Interlaboratory comparison 2020 Determination of radionuclides in seawater, sediment and fish

Marine Monitoring: Confidence Building and Data Quality Assurance

IAEA Project Interim Report

IAEA
International Atomic Energy Agency

SUMMARY REPORT

The IAEA Environment Laboratories in Monaco are assisting the Government of Japan in ensuring that its regularly updated Sea Area Monitoring Plan is comprehensive, credible and transparent through the project "Marine Monitoring: Confidence Building and Data Quality Assurance". During the period 2014 – 2019, nine interlaboratory comparisons (ILCs) and six proficiency tests (PTs) were organised within this project to test the sampling and analytical performance of Japanese laboratories monitoring radionuclides in seawater, sediment and fish as part of the Sea Area Monitoring Plan.

This report focuses on the ILC which was organised in 2020. As for previous ILCs in this project, a joint sampling campaign to collect seawater, sediment and fish samples was undertaken. In this case, sampling was conducted in November 2020 with observation from IAEA-designated independent Japanese experts and representatives from Japanese authorities involved in the Sea Area Monitoring Plan. Seawater and sediment samples were collected at offshore locations close to the Fukushima Daiichi Nuclear Power Station. Several species of fish were sampled from a market in Fukushima Prefecture. The samples were then homogenised, split and sent to each participating laboratory for analysis. The results of the analyses of each participating laboratory – eight from Japan (participating on behalf of the Japanese authorities); and the IAEA Environment Laboratories – were subsequently collected and evaluated by the IAEA.

Comparisons of the results received for each sample and radionuclide demonstrate that the overwhelming majority are not significantly different from each other. A statistical analysis of the results shows that over 98% of the statistical tests applied passed with a high level of confidence (99%).

It can therefore be concluded with confidence that participating laboratories reported reliable and comparable results for the tested radionuclides in seawater, sediment, and fish samples, prepared and analysed according to each laboratory's regularly used methods (although levels of ^{134}Cs and ^{238}Pu are close to the limits of detection in all sample types and thus difficult to intercompare).

On the basis of the results of ILC 2020, the IAEA can report that Japan's sample collection procedures continue to adhere to the appropriate methodological standards required to obtain representative samples. The results, as for those from other ILCs and PTs in this project, demonstrate a high level of accuracy and competence on the part of the Japanese laboratories involved in the analyses of radionuclides in marine samples as part of the Sea Area Monitoring Plan.

1. INTRODUCTION

The IAEA Environment Laboratories are assisting the Government of Japan in ensuring that its regularly updated Sea Area Monitoring Plan is comprehensive, credible and transparent through the project “Marine Monitoring: Confidence Building and Data Quality Assurance”. During the period 2014 – 2019, nine interlaboratory comparisons (ILCs) and six proficiency tests (PTs) have been organised within this project to test the sampling and analytical performance of Japanese laboratories monitoring radionuclides in seawater, sediment and fish as part of the Sea Area Monitoring Plan.

PTs and ILCs are standard methods for participating laboratories to assess the quality of their measurement results in comparison with those of other participating laboratories, and to identify any potentially needed improvements. PTs involve evaluation of performance against pre-established criteria whereas ILCs involve organization, performance and evaluation of measurements on the same or similar items by two or more laboratories in accordance with predetermined conditions [1]. The PT and ILC results from this project published so far can be accessed on the IAEA web pages[1].

This report focuses on the ILC which was organised in 2020. It describes the joint sampling campaign to collect seawater, sediment and fish samples, the measurement results and the statistical evaluation of the results. Normally observers from the IAEA participate in the joint sampling campaign. However, for this ILC, this was impossible due to COVID-19 related travel restrictions and, instead, IAEA-designated independent Japanese experts joined representatives from Japanese authorities involved in the Sea Area Monitoring Plan as observers. These experts were selected from Japanese member laboratories of the IAEA ALMERA network (Analytical Laboratories for the Measurement of Environmental Radioactivity)[2], none of which are involved in the in the Sea Area Monitoring Plan, and are all internationally recognised in their respective areas of scientific expertise. The experts helped to ensure the integrity of sample collection, identification, tracking and pre-treatment and were required to provide written reports and photos to the IAEA.

