international environmental agencies

# DISPERSION Polycyclic Aromatic Hydrocarbons

## ROLE OF RIVERS

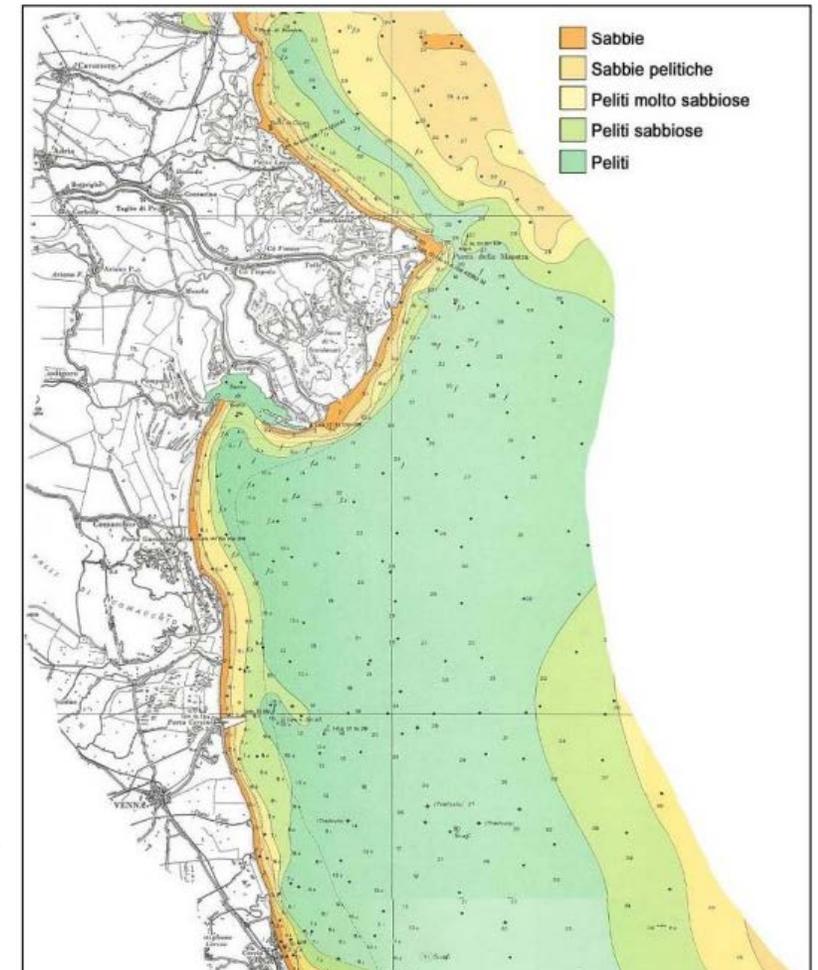
The deposition of suspended particulate increases the phenomena of accumulation of PAHs in the sediment

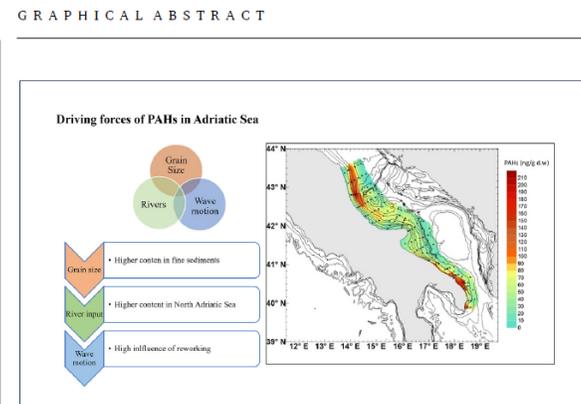
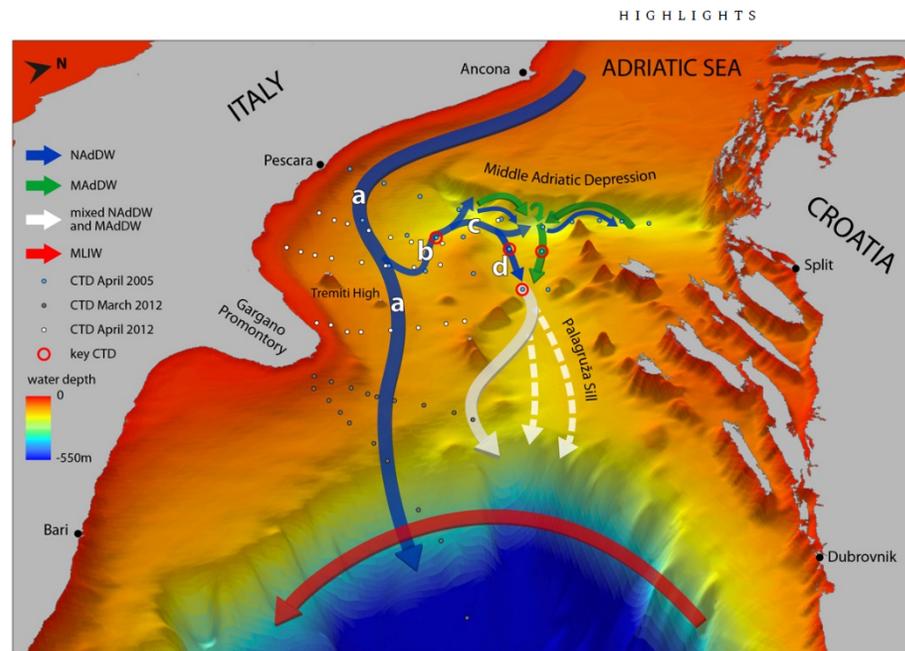
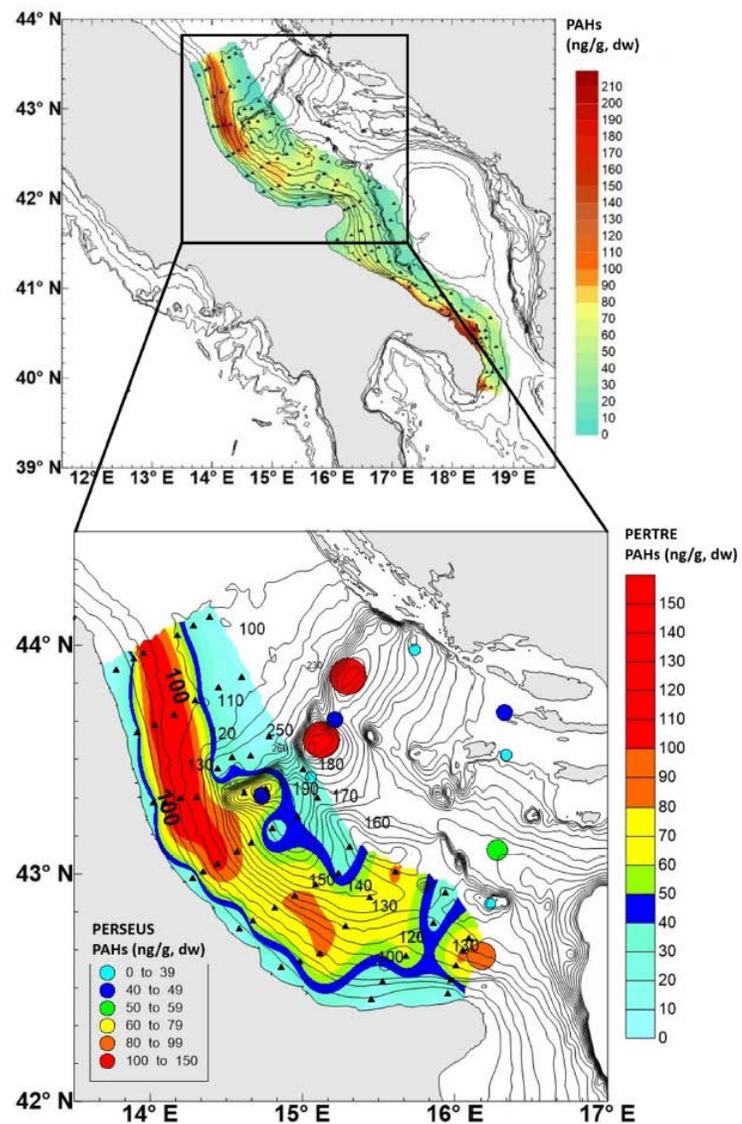
## GRANULOMETRY OF THE SEDIMENT

PAHs are found in highest concentration in fine sediment ( $< 2 \mu\text{m}$ ). Fine particles adsorb more as they have a larger specific surface area

- The PAHs that we find in the Adriatic come mainly from anthropic sources and have a pyrolytic origin (combustion of organic material). Low PM/High PM  $< 1$ .
- The mainly polluted areas are the Po Delta (333.9 ng/g d.w.); the Gulf of Trieste ( $> 500$  ng/g d.w.). The Ancona area is less polluted (184.6 ng/g d.w.). The quantification of PAHs contained in marine sediments is of the order of ppb, these values can be considered moderately low.
- The presence of PAHs decreases going from the western to the eastern Adriatic and from the coast to the open sea

Mauro Marini

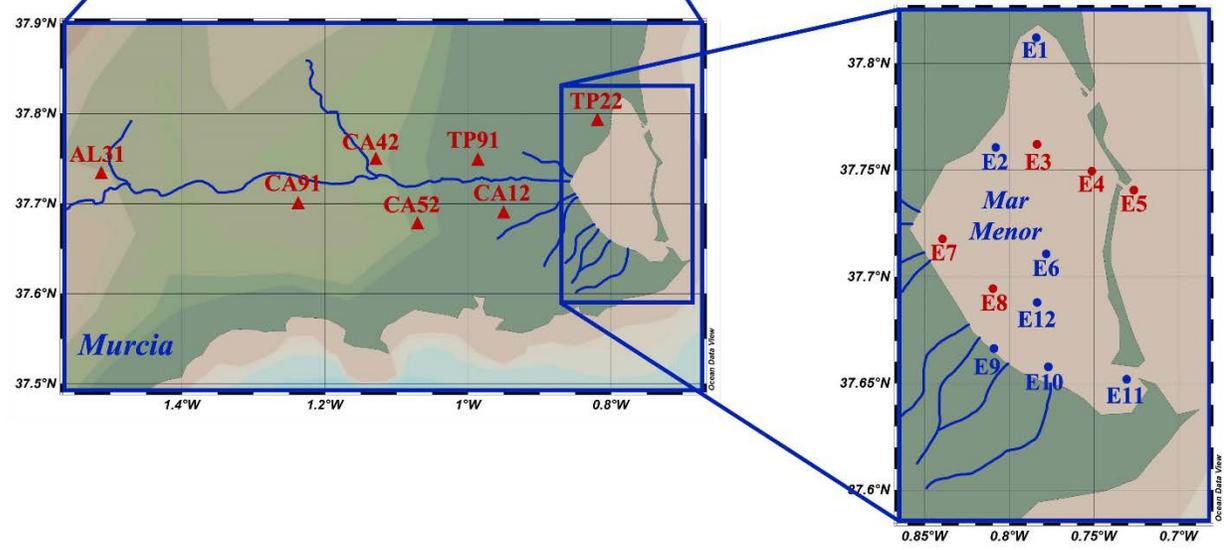
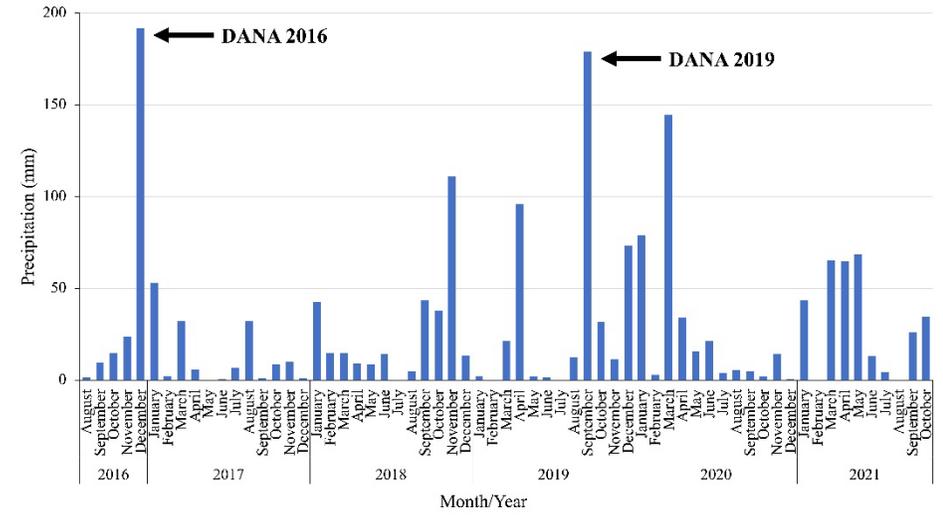
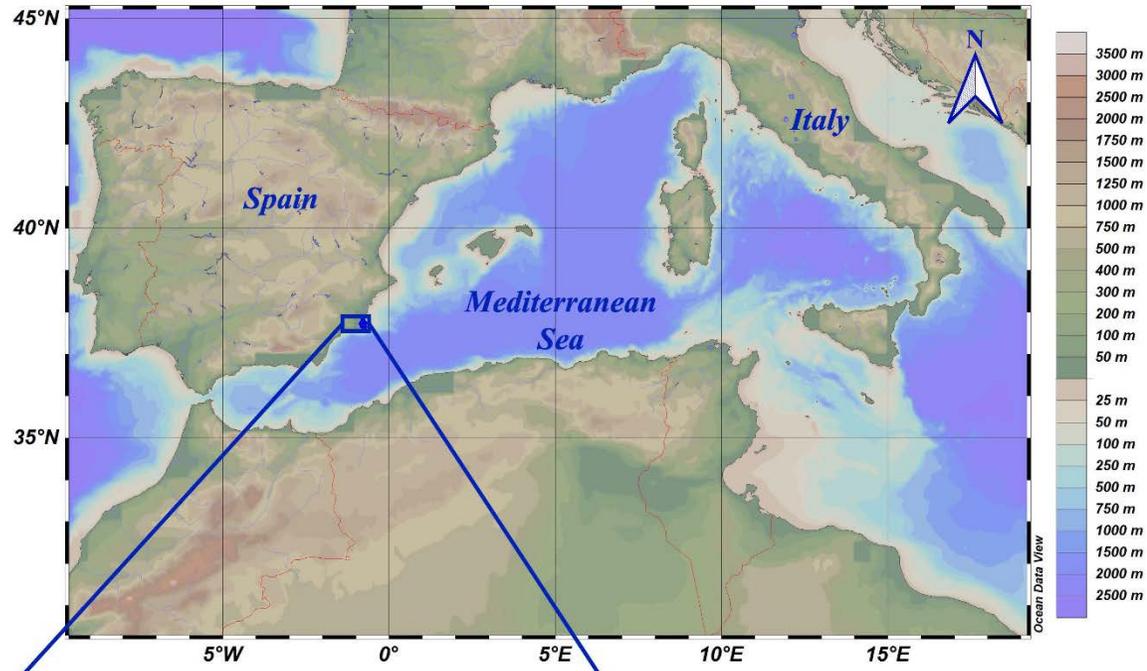


