


Applying a risk framework to the marine litter issue at local, national and global levels

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https://research.csiro.au/marinedebris/

Commonwealth Scientific and Industrial Research Organisation

- Agriculture and Food
- Health and Biosecurity
- Data61
- Energy
- Land and Water
- Manufacturing
- Mineral Resources
- Oceans and Atmosphere (marine debris)
- Facilities and National Collections

CSIRO Marine Debris Research Program

Research

- Document distribution of marine litter on coast and in ocean (incl. ghost gear)
- Identify sources of marine debris
- Collect data on exposure of wildlife
- Assess likely **risk** to wildlife and food fish
- Modelling & monitoring marine litter movement, transport, accumulation
- Identify potential **policy solutions** at local, regional, national and international scales
- Monitoring methods comparisons/data harmonization

Engagement

- Citizen science program with Schools, Educators, Coastal Volunteers and Industry Leaders (~8,000 participants)
- Materials developed for schools, linked to national science/maths curriculum
- Engage w/ government to deliver information on effective, affordable solutions

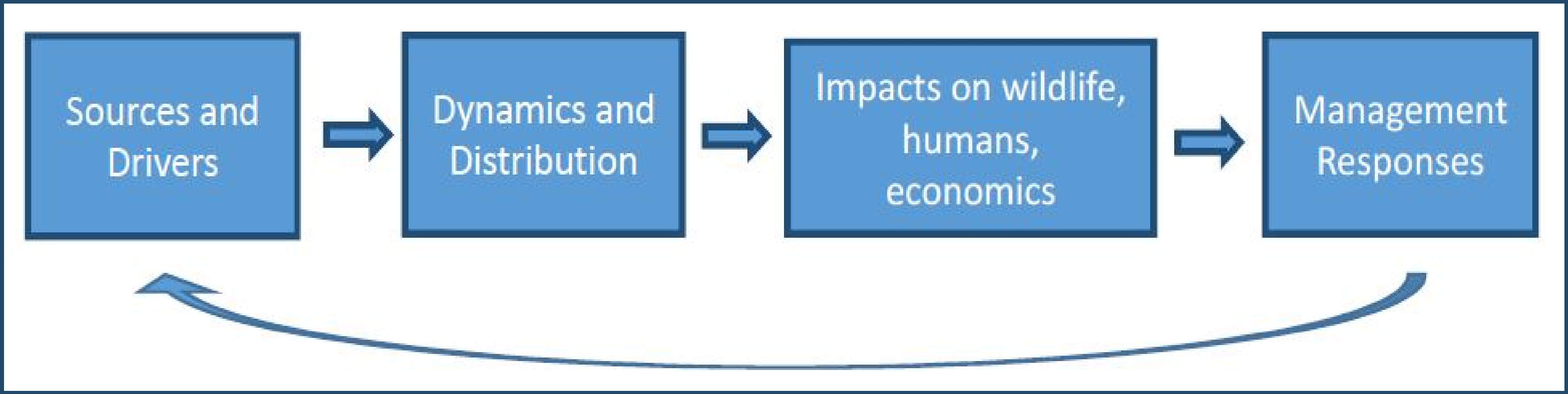
https://research.csiro.au/marinedebris/

Research Partners/ Collaborators

- Department of Environment of Australia
- Various state governments/bodies
- Ocean Conservancy
- NOAA
- United Nations Environment Programme
- NCEAS Working group (led by Kara Lavender Law)
- Convention on Biological Diversity
- International Whaling Commission
- Universities, individual researchers, etc.

Why a risk framework?

Framework components



- Conceptually broad remit
- Framework for tackling issues with variable amounts/quantities of information
- Data to underpin/drive action
- Understand (*quantify) our **uncertainty**

Four key questions – Marine Litter Framework

- Could it happen?
- Does/Did it happen?
- If so, *what* happens and what is the impact?
- How could the impact *change*?

(with intervention/ management?)

What is the likelihood of ***x***? (e.g. plastic to be eaten, animal to get tangled)

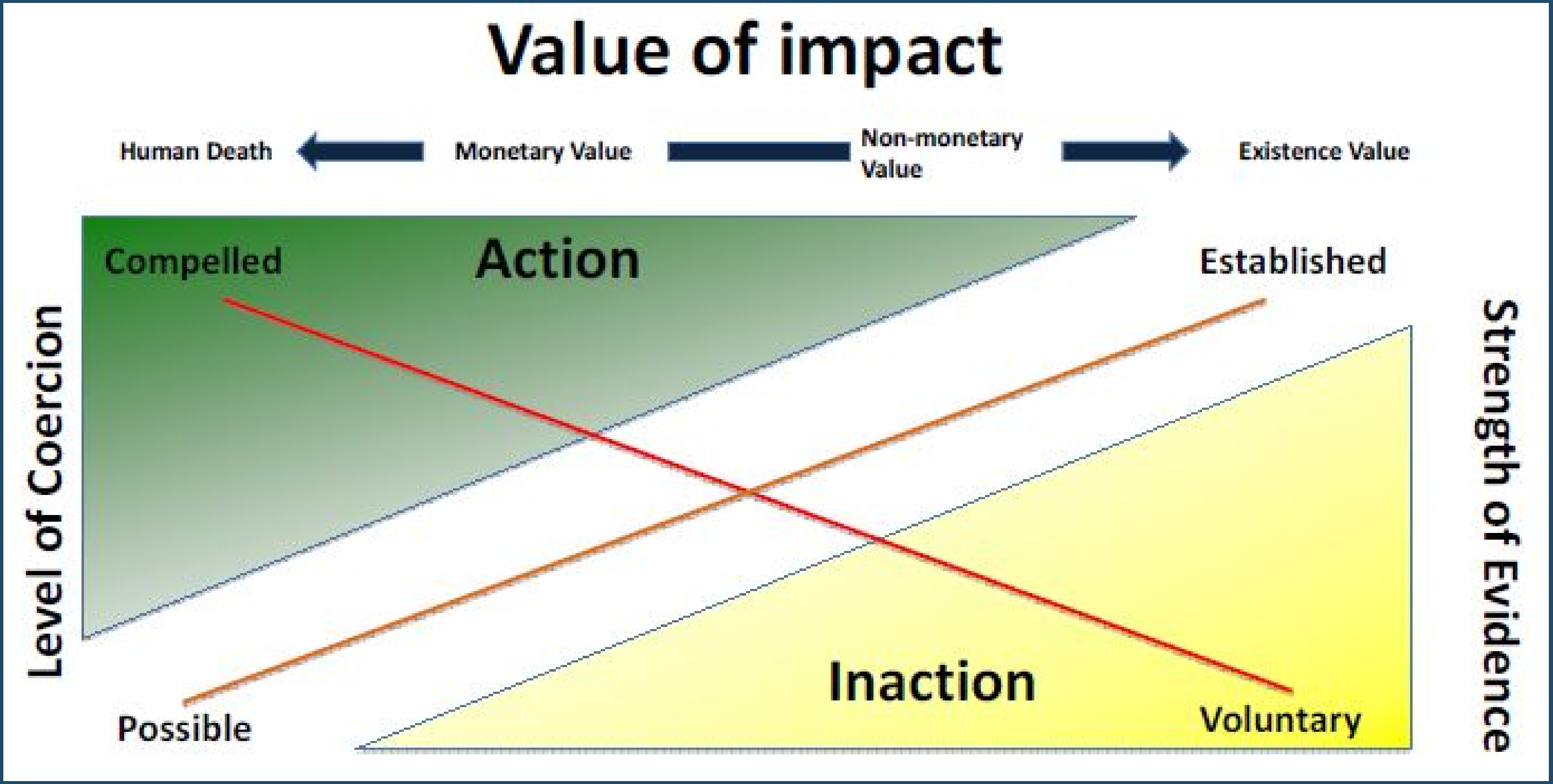
First step is *exposure*;
Next step is addressing *impact*

Plastic is there

Animal is there

Animal interacts with item (eat/entangled)

Where are we? When do we act?



