Physical and chemical characterisation of sea-surface microplastics collected from coastal and inland waters of Scotland in the summer of 2017

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Greenpeace Research Laboratories[1] *Technical Report 01-2018*

Contents

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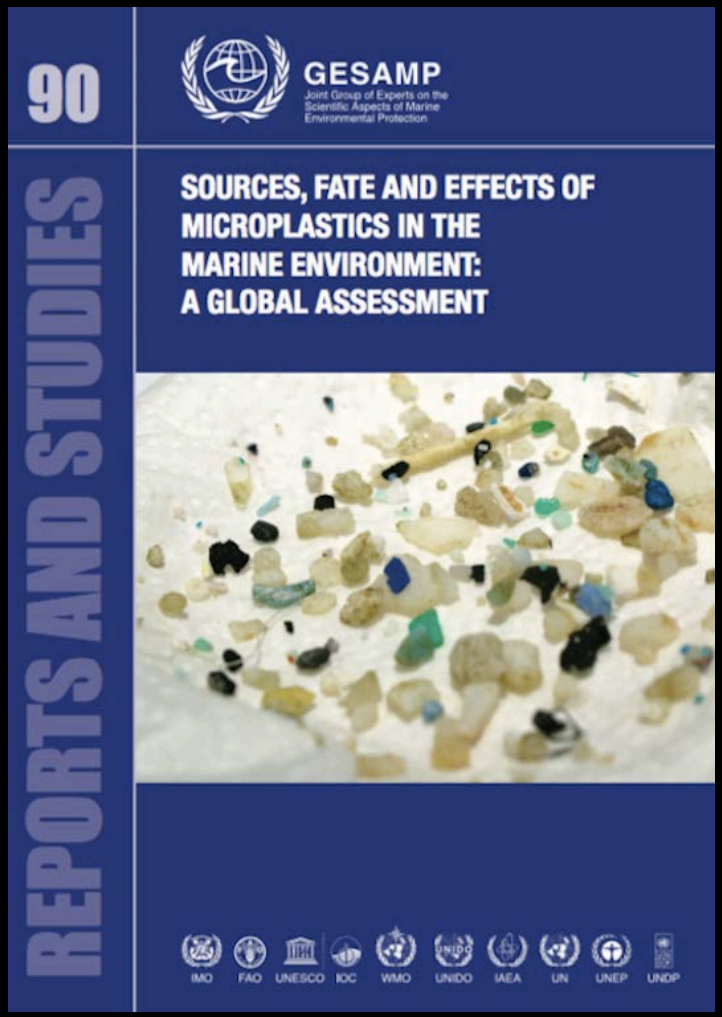
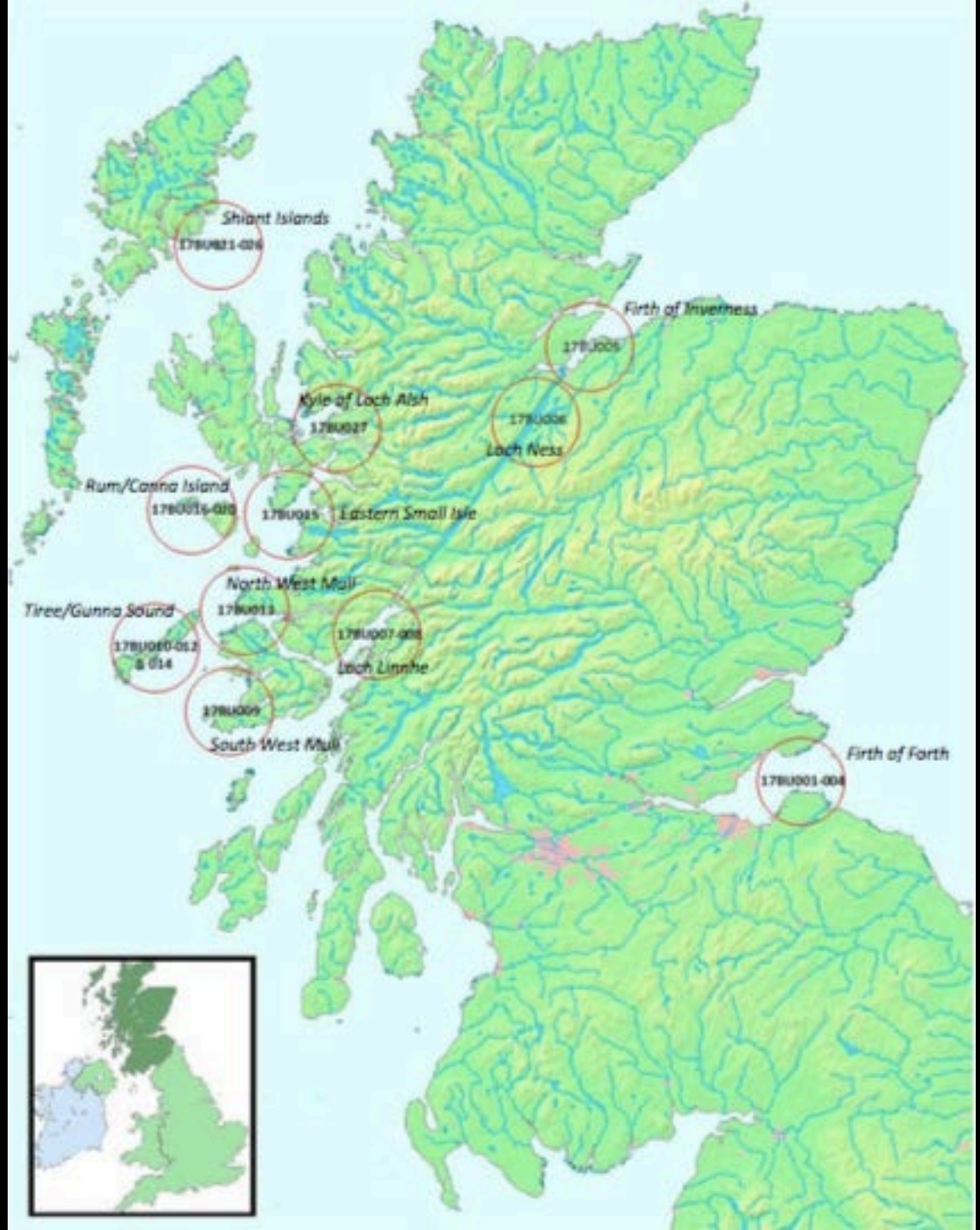
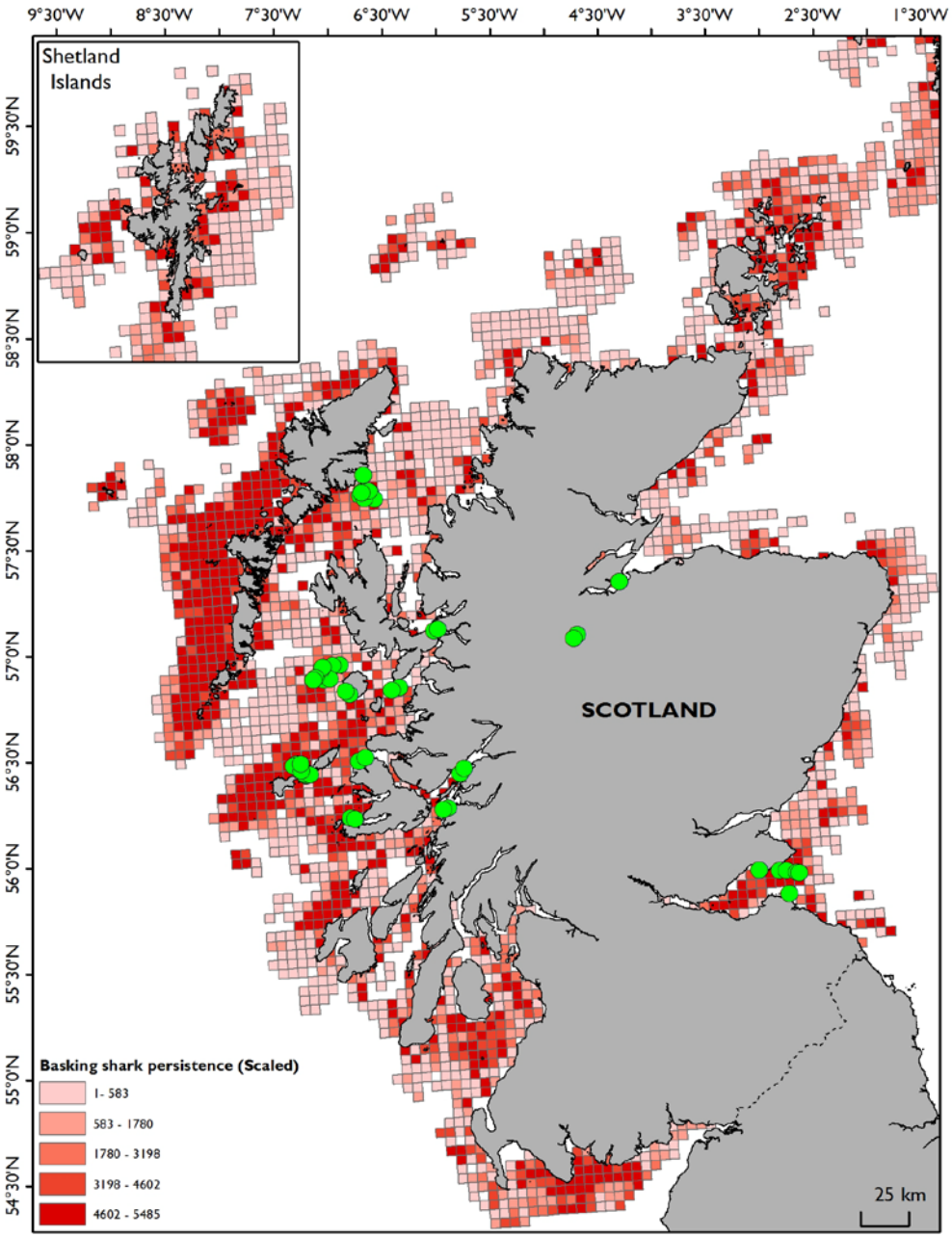
Microplastics are globally distributed contaminants…



…but what is the situation in Scottish waters…?

