THE ABUNDANCE AND DISTRIBUTION OF NANOPLASTICS IN THE CALIFORNIA CURRENT AND THE NORTH PACIFIC SUBTROPICAL GYRE, IMAGED WITH A NOVEL METHOD

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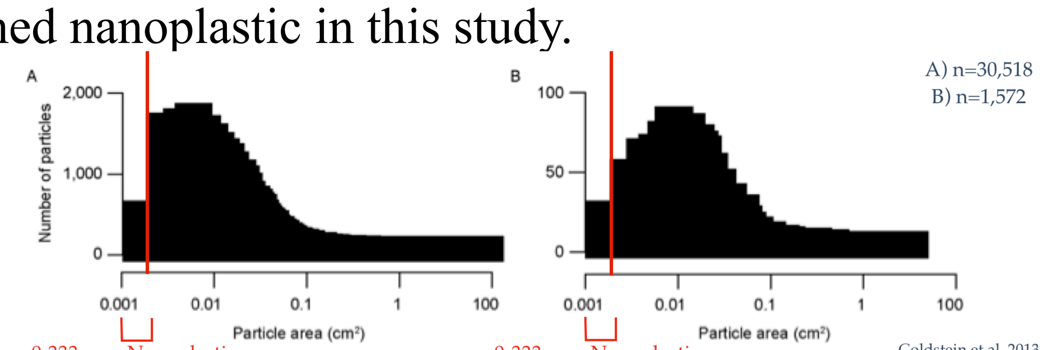
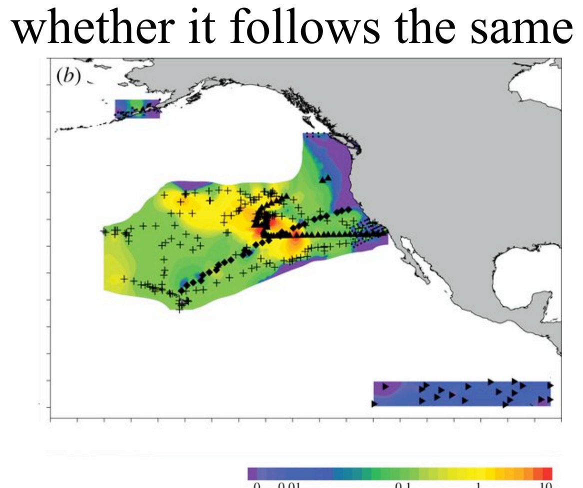
Introduction

Marine debris has been a concern for decades, and recent research has shown that the vast majority of marine debris is microplastic (<5mm). However almost all of these studies have used nets to measure marine debris, hence plastics smaller than the net mesh (often 333 µm) have most likely been undersampled. Plastics smaller than 333 µm are termed nanoplastic in this study.

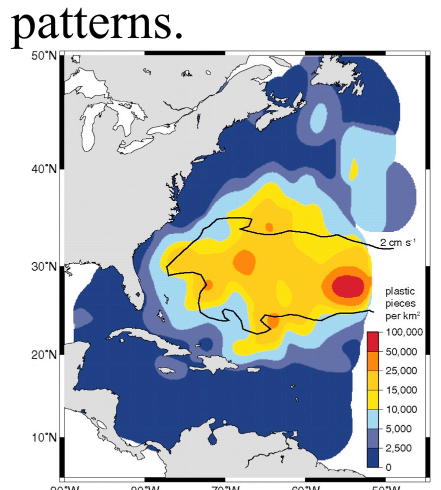


Goldstein et al. (2013) found that 90% of their sampled plastic was smaller than 1 cm^2, but they undersampled plastic <333 µm.

Large marine debris follows gyre circulation patterns and accumulates most heavily in the center of gyres. Marine debris is also abundant near areas of coastal effluent. Because nanoplastic is so undersampled, it is not known whether it follows the same spatial patterns.



Goldstein et al. 2012, 505 and 333 µm nets. Max abundance: 10/m^3



Law et al. 2010, 335 µm nets. Max abundance: 0.4/m^3

Questions

- Can we identify nanoplastics (<333 µm) for a more accurate abundance estimate of total plastic debris?
- Do spatial trends in nanoplastic abundance mirror the trends in larger plastics?

