Reducing Plastic Pollution with Better Products and Policies

EPA Trash-Free Waters Webinar Series
August 29, 2017

Jason McDevitt
jpmcde@wm.edu

WILLIAM & MARY
CHARTERED 1693

I am not an environmental researcher

- PhD chemist by training
- Worked in R&D
  - Chemical industry
  - Biotech
  - Consumer Products
- Entrepreneur (biotech, consumer goods)
- Licensed to practice patent law for nearly 20 years

WILLIAM & MARY

VIMS

VIRGINIA INSTITUTE OF MARINE SCIENCE

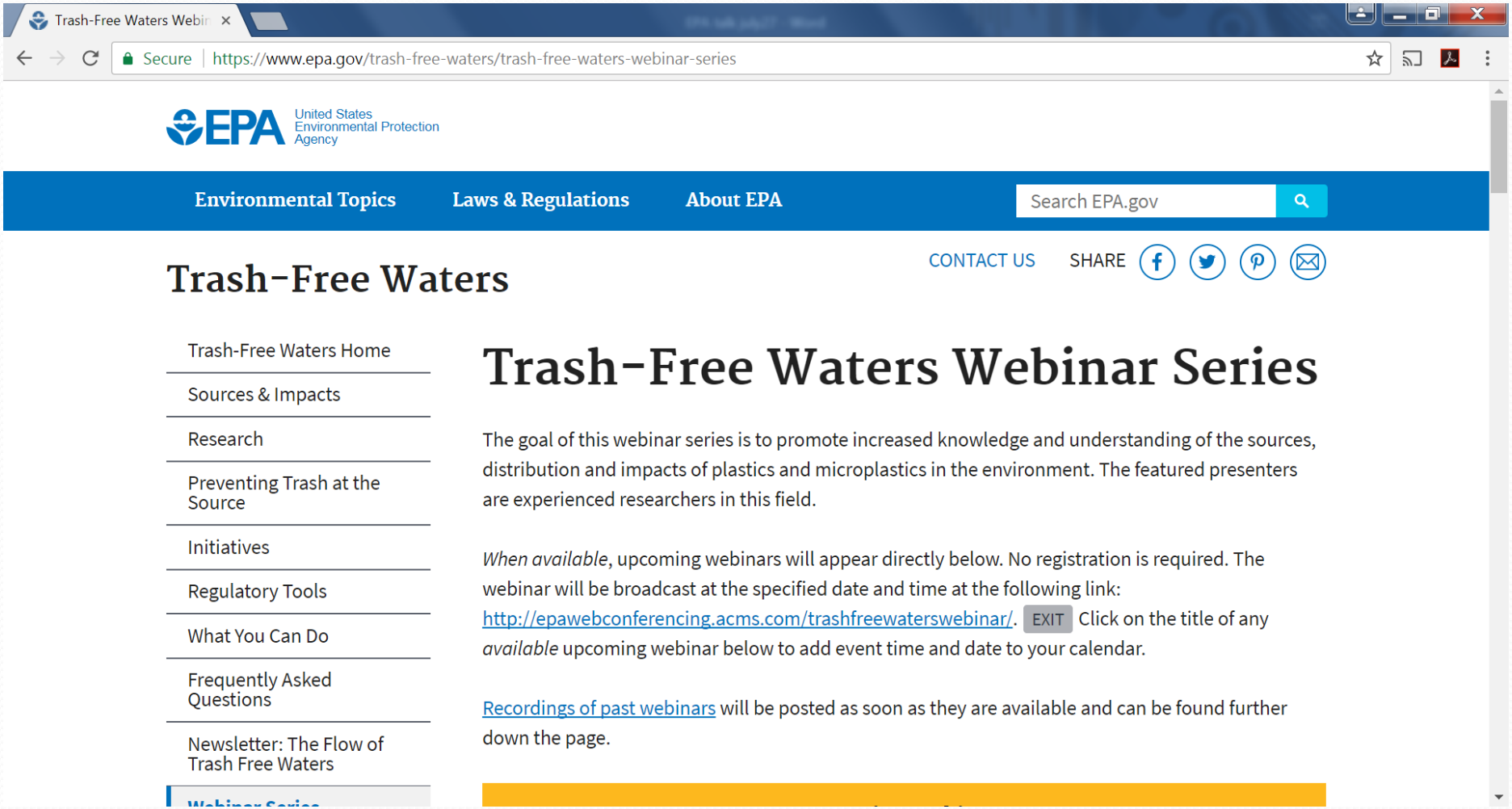
SCHOOL OF MARINE SCIENCE

(Center for Coastal Resources Management)

Kory Angstadt
Donna Bilkovic
Kirk Havens
David Stanhope

WILLIAM & MARY

CHARTERED 1693



WILLIAM & MARY
CHARTERED 1693

Today's Talk: Two Stipulations

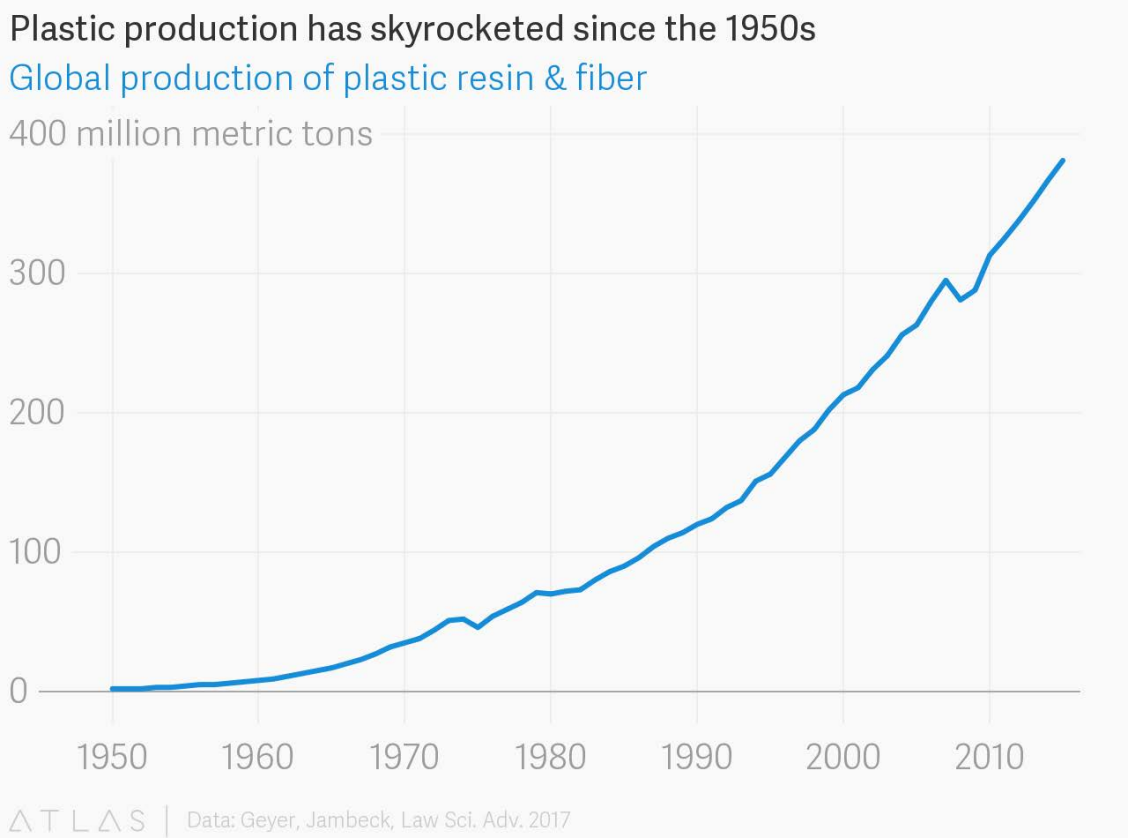
- Plastic pollution is a serious problem, including in aquatic environments, and it should be addressed
- Reduce, reuse, recycle

Why do we have so much plastic trash in our waters?

