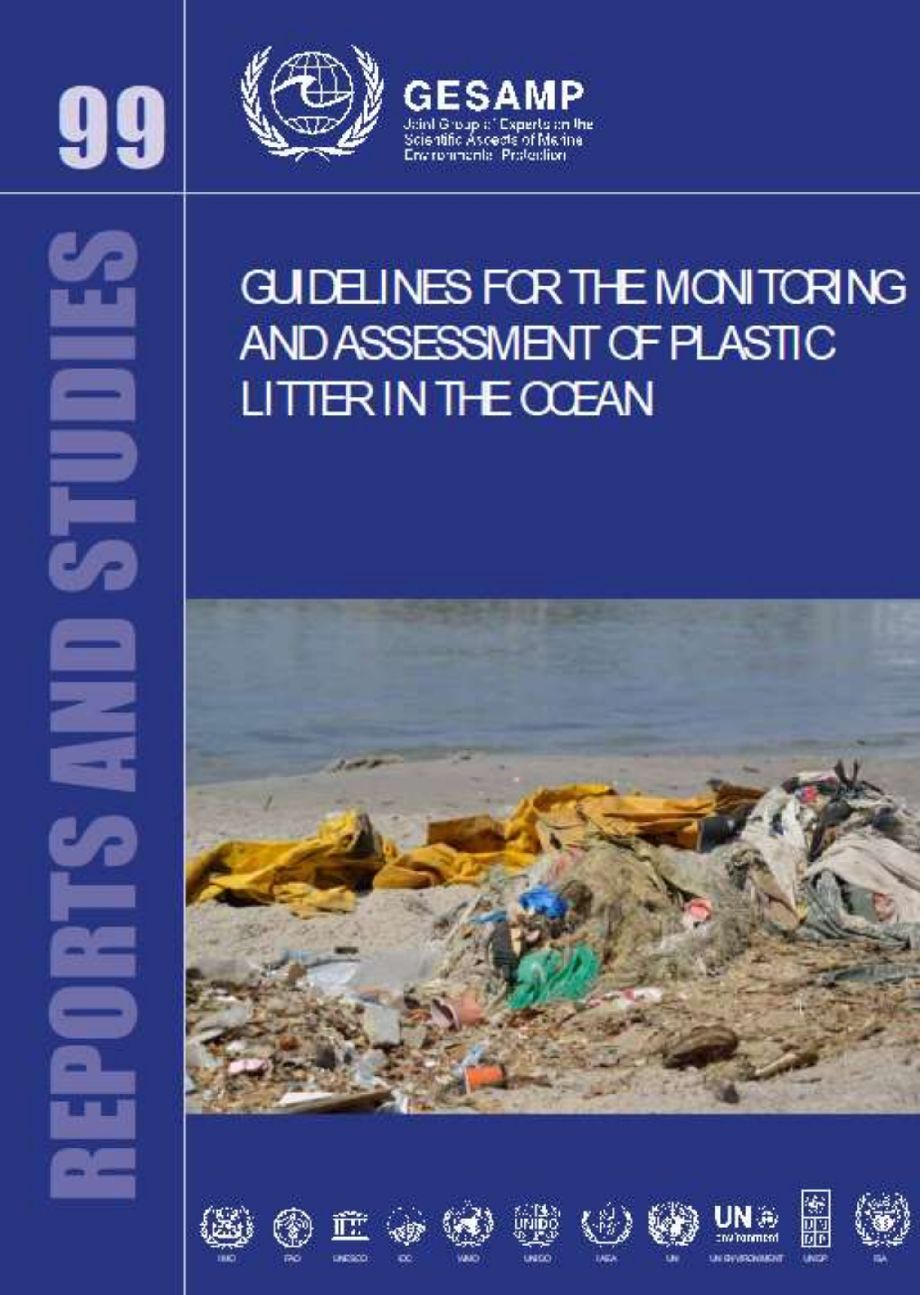
Monitoring marine plastics

Peter Ryan

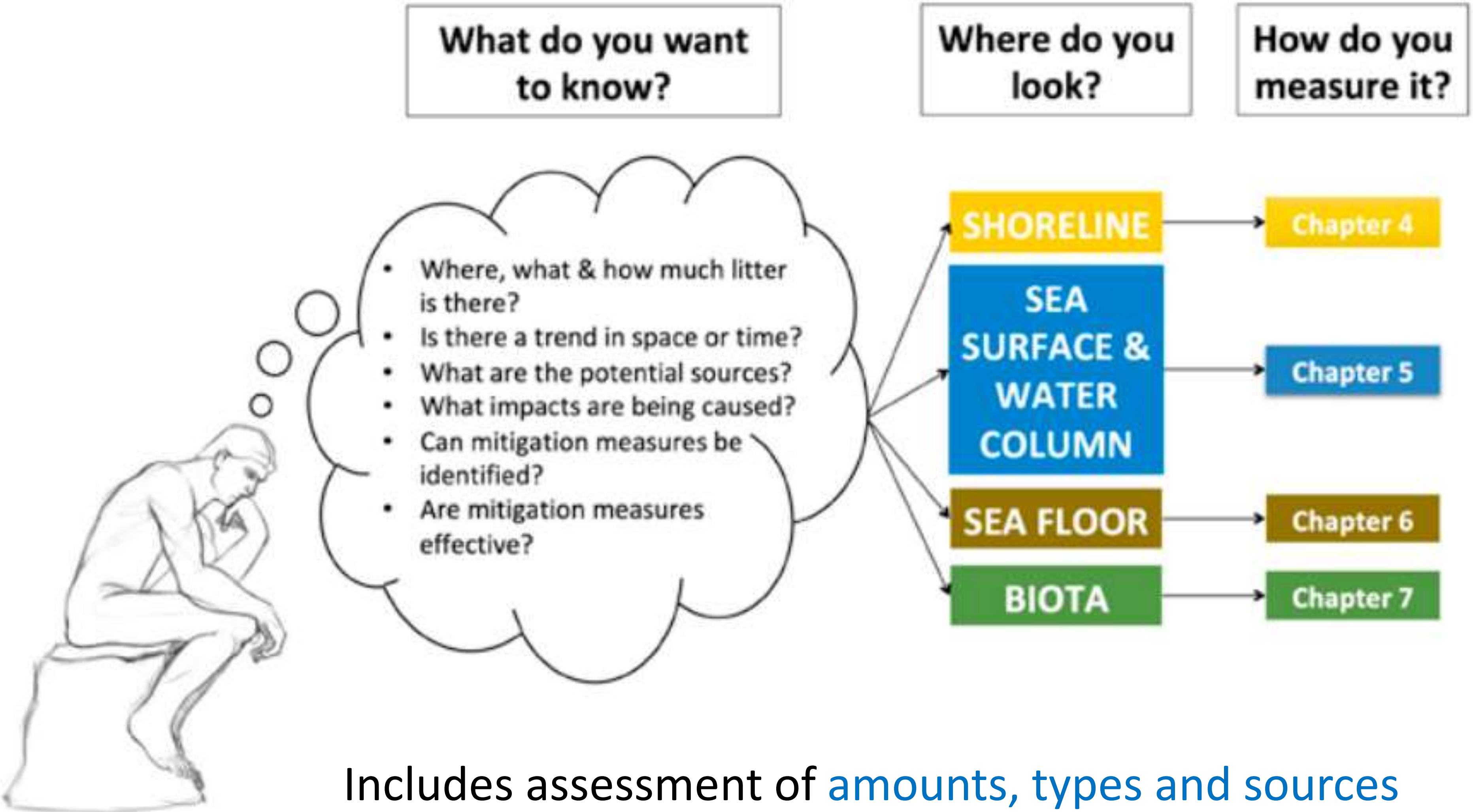


UN Joint Group of Experts on the Scientific Aspects of Marine Environmental Pollution

2019

Kershaw, Turra and Galgani (editors)

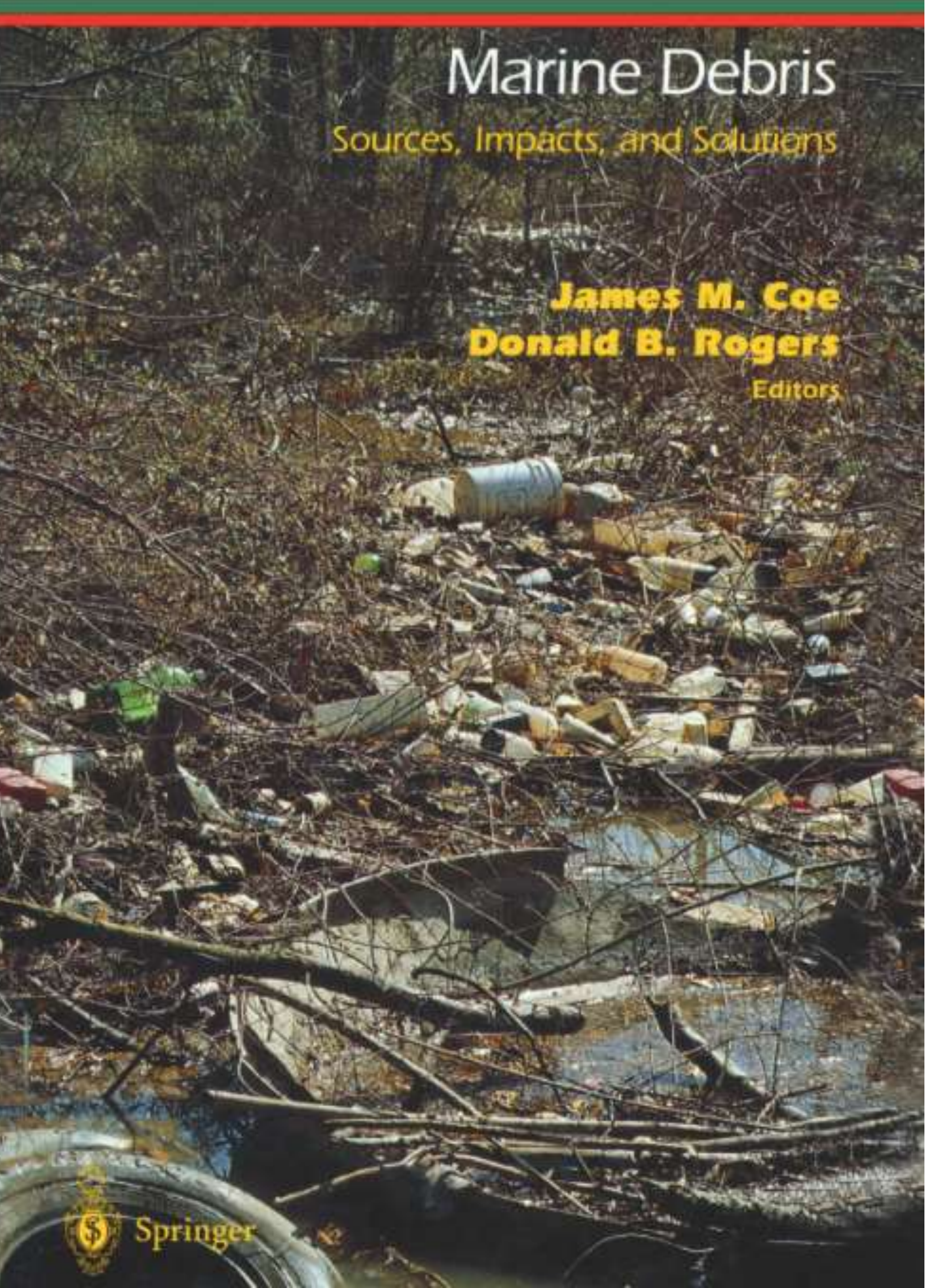
Monitoring should address specific questions



Includes assessment of amounts, types and sources in addition to monitoring

Monitoring = repeated measures over time
to attain a specific goal

Essential to know what your goal is...



