Foodservice®
Sustainability
Solutions

Empowering Zero Waste!

Kerry Flickner
National Director – Waste Solutions

As Director for one of the nation's most forward thinking companies in the domain of environmental sustainability and recycling for commercial and institutional foodservice, Kerry Flickner possesses an extensive background in sustainable waste management practices, climate change, and circular economics.

He began his career in environmental sustainability while serving in the country of Tanzania, Africa. As a board member and program manager for an international non-profit organization focused on building orphanages for HIV children, he worked in close partnership with FeedTheChildren, Red Cross, UNICEF, and the Clinton Foundation-Malawi, as he developed and implemented clean drinking water and renewable energy programs for local communities.

He has also worked extensively as a volunteer educator with Colorado Association of Black Professional Engineers and Scientists (CABPES) as well as with Junior Engineering Technical Society (JETS) — both non-profits dedicated to educating youth in their pursuit of science, technology, engineering, and math (STEM).

Kerry has over 10 years' professional experience in the field of renewable energy and sustainable practices. During this time, he's developed a passion as an educator and currently works with primary and secondary education administrators, universities, Federal Bureau of Prisons, and U.S. Military implementing practicable foam foodservice waste and food waste management strategies.

His expertise provides communities and institutions a frame work for education, advocating responsible use of consumer products that minimize energy consumption and waste generation, mitigates waste related GHG/CO2 emissions – while also diverting, recovering, and converting these waste streams back into natural resources from which they originated.

Kerry has been a trade conference panelist and a presenter for multiple academic and community sustainability organizations.

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The Safety of Polystyrene Foodservice

Health Experts' and Agencies' Views

U.S. National Toxicology Program (NTP)

Dr. Linda Birnbaum, Ph.D., Director, U.S. National Toxicology Program was quoted widely in Associated Press reports in June 2011: "Let me put your mind at ease right away about polystyrene foam*" … [the levels of styrene from polystyrene containers] "are hundreds if not thousands of times lower than have occurred in the occupational setting...In finished products, certainly styrene is not an issue." *Source: news reports of Associated Press story, June 2011*

John Bucher, associate director of the National Toxicology Program, was quoted in Associated Press reports in August 2011: "The risks, in my estimation, from polystyrene are not very great," he said. "It's not worth being concerned about."
Source: news reports of Associated Press story, August 2011

U.S. National Institutes of Environmental Health Sciences (NIEHS)

NIEHS in June 2011 noted: "Styrene should not be confused with polystyrene (foam)*. Although styrene, a liquid, is used to make polystyrene, which is a solid plastic, we do not believe that people are at risk from using polystyrene products."
Source: NIEHS web site

Otis Brawley, Chief Medical Officer, American Cancer Society

Bloomberg News in June 2011 reported that Brawley said, "Consumers don't need to worry about polystyrene cups and food containers..." Quote: "I see no problems with polystyrene foam* cups."
Source: Bloomberg News, June 2011

Food & Drug Administration

Based on scientific tests over five decades, FDA has determined that polystyrene is safe for use in foodservice products. Polystyrene meets the FDA's stringent standards for use in packaging both to store and to serve food.

Harvard Center for Risk Analysis

A twelve-member panel of international experts selected by the Harvard Center for Risk Analysis reported in 2002 that the very low levels of styrene present in foods – whether naturally occurring or from polystyrene foodservice products – does not represent a concern to human health.

For more information on polystyrene foodservice: www.plasticfoodservicefacts.com
For more information on styrene: youknowstyrene.org

* Original quotes used the term "Styrofoam". STYROFOAM™ is a registered trademark of The Dow Chemical Company that represents its branded building material products, including rigid foam and structural insulated sheathing, and more. The brand name often is misused as a generic term for foam foodservice products.

County of Maui – Polystyrene Bill #127
Testimony / May 8, 2017

Kerry Flickner
Foodservice Sustainability Solutions

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PS Foam Foodservice Recovery & Recycling

Annual Performance

- 200 programs fielded
- 240,000 trays daily recovery
- 28 million foam trays
- 280 tons recovered and diverted for recycling.

Performance 2012-16

- 60 million PS foam trays

Reality of Commercial Composting

- The compost industry in the U.S. *is not being driven by demand for compost products.*

- But by the increased cost of landfill disposal, public support for resource conservation, and local mandates on waste diversion.

- *End Market* demand for compost by the consumer does not meet the growing supply. (i.e. Peninsula)

Maui 3-Can Guidelines

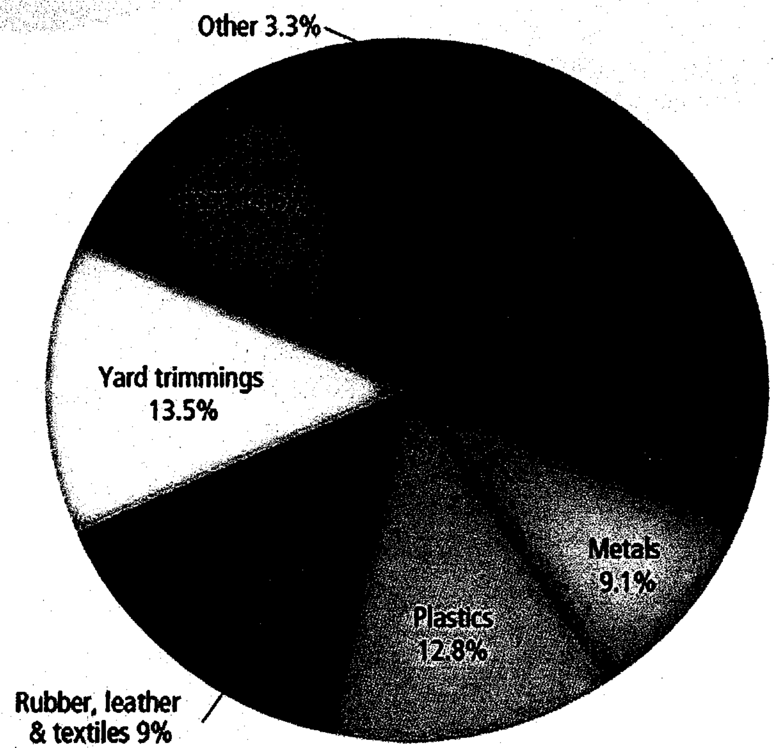
Mixed Recycling & Green Waste

"DO NOT PUT THIS IN THE CART"

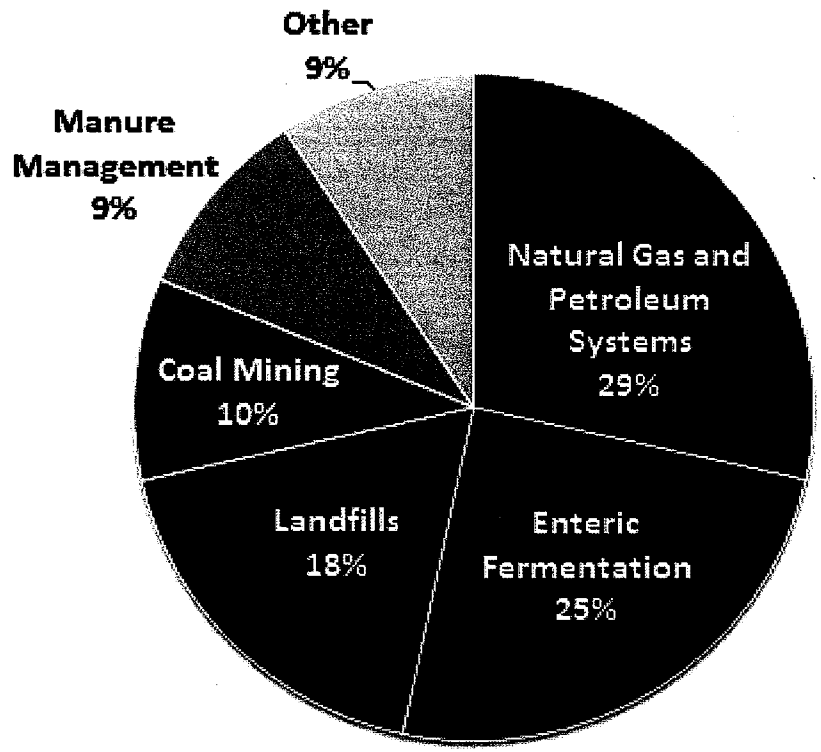
- No Food Residue or Waste
- No Paper Plates
- No Shredded Paper
- No Food-Soiled Paper:
  - Towels & Napkins
  - Paper Plates
  - Pizza Boxes, Cartons
  - Biodegradable Food Containers

55% MSW Composition is *Organic*

U.S. MSW Composition



Methane Impacts



False Equivalency and Conformity

- "Follow in the footsteps of nearly 100 other cities….by allowing only items that are readily compostable or recyclable"

- "A ban on EPS will improve our quality of life, the natural environment,…….and impacts on marine life and birds.

- "Alternatives to polystyrene food service that are renewably sourced rather than fossil-fuel based are thus more environmentally sound"

- "Prohibiting PS disposable containers would reduce amount of liter entering the environment by displacing toxic material with non-toxic biodegradable materials"

Follow the others -

- Urban School Food Alliance
  "Incorporating sound environmental practices"
- 5 of U.S. largest school districts
- 4,700 schools
- Switched from polystyrene trays to paper fiber compostable, "cutting *225 million PS trays per year* (9 months) from the waste stream"

None of these trays are being composted.

- Volume prohibits / Weak Infrastructure / Weak end-markets
- Landfilled = Methane = Ocean Warming

What are we teaching this next generation?

NYC Public Schools / 850,000 meals per day

	PS Foam	*NYC Schools Foam Ban Organic Based "Compostable"*	
Cost — Student Nutrition Budget	$4.5 million	$8 million	*> 78%*
Waste Stream Weight Per Day	4 Tons	11.5 Tons	*> 175%*
Waste Volume Reduction		0	
Resource Recovery / Reuse		0	
Transportation Demand		Increase	
Commercial Composting	N/A	No — Volume Prohibits	
Landfill Biodegradation	N/A	No - Anaerobic Degradation	
Equivalent Landfill Methane Emissions	N/A	Approx. 1700 lbs (CH_4)	
Sustainable Practice		No	

International Union for Conservation

- ICUN Director General – Inger Anderson

  "Ocean warming is this generations greatest hidden challenge – and one for which we are completely unprepared". "The only way to preserve the rich diversity of marine life, and to safeguard the protection of resources the ocean provides, is to cut greenhouse gas emissions rapidly and substantially" (*IUCN World Conservation Congress, Hawaii – 2016*)

  "Most of the heat from human-induced warming since 1970 – staggering 93% - has been absorbed by our oceans, which acts as a buffer against climate change, but this comes at a price. We are surrounded by the scale by the scale and extent of ocean warming effects on the entire eco system" (*Dan Laffoley, Marine Vice Chair of World Commission on Protected Areas at ICUN, 2016*)

Environmental Impact Feedback Loop currently being observed, due to GHG and ocean warming.

- Coral Bleaching
- Ocean Acidification
- Fish migration
- Species die-offs

Example:

The Starfish Wasting Disease that decimated more than 20 species of starfish from Alaska to Mexico is now understood to be the largest observed die-of of a wild animal in the ocean. All due to warmer ocean temperatures.

Transitioning to Practicable Solutions

- Transforming current systems instead of banning.

- Holistic and comprehensive approach to waste management, litter control, public education and accountability.

- Quantifying environmental impacts of purposed alternative organic waste stream.

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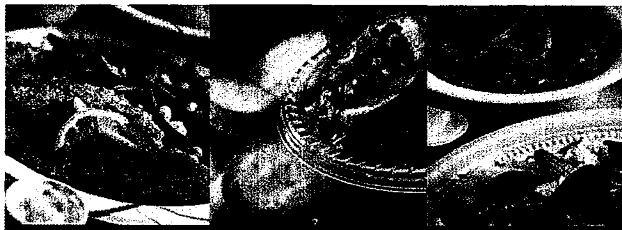
COMMENTS ON COUNTY OF MAUI'S PROPOSED POLYSTYRENE BAN

FPI
FOODSERVICE PACKAGING

Foodservice Packaging

Lynn Dyer
Maui County Council Meeting
May 8, 2017



ABOUT FPI

- Established in 1933
- Only industry trade association in North America solely focused on all single-use foodservice packaging products
- Members include:
  - Converters and their raw material and machinery suppliers (approximately 90% of the industry);
  - Foodservice distributors and operators

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IMPACT ON HAWAII FOAM PRODUCTS

- Manufacturing facility on Oahu, along with K. Yamada Distributors
- In business for over 50 years
- Has contributed $millions to economy through payroll and taxes
- Employs ~100 people

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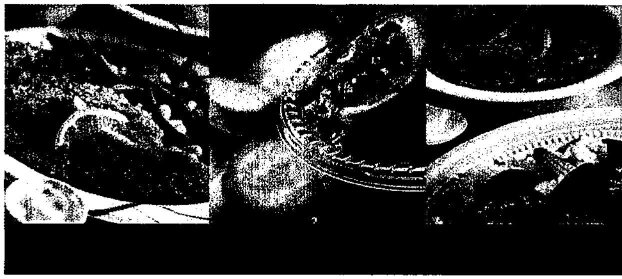
MOST ALTERNATIVES WILL NOT BE RECYCLED OR COMPOSTED

- Recyclables:
  - Only recyclable alternatives are PET and aluminum (no paper, polypropylene)
- Compostables:
  - EKO Compost only accepts wood and yard waste (no compostable cups and containers)



COMMENTS ON MAUI COUNTY'S PROPOSED POLYSTYRENE BAN

SCOPE OF BAN

- Definition of "food service container"
  - Clear that it includes cups, containers, dinnerware, trays
- Definition of "polystyrene"
  - Not clear whether scope is rigid <u>and</u> foam polystyrene, or just foam polystyrene

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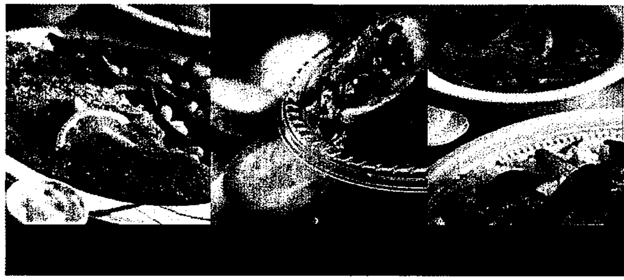
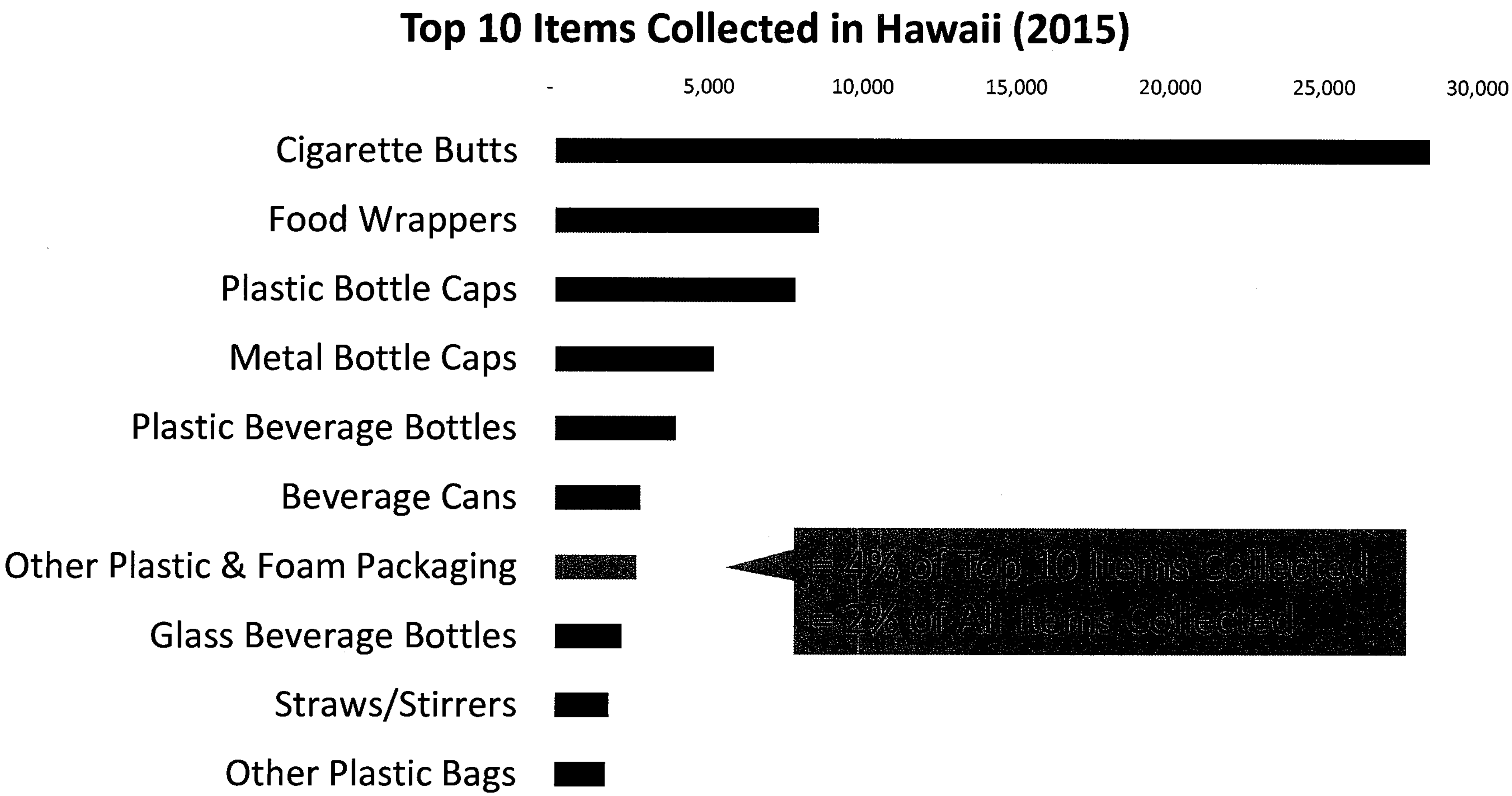


COMMENTS ON MAUI COUNTY'S PROPOSED POLYSTYRENE BAN

WILL DO LITTLE TO REDUCE LITTER



Source: Ocean Conservancy's Coastal Cleanup Annual Report (2016)

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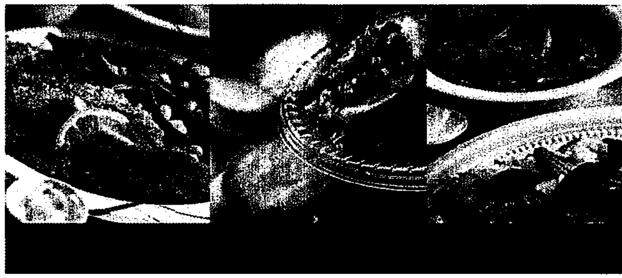
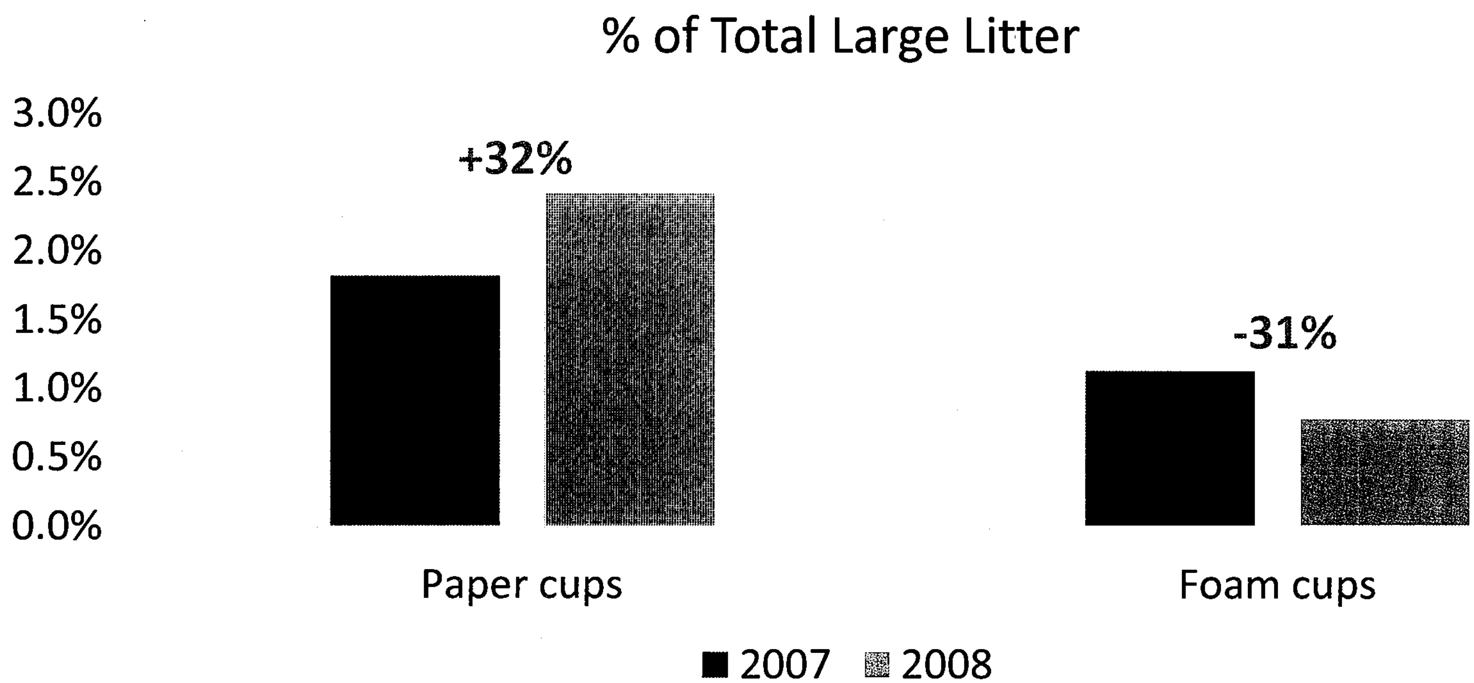


WILL DO LITTLE TO REDUCE LITTER

- Real-world example: San Francisco's litter audits, conducted before and after foam polystyrene ban



Source: City of San Francisco Department of Environment Litter Survey Report (2008)

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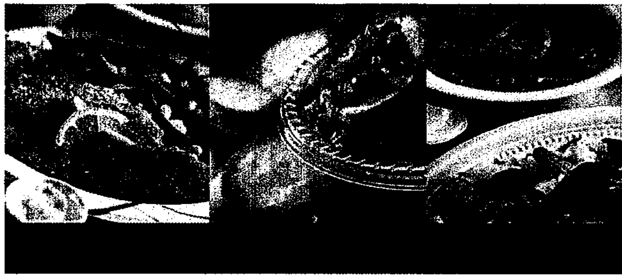

LEARNING LEADS TO SOLUTIONS

- Where does litter come from?
  - Motorists (52%)
  - Pedestrians (22.8%)
  - Improperly covered truck or cargo loads, including collection vehicles (16.4%)
  - Improperly secured containers, dumpsters, trash cans or residential waste or recycling bins (1.5%)

Source: Keep America Beautiful's Littering Behavior in America (2009)

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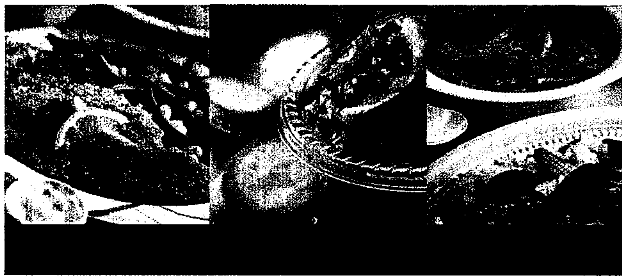

LEARNING LEADS TO SOLUTIONS

- Why do people litter?
  - Personal choice: Most littering (81%) was committed "with intent" by the individual, e.g., flicking, flinging, or dropping.
  - Litter begets litter: Individuals are much more likely to litter into a littered environment.
  - Options to "do the right thing:" Availability of, proximity to and distance between trash and recycling receptacles.
  - It's "not my responsibility."

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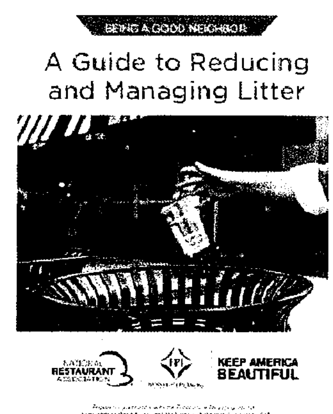
Source: Keep America Beautiful's Littering Behavior in America (2009)

MORE EFFECTIVE LITTER REDUCTION SOLUTIONS

- Consider a more comprehensive solution to litter by focusing on the real problem: human behavior
- Increase public awareness and anti-litter education efforts by engaging your citizens, visitors and businesses



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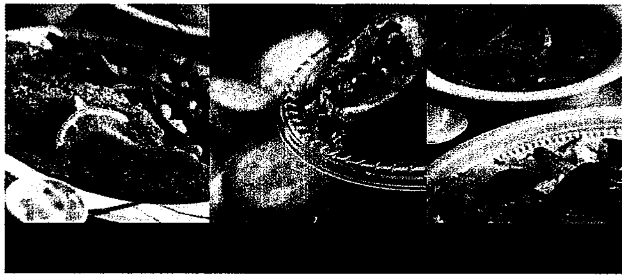

MORE EFFECTIVE LITTER REDUCTION SOLUTIONS

- Increase the number of trash/recycling bins, carefully considering where to place them and what type of bins are needed (lidded!) and decrease the distance between them
- Use carts – not bags – for curbside collection of trash and recycling
- Emphasize litter policies (like Hawaii's Uncovered Truck Law) and consider stricter enforcement of existing litter laws

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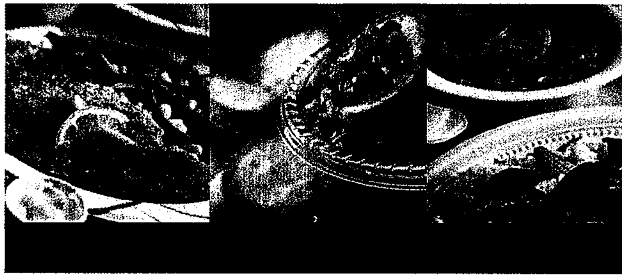

COMMENTS ON MAUI COUNTY'S PROPOSED POLYSTYRENE BAN

THANK YOU!

QUESTIONS?

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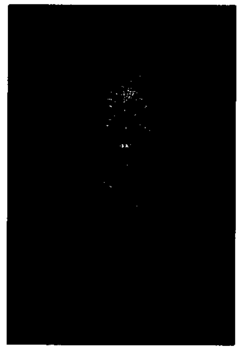


Lynn Dyer

Dyer Biography: Short Version
Lynn Dyer is president of the Foodservice Packaging Institute, the trade association for the North American foodservice packaging industry. At FPI, she advocates for the interests of the industry and champions its efforts to expand recycling and composting of foodservice packaging. Prior to joining FPI in 1998, Lynn worked with the European Food Service & Packaging Association (now Pack2Go Europe) in Brussels, Belgium. Lynn holds a Bachelor of Arts degree from the University of Richmond.

Dyer Biography: Long Version
Lynn Dyer is president of the Foodservice Packaging Institute, the trade association representing the foodservice packaging industry in North America. Members include packaging converters and their raw material and machinery suppliers, as well as foodservice operators, distributors and group purchasing organizations.

Lynn brings more than 20 years of experience to the field of foodservice packaging. At FPI, she advocates for the industry through communications, market research, public affairs and technical initiatives. She also champions the industry's efforts to recycle and compost more foodservice packaging by collaborating with dozens of stakeholders and tackling barriers to achieve sustainable recovery.

Prior to joining FPI in 1998, Lynn worked with the European Food Service & Packaging Association (now Pack2Go Europe) in Brussels, Belgium.

Lynn holds a Bachelor of Arts degree from the University of Richmond.

Dyer Headshot: May be found here https://fpi.smugmug.com/Personnel/i-Xb9nkRC/A.

Foodservice Packaging
The Sensible Solution

MEGAN LAMSON

Megan Lamson is a marine biologist with a specialty in coral reef fish ecology and community-based management projects. She received her Bachelor's degree in Marine Biology from the University of California in Santa Cruz and a Master's degree in Tropical Conservation Biology and Environmental Science from the University of Hawai'i at Hilo. She is currently the Vice President and Hawai'i Island Program Director for the nonprofit organization, Hawai'i Wildlife Fund. She also works with the Pacific Cooperative Studies Unit within the Research Corporation of the University of Hawai'i for the Hawai'i State DLNR Division of Aquatic Resources in Kona, surveying fish and coral habitats along the West Hawai'i coastline. Lamson has been working and volunteering for Hawai'i Wildlife Fund since 2008, and during that time she has helped to coordinate the removal of 100+ tons of marine debris from the shores of Hawai'i Island, Maui, and Lana'i. In 2016, Lamson participated in the Hawai'i County Council sponsored Hawai'i Island Packaging and Sustainability Task Force.

In addition, Lamson has given presentations on marine debris and marine resources in college classrooms, professional meetings, and at several international conferences around the world. She has co-authored several papers and studies related to marine debris and coral reefs in Hawai'i nei.

HOLD the FOAM
KEEP THE 'ĀINA CLEAN

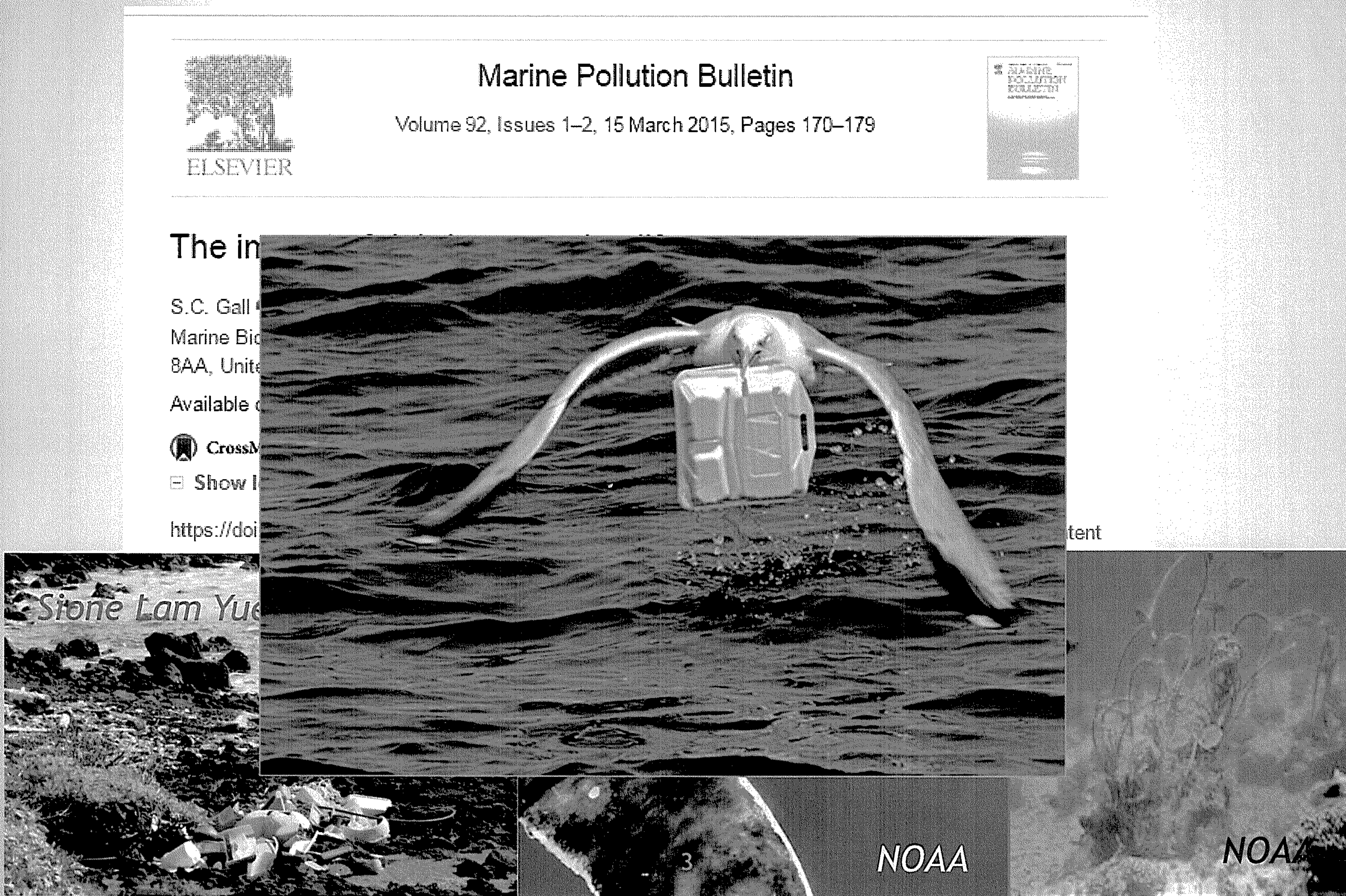
Maui Polystyrene Food Service Bill 127

Megan Lamson, Hawai'i Wildlife Fund
May 2017 – megan@wildhawaii.org

HAWAI'I WILDLIFE FUND

Over **242 tons of marine debris removed** from Maui, Hawai'i Island, Midway & French Frigate Shoals.

From **Marine Pollution Bulletin** 92:1-2 pp. 170-179 (March 2015)



1) Science

* Negative impact to marine resources (fish, turtles, seabirds, etc.)
* Global chemical contamination from polystyrene

2) Locally-sourced marine debris

* Sources vs. Sinks paper
* International Coastal Cleanup Data (Maui County)
* The success of the Maui plastic-bag ban (2011)

3) Common sense

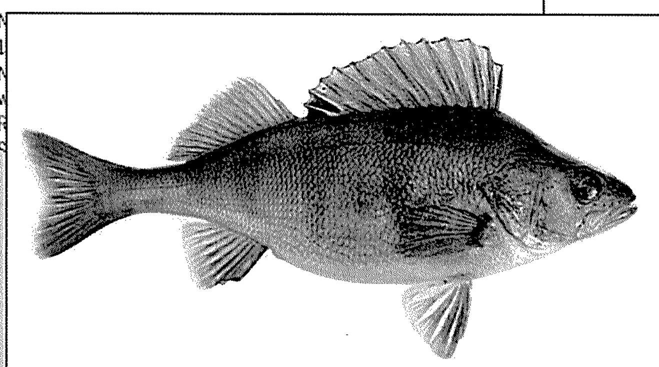
* Overflowing landfills and DOT report
* Solid Waste Management for Island Ecosystems

From Science Magazine 252:6290 p. 1213 (June 2016)

24-hour maximum of η_{elec} = 27 ± 4% (n = 3) (Fig. 3F). The achieved titers are higher than previous reported values, and η_{elec} values have increased by a factor of at least 20 to 50 (*10*, *18*). *R. eutropha* has demonstrated tolerance toward isopropanol (fig. S14), allowing for enriched product concentrations under extended operation.

Our combined catalyst design mitigates biotoxicity at a systems level, allowing water-splitting catalysis to be interfaced with engineered organisms to realize high CO_2 reduction efficiencies that exceed natural photosynthetic systems. Because E_{appl} required for water splitting is low (1.8 to 2.0 V), high η_{elec} values are achieved that translate directly to high solar-to-chemical efficiencies (η_{SCE}) when coupled to a typical solar-to-electricity device ($\eta_{SCE} = \eta_{solar} \times \eta_{elec}$). For a photovoltaic device of η_{solar} = 18%, the Co-P|CoP$_i$| *R. eutropha* hybrid system can achieve η_{SCE} = 9.7% for biomass, 7.6% for bioplastic, and 7.1% for fusel alcohols. This approach allows for the development of artificial photosynthesis with efficiencies well beyond that of natural photosynthesis, thus providing a platform for the distributed solar production of chemicals.

REFERENCES AND NOTES



Appl. Microbiol. Biotechnol. 98, 4277–4290 (2014).

10.1126/science.aaf5039

ECOTOXICOLOGY

Environmentally relevant concentrations of microplastic particles influence larval fish ecology

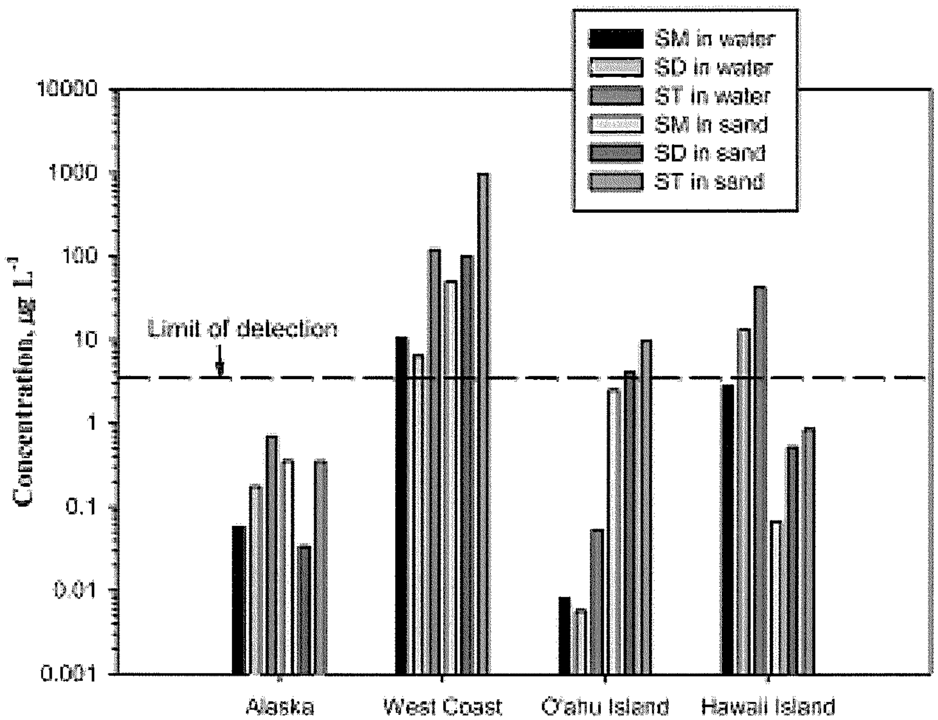
Oona M. Lönnstedt* and Peter Eklöv

The widespread occurrence and accumulation of plastic waste in the environment have become a growing global concern over the past decade. Although some marine organisms have been shown to ingest plastic, few studies have investigated the ecological effects of plastic waste on animals. Here we show that exposure to environmentally relevant concentrations of microplastic polystyrene particles (90 micrometers) inhibits hatching, decreases growth rates, and alters feeding preferences and innate behaviors of European perch (*Perca fluviatilis*) larvae. Furthermore, individuals exposed to microplastics do not respond to olfactory threat cues, which greatly increases predator-induced mortality rates. Our results demonstrate that microplastic particles operate both chemically and physically on larval fish performance and development.

...bal plastic production is estimated to be ...bout 300 million metric tons (MMT) an-...ually and is increasing by 20 MMT per ...

years, where they break down into smaller pieces owing to ultraviolet radiation, physical forces, and hydrolysis (*4*). Hence, plastic particles continue to ...

From **Environmental Pollution 188:45-49** (2014)



Note that in cases where the concentrations are below the limit of detection, the concentrations of styrene analogues as trace levels were calculated from the signal intensities of the GC/MS and calibration curve.

Fig. 2. The mean concentrations of styrene analogues in seawater and sand samples from Alaska, the West Coast of the USA, Hawaii Island and O'ahu Island.

"Our results suggest the presence of new global chemical contaminants derived from PS in the ocean, and along coasts."

FOAM
FREE
FUTURE

From Marine Environmental Research 84 pp. 76-83 (2013)

Marine Environmental Research 84 (2013) 76–83

Contents lists available at SciVerse ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

Tracking the sources and sinks of local marine debris in Hawai'i

Henry S. Carson [a,*], Megan R. Lamson [b], Davis Nakashima [a], Derek Toloumu [a], Jan Hafner [c], Nikolai Maximenko [c], Karla J. McDermid [a]

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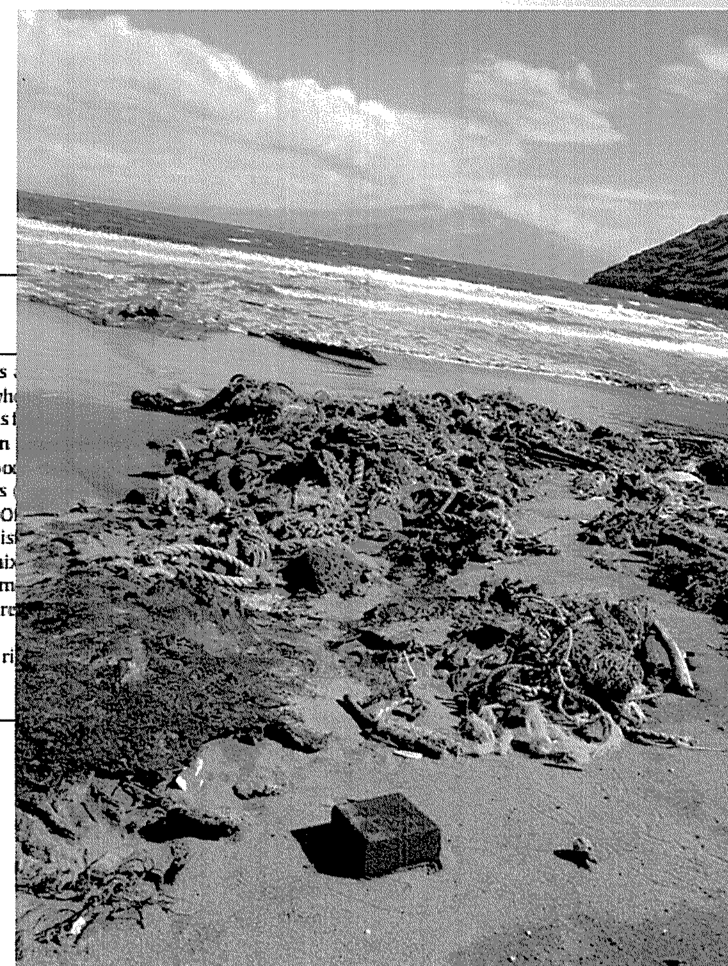
A R T I C L E I N F O

Article history:
Received 14 July 2012
Received in revised form
3 December 2012
Accepted 4 December 2012

Keywords:
Plastics
Marine debris
Hawaii
Drifters
Retention booms
Ocean models
Sources
Pathways
Waste disposal

A B S T R A C T

Plastic pollution has biological, chemical, and physical effects on marine environments
effects on coastal communities. These effects are acute on southeastern Hawai'i Island, wh
remove 16 metric tons of debris annually from a 15 km coastline. Although the majority is
a portion is locally-generated. We used floating debris-retention booms in two urban
measure the input of debris from Hilo, the island's largest community, and released woo
nearby coastal waters to track the fate of that debris. In 205 days, 30 kilograms of debris
were retained from two watersheds comprising 10.2% of Hilo's developed land area. O
drifters released offshore of Hilo in four events, 23.3% were recovered locally, 1.4% at dis
and 6.5% on other islands. Comparisons with modeled surface currents and wind were mix
the importance of nearshore and tidal dynamics not included in the model. This study dem
local pollutants can be retained nearby, contribute to the island's debris-accumulation are
contaminate other islands.



MĀLAMA MAUI NUI
KEEP AMERICA BEAUTIFUL AFFILIATE

Ocean Conservancy

Summary – Maui County, HI, USA

#	Clean Up Summary	Total	%
1	Cigarette Butts	16628	34.96%
2	Plastic Pieces	5817	12.23%
3	Food Wrappers (candy, chips, etc.)	3462	7.28%
4	**Foam Pieces**	**3324**	**6.99%**
5	Bottle Caps (Metal)	3139	6.60%
6	Bottle Caps (Plastic)	1869	3.93%
7	Glass Pieces	1645	3.46%
8	**Other Plastic/Foam Packaging**	**886**	**1.86%**
9	Fishing Line (1 yard/meter = 1 piece)	792	1.67%
10	Beverage Bottles (Plastic)	749	1.57%

FOAM Total - MAUI	Total	%
Foam Pieces	3324	6.99%
Other Plastic/ Foam Packaging	886	1.86%
Take Out/Away Containers (Foam)	436	0.92%

4,646 foam items / 9.77% of total collected

2015 worldwide ICC data.

PHOTOS COURTESY OF THE MAUI NEWS / MATTHEW THAYER

From **Marine Pollution Bulletin105:292-298** (April 2016)

Marine Pollution Bulletin 105 (2016) 292–298

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Trends and drivers of debris accumulation on Maui shorelines: Implications for local mitigation strategies

Lauren C. Blickley *, Jens J. Currie, Gregory D. Kaufman

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A R T I C L E   I N F O

Article history:
Received 18 August 2015
Received in revised form 29 December 2015
Accepted 1 February 2016
Available online 28 February 2016

Keywords:
Marine debris
Hawaii
Accumulation rates

A B S T R A C T

Marine debris, particularly plastic, is an identified concern for coastal areas and is known to accumulate in large quantities in the North Pacific. Here we present results from the first study to quantify and compare the types and amounts of marine debris on Maui shorelines. Surveys were conducted monthly between May 2013 and December 2014, with additional daily surveys conducted on Maui's north shore during January 2015. Debris accumulation rates, loads, and sources varied between sites, with plastics being the most prevalent type of debris at all sites. Large debris loads on windward shores were attributed to the influence of the North Pacific Subtropical Gyre and northerly trade winds. Daily surveys resulted in a significantly higher rate of debris deposition than monthly surveys. The efficacy of local policy in debris mitigation showed promise, but was dependent upon the level of enforcement and consumer responsibility.

"Over the course of 17 months, 78 debris clean ups, and a total of 10,074 debris items, we did not collect any plastic grocery bags." -- **Lauren Blickley**


#HOLDTHEFOAM

From **Marine Pollution Bulletin** 28:11 pp. 649-652 (1994)

Pergamon

0025-326X(94)00146-4

Marine Pollution Bulletin, Vol. 28, No. 11, pp. 649–652, 1994

0025-326X/94 $7.00+0.00

LAWS OF THE SEA

Land-Based Discharges of Marine Debris: From Local to Global Regulation

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This article outlines the major regulatory requirements involved in the control of land-based discharges of marine debris, and reviews the main developments in the process towards more appropriate international controls of such discharges.

Marine debris poses a continuing threat to marine ecosystems. Most visibly, it has resulted in entanglement of marine wildlife. Debris washing up on beaches may

Sea, the Baltic Sea, the Black Sea and the Arctic) are covered by more or less operational programmes for land-based pollution, whereas programmes for the South East Pacific and the Persian Gulf are as yet dormant (Nollkemper, 1992). Equally significant, existing programmes have been inadequate. They have not addressed the full range of sources of marine debris; they have treated land-based pollution too much as an isolated problem, as if unrelated to waste generation; and have provided insufficient inducements by way of information exchange, technical co-operation and financial assistance to move marine debris higher on the agenda of, in particular, developing states. Each of these problems will be elaborated below.

The bleak prospects for adequate regional solutions rightly has set in motion a global process. Responding to the imperatives set forth in Agenda 21 (adopted at the 1992 UNCED), a global programme of action for land-based sources of marine pollution is now being

"The very policies that reduce generation of solid wastes will prevent them from entering the environment."

From **NRDC Report** "WASTE IN OUR WATER: THE ANNUAL COST TO CALIFORNIA COMMUNITIES OF REDUCING LITTER THAT POLLUTES OUR WATERWAYS" (2013):

Table 7: Total Annual Direct Cost of Debris Management

Community Size	Population Range	Range of Reported Annual Costs	Average Reported Annual Cost	Average Reported Per Capita Cost
Largest	250,000 or more	$2,877,400–$36,360,669	$13,929,284	$11.239
Large	75,000–249,999	$350,158–$2,379,746	$1,131,156	$8.938
Midsize	15,000–74,999	$44,100–$2,278,877	$457,100	$10.486
Small	Under 15,000	$300–$890,000	$144,469	$18.326

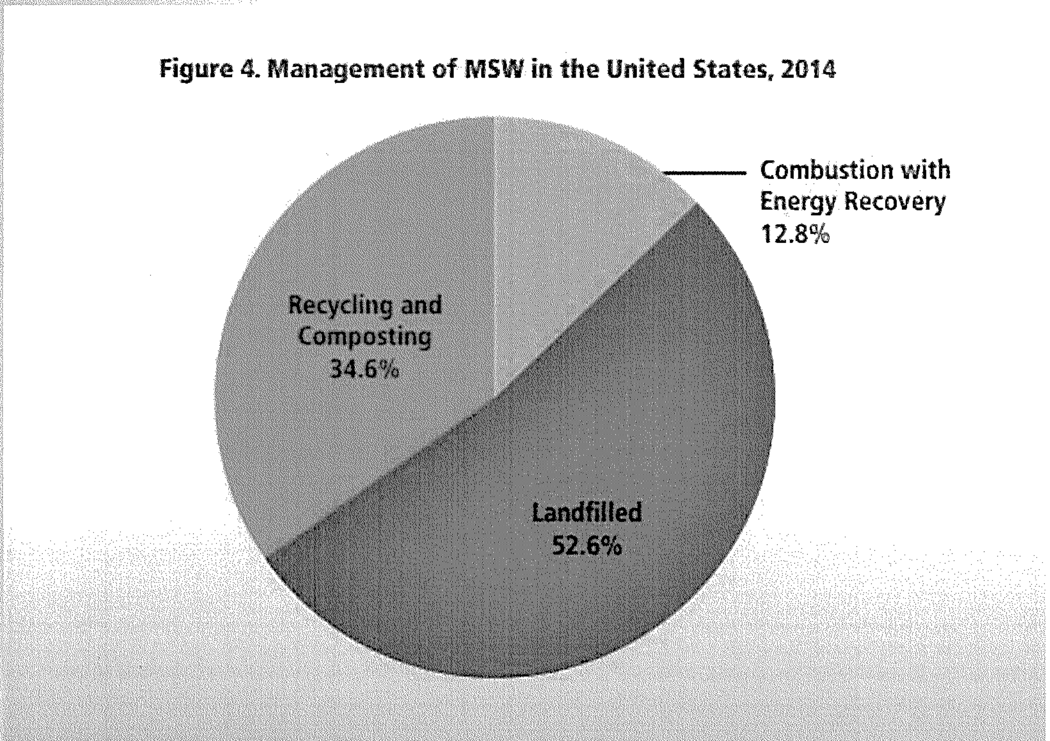
For detail, see Appendix B: Data Tables.

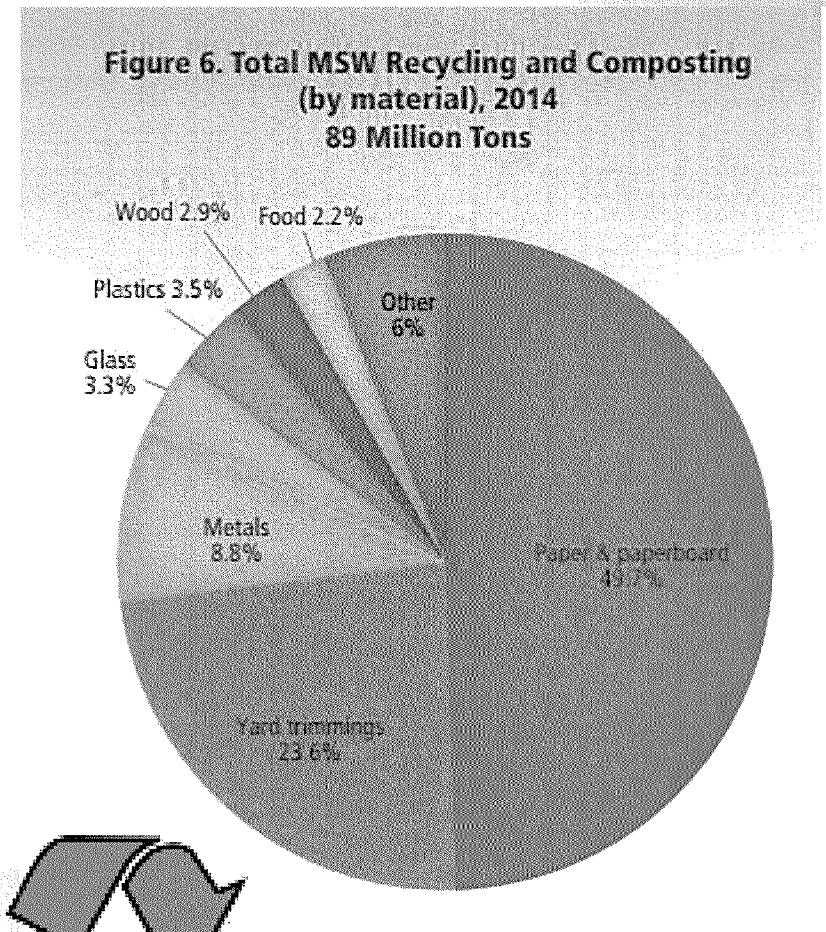
From Hawai'i State DOT "**Trash Protection Plan**" (2016)

6.4 Long-Term Plan Enhanced Control Measures (p. 73)

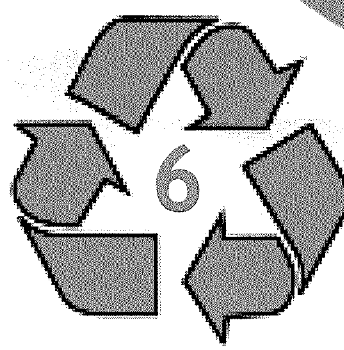
- **Consider an ordinance to ban Styrofoam.**
- Expand the Plastic Bag Ordinance.
- Increase school and community outreach related to trash.
- Conduct additional outreach and/or inspections of businesses that may exacerbate trash issues (e.g., fast food restaurants).
- Review the street sweeping schedule to enhance the effectiveness of street sweeping.
- Install additional full trash capture devices, such as trash skimmers

From **EPA.gov Advancing Sustainable Materials Management** 2014 Fact Sheet





According to Smithsonian Magazine (2014): “Styrofoam or expanded polystyrene is made of plastic #6. The general rule is the higher the number of plastic, the harder it is to recycle.”



From **SpringerPlus 2:398** (2013)

Yousif and Haddad *SpringerPlus* 2013, **2**:398
http://www.springerplus.com/content/2/1/398

SpringerPlus
a SpringerOpen Journal

REVIEW **Open Access**

Photodegradation and photostabilization of polymers, especially polystyrene: review

Emad Yousif* and Raghad Haddad

Abstract

Exposure to ultraviolet (UV) radiation may cause the significant degradation of many materials. UV radiation causes photooxidative degradation which results in breaking of the polymer chains, produces free radical and reduces the molecular weight, causing deterioration of mechanical properties and leading to useless materials, after an unpredictable time. Polystyrene (PS), one of the most important material in the modern plastic industry, has been used all over the world, due to its excellent physical properties and low-cost. When polystyrene is subjected to UV irradiation in the presence of air, it undergoes a rapid yellowing and a gradual embrittlement. The mechanism of PS photolysis in the solid state (film) depends on the mobility of free radicals in the polymer matrix and their bimolecular recombination. Free hydrogen radicals diffuse very easily through the polymer matrix and combine in pairs or abstract hydrogen atoms from polymer molecule. Phenyl radical has limited mobility. They may abstract

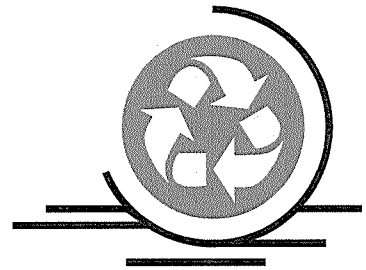
"Polystyrene waste requires the transportation of big large volume of materials, which is costly and makes recycling economically unfeasible."

* According to Mauicounty.gov

Recycling, Refuse & Landfill Guide (pg. 4)

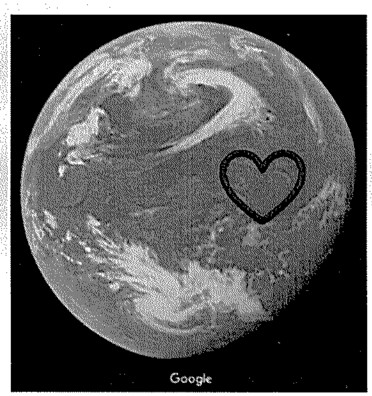
Plastics:

- #1 and #2 only
- Rinse clean, discard lids
- No food residue
- No toys
- No Styrofoam
- No plastic bags



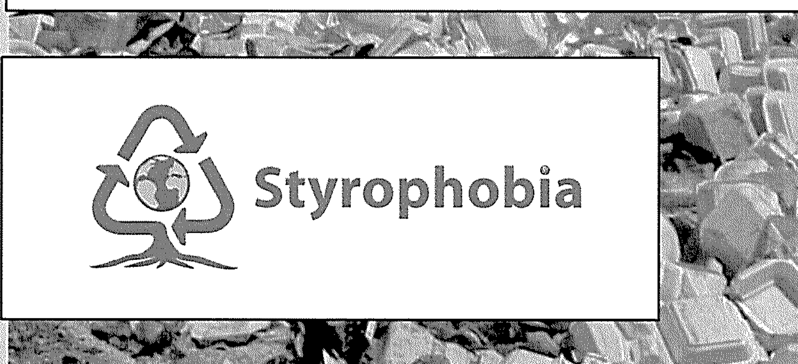
Plastic #6 or PS is NOT recyclable on Maui

… or Hawai'i Island or O'ahu …



* Foam Alternatives are Available

SUSTAINABLE
ISLAND PRODUCTS

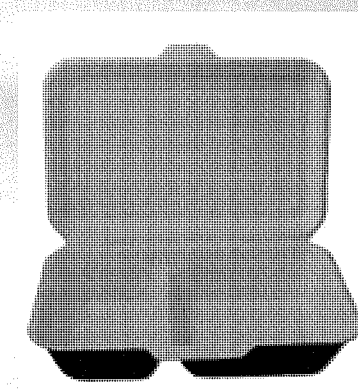


Styrophobia

COMPOSTABLE
Biodegradable Products Institute | US COMPOSTING COUNCIL

Maui Chemical & Paper Products
Supplying Hawaii Since 1969

VIP Foodservice
NATURAL MARKET



HOLD the FOAM
KEEP THE ʻĀINA CLEAN

Mahalo nui loa...

Megan Lamson, Hawaiʻi Wildlife Fund

www.wildhawaii.org / megan@wildhawaii.org

HAWAIʻI WILDLIFE FUND

Marine Environmental Research 84 (2013) 76–83

Contents lists available at SciVerse ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

Tracking the sources and sinks of local marine debris in Hawai'i

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ARTICLE INFO

Article history:
Received 14 July 2012
Received in revised form
3 December 2012
Accepted 4 December 2012

Keywords:
Plastics
Marine debris
Hawaii
Drifters
Retention booms
Ocean models
Sources
Pathways
Waste disposal

ABSTRACT

Plastic pollution has biological, chemical, and physical effects on marine environments and economic effects on coastal communities. These effects are acute on southeastern Hawai'i Island, where volunteers remove 16 metric tons of debris annually from a 15 km coastline. Although the majority is foreign-origin, a portion is locally-generated. We used floating debris-retention booms in two urban waterways to measure the input of debris from Hilo, the island's largest community, and released wooden drifters in nearby coastal waters to track the fate of that debris. In 205 days, 30 kilograms of debris (73.6% plastic) were retained from two watersheds comprising 10.2% of Hilo's developed land area. Of 851 wooden drifters released offshore of Hilo in four events, 23.3% were recovered locally, 1.4% at distant locations, and 6.5% on other islands. Comparisons with modeled surface currents and wind were mixed, indicating the importance of nearshore and tidal dynamics not included in the model. This study demonstrated that local pollutants can be retained nearby, contribute to the island's debris-accumulation area, and quickly contaminate other islands.

1. Introduction

Plastic pollution in the marine environment impacts human communities directly through reduced tourism income, increased cost of cleanup, threats to navigation and safety, contamination of food sources, loss of aesthetic value, and other public health hazards (reviewed in Thompson et al. 2009). It impacts those same communities indirectly by threatening marine organisms and habitats though entanglement and ingestion by invertebrates, fishes, birds, turtles, and marine mammals, smothering of the benthos, leaching of plasticizers, concentration of persistent organic pollutants in seawater, changing the physical properties of sediment, and the transport of organisms via rafting (reviewed in Cole et al. 2011, Gregory 2009).

These effects are particularly acute in the Hawaiian Archipelago, in part because of its location proximal to the major debris accumulation zone of the North Pacific Gyre (Howell et al. 2012). In the northwestern portion of the island chain, the sensitive habitats of the Papahānaumokuākea Marine National Monument are threatened by marine debris, especially derelict fishing gear (Donohue et al. 2001). Marine debris also affects the marine environment and human communities on the southeastern inhabited islands. Residents are tied to the ocean, not only through a dependence on tourism and shipping, but also via aquatic activities (such as fishing, surfing, and canoeing) that are integral to their lifestyle and culture. Near the southern end of the archipelago's largest island, Hawai'i, lies Kamilo Point, an area famous for debris accumulation (Fig. 1). Since 2003, the Hawai'i Wildlife Fund (www.wildhawaii.org) has removed an average of 16 metric tons of debris per year from this 15 kilometer coastline.

The plastic debris at Kamilo consists of derelict fishing gear, miscellaneous large items, and a high, but patchily distributed, concentration of polyethylene and polypropylene fragments (Carson et al. 2011). The majority of identifiable items appear to be of non-Hawai'i origin, as evidenced by heavily degraded or fouled surfaces, foreign-language labels, markings, and logos on items not labeled for sale in the United States, or aquaculture and fishing industry equipment not in use on the islands (e.g. Ebbesmeyer et al. 2012). However, some items do appear to be of local origin, as evidenced by fresh, unfouled surfaces, and commonly used brand names. The local-origin debris is unlikely to have been littered directly on the coastline because the area is difficult to access and

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http://dx.doi.org/10.1016/j.marenvres.2012.12.002

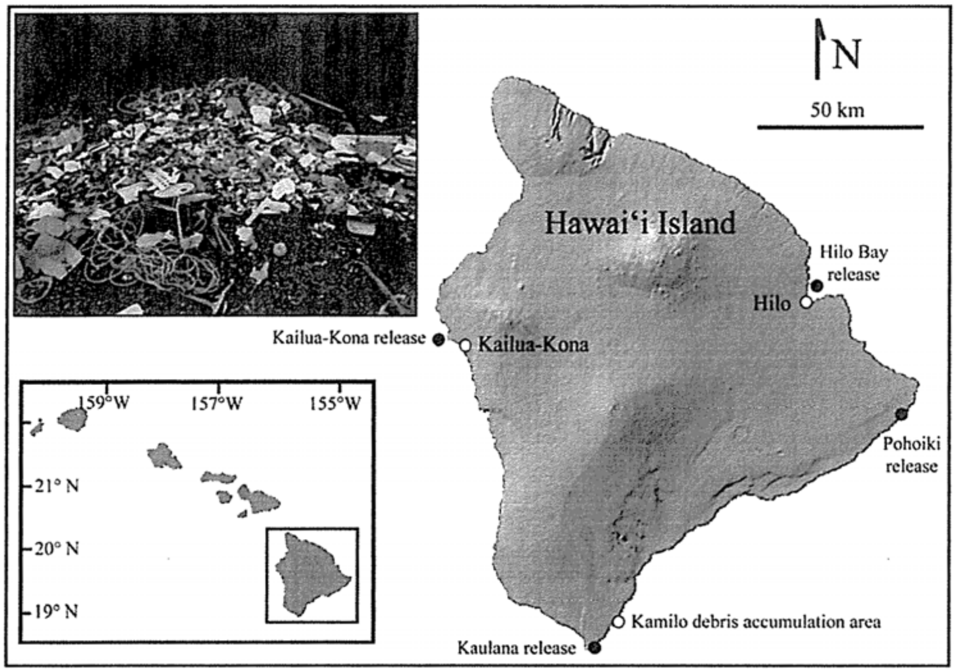

Fig 1. Map of the study areas around Hawai'i Island, and inset picture of typical debris accumulation on Kamilo Point.

not a tourist destination. Therefore, the same hydrodynamic forces which deposit large amounts of foreign debris on this coastline may also carry local debris. We hypothesize that prevailing northeasterly trade winds, and their associated surface currents (Jia et al. 2012), make the east coast of Hawai'i Island the most likely source of local debris to the Kamilo area.

Although plastic pollution from distant locations in the Pacific poses a great threat to Hawai'i (Brainard et al. 2001, Donohue 2005, Ebbesmeyer et al. 2012), this pollution is also more difficult to prevent with local action than Hawai'i-sourced debris. In this study, we test whether or not waste from the island's large population centers washes up on the island's main debris accumulation areas. Specifically, we investigate the following two questions:

1) What is the amount, composition, and timing of debris reaching the ocean from the island's largest population center, as measured by floating debris retention booms in two urban waterways?
2) What are the pathways of Hilo debris and debris from other island areas once it reaches the ocean, as traced by drifters and simulated by ocean models?

2. Design of experiments

2.1. Debris-retention Booms

One floating debris-retention boom was placed in each of two waterways in Hilo (Fig. 2), the largest population center on the island of Hawai'i (43,263 people as of the 2010 census). The first (#1 in Fig. 2) was placed in the Wailoa River watershed, which drains the predominantly residential southern portion of the city. The watershed area is 255.4 km^2 extending to the top of the massive Mauna Loa volcano; however, due to the highly porous nature of the basaltic rock, surface runoff only becomes a relevant factor in the movement of debris in the lower, developed 10.0 km^2 of the watershed (Parham et al. 2008). The boom spanned a 25-meter-wide concrete flood-control channel at the mouth of the river as it flows into Waiākea Pond. The pond is a brackish-water, tidally-influenced water body that opens to Hilo Bay 1.5 km north of the boom.

The second boom (#2 in Fig. 2) was placed in the 'Alenaio Stream watershed, which drains a smaller portion of urban Hilo, including the southern end of the downtown commercial district. The watershed area extends 187.3 km^2 up the slopes of the Mauna Loa volcano; however, only the developed lower 4.3 km^2 (Parham et al. 2008) is likely to produce significant synthetic debris runoff. The boom crossed a six-meter-wide stone flood-control channel as the stream empties into Waiākea Pond. The bay entrance is located 1.2 km east of the boom.

The booms collected debris from only 10.2% of Hilo's developed land area, representing approximately 4,400 people. Northern portions of the city are drained by the Wailuku River, a large watershed (653.2 km^2) of forested land that experiences extreme flows during frequent storm events which would be likely to destroy attempted boom placements with the force of water and drifting logs. The majority of runoff from the downtown commercial district reaches the bay via a decentralized network of underground storm drains which are difficult to sample effectively. To the south of the study area, the Keaukaha area is also drained via groundwater and decentralized channels that would be impossible to sample effectively for debris. These logistical considerations prevented more of Hilo's drainage area from being studied. The boom placements at the point where the two study watersheds empty into Waiākea Pond are advantageous because standing water supports the booms during low flow while dissipating some of the energy from high flow events.

The booms were anchored to either side of the two drainage channels, and remained in place for 205 days from September 2011 to April 2012. They consisted of flotation chambers extending about 0.3 m above the water surface (Fig. 2), and a solid, impermeable curtain weighted with chain extending about 0.3 m below the water surface. Debris was removed twice a week during the study period, with additional checks after storm events. To collect the debris, the booms were detached from one shoreline and pulled across to encircle the debris close to the other shoreline where it

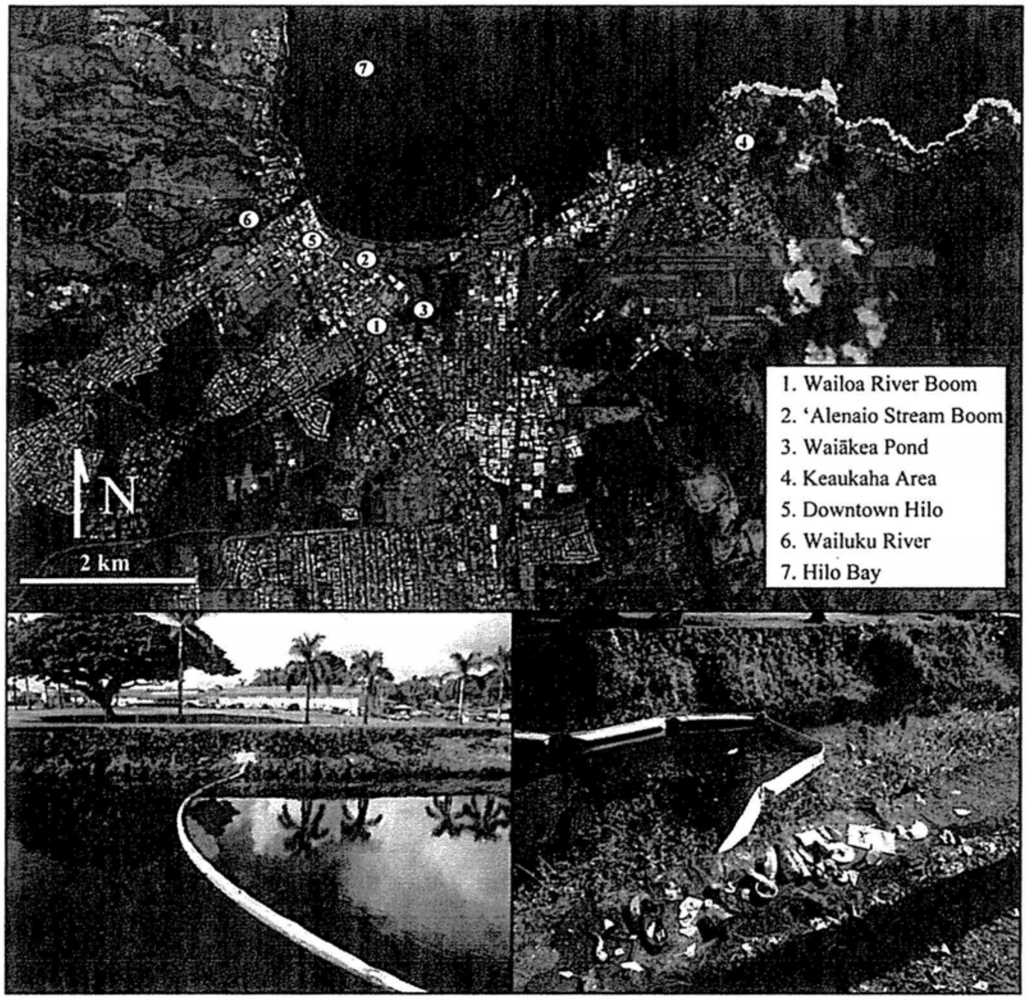

Fig 2. Satellite photo of the study area in Hilo, Hawai'i Island, and pictures of the Wailoa River Boom (left) and 'Alenaio Stream Boom (right) with typical debris shown in the foreground.

could be easily removed with a dip net. In the laboratory, captured items were separated from organic debris, rinsed, and then dried for weighing and classification into one of ten categories (Table 1). We have no quantitative data on the efficiency of debris capture by the booms. Visual observations showed that the booms were most efficient at capturing high-buoyancy items such as plastic bottles, and could not always retain low-buoyancy items such as plastic bags, especially during high flow conditions.

We used linear regression to test for a relationship between the timing of plastic captures and local precipitation, as measured by National Weather Service rainfall gauges. Cumulative rainfall that occurred between debris samplings was compared to the total weight of debris found in the booms during the corresponding sampling period.

2.2. Drifter Experiments

Degradable wooden drifters were constructed to approximate the movement of Hawai'i-sourced debris. The drifters were made of pine blocks approximately 7.6 cm long, 8.9 cm wide, and 3.8 cm high, branded with a message including release location code, contact phone number, and email address. In seawater, the blocks initially floated with approximately 1 cm of windage, which was reduced to almost zero after several hours of water absorption. A test block placed in a bucket of seawater remained positively buoyant for approximately 80 days before sinking.

We released 851 blocks at the same Hilo Bay location (19° 45' 06" N, 155° 03' 51" W) in two deployments, one in October 2011 and another in March 2012. To assess the effect of hypothetical along-

Table 1
Dry weight of debris captured by two floating retention booms in Hilo, HI, USA over 205 days. Numerals in parenthesis below the weights are the number of items of that category. "Misc." = miscellaneous items that do not belong in the other categories, including plastic items and items made of multiple materials; PET = polyethylene terephthalate; PE = polyethylene.

boom	plastic items (kg)							aluminum (kg)	glass (kg)	misc. (kg)	total (kg)
	PET bottles	cigarettes	PE packaging	bags	cups / lids	footwear	styrofoam				
Wailoa River	1.79 (69)	0.34 (1004)	0.80	0.43 (50)	0.50 (15)	0.15 (1)	0.76	0.13	0.01	5.60	10.52
'Alenaio Stream	3.30 (121)	0.07 (263)	1.05	1.83 (121)	1.05 (53)	2.04 (8)	0.63	1.08	2.08	6.29	19.43
Total	5.09 (190)	0.41 (1267)	1.85	2.26 (171)	1.55 (68)	2.19 (9)	1.39	1.21	2.09	11.89	29.95

shore jets, induced by tides, each event was split into two tide-state releases: at slack-before-flood (low tide) and at slack-before-ebb (high tide). Prevailing westward flow around Hawaiian Islands (Jia et al. 2012) reduces the probability of debris transport from the west coast of Hawai'i Island to the Kamilo accumulation area. To verify this hypothesis, we also released drifters near the island's second-largest population center at Kailua-Kona. We placed 230 drifters offshore of Kailua-Kona (19° 40′ 2″ N, 156° 2′ 15″ W) in two tide-state releases in October 2011. Two additional release locations not near population centers were used to help describe the movement of debris around the island. We deployed 236 drifters offshore of Pohoiki, near the eastern tip of the island, and 230 blocks offshore of Kaulana, near the southern tip of the island (Fig. 1), each in two tide-state releases in October 2011. All releases were made from watercraft approximately 1 km offshore, because we were not interested in studying surf zone debris-movement processes.

The telephone hotline and email account were monitored continuously after releases to receive reports of recoveries. Members of the public that located blocks were asked to report the time, date, and location of the recovery event, as well as block release code and whether or not they removed the block from the shore (to prevent duplicate reports). First reports from certain areas were used to calculate maximum drift speeds from release to destination, and subsequent recoveries were assumed to have been beached nearby and not recovered immediately.

2.3. Ocean Model of Surface Currents

The SCUD (Surface CUrrents from Diagnostics) model was developed at the International Pacific Research Center (IPRC) to assess surface velocities using global, near-real time satellite data of altimetric sea level anomaly and scaterometric vector wind (Maximenko and Hafner 2010). Sea level anomaly, referenced to the mean dynamic topography found in Maximenko et al. (2009), was used to compute absolute geostrophic velocity and wind to assess Ekman currents. Geographically-varying coefficients of the model were tuned using trajectories of almost 15,000 satellite-tracked drifting buoys of the Surface Velocity Program and Global Drifter Program (http://www.aoml.noaa.gov/phod/dac/index.php). Model velocities are calculated daily, on a 1/4° global grid. The accuracy of the model deteriorates near shore due to higher errors in satellite data and increased complexity of dynamics. It is challenging to use the SCUD model to assess the movement of a wooden block, whose design is very different from the drifters employed by the Global Drifter Program. However, SCUD currents were found informative to trace such differently shaped instruments as the whale-tracking gear, operated by the US National Oceanic and Atmospheric Administration's (NOAA) Hawaiian Islands Humpback Whale Sanctuary, and the experimental profiling float (during its visits to the ocean surface) of the US National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory. Specific to marine debris, the solution of the statistical version of the model corresponds satisfactorily to the distribution of plastic fragments in open waters (Maximenko et al. 2012). Additionally, SCUD was found helpful in simulating the motion of heterogeneous tsunami debris from Japan, including its circulation in the North Pacific and landing on shorelines of different countries (Maximenko and Hafner, unpublished data[1]). Despite the limited applicability of the SCUD model to the motion of wooden blocks in the nearshore area, the overall simplistic formulation of the drifter exchange between different islands, and limited instrumental power, make reasonable the use of the readily-available SCUD model as a framework for the project.

The virtual release point for simulations was moved 24 km offshore of the drifter release point to conform to the model space of SCUD. 10,000 virtual drifters were randomly placed within the 1/4° squared grid cell offshore of Hilo Bay on the October and March drifter release dates. Their trajectories were computed for 14 days to encompass the approximate period of first recoveries for the wooden drifters. Duplicate simulations were run for each release including a 2% windage factor to compare with the previous simulations.

3. Results and Discussion

3.1. Debris-retention Booms

In 205 days, the two booms captured 29.9 kg of anthropogenic debris, 73.6% of which was plastic by weight (Table 1). The largest defined category was polyethylene terephthalate (PET, "#1") bottles, which comprised 17% of the total by weight. They were followed by disposable plastic bags (7.5%), footwear (7.3%), glass (7.0%), and polyethylene (PE) packaging (6.2%). A large portion of the total debris was miscellaneous items, including sports equipment, fishing gear, toiletries, household items, and fabrics. The most numerous category was cigarette butts (1267 items), although they only made up 1.4% of the debris by weight. Over a third (35.6%) of the material included plastic, aluminum, and glass packaging for which recycling facilities are readily available.

The accumulation of debris at the booms was significantly related ($p < 0.001$) to precipitation events in a linear regression (Fig. 3), although rainfall did not explain the variation in debris weight collected to the extent that might be expected given that surface runoff is the most likely transport mechanism to waterways. Only 37% of the variation in total debris weight collected could be explained by variation in rainfall. However, if littering rates are more or less constant in time (Seco Pon and Becherucci 2012), the first precipitation event after a dry period is likely to carry a disproportionate amount of debris compared to subsequent rainfall events, regardless of their magnitude, that occur before new litter can accumulate (Moore et al. 2011).

The amount of debris collected at each boom did not correspond to the land area drained by the waterway. The Wailoa River drains over twice the developed land area as 'Alenaio Stream, but collected half the debris (Table 1). Differing land-use within the urban area is the most likely explanation (Seco Pon and Becherucci 2012), with

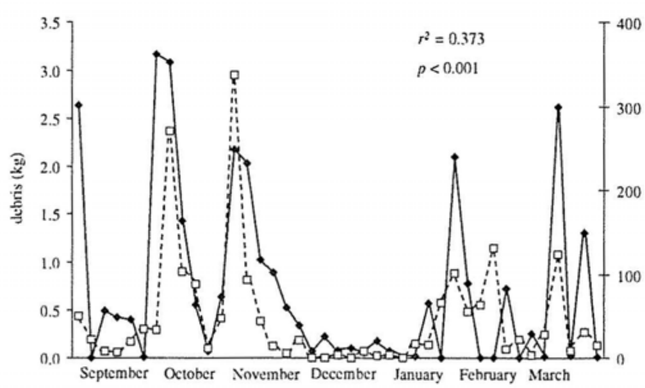

Fig 3. Total anthropogenic debris (filled diamonds, solid lines) at debris retention booms in two watersheds and accumulated rainfall (open squares, dashed lines) in between monitoring events at the booms. The r^2 and p-values are from a linear regression between accumulated debris and rainfall at each sampling.

