Rethinking Microplastic Exposure in Aquatic Mammals: Evidence for Atmospheric Transfer and Chemical Accumulation



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Presentation Outline



1. Introduction

2. Materials & Methods

3. Results

4. Discussion

5. Limitations and future directions

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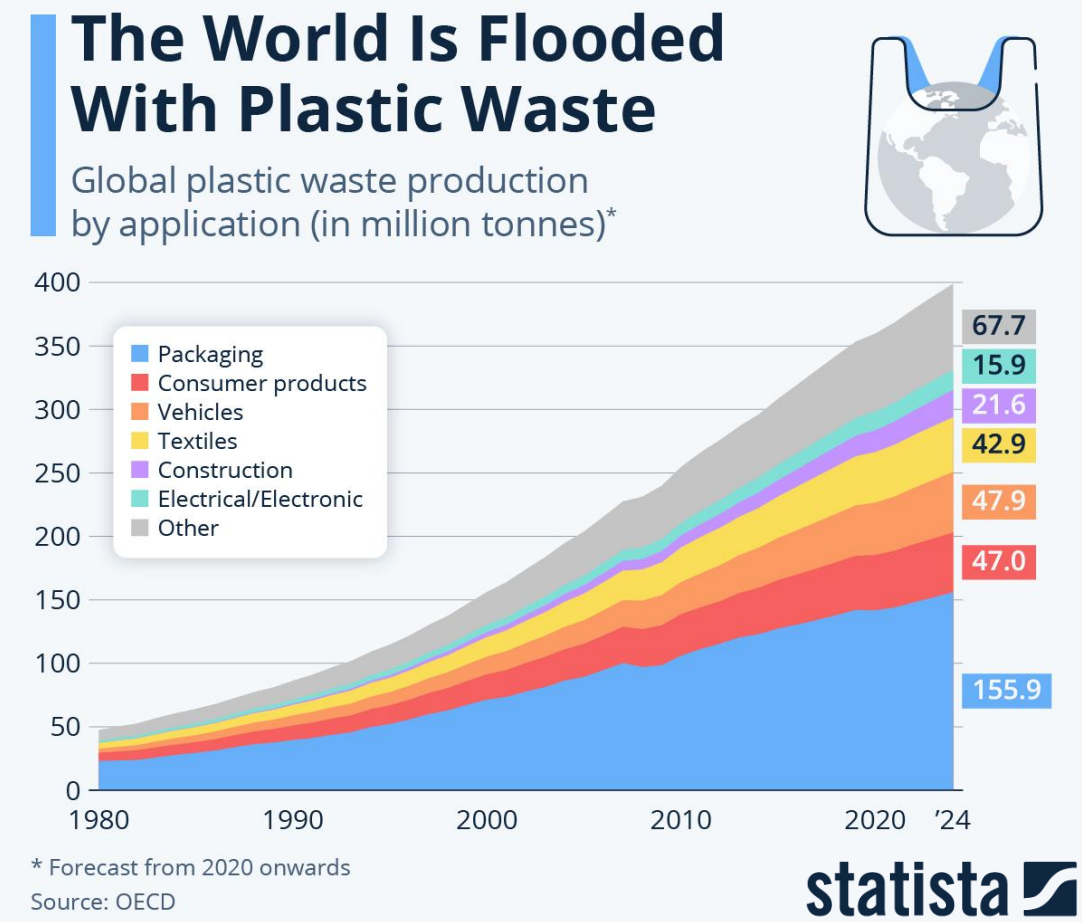
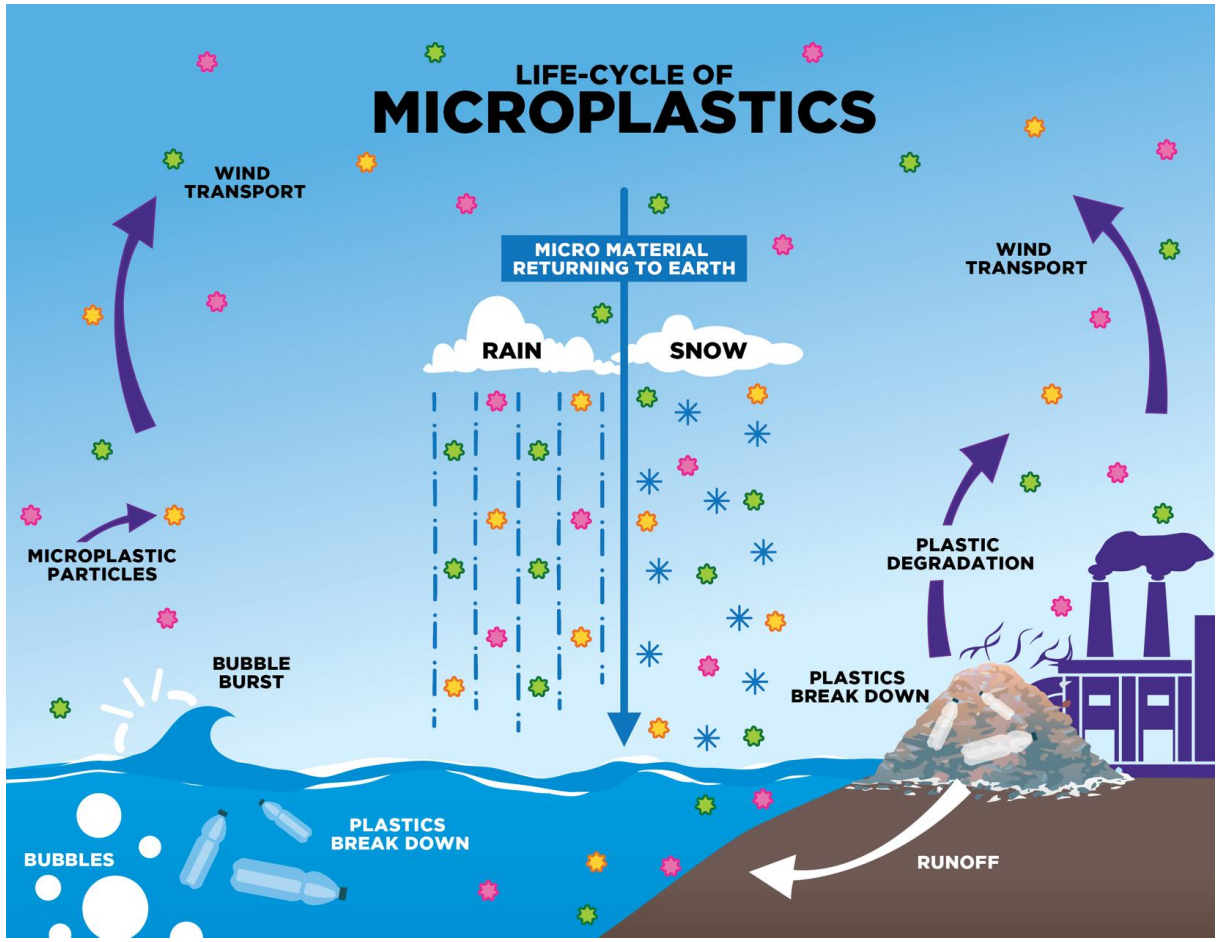
1. Introduction

