

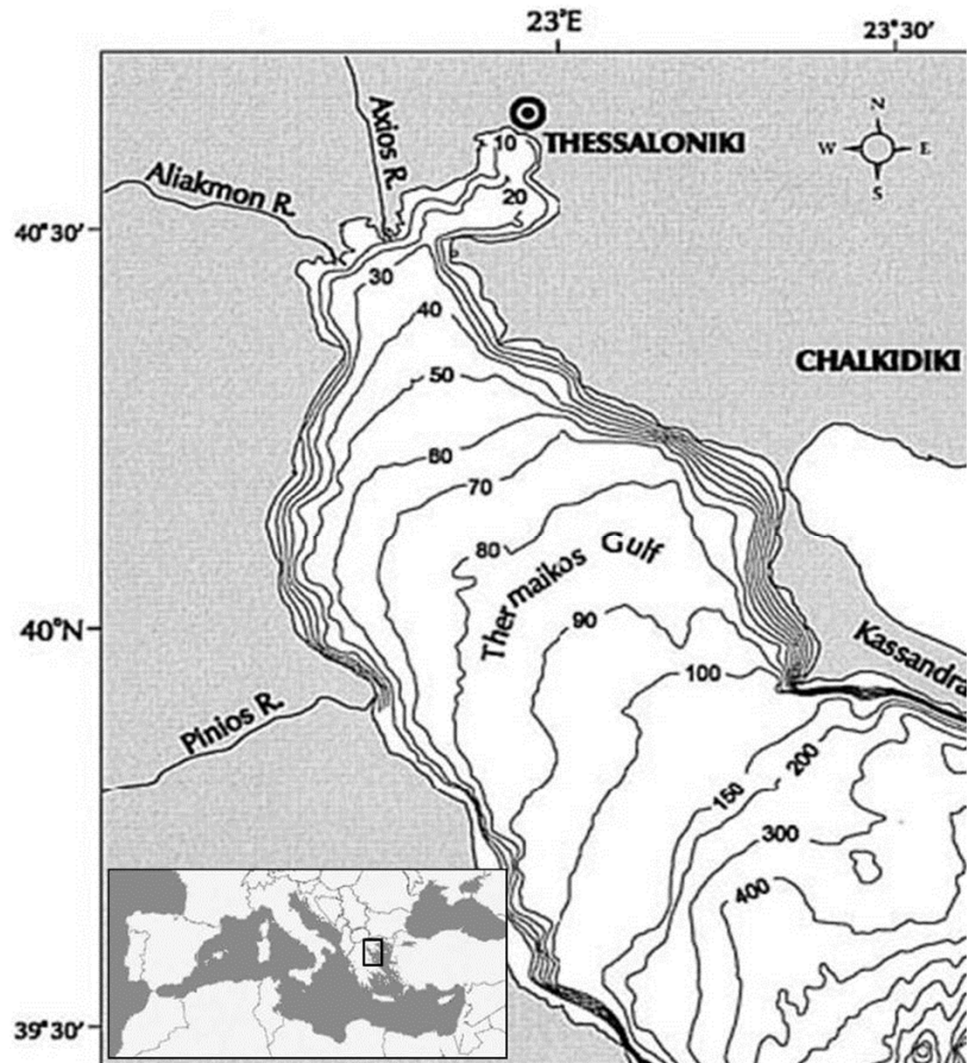
EMRAS II WG8 GROUP MEETING

Brussels, 27-28 Sept. 2011

**Mediterranean Coastal Regions:  
Thermaikos Gulf (Greece) modeling  
exercise with MOIRA-PLUS**

Monte L., Brittain J., Eleftheriou G.

# Thermaikos Gulf, Thessaloniki – Arguments for the scenario application



- Urban zone ( $\sim 10^6$  habit.)
- Operating nuclear plants in Cernavoda, RO (360 Km) and Kozloduy, BU (580 Km) – the most contaminated costal region in Greece from Chernobil accident ( $\sim 30$  kBq/m<sup>2</sup>)
- Characteristic Medit. Envir.: closed costal environment, big rivers' incomes, high influence from Black Sea Water circulation
- Good oceanographic knowledge of the region & accessibility to accurate datasets (HCMR)