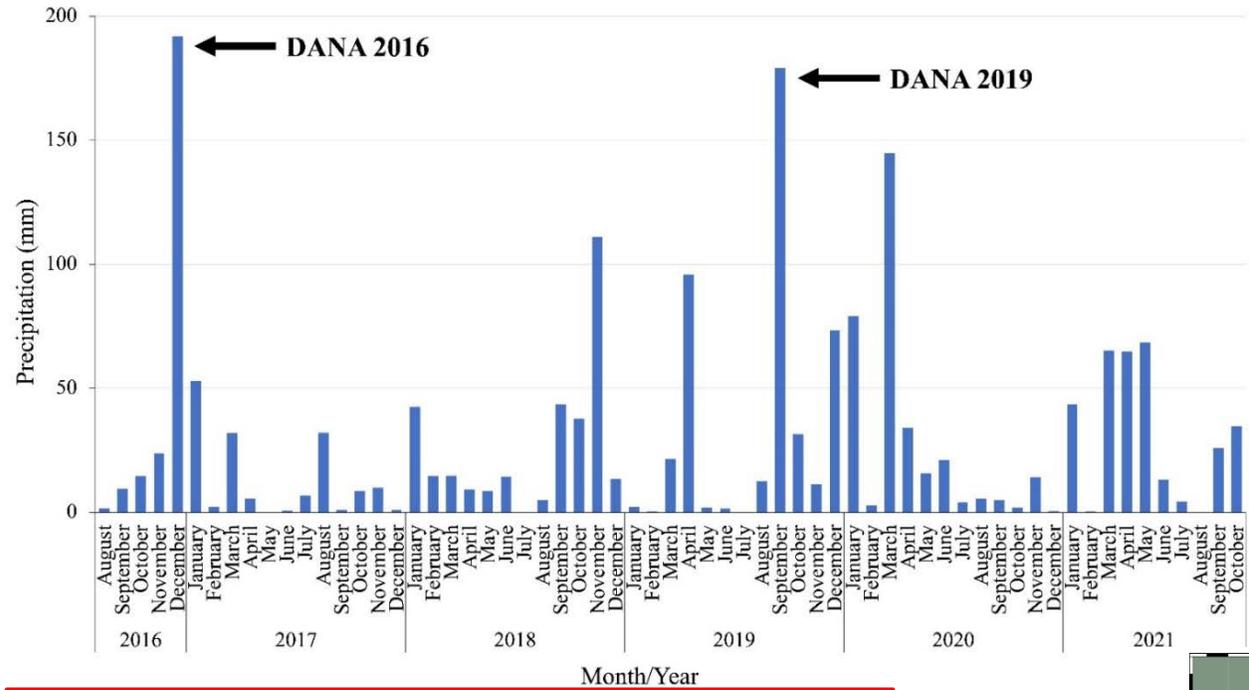


### Anthropogenic contribution, transport, and accumulation of Polycyclic Aromatic Hydrocarbons in sediments of the continental shelf and slope in the Mediterranean Sea

Emanuela Frapiccini<sup>a,\*</sup>, Rocco De Marco<sup>a</sup>, Federica Grilli<sup>a</sup>, Mauro Marini<sup>a,b</sup>, Anna Annibaldi<sup>b,c</sup>, Emanuela Prezioso<sup>c</sup>, Mario Tramontana<sup>d</sup>, Federico Spagnoli<sup>a,e</sup>

<sup>a</sup> Institute for Marine Biological Resources and Biotechnology (IRBIM), National Research Council (CNR), Largo Fiera della Pesca 2, 60125, Ancona, Italy  
<sup>b</sup> Fano Marine Center, The Inter-Institute Center for Research on Marine Biodiversity, Resources and Biotechnologies (FMC), 61032, Fano, Italy  
<sup>c</sup> Department of Life and Environmental Sciences, Università Politecnica delle Marche, Via Brecce Bianche, 60131, Ancona, Italy  
<sup>d</sup> Department of Pure and Applied Sciences (DISPeA), University of Urbino Carlo Bo, Campus Scientifico E. Mattei, 61029, Urbino, Italy  
<sup>e</sup> University of Camerino, School of Science and Technology, Geology Division, Via Gentile III da Varano, Camerino, Italy





Journal of Marine Science and Engineering

Article

**Extreme Flooding Events in Coastal Lagoons: Seawater Parameters and Rainfall over A Six-Year Period in the Mar Menor (SE Spain)**

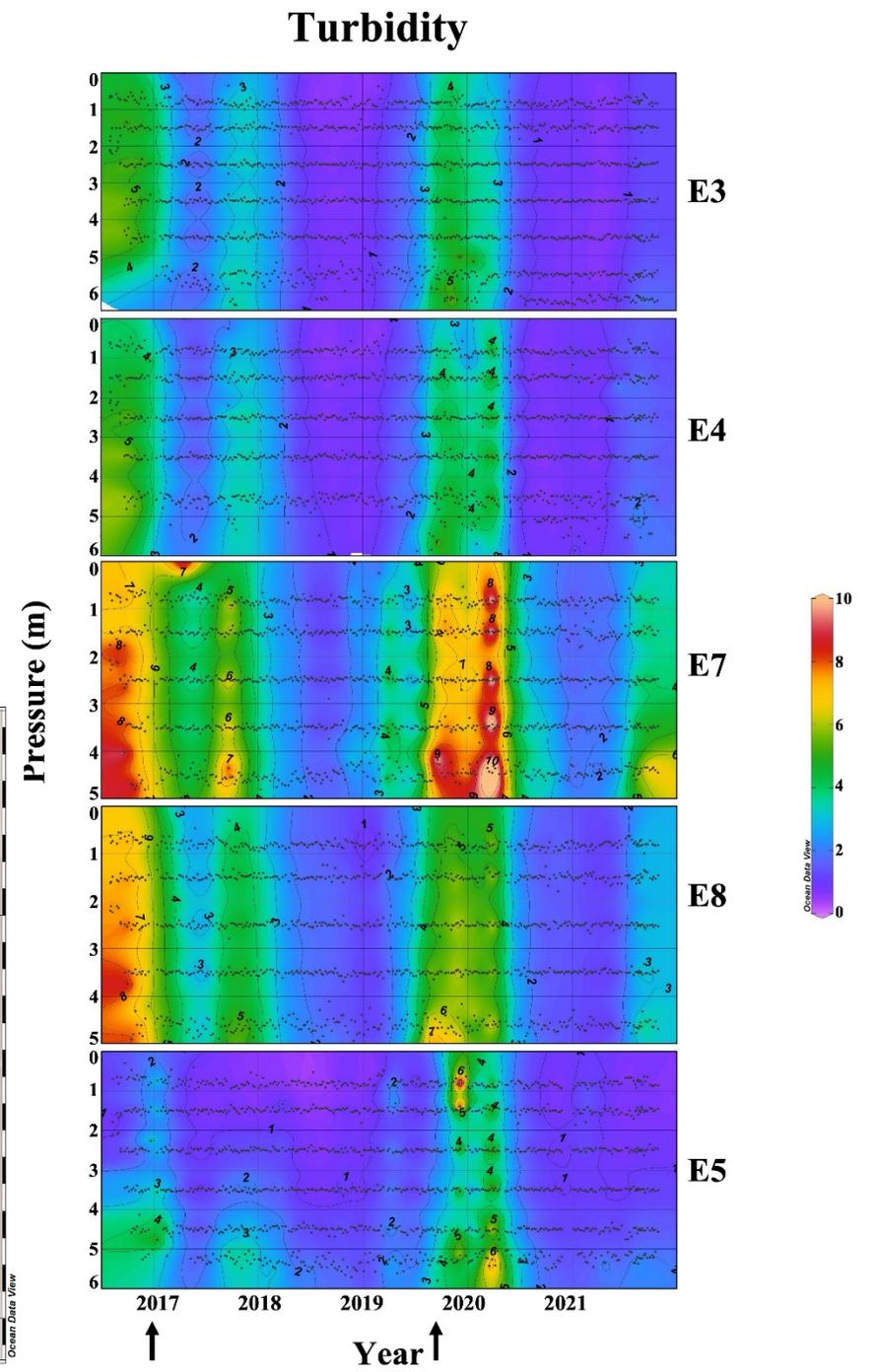
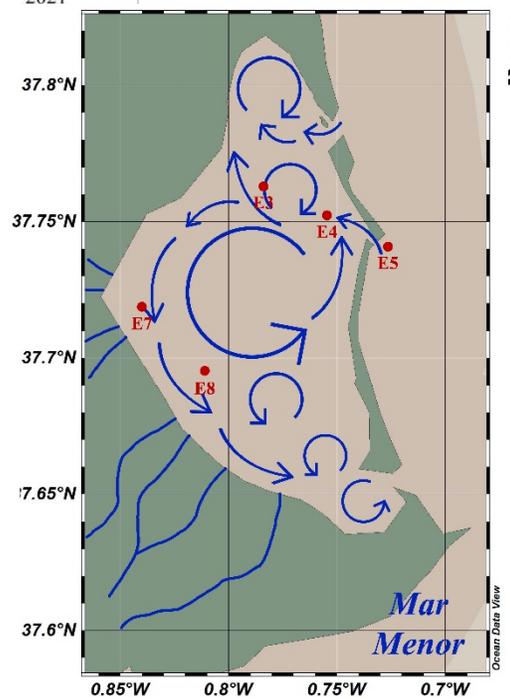
Mariana Machado Toffolo <sup>1,2,†</sup>, Federica Grilli <sup>3,†</sup>, Catia Prandi <sup>4,5</sup>, Stefano Goffredo <sup>1,2</sup> and Mauro Marini <sup>2,3,\*</sup>

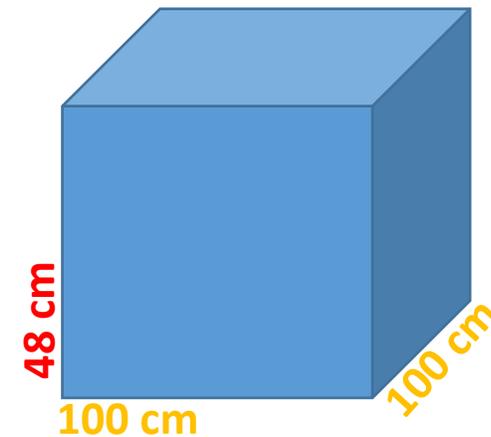
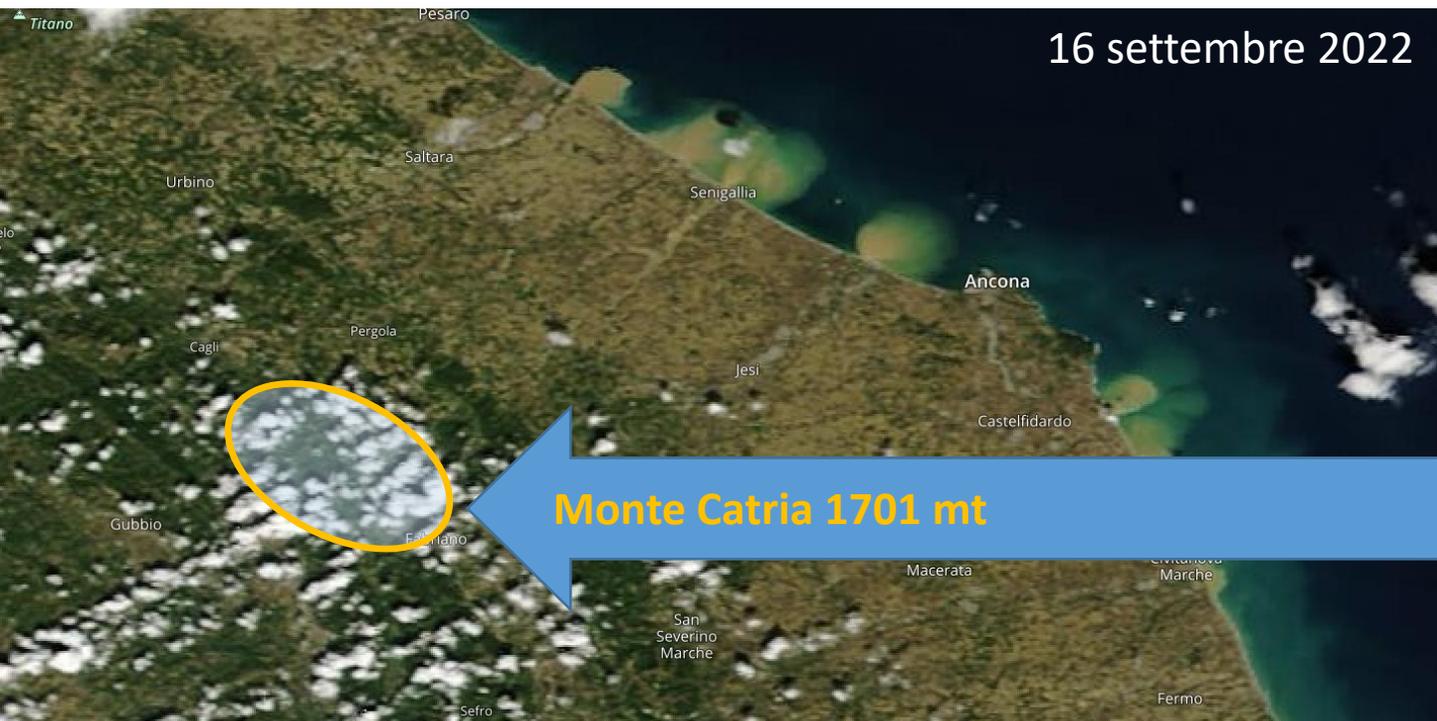
Journal of Operational Oceanography

Published online: 14 Jul 2025

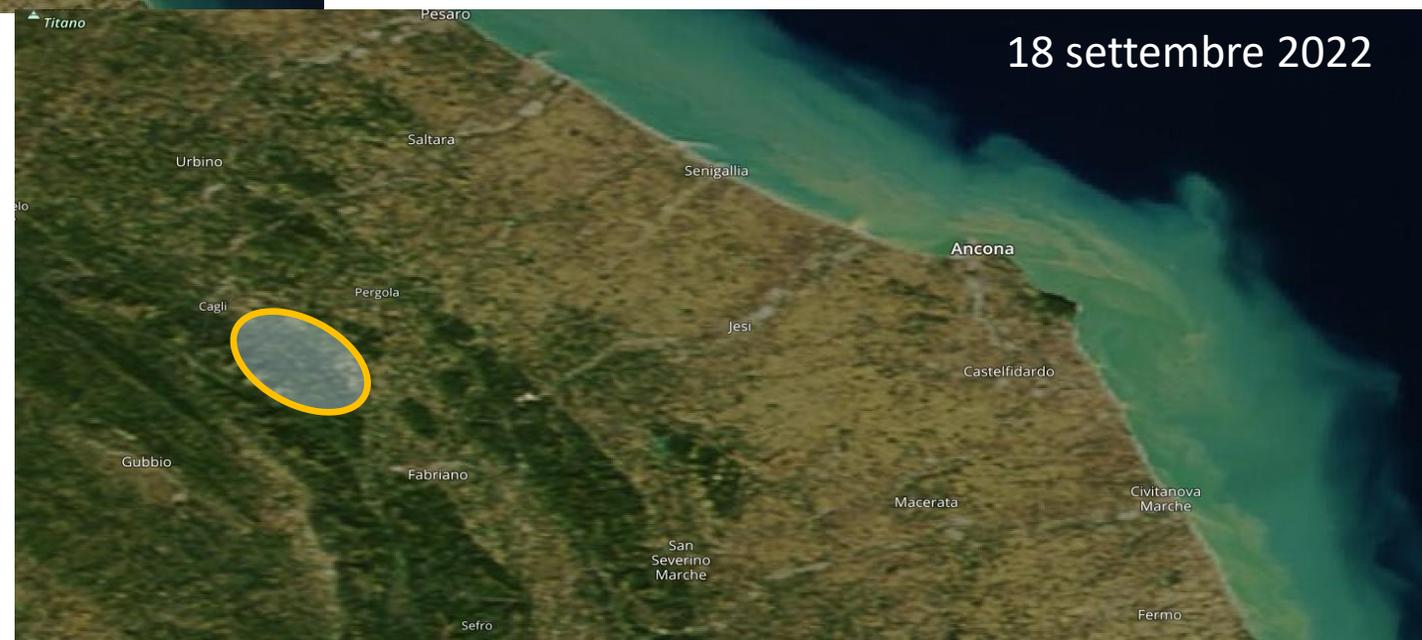
**Effect of extreme rainfall events in the Mar Menor lagoon (SE, Spain): The use of a Smartbuoy for environmental monitoring**

Mariana Machado Toffolo, Catia Prandi, Stefano Goffredo, Mauro Marini & Federica Grilli





Il 15 settembre 2022 sull'appennino umbro-marchigiano, massiccio del Monte Catria (1701mt), sono precipitati 480 mm di pioggia, in circa 12 ore.

