Zooplankton fecal pellets as a vector transporting microplastics and associated toxins to the deep ocean

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Abstract:

Toxins within the fecal pellets of zooplankton were measured along a transect from Hawaii to San Diego, passing through the southern edge of the Great Pacific Garbage Patch. Zooplankton were collected via a vertical net tow at 4 different stations. Fecal pellets were analyzed in the lab using gas chromatography – time of flight mass spectrometry. At three of the four stations, the fecal pellets contained anthropogenic compounds- mainly phthalic acid. Station 6 (25.6595, -149.5) possessed the highest concentrations of phthalic acid at around 0.87 g/m^3, yet this station was not within the Great Pacific Garbage Patch. Fatty acids such as Hexadecenoic acid were also common within the samples collected. The prevalence of plasticizers and the locations at which they were found in this study can question current assumptions about the exact size and location of the Great Pacific Garbage Patch and suggest it is larger than previously known. The data in this study also suggests that more research should be done to assess how chemicals like phthalic acid can alter the settling rate of zooplankton fecal matter and what implications this can have on the ocean's biological pump.

Plain Language Summary

For my research, I wondered if the fecal pellets of zooplankton might carry toxic chemicals and microplastics from the Great Pacific Garbage Patch into the deep ocean. While aboard the UW's research ship R/V Thomas G. Thompson, I took samples by towing a net vertically up from the deep water to the surface, and I collected living zooplankton. I did this at 4 different stations. I left the zooplankton in a jar so they'd poop, and then I collected their poop onto a filter, which I then processed in a lab using fancy chemistry. I ran the samples on a machine called a time of flight mass spectrometer. The fecal pellets contained toxins at three out

of the four stations that I sampled. However, the station with the most prevalent levels of plastic toxins was not within the Great Pacific Garbage Patch. I found that puzzling, and it leads me to question previous knowledge about the exact position of the Great Pacific Garbage Patch. I hypothesize it has grown in size and/or increased in severity. I suggest further research needs to be done to examine how the presence of these toxins in the fecal pellets of zooplankton affects the deep ocean. When particle settle within the ocean, it is an important part of how the ocean sequesters carbon, and the presence of additional toxins and plastics could lower the rate at which particles settle in turn lowering the efficiency of this oceanic process.

Introduction

The scientific community has been aware of the presence of microplastics in our oceans since the 1970s, yet much remains unknown about this anthropogenic material and how it affects oceanic and biological processes (Andrady 2011; Kvale et al. 2020). There is an urgency to understand the potential negative implications of microplastics in our marine systems as their concentrations in our oceans continue to increase. (Andrady, 2011; Galloway et al. 2017). Particularly, the harmful chemicals associated with plastics can transfer and accumulate throughout the food web, can harm marine life, contaminate valuable food sources, and ultimately jeopardize human health (Campanale et al. 2020; Oehlmann et al. 2009).

The Pacific Ocean receives the highest amount of plastic waste out of all the world's oceans and the highest volumes are detected in a region known as the Great Pacific Garbage Patch (GPGP) (Isobe et al., 2019). The most common plastic additives found in this marine environment are polybrominated diphenyl ethers (PBDE), phthalates, nonylphenols (NP), bisphenol A (BPA), and antioxidants (Hermabessiere et al. 2017).

Recent microplastic research has been attempting to determine exactly where in the water column these plastics and associated toxins accumulate. Previous literature has suggested they remain buoyant in the surface ocean, however more recent work has suggested considerable amounts of microplastics are scattered from the surface waters and stored in the ocean's interior (Pabortsava and Lampitt 2020). As a result, previous assessments of microplastic abundance in the oceans are likely undervalued because these measurements do not account for plastics below the surface ocean. Previous literature has demonstrated that settling zooplankton fecal pellets can be a novel vector for microplastics in the ocean especially when other marine organisms consume these pellets (Cole et al. 2016). In addition, research has found that in the NE Pacific

Ocean, organisms consume microplastics (size range: 400−920µm) at a rate of 1 particle per 34 copepods and 17 euphausiids (Cole et al., 2016;Desforges, Galbraith, and Ross 2015). These papers hypothesize that microplastic toxins will be egested from zooplankton then transported down the water column contributing the levels of plastics within the ocean's interior. Zooplankton consumption and egestion is a critical part of the ocean biological pump as well which is a main pathway for the transport of organic matter and carbon sequestration (Figure 1).

For my research, I examined whether fecal pellets could then be a novel vector for transporting toxins associated with plastics away from the surface ocean and into the deep ocean. My hypothesis was that the fecal pellets of zooplankton would be a vector for the toxins associated with microplastics, especially at the samples within the Great Pacific Garbage Patch. The toxins I expected to see were polybrominated diphenyl ethers (PBDE), phthalates, nonylphenols (NP), bisphenol A (BPA), and antioxidants.

