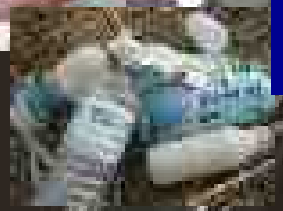
Study on ocean microplastic pollution in Japan, and its future perspective

Atsuhiko ISOBE (Research Institute for Applied Mechanics, Kyushu Univ., JPN)
with a collaborator, Dr. Shinsuke Iwasaki (RIAM, Kyushu Univ)

[This presentation is focused on the physical aspect of oceanic microplastics, because studies on environmental chemical topics were presented by Prof. Takada, and on macroplastics were by Dr. Uchida.]

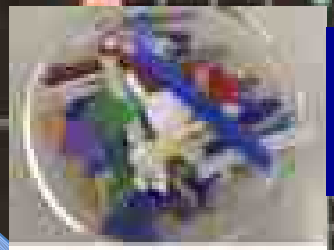
How do we define marine plastic debris ?

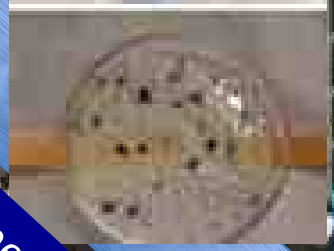
Andrady (2011, MPB)



Plastic debris that we can deduce their original products

Macroplastics





Small plastic fragments with sizes > 5 mm

Mesoplastics

Degradation & Fragmentation by ultraviolet radiation and mechanical erosion

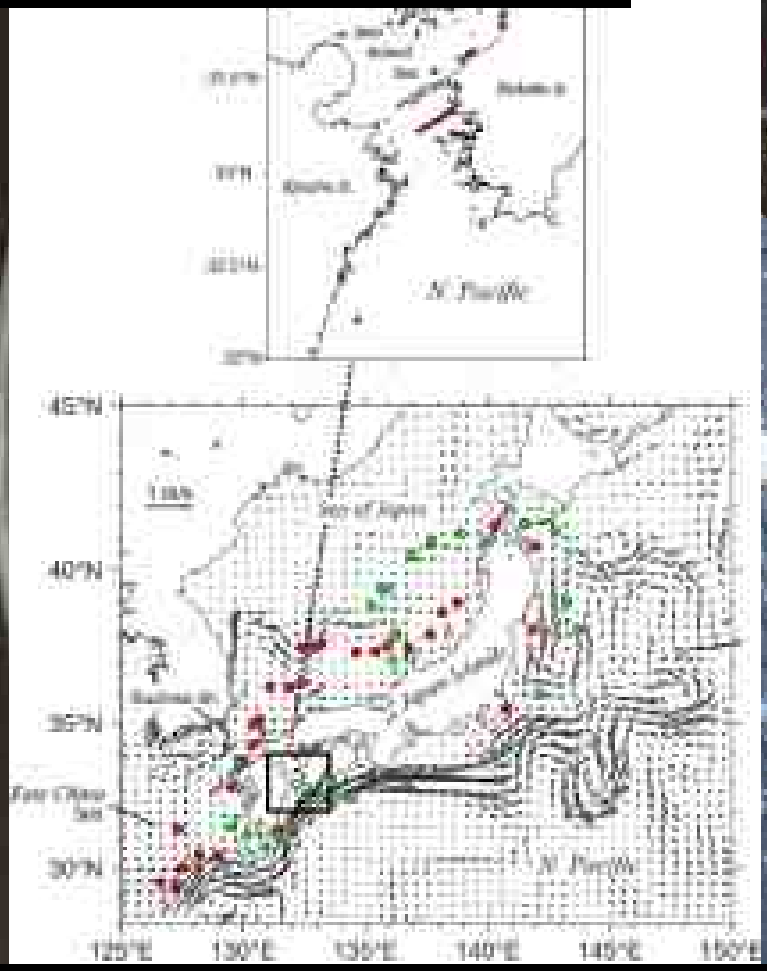
Small plastic fragments with sizes < 5 mm

Microplastics (may act as a transport vector of POPs into the marine ecosystem)

Recent field surveys of meso- and microplastics around Japan, and planned surveys

Seto Inland Sea (2010-2012)

Isobe et al. (2014, Marine Pollution Bull)



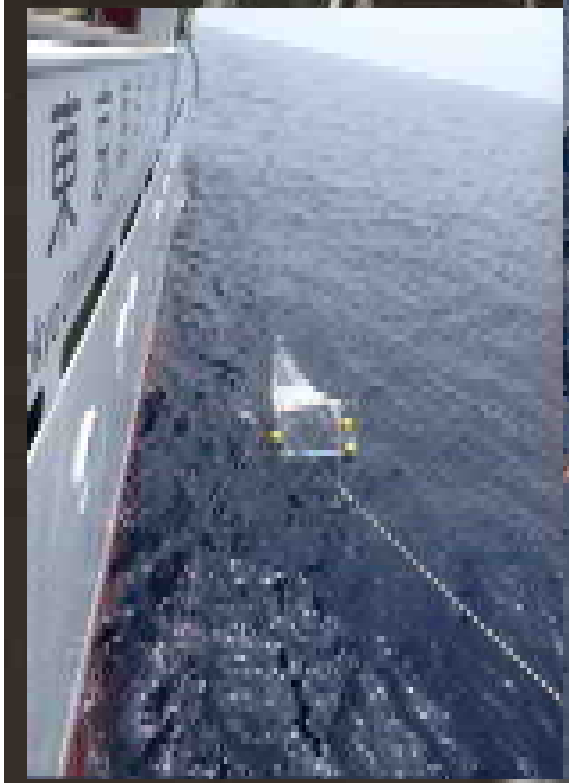
East Asian Seas around Japan (2014-2016)

Isobe et al. (2015, Marine Pollution Bull)

UMITAKA-Maru (2016/Feb.-Mar.)

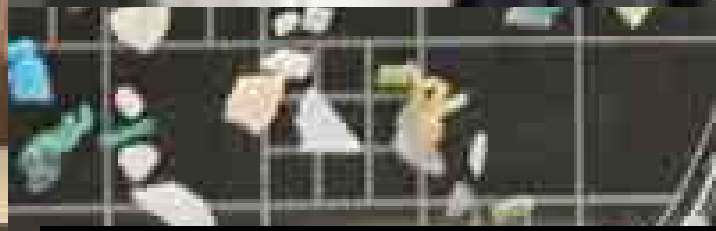
Sampling & analyses

1. Sampling small plastic fragments using neuston net (0.75 x 0.75 m^2, net size of 350 μm) with a flow meter. The net was towed during 15-20 min. by research vessels



Sampling & analyses

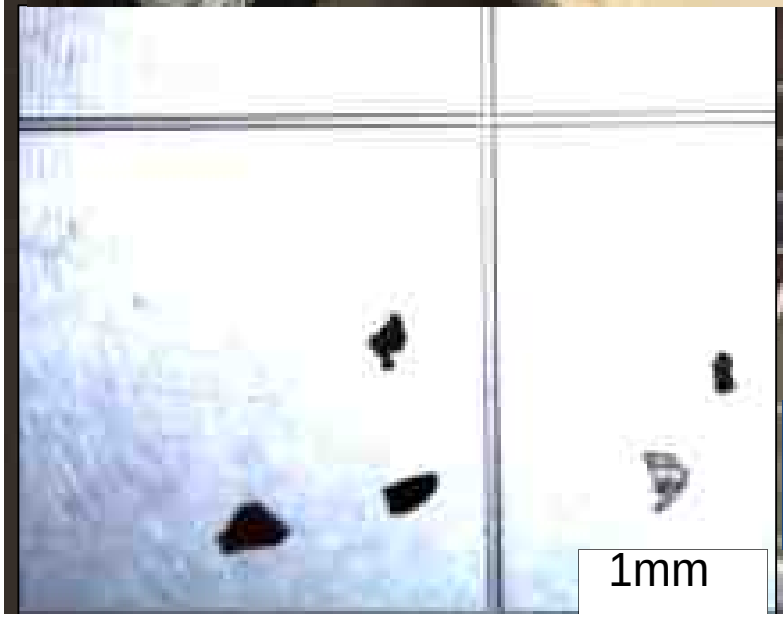
2. Taking pieces of small plastic fragments from sample bottles

