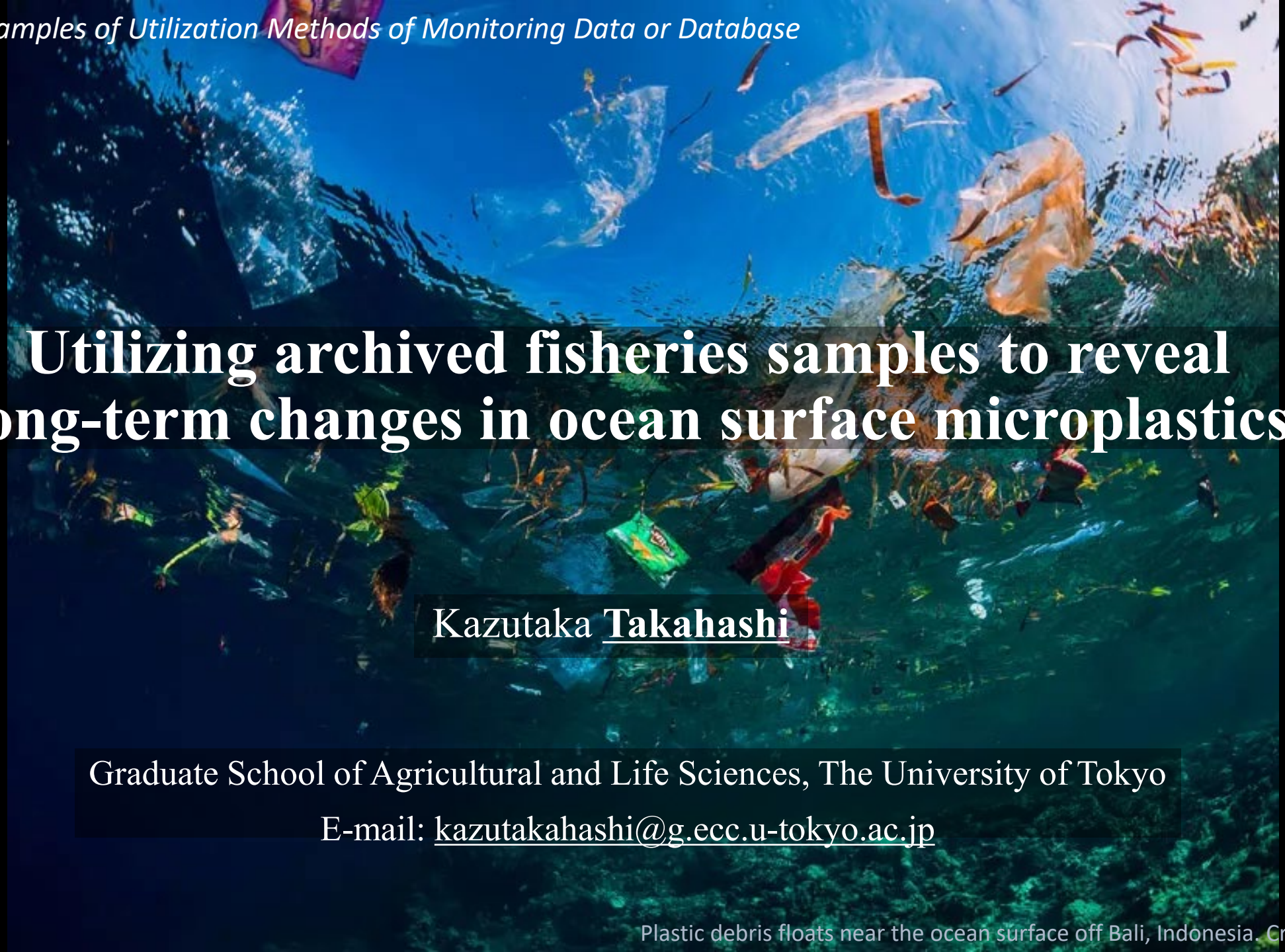


Utilizing archived fisheries samples to reveal long-term changes in ocean surface microplastics

Kazutaka **Takahashi**

Graduate School of Agricultural and Life Sciences, The University of Tokyo

E-mail: kazutakahashi@g.ecc.u-tokyo.ac.jp

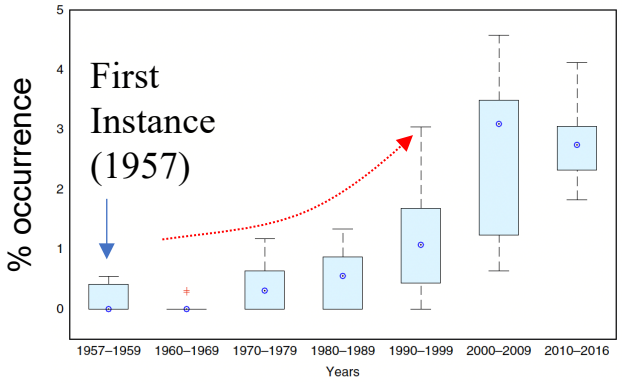
Plastic debris floats near the ocean surface off Bali, Indonesia. Credit: iStock/Nuture

Long-term trend of plastic pollution at Ocean Surface Layer

North Atlantic

Archived CPR samples

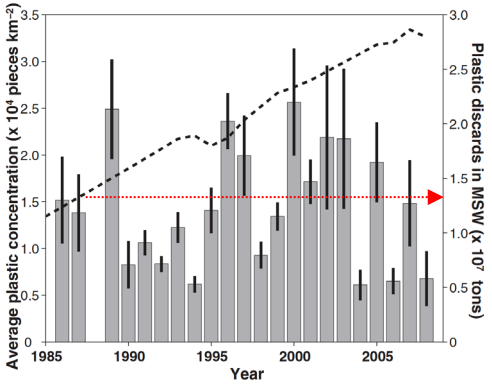
(Ostle et al. 2019)



increasing trend in macroplastic entanglement frequency since the late 1950s

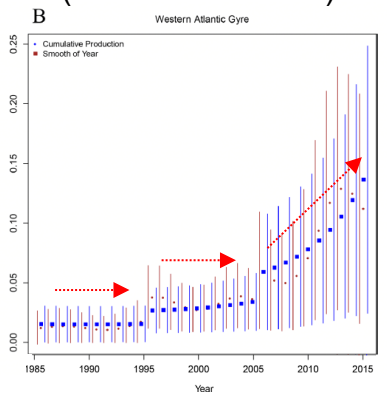
Surface plankton net tows

(Law et al. 2010)



no strong temporal trends in plastic concentration in the 22-year data set (1986-2007)

(Wilcox et al. 2020)

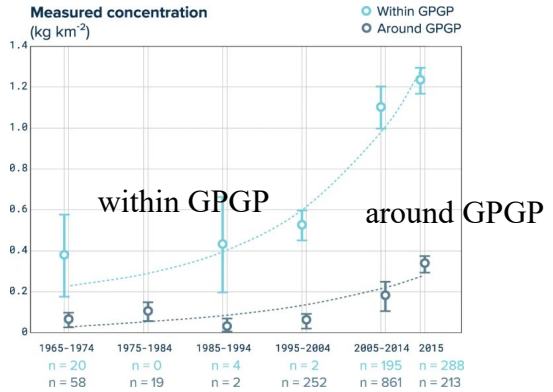


significant increasing trend in plastic particle concentration (1986-2015)

Subtropical North Pacific

Surface plankton net tows

(Lebreton et al. 2018)



an exponential increase during the last decade, particularly within the Great Pacific Garbage Patch (GPGP)

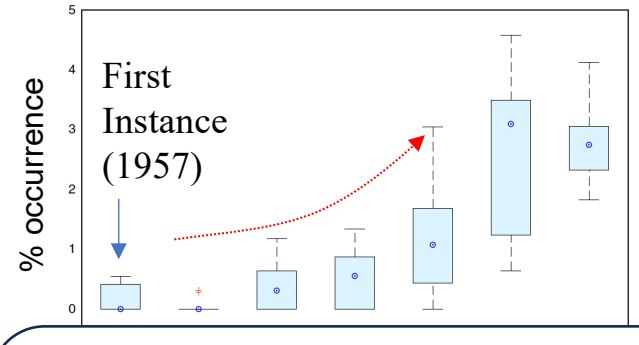
No time series analysis covering the period from the first plastic discharge to the present

Long-term trend of plastic pollution at Ocean Surface Layer

North Atlantic

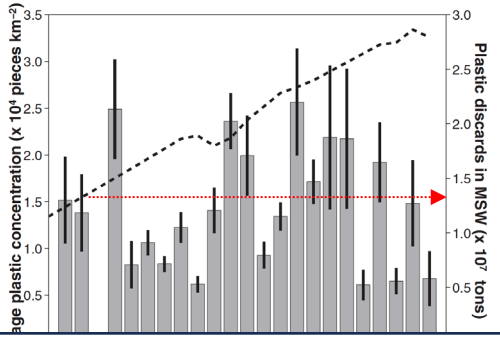
Archived CPR samples

(Ostle et al. 2019)

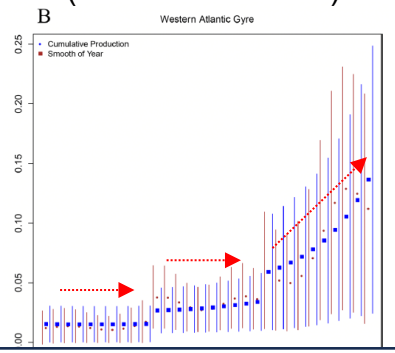


Surface plankton net tows

(Law et al. 2010)



