

Impacts of Environmentally-Relevant Concentrations of Polypropylene Microplastic fibers on Pacific Mole Crab (*Emerita analoga*) Development and Lifespan

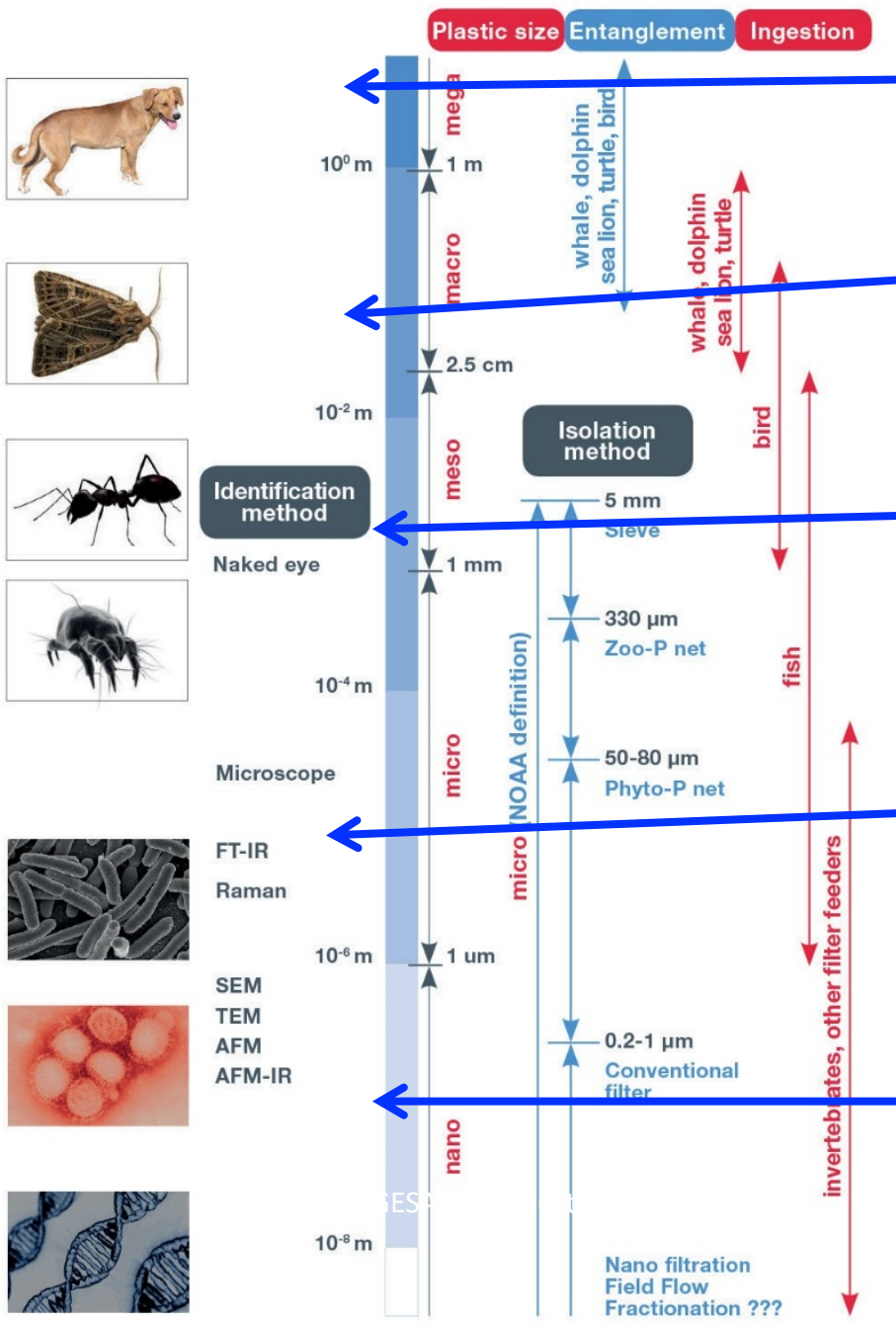
Dorothy Horn, Elise Granek and Clare Steele



California State
University

C H A N N E L
I S L A N D S





- **Mega** plastics are those > 100mm
- **Macro** plastics are those 20 - 100mm
- **Meso** plastics are those 5 - 20mm
- **Micro**plastics are those < 5 mm
- **Nano**-plastics are those < 1μm

Microplastic types

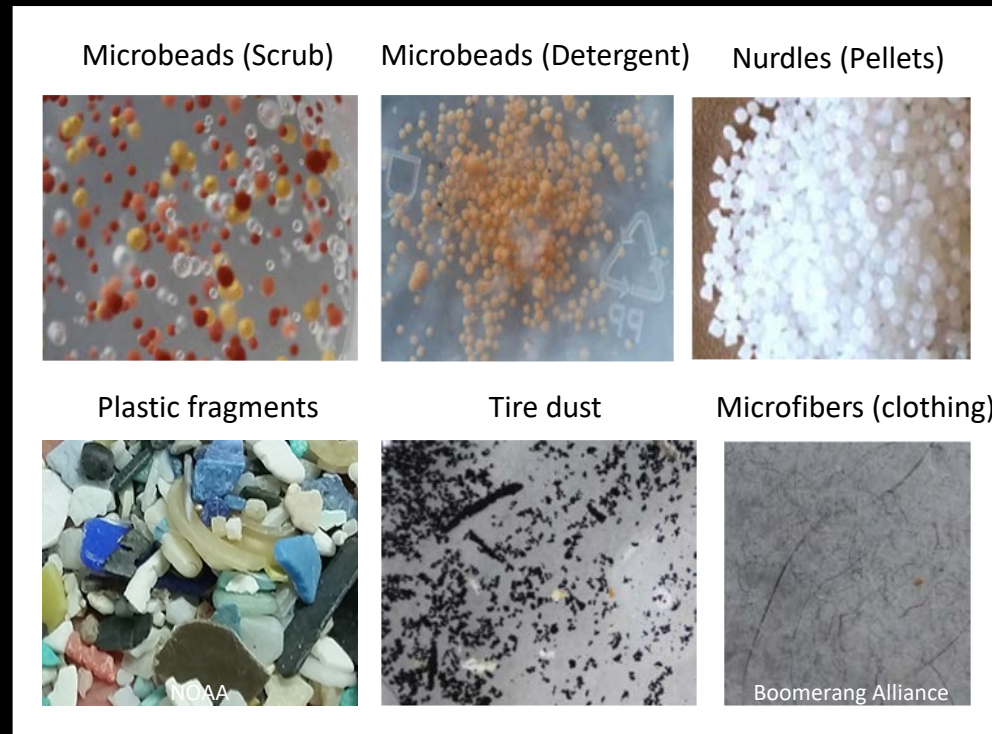
Plastic particles and fibers less than **5 mm – 0.001 mm**

Primary microplastics

Manufactured microbeads,
nurdles

Secondary microplastics

Fragments of larger items



Microfibers



<https://www.earth.com/news/microfibers-clothing-polluting-oceans/>

MICROFIBER CONTAMINATION



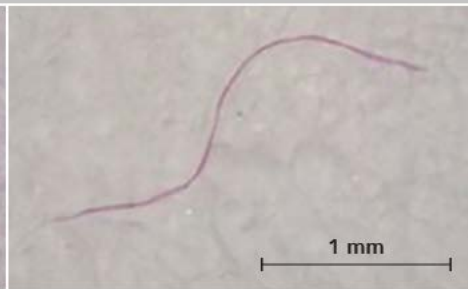
Sea Salt

1.5 mm microfiber from Atlantic Ocean sourced sea salt.



