Assessing litter loads and estimating macroplastic emission rates of three major North Sea tributaries – Ems, Weser, and Elbe – through holistic, field-based observations

Rosanna Schöneich-Argent[1]*, Kirsten Dau[2], Holger Freund[1]

[1] Institute for Chemistry and Biology of the Marine Environment (ICBM), Carl von Ossietzky University of Oldenburg, Germany
[2] Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency (NLWKN), Brake, Germany
*contact: rosanna.schoeneich-argent@uni-oldenburg.de

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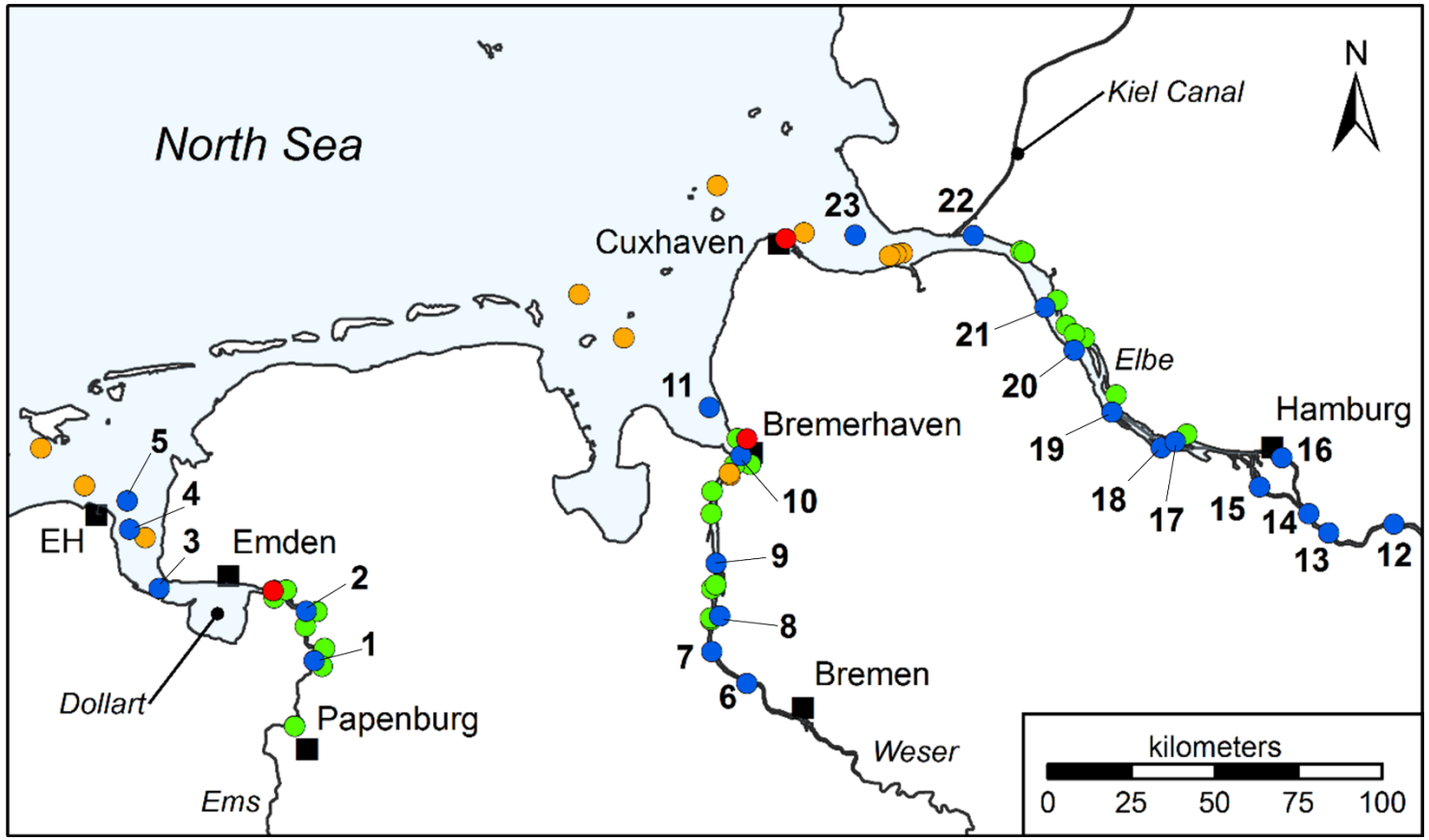
Incentives

