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Ginevra Rosati,
C. Solidoro, D. Canu

Modelling mercury bioaccumulation in reared clams from a temperate polluted lagoon

OGS

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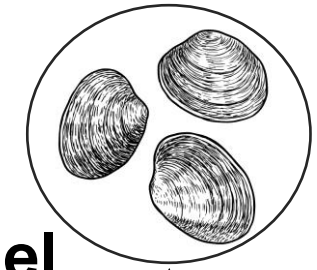
Graphical abstract

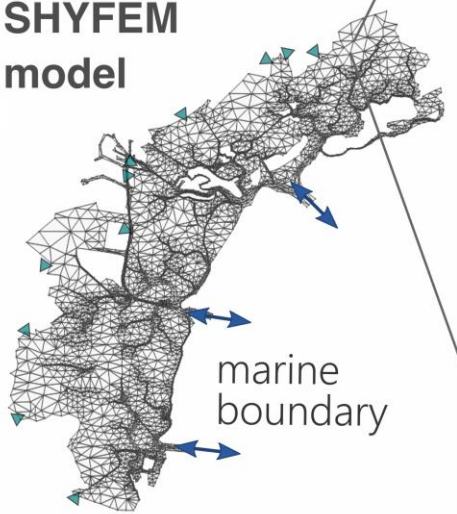
Clam growth and bioaccumulation model



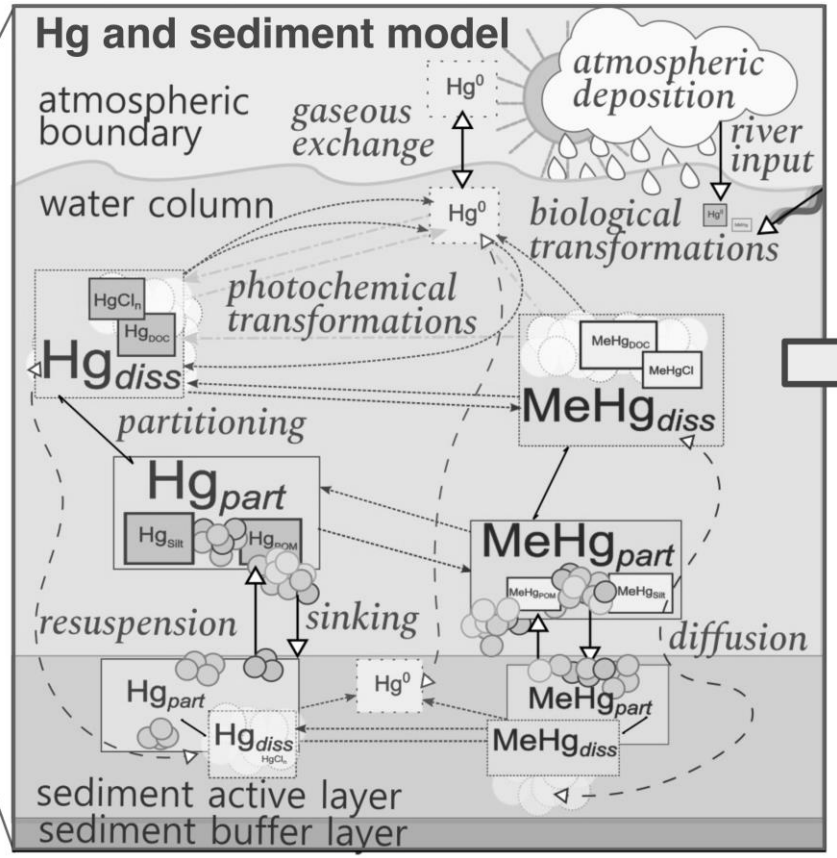
Hg^{II} and MeHg in water, labile POM and refractory POM