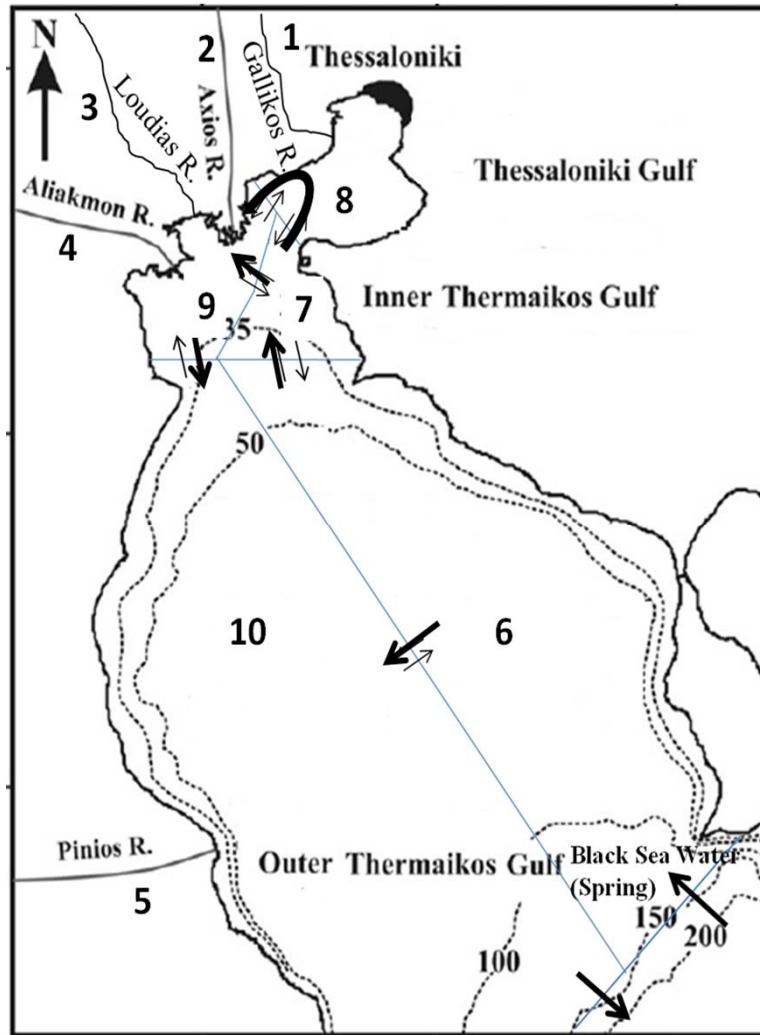
# Model Characteristics

## MOIRA-PLUS modifications:

- Two-way water movements and recirculation (Marine comp.)
- Combination of different type of comp. (up to 20)
- Migration parameters assignment (sedimentation, sediment migration rate, bioaccumulation factors...)
- Biota types:
  - a) Radionuclides' accumulation: predator (water and food chain), prey (only from water),
  - b) Mobility: stationary (no movement) and non-stationary (random walk between compartments)

## Gulf hydrology:

- 12 month water flux hydrology (prec., evapor., BSWater income, rivers, catch. run off)
- main anticlockwise monthly circulation
- Compartments: 5 river & 5 marine boxes
- Water mixing rate ( $10^3 \text{ m}^3/\text{s}$ ) between marine comp.
- Two biota groups: Mussels (preys, stationary) & Fishes (predators, non-stationary)

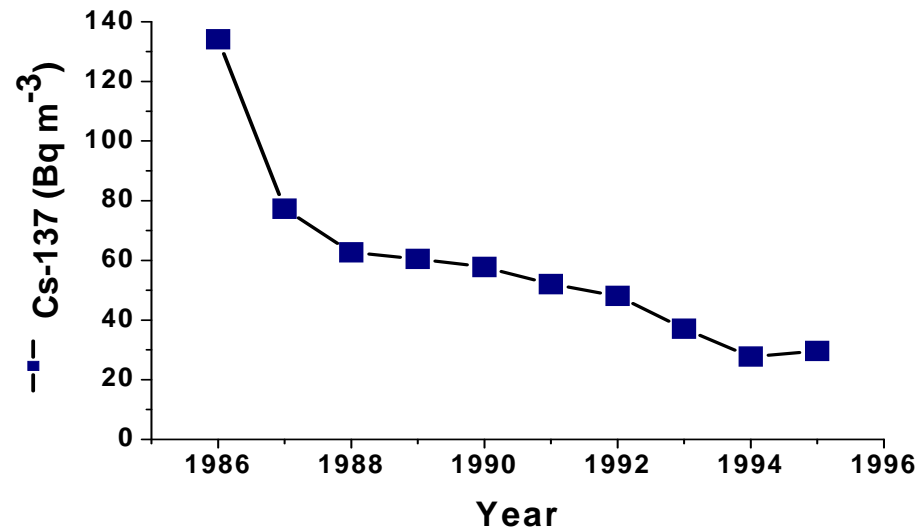


# Morphology

Box number	Name	Average depth (m)	Average length (km)	Average width (km)	Average flux (m <sup>2</sup> /month)	Catchment area (km <sup>2</sup> )
1	Gallikos River	0.49	65.00	0.03	3.09E+07	9.30E+02
2	Axios River	1.29	388.00	0.08	2.64E+08	2.37E+04
3	Loudias River	0.67	130.00	0.04	6.10E+07	1.00E+03
4	Aliakmon River	0.71	322.00	0.05	6.97E+07	9.25E+03
5	Pinios River	1.04	216.00	0.07	1.64E+08	1.08E+04
6	East. Outer Thermaikos Gulf	72.50	67.30	22.70		7.50E+02
7	East. Inner Thermaikos Gulf	16.32	17.40	7.80		3.00E+01
8	Thessaloniki Gulf	40.37	14.50	19.30		
9	Weast. Inner Thermaikos Gulf	31.23	16.40	9.40		
10	Weast. Outer Thermaikos Gulf	81.20	67.30	25.60		

