SUPPLEMENTARY INFORMATION

PLASTIC POLLUTION OUTLOOK IN THE MEDITERRANEAN REGION AND SEA: A BOX-MODEL APPROACH BASED ON OECD POLICY SCENARIOS.

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I. Code availability

The model code is available on: https://github.com/TheoSEGUR/Med_Plastic_BoxModel.git

II. Model parameters

Table S1: Model parameters and their probability distribution (miscellaneous parameters).

R1: S. Europe, R2: N. Africa & M. East, R3: Nile basin.

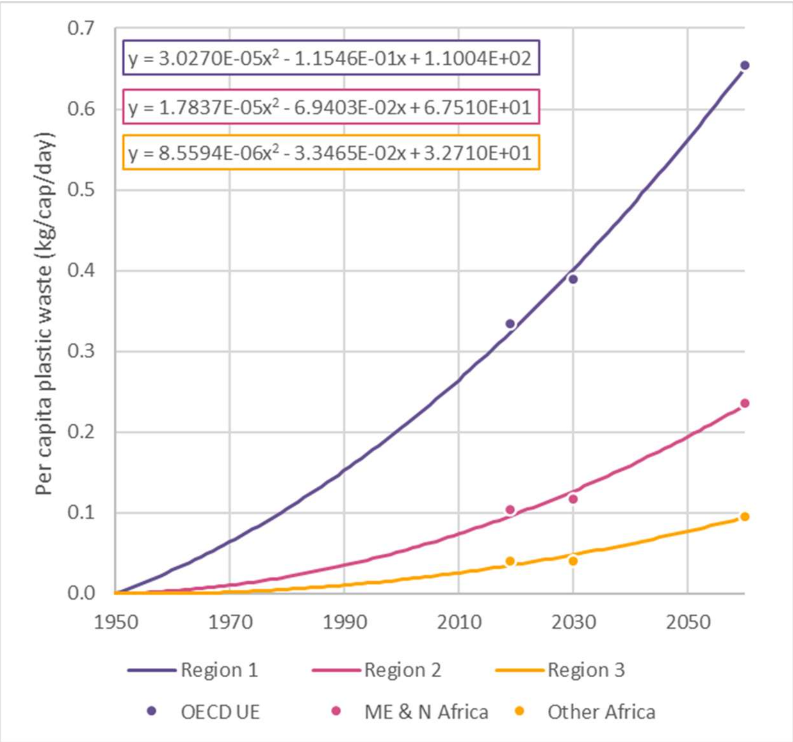
Parameter name	Description	Mean ± sd	Median (IQR 25%-75%)
LB19	Fragmentation rate (3% per year)	3.0E-2 ± 5.7E-3	3.0E-2 (2.6E-2 - 3.4E-2)
f_LMP	Fraction of LMP in waste	1.4E-1 ± 2.7E-2	1.4E-1 (1.2E-1 - 1.6E-1)
f_burn_R1	Fraction of mismanaged plastic waste that is open burned each year (from OECD)	3.1E-1 ± 0.0E+0	3.1E-1 (3.1E-1 - 3.1E-1)
f_burn_R2		3.1E-1 ± 0.0E+0	3.1E-1 (3.1E-1 - 3.1E-1)
f_burn_R3		3.1E-1 ± 0.0E+0	3.1E-1 (3.1E-1 - 3.1E-1)
f_inc_random	Normal randomisation of waste fractions	1.0E+0 ± 4.9E-2	1.0E+0 (9.7E-1 - 1.0E+0)
f_mism_random		1.0E+0 ± 5.0E-2	1.0E+0 (9.7E-1 - 1.0E+0)
f_rec_random		1.0E+0 ± 4.9E-2	1.0E+0 (9.7E-1 - 1.0E+0)
f_runoff_R1	Fraction of total runoff attributed to each regions	1.1E-1 ± 0.0E+0	1.1E-1 (1.1E-1 - 1.1E-1)
f_runoff_R2		7.5E-1 ± 0.0E+0	7.5E-1 (7.5E-1 - 7.5E-1)
f_runoff_R3		1.5E-1 ± 0.0E+0	1.5E-1 (1.5E-1 - 1.5E-1)
f_soil_R1	Fraction of each region surface considered as remote soil	5.7E-1 ± 0.0E+0	5.7E-1 (5.7E-1 - 5.7E-1)
f_soil_R2		6.6E-1 ± 0.0E+0	6.6E-1 (6.6E-1 - 6.6E-1)
f_soil_R3		8.0E-1 ± 0.0E+0	8.0E-1 (8.0E-1 - 8.0E-1)
f_ssed	Fraction of seafloor considered as shelf sediment	1.8E-1 ± 0.0E+0	1.8E-1 (1.8E-1 - 1.8E-1)