High resolution Hg model

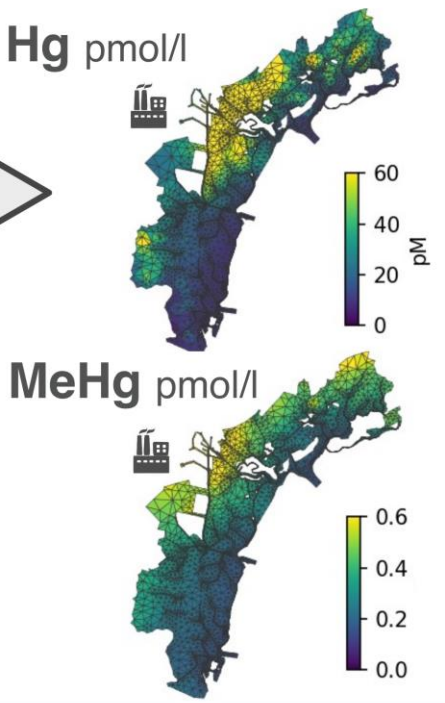
Hydrodynamic SHYFEM model



Hg and sediment model

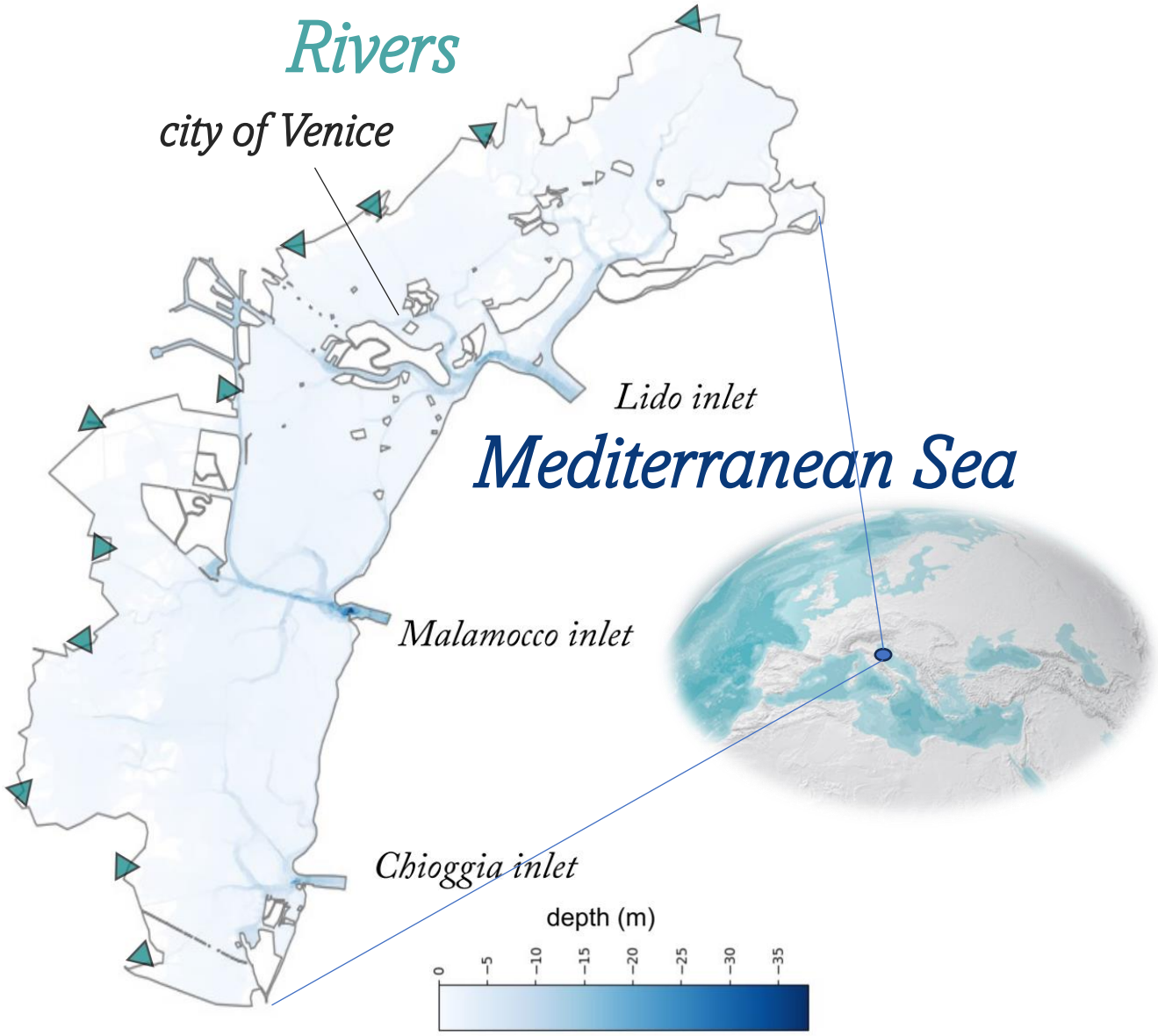


Hg species in water and sediment



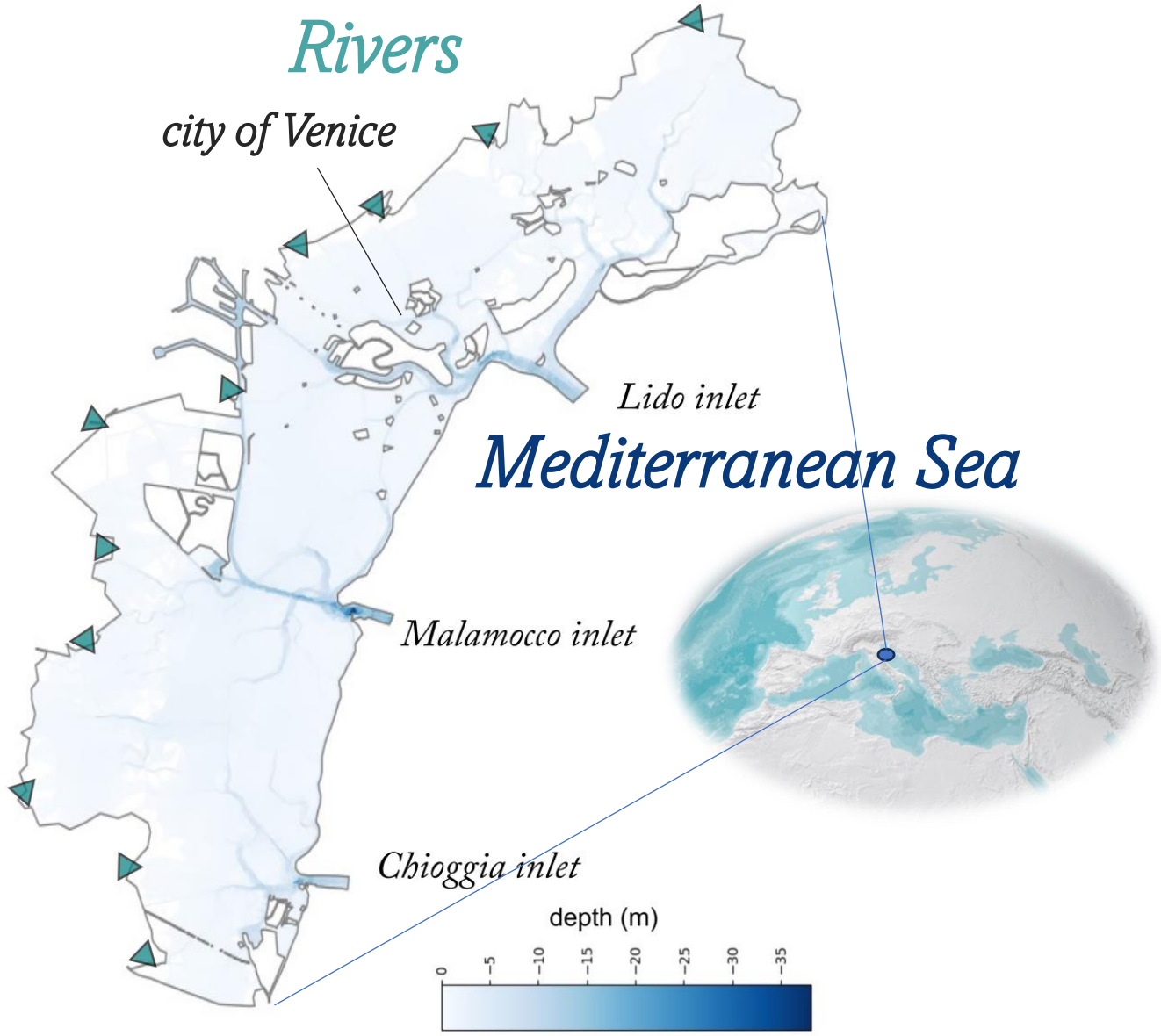
Rosati et al., 2024

Study area – The Venice Lagoon



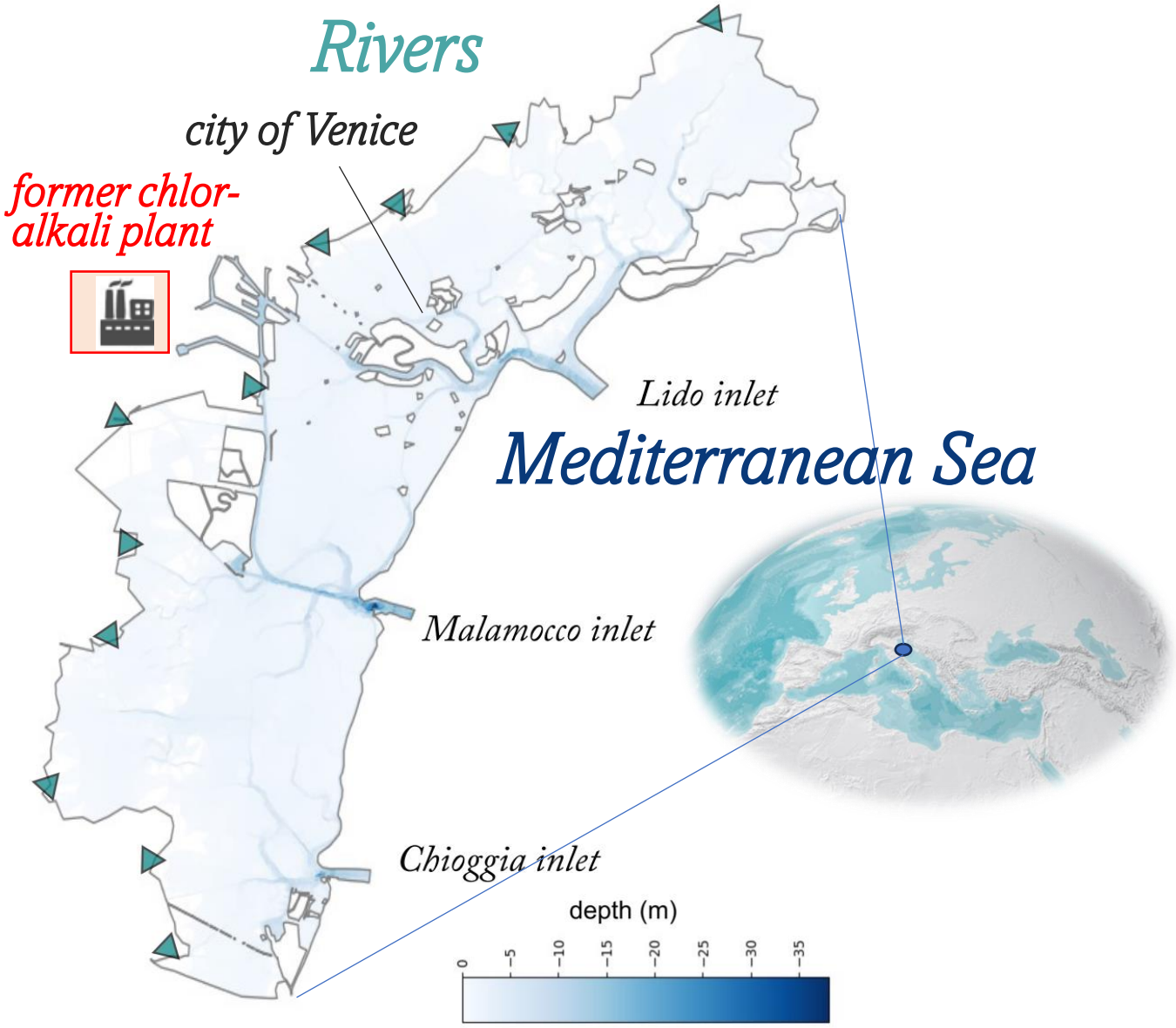
- shallow coastal lagoon (average depth < 1 m)

Study area – The Venice Lagoon



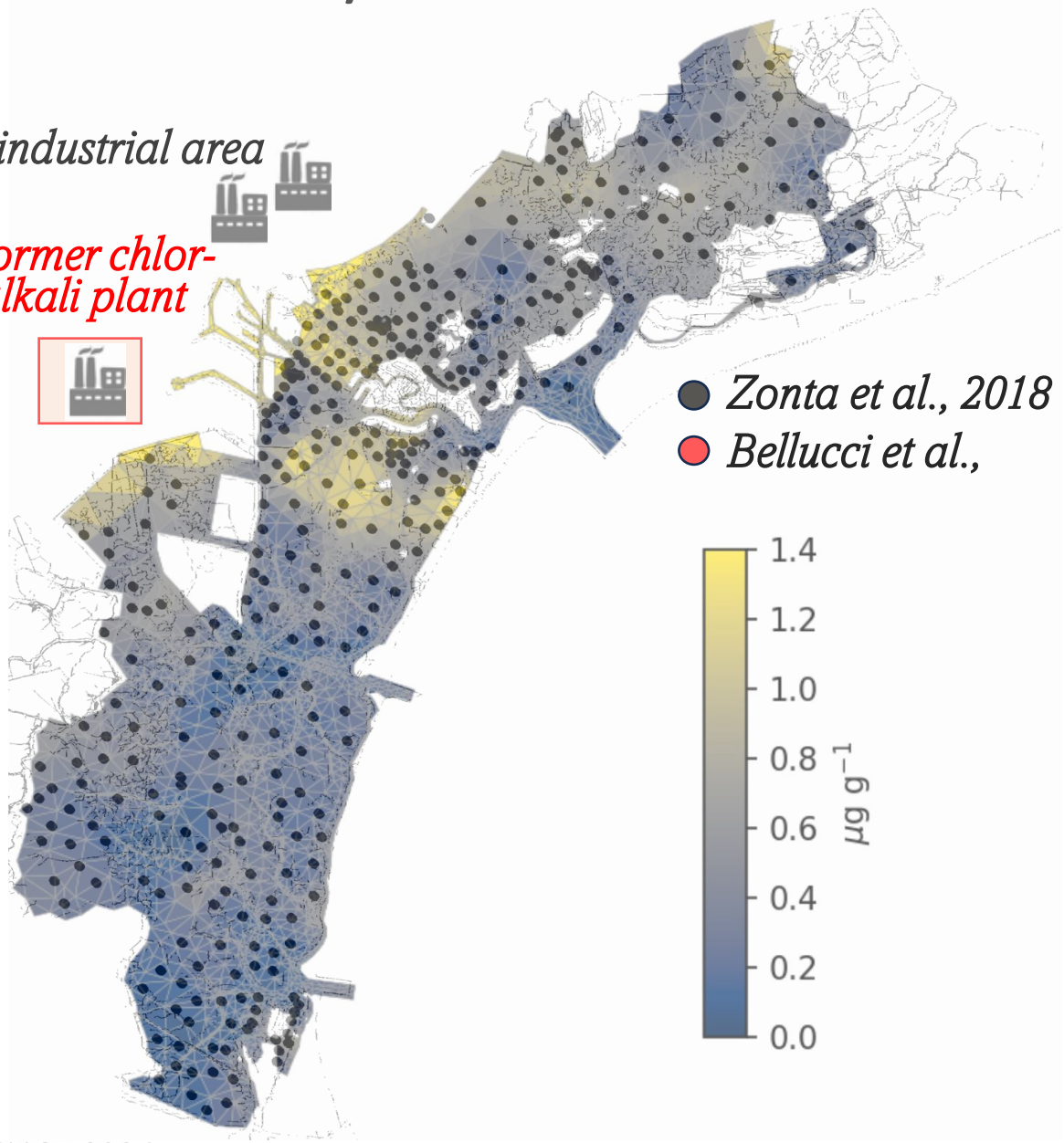
- shallow coastal lagoon (average depth < 1 m)
- socio-economic importance of artisanal fishery and aquaculture

Study area – The Venice Lagoon



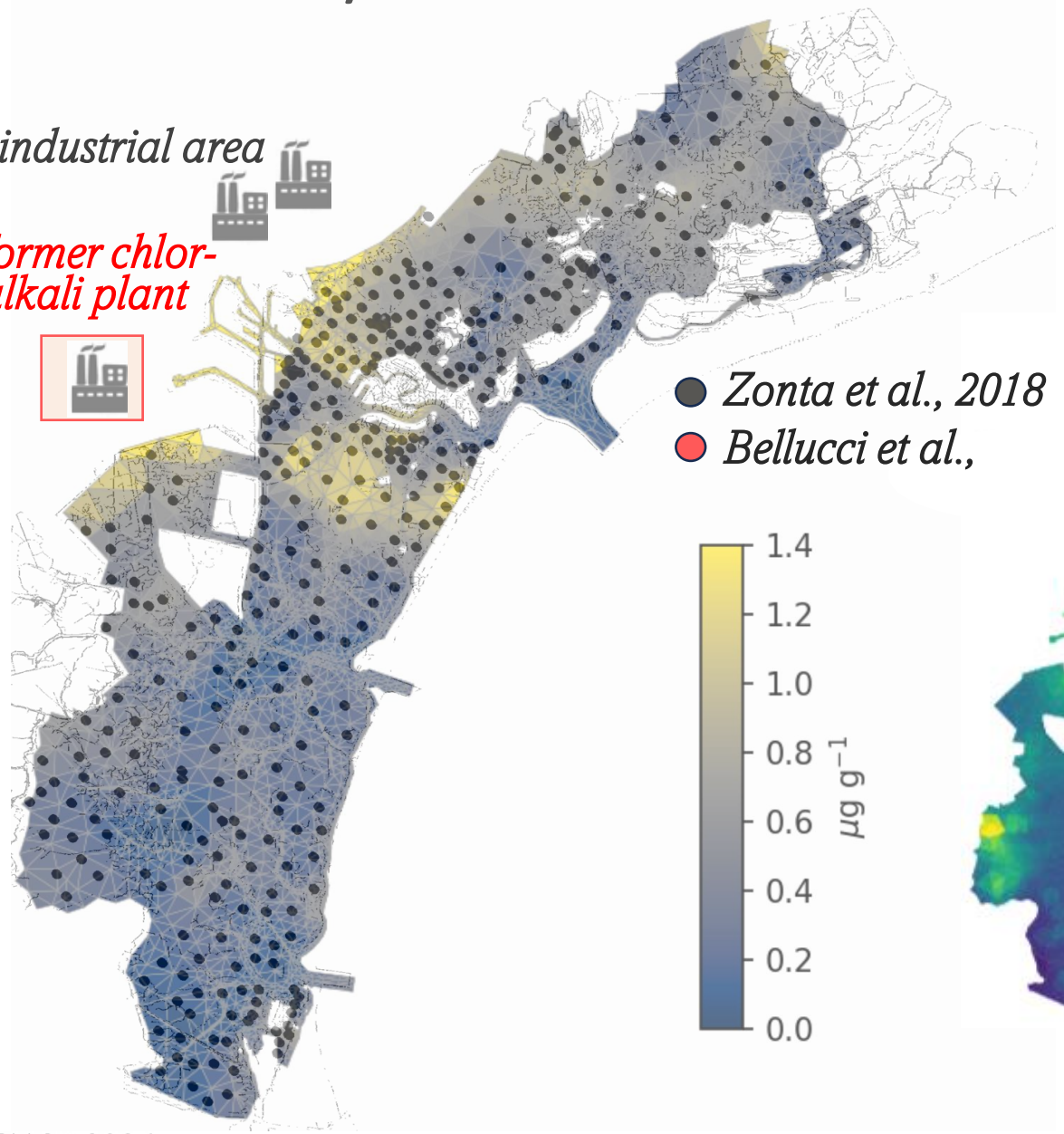
- shallow coastal lagoon (average depth < 1 m)
- socio-economic importance of artisanal fishery and aquaculture
- historical contamination: chlor-alkali plant (1920-2000)