Conclusions

- Almost all small fibers and fragments were <333 µm, therefore missed with other methods
- Nanoplastic abundances are ~5 orders of magnitude greater than previously published estimates of microplastics
- There was no detectable spatial heterogeneity in nanoplastics, but the plankton:plastic ratio of the CCE is higher than the NPSG

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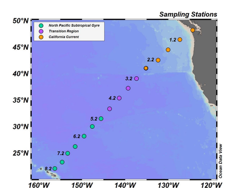
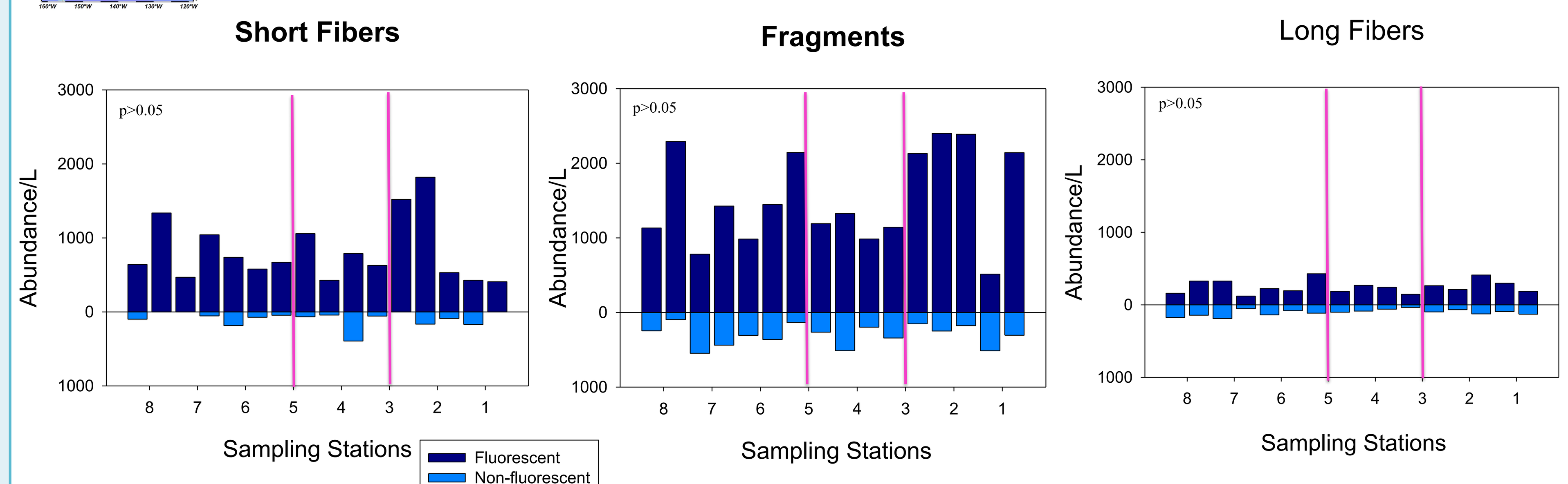
Results