Sampling locations for surface microplastics in our study

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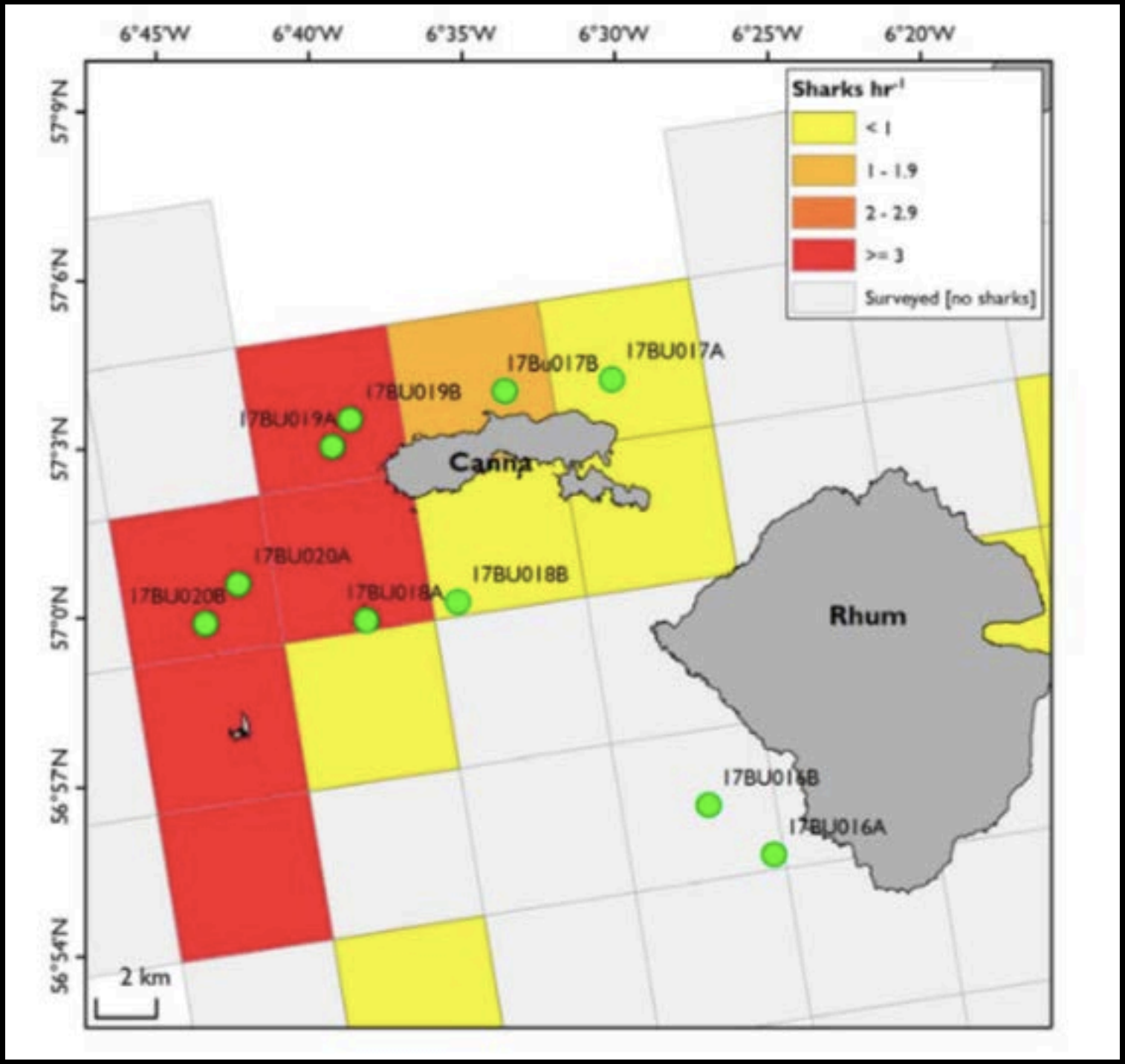
8°30'W
7°30'W
6°30'W
5°30'W
4°30'W
3°30'W
2°30'W
1°30'W
59°30'N
59°0'N
58°30'N
58°0'N
57°30'N
57°0'N
56°30'N
56°0'N
55°30'N
55°0'N
54°30'N
Shetland Islands
SCOTLAND
Basking shark persistence (Scaled)
1 - 583
583 - 1780
1780 - 3198
3198 - 4602
4602 - 5485
25 km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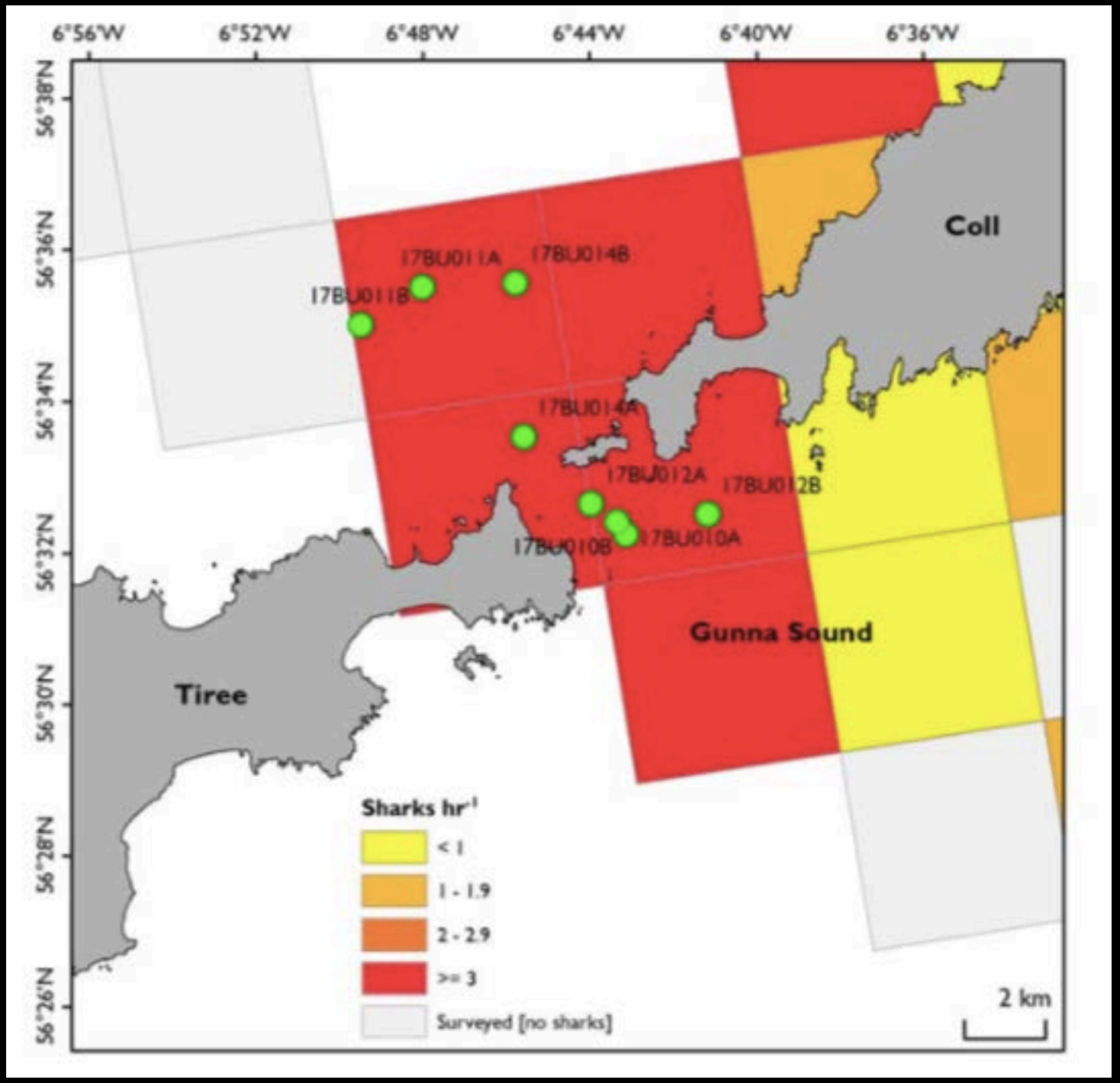
6°40'W
6°35'W
6°30'W
6°25'W
6°20'W
57°9'N
57°6'N
57°3'N
57°0'N
56°57'N
56°54'N
Sharks hr-1
< 1
1 - 1.9
2 - 2.9
>= 3
Surveyed [no sharks]
17BU017B
17BU017A
17BU019B
17BU019A
Canna
17BU020A
17BU020B
17BU018A
17BU018B
Rhum
17BU016B
17BU016A
2 km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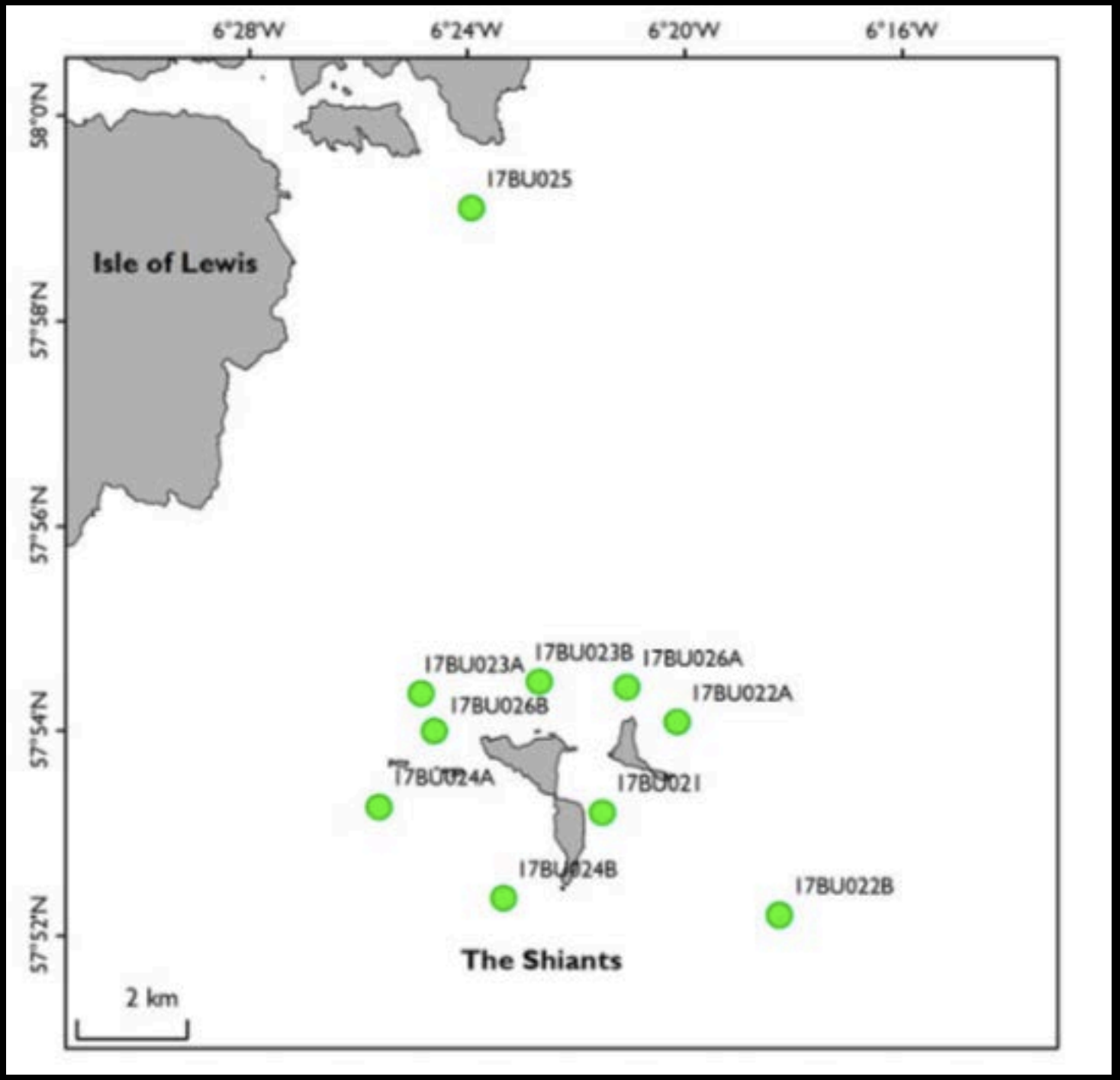
6°40'W
6°36'W
56°38'N
56°36'N
56°34'N
56°32'N
56°30'N
56°28'N
56°26'N
Coll
Tiree
Gunna Sound
17BU011A
17BU014B
17BU011B
17BU014A
17BU012A
17BU012B
17BU010B
17BU010A
Sharks hr-1
< 1
1 - 1.9
2 - 2.9
>= 3
Surveyed [no sharks]
2 km