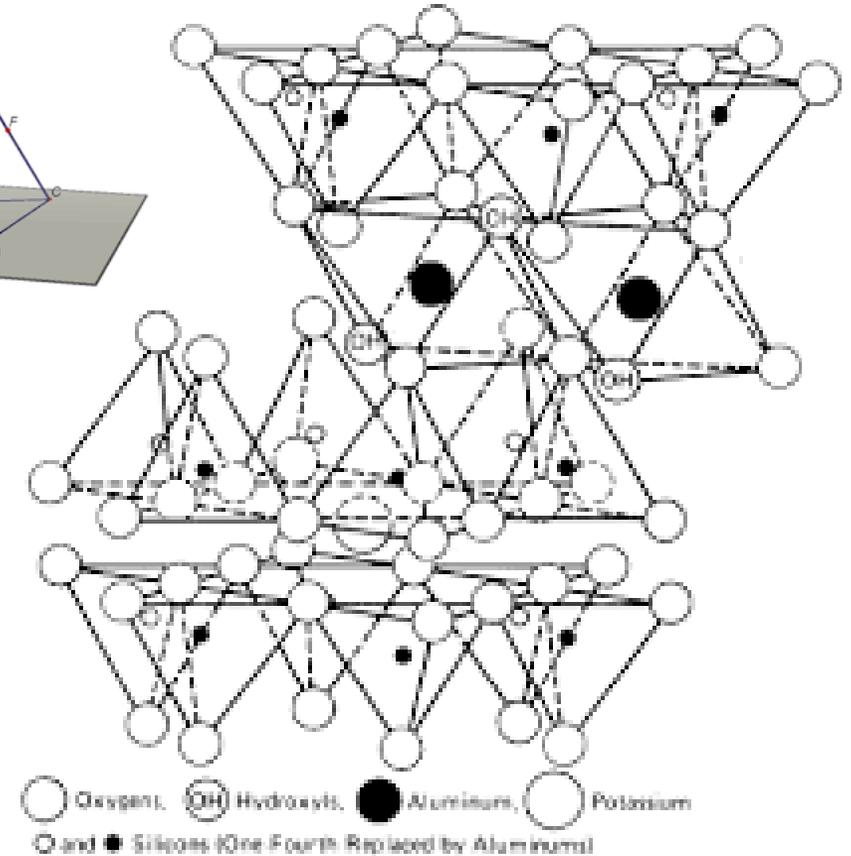
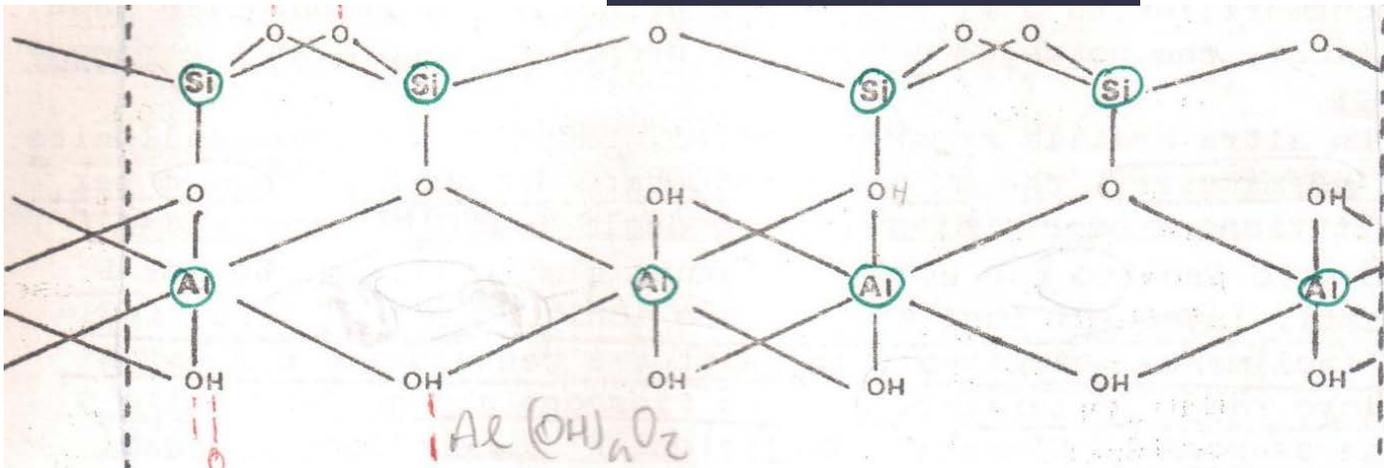
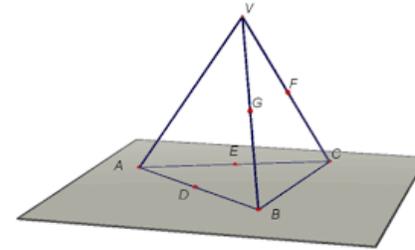
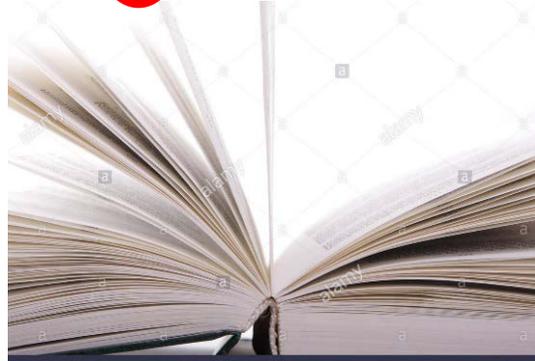


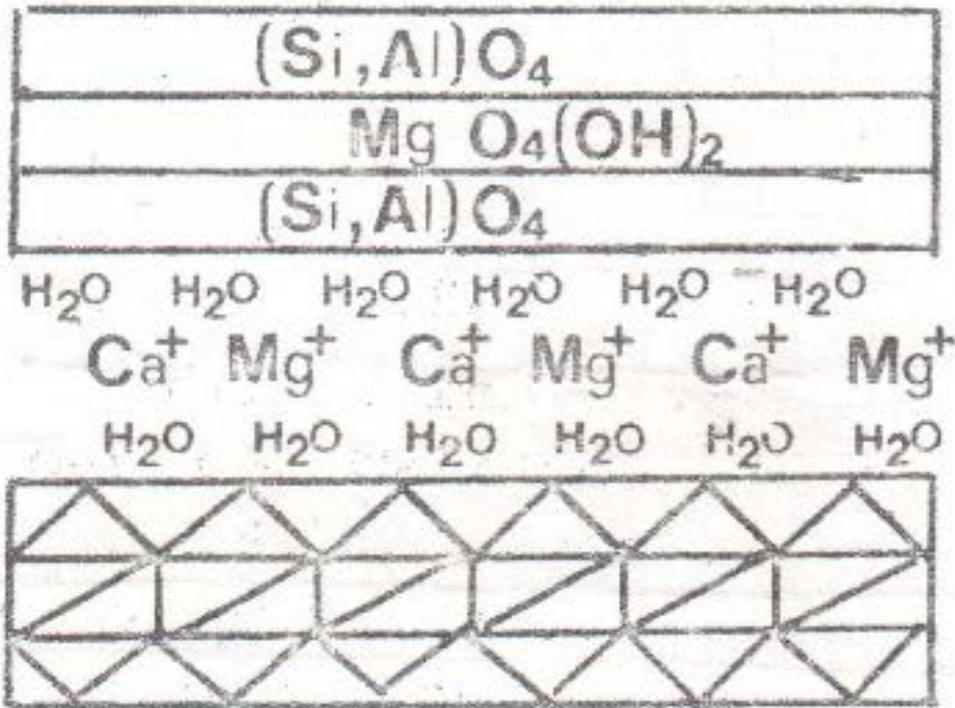
# Soil: Clay! Particle size < 2μm

- lamellar structure consisting of silica hydrogel (SiO<sub>2</sub>) and alumina (Al<sub>2</sub>O<sub>3</sub>), related to nH<sub>2</sub>O



- Caolinite - Al<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>(OH)<sub>4</sub>
- Piروفillite - Al<sub>2</sub>Si<sub>4</sub>O<sub>10</sub>(OH)<sub>2</sub>





10-15  $\text{\AA}$

Periodo d'Identità  $\text{\AA}$

Superficie Specifica =  $m^2/g$

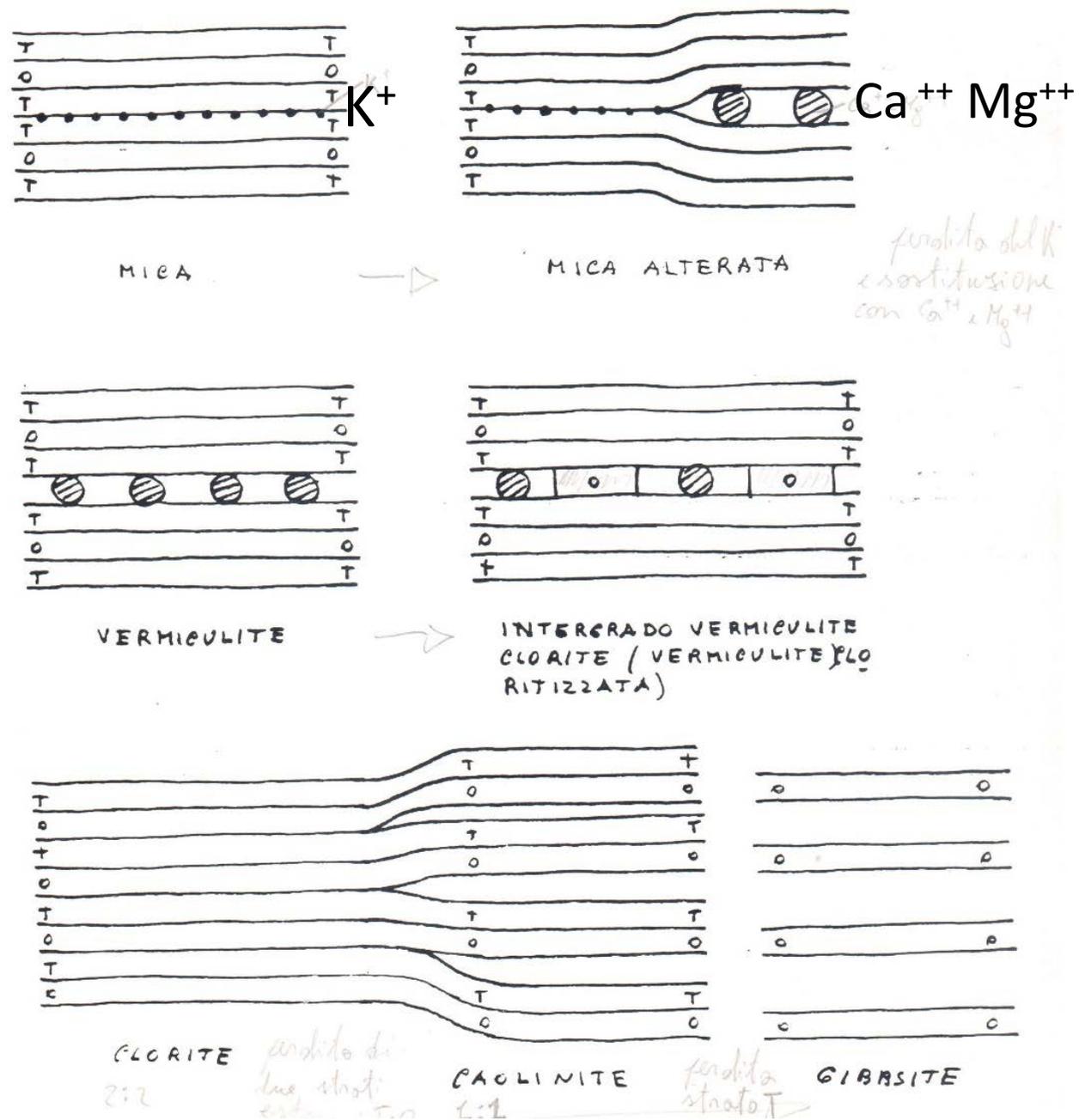
SS. = 600 / 1000  $m^2/g$

$n = 0,6-0,8$

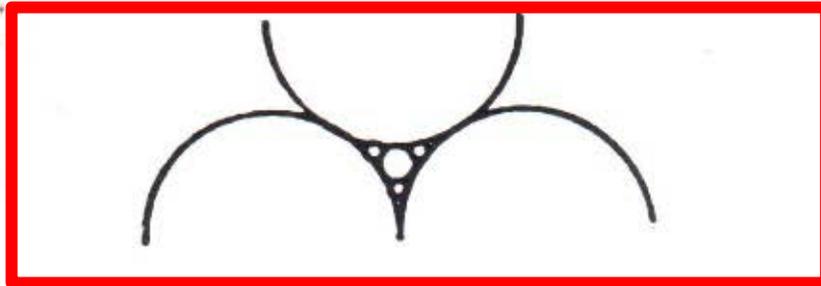
VERMICULITE

Gruppo della Caolinitie,  
 Processo di trasformazione

Rapporto Si:Al = 1:1

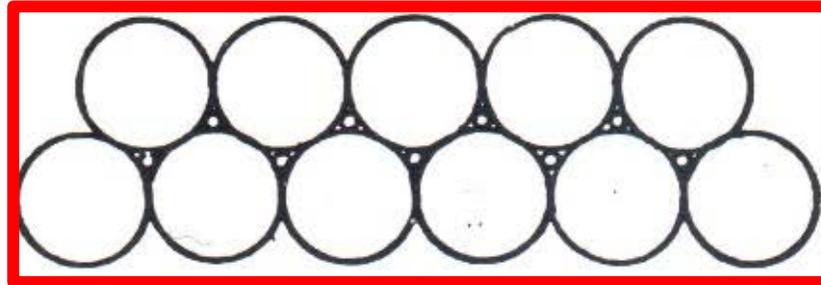


Specific surface =  $\text{m}^2/\text{g}$

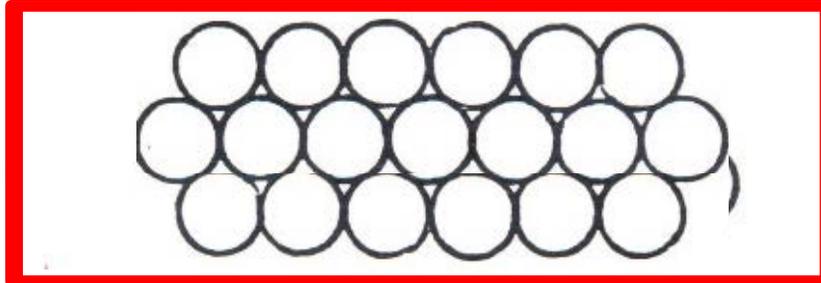


Porosity %  
(empty spaces)

2%



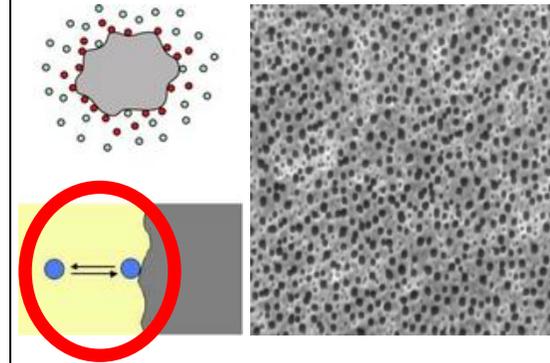
7%



26%

## WHAT IS ADSORPTION?

**Adsorption is a chemical-physical phenomenon** involving two parts: the **adsorbed molecule** and the **adsorbent matrix**, in which the interactions (chemical bonds) between them occur only on the external surface of the adsorbent, in the wall directly exposed to the aqueous phase and in the porous walls present within the matrix



