Centre for Environment Fisheries & Aquaculture Science

Cefas

FAO Reference Centre for Bivalve Mollusc Sanitation

Norovirus (Genogroup I and II) and Hepatitis A virus Proficiency Testing (PT 82)

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Date in format: January 2021

This publication is available at www.gov.uk/government/publications

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Cefas Document Control

Submitted to:	PT 82 participants
Date submitted:	13.01.21
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Quality control by:	Dr J. Lowther
Approved by and date:	Dr J. Lowther 21.01.22
Version:	Final V2
Recommended citation for this report:	N/A

Version control history

Version	Author	Date	Comment
Draft V1	L. Stockley	06.12.21	Sent for review
Draft V2	J. Lowther	12.01.22	Reviewed and updated method data
Draft V3	M. Price-Hayward	20.01.22	Reviewed with minor comments
Draft V4	J. Lowther	21.02.22	Review final changes before issuing
Final V1	Participants	24.01.22	Minor changes to be made
Final V2	J. Lowther	07.02.22	Changes made following participants review.

Contents

1. Preparation of sample material

1.1. Sample and virus strain origin

Materials dispatched consisted of whole Pacific oysters (*C. gigas*), blended digestive glands from the same species and dsDNA control solutions for quantification (1 x 10^5 copies/µl) for each target virus. The origin of the viruses used for preparing the samples are given in Table 1. All samples were held at <-15°C until required for quality control testing, dispatch and/or reference analysis.

Table 1 - Origin and strain/genotype of viruses used for shellfish contamination

Description	Source	Strain ID / genotype
Hepatitis A virus	Cell culture supernatant	HM175/43c
Norovirus genogroup I	Faecal material	GI.7 (based on capsid sequence)
Norovirus genogroup II	Faecal material	GII.4 (based on capsid sequence)

1.2. Preparation of negative digestive glands

Batches of approximately 2000 Pacific oysters (*C. gigas*) each were collected from a UK commercial harvesting area in successive summer periods between 2019 and 2021 and were tested to demonstrate the absence of norovirus (NoV) genogroups I and II (GI and GII) and hepatitis A virus (HAV). In each year, following testing, the remaining shellfish were shucked, and the digestive glands removed. The digestive glands were pooled together before being blended to form a homogenous mixture. Different batches of negative digestive glands were used to prepare different samples depending on availability.

1.3. Preparation of highly contaminated digestive gland blends

Approximately 1000 Pacific oysters (*C. gigas*) were collected from a UK commercial harvesting area and a representative sample was tested to demonstrate the absence of NoV GI, NoV GII and HAV. The remaining live shellfish were placed in trays and immersed in 500 litres of re-circulating natural seawater at 16±1 °C. The shellfish were left to acclimatise for approximately 24 hours and checked for filtering behaviour before 50 ml of commercial shellfish food mix containing high levels of NoV GII from human faeces (provided by UKHSA) was added to the

tank. The shellfish were left to feed for approximately 16 hours to allow bioaccumulation to occur after which they were removed from the tank, shucked and the digestive glands removed. The digestive glands were pooled together before being blended to form a homogenous mixture. In a separate tank this procedure was repeated with HAV cell culture supernatant instead of NoV GII to produce two highly contaminated blends, each contaminated with a single target virus.

1.4. Sample preparation

1.4.1. Sample 1

Pacific oysters (*C. gigas*) were collected from a UK commercial harvesting area in July 2021. After initial testing demonstrated the absence of all 3 target viruses, the shellfish were placed in a large sterile container and thoroughly mixed before subsamples of 10 oysters were randomly selected and placed in sample bags and stored at <-15°C.

1.4.2. Samples 2 and 4

Blended negative glands (see above) were mixed with NoV GI positive faecal material and the highly contaminated digestive gland blend containing NoV GII (as described above) to obtain the desired target levels (see Table 2 for target levels) before being split into 2 g aliquots. The samples were held at <-15 °C until required for quality control testing, dispatch and/or reference analysis. These samples were used for both samples 2 and 4.

1.4.3. Sample 3

Blended negative glands (see above) were mixed with the highly contaminated blend containing HAV (as described above) to obtain the desired target levels (see Table 2 for target levels) before being split into 2 g aliquots. The samples were held at <-15 °C until required for quality control testing, dispatch and/or reference analysis.

2. Sample distribution

Samples were dispatched on dry ice in accordance with IATA packing instructions 650 for UN3373 'Diagnostic Specimens' on 27th September 2021 to 24 participating laboratories. Participants were requested to analyse the test samples using their routine method. Those laboratories using quantitative real-time RT-PCR were requested to calculate the quantity of

target virus in each sample using both their own standard material and using the dsDNA control solutions provided with this PT distribution.

3. Results

3.1. Reference results

Reference analyses were performed by the FAO Reference Centre (FAO RC) for Bivalve Mollusc Sanitation on samples stored at <-15˚C. Six randomly selected samples from each sample type were extracted in duplicate and qRT-PCR (TaqMan™) was carried out using duplicate PCR reactions for each RNA extract and each target. Reference results for each sample are shown in Table 2, with box and whisker plots included in Appendix I.

Table 2 - Reference results for PT 82 Proficiency testing material

Sample	Norovirus		HAV
	GI	GII	
Sample 1 (Whole animal)	-	-	-
Sample 2 (Digestive gland)	+ ($4.18 \times 10^3 – 9.17 \times 10^3$)	+ ($1.85 \times 10^3 – 4.07 \times 10^3$)	-
Sample 3 (Digestive gland)	-	-	+ ($3.72 \times 10^2 – 2.04 \times 10^3$)
Sample 4 (Digestive gland)	+ ($4.18 \times 10^3 – 9.17 \times 10^3$)	+ ($1.85 \times 10^3 – 4.07 \times 10^3$)	-

Quantities in copies/g.