- riverine litter being an emerging field of research
- scarcity of field-based studies on riverine macrolitter pollution and emission estimates
- lack of (holistic) research on the role of the Ems, Weser, and Elbe as litter pathways into the North Sea

Aims

- to assess the quantities and composition of litter deposited and transported by the Ems, Weser, and Elbe
- to investigate potential differences in litter abundance and diversity between the river compartments (embankment, surface, water column, river bed)
- to estimate litter emission rates from surface-floating litter and negatively buoyant, suspended debris

Methods: Data collection



Survey locations in northern Germany [Fig. 1 from Schöneich-Argent et al. (2020)]

embankment
- survey frequency: 2x per week
- duration: 10 weeks per river (July-Sept)
- 4 river bank types (beaches, vegetation, stones, harbour structures; 100 m length)

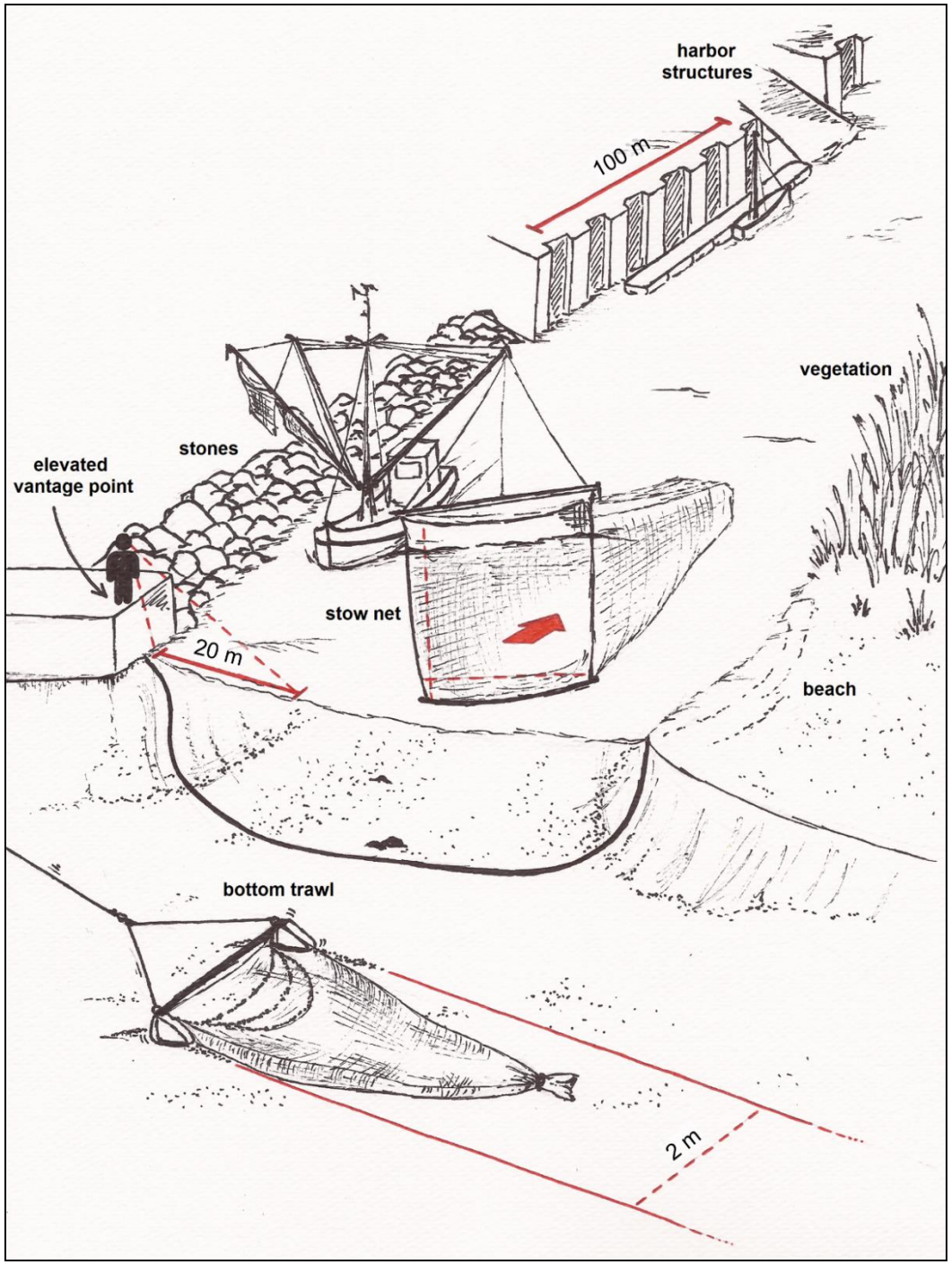
surface
- survey frequency: 1-2x per month (30 minutes)
- duration: 16 months