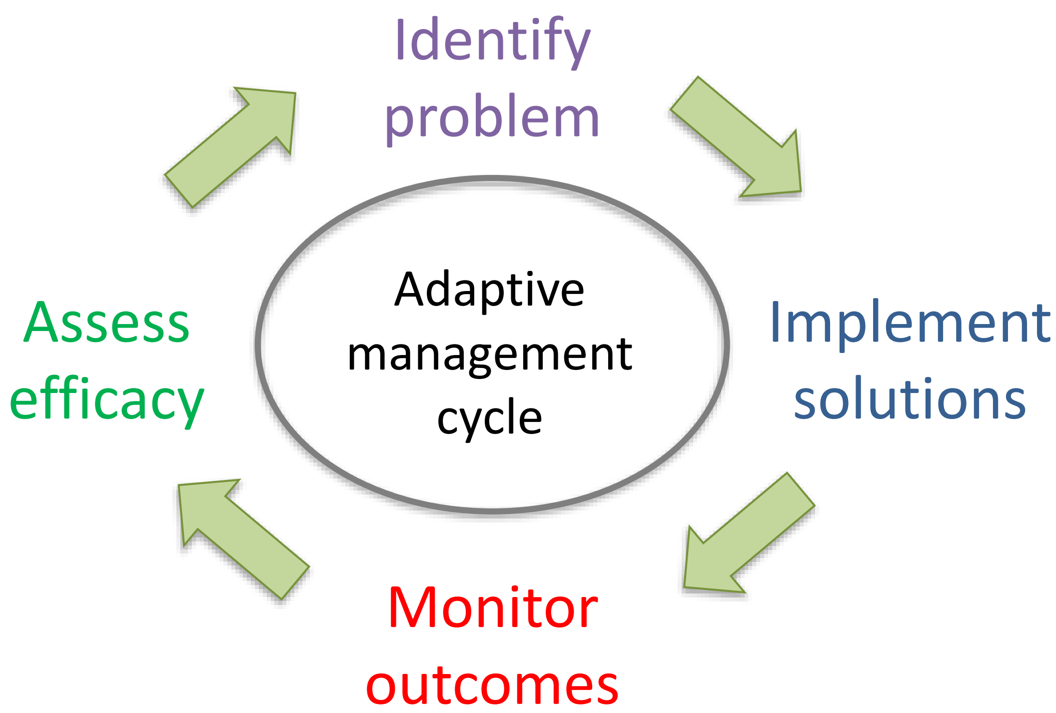
Third International
Marine Debris Conference
Miami 1994

"We know there's
a problem –
need to focus on
solutions"

Primary goal should be
to assess efficacy of
mitigation measures

Monitoring = repeated measures over time to attain a specific goal

- To assess efficacy of mitigation measures key part of the adaptive management cycle



Monitoring = repeated measures over time to attain a specific goal

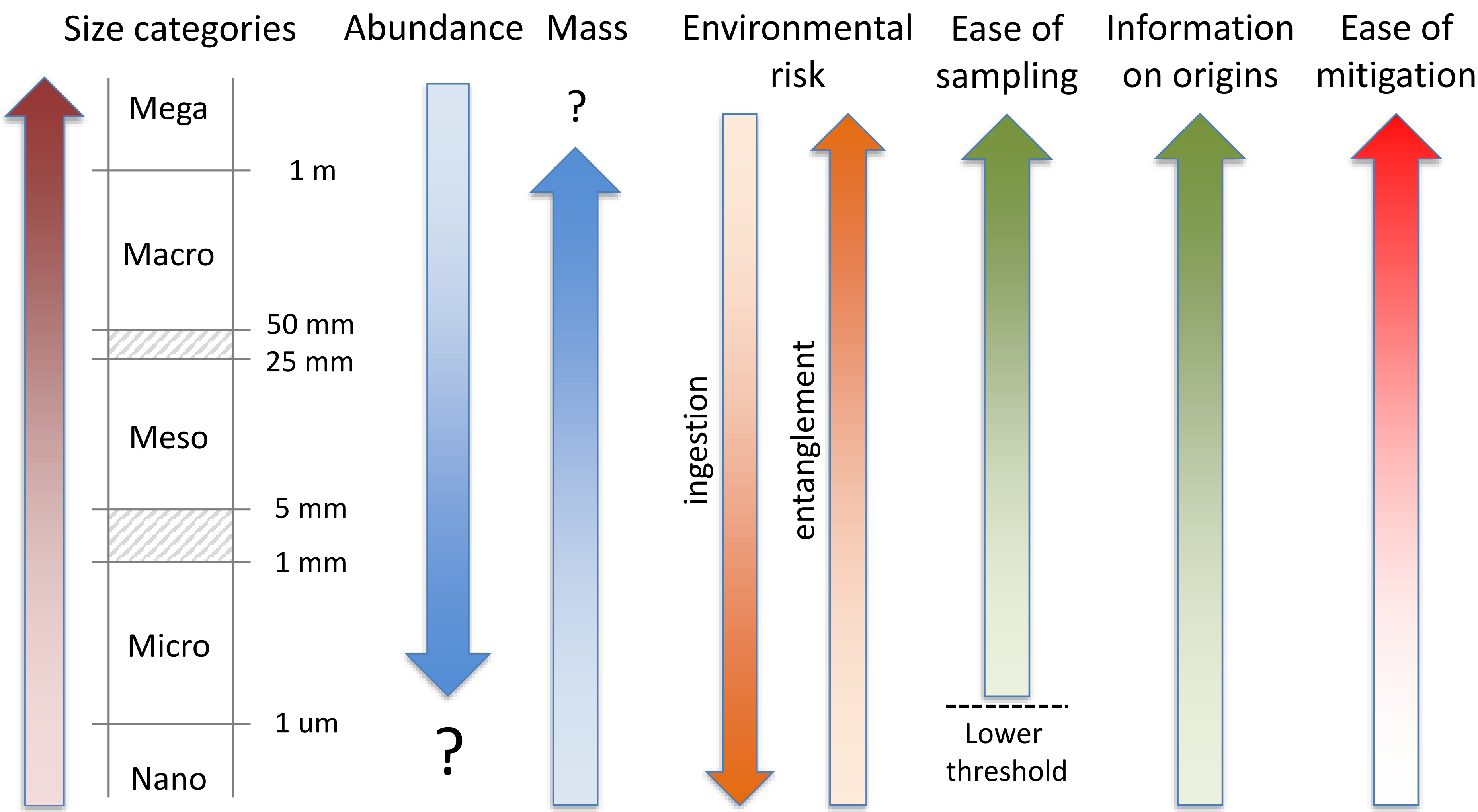
- To assess efficacy of mitigation measures
  key part of the adaptive management cycle

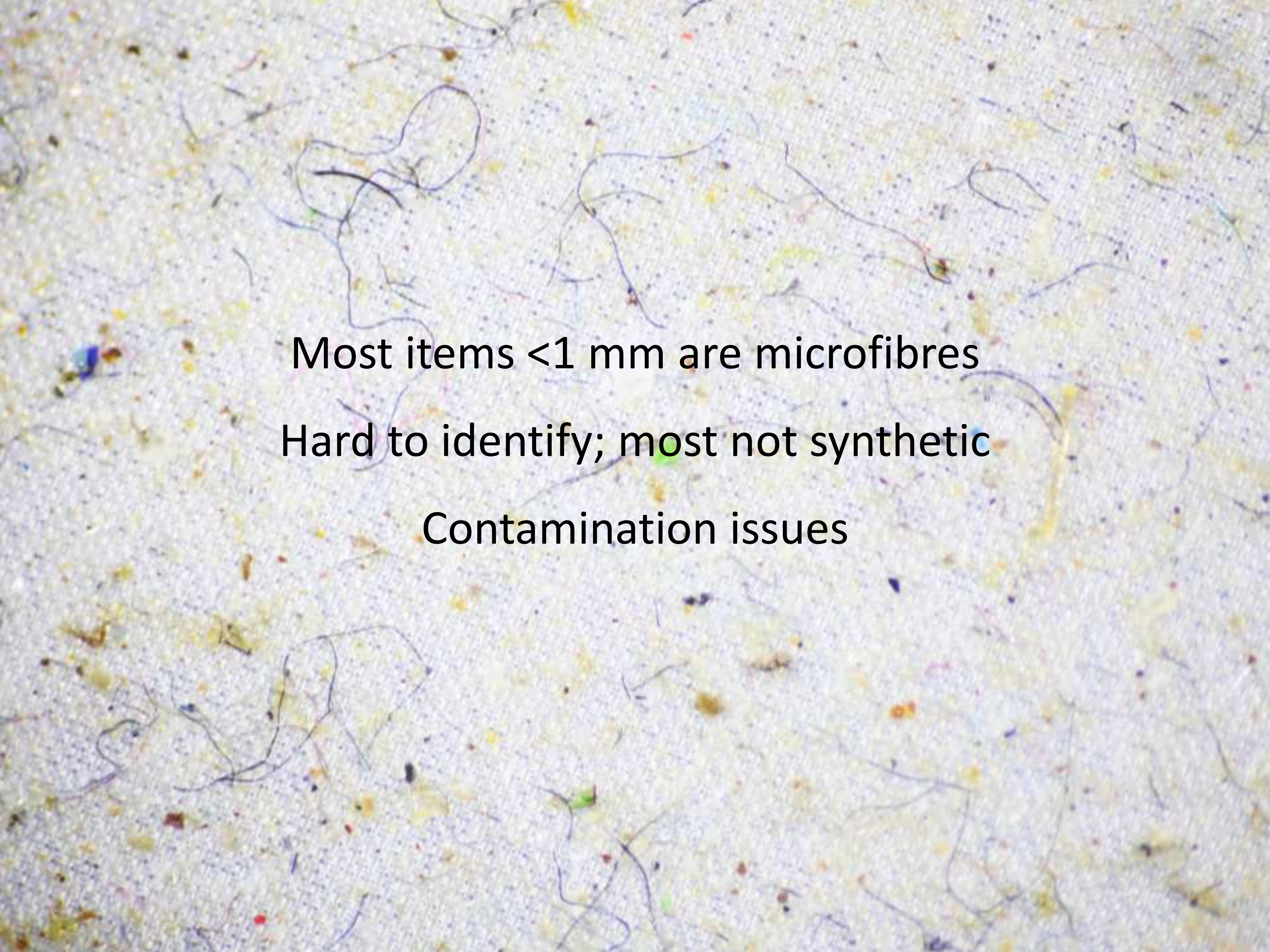
- Identify emerging problems
  (new litter items, new impacts)

Monitoring = repeated measures over time to attain a specific goal

- To assess efficacy of mitigation measures key part of the adaptive management cycle
- Identify emerging problems (new litter items, new impacts)
- Ensure compliance with standards (but few standards for plastics yet)

What sizes of plastics should we monitor?

