

Horizontal and vertical distribution of microplastics in coastal and shelf waters from Yellow Sea of Korea

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Background

■ **Baseline of microplastic (MP) in coastal and shelf water in South Korea**

- To understand microplastic baseline level in salt water environments of South Korea
- To contribute for establishment of national marine (micro)plastic debris management policy

■ **Limitation of conventional sampling methods (>300 μm)**

Song et al. (2014), Van Cauwenberghe and Janssen. (2014), Van Cauwenberghe et al. (2015)

- Neuston net (300-500 μm mesh) sampling has advantage in worldwide data comparison
- But, Neuston sampling missed smaller MP than the mesh size
- The MP ingested by marine invertebrates was well less than 300 μm
- Mismatch of size range of microplastics between bioassays in laboratory and monitoring data

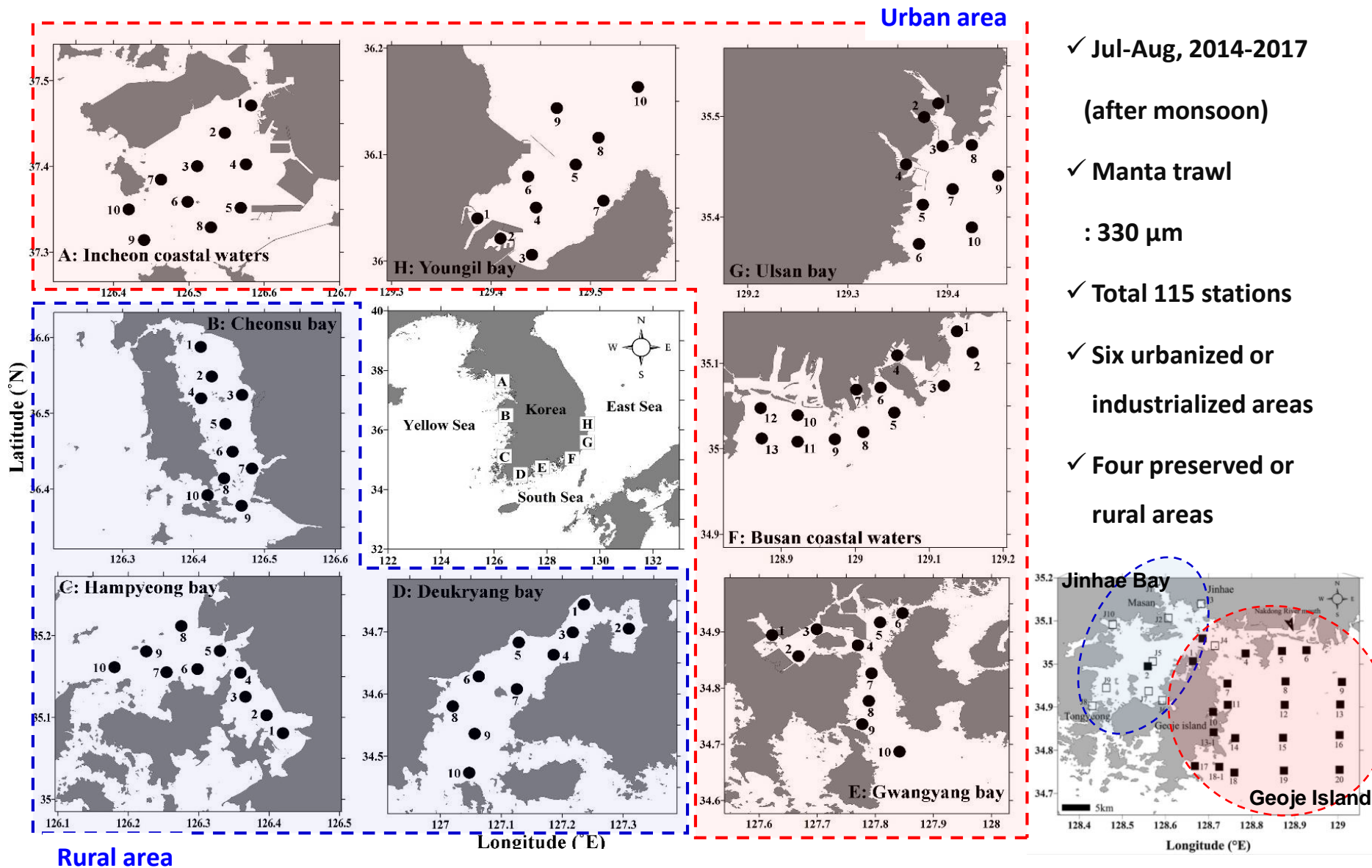
■ **Vertical movement of MP in water column**

Dai et al. (2018), Cole et al. (2016), Kowalski et al. (2016), Kooi et al. (2017)

- Most of monitoring studies have focused surface water, but further studies have increasingly described the prevalence of MP in sub-surface water
- Many of marine organisms are expected to be exposed to MP in sub-surface water
- Limitation of distribution of size, shape and polymer composition in surface vs sub-surface
- Ups and downs of MP by vertical mixing and biofilm formation and removal were predicted and measured in laboratory, but not validated in the environment

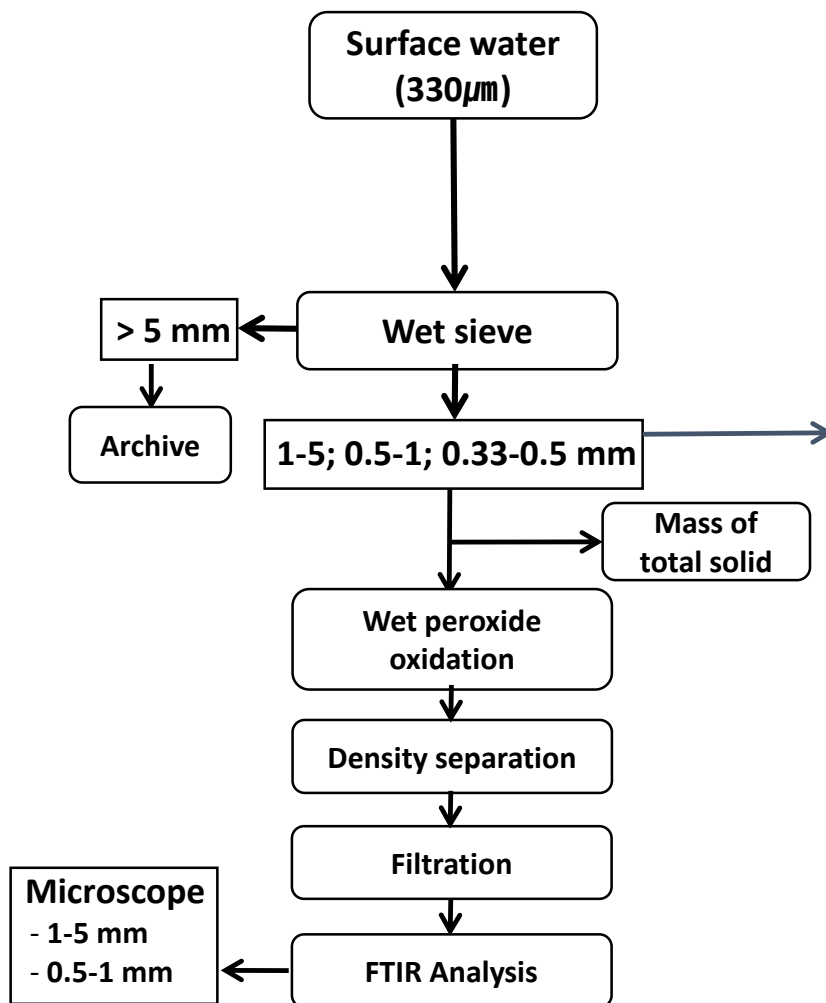
Horizontal distribution of microplastics in coastal and shelf surface water (330 μm Manta trawl sample)

Sampling locations

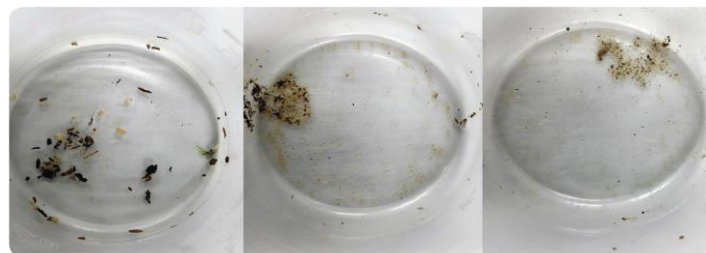
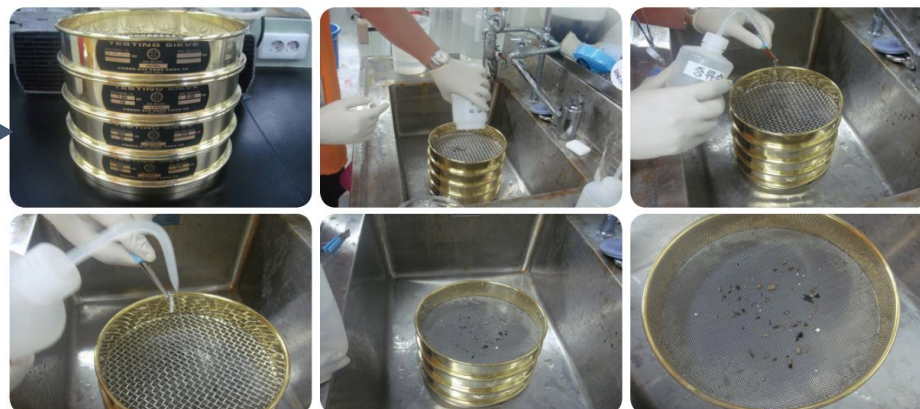


