An Ecological Perspective on Microplastics in the Great Lakes

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SCHOOL OF NATURAL RESOURCES & ENVIRONMENT
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New life forms discovered on plastics “plastisphere!”

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NEWS

New life discovered growing on plastic waste dubbed the 'plastisphere'

BY PENNY ORBELL

ABC Environment | 13 NOV 2013

Comments

A whole new group of mic
been found growing of the
discarded plastic floating i

VAST AMOUNTS OF plastic d
are supporting new forms of m
new ecosystems. Scientists wr
Environmental Science & Tech
calling this new life the 'plastisp

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February 11, 2014, 1:44 p.m. ET

NY legislation would ban plastic bits in cosmetics

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eads?

Visa's Zero Liability P

of the U.S.

The accumulation of plastic debris in nature is “one of the most ubiquitous and long-lasting recent changes to the surface of our planet” (Barnes et al., 2009)

Top > Nature & Earth > Biol

Biologists Reco
Arctic Deep Sea

Published: October 23, 2012. By Helmholtz Association of German Research Centres
http://www.helmholtz.de/en/index.html

Go to mobile page.

Biologists record increasing amounts of plastic litter in the Arctic deep sea: studies confirm that twice as much marine debris is lying on the seabed today compared to ten years ago

Bremerhaven, 22nd October 2012. The seabed in the Arctic deep sea is increasingly strewn with litter and plastic waste. As reported in the advance online publication of the scientific journal *Marine Pollution Bulletin* by Dr. Melanie Bergmann, biologist and deep-sea expert at the Alfred Wegener Institute for Polar and Marine Research in the Helmholtz

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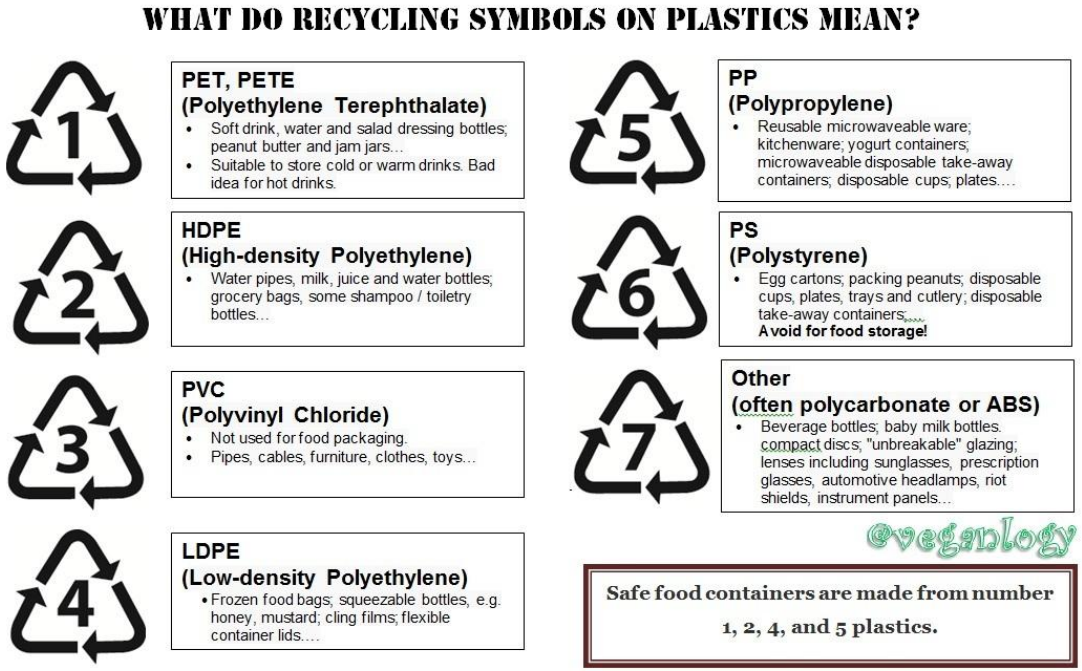
Increasing amounts of Plastics in Arctic Deep Sea

The “Great” Pacific Garbage Patch

Plastics include a wide range of polymeric materials



e.g. polypropylene, polyethylene, polyvinyl chloride

- Plastics are petrochemical based polymers
- In 2007, global plastic production was 24% PP, 21% PE, and 19% PCV in 2007 (Andrady 2011)

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Over the past half century, global plastic production has increased rapidly

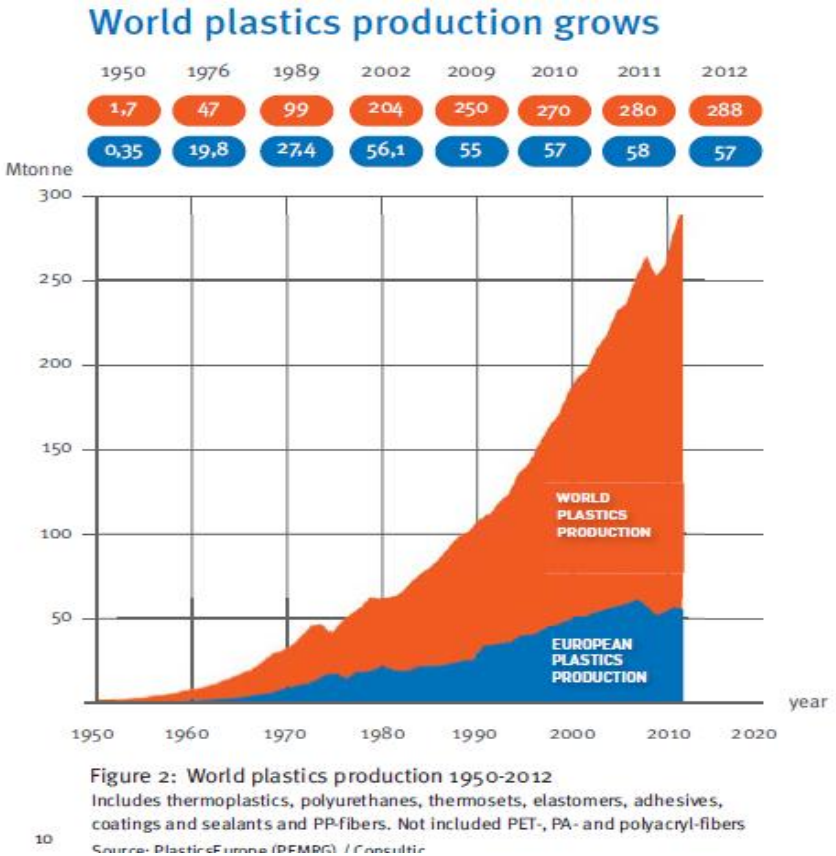

Figure: World Plastics Production, 1950 – 2012. The Facts about Plastic, PlasticsEurope (2013), p. 10.

Continuous growth for >50 yrs, production rose to 280 million tonnes in 2012 – a 2.8% increase from 2011

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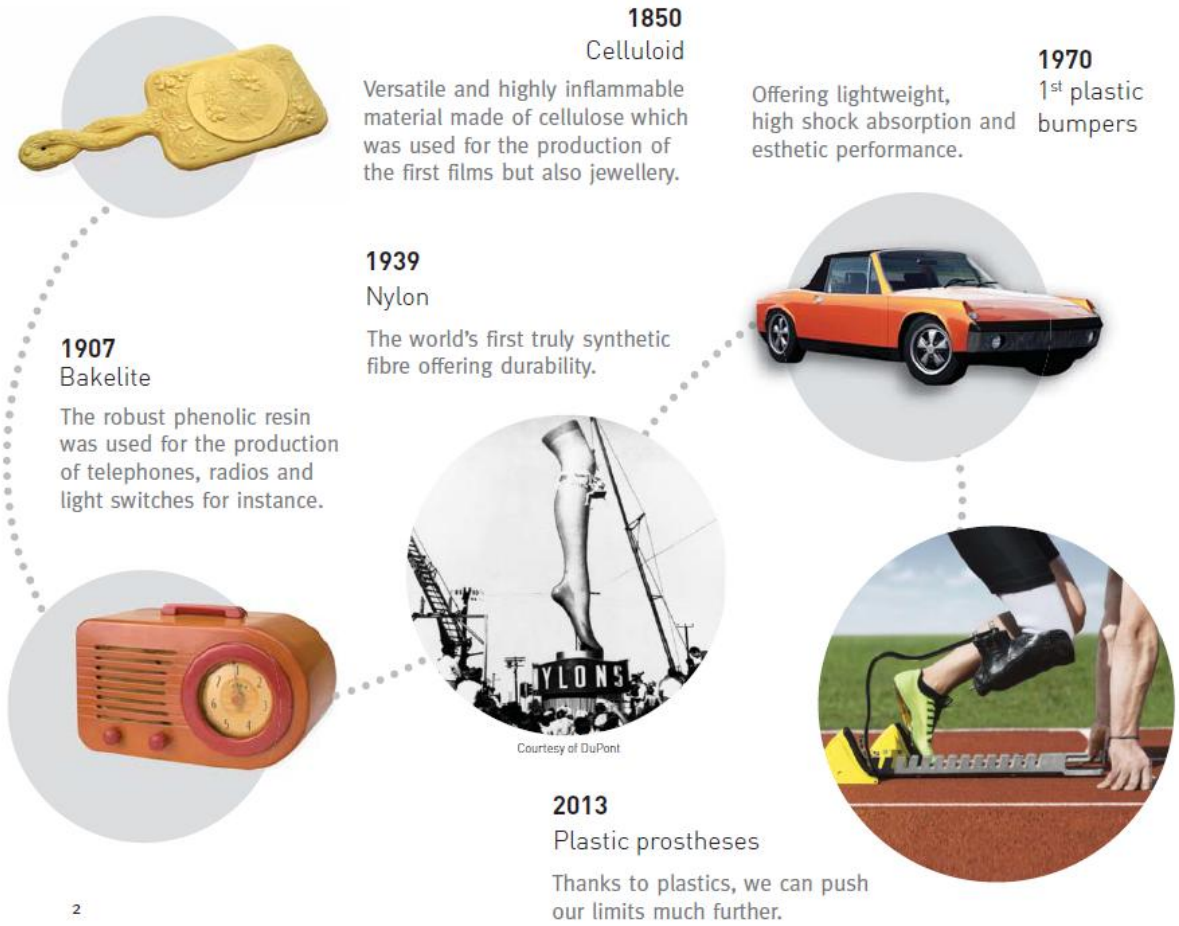
The amount of plastic will continue to rise

Rochman et al. Nature. 2013



Increase in global demand

Figure: World Plastics Production, 1950 – 2012. The Facts about Plastic, PlasticsEurope (2013), p. 4.

