nature portfolio

https://doi.org/10.1038/s41893-021-00722-6

Supplementary information

Floating macrolitter leaked from Europe into the ocean

In the format provided by the authors and unedited

Supplementary Information

Floating macro-litter leaked from Europe to the ocean

(González-Fernández et al., 2020)

Supplementary Methods

Delimitation of small drainage basins

Due to mismatches between the monitoring stations at the outlet of several studied small rivers and the drainage basin polygons provided in the CCM River and Catchment Database[1], additional resources were used for further checking. The German official regional hydrology resources[2] have been used to delimitate the drainage basin polygons for the rivers: Dangaster Binnentief, Hooksieler Binnentief, and Maade. SAGA GIS hydrological modelling tools have been used to delimitate the drainage basin polygons in QGIS (www.qgis.org) for the Portuguese rivers: Aguda, Atiaes, Canelas, Canide, Espirito Santo, Granja, Juncal, Madalena, Prego, Ralo, and Valadares.

Additional comparable data in the regression model

In addition to the 38 rivers selected from the RIMMEL database, comparable data was extracted from the literature to improve the geographical coverage of the regression model. We tested the regression analysis including the mid annual estimates for the rivers Ems, Weser and Elbe in Germany[3], and the River Seine in France[4], to account for rivers running through highly populated areas in NW Europe.

For the rivers Ems (20 monitoring sessions), Weser (22 monitoring sessions) and Elbe (22 monitoring sessions), we calculated their mid annual estimates of floating macro litter input to the sea based on the low and high estimates of daily macro-litter emission provided in Schöneich-Argent et al. (2020)[3]:

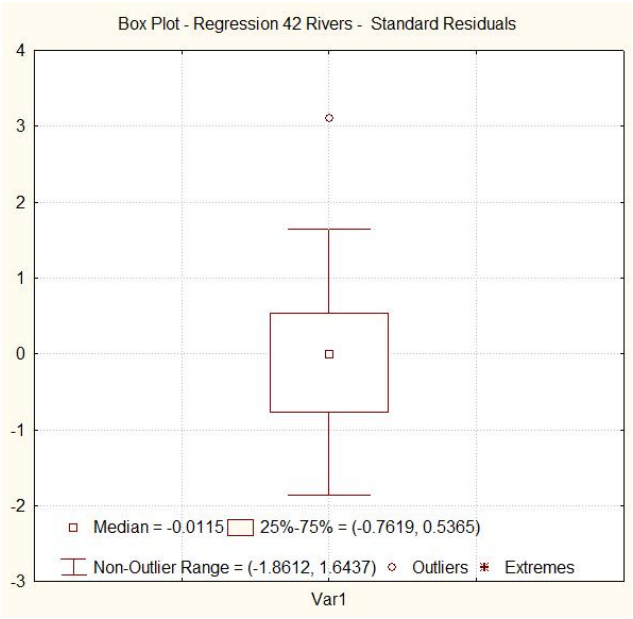
	Annual loading (items/year)		
	low estimate	high estimate	**mid estimate**
Ems	6,935	185,055	**95,995**
Weser	43,070	1,049,010	**546,040**
Elbe	814,680	74,966,985	**37,890,833**

For the River Seine, data was collected during two short periods: 17-21 September 2018 - low discharge and low tidal coefficients, and 21-23 March 2019 - high discharge and high tidal coefficients in Rouen[4], 8 monitoring days. In this case, we have calculated a mid litter flux estimate between the two periods to extrapolate to annual loading, Further, since the results in van Emmerik et al.[4] referred only to plastic items, we have approximated the data to total litter items assuming 82% of plastic items, based on the RIMMEL database results (Fig. 1 main text):

	litter flux (items/hour)*			**Annual loading (items/year)**
	low flux	high flux	mid flux	**mid estimate**
Seine	129	1,288	709	**6,206,780**