1. We produce and use a huge amount of plastic (roughly 600 billion pounds per year)
   - Use less plastic
2. Much of it is not properly disposed
   - Better waste management systems with appropriate incentives/punishments
3. Once it is in aquatic environments, it tends not to break down into chemicals that are taken up in the natural carbon cycle
   - Use degradable polymers

Relative to price, plastics provide a lot of benefits

- Inexpensive ($0.50 - $1.50 for commodity plastics)
- Light
- Relatively inert
- Easily molded into any shape
- Barrier properties
- Huge variety of performance attributes



WILLIAM & MARY
CHARTERED 1693

Plastics are artificially cheap – the full costs of plastics are often not reflected in pricing

- Environmental costs associated with both production and disposal
- Neither plastic producers nor processors nor retailers nor consumers pay the true costs

Some Underaccounted-For Costs of Plastics

- Production Side (front-end)
  - Pollution associated with production
  - Destruction of environment and habitat
- Disposal Side (back-end)
  - Plastic debris can injure or kill wildlife by ingestion or entanglement
  - Plastic debris can leach harmful chemicals (e.g., stabilizers, plasticizers)
  - Plastic debris can sorb toxins that are then ingested and propagated up the food chain
  - Floating plastic debris can serve as transportation for invasive species
  - Environmental costs of landfilling or shipping waste

WILLIAM & MARY
CHARTERED 1693

Example: Plastic Grocery Bags

- Cost about 1 cent to produce
- Sell to grocers for a little less than 2 cents
- Consumers get them for free
- Incredible technological achievement to produce them for a penny
- Who pays for this mess?

Subsidized by the planet!

www.leesburgva.gov

WILLIAM & MARY
CHARTERED 1693

Restrictions on Plastic Bags

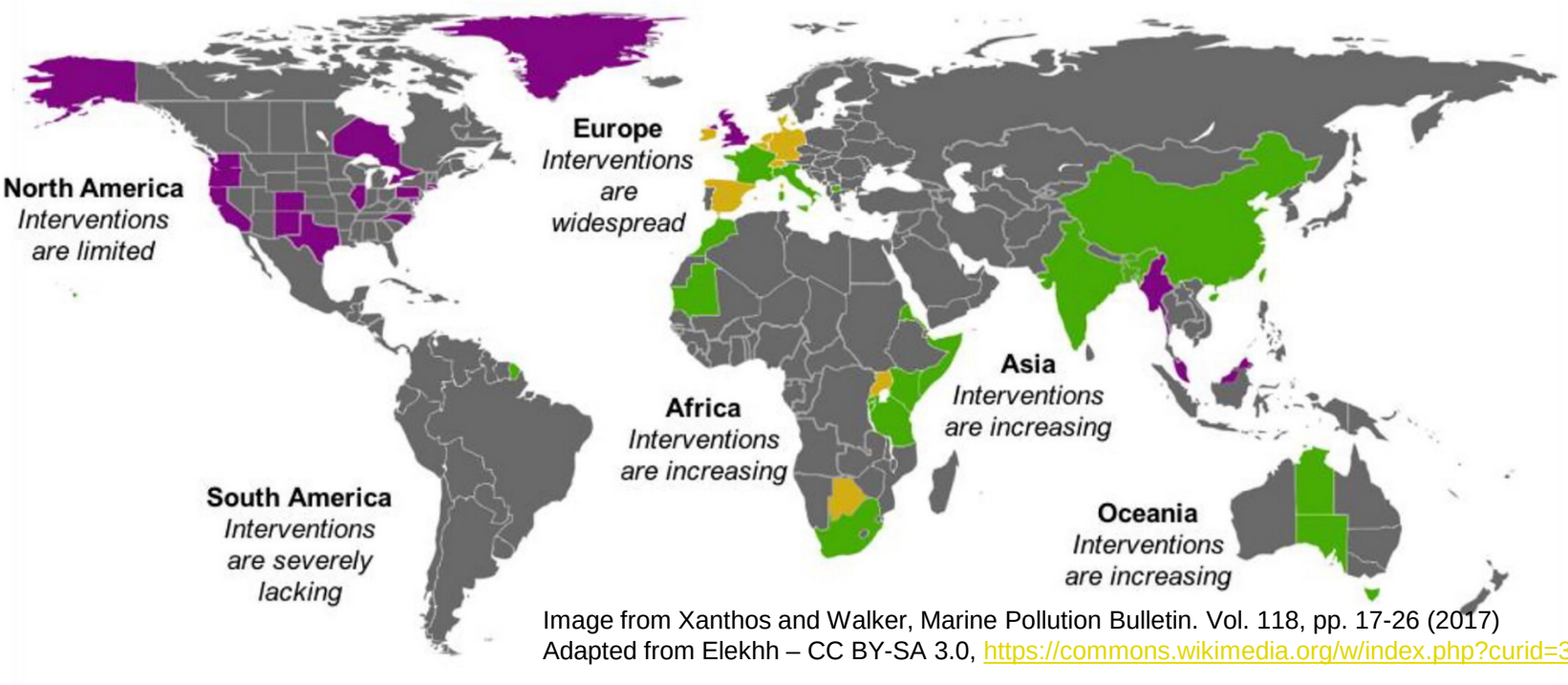


Image from Xanthos and Walker, Marine Pollution Bulletin. Vol. 118, pp. 17-26 (2017)
Adapted from Elekhh – CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=32400659

- Plastic bags banned
- Taxes on some plastic bags
- Partial tax or ban (municipal or regional levels)

WILLIAM & MARY
CHARTERED 1693

Unaccounted-for Costs Complicate Market-Based Solutions and Policy-Based Solutions

WILLIAM & MARY

CHARTERED 1693

Reasons for Optimism

- Product Development:
  - More bioplastics being produced, both type and scale
  - Interventions at other points (e.g., containment)
  - Circular design principles (Ellen MacArthur Foundation)
    - (https://www.ellenmacarthurfoundation.org/circular-economy)
- Policy Development: More regulation and legislation (e.g., microbeads, bags, cutlery)
- Behavioral Development: Awareness of the issue from industry and consumers with desire to be environmentally responsible citizens.