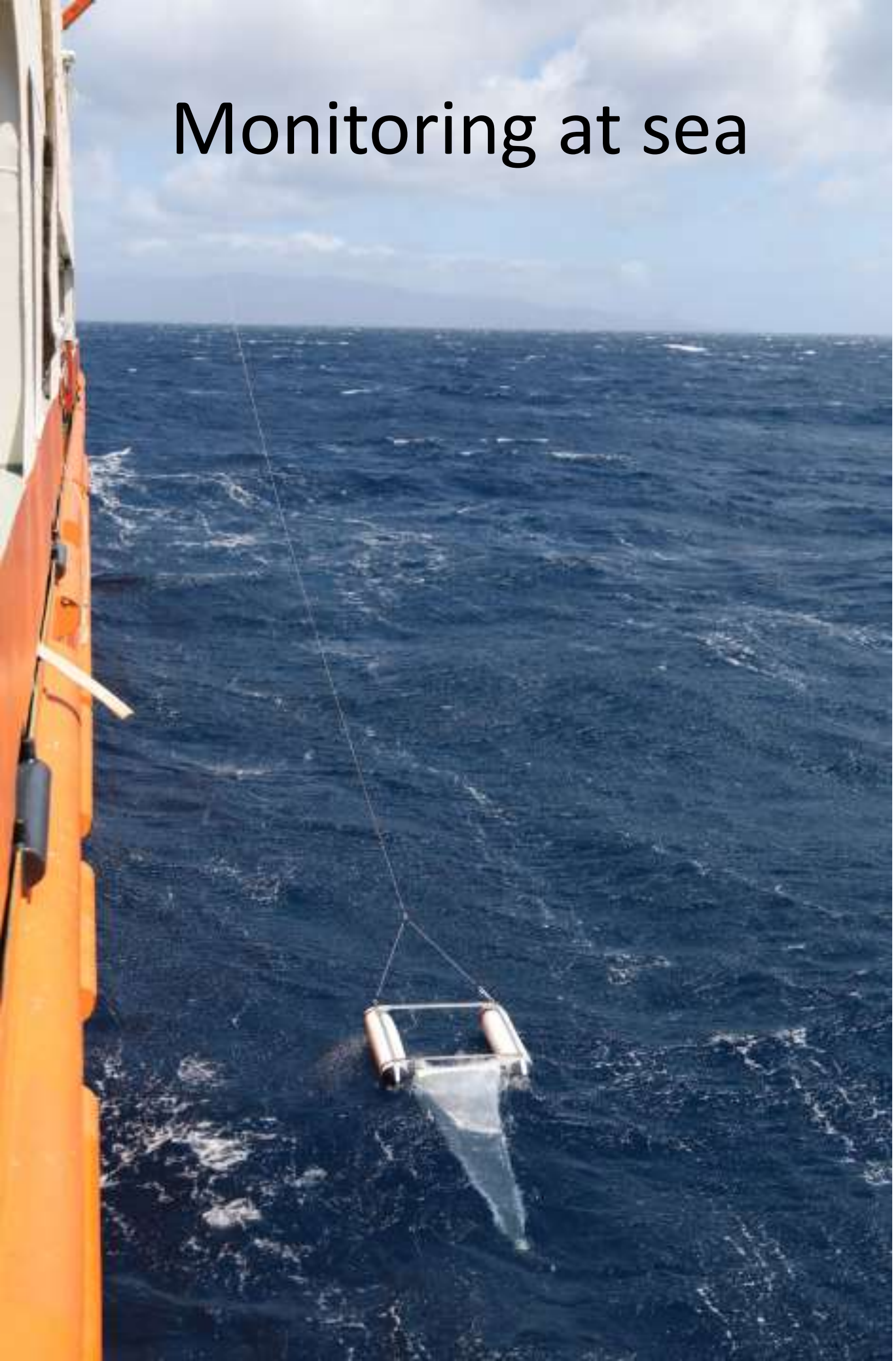



Most items <1 mm are microfibres
Hard to identify; most not synthetic
Contamination issues

Ability to detect change depends on:

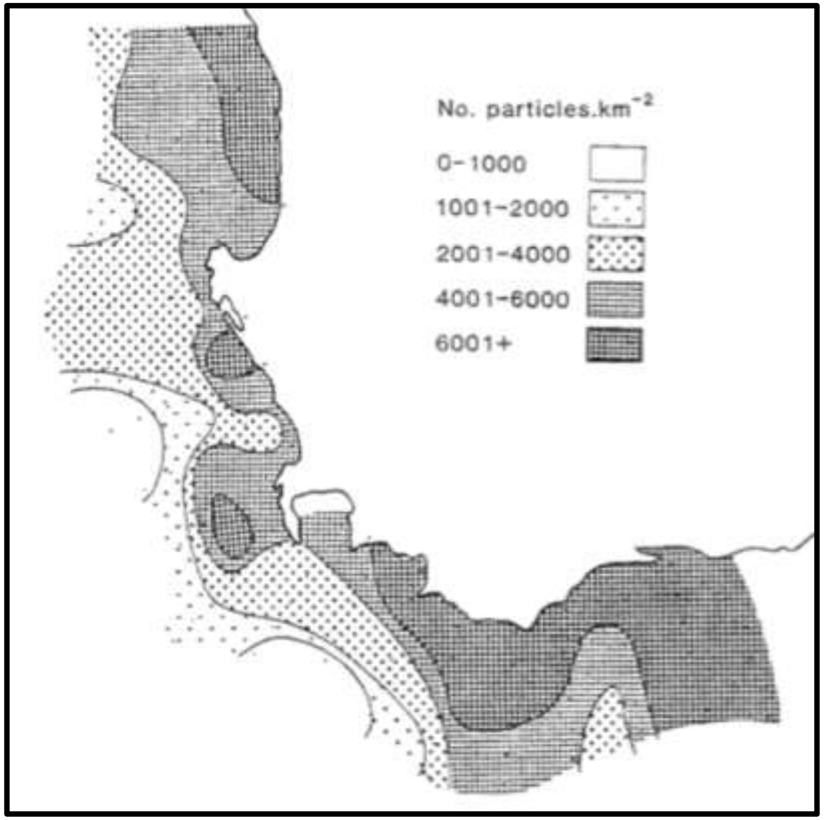
- Rate of change (signal strength)
- Measurement precision – improve by:
  - increasing sample size
  - standardizing techniques
  - minimizing observer effects (training)
- Duration of time series (existing baselines)

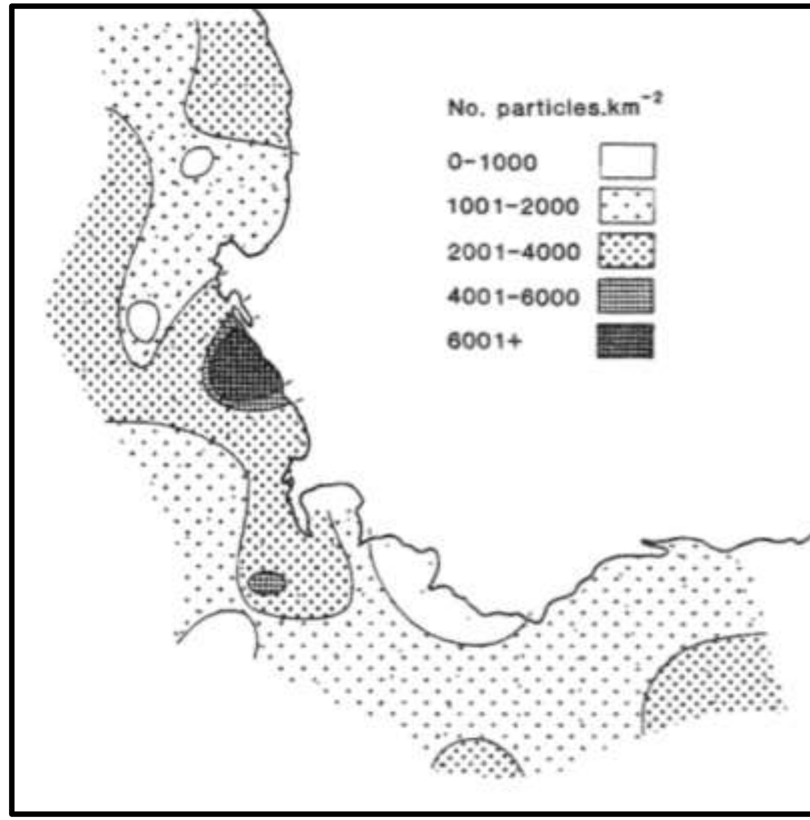
Monitoring at sea



Marine Environmental Research **25** (1988) 249–273

The Characteristics and Distribution of Plastic Particles at the Sea-surface off the Southwestern Cape Province, South Africa





Winter 1977/78 Summer

Marine Environmental Research **25** (1988) 249–273

The Characteristics and Distribution of Plastic Particles at the Sea-surface off the Southwestern Cape Province, South Africa

1224 neuston net samples (900 micron mesh)

Average density (n·km^{-2})	1977/78	2016-2019
Industrial pellets	850	190
All microplastics	3600	11000
% industrial pellets	23%	2%

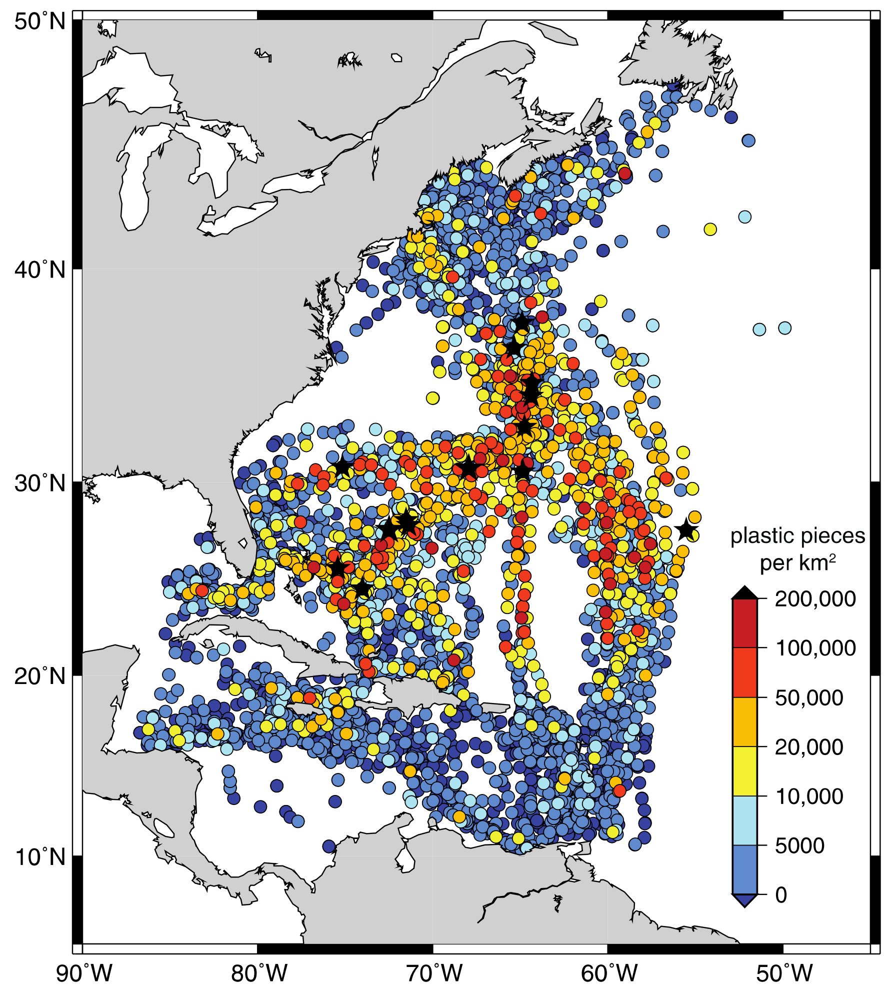
73 net samples in SA EEZ since 2016 (items >1 mm)