water column
- survey frequency: 2x per year (spring/autumn); 1 ebb/1 flow haul (stow nets)
- duration: since 2013 (as part of Water Framework Directive 2000/60/EC)

river bed
- survey frequency: 1-3 replicates (bottom trawl)
- duration: 10 minutes per trawl

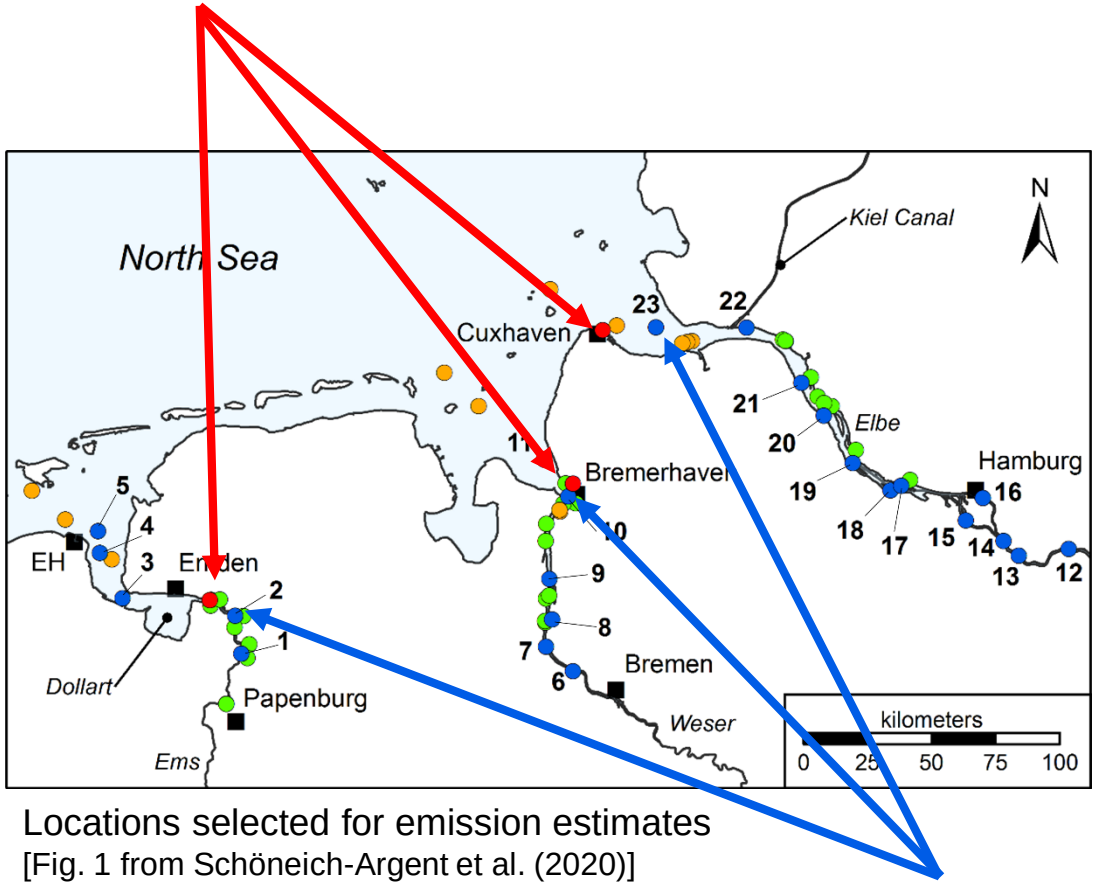
Litter categorisation followed:

