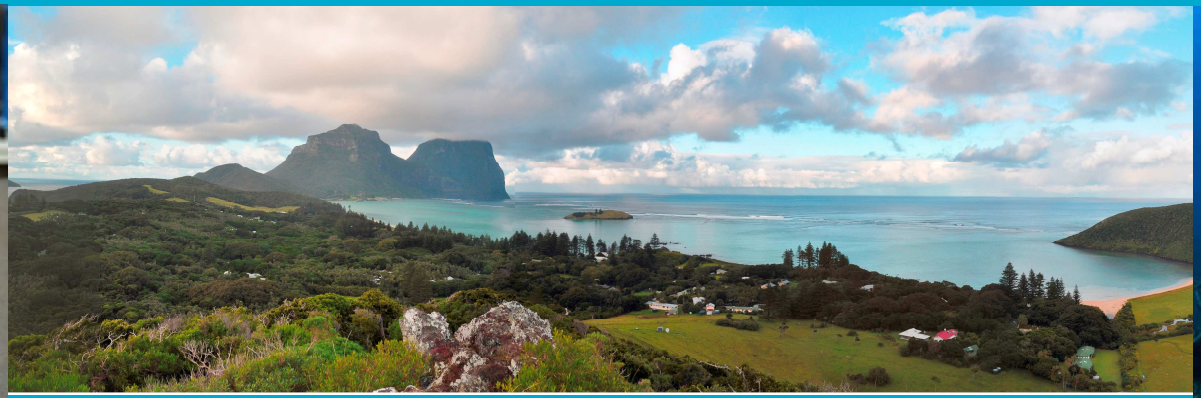


Risk Analysis for Marine Debris Impacts on Wildlife

Britta Denise Hardesty and Chris Wilcox

Saturday 23 January 2016

Roadmap

Overview of Australia's national MD program

Risk Analysis
Approaches we are taking to:

Understand exposure

1a. Seabirds & ingestion
2b. Turtles & entanglement (won't show)

Translate exposure into impact

2a. Measuring fitness effects on seabirds
2b. Expert elicitation and waste

Where does it come from?

- Beachgoers
- Storm sewers
- Commercial & recreations vessels
- Industrial facilities
- Landfill
- Waste disposal activities
- Offshore industrial activities

Land and Sea based sources

It's everywhere, all the time, increasing

How much is there?

TOP 10 DEBRIS ITEMS

Item	20 Year Total
Cigarettes and Cigarette Filters	12,848,255
Caps/Lids	4,186,593
Cups/Plates/Utensils	3,575,209
Bags	3,346,666
Food Wrappers and Containers	3,318,729
Beverage Bottles (Glass)	2,329,142
Beverage Cans	2,293,559
Beverage Bottles (Plastic)	1,965,210
Straws/Stirrers	1,960,122
Rope	925,301
Total	**36,748,786**

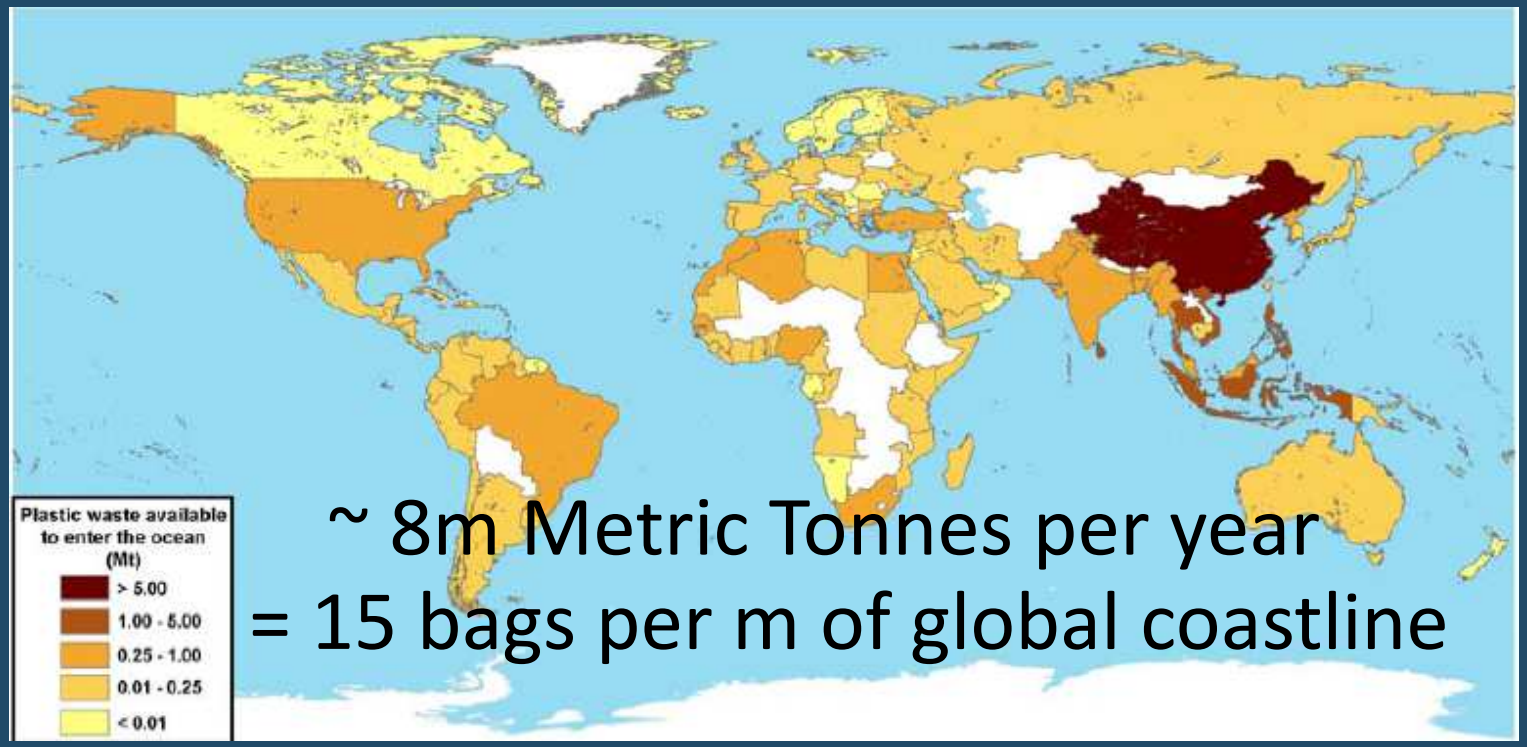
Source: www.oceanconservancy.org/ICC

~ 8.4 M metric tonnes goes in per year

~ 51 trillion particles in the ocean

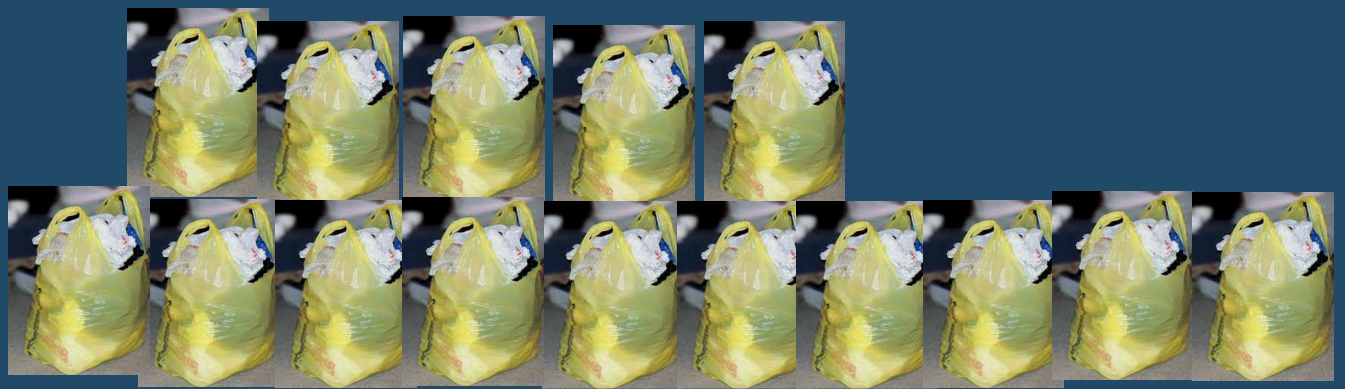
~ 115M pieces on Au Coast – 5.2 per person!

Plastic entering the oceans



~ 8m Metric Tonnes per year

= 15 bags per m of global coastline



How does it move?

ARCTIC OCEAN

These patches also contain ch
sludge and other debris and t
can absorb organic pollutants
seawater. Fish and birds even
plastic once it has broken dow
enough pieces, which humans

The patch mostly consists of pelagic plastics, formed from plastic bags, plastic water bottles, bottle caps and styrofoam. **Plastic do not biodegrade**, the sun breaks these down into smaller and smaller pieces through photodegradation, which is why it is so difficult to judge the size of the patches, since these pieces are not visible from satellites or planes.

The plastic flotsam collects in the first 10 meters of the water column.

GYRE CURRENT

An estimated 70% of this garbage sinks to the ocean floor.

