A marine plastic cloud
Global oceanic plastic pollution mass balance in relation to the Arctic

Arctic Plastic Symposium

THEME 6: Tackling plastic pollution: international collaboration, policies, best practices and novel developments from around the world

23/11/23

Dr. Thomas Maes (GRID-Arendal)

Dr. Peter Harris (GRID-Arendal)

Dr Karen Raubenheimer (Wollongong University)

Dr J.P. Walsh (University of Rhode Island)

GRID ARENDAL
A UNEP Partner

Where is all the plastic?

GRID ARENDAL

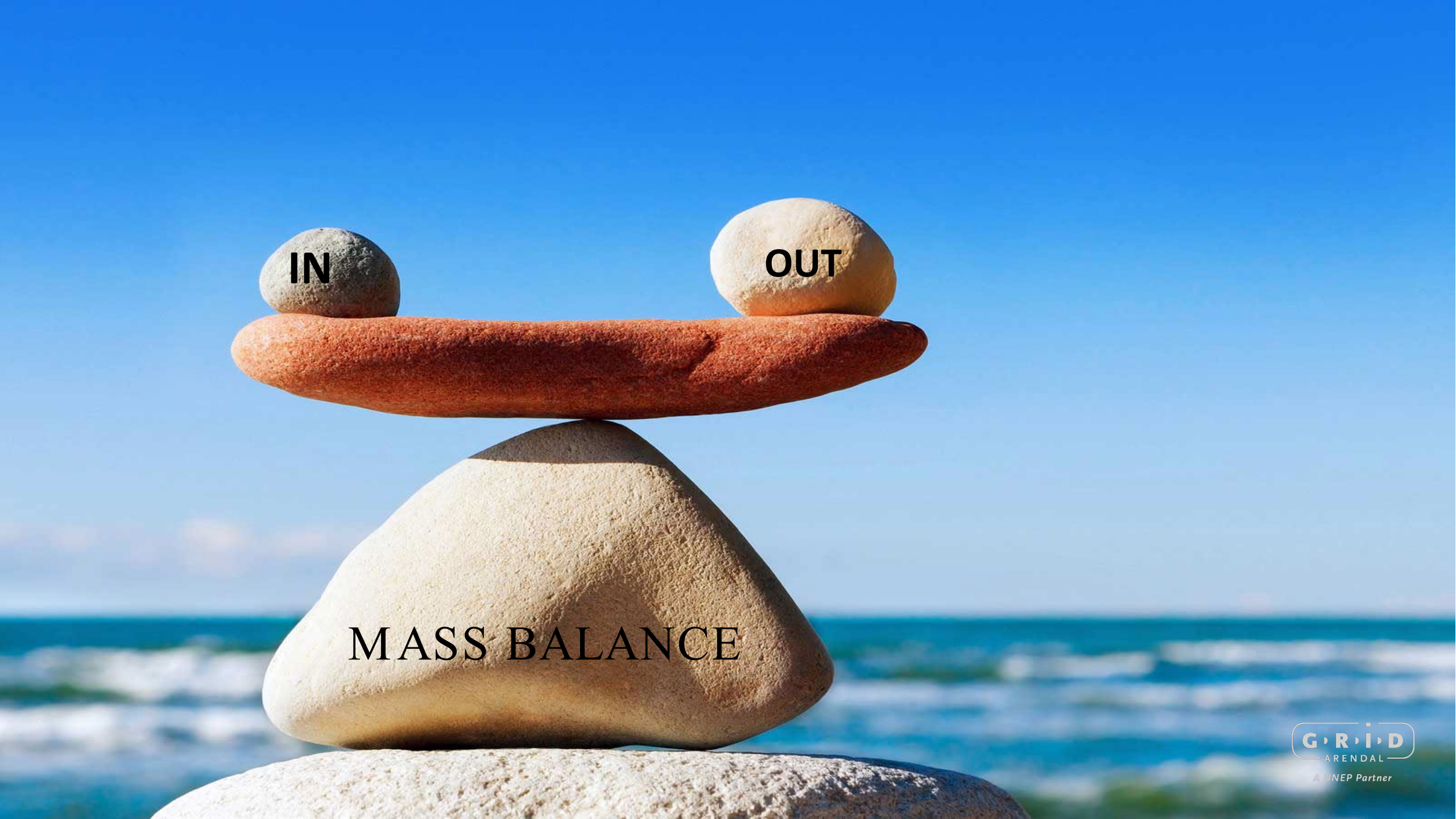
A Centre collaborating with UNEP

Abracadabra?
THE MAGIC FORMULA

In 1756, the Russian scientist Mikhail Lomonosov formulated the law of mass conservation:

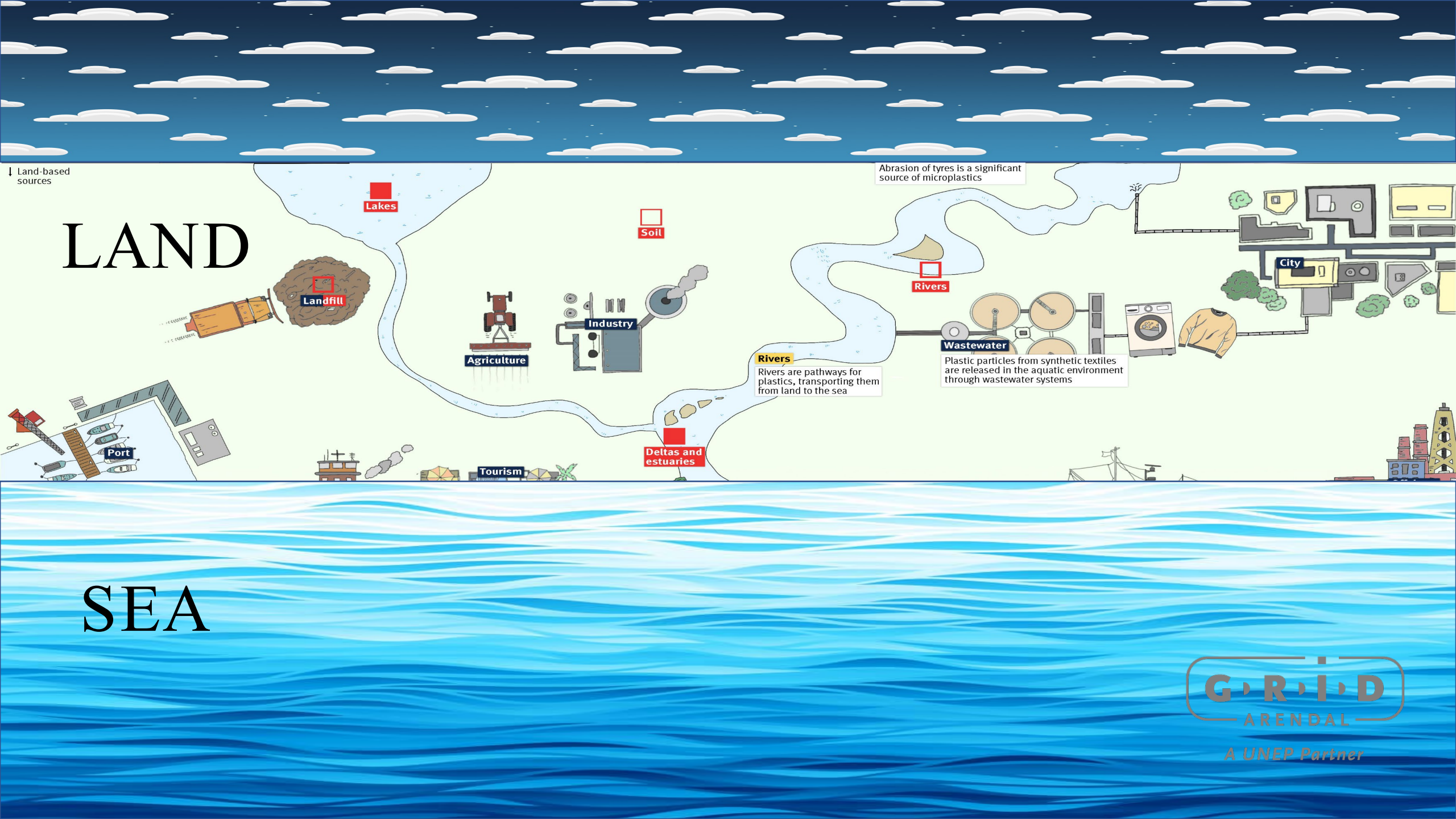
"In an isolated system, matter is neither created nor destroyed!"

