AN ABSTRACT OF THE THESIS OF

Katherine Schuyler Lasdin for the degree of Master of Science in Fisheries Science presented on June 8, 2021.

Title: Characterizing Microplastic Ingestion in Black Rockfish (*Sebastes melanops*) along the Oregon Coast

Abstract approved: ____

Susanne M Brander

Microplastics (<5mm diameter) are present in a considerable number of marine and aquatic species. Understanding which species, the global spatial distribution, and what quantities of microplastics are present is extremely important for understanding the potential impacts they could have on recreationally important organisms and for the assessment of risk. We analyzed the gastrointestinal tract (GI) of wild caught Black Rockfish (*Sebastes melanops*) off the Oregon coast for the presence of microplastics, with a specific focus on marine protected areas (Cape Falcon, Cascade Head, Cape Perpetua, and Redfish Rocks). Suspected synthetic materials were found in 93.1% of the Black Rockfish caught off the coast of Oregon and were present in fish from every site. Of the potential synthetics, fibers were the most prevalent morphology with clear being the overall abundant color. Black rockfish are both recreationally and commercially important fish in the state of Oregon, and understanding the impact anthropogenic factors such as microplastics may have on them, and the implications to having plastics in marine reserves, will be valuable for risk assessment, as well as future policy plans and actions. In addition to understanding the number of plastics found in organisms, it is also important to have a basic understanding in how plastics may degrade. Through a National Science Foundation Research Traineeship (NSF-NRT), my

transdisciplinary team and I looked at the history of plastics, how plastics are recycled and projections for the future, and a model for how plastics may degrade. In addition to the teamwork, a few methods of PET(E) degradation were examined. With this knowledge, a more complete story of plastic exposure in Oregon marine fish is now in hand.

Characterizing Microplastic Ingestion in Black Rockfish (*Sebastes melanops*) along the Oregon Coast

by

Katherine Schuyler Lasdin

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APPROVED:

Major Professor, representing Fisheries Science

Head of the Department of Fisheries and Wildlife

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Katherine Schuyler Lasdin, Author

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There are many people I need to acknowledge as they have aided in my success throughout my time at Oregon state. First and foremost, I need to thank my advisor, Dr. Susanne Brander. As her first OSU student, I am extremely grateful for the trust she put in me to work and train other students in the lab. I appreciate all the lessons she has taught and perspectives she has given me. Next, I need to thank my co-advisor, Scott Heppell, and my committee members, Dr. Stacey Harper, Dr. Vrushali Boil, my GCR Dr. Felipe Barreto, and Dr. Rachael Orben who was my departmental research reviewer.

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CONTRIBUTION OF AUTHORS

In addition to my major professor, Ruby Chick and Heidi J Rockney contributed to the second Chapter of this document. Most of the text was taken directly from the Transdisciplinary Report that we co-wrote for the requirements of the National Science Foundation Research Traineeship (NSF-NRT) program from September 2019 through September 2020.

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DEDICATION

I dedicate this thesis to my family. Thank you for all the love and support.

1. Introduction chapter

Plastics are lightweight polymers that have been used to create and build a wide variety of products. As a fossil fuel-based product, plastics grew rapidly in popularity from the 1940s to today. With uses ranging from computers to cars, to containers, and writing utensils, our dependency on and improper disposal of these polymers have grown so much that now we are seeing large numbers of plastics in the natural environment.

Plastics have been produced since the late 1800s (American Chemical Society, 1993), but their impacts have become evident only relatively recently, over the past two decades. Thermoset plastics (polyurethane) consist of plastics that cannot be recycled into other shapes, while thermoplastics (polyvinyl chloride, polyethylene, polystyrene, polyethylene terephthalate) can be recycled into other types (UNEP, 2016). These 2 groups contain the 6 types of plastics currently in production: polyvinyl chloride, polyethylene, polyurethane, polyethylene terephthalate, polystyrene, and polypropylene (Miller et al 2017 and UNEP, 2016). Plastics are classified into five size categories. Mega plastics are the largest, and they are greater than 1000mm in diameter, followed by macro plastics, meso plastics, micro plastics, and nano plastics. Macro plastics are greater than 20mm, meso plastics are 5-20mm, micro plastics are less than 5 mm and nano plastics are sometimes classified as being <1um, and less frequently < 100 nm (Barnes et al 2009, Miller et al 2017, Shupe et al. 2021). Processes can break down larger plastics to micro or nano sized pieces and possibly even smaller.

There are several transport pathways plastics can take to the ocean. Plastics can be thrown out as trash or rinsed down the drain. Then they can enter the ocean via wind, water, animals, and humans. Wind can pick up light weight plastics and carry them long distances and deposit them into waterways, and eventually into the ocean. Lost, abandoned, and discarded gear (Macfadyen et al 2009) is found in water and may be a source of plastic fibers (Xue et al 2020).

Plastics now contaminate ecosystems globally and are ubiquitous in the aquatic environment. One estimate, which acknowledges they are missing many plastic sources, is that 10-23 Mt of plastic was introduced into the aquatic environment in 2016 but predicts this could increase to 90 MT/year within 10 years (Borrelle et al 2020). But, it's not just the presence of plastics that is of concern, it's that plastic debris is now found in the bodies of numerous aquatic biota, including European Seabass (*Dicentrarchus labrax*) (Espinosa et al 2018, Espinosa et al 2019, Pedà et al 2016 Barboza et al 2018a, Barboza et al 2018b, Mazurais et al 2015, Brandts et al 2018, Caruso et al 2018, Zitouni et al 2021), Korean Rockfish (*Sebastes schlegelii*) (Yin et al 2018, 2019), and Clown Anemonefish (*Amphiprion ocellaris)* (Nanninga et al 2020) and numerous other marine organisms including Pacific Oysters (*Crassostrea gigas*) and Pacific Razor Clams (*Siliqua patula*) (Baechler et al 2020a). Responses to plastics consumption include impacts on feeding, energy availability (Cole et al 2015), stress, and survival (Jacob et al 2020).

Due to these concerns described above, I (1) evaluated the occurrence of ingested plastics in the Black Rockfish (*Sebastes melanops)* off the Oregon coast, and (2) modeled degradation rates for plastics. As part of this work, I evaluated the presence of microplastics in the vicinity of Oregon marine reserves. Presence of plastics in marine reserves, either in the water column, sediments, or organisms, is expected, but nonetheless concerning. Marine Protected Areas are intended to protect species from anthropogenic stresses such as fishing, however, there is accumulating evidence that marine protected areas are far from pristine (Abessa et al 2018). By evaluating the number of plastics found in fish in the vicinity of the marine reserves and protected areas, appropriate studies and monitoring can occur to aid in better understanding the quality of water in and around these areas.

Knowing that plastics are in the water and in the bodies of marine animals is important, but further research is needed to understand how plastics degrade. By combining degradation information along with knowledge of where plastics are and what is consuming them, we can better create and fund future research projects to aid in the prevention of plastics in the marine environment as well as our seafood.

2. Spatial distribution of Black Rockfish (*Sebastes melanops*) consuming microplastics in Oregon waters

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2.1 Abstract

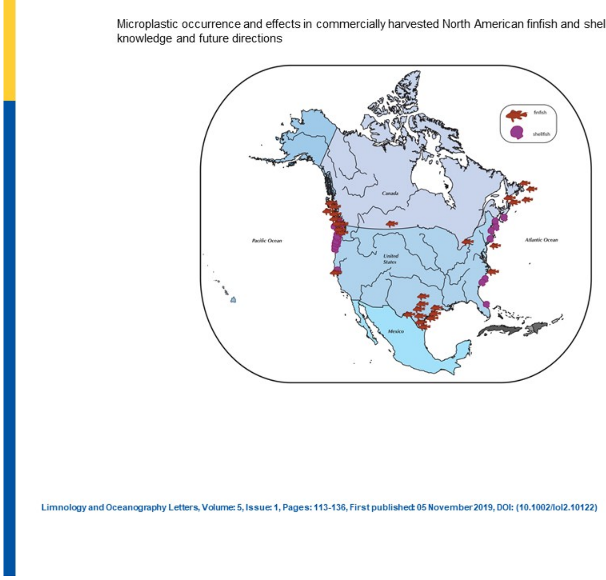
Microplastics (<5mm diameter) are present in a considerable number of marine and aquatic species. Understanding which species, the global spatial distribution, and what quantities microplastics are present is extremely important for understanding the potential impacts they could have on recreationally important organisms and for the assessment of risk. We analyzed the gastrointestinal tract (GI) of wild caught Black Rockfish (*Sebastes melanops*) off the Oregon coast for the presence of microplastics, with a specific focus on marine protected areas (Cape Falcon, Cascade Head, Cape Perpetua, and Redfish Rocks). Suspected synthetic materials were found in 93.1% of the Black Rockfish caught off the coast of Oregon and were present in fish from every site. Of the potential synthetics, fibers were the most prevalent morphology with clear being the overall abundant color. Black rockfish are recreationally and commercially important fish to the state of Oregon and understanding the impact anthropogenic factors such as microplastics may have on them, and the implications to having plastics in marine reserves, will be valuable for risk assessment, as well as future policy plans and actions.

2.2 Introduction

Plastic pollution affects marine organisms across life stages and taxonomic groups. Concern is warranted regarding larval and juvenile life stages (Steer et al 2017), as the presence of microplastics may affect settlement, recruitment, transport, and other processes critical to survival and fitness (White et al 2019). Plastic presence and the effects on fishery species, leads to numerous questions regarding how plastics make their way into food chains and the impact it will have on organisms and potentially people (Wang et al 2020b, Choy et al 2019). The impacts of plastics can range from subtle, to drastic and deadly.

Interactions with plastics can lead to problems with feeding (Yin et al 2018), swimming (Pannetier et al 2020, heart rate (Li et al 2020) , gene expression (Li et al 2020, Wang et al 2019) and survival (Assas et al 2020, Pannetier et al 2020Brander et al. in review). But, beyond these immediate impacts, fishery species are caught for consumption as food.

Baechler (2020b), identified a long list of knowledge gaps regarding studies on internalization of microplastics in commercial fishery species, including the need to study a variety of species and pointing to critical gaps in the spatial spread of finfish studies in North America (Figure 1).



Microplastic occurrence and effects in commercially harvested North American finfish and shellfish: Current knowledge and future directions

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Figure 1: Map from Baechler et al. (2020b) showing the location of plastic studies of commercial finfish and shellfish studies in North America. Used with Permission by Authors and *Limnology and Oceanography Letters*.

To fill the knowledge gap surrounding microplastic prevalence in finfish in the Pacific Northwest region of North America, Black Rockfish (*Sebastes melanops*) gastrointestinal (GI) tracts were examined for the presence of plastics, specifically microplastics (<5mm). Chosen as a test species due to their mode of feeding, relatively small home range, and importance to the state of Oregon, this opportunistic predator is an important recreational and commercial species, as well as being important culturally. Black Rockfish are known to consume a variety of organisms including mysid shrimp, juvenile fish, amphipods, shrimp, euphasiids, Dungeness crab megalopa, and squid, along with miscellaneous, Nedmatoes/Nemertean and non-prey items (Love et al. 2002, Doran 2020). Of the seven groundfish groups Oregon Department of Fish and Wildlife (ODFW) tracks, Black Rockfish has the highest recreational quota allocated at 373.1 MT for 2021 (Oregon Department of Fish and Wildlife, Marine Resources Program 2021). These organisms are ideal for the study of local pollutant effects in part due to their smaller home range (Parker et al 2007, Green and Starr 2011). Parker et al 2007 showed that a majority of fish stay within : 0.55 +/- 0.09 km2 (converted from original units of ha), while Green and Starr et al (2011) showed that the home range was between 0.07 and 0.56 km2.

2.2.1 Hypotheses

We predict that both macro and micro pieces of plastic will be found in the black rockfish GI tracts, that there will be no difference in the number of plastics found in the fish in the vicinity of marine reserves and from off the coast of Newport, Oregon, and that there will be minimal spatial variation in the number of pieces of plastics between the 4 marine reserve locations. Understanding the size and abundance of microplastics in these fish will provide us with a better understanding of the ubiquity and spatial distribution of these pollutants. These predictions were made based off the understanding that plastics are pervasive in the marine environment, and as of yet no location has been deemed unexposed. There are many positive outcomes from marine reserves that are no-take (Sala and Giakoumi 2018), but marine protected areas are not generally effective in protecting deep sea areas from pollution, including plastic pollution (Chiba et al 2018), even though Oregon reserves are not in the deep sea. As such, management strategies should include consideration of exposure to this emerging pollutant, especially for no-take MPAs which are the most valuable in terms of protecting marine life (Sala and Gaikoumi 2018).

2.3 Materials and Methods

2.3.1 Sample collection

Samples came from 2 different types of sites, 1. the port town of Newport, Oregon and 2. in proximity to four geographically distinct Oregon marine reserves, where samples were collected by the Oregon Department of Fish and Wildlife. Near-reserve fish were collected on average 13.23km away from the respective reserve (see table 2). Newport samples were collected in cooperation with a local recreational charter fishing company. Due to the wide spatial spread of where the Newport Marina Store and Charter company can sample, the Newport site is not geographically explicit, although it is geographically distinct from the reserve locations. The samples caught in Newport, Oregon (herein referred to as Newport samples) and samples collected from near/outside four Oregon marine reserves (from here referred to as Reserve samples) were placed into plastic bags and frozen until dissection in a clean lab space. Once in the lab, the reserve samples were removed and wiped with ethanol before being dissected. There were a total of 58 samples (GI tracts dissected from whole fish) from the five sites (Newport: 14, Cascade Head: 10, Cape Perpetua: 13, Cape Falcon: 10 and Redfish Rocks: 11) (Figure 2).

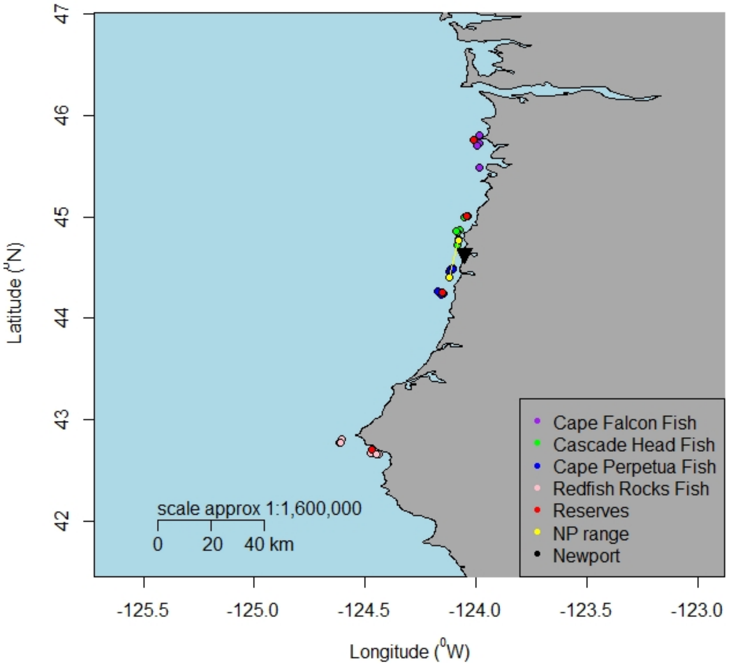

Figure 2. Location of sample sites on the Oregon coast. The Newport range approximates the range from which Newport (NP) fishing charters operate. These data were provided to us by a captain from the charter company.

2.3.2 Sample dissection and digestion

All dissections and microscopic analyses were completed in a laminar flow hood (Erlab Captair Flow 391, Rowley, Massachusetts, USA) with a HEPA filter, or a fume hood with HEPA filter, using a Leica EZ4W scope (Leica, Letzar, Germany) and camera set up, following recent recommendations for maintaining clean spaces and low levels of background contamination (Cowger et al. 2020, Brander et al. 2020).

Samples were weighed and dissected prior to contents of the stomach being removed. The remaining GI tract was placed into mason jars capped with lids turned lining-side out with a 20% solution of potassium chloride (KOH) in a 1:3 w.v. solution or a minimum of 100ml and digested for 48-72 hours at 50˚C in a water bath (either a Fisher Scientific Model Isotemp 220, Waltham, Massachusetts, USA or a

Precision Scientific 180 Series Water Bath, Chicago, Illinois, USA). Next, the samples were sized on a 63micron sieve before being vacuumed on a 5µm Whatman polycarbonate filter using a Büchner funnel (per Joseph et al. in prep). Approximately 100ml-300ml of sample was vacuumed per filter. Due to the volume of the samples, a separatory funnel was used. When samples were too lipid-rich to digest completely with KOH a 10% Alcojet solution was used to aid in the breakdown of organic matter (personal communication, Hannah De Frond, University of Toronto), followed by being sieved on a 1mm and 63µm filter. Glassware was cleaned using soap and water, rinsed with DI and RO water then rinsed with 70% ethanol and wrapped in foil prior to being baked at 400 degrees Celsius for four hours (Thermo Scientific Model F30420C, Asheville, North Carolina, USA). See Figure S1 for a Schematic of Methods.