Serious plastic and microplastics problems in the ocean





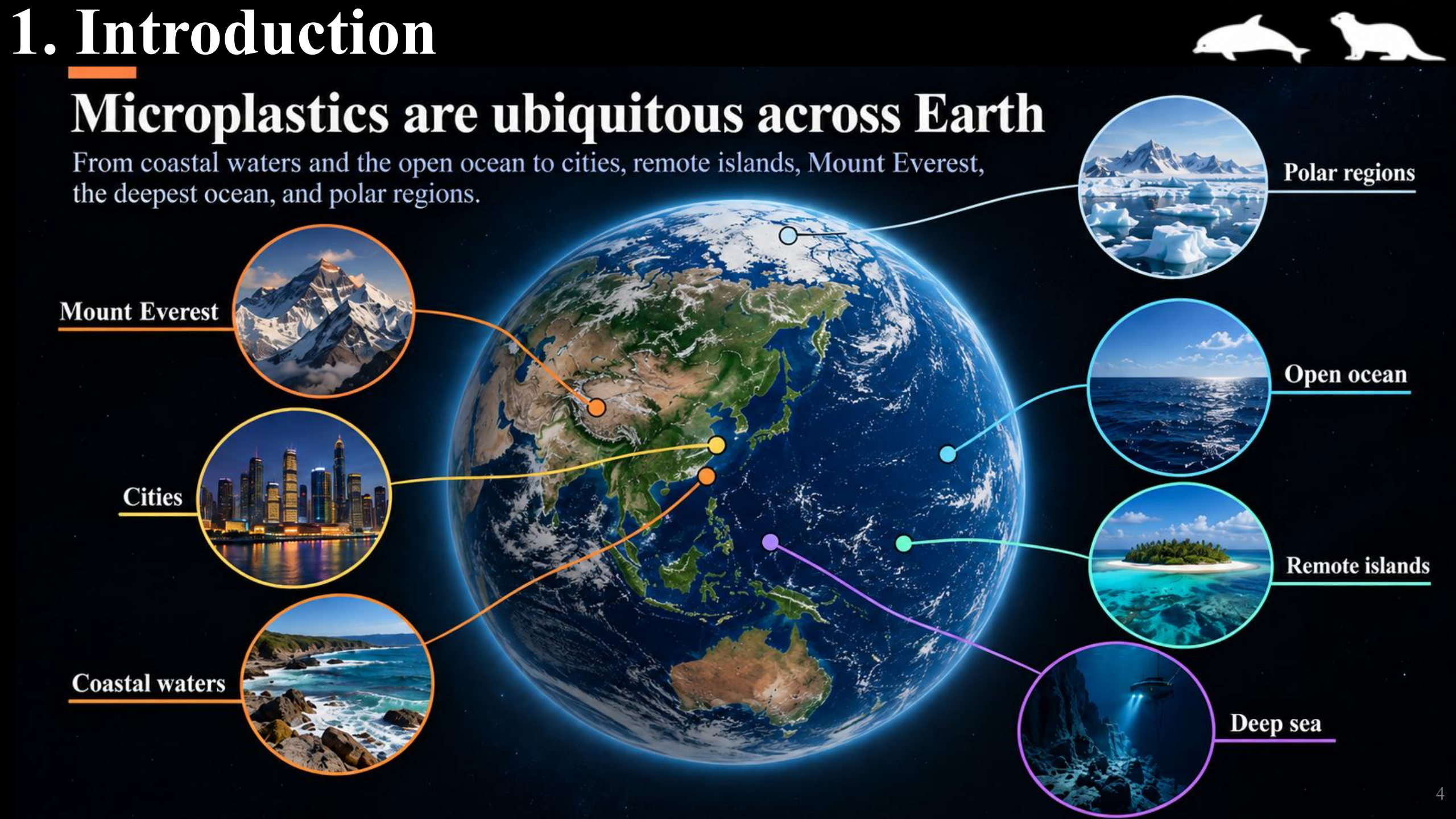
- Plastic pollution continues to grow up.
- Every year, 4 million tons of plastic waste is generated and ends up in the ocean.

- Plastic waste degrades into microplastics (MPs), becoming ubiquitous across terrestrial, marine, and atmospheric environments.

1. Introduction

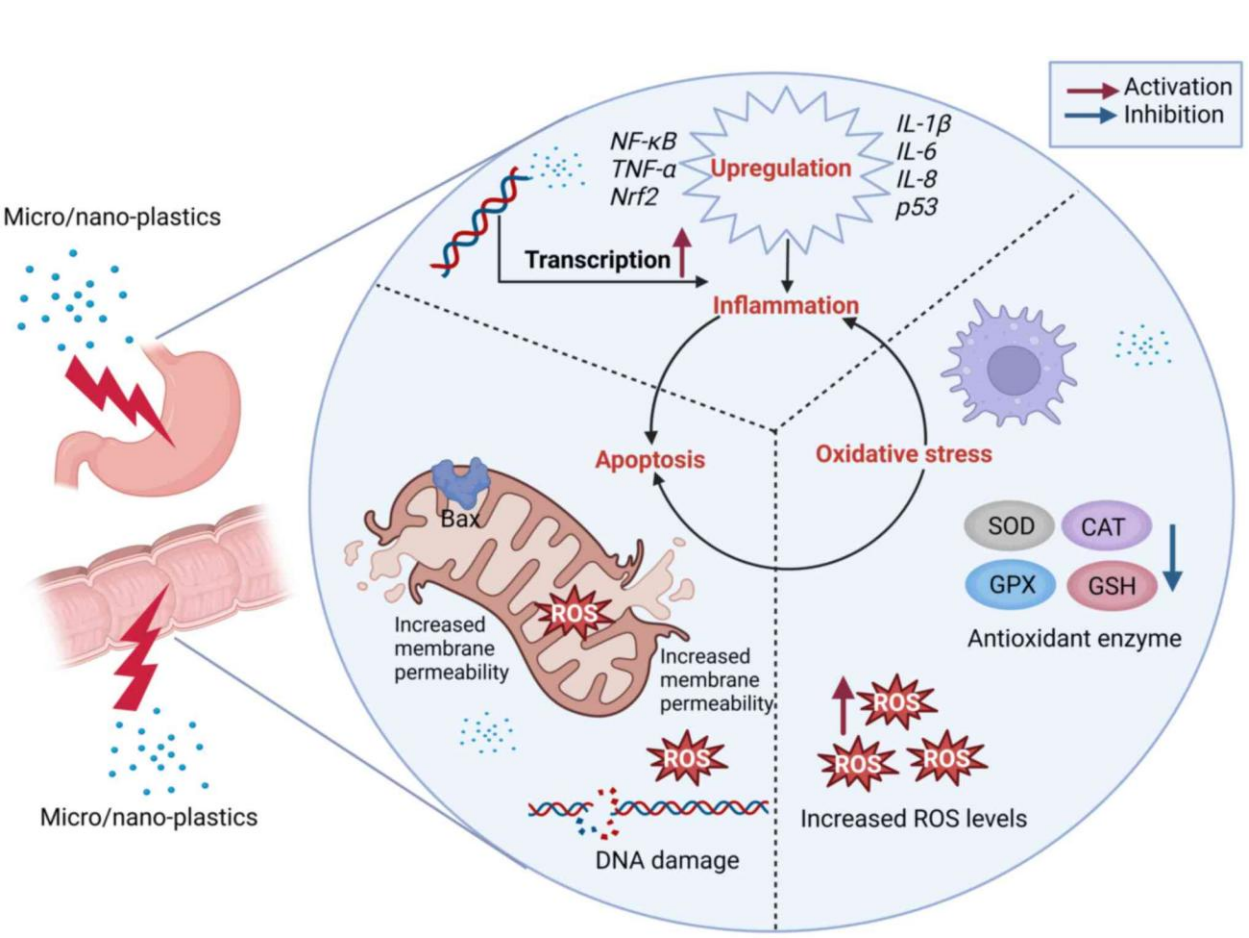
Microplastics are ubiquitous across Earth