Table S2: Model parameters and their probability distribution (fluxes between boxes).

R1: S. Europe, R2: N. Africa & M. East, R3: Nile basin. Note that the “Terrestrial” compartment incorporates the terrestrial mismanaged and the remote land compartment.

Parameter name	Compartment from	Compartment to	Plastic size category	Mean ± sd	Median (IQR 25%-75%)
k_R1_P_terr_to_surf	Terrestrial (R1)	Sea surface	P	2.5E-3 ± 1.6E-3	2.1E-3 (1.2E-3 - 3.4E-3)
k_R1_LMP_terr_to_surf	Terrestrial (R1)	Sea surface	LMP	7.2E-2 ± 1.0E-1	2.6E-2 (4.7E-3 - 9.7E-2)
k_R1_sMP_terr_to_surf	Terrestrial (R1)	Sea surface	SMP	4.4E-3 ± 1.3E-3	4.2E-3 (3.4E-3 - 5.2E-3)
k_R1_sMP_terr_to_atmo	Terrestrial (R1)	Atmosphere	SMP	2.4E-3 ± 1.0E-3	2.3E-3 (1.6E-3 - 3.0E-3)
k_R2_P_terr_to_surf	Terrestrial (R2)	Sea surface	P	3.1E-4 ± 2.0E-4	2.6E-4 (1.5E-4 - 4.2E-4)
k_R2_LMP_terr_to_sur	Terrestrial (R2)	Sea surface	LMP	9.1E-3 ± 1.3E-2	3.3E-3 (6.0E-4 - 1.2E-2)
k_R2_sMP_terr_to_surf	Terrestrial (R2)	Sea surface	SMP	8.9E-4 ± 2.6E-4	8.6E-4 (6.9E-4 - 1.1E-3)
k_R2_sMP_terr_to_atmo	Terrestrial (R2)	Atmosphere	SMP	2.4E-3 ± 1.0E-3	2.3E-3 (1.6E-3 - 3.0E-3)
k_R3_P_terr_to_surf	Terrestrial (R3)	Sea surface	P	4.7E-6 ± 3.0E-6	3.9E-6 (2.3E-6 - 6.2E-6)
k_R3_LMP_terr_to_surf	Terrestrial (R3)	Sea surface	LMP	1.4E-4 ± 2.0E-4	4.9E-5 (8.9E-6 - 1.8E-4)
k_R3_sMP_terr_to_surf	Terrestrial (R3)	Sea surface	SMP	3.0E-2 ± 5.7E-3	3.0E-2 (2.6E-2 - 3.4E-2)
k_R3_sMP_terr_to_atmo	Terrestrial (R3)	Atmosphere	SMP	3.0E-2 ± 5.7E-3	3.0E-2 (2.6E-2 - 3.4E-2)