Note: Ranges based on a 95% confidence limit determined as 2 geometric standard deviations above and below the geometric mean.

3.2. Participants' results

Participant's results are tabulated in Appendices II, III and IV and quantitative results are shown in graphical form alongside the reference values in Appendix V.

3.3. Performance scoring

3.3.1. Presence / absence

For all laboratories, performance scoring was undertaken on each participant's presence/absence results. A single score for each sample and each target virus (NoV GI, NoV GII and HAV) was assigned as follows: Correct = 2 points, Incorrect = 0 points. For each laboratory an overall score is provided for each target virus, taking into account the results of all 4 samples (Table 4).

3.3.2. Quantification

For those laboratories submitting quantitative results, an additional performance scoring for quantification was undertaken following the median absolute deviation from the median (MAD) approach described in ISO/TS 22117 Microbiology of food and animal feeding stuffs – specific requirements and guidance for proficiency testing by interlaboratory comparison (ISO, 2019). The MAD approach is recommended for assessment of PT data where less than 50 participants return quantitative results and/or for new proficiency assessment. Where laboratories submitted quantitative results determined using both their own quantification standards, and those provided by the FAO RC, only the results using their own standards were considered for performance scoring; however, where laboratories submitted quantitative results using the FAO RC standards only, these were considered.

For each sample/target virus combination where the intended result was positive, a statistically robust acceptability range was determined by calculation of the median absolute deviation (MAD) of each participant's result from the median of all participants' results. This figure was then multiplied by a constant (1.4826) to obtain a robust estimate of the standard deviation (σ_{MAD}; Table 3). For each individual result, its absolute deviation from the participants' median was compared with the calculated σ_{MAD} to determine its acceptability and score as follows:-

- Difference between result and participants' median <2 σ_{MAD} = satisfactory (2 points)
- Difference between result and participants' median >2 σ_{MAD} and <3 σ_{MAD} = questionable (1 point)
- Difference between result and participants' median >3 σ_{MAD} = unsatisfactory (0 points)
- Result reported as negative = unsatisfactory (0 points)

Where laboratories reported quantities for some samples as below or above a specific limit, these samples were not considered for quantitative performance scoring. The differences

between individual participants' results and the participants' median, expressed in terms of σ_{MAD} are shown in Appendix IV, and the graphs in Appendix V include lines showing the boundaries of the satisfactory and questionable ranges for each sample/target matrix combination.

For each sample/target virus combination where the intended result was negative, its acceptability and score was determined as follows:-

- Result reported as negative = satisfactory (2 points)
- Result reported as positive = unsatisfactory (0 points)

Table 3 - Dataset characteristics for quantitative results

Quantity	Sample 2		Sample 3	Sample 4	
	GI	GII	GI	GI	GII
MEDIAN	3.698	3.228	2.797	3.716	3.210
MAD	0.252	0.248	0.250	0.275	0.224
σMAD	0.373	0.368	0.370	0.407	0.332

Values in $\log_{10}$ copies/g

For each laboratory an overall score (usually out of 8) is provided for each target virus, taking into account the results of all 4 samples (Table 4).

Table 4 - Performance scoring

Lab ID	Presence / absence			Quantification		
	NoV		HAV	NoV		HAV
	GI	GII		GI	GII	
2	8	8	8	NQ	NQ	NQ
3	8	8	8	8	8	NQ
10	8	8	8	8	8	8
20	8	8	8	NQ	NQ	NQ
47	8	8	8	8	8	6
48	8	8	8	8	8	8
53	NE	NE	8	NE	NE	NQ
57	8	8	8	8	8	8
96	8	8	8	8	8	8
113	4	4	6	NQ	NQ	NQ
122	8	8	8	8	8	8
158	8	8	8	NQ	NQ	NQ
177	NE	NE	8	NE	NE	NQ
210	8	8	8	NQ	NQ	NQ
214	6	6	6	NQ	NQ	NQ
237	8	8	8	8	8	7
303	8	8	8	7	4	6
327	8	8	8	8	8	8
361	4	4	6	NQ	NQ	NQ
394	8	4	6	NQ	NQ	NQ
423 *	6	6	NE	6	NQ **	NE
462	8	8	8	8	8	8

Key: NE = Target virus not examined; NQ = Target virus not quantified; labs that scored less than full marks (normally 8) are highlighted in yellow. * = Scores are out of 6 rather than 8 due to one sample not being tested: ** = Results were quantified but all GII positive samples were reported as below the limit of quantification. This laboratory was therefore excluded from quantification scoring for GII.

4. Discussion

Twenty-three laboratories received samples, with 22 laboratories returning results. Laboratories 53 and 177 only examined the samples for HAV. Laboratory 423 did not test Sample 1 due to deterioration in transit and tested Samples 2, 3 and 4 for GI and GII only.

Methods used by participants to analyse the test samples are shown in Appendix VI, while brief details of the types of materials used as quantification standards are included as Appendix VII.

4.1. Presence / absence determination

Eighteen laboratories out of the 22 that returned results (82%) obtained the intended presence/absence result (as determined by the FAO RC) for all samples and all target viruses tested (See Appendix 2). Overall sensitivity, specificity and accuracy levels were 86%, 99% and 93% respectively.

For NoV, 16 out of 20 labs (80%) obtained the intended presence/absence result (as determined by the FAO RC) for all samples and both genogroups. A total of 10 false negative results (4 for GI, 6 for GII) were reported by 43 different laboratories, resulting in an overall sensitivity of 88%. A total of 2 false positive results (1 each for GI and GII) were reported by a single laboratory, resulting in an overall specificity 97%. The overall accuracy for norovirus results was 92%.