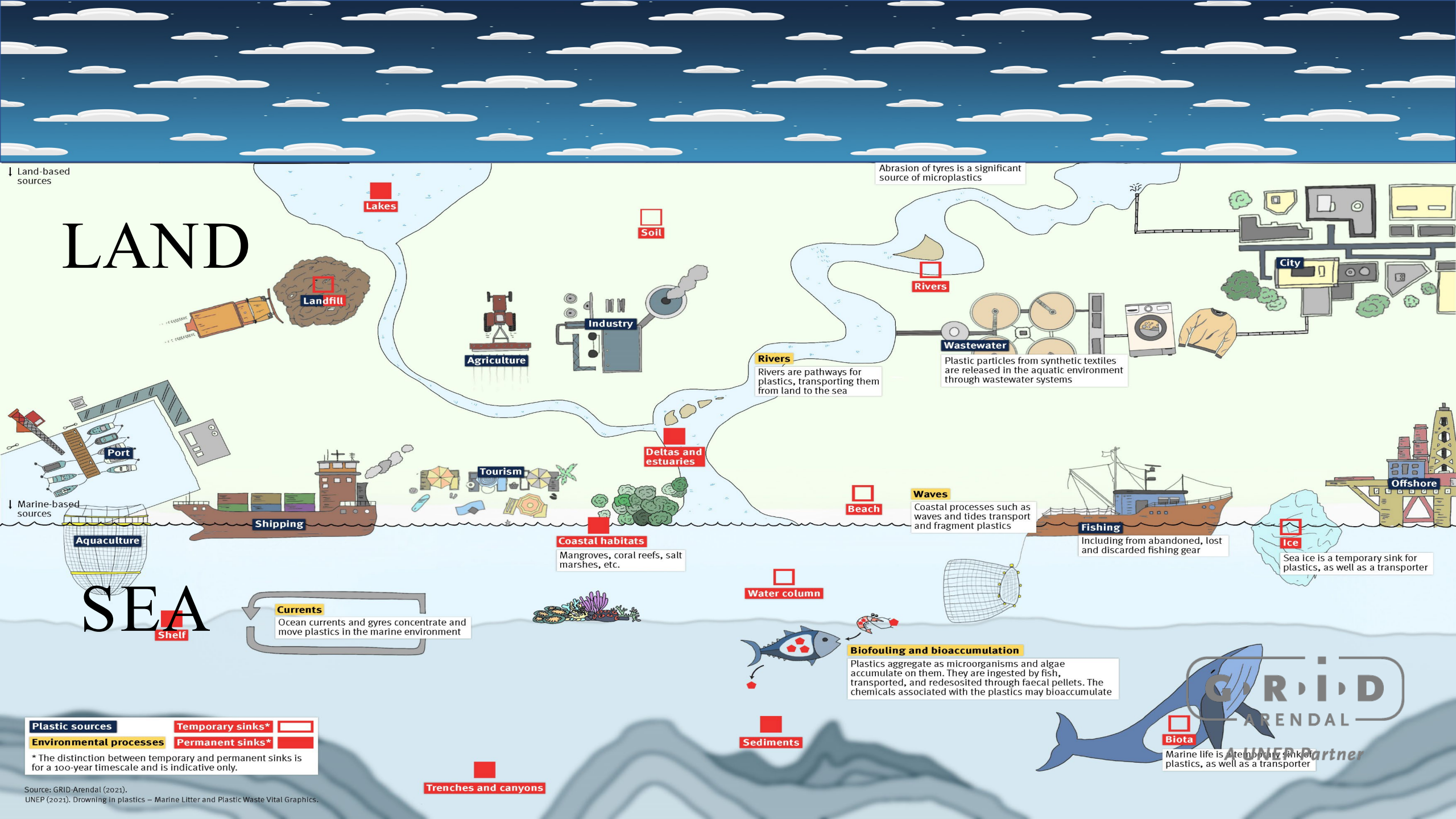
GRID ARENDAL
A UNEP Partner



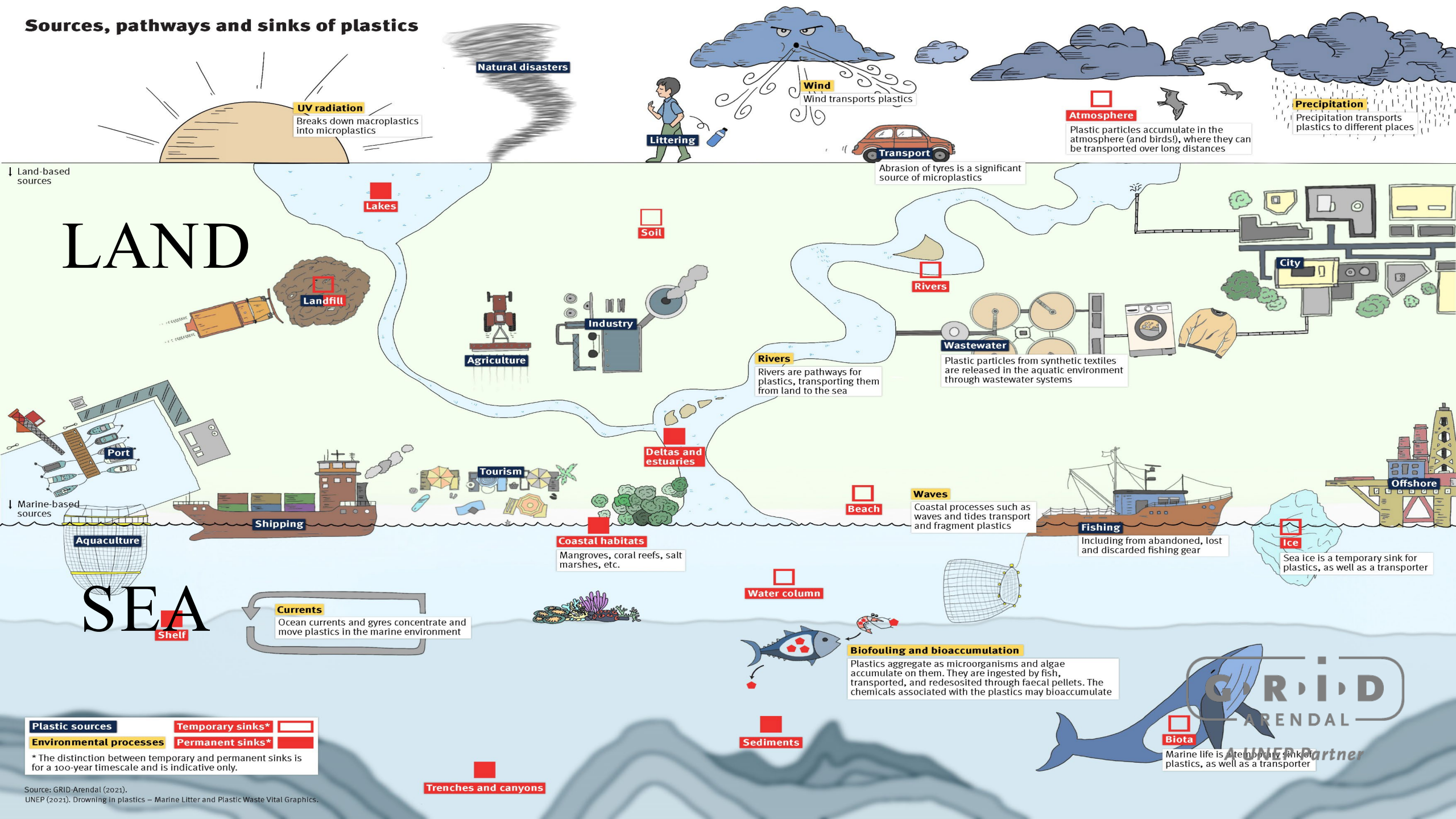
GRID ARENDAL
A UNEP Partner

GRID ARENDAL
A UNEP Partner


Land-based sources
LAND
Lakes
Soil
Landfill
Industry
Agriculture
Rivers
Abrasion of tyres is a significant source of microplastics
City
Wastewater
Plastic particles from synthetic textiles are released in the aquatic environment through wastewater systems
Rivers
Rivers are pathways for plastics, transporting them from land to the sea
Port
Deltas and estuaries
Tourism
SEA
G·R·I·D
ARENDAL
A UNEP Partner