Beer

1 mm microfiber from brewery drawing water from Lake Erie.



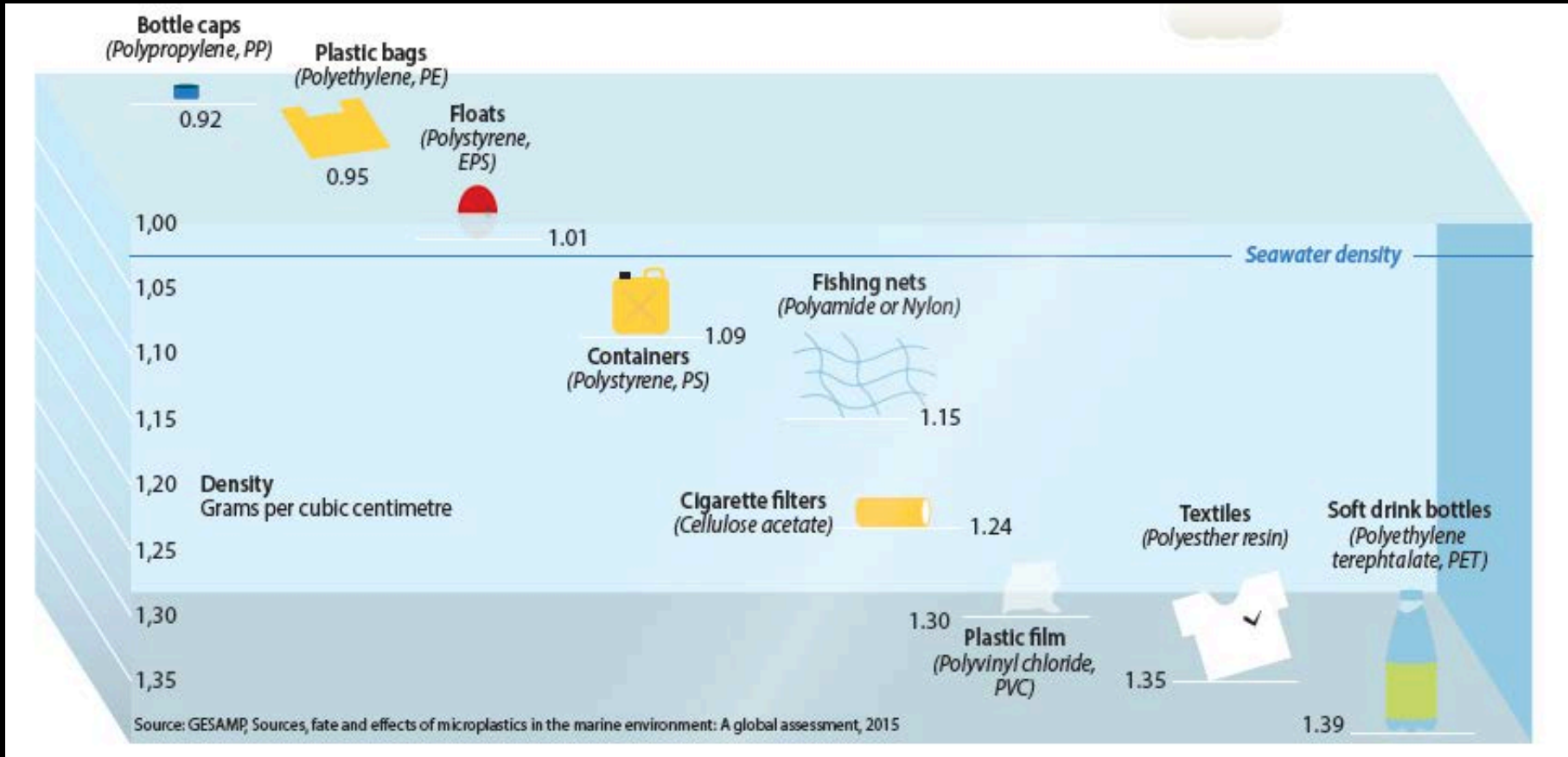
Tap Water

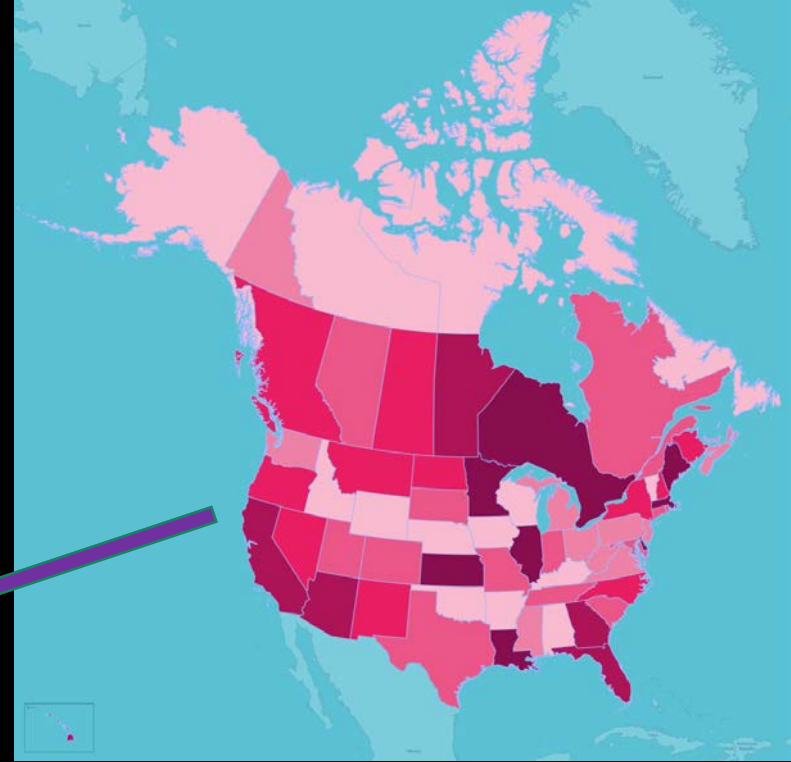
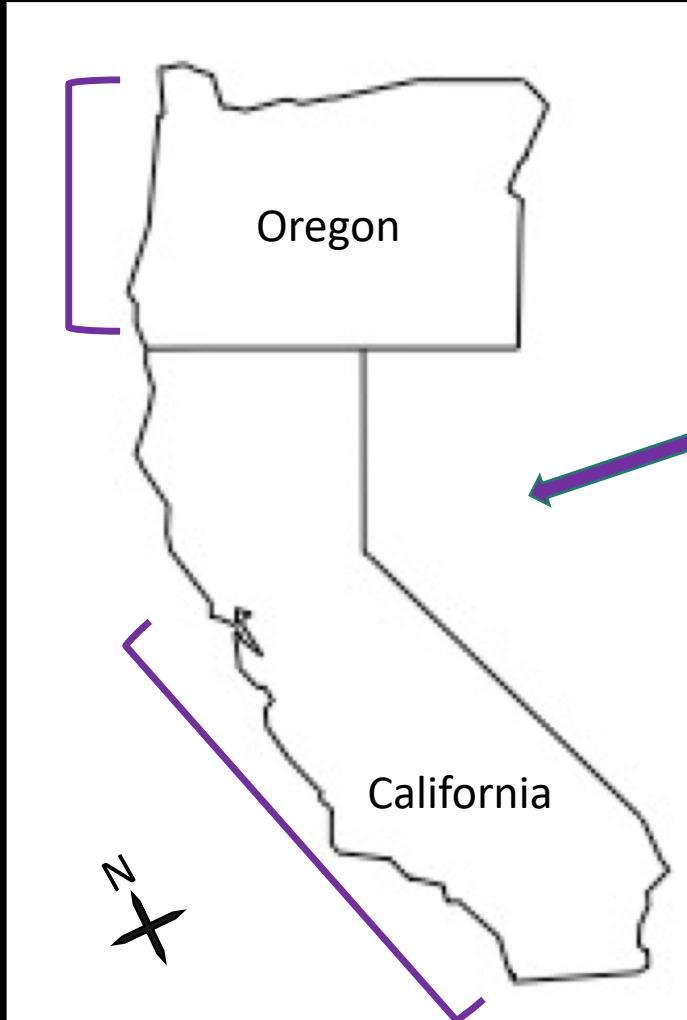
2.5 mm microfiber from U.S. tap water sample.