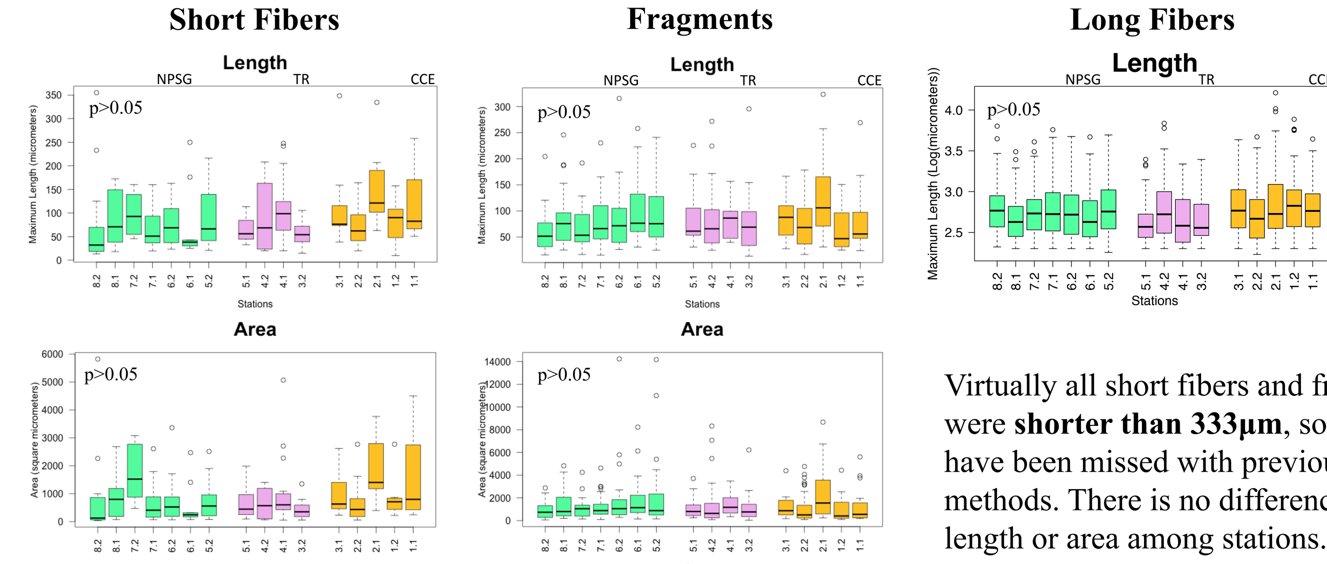
CCE=California Current Ecosystem
TR=Transition Region
NPSG=North Pacific Subtropical Gyre

Plastic Abundance



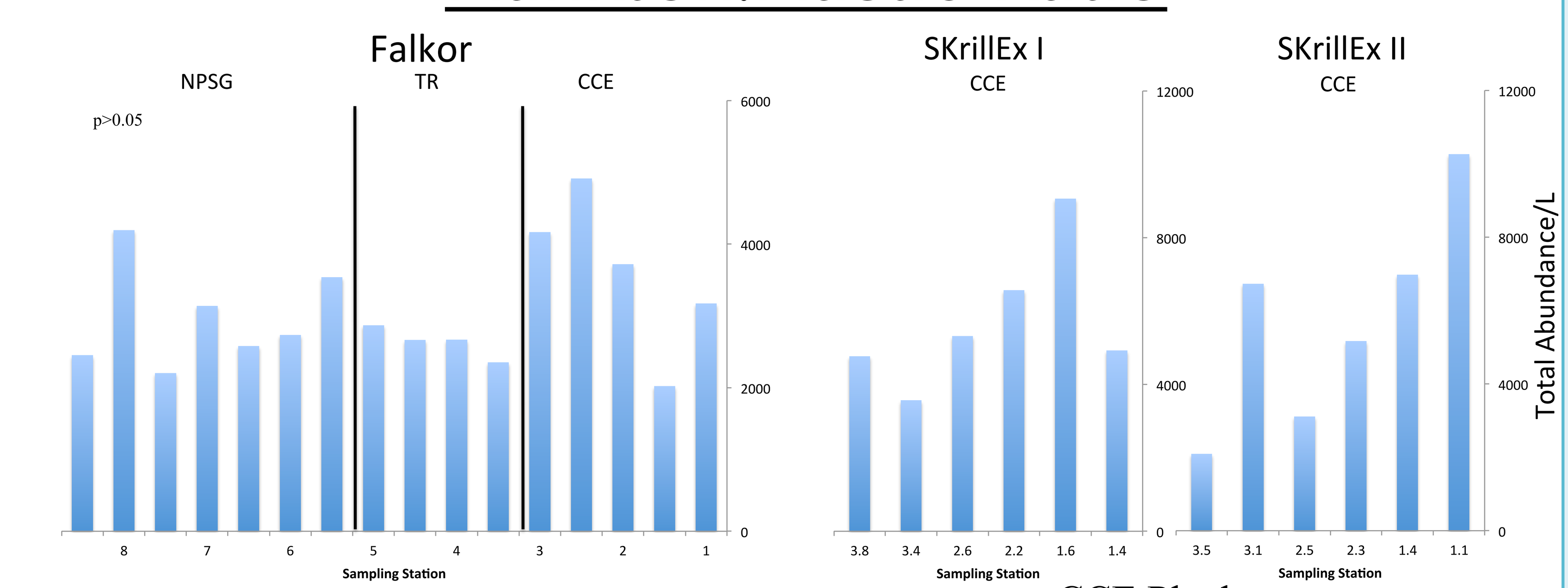
Epifluorescent microscopy successfully differentiated plastic from non-plastic particles. All 3 types of plastic (short fibers, fragments, and long fibers(>200µm)) had high abundances. Abundances averaged **10^3/L**, whereas previous published microplastic studies are **0.0004-.01/L**, a~5 orders of magnitude difference. Fluorescent particles (the majority of consumer plastics) dominated compared to more industrial, non-fluorescent plastics (nylons, polyesters).