2.3.3 Measurements

All suspected plastics were imaged using a Leica EZ4W microscope with included camera (8, 10, 12.5, 16, 20, 25, 30, 35X) in the laminar flow hood described above, with HEPA filter (H 14, >0.3um is filtered 99.995%). Measurements of plastics were completed using the Las EZ software or with the LevenhukLite software, all measurements were in mm. The LevenhukLite software provided measurements in pixels and were converted to mm. Vacuum filters used to process fish samples were picked on average for between 1 and 3- hours due to time constraints. Morphology and color of the suspected plastic were determined at time of picking or with the images, and protocols from Rochman et al. (2019) were followed as closely as possible. However, anything long and with a width that appeared to be smaller than the length was called a fiber due to the difficulties in deciding between fiber, fragment and film. For example, items were called fibers even if they were not the same thickness along the entire length. Some of this difficulty in assigning morphologies was due to the highly weathered nature of these microparticles retrieved from the gut.

Once picked, putative plastic pieces were placed into an acrylic container or on a piece of projection paper with double sided sticky tape. All pieces were visually inspected a second time at a later date to determine if they would break; to determine if they were plastic. Although weathered plastics can be fragile, organic materials are more likely to break with small amounts of force (Lusher et al 2020). If they broke, most of these pieces were not included in the final number of potential plastics or anthropogenically impacted materials. However, a small portion of pieces were verified with OMNIC as plastic prior to being poked and were kept in the final analysis.

2.3.4 Fournier Transform Infrared Spectroscopy

A subset (~ 25%, per Brander et al. 2020, Cowger et al. 2020) of all suspected plastics from fish and blanks were verified on a Thermo Fisher Nicolet iN5, smart iTX, and Nicolet iS20 FTIR (Waltham, MA). These readings produce a spectrum that can be compared to a standard and a correlation value is provided. All pieces were run measuring reflectance, many with a fixed aperture, followed by micro-Attenuated Total Reflectance (μATR)/ATR using OMNIC software initially. OMNIC readings were then smoothed and matched to plastic-specific databases in Open Specy (Cowger et al 2021). A majority of the pieces run with reflectance, or a diamond/germanium tip for uATR, had the gain set to autogain. 64-256 scans were conducted on each item. Over 43% of suspected microplastics were run in this way, and these were subsampled and mostly fibers were run as they were the most common morphology. Several libraries were used including the standards that come with the machine, a library from Sebastian Primpke (Primpke et al 2018), one created by the NOAA marine debris program research at UNCW, and other libraries created in-house. These libraries contained standards, and commonly used plastics in our lab as well. In order for a spectrum to be deemed acceptable and usable, all 10 math matches in OMNIC needed to be above 40. Further, baseline correction, smoothing of the spectra, and the wavelengths were adjusted with OpenSpecy (Cowger et al 2021). Open Specy provides a range of values for applying a baseline correction polynomial and smoothing, as well as additional plastic-specific spectral databases, which can adjust the math match and potentially the material. However, to be consistent, all smoothing values were kept at 3 and all baseline correction values were kept at 8. Final spectra were used if Open Specy had the top 5 matches above 70. Items where ATR readings could be not obtained were not used and run through Open Specy.

The pieces that were run through Open Specy were categorized into 4 categories: synthetic, natural, anthropogenic unknown, and anthropogenic origin. Definitions for anthropogenic unknown and anthropogenic origin were adapted from Miller et al (2021). We used anthropogenic unknown to classify particles that had a mixture of synthetic, natural and cellulose readings within the top 5 Open Specy matches (see appendix). Anthropogenic origin is used for materials that had the top 5 Open Specy readings as a mixture of cellulose (e.g., paper cup, cardboard). For a particle to be classified as synthetic or natural, all top 5 Open Specy matches had to be synthetic (e.g., polymer) or natural materials (e.g., shell), respectively.

2.3.5 Blanks

Several blanks were used throughout this project including DI, Milli-Q and RO water (water source was switched mid-project), air blanks and KOH procedural blanks, however only a subset was included in final analysis (see Table 1 for the number of blanks used in analysis). DI, RO, and Milli-Q water was used to make solutions and to wet filters. To account for any contamination from these water samples, a sample was collected, and vacuumed following procedures listed above. A Whatmann filter was stamped with a 12X12 (see appendix Figure 2) box grid and placed into a glass petri dish each day a fish sample was open under the hood. This allowed us to account for plastic pieces that potentially deposited from the air into our samples within the hood. Finally, we used a KOH procedural blank to track contamination throughout the process of sample digestion, sieving, and vacuuming.

2.3.6 Method Limitations

There are limitations in methodology, for example the size of the vacuum filter or varying with ones' dexterity that leads us to believe that there is an underestimation in the number of plastics found. There are also several changes in methodology throughout this project leading to differences in how items were subsampled for picking, how long filters were picked for, how information was recorded, how materials on the sieves were handled, and settings used on the FTIR. Due to these changes, it could be expected that we lost and/or underestimated the number of plastics found in these Black Rockfish.

2.3.7 Statistics:

All statistics and figures (e.g., maps) were completed using RStudio (version 1.4.1106) or Excel (version 2104). In order to determine the proportion of plastics in the NP fish and reserve fish and the likelihood of obtaining the same results again, a Wilson's score interval was calculated: $((\frac{(\#\ fish\ with\ or\ \ without\ plastics)(1.96)}{(total\ fish\ from\ the\ site+1.96)} \pm \frac{1.96}{(total\ fish\ from\ the\ site+1.96)} * ((\frac{(\#\ of\ fish\ with\ or\ without\ plastics}{total\ fish} + 1.96^{2/4})^{\ 0.5}$. An ANOVA using a Poisson distribution and a Tukey post-hoc test was used to identify any differences in the total number of pieces per fish across sites, at an alpha of 0.05.

2.4 Results:

Of the 424 pieces, 115 (27.1%) were categorized as good matches (top 10 over 40 in OMNIC and top 5 above 70 in Open Specy) with FTIR and OMNIC. Anthropogenic origin had the highest percentage of the pieces verified with OMNIC and Open Specy, with 68 pieces out of 115 total (59.1%) (Figure 3). Synthetics made up 15.6%, and anthropogenic unknown and natural made up 22.6% and 0.03%, respectively (Figure 3). 74.8% of the pieces verified by OMNIC and Open Specy as good matches were fibers (Figure 4). 10 colors made up the 18 pieces of synthetics verified, with black being the most common color (Figure 5). Seven colors were found in the Anthropogenic Origin category of pieces collected from fish (Figure 6).

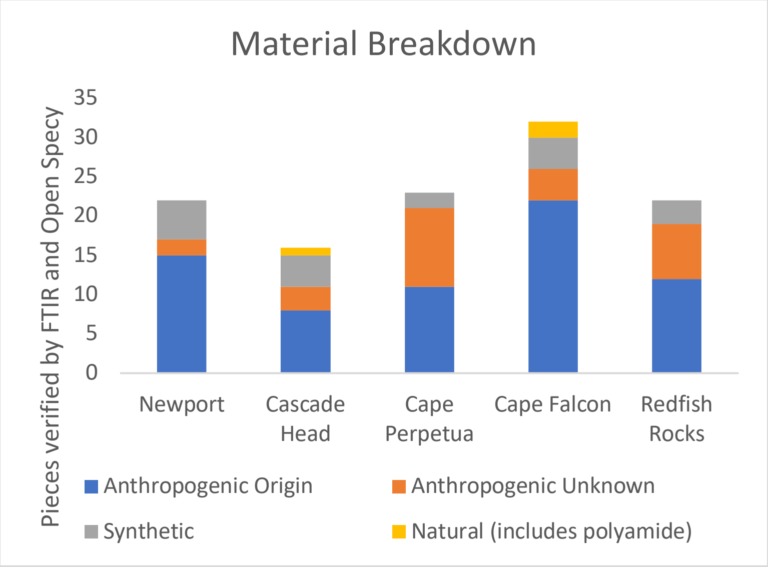

Figure 3. Characterization of the suspected synthetics after OMNIC and Open Specy.

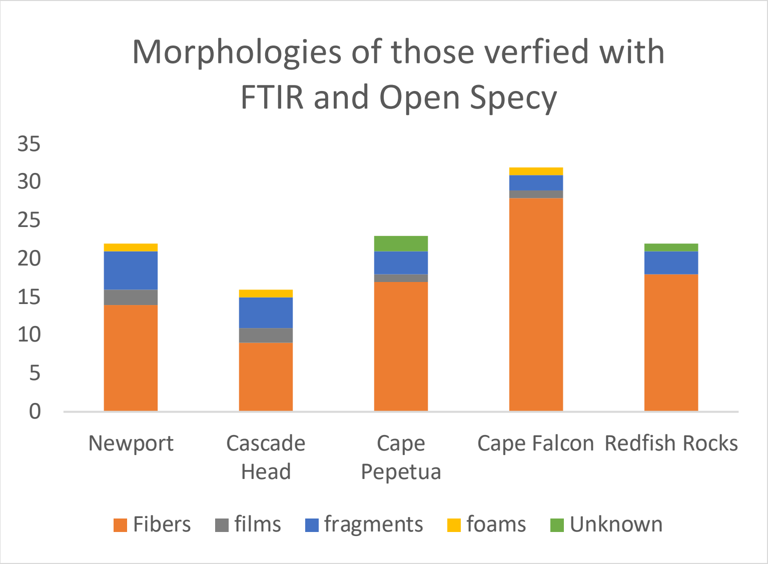

Figure 4. Morphologies of good matches from FTIR and Open Specy

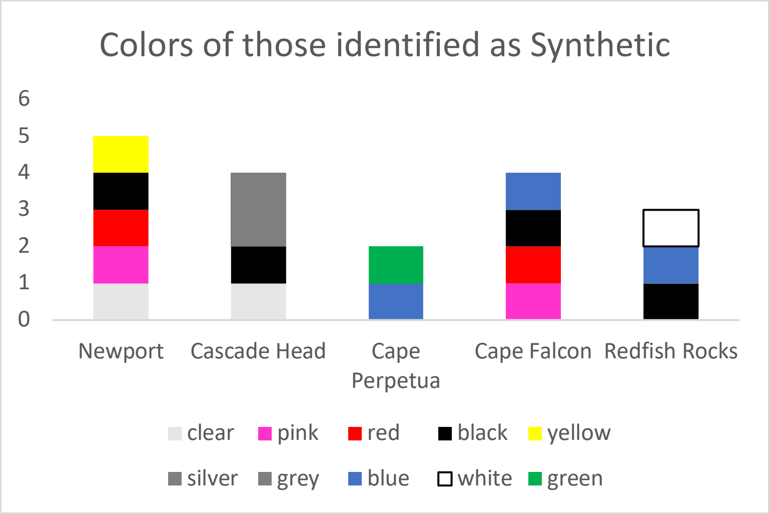

Figure 5. Colors of pieces verified as synthetic after FTIR and Open Specy from fish samples

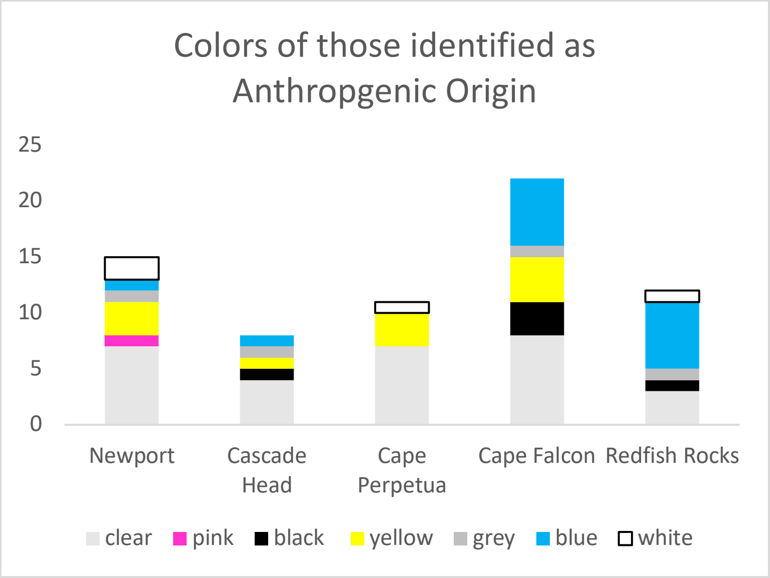

Figure 6: Colors of pieces identified as Anthropogenic Origin from fish samples

Suspected synthetics were picked from 93% (54/58 fish) of all fish and 92.9% of the NP fish and 93.2% of the fish from all the reserves. Redfish Rocks had the lowest percentage of total plastic pieces, while Cape Falcon had the largest percentage of pieces, while only having 10 fish (Figure 7).

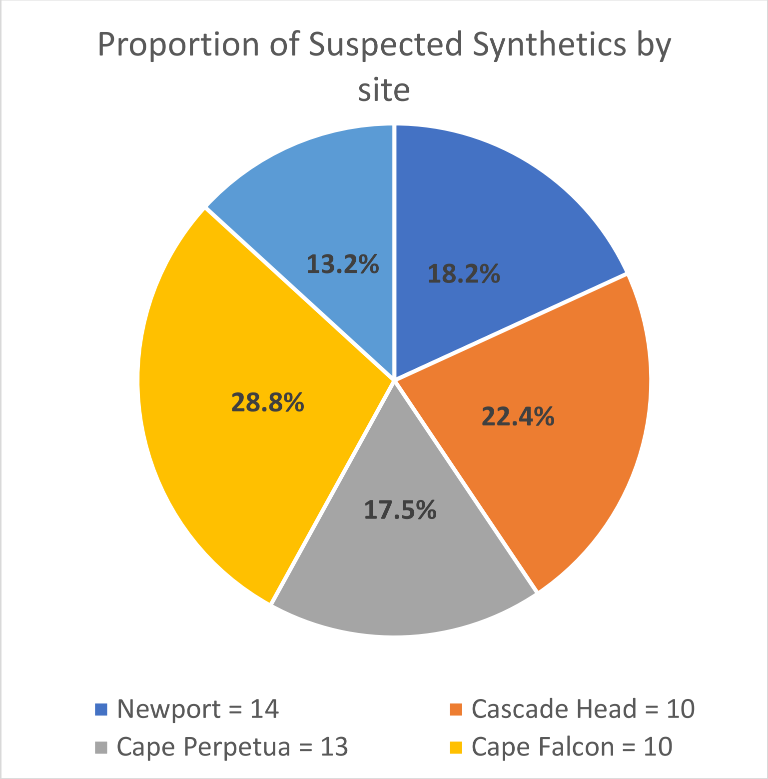

Figure 7: Percentages of all pieces by site. There were 424 total potential plastic pieces collected from 58 fish across the five sites. The values in the ovals are the number of fish from the respective site.

Fibers were the most abundant morphology found in Black Rockfish, followed by fragments (Figure 8), except at Cascade Head, where there was one more fragment than fiber (Figure 8). Since fibers were the most prevalent morphology, we included the average, minimum, and maximum length from each site. Newport had an average length of 1.17mm, with a minimum length of 0.21mm and a maximum length of 3.11mm. Cascade Head had an average length of 1.36mm with a minimum length of 0.15mm and a maximum of 9mm. Cape Perpetua had an average length of 1.01mm, a minimum length of 0.08mm and a maximum length of 2.43mm. Cape Falcon had an average length of 1.03mm, a minimum length of 0.18mm and a maximum length of 2.54mm. Finally, Redfish rocks had an average fiber length of 1.14mm, a minimum length of 0.17mm and a maximum length of 8.54mm.

