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Transocean Winner Rig Incident**

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# **Taint, Polycyclic Aromatic Hydrocarbon (PAHS) and N-Alkane Analysis of Farmed Mussels and Salmon Samples Following the Transocean Winner Rig Incident**

L Webster, N Shepherd, M Russell, P Walsham, G Packer, P Hayes and W Turrell

## **Executive Summary**

This report covers the polycyclic aromatic hydrocarbon (PAHs) and *n*-alkane analysis of farmed mussels and salmon (liver and muscle) from Loch Roag following the Transocean Winner rig grounding incident, August 2016. Samples were collected from three fish farms and three shellfish farms in Loch Roag on 10/11, 16/17 and 23 August. PAH concentrations were low on all sampling occasions, with a number of PAHs being below the limit of detection. Concentrations were at background levels in both the mussels and in the salmon muscle. *n*-Alkane profiles showed no evidence of petrogenic contamination.

In addition, sensory analyses of the salmon muscle samples were undertaken and no taint was detected in any of the samples.

## Background

Transocean Winner semi-submersible rig ran aground at 0652 local time on 8 August 2016, at 58° 18.51'N 006° 46.2'W near Dalmore on the Isle of Lewis.

Loch Roag was approximately 4 nm southwest of where the incident occurred. The Isle of Lewis coastline north of Loch Roag is characterised by uniform small sandy bays and located within a rocky foreshore. The seabed in the immediate vicinity of the incident was characterised by a high energy environment dominated by sand, gravel and exposed bedrock.

Sensitivities local to the area were contained in Loch Roag, comprising two special areas of conservation for saline lagoons and Atlantic salmon and 27 active aquaculture sites. Other potential receptors such as offshore pipelines, telecommunication or power cables were not present.

It was considered at the time that the primary marine hazard associated with the incident was the 280 tonnes of diesel on-board the rig. The diesel was split between four separate storage tanks. Diesel comprises a number of light volatile hydrocarbon compounds that readily evaporate. Poor weather can aid dispersive spreading and evaporation of spilt diesel. In the event, it was estimated that 53 tonnes of diesel actually entered the sea at some time after the grounding of the rig.

Modelling the total loss of 280 tonnes of diesel from the rig, as a worse case scenario, using the weather conditions encountered indicated that the majority of the spill would have migrated towards the northeast along the Lewis coastline. Some residual diesel might have moved into Loch Roag. However, the modelling indicated that a continuous 10 knot north easterly wind was needed to drive the spill consistently south-westwards, towards Loch Roag and such conditions were not experienced

The key sensitivity identified in Loch Roag at the time of the incident were aquaculture sites. However, the distance from the incident, the composition of the hydrocarbons involved, and the modelled trajectory of the spill under the actual weather conditions experienced all suggested a greatly reduced risk to aquaculture within Loch Roag to exposure from the spilt diesel.

## Methods

### Loch Roag Sampling

As a precaution, the Environment Group requested samples to be collected from three mussel and three salmon aquaculture sites (Figure 1). The shellfish samples were collected by a Food Standard Scotland (FSS) sampling officer on 10 August 2016 and again on 16 and 23 August 2016. Details of the sampling sites are shown in Table 1. Salmon samples were taken from fish farms, detailed in Table 1, by the Local Authority in the area on 11 August 2016 and again on 16/17 and 23 August 2016.

Approximately 30 mussels of a similar size range (shell length 40-60 mm) were collected at each site. The shells were rinsed in potable water to remove any surface debris, wrapped in aluminium foil and sealed in polythene bags which were then appropriately labelled. Samples were sent to Marine Scotland Science (MSS) in cool boxes with ice packs.

Whole individual salmon were wrapped in tin foil, stored on ice, along with ice packs and returned to MSS.

Samples arrived at MSS the day after collection.

**Table 1**

Shellfish and fish farms sites sampled in Loch Roag.

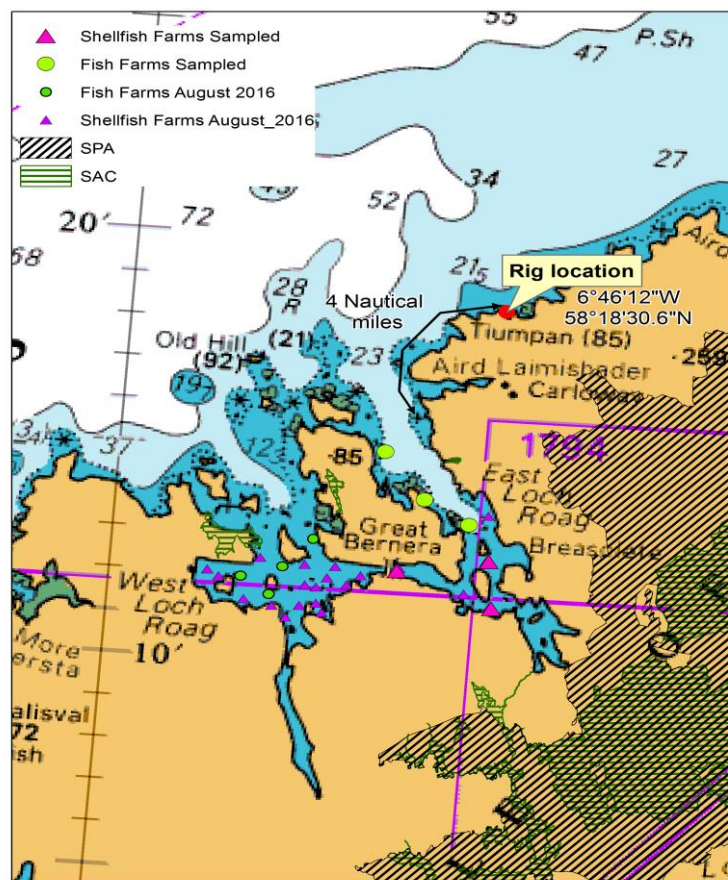
	Salmon			Mussels		
Site ID	FS0752	FS1233	FS1091	LH-381-772-08	LH-344-791-08	LH-185-120-08
Site Name	Taranaish	Eughlam	Vacasay	Ceabhagh	Eilean Chearstaigh	Barraglom
Latitude	58.2327	58.2506	58.2239	58.2096	58.1907	58.2049
Longitude	-6.8112	-6.8375	-6.7827	-6.7690	-6.7629	-6.8252

On arrival at MSS, salmon were gutted, filleted and skinned. One of the salmon, from Eughlam, collected on 23 August was gutted before sending and, therefore, there was no liver for this sample. A portion of fillet from the left and right fillets of each fish was taken for sensory assessment and a second portion from each side for hydrocarbon analysis. The liver was also kept for hydrocarbon analysis. The samples for hydrocarbon analysis were finely chopped and stored in solvent washed

aluminium cans at  $-20\pm 5^{\circ}\text{C}$  until required for analysis. The sample for sensory assessment was placed in aluminium foil, labelled and stored at  $-20\pm 5^{\circ}\text{C}$  until required

On arrival at MSS, the soft tissue was removed from each mussel and homogenised. Samples were stored in solvent washed aluminium cans at  $-20\pm 5^{\circ}\text{C}$  until required for analysis.

**Figure 1:** Map showing the location of the shellfish and fish farms sampled in Loch Roag following the Transocean Winner incident.



## Taint Assessment

Samples of fish muscle tissue were cooked by microwave heating to a core temperature of  $65^{\circ}\text{C}$  and presented to the MSS Sensory Panel in lidded glass casseroles identified by a three digit random code<sup>1</sup>. Assessors were asked to taste the fish and score any taint on a six point intensity scale (Table 2) recording the results on score sheets provided. Taint can be defined as a taste or odour foreign to the product originating from external contamination. For the purpose of this investigation the panel were asked to assess samples for the presence of

hydrocarbon taint. However, if any taint was observed, assessors were asked to describe the nature of the taint. A sample of farmed salmon (Shetland) purchased from a local fish processor was tasted alongside the test samples as a point of reference or control.

**Table 2**

The sensory assessment intensity scale.

Score	Interpretation
0	absence
1	slight
2	moderate
3	strong
4	very strong
5	extremely strong

A sample is classified as tainted if more than half the assessment panel scores are positive for the fish sample, regardless of the intensity rating as detailed in Table 3.