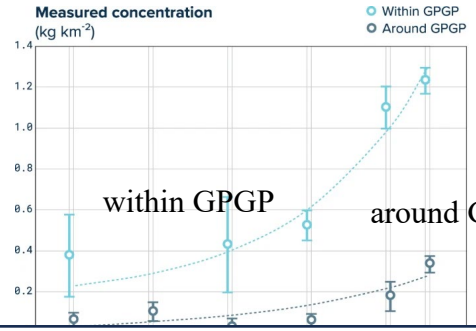
(Wilcox et al. 2020)



Subtropical North Pacific

Surface plankton net tows

(Lebreton et al. 2018)

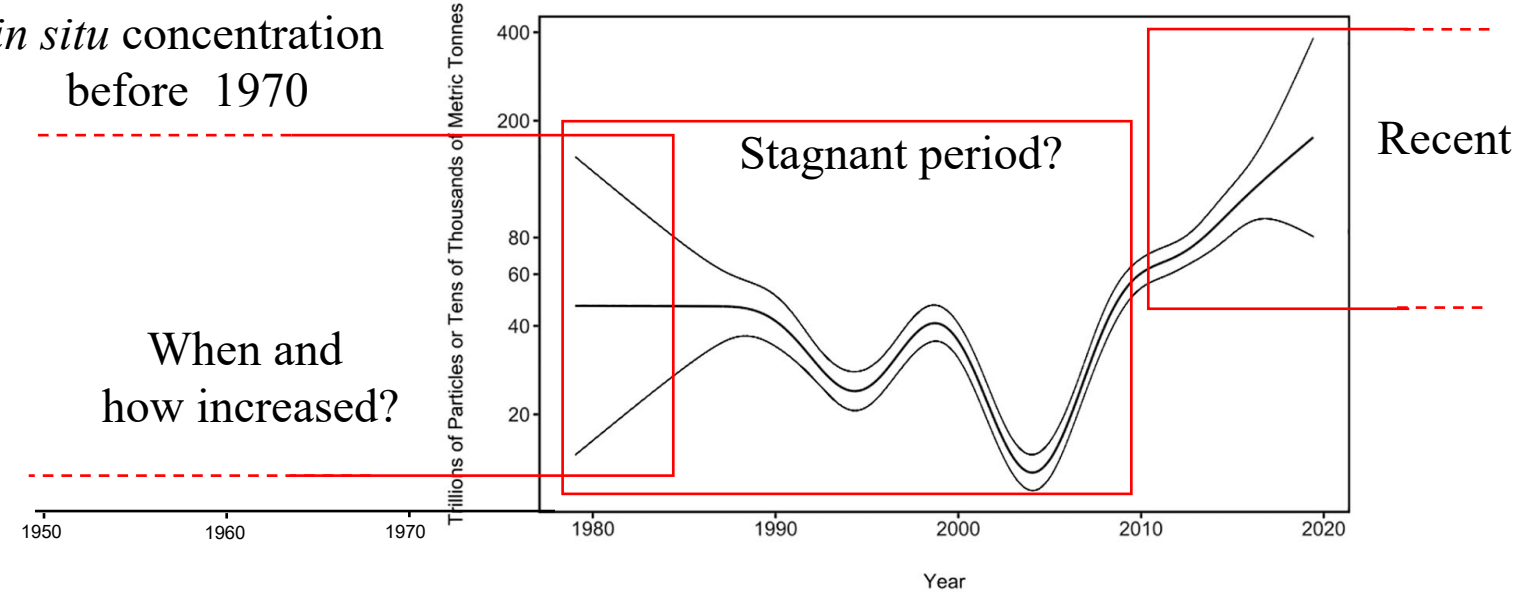


Global trend from 1979 to 2019

(Eriksen et al. 2023)

No information on *in situ* concentration before 1970

When and how increased?



Recent increase?

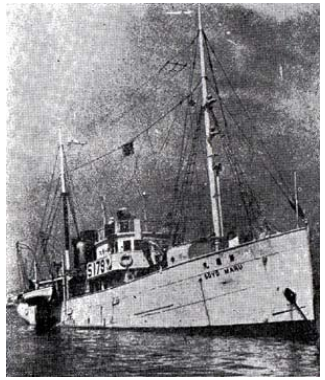
Sample collection by the FRA (Japan Fisheries Research and Education Agency)

Surface-towed plankton net-sample series around Japan
for monitoring programs for eggs, larvae, and early juveniles of small pelagic fish

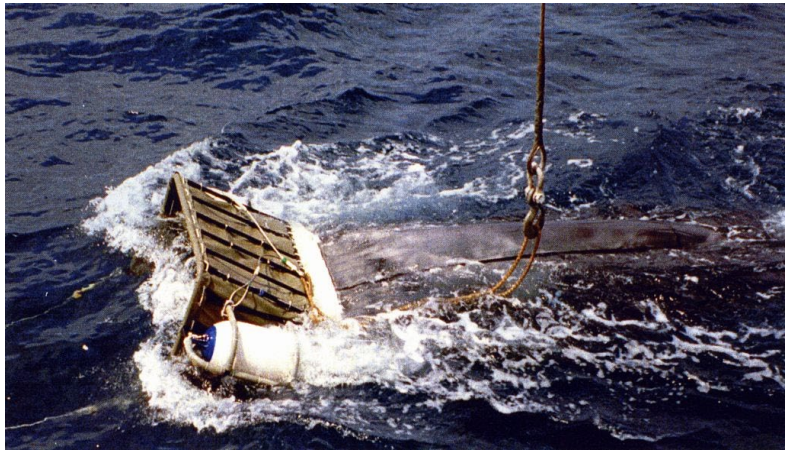
>10,000 samples taken from 1949 to present were archived

Longest-time series samples of the surface plankton-net tow


写真 1. 蒼鷹丸一世.

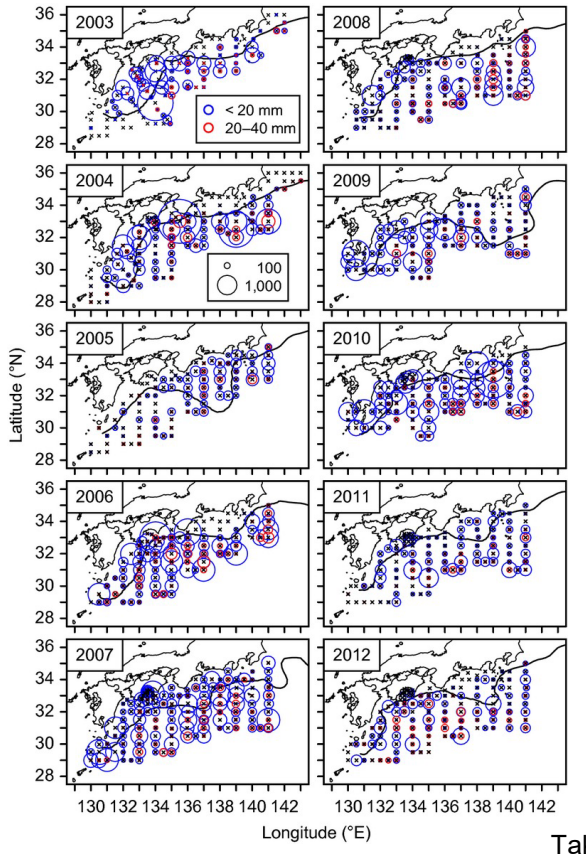


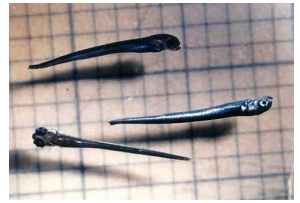
Surface ring-net: 1949-1998
(5-10 min tow)



Neuston Net: 1998-present
(10 min tow)

Horizontal distributions of Pacific saury larvae and juveniles





Takasuka et al. 2014

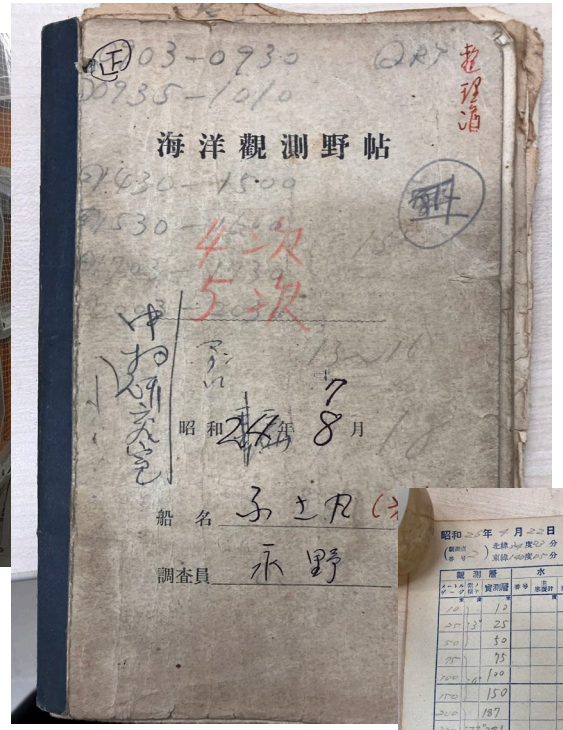
Sample collection by the FRA (Japan Fisheries Research and Education Agency)