In total, nine laboratories participated in the ILC: eight from Japan (participating on behalf of the Japanese authorities); and the IAEA Environment Laboratories in Monaco. The participating laboratories are presented in Table 1, and participation of each in specific analyses in Table 2.

TABLE 1. PARTICIPATING LABORATORIES IN ILC 2020

Identifier	Participant
FP	Fukushima Prefectural Centre for Environmental Creation, Fukushima, Japan
IAEA	IAEA Environment Laboratories, Monaco
JCAC	Japan Chemical Analysis Center, Chiba, Japan
JFRL	Japan Food Research Laboratories, Tama, Japan
KANSO	The General Environmental Technos Co. Ltd. (KANSO Ltd.), Japan
KEEA	Kyushu Environmental Evaluation Association, Fukuoka, Japan
MERI	Marine Ecology Research Institute, Onjuku, Japan
SKC	Seikan Kensa Center Inc., Fujieda, Japan
TPT	Tokyo Power Technology Ltd., Fukushima, Japan

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[1] Published ILC and PT reports are accessible at:
Interlaboratory Comparisons 2014–2016: Determination of Radionuclides in Sea Water, Sediment and Fish | IAEA
http://www-pub.iaea.org/MTCD/Publications/PDF/IAEA_AQ_43_web.pdf
http://www-pub.iaea.org/MTCD/Publications/PDF/AQ-51_web.pdf
IAEA/AQ/58

[2] More information on the ALMERA network is available from the following website: https://nucleus.iaea.org/sites/ReferenceMaterials/Pages/ALMERA.aspx

TABLE 2. PARTICIPATION OF EACH LABORATORY IN SPECIFIC ANALYSES IN ILC 2020

Sample type	Nuclide	IAEA	FP	JCAC	JFRL	KANSO	KEEA	MERI	SKC	TPT
Seawater	^{3}H	✓	✓[1]	✓	✗	✓	✓	✓	✗	✓[a]
	^{90}Sr	✓	✓	✓	✗	✓	✗	✗	✗	✓[a]
	^{134}Cs	✓	✓	✓	✗	✓	✗	✓	✗	✓[a]
	^{137}Cs	✓	✓	✓	✗	✓	✗	✓	✗	✓[a]
Sediment	^{134}Cs	✓	✓	✓	✗	✗	✗	✗	✗	✓
	^{137}Cs	✓	✓	✓	✗	✗	✗	✗	✗	✓
	^{238}Pu	✓	✓	✓	✗	✗	✓	✗	✗	✗
	^{239,240}Pu	✓	✓	✓	✗	✗	✓	✗	✗	✗
Fish	^{134}Cs	✓	✗	✗	✓	✗	✗	✓	✓	✗
	^{137}Cs	✓	✗	✗	✓	✗	✗	✓	✓	✗

NOTE: The symbol ✓indicates that the laboratory participated in the specific analysis (sample type and radionuclide), the symbol ✗ indicates that it did not participate.

Note 1: FP were unable to report results for ^{3}H due to a technical malfunction.

[a] Sampling location T-D1 only.

2. SEAWATER, SEDIMENT AND FISH SAMPLING AND PREPARATION

2.1. SEAWATER AND SEDIMENT SAMPLING LOCATIONS

Surface seawater samples were collected at five sampling locations (M-101, M-102, M-103, M-104, and T-D1) and sediment samples at three locations (F-P04, T-S3, and T-S8) offshore the Fukushima Daiichi Nuclear Power Station. The sampling locations are shown in Figure 1 and their coordinates are provided in Table 3.