# Black Sea Water flux into the Gulf

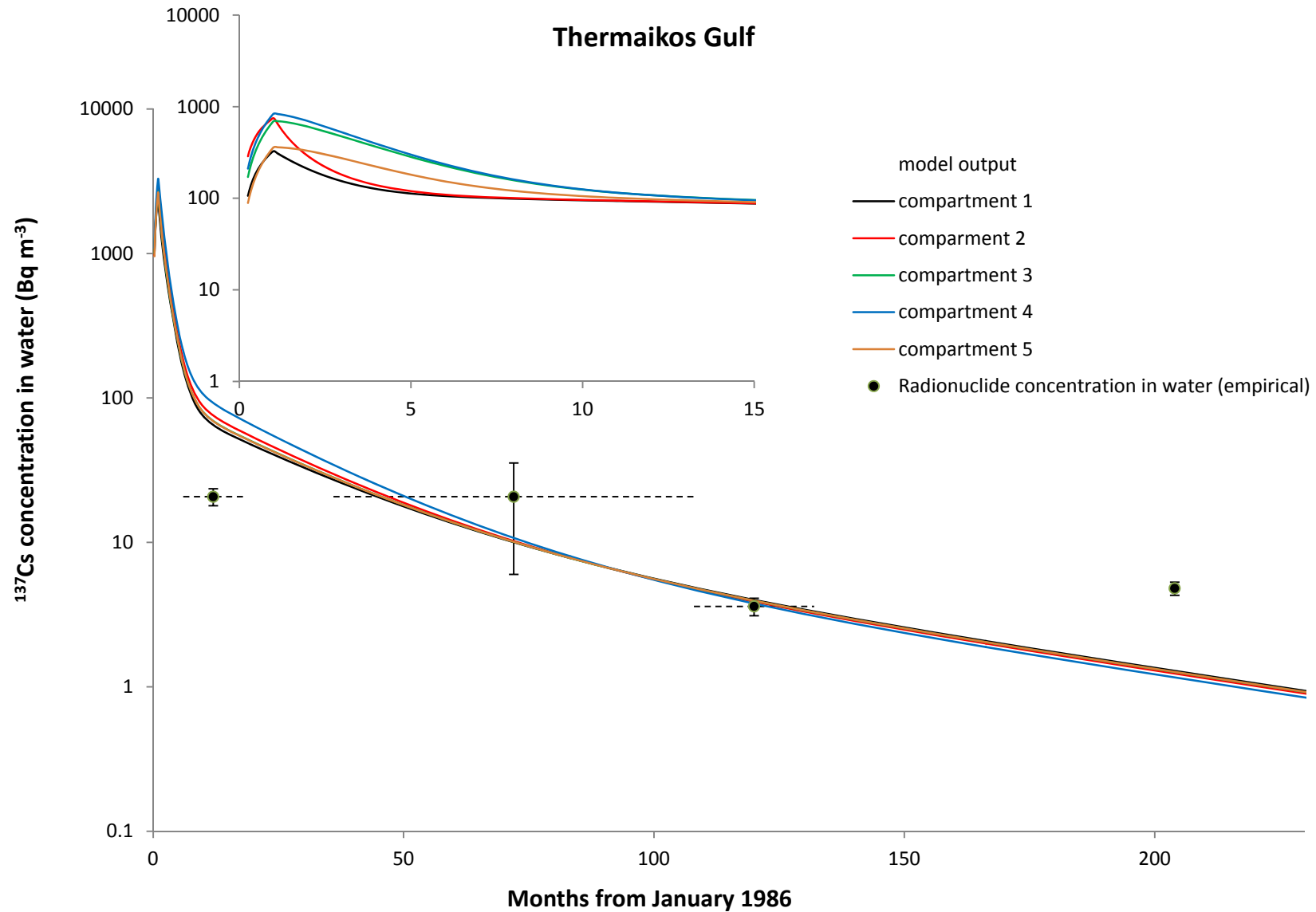
- Flux: calculation of the average monthly flux into the Gulf from the currents velocity field grid (X,Y,Z) based on 1 year (2008) Aegean Sea hydrodynamic model dataset ([Poseidon system, HCMR](#))
- Radionuclide's conc.: based on the  $^{137}\text{Cs}$  fraction from the Dardanelle straights (upper 50 m and for  $60 \text{ Bq/m}^3$  in Black Sea)([Egorov et al., 1999](#))



