

Plastic pollution in the North Pacific Subtropical Gyre

Miriam C. Goldstein

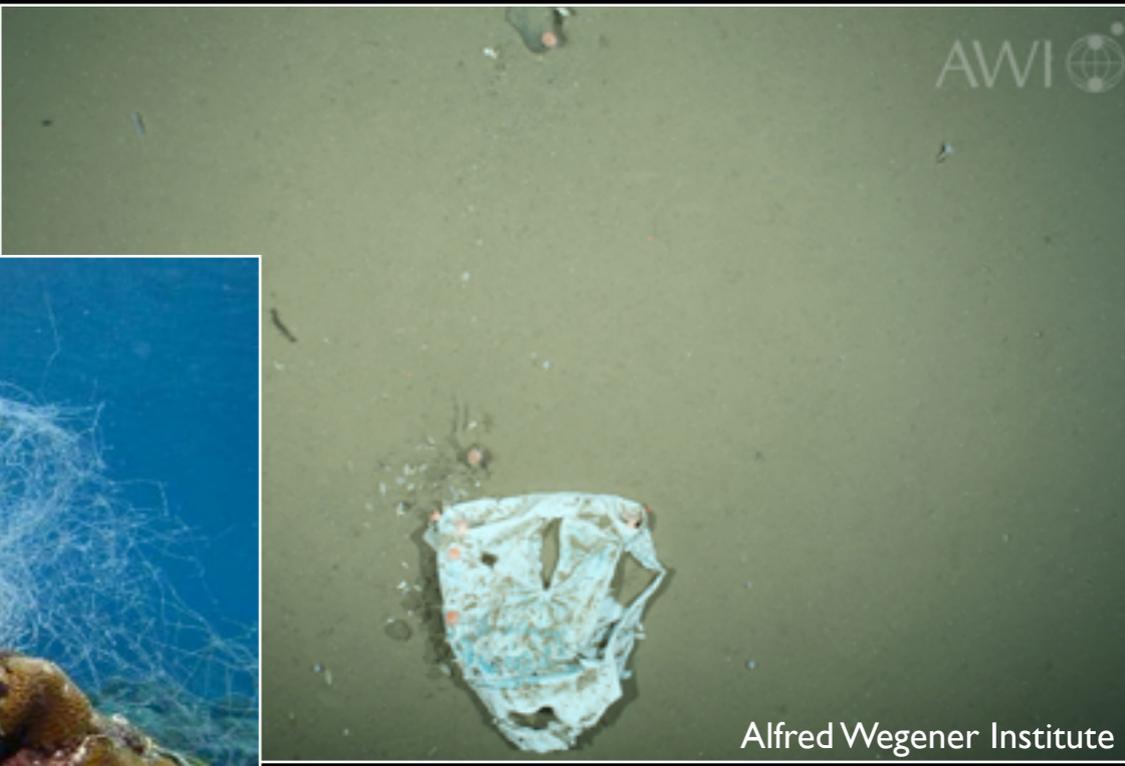
California Sea Grant, 2013 Knauss Fellow
Scripps Institution of Oceanography, UCSD

Email: miriam.goldstein@gmail.com

Twitter: [@MiriamGoldste](https://twitter.com/MiriamGoldste)

Twitter hashtag: [#GarbagePatchFacts](https://twitter.com/hashtag/GarbagePatchFacts)

Plastic pollution ubiquitous in marine environments



Macroplastic: wildlife impacts



NOAA Marine Debris Program



Chris Jordan



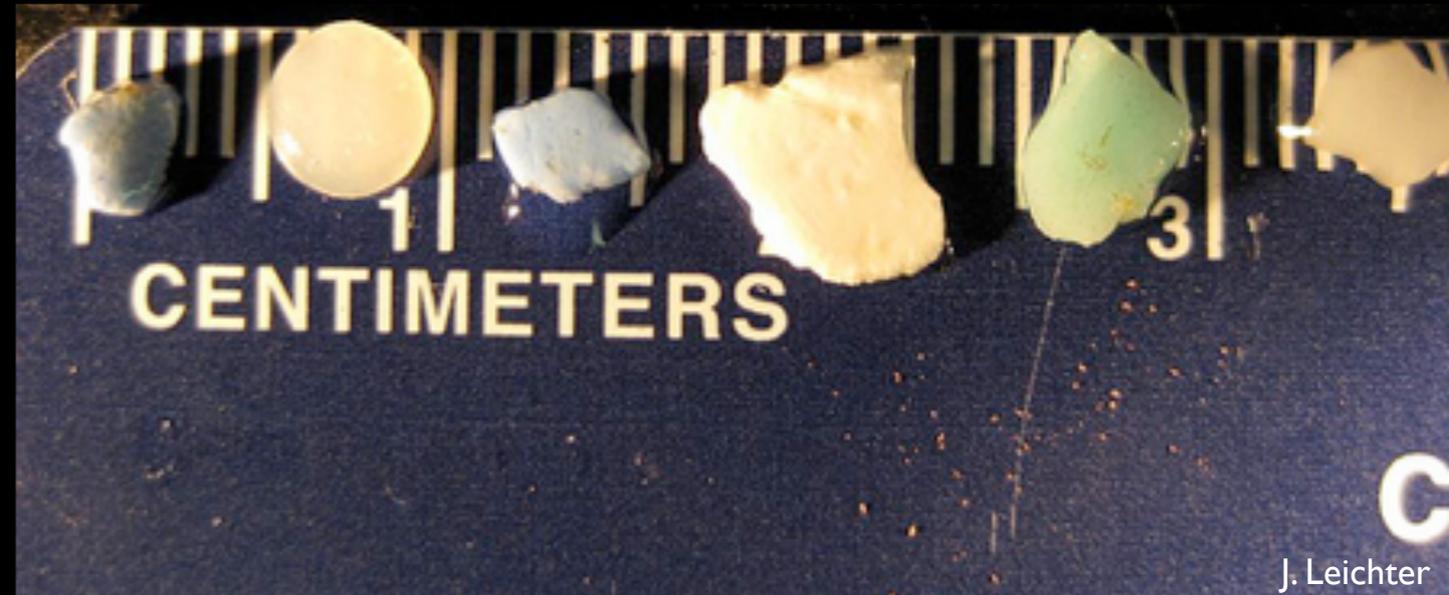
Kay Wilson



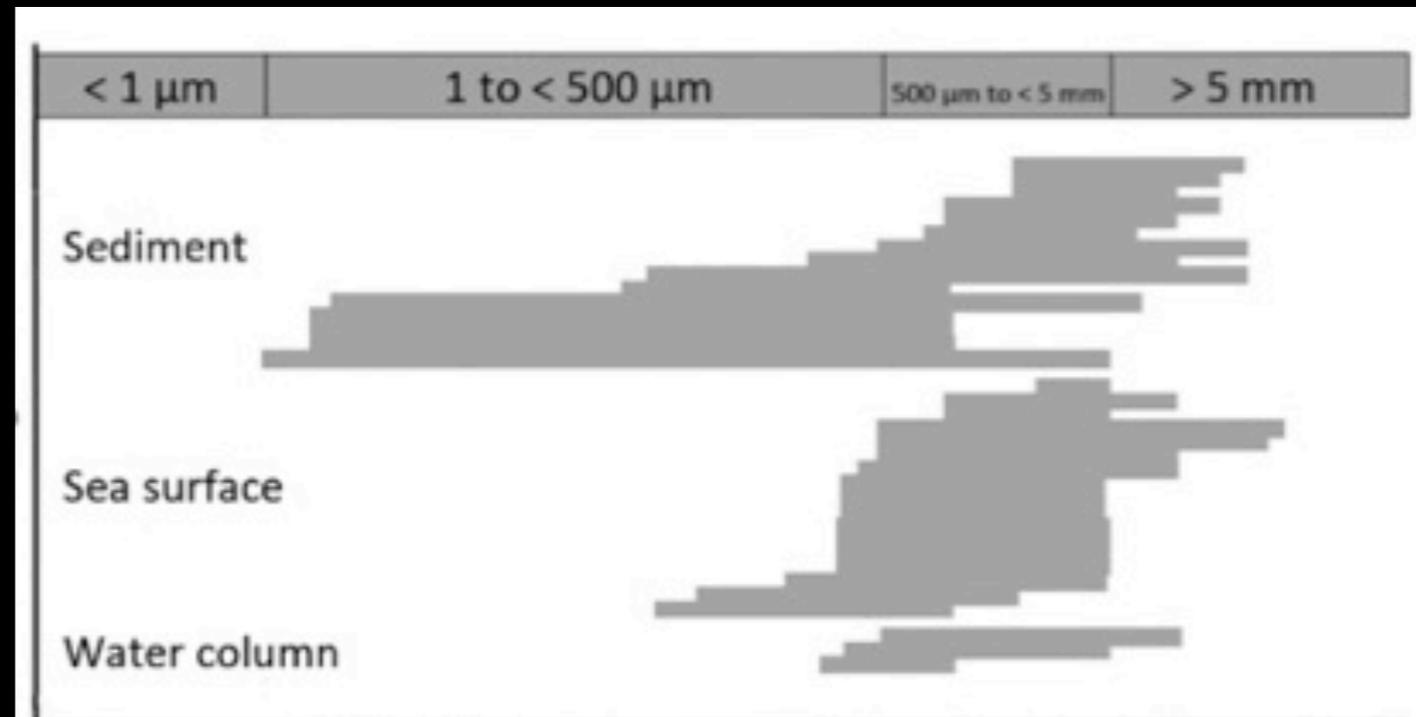
Tom Campbell

Microplastic

- Can be released directly (nurdles; microfibers) or formed by the photodegradation of larger objects
- Found in sediment, sea surface, and water column
- Ingested by fishes and benthic marine invertebrates