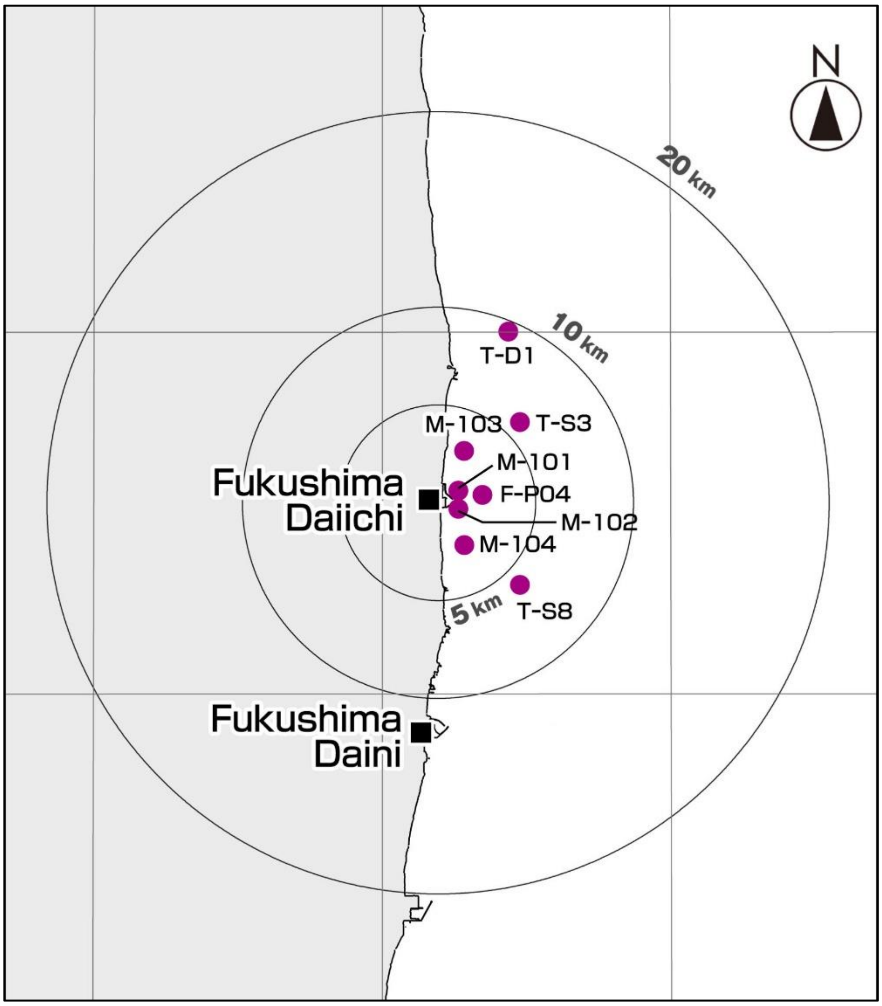

FIG. 1. Surface seawater and sediment sampling locations offshore the Fukushima Daiichi Nuclear Power Station.

TABLE 3. COORDINATES OF THE SURFACE SEAWATER AND SEDIMENT SAMPLING LOCATIONS

Sampling location	Latitude (N)	Longitude (E)
M-101 (seawater)	37°25′36″	141°02′36″
M-102 (seawater)	37°25′06″	141°02′36″
M-103 (seawater)	37°26′42″	141°02′48″
M-104 (seawater)	37°24′06″	141°02′48″
T-D1 (seawater)	37°30′00″	141°04′20″
F-P04 (sediment)	37°25′27″	141°03′26″
T-S3 (sediment)	37°27′30″	141°04′44″
T-S8 (sediment)	37°23′00″	141°04′44″

2.2. SEAWATER

During this mission, seawater samples were collected on 4-6 November 2020 from each sampling location for subsequent analysis for ^{90}Sr, ^{134}Cs and ^{137}Cs and, separately, for ^{3}H.