**Table 3**

Criteria used for determining whether a sample is tainted, suspected of being tainted or untainted based on sensory assessment.

Assessment	Criteria
Tainted	At least 50% of the taste panel members must give a score of 1 or above
Suspect Taint	Between 20% and 50% of the panel must give a score of 1 or above
Untainted	Less than 20% of the panel must give a score of 1 or above

### Isolation of Hydrocarbons from Fish Muscle and Liver

To a homogenised sample of mussels (~8 g), salmon muscle (~5 g) or salmon liver (~0.5 g) was added aliphatic internal standards (*heptamethylnonane and squalane*) and deuterated aromatic standards (*d<sub>8</sub>-naphthalene, d<sub>10</sub>-biphenyl, d<sub>8</sub>-dibenzothiophene, d<sub>10</sub>-anthracene, d<sub>10</sub>-pyrene, d<sub>12</sub>-benzo[*a*]pyrene and d<sub>14</sub>-dibenz[*a,h*]anthracene*). This was mixed with sodium hydroxide (10%, m/v) in

methanol-water (9:1, v/v; 40 ml). The mixture was refluxed for 3 hours 45 minutes before the addition of water (10 ml). Refluxing was then continued for a further 15 minutes. The resulting hot solution was extracted with *iso*-hexane (2 x 80 ml). The combined extracts were washed with water (3 x 40 ml) before drying over sodium sulphate. The dried extract was concentrated to approximately 300  $\mu$ l then fractionated by isocratic, normal phase high performance liquid chromatography (HPLC) to separate the aliphatic and aromatic components prior to analysis. An aliquot (150  $\mu$ l) of the *iso*-hexane extract was injected on to a previously calibrated Genesis SIL 4  $\mu$ m HPLC column (25 x 4.6 cm id; Jones Chromatography, Mid Glamorgan, UK) and eluted with *iso*-hexane at a flow rate of 2 ml min<sup>-1</sup>. The aliphatic fraction (first fraction, 0 to 2.5 minutes) was collected and concentrated to approximately 50  $\mu$ l for the analysis of aliphatic hydrocarbons (*n*-alkanes) by gas chromatography - mass spectrometry (GC-MS). The second fraction, (containing the aromatic hydrocarbons), was collected between approximately 2.5 and 20 minutes (split time accurately determined) and concentrated to approximately 50  $\mu$ l for polycyclic aromatic hydrocarbon (PAH) analysis by GC-MS. Both fractions were stored at -20 $\pm$ 5 $^{\circ}$ C prior to analysis.

### **Determination of Aliphatic Hydrocarbons (Including *n*-alkanes) in Fish Muscle and Liver**

The aliphatic hydrocarbon distribution, with a focus on the *n*-alkanes, was determined by GC-MS using an HP6890 Series gas chromatograph interfaced with an HP5973 MS and fitted with a cool on-column injector and a HP 5 MS column (30 m x 0.25 mm, 0.25  $\mu$ m film thickness; Agilent, Stockport, UK). Helium was used as the carrier gas in constant flow mode (0.7 ml min<sup>-1</sup>). Injections were made at 60 $^{\circ}$ C and the oven temperature held at this for three minutes. Thereafter, the temperature was raised at 4 $^{\circ}$ C min<sup>-1</sup> up to 280 $^{\circ}$ C and held at this temperature until the end of the run. The MS was set for selective ion monitoring (SIM) with a dwell time of 50 ms with quantification carried out on *m/z* 57.

### **Determination of PAHs in Sediment and Fish Muscle and Liver by Gas Chromatography-Mass Spectrometry (GC-MS)**

The concentration and composition of the PAHs (2- to 6-ring, parent and branched) were determined by GC-MS using an HP6890 Series gas chromatograph interfaced with an HP5973 MS and fitted with a cool on-column injector and a HP 5 MS column (30 m x 0.25 mm, 0.25  $\mu$ m film thickness; Agilent, Stockport, UK). Helium was used as the carrier gas in constant flow mode (0.7 ml min<sup>-1</sup>). Injections were made at 50 $^{\circ}$ C and the oven temperature held constant for 3 minutes. Thereafter, the



temperature was raised at 20°C min<sup>-1</sup> up to 100°C. This was followed by a slower ramp of 4°C min<sup>-1</sup> up to 270°C, then at 40°C min<sup>-1</sup> up to 290°C, where it was held for three minutes, then at 40°C min<sup>-1</sup> to a final temperature of 300°C, where it was held for 22 minutes. The MS was set for selective ion monitoring (SIM) with a dwell time of 50 ms. Calibration standards, covering the concentration range 0.01 to 6.0 ng µl<sup>-1</sup> were analysed, in triplicate, and the average response used to compute the calibration curve. Correlation coefficients of at least 0.99 were achieved for all PAHs. Instrument limits of detection ranged from 0.05 to 0.2 µg kg<sup>-1</sup> for individual PAHs.

## **Quality Control**

A procedural blank was analysed with the relevant batch of samples and final PAH concentrations adjusted accordingly. Instrument suitability checks were run prior to analysing samples as a check on instrument performance. The analytical methods for the determination of PAHs in biota and the sensory assessment method is accredited by the United Kingdom Accreditation Services to ISO 17025. Internal quality control procedures include the incorporation of at least one laboratory reference material (LRM) in each batch of samples. The data from the LRMs were transferred to control charting software (NWA Quality Analyst) and Shewhart charts were produced with warning and action limits drawn at ± 2 x and ± 3 x the standard deviation of the mean. Quality assurance was further demonstrated through successful participation in the QUASIMEME (Quality Assurance of Information for Marine Environmental Monitoring in Europe) Laboratory Performance Studies.

## **Results**

### **Mussel Samples**

Mussel samples were collected on the 10, 16 and 23 August from three shellfish farms in Loch Roag (Figure 1). One mussel sample (pool of ~30 individuals) from each of the three shellfish farms in Loch Roag was analysed for PAHs. On all three sampling occasions concentrations were low with a number of PAH compounds being below the limit of detection. Total PAH concentrations (2- to 6-ring parent and alkylated PAHs) ranged from 5.18 to 10.01 µg kg<sup>-1</sup> wet weight (Table 4).

MSS studies looking at PAH concentrations in mussels from sites (wild and farmed) around Scotland have shown that the majority of the rope grown mussels from remote locations had total PAH (44 PAH groupings, 2- to 6-ring PAHs) concentrations of < 50 µg kg<sup>-1</sup> wet weight (Table 4)<sup>2</sup>. PAH concentrations in mussels

vary with season. They are highest in late winter when fat levels are relatively high. They fall during spring as fat rich, and, therefore, PAH rich, eggs and sperm are shed during the spawning and rise again during the subsequent feeding period. Therefore, samples collected in August would be expected to have lower concentrations.

MSS has access to polycyclic aromatic hydrocarbon (PAH) temporal datasets (2006-2015) from an on-going monitoring programme conducted by Food Standards Scotland. These include mussel samples collected from Loch Barraglom located at the top of Loch Roag and Eilean Chearstaigh. The suite of PAHs measured for this FSS study is different to the PAHs analysed by MSS, 27 parent PAHs (not including naphthalene) and one alkylated PAH (5-methyl chrysene) were analysed. Total PAH concentrations (sum of 28) ranged from 1.16 to 6.23  $\mu\text{g kg}^{-1}$  wet weight.