Contaminant

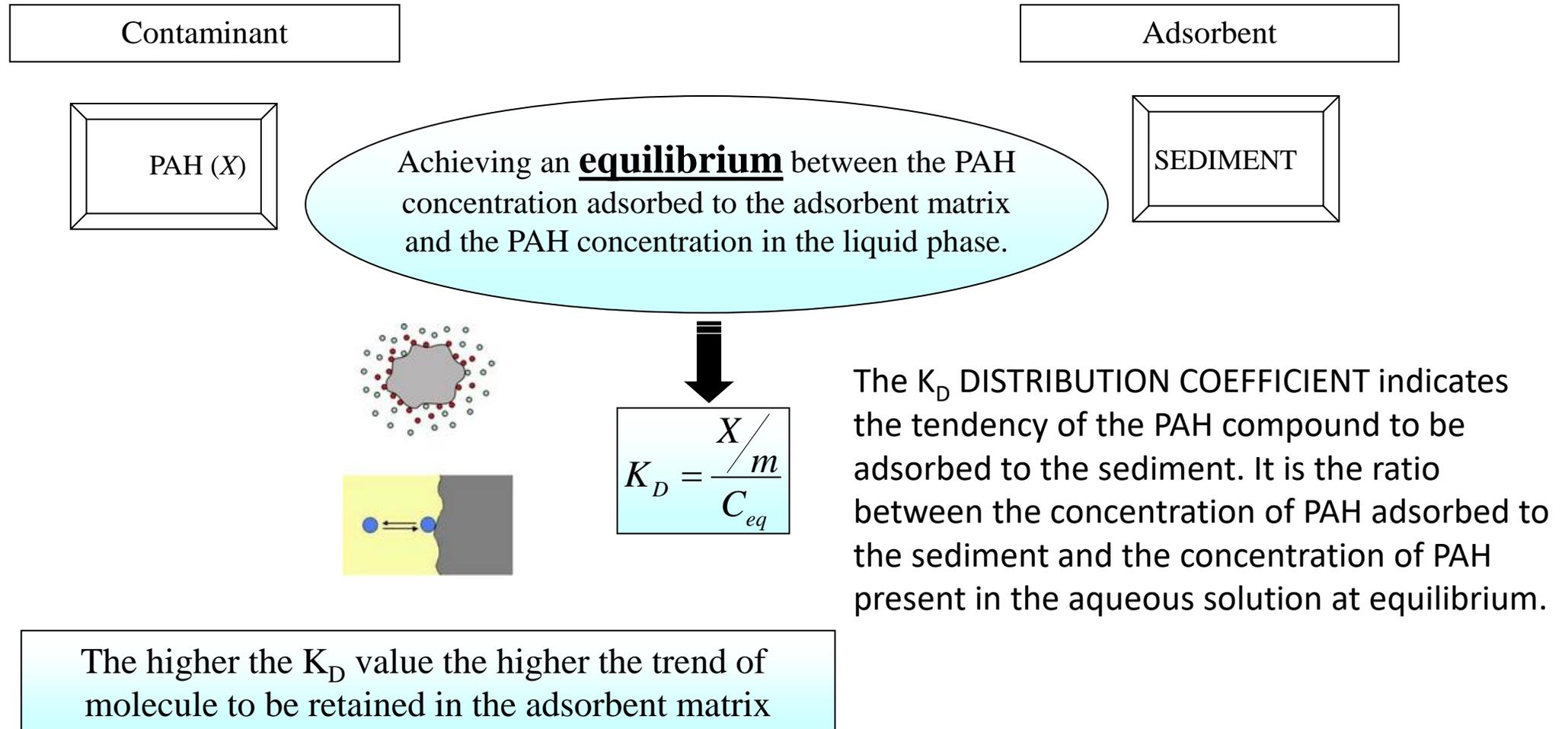
- Molecular shape
- Chemical structure
- Dimensions
- Solubility
- Polarity

Sediment

- Chemical-physical properties
- Qualitative and quantitative composition
- Humidity
- Temperature
- pH

## PAH adsorption process in marine sediments

WHAT HAPPENS IN THE ADSORPTION PROCESS?



Chemosphere 90 (2013) 1839–1846

Contents lists available at SciVerse ScienceDirect



# Chemosphere

journal homepage: [www.elsevier.com/locate/chemosphere](http://www.elsevier.com/locate/chemosphere)

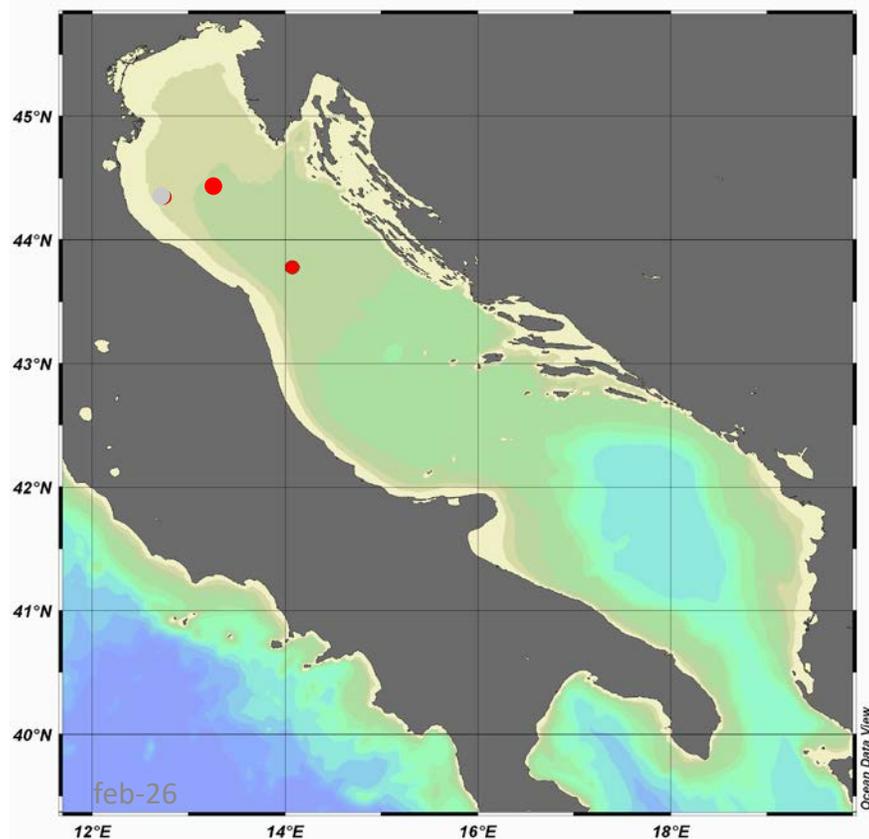


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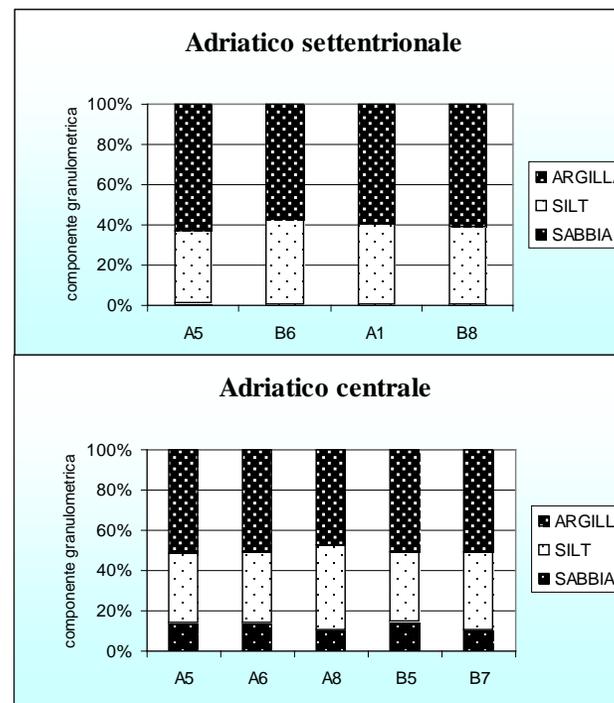
Persistence of polycyclic aromatic hydrocarbons in sediments in the deeper area of the Northern Adriatic Sea (Mediterranean Sea)

Mauro Marini \*, Emanuela Frapiccini

This study describes the persistence of PAHs in the deep and coastal sediments of the Northern Adriatic. Different environmental conditions were studied: salinity, temperature, sunlight, sediment particle size and organic matter in sediment. The average **conditions in the deep areas of the Northern Adriatic** are: salinity higher than 37, temperature lower than 11 °C, darkness and clayey sediments with a high organic matter content. These conditions increase the persistence of the PAHs in the deep area of the Northern Adriatic.



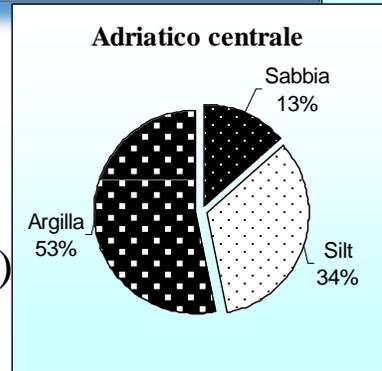
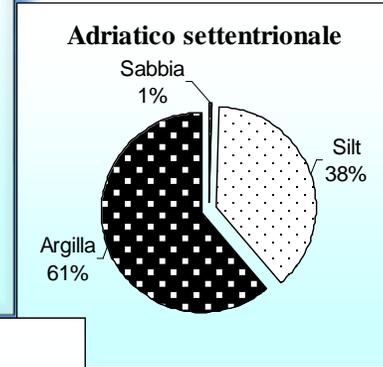
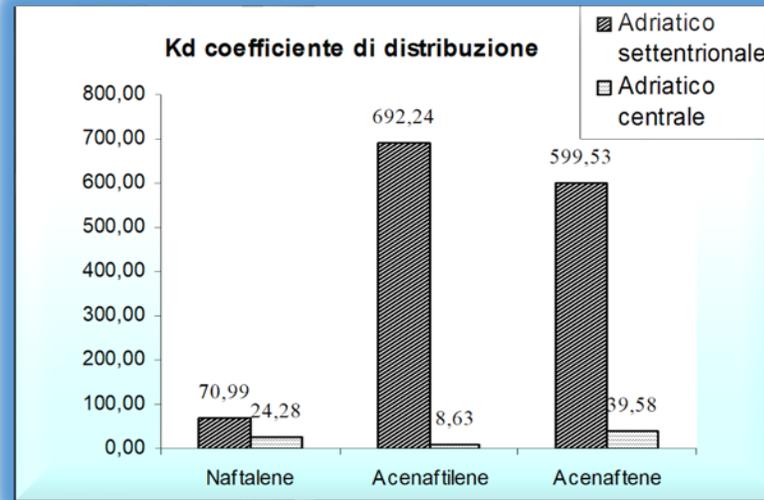
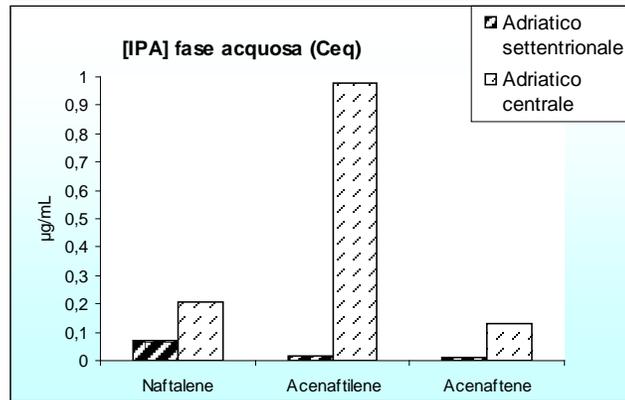
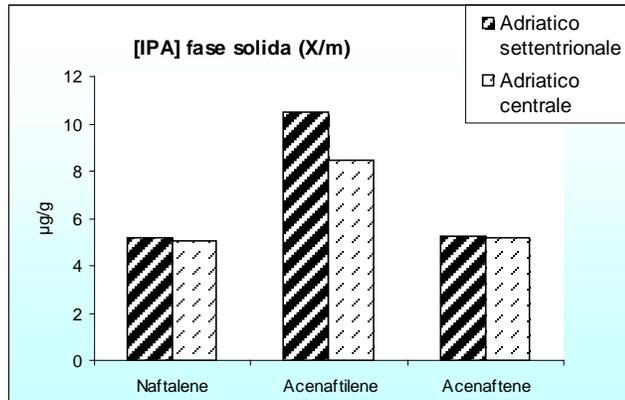
### Granulometric characteristics



Mauro Marini

## Adsorption process of PAHs in marine sediments of the Adriatic

### ADSORPTION VS SEDIMENT GRANULOMETRY



Le molecole IPA sono fortemente adsorbite al sedimento ( $C_{eq} < 1ppm$ )

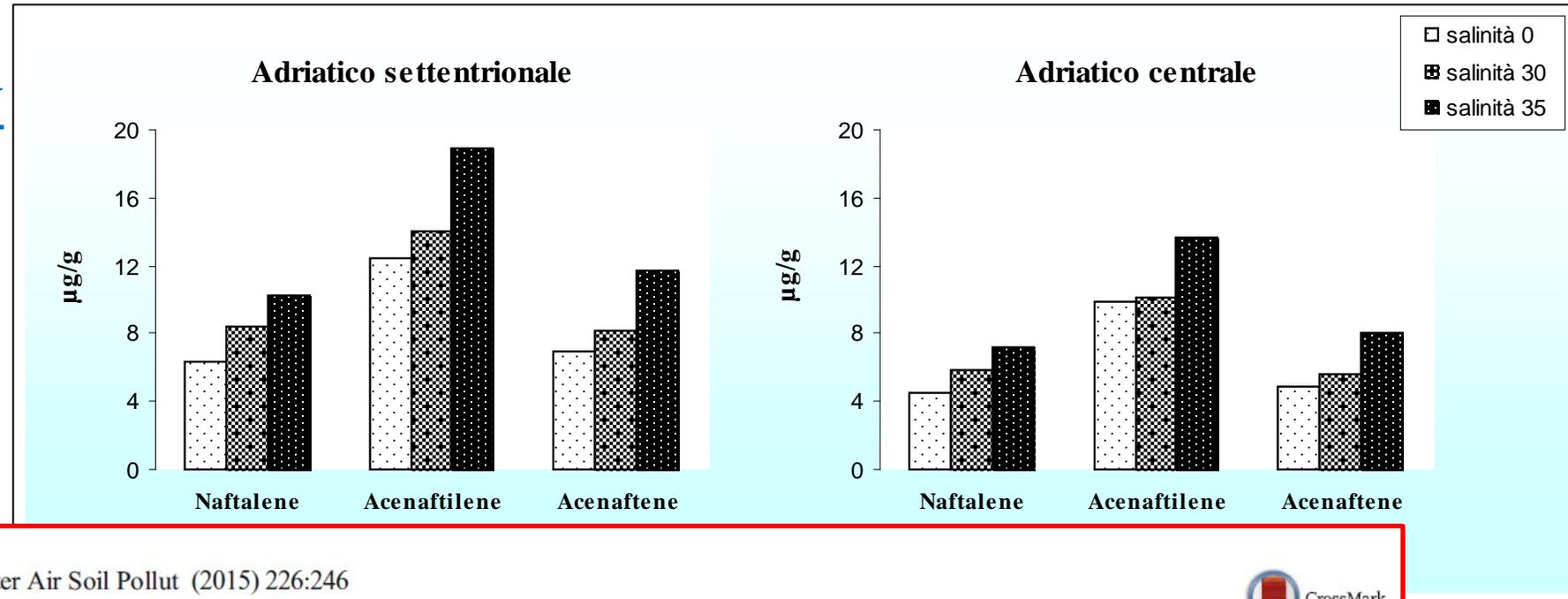
The finer textured sediment (northern Adriatic) shows higher  $K_D$  values.