6°28'W
6°24'W
6°20'W
6°16'W
58°0'N
57°58'N
57°56'N
57°54'N
57°52'N
17BU025
Isle of Lewis
17BU023A
17BU023B
17BU026A
17BU022A
17BU026B
17BU024A
17BU021
17BU024B
17BU022B
The Shiants
2 km


(a)
© Gavin Newman / Greenpeace


(b)
© Will Rose / Greenpeace

Summary of methods used

- Total of 49 surface net tow samples analysed from 27 locations around Scotland
- Debris caught in net was sieved and sorted to separate out possible microplastics
- Microplastic identities were confirmed by infra-red spectrometry
- Confirmed microplastics were analysed for chemical additives & contaminants

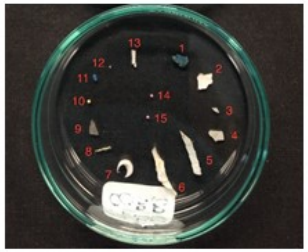
Microplastics were widespread but not evenly distributed

- Almost two thirds of samples (31 of 49) contained at least one piece of microplastic in the size range 0.5 - 5.0 mm diameter
- 4 samples contained 10 or more pieces of microplastic (one sample from the Firth of Forth, one from Gunna Sound, close to Tiree, and two from waters around the Shiant Islands)
- Estimated 600 - 12 600 microplastics per square kilometre (average 1772 km^2)
- Samples collected one after another from the same locations often gave very different results

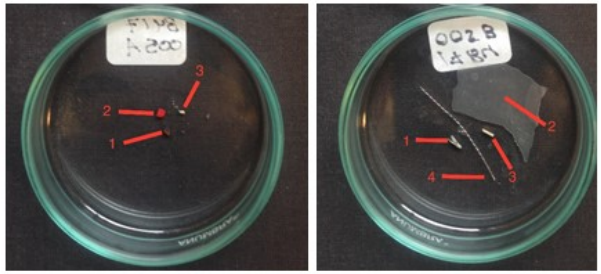
Location	Sample code	Location of net tow start	Date and time of net tow start	Distance towed (m)	Area swept (m^2)	Approx. volume swept (m^3)	Number of microplastic pieces found	Equivalent microplastic pieces per km^2
Firth of Forth	17BU001	N56° 11.067' W2° 53.557'	09/05/2017, 18:39	2089	1817	282	4	2201
	17BU002	N56° 04.328' W2° 38.443'	09/05/2017, 18:47	2058	1790	277	n/a	n/a
	17BU003A	N56° 10.909' W2° 43.432'	10/05/2017, 09:19	1817	1581	245	0	0
	17BU003B	N56° 10.883' W2° 39.914'	10/05/2017, 10:22	2098	1825	283	15	8218
	17BU004A	N56° 10.446' W2° 34.612'	10/05/2017, 13:39	1729	1504	233	1	665
	17BU004B	N56° 10.324' W2° 33.399'	10/05/2017, 14:37	1920	1670	259	1	599
Firth of Inverness	17BU005A	N57° 32.428' W4° 07.724'	12/05/2017, 09:37	2017	1755	272	3	1710
	17BU005B	N57° 32.427' W4° 07.724'	12/05/2017, 10:32	2033	1768	274	4	2262
Loch Ness	17BU006A	N57° 16.899' W4° 28.566'	13/05/2017, 16:30	1882	1638	254	1	611
	17BU006B	N57° 15.716' W4° 30.268'	13/05/2017, 17:20	1931	1680	260	0	0
Loch Linnhe	17BU007A	N56° 35.798' W5° 24.846'	17/05/2017, 10:49	2403	2090	324	0	0
	17BU007B	N56° 37.408' W5° 23.199'	17/05/2017, 11:44	2239	1948	302	2	1027
	17BU008A	N56° 25.941' W5° 30.203'	17/05/2017, 15:03	1733	1508	234	0	0
	17BU008B	N56° 25.407' W5° 32.415'	17/05/2017, 15:57	2390	2079	322	0	0
South West Mull	17BU009A	N56° 21.440' W6° 18.615'	19/05/2017, 16:32	1880	1636	254	3	1834
	17BU009B	N56° 21.333' W6° 16.403'	19/05/2017, 17:22	1791	1558	242	0	0
Tiree/ Gunna Sound	17BU010A	N56° 32.753' W6° 42.396'	20/05/2017, 07:45	1961	1706	264	0	0
	17BU010B	N56° 32.910' W6° 42.621'	20/05/2017, 09:16	2171	1889	293	0	0
	17BU011A	N56° 35.837' W6° 47.662'	20/05/2017, 10:56	2057	1789	277	5	2794
	17BU011B	N56° 35.279' W6° 49.080'	20/05/2017, 11:52	1982	1725	267	5	2899
	17BU012A	N56° 33.128' W6° 43.276'	20/05/2017, 13:15	1708	1486	230	0	0
	17BU012B	N56° 33.095' W6° 40.474'	20/05/2017, 13:59	3054	2657	412	12	4517
North West Mull	17BU013A	N56° 37.837' W6° 16.447'	23/05/2017, 11:48	3666	3189	494	2	627
	17BU013B	N56° 39.026' W6° 13.233'	23/05/2017, 12:51	2238	1947	302	0	0
Tiree/ Gunna Sound	17BU014A	N56° 33.950' W6° 45.001'	25/05/2017, 12:14	2162	1881	292	5	2658
	17BU014B	N56° 35.974' W6° 45.452'	25/05/2017, 13:16	1914	1665	258	4	2402