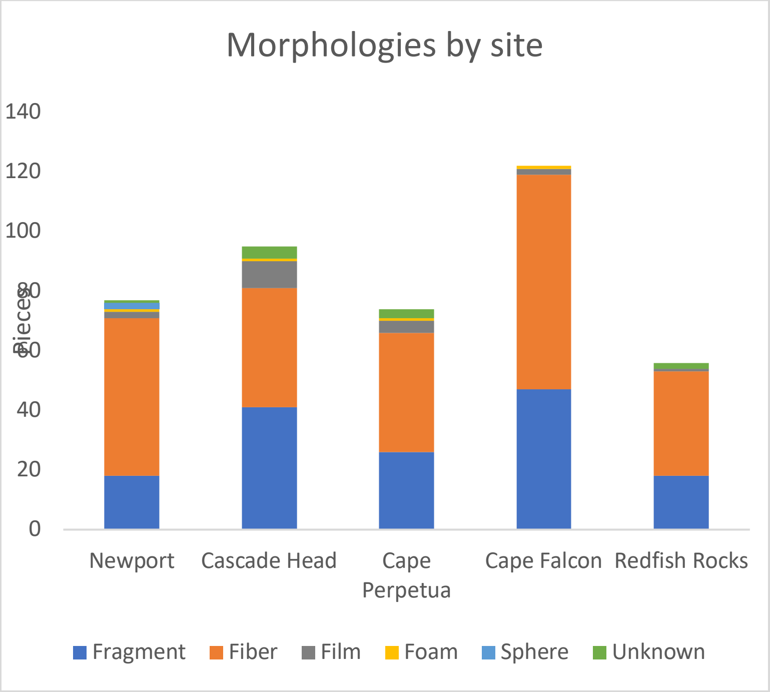

Figure 8: Breakdown of plastic types by site

Clear, which includes opaque pieces, was the most abundant color overall, except at Redfish Rocks. The second most abundant color was dependent on the site. White was the second most abundance color at Newport, grey at Cascade Head, yellow at Cape Perpetua, black at Cape Falcon, and clear at Redfish Rocks (Figure 9). 4.4732 pieces is the calculated impact of the three controls used in this study (Table 1; Figure 10 and 11). There were significant differences in the amount of ingested plastics in fish by site (Figure 15).

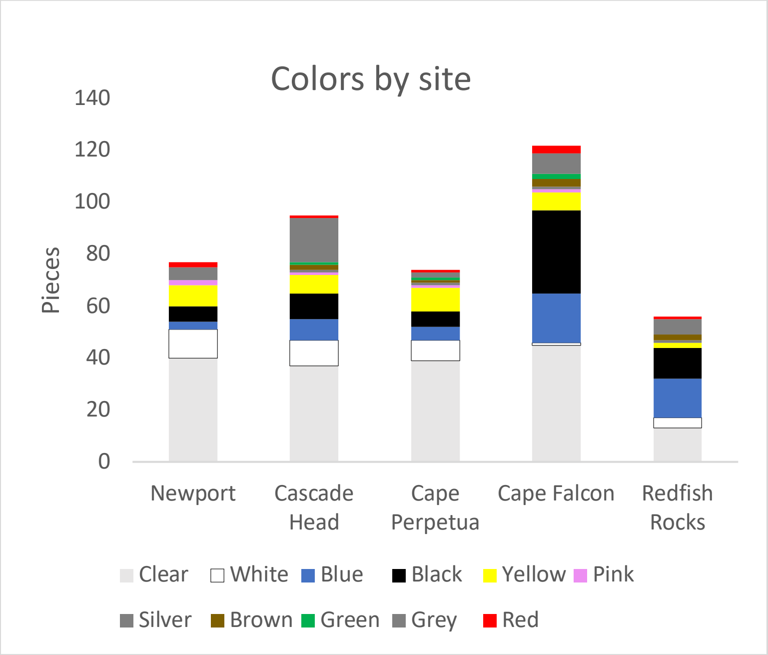

Figure 9: Break down of the potential plastics colors by site.

Table 1: Background estimation across air, water, and procedural blanks.

Control Type	Description	# Of plastics	# Of controls	Plastics/control	# controls/total fish	(plastics/control)(#controls/total fish)
KOH	Procedural blank	172	17	10.1176	0.2931	2.9655
Air	Blank	18	10	1.8	0.1724	0.3103
Water	Blank	100	12	8.3333	0.1437	1.1973
SUM						4.4732

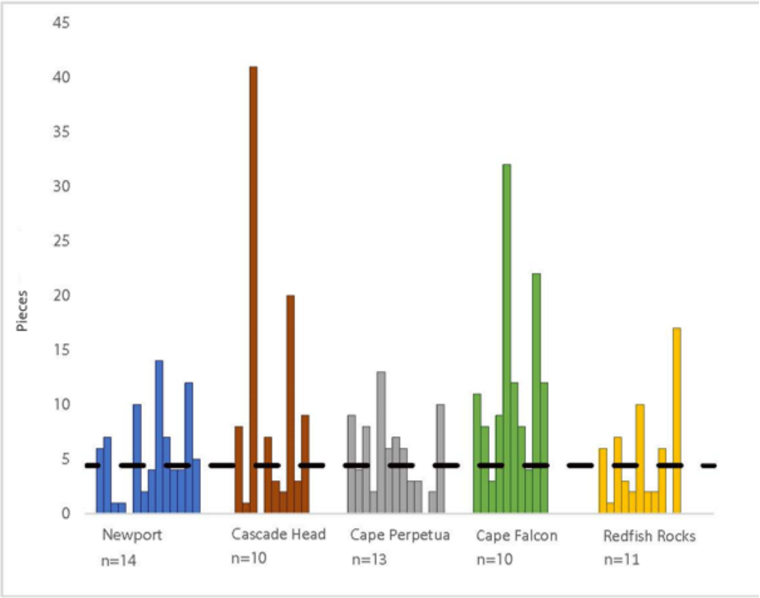

Figure 10: The number of pieces of suspected plastics per fish. The target line (horizontal y = 4.4732) shows the value of contamination from controls. The dashed line shows the potential impact of background contamination.

A subset of pieces from each of the controls were run under FTIR. 50 of 172 KOH pieces (29.1%) were verified as good matches, while 26 out 100 (26%) and 5 of 18 (27.8%) came from water and air, respectively (Figure 11). Fibers were the most common morphology in the good pieces verified by FTIR (Figure 12). Red was the most common synthetic color found in the background pieces, and they were both from KOH pieces (Figure 13). Finally, of the good readings from FTIR and Open Specy, seven colors were present in the Anthropogenic Origin (Figure 14).

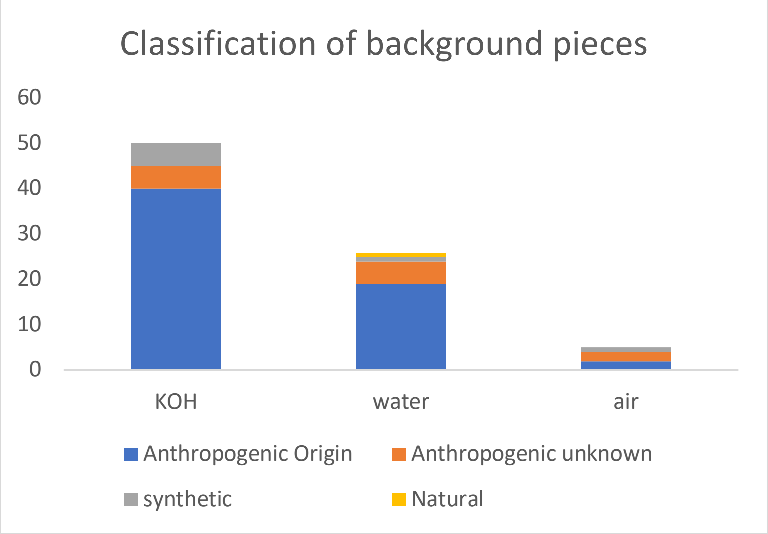

Figure 11: Classification of background pieces run on FTIR by where the background pieces came from (KOH, water, air).

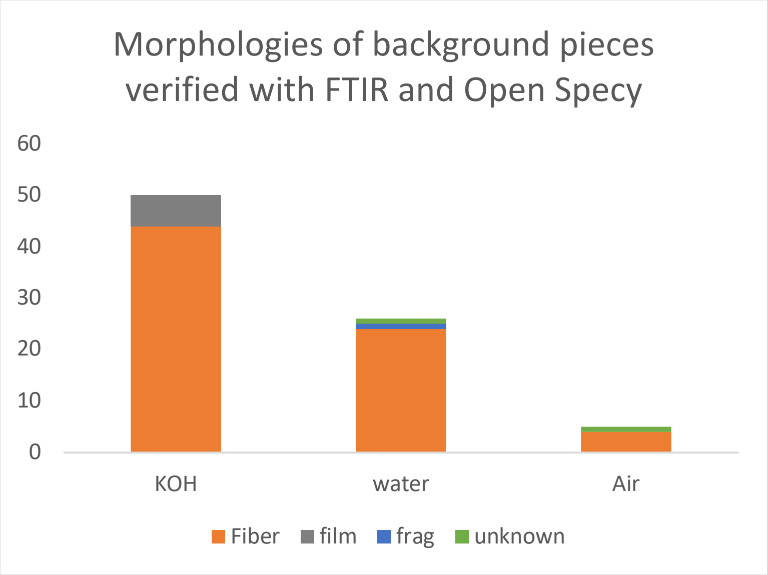

Figure 12: Morphology breakdown of background pieces verified with FTIR and Open Specy

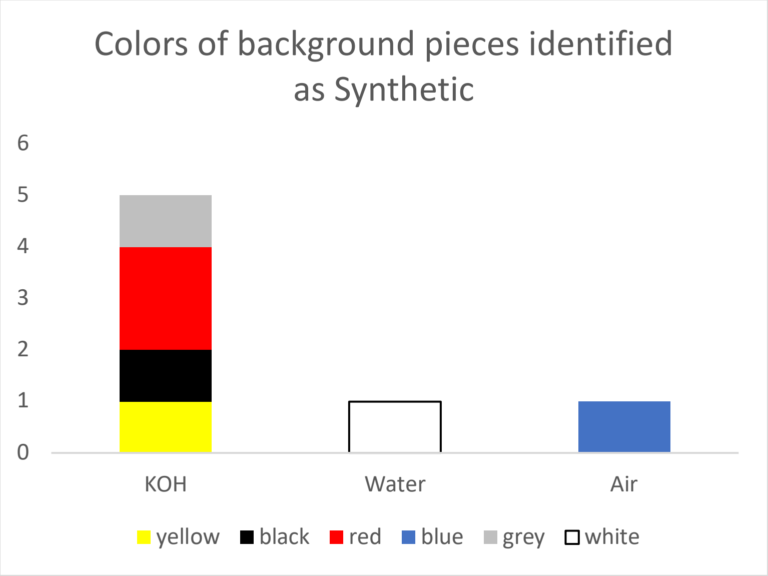

Figure 13: Colors of background pieces identified as synthetic by type of control

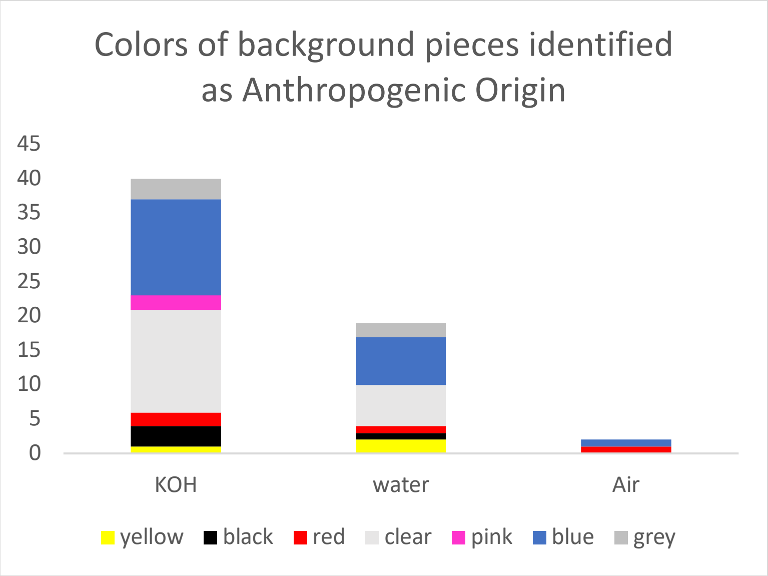

Figure 14: The colors of pieces identified as Anthropogenic Origin in background samples via FTIR and Open Specy

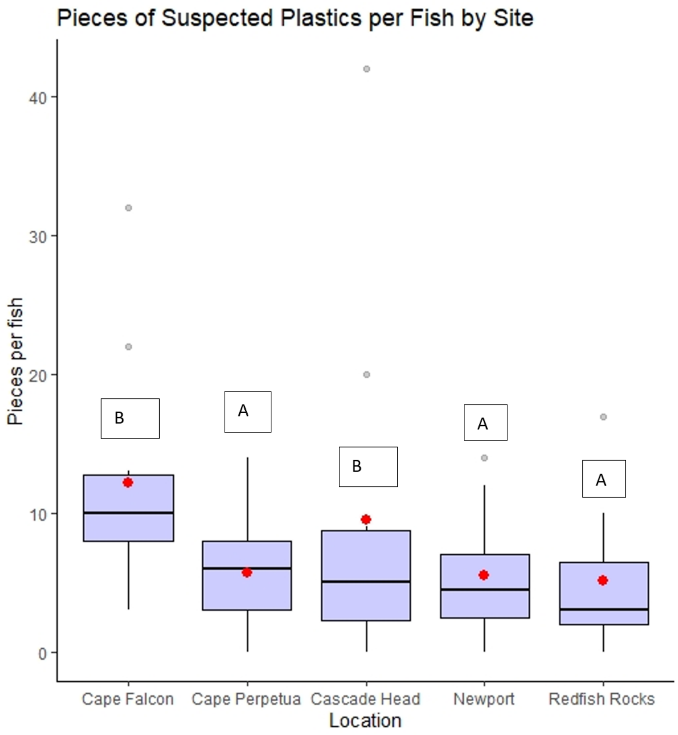

Figure 15: Range of individual plastic pieces in fish by site. ANOVA (Poisson distribution), Tukey HSD post-hoc, alpha = 0.05. The black lines across each box are the median, the red circles represent the mean. Different letters represent significance between sites. See Table S1 for p-values.

There are significant differences in average plastic ingestion presence between sites (ANOVA, Poisson, Tukey HSD) with p-values ranging from <0.01- <0.05 (Table 3).

Table 2: Average distance of Reserve fish from the Respective Reserve

Location	Average Distance (km)
Cascade Head	16.7
Cape Perpetua	14.6
Cape Falcon	15

Redfish Rocks	6.8

Table 3: 95% CI for the proportion of fish with and without suspected synthetics using Wilson's score interval.

Location	Plastics	Positive CI	Negative CI	Range
All reserve fish	YES	0.9765	0.8177	35.98-42.97
Cascade Head fish	YES	0.9821	0.5958	5.96-9.82
Cape Perpetua fish	YES	0.9863	0.6669	8.67-12.82
Cape Falcon fish	YES	1	0	7.22-10
Redfish Rocks fish	YES	0.9838	0.6226	6.85-10.82
Newport fish	YES	0.9873	0.6853	9.59-13.82

2.5 Discussion

Black Rockfish are opportunistic feeders and eat a variety of organisms (Doran 2020, Love et al 2002), therefore it is expected that they also ingested microplastics. These fish consumed a variety of anthropogenic materials, similar to results found in Rochman et al 2015. Rochman et al (2015) looked at the GI tracts of fish sold for human consumption from both Indonesia and California and determined that 25% of all the fish in the USA had some type of anthropogenically impacted material in them (Rochman et al 2015). This is slightly lower than the 35% of fish (*Trachurus trachurus, Dicentrachus labrax and Scomber colias*) GI tracts examined by Barboza et al 2020 that contained microplastics and 49% of the total fish examined that microplastics were found in (Barboza et al 2020). *Mullus surmuletus* were examined and 27.3% of the organisms had plastics within the GI track from Mallorca Island ports (Alomar et al 2017). Anthropogenic fibers, which were the most common morphology found, were specifically found in 2 blue rockfish and 1 yellowtail rockfish (Rochman et al 2015), verifying that *Sebastes spp* will consume anthropogenic materials, similar to results found in this study. Fibers or filaments are found to be the most common morphology in much research looking at ingestion of plastics (Alomar et al 2020, Barboza et al 2020, Rochman et al 2015). Barboza et al 2020 showed that most of the microplastics in the fish species were found in the GI tract, followed by gills and muscle (Barboza et al 2020), and in the GI tract and muscle in *Serranus scriba* (Zitouni et al 2020). Unlike the results presented above, the most common color of microplastics from all fish species was blue followed by whitish (Barboza et al 2020), blue, black then transparent (Alomar et al 2017), and blue (Amorim et al 2020). Amorim et al 2020 looked at the difference in ingestion of plastics in the GI tract by different ontogenetic stages and found similar results that fibers were the most common morphology found.

Ingestion of plastics by fishes is common, however the range of plastics found in different fishes is broad and difficult to compare. Although this work did not include an investigation into the toxicological effects of the ingested plastics in Black Rockfish, there is accumulating evidence that exposure to plastics can lead to harmful effects for individuals as well as entire populations, including behavioral impacts (Li et al 2020, Pannetier et al 2020, Barboza et al 2020b, de Sá et al 2015, , Choi et al 2018, Schmieg et al 2020, Nanninga et al 2020, Yang et al 2020, Steinburger et al (in review), McCormick et al 2020, Xu and Li 2021) and changes in energy reserves due to food dilution from ingested plastics (Yin et al 2019, Yin et al 2018, Barboza et al 2018a, Ma et al 2020).