Land-based sources
LAND
Lakes
Soil
Landfill
Industry
Agriculture
Abrasion of tyres is a significant source of microplastics
Rivers
City
Wastewater
Plastic particles from synthetic textiles are released in the aquatic environment through wastewater systems
Rivers
Rivers are pathways for plastics, transporting them from land to the sea
Port
Tourism
Deltas and estuaries
Marine-based sources
Shipping
Beach
Waves
Coastal processes such as waves and tides transport and fragment plastics
Fishing
Including from abandoned, lost and discarded fishing gear
Offshore
Aquaculture
Coastal habitats
Mangroves, coral reefs, salt marshes, etc.
Ice
Sea ice is a temporary sink for plastics, as well as a transporter
SEA
Water column
Currents
Ocean currents and gyres concentrate and move plastics in the marine environment
Shelf
Biofouling and bioaccumulation
Plastics aggregate as microorganisms and algae accumulate on them. They are ingested by fish, transported, and redesosited through faecal pellets. The chemicals associated with the plastics may bioaccumulate
Plastic sources
Environmental processes
Temporary sinks*
Permanent sinks*
* The distinction between temporary and permanent sinks is for a 100-year timescale and is indicative only.
Sediments
Biota
Marine life is a temporary sink of plastics, as well as a transporter
Trenches and canyons
GRID ARENDAL
A UNEP Partner
Source: GRID-Arendal (2021).
UNEP (2021). Drowning in plastics – Marine Litter and Plastic Waste Vital Graphics.

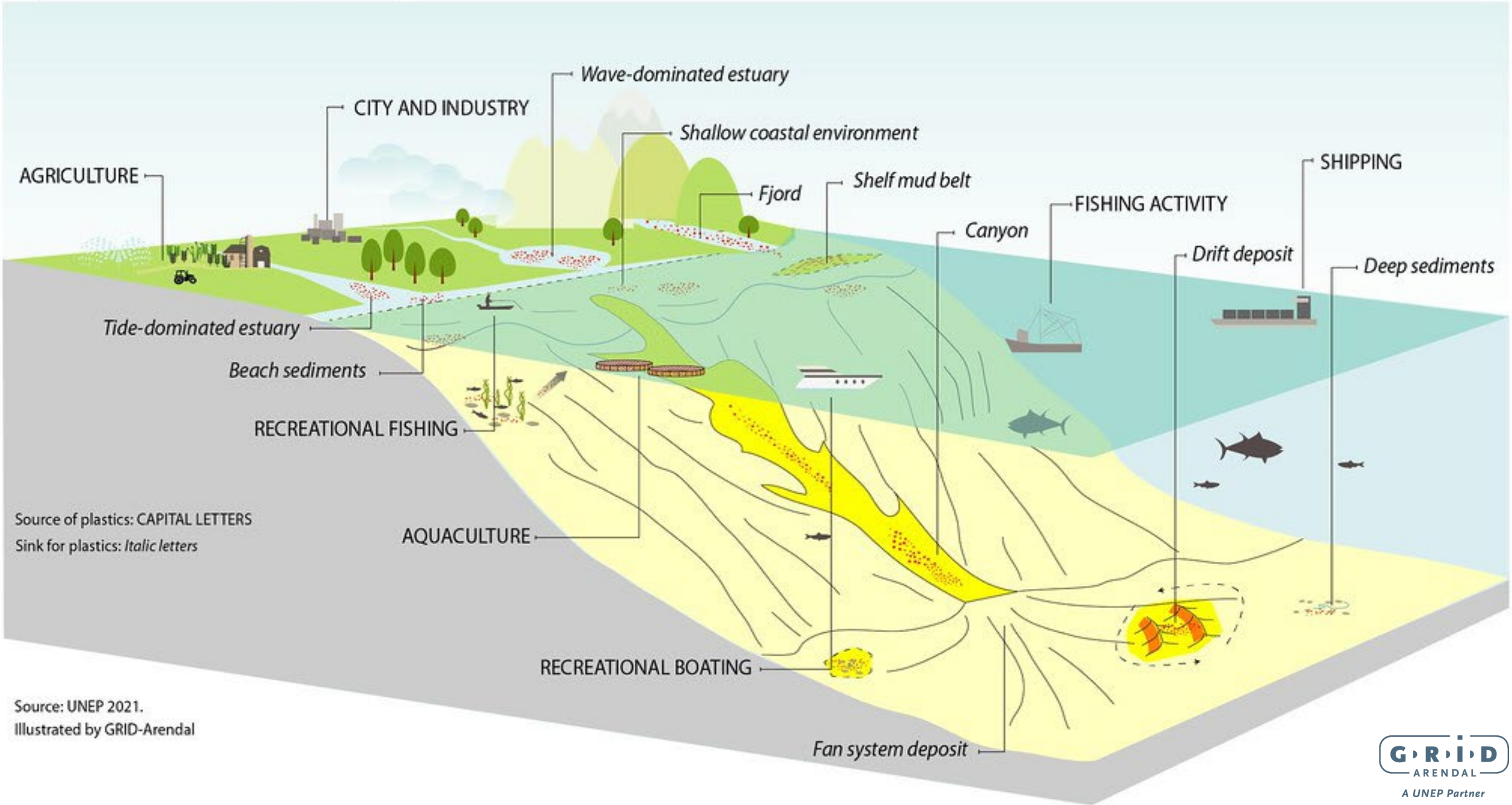
Sources, pathways and sinks of plastics



Source: GRID-Arendal (2021).
UNEP (2021). Drowning in plastics – Marine Litter and Plastic Waste Vital Graphics.