[1] Model results available at: http://iprc.soest.hawaii.edu/news/marine_and_tsunami_debris/IPRC_tsunami_debris_models.php1.

higher littering rates possible in the downtown commercial district, partially drained by the 'Alenaio Stream, compared to residential districts. Because of the potential variation in litter by specific land-use, it is difficult to calculate the total input of debris from an urban area on the basis of two retention booms. However, under the reasonable assumption that littering rates do not vary significantly with season (Seco Pon and Becherucci 2012), the booms captured debris at a rate of 53.3 kg per year. Extrapolating that collection rate from 10.2% of the city's land area to the entire city yields more than 500 kg of marine debris produced each year for a city of over 43,000 people. This estimate does not include litter that is blown into the ocean by wind, or litter directly deposited into the marine environment on beaches or from boats.

There are many reasons why that rough calculation may be a significant underestimate of debris produced, and chief among them is the inefficiency of capture by the booms. During high flow events that are common in Hilo, we observed low-buoyancy items such as plastic bags slide underneath the booms and avoid capture. Estimates of the amount of high-buoyancy items such as capped PET bottles are probably more accurate, as they seemed to be retained on the surface even during high-flow conditions. Floating retention booms with subsurface netting anchored to the bottom would perform better at both quantifying debris and preventing its entry into the ocean. Such devices were not possible at these locations due to risk of sea turtle entanglement and other threats to wildlife.

Several studies have attempted to quantify marine debris inputs from stormwater runoff using a variety of capture devices, but few are published in the primary literature (reviewed in Ryan et al. 2009). Our impermeable curtains across entire drainage channels were better suited to prevent buoyant debris from entering the ocean in moderate flows than they were to quantify all debris inputs accurately under a variety of conditions. Sampling a portion of the stream with fine-mesh netting, as did Moore et al. (2011) in Los Angeles, would provide more accurate estimates of input rates, especially for micro-debris in high flow regimes.

3.2. Drifter Experiments

Of the 1547 wood-block drifters released at four locations around the island, 387 (25%) were reported recovered. Of those recovered, 302 (78%) were found within 25 km of the release point. The remaining 85 (22%) were found at distant locations on Hawai'i Island or on one of three other Hawaiian islands (Table 2, Fig. 4). The two October 2011 releases from Hilo Bay had markedly different outcomes. No recoveries were made from the low-tide release, whereas 24.3% of the blocks released at high-tide were recovered on the islands of Maui (42 blocks), Lana'i (8 blocks), and uninhabited Kaho'olawe (5 blocks). The Maui recoveries, in particular, were spread over the entire island, although a majority were encountered in the Makena (22 blocks) and Kahikinui (10 blocks) portions of the southern coastline. The first recovery, at Hana on the eastern tip of Maui, occurred eight days after release. This corresponds to a 23 cm s^{-1} mean drift speed. The first recovery on the north coast of Lana'i occurred 10 days after release (30 cm s^{-1} drift speed).

The two March 2012 releases from Hilo Bay had similar outcomes, although they did not match the results of the earlier releases. A large proportion of both the low-tide (51.5%) and high-tide (46.8%) releases were retained within the bay, recovered on the bay's southern Keaukaha coastline (Fig. 2) as soon as two days after release. Only thirteen blocks from the high-tide release were recovered outside the bay. One block drifted north to the northernmost tip of the island, and the other twelve drifted south, reaching as far as Kamilo Point near South Point (Fig. 4).

Releases from the island's other major population center, Kailua-Kona, had no reported recoveries. Both releases from Pohoiki on the eastern tip of the island were recovered locally (within 10 km) in large numbers, 49.6% and 37.4% for the low- and high-tide events, respectively (Table 2). Thirteen blocks from the high-tide release traveled southwest and were found at the major debris-accumulation area at Kamilo Point (Fig. 4). Only four drifters were reported from the Kaulana releases at the southern tip of the island. Two each from the high- and low-tide releases were encountered on the island of Lana'i. In contrast to other drift block recoveries on Lana'i, these were all found 61 or more days after release. These blocks, drifting at a considerably slower speed (5 cm/s) than other Lana'i recoveries, could have taken an offshore path through the field of eddies which often form in the lee of Hawai'i Island (Jia et al. 2012).

The drifter results show that buoyant pollution from Hawai'i Island's largest population center can take a variety of paths. Tidal cycles or other variations that occur on the timescale of hours can cause strong dispersion of blocks released together, or result in completely different trajectories. Hilo Bay drift blocks traveled northwest, quickly beaching on three other islands, and they were also retained locally, washing up at local beach parks after a short residence in the bay. Although only one drifter out of over 800 released was recovered at Kamilo, this block establishes the drift path for Hilo debris to beach at the island's debris-accumulation area. The same path was also demonstrated in two steps - Hilo Bay blocks found at Pohoiki near the eastern tip of the island, and blocks released at Pohoiki found at Kamilo (Fig. 4). Ongoing experiments carried out while this manuscript was in review support the Hilo to Kamilo pathway. Six of 200 blocks released from Hilo Bay in late October 2012 have been recovered at Kamilo or

Table 2
Wood-block drifter releases and reported recoveries in the Hawaiian Islands.

release				recovery					
location	tide	number	date	total	Hawai'i Island		Maui	Lana'i	Kaho'olawe
					local	distant			
Hilo Bay 1	low	220	10/24/11	0.0%					
	high	226		24.3%			18.6%	3.5%	2.2%
Hilo Bay 2	low	200	03/23/12	51.5%	51.5%				
	high	205		53.2%	46.8%	6.3%			
Pohoiki (East Point)	low	121	10/24/11	60.3%	49.6%	10.7%			
	high	115		37.4%	37.4%				
Kaulana (South Point)	low	115	10/27/11	1.7%				1.7%	
	high	115		1.7%				1.7%	
Kailua-Kona	low	115	10/26/11	0.0%					
	high	115		0.0%					
total		1547		25.0%	19.5%	1.7%	2.7%	0.8%	0.3%

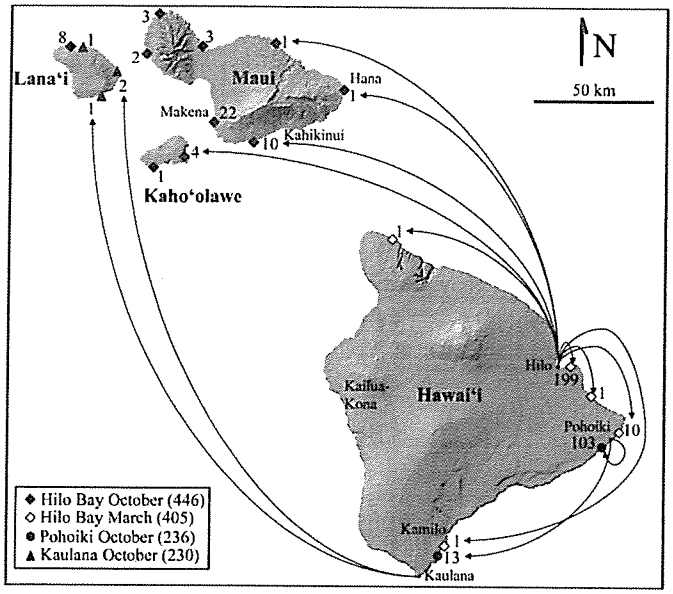

Fig 4. Locations of all reported drifter recoveries. Multiple recoveries in one area are represented by one symbol, with the adjacent numeral denoting the number of recoveries in that area. Numbers in parenthesis in the figure legend are the total number of blocks released at that event. Arrows connect release and recovery locations, and do not represent drift paths. Not all of the release-recovery connections are shown for clarity.

along this coastline at press time, with no recoveries elsewhere. The eastern half of the island, including Hilo, remains the most probable source of the local debris that arrives at Kamilo.

No drift blocks were recovered from the Kailua-Kona releases, and only four were recovered from Kaulana releases. The paucity of recoveries for blocks released on the leeward (i.e. westward) side of the island is not surprising. The same prevailing currents that sweep debris from east Hawai'i westward would send west Hawai'i debris toward open water and keep leeward beaches relatively clean. This finding matches the observation of larval dispersal by direct detection of parent-offspring pairs in reef fish on Hawai'i Island (Christie et al. 2010). Parents located on the eastern and southern coasts of the island seeded recruits to the western coast, but the reverse was not detected.

The 75% of blocks not reported recovered could have traveled to a variety of destinations. SCUD model results (see below and Fig. 5) show many could have been advected away from the islands into the open ocean. These drifters will likely degrade or sink within months. Others may have landed on seldom-visited parts of the state such as much of the coastline of Kaho'olawe Island. Others could be lodged or buried in sediment, rocks, or crevices and difficult to see. Still others may have been found and not reported, as suggested by some who called many weeks after recovery because they forgot about the block for some time. Many blocks may have beached one or more times, been refloated, and beached in secondary locations, as evidenced by some blocks that appeared more abraded (in pictures sent by recoverers) than others. Although difficult to quantify, beaching and refloating is a common

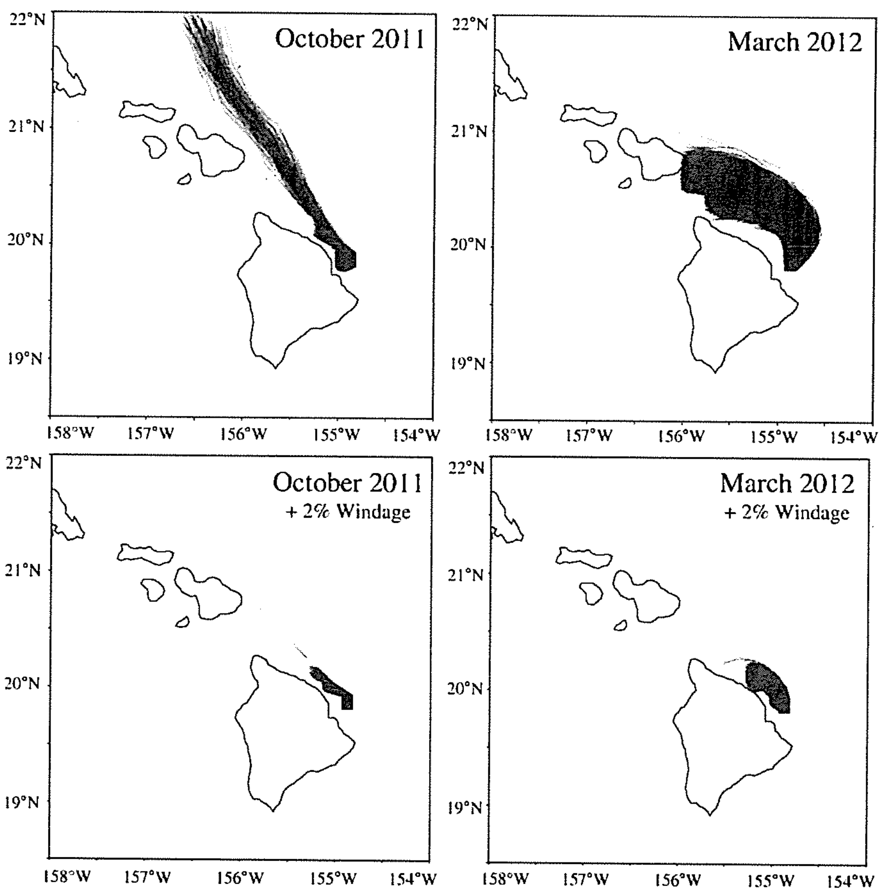

Fig 5. Results of SCUD model particle releases corresponding to the drifter releases in Hilo Bay. Particle trajectories represent drift pathways during the first two weeks after release. The virtual release point was moved 24 km offshore of the drifter release points to allow for model function. Top panels show model runs without any windage factor included. The bottom panels depict identical model runs with the addition of a 2% windage factor.

behavior of the plastic debris the blocks are meant to represent (Garrity and Levings 1993).

How representative our drifter results are to the drift of marine debris depends on how well their trajectories reproduce the motion of plastic pollution. Matching the ratio of surface area exposed to the wind to the submerged drag area is the key criterion for similarity (Wiese and Jones 2001). The complication with plastic litter, of course, is the diversity of shapes and buoyancies represented. We designed our drifters with minimal windage, similar to a large amount of the debris captured by our booms (Table 1) such as bags, fragments, and packaging. However, more buoyant items with more windage such as capped PET bottles are likely not well represented by the drift blocks. Heterogeneity of debris found on some beaches and missing from others indicates significant robustness of pathways of different objects on a local scale and justifies the design of our drifter experiment.

3.3. Comparison with Ocean Model

The results of SCUD model simulation for Hilo Bay releases (Fig. 5) corresponded generally to the observed drifter recoveries in some cases. In October 2011, both the modeled particles and the drifters were quickly transported northward. In the model, however, they were swept past Maui toward the subtropical gyre accumulation zone and did not make landfall. It is possible that many blocks from both tide-state releases traveled the modeled path, especially from the low-tide release for which no blocks were recovered. Model-predicted current speeds of 20 - 30 cm/s corresponded well to the timing of first recoveries on the islands of Maui and Lana'i. Including an estimate of the direct impact of the wind changed the modeled results considerably, as the onshore winds pushed most of the particles onto the shoreline north of Hilo (Fig. 5) where no blocks were recovered. The actual block recoveries in Maui represent a middle ground between the two scenarios, suggesting that both wind and surface currents affected the blocks' drift. A small number of particles in SCUD traveled toward actual block recovery locations on Maui (Fig. 5).

Ironically, the surface current model did predict a large amount of Maui recoveries for the March 2012 release (Fig. 5), when there were none. One block, recovered on the northern tip of Hawai'i Island, conformed to the model prediction. The other 211 recoveries, however, were local or southward. A major possible reason for the discrepancy between model predictions and drifter observations was the need to move the virtual release point offshore of the actual release point. The SCUD model does not include nearshore processes, the same processes which necessarily transport land-sourced debris for at least a portion of their journey. In the case of the March release, many blocks retained in the bay probably did not ever enter the model space of SCUD. In October, the blocks were apparently quickly moved offshore and into the modeled current area. Adding the effect of windage to the SCUD model for the March release (Fig. 5) shows increased transport of the particles onshore, closer to realized drift of the blocks.

The differences between the modeled particles and the drift blocks can be partially attributed to the uncertain effects of windage, especially before the blocks waterlogged and floated lower in the water. This uncertainty increases when the shape or buoyancy of the floating object is unknown, as is often the case for the variety of objects that constitute marine debris. Other discrepancies may result because the SCUD model is a daily product and does not account for differences in mixed, semi-diurnal tidal state, which probably affected the drifter results considerably.

Most ocean models used to predict the spread of marine debris operate on a larger-scale than the questions presented here (reviewed in Potemra 2012). The development of ocean models that accurately describe the nearshore environment around Hawai'i would aid in the study of the transport of marine debris around the islands. Particles which enter the nearshore environment in the SCUD model are considered beached (Fig. 5), despite the fact that they are kilometers from shore in reality and would likely continue their drift. Drifter experiments are useful tools, but cannot be deployed continuously to describe hourly or daily fluctuations in surface currents throughout the year as models can. With more nearshore data from high-frequency radar or current meters, models validated with episodic drifter experiments could better describe the factors that control the local sources and sinks of marine debris.

4. Implications

These results demonstrate the increased importance of East Hawai'i's waste management practices to the rest of the state. In the prevailing currents, Hilo lies "upstream" of the state's other communities and habitats, and material entering the ocean there can begin to pollute other islands quickly. Our October release of drift blocks shows that pollutants entering the ocean at Hilo can reach widespread locations around the islands of Maui County in as little as eight days. Hilo is the only deepwater port for the island of Hawai'i, and as such receives a large amount of shipping, cruise liner, and oil barge traffic. Of course, the results of this study cannot be automatically extrapolated to all kinds of pollution. For example, oil spilled originally at the sea surface is known to gradually evaporate, dissolve, change chemically, and, finally, sink. Based on our observations, any pollutant surviving on the ocean surface for a period of weeks has a good chance to spread among the Hawaiian Islands.

The steady stream of plastic debris from Hilo and many communities is an ongoing spill of solid-phase petroleum that occurs with each rain storm. This spill is quite preventable. There are no fees for domestic waste disposal at island transfer stations. Several private and public recycling facilities in Hilo accept or purchase materials that made up a third of the debris collected in the booms. Much of the waste collected was single-use containers or bags, most likely used for a short period of time (minutes or hours) before being discarded. If such containers were designed for multiple reuses, both the volume of waste and the impacts to habitats and communities could be reduced. All four counties of the State of Hawai'i, for instance, have each recently passed legislation to limit the use of disposable plastic shopping bags (Bly 2012).

Although waste that travels from local sources to local sinks is the easiest to track and potentially mitigate, it is often a small portion of both pollution produced and pollution received by a given area. Even if all of the minimum 0.5 metric tons of marine debris from Hilo traveled to Kamilo Point each year, it would only make up 3% of the total debris removed from that coastline annually. Similarly, plastic waste from Hilo, other parts of the island, or the rest of the state still persists in the ocean even if it is not beached on one of the inhabited or uninhabited islands of the Hawaiian Archipelago. Local waste-management and consumer choices that reduce the amount of plastic entering the ocean will certainly reduce local impacts, but of equal importance is reducing each community's contribution to the global marine debris problem.

Disclosures

The sponsors, Will J. Reid Foundation, had no involvement in study design, collection or interpretation of data, or manuscript preparation. The authors declare no conflicts of interest. H. Carson designed the study, supervised data collection of both booms and drifters, performed statistical analysis, and drafted the manuscript. M. Lamson helped design the study, assisted with drifter deployment and data collection, and edited the manuscript. D. Nakashima and D. Toloumu helped design the study, collected the boom data, assisted with drifter construction and deployment, and edited the manuscript. J. Hafner and N. Maximenko helped design the study, carried out ocean modeling, and edited the manuscript. K. McDermid helped design the study, provided lab space and technical advice, mentored students, and edited the manuscript. All authors have approved the manuscript as submitted.

Acknowledgments

The authors wish to thank the Will J. Reid Foundation for funding. N. Maximenko and J. Hafner were partially supported by NASA Ocean Surface Topography Science Team grant NNX08AR49G, NASA grant NNX07AG53G, NOAA National Climate Data Center grant NA17RJ1230, and the Japan Agency for Marine-Earth Science and Technology through their sponsorship of research at the International Pacific Research Center. Megan Lamson was partially supported by the NOAA Fisheries grant NA11NMF4630052 to the Hawai'i Wildlife Fund. The authors thank Joseph Atafua, Rachel Cabanilla, Sean Felise, April Goodson, Zach Johnson, Emily Lindstrum, Lydia Morales, Robin Lamson, and participants of "Block Party" drifter construction events for assistance. Captain Michael Childers, Gabe Hawelu, and Mike Pearson assisted with drifter releases. The suggestions of two reviewers greatly improved the manuscript. The authors especially wish to thank the many people who reported drifter recoveries.

References

Bly, L., May 17, 2012. Hawaii will be first state to ban disposable plastic bags. accessed September 14, 2012. USA Today on the web. **http://travel.usatoday.com**.

Brainard, R.E., Foley, D.G., Donohue, M.J., 2001. Origins, types, distribution and magnitude of derelict fishing gear. In Proceedings of the International Conference on Derelict Fishing Gear and the Ocean Environment. NOAA National Marine Sanctuaries.

Carson, H.S., Colbert, S.L., Kaylor, M.J., McDermid, K.J., 2011. Small plastic debris changes water movement and heat transfer through beach sediments. Marine Pollution Bulletin 62, 1708–1713.

Christie, M.R., Tissot, B.N., Albins, M.A., Beets, J.P., Jia, Y., Ortiz, D.M., Thompson, S.E., Hixon, M.A., 2010. Larval Connectivity in an Effective Network of Marine Protected Areas. PLoS ONE 5 (12), e15715. http://dx.doi.org/10.1371/journal.pone.0015715.

Cole, M., Lindeque, P., Halsband, C., Galloway, T.S., 2011. Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin 62, 2588–2597.

Donohue, M.J., 2005. Eastern Pacific Ocean source of Northwestern Hawaiian Islands marine debris supported by errant fish aggregating device. Marine Pollution Bulletin 50, 886–888.

Donohue, M.J., Boland, R., Sramek, C., Antonelis, G., 2001. Derelict fishing gear in the Northwestern Hawaiian Islands: diving surveys and debris removal in 1999 confirm threat to coral reef ecosystems. Marine Pollution Bulletin 42, 1301–1312.

Ebbesmeyer, C., Ingraham, W.J., Jones, J.A., Donohue, M.J., 2012. Marine debris from the Oregon Dungeness crab fishery recovered in the Northwestern Hawaiian Islands: identification and oceanic drift paths. Marine Pollution Bulletin 65, 69–75.

Garrity, S.D., Levings, S.C., 1993. Marine Debris along the Caribbean Coast of Panama. Marine Pollution Bulletin 26, 317–324.

Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings: entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philosophical Transactions of the Royal Society B: Biological Sciences 364, 2013–2025.

Howell, E.A., Bograd, S.J., Morishige, C., Seki, M.P., Polovina, J.J., 2012. On North Pacific circulation and associated marine debris concentration. Marine Pollution Bulletin 65, 16–22.

Jia, Y., Calil, P.H.R., Chassignet, E.P., Metzger, E.J., Potemra, J.T., Richards, K.J., Wallcraft, A.J., 2012. Generation of mesoscale eddies in the lee of the Hawaiian Islands. Journal of Geophysical Research-Oceans 116, 18.

Maximenko, N.A., Hafner, J., Niiler, P., 2012. Pathways of marine debris from trajectories of Lagrangian drifters. Marine Pollution Bulletin 65, 51–62.

Maximenko, N.A., Niiler, P., Rio, M.H., Melnichenko, O., Centurioni, L., Chambers, D., Zlotnicki, V., Galperin, B., 2009. Mean dynamic topography of the ocean derived from satellite and drifting buoy data using three different techniques. Journal of Atmospheric and Oceanic Technology 26, 1910–1919.

Maximenko, N.A., Hafner, J., 2010. SCUD: Surface CUrrents from Diagnostic model. International Pacific Research Center Technical Note 5, 17. **http://apdrc.soest.hawaii.edu/projects/SCUD/SCUD_manual_02_17.pdf**.

Moore, C.J., Lattin, G.L., Zellers, A.F., 2011. Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of Southern California. Journal of Integrated Coastal Zone Management 11, 65–73.

Parham, J.E., Higashi, G.R., Lapp, E.K., Kuamo'o, D.G.K., Nishimoto, R.T., Hau, S., Fitzsimons, J.M., Polhemus, D.A., Devick, W.S., 2008. Atlas of Hawaiian Watersheds & Their Aquatic Resources. **http://www.hawaiiwatershedatlas.com/index.html**, last accessed 06/2012.

Potemra, J.T., 2012. Numerical Modeling with Application to Tracking Marine Debris. Marine Polution Bulletin 65, 42–50.

Ryan, P.G., Moore, C.J., van Franeker, J.A., Moloney, C.L., 2009. Monitoring the abundance of plastic debris in the marine environment. Philosophical Transactions of the Royal Society B: Biological Sciences 364, 1999–2012.

Seco Pon, J.P., Becherucci, M.E., 2012. Spatial and temporal variations of urban litter in Mar del Plata, the major coastal city of Argentina. Waste Management 32, 343–348.

Thompson, R.C., Moore, C.J., vom Saal, F.S., Swan, S.H., 2009. Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B: Biological Sciences 364, 2153–2166.

Wiese, F.K., Jones, I.L., 2001. Experimental support for a new drift block design to assess seabird mortality from oil pollution. Auk 118, 1062–1068.

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OAHU DISTRICT
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IN REPLY REFER TO:

HWY-OW 2.16-0777

August 29, 2016

Dear Ladies and Gentlemen:

Subject: State of Hawaii, Department of Transportation, Highways Division (DOT-HWYS)
Oahu Municipal Separate Storm Sewer System (MS4) Permit
National Pollutant Discharge Elimination System (NPDES) No. HI S000001
Trash Reduction Plan

In accordance with the requirements of the DOT-HWYS MS4 NPDES Permit No. HI S000001, Part D.1.f.(1).(v), a draft Trash Reduction Plan has been developed.

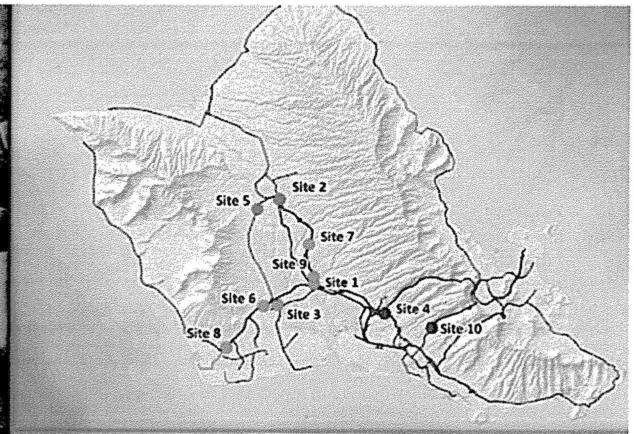
According to MS4 NPDES Permit Part A.6, the plan is required to be made available to the public on the DOT-HWYS website for a minimum of 30 calendar days for public review and comment.

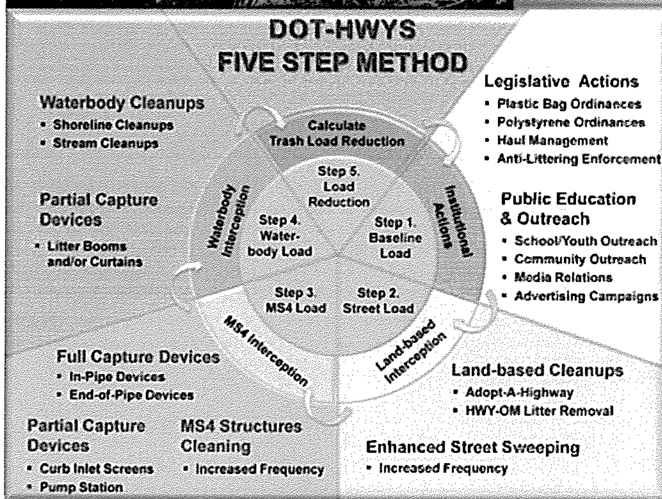
Persons wishing to comment upon the draft Trash Reduction Plan should submit their comments no later than 30 calendar days after the date of this notice. Please submit all comments as a word document attachment on our comment form (http://www.stormwaterhawaii.com/contact/) or email to info@stormwaterhawaii.com. All comments received on time will be considered.

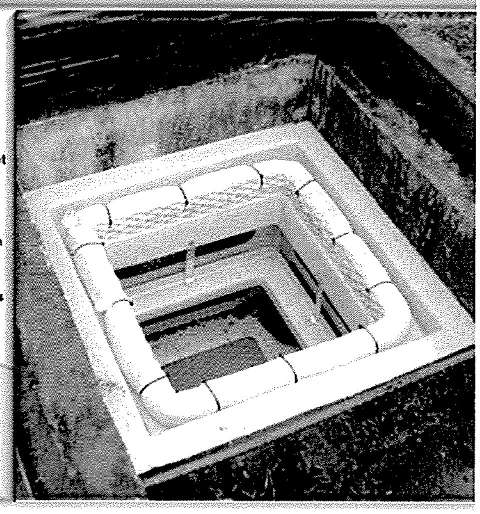
Should you have any questions, please contact Kelly Lee Sato of our DOT-HWYS, Oahu District Office at (808) 483-2569.

Sincerely,

Pratt M. Kinimaka
Oahu District Engineer







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Trash Reduction Plan

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NPDES Permit No. HI S000001

October 2016

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October 2016
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Public Review

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ACRONYMS AND ABBREVIATION

ADT	Average Daily Traffic
BMP	Best Management Practice
CCH	City and County of Honolulu
CWA	Clean Water Act
cy	Cubic Yard
DOH	State of Hawaii Department of Health
DOT-HWYS	State of Hawaii Department of Transportation, Highways Division, Oahu District
EDOP	Effective Date of the MS4 Permit
GIS	Geographic Information System
ha	Hectare
HoLIS	Honolulu Land Information System
HRS	Hawaii Revised Statute
HWY-OM	State of Hawaii Department of Transportation, Highways Division, Oahu District, Maintenance Section
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
PBMP	Permanent BMP
PSA	Public Service Announcements
RF	Reduction Formula
RC	Reduction Credit
ROW	Right-of-Way
ROH	Revised Ordinances of Honolulu
SWMP	Storm Water Management Program
SWMPP	Storm Water Management Program Plan
TMDL	Total Maximum Daily Load
TRP	Trash Reduction Plan
WLA	Waste Load Allocation
yr	Year

TERMINOLOGY

Area-specific (with regard to control measures or reductions): Control measures which are implemented *within defined areas* of the DOT-HWYS jurisdictional area (e.g., full capture treatment devices or street sweeping).

Area-wide (with regard to control measures or reductions): Control measures which are implemented throughout DOT-HWYS jurisdictional area (e.g., region-wide public education).

Baseline Implementation: The level of implementation for a specific trash control measure that forms the starting point for tracking progress towards trash load reduction.

Baseline Load: Sum of trash volume from DOT-HWYS jurisdictional areas and adjusted for baseline implementation of existing control measure.

Best Management Practices or Control Measures: Best Management Practices include any schedules of activity, prohibitions of practices, maintenance procedures [40 CFR § 122.2], as well as any technology, process, operational method or measure, or engineered system, which when implemented prevents, controls, removes, or reduces pollution/trash from entering waters of the United States.

Clean Water Act 303(d) List: Under Section 303(d) of the Clean Water Act, the States are required to compile a list of impaired waters that fail to meet any of their applicable water quality standards or cannot support their designated or existing uses. This "303(d) list" is submitted to Congress every two years, and States are required to develop a total maximum daily load (TMDL) for each pollutant causing impairment for waterbodies on the list.

Drainage Area: An area of land where all surface water from rain converges to a single point at a lower elevation.

Enhanced (with regard to control measures): New or expanded control measures which have been implemented *after* the effective date of the MS4 Permit (October 28, 2013) baseline year.

Effectiveness (with regard to control measure): A measure of how well a control measure reduces trash from entering the MS4.

Existing (with regard to control measures): Existing control measures which have been implemented *prior to* the effective date of the MS4 Permit (October 28, 2013) baseline year.

Full Trash Capture Devices: Full trash capture devices have removal efficiencies of 100% up to their intended design flow.

Geographical Targets: Trash management areas where the pollutant of concern is observed in high and very high quantities, and should be prioritized with future control measures.

Institutional Control Measures: Control measures that alter people's behavior, either through corrective actions, such as the implementation of new laws or better enforcement of existing ones; or preventive actions, such as Public Education and Outreach.

Interception (with regard to control measures): The process of removing trash with an *area-specific* or *area-wide* control measure.

Land-Based Interception Control Measures: Control measures that intercept trash on the streets and roadsides, such as *land-based trash cleanups* and *enhanced street sweeping*.

Litter: As defined in the Revised Ordinances of Honolulu Section 29-4.1, "litter" means rubbish, waste material, garbage, or trash; and includes improperly discarded paper, metal, plastic, glass or solid waste thrown or deposited on the land and water. Litter does not include non-manmade materials (such as branches, leaves, and other vegetation) naturally deposited in the waterbodies.

Moku: Land division that sections the island into districts.

Municipal Separate Storm Sewer System (MS4) Network: A conveyance including roads with drainage systems, catch basins, curbs, gutters, ditches, manmade channels, or storm drains that is designed or used for collecting or conveying storm water, that is not a combined sewer, and that is not part of a publicly owned treatment work [40 CFR 122.26(b)(8)].

MS4 Load: Volume of trash estimated to enter the MS4 through storm drain inlets. Volume of trash estimated to enter the MS4 after the implementation of *Institutional Control Measures* and *Land-Based Interception Control Measures*, and available for interception via *MS4 Interception Control Measures*.

MS4 Interception Control Measures: Control measures that intercept trash in the MS4, such as *full* and *partial* capture devices, or *enhanced MS4 structure inlet cleaning*.

Outfall: The discharge point of an MS4 to a receiving State waterbody; and does not include open conveyances connecting two MS4s, pipes, tunnels, or other conveyances which connect segments of the same stream or State waterbodies and are used to convey State waterbodies [40 CFR 122.26(b)(9)].

Partial Trash Capture Devices: Partial trash capture devices may be similar to full trash capture devices, but due to engineering challenges do not meet the full capture definition; or they may be completely different types of devices (e.g., trash booms or retractable curb inlet screens).

Reduction Credit: Institutional control measures, such as public education, can result in trash reductions but remain challenging to quantify. Therefore, trash load reduction credits were adopted for institutional control measures to reflect their trash reductions. The recommended theoretical percent reductions from the trash baseline load were derived from discussions amongst members of the Bay Area Stormwater Management Agencies Associations Trash Committee in California (BASMAA 2011).

Reduction Formula: Trash load reduction formulas are applied to land-based, MS4, and waterbody interception control measures, such as street sweeping and MS4 cleaning (BASMAA 2011). The application of the trash load reduction formulas relies on readily available information. In cases where information is very limited, assumptions are made and may be tested and revised accordingly as methods evolve.

State waterbodies: Natural waterbodies, such as streams, bays, and estuaries, which receive discharges from municipal storm water drainage systems.

Storm water: Runoff generated during rainfall events from roads and surfaces into the MS4.

Storm Drain Inlets: Part of the storm water drainage system where surface runoff enters the MS4.

Street Load: Volume of trash estimated to enter the environment after the implementation of *Institutional Control Measures*, and available for interception via *Land-Based Interception Control Measures.*

Trash: Manmade litter that cannot pass through a 5 mm mesh screen; excluding sediment, sand, vegetation, oil and grease, and exotic species (refer to Litter definition).

Trash Baseline Load: Total amount of trash that originates from DOT HWYS jurisdictional area and enters a waterbody during a given time (e.g., cubic yards of trash per year), prior to the implementation of enhanced or new control measures to target trash removal.

Trash Generation: Volume of trash that accumulates in a specific geographical area. Trash generated is the sum of trash loads and trash intercepted by control measures.

Trash Interception: Volume of trash intercepted through implementation of control measures (e.g., street sweeping).

Trash Impaired Watersheds: Waterbodies listed as impaired for trash on the State's Clean Water Act Section 303(d) list.

Trash Load: Total amount of trash discharged from the MS4 and entering a waterbody during a given time (e.g., cubic yards of trash per year).

Trash Load Reduction: The amount by which the trash load is reduced by implementing enhanced control measures.

Trash Loading Rates: The rate in cubic yards per hectare per year for a specific land use type at which trash is available to enter an MS4 outfall or waterbody.

Trash Management Areas: Delineation of DOT-HWYS ROW into six smaller management units to track trash control measure implementation, and assess progress towards trash reduction targets.

Trash Removal Efficiency (with regard to BMPs): A measurement that indicates how well a BMP system removes trash from a designated treated area.

Waterbody Load: Volume of trash discharge to a receiving State waterbodies from the MS4.

Water-Based Interception Control Measures: Control measures that intercept trash in streams or coastal waters, such as *Water-Based Trash Cleanups* or *Partial Capture Devices*.

EXECUTIVE SUMMARY

This Trash Reduction Plan (TRP) is submitted to satisfy Part D.1.f.(1)(v) of the State of Hawaii Department of Transportation, Highways Division, Oahu District (DOT-HWYS) National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit No. HI S000001, effective October 28, 2013, and modified April 1, 2016 (hereinafter MS4 Permit). The MS4 Permit requires DOT-HWYS to develop and submit a TRP within three years of the effective date of the MS4 Permit (October 28, 2016).This TRP intends to reduce trash discharged from the DOT-HWYS MS4 and its associated impacts on receiving State waterbodies to protect their associated beneficial uses.

The TRP includes the following six elements that describe how the MS4 Permit requirements will be met:

1. Quantification of DOT-HWYS trash baseline load.
2. Description of existing trash reduction control measures.
3. Presentation of trash load reduction calculation method.
4. Delineation of trash management areas and identification of key geographical targets for future enhanced control measures.
5. Presentation of an Implementation Schedule, which includes a Short-Term Plan and Long-Term Plan, to reduce trash load from the MS4 by 50% and 100% from the baseline, respectively.
6. Description of a monitoring plan to quantify trash load reductions.

DOT-HWYS conducted a literature review and a Trash Characterization Study to quantify the trash baseline load discharged from the MS4. The baseline year is 2013. The literature review identified and assigned preliminary trash loading rates to these eight key land use types present in the DOT-HWYS jurisdictional area: industrial, commercial and business, park land, agriculture, mixed use, and residential (low, moderate, and high density). DOT-HWYS conducted a Trash Characterization Study from May 2015 to May 2016, to evaluate whether the trash loading rates from the literature review were applicable to Hawaii. The Trash Characterization Study focused on residential high density, park land, and agriculture land use types that constitute the majority (> 85%) of DOT-HWYS jurisdictional area. The selected trash loading rates were extrapolated geographically to obtain a trash baseline load of 297 cubic yards per year for the entire DOT-HWYS jurisdictional area.

DOT-HWYS used historical data on trash removed by existing control measures and Geographic Information System tools to inform the development of this TRP and the proposed Implementation Schedule. DOT-HWYS will utilize a comprehensive suite of feasible Best Management Practices (BMPs), which include legislative actions, public education and outreach, land-based cleanups, street sweeping, and Permanent BMPs to reduce trash discharged from the MS4.

DOT-HWYS adapted a quantitative tracking method to document compliance with the required trash load reductions and avoid double counting. The DOT-HWYS Five Step Method applies a combination of two trash load reduction methods to the trash baseline load, and demonstrates trash load reductions attributable to specific control measures: 1) trash load reduction credits; and 2) trash load reduction formulas. Due to natural variability, DOT-HWYS will report compliance with required trash reduction goals using a three-year running average.

Given the geographical extent of DOT-HWYS ROW and the complexity of the MS4 network, DOT-HWYS conducted a Geographical Targets Analysis to define trash management areas and key geographical targets for future enhanced control measures, and attain the trash reduction targets in the shortest practicable timeframe.

The proposed Implementation Schedule consists of a Short-Term Plan and Long-Term Plan to meet the set trash reduction targets. The Short-Term Plan intends to meet a trash load reduction requirement of 50% from the baseline by 2023, through the implementation of new programs and enhancement of existing control measures, as described in the table below.

FIVE STEP METHOD	EXISTING AND FUTURE BMP PROGRAM	ENHANCEMENT	ANTICIPATED TRASH REDUCTION	
			CY/YR	PERCENTAGE
Step 1 Institutional Actions[1]	Legislative Action	Plastic Bag Ban	17.8	6.00%
	Existing Public Education	Targeted Outreach	5.9	2.00%
	Future Public Education	PSAs	8.9	3.00%
Step 2 Land-Based Interception	Land-Based Cleanups	Semiannual	91.0	30.64%
	Street Sweeping	Increase	14.4	4.84%
Step 3 MS4 Interception	Existing Permanent BMPs	16 ha	3.6	1.20%
	Future Permanent BMPs	30 ha	6.9	2.32%
Step 4 Waterbody Interception[2]	Not Applicable	N/A	0.0	0.00%
Step 5 Load Reduction	**TOTAL ANTICIPATED REDUCTION**		**148.5**	**50.00%**
		REDUCTION REQUIRED	**148.5**	**50.00%**

[1] These programs may result in trash load reductions on Oahu; however, reductions are not quantified at this time and therefore considered as percent reduction in this TRP (refer to Section 4.2 on Institutional Control Measures).
[2] DOT-HWYS does not anticipate using waterbody interception control measures at this time.

The Long-Term Plan intends to meet a trash load reduction requirement of 100% from the baseline by 2036, through the implementation of new programs and enhancement of existing control measures. The Long-Term Plan development will rely on an assessment of data collected during the Short-Term Plan implementation.

DOT-HWYS will utilize a combination of existing monitoring procedures, as described in the current *Storm Water Management Program Plan (SWMPP),* and a Visual Trash Rapid Assessment to provide an evaluation of trash conditions and effectiveness of control measures.

1. INTRODUCTION

1.1 DOT-HWYS NPDES Permit

This Trash Reduction Plan (TRP) is submitted to satisfy Part D.1.f.(1)(v) of the State of Hawaii Department of Transportation, Highways Division, Oahu District (DOT-HWYS) National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit No. HI S000001, effective October 28, 2013, and modified April 1, 2016 (hereinafter MS4 Permit). The MS4 Permit requires DOT-HWYS to develop and submit a TRP within three years of the effective date of the MS4 Permit (October 28, 2016).

Table 1 describes how the specific MS4 Permit requirements are addressed in the TRP Sections.

Table 1. MS4 Permit requirements.

MS4 PERMIT REQUIREMENTS	TRP SECTIONS
Part D.1.f.(1)(v) Trash Reduction Plan – *Within three (3) years after the effective date of this permit, the Permittee shall develop and submit to DOH for review and acceptance, a trash reduction plan which assesses the issue, identifies and implements control measures, and monitor these activities to reduce trash loads from the MS4. The plan shall include, at a minimum and be formatted consistent with the following:*	
Quantitative estimate of the debris currently being discharged (baseline load) from the MS4, including methodology used to determine the load.	Section 2
Description of control measures currently being implemented as well as those needed to reduce debris discharges from the MS4 consistent with short-term and long-term reduction targets.	Section 3 & 4
A short-term plan and proposed compliance deadline for reducing debris discharges from the MS4 by 50% from the baseline load.	Section 6.3
A long-term plan and proposed compliance deadline for reducing debris discharges from the MS4 to zero.	Section 6.4
Geographical targets for trash reduction activities with priority on water bodies listed as impaired for trash on the State's Clean Water Act (CWA) Section 303(d) list.	Section 5
Trash reduction-related education activities as a component of Part D.1.a.	Section 4.2.2
Integration of control measures, education and monitoring to measure progress toward reducing trash discharges.	Section 4.2.2 & 6
An implementation schedule.	Section 6
Monitoring plan to aid with source identification and loading patterns as well as measuring progress in reducing the debris discharges from the MS4.	Section 7
The Annual Report shall include a summary of its trash load reduction actions (control measures and best management practices) including the types of actions and levels of implementation, the total trash loads and dominant types of trash removed by its actions, and the total trash loads and dominant types of trash for each type of action.	Section 7.3
The plan shall provide for compliance with the above short-term and long-term discharge limits in the shortest practicable timeframe.	Section 6

1.2 Definitions, Sources, Pathways, and Drivers

For the purpose of this TRP, "debris" is considered analogous to litter and trash (> 4.75 millimeter) as defined in the Revised Ordinances of Honolulu (ROH), but excluding sediment, sand, vegetation, oil and grease, and exotic species. The ROH Section 29-4.1 defines "litter" as rubbish, waste material, garbage, or trash; and includes improperly discarded paper, metal, plastic, glass or solid waste. Litter also includes "refuse", as defined in the ROH Section 29-1.1, as all solid wastes, such as animal feces, garbage, rubbish, ashes, street cleanings, dead animals, abandoned automobiles, and solid market and industrial wastes capable (or not) of decaying.

Previous studies concluded that trash composition, deposition in the environment and transportation to waterbodies are highly variable, and likely depend on both anthropogenic and natural factors (Armitage and Rooseboom 1999, County of Los Angeles 2004). Trash originates from automobiles and uncovered loads; inadequate waste management, such as overflowing containers; and dispersion of household and business-related trash, before, during, and after trash collection. Once trash enters the environment, it can deposit on roadways and street surfaces, and be transported by the wind or through the MS4 to receiving State waterbodies. The volume of trash discharged from MS4s is influenced by land use type, population density, existing control measures, and climatic conditions (Marais et al. 2004, BASMAA 2012).

1.3 Characteristics DOT-HWYS Right-of-Way and MS4 Network

DOT-HWYS owns and operates approximately 250 miles of highways covering 2,031 hectares on Oahu in terms of Right-of-Way (ROW). The DOT-HWYS MS4 network is complex and consists of the following key structures to drain storm water from highway surfaces:

- 8,133 Inlets
- 1,588 Manholes
- 1,387 Outfalls
- 872 Culverts Entrances
- 868 Culverts
- 629 or 33 miles of Open Channels
- 7,421 or 150 miles of Pipes

Figure 1 shows the DOT-HWYS ROW map on Oahu with an inset of the MS4 network.

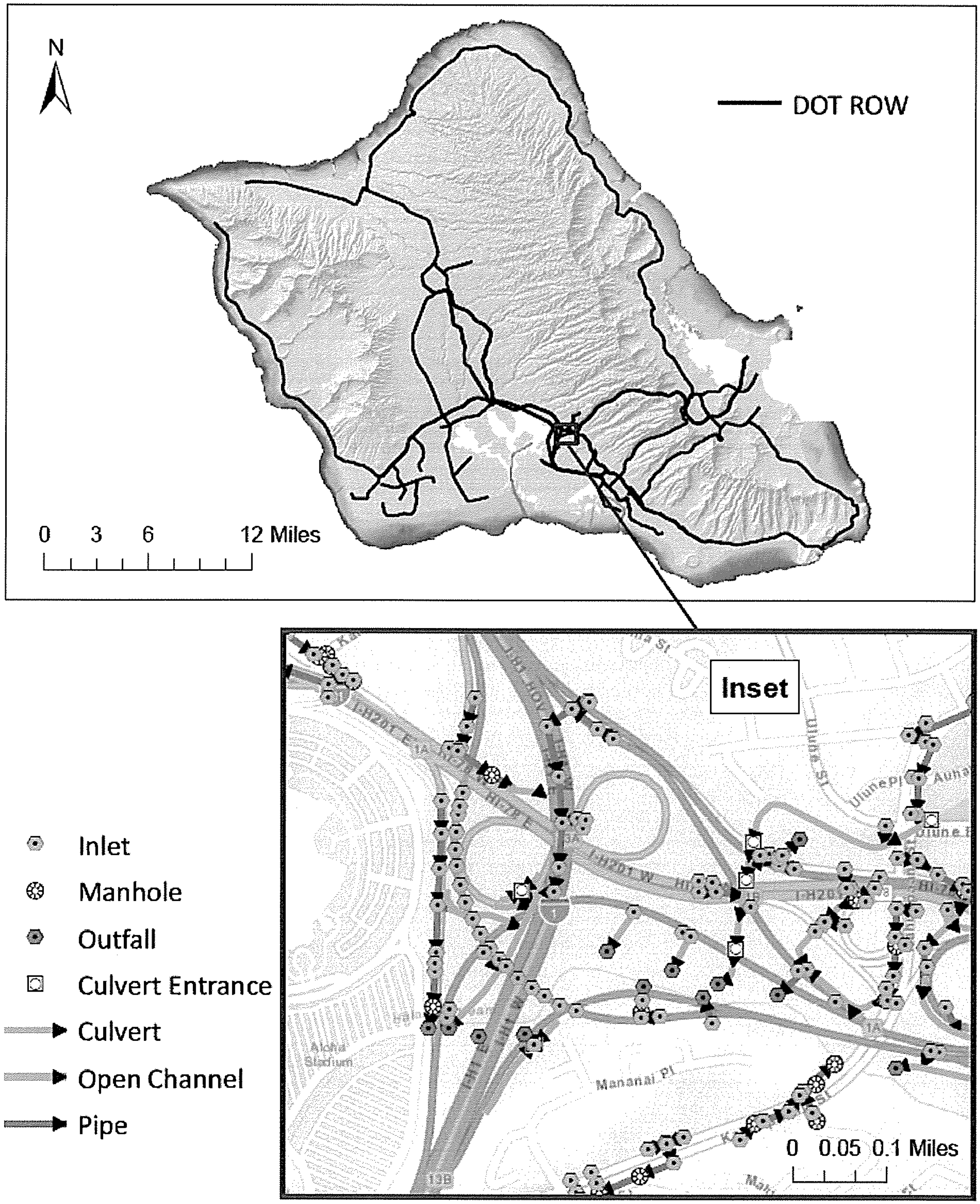


Figure 1. DOT-HWYS ROW map and inset of the MS4 network.

1.4 Trash Reduction Plan Overview

The TRP includes the following six elements that describe how the MS4 Permit requirements will be met:

1. Quantification of DOT-HWYS trash baseline load.
2. Description of existing trash reduction control measures.
3. Presentation of the trash load reduction calculation method.
4. Delineation of trash management areas and identification of key geographical targets for future enhanced control measures.
5. Presentation of an Implementation Schedule, which includes a Short-Term Plan and Long-Term Plan, to reduce trash load from the MS4 by 50% and 100% from the baseline, respectively.
6. Description of a monitoring program to quantify and track trash load reductions.

This TRP focuses on reducing trash discharged from the DOT-HWYS MS4 and its associated impacts on receiving State waterbodies to protect their associated beneficial uses.

2. DOT-HWYS TRASH BASELINE LOAD

DOT-HWYS conducted a literature review and a Trash Characterization Study to quantify the trash baseline load. The literature review identified and assigned preliminary trash loading rates to the eight key land use types present in the DOT-HWYS jurisdictional area: industrial, commercial, park land, agriculture, mixed use, and residential (low, moderate, and high density). DOT-HWYS conducted a yearlong Trash Characterization Study from May 2015 to May 2016 to evaluate whether the trash loading rates from the literature review were applicable to Hawaii. The Trash Characterization Study focused on the three land use types (residential high density, park land, and agriculture), which constitute the majority (> 85%) of DOT-HWYS jurisdictional area. Data from the literature review and the Trash Characterization Study were then extrapolated geographically to derive the trash baseline load for the entire DOT-HWYS ROW.

2.1 Trash Baseline Load Quantification Method

Key land use types within DOT-HWYS jurisdictional area were defined and their associated trash loading rates were quantified. The DOT-HWYS trash baseline load was calculated by multiplying the total area of each land use type by its trash loading rate, using the following equation (adapted from Armitage and Rooseboom 1999):

$$L = \sum_{i}^{n} (Lr_i A_i)$$

Equation 1. Calculation of Trash Baseline Load.

where:

- L = Trash baseline load discharged from the MS4 (cy/yr)
- i = Total number of land use types
- Lr_i = Average annual trash loading rate (cy/ha-yr) for land use type i
- A_i = Total area of land use type i (ha)

2.1.1 Land Use Types Definition

DOT-HWYS utilized the Honolulu Land Information System (HoLIS) zoning layer that geographically delineates Oahu into 36 classes. DOT-HWYS reclassified the HoLIS zoning layer into eight practical key land use types for calculating trash loads.

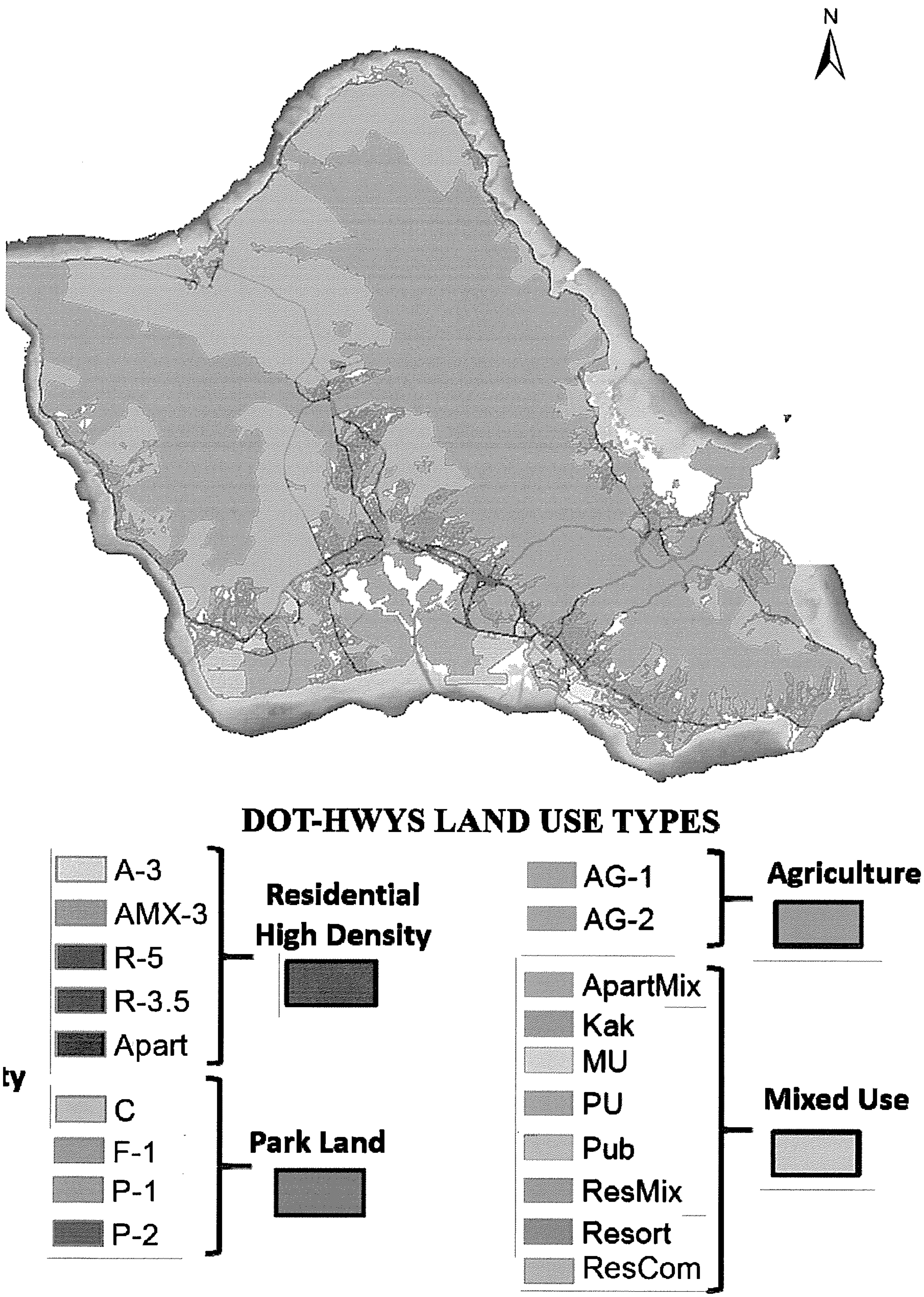
Table 2 describes these eight land use types and the corresponding HoLIS zoning classes in terms of total area and relative percent within DOT-HWYS jurisdictional area.

Table 2. Total area and relative percent of land use types within DOT-HWYS jurisdictional area.

Land Use Type	HoLIS Zoning Classes	Area (ha)	% Area
Industrial	I-1, I-2, I-3, IMX-1, Waterfront Industrial Precinct	46.93	2.31%
Commercial and Business	B-1, B-2, BMX-3, BMX-4, Aloha Towers Project	56.18	2.77%
Residential Low Density	A-1, AMX-1, R-10, R-20	81.43	4.01%
Residential Moderate Density	A-2, AMX-2, R-7.5	64.04	3.15%
Residential High Density	A-3, AMX-3, R-5, R-3.5, Apartment Precinct	602.60	29.66%
Park Land	C, F-1, P-1, P-2	552.40	27.19%
Agriculture	AG-1, AG-2	617.00	30.37%
Mixed Use*	Apartment Mixed Use Sub-precinct, Kakaako Community Development District, Mixed Use Precinct, Public Use Precinct, Public Precinct, Resort Mixed Use Precinct, Resort, Resort Commercial Precinct	10.89	0.54%
TOTAL		**2,031.47**	**100.00%**

**Land use that includes a mix of Industrial, Commercial, and Residential (low, moderate, and high density) land use types.*

Figure 2 shows the HoLIS zoning layer and the reclassified eight key land use types on Oahu.


N
DOT-HWYS LAND USE TYPES
A-3
AMX-3
R-5
R-3.5
Apart
Residential High Density
C
F-1
P-1
P-2
Park Land
AG-1
AG-2
Agriculture
ApartMix
Kak
MU
PU
Pub
ResMix
Resort
ResCom
Mixed Use

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2.1.2 Quantification of Trash Loading Rates

The trash loading rates for the eight land use types in DOT-HWYS jurisdictional area were derived from both a literature review and the Trash Characterization Study.

2.1.2.1 Literature Review

Trash loading rates for the eight land use types were obtained from a literature review of trash baseline studies around the world with similar climate, geographical proximity, and regulatory management as Hawaii (e.g., California). Trash loading rates from selected studies were averaged, or converted to provide a single trash loading rate per land use type, in cubic yards per hectare (BASMAA 2011, 2012, 2014a, 2014b, 2014c; Black & Veatch 2013; and Cornelius et al. 1994).

Table 3 summarizes the trash loading rate values per land use type derived from the literature review.

Table 3. Trash loading rates per land use type derived from the literature review.

Land Use Types	Average Trash Loading Rates (CY/HA-YR)
Industrial[1]	0.145
Commercial and Business[1]	0.103
Residential Low Density[1]	0.019
Residential Moderate Density[2]	0.530
Residential High Density[1]	0.128
Park Land[3]	0.140
Agriculture[4]	0.044
Mixed Use[5]	0.185

[1] *Average of the mean values from studies in Auckland, New Zealand (Cornelius et al. 1994); Los Angeles (Black & Veatch 2013); and San Francisco, Oakland, San Leandro, Sunnyvale, and Vallejo (BASMAA 2011, 2012, 2014a, 2014b, 2014c).*

[2] *Mid-point between lower and higher values of the Residential land use loading rate range from studies in Oakland, San Leandro, Sunnyvale, and Vallejo (BASMAA 2012, 2014a, 2014b, 2014c).*

[3] *90th percentile of the Urban Park loading rate from studies in San Francisco, Oakland, San Leandro, Sunnyvale and Vallejo (BASMAA 2011, 2012, 2014a, 2014b, 2014c).*

[4] *Value from Los Angeles study (Black & Veatch 2013).*

[5] *Average trash loading rates from Industrial, Commercial, and Residential (low, moderate, and high density) land use types.*

2.1.2.2 Trash Characterization Study

The Trash Characterization Study focused on the three land use types (residential high density, park land, and agriculture) that constitute the majority (> 85%) of DOT-HWYS jurisdictional area. The methodology to evaluate whether the trash loading rates from the literature review were applicable to Hawaii required the following process: Site Selection; Data Collection; Trash Characterization; and Calculation of Trash Loading Rates.

A. Site Selection

Ten sampling sites were selected according to land use type, average daily traffic (ADT) volume, drainage area, and accessibility criteria.

Land Use. The land use types of residential high density, park land, and agriculture were selected for the Trash Characterization Study as these land use types constituted the majority (> 85%) of DOT-HWYS jurisdictional area.

Average Daily Traffic Volume. Sampling sites were selected in varying traffic volume areas as literature studies show a high correlation between levels of trash along highway segments and ADT volumes (CalTrans 2003).

Drainage Area. Sampling sites were specifically selected in areas of DOT-HWYS ROW which had a contributing drainage area of at least one acre. The drainage area for each sampling site was delineated using a Geographic Information System (GIS). The drainage area of each sampling site was assumed to consist of homogeneous land use to calculate the trash loading rate for each land use type (i.e., composed of a single land use type).

Accessibility. Sampling sites were placed at outfall locations that allowed for safe accessibility for weekly inspections and maintenance. By placing the sample sites at outfall locations, DOT-HWYS measured trash loading rates that account for existing control measures.

Figure 3 shows the location of the ten sample sites of Trash Characterization Study

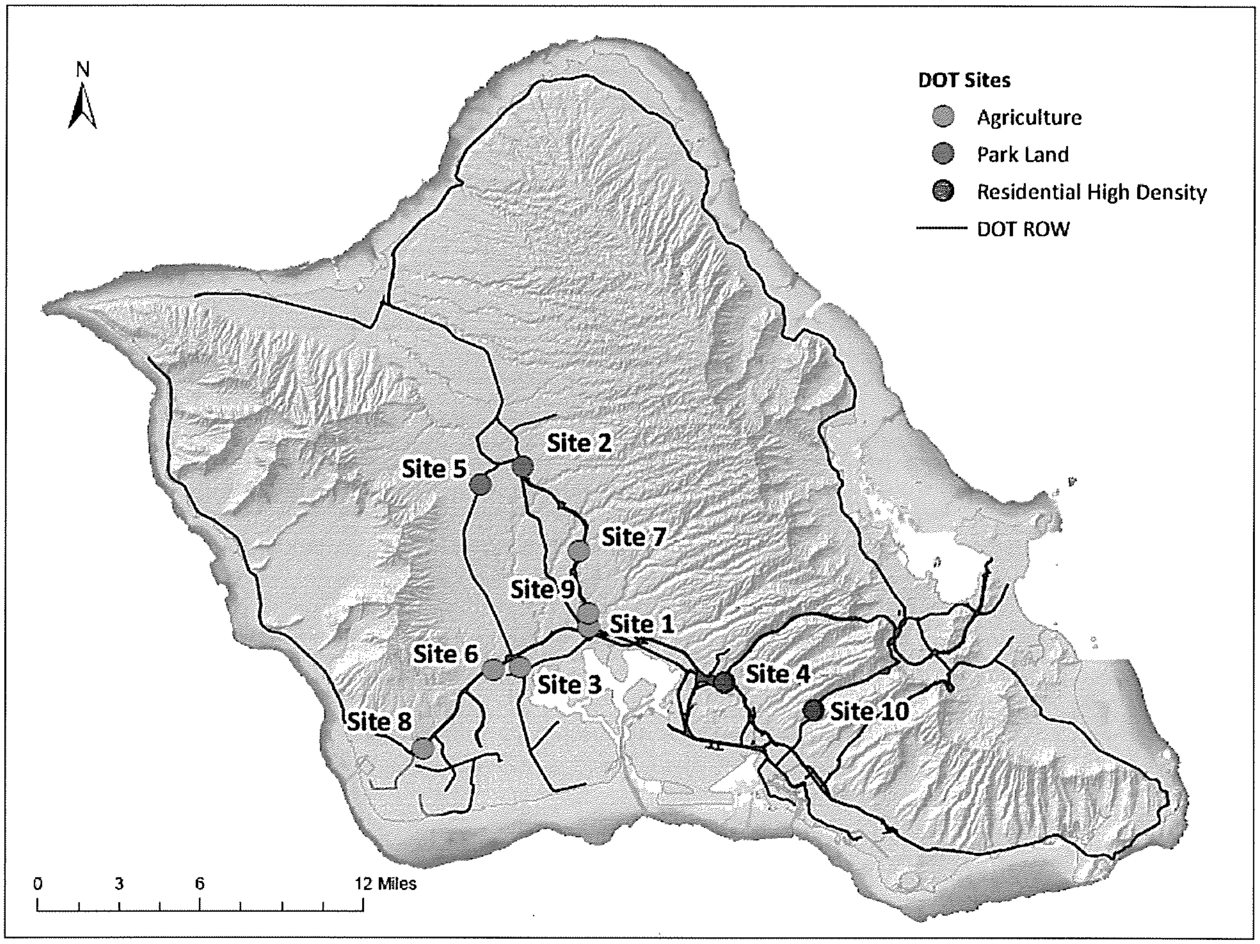

Figure 3. Trash Characterization Study sampling sites location.

Table 4 describes the 10 Trash Characterization Study sampling site locations, land use types, the annual ADT volumes, and the contributing drainage areas.

Table 4. Description of Trash Characterization Study sampling sites.

SITE #	ROUTE #	DESCRIPTION	MILE POST	LAND USE TYPE	ANNUAL ADT	DRAINAGE AREA (HA)
1	H2	Eastbound *(left)*	8.45	Agriculture	62,463	28.72
2	H2	Inbound *(right)*	7.85	Park Land	45,148	2.86
3	76	South *(right)*	6.30	Agriculture	29,408	9.15
4	H1/78	Westbound *(right)*	3.35	Residential High Density	81,261	5.51

SITE #	ROUTE #	DESCRIPTION	MILE POST	LAND USE TYPE	ANNUAL ADT	DRAINAGE AREA (HA)
5	H1/750	Southbound *(right)*	5.90	Park Land	47,254	17.14
6	H1	Eastbound *(right)*	4.60	Agriculture	107,800	9.79
7	H2	Outbound *(median)*	7.85	Agriculture	91,547	1.45
8	H1	Eastbound *(right)*	0.55	Agriculture	49,254	4.02
9	H2	Outbound *(right)*	0.90	Agriculture	98,952	1.52
10	63	Inbound *(right)*	2.70	Residential High Density	30,000	0.55

Figure 4 provides an example of a typical trash trap.

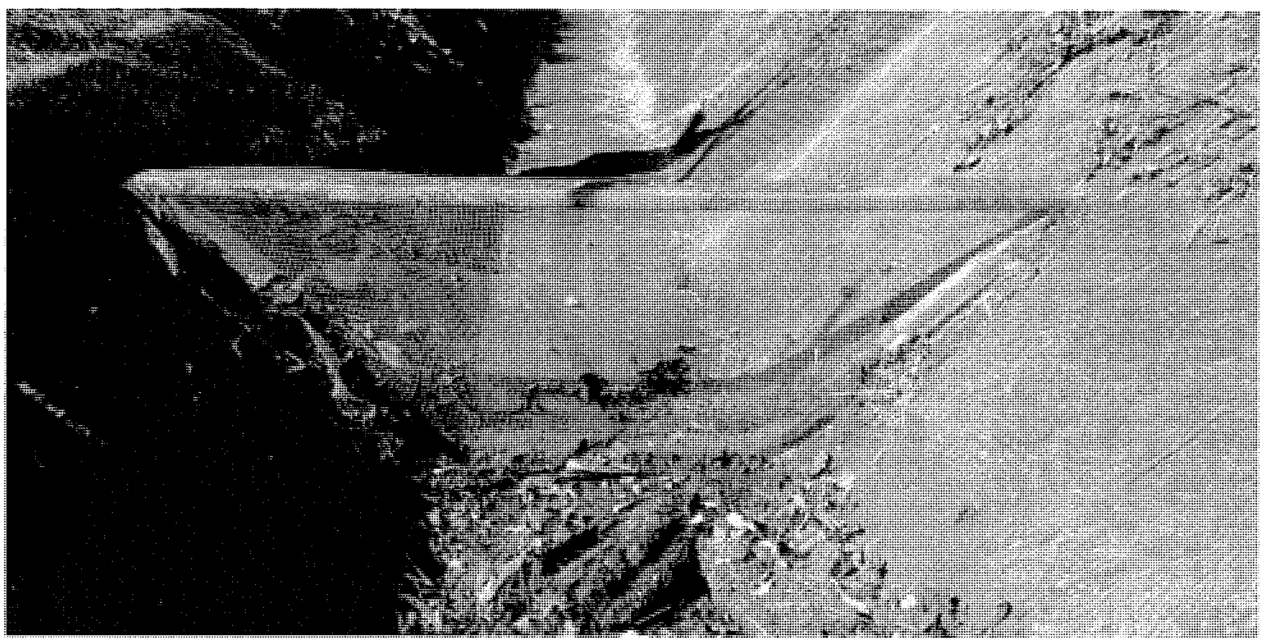

Figure 4. Trash trap located at Site #3.

B. Data Collection

The Trash Characterization Study collected organic debris and trash samples from the 10 sites between May 2015 and May 2016 to account for any seasonal variability. The sampling sites were inspected on a weekly basis or within 24 hours of any rainfall event greater than 1 inch. Inspected traps less than 50% full received cleaning within 90 calendar days. Inspected traps more than 50% full received cleaning within a week of the inspection.

During the cleaning events, the accumulated material was separated into organic debris and trash material. The volumes of organic debris and trash were recorded. Trash samples were stored for further characterization. Overall, organic debris represented the majority of material accumulated at the sample sites.

Figure 5 describes the total volume of organic debris and trash accumulated over the course of the yearlong study, standardized by drainage area.

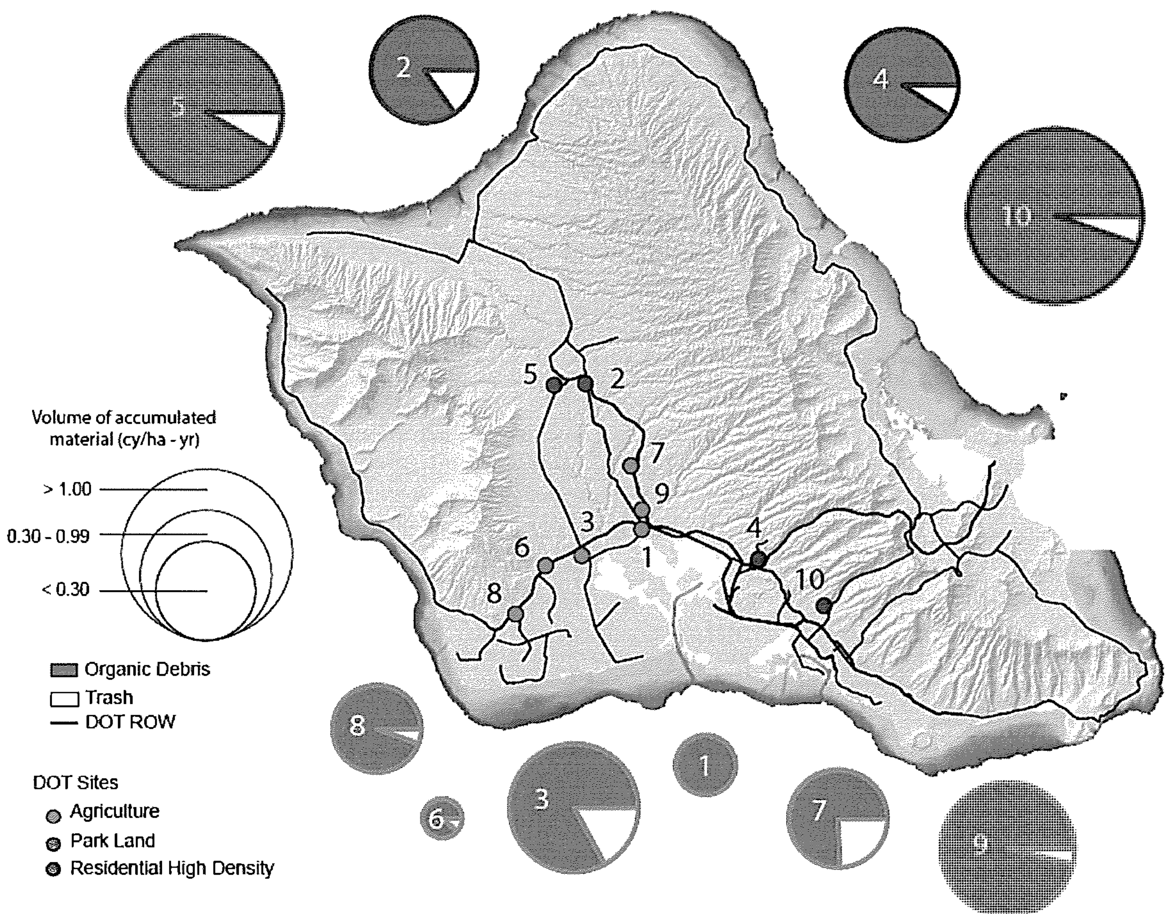

Figure 5. Volume of both organic debris and trash accumulated at each sample site.

C. Trash Characterization

Over the course of this yearlong study (May 2015 and May 2016), a total of 67 trash samples were collected, sorted, and characterized according to the following 7 categories:

- Single-use plastic bags and packaging
- Polystyrene foam (Styrofoam)
- Cigarette butts
- Metal
- Paper
- Recyclable beverage containers
- Miscellaneous

After sorting the trash samples into appropriate categories, the weight and volume of the materials were recorded.

Table 5 describes the trash composition for each site in terms annual volume standardized by drainage area.

Table 5. Trash composition in volume (x 10^{-3} cy/ha-yr) per sample site.

SITE #	PLASTIC BAGS AND PACKAGING	POLYSTYRENE FOAM	CIGARETTE BUTTS	METAL	PAPER	RECYCLABLE BEVERAGE CONTAINERS	MISCELLANEOUS
1	0.19	0.00	0.00	0.00	0.00	0.00	0.00
2	31.15	0.90	0.55	0.39	5.98	0.99	12.92
3	63.28	4.64	0.01	10.53	39.32	7.86	30.33
4	29.97	1.37	1.66	0.47	7.23	1.27	0.29
5	43.67	1.17	0.03	2.72	37.06	1.87	85.04
6	0.23	0.04	0.00	0.30	0.00	0.00	0.00
7	43.68	0.81	0.00	0.00	2.39	2.50	12.75
8	4.80	1.40	0.00	0.41	1.69	0.00	0.00
9	18.01	0.10	0.00	1.35	3.27	8.81	8.00
10	146.99	0.48	0.09	0.00	34.82	25.26	7.20

Figure 6 shows the trash volume and composition at each sample site.

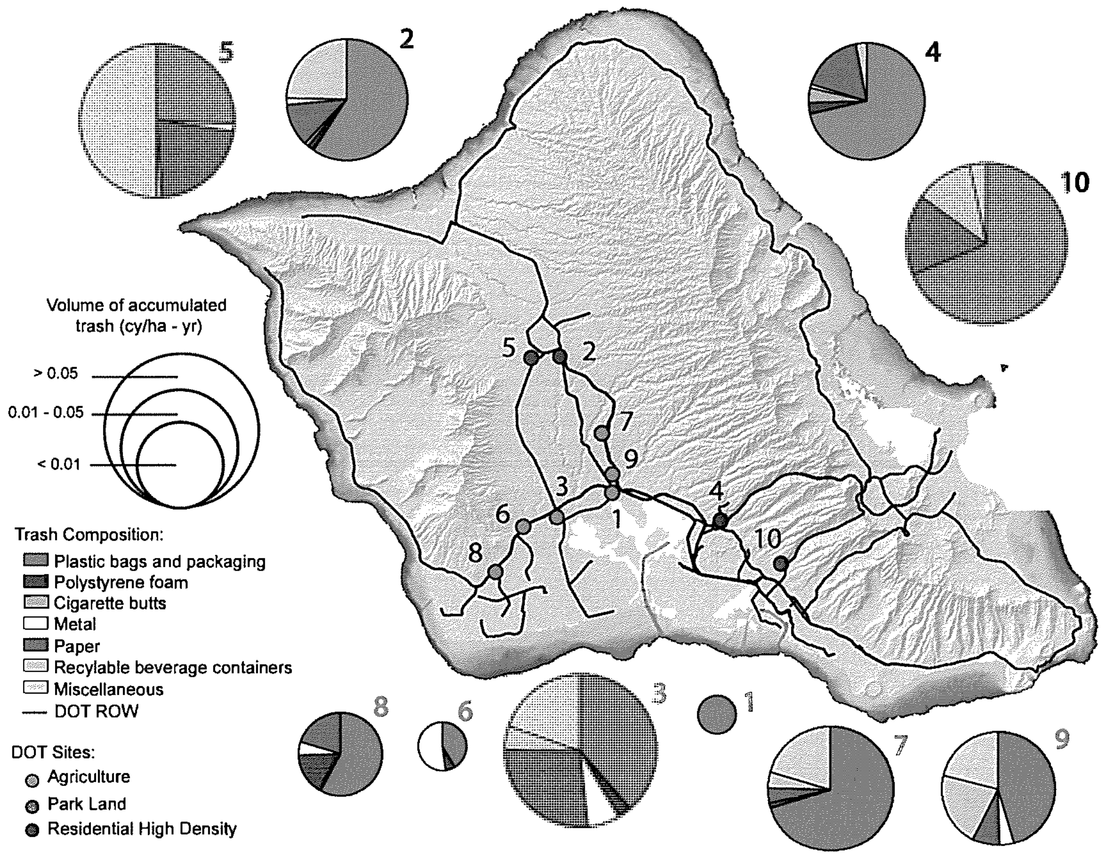

Figure 6. Trash volume and composition at each sample site.

D. Calculation of Trash Loading Rates

Trash loading rates at each sample site were standardized by drainage area, as shown in Equation 2.

$$Lr_i = \frac{(T_i / d_i)}{DA_i} \times 365$$

Equation 2. Calculation of trash loading rates per sample site.

where:

Lr_i = Annual trash loading rate (cy/ha-yr) of sample site *i*

T_i = Trash volume accumulated per sample site *i* (cy)

d_i = Number of days since the last cleaning of sample site

DA_i = Contributing drainage area of sample site *i* (ha)

Annual trash loading rates per sample site were averaged by land use type, as shown below:

- Residential high density trash loading rate: **0.187** cubic yards per hectare
- Park land trash loading rate: **0.194** cubic yards per hectare
- Agriculture trash loading rate: **0.044** cubic yards per hectare

The Trash Characterization Study yielded trash loading rates for residential high density, park land, and agriculture land use types, within the range of the values identified in the literature review. For this reason, DOT-HWYS adopted these locally derived values and used the literature values for the remaining five land use types to calculate the trash baseline load for the ROW. Due to the variability observed in the data, the trash loading rates presented in this plan should be considered preliminary estimates.

2.2 DOT-HWYS Trash Baseline Load

DOT-HWYS utilized the eight land use types and their respective trash loading rates, derived from the literature review and the Trash Characterization Study, to calculate the DOT-HWYS trash baseline load. DOT-HWYS utilized Equation 1 to obtain the annual trash load of each land use type. The annual trash loads of the eight key land use types were summed to provide a trash baseline load for DOT-HWYS of **297 cubic yards per year** (rounded to the nearest integer).

Table 6 summarizes DOT-HWYS key land use types, areas, associated trash loading rates and resulting trash loads.

Table 6. DOT-HWYS ROW land use types, areas, associated trash loading rates, and trash baseline loads.

Land Use Types	Areas (HA)	Trash Loading Rates (CY/HA-YR)	Annual Trash Load (CY/YR)
Industrial	46.93[a]	0.145[b]	6.81
Commercial and Business	56.18[a]	0.103[b]	5.79
Residential Low Density	81.43[a]	0.019[b]	1.55
Residential Moderate Density	64.04[a]	0.530[b]	33.94
Residential High Density	602.60[a]	0.187[c]	112.69
Park Land	552.40[a]	0.194[c]	107.17
Agriculture	617.00[a]	0.044[c]	27.15
Mixed Use	10.89[a]	0.197[d]	2.15
TOTAL DOT-HWYS TRASH BASELINE LOAD			**297.25**

[a] Values derived from Table 2.
[b] Values derived from literature review (refer to Table 3).
[c] Values derived from DOT-HWYS Trash Characterization Study.
[d] Average trash loading rates of Industrial, Commercial, and Residential (low, moderate, and high density) land use types.

3. EXISTING TRASH CONTROL MEASURES

This section describes the control measures that DOT-HWYS implemented prior to the baseline year (2013) to manage storm water runoff, and therefore current levels of BMP implementation are considered part of the baseline. DOT-HWYS currently utilizes the following control measures:

- Institutional control measures that include legislative actions and public education and outreach.
- Land-based interception control measures that include HWY-OM Litter Removal and Disposal Program, Adopt-A-Highway cleanups, and street sweeping.
- MS4 interception control measures that include MS4 cleaning and Permanent BMPs.

These BMP programs are implemented to reduce trash discharges from the DOT-HWYS MS4 to receiving State waterbodies. Due to the inherent variability in monitoring and measuring trash generation and accumulation in the environment, DOT-HWYS used a three-year running average to estimate current trash removal from existing control measures. These control measures are also discussed in more detail in the comprehensive State of Hawaii Department of Transportation, Highways Division, Oahu District *Storm Water Management Program Plan* (SWMPP).

3.1 Institutional Control Measures

Institutional control measures prevent or reduce the potential of trash to be deposited into the environment. DOT-HWYS utilizes two types of institutional control measures:

- Corrective measures, such as legislative actions.
- Preventive measures, such as public education.