k_R1_sMP_atmo_to_terr	Atmosphere	Terrestrial (R1)	SMP	5.7E+1 ± 1.8E+1	5.5E+1 (4.3E+1 - 7.1E+1)
k_R2_sMP_atmo_to_terr	Atmosphere	Terrestrial (R2)	SMP	5.7E+1 ± 1.8E+1	5.5E+1 (4.3E+1 - 7.1E+1)
k_R3_sMP_atmo_to_terr	Atmosphere	Terrestrial (R3)	SMP	5.7E+1 ± 1.8E+1	5.5E+1 (4.3E+1 - 7.1E+1)
k_sMP_atmo_to_surf	Atmosphere	Sea surface	SMP	4.0E+1 ± 2.4E+1	3.5E+1 (2.1E+1 - 5.4E+1)
k_sMP_surf_to_atmo	Sea surface	Atmosphere	SMP	1.3E+0 ± 9.2E-1	1.0E+0 (5.6E-1 - 1.7E+0)
k_P_surf_to_sand	Sea surface	Sandy beach	P	2.3E-1 ± 3.8E-15	2.3E-1 (2.3E-1 - 2.3E-1)
k_LMP_surf_to_sand	Sea surface	Sandy beach	LMP	0.0E+0 ± 0.0E+0	0.0E+0 (0.0E+0 - 0.0E+0)
k_sMP_surf_to_sand	Sea surface	Sandy beach	SMP	0.0E+0 ± 0.0E+0	0.0E+0 (0.0E+0 - 0.0E+0)
k_P_surf_to_ssed	Sea surface	Shelf sediment	P	2.0E+2 ± 0.0E+0	2.0E+2 (2.0E+2 - 2.0E+2)
k_LMP_surf_to_ssed	Sea surface	Shelf sediment	LMP	1.5E+4 ± 2.4E+4	5.1E+3 (7.9E+2 - 1.9E+4)
k_sMP_surf_to_ssed	Sea surface	Shelf sediment	SMP	1.2E+2 ± 2.5E+1	1.2E+2 (9.9E+1 - 1.4E+2)
k_P_surf_to_wcol	Sea surface	Water column	P	0.0E+0 ± 0.0E+0	0.0E+0 (0.0E+0 - 0.0E+0)
k_LMP_surf_to_wcol	Sea surface	Water column	LMP	2.5E+2 ± 0.0E+0	2.5E+2 (2.5E+2 - 2.5E+2)
k_sMP_surf_to_wcol	Sea surface	Water column	SMP	3.0E-2 ± 5.7E-3	3.0E-2 (2.6E-2 - 3.4E-2)
k_LMP_wcol_to_dsed	Water column	Deep sediment	LMP	1.0E-3 ± 6.5E-19	1.0E-3 (1.0E-3 - 1.0E-3)
k_sMP_wcol_to_dsed	Water column	Deep sediment	SMP	3.0E-2 ± 5.7E-3	3.0E-2 (2.6E-2 - 3.4E-2)