1 fleece jacket
~250,000 fibers
released per
load

WASH, C. (2015). Featured products

Where does the plastic go?





North American Study Sites

Oregon and California, US

Collected Sand: Marin County to San Diego - California

Microplastics in sand

(n = 51 beaches):

- 200ml of sand was collected from each beach & dried
- supernatant filtered through 1.6 μm glass fiber filters
- categorized visually by color & type – then tested using FTIR



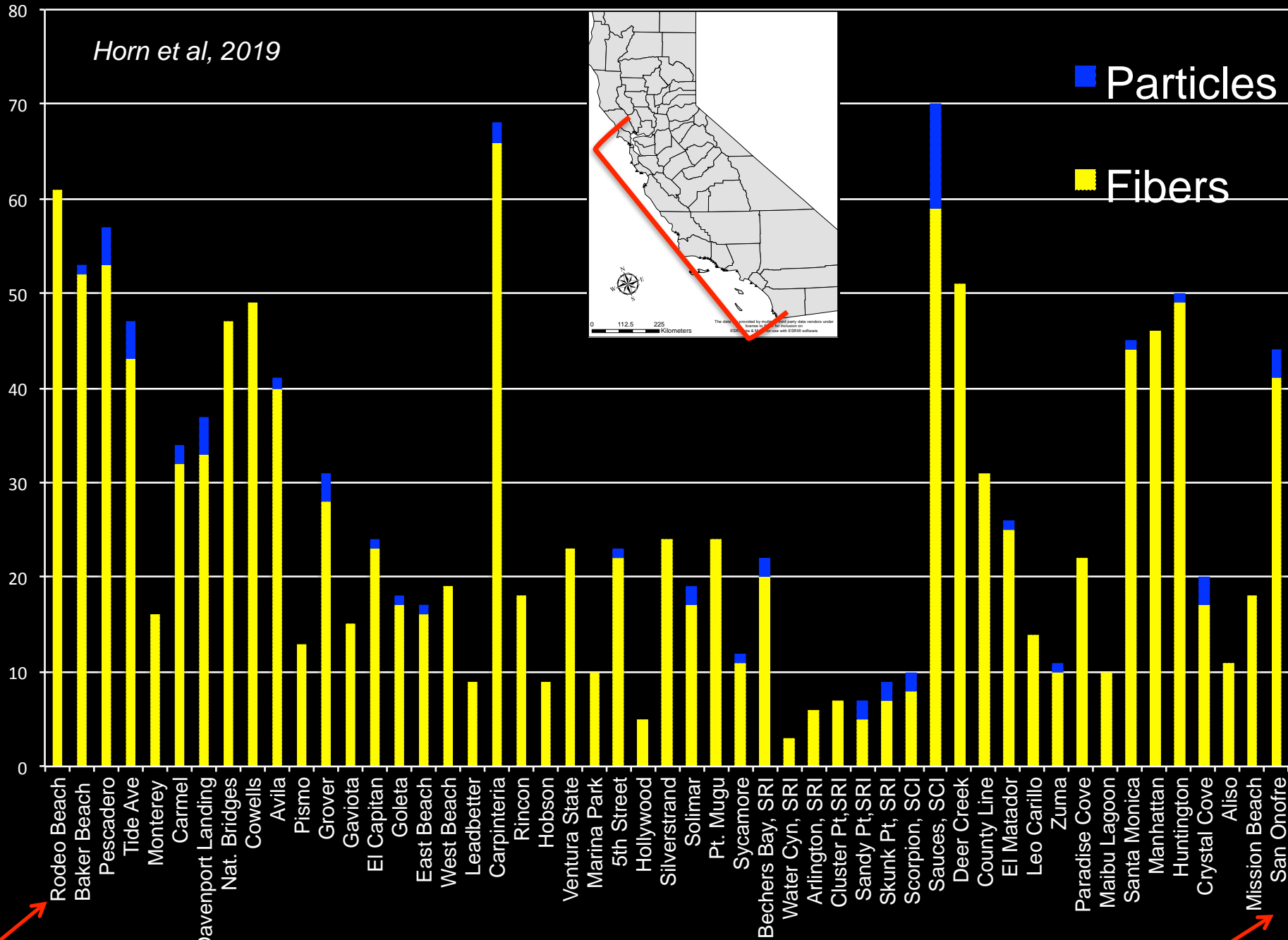
Horn et al, 2019



■ Particles

■ Fibers

Number of Fibers/Particles



Near San Francisco

Sample Beaches

Closest to the border



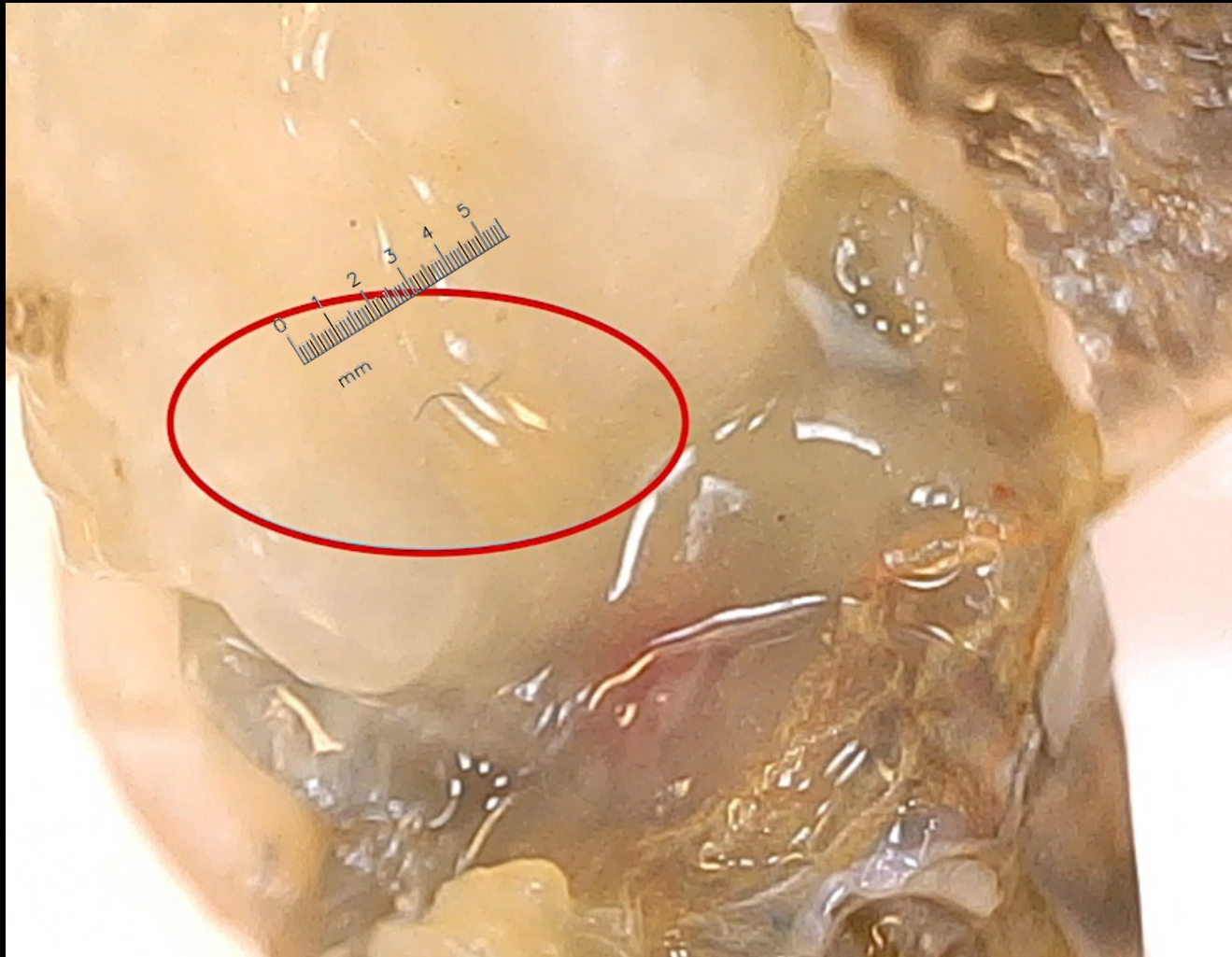
Microfiber in sand





- Highly abundant sandy beach invertebrate
- Filter feeders

Microfiber in Pacific mole crab:



Ingest microplastics (*Horn et al, 2019 Marine Pol. Bul*)

Pacific mole crab (*Emerita analoga*)



Surf Perch (crabs = 90% of diet)



Shore Birds



~ 2 million sand crabs used for bait per year



Mammalian predator: Sea Otter

Give Dorothy Crabs

Channel Islands
Environmental Science and Resource Management Program

Dorothy Horn, Seal Assistant, Case Steele
Environmental Science and Resource Management Program,
California State University Channel Islands
e-mail: dorothy.horn078@myci.csuci.edu *http://capstone.dorothyhorn.cikaye.com

ESRM Program

Pervasive Plastics: A New Challenge for Crabs and our Sandy Beach Ecosystem

Introduction

Sandy beaches cover ~75% of the world's shoreline, 80-90% of the coastline of Southern California counties and are fundamental to most coastal economies and cultures. The sand crab (*Erimacrus* sp.) is found ubiquitously upon almost every California sandy beach, and is an unappreciated sentinel of ecosystem change across shorelines in a global geographic area. Given the rate of plastic pollution across our seas and coasts over recent decades, there is a high likelihood plastics are affecting marine food webs and impacting coastal ecosystems. We recently demonstrated microplastics (particles or fibers <5mm) are present in beach sands and experimentally demonstrated that sand crabs ingest microplastics under controlled laboratory conditions. In addition, we have now confirmed background levels of microplastics in the bodies of adult *E. imitator* from beaches across Southern California. The ubiquity of this contamination makes it difficult to assess the effects upon sand crabs and their associated food webs. It appears to be no areas free from plastic exposure.

Trash on Beaches

Approximately 80 million plastic bottles are discarded in the U.S. each year. In California, approximately 1.5 million plastic bottles are discarded each year. In California, approximately 1.5 million plastic bottles are discarded each year.

Is Microtrash in California's Sandy Beach Ecosystem?

Beach Location	% of sand samples containing microtrash
Aitutaki Cook Islands	00
Channel Islands Southern California	100
Central California	100

Table 1 (Above) shows the percent of beaches with Microtrash found on sandy beaches sampled.

Top: Microtrash found in sand sample from Crystal Cove, Orange County. Bottom: Microtrash in sand sample from Seal Beach, Santa Barbara County.

Is the Microtrash Being Ingested? YES!

Microtrash found in the stomach of a Sand Crab from El Matador Beach, Santa Barbara County.

Microtrash found inside Sand Crab from Seal Beach, Santa Barbara County.

Ingested Microtrash: El Matador, Los Angeles County. Ingested Microtrash: Seal Beach, Santa Barbara County.

Is Microtrash Ambient in Nature? YES!

Microtrash found inside of Sand crabs from Crystal Cove, Orange County.

Microtrash on Silverstrand Beach, Ventura County.

Is there Microtrash in the Food Web?

Many planktonic organisms, including fish larvae, are known to ingest plastic. Ingested plastic can be found in the digestive tract of many marine organisms, including fish larvae, and can be found in the digestive tract of many marine organisms, including fish larvae.

Sand Crab Sample Population Locations

Results

Samples collected this summer show that microplastics are pervasive within sandy beaches in Southern California. Based on this study we collected *E. imitator* from 11 beaches of the original 51 beaches sampled for microplastics in the sand. These sand crabs were dissected and analyzed for the presence of microtrash. The sample locations were Crystal Cove (Orange County), Deer Creek, County Line and El Matador (Los Angeles County), Silverstrand and Schlar (Ventura County), East Beach, West Beach and Linderoth (Santa Barbara County) and Pismo and Avila Beach (San Luis Obispo County). In total 78 Sand Crabs were dissected and 41% of them contained Microtrash, 2% contained microplastic particles and 91% contained microfibers.