Location	Sample code	Location of net tow start	Date and time of net tow start	Distance towed (m)	Area swept (m^2)	Approx. volume swept (m^3)	Number of microplastic pieces found	Equivalent microplastic pieces per km^2
Eastern Small Isle	17BU015A	N56° 59.475' W5° 58.259'	29/05/2017, 10:46	2092	1820	282	0	0
	17BU015B	N56° 58.635' W6° 01.977'	29/05/2017, 11:50	1835	1596	247	3	1880
South West Rhum	17BU016A	N56° 56.613' W6° 23.167'	29/05/2017, 14:33	1976	1720	267	0	0
	17BU016B	N56° 57.421' W6° 25.405'	29/05/2017, 15:24	2403	2090	324	3	1435
Canna Island	17BU017A	N57° 04.878' W6° 29.458'	31/05/2017, 11:37	1905	1657	257	6	3620
	17BU017B	N57° 04.539' W6° 32.907'	31/05/2017, 12:32	1550	1348	209	4	2967
	17BU018A	N57° 00.299' W6° 36.923'	31/05/2017, 15:08	1986	1728	268	4	2315
	17BU018B	N57° 00.736' W6° 33.995'	31/05/2017, 16:04	2018	1756	272	4	2278
	17BU019A	N57° 03.345' W6° 38.399'	02/06/2017, 11:31	1793	1560	242	5	3206
	17BU019B	N57° 03.847' W6° 37.883'	02/06/2017, 13:00	1723	1499	232	0	0
	17BU020A	N57° 00.789' W6° 41.154'	02/06/2017, 14:58	1429	1243	193	2	1609
	17BU020B	N57° 00.044' W6° 42.136'	02/06/2017, 15:58	1331	1158	179	1	864
Shiant Isles	17BU021	N57° 53.532' W6° 20.676'	05/06/2017, 10:47	1500	1305	202	0	0
	17BU022A	N57° 54.456' W6° 19.410'	05/06/2017, 15:49	3523	3065	475	0	0
	17BU022B	N57° 52.635' W6° 17.301'	05/06/2017, 16:58	2759	2400	372	1	417
	17BU023A	N57° 54.574' W6° 24.137'	08/06/2017, 15:10	1591	1384	215	10	7225
	17BU023B	N57° 54.770' W6° 21.980'	08/06/2017, 16:01	1269	1104	171	17	15397
	17BU024A	N57° 53.444' W6° 24.767'	09/06/2017, 10:10	1556	1353	210	1	739
	17BU024B	N57° 52.629' W6° 22.382'	09/06/2017, 11:02	1576	1371	212	4	2918
	17BU025	N57° 59.345' W6° 23.788'	09/06/2017, 17:14	1033	899	139	1	1112
	17BU026A	N57° 54.769' W6° 20.366'	10/06/2017, 14:22	1734	1509	234	0	0
	17BU026B	N57° 54.218' W6° 23.846'	10/06/2017, 15:32	2404	2091	324	8	3826
Loch Alsh- Kyle	17BU027A	N57° 16.207' W5° 42.329'	16/06/2017, 09:55	2074	1804	280	0	0
	17BU027B	N57° 16.603' W5° 40.161'	16/06/2017, 11:00	2388	2077	322	0	0

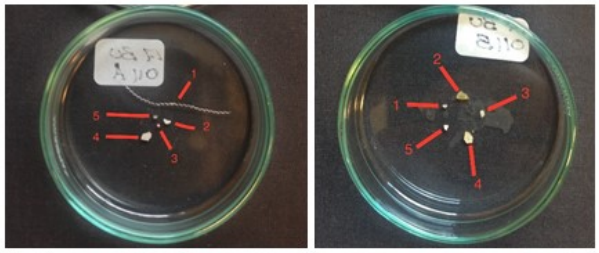
Microplastics confirmed by infra-red analysis in a selection of surface water samples