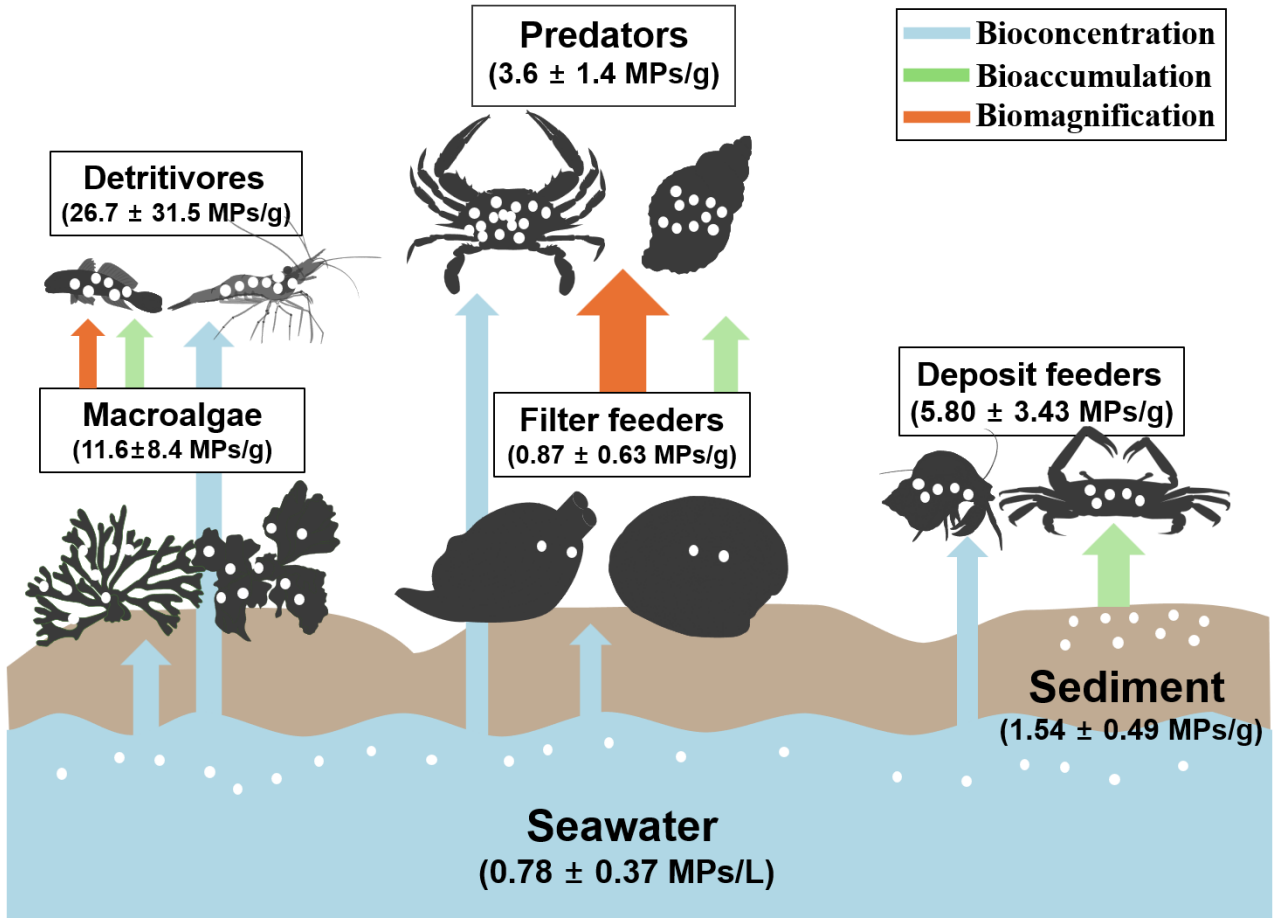
From coastal waters and the open ocean to cities, remote islands, Mount Everest, the deepest ocean, and polar regions.