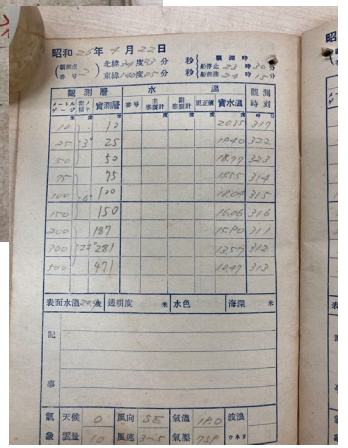
Surface-towed plankton net-sample series around Japan
for monitoring programs for eggs, larvae, and early juveniles of small pelagic fish

>10,000 samples taken from 1949 to present were archived in Shiogama Branchi of Fisheries Resources Institute, Fisheries Research and Education Agency, Japan

Longest-time series samples of the surface plankton-net tow

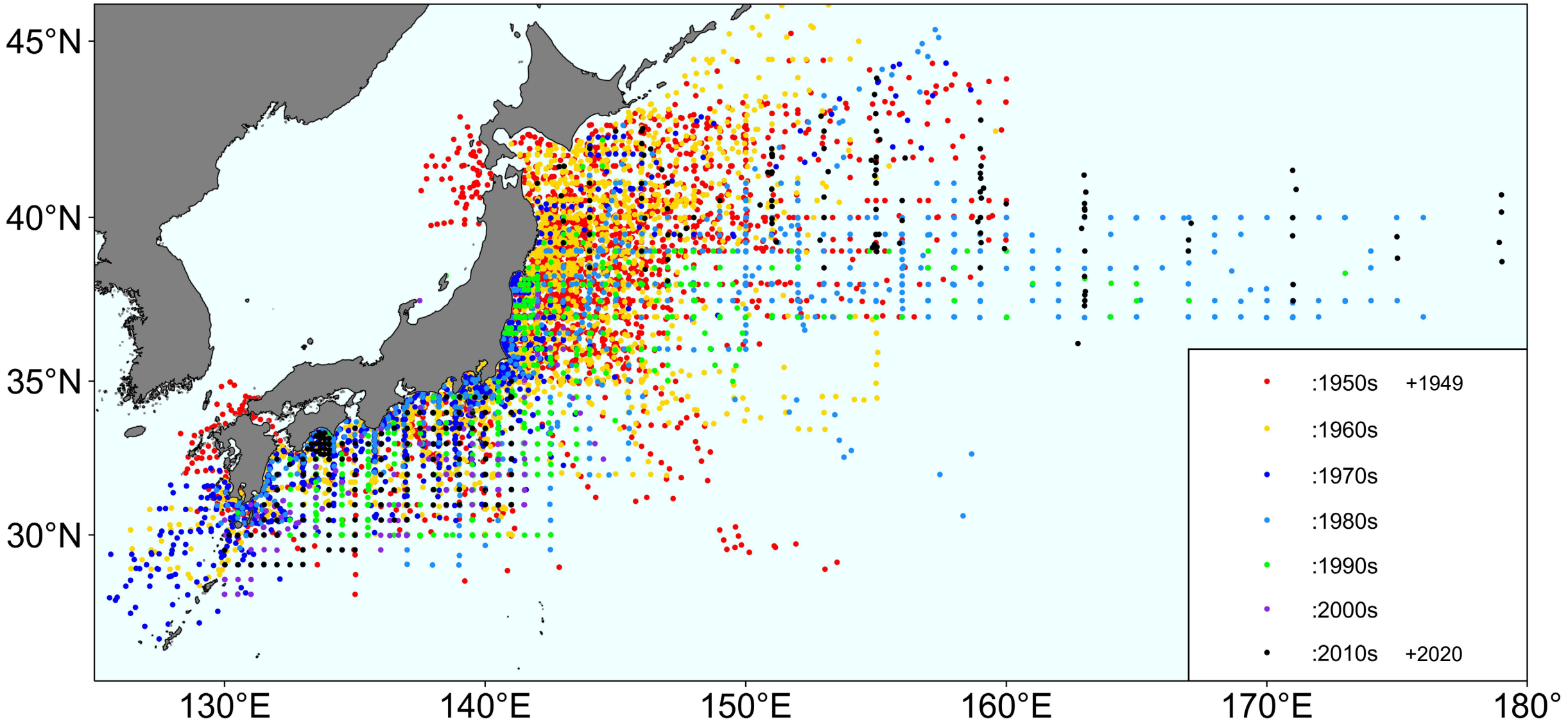
The oldest field note in 1949



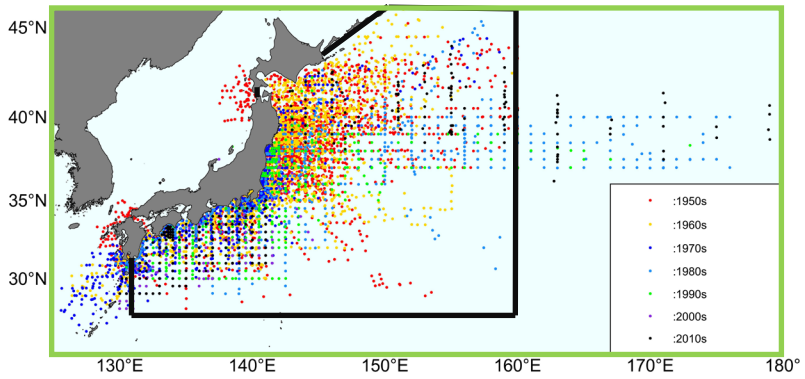


Sample collection by the FRA (Japan Fisheries Research and Education Agency)

Locations of surface plankton net tows over 70 years for the analysis of long term fluctuation of plastic debris



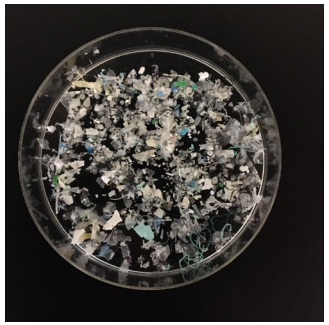
Objectives & Method of Analysis



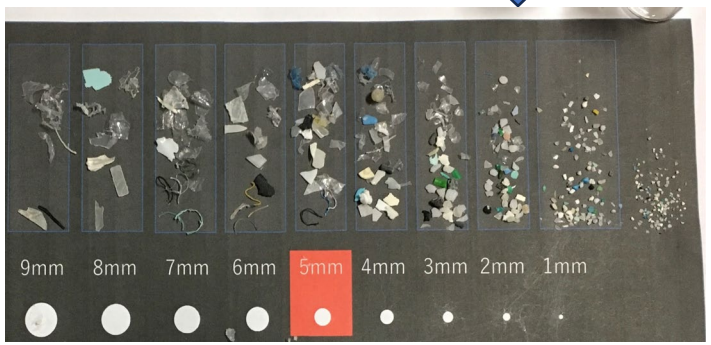
Objectives:
To reveal the long-term change of plastic pollution around Japan based on the longest-time series samples for 70 years

Analysis : a total of 8922 samples collected during 1949–2020 by 298 cruises from an area between 131°E and 160°N and 25°N and 47° N.

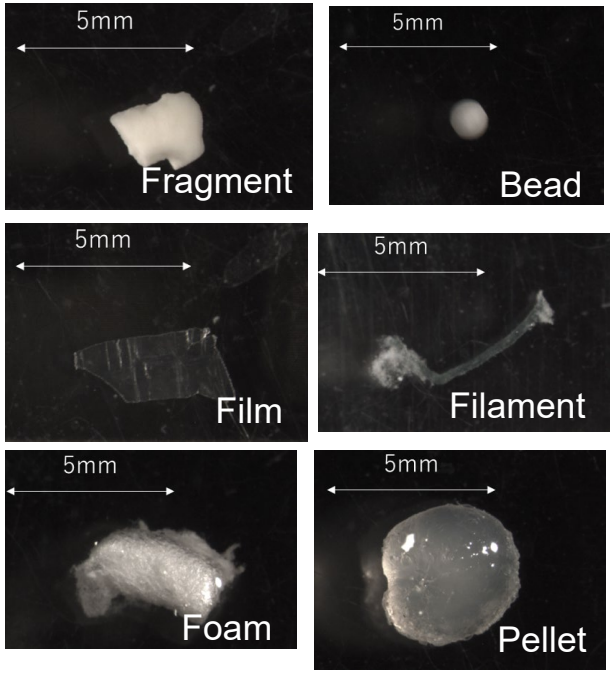
Sample



Sorting & drying



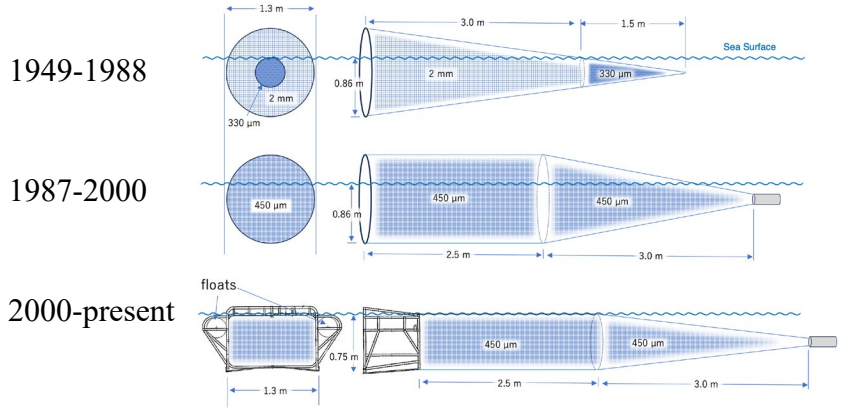
Sizing



Counting for each morphotype

Abundance (pieces/km^2), size, and morphotype composition were determined

Calibration made between a ring net and a neuston net for smaller size class (<3 mm)