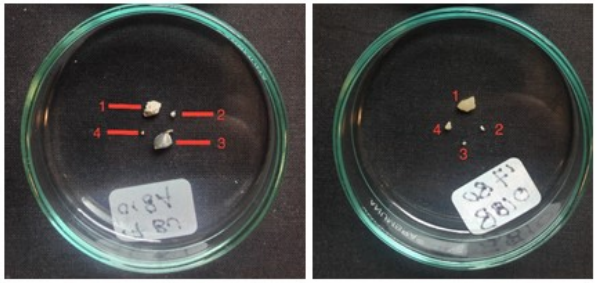
(a) 17BU003A:
Firth of Forth



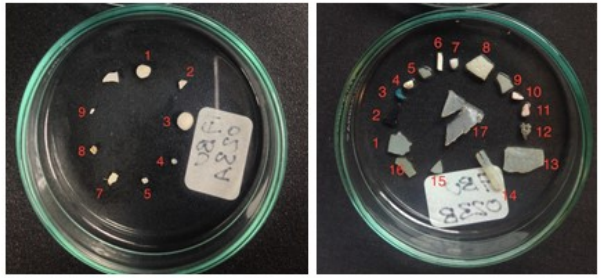
(b) 17BU005A & B:
Firth of Inverness



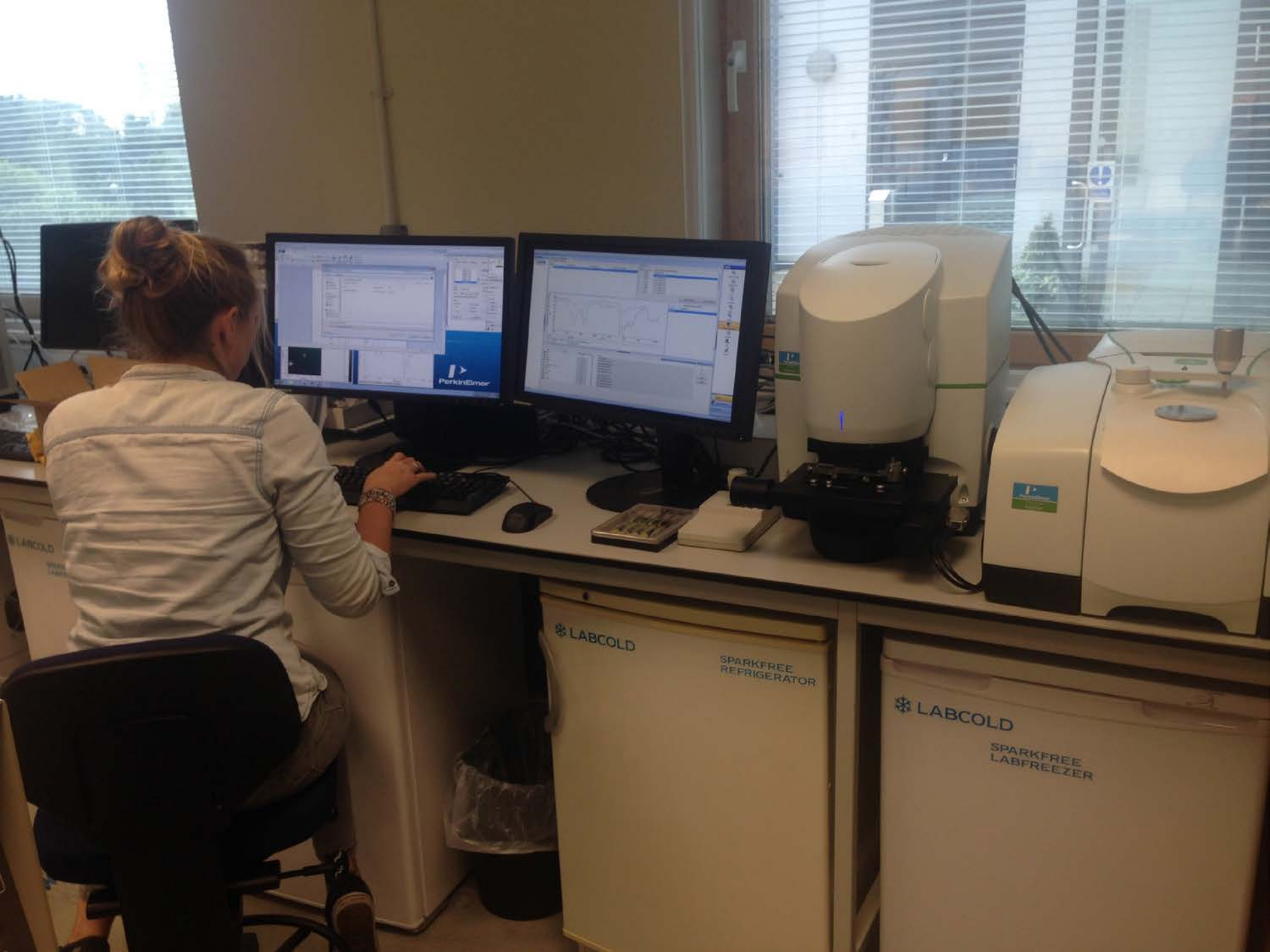
(c) 17BU011A & B:
Gunna Sound, Tiree



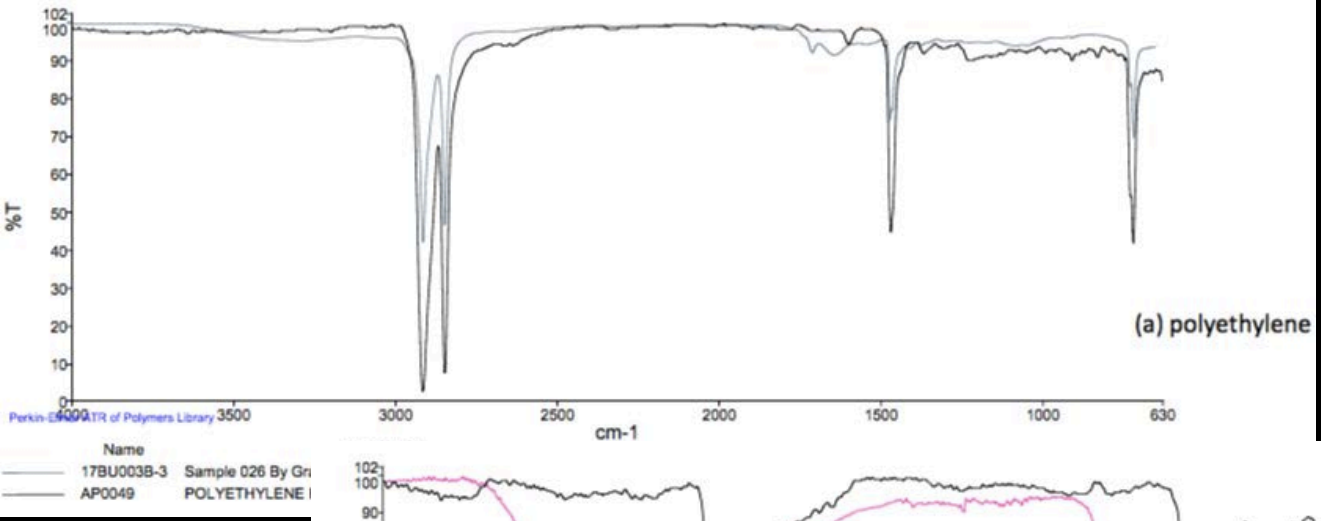
(d) 17BU018A & B:
Canna Island



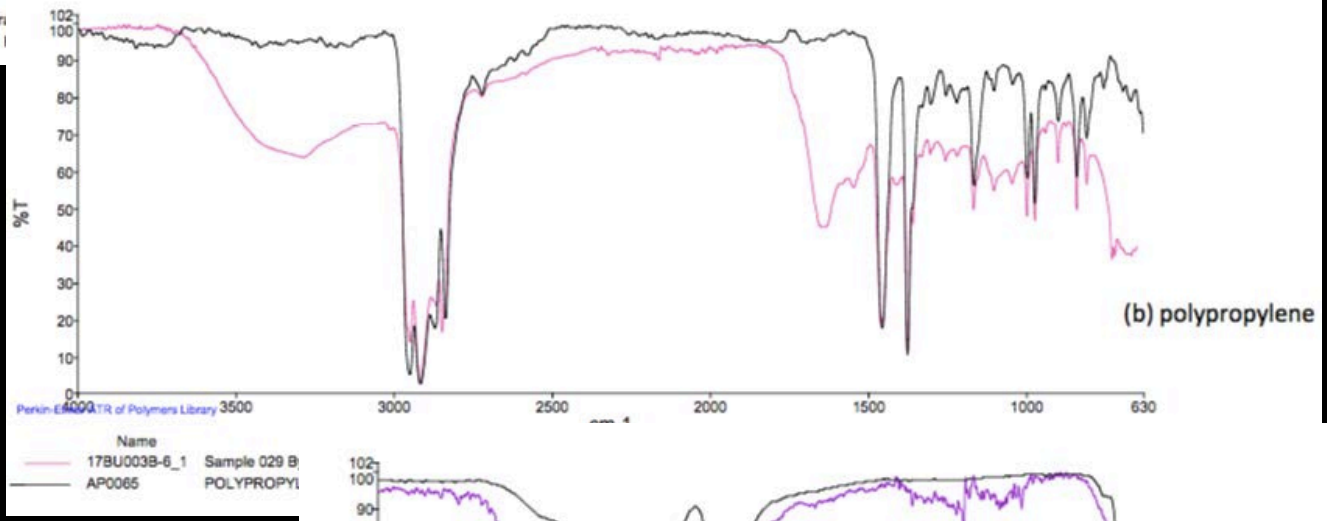
(e) 17BU023A & B:
Shiant Islands


PerkinElmer
LABCOLD
SPARKFREE
REFRIGERATOR
LABCOLD
SPARKFREE
LABFREEZER

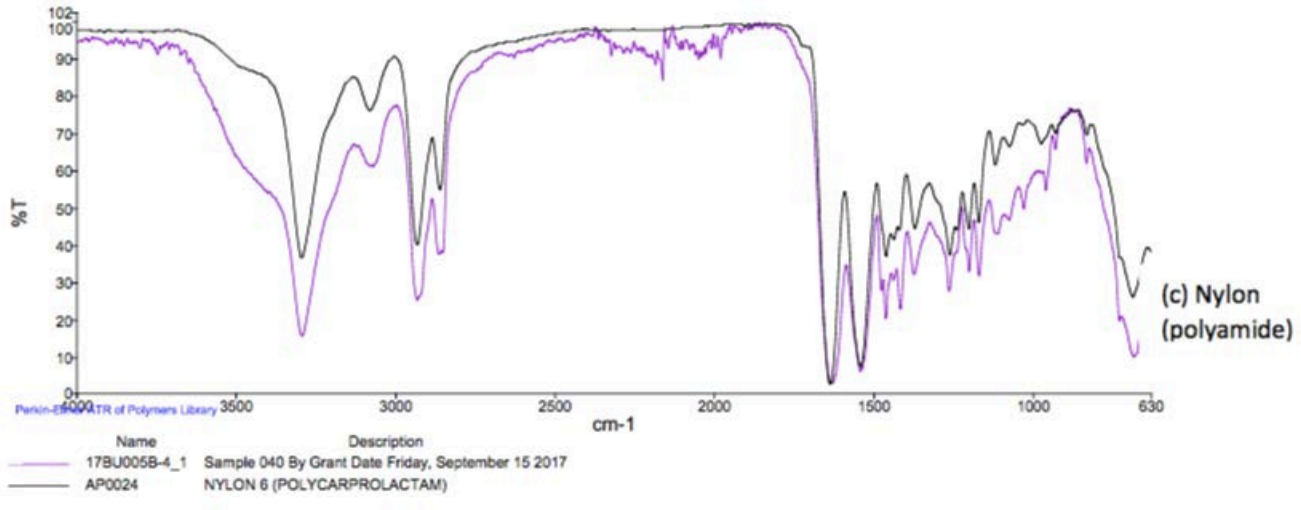
Typical infra-red spectra for plastics most commonly found in the samples