Sampling and analytical methods

Assessment of MP >330 μm



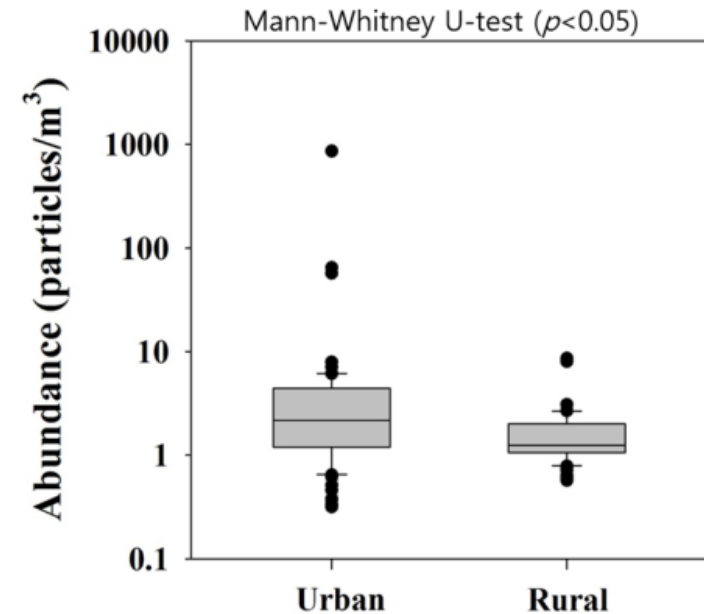
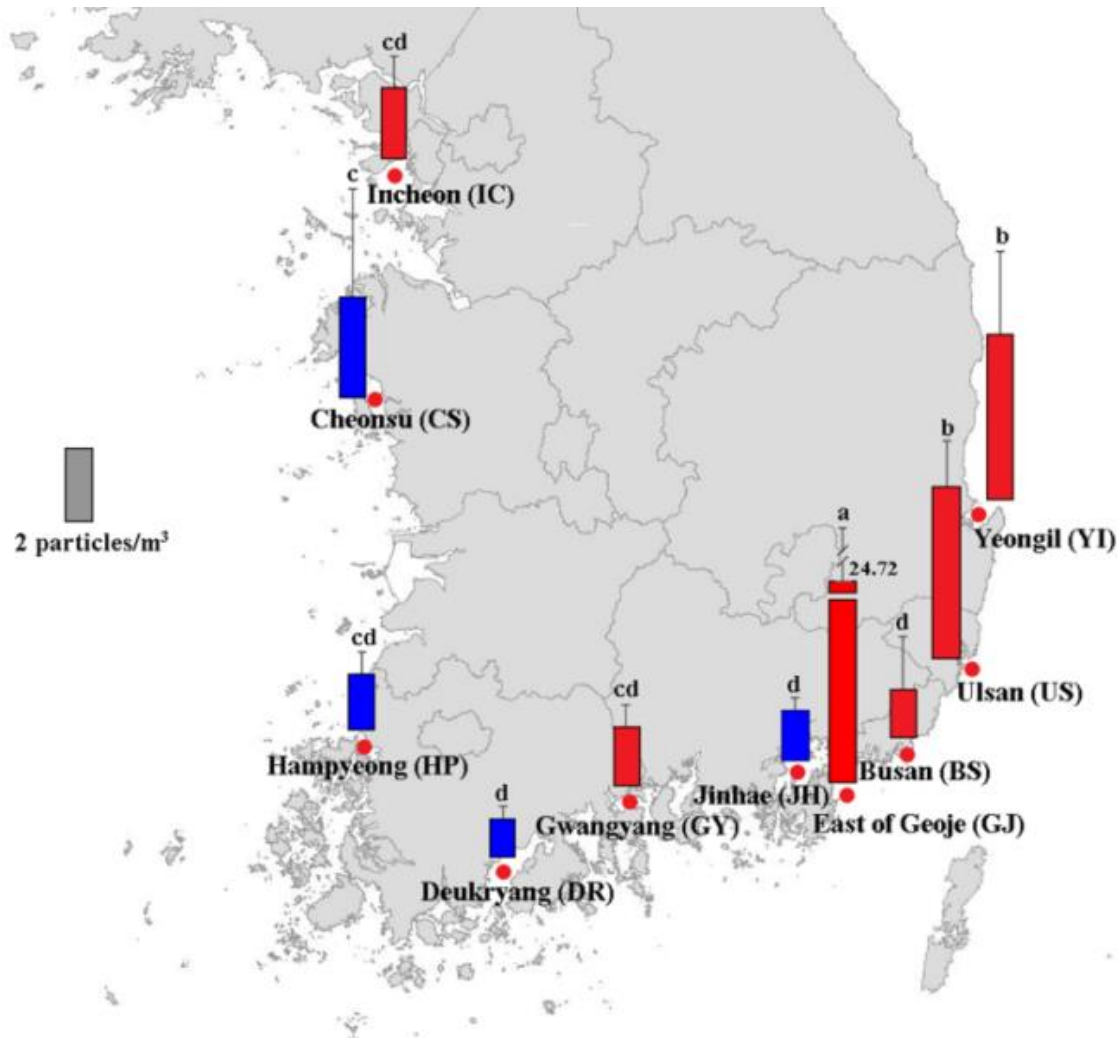
✓ Towing at 1-2 knot
for 10 min



✓ Wet peroxide oxidation: $\text{Fe(II)} + 30\% \text{H}_2\text{O}_2$

✓ Density separation: Lithium metatungstate

Abundance of microplastics >330 μm by region



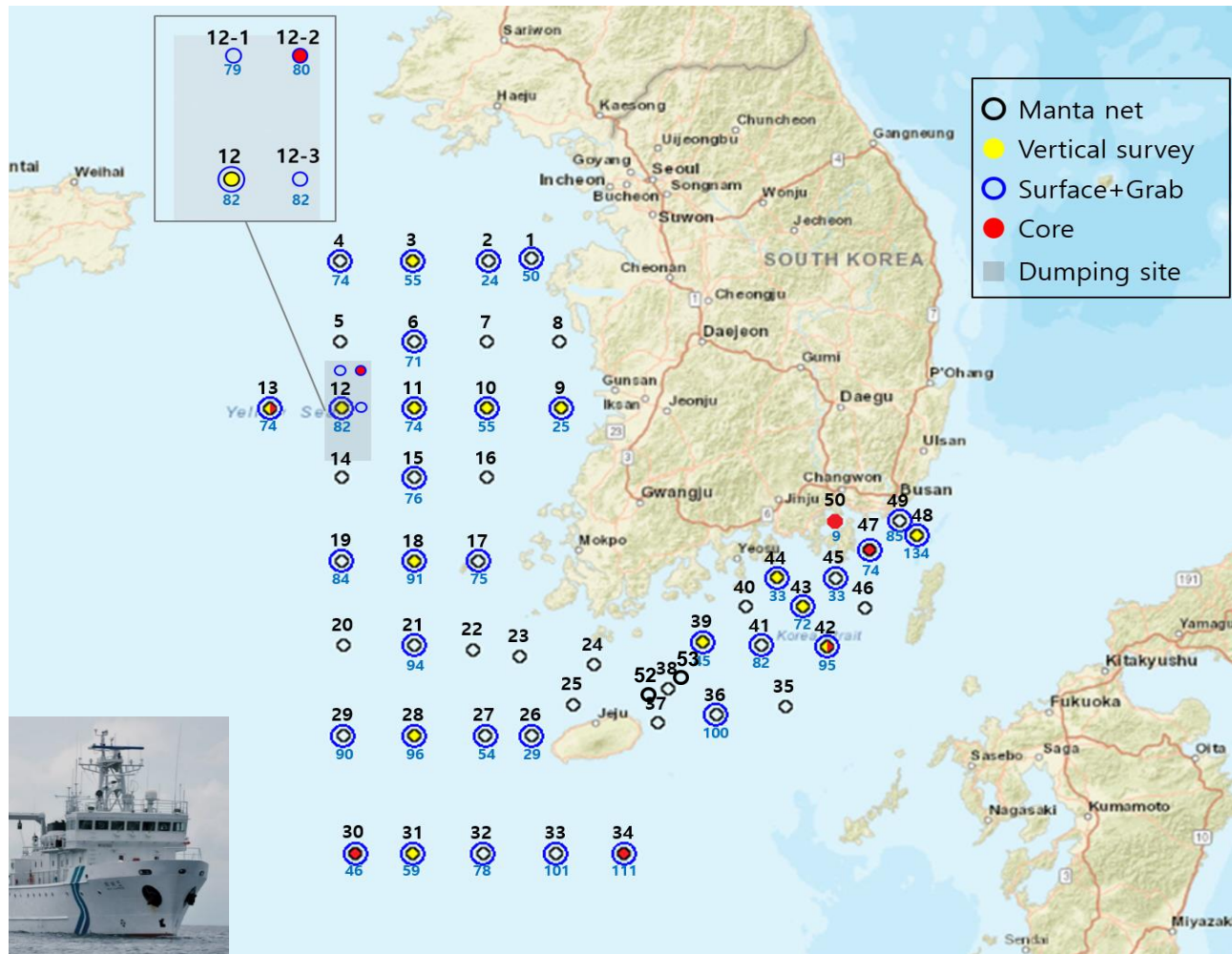
- ✓ The abundance of microplastics were significantly ($p < 0.05$) higher in urbanized or industrialized areas than those in rural or preserved areas.

Abundance of microplastics >330 μm by size and shape

Divide	Study sites	Fragment	Fiber	Sphere	Film	EPS	Paint particle	particles/m ³
								Total
Urban	1-5 mm	0.19	0.30	0.00	0.01	0.07	0.14	0.71
	0.5-1 mm	0.22	0.34	0.01	0.01	0.12	0.19	0.89
	0.33-0.5 mm	0.28	0.38	0.01	0.00	0.26	0.32	1.25
	Sub-total	0.69	1.02	0.02	0.02	0.45	0.65	2.85
Rural	1-5 mm	0.09	0.13	0.00	0.01	0.32	0.03	0.57
	0.5-1 mm	0.09	0.23	0.00	0.01	0.29	0.10	0.72
	0.33-0.5 mm	0.11	0.23	0.00	0.00	0.10	0.12	0.58
	Sub-total	0.29	0.59	0.00	0.02	0.71	0.25	1.87

- ✓ Urbanized or industrialized area: Size of 0.33-0.5 mm and fiber were dominant.
- ✓ Rural or preserved area: Size of 0.5-1 mm, fiber in 0.33-0.5 mm and EPS in 1-5 mm
*EPS (expanded polystyrene)

Sampling stations in shelf waters



✓ 25 Jul- 8 Aug, 2018

(after monsoon)