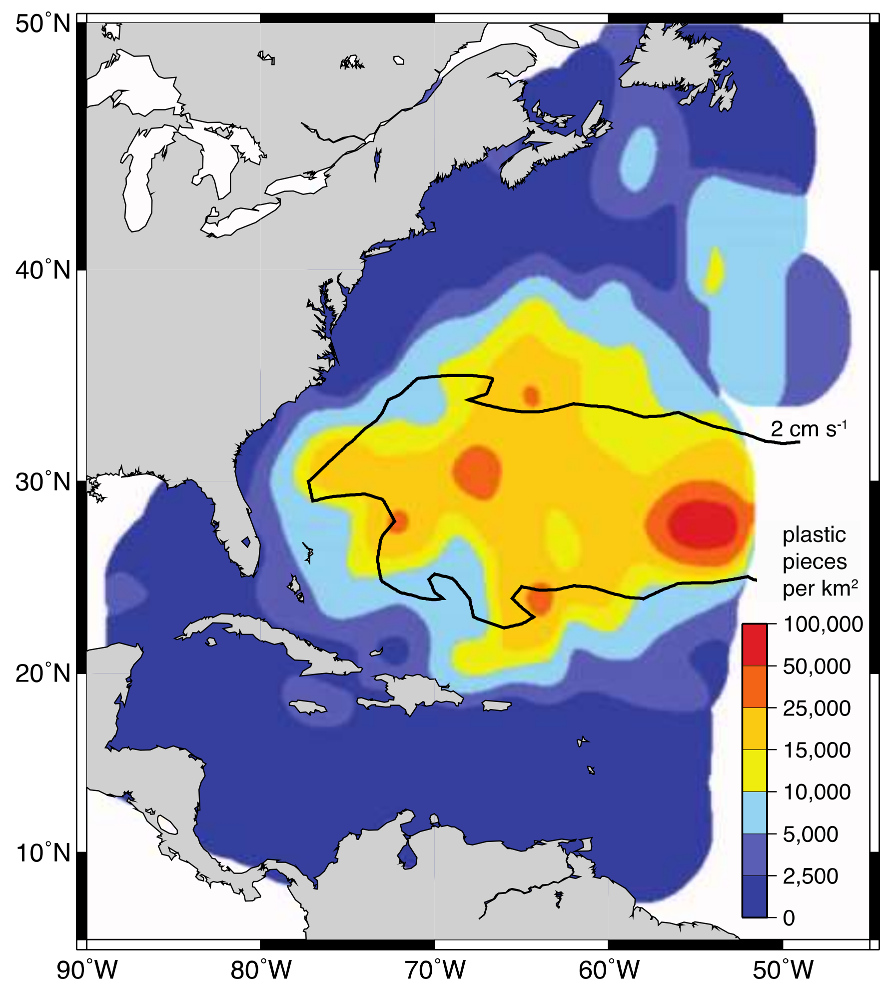
(43 off KwaZulu-Natal, 30 in oceanic waters throughout EEZ)

Plastic Accumulation in the North Atlantic Subtropical Gyre

Kara Lavender Law,[1*] Skye Morét-Ferguson,[1,2] Nikolai A. Maximenko,[3] Giora Proskurowski,[1,2] Emily E. Peacock,[2] Jan Hafner,[3] Christopher M. Reddy[2]

Science, 2010





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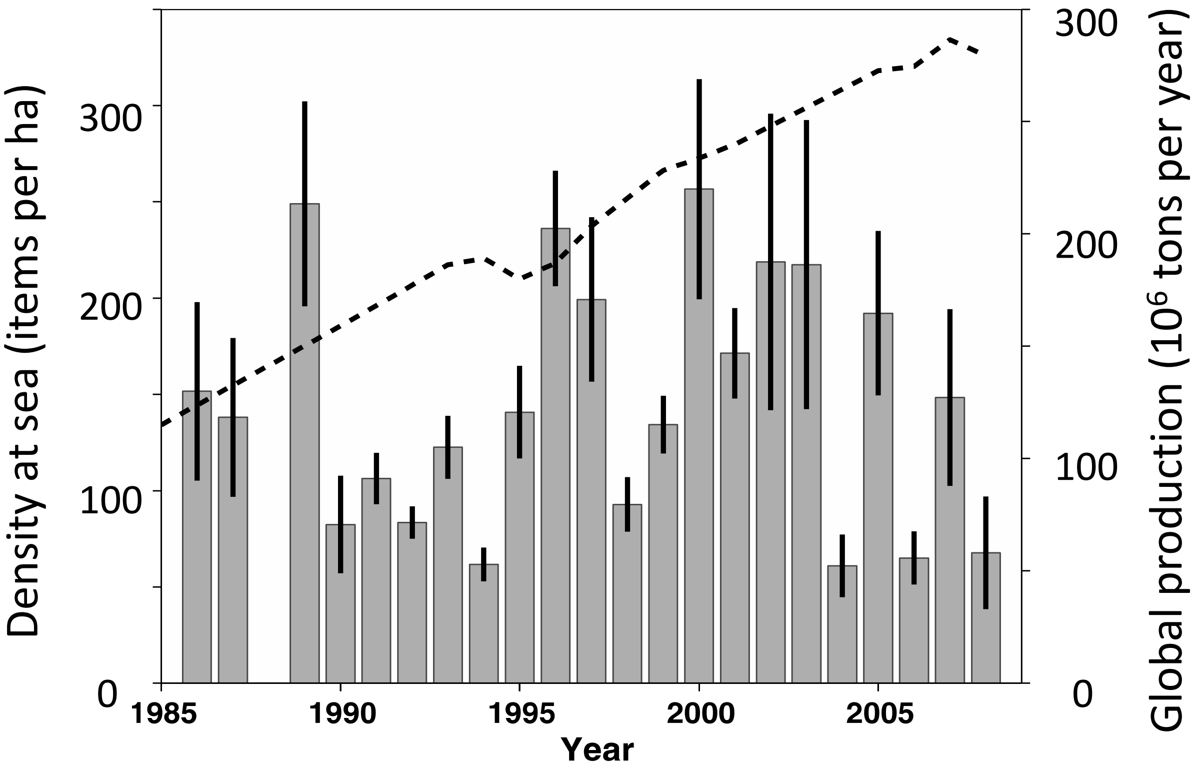


No trend despite >6000 net tows

Small sample area

Fine-scale heterogeneity

Macroplastics at sea

Limited to vessels of opportunity; few regular ship routes

Monitoring seafloor litter

Surveys of False Bay seafloor litter

Low densities of macroplastics at 18 sites in 1991

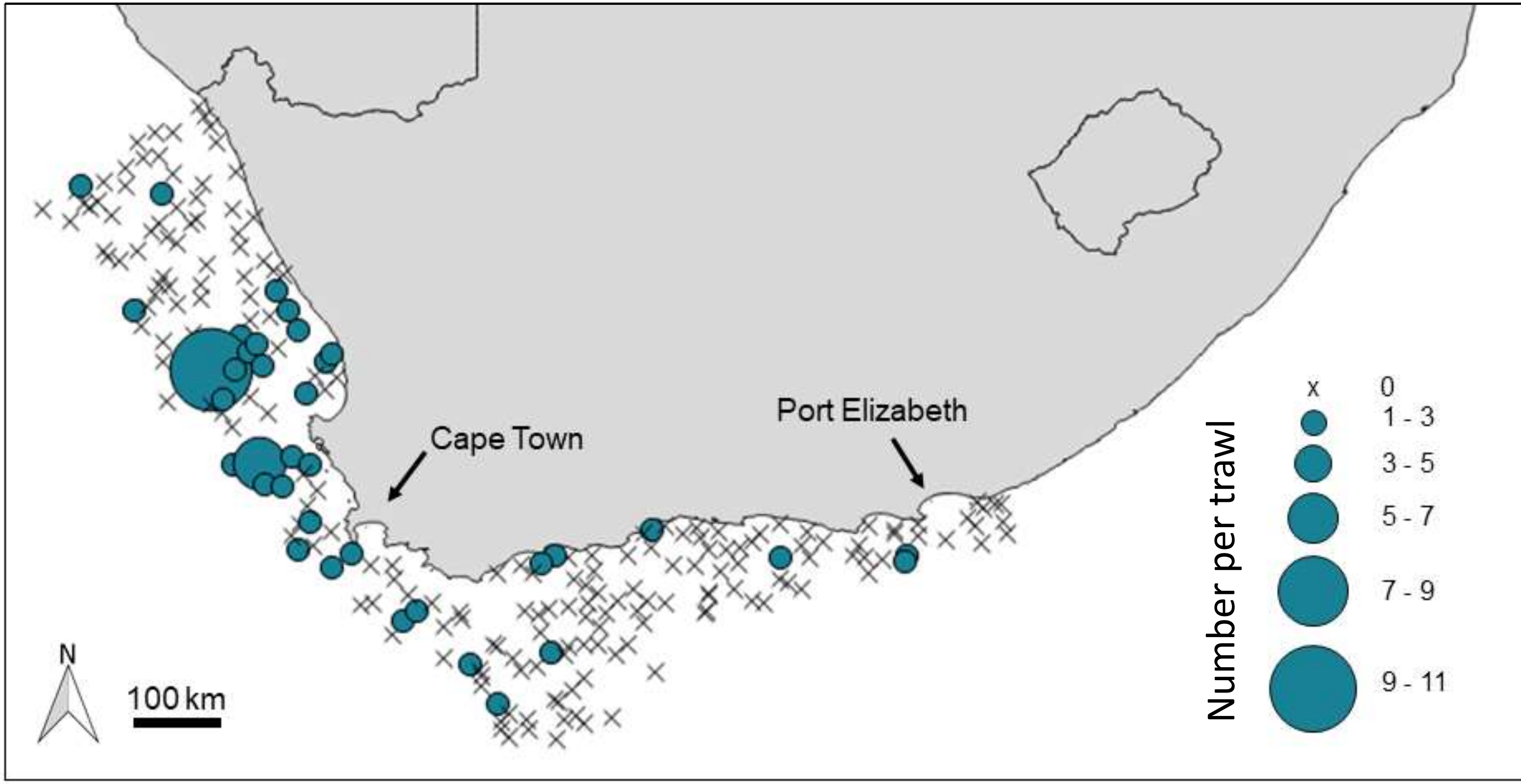
- ~80% flexible packaging (bags and food wrapping)
- ~20% bottles