III. Per capita plastic waste generation



S1: Per capita plastic waste generation by region.

Dots are data points from OECD reports (OECD, 2022). Quadratic regression lines with y=0 at x=1950 were used to extrapolate these points to the full 1950 to 2060 range.

Region 1: S. Europe, Region 2: N. Africa & M. East, Region 3: Nile basin.

IV. Demography data per country

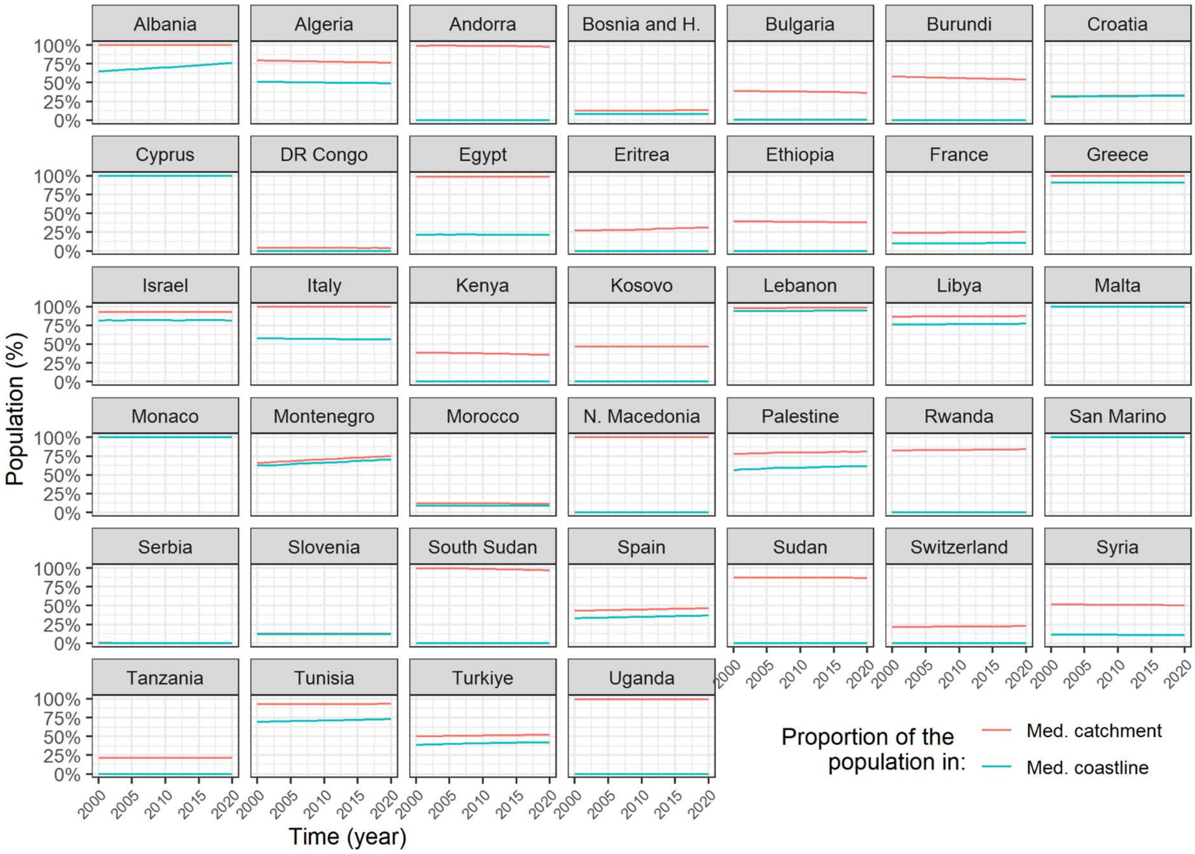


Figure S2: Fraction of the country population living inside the Mediterranean (Med.) catchment and 50 km coastline from 2000 to 2020. Obtained using georeferenced population data from WorldPop database (WorldPop, 2020).

This fraction is constant from 2000 to 2020 for most countries, that is why we decided to consider it constraint for the whole study timeframe. Increasing fraction observed for low population countries (such as Albania or Montenegro) should have a negligible impact on the overall population estimation.