Study area – The Venice Lagoon

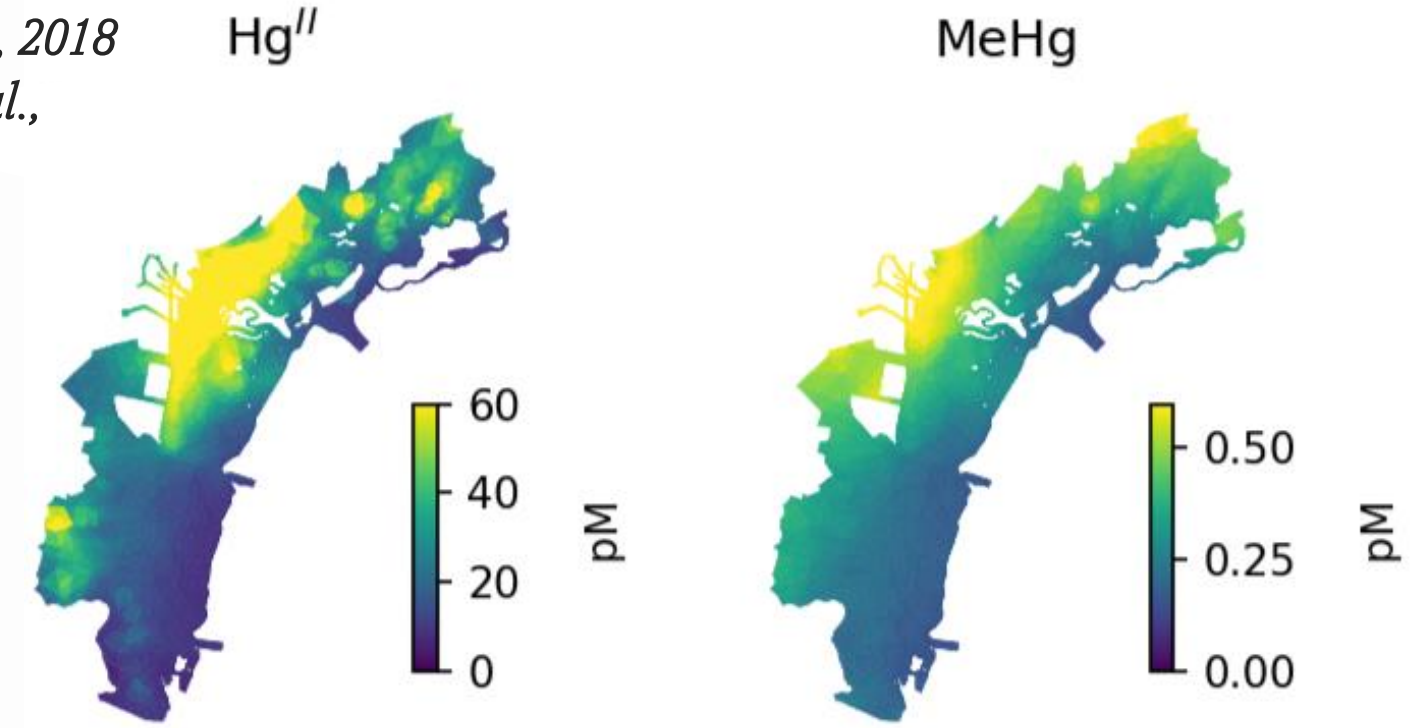


High concentrations of Hg species in sediment

Study area – The Venice Lagoon



High concentrations of Hg species in sediment and water

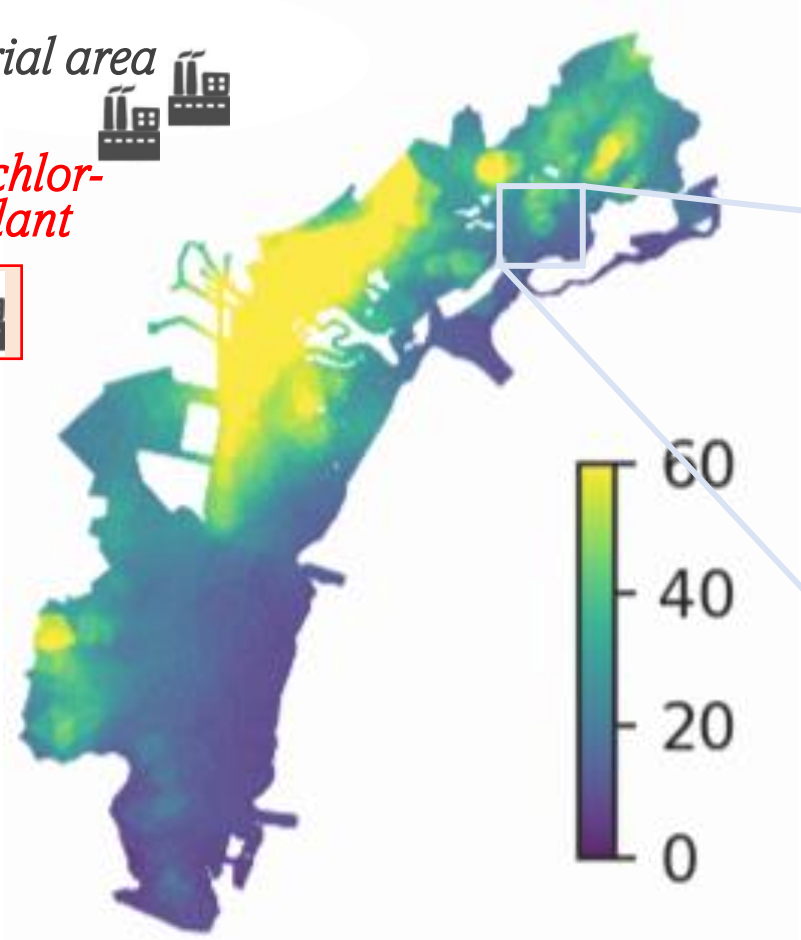


Rosati et al., 2024

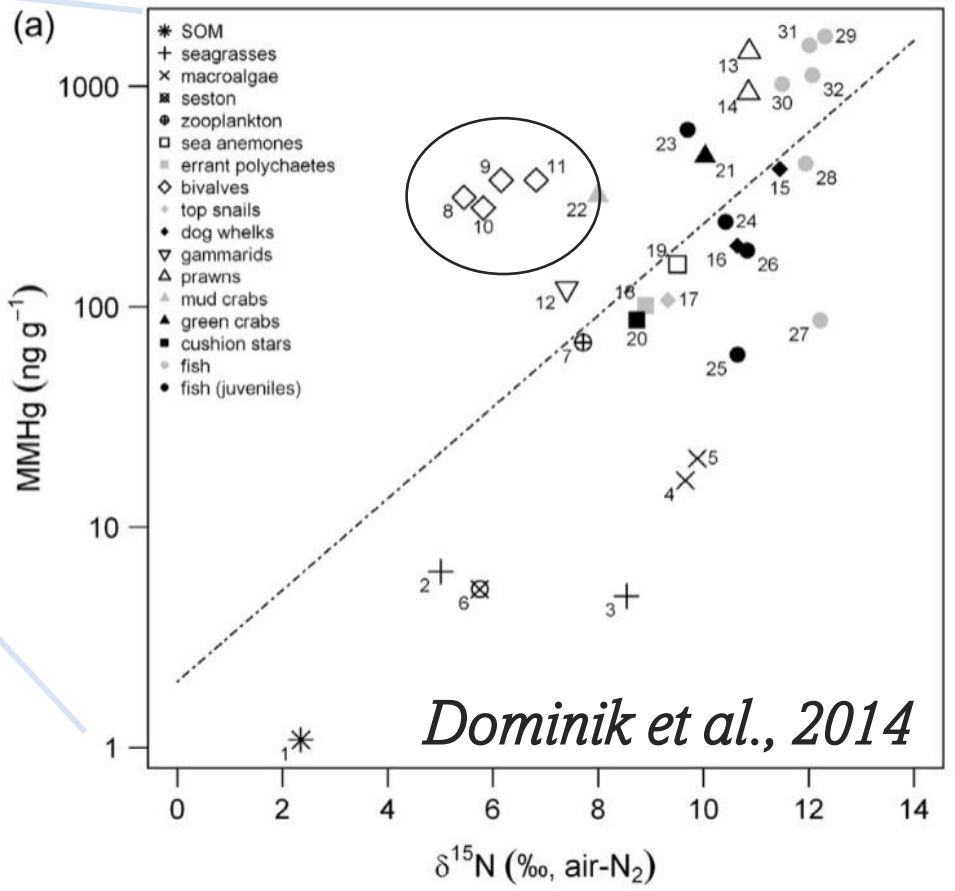
Study area – The Venice Lagoon

industrial area

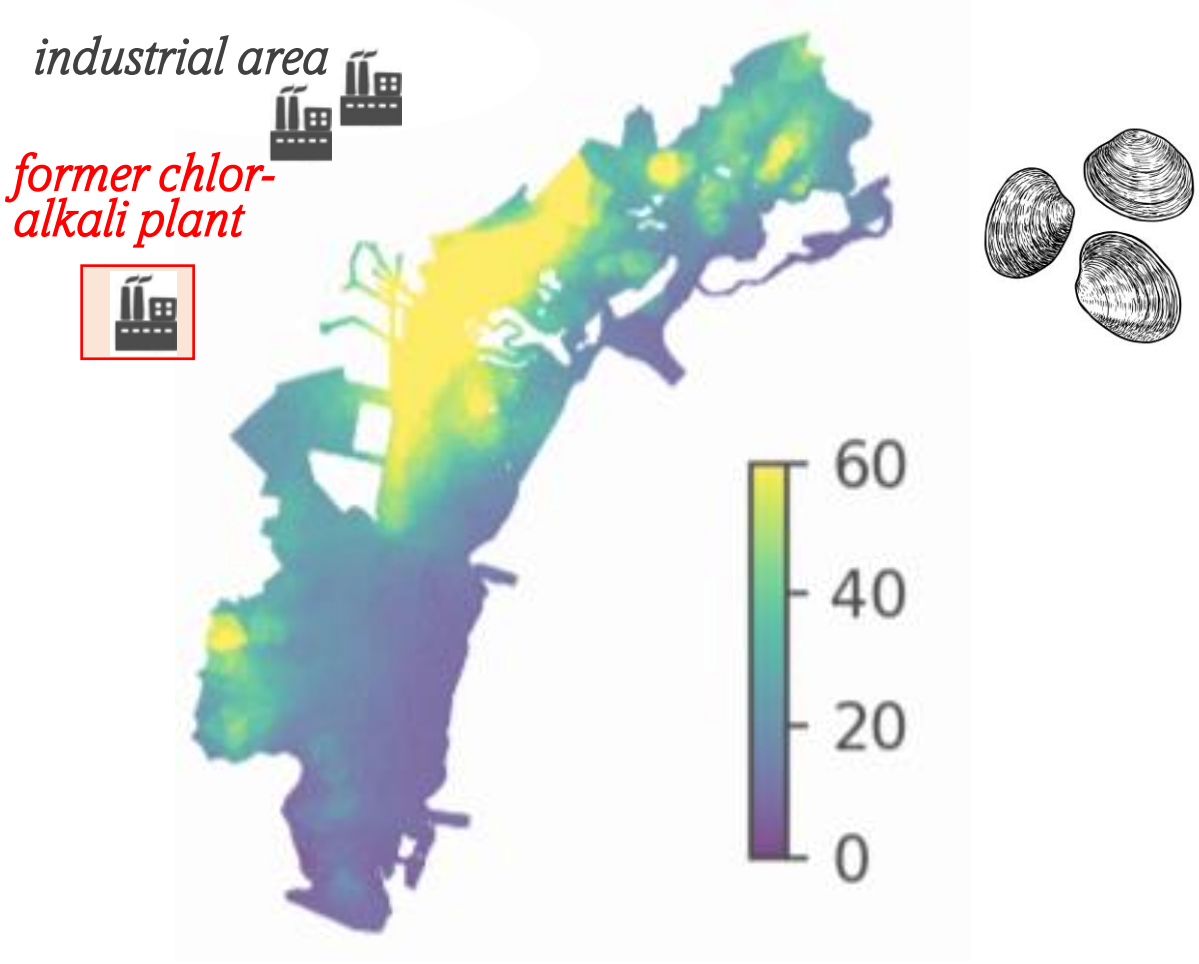
former chlor-alkali plant



Bioaccumulation is 3–4 times higher than in the Mediterranean Sea

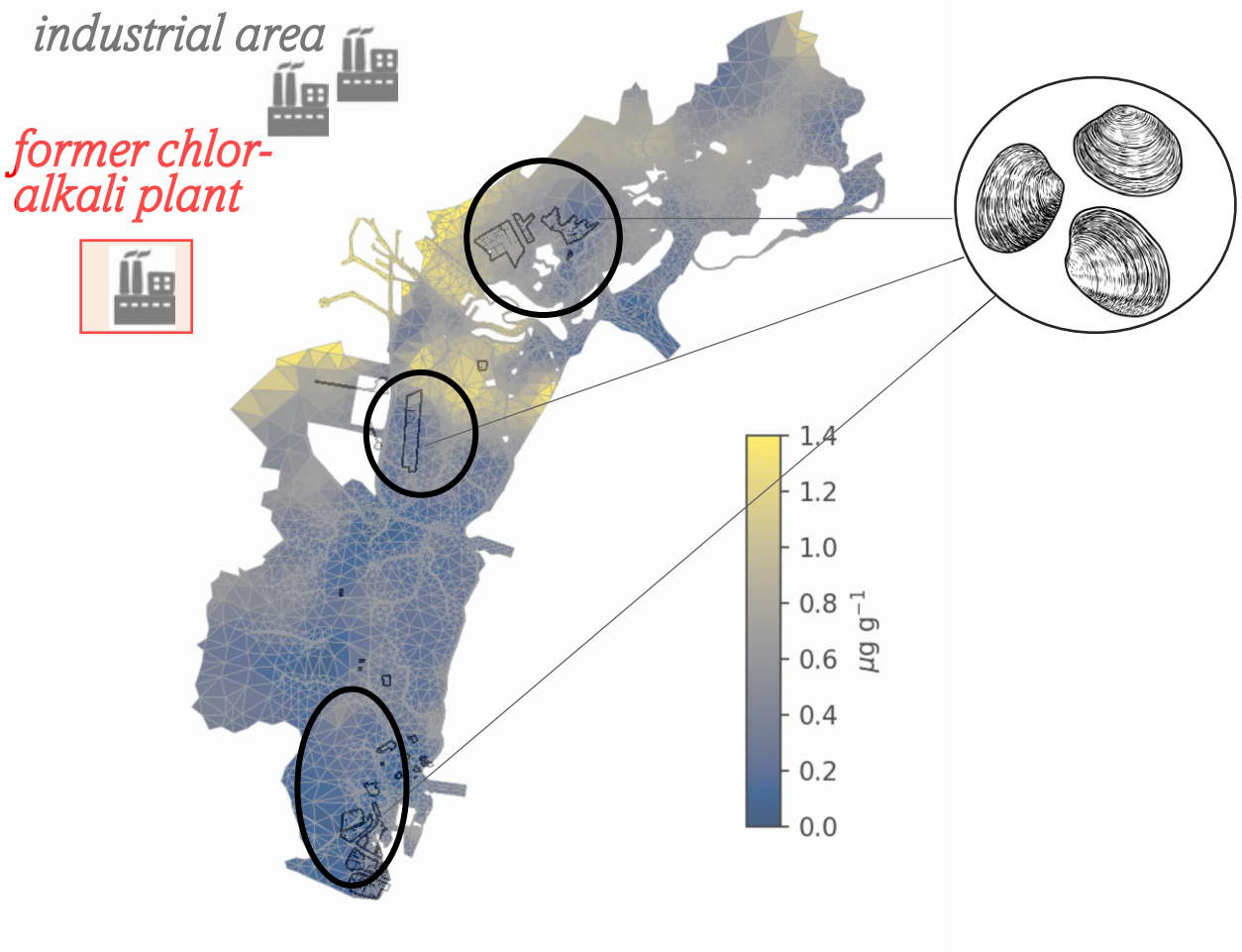


Manila clam in the Venice Lagoon



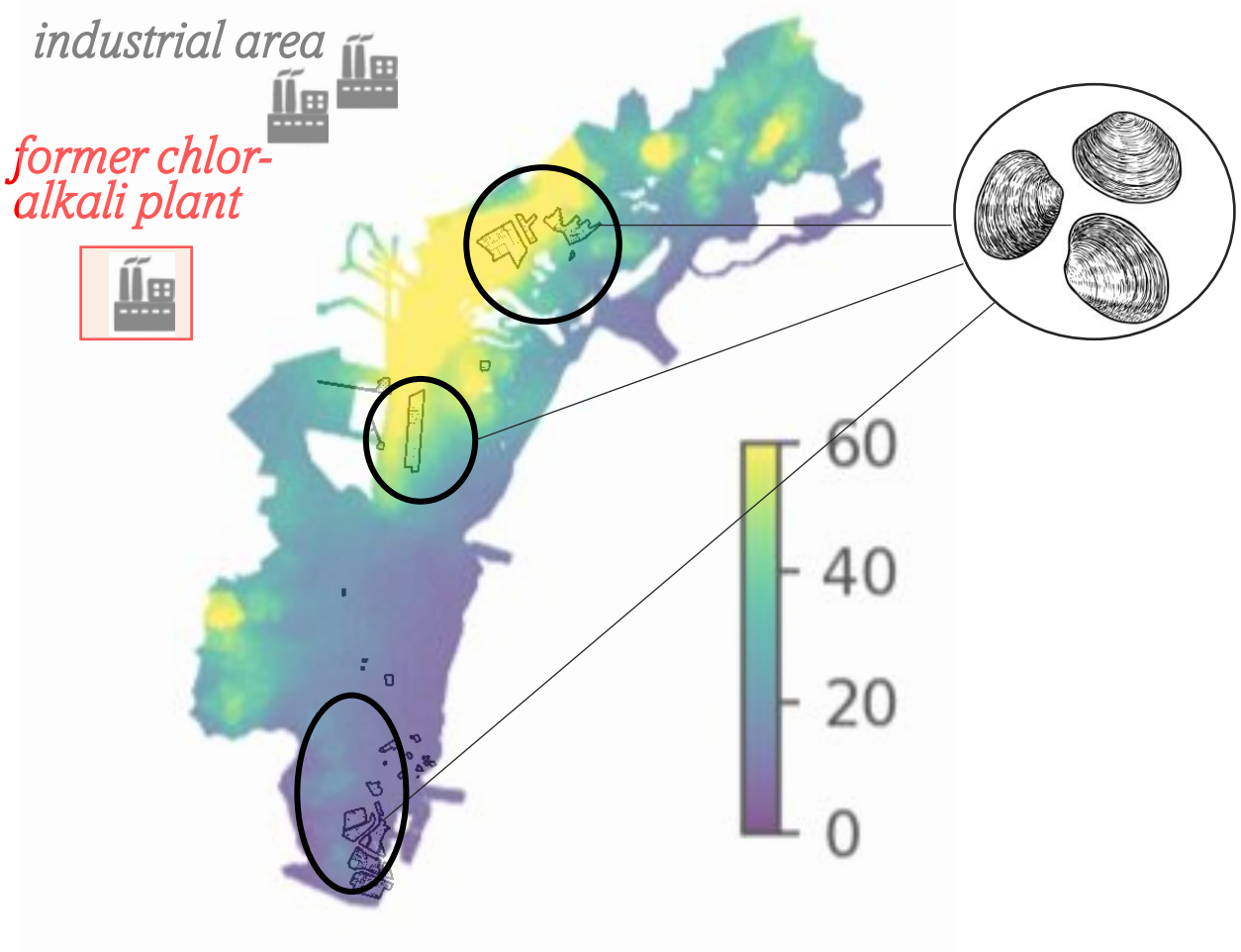
- introduced in the lagoon in the 1980s due to the rapid decline of the population of local clam *Tapes decussatus (Solidoro et al., 2020)*
- *Tapes philipinarum* colonized large areas of the lagoon replacing *T. decussatus* becoming an important economic resource

Manila clam in the Venice Lagoon