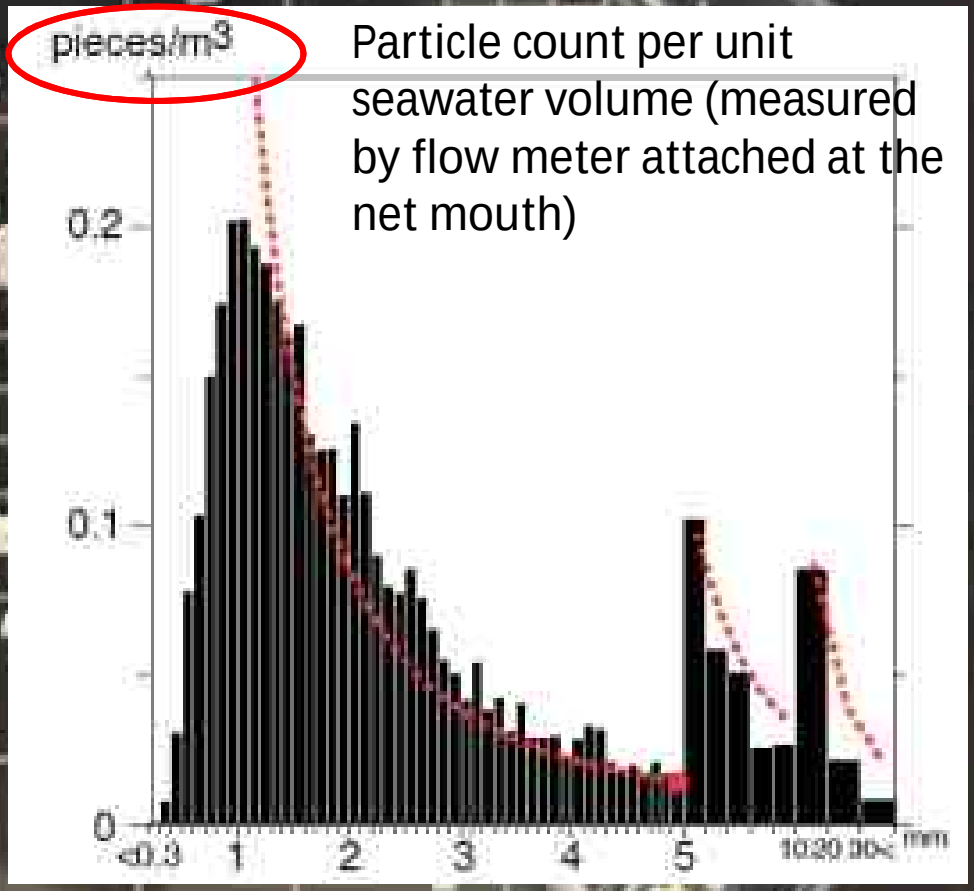


Fourier transform infrared spectrophotometer (FT-IR alpha; Bruker Optics K.K., Tokyo, Japan) to identify polymer types of plastics

Sampling & analyses

3. Measuring particle count by each size bin of small plastic fragments



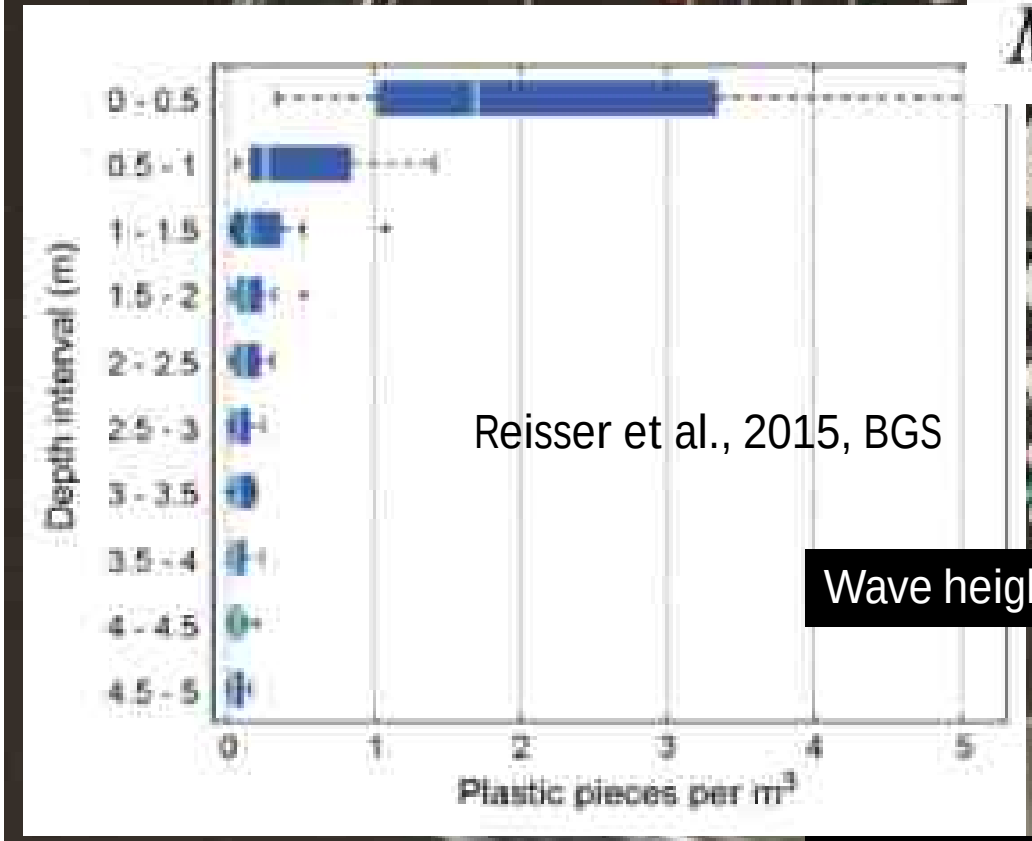


Particle count per unit seawater volume (measured by flow meter attached at the net mouth)

Particle count (numbers) per unit volume of seawater is estimated.

Sampling & analyses

4. Converting the particle count per unit volume (N_0; pieces/m^3) to total particle count over the water column (M; pieces/km^2); otherwise the concentrations depend on oceanic conditions such as waves and their related vertical mixing



Reisser et al., 2015, BGS

$$M = N_0 A_0 / w,$$

Observed particle count (pieces/m^3)

Rise velocity of plastic fragments (experimental values)

$$A_0 = 1.5\, u_* k H_S,$$

Wave height (observed or computed by wind speed)

$$(u_* = 0.0012\ W_{10})$$

Wind speed (observed by satellites above the oceans)

Sampling at 15 stations in the Seto Inland Sea, Japan

Samplings of meso & microplastics using R/V "Isana" & T/V "Yuge" were conducted from 2010-2012. We first sought oceanic fronts along which plastic debris are accumulated, and thereafter towed a neuston net (350 um)