1. Introduction

Biological effects and trophic transfer of microplastics

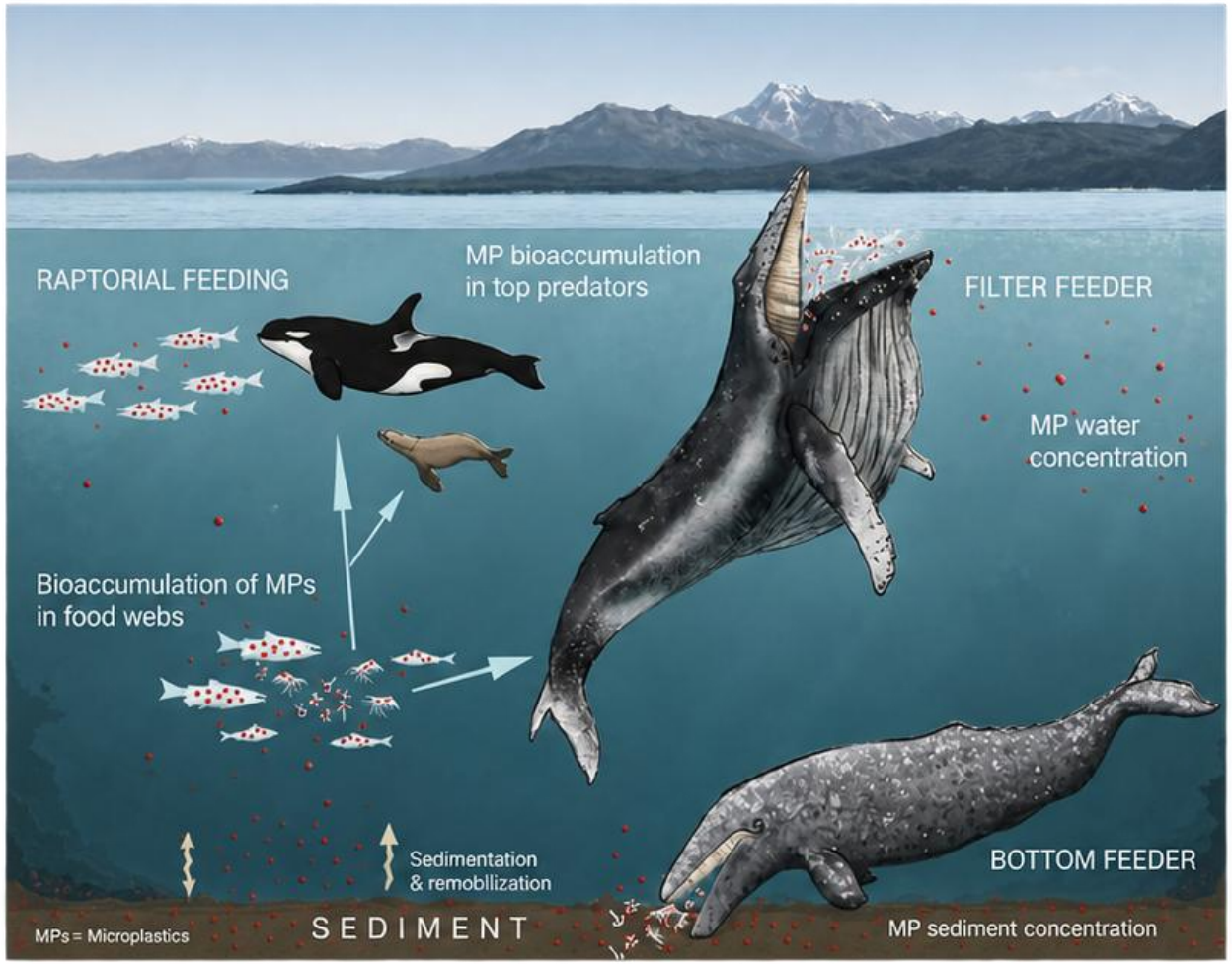


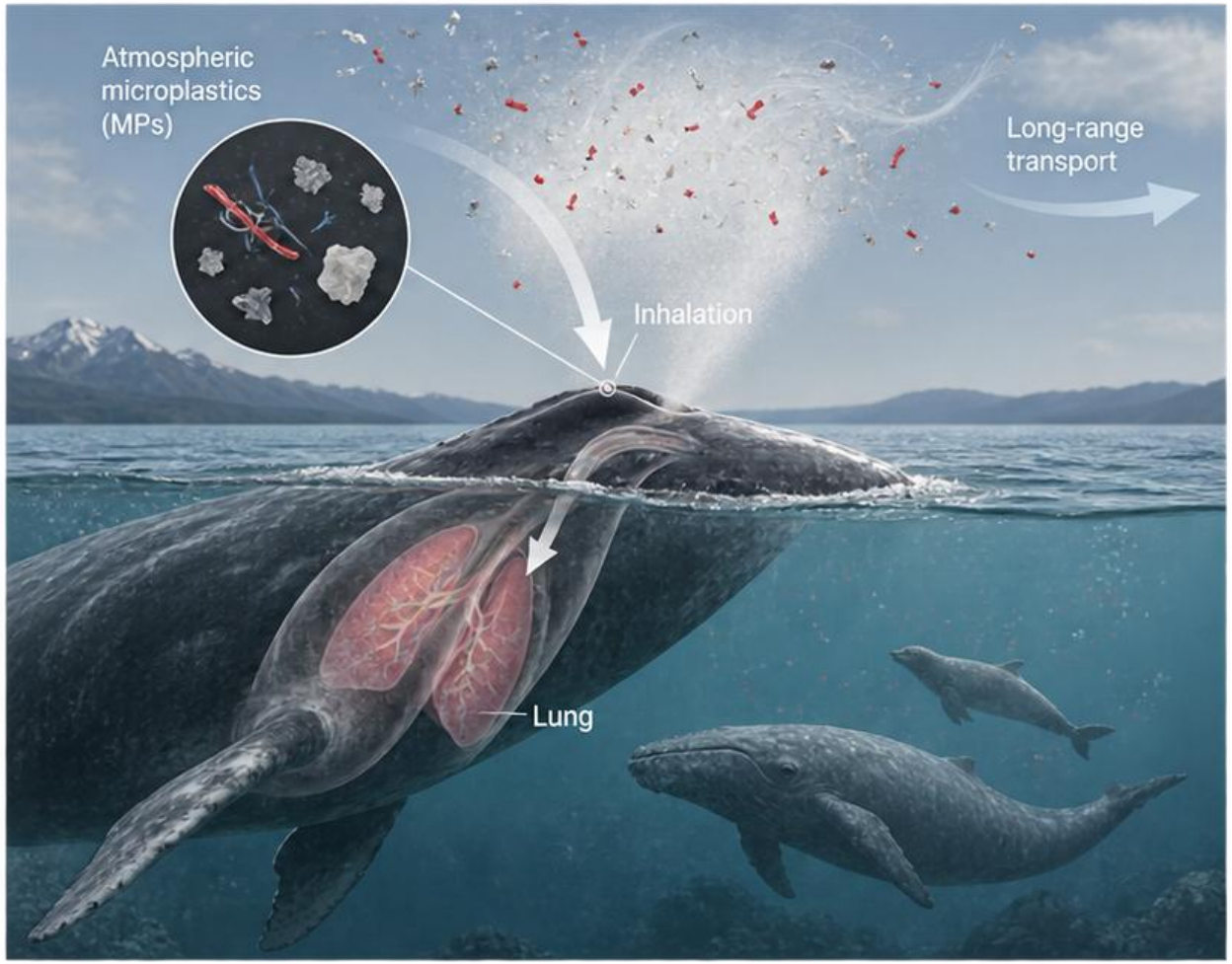


Crucially, ingested plastics can bioaccumulate across food webs, transferring to higher trophic levels

1. Introduction

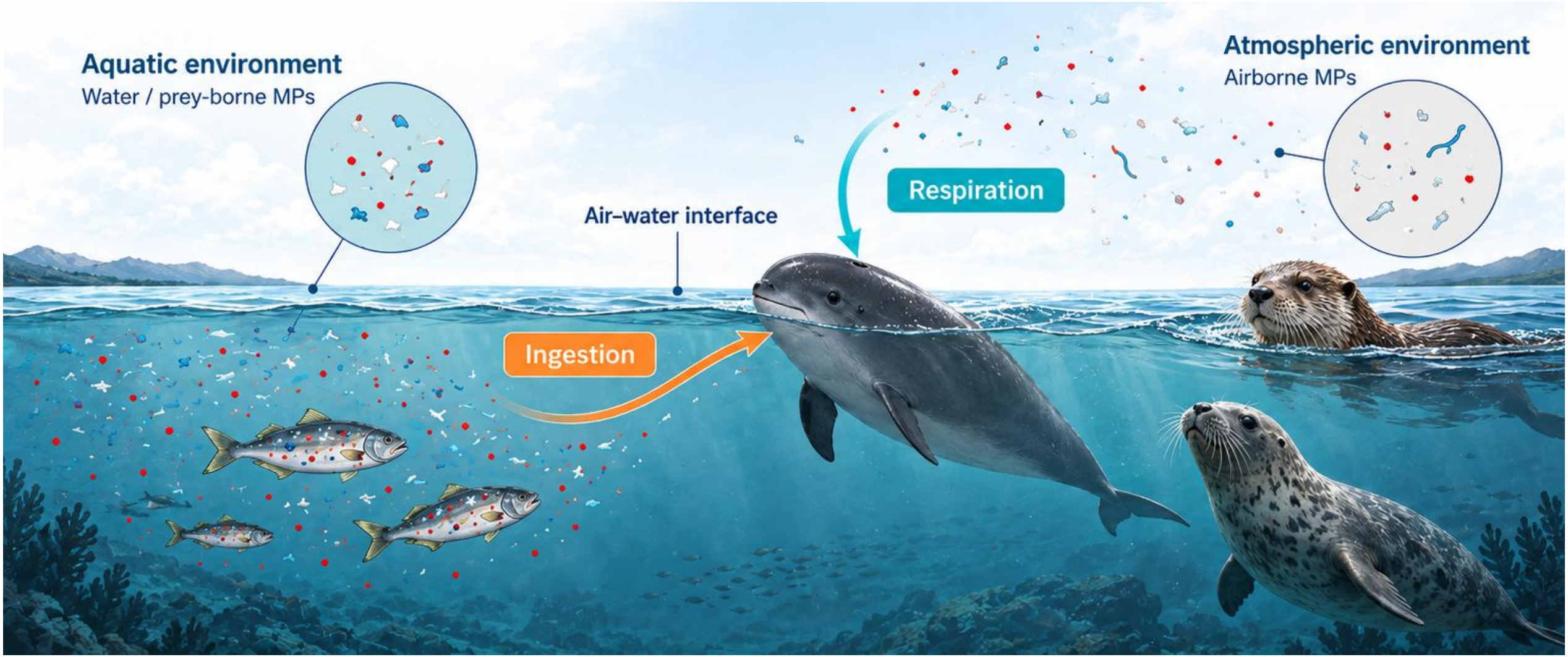
Beyond ingestion: respiratory exposure to microplastics





1. Introduction

- **Aquatic mammals are particularly interesting in this context.**



Aquatic mammals may be exposed through both ingestion and respiration

1. Introduction

Contrasting lifestyles, shared exposure interface





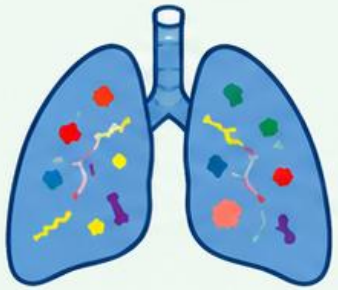
Species	Finless porpoise (Neophocaena asiaeorientalis)	Eurasian otter (*Lutra lutra*)
Lifestyle	**Fully aquatic**	**Semi-aquatic**
Habitat	Marine/coastal	Freshwater / estuarine / coastal
Habitat use	Entire life in water	Moves between land and water

Therefore, we investigated whether microplastics in respiratory and gastrointestinal compartments show different patterns in two aquatic mammals with contrasting lifestyles.

1. Introduction



We hypothesized that respiratory exposure might represent an additional exposure pathway, and that MP ingestion might be associated with chemical accumulation.

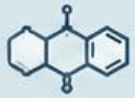


Lung
airborne MPs
respiratory compartment

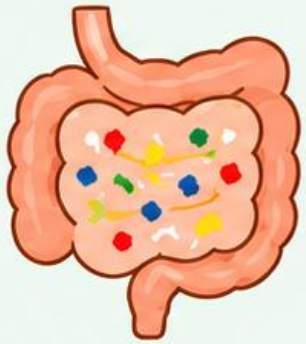
Predicted difference in particle characteristics