- introduced in the lagoon in 1983 due to the rapid decline of the population of local clam *Tapes decussatus*
- *Tapes philipinarum* colonized large areas of the lagoon replacing *T. decussatus* becoming an important economic resource *(Solidoro et al., 2000)*
- Seeds from wild population are rearead in controlled farming areas

Manila clam in the Venice Lagoon



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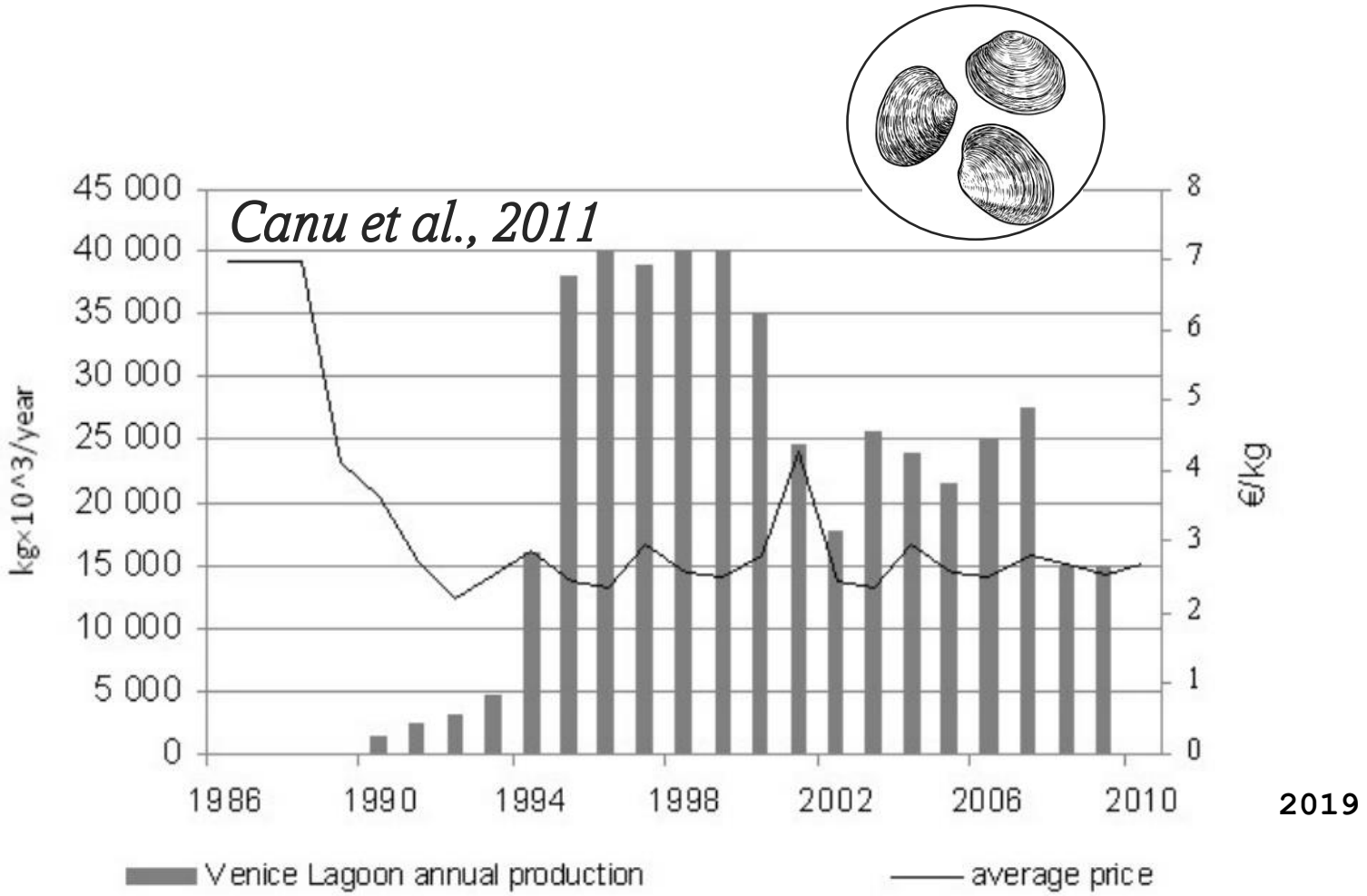
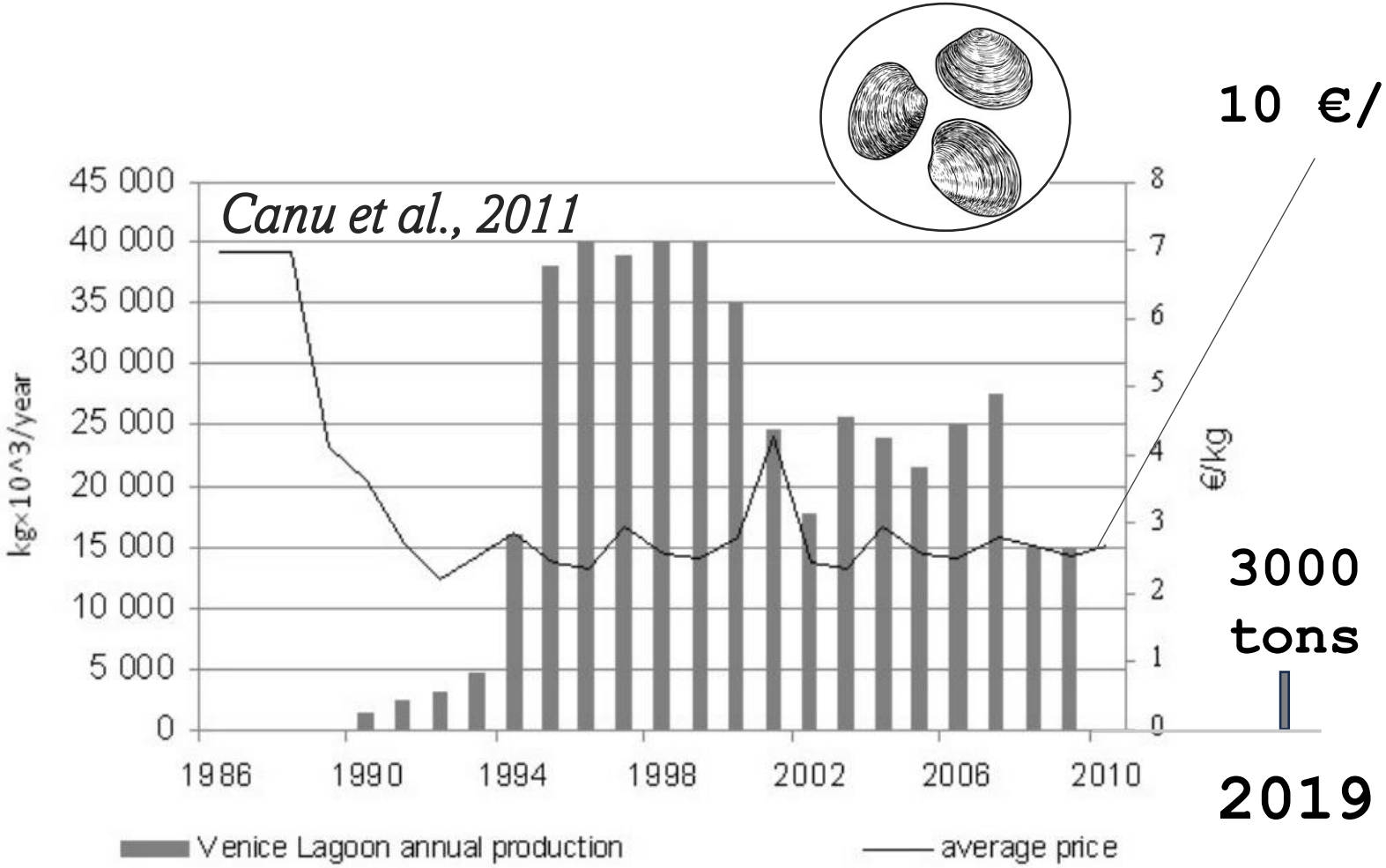


Annual production decreased from 40 000 tons in the 1990s to 3 000 tons in 2019 (Canu et al., 2011, Bernardini et al., 2023)

Manila clam in the Venice Lagoon

Recent increase of mortality events and very low recruitment in the wild population of Manila Clam *Tapes philippinarum* (*Bernardini et al., 2023)*



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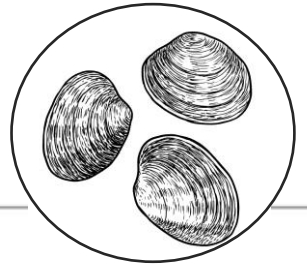
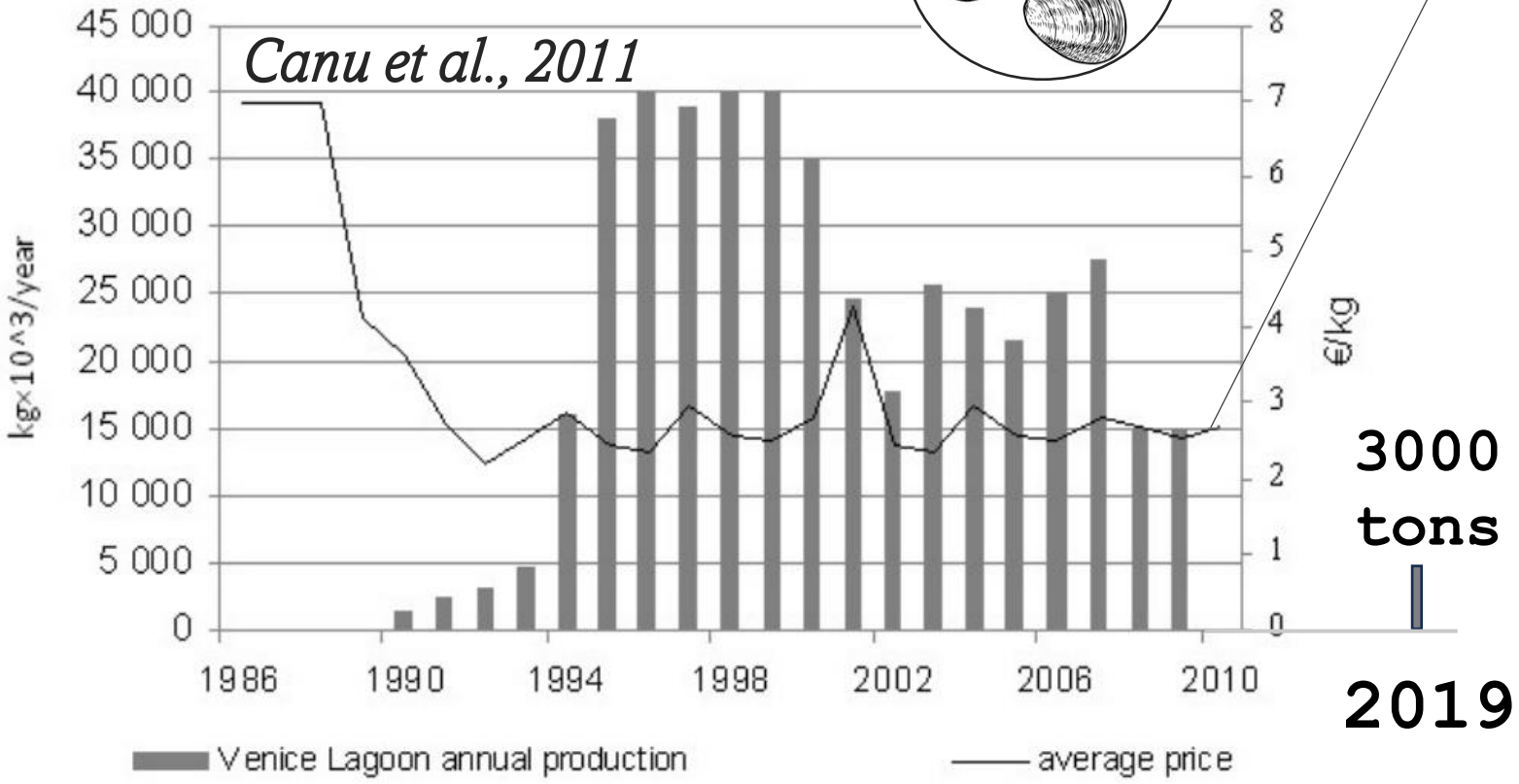