Extinction Learning

- I previously founded a company to develop a drug for treatment of anxiety disorders, addiction, and related conditions
- Our drug facilitated a process called extinction learning, and the drug was given in conjunction with talk therapy to consolidate learning during therapy
- Extinction learning is key to treatment of anxiety disorders

Extinction Learning (Pavlov)

1. Pair bell (conditioned stimulus) with food (unconditioned stimulus)
2. Dog learns to salivate at sound of bell
3. Remove the food, keep ringing the bell
4. Eventually, dog stops salivating (extinction)

Extinction learning is focus of exposure therapy for treatment of anxiety disorders

- Conditions such as PTSD, OCD, social anxiety disorder, panic, and simple phobia
- Patients have deleterious, high-anxiety responses to relatively benign situations
  - Consider a patient with fear of heights driving over a bridge
- Goal is to replace high-anxiety response with a more appropriate, learned response

Extinction learning as it relates to plastic pollution

Traditional:

Stimulus: plastic pollution → *Response:* no big deal

Replace with:

Stimulus: plastic pollution → *Response:* BIG PROBLEM

Inverse of exposure therapy for treatment of anxiety disorders, where you want to replace a high-anxiety response with a low-anxiety response

To get to trash-free waters, behavioral change is the most important change, because it guarantees changes in policies and products.

"*Courage is rightly considered the foremost of the virtues, for upon it all others depend*" - *Churchill*

- Great to see NOAA making behavioral change such a priority, see Krista Stegemann's webinar in this Trash-Free Waters series

WILLIAM & MARY
CHARTERED 1693

Ad from 1971

WILLIAM & MARY
CHARTERED 1693

Small groups and individuals can have a huge impact in promoting desired behavioral changes

- Plastic microbeads in cosmetics
- Five Gyres and other groups:
  - convinced consumer products companies to pledge to stop using plastic microbeads
  - initiated legislation in states
  - led to federal legislation in U.S., and now other countries

Product/Policy Development Targets

Non-toxic, biodegradable plastic

Capture waste more efficiently

Plastic

Products

Aquatic Plastic Pollution

Don’t use plastic at all

Use less plastic

Reduce waste generation

Clean-up waste

WILLIAM & MARY
CHARTERED 1693

Synthetic Microfibers: Intervention Possibilities

(http://storyofstuff.org/movies/story-of-microfibers/)

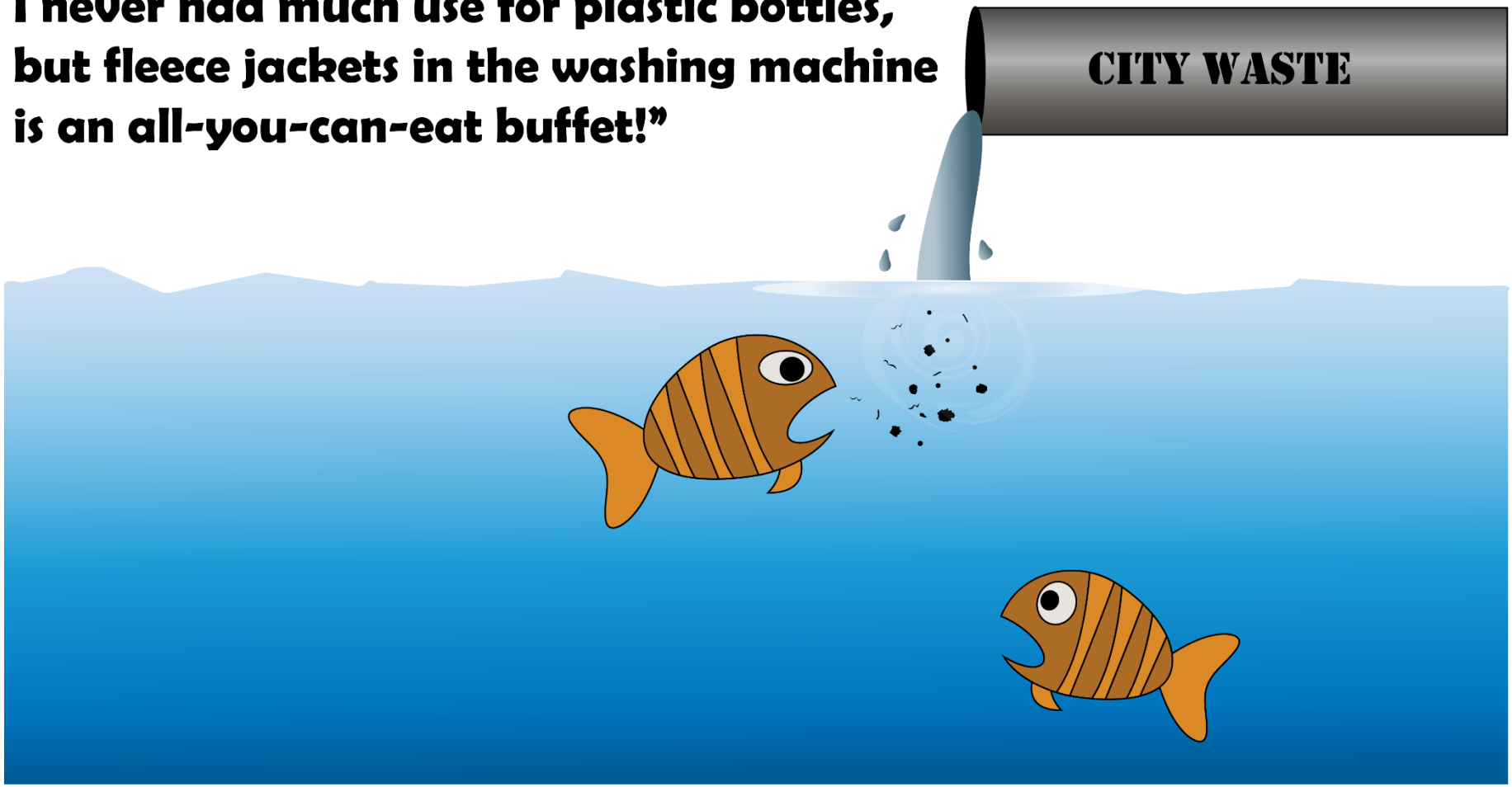
Plastic

Products (Textiles)

Aquatic Plastic Pollution
(microfibers are in there!)

WILLIAM & MARY
CHARTERED 1693

“This Microfiber Distribution Technology is great - I never had much use for plastic bottles, but fleece jackets in the washing machine is an all-you-can-eat buffet!”



WILLIAM & MARY
CHARTERED 1693

Synthetic Microfibers: Intervention Possibilities

(http://storyofstuff.org/movies/story-of-microfibers/)

Non-toxic bioplastics

Plastic

Reduce fiber breaking, gentler wash cycle

Products (Textiles)

Better filters at wastewater treatment facility

Aquatic Plastic Pollution
(microfibers are in there!)

Forget synthetics: use natural fibers (e.g., wool, cotton, silk)

Same composition, change fibers (thicker, coated, etc.)