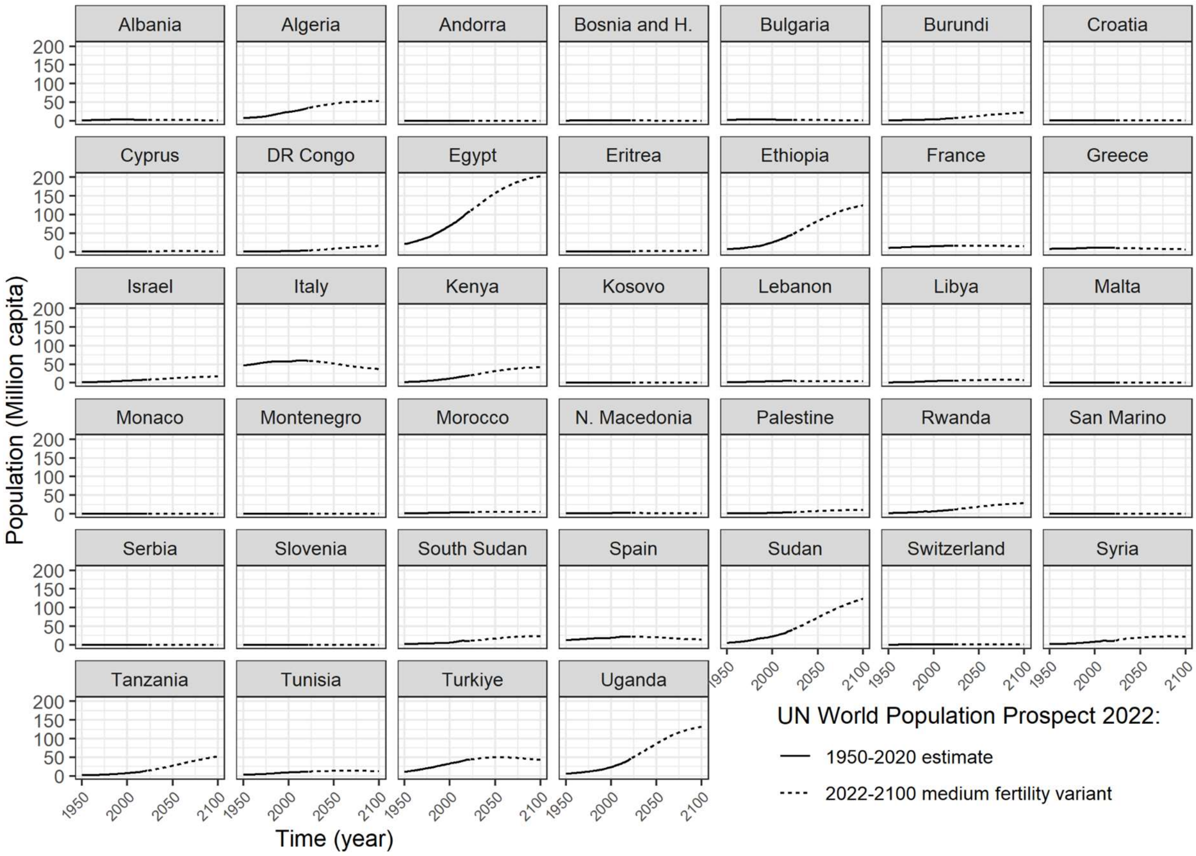


Figure S3: Population inside the Mediterranean catchment. Obtained using UN World Population Prospect 2022 (United Nations, 2022), combined with extrapolation from Figure S.4.1.

V. Sediment extrapolation

To estimate the quantity of LMP accumulated from 1950 ($t=0$) to 2015 ($t=T$ [y]) in the marine sediment, an extrapolation method was used. The available observations provide plastic concentrations q [g.m^{-3}] in the d [m] first meter of sediment, d being the sampling depth of the core.

The d first meters of sediment were deposited on the seafloor during an accumulation time Δt [y]:

$$\Delta t = \frac{d}{S_r}$$ with S_r [m.y^{-1}] the sedimentation rate of the study area.

From 1950 ($t=0$) to 2015 ($t=T$), a sediment layer of height D [m] was deposited on the seafloor:

$$D = T.S_r$$

Let's convert the volumetric concentration q [g.m^{-3}] into an observed concentration per surface unit c_{obs} [g.m^{-2}]:

$$c_{obs} = q\,.\,d$$

This quantity c_{obs} corresponds to the plastic mass accumulated on 1m² of seafloor during the Δt years before 2015.

Let's introduce a plastic sedimentation rate S [g.m^{-2}.y^{-1}], i.e. a plastic flux from the water column to 1m² of seafloor. The function S is unknown, but we can suppose that it is approximated by a quadratic equation according to the model of Sonke et al., 2022 (Sonke et al., 2022). Furthermore, $S(t \leq 0) = 0$ since no plastic contaminated the environment before 1950. Therefore:

$S(t \geq 0) = a.t^2$ and $S(t < 0) = 0$ with a a parameter to determine.

Let's compute the parameter a in order to observe a concentration c_{obs} during the last Δt years. The quantity of plastic precipitated over one unit of surface between $T\text{-}\Delta t$ and T is can be expressed as:

$$c_{obs} = \int_{t=T-\Delta}^{t=T} S(t).dt$$

- If $d \leq D$ (the core only sampled sediment deposited after 1950) :

$$c_{obs} = \int_{t=T-\Delta t}^{t=T} S(t).dt = \int_{t=T-\Delta}^{t=T} a.t^2.dt = \frac{a}{3}\left[t^3\right]_{T-\Delta t}^{T} = \frac{a}{3}\left[T^3 - (T-\Delta t)^3\right]$$