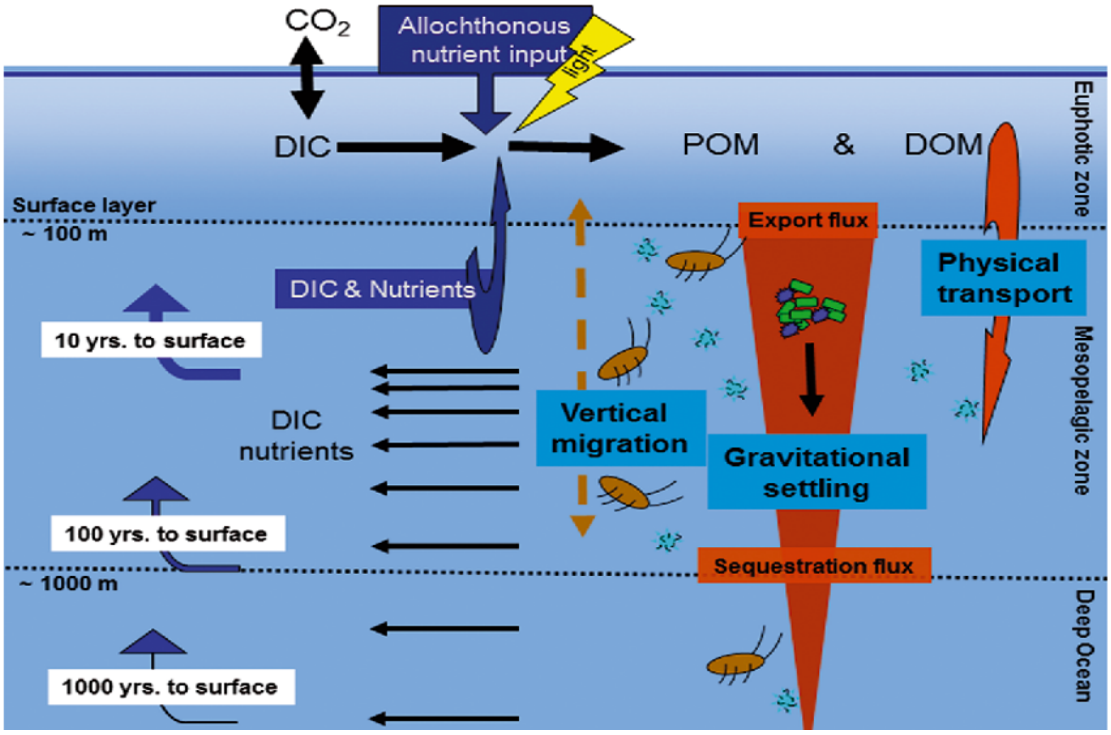

Figure 1: *Schematic of the biological pump. Reproduced from* (Passow and Carlson 2012).

Methods:

Samples were obtained between December 17th- December 30th from aboard the R/V Thomas G Thompson during a transect from Honolulu, Hawaii to San Diego, California. Zooplankton was collected using a vertical net tow that was pulled up the water column at a rate of 15 meters per minute with a 1-meter diameter and a mesh size of 333 μm. Four stations for this study were sampled during the duration of the cruise (Figure 2). Each vertical net tow sampled the top 200 meters of the water column and were taken at night between the hours of 2100 and 0300 when zooplankton are feeding to capture the highest number of zooplankton. After each tow was taken, the zooplankton was rinsed with a saltwater hose from the cod-ends into 1-gallon glass jars to avoid plastic contamination. Additional surface water from the CTD was added to the jars as well to create a more hospitable environment for the zooplankton. The sample jars with zooplankton were aerated with air stones attached to pumps then kept in the cold, dark room at 42 degrees F which are the conditions best suited to keep the samples alive for approximately 48 hours. This time allowed for maximum excretion to occur while the samples were still alive.

Figure 2: *Map showing each sample station with coordinates.*

To separate the fecal pellets from the organisms in the water, the sample was filtered through a 33-micron mesh sieve. I used a 47mm, a glass fiber filter (GFF filter), with a 0.7 pore size to isolate the fecal pellets (Figure 3, Step 1). Each station had multiple filters with isolated pellets. At Station Aloha, I collected 6 filters and 2 samples of a larger surface organism (identity undetermined). At station 6, I collected 8 filters with fecal samples. Station 10 had 4 filters, and station 16 had 2 filters. The variation in the number of filters used depended on how rapidly each filter became saturated with particulate. Each filter was folded with the particulate-carrying side facing inward to protect the sample then wrapped them in aluminum foil to keep plastic unintroduced to the sample. The filters were shipped back to Seattle, WA for further laboratory analysis.

Methods of Analysis:

Laboratory analysis occurred in the Keil Lab. A broad step-by-step depiction of lab work can be seen in Figure 3 steps 2 through 6. Samples were freeze thawed and were lacerated with alcohol cleaned scissors into bead beating tubes. The sample was lysed via three cycles each of mechanical disruption with silica beads (50% 100 µm diameter and 50% 400 µm) and 30 seconds in a high-power water bath sonicator. The resulting lysate was centrifuged at 4800 rpm to isolate fecal pellets in the supernatant.

An ethyl acetate liquid extraction was performed as described by Keil and Neibauer (2009). To evaporate the ethyl acetate, each vial was heated in the Turbovap at 45 deg. C and dried under a low N_2 flow. 200 μL of ethyl acetate was pipetted back into each tube with a dried standard. The sample was transferred to a 2 mL glass gas chromatography (GC) vial leaving as much sodium sulfate crystals in the tube. The following analytical methods were slightly

modified from the methods used in Keil and Neibauer (2009). Briefly, samples were analyzed by gas chromatography mass spectrometry (GCMS) using an Agilent 6890 Gas Chromatograph fitted with a J&W DB-1MS analytical column (60 m length, 320 μm internal diameter, 0.25 μm film thickness). Helium was used as a carrier gas in the GC, and samples were detected using a LECO Time-of-Flight Mass Spectrometer. Compounds were identified by comparing the mass spectral output of compounds in the samples to the NIST (National Institute of Standards and Technology) GCMS database. The data gathered was analyzed on Excel.

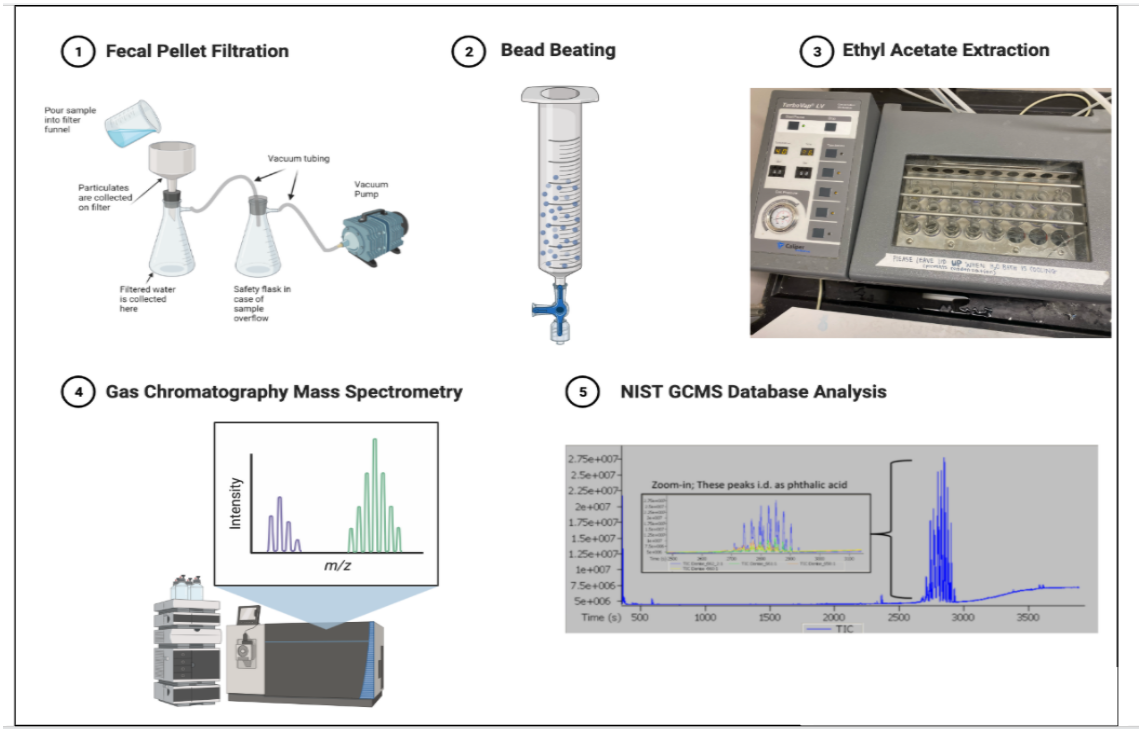

Figure 3: *An overview, step-by-step visual representation of the methods done in this analysis*