(a) polyethylene

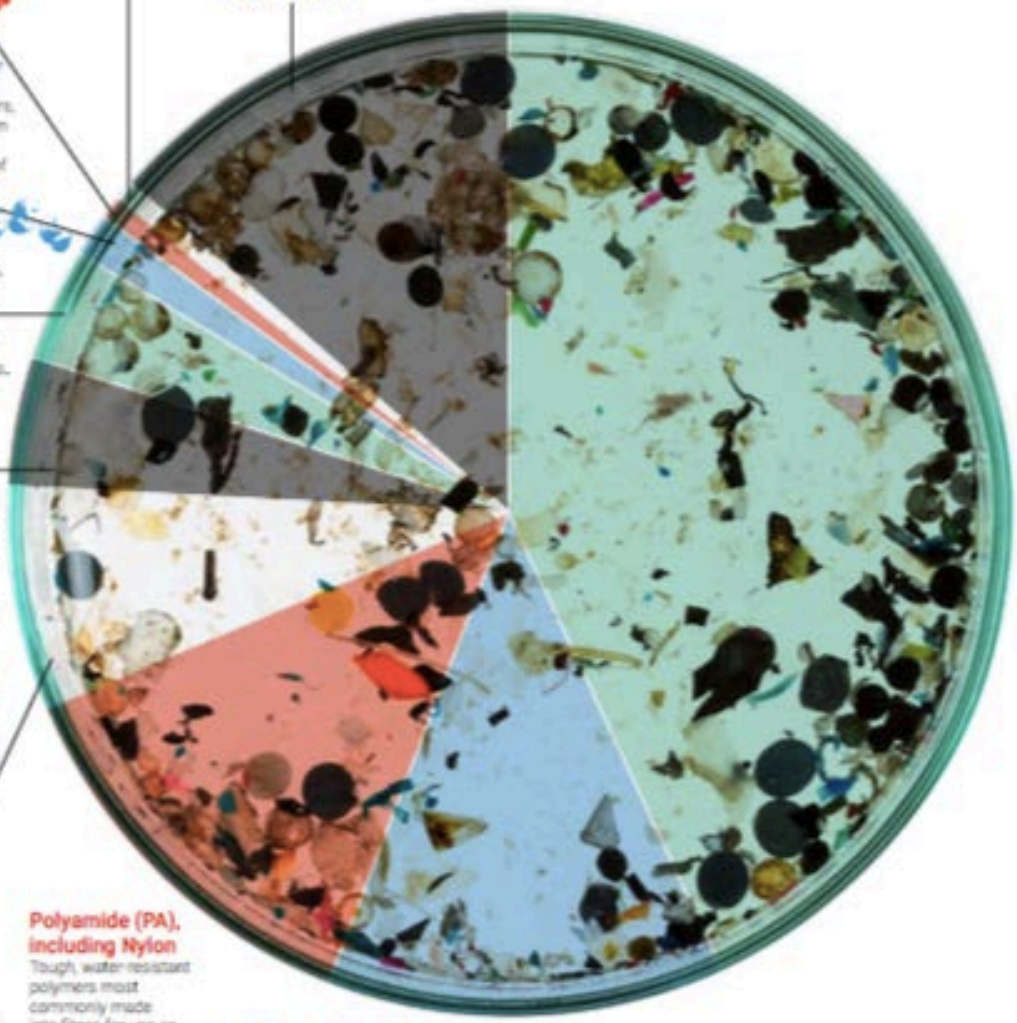


(b) polypropylene



(c) Nylon (polyamide)

coastal waters.



Vinyl acetate copolymer
One of a family of mixed polymers used as adhesives and in coatings, as well as in synthetic foams.

PV Stearate
A soft, waxy polymer with some specialist industrial applications, commonly as a co-polymer with other plastics.

Unidentified

Polystyrene (PS)
Used as a rigid plastic for yoghurt pots and some other rigid food containers, and as an expanded foam for packaging, insulation panels and some types of fishing floats and buoys.

Polyacrylate
A family of flexible polymers used in textiles, leather finishing, paints and some synthetic rubbers, as well as in mixtures to increase the flexibility of other plastics.

Vinyl Acetates:

Polyvinyl acetate (PVA) is most familiar as an adhesive, but can also be used in textile finishes, industrial coatings and even some sanitary products.

Ethylvinyl acetate (EVA) can be used as a component of padding in sports shoes and other sports equipment, as well as in some floats used for fishing gear.

Polyethylene (PE)
Manufactured in high density (HDPE) and low density (LDPE) forms, both of which have a wide diversity of uses, including bottles for milk or household cleaning products, carrier bags and smaller plastic grocery bags and a range of other containers for consumer or industrial use.

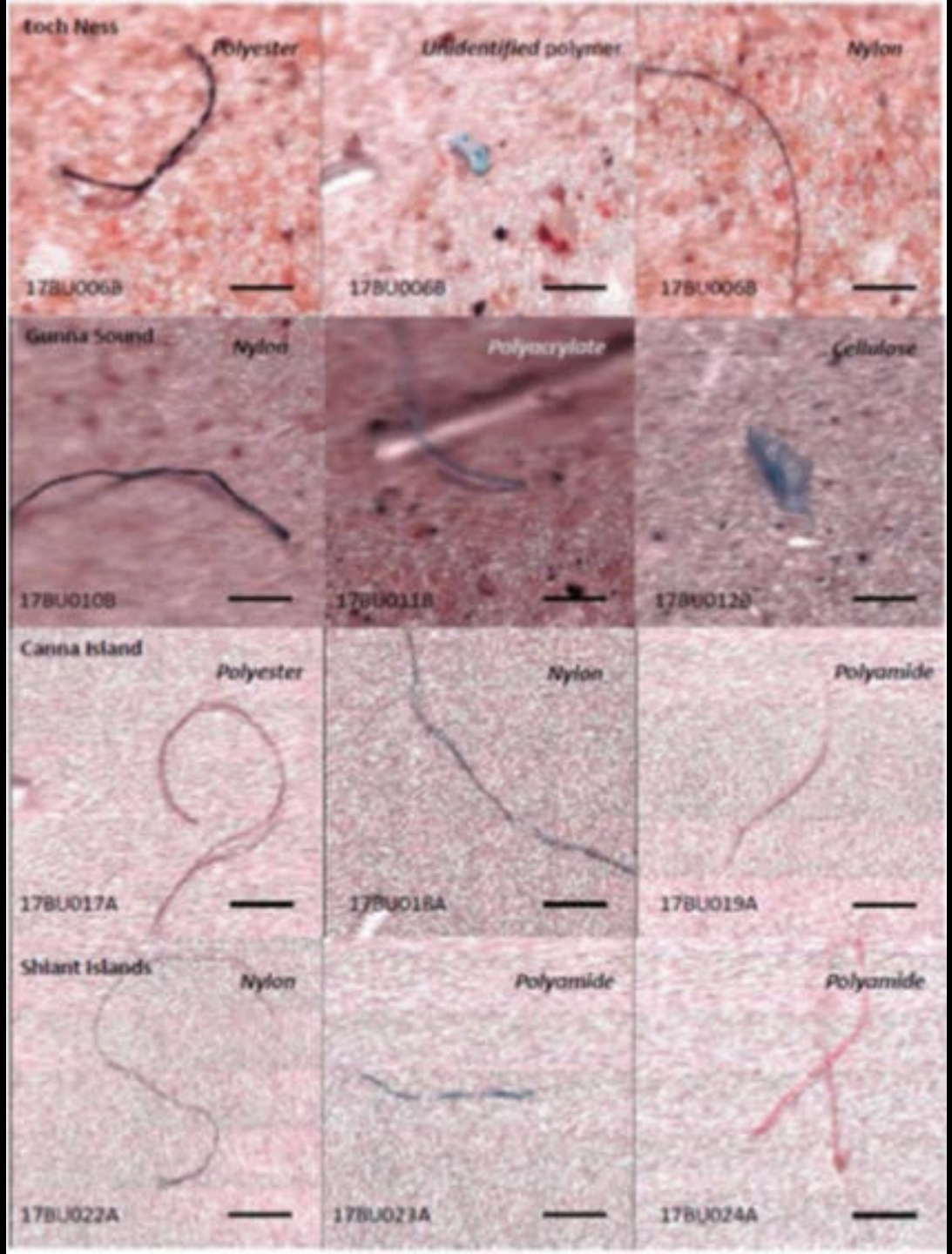
Polyester
Including polybutylene terephthalate (PBT), a high strength and electrically insulating polyester used in a range of electrical goods, as well as in some clothing and as fibres on toothbrushes.

Polyamide (PA), including Nylon
Tough, water-resistant polymers most commonly made into fibres for use as a component of clothing, carpets, ropes and fishing lines.