**Table 4**

Summary of total PAH concentrations ( $\mu\text{g kg}^{-1}$  wet weight) in farmed, rope grown Scottish mussels

Year	Site	Month(s)	Total PAH concentration Range	Total PAH concentration Mean
2004/2005	Loch Etive	April–October	12.5–33.4 <sup>1</sup>	21.7
		November–March	39.0–53.8 <sup>1</sup>	47.1
2005/2006	Loch Etive	April–October	8.5 – 24.7 <sup>1</sup>	17.7
		November–March	32.8 – 64.6 <sup>1</sup>	53.2
2006/2007	Loch Etive	April–October	11.9 –52 <sup>1</sup>	24.8
		November–March	13.8 – 59.6 <sup>1</sup>	36.7
2005/2006	Loch Ewe	April–October	4.0 – 27.6 <sup>1</sup>	19.8
		November–March	21.2 – 62.6 <sup>1</sup>	35.3
2006/2007	Loch Ewe	April–October	11.6 – 48.9 <sup>1</sup>	22.2
		November–March	11.0 – 61.2 <sup>1</sup>	29.2
2006 - 2015	Loch Roag (FSS data)	February	1.16 – 6.23 <sup>2</sup> 0.37 – 1.21 <sup>4</sup>	2.87 0.78
2016	Loch Roag (MSS data)	10 August	7.66, 9.97, 10.01 <sup>3</sup> 1.13, 1.63, 1.23 <sup>4</sup>	9.21 1.33
2016	Loch Roag (MSS data)	16 August	5.18, 6.63, 7.65 <sup>3</sup> 0.56, 0.77, 0.75 <sup>4</sup>	6.49 0.69
2016	Loch Roag (MSS data)	23 August	6.36, 7.06, 9.17 <sup>3</sup> 0.74, 1.06, 1.20 <sup>4</sup>	7.53 1.0

<sup>1</sup>Total PAH is the sum of 36 compounds (2- to 6-ring parent and alkylated)

<sup>2</sup>Total PAH is the sum of 27 parent PAHs and 4-methyl chrysene

<sup>3</sup>Total PAH is the sum of 46 compounds (2- to 6-ring parent and alkylated)

<sup>4</sup>Total PAH is the sum of 26 parent PAHs

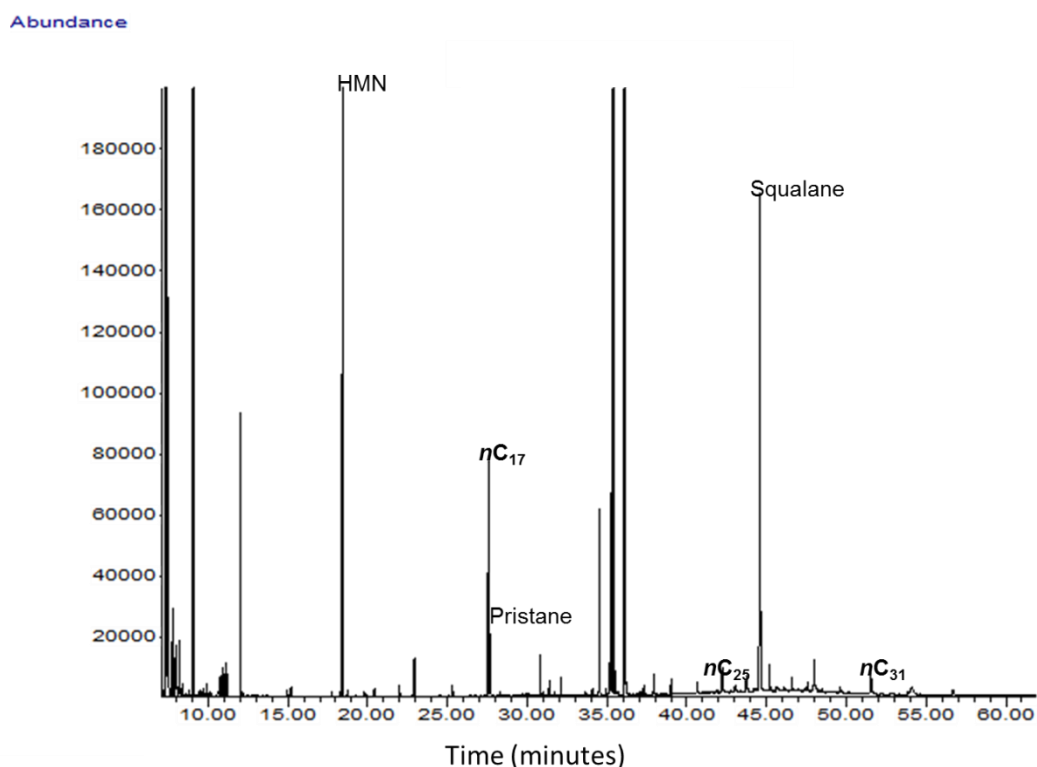
The Commission Regulation (EC) No 835/2011 sets a maximum permitted concentration (MPC) concentration of  $5 \mu\text{g kg}^{-1}$  wet weight for benzo[a]pyrene in shellfish<sup>3</sup>. In addition, an evaluation by the European Food Safety Authority's

(EFSA) panel on Contaminants in the Food Chain (CONTAM) concluded that a set of four compounds, namely benzo[a]pyrene, chrysene, benz[a]anthracene and benzo[b]fluoranthene (collectively referred to as PAH4) were more suitable indicators of PAH toxicity in food (EFSA, 2008)<sup>4</sup>. An MPC of 30  $\mu\text{g kg}^{-1}$  wet weight for the sum of these four compounds was subsequently included in the updated Commission Regulation (EC) No. 835/2011, which came into force from September 2012. Where concentrations exceed the maximum limit, the product should not be placed on the market

Benzo[a]pyrene concentrations in the three mussel samples ranged from <0.07 to 0.13  $\mu\text{g kg}^{-1}$  wet weight, and, therefore, well below the MPC of 5  $\mu\text{g kg}^{-1}$  wet weight. Concentrations for PAH4 ranged from 0.56 to 1.63  $\mu\text{g kg}^{-1}$  wet weight and again well below the MPC of 30  $\mu\text{g kg}^{-1}$  wet weight and very similar to what was seen in the FSS Loch Roag data (0.37-1.21  $\mu\text{g kg}^{-1}$  wet weight) .

Mussel samples were also analysed for *n*-alkanes. The *n*-alkane profiles showed an odd carbon predominance, typical of biogenic material, with no evidence of any petrogenic contamination (Figure 2).

**Figure 2:** Aliphatic hydrocarbon profile of a mussel sample from a Loch Roag shellfish farm. Heptamethylnonane (HMN) and squalane were used as internal standards.



## Taint Assessment of Salmon Muscle Samples

The muscle tissue of farmed salmon from three Loch Roag fish farms was assessed, in duplicate, for taint. The scoring from the sensory assessment of the fish collected on 11 August is shown in Table 5. The fish from Loch Roag were much fresher than the reference sample fish giving rise to a firmer, tougher texture with a metallic aftertaste. This may account for the few anomalous positive scores. The overall assessment is that there is no petrogenic taint present. Sensory assessment of duplicate samples collected from the same farms on 16/17 and 23 August was also undertaken. All scores were zero, there was no evidence of petrogenic taint.

**Table 5**

Summary of results from sensory assessment of Loch Roag farmed salmon, sampled 11 August 2016. NT, No taint; S, suspect; T, Tainted

Site Name	LIMS ID	Sensory Score												Mean	SD	% Positive	NT/S/T	
Vacasay	MAR-2016-31581/1	0	0	0	1	0	0	0	0	0	0	0	0	0	0.08	0.29	8.3	NT
Vacasay	MAR-2016-31581/2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0	NT
Eughlam	MAR-2016-31582/1	0	2	0	0	1	0	0	0	0	0	0	0	0	0.25	0.62	16.6	NT
Eughlam	MAR-2016-31582/2	0	0	0	0	0	0	0	0	1	0	0	0	0	0.08	0.29	8.3	NT
Taranaish	MAR-2016-31583/1	0	2	0	0	1	0	0	0	0	0	0	0	0	0.25	0.62	16.6	NT
Taranaish	MAR-2016-31583/2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0	NT

The muscle and the liver of each of the ythree salmon collected from fish farms in Loch Roag were analysed for PAHs. Concentrations were low in both the muscle and liver with a number of PAH compounds being below the limit of detection. Total PAH concentrations (2- to 6-ring parent and alkylated PAHs) in the salmon muscle ranged from 3.73 to 32.99  $\mu\text{g kg}^{-1}$  wet weight (Table 6, Appendix 2). In the liver concentrations ranged from <LoD to 48.65  $\mu\text{g kg}^{-1}$  wet weight. The muscle tissue of

two control farmed salmon from Shetland were also analysed alongside the Loch Roag salmon and gave total PAH concentrations of 10.50 and 11.98  $\mu\text{g kg}^{-1}$  wet weight. Concentrations were similar to farmed salmon (muscle tissue) from reference sites. Following the *Braer* incident in 1993 reference farmed Shetland salmon, collected out-with the Exclusion zone, were analysed for PAHs<sup>1</sup>. Total PAH concentrations (2- to 6-ring parent and alkylated) in farmed salmon muscle tissue ranged from 9.0 – 83.0  $\mu\text{g kg}^{-1}$  wet weight, with a mean of 29  $\mu\text{g kg}^{-1}$  wet weight. Total PAH concentrations have also been measured in farmed salmon from Kingairloch, Loch Linnhe in 2001 for a contract looking at PAHs in commercial species from Loch Leven in relation to the aluminium smelter<sup>5</sup>. Kingairloch was the reference site and total PAH concentrations in farmed salmon ranged from 21.2-49.3  $\mu\text{g kg}^{-1}$  wet weight, with a mean of 36.3  $\mu\text{g kg}^{-1}$  wet weight.