**Litter flux approximated from plastic items data, assuming 82% plastic items in total litter*

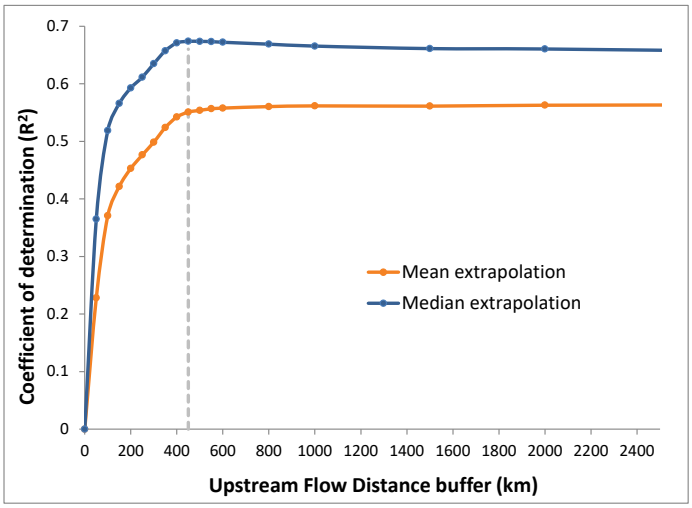
However, the inclusion of the River Elbe in the regression analysis raised some concerns about the validity of its annual estimates for this study. The standard residuals of the linear regression were analysed to calculate the non-outlier range using the '1.5 x interquartile range' method and identified the River Elbe as an outlier, justifying its exclusion from the analysis:



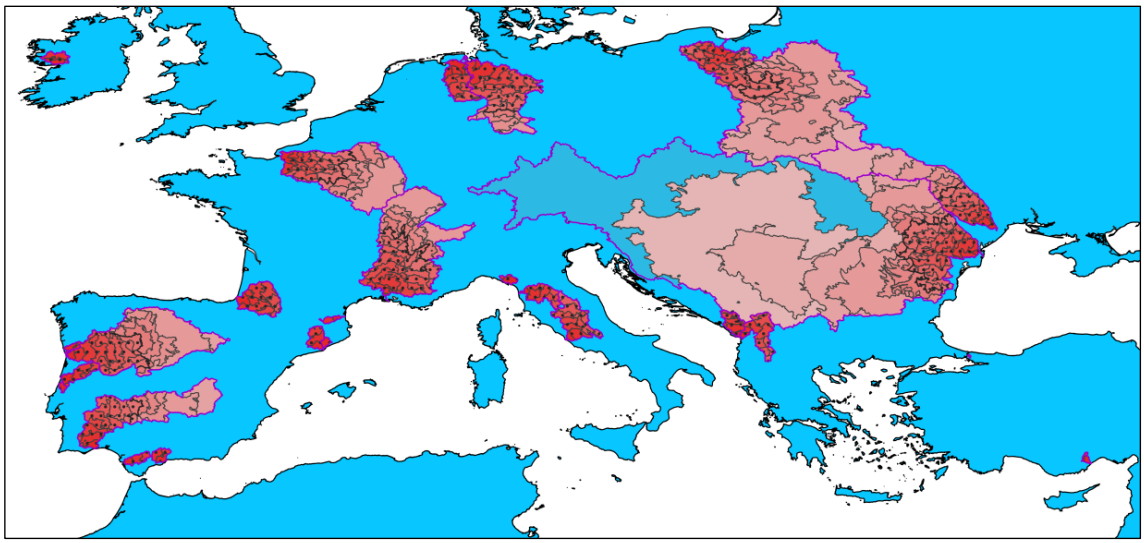
The final regression model included 41 rivers: 38 rivers from the RIMMEL database and the rivers Ems, Weser and Seine (Supplementary Data 3).