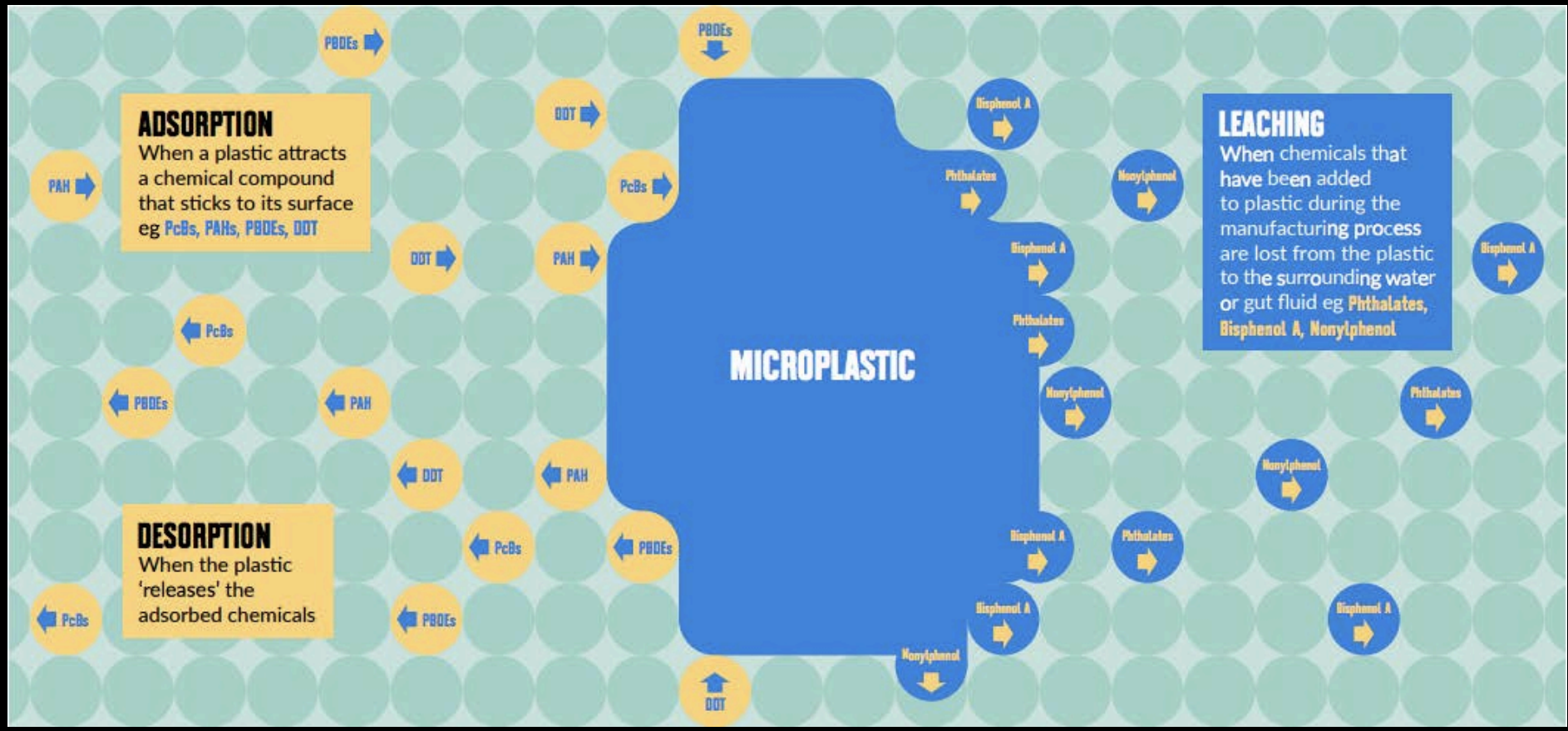
Polypropylene (PP)
A high strength plastic, resistant to chemical and temperature degradation, used for rigid containers, bottle caps and some types of rope used on ships and in fishing gear.

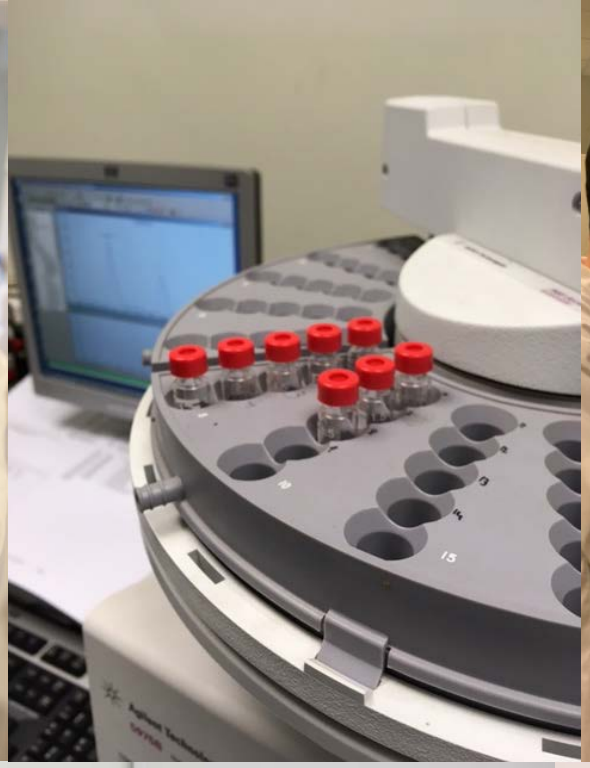
Some examples of microplastics found in the size range <63 um (0.063 mm)

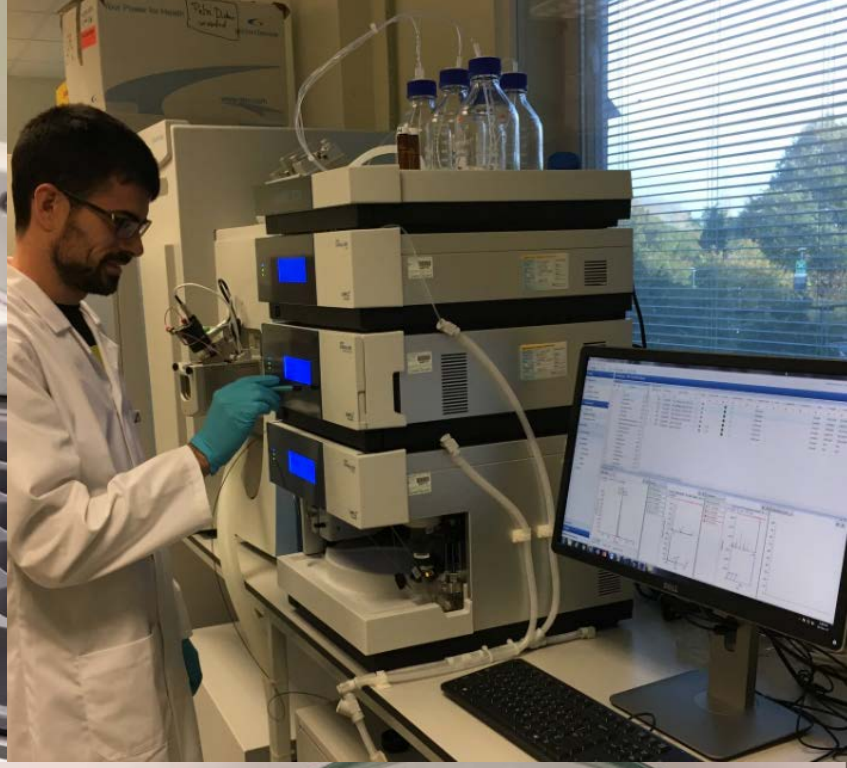
(not analysed quantitatively in this study)



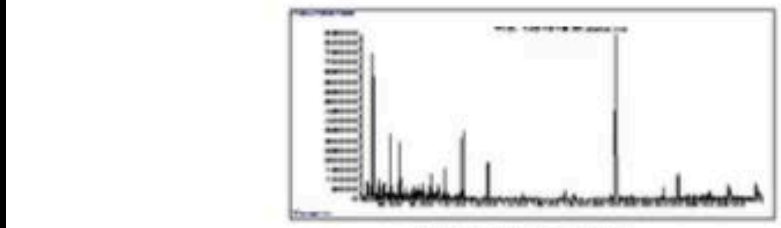
Microplastics carry a chemical burden…



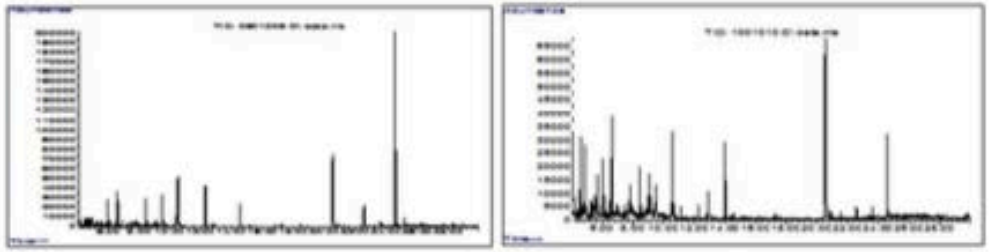




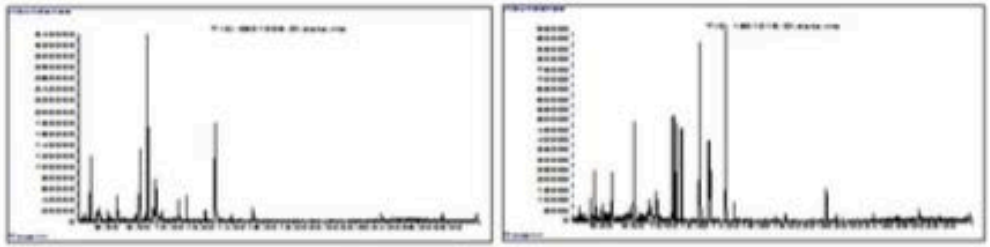
Complex mixtures of additives and contaminants associated with the microplastics found