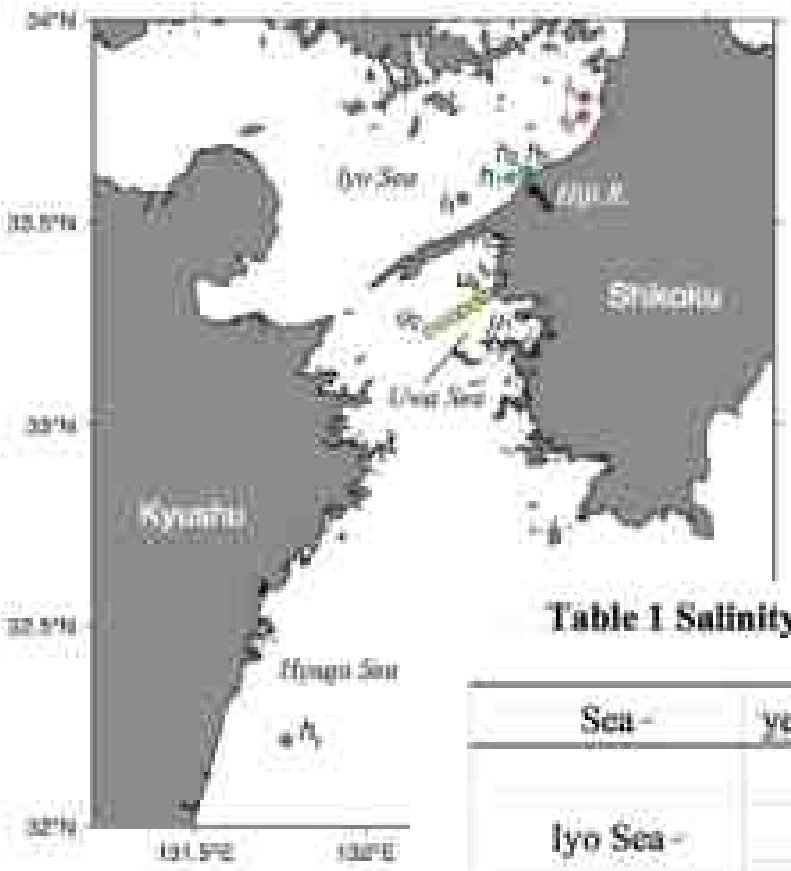
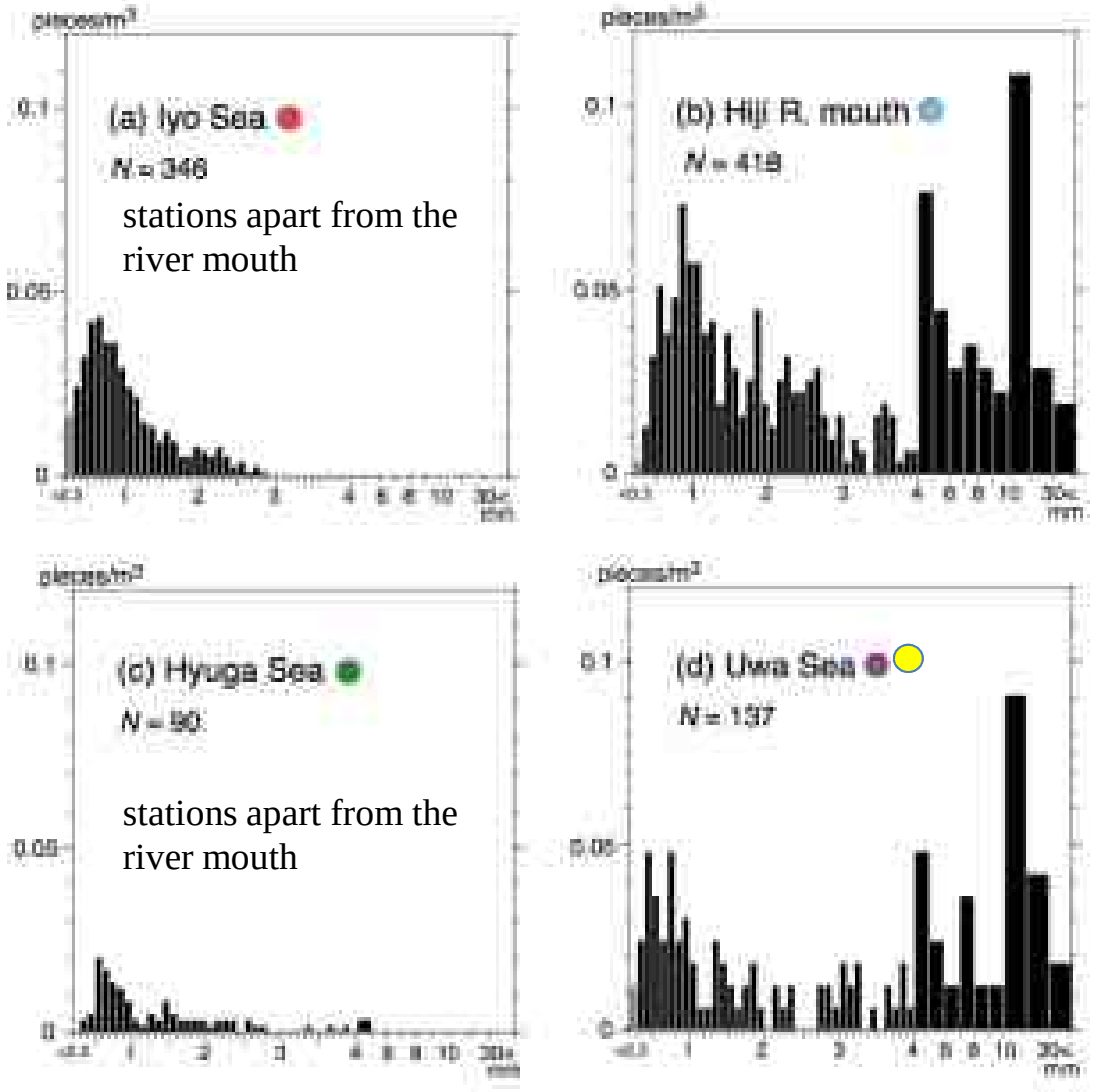


Table 1 Salinity and distance from the nearest coast of the sampling stations

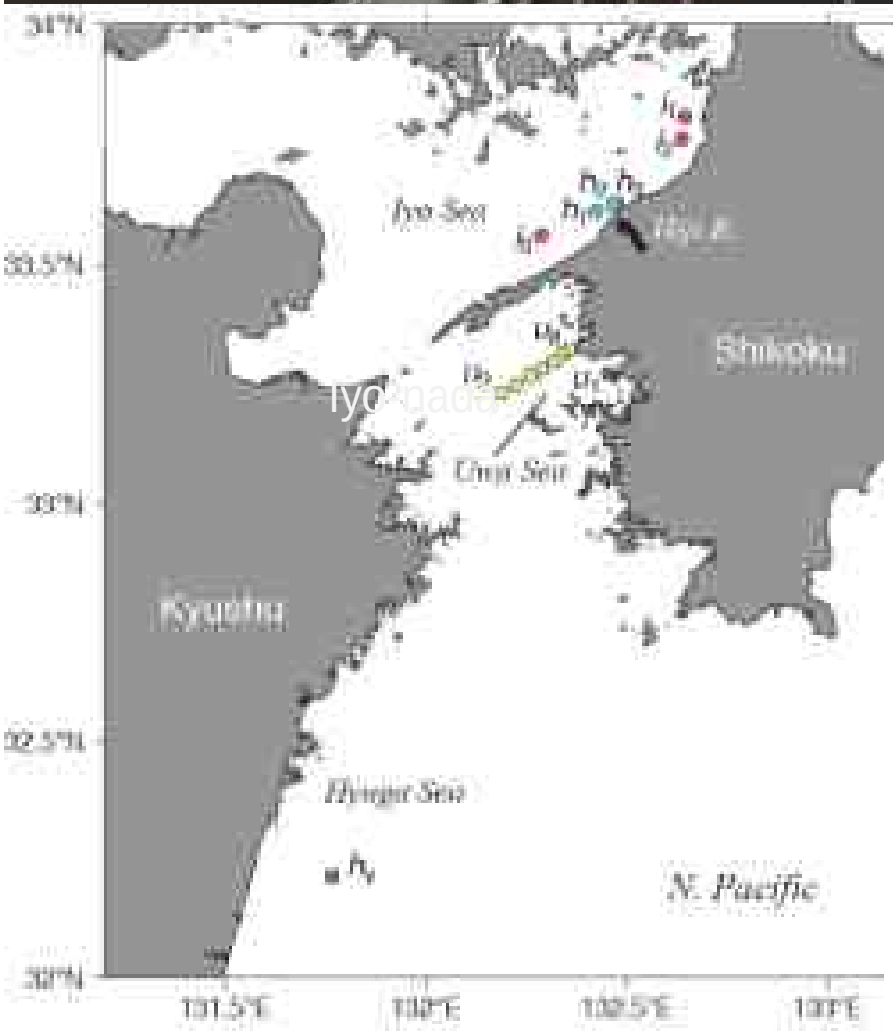
Sea	year/month/date	Stas.	Salinity	Distance (km)
Iyo Sea	2010/06/11	i_1	32.0	4.5
	2010/09/01	i_2	31.4	5.0
	2011/07/14	i_3	31.8	9.5
Hiji R. mouth	2011/07/14	h_1	26.1	1.2
	2011/08/09	h_2	31.2	4.2
	2011/09/13	h_3	30.2	1.6
Hyuga Sea	2011/06/01	hy	32.1	21.6
Uwa Sea	2011/08/09	u_1	31.7	2.2
	2012/05/17	u_2, u_3, u_4	33.4, 32.5, 32.4	19.7, 15.6, 11.6
	2012/05/17	u_5, u_6, u_7	32.4, 32.5, 32.6	5.5, 2.9, 1.1