Plankton nets used for the monitoring

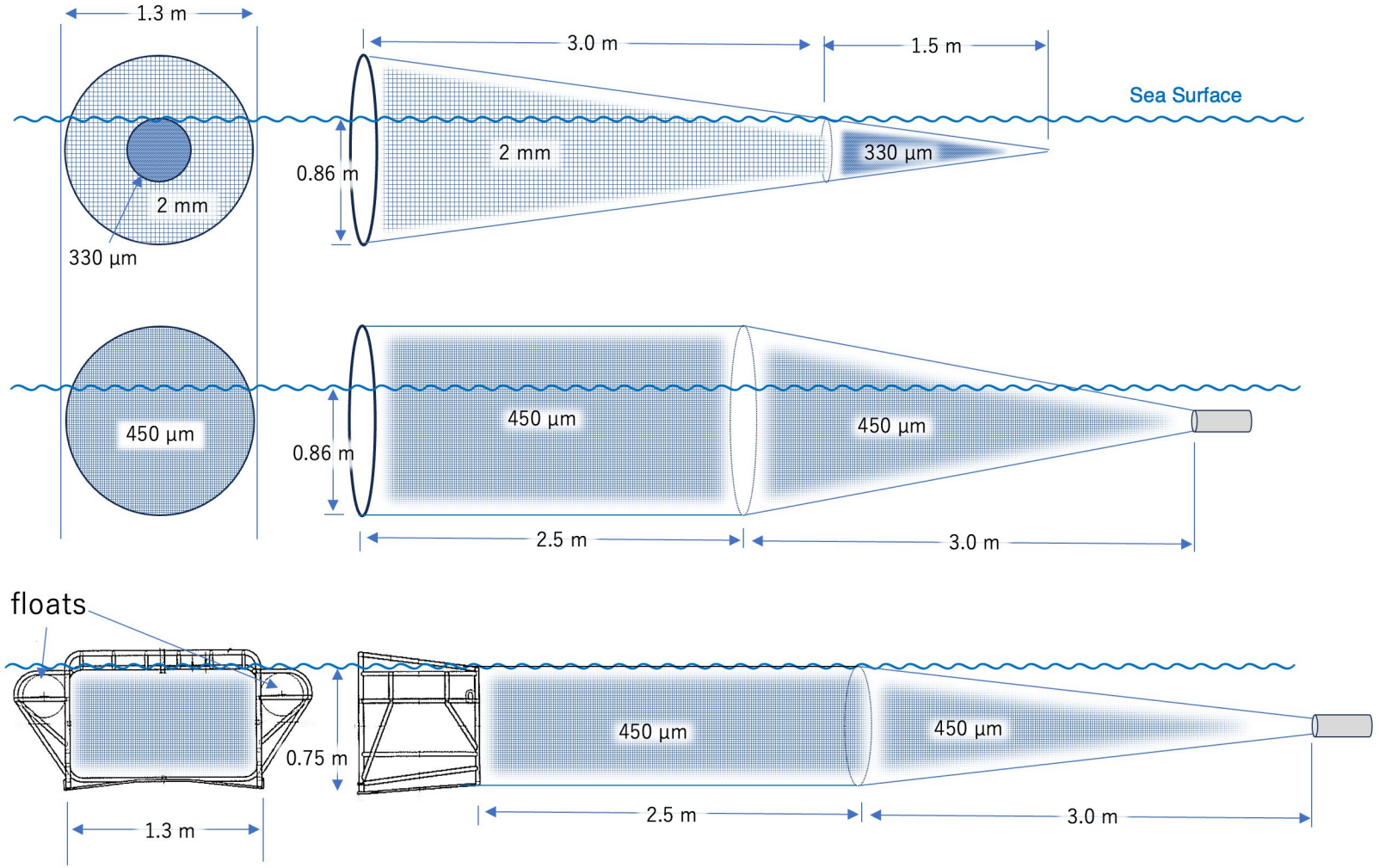
Surface ring net

Modified neuston net
(Oozeki et al. 2001)

1949–1988
(Old type)

1987–2000
(New type)