Supplementary Figures

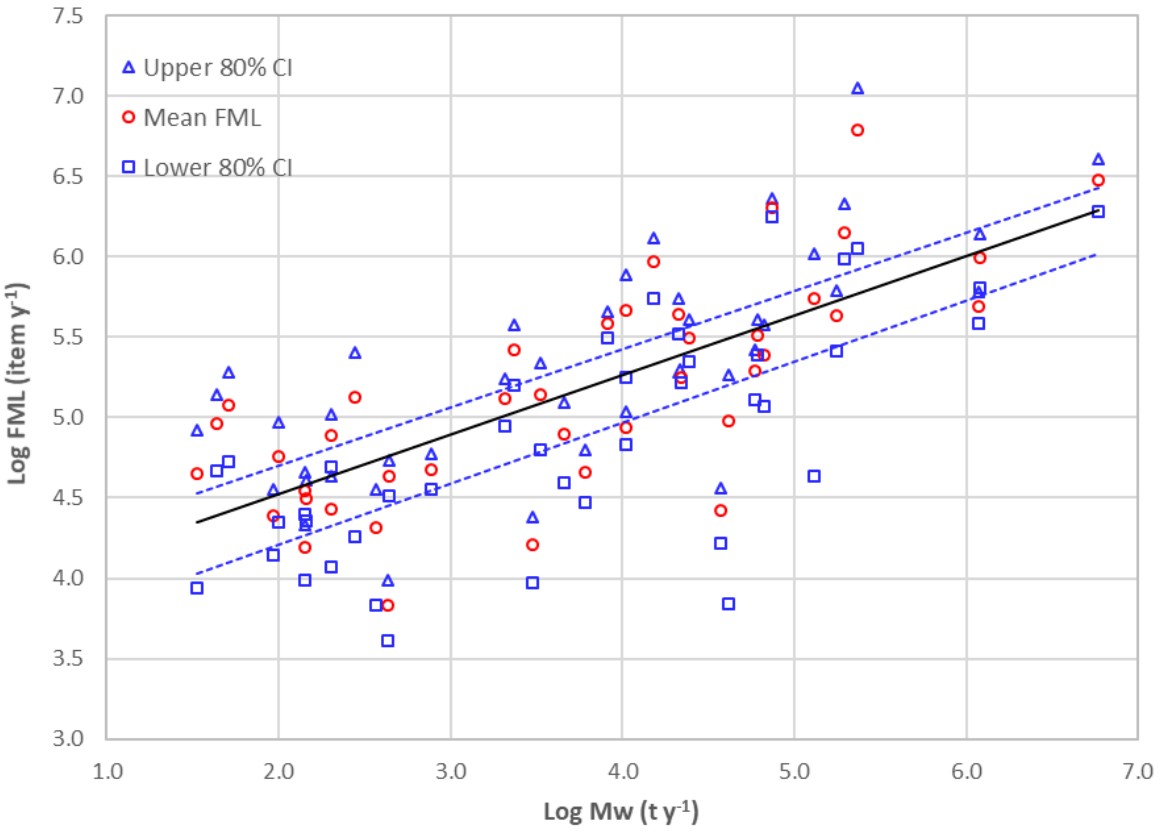
a



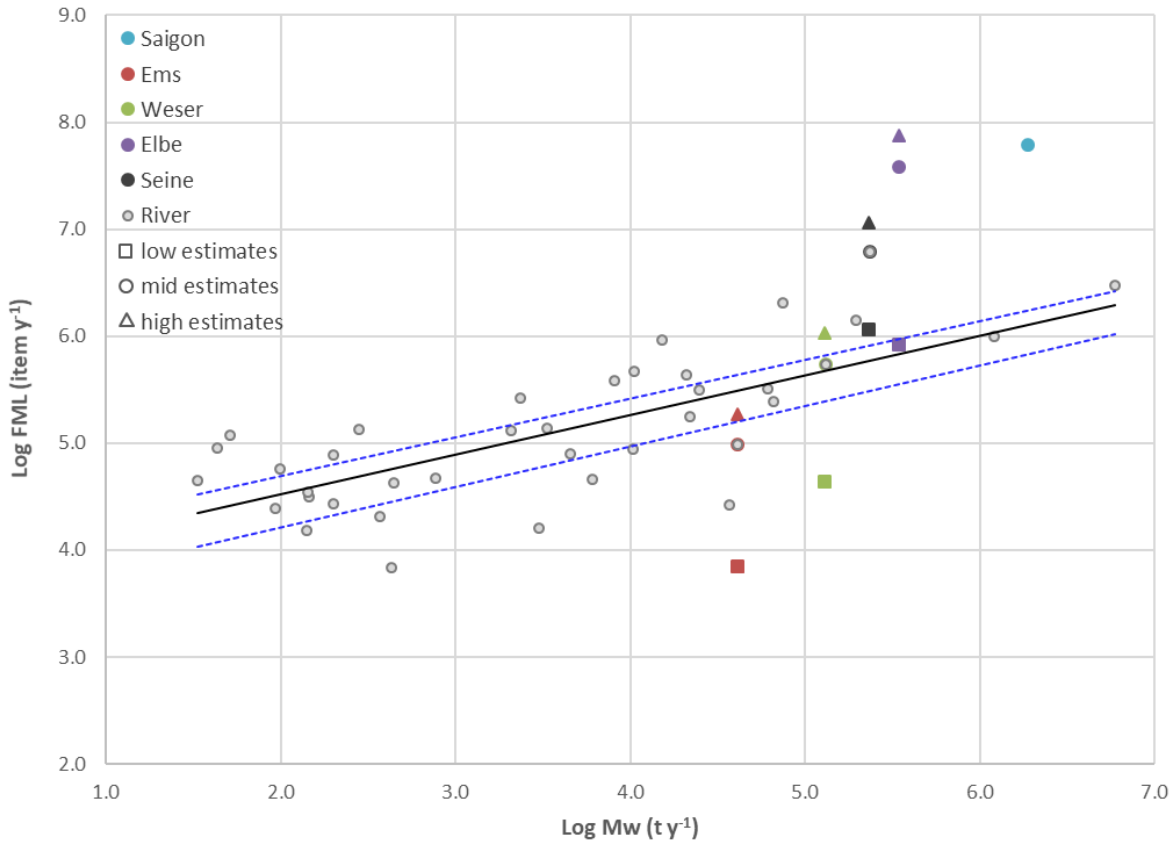
b



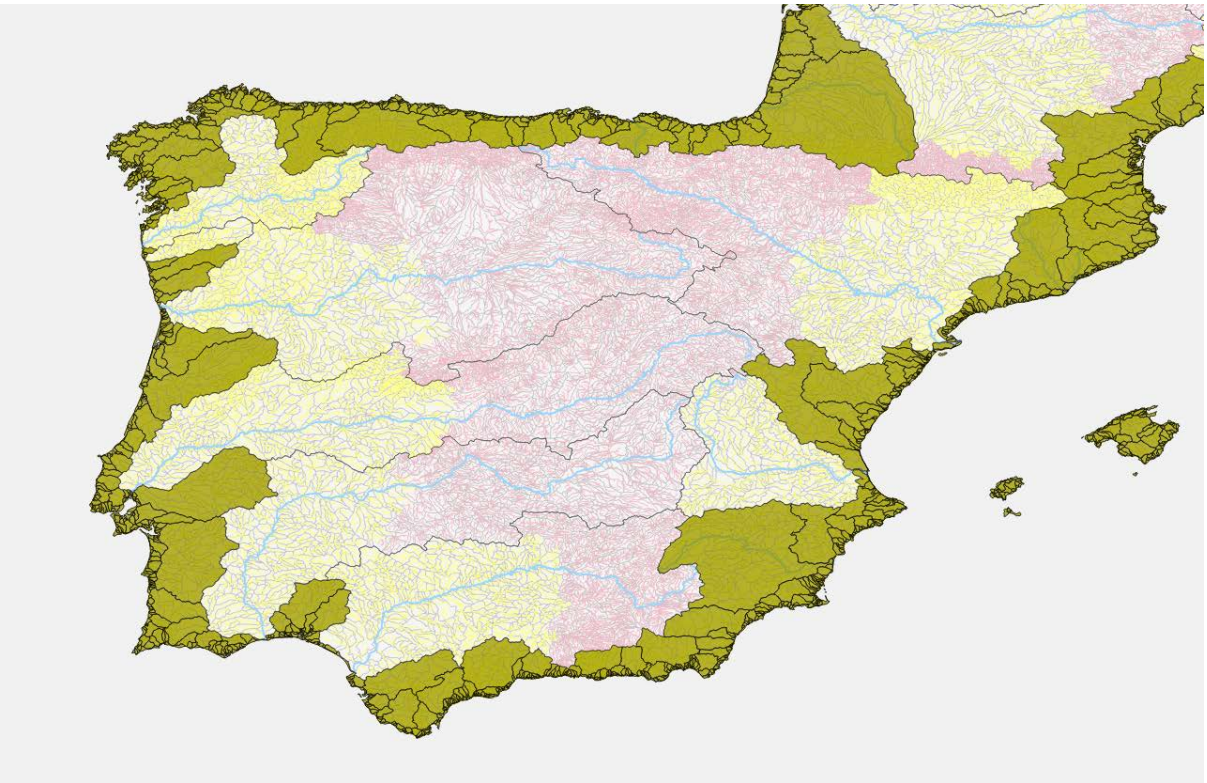
Supplementary Figure 1. ***a) Optimization of coastal distance buffer related to FML****. Variation of the coefficient of determination (R^2) in the MW-FML regression (Equation 1). MW was estimated using increasing upstream flow distance buffers from the basin outlet: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 800, 1000, 1500, 2000 km and whole basin. The dashed line represents the optimal flow distance buffer for the median annual extrapolation at 450 km.* ***b) Graphical representation of distance buffers*** *for the river drainage basins included in the study. Dotted sections correspond to the basin area included in the 450 km flow distance buffer.*