Plastics in the environment

- With this increased use and production, more plastic material is ending up in the **environment**

DIMITAR DILKOFF/AFP/GETTY

Volunteer cleaners negotiate a Bulgarian reservoir jammed with plastics.

Image: from Rochman et al. Nature. 2013

C. Morishige, NOAA Marine Debris Program

Image: from NOAA Marine Debris Program

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Once released into the environment, plastics find their way around the world

- First reports of plastics in Sargasso Sea 1972 (Carpenter and Smith, *Science*)
- Major *call to awareness* a few decades later: “Great Pacific Garbage Patch” in North Pacific gyre (Captain Charles Moore and *Algalita* http://algalita.org).
- ***5-Gyres*** project is surveying plastics in 5 major ocean gyres (Marcus Eriksen http://www.5gyres.org)

Charles Moore, Algalita Foundation

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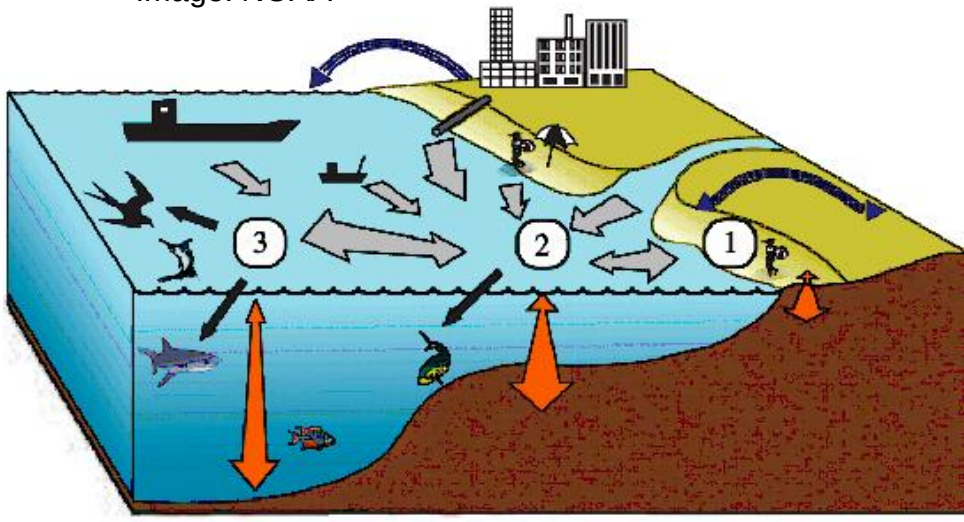
Most plastic debris originates from land-based sources, it quickly finds its way into aquatic environments

There are several process that affect plastic debris movement:

- **Sources** are wind-blown litter (curved arrows) and water-borne litter (grey arrows)
- **Pathways** include movement through the water column such as suspension, sinking (ie. biofouling, sedimentation) (orange arrows),
- **Sinks** include sediments and ingestion by organisms (black arrows)

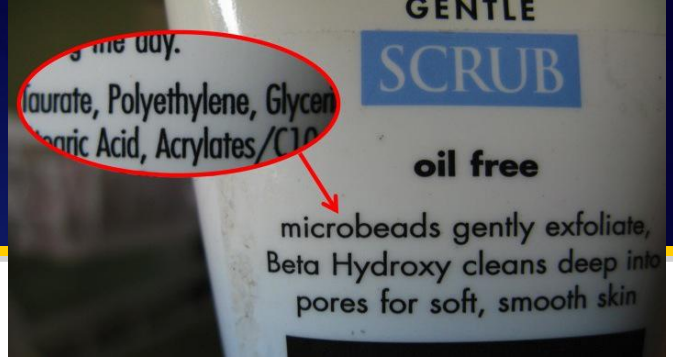
Image: NOAA

Image: NOAA



(from UNEP Year Book, Kershaw et al. 2011)

What about microplastics?



Microbeads. Image from 5Gyres

- Plastic particles <5 mm
- Primary or Secondary Materials

Microbeads: small primary material

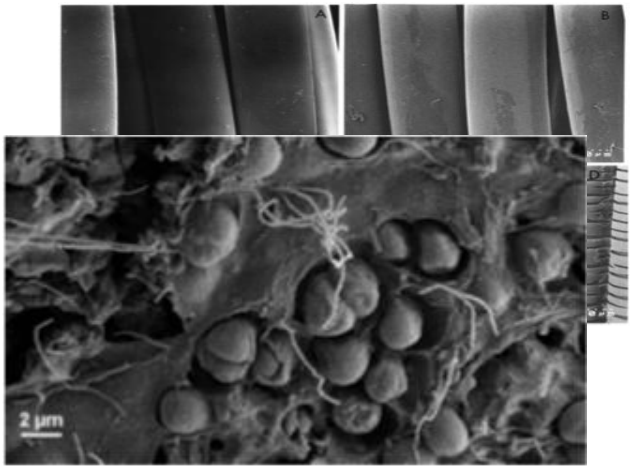
Nurdles: pre-production plastic material for manufacturing

Nurdles spill. Image from Wikipedia

Degradation products:

- Polymer characteristics play an important role in plastic degradation

-Degradation by photo (UV) irradiance, oxidation, mechanical , microbes, microbial enzymes etc.



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Where do we find aquatic based microplastics?

- Floating on the water surface
- Mixed into the water column
- Embedded in bottom sediments
- Mixed into beach sands
- **Organisms**

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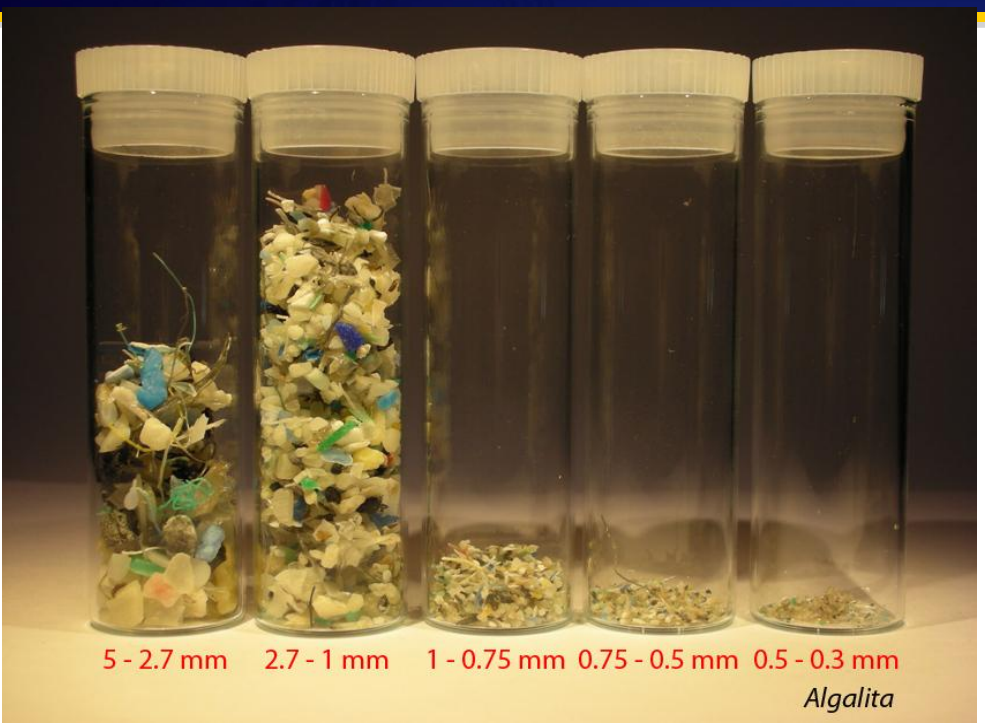
Microplastics are small enough to be taken up by different organisms



Size distribution of microplastics from a typical Manta trawl

Credit: Claire Johnson/NOAA

Credit: Marcus Eriksen, 5 Gyres Institute

Small enough for consumption across trophic levels

Credit: Imhof et al. 2013. *Current Biology*, Contamination of beach sediments of a subalpine lake with microplastic particles