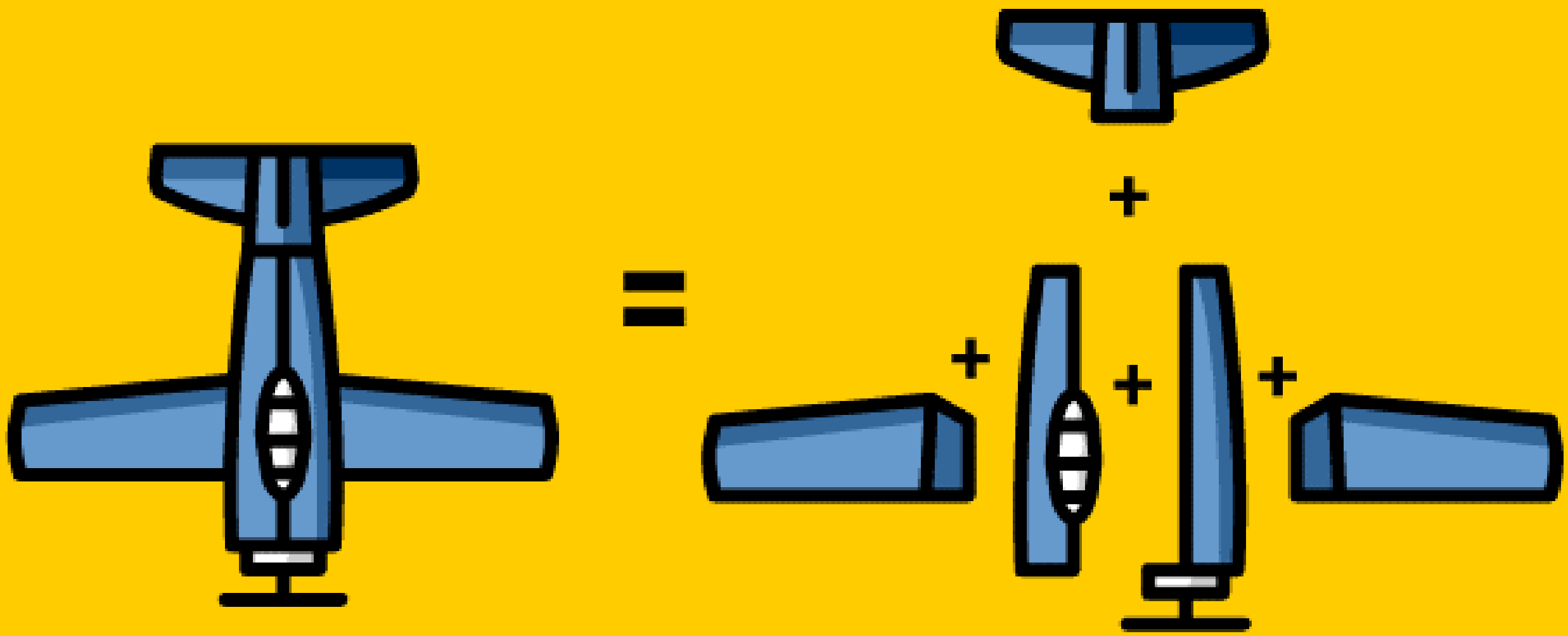
GRID-ARENDAL
A UNEP Partner

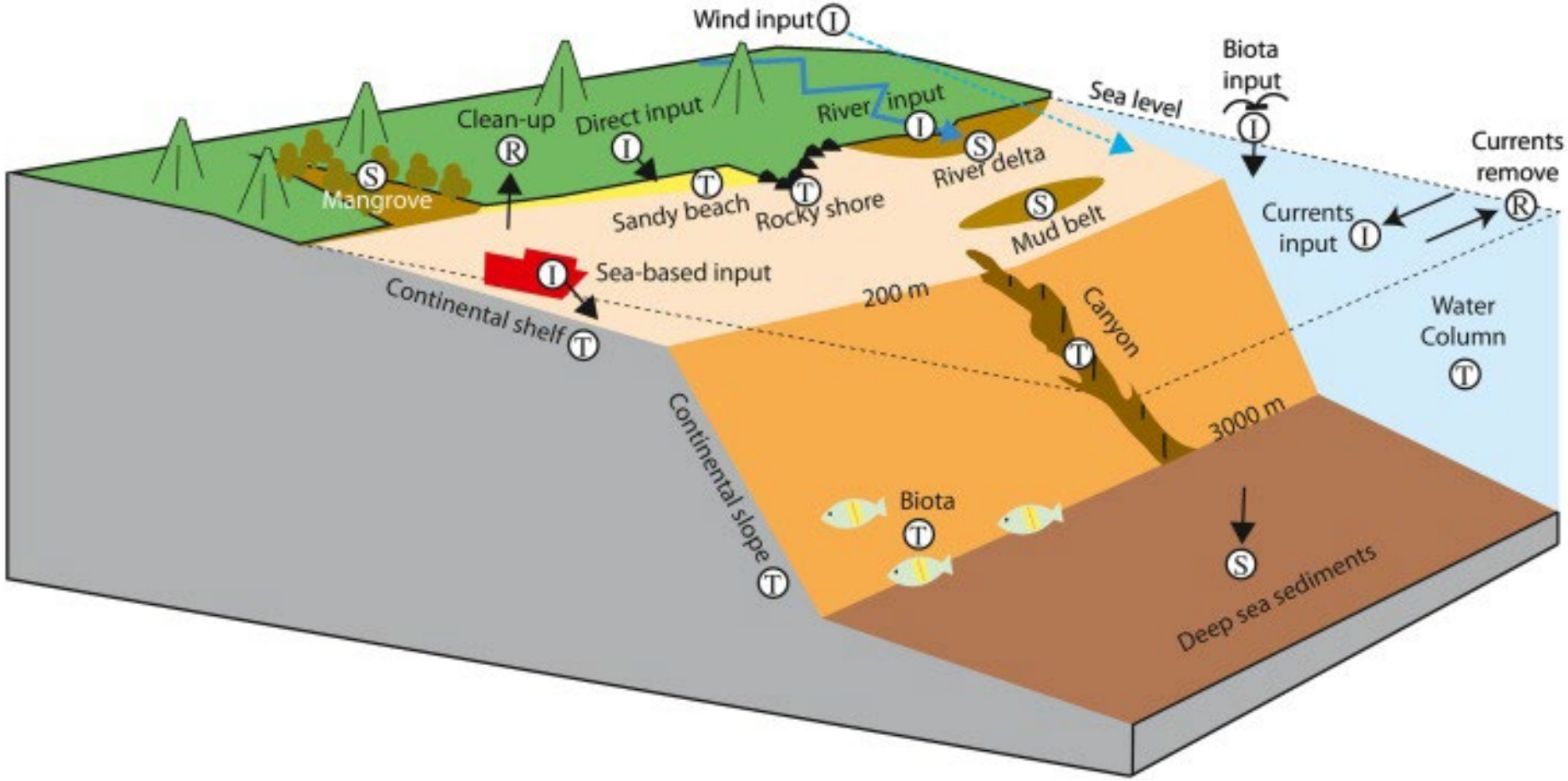
Major sources and sinks of microplastics and marine litter



Source: UNEP 2021.
Illustrated by GRID-Arendal

GRID ARENDAL
A UNEP Partner



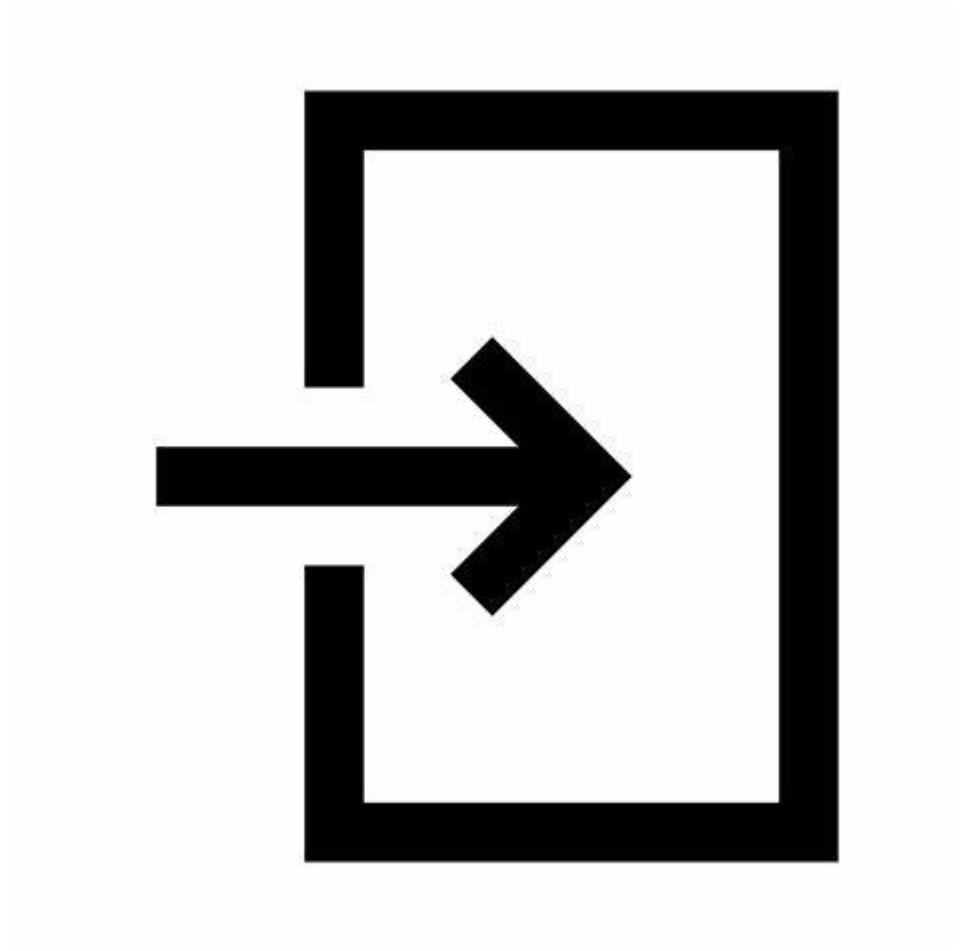


$$I_{land-based} + I_{sea-based} + I_{river} + I_{wind} + I_{biota} (+ I_{currents}) = T_{watercolumn} + T_{coast} + T_{biota} + T_{shelf} + T_{deepsea} + S_{coast} + S_{shelf} + S_{deepsea} - R_{cleanup} (- R_{currents})$$