Rundgren 1992 MSc thesis

Attempt to repeat in 2013 cancelled due to lack of litter

No litter in 421 photos of the False Bay seafloor in 2015

Macrolitter in 235 benthic fish survey trawls (2019)



Low macroplastic density: 3.0 items·km^{-2} and 0.3 kg·km^{-2}

Litter sampling will be added to annual surveys

Monitoring in biota

Ingested plastic in stranded turtles in late 1960s/1970s

Hughes 1970, 1974

	1960-70s	2015
Incidence of ingested plastic	12%	60%
% industrial pellets	70%	3%

Loggerhead Turtle hatchlings in 2015

Ryan et al. 2016

Marine Environmental Research **23** (1987) 175–206

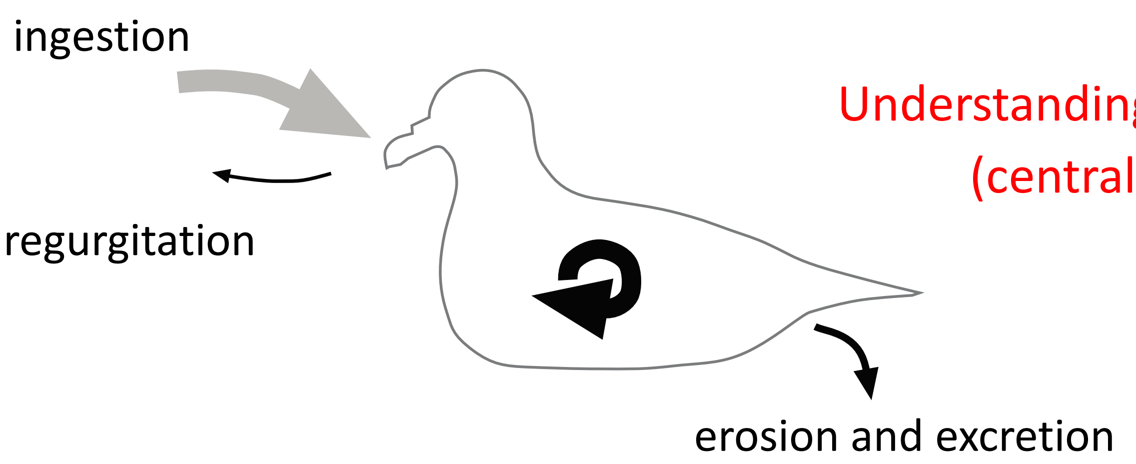
The Incidence and Characteristics of Plastic Particles Ingested by Seabirds

Baseline: plastic in 36 of 60 seabirds species sampled in 1980s (n=3500)

10 species >50% of individuals; 4 species >80 %

The Condor 90:446–452 (1988)

INTRASPECIFIC VARIATION IN PLASTIC INGESTION BY SEABIRDS AND THE FLUX OF PLASTIC THROUGH SEABIRD POPULATIONS



Understanding ingestion dynamics (central to monitoring)

The good old days…

Seabird bycatch

White-chinned Petrel only bycatch species with much plastic

>2000 examined since 1980s; no trend in rate/amount

> 3700 seabird plastic loads examined since 1980s

Greatest change in % industrial pellets: 64% in 1980s, 11% post 2000

Methods in Ecology and Evolution

Methods in Ecology and Evolution 2014 doi: 10.1111/2041-210X.12277

APPLICATION

A biochemical approach for identifying plastics exposure in live wildlife

Britta D. Hardesty*, Daniel Holdsworth, Andrew T. Revill and Chris Wilcox

Preen gland oil is a non-destructive sampling approach for seabirds

Edward D. Goldberg's proposal of “the Mussel Watch”: Reflections after 40 years

John W. Farrington [a,*], Bruce W. Tripp [a], Shinsuke Tanabe [b], Annamalai Subramanian [c], José L. Sericano [d], Terry L. Wade [d], Anthony H. Knap [d]

Marine Pollution Bulletin 110 (2016) 501–510

Mussels already used to monitor a wide range of marine pollutants

Monitoring nest pollutants

Plastic debris as nesting material in a Kittiwake-(Rissa tridactyla)-colony at the Jammerbugt, Northwest Denmark

Eike Hartwig, Thomas Clemens, Mathias Heckroth *

MARINE POLLUTION BULLETIN
2007

The proportion of Kittiwake nests containing plastic at a Danish colony increased from 39% in 1992 to 57% in 2005

Anthropogenic debris in the nests of kelp gulls in South Africa

Minke Witteveen [a,*], Mark Brown [b], Peter G. Ryan [a]

2017

Plastic in Kelp Gull nests is related to distance to dump sites and the availability of alternative nesting material near the colony

Guano island seabirds

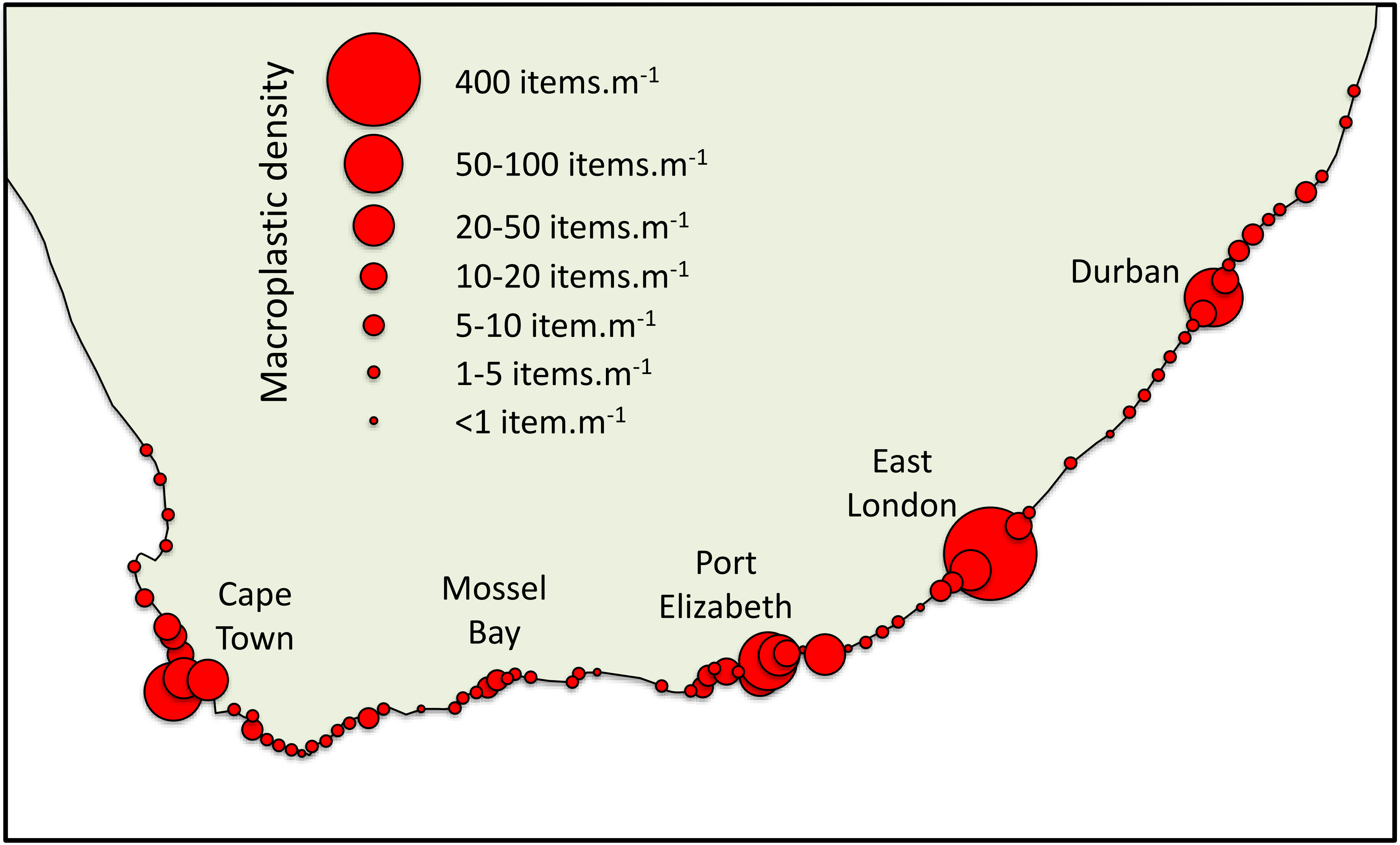
No trend 1992-2000, but marked inter-species and inter-island differences in plastic loads

Monitoring on beaches

Standing stock versus flux

Standing stocks tell us about:

- The abundance and composition of litter
- Identify spatial patterns/hotspots – useful for identifying sources of litter



Urban centres are key sources of macro- and microplastics

Standing stocks tell us about:

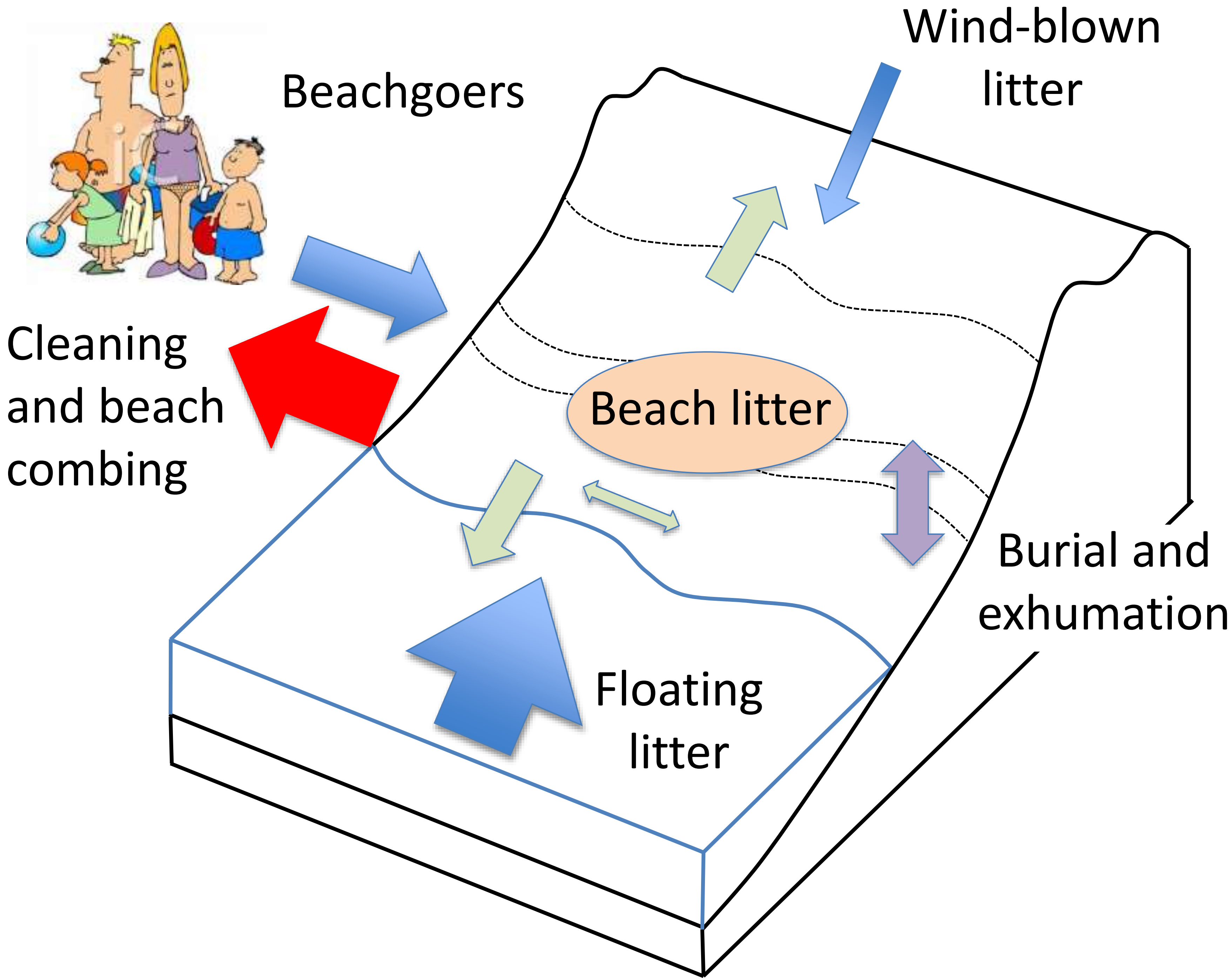
- The abundance and composition of litter
- Identify spatial patterns/hotspots – useful for identifying sources of litter