Supplementary Figure 2. ***Regression of the MW generated in the drainage basins and mean-based FML****. Regression analysis was based on Equation 1. Dashed blue lines refer to 80% confidence intervals (10^{th} and 90^{th} percentiles). See Supplementary Table 1 for regression parameters.*



Supplementary Figure 3. ***Comparison between the regression analysis presented in this study (41 rivers) and existing floating macro-litter estimates****. Floating macro-litter estimates correspond to the rivers Ems (orange), Elbe (purple), and Weser (green) [3]; Seine (black)[4]; and Saigon (light blue) [5]. MW was estimated for the whole basin area. Squares, dots and triangles correspond to low, mid and high floating macro-litter estimates, respectively. In the rivers Seine and Saigon, floating macro-litter was calculated from floating macroplastic estimates, considering 82% fraction of plastic items[6]. Dashed blue lines refer to 80% confidence intervals (10th and 90th percentiles). See Supplementary Table 1 for regression parameters.*



Supplementary Figure 4. ***Application of the 450 km upstream flow distance buffer from the basin outlets*** *for the optimized calculation of MW generated in river basins of the Iberian Peninsula. Green polygons indicate drainage basins fully contained in the 450 km flow distance buffer from their basin outlets. Yellow polygons indicate the 450 km upstream flow distance buffer overlapping section selected for the optimized MW calculation in medium, large and transboundary drainage basins. Blue lines correspond to main rivers.*

Supplementary Tables

Supplementary Table 1. ***Sentivity analysis of the regression parameters and model output for the mean- and median-based FML extrapolations****. Confidence intervals refer to the bootstrapping (percentile method) of the mean and median litter fluxes for each river considered in the regression analysis.*