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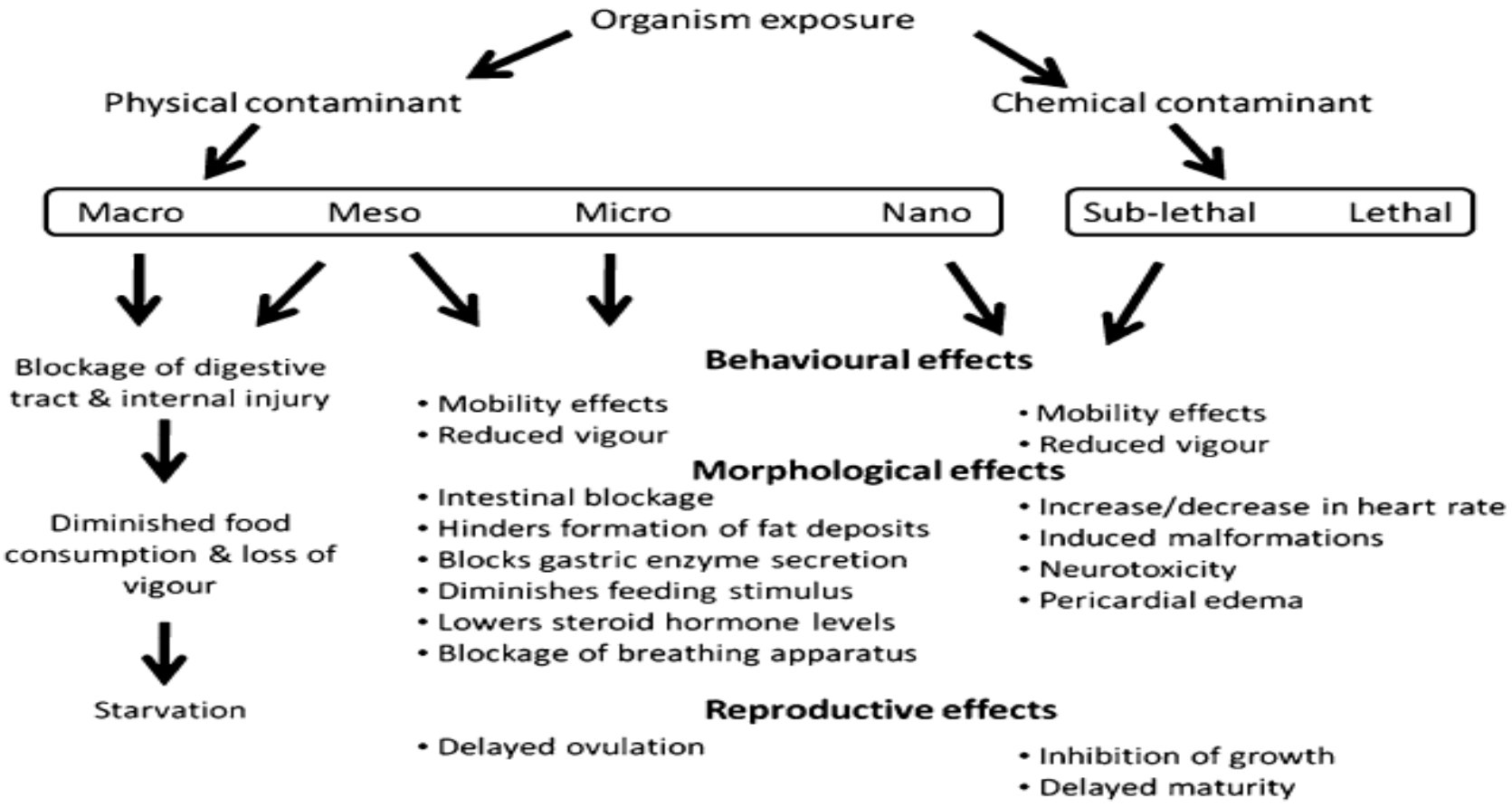
What are the exposure risks to organisms?

Conceptual Model of Organism Exposure from Lambert et al. 2014



From Lambert et al. 2014. Reviews in Environmental Contamination and Toxicology. V227

The ecological effects of microplastics are currently being investigated and assessed

- What are the ecological impacts from ingestion of plastics and contaminated plastics? Do we see reductions in survival/growth/reproduction?
- Secondary impacts from exposure to chemicals adhering/leaching to and/or from microplastics?
  - -how does this compare to other sources?
- Potential for trophic transfer of POPs?
  - -bioaccumulation may increase or decrease?
- What are the target receptors (organisms)?
- Does plastic size/type and biofouling matter?

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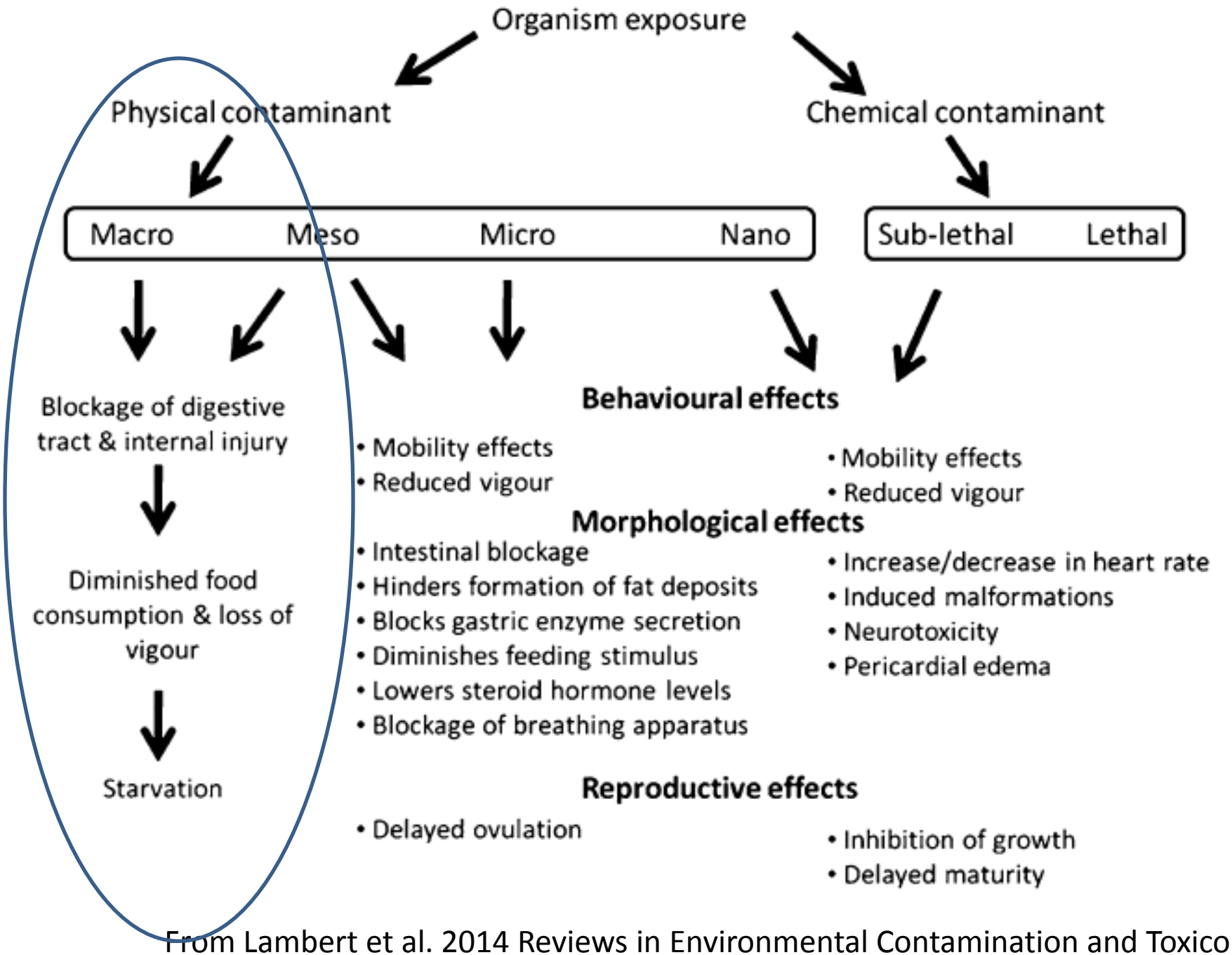


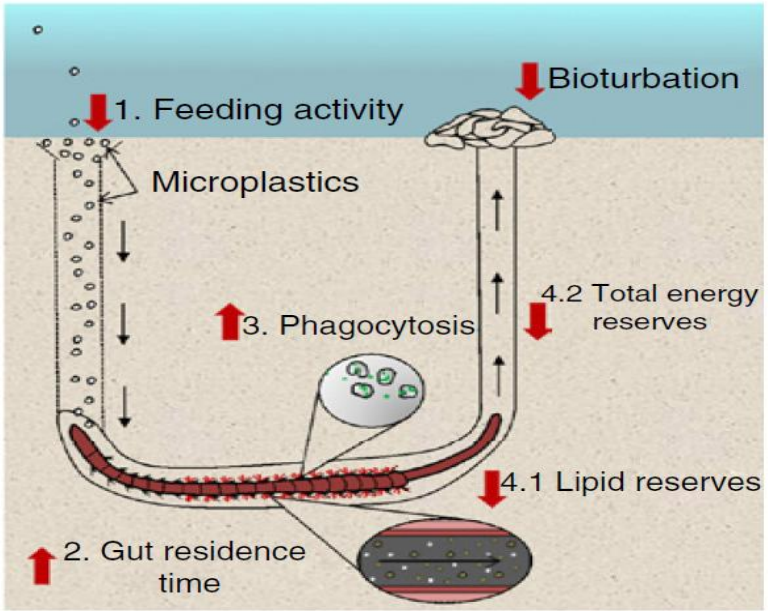
From Lambert et al. 2014 Reviews in Environmental Contamination and Toxicology