Knowing the apparent surface concentration c_{obs}, we can then find the parameter a that define the precipitation function S:

$$a = c_{obs}.\frac{3}{T^3-(T-\Delta t)^3}$$

We can then compute C [g.m^{-2}], the plastic mass accumulated on 1m² of seafloor from 1950 ($t=0$) to 2015 ($t=T$) :

$$C = \int_{t=0}^{t=T} S(t).dt = a.\int_{t=0}^{t=T} t^2.dt = \frac{a}{3}\left[t^3\right]_0^T = \frac{a}{3}.T^3 = c_{obs}.\frac{T^3}{T^3-(T-\Delta t)^3}$$

Expressing T and Δt according to D and d, we have:

$$C = c_{obs}\frac{1}{1-(1-\frac{d}{D})^3}$$

- if $d > D$ (the core sampled some sediment deposited before 1950 that did not contain any plastics):

$$c_{obs} = \int_{t=T-\Delta}^{t=T} S(t).dt = \int_{t=T-\Delta}^{t=0} S(t).dt + \int_{t=0}^{t=T} S(t).dt = 0 + \int_{t=0}^{t=T} S(t).dt$$

since S is null before 1950 (no plastic contamination yet)

$$\Rightarrow c_{obs} = a.\int_{t=0}^{t=T} t^2.dt = \frac{a}{3}\left[t^3\right]_0^T = \frac{a}{3}.T^3 \qquad \Rightarrow a = c_{obs}.\frac{3}{T^3}$$

$$\Rightarrow C = \int_{t=0}^{t=T} S(t).dt = a.\int_{t=0}^{t=T} t^2.dt = \frac{a}{3}\left[t^3\right]_0^T = \frac{a}{3}.T^3 = c_{obs}$$

Therefore:

$$C = q \, . \frac{d}{1-(1-\frac{d}{D})^3} \qquad \text{if} \quad d \leq D \qquad \text{(S1)}$$

$$C = q \, . \, d \qquad \text{if} \quad d > D$$

To estimate *M* [Mt] the quantity of plastic stoked in the Mediterranean seafloor, we multiply *C* by the surface of the sediment A [km²]:

$$M = A \; . C \; .10^6$$

VI. Geographical distribution of plastic runoff

Table S3: Comparison between different studies providing geographical distribution of plastic runoff to sea.

	Lebreton et al., 2017	**Meijer et al., 2021**	**Nyberg et al., 2023**	**Cózar et al., 2024**
# of river (global)	40 760	31 819	156 163	-
# of river (Med.)	2 724 (6.7%)	1 328 (4.2%)	4 004 (2.6%)	-
Global flux (Tg/y)	1.41	1.00	19.19	-
Med. flux (Tg/y)	0.001 (0.1%)	0.02 (2.3%)	1.24 (6.5%)	-
Regional contribution to plastic runoff from land to sea	S.Eu : 16.3% N. Af : 60.1% Nile : 23.7%	S.Eu : 5.6 % N. Af : 82.3 % Nile : 12.1 %	S.Eu : 11.0 % N. Af : 78.5 % Nile : 10.5 %	S.Eu : 11.0 % N. Af : 78.5 % Nile : 10.5 %
Calibration	13 rivers 30 records No african rivers	67 rivers 136 records No african rivers	No calibration	Calibration with Mediterranean data over 75 months
Plastic type	P + LMP	P	Not mentioned	P
Runoff	Monthly runoff used Dams and floods are modeled	Annual wind and precipitation used, Land use. Don't account for dams, nor for flood	Do not account for water discharge change, but for river connectivity	Account for precipitation and runoff (at least monthly)
Method	Population density + MMPW statistics generates flux that follows gradients and can be blocked by a dam. Monthly runoff is used	Probability model P(MMPW emission to the ocean) = P(mobilization on land) * P(transport from land to river) * P(transport from river to ocean)	MMPW input per km^2 is computed using the Lebreton and Andrady method. Connectivity of river is computed and maximum discharge estimated	Optimize plastic runoff distribution around the mediterranean coast with hotspots of floating macroplastics identified via satellite imaging.
Positive point	Include dams Include monthly runoff and some data during floods	Include land use, wind and annual runoff	High number of rivers	Calibrated on Mediterranean observation Accounts for precipitation and runoff
Negative point	Low number of calibration points (30) No african rivers Only 1 Mediterranean river (Po)	Don't account for dams nor floods. No african rivers Only 2 Mediterranean rivers for calibration (and 2 others for validation)	No calibration Don't account for runoff	Still a proof of concept Calibrated on proxy (macro litter hotspots)

VII. Per capita results

Table S4. Comparison of per capita plastic leakage with Global estimate and between Global estimations and Mediterranean regions.