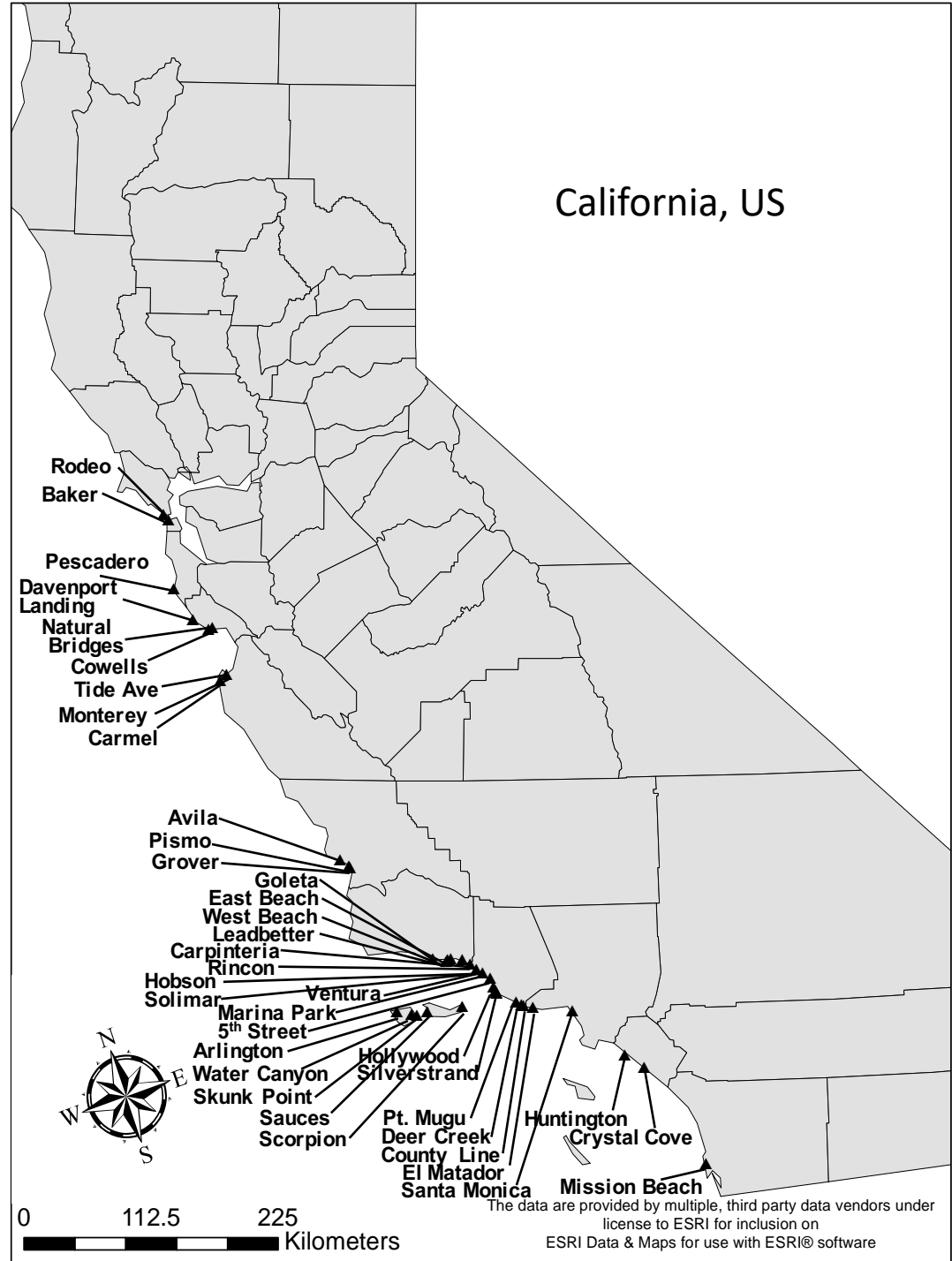
Next steps: I have sand crab samples from 14 more beaches but need additional samples from a wider geographic area as sand crabs are found along the coast from Alaska to Baja California.

Acknowledgements

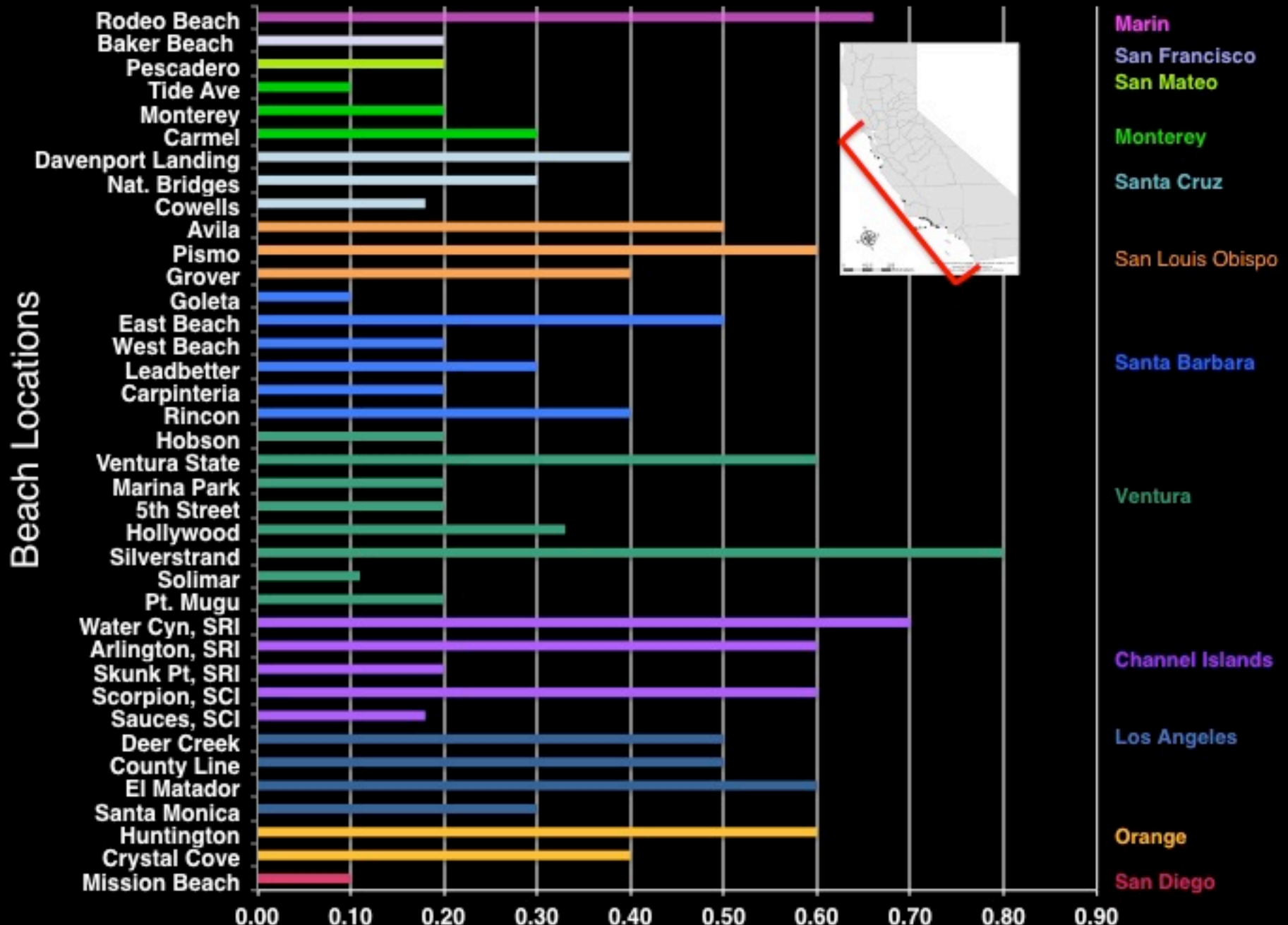
CSUCI Environmental Science and Resource Management Dept., Vanessa van Pelt, Dr. Linda O'Hara, Joost Doran, Dr. Diane Barber