3.1.1 Legislative Actions

Legislative actions correct societal behavior through the creation of new laws, improved enforcement, and compliance with existing laws. DOT-HWYS trash reduction efforts benefit from several existing laws aimed at reducing the amount of trash entering the environment.

Anti-Littering and Illegal Dumping Enforcement. The HRS § 291C-131 addresses spilling loads on highways, HRS § 291C-132 addresses littering from vehicles, and HRS § 339 addresses littering in public and private areas. Penalties for violation of any of these provisions may include fines, community service, and suspension of license and registration.

The criminal littering law HRS § 708-829 addresses illegal littering in any public or private property or waterbody, except in places designated by the Department of Health or the CCH for the disposal of garbage and refuse. This law is cross-referenced in HRS § 291C-131 and HRS § 291C-132 for Highways, and Litter Control HRS § 339-1 to 11.

The ROH Chapter 29, Article 4 on Litter Control is an enforcement authority for litter control; and states that any person who witnesses the disposal of litter in violation of this ordinance, may report the date, time of day, license number, and location of the littering from the vehicle, which shall constitute *prima facie* evidence.

3.1.2 Public Education and Outreach Program

The Public Education and Outreach Program (Public Education Program) increases the general public's awareness about how daily activities affect storm water runoff quality and prevent trash from entering the environment.

3.1.2.1 School and Youth Outreach

DOT-HWYS has a long-standing partnership with the Department of Education which continues to be mutually beneficial. Elementary school-aged children are the best target audience to influence long-term change because they are able to take home the lessons learned, and share them with their family.

Currently, as a part of the Public Education Program, DOT-HWYS actively engages these students through school presentations, and provides an average of five events per year. The school presentations include a PowerPoint presentation, a "Find the Storm Water Pollutants" worksheet, and a hands-on demonstration with a storm water inlet model.

3.1.2.2 Community Outreach

Community outreach activities provide opportunities for hands-on learning and fun educational experiences for a variety of target groups. Communities actively involved at events are more likely to commit to sustainable activities at their workplace and at home.

Events are regularly held in partnership with various organizations throughout the year, and DOT-HWYS provides an average of 10 events per year. Participation at past events proved to be an effective way to deliver the Program's message, and increase storm water awareness and education. Typical event activities include an interactive storm water model, prize wheel, photo booth, survey, and the distribution of education material.

In general, events are targeted in waste load allocation (WLA) watersheds, to engage audiences likely to have a direct impact on DOT-HWYS ability to meet its WLA reduction requirements.

3.1.2.3 Advertising Campaigns

Advertising is an effective means to generate awareness through placement of advertisements in mediums to reach a broader audience. Public Services Announcements (PSAs) are a constructive way to use television or radio airtime to raise public awareness about storm water.

DOT-HWYS has both television and radio Public Services Announcements in stock, and continues to explore both paid and free options to air the PSAs on a biannual basis.

3.1.2.4 Media Relations

Mass media formats are cost-effective and efficient alternatives to deliver DOT-HWYS message. Opportunities for media coverage include informational news stories, human interest stories, guest commentaries, and social media. Expansion of media coverage through a planned, proactive approach can help build and support new attitudes and changes in behavior.

In general, DOT-HWYS actively promotes creative story angles to obtain editorial coverage in local print, broadcast, and online media. The news media has focused on reaching both targeted and broad audiences, and communicating about watershed messages to support meeting the WLA reduction requirements.

3.2 Land-Based Interception Control Measures

Once trash enters the environment, it may be intercepted and removed through land-based interception control measures prior to reaching the MS4 network. Land-based trash cleanups include those conducted by DOT-HWYS Oahu District Maintenance Section (HWY-OM) or volunteer-based programs, and street sweeping control measures.

3.2.1 Land-Based Trash Cleanup Programs

Land-based cleanups are currently conducted by HWY-OM or volunteer-based programs.

<u>HWY-OM Litter Removal & Disposal Program</u>. HWY-OM implements a Litter Removal and Disposal Program that maintains and cleans the State highways.

The HWY-OM Litter Removal and Disposal Program removes an average of 11,300 cubic yards of trash, based on data from 2013 to 2015 (see Figure 7). Higher levels of trash removal occur along the south shore and west side of Oahu.

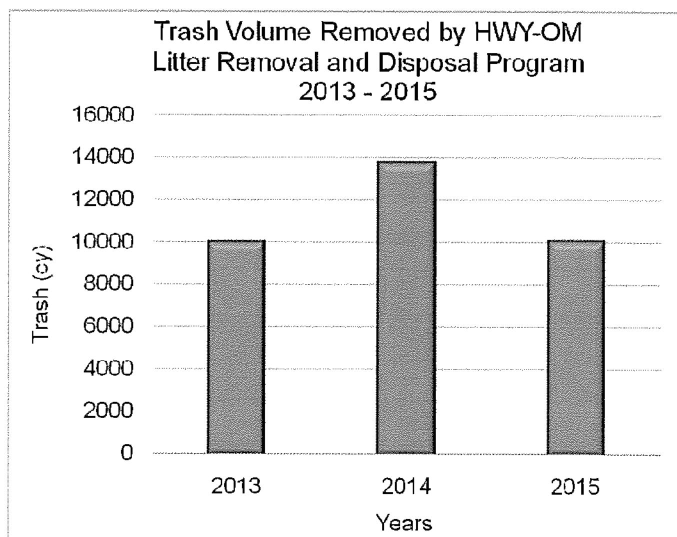

Figure 7. Total volume of trash removed by HWY-OM Litter Removal and Disposal Program on Oahu, 2013-2015.

Adopt-A-Highway Program.

DOT-HWYS sponsors an Adopt-A-Highway Program for volunteers from organizations to remove trash along State highways. Adopt-A-Highway groups agree to adopt a two-mile portion of a State highway for a minimum of two years, and remove trash at least four times a year. DOT-HWYS provides all safety materials and trash bags, schedules trash pickups, and erects highway signs to recognize the organizations cleaning efforts.

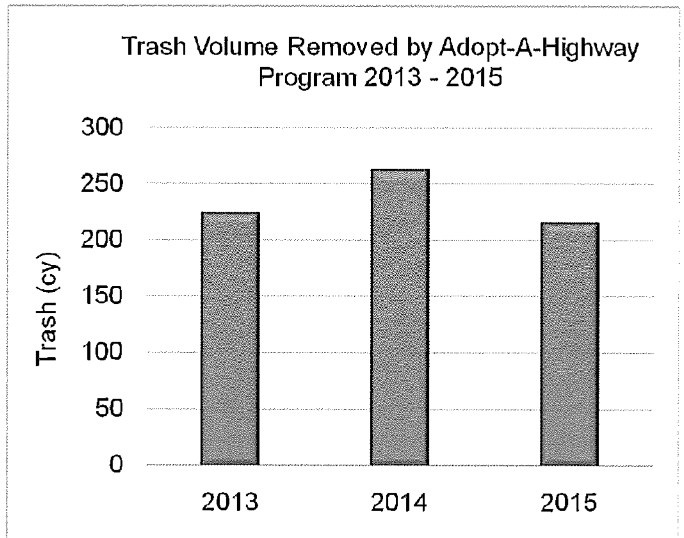

Figure 8. Total volume of trash removed by Adopt-A-Highway Program on Oahu, 2013-2015.

The Adopt-A-Highway Program removes on average 233 cubic yards of trash, based on data from 2013 to 2015 (see Figure 8). In general, higher levels of trash removal occur near densely populated areas such as Haleiwa, Waianae, Laie, Kapolei, Honolulu, Waimanalo, and Kaneohe.

Since January 2013, there have been 104 Adopt-A-Highway groups responsible for cleaning over 200 miles of highways around Oahu, as shown in Figure 9.

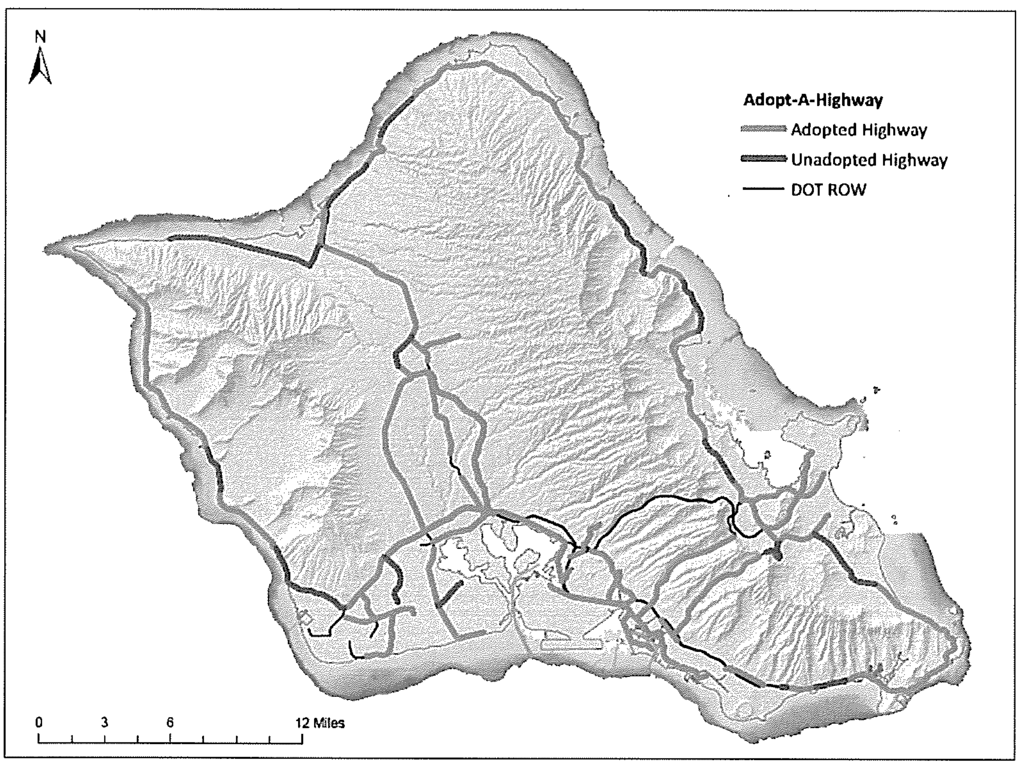

Figure 9. Adopt-A-Highway Program on Oahu in 2015.

3.2.2 Street Sweeping Program

Street sweeping is a cost-effective method to remove particulate debris from streets and roadways. Street sweeping focuses on the removal of trash, leaves, and other large debris, thereby reducing the potential to enter the MS4 by storm water runoff events.

DOT-HWYS tracks debris removed through street sweeping operations and estimates the volume of sediment, organic matter, and trash removed.

The Street Sweeping Program removes on average 332 cubic yards of trash, based on data from 2013 to 2015 (see Figure 10). Higher levels of trash were removed along the south shore.

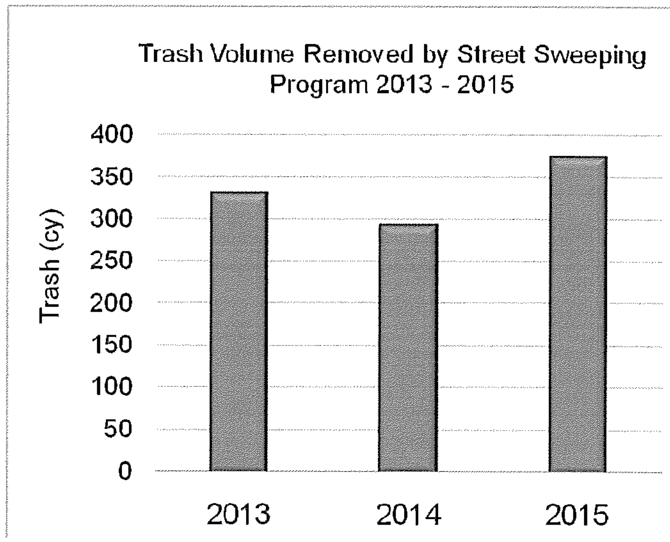

Figure 10. Total volume of trash collected by Street Sweeping Program on Oahu, 2013-2015.

Street sweeping on Oahu follows three cycles:

- Cycle A: Sweeping occurs once every 5 weeks.
- Cycle B: Sweeping occurs once every 15 weeks.
- Cycle C: Sweeping occurs twice every 5 weeks (enhanced Cycle A).

Figure 11 shows the current street sweeping cycles.

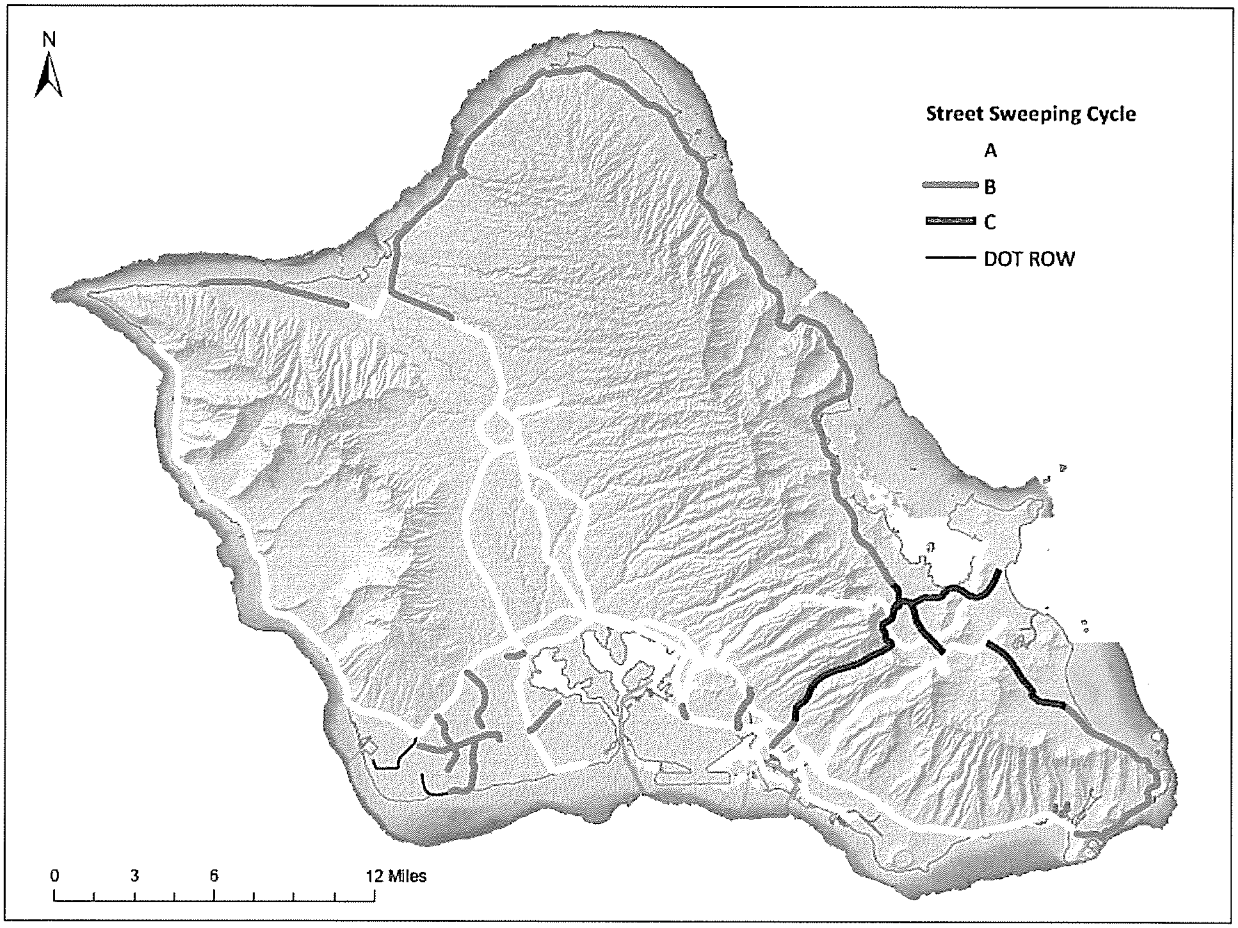

Figure 11. Existing Street Sweeping Program schedule.

3.3 MS4 Interception Control Measures

Once trash enters the MS4, it may be intercepted and removed through MS4 structure cleaning and Permanent BMPs.

3.3.1 MS4 Inspection and Cleaning Program

The cleaning of MS4 structures is a proven cost-effective method to capture and remove gross pollutants from storm water runoff. Portions of selected State routes are classified as high priority due to relatively high traffic volume and their location in a High Priority Watershed *(designated by the Consent Decree Civil Action No. CV 05-00636-HG- KSC, and terminated on April 14, 2016).* Hence, these high priority inlets are inspected at least once every six months.

Portions of selected State routes are classified as low priority due to relatively low traffic volume and their location in a Non-High Priority Watershed *(designated by the Consent Decree Civil Action No. CV 05-00636-HG-KSC, and terminated on April 14, 2016).* Hence, these low priority drains are inspected once per year and cleaned, if necessary.

Figure 12 displays the inlets and manholes with their respective inspection schedule.

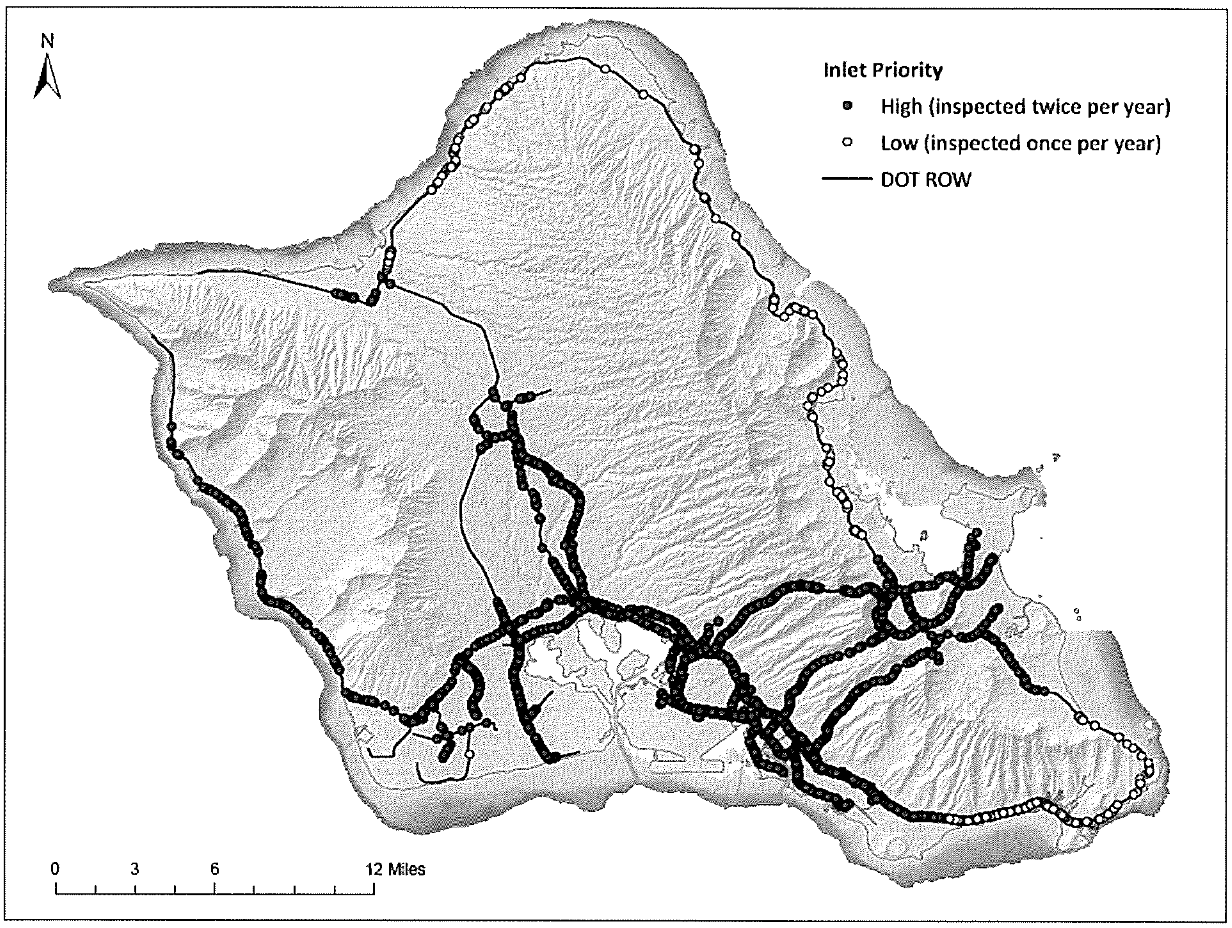

Figure 12. Existing MS4 Inspection and Cleaning Program schedule.

DOT-HWYS tracks debris removed through MS4 cleaning operations and estimates the volume of sediment, organic matter, and trash removed. The MS4 Inspection and cleaning Program removes on average 42 cubic yards of trash, based on the data from 2013 to 2015 (see Figure 13). Higher levels of trash were removed along the south shore, west side, and near other densely populated areas, such as Wahiawa and Kaneohe.

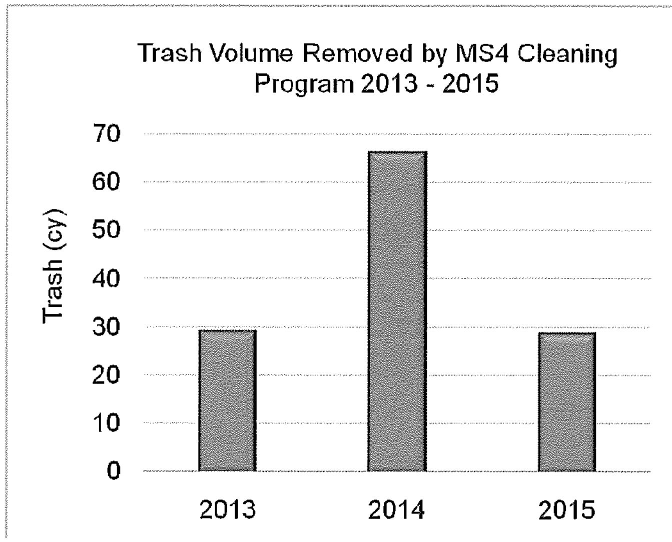

Figure 13. Total volume of trash removed from inlets and manholes cleaning on Oahu, 2013-2015.

3.3.2 Permanent BMP Program

DOT-HWYS implements a Permanent BMP Program to fulfill the MS4 Permit requirements, and to address storm water pollution associated with highway runoff. DOT-HWYS utilizes both partial and full trash capture devices in the MS4 to reduce trash and other land-based source pollutant runoffs, as shown in Figure 14.

Partial Trash Capture Devices. Partial trash capture devices have removal efficiencies that are less than 100%. There is currently one partial trash capture devices in DOT-HWYS MS4 with a grated-inlet skimmer box.

Full Trash Capture Devices. Full trash capture devices have removal efficiencies of 100% up to their intended design flow. There are currently 10 full trash capture devices in DOT-HWYS MS4: 9 hydrodynamic separators and 1 catch basin insert filter.

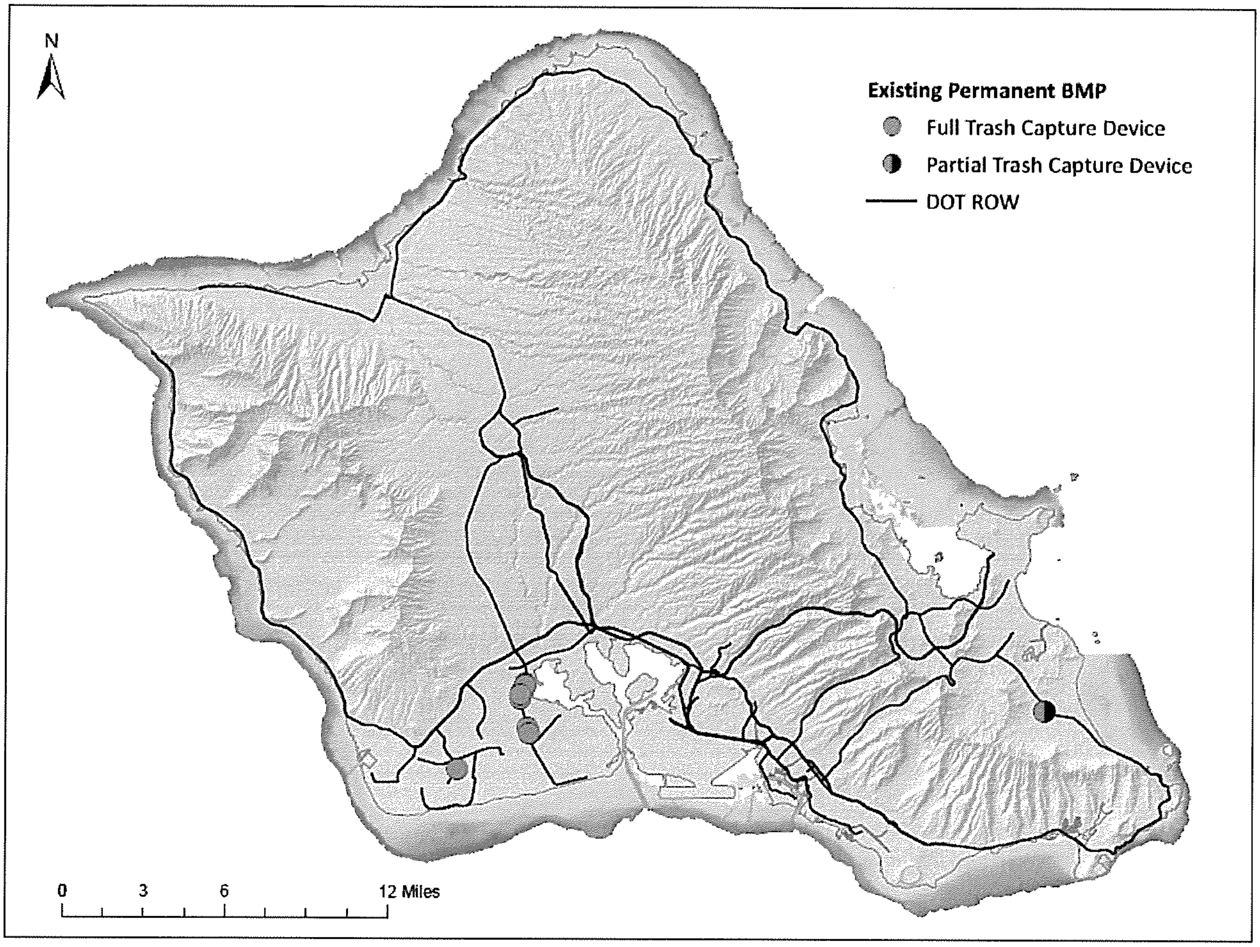

Figure 14. Location of existing Permanent BMPs.

Section 3 summarizes the control measures that DOT-HWYS implemented prior to the baseline year (2013) to manage storm water runoffs, and therefore this current level of implementation is referred to as *baseline implementation*.

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4. DOT-HWYS FIVE STEP METHOD TO TRACK FUTURE TRASH REDUCTIONS

This section describes the quantitative tracking methods to document compliance with the required trash load reductions. A literature review was conducted to evaluate quantification methods used by other agencies, which guided the development of DOT-HWYS trash reduction calculation method.

Consistent with the MS4 Permit requirements, DOT-HWYS has established 2013 as the baseline year for the DOT-HWYS TRP. Progress towards load reduction goals will be demonstrated by applying the *DOT-HWYS Five Step Method.* This Five Step Method applies a combination of two trash load reduction methods to the trash baseline load, and demonstrates trash load reductions attributable to specific control measures: 1) trash load reduction credits; and 2) trash load reduction formulas. This methodology should be considered preliminary and are subject to revision based on additional information and implementation experiences.

4.1 DOT-HWYS Five Step Method

4.1.1 Overview

DOT-HWYS utilizes the *Five Step Method* to calculate trash load reductions and account for the trash generation and transport process, as follows:

Step 1 – Institutional Control Measures

Step 2 – Land-Based Interception Control Measures

Step 3 – MS4 Interception Control Measures

Step 4 – Waterbody Interception Control Measures

Step 5 – Calculate Trash Load Reduction

Step 1 utilizes trash load reduction credit implemented on an "area-wide" basis and therefore load reductions are applied to the entire DOT-HWYS jurisdictional area.

In contrast, Steps 2 through 4 utilize trash load reduction formulas on an "area-specific" basis.

Reductions are generally applied in the sequence presented in Figure 15, although some reductions may be applied "in-parallel" and are calculated during the same substep of the method.

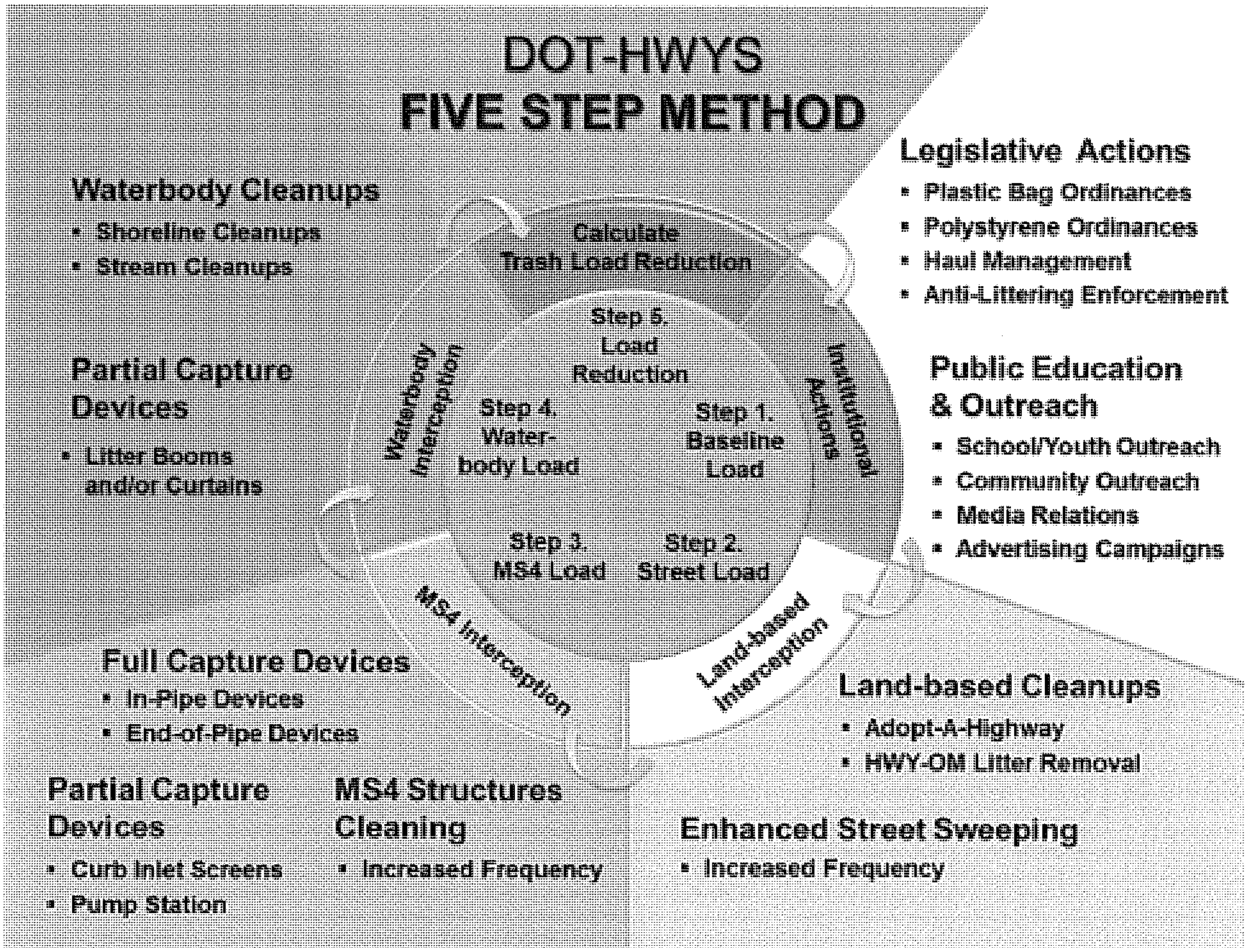

Figure 15. DOT-HWYS Five Step Method (adapted from BASMAA 2011).

4.1.2 Principles and Assumptions

The principles and underlying assumptions utilized in the *Five Step Method* are as follows.

Reduction Credits. Institutional control measures, such as public education, may result in trash reductions but remain challenging to quantify. Therefore, trash load reduction credits were adopted for institutional control measures to reflect their trash reductions. recommended theoretical percent reductions from the trash baseline load were derived from discussions amongst members of the Bay Area Stormwater Management Agencies Associations Trash Committee in California (BASMAA 2011).

Reduction Formulas. Trash load reduction formulas were adapted for land-based, MS4, and waterbody interception control measures, such as street sweeping and MS4 cleaning. The application of the trash load reduction formulas relies on readily available information. In cases where information is very limited, assumptions are made and may be tested and revised accordingly as methods evolve.

Data Availability. The application of the trash load reduction formulas requires DOT-HWYS to track inputs to formulas using data that DOT-HWYS collects and submits as part of the Annual Reports. To provide a holistic picture of loads reduced from DOT-HWYS storm water runoff during a given year, additional information tracked by other public agencies or private entities (e.g., volunteer groups) may needed.

Baseline vs Enhanced Control Measures. DOT-HWYS may only count trash load reductions associated with the implementation of new or enhanced control measures after the baseline year 2013 or EDOP. Control measures level of implementation prior to 2013 is considered baseline implementation.

Jurisdictional Area. DOT-HWYS jurisdictional area is defined as the ROW. DOT-HWYS will receive "area-wide" trash load reductions credit for institutional control measures implemented after the EDOP.

Double Counting. DOT-HWYS may implement multiple control measures within the same geographical area. In these instances, trash load reductions from one control measure must be accounted for in the reduction formula applied to subsequent control measures. The Five Step Method addresses this issue.

Geographical Uniformity. A practical assumption is that studies conducted at specific locations may be extrapolated to the island, drainage area, land use type, or other defining factors. Data collected by DOT-HWYS will be considered spatially representative, and will be disaggregated or aggregated, as applicable.

4.2 Step 1 – Institutional Control Measures

Trash load reduction credits (RC) can be obtained from the implementation of institutional control measures as they reduce the likelihood of trash being deposited into the environment. Reduction credits include the following examples of area-wide control measures:

- **RC-1** Single-Use Carryout Plastic Bag Ordinances
- **RC-2** Polystyrene Foam Food Service Ware Ordinances
- **RC-3** Uncovered Loads Enforcement
- **RC-4** Anti-Littering and Illegal Dumping Enforcement
- **RC-5** Public Education and Outreach Programs

Load reductions associated with institutional control measures are applied on an area-wide basis and in parallel. Therefore, the trash baseline load is adjusted islandwide based on the implementation of selected institutional control measures and their associated trash load reduction credits.

The **trash baseline load** will be reduced by the implementation of enhanced institutional control measures, and the remaining trash may contribute to the **street load**. The **street load** is the volume of trash estimated to enter the environment and is available for transport into the MS4, if not intercepted via the land-based control measures described in Section 4.3 (Step 2).

4.2.1 Legislative Actions

Trash load reduction credits are available for existing or potentially introduced legislative actions, which includes single-use carryout bag ordinances, polystyrene foam food service ware ordinances, uncovered loads enforcement, and anti-littering and illegal dumping enforcement.

4.2.1.1 Single-Use Carryout Plastic Bag Ordinances

Single-use carryout bags adversely affects streams and marine wildlife (United Nations 2009, CIWMB 2007, County of Los Angeles 2007). Additionally, the prevalence of plastic bags in the landscape compromises the MS4 efficiency.

DOT-HWYS can benefit from a municipal ordinance designed to reduce the environmental impacts of single use carryout plastic bags. Since ordinances may vary in scope, a tiered trash load reduction credit system based on the anticipated magnitude of reduction was adopted (BASMAA 2011). DOT-HWYS will receive trash load reduction credits for the implementation of any of the following municipal ordinance control measures:

- **Tier 1 – Prohibit Distribution at Large Supermarkets**
  Prohibit large supermarkets from distributing single-use carryout plastic bags within their jurisdictional boundaries will receive a trash load reduction credit of **6 percent**.
- **Tier 2 – Prohibit Distribution at Retail Establishments that Sell Packaged Foods**
  Prohibit retail establishments that sell packaged foods from distributing single-use carryout plastic bags within their jurisdictional boundaries will receive a trash load reduction credit of **8 percent.**
- **Tier 3 – Prohibit Distribution at All Retail Establishments (with the Exception of Restaurants)**
  Prohibit all retail establishments (with the exception of restaurants) from distributing single-use carryout plastic bags within their jurisdictional boundaries will receive a trash load reduction credit of **10 percent.**
- **Additional Credit**
  DOT-HWYS will receive up to **2 percent** of trash load reduction from the implementation of a more far reaching ordinance that significantly reduces the

distribution and usage of **all** types of single-use carryout bags. Actions may include banning the distribution of, or charging a fee for, single-use paper bags in retail establishments.

To receive the trash load reduction credits described above, DOT-HWYS needs to implement in parallel with the ordinance/action, public education and outreach that focus on reducing the distribution of single-use plastic bags.

4.2.1.2 Polystyrene Foam Food Service Ware Ordinances

Polystyrene foam is used as food ware in the food service industry and may impact human health, wildlife, and the aquatic environment (USEPA 2002). Since ordinances may vary in scope, a tiered trash load reduction credit system based on the anticipated magnitude of reduction was adopted (BASMAA 2011). DOT-HWYS will receive trash load reduction credits for the implementation of any of the following municipal ordinance control measures:

- **Tier 1 – Prohibit Distribution at DOT-HWYS-sponsored Events and DOT-HWYS-owned Property**
  Prohibit food vendors from distributing polystyrene foam food ware at DOT-HWYS-sponsored events and on DOT-HWYS owned property will receive a trash load reduction credit of **2 percent.**
- **Tier 2 –Prohibit Distribution by Food Service Vendors**
  Prohibit food vendors from distributing polystyrene foam food ware within their jurisdictional boundaries will receive a trash load reduction credit of **8 percent.**

To receive the trash load reduction credits described above, DOT-HWYS will need to implement, in parallel with the ordinance/action, public education and outreach focusing on food service vendors,.

4.2.1.3 Uncovered Loads Enforcement

Currently, it is illegal to operate an improperly covered vehicle and uncovered loads remain a major trash source. Vehicles that do not secure or cover their loads when transporting trash and organic debris may be a major source of trash to the MS4 and local waterbodies. DOT-HWYS will support local government actions that reduce improperly covered vehicles and receive trash load reduction credits for increased compliance with the control measures described here.

- **Require Municipal Trash Haulers to Cover Loads**
  The development and inclusion of language in DOT-HWYS contracts requires haulers to secure and cover loads when transporting material, and will result in a trash load reduction credit of **1 percent**.
- **Enhanced Enforcement Program for Vehicles with Uncovered Loads**
  An enhanced enforcement program for vehicles with uncovered loads will result in a trash load reduction credit of **4 percent**.

4.2.1.4 Anti-Littering and Illegal Dumping Enforcement

Successful anti-littering and illegal dumping enforcement activities include laws and ordinances which prohibit littering or dumping. Laws are enforced by various municipal agency staff (e.g., police and public works department staff) who issue citations in response to citizen complaints or other enforcement methods (e.g., surveillance cameras, signage and/or physical barriers installed at illegal dumping hotspots). DOT-HWYS will support local government actions that reduce illegal littering, and will receive trash load reduction credits for increased compliance with the control measures described here.

- **Anti-Littering and Illegal Dumping Enforcement Program**
  Municipal implementation of an active anti-littering and illegal dumping enforcement program will result in a trash load reduction credit of **2 percent.**
- **Use of Surveillance**
  Use of surveillance techniques to deter and prosecute illegal dumping will result in a trash load reduction credit of up to **2 percent** (based on the tiers described in Table 7).
- **Use of Physical Barriers or Improvements**
  Installation and use of physical barriers (e.g., fences, walls) or physical improvements (e.g., maintenance) which eliminate or deter illegal dumping will result in a trash load reduction credit of up to **2 percent** (based on the tiers described in Table 7).

4.2.2 Public Education and Outreach

DOT-HWYS will continue to evaluate potential partnerships with agencies and other stakeholders to more effectively promote anti-littering and affect behavioral change islandwide. Public education and outreach efforts include developing and distributing brochures and other print media, posting messages on websites and social networking media (e.g., Facebook, Twitter, etc.), attending community events, and conducting media advertising.

Trash load reduction credits are available for the following new or enhanced public education and outreach activities implemented by DOT-HWYS.

School and Youth Outreach. Enhanced implementation of outreach programs designed to promote anti-littering behavior in school-age children (K through 12) will result in a trash load reduction credit of **2 percent.**

Community Outreach. Enhanced community outreach in high priority communities where trash is prevalent will result in a trash load reduction credit of **2 percent.**

Advertising Campaigns. Participation in advertising campaigns (e.g., print advertising and PSAs) on trash issues will result in trash load reduction credit of **3 percent.**

Media Relations. Participation in a media relations campaign (e.g., social media) which focuses on trash issues will result in a trash load reduction credit of **1 percent.**

All public education and outreach control measures may include an evaluation assessment (e.g., teacher or student survey) to determine the trash reduction effectiveness.

4.2.3 Summary of Trash Load Reduction Credits

Table 7 provides a summary of potential available Institutional Control Measures and associated trash load reduction credits

Table 7. Summary of potential available Institutional Control Measures and associated trash load reduction credits.

CONTROL MEASURE	TIERS OR CONTROL MEASURE DESCRIPTION	REDUCTION CREDIT
Single-Use Carryout Plastic Bag Ordinances	Tier 1 – Prohibit Distribution at Large Supermarkets	6%
	Tier 2 – Prohibit Distribution at Retail Establishments that Sell Packaged Foods	8%
	Tier 3 – Prohibit Distribution at All Retail Establishments (with the Exception of Restaurants)	10%
	Additional Credit	2%
Polystyrene Foam Food Service Ware Ordinances	Tier 1 – Prohibit Distribution at DOT-HWYS-sponsored Events and DOT-HWYS-owned Property	2%
	Tier 2 – Prohibit Distribution by Food Service Vendors	8%
Uncovered Loads Enforcement	Require Municipal Trash Haulers to Cover Loads	1%
	Enhanced Enforcement Program	4%
Anti-Littering and Dumping Enforcement	Anti-Littering and Illegal Dumping Enforcement Program	2%
	Tier 1 – 20-50% of Identified Hotspots Under Camera Surveillance	1%
	Tier 2 – > 50% of Identified Hotspots Under Camera Surveillance	2%
	Tier 1 – Physical Barriers or Improvements Implemented at 20-50% of Identified Hotspots	1%
	Tier 2 – Physical Barriers or Improvements Implemented at > 50% of Identified Hotspots	2%
Public Education and Outreach	School and Youth Outreach	2%
	Community Outreach	2%
	Advertising Campaigns	3%
	Media Relations	1%

4.3 Step 2 – Land-Based Interception Control Measures

Once trash enters the environment, it may be intercepted and removed through area-specific, land-based control measures prior to reaching the MS4. Trash load reduction formulas (RF) were adapted for the following land-based control measures:

RF-1 Land-Based Trash Cleanups

RF-2 Enhanced Street Sweeping

Since land-based trash cleanups effect the amount of trash available to street sweepers, load reductions associated with their implementation will be quantified first, followed by street sweeping enhancements.

The **street load** will be reduced by the implementation of enhanced land-based control measures, and remaining trash may contribute to the **MS4 load**. The **MS4 load** is the volume of trash estimated to enter the MS4, if not intercepted via the MS4 control measures described in Section 4.4 (Step 3).

4.3.1 Land-Based Trash Cleanups

DOT-HWYS may benefit from the following land-based trash cleanup programs:

- **Enhanced DOT-HWYS Land-Based Cleanups**
  DOT-HWYS may enhance land-based cleanup activities through the implementation of the proposed Trash Removal and Prevention Program (TRAPP), or enhance existing programs. The proposed TRAPP would remove trash that accumulates along highways and areas where street sweeping is not feasible.
- **Enhanced Volunteer Land-Based Cleanups**
  DOT-HWYS may enhance the Adopt-A-Highway Program through the adoption of new highway segments and/or increasing the frequency of volunteer trash removal activities.

Ongoing land-based cleanup activities conducted prior to the baseline year 2013 and continued through current Permit's term are assumed to be accounted for in the trash baseline load, and cannot be used to demonstrate progress towards trash load reduction goals.

The trash load reduction formulas used to calculate trash load reductions that result from the implementation or enhancement of the land-based control measures are described below.

4.3.1.1 Land-Based Cleanups Trash Load Reduction Formula

Based on a review of available data and information gained through literature reviews, the trash load reduction formulas (RF) will provide DOT-HWYS with a method to estimate the volume of trash annually removed from all applicable land-based cleanup activities conducted in a given year. The trash removed from these land-based cleanups are tracked as a volume, as opposed to mass; and only trash with the potential to enter the MS4 should be counted towards load reductions.

The load reduction variable is signified as $\mathbf{Reduction}_{\text{Cleanups}}$ in the following RF-1 formulas:

$$\mathbf{Reduction}_{\text{Cleanups}} = \mathbf{Enhanced}_{\text{Cleanups}} - \mathbf{Baseline}_{\text{Cleanups}} \qquad \text{(RF-1)}$$

where:

$\mathbf{Enhanced}_{\text{Cleanups}}$ = Volume of trash removed (cy) from all applicable land-based cleanup activities in year of interest.

$\mathbf{Baseline}_{\text{Cleanups}}$ = Annual average volume of trash removed (cy) from all applicable land-based cleanup activities in years prior to the baseline year 2013.

and

$$\mathbf{Enhanced}_{\text{Cleanups}} = \mathbf{State}_{\text{EnhancedVol}} + \mathbf{Volunteer}_{\text{EnhancedVol}} \qquad \text{(RF-1)}$$

$$\mathbf{Baseline}_{\text{Cleanups}} = \mathbf{State}_{\text{BaselineVol}} + \mathbf{Volunteer}_{\text{BaselineVol}} \qquad \text{(RF-1)}$$

where:

$\mathbf{State}_{\text{EnhancedVol}}$ = Total volume of trash removed (cy) by DOT-HWYS land-based cleanups in year of interest.

$\mathbf{Volunteer}_{\text{EnhancedVol}}$ = Total volume of trash removed (cy) by volunteer land-based cleanups in year of interest.

$\mathbf{State}_{\text{BaselineVol}}$ = Total volume of trash removed (cy) by DOT-HWYS land-based cleanups in years prior to the baseline year 2013.

$\mathbf{Volunteer}_{\text{BaselineVol}}$ = Total volume of trash removed (cy) by volunteer land-based cleanups in years prior to the baseline year 2013.

4.3.2 Street Sweeping

Street sweeping is implemented by DOT-HWYS to remove trash and debris collected on the highway, which may contribute to unsafe conditions and/or reductions in the capacity of the MS4.

Trash removal effectiveness of street sweeping may be directly affected by sweeper operation (e.g., speed of operation), and sweeping frequency. Additionally, rainfall storm events can reduce the effectiveness of a street sweeper's ability to capture trash (Sartor et al. 1974, Sartor and Gaboury 1984, Walker and Wong 1999, Armitage 2001). Literature review concludes that the street sweeper type (e.g., mechanical broom or vacuum assisted) does not influence trash removal efficiency (BASMAA 2011). Therefore, changes in sweeper type are not considered as an applicable trash control measure enhancement.

- **Enhanced Street Sweeping**

  DOT-HWYS may enhance the street sweeping program through an increase in street sweeping frequency.

The trash load reduction formulas used to calculate trash load reductions that results from the increased frequency of street sweeping activities are described as follows.

4.3.2.1 Street Sweeping Trash Load Reduction Formula

Based on a review of available data and information gained through literature reviews, the trash load reduction formulas (RF) will allow DOT-HWYS to estimate the volume of trash annually removed from street sweeping conducted in a given year. The trash removed from street sweeping is tracked as a volume, as opposed to mass.

The load reduction variable is signified as $\mathbf{Reduction}_{\text{Sweep}}$ in the following RF-2 formulas:

$$\mathbf{Reduction}_{\text{Sweep}} = \mathbf{Enhanced}_{\text{Sweep}} - \mathbf{Baseline}_{\text{Sweep}} \qquad \text{(RF-2)}$$

where:

$\mathbf{Enhanced}_{\text{Sweep}}$ = Volume of trash removed (cy) due to enhanced street sweeping in a year of interest.

$\mathbf{Baseline}_{\text{Sweep}}$ = Annual average volume of trash removed (cy) from all applicable street sweeping activities in years prior to the baseline year 2013.

and

$$\mathbf{Enhanced}_{\text{Sweep}} = \mathbf{HWYS}_{\text{Sweep}} \cdot \boldsymbol{\eta}_{\text{SweepEnhanced}} \qquad \text{(RF-2)}$$

$$\mathbf{Baseline}_{\text{Sweep}} = \mathbf{HWYS}_{\text{Sweep}} \cdot \boldsymbol{\eta}_{\text{SweepBaseline}} \qquad \text{(RF-2)}$$

where:

$\mathbf{HWYS}_{\text{Sweep}}$ = Total miles swept by DOT-HWYS.

$\boldsymbol{\eta}_{\text{SweepEnhanced}}$ = Trash removal efficiency of enhanced street sweeping (cy/mi) during the year of interest.

$\boldsymbol{\eta}_{\text{SweepBaseline}}$ = Trash removal efficiency of street sweeping (cy/mi) in years prior to the baseline year 2013.

4.4 Step 3 – MS4 Interception Control Measures

Once trash enters the MS4, it may be intercepted and removed through the area-specific control measures prior to entering State waterbodies. Trash load reduction formulas (RF) were adapted for the following MS4 interception control measures:

- **RF-3** Enhanced MS4 Inspection and Cleaning
- **RF-4a** Partial Trash Capture Device Installation
- **RF-4b** Storm Water Pump Station Enhancements
- **RF-5** Full Trash Capture Device Installation

The **MS4 load** will be reduced by the implementation of enhanced MS4 control measures, and the remaining trash may contribute to the **waterbody load**. The **waterbody load** is the volume of trash estimated to enter the waterbody, if not intercepted via waterbody interception control measures described in Section 4.5 (Step 4).

4.4.1 MS4 Inspection and Cleaning

DOT-HWYS maintains and cleans the MS4 on a semiannual or annual basis, and may benefit from the following:

- **RF 3: Enhanced MS4 Inspection and Cleaning**
  DOT-HWYS may enhance the MS4 inspection and cleaning program through increased frequency.

4.4.1.1 MS4 Inspection and Cleaning Trash Load Reduction Formula

Based on a review of available data and information gained through literature reviews, the trash load reduction formulas (RF) will allow DOT-HWYS to estimate the volume of trash annually removed from MS4 inspection and cleaning in a given year. The trash removed from MS4 cleaning is tracked as a volume, as opposed to mass.

The load reduction variable is signified as $\mathbf{Reduction}_{MS4Clean}$ in the following RF-3 formulas:

$$\mathbf{Reduction}_{MS4Clean} = \mathbf{Enhanced}_{MS4Clean} - \mathbf{Baseline}_{MS4Clean} \qquad \text{(RF-3)}$$

where:

$\mathbf{Enhanced}_{MS4Clean}$ = Volume of trash removed (cy) due to enhanced MS4 inspection and cleaning in a year of interest.

$\mathbf{Baseline}_{MS4Clean}$ = Annual average volume of trash removed (cy) from MS4 inspection and cleaning activities in years prior to the baseline year 2013.

and

$$\mathbf{Enhanced}_{MS4Clean} = \mathbf{DA}_{MS4Clean} \bullet \boldsymbol{\eta}_{MS4CleanEnhanced} \qquad \text{(RF-3)}$$

$$\mathbf{Baseline}_{MS4Clean} = \mathbf{DA}_{MS4Clean} \bullet \boldsymbol{\eta}_{MS4CleanBaseline} \qquad \text{(RF-3)}$$

where:

$\mathbf{DA}_{MS4Clean}$ = Total drainage area (ha) of MS4 structures cleaned by DOT-HWYS. DOT-HWYS used a conservative average drainage area of 0.6 hectare (1.5 acres) per inlet (adapted from BASMAA 2011).

$\boldsymbol{\eta}_{MS4CleanEnhanced}$ = Trash removal efficiency of enhanced MS4 cleaning (cy/ha) during the year of interest.

$\boldsymbol{\eta}_{MS4CleanBaseline}$ = Trash removal efficiency of MS4 cleaning (cy/ha) in years prior to the baseline year 2013.

4.4.2 Partial Trash Capture Devices

Partial trash capture devices are similar to full trash capture devices, however trash may bypass these devices. For example, some devices may allow trash to bypass at higher flow rates due to design constraints within the existing MS4. Partial trash capture devices are area-specific control measures, and may include curb inlet screens (e.g., automated retractable screens) and enhancements to the pump station. DOT-HWYS may benefit from the following:

- **RF-4a: Partial Trash Capture Device Installation**
  DOT-HWYS may install additional partial trash capture devices that capture trash moving through the MS4.
- **RF-4b: Storm Water Pump Station Enhancements**
  Enhancements to existing pump station structure may increase the effectiveness of trash removal.

4.4.2.1 Partial Trash Capture Devices Trash Load Reduction Formula

Based on a review of available data and information gained through literature reviews, the trash reduction formulas (RF) will allow DOT-HWYS to estimate the volume of trash annually removed from all partial trash capture devices in a given year. The trash removed from all partial trash capture devices is tracked as a volume, as opposed to mass

This load reduction variable is signified as $\mathbf{Reduction}_{PTCDevices}$ in the following RF-4a formulas:

$$\mathbf{Reduction}_{PTCDevices} = \mathbf{Enhanced}_{PTCDevices} \qquad \text{(RF-4a)}$$

where:

$\mathbf{Enhanced}_{PTCDevices}$ = Volume of trash (cy) removed by all partial trash capture devices implemented in a year of interest.

and

$$\mathbf{Enhanced}_{PTCDevices} = \mathbf{TA}_{PTCDevices} \cdot \boldsymbol{\eta}_{PTCDevicesEnhanced} \qquad \text{(RF-4a)}$$

where:

$\mathbf{TA}_{PTCDevices}$ = Total treated area (ha) by all partial trash capture devices in DOT-HWYS jurisdictional area.

$\boldsymbol{\eta}_{PTCDevicesEnhanced}$ = Trash removal efficiency (cy/ha) by all partial trash capture devices in year of interest.

4.4.2.2 Punahou Pump Station Trash Load Reduction Formula

$$\mathbf{Reduction}_{Pump} = \mathbf{Enhanced}_{Pump} - \mathbf{Baseline}_{Pump} \qquad \text{(RF-4b)}$$

where:

$\mathbf{Enhanced}_{Pump}$ = Volume of trash (cy) removed by pump station in year of interest.

$\mathbf{Baseline}_{Pump}$ = Annual average volume of trash removed (cy) by pump station in years prior to the baseline year 2013.

and

$$\mathbf{Enhanced}_{Pump} = \mathbf{TA}_{Pump} \bullet \eta_{PumpEnhanced} \qquad \text{(RF-4b)}$$

$$\mathbf{Baseline}_{Pump} = \mathbf{TA}_{Pump} \bullet \eta_{PumpBaseline} \qquad \text{(RF-4b)}$$

where:

$\mathbf{TA}_{Pump}$	=	Total treated area (ha) by Punahou Station.
$\eta_{PumpEnhanced}$	=	Trash removal efficiency (cy/ha) by Punahou Station in a year of interest.
$\eta_{PumpBaseline}$	=	Trash removal efficiency (cy/ha) by Punahou Station in years prior to the baseline year 2013.

4.4.3 Full Trash Capture Devices

Full trash capture devices are designed to retain all trash up to their intended design flow. Full trash capture devices are area-specific control measures and may include baffle boxes. DOT-HWYS may benefit from the following:

- **RF-5: Full Trash Capture Device Installation**
  DOT-HWYS may install additional full trash capture devices that capture trash moving through the MS4.

4.4.3.1 Full Trash Capture Devices Trash Load Reduction Formula

Based on a review of available data and information gained through literature reviews, the trash load reduction formulas (RF) will allow DOT-HWYS to estimate the volume of trash annually removed from all full trash capture devices in a given year. The trash removed from all full trash capture devices is tracked as a volume, as opposed to mass.

This load reduction variable is signified as $\mathbf{Reduction}_{FTCDevices}$ in the following RF-5 formulas:

$$\mathbf{Reduction}_{FTCDevices} = \mathbf{Enhanced}_{FTCDevices} \qquad \text{(RF-5)}$$

where:

$\mathbf{Enhanced}_{FTCDevices}$	=	Volume of trash (cy) removed by all full trash capture devices implemented in a year of interest

and

$$\mathbf{Enhanced}_{FTCDevices} = \mathbf{TA}_{FTCDevices} \bullet \eta_{FTCDevicesEnhanced} \qquad \text{(RF-5)}$$

where:

$\mathbf{TA}_{FTCDevices}$	=	Total treated area (ha) by all full trash capture devices in DOT-HWYS jurisdictional area.
$\eta_{FTCDevicesEnhanced}$	=	Trash removal efficiency (cy/ha) by all full trash capture devices in year of interest.

4.5 Step 4 – Waterbody Interception Control Measures

Once trash enters State waterbodies, it may be intercepted and removed through the area-specific control measures. Trash load reduction formulas (RF) were adapted for the following waterbody interception control measures:

RF-6 Litter Booms and/or Curtains Installation

RF-7 Stream and/or Beach Cleanups

DOT-HWYS, however, do not anticipate using these control measures at this stage.

The **waterbody load** will be reduced by the implementation of waterbody interception control measures and may contribute to the **remaining trash load**. The **remaining trash load** is the estimated volume of trash not intercepted via waterbody interception control measures.

4.5.1 Litter Booms and/or Curtains

Litter booms and/or curtains are similar to partial trash capture devices and remove floatable and partially floatable trash from waterbodies.

- **RF-6: Litter Booms and/or Curtains Installation**
  DOT-HWYS may install litter booms and/or curtains that capture trash in State waterbodies.

4.5.1.1 Litter Booms and/or Curtains Trash Load Reduction Formula

Based on a review of available data and information gained through literature reviews, the trash load reduction formula (RF) will allow DOT-HWYS to estimate the volume of trash removed annually from litter booms and/or curtains in a given year. The trash removed from all litter booms and/or curtains is tracked as a volume, as opposed to mass

The load reduction variable is signified as $\mathbf{Reduction}_{\text{Booms}}$ in the following RF-6 formula.

$$\mathbf{Reduction}_{\text{Booms}} = \mathbf{Enhanced}_{\text{Booms}} \qquad \text{(RF-6)}$$

where:

$\mathbf{Enhanced}_{\text{Booms}}$ = Volume of trash (cy) removed from all litter booms and/or curtains in the year of interest.

4.5.2 Stream and/or Beach Cleanups

Stream and/or beach cleanups are events periodically conducted throughout the year by volunteers to reduce the amount of trash entering into waterbodies.

- **RF-7: Stream and/or Beach Cleanups**
  DOT-HWYS may benefit from stream and/or beach cleanups that reduce the amount of trash in State waterbodies.

4.5.2.1 Stream and/or Beach Cleanups Trash Load Reduction Formula

Based on a review of available data and information gained through literature reviews, the trash load reduction formula (RF) will allow DOT-HWYS to estimate the volume of trash removed annually from stream and/or beach cleanups in a given year. The trash removed from all stream and/or beach cleanups are tracked as a volume, as opposed to mass

The load reduction variable is signified as $\mathbf{Reduction}_{\text{StreamCleanups}}$ in the following RF-7 formula.

$$\mathbf{Reduction}_{\text{StreamCleanups}} = \mathbf{Enhanced}_{\text{StreamCleanups}} \qquad \text{(RF-7)}$$

where:

$\mathbf{Enhanced}_{\text{StreamCleanups}}$ = Volume of trash (cy) removed from all applicable stream and/or beach cleanup activities in the year of interest.

4.6 Step 5 – Calculate Trash Load Reduction

The application of the previous four steps will yield the estimated **remaining trash load**. Step 5 calculates the relative percent difference between the **trash baseline load** and the **remaining trash load**, which will be used to assess progress towards the required trash reduction goals.

Equation 3 shows the calculation for the trash load reduction.

$$R = \frac{(T_{T0} - T_{T1})}{T_{T0}} \times 100$$

Equation 3. Calculation of percent load reduction.

where:

R = Trash Load Reduction (%)

T_{T0} = Trash Baseline Load (cy/yr)

T_{T1} = Trash Remaining Load (cy/yr)

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5. GEOGRAPHICAL TARGETS

DOT-HWYS ROW consists of approximately 250 miles of highways covering 2,031 hectares. The ROW crosses 90 watersheds on Oahu, including all the listed impaired trash waterbodies on the State's Clean Water Act (CWA) Section 303(d) list (hereinafter EPA Trash Impaired Watersheds). Given the geographical extent of DOT-HWYS ROW and the complexity of the MS4 network, DOT-HWYS conducted a Geographical Targets Analysis to inform the implementation of future control measures and reach the 50% and 100% trash reduction targets in the shortest practicable timeframe.

This section describes the methods used to define and prioritize DOT-HWYS geographical targets. This Geographical Targets Analysis resulted in the following two maps:

- A map with trash management areas representing varying levels of trash accumulation and interception in DOT-HWYS ROW (see Figure 16).
- A map highlighting potential trash accumulation hotspots in DOT-HWYS MS4 network (see Figure 17).

DOT-HWYS will use these maps to visualize trash hotspot areas, and identify locations in the ROW and MS4 network to prioritize and target future control measures.

5.1 Delineation and Prioritization of Trash Management Areas

To delineate the trash management areas, DOT-HWYS subdivided the islandwide ROW into six smaller management units, in accordance with the existing *moku* land subdivision of Oahu. Then, DOT-HWYS quantified the total volume of trash generated in each management area. The volume of trash generated by a trash management area is the sum of trash loads plus trash intercepted by existing control measures within DOT-HWYS jurisdictional area, as shown in Equation 4.

$$TG_j = TL_j + TI_j$$

Equation 4. Calculation of trash generated by trash management area.

where:

TG_j = Trash volume generated (cy/yr) by trash management area j

TL_j = Trash load (cy/yr) discharged from the MS4 by trash management area j

TI_j = Trash volume intercepted (cy/yr) by trash management area j

DOT-HWYS utilized two sources of information to estimate the total volume of both trash loads and trash intercepted by trash management area, as follows:

- Trash loads were calculated by multiplying the total area of each land use type by the trash loading rate using an adaption of Equation 1 (see Section 2.1).
- Historical data collected on trash intercepted over the past three years by existing control measures (see Section 3).

Equation 5 calculates the trash load for each trash management area.

$$TL_j = \sum_{i}^{n} (Lr_i A_i)$$

Equation 5. Calculation of trash baseline load for trash management area.

where:

TL_j = Trash load discharged from MS4 (cy/yr) in trash management area j

i = Total number of land use types in trash management area j

Lr_i = Average annual trash loading rate (cy/ha-yr) for land use type i

A_i = Total area of land use type i (ha) in trash management area j

Equation 6 calculates the volume of trash intercepted by existing control measures for each trash management area.

$$TI_j = R_{OM} + R_{AAH} + R_{SS} + R_{MS4}$$

Equation 6. Calculation of trash intercepted by trash management area.

where:

TI_j = Trash volume intercepted by trash management area *j*

R_{OM} = Trash volume intercepted by HWY-OM Litter Removal and Disposal Program

R_{AAH} = Trash volume intercepted by Adopt-A-Highway Program

R_{SS} = Trash volume intercepted by Street Sweeping Program

R_{MS4} = Trash volume intercepted by MS4 Inspection and Cleaning Program

Table 8 summarizes the trash loads and trash intercepted by trash management area.

Table 8. Trash generated in terms of trash loads and trash intercepted by trash management area.

Trash Management Area	Trash Load (c/yr)	Trash Intercepted – TI (cy/yr)				Trash Generated (cy/yr)
	TL	R_{OM}	R_{AAH}	R_{SS}	R_{MS4}	TG
Ewa	125	2,496	75	165	18	2,879
Kona	71	6,755	57	112	20	7,015
Koolauloa	8	232	14	4	0	258
Koolaupoko	75	321	40	41	2	479
Waialua	9	224	27	7	0	267
Waianae	9	1,272	20	3	2	1,306
TOTAL	**297**	**11,300**	**233**	**332**	**42**	**12,204**

The trash generated in each trash management area were ranked and assigned a trash level of low, moderate, high, or very as high symbolized by four different colors, to derive the geographical target map shown in Figure 16.

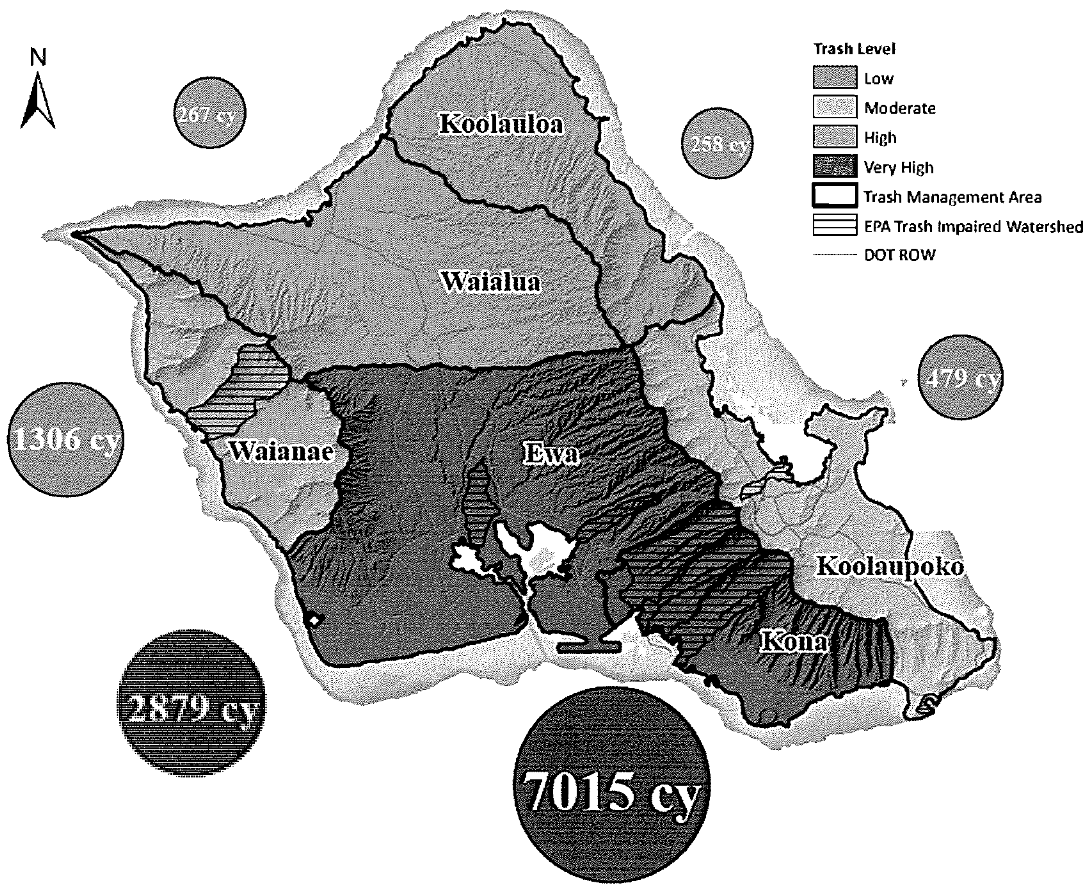


Figure 16. DOT-HWYS total trash generated by trash management area.

Based on total trash volume, this map identifies Ewa, Kona and Waianae trash management areas as geographical targets to focus future institutional and land-based interception control measures.

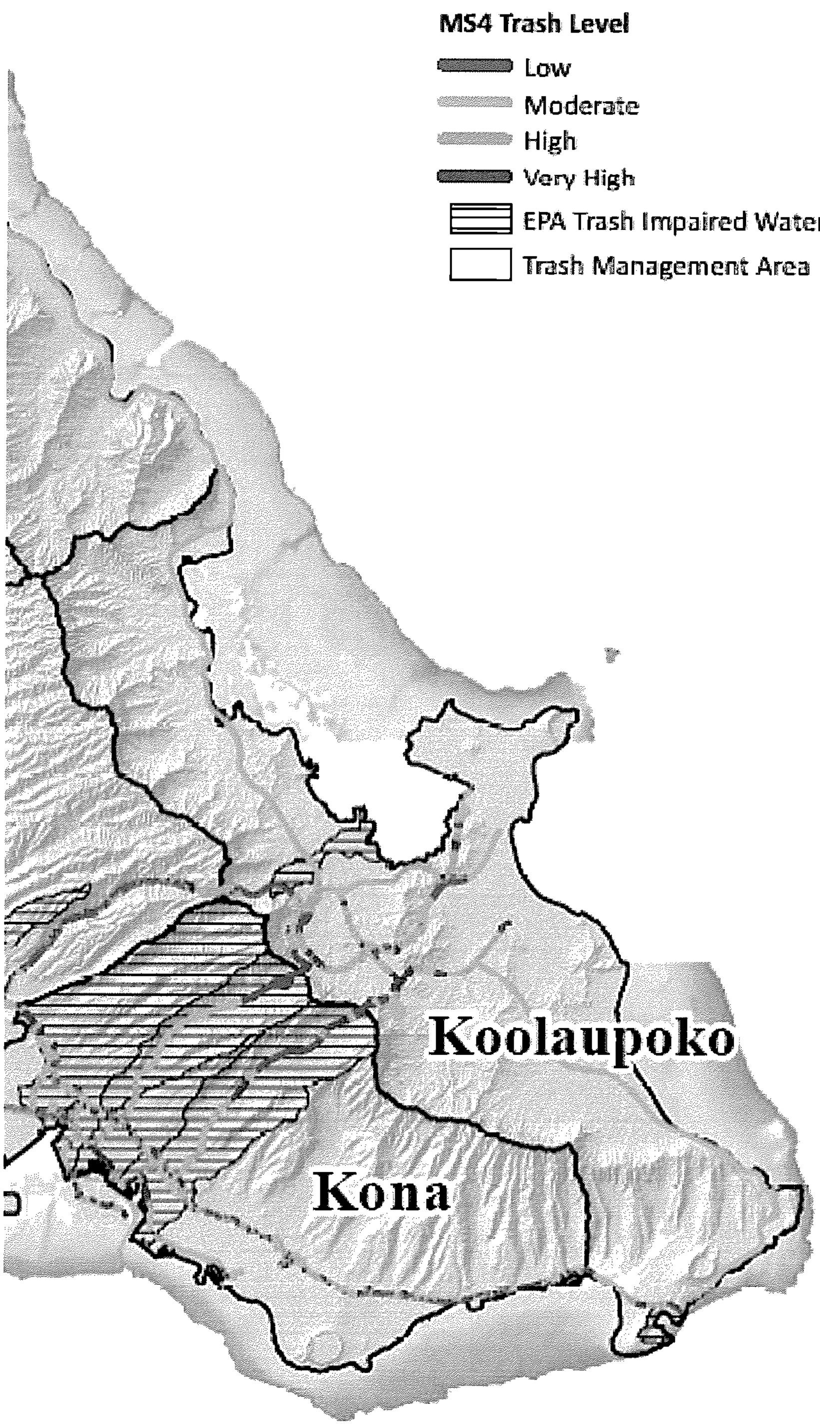
5.2 MS4 Trash Hotspots

Once trash enters the MS4, it may be intercepted with control measures that target trash in the MS4. DOT-HWYS created a map that highlights potential trash hotspots in the MS4 network to inform the allocation of future MS4 interception control measures. DOT-HWYS used historical cleaning data from the MS4 Inspection and Cleaning Program, and the locations of the EPA Trash Impaired Watersheds (CWA Section 303(d) list), to identify areas to prioritize and target with Permanent BMPs or MS4 cleaning.

The MS4 trash cleaning records were standardized into annual trash accumulation rates per inlet. These annual trash accumulation rates by inlet were then interpolated in GIS to generate values for the entire MS4 network. These annual trash accumulation rates were assigned a level of low, moderate, high, or very high and symbolized by four different colors as illustrated in Figure 17.

5.3 Findings

The trash management area and MS4 hotspot maps will guide DOT-HWYS selection and implementation of future control measures to most effectively intercept and reduce trash in the ROW. This Geographical Target Analysis reveals that Ewa, Kona, and Koolaupoko trash management areas, which also include most EPA Trash Impaired Watersheds, are priority targets for future trash control measures. These areas correspond to central, south, and southeast Oahu and are the most densely populated areas on Oahu.


MS4 Trash Level
Low
Moderate
High
Very High
EPA Trash Impaired Watershed
Trash Management Area
Koolaupoko
Kona

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6. IMPLEMENTATION SCHEDULE

This section describes the implementation schedule, which consists of a Short-Term Plan and Long-Term Plan, to meet the trash reduction targets set at 50% by 2023 and at 100% by 2036, respectively.

6.1 Considerations of Uncertainty

The trash baseline load and load reduction estimates are based on the best available information at the time of this TRP development and required a number of assumptions for calculations. Due to this inherent uncertainty, the baseline load presented in this TRP is considered a preliminary estimate. During the implementation of the Short-Term Plan and Long-Term Plan, additional information may become available to reduce this uncertainty.

6.2 Trash Baseline Load

Section 2 describes the methodology and presents DOT-HWYS trash baseline load. The baseline load was quantified using trash loading rates for eight key land use types derived from a literature review and the Trash Characterization Study. This information yielded a trash baseline load of 297 cubic yards per year.

6.3 Short-Term Plan Enhanced Control Measure

DOT-HWYS plans to adopt a suite of feasible control measures to efficiently meet the 50% reduction from the trash baseline load, which corresponds to an annual trash reduction of 148.5 cubic yards. DOT-HWYS will benefit from existing and future enhanced control measures to reach the set trash reduction target.

6.3.1 Existing Enhanced Control Measures

DOT-HWYS will receive trash load reductions from existing enhanced control measures. Since 2013, the following enhanced control measures were implemented.

Legislative Actions. On April 25, 2012, the Honolulu City Council passed a bill to ban all non-recyclable paper and non-biodegradable plastic bags on Oahu. The Mayor signed the bill into law on May 10, 2012, and the bill took effect on July 1, 2015. As a result of the plastic bag ban, DOT-HWYS will benefit from a 6% annual reduction credit from the baseline, which corresponds to 17.8 cubic yards of trash removed per year (rounded to the nearest tenth decimal).

Public Education. In addition to participating in outreach campaigns related to trash, DOT-HWYS continues the School Outreach Program that includes education on storm water issues.

Since the EDOP, DOT-HWYS redeveloped the school activity book, *Hawaii Storm Patrol: New Recruits*, and a companion website, with a refined focus on the importance of keeping the MS4 free of trash. The activity book was distributed to over 10,000 first graders in public and private schools across Oahu. As a result of the trash-targeted Public Education activities, DOT-HWYS will benefit from a 2% annual reduction credit from the baseline, which corresponds to 5.9 cubic yards of trash removed per year (rounded to the nearest tenth decimal).

Permanent BMPs. There are currently 10 Permanent BMPs installed and 14 in design and construction, which can function as trash capture devices, as shown in Figure 18. As a result, DOT-HWYS will treat 16 hectares and anticipates an annual trash removal of 3.6 cubic yards or 1.2% reduction from the baseline (rounded to the nearest tenth decimal). In addition, DOT-HWYS recently constructed a series of bioswales and grassy swales, which can act as partial trash capture devices. DOT-HWYS will monitor, maintain, and evaluate their trash removal efficiency to estimate potential future trash load reductions.

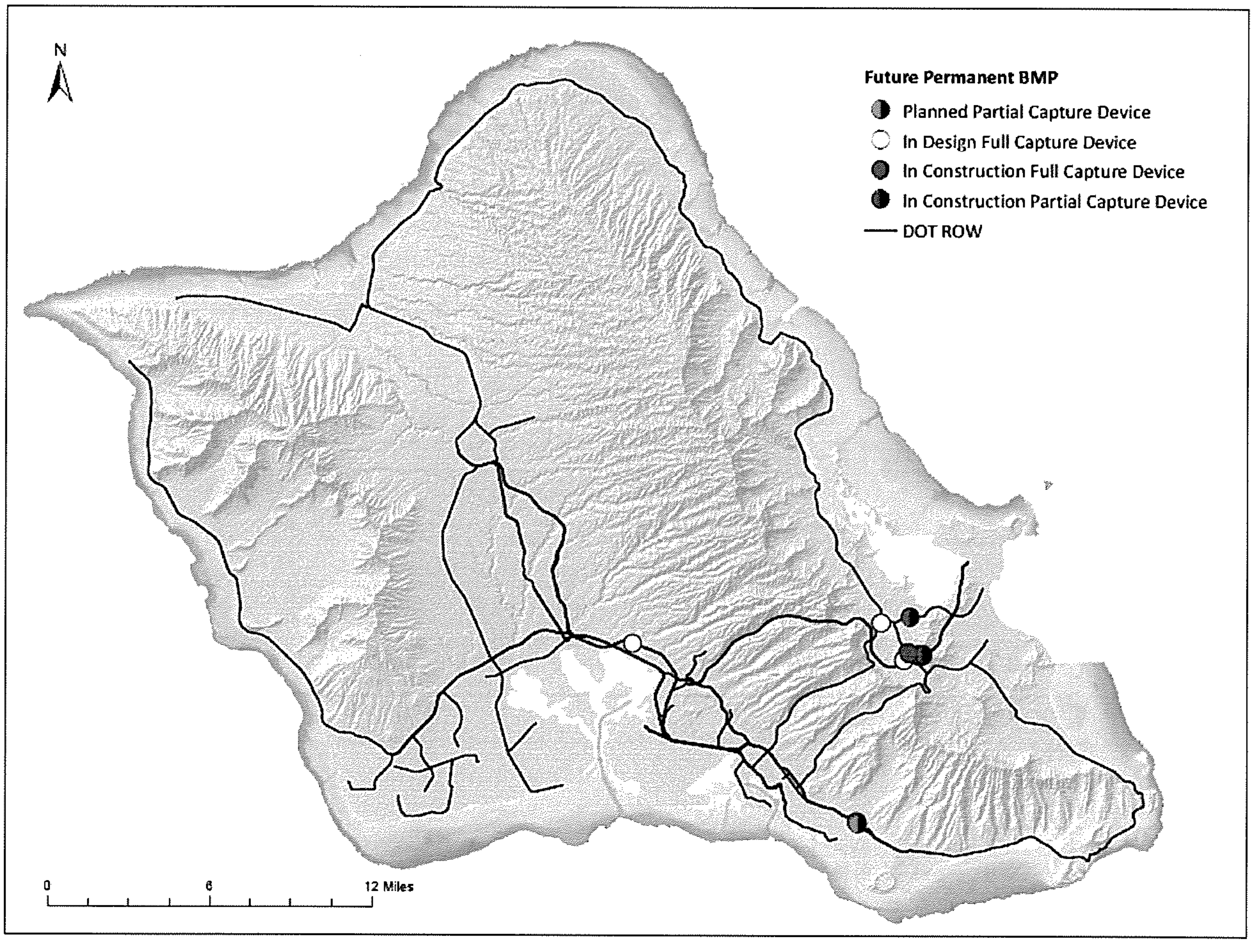


Figure 18. Sites of planned Permanent BMPs and their implementation phase.