		Global (From Sonke *et al.*, 2024 (Sonke et al., 2024))		Mediterranean region		S. Europe		N. Africa & M. East		Nile basin	
	Unit \ Year	2023	2060	2023	2060	2023	2060	2023	2060	2023	2060
Population	M capita	8119	10067	536	775	124	107	140	186	273	482
Plastic waste generation	Mt/y	272	656	26	59	16	26	6	16	4	17
	kg/y/capita	34	65	49	76	129	239	40	86	15	35
Mismanaged plastic waste generation	Mt/y	75	148	5.5	11.5	0.8	0.2	2.8	5.5	2.0	5.8
	kg/y/capita	9	15	10.3	14.8	6.5	1.9	20.0	29.6	7.3	12.0
Plastic runoff to sea	Mt/y	18	43	0.4	0.5	0.30	0.27	0.1	0.2	0.0005	0.0027
	kg/y/capita	2.2	4.3	0.7	0.6	2.4	2.5	0.4	1.1	0.0018	0.0055

VIII. Total marine plastic

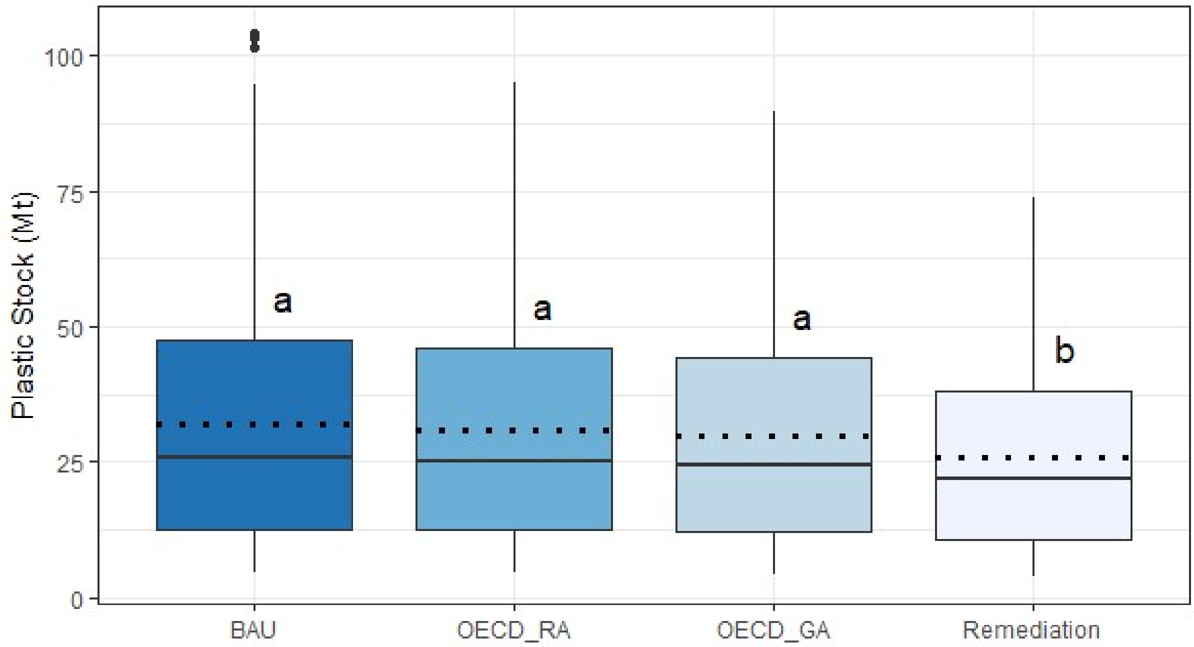


Figure S4: Total marine plastic in 2060 according to the 4 modelled scenarios. Letters indicate significance according to the Dunn post-hoc test. Dotted lines represent the mean, and solid lines the median.

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