Size distribution


Morphology


Polymer composition


Hazard profile



GI tract
prey / water MPs
digestive compartment

2. Materials and Methods

FINLESS PORPOISE

Neophocaena asiaeorientalis

n = 10, stranded individuals





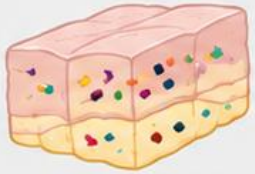
Lung



Stomach contents



Intestinal contents



Blubber

EURASIAN OTTER

Lutra lutra

n = 8, stranded/carcass individuals





Lung



Stomach contents



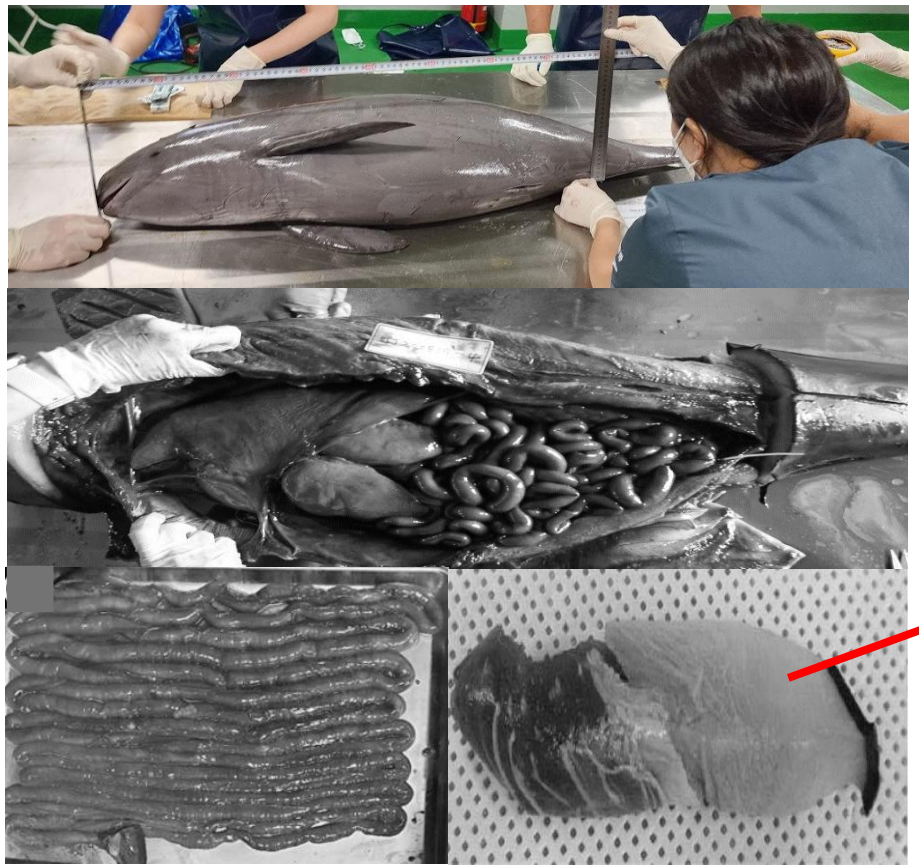
Intestinal contents

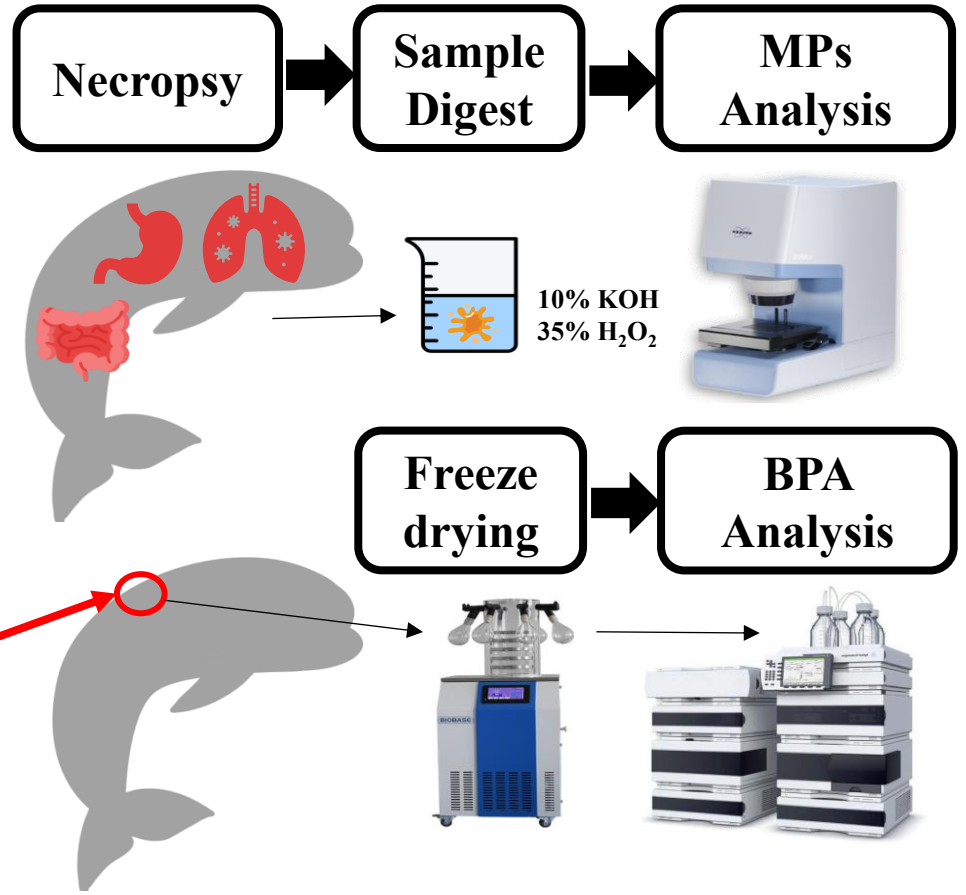
= Respiratory exposure

= Gastrointestinal exposure

= Chemical accumulation

2. Materials and Methods





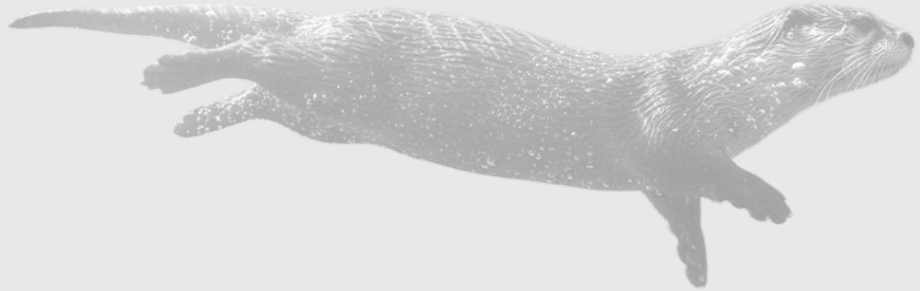
- For the cetacean necropsy conducted with the vet, we used metal tools and 100% cotton clothes to minimize contamination.
- For MP analysis, we digested the GIT content and analyzed it using FT-IR.
- For BPA analysis, we freeze drying the blubber and analyzed it using LC-MS/MS.