California Sand Crab Collection Sites

Horn et al 2019



Microplastics: Common Across California



Horn et al, 2019

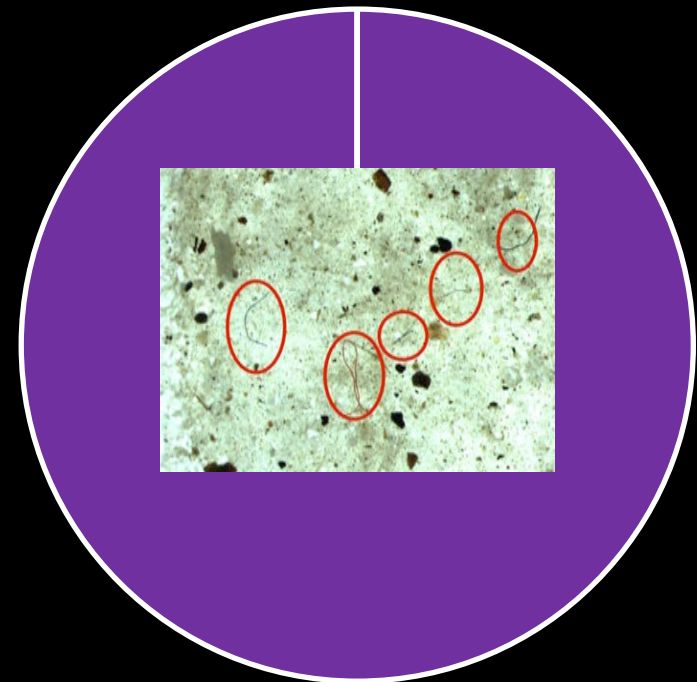
Proportion of Sand Crabs with Ingested Microplastics