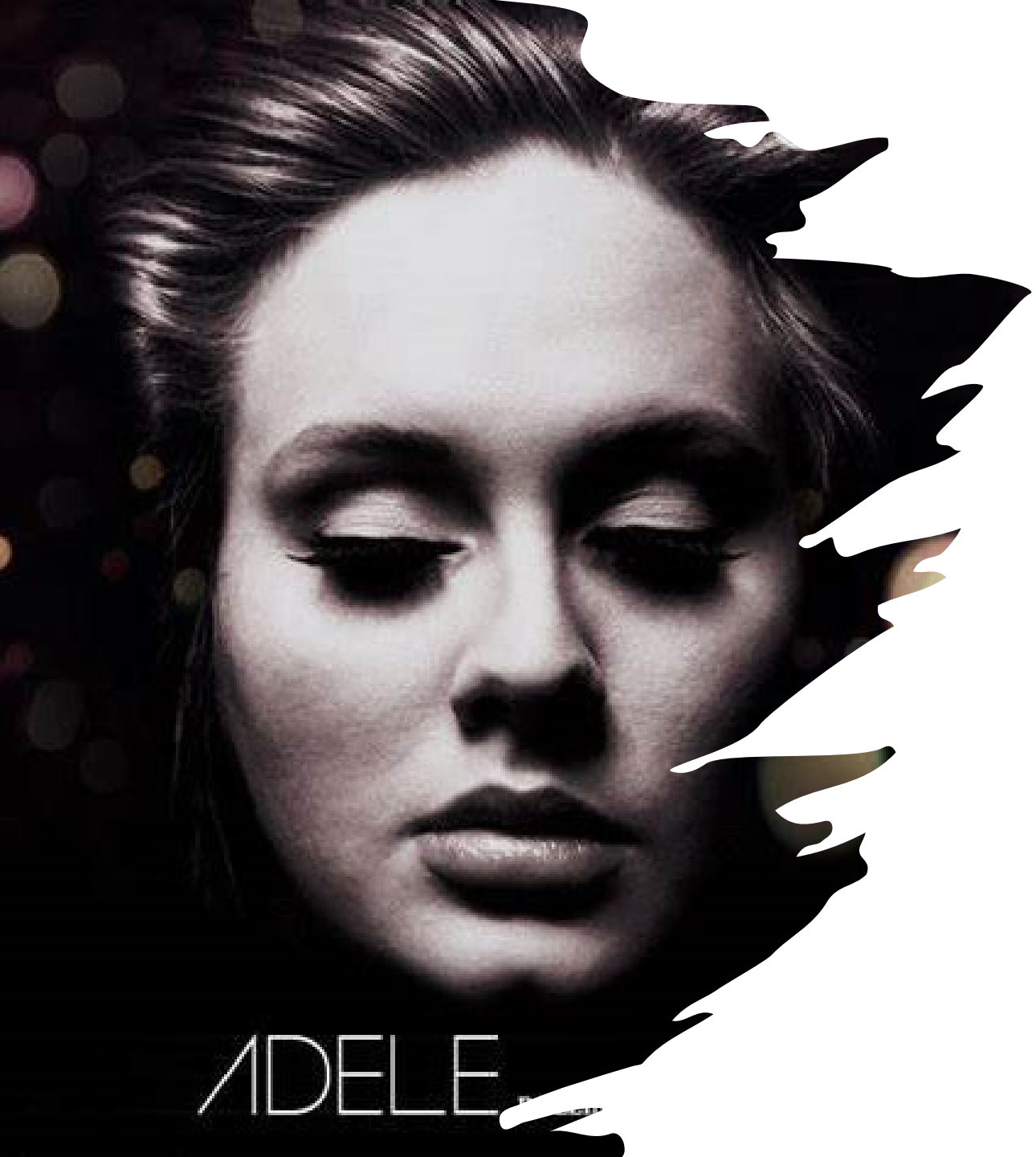
DIRECT PLASTIC INPUTS | INDIRECT PLASTIC INPUTS | TRANSITORY PLASTIC | PLASTIC SINKS | PLASTIC REMOVAL

Harris et al., 2021 - Taking a mass-balance approach to assess marine plastics in the South China Sea

GRID ARENDAL
A UNEP Partner



Estimated emissions of plastic waste (million metric tons per year)	Source-to-sea aspect	Projected emissions of plastic waste (million metric tons per year) under certain conditions	Approach used
19-23	Entered aquatic ecosystems in 2016	53 by 2030	Integrating expected population growth, annual waste generation per capita, the proportion of plastic in waste; incorporating an increase in plastic materials associated with predicted production increases, and the proportion of inadequately managed waste by country (Borelle et al. 2020)
9-14	Entered the aquatic systems in 2016	23-37 by 2040 (equivalent to 50 kg of plastic per metre of coastline worldwide)	Modelled stocks and flows of municipal solid waste and four sources of microplastics through the global plastic system, using five scenarios (2016–2040) and assuming no effective action is taken (Lau *et al.* 2020
0.8-2.7	Entered the oceans from global riverine systems in 2015	--	Based on >1,000 rivers, calibrated using field observations (Meijer *et al.* 2021)