Plastic Dimensions



Virtually all short fibers and fragments were shorter than 333µm, so would have been missed with previous methods. There is no difference in length or area among stations.

Plankton:Plastic Ratio



NPSG Plankton

Organism	Abundance/L	Plankton:Plastic Ratio
Autotrophs[A]	$1.2x10^6$	403:1
Heterotrophic Eukaryotes[A]	$1.1x10^6$	370:1
Autos and Heteros[A]	$2.3x10^6$	773:1

[A]Pasulka et al. 2013, Depth integrated 0-50m, divided by 50, for the month of October at Station ALOHA

CCE Plankton

Organism	Abundance/L	Plankton:Plastic Ratio
Heterotrophic Bacteria[B]	$1.3x10^9$	113848:1
Autotrophs[B]	$1.3x10^8$	11385:1
Heterotrophic Eukaryotes (<5µm)[B]	$2.9x10^5$	25:1
Autos and Heteros[B]	$1.3x10^8$	11330:1
Mesozooplankton (<200µm)[C]	$2.5x10^{-2}$	$2.2x10^{-6}$:1

[B]CCE DATAZOO, averaged surface data from multiple cruises
[C]Ohman et al. 2012, Average data integrated over top 100m, divided by 100, without frontal values included

There was no spatial heterogeneity in nanoplastic abundance among the three study regions (NPSG vs. TR vs. CCE) on the Falkor cruise (top left). **The plankton:plastic ratio of CCE is higher than NPSG.**

Methods

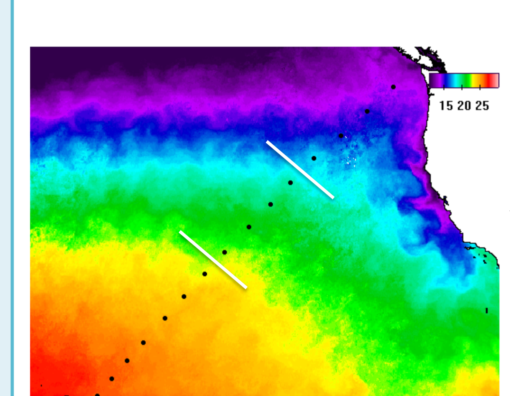
At-Sea Collection

Surface seawater samples were taken by metal bucket on 3 cruises:

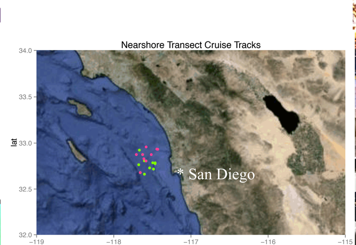
(1) R/V *Falkor,* a transect from Seattle to Honolulu, sampling every 12 hours

(2,3) SKrillEx I and II sampled the nearshore coastal water of the California Current

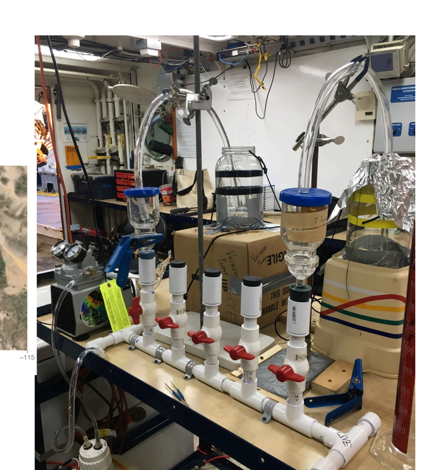
Surface water was filtered in an all-glass system onto 5 µm polycarbonate filters. Filters were then wrapped in tin foil and frozen at -80°C until analysis.