Capture fibers in or exiting washing machine

Clean-up waste

WILLIAM & MARY
CHARTERED 1693

Product Development Targets

Non-toxic, biodegradable plastic

Capture waste more efficiently

Plastic

Products

Aquatic Plastic Pollution

Don’t use plastic at all

Use less plastic

Reduce waste generation

Clean-up waste

WILLIAM & MARY
CHARTERED 1693

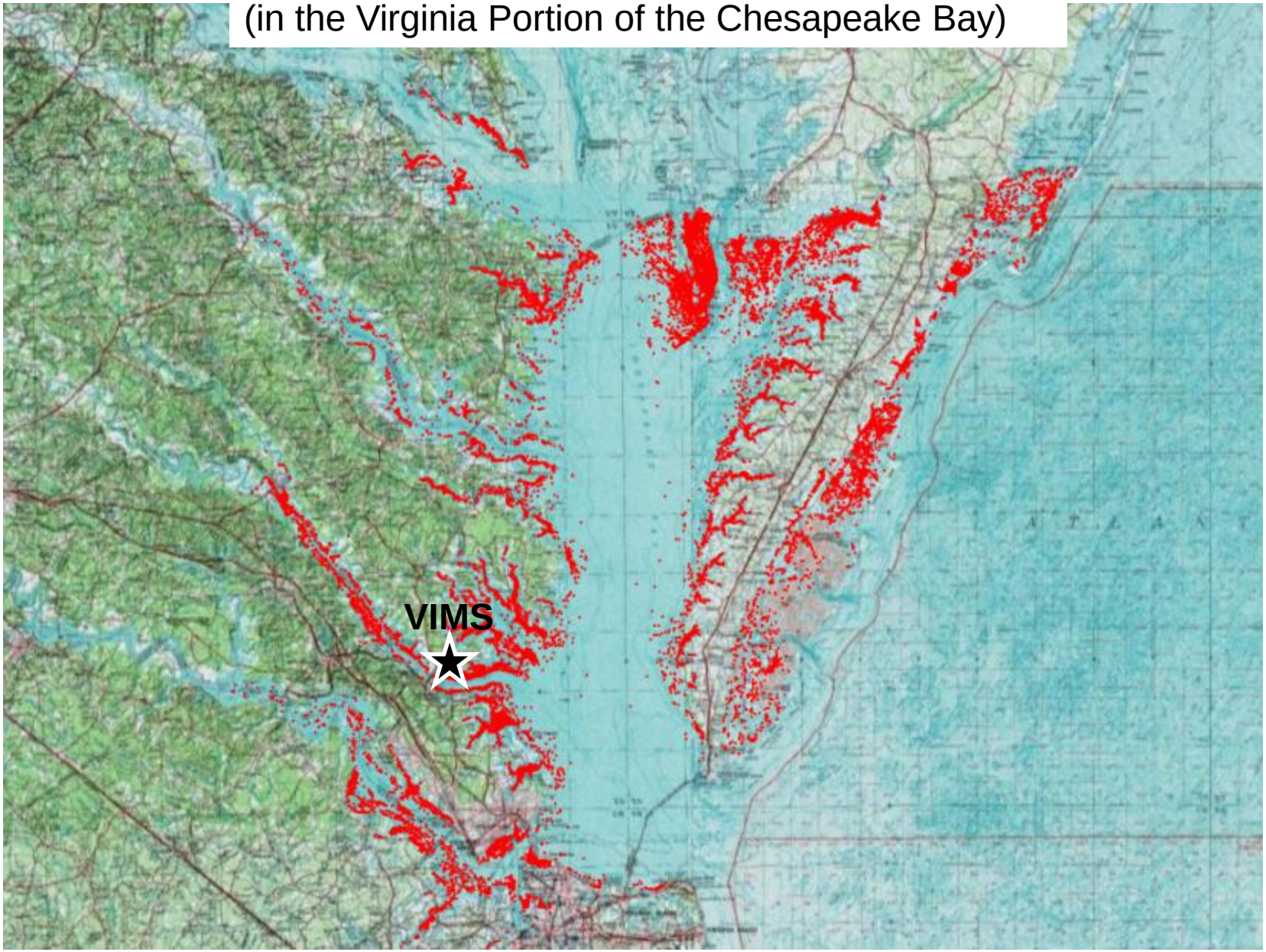
Ghost Fishing

Photo by CCRM/VIMS

http://www.vims.edu/research/topics/blue_crabs/ts_archive/ghost_pot_watermen.php

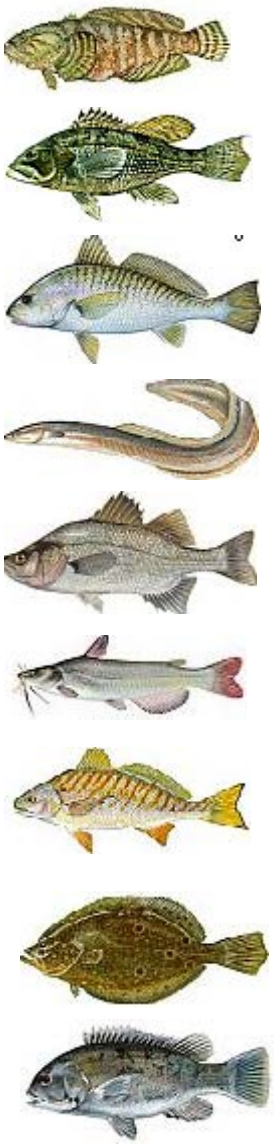
WILLIAM & MARY
CHARTERED 1693

Locations of Derelict Crab Traps Removed (in the Virginia Portion of the Chesapeake Bay)



Derelict traps keep fishing

Fish Catch in Derelict Pots



FISH - Bycatch	ABUNDANCE	% of TOTAL	Cumulative %
OYSTER TOADFISH	3348	66.8	66.8
BLACK SEABASS	415	8.3	75.1
ATLANTIC CROAKER	313	6.2	81.3
AMERICAN EEL	184	3.7	85.0
WHITE PERCH	174	3.5	88.5
CATFISH SPP	171	3.4	91.9
SPOT	93	1.9	93.7
FLOUNDER	52	1.0	94.8
TAUTOG	52	1.0	95.8
MINNOW	47	0.9	96.7
UNKNOWN FISH	43	0.9	97.6
SHEEPSHEAD	29	0.6	98.2
STRIPED BASS	24	0.5	98.7
PIGFISH	19	0.4	99.0
ATLANTIC SPADEFISH	6	0.1	99.2
REDDRUM	6	0.1	99.3
STARGAZER	5	0.1	99.4
MULLET	4	0.1	99.5
PUFFERFISH	4	0.1	99.5
BUTTERFISH	3	0.1	99.6
ATLANTIC MENHADEN	2	0.0	99.6
HOGCHOKER	2	0.0	99.7
BLACK DRUM	2	0.0	99.7
SOLE	2	0.0	99.8
STRIPED BURRFISH	2	0.0	99.8
BOWFIN	1	0.0	99.8
CUNNER	1	0.0	99.8
PORGY SPP	1	0.0	99.9
SCUP	1	0.0	99.9
BLUEFISH	1	0.0	99.9
FEATHER BLENNY	1	0.0	99.9
PINFISH	1	0.0	99.9
SHAD	1	0.0	100.0
SPADEFISH	1	0.0	100.0
STRIPED KILLIFISH	1	0.0	100.0

9 species groups made up >95% of catch

Oyster toadfish
Black Sea Bass
Atlantic croaker
America eel
White perch
Catfish
Spot
Flounder
Tautog

5,112 total fish *during winter*

Photo credit: Randy Chambers

Photo credit:
Grosse et al., 2009

WILLIAM & MARY
CHARTERED 1693

In addition to being an environmental hazard, derelict traps deplete fisheries

- 12%-20% of traps become abandoned annually
- Traps kill nearly 5% of the annual harvested catch of crabs, and kill many more fish than crabs
- Large economic impact