## Adsorption process of PAHs in marine sediments of the Adriatic

### ADSORPTION VS SALINITY

The presence of ionic solutes in water causes a decrease in the solubility of the contaminant

As the salt concentration increases, the PAH molecules are more adsorbed to the sediment



Water Air Soil Pollut (2015) 226:246  
DOI 10.1007/s11270-015-2510-7



### Polycyclic Aromatic Hydrocarbon Degradation and Sorption Parameters in Coastal and Open-Sea Sediment

Emanuela Frapiccini • Mauro Marini

# Degradation kinetics of PAHs in marine sediments of the Adriatic

## WHAT IS A DEGRADATION KINETIC?

Degradation is a set of phenomena that transform the contaminant into substances of lower atomic weight and into inorganic substances

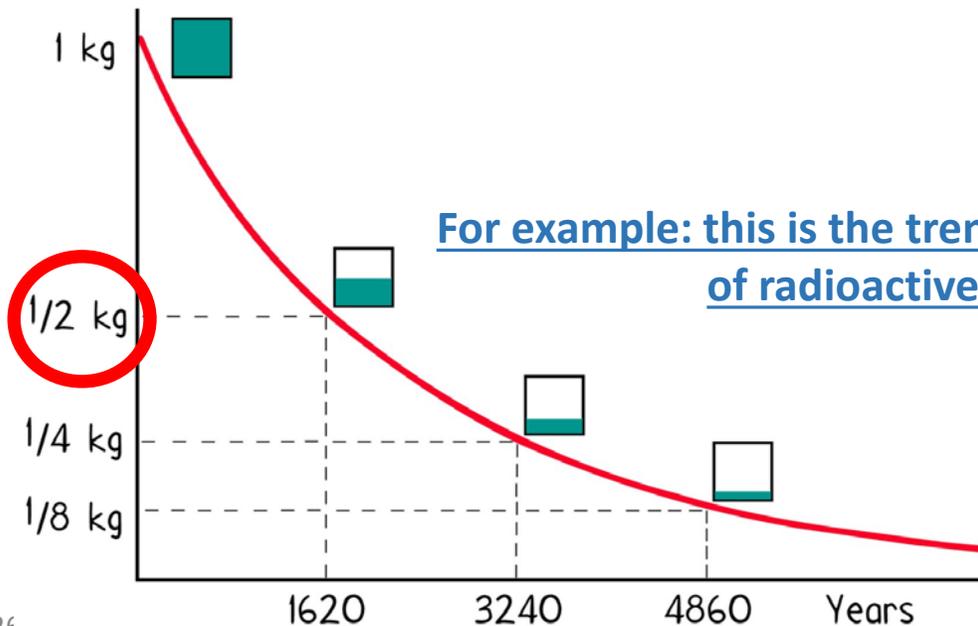
DEGRADAZIONE



REAZIONE DI TRASFORMAZIONE

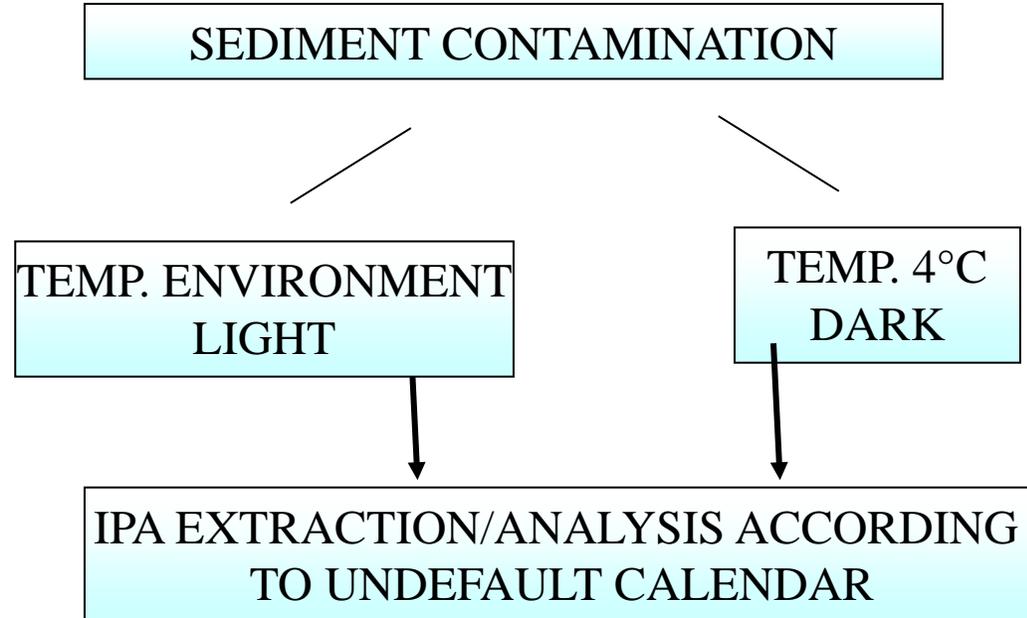


CINETICA DI DEGRADAZIONE



The kinetics of a reaction studies the speed with which this reaction takes place

## HOW TO STUDY DEGRADATION KINETICS?



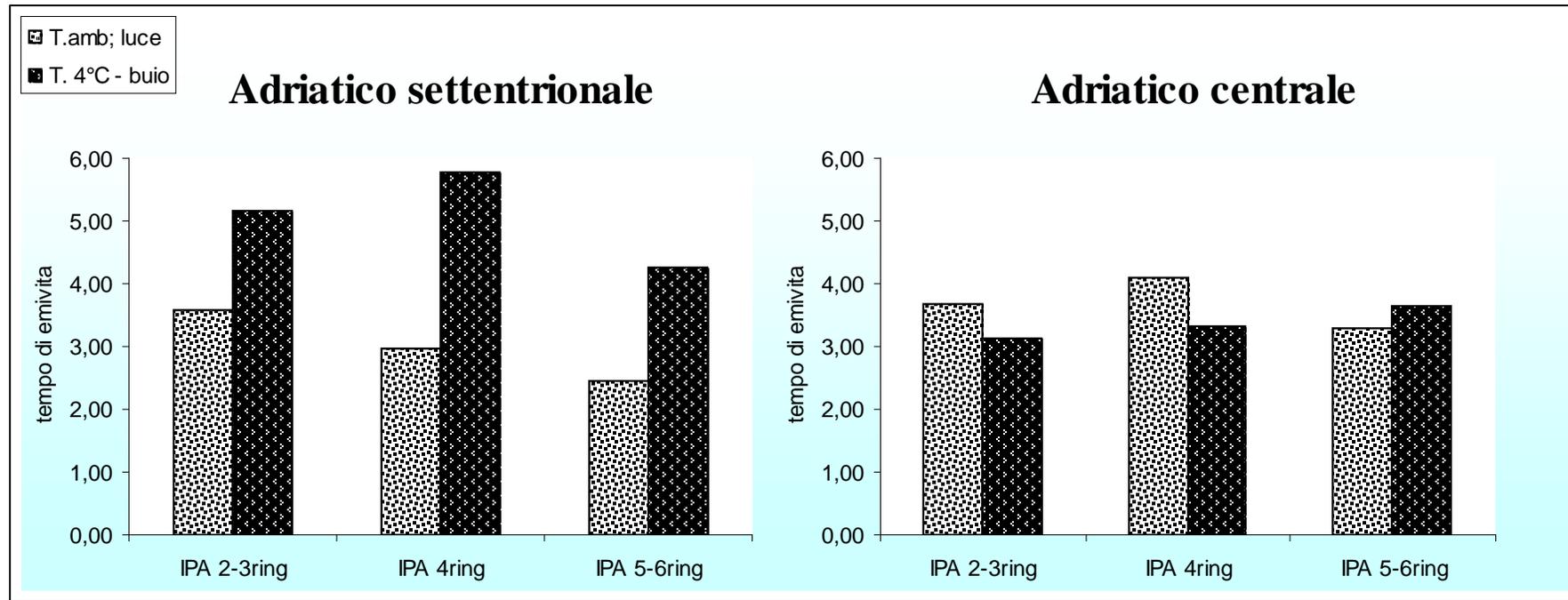
Water Air Soil Pollut (2015) 226:246  
DOI 10.1007/s11270-015-2510-7



**Polycyclic Aromatic Hydrocarbon Degradation and Sorption Parameters in Coastal and Open-Sea Sediment**

Emanuela Frapiccini • Mauro Marini

# Example of PAH degradation kinetics in marine sediments of the Adriatic



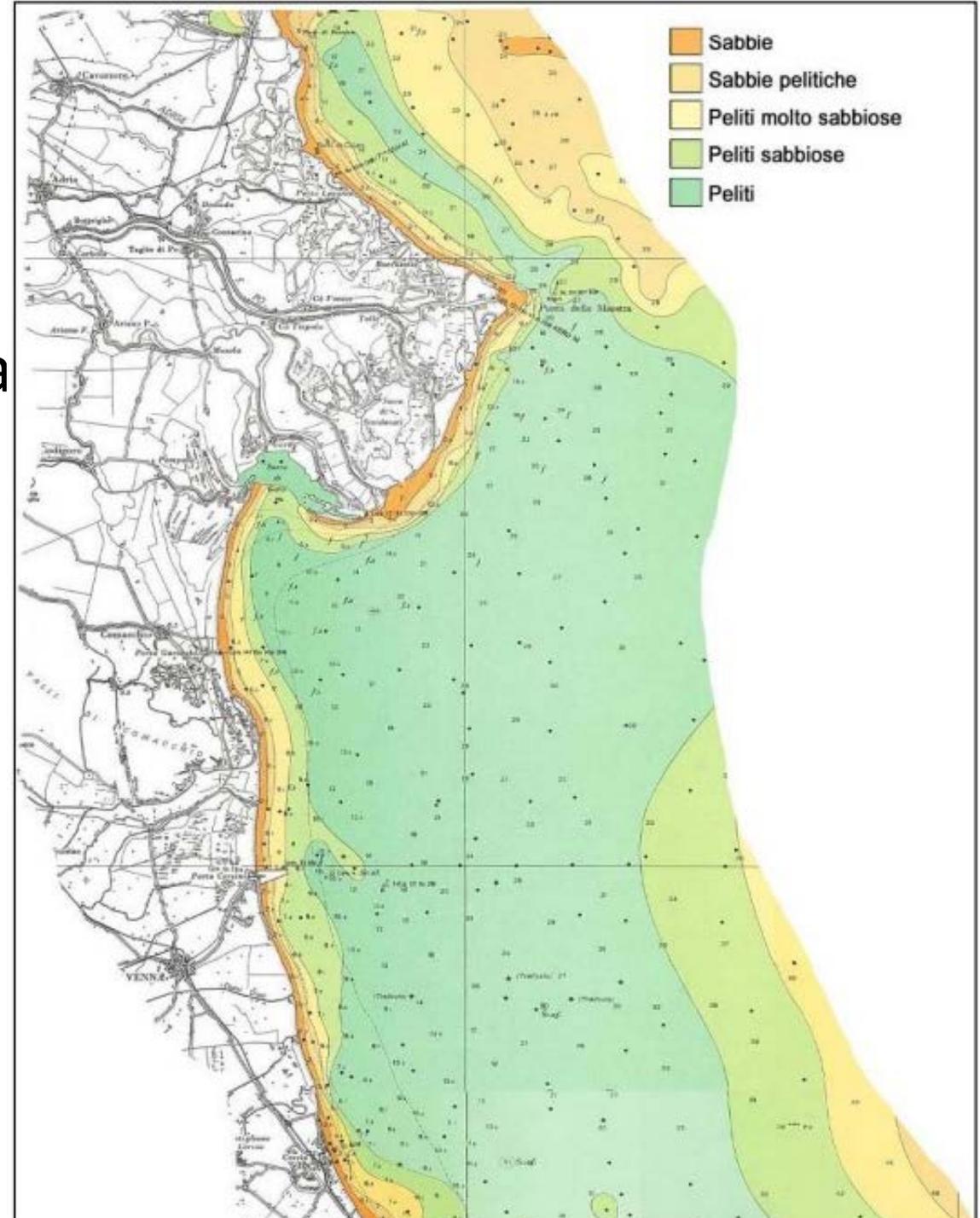
La cinetica di degradazione delle molecole IPA esaminate è veloce. Il tempo di emivita lo si raggiunge mediamente entro i primi tre giorni.

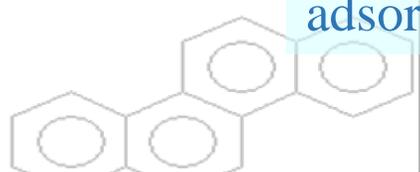
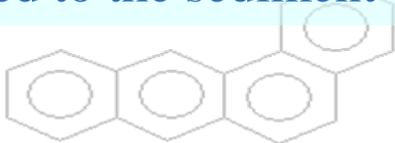
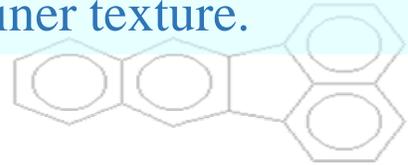
The degradation kinetics is slower in conditions of low temperature and in the absence of light.

Non vi è una chiara relazione tra diverso numero di anelli aromatici e velocità di degradazione.

# Questions?

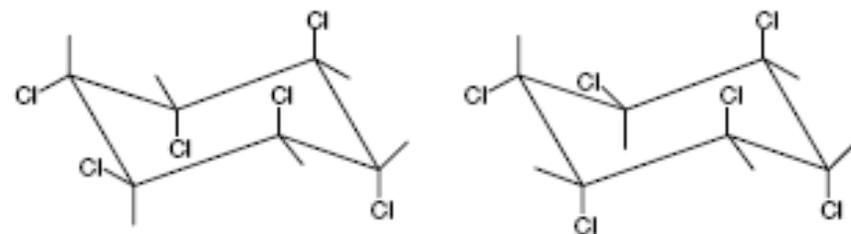
- On which side of the Adriatic bay contamination of PAHs?
- Will IPAs be found very close to



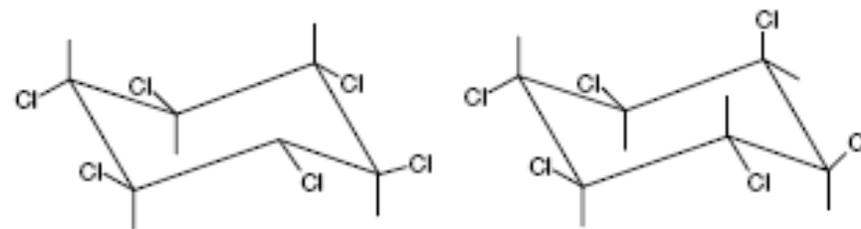
<i>Naftalene</i>	<i>Acenaftilene</i>	<i>Acenaftene</i>	<i>Fluorene</i>
			
<b>GENERAL CONSIDERATION</b>			
<p>The <b>degradation kinetics is slower in conditions of low temperature and absence of light</b>, but there are many factors that condition the degradation (pH, presence of microorganisms, organic content, nutrients, oxygen, electron acceptors, PAH aqueous concentration)</p>			
<i>Fenantrene</i>	<i>Antracene</i>	<i>Fluorantene</i>	<i>Pirene</i>
			
<p>The <b>granulometry of the sediment</b> has a decisive influence on the process of accumulation of PAHs. These compounds are strongly adsorbed to the sediment especially when it has a finer texture.</p>			
<i>Crisene</i>	<i>Benzo(a)antracene</i>	<i>Benzo(b)fluorantene</i>	<i>Benzo(k)fluorantene</i>
			
<p><b>Salinity</b> controls the solubility and bioavailability of PAHs in the aquatic environment as with <b>increasing salinity the PAH molecules tend to be adsorbed to the sediment</b> and therefore are less bioavailable for the microorganisms involved in the degradation</p>			
<i>Benzo(a)pirene</i>	<i>Dibenzo(a,h)antracene</i>	<i>Benzo(g)hifenanthrene</i>	<i>Indeno(1,2,3,c,d)pirene</i>
			

# Organic substances used in agriculture/industry: pesticides

Example of Lindane (hexachlorocyclohexane) its various isomers

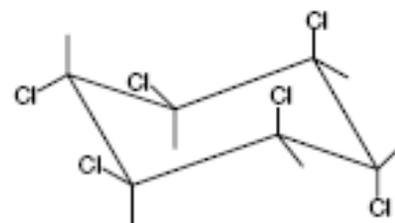


Alpha isomer pair



Beta

Delta



Gamma

Organo-chlorinated insecticides such as, for example, hexachlorocyclohexane (lindane) and dichlorodiphenyltrichloroethane (DDT), have been extensively studied in the last 30-40 years: for their widespread diffusion, for their impact on non-target organisms, for their bioaccumulation and for toxicity in humans. Little is known about the accumulation in marine fish. Survey made 7 km north of the city of Durres (Albania).

About 0.7 km from the coast there was a pesticide factory. The production activity of the factory was stopped in 1991 and the sludge and processing residues containing lindane were buried in the production site. The whole area is below sea level and the surface waters reach the sea through a dewatering pump.