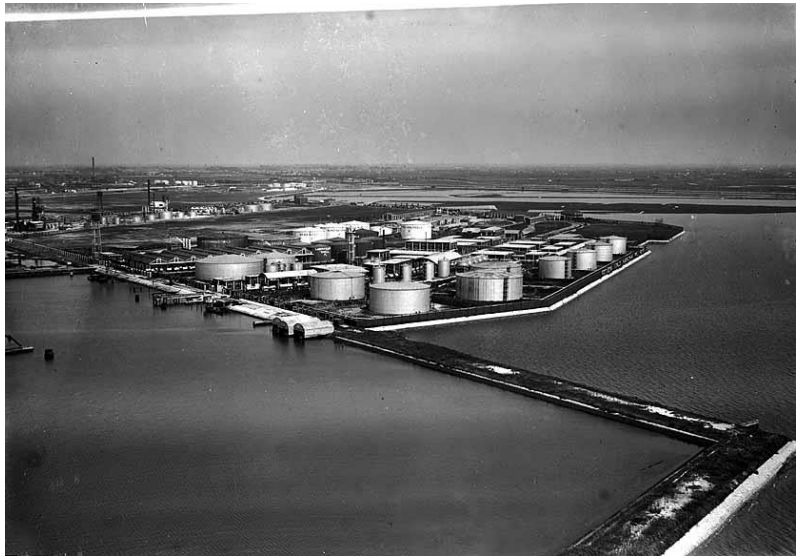


10 €/kg

3000 tons

2019

Pollution?



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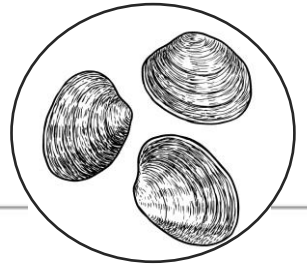
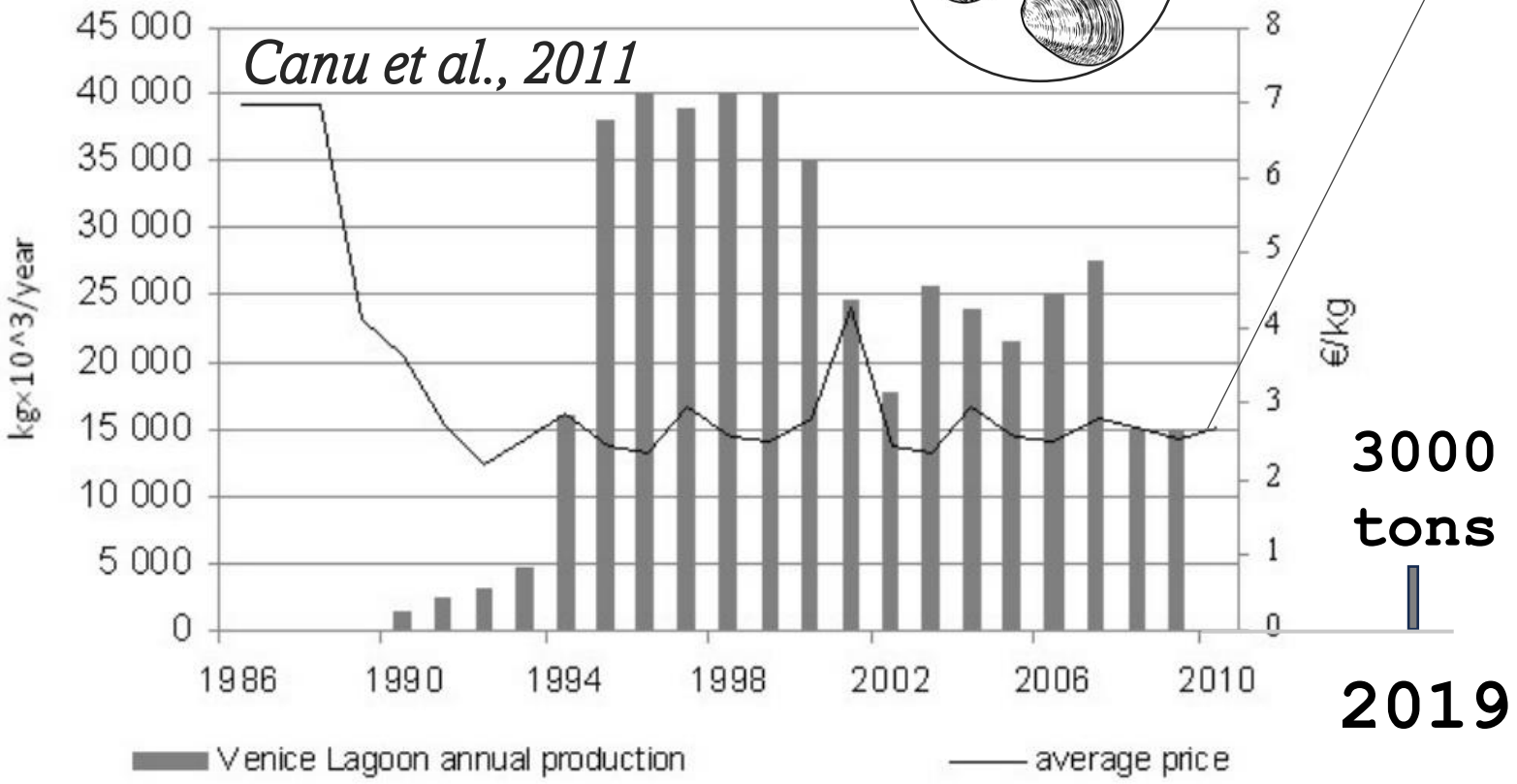




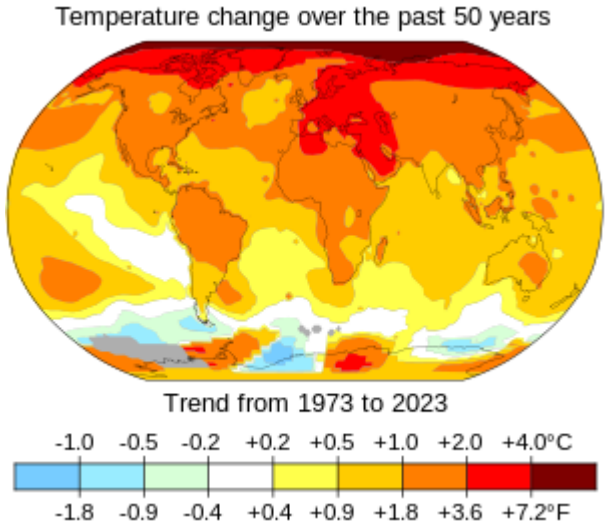
10 €/kg

3000 tons

2019

Pollution?

Climate change?



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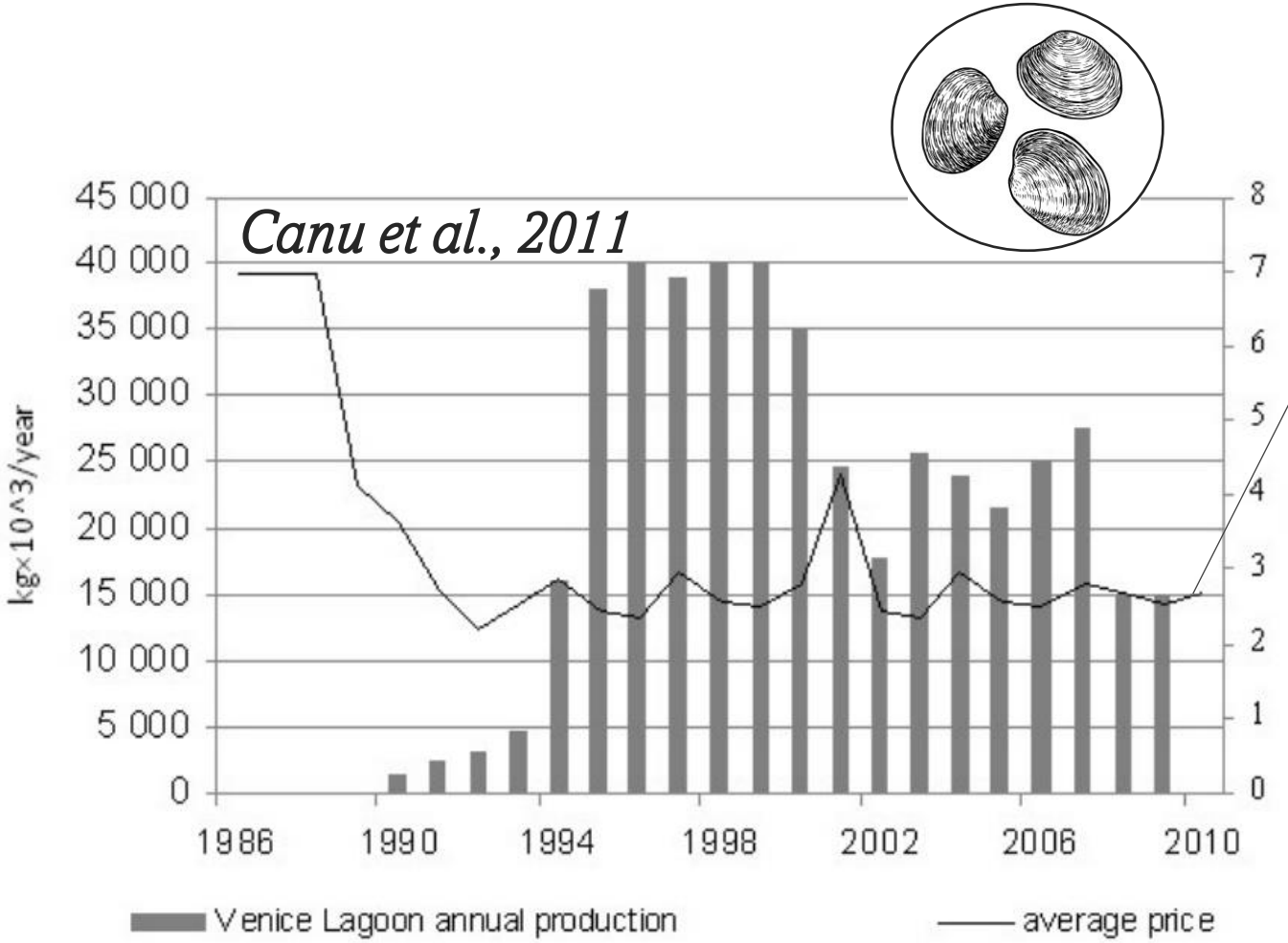

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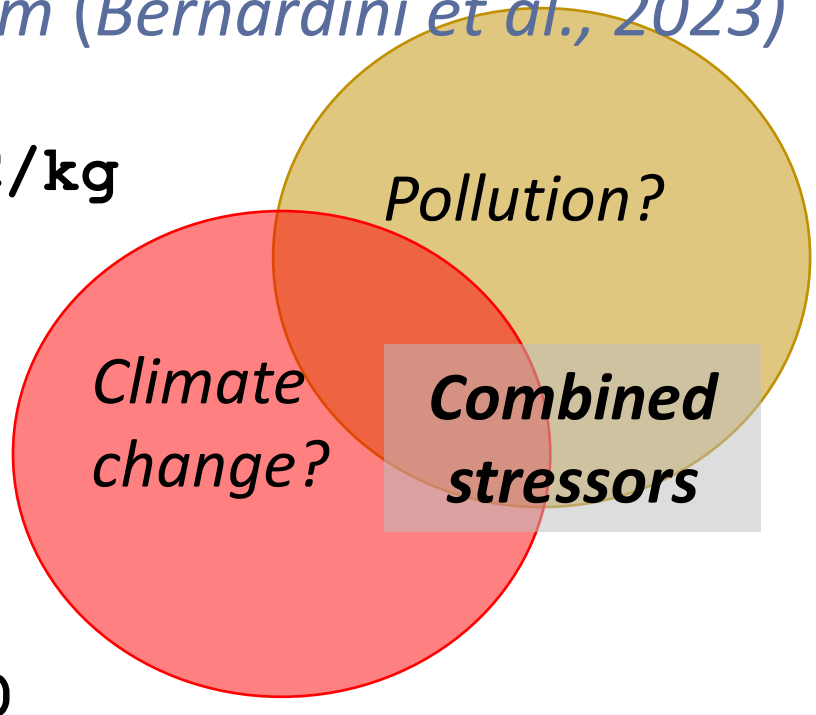
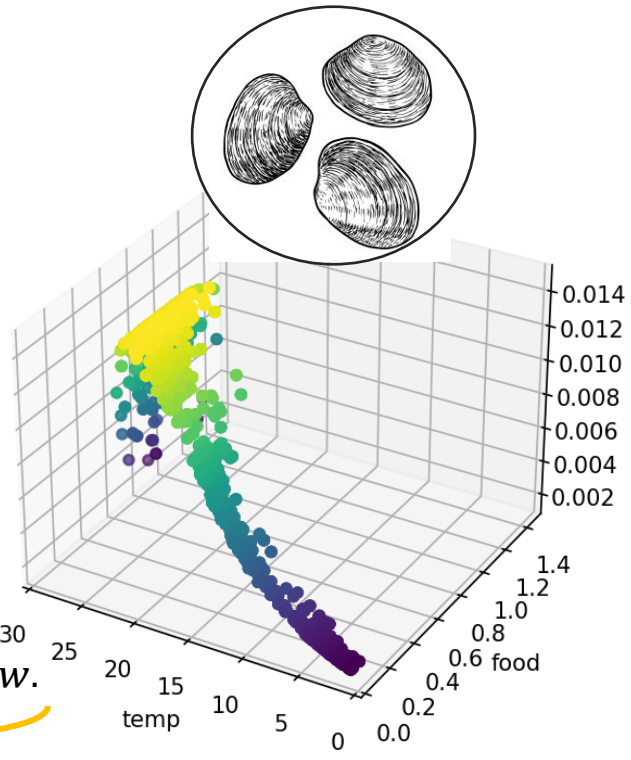