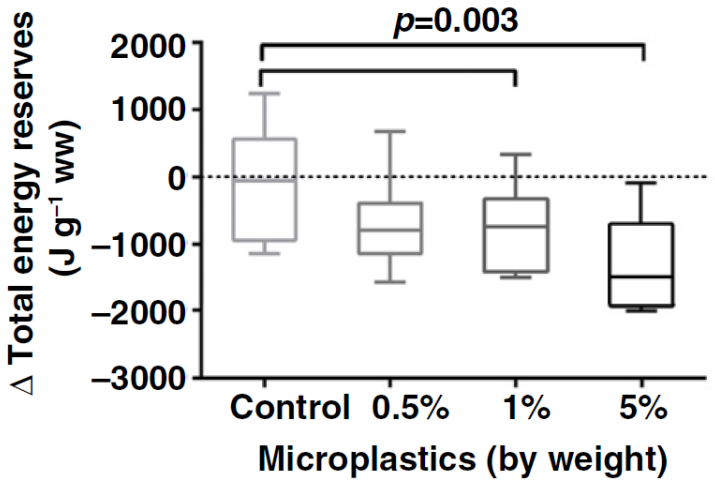
Bioenergetics and Plastics

Correspondences

Microplastic ingestion decreases energy reserves in marine worms

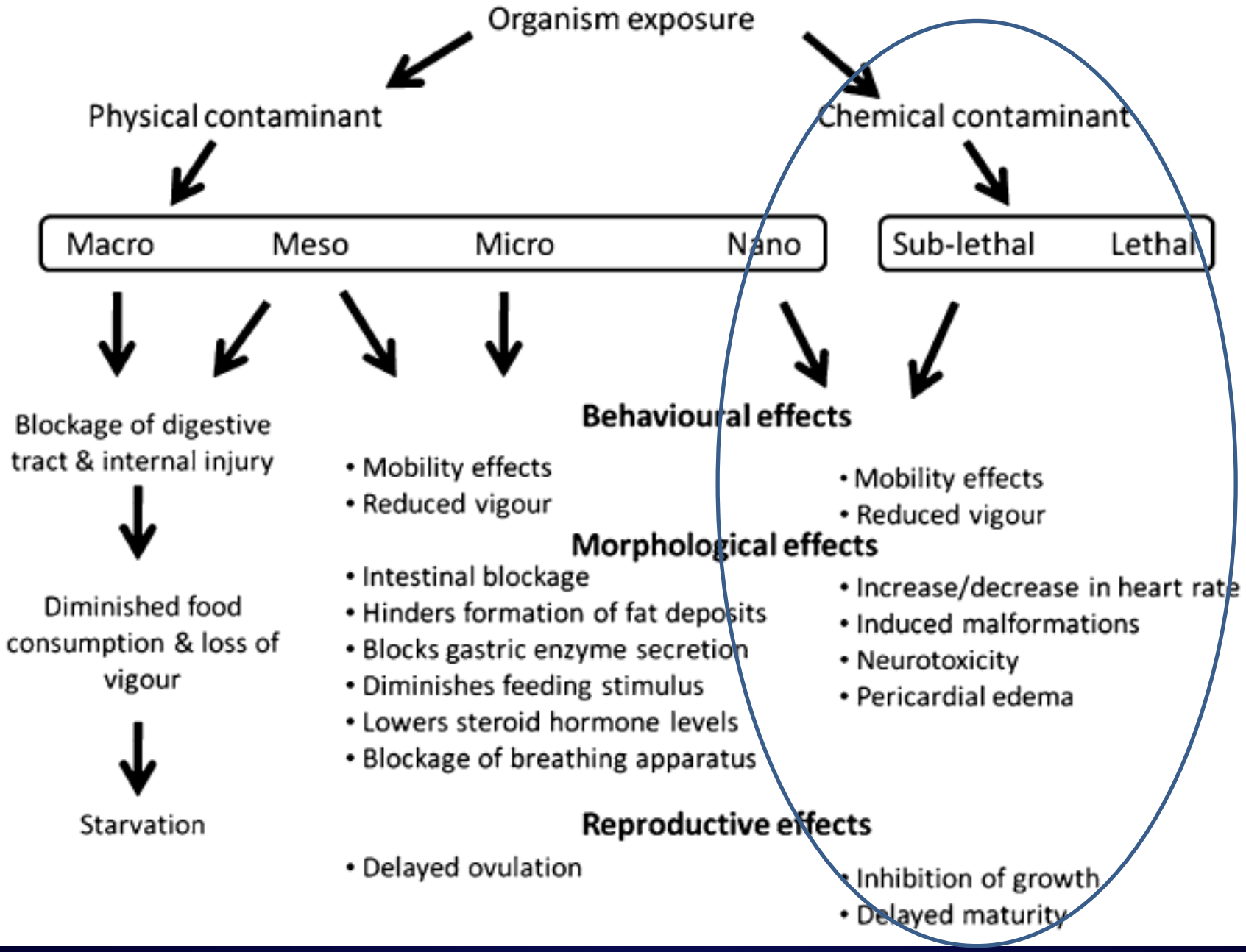
Stephanie L. Wright[1], Darren Rowe[1], Richard C. Thompson[2], and Tamara S. Galloway[1,*]





30% decrease in energy reserves in worms from a 1% by weight microplastics ingestion

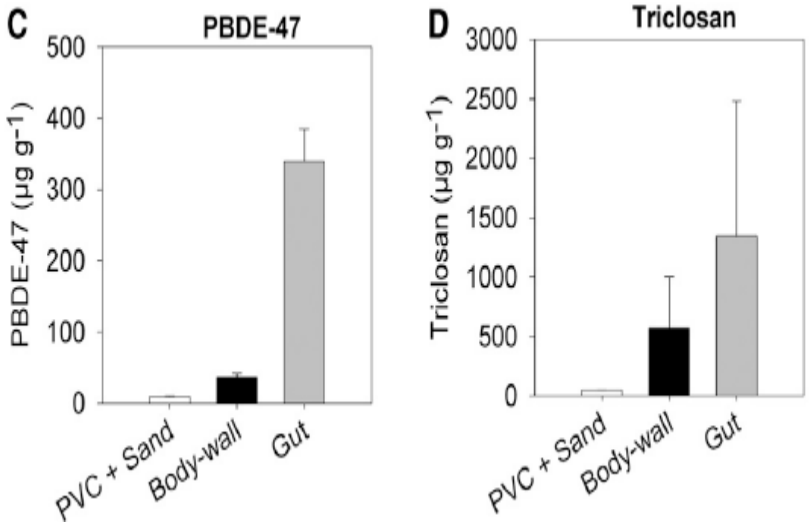
Wright et al. Current Biology. Dec. 2013



From Lambert et al. 2014. Reviews in Environmental Contamination and Toxicology. V227

Contaminants, Energetics and Plastics

Microplastic Moves Pollutants and Additives to Worms, Reducing Functions Linked to Health and Biodiversity



Browne et al. Current Biology. Dec. 2013

Microplastics and Pollutants

Peer-reviewed literature tells us:

Plastics can adsorb and concentrate pollutants

Persistent Organic Pollutants (ie. PAHs, PCBs, pesticides)

Metals (ie. mercurcy, iron, zinc, lead)

Degraded polymers can leach chemical additives

ie. BPA, phthalates, flame retardants

What are the secondary impacts from exposure to POPs adhering to microplastics? Compared to other sources?

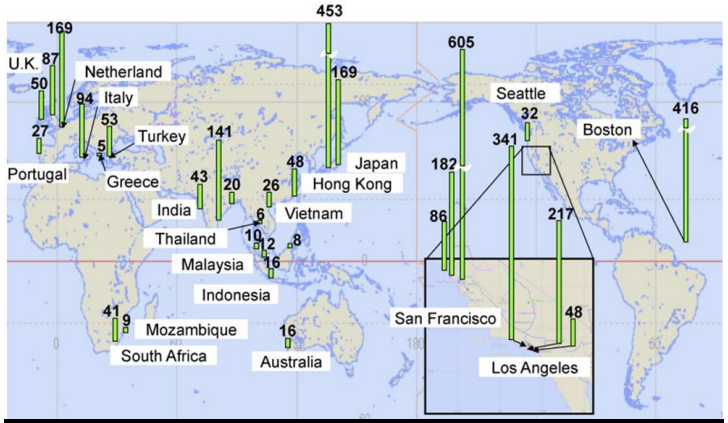


Figure: Concentrations of PCBs in beached plastic pellets. Figure from Europea EU 2011, data from Teuten et al. 2009 and also International Pellet Watch, Ogata et al. 2011.