For HAV, 17 out of 21 labs (81%) obtained the intended presence/absence result (as determined by the FAO RC) for all samples. A total of 4 false negative results were reported by 4 different laboratories, resulting in an overall sensitivity of 81%. No false positive results were reported, resulting in an overall specificity of 100%. The overall accuracy for HAV results was 95%.

4.2. Quantification

A total of 12 laboratories (55%) reported quantitative data for at least one sample/virus combination. Of the 12 laboratories reporting quantitative data, 9 (75%) reported all results in the satisfactory range, scoring full marks for quantification for all target viruses for which they reported quantitative data. Three laboratories (25%) reported at least one questionable or unsatisfactory result.

The FAO RC recommends any laboratory with unsatisfactory results for either presence / absence or quantification refers to the trouble shooting guide available on the FAO RC website [Troubleshooting guidance for virus PT (cefas.co.uk)]

5. References

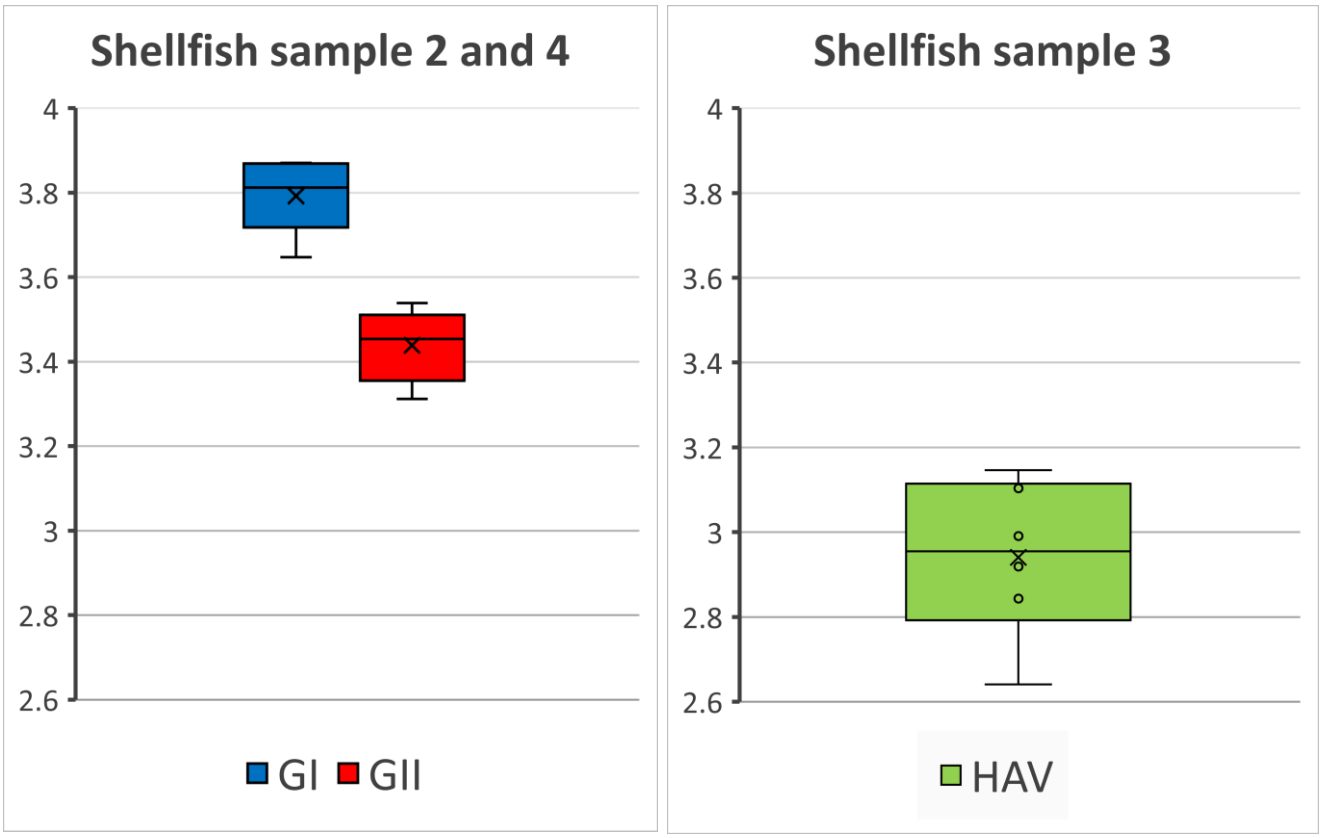
Codd AA, Richardson IR, Andrews N. 1998. Lenticules for the control of quantitative methods in food microbiology. J Appl Microbiol. 85(5):913–7.

Anon 2017. ISO 15216-1:2017 Microbiology of the food chain -- Horizontal method for determination of hepatitis A virus and norovirus using real-time RT-PCR -- Part 1: Method for quantification.

Anon 2019. ISO 22117:2019 Microbiology of the food chain -- Specific requirements and guidance for proficiency testing by interlaboratory comparison.

6. Appendix

Appendix 1 - FAO Reference Centre results displayed as box and whisker plots (log scale) of detectable genome copies per gram.



Key: Box and whisker plots (log scale) showing FAO Reference Centre results of detectable genome copies per gram.