Results

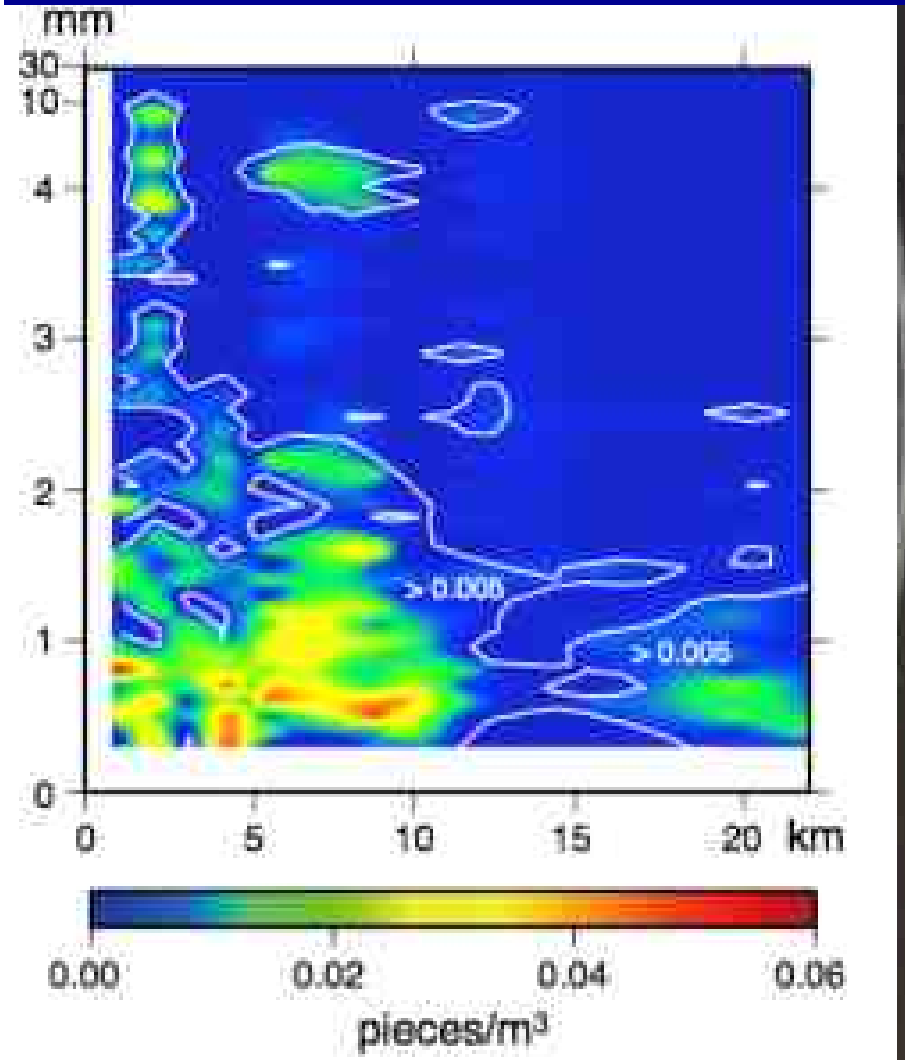


Microplastics (<5 mm)
76,000 pieces/km^2

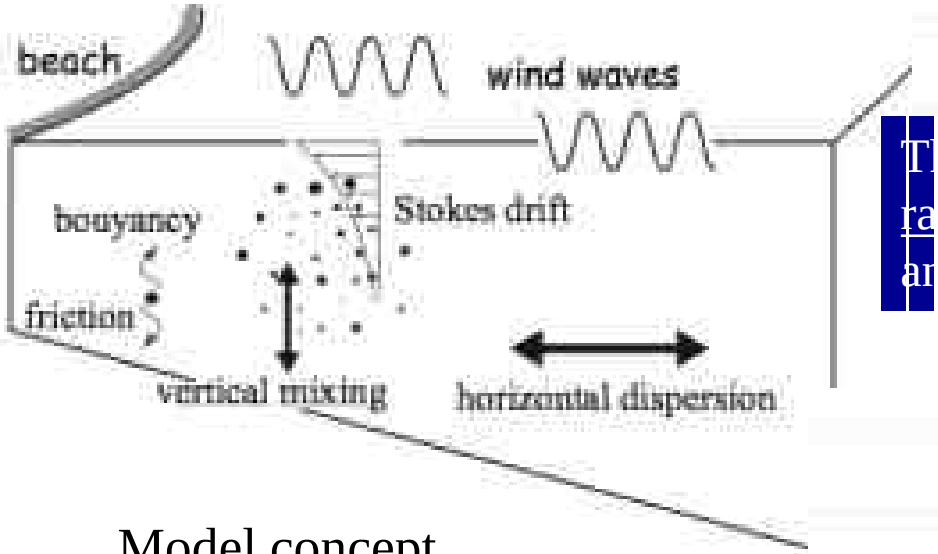
The size and quantity of mesoplastics gradually increased close to the coast, while microplastics were more dominant as we moved further offshore.



Particle count (colors) of plastic fragments as a function of their size and distance from the nearest coast. The samples near the river mouth(h1-3) are NOT used in depicting this figure.



Transport model of meso & microplastics



Model concept

$$u = -\frac{a^2 \sigma k \cosh\{2k(h+z)\}}{2(\sinh kh)^2} + \frac{R\sqrt{2K_h \Delta t}}{\Delta t}, \quad (2)$$

The horizontal motion is governed by random walk (ocean currents & turbulence) and Stokes drift generated by wind waves.

$$w = \frac{d^2(\rho - \rho')g}{18\eta} + \frac{R\sqrt{2K_v \Delta t}}{\Delta t}, \quad R_e < 1, \quad (3)$$