Results

Microplastic characteristics across biological compartments

Eurasian otter · Finless porpoise · BPA

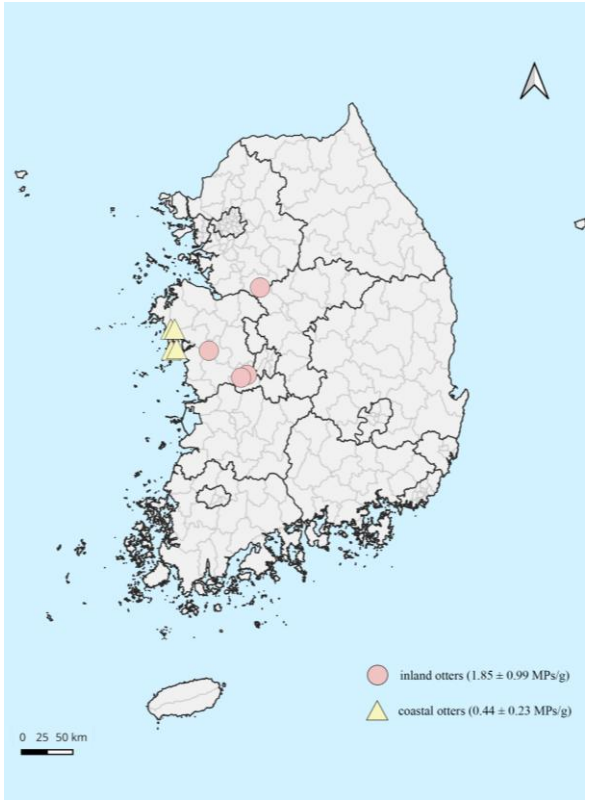


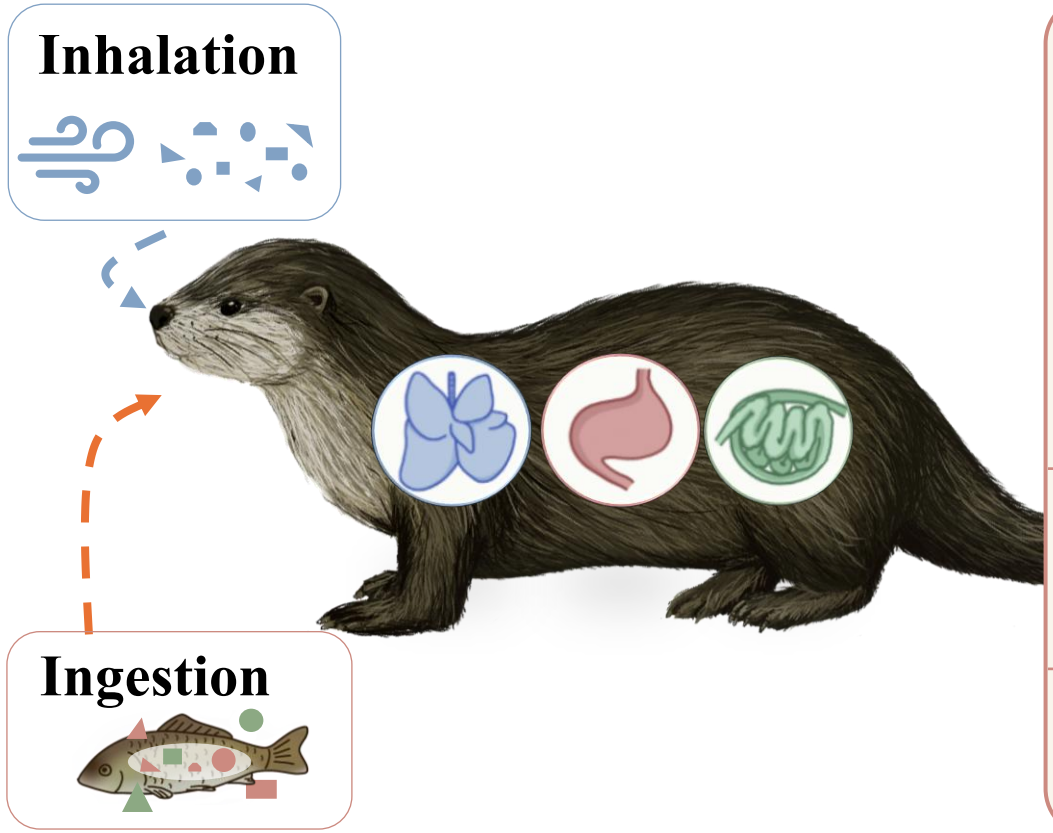


3. Results

Eurasian otter (*Lutra lutra*)

Microplastics were detected in respiratory and gastrointestinal compartments



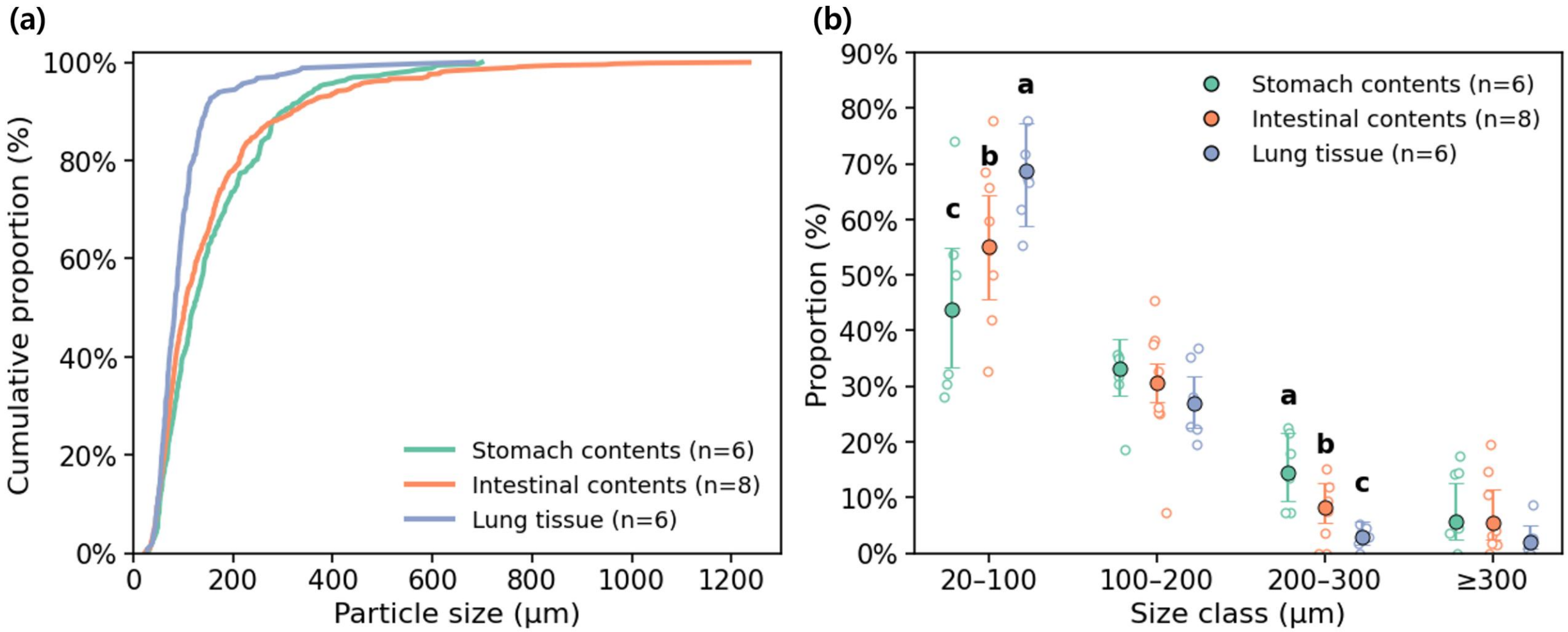


Stomach contents	Intestinal contents	Lung tissue
2.05 ± 1.48 MPs/g	1.75 ± 2.04 MPs/g	1.07 ± 1.10 MPs/g
Large MPs	Small MPs	Small MPs

No significant difference in overall abundance among compartments; smaller MPs were more prevalent in lung tissue.

3. Results

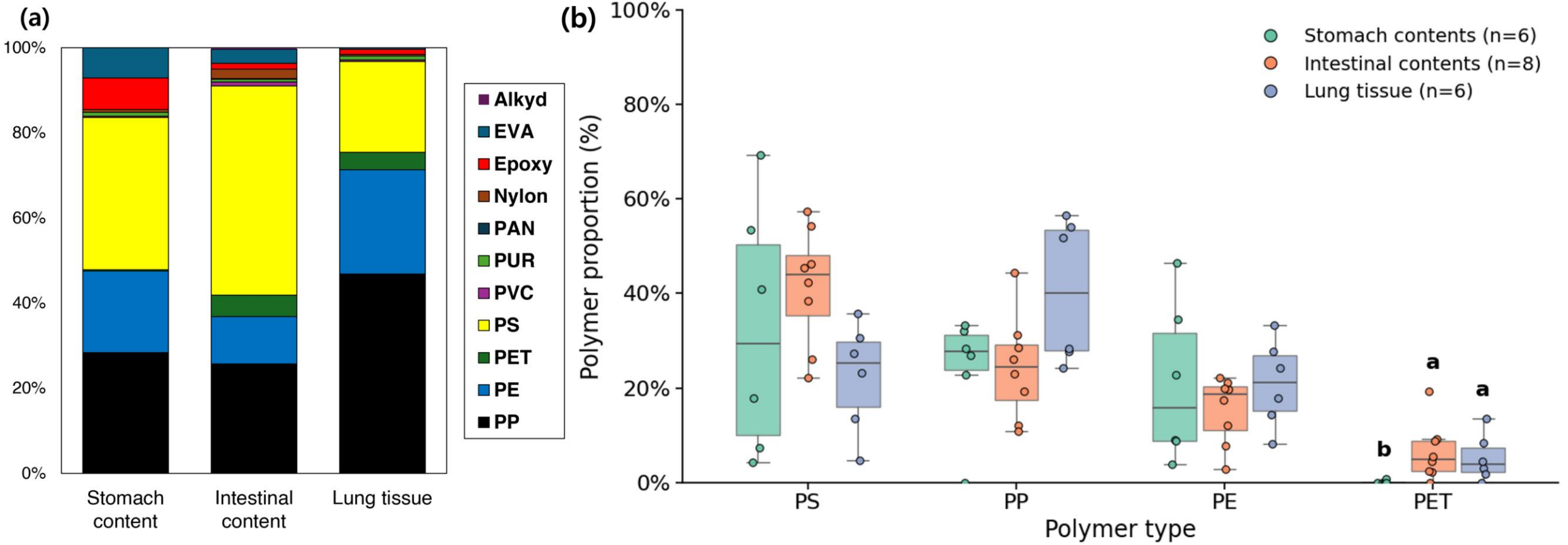
Smaller microplastics were more prevalent in lung tissue



Lung tissue showed a greater proportion of 20–100 μm MPs than the gastrointestinal compartments.