# 137Cs empirical data

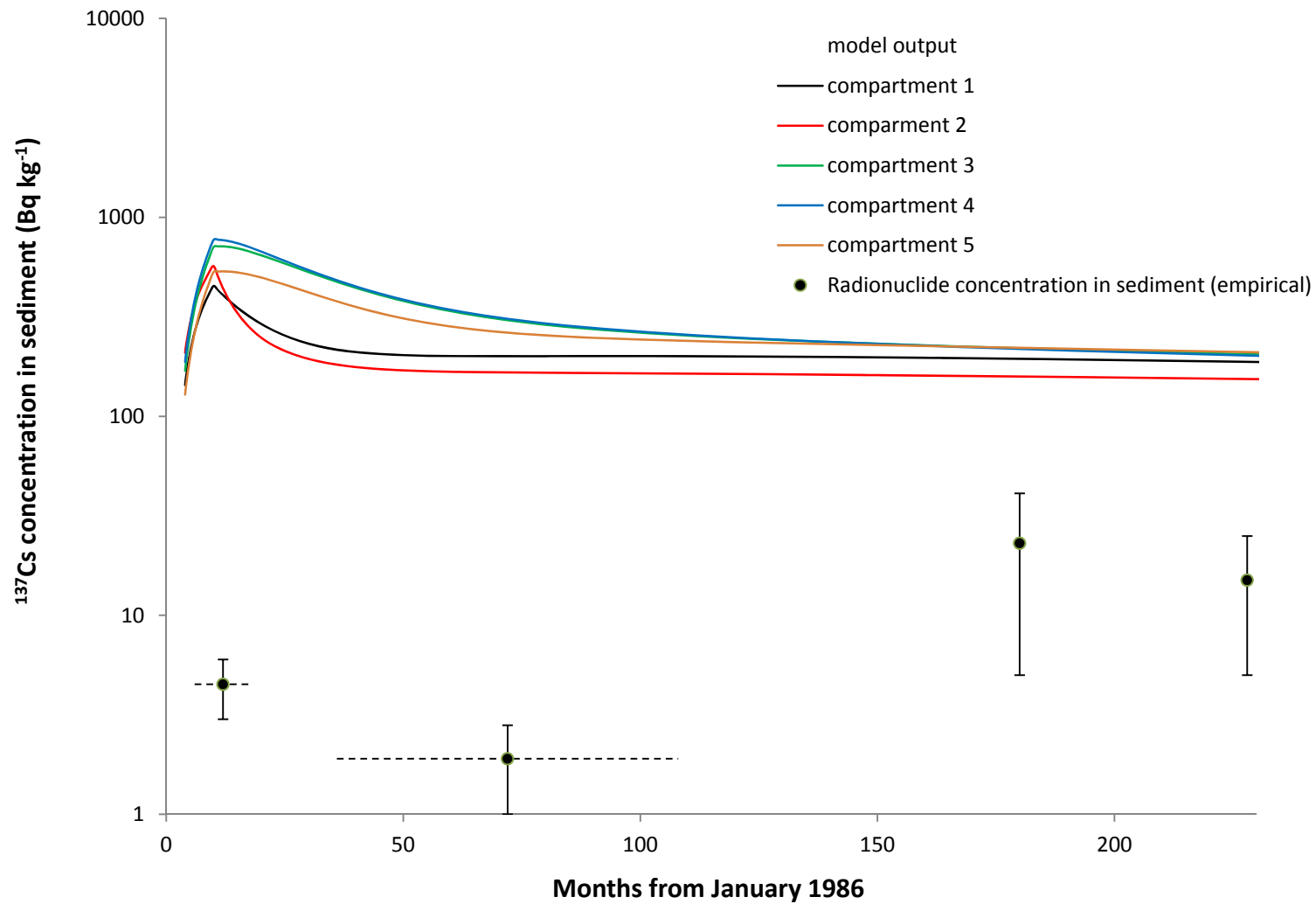
Sampling Location	Date	Concentration (Bq/kg or Bq/m <sup>3</sup> )			Type	Reference
		Average	Min	Max		
Western Thermaikos	2004 - 2006	0.1	0.07	0.13	Mussels	(Thebaultt, 2008)
Western Thermaikos	May-2000	1.4	1.11	1.69	Mussels	(Katsiki, 2006)
Thermaikos Gulf	1999-2001	0.92	0.24	1.6	Mussels	(Florou, 2002)
North Aegean Sea	1986-1987	7.1	5.3	8.9	Mussels	
	1984-1985	0.68	0.58	0.78	Mussels	
	1988-1995	0.46	0.18	0.74	Mussels	
Aegean Sea	1985	0.63	-	-	Mussels	(Pappuci, 1996)
	1987	0.55	-	-	Mussels	
	1988	0.53	-	-	Mussels	
	1989	0.3	-	-	Mussels	
	1985	0.93	0.31	1.55	Fish	
	1987	0.37	0.06	1.24	Fish	
	1988	0.66	0.31	1.28	Fish	
	1989	0.9	-	-	Fish	
	1990	0.51	0.31	1.13	Fish	
	NorthEast Aegean	1984-1985	0.34	0.27	0.41	Fish
1986		10.14	2.69	17.59	Fish	
1987-1995		0.65	0.28	1.02	Fish	
1984-1985		2.42	2.08	2.76	Sediment	
1986-1987		4.54	2.55	6.53	Sediment	
1988-1995		1.88	0.92	2.84	Sediment	
Thermaikos Gulf	2005	15	5	30	Sediment	(Euaggelou, 2011)
	2007	25	5	35	Sediment	
Thessaloniki Gulf	2006	41	22	22	Sediment	(Tsabaris, 2011)
Inner Thermaikos	Sept - 2001	38	34	41	Sediment	(Karagiorgis, 2005)
Outer Thermaikos	Sept - 2001	20	5	35	Sediment	
NorthEast Aegean	1984-1985	2.7	2.42	2.98	water	(Florou, 2006)
	1986-1987	20.7	17.9	23.5	water	
	1988-1995	20.7	6	35.4	water	
Thessaloniki Gulf	2009	5.7	2.1	14.7	surf water	(Florou, 2011)
NorthEast Aegean	Dec - 2005	5.5	4.6	7.3	surf water	(Evangelidou, 2009)
	Jun - 2006	10.3	8.5	12.8	surf water	
Eastern Mediteranian	1995-1997	3.6	3.3	4	surf water	(Delfanti,2003)
Outer Thermaikos	2003	4.8	4.5	5.1	surf water	(Tsabaris, pr. com.)