Debris ranges in size from abandoned fishing nets to micro-pellets found in abrasive cleaners. Garbage from Asia's east coast takes about a year or less to enter the Pacific gyre, while trash from the west coast of North America can take up to 6 years.

31

10 per
annual 200 billion pounds
of plastic produced winds
up in the ocean.

OYASHIO
BERING
ALASKA
NORTH PACIFIC
KUROSHIO
CALIFORNIA

NORTH PACIFIC GYRE
SUBTROPICAL CONVERGENCE ZONE
The wind-driven, swirling current of the North Pacific Gyre gathers marine pollution, slowly moving it towards the center of the region and **trapping it**.

WESTERN GARBAGE PATCH

EASTERN GARBAGE PATCH

The size of the patch is unknown and estimated to be anywhere from 0.41% to 8.1% of the size of the Pacific Ocean. Most scientists estimate it to be **twice the size of Texas**.

2X

NORTH ATLANTIC GYRE

ATLANTIC OCEAN

Cleanup of the patch is difficult due to the size of these patches and that the areas of high concentration are constantly shifting, along with prohibitive operating costs, and that **no nation will take responsibility** for it.

Water skater insects (Halobates Sericeus) lay their eggs on bird feathers, pumice and seashells and both insect and egg are important to the marine food chain. The accumulating microplastic has caused them to alter their mating habits and are now laying their eggs on the floating plastic carrying them out of their natural ecosystem.

NORTH EQUATORIAL

EQUATORIAL COUNTERCURRENT

SOUTH EQUATORIAL

SOUTH ATLANTIC GYRE

INDIAN OCEAN

PACIFIC OCEAN

90% of the garbage floating in the Earth's oceans is plastic. **Less than 5%** of all plastic is recycled.

5%

ESTIMATED DECOMPOSITION RATES

Cardboard Box	2 Months
Cigarette Butt	1-5 Years
Plastic Grocery Bag	10-20 Years
Styrofoam Cup	50 Years
Foam Buoy	50 Years
Tin Can	50 Years
Aluminum Can	200 Years
6 Pack Rings	400 Years
Plastic Bottle	**450 Years**
Fishing Line	600 Years
Glass Bottle	Unknown

SOUTH PACIFIC GYRE

It is estimated that 80% of the plastics in the garbage patch come from land-based sources (rivers and sewer systems emptying into the sea) and the other 20% from ship and ocean sources, (cruise ships, fishing vessels).

20%

80%

A typical 3,000 passenger cruise ship produces over **8 tons of solid waste** a week, much of which ends up in the ocean.

INDIAN OCEAN GYRE

CSIRO

How does it affect wildlife?

- ~700 species interact (from plankton to top predators)
- It works in two ways:
  - Ingestion (+ chemical contamination)
  - Entanglement

What are the outcomes?

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

175+ pieces of plastic in one bird
26 grams (~5-8% total weight)

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

Plastic Impacts

- Environmental
- Aesthetic
- Cultural
- Commercial/economic

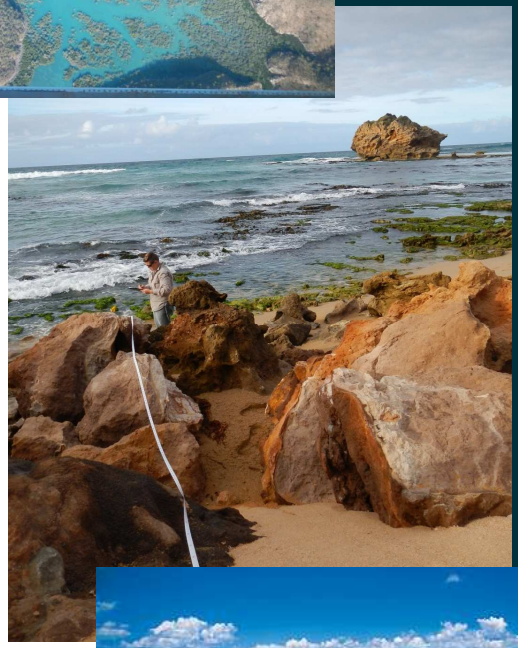
Pervasive

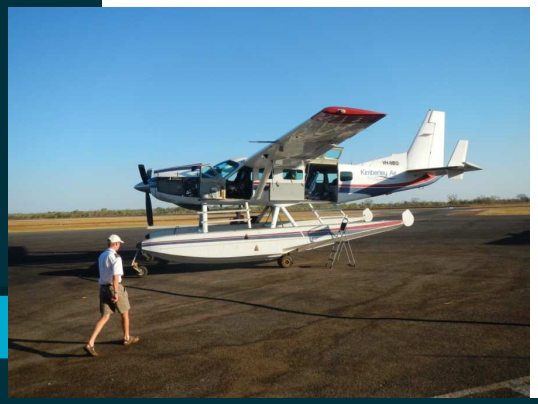
Plastics in fur seal scats in sub-Antarctic– likely via fish prey