3. Results

Polymer composition differed among compartments

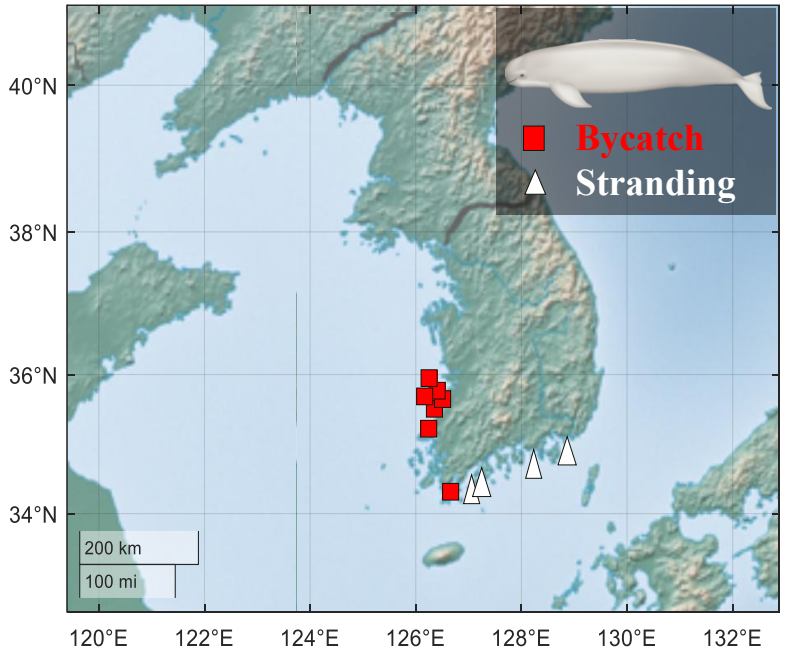


Among individual polymers, only PET showed a significant difference among compartments.

3. Results

Finless porpoise *Neophocaena asiaeorientalis*

Similar physical characteristics between respiratory and gastrointestinal compartments





Lung tissue

0.14 ± 0.11 MPs/g
Fragment 89%
Transparent-white 93%



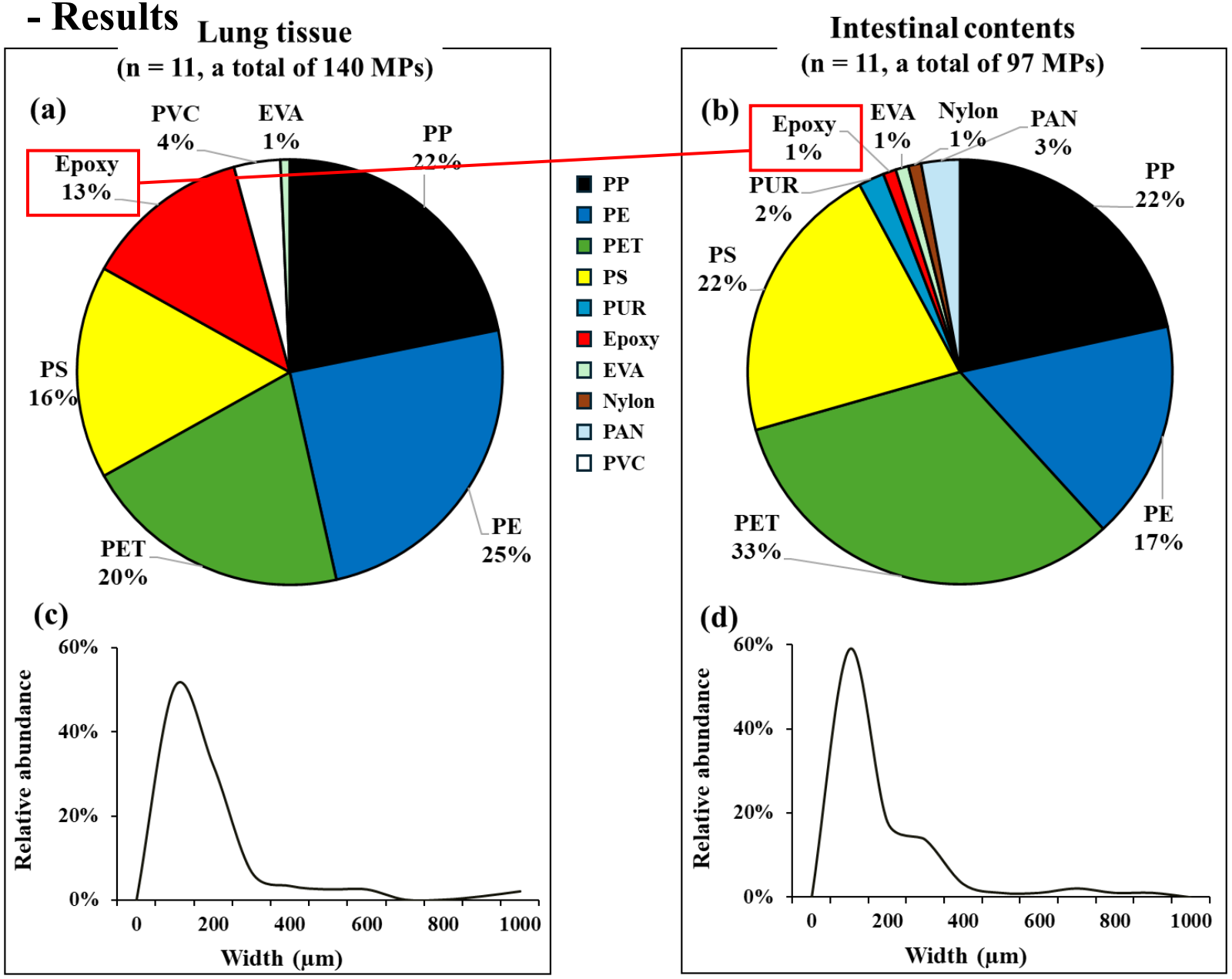
Intestinal contents

0.35 ± 0.36 MPs/g
Fragment 85%
Transparent-white 96%

Fragments and transparent-white particles dominated both compartments.

3. Results

- Results



- **The shape and size of the plastics found were similar** between the intestinal contents and lung tissues, with a predominance of fragments ranging from 20 to 200 μm in size.

- However, significant differences were observed in **polymer types** (Chi-square test, $p < 0.001$), with a higher proportion of epoxy found in the lungs (Mann-Whitney U test, $p < 0.05$)

3. Results

- **Microplastic Health Risk Evaluation: Polymer Hazard Index (PHI)**

$$PHI = \sum pnSn$$

- **Lung tissues** were classified as **a high-risk group**, whereas the **intestinal contents** were classified as **a low-risk group** (Mann-Whitney *U* test, $U_{11,11} = 24.00$, $Z = -2.53$, $p < 0.05$)

- **Inhaled MPs can pose greater risks than ingested MPs.**

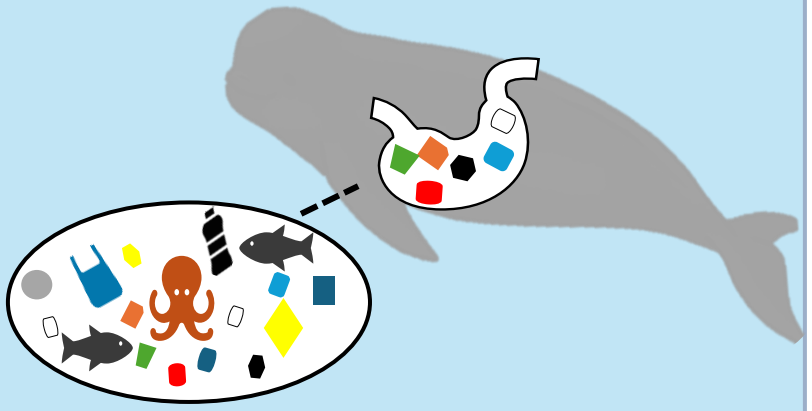
	Lung tissue		Intestinal contents	
Sample number	Hazard index	Category	Hazard index	Category
FP-1	12	Medium	15	Medium
FP-2	982	High	3	Low
FP-3	1515	Danger	10	Low
FP-4	897	High	195	High
FP-5	1656	Danger	4	Low
FP-6	13	Medium	9	Low
FP-7	17	Medium	15	Medium
FP-8	571	High	8	Low
FP-9	17	Medium	5	Low
FP-10	421	High	15	Medium
FP-11	11	Medium	198	High

(Pn ≤ 10 indicates a low risk; 10 < Pn ≤ 100 indicates a medium risk; 100 < Pn ≤ 1000 indicates a high risk; and Pn > 1000 indicates a dangerous risk of MP pollution)