Plastic ingestion rates by marine animals is increasing, and this includes a number of commercially harvested species (Savoca et al 2021). This study adds to the abundance of data showing that plastics are being ingested by marine species, while also filling data gaps regarding the presence and abundance of ingested microplastics by fish in the northeast Pacific Ocean. There is a significant spatial variability in the number of plastics found within the digested GI tract of Black Rockfish off the Oregon coast. Our study, like many others shows that fibers are the most abundant morphology of microplastics found ingested by organisms (Baechler et al 2020a, Amorim et al 2020).

Elevated levels of plastics in fish caught near the reserves is alarming, as reserves are set-aside as a refuge for marine life. These marine reserves are indeed young, with the earliest restrictions starting in

2010, but with plastics being found in some of the most secluded locations globally (e.g., Mariana Trench (Chiba et al 2018)) it should be expected that microplastics are delivered to and found within biota in these regions too. Plastics have also been found in other hadal areas (Peng et al 2020), snow (Bergmann et al 2019), sediments (Peng et al 2020, Xue et al 2020) and other locations.

Oregon's Ocean Policy Advisory Council defined a marine reserve in 2008 as

> … an area within Oregon's Territorial Sea or adjacent rocky intertidal area that is protected from all extractive activities, including the removal or disturbance of living and non-living marine resources, except as necessary for monitoring or research to evaluate reserve condition, effectiveness, or impact of stressors (OPAC 2008)." (Oregon Marine Reserves Ecological Monitoring Report 2010-2011) (Oregon Department of Fish & Wildlife, Marine Resources Program 2014).

The Oregon Marine Reserves Ecological Monitoring Report 2010-2011 also states that the goal of the marine reserve is to:

> Protect and sustain a system of fewer than ten marine reserves in Oregon's Territorial Sea to conserve marine habitats and biodiversity; provide a framework for scientific research and effectiveness monitoring; and avoid significant adverse social and economic impacts on ocean users and coastal communities. (Oregon Marine Reserves Ecological Monitoring Report 2010-2011) (Oregon Department of Fish & Wildlife, Marine Resources Program 2014).

Just as stated above, marine reserves have several reasons for being selected. Giakoumi et al (2018), evaluated what defines success and failure in marine protected areas. These authors determined several ways in which success can be measured including legislation, explicit objectives, communications and networks, leadership, and participation of stakeholders. However, for a reserve to be a failure, they listed information regarding stakeholders, surveillance, compliance, rivalries, and politics (Giakoumi et al 2018). However, no information was provided about preventing pollutant exposure. Marine reserves are often not protected from pollutants, in fact over 80% of the reserves examined in a study by Abessa et al 2018 were contaminated and this is a threat to them (Abessa et al 2018). Notably, many reserves are placed near areas that are sources of contamination (Abessa et al 2018). Understanding that these areas are contaminated is valuable because no-take MPAs are effective in conserving and rehabilitating the areas encompassed by them (Sala and Giakoumi 2017).

There are many reasons to have reserves (White et al 2010, Abessa et al 2018), and one of them is for the production of larvae. Larvae were shown to have high levels of retention in marine reserve locations in Oregon based on particle-tracking modeling approaches (Kim and Barth 2011). Cape Perpetua and Heceta Bank were designated as areas with higher than average retention (Kim and Barth 2011). This information is important as it can be used to predict how we would expect certain plastics to respond; these areas will probably have higher amounts of plastics due to the high retention.

It is also well established that many types of plastic are buoyant and can be easily moved large distances in water, and that oceans are receiving microplastics from aerial deposition (Brahney et al. 2021). Several models have examined the potential ways plastics can move around the globe. Plastic Adrift[1] (van Sebille et al 2012), is a website showing where ocean-borne plastics could land based on a specific starting location. These data are based on observations and can show data for up to 10 years. Despite there being areas with no data, you can place a piece of plastic on the map and get a prediction of where it may land, particularly in offshore areas where currents and gyres are well-understood. We do know that there are many forces affecting transport of larval organisms (White et al 2019), and potentially microplastics too, which can be of similar size and buoyancy. Wichmann et al 2019 shows that the spread of plastics in the ocean is in approximate equilibrium from their simulated models of Lagrangian particles. However, with all the sources of plastics entering the Pacific Ocean, not being able to determine a specific source of plastics, researchers need to be careful with explaining the spatial spread of plastics to just one thing. With this information, we can try to understand how plastics can and may move. In addition, we must also consider the impacts of rivers on the abundance of plastics found in coastal environments (Harris 2021). Different coastal environments are impacted (exposed) to plastics from river sources differently (Harris et al 2021).

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[1] http://plasticadrift.org/?lat=43.5&lng=-125.3&center=-5&startmon=jan&direction=fwd

2.5.1 Human exposure to plastics

Humans also consume plastics (Cox et al 2029). Plastics have been found in the air, bottled water, sugar, salt, seafood, honey, tap water, and alcohol (Cox et al 2019). Multiple different morphologies were found in these commonly used ingredients, however fibers predominated (Cox et al 2019). Even though we did not calculate the number of plastics humans may be exposed to from eating Black Rockfish, there is evidence supporting the fact that humans are exposed to plastics via seafood (Barboza et al 2020, Rochman et al 2015, Cox et al 2019). Barboza et al 2020, using the European Food Safety Authority recommendations, determined that ingesting just the three fish species from their study, adults could be consuming 842 pieces of mp/year while children could be intaking 112-562 mp/year (ages 1 to great than 6) (Barboza et al 2020).

2.5.2 Method Development

There is currently no standardized methodology for extracting microplastics from different matrices, although much work has been done recently to make studies more consistent, comparable, and reproducible (Brander et al 2020, Cowger et al 2020). As part of trying to standardize and determine the best methods to use, we participated in the clean water portion of the Southern California Coastal Water Research Project (SCCWRP) study. This study sent out spiked samples to many labs across many countries to try and understand which steps and overall methods are the most appropriate and accurate for a variety of sample types.

It is common in plastics literature to report the morphologies and colors of the potential/verified plastics, but this process is also not standardized. There are several different plastic morphologies, but there is an inconsistency with how they are reported in the literature. Rochman et al (2019) included spheres, fragments, pellets/nurdles, fiber bundles, fibers, foams and films. However, Lusher et al (2020) only includes three main categories (bead, fiber, fragments) and then lists sub-categories for each. In the Bead category, the sub-category includes beads, nurdles, spheres, ball, grain and EPS balls), while the fiber category includes filament, string, fibrous, fiber bundles, and the fragment category includes films, and foams (Lusher et al 2020). Although we did not use the key found in Lusher et al (2020), it could be a great tool for determining the morphology and potential material of pieces found in fish and other matrices. Similarly, to morphologies, there are several different colors that are reported in the literature. Rochman et al (2019) includes Red, Orange, Yellow, Tan, Brown, Off-white, White, Grey, Blue, and green. However, in Lusher et al (2020), they recommend including white, clear, black, and then primary and secondary colors. The authors also acknowledge that KOH has shown to effect color, but still recommend recording them (Lusher et al 2020). There are other issues when it comes to identifying colors including the perception by the researcher picking the color, and the equipment (microscope, light, camera) used while identifying the colors (Lusher et al 2020).

While we adapted methods to improve recoveries and to reduce background contamination throughout the project, we need a more efficient and higher throughput method to carefully obtain all plastic pieces and safeguard them from being lost while continuing to eliminate background contamination. We also need methodological approaches for digesting lipids within samples as current methods do not always work. Many of the method limitations listed in the methods section of this paper are based off what we have and continue to learn as a relatively new field.

2.6 Conclusion

This paper adds to the growing body of research that demonstrates the presence of microplastics in marine organisms. We show herein microplastics are indeed present in fish off the Oregon coast. By understanding what the current plastic levels are, we can better understand water quality issues facing marine fishes off the Oregon coast. Based on this research, we recommend that studies be performed looking at the toxicological impacts of the plastic being found in these fish along with more work looking at the quality of the water in these regions along the Oregon coast, as well as gaining a better understanding of nearshore particle transport.

Examining ways plastics can degrade

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3.1 Introduction

In September of 2019, I started as a National Science Foundation Research traineeship fellow. I was part of a team with two brilliant early career scientists who were also graduate students at Oregon State University. We set off to try and tackle a problem that encompassed three main concepts: Risk and Uncertainty Analyses and Communication, Bid Data, and Coupled Natural Human Systems and how they relate to plastics. My teammates were both masters or PhD student and came from different backgrounds, lives, colleges, and disciplines, with a science communicator, a mathematician, and myself. However, we were able to use our knowledges and strength to create and research a question regarding plastics in the natural world, titled: Plastics in our World.

Together, we passed in a transdisciplinary (TD) report of our overall work. In addition to the TD report, we each need to write an interdisciplinary (ID) report, and this chapter fulfills that requirement for the “OSU-NRT program in Risk and Uncertainty quantification in marine science and policy” program.

3.2 Background

The original plastic assumption, that plastics are benign and harmless to the environment and us was a claim made before we had the capability to fully understand and appreciate plastics and the chemicals present in plastics. Today, over a century after the first plastic was invented, we have a much better understanding of the effects plastics do and can have on the environment and ourselves (Rochman et al 2016).

Plastics create tiny microworlds that separate and keep our stuff, such as food, safe from fungi and bacteria. We wear plastic, we use it in pretty much everything. Phones, computers, electrical wiring – these things are part of our everyday global culture, and they all rely on plastics (Davis 2015, Geyer et al 2017; Worm et al 2017). Yet, research has now shown that several chemicals and other additives in the plastics, are not as innocuous as originally thought. One of the more famous examples of controversial toxic (poisonous) chemicals added to plastics that cause severe dysfunction (i.e., endocrine disruption - which affects our reproductive ability, heart rate, sleep cycle among other essential tasks) is Bisphenol A (BPA). But that is just one of the additives – there are thousands of different chemicals added and hundreds of different formulas for plastics – and we do not know how most of those chemicals affect us or the natural environment or in what amounts or abiotic scenarios these chemical effects may be exacerbated (Webb et al 2012).

We know that plastic does not biodegrade – but breaks down into tinier and tinier pieces, and these tiny pieces of plastic are everywhere (Allen et al 2019; Chiba et al 2018, Kershaw et al 2011). We also know that plastic leaches (expels) it's chemicals and that other chemicals like to attach (adsorb) to plastic (Koelmans et al 2014; Rios et al 2007). This means that every piece of plastic slowly becomes an attractant and then carrier of known toxic and dangerous chemicals, essentially a 'life raft' of toxins (Amaral-Zettler et al 2015, Brander et al 2011, Rios et al 2007, Rochman et al 2019). This microbial world, coined 'the plastisphere' by Amaral-Zettler et al (2015), permeate our air, water and dirt, and significant research has shown that wildlife and ourselves now eat and breathe in them in (Amaral-Zettler et al 2015, Kosuth et al 2018, Moore 2008, Prata 2018). In the marine environment, empirical research supports the significant amount of damage plastic ingestion has on filter feeders (clams, oysters), and things that eat the filter feeders (fish, mammals, sharks), and so on, up the food chain (Allen et al 2019, Sussarellu et al 2016). This is also part of the human food chain. There is still debate on how the ingestion of these plastic particles directly impacts us and whether plastic is as big of an environmental concern as some research has claimed (Koelmans et al 2017, Lenz et al 2016, Stafford & Jones 2019, Wright et al 2013). However, prior to looking at the empirical evidence of the impacts of plastics, it is important to understand the basic plastic life cycle.

The life cycle of plastic consists of four major stages: production, consumption, waste management/recycling, and pollution (Nielsen et al 2020). Each of these stages has its own issues and contributions to the physical effects that plastics create. The first stage, production, is often overlooked as the waste management and pollution stages tend to get the most media attention. However, there are multiple ecosystem and human impacts from the production of plastics, especially as their production is highly linked to the petroleum industry and accounts for 8-9% of our global petroleum use (Andrady 2015, Hopewell et al 2009). To create plastics, small pellets of plastics are first manufactured (called primary microplastics). These pellets have been known to spill into the ocean during shipments or storms and are a significant contributor to the microplastic debris issue and its effects. In addition to the plastic itself, approximately 50% of the weight of plastic is actually fillers and additives, many of which have unknown impacts, whereas some have evidence of harmful effects on both the environment and on human health (Colton et al 1974). The second stage, consumption of plastic – is a highly politicized stage. A quick look around a typical household will confirm that plastic is used for the packaging of almost everything we use. Most of the plastic consumption is from single use items, like plastic bags, water bottles and food packaging (Moore 2008, Nielsen et al 2020). The lack of alternatives from the production side of plastics, drives our high plastic consumption and demand. Because plastics are so cheap to make, the capitalistic global economic network keeps plastics as the most financially competitive packaging material (Hopewell et al 2009). The third stage of the plastic life cycle is the waste management of plastics. Within the waste management stage, there are three pathways that used plastics can take: recycling, incineration, or trashed (Nielsen et al 2020). The incineration can produce fuel from plastics, however, emissions from plastic burning plastic contributes to local and global air pollution (Geyer et al 2017, Vince & Stoett 2018). Recycling plastic means that plastics are reprocessed to produce secondary plastics – but this only delays the eventual discarding of the plastic as there are issues with secondary plastics “low technical and economic value" (Geyer et al 2017). Despite the ability to recycle a lot of the plastic produced, only approximately 14% of plastics are even reprocessed for recycling (Nielsen et al 2020). The plastic recycling infrastructure is currently lacking, especially since China started to refuse taking on the world's garbage (Nielsen et al 2020). This lack of recycling leads to the fourth stage in the plastic life cycle – waste. This stage is where physical impacts of our societal addiction to, and reliance on, plastic is directly seen on the environment.

Also, plastic formulas can be proprietary so it hard to know what is exactly in them. This is all to say that understanding how plastics will react and degrade in a lab setting or the natural world is quite different.

Although the first report of tiny, micro pieces of plastic particles found floating in the ocean was in 1972, it wasn't until Thompson et al (2004) that these particles became known as 'microplastics' (plastic particles that range in size between 1 and 5 mm) (Carpenter & Smith 1972, Thompson et al 2004). Microplastics are split up into two categories: primary microplastics (tiny pellets of plastic that are used as microplastics; in beauty products and in the production of larger macroplastics and secondary microplastics (tiny pieces of plastic that are produced from the breakdown of larger pieces of plastics) (Amaral-Zettler et al 2015, Vince & Stoett 2018). These tiny pieces of plastic are everywhere and have been found in the arctic ice, in the sediments in the deep seas, in the air, on mountain tops, in soil and in fresh and marine water (Allen et al 2019, Andrady 2017, Bouwmeester et al 2015, Cox et al., 2019, Jamieson et al 2019, Kanhai et al 2018).

3.3 Methods

We all worked together but also tried to do separate parts to equalize the work. One teammate read most of the papers and wrote most of the plastics background in both the TD report and ID chapter, as the text came directly from the TD report. Whereas my other teammate and I did a lot more of the modeling work. My portion, as my masters is looking at the presence of plastics in fish, was to try and understand how plastics breakdown.

Since we were only given 1 year to complete this project, we decided to look to the literature for information on how plastics may degrade. With a mathematician in our group, we decided to go with a modeling paper as it could be done in a shorter time than an experiment. We decided to a model created by ter Halle et al 2016 who shows that plastics likely break down faster the smaller they are.

My portion of the project consisted at looking at how many fragmentations periods it would take to break down a 32g piece to be less than 1mg. Since I am new to modeling and using computing languages, my teammate helped me at every step. Once we figured out what we wanted to do, she helped me write the code and gave me time to play with it and learn the basic of MATLAB. We used MATLAB as that language was more familiar to her. Once we started getting outputs and obtained help from a statisticss class, we started to discuss exactly the outputs we wanted and started adding to the code.

With the TD report, *"we wanted to examine plastic fragmentation"*, the process by which plastic breaks down into smaller pieces. There are lab studies and environmental studies showing how specific types of plastics, fragments, but we wanted to approach this problem in a more general way. To better understand how plastics in waterways fragment over time, we decided to look at the process in just a physical sense. Due to the number of plastic types, modes of degradation, and the lack of data, we chose to use a theoretical model found in a study by ter Halle et al (2016). This model has several limitations including being used for plastics in general and having a lower mass limitation limit of 1mg. This means that we cannot predict fragmentation of pieces smaller than 1mg, which is true of most if not all microplastic pieces. Thus, we make a few assumptions to bridge the gap into the microplastic realm.