**Table 6**

Summary of Total PAH concentrations (2- to 6-ring parent and alkylated,  $\mu\text{g kg}^{-1}$  wet weight) in farmed salmon from Loch Roag and reference sites.

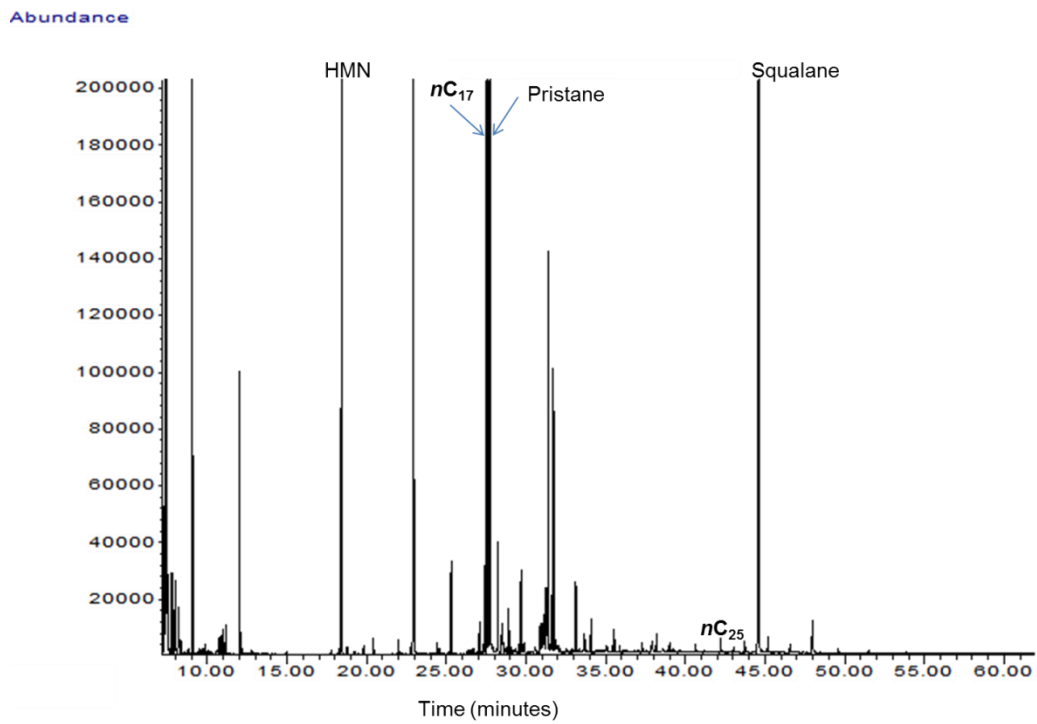
Matrix	Area	Year	Total PAH concentration Range	Total PAH concentration Mean
Muscle	Shetland (reference, outside exclusion zone)	1993	9.0 – 83	29.0
Muscle	Kingairloch, Loch Linnhe	2001	21.2 – 49.3	36.3
Muscle	Shetland	2016	10.50, 11.98	11.24
Muscle	Loch Roag	10 August 2016	4.45, 10.62, 32.99	16.02
Liver	Loch Roag	10 August 2016	48.65, 7.71, 14.4	23.59
Muscle	Loch Roag	16/17 August 2016	9.69, 27.1, 12.0	16.26
Liver	Loch Roag	16/17 August 2016	0.11, < LoD, <LoD	
Muscle	Loch Roag	23 August 2016	3.73, 8.67, 9.83	7.41
Liver	Loch Roag	23 August 2016	<LoD	

In 2012 the MPC for benzo[a]pyrene in fish muscle (2  $\mu\text{g kg}^{-1}$  wet weight) was removed from regulation EC/1881/2006. However, concentrations for benzo[a]pyrene in the salmon muscle were less than the detection limit in all salmon muscle samples analysed.

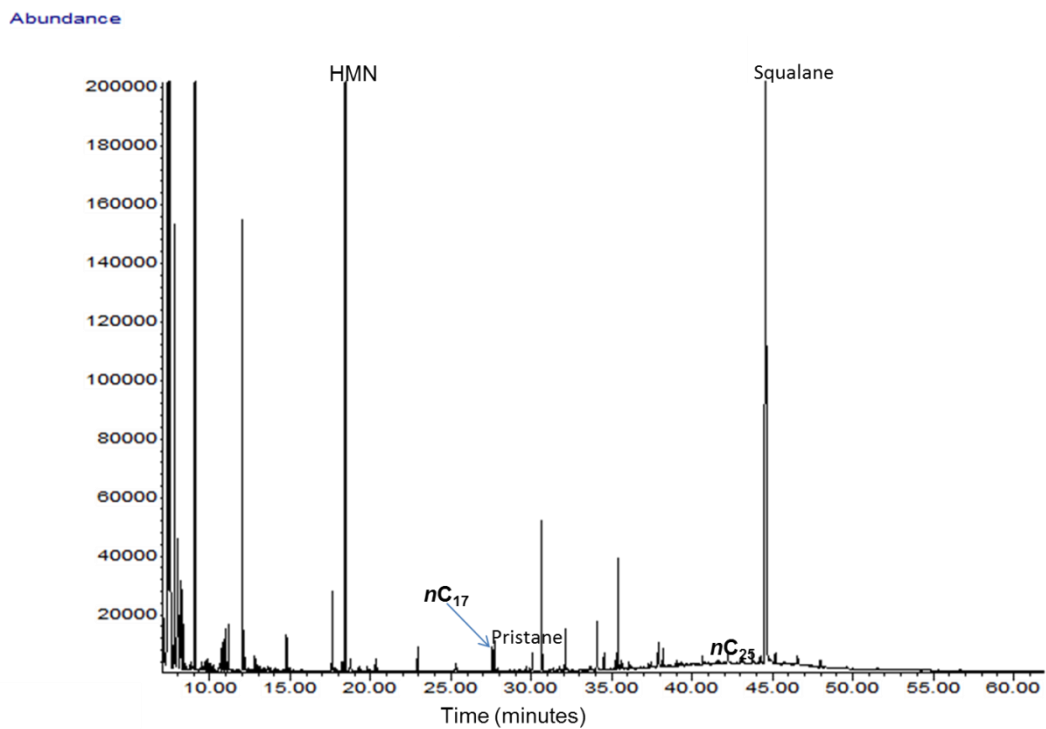
The muscle and liver profiles showed an odd carbon predominance and high proportion of pristane, the liver also had a high boiling UCM which is often found in such liver samples. There was no indication of any petrogenic contamination (Figure 3).

**Figure 3:** Aliphatic hydrocarbon profiles of a salmon (a) muscle and (b) liver sample from Loch Roag fish farms. Heptamethylnonane (HMN) and squalane were used as internal standards.

(a)



(b)



## Conclusions

The mussels, salmon muscle and liver samples collected from Loch Roag farms showed no evidence of petrogenic contamination, with PAH concentrations being typical of reference sites. In addition the aliphatic profiles showed no evidence of petrogenic contamination. Benzo[a]pyrene was below EC food safety levels in all shellfish samples, and, therefore, there is no concern with respect to human health. Sensory assessment of the salmon showed no evidence of petrogenic taint.

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## **Definitions used within the Appendices 1 and 2**

The numbers in brackets following a chemical name refers to ion monitored for that compound. For example, Benzo[c]phenanthrene (228) means that the ion 228 was monitored to allow quantitative analysis of Benzo[c]phenanthrene.