2.2.1. Samples M-101, M-102, M-103 and M-104

Four laboratories planned to participate in the analyses for ^{90}Sr from sampling locations M-101, M-102, M-103 and M-104. For ^{134}Cs and ^{137}Cs, five laboratories planned to participate. The collection and distribution methods at each sampling location were:

- A 400 L plastic container with four valves was first filled with seawater. As this container cannot be filled to full capacity, two separate fills were required to facilitate provision of the required sample volume to all participants.
- Separate 20 L cubitainers were filled simultaneously from each of the four valves. Seven cubitainers were filled from valves 1 and 2 and six from valves 3 and 4, resulting in a total of 13 20 L samples from each sampling location.
- Each sample was acidified to pH 1–2 with concentrated HCl.
- Three 20 L samples from each sampling location were provided to each laboratory planning to participate in analyses for both radiocaesium (^{134}Cs and ^{137}Cs) and ^{90}Sr. One 20 L sample was provided to the laboratory planning to participate in analysis for radiocaesium only.

The seawater sampling procedure and distribution matrix, meant to ensure the homogenisation of the samples, are shown in Table 4.

TABLE 4. SAMPLE DISTRIBUTION BETWEEN FOUR LABORATORIES (^{90}Sr, ^{134}Cs AND ^{137}Cs) AND BETWEEN FIVE LABORATORIES (^{134}Cs AND ^{137}Cs ONLY)

<table>
<tr><td>Valve number</td><td colspan="5">1</td><td colspan="5">2</td><td colspan="5">3</td><td colspan="5">4</td></tr>
<tr><td rowspan="4">Seawater sample codes</td><td colspan="5">1-1-1</td><td colspan="5">1-2-1</td><td colspan="5">1-3-1</td><td colspan="5">1-4-1</td></tr>
<tr><td colspan="5">1-1-2</td><td colspan="5">Not used</td><td colspan="5">Not used</td><td colspan="5">Not used</td></tr>
<tr><td colspan="5">2-1-1</td><td colspan="5">2-2-1</td><td colspan="5">2-3-1</td><td colspan="5">2-4-1</td></tr>
<tr><td colspan="5">2-1-2</td><td colspan="5">2-2-2</td><td colspan="5">2-3-2</td><td colspan="5">2-4-2</td></tr>
<tr><td rowspan="4">Distribution pattern of the participating laboratories coded A, B, C, D and E</td><td colspan="4">A</td><td colspan="4">B</td><td colspan="4">C</td><td colspan="4">D</td><td colspan="4">E</td></tr>
<tr><td colspan="4">1-1-1</td><td colspan="4">1-2-1</td><td colspan="4">1-3-1</td><td colspan="4">1-4-1</td><td colspan="4">1-1-2</td></tr>
<tr><td colspan="4">2-1-1</td><td colspan="4">2-2-1</td><td colspan="4">2-3-1</td><td colspan="4">2-4-1</td><td colspan="4">-</td></tr>
<tr><td colspan="4">2-1-2</td><td colspan="4">2-2-2</td><td colspan="4">2-3-2</td><td colspan="4">2-4-2</td><td colspan="4">-</td></tr>
</table>

For ^{3}H, six laboratories planned to participate. The sample collection and distribution methods were:

- From the same 400 L plastic container from which the samples to be analysed for ^{90}Sr, ^{134}Cs and ^{137}Cs were taken, were taken, separate 2 L containers were filled, one or two at a time, from the four valves, resulting in a total of six 2 L samples from each sampling location.
- One 2 L sample was provided to each laboratory.

The seawater sampling procedure and the distribution matrix for ^{3}H are shown in Table 5.