Hardesty & Wilcox 2017

Mixed Data

Data Rich

Data Poor

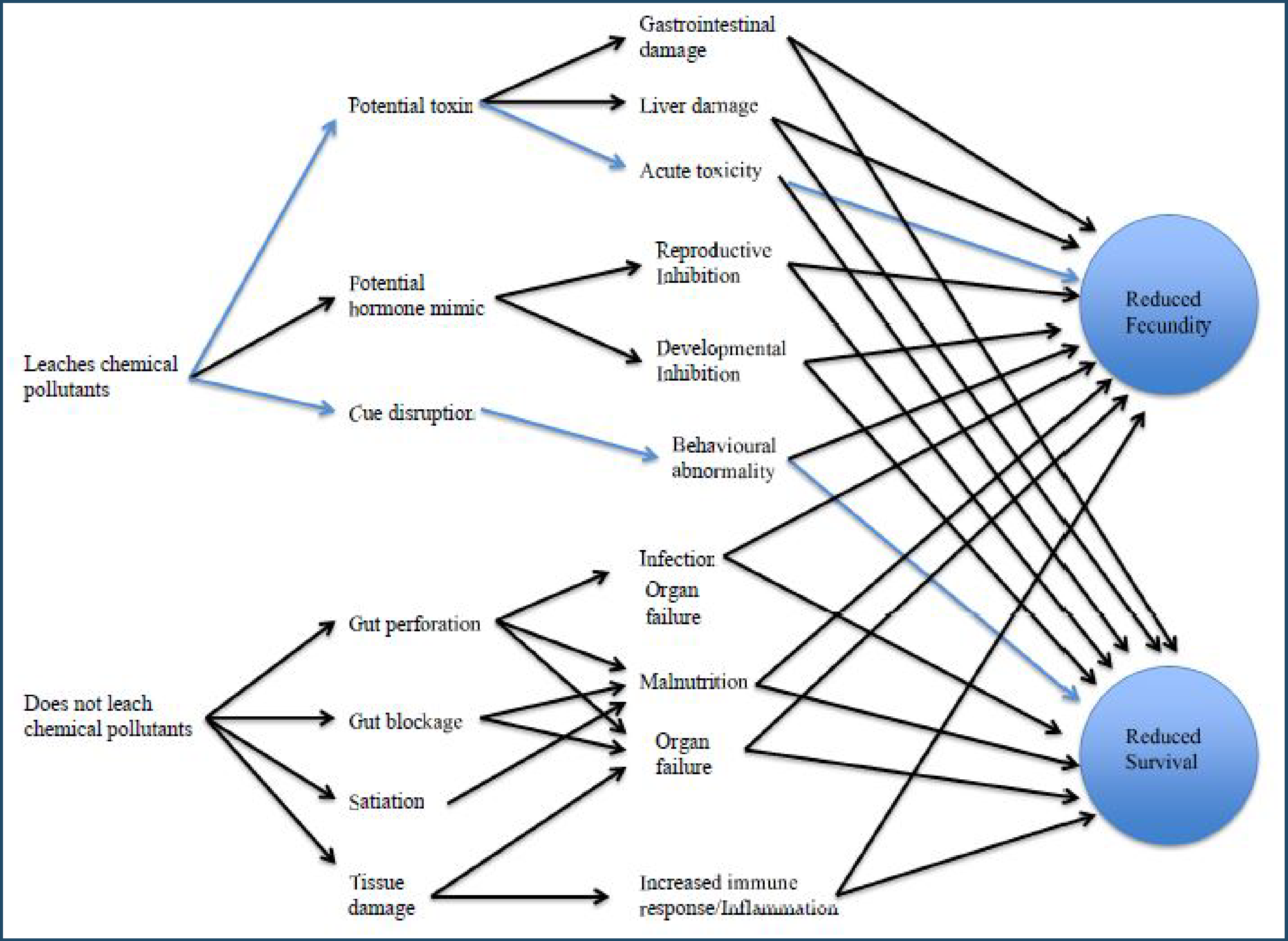
Empirical Data

Ask an expert

What is the cause?

What is the action required?

Causal Networks



Causal network for direct/indirect effects of plastic. Edges can be binary, probability (e.g. freq, intensity) or distribution. Can include variables such as species, dosage, polymer type.

Hardesty & Wilcox 2017

Risk Analysis

I. Understanding exposure

a. Seabirds and ingestion

b. Turtles and ingestion

II. Translating exposure into impact

a. Expert elicitation and coastal litter

b. Fitness effects on seabirds

c. How much plastic to kill a turtle?

III. Cost effective actions, activities, policies

Marine fauna:
What are the outcomes of ingestion?

- **Significant effects at an individual level**
  - toxins in animal tissues
  - Disruption of feeding
  - Increased energetic costs

- **Population level consequences**
  - reduced migratory ability
  - increased mortality
  - lower reproduction
  - reduced population numbers

Translating predictions into biodiversity risk

- Probability of ingestion & hotspots
- Predictions summed over ~ 200 seabird species

Threat of plastic pollution to seabirds is global, pervasive, and increasing

Chris Wilcox[a,1], Erik Van Sebille[b,c], and Britta Denise Hardesty[a]