C2, C3, and C4 refer to the number of alkyl groups attached to the parent ring structure. For example, C2 naphthalene has 2 alkyl groups.

Total PAH is the sum of all PAHs measured (2- to 6-ring parent and alkylated PAHs)

AS, Accreditation status, T, result accredited, F, result not accredited; M, Masked

## Appendix 1

Summary of results from the PAH analysis of Loch Roag farmed mussels. Concentrations are in  $\mu\text{g kg}^{-1}$  wet weight.

Text id	AS	MAR-2016-31545	MAR-2016-31546	MAR-2016-31547
Field id		Eilean	Ceabhagh Keava	Barraglom
Date Collected		10/08/16	10/08/16	10/08/16
Naphthalene	T	< 0.18	< 0.18	< 0.18
2 Methyl Naphthalene	T	< 0.13	< 0.13	< 0.13
1 Methyl Naphthalene	T	< 0.09	< 0.09	< 0.09
C2 Napthalenes	T	0.34	0.44	0.31
C3 Napthalenes	T	< 0.37	0.55	< 0.37
C4 Napthalenes	T	< 0.17	0.38	< 0.36
total Naphthalenes	F	<b>0.34</b>	<b>1.37</b>	<b>0.31</b>
Phenanthrene (178)	T	0.37	0.45	0.36
Anthracene (178)	T	< 0.20	< 0.20	< 0.20
C1 178	T	0.98	1.20	0.72
C2 178	T	0.83	0.83	0.57
C3 178	T	M	M	M
total 178	F	2.18	2.48	1.65
Dibenzothiophene	T	< 0.05	< 0.05	< 0.05
C1 Dibenzothiophenes	F	< 0.11	< 0.11	< 0.11
C2 Dibenzothiophenes	F	< 0.08	< 0.08	< 0.16
C3 Dibenzothiophenes	F	< 0.16	< 0.16	< 0.16
total DBTs	F	TR	TR	TR
Fluoranthene (202)	T	0.37	0.31	0.30
Pyrene (202)	T	0.38	0.35	0.28
C1 202	T	1.0	0.93	0.78
C2 202	T	0.47	0.42	0.34
C3 202	F	M	M	M
total 202	F	2.22	2.01	1.70
Benzo[c]phenanthrene	T	< 0.13	< 0.13	< 0.13
Benz[a]anthracene (228)	T	< <b>0.20</b>	< <b>0.20</b>	< <b>0.20</b>
Chrysene & Triphenylene	T	< <b>0.57</b>	< <b>0.26</b>	< <b>0.26</b>
Benz[b]anthracene (228)	F	< 0.10	< 0.10	< 0.10
C1 228	T	M	M	M
C2 228	T	M	< 0.75	< 0.75
total 228	F	TR	ND	ND
Benzofluoranthenes (252)	T	<b>1.47</b>	<b>1.10</b>	<b>1.03</b>
Benzo[e]pyrene (252)	T	0.83	0.67	0.71
Benzo[a]pyrene (252)	T	<b>0.16</b>	<b>0.13</b>	<b>0.11</b>
Perylene (252)	T	1.14	0.65	0.80
C1 252	T	0.62	0.64	0.47
C2 252	F	< 0.26	< 0.26	< 0.26
total 252	F	4.22	3.19	3.12
Indenopyrene (276)	T	0.43	0.43	0.35
Benzoperylene (276)	T	0.58	0.53	0.53
C1 276	F	< 0.25	< 0.25	< 0.25
C2 276	F	< 0.10	< 0.10	< 0.10
total 276	F	1.01	0.96	0.88
Acenaphthylene (152)	T	< 0.08	< 0.08	< 0.08
Acenaphthene (154)	T	< 0.02	< 0.02	< 0.02
Fluorene (166)	T	< 0.08	< 0.08	< 0.08
Dibenz[a,h]anthracene	T	< 0.13	< 0.13	< 0.06
Cyclopenta[c,d]pyrene	F	< 0.02	< 0.02	< 0.02
Dibenz[a,l]pyrene (302)	F	< 0.22	< 0.22	< 0.22
Dibenz[a,e]pyrene (302)	F	< 0.07	< 0.07	< 0.07
Naphtho[2,1-a]pyrene	F	< 0.08	< 0.08	< 0.08
Dibenz[a,i]pyrene (302)	F	< 0.04	< 0.04	< 0.04
Dibenz[a,h]pyrene (302)	F	< 0.02	< 0.02	< 0.02
total PAH (46)	F	<b>9.97</b>	<b>10.01</b>	<b>7.66</b>
Sum of 4	F	<b>1.63</b>	<b>1.23</b>	<b>1.13</b>

Text id Field id Date	AS	MAR-2016-31591	MAR-2016-31592	MAR-2016-31593
		Eilean	Ceabhagh Keava	Barraglom
		16/08/16	16/08/16	16/08/16
Naphthalene	T	< 0.18	< 0.18	< 0.18
2 Methyl Naphthalene	T	< 0.13	< 0.13	< 0.13
1 Methyl Naphthalene	T	< 0.09	< 0.09	< 0.09
C2 Napthalenes	T	0.42	0.35	0.33
C3 Napthalenes	T	< 0.37	< 0.37	< 0.37
C4 Napthalenes	T	< 0.17	< 0.17	< 0.17
total Napthalenes	F	0.42	0.35	0.33
Phenanthrene (178)	T	0.27	0.25	0.28
Anthracene (178)	T	< 0.20	< 0.20	< 0.20
C1 178	T	0.48	0.41	0.62
C2 178	T	0.39	< 0.13	0.68
C3 178	T	< 0.42	< 0.42	< 0.42
total 178	F	1.14	0.66	1.58
Dibenzothiophene	T	< 0.02	< 0.02	< 0.02
C1 Dibenzothiophenes	F	< 0.11	< 0.05	< 0.11
C2 Dibenzothiophenes	F	< 0.16	< 0.16	0.38
C3 Dibenzothiophenes	F	< 0.16	< 0.16	0.240
total DBT	F	TR	TR	0.62
Fluoranthene (202)	T	0.25	0.20	0.25
Pyrene (202)	T	0.26	0.22	0.29
C1 202	T	0.72	0.73	0.87
C2 202	T	0.29	0.24	0.28
C3 202	F	M	M	M
total 202	F	1.52	1.39	1.69
Benzo[c]phenanthrene (228)	T	< 0.13	< 0.13	< 0.13
Benz[a]anthracene (228)	T	< <b>0.20</b>	< <b>0.20</b>	< <b>0.20</b>
Chrysene & Triphenylene (228)	T	< <b>0.26</b>	< <b>0.26</b>	< <b>0.26</b>
Benz[b]anthracene (228)	F	< 0.10	< 0.10	< 0.10
C1 228	T	0.93	0.82	0.90
C2 228	T	< 0.75	< 0.75	< 0.75
total 228	F	0.93	0.82	0.90
Benzofluoranthenes (252)	T	<b>0.69</b>	<b>0.56</b>	<b>0.68</b>
Benzo[e]pyrene (252)	T	0.48	0.36	0.42
Benzo[a]pyrene (252)	T	<b>0.08</b>	< <b>0.07</b>	<b>0.07</b>
Perylene (252)	T	0.75	0.50	0.75
C1 252	T	0.37	0.31	0.35
C2 252	F	< 0.26	< 0.26	< 0.26
total 252	F	2.37	1.73	2.27
Indenopyrene (276)	T	0.25	0.23	0.26
Benzoperylene (276)	T	< 0.50	< 0.50	< 0.50
C1 276	F	< 0.25	< 0.25	< 0.25
C2 276	F	< 0.10	< 0.10	< 0.10
total 276	F	0.25	0.23	0.26
Acenaphthylene (152)	T	< 0.08	< 0.08	< 0.08
Acenaphthene (154)	T	< 0.02	< 0.02	< 0.02
Fluorene (166)	T	< 0.08	< 0.08	< 0.04
Dibenz[a,h]anthracene (278)	T	< 0.06	< 0.06	< 0.06
Cyclopenta[c,d]pyrene (226)	F	< 0.02	< 0.02	< 0.02
Dibenz[a,l]pyrene (302)	F	< 0.22	< 0.22	< 0.22
Dibenz[a,e]pyrene (302)	F	< 0.07	< 0.07	< 0.07
Naphtho[2,1-a]pyrene (302)	F	< 0.08	< 0.08	< 0.08
Dibenz[a,i]pyrene (302)	F	< 0.04	< 0.04	< 0.04
Dibenz[a,h]pyrene (302)	F	< 0.02	< 0.02	< 0.02
total PAH (46 47)	F	<b>6.63</b>	<b>5.18</b>	<b>7.65</b>
Sum of 4		<b>0.77</b>	<b>0.56</b>	<b>0.75</b>