Results:

Station 6 had the most amount of overall chemicals with 132 different chemicals detected (Figure 4). Many of these chemicals are naturally occurring in the environment, but Table 1 shows the 5 most prominent chemicals found at each location. This was determined by looking at the highest signal-to-noise ratios (S/N), a GCMS measurement indicative of concentration. Stations 6, 10, and 19 have a similar distribution of chemicals. Phthalic acid, Hexadecenoic acid, and Silane were found in all 3 stations at high abundance. Phthalic acid and Silane are both compounds common in plastics and are anthropogenic. Hexadecenoic acid is a common fatty acid within the ocean. Significant traces of plasticizers were found in 3 out of 4 of the stations sampled (Figure 5). The station with the highest concentration of phthalic acid was station 6 and that value was approximately 0.87 g/m^3 and the station with the lowest concentration of Phthalic Acid was Station Aloha at 0.045 g/m^3 (Figure 5). Approximate concentrations of Phthalic Acid were determined converting values of S/N from the GCMS analysis.

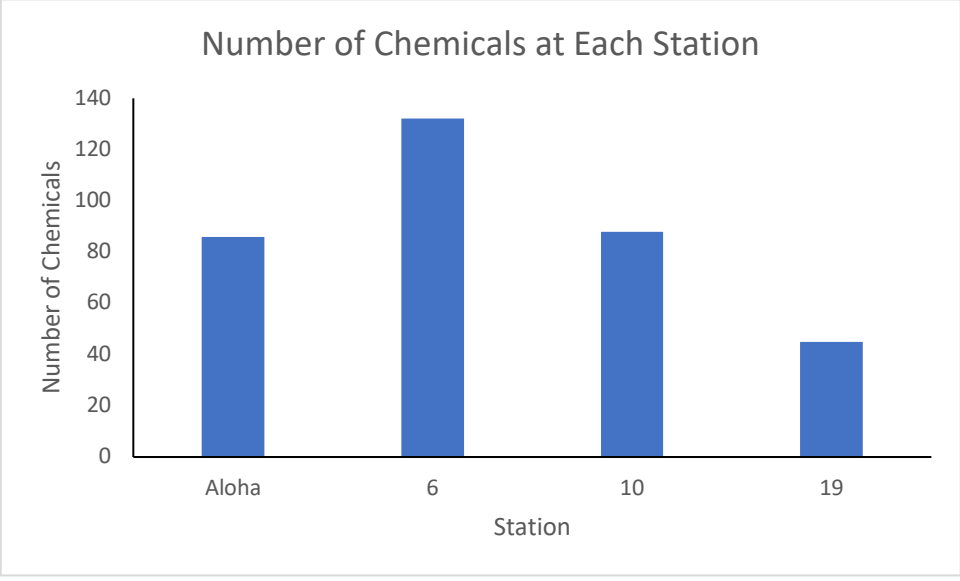

Figure 4: *Total amount of chemicals found from GCMS analysis at each station.*

Table 1: *The top 5 chemicals at each station with the highest signal-to-noise ratio.*

Most Abundant Chemicals at Each Station			
Station Aloha	**Station 6**	**Station 10**	**Station 19**
Hexadecanoic acid	Phthalic acid	Phthalic acid	Phthalic acid
Octadecanoic acid	Hexadecanoic acid	Hexadecanoic acid	Cholesterol trimethylsilyl ether
cis-4,7,10,13,16,19-Docosahexaenoic acid	Silane	Silane	Hexadecanoic acid
Hexadecanoic acid	Octadecanoic acid	Cholesterol trimethylsilyl ether	Silane
cis-5,8,11,14,17-Eicosapentaenoic acid	Stigmasterol trimethylsilyl ether	Octicizer	2,3-Dimethyldecane

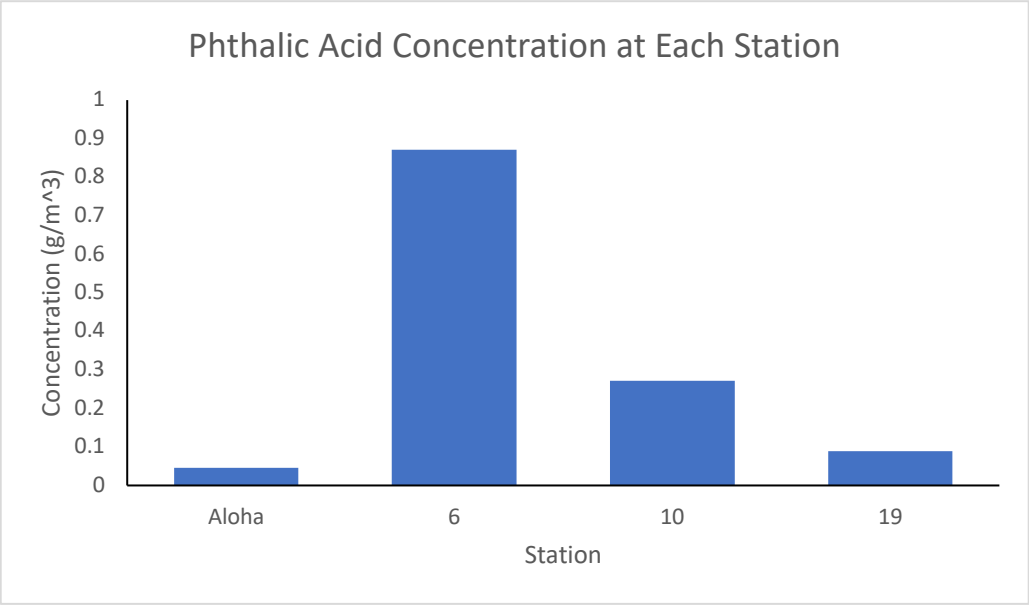

Figure 5: *Relative Concentration of Phthalic acid of each sample in each station.*

Discussion:

My hypothesis was that the fecal pellets of zooplankton would be a vector to the deep sea for the toxins associated with microplastics, especially at the samples within the Great Pacific Garbage Patch. The toxins I expected to see were polybrominated diphenyl ethers (PBDE), phthalates, nonylphenols (NP), bisphenol A (BPA), and antioxidants (Hermabessiere et al. 2017). I can confirm this hypothesis because phthalates are esters of phthalic acid which were found in my samples.