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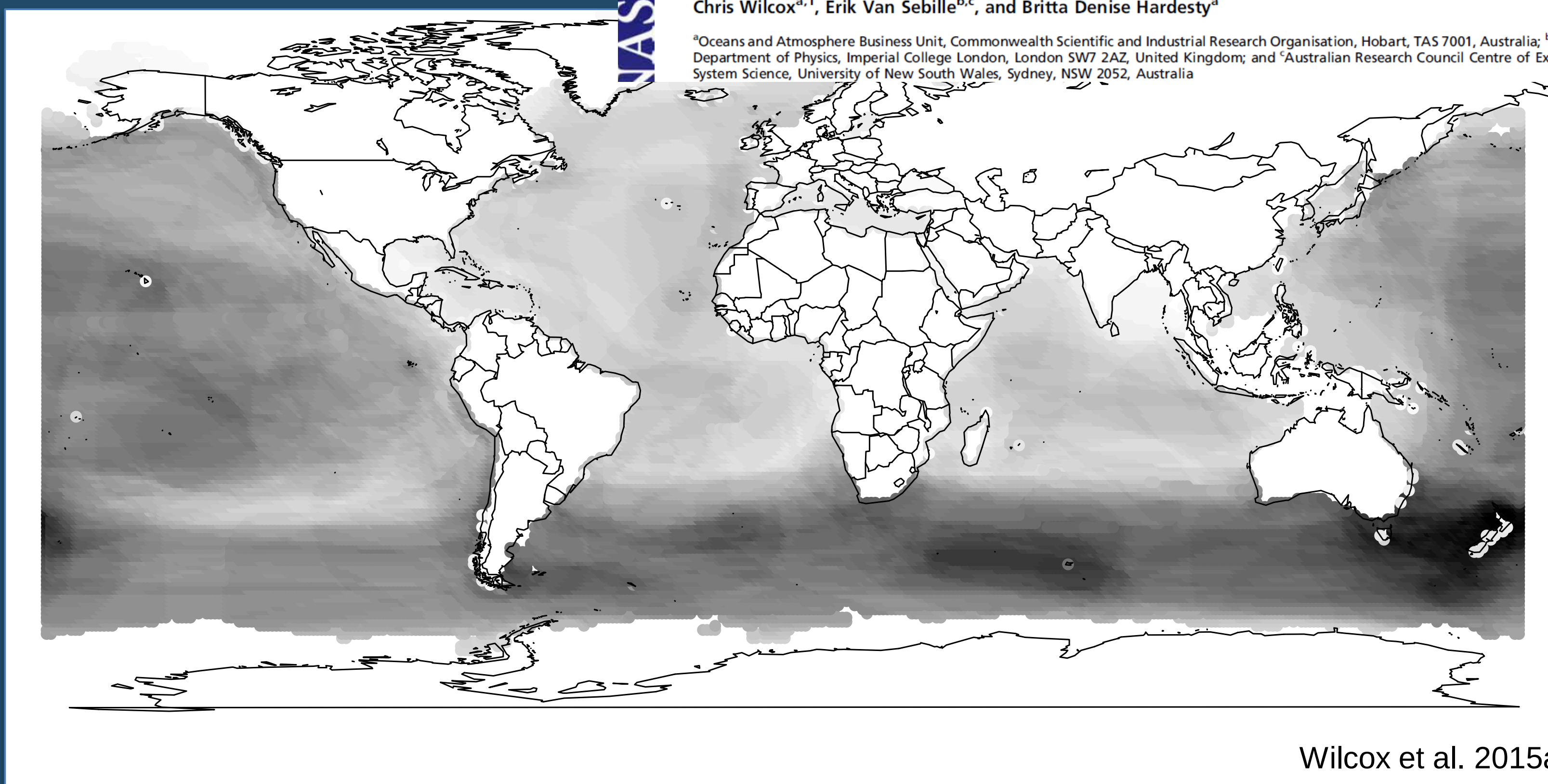
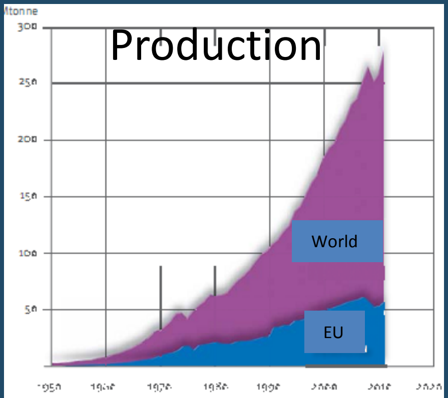
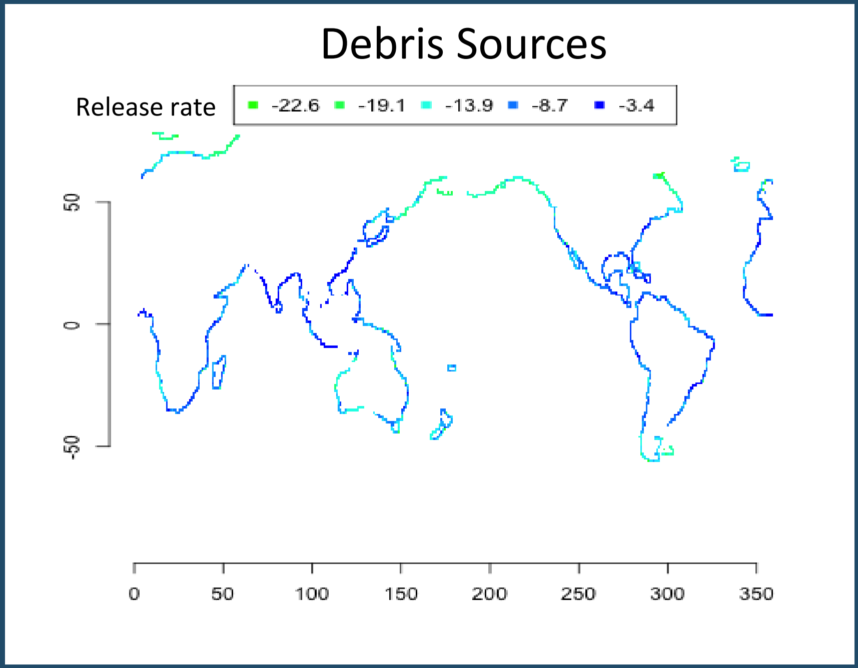


Wilcox et al. 2015a

Estimating debris encounter rates

- Used a global model of drift – based on tracking oceanic drifters
- Exponential increase in release since 1950s (Plastics Europe)
- Proportional to coastal pop.

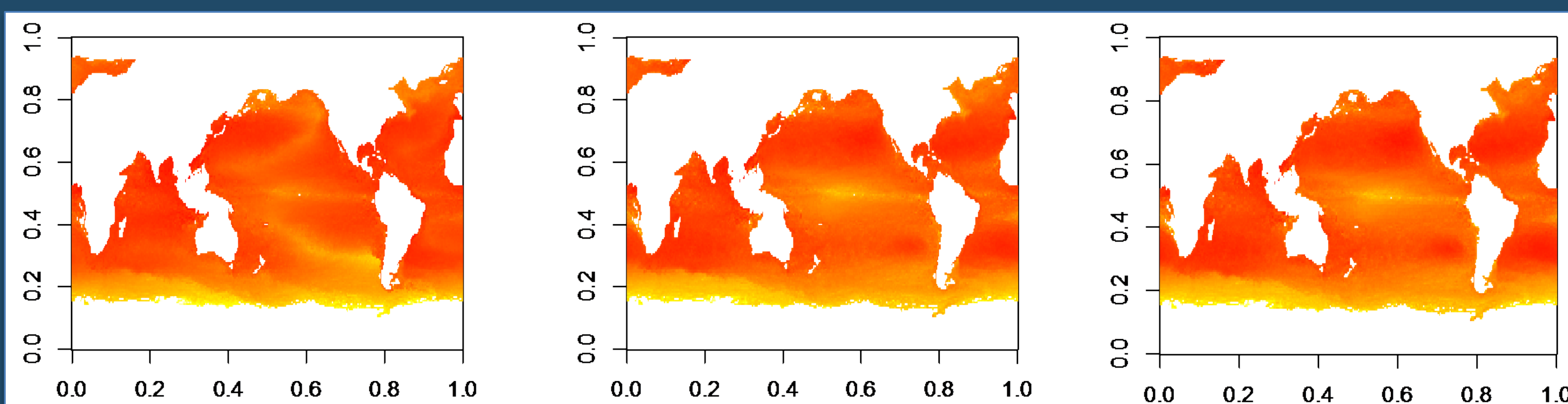




Estimating encounter rates

- Distribution of debris stabilizes quickly
- Coastal zones always high (sources)
- Major gyres high within 16 years