✓ R/V Eado

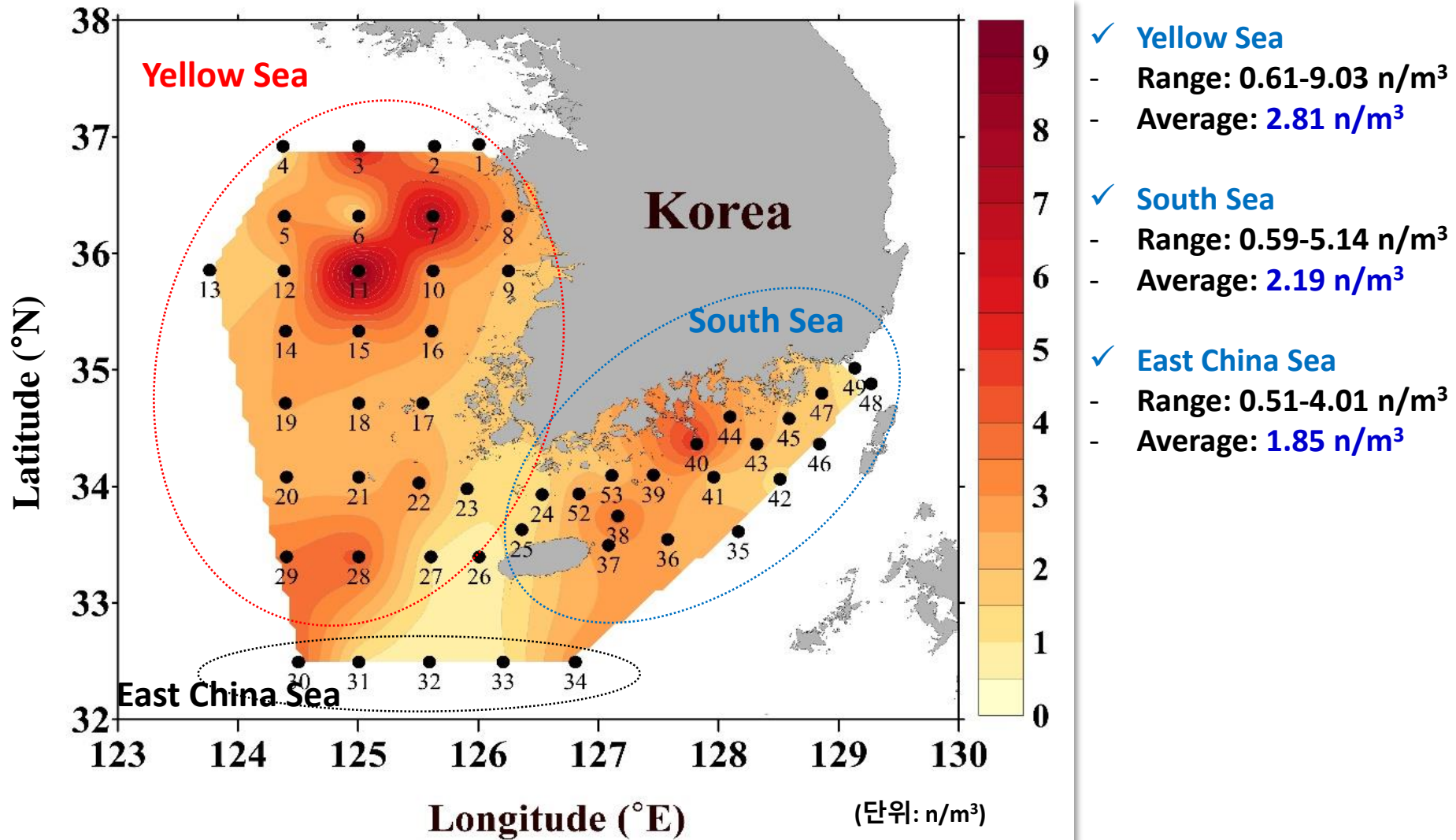
✓ Total 53 stations

✓ Manta trawl

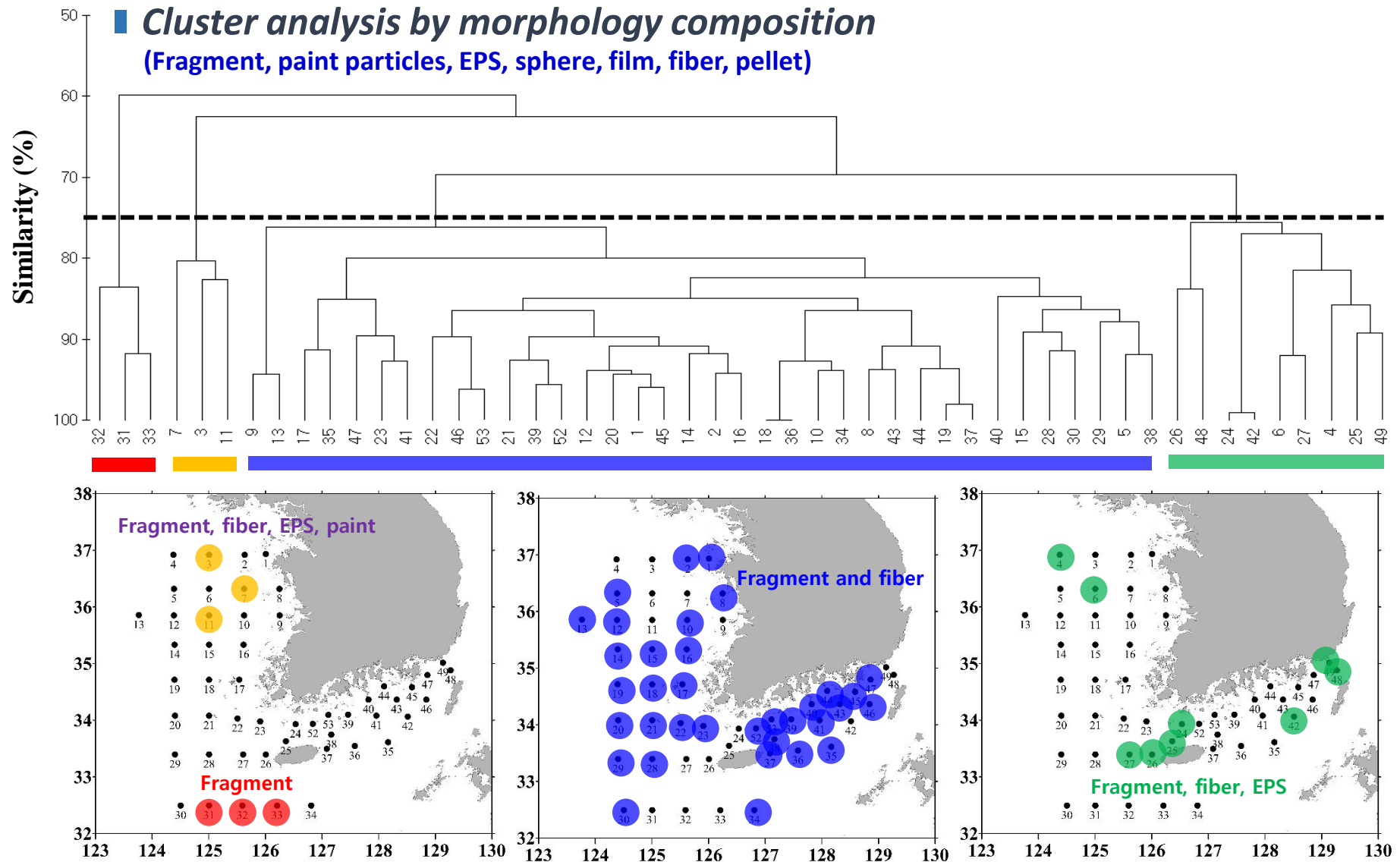
: 330 μ m

✓ Towing at 2 knot for 30 min

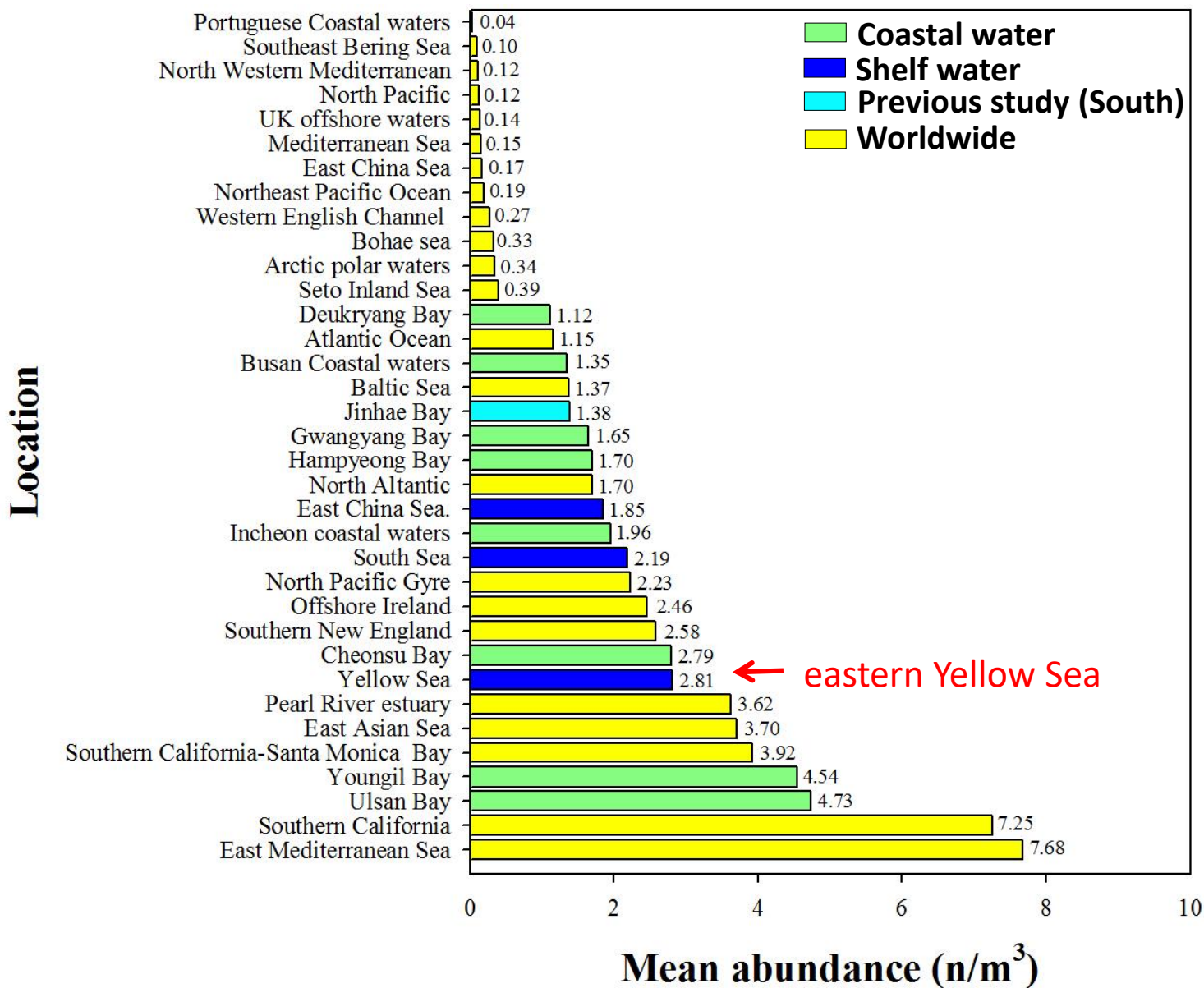
Abundance of microplastics >330 μm in shelf waters



Similarity of microplastics >330 μm by morphology



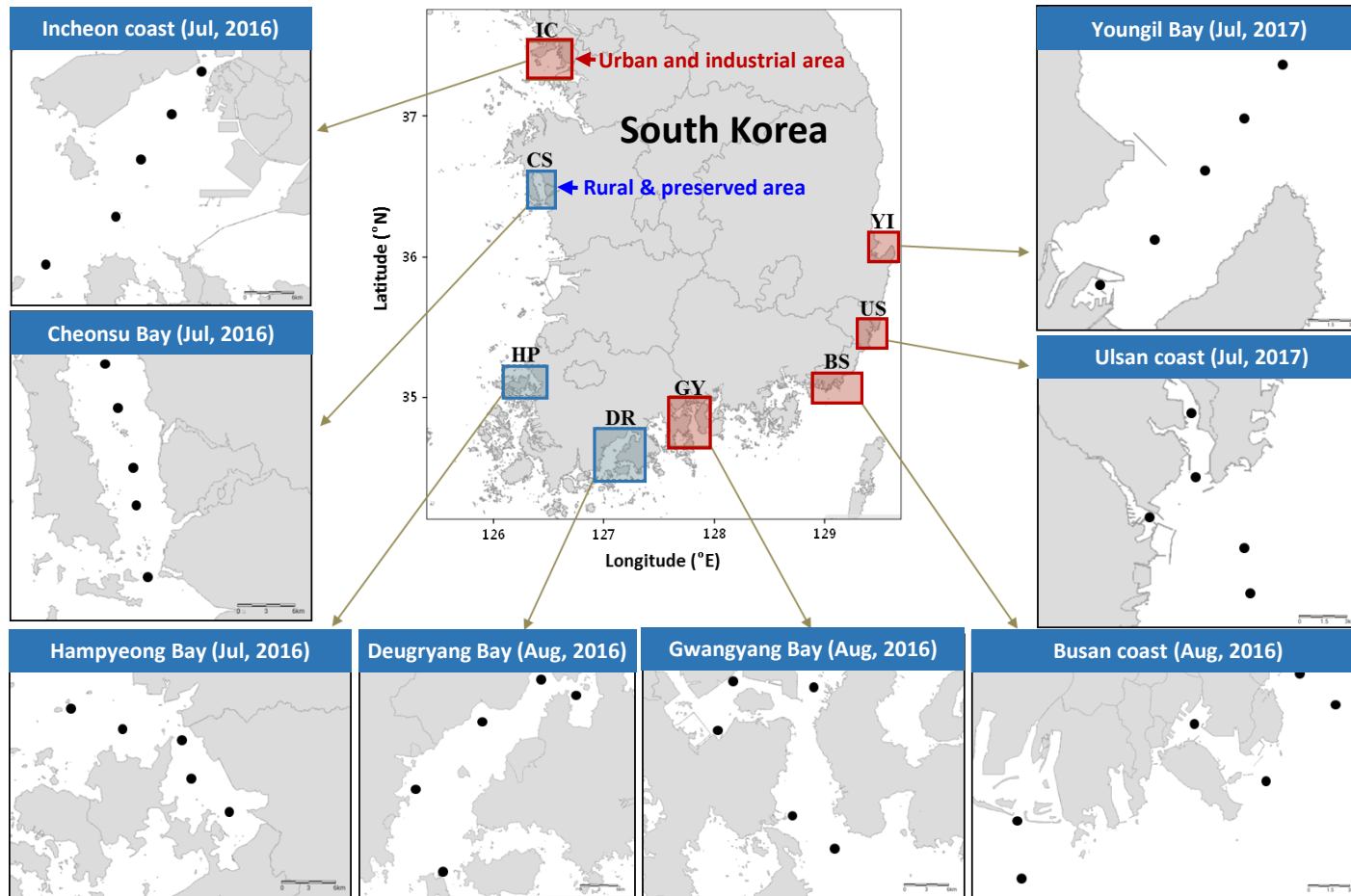
Comparison of microplastic >330 μm abundance