# $^{137}\text{Cs}$ model calibration (water conc.)



# $^{137}\text{Cs}$ model calibration (sediment conc.)

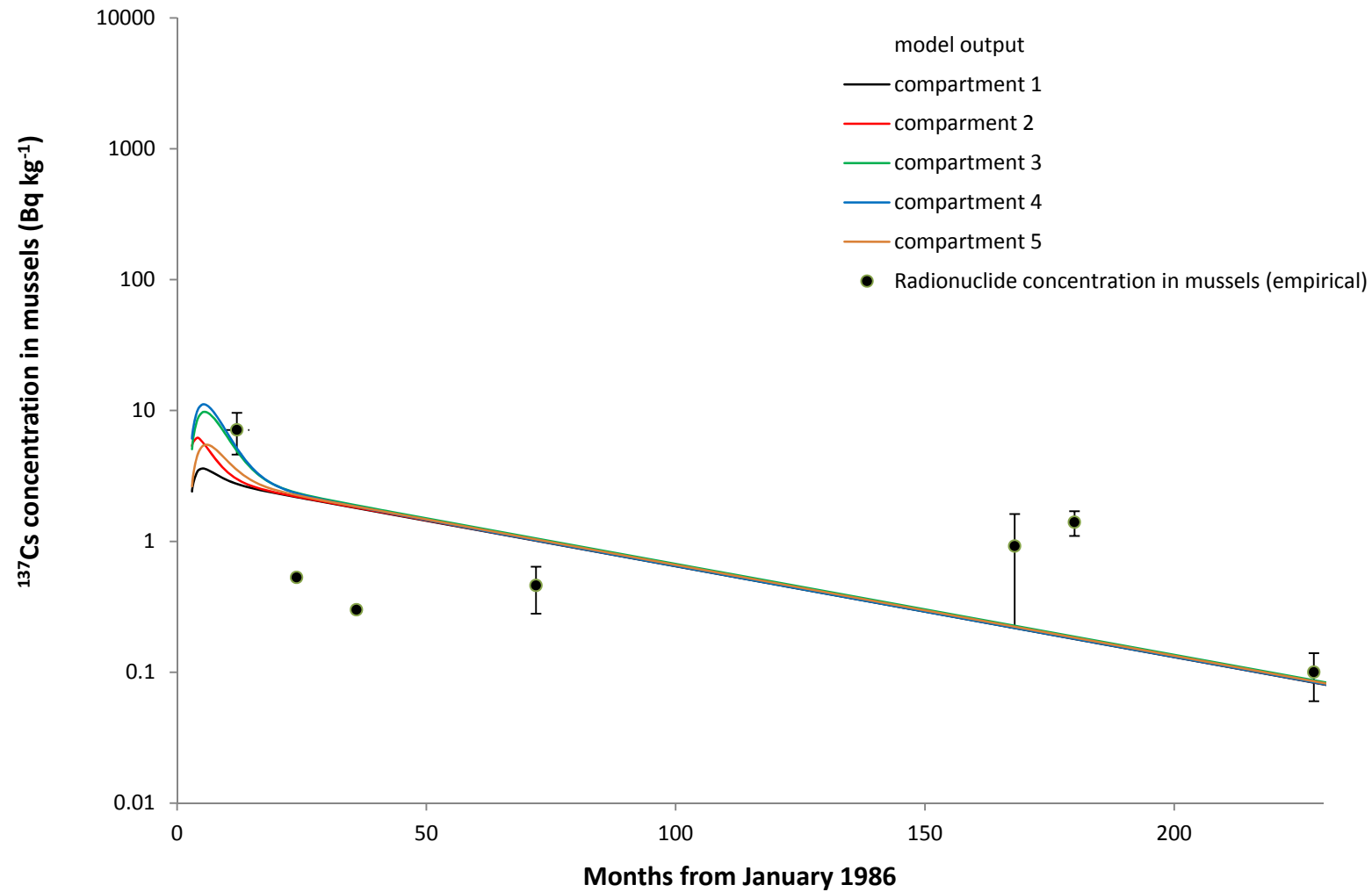
Thermaikos Gulf





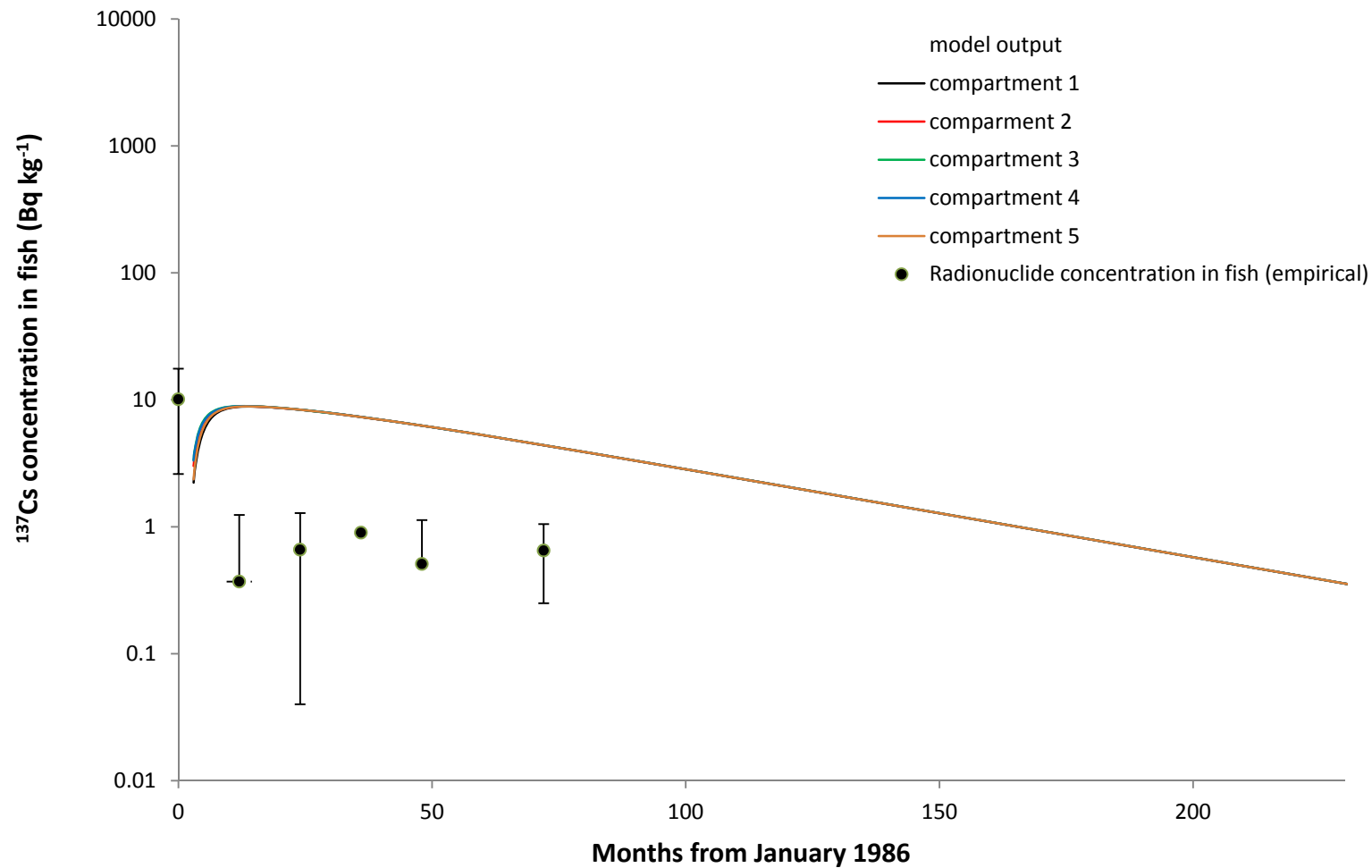
# $^{137}\text{Cs}$ model calibration (mussels conc.)