California Results

35% of Sand Crabs Ingested
Plastics



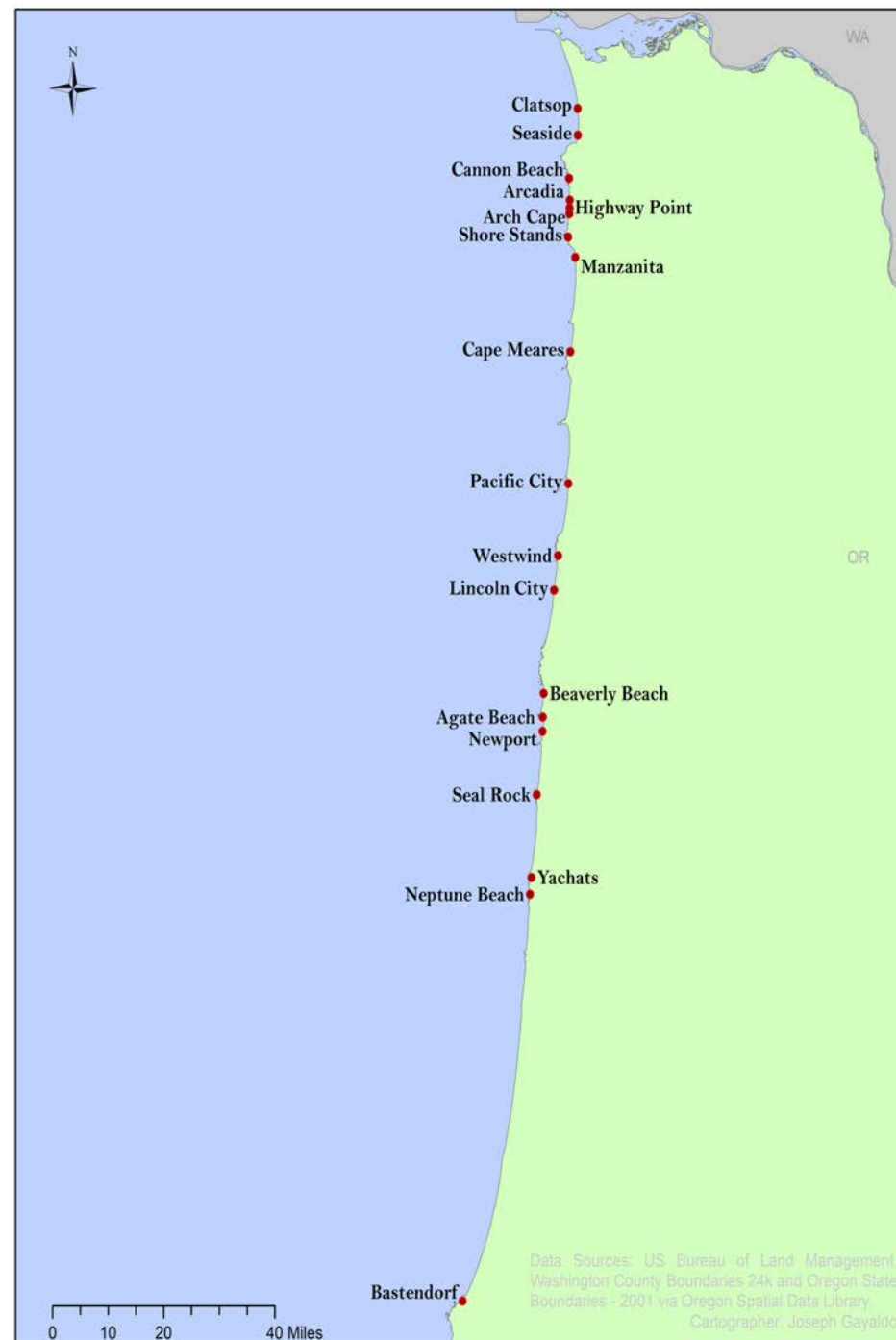
100% Sand Samples had
Microplastics



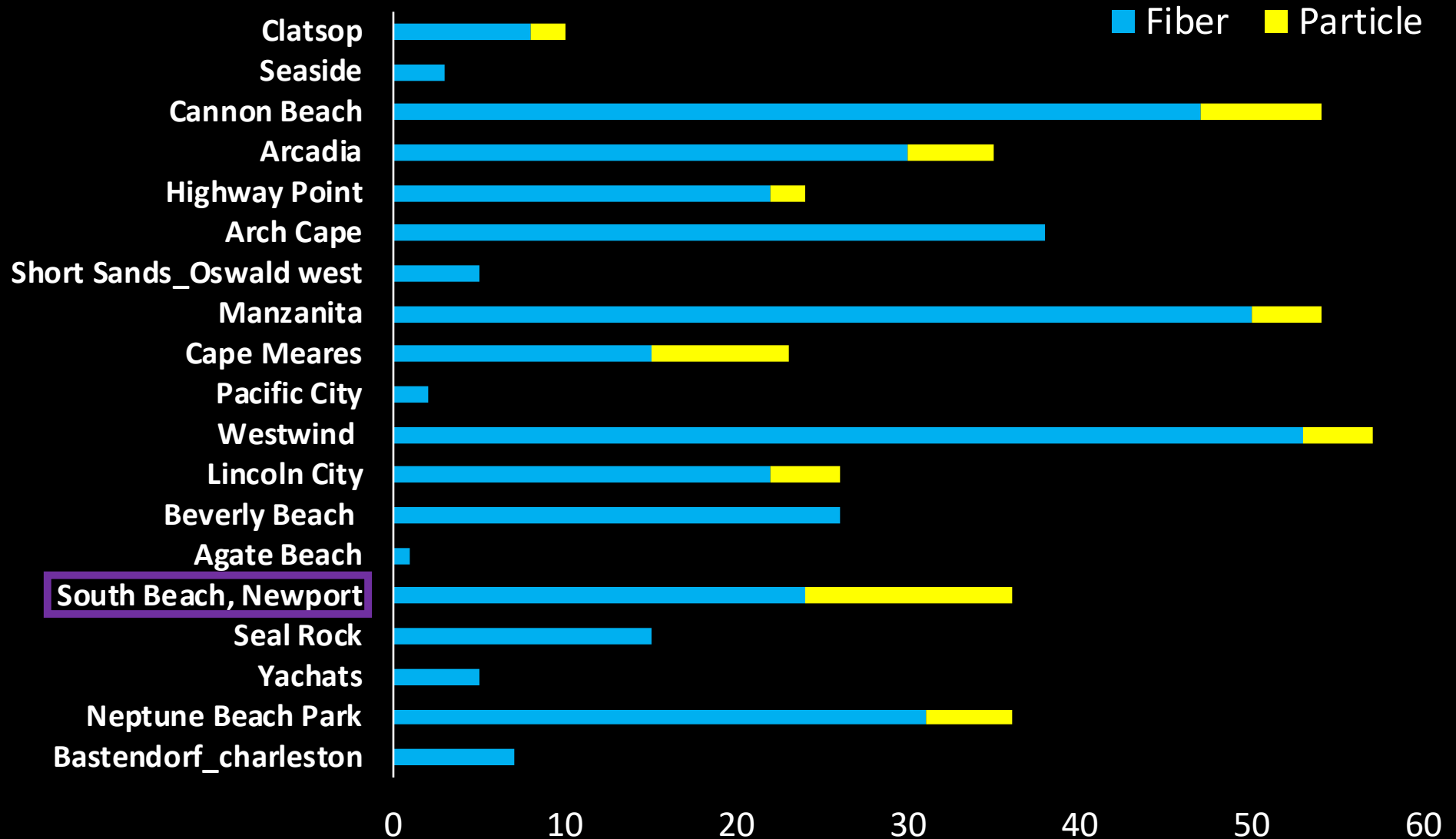
Oregon, US Collection Sites

(n = 19 beaches):

- 100ml of sand was collected from each beach & dried
- supernatant filtered through 1.6 μm glass fiber filters
- Plastic Identification by Nile Red fluorescence (Hidalgo-Ruz et al. 2012, Shim et al. 2016, Wiggin & Holland 2019)



Fibers and Particles in Oregon Sand



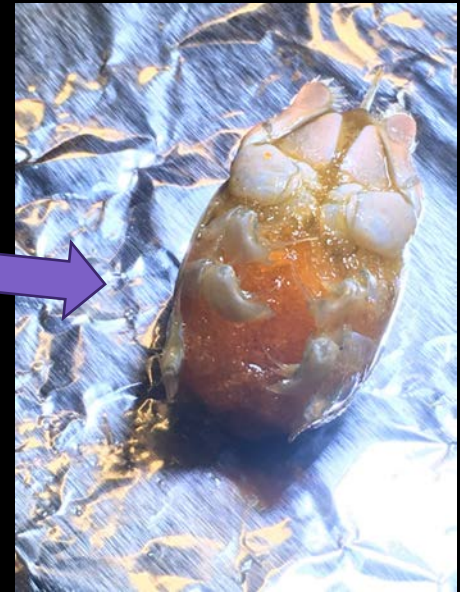
Number of Fibers and Particles