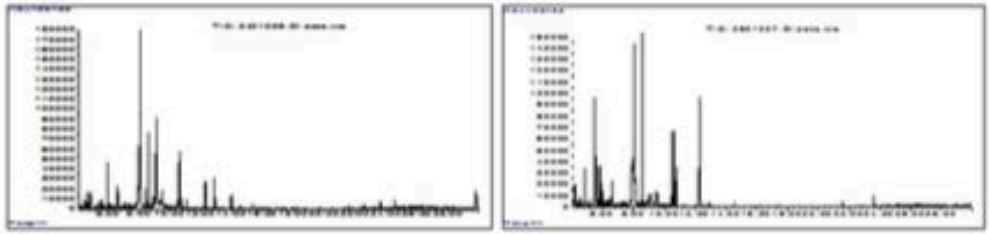
(a) 17BU003B: Firth of Forth



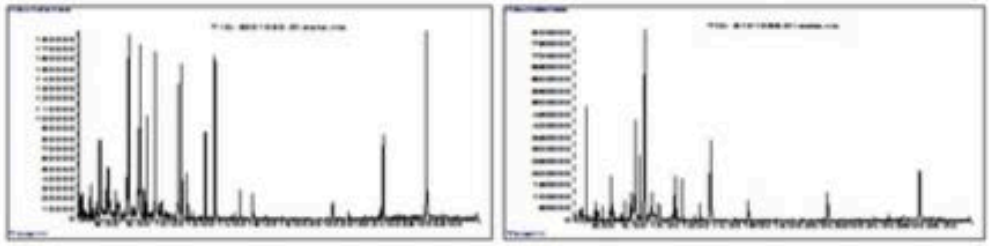
(b) 17BU005A & B: Firth of Inverness



(c) 17BU011A & B: Gunna Sound, Tiree



(d) 17BU018A & B: Canna Island



(e) 17BU023A & B: Shiant Islands

A complex chemical burden

- total of 95 different organic compounds associated with the microplastics, as well as some toxic metals, though only a fraction of this number was found in any one sample
- list includes some chemicals probably of natural origin but also a range of man-made chemicals, including some hazardous ones
- number and mix of chemicals found on/in microplastics varied greatly from sample to sample, with no clear geographical patterns, nor relationship to numbers, sizes or type of microplastics

chemical group	common uses	health concerns	frequency
12 phthalate esters, incl.: • **DEHP** • **DiBP** • **BBP** • **DINP**	• additives in flexible plastics and printing inks	• many phthalates are toxic to reproduction and can interfere with hormone systems	• 3 samples • 6 samples • 1 sample • 2 samples
4 pesticides, including: • **chlorpyrifos-ethyl** • **flufenacet** • **tebuconazole** • **buprofezin**	• insecticide (organophosphate) • herbicide • fungicide • insecticide	• toxic to nervous & immune systems • toxic to aquatic plants and algae • possibly toxic to reproduction • possibly toxic to nervous system	• 5 samples • 1 sample • 1 sample • 1 sample
3 organophosphates, incl.: • **TCEP** • **TPP** • **TPPO**	• fire retardant • fire retardant, plasticiser • chemical manufacture	• toxic to reproduction & carcinogenic • toxic to nervous system •	• 1 sample • 1 sample • 1 sample
2 UV stabilizers, including: • **UV P** • **UV 326**	• reduce degradation of plastics	• possible hormone disruptor • toxic to aquatic animals	• 4 samples • 3 samples
1 polycyclic musk • **Galaxolidone**	• breakdown product of fragrance enhancer in personal care products	• not known	• 4 samples
1 perfluorinated chemical • **PFOS**	• water/grease-proofing of fabrics and other textiles	• toxic to liver and to development	• 1 sample
5 heavy metals, including: • **lead** • **copper** • **chromium** • **manganese** • **cadmium**	• plastic stabilizers, pigments • antifoulants, biocides, electronics • pigments, metal plating • steel, pigments, cosmetics • batteries, pigments	• toxic to nervous system and kidneys • toxic to algae • some forms are carcinogenic • toxic to nervous system at high doses • toxic to kidneys	• 3 samples • 5 samples • 5 samples • 4 samples • 1 sample

Testing the waters

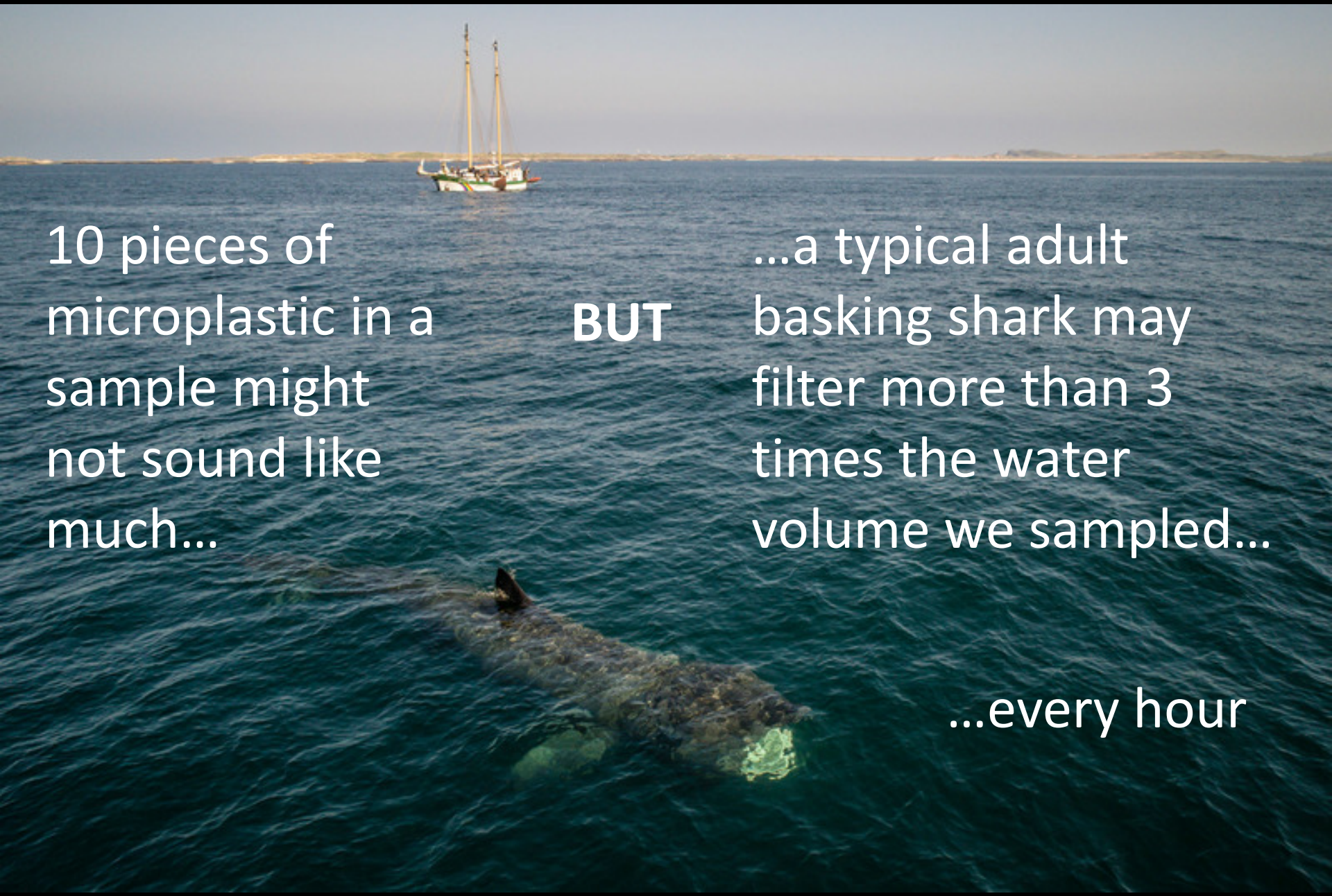
As far as we are aware…

- the most detailed survey of microplastics in Scottish surface waters published to date
- the first to apply such a depth of analysis to determine plastic type and associated chemical additives and contaminants

Does not address microplastics already beneath the surface, in sediments or on beaches

A complex and troubling signal of unsustainable use of plastics

- Even in relatively remote waters around the Hebrides, microplastics have become an unwelcome part of the fabric of marine ecosystems
- What might appear as a ‘hotspot’ for floating microplastics during one hour might appear relatively clear of microplastics the next, and vice versa.
- Similar variability in microplastic types and in chemicals carried on their surface or in their structures
- High variability/low predictability illustrates difficulties in assessing and mapping the risks they may pose.


10 pieces of microplastic in a sample might not sound like much…
BUT
…a typical adult basking shark may filter more than 3 times the water volume we sampled…
…every hour

Conclusions

- The abundance and types of microplastics vary greatly at different locations and different times in Scottish waters
- These results only represent one aspect of the total pollution problem
- Microplastics are an unwelcome part of marine ecosystems even in remote waters