To respond to a problem, you need information

Coastal debris surveys

175+ survey sites
580 transects





Hardesty et al. in press

Citizen science coastal surveys

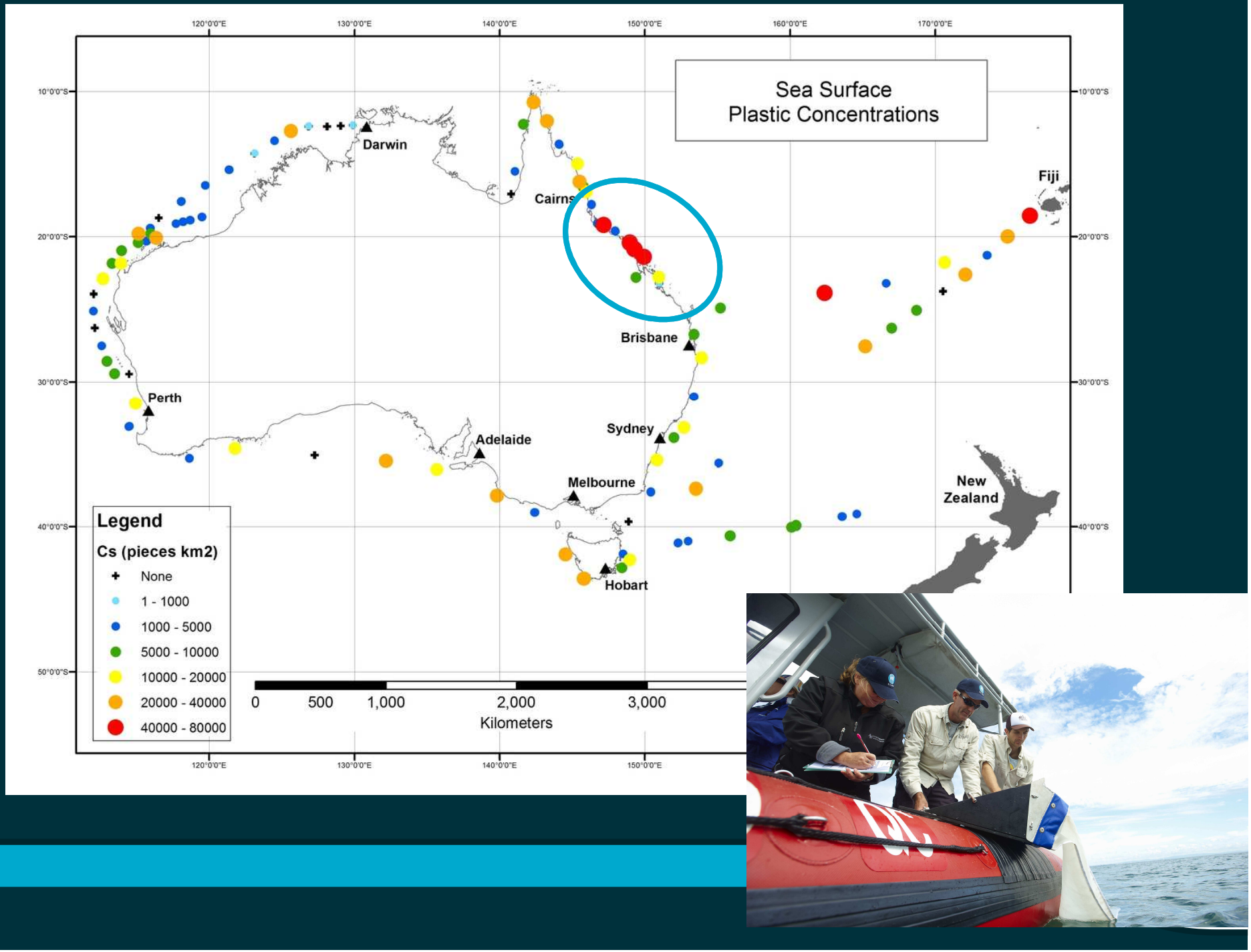
~7,000 students

50+ class/school programs

Online database/curriculum materials

van der Velde et al. in press

15 Intensive field-based science educator trips


Sea Surface
Plastic Concentrations
Darwin
Cairns
Brisbane
Perth
Adelaide
Sydney
Melbourne
Hobart
Fiji
New
Zealand
Legend
Cs (pieces km2)
None
1 - 1000
1000 - 5000
5000 - 10000
10000 - 20000
20000 - 40000
40000 - 80000
0
500
1,000
2,000
3,000
Kilometers
120°0'0"E
130°0'0"E
140°0'0"E
150°0'0"E
160°0'0"E
170°0'0"E
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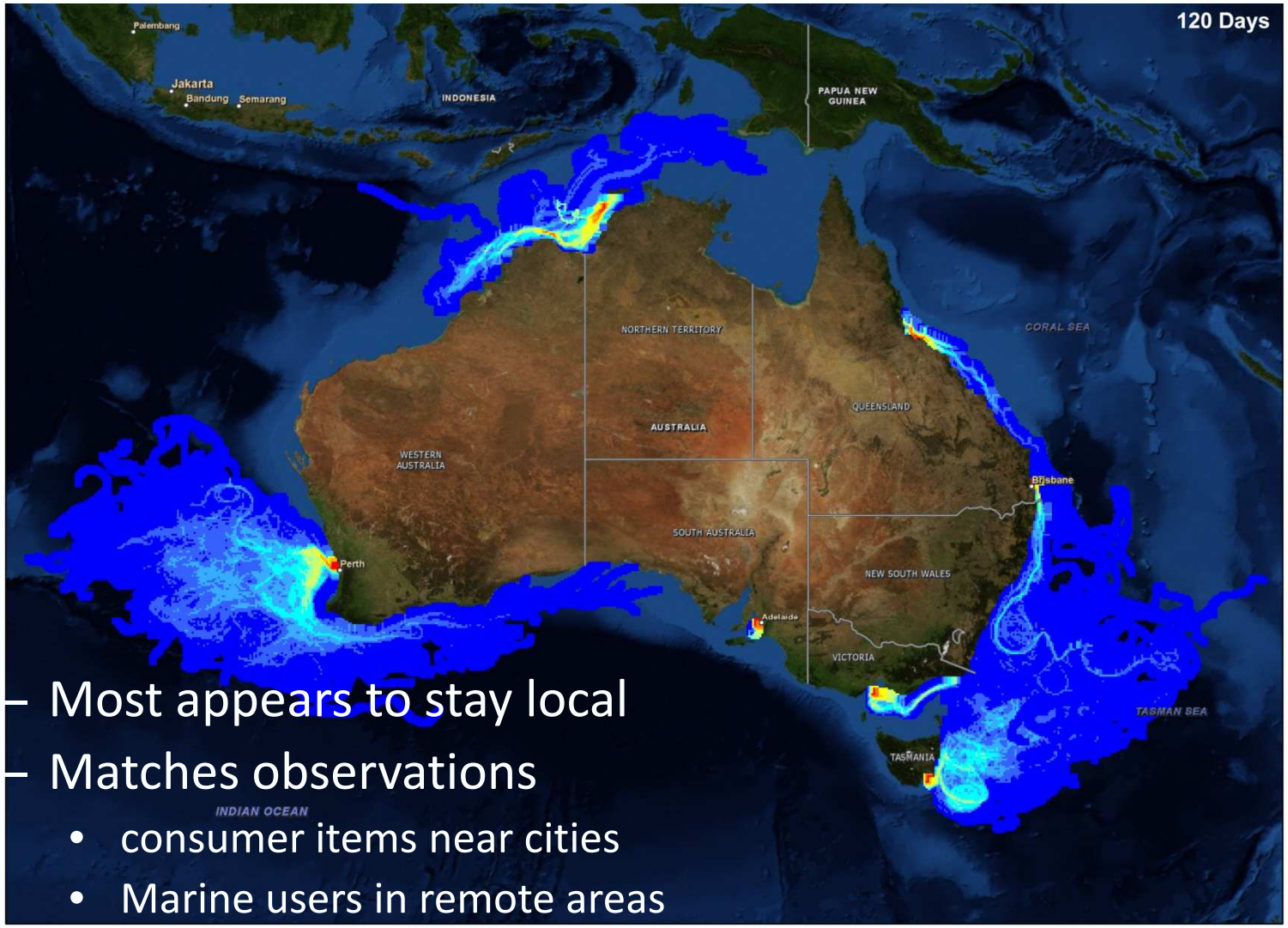
50°0'0"S

Coastal litter near cities



- Most appears to stay local
- Matches observations
  - consumer items near cities
  - Marine users in remote areas

Roadmap

Overview of Australia's national MD program

Approaches we are taking to:

Risk Analysis

Understand exposure

1a. Seabirds & ingestion

2b. Turtles & entanglement (won't show)

Translate exposure into impact

2a. Measuring fitness effects on seabirds

2b. Expert elicitation and waste

1a. Exposure, risk and ingestion by seabirds

Steps in the analysis:

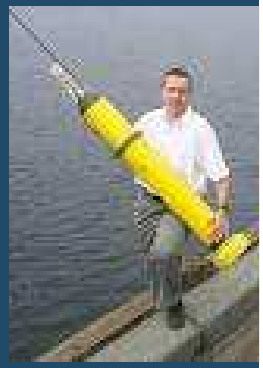
1. Use encounter rates to estimate exposure

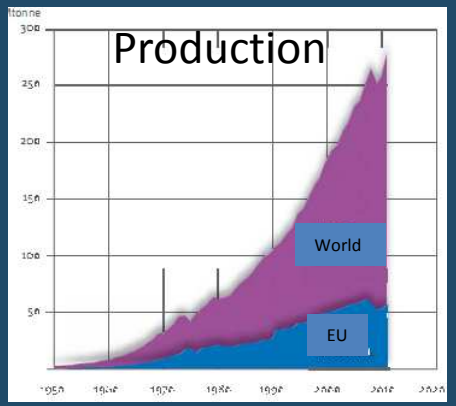
2. Validate based on observed rates of ingestion in literature

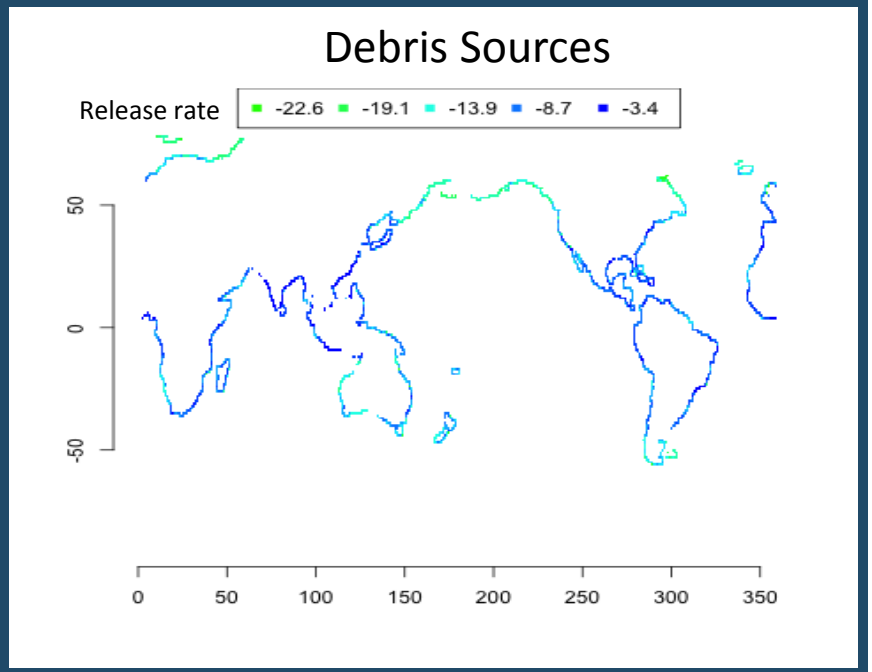
3. Predict areas of high risk

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.