**Vertical distribution of microplastics in
coastal and shelf surface water
(20 μm net sample)**

Sampling location for coastal water

■ Eight semi-enclosed bays or near shore areas (total 41 stations)

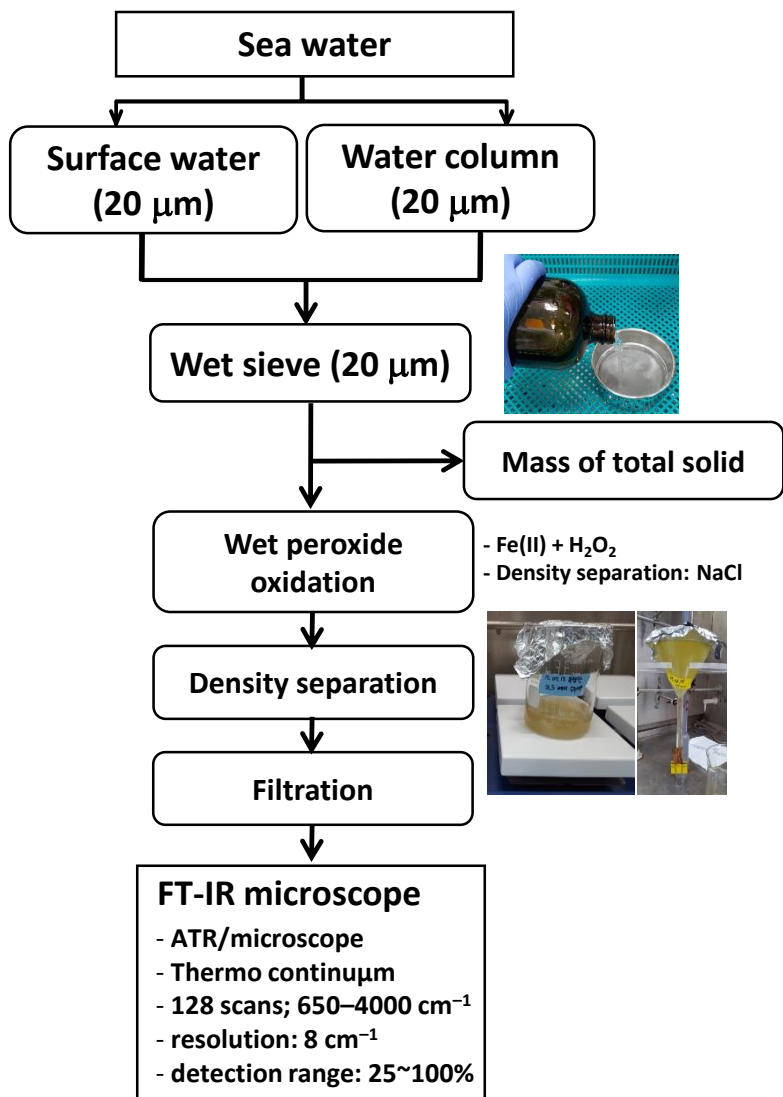


■ Surface (20 cm), mid-column and bottom water (1 m above bottom) samples (n=123)

- ✓ To grab 100 L of water sample using a stainless bucket (surface) or a submerged pump (sub-surface)
- ✓ To filter 100 L of water sample through a 20 μm mesh hand net on board

Sampling and analytical methods

Assessment of MP >20 μm



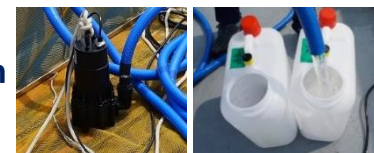
1) Surface water

- Depth: 20 cm
- 100 L



2) Middle water

- Thermocline or middle of water column
- Water-jet pump
- 100 L

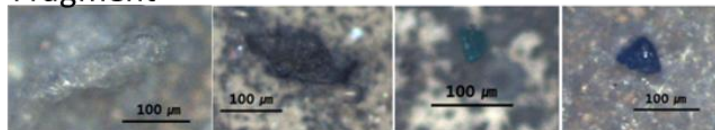


3) Bottom water

- 0.5~1 m upper surface of the bed
- Water-jet pump
- 100 L

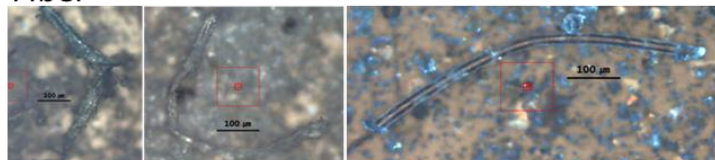


Fragment

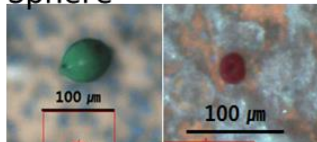


✓ Micro-FTIR (ATR mode)

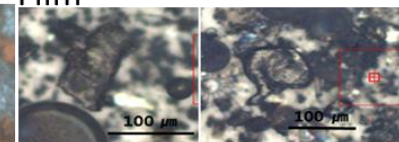
Fiber



Sphere

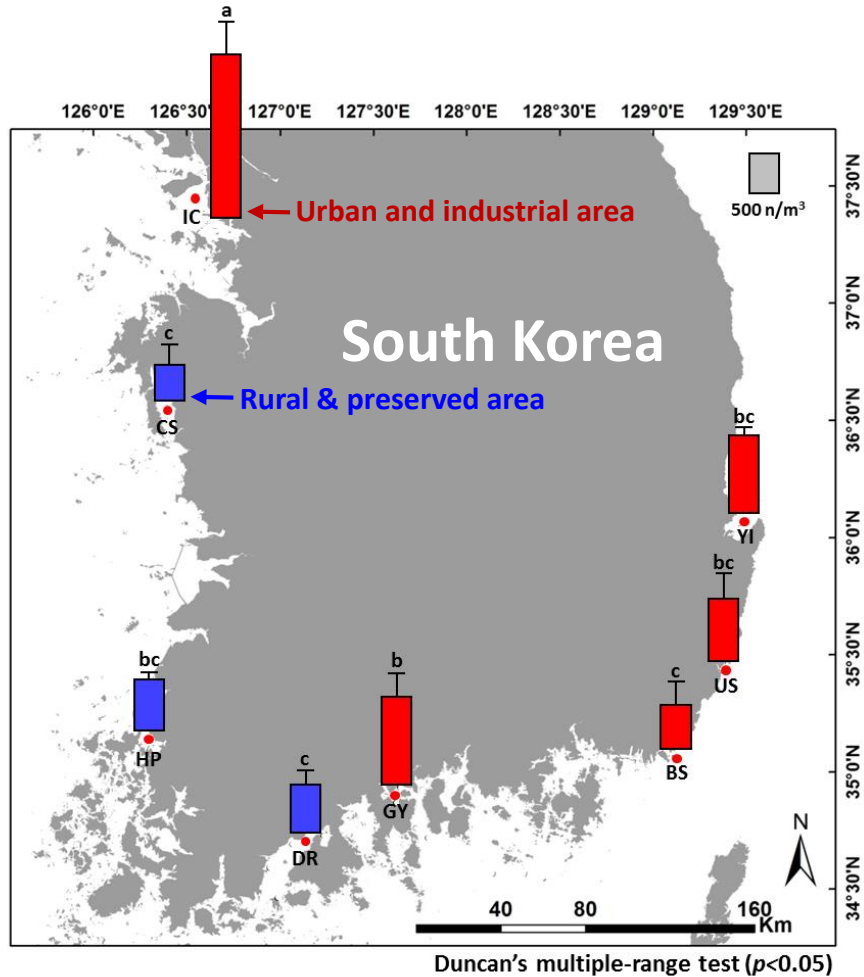


Film

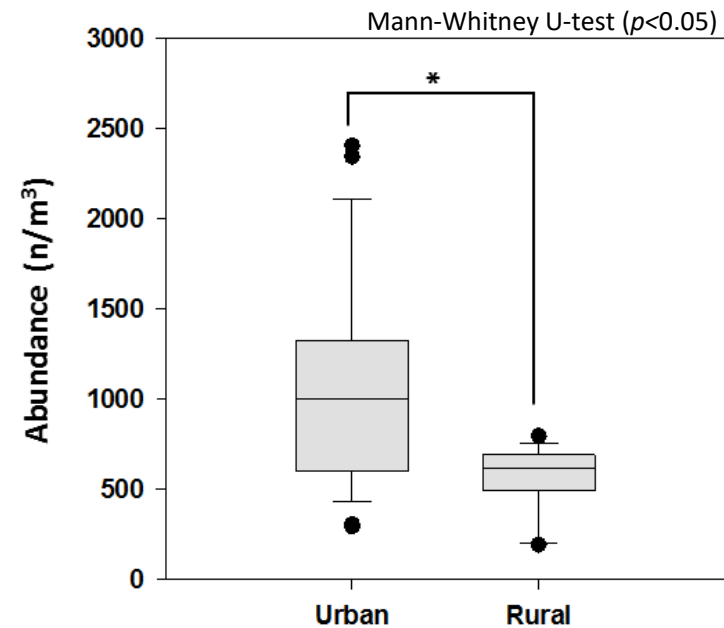


Abundance of microplastics >20 μm in coastal water

Spatial distribution



Urban vs Rural areas



✓ Urban ($1,051 \pm 571$ n/m³) > Rural (560 ± 184 n/m³)

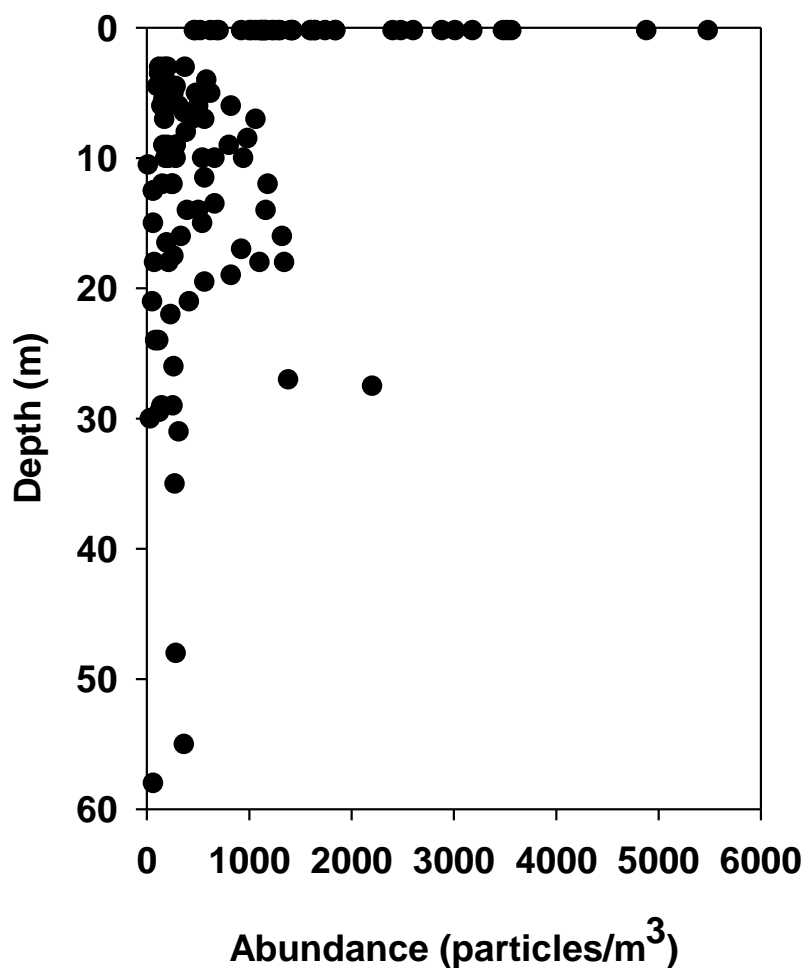
* Spearman's rank correlation (excluding BS)