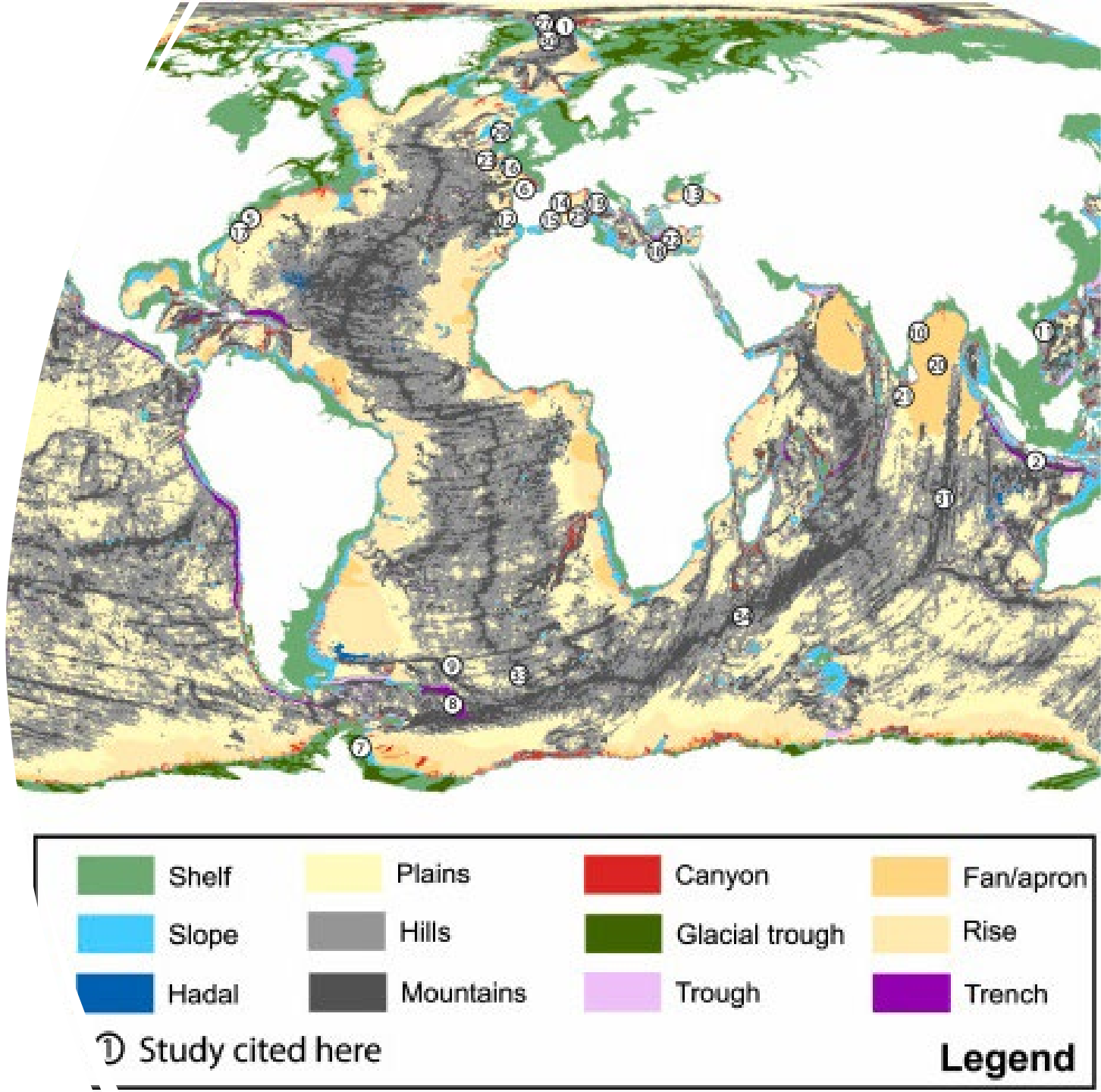
Rolling in the Deep

- Literature review
  - (i) the sedimentary environment
    1) slope
    2) submarine canyon
    3) submarine fan/continental rise
    4) abyssal plain
    5) deep trench, trough or other hadal areas
    6) other deep ocean areas
  - (ii) the methods used to measure microplastic
  - (iii) the shape of microplastic particles (fibres, pellets, fragments, beads, etc.)
  - (iv) the number of microplastic particles kg^{-1} of sediment.
    - the mass of microplastic kg^{-1} of sediment
    - sediment accumulation rates
- Microplastic mass concentration:
  - assumed microplastic particle size of a 100 µm diameter sphere
  - microplastic density of 1.099 g/cm^3
  - sediment bulk density of 0.6 g/cm^3.
  - sediment depth of 9 cm