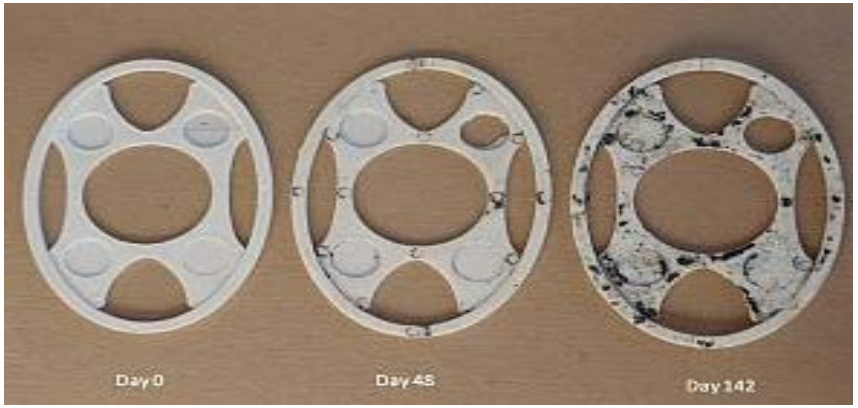
Scheld, A. M. *et al.* The Dilemma of Derelict Gear. *Sci. Rep.* **6**, 19671; doi: 10.1038/srep19671 (2016)

Bilkovic, D. *et al*. Ecological and Economic Effects of Derelict Fishing Gear in the Chesapeake Bay 2015/2016 Final Assessment Report (2016)

Solution: Biodegradable Panel

- Biochemical Solution: Escape panel made from a PHA formulation

- PHA (polyhydroxyalkanoate)
  - natural class of biopolymers
  - energy storage for bacteria
  - biodegrades on land and at sea

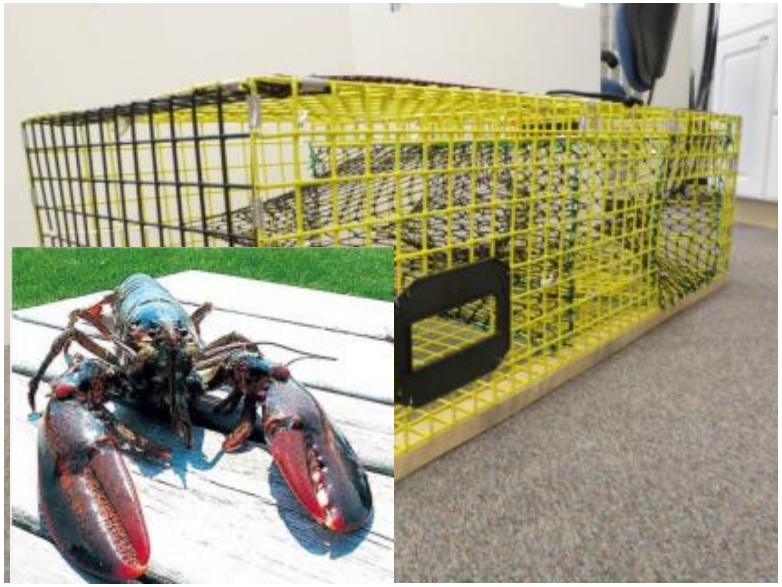


R&D funded by NOAA, NFWF, and Virginia CRCF Program

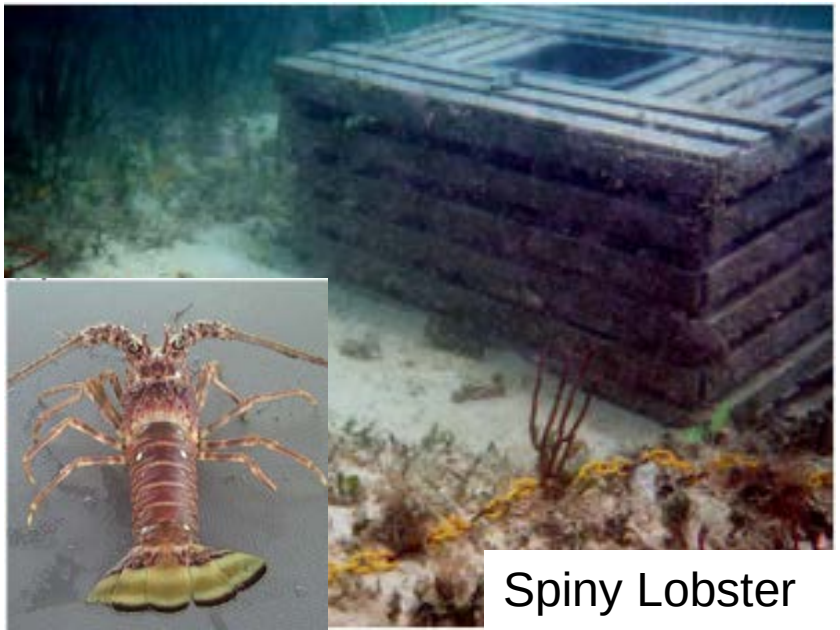
WILLIAM & MARY
CHARTERED 1693

Dungeness Crab

American Lobster



Stone Crab



Spiny Lobster

www.mobjackbp.org

Welcome

Mobjack Binnacle Products, LLC specializes in developing innovative ideas into products for the marketplace. Mobjack's primary focus is the manufacturing and distribution of specialized products for individual or commercial use.

Our targeted market segment is retailers who carry specific environmentally friendly products for, but not limited to, watermen, hunters, commercial and individual fishermen, outdoorsmen, and those who recreate outdoors. Mobjack strives to provide products that enhance the outdoor experience while

Our Mission

Mobjack uses state of the art, environmentally responsible materials to produce high quality products that support a sustainable environment for professionals and outdoor enthusiasts.

MORE

Our Products

Mobjack's products are a fail safe against lost crab, lobster and fish traps (known as "ghost pots" or "ghost fishers"). Our products use our patented technology to prevent traps from continuing to catch and kill marine life. Mobjack products degrade completely into naturally occurring, environmentally friendly microbes. Our products address the ghost pots issue that depletes marine resources.

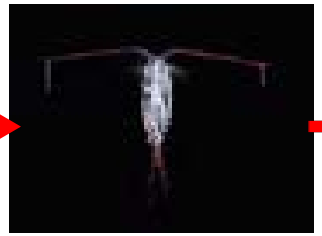
MORE

Plastic microbeads are great for cosmetics, but bad for the environment

WILLIAM & MARY
CHARTERED 1693

Microplastics, and the toxins they adsorb, propagate through the food chain

Microplastics



Zooplankton

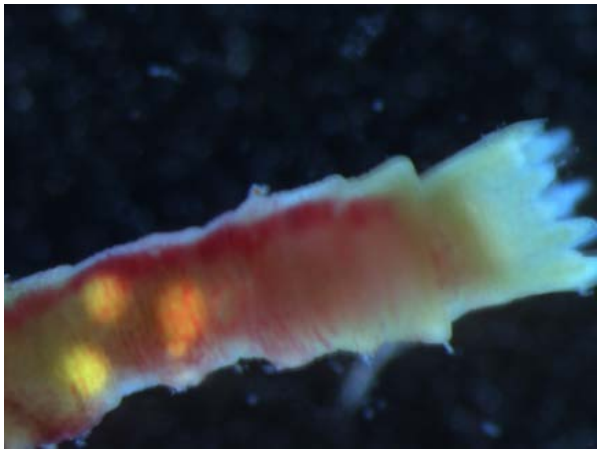
Mussels

Blue Crab

Shore birds

Turtle

Striped Bass



Labeled microbeads taken up by benthic worm.