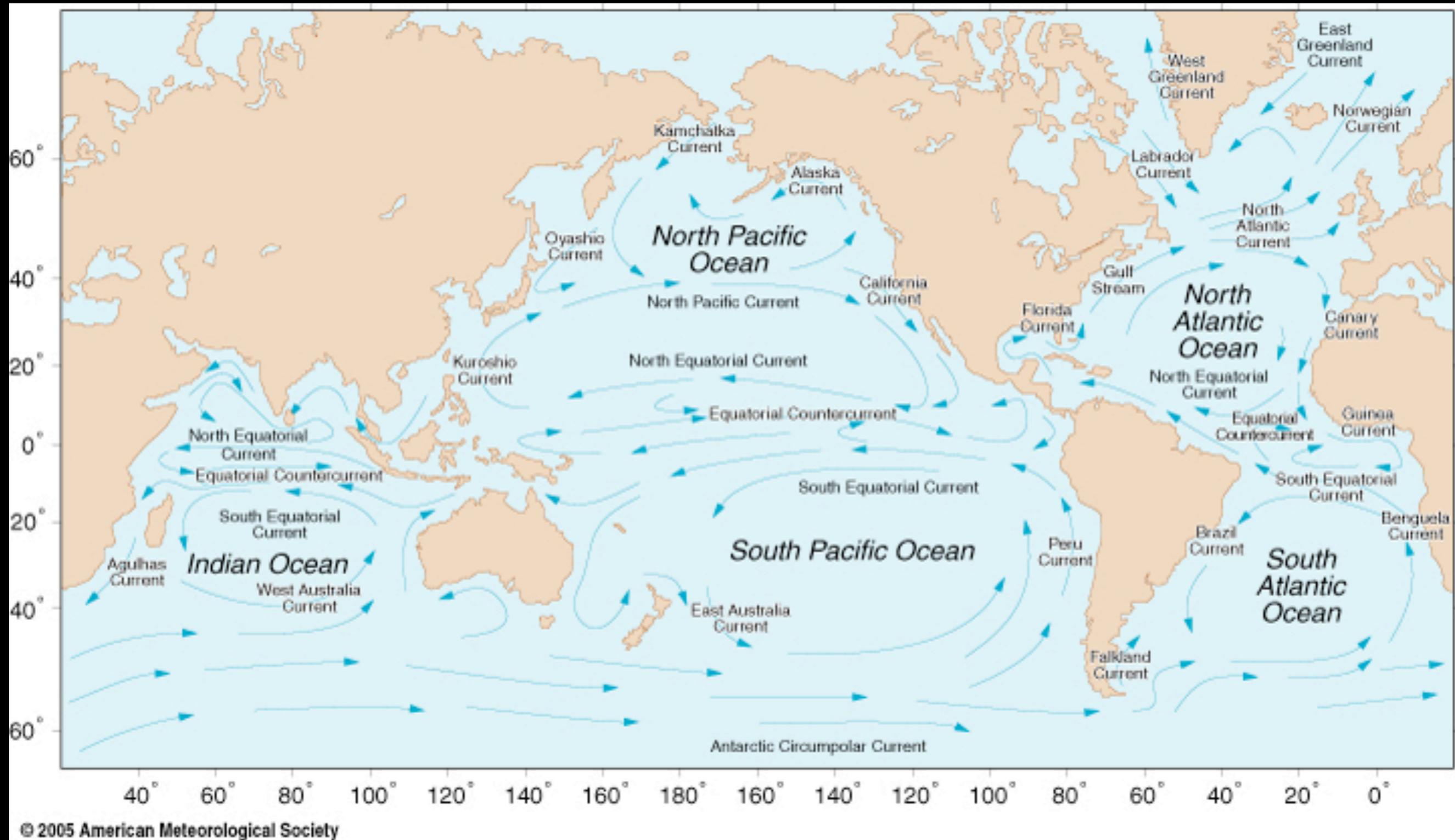


J. Leichter



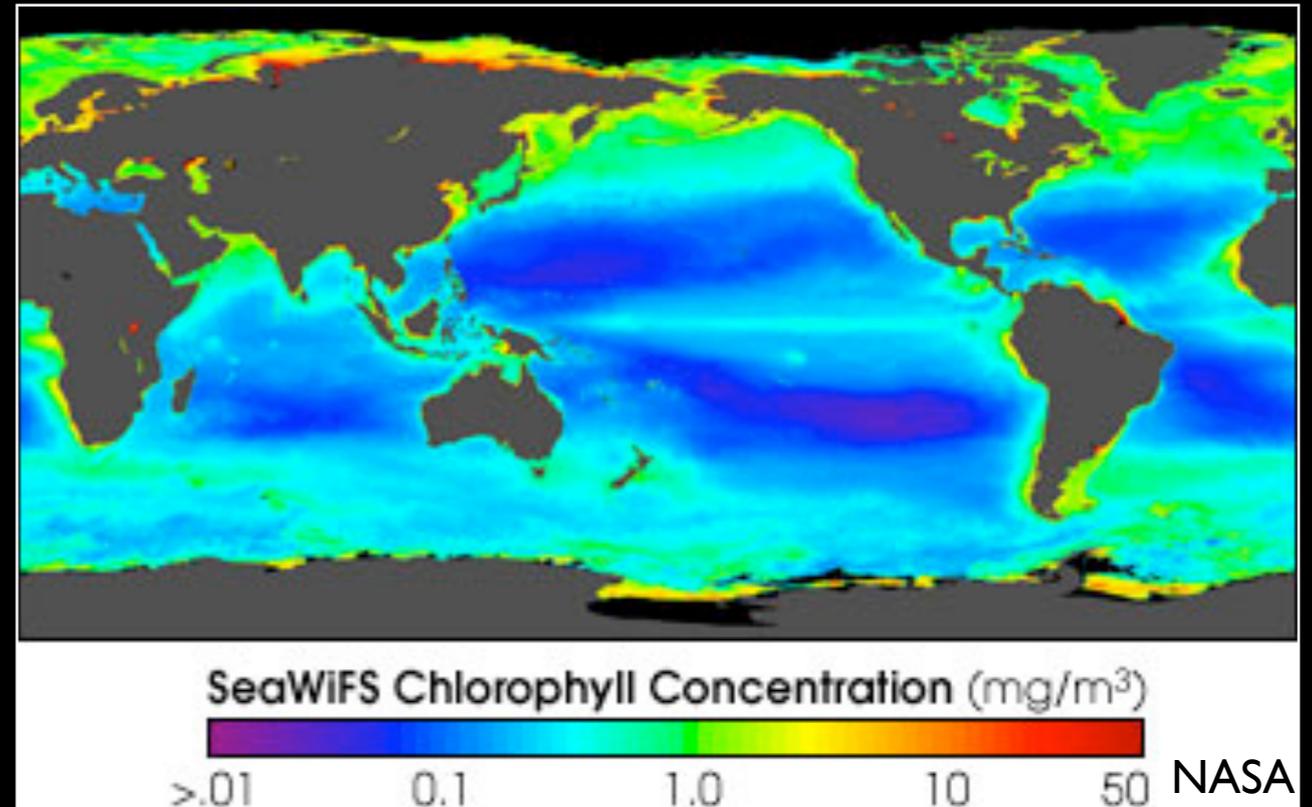
Hidalgo-Ruz et al. 2012 *Environ Sci Technol*

Subtropical gyres formed by convergence of wind-driven ocean currents; cover 40% of the earth's surface

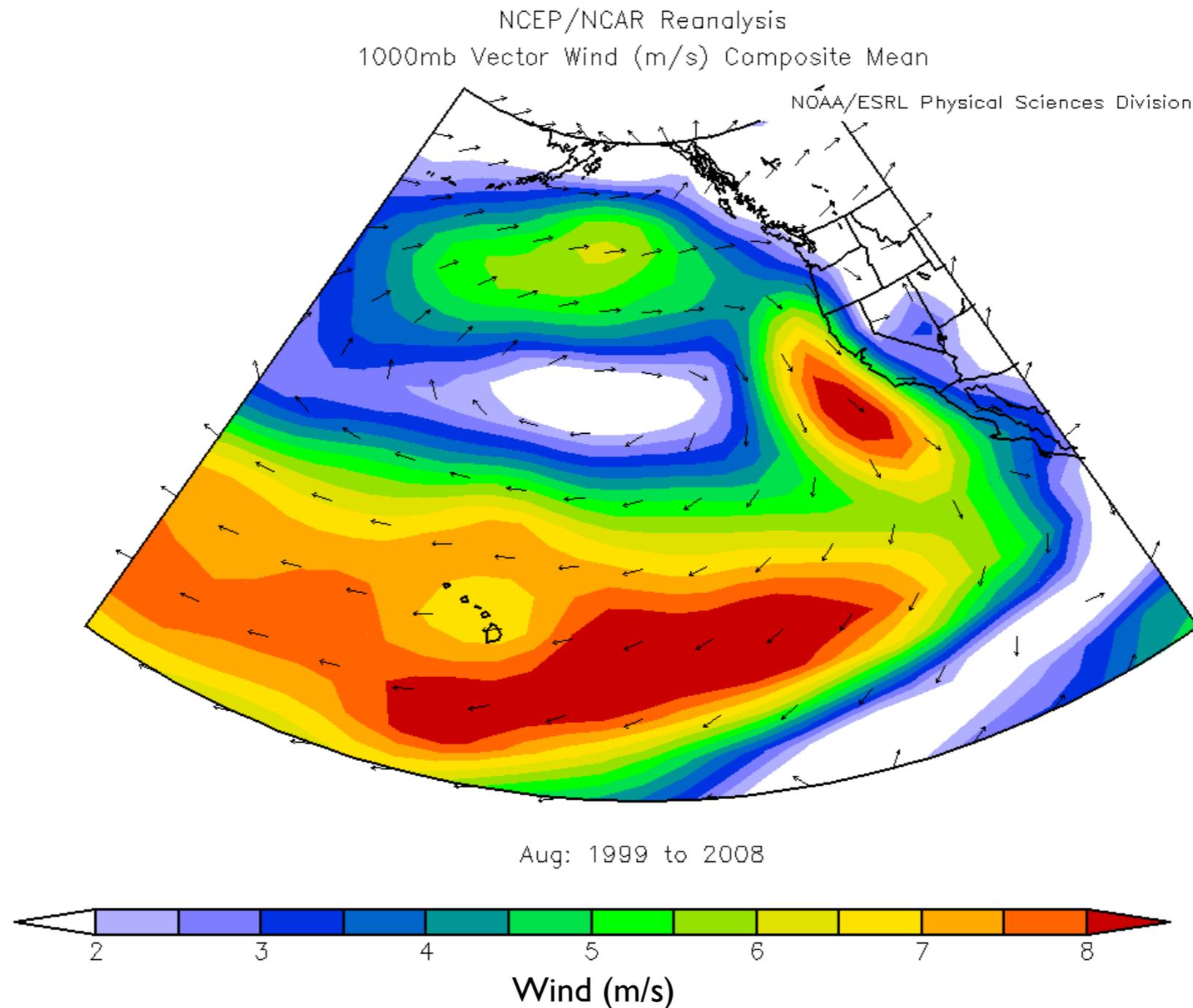


The North Pacific Subtropical Gyre (NPSG)

- Low productivity, high biodiversity
- Largest contiguous biome on earth
- In place since the Pliocene
- Originally studied as stable climax community, but now recognized to be influenced by mesoscale & climatic variability (Venrick et al. 1998, McGowan et al. 1998)



Oceanic circulation interacts with atmospheric circulation to trap floating material



Introducing the “Great Pacific Garbage Patch”

Introducing the “Great Pacific Garbage Patch”

SCUBA DIVING NEWS :: SCUBALINX :: SCUBA FORUM :: SCUBA POLL :: CYBER DIVER

 WORLD NEWS WORTH KNOWING

TRAVEL SAFETY SCIEN

newsletter :: alert :: interview :: special report :: act now :: opinion

PAGE ONE :: WORLD NEWS :: ARTICLES

Plastic ocean: The Great Pacific Garbage Patch

Powered by CDNN - CYBER DIVER News Network
by SUSAN CASEY

A vast swath of the Pacific, twice the size of Texas, is full of a plastic stew that is entering the food chain. Scientists say these toxins are causing obesity, infertility...and worse...

Introducing the “Great Pacific Garbage Patch”

SCUBA DIVING NEWS :: SCUBALINX :: SCUBA FORUM :: SCUBA POLL :: CYBER DIVER

 WORLD NEWS WORTH KNOWING

TRAVEL SAFETY SCIEN

newsletter :: alert :: interview :: special report :: act now :: opinion

PAGE ONE :: WORLD NEWS :: ARTICLES

Plastic ocean: The Great Pacific Garbage Patch

Powered by CDNN - CYBER DIVER News Network
by SUSAN CASEY

A vast swath of the Pacific, twice the size of Texas, is full of a plastic stew that is entering the food chain. Scientists say these toxins are causing obesity, infertility...and worse...

 **seattlepi.com**

Local US/World Sports Business A&E Life Comics Photos Opin

NATION/WORLD

Last updated October 30, 2007 8:05 p.m. PT  E-mail this  Print this  RSS

Enormous ocean dump poses huge cleanup challenge

The Great Pacific Garbage Patch lies west of California

By JUSTIN BERTON
SAN FRANCISCO CHRONICLE

Introducing the “Great Pacific Garbage Patch”

SCUBA DIVING NEWS :: SCUBALINX :: SCUBA FORUM :: SCUBA POLL :: CYBER DIVER

 WORLD NEWS WORTH KNOWING

TRAVEL SAFETY SCIENCE

newsletter :: alert :: interview :: special report :: act now :: opinion

PAGE ONE :: WORLD NEWS :: ARTICLES

Plastic ocean: The Great Pacific Garbage Patch

Powered by CDNN - CYBER DIVER News Network
by SUSAN CASEY

A vast swath of the Pacific, twice the size of Texas, is full of a plastic stew that is entering the food chain. Scientists say these toxins are causing obesity, infertility...and worse...

Mail Online

Home News Sport TV&Showbiz Femail Health Science&Tech Money Debate

News Home | World news | Headlines | Pictures | Most read | News Board

Rubbish dump found floating in Pacific Ocean is twice the size of America

Last updated at 00:20:06 February 2008

[Comments \(22\)](#) [Add to My Stories](#)

A rubbish dump twice the size of the United States has been discovered floating in the Pacific Ocean.

The vast expanse of debris, made up of plastic junk including footballs, kayaks, Lego blocks and carrier bags, is kept together by swirling underwater currents.

It stretches from 500 nautical miles off the Californian coast, across the northern Pacific, past Hawaii and almost as far as Japan.

 **seattlepi.com**

Local US/World Sports Business A&E Life Comics Photos Opinions

NATION/WORLD

Last updated October 30, 2007 8:05 p.m. PT [E-mail this](#) [Print this](#) [RSS](#)

Enormous ocean dump poses huge cleanup challenge

The Great Pacific Garbage Patch lies west of California

By JUSTIN BERTON
SAN FRANCISCO CHRONICLE

Introducing the “Great Pacific Garbage Patch”

SCUBA DIVING NEWS :: SCUBALINX :: SCUBA FORUM :: SCUBA POLL :: CYBER DIVER

 WORLD NEWS WORTH KNOWING

TRAVEL SAFETY SCIENCE

newsletter :: alert :: interview :: special report :: act now :: opinion

PAGE ONE :: WORLD NEWS :: ARTICLES

Plastic ocean: The Great Pacific Garbage Patch

Powered by CDNN - CYBER DIVER News Network
by SUSAN CASEY

A vast swath of the Pacific, twice the size of Texas, is full of a plastic stew that is entering the food chain. Scientists say these toxins are causing obesity, infertility...and worse...

Mail Online

Home News Sport TV&Showbiz Femail Health Science&Tech Money Debate

News Home | World news | Headlines | Pictures | Most read | News Board

Rubbish dump found floating in Pacific Ocean is twice the size of America

Last updated at 00:20:06 February 2008

Comments (22) | Add to My Stories

A rubbish dump twice the size of the United States has been discovered floating in the Pacific Ocean.

The vast expanse of debris, made up of plastic junk including footballs, kayaks, Lego blocks and carrier bags, is kept together by swirling underwater currents.

It stretches from 500 nautical miles off the Californian coast, across the northern Pacific, past Hawaii and almost as far as Japan.

 **seattlepi.com**

Local US/World Sports Business A&E Life Comics Photos

NATION/WORLD

Last updated October 30, 2007 8:05 p.m. PT

E-mail this Print this

Enormous ocean dump poses huge cleanup challenge

The Great Pacific Garbage Patch lies west of California

By JUSTIN BERTON
SAN FRANCISCO CHRONICLE

THE INDEPENDENT ENVIRONMENT

DEBORAH ORR
We should return to council housing

News Opinion Environment Sport Life & Style Arts & Entertainment Trav

Climate Change Green Living Nature Sound & Vision

Home > Green Living

The world's rubbish dump: a garbage tip that stretches from Hawaii to Japan

By Kathy Marks, Asia-Pacific Correspondent, and Daniel Howden

Tuesday, 5 February 2008

SHARE | PRINT ARTICLE | EMAIL ARTICLE | TEXT SIZE

Introducing the "Great Pacific Garbage Patch"

SCUBA DIVING NEWS :: SCUBALINX :: SCUBA FORUM :: SCUBA POLL :: CYBER DIVER

WORLD NEWS WORTH KNOWING

CDNN TRAVEL SAFETY SCIENCE

newsletter :: alert :: interview :: special report :: act now :: opinion

PAGE ONE :: WORLD NEWS :: ARTICLES

Plastic ocean: The Great Pacific Garbage Patch

Powered by CDNN - CYBER DIVER
by SUSAN CASEY

A vast swath of the Pacific, twice the size of the United States has been discovered floating in the

Mail Online

Home News Sport TV&Showbiz Femail Health Science&Tech Money Debate

News Home | World news | Headlines | Pictures | Most read | News Board

Rubbish dump found floating in Pacific Ocean is twice the size of America



[Home](#) > [GMA](#)

Hidden, a 3.5 Million Trash Heap Lies in the Ocean

The Great Pacific Garbage Dump Stretches From California to China

By DARCY BONFILS and IMAEYEN IBANGA
Aug. 6, 2008

GOOD MORNING AMERICA

38 comments

Local US/World Sports

NATION/WORLD

Last updated October 30, 2007 8:05 p.m. PT

[E-mail this](#) [Print this](#)

Enormous ocean dump poses huge cleanup challenge

The Great Pacific Garbage Patch lies west of California

By JUSTIN BERTON
SAN FRANCISCO CHRONICLE

council housing

News Opinion **Environment** Sport Life & Style Arts & Entertainment Trav

Climate Change Green Living Nature Sound & Vision

[Home](#) > [Green Living](#)