Text id	AS	MAR-2016-31603	MAR-2016-31604	MAR-2016-31605
Field id		Eilean	Ceabhagh Keava	Barraglom
Date		23/08/16	23/08/16	23/08/16
Naphthalene	T	< 0.18	< 0.18	< 0.18
2 Methyl Naphthalene	T	< 0.29	< 0.13	< 0.13
1 Methyl Naphthalene	T	< 0.09	< 0.09	< 0.09
C2 Napthalenes	T	0.44	0.25	0.32
C3 Napthalenes	T	< 0.37	< 0.37	< 0.37
C4 Napthalenes	T	< 0.17	< 0.17	< 0.17
total Naphthalenes	F	0.44	0.25	0.32
Phenanthrene (178)	F	0.34	0.27	0.26
Anthracene (178)	T	< 0.20	< 0.20	< 0.20
C1 178	T	0.59	0.42	0.49
C2 178	T	0.43	0.35	0.38
C3 178	T	0.49	0.68	0.74
total 178	F	1.85	1.72	1.87
Dibenzothiophene	T	< 0.02	< 0.02	< 0.02
C1 Dibenzothiophenes	F	< 0.05	< 0.05	< 0.05
C2 Dibenzothiophenes	F	< 0.16	< 0.16	< 0.16
C3 Dibenzothiophenes	F	< 0.08	< 0.08	< 0.08
total DBTs	F	TR	TR	TR
Fluoranthene (202)	F	0.36	0.28	0.24
Pyrene (202)	F	0.35	< 0.09	0.23
C1 202	T	0.55	0.51	0.41
C2 202	T	0.36	0.30	0.25
C3 202	F	M	M	M
total 202	F	1.62	1.09	1.13
Benzo[c]phenanthrene (228)	T	< 0.13	< 0.13	< 0.13
Benz[a]anthracene (228)	T	<b>&lt; 0.20</b>	<b>&lt; 0.20</b>	<b>&lt; 0.20</b>
Chrysene & Triphenylene (228)	T	<b>&lt; 0.26</b>	<b>&lt; 0.26</b>	<b>&lt; 0.26</b>
Benz[b]anthracene (228)	F	< 0.10	< 0.10	< 0.10
C1 228	T	0.65	0.50	0.41
C2 228	T	< 0.75	< 0.75	< 0.75
total 228	F	0.65	0.50	0.41
Benzofluoranthenes (252)	T	<b>1.08</b>	<b>0.98</b>	<b>0.74</b>
Benzo[e]pyrene (252)	T	0.59	0.62	0.49
Benzo[a]pyrene (252)	T	<b>0.12</b>	<b>0.08</b>	<b>&lt; 0.07</b>
Perylene (252)	T	0.98	0.70	0.65
C1 252	T	0.65	0.51	0.48
C2 252	F	0.26	0.28	< 0.26
total 252	F	3.69	3.17	2.36
Indenopyrene (276)	T	0.39	0.33	0.27
Benzoperylene (276)	T	0.53	< 0.50	< 0.50
C1 276	F	< 0.25	< 0.25	< 0.25
C2 276	F	< 0.10	< 0.10	< 0.10
total 276	F	0.92	0.33	0.27
Acenaphthylene (152)	T	< 0.08	< 0.08	< 0.08
Acenaphthene (154)	T	< 0.02	< 0.02	< 0.02
Fluorene (166)	T	< 0.08	< 0.08	< 0.08
Dibenz[a,h]anthracene (278)	T	< 0.13	< 0.06	< 0.06
Cyclopenta[c,d]pyrene (226)	F	< 0.02	< 0.02	< 0.02
Dibenz[a,l]pyrene (302)	F	< 0.22	< 0.22	< 0.22
Dibenz[a,e]pyrene (302)	F	< 0.07	< 0.07	< 0.07
Naphtho[2,1-a]pyrene (302)	F	< 0.08	< 0.08	< 0.08
Dibenz[a,i]pyrene (302)	F	< 0.04	< 0.04	< 0.04
Dibenz[a,h]pyrene (302)	F	< 0.02	< 0.02	< 0.02
total PAH (46 47)	F	<b>9.17</b>	<b>7.06</b>	<b>6.36</b>
Sum of 4	F	<b>1.20</b>	<b>1.06</b>	<b>0.74</b>

## Appendix 2

Summary of results from the PAH analysis of Loch Roag farmed salmon muscle (MU) and liver (LI). Concentrations are in  $\mu\text{g kg}^{-1}$  wet weight.

Text id	AS	MAR-2016-31581	MAR-2016-31581	MAR-2016-31582	MAR-2016-31582	MAR-2016-31583	MAR-2016-31583
		LI	MU	LI	MU	LI	MU
		Vacasay	Vacasay	Eughlam	Eughlam	Taranaish	Taranaish
Naphthalene	T	21.1	0.60	< 3.48	< 0.52	4.72	1.21
2 Methyl Naphthalene	T	< 1.28	0.87	< 1.28	0.44	< 1.28	2.57
1 Methyl Naphthalene	T	< 0.99	0.46	< 0.99	< 0.32	< 0.99	1.45
C2 Naphthalenes	T	< 4.85	1.84	< 4.85	0.94	< 4.85	7.42
C3 Naphthalenes	F	< 3.58	3.67	< 1.66	2.10	< 3.58	11.7
C4 Naphthalenes	T	< 2.93	< 0.44	< 2.94	< 0.44	< 2.94	1.92
total Naphthalenes	F	21.1	7.44	TR	3.48	4.72	26.27
Phenanthrene (178)	T	< 1.02	0.92	< 1.02	0.49	< 1.02	1.41
Anthracene (178)	T	3.30	< 0.06	1.34	0.14	1.83	< 0.12
C1 178	T	< 2.53	1.29	< 2.53	< 0.82	< 2.53	1.76
C2 178	T	< 3.51	< 0.53	< 3.51	< 0.53	< 3.51	< 1.13
C3 178	T	< 2.02	< 0.30	< 2.02	< 0.65	< 2.02	< 0.30
total 178	F	3.30	2.21	1.34	0.63	1.83	3.17
Dibenzothiophene	T	< 0.44	< 0.14	< 0.44	< 0.07	< 0.44	0.18
C1 Dibenzothiophenes	F	< 1.02	< 0.15	< 1.02	< 0.15	< 1.02	0.83
C2 Dibenzothiophenes	F	< 0.95	0.416	< 0.95	< 0.14	< 0.95	0.57
C3 Dibenzothiophenes	F	< 1.73	< 0.26	< 1.73	< 0.26	< 1.73	< 0.56
total DBTs	F	ND	0.42	ND	ND	ND	1.58
Fluoranthene (202)	T	< 0.63	< 0.20	< 0.63	< 0.10	< 0.63	0.23
Pyrene (202)	T	< 0.75	< 0.11	< 0.75	< 0.11	< 0.75	< 0.24
C1 202	T	< 1.06	< 0.16	< 1.06	< 0.16	< 1.06	< 0.34
C2 202	T	< 1.80	< 0.27	< 1.80	< 0.27	< 1.80	< 0.58
C3 202	F	< 2.85	< 0.43	< 2.85	< 0.43	< 2.85	M
total 202	F	ND	TR	ND	ND	ND	0.23
Benzo[c]phenanthrene (228)	T	< 0.51	< 0.08	< 0.51	< 0.08	< 0.51	< 0.08
Benz[a]anthracene (228)	T	< 1.10	< 0.08	< 0.51	< 0.08	< 0.51	< 0.08
Chrysene & Triphenylene (228)	T	3.46	< 0.09	1.90	< 0.20	1.63	< 0.09
Benz[b]anthracene (228)	F	4.75	< 0.36	3.08	< 0.36	< 2.86	< 0.17
C1 228	T	3.17	< 0.18	< 2.51	< 0.18	< 2.51	< 0.18
C2 228	T	< 1.69	< 0.25	< 1.69	< 0.25	< 1.69	< 0.25
total 228	F	11.38	TR	4.98	TR	1.63	ND
Benzo[fluoranthene] (252)	T	4.12	< 0.15	< 2.09	< 0.31	2.18	< 0.15
Benzo[e]pyrene (252)	F	< 0.58	< 0.09	< 0.58	< 0.09	< 0.58	< 0.09
Benzo[a]pyrene (252)	T	< 1.09	< 0.16	< 1.09	< 0.16	< 1.09	< 0.16
Perylene (252)	T	< 0.85	< 0.06	< 0.39	< 0.06	< 0.39	< 0.06
C1 252	T	< 1.80	< 0.27	< 1.80	< 0.27	< 1.80	0.58
C2 252	F	< 1.37	< 0.21	< 1.37	< 0.21	< 1.37	< 0.21
total 252	F	4.12	ND	TR	TR	2.18	0.58
Indenopyrene (276)	T	< 1.26	< 0.09	< 0.58	< 0.09	< 0.58	< 0.09
Benzoperylene (276)	T	< 0.67	< 0.10	< 0.67	< 0.10	< 0.67	< 0.10
C1 276	F	< 0.60	< 0.09	< 0.60	< 0.09	< 0.60	< 0.09
C2 276	F	< 0.76	< 0.12	< 0.76	< 0.12	< 0.76	< 0.12
total 276	F	TR	ND	ND	ND	ND	ND
Acenaphthylene (152)	T	< 0.34	< 0.11	< 0.34	< 0.11	< 0.34	< 0.11
Acenaphthene (154)	T	< 0.53	0.11	< 0.25	0.10	< 0.25	0.34
Fluorene (166)	T	< 0.90	0.44	< 0.42	0.24	< 0.90	0.82
Dibenz[a,h]anthracene (278)	T	4.32	< 0.08	1.39	< 0.17	2.07	< 0.08
Cyclopenta[c,d]pyrene (226)	F	< 0.04	< 0.21	< 0.04	< 0.21	< 0.04	< 0.21
Dibenz[a,l]pyrene (302)	F	< 0.37	< 0.50	< 0.37	< 0.50	< 0.37	< 0.50
Dibenz[a,e]pyrene (302)	F	< 0.57	< 0.36	< 0.27	< 0.36	< 0.27	< 0.36
Naphtho[2,1-a]pyrene (302)	F	< 0.45	< 0.45	< 0.21	< 0.45	< 0.21	< 0.45
Dibenz[a,i]pyrene (302)	F	M	M	M	M	M	< 0.33
Dibenz[a,h]pyrene (302)	F	4.43	< 0.40	< 0.03	< 0.40	1.85	< 0.40
total PAH (46 47)	F	<b>48.65</b>	<b>10.62</b>	<b>7.71</b>	<b>4.45</b>	<b>14.28</b>	<b>32.99</b>