WILLIAM & MARY
CHARTERED 1693

Proposed Solution:
PHA Microbeads for Cosmetics

- Drop-in Replacement for Conventional Plastic Microbeads
- Typical loading: 2% of product
- Minimal impact on cost of goods
- Most major personal care products companies voluntarily agreed to phase out conventional plastic microbeads
- Legislation ended up banning all plastic microbeads (which ended our attempts to develop PHA microbeads)

WILLIAM & MARY
CHARTERED 1693

R&D funded by Virginia Innovation Partnership

Shotgun Ammunition with Biodegradable Wads

Image by Kirk Havens

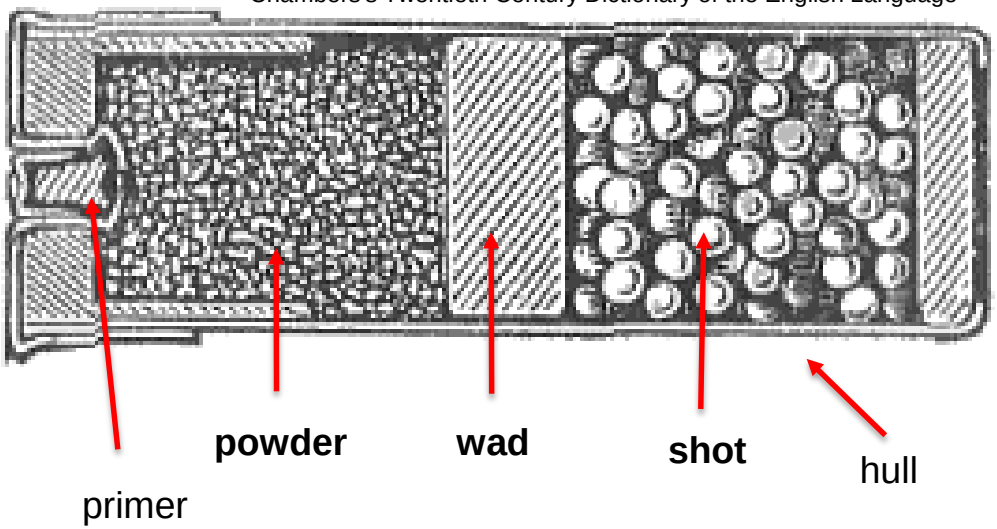
R&D funded by Virginia CRCF Program

WILLIAM & MARY
CHARTERED 1693

A wad is a critical component of a shotgun shell

- Separates charge from powder
- Protects the barrel from shot
- Obturates to provide gas seal
- Can improve shot patterns

Rev. Thomas Davidson 1856-1923 (*ed.*) – illustration from Chambers's Twentieth Century Dictionary of the English Language



WILLIAM & MARY
CHARTERED 1693

Why are wads littered?

- Case (hull) is discharged next to the gun and picked up
- Wad typically travels downfield 20 – 40 yards, not collected

U.S. Navy Photo by Photographer's Mate Second Class Chantel M. Clayton

Video Link: https://www.youtube.com/watch?v=hgVCOA4g2DA

WILLIAM & MARY
CHARTERED 1693

Project Hotspot: New Zealand students found shotgun wads all over pristine beaches

Images courtesy of Emily Roberts

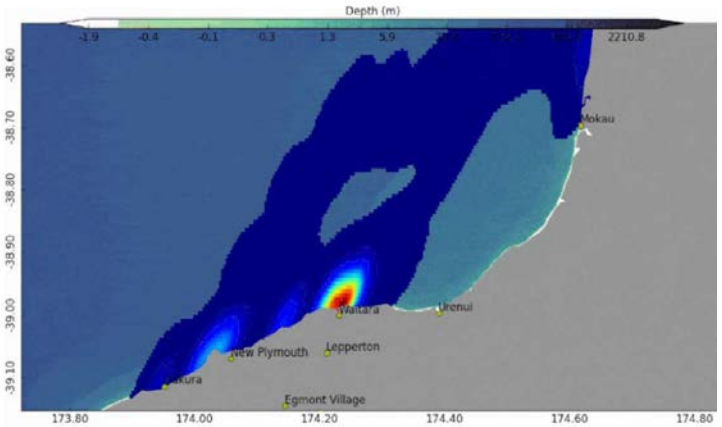


Image by MetOcean Solutions
http://www.metocean.co.nz/news/2016/10/31/4f6qyojptsgspegisbe2qf0nq762ur

- Wads migrated from inland shooting range to mouth of Waitara River and then north and south along coast
- Gun club switched to biodegradable wads
- Thanks to Emily Roberts (Project Hotspot), Allen Stancliff (NZ Fish and Game), MetOcean Solutions, & Inglewood Rod and Gun Club

WILLIAM & MARY
CHARTERED 1693

Whatungarongaro te tangata, Toitū te whenua

Solution: Novel Design with Biodegradable Polymer

- We wanted a drop-in replacement, but no bioplastics worked well
- Revolutionary design to make high-performance ammo with biodegradable, nontoxic plastic
- Our wad fractures soon after exiting barrel, before hitting ground
  - less visual pollution
  - faster degradation
  - Cleaner release provides better patterns
- Commercial launch 1Q 2018

www.greenopsammo.com

Video Link: https://youtu.be/mcwf1esIjeo

WILLIAM & MARY
CHARTERED 1693

Better Policies

WILLIAM & MARY

CHARTERED 1693

Caveat: Well-intended government regulation does not always yield societally beneficial results

- Flame Retardants (http://greensciencepolicy.org/topics/furniture/)
  - California TB 117 (1975) – regulation in California requiring flame retardants in furniture foam
  - Manufacturers added flame retardants to furniture all over US
  - Little if any real benefit in the event of a fire
  - Highly toxic additives (e.g., PentaBDE) are not bound to foam and become part of airborne dust
  - Found in over 80% of US couches
  - California enacted updated standard in 2014 (39 years later)
- Fuel ethanol standard

Plastic legislation/regulations

- Cosmetic microbeads
- Grocery bags
- Disposable cutlery
- Packaging
- Single-use plastics

Microbeads Legislation - Rationale

- Plastic microbeads are widely used in cosmetics
- Products are rinsed off, and microbeads are often not captured by wastewater treatment facilities
- Microplastics persist and are an environmental hazard
- Drop-in replacements available w/o significant cost/performance downside
- Do we really need to be using polyethylene microbeads???