Bioenergetic model

Food limitations and thermal optimum for growth, filtration and respiration are taken into account



If Food > Food_threshold:

$$\frac{dB_{d.w.}}{dt} = \underbrace{G_{max} \cdot f_G(T) \cdot \mathrm{B}_{d.w.}^{(1-\frac{1}{3p})}}_{\text{Growth}} - \underbrace{R_{max} \cdot f_R(T) \cdot B_{d.w.}}_{\text{Respiration}}$$

If Food < Food_threshold:

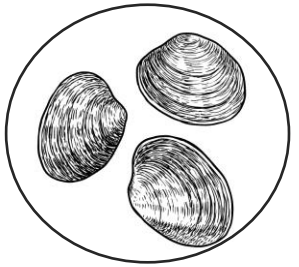
$$\frac{dB_{d.w.}}{dt} = \frac{\boldsymbol{F}}{\boldsymbol{F_{tresh}}} \cdot \underbrace{G_{max} \cdot f_G(T) \cdot \mathrm{B}_{d.w.}^{(1-\frac{1}{3p})}}_{\text{Growth}} - \underbrace{R_{max} \cdot f_R(T) \cdot B_{d.w.}}_{\text{Respiration}}$$

with Food_threshold:

$$F_{tresh} = \frac{G_{max} \cdot f_G(T) \cdot \mathrm{B}_{d.w.}^{(1-\frac{1}{3p})} \cdot \varepsilon_{clam}}{V_f \cdot f_v(T) \cdot \mathrm{B}_{d.w.}^{q} \cdot \varepsilon_{food}}$$

Solidoro et al., 2000, 2003, Canu et al., 2011

Bioaccumulation model



dietary intake

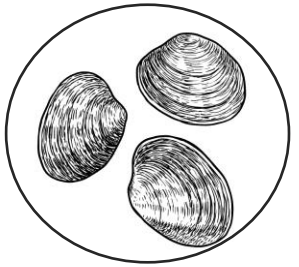
$$\frac{dHg_{clam}}{dt} = V_f \cdot f_v(T) \cdot \mathrm{B}^{q}_{d.w.} \cdot \mathrm{AE}_{Hgi} \cdot \left[\mathrm{Hg}_{POM\_l} + \propto \mathrm{Hg}_{POM\_r}\right]$$

$$+ \; V_f \cdot f_v(T) \cdot \mathrm{B}^{q}_{d.w.} \cdot \eta_{Hgi} \cdot \left[\mathrm{Hg}_{diss}\right] - \beta e^{\gamma T} \left[\mathrm{Hg}_{clam}\right]$$

uptake from water

excretion

Bioaccumulation model



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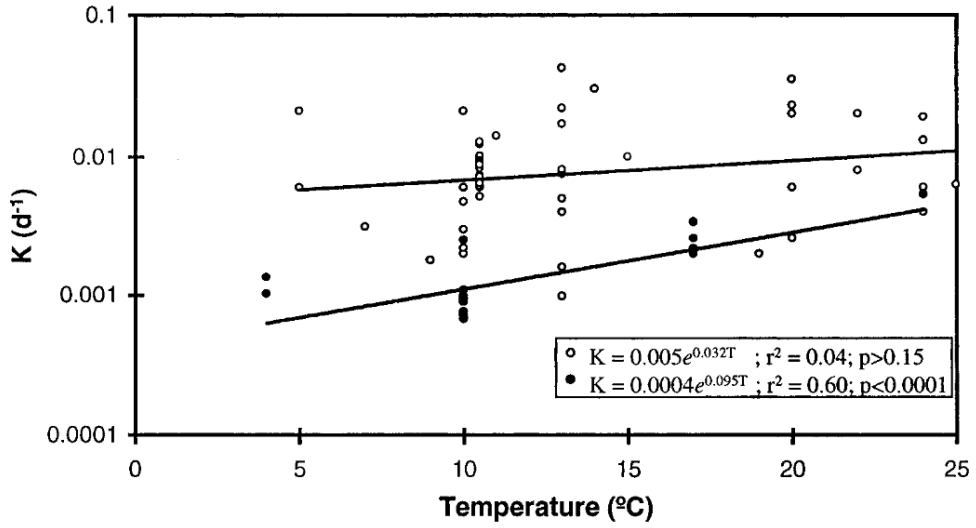
uptake from water

excretion

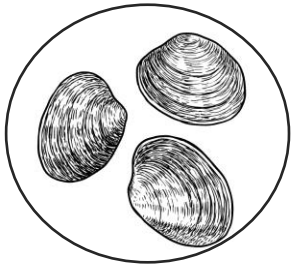
Bioaccumulation model

par	HgII	MeHg	reference	
AE	0.09 - 0.46	0.67 - 0.86	*Pan and Wang, 2011*	*clams*
η	0.08	0.72	*Pan and Wang, 2011*	
β	$4 \cdot 10^{-2}$	$5 \cdot 10^{-3}$	*Pan and Wang, 2011*	
	$6 \cdot 10^{-3}$	-	*Casas and Backer 2006*	*mussels*
	-	$4 \cdot 10^{-4}$	*Trudel and Rasmussen, 1997*	*fish*
γ	-	0.095	*Trudel and Rasmussen, 1997*	



Short term experiments overestimates excretion rates (*Trudel and Rasmussen, 1997)*

Bioaccumulation model



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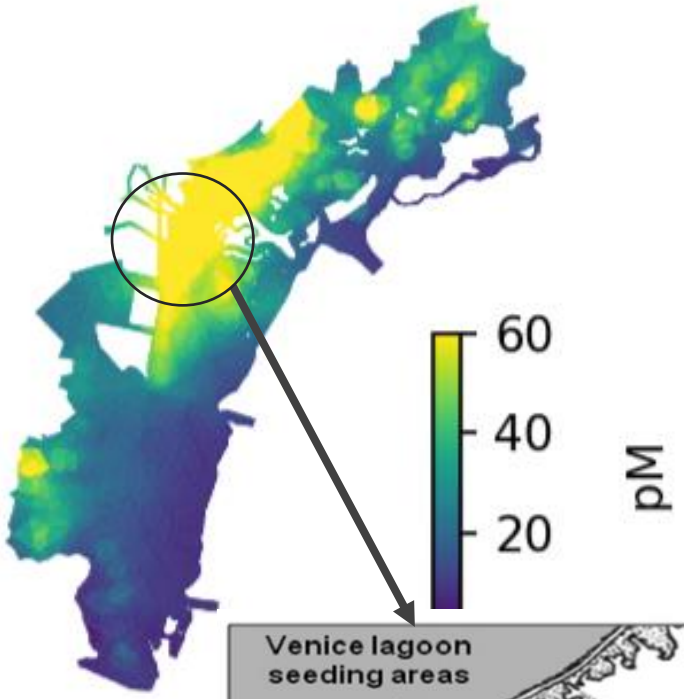
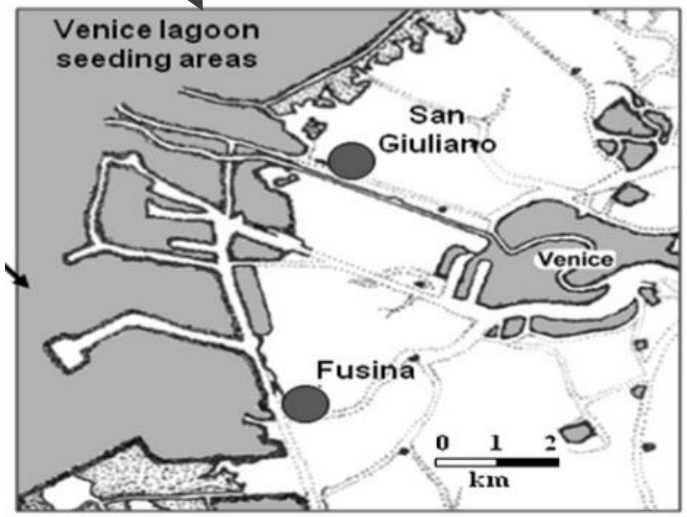
uptake from water

excretion

Model calibration





Sfriso et al., 2008

Estuarine, Coastal and Shelf Science 79 (2008) 581–590

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journal homepage: www.elsevier.com/locate/ecss

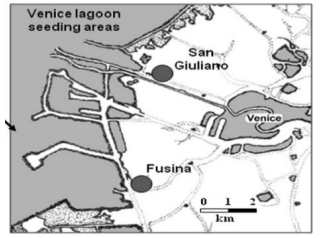
Tapes philippinarum seed exposure to metals in polluted areas of the Venice lagoon

A. Sfriso*, E. Argese, C. Bettiol, C. Facca

Clam seeded in polluted areas and monitored for HgT over 2 years (2001-2003)

			As (μg g⁻¹ dwt)	Cd (μg g⁻¹ dwt)	Cr (μg g⁻¹ dwt)	Co (μg g⁻¹ dwt)	Cu (μg g⁻¹ dwt)	Pb (μg g⁻¹ dwt)	Mn (μg g⁻¹ dwt)	Ni (μg g⁻¹ dwt)	V (μg g⁻¹ dwt)	Zn (μg g⁻¹ dwt)	Fe (μg g⁻¹ dwt)	Hg (μg g⁻¹ dwt)
Fusina	S-clams	1st Period	27.0	0.99	2.22	1.99	9.79	1.62	14.9	5.82	<d.l.	92.0	624	0.37
	B-clams		22.1	1.17	3.11	1.67	29	1.83	11.9	4.05	<d.l.	90.3	662	0.34
	Sediment		11.8	0.40	58.4	6.6	7.6	12.9	244	34.3	22.8	83.0	10,793	0.13
	SPM		8.8	0.58	116	6.8	15.2	22.1	293	62.4	29.0	111	13,744	0.66
	S-clams	2nd Period	27.4	0.95	1.93	1.34	8.8	1.19	17.8	0.93	<d.l.	105.4	607	0.39
	B-clams		18.9	0.76	1.97	0.78	13.2	0.96	8.45	0.15	<d.l.	90.4	239	0.18
	Sediment		7.10	0.43	86.19	6.73	7.46	12.72	260	59.1	21.2	49.4	10,319	0.10
	SPM		8.60	0.62	132.6	7.91	14.25	22.18	261	70.2	27.7	90.9	13,602	0.28
	S-clams	3rd Period	30.7	1.76	2.63	1.75	18.4	1.15	10.5	3.92	<d.l.	105	607	0.40
	B-clams		30.7	2.19	3.56	2.38	13.3	2.54	19.0	5.20	<d.l.	111	1079	0.41
	Sediment		8.5	0.28	95.4	7.17	5.69	8.37	263	52.0	18.6	104	14,075	0.22
	SPM		4.9	0.34	174	6.7	8.71	10.3	236	83.0	18.0	91	10,690	0.16
San Giuliano	S-clams	1st Period	22.4	0.94	2.26	2.45	10.5	1.3	29.1	2.22	<d.l.	94.6	579	0.23
	B-clams		26.2	0.98	3.01	2.07	10.4	1.77	18.5	3.10	<d.l.	102	672	0.27
	Sediment		8.7	1.20	50.2	13.6	39.8	40.5	333	27.9	53.0	272	19,222	0.99
	SPM		22.9	1.90	58.5	15.6	51.5	57.1	410	36.5	58.5	411	23,067	2.18
	S-clams	2nd Period	18.9	0.87	2.47	1.35	10.29	1.2	20.4	2.28	<d.l.	84.4	544	0.19
	B-clams		22.3	0.95	1.89	1.15	15.79	0.62	10.3	2.5	<d.l.	110	367	0.18
	Sediment		16.1	1.43	57.4	13.4	42.94	47.28	360	53.2	57.8	263	20,720	0.91
	SPM		18.5	1.48	60.1	13.7	44.64	50.41	425	50.7	63.6	261	23,446	1.24