OSPAR Guideline for Monitoring Marine Litter […] (OSPAR Commission 2010)
JRC Floating Litter Monitoring Application (only surface litter; González-Fernández & Hanke 2017)



Schematic visualisation of survey techniques and river compartments
[Fig. A from Schöneich-Argent et al. (2020)]

Methods: Emission estimates



Locations selected for emission estimates
[Fig. 1 from Schöneich-Argent et al. (2020)]

Approach 1

Surface-floating litter:

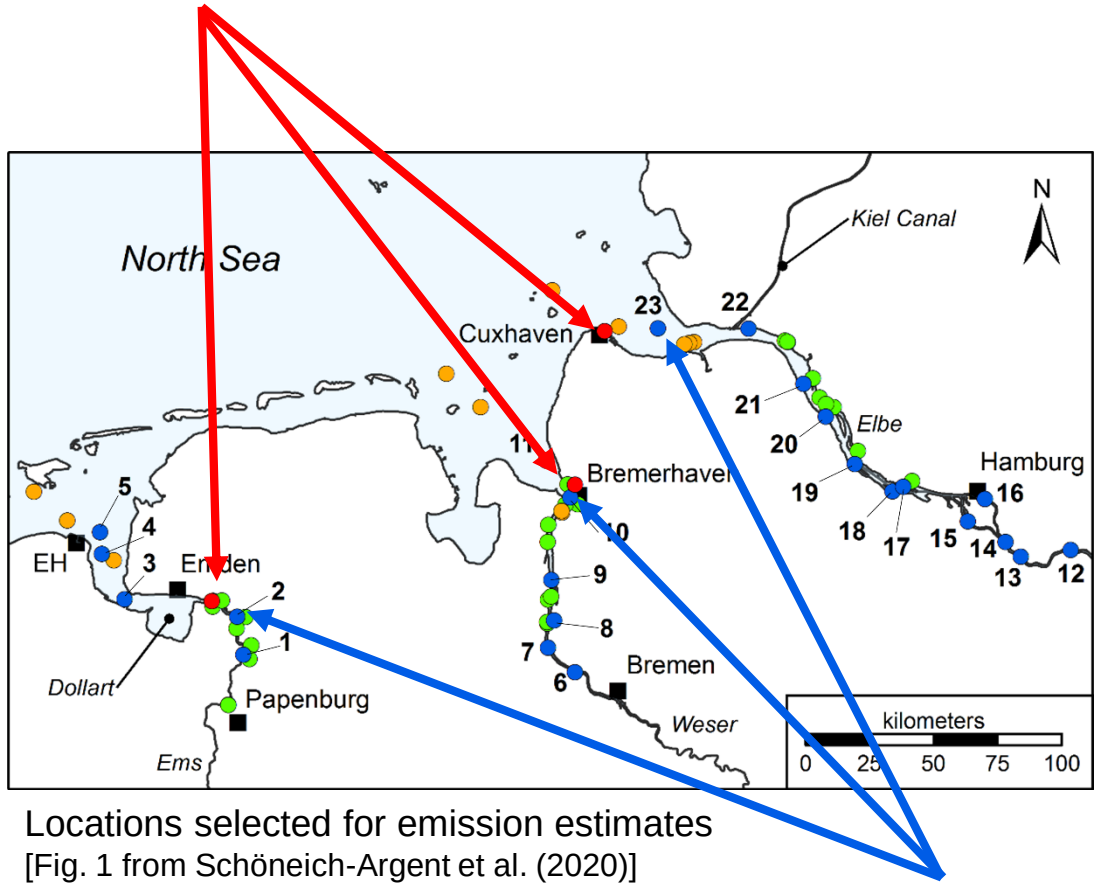
1) extrapolation of number of litter items across entire river width at survey point (assuming a homogeneous distribution)
2) extrapolation to daily number of items emitted, **based on river-specific long-term mean flow speed (m s^{-1}) at survey point**
3) mean daily litter discharge quantities extrapolated to a year (365 d)