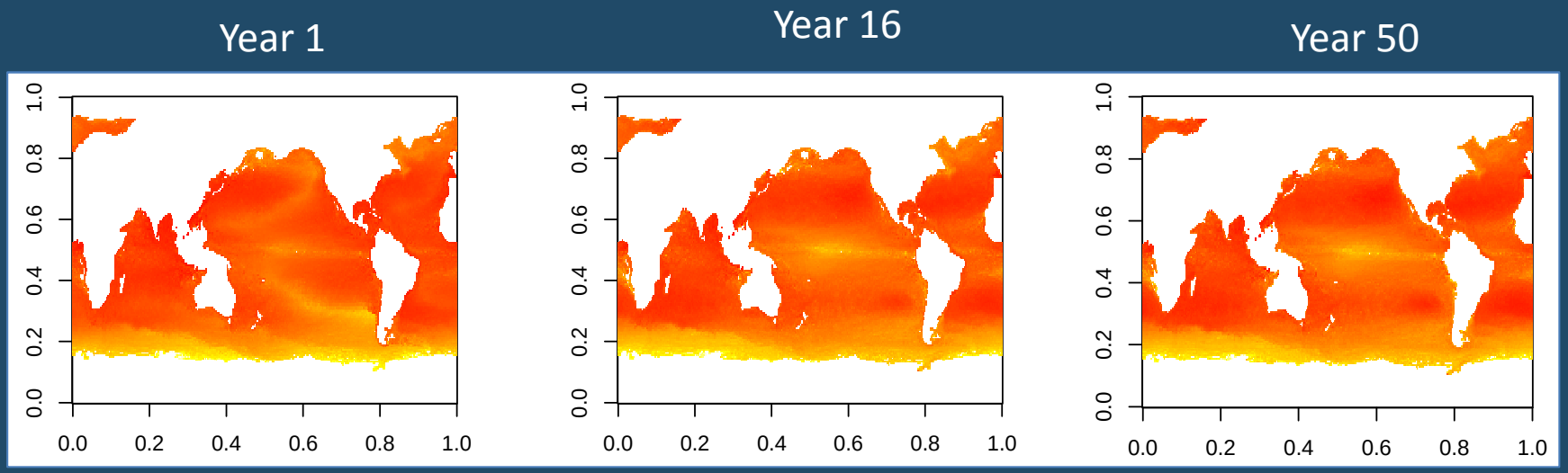






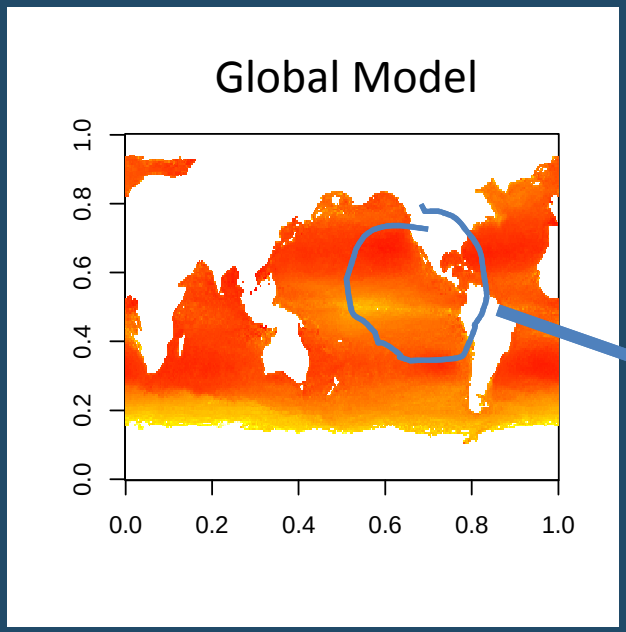
Estimating encounter rates

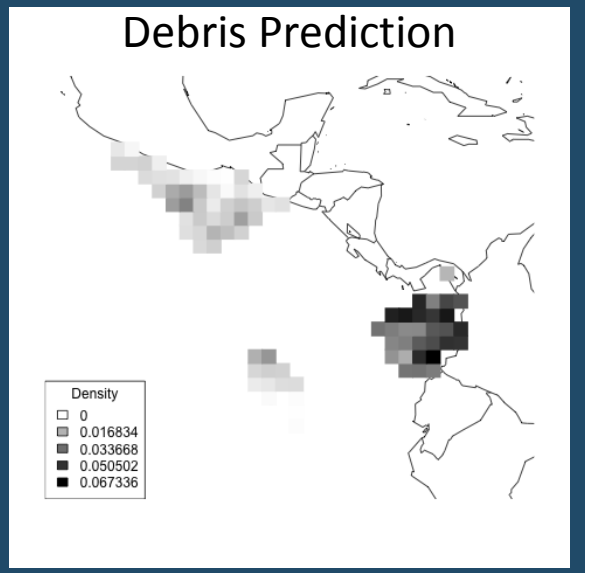
- Distribution of debris stabilizes quickly
- Coastal zones always high (sources)
- Major gyres high within 16 years



Estimating encounter rates

- Use species range to find relevant areas
- Estimate plastic density within the area