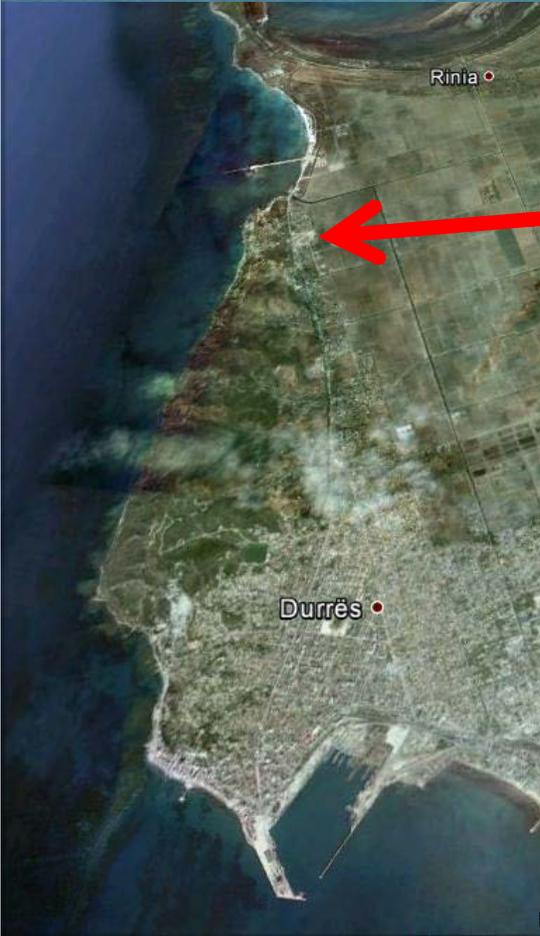


Symbols used according to the law for toxic substances



Old piston pump for DDT Used in the 60s

Marini et al., Marine Pollution Bulletin, 2012



Durazzo, Albania



Mauro Marini

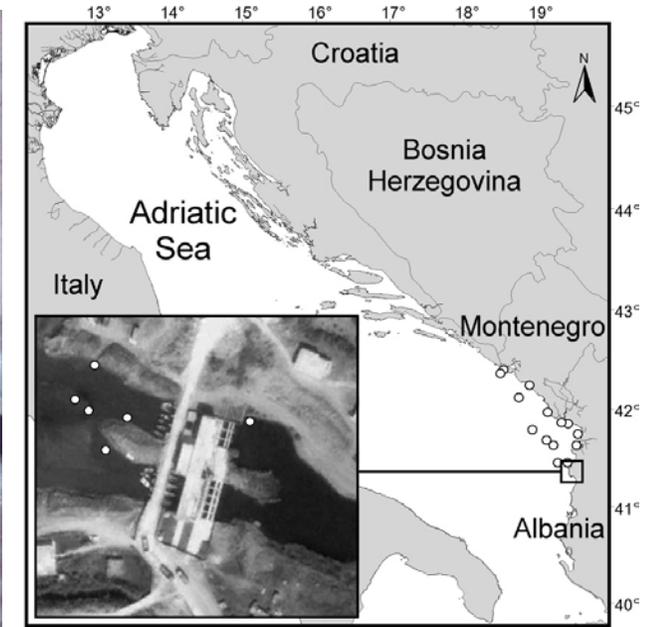


Concentrations of Lindane in the sediments at the mouth of the channel are in the range of 46 - 80 ng/g

Marini et al., Marine Pollution Bulletin, 2012



Mauro Marini



Ex pesticide factory  
**Porto Romano** area

Durrës city



Lindane concentrations in ng/g in marine sediments sampled inshore and offshore along the 100 m bathymetry

Marine Pollution Bulletin 64 (2012) 472–478

Contents lists available at ScienceDirect

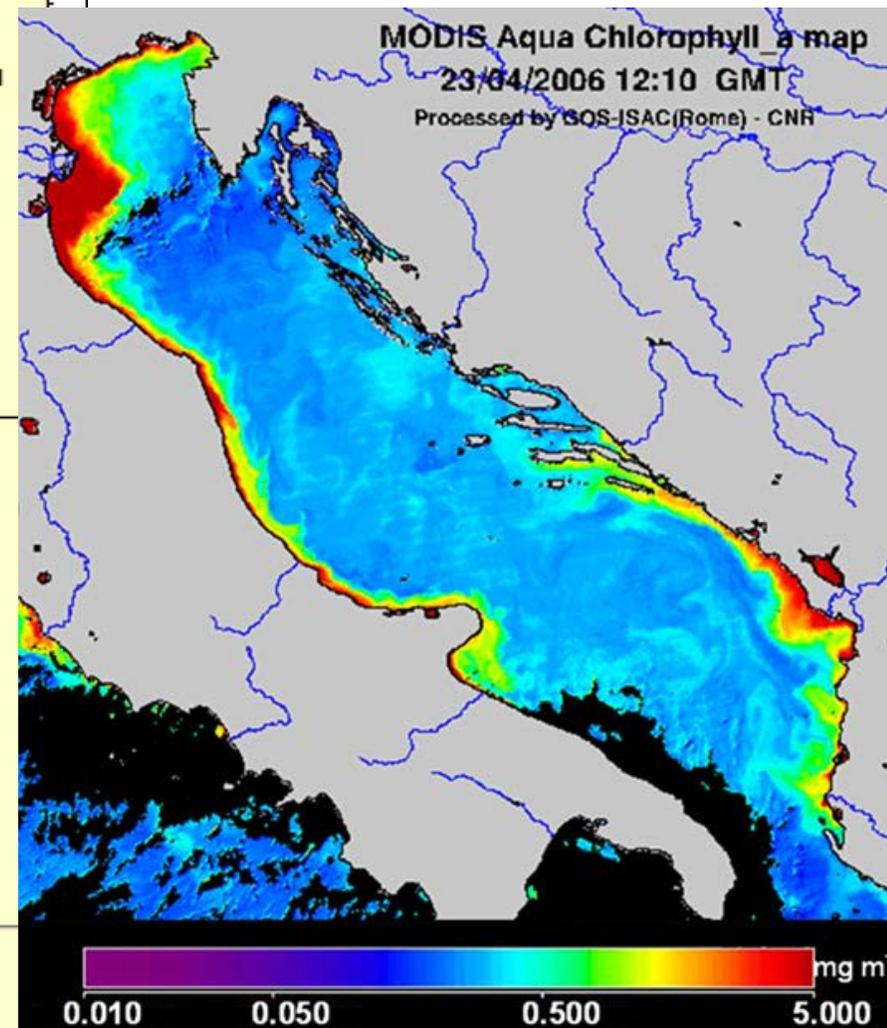
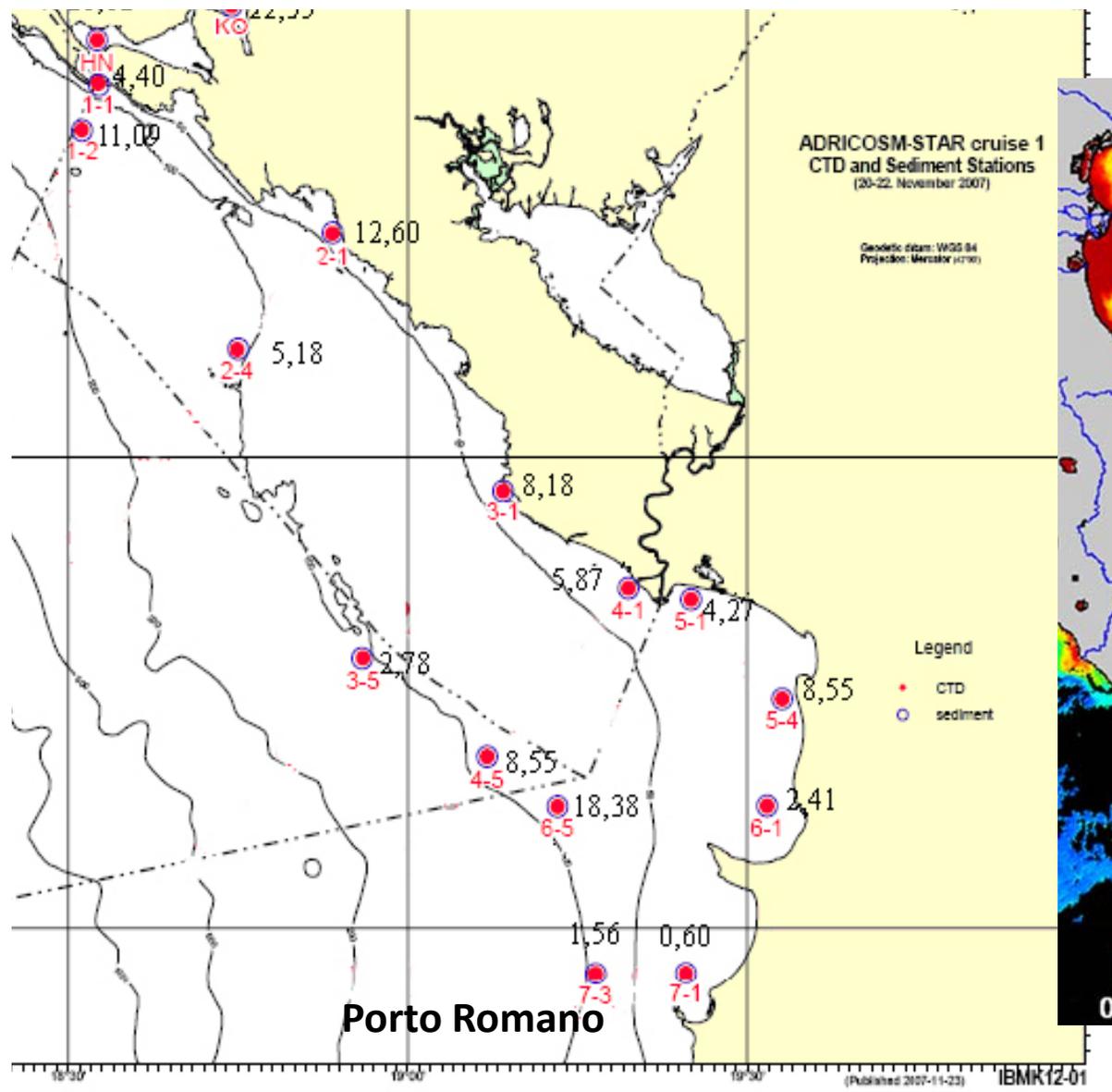
**Marine Pollution Bulletin**

journal homepage: [www.elsevier.com/locate/marpolbul](http://www.elsevier.com/locate/marpolbul)

**ELSEVIER**

Evaluation of lindane diffusion along the southeastern Adriatic coastal strip (Mediterranean Sea): A case study in an Albanian industrial area

Mauro Marini<sup>a,\*</sup>, Mattia Betti<sup>a</sup>, Fabio Grati<sup>a</sup>, Valerio Marconi<sup>b</sup>, Anna Rita Mastrogiacomo<sup>b</sup>, Piero Polidori<sup>a</sup>, Mitat Samxhaku<sup>c</sup>



# Topics in this lesson:

1. Description of the Adriatic basin, main oceanographic processes.
2. Nutrients that reach the sea via rivers.
3. Organic contaminants that are dispersed in the sea, for example: polycyclic aromatic hydrocarbons, pesticides .....
4. Fate and accumulation of chemical contaminants in marine organisms.



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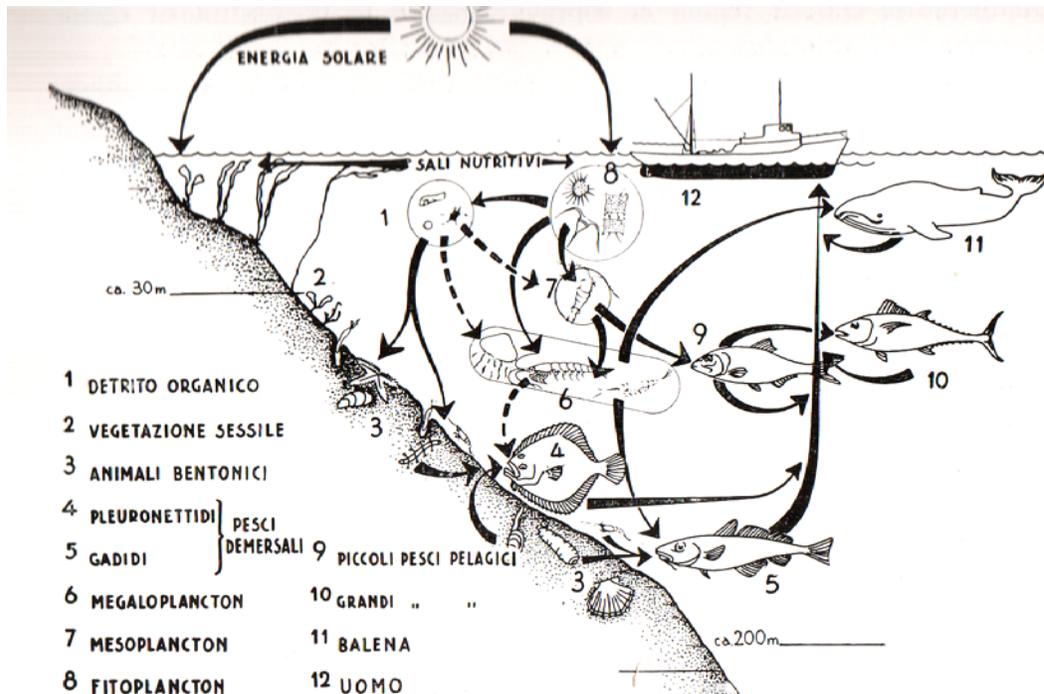


Fig. 17. Schema delle catene alimentari o di nutrizione nel mare (da Maldura in « Enciclopedia della Natura »).

**Table 3**  
Morphometric parameters, sex, age and lindane concentration of fish caught in the surroundings of chemical factory located 7 km northward Durres (Albania). F = female; M = male; nd = not determined.

Species	Total length (cm)	Weight (g)	Sex	Age (years)	Lindane concentration (ng g <sup>-1</sup> )	
					Muscle	Liver
<i>Merluccius merluccius</i>	14.0	22.2	nd	1.0	12.53	1940.8
<i>Merluccius merluccius</i>	15.2	26.9	nd	1.2	11.58	1655.32
<i>Merluccius merluccius</i>	15.5	28.6	nd	1.2	14.51	1526.30
<i>Merluccius merluccius</i>	16.8	30.5	F	1.4	8.85	497.19
<i>Merluccius merluccius</i>	18.7	44.8	M	1.6	10.45	914.60
<i>Merluccius merluccius</i>	22.5	78.7	F	2.2	25.38	4196.88
<i>Merluccius merluccius</i>	23.5	109.9	F	2.3	9.07	1048.30
<i>Solea solea</i>	19.0	54.4	M	1.0	4.05	924.73
<i>Solea solea</i>	20.5	71.8	M	1.2	12.50	1051.74
<i>Solea solea</i>	21.0	63.9	M	1.3	5.15	918.39
<i>Solea solea</i>	21.0	78.7	F	1.3	6.81	552.04
<i>Solea solea</i>	22.0	82.2	M	1.4	10.52	642.56
<i>Solea solea</i>	28.5	218.4	F	2.4	4.02	437.04
<i>Trisopterus minutus capelanus</i>	13.2	20.5	nd	1.0	9.61	1680.77
<i>Trisopterus minutus capelanus</i>	13.5	29.2	F	1.1	18.41	682.11
<i>Trisopterus minutus capelanus</i>	14.6	31.0	F	1.2	4.35	105.19
<i>Trisopterus minutus capelanus</i>	14.7	30.9	M	1.2	2.59	408.77
<i>Trisopterus minutus capelanus</i>	16.5	48.8	F	1.6	14.00	1640.93
<i>Trisopterus minutus capelanus</i>	16.7	55.8	F	1.6	14.95	2076.47

ARTICLE INFO

Keywords:  
Adriatic Sea  
Bioaccumulation  
Lindane  
Fish  
Sediment  
Organochlorine compound

ABSTRACT

This study aimed to analyze the impact at sea of a pesticide factory located 7 km north of Durres (Albania) by investigating a lowland area under the sea situated 0.7 km from the shoreline. The main product of this factory was lindane. Production ceased in 1991 during the Albanian civil war, and a large amount of industrial waste was dispersed over the ground surrounding the factory, resulting in a high level of lindane pollution. A water-scoop channels the ground water accumulated around the disused factory directly into the sea.

The concentrations of lindane in sediments collected along the coasts of the region ranged from 0.60 to 22.55 ng g<sup>-1</sup>. The average concentration in the muscles of fish did not exceed the limits specified by European Commission legislation, whereas the concentration in the liver did exceed these limits; consequently, liver is not recommended for consumption.