Table 9 summarizes trash removed by these existing enhanced control measures, in terms of volume (rounded to the tenth decimal) and percent reduction (rounded to the nearest hundredth decimal).

Table 9. Anticipated annual trash reductions based on existing enhanced control measures.

EXISTING BMP PROGRAM	ENHANCEMENT	TOTAL ANTICIPATED TRASH REDUCTION	
		CY/YR	PERCENTAGE
Legislative Action*	Plastic Bag Ban	17.8	6.0%
Existing Public Education*	Targeted Outreach	5.9	2.0%
Existing Permanent BMPs	16 ha	3.6	1.2%
TOTAL EXISTING ENHANCED REDUCTION		**27.3**	**9.2%**

* *These programs may result in trash load reductions on Oahu; however, reductions are not quantified at this time and therefore considered as a theoretical percent reduction in this TRP (refer to Section 4.2 on Institutional Control Measures).*

6.3.2 Future Enhanced Control Measures

Enhancement of several control measures are needed for DOT-HWYS to meet a 50% trash load reduction from the baseline. At this stage, several BMPs options are available to meet the stated 50% trash reduction targets.

Public Education. In addition to continuing the existing outreach campaigns related to trash, DOT-HWYS plans to launch a PSA targeting trash reduction islandwide. As a result of the trash targeted advertising campaign, DOT-HWYS will benefit from a 3% annual reduction credit from the baseline, which corresponds to 8.9 cubic yards of trash removed per year (rounded to the nearest tenth decimal).

Land-Based Cleanups. DOT-HWYS will initiate a new program TRAPP to perform extensive land-based cleanups as described in Section 4.3.1. The proposed TRAPP will enhance existing trash removal programs, such as HWY-OM Litter Disposal and Removal Program and the volunteer-based Adopt-A-Highway Program.

The anticipated trash removal by TRAPP was simulated using data-driven models in GIS to guide the Implementation Schedule; and the models utilize assumptions from similar existing programs (i.e., Adopt-A-Highway). TRAPP will target trash reduction along highways and grassy areas in DOT-HWYS jurisdictional area. With TRAPP, DOT-HWYS anticipates a trash removal of 91 cubic yards per year, equivalent to a 30.64% annual reduction from the baseline (rounded to the nearest hundredth decimal). The allocation of Land-Based Cleanups will be determined by the priority trash management areas shown in Figure 16.

Street Sweeping. High-priority areas are swept once every 5 weeks; other areas are swept once every 15 weeks. Potential future changes to the Street Sweeping Program may include increasing frequency in selected geographical targets to ensure compliance with the trash reduction requirements. Based on historical trends, DOT-HWYS anticipates a 25% increase of trash removal efficiency from this enhanced street sweeping activities, which results in an additional trash removal of 14.4 cubic yards per year, equivalent to a 4.84% annual reduction from the baseline (rounded to the nearest hundredth decimal). The allocation of enhanced street sweeping will be determined by the priority trash management areas shown in Figure 16.

Permanent BMPs. DOT-HWYS may install partial and full trash capture devices, which may include hydrodynamic separators, baffle boxes, and retractable inlet screens to intercept trash in the MS4. Based on the trash loading rates per land use type discussed in Section 2, DOT-HWYS anticipates treating an additional 45 hectares with planned and future full trash capture devices, or approximately 65 hectares with partial capture devices. A combination of both corresponds to an annual trash removal of 6.9 cubic yards, equivalent to a 2.32% reduction from the baseline (rounded to the nearest hundredth decimal). The allocation of these devices will be guided by the MS4 hotspot map shown in Figure 17.

Waterbody Control Measures. DOT-HWYS does not anticipate using waterbody interception control measures at this time, but may do so in the future.

Table 10 summarizes anticipated additional trash removals, in terms of volume (rounded to the tenth decimal) and percent reduction (rounded to the nearest hundredth decimal), to reach 50% load reduction (rounded to the nearest hundredth decimal).

Table 10. Anticipated additional annual trash reductions based on future enhanced control measures.

FUTURE BMP PROGRAM	ENHANCEMENT	TOTAL ANTICIPATED TRASH REDUCTION	
		CY/YR	PERCENTAGE
Future Public Education*	PSAs	8.9	3.00%
Land-Based Cleanups	Semiannual	91.0	30.64%
Street Sweeping	Increase	14.4	4.84%
Future Permanent BMPs	65 ha	6.9	2.32%
Waterbody control measures	NA	0.0	0.00%
TOTAL FUTURE ENHANCED REDUCTION		**121.2**	**40.80%**

** These programs may result in trash load reductions on Oahu; however, reductions are not quantified at this time and therefore considered as a theoretical percent reduction in this TRP (refer to Section 4.2 on Institutional Control Measures).*

6.3.3 Short-Term Plan Summary

A combination of enhanced existing and future enhanced control measures is expected to achieve the required 50% trash load reduction by 2023, as shown in Table 11.

Table 11. Summary of anticipated annual trash reductions based on existing and future enhanced control measures.

BMP PROGRAMS	TOTAL ANTICIPATED TRASH REDUCTION	
	CY/YR	PERCENTAGE
Total Existing Enhanced Reduction[1]	27.3	9.20%
Total Future Enhanced Reduction[2]	121.2	40.80%
TOTAL ENHANCED TRASH REDUCTION	**148.5**	**50.00%**
SHORT-TERM TRASH REDUCTION TARGET	**148.5**	**50.00%**

[1] *Values derived from Table 9.*
[2] *Values derived from Table 10.*

Based on the DOT-HWYS Five Step Method, Figure 19 presents the anticipated trash percent reduction by types of control measures to achieve the required 50% trash load reductions.

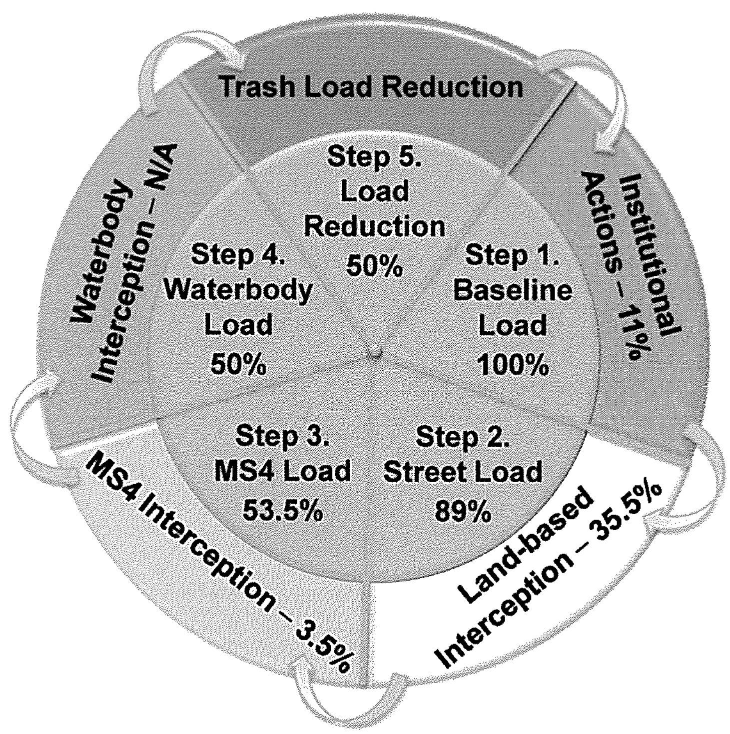


Figure 19. Short-Term Plan anticipated trash load reductions.

Table 12 combines the existing and future enhanced control measures, and their associated trash removal, in terms of both volume (rounded to the tenth decimal) and percent reduction (rounded to the nearest hundredth decimal), to efficiently reduce the trash baseline load by 50%.

Table 12. Short-Term Plan anticipated trash reductions by BMP Programs.

Five Step Method	Existing and Future BMP Program	Enhancement	Anticipated Trash Reduction	
			CY/YR	Percentage
Step 1 Institutional Actions[1]	Legislative Action	Plastic Bag Ban	17.8	6.00%
	Existing Public Education	Targeted Outreach	5.9	2.00%
	Future Public Education	PSAs	8.9	3.00%
Step 2 Land-Based Interception	Land-Based Cleanups	Semiannual	91.0	30.64%
	Street Sweeping	Increase	14.4	4.84%
Step 3 MS4 Interception	Existing Permanent BMPs	16 ha	3.6	1.20%
	Future Permanent BMPs	65 ha	6.9	2.32%
Step 4 Waterbody Interception[2]	Not Applicable (N/A)	N/A	0.0	0.00%
Step 5 Load Reduction	**TOTAL ANTICIPATED REDUCTION**		**148.5**	**50.00%**
		REDUCTION REQUIRED	**148.5**	**50.00%**

[1] These programs may result in trash load reductions on Oahu; however, reductions are not quantified at this time and therefore considered as percent reduction in this TRP (refer to Section 4.2 on Institutional Control Measures).
[2] DOT-HWYS does not anticipate using waterbody interception control measures at this time .

DOT-HWYS may amend or revise the level of enhancement for each BMP as new information becomes available during implementation of the Short-Term Plan (e.g., reduction credits and formulas). If revisions or amendments occur, a revised Short-Term Plan and implementation schedule will be submitted to DOH in the Annual Reports.

6.4 Long-Term Plan Enhanced Control Measures

The Long-Term Plan development will be based on an assessment of data collected during implementation of the Short-Term Plan, to verify the efficiency of enhanced trash control measures and revise key geographical targets. During the Long-Term Plan, DOT-HWYS plans to enhance the successful control measures to meet the 100% trash load reduction from the baseline, which corresponds to an annual trash reduction of 297 cubic yards.

The Long-Term Plan may include these enhanced control measures:

- Consider an ordinance to ban Styrofoam.
- Expand the Plastic Bag Ordinance.
- Increase school and community outreach related to trash.
- Conduct additional outreach and/or inspections of businesses that may exacerbate trash issues (e.g., fast food restaurants).
- Review the street sweeping schedule to enhance the effectiveness of street sweeping.
- Install additional full trash capture devices, such as trash skimmers

6.5 Implementation Schedule

The TRP provides an implementation schedule to meet the 50% and 100% trash reduction targets in the shortest practicable timeframe.

6.5.1 Short-Term Plan Schedule (2013 – 2023)

DOT-HWYS will implement the Short-Term Plan to meet the **trash load reduction requirement of 50% from the baseline by 2023**, which will allow 7 years to create new programs and significantly alter existing ones.

Implementation of the TRAPP will require approximately three years to mobilize funds and design the pilot program. Upon completion of the pilot program, the TRAPP will be revised and scaled islandwide. Due to the natural variability, a three-year average will be necessary to establish the actual trash removal efficiency of this program.

Concurrently, street sweeping frequency will be increased in selected geographical targets. DOT-HWYS current contract for street sweeping ends in 2018, therefore enhanced street sweeping will not take effect at the islandwide scale until 2019. Similar to the TRAPP, it will require three years to evaluate the actual trash removal efficiency of the enhanced street sweeping program, and whether additional enhancements may be needed.

Lastly, the remaining reduction gap will be addressed by Permanent BMPs. DOT-HWYS anticipates that the design and construction of Permanent BMPs will be completed by the end of

2023. It will require three years to evaluate the actual trash removal efficiency of the installed Permanent BMPs, and whether additional enhancements may be needed.

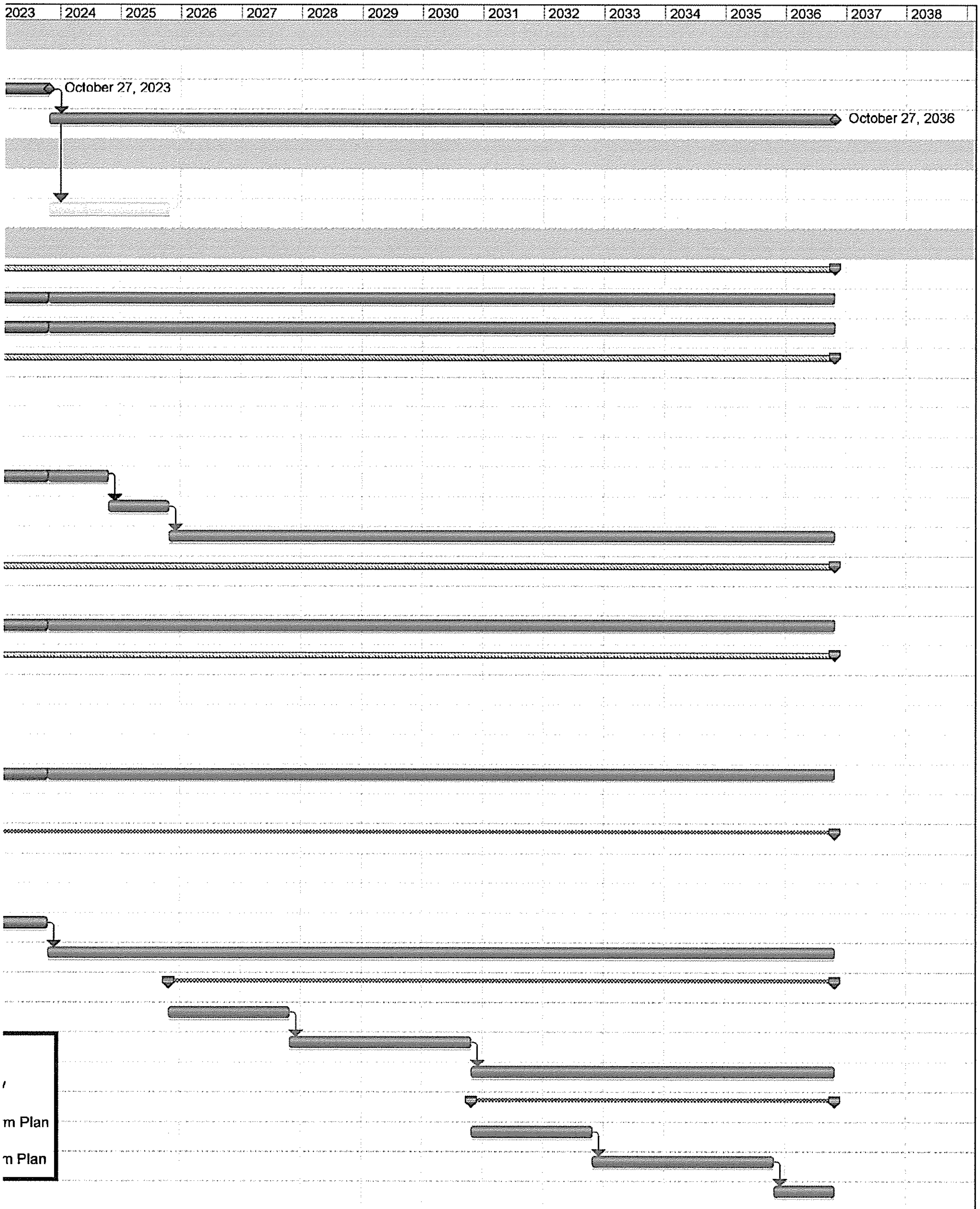
6.5.2 Long-Term Plan Schedule (2013 – 2036)

DOT-HWYS will implement the Long-Term Plan to meet the **trash load reduction requirement of 100% from the baseline by 2036**, which will allow an additional 13 years after completion of the Short-Term Plan to create new programs and significantly alter existing ones.

The Long-Term Plan will be developed based on an assessment of data collected during implementation of the Short-Term Plan. For instance, TRAPP implementation frequency may be increased based on the actual trash removal efficiency of this new program, as more data becomes available. In addition to TRAPP, the remaining reduction gap may be addressed by treating more areas with Permanent BMPs.

Due to the natural variability, a three-year average will be necessary to establish the trash removal efficiency of these programs after additional enhancements.

Figure 20 presents the proposed implementation schedule.


2023
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7. TRASH LOAD REDUCTION MONITORING AND REPORTING

This section describes how DOT-HWYS will monitor and report compliance with required trash reduction goals.

Monitoring trash generation and accumulation in the environment is challenging due to natural variability in sources, transport processes, and deposition in waterbodies. Previous studies showed that the volume of trash discharged from the MS4 is influenced by land use type, population density, existing control measures, and climatic conditions (Marais et al. 2004, BASMAA 2012). For example, there is strong evidence that rainfall in Hawaii is affected by the occurrence of *El Niño* and *La Niña* events, which can result in high year-to-year variability (Giambelluca et al. 2012). Due to these inherent challenges, DOT-HWYS intends to demonstrate compliance with trash load reductions based on a three-year running average of trash reduction data.

The TRP tracking and monitoring tools utilize a combination of existing monitoring procedures, as described in the current *Storm Water Management Program Plan (SWMPP),* and a Visual Trash Rapid Assessment to provide an evaluation of trash conditions and effectiveness of control measures.

7.1 Trash Load Reduction Monitoring Plan

DOT-HWYS will monitor trash removal from selected enhanced trash control measures, as described in the proposed Implementation Schedule, to demonstrate compliance with required trash reduction goals, as follows:

- Institutional Actions
    - Legislative Actions
    - Public Education and Outreach
- Land-Based Interception Control Measures
    - Land-Based Cleanups
    - Street Sweeping
- MS4 Interception Control Measures
    - Planned Permanent BMPs
    - Future Permanent BMPs

7.1.1 Monitoring Institutional Control Measures

DOT-HWYS will monitor enhanced institutional control measures that benefit the TRP. For instance, DOT-HWYS will monitor and report on the effectiveness of the existing and enhanced Public Education and Outreach Program, as described in the current *SWMPP Appendix B.1 Public Education and Outreach Plan.*

7.1.2 Monitoring Land-Based Interception Control Measures

DOT-HWYS will track the volume and composition of trash removed by TRAPP. Data will be maintained in a database for future analysis.

DOT-HWYS will monitor trash removal from both existing and enhanced street sweeping, as described in the current *SWMPP Chapter 6 Pollution Prevention/Good House Keeping Debris Control BMP Program.*

7.1.3 Monitoring MS4 Interception Control Measures

DOT-HWYS will monitor trash removal from both planned and future Permanent BMPs as described in the current *SWMPP Chapter 6: Pollution Prevention/Good House Keeping Debris Control BMP Program.*

7.2 Visual Trash Rapid Assessment

In addition to the proposed monitoring plan that quantitatively tracks trash removal from enhanced control measures, DOT-HWYS will adopt a Visual Trash Rapid Assessment (EOA Inc., 2013).

This assessment provides qualitative estimates of trash conditions on selected routes and adjacent land areas. This assessment serves the following two purposes:

- ***Confirmation of trash geographical targets*** to confirm or redesignate priority geographical targets assigned to specific areas via trash hotspots modeling (see Section 5).
- ***Assessment of changes in land-based trash conditions*** to provide a qualitative tool that evaluates changes in trash levels in the environment.

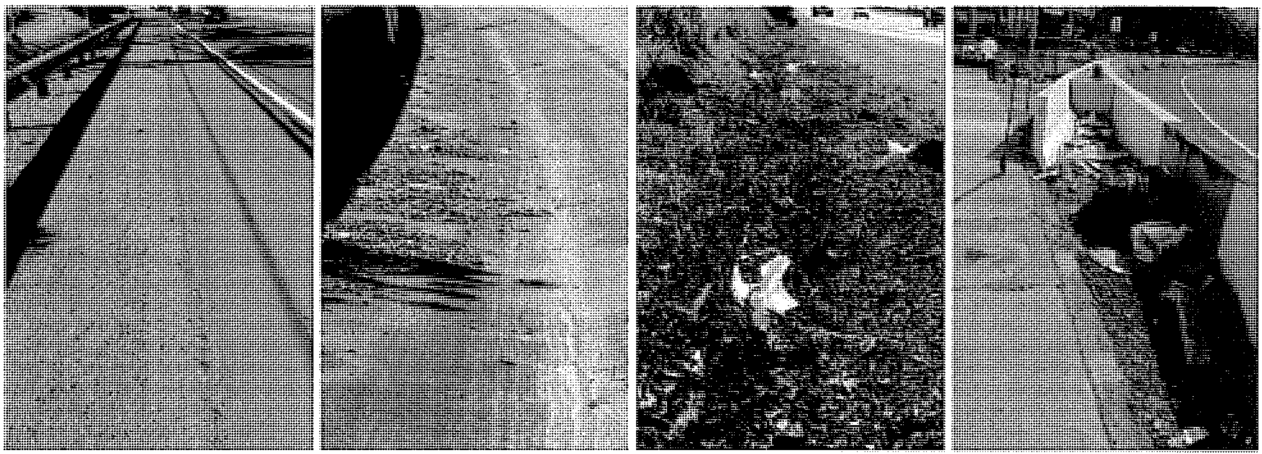
The Visual Trash Rapid Assessment protocol involves the following actions:

1. Identify assessment areas to monitor. The assessment areas should include DOT-HWYS jurisdictional area and adjacent areas where trash has the potential to enter the MS4.
2. Identify trash levels in the assessment area and in the MS4.

3. Rate the trash level observed in the assessment area based on the following categories:

Low:	Little to no trash observed.
Moderate:	Few pieces of trash evenly distributed observed.
High:	Trash widely distributed observed.
Very High:	Significant accumulation of trash observed.

Figure 21 shows examples of each trash category level.



Low trash level **Moderate trash level** **High trash level** **Very high trash level**

Figure 21. Trash rate categories and visual indicators.

All findings will be accordingly documented, and utilized to monitor and assess trash conditions in DOT-HWYS jurisdictional area.

7.3 Annual Reporting

DOT-HWYS will document implementation of the Short-Term Plan and Long-Term Plan and, progress of trash load reduction goals in the *Annual Report*. The reporting details include the following:

- Brief summary of all trash load reduction control measures implemented to date.
- Composition of trash removed via each control measure.
- Quantity of trash removed via each control measure.
- Status of trash load reduction progress.

DOT-HWYS will retain documentation on trash load reduction control measures at appropriate levels consistent with the *Five Step Method* described in this Trash Reduction Plan.

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REFERENCES

Armitage, Neil. 2001. The Removal of Urban Litter from Stormwater Drainage Systems. Chapter 19. *In* L.W. Mays (Ed.) *Stormwater Collection Systems Design Handbook.* McGraw-Hill Companies, Inc. ISBN 0-07-135471-9, New York, USA.

Armitage, N. and Rooseboom, A. 1999. *The Removal of Urban Litter from Stormwater Conduits and Streams. The quantities involved and catchment litter management options.* URL: http://www.wrc.org.za/Knowledge%20Hub%20Documents/Water%20SA%20Journals/Manuscripts/2000/02/WaterSA_2000_02_1283a.pdf.

BASMAA (Bay Area Stormwater Management Agencies Association). 2011. *Trash Load Reduction Tracking Method: Technical Memorandum #1 – Literature Review.* Prepared by Eisenberg, Olivieri and Associates (EOA). Oakland. URL: http://www.swrcb.ca.gov/rwqcb2/water_issues/programs/stormwater/MRP/02-2012/BASMAA/TL_ReductionTracking_Method.pdf

BASMAA. 2012. *Preliminary Trash Generation Rates – Technical Memorandum.* Prepared by Eisenberg, Olivieri and Associates (EOA). Oakland. URL: http://www.swrcb.ca.gov/rwqcb2/water_issues/programs/stormwater/MRP/02-2012/BASMAA/Baseline_Trash_Loads.pdf

BASMAA. 2014a. *City of San Leandro Trash Long-Term Reduction Plan and Progress Assessment Strategy.* URL: *http://www.swrcb.ca.gov.*

BASMAA. 2014b. *City of Sunnyvale Long-Term Trash Load Reduction Plan and Assessment Strategy.* URL: http://sunnyvale.ca.gov.

BASMAA. 2014c. *Vallejo Sanitation and Flood Control District, Trash Long-Term Reduction Plan and Progress Assessment Strategy.*

Berretta, C., S. Saurabh, and J.J. Sansalone. 2011. *Quantifying Nutrient Loads Associated With Urban Particulate Matter (PM) and Biogenic/Litter Recovery Through Current MS4 Source Control and Maintenance Practices.* Final Report to Florida Stormwater Association Educational Foundation.

Black & Veatch. 2013. *Quantification Study of Institutional Measures for Trash TMDL Compliance* [PowerPoint]. URL: https://www.casqa.org/asca/demonstrating-trash-tmdl-compliance-using-combination-structural-and-institutional-measures

California Integrated Waste Management Board (CIWMB). 2007. *Board Meeting Agenda, Resolution: Agenda Item 14.* Sacramento, California. June 12, 2007.

Caltrans. 2003. *Drain Inlet Cleaning Efficacy Study, CTSW-RT-03-057.36.1.* California Department of Transportation. URL: http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-03-057.pdf

Cornelius M., T. Clayton, G. Lewis, G. Arnold, and J. Craig. 1994. *Litter Associated with Stormwater Discharge in Auckland City New Zealand.* Island Care New Zealand Trust.

County of Los Angeles, Department of Public Works, Watershed Management Division. 2004. *Trash Baseline Monitoring Results Los Angeles River and Ballona Creek Watershed.* URL: http://dpw.lacounty.gov/wmd/T rashBaseline/Trash%20Monitoring%20rpt.pdf.

County of Los Angeles, Department of Public Works, Environmental Programs Division. 2007. *An Overview of Carryout Bags in Los Angeles County: A Staff Report to the Los Angeles County Board of Supervisors.* Alhambra, California. URL: http://dpw.lacounty.gov/epd/PlasticBags/PDF/PlasticBagReport_08-2007.pdf.

EOA (Eisenberg, Olivieri and Associates), Inc. 2013. *Visual On-Land Trash Assessment Protocol for Stormwater.* Draft Version 1.0. Oakland, California. URL: http://www.scvurppp-w2k.com/pdfs/1213/Visual_Trash_Assessment_Methodology-DRAFT_050213.pdf.

Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, D.M. Delparte. 2012. Online Rainfall Atlas of Hawaii. *Bulletin of the American Meteorological Society*, doi: 10.1175/BAMS-D-11-00228.1.

Marais M., N. Armitage, and Wise C. 2004.The measurements and reduction of urban litter entering stormwater drainage systems: Paper 1 – Quantifying the problem using the City of Cape Town as a case study. *Water South Africa*, **30**(4): 469-482

Sartor, J.D., G. B. Boyd, and F.J. Argardy. 1974. Water pollution aspects of street surface contaminants. *Journal Water Pollution Control Federation*, **46:** 458-467. March 1974.

Sartor, J.D and D.R. Gaboury. 1984. Street sweeping as a water pollution control measure: lessons learned over the past ten years. *The Science of the Total Environment*, **33:** 171-183.

State of Hawaii Department of Transportation, Highways Division, Oahu District. 2013. *National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit No. HI S000001*, effective October 28, 2013, modified April 1, 2016.

State of Hawaii, Department of Transportation, Highways Division, Oahu District. 2015. *Storm Water Management Program Plan (April 2015)*, NPDES MS4 Permit No. HI S000001. Storm Water Management Program, Honolulu, Hawaii.

Hawaii State Department of Transportation, Highways Division, Oahu District. 2015. *Storm Water Permanent Best Management Practices Manual (April 2015)*, NPDES MS4 Permit No. HI S000001. Storm Water Management Program, Honolulu, Hawaii.

Walker, T.A. and T.H.F. Wong. 1999. *Effectiveness of Street Sweeping for Stormwater Pollution Control.* Technical Report 99/8. Cooperative Research Centre for Catchment Hydrology, Victoria, Australia. December 1999.

USEPA (United States Environmental Protection Agency). 2002. *Assessing and Monitoring Floatable Debris.* August 2002. URL: http://water.epa.gov/type/oceb/marinedebris/upload/2006_10_6_oceans_debris_floatingdebris_debris-final.pdf.

Cheryl King, MSc.

Cheryl King has a Bachelor's of Science degree in biology/psychology from Southampton College of Long Island University and a Master's of Science degree in marine biology from Nova Southeastern University Oceanographic Center (her master's research was a comprehensive study of Kaho'olawe's sea turtle population). In addition to being on research teams around the world, as a 17-year Maui resident she has gained a vast amount of experience in ocean conservation and marine animal rescue and management while working for the State, tourism and non-profit sectors. Cheryl has been fascinated by marine debris and passionate about cleaning coastlines since witnessing, for the first time in 2002, the tons that had accumulated at Kanapou Bay, Kaho'olawe from Hawai'i and all over the Pacific. Conducting annual cleanups there wasn't enough, so through a NOAA Marine Debris Program grant to the Kaho'olawe Island Reserve Commission, Cheryl spearheaded the removal of 31 tons of debris in 10 cleanup campouts (2010-2011). They sent 6.6 of these tons of marine debris (what filled a 40-ft container) to the Museum fur Gestaltung in Zurich, Switzerland for an exhibit that has since been traveling all around Europe and Asia (it is currently in Stockholm, Sweden). Cheryl has observed seabirds dying from ingesting marine debris in the remote Papahanaumokuakea Marine National Monument and started a marine debris accumulation study on the even more remote Palmyra Atoll. She created www.SHARKastics.org in 2010 to spread the word about the harmful impacts of marine debris on multiple marine species. She is a member of the NOAA Hawai'i Marine Debris Hui and the Hawai'i Environmental Cleanup Coalition, and she regularly reports on the data she and her trash team collects during the community-based marine debris cleanups on the 4th Sunday of every month at Ka'ehu, Waiehu (since July 2012). She also plays key roles in NOAA's South Maui Marine Turtle Strandings Response Team, the Hawaiian Islands Large Whale Entanglement Response Network and Maui Nui's Marine Mammal Health and Strandings Response Team. She runs the statewide Hawaiian hawksbill photo-ID catalog that showcases research and recovery efforts for the critically endangered Hawaiian hawksbill sea turtle (one of the most endangered populations on the planet, that she has been working closely with since the year 2000): www.HIhawksbills.org. Cheryl is currently on the Board of Directors for the Hawai'i Association of Marine Education and Research, whose mission is to conduct sound research to better understand the health and status of our marine resources and how to conserve them: www.HAMERinHawaii.org. She appreciates the opportunity and looks forward to discussing the important topic of marine debris with the council to find solutions!

SHARKASTICS™
TAKING A BITE OUT OF MARINE DEBRIS
WWW.SHARKASTICS.ORG

Polystyrene Data Summary from Ka'ehu Cleanups
May 2, 2017

We spearhead community-based marine debris cleanups on the 4th Sunday of every month at Ka'ehu, in Waiehu, to help restore this important habitat for the marine and terrestrial resources that utilize this special place. Marine debris is removed from a ~100 to 200 yard stretch of this rocky/sandy coast. The effort varies depending on the participants, not due to the shortage of marine debris- it's always washing ashore! It comes from all over the Pacific Ocean and from Hawai'i-based sources. To bring this global issue into context with this Maui County polystyrene reduction bill, here are some numbers to quantify this pollution problem we're dealing with:

In addition to simply removing the debris from this coast every month, we also sorted and counted each piece of marine debris at our monthly cleanups from July 22, 2012 through June 28, 2015, on September 27, 2016 ("Get the Drift and Bag It" campaign), and 4 months in 2017 so far: January through April. This process is very time consuming with all of our specific categories we're analyzing, but collecting data during 40 out of the 56 monthly cleanups yielded:

- **175,825** pieces of marine debris collected/sorted/counted
    - **4,395.6** pieces of marine debris on average per cleanup

- The majority of the debris items were plastics followed by polystyrene/foam, fabric, metal, rubber, glass, and processed wood (see charts below).

    - **15,728** total pieces of expanded polystyrene foam
        - **393.2** pieces on average per cleanup

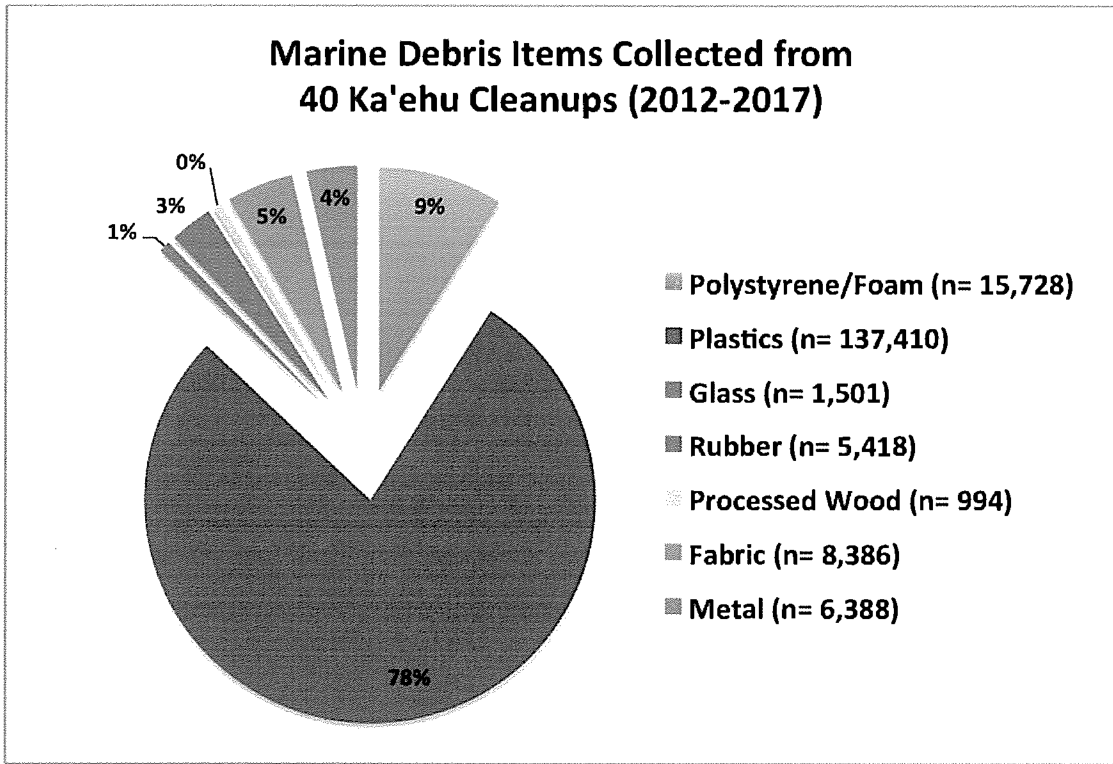
- This equates to a depressing reality that expanded polystyrene foam pieces have been **8.9%** of the total marine debris items we've removed from Ka'ehu.

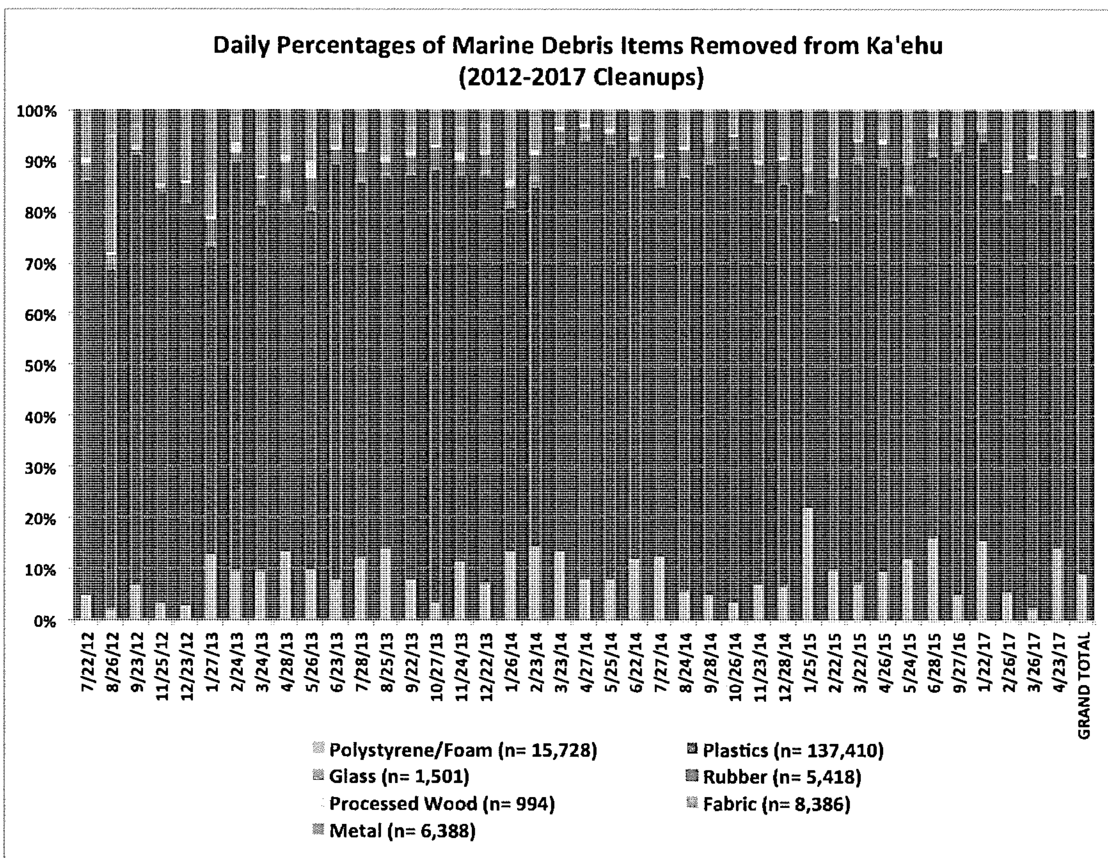
These data are not published; but that process will be pursued after all 2017 cleanups are completed. For the remainder of 2017, we will be sub-categorizing the polystyrene/foam options so we have a more specific summary of the debris types when possible. Please let me know if you have any questions.

Sincerely,

~Cheryl S. King

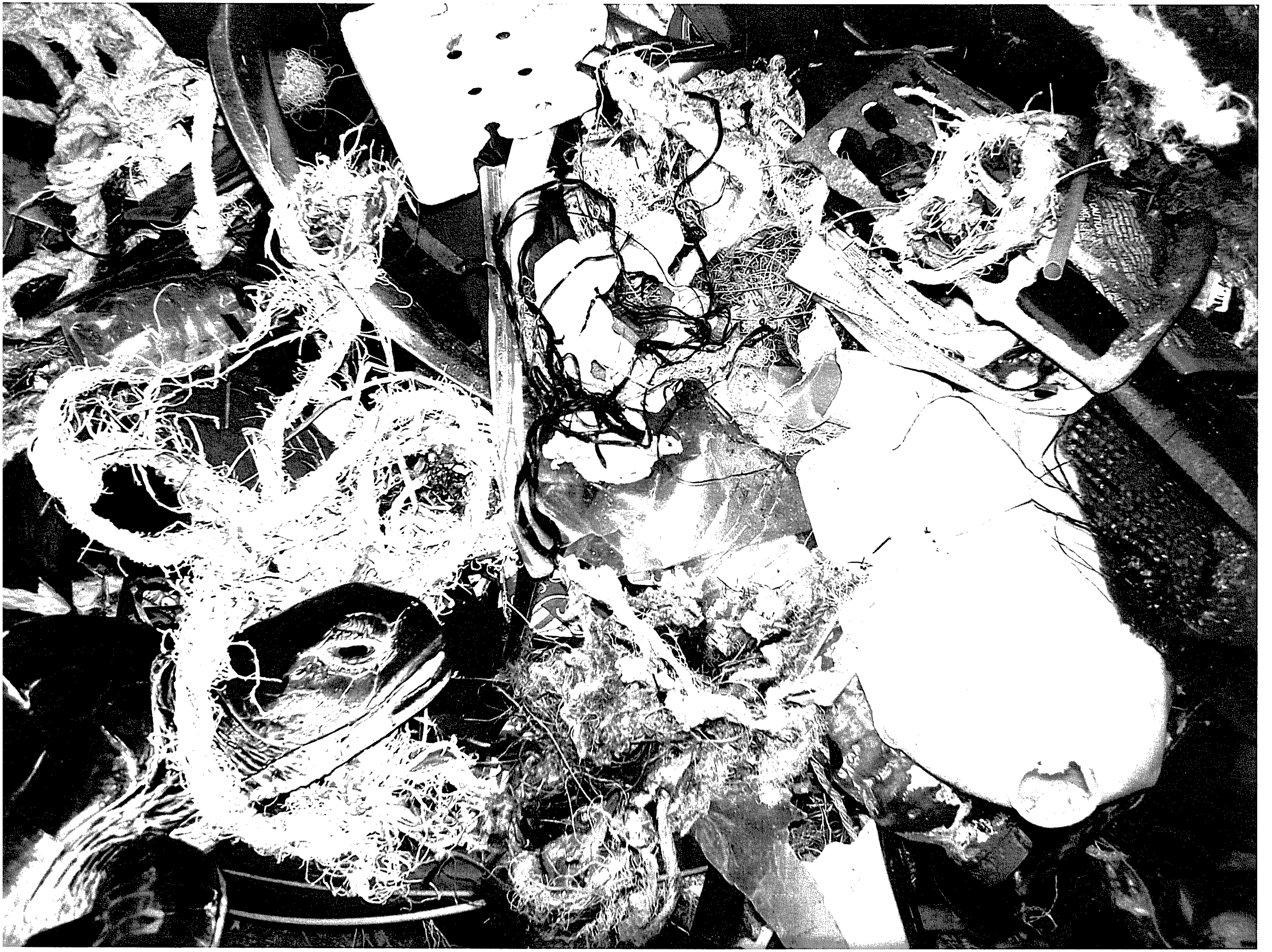
Cheryl King, MSc.
SHARKastics.org Founder


Marine Debris Items Collected from
40 Ka'ehu Cleanups (2012-2017)
0%
3%
1%
5%
4%
9%
78%
Polystyrene/Foam (n= 15,728)
Plastics (n= 137,410)
Glass (n= 1,501)
Rubber (n= 5,418)
Processed Wood (n= 994)
Fabric (n= 8,386)
Metal (n= 6,388)

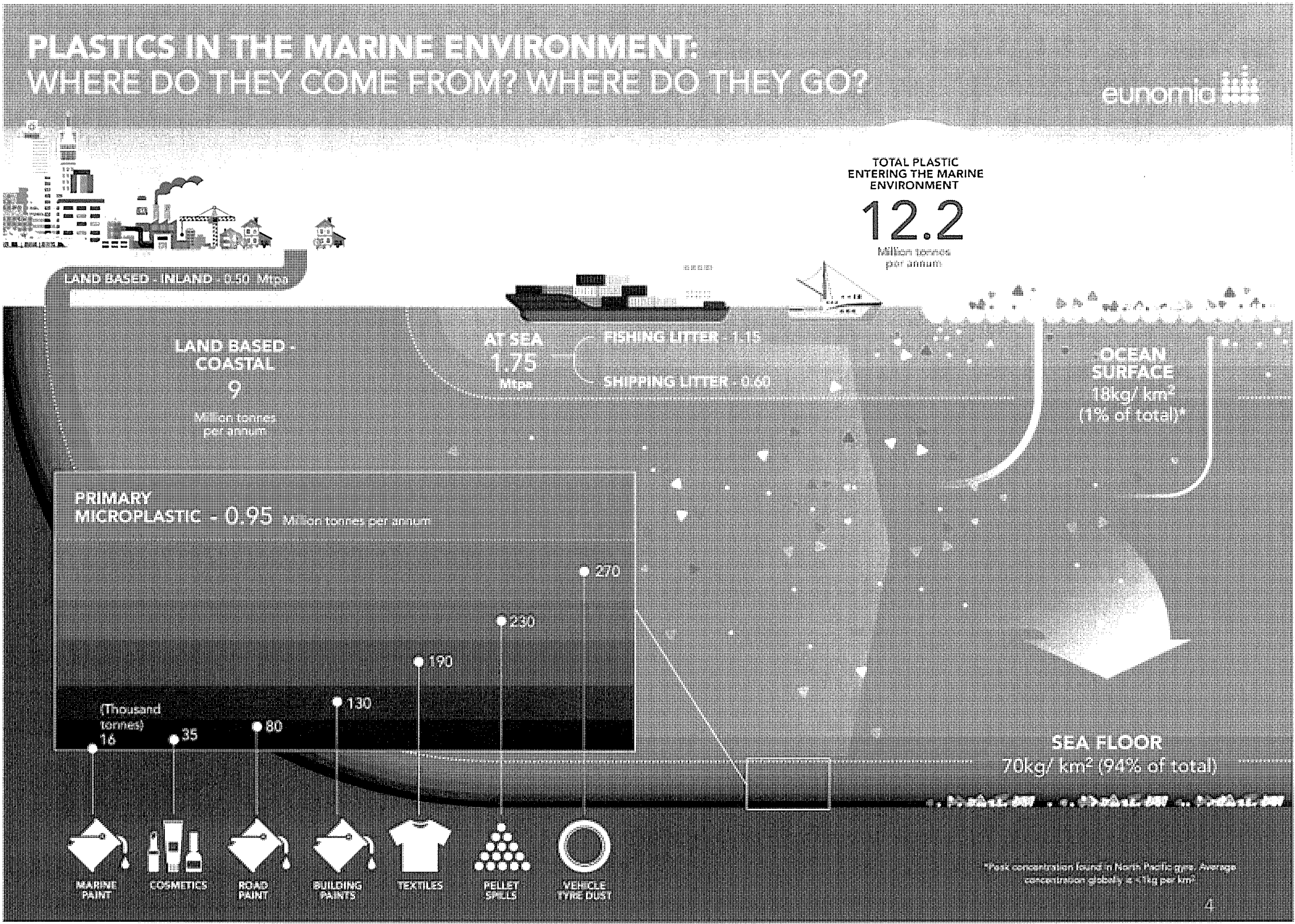

Daily Percentages of Marine Debris Items Removed from Ka'ehu
(2012-2017 Cleanups)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
7/22/12
8/26/12
9/23/12
11/25/12
12/23/12
1/27/13
2/24/13
3/24/13
4/28/13
5/26/13
6/23/13
7/28/13
8/25/13
9/22/13
10/27/13
11/24/13
12/22/13
1/26/14
2/23/14
3/23/14
4/27/14
5/25/14
6/22/14
7/27/14
8/24/14
9/28/14
10/26/14
11/23/14
12/28/14
1/25/15
2/22/15
3/22/15
4/26/15
5/24/15
6/28/15
9/27/16
1/22/17
2/26/17
3/26/17
4/23/17
GRAND TOTAL
Polystyrene/Foam (n= 15,728)
Plastics (n= 137,410)
Glass (n= 1,501)
Rubber (n= 5,418)
Processed Wood (n= 994)
Fabric (n= 8,386)
Metal (n= 6,388)

Polystyrene:
A Pesky Pollution Problem
with a Positive People Solution: Bill 127!

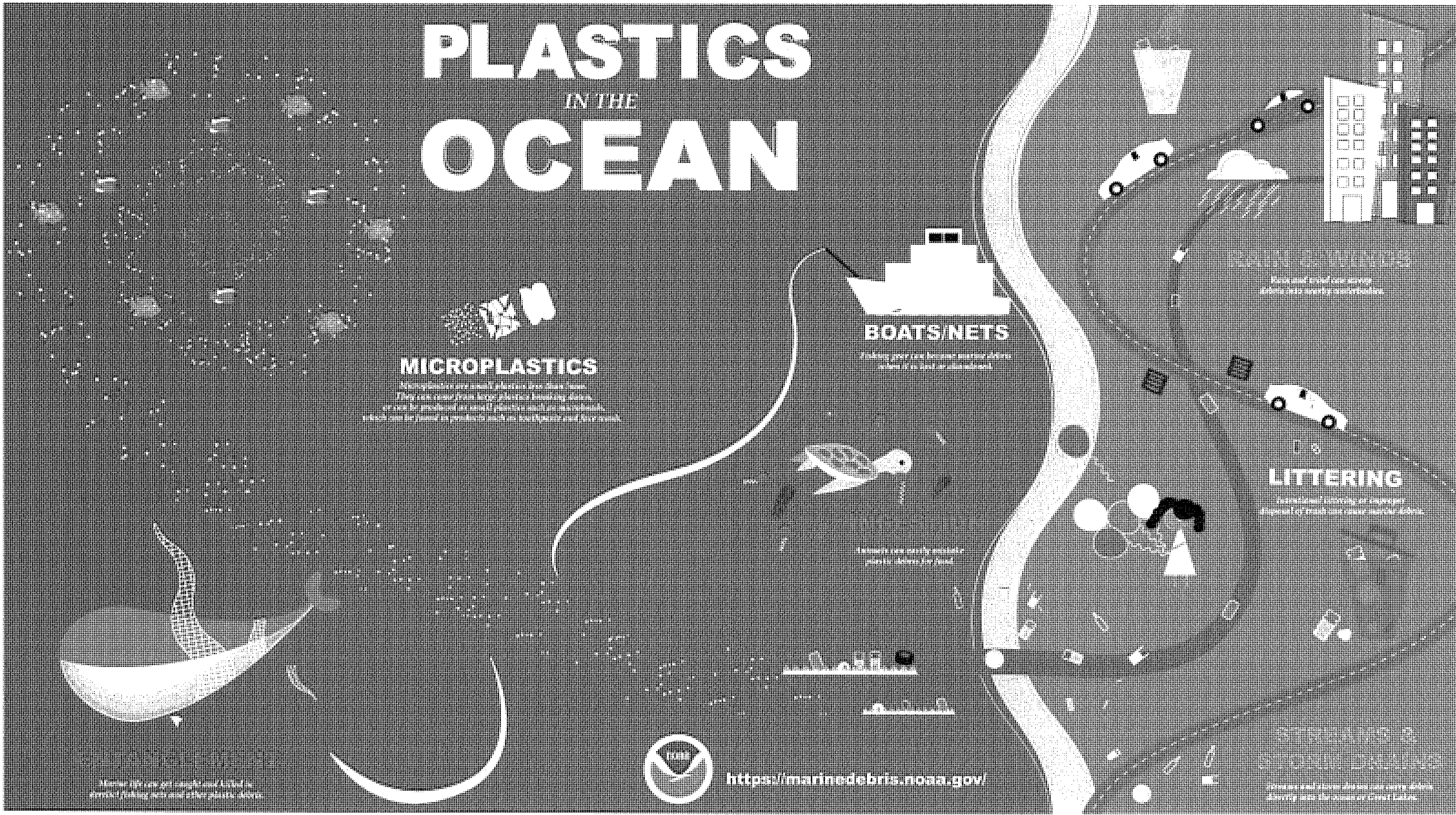
~Cheryl King, MSc.




More
Turtles
Less
Nurdles!



PLASTICS IN THE MARINE ENVIRONMENT:
WHERE DO THEY COME FROM? WHERE DO THEY GO?
eunomia
TOTAL PLASTIC ENTERING THE MARINE ENVIRONMENT
12.2
Million tonnes per annum
LAND BASED - INLAND - 0.50 Mtpa
LAND BASED - COASTAL
9
Million tonnes per annum
AT SEA
1.75
Mtpa
FISHING LITTER - 1.15
SHIPPING LITTER - 0.60
OCEAN SURFACE
18kg/ km²
(1% of total)*
PRIMARY MICROPLASTIC - 0.95 Million tonnes per annum
(Thousand tonnes)
16
35
80
130
190
230
270
SEA FLOOR
70kg/ km² (94% of total)
MARINE PAINT
COSMETICS
ROAD PAINT
BUILDING PAINTS
TEXTILES
PELLET SPILLS
VEHICLE TYRE DUST
*Peak concentration found in North Pacific gyre. Average concentration globally is <1kg per km²
4


PLASTICS
IN THE
OCEAN
MICROPLASTICS
BOATS/NETS
LITTERING
https://marinedebris.noaa.gov/

Marine Debris is a Global Issue

LITTERBASE Deutsch

1,333 species are affected by litter (818 publications)

Species / genera were classified using the World Register of Marine Species and assigned to habitats using e.g. SeaLifeBase and FishBase. Seals and seabirds were assigned to beach and surface, whales to pelagic and surface, turtles to beach, surface and pelagic environments. Organisms from flotsam were classified as benthic; bacteria and lower taxa were not assigned to any habitat. Values are shown by clicking on pie charts.

References

Amorocho, D.F., Reina, R.D., 2007. Feeding ecology of the east Pacific green sea turtle *Chelonia mydas agassizii* at Gorgona National Park, Colombia. Endanger. Species Res. 3:43–51. http://dx.doi.org/10.3354/esr003043.

Ayres, M.A., Ayres-Jr, M., Ayres, D.L., Santos, A.A., 2007. BioEstat – Aplicações estatísticas nas áreas das ciências bio-médicas. Ong Mamirauá, Belém.

Balazs, G.H., 1985. Impact of ocean debris on marine turtles: entanglement and ingestion. Proceedings of the Workshop on the Fate and Impact of Marine Debris US National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum 54. National Marine Fisheries Service, Honolulu, pp. 387–429.

Barnes, D.K.A., Galgani, F., Thompson, R.C., Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments. Philos. Trans. R. Soc. B 364:1985–1998. http://dx.doi.org/10.1098/rstb.2008.0205.

Baulch, S., Perry, C., 2014. Evaluating the impacts of marine debris on cetaceans. Mar. Pollut. Bull. 80:210–221. http://dx.doi.org/10.1016/j.marpolbul.2013.12.050.

Benedito, A.P.M., Awabdi, D.R., 2014. How marine debris ingestion differs among megafauna species in a tropical coastal area. Mar. Pollut. Bull. 88:86–90. http://dx.doi.org/10.1016/j.marpolbul.2014.09.020.

Bjorndal, K.A., 1979. Cellulose digestion and volatile fatty acid production in the green turtle, *Chelonia mydas*. Comp. Biochem. Physiol. A Physiol. 63:127–133. http://dx.doi.org/10.1016/0300-9629(79)90638-8.

Bjorndal, K.A., 1997. Foraging ecology and nutrition of sea turtles. In: Lutz, P.L. (Ed.), The Biology of Sea Turtles. CRC Press, Boca Raton, FL, pp. 199–231.

Bjorndal, K.A., Bolten, A.B., Lagueux, C.J., 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. Mar. Pollut. Bull. 28:154–158. http://dx.doi.org/10.1016/0025-326X(94)90391-3.

Bolten, A.B., 1999. Techniques for measuring sea turtles. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., Donnely, M. (Eds.), Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No Vol. 4, pp. 110–114.

Bugoni, L., Krause, L., Petry, M.V., 2001. Marine debris and human impacts on sea turtles in southern Brazil. Mar. Pollut. Bull. 41:1330–1334. http://dx.doi.org/10.1016/S0025-326X(01)00147-3.

Bugoni, L., Krause, L., Petry, M.V., 2003. Diet of sea turtles in southern Brazil. Chelonian Conserv. Biol. 4, 685–688.

Casale, P., Freggi, D., Paduano, D., Oliverio, M., 2016. Biases and best approaches for assessing debris ingestion in sea turtles, with a case study in the Mediterranean. Mar. Pollut. Bull. 110:238–249. http://dx.doi.org/10.1016/j.marpolbul.2016.06.057.

Ceppa, E.P., Fuh, K.C., Bulkley, G.B., 2003. Mesenteric hemodynamic response to circulatory shock. Curr. Opin. Crit. Care 9, 127–132.

Codina-García, M., Militão, T., Moreno, J., González-Solís, J., 2013. Plastic debris in Mediterranean seabirds. Mar. Pollut. Bull. 77:220–226. http://dx.doi.org/10.1016/j.marpolbul.2013.10.002.

Erlacher-Reid, A.C.D., Norton, T.M., Harms, C.A., Thompson, R., Reese, D.J., Walsh, M.T., Stamper, M.A., 2013. Intestinal and cloacal strictures in free-ranging and aquarium-maintained green sea turtles (*Chelonia mydas*). J. Zoo Wildl. Med. 44:408–429. http://dx.doi.org/10.1638/2012-0071R1.

European Commission, 2013. Guidance on Monitoring of Marine Litter in European Seas. JRC Scientific and Policy Reports, Luxembourg (125 pp).

Faris, J., Hart, H., 1994. Sea of debris: a summary of the Third International Conference on Marine Debris. North Carolina Sea Grant College Program.

Fendall, L.S., Sewell, M.A., 2009. Contributing to marine pollution by washing your face. Microplastics in facial cleansers. Mar. Pollut. Bull. 58:1225–1228. http://dx.doi.org/10.1016/j.marpolbul.2009.04.025.

Ferreira, M.B.M.S., Garcia, M., Jupp, B.P., Al-Kiyumi, A., 2006. Diet of the green turtle (*Chelonia mydas*) at Ra's Al Hadd, Sultanate of Oman. Chelonian Conserv. Biol. 5:141–146. http://dx.doi.org/10.2744/1071-8443(2006)5[141:DOTGTC]2.0.CO;2.

Gall, S.C., Thompson, R.C., 2015. The impact of debris on marine life. Mar. Pollut. Bull. 92:170–179. http://dx.doi.org/10.1016/j.marpolbul.2014.12.041.

González-Carman, V., Botto, F., Gaitán, E., Albareda, D., Campagna, C., Mianzan, H., 2014a. A jellyfish diet for the herbivorous green turtle *Chelonia mydas* in the temperate SW Atlantic. Mar. Biol. 161:339–349. http://dx.doi.org/10.1007/s00227-013-2339-9.

González-Carman, V., Machain, N., Albareda, D., Mianzan, H., Campagna, C., 2014b. Young green turtles, *Chelonia mydas*, exposed to plastic in a frontal area of the SW Atlantic. Mar. Pollut. Bull. 78:56–75. http://dx.doi.org/10.1016/j.marpolbul.2013.11.012.

Goshe, L., Avens, L., Scharf, F.S., Southwood, A.L., 2010. Estimation of age at maturation and growth of Atlantic green turtles (*Chelonia mydas*) using skeletochronology. Mar. Biol. 157:1725–1740. http://dx.doi.org/10.1007/s00227-010-1446-0.

Gregory, M., 1996. Plastic 'scrubbers' in hand cleansers: a further (and minor) source for marine pollution identified. Mar. Pollut. Bull. 32:867–871. http://dx.doi.org/10.1016/S0025-326X(96)00047-1.

Guebert-Bartholo, F., Barletta, M., Costa, M.F., Monteiro-Filho, E.L.A., 2011. Using gut contents to assess foraging patterns of juvenile green turtles *Chelonia mydas* in the Paranaguá Estuary, Brazil. Endanger. Species Res. 13:131–143. http://dx.doi.org/10.3354/esr00320.

Hopewell, J., Dvorak, R., Kosior, E., 2009. Plastics recycling: challenges and opportunities. Philos. Trans. R. Soc. B 364:2115–2126. http://dx.doi.org/10.1098/rstb.2008.0311.

Ivar-do-Sul, J.A., Costa, M.F., 2007. Marine debris review for Latin America and the wider Caribbean region: from the 1970s until now, and where do we go from here? Mar. Pollut. Bull. 54:1087–1104. http://dx.doi.org/10.1016/j.marpolbul.2007.05.004.

Lemons, G., Lewison, R., Komoroske, L., Gaos, A., Lai, C.T., Dutton, P., Eguchi, T., Leroux, R., Seminoff, J.A., 2011. Trophic ecology of green sea turtle in a highly urbanized bay: insights from stable isotopes and mixing models. J. Exp. Mar. Biol. Ecol. 405:25–32. http://dx.doi.org/10.1016/j.jembe.2011.05.012.

Lusher, A.L., McHugh, M., Thompson, R.C., 2013. Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Mar. Pollut. Bull. 67:94–99. http://dx.doi.org/10.1016/j.marpolbul.2012.11.028.

Magalhães, M.S., Freitas, M.L., Silva, N., Moura, C.E.B., 2010. Morfologia do tubo digestório da tartaruga verde (*Chelonia mydas*). Pesqui. Vet. Bras. 30:676–684. http://dx.doi.org/10.1590/S0100-736X2010000800012.

Magalhães, M.S., Santos, A.J.B., Silva, N.B., Moura, C.E.B., 2012. Anatomy of the digestive tube of sea turtles (Reptilia: Testudines). Zoologia 29:70–76. http://dx.doi.org/10.1590/S1984-46702012000100008.

Márquez, R., 1990. FAO species catalogue. Sea Turtles of the World, an Annotated and Illustrated Catalogue of Sea Turtles Known to Date. 11. FAO, Rome.

McCauley, S.J., Bjorndal, K., 1999. Conservation implications of dietary dilution from debris ingestion: sublethal effects in post-hatchling loggerhead sea turtles. Conserv. Biol. 13:925–929. http://dx.doi.org/10.1046/j.1523-1739.1999.98264.x.

Meylan, A.B., Meylan, P.A., 1999. Introduction to the evolution, life history, and biology of sea turtles. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., Donnelly, M. (Eds.), Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No Vol. 4, pp. 3–5.

Monteiro, D.S., Estima, S.C., Gandra, T.B., Silva, A.P., Bugoni, L., Swimmer, Y., Seminoff, J.A., Secchi, E.R., 2016. Long-term spatial and temporal patterns of sea turtle strandings in southern Brazil. Mar. Biol. 163:247. http://dx.doi.org/10.1007/s00227-016-3018-4.

Murray, F., Cowie, P.R., 2011. Plastic contamination in the decapod crustacean *Nephrops norvegicus* (Linnaeus, 1758). Mar. Pollut. Bull. 62:1207–1217. http://dx.doi.org/10.1016/j.marpolbul.2011.03.032.

Musick, J.A., Limpus, C.J., 1997. Habitat utilization and migration in juvenile sea turtles. In: Lutz, P.L., Musick, J.A. (Eds.), The Biology of Sea Turtles, Boca Raton, FL, pp. 137–164.

Nelms, S.E., Duncan, E.M., Broderick, A.C., Galloway, T.S., Godfrey, M.H., Hamann, M., Lindeque, P.K., Godley, B.J., 2016. Plastic and marine turtles: a review and call for research. ICES J. Mar. Sci. 73:165–181. http://dx.doi.org/10.1093/icesjms/fsv165.

Parks, D.A., Bulkley, G.B., Granger, D.N., 1983. Role of oxygen-derived free radicals in digestive tract diseases. Surgery 94, 415–422.

Plastics Europe, 2012. Plastics – The Facts 2012: An Analysis of European Plastics Production, Demand and Waste Data for 2011. Brussels, Belgium (36 pp).

Reisser, J., Proietti, M., Sazima, I., Kinas, P., Horta, P., Secchi, E., 2013. Feeding ecology of the green turtle (*Chelonia mydas*) at rocky reefs in western South Atlantic. Mar. Biol. 160:3169–3179. http://dx.doi.org/10.1007/s00227-013-2304-7.

Ryan, P.G., Moloney, C.L., 1993. Marine litter keeps increasing. Nature 361:23. http://dx.doi.org/10.1038/361023a0.

Santos, R.G., Andrades, R., Boldrini, M.A., Martins, A.S., 2015. Debris ingestion by juvenile marine turtles: an underestimated problem. Mar. Pollut. Bull. 93:37–43. http://dx.doi.org/10.1016/j.marpolbul.2015.02.022.

Schuyler, Q., Hardesty, B.D., Wilcox, C., Townsend, K., 2014a. Global analysis of anthropogenic debris ingestion by sea turtles. Conserv. Biol. 28:129–139. http://dx.doi.org/10.1111/cobi.12126.

Schuyler, Q., Wilcox, C., Townsend, K., Hardesty, B.D., Marshall, N.J., 2014b. Mistaken identity? Visual similarities of marine debris to natural prey items of sea turtles. BMC Ecol. 14:14. http://dx.doi.org/10.1186/1472-6785-14-14.

Shulman, A., Lutz, A., 1995. The effect of plastic ingestions on lipid metabolism in the green sea turtle (*Chelonia mydas*). NOAA technical memorandum no. 36, pp. 122–124.

Thompson, R.C., Moore, C.J., VomSaal, F.S., Swan, S.H., 2009. Plastics, the environment and human health: current consensus and future trends. Philos. Trans. R. Soc. B 364:2153–2166. http://dx.doi.org/10.1098/rstb.2009.0053.

Tourinho, P.S., Ivar-do-Sul, J.A., Fillmann, G., 2009. Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil? Mar. Pollut. Bull. 60:396–401. http://dx.doi.org/10.1016/j.marpolbul.2009.10.013.

UNEP (United Nations Environment Programme), 2005. Marine Litter, an Analytical Overview. UNEP, Nairobi (49 pp).

Vélez-Rubio, G.M., Estrades, A., Fallabrino, A., Tomás, J., 2013. Marine turtle threats in Uruguayan waters: insights from 12 years of stranding data. Mar. Biol. 160:2797–2811. http://dx.doi.org/10.1007/s00227-013-2272-y.

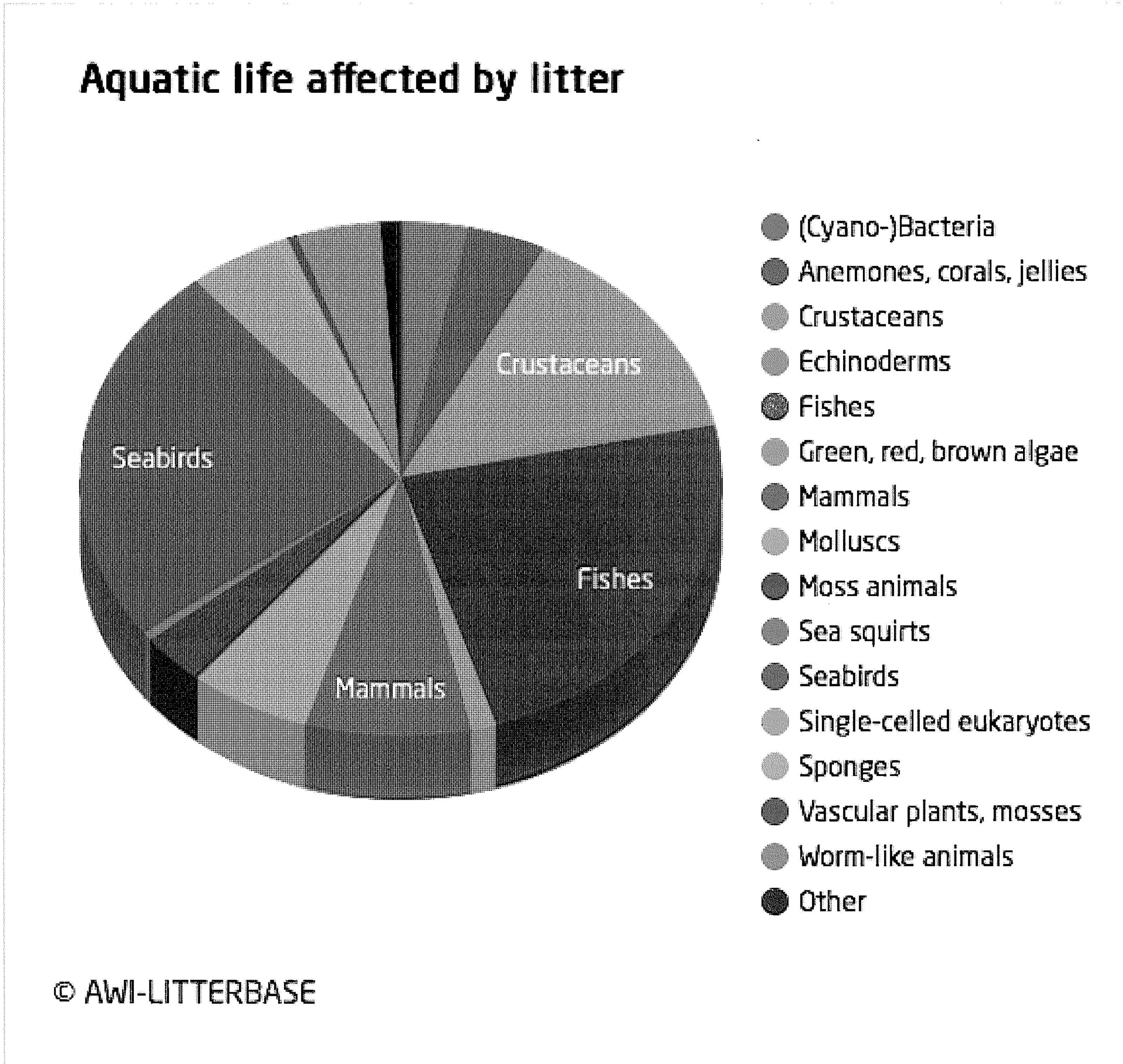
Walsh, M., 1999. Rehabilitation of sea turtles. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., Donnelly, M. (Eds.), Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No Vol. 4, pp. 202–207.

Wedemeyer-Strombel, K.R., George, S., James, H.B., Peterson, T.D., Wicksten, M.K., Plotkin, P.T., 2015. High frequency of occurrence of anthropogenic debris ingestion by sea turtles in the North Pacific Ocean. Mar. Biol. 162:2079–2091. http://dx.doi.org/10.1007/s00227-015-2738-1.

Work, T.M., 2000. Manual de necropsia de tortugas marinas para biólogos en refugios o areas remotas. National Wildlife Health Center, Hawaii Field Station (25 pp).

Wright, S.L., Rowe, D., Thompson, R.C., Galloway, T.S., 2013. Microplastic ingestion decreases energy reserves in marine worms. Curr. Biol. 23:1031–1033. http://dx.doi.org/10.1016/j.cub.2013.10.068.

Wyneken, J., 2001. The anatomy of sea turtles. NOAA Technical Memorandum NMFS-SEFSC-470, Miami (172 pp).


Aquatic life affected by litter
Crustaceans
Seabirds
Fishes
Mammals
(Cyano-)Bacteria
Anemones, corals, jellies
Crustaceans
Echinoderms
Fishes
Green, red, brown algae
Mammals
Molluscs
Moss animals
Sea squirts
Seabirds
Single-celled eukaryotes
Sponges
Vascular plants, mosses
Worm-like animals
Other
© AWI-LITTERBASE

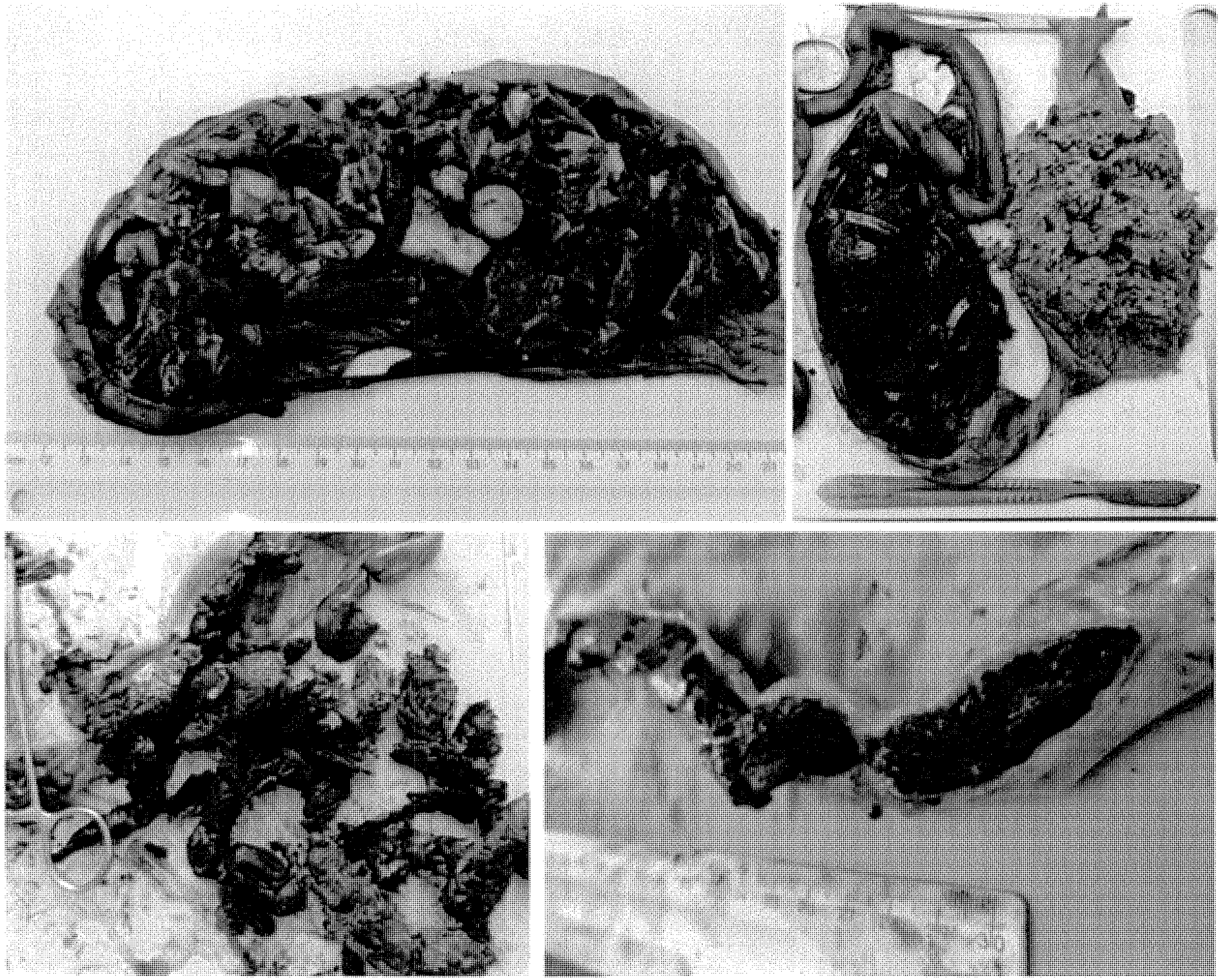
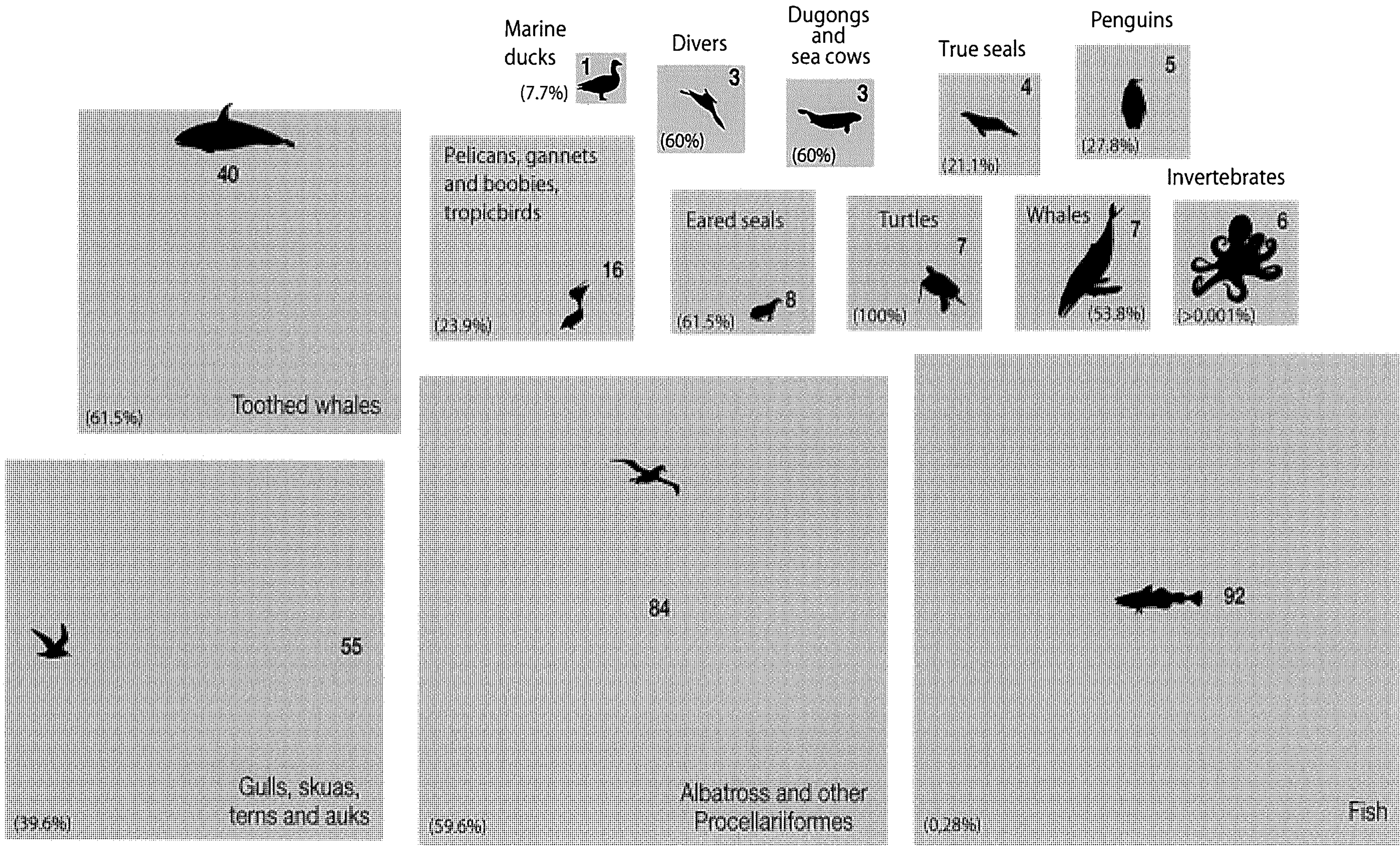


Fig. 2. Above are two examples of obstructions found in stomach of green sea turtles (*Chelonia mydas*) in southern Brazil, composed by compacted food material and anthropogenic solid debris. Obstructions could also be found in intestines. Faecalomas (below) are found in intestines only, also composed by food and plastics or other debris, but food is at a more advanced digestion stage and with a hardened consistency. Photos: CRAM archives.