2000–present

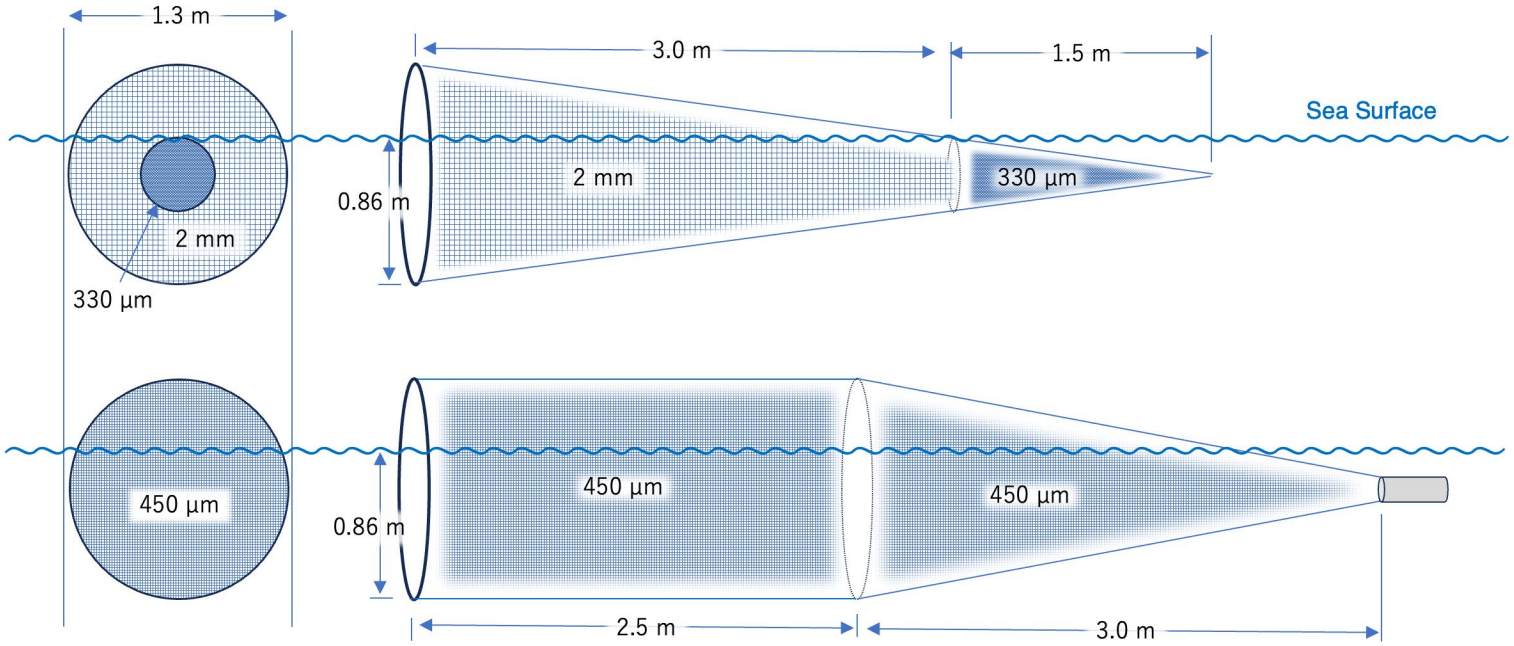


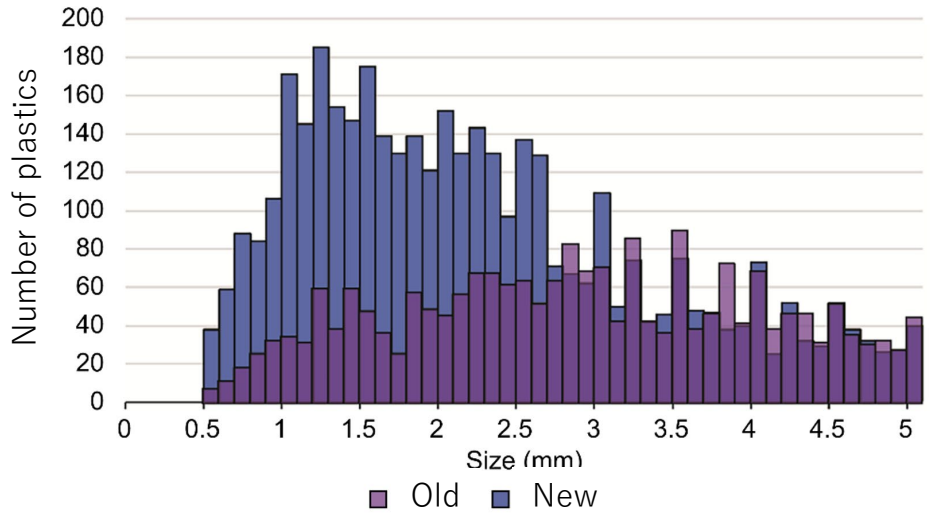
Plankton nets used for the monitoring

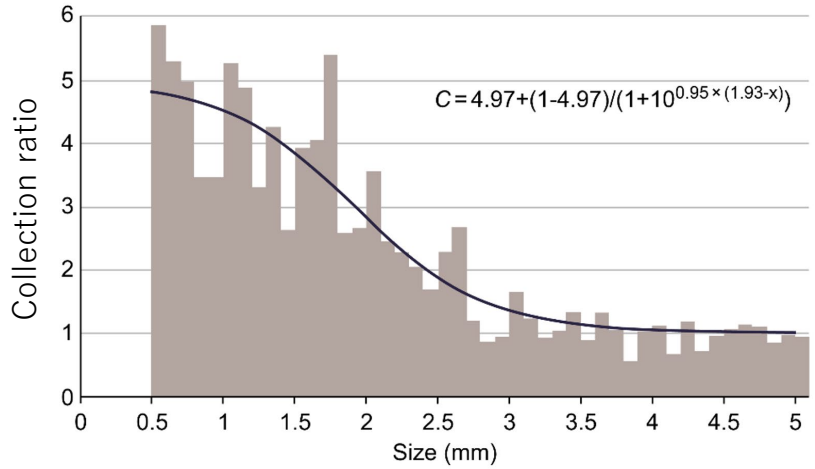
Surface ring net

1949–1988
(Old type)

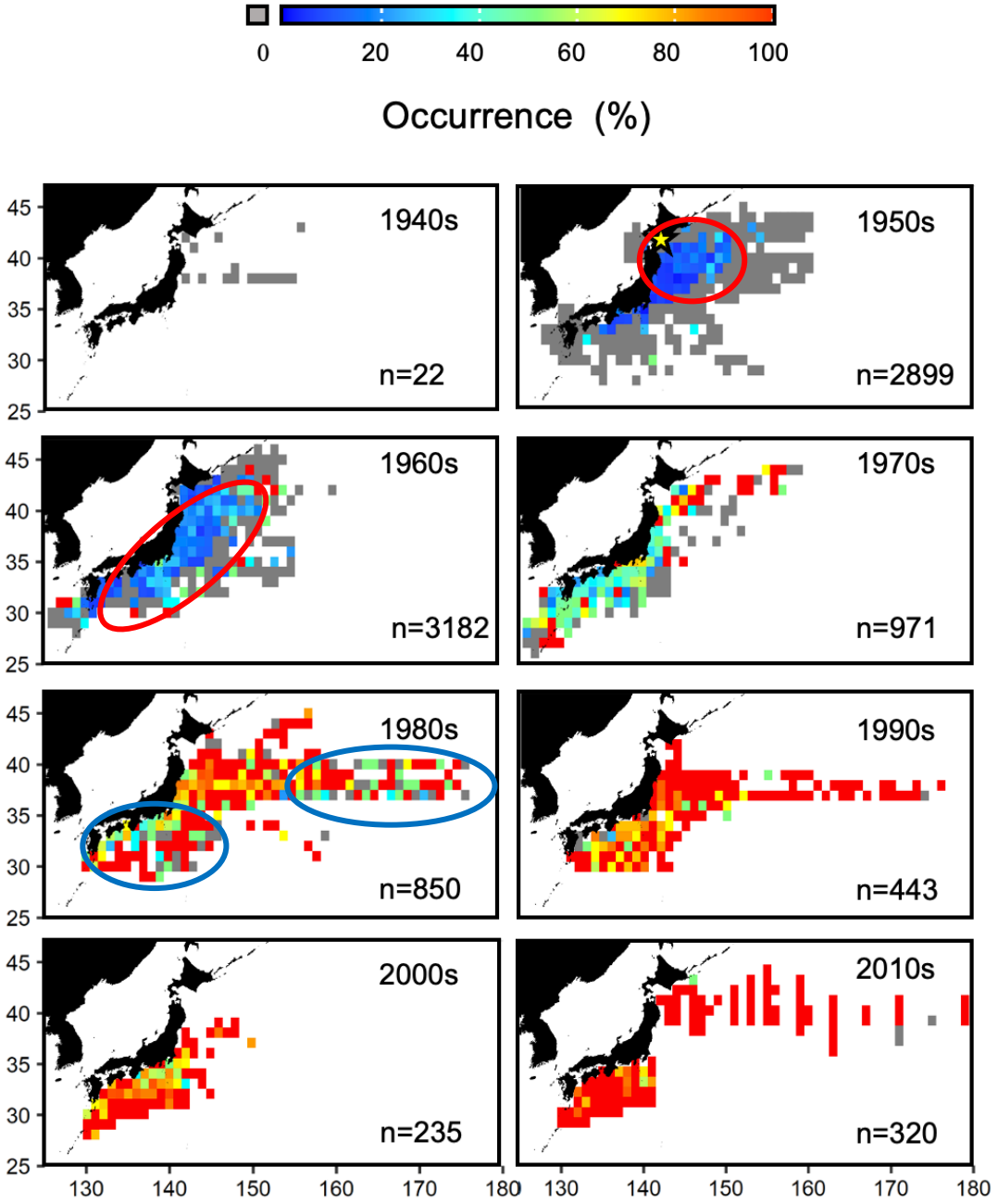
1987–2000
(New type)







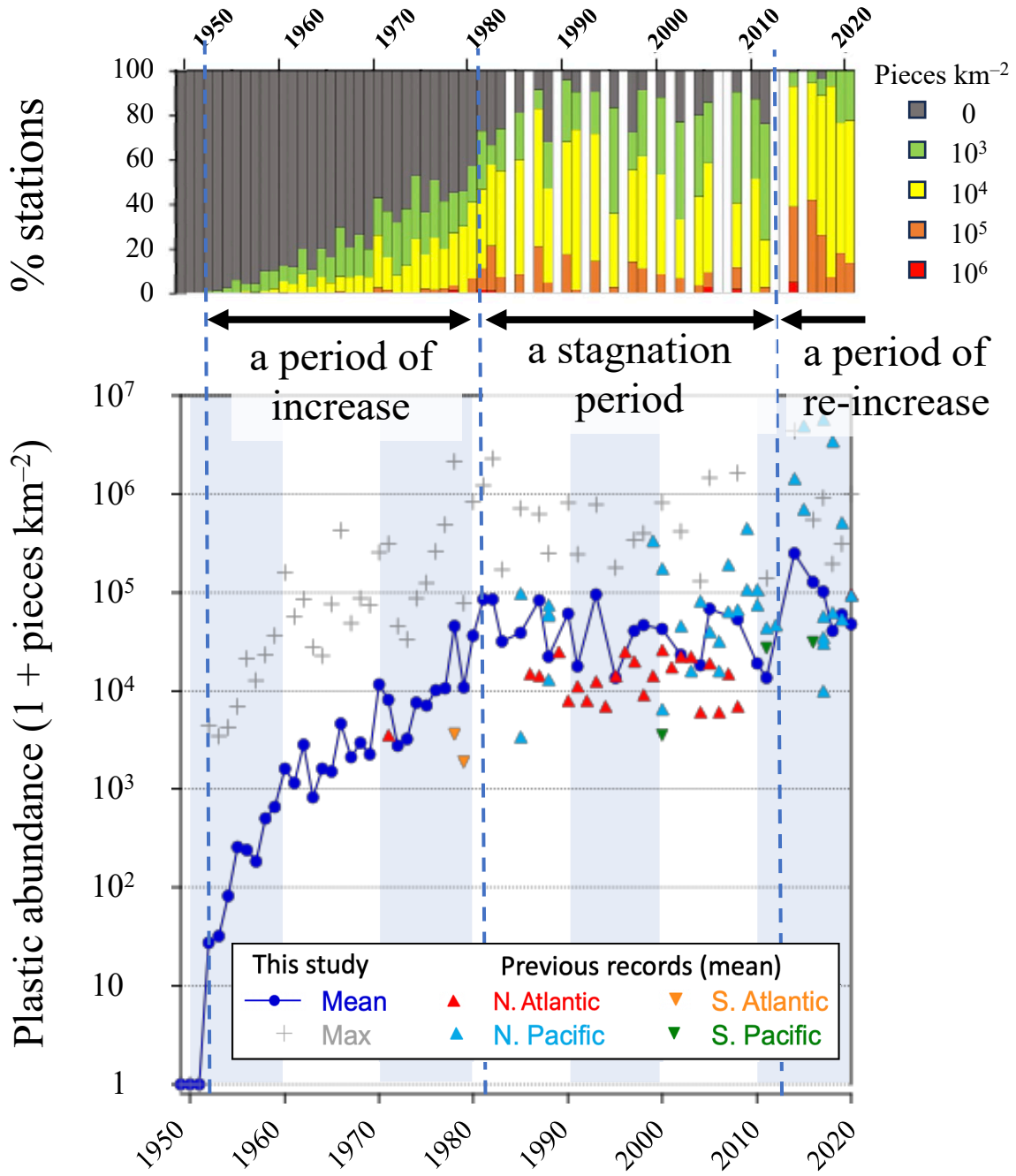
Spatiotemporal change in distribution (%occurrence)