Minimal to no research has been done to assess these plasticizers in zooplankton fecal pellets specifically. However, as plastic concentrations are increasing globally, research has found phthalates in the both the water column and in other marine organisms. In a study conducted alongside this project, zooplankton from the NE Pacific Ocean were measured ingesting up to 2.32 particles of polystyrene beads per day per copepod (Brooks, 2022). At station 6 where this study measured the highest concentrations of plasticizers in fecal pellets, zooplankton were quantified to ingest approximately 1.11 particles of polystyrene beads per day per copepod (Brooks, 2022). In other research measuring pollutants in the Korean coastal area and the Jeju Strait (regions with prevalent plastic contamination), the highest concentration of phthalates acid esters (PAE) in the water column was 0.000109 g/m^3 (Paluselli and Kim 2020). This was significantly less than the highest concentration found in the fecal pellet samples suggesting that pollutants can accumulate at higher magnitudes in fecal pellets. However, in a similar study also conducted aboard the R/V Thompson during the duration of the cruise, no significant measurements of phthalic acid were detected at any of the surface water samples (Hull, 2022). In another study also using a GCMS procedure to survey plastic contamination in marine sponges in the Maldivian Reef, average PAE concentrations of 15.2 ± 3.0 ng/g were

detected in *Haplosclerida* sponges as microplastics were found to accumulate in their tissue (Saliu et al. 2022). My data found comparable levels of toxins in marine organic matter, and emerging research should continue to assess the impacts of PAEs in marine systems. It has been estimated that approximately 6,000,000 t/year phthalates have been produced throughout the world, and significantly PAEs have been shown to act as endocrine disrupters. (Campanale et al. 2020). Quantitative assessments of this chemical in marine systems should continue to be documented.

While plastic contamination can commonly occur in laboratory analysis considering its prevalence in lab equipment, we can dismiss phthalic acid as a potential contaminant for a few reasons. A blank was processed through the GCMS to be able to determine the chemicals produced and introduced into the samples because of the procedure used for GCMS analysis. Phthalic acid was not a chemical detected in the blank. An example of a plasticizer that was detected in the blank and occurred in many of my samples was 1,2,4-Benzenetricarboxylic acid, so we can deduce that the presence of this plasticizer in the samples was a result of the methods used. If phthalic acid was a contaminant, a similar pattern to 1,2,4-Benzenetricarboxylic acid would have been observed. In addition, the top panel in Figure 6 shows what many of my chromatography samples captured in comparison to what the samples detected when phthalic acid was prevalent. If phthalic acid was a contaminant, we would have observed the S/N peaks occurring more frequently in my other samples. Rather, the occurrence of phthalic acid is stochastic across the NE Pacific Ocean.

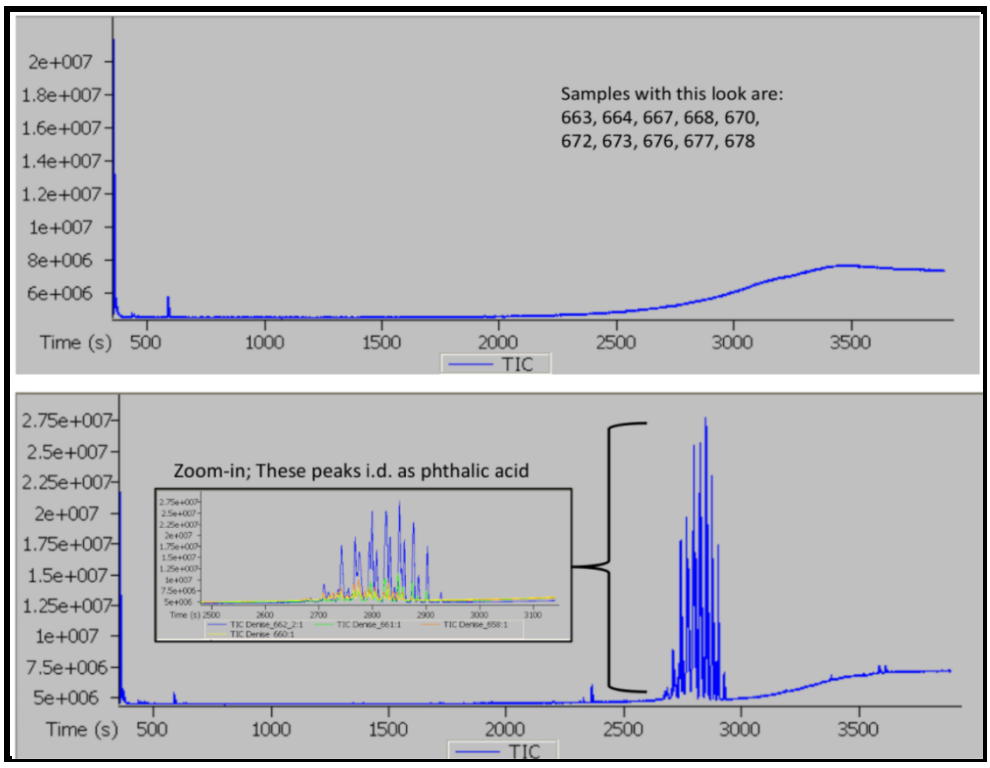

Figure 6: Images from chromatogram showing differences in samples with no traces of phthalic acid versus samples with peaks in phthalic acid. The top panel shows how the majority of samples looked like.