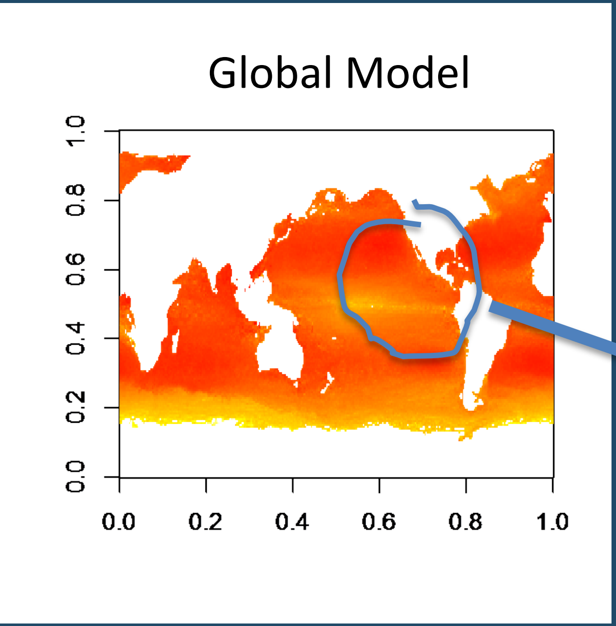
Year 1 Year 16 Year 50

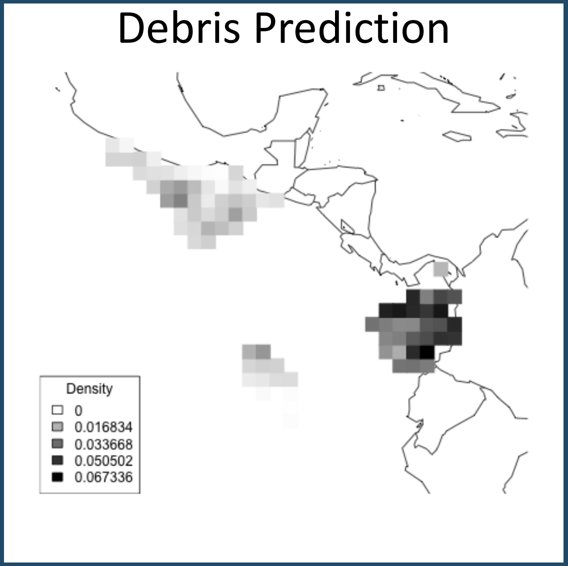


Estimating encounter rates

- Use species range to find relevant areas

- Estimate plastic density within the area



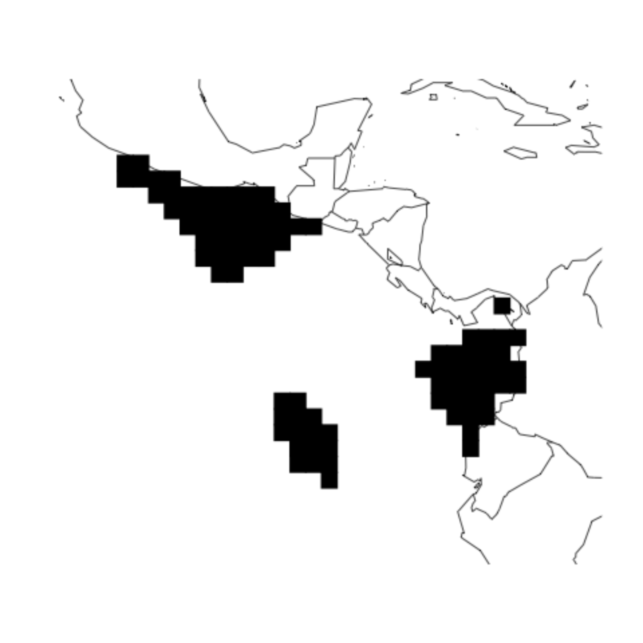


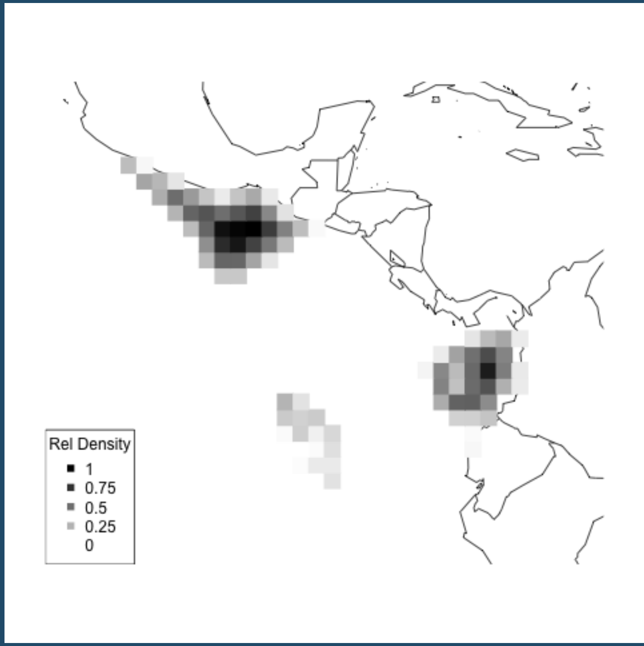
- 188 seabird species, global scale

Combined with seabird distribution

Two models for distribution

- Density is even across breeding and nonbreeding regions
- Density is proportional to the distance from the edge of the distribution



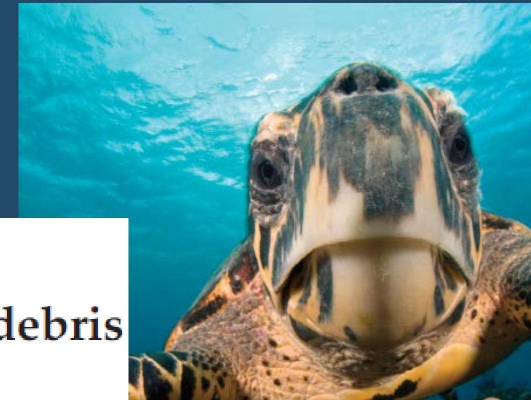


Encounter rates across species

- Birds range widely in expected encounter rates
  - Six orders of magnitude difference across species

  - South Polar Skua mean: 0.000005 items/area
  - Northern Fulmar mean: 0.36 items/area

Estimating debris encounter rates



Global Change Biology (2015), doi: 10.1111/gcb.13078

Risk analysis reveals global hotspots for marine debris ingestion by sea turtles

QAMAR A. SCHUYLER[1], CHRIS WILCOX[2], KATHY A. TOWNSEND[3], KATHRYN R. WEDEMEYER-STROMBEL[4], GEORGE BALAZS[5], ERIK VAN SEBILLE[6,7] and BRITTA DENISE HARDESTY[2]

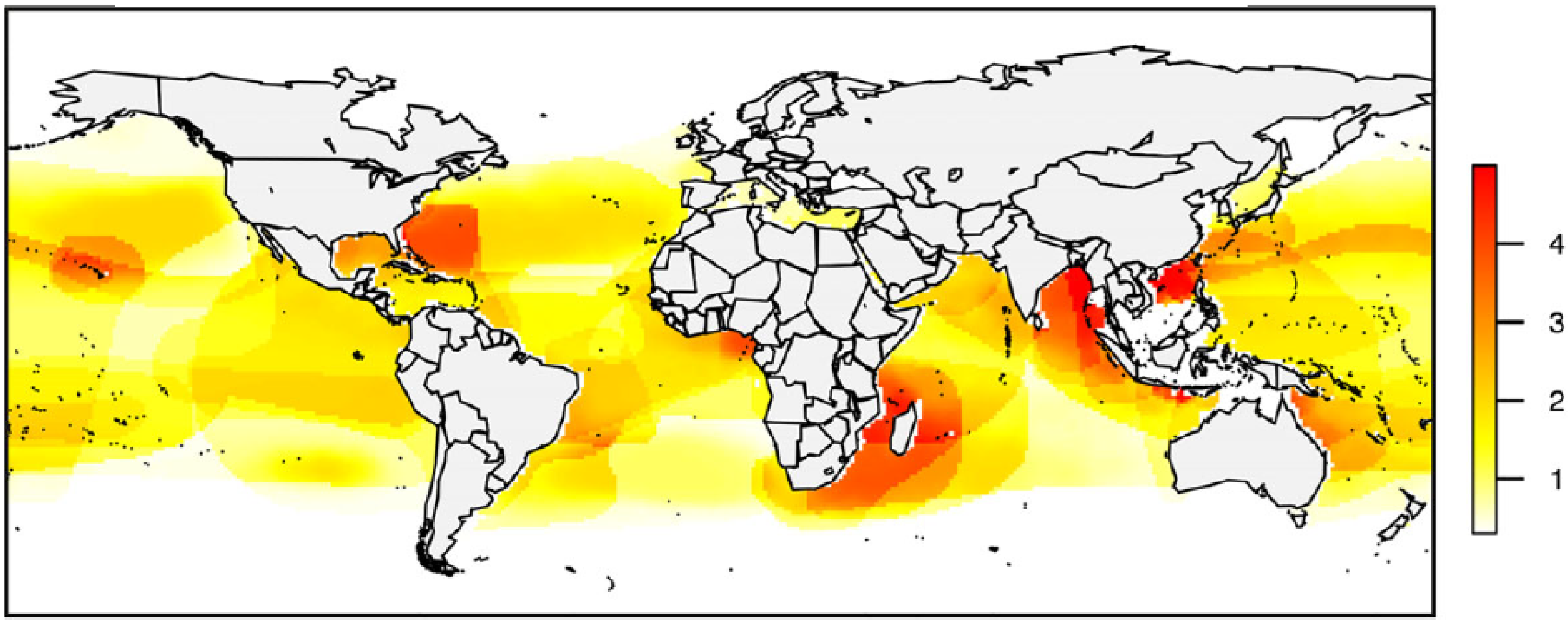


Fig. 1 Predicted probability of debris ingestion risk for all species. Red indicates a high probability of debris ingestion while lighter colours indicate lower probability of debris ingestion.