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**Table 4**

Lindane concentration and normalized lindane concentration in muscles and liver of fish caught in the surroundings of chemical factory located 7 km northward Durres (Albania). Lindane concentration limit from CEE Regulation 850/2004 = 20 ng g<sup>-1</sup>.

Species	Mean lindane concentration (ng g <sup>-1</sup> ) ± SD		Mean lindane concentration normalized on TL (ng g <sup>-1</sup> cm <sup>-1</sup> ) ± SD	
	Muscle	Liver	Muscle	Liver
<i>Solea solea</i>	7.2 ± 3.6	754.4 ± 244.3	0.34 ± 0.18	35.76 ± 14.29
<i>Merluccius merluccius</i>	13.2 ± 5.7	1682.8 ± 1211.8	0.74 ± 0.26	93.66 ± 56.89
<i>Trisopterus minutus capelanus</i>	10.7 ± 6.3	1099.0 ± 803.2	0.72 ± 0.43	72.78 ± 51.31



## Comparison of Lindane and Carbaryl Pesticide Bioaccumulation in the Common Sole (*Solea solea*)

Frapiccini Emanuela<sup>1</sup> · Scarcella Giuseppe<sup>1</sup> · Guicciardi Stefano<sup>1</sup> · Betti Mattia<sup>1</sup> · Marini Mauro<sup>1</sup>

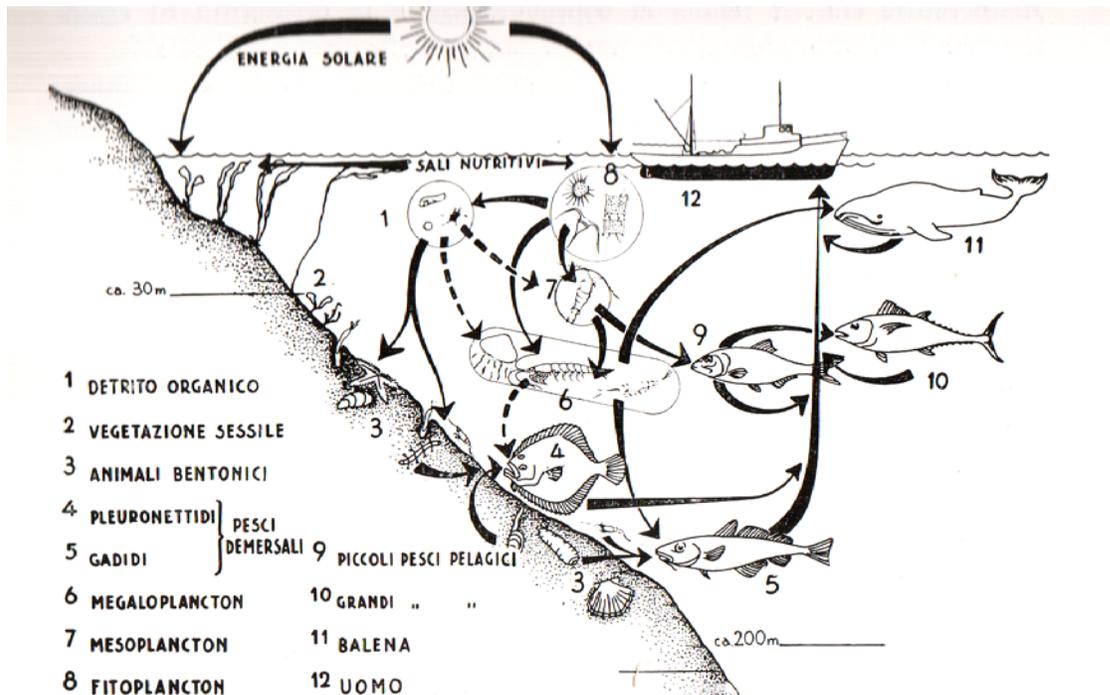


Fig. 17. Schema delle catene alimentari o di nutrizione nel mare (da Maldura in « Enciclopedia della Natura »).

**Organochlorines and carbamates are common pesticides** predominantly employed in agriculture.

Large amounts of pesticides make their way into rivers and marine habitats. They accumulate in aquatic organisms through different exposure routes and gradually move up the food chain. Since contaminant bioaccumulation in animals is affected by several factors, this work harnessed several different approaches to explore the persistence of lindane, a long banned organochlorine pesticide, and carbaryl, a newer generation pesticide, in common sole (*Solea solea*), a major commercial species in Adriatic fisheries.

**Lindane was not only more accumulated than carbaryl in sole liver, but it was also detected in greater amount in muscle tissue, the edible part (lindane, 7 ng/g; carbaryl, <0.004 ng/g w/w).** Additional assays documented a greater accumulation of lindane in adults compared with juveniles and in specimens caught offshore than in those collected close to the coast. **The present findings demonstrate the different accumulation dynamics of the two pesticides to confirm the benefits derived from the replacement of organochlorine pesticides with carbamate compounds.**



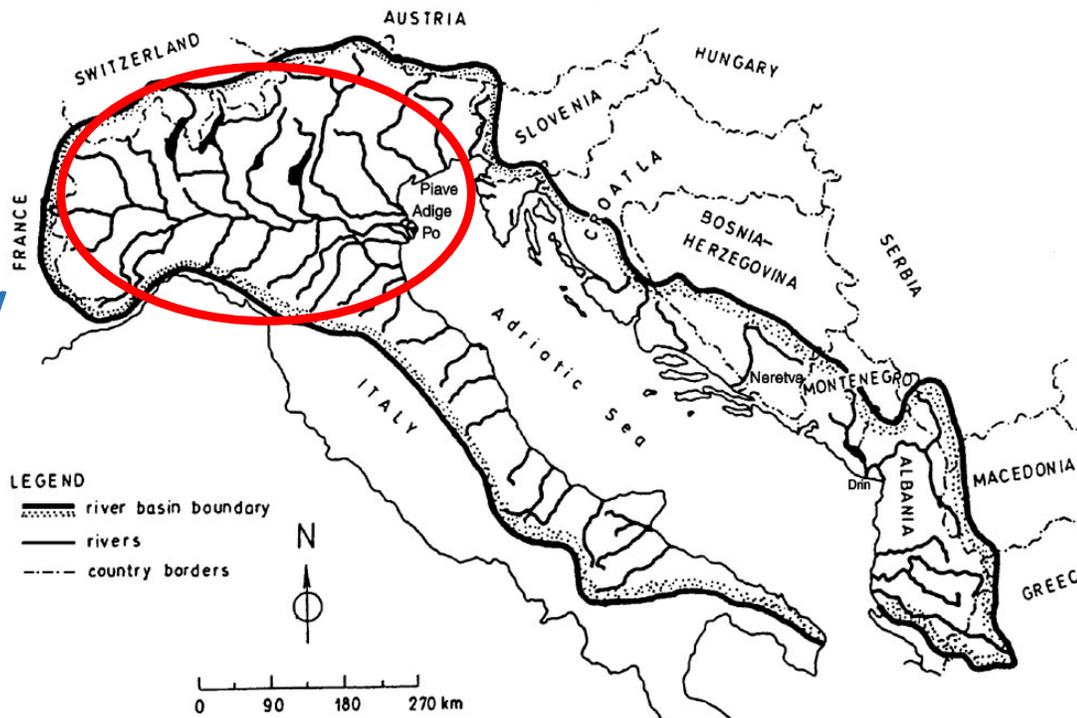
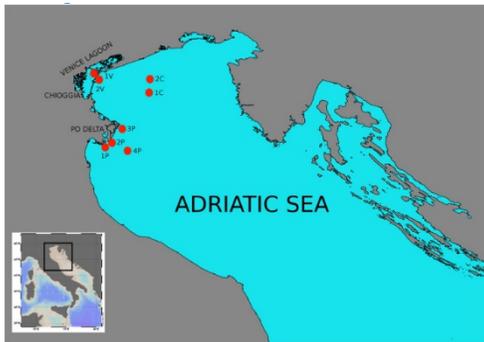
Baseline

Polycyclic aromatic hydrocarbon (PAH) accumulation in different common sole (*Solea solea*) tissues from the North Adriatic Sea peculiar impacted area

Frapiccini Emanuela<sup>a</sup>, Annibaldi Anna<sup>b</sup>, Betti Mattia<sup>a</sup>, Polidori Piero<sup>a</sup>, Truzzi Cristina<sup>b</sup>, Marini Mauro<sup>a,\*</sup>



Po Valley, a very important agricultural region, the industrial heart of northern Italy and intensity

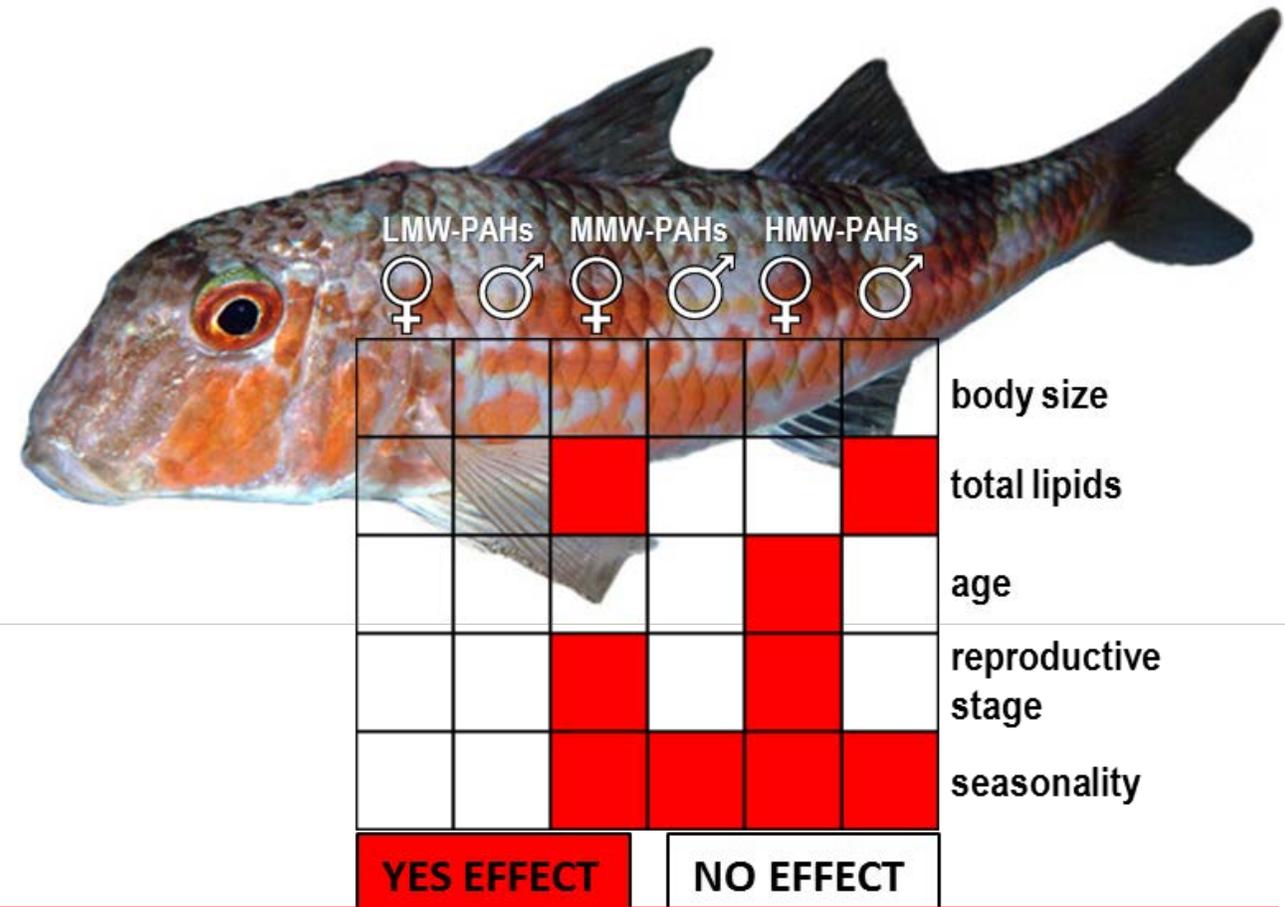


This study extends our knowledge of the bioaccumulation of polycyclic aromatic hydrocarbons (PAHs) in marine organisms and investigates its possible determinants. PAH levels were measured in *Solea solea* tissue and in marine sediments collected from three areas of the northern Adriatic Sea characterized by different anthropic impacts (Venetian Lagoon, Po Delta, and fishing grounds off Chioggia). The possibility of differential PAH bioaccumulation in different tissues (**muscle, liver and gills**) was investigated by seeking relationships between mean individual and total PAH concentrations in tissue and sediment samples, the physicochemical properties of PAHs (rings and Kow), and some key biological variables (lipid content of tissues, body size, habitat). The present study demonstrated that the lipid content might not be the only determinant of PAH bioaccumulation in common sole tissues. **The habitat characteristics, the tissue types and some physicochemical properties of compounds were closely related to PAH bioaccumulation.**

This study evaluates the effects of biological factors of fish and seasonality on Polycyclic Aromatic Hydrocarbon (PAH) accumulation in red mullet (*Mullus barbatus*) tissue. Specimens were collected monthly with a bottom trawl net in an offshore fishing ground in the Northern and Central Adriatic Sea (Geographical Sub Area 17) throughout 2016.

The edible fillets of 380 individuals were analyzed for the concentrations of individual PAH, total PAH, and low, medium and high molecular weight (MW) PAHs. PAH bioaccumulation was related to their physicochemical characteristics (MW, and logarithm of the octanol-water partition coefficient, log Kow), some biological parameters of fish (body size, age, sex, reproductive stage and total lipid content), and catch season. The PAH bioaccumulation pattern and the effects of the different factors varied according to PAH MW.

The heavier (medium and high MW) PAHs showed higher levels in winter-autumn and in pre-spawners compared with spawners and post-spawners. Our findings suggest that an important detoxification mechanism, albeit limited to the heavier PAHs, acts in the spawning and post-spawning stage. Low MW PAHs appeared to be unaffected by reproductive stage, lipid content and seasonality. **Reproductive stage and seasonality seem to play an important role in the accumulation of heavier PAH, whereas total lipid content and age seem to exert a limited influence, and body size no effect at all.**



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journal homepage: [www.elsevier.com/locate/envpol](http://www.elsevier.com/locate/envpol)

Effects of biological factors and seasonality on the level of polycyclic aromatic hydrocarbons in red mullet (*Mullus barbatus*)<sup>☆</sup>

E. Frapiccini<sup>a,1,\*</sup>, M. Panfili<sup>a,1</sup>, S. Guicciardi<sup>a</sup>, A. Santojanni<sup>a</sup>, M. Marini<sup>a</sup>, C. Truzzi<sup>b</sup>, A. Annibaldi<sup>b</sup>

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## Marine Pollution Bulletin

journal homepage: [www.elsevier.com/locate/marpolbul](http://www.elsevier.com/locate/marpolbul)



### Mercury levels in *Merluccius merluccius* muscle tissue in the central Mediterranean Sea: Seasonal variation and human health risk

Federico Girolametti<sup>a</sup>, Monica Panfili<sup>b</sup>, Sabrina Colella<sup>b</sup>, Emanuela Frapiccini<sup>b,\*</sup>, Anna Annibaldi<sup>a,c</sup>, Silvia Illuminati<sup>a</sup>, Mauro Marini<sup>b,c</sup>, Cristina Truzzi<sup>a</sup>

Is the first study evaluating THg levels in hake fillets in relation to ecological (season) and biological (body size, sex, sexual maturity, lipid content) parameters. THg levels in muscle showed no sex-related differences; in contrast, significant season-related differences were found in females, with higher levels in spring-summer compared with autumn-winter. No season-related differences were seen in males. A significant sex effect was found for body size and sexual maturity. Females showed a correlation between THg level and length, THg being significantly higher in mature compared with immature specimens. No significant sex effect was found for muscle lipid content, because a correlation between THg concentration and tissue lipids was found in both sexes.