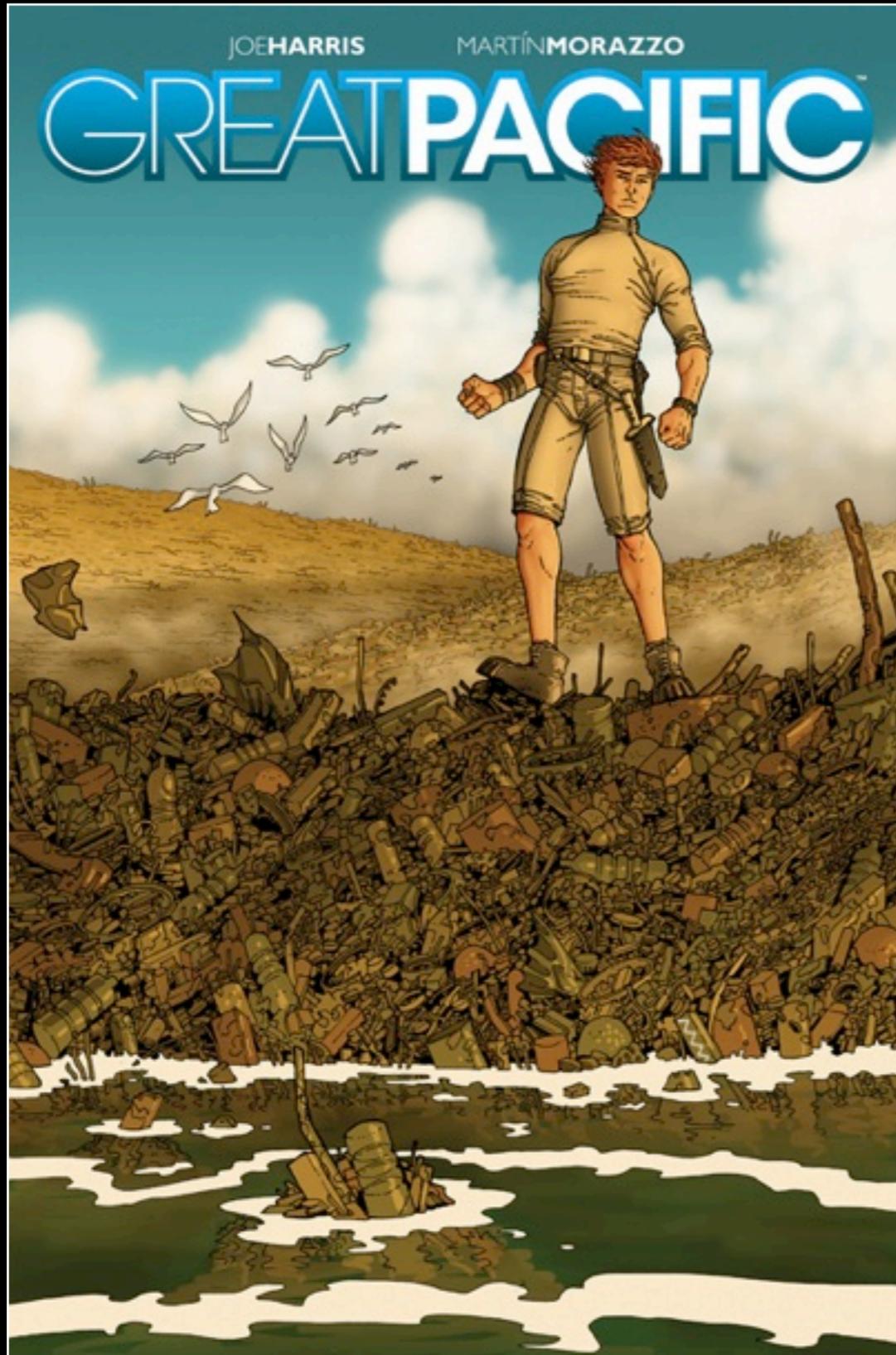
The world's rubbish dump: a garbage tip that stretches from Hawaii to Japan

By Kathy Marks, Asia-Pacific Correspondent, and Daniel Howden

Tuesday, 5 February 2008

[SHARE](#) [PRINT ARTICLE](#) [EMAIL ARTICLE](#) [TEXT SIZE](#)

Popular conceptions of the “Garbage Patch”



RH Allison



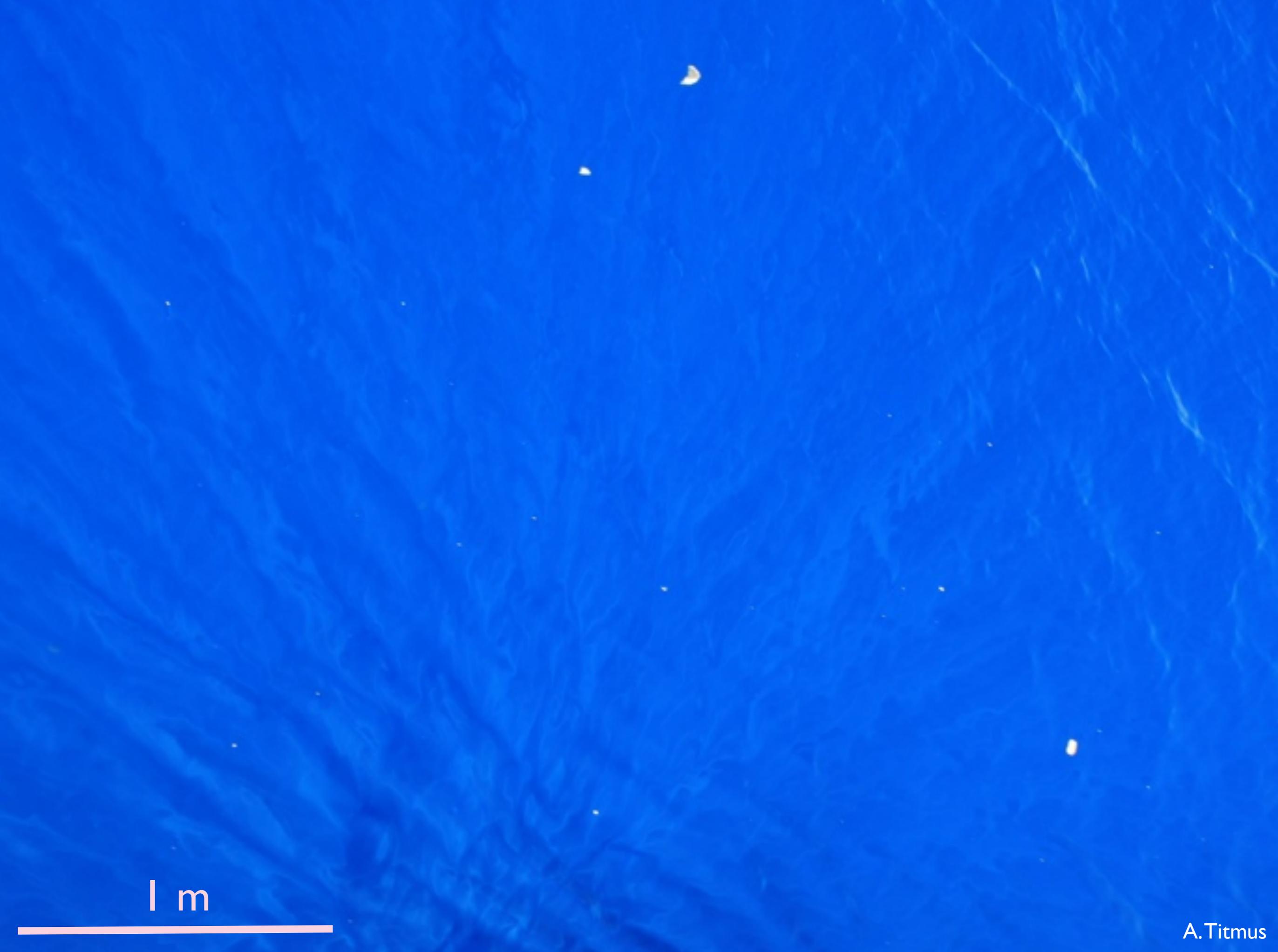
Jay Directo/AFP/Getty Images



R. Bahrani

The real “Garbage Patch”

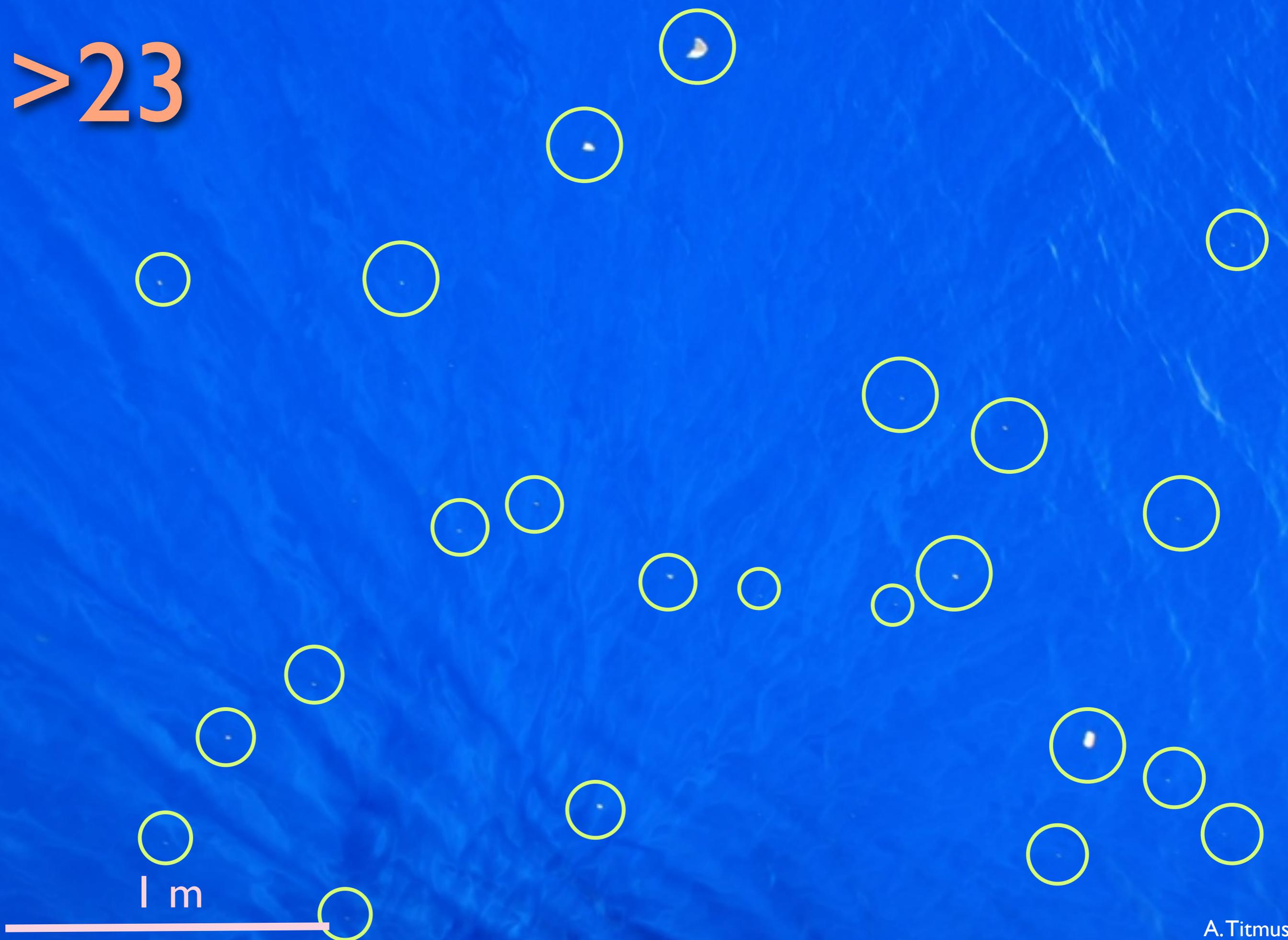




1 m

A. Titmus

>23

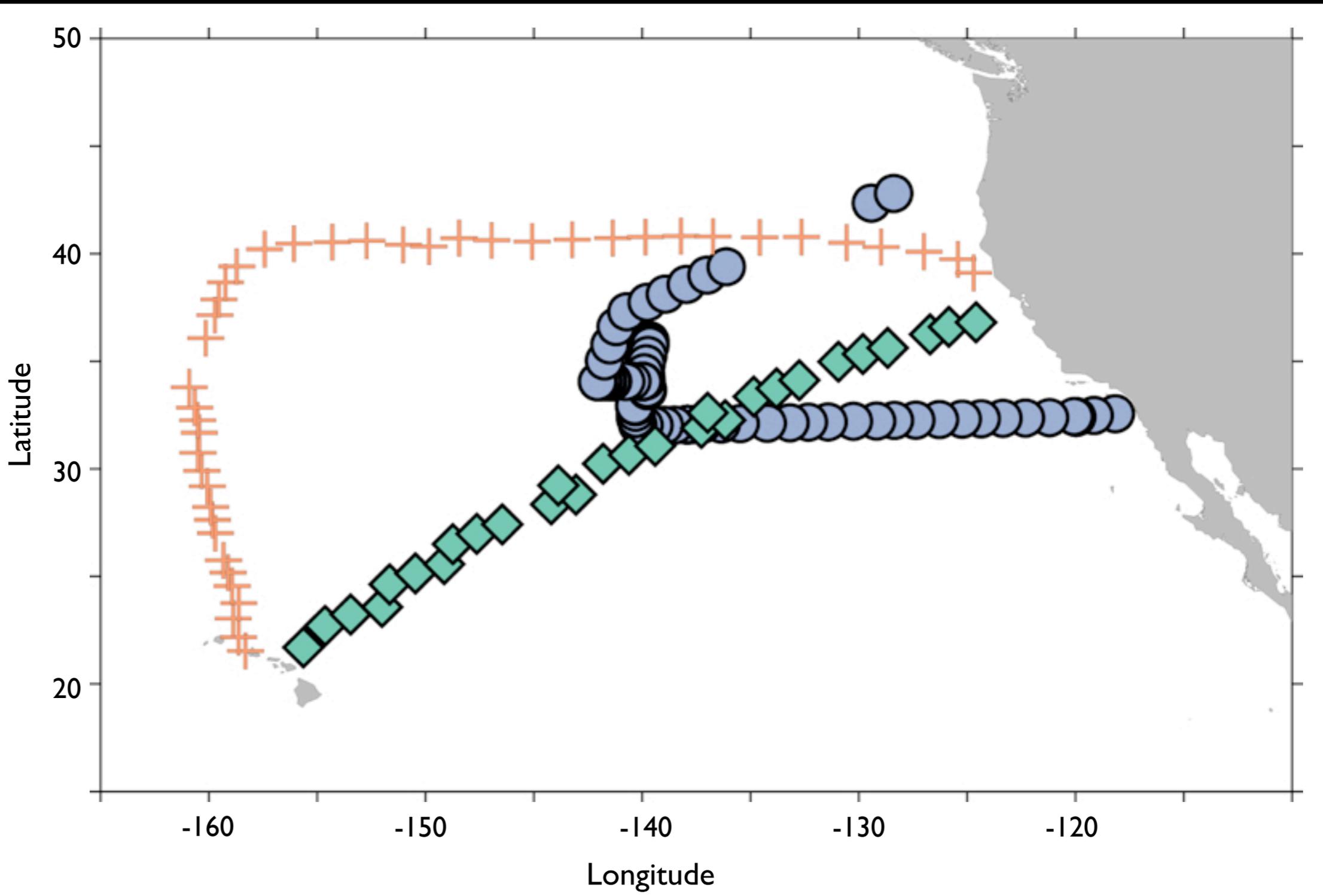


Assessing ecological impacts of North Pacific microplastic

1. What is the abundance and distribution of microplastic in the northeast Pacific?
2. How are surface-dwelling marine invertebrates impacted by microplastic?