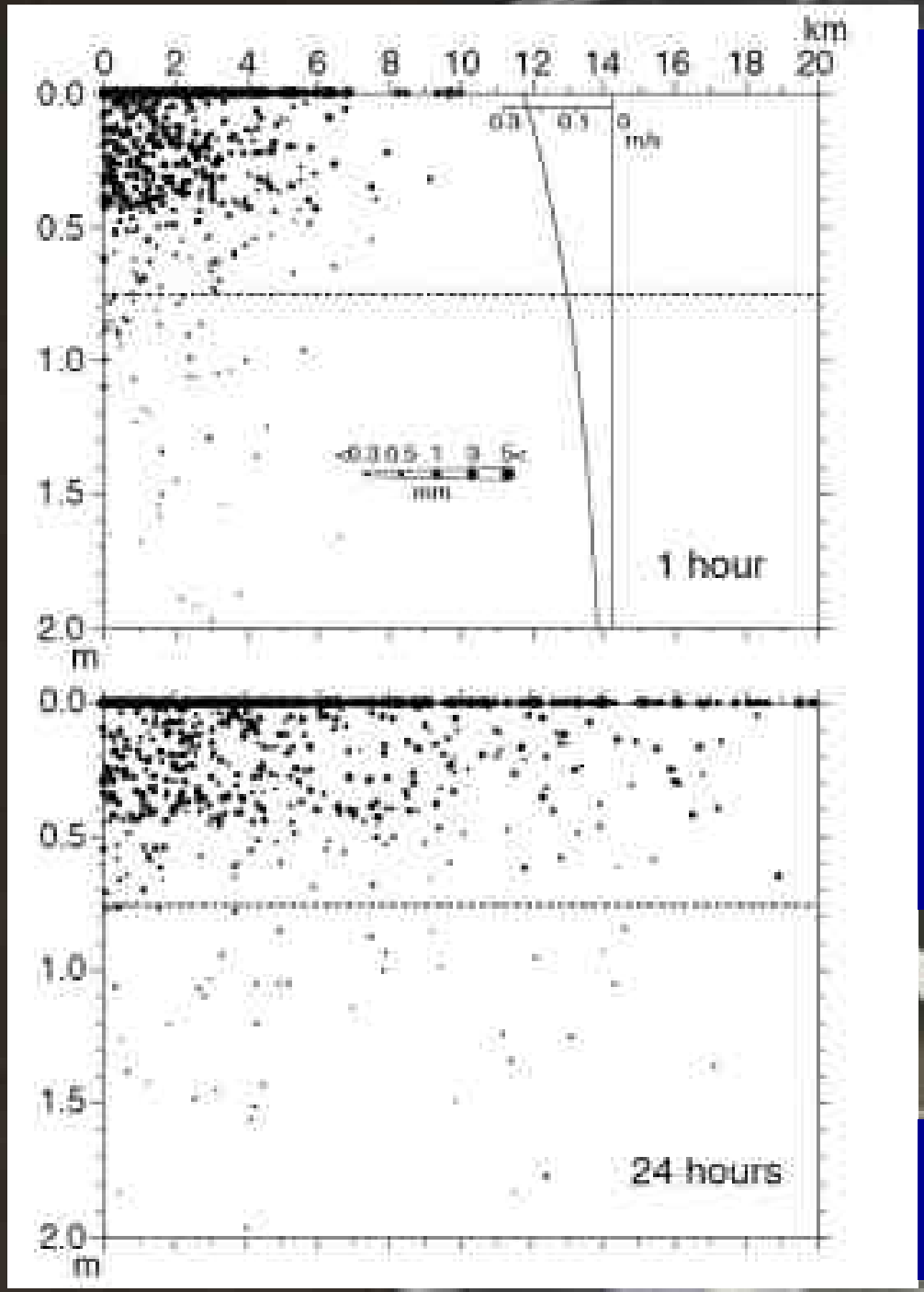
$$w = 0.223d\left\{\frac{(\rho - \rho')^2 g^2}{\rho\eta}\right\}^{1/3} + \frac{R\sqrt{2K_v \Delta t}}{\Delta t}, \quad 1 \le R_e \le 100, \quad (4)$$

$$w = 1.82\left\{\frac{(\rho - \rho')gd}{\rho}\right\}^{1/2} + \frac{R\sqrt{2K_v \Delta t}}{\Delta t}, \quad 100 < R_e, \quad (5)$$

particle tracking model on vertical 2D plain

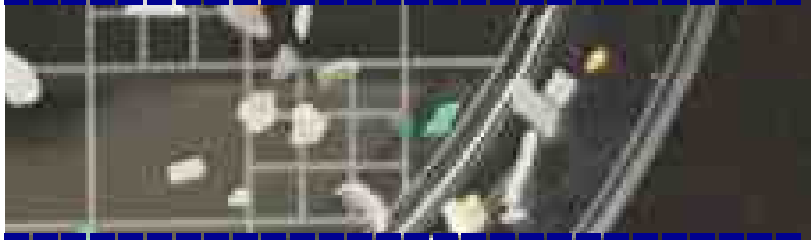
$$\mathbf{x}(t + \Delta t) = \mathbf{x}(t) + \mathbf{u}\Delta t, \quad (1)$$

The vertical motion is governed by terminal velocities dependent on Reynolds number (determined by particle sizes)