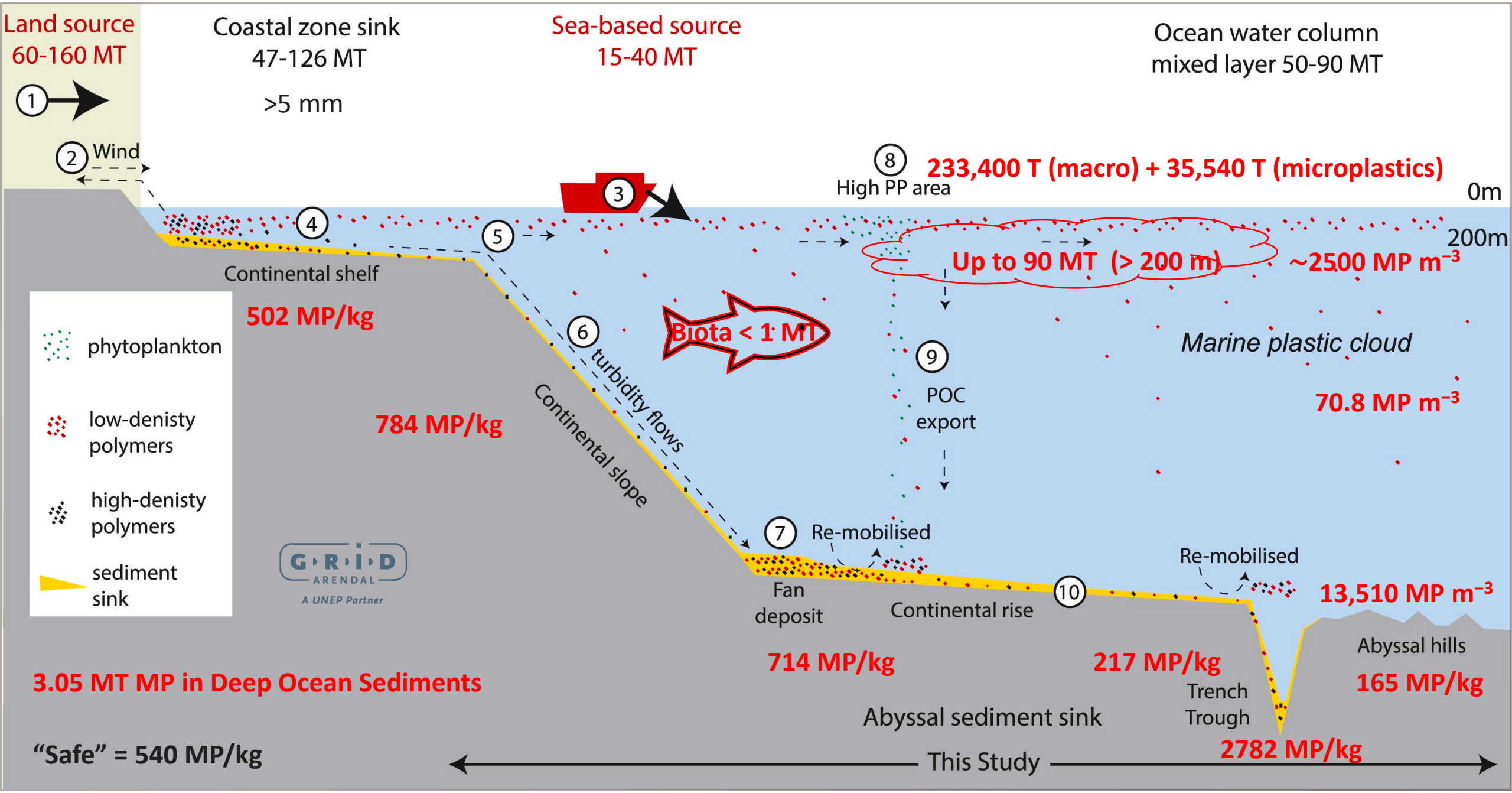
GRID ARENDAL
A UNEP Partner

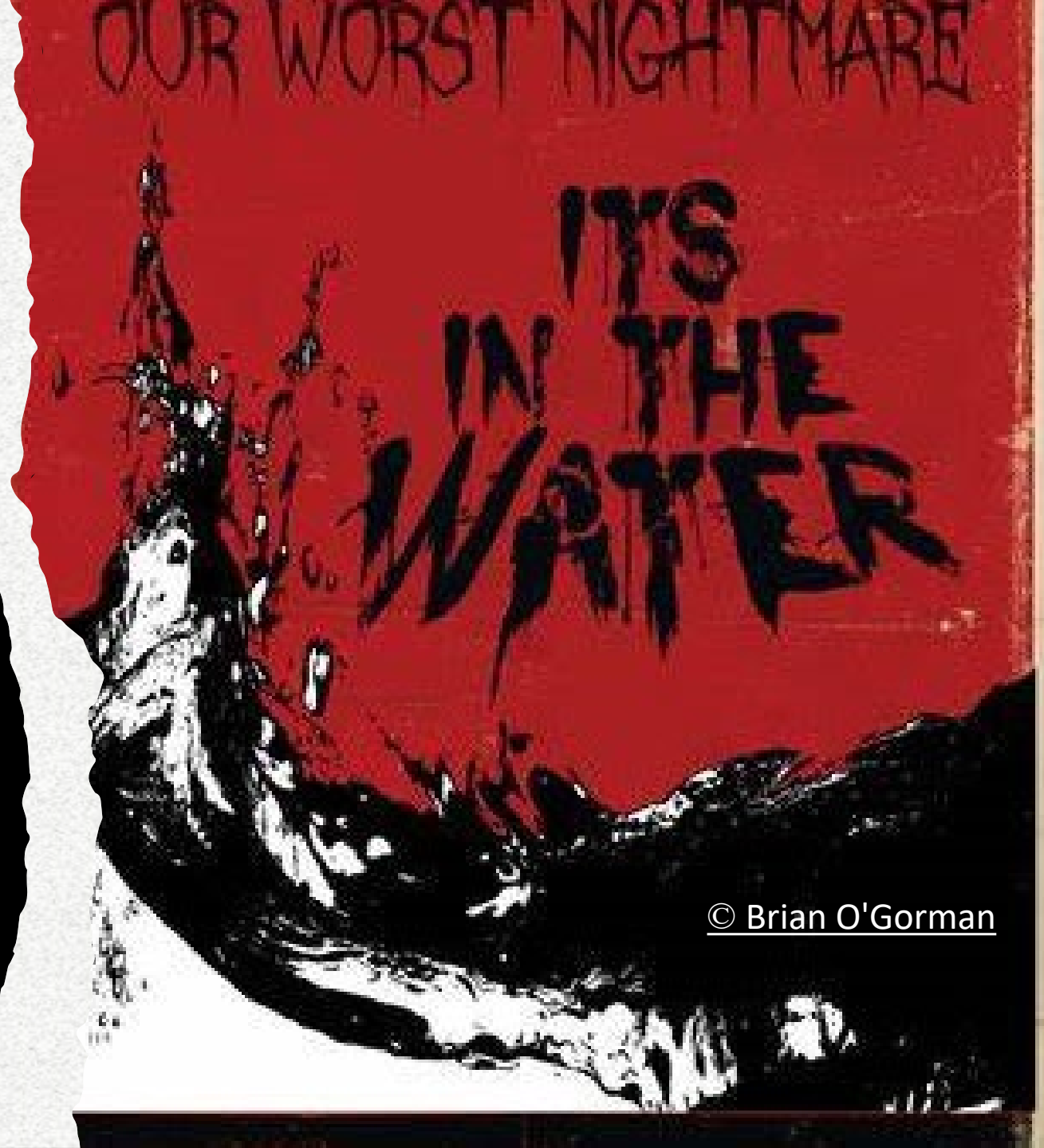
Deep-Sea Plastic

Data were extracted from 23 separate research papers which covered 34 geographic locations and provided a total of 280 observations of deep-sea sediment microplastic concentration



GRID ARENDAL
A UNEP Partner

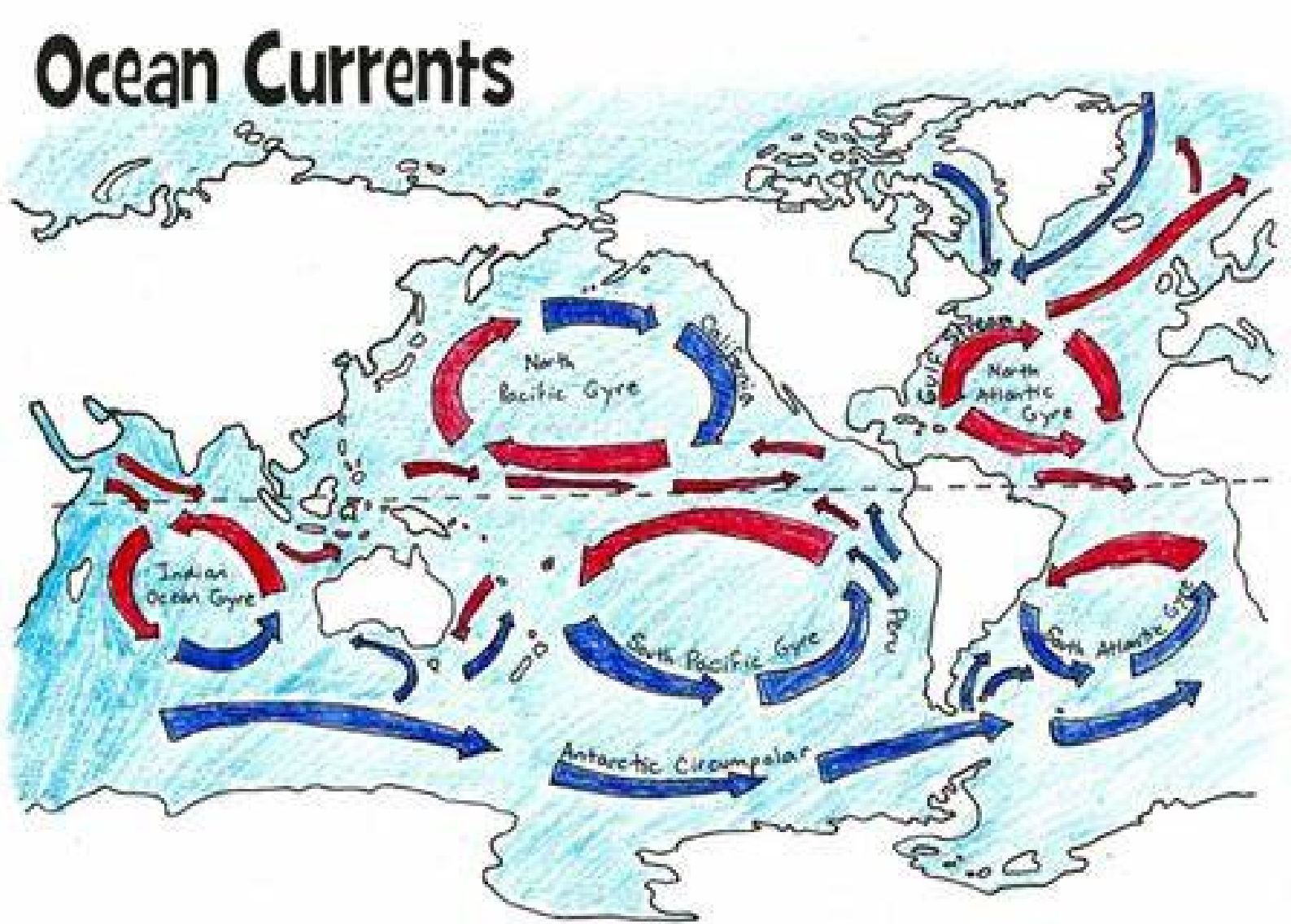

Land source
60-160 MT
Coastal zone sink
47-126 MT
>5 mm
Sea-based source
15-40 MT
Ocean water column
mixed layer 50-90 MT
1
2 Wind
3
4
5
6 turbidity flows
7 Re-mobilised
8 High PP area
9 POC export
10
233,400 T (macro) + 35,540 T (microplastics)
0m
200m
Up to 90 MT (> 200 m)
~2500 MP m-3
Continental shelf
502 MP/kg
Biota < 1 MT
Marine plastic cloud
70.8 MP m-3
784 MP/kg
Continental slope
phytoplankton
low-denisty polymers
high-denisty polymers
sediment sink
G·R·I·D ARENDAL
A UNEP Partner
Fan deposit
714 MP/kg
Continental rise
Re-mobilised
13,510 MP m-3
217 MP/kg
Abyssal hills
165 MP/kg
Trench Trough
2782 MP/kg
Abyssal sediment sink
3.05 MT MP in Deep Ocean Sediments
"Safe" = 540 MP/kg
This Study