R/V *Falkor* cruise track over satellite SST, 8 km resolution. White lines delineate study regions



SKrillEx I and II Cruise tracks



Glass filtering setup

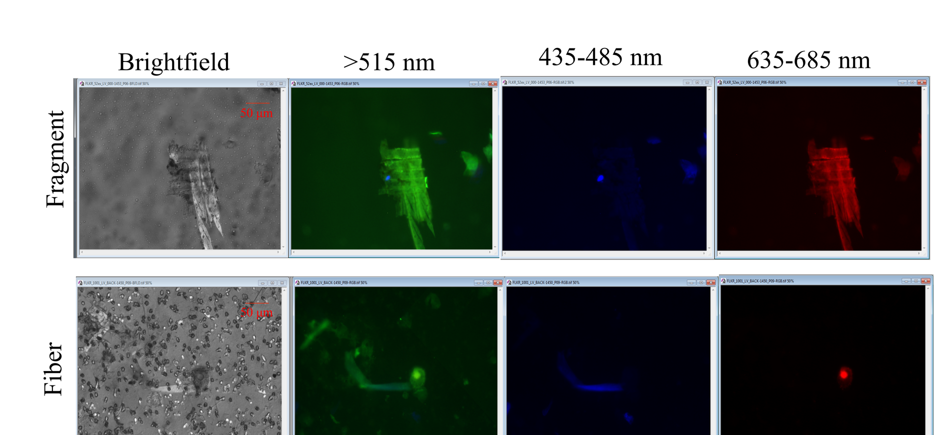
Epifluorescence Microscopy

Samples were analyzed by epifluorescence microscopy, at 4 different excitation/emission combinations. Autofluorescent plastic (≥5µm) could be clearly differentiated from the autofluorescence of living cells by wavelength-specific fluorescence signatures.

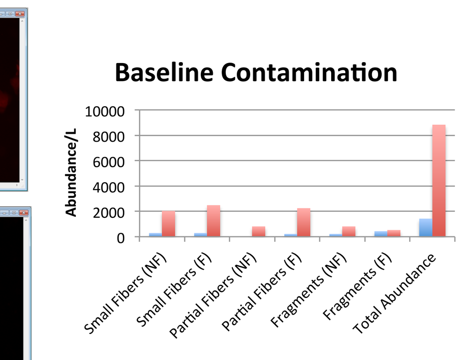
Intensity of Fluorescence of Standard Plastics

Excitation Wavelength	340-380 nm	450-490 nm	465-495 nm	536-556 nm
Emission Wavelength	**435-485 nm**	**>515 nm**	**635-685 nm**	**550-610 nm**
HDPE	++	++++	-	++++
LDPE	++	+++	-	++
PS	++++	++++	++++	++++
PP	+++	++++	-	++
PET	++	++	-	+
PVC	+++	++++	-	++
Nylon	+	++	-	-
Rubber	+++	+++	-	+
Polyester	-	-	-	-
Vinyl	+++	++++	-	+

- = no fluorescence
+ = very low fluorescence
++++ = high fluorescence



The degree of opacity in Brightfield and intensity of fluorescence under different wavelengths helps identify different plastic types.



Across each plastic type, the baseline contamination present, as measured by filtering Milli-Q water, is very low.

I quantified fluorescent (mainly PE,PS, and PP) and non-fluorescent (mainly polyesters, nylons) plastics and differentiated from non-plastics on the slide images. Milli-Q water under the same filtration protocol revealed that the baseline contamination of nanoplastics and fibers was very low.