But not useful for assessing temporal patterns unless you fully understand the turnover rate

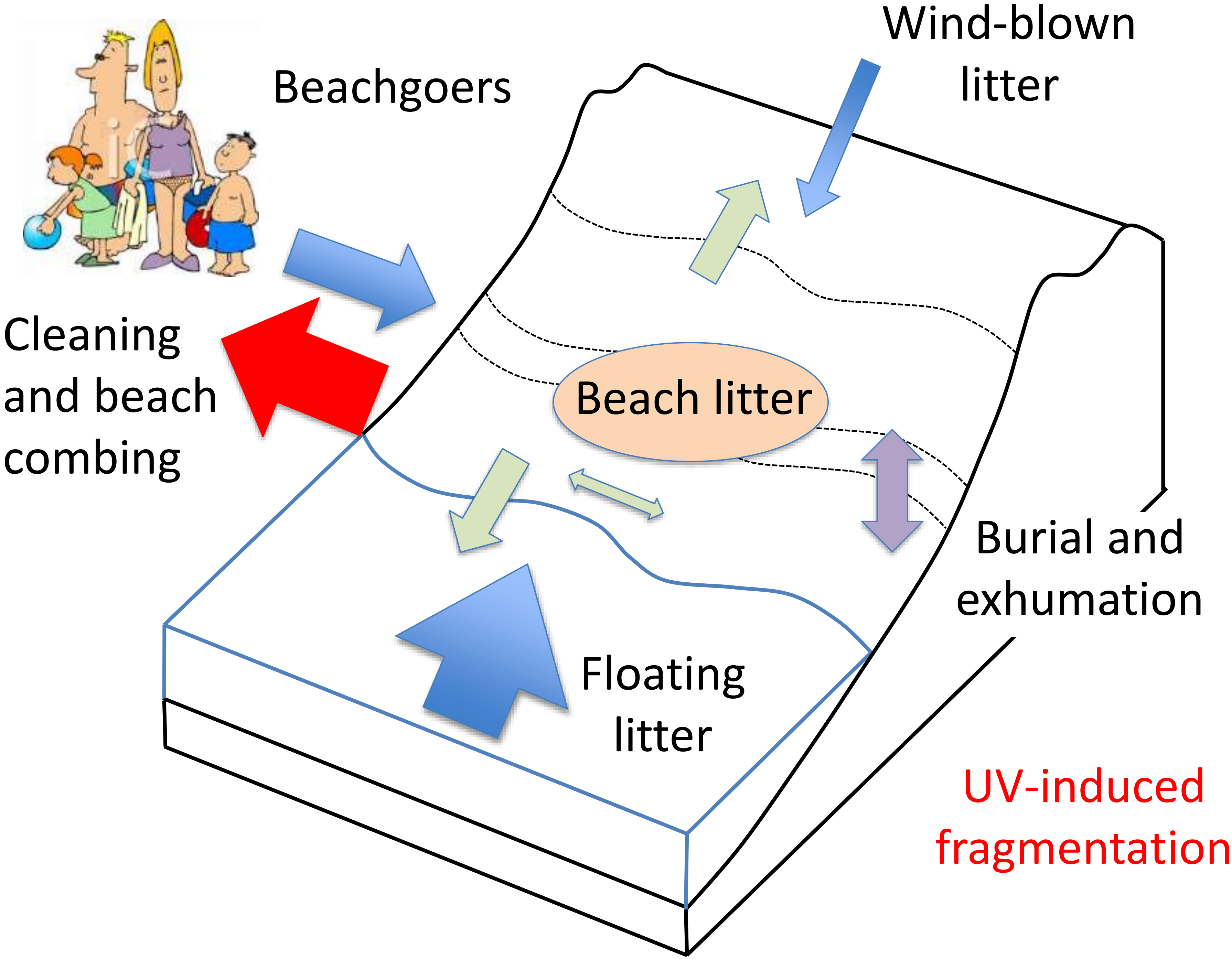
Marine litter input = what we want to monitor

Beach litter standing stock

Turnover due to export, burial, degradation and especially beach cleaning


Wind-blown litter
Beachgoers
Cleaning and beach combing
Beach litter
Burial and exhumation
Floating litter

Exhumation of buried litter exacerbated by sea level rise


Wind-blown litter
Beachgoers
Cleaning and beach combing
Beach litter
Burial and exhumation
Floating litter
UV-induced fragmentation

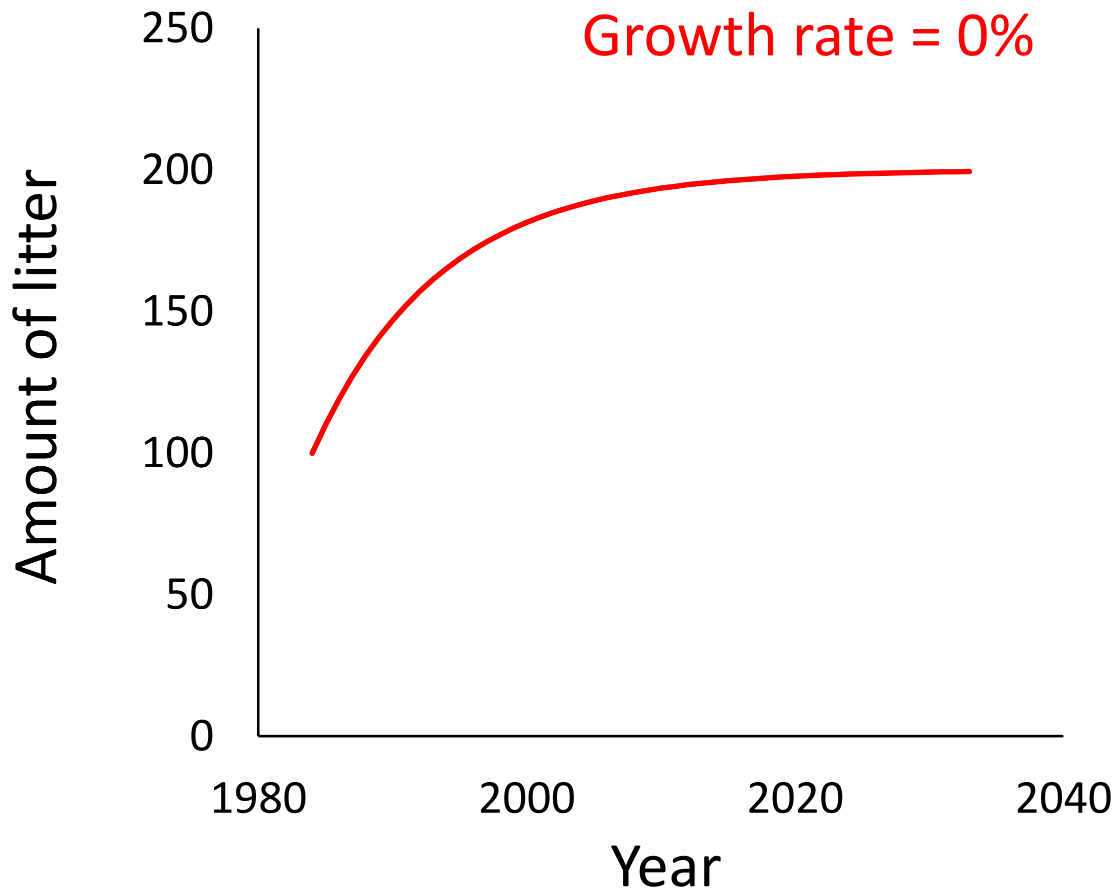
What can we infer from monitoring standing stocks?

Simple model based on two factors:

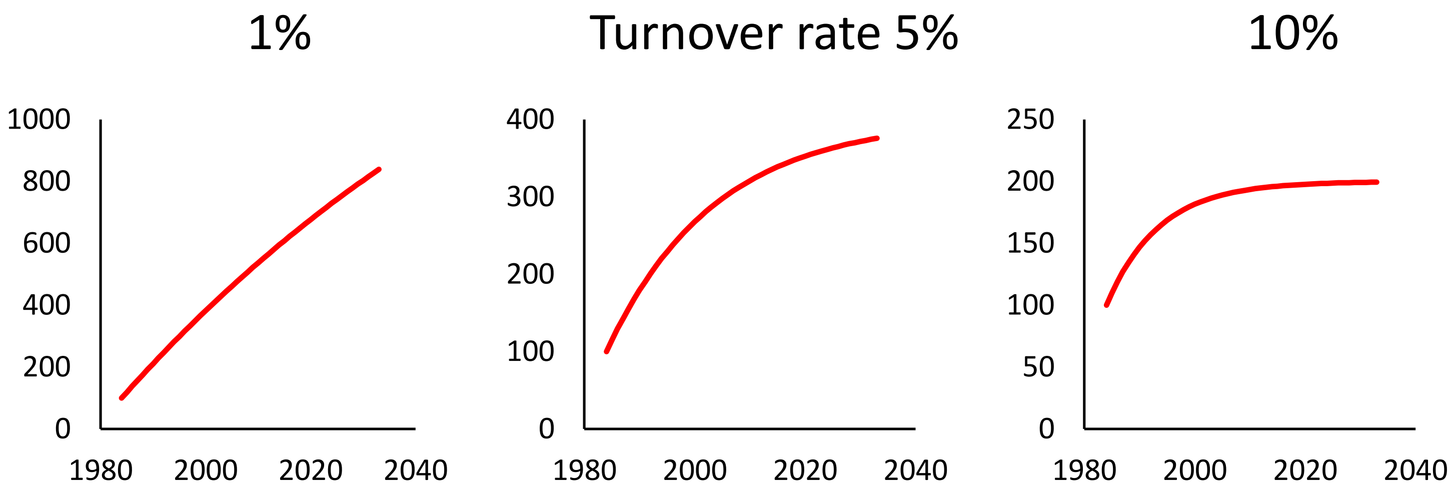
- Growth rate in amount of plastic
- Turnover rate in the compartment