Suspended litter:

1) standardisation to number of litter items per m^3 of water column
2) extrapolation to daily number of items emitted, based on river-specific long-term mean discharge volume (m^3 s^{-1}) at survey point
3) mean daily litter discharge quantities extrapolated to a year (365 d)

→ calculation of number of macroplastic items, based on compartment-specific proportion of plastics per river (see slide 9)
→ addition of annual plastic emission quantities of both compartments
→ calculation of annual mass emission estimates, based on mean (median) per plastic item mass, i.e. 6.3 g (1.7 g)

Methods: Emission estimates



Locations selected for emission estimates
[Fig. 1 from Schöneich-Argent et al. (2020)]

Approach 2*

*** This second extrapolation approach was added during the review process of the manuscript.**

Surface-floating litter:

1) extrapolation of number of litter items across entire river width at survey point (assuming a homogeneous distribution)
2) extrapolation to daily number of items emitted, **based on river-specific long-term mean ebb flow speed during survey and long-term mean flow speed (m s^{-1}) at survey point**
3) mean daily litter discharge quantities extrapolated to a year (365 d)

Suspended litter:

same as with approach 1

→ calculation of number of macroplastic items, based on compartment-specific proportion of plastics per river (see slide 9)
→ addition of annual plastic emission quantities of both compartments
→ calculation of annual mass emission estimates, based on mean (median) per plastic item mass, i.e. 6.3 g (1.7 g)

Results: Abundance and composition

- **Litter abundance** (mean number of debris items per unit):

  along embankment (per 100 m): Elbe > Ems > Weser
  river bank type (per 100 m): beaches > vegetation > harbour structures > stones
  on river surface (items per day): Elbe > Weser > Ems
  water column (per m^3): Elbe > Ems > Weser
  river bed (per km^2): Elbe > Weser > Ems