## Thermaikos Gulf



# $^{137}\text{Cs}$ model calibration (fish conc.)

## Thermaikos Gulf



# Population

Marine Box	0-5 yr	6-15 yr	16 < yr
6	5,224	3,527	55,860
7	3,083	2,062	31,141
8	76,043	53,391	812,982
9	14,429	9,594	147,443
10	32,317	21,707	320,524

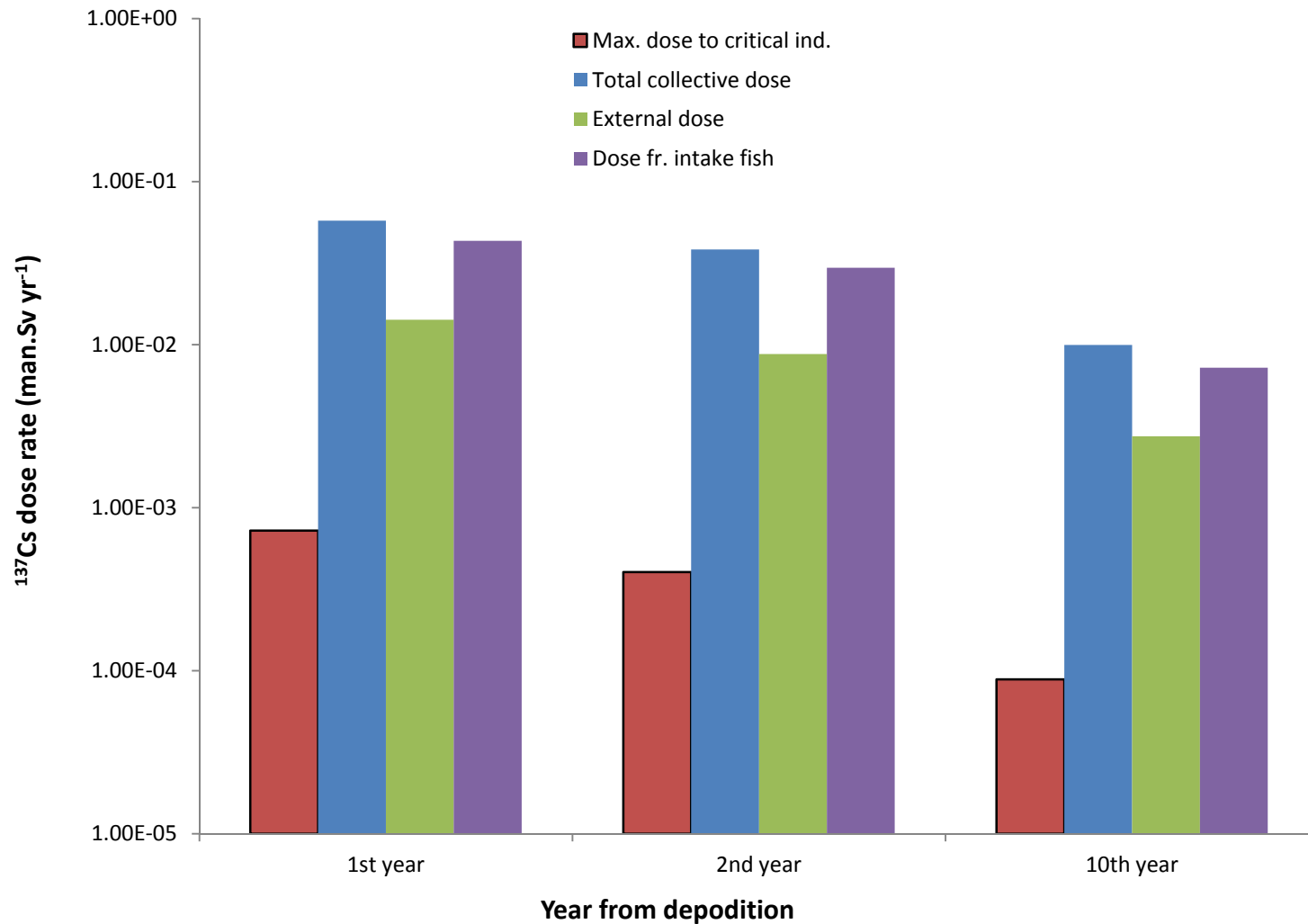
# Fish production (kg/yr)

Marine Box	Fish	Mussels
6	1,011,6901	
7	247,713	
8	217,342	
9	422,918	6,551,750
10	12,243,426	3,527,865