- ✓ No plastic debris collected between 1949 and 1951
- ✓ Area with plastics expanded to western Japan, while the occurrence remained at a low level (~20 %)
- ✓ % of occurrence increased to ~90% in the most stations
- ✓ Lower frequency (0–60 %) stations still existed in western Japan and offshore areas

- ✓ Earliest instance was observed in 1952, off the coast of Aomori (☆)
- ✓ Plastic pollution begun from the northeastern Japan in 1950s
- ✓ % of occurrence increased to ~50% throughout the Pacific coast in Japan
- ✓ Plastic debris occurred in almost all stations, including offshore areas in 1990s onwards

Long-term change of plastic pollution around Japan



1) A period of increase (1952–1970s)

- ✓ Exponential increase: 1000 times in 30 years
  →Lagely corresponds to plastic production in Japan

First report of the actual abundance of plastic debris before 1970

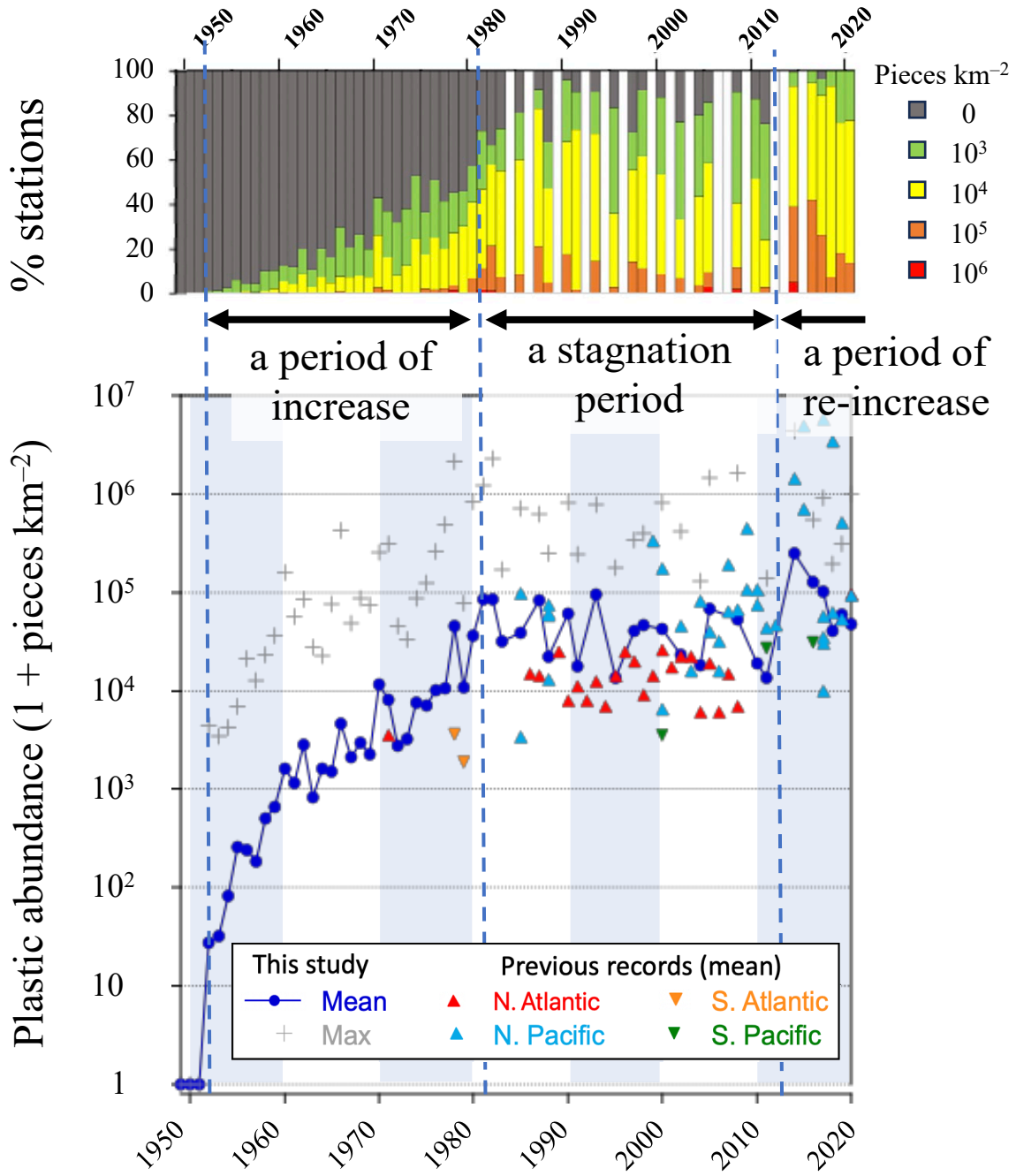
2) A stagnation period (1980s–early 2010s)

- ✓ Fluctuated between 10^4 and 10^5 pieces/km2, despite the continuous increase in the domestic plastic production

3) A period of re-increase (mid-2010s–2020)

- ✓ Extremely high plastic debris densities ($\geq 10^5$ pieces/km^2) and disappearance of stations with no plastic debris

Long-term change of plastic pollution around Japan



1) A period of increase (1952–1970s)

- ✓ Exponential increase: 1000 times in 30 years
  →Lagely corresponds to plastic production in Japan

First report of the actual abundance of plastic debris before 1970

2) A stagnation period (1980s–early 2010s)

- ✓ Fluctuated between 10^4 and 10^5 pieces/km2, despite the continuous increase in the domestic plastic production

3) A period of re-increase (mid-2010s–2020)

- ✓ Extremely high plastic debris densities ($\geq 10^5$ pieces/km^2) and disappearance of stations with no plastic debris

Trends found in 2) and 3) are largely consistent with previous reports on the North Pacific and other area

Global trends

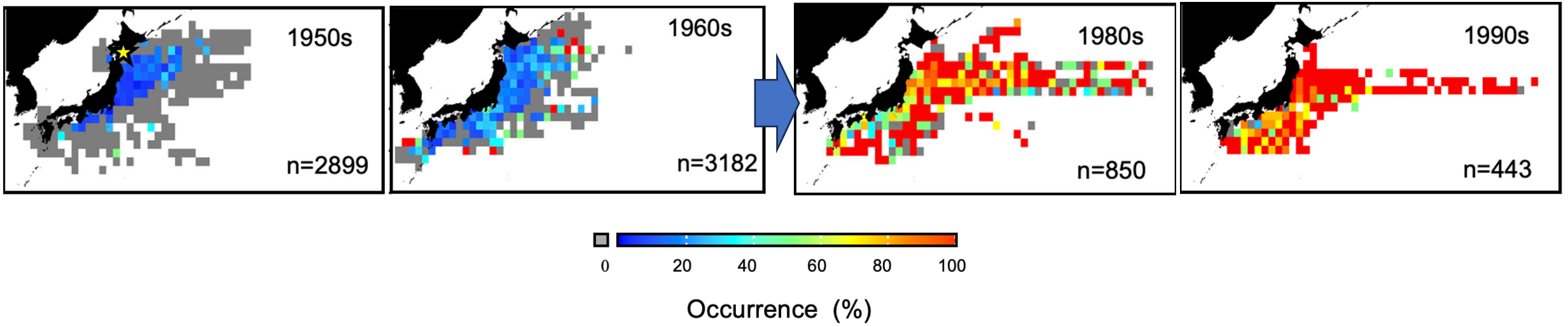
Long-term change of plastic pollution around Japan

2) A stagnation period (1980s–early 2010s)

Why didn't plastic debris abundance increase?

1) **Legislation** since the 1970s may have reduced the discharge of plastic from Japan into the surrounding oceans.

2) **Offshore dispersal** of plastic debris, resulting in density dilution and, consequently, a suppression in the apparent increase of plastic abundance per unit area.