Schuyler et al. 2015

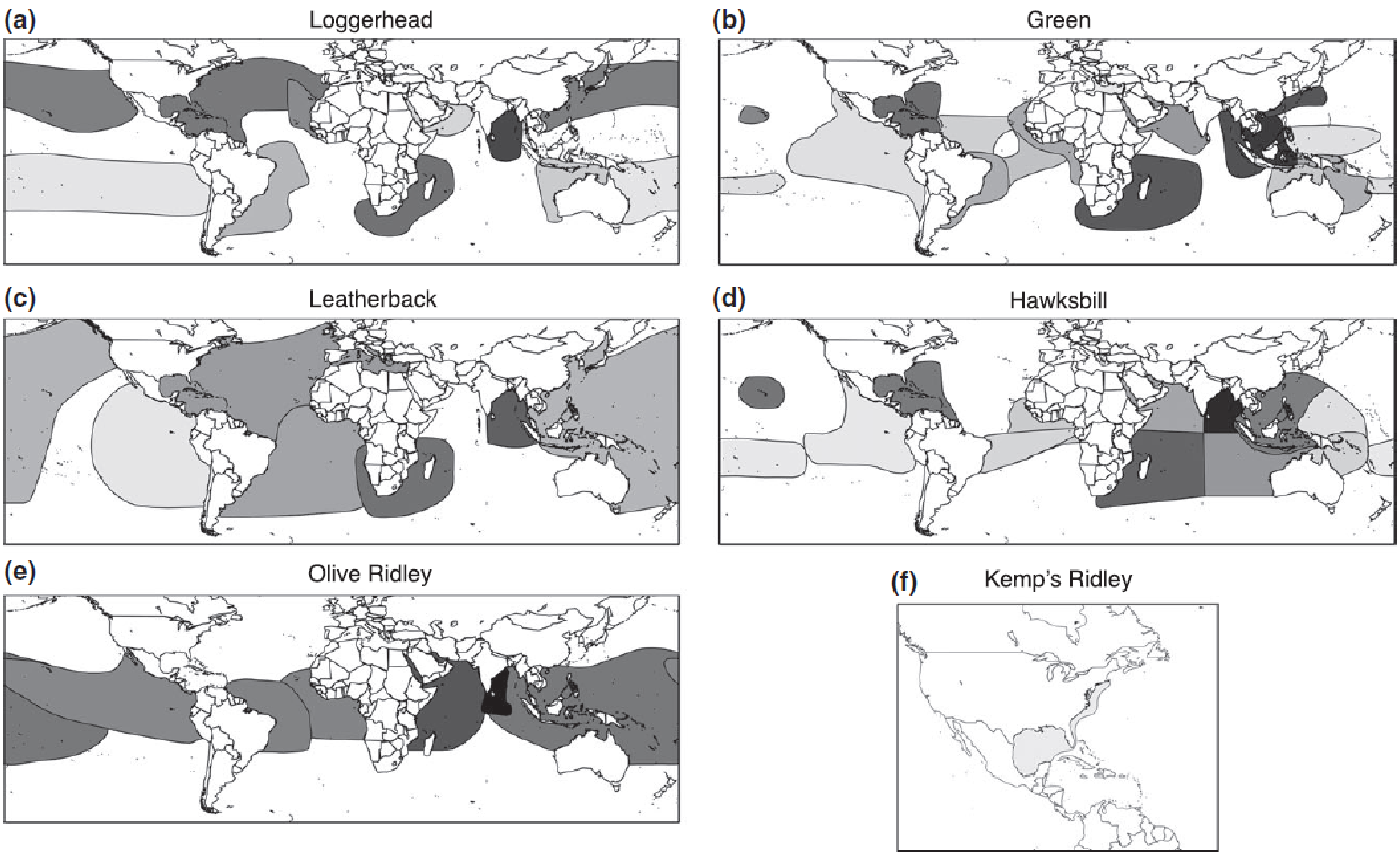


Fig. 3 Locations and relative risk values [scaled from lowest risk (white) to high risk (black)] of each regional management unit (RMU). (a) Loggerhead turtles, (b) green turtles, (c) leatherback turtles, (d) hawksbill turtles, (e) olive ridley turtles, and (f) Kemp's ridley turtles. Values are scaled across all species to allow comparison between species.

Schuyler et al. 2015

Ask an expert – or several!

Ocean Conservancy survey (opportunities for intervention)

- 3 taxa: Seabirds, Turtles, Marine Mammals
- 3 impacts: Entanglement, Ingestion, Contamination
- 20 most frequent items found in coastal cleanups – global, 30 year dataset

SEVERITY

If a single, individual animal within the animal group experiences the threat, what is the impact of the interaction? When considering the severity of a product's impact, account for the product's impact both in its entirety as well as its fragmented or degraded state. [**Example:** If a whale becomes entangled in a fishing net, what is the impact ? ***NOTE***: *We are NOT asking what the chance is of that whale becoming entangled.*]

4 = Very High: The individual animal **dies** as a result of the interaction.
3 = High: The individual animal **may die** as a result of the interaction
2 = Medium: The individual animal experiences a **nonlethal impact** (e.g., reduced mobility, increased risk of predation, etc.) as a result of the interaction.
1 = Low: There is **no impact** to the individual animal as a result of the interaction.

SPECIFICITY

For the group of animals impacted by the product, what fraction of animals do you expect to experience this level of severity? [**Example:** What fraction of whales do you expect to die from becoming entangled in a fishing net.]

4 = Very High: 76-100% of animals experience the specified severity.
3 = High: 26-75% of animals experience the specified severity.
2 = Medium: 11-25% of animals experience the specified severity.
1 = Low: Less than 10% of animals experience the specified severity.