Regression parameters - MEAN-based regression				Model output (32,651 drainage basins)		
Annual Load estimate	**intercept**	**slope**	**R^2**	**Total load (items y^{-1})**	**Basins <100km^2 (total load %)**	**Basins >100km^2 (total load %)**
Lower 80% CI (Percentile 10th)	*3.4516*	*0.3795*	*0.5312*	**306,580,031**	***70.5***	***29.5***
Lower 50% CI (Percentile 25th)	*3.6374*	*0.3560*	*0.4961*	413,303,327	*72.4*	*27.6*
Mean	*3.7837*	*0.3704*	*0.5634*	**626,327,415**	***71.3***	***28.7***
Upper 50% CI (Percentile 75th)	*3.8857*	*0.3698*	*0.5439*	789,320,805	*71.3*	*28.7*
Upper 80% CI (Percentile 90th)	*3.9723*	*0.3624*	*0.5382*	**925,282,308**	***71.9***	***28.1***

Regression parameters - MEDIAN-based regression				Model output (32,651 drainage basins)		
Annual Load estimate	**intercept**	**slope**	**R^2**	**Total Load (items y^{-1})**	**Basins <100km^2 (total load %)**	**Basins >100km^2 (total load %)**
Lower 80% CI (Percentile 10th)	*2.3583*	*0.5765*	*0.605*	**87,332,433**	**54.1**	**45.9**
Lower 50% CI (Percentile 25th)	*2.5949*	*0.5466*	*0.549*	121,131,545	56.9	43.1
Median	*2.8442*	*0.5576*	*0.6738*	**232,793,303**	**55.9**	**44.1**
Upper 50% CI (Percentile 75th)	*3.0441*	*0.5401*	*0.6656*	325,334,745	57.6	42.4
Upper 80% CI (Percentile 90th)	*3.3222*	*0.4922*	*0.5983*	**444,770,735**	**61.9**	**38.1**

Regression parameters - 450 km buffer MW vs. Whole basin MW				Model output (32,651 drainage basins)		
Annual Load estimate	**intercept**	**slope**	**R^2**	**Total Load (items y^{-1})**	**Basins <100km^2 (total load %)**	**Basins >100km^2 (total load %)**
Mean-based FML vs. Whole basin MW	*3.7837*	*0.3704*	*0.5634*	**626,327,415**	***71.3***	***28.7***
Mean-based FML vs. 450 km buffer MW	3.7021	0.4009	0.5509	608,381,746	69.7	30.3
				2.9% variation		
Median-based FML vs. Whole basin MW	2.9982	0.5043	0.6601	237,287,488	58.6	41.4
Median-based FML vs. 450 km buffer MW	*2.8442*	*0.5576*	*0.6738*	**232,793,303**	**55.9**	**44.1**
				1.9% variation		

Additional references,

1. De Jager, A. & Vogt, J. Rivers and Catchments of Europe - Catchment Characterisation Model (CCM). European Commission, Joint Research Centre (JRC) [Dataset] PID. (2007). Available at: http://data.europa.eu/89h/fe1878e8-7541-4c66-8453-afdae7469221.

2. Niedersächsisches Ministerium für Umwelt, Energie, B. und K. Interaktive Umweltkarten der Umweltverwaltung. Available at: https://www.umweltkarten-niedersachsen.de/umweltkarten/.

3. Schöneich-Argent, R. I., Dau, K. & Freund, H. Wasting the North Sea? – A field-based assessment of anthropogenic macrolitter loads and emission rates of three German tributaries. *Environ. Pollut.* **263**, 114367 (2020).

4. van Emmerik, T. *et al.* Seine Plastic Debris Transport Tenfolded During Increased River Discharge. *Front. Mar. Sci.* **6**, 642 (2019).

5. van Emmerik, T., Strady, E., Kieu-Le, T.-C., Nguyen, L. & Gratiot, N. Seasonality of riverine macroplastic transport. *Sci. Rep.* **9**, 13549 (2019).

6. González-Fernández, D., Hanke, G. & the RiLON network. *Floating Macro Litter in European Rivers - Top Items, EUR 29383 EN, Publications Office of the European Union, Luxembourg*. (2018). doi:10.2760/316058