Appendix 2 - Participants' results and C_t values

Lab ID	Shellfish sample 1						Shellfish sample 2						Shellfish sample 3						Shellfish sample 4					
	GI		GII		HAV		GI		GII		HAV		GI		GII		HAV		GI		GII		HAV	
	-	Ct	-	Ct	-	Ct	+	Ct	+	Ct	-	Ct	-	Ct	-	Ct	+	Ct	+	Ct	+	Ct	-	Ct
2	-		-		-		+	33.836	+	36.734	-		-		-		+	33.394	+	33.067	+	36.865		
3	-		-		-		+	35.17 / 34.57	+	34.06 / 34.23	-		-		-		+	37.24 / 38.78	+	35,34 / 34,96	+	34,47 / 34,27	-	
10	-		-		-		+	32.67	+	34.35	-		-		-		+	36.05	+	32.62	+	34.49	-	
20	-		-		-		+	29.68	+	32.13	-		-		-		+	30.06	+	29.59	+	31.15	-	
47	-		-		-		+	33.31	+	33.1	-		-		-		+	42.05	+	32.56	+	33.02	-	
48	-		-		-		+	34.91	+	35.27	-		-		-		+	35.06	+	34.48	+	34.04	-	
53	NE		NE		-		NE		NE		-		NE		NE		+	35.45	NE		NE		-	
57	-		-		-		+	31.9	+	33.42	-		-		-		+	34.27	+	31.54	+	33.86	-	
96	-		-		-		+	33.02	+	34.17	-		-		-		+	33.49	+	33.15	+	34.52	-	
113	-		-		-		-		-		-		-		-		-		-		-		-	
122	-		-		-		+	32.235	+	32.761	-		-		-		+	37.148	+	32.621	+	32.825	-	
158	-		-		-		+	30.71	+	33.22	-		-		-		+	33.49	+	30.74	+	33.23	-	
177	NE		NE		-		NE		NE		-		NE		NE		+	34.85	NE		NE		-	
210	-		-		-		+	38.52	+	38.39	-		-		-		+	41.32	+	35.81	+	36.34	-	
214	-		-		-		+	33.52	+	35.86	-		+	33.39	+	35.65	-	50	+	34.18	+	35.27	-	
237	-		-		-		+	33.2	+	32.68	-		-		-		+	33.8	+	33.01	+	33.2	-	
303	-	50	-	50	-	50	+		+		-	50	-		-		+		+		+		-	50
327	-		-		-		+	31.3	+	36.9	-		-		-		+	38.4	+	31.6	+	36.6	-	
361	-		-		-		-		-		-		-		-		-		-		-		-	
394	-		-		-		+	31.7	-		-		-		-		-		+	32	-		-	
423	NE		NE		NE		+	35.19	+	37.9	NE		-		-		NE		+	36.32	+	36.28	NE	
462	-		-		-		+	32.91	+	33.63	-		-		-		+	35.25	+	33	+	33	-	

Key: NE= sample/target virus combination not examined. Yellow shading denotes false negative results. Red shading denotes a false positive.

Appendix 3 - Participants reported quantities for each target (copies/g)

Lab ID	Shellfish sample 2				Shellfish sample 3		Shellfish sample 4			
	GI		GII		HAV		GI		GII	
	A	B	A	B	A	B	A	B	A	B
3	3.14E+03	4.72E+03	2.38E+03	3.47E+03			2.54E+03	3.85E+03	2.03E+03	2.98E+03
10	5.08E+03		2.25E+03		6.18E+02		5.06E+03		1.97E+03	
47	2.55E+03	1.33E+03	8.38E+02	4.74E+02	1.86E+01	1.06E+01	4.25E+03	2.22E+03	9.68E+02	5.48E+02
48		1.50E+03		5.00E+02		6.35E+02		3.18E+03		1.06E+03
57	7.65E+03	8.90E+03	1.17E+03	1.60E+03	2.90E+02	1.77E+03	9.70E+03	1.12E+04	8.20E+02	1.15E+03
96	2.52E+03	3.26E+03	2.45E+03	2.46E+03	9.16E+02	7.25E+02	2.38E+03	3.10E+03	2.01E+03	2.02E+03
122		8.13E+03		1.69E+03		5.13E+02		6.25E+03		1.62E+03
237	4.90E+03	1.90E+03	9.55E+02	7.07E+02	5.53E+03	7.65E+02	5.35E+03	2.08E+03	6.34E+02	4.76E+02
303	3.63E+04		5.66E+04		2.48E+04		2.96E+04		4.48E+04	
327		1.59E+04		4.32E+02		4.51E+02		1.30E+04		5.19E+02
423	4.15E+03	2.56E+03	<LOQ	<LOQ			2.47E+03	1.67E+03	<LOQ	<LOQ
462		1.06E+04		4.51E+03		2.05E+03		9.89E+03		5.20E+03

Key: A = Results obtained with lab's own quantification standards; B = Results obtained with FAO Reference Centre quantification standards; results reported as <x or >x are included for information and are presented as reported by the relevant participant.

Appendix 4 - Differences between participants' results and the participants' median, expressed in terms of σ_{MAD}