Study Area

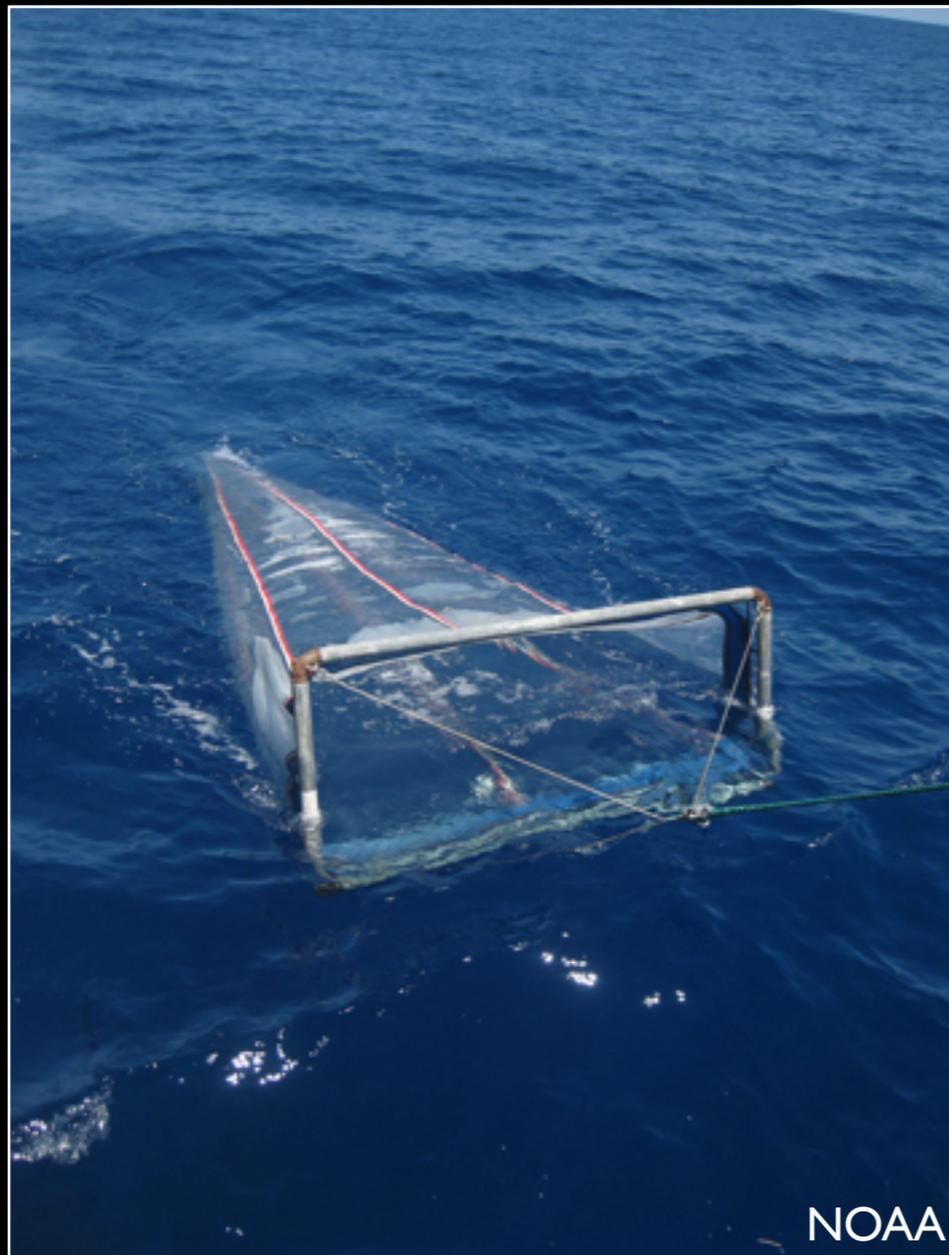
- 2009
- ◆ 2010
- ✚ 2011



Methods: Plastic and plankton collected with quantitative net tows

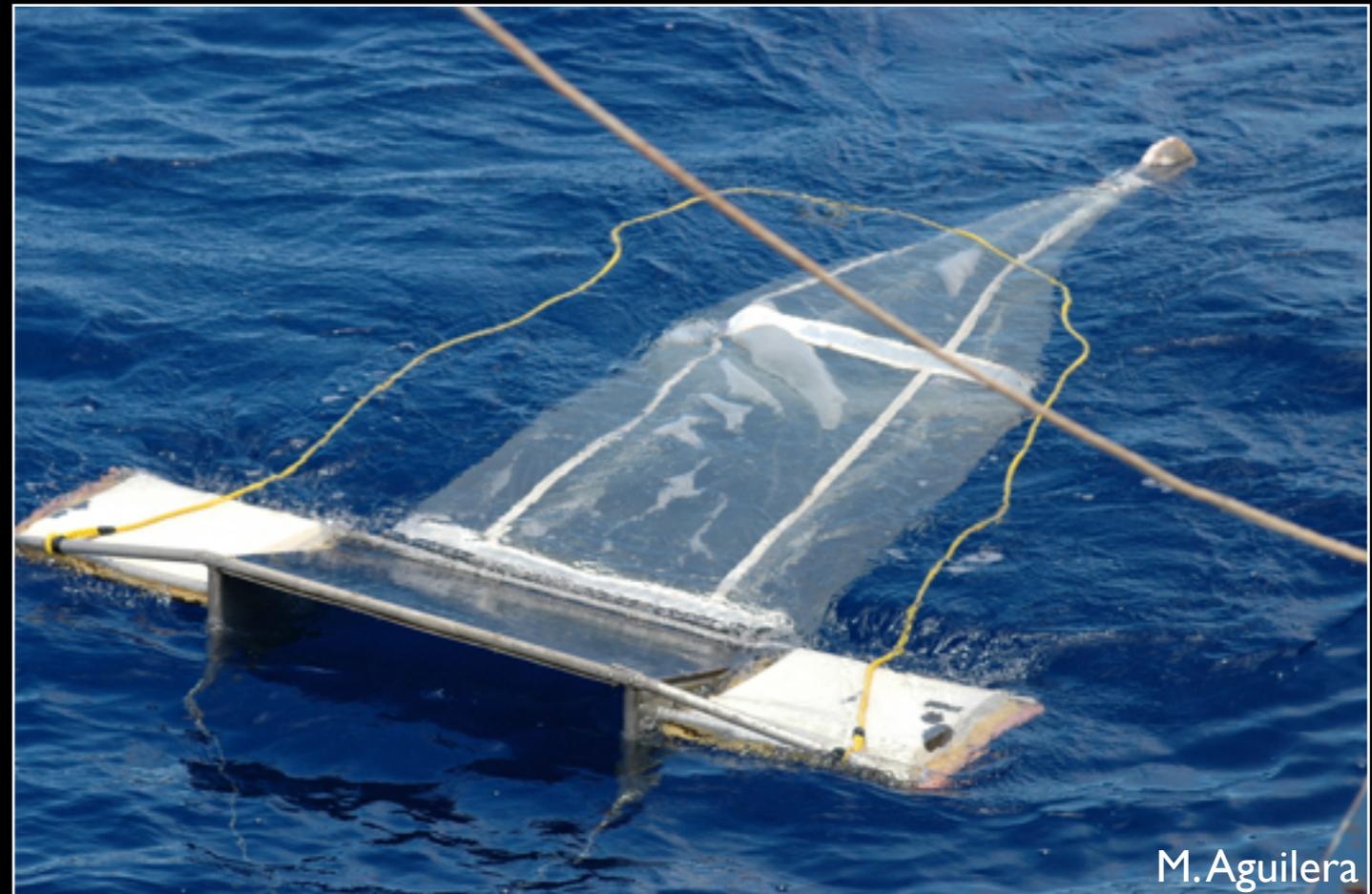
Neuston net

1970s-1980s



Manta net

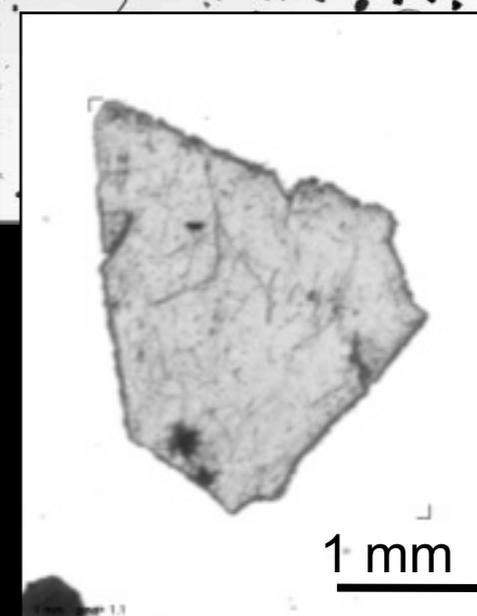
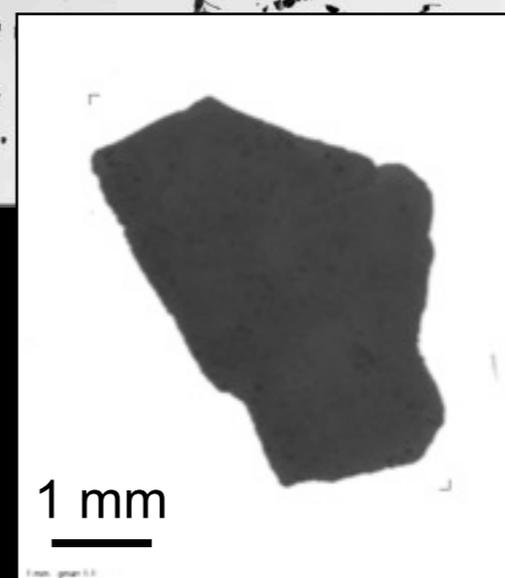
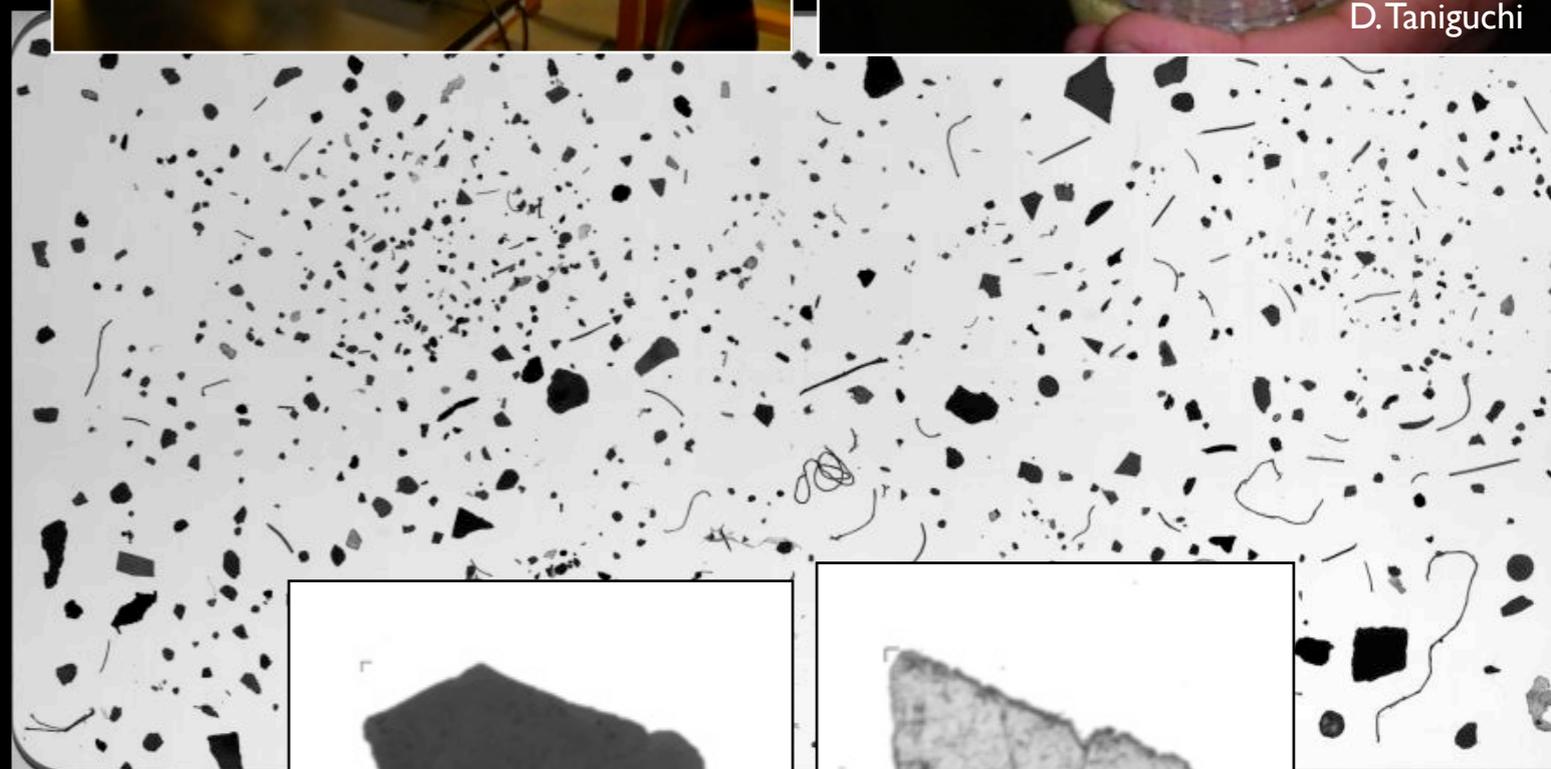
1990s-today