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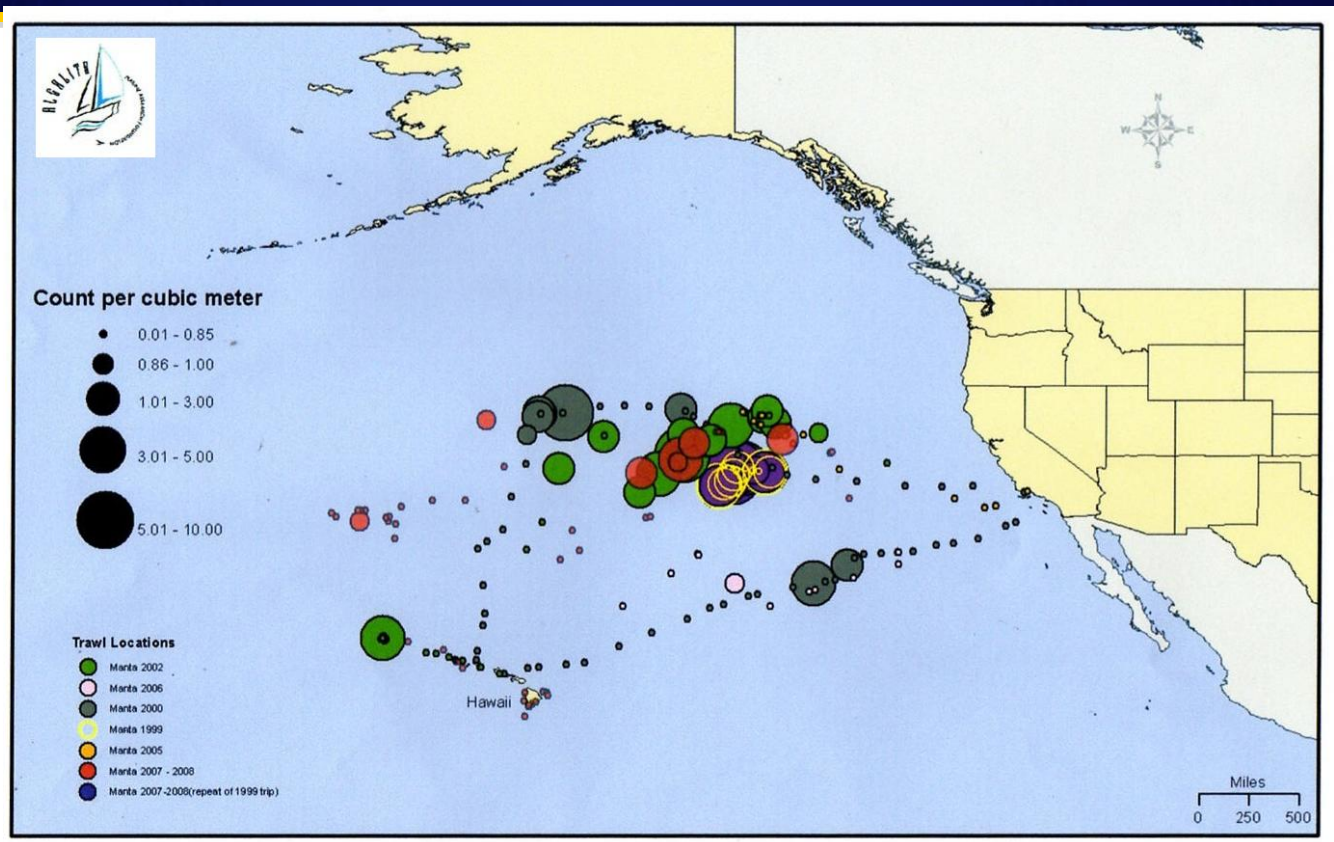
Heavy marine focus to date



North Central Pacific Gyre Plastic Pollution Study
Manta(surface) Trawls 1999 - 2008

What about microplastics in freshwater, particularly the Great Lakes?

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What about microplastics in the Great Lakes?

Plastic debris in Lake Huron accumulated on the SE shore in 2010

Article from: The Globe and Mail, Oct 14 2010

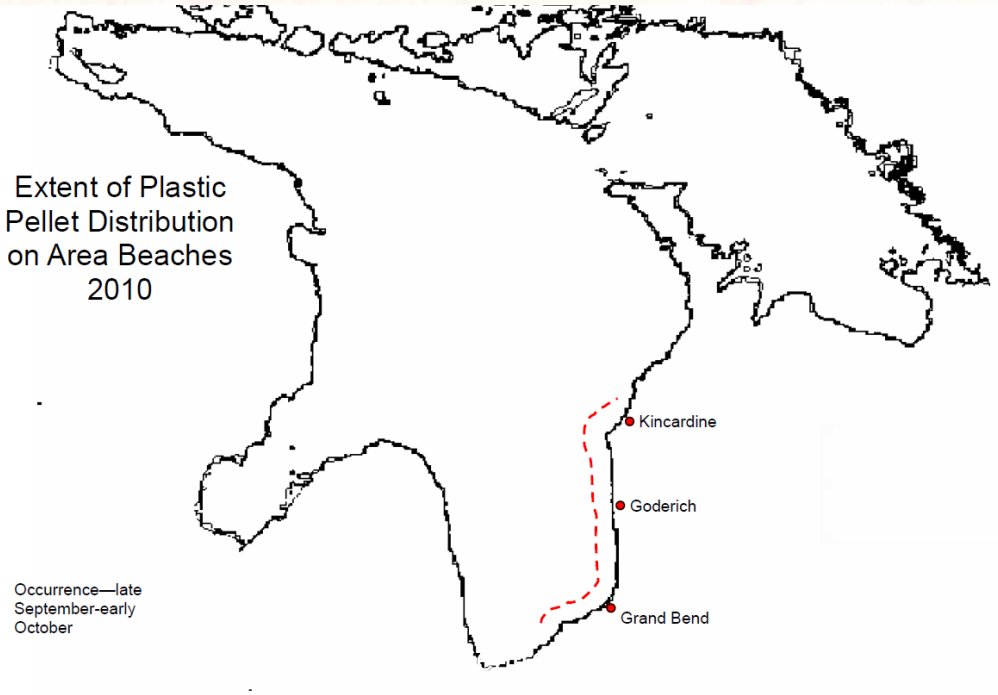
THE GLOBE AND MAIL • THURSDAY, OCTOBER 14, 2010

ENVIRONMENT

Mysterious pellets litter Lake Huron

Conservationists warn that plastic flotsam washing ashore on beaches could have deadly effect on area's marine wildlife

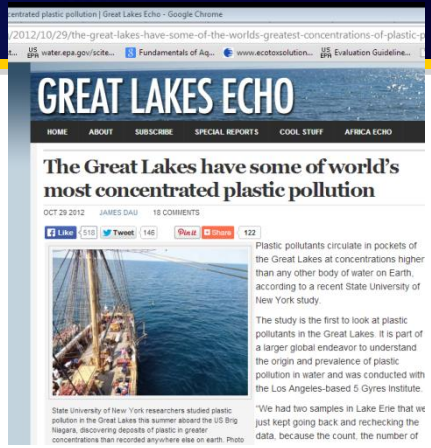
Nurdles along the SE shore of Lake Huron. Image: The Lake Huron Centre for Coastal Conservation

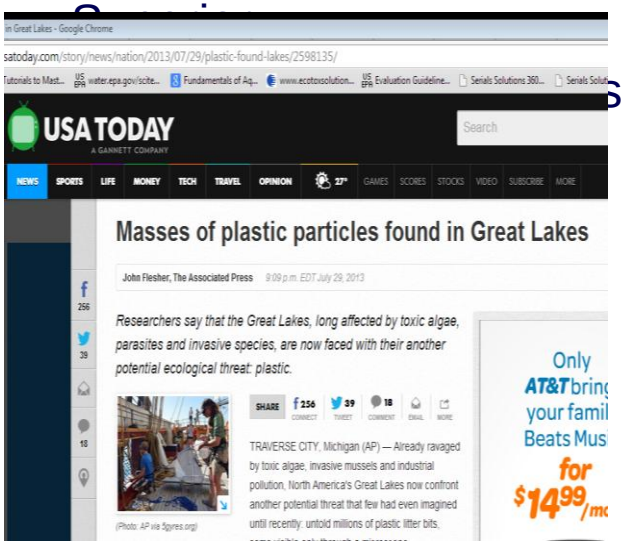


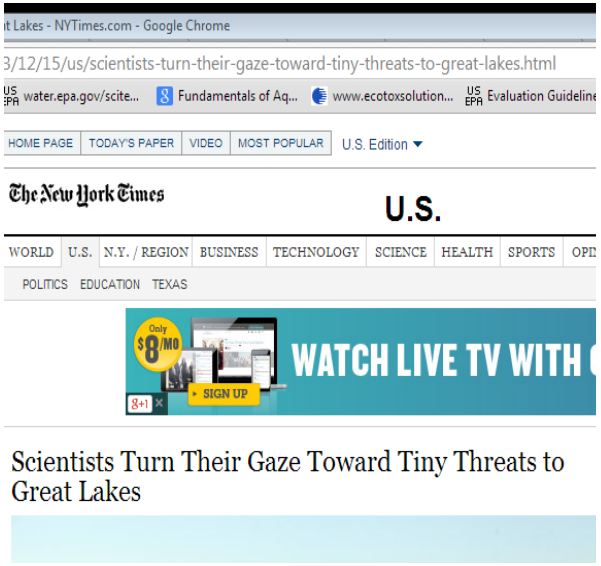
What about Plastics in the Great Lakes

- Late 2012, limited media attention on plastics in the Great Lakes
- More significant media attention in 2013-2014

5-Gyres Institute, Great Lakes and St. Lawrence Cities Initiatives, University of New York- Fredonia, UW-