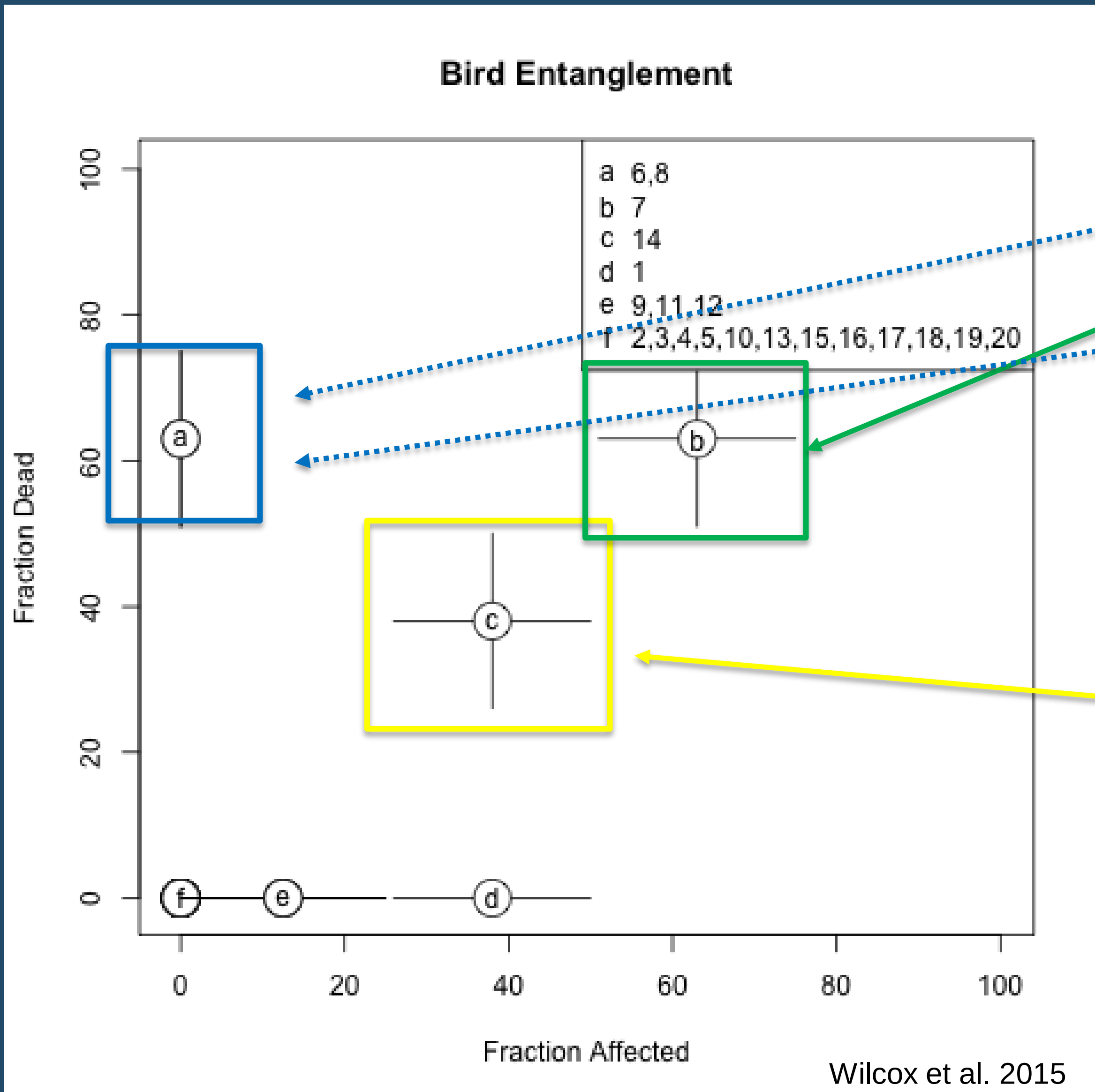
Wilcox et al. 2015

	Rank of expected impact			
Item name	Mean	Bird	Turtle	Mammal
Buoys/traps/pots	1.0	1	1	1
Monofilament	2.3	3	2	2
Fishing nets	2.7	2	3	3
Plastic bags	5.7	4	9	4
Plastic utensils	5.7	7	4	6
Balloons	6.7	8	5	7
Butts	7.3	5	12	5
Caps	7.7	9	6	8
Food packaging	8.7	10	7	9
Other EPS packaging	9.7	11	8	10
Hard plastic cont.	11.3	6	13	15
Plastic food lids	11.3	13	10	11
Straws/stirrers	12.3	14	11	12
Takeout containers	15.3	15	18	13
Cans	15.7	17	14	16
Beverage bottles	16.0	12	17	19
Unidentified plastic fragments	16.3	16	19	14
Cups/plates	16.7	18	15	17
Glass bottles	17.7	19	16	18
Paper bags	20.0	20	20	20

[a] Note: rankings are based on the most expected severe impacts from entanglement, ingestion and chemical contamination. Mean rank is the arithmetical mean of the scores across all three taxa.

Hardesty & Wilcox 2017

Results - Severity



1. Balloons
2. Caps
3. Beverage cans
4. Cigarette butts
5. Cups and plates
6. Fishing buoys, traps and pots
7. Fishing line
8. Fishing nets
9. Wrappers
10. Glass beverage bottles
11. Hard plastic containers
12. Other EPS Packaging
13. Paper bags
14. Plastic bags
15. Plastic beverage bottles
16. Plastic Food and Beverage Lids
17. Plastic utensils
18. Straws and Stirrers
19. Takeout food containers
20. Unidentifiable plastic fragments