- Towed on ocean surface
- Mouth ~1 meter across, mesh 505/333 μm respectively

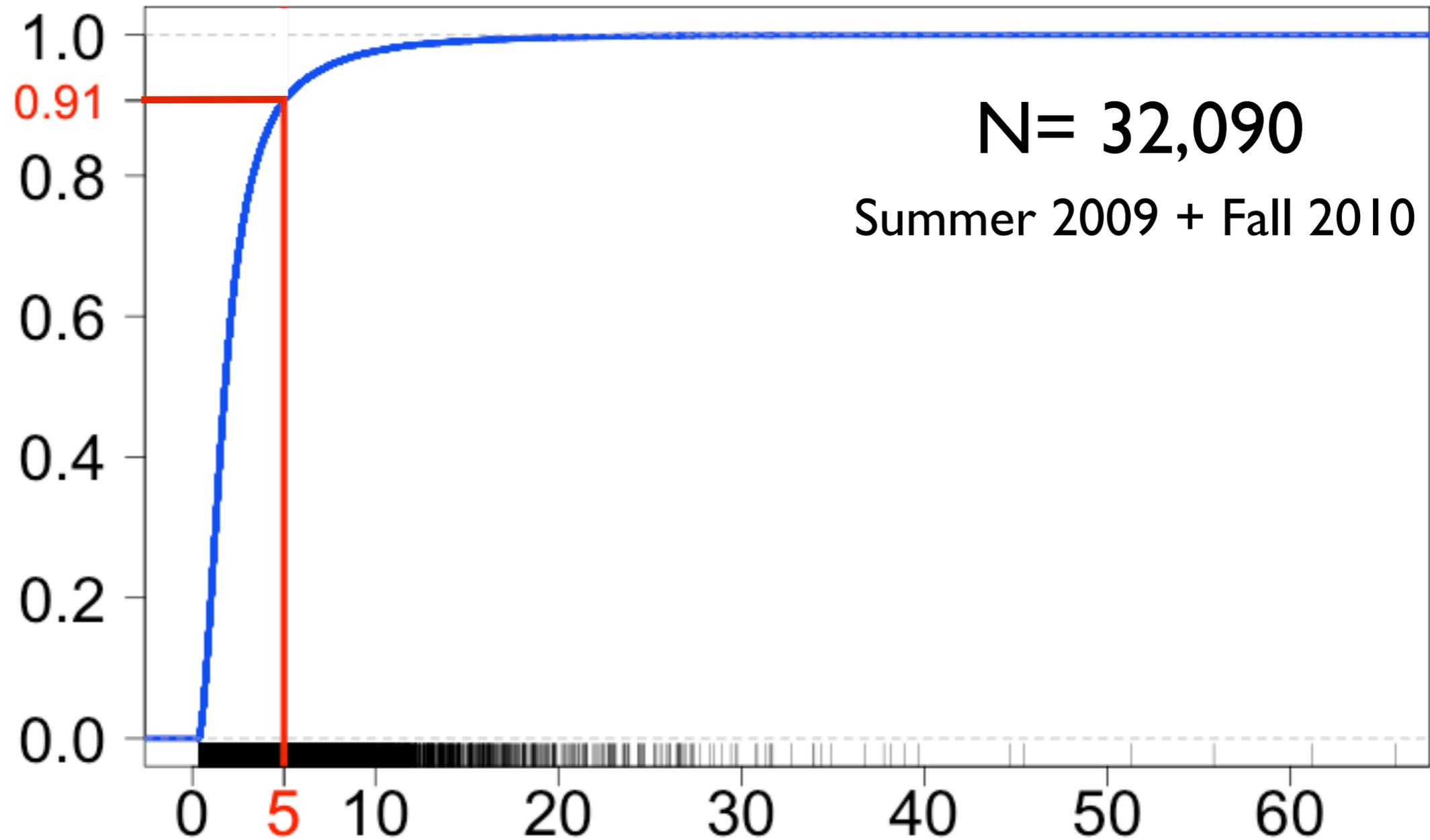
Methods: Quantifying microplastic & preserved plankton

- Sorted under dissecting microscope for microplastic & plankton
- Scanned with Zooscan (Gorsky et al 2010)
- Individual particles optically counted and measured
 - Number
 - Cross-sectional area
 - Maximum diameter



Results: 91% of surface marine debris is microplastic

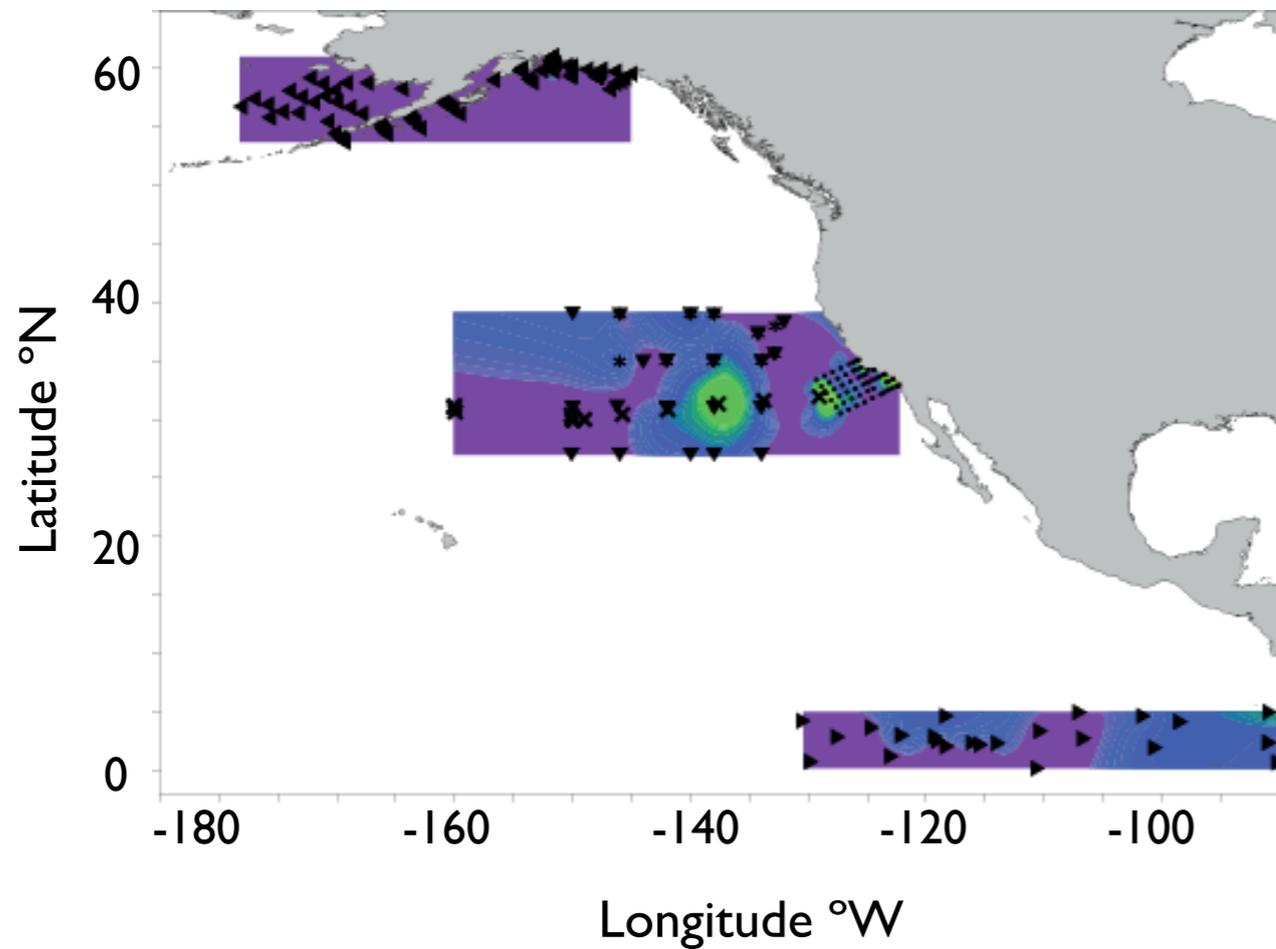
Cumulative distribution function



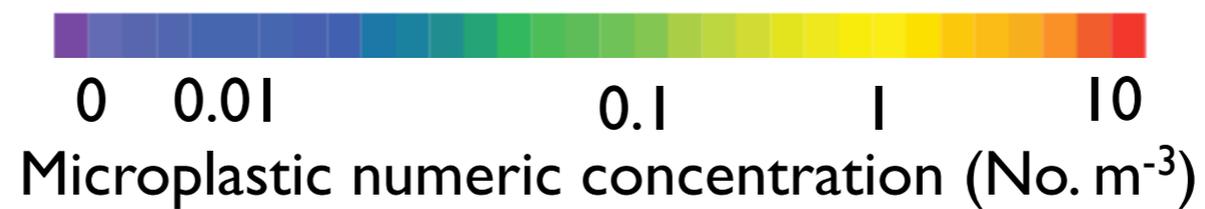
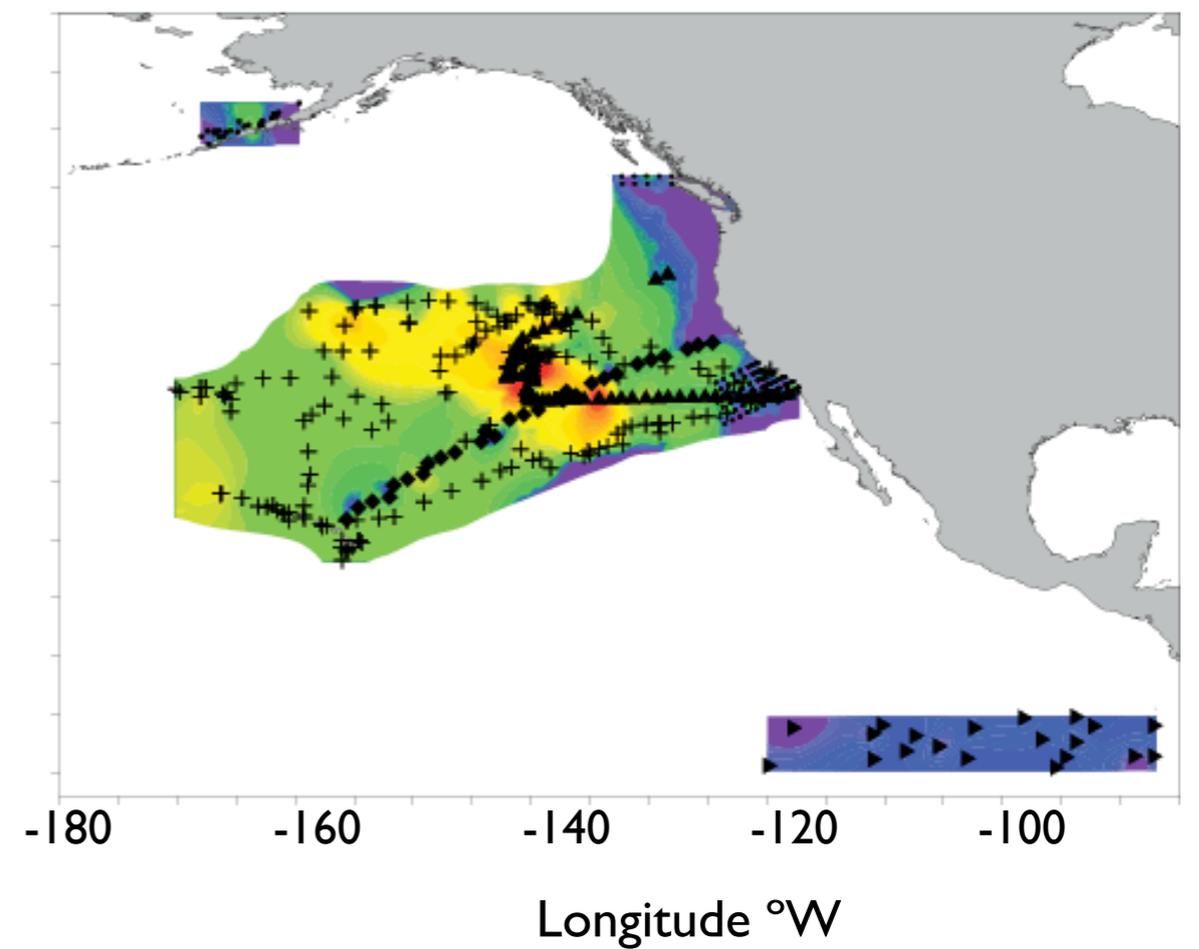
Particle diameter (mm)