Plasticized animal species - Ingestion

Number of species with documented records of marine debris ingestion

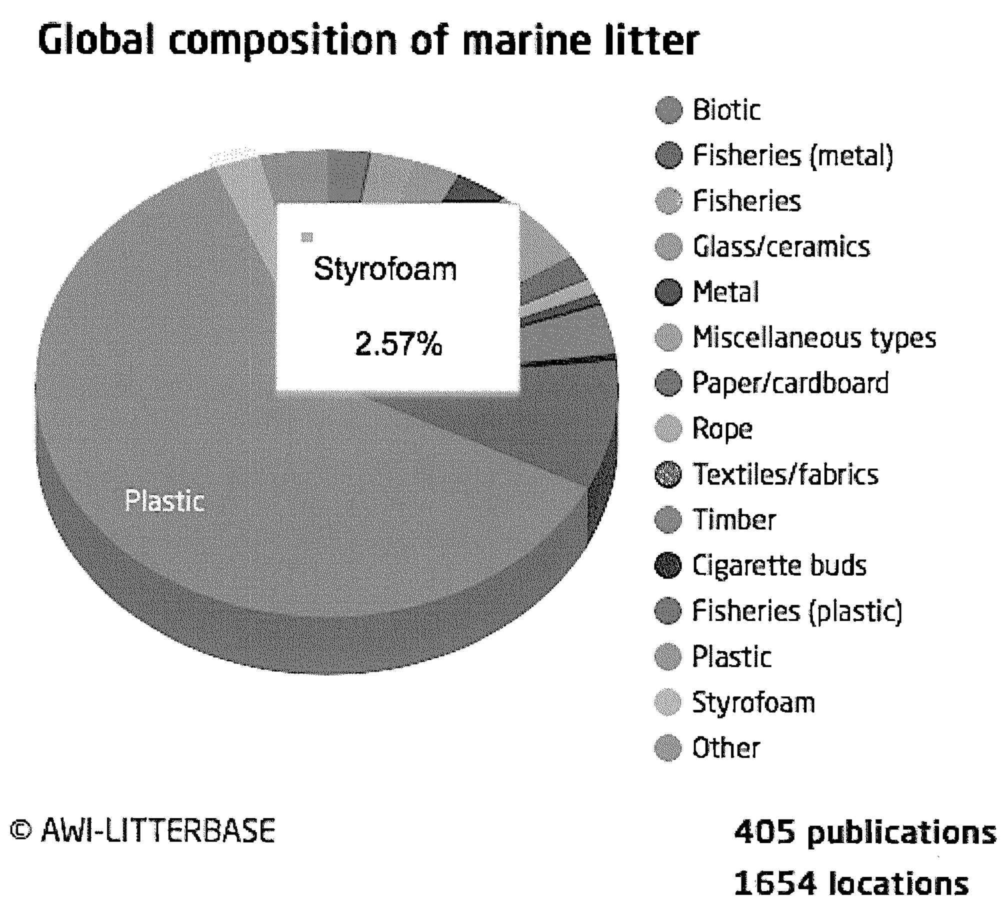


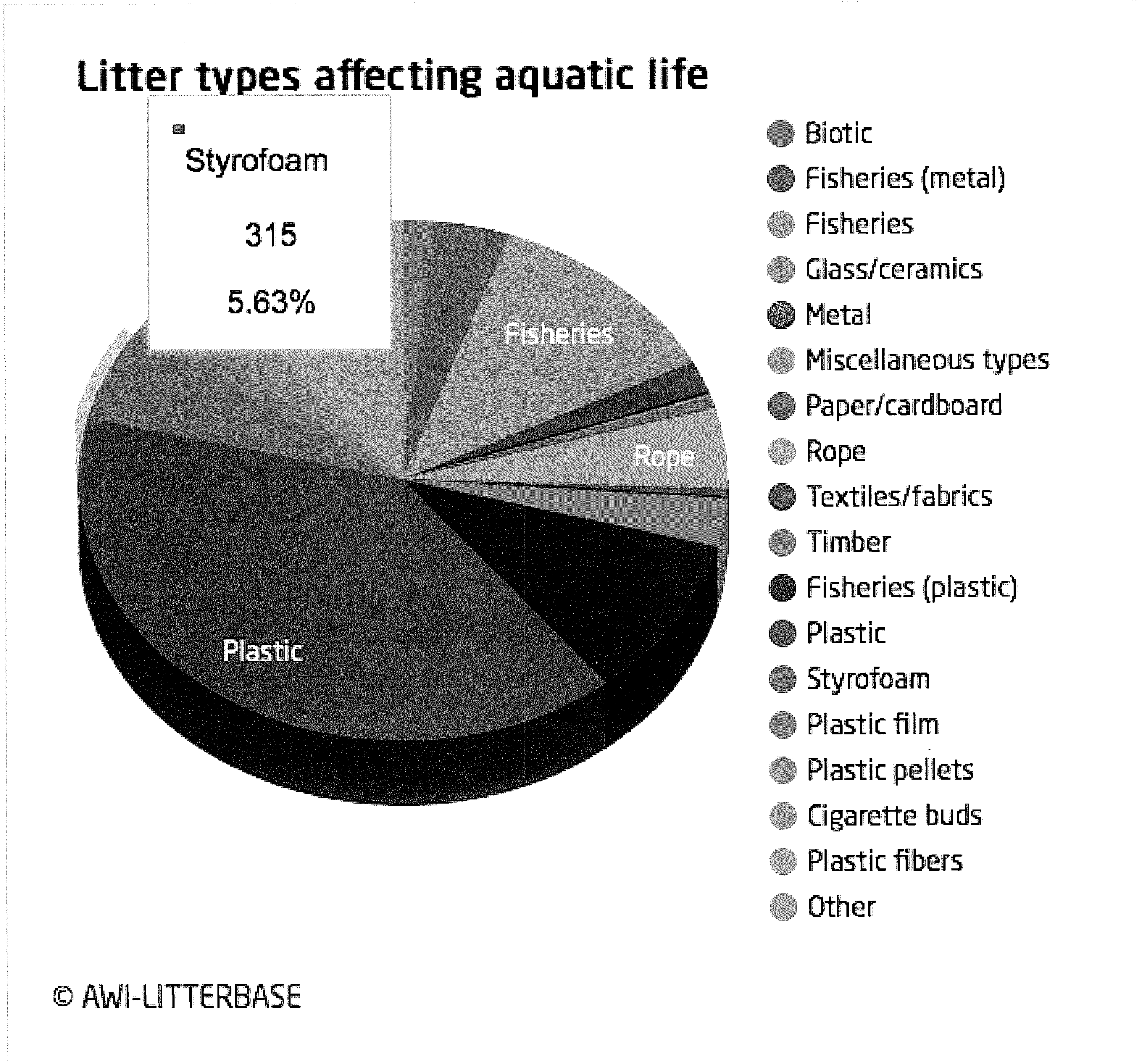
Source: Kühn, S., et al., Deleterious Effects of Litter on Marine Life, in Bergmann, M., et al., Marine Anthropogenic Litter, Springer, 2015


12

Distribution of litter types in different realms (612 publications)

The proportion of different litter types contributing to the global composition was calculated as the weighted means from all considered studies, irrespective of units. Values are shown by clicking on pie charts.




Litter types affecting aquatic life
Styrofoam
315
5.63%
Fisheries
Rope
Plastic
Biotic
Fisheries (metal)
Fisheries
Glass/ceramics
Metal
Miscellaneous types
Paper/cardboard
Rope
Textiles/fabrics
Timber
Fisheries (plastic)
Plastic
Styrofoam
Plastic film
Plastic pellets
Cigarette buds
Plastic fibers
Other
© AWI-LITTERBASE

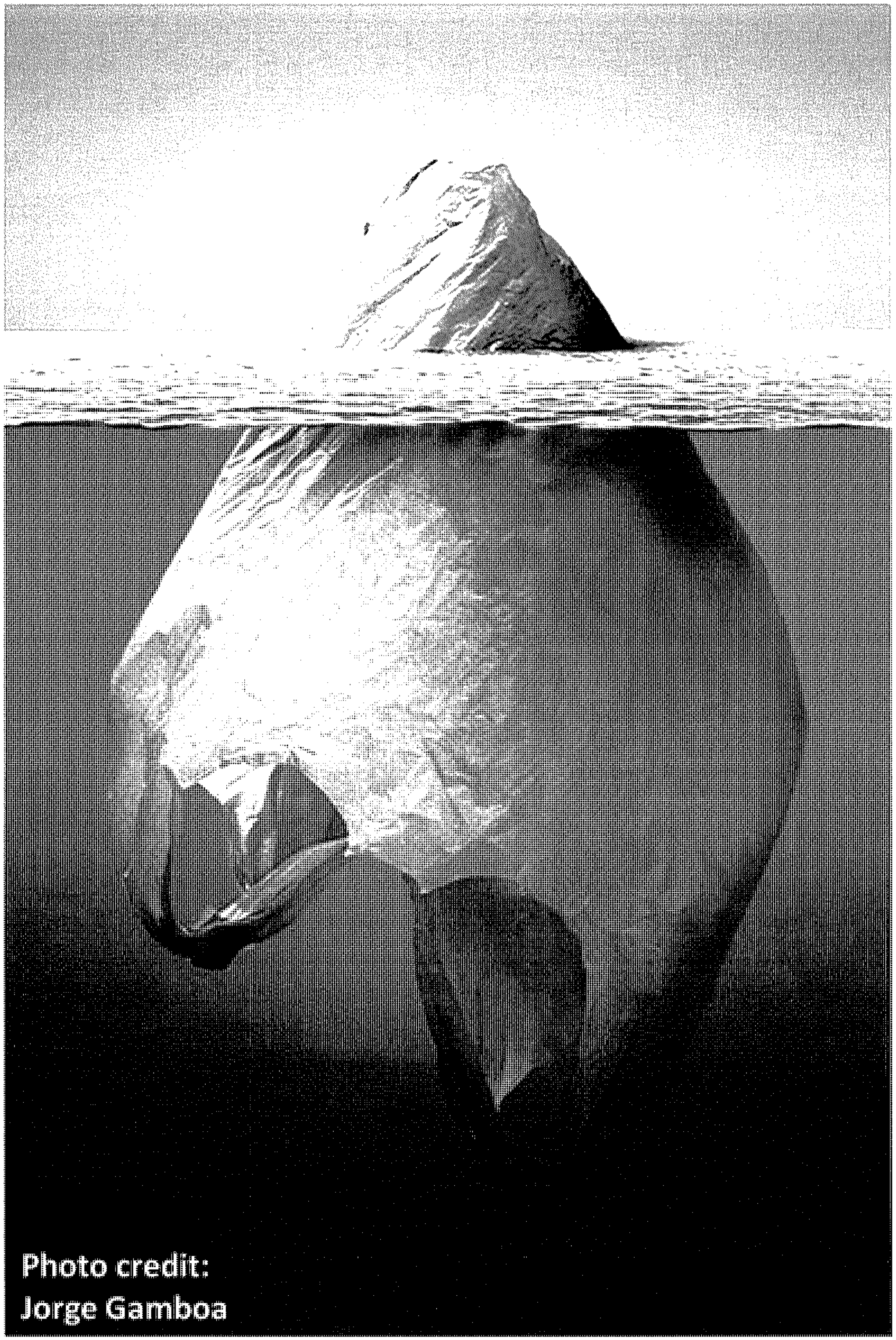
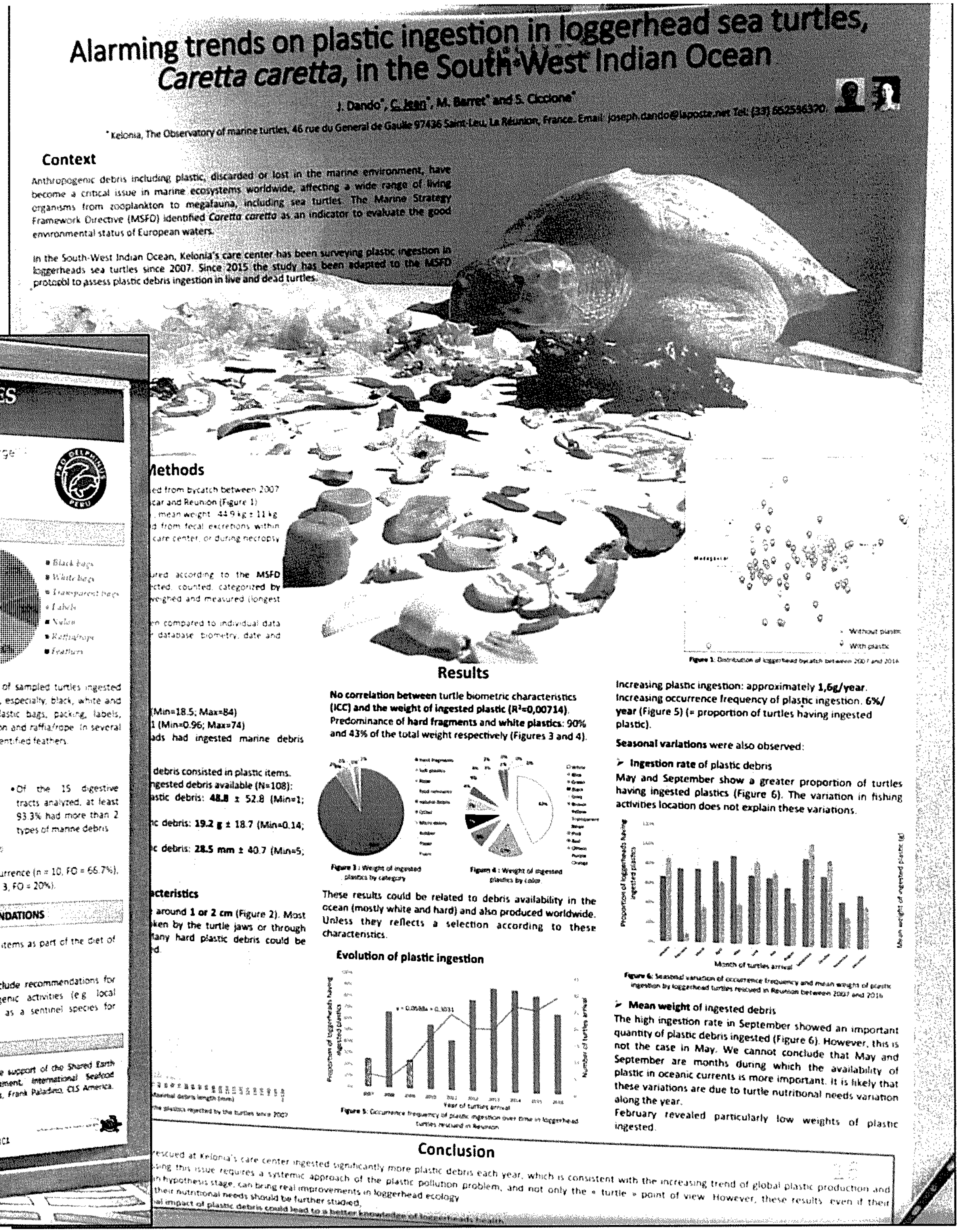
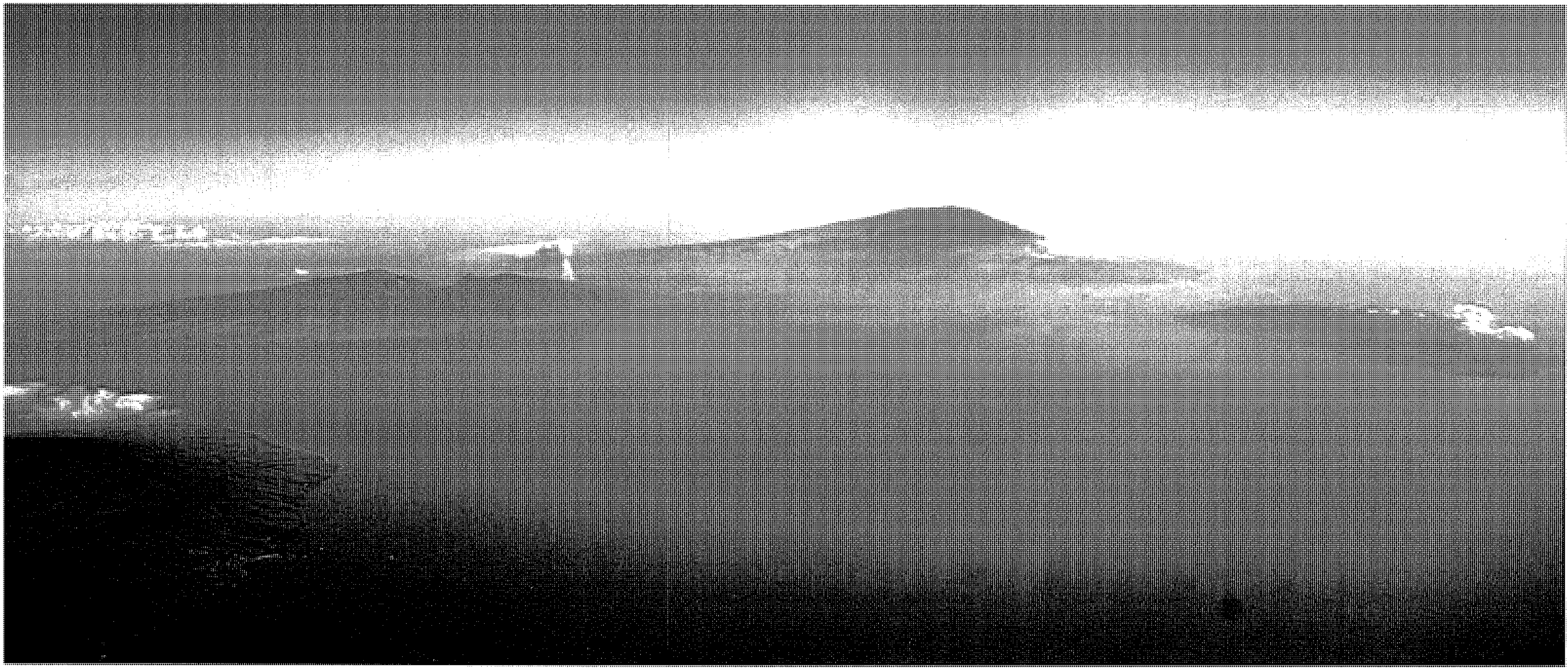


Photo credit:
Jorge Gamboa

Global studies



Where does our debris come from?



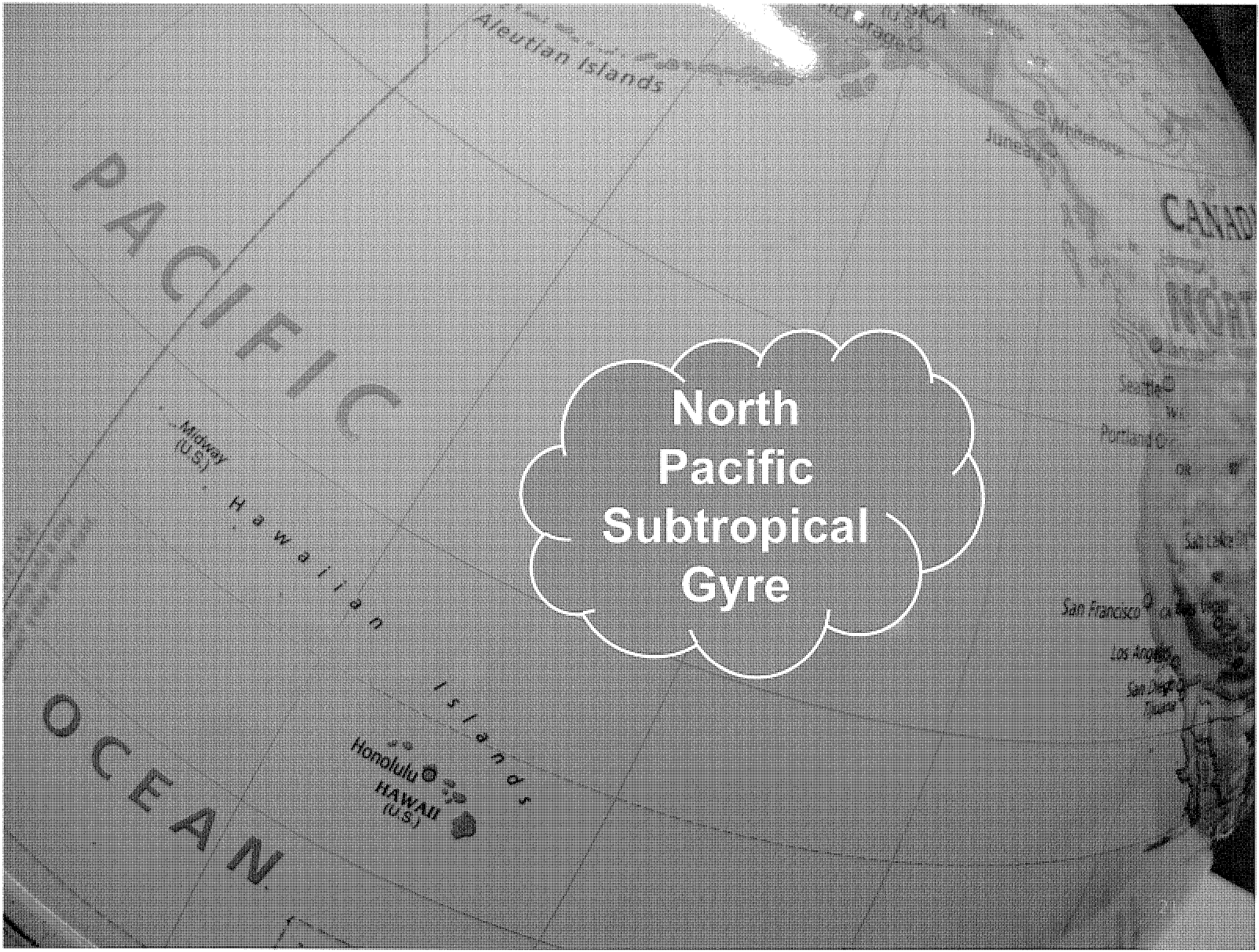
Our friendly neighbor islands!

“Slipper Island”, O‘ahu

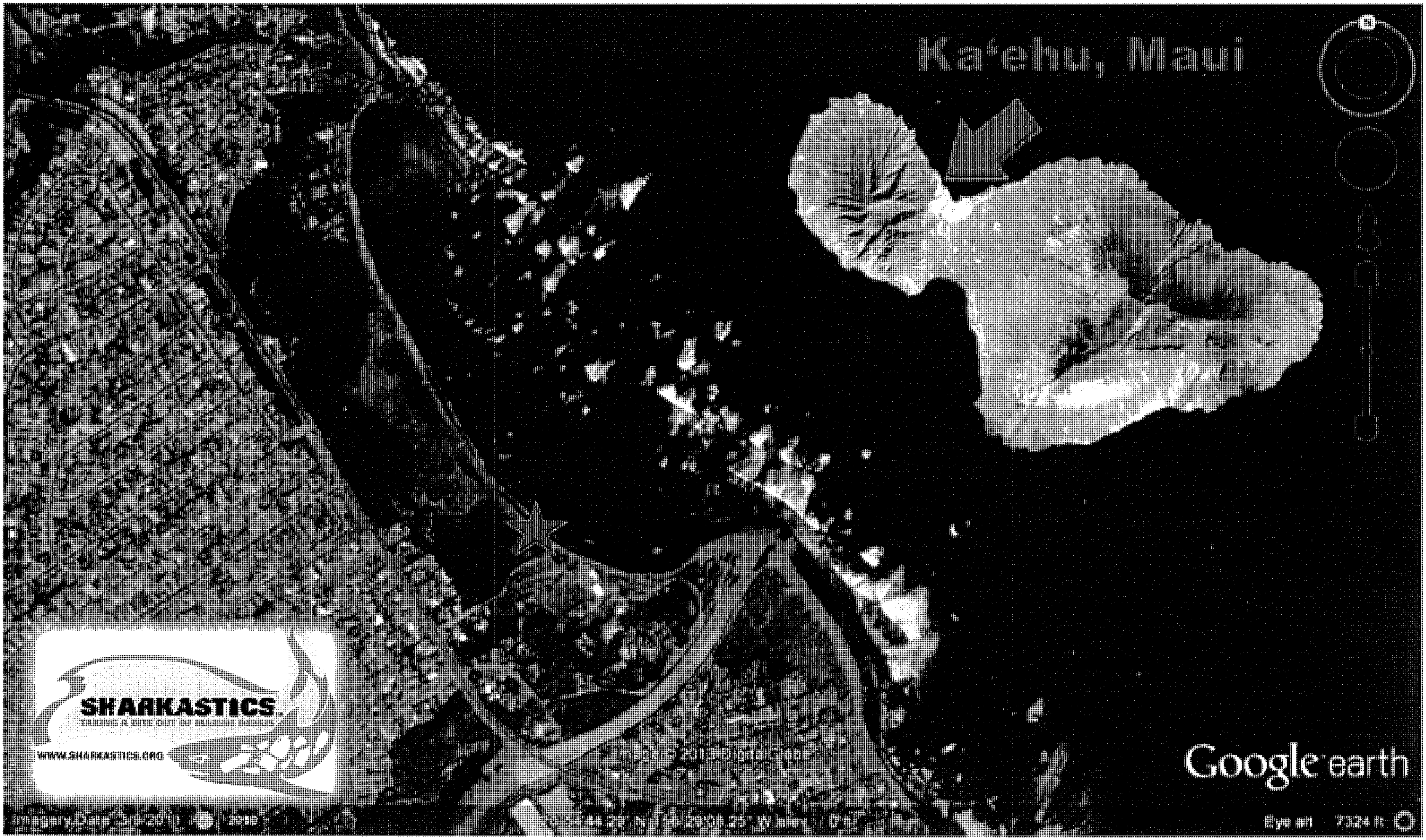
Photo credit: Matt Bickel

“Slipper Island”, O‘ahu

Photo credit: Matt Bickel


North Pacific Subtropical Gyre
PACIFIC
OCEAN
Aleutian Islands
Midway (U.S.)
Hawaiian Islands
Honolulu
HAWAII (U.S.)
Seattle
Portland
San Francisco
Los Angeles

Data Summary from Ka'ehu Cleanups




Turtles don't want to nest amongst trash…
Please help us clean Ka'ehu, Waiehu!
4th Sunday of every month (9am-noon)
SHARKASTICS
WWW.SHARKASTICS.ORG


"Hey, please pick up your rubbish- this stuff is dangerous to us!"


Mahalo to all who've helped!
MĀLAMA MAUI NUI
KEEP AMERICA BEAUTIFUL AFFILIATE
Maui Huliau Foundation
808 CLEANUPS
sustainable coastlines Hawaii
LOVE THE SEA
HaMeR
SURFRIDER
Maui Chapter
BOTTLES 4Change
HAWAI'I WILDLIFE FUND
RESEARCH · CONSERVATION · EDUCATION
MANAKAI
SWIMWEAR
SHARKASTICS

SHARKastics Marine Debris	Weather:			# of Bags:	
Location: Ka'ehu	Vols:	Date:		Pounds:	
PLASTICS	**# of pieces**	**TOTAL**		**# of pieces**	**TOTAL**
FOAM fragments:	foam food-related:		insulation/packaging:	buoys:	
Plastic fragments (hard)					
Plastic fragments (film)					
Food wrappers:			Food packaging:		
Beverage bottles			**GLASS**	**# of pieces**	**TOTAL**
Cleaning bottles: oil bottles:			Beer or other bottles:	wine bottles:	
Fishing containers/packaging:			Jars		
Bottle or container caps/lids			Glass fragments		
Cigarettes/filters/cigars: cigar tips:			*Fiberglass pieces*		
Cigarette lighters			*Other- lightbulb*		
6 pack rings			*Other- ceramics*		
Bags			***TOTAL All Glass***		
Plastic rope/small net pieces			**Rubber**	**# of pieces**	**TOTAL**
Buoys and floats			Flip-flops/slippers		
Fishing lures: line:			Gloves		
Cups: plates:			Tires		
Plastic utensils			Rubber fragments		
Straws			*Auto parts*		
Balloons: ribbons:			*Rubber toys (tennis balls)*		
Sanitary: Diapers: 1st Aid:	Pers.Care:		***TOTAL All Rubber***		
Toothbrushes			**Processed Lumber**	**# of pieces**	**TOTAL**
Combs/brushes			Cardboard cartons		
:^^SHARKASTICS^^:			Paper and cardboard		
Oyster spacer Small			Paper bags		
Oyster spacer Large			Lumber/building material		
Hagfish traps			***TOTAL All Lumber***		
Strapping bands			**Cloth/Fabric**	**# of pieces**	**TOTAL**
Weed whacker pieces			Clothing (including hats)		
Zipties			Shoes (non rubber)		
Irrigation tubing/parts (pvc too)			Gloves (non-rubber)		
Toys (plastic only)			Towels/rags		
Firecracker remnants			Rope/net (non-nylon)		
Duct tape pieces			Fabric pieces		
Golf balls			*Carpet pieces:*	*padding:*	
Christmas tree parts/ornaments			*Linoleum*		
Pens/markers/pencils			*Vinyl pieces*		
Melted plastic			***TOTAL All Cloth/Fabric***		
Snorkel/dive/surf/kayak/camping gear			**Metal**	**# of pieces**	**TOTAL**
DVD/cd/cassette/records			Aluminum cans:	food tins:	
Spools			Aerosol cans:	roofing:	
Popsicle sticks			Metal fragments		
Shotgun shells			*Auto parts*		
Lightsticks			*Bottle caps*		
Gardening pots/trays			*Batteries*		
Crates/trays: large drums/jugs:			*Fishing pole/gear*		
Auto parts			*Wire, stakes & pipes*		
Shipping Tags			*Foil*		
Drug: personal stuff: pet stuff:			***TOTAL All Metals***		
Misc. household items			**GRAND TOTAL ITEMS**		
TOTAL All Plastics					
Large debris or labeled items	**Description**	**Width(m)**	**Length (meters)**	**Status**	**Pix**

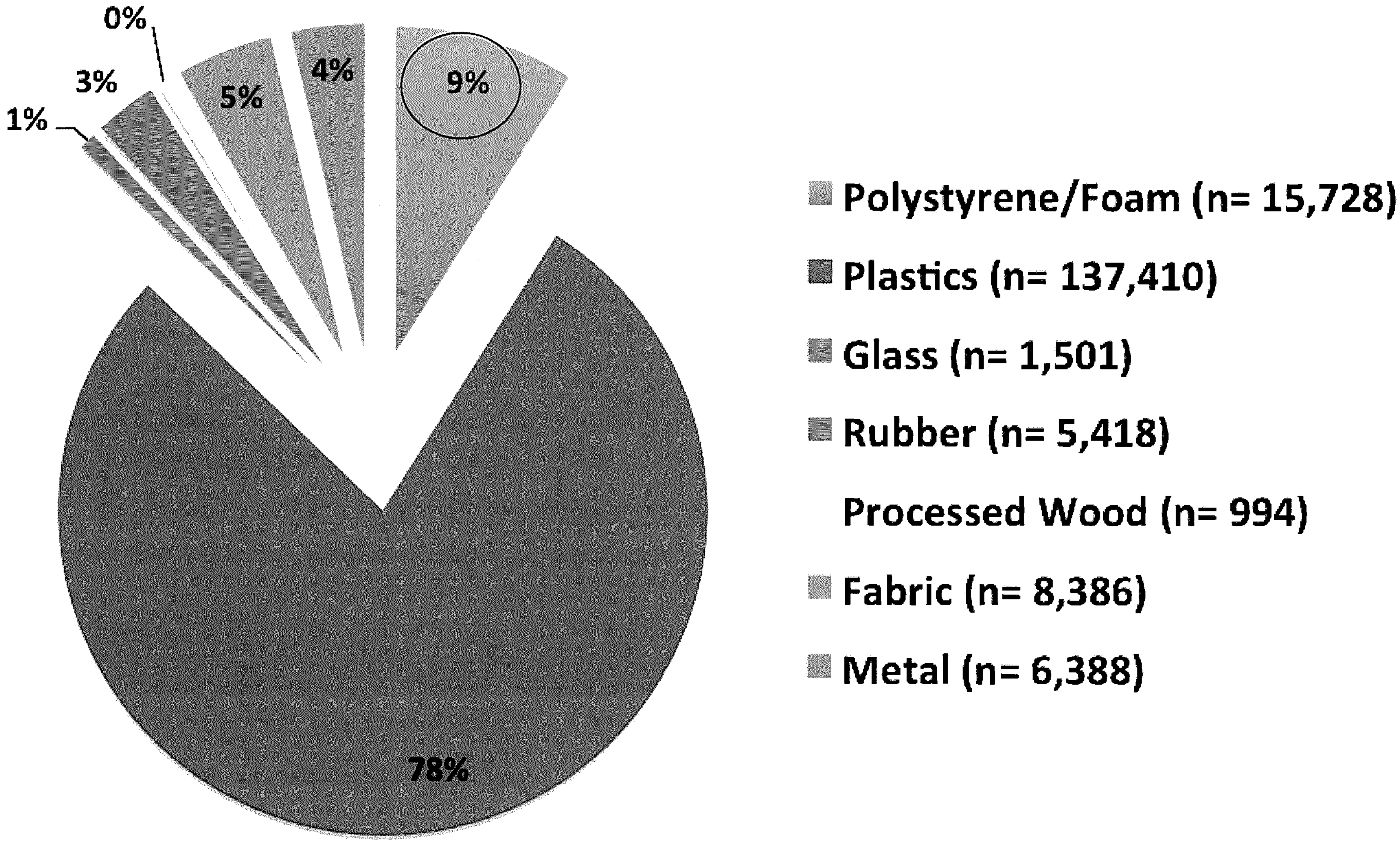
Polystyrene Data Summary from Ka'ehu Cleanups

May 2, 2017

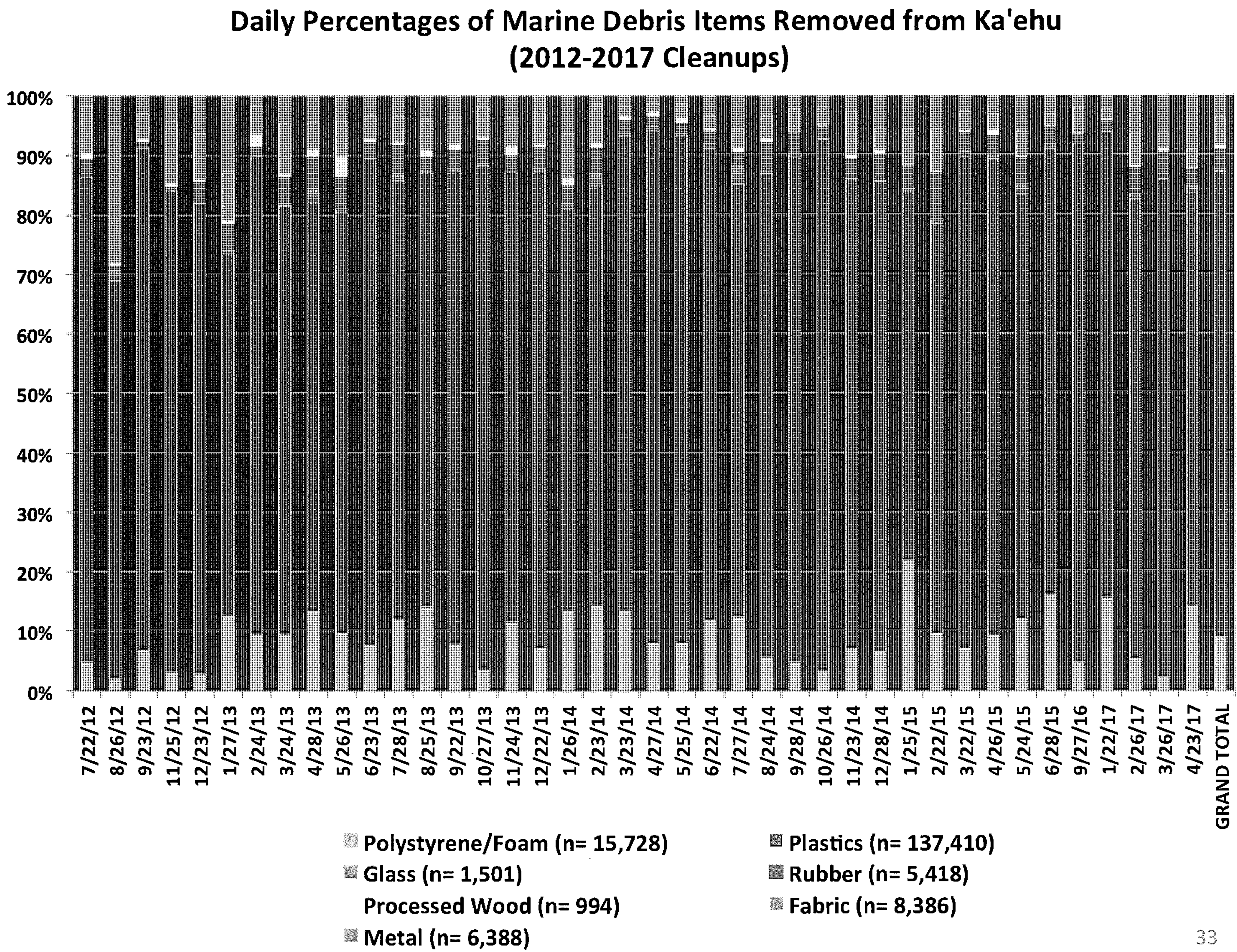
We spearhead community-based marine debris cleanups on the 4th Sunday of every month at Ka'ehu, in Waiehu, to help restore this important habitat for the marine and terrestrial resources that utilize this special place. Marine debris is removed from a ~100 to 200 yard stretch of this rocky/sandy coast. The effort varies depending on the participants, not due to the shortage of marine debris- it's always washing ashore! It comes from all over the Pacific Ocean and from Hawai'i-based sources. To bring this global issue into context with this Maui County polystyrene reduction bill, here are some numbers to quantify this pollution problem we're dealing with:

In addition to simply removing the debris from this coast every month, we also sorted and counted each piece of marine debris at our monthly cleanups from July 22, 2012 through June 28, 2015, on September 27, 2016 ("Get the Drift and Bag It" campaign), and 4 months in 2017 so far: January through April. This process is very time consuming with all of our specific categories we're analyzing, but collecting data during 40 out of the 56 monthly cleanups yielded:

Marine Debris Items Collected from 40 Ka'ehu Cleanups (2012-2017)



Total # of pieces of marine debris collected/analyzed (in 40 out of the 54 cleanups): **175,825**!


Daily Percentages of Marine Debris Items Removed from Ka'ehu
(2012-2017 Cleanups)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
7/22/12
8/26/12
9/23/12
11/25/12
12/23/12
1/27/13
2/24/13
3/24/13
4/28/13
5/26/13
6/23/13
7/28/13
8/25/13
9/22/13
10/27/13
11/24/13
12/22/13
1/26/14
2/23/14
3/23/14
4/27/14
5/25/14
6/22/14
7/27/14
8/24/14
9/28/14
10/26/14
11/23/14
12/28/14
1/25/15
2/22/15
3/22/15
4/26/15
5/24/15
6/28/15
9/27/16
1/22/17
2/26/17
3/26/17
4/23/17
GRAND TOTAL
Polystyrene/Foam (n= 15,728)
Plastics (n= 137,410)
Glass (n= 1,501)
Rubber (n= 5,418)
Processed Wood (n= 994)
Fabric (n= 8,386)
Metal (n= 6,388)

Marine Pollution Bulletin 105 (2016) 292–298

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Trends and drivers of debris accumulation on Maui shorelines: Implications for local mitigation strategies

Lauren C. Blickley *, Jens J. Currie, Gregory D. Kaufman

Monthly and daily accumulation surveys at three sites using NOAA marine debris shoreline survey methodologies…

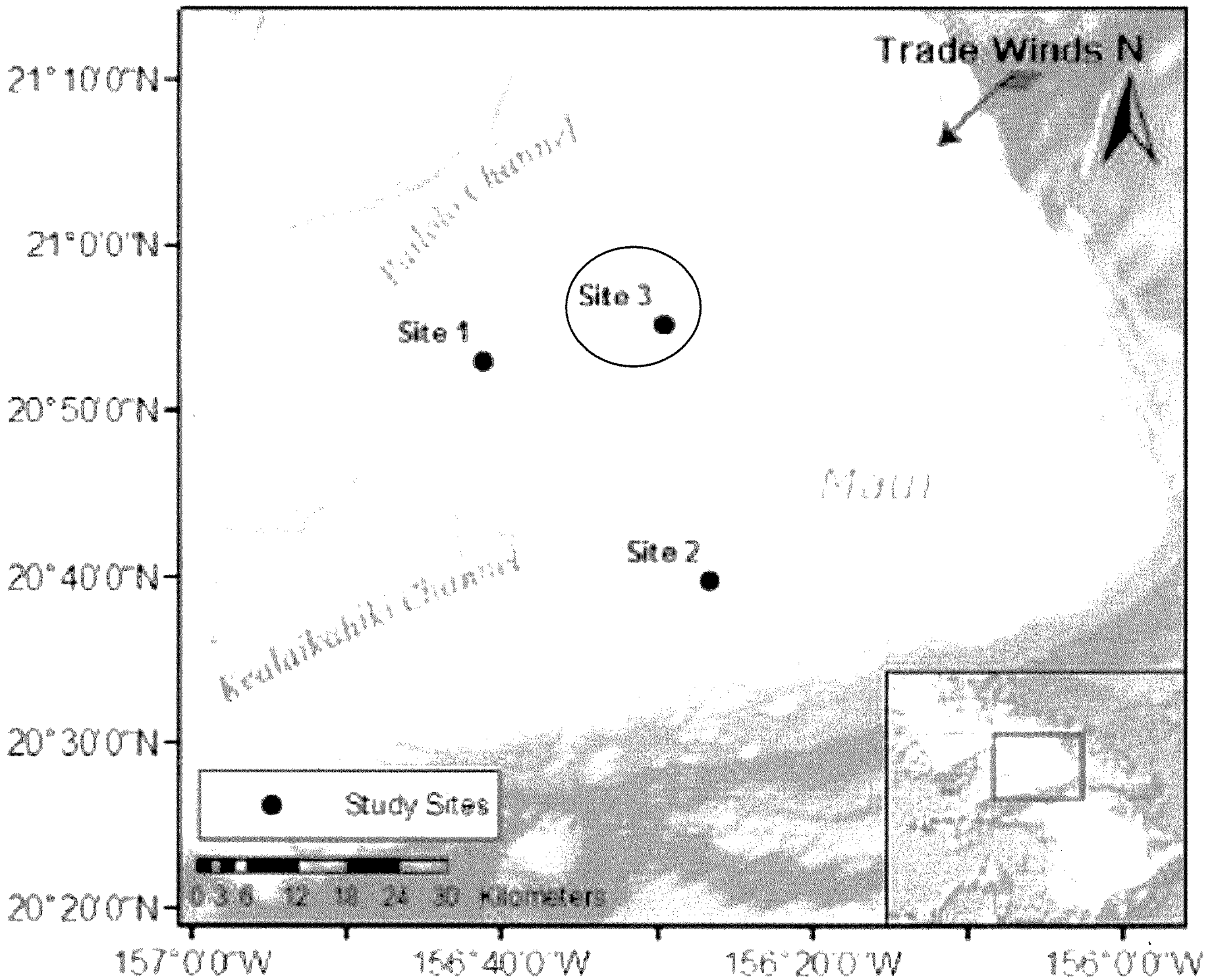


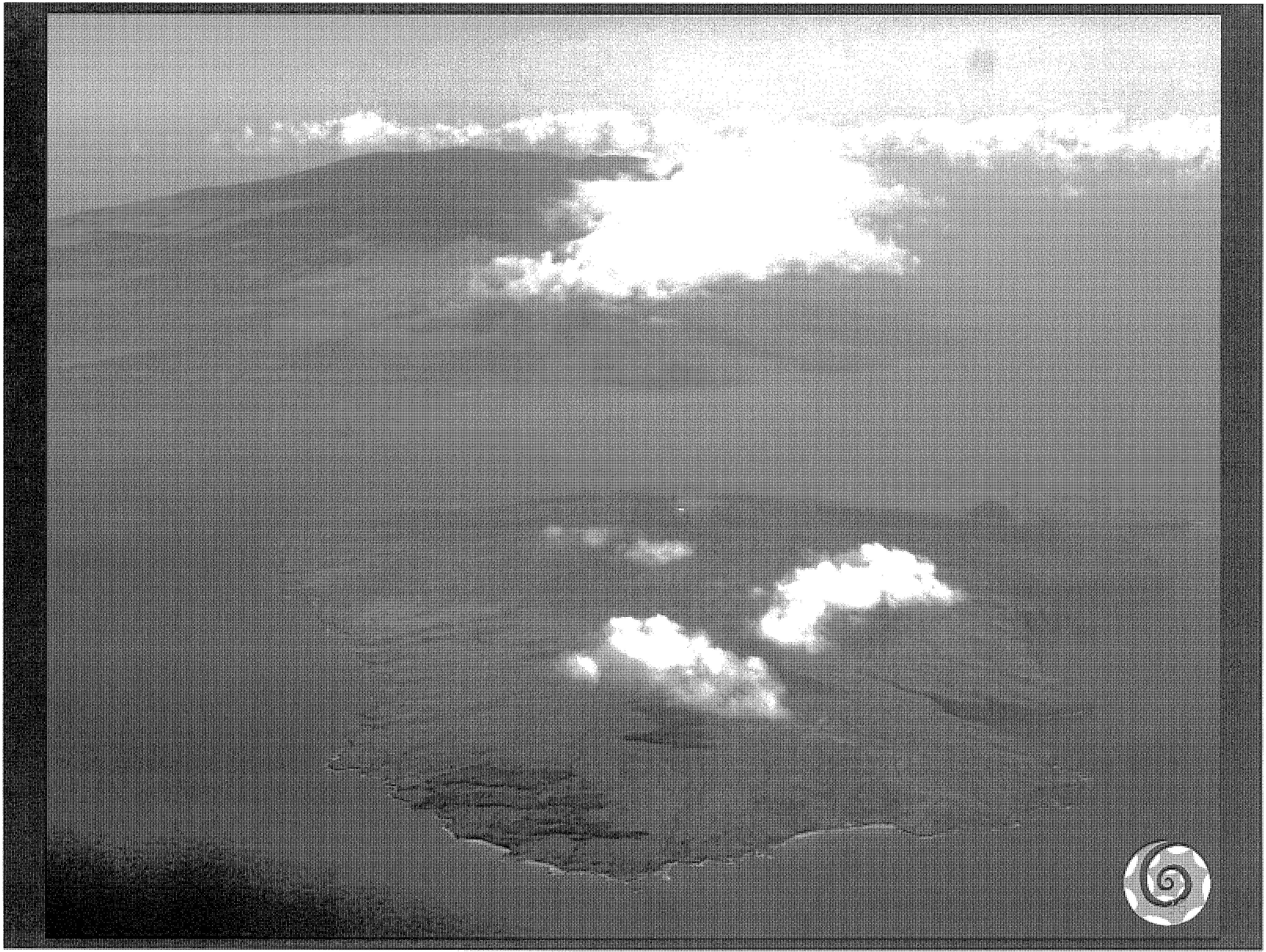
Fig. 1. Map showing the direction of prevailing trade winds and location of the three study sites on Maui. Site 1 = Pu'unoa Beach; Site 2 = Po'olenalena Beach; Site 3 = Lower Waiehu Beach.

Percentages of the total debris items collected that were foam:

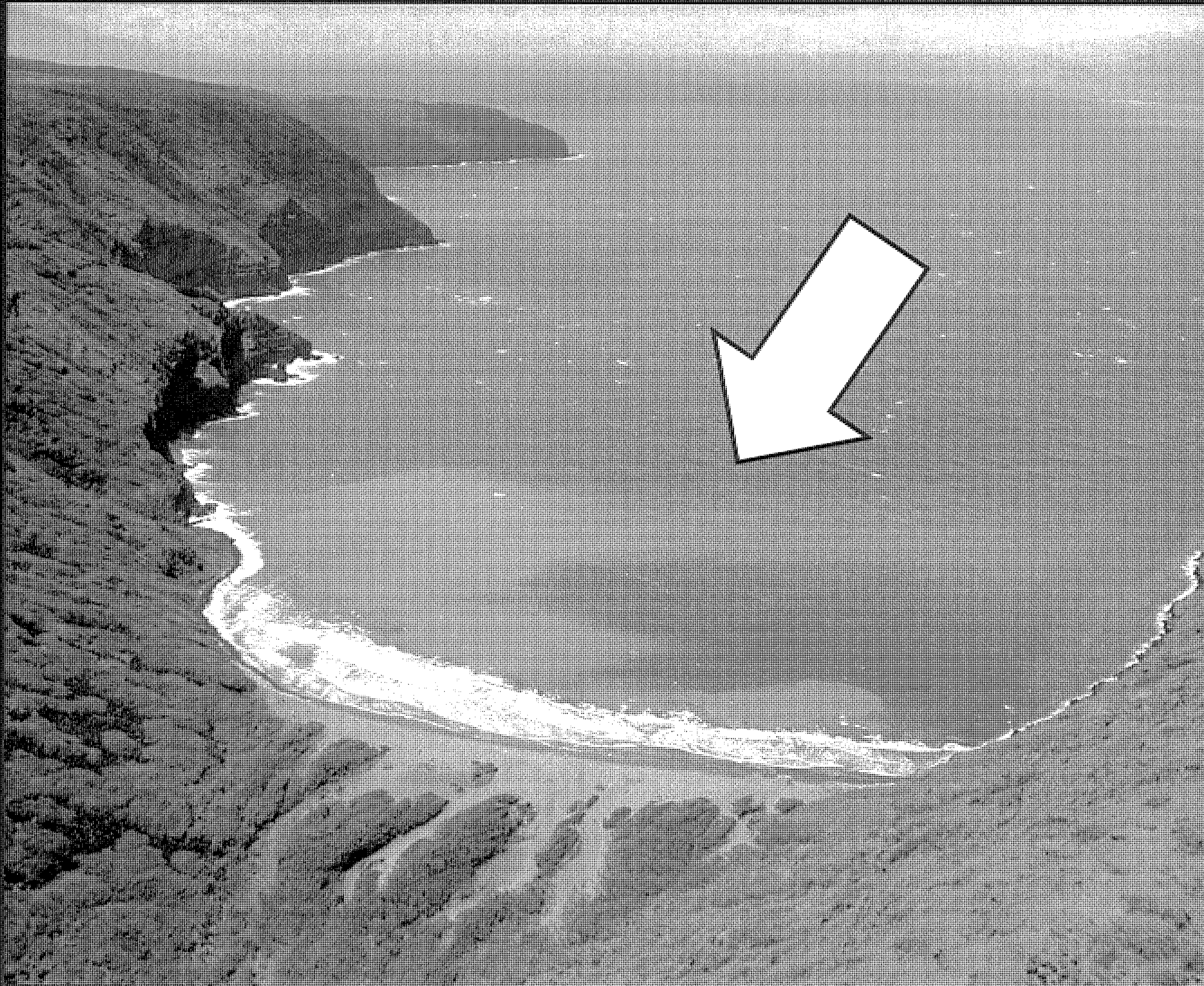
Site 1= 3.45%

Site 2= 7.42%

Site 3= 7.82%



Kanapou Bay, Kaho'olawe




6/16/2008
DANGER
KEEP AWAY - KAPU
BOMBS IN LAND & WATER
9/25/2010
CLEANED!
DANGER
KEEP AWAY - KAPU
BOMBS IN LAND & WATER
Kanapou Debris Re-accumulation
11/4/2010
KEEP AWAY - KAPU
BOMBS IN LAND & WATER
12/20/2010
KEEP AWAY - KAPU
BOMBS IN LAND & WATER

Marine Debris Data from Sept 25th, 2010 Kanapou Cleanup (~1/2 acre)

"Sharkastics" (plastics with bite marks)	203
Oyster fishery plastic tubes	486
Plastic baskets/crates	76
Fishing lures/bobbers	21
Hagfish traps	725
Plastic buoys	69
Lighters	35
Toys	76
Toothbrushes	23
Plastic bottles	1086
Plastic caps/lids	421
Plastic pieces <6"	1566
Plastic pieces >6"	6562
Snorkel/dive fins	14
Shoes/slippers (68 rights & 114 lefts)	182
Plastics TOTAL (75.4%)	

Rope/net (ft)	804
Rope/net (pieces)	529
Rope/Net TOTAL (8.7%)	**1333**
Styrofoam floats	323
Styrofoam pieces <6"	826
Styrofoam pieces >6"	1090
Styrofoam TOTAL (14.6%)	**2239**
Misc. TOTAL (1.3%)	**~200**

Bags of recyclables (glass)	2
Bags of recyclables (plastic)	13
Bags of recyclables (aluminum)	2
Bags of recyclables TOTAL	**17**

Aerial Circumnavigation Surveys

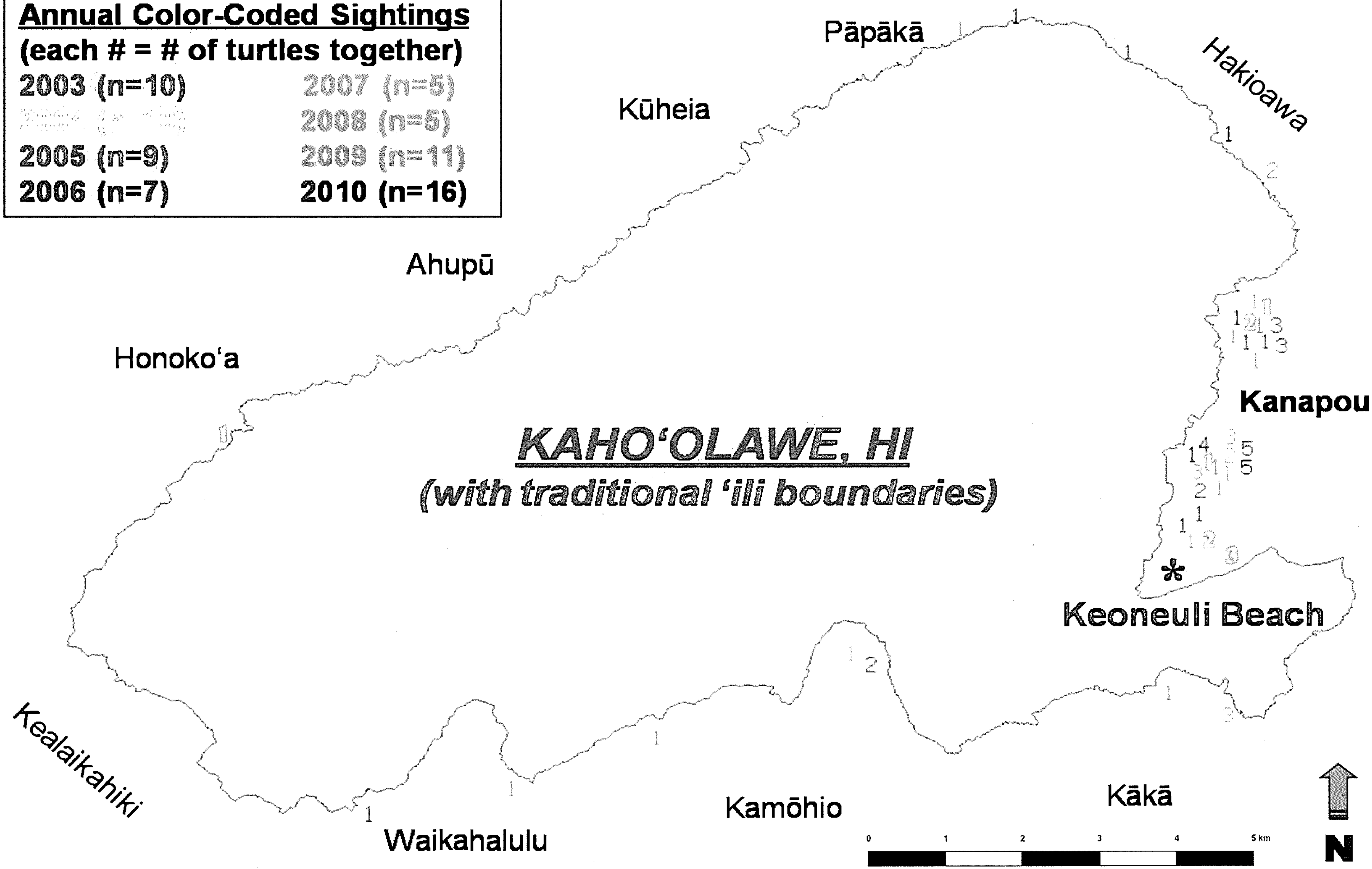
- 87 monthly surveys (2003-2010)
- 576 turtle sightings
- Range = 1-20
- Mean = 6.2 ± 3.6

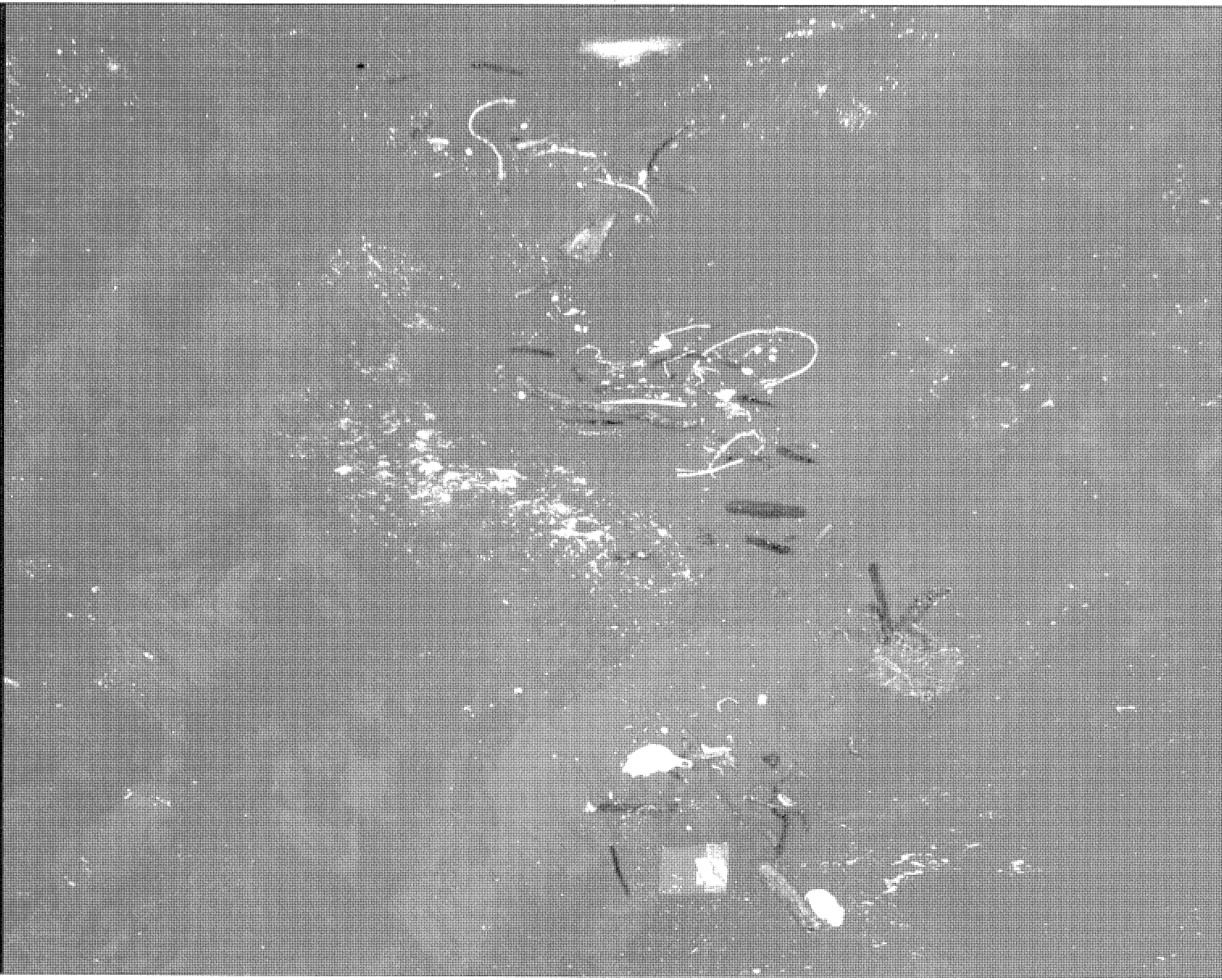
- 73 were associated with debris (12.7%)

2003-2010 Aerial Survey Sightings of Turtles Associated with Marine Debris (n=73)

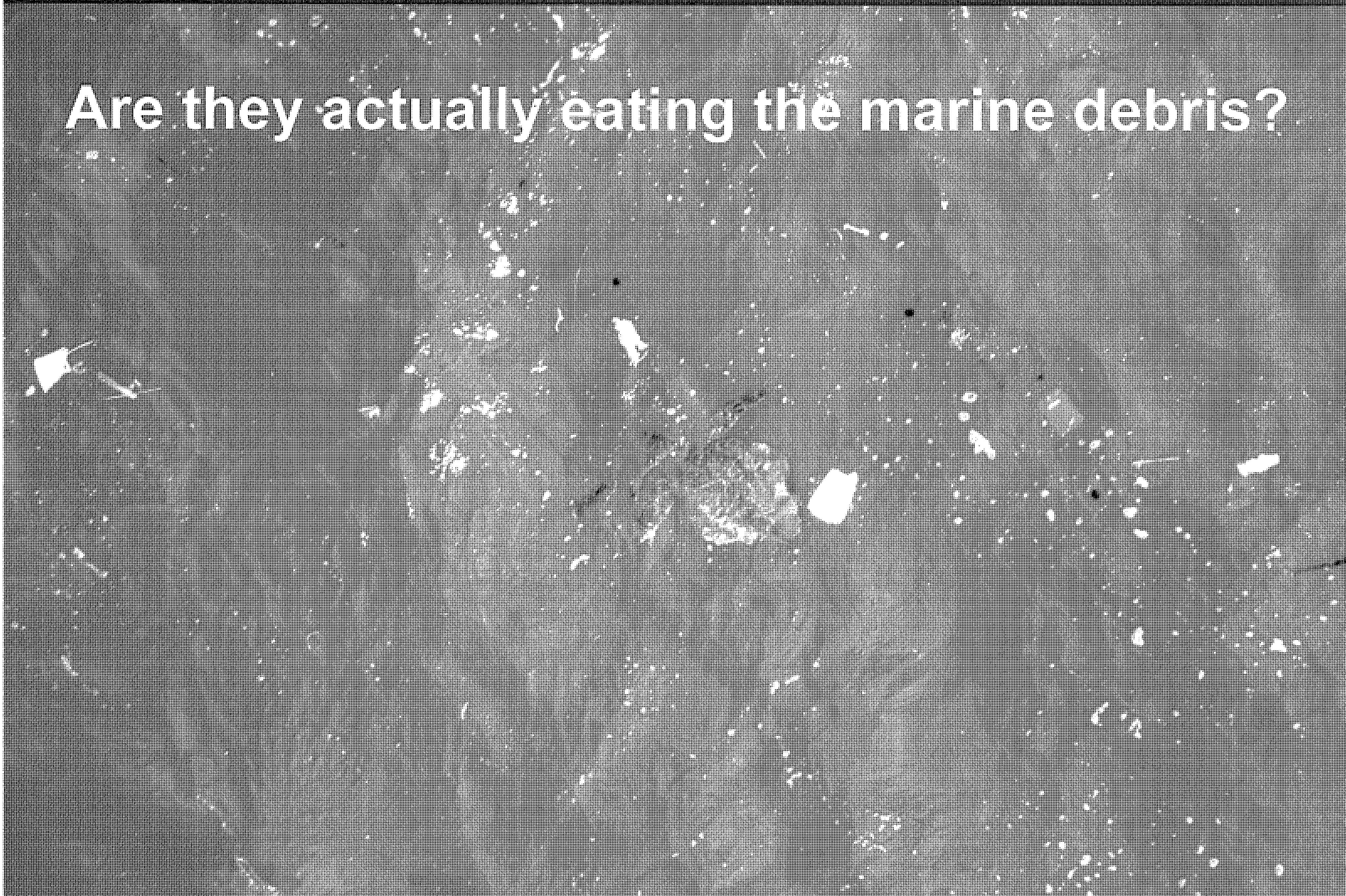
Annual Color-Coded Sightings
(each # = # of turtles together)

2003 (n=10)
2005 (n=9)
2006 (n=7)
2007 (n=5)
2008 (n=6)
2009 (n=11)
2010 (n=16)



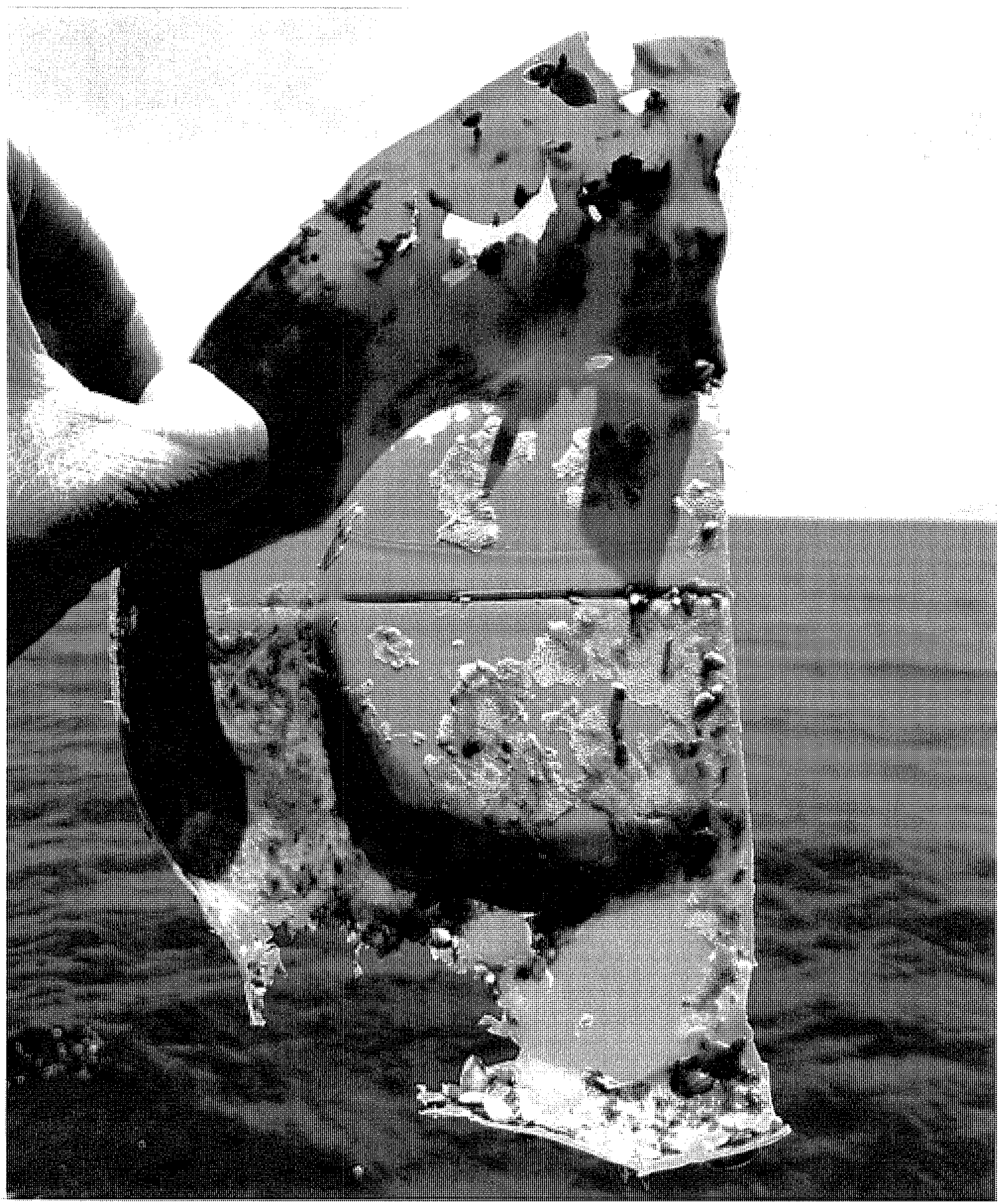


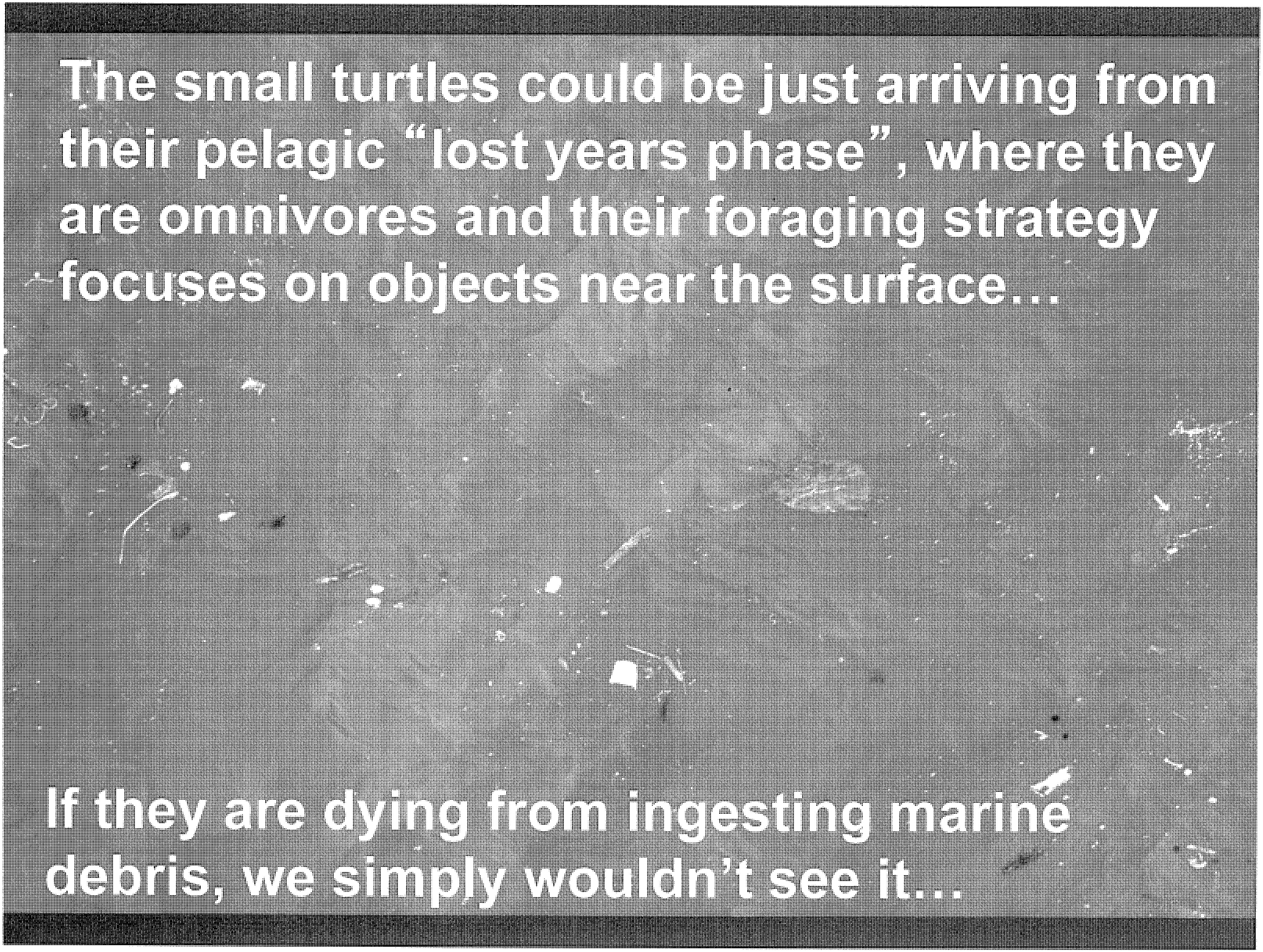
Are they actually eating the marine debris?

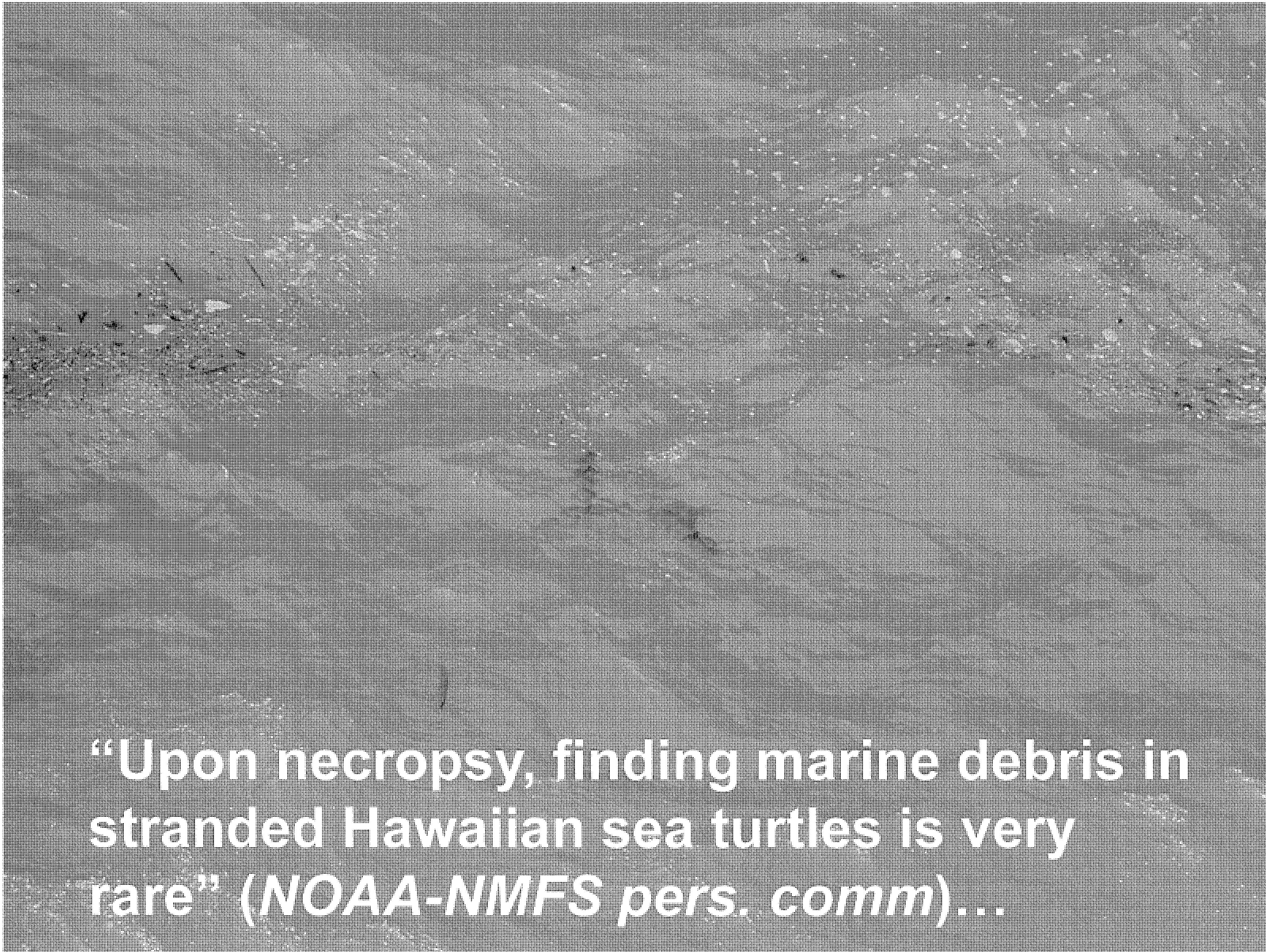



They're "attracted to it" for some reason(s)…

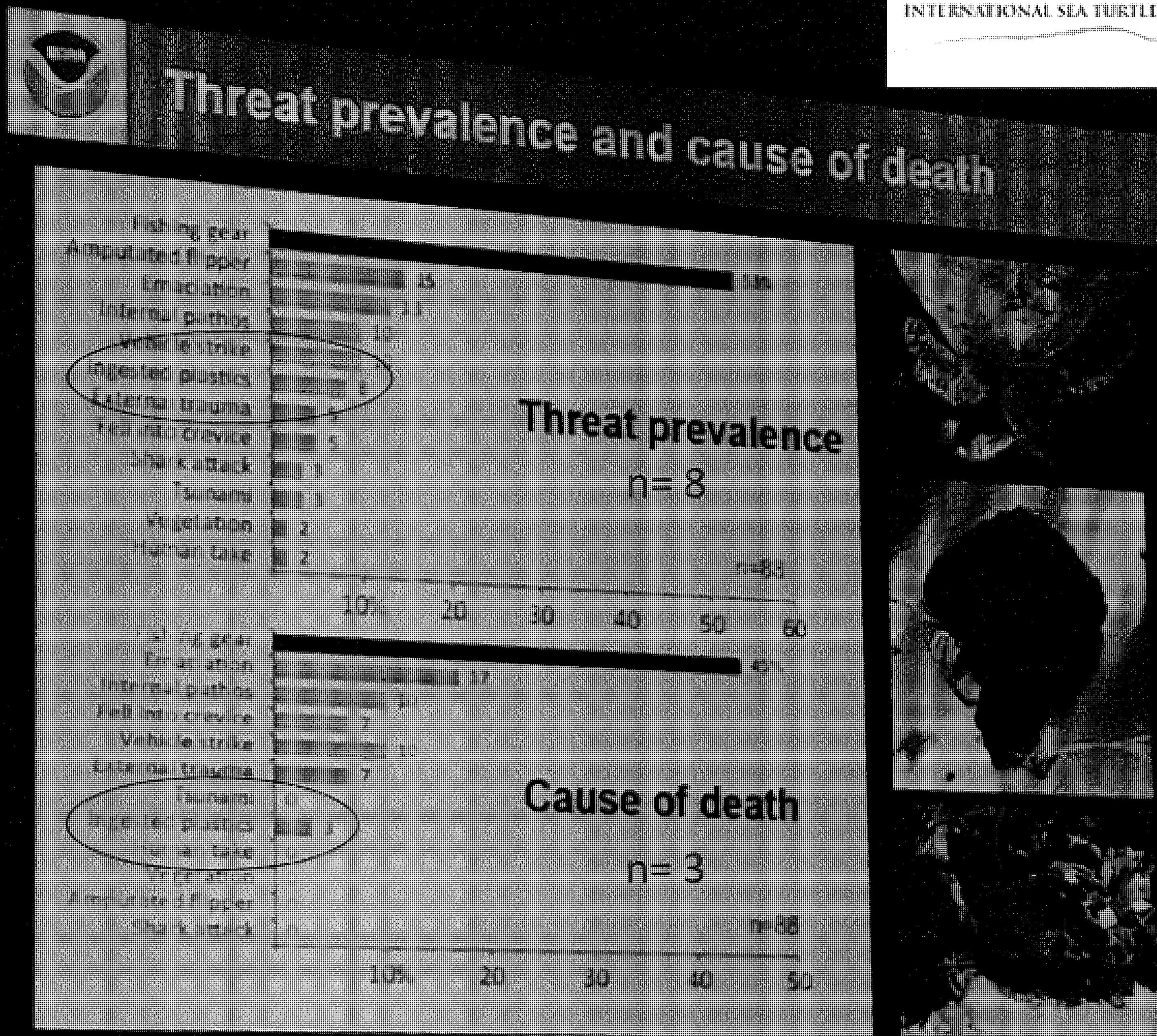
Photo credit:
Megan Lamson, DAR




The small turtles could be just arriving from their pelagic "lost years phase", where they are omnivores and their foraging strategy focuses on objects near the surface…
If they are dying from ingesting marine debris, we simply wouldn't see it…


"Upon necropsy, finding marine debris in stranded Hawaiian sea turtles is very rare" (*NOAA-NMFS pers. comm*)…

INTERNATIONAL SEA TURTLE SOCIETY



"Population Threats to Hawaiian Hawksbill Sea Turtles Revealed from Three Decades of Strandings"- Shandell Brunson

Ecology and Evolution 2016; 6(8): 2378-2389

Open Access

The developmental biogeography of hawksbill sea turtles in the North Pacific

Kyle S. Van Houtan[1,2]*, Devon L. Francke[3], Sarah Alessi[3], T. Todd Jones[1], Summer L. Martin[4], Lauren Kurpita[5,6], Cheryl S. King[7] & Robin W. Baird[8]

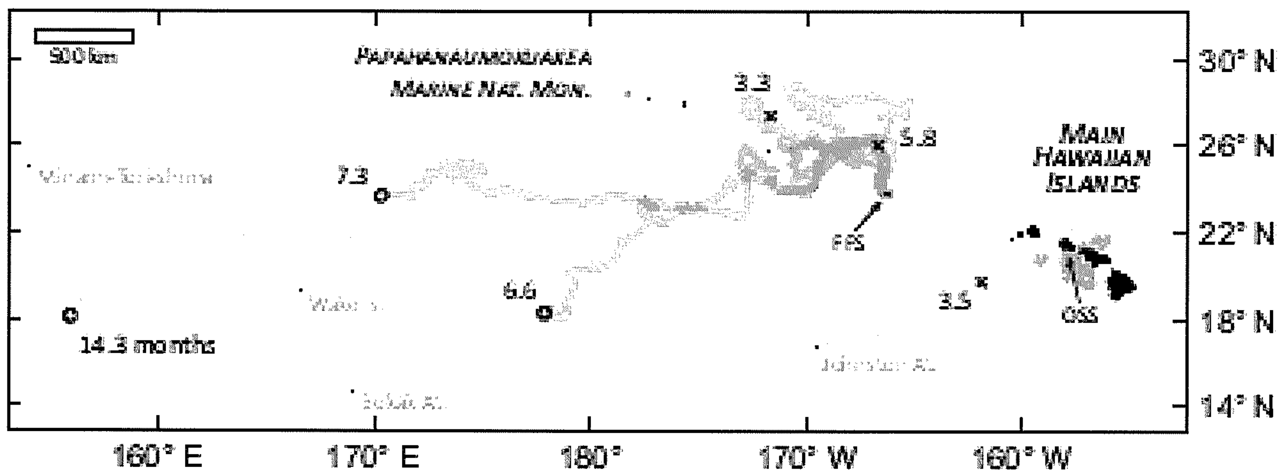
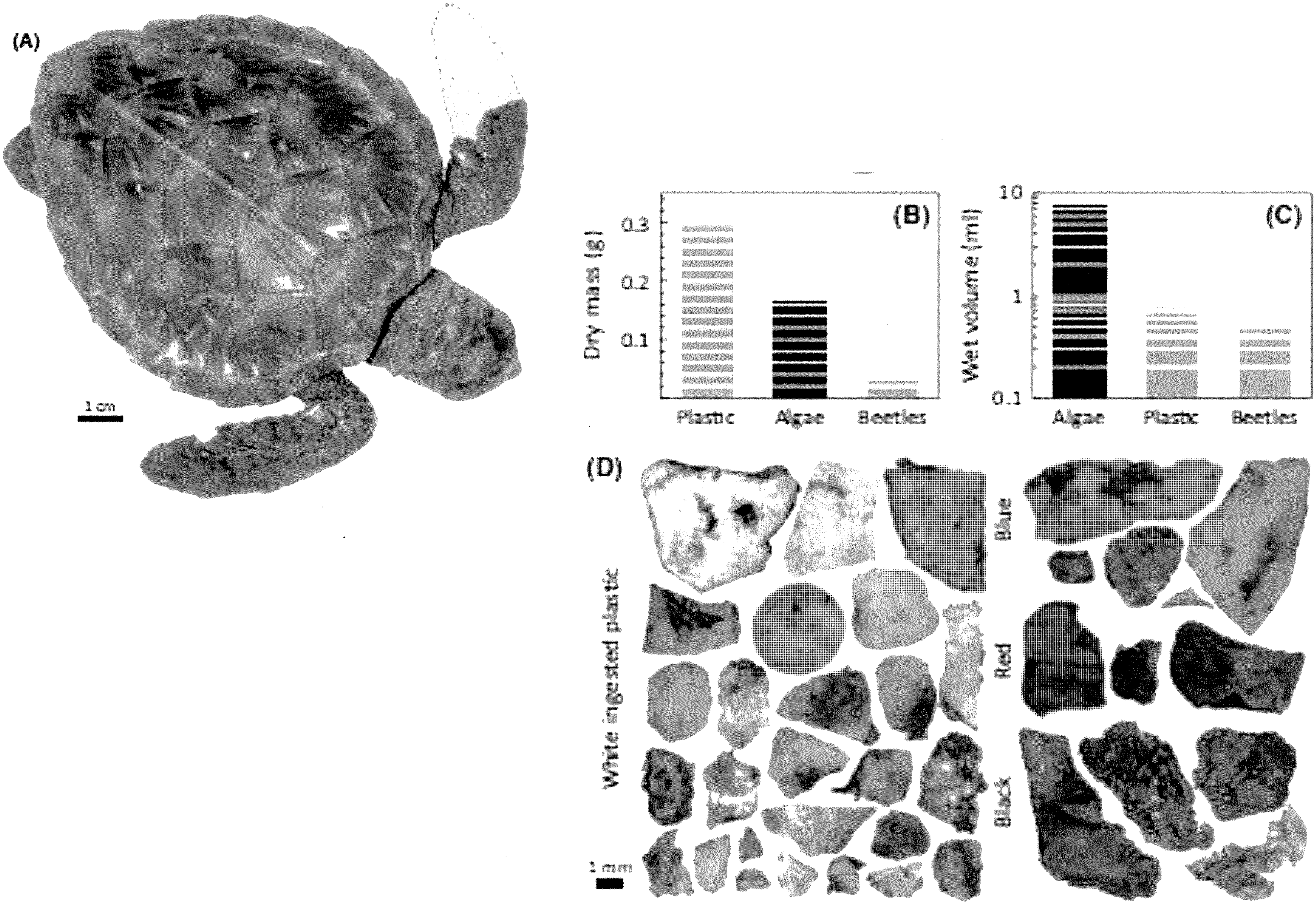


Figure 2. Surface drifter trajectories from hawksbill and green turtle nesting areas in the Hawaiian Archipelago indicate young juveniles may reside near the archipelago for several months or more. Green lines are 4 PSAT drifters released from French Frigate Shoals (FFS) in July–August 2014, simulating green turtle posthatchling trajectories from their primary nesting beach in the northwestern Hawaiian Islands. Orange lines are 2 PSAT surface drifters released near Oahu's south shore (OSS) in December 2013, simulating hawksbill posthatchling trajectories from the Main Hawaiian Islands. The timing and location of release parallel predominant conditions for both populations. Paths are Argos location codes 3-B, "x" at path endpoint indicates transmission ends, "o" indicates drifter still active, and number is trajectory age in months. Gray region is the extent of the Papahanaumokuakea Marine National Monument.