Horn et al, in review (Limnology and Oceanography Letters)



Methods

- 74 Days = 2 reproductive cycles (Booolootian et al 1959)
- 32 Control
- 32 Treatment
- 64 Jars w/1 Female gravid crab



Methods

Treatment Dose: 3x1mm pieces

Polypropylene rope every 4 days

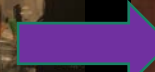


All crabs: food and fresh water daily

*Horn et al, in review (Limnology
and Oceanography Letters)*

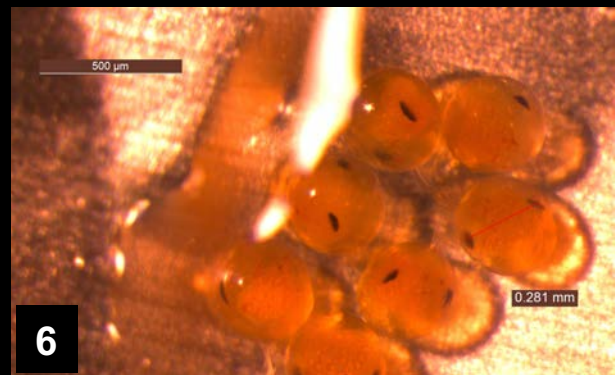
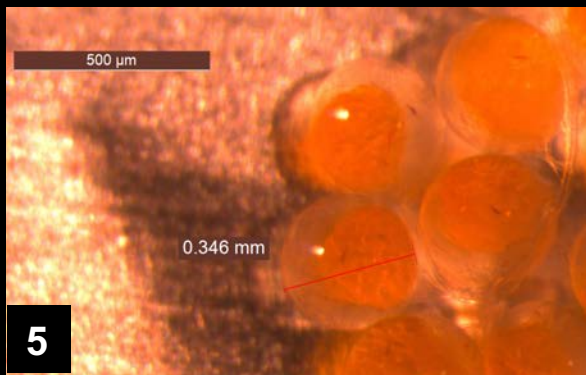
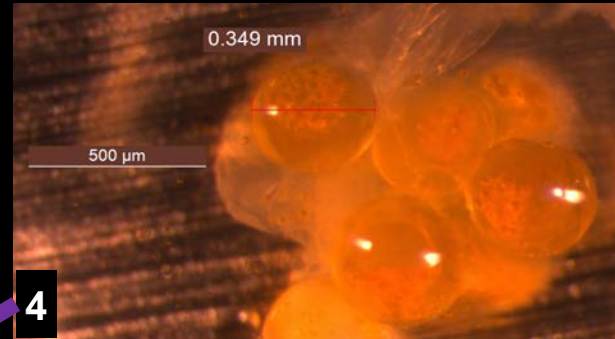
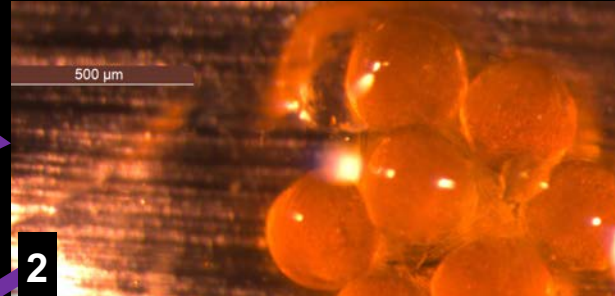
Methods