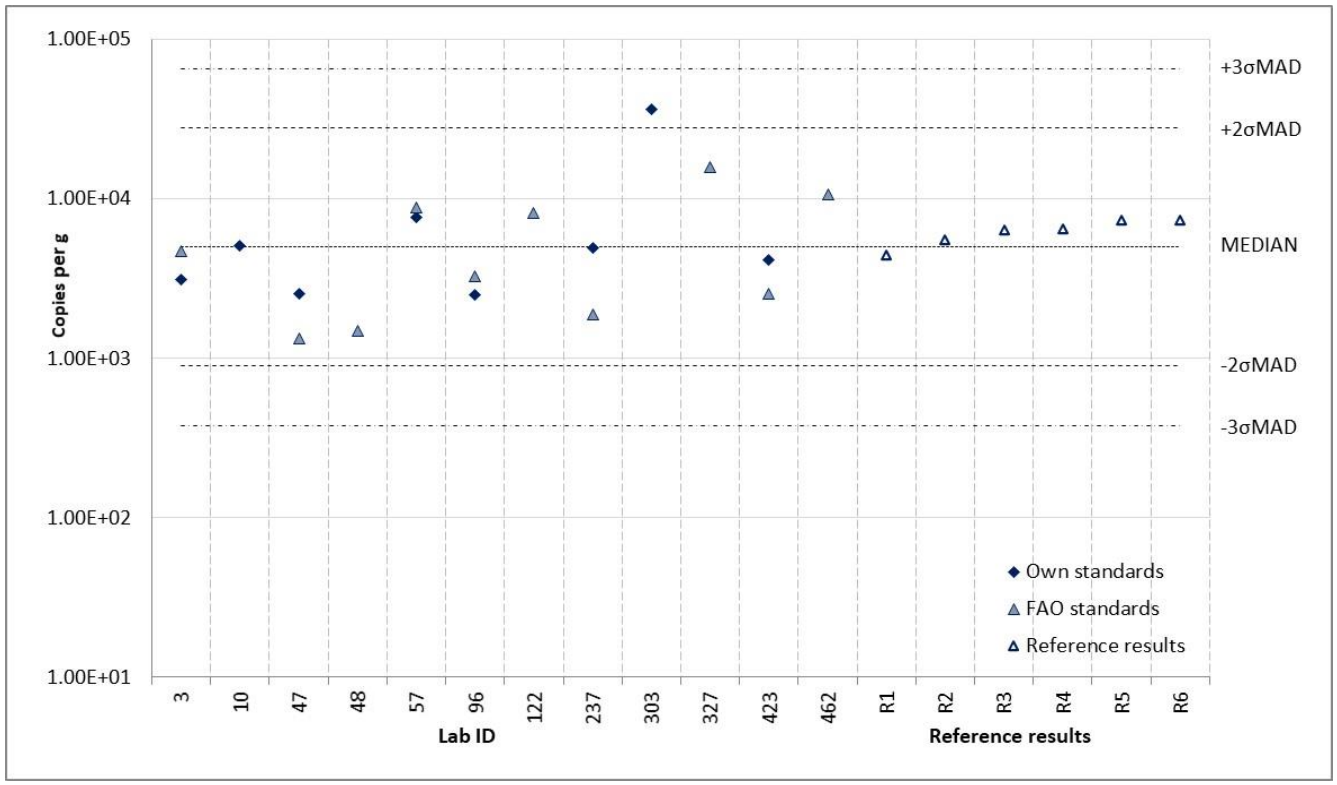
Lab ID	Shellfish sample 2		Shellfish sample 3	Shellfish sample 4	
	GI	GII	HAV	GI	GII
3	-0.54	0.41		-0.76	0.30
10	0.02	0.34	-0.02	-0.03	0.25
47	-0.78	-0.83	-4.12	-0.22	-0.67
48	-1.40	-1.44	0.02	-0.52	-0.55
57	0.50	-0.43	-0.90	0.66	-0.89
96	-0.79	0.44	0.45	-0.83	0.28
122	0.57	0.00	-0.23	0.20	0.00
237	-0.02	-0.67	2.55	0.03	-1.23
303	2.31	4.15	4.32	1.85	4.35
327	1.35	-1.61	-0.39	0.98	-1.49
423	-0.21	<LOQ	NQ	-0.79	<LOQ
462	0.88	1.16	1.39	0.68	1.53

Key: Red shading = Unsatisfactory results (false negative, or magnitude of difference between result and participants' median >3 σ_{MAD}); Orange shading = Questionable results (magnitude of difference between result and participants' median >2 σ_{MAD} and <3 σ_{MAD}); NQ = quantitative results not reported, excluded from scoring; <LOQ = results reported as below limit of quantification, excluded from scoring.

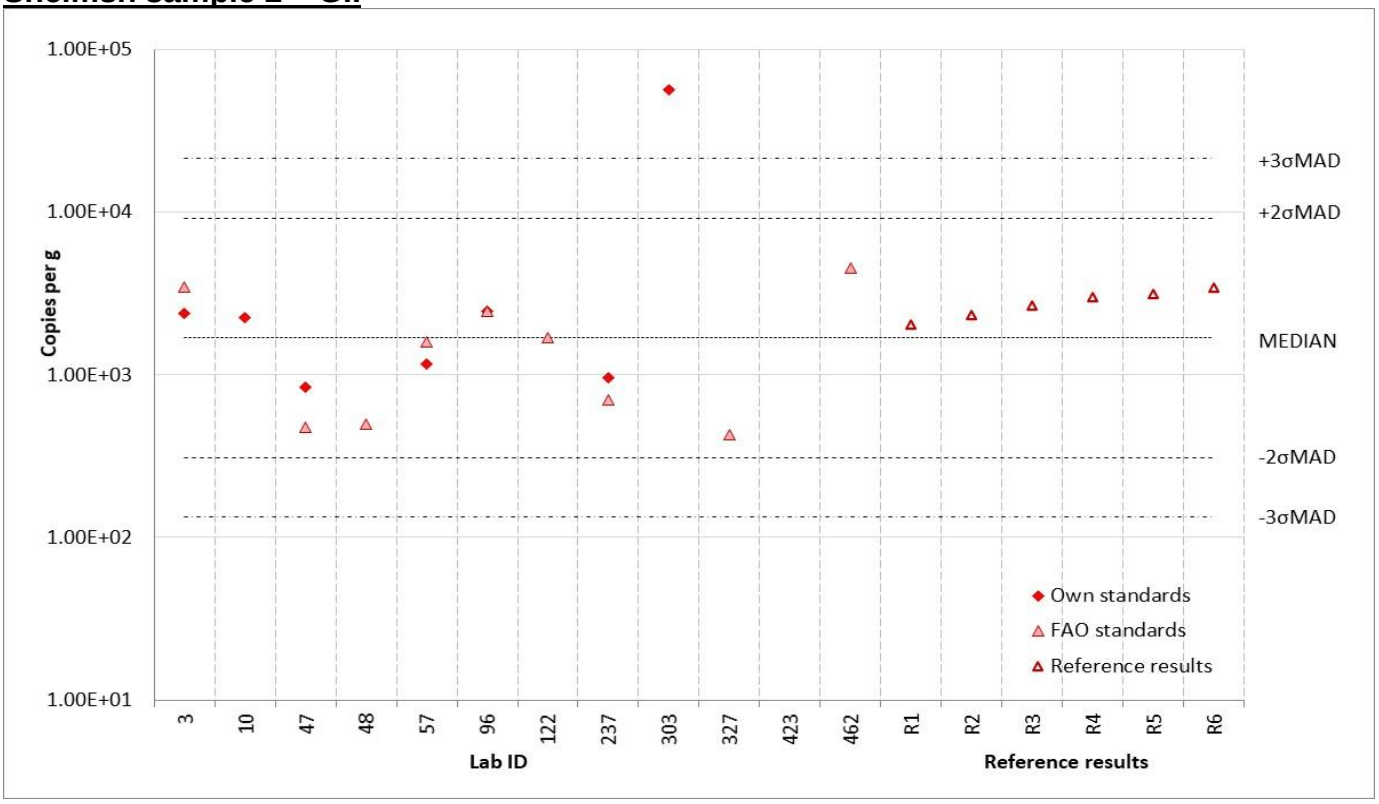
Appendix 5 - Participants' and reference quantities for each sample.