(A)
1 cm
Dry mass (g)
0.3
0.2
0.1
(B)
Plastic
Algae
Beetles
Wet volume (ml)
10
1
0.1
(C)
Algae
Plastic
Beetles
(D)
White ingested plastic
Blue
Red
Black
1 mm

Marine Pollution Bulletin xxx (2017) xxx-xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com

Investigation of plastic debris ingestion by four species of sea turtles collected as bycatch in pelagic Pacific longline fisheries

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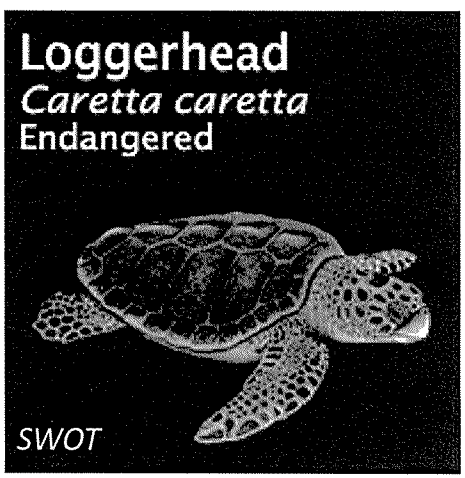
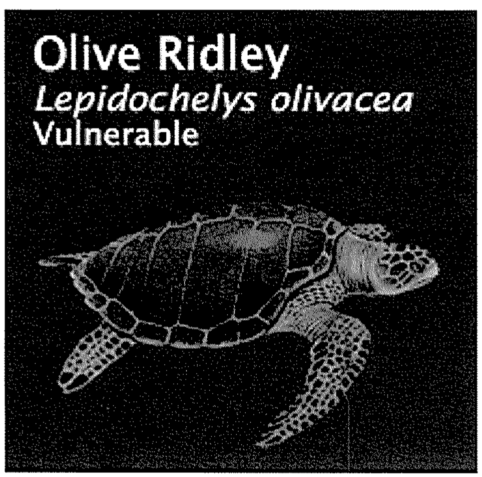
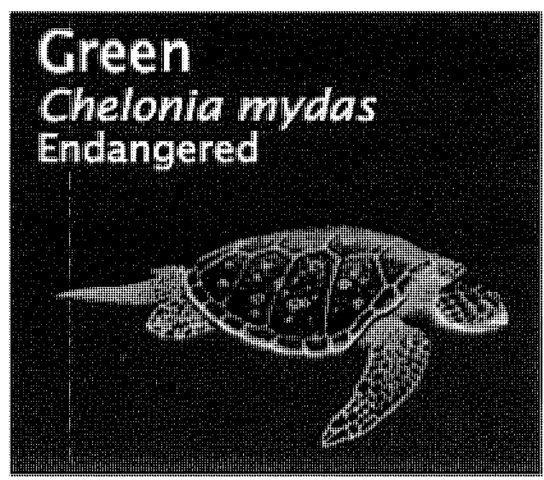
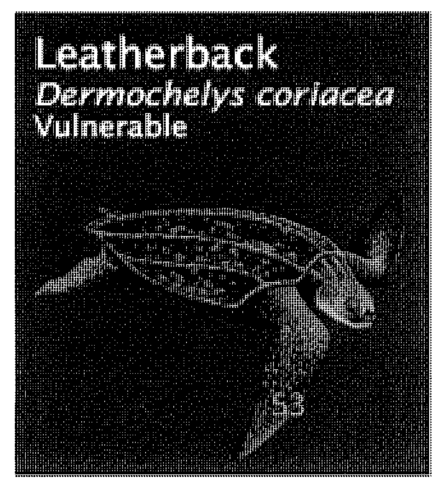








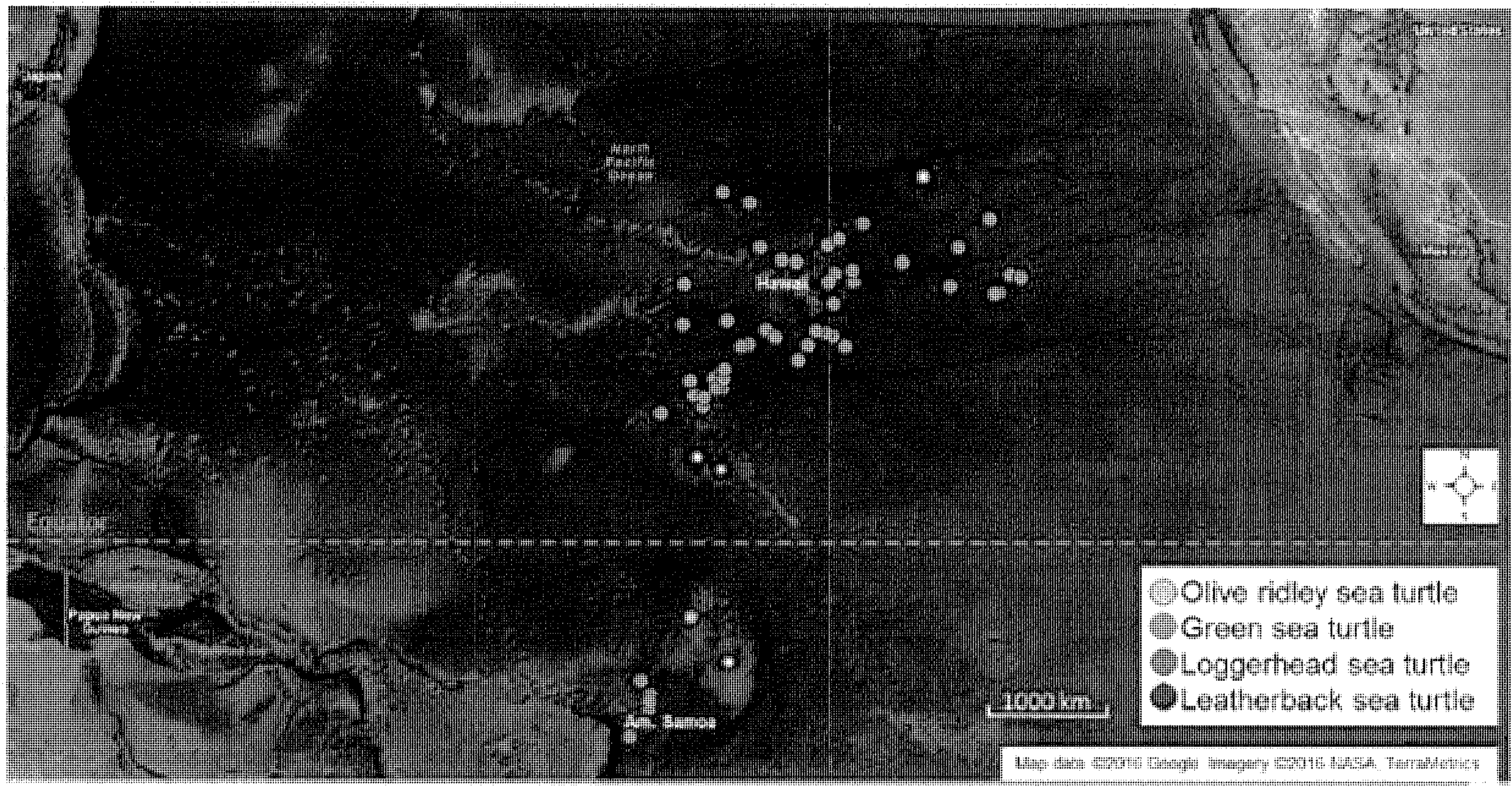
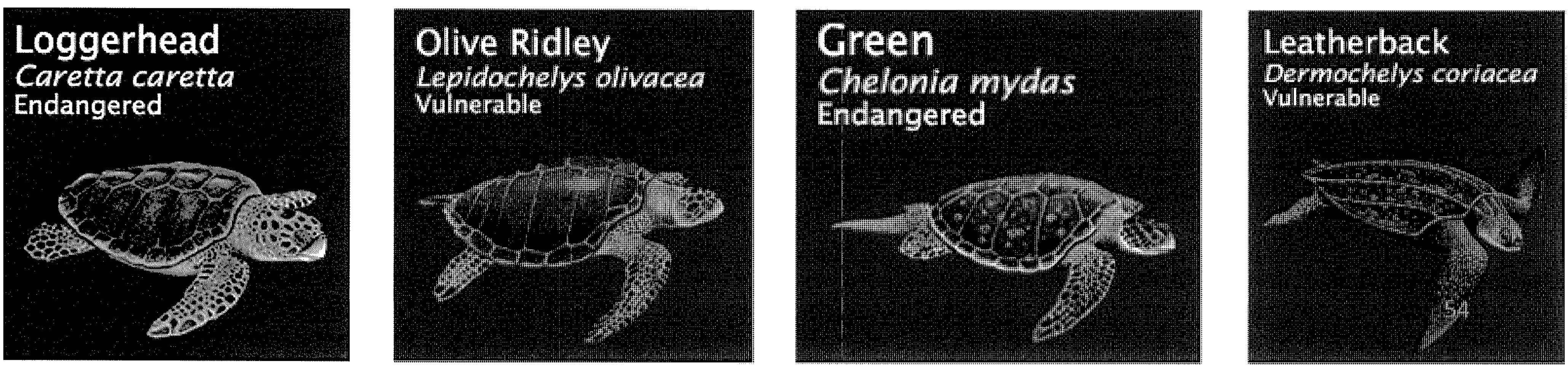
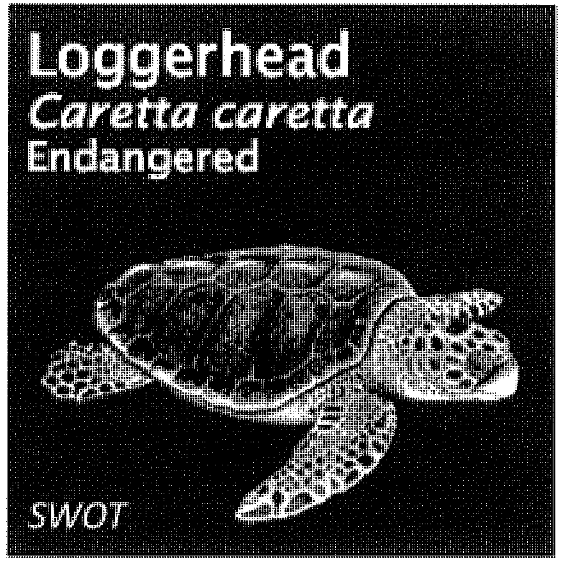


Fig. 1. Pacific pelagic longline capture locations of sea turtles sampled in this study. Olive ridley turtles (brown, n = 37), green turtles (green, n = 10), loggerhead turtles (orange, n = 5) and leatherback turtles (red, n = 3). Capture locations of turtles that had no ingested plastic are indicated with inner white circles. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)





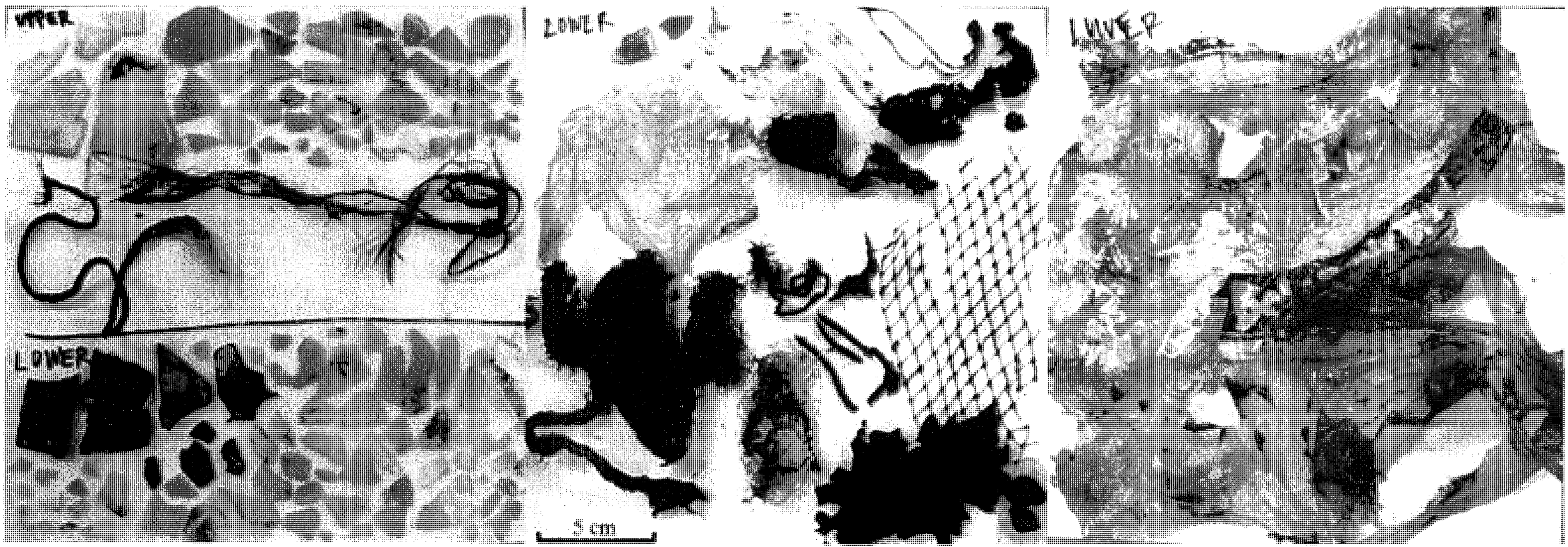


Figure S3. Anthropogenic debris ingested by a pelagic Pacific loggerhead sea turtle (*Caretta caretta*), turtle ID LL554807.

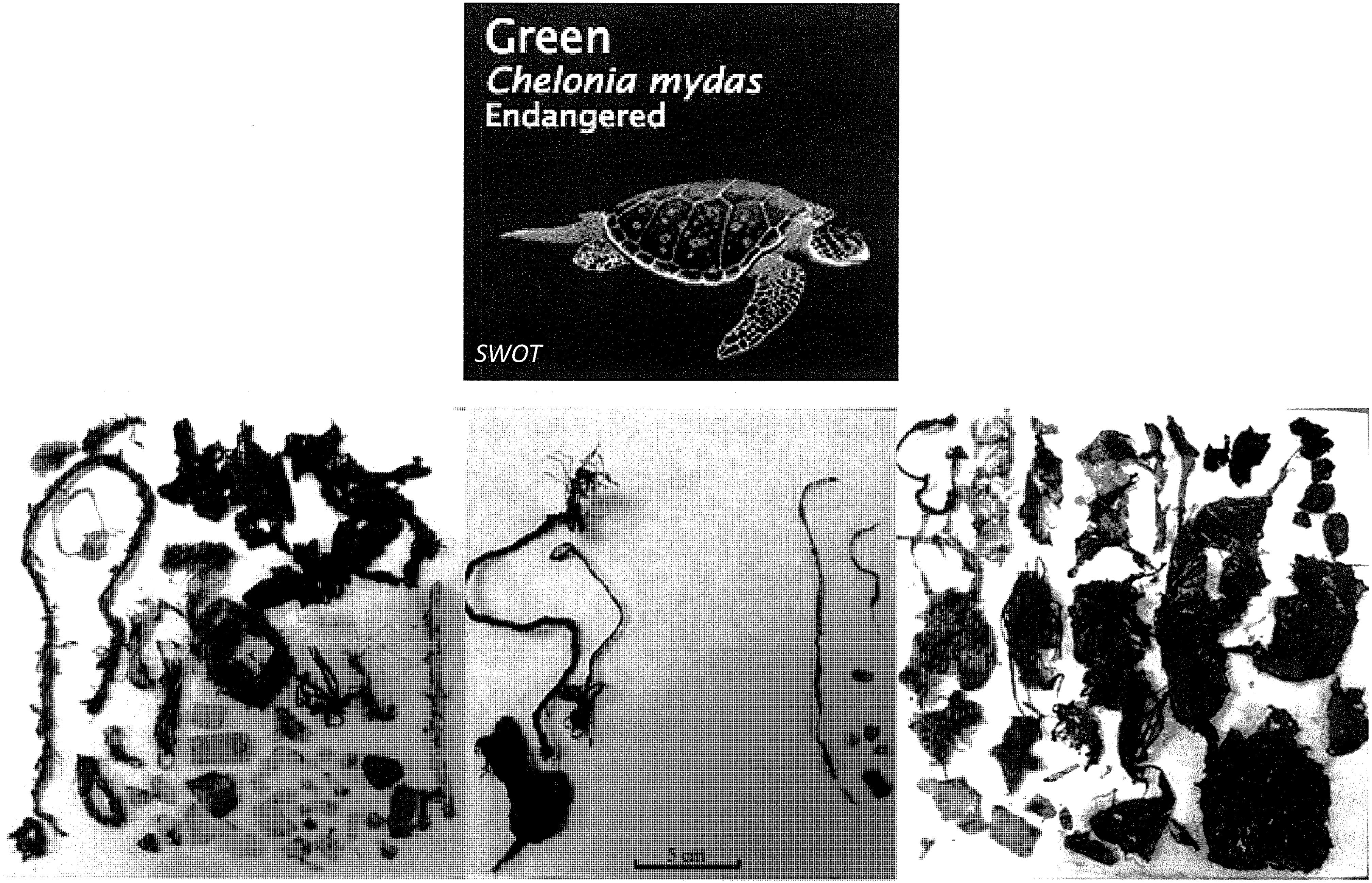
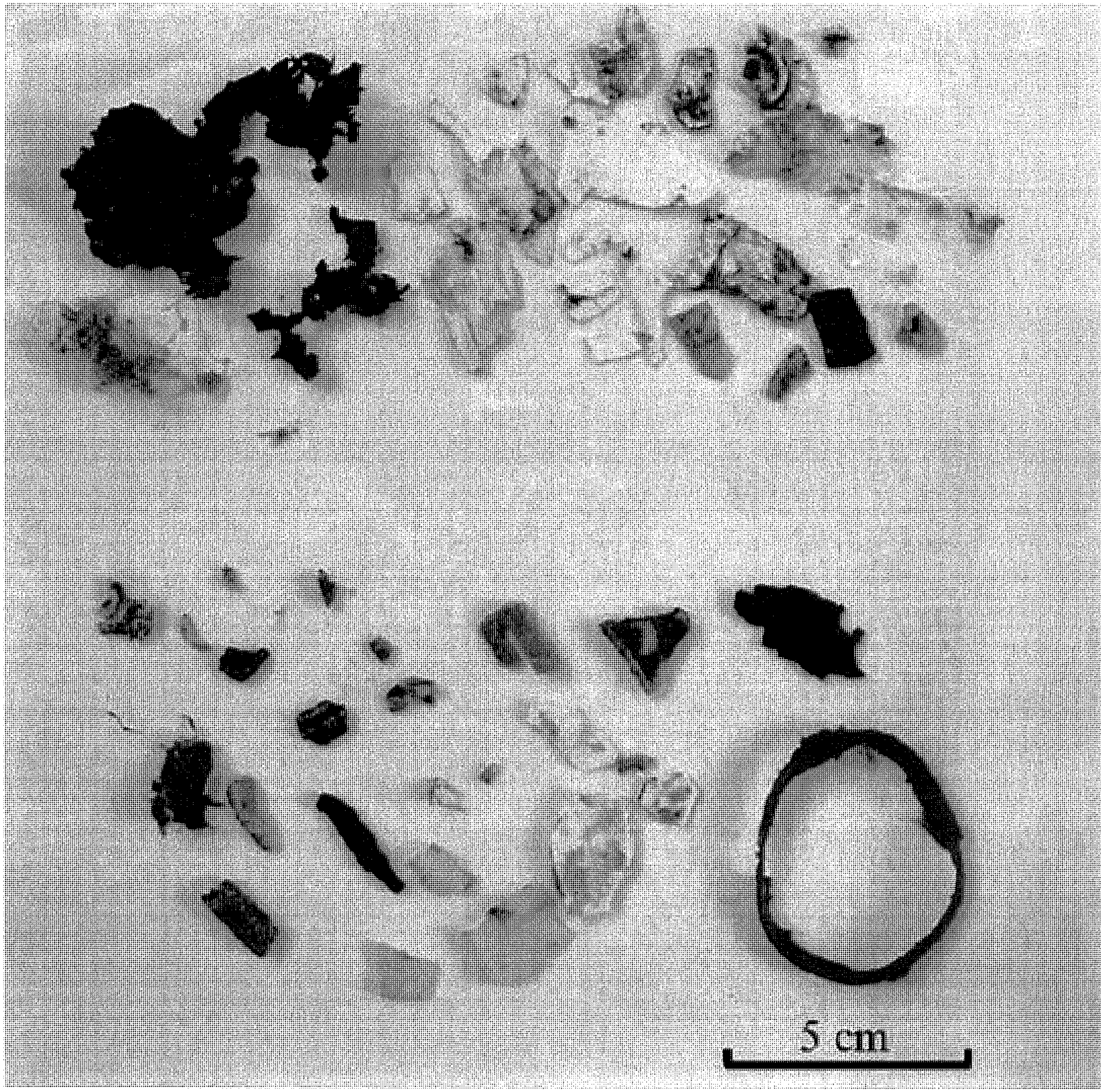


Figure S2. Anthropogenic debris ingested by a pelagic Pacific green sea turtle (*Chelonia mydas*), turtle ID LL513310.



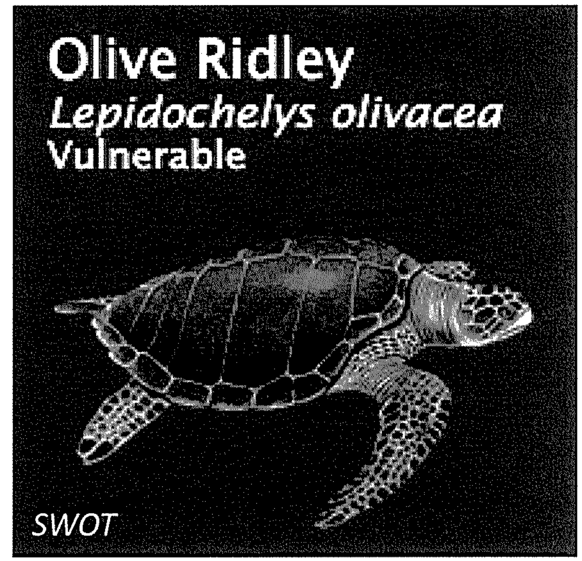


Figure S1. Anthropogenic debris ingested by a pelagic Pacific olive ridley sea turtle (*Lepidochelys olivacea*), turtle ID LL450502.

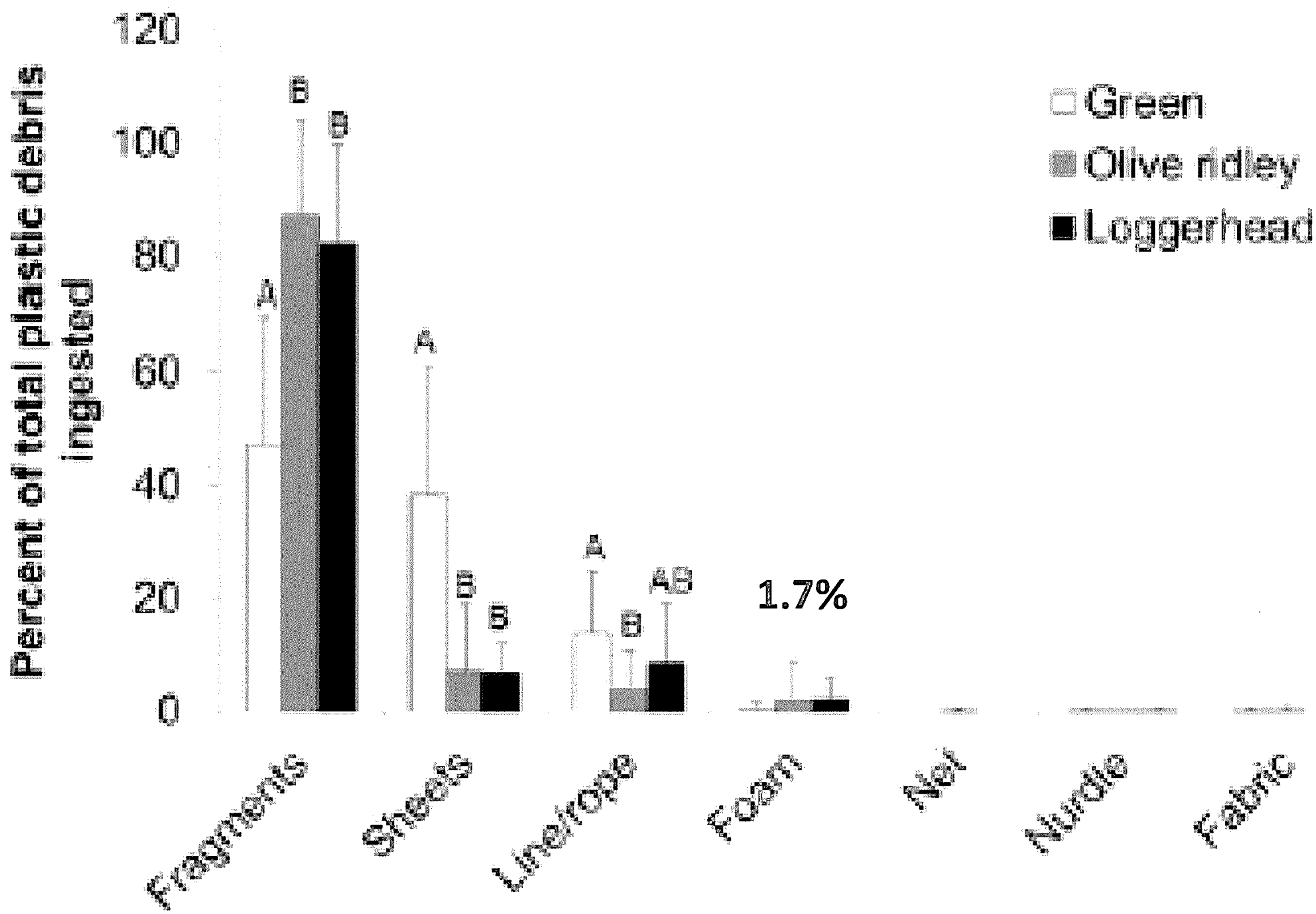


Fig. 5. Debris types ingested by three species of pelagic Pacific sea turtles. Data are the percentage of total plastic pieces consisting of each particular type ingested by each turtle, and shown as mean and standard deviation across turtles of each species. Turtles that did not consume plastic were excluded from this analysis. Different letters above bars indicate significant differences between species for that debris type (Wilcoxon each pair tests, $p < 0.05$).

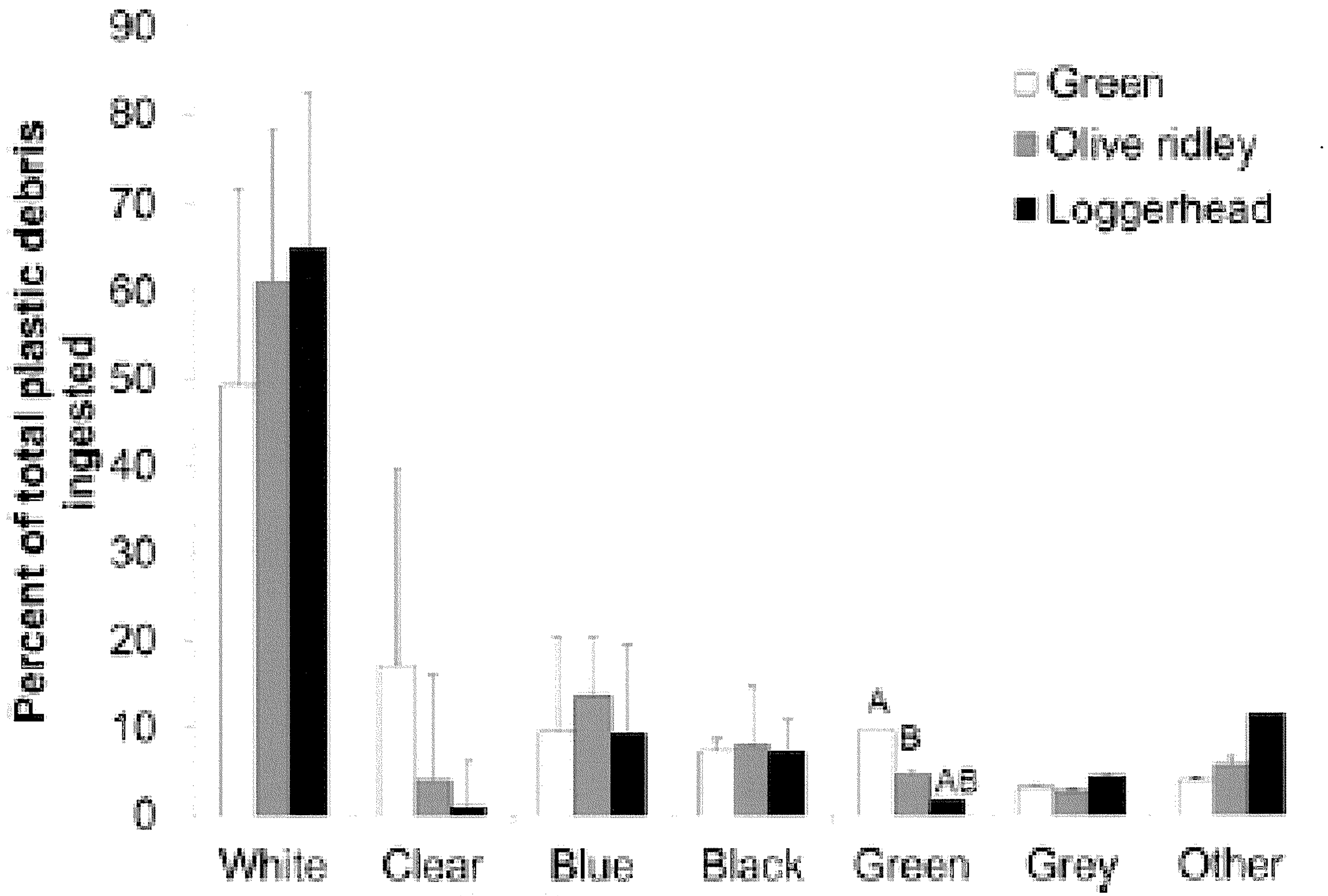
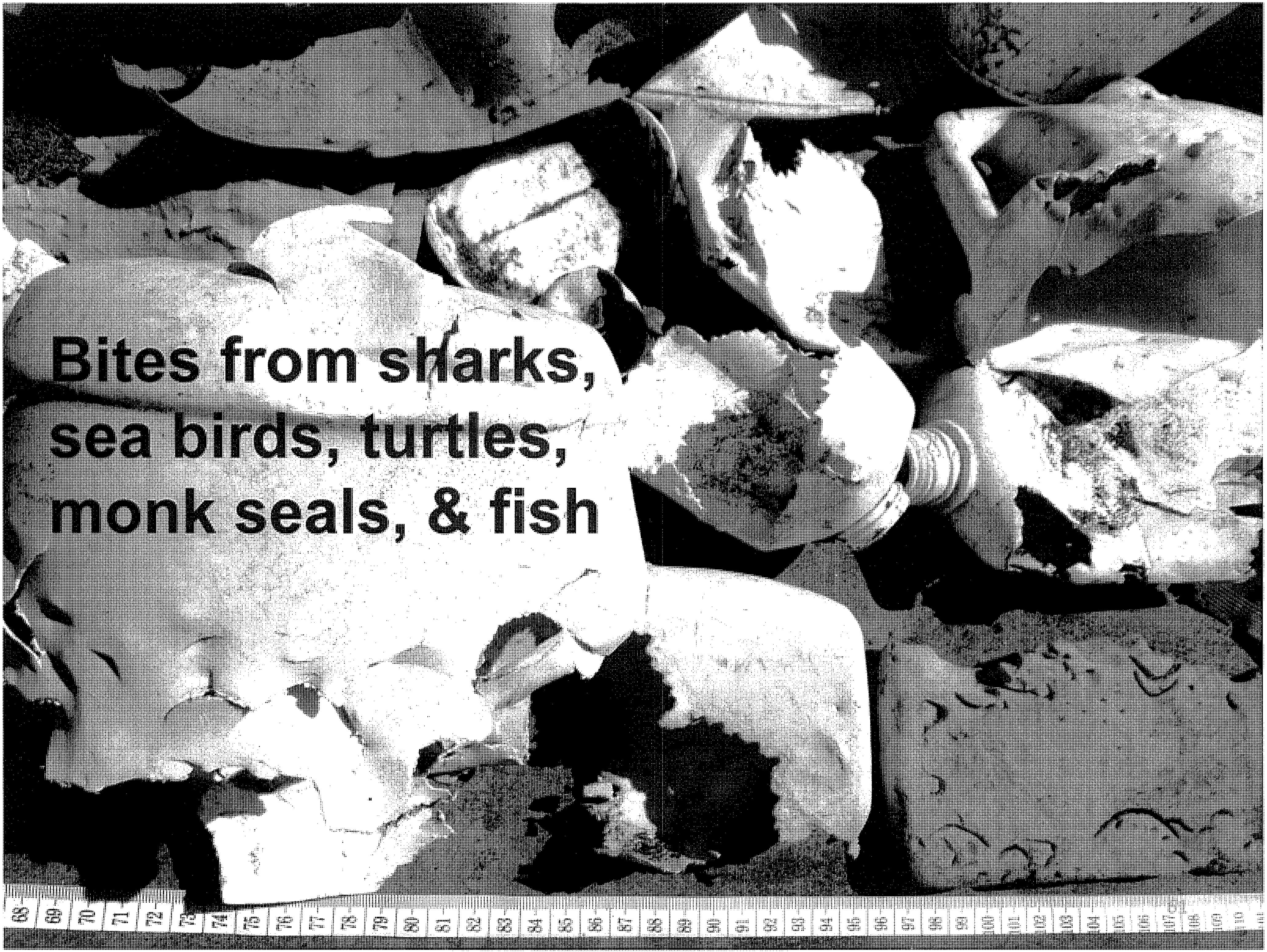
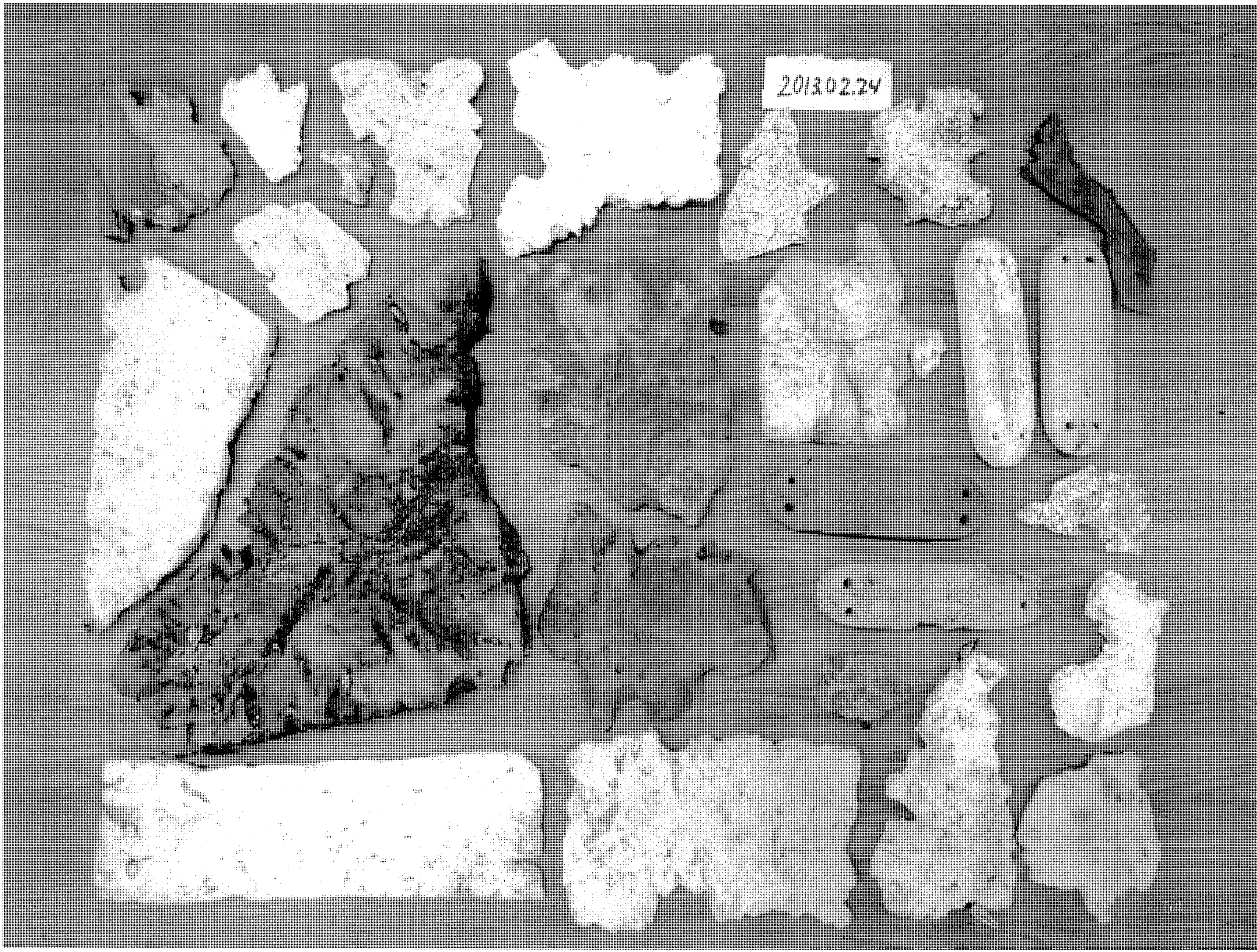


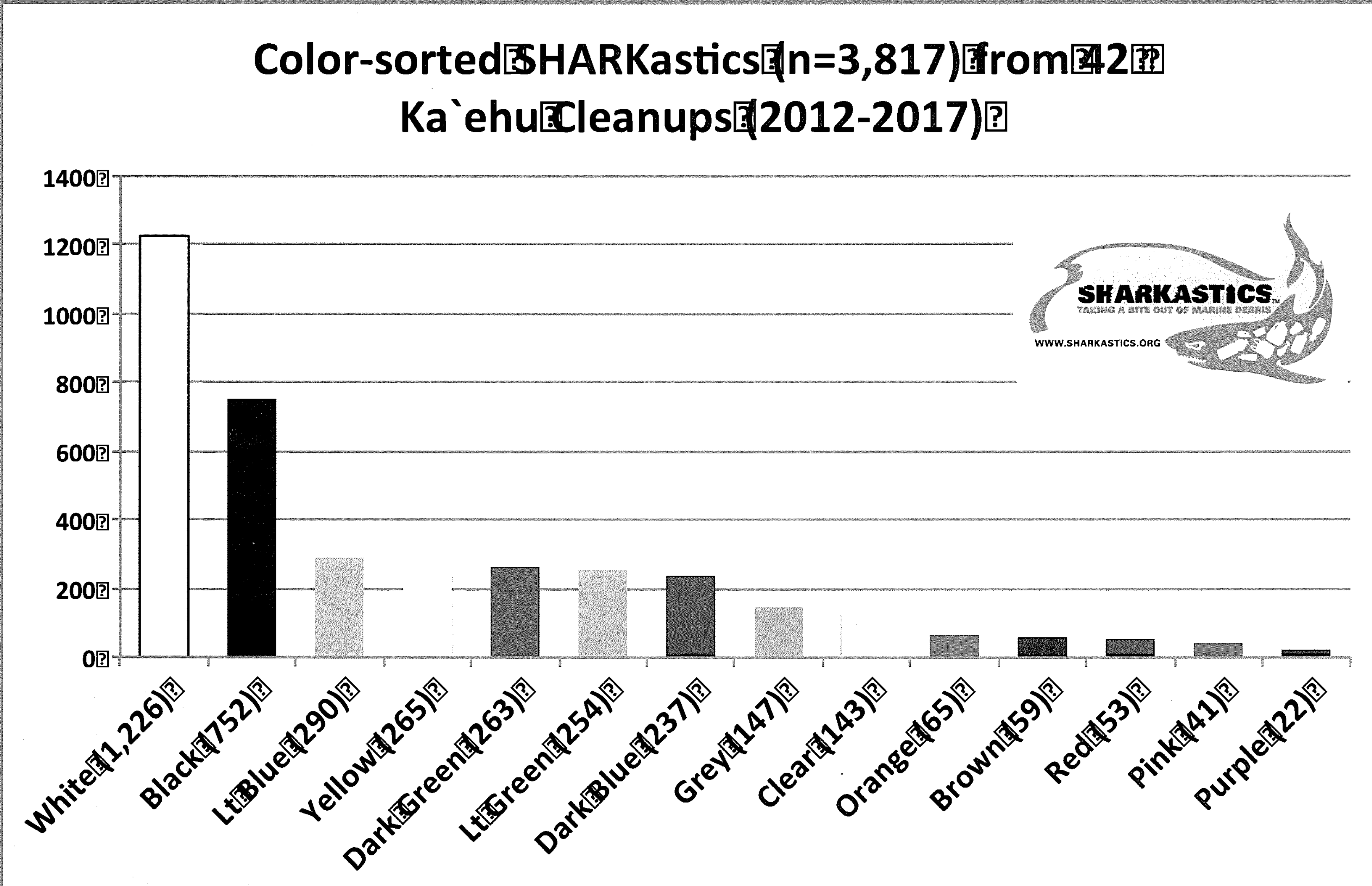
Fig. 6. Debris colors ingested by three species of pelagic Pacific sea turtles. Data are the percentage of total plastic pieces consisting of each particular color ingested by each turtle, and shown as mean and standard deviation across turtles of each species. "Other" colors include pink, orange, red and silver. Turtles that did not consume plastic were excluded from this analysis. Different letters above bars indicate significant differences between species for that debris color (Wilcoxon each pair tests, $p < 0.05$).

SHARKASTICS

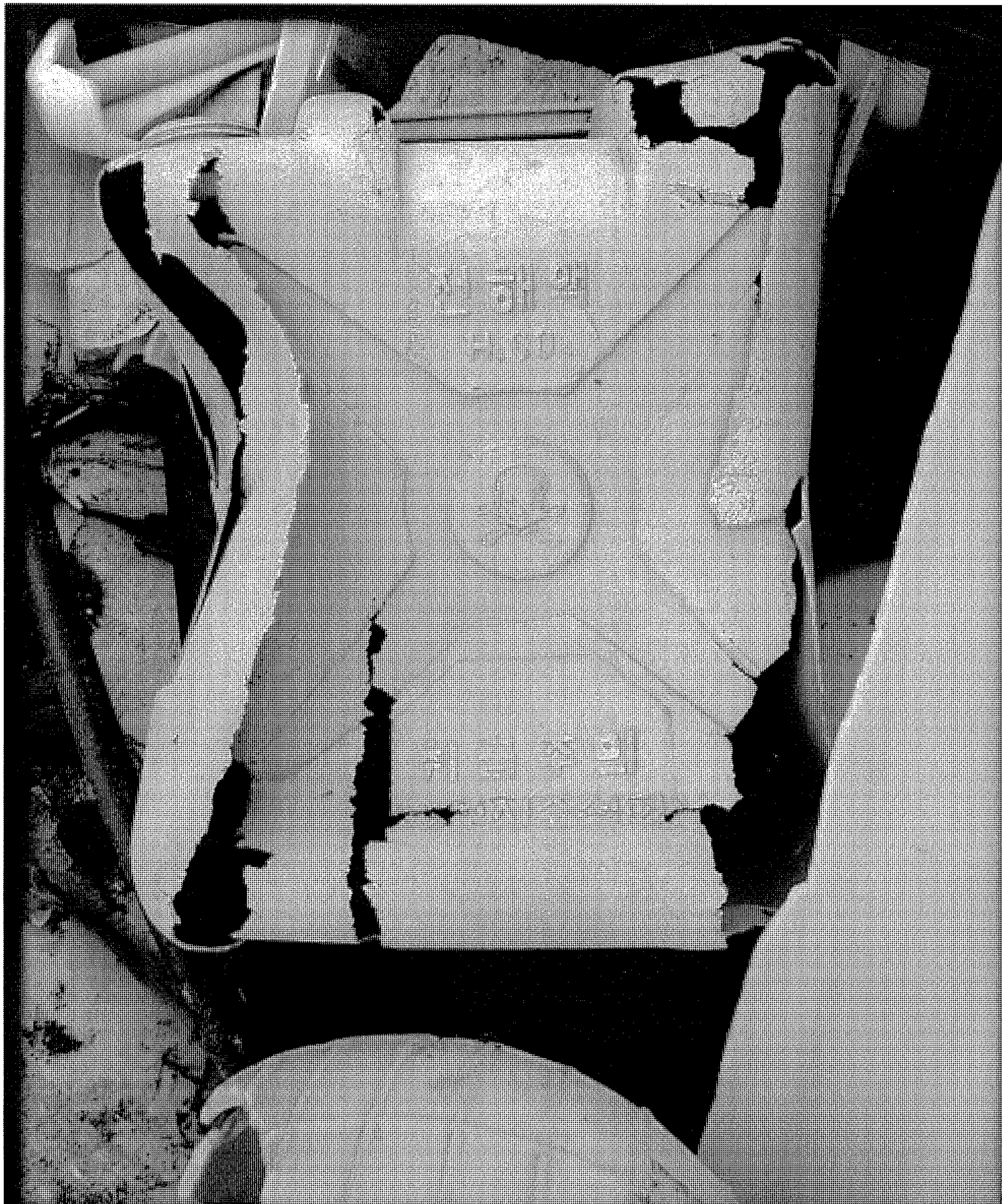
"SHARKASTICS" are what we've termed pieces of plastic marine debris with obvious bite marks (jagged serrations &/or punctures)...


Bites from sharks,
sea birds, turtles,
monk seals, & fish

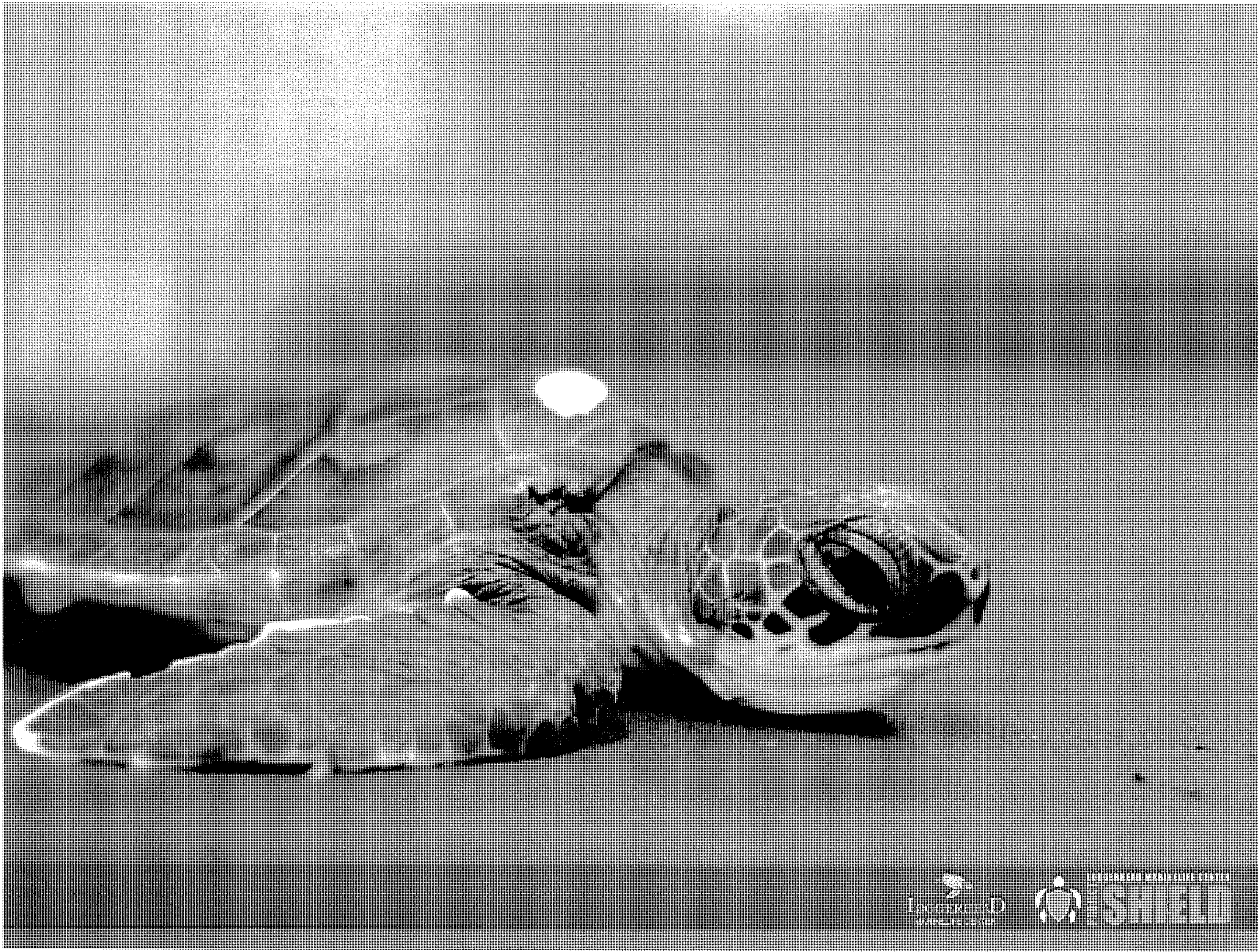

2013.02.24



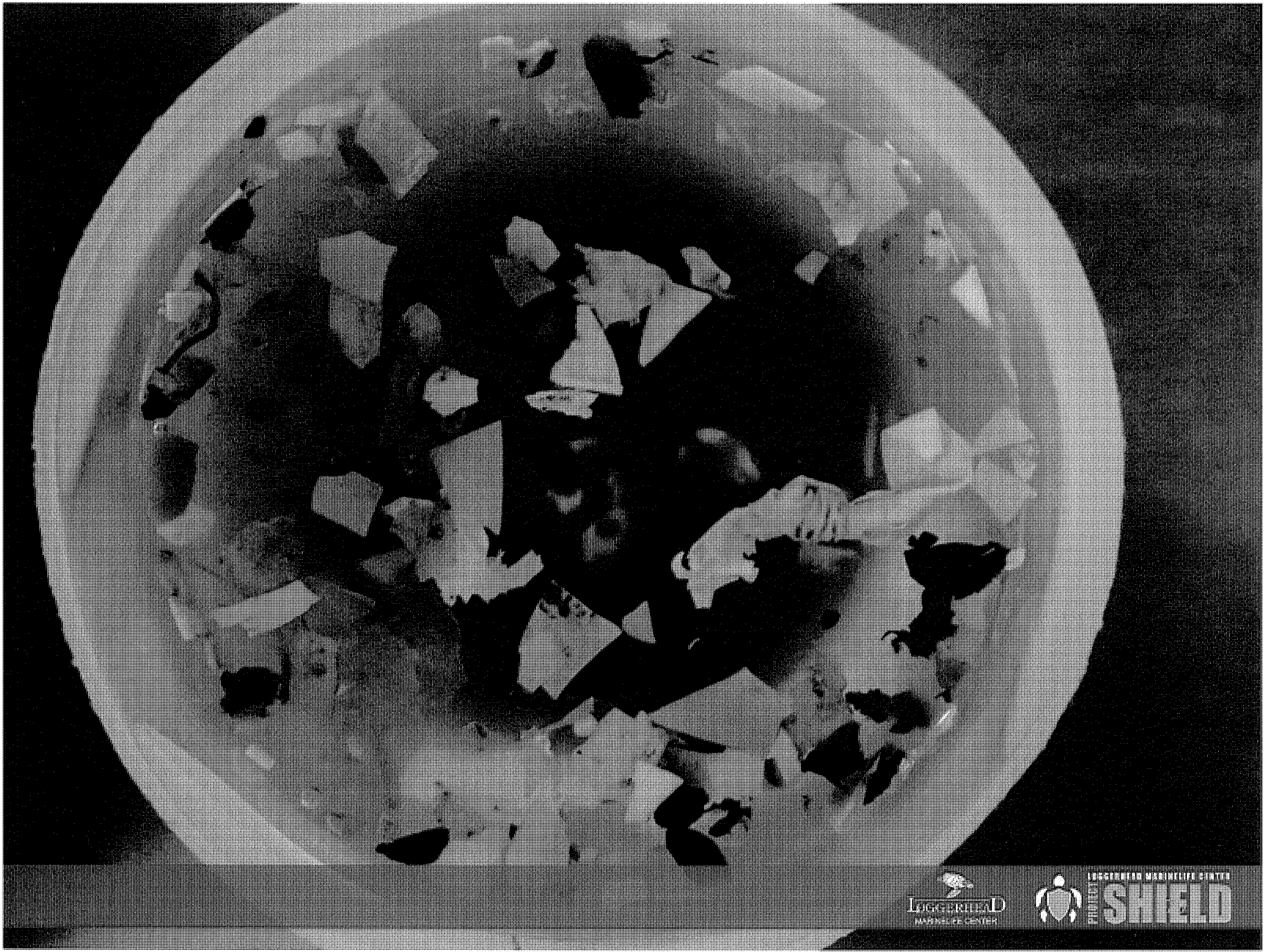
Color-sorted SHARKastics (n=3,817) from 42
Ka`ehu Cleanups (2012-2017)
1400
1200
1000
800
600
400
200
0
White (1,226)
Black (752)
Lt Blue (290)
Yellow (265)
Dark Green (263)
Lt Green (254)
Dark Blue (237)
Grey (147)
Clear (143)
Orange (65)
Brown (59)
Red (53)
Pink (41)
Purple (22)
SHARKASTICS
TAKING A BITE OUT OF MARINE DEBRIS
WWW.SHARKASTICS.ORG



Maybe these animals are just "test biting" the plastics… but if they're actually ingesting these materials, it can't be good for them…


LOGGERHEAD MARINELIFE CENTER
SHIELD


Cc1
LOGGERHEAD
MARINELIFE CENTER
LOGGERHEAD MARINELIFE CENTER
SHIELD


SHIELD


The fate of our ocean is in your hands!


PLEASE
SUPPORT
Bill 127!
"Keep the sea foam-free
for you & me!"
SHARKASTICS
WWW.SHARKASTICS.ORG

ToxWorks

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George Cruzan has a PhD in Biochemistry from Purdue University. He has been a diplomate of the American Board of Toxicology from 1980 to 2015 and a Member of the Society of Toxicology since 1987. After 3 years in Animal Health Research and 4 years in Toxicology at Rohm and Haas, he spent 16 years in the Toxicology Department of Mobil Oil Corporation. Since 1995 he has been the principle toxicologist at ToxWorks, providing consulting services to petroleum, petrochemical and chemical industries. Clients have included trade associations and individual companies. Projects have included business unit interactions, literature reviews, toxicological evaluations, regulatory interactions, litigation support, study design and monitoring.

Since 1988, styrene health and environmental effects has been a main focus of his research and regulatory activities. Since 1995, he has provided science consulting and project management to The Styrene Information and Research Center, Washington, DC. He has authored 17 papers on styrene toxicity.

Polystyrene Health Effects

George Cruzan, PhD
ToxWorks

Incorrect Statement

- "polystyrene.......is a suspected human carcinogen."

- Polystyrene in NOT a suspected carcinogen
- It should not be confused with styrene

Are You Confused ?

- Polystyrene is a solid; styrene is a liquid
- Polystyrene is unreactive; styrene is reactive

Chemical Reactions

- When chemicals react, the product has its own properties, not those of reactants.
- Example
  - Sodium – very reactive solid metal
  - Chlorine – poisonous gas
  - When sodium reacts with chlorine, table salt is produced (sodium chloride)

Polymers Differ from Monomers

- Polymers do not have the same properties as the monomers that compose them.
- Example
  - ➢Glucose – sweet tasting
  - ➢Polymerize by joining glucose molecules together,

  Produces cellulose – wood or plant fiber
- Same for styrene and polystyrene

Sources of Styrene Exposure

- Ambient air (autombile exhaust, factory discharge, cigarette smoking, etc) – 80 ug/day
- Naturally occurring in foods – 9 ug/day
- Migration from polystyrene food packaging – 6.6 ug/day
  - Migration from foam food service items – 4 ug/day (of the 6.6 ug/day for all PS)
- 4 ug = 1millionth of a teaspoon

Styrene Health Effects

- US NTP (2011) lists styrene as "Reasonably Anticipated to be a Human Carcinogen"
  - Based on suggestive increases in reinforced plastic workers
  - Based on lung tumors in mice
  - No other tumors increased in mice
  - No tumors increased in rats

New Human Studies

- Since ROC listing, most human cohorts (groups of workers) have been re-examined as older workers have died
- Tumors suggested among earlier evaluations are no longer increased

Mouse Lung Tumors

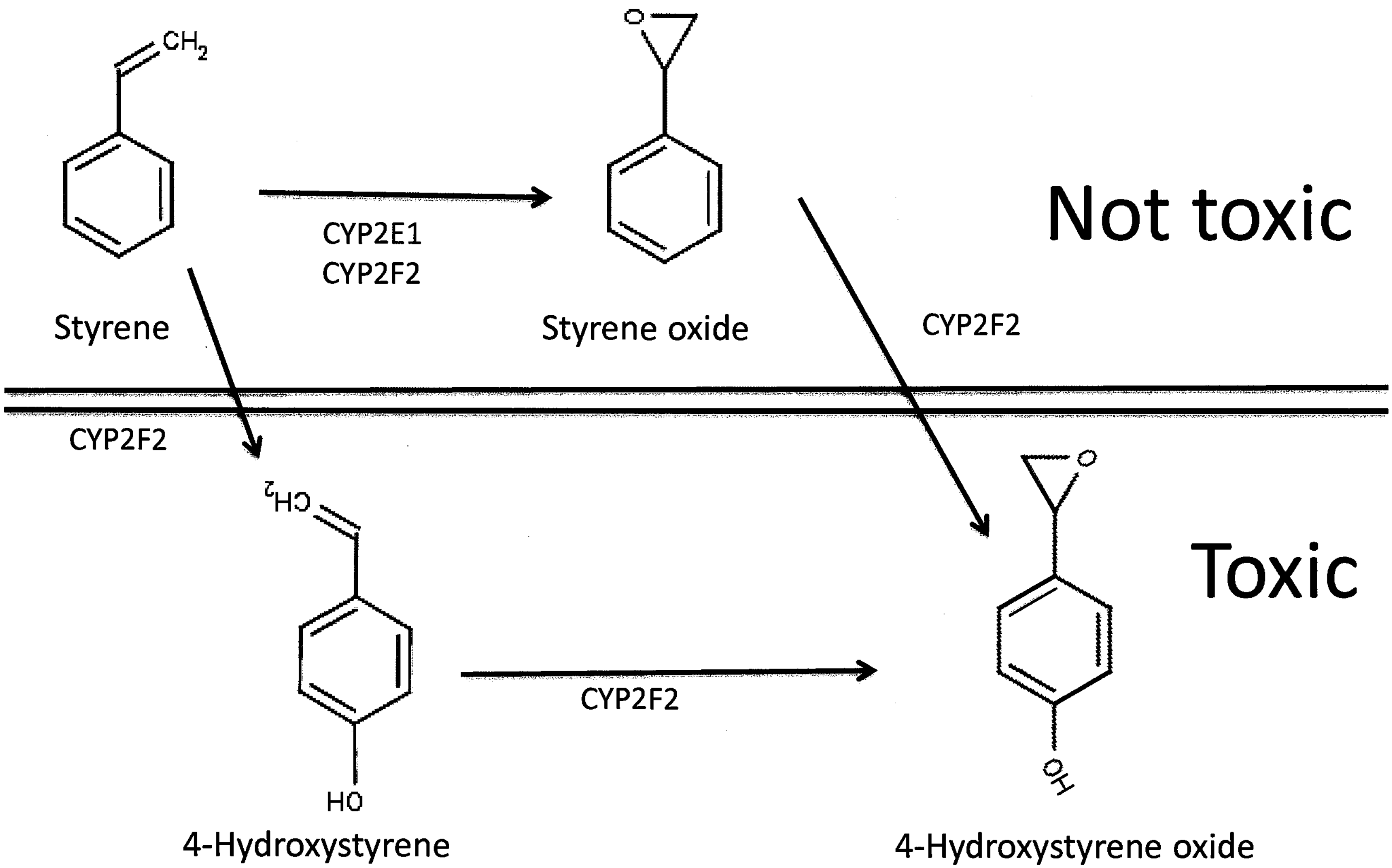
- 55 of 70 (78%) normal mice had preneoplastic or neoplastic lesions in lung after lifetime (2 years) exposure to 120 ppm styrene by inhalation.

- 0 of 70 mice without CYP2F2 had lung lesions

Mode of Action

- Key Events
  - Metabolism by CYP2F2
  - No evidence of genotoxicity
  - Metabolites damage and kill some lung cells
  - Metabolites stimulate production of new lung cells
  - Increased cells produce hyperplasia (excessive cells lining airways)
  - In some mice, tumors develop

- Normal metabolism of styrene is catalyzed by CYP2E1 – produces styrene oxide
- Mouse lung – CYP2F2 metabolizes styrene to different metabolites – oxidation of aromatic ring
- Styrene oxide is not toxic to mouse lung cells without further CYP2F2 metabolism



CH2
Styrene
CYP2E1
CYP2F2
Styrene oxide
Not toxic
CYP2F2
CYP2F2
HO
4-Hydroxystyrene
CYP2F2
Toxic
OH
4-Hydroxystyrene oxide

Summary of MOA

- Lung tumors in mice, not in rats
- Lung toxicity in mice, not in rats
- Toxicity and metabolism in Club (Clara) cells in mice, not rats
- Lung toxicity from 4HS in mice, not rats
- Elimination of lung toxicity from styrene and SO in CYP2F2-KO mice
- 80% reduction on ring-oxidized metabolites in CYP2F2-KO mice
- Lower level of CYP2F4 in rats does not produce toxicity
- Greater lung toxicity in mice from 4HS than from SO
- Limited toxicity from 4HS in 2F2-KO mice
- 3- or 4-methylstyrene do not cause lung tumors in mice
- Enhanced expression of cell cycle genes in WT mice
- No enhanced gene expression from styrene in KO mice

Human Relevance of Mouse Lung Tumors

- Rats have less CYP2F than mice; no toxicity, no lung tumors

- Humans have less CYP2F than rats; no toxicity no lung tumors

Risk Assessment

- Reinforced plastics workers – 2,000,000 ug/day
- Ambient styrene – 80 ug/day
- Food-derived styrene – 9 ug/day
- Polystyrene food service styrene – 4 ug/day
- Total non-occupational exposure – 96 ug/day

- Banning ps foodservice reduces styrene exposure by less than 5%

Risk Assessment

- "Let me put your mind at ease right away about polystyrene foam*" ... [the levels of styrene from polystyrene containers] "are hundreds if not thousands of times lower than have occurred in the occupational setting...In finished products, certainly styrene is not an issue." Linda Birnbaum, Director NTP, 2011.
- "The risks, in my estimation, from polystyrene are not very great. It's not worth being concerned about." John Bucher, Associate Director NTP, 2011.

Conclusion

- Very high exposures to styrene may or may not present a risk
- USEPA acceptble exposure 20,000 ug/day; exposure from PS 4 ug/day
  - 5000-fold safety factor
- No government agency considers PS to be carcinogenic
- Styrene from polystyrene products do not present a measurable risk.

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Report from George Cruzan, PhD on proposed Bill 127

The proposed County of Maui Ordinance (Bill 127(2016)), states in Section 1 "polystyrene has significant negative impacts on the environment, contributes to the potential death of marine animals and avian populations through ingestion, and is a suspected human carcinogen." The last phrase is not correct. Polystyrene is not a suspected carcinogen, nor should it be confused with styrene.

1. Credentials

George Cruzan, PhD. BA in chemistry 1965 The King's College. PhD in biochemistry 1969 Purdue University. Professional toxicologist 1976 to present (41 years), Diplomate of American Board of Toxicology 1980-2015. President of ToxWorks (toxicology consulting firm) 1995 to present (22 years).

Studying health and environmental effects of styrene and leading $20 million research program, 1989 to present (28 years)

2. Polystyrene

Polystyrene is a polymer synthesized by connecting many molecules of styrene together, and should not be confused with the styrene. Styrene is a liquid; polystyrene is a solid. Although the names sound familiar and may be confusing, styrene and polystyrene are different and have completely different properties. Styrene is reactive; polystyrene is inert. In other words, polystyrene does not have the properties of styrene. This is true of all polymers; they are different from the monomer they are synthesized from. A common example is the difference between sugar and wood. Sugar is a monomer with distinct properties. Join many sugar molecule together and you get cellulose, the main polymer in wood.

Thus the health effects of polystyrene should be based on polystyrene, not on styrene. There are no adverse health effects on humans from polystyrene.

Polystyrene contains some residual unreacted styrene. Typical products contain less than 300 ppm. Thus a typical foam cup, weighing 1.6 grams, will contain less than 0.5 milligram (mg) styrene trapped within the polymer.

2. Sources of Styrene Exposure

Styrene is everywhere in minute amounts. Ambient air always contains styrene from automobile exhaust, cigarette smoke, wood smoke, plant emissions. Average concentration is about 4 microgram (ug)/ cubic meter (m^3). Typical human breathing is 20 m^3/day. Therefore, normal inhalation of ambient styrene from air is 80 ug/day (4 ug/m^3 * 20 m^3/day).

Styrene is naturally present in several foods. It has been measured in foods that have not had contact with polystyrene containers. It is present in the highest concentration in coffee, cinnamon, beer and nuts. Based on average consumption, it is estimated that the average person ingests 9 ug styrene per day from naturally occurring styrene in their food.

There is a small amount of unreacted styrene within polystyrene; some of this may migrate into food in the container. The residual styrene will migrate from areas of higher concentration to lower areas of concentration. The only styrene that can migrate into food or drink is the styrene that is at the interior surface of the cup. As this styrene migrates from the surface of the cup into the food or drink, additional molecules of styrene migrate to the surface and then into the food. About half of the unreacted styrene will migrate over time to the inside surface and half to the outside surface.

The results of a 2013 study show that the maximum amount of styrene that could migrate from polystyrene food-contact packaging is calculated to be 6.6 micrograms (about 1 millionth of a teaspoon) per person per day. As mentioned above, several foods (e.g., coffee, cinnamon) naturally contain styrene; the average consumption of styrene from natural food sources is about 9 ug/day. The FDA's acceptable daily intake of styrene is calculated to be 90,000 micrograms per person per day. This demonstrates a safety factor of more than four orders of magnitude (10,000 times). Link: https://plasticfoodservicefacts.com/main/Safety/Safety-of-PS-Foodservice-Products

Total styrene migration from all PS foam food service products results in ingestion of 4 ug/day styrene.

Total styrene exposure averages about 96 ug/day.

3. Health Effects of Styrene

Fiberglass workers have highest exposures, especially in the past. Exposure greater than 50 ppm for 8 hrs. may cause headaches, or slowed reaction time. Exposures greater than 30 ppm 8 hr./day for more than 10 years may cause a slight reduction in hearing.

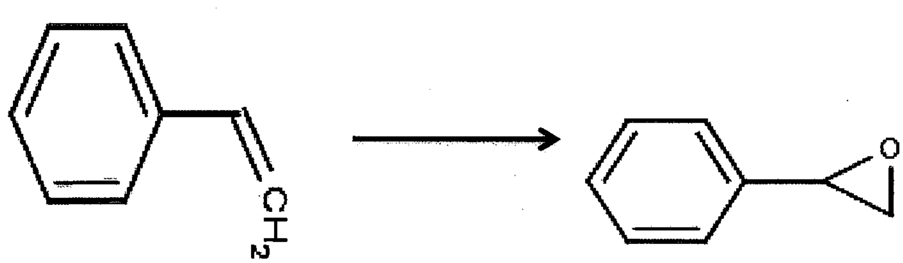
US National Toxicology Program lists styrene as reasonably anticipated to be a human carcinogen in Report on Carcinogens (ROC). This is based on suggestive increases in cancer among highly exposed reinforced plastics works and on increased lung tumors in mice exposed to styrene for 2 years.

The causes of deaths in most of the cohorts (or groups) of reinforced plastics workers have been updated since the ROC in 2011. The further evaluations of these workers do not support a conclusion that styrene induces cancer in these workers. Furthermore, even if there were evidence of cancer in these workers, it would not imply a cancer hazard from residual styrene in polystyrene. Exposure of these workers is 500,000 fold higher than exposure from polystyrene products.

Recent research, since the evaluation by the NTP, has demonstrated that styrene-induced lung tumors in mice is caused by specific metabolism of styrene in mouse lung, which does not occur to a significant extent in rats or humans.

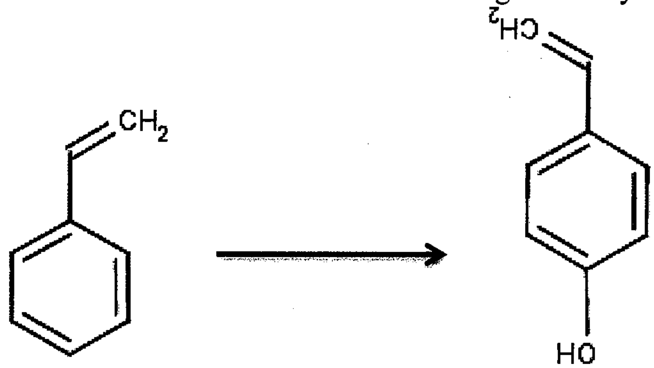
An enzyme CYP2F2 is present in high concentration in mouse lungs. In genetically modified mice that do not produce CYP2F2, styrene has no effect in the lung (Cruzan et al., 2012, 2017). In a recently completed study, 78% of normal mice (that produce CYP2F2) exposed for their lifetime to a very high concentration of styrene had neoplastic or pre-neoplastic lung alterations (Cruzan et al., 2017). There were no neoplastic or pre-neoplastic alterations in CYP2F2-deficient mice from lifetime exposure to a very high concentration to styrene (Cruzan et al., 2017). Furthermore, assessment of gene expression clearly demonstrated that these alterations were not caused by any genotoxic reactions (Andersen et al., 2017). Rats and humans have much lower levels of CYP2F in the lung and do not have any lung toxicity from styrene.

Metabolism of styrene by CYP2F2 causes the formation of different metabolites than normal styrene metabolism. Styrene metabolism in rats and humans is mainly by CYP2E1, which produces styrene-7,8-oxide. It has been postulated that any toxic or neoplastic effects of styrene are caused by styrene-7,8-oxide. A recent study demonstrates that styrene-7,8-oxide has no effect on mouse lung unless it is metabolized further by CYP2F2 (Cruzan et al., 2012); i.e., in the absence of CYP2F2, styrene-7,8-oxide has no effect on mouse lung.



Styrene CYP2E1 Styrene-7,8-oxide

CYP2F2 cause oxidation of the aromatic ring of styrene, producing 4-hydroxystyrene, 3,4-dihydroxystyrene, and 4-hydroxystyrene-7,8-oxide. 4-Hydroxystyrene was toxic to mouse lungs at a 50-fold lower dose than styrene-7,8-oxide following 2 weeks of exposure (Cruzan et al., 2005). Ring oxidation of styrene by CYP2F2 could be expected because the normal function of CYP2F2 is the oxidation of aromatic rings in the synthesis of Coenzyme Q.



Styrene CYP2F2 4-hydroxystyrene

Summary of the mode of action

	Mouse	Rat
Lung tumors in mice, not in rats	Supporting	Supporting
Lung toxicity in mice, not in rats	Supporting	Supporting
Toxicity and metabolism in Club (Clara) cells in mice, not rats	Supporting	Supporting
Lung toxicity from 4HS in mice, not rats	Supporting	Supporting
Elimination of lung toxicity from styrene and SO in CYP2F2-KO mice	Supporting	
80% reduction on ring-oxidized metabolites in CYP2F2-KO mice	Supporting	
Lower level of CYP2F4 in rats does not produce toxicity		Supporting
Greater lung toxicity in mice from 4HS than from SO	Supporting	
Limited toxicity from 4HS in 2F2-KO mice	Supporting	
3- or 4-methylstyrene do not cause lung tumors in mice	Supporting	
Enhanced expression of cell cycle genes in WT mice	Supporting	
No enhanced gene expression from styrene in KO mice	Supporting	

Inconsistent and questionable increases in cancer deaths among workers with very high exposures to styrene do not imply a cancer hazard from residual styrene in polystyrene products because the exposures are 500,000 fold lower. Increased tumors in mice are not indicative of human cancer risk from styrene because the effects in mouse lung are caused by metabolism of styrene by CYP2F2, which does not occur in rats or humans to a biologically meaningful extent.

4. Risk Assessment

Exposure of reinforced plastics workers has been 2,000,000 ug/day over many years. A microgram (ug) is 1 millionth of a gram, about 1 4 millionth of a teaspoon.

Total styrene naturally in food results in ingestion of 9 ug/day styrene. Total styrene migration from all PS foam food service products results in ingestion of 4 ug/day styrene (about 1 millionth of a teaspoon). Inhaled styrene from ambient air results in intake of 80 ug/day styrene. The total styrene intake is about 96 ug/day. Banning PS foam products would reduce that by less than 5%.

US EPA acceptable exposure is 20,000 ug/day. Exposure from PS foam is less than 4 ug/day. 5000 fold safety factor.