The model (see below) utilizes the following mechanism. First, *U* is a random number between 0 and 1, chosen from the uniform distribution on that interval (ter Halle et al 2016). Given a piece weighing mass m in milligrams, one fragmentation results in two pieces.

$$(U*m) \text{ and } (1-U)*m$$

Authors ter Halle et al (2016) tested the model using a Kolmogorov-Smirnov test, where they demonstrated that simulated data obtained by this model was not markedly different from the real-world data collected in their study. Using this fact, we chose this model to demonstrate plastic fragmentation.

To demonstrate the model, we constructed a simplistic scenario with one initial plastic piece weighing 32,000mg (32grams). Our model consists of a list that changes at each fragmentation step. Initially, the list consists of the original mass. After one fragmentation step, the list consists of two numbers, $U \cdot m$ and $(1-U) \cdot m$ for some random number U between 0 and 1. At each iteration, the i^{th} element in the list of masses, m_i, is replaced with two numbers $U_i \cdot m_i$ and $(1-U_i) \cdot m_i$, where U_i is a newly chosen random number between 0 and 1. We continue for a finite number of fragmentation steps.

Since the numbers U_i are chosen randomly, each run-through will produce a different result. To demonstrate the model, we ran the 32g plastic mass through the fragmentation process for a total of 11 fragmentations and 10,000 replications. With these selected parameters, the model will output a minimum of 2048 pieces as each fragmentation leads to 2 additional pieces and it is occurring 11 times (2^{11}).

The quantity of interest is the total mass of plastic pieces weighing less than 1 mg. Some subsets of these pieces will be microplastics. As in ter Halle et al (2016), we assume that once pieces weigh less than 1 mg, they will quickly fragment to become microplastics. Thus, we keep track of these small pieces by totaling their masses throughout the simulation.

3.4 After the NRT program ended

Since, the plastic I removed from marine fish are small, I did not use the model to see how they could potentially continue to degrade. However, I decided to look at a few different ways that plastic degradation of PETE can occur in the literature. Andrady et al (2011) stated that there are five methods for degradation including photodegradation, thermooxidative degradation, hydrolysis, biodegradation, and thermal degradation. These several methods will be further examined.

3.5 Results and Discussion

As a transdisciplinary exercise, my teammate, Ali Chick and I wrote code together in MATLAB to implement the fragmentation model described in the previous section. Beginning with a 32-gram initial plastic mass, we allowed the model to run for 10,000 replications, 11 fragmentations each (Figure 16). We then used an initial mass distribution (see Table 4) to initiate the simulation, which we then ran for 100 trials, 26 fragmentations each.

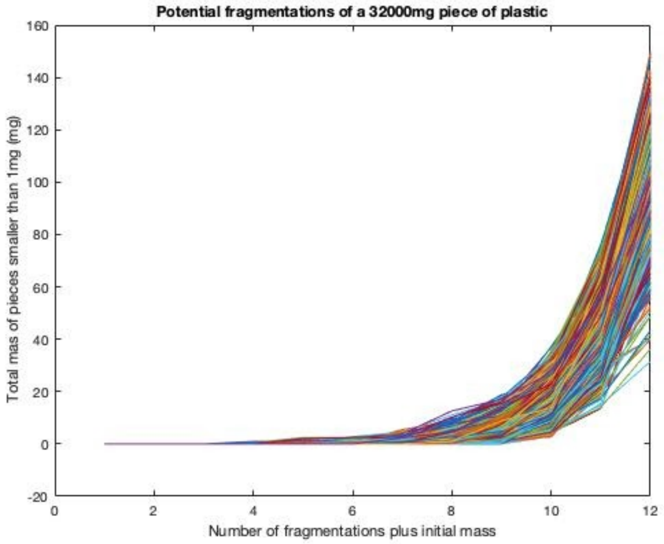

Figure 16: Plastic fragmentations of a 32gram piece of plastic can degrade over 11 fragmentations and 10,000 replications.

Table 4. Statistics on the set of final masses of pieces weighing <1 mg over all 100 trials (initial mass distribution)

Measurement	Value at X=12 (11 fragmentations)
Median	102.94 mg
Mean	103.04 mg
Standard Deviation	12.57
Maximum	149.82 mg
Minimum	31.51 mg

Range	118.31 mg

This information is not based on true numbers or time, rather fragmentations which can be a hard thing to understand. However, without having more information about the specific type of plastic being examined this is a mathematical way of trying to understand this difficult process.

3.5.1 Degradation:

Due to the complex nature of plastics, much research is looking into how plastics, or specific types of plastics degrade. Several studies have examined PET(E) and/or requirements for degradation (Webb et al 2013, Venkatachalam et al 2012, Chaisupakitisin et al 2019, Moog et al 2019). Webb et al (2013) discusses the how PET is a plastic with many applications and explains how manufactures have several different names (Webb et al 2012, Venkatachalam et al 2012). Chemical reactions occur for the creation of PET and there are two pathways before HBET is made and then finally PET. There are many requirements needed for mechanical recycling to occur including specifics in metal content, flake size, water content, viscosity and more (Webb et al 2012). Venkatachalam et al (2012) says that PET can degrade by oxidative degradation, photo degradation, enzymatic catalyzed, degradation, thermal degradation, chemical and hydrolytic degradation. Chemical degradation involves specific chemicals or weathering via several other factors including UV/light, gas/oil, moisture, and temperature (Ventkatachalam et al 2012). For example, thermal degradation can start at the ester linkage or at carbonyl groups forming at the end of the structure (Venkatachalam et al 2012). Next, Chaisupakitsin et al (2019) completed a study looking at degradation of PET by sunlight. These authors used three different colored bottles with liquids and left them outside between May and January (2016-2017) to see how the bottles would degrade. Hydrolysis occurred specifically at the ester bond (Chaisupakitsin et al 2019). Another mode of degradation is biological degradation. Finally, Moog et al (2019), decided to look at ways to use PETase, an enzyme produced by the bacterium *Ideonella sakaiensis.* The authors acknowledged that *I. sakaiensis*, along with other bacteria (bacteria systems) are not appropriate for the marine environment. To account for this problem, these authors looked at synthetically creating PETase in *Phaeodacttylum tricornutum*, a marine eukaryote. They concluded that a type of PETase, PETase^{R280A}-FLAG can degrade PET with respect to growth under certain conditions and with certain by products (Moog et al 2019).

3.6 Conclusion

Trying to understand how plastics fragment or break is crucial to understanding the full impacts of their presence in the water. This is a complex problem due to the many chemicals and properties of the plastics themselves. Understanding and studying plastics in the environment is a great topic for trying to look at the three main concepts of the NRT project: Risk and uncertainty, big data, and coupled natural human systems. Much is unknown regarding how plastics act and degrade in the marine environment. However, trying to study this pollutant while understanding that it is still needed in several parts of the world for sanitation is important; we cannot completely rid ourselves and our communities of plastic. The second main concept is big data, is relevant because this field is growing exponentially. As more people are becoming concerned with plastics being in our world, the amount of research being completed is growing. This includes modeling, different matrices, degradation, new types and even more. Finally, the third concept is the coupled natural human system. This is the one that I see most important. Plastics are in the environment, and they have been found within humans. Humans are directly responsible for plastics being in the environment and we need to fix it.

4 Conclusion chapter

Grasping the complexities of plastics of any size and the concentration at which they are present in animals is pertinent to understanding the larger plastic pollution problem. With the wide array of compounds and characteristics that compose plastics a diversity of research is needed (Rochman et al 2019). There are a range of specialists working in the field which aid in our knowledge between modeling, ecology, biology, toxicology and more.

Plastics are a daily commodity that we have become reliant on and cannot be removed entirely from our daily lives. They have been used in everything from water bottles and phone cords to turf fields and cars. But we are starting to see the dangerous implications that plastics are causing. Plastics are found globally and have been found in air, soil, water, humans and an abundance of animals.

While the debate over which way the field should move or how quickly it should move is still occurring, we know that the problem is on-going. The research presented here is the first to look at the levels of microplastics in Black Rockfish off the Oregon coast. This valuable fishery needs to be protected in Oregon for continued recreational and commercial success so future generations can enjoy them.

Here we show that plastics are found in Black Rockfish like many other marine species (Amorim et al 2020, Barboza et al 2020, Arias et al 2019, Li et al 2020b, Alomar et al 2017, Rochman et al 2015). These plastics can cause many problems due to their complex makeup, but the location of the plastics is also concerning. With the data we collected, which is just a snapshot of what these fish consume, we can see that they are consuming plastics in Oregon waters. Potential synthetics or anthropogenically impacted materials were found in 91.10% of all fish analyzed. However, what is most concerning is that 93.2% of fish in the vicinity of the reserves contained potential synthetics or anthropogenically impacted materials, with individual reserves ranging from 90% to 100%. As with many other studies, we also found that fibers are the most prevalent morphology of plastics found in wild marine organisms (Baechler et al 2020a, Amorim et al 2020). Determining the color of plastics is arbitrary, but other studies show that clear (or transparent/opaque in the literature) is also commonly found for plastics (Arias et al 2019, Alomar et al 2017, Peng et al 2020).

However, we cannot just focus on the plastics currently being used by humans or present in animals; we need to learn about how plastics are made and therefore degrade. The proprietary nature of plastics makes this step difficult. This is where analytical techniques, spectral libraries, and standards are necessary. With these added tools, we are starting to understand how plastics break down and become sizes that are easily and potentially unknowingly consumed by animals.

Several studies have looked at how a variety of plastics degrade: whether chemically, biologically, photooxidatively, thermooxidatively or more. My NRT teammates and I used a model by ter Halle et al 2016 to look how plastics degrade. To try and simplify the large plastic problem, we decided on a 32gram piece of plastic. This small mass allows one to more easily see the impact that plastics have in the marine system. Understanding that one 32g piece can turn into a minimum of 2048 pieces with 11 fragmentations and many of those pieces will still be over 1mg in mass, we can start to understand the impacts of plastics degrading. Finally, I looked at a few papers in the literature to obtain more knowledge about how PET(E) can be degraded.

By understanding where plastics are, and some of the modes of degradation, management can be informed for fishery protection . This could be extremely useful for valuable fishery species and fisheries that have been exploited. In our current times, when global warming is occurring, and the oceans are still an important carbon sink we need to preserve and protect it. We hope that managers will use information about plastics presence and abundance when making decisions regarding where reserves should be located and the complexities of plastics.

In addition to animals just consuming plastics, several studies have shown both short- and long-term effects from plastic exposure including hematology, gene upregulation, behavioral changes (Choi et al 2018, de Sá et al 2015, Solomando et al 2020) and more. This is a further motive to cease using plastics in excess and avert them from reaching the marine system.

Even though the field is pushing to stop looking at presence and abundance studies, and instead look at the toxicological, biological, and ecological effects, I believe that these studies are indeed important. Without the continuation we do not have a way to determine accurate ecological and environmental relevance. Plastics are a complex issue that cannot be solved overnight, but triggering human emotions through obtainable, and understandable research has a way of changing ideas.

Even with all these problems and complexities there is hope for the future. This rapidly changing field has necessitated adapting my methods during my time here at Oregon State University. Plastics are a complex issue as we have seen and having people that think differently and approach the difficulties in contrasting ways is necessary. We cannot tackle this intricate problem without expertise from several fields. Additional research is needed to solve the plastics problem, including a long-term study looking at how the chemicals used for dissolving tissue impact plastics.

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6. APPENICES

Table S1: P-values for Figure 15

Site	P-value
CP – CF	< 0.001*
CH – CF	0.35478
NP – CF	< 0.001*
RR – CF	< 0.001*
CH – CP	0.00842
NP – CP	0.99955
RR – CP	0.96986
NP – CH	0.00334*
RR – CH	0.00196*
RR – NP	0.99214

Field:

Outside Reserves:

- Two air controls were used to account for all trips
- Fish were collected and placed into plastic bags for transport
    - Kept in coolers and placed into a freezer

Newport:

- Air control was placed onto the table and wet with water
- Blue robes were worn over clothing to prevent contamination
- Total length and fork length taken
- GI tracts were dissected out and placed into aluminum foil packets

Lab: HEPA filters in a laminar flow hood, cotton lab coats, sticky mats, stamped filters papers, water, and KOH blanks

Outside Reserves:

- Fish and defrosted and removed from plastic transport bag
- Wiped with 70% EtOH and placed into foil packets until analysis

Analysis:

- Fish weight, total length, and fork length are all taken prior to removing the GI tract
- GI tract is removed and placed into foil packet

Newport:

- These samples are ready for the next step

Together:

- GI tract is weighed, and lengths are recorded
- GI tract is cut open and contents are removed
- GI tract is cut into small pieces
- Add 20% KOH: 1:3 (Gut to KOH ratio), 100ml minimum
- Sieve guts on 63um sieve
- Add 10% Alcojet solution if sample is fatty
    - Sieve on both 1mm and 63um
- Vacuum

Figure S1: Schematic showing the difference in methodologies between fish caught outside marine reserves and Newport, Oregon

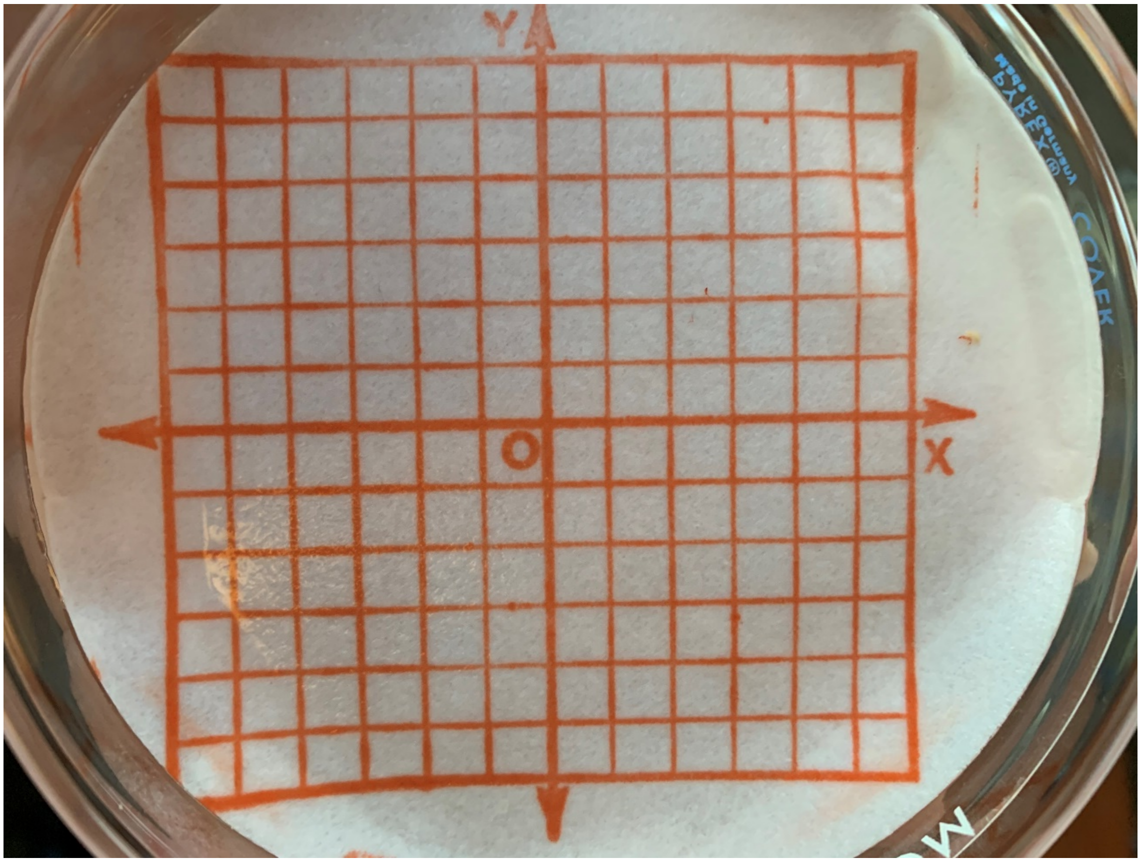


Figure S2: Example of air filter with 12X12 grid stamp

Type
○ Raman
● FTIR

Analysis
● Processed
○ Uploaded

Region
● Full
○ Peaks

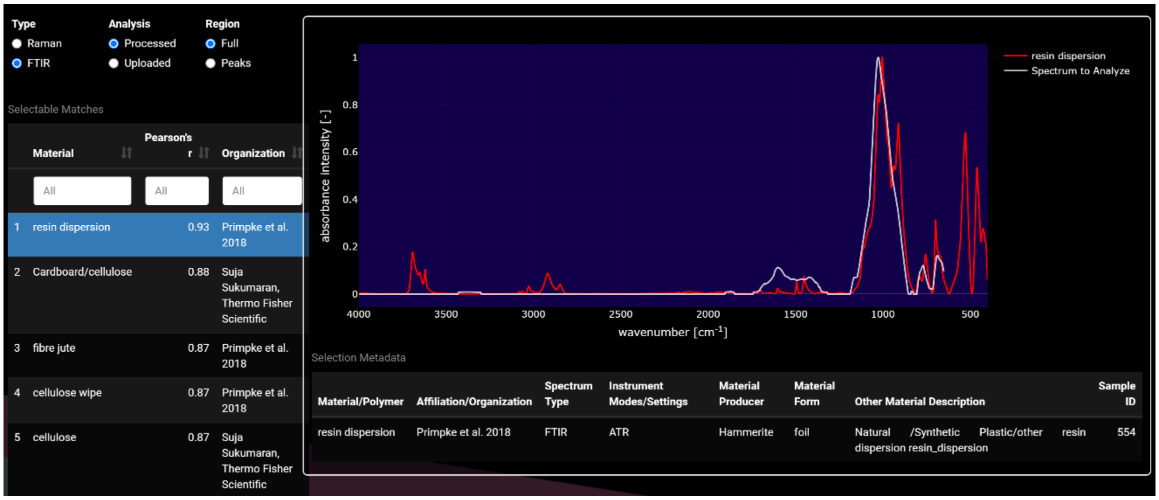
Selectable Matches

	Material	Pearson's r	Organization
	All	All	All
1	Cardboard/cellulose	0.97	Suja Sukumaran, Thermo Fisher Scientific
2	papercup_cellulosic	0.97	Suja Sukumaran, Thermo Fisher Scientific
3	methyl cellulose	0.95	Primpke et al. 2018
4	hydroxyethyl cellulose	0.94	Primpke et al. 2018
5	hydroxypropyl methyl cellulose	0.93	Primpke et al. 2018