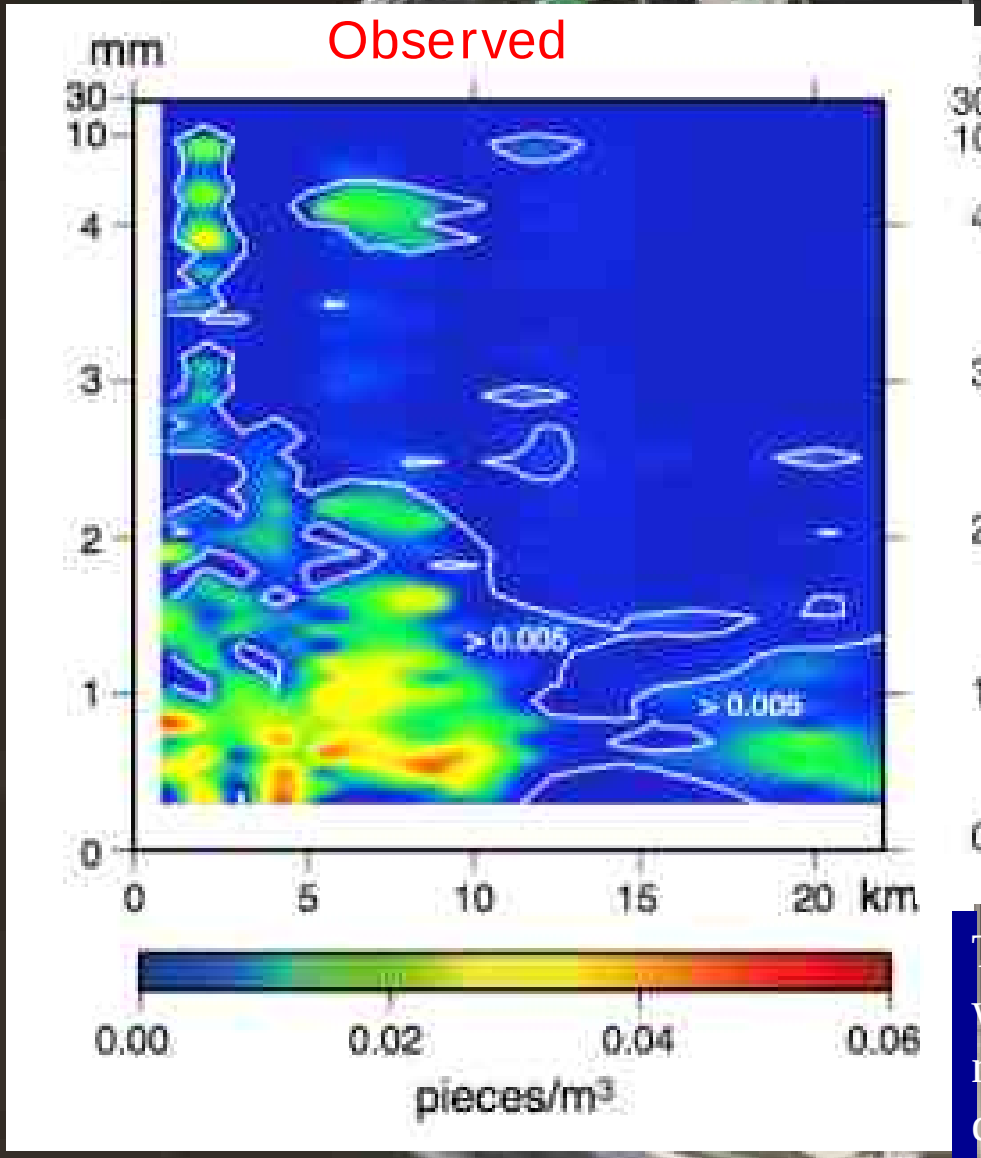
Procedures

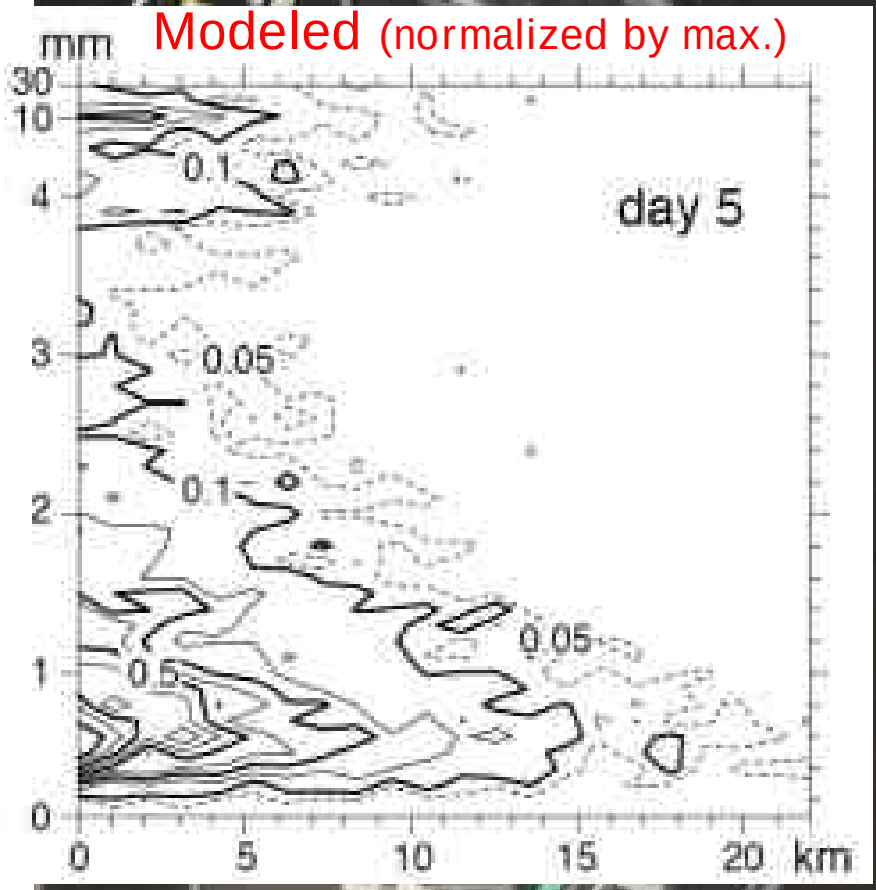
- 10,000 particles were first released at x=0 km, z=0 m (upper left), and thereafter we compute the motions of all particles until an equilibrium state was reached (5 days).
- The size composition used for the modeled particles were consistent with those observed in the actual ocean
- The drift density was examined in the upper 0.75 m, which is the same as the neuston net height used in the present study



Particle locations in the 2D plain at 1 hour after (upper) and 24-hours after the beginning of the computation.

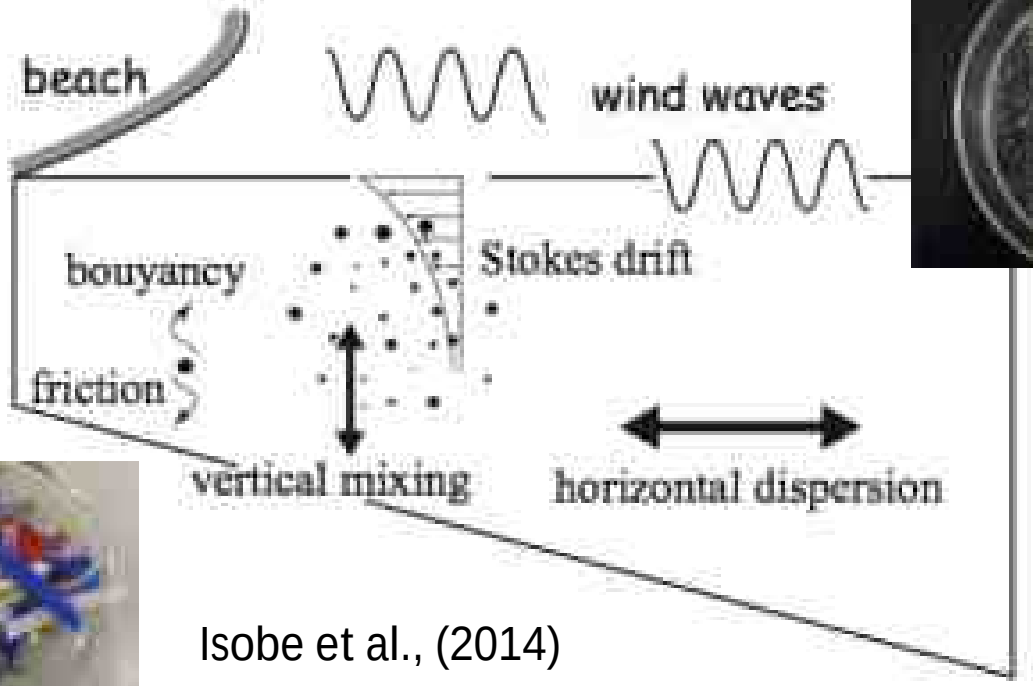
Particle count (colors) of plastic fragments as a function of their size and distance from the nearest coast.

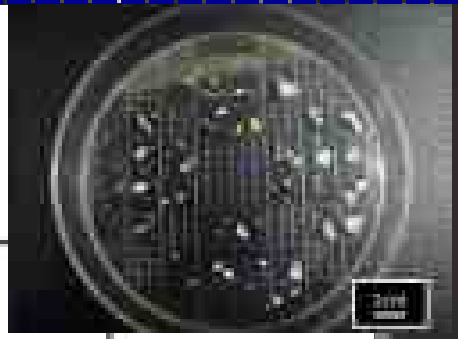




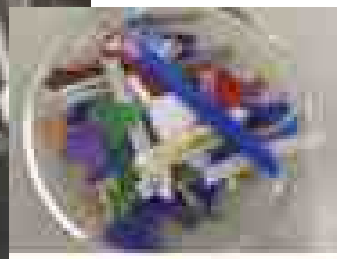
The model including Stokes drift, random walk, and terminal velocities well reproduces the situation that mesoplastics disappear in the offshore.

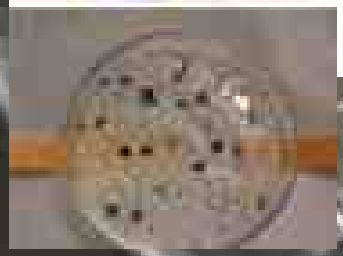
The mesoplastics are selectively conveyed onshore by a combination of Stokes drift and terminal velocity, dependent on fragment sizes. It is suggested that mesoplastics washed ashore on beaches degrade into microplastics, and that the microplastics, which are free from near-shore trapping, are thereafter spread offshore in coastal waters.