Long-term change of plastic pollution around Japan

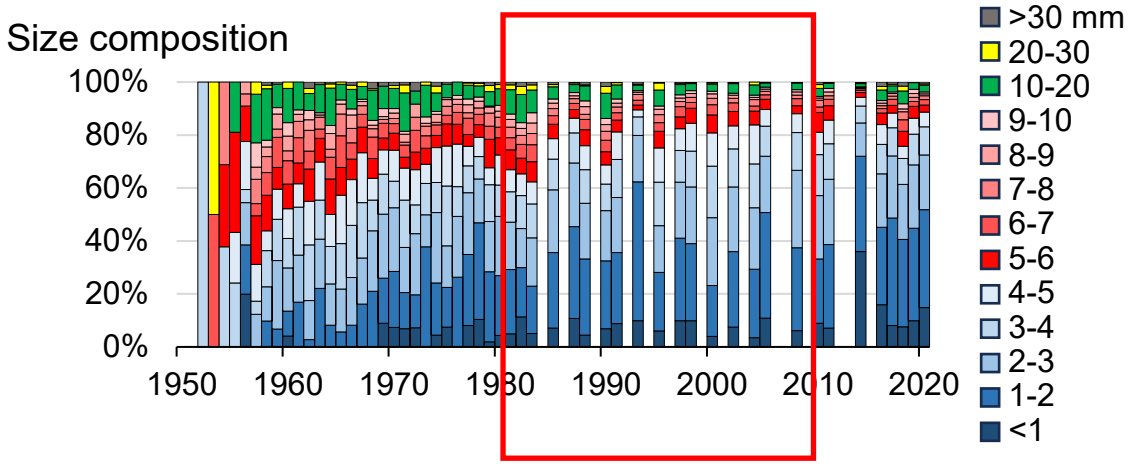
2) A stagnation period (1980s–early 2010s)

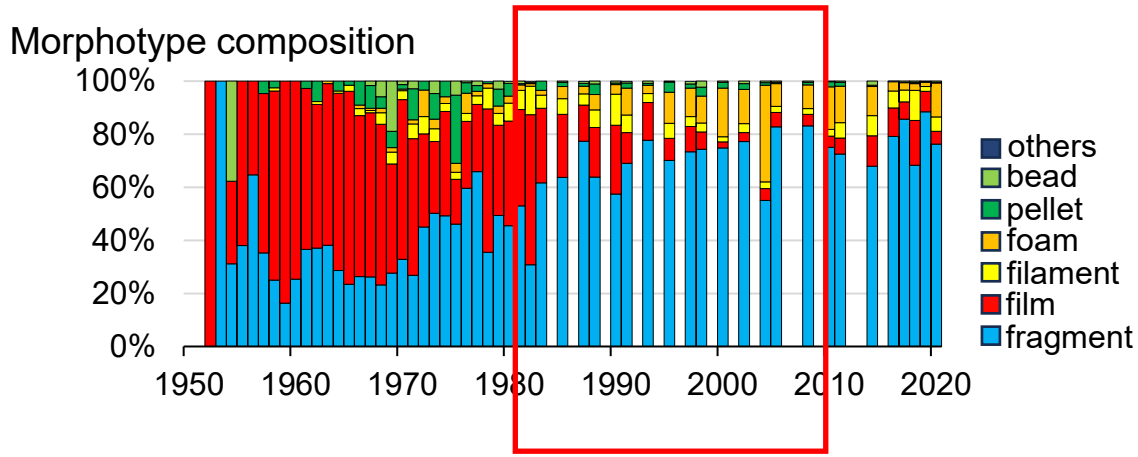
Why didn't plastic debris abundance increase?

1) **Legislation** since the 1970s may have reduced the discharge of plastic from Japan into the surrounding oceans.

2) **Offshore dispersal** of plastic debris, resulting in density dilution and, consequently, a suppression in the apparent increase of plastic abundance per unit area.

The increase in small-sized fragment- and foram-type plastic debris might have enhanced their offshore transport.





Long-term change of plastic pollution around Japan

2) A stagnation period (1980s–early 2010s)

Why didn't plastic debris abundance increase?

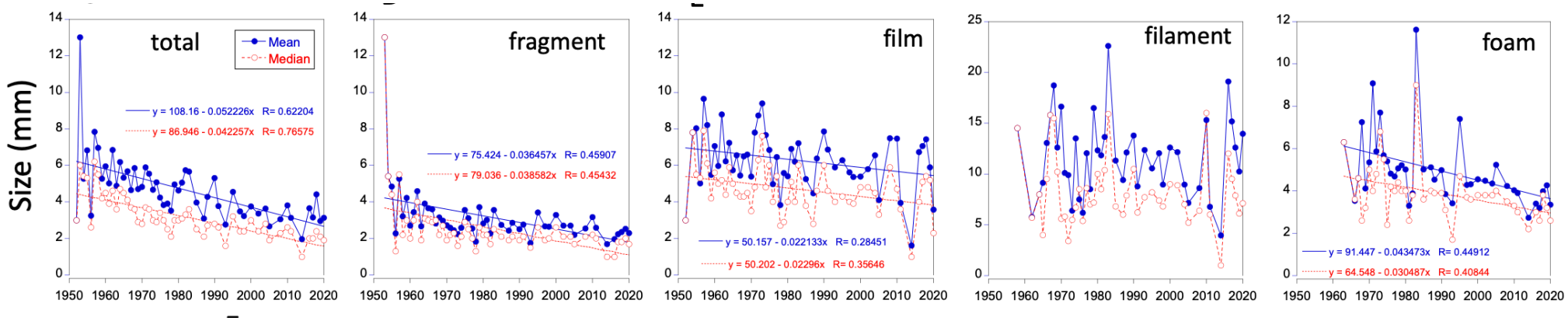
1) **Legislation** since the 1970s may have reduced the discharge of plastic from Japan into the surrounding oceans.

2) **Offshore dispersal** of plastic debris, resulting in density dilution and, consequently, a suppression in the apparent increase of plastic abundance per unit area.

The increase in small-sized fragment- and foram-type plastic debris might have enhanced their offshore transport.

3) **Accumulation on beaches (beaching)** might have contributed to preventing the increase in the abundance of plastic.

Long-term successive size decreases indicate the growth of a reservoir supplying degraded plastic, i.e., beaches



Long-term change of plastic pollution around Japan

2) A stagnation period (1980s–early 2010s)

Why didn't plastic debris abundance increase?

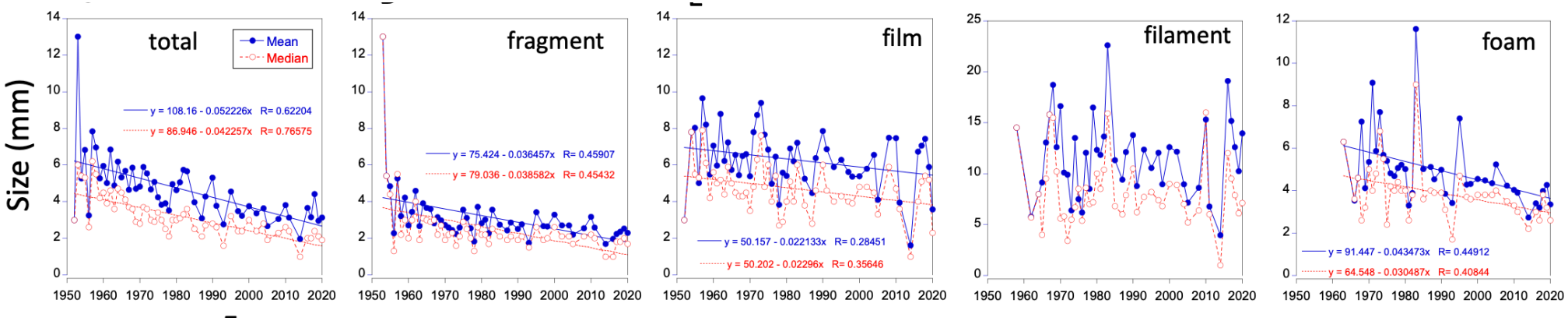
1) **Legislation** since the 1970s may have reduced the discharge of plastic from Japan into the surrounding oceans.

2) **Offshore dispersal** of plastic debris, resulting in density dilution and, consequently, a suppression in the apparent increase of plastic abundance per unit area.

The increase in small-sized fragment- and foram-type plastic debris might have enhanced their offshore transport.

3) **Accumulation on beaches (beaching)** might have contributed to preventing the increase in the abundance of plastic.

Long-term successive size decreases indicate the growth of a reservoir supplying degraded plastic, i.e., beaches



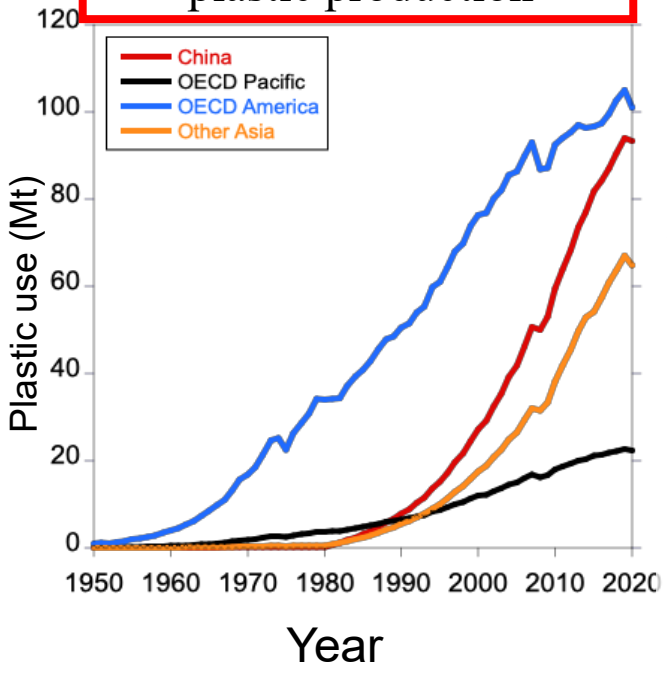
4) **Sedimentation** might have enhanced due to the size reduction of plastic, resulting in rapid elimination from the OSL as aggregates by phytoplankton and/or zooplankton ingestion/defecation

Long-term change of plastic pollution around Japan

3) A period of re-increase (mid-2010s–2020)

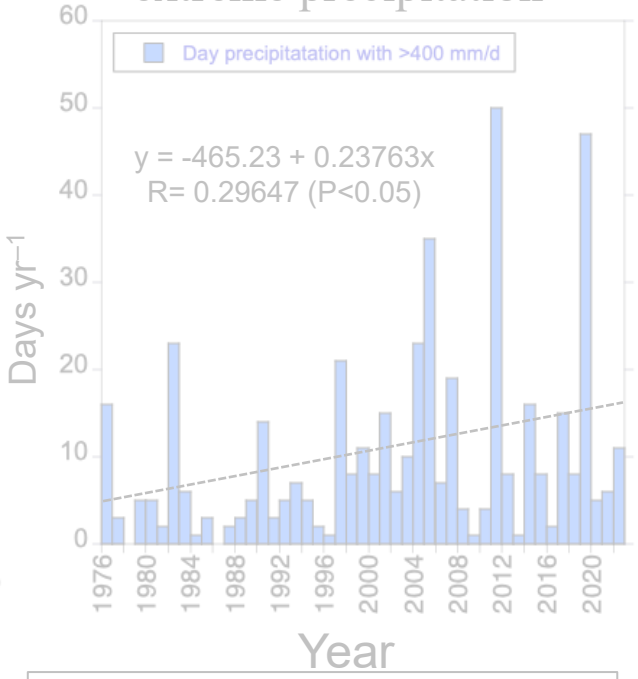
Why has plastic started to increase again?