Selection Metadata

Material/Polymer	Affiliation/Organization	Spectrum Type	Material Form	Other Material Description	Sample ID
Cardboard/cellulose	Suja Sukumaran, Thermo Fisher Scientific	FTIR	particle	Omnic Correlation: 89	626

Figure S3. Open Specy example for a spectrum classified as Anthropogenic Origin



Type ○ Raman ● FTIR

Analysis ● Processed ○ Uploaded

Region ● Full ○ Peaks

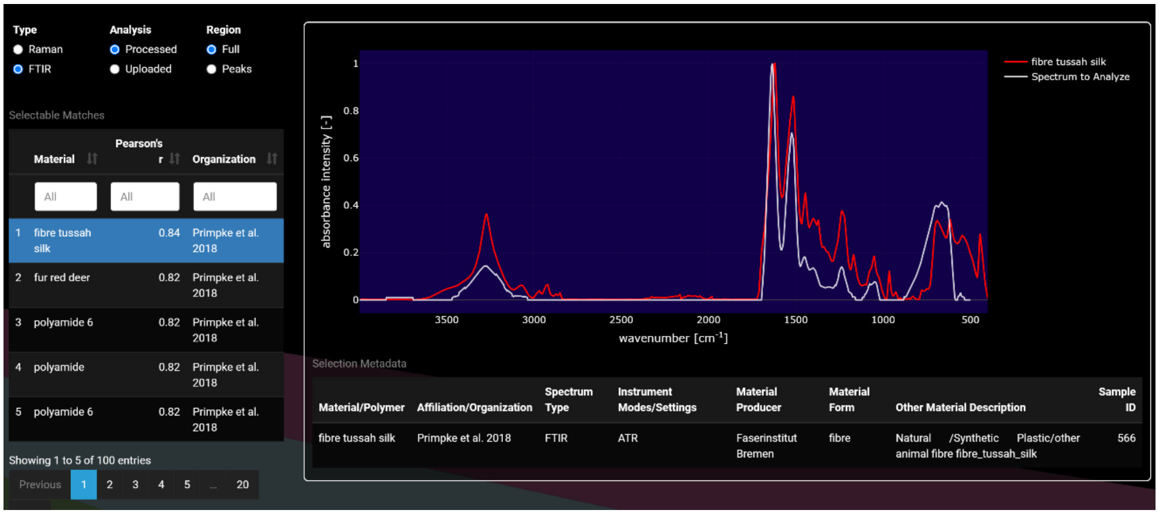
Selectable Matches

	Material	Pearson's r	Organization
	All	All	All
1	resin dispersion	0.93	Primpke et al. 2018
2	Cardboard/cellulose	0.88	Suja Sukumaran, Thermo Fisher Scientific
3	fibre jute	0.87	Primpke et al. 2018
4	cellulose wipe	0.87	Primpke et al. 2018
5	cellulose	0.87	Suja Sukumaran, Thermo Fisher Scientific

Selection Metadata

Material/Polymer	Affiliation/Organization	Spectrum Type	Instrument Modes/Settings	Material Producer	Material Form	Other Material Description	Sample ID
resin dispersion	Primpke et al. 2018	FTIR	ATR	Hammerite	foil	Natural /Synthetic Plastic/other resin dispersion resin_dispersion	554

Figure S4. Open Specy example for a spectrum classified as Anthropogenic Unknown



Type ○ Raman ● FTIR

Analysis ● Processed ○ Uploaded

Region ● Full ○ Peaks

Selectable Matches

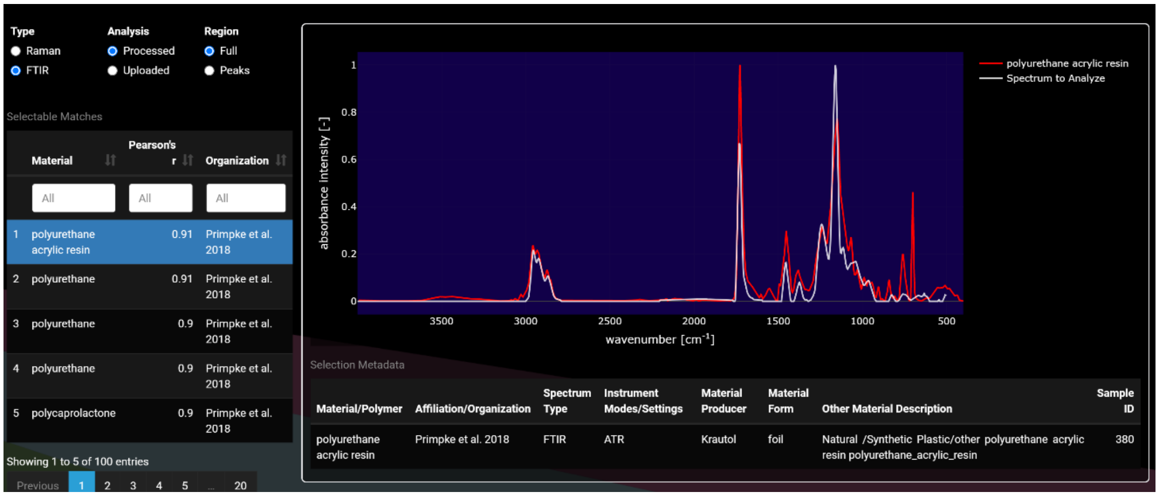
	Material	Pearson's r	Organization
	All	All	All
1	fibre tussah silk	0.84	Primpke et al. 2018
2	fur red deer	0.82	Primpke et al. 2018
3	polyamide 6	0.82	Primpke et al. 2018
4	polyamide	0.82	Primpke et al. 2018
5	polyamide 6	0.82	Primpke et al. 2018

Showing 1 to 5 of 100 entries

Selection Metadata

Material/Polymer	Affiliation/Organization	Spectrum Type	Instrument Modes/Settings	Material Producer	Material Form	Other Material Description	Sample ID
fibre tussah silk	Primpke et al. 2018	FTIR	ATR	Faserinstitut Bremen	fibre	Natural /Synthetic Plastic/other animal fibre fibre_tussah_silk	566

Figure S5. Open Specy example for a spectrum classified as Natural



Type
○ Raman
● FTIR

Analysis
● Processed
○ Uploaded

Region
● Full
○ Peaks

Selectable Matches

	Material	Pearson's r	Organization
	All	All	All
1	polyurethane acrylic resin	0.91	Primpke et al. 2018
2	polyurethane	0.91	Primpke et al. 2018
3	polyurethane	0.9	Primpke et al. 2018
4	polyurethane	0.9	Primpke et al. 2018
5	polycaprolactone	0.9	Primpke et al. 2018

Showing 1 to 5 of 100 entries

Selection Metadata

Material/Polymer	Affiliation/Organization	Spectrum Type	Instrument Modes/Settings	Material Producer	Material Form	Other Material Description	Sample ID
polyurethane acrylic resin	Primpke et al. 2018	FTIR	ATR	Krautol	foil	Natural /Synthetic Plastic/other polyurethane acrylic resin polyurethane_acrylic_resin	380

Figure S6. Open Specy example for a spectrum classified as Synthetic

Table S2: Top 5 OMNIC and Open Specy readings for all fish samples with good readings

Sample	Piece Number	OMNIC	OMNIC math	Open Specy	Open Specy Math	classified as
NP13	2	wood mahagoni#96	82.29	cardboard/cellulose	0.97	anthropogenic origin
		wood pink#94	81.73	papercup_cellulosic	0.96	
		bentonite(brown)	79.07	cellulose	0.92	
		fiber grass#85	78.41	cellulose	0.91	
		fiber turf#301	78.17	hydroxyethyl cellulose	0.89	
NP13	4	fiber grass#85	82.79	cardboard/cellulose	0.96	anthropogenic origin
		cellulose#34	81.64	papercup_cellulosic	0.95	
		cellophane	77.74	cellulose	0.9	
		wood mahagoni#96	77.08	cellulose	0.9	
		wood pine#94	76.45	hydroxyethyl cellulose	0.88	
NP13	5	cellulose#34	87	cardboard/cellulose	0.97	anthropogenic origin
		fiber grass#85	82.24	papercup_cellulose	0.95	

		fiber viscose#308	82.05	cellulose	0.91	
		wood mahagoni#96	78.4	cellulose	0.9	
		wood pine#94	78.15	fiber viscose dyed	0.89	
NP14	5	cellulose#34	86.58	cardboard/cellulose	0.96	anthropogenic origin
		cellophane	81.49	papercup_cellulosic	0.95	
		fiber viscose#308	78.49	cellulose	0.91	
		fiber viscose dyed#309	77.5	cellulose	0.9	
		fiber grass#85	74.9	cellulose	0.88	
NP14	10	methyl alcohol, 99.9% A.C.S. spectrophotometric grade	72.88	cardboard/cellulose	0.85	anthropogenic unknown
		methyl alcohol	72.88	papercup_cellulosic	0.84	
		bentonite (brown)	72.36	polyethylene chlorinated	0.79	
		2-Butene-1,4-diol, 95%	71.23	cellulose	0.77	
		methanol	69.5	cellulose	0.77	
np36	3	polyester epoxide#18	75.9	polytehylene terephthalate amorphous	0.87	synthetic
		polyester#21	74.6	copolyester	0.85	
		epoxide resin#20	73.6	polyester	0.85	
		polyester epoxide#23	72.99	copolyester	0.85	
		copolyester#65	68.45	polyesterterpthalate	0.85	
NP39	4	polyethylene_high_density#224	98.01	polyethylene wax	0.92	synthetic
		Polyethylene_high_density#87	97.88	polyethylene wax oxidized	0.92	
		polyethylene_high_density#277	97.42	polyethylene wax	0.91	
		polyethylene_high_density#124	97.27	polyethylene high density	0.91	
		polyethylene_high_density#80	97.25	polethylene wax oxidized	0.91	
NP39	1	polyester epoxide#18	75.29	polyvinylchloride	0.83	synthetic

		poly(2,3-butanediyl isophthatlate)	61.96	polyester epoxide	0.77	
		poly(2-butyl-2-ethyl-1,3-propanediyl isophthalate)	59.53	PET	0.76	
		poly(2,2-diethyl-1,3-propanediyl isophthalate)	58.57	PET	0.75	
		poly(2-ethyl-2-methyl-1,3-propanediyl isophthalate)	58.47	PET	0.75	
NP39	13	cellulose#34	84.38	cardboard/cellulose	0.97	anthropogenic origin
		fiber viscose#308	78.99	papercup_cellulosic	0.97	
		cellophane	77.34	cellulose	0.92	
		wood mahagoni#96	77.12	cellulose	0.92	
		fiber grass#85	75.9	hydroxyethyl cellulose	0.9	
NP60	1	cellophane	79.18	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#34	78.39	papercup_cellulosic	0.97	
		fiber grass#85	75.38	methyl cellulose	0.95	
		wood mahagoni#96	73.25	hydroxyethyl cellulose	0.94	
		fiber viscose#308	71.31	hydroxypropyl methyl cellulose	0.93	
NP65	6	cellulose#34	89.9	cardboard/cellulose	0.98	anthropogenic origin
		fiber viscose#308	85.24	papercup_cellulosic	0.97	
		cellophane	82.98	cellulose	0.94	
		fiber viscose dyed#309	79.93	cellulose	0.93	
		fiber grass#85	79.75	cellulose	0.91	
NP65	8	fiber grass#85	82.1	cardboard/cellulose	0.98	anthropogenic origin
		cellulose#34	81.59	papercup_cellulosic	0.97	
		fiber viscose#308	79.37	cellulose	0.92	
		cellophane	78.6	cellulose	0.92	
		wood mahagoni#96	75.45	cellulose	0.9	
NP66	2	poly(propylene), syndiotactic	81.56	polypropylene	0.97	synthetic

		polypropylene#143	81.15	polypropylene	0.97	
		polypropylene	78.86	polypropylene	0.97	
		fiber polypropylene#229	78.11	polypropylene	0.96	
		polypropylene#247	77.85	poly(4 methyl 1 pentene)	0.96	
NP66	8	cellulse#34	82.91	cardboard/cellulose	0.97	anthropogenic origin
		cellophane	82.3	papercup_cellulosic	0.97	
		bentonite(brown)	80.42	cellulose	0.93	
		hydroxyethyl cellulose #100	75.18	cellulose	0.92	
		fiber grass#85	75	hydroxyethyl cellulose	0.9	
NP67	1	cellulose#34	87.75	cardboard/cellulose	0.98	anthropogenic origin
		fiber viscose#308	85.74	papercup_cellulosioc	0.97	
		fiber grass#85	84.21	cellulose	0.93	
		cellulose wipe#113	82.45	cellulose	0.93	
		cellophane	81.82	fiber viscose dyed	0.91	
NP68	1	cellulose#34	90.58	cardboard/cellulose	0.98	anthropogenic origin
		fiber viscose#308	86.26	papercup_cellulosic	0.97	
		cellophane	83.13	cellulose	0.94	
		fiber viscose dyed#309	80.99	cellulose	0.93	
		fiber grass#85	80	cellulose	0.91	
NP68	4	cellulose#34	78.36	cardboard/cellulose	0.96	anthropogenic origin
		cellophane	78.14	papercup_cellulosic	0.95	
		fiber viscose#308	73.66	cellulose	0.91	
		cellophane	71.45	hydroxyethyl cellulose	0.9	
		fiber viscose dyed#309	71.07	cellulose	0.9	
NP68	5	cellulose#34	85.16	cardboard/cellulose	0.98	anthropogenic origin
		cellophane	81.7	papercup_cellulosic	97	
		bentonite (brown)	80.41	cellulose	0.93	
		fiber grass#85	80.08	cellulose	0.93	
		fiber viscose#308	79.77	cellulose	0.91	