# Results (deposition of 1kBq/m<sup>2</sup> in 1<sup>st</sup> month duration): only marine pathways – <sup>137</sup>Cs

E1

Thermaikos Gulf



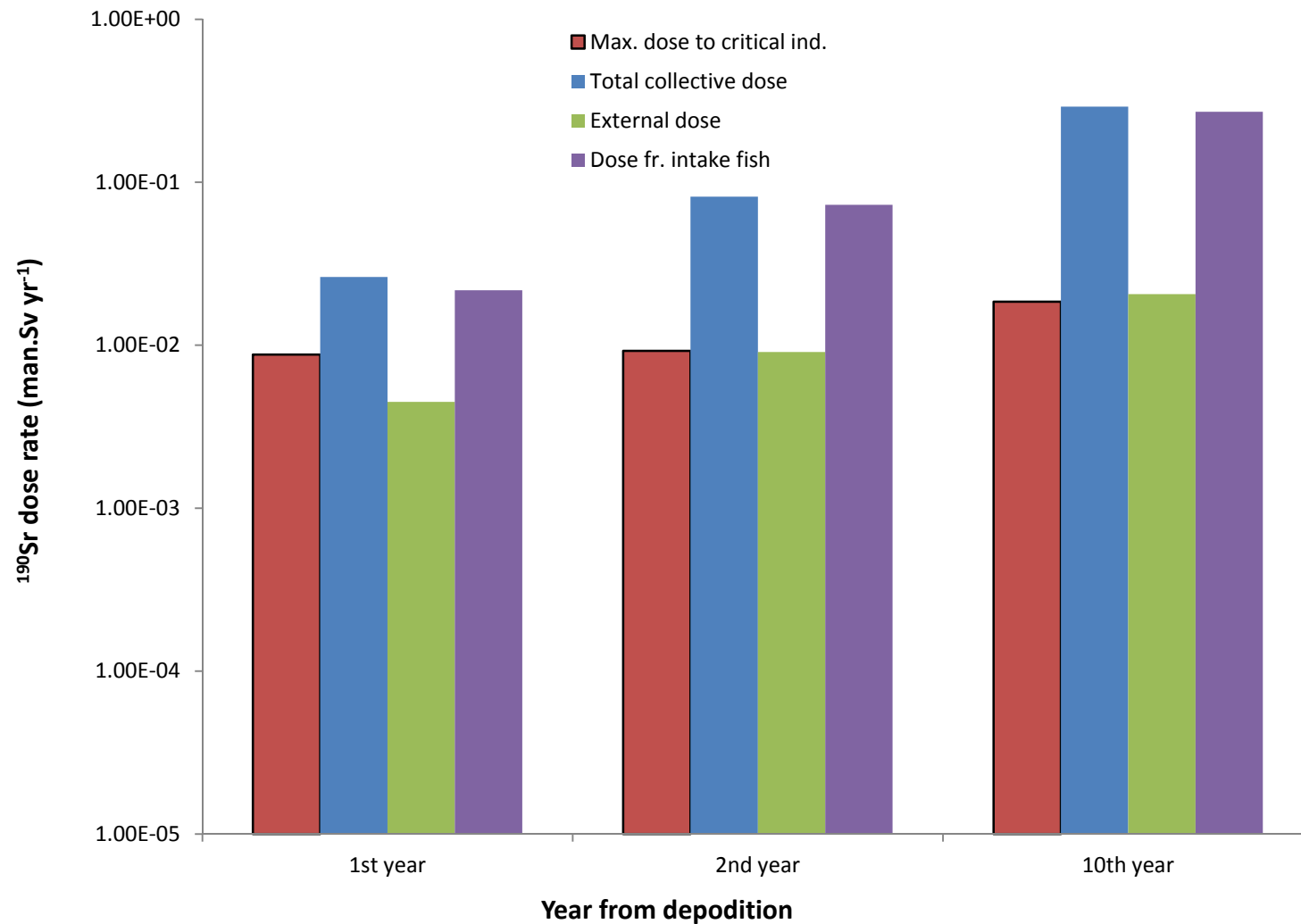
E1

Mora Plus limitation

G. ELEFThERIOU, 2011-09-26

# Results (deposition of 1kBq/m<sup>2</sup> in 1<sup>st</sup> month duration): only marine pathways – <sup>90</sup>Sr

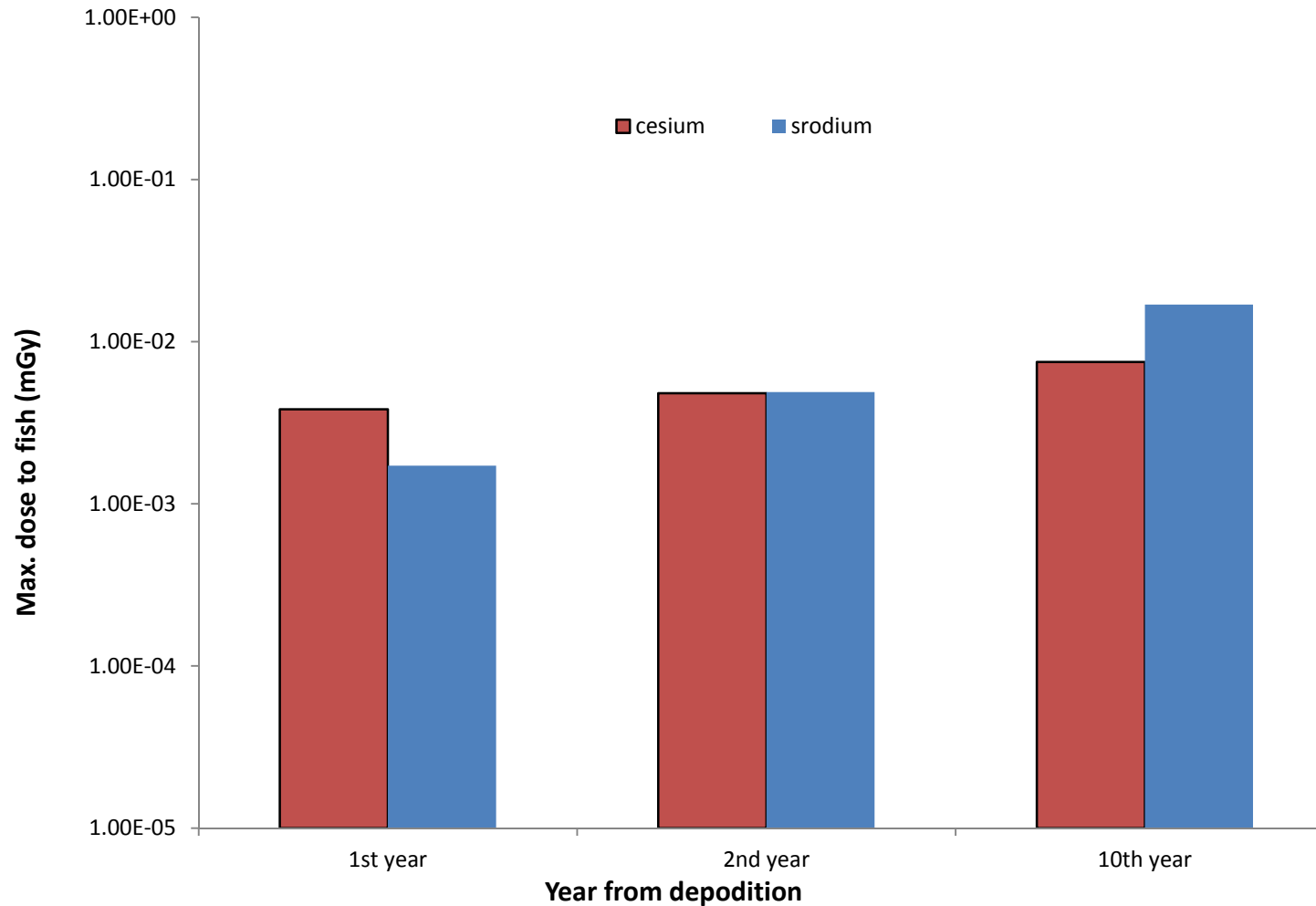
## Thermaikos Gulf



# Results (deposition of 1kBq/m<sup>2</sup> in 1<sup>st</sup> month duration):

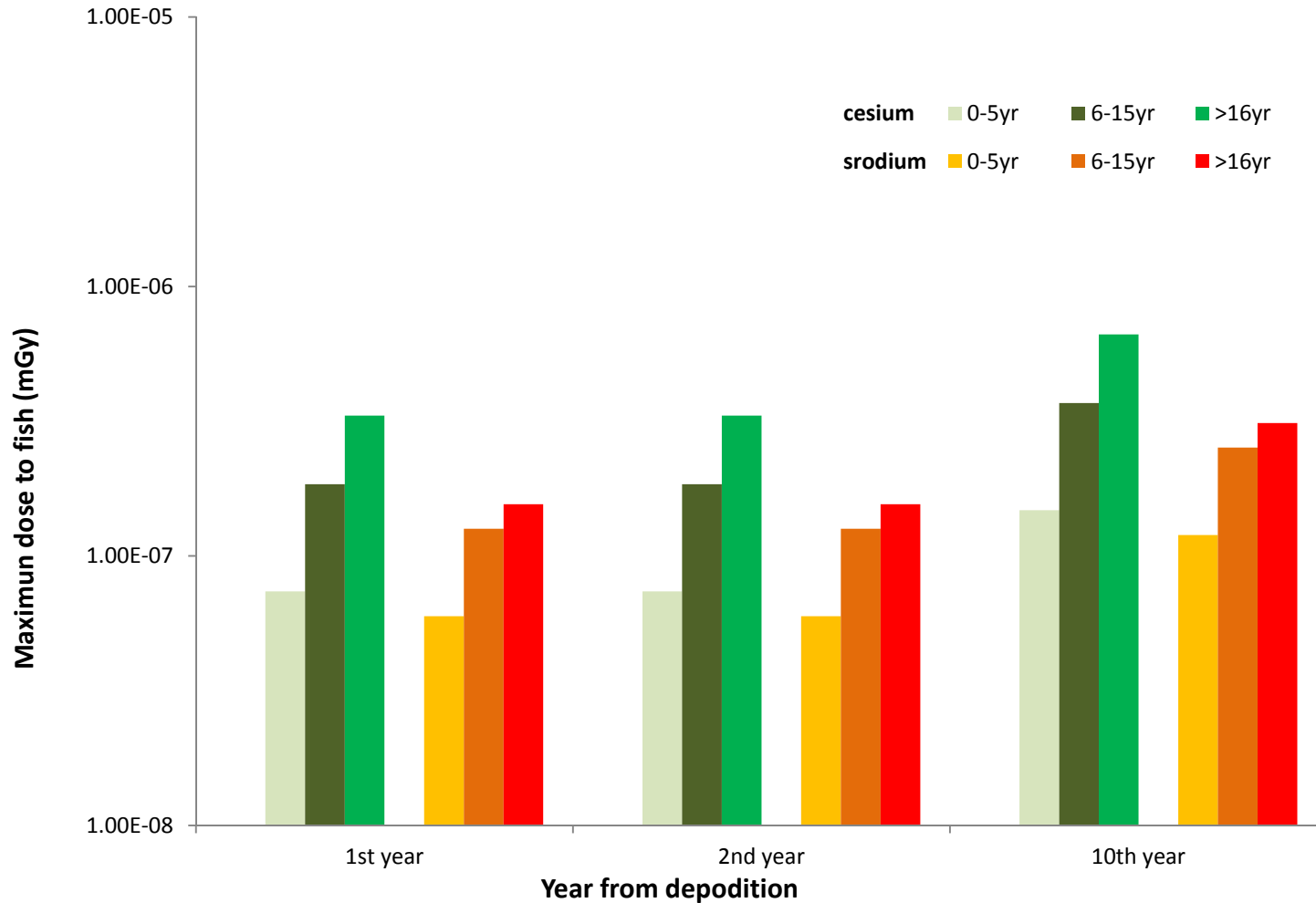
## Dose to Fish

Thermaikos Gulf



# Comparison of age groups – $^{90}\text{Sr}$ , $^{137}\text{Cs}$ Ind. Doses from all compartments

Thermaikos Gulf





# Comparison with North Seas – $^{90}\text{Sr}$ , $^{137}\text{Cs}$ Ind. Doses after 1 year (Iosjpe, GM Vienna)

	Cs-137			Sr-90		