Decadal-scale 100-fold increase in microplastic

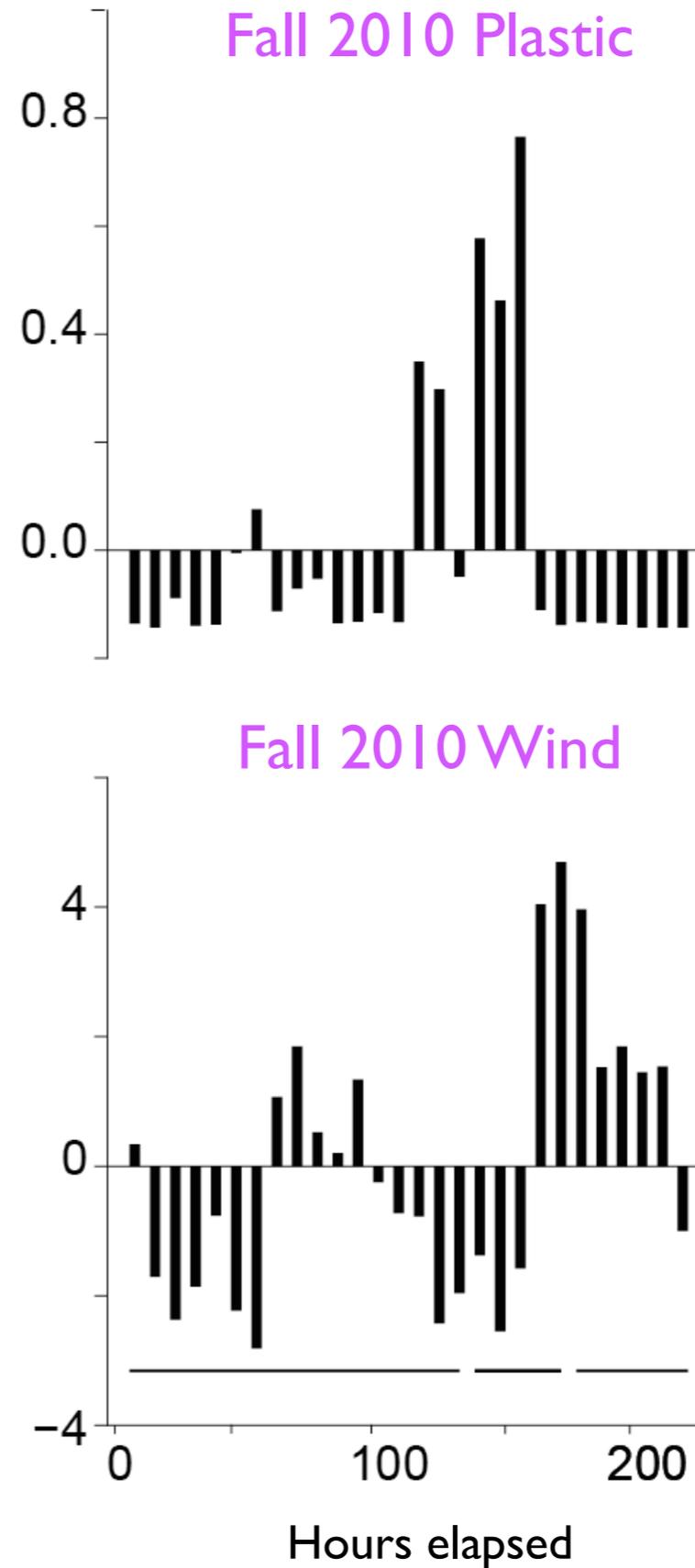
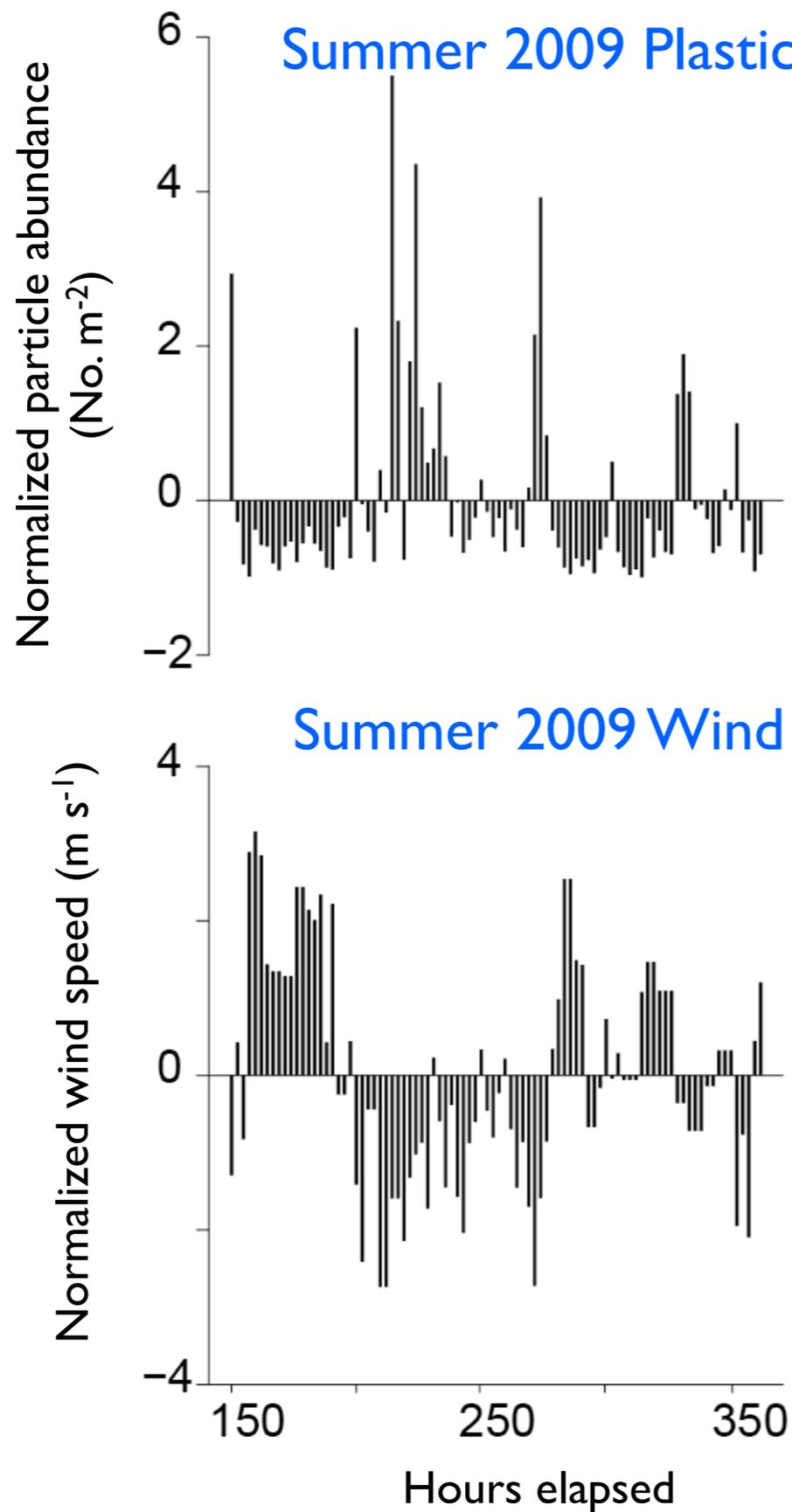
1972-1987



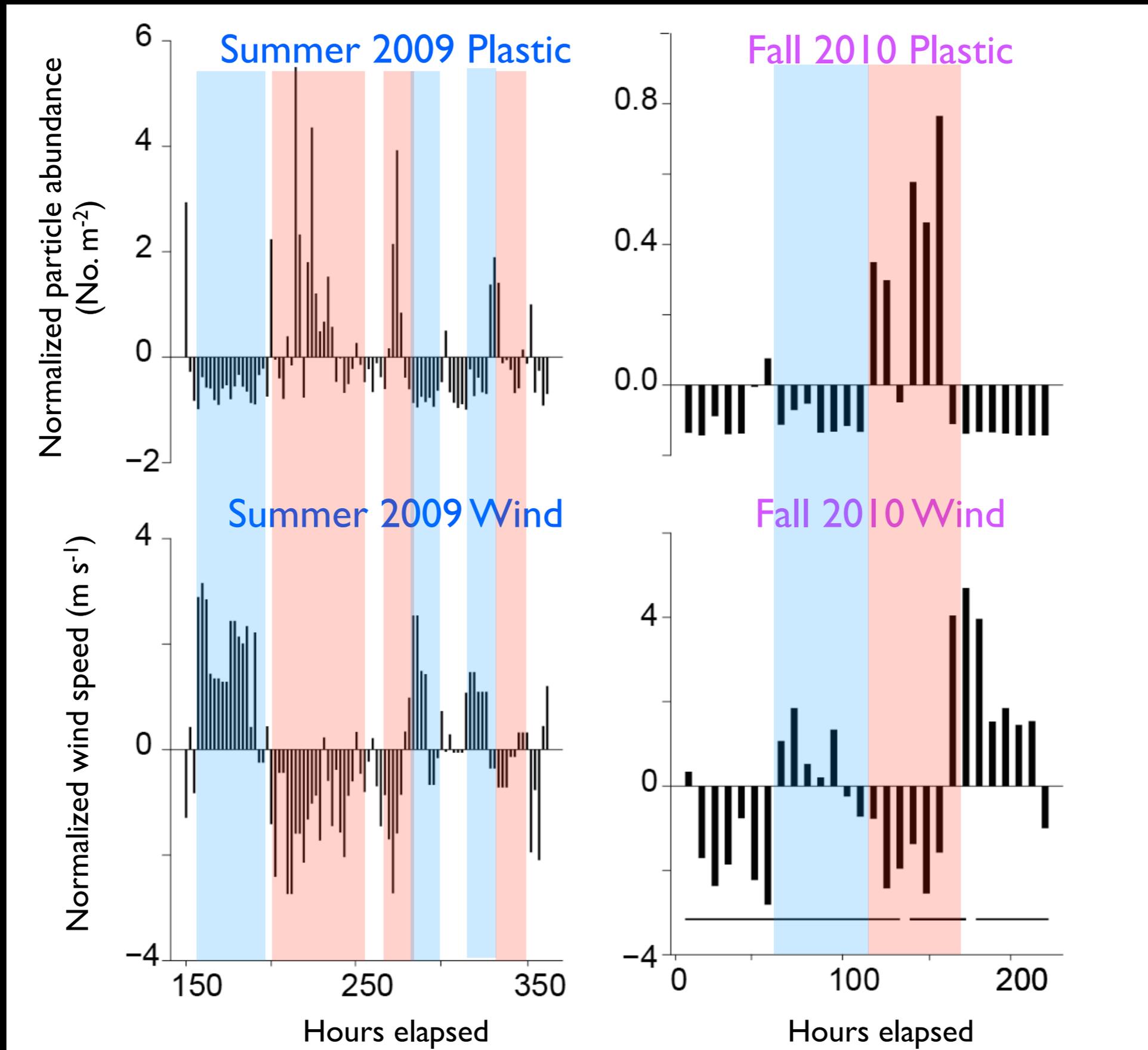
1999-2010



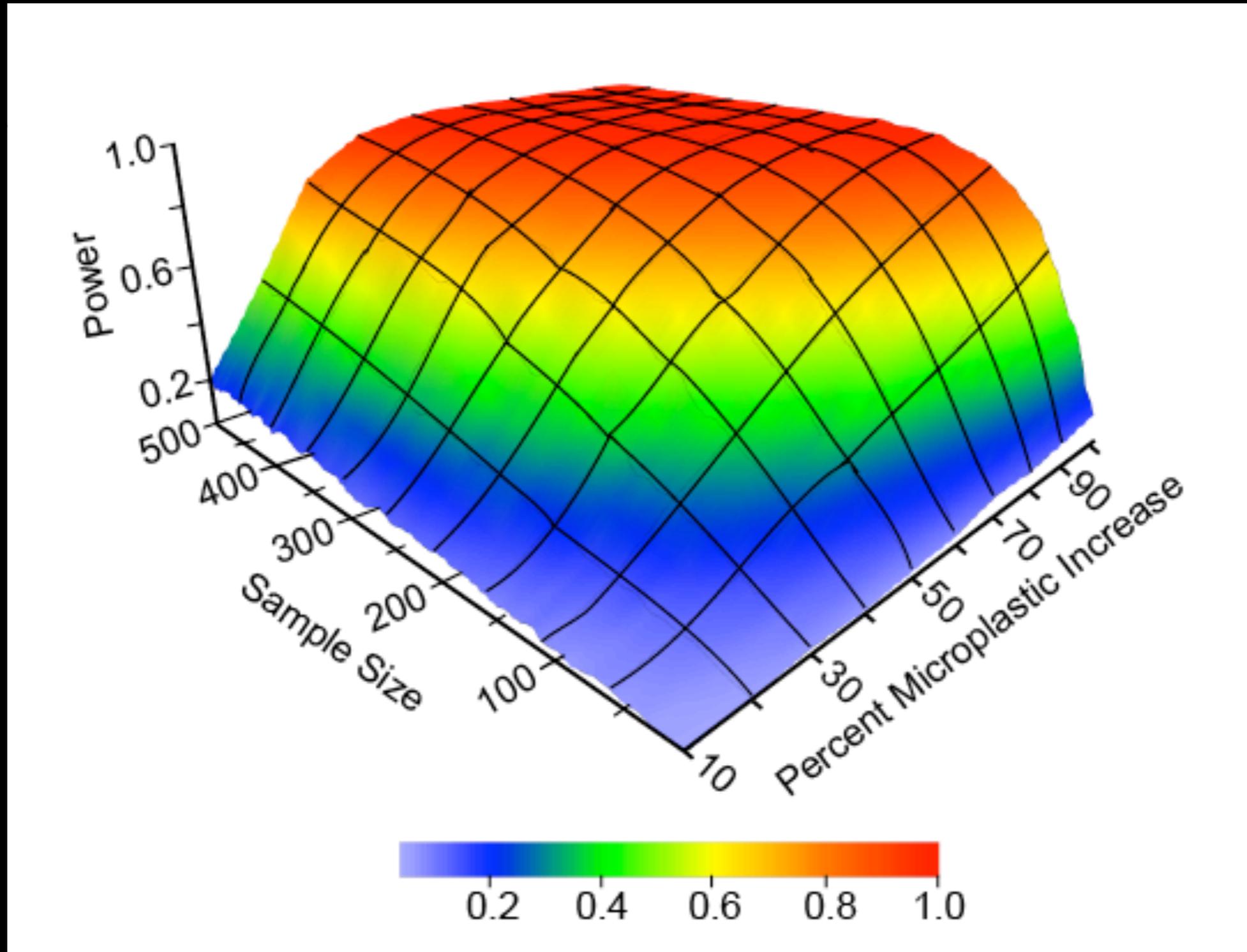
One cause of spatial heterogeneity: wind