**[This study demonstrates that European hake caught in the northern and central Adriatic is safe for human consumption, with respect to this contaminant.](#)**



Published: 25 November 2021



*Review*

# Methylmercury and Polycyclic Aromatic Hydrocarbons in Mediterranean Seafood: A Molecular Anthropological Perspective

Andrea De Giovanni <sup>1,2,\*</sup>, Cristina Giuliani <sup>3</sup>, Mauro Marini <sup>2,4</sup> and Donata Luiselli <sup>1,2</sup>

In the present review, we summarize the results of epidemiological investigations on the genetic component of individual susceptibility to methylmercury and polycyclic aromatic hydrocarbons exposure in humans, and on the effects that these two pollutants have on human epigenetic profiles (DNA methylation). Then, we provide evidence that Mediterranean coastal communities represent an informative case study to investigate the potential impact of methylmercury and polycyclic aromatic hydrocarbons on the human genome and epigenome, since they are characterized by a traditionally high local seafood consumption, and given the characteristics that render the Mediterranean Sea particularly polluted.

Article

# Meta-Analysis of a New Georeferenced Database on Polycyclic Aromatic Hydrocarbons in Western and Central Mediterranean Seafood

Andrea De Giovanni <sup>1,2,\*</sup>, Paolo Abondio <sup>1,3</sup>, Emanuela Frapiccini <sup>4</sup>, Donata Luiselli <sup>1,2</sup> and Mauro Marini <sup>2,4</sup>

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**Featured Application:** The database featured in the present work aims to support researchers and decisionmakers in planning future investigations and in evaluating current knowledge on polycyclic aromatic hydrocarbons when it comes to fixing the limits to PAH levels in fishery products.

**Abstract:** The aim of this work was to collect and harmonize the results of several studies achieved over the years, in order to obtain a database of georeferenced observations on polycyclic aromatic hydrocarbons (PAHs) in Western and Central Mediterranean seafood. For each observation, some information on the taxonomy and the ecology of the sampled species are reported, as well as details on the investigated hydrocarbon, and spatial and temporal information on sampling. Moreover, two health risk indexes were calculated for each record and included in the database. Through several statistical methods, we conducted a meta-analysis of the data on some of the species in this database, identifying trends that could be related to the biology of the investigated organisms, as well as to the physico-chemical properties of each hydrocarbon and to the oceanographic characteristic of this part of the Mediterranean. The analysis of the data showed that, at a consumption rate like the one typical of the Italian population, seafood caught from the area considered in the present work seems to pose a minimal risk to health. However, we also found evidence of an increasing trend of PAH concentrations in Mediterranean mussels, pointing to the need for constant monitoring.

**Citation:** De Giovanni, A.; Abondio, P.; Frapiccini, E.; Luiselli, D.; Marini, M. Meta-Analysis of a New Georeferenced Database on Polycyclic Aromatic Hydrocarbons in Western and Central Mediterranean Seafood. *Appl. Sci.* **2022**, *12*, 2776. <https://doi.org/10.3390/app12062776>

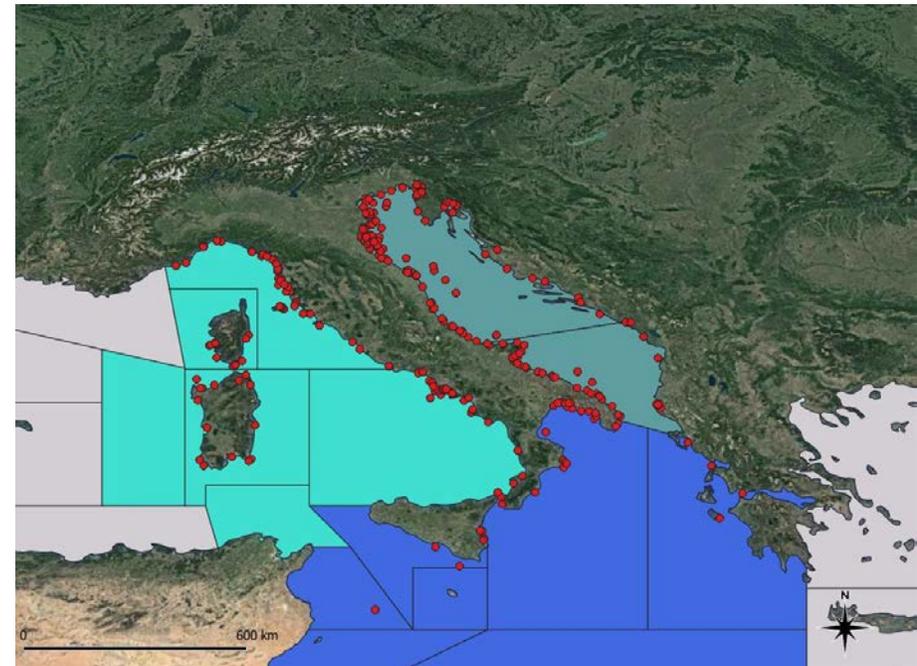
Academic Editors: Raffaele Marotta and Anna Annibaldi

Received: 17 February 2022

Accepted: 3 March 2022

## [On line Database](#)

[De Giovanni, Andrea; Abondio, Paolo; Frapiccini, Emanuela; Luiselli, Donata; Marini, Mauro \(2022\): Polycyclic aromatic hydrocarbons in seafood caught in Western and Central Mediterranean from 1981 to 2019 \[dataset\]. PANGAEA, <https://doi.org/10.1594/PANGAEA.943169>](#)





Marine Pollution Bulletin 184 (2022) 114109

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Marine Pollution Bulletin

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Peculiar polycyclic aromatic hydrocarbons accumulation patterns in a non-zooxanthellate scleractinian coral

Frapiccini Emanuela<sup>a,d,1</sup>, Caroselli Erik<sup>b,d,1</sup>, Franzellitti Silvia<sup>c,d</sup>, Prada Fiorella<sup>a,d,2</sup>, Marini Mauro<sup>b,d,\*</sup>, Goffredo Stefano<sup>a,d</sup>

Science of the Total Environment 743 (2020) 140781

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Science of the Total Environment

journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)



Accumulation of PAHs in the tissues and algal symbionts of a common Mediterranean coral: Skeletal storage relates to population age structure

Erik Caroselli<sup>a,e,1</sup>, Emanuela Frapiccini<sup>b,e,1</sup>, Silvia Franzellitti<sup>c,e</sup>, Quinzia Palazzo<sup>d,e</sup>, Fiorella Prada<sup>a,e</sup>, Mattia Betti<sup>b,e</sup>, Stefano Goffredo<sup>a,c,e</sup>, Mauro Marini<sup>b,e,\*</sup>



10 mm

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## In conclusions.

Assessing the sources and accumulation patterns of polycyclic aromatic hydrocarbons (PAHs) in corals is critical, as they threaten coral ecosystem resilience in addition to other anthropogenic pressures. We determined acenaphthene, fluorene, fluoranthene, and pyrene concentration in the skeleton and soft tissue of 7 adult and 29 old specimens of the non-zooxanthellate coral *Leptopsammia pruvoti* from the Mediterranean Sea.

*Leptopsammia pruvoti* accumulated 2–72 times higher PAH concentrations than the previously investigated zooxanthellate *Balanophyllia europaea* living at the same site at shallower depth, likely in relation to the different trophic strategy. Low molecular weight PAHs were preferentially accumulated compared to high molecular weight PAHs.

Detected PAHs were mainly petrogenic, consistently with local pollution sources. **Populations of *L. pruvoti* immobilized PAHs in the skeleton 3–4 orders of magnitude more efficiently than *B. europaea*.** This highlights the need to investigate other non-zooxanthellate species, which represent the majority of Mediterranean scleractinians, but are widely overlooked with respect to the few zooxanthellate species.



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## Regional Studies in Marine Science

journal homepage: [www.elsevier.com/locate/rsma](http://www.elsevier.com/locate/rsma)



First assessment of heavy metals contamination and human health risk in *Chelon auratus* (Risso, 1810) from Tunisian aquatic ecosystems: Case of Bizerte Lagoon and Ghar El Melh Lagoon (Ramsar site)

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**Most metal levels in muscle tissue, the edible part, remain below international safety limits, the presence of cadmium near or above quantification thresholds in some samples raises concern for long-term exposure through fish consumption. From an environmental perspective, elevated Cd levels, particularly in liver tissues, reflect persistent contamination and pose a serious threat to fish health. Moreover, its bioaccumulative nature can disturb the aquatic food web by transferring toxicity across trophic levels. These findings underline the urgent need for continued monitoring, pollution control, and conservation measures to protect both ecosystem integrity and public health.**

In this study, the concentrations of heavy metals (**Cu, Zn, Pb, and Cd**) were measured in the liver and muscle of golden grey mullet (*C. auratus*) collected from the lagoons of Bizerte and Ghar El Melh. A total of 30 fish samples from each lagoon were collected. Mean concentrations of Cd, Cu, and Zn varied between lagoons and tissues, with **Cd** levels ranging from 0.95 to **3.18 mg/kg** dry weight, **Cu** detected only in liver reaching up to **477.66 mg/kg**, and **Zn** ranging from 6.91 to **188.29 mg/kg**, generally higher in liver than muscle and higher in Ghar El Melh Lagoon compared to Bizerte Lagoon. The results showed that Pb was not detected in any of the samples analyzed. Zn and Cu exhibited the highest concentrations, particularly in liver tissues.



# Acquaculture and circular economy

Heliyon 10 (2024) e27443



Contents lists available at [ScienceDirect](#)

Heliyon

journal homepage: [www.cell.com/heliyon](http://www.cell.com/heliyon)



Review article

## Use of grape by-products in aquaculture: New frontiers for a circular economy application

Martina Quagliardi <sup>a,\*</sup>, Emanuela Frapiccini <sup>b</sup>, Mauro Marini <sup>b</sup>, Monica Panfili <sup>b</sup>, Agnese Santanatoglia <sup>c</sup>, Manuella Lesly Kouamo Nguefang <sup>c</sup>, Alessandra Roncarati <sup>a</sup>, Sauro Vittori <sup>c</sup>, Germana Borsetta <sup>c</sup>



oils rich in  
unsaturated  
fatty acids (n-6)

dietary fibre  
and phenolic  
compounds

detritus | Multidisciplinary Journal for  
Circular Economy and Sustainable  
Management of Residues



## AGRI-FISH: SUSTAINABLE AND INNOVATIVE FEEDS FROM AGRICULTURAL WASTES FOR A RESILIENT AND HIGH-QUALITY AQUACULTURE

Germana Borsetta <sup>1,\*</sup>, Emanuela Frapiccini <sup>2</sup>, Alessandra Roncarati <sup>1</sup>, Martina Quagliardi <sup>1</sup>, Mauro Marini <sup>2</sup>, Monica Panfili <sup>2</sup> and Sauro Vittori <sup>1</sup>

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One Health

### ABSTRACT

The Agri-fiSh project has been funded under Horizon 2020 - PRIMA, with the research partnership of three Mediterranean countries: Algeria, Italy and Spain. The project will contribute to the transition to a more resilient agro-livelihood system through an innovative and circular farming approach, which promotes an efficient use of biological and natural resources with a valuable increase in productivity. New potential for farms, agri-food systems and local markets will arise from the valorization of agricultural wastes to be used for the creation of high-value plant-based feeds for a sustainable inland aquaculture. Nutraceutical potential of specific agricultural wastes (i.e grape seeds, legumes and cereals), in combination with other components, as Lactic Acid Bacteria (LABs) fermented whey and medicinal herbs) to create plant-based feeds for aquaculture, will foster animal and human health with consequent benefits for the environment, local economies and consumers.

## Conclusions:

Contaminants spread easily into the sea mainly through **rivers**;

In fish, the contaminants are found accumulated in the various organs: **gills, liver and muscle**;

The contaminants are also **present in other marine organisms and sediments** in non-negligible concentrations;

The results of research on edible marine products do **not show dangerous concentrations** for human health **but** we must always bear in mind that they **accumulate**.

Human toxicity may develop in human tissue over time.



Credit: Marco Faimali

Mauro Marini CNR-IRBIM-Ancona

<https://orcid.org/0000-0002-9674-7197>

## The exam to assess students' qualifications: one take-home essay.

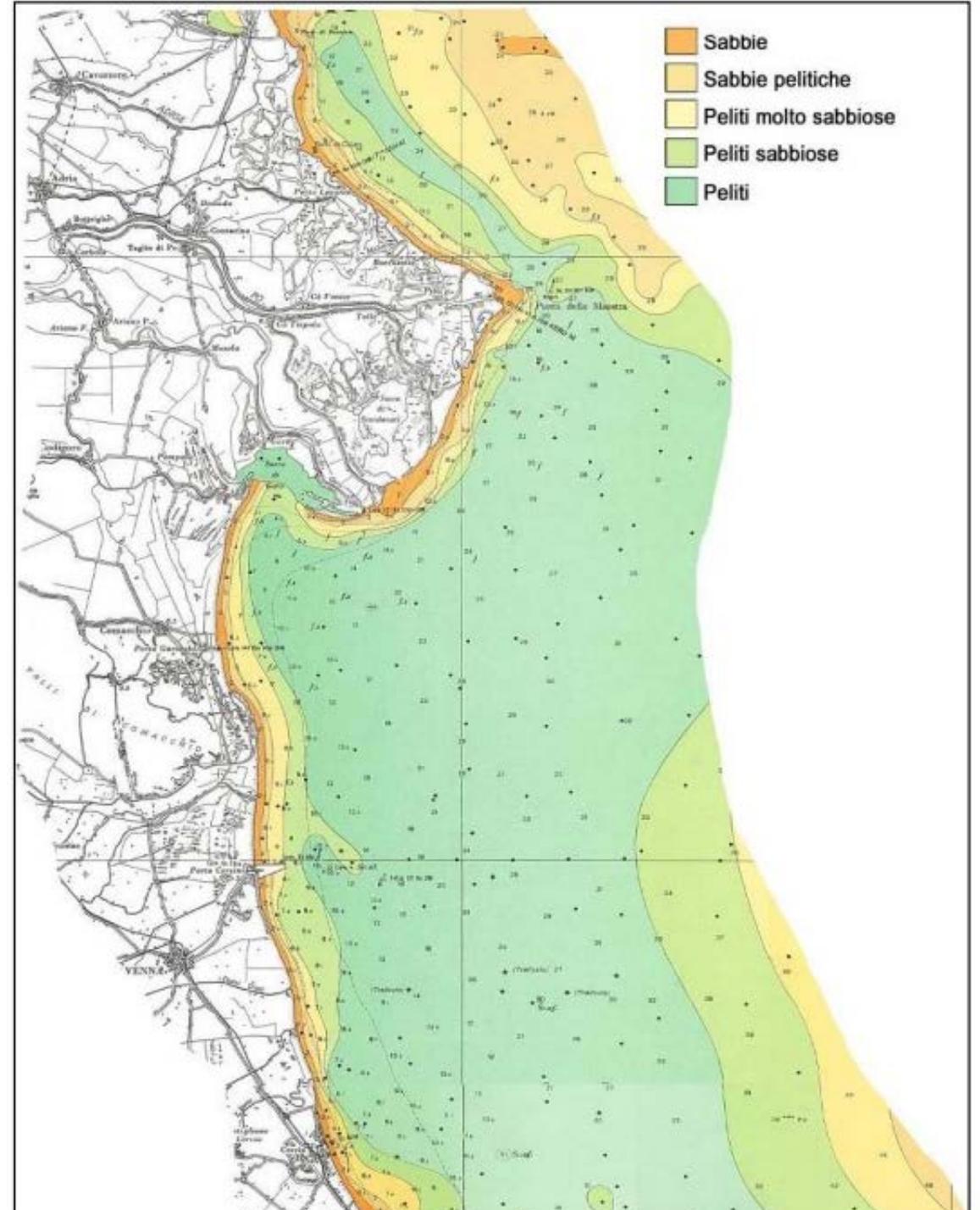
The exam will be limited to a maximum of two pages of text plus figures (e.g., graphical abstract or specific figures with caption and title) and references to submit ([mauro.marini@cnr.it](mailto:mauro.marini@cnr.it)) their essays to you by June 12, 2026.

The essay will be evaluated as either “Pass” or “Fail.”

The references for my lecture are all in the text and can also be downloaded by clicking the link on my ResearchGate or Scopus profile, <https://orcid.org/0000-0002-9674-7197>.



Credit: Marco Faimali



Mauro Marini CNR-IRBIM-Ancona

<https://orcid.org/0000-0002-9674-7197>