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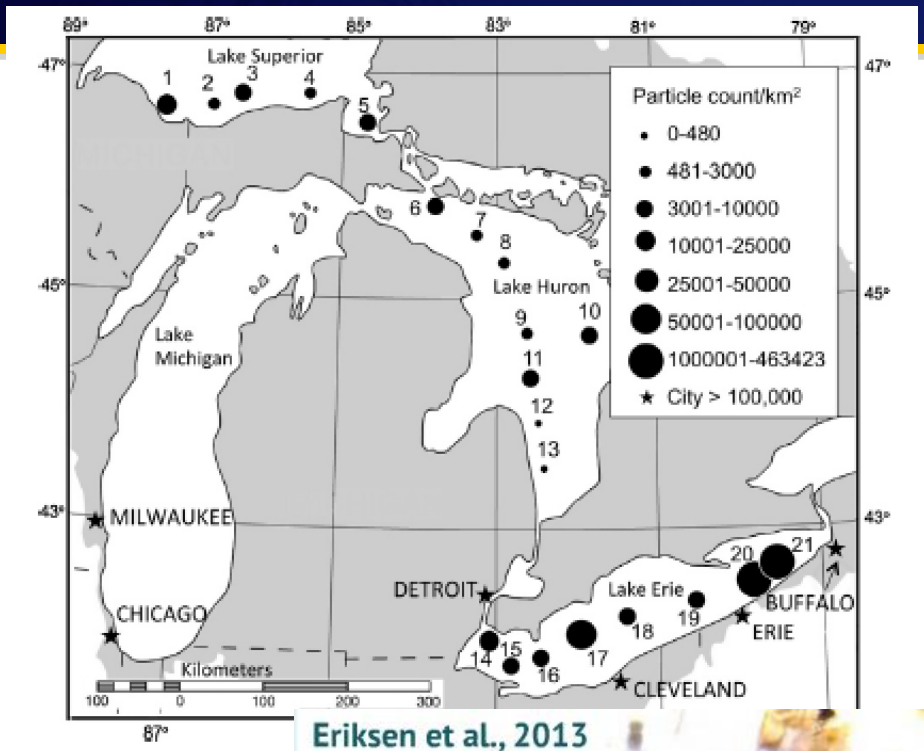
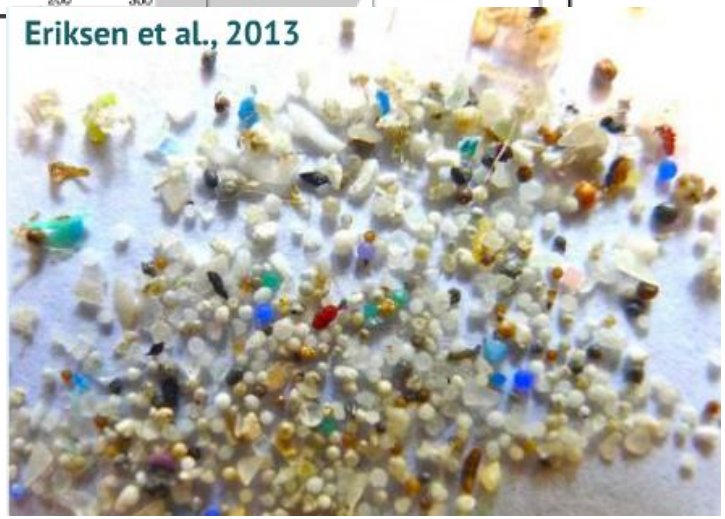
Eriksen et al. 2013 Marine Pollution Bulletin. Microplastic pollution in the surface waters of the Laurentian Great Lakes



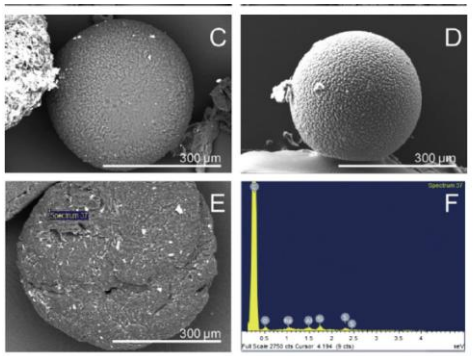


How much and where?

- Average abundance: ~43,000 microplastic particles / km^2
- L. Erie > 466,000 particles/km^2

What was there?

- Most particles 0.3 – 1 mm "pellets"
  - Microbeads, coal/coal fly ash (Al2O3, SiO2)
  - Wastewater, aeolian (point sources?)



MICROPLASTICS IN THE GREAT LAKES RESEARCH:

TOWARDS ESTABLISHING A LONG-TERM MULTI-DISCIPLINARY RESEARCH PLATFORM TO ASSES S THE IMPACT OF MICROPLASTICS ON LAURENTIAN GREAT LAKES ECOSYSTEM HEALTH

"this project takes a cross-disciplinary and multi-scale approach to help define the ecological and environmental health risks of plastics in the Great Lakes."

http://graham.umich.edu/media/files/watercenter-tier2-duhaime.pdf

UM and UW-Superior Research Team

- **Melissa Duhaime (PI)**, Ecology and Evolutionary Biology – UM
- **Zhan Chen**, Chemistry – UM
- **Krista Wigginton**, Civil & Environmental Engineering – UM
- **Dmitry Beletsky & Raisa Beletsky**, Cooperative Institute for Limnology and Ecosystems Research – UM
- **Allen Burton, Jennifer Daley, & Larissa Sano,** School of Natural Resources & Environment – UM
- **Lorena Rios Mendoza**, University of Wisconsin - Superior

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Duhaime: Characterization of microbial community on microplastics, and associated degradation dynamics

- How does polymer type alter the microbial *community*?

"Which microbes live on which plastics"

- How does polymer type affect microbial metabolism.

"What are the microbes doing?"

"Do they have novel enzymes to break down plastics?"

"Can they degrade toxics affiliated with plastics?"

- Can community structure tell us anything about the history of plastic? (age, origin?)

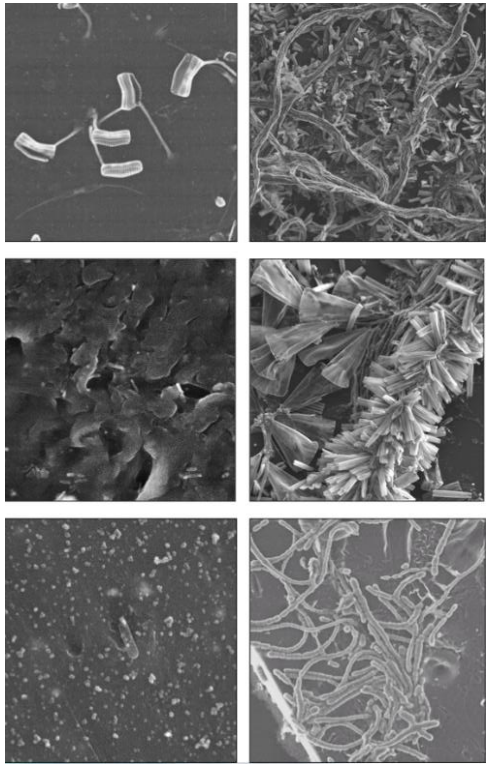

Image of biofilms: M. Duhaime

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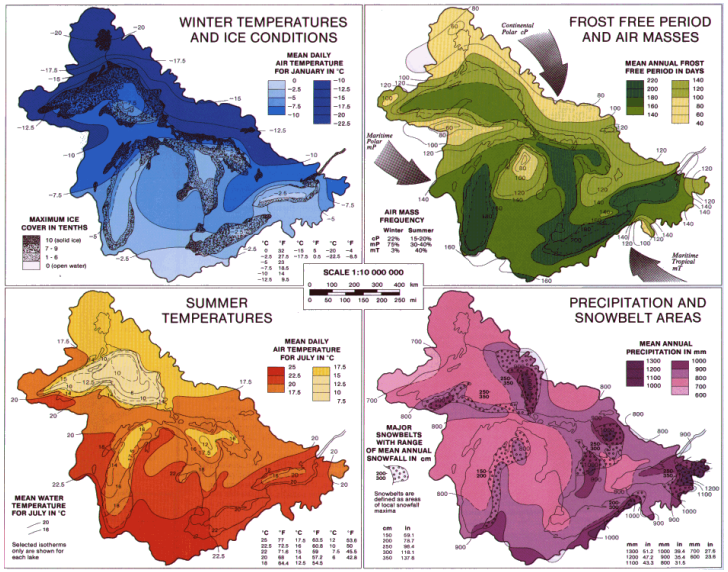
Duhaime: How specific are these communities?

Spatial – Do plastic communities differ by lakes/regions?

Seasonal - Do plastic communities differ between seasons?

Material - Do microbial biofilm communities differ by material?