Start with 100 items, initially adding 20 items per year and track for 50 years

With no change in growth rate, standing stock converges on a steady-state equilibrium



But time to equilibrium and equilibrium value depend critically on turnover rate



Growth rate = 0% per year

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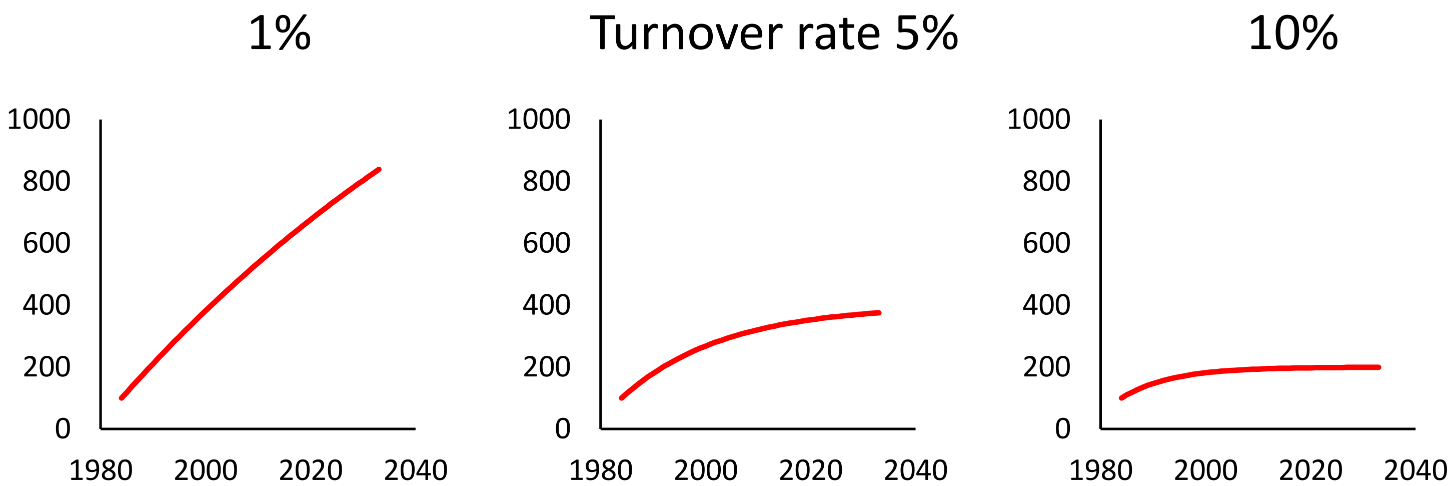
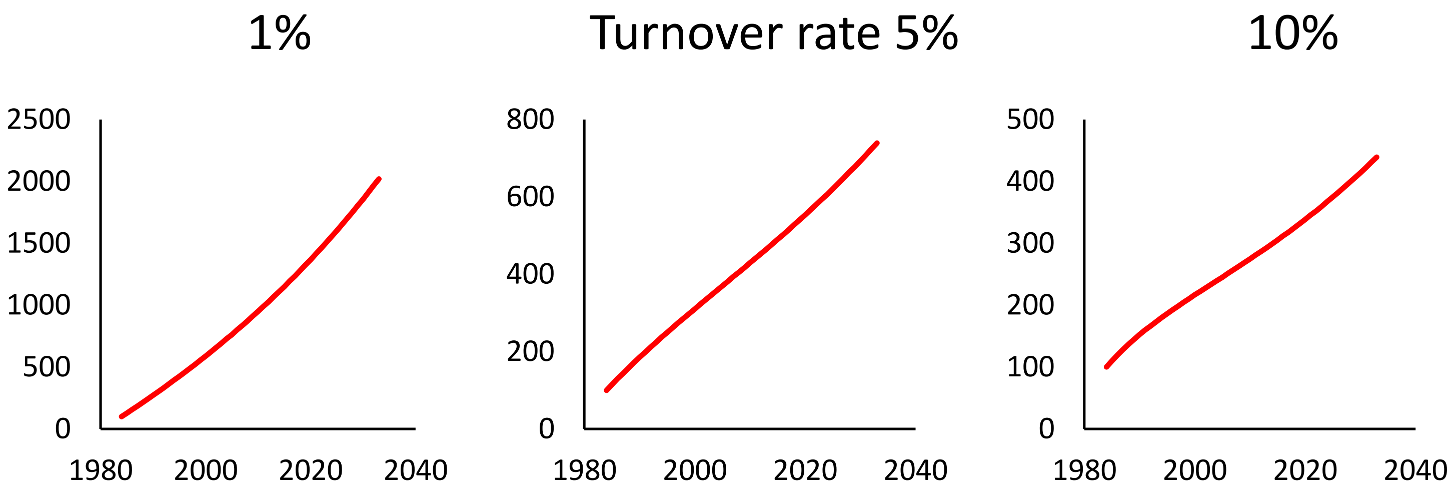


Growth rate = 0% per year

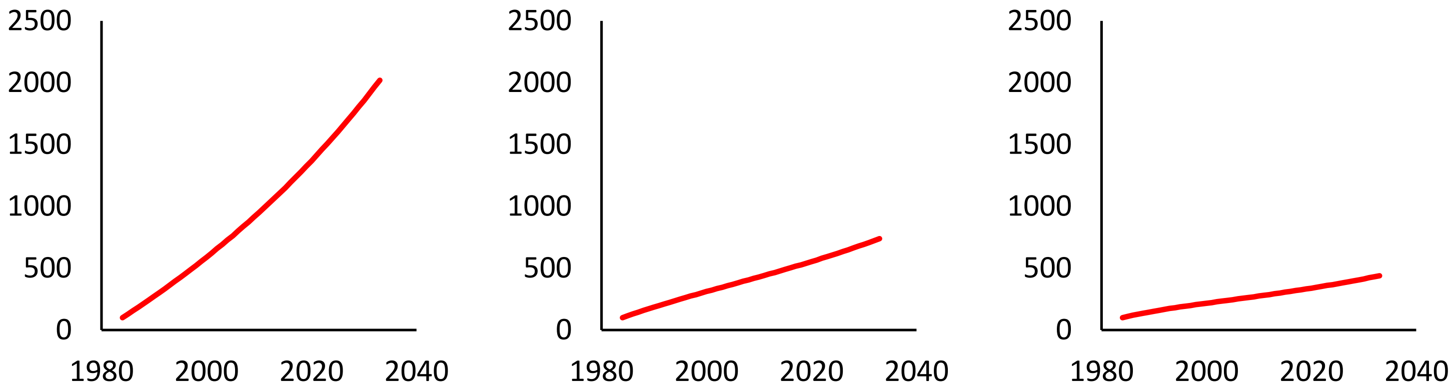
If litter increases, standing stock increases, but rate depends on turnover rate



Growth rate = 2% per year

If litter increases, standing stock increases, but rate depends on turnover rate

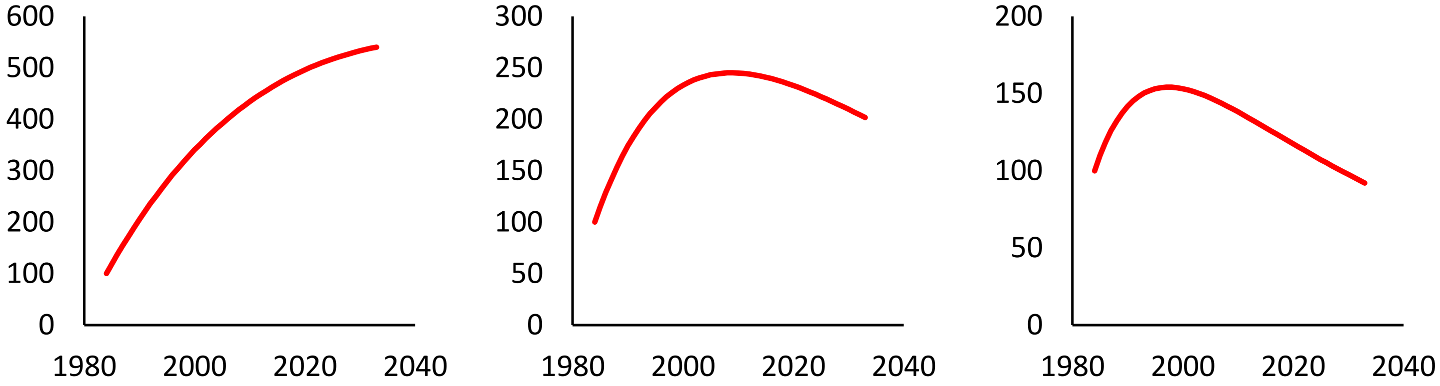
1% Turnover rate 5% 10%



Growth rate = 2% per year

If litter decreases, standing stock decreases, but rate also depends on turnover rate