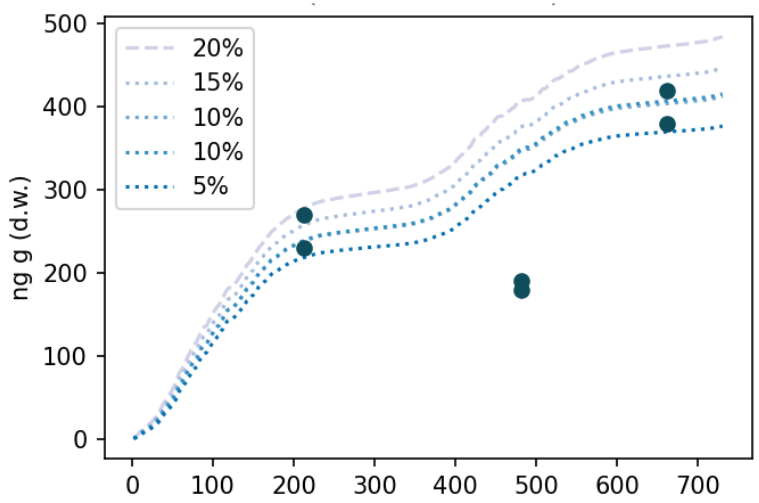
Model calibration



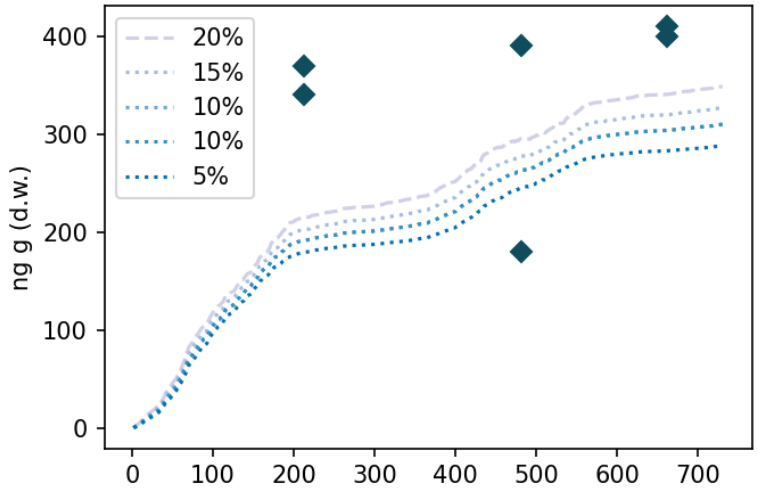
St. 1

St. 2

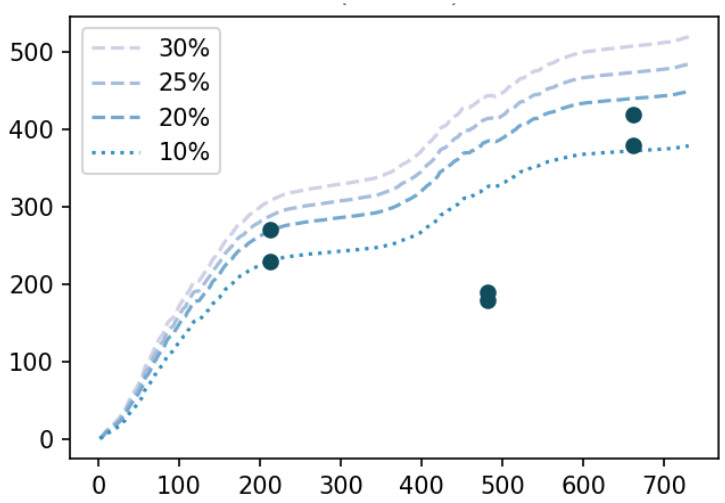
SLOW



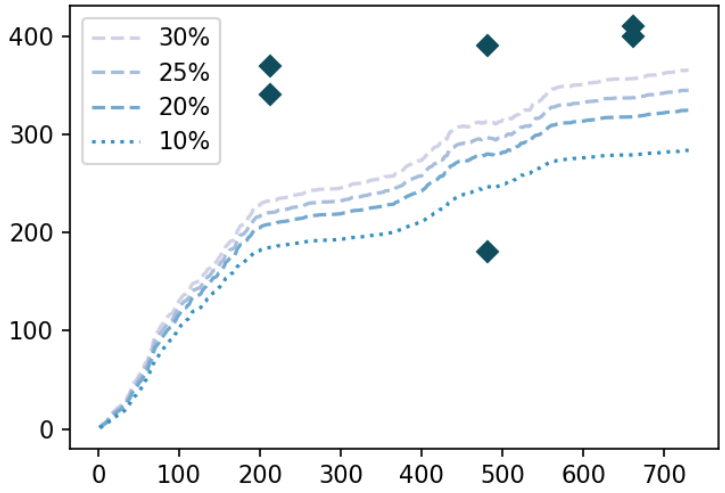
Slow excretion
($4x10^{-7}$ - $4x10^{-5}$)



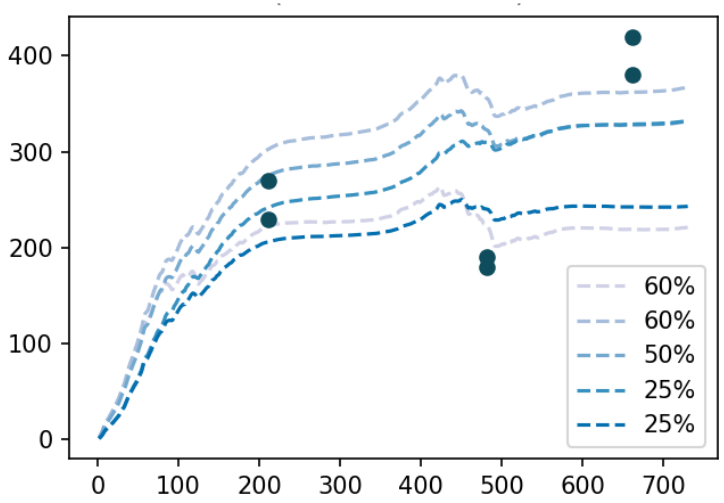
MEDIUM



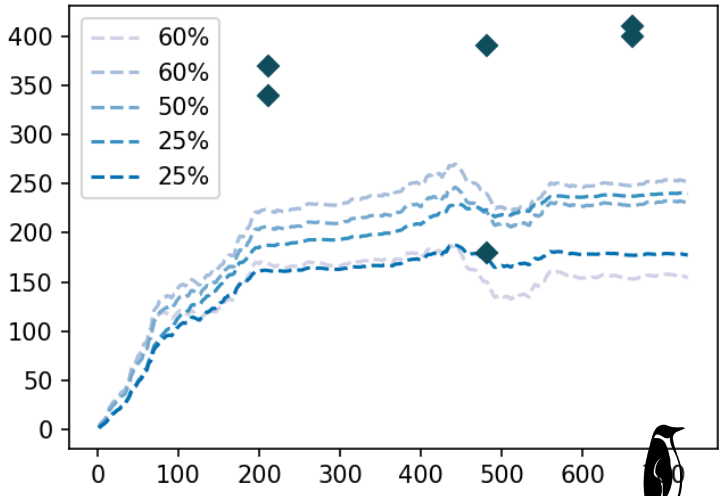
Medium excretion
($2x10^{-4}$)



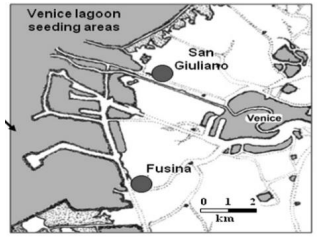
FAST



Fast excretion
($1x10^{-3}$ - $4x10^{-3}$)

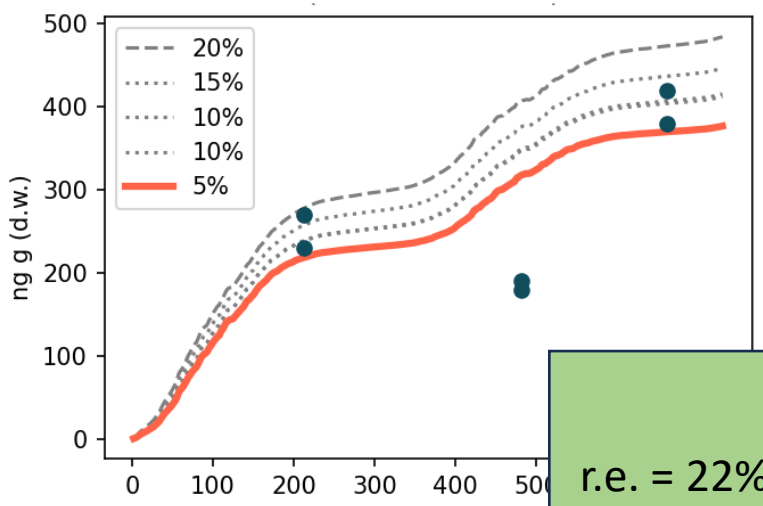


Model calibration



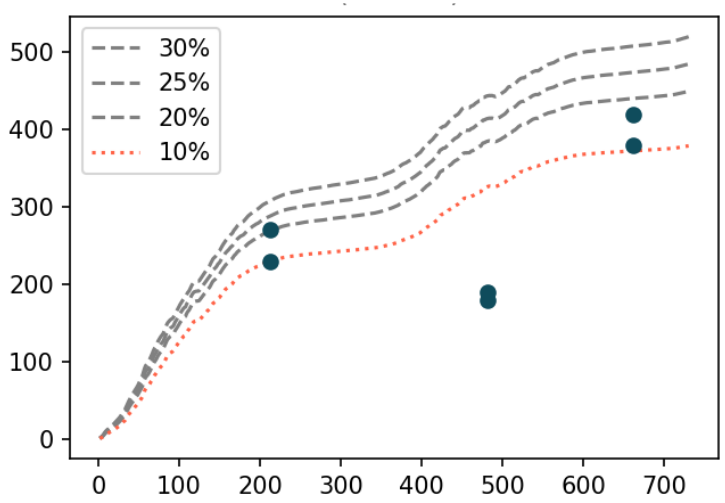
St. 1

SLOW

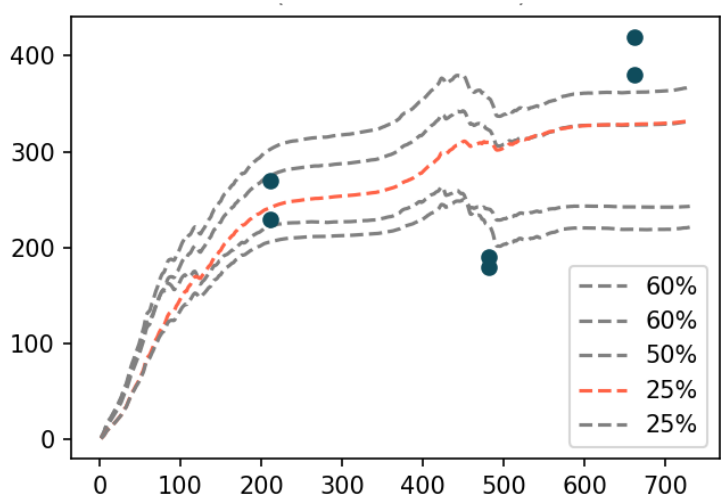


r.e. = 22%

MEDIUM

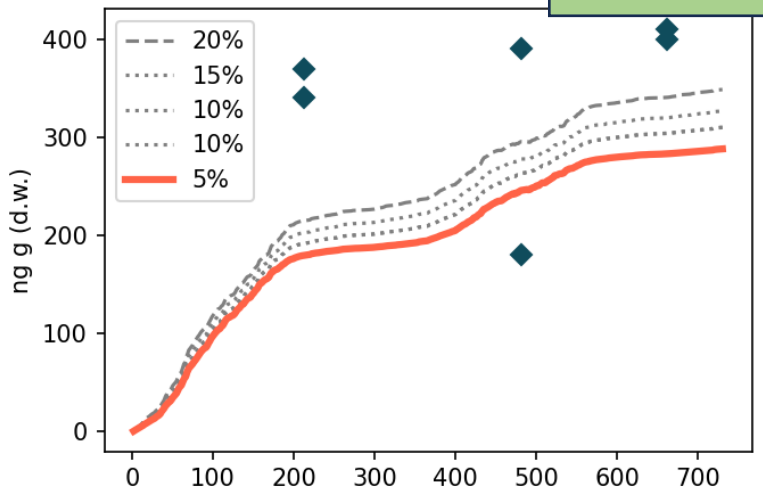


FAST

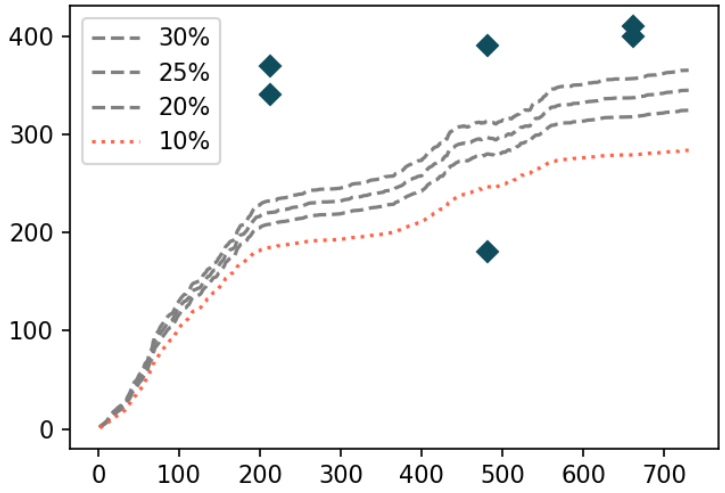


St. 2

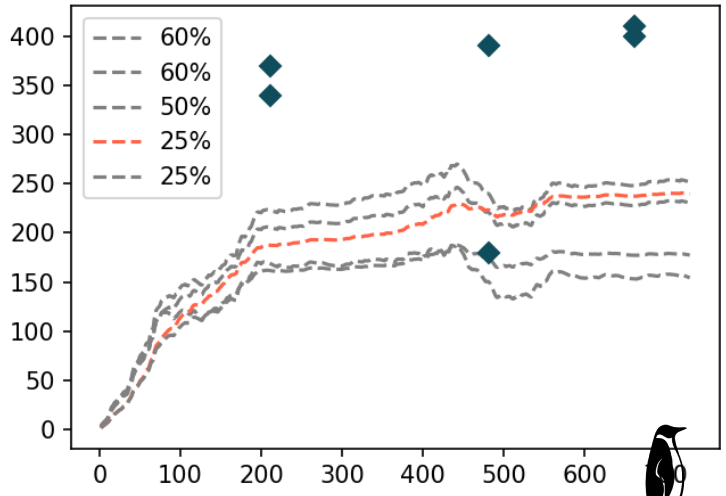
Slow excretion
($4x10^{-7}$ - $4x10^{-5}$)