Credit:Great Lakes Atlas: Climate

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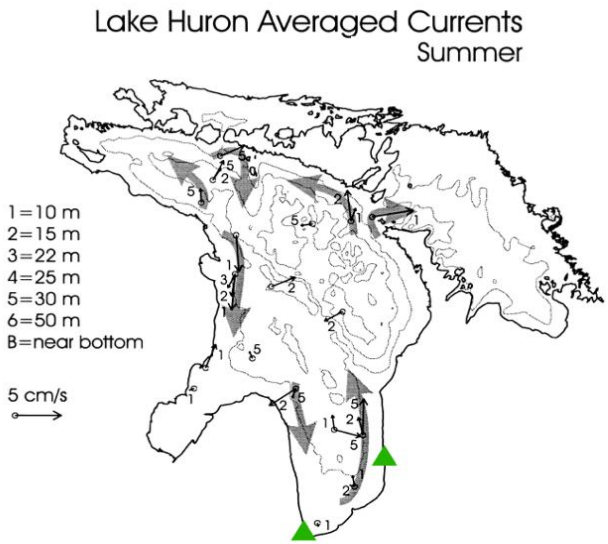
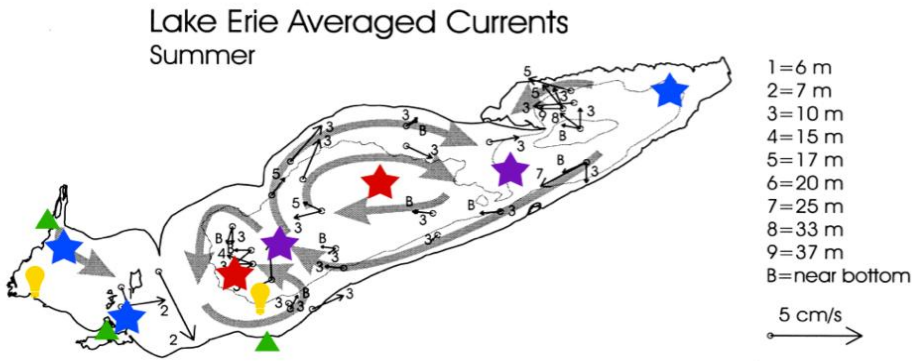
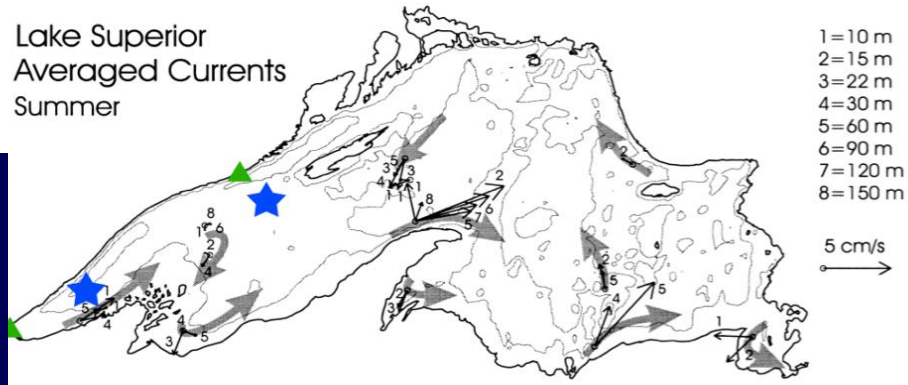
Beletsky & Beletsky: Microplastic – circulation connection

Towards Building a Laurentian Microplastic Transport Model

Can we predict plastic movement through GL systems?







Factors affecting lake circulation

- **Wind stress**
- **Bottom topography**
- **Earth's rotation**
- **Temperature gradients**
- **Tributary flow**

Image: Beletsky et al. 1999. Journal Great Lakes Research.

To connect Great Lakes currents with particle transport, we will use a particle transport model to evaluate distribution of a range of microplastic materials

- A 3-D particle transport model will be used for microplastic simulation in Lake Erie.
- Compare maps of particle locations released during different seasons
- Determine particle residence time for each source to determine its impact

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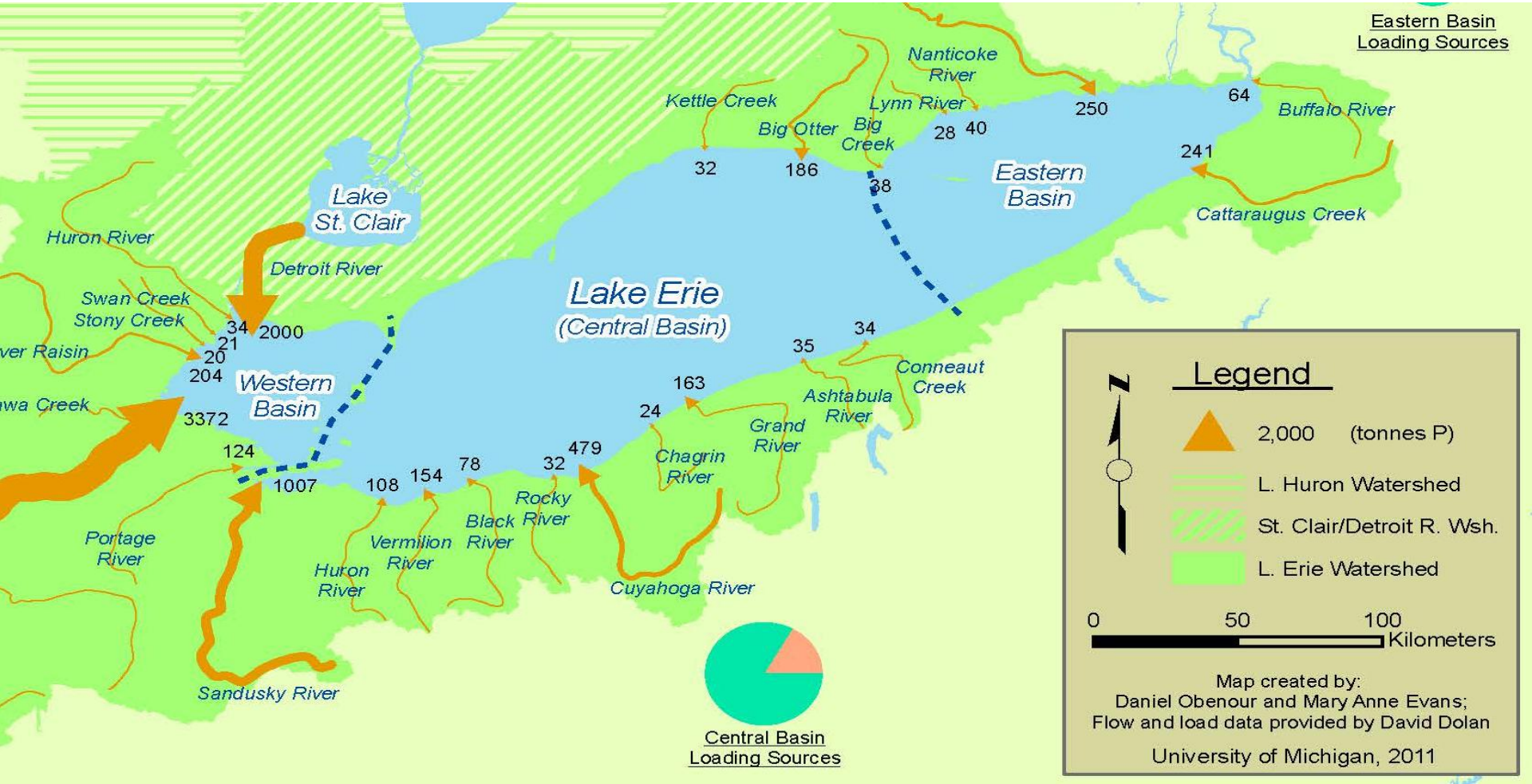
Beletsky & Beletsky: Microplastic – circulation connection

Towards Building a Laurentian Microplastic Transport Model

Why more concentrated in Erie?

More prolific point sources? Result of anticyclonic circulation in the Central Basin?



Wigginton: Characterize chemicals extracted from Great Lakes microplastics

1) Sample wastewater effluents (point sources?) for microplastics and assess the presence of emerging organic contaminants

2) Develop methods to extract nonvolatile organics from sampled microplastics and measure with qExactive Orbitrap

3) Benchscale studies with solar simulator to determine importance of direct photoxidation on organic compound transformations

Image: Thermo Fisher

Orbitrap analysis:
high sensitivity, good range, excellent resolution & accuracy, full scan & targeted methods

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Rios-Mendoza: Chemical and physical analysis of microplastic particles

- Persistent organic pollutants (POPs) have been associated with plastic marine debris (Rios-Mendoza et al., 2010)

  But we need to gain a better understanding of

  "what chemicals are present"

  "how does this compare to other environment sources of chemicals"

  "freshwater plastic debris"

- Samples: surface, thermocline and sediment

- Use various extraction techniques (e.g, Soxhlet extractor, accelerated solvent extractors) to optimize the recovery of different compound classes and analyze POPs with gas chromatography-mass spectrometry (GC-MS) and electron capture detectors (ECD)

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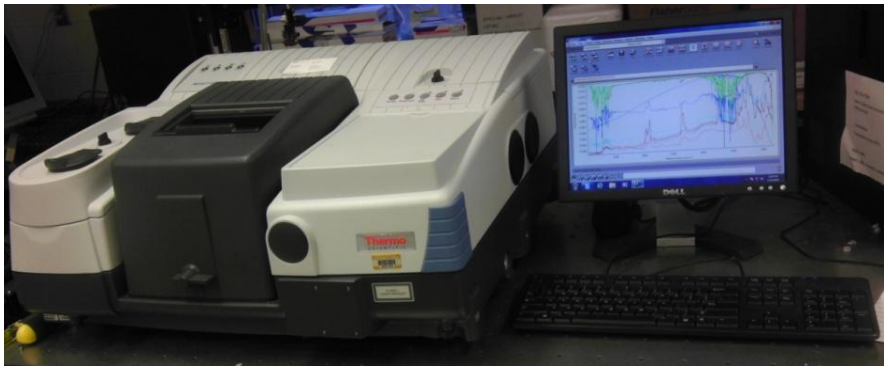
Chen: Identification of polymers using ATR-FTIR



Nicolet 6700 FTIR in use

Attenuated total reflection-Fourier transform infrared spectroscopy (ATR-FTIR)

- Determine polymer type by identifying characteristic spectral peaks
  - -Spectra library in print
  - -Comparison to known standards (original papers, government databases)

- Potentially identify unique characteristics of plastics
  - -high or low density polymer
  - -Identify specific functional groups or recognize spectral fingerprints of plastic fillers/contamination