Location	Adult	10 y	1 y	Adult	10 y	1 y
Irish Sea: Cumbrian Waters	1.65E-6	2.60E-7	5.52E-8	2.83E-7	1.23E-7	1.32E-8
English Channel: Lyme Bay	9.45E-7	1.49E-7	7.62E-9	1.32E-7	5.72E-8	6.13E-9
North Sea: Norwegian Current Surface	6.16E-7	9.70E-8	2.06E-8	8.72E-8	3.79E-8	4.07E-9
Skagerrak	8.77E-7	1.38E-7	2.93E-8	1.28E-7	5.55E-8	5.95E-9
Baltic Sea: Gulf of Riga	2.58E-6	4.06E-7	8.62E-8	4.22E-7	1.84E-7	1.98E-8
Kara Sea: Ob Bay	2.86E-6	4.51E-7	9.57E-8	5.09E-7	2.21E-7	2.37E-8
<b>Thermaikos Gulf</b>	<b>3.32E-07</b>	<b>1.85E-07</b>	<b>7.39E-08</b>	<b>1.56E-07</b>	<b>1.26E-07</b>	<b>5.98E-08</b>

- Good agreement (order of magnitude) between different model predictions (MOIRA, NRPA)
- The same behavior with analogues closed costal environment ( Gulf of Riga)
- Perspectives: comparison with river and/or terrestrial contribution to the total dose