3. Results

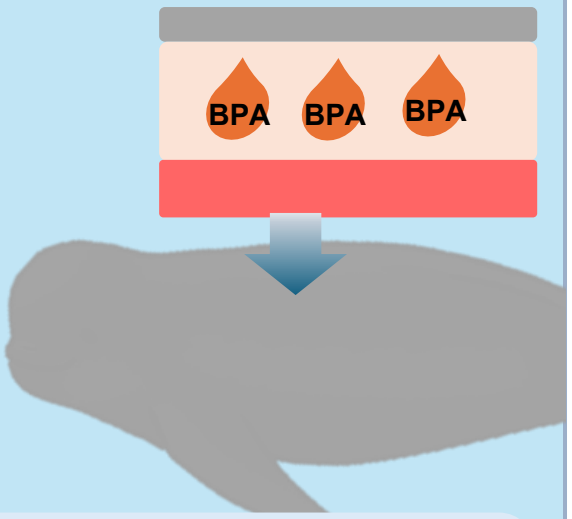
Microplastic abundance covaried with BPA concentration in finless porpoises

Stomach-content MPs



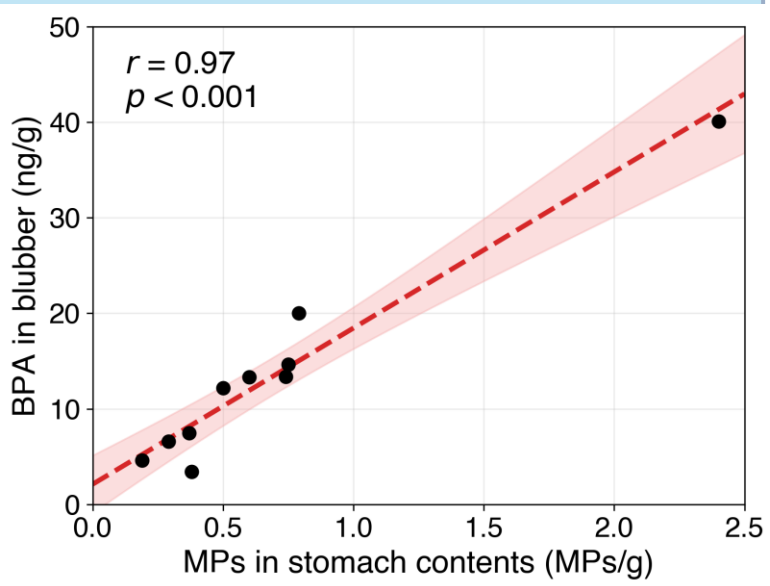
Mean MP abundance
0.70 ± 0.63 MPs/g ww
(0.19–2.40)

Blubber bisphenol A (BPA)



Mean BPA concentration
13.57 ± 10.63 ng/g dw
(3.44–40.09)

Strong MP–BPA association

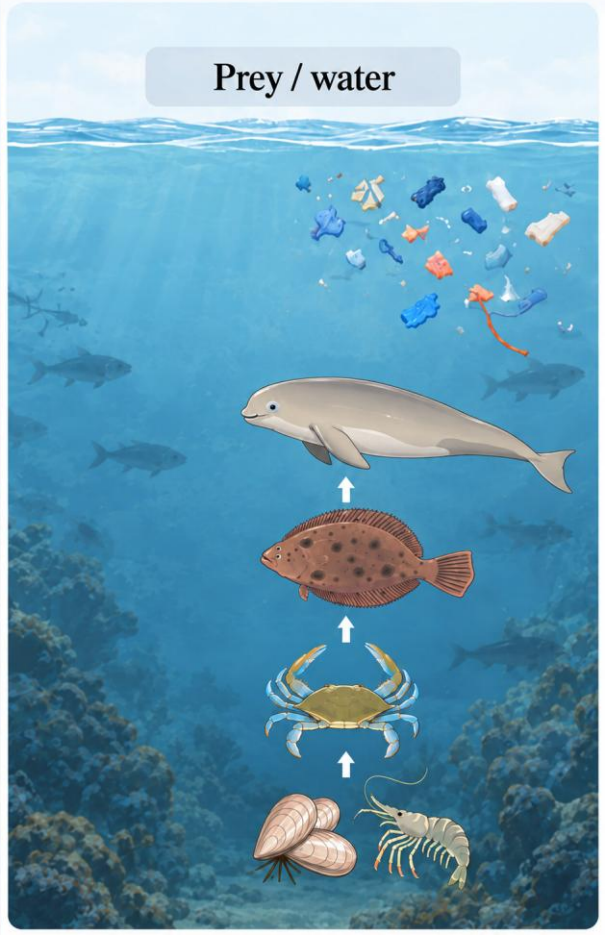


Stomach-content MP abundance was strongly correlated with BPA concentration in blubber ($r = 0.971$, $p < 0.001$).

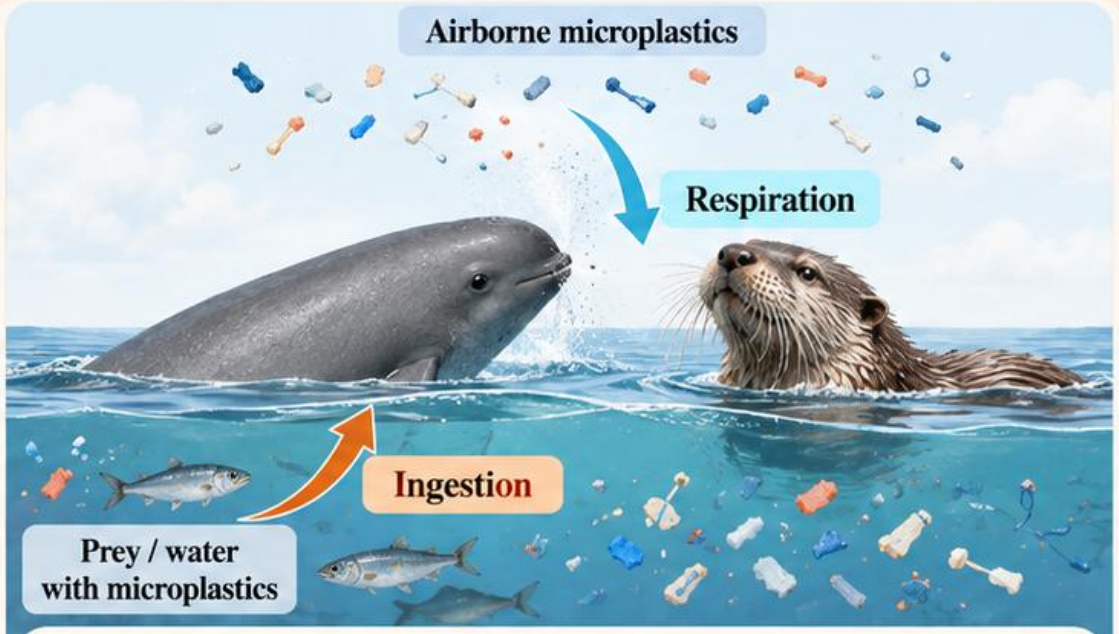
4. Discussion

From ingestion-only to dual particle and chemical exposure

1 Traditional view



2 Aquatic mammals at the air–water interface



Dual exposure pathways
Ingestion + Respiration

Compartment-specific patterns

Respiratory compartments

Gastrointestinal compartments

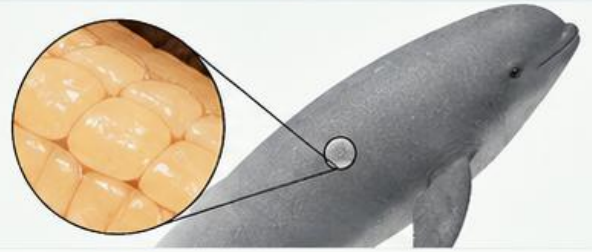
3 Beyond particles

Plastic-associated chemicals

Microplastics ⟷ BPA



In tissues (e.g. blubber)



Particle exposure + chemical burden

Aquatic mammal exposure assessment should consider both respiratory and gastrointestinal pathways, together with plastic-associated chemicals.

5. Limitations and future directions

Limitations

1. Lung MPs do not directly confirm inhalation
- Whole lung tissue analysis; possible bloodstream transport
2. Limited sample size
- Protected species; limited availability of fresh carcasses
3. MP–BPA correlation does not imply causation
- Recent MP ingestion vs. potentially different BPA exposure timescales

Future directions

- Concurrent atmospheric and aquatic MP sampling
- Larger datasets across individuals, regions, and species
- Controlled exposure studies and polymer-specific chemical analysis

Thanks for attention



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