Text id Matrix		MAR-2016- 31584	MAR-2016- 31594	MAR- 2016- 31594	MAR- 2016- 31595	MAR- 2016- 31595	MAR-2016- 31596	MAR- 2016- 31596
		MU	LI	MU	LI	MU	LI	MU
Text id	AS	MAR-2016- 31606	MAR-2016- 31607	MAR-2016- 31607	MAR-2016- 31608	MAR-2016- 31609	MAR-2016- 31609	MAR-2016- 31609
Naphthalene	T	0.82	< 1.62	< 0.52	< 1.62	2.49	< 1.62	< 0.52
2 Methyl Naphthalene	T	1.06	< 1.28	0.64	< 1.28	1.68	< 1.28	1.01
1 Methyl Naphthalene	T	0.66	< 0.99	0.36	< 0.99	0.92	< 0.99	0.54
C2 Naphthalenes	T	2.08	< 4.85	1.81	< 4.85	3.82	< 4.85	3.72
C3 Naphthalenes	T	3.62	< 1.66	2.23	< 1.66	3.97	< 1.66	3.31
C4 Naphthalenes	T	< 0.95	< 2.94	< 0.95	< 2.94	5.44	< 2.94	M
total Naphthalenes	F	8.24	TR	5.04	TR	18.32	TR	8.58
Phenanthrene (178)	T	1.28	< 1.02	0.94	< 1.02	1.30	< 1.02	0.75
Anthracene (178)	T	< 0.06	< 0.37	< 0.06	< 0.37	< 0.055	< 0.37	< 0.06
C1 178	T	0.96	< 2.53	1.31	< 2.53	2.26	< 2.53	0.90
C2 178	T	< 0.53	< 3.51	< 1.13	< 3.51	M	< 3.51	< 1.13
C3 178	T	< 0.303	< 2.02	1.44	< 2.02	< 0.303	< 4.34	< 0.30
total 178	F	2.24	ND	3.69	ND	3.56	TR	1.65
Dibenzothiophene	T	< 0.07	< 0.44	< 0.14	< 0.44	0.27	< 0.44	< 0.14
C1 Dibenzothiophenes	F	< 0.15	< 1.02	< 0.33	< 1.02	0.48	< 1.02	0.37
C2 Dibenzothiophenes	F	0.57	< 0.95	0.36	< 0.95	0.60	< 0.95	0.87
C3 Dibenzothiophenes	F	< 0.56	< 1.73	< 0.26	< 1.73	< 0.26	< 1.73	< 0.26
total DBTs	F	0.57	ND	0.36	ND	1.35	ND	1.24
Fluoranthene (202)	T	< 0.20	< 0.63	0.23	< 0.63	< 0.20	< 0.63	< 0.10
Pyrene (202)	T	< 0.11	< 0.75	< 0.24	< 0.75	< 0.11	< 0.75	< 0.11
C1 202	T	< 0.16	< 1.06	< 0.34	< 1.06	< 0.34	< 1.06	< 0.16
C2 202	T	< 0.27	< 1.80	< 0.27	< 1.80	M	< 3.86	< 0.58
C3 202	F	< 0.43	< 2.85	< 0.43	< 2.85	1.26	< 6.13	< 0.43
total 202	F	TR	ND	0.23	ND	1.26	TR	TR
Benzo[c]phenanthrene (228)	T	< 0.08	< 0.51	< 0.08	< 0.51	< 0.08	< 0.51	< 0.08
Benz[a]anthracene (228)	T	< 0.08	< 0.51	< 0.08	< 0.51	< 0.08	< 0.51	< 0.08
Chrysene & Triphenylene (228)	T	< 0.09	< 0.61	< 0.09	< 0.61	< 0.09	< 1.31	< 0.09
Benz[b]anthracene (228)	F	< 0.17	< 1.33	< 0.17	M	< 0.17	< 1.33	< 0.17
C1 228	T	< 0.18	< 1.16	< 0.38	< 1.16	0.404	< 2.51	< 0.18
C2 228	T	< 0.25	< 1.69	< 0.25	< 1.69	< 0.25	< 1.69	< 0.25
total 228	F	ND	ND	TR	ND	0.40	TR	ND
Benzo[fluoranthenes] (252)	T	< 0.15	< 0.97	< 0.15	< 0.972	< 0.15	< 0.97	< 0.15
Benzo[e]pyrene (252)	T	< 0.09	< 0.58	< 0.09	< 0.58	< 0.087	< 0.58	< 0.09
Benzo[a]pyrene (252)	T	< 0.16	< 1.09	< 0.16	< 1.09	< 0.16	< 1.09	< 0.16
Perylene (252)	T	< 0.06	< 0.39	< 0.06	< 0.39	< 0.06	< 0.39	< 0.06
C1 252	T	< 0.58	< 1.80	< 0.27	< 3.86	1.13	< 1.80	< 0.58
C2 252	F	< 0.21	< 1.37	< 0.21	< 1.37	< 0.21	< 1.37	< 0.21
total 252	F	TR	ND	ND	TR	1.13	ND	TR
Indenopyrene (276)	T	< 0.09	< 0.58	< 0.09	< 0.58	< 0.09	< 0.58	< 0.09
Benzoperylene (276)	T	< 0.10	< 0.67	< 0.10	< 0.67	< 0.10	< 0.67	< 0.10
C1 276	F	< 0.09	< 0.60	< 0.09	< 0.60	0.25	< 0.60	< 0.09
C2 276	F	< 0.12	< 0.76	< 0.12	< 0.76	< 0.12	< 0.76	< 0.11
total 276	F	ND	ND	ND	ND	0.25	ND	ND
Acenaphthylene (152)	T	< 0.11	< 0.34	< 0.11	< 0.34	< 0.11	< 0.34	< 0.11
Acenaphthene (154)	T	0.21	< 0.25	0.08	< 0.25	0.14	< 0.25	0.18
Fluorene (166)	T	0.72	< 0.42	0.28	< 0.42	0.61	< 0.42	0.35
Dibenz[a,h]anthracene (278)	T	< 0.08	< 0.53	< 0.08	< 0.53	< 0.08	< 0.53	< 0.08
Cyclopenta[c,d]pyrene (226)	F	< 0.21	0.11	< 0.21	< 0.04	< 0.21	< 0.04	< 0.21
Dibenz[a,i]pyrene (302)	F	< 0.50	< 0.37	< 0.50	< 0.37	< 0.50	< 0.37	< 0.50
Dibenz[a,e]pyrene (302)	F	< 0.36	< 0.27	< 0.36	< 0.27	< 0.36	< 0.27	< 0.36
Naphtho[2,1-a]pyrene (302)	F	< 0.45	< 0.21	< 0.45	< 0.21	< 0.45	< 0.21	< 0.45
Dibenz[a,i]pyrene (302)	F	< 0.33	< 0.08	< 0.33	< 0.08	< 0.33	< 0.08	< 0.33
Dibenz[a,h]pyrene (302)	F	< 0.4	< 0.03	< 0.40	< 0.03	< 0.40	< 0.03	< 0.40
total PAH (46 47)	F	<b>11.98</b>	<b>0.11</b>	<b>9.68</b>	<b>TR</b>	<b>27.02</b>	<b>TR</b>	<b>12.0</b>