NP68	14	cellulose#34	80.52	cardboard/cellulose	0.96	anthropogenic origin
		fiber viscose#308	76.64	papercup_cellulosic	0.95	
		cellophane	76.13	cellulose	0.89	
		fiber viscose dyed#309	72.27	cellulose	0.89	
		fiber grass#85	70.39	methyl cellulose	0.88	
NP117S	3	cellophane	67.6	cardboard/cellulose	0.96	anthropogenic origin
		methyl alcohol, 99.9% spectrophotometric grade	56.78	papercup_cellulosic	0.96	
		mask	54.19	cellulose	0.92	
		indigo, synthetic	52.96	cellulose	0.91	
		fiber grass#85	50.32	methyl cellulose	0.9	
NP117S	6	styrene ethylene butylene#296	88.54	sealing ring Gardena 1124 large	0.84	synthetic
		styrene acrylonitrile#291	70.69	PE+silicate+bio	0.84	
		styrene isoprene#297	70.12	PE with silicate inorganic	0.84	
		styrene allyl alcohol#293	69.66	polyethylene chlorinated	0.81	
		1,2,3,4-tetraphenylnaphthalene, 97%	68.5	styrene ethylene butylene	0.79	
NP117S	7	trimethyltin bromide, 95%	54.58	silicone seal reactor	0.91	Anthropogenic unknown
		carbon tetrachloride	53.31	HDPE	0.89	
		carbon tetrachloride	52.66	silicone seal reactor	0.89	
		carbon tetrachloride, 99%	52.66	silicone /PDMS	0.89	
		trimethyltin chloride	51.58	PDMS	0.88	
FW12#1	11	cellophane	73.62	cardboard/cellulose	0.96	anthropogenic origin
		mask	59.18	papercup_cellulosic	0.95	
		fiber grass#85	56.98	cellulose	0.9	
		cellulose#31	56.7	cellulose	0.9	
		cellulose wipe#113	56.64	cellulose wipe	0.9	
FW12#1	9	polyester#21	75.16	epoxide resin	0.94	synthetic

		epoxide resin#20	71.98	polytehylene terephthalate amorphous	0.94	
		polyester epoxide#23	71.57	polyethylene terephtalate	0.93	
		polyester epoxide#18	66.78	polyesterterpthalate	0.93	
		polyester275	65.78	PET	0.92	
FW12#1	13	cellulose acetate filter 64	84	fiber cotton US pima	0.9	anthropogenic unknown
		fiber linen#122	82.89	resin dispersion	0.9	
		fiber cotton uzbekistan#49	81.14	fiber cotton combers	0.9	
		cellulose wipe#113	81.08	polychloroprene	0.9	
		fiber cotton US pima#48	81.07	fiber Indian raw cotton	0.89	
FW12#2	25	cellophane	83.45	cardboard/cellulose	0.97	anthropogenic origin
		fiber grass#85	81.02	papercup_cellulosic	0.97	
		mask	80.23	cellulose	0.95	
		cellulose wipe#113	77.11	cellulose	0.93	
		fiber kapok#106	76.65	cellulose	0.91	
FW12#2	26	mask	75.41	cardboard/cellulose	0.96	anthropogenic origin
		cellulose wipe#113	72.75	papercup_cellulosic	0.95	
		fiber linen#122	71.94	cellulose	0.89	
		cellulose#31	71.74	cellulose	0.89	
		fiber grass#85	71.48	cellulose wipe	0.88	
FW21	3	polyester#21	88.26	polyesterterpthalate	0.96	synthetic
		epoxide resin#20	87.9	polytehylene terephthalate amorphous	0.96	
		polyester epoxide#23	84.87	polyester	0.95	
		polyester#275	80.81	poly(ethylene terepthalate)	0.95	
		polyester#274	80.56	polyesterterpthalate	0.95	
FW21	4	cellophane	73.64	cardboard/cellulose	0.97	anthropogenic origin
		fiber grass#85	70.49	papercup_cellulosic	0.97	
		cellulose#34	70.1	methyl cellulose	0.93	

		fiber viscose#308	65.59	hydroxyethyl cellulose	0.92	
		wood mahagoni#96	65.14	cellulose	0.92	
FW21	10	cellulose#34	85.88	cardboard/cellulose	0.96	anthropogenic origin
		fiber viscose#308	81.16	papercup_cellulosic	0.96	
		fiber grass#85	79.58	cellulose	0.89	
		cellophane	78.12	cellulose	0.88	
		fiber viscose dyed#309	77.17	methyl cellulose	0.88	
FW21	12	mask	87.95	cardboard/cellulose	0.98	anthropogenic origin
		fiber linen#122	87.35	papercup_cellulosic	0.97	
		cellulose wipe#113	85.73	cellulose	0.93	
		cellulose#31	85.1	cellulose	0.93	
		fiber flax#82	84.35	cellulose wipe	0.93	
FW77	1	poly(ethylacrylate:st:acrylamide)	65.72	lahmian medium acrylic paint	0.85	synthetic
		poly(methacrylate), w/oh groups	62.24	alkyd varnish	0.82	
		poly(1,4-butylene adipate)	61.37	PET	0.81	
		poly(vinyl propionate: acrylate)	61.18	HDPE	0.81	
		diisooctyl azelate	60.02	PET	0.81	
FW77	15	poly(ethylacrylate:st:acrylamide)	84.21	polycaprolactone	0.81	synthetic
		poly(ethyl acrylate)	78.09	polycaprolactone	0.81	
		tape	74.58	acrylonitrile butadiene styrene	0.79	
		poly(methacrylate), w/oh groups	74.53	polyurethane	0.78	
		poly(methyl acrylate)	72.83	polyurethane acrylic resin	0.77	
FW77	23	bentonite (brown)	59.92	resin dispersion	0.93	anthropogenic unknown
		fiber grass#85	54.64	cardboard/cellulose	0.77	
		fiber cocoanut#40	51.16	fiber jute	0.87	
		cellulose wipe#113	50.9	cellulose wipe	0.87	
		wood mahagoni#96	49.83	cellulose	0.78	
FW77	27	mask	92.41	cardboard/cellulose	0.97	anthropogenic

		cellulose#31	83.1	papercup_cellulosic	0.96	origin
		fiber cotton combers#47	81.16	cellulose	0.95	
		cellulose acetate filter ATR 64	80.77	cellulose	0.93	
		fiber cotton US pima#48	79.83	hydroxyethyl cellulose	0.9	
FW77	28	mask	93.75	cardboard/cellulose	0.95	anthropogenic origin
		cellulose#31	84.43	papercup_cellulosic	0.94	
		fiber cotton combers#47	84.24	cellulose	0.88	
		cellulose acetate filter ATR 64	84.05	cellulose	0.87	
		fiber cotton US pima#48	82.65	methyl cellulose	0.87	
FW79	black	wool cashmere afghanistan#266	75.79	fiber silk slubbing	0.83	natural
		wool#311	75.69	fiber mulberry silk	0.82	
		wool cashmere mahgolia#29	75.53	fur red deer	0.79	
		scoured wool not made rough#287	75.14	fiber tussah silk	0.78	
		wool raw cashmere afghanistan#267	75.07	fur angora rabbit	0.74	
FW12#1	1	wood mahagoni#96	83.5	cardboard/cellulose	0.91	Anthropogenic unknown
		fiber grass#85	83.19	papercup_cellulosic	0.9	
		wood_beech#93	80.61	cellulose	0.82	
		cellulose_wipe#113	79.93	cellulose	0.82	
		fiber_poplar_down#245	79.73	fiber poplar down	0.82	
FW14	2	wood pine#94	84.77	cardboard/cellulose	0.96	anthropogenic origin
		wood mahogoni#96	83.28	papercup_cellulosic	0.95	
		fiber grass #85	81.36	cellulose	0.89	
		fiber turf#301	77.86	cellulose	0.88	
		cellophane	76.47	methyl cellulose	0.88	
FW20	1	poly(ethylacrylate:st:acrylamide)	89.34	polycaprolactone	0.9	synthetic

		tape	82.67	polycaprolactone	0.86	
		poly(ethyl acrylate)	82.32	polyurethane	0.86	
		amyl formate, 97+%	79.03	polyurethane	0.85	
		poly(methacrylate), w/OH groups	78.97	polyurethane	0.85	
FW20	6	Fiber grass#85	70.03	cardboard/cellulosic	0.93	Anthropogenic unknown
		tape	66.91	papercup_cellulosic	0.93	
		fiber kapok#106	66.37	cellulose	0.86	
		fiber linen#122	62.66	cellulose	0.86	
		mask	62.65	leaf-plant	0.84	
FW25	4	mask	92.63	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#31	88.16	papercup_cellulosic	0.97	
		cellulose wipe#113	87.82	cellulose	0.93	
		fiber linen#122	86.1	cellulose	0.92	
		cellulose acetate filter ATR 64	84.45	hydroxyethyl cellulose	0.89	
FW25	14	mask	88.08	cardboard/cellulose	0.98	anthropogenic origin
		cellulose#31	84.14	papercup_cellulosic	0.97	
		cellulose wipe#113	83.85	cellulose	0.95	
		cellophane	81.75	cellulose	0.94	
		fiber grass#85	80.9	hydroxyethyl cellulose	0.91	
FW26	4	cellophane	66.3	cardboard/cellulose	0.85	anthropogenic unknown
		fiber grass#85	66.16	papercup_cellulosic	0.85	
		fiber kapok#106	64.56	cellulose	0.78	
		tape	64.41	cellulose	0.77	
		mask	63.3	PDMS	0.75	
FW27	14	bentonite(brown)	56.7	resin dispersion	0.9	synthetic
		fiber grass#85	53.92	polychloroprene	0.89	
		fiber jute#104	53.16	polyethylene chlorosulfonated	0.87	
		cellulose wipe#113	51.69	fiber jute	0.85	

		fiber urtica dioica L conar fibra#81	50.77	cellulose wipe	0.84	
FW27	17	2-Fluoroethanol, 85%	65.62	cardboard/cellulose	0.9	anthropogenic unknown
		boron trifluoride dihydrate, 95\6%	61.37	papercup_cellulosic	0.89	
		ethylene glycol	60.22	vinylidene chloride acrylonitrile	0.88	
		methanol	60.08	cellulose	0.82	
		nitrosonium tetrafluoroborate	59.75	methyl cellulose	0.81	
FW27	22	cellulose#34	87.54	cardboard/cellulose	0.95	anthropogenic unknown
		fiber viscose#308	82.28	papercup_cellulosic	0.94	
		fiber grass#85	80.92	cellulose	0.88	
		fiber viscose dyed#309	78.62	cellulose	0.87	
		wood mahagoni#96	75.58	leaf-plant	0.86	
FW28	6	cellulose#34	87.81	cardboard/cellulose	0.98	anthropogenic origin
		cellophane	82.27	papercup_cellulosic	0.97	
		fiber viscose#308	80.78	cellulose	0.93	
		fiber viscose dyed#309	78.33	cellulose	0.92	
		fiber grass#85	75.27	hydroxyethyl cellulose	0.9	
FW30	2	cellulose#34	88.91	cardboard/cellulose	0.98	anthropogenic origin
		fiber viscose#308	85.04	papercup_cellulosic	0.97	
		cellophane	82.23	cellulose	0.92	
		fiber grass#85	81.17	cellulose	0.92	
		fiber viscose dyed#309	79.7	hydroxyethyl cellulose	0.9	
FW30	3	cellulose#34	88.84	cardboard/cellulose	0.96	anthropogenic origin
		fiber viscose#308	82.39	papercup_cellulosic	0.95	
		fiber viscose dyed#309	79.25	cellulose	0.9	
		cellophane	77.58	cellulose	0.89	
		fiber grass#85	77.03	hydroxyethyl cellulose	0.87	
FW30	11	cellulose#34	72.55	PVA with Kaolin clay	0.84	anthropogenic

		fiber viscose#308	69.75	cardboard/cellulose	0.8	unknown
		fiber grass#85	69.54	polyethylene chlorinated	0.8	
		fiber viscose dyed#309	66.96	papercup_cellulosic	0.79	
		bentonite (brown)	64.66	polyethylene chlorinated	0.75	
FW34	3	bentonite (brown)	82.67	cardboard/cellulose	0.92	Anthropogenic unknown
		polyethylene chlorinated#221	71.52	papercup_cellulosic	0.91	
		fiber grass#85	70.36	cellulose	0.84	
		coal#333	67.41	cellulose	0.84	
		wood pine#94	66.92	leaf-plant	0.83	
FW34	6	fiber_grass#85	66.66	cardboard/cellulose	0.91	anthropogenic unknown
		fiber kapok#106	63.36	papercup_cellulosic	0.91	
		bentonite(brown)	61.41	leaf-plant	0.84	
		calcium phosphate, powder	61.07	cellulose	0.84	
		wood mahagoni#96	61.01	cellulose	0.84	
FW34	11	mask	84.25	cardboard/cellulose	0.96	anthropogenic origin
		fiber grass#85	82.2	papercup_cellulosic	0.95	
		cellulose#31	81.06	cellulose	0.89	
		fiber linen#122	81.04	cellulose	0.89	
		cellulose wipe#113	80.85	methyl cellulose	0.86	
FW35	2	bentonite(brown)	74.91	cardboard/cellulose	0.89	anthropogenic unknown
		methyl alcohol, 99.9% A.C.S. spectrophotometric grade	70.86	papercup_cellulosic	0.89	
		methyl alcohol	70.86	cellulose	0.82	
		methanol	69.61	cellulose	0.81	
		fiber grass#85	67.01	leaf-plant	0.81	
FW35	7	mask	90.11	cardboard/cellulose	0.98	anthropogenic origin
		cellulose#31	85.23	papercup_cellulosic	0.97	
		cellulose wipe#113	84.34	cellulose	0.94	
		fiber linen#122	83.08	cellulose	0.93	

		fiber grass#85	81.99	hydroxyethyl cellulose	0.9	
FW42	1	cellulose#34	84.25	cardboard/cellulose	0.97	anthropogenic origin
		cellophane	80.1	papercup_cellulosic	0.97	
		fiber viscose#308	79.72	cellulose	0.91	
		fiber grass#85	77.76	cellulose	0.9	
		fiber viscose dyed#309	77.22	methyl cellulose	0.89	
FW64#1	7	fiber grass#85	83.27	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#34	79.62	papercup_cellulosic	0.96	
		bentonite (brown)	79.32	cellulose	0.91	
		wood mahagoni#96	77.48	cellulose	0.9	
		wood pine#94	76.86	hydroxyethyl cellulose	0.88	
FW64 #1	9	fiber grass#85	83.69	cardboard/cellulose	0.98	anthropogenic origin
		cellulose#34	83.69	papercup_cellulosic	0.97	
		cellophane	81.44	cellulose	0.92	
		fiber viscose#309	79.51	cellulose	0.91	
		wood mahagoni#96	78.89	methyl cellulose	0.9	
FW64#2	1	fiber grass#85	71.8	cardboard/cellulose	0;93	anthropogenic unknown
		fiber kapok#106	70.34	papercup_cellulosic	0.93	
		mask	68.78	cellulose	0.88	
		wood mahogoni#96	66.75	cellulose	0.87	
		fiber poplar down#245	66.23	fiber kapok	0.87	
FW27	13	bentonite (brown)	71.45	cardboard/cellulose	0.91	anthropogenic unknown
		cellulose#34	58.82	papercup_cellulosic	0.9	
		fiber grass#85	55.82	polyethylene chlorinated	0.86	
		hydroxyethyl cellulose #100	55.55	fiber viscose dyed	0.86	
		wood pine#94	54.77	cellulose	0.84	
FW89	6	diisooctyl azelate	85.54	polycaprolactone	0.87	synthetic
		poly(ethyl acrylate)	83.99	polycaprolactone	0.84	

		bis(2-ethylhexyl) sebacate, tech., 90%	81.71	polyurethane	0.2	
		dihexyl azelate, tech., 65%	81.46	polyurethane	0.82	
		dibutyl suberate, 99%	81.42	polyurethane	0.82	
FW90G	1	cellulose acetate filter ATR 64	92.47	cardboard/cellulose	0.97	anthropogenic origin
		fiber cotton combers#47	91.87	papercup_cellulosic	0.96	
		fiber cotton US pima#48	88.45	cellulose	0.95	
		fiber cotton uzbekistan#49	87.45	cellulose	0.94	
		cellulose#31	86.92	cellulose	0.9	
GW90G	5	mask	93.05	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#31	87.98	papercup_cellulosic	0.96	
		cellulose wipe#113	86.98	cellulose	0.93	
		cellulose acetate filter ATR 64	86.41	cellulose	0.092	
		fiber cotton comners#47	85.7	cellulose	0.89	
FW90 G+A	5	mask	91.8	cardboard/cellulose	0.98	anthropogenic origin
		cellulose wipe#113	87.06	papercup_cellulosic	0.98	
		cellulose#31	86.7	cellulose	0.96	
		fiber linen#122	83.83	cellulose	0.95	
		fiber hemp rough#90	81.56	cellulose	0.93	
FW93 G+A	7	mask	59.52	cardboard/cellulose	0.87	anthropogenic unknown
		fiber linen#122	56.56	papercup_cellulosic	0.85	
		cellulose acetate filter ATR 64	56.07	cellulose	0.83	
		fiber cotton combers#47	56.02	vinylidene chloride acrylonitrile	0.83	
		fiber cotton US pima#48	55.94	cellulose	0.82	
FW93	6	polyethylene low density#116	68.3	sealing ring Gardena 2824 large	0.83	anthropogenic unknown