Note: Where quantities were reported using both the laboratory's own quantification standards and those provided by the FAO Reference Centre, only those using the lab's own standards are considered for performance scoring.

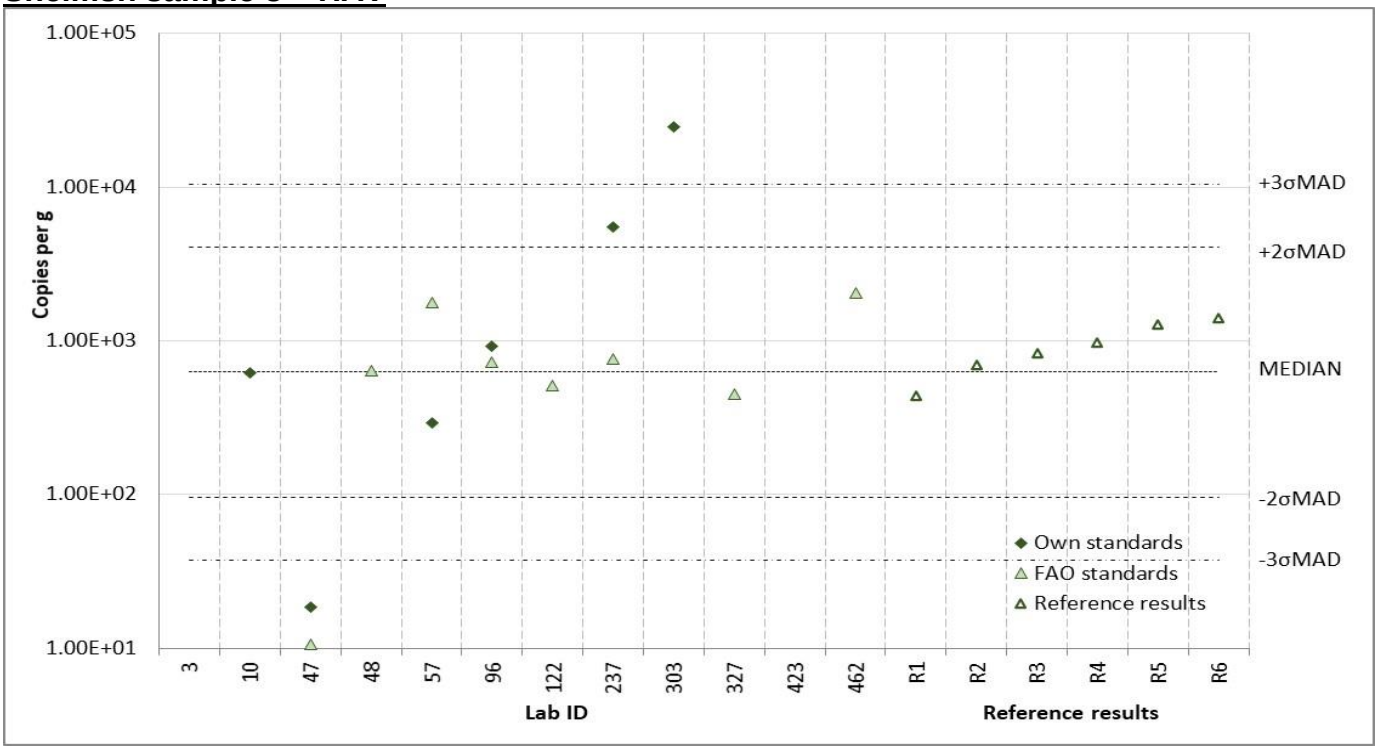