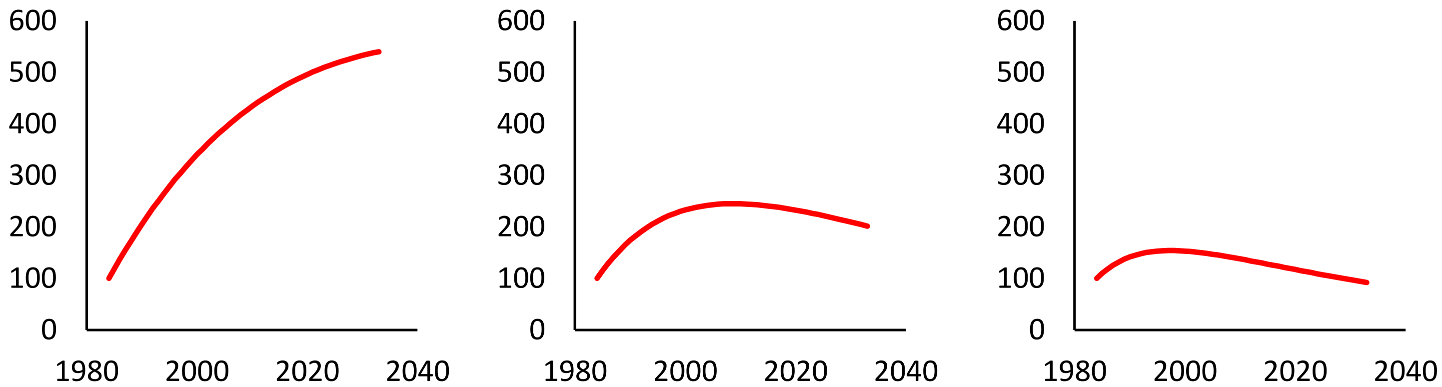
1% Turnover rate 5% 10%



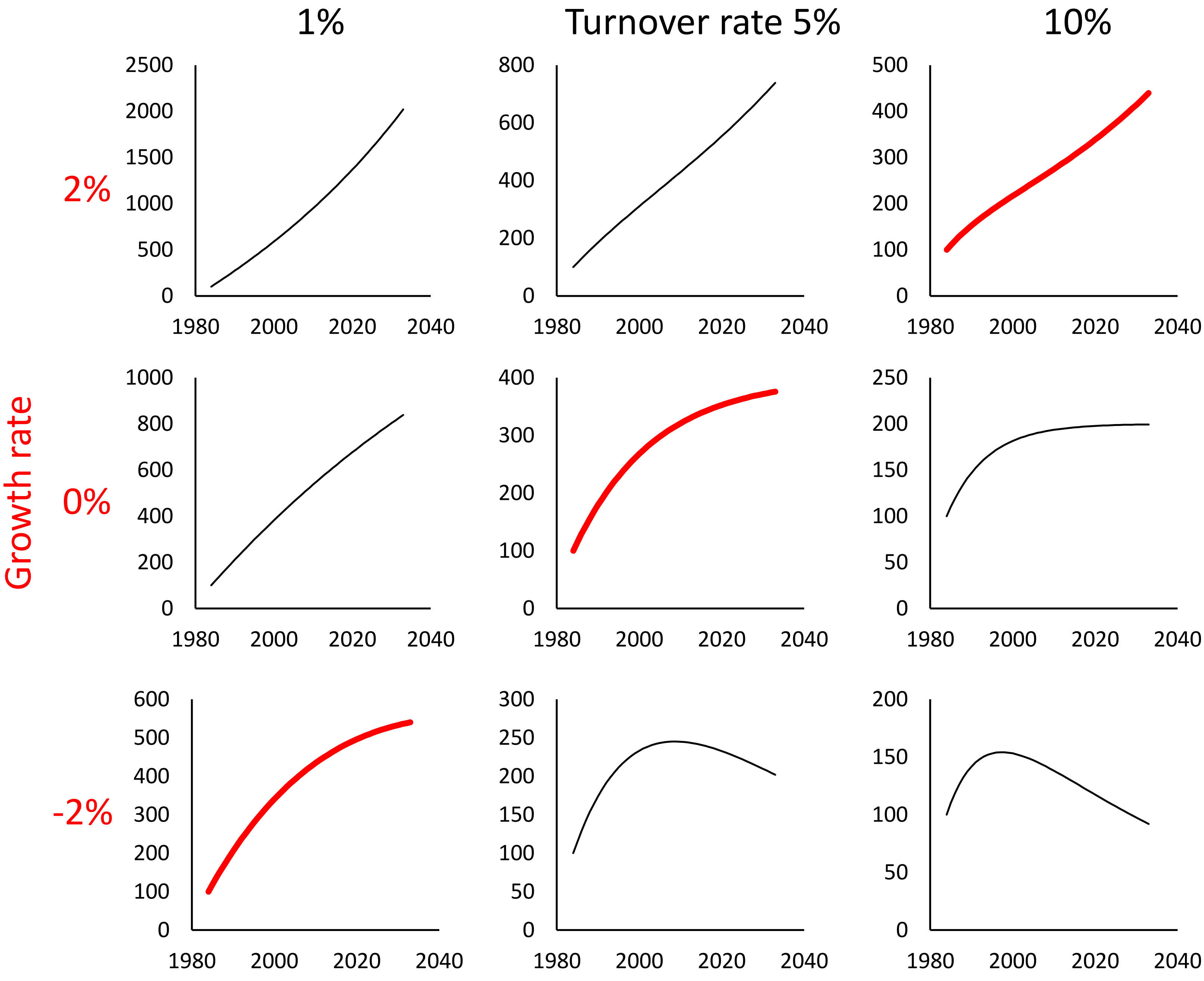
Growth rate = -2% per year

If litter decreases, standing stock decreases, but rate also depends on turnover rate

1% Turnover rate 5% 10%



Growth rate = -2% per year


1%
Turnover rate 5%
10%
Growth rate
2%
0%
-2%
2500
2000
1500
1000
500
0
800
600
400
200
500
300
100
250
150
50
1980
2000
2020
2040

Turnover rates vary with litter type due to differential export/burial/degradation

Light-weight items turn over faster due to wind-driven export

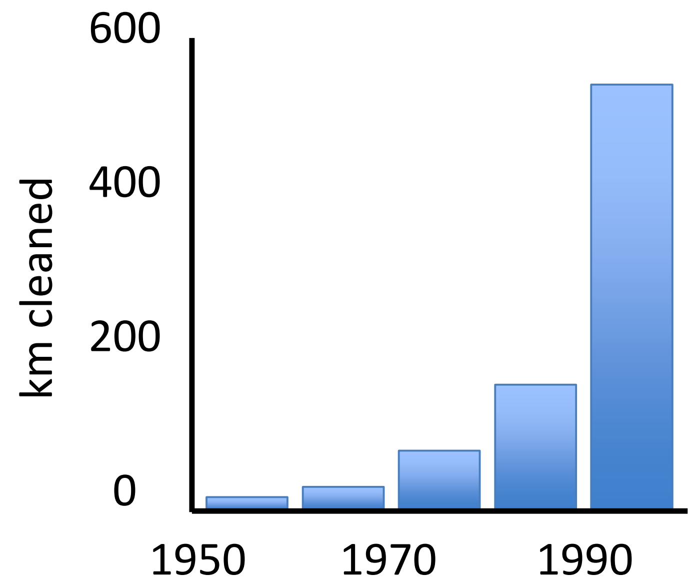
Small items buried by sand much faster than large items

At Inaccessible Island:	% number		% mass	
Fishery/marine litter	33	10	87	68
Bottles (mostly off ships)	34	73	3	12
Polystyrene	10	5	0.1	0.3

Cleaning beaches: sweeping the rubbish under the carpet

Peter G. Ryan and Debbie Swanepoel

South African Journal of Science Vol. 92 June 1996



By 1995, 70% of beaches cleaned

Total effort ~55,000 km cleaned per year

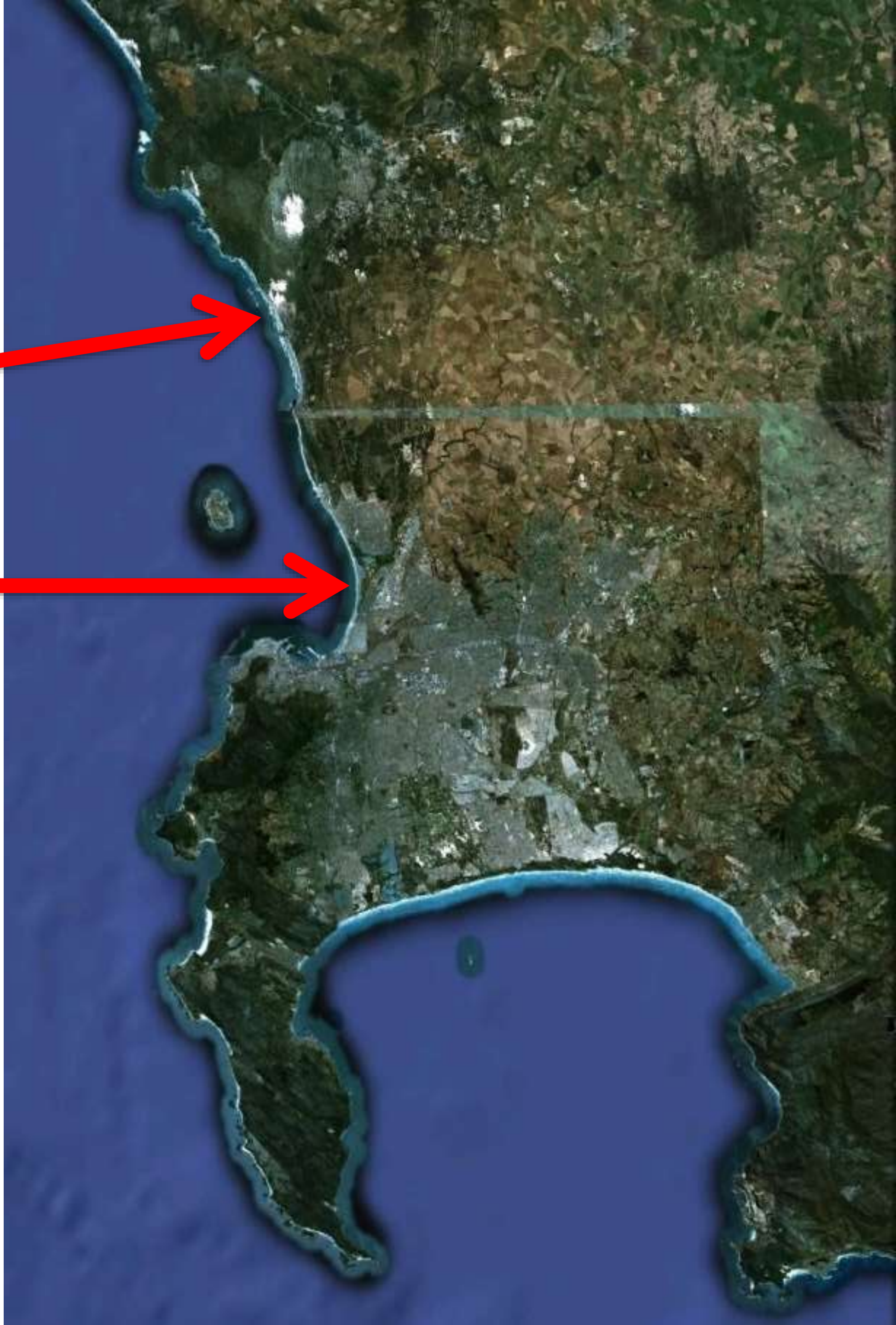

Eastern Beach, East London,
cleaned daily has…


399 macro litter items per metre:
124 polystyrene, 66 lids, 52 earbuds, 39 straws…

What is really going on with macro litter?

Koeberg

Milnerton



Accumulation studies:

500 m cleaned daily in 1994 and 2012

Should we be monitoring at sea?

If the goal is to assess success of mitigation measures to reduce plastic inputs, monitoring at sea is not ideal

For land-based sources, monitor inputs:

- Rivers, storm drains, aerial deposition, etc.

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Beach accumulation surveys are easy to perform;
integrate inputs over time/space

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Monitor microplastics/contaminants in seafood?

Recommended questions and monitoring approaches

Macroplastics

Is the amount/composition from land-based sources changing?

- Monitor inputs in rivers and storm drains
- Beach accumulation studies (frequency depends on beach use)

Is the amount/composition from offshore sources changing?

- Monitor origins of beach litter (bottles, marine equipment)
- Monitor use of port reception facilities

Is the amount/composition on the seabed changing?

- Monitor litter in benthic fish survey trawls
- ROV surveys of accumulation zones

Recommended questions and monitoring approaches

Microplastics

Is the amount/composition changing?

- Monitor ingestion by biota
- Soft sediment cores from the seabed
- Beach arrival studies (tidal stranding)

Are marine foodwebs being contaminated?

- Monitor microplastics and/or contaminants (plastic-specific additives) in selected biota (mussels, fish, top predators)