Pair	Total	Surface	Middle	Bottom
Population -MP	0.857*	0.893**	0.464	0.143

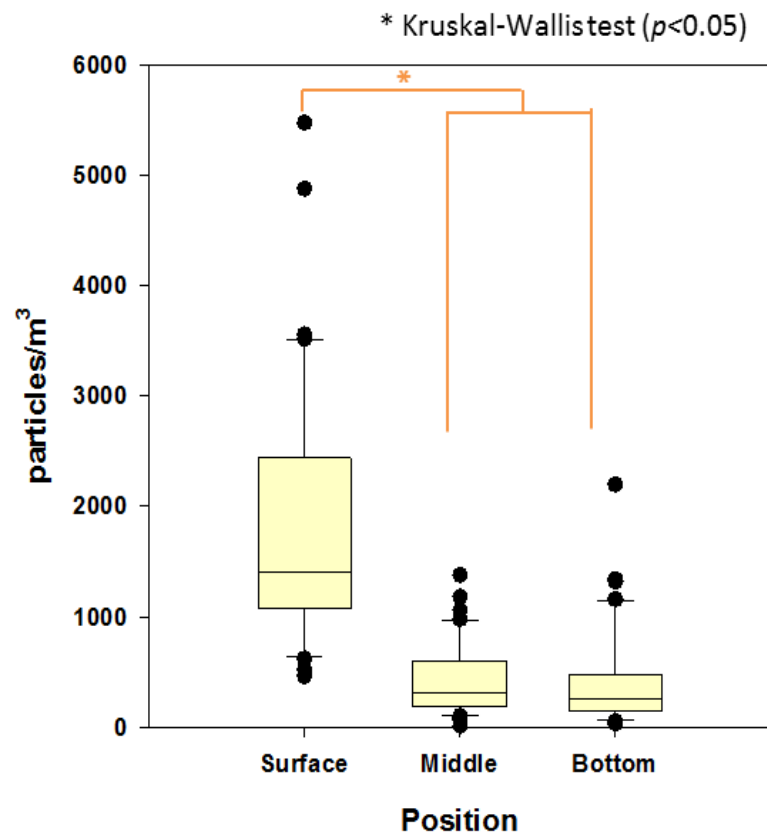
Song et al. (2018) Environ. Sci. Technol.

Vertical distribution of MP >20 μm in coastal water

Vertical profile



Surface vs water column



✓ Surface: 1736 ± 1179 n/m³

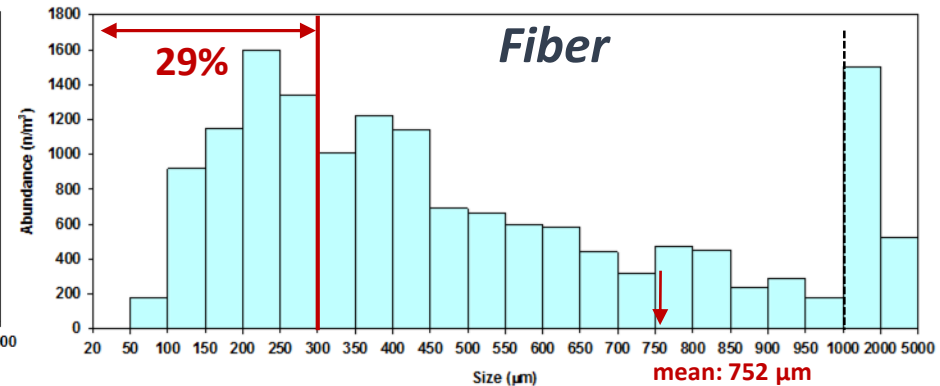
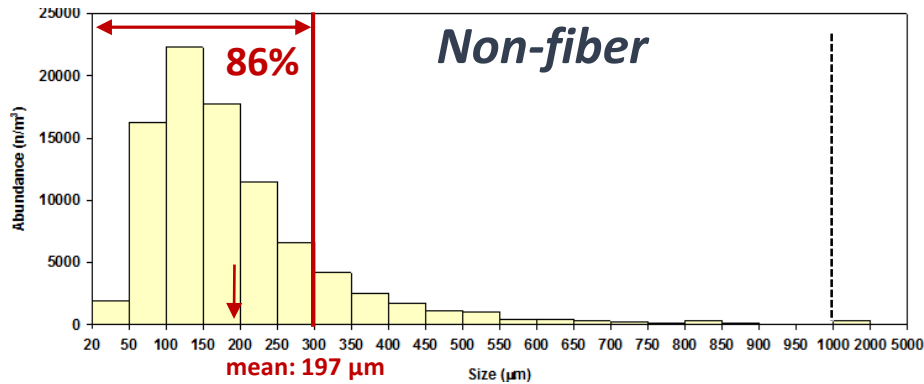
✓ Middle: 423 ± 342 n/m³

✓ Bottom: 394 ± 443 n/m³

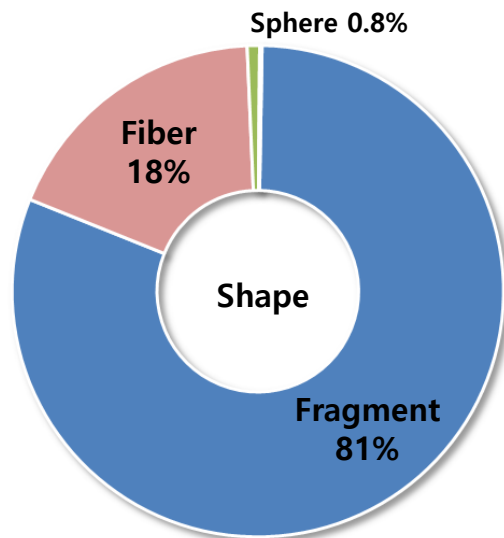
Song et al. (2018) Environ. Sci. Technol.

Size distribution and shape & polymer composition in coastal water

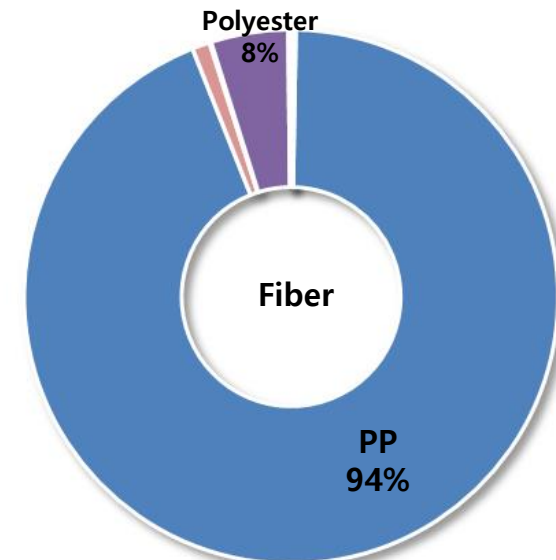
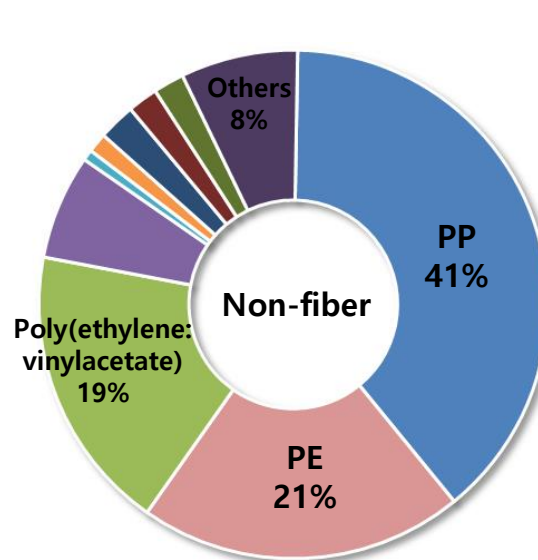
Size distribution



Shape composition



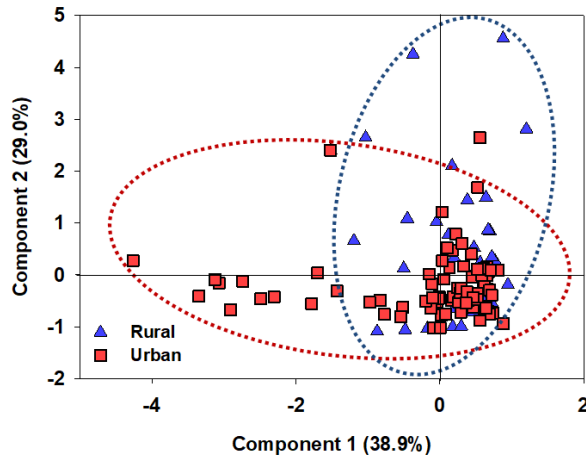
Polymer composition



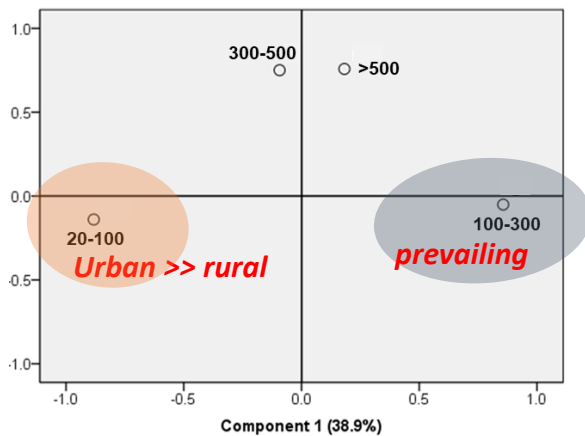
Characteristic of microplastics >20 μm in water column