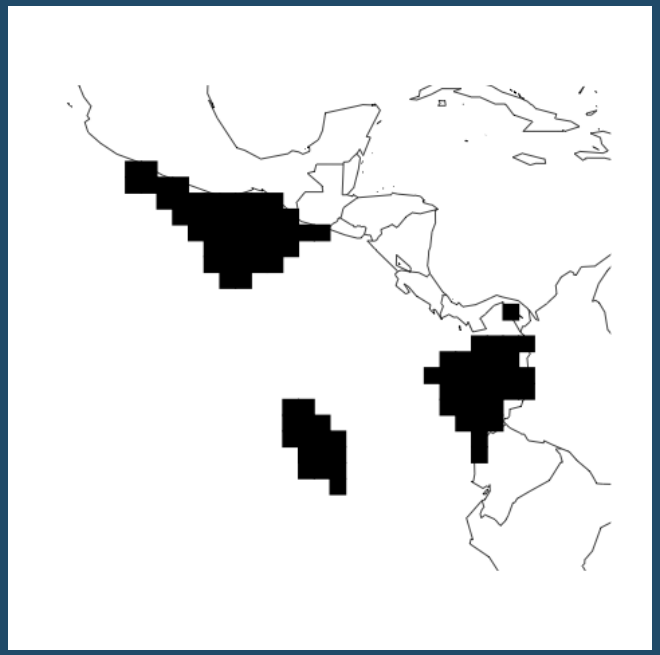


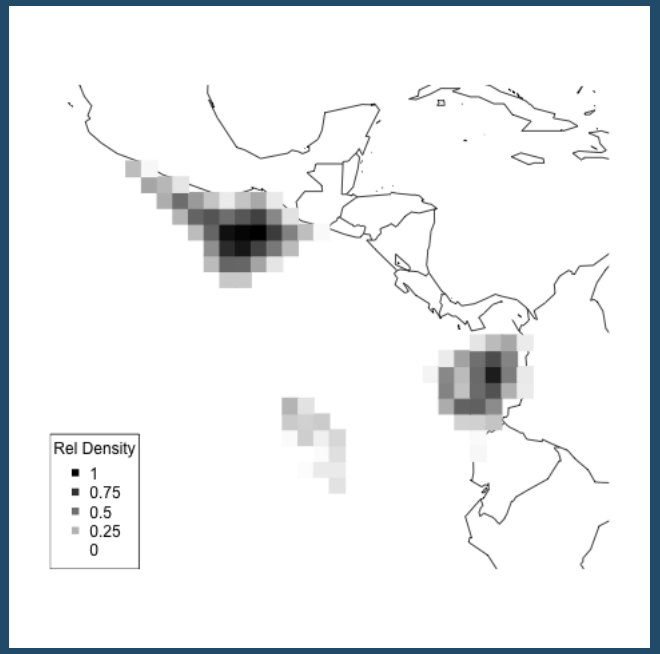
- 188 seabird species, global scale

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



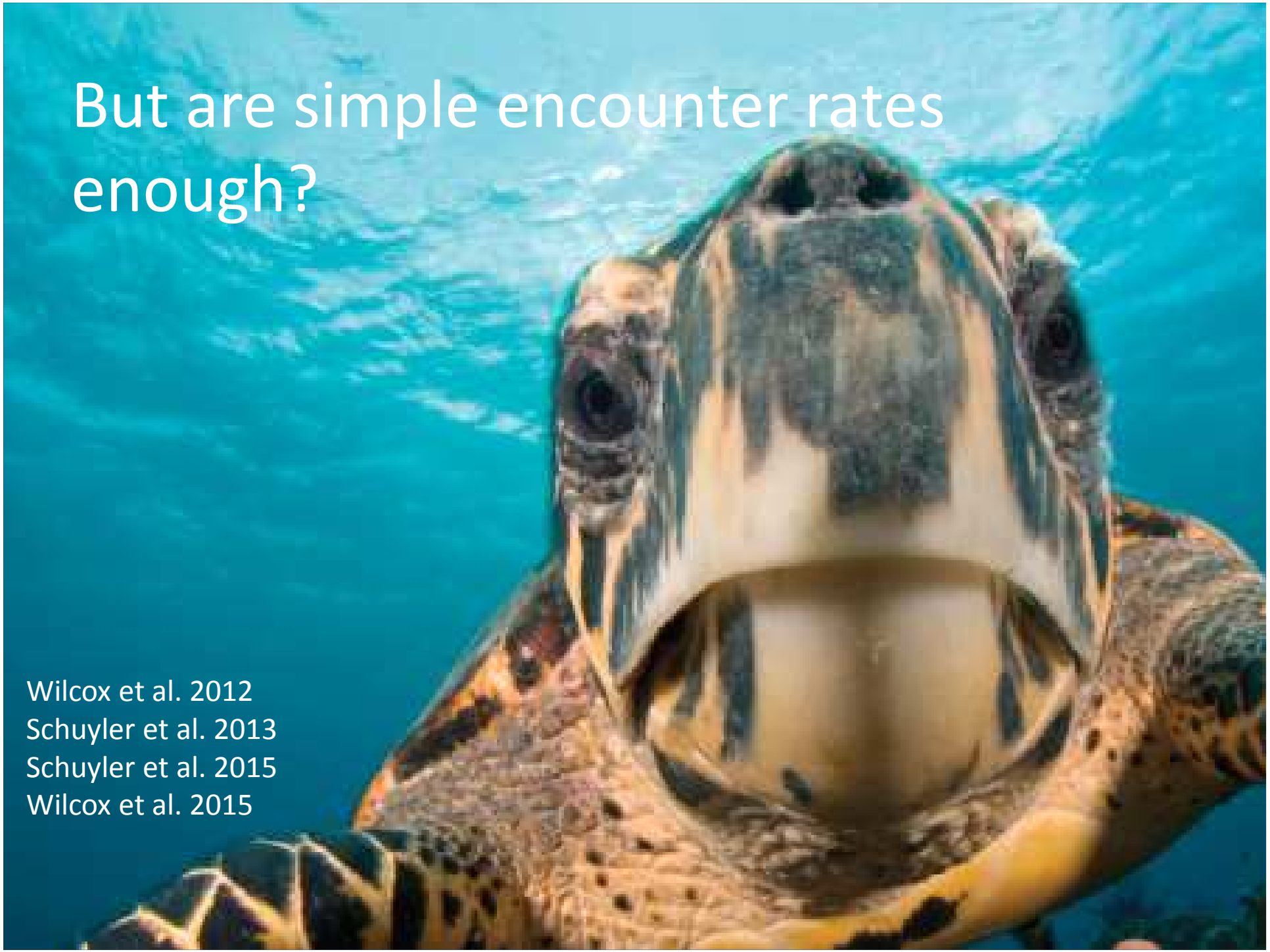


Encounter rates across species

- 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

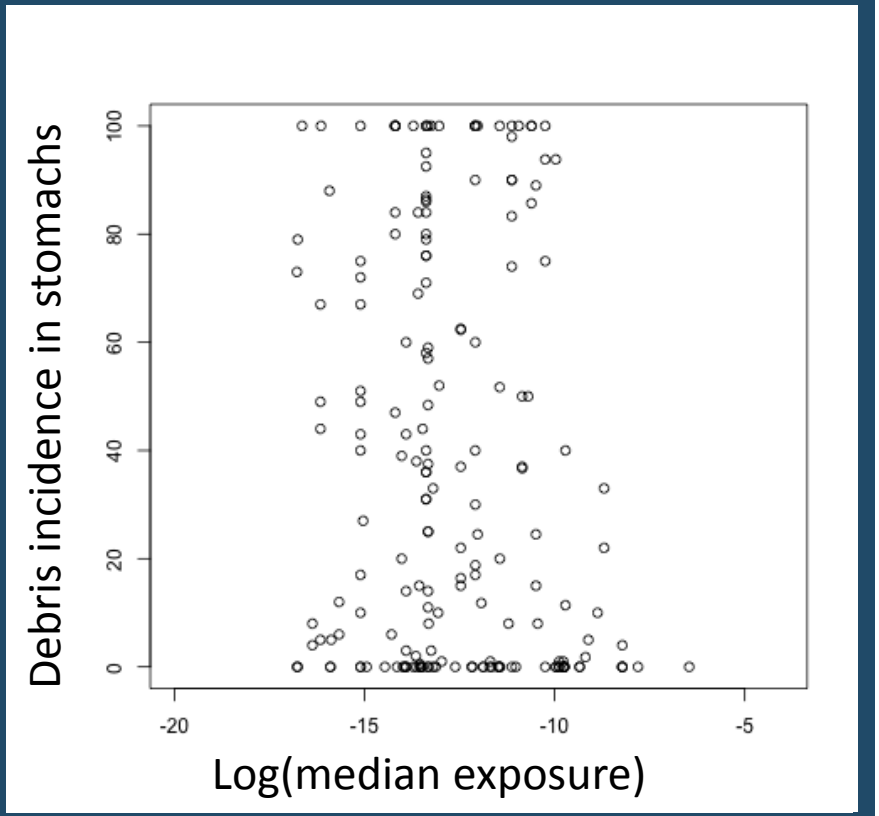
But are simple encounter rates enough?



Wilcox et al. 2012
Schuyler et al. 2013
Schuyler et al. 2015
Wilcox et al. 2015

Predictions compared with data

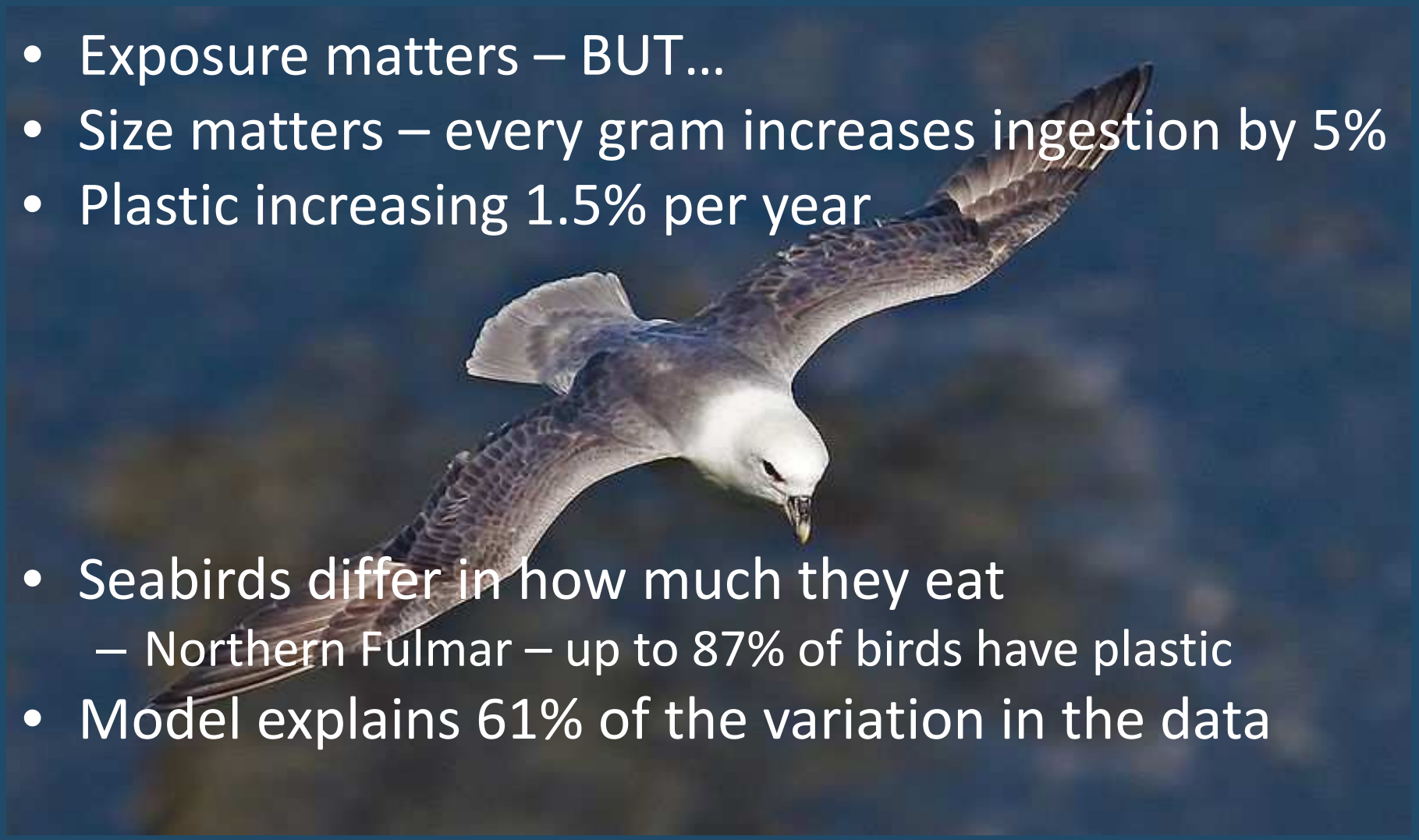
- Comparison with diet studies
  - 272 species/studies
  - No relationship!
  - But other factors relevant
    - Foraging style
    - Size
    - Regurgitation