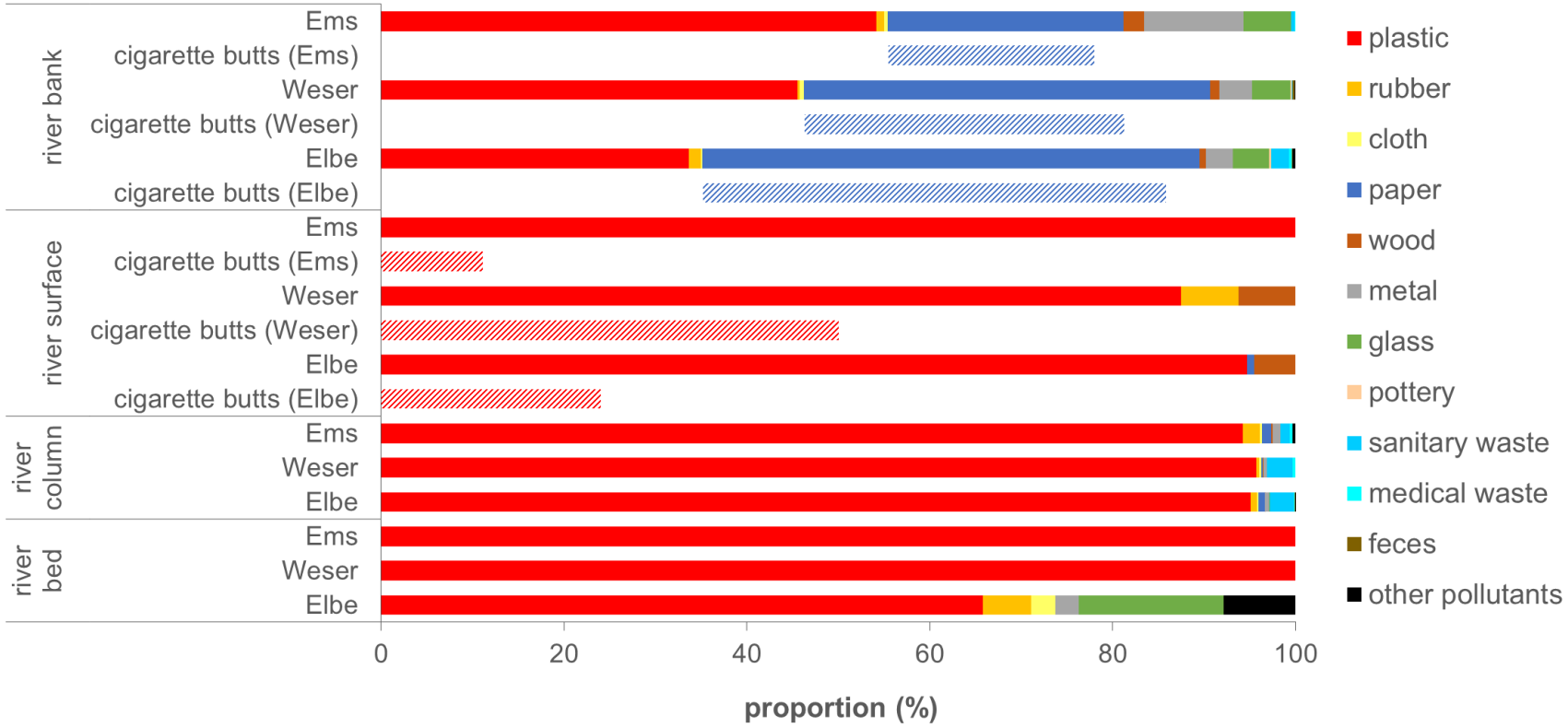
- Litter quantities varied spatio-temporally in all four river compartments.

- **Litter diversity** (total number of different debris types):

  Elbe > Weser > Ems
  embankment > water column > surface > river bed
  beaches > vegetation > harbour structures > stones

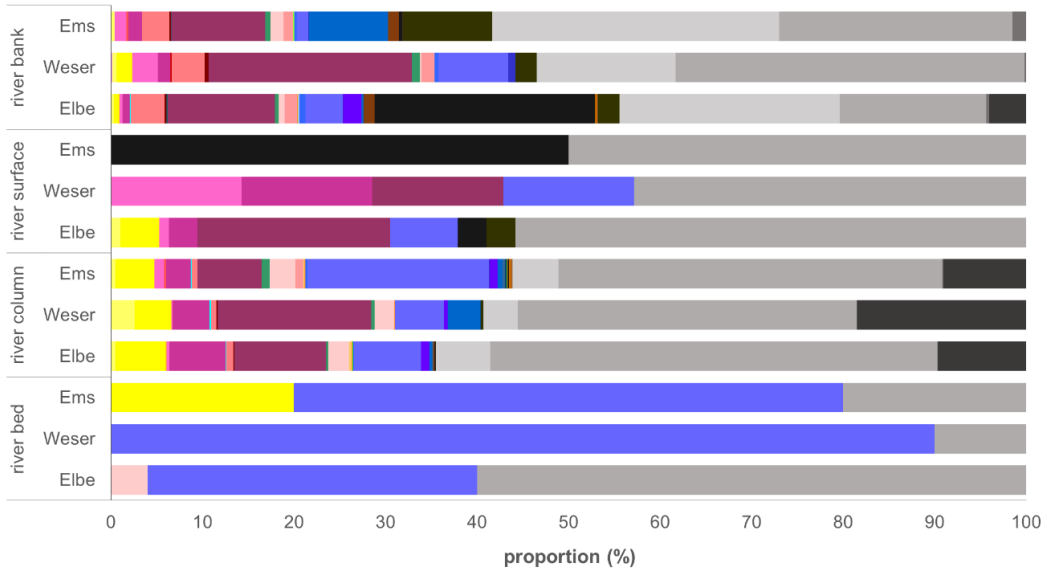
Results: Composition

High proportion of plastic items in all rivers and all four river compartments.