Sub-sample of eggs collected every 4 days

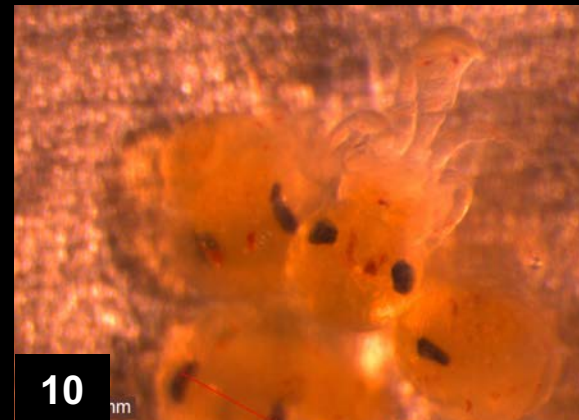
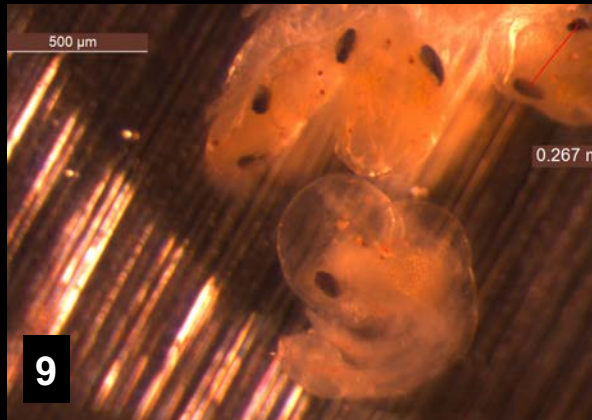
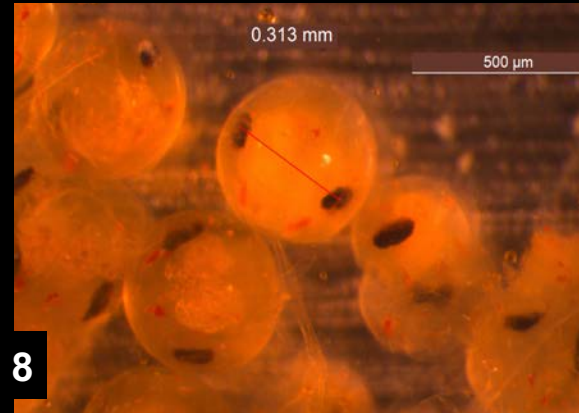


Horn et al, in review (Limnology and Oceanography Letters)

Pacific Mole Crab Egg Development Stages



Pacific Mole Crab Egg Development Stages



Larval Stages

Linear Mixed Effects Model

Does the water bottle in the backpack effect hiking speed?



mdl1



mdl2

mdl1 = hiking speed ~ gallon of water + flashlight

mdl2 = hiking speed ~ flashlight

Using lme4 in R Studio

Likelihood Ratio Test to compare the likelihood of the two models to each other (Winter 2013).

Output from ratio test \rightarrow Chi sq (χ^2) = 9.55, df = 4, **p = 0.04**

Linear Mixed Effects Model

Random Effects

- Number of microplastic fibers internalized by the adult crab
- Adult crab size
- Molting event
- Number of parasites
- Starting stage of egg clutch



Fixed Effects

- Exposed to polypropylene microfibers

Response Variables

- Adult mortality
- Number of days adult crabs held live/viable eggs
- Number of development stages egg clutches went thru

Likelihood Ratio Test to compare the likelihood of the two models to each other (Winter 2013).

What did we find?



Adult Crabs exposed to plastic had higher mortality rates

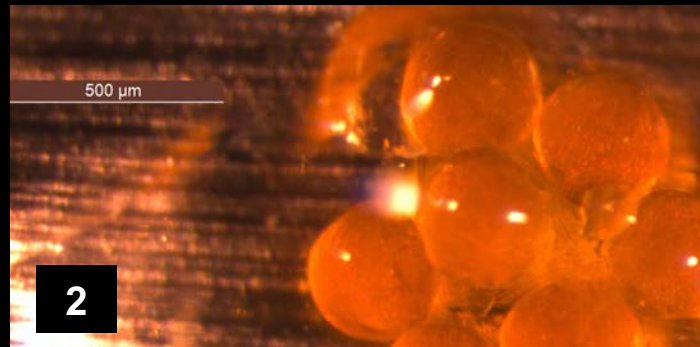
Chi sq (χ^2) = 45.83, df = 30, p = 0.03

What did we find?

adult crab



stage two of
egg development



microplastic
exposure



- The number of days an adult crab held live/viable eggs in her clutch was negatively affected by microplastic exposure when those eggs were at stage two of egg development at the study start (Chi sq (χ^2) = 9.55, df = 4, p = 0.04).

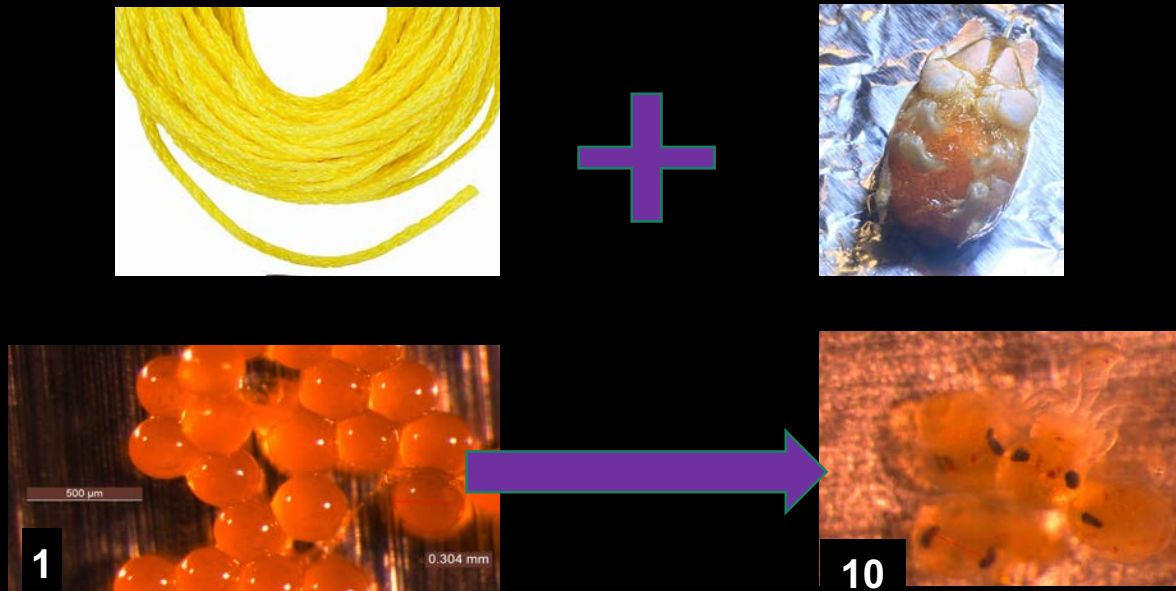
What did we find?



The number of polypropylene microplastic fibers internalized decreased the number of days that an adult sand crab held live/viable eggs.

(Likelihood Ratio test($\chi^2(1) = 27.54$, $p < 0.001$), by 4.46 days ± 0.75 SE)

What did we find?



- Microplastic fibers internalized by the adult crab *increased* the number of egg stages by 1.04 stages ± 0.5 SE ($\chi^2(1) = 11.53, p = 0.04$)

Additives & POPs in the food web

Additives:

Plasticizers, antioxidants, anti-static agents and flame retardants

Adsorbed chemicals:

PCBs, DDT, brominated flame-retardants

Concentration of POPs in plastic pellets a million times higher than in the surrounding seawater (Mato *et al.* 2001)



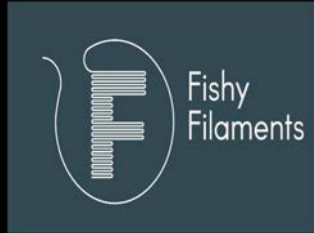
Take Home

- Microplastics in sand of every beach sampled across the California and Oregon coast.
- Polypropylene microfibers negatively affected sand crab mortality and reproductive output

Take Home

- Pathway of ingestion into coastal food webs.
- Microplastics known to accumulate and transfer harmful chemicals into tissue (Browne *et. al* 2013)

What can you do?



It's Worth the Effort

- Consistent monitoring of debris is important
- 15,000 tons of Debris is removed each year on coastal clean up



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Dorothy Horn, Elise Granek and Clare Steele



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