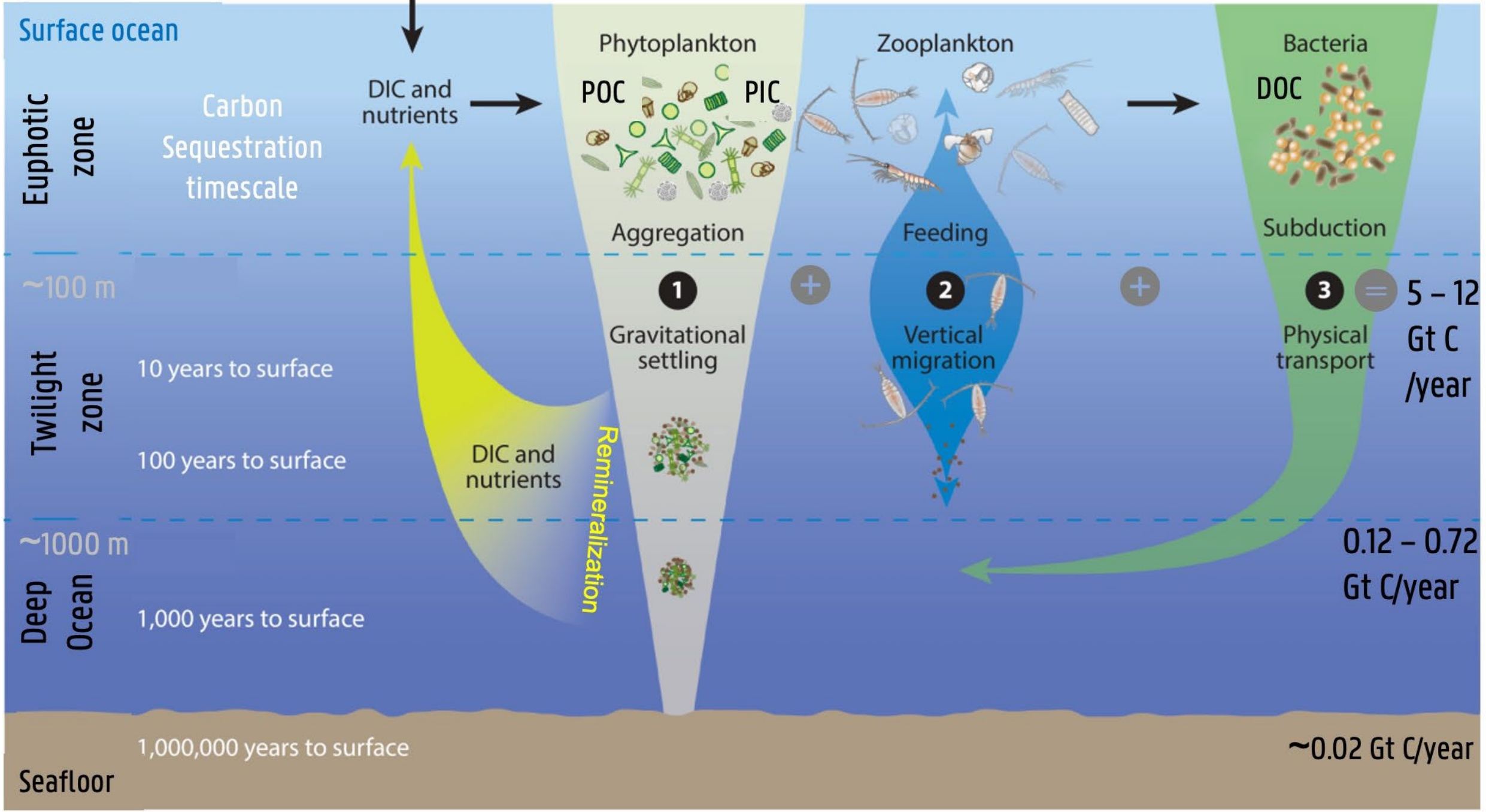


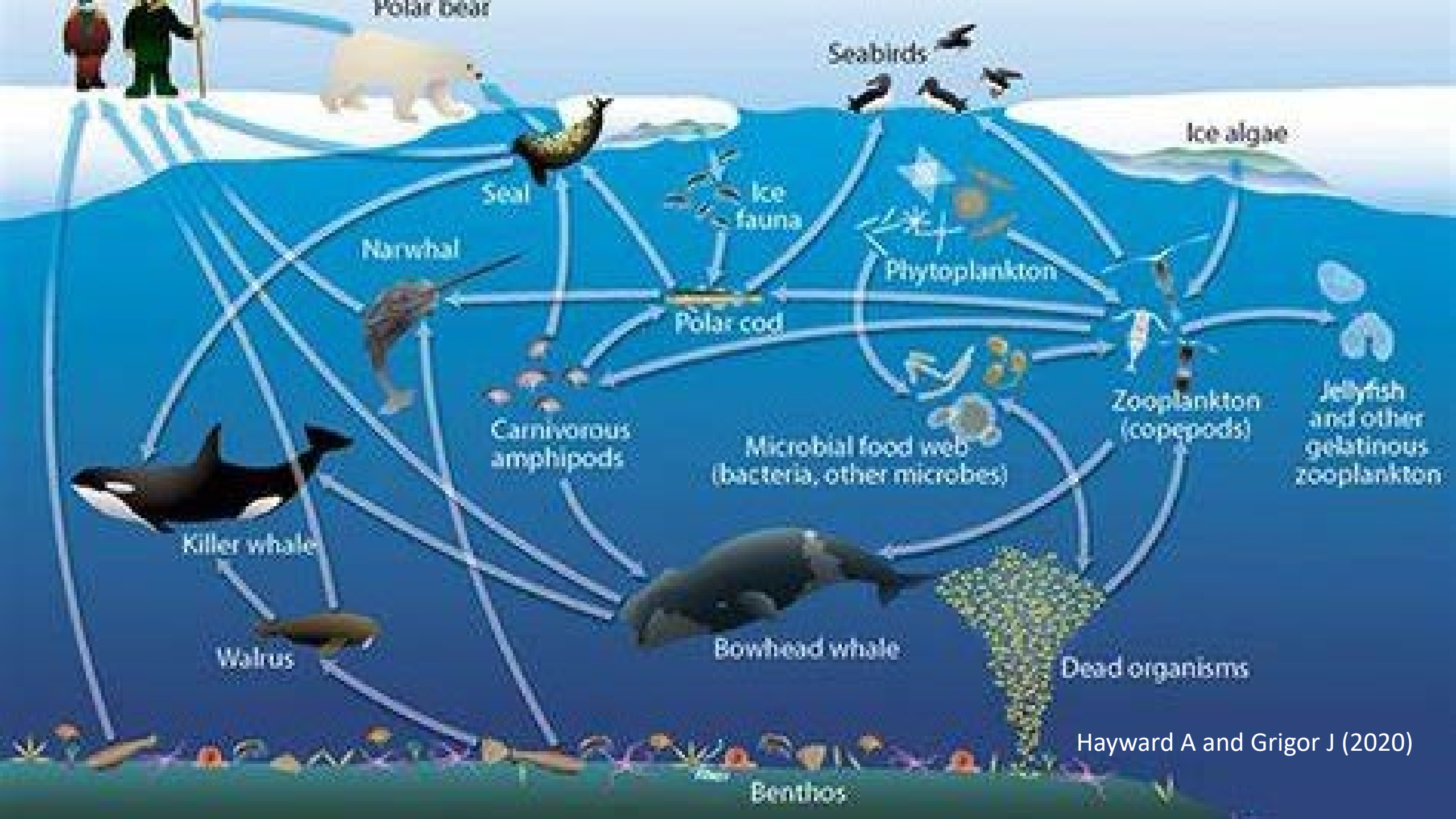
© Brian O'Gorman

GRID ARENDAL
A UNEP Partner

Ocean Currents







Hayward A and Grigor J (2020)

Conclusions

A Marine Plastic Cloud

The ocean water column behaves as a transitory, temporary storage area for plastic

GRID ARENDAL
A UNEP Partner

Want to find out more?

- **Harris et al., 2023 - Global mass balance assessment of oceanic plastic pollution - Continental Shelf Research**
- **Harris et al., 2021 - Taking a mass-balance approach to assess marine plastics in the South China Sea – Marine Pollution Bulletin**

Thank you for your attention!

GRID ARENDAL

A UNEP Partner

thomas.maes@grida.no