Urban vs Rural on size

Score plot

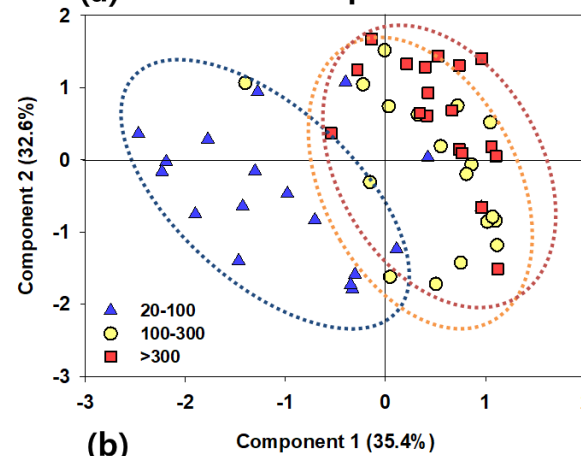


Loading plot

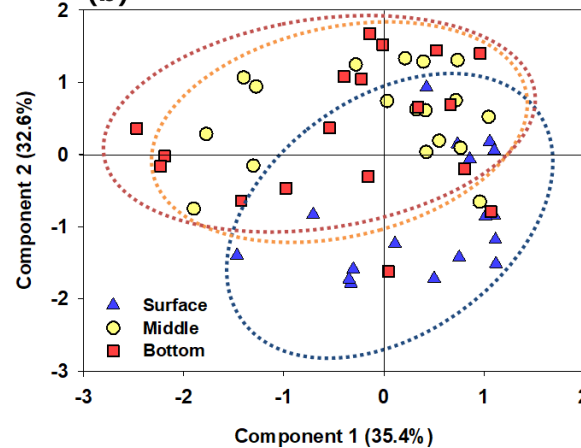


Size distribution and composition in water column

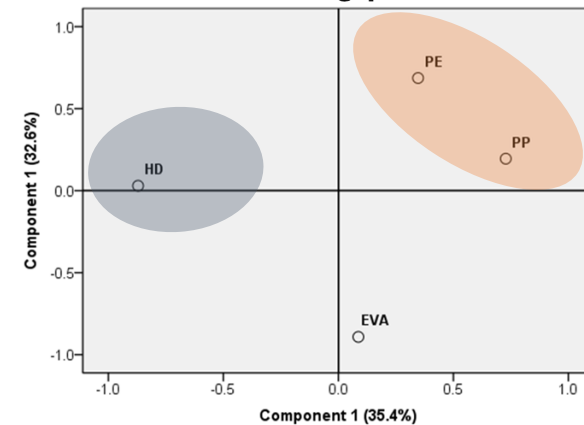
(a) Score plot



(b) Score plot



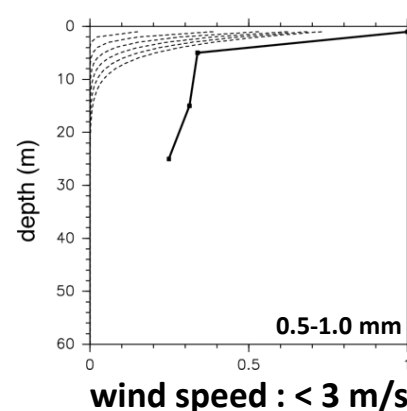
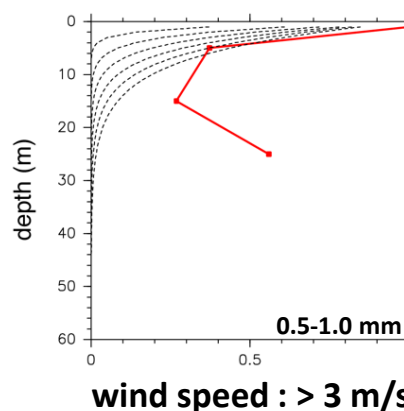
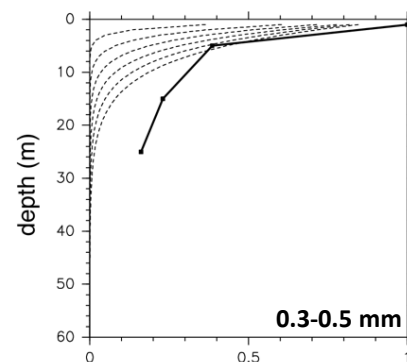
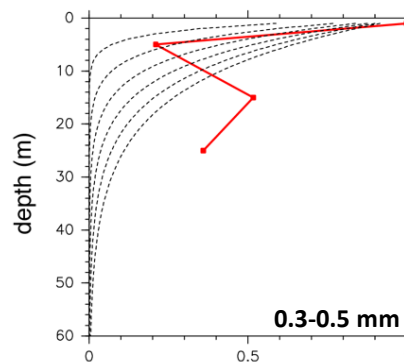
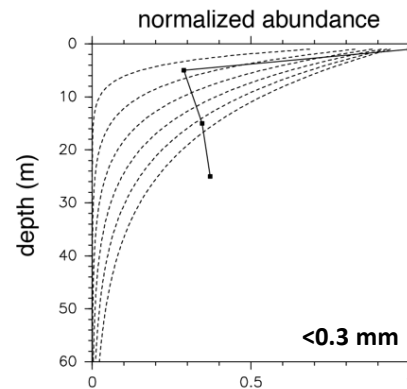
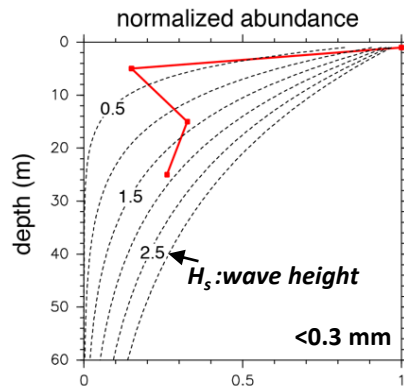
Loading plot



- ✓ HD
 - >> 20-100 μm
 - Middle or bottom >> surface
- ✓ PE & PP
 - >> larger than 100 μm
 - Prevailing in all depth

- * With non-fiber(fragment) microplastics
- * HD: high density polymer than seawater
- * EVA: poly(ethylene:vinyl acetate)

Vertical distribution: physical mixing model vs in situ observation



- ✓ Average MP abundance normalized to the abundance at the surface layer superimposed over the exponential curves calculated with equation (dotted curves).

$$N = e^{w/A_0 z}$$

Z: depth measured downward from the sea surface

N: denotes the MP abundance normalized to the abundance at the sea surface

W: rise velocity

A_0 : vertical diffusivity

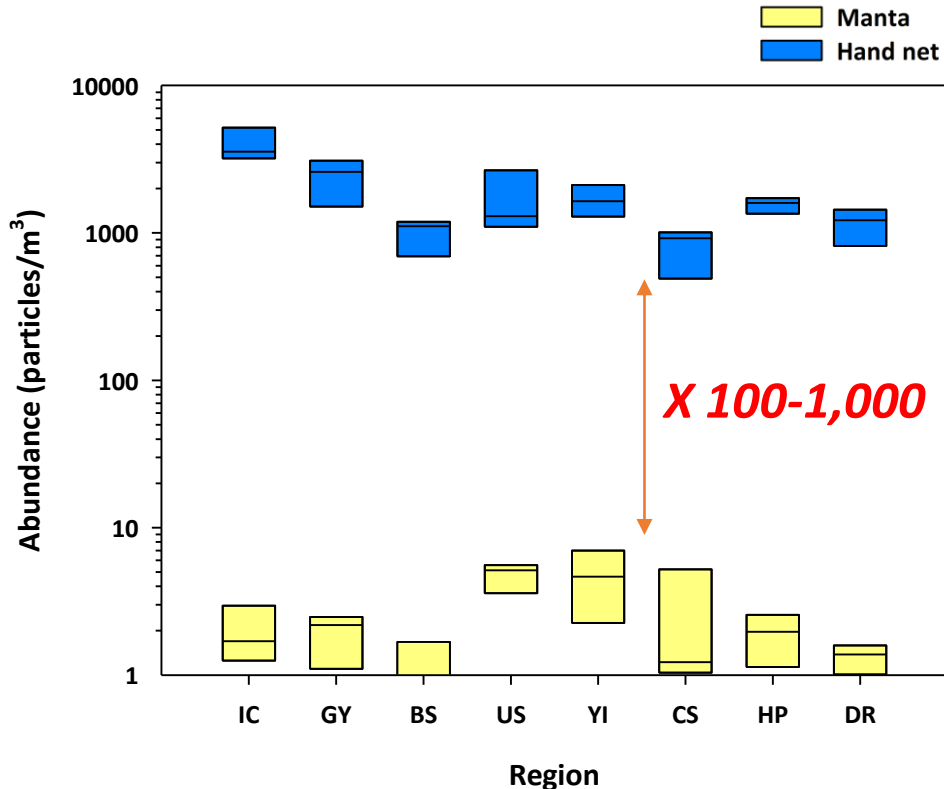
- ✓ Middle and bottom water samples contained higher abundance of MP than predicted by a model based on physical mixing

* Collaboration with Prof. Atsuhiko Isobe at Kyushu University

Song et al. (2018) Environ. Sci. Technol.

Manta trawl (330 μm) vs Hand net (20 μm)

Manta vs hand net



Fragment/fiber ratio

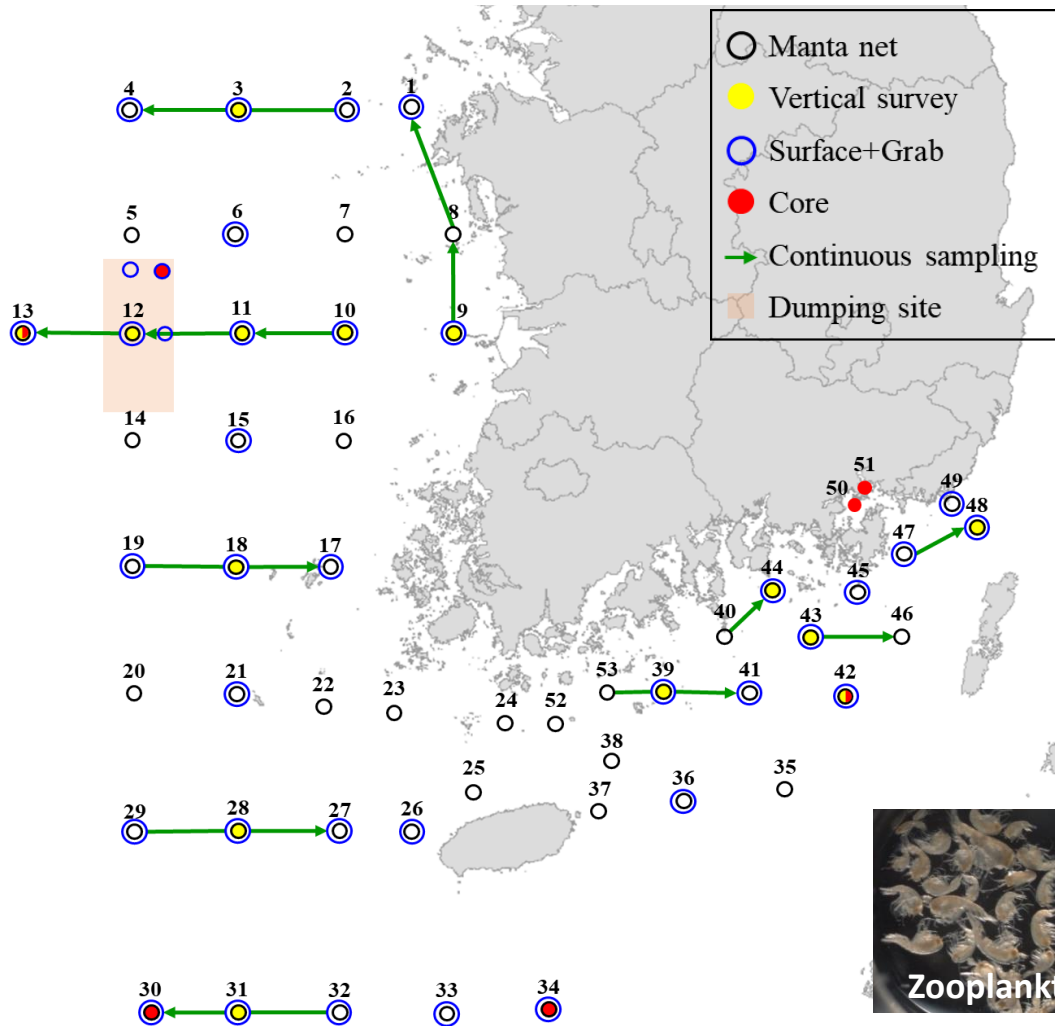
- ✓ < 300 μm MP in hand net
 - fragment: 86%
 - fiber: 29%
- ✓ Average of **fragment/fiber ratio** in each stations:
 - Manta: 2.3
 - Hand net: **7.8 -> 1.5 (>300 μm)**
- ✓ Depending on sampling methods (mesh size), the ratio of fragment/fiber changed and could be fragmented MP underestimated in sea water!