Dr. Linda Birnbaum, Ph.D., Director, U.S. National Toxicology Program was quoted widely in Associated Press reports in June 2011: "Let me put your mind at ease right away about polystyrene foam*" ... [the levels of styrene from polystyrene containers] "are hundreds if not thousands of times lower than have occurred in the occupational setting...In finished products, certainly styrene is not an issue." *Source: news reports of Associated Press story, June 2011*

John Bucher, associate director of the National Toxicology Program, was quoted in Associated Press reports in August 2011: "The risks, in my estimation, from polystyrene are not very great," he said. "It's not worth being concerned about."
Source: news reports of Associated Press story, August 2011

U.S. National Institutes of Environmental Health Sciences (NIEHS)

NIEHS in June 2011 noted: "Styrene should not be confused with polystyrene (foam)*. Although styrene, a liquid, is used to make polystyrene, which is a solid plastic, we do not believe that people are at risk from using polystyrene products."
Source: NIEHS web site

The amount of styrene migrating from PS foam foodservice products is so small that there is no measurable risk. Styrene from foam is not a health issue. In conclusion, no government agencies consider polystyrene to be a carcinogen, nor to pose any health risk.

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ToxWorks

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Report from George Cruzan, PhD on proposed Bill 127

The proposed County of Maui Ordinance (Bill 127(2016)), states in Section 1 "polystyrene has significant negative impacts on the environment, contributes to the potential death of marine animals and avian populations through ingestion, and is a suspected human carcinogen." The last phrase is not correct. Polystyrene is not a suspected carcinogen, nor should it be confused with styrene.

1. Credentials

George Cruzan, PhD. BA in chemistry 1965 The King's College. PhD in biochemistry 1969 Purdue University. Professional toxicologist 1976 to present (41 years), Diplomate of American Board of Toxicology 1980-2015. President of ToxWorks (toxicology consulting firm) 1995 to present (22 years).

Studying health and environmental effects of styrene and leading $20 million research program, 1989 to present (28 years)

2. Polystyrene

Polystyrene is a polymer synthesized by connecting many molecules of styrene together, and should not be confused with the styrene. Styrene is a liquid; polystyrene is a solid. Although the names sound familiar and may be confusing, styrene and polystyrene are different and have completely different properties. Styrene is reactive; polystyrene is inert. In other words, polystyrene does not have the properties of styrene. This is true of all polymers; they are different from the monomer they are synthesized from. A common example is the difference between sugar and wood. Sugar is a monomer with distinct properties. Join many sugar molecule together and you get cellulose, the main polymer in wood.

Thus the health effects of polystyrene should be based on polystyrene, not on styrene. There are no adverse health effects on humans from polystyrene.

Polystyrene contains some residual unreacted styrene. Typical products contain less than 300 ppm. Thus a typical foam cup, weighing 1.6 grams, will contain less than 0.5 milligram (mg) styrene trapped within the polymer.

2. Sources of Styrene Exposure

Styrene is everywhere in minute amounts. Ambient air always contains styrene from automobile exhaust, cigarette smoke, wood smoke, plant emissions. Average concentration is about 4 microgram (ug)/ cubic meter (m^3). Typical human breathing is 20 m^3/day. Therefore, normal inhalation of ambient styrene from air is 80 ug/day (4 ug/m^3 * 20 m^3/day).

Styrene is naturally present in several foods. It has been measured in foods that have not had contact with polystyrene containers. It is present in the highest concentration in coffee, cinnamon, beer and nuts. Based on average consumption, it is estimated that the average person ingests 9 ug styrene per day from naturally occurring styrene in their food.

There is a small amount of unreacted styrene within polystyrene; some of this may migrate into food in the container. The residual styrene will migrate from areas of higher concentration to lower areas of concentration. The only styrene that can migrate into food or drink is the styrene that is at the interior surface of the cup. As this styrene migrates from the surface of the cup into the food or drink, additional molecules of styrene migrate to the surface and then into the food. About half of the unreacted styrene will migrate over time to the inside surface and half to the outside surface.

The results of a 2013 study show that the maximum amount of styrene that could migrate from polystyrene food-contact packaging is calculated to be 6.6 micrograms (about 1 millionth of a teaspoon) per person per day. As mentioned above, several foods (e.g., coffee, cinnamon) naturally contain styrene; the average consumption of styrene from natural food sources is about 9 ug/day. The FDA's acceptable daily intake of styrene is calculated to be 90,000 micrograms per person per day. This demonstrates a safety factor of more than four orders of magnitude (10,000 times). Link: https://plasticfoodservicefacts.com/main/Safety/Safety-of-PS-Foodservice-Products

Total styrene migration from all PS foam food service products results in ingestion of 4 ug/day styrene.

Total styrene exposure averages about 96 ug/day.

3. Health Effects of Styrene

Fiberglass workers have highest exposures, especially in the past. Exposure greater than 50 ppm for 8 hrs. may cause headaches, or slowed reaction time. Exposures greater than 30 ppm 8 hr./day for more than 10 years may cause a slight reduction in hearing.

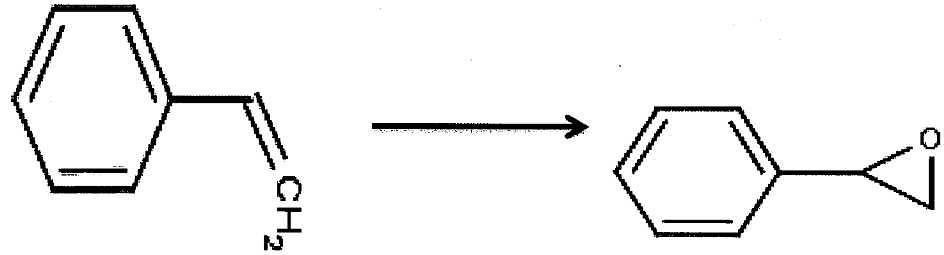
US National Toxicology Program lists styrene as reasonably anticipated to be a human carcinogen in Report on Carcinogens (ROC). This is based on suggestive increases in cancer among highly exposed reinforced plastics works and on increased lung tumors in mice exposed to styrene for 2 years.

The causes of deaths in most of the cohorts (or groups) of reinforced plastics workers have been updated since the ROC in 2011. The further evaluations of these workers do not support a conclusion that styrene induces cancer in these workers. Furthermore, even if there were evidence of cancer in these workers, it would not imply a cancer hazard from residual styrene in polystyrene. Exposure of these workers is 500,000 fold higher than exposure from polystyrene products.

Recent research, since the evaluation by the NTP, has demonstrated that styrene-induced lung tumors in mice is caused by specific metabolism of styrene in mouse lung, which does not occur to a significant extent in rats or humans.

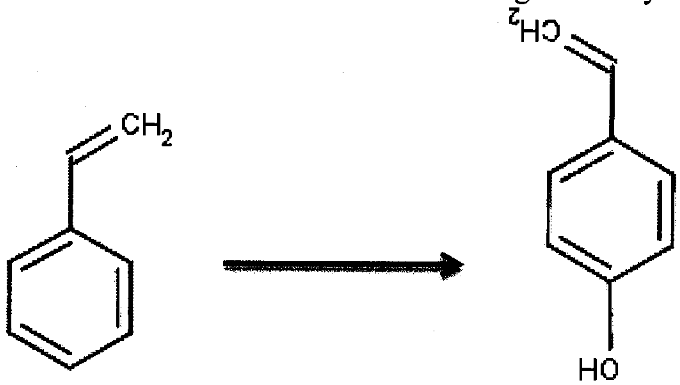
An enzyme CYP2F2 is present in high concentration in mouse lungs. In genetically modified mice that do not produce CYP2F2, styrene has no effect in the lung (Cruzan et al., 2012, 2017). In a recently completed study, 78% of normal mice (that produce CYP2F2) exposed for their lifetime to a very high concentration of styrene had neoplastic or pre-neoplastic lung alterations (Cruzan et al., 2017). There were no neoplastic or pre-neoplastic alterations in CYP2F2-deficient mice from lifetime exposure to a very high concentration to styrene (Cruzan et al., 2017). Furthermore, assessment of gene expression clearly demonstrated that these alterations were not caused by any genotoxic reactions (Andersen et al., 2017). Rats and humans have much lower levels of CYP2F in the lung and do not have any lung toxicity from styrene.

Metabolism of styrene by CYP2F2 causes the formation of different metabolites than normal styrene metabolism. Styrene metabolism in rats and humans is mainly by CYP2E1, which produces styrene-7,8-oxide. It has been postulated that any toxic or neoplastic effects of styrene are caused by styrene-7,8-oxide. A recent study demonstrates that styrene-7,8-oxide has no effect on mouse lung unless it is metabolized further by CYP2F2 (Cruzan et al., 2012); i.e., in the absence of CYP2F2, styrene-7,8-oxide has no effect on mouse lung.



Styrene CYP2E1 Styrene-7,8-oxide

CYP2F2 cause oxidation of the aromatic ring of styrene, producing 4-hydroxystyrene, 3,4-dihydroxystyrene, and 4-hydroxystyrene-7,8-oxide. 4-Hydroxystyrene was toxic to mouse lungs at a 50-fold lower dose than styrene-7,8-oxide following 2 weeks of exposure (Cruzan et al., 2005). Ring oxidation of styrene by CYP2F2 could be expected because the normal function of CYP2F2 is the oxidation of aromatic rings in the synthesis of Coenzyme Q.



Styrene CYP2F2 4-hydroxystyrene

Summary of the mode of action

	Mouse	Rat
Lung tumors in mice, not in rats	Supporting	Supporting
Lung toxicity in mice, not in rats	Supporting	Supporting
Toxicity and metabolism in Club (Clara) cells in mice, not rats	Supporting	Supporting
Lung toxicity from 4HS in mice, not rats	Supporting	Supporting
Elimination of lung toxicity from styrene and SO in CYP2F2-KO mice	Supporting	
80% reduction on ring-oxidized metabolites in CYP2F2-KO mice	Supporting	
Lower level of CYP2F4 in rats does not produce toxicity		Supporting
Greater lung toxicity in mice from 4HS than from SO	Supporting	
Limited toxicity from 4HS in 2F2-KO mice	Supporting	
3- or 4-methylstyrene do not cause lung tumors in mice	Supporting	
Enhanced expression of cell cycle genes in WT mice	Supporting	
No enhanced gene expression from styrene in KO mice	Supporting	

Inconsistent and questionable increases in cancer deaths among workers with very high exposures to styrene do not imply a cancer hazard from residual styrene in polystyrene products because the exposures are 500,000 fold lower. Increased tumors in mice are not indicative of human cancer risk from styrene because the effects in mouse lung are caused by metabolism of styrene by CYP2F2, which does not occur in rats or humans to a biologically meaningful extent.

4. Risk Assessment

Exposure of reinforced plastics workers has been 2,000,000 ug/day over many years. A microgram (ug) is 1 millionth of a gram, about 1 4 millionth of a teaspoon.

Total styrene naturally in food results in ingestion of 9 ug/day styrene. Total styrene migration from all PS foam food service products results in ingestion of 4 ug/day styrene (about 1 millionth of a teaspoon). Inhaled styrene from ambient air results in intake of 80 ug/day styrene. The total styrene intake is about 96 ug/day. Banning PS foam products would reduce that by less than 5%.

US EPA acceptable exposure is 20,000 ug/day. Exposure from PS foam is less than 4 ug/day. 5000 fold safety factor.

Dr. Linda Birnbaum, Ph.D., Director, U.S. National Toxicology Program was quoted widely in Associated Press reports in June 2011: "Let me put your mind at ease right away about polystyrene foam*" … [the levels of styrene from polystyrene containers] "are hundreds if not thousands of times lower than have occurred in the occupational setting...In finished products, certainly styrene is not an issue." *Source: news reports of Associated Press story, June 2011*

John Bucher, associate director of the National Toxicology Program, was quoted in Associated Press reports in August 2011: "The risks, in my estimation, from polystyrene are not very great," he said. "It's not worth being concerned about."
Source: news reports of Associated Press story, August 2011

U.S. National Institutes of Environmental Health Sciences (NIEHS)

NIEHS in June 2011 noted: "Styrene should not be confused with polystyrene (foam)*. Although styrene, a liquid, is used to make polystyrene, which is a solid plastic, we do not believe that people are at risk from using polystyrene products."
Source: NIEHS web site

The amount of styrene migrating from PS foam foodservice products is so small that there is no measurable risk. Styrene from foam is not a health issue. In conclusion, no government agencies consider polystyrene to be a carcinogen, nor to pose any health risk.

May 1, 2017

MEMO TO: Mike White, Council Chair

F R O M: Gary Saldana
Legislative Analyst

SUBJECT: **POLYSTYRENE RESEARCH**

As a follow-up to our discussions relating to the Council's deliberations on Bill 127 (2016) entitled "A BILL FOR AN ORDINANCE ESTABLISHING A NEW CHAPTER 20.26, MAUI COUNTY CODE, RESTRICTING THE USE AND SALE OF POLYSTYRENE FOOD SERVICE CONTAINERS," research was conducted with the Environmental Protection Agency and the Food and Drug Administration.

Below is a review of statements, observations, studies, and reports that relates to potential impacts of polystyrene to health and safety of humans, animals, and the environment.

The following inquiries were forwarded to Timonie Hood, Building Waste and Green Building Coordinator for the Southwest Region of the EPA, in an effort to identify potential toxicity of polystyrene; substantiate and determine the source of statements and observations found during research; and identify various positions on polystyrene:

Question One-

1. Can you reiterate if the EPA has an official position on the use of polystyrene food containers?

   Answer:

   a. Under the Pollution Prevention Act, Congress clearly established a preference for reducing pollution at the source ("source reduction"). EPA's Waste Management Hierarchy supports this framework: https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy

   b. *"EPA does not have a specific policy statement on polystyrene food containers; however, the EPA has supported projects to reduce disposable plastic food packaging,"* specifically:

      i. The Marine Debris and Plastic Source Reduction Toolkit (May 2015) supported the source reduction of disposable plastic (including polystyrene) food service items. The Toolkit provides numerous polystyrene ban policies.

ii. The Rethink Disposables project targeting source reduction of takeout food packaging, the largest documented source of trash in urban runoff that in turn ends up in our bays and oceans.

Question Two-

2. Can you identify the source or reference the EPA utilized to make the following statements or observations?

Statement or Observation One-

a. Organization: Clean Water Action California;
Document: "Health Effects and Regulation of Styrene" (CASRN 100-42-5);
Statement: "According to the US EPA, 100% of Americans have styrene in their bodies." "The principle form of styrene exposure [is]...consuming food items in contact with polystyrene foam packaging and to-go containers."

Answer:

i. The Source of this statement was the U.S. EPA Broad Analysis of the FY82 National Human Adipose Tissue Survey (1986).
ii. The Study was a broad scan chemical analysis of composite of human adipose tissue samples, conducted by the Office of Toxic Substances for estimating the general population exposure to toxic organic chemicals.
iii. The Study observed that "several compounds, including styrene, the xylene isomers, 1.4-dichlorobenzene, and ethylphenol, were detected in all composite samples."
iv. Which confirms that statement that "100% of Americans have styrene in their bodies".
v. However, the Study does not address the cause of the exposure.

Statement or Observation Two-

b. Organization: City and County of San Francisco (SFO);
Document: Ordinance Number 140-16 (c): "Findings" (November 2016);
Statement: "Due to the physical properties of polystyrene foam, the U.S. Environmental Protection Agency (EPA) states: "that such materials can have

serious impacts upon human health, wildlife and aquatic environment, and the economy."

Answer:

i. The source of the statement was from an EPA study entitled "Assessing and Monitoring Floatable Debris," August 2002.
ii. The Study is based on floatable materials, debris and trash, which is defined as "foreign matter that may float or remain suspended in the water column and includes plastic, aluminum cans, wood, projects, bottles, and paper products."
iii. In its discussion of the floatable debris the Study states: "Unless we better control the disposal of trash and other wastes, it is likely that the amount of such debris entering our waterways will increase." It further states: "It has now become evident, however, that such materials can also have serious impacts on human health, wildlife, the aquatic environment, and the economy, and therefore the problem of floatable debris should be addressed." This confirms the statement from the SFO Findings Ordinance 140-16, which was used in part according to the reference source.

Statement or Observation Three-

c. Organization: "Way to Go";
   Document: "Polystyrene Fast Facts" copyrighted 2008;
   Statement: "Polystyrene food containers leach the toxin Styrene when they come into contact with warm food or drink, alcohol, oils and acidic foods causing human contamination and posing a health risk to people."

Answer:

i. Unfortunately, EPA was unable to substantiate this statement, however, please refer to question 5 below referencing a report by the Agency for Toxic Substances and Disease Registry.

Question Three-

3. Can the EPA substantiate the above referenced statements?

   Answer:

   a. See responses to Questions Two and Five.

Question Four-

4. Has the EPA made a determination that polystyrene food containers are a hazard to the health of humans, marine or wildlife?

   Answer:

   a. The EPA points to two reports on this matter, they are:
      i. "Summary of Expert Discussion Forum on Possible Human Health Risk from Microplastics in the Marine Environment," April 2014.
         1. The report received recommendations and perspectives on possible human health risks from the ingestion of seafood contaminated with microplastic-derived persistent bioaccumulative, and toxic chemicals (PBT).
         2. Participants concluded:
            a. A split of opinion on the connection between PBT to aquatic life tissue and to human tissue.
            b. More research is required on this subject.
            c. Research is needed to determine if the PBT's in seafood are derived by microplastics or other sources.
            d. Research is needed to identify sources of other PBT into marine life tissue.
      ii. "State of the Science White Paper: A Summary of the Effects of Plastic Pollution on Aquatic Life and Aquatic-Dependent Wildlife," December 2016.
         1. The report focused on the science of chemical toxicity of ingested plastic and associated chemicals on aquatic organisms and aquatic-dependent wildlife. The report noted the following:
            a. There is growing concern about the toxicological impacts of chemicals associated with plastics on aquatic-organisms.
            b. The report noted various studies that identify marine and wildlife that have ingested plastics which have impacted reproduction, feeding, and growth.
            c. One study, referenced Lavers et al. (2014), found that body condition is negatively influenced by the amount of ingested plastic in flesh footed shearwaters.

   d. Another study by Avio et al. (2015) observed neurotoxic effects and genotoxicity on mussels.
   e. In a study by Rochman et al. (2013), certain fish were found to have induced liver toxicity, glycogen depletion, fatty vacuolation, and single cell necrosis.
2. The report concluded the following:
   a. "Numerous research studies demonstrate that plastics are ingested by aquatic, invertebrates, fish, seabirds, sea turtles, and marine mammals."
   b. "Plastics in aquatic systems contain chemicals originating from the plastic .material, chemicals added during the manufacturing process."
   c. "Many of these chemicals have been found to have harmful effects once in the aquatic environment, the potential toxicological impacts of these chemicals associated with plastic once ingested by aquatic organisms and aquatic-dependent wildlife is an area of concern."
   d. "There is evidence that aquatic organisms and aquatic-dependent wildlife accumulate chemicals from ingested plastics."
   e. "Because organisms in the environment can accumulate the same classes of chemicals from other sources, further research on the relative role plastics play in chemical contaminant to the tissues of organisms compared to other exposure pathways is needed."

Question Five-

5. Beyond the obvious that polystyrene can be ingested by marine and wildlife, is there any conclusive scientific/unbiased studies you can identify that prove toxicity of polystyrene food containers?
   Answer:
   a. Under the Pollution Prevention Act and EPA's work to advance Sustainable Materials Management, EPA encourages consideration of the full lifecycle impacts of products. Polystyrene

is made from styrene, and the toxicity of styrene has been well documented:

   i. "EPA lists styrene in our Toxics Release Inventory, and has found red blood cell, liver, and central nervous system effects but has not evaluated styrene as a carcinogen":
      1. Styrene – EPA Toxics Release Inventory - https://www.epa.gov/sites/production/files/2016-09/documents/styrene.pdf
      2. Styrene – EPA Integrated Risk Information System - https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=104

b. The Centers for Disease Control and Prevention and the Agency for Toxic Substances and Diseases Registry provided the following report in response to this question:
   i. "Toxicological Profile for Styrene," November 2010.
   ii. The profile explores various issues associated with styrene, such as: effects on health, what is styrene, exposure, how it enters or exists in the body, and impacts to children.
   iii. Section 6 of the profile focuses on "Potential for Human Exposure," this includes such observations as:
      1. Contaminated indoor air, tobacco smoke, emissions from building materials, emissions from laser printers and photocopiers.
      2. Additionally, it states that "most styrene associated with food is the result of packaging of the food material in polystyrene containers."
      3. The profile further states that the migration of styrene is not only from polystyrene food containers, but also has been found in yogurt, dairy products, corn and sunflower oil, alcohol, coffee, and tea.
      4. The profile also states "smokers and those eating a high proportion of foods packaged in polystyrene, may have above average exposure to styrene."

c. Another resource provide by the EPA was a document entitled "Polystyrene: A review of the Literature on the Products of Thermal Decomposition and Toxicity," January 1987.
   i. The report is an accumulation of 11 studies on the effect of heat on polystyrene and the toxicity of gases associated with combustion.

ii. The various studies in the report utilized different forms of polystyrene, such as crystal, impact, or expandable, rigid, and sheet foam.
iii. In each study, laboratory rats were used to determine the toxicity of gases produced when polystyrene was heated.
iv. The conclusions of the various studies were:
    1. The main volatile product is the styrene monomer.
    2. Carbon monoxide and carbon dioxide (CO and CO2) were formed during the heating process and appeared to be responsible for the subject animals' deaths.
    3. Effluents produced during flaming of the polystyrene were more toxic than those produced under non-flaming conditions.
    4. In non-flaming conditions of polystyrene, CO and CO2 were not attributed to deaths, however, "other toxicants, perhaps styrene, was responsible."

Food and Drug Administration (FDA)

According to the FDA, Code of Federal Regulations, Title 21, Food and Drugs, Chapter 1 Food and Drug Administration, Department of Health and Human Services states the following:

Section 177.1640 Polystyrene and rubber-modified polystyrene.
"Polystyrene and rubber-modified polystyrene identified in this section may be safely used as components of articles intended for use in contact with food, subject to the provisions of this section.

a. Polystyrene is identified as basic polymers produced by the polymerization of styrene.
b. Polystyrene polymers shall contain not more than 1 weight percent of total residual styrene monomer

In response to an inquiry of the FDA, Catherine McDermott, FDA/Office of Foods & Veterinary Medicine, provided the following response in answer to a question relative to FDA performed studies on impacts of polystyrene on health of humans, marine or wildlife and environment:

"In evaluating the safety of an intended food contact use of a substance, FDA reviews the toxicology information submitted by the proponent of the use. This includes toxicological studies on any chemicals that might migrate into food as a result of the intended use of a food contact substance."

"In addition to the toxicological information provided by industry when submitting their intended use for approval, FDA also reviews applicable publicly available information on substances that migrate to food as that information becomes available."

International Agency for Research on Cancer

Report titled "Styrene 1, Exposure Data", noted the following:

1. "Polystyrene and its copolymers have been used widely as food packaging materials, and residual styrene monomer can migrate into food from such packaging (WHO, 1983)."
2. In a United Kingdom study, it noted that "Within each food type, higher levels of styrene were generally found for products with high fat contact or packed in small containers (ministry of Agriculture, Fisheries and Food, 1994)."
3. The report concludes: "Exposure to the general population occurs at levels of micro-grams per day due mainly to inhalation of ambient air and cigarette smoke and intake of food that has been in contact with styrene-containing polymers."

The above research summary is submitted to assist the Council in its consideration of Bill 127 (2016). Should your require additional research, or would like copies of any of the documents referenced in this memorandum, please let me know.

paf:grs:17-100a

cc: Corporation Counsel
Deputy County Clerk
Director of Council Services

May 4, 2017

MEMO TO: Mike White, Council Chair

F R O M: Gary Saldana
Legislative Analyst

SUBJECT: **POLYSTYRENE RESEARCH** (PAF17-100B)

During research on Bill 127 (2016) entitled "A BILL FOR AN ORDINANCE ESTABLISHING A NEW CHAPTER 20.26, MAUI COUNTY CODE, RESTRICTING THE USE AND SALE OF POLYSTYRENE FOOD SERVICE CONTAINERS," review included various communities throughout the United States to determine the extent of restrictions cities and counties have imposed on the use of polystyrene food containers.

Surfrider.org and The 5Gyres Institute provide interactive lists of communities that have adopted some level of restriction on the use of polystyrene containers. The 5Gyres Institute snotes, within the State of California, 100 cities and counties have enacted polystyrene bans.

Many communities focus their restrictions on polystyrene foam containers (expanded and extruded polystyrene), and typically do not include polystyrene containers utilizing a plastic polymer (clear or colored container).

The City and County of San Francisco is considered to have one of the most restrictive Polystyrene Bans in the country.

San Francisco in 2007 initially passed a ban on "polystyrene foam food ware for food prepared and served" in the City and County.

In 2016 San Francisco increased the ban to include polystyrene foam (extruded and blown) containers to include:

1. meat, fish trays and egg cartons
2. packaging material
3. cooler, ice chests *
4. pool toys*
5. dock floats, mooring buoys or anchor and navigational markers*
   * That are encased in a more durable material.

The San Francisco ban does not restrict polystyrene containers that are non-foam because they are not known to break into smaller pieces like the foam containers and become potential health hazards.

At its meeting of December 16, 2016, the former County Council (Term 2015-2017) when discussing Bill 127(2016), voted to require food prepackaged outside of the County to comply with the provisions of Bill 127. However, concerns were noted relative potential "Commerce Clause" and possible defense of the Bill.

Accordingly, during the research and while consulting with the aforementioned entities that are keeping a tally of communities with polystyrene bans, to date no community has restricted the use of pre-packaged polystyrene food containers where the item is sealed prior to receipt of the local food service provider or store.

In fact, many communities state in their ordinances "restrictions not apply to prepared food packaged outside the city and sold or otherwise provided to the consumer in the same food service ware in which it originally was packaged."

Additionally, many such ordinances also have a statement that reads as follows: "Businesses packaging prepared food outside of the City are encouraged to use food service ware that is compostable or recyclable and is not made, in whole or in part, from Polystyrene Foam."

The above research summary is submitted to assist the Council in its consideration of Bill 127 (2016). Should you require additional research, or would like copies of any of the documents referenced in this memorandum, please let me know.

Paf:grs:17-100b

cc: Deputy County Clerk
Director of Council Services
Corporation Counsel

May 4, 2017

MEMO TO: Mike White, Council Chair

F R O M: Gary Saldana, Legislative Analyst

SUBJECT: **POLYSTYRENE RESEARCH** (PAF 17-100C)

Below is an assessment of definitions of polystyrene food containers from various cities and counties that have enacted polystyrene food container bans.

The definition of "Polystyrene" in the County of Maui Bill 127(2016) is identified followed by definitions from the City of San Jose, Montgomery County in Maryland, Alameda County in California and City and County of San Francisco.

You will note that some language is highlighted in red. The red highlighted language will identify wording that is the same in the County of Maui Bill 127 definition of polystyrene. The wording in black is language that is not include in Bill 127.

Please note there exists a lot of similarities in each of the bills to Bill 127. Also, all of the communities that have been identified below are ordinances that restrict polystyrene foam containers and they do not restrict clear or colored polystyrene containers.

Maui-
"Polystyrene" means a thermoplastic petrochemical material utilizing a styrene monomer, including all polystyrene, meaning any styrene or vinyl chloride polymer which is blown into a foam-like material. Polystyrene may be processed by any number of techniques, including fusion of polymer spheres (expandable bead polystyrene), injection molding, foam molding, and extrusion-blow molding (extruded foam polystyrene).

San Jose-
Polystyrene foam" means a thermoplastic petrochemical material made from a styrene monomer and expanded or blown using a gaseous agent (expanded polystyrene) including, but not limited to] fusion of polymer spheres (expandable bead polystyrene), injection molding, form molding, and extrusion-blow molding (extruded foam polystyrene). "Polystyrene foam: is commonly made into disposable food service ware products. Polystyrene foam: does not include clear or solid polystyrene (oriented polystyrene).

Montgomery County, MD-
“Expanded polystyrene” means blown polystyrene and expanded and extruded foams that are thermoplastic petrochemical material utilizing a styrene monomer and processed by a number of techniques, including fusion of polymer spheres (expandable bead polystyrene), injection molding, foam molding, and extrusion-blow molding (extruded foam polystyrene).

Alameda County, CA-
Polystyrene" means a thermoplastic petrochemical material utilizing styrene monomers. It includes all Polystyrene, meaning any styrene or vinyl chloride polymer which is blown into a foam-like material. This includes the thermoplastic petrochemical material utilizing the styrene monomer, which may be marked with resin symbol #6. sometimes referred to as Styrofoam, a Dow Chemical Company trademarked form of Polystyrene insulation
Polystyrene is generally used to make cups, bowls, plates, trays, clamshell containers, meat trays and egg cartons

San Francisco-
"Polystyrene Foam" means blown polystyrene and expanded and extruded foams which are thermoplastic petrochemical materials utilizing a styrene monomer and processed by any number of techniques including, but not limited to, fusion of polymer spheres (expandable bead polystyrene), injection molding, foam molding, and extrusion-blown molding (extruded foam polystyrene). Polystyrene foam is generally used to make cups, bowls, plates, trays, clamshell containers, meat trays, and egg cartons.

Paf:grs:17-100c

cc: Deputy County Clerk
Corporation Counsel
Director of Council Services

Prof. Douglas McCauley began his career as a fisherman working as a deckhand in the sport fishing industry but migrated to marine science and now serves as an Assistant Professor at the University of California Santa Barbara.

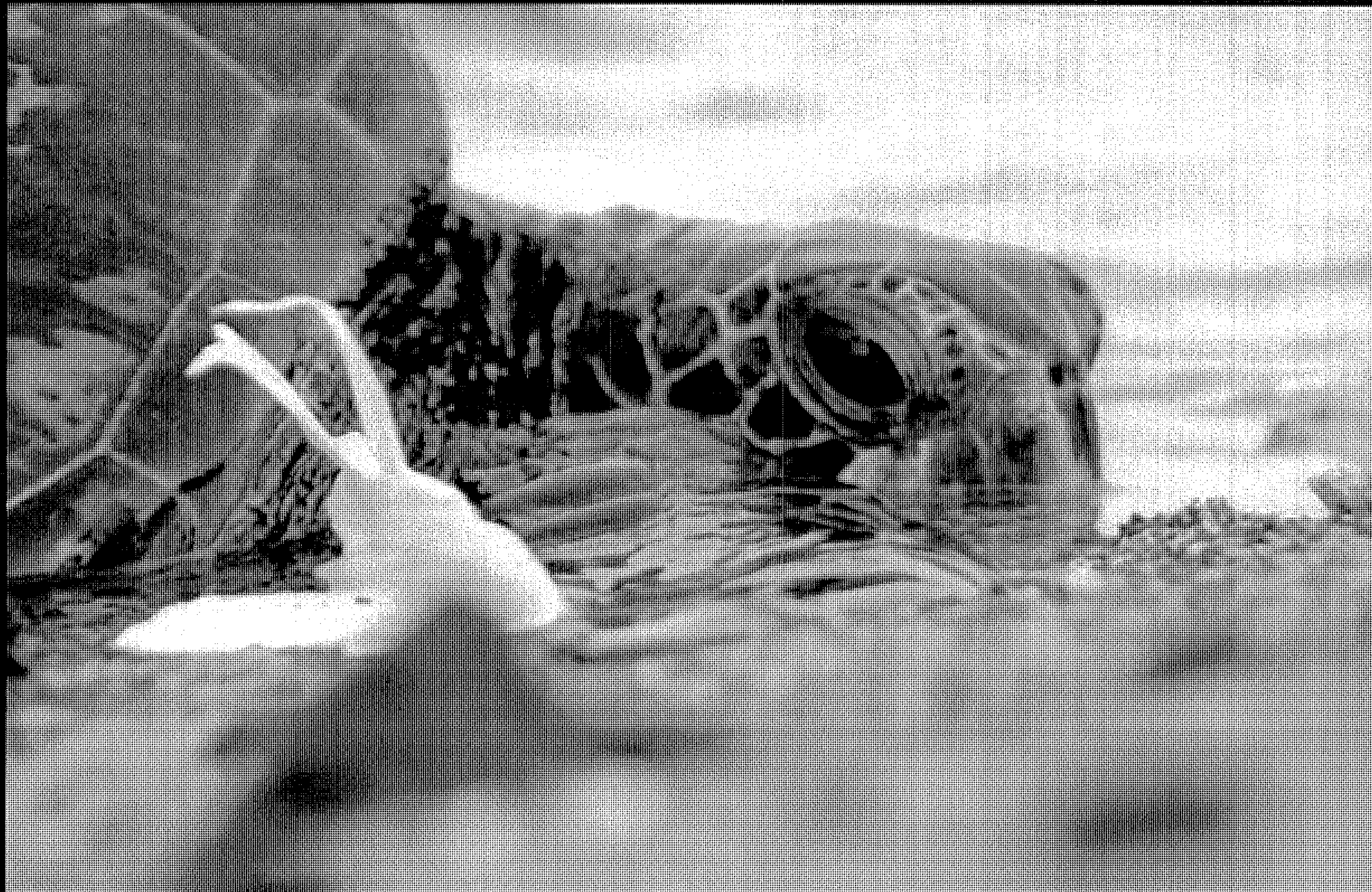
Prof. McCauley has a degree in political science and a degree in biology from the University of California at Berkeley. His PhD research was done at Stanford University where he studied the ecology of sharks, manta rays, and coral reef ecosystems in the tropical Pacific. Prof. McCauley did postdoctoral research at Stanford University, Princeton University, and UC Berkeley.

Prof. McCauley served as the Midway Atoll Acting Deputy Refuge Manager in the Papahānaumokuākea Marine National Monument and has conducted research across the Pacific Remote Islands Marine National Monument. McCauley also served as a biologist with NOAA observing bycatch in the Hawaiian long line fishing fleet.

Prof. McCauley is a Sloan Research Fellow in the Ocean Sciences. He serves as the Director of the Benioff Ocean Initiative.

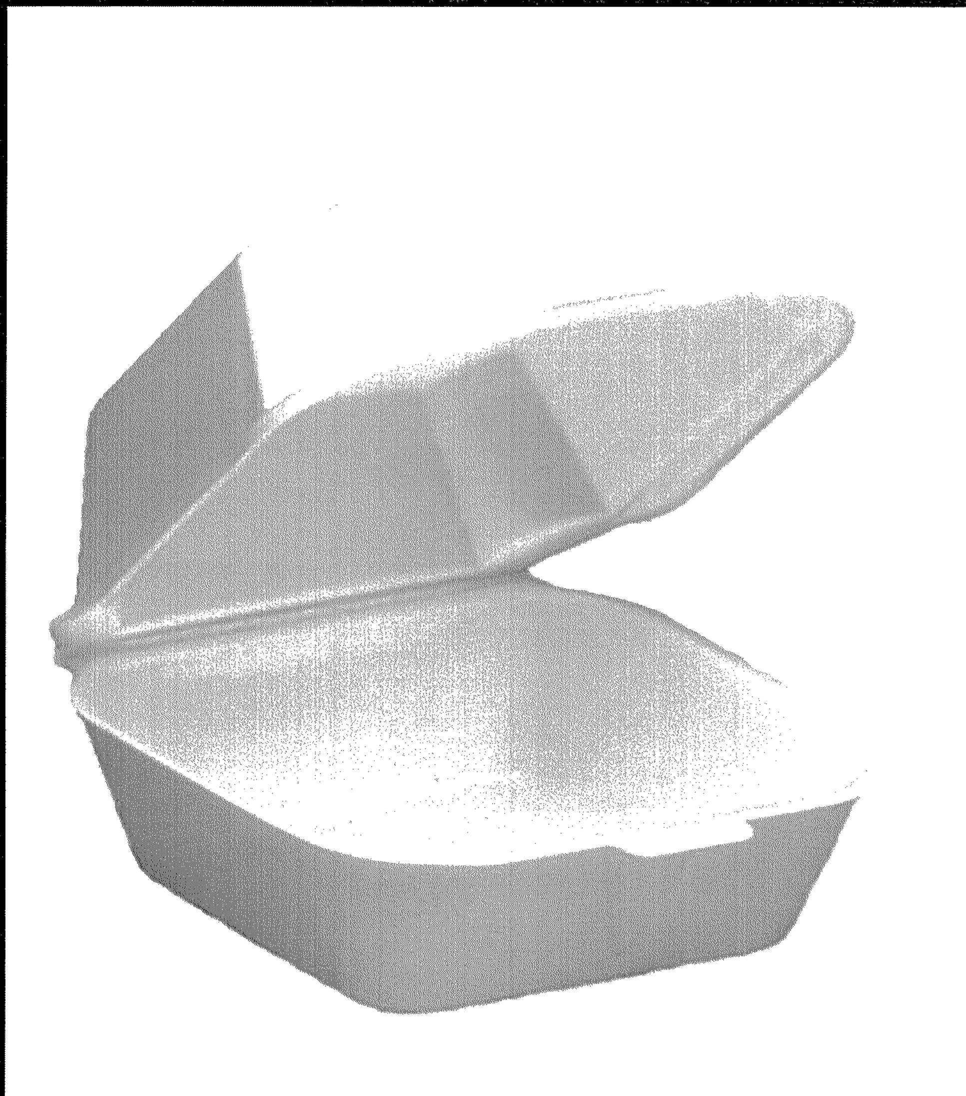
Research from the McCauley Lab has been published in journals such as Science, Nature, and the Proceedings of the National Academy of Sciences USA and has been featured in media outlets such as the New York Times, BBC, Time, and US National Public Radio.

Impacts of EPS on ocean health in Maui

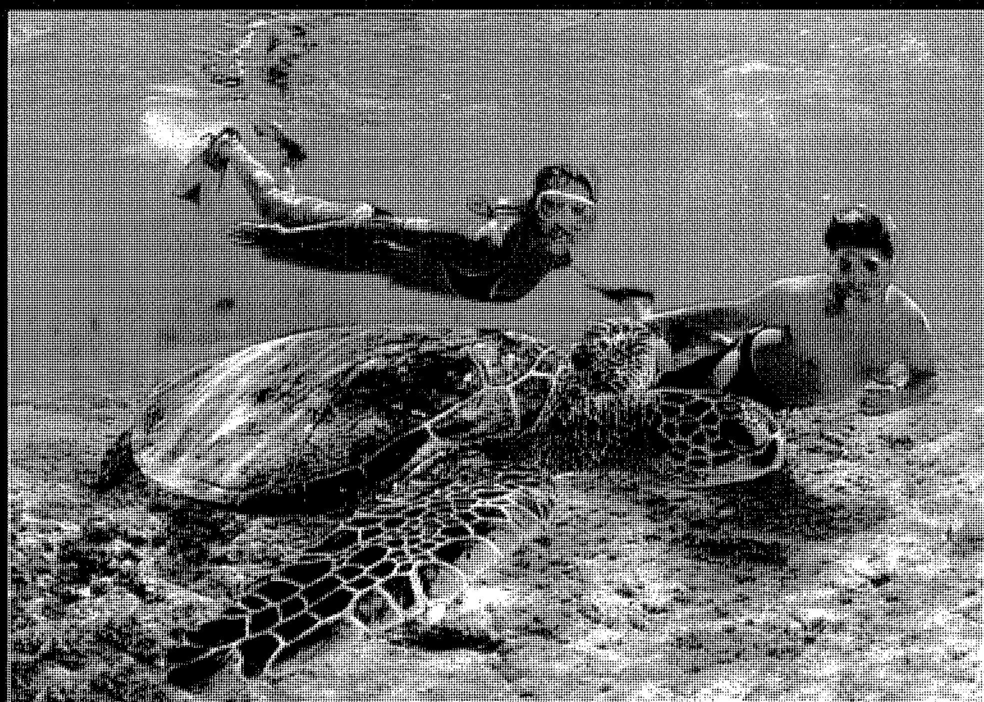


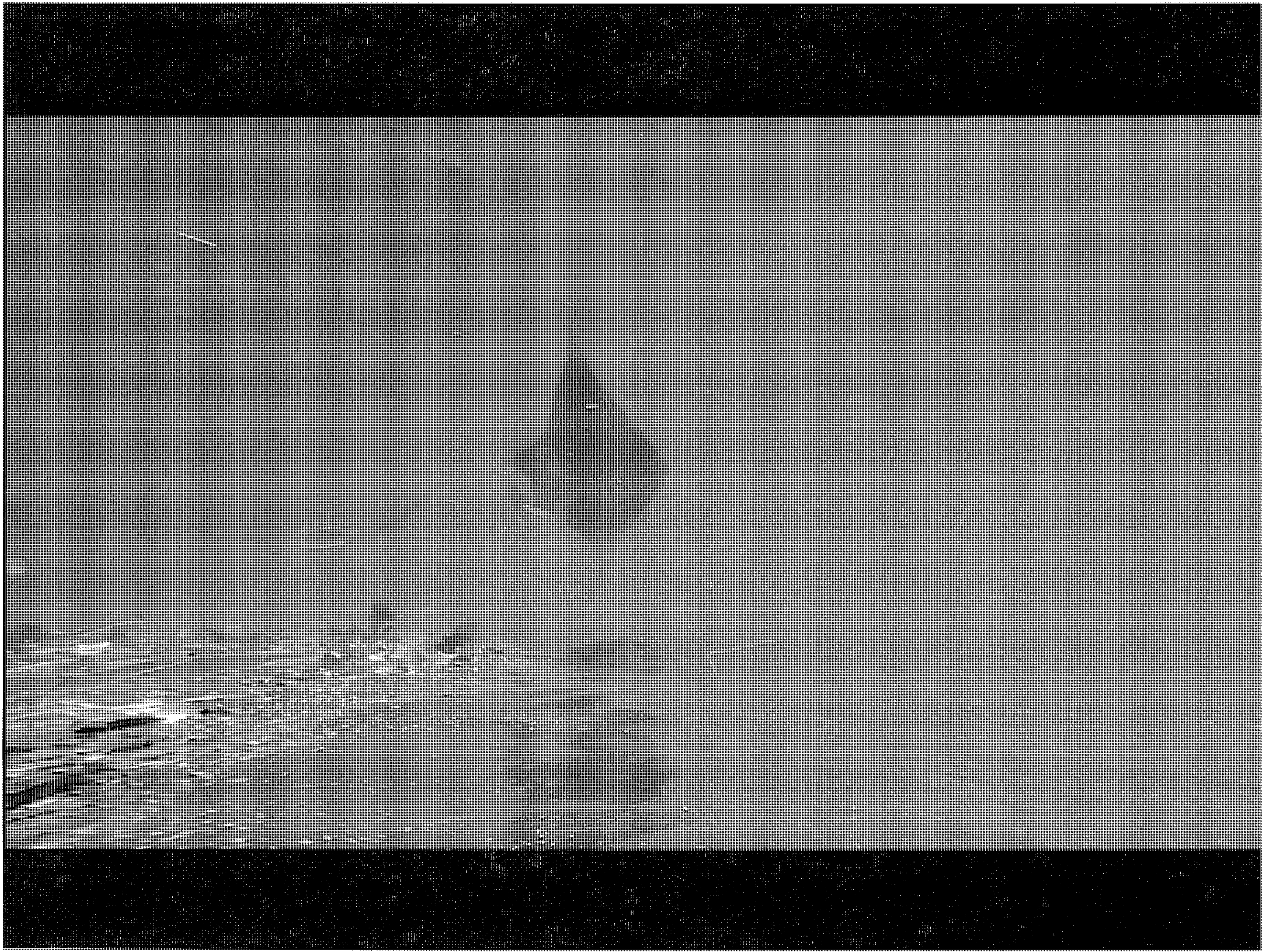
Dr. Douglas McCauley
Assistant Professor
University of California Santa Barbara

~65,000 pounds of styrofoam (EPS) produced daily in HI







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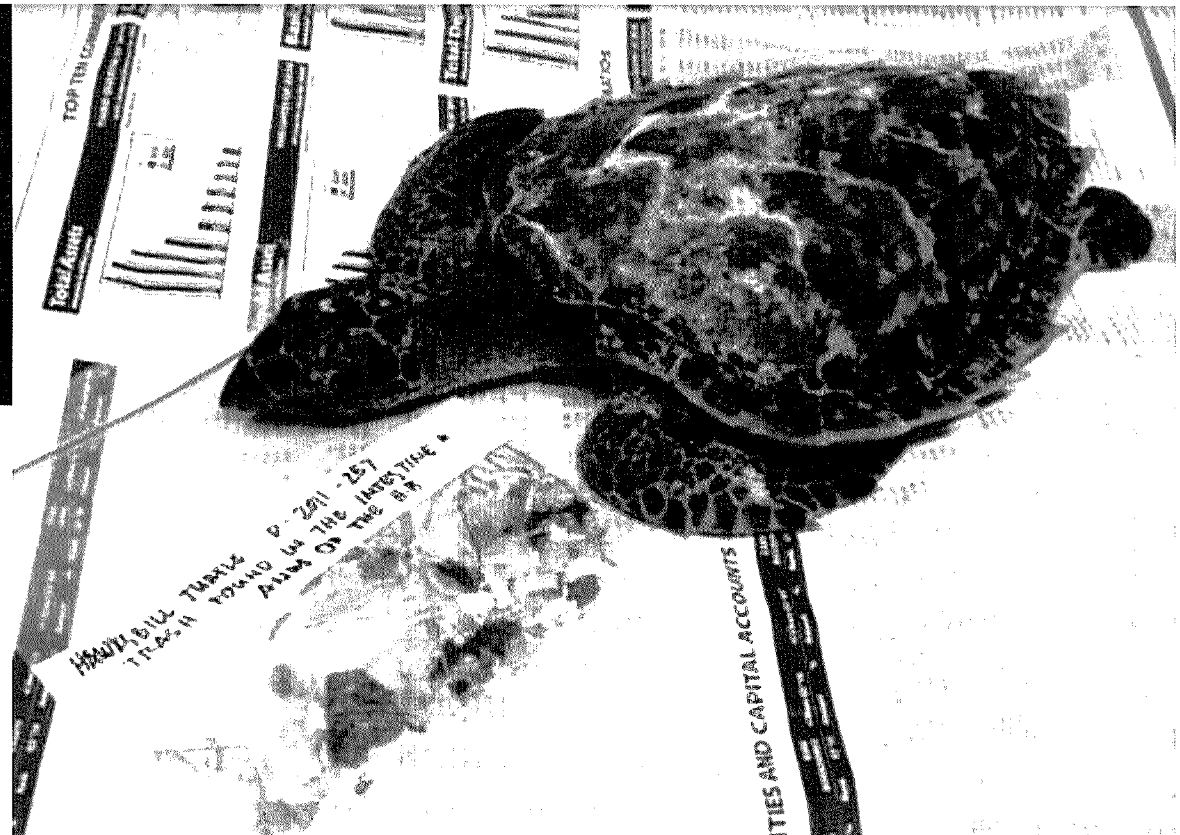

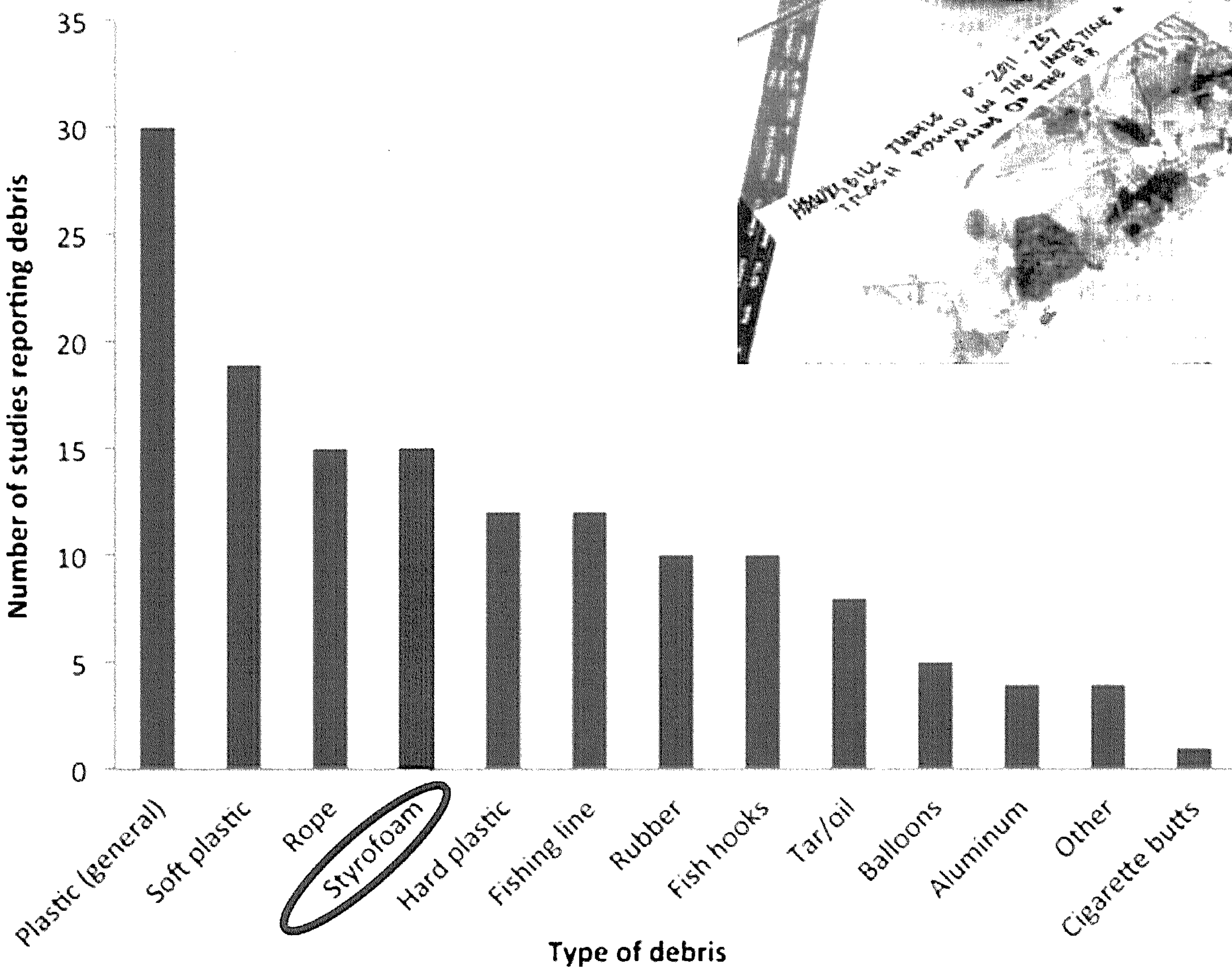

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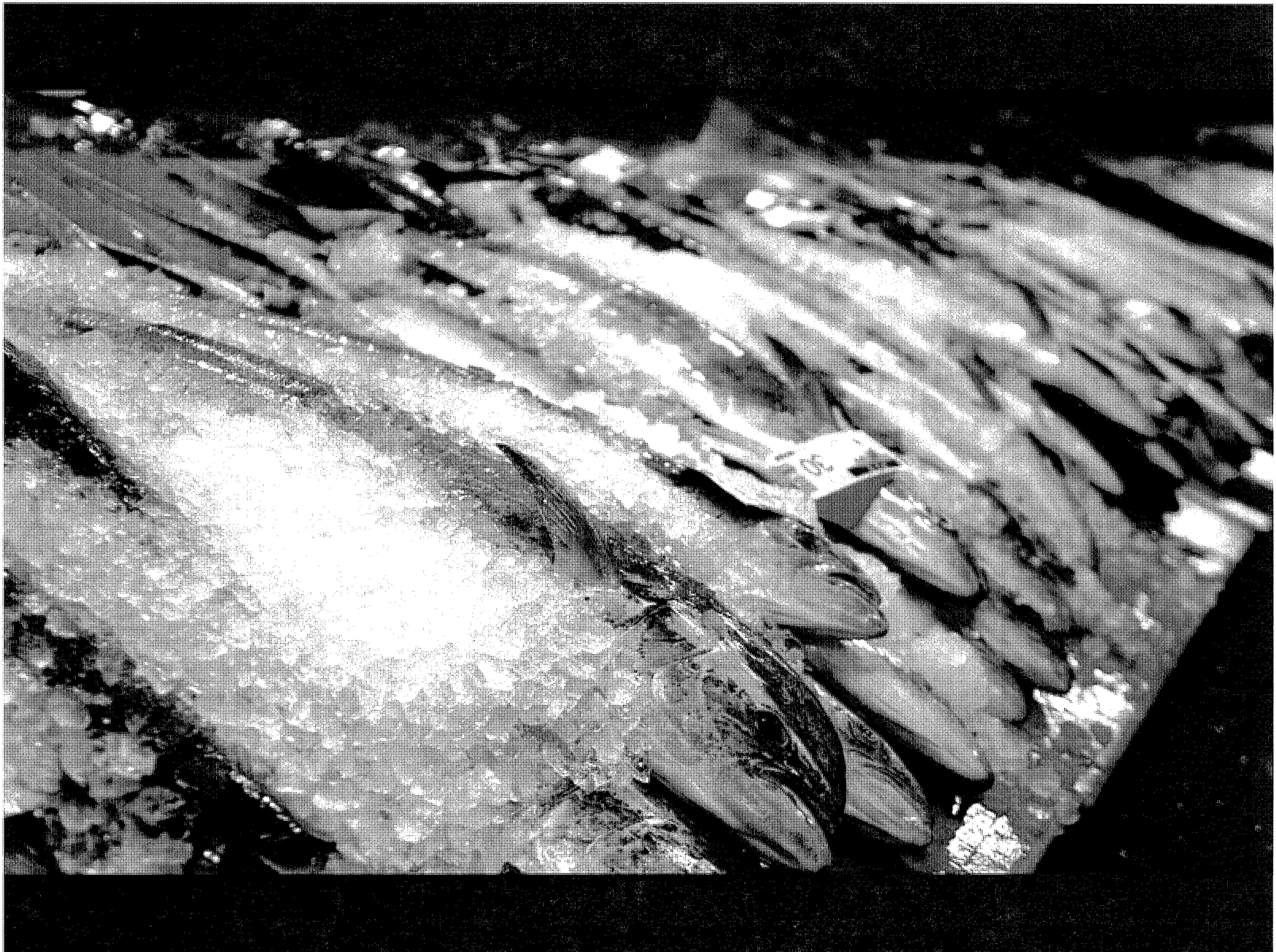
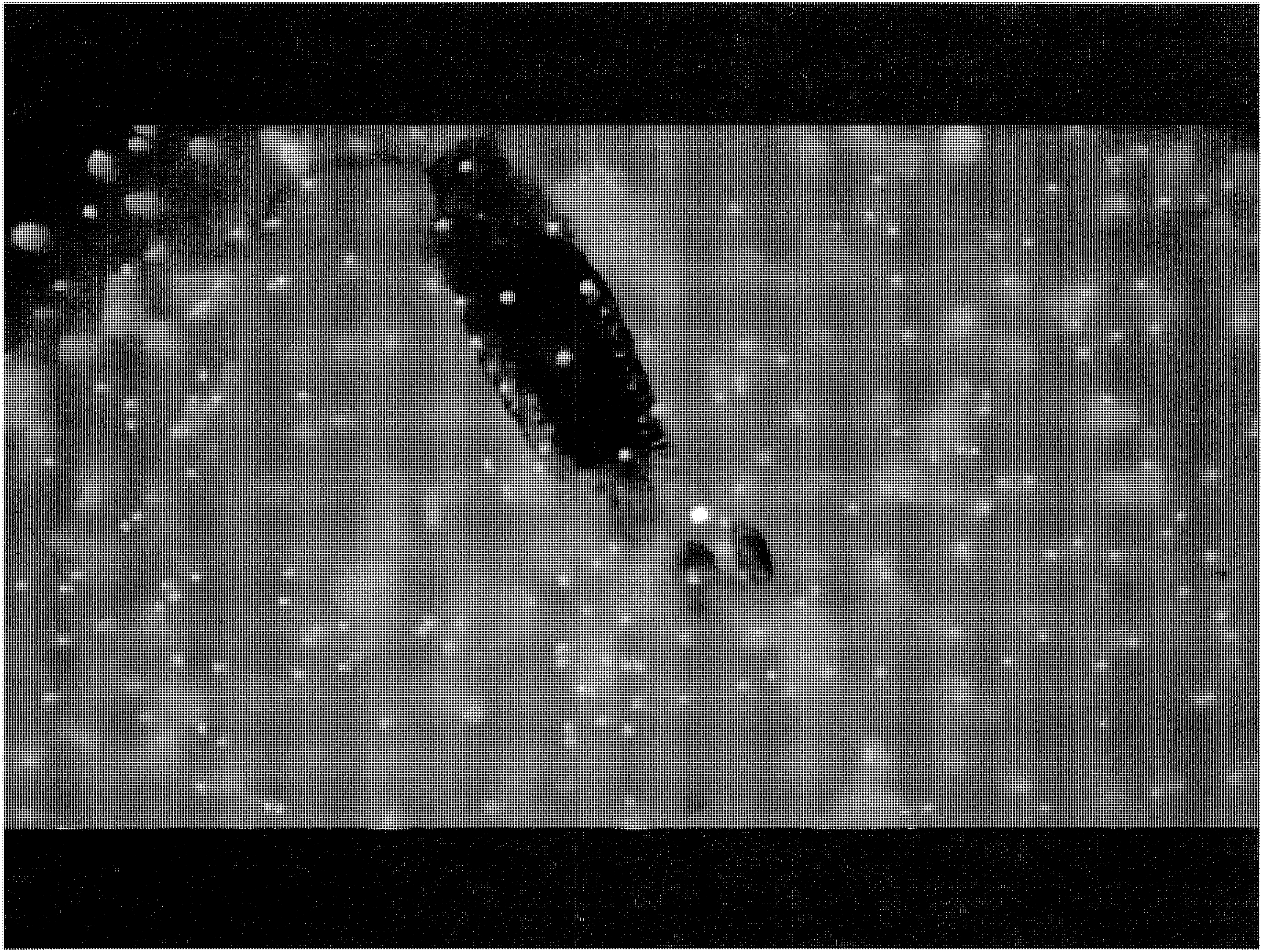
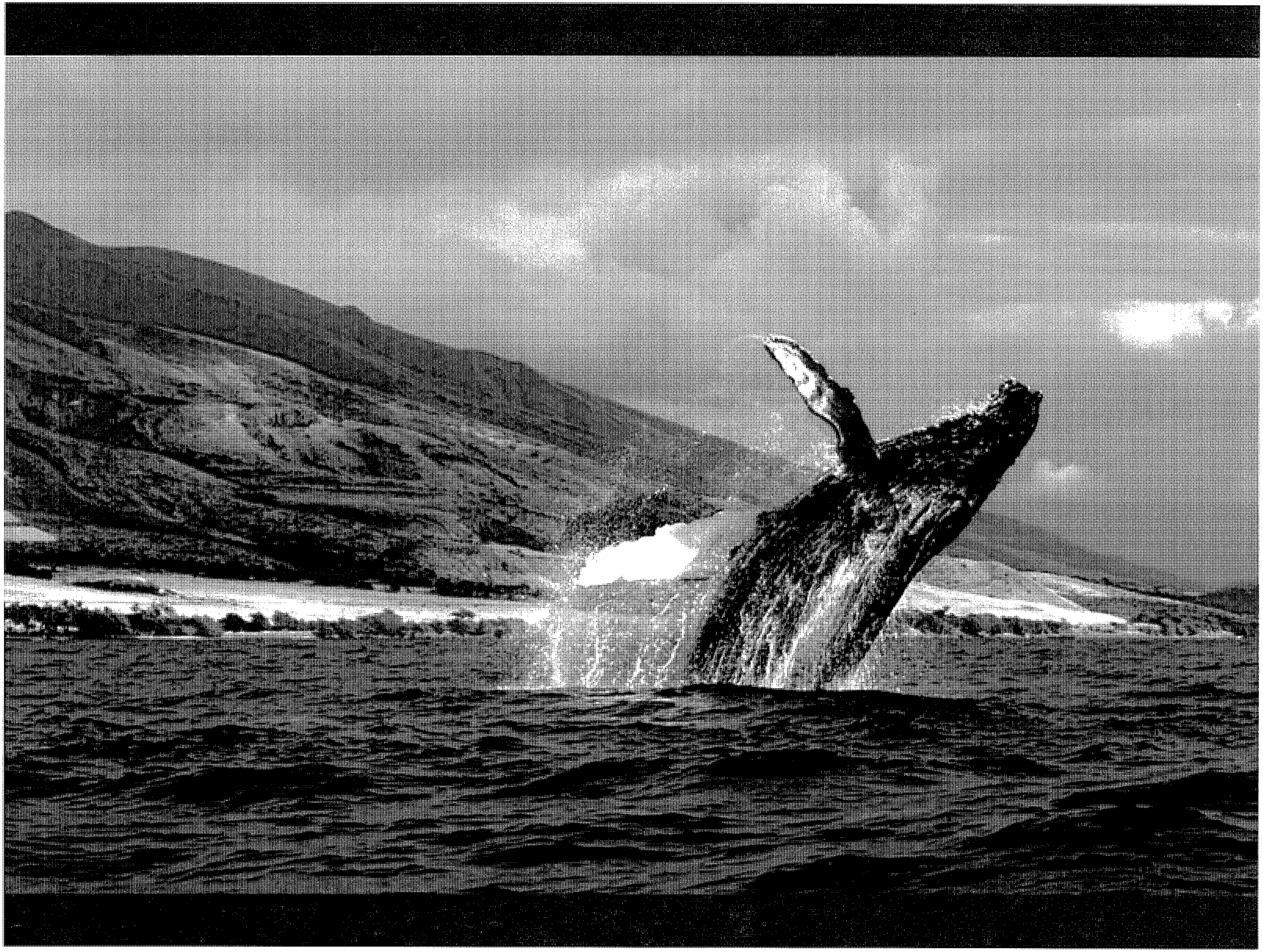




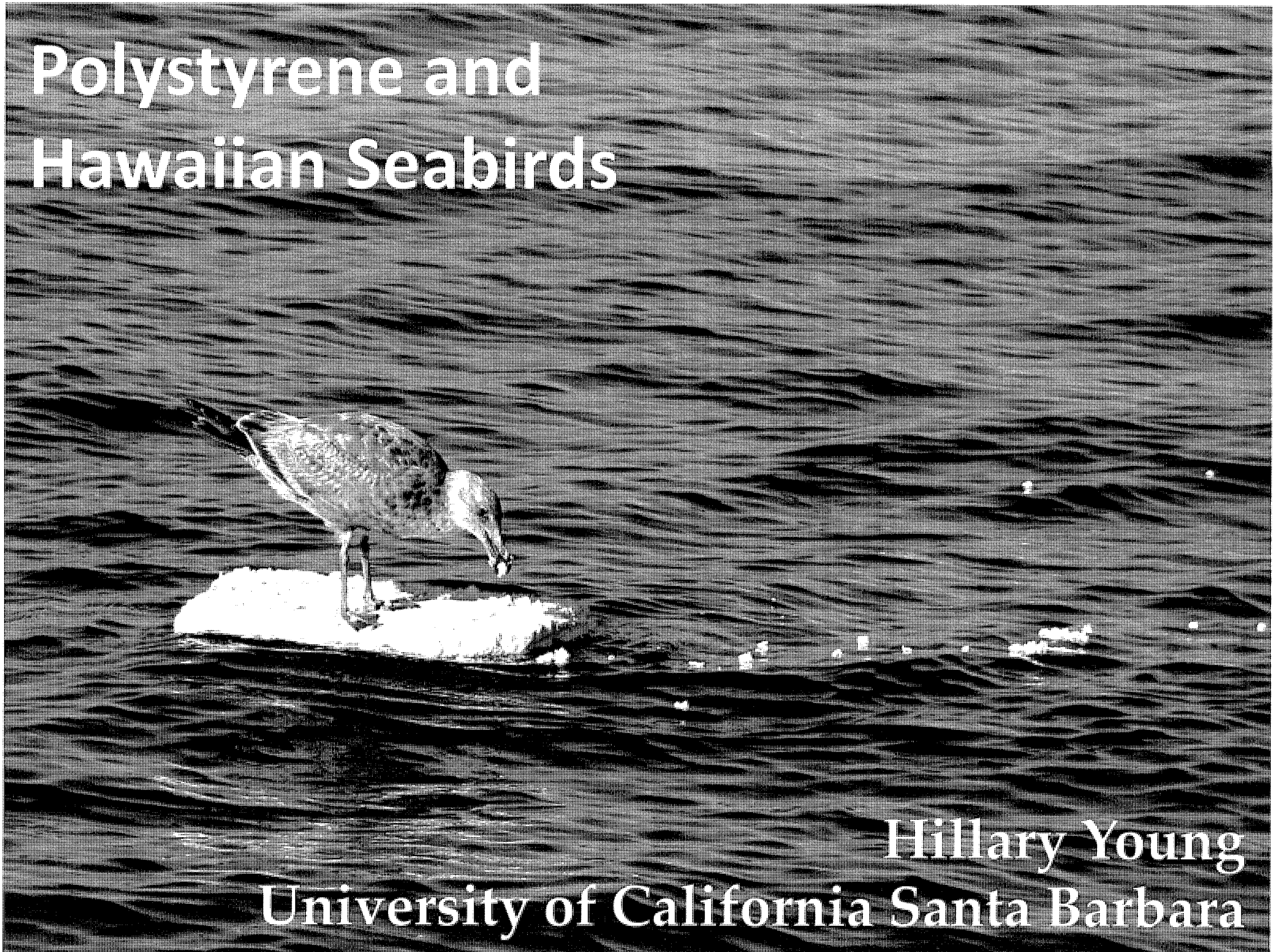


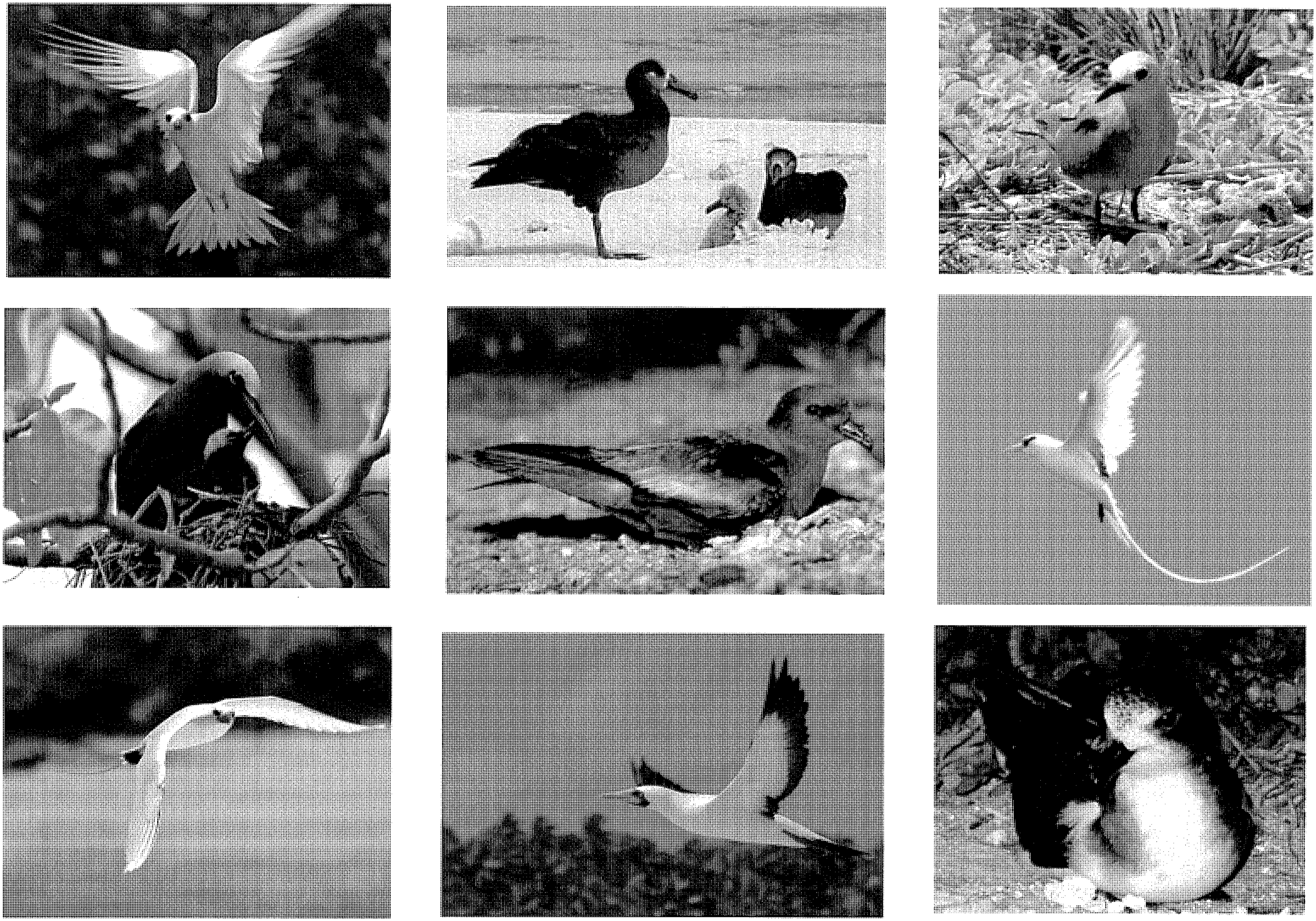
Prof. Hillary Young works on seabird foraging ecology in the central Pacific Ocean. She serves as an Associate Professor at the University of California Santa Barbara.

Prof. Young has a B.A in Ecology and Evolutionary Biology from Princeton University (2001) and a Masters in environmental management from Yale University (2004). Her PhD research was done at Stanford University where she studied the foraging ecology of tropical seabirds, with a strong focus in the Pacific Remote Islands and Papahānaumokuākea monuments. Prof. Young conducted her postdoctoral research at Harvard University Center for the Environment and Smithsonian Institution, in the division of Vertebrate Zoology.

Prof. Young is an Early Career Fellow at the Ecological Society of America and a curator at the Center for Conservation Biology and Ecological Restoration.

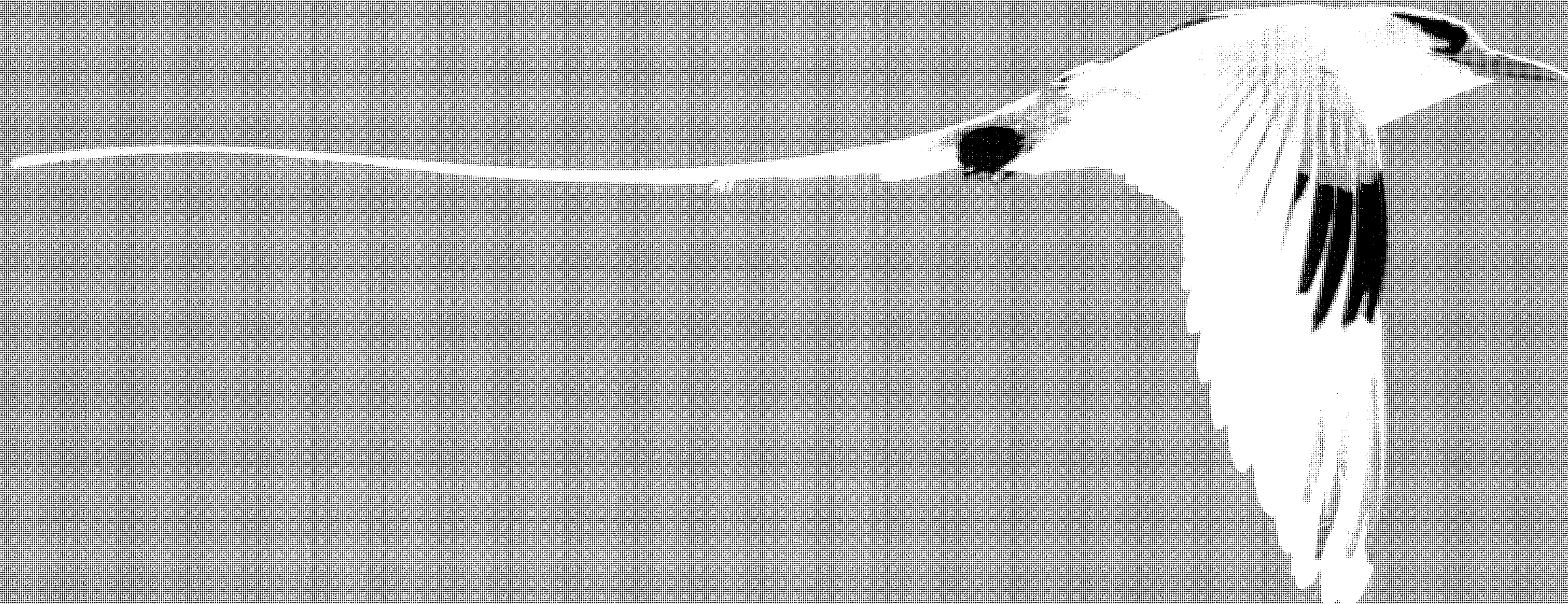
Research from the Young Lab has been published in journals such as Science, Proceedings of the National Academy of Sciences USA, Ecology Letters and has been featured in a wide range of media outlets such as the New York Times, BBC, Time, and US National Public Radio.