- Logistic regression

  Pr(ingestion) = exposure + genus + size + time

Some seabirds like trash

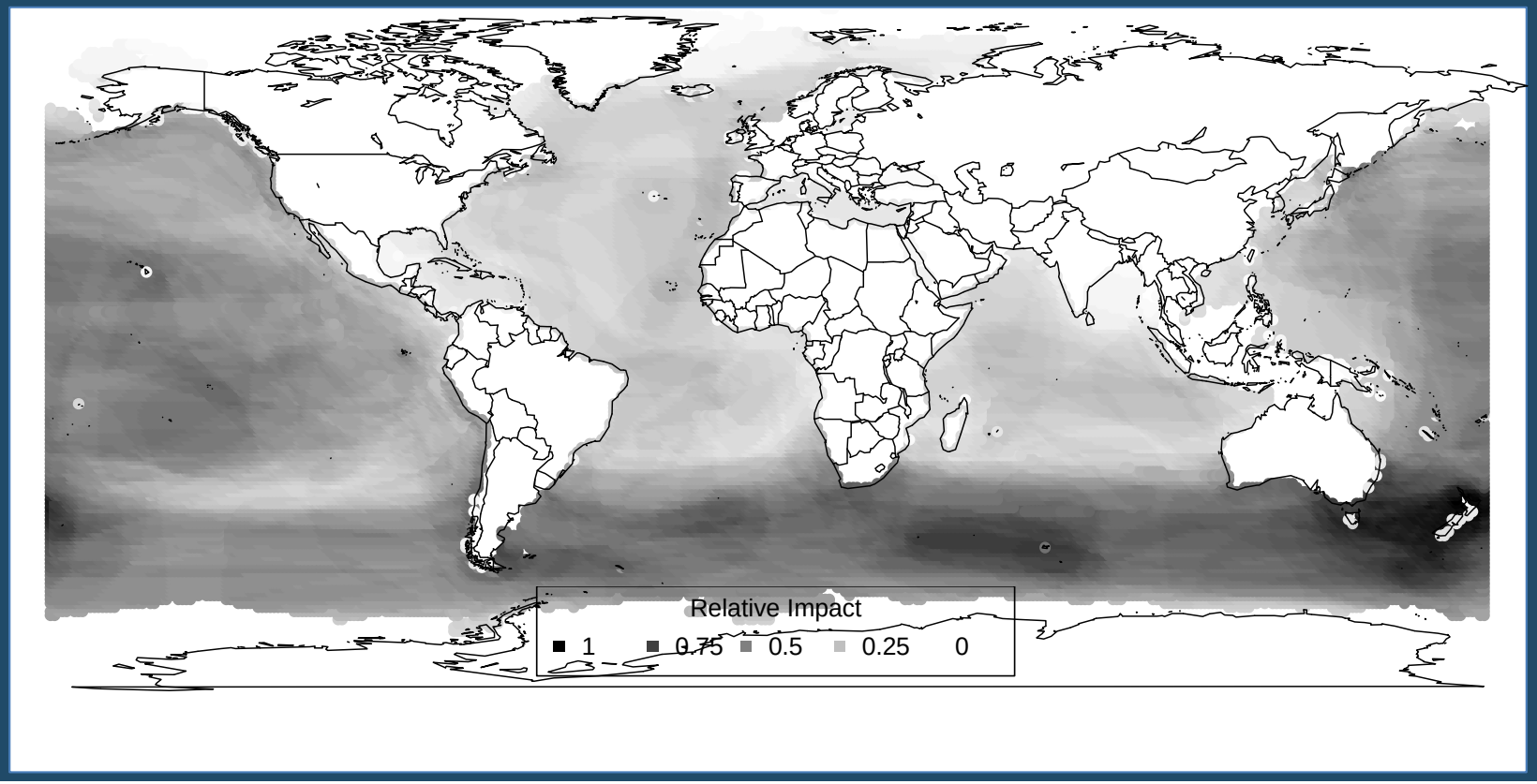


- Exposure matters – BUT…
- Size matters – every gram increases ingestion by 5%
- Plastic increasing 1.5% per year

- Seabirds differ in how much they eat
  - Northern Fulmar – up to 87% of birds have plastic
- Model explains 61% of the variation in the data

Translating predictions into biodiversity risk

- Statistical model – probability of ingestion
- Predictions summed for all species to ID high risk regions



I. Summary

Risk analysis is a useful lens for the problem

Identify species and areas with high impacts

Good news on gathering information

Encounters are a reasonable measure of risk

- Global debris for seabirds - Wilcox et al. 2015
- Global debris for turtles - Schuyler et al. 2013, 2015
- Ghost nets and turtles - Wilcox et al. 2013, 2015

Ecology is important

Traits are essential in making predictions

Utility????

We can make REAL management recommendations

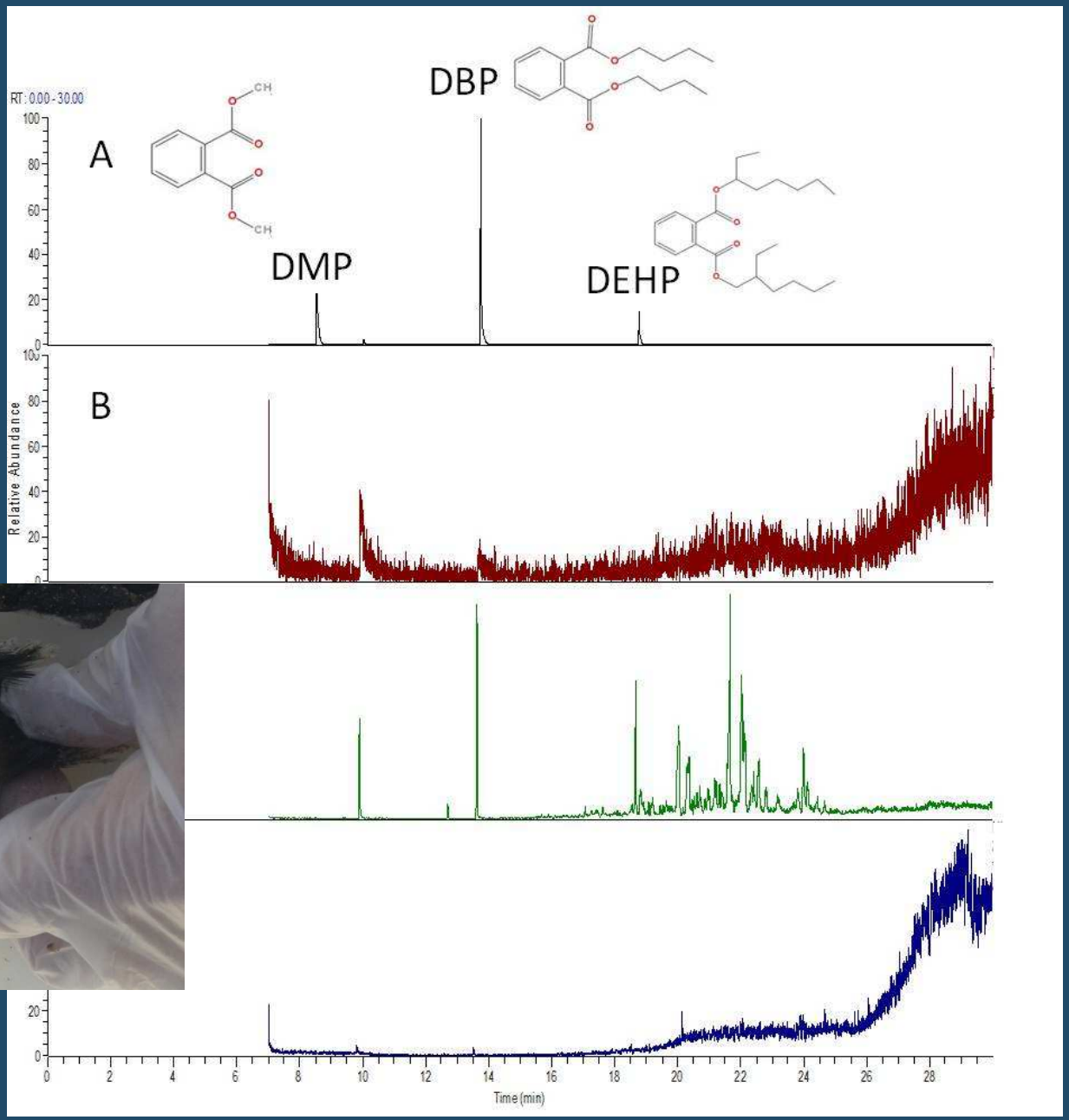
- Species at risk
- Opportunities for intervention

II. Understanding Impact

- Difficult problem
  - Often don't observe animals that are dead
  - Sublethal impacts are hard to distinguish
  - Confounding factors probably the rule, not the exception
    - E.g. seabird ingestion of plastic – hard to distinguish impacts
- Trying three approaches
  - Noninvasive measurement of ingestion and correlation with condition
    - Hardesty et al. 2015
  - Retrospective analysis of strandings data, with projection of unobserved impacts
    - Wilcox et al. 2014
  - Expert elicitation to predict impacts
    - Wilcox et al. 2016

2a. Plastic ingestion and seabird fitness

- Lots of studies on seabird ingestion
  - Early experiments show body condition impacts
  - Field studies confusing
    - more plastic = higher weight
- Need noninvasive methods so sampling can be done on random birds
  - Random dead birds – limited supply by location, species, etc.
  - Lavage – increasingly difficult permitting, incomplete sampling
  - Biochemical markers