Shellfish sample 2 – GI



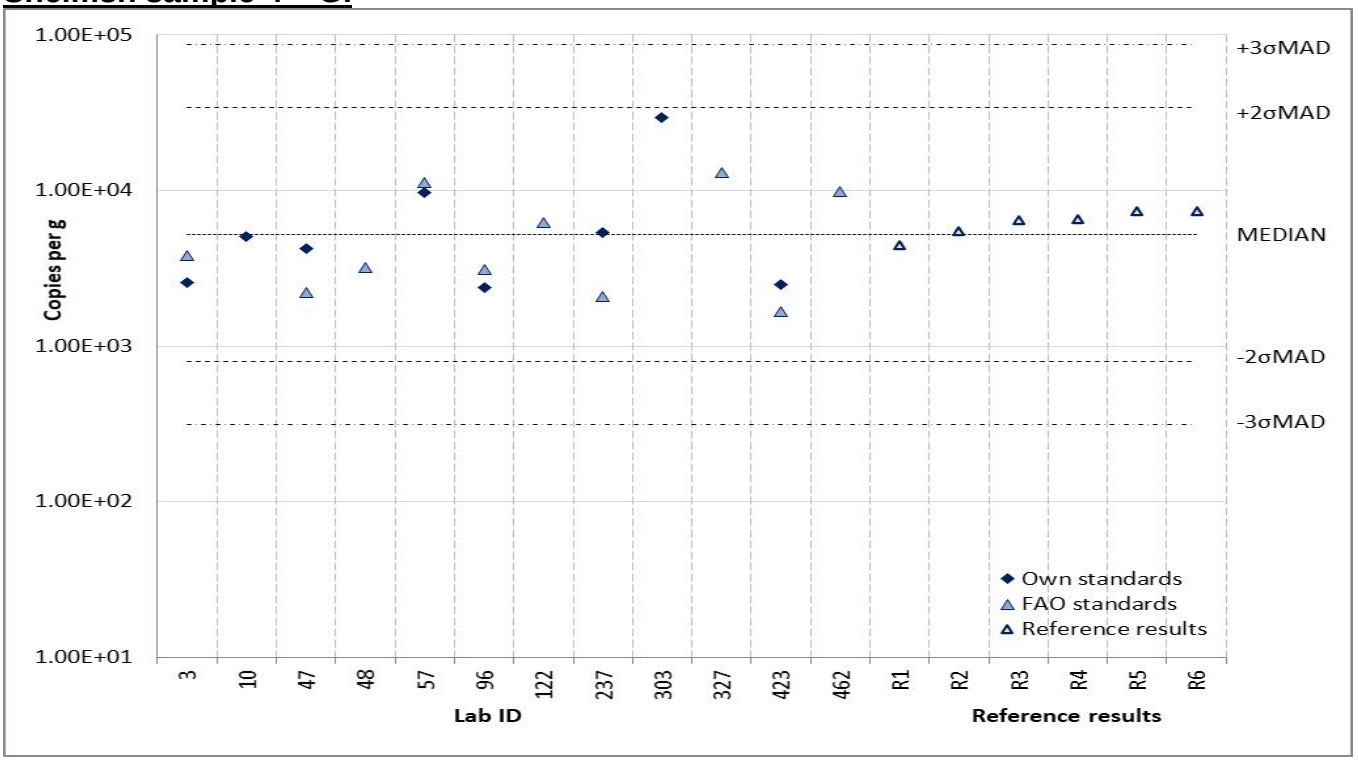
Shellfish sample 2 – GII



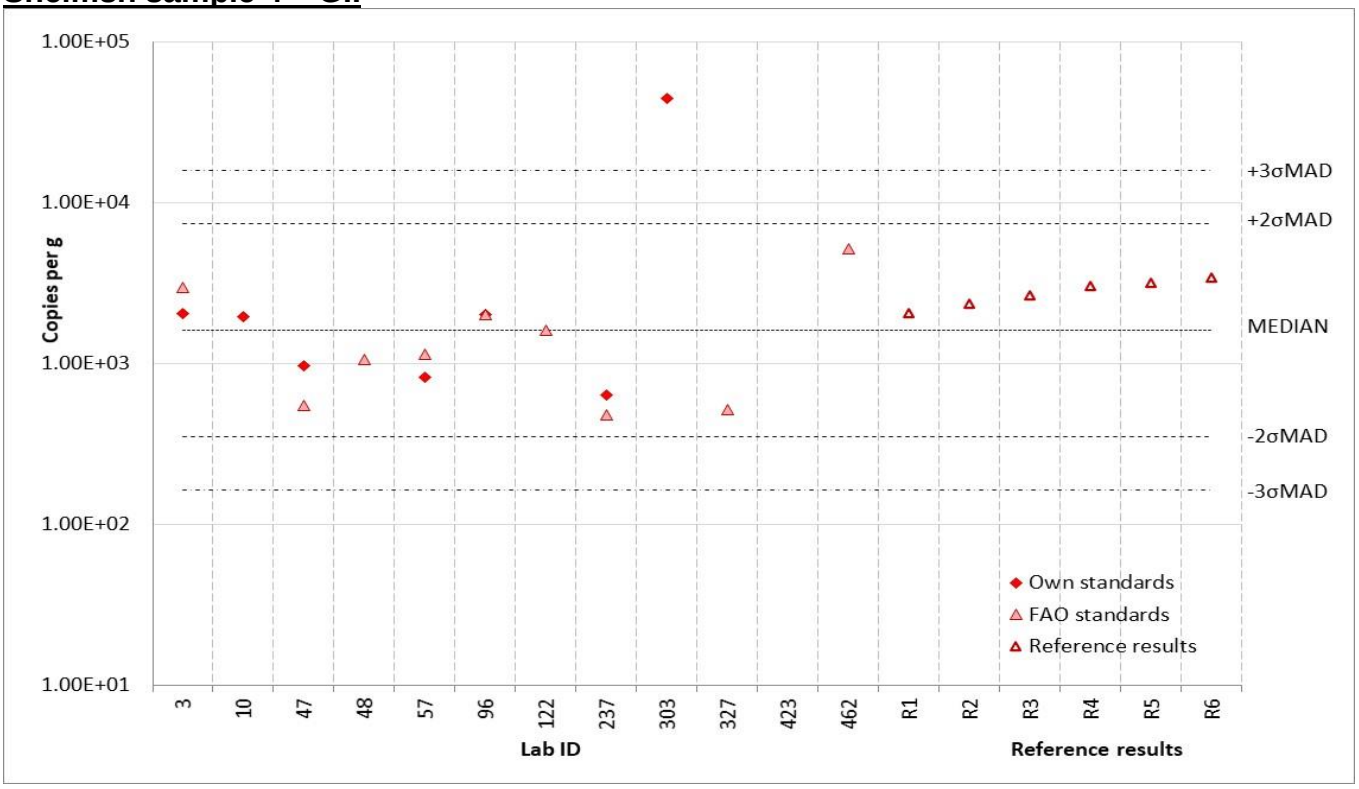
Shellfish sample 3 – HAV



Shellfish sample 4 – GI



Shellfish sample 4 – GII



Appendix 6 - Results and methods used.