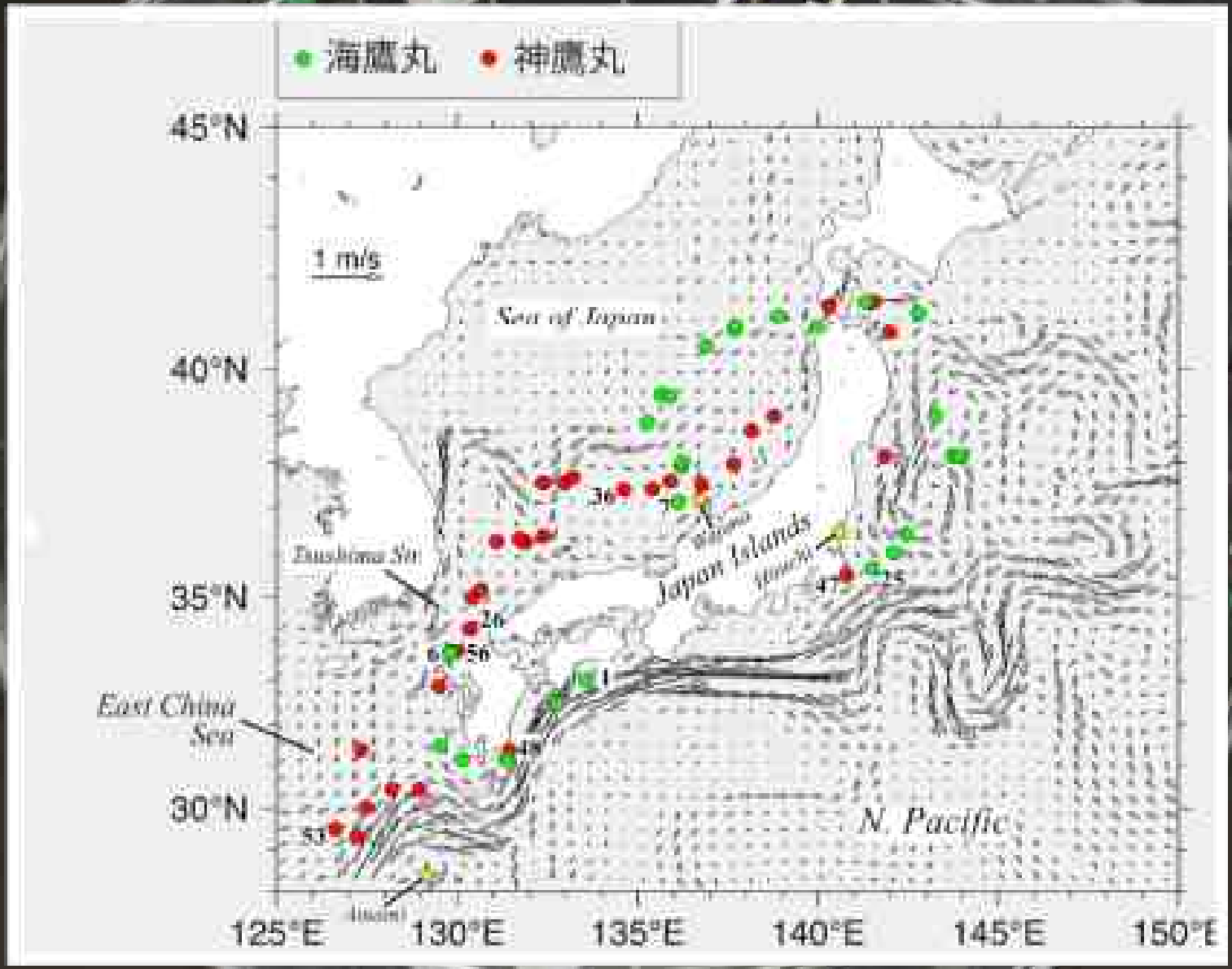
Isobe et al., (2014)





Coastal waters have an effective "function" for changing mesoplastics to microplastics.

Results


海鷹丸
神鷹丸
45°N
40°N
35°N
30°N
1 m/s
Sea of Japan
Tsushima Str.
Japan Islands
East China Sea
N. Pacific
125°E
130°E
135°E
140°E
145°E
150°E

Results

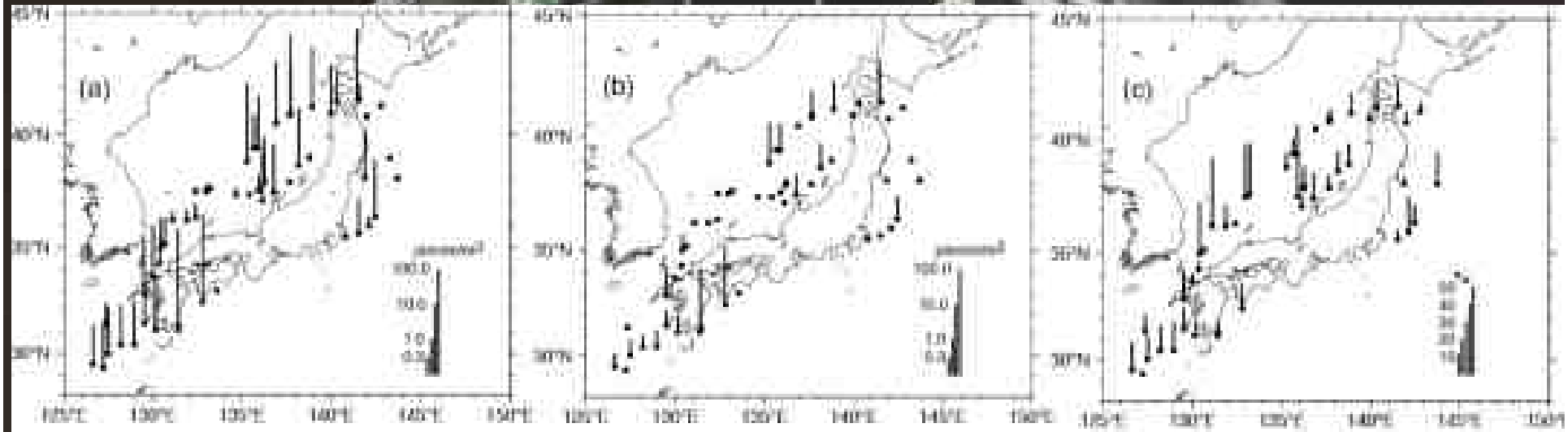


Figure 3 Maps of concentrations of (a) microplastics, (b) mesoplastics, and (c) mesoplastics ratio. The stations with quantities of <10 pieces are removed in (c).