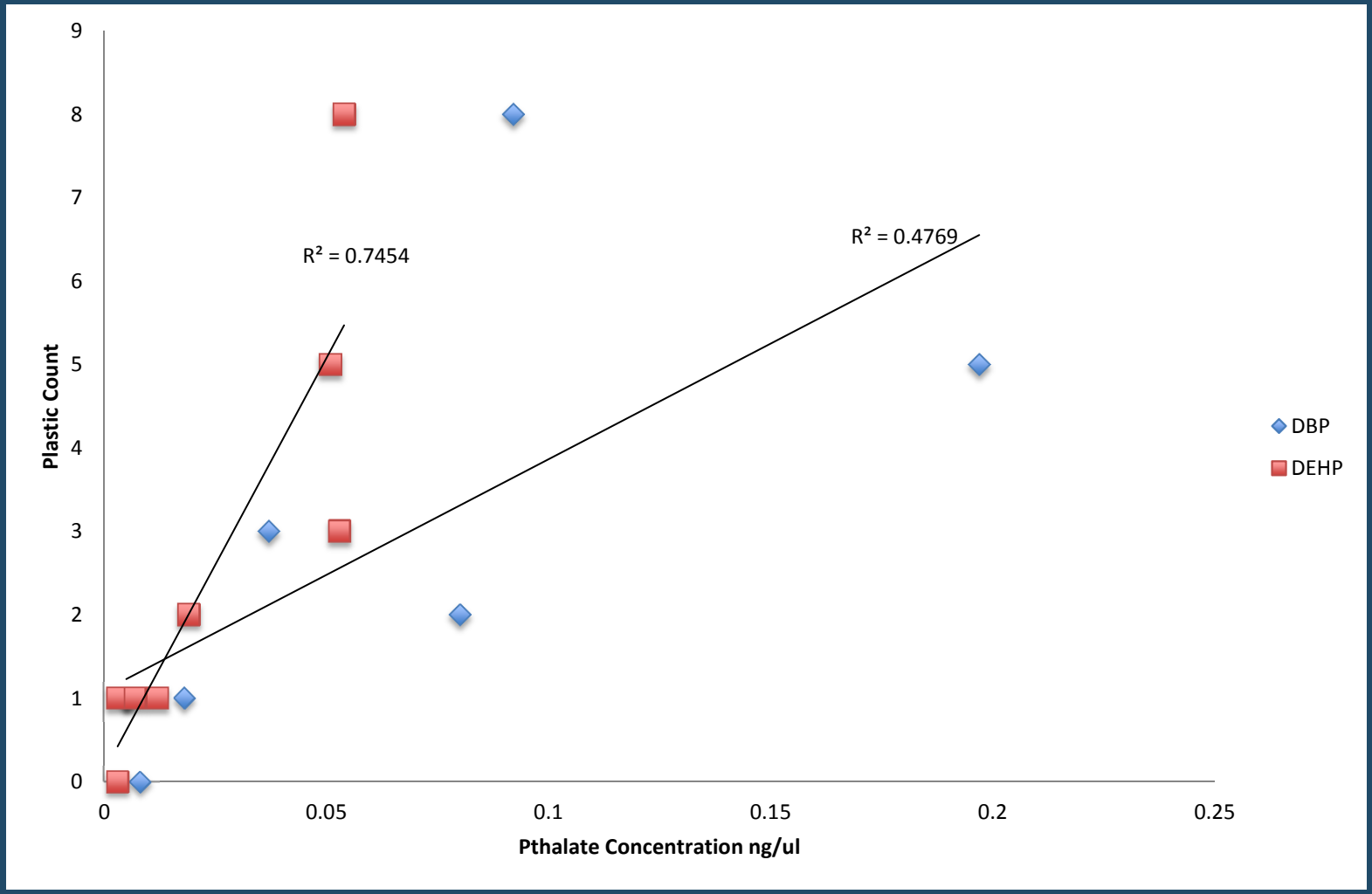
Plasticizers

Blank

Flesh-footed shearwater

Bridled tern

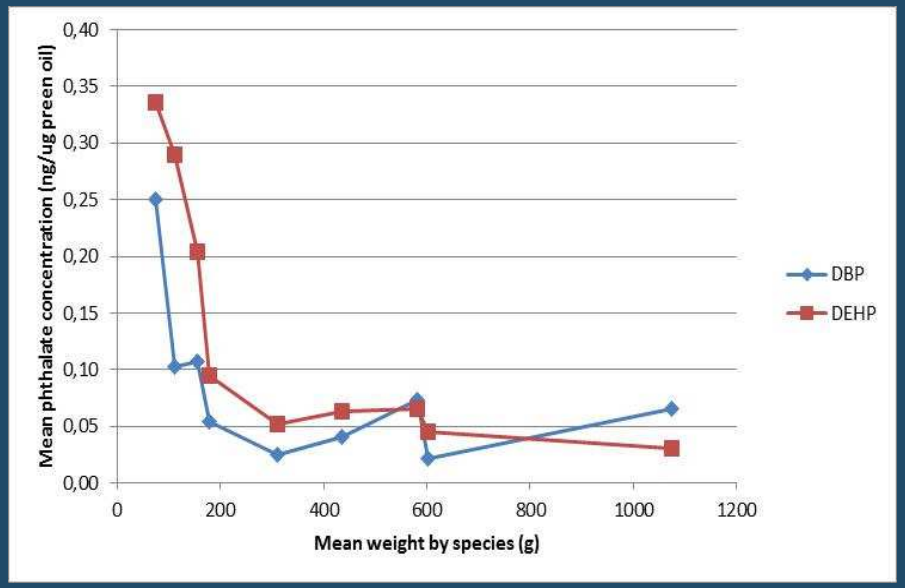
Are break-down products a reliable marker?

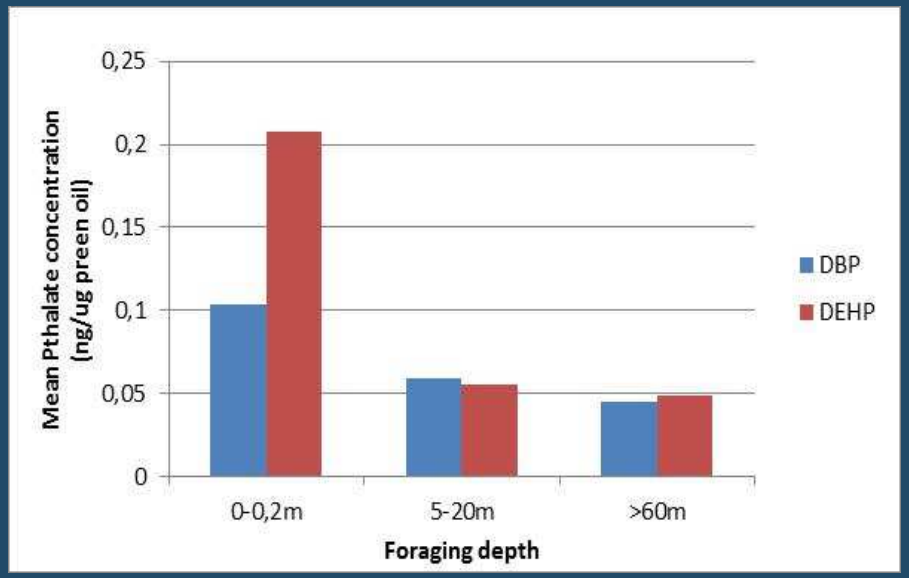


Using markers to understand plastic ingestion and impacts

- Trial phase –8 species in Australia
  - Targeting a global survey with collaborators

- But, we can already get useful things from the markers
  - e.g. how does seabird ecology relate to ingestion rates





2b. What to do where there is little data?

- Retrospective data analysis isn't possible
- Expert elicitation is an alternative
  - Multiple approaches – few experts, many experts, qualitative, quantitative
  - See "Wisdom of the Crowds" by James Surowiecki
- Structured questionnaire
  - Broken into components that respondents can conceptualize
  - Categories, but quantitative

Ocean Conservancy's survey

- 3 marine taxa: Seabirds, Turtles, Marine Mammals
- 3 impacts: Entanglement, Ingestion, Contamination
- 20 most frequent items found in coastal cleanups (ICC)

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

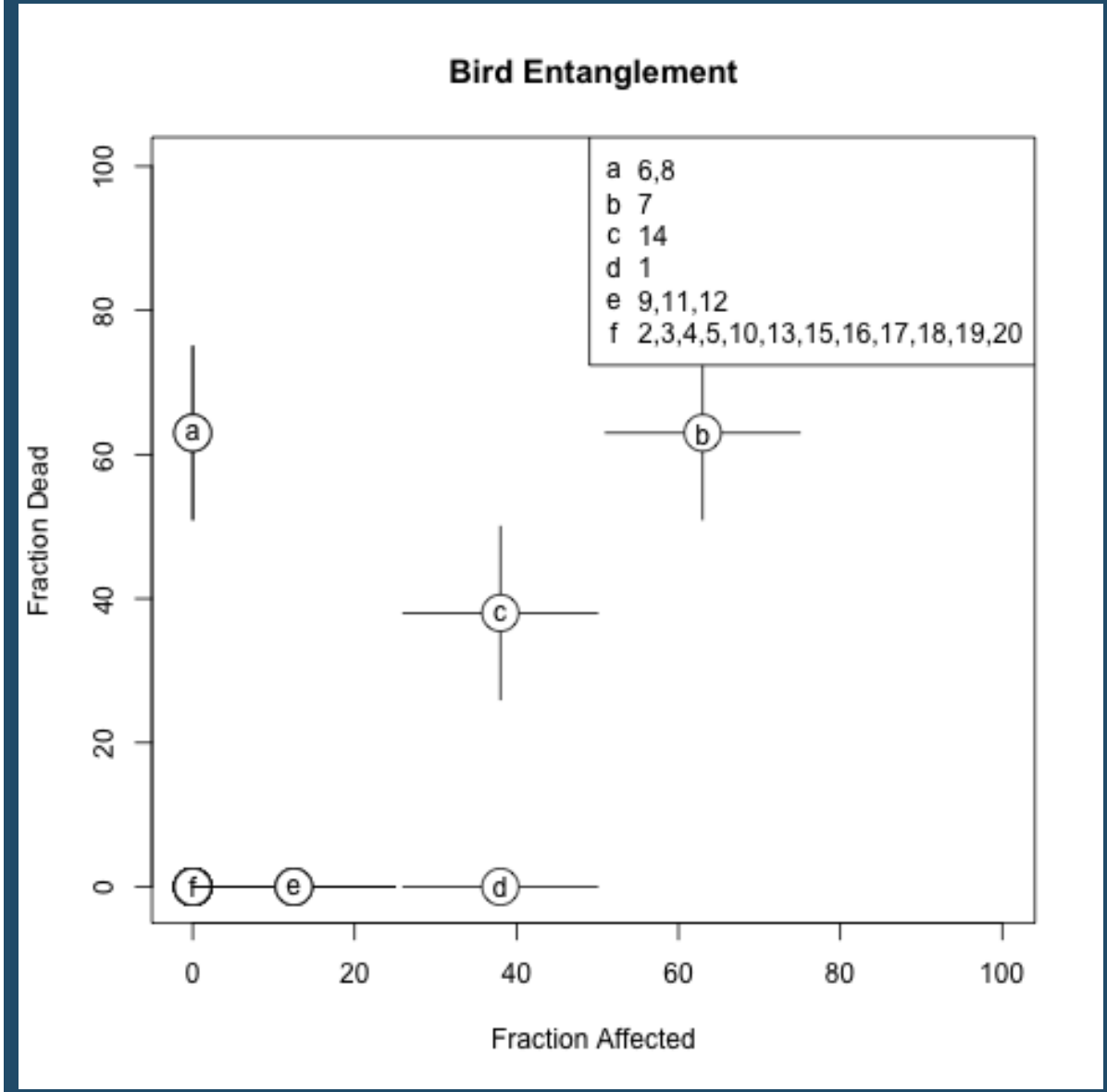
For the group of animals impacted by the product, what fraction of animals do you expect to experience this level of severity? [**Example:** What fraction of whales do you expect to die from becoming entangled in a fishing net.]