Polystyrene and
Hawaiian Seabirds
Hillary Young
University of California Santa Barbara

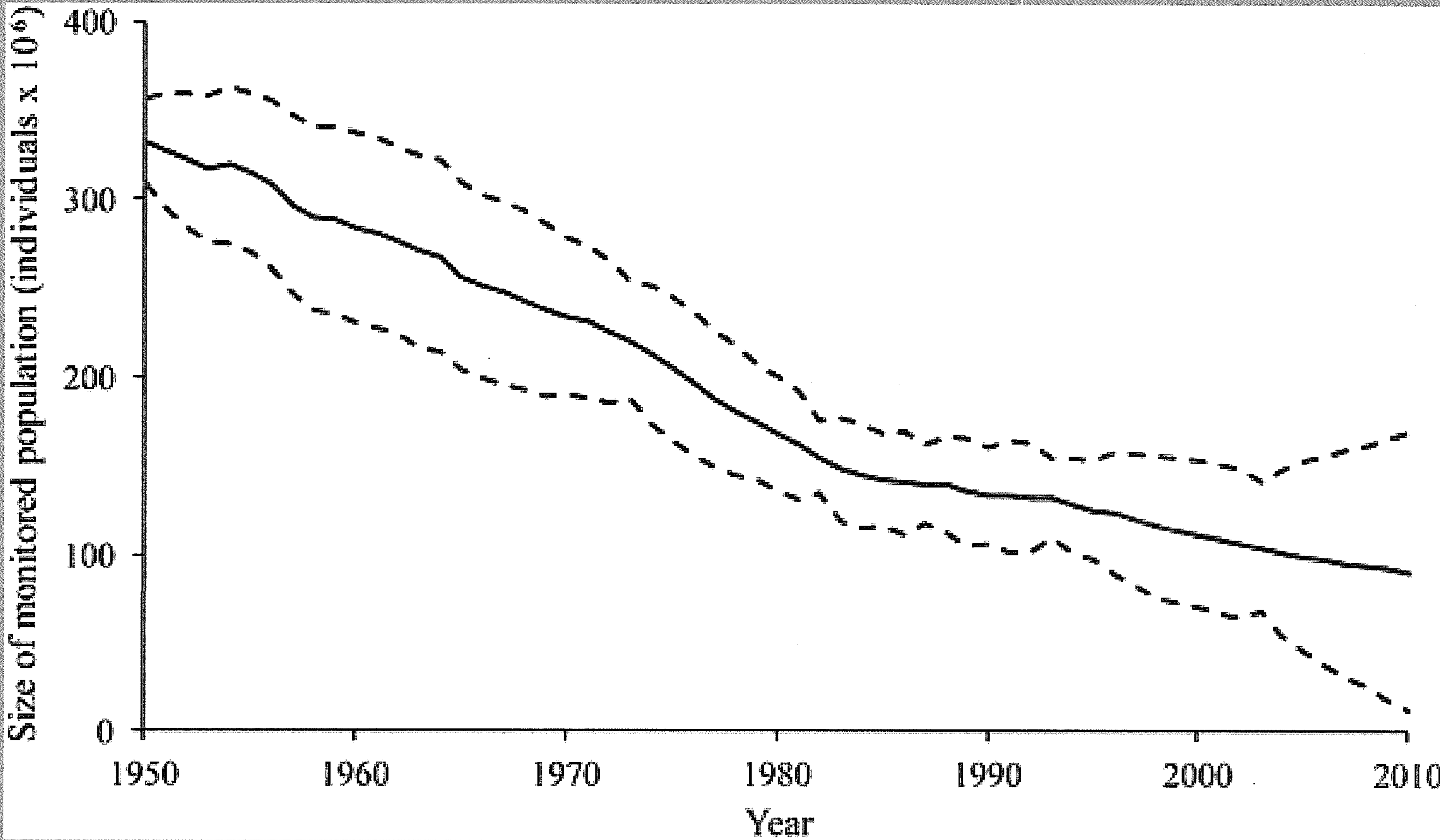


Hawaiian islands are a seabird hotspot

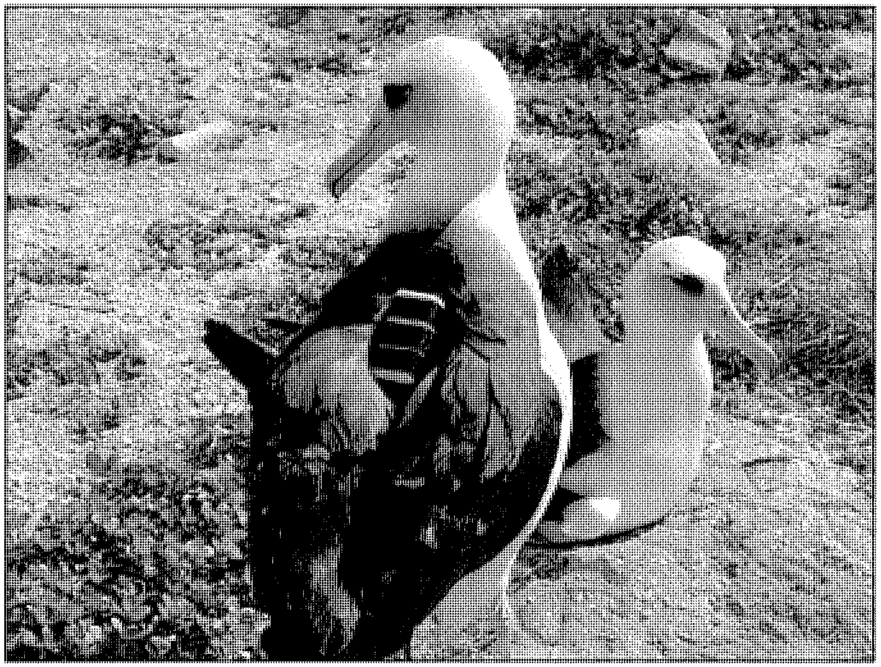
Globally, seabirds have declined by 70% since 1950

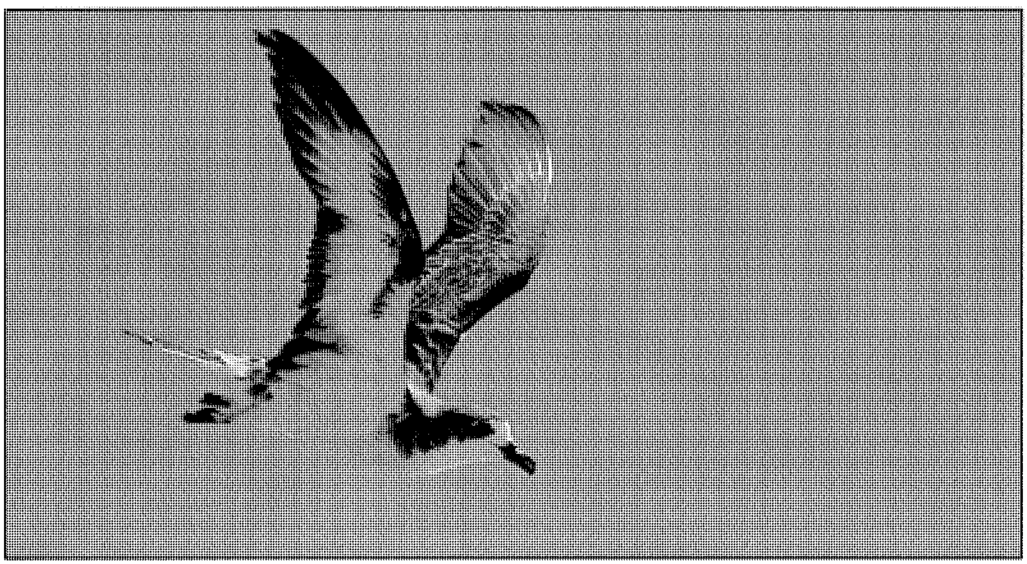


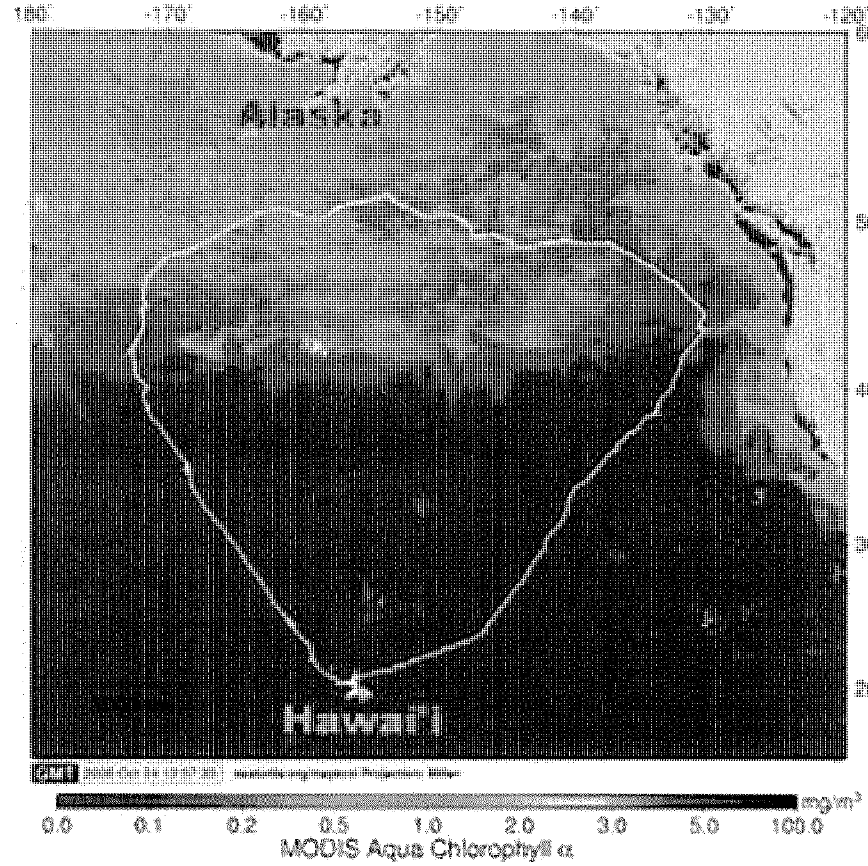
Globally, seabirds have declined by 70% since 1950



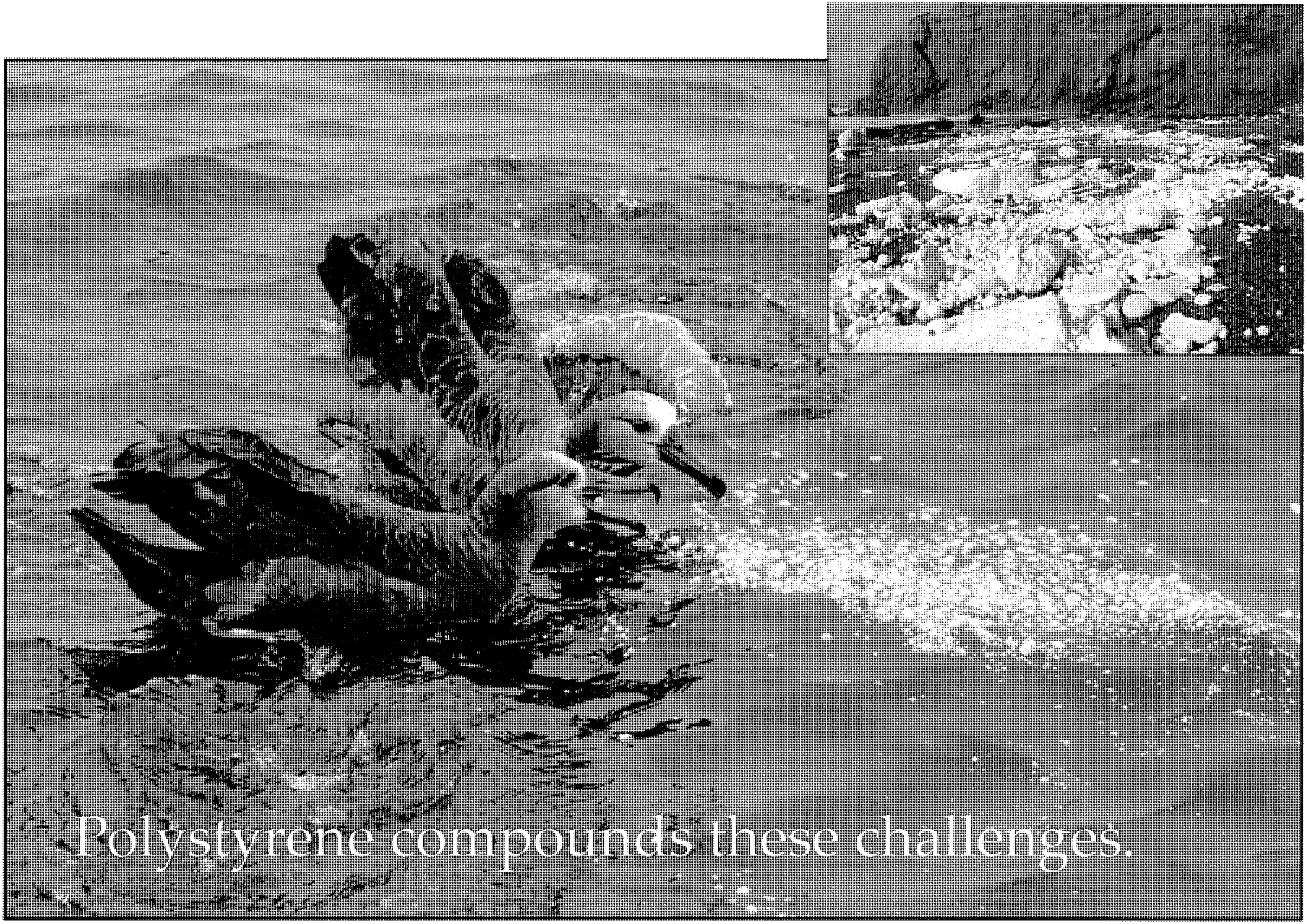
Largest declines in long-ranging species including many Hawaiian species such as albatross

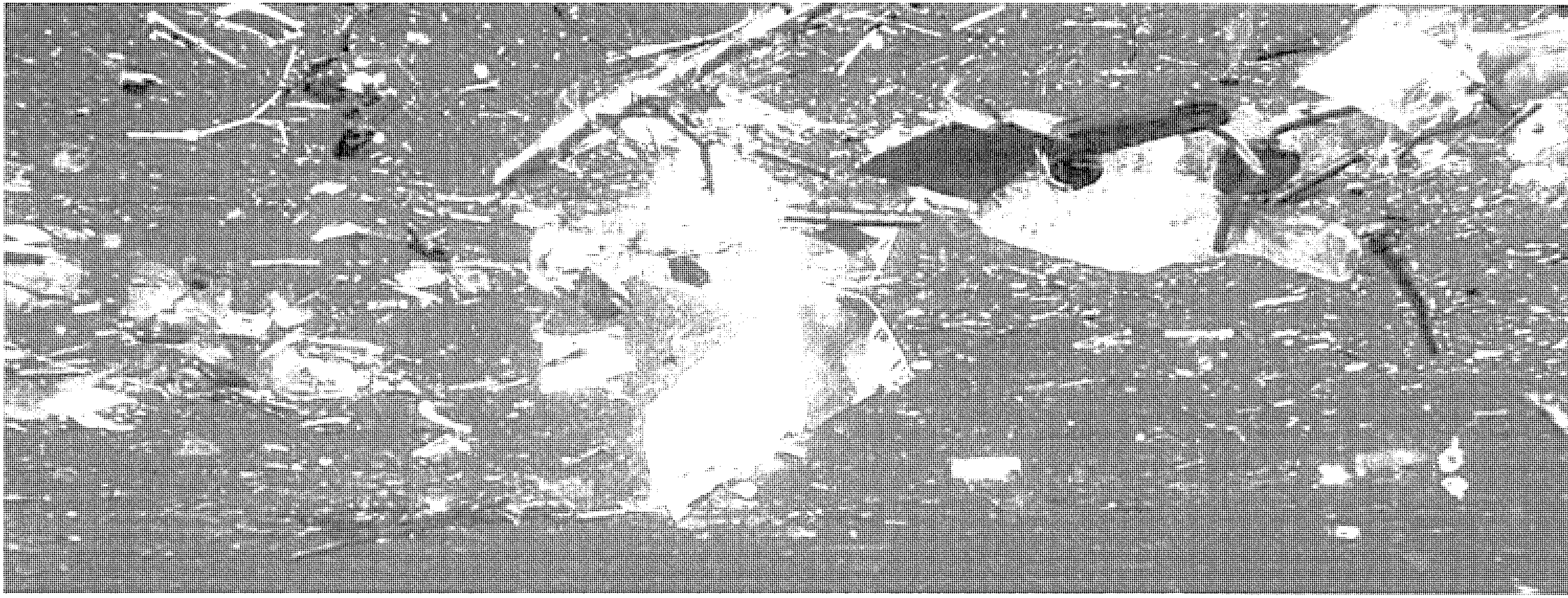
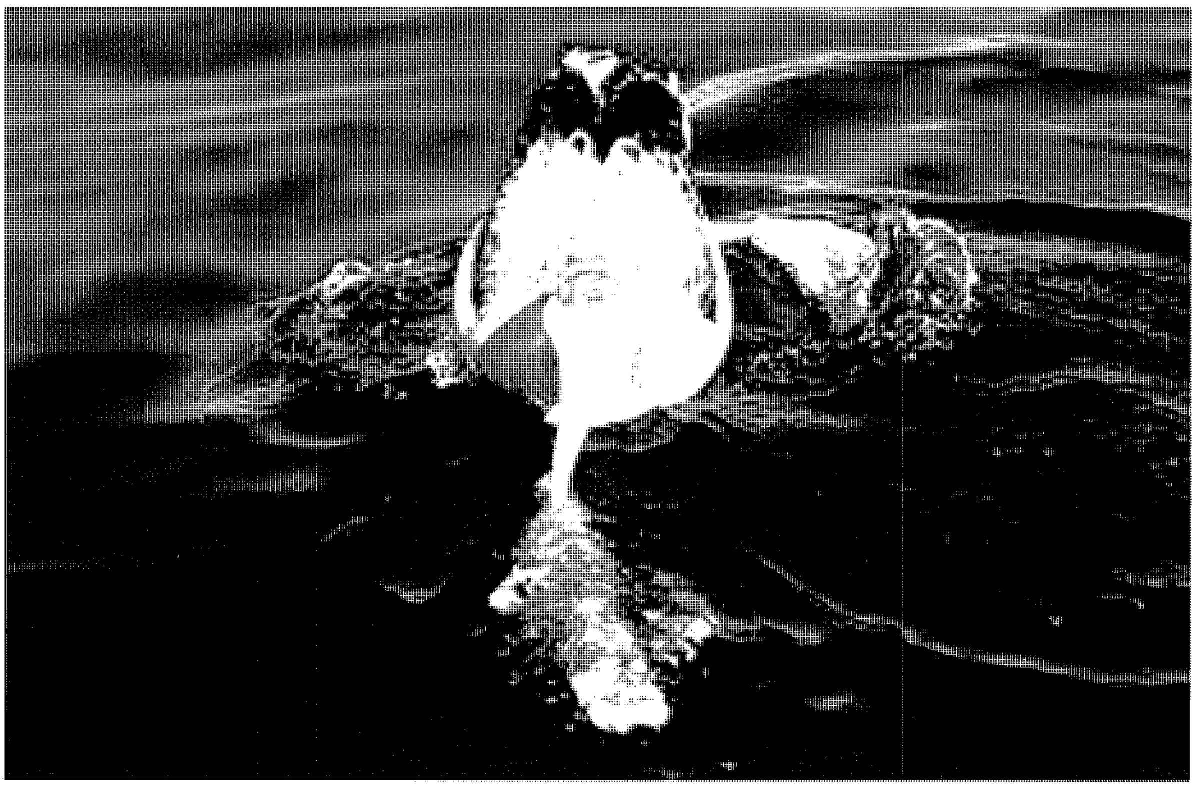
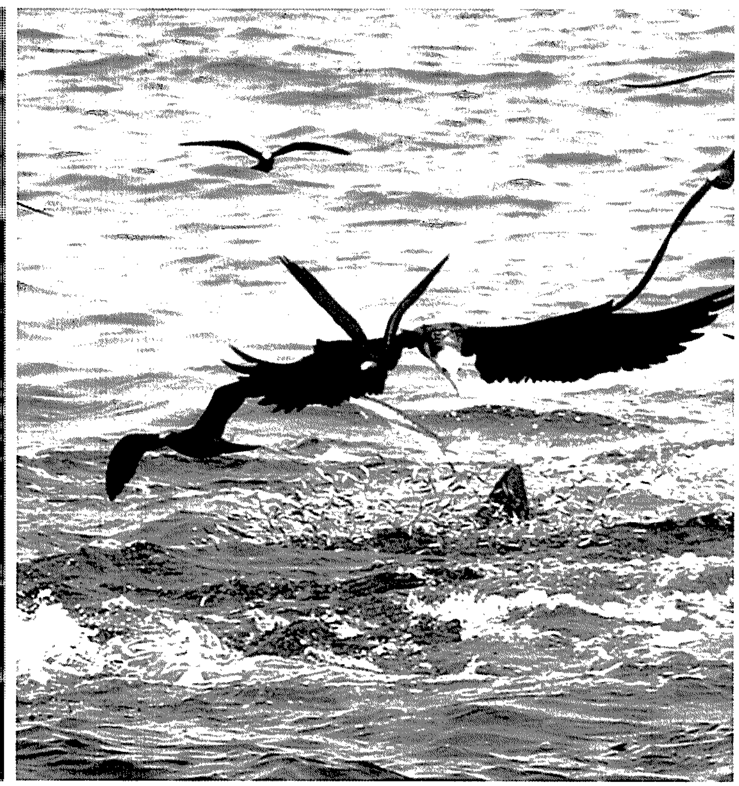


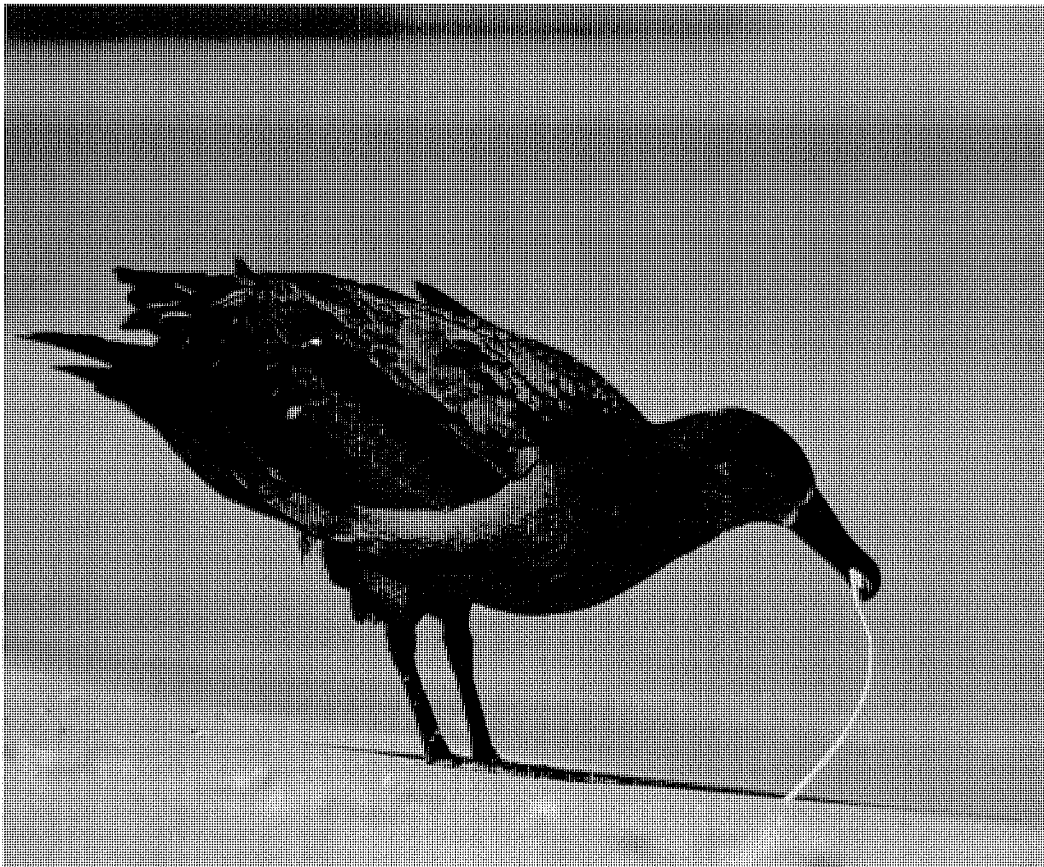




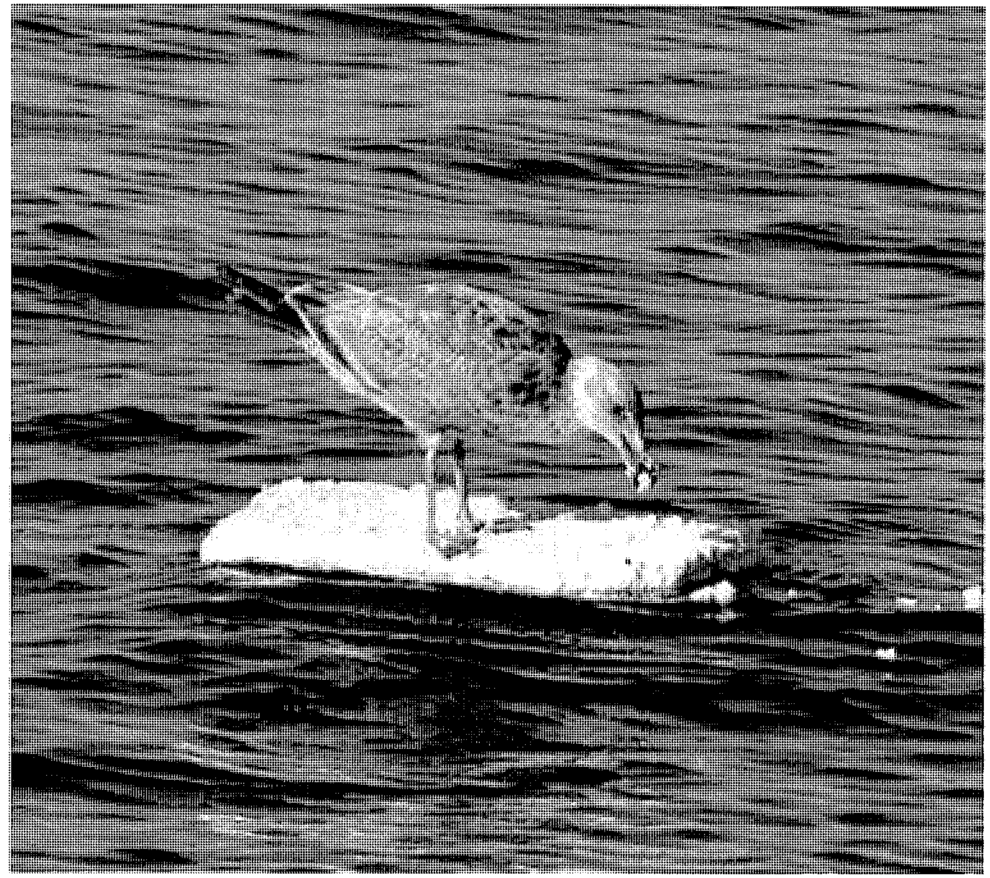
Tropical seabirds face particular foraging challenges


Polystyrene compounds these challenges.

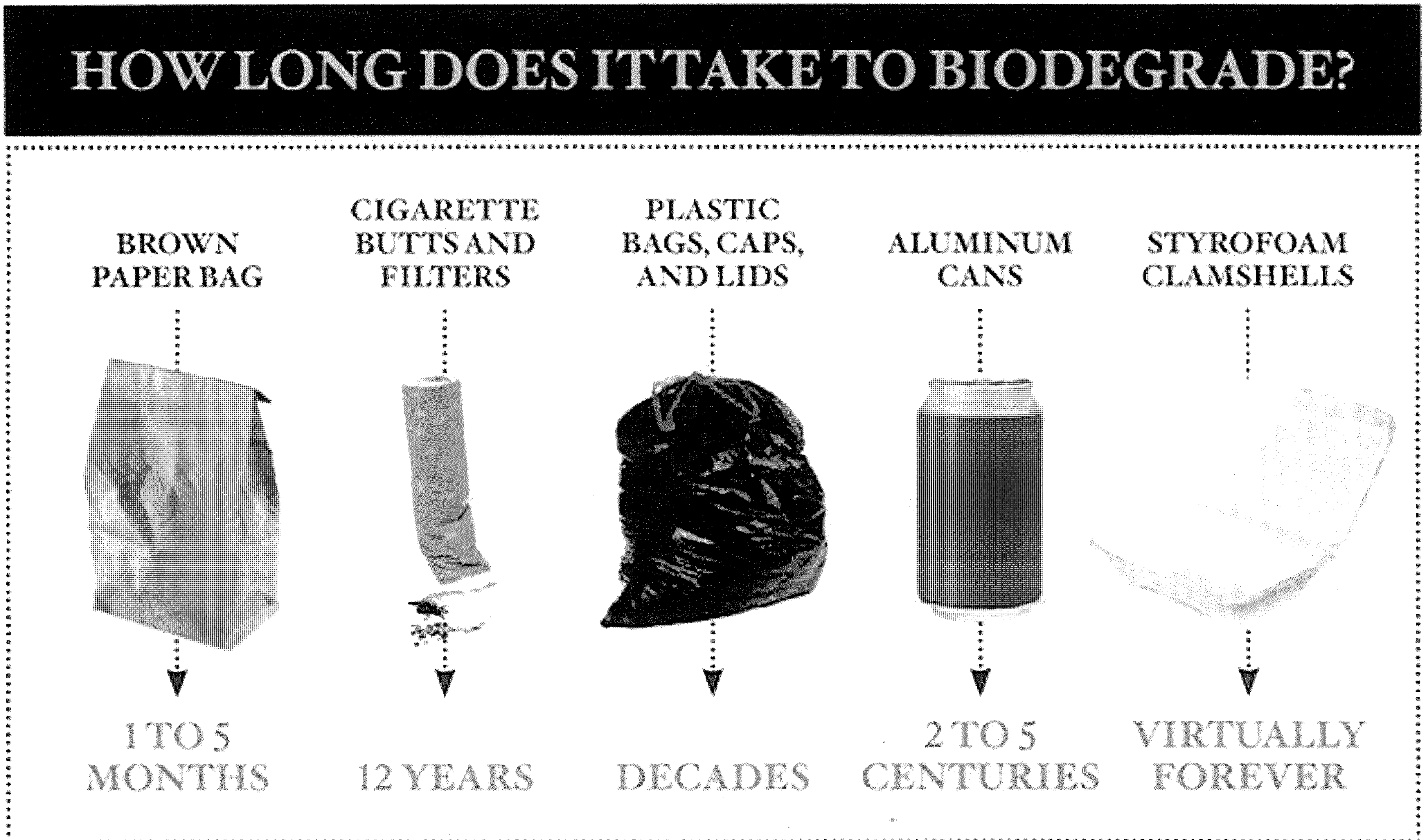


Frans Lanting, National Geographic

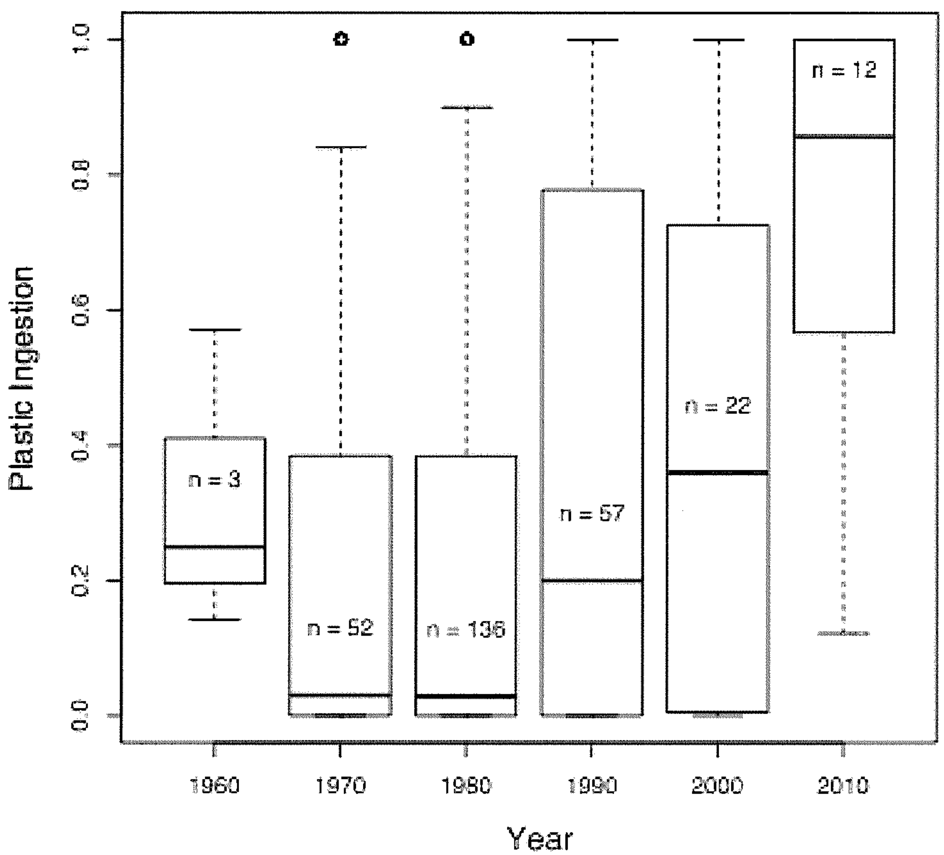


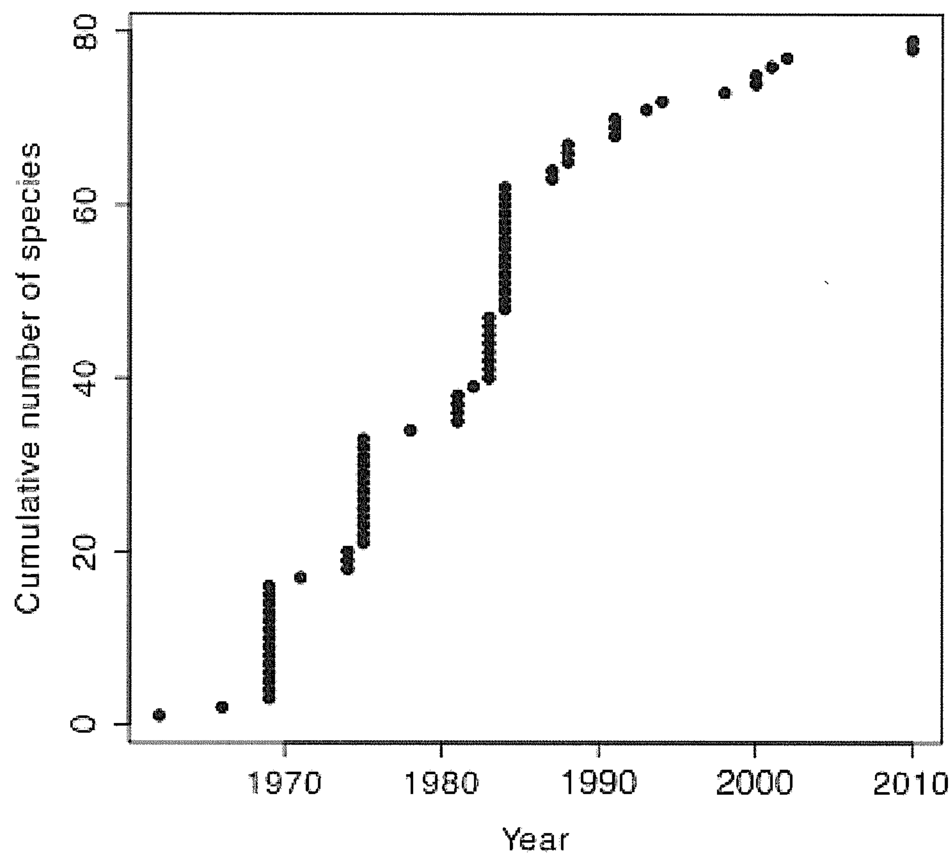
Vericool Packaging

Polystyrene resistant to biodegredation

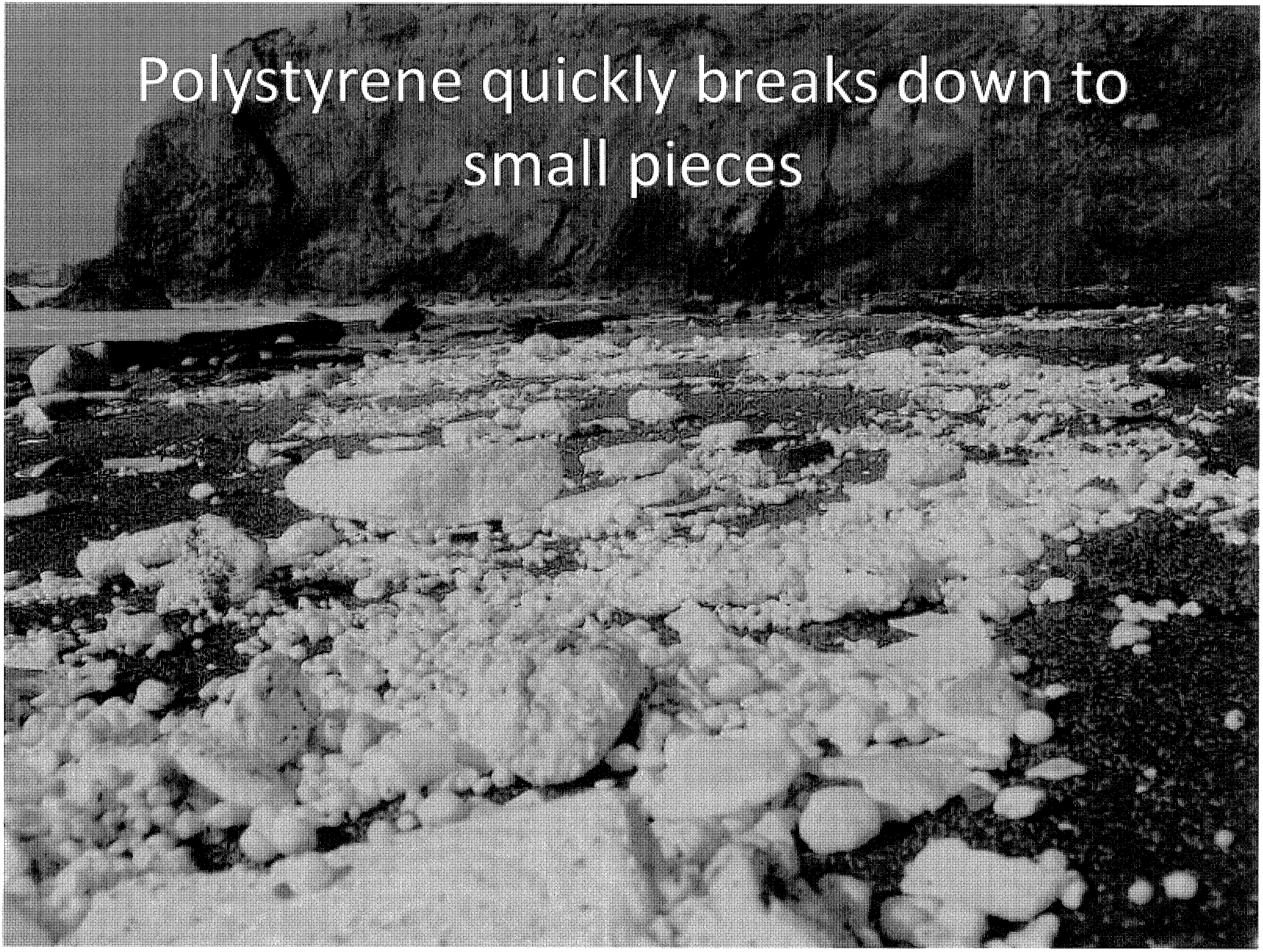


Thus we expect that by 2050 polytsyrene and other plastics will be found in 99% of seabirds

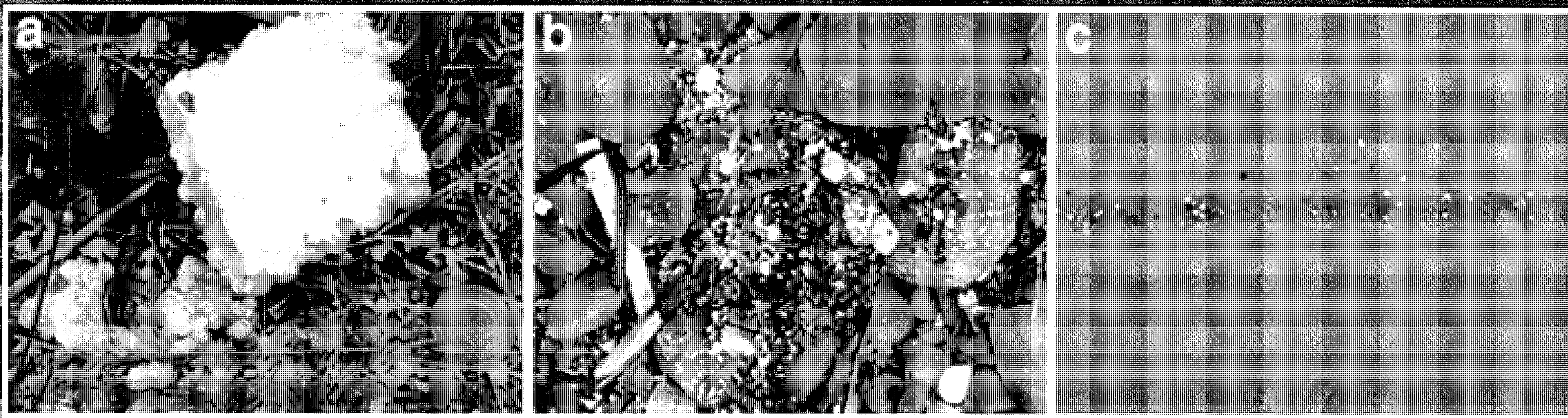




Wilcox et al., 2015

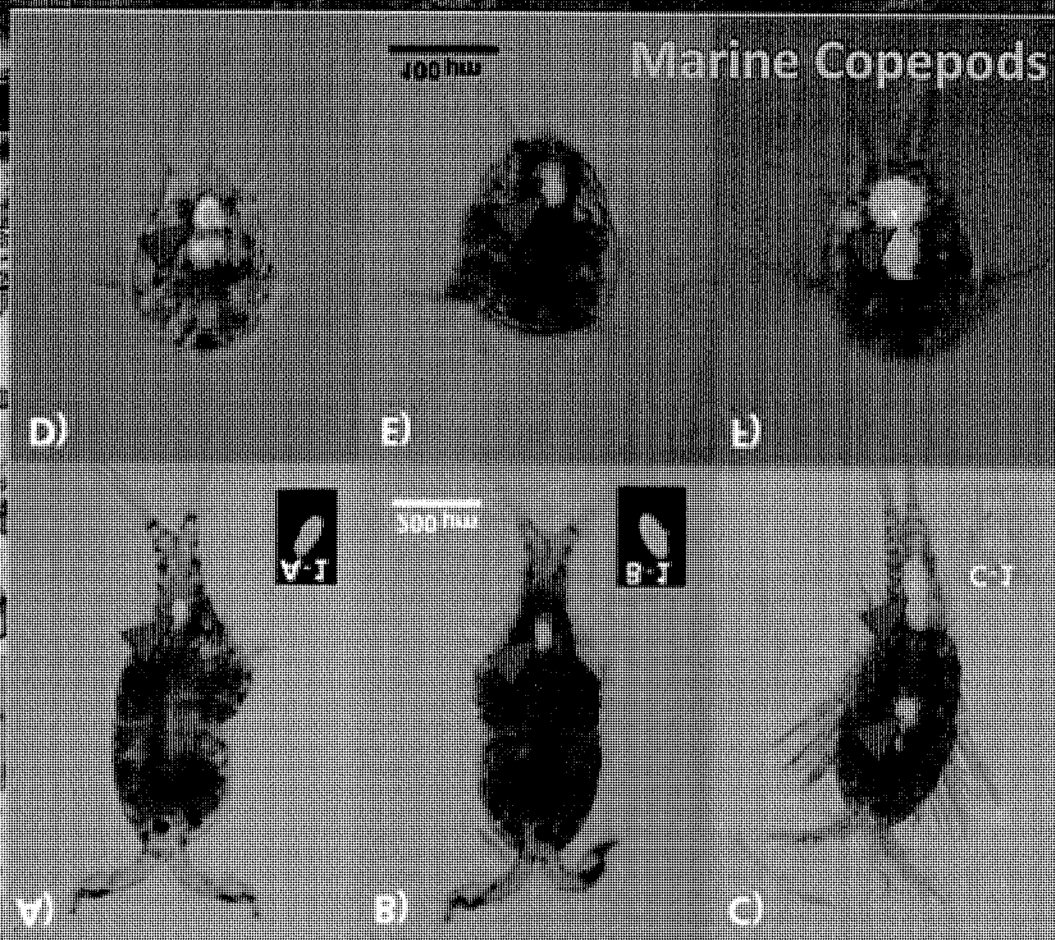

Polystyrene quickly breaks down to small pieces

Polystyrene quickly breaks down to small pieces



Lee et al., 2013

These pieces accumulate in the smallest prey species



Flourescently labeled polystyrene microfragments

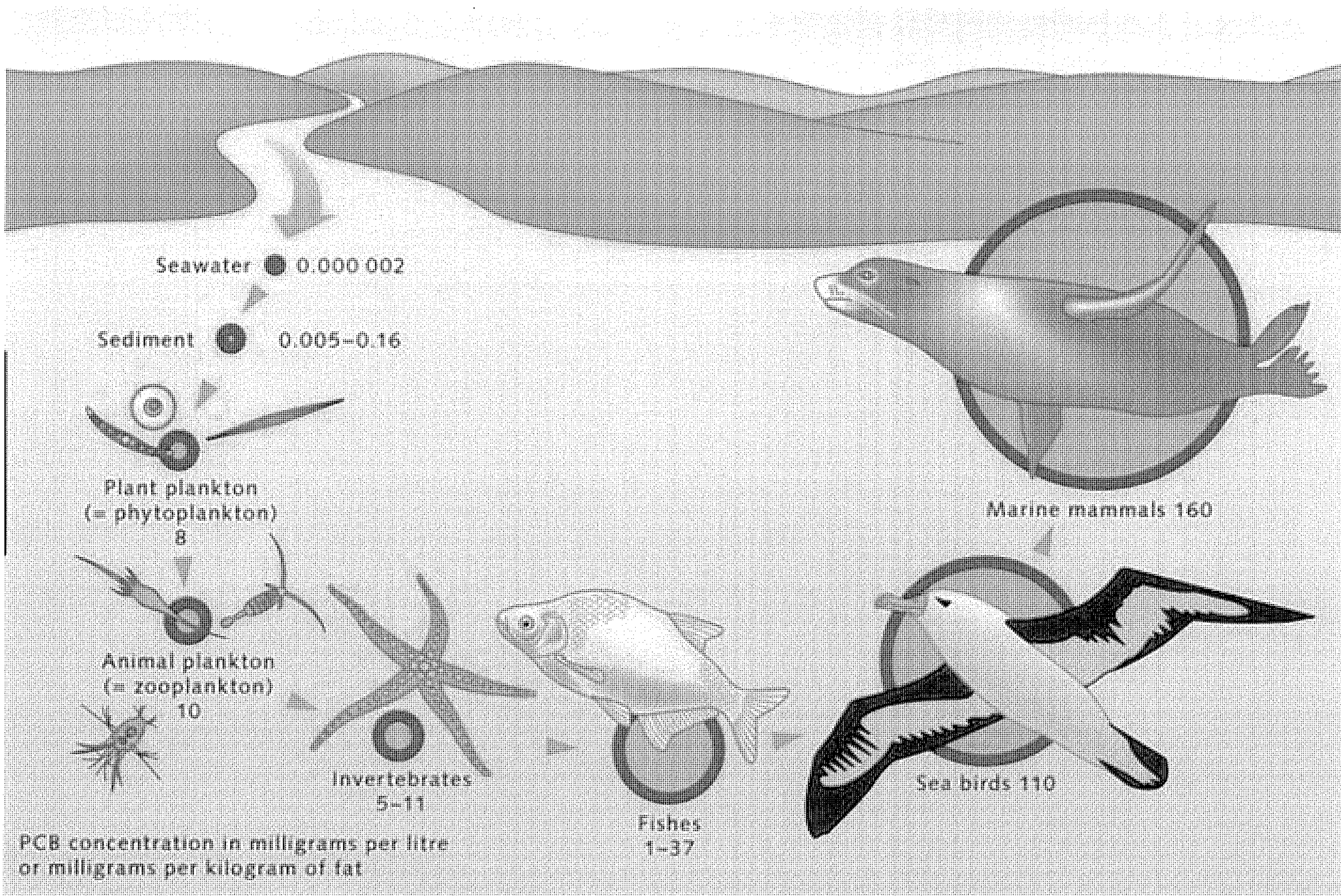
Lee et al., 2013

Polystyrene fragments then accumulate toxins (e.g. Hg & PCBs)

	n^{a}	Mean±SD	Range ($ng\ g^{-1}$ d.w.)
Virgin styrofoam	22	0.23±0.17	0.03–0.68
Styrofoam debris	214	46.8±299	0.02–3863
Beach sediment	163	0.85±0.59	0.15–4.32
Mosses	111	42.1±23.1	0.21–126

Graca et al., 2014

Toxins bioccumulate



This can cause secondary poisoning in marine animals, including seabirds

Jaymi Heimboch

Table 1
Trace element concentrations in Flesh-footed Shearwater fledgling breast feathers from Lord Howe Island during April 2011. Sample size (number of samples above the limit of detection) is provided in parentheses.

Element	Concentration (μg/g)
Aluminium (Al)	112.53 ± 72.79 (37)
Antimony (Sb)	0.02 ± 0.08 (11)
Barium (Ba)	0.82 ± 1.16 (37)
Beryllium (Be)	0.76 ± 0.08 (2)
Bismuth (Bi)	0.03 ± 0.01 (9)
Arsenic (As)	0.22 ± 0.13 (29)
Cadmium (Cd)	0.49 ± 0.17 (6)
Chromium (Cr)	1.82 ± 2.51 (9)
Cobalt (Co)	33.28 ± 22.27 (38)
Copper (Cu)	14.64 ± 16.99 (38)
Lead (Pb)	0.30 ± 0.29 (37)
Mercury (Hg)	2.40 ± 1.70 (37)
Silver (Ag)	0.62 ± 1.04 (8)
Thallium (Tl)	0.01 ± 0.01 (3)
Tin (Sn)	22.62 ± 7.70 (37)
Uranium (U)	0.05 ± 0.06 (11)
Zinc (Zn)	91.70 ± 11.23 (37)

J.L. Lavers et al., 2014

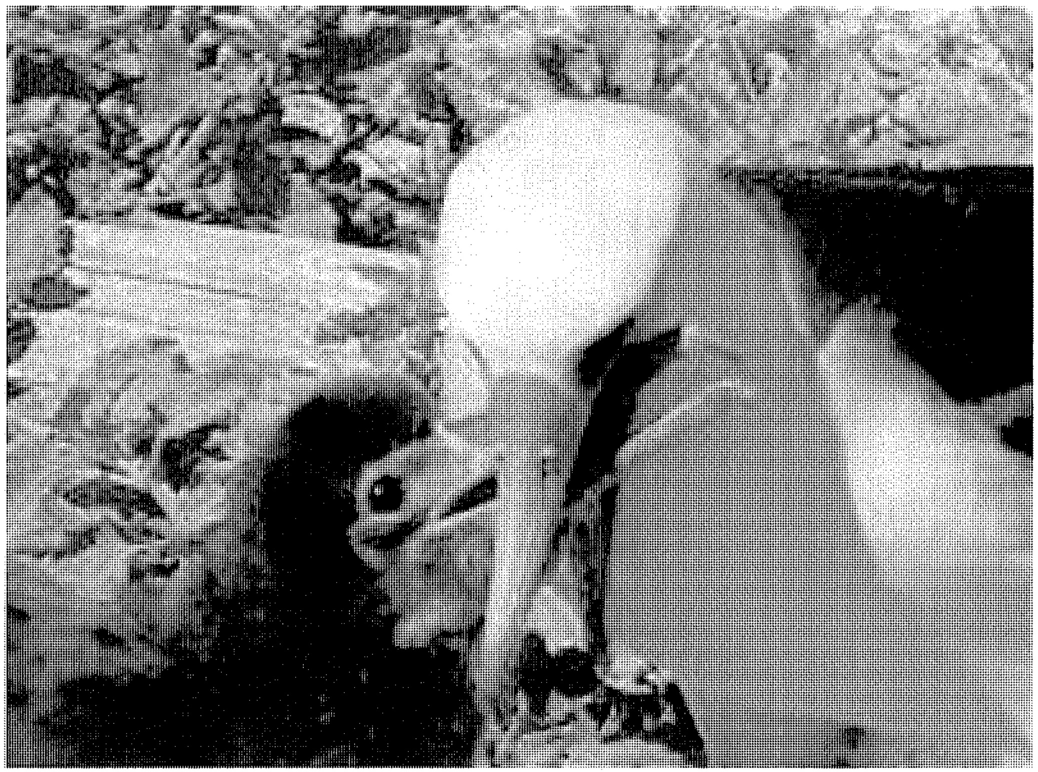
This can cause secondary poisoning in marine animals, including seabirds

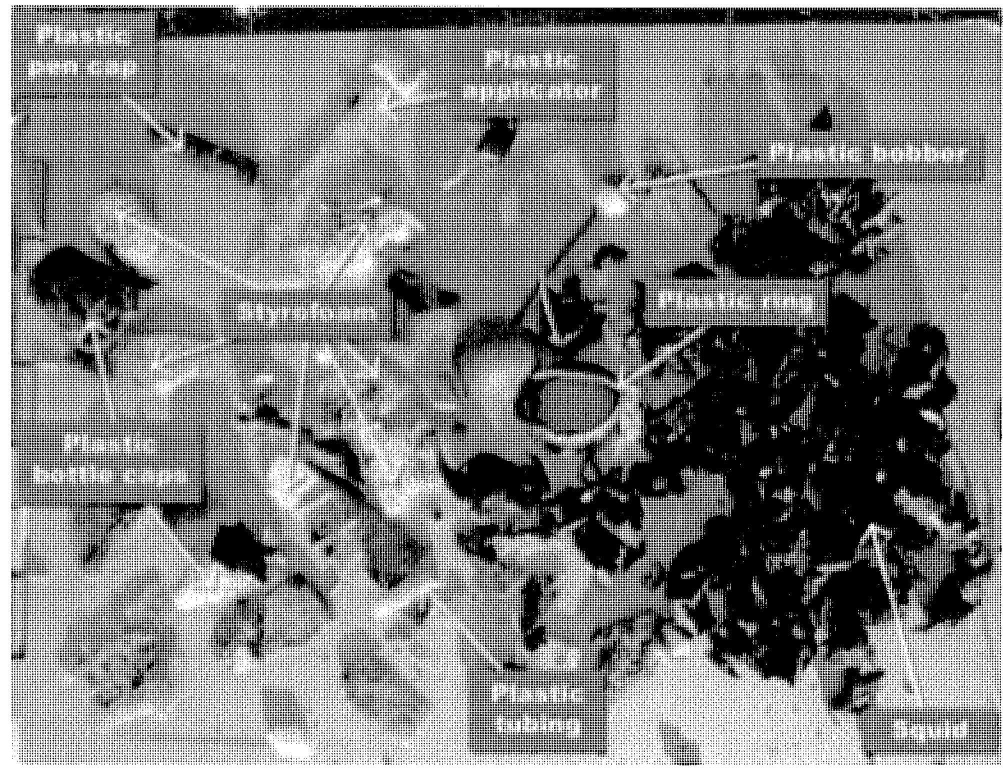
Jaymi Heimboch

- Mortality
- Reduced Body Size
- Infertility
- Disrupted Neurological Function
- Altered Sex Ratios

J.L. Lavers et al., 2014

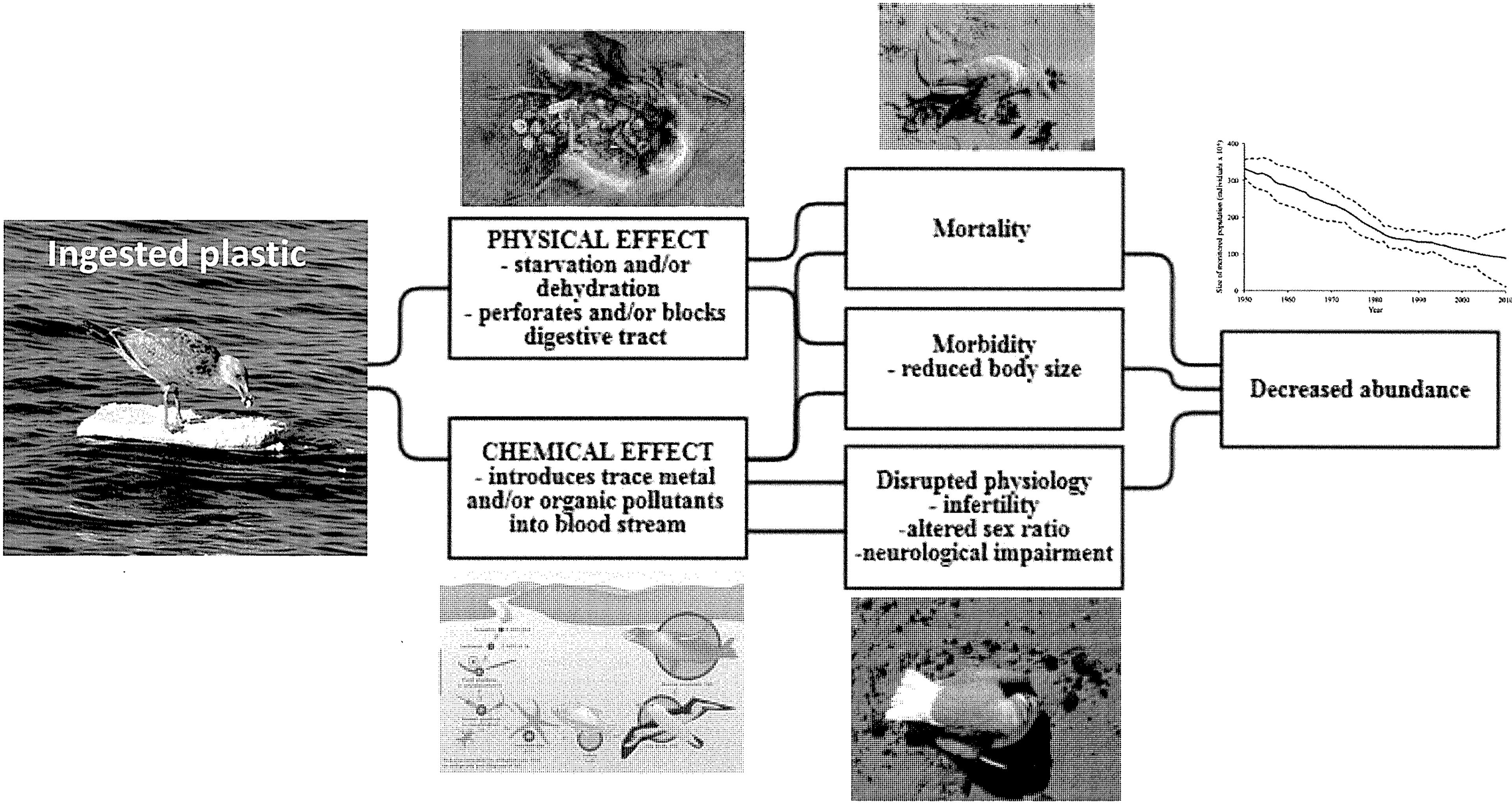
Polystyrene also causes mechanical blockages, false feelings of 'fullness', and interrupted breathing





98% of dead albatross chicks are found to have plastics in their stomachs

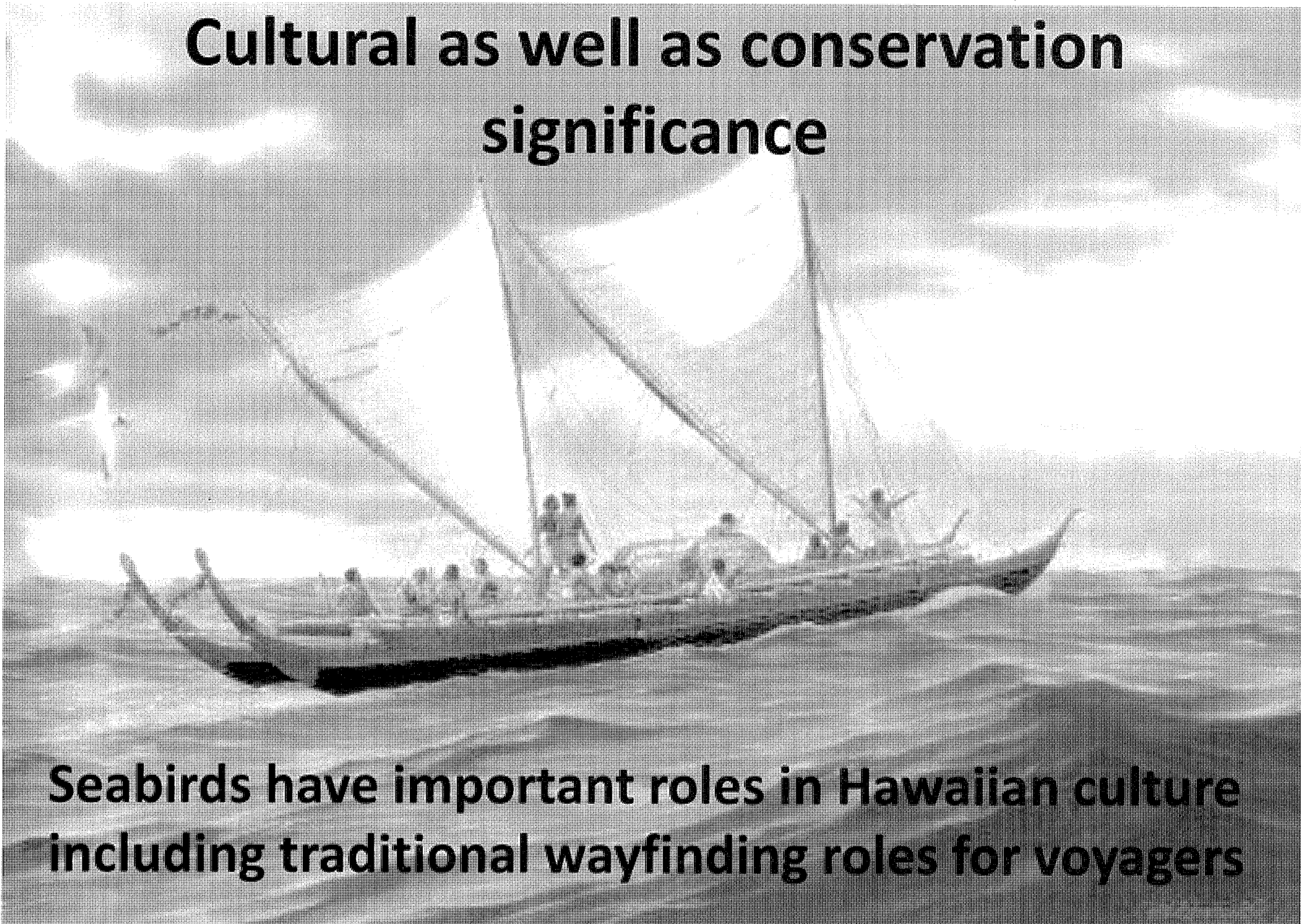
Polystyrene → seabird declines



J.L. Lavers et al., 2014


Wide range of wildlife exposed
More than **180 marine species** documented eating plastics, including many of Hawaii's most iconic species

Cultural as well as conservation significance



Seabirds have important roles in Hawaiian culture including traditional wayfinding roles for voyagers

This study employs Conjoint Choice Experiment (CCE) to determine consumer preference and willingness to pay for plant-based EPS alternative takeout food containers and their various product attributes in the urban center of Honolulu, Hawaii. Latent Class Analysis (LCA) is used to cluster respondents into four distinct classes based on their observable attributes of choice. ***Results show that the majority of respondents (81.0%) are in favor of a ban on EPS takeout food containers.*** As an alternative, the majority of respondents prefer a container constructed out of a sugarcane material (66.49%) that is microwaveable (88.94%), water resistant (100%), and locally produced (51.23%).

Barnes et al. 2011
Journal of Environmental Protection
Consumer Preference and Willingness to Pay for Non-Plastic Food Containers in Honolulu, USA

Ruth M. Lunn, Dr.P.H.

Director, Office of the Report on Carcinogens

Ruth Lunn, Dr.P.H., is the director of the Office of the Report on Carcinogens. The RoC is a congressionally-mandated document, prepared on behalf of the Secretary of the Department of Health and Human Services that lists and discusses substances that cause or are anticipated to cause cancer. Preparation of the RoC follows a formal, multi-step process that includes scientific review and opportunity for public comment. Lunn provides scientific expertise needed for the overall evaluation of substances for their potential to cause cancer in humans and is responsible for preparing the final draft of the RoC. She has worked with the RoC since 2000, initially as a staff scientist, and more recently as director. During this time, she has contributed to the preparation of numerous scientific background documents that are used in the scientific review process.

Prior to joining the RoC, Lunn's more recent research interests were molecular epidemiology studies evaluating carcinogenicity and genetic susceptibility. She completed postdoctoral work at the National Institute of Environmental Health Sciences in Research Triangle Park, North Carolina, and received a Dr.P.H. in environmental health sciences from Columbia University, New York, New York. She also earned a M.S. in microbiology and immunology and a Master of Clinical Microbiology (M.C.M.) from Hahnemann University, Philadelphia, Pennsylvania.

Selected Publications

1. Rooney AA, Cooper GS, Jahnke GD, Lam J, Morgan RL, Boyles AL, Ratcliffe JM, Kraft AD, Schünemann H, Schwingl P, Walker TD, Thayer KA, Lunn RM. How credible are the study results? Evaluating and applying internal validity tools to literature-based assessments of environmental health hazards. *Environment International* 2016 92-93():617-629 [Abstract]
2. Cooper GS, Lunn RM, Ågerstrand M, Glenn BS, Kraft AD, Luke A, Ratcliffe JM. Study sensitivity: Evaluating the ability to detect effects in systematic reviews of chemical exposures. *Environment international* 2016 92-93():605-610. [Abstract]
3. Ward, E.M., Schulte, P.A., Straif, K., Hopf, N.B., Caldwell, J.C., Carreén T., DeMarini, D.M., Fowler, B.A., Goldstein, B.D., Hemminki, K., Husgafvel, Pursiainen K., Kuempel, E., Lewtas, J., Lunn, R.M., Lynge, E., McElvenny, D.M., Muhle, H., Nakajima, T., and Robertson, L.W.; IARC Working group. Research Recommendations for Selected IARC-Classified Agents. Environ Health Perspect, 118(10):1355-1362, 2010. [Abstract]
4. Brewster, A.M., Jorgensen, T.J., Ruczinski, I., Huang, H.Y., Hoffman, S., Thuita, L., Newschaffer, C., R.M. Lunn, R.M., Bell, D., and Helzlsouer, K. J., Polymorphisms of the DNA repair genes XPD (Lys751Gln) and XRCC1 (Arg399Gln and Arg194Trp): relationship to breast cancer risk and familial predisposition to breast cancer. Breast Cancer Res Treat, 95(1): 73-80, 2006. [Abstract]
5. Zhang, Y-J., Chen, Y., Ahsan, H., Lunn, R.M., Chen S-Y., Lee, P-H., Chen, C-J., and Santella, R.M., Silencing of glutathione S-transferase P1 by promoter hypermethylation and its relationship to environmental chemical carcinogens in hepatocellular carcinoma. Cancer Lett, 221(2):135-143, 2005. [Abstract]
6. Stern, M.C., Umbach, D.M., Lunn R.M., and Taylor J.A., DNA repair gene XRCC3 codon 241 polymorphism, its interaction with smoking and XRCC1 polymorphisms, and bladder cancer risk. Cancer Epidemiol Biomarkers Prev, 11: 939-943, 2002. [Abstract]
7. Duell, E.J., Millikan, R.C., Pittman, G.S., Winkel, S., Lunn, R.M., Tse, C-K J., Eaton, A., Mohrenseiser, H.W., Newman, B., and Bell, D.A., Polymorphisms in the DNA repair gene XRCC1 and breast cancer. Cancer Epidemiol Biomarkers Prev, 10: 217-22, 2001. [Abstract]
8. Lunn, R.M., Helzlsouer, K.J., Parshad, R., Sanford, K.K., and Bell, D.A, XPD polymorphisms: Effects on DNA repair proficiency. Carcinogenesis, 21: 551-555, 2000. [Abstract]
9. Lunn R.M., Langlois, R.G., Hsieh, L.L., Thompson, C.L., and Bell, D.A., XRCC1 polymorphisms: Effects on AFB1-DNA adducts and GPA variant frequency. Cancer Res., 59: 2557-2561, 1999. [Abstract]
10. Lunn R, M., Bell, D.A., Mohler, J.A., and Taylor, J.A. Prostate cancer risk and polymorphism in 17 hydroxylase (CYP17) and steroid reductase (SRD5A2). Carcinogenesis, 20: 1727-1731, 1999. [Abstract]
11. Suyama K., Lunn R., Smith B.L., Haller S., Expression of the Rh-related glycoprotein (Rh50). Acta Haemateol, 100: 181-186, 1998. [Abstract]
12. Lunn, R. M., Zhang, Y. J., Wang, L. Y., Chen, C. J., Lee, P. H., Lee, C. S., Tsai, W. Y., and Santella, R. M. p53 mutations, chronic hepatitis B virus infection, and aflatoxin exposure in hepatocellular carcinoma in Taiwan. Cancer Res, 57: 3471-3477, 1997. [Abstract]

NTP
National Toxicology Program

Styrene and the Report on Carcinogens (RoC)

Ruth M. Lunn, DrPH, Director Office of the RoC
Division of the National Toxicology Program
National Institute of Environmental Health Sciences

Maui County Council
May 9, 2017

Purpose and Outline

Styrene was first listed in the 12th Report on Carcinogens as *Reasonably Anticipated to be a Human Carcinogen*

What is the National Toxicology Program and the Report on Carcinogens?

What does reasonably anticipated to be a human carcinogen mean?

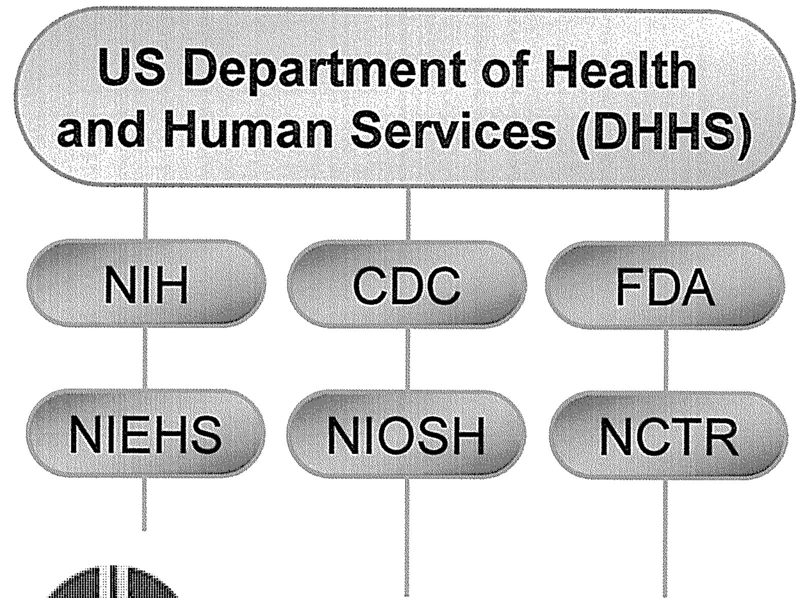
What was the process used and the scientific evidence for the styrene listing?

How are people exposed to styrene?

What is the potential exposure to styrene from polystyrene containers?

Expands the scientific basis for making public heath decisions on potential toxicity of environmental agents

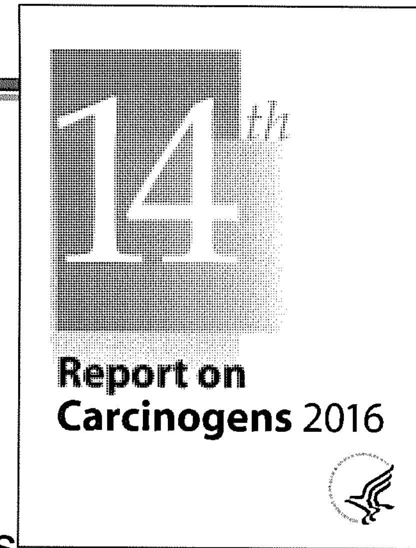
- **Interagency program**
  - Established in 1978
  - Headquartered at NIEHS
- **Research**
  - Thousands of agents evaluated in comprehensive toxicology studies
- **Analysis activities**
  - Office of Report on Carcinogens (ORoC)
  - Office of Health Assessment & Translation (OHAT)
  - NTP Interagency Center for the Evaluation of Alternative Toxicological Methods (NICEATM)



National Toxicology Program
U.S. Department of Health and Human Services

http://ntp.niehs.nih.gov

The Report on Carcinogens (RoC) is congressionally mandated



- Public Health Service Act, Section 301(b)(4) (1978, amended 1993)
  - Directs Secretary, Health and Human Services (HHS) to publish a list of carcinogens for people in the United States
  - Defines the language and number of listing categories: "*known*" or *"reasonably anticipated human carcinogens"*
  - Does not define the listing criteria or process for listing a substance
- Cancer hazard evaluation; does not address "risk"
- National Toxicology Program (NTP) prepares the RoC for the HHS Secretary using a four-part formal process and established listing criteria
- Each edition of the report is cumulative

Reasonably anticipated to be a human carcinogen means.....

- Causal relationship in humans has not been clearly established
- NTP has established to standards (RoC Listing Criteria) for listing substances
- Examples of other substances listed as reasonably anticipated to be a human carcinogen
  - Acrylamide
  - Di(2-ethylhexyl) Phthalate (used in plastics)
  - Lead and lead compounds
  - Polycyclic aromatic hydrocarbons

NTP developed criteria for each listing category

Known to be a human carcinogen

- Sufficient evidence of carcinogenicity from studies in humans

Reasonably anticipated to be a human carcinogen

- Limited evidence from studies in humans
  OR
- Sufficient evidence from studies in experimental animals
  OR
- Belongs to well-defined structurally related class of substances listed in the RoC or demonstrates convincing mechanistic evidence

Conclusions based on scientific judgment using all relevant information

Preparation of the 12th RoC followed an established process

(scientific input, external peer review, public comments)

Nominations and Selection of Candidate Substances →

Invite nominations
↓
Propose nominations for review
↓
Solicit public comments on nominations
↓
Select candidate substances

Scientific Review of Candidate Substances →

Prepare & release draft background document
↓
Solicit public comments on draft background document
↓
Expert Panel
(public meeting: peer review draft background document & recommend listing status)
↓
Release final background document
↓
Solicit public comments on panel's recommendation
↓
Interagency Scientific Review Group
(closed meeting: recommend listing status)

NIEHS/NTP Scientific Review Group
(closed meeting: recommend listing status)

Peer Review of Draft Substance Profiles →

Prepare & release draft substance profiles
↓
Solicit public comments on draft substances profiles
↓
NTP Board of Scientific Counselors
(public meeting: peer review draft substance profiles)

Preparation of RoC and Transmittal

Prepare draft RoC
↓
Director, NTP
↓ **NTP Executive Committee**
Secretary, HHS
(transmit RoC to Congress and public)
↓
Release NTP response documents
(NTP's response to the expert panel peer review report, the BSC peer review report, and the public comments)

BSC = Board of Scientific Counselors
HHS = Health and Human Services
NIEHS = National Institute of Environmental Health Sciences
NTP = National Toxicology Program
RoC = Report on Carcinogens

NTP Evaluation of Styrene

Styrene is *reasonably anticipated to be a human carcinogen*

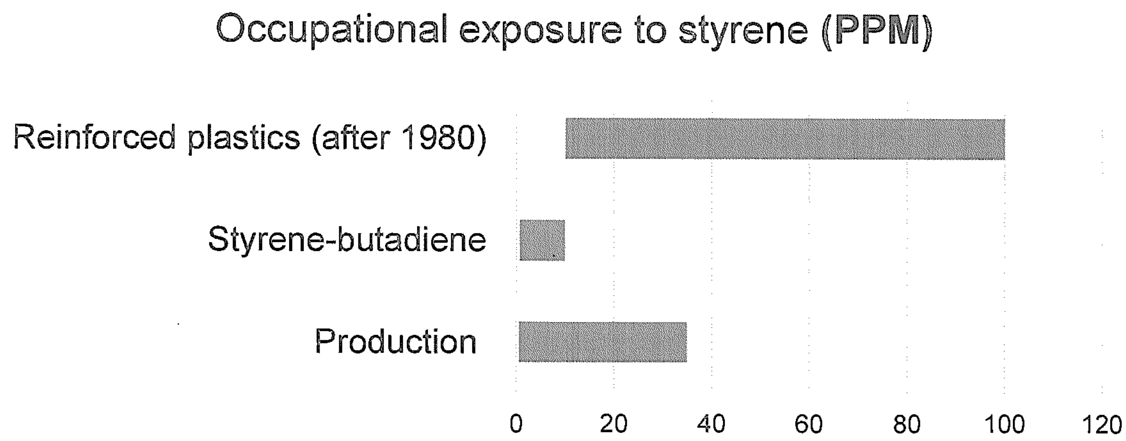
- Rationale for NTP conclusions (2009)
  - Studies of styrene-exposed workers show an association between exposure to styrene and lymphohematopoietic cancer and genetic damage in their lymphocytes (**limited evidence**)
  - Styrene causes lung tumors in laboratory mice by two routes of exposure (**sufficient evidence**)
  - Styrene is metabolized to styrene-7,8-oxide, which is listed as a *reasonably anticipated human carcinogen* in the RoC
- National Academy of Sciences (National Research Council) (2014)
  - Endorsed listing of styrene in the 12^{th} RoC as reasonably anticipated to be a human carcinogen and agreed with NTP conclusions for each type of evidence (human, animal and mechanistic)

People are potentially exposed to styrene in the workplace, from the environment, indoor air, food and tobacco smoke

Workplace

High exposure
Parts per million (PPM) range

Blood levels (µg/L)
8.9 to 83

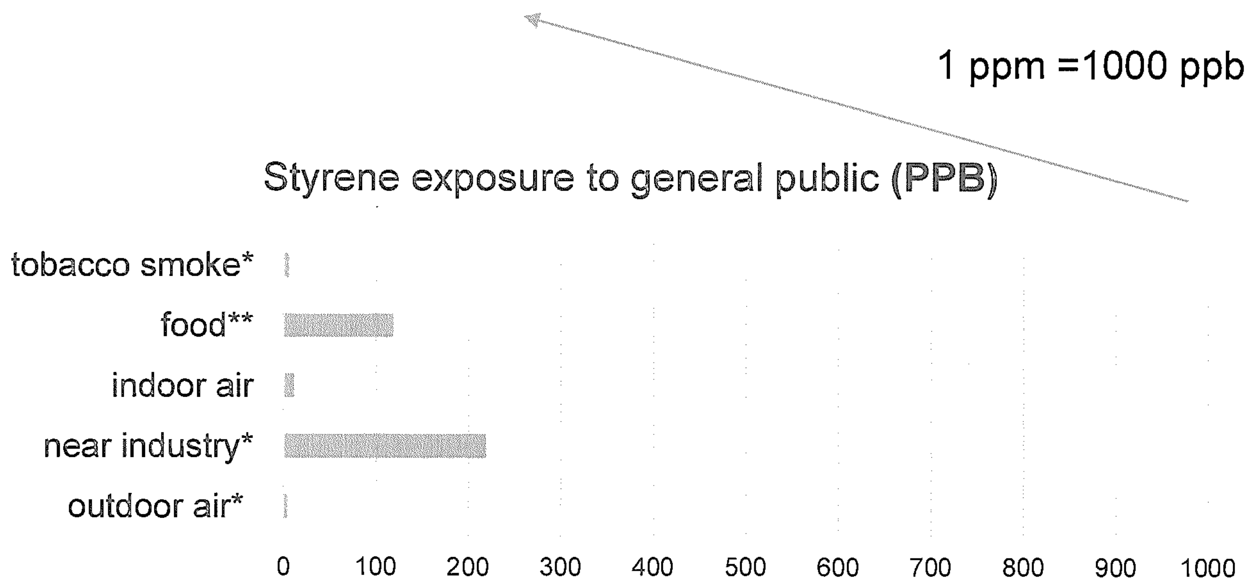


1 ppm =1000 ppb

General public

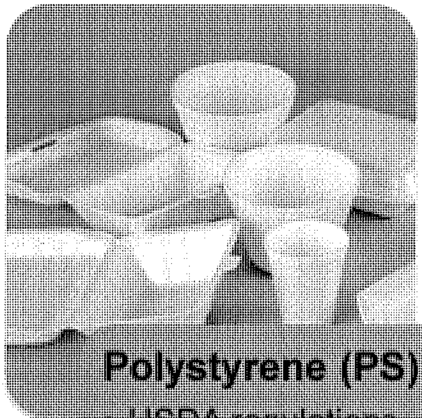
Low exposure
Parts per billion (PPB) range

Blood levels (µg/L)
0.13 (95 percentile)

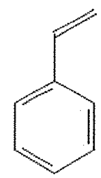


* lifetime; **most 0.05-119

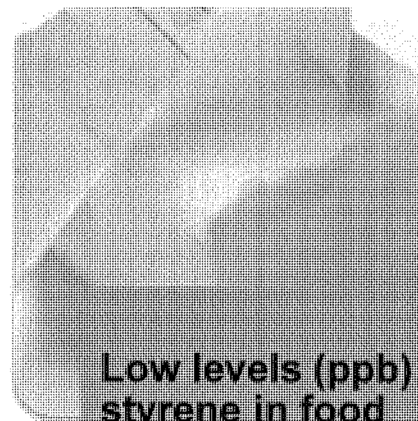
Low exposure to styrene from food in polystyrene containers



Polystyrene (PS)
- USDA regulations (mg/kg) for PS
  - Fatty food: 10,000
  - Non-fatty food: 5,000

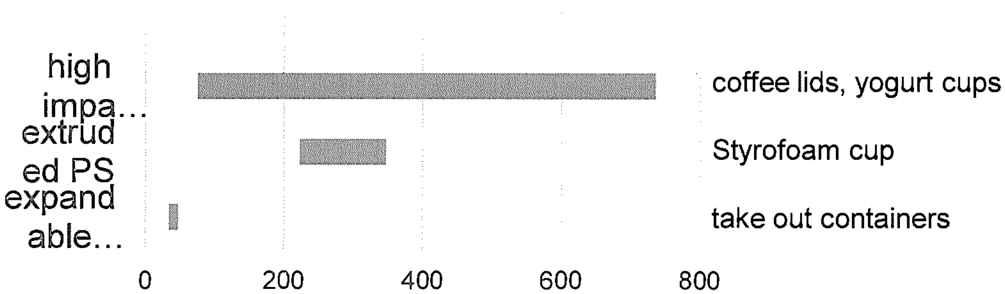


Low migration of styrene monomer
- Food: lipophilicity
- Container: surface to volume ratio
- Conditions: duration, contact, temperature

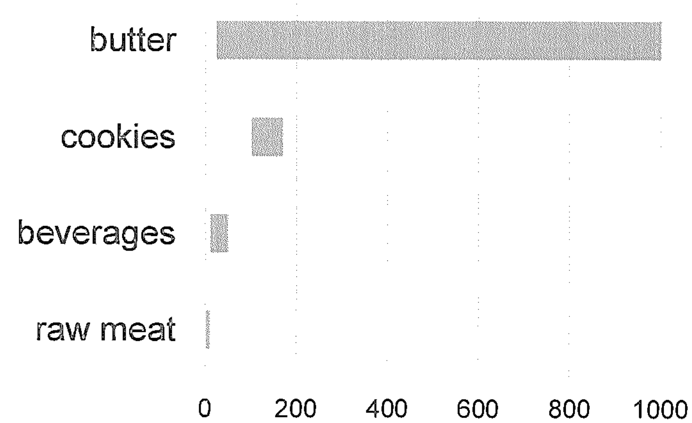


Low levels (ppb) of styrene in food

Styrene levels (mg/kg) in polystyrene containers



Styrene levels (µg/kg) food packaged with PS



Summary

- Styrene is listed as *reasonably anticipated to be a human carcinogen* in the Report on Carcinogens
  - Cancer studies in workers exposed to high levels of styrene reported an increased risk of cancer
  - Lung tumors developed in mice exposed to 20 to 160 ppm (almost lifetime)
- NTP evaluation is a cancer hazard evaluation and does not not estimate cancer risks to individuals associated with exposures in their daily lives
- The general public is exposed to low levels of styrene (orders of magnitude lower than workers) from the environment, indoor air, food, and tobacco smoke
  - Low levels of styrene in food can occur from the environment, natural sources, mold contamination (e.g. cinnamon), or contact with polystyrene