Zooplankton have been called "the gatekeepers of the biological pump" due to their importance in transferring organic matter throughout the water column and their settling fecal matter is a significant part of this process (Kiko et al. 2020). The incorporation of microplastics into sinking fecal pellets may decrease sinking rates (AM et al. 2019; Shore, deMayo, and Pespeni 2021). As a result, there have been concerns that long-term increases of microplastics concentrations in the ocean can decrease the efficacy of the biological pump (AM et al., 2019). The biological pump describes the movement of organic matter from the surface ocean to deeper layers, and this active flux is critical to the transport of organic material in the water column (Shore et al., 2021). Considering the high abundance of PAE in the fecal pellets of zooplankton, I would also project slower sinking rates like the decreasing sinking speeds in the fecal pellets seen by Alina M. Wieczorek who tested this using polyethylene and polystyrene samples *(*AM et

al., 2019*).* Carbon emissions are already reaching unprecedented levels, so further slowing of an important carbon cycle would only exasperate climate change. However, more research needs to be done on whether PAE contamination versus polyethylene and polystyrene is significant in this process.

The observation of plasticizers in the fecal pellets of zooplankton is significant because it questions what we know about the distribution of PAEs in the water column. In a previous study conducted on PAEs, data found that the vertical distributions of ΣPAEs were high in the surface waters but then generally decreased with depth (Zhang et al. 2020). I propose that the long-term trend should see an increase in PAEs with depth as zooplankton fecal pellets are transferring these pollutants into the deep ocean. Further research should look to expand the analysis of plastic pollution beyond just the surface ocean after observing chemicals like phthalic acid in settling fecal pellets so more accurate measurements on the abundance of plastics in the ocean can be quantified.

The next notable result from my data was that the high concentrations of plastic contamination were not at the station within the GPGP (station 10) but rather at station 6 which is further south than the region typically considered the GPGP. Not only did the fecal pellets have high levels of plasticizers, but the amount of plastic taken from the surface Manta Net tows in a study conducted also aboard the R/V Thompson was higher at station 6 than at station 10 (Miller, 2021). While this research cannot affirm a reason behind this occurrence, one hypothesis is that the GPGP is spreading over a larger area than originally believed. Current models suggest that the garbage patch is located about 30 to 40 degrees north latitude and 130 to 140 west longitudes (Figure 7). Recent studies to map the region of the GPGP relied on sea surface models and aircraft surveys to calculate abundance and distribution of plastic debris (Lebreton et al.

2018). While aerial imagery has created more accurate assessments of plastic distributions as it can account for larger sea surface areas, throughout the literature on marine plastic pollution, there are still a large discrepancy between predicted and observed ocean plastic concentrations (Lebreton et al. 2018). My research suggests that there are high levels of plastics below the sea surface. Zooplankton can be great biological tracers for this assessment since they interact with the top 200 meters of the water column as they undergo diel vertical migration. I would suggest further research needs to be done to more clearly understand the region the GPGP occupies and determine concentrations on plastics below the surface ocean as this can effect what we know about the distributions of plastic within the ocean.

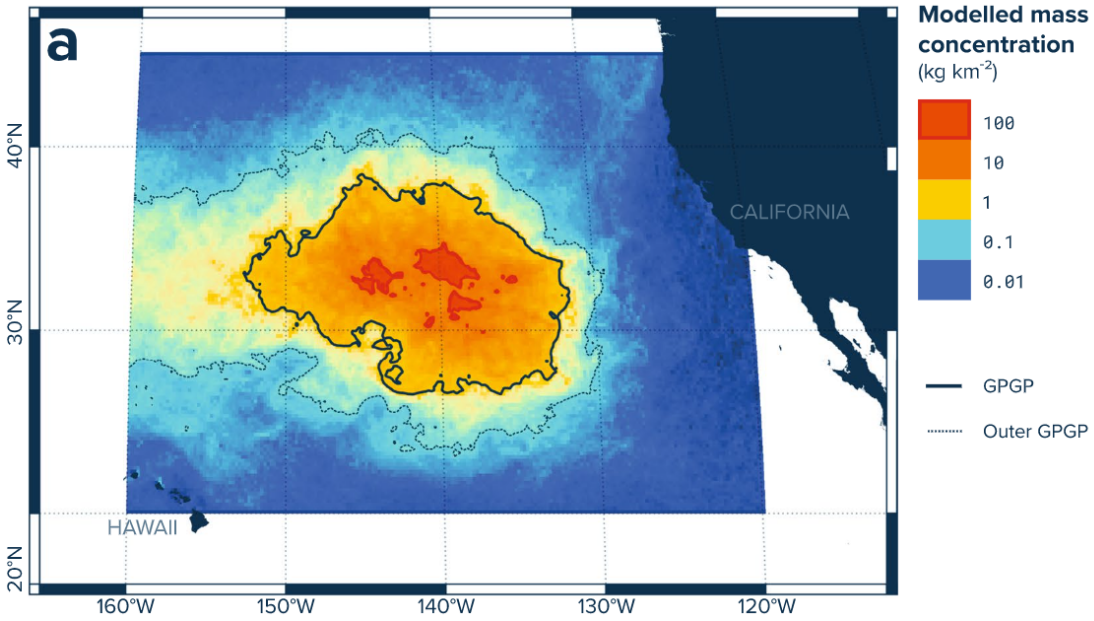

Figure 7: *Map depicting established limits and concentrations of the Great Pacific Garbage Patch. Produced from* (Lebreton et al. 2018).

Conclusion

In this paper, I analyzed the presence of microplastic toxins in the fecal pellets of zooplankton along a transect from the Hawaiian Islands through the southern edge of the Great Pacific Garbage Patch on the R/V Thompson. The data confirmed my hypothesis that fecal pellets act as a vector for plastic chemicals into the deep sea such as PAEs. Current research tends to focus more on microplastic ingestion and concentrations of pollutants in the surface ocean, but less is known about egestion and levels of pollutants in the water column beyond the surface. This data addresses that gap in the literature and highlights that there could be more pollutants in the deep sea than previously known. My hypothesis also assumed that the highest levels of pollutants would be within GPGP, but instead, the data in this paper found high concentrations further south of the region typically referred to as the Great Pacific Garbage Patch. This finding can question assumptions about the exact size and location of the GPGP.

I propose more work be done to determine how many and what type of chemicals are in the fecal pellets of zooplankton in other areas known for high levels of plastic pollution. It is important for research to determine where these pollutants are and how much of them are there. I would also encourage further research on the implication these pollutants can have on particle settling rate as it is a vital part of the carbon cycle on our planet. With carbon emissions already reaching unprecedented levels, further slowing of an important carbon sink can only exasperate climate change. Finally, I would also encourage more research to assess plastic abundance below the surface ocean as this area of research can close the gap on predicted versus observed levels of plastics in the ocean.