Lab ID	Shellfish sample 1			Shellfish sample 2			Shellfish sample 3			Shellfish sample 4			Extraction		RT PCR		Primers		
	GI	GII	HAV	GI	GII	HAV	GI	GII	HAV	GI	GII	HAV	Virus	RNA	Method	Reagents	GI	GII	HAV
2	-	-	-	+	+	-	-	-	+	+	+		A	D	J	L	AA-1	AA	FF
3	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-1	AA	AA
10	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-1	AA	AA
20	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	N	BB	BB	BB
47	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-1	AA	AA
48	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-1	AA	AA
53	NE	NE	-	NE	NE	-	NE	NE	+	NE	NE	-	A	D	J	N	-	-	BB
57	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-2	AA	AA
96	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-2	AA	AA
113	-	-	-	-	-	-	-	-	-	-	-	-	A	D	J	O	AA-2	AA	AA
122	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-2	AA	AA
158	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	N	BB	BB	BB
177	NE	NE	-	NE	NE	-	NE	NE	+	NE	NE	-	A	D	J	M	-	-	AA
210	-	-	-	+	+	-	-	-	+	+	+	-	A	V	J	P	AA-2	AA	AA
214	-	-	-	+	+	-	+	+	-	+	+	-	A	E	J	N	BB	BB	BB
237	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-2	AA	AA
303	-	-	-	+	+	-	-	-	+	+	+	-	B	F	K	Q	CC	CC	GG
327	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	R	AA-2	AA	AA
361	-	-	-	-	-	-	-	-	-	-	-	-	C	G	J	S	DD	DD	DD
394	-	-	-	+	-	-	-	-	-	+	-	-	A	E	J	T	EE	EE	EE
423	NE	NE	NE	+	+	NE	-	-	NE	+	+	NE	A	H	J	U	AA-2	AA	-
462	-	-	-	+	+	-	-	-	+	+	+	-	A	D	J	M	AA-1	AA	AA

(For key to method codes see page 15)

Key: NE = target virus not examined, yellow shading = denotes false negative results, red shading = false positive results, grey shading = method elements as described in the main body and informative annexes of ISO 15216-1.

Key to method codes

Virus extraction methods	
A	Proteinase K digestion
B	Plante et al, 2021
C	Congen Surefast Prep DNA/RNA virus
RNA extraction methods	
D	NucliSens Magnetic extraction reagents (BioMerieux)
E	foodproof® Sample Preparation Kit IV (BIOTECON Diagnostics GmbH)
F	Plante et al, 2021
G	Surefast Prep DNA/RNA virus (Congen)
H	QIAmp viral RNA mini kit (Qiagen)
V	Guanidinium thiocyanate and phenol:chloroform
RT-PCR methods	
J	Real-time (quantitative) PCR - one-step
K	Droplet digital PCR - one-step
RT-PCR reagents	
L	Norovirus GI and HAV: TaqMan® Fast Virus 1-Step Master Mix (Applied Biosystems). Norovirus GII: RNA Ultrasense (Invitrogen)
M	RNA Ultrasense (Invitrogen)
N	Ceeram Tools
O	qRT PCR LC 480 Master Hydrolysis Probes (Roche)
P	Luna® Universal Probe One-Step RT-qPCR Kit (NEB)
Q	One-Step RT-ddPCR Kit for Probes (BioRad)
R	AgPath-ID One-Step RT-PCR (Applied Biosystems)
S	Surefast Norovirus/HAV 3plex realtime PCR (Congen)
T	foodproof® Detection Kits (BIOTECON Diagnostics GmbH)
U	GoTaq® Probe qPCR and RT-qPCR Systems (Promega)
Primers/probes	
AA	ISO 15216-1; 1) with TM9 probe for NoV GI; 2) with NVGG1p probe for NoV GI
BB	Ceeram Tools (sequences as AA-2)
CC	Kageyama et al, 2003
DD	Surefast Norovirus/HAV 3plex realtime PCR (Congen)
EE	foodproof® Detection Kits (BIOTECON Diagnostics GmbH)
FF	OPFLP-07
GG	Guevremont et al., 2006; Houde et al., 2007

Appendix 7 - Details of laboratory's own quantification standards (preparation and quantification)

LAB ID	
3	Linearised ISO 15216-1 plasmid DNA, quantified using fluorimetry
10	PCR product amplified from ISO 15216-1 plasmid, quantified using A260 spectrophotometry
47	Linearised ISO 15216-1 plasmid DNA
57	cDNA from a commercial supplier
96	Linearised ISO 15216-1 plasmid DNA, quantified using A260 spectrophotometry and fluorimetry
237	Commercially produced linear dsDNA (quantified by supplier)
303	Quantification using ddPCR does not require quantification standards
423	Commercial standards (Biomerieux)

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We are the government's marine and freshwater science experts. We help keep our seas, oceans and rivers healthy and productive and our seafood safe and sustainable by providing data and advice to the UK Government and our overseas partners. We are passionate about what we do because our work helps tackle the serious global problems of climate change, marine litter, over-fishing and pollution in support of the UK's commitments to a better future (for example the UN Sustainable Development Goals and Defra's 25 year Environment Plan).

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