One cause of spatial heterogeneity: wind



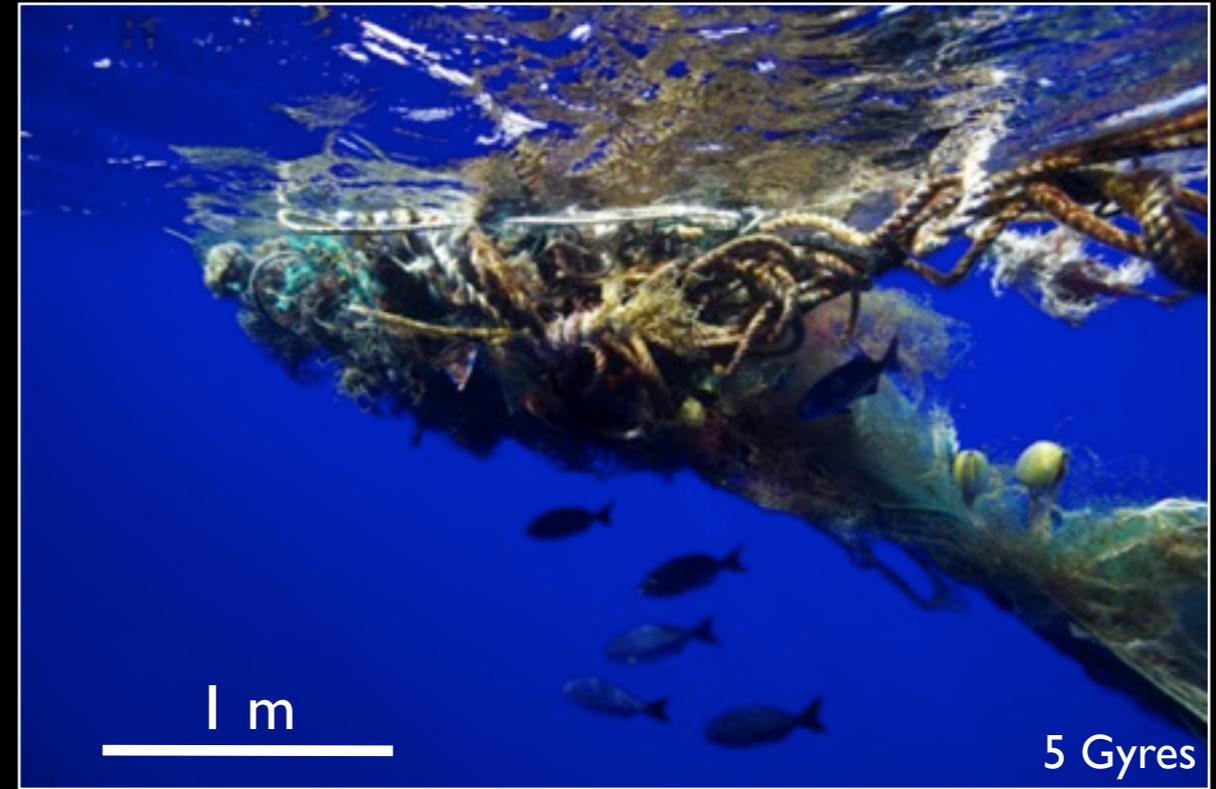
Detecting increases (or decreases) in microplastic



- Monte Carlo simulation of Mann-Whitney test
- 1000 replicates per test
- $\alpha=0.05$

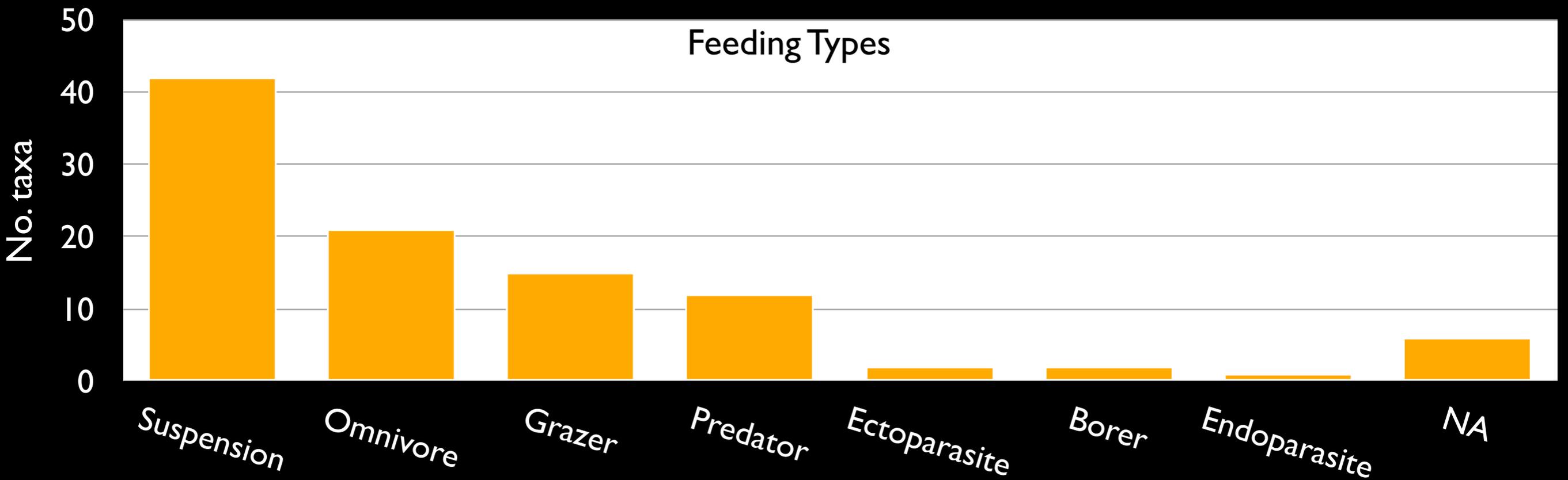
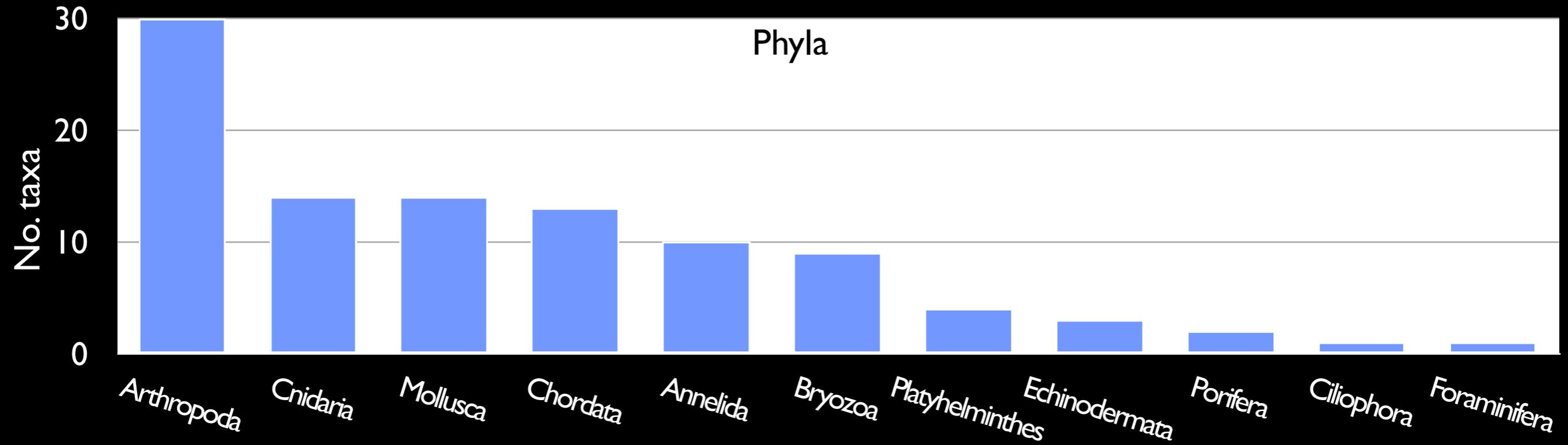
Floating plastic debris as “islands” of hard substrate

- Increase in plastic has added hard substrate habitat to open ocean
- Specialized suite of species inhabit open floating material - “rafting community”
- Transport of potentially invasive species
 - Collaboration with Hank Carson & Marcus Eriksen



96 rafting taxa from 11 phyla

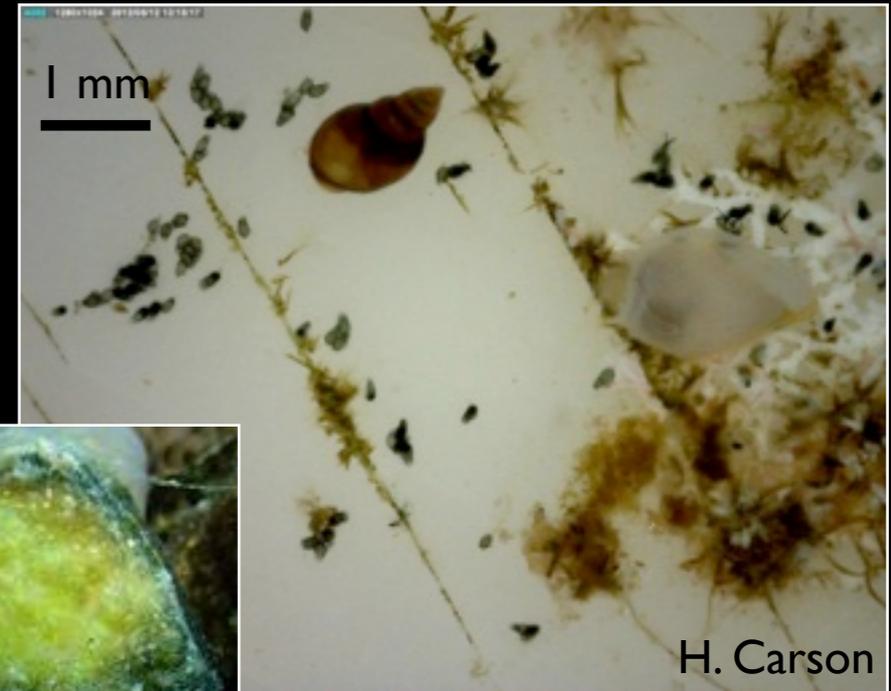
26 taxa=first time documented as rafting



N=242 debris items

Potentially invasive rafting species

- New potentially invasive species (W Pacific): coral pathogen *Halofolliculina* spp. and the majid crab *Herbstia* spp.
- Known Pacific rim invaders found on plastic:
 - Acorn barnacles: *Megabalanus rosa* & *Amphibalanus amphitrite*
 - Bryozoans *Bugula* spp. & *Victorella* spp.
 - Mussel *Mytilus galloprovincialis*