Desired Law:

(1) ban plastic microbeads in cosmetic products

(2) exempt plastic microbeads that don't harm the environment

Microbeads Legislation – Illinois (loopholes)

- *"Effective December 31, 2017, no person shall manufacture for sale a personal care product, except for an over the counter drug, that contains synthetic plastic microbeads as defined in this Section."*
- *"Plastic" means a synthetic material made from linking monomers through a chemical reaction to create an organic polymer chain that can be molded or extruded at high heat into various solid forms retaining their defined shapes during life cycle and after disposal.*
- *"Synthetic plastic microbead" means any intentionally added non-biodegradable solid plastic particle measured less than 5 millimeters in size and is used to exfoliate or cleanse in a rinse-off product*

- No definition for biodegradable – everything is biodegradable on geologic time scale
- Flawed definition of plastic, e.g., cellulose acetate (polymer in cigarette filter tow) would not qualify

ULTIMATE OUTCOME: Flawed Legislation

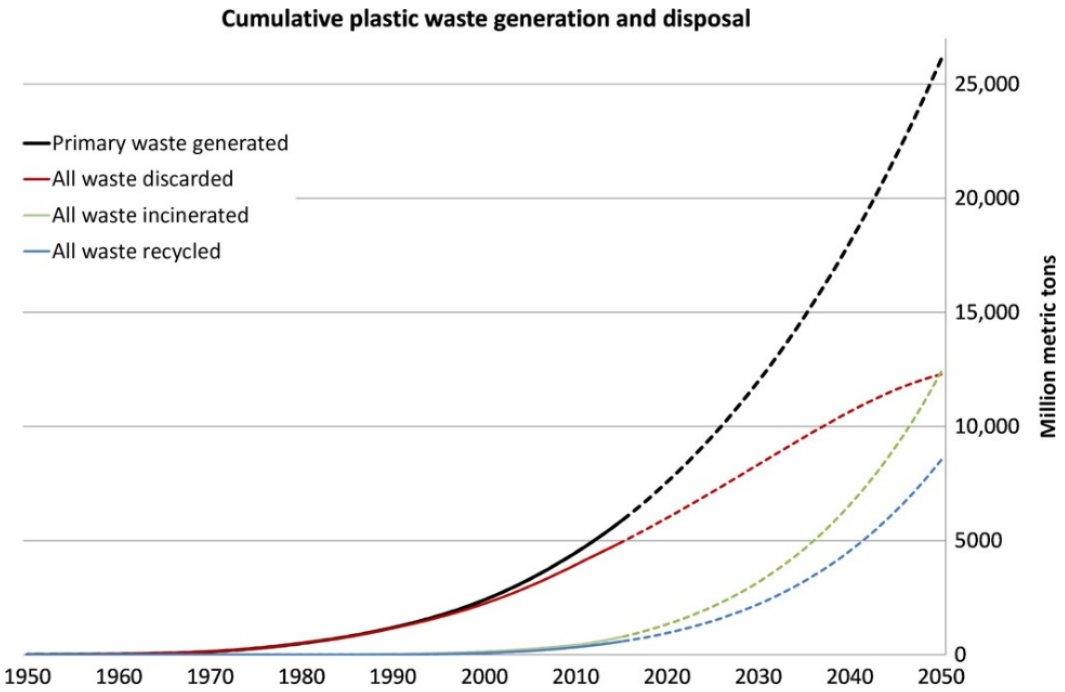
Cause: Inability to agree on language distinguishing plastics that are environmentally harmful from those that are benign

- To avoid loopholes, California bill (and subsequent federal bill) banned all plastic microbeads in rinse-off cosmetic products
- Inability to use microbeads from bioplastics in cosmetics – no big deal
- As a template for other legislation – Big Problem

WILLIAM & MARY
CHARTERED 1693

Why is this so important?

- Plastic waste being generated keeps increasing
- 60% of all plastics ever produced are accumulating in landfills or in natural environment
- Less than 10% of plastics are recycled
- Reduce/reuse/recycle is great, but not THE solution.
- Two possible solutions:
  - Revolutionize waste management
  - Revolutionize/Replace plastics



ROLAND GEYER, JENNA R. JAMBECK, KARA LAVENDER LAW
SCIENCE ADVANCES 19 JUL 2017 : E1700782

WILLIAM & MARY
CHARTERED 1693

Plastic is the problem, but better plastic is the solution

- Long-term goal: plastics that become good compost
- Policy-makers and advocates should keep long-term goal in mind
- Unfortunately, translating this goal into policies is complex
  - Not all plastics are equal
  - Not all bioplastics are equal
  - Not all formulations with the same plastic are equal
- We need policies that don't treat all plastics the same

WILLIAM & MARY
CHARTERED 1693

Environmentally Responsible Plastic???

- Biodegradability?
  - How fast? To what extent?
  - What about oxo-degradability, or photo-degradability?
  - Are naturally occurring plastics excluded? If so, how many species? What about synthetic biology?
- Toxicity?
  - How many species need to be tested? Which ones? Is mortality the only consideration? What about bioaccumulation?
  - What if the plastic is safe, but is a carrier for other toxins?
- Additives?
  - Does every different formulation require testing?
- Absolute standards or relative standards?

Should legislators and regulators be the ones answering these very technical questions? Based on whose input?

Problems with existing standards which complicate policy development

- Too many standards in too many different jurisdictions
- Often not openly published – must pay to see them
- Often driven by commercial interests
- Expensive and time-consuming to do testing to show compliance
- Difficult to know or predict whether formulations are compliant

COUNTRY	ORGANIZATION	STANDARDS	LOGO
CERTIFICATES ATTESTING COMPOSTABILITY			
Germany	DIN Certco	EN 13432, ASTM D6400, ISO 17088, EN 14995	
Belgium	Vinçotte	EN 13432, EN 14995	
USA	Biodegradable Products Institute	ASTM D6400	
Italy	Italian Composting Association (CIC) together with Certiquality	EN13432	
Australia	Australasian Bioplastics Association (ABA) together with SGS	AS4736	
Belgium	Vinçotte	Specific Vincotte testing program based on EN 13432, and including testing with ISO 14851 or ISO 14855 or ISO 14852 or ISO 17556 at low temperature	

http://www.plastice.org/fileadmin/files/Certification_biodegradable_Plastics_V2marec.pdf

Problems with existing standards which complicate policy development

- Too many standards in too many different jurisdictions
- Often not openly published – must pay to see them
- Often driven by commercial interests
- Expensive and time-consuming to do testing to show compliance
- Difficult to know or predict whether formulations are compliant

Example Biodegradable Standard

- Biodegradability, which is determined by measuring the actual metabolic conversion of the compostable material into carbon dioxide. This property is quantitatively measured using the standard test method, EN 14046 (which is also published as ISO 14855: biodegradability under controlled composting conditions). The acceptance level is 90%, which must be reached in less than 6 months.
- Disintegrability, that is, the fragmentation and loss of visibility in the final compost (absence of visual contamination). This is measured with a composting test (EN 14045). The test material is degraded, together with organic waste, for 3 months. After this time, the compost is sieved with a 2 mm sieve. The residues of test material with dimensions higher than 2 mm are considered as not having disintegrated. This fraction must be less than 10% of the initial mass.
- Absence of negative effects on the composting process. This is checked with a composting test.
- Low levels of heavy metals (below the predefined maximum values), and absence of negative effects on the quality of the compost (e.g. reduction of the agronomic value and presence of eco-toxicological effects on the growth of plants). A plant growth test (OECD test 208, modified) is carried out on compost samples where the degradation of the test material has taken place. There must be no difference from control compost. Other chemical-physical parameters that must not be different from those of the control compost after the degradation are the pH, salinity, volatile solids, N, P, Mg, K.
- Each of these requirements must be met simultaneously for a material to be defined as compostable. For example, a biodegradable material is not necessarily compostable because it must also break up during one composting cycle. On the other hand, a material that breaks up, over one composting cycle, into microscopic pieces that are not totally biodegradable, is not compostable.