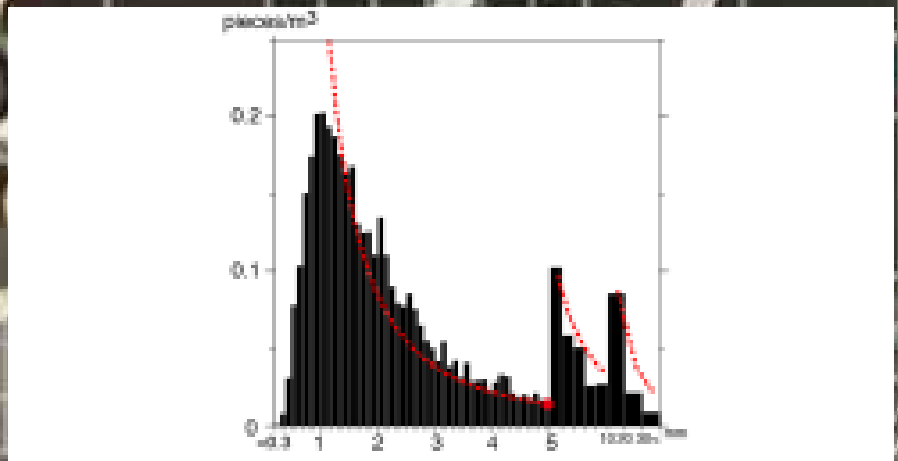
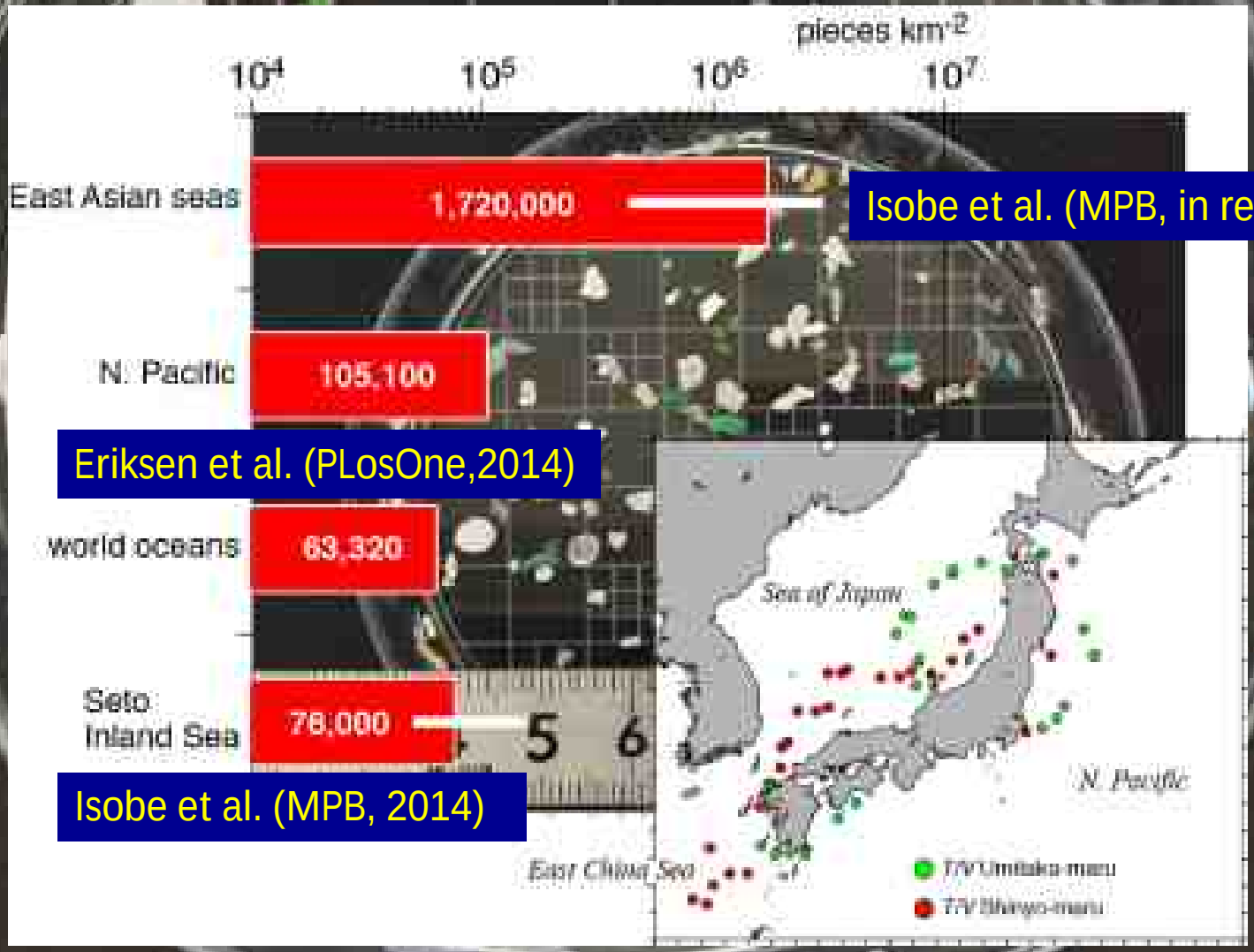
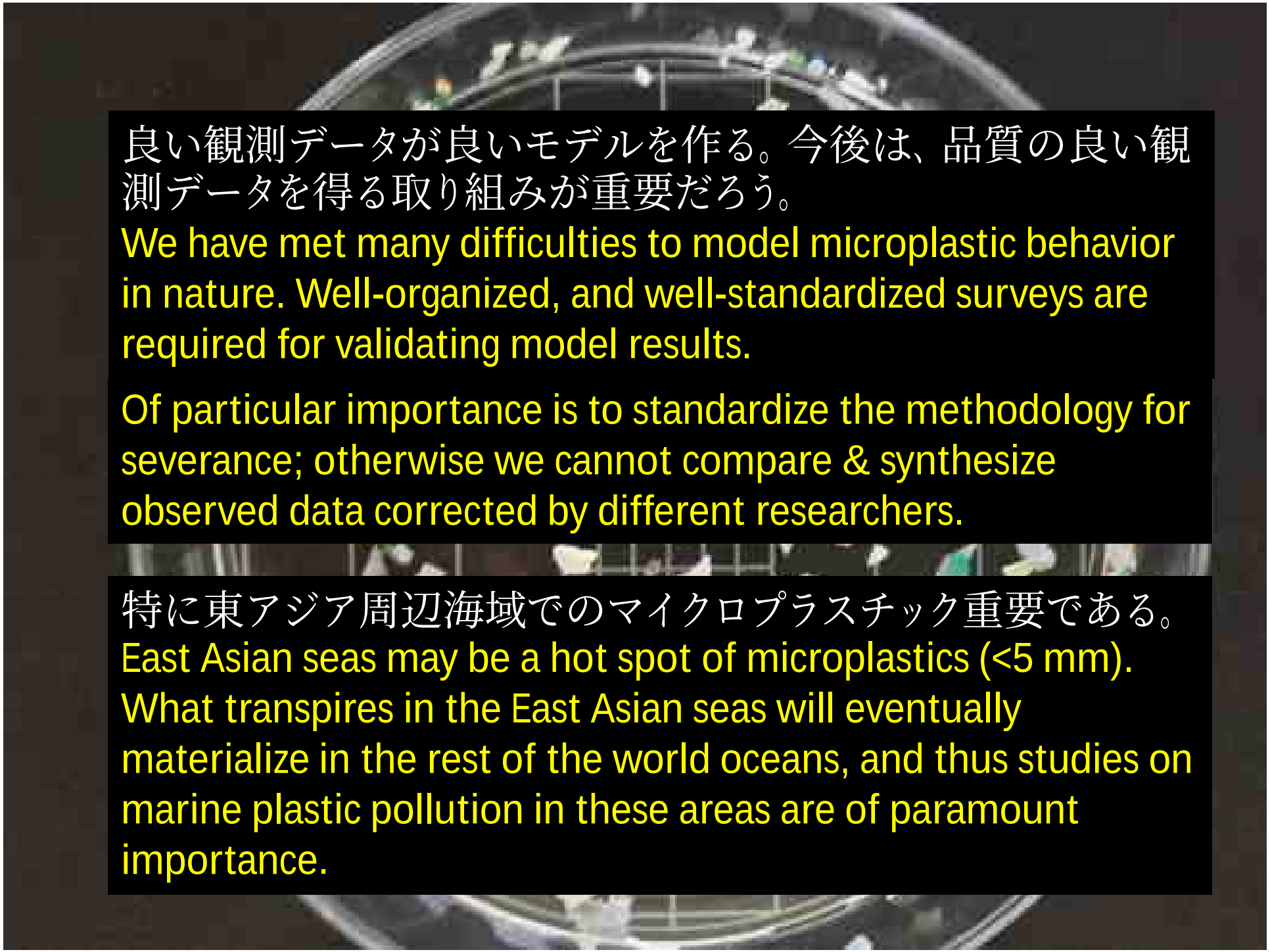


Figure 2 Size distribution of small plastic fragments. The bars indicate the concentration in each size range on the abscissa. Note that the intervals of size ranges are 0.1 mm for microplastics, 1 mm for mesoplastics <10 mm, and 10 mm for mesoplastics >10 mm. The red curves represent the size distribution predicted using the reference size shown by the red spot (see text for stepwise approach applied to the prediction).

East Asian seas may be a hot spot of microplastics (<5 mm). What transpires in the East Asian seas will eventually materialize in the rest of the world oceans, and thus studies on marine plastic pollution in these areas are of paramount importance.





良い観測データが良いモデルを作る。今後は、品質の良い観測データを得る取り組みが重要だろう。

We have met many difficulties to model microplastic behavior in nature. Well-organized, and well-standardized surveys are required for validating model results.

Of particular importance is to standardize the methodology for severance; otherwise we cannot compare & synthesize observed data corrected by different researchers.

特に東アジア周辺海域でのマイクロプラスチック重要である。

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