Results - Severity

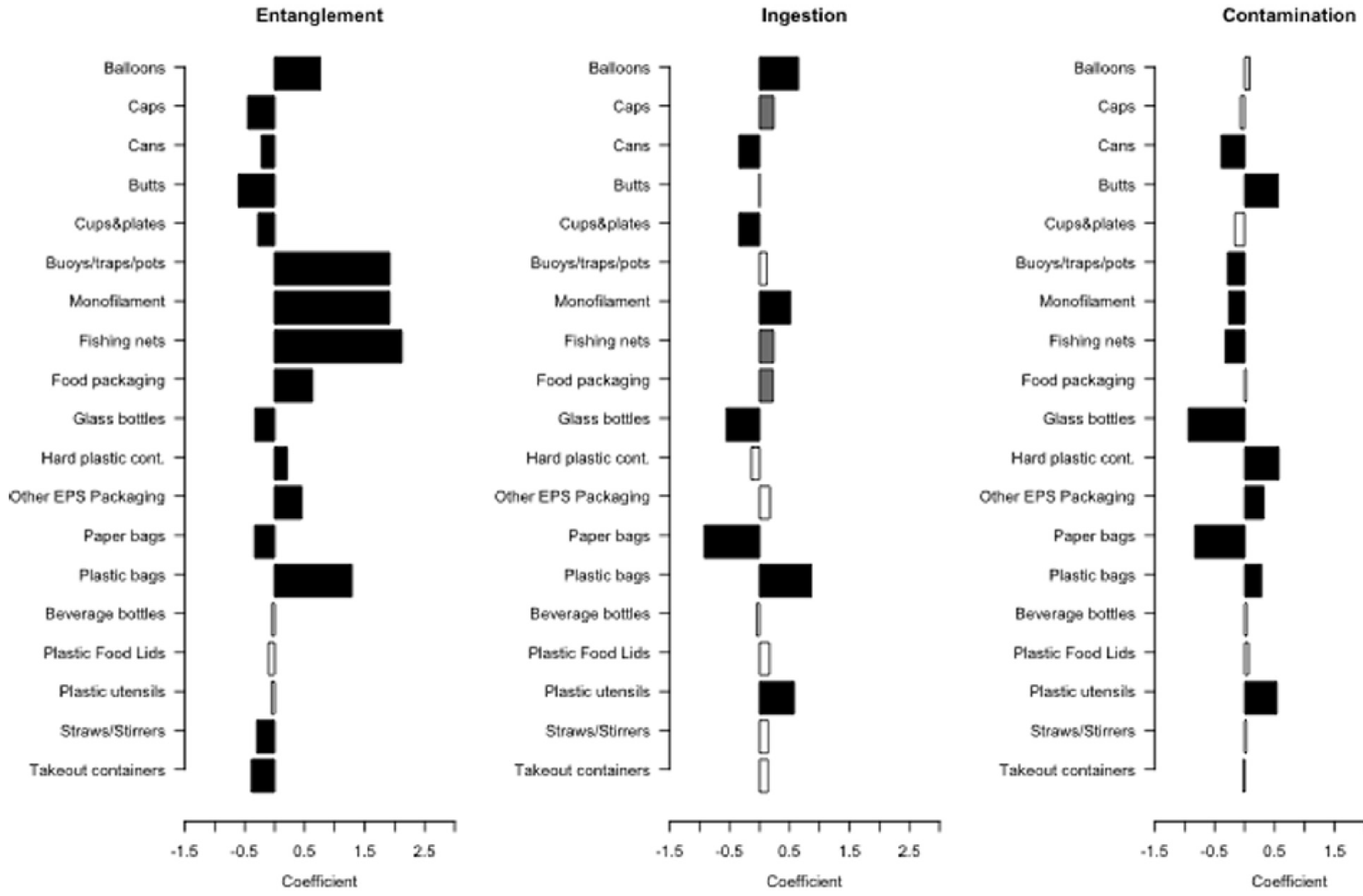
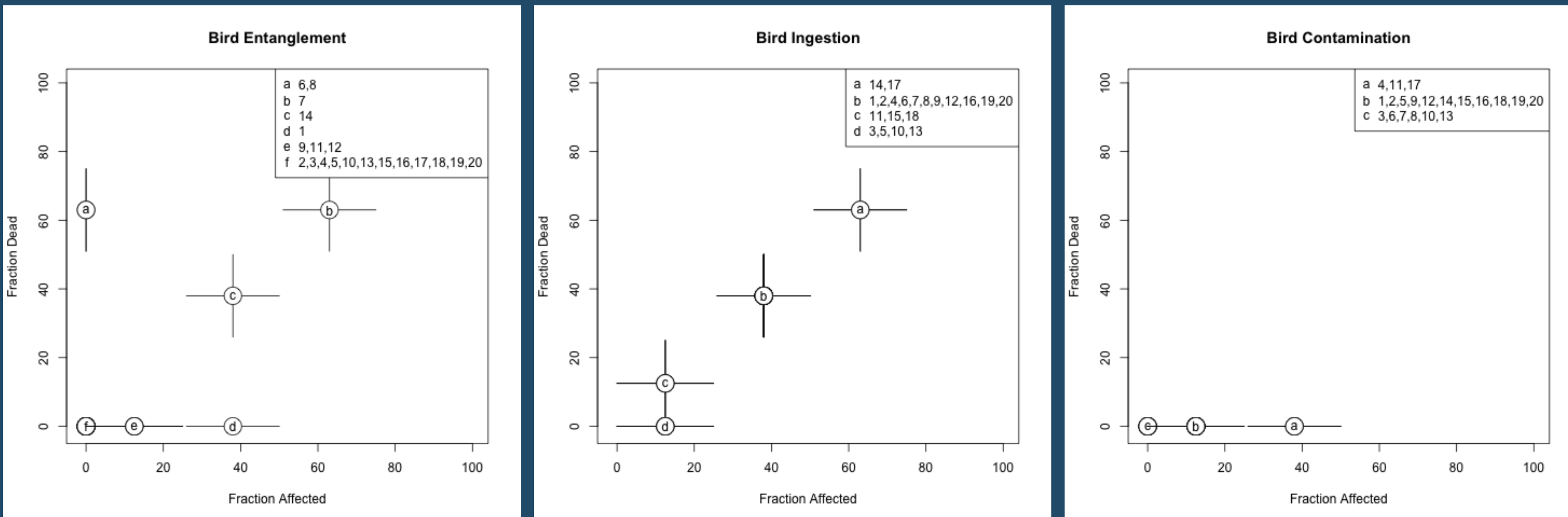


Fig. 2. Relative severity of different types of debris. Respondents were asked to score based on the likelihood of an interaction between the specific debris item and animals in each taxa. Score 1 – $<$25% of animals will experience the interaction; 2 – 26–50% of animals will experience the interaction; 3 – 51–25% of animals will experience the interaction; 4 – 76–100% of animals will experience the interaction. Bars represent the coefficients in the best fitting model for each debris category, relative to plastic fragments. Bar shading denotes the statistical significance of a coefficient, black is significant ($p < 0.05$ level), grey is non-significant but trending ($p < 0.10$), white is non-significant.

Wilcox et al. 2015

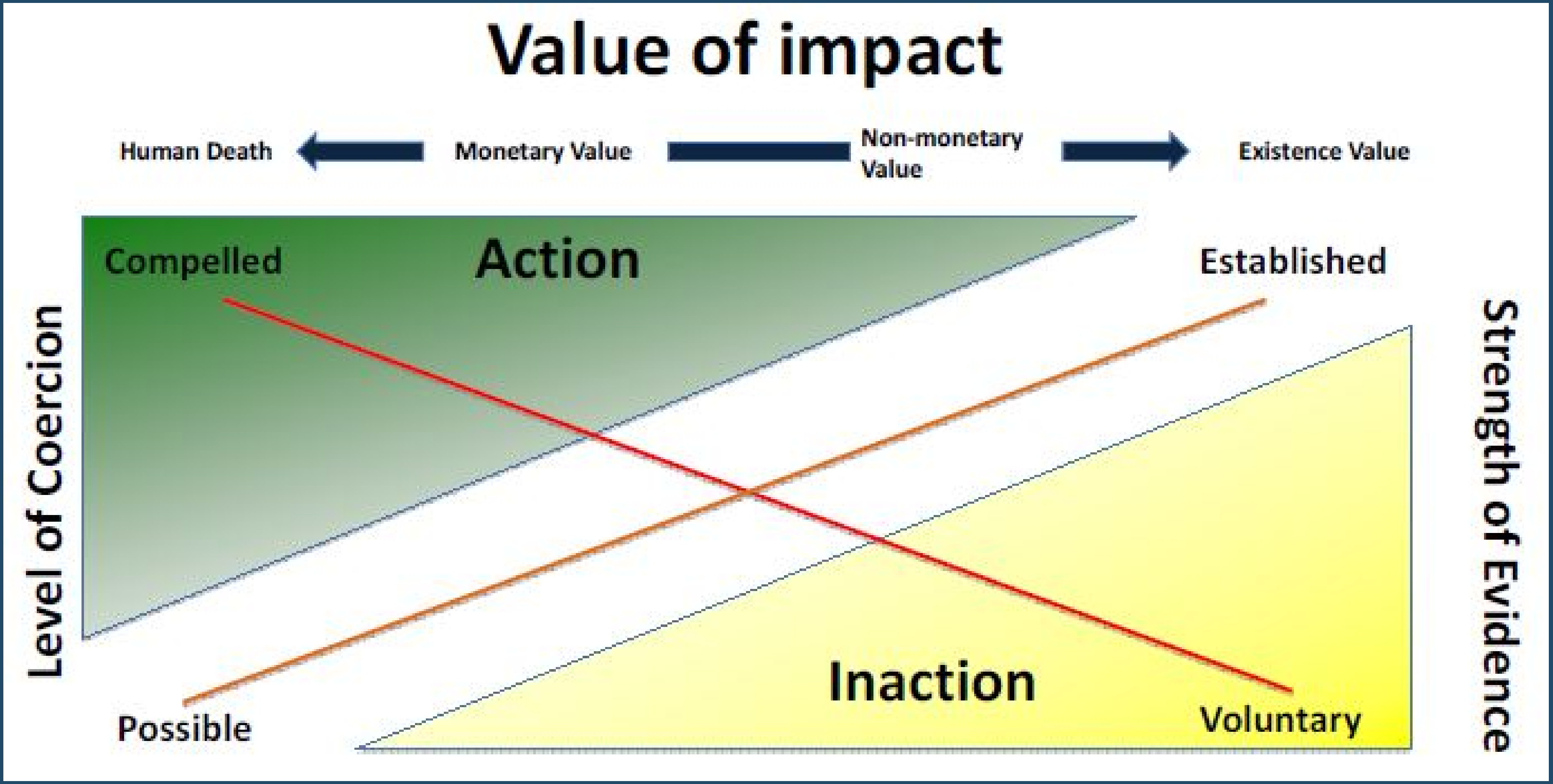
Results - Summary



- Entanglement > Ingestion >> Contamination
- Contamination reflects level of uncertainty
- Generally matches observations
  - linear things (rope, fishing gear, plastic bags) worst for ***entanglement*** – fairly specific risks
  - Ingestion of ***bags***, food utensils worst, but many other items trail closely
  - Contamination – low level, items fairly similar, most impacts nonlethal