Composition chart of the absolute abundance of all litter items recorded per river compartment (embankment, surface, water column, river bed). [Fig. B from Schöneich-Argent et al. (2020)]

Results: Composition



consumer waste

- small bags (e.g. freezer bags)
- large bags (e.g. shopping)
- plastic bag ends
- drinks (bottles, containers and drums)
- cleaner (bottles, containers and drums)
- food containers
- 4/6-pack yokes
- cups
- caps/lids
- crisp/sweet packets and lolly sticks
- cutlery/trays/straws
- cigarette lighters
- toys & party poppers
- pens
- cosmetics
- household gloves
- shotgun cartridges

industrial waste (fishing)

- oyster nets or mussel bags
- nets & pieces of nets <50 cm
- tangled nets/cord/rope & string
- fishing line (angling)
- floats/buoys
- light sticks
- lobster & fish tags

miscellaneous plastic waste

- foam sponge
- plastic/polystyrene pieces >50 cm
- plastic/polystyrene pieces 2.5-50 cm
- plastic/polystyrene pieces 0-2.5 cm
- other plastic/polystyrene items

industrial waste (shipping/other)

- rope (diameter >1 cm)
- string & cord (diameter <1 cm)
- mesh vegetable bags
- fertilizer/animal feed bags
- strapping bands
- jerry cans
- engine oil containers >50 cm
- industrial gloves
- shoes/sandals
- buckets
- hard hats
- industrial packaging, plastic sheet

High proportion of consumer waste along the embankments, on the river surface, and in the water column.

Fishing-related items in all compartments.

Approx. half of all plastic items could not be attributed to a source.

Composition chart of all litter categories in the material debris group “plastic”.
[Fig. 3 from Schöneich-Argent et al. (2020)]

Results: Plastic emission estimates

	Ems	Weser	Elbe
Approach 1* mean (median) t y^{-1}	1.6 (0.4)	6.3 (1.7)	451 (122)

*These results appeared in the presentation abstract submitted to the EGU in January 2020, based on the findings of the original manuscript.

Approach 2** mean (median) t y^{-1}	0.5 (0.1)	0.7 (0.2)	8.3 (2.2)

**These results were included in the revised manuscript after the second extrapolation approach (see Slide 7) was suggested during the review process. These values therefore do not appear in the presentation abstract.

Results: Plastic emission estimates

- Field-based emission estimates of the Ems and Weser are lower than previous model-based estimates by Lebreton et al. (2017) and Schmidt et al. (2017).