✓ Manta: 2.490 ± 1.953 particles/m³

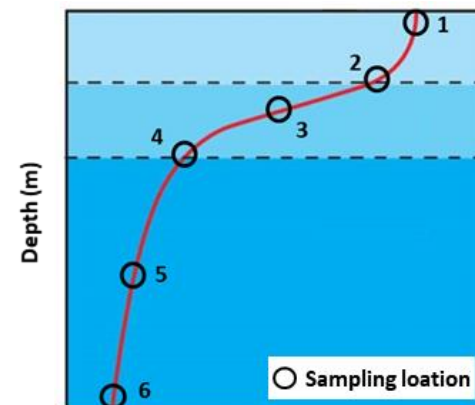
✓ Hand net: $1,778 \pm 1,161$ particles/m³

Sampling location for shelf water

Sampling station



***Surface sample taken 1m below from the sea surface**



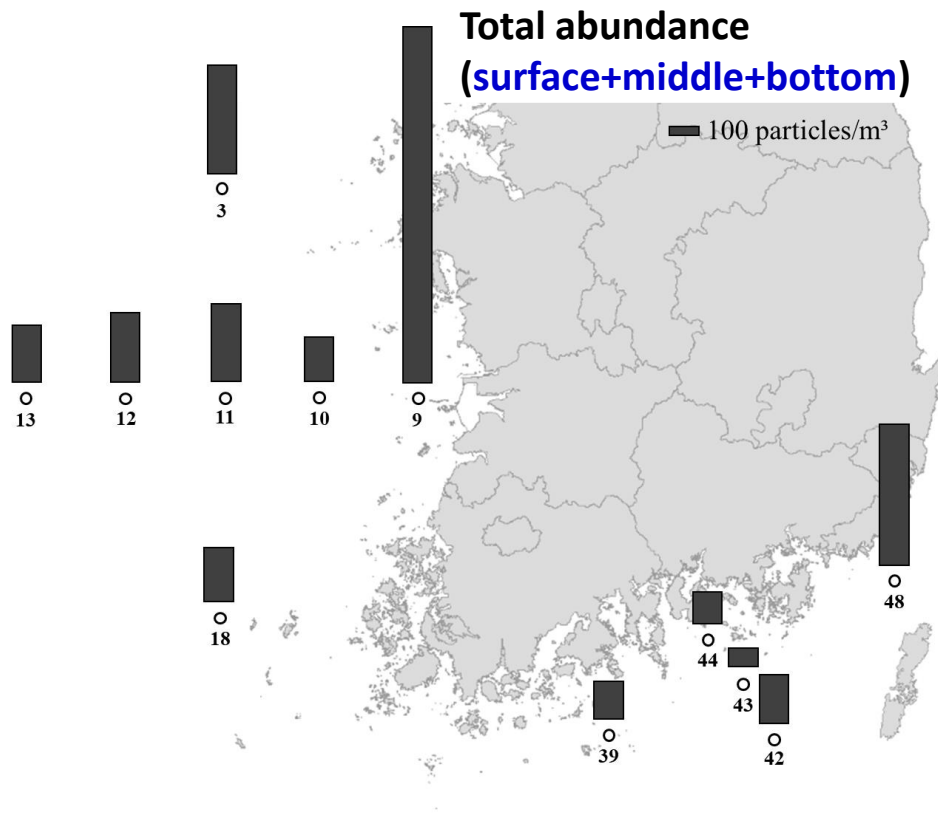
Temperature (°C)

[Vertical sampling layer v1-6]

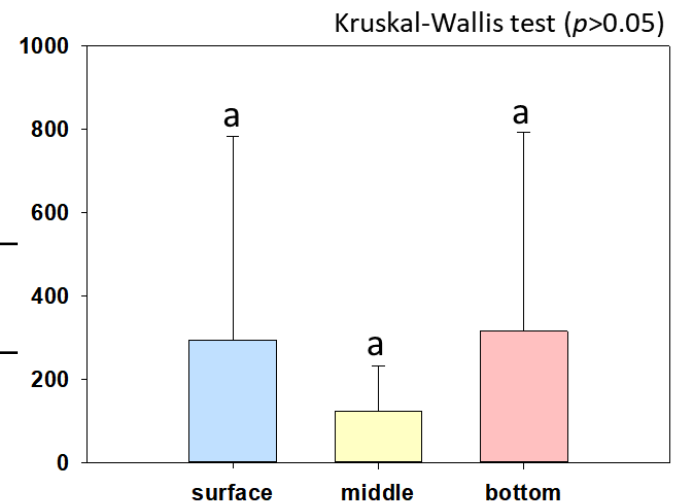
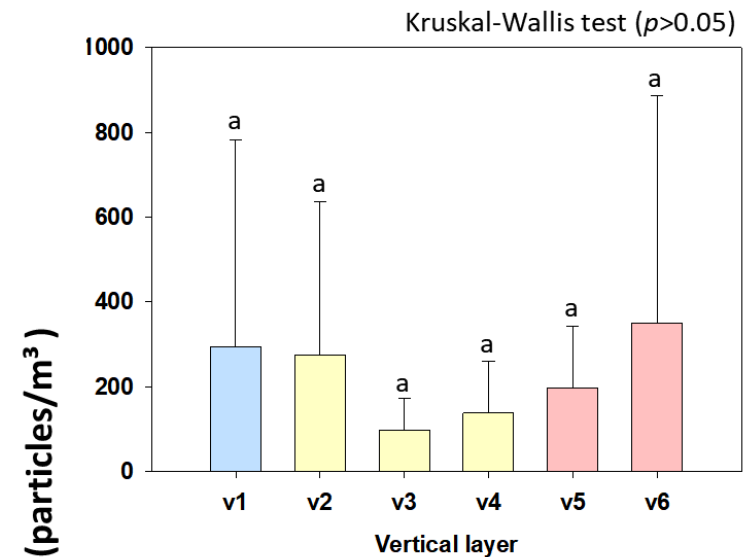


[Collected samples]

Abundance of microplastics >20 μm in shelf water

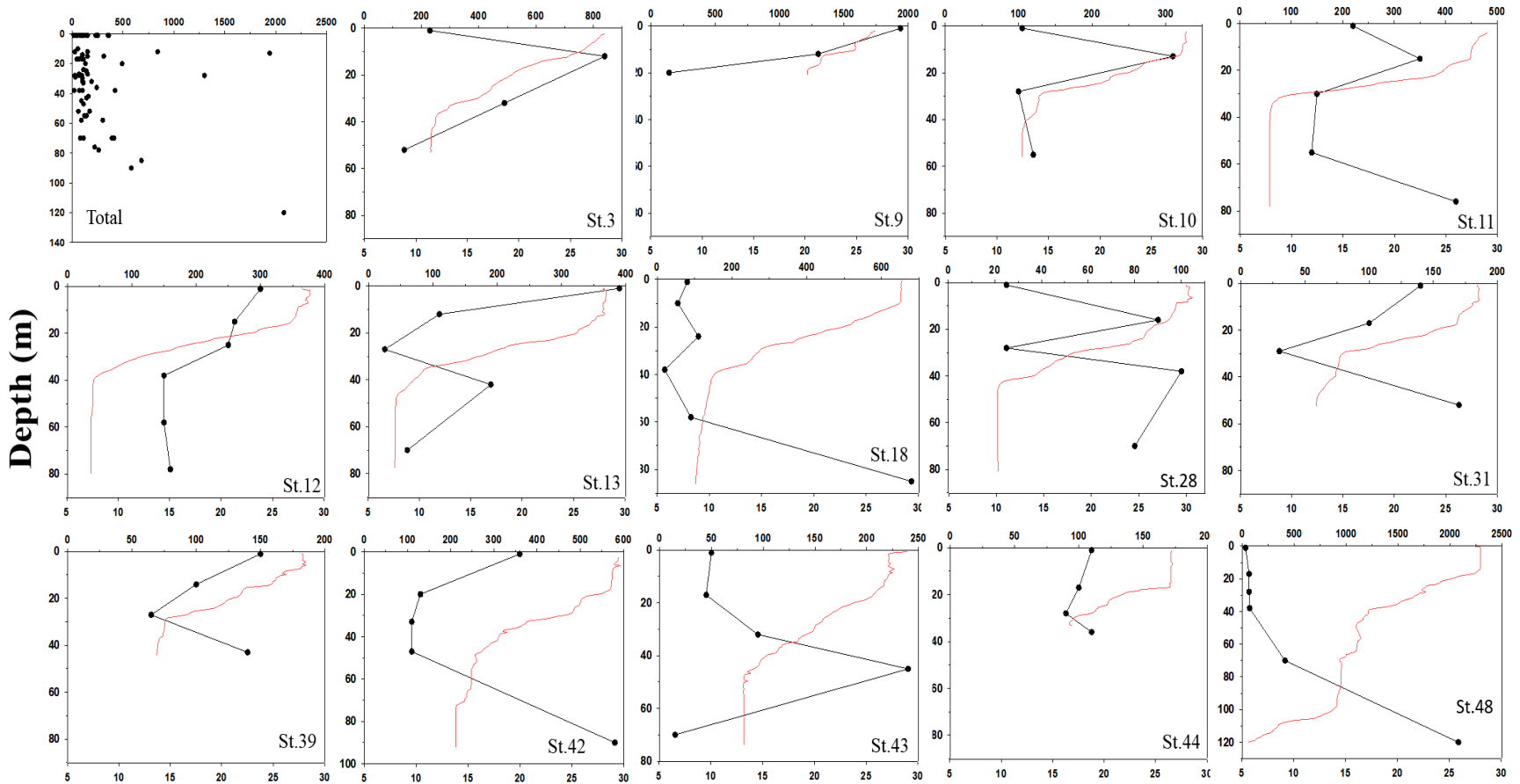


	Surface (v1)	Middle (v2-4)	Bottom (v5-6)
Range	25 – 1940	65 – 1300	60 – 1245
Mean \pm STD	295 \pm 488	124 \pm 108	315 \pm 477



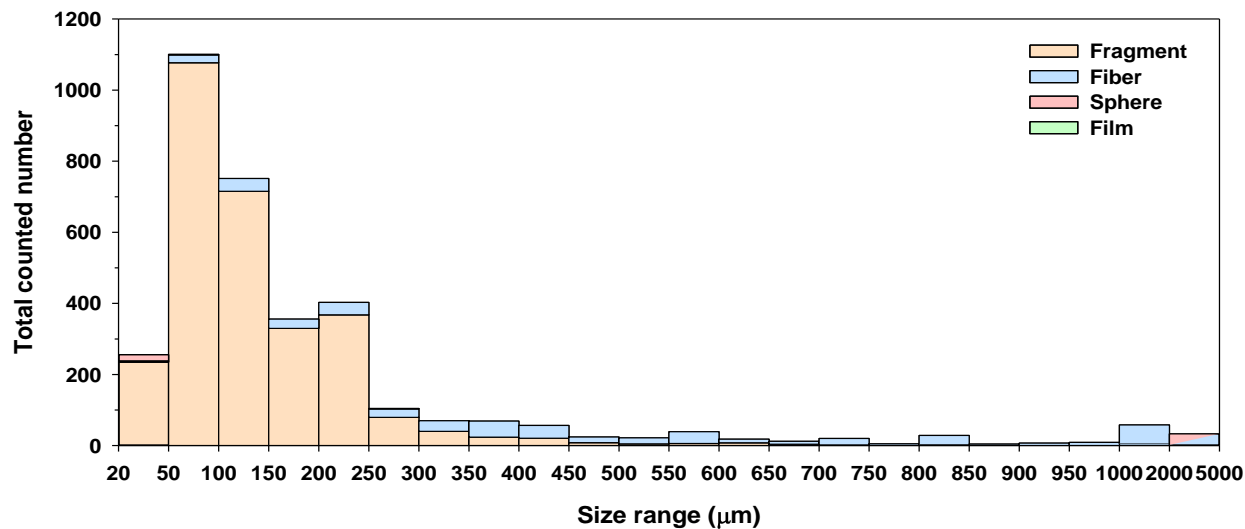
Vertical distribution of microplastics >20 μm in shelf water