		polyethylene low density linear #270	67.64	chitin from crustacean shells	0.78	
		polyethylene low density #118	67.14	sealing ring Gardena 2824 medium	0.76	
		polyethylene low density #117	67.1	algae fucus serratus	0.73	
		polyethylene foamed#109	66.9	polyethylene chlorinated	0.72	
FW95 S2(119)	8	bentonite(brown)	67.14	cardboard/cellulose	0.95	anthropogenic origin
		fiber grass#85	53.18	methyl cellulose	0.94	
		cellophane	51.33	hydroxypropyl methyl cellulose	0.94	
		cellulose wipe#113	48.98	papercup_cellulosic	0.94	
		fiber cocoanut#40	48.55	hydroxyethyl cellulose	0.92	
FW95 S2(119)	9	fiber grass#85	86.91	cardboard/cellulose	0.98	anthropogenic origin
		wood mahagoni#96	85.15	papercup_cellulosic	0.97	
		wood pine#94	82.83	cellulose	0.92	
		fiber poplar down#245	81.62	cellulose	0.92	
		fiber kapok#106	81.59	cellulose	0.89	
FW95 S3(119)	1	cellulose#34	85	cardboard/cellulose	0.97	anthropogenic origin
		cellophane	81.1	papercup_cellulosic	0.96	
		fiber viscose#308	77.71	cellulose	0.91	
		fiber grass#85	77.3	cellulose	0.91	
		wood mahagoni#96	77.11	hydroxyethyl cellulose	0.89	
FW95 S3(119)	5	polyethylene terephthalate#99	88.13	polyester	0.96	synthetic
		polyethylene terephtalate#227	88.05	polyester	0.96	
		polyester#171	86.47	polyesterterpthalate	0.95	
		epoxide resin#20	86.1	poly(ethylene terepthalate)	0.95	
		polyethylene terephthalate#172	85.78	polyesterterpthalate	0.95	
FW95 S3(119)	7	poly(ethyl acrylate)	87.37	polyurethane acrylic resin	0.87	synthetic

		poly(ethylacrylate:st:acrylamide)	86.14	polycaprolactone	0.85	
		poly(methyl acrylate)	80.73	polyurethane	0.85	
		poly(1,2-butylene adipate)	79.82	polycaprolactone	0.85	
		poly(methacrylate), w/oh groups	78.34	polyurethane	0.84	
FW95#2	4	mask	87.89	cardboard/cellulose	0.97	anthropogenic origin
		cellulose wipe#113	83.65	papercup_cellulosic	0.96	
		cellulose#31	83.37	cellulose	0.92	
		fiber linen#122	81.56	cellulose	0.91	
		fiber grass#85	81.33	cellulose	0.88	
FW96	1	mask	92.88	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#31	84.15	papercup_cellulosic	0.96	
		fiber cotton combers#47	82.47	cellulose	0.93	
		cellulose acetate filter ATR 64	82.23	cellulose	0.92	
		fiber cotton US pima#48	81.17	methyl cellulose	0.9	
FW96	3	cellophane	83.85	cardboard/cellulose	0.98	anthropogenic origin
		mask	83.13	papercup_cellulosic	0.97	
		fiber grass#85	81.35	cellulose	0.93	
		cellulose wipe#113	80.76	cellulose	0.92	
		cellulose#31	80.34	hydroxyethyl cellulose	0.91	
FW96	5	cellophane	85.3	cardboard/cellulose	0.98	anthropogenic origin
		cellulose#34	85.13	papercup_cellulosic	0.97	
		fiber viscose#308	76.92	cellulose	0.93	
		fiber grass#85	75.78	hydroxyethyl cellulose	0.92	
		fiber viscose dyed#309	75.43	cellulose	0.92	
FW96	7	wool slubbing rough#313	90.68	fiber tussah silk	0.84	natural
		merino scoured wool made rough#126	90.44	fur red deer	0.82	

		wool cashmere kasakhstan#28	90.32	polyamide 6	0.82	
		wool raw cashmere afghanistan#266	90.12	polyamide 6	0.82	
		fur dog#62	89.84	polyamide 6	0.82	
FW96	8	mask	89.54	cardboard/cellulose	0.96	anthropogenic origin
		cellulose wipe#113	88.89	papercup_cellulosic	0.95	
		fiber linen#122	87.19	cellulose	0.89	
		cellulose#31	87.19	cellulose	0.89	
		fiber grass#85	85.07	cellulose	0.88	
FW96	10	mask	95.07	cardboard/cellulose	0.98	anthropogenic origin
		cellulose#31	91.55	papercup_cellulosic	0.97	
		cellulose wipe#113	89.94	cellulose	0.94	
		fiber linen#122	89.08	cellulose	0.94	
		cellulose acetate filter ATR 64	88.2	cellulose	0.9	
FW96	12	mask	92.34	cardboard/cellulose	0.95	anthropogenic unknown
		cellulose#31	89.57	papercup_cellulosic	0.94	
		fiber linen#122	87.99	cellulose	0.88	
		cellulose wipe#113	87.98	cellulose	0.88	
		cellulose acetate filter ATR 64	86.97	leaf-plant	0.86	
FW104S	2	mask	98.71	cardboard/cellulose	0.98	anthropogenic origin
		cellulose#31	91.3	papercup_cellulosic	0.97	
		cellulose acetate filter ATR 64	91.26	cellulose	0.93	
		fiber cotton combers#47	90.12	cellulose	0.93	
		fiber cotton US pima#48	89.43	cellulose	0.9	
FW104S	5	mask	89.32	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#31	83.49	papercup_cellulosic	0.96	
		cellulose wipe#113	81.56	cellulose	0.92	

		fiber linen#122	81.06	cellulose	0.91	
		fiber grass#85	780.62	hydroxyethyl cellulose	0.89	
FW112 G+A#1	5	cellophane	71.4	cardboard/cellulose	0.95	anthropogenic origin
		mask	56.08	papercup_cellulosic	0.95	
		fiber grass#85	54.17	cellulose	0.92	
		bentonite (brown)	52.77	cellulose	0.9	
		sucrose in KBR	52.22	hydroxyethyl cellulose	0.88	
FW112 G+A#1	6	mask	86.13	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#31	80.69	papercup_cellulosic	0.96	
		fiber linen#122	78.37	cellulose	0.91	
		cellulose acetate filter ATR 64	77.53	cellulose	0.9	
		fiber cotton combers#47	77.06	methyl cellulose	0.89	
FW112 G+A#1	9	fiber linen#122	71.04	cardboard/cellulose	0.95	anthropogenic origin
		fiber flax#82	69.44	papercup_cellulosic	0.94	
		cellulose wipe#113	68.22	cellulose	0.88	
		cellulose acetate filter ATR 64	67.77	cellulose	0.88	
		mask	66.86	cellulose	0.86	
FW112 G+A#1	10	tape	91.53	polyurethane acrylic resin	0.91	synthetic
		poly(ethylacrylate:st:acrylamide)	83.37	polyurethane	0.91	
		poly(ethyl acrylate)	80.56	polyurethane	0.9	
		poly(methacrylate), with OH groups	77.3	polyurethane	0.9	
		poly(butyl methacrylate)	73.53	polycaprolactone	0.9	
FW112 G+A#1	13	mask	91.89	cardboard/cellulose	0.98	anthropogenic origin
		cellulose acetate filter ATR 64	87.39	papercup_cellulosic	0.97	
		fiber linen#122	85.66	cellulose	0.94	
		fiber cotton combers#47	85.21	cellulose	0.94	

		cellulose#31	85	cellulose	0.91	
FW112#2	2	fiber kapok#106	81.07	cardboard/cellulose	0.99	anthropogenic unknown
		fiber grass#85	80.15	papercup_cellulosic	0.98	
		mask	79.79	cellulose	0.96	
		fiber poplar down#245	78.52	hydroxyethyl cellulose	0.96	
		cellophane	78.01	fiber popular down	0.95	
FW120#1	1	mask	94.21	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#31	87.46	papercup_cellulosic	0.96	
		fiber linen#122	84.46	cellulose	0.92	
		cellulose acetate filter ATR 64	83.22	cellulose	0.91	
		cellulose wipe#113	83.08	hydroxyethyl cellulose	0.88	
FW120#1	19	mask	92.41	cardboard/cellulose	0.97	anthropogenic origin
		cellullose#31	86.83	papercup_cellulosic	0.96	
		cellulose wipe#113	85.27	cellulose	0.91	
		fiber linen#122	82.9	methyl cellulose	0.9	
		cellulose acetate filter ATR 64	81.74	cellulose	0.9	
FW93S	1	cellophane	74.14	cardboard/cellulose	0.98	anthropogenic origin
		mask	68.5	papercup_cellulosic	0.97	
		fiber grass#85	66.67	cellulose	0.93	
		cellulose#31	64.99	cellulose	0.93	
		cellulose wipe#113	64.3	methyl cellulose	0.91	
FW95(119) #2	7	cellulose#34	67.7	cardboard/cellulose	0.88	anthropogenic origin
		fiber-urtica-dioica-L-conar-fibra#81	66.42	papercup_cellulosic	0.87	
		fiber viscose#308	65.64	cellulose	0.85	
		fiber grass#85	64.02	cellulose	0.83	
		fiber viscose dyed#309	62.3	cellulose	0.83	
FW89S	1	scoured wool not made rough#287	46.65	fiber tussah silk	0.72	natural
		fur cow#50	46.63	fiber mulberry silk	0.72	

		disperse blue 3	46.3	fiber silk slubbing	0.71	
		wool raw cashmere afghanistan#266	45.38	fur cat European shorthair	0.71	
		fur cat European shorthair#30	45.35	fiber polyamide 6	0.71	
FW106S	5	fiber grass#85	83.44	cardboard/cellulose	0.97	anthropogenic origin
		fiber kapok#106	78.88	papercup_cellulosic	0.96	
		wood mahagoni#96	78.04	cellulose	0.9	
		cellulose wipe#113	76.53	cellulose	0.9	
		fiber polar down#245	76.48	leaf-plant	0.98	
FW126	4	poly(ethylacrylate:st:acrylamide)	87.68	polycaprolactone	0.93	synthetic
		tape	85.28	polycaprolactone	0.9	
		poly(ethyl acrylate)	81.3	polyurethane	0.9	
		poly(methacrylate), w/OH groups	78.38	polyurethane	0.89	
		amyl formate, 97+%	77.85	polyurethane	0.89	
FW126	11	mask	84.84	cardboard/cellulose	0.98	anthropogenic origin
		cellulose wipe#113	84.19	papercup_cellulosic	0.98	
		cellulose#31	83.39	cellulose	0.95	
		fiber grass#85	82.63	cellulose	0.95	
		cellophane	81.57	cellulose	0.91	
FW127	1	fiber grass#85	50.72	polychloroprene	0.86	anthropogenic unknown
		cellulose wipe#113	48.31	polyethylene chlorosulfonated	0.85	
		fiber jute#104	47.79	fiber viscose	0.84	
		bentonite(brown)	46.06	cardboard/cellulose	0.83	
		fiber linen#122	46	fiber jute	0.83	
FW129	4	bentonite(brown)	62.05	resin dispersion	0.89	anthropogenic unknown
		fiber grass#85	57.44	cardboard/cellulose	0.87	
		cellulose#34	53.65	polyethylene chlorinated	0.86	
		wood pine#94	52.59	fiber viscose dyed	0.86	

		fiber urtica dioica L conar fibra#81	52.29	fiber jute	0.85	
FW131 A	4	mask	93.67	cardboard/cellulose	0.93	anthropogenic origin
		cellulose acetate filter ATR 64	88.58	papercup_cellulosic	0.92	
		cellulose #31	87.06	cellulose	0.87	
		fiber cotton combers#47	86.86	cellulose	0.87	
		fiber cotton US pima#48	85.52	cellulose	0.83	
FW131 A	16	mask	90.56	cardboard/cellulose	0.97	anthropogenic unknown
		cellulose#31	82.72	papercup_cellulosic	0.97	
		fiber linen#122	80.52	cellulose	0.92	
		cellulose acetate filter ATR 64	80.11	cellulose	0.91	
		fiber cotton combers#47	79.92	methyl cellulose	0.91	
FW131A	2	mask	85.46	cardboard/cellulose	0.96	anthropogenic origin
		fiber cotton combers#47	78.46	papercup_cellulosic	0.95	
		cellulose#31	78.43	cellulose	0.91	
		cellulose acetate filter ATR 64	78.22	cellulose	0.91	
		fiber linen#122	77.99	cellulose	0.87	
FW131	2	mask	76.78	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#31	69.25	papercup_cellulosic	0.96	
		fiber cotton combers#47	68.4	cellulose	0.93	
		cellulose acetate filter ATR 64	68.34	cellulose	0.91	
		fiber cotton US pima#48	67.57	methyl cellulose	0.91	
FW139S	1	mask	83.86	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#31	78.68	papercup_cellulosic	0.96	
		fiber grass#85	75.75	cellulose	0.93	
		fiber linen#122	74.94	cellulose	0.92	
		cellophane	74.49	methyl cellulose	0.91	

FW147	1	cellulose#34	89.59	cardboard/cellulose	0.97	anthropogenic origin
		fiber viscose#308	83.26	papercup_cellulosic	0.96	
		cellophane	79.97	cellulose	0.91	
		fiber viscose dyed#309	79.86	cellulose	0.91	
		fiber grass#85	77.95	cellulose	0.89	
FW147	2	poly(ethyl acrylate)	85.52	cellulose propionate	0.89	synthetic
		poly(ethylacrylate:st:acrylamide)	84.28	acrylonitrile butadiene styrene	0.82	
		tape	80.54	lahmian medium acrylic paint	0.81	
		poly(methyl acrylate)	77.76	cellulose acetate butyrate	0.79	
		poly(methacrylate), w/oh groups	74.97	polycaprolactone	0.79	
FW147	8	cellophane	86.29	cardboard/cellulose	0.97	anthropogenic origin
		cellulose#34	85.41	papercup_cellulosic	0.97	
		fiber viscose#308	77.18	cellulose	0.95	
		fiber viscose dyed#309	75.9	cellulose	0.94	
		fiber grass#85	75.09	cellulose	0.91	
FW147	9	cellulose#34	89.69	cardboard/cellulose	0.98	anthropogenic origin
		fiber viscose#308	84.87	papercup_cellulosic	0.98	
		cellophane	83.46	cellulose	0.93	
		fiber viscose dyed#309	80.72	cellulose	0.93	
		fiber grass#85	78.73	hydroxyethyl cellulose	0.92	
FW157#2	1	poly(ethyl acrylate)	77.01	cardboard/cellulose	0.88	anthropogenic unknown
		poly(ethylacrylate:st:acrylamide)	74.83	papercup_cellulosic	0.88	
		tape	72.38	leaf-plant	0.88	
		poly(methyl arylate)	71.22	fiber kapok	0.84	
		poly(1,4-butylene adipate)	67.97	fiber poplar down	0.83	
FW157#2	4	cellophane	74.3	cardboard/cellulose	0.97	anthropogenic origin
		fiber grass#85	72.37	papercup_cellulosic	0.96	

		mask	70.87	cellulose	0.92	
		fiber kapok#106	66.93	cellulose	0.91	
		cellulose#31	66.88	methyl cellulose	0.89	
FW157A	1	mask	90.12	cardboard/cellulose	0.97	anthropogenic origin
		cellulose	77.03	paperup_cellulosic	0.95	
		fiber cotton combers#47	76.74	cellulose wipe	0.95	
		fiber cotton US pima#48	76.47	cellulose	0.94	
		fiber cotton uzbekistan#49	76.34	fiber viscose dyed	0.94	
FW157A	2	cellophane	65.37	cardboard/cellulose	0.9	anthropogenic origin
		mask	62.13	papercup_cellulosic	0.88	
		fiber linen#122	59.33	cellulose	0.84	
		fiber grass#85	58.23	cellulose	0.84	
		fiber flax#85	56.77	cellulose	0.79	
FW157A	8	mask	81.47	cardboard/cellulose	0.97	anthropogenic unknown
		fiber grass#85	79.8	papercup_cellulosic	0.96	
		cellulose#31	78.25	cellulose	0.91	
		fiber linen#122	78.18	cellulose	0.9	
		cellulose wipe#113	76.79	leaf-plant	0.89	
FW157SG+A	1	mask	92.99	cardboard/cellulose	0.97	anthropogenic unknown
		fiber linen#122	91.24	papercup_cellulosic	0.95	
		cellulose wipe#113	90.23	cellulose wipe	0.95	
		cellulose#31	90.04	cellulose	0.94	
		cellulose acetate filter ATR 64	89.28	fiber viscose dyed	0.94	
FW157#1	1	poly(ethyl acrylate)	84.81	polycaprolactone	0.89	synthetic
		poly(ethylacrylate:st:acrylamide)	84.77	polycaprolactone	0.87	
		tape	81.42	polyurethane	0.86	
		poly(methyl acrylate)	78.71	polyurethane	0.86	
		poly(styrene/acrylate ester)	75.88	polyurethane	0.85	

FW157#1	5	polyethylene low density #117	76.12	PE+silicate+bio	0.79	anthropogenic unknown
		polyethylene foamed#109	76.03	PE with silicate inorganic	0.79	
		polyethylene low density#272	76	broodcomb once brooded	0.76	
		polyethylene oxidized#226	75.37	sealing ring Gardena 1124 small	0.73	
		polyethylene low density#225	75.02	polyethylene	0.73	