Acknowledgments

I would like to thank the School of Oceanography for providing me the opportunity to pursue this research for my undergraduate thesis and the staff of the R/V Thompson for helping in the sample collection of my data. Thank you to the Leo Maddox Foundation for support this research as well.

Specifically, I would like to thank Rick Keil, Jaqui Neibauer, and Kathy Newell for their mentorship throughout my research. Additional thank you to my peers who also helped with data collection and provided their support throughout the past few months. Thank you to peers Dylan Hull, Sidney Brooks, and Allison Miller whose senior projects were referenced and added more depth and data to my project.

Appendix:

Table 1: List of all the chemicals found at each station from GCMS data.

Chemicals Found at Each Staion			
Station Aloha	Staion 6	Station 10	Station 19
1-Docosene	1-(1-Cyclopropyl-pentyl)piperidine	1-Propanamine, 2-methyl-N-(2-methylpropylidene)-	1,2-Benzenedicarboxylic acid, bis(trimethylsilyl) ester
1-O-Hexadecenylglycerol, bis(trimethylsilyl) ether	1-Heptanamine, N,N-dimethyl-	1,2-Benzenedicarboxylic acid, bis(trimethylsilyl) ester	1,2-Benzenedicarboxylic acid, dinonyl ester
1-O-hexadecylglycerol - bis-trimethylsilyl ether derivative	1-Iodoundecane	1,2-Benzenedicarboxylic acid, diisooctyl ester	1,2,4-Benzenetricarboxylic acid, 1,2-dimethyl ester
1-O-Tetradecylglycerol, bis(trimethylsilyl) ether	1-O-Hexadecenylglycerol, bis(trimethylsilyl) ether	1,2-Benzenedicarboxylic acid, dinonyl ester	1,5-Heptadiene, 2,6-dimethyl-
1,2-Benzenedicarboxylic acid, bis(trimethylsilyl) ester	1-O-hexadecylglycerol - bis-trimethylsilyl ether derivative	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	2-(4'-Methoxyphenyl)-2-(3'-methyl-4'methoxyphenyl)propane
1,2-Benzenedicarboxylic acid, diisooctyl ester	1-O-Octadecylglycerol,- bis(trimethylsilyl) ether	1,2,4-Benzenetricarboxylic acid, 1,2-dimethyl ester	2,3-Dimethyldecane
1,2-Benzenedicarboxylic acid, dinonyl ester	1-O-Tetradecylglycerol, bis(trimethylsilyl) ether	3-Fluoro-5-(trifluoromethyl)benzaldehyde	3-Fluoro-5-(trifluoromethyl)benzaldehyde
1,2,4-Benzenetricarboxylic acid, 1,2-dimethyl ester	1-Trimethylsilyloxyheptadecane	4-Fluoro-3-(trifluoromethyl)benzaldehyde	3-Nonene, (E)-
11-Eicosenoic acid, trimethylsilyl ester	1-Trimethylsilyloxypentadecane	4-Methyl-2,4-bis(4'-trimethylsilyloxyphenyl)pentene-1	4-Methyl-2,4-bis(4'-trimethylsilyloxyphenyl)pentene-1
17-Pentatriacontene	1-Trimethylsilyloxytetradecane	5-Methyl-2-trimethylsilyloxy-acetophenone	5-Methyl-2-trimethylsilyloxy-acetophenone
1H-Indole, 1-(trimethylsilyl)-5-[(trimethylsilyl)oxy]-	1,2-Benzenedicarboxylic acid, bis(trimethylsilyl) ester	Acetic acid, trifluoro-, 3,7-dimethyloctyl ester	7-Phenyl-7H-triazolo[e]benzofurazan
2-(2-Naphthyl)-1,2-propanediol	1,2-Benzenedicarboxylic acid, diisooctyl ester	Cholesterol trimethylsilyl ether	Butanedioic acid, methyl-, bis(trimethylsilyl) ester
2-Piperidinecarboxylic acid, 1-(trimethylsilyl)-, trimethylsilyl ester	1,2-Benzenedicarboxylic acid, dinonyl ester	Cyclohexasiloxane, dodecamethyl-	Cholesterol trimethylsilyl ether
2,2'-Bi-1,3-dioxolane	1,2,4-Benzenetricarboxylic acid, 1,2-dimethyl ester	Cyclopentasiloxane, decamethyl-	cis-10-Heptadecenoic acid, trimethylsilyl ester
2,4(1H,3H)-Pyrimidinedione, 6-methyl-5-nitro-	1,3-Dioxolane	Cyclotrisiloxane, hexamethyl-	Cyclohexasiloxane, dodecamethyl-
3-Fluoro-5-(trifluoromethyl)benzaldehyde	1,3-Dioxolane, 2-heptyl-	Disilathiane, hexamethyl-	Cyclopentasiloxane, decamethyl-
4-Fluoro-3-(trifluoromethyl)benzaldehyde	11-Eicosenoic acid, trimethylsilyl ester	Disiloxane, hexamethyl-	Cyclotrisiloxane, hexamethyl-
4-Methyl-2,4-bis(4'-trimethylsilyloxyphenyl)pentene-1	2-Butanone, 3-methoxy-3-methyl-	Dodecanoic acid, trimethylsilyl ester	Disiloxane, hexamethyl-
5-Methyl-2-trimethylsilyloxy-acetophenone	2-Chloroaniline-5-sulfonic acid	Ethanedioic acid, bis(trimethylsilyl) ester	Dodecanoic acid, trimethylsilyl ester
9,12-Octadecadienoic acid (Z,Z)-, trimethylsilyl ester	2-Mono-isobutyrin, bis(trimethylsilyl)-	Ethylbis(trimethylsilyl)amine	Ethanedioic acid, bis(trimethylsilyl) ester
à-Linolenic acid, trimethylsilyl ester	2-Naphthalenemethanol, à-methyl-à-(1-methyl-2-propenyl)-	Hexadecanoic acid, trimethylsilyl ester	Ethylbis(trimethylsilyl)amine
Acetic acid, trifluoro-, 3,7-dimethyloctyl ester	2-Octene	Hexanedioic acid, bis(2-ethylhexyl) ester	Heptadecanoic acid, trimethylsilyl ester
Arachidonic acid, trimethylsilyl ester	2-Piperidinecarboxylic acid, 1-(trimethylsilyl)-, trimethylsilyl ester	Hexanedioic acid, mono(2-ethylhexyl)ester	Hexadecanoic acid, trimethylsilyl ester
Benzene, 1,1'-(1,1,10,10-tetramethyl-1,10-decanediyl)bis[3,4-dimethyl-	2-Piperidinone, N-[4-bromo-n-butyl]-	n-Pentadecanoic acid, trimethylsilyl ester	Hexanedioic acid, bis(2-ethylhexyl) ester
Chola-5,22-dien-3-ol, (3á,22Z)-	2,3-Dimethyldecane	N,N-Diethyl(trimethylsilyl)carbamate	n-Pentadecanoic acid, trimethylsilyl ester
Cholesterol trimethylsilyl ether	3-Fluoro-5-(trifluoromethyl)benzaldehyde	Octadecanoic acid, trimethylsilyl ester	N,N-Diethyl(trimethylsilyl)carbamate
cis-13-Docosenoic acid, trimethylsilyl ester	3,6-Dioxa-2,7-disilaoctane, 2,2,4,4,5,5,7,7-octamethyl-	Octicizer	Octadecanoic acid, trimethylsilyl ester
cis-15-Tetracosenoic acid, trimethylsilyl ester	4-Methyl-2,4-bis(4'-trimethylsilyloxyphenyl)pentene-1	Oleic acid, trimethylsilyl ester	Octane, 2,3,6,7-tetramethyl-
cis-4,7,10,13,16,19-Docosahexaenoic acid, trimethylsilyl ester	4-Oxo-2-pentene-2-amine, 1,1,1,5,5,5-hexafluoro-, (E)-	Phthalic acid, bis(7-methyloctyl) ester	Oleic acid, trimethylsilyl ester
cis-5,8,11,14,17-Eicosapentaenoic acid, trimethylsilyl ester	4,6-Dimethyl-2-thioxo-1,2-dihydro-3-pyridinecarbonitrile tbdms	Propanoic acid, 2-[(trimethylsilyl)oxy]-, trimethylsilyl ester	Palmitelaidic acid, trimethylsilyl ester
Cyclotrisiloxane, hexamethyl-	5-Methyl-2-trimethylsilyloxy-acetophenone	Propanoic acid, 2-oxo-, trimethylsilyl ester	Pentasiloxane, dodecamethyl-