— MP abundance (particles/m³) — Temperature (°C)

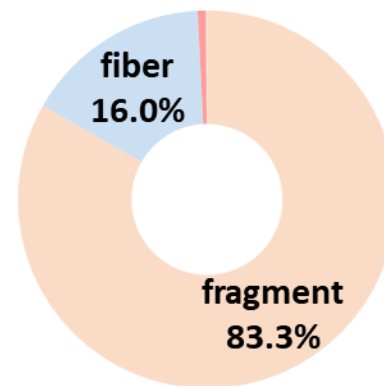


✓ There is no distinct vertical distribution pattern

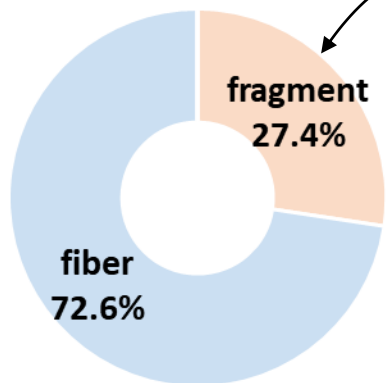
Size distribution and shape composition in shelf water



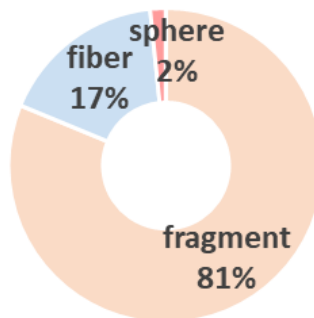
Total (0.02-5 mm)



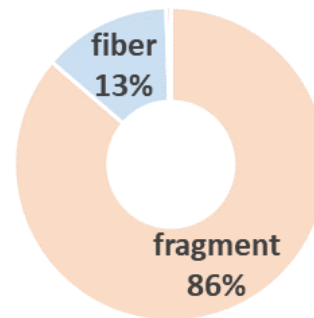
Total (0.3-5 mm)



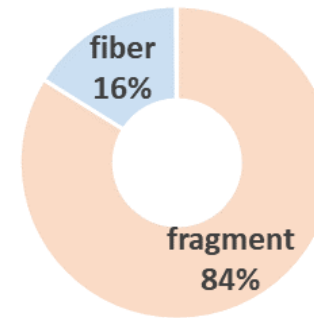
Surface



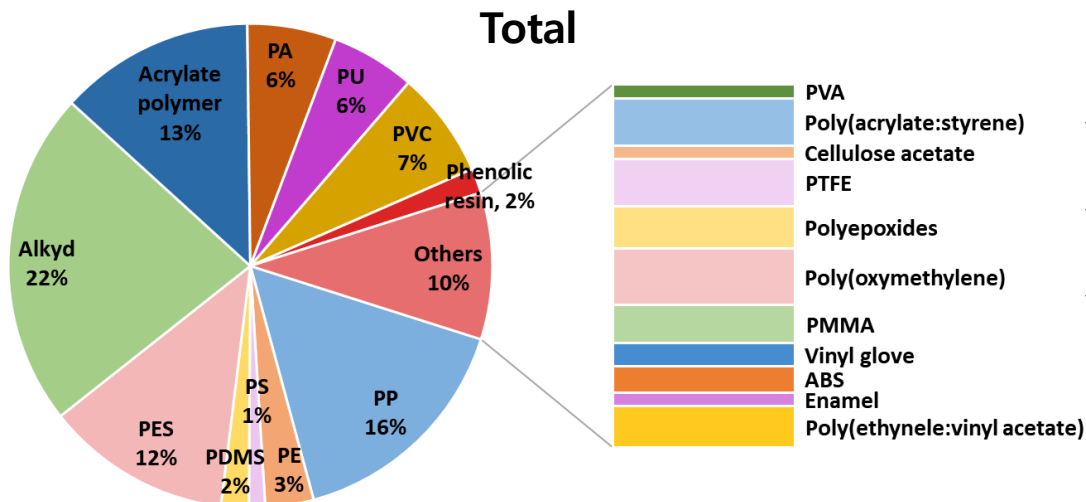
Middle



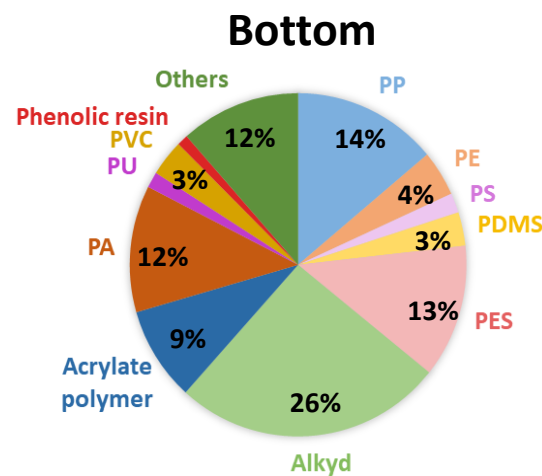
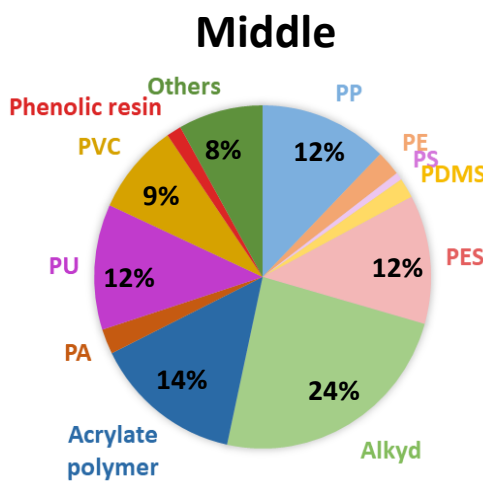
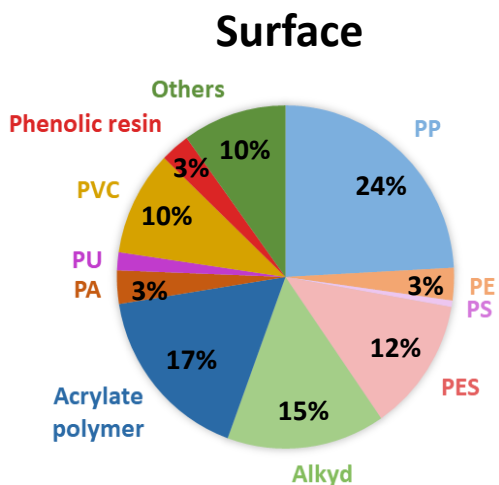
Bottom



Polymer composition in shelf water

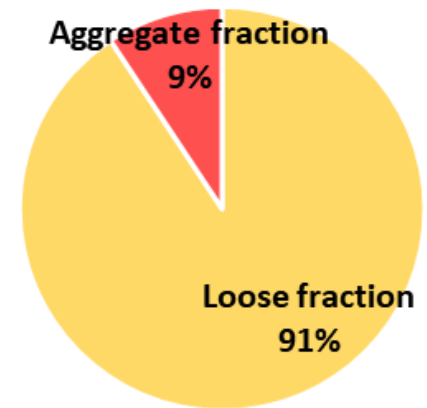
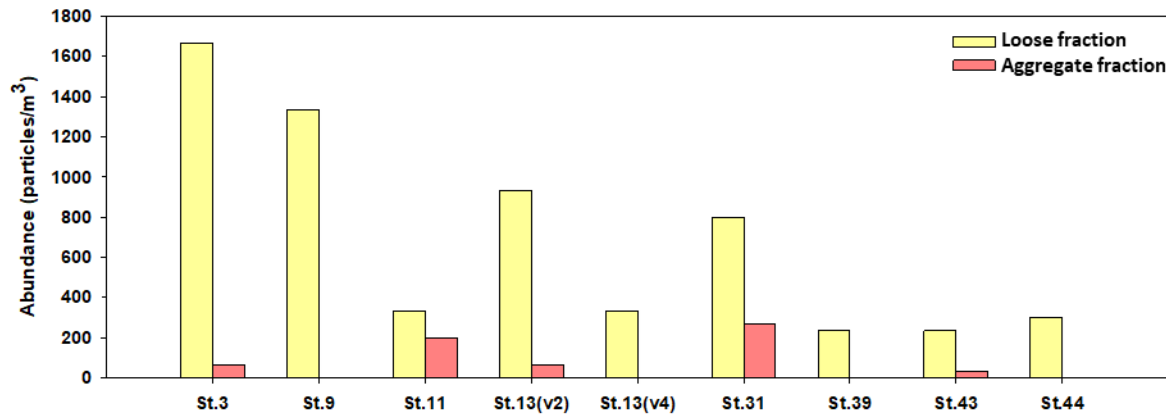


- ✓ Total 33 polymer types
- ✓ Dominance of PP in surface
- ✓ Dominance of alkyd in middle and bottom



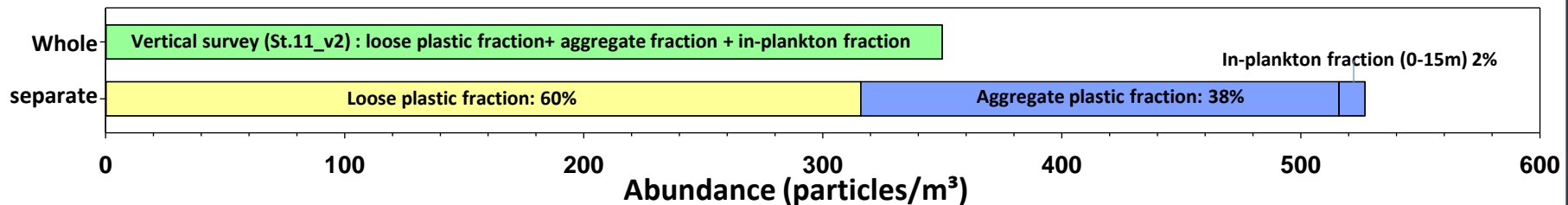
Microplastic in 'loose' and 'aggregate' fraction and in zooplankton

Loose and aggregate microplastic fraction



- ✓ Aggregate fraction accounted for 9% of the total MPs in the study area
- ✓ 0.03 microplastic particles/aggregate

Microplastic distribution in seawater (St.11)



- ✓ Abundance of microplastic was higher in separate analysis than whole analysis

Conclusion

- ❖ **The relatively high microplastic contamination level was found in Korean coastal and shelf waters**
- ❖ **The positive correlation between microplastic abundance in coastal water and surrounding population indicates input of microplastics from the land based sources**
- ❖ **Although the levels are lower than the surface water, sub-surface water contained considerable levels of microplastics including low-density polymer (e.g. PE and PP)**
- ❖ **Further study is required to evaluate relative contribution of various biological interactions for the downward movement of microplastics**

Thank you!