Ecocyclable Standard

https://ecocyclable.wm.edu/ecocyclable-definition/
Environ. Sci. Technol., 2017, 51 (12), pp 6611–6617

- Intended to serve as an open, free, published, iterative standard to facilitate legislation/regulation of plastics
- Idea is to allow policymakers to more easily set policy (e.g., through incentives, bans) without having to define all the terms
- Pluses:
  - Incorporates degradation, toxicity, bioavailability
  - Relative standards of cellulose and PHB
- Minuses:
  - Expensive and time-consuming to show compliance
  - Hard to predict, don't know if materials that should pass will pass

WILLIAM & MARY
CHARTERED 1693

In order to facilitate better policy, a better standard for environmentally acceptable plastics is needed

- Modified list-based approach is ideal:
  - Hybrid of GRAS and GreenScreen and something new
  - An open, iterative, free, list-based approach (perhaps including ratings) that must include polymers and additives
  - Should consider degradability, toxicity, and bioaccumulation
  - Use existing tests/standards to inform list
  - Manufacturers and product developers should be able to easily determine if materials are compliant
  - New products can be added to list

In order to facilitate better policy, a better standard for environmentally acceptable plastics is needed

- Need sponsor with money and credibility, e.g., EPA, UNESCO, Gates Foundation
  - Difficult work, expertise required, not a lot of fun
  - Significant costs, but not really that high
  - Comparable to costs of lobbying for plastic bag ban in one state, or cost to build a mile of road
- Tremendous potential environmental return of investment
  - Better policies worldwide
  - Incentivize industry to develop better plastics

Final thoughts

- Encourage reduce/reuse/recycle
- Global production of plastics likely to increase, therefore we should encourage use of plastics that are environmentally preferable (and not subsidized by the planet)
- We need a better standard for environmentally responsible materials to facilitate productive policy-making
- Many opportunities for product development, interventions at various points to prevent/reduce trash in the waters

Microbead Legislation: Canada

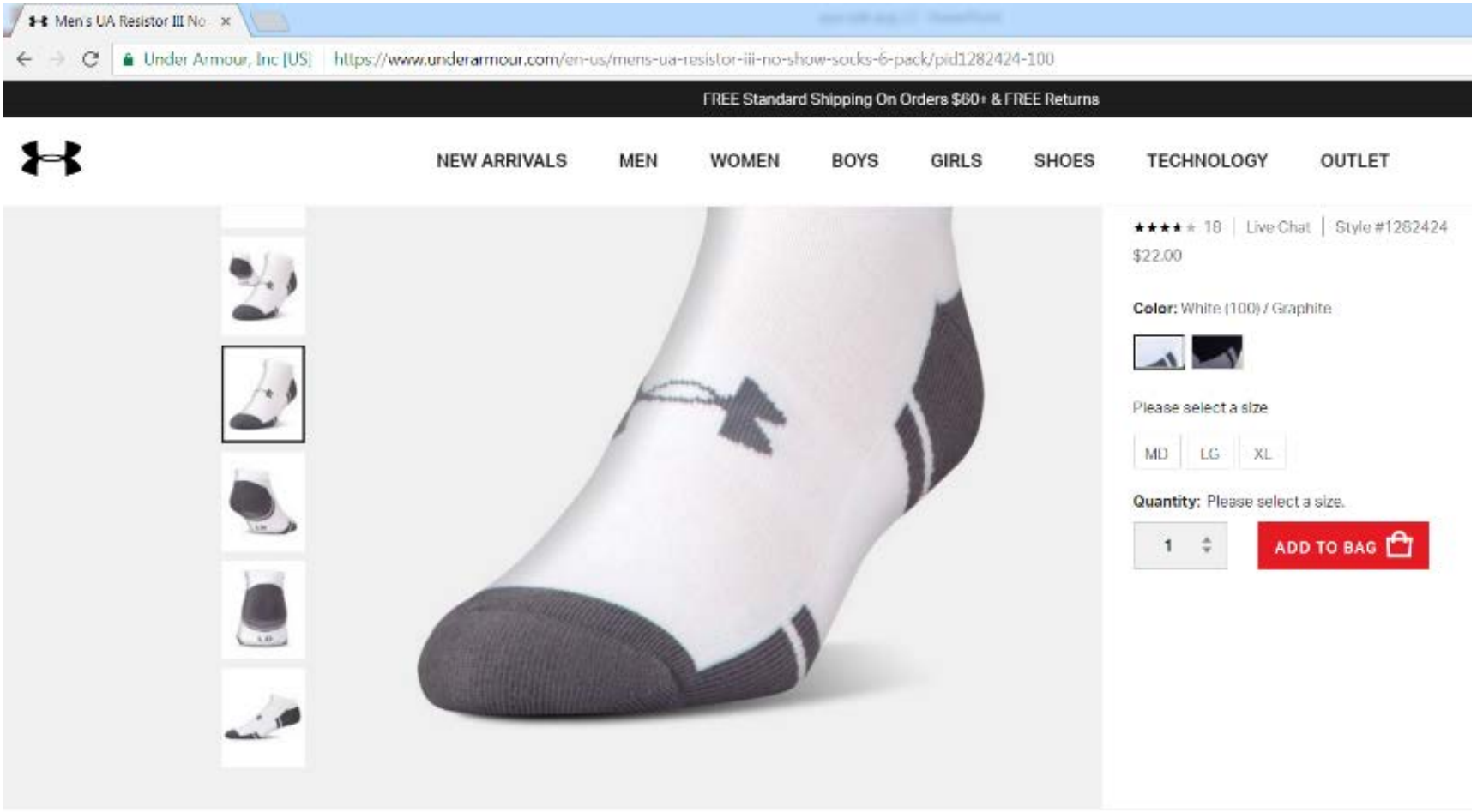
- Considered exemption for biodegradable plastics, but concerned about biodegradability in cold Canadian waters
- True, but natural products such as wood or cellulose-based fibers might not do any better
- Image of shipwrecked J.S. Seaverns in Lake Superior near Michipicoten Harbor, Ontario, sunk in 1884

(Photo by Ken Merryman via Forum News Service, http://www.twincities.com/2016/11/02/lake-superior-shipwreck-discovered-and-even-the-dishes-survived/)

WILLIAM & MARY
CHARTERED 1693

In the absence of scientifically informed standards with broad acceptance . . .

- Policies regulating plastics will be more difficult to enact
- The letter of the law and spirit of the law are likely to diverge
- Negative unintended consequences are likely
- Significant economic inefficiencies will result in order to accommodate policy
- Commercial development and use of new bioplastics to replace conventional plastics is likely to be delayed and scaled back



Great socks - neither buyer nor seller is paying the unaccounted-for costs of microfibers.

Product DNA

- Strategic Cushioning protects high-impact areas of the foot
- Material wicks sweat & dries really fast
- Anti-odor technology prevents the growth of odor-causing microbes
- Embedded arch support reduces foot fatigue
- Six pairs of socks
- Polyester/Spandex Imported

Shop all Men's Socks >

SIZE CHART

	Youth
YMD	10½-13½
YLG	1-4

Men Women

Society's behavioral change regarding plastic pollution is analogous to biodegradation of plastic

- Not exactly "gradually, and then suddenly", more like "imperceptibly, and then gradually"
- We are just establishing a foothold now
  - increased unwillingness to accept status quo
  - increased bioplastics
  - increased regulation
  - increased awareness
  - increased circular design

Biodegradable escape panel for fishing traps

WILLIAM & MARY
CHARTERED 1693