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.

Turning survey results into estimates of impact

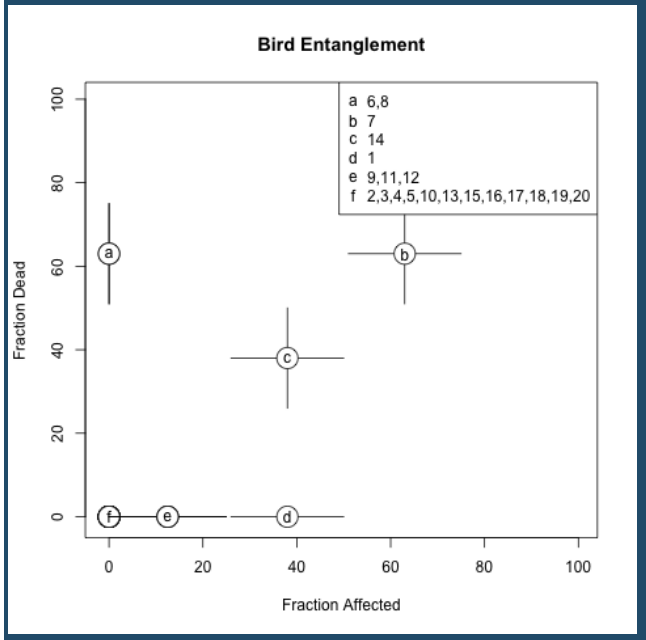
- Need to deal with respondent bias
  - Some observers score their species/threat/area higher or lower
  - Donlan et al. 2010 Cons Letters
- Need to deal with semi-quantitative scores
  - Intervals – e.g. 26% - 75%
- Use 2 tools
  - Random effects models – account for observer bias
  - Interval statistics – can deal with intervals properly
- Goal
  - Standardize survey data to remove bias
  - Impact = Severity x Specificity
    - i.e. how bad is individual affected x how many are effected

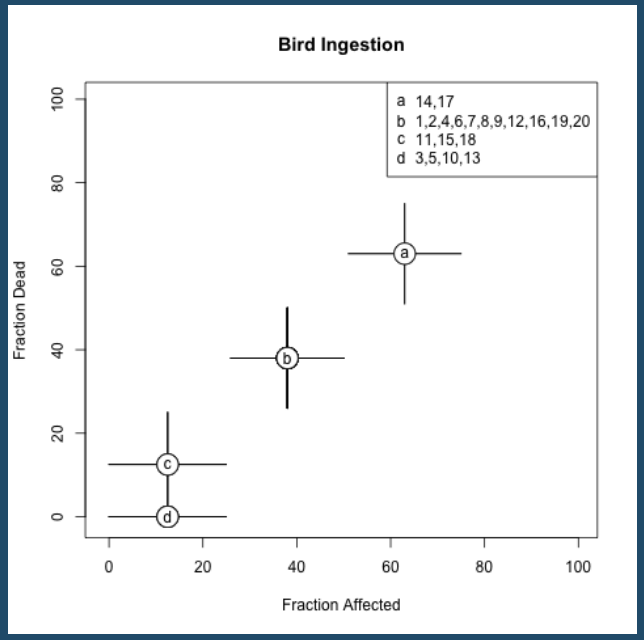
Results

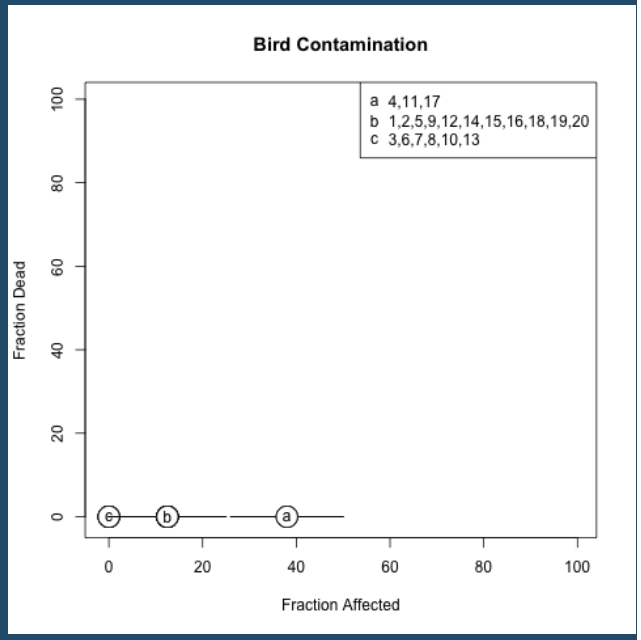


1. Balloons
2. Caps
3. Beverage cans
4. Cigarette butts
5. Cups and plates
6. Fishing buoys, traps and pots
7. Fishing line
8. Fishing nets
9. Film-like plastic wrappers
10. Glass beverage bottles
11. Hard plastic containers
12. Other EPS Packaging
13. Paper bags
14. Plastic bags
15. Plastic beverage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

Results







- Entanglement > Ingestion >> Contamination
- Contamination reflects level of uncertainty
- Generally matches observations
  - Rope, fishing gear, bags worst for entanglement – fairly specific risks
  - Ingestion: bags, food utensils worst, but many other items trail closely – some specific, followed by larger items
  - Contamination – low level, most things fairly similar, most impacts nonlethal

What does all this mean?

- Risk analysis is a useful lens for the problem
  - Good for structuring the problem
  - Can make estimates of both scope of the problem and impacts
  - Can adjust methods based on data available
- Impacts harder than exposure
  - New data needed, but manageable?
    - e.g. exposure via phthalates in fat
    - Combine with existing data sets like photo mark-recapture
  - but some ways to use existing information
    - Strandings etc.
- This can be connected to policy in a direct way
  - We compared debris distribution to local policy
  - Strong effect of a) regs on illegal dumping and b) education/outreach

Opportunities and Solutions

Societal viev

Technology

Product

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arco

Targeted

Illegal

Ga

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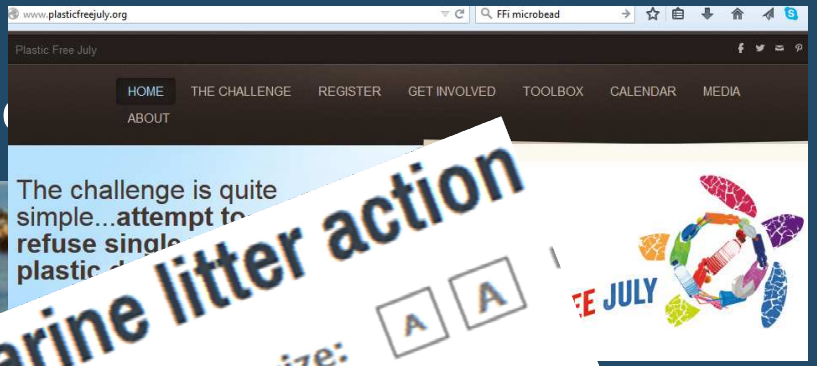

Science should drive marine litter action

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By Steve Toloken
STAFF REPORTER / ASIA BUREAU CHIEF
Published: November 12, 2014 11:31 am ET

waste2energy

RECYCLE
REUSE
REDUCE

CSIRO Oceans and Atmosphere

Denise Hardesty
denise.hardesty@csiro.au

Chris Wilcox
chris.wilcox@csiro.au

Thanks!