Gobal increase in plastic production



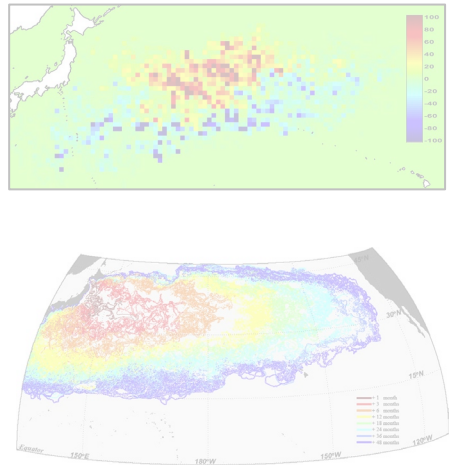
Plastic production has increased dramatically in China and non-OECD) Asian countries and has far surpassed that of Japan since the 1990s

Recent increase in extreme precipitation



Extreme heavy rain partly due to climate change may have contributed to the increase in plastic inflows from rivers debris.

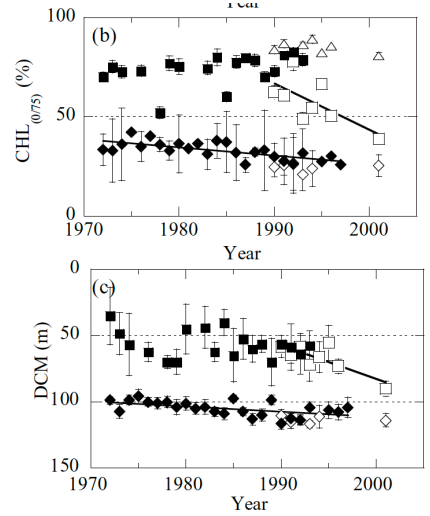
The 11, March 2011 Tohoku tsunami



(Lebreton et al. 2013)

The tsunami released more than 13 times the total amount of plastic contained in the Atlantic Ocean into the Pacific Ocean, and the plastic spread to the WNP within a year

Decrease in the primary productivity



(Ishida et al. 2009)

A decrease in the sediment-removal potential by phytoplankton aggregation may also have contributed to the increase in plastic

The recent increase in microplastics suggests that plastic discharge is outpacing its removal capacity

Summary for long-term fluctuation of ocean surface plastic debris

- We present a long-term empirical dataset (70 years) on floating marine plastic debris collected from 1949 to 2020 around Japan in the western North Pacific.

- Three periods were detected in plastic pollution on the OSL
  1) a period of increase (0–10^4 pieces/km^2) from the 1952 (first incident) to the 1970s;
  2) a stagnation period, with high abundance (10^4–10^5 pieces/km^2), from the 1980s to the early 2010s
  3) a period of re-increase (>10^5 pieces/km^2), from the mid-2010s to the present.

- The shift from film to fragmented plastic in the 1980s and the continuous downsizing may have caused the expansion of the offshore polluted area, resulting in the stagnation period by enhancing surface removal.

- The recent increase in microplastics suggests that plastic discharge is now outpacing its surface removal capacity, suggesting that the impact of pollution on ocean surface biota is becoming increasingly evident.

Please check the details in

Miyazono et al. (2025) Long-term changes in the abundance, size, and morphotype of marine plastics in North Pacific. *Environmental Science & Technology*, 59: 4608-4617

Utilization of archived fisheries samples for plastic monitoring

Disadvantages:

- The sampling gear differs from the standard equipment, particularly in terms of the net mesh size (450 μm).
- This is not a programme for monitoring plastic; some of the larger debris may be discarded without preservation.

Advantages:

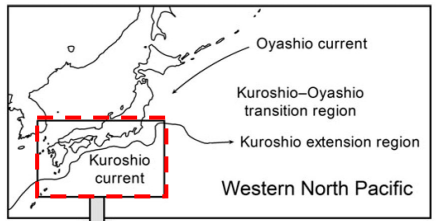
- Grid observation over a wide area, regardless of the quantity of plastic. Enables understanding of average distribution.
- Simultaneous acquisition of data and samples on environmental and biological factors, such as current, water temperature, chlorophyll concentration, zooplankton, and fish larvae.
- Every year, more than 100 samples can be obtained from the same area and season.

But no plan to analyze plastic debris

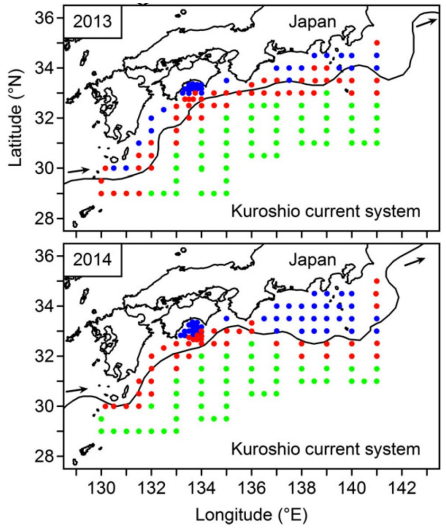
On-going monitoring by Fisheries Research Agency

Possible collaboration with MOE or other organisation?

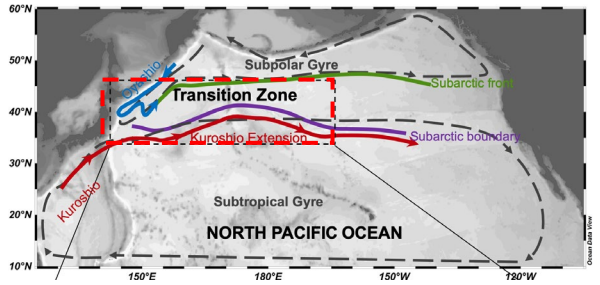
Pacific saury
Spawing ground survey
Kuroshio current
(Feb-May)



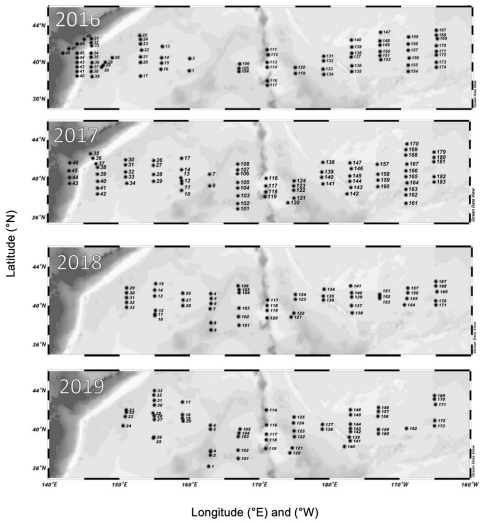
Takasuka et al. 2016



Pacific saury stock assessment in
Transition zone (June-July)



Ishak et al. 2023



Thank you for your attention

This presentation is primarily based on the contents of the references listed below. I would like to express my gratitude to the co-authors.

・Miyazono, K., K. Tadokoro, G. G. N. Thushari, H. Miyamoto, A. Takasuka, M. Watai, T. Yasuda, T. Sato, R. Yamashita, T. Kodama, and K. Takahashi (2025), *Environmental Science & Technology*, 59: 4608-4617

Acknowledgments We would like to thank all those involved in collecting, organizing, and managing the plankton samples over the past 70 years. In particular, C. Kamata and I. Ito made enormous contributions to the sample management and archiving. K. Motoki, A. Nakamura, and N. H. A. Ishak assisted in sorting plastic debris samples. We would also like to thank A. Tsuda and Y. Michida for inspiring us to conduct this study. This study was supported by the University of Tokyo FSI-Nippon Foundation Research Project on Marine Plastics and the Environment Research and Technology Development Fund (Grant no: JPMEERF20221001) of the Environmental Restoration and Conservation Agency of Japan.

日本財団 THE NIPPON FOUNDATION For Social Innovation

独立行政法人 環境再生保全機構 ERCA Environmental Restoration and Conservation Agency

東京大学 THE UNIVERSITY OF TOKYO

国立研究開発法人 水産研究・教育機構