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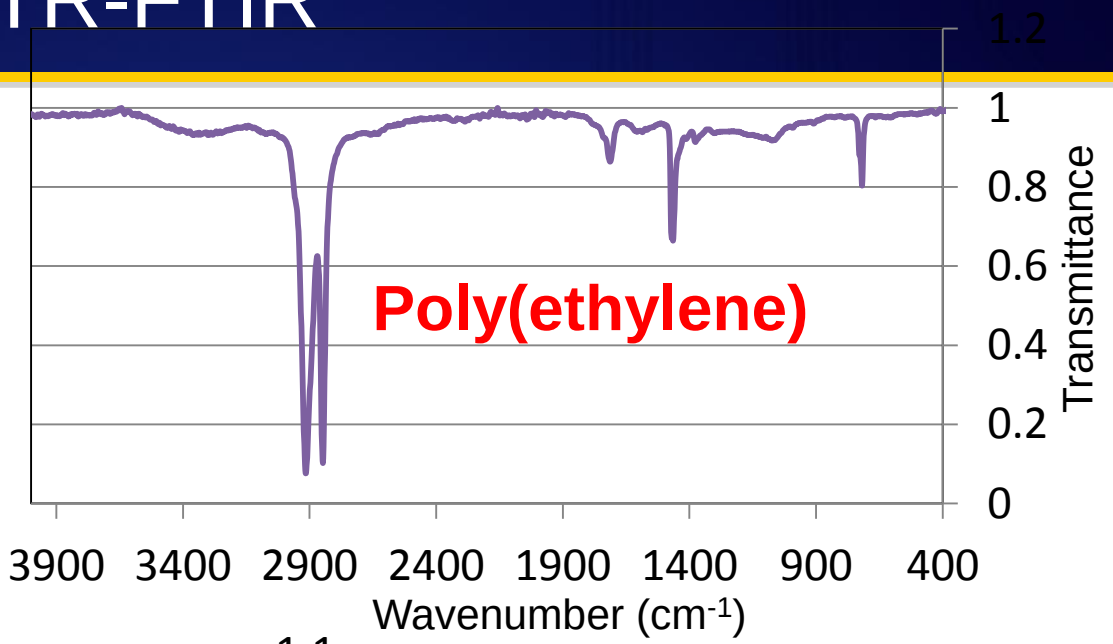
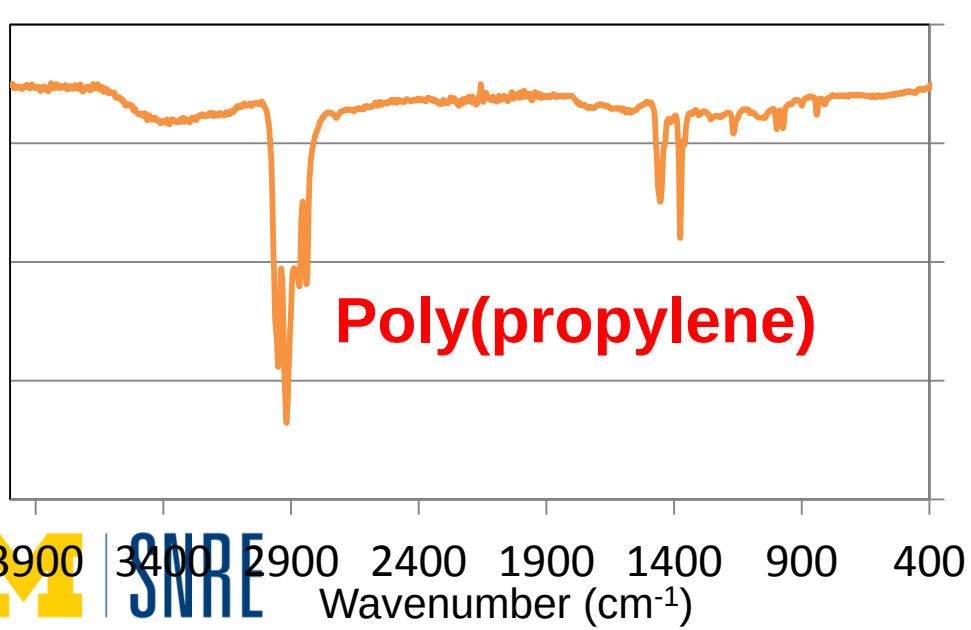
Chen: Identification of polymers using ATR-FTIR

Plastic samples collected from N. Pacific Gyre were cut into cm size pieces and analyzed directly

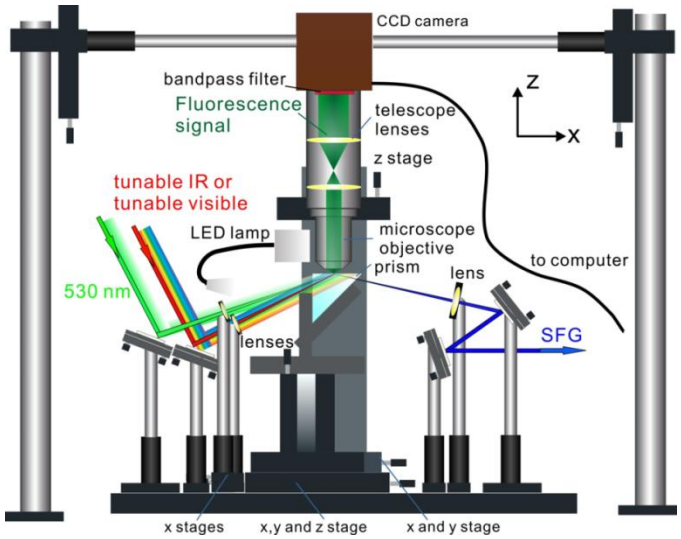




Most common polymers identified are poly(ethylene)s, poly(propylene)s, and nylons

Chen and Duhaime Group

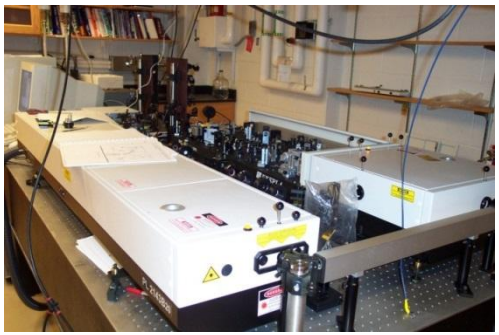
Chen: Assessment of polymer types, and changes at polymer interfaces



Use state-of-the-art Sum Frequency Generation (SFG) spectroscopy combined with optical/fluorescence microscopy

- To investigate polymer-toxin and polymer-biofilm interactions
  - Interfacial structures of polymers and proteins at the molecular level

Three SFG Systems in the Chen Group



EKSPLA, Altos

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Daley, Sano, Burton: Ecological impacts of microplastics in the Great Lakes

- What classes of organisms are most exposed to microplastics? – based on previous observations marine, freshwater
- To what degree are GL organisms exposed?
- Is plastics consumption a “real” source for increased POPs introduction to the food web?
- What are the energetic costs of plastics consumption-realistic ingested quantities of microplastics
- What are the comparative ecological risks from this exposure pathway?

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Stressor

Microplastic particles in the Great Lakes

Physical Contaminant | Chemical Contaminant

Source

Runoff/Wind
- Terrestrial

WWTP/stormwater releases

Accidential/intentional dumping

Degradation – produces secondary microplastics + additives

Exposure Media

Water - pelagic

Sediments – benthos

Receptors

Ingestion by zooplankton
-filter feeders

Ingestion by fishes
-planktivorous fishes (early life stages?)- evaluate high risk species- rainbow smelt, drum

Ingestion by benthic invertebrates
-depositional zones: downstream WWTP

Effect/ Attribute Change

Reduced survival?
Reduced growth?
Reduced reproduction?

Spread of alien species?
Biofouling?

Ecological Effects Research

- Characterize exposures to indigenous organisms based on GL microplastics and those at highest risk from exposures.

- Establish spatial/temporal variation and realistic exposures and densities (ie. Hypoxia, especially in central basin of L.Erie - field responses in mid-July to October)

- Experimental studies (lab and field mesocosms) to determine uptake rates, energetic costs and biological effects

Microplastics Research in the Great Lakes

THANKS!

"How can I help?"

Think about the plastic in your life and ***use less (or none)*** whenever you can, espcially *one time use-plastics*.
Plastic can last more than 800 years after it's made.
Are disposable items worth such a long life?

Recycling is progress, but ***not a solution***. Recycling is expensive and often paused during economic recession. Many products are shipped overseas to recycle, wasting fossil fuels. *The only solution is using less plastic.*

With every purchase, ask yourself "Is this made of plastic? Is there an alternative product? Is there plastic wrapping? Do I really need this?"

Every purchase you make is a vote for what you believe in. By changing our behavior, industries will realize that we care about our planet. You have the power to create change!

- **carry a water bottle** to re-fill, stop buying disposables! ...water from the tap is better regulated and often healthier anyway!
- **carry silverware** in your backpack or purse
- **buy food in bulk**, not individually wrapped items, then use re-usable containers to transport them
- **Avoid more than BPA**, the chemical that can leach from hard plastics 7, tin can liners, and receipt paper. Many other toxins leach from plastics: the soft, flexible form of vinyl 3 (ex: shower curtains, tubing) can leach DEHP. Foam upholstery can leach fire retardants (look for soy-based foams); a new plastic in baby bottles, PES, can leach BPA relatives.
- **use matches** or a Zippo, instead of single-use lighters
- **Avoid plastic clothing**: polyester, nylons, micro-fibers, Fleece are all plastic!
  Don't forget natural,
  old fashion wool.

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