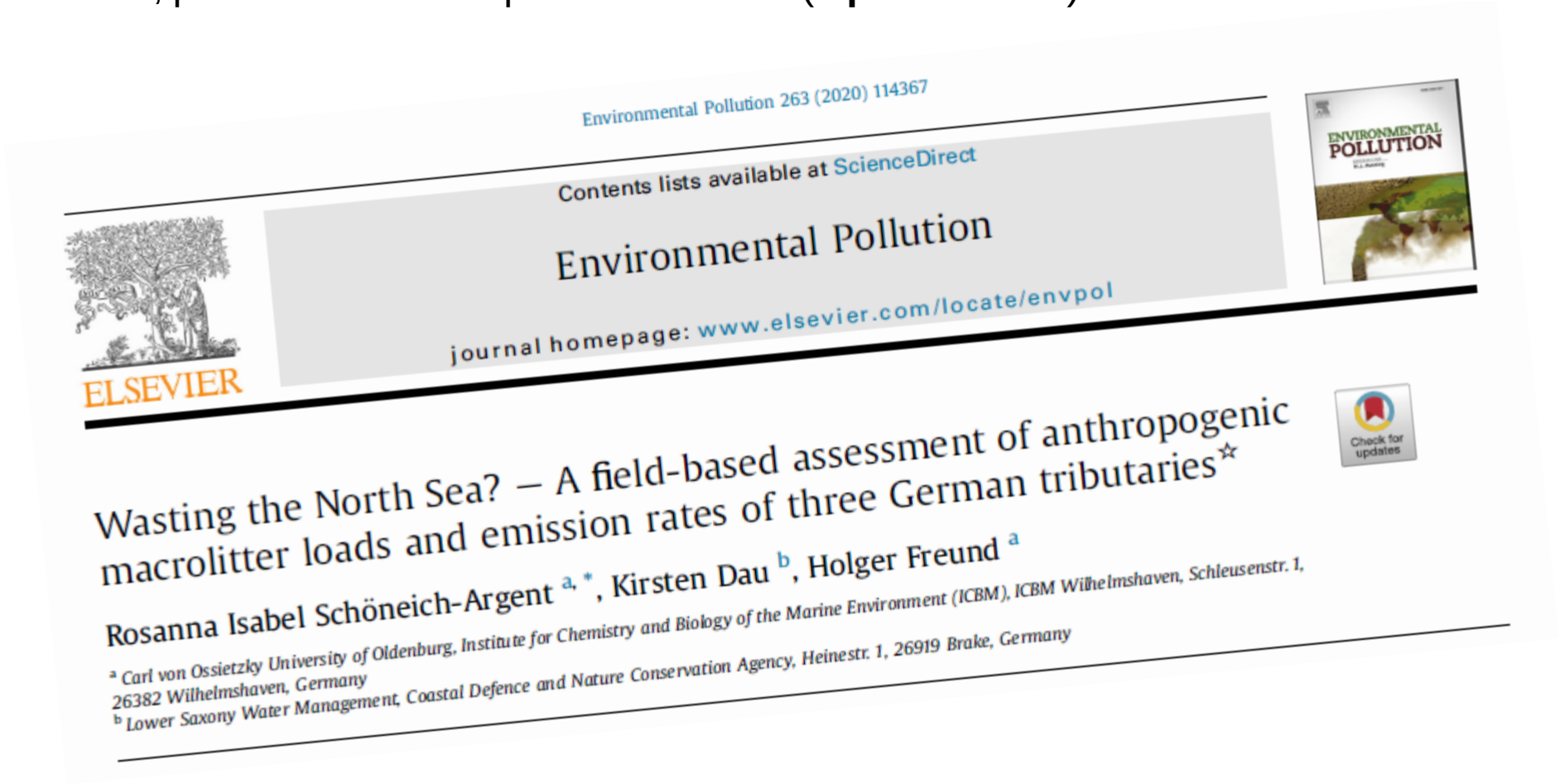
- Emission estimates of the Elbe with Approach 2 are also below previous model-based estimates, but discharge quantities of Approach 1 are similar to or exceed the highest values calculated by Lebreton et al. (2017) and Schmidt et al. (2017).

- The plastic discharge quantities account for only 0.001-0.76 % of the total mismanaged plastic waste mass estimated for each catchment (see Lebreton et al. 2017; Schmidt et al. 2017).

Conclusions

- Larger rivers generally appear to have higher pollution levels.
- Spatio-temporal variation in litter quantities seems to be as common at riverine locations as it is at coastal sites.
- Debris quantities and composition (per river, per compartment, per river bank type) reflect human activities and potential source points.
- Discrepancies between field- and model-based plastic litter emission estimates call for more ground-truthing of models and the inclusion of river-specific influencing factors.
- The vast majority of mismanaged plastic waste per catchment is likely not emitted but appears to accumulate on land (within the catchment), along the waterways or on the river bed.

For more information, please refer to the published article (**Open Access**):



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Wasting the North Sea? – A field-based assessment of anthropogenic macrolitter loads and emission rates of three German tributaries☆

Rosanna Isabel Schöneich-Argent [a, *], Kirsten Dau [b], Holger Freund [a]

[a] Carl von Ossietzky University of Oldenburg, Institute for Chemistry and Biology of the Marine Environment (ICBM), ICBM Wilhelmshaven, Schleusenstr. 1, 26382 Wilhelmshaven, Germany

[b] Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency, Heinestr. 1, 26919 Brake, Germany

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