Matrix		MU	LI	MU	MU	LI	MU
Field id		Salmon control	Vacasay	Vacasay	Eughlam	Taranaish	Taranaish
Date		24/08/16	23/08/16	23/08/16	23/08/16	23/08/16	23/08/16
Naphthalene	T	< 0.52	< 1.62	< 0.52	< 0.52	< 1.62	0.58
2 Methyl Naphthalene	T	0.67	< 1.28	0.43	0.62	< 1.28	0.62
1 Methyl Naphthalene	T	0.38	< 0.99	< 0.32	< 0.32	< 0.99	0.33
C2 Napthalenes	T	2.06	< 2.26	0.97	1.66	< 2.256	1.66
C3 Napthalenes	T	4.61	< 1.66	1.57	5.12	< 1.66	3.04
C4 Napthalenes	T	< 0.44	< 2.94	< 0.44	< 0.95	< 6.32	< 0.44
total Napthalenes	F	7.72	ND	2.97	7.40	TR	6.23
Phenanthrene (178)	F	0.72	< 2.18	0.38	0.65	< 1.02	0.97
Anthracene (178)	T	< 0.06	< 0.37	< 0.06	< 0.06	< 0.37	< 0.06
C1 178	T	1.10	< 2.53	< 0.82	< 0.82	< 2.53	< 0.82
C2 178	T	< 0.53	< 3.51	< 0.53	< 0.53	< 3.51	< 0.53
C3 178	T	< 0.30	< 4.34	< 0.30	< 0.30	< 2.02	0.81
total 178	F	1.82	TR	0.38	0.65	ND	1.78
Dibenzothiophene	T	< 0.14	< 0.44	< 0.07	< 0.07	< 0.44	< 0.07
C1 Dibenzothiophenes	F	< 0.15	< 1.02	< 0.15	< 0.15	< 2.20	< 0.15
C2 Dibenzothiophenes	F	0.49	< 2.05	0.38	< 0.31	< 0.95	< 0.31
C3 Dibenzothiophenes	F	< 0.26	< 1.73	< 0.26	< 0.26	< 1.73	< 0.26
total DBTs	F	0.49	TR	0.38	TR	TR	TR
Fluoranthene (202)	F	< 0.10	< 0.63	< 0.10	< 0.20	< 0.63	0.22
Pyrene (202)	F	< 0.11	< 0.75	< 0.11	< 0.11	< 0.75	< 0.24
C1 202	T	< 0.34	< 1.06	< 0.16	< 0.34	< 1.06	< 0.34
C2 202	T	< 0.27	< 1.80	< 0.27	1.37	< 1.80	< 0.27
C3 202	F	< 0.43	< 2.85	< 0.43	< 0.43	< 2.85	< 0.43
total 202	F	TR	ND	ND	1.37	ND	0.22
Benzo[c]phenanthrene (228)	T	< 0.08	< 0.51	< 0.08	< 0.08	< 0.51	< 0.08
Benz[a]anthracene (228)	T	< 0.08	< 0.51	< 0.08	< 0.08	< 0.51	< 0.08
Chrysene & Triphenylene (228)	T	< 0.09	< 0.61	< 0.09	< 0.09	< 0.61	< 0.09
Benz[b]anthracene (228)	F	< 0.17	< 1.33	< 0.17	< 0.17	< 1.33	< 0.17
C1 228	T	< 0.18	< 1.16	< 0.18	< 0.18	< 1.16	< 0.18
C2 228	T	< 0.25	M	< 0.25	< 0.25	< 1.69	< 0.25
total 228	F	ND	ND	ND	ND	ND	ND
Benzofluoranthenes (252)	T	< 0.15	< 0.97	< 0.15	< 0.15	< 0.97	< 0.15
Benzo[e]pyrene (252)	T	< 0.09	< 0.58	< 0.09	< 0.09	< 0.58	< 0.09
Benzo[a]pyrene (252)	T	< 0.16	< 1.09	< 0.16	< 0.16	< 1.09	< 0.16
Perylene (252)	T	< 0.06	< 0.39	< 0.06	< 0.06	< 0.39	< 0.06
C1 252	T	< 0.27	< 1.80	< 0.27	< 0.27	< 1.80	< 0.58
C2 252	F	< 0.21	< 2.96	< 0.21	< 0.21	< 1.37	< 0.21
total 252	F	ND	TR	ND	ND	TR	TR
Indenopyrene (276)	T	< 0.09	< 0.58	< 0.09	< 0.09	< 0.58	< 0.09
Benzoperylene (276)	T	< 0.10	< 0.67	< 0.10	< 0.10	< 0.67	< 0.10
C1 276	F	< 0.19	< 0.60	< 0.09	< 0.09	< 0.60	< 0.09
C2 276	F	< 0.12	< 0.77	< 0.12	< 0.12	< 0.76	< 0.12
total 276	F	TR	ND	ND	ND	ND	ND
Acenaphthylene (152)	T	< 0.11	< 0.34	< 0.05	< 0.11	< 0.34	< 0.11
Acenaphthene (154)	T	0.10	< 0.25	< 0.08	0.08	< 0.25	0.10
Fluorene (166)	T	0.37	< 0.42	< 0.13	0.33	< 0.42	0.34
Dibenz[a,h]anthracene (278)	T	< 0.08	< 0.53	< 0.08	< 0.08	< 0.53	< 0.08
Cyclopenta[c,d]pyrene (226)	F	< 0.21	< 0.09	< 0.21	< 0.21	< 0.09	< 0.21
Dibenz[a,l]pyrene (302)	F	< 0.50	< 0.37	< 0.50	< 0.50	< 0.37	< 0.50
Dibenz[a,e]pyrene (302)	F	< 0.36	< 0.27	< 0.36	< 0.36	< 0.27	< 0.36
Naphtho[2,1-a]pyrene (302)	F	< 0.45	< 0.21	< 0.45	< 0.45	< 0.21	< 0.45
Dibenz[a,i]pyrene (302)	F	< 0.33	< 0.08	< 0.33	< 0.33	< 0.08	< 0.33
Dibenz[a,h]pyrene (302)	F	< 0.40	< 0.03	< 0.40	< 0.40	< 0.03	< 0.40
total PAH (46 47)	F	<b>10.50</b>	<b>TR</b>	<b>3.73</b>	<b>9.83</b>	<b>TR</b>	<b>8.67</b>