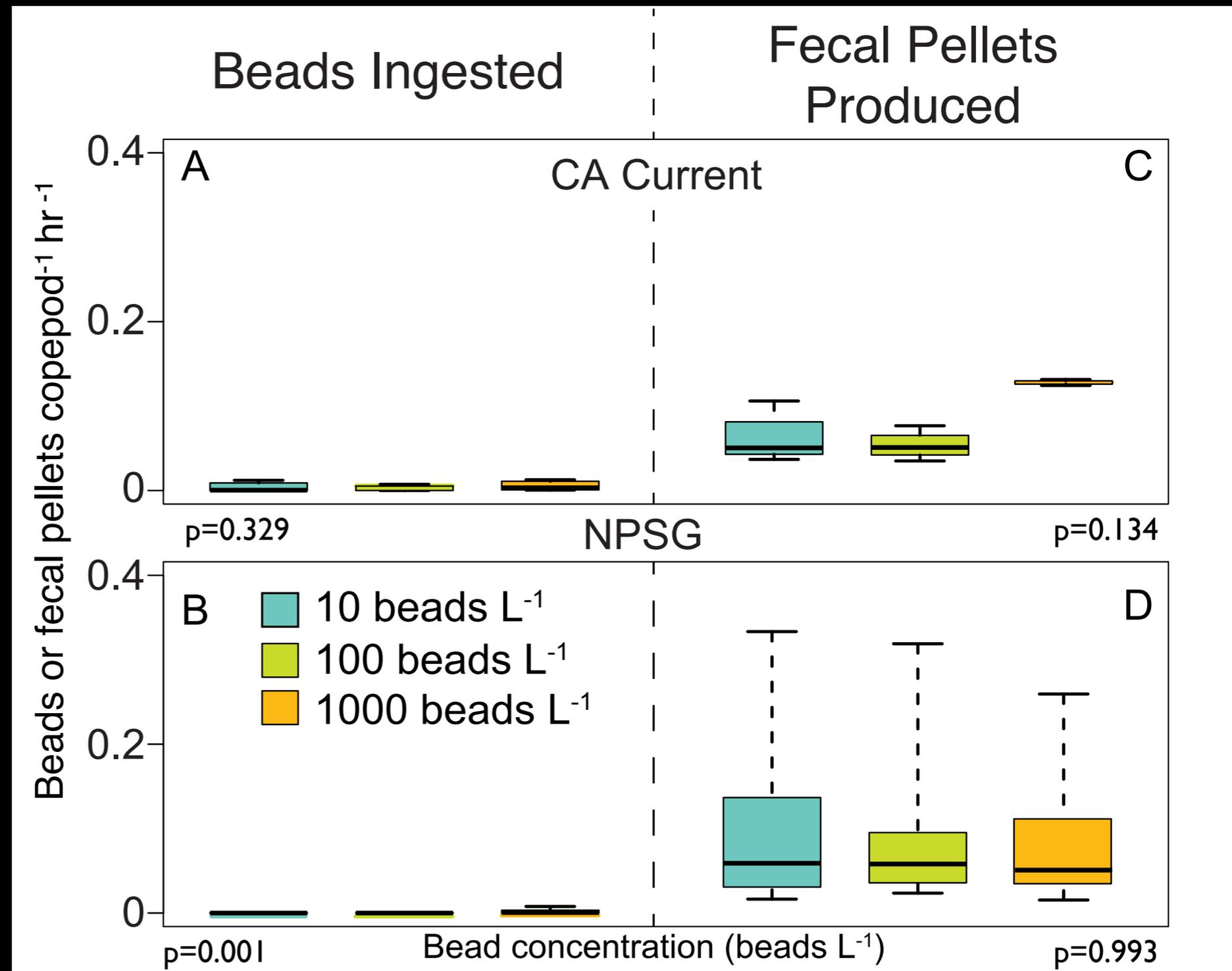
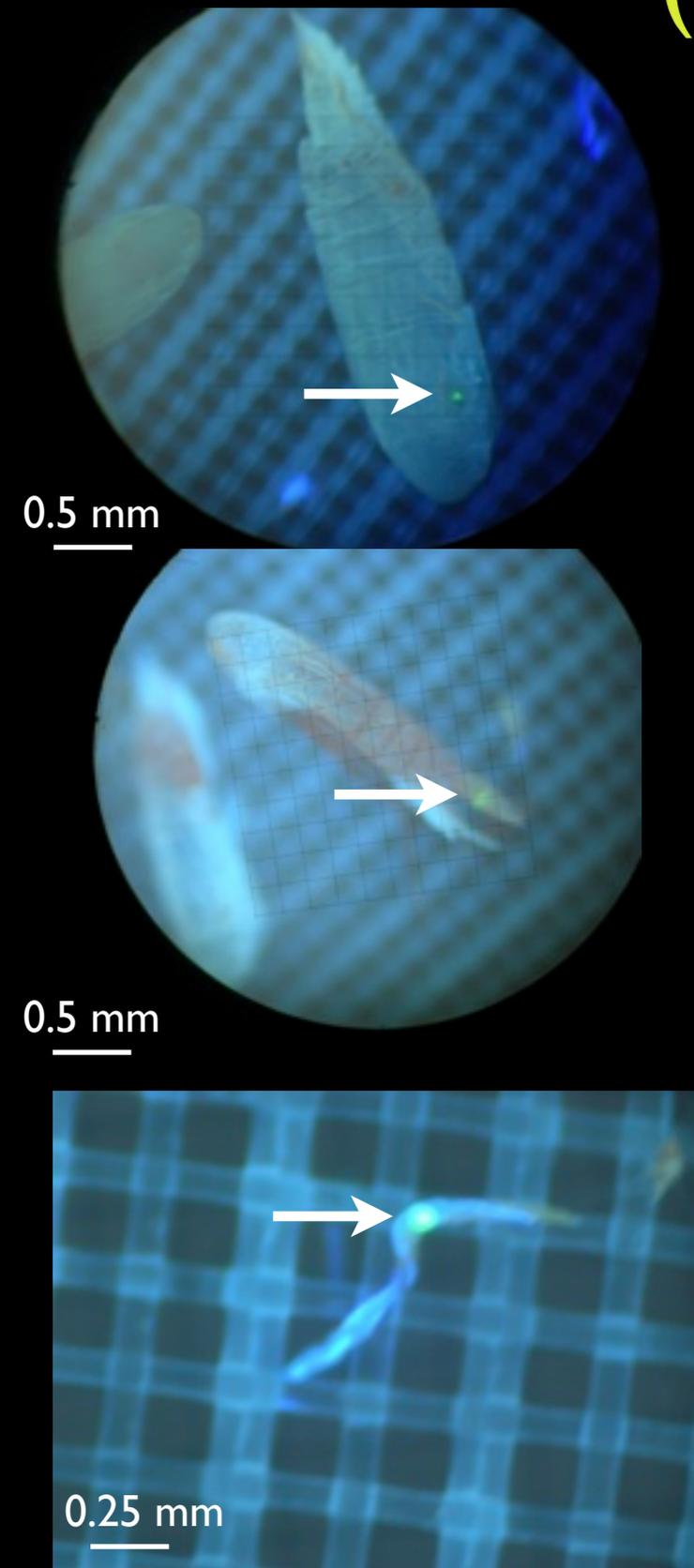


Methods: Plastic ingestion experiments

- NPSG copepods collected with live collection net
 - 10-20 copepods incubated with 25-45 μm fluorescent polyethylene beads.
 - Fecal pellets and ingested beads examined under an epifluorescence microscope
- Gooseneck barnacles (*Lepas* spp.) opportunistically collected
 - Gut contents examined under dissecting microscope

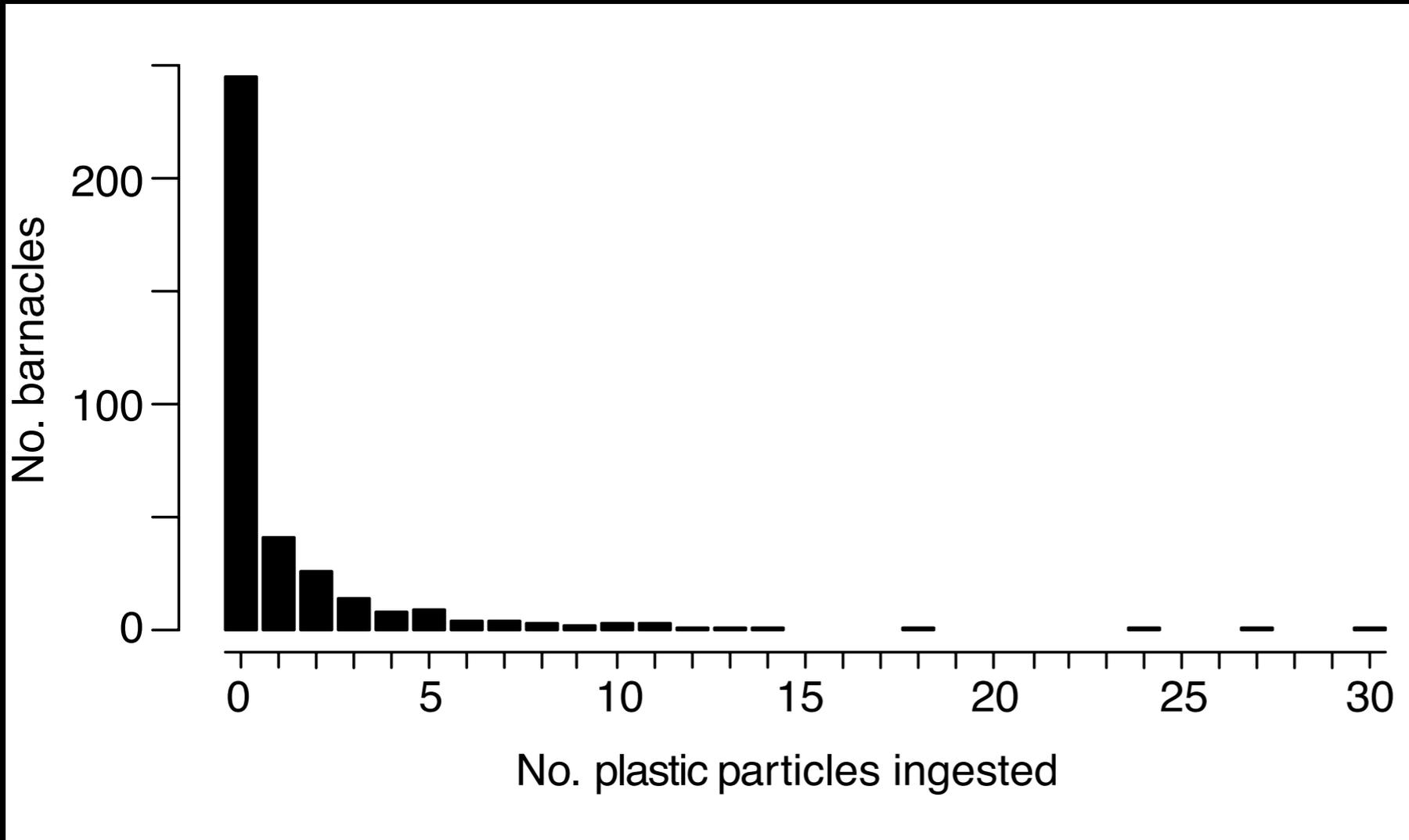


Copepods ingest minimal amounts of microplastic (in experimental conditions)



All p-values from Kruskal-Wallis test

33.5 % of gooseneck barnacles ingest microplastic (in natural habitat)



N=385

Lepas pacifica and *Lepas anatifera*

Goldstein & Goodwin 2013, *PeerJ*



Summary of results

- Most plastic in the NPSG is microplastic
- Microplastic has substantially increased over the past four decades
- Potentially harmful species inhabit plastic rafts
- Gooseneck barnacles ingest microplastic, but copepods may not

Ecological implications

- Microplastic = widespread alteration of the NPSG ecosystem
 - Introduction of novel substrate with associated assemblage (Barnes 2002, Winston 1997, Zettler et al. 2013)
 - Ingestion in invertebrates, mesopelagic fishes (Davison & Asch 2010), and seabirds (Spear et al. 1995)
 - Plastic-associated toxins (Mato et al. 2001, Teuten et al. 2009)
- Unknown effects on oceanic biogeochemical cycling and pelagic community structure



Acknowledgments



UC Ship Funds
Project Kaisei

Jim & Kris McMillan
Jeffrey & Marcy Krinsk

NOAA

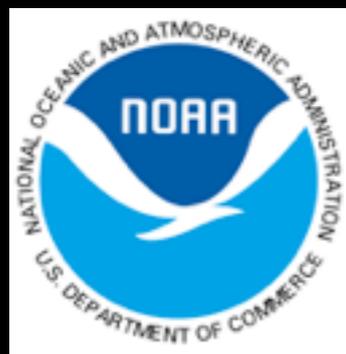
Lyn & Norman Lear

Sea Education Association

Ellis Wyer

Knauss Marine Policy Fellowship

Peterson Charitable Fndn



Association for Women in Science - San Diego

Centers for Ocean Sciences Education Excellence

Michael M. Mullin Graduate Student Fellowship in Biological Oceanography

Scripps Center for Marine Biodiversity and Conservation

Scripps Director's Office

National Science Foundation

SIO

- Mark Ohman & the Ohman lab
- SIO Pelagic Invertebrates Collection (Annie Townsend & Linsey Sala)
- Lisa Gilfillan
- Science party & crew of R/V *New Horizon*

NOAA

- Michael Ford
- Stephanie Oakes
- Amy Hays & SWFSC
- Officers & crew of NOAA ship *Okeanos Explorer*

SEA

- Erik Zettler, Mary Engels, Paul Joyce
- Crew & students of SSV *Robert C. Seamans*, S230 & S236

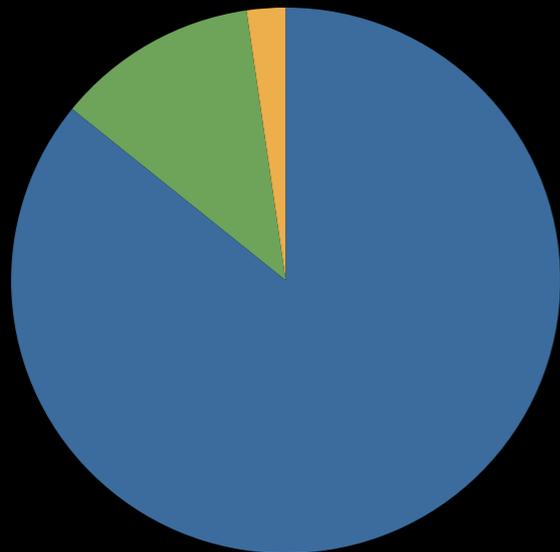
Plastic Sorting Volunteers

Olivia Bengé
Carri-Lyn Cameron
Patrick Chung
Dominic Dufour
Andy Pin-Hsien Fan
Chris Gawad
Adam Greco
Rose Hill
Catherine Nickels

Erin Reed
Erik Raudzens
Marci Rosenberg
Marie Ryder
Ashley Salas
Summer Strutt
Thanh Trinh
Alex Warneke

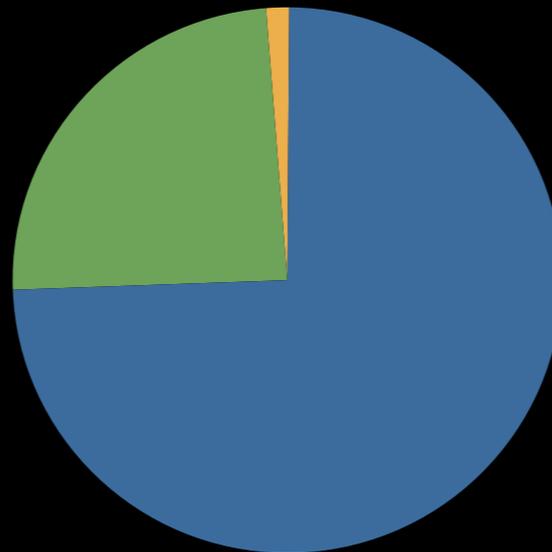
Plastic type

N Pacific Gyre



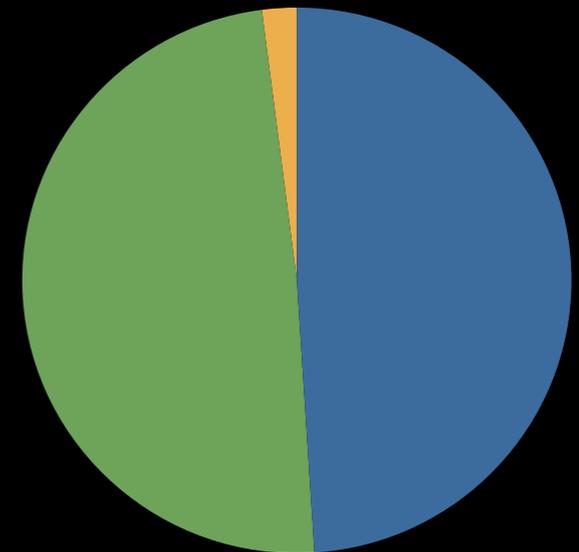
N=437

Transition Area



N=74

CA Current



N=49

● Polyethylene

● Polypropylene

● Polystyrene