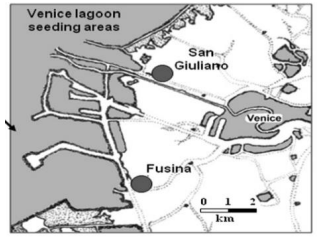
Medium excretion
($2x10^{-4}$)



Fast excretion
($1x10^{-3}$ - $4x10^{-3}$)

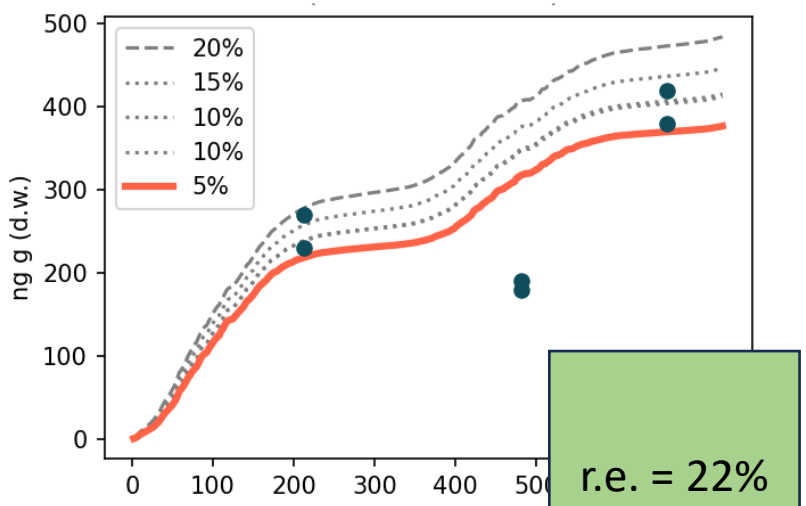


Model calibration



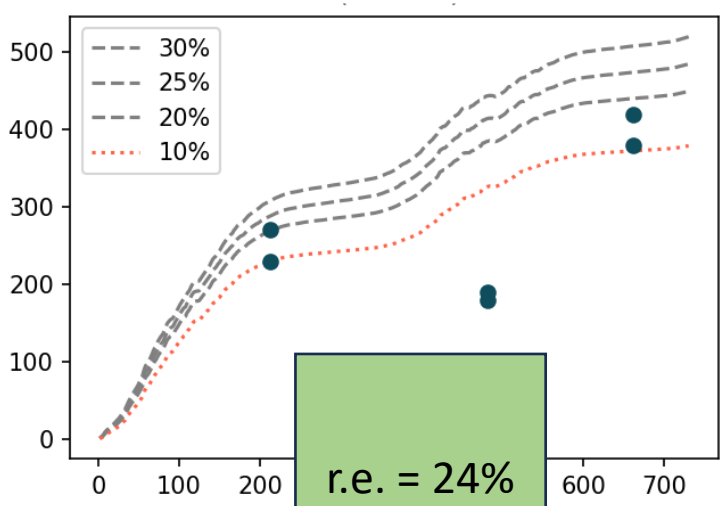
St. 1

SLOW



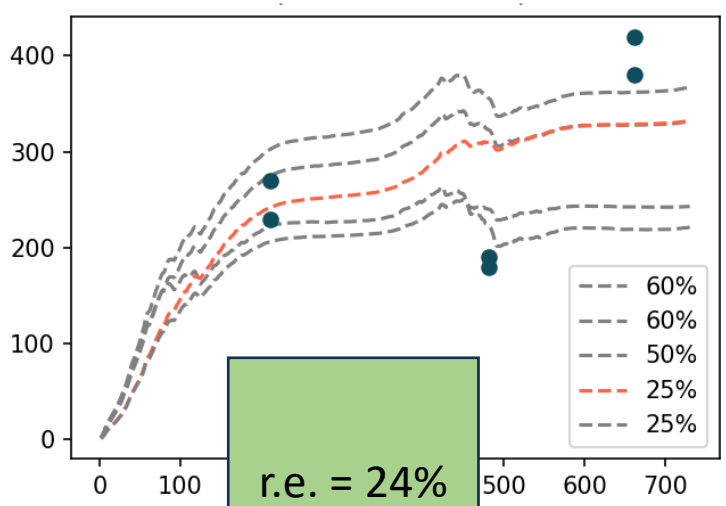
r.e. = 22%

MEDIUM



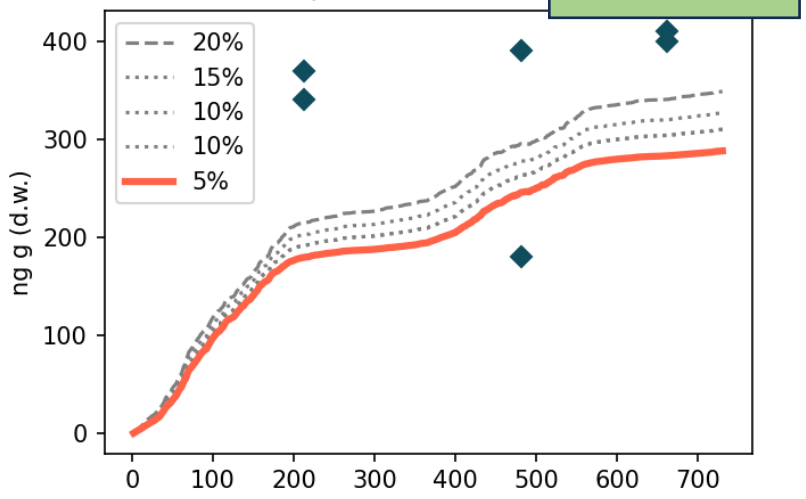
r.e. = 24%

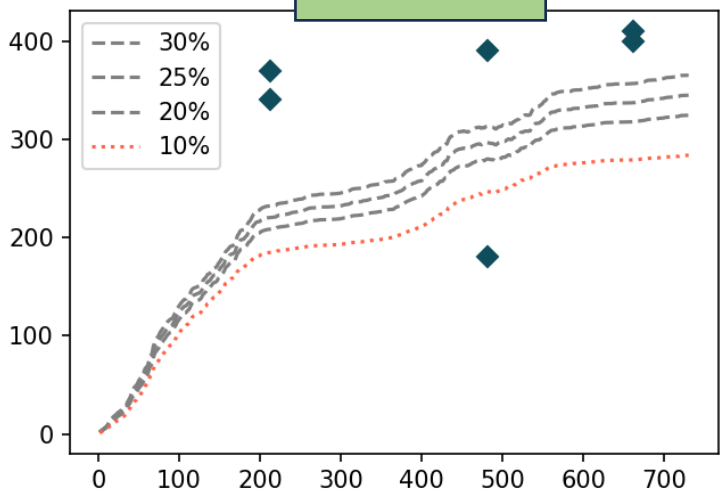
FAST

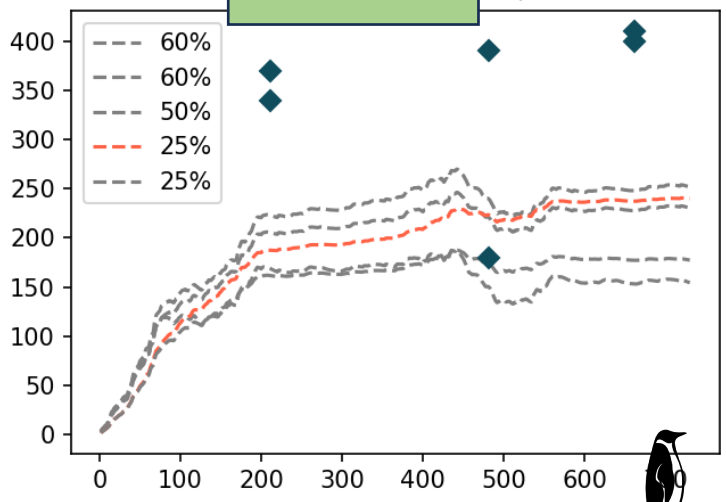


r.e. = 24%

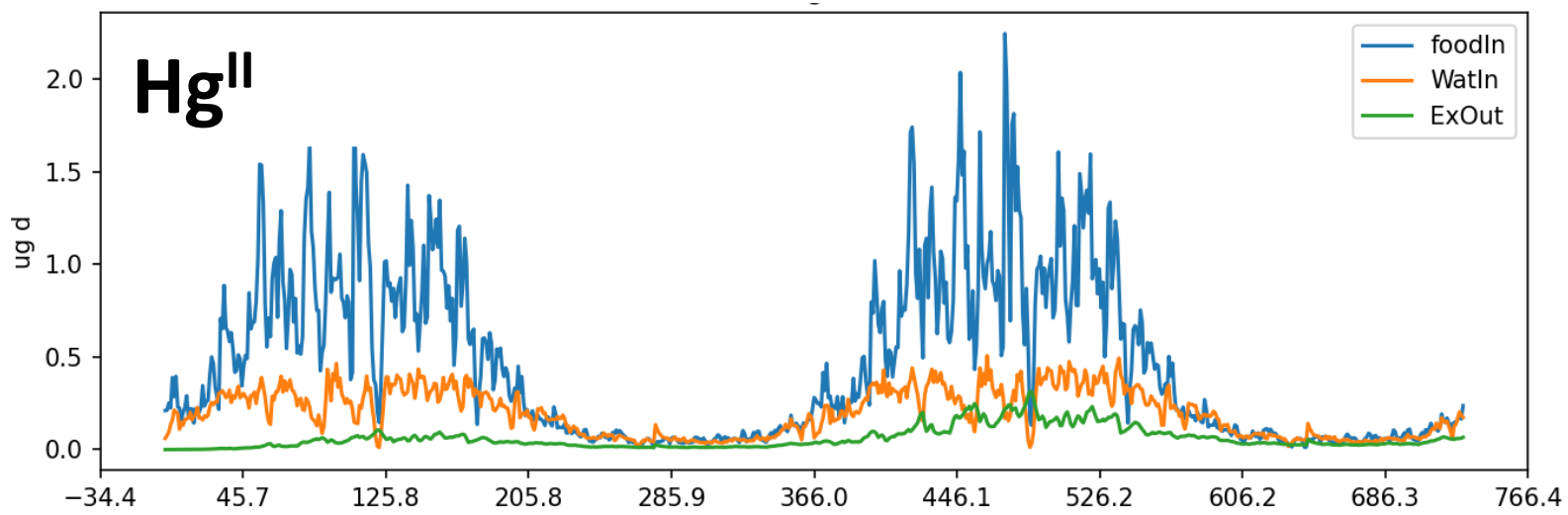
St. 2

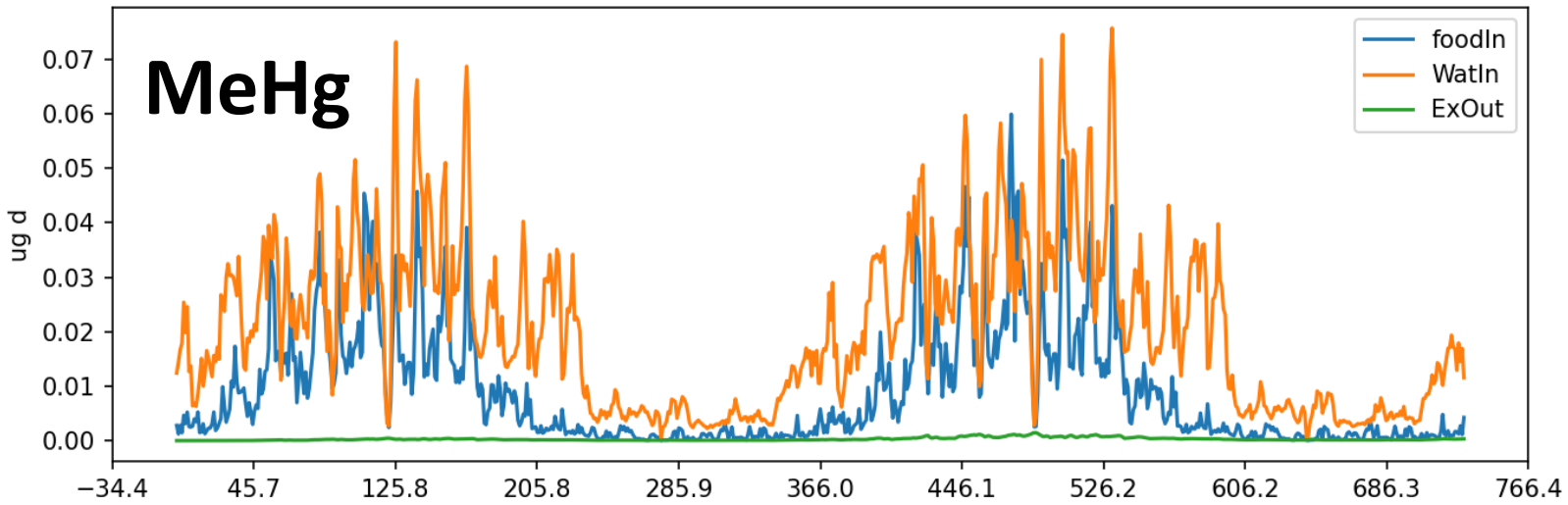






Modeled Fluxes





Modeled fluxes suggest comparable intake from water and food for MeHg

Contaminated site with low fraction of water MeHg (<1%)

Modeled MeHg in clam is ~6% of HgT

Next steps

- *Move from individual-based to population model (sexual maturity, spawning, death, different cohorts)*
- *Introduce a reduction of the fitness related to pollution (data?)*
- *Explore bioaccumulation dynamics in rearing areas*

OGS

Thank you!

Return

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