Decane, 2,5,9-trimethyl-	5-Methyl-3-phenyl-1H-indazole	Pyridine, 2,4,6-trimethyl-	Phthalic acid, bis(7-methyloctyl) ester
Disilathiane, hexamethyl-	7-Phenyl-7H-triazolo[e]benzofurazan	Silanamine, N,N'-methanetetraylbis[1,1,1-trimethyl-	Propanoic acid, 2-[(trimethylsilyl)oxy]-, trimethylsilyl ester
Disiloxane, hexamethyl-	9,12-Octadecadienoic acid (Z,Z)-, trimethylsilyl ester	Silane, 1,4-phenylenebis[trimethyl-	Pyridine, 2,4,6-trimethyl-
Dodecane, 2-methyl-	9H-Purin-6-amine, N,9-bis(trimethylsilyl)-	Stigmasterol trimethylsilyl ether	Pyrimidine, 2,4-bis[(trimethylsilyl)oxy]-
Dodecane, 2,6,11-trimethyl-	à-D-Glucopyranoside, methyl 2-(acetylamino)-2-deoxy-3-O-(trimethylsilyl)-, cyclic methylboronate	Tetrasiloxane, decamethyl-	Silanamine, N,N'-methanetetraylbis[1,1,1-trimethyl-
Dodecanoic acid, trimethylsilyl ester	Acetamide, N,N-diethyl-	Triethylamine, 2-chloro-2'-(trimethyl)silyloxy-	Stigmasterol trimethylsilyl ether
Eicosanoic acid, trimethylsilyl ester	Adipic acid, di(oct-4-yl ester)	Trifluoromethyl-bis-(trimethylsilyl)methyl ketone	Tetradecanoic acid, trimethylsilyl ester
Ethanedioic acid, bis(trimethylsilyl) ester	Arachidonic acid, trimethylsilyl ester	Trimethyl[4-(1,1,3,3,-tetramethylbutyl)phenoxy]silane	Tetrasiloxane, decamethyl-
Ethylbis(trimethylsilyl)amine	Benzenamine, 2-ethyl-	Tris(trimethylsilyl)borate	Triethylamine, 2-chloro-2'-(trimethyl)silyloxy-
Heptacosane	Butane, 1-(1-ethoxyethoxy)-	Trisiloxane, octamethyl-	Trifluoromethyl-bis-(trimethylsilyl)methyl ketone
Heptadecanoic acid, trimethylsilyl ester	Cholest-4-en-3-one		Trimethyl[4-(1,1,3,3,-tetramethylbutyl)phenoxy]silane
Hexadecanoic acid, trimethylsilyl ester	Cholesterol trimethylsilyl ether		Tris(trimethylsilyl)borate
Hexanedioic acid, mono(2-ethylhexyl)ester	cis-10-Heptadecenoic acid, trimethylsilyl ester		Trisiloxane, octamethyl-
L-Leucine, N-(trimethylsilyl)-, trimethylsilyl ester	cis-13-Docosenoic acid, trimethylsilyl ester		
l-Proline, N-(2,2,2-trichloroethoxy)carbonyl-, pentyl ester	cis-15-Tetracosenoic acid, trimethylsilyl ester		
n-Pentadecanoic acid, trimethylsilyl ester	cis-2-Nonene		
N,N-Diethyl-1,1,1-trimethylsilylamine	cis-4,7,10,13,16,19-Docosahexaenoic acid, trimethylsilyl ester		
N,N-Diethyl(trimethylsilyl)carbamate	cis-5,8,11,14,17-Eicosapentaenoic acid, trimethylsilyl ester		
N,O-Bis-(trimethylsilyl)-N-methylleucine	Cyclobutyl methylphosphonofluoridoate		
Nonane, 1-iodo-	Cyclohexasiloxane, dodecamethyl-		
Octadec-9Z-enol trimethylsilyl ether	Cyclopentasiloxane, decamethyl-		
Octadecane, 3-ethyl-5-(2-ethylbutyl)-	Cyclopropane, octyl-		
Octadecanoic acid, trimethylsilyl ester	Cyclotetrasiloxane, octamethyl-		
Octane, 2,7-dimethyl-	Cyclotrisiloxane, hexamethyl-		
Oleic acid, trimethylsilyl ester	Decahydroisoquinoline-3-carboxylic acid, methyl ester		
Palmitelaidic acid, trimethylsilyl ester	Decane, 2,4,6-trimethyl-		
Pentasiloxane, dodecamethyl-	Dihydromorphine , di(trimehylsilyl) ether		
Phthalic acid, bis(7-methyloctyl) ester	Disilathiane, hexamethyl-		
Phthalic acid, nonyl 2-pentyl ester	Disiloxane, hexamethyl-		
Propanoic acid, 2-[(trimethylsilyl)oxy]-, trimethylsilyl ester	Docosanoic acid, trimethylsilyl ester		
Propanoic acid, 2-oxo-, trimethylsilyl ester	Dodecanoic acid, trimethylsilyl ester		
Pyridine, 2,4,6-trimethyl-	Eicosanoic acid, trimethylsilyl ester		
Pyrimidine, 2,4-bis[(trimethylsilyl)oxy]-	Ethanedioic acid, bis(trimethylsilyl) ester		
Pyrimidine, 5-methyl-2,4-bis[(trimethylsilyl)oxy]-	Ethylamine, 2-((p-bromo-à-methyl-à-phenylbenzyl)oxy)-N,N-dimethyl-		
Sebacic acid, bis(trimethylsilyl) ester	Ethylbis(trimethylsilyl)amine		
Silanamine, N,N'-methanetetraylbis[1,1,1-trimethyl-	Formamide, N,N-diethyl-		
Silane, (hexadecyloxy)trimethyl-	Heptacosane		
Silane, [bicyclo[4.2.0]octa-3,7-diene-7,8-diylbis(oxy)]bis[trimethyl-	Heptadecanoic acid, trimethylsilyl ester		
Silanol, trimethyl-, carbonate (2:1)	Hexadecanoic acid, 3,7,11,15-tetramethyl-, trimethylsilyl ester		