Wilcox et al. 2015

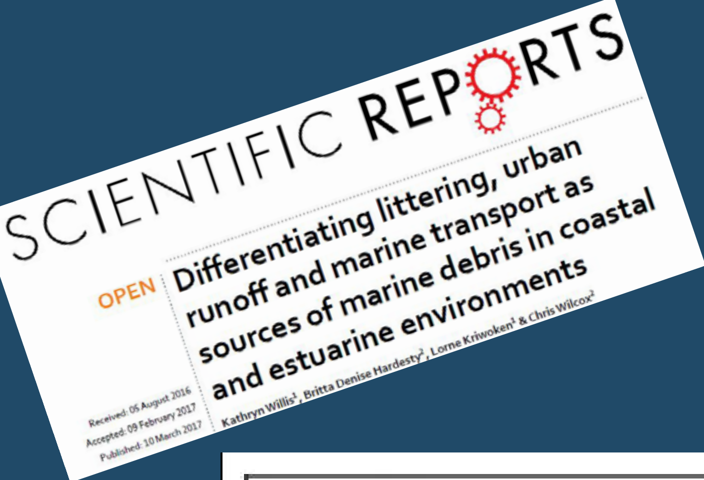
Where are we? When do we act?



Consumer decisions, waste infrastructure, economic impacts, tourism, transport, biodiversity values

Hardesty and Wilcox 2017

One example… from Jakarta


SCIENTIFIC REPORTS

OPEN

Differentiating littering, urban runoff and marine transport as sources of marine debris in coastal and estuarine environments

Kathryn Willis[1], Britta Denise Hardesty[2], Lorne Kriwoken[1] & Chris Wilcox[2]

Received: 05 August 2016
Accepted: 09 February 2017
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RESEARCH COMMUNICATIONS RESEARCH COMMUNICATIONS

Estimating quantities and sources of marine debris at a continental scale

Britta Denise Hardesty*, TJ Lawson, Tonya van der Velde, Matt Lansdell, and Chris Wilcox

Where to from here?

Rank	Country
1	China
2	Indonesia
3	Philippines
4	Vietnam
5	Sri Lanka
6	Thailand
7	Egypt
8	Malaysia
9	Nigeria
10	Bangladesh
11	South Africa
12	India
13	Algeria
14	Turkey
15	Pakistan
16	Brazil
17	Burma
18*	Morocco
19	North Korea
20	United States

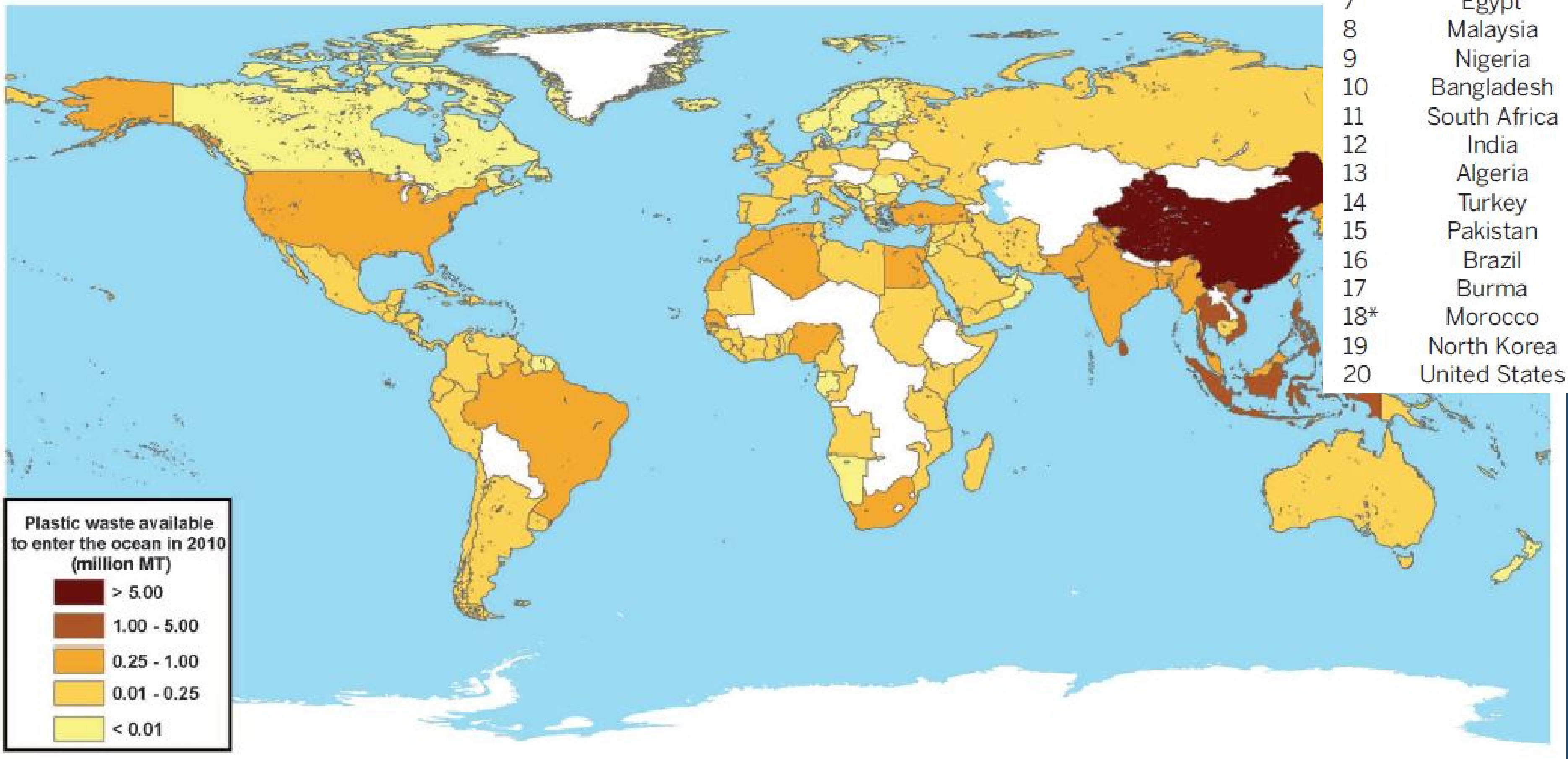

Fig. 1. Global map with each country shaded according to the estimated mass of mismanaged plastic waste [millions of metric tons (MT)] generated in 2010 by populations living within 50 km of the coast. We considered 192 countries. Countries not included in the study are shaded white.

Jambeck et al. 2015

… A New project

Rank	Country
1	*China
2	*Indonesia
3	*Philippines
4	* Vietnam
5	* Sri Lanka
6	* Thailand
7	Egypt
8	*Malaysia
9	Nigeria
10	* Bangladesh
11	* South Africa
12	* India
13	Algeria
14	Turkey
15	*Pakistan
16	* Brazil
17	Burma
18*	Morocco
19	North Korea
20	* United States

We welcome partners!

Take Home Messages:

- Risk framework is a useful lens for the problem
- Entanglement > Ingestion >> Contamination
- Missing marine mammal (and inverts) risk assessment (working on fish)
- Acknowledge uncertainty/knowledge gaps – don't be hampered
- Combining empirical data and modelling allows us to better identify interdiction points, sources and sinks
- Working with industry is key – economic benefits/viability and circular economy framework is critical

Thank you

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