Silicic acid, diethyl bis(trimethylsilyl) ester	Hexadecanoic acid, trimethylsilyl ester		
Sulfurous acid, 2-ethylhexyl hexyl ester	Hexanedioic acid, bis(2-ethylhexyl) ester		
Sulfurous acid, 2-ethylhexyl isohexyl ester	Hexanedioic acid, mono(2-ethylhexyl)ester		
Sulfurous acid, 2-ethylhexyl undecyl ester	Hexasiloxane, tetradecamethyl-		
Tetradecanoic acid, trimethylsilyl ester	L-Norleucine, N-(trimethylsilyl)-, trimethylsilyl ester		
Tetrasiloxane, decamethyl-	l-Proline, N-(2,2,2-trichloroethoxy)carbonyl-, isobutyl ester		
trans-9-Octadecenoic acid, trimethylsilyl ester	l-Proline, N-(2,2,2-trichloroethoxy)carbonyl-, pentyl ester		
Tricarbomethoxyethylene	Mefloquine		
Triethylamine, 2-chloro-2'-(trimethyl)silyloxy-	n-Pentadecanoic acid, trimethylsilyl ester		
Trifluoromethyl-bis-(trimethylsilyl)methyl ketone	N-Trifluoroacetylmorpholine		
Trimethyl[4-(1,1,3,3,-tetramethylbutyl)phenoxy]silane	N,N-Diethyl(trimethylsilyl)carbamate		
Trimethylsilyl ether of glycerol	N,O-Bis-(trimethylsilyl)valine		
Tris(trimethylsilyl)borate	Nonadecanoic acid, trimethylsilyl ester		
Trisiloxane, octamethyl-	Octadec-9Z-enol trimethylsilyl ether		
Undecane, 2,10-dimethyl-	Octadecanoic acid, trimethylsilyl ester		
Unknown	Octanoic acid, hexadecyl ester		
	Oleic acid, trimethylsilyl ester		
	Oxalic acid, allyl tridecyl ester		
	Palmitelaidic acid, trimethylsilyl ester		
	Pentasiloxane, dodecamethyl-		
	Phenanthrene, 9-methyl-		
	Phthalic acid, bis(7-methyloctyl) ester		
	Phthalic acid, nonyl 2-pentyl ester		
	Propanoic acid, 2-[(trimethylsilyl)oxy]-, trimethylsilyl ester		
	Propanoic acid, 2-methyl-, anhydride		
	Propanoic acid, 2-oxo-, trimethylsilyl ester		
	Pyridine, 2,4,6-trimethyl-		
	Pyridine, 3,5-dimethyl-		
	Pyrimidine, 5-methyl-2,4-bis[(trimethylsilyl)oxy]-		
	Silanamine, 1,1,1-trimethyl-N-(trimethylsilyl)-N-[2-[(trimethylsilyl)oxy]ethyl]-		
	Silanamine, N,N'-methanetetraylbis[1,1,1-trimethyl-		
	Silane, (hexadecyloxy)trimethyl-		
	Silane, [(1-ethylpentyl)oxy]trimethyl-		
	Silane, [[(3á,5à)-cholestan-3-yl]oxy]trimethyl-		
	Silane, dimethyl(2,5-dimethylphenoxy)tetradecyloxy-		
	Silane, trimethyl(octadecyloxy)-		
	Silane, trimethylphenoxy-		
	Silanol, (1,1-dimethylethyl)dimethyl-, benzoate		
	Silanol, trimethyl-, carbonate (2:1)		
	Silanol, trimethyl-, phosphate (3:1)		
	Stigmasterol trimethylsilyl ether		
	Sulfurous acid, 2-ethylhexyl hexyl ester		
	Sulfurous acid, 2-ethylhexyl isohexyl ester		

	Sulfurous acid, 2-ethylhexyl undecyl ester		
	Sulfurous acid, hexyl nonyl ester		
	Tetradecane, 1-iodo-		
	Tetradecanoic acid, trimethylsilyl ester		
	Tetrasiloxane, decamethyl-		
	trans-13-Octadecenoic acid		
	trans-9-Octadecenoic acid, trimethylsilyl ester		
	Tricarbomethoxyethylene		
	Triethylamine, 2-chloro-2'-(trimethyl)silyloxy-		
	Trifluoromethyl-bis-(trimethylsilyl)methyl ketone		
	Trimethyl[4-(1,1,3,3,-tetramethylbutyl)phenoxy]silane		
	Trimethylsilyl ether of glycerol		
	Tris(trimethylsilyl)borate		
	Trisiloxane, octamethyl-		
	Undecane, 3,8-dimethyl-		
	Uracil, 1,3-bis(trimethylsilyl)-		
	Urea, triethyl-		
	Unknown		

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