TABLE 5. SAMPLE DISTRIBUTION BETWEEN SIX LABORATORIES (^{3}H)

<table>
<tr><td>Valve number</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td></tr>
<tr><td rowspan="2">Seawater sample codes</td><td colspan="3">1-1-1</td><td colspan="3">1-2-1</td><td colspan="3">1-3-1</td><td colspan="3">1-4-1</td></tr>
<tr><td colspan="3">1-1-2</td><td colspan="3">1-2-2</td><td colspan="3">Not used</td><td colspan="3">Not used</td></tr>
<tr><td></td><td colspan="2">A</td><td colspan="2">B</td><td colspan="2">C</td><td colspan="2">D</td><td colspan="2">E</td><td colspan="2">F</td></tr>
</table>

Distribution pattern of the participating laboratories coded A, B, C, D, E and F	1-1-1	1-2-1	1-3-1	1-4-1	1-1-2	1-2-2

2.2.2. Sample T-D1

Five laboratories planned to participate in the analyses for ^{90}Sr from sampling location T-D1. For ^{134}Cs and ^{137}Cs, six laboratories planned to participate. The collection method was essentially the same as described above. The sampling procedure and distribution matrix are shown in Table 6.

TABLE 6. SAMPLE DISTRIBUTION BETWEEN FIVE LABORATORIES (^{90}Sr, ^{134}Cs AND ^{137}Cs) AND BETWEEN SIX LABORATORIES (^{134}Cs AND ^{137}Cs ONLY)

<table>
<tr><td>Valve number</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td></tr>
<tr><td rowspan="6">Seawater sample codes</td><td colspan="3">1-1-1</td><td colspan="3">1-2-1</td><td colspan="3">1-3-1</td><td colspan="3">1-4-1</td></tr>
<tr><td colspan="3">1-1-2</td><td colspan="3">1-2-2</td><td colspan="3">Not used</td><td colspan="3">Not used</td></tr>
<tr><td colspan="3">2-1-1</td><td colspan="3">2-2-1</td><td colspan="3">2-3-1</td><td colspan="3">2-4-1</td></tr>
<tr><td colspan="3">2-1-2</td><td colspan="3">Not used</td><td colspan="3">Not used</td><td colspan="3">Not used</td></tr>
<tr><td colspan="3">2-1-3</td><td colspan="3">2-2-3</td><td colspan="3">2-3-3</td><td colspan="3">2-4-3</td></tr>
<tr><td colspan="3">2-1-4</td><td colspan="3">Not used</td><td colspan="3">Not used</td><td colspan="3">Not used</td></tr>
<tr><td rowspan="4">Distribution pattern of the participating laboratories coded A, B, C, D, E and F</td><td colspan="2">A</td><td colspan="2">B</td><td colspan="2">C</td><td colspan="2">D</td><td colspan="2">E</td><td colspan="2">F</td></tr>
<tr><td colspan="2">1-1-1</td><td colspan="2">1-2-1</td><td colspan="2">1-3-1</td><td colspan="2">1-4-1</td><td colspan="2">1-1-2</td><td colspan="2">1-2-2</td></tr>
<tr><td colspan="2">2-1-1</td><td colspan="2">2-2-1</td><td colspan="2">2-3-1</td><td colspan="2">2-4-1</td><td colspan="2">-</td><td colspan="2">2-1-2</td></tr>
<tr><td colspan="2">2-1-3</td><td colspan="2">2-2-3</td><td colspan="2">2-3-3</td><td colspan="2">2-4-3</td><td colspan="2">-</td><td colspan="2">2-1-4</td></tr>
</table>

For ^{3}H, seven laboratories planned to participate in the analyses. The sample collection and distribution methods were essentially the same as described above. The seawater sampling procedure and the distribution matrix for ^{3}H are shown in Table 7.

TABLE 7. SAMPLE DISTRIBUTION BETWEEN SEVEN LABORATORIES (^{3}H)

<table>
<tr><td>Valve number</td><td colspan="7">1</td><td colspan="7">2</td><td colspan="7">3</td><td colspan="7">4</td></tr>
<tr><td rowspan="2">Seawater sample codes</td><td colspan="7">1-1-1</td><td colspan="7">1-2-1</td><td colspan="7">1-3-1</td><td colspan="7">1-4-1</td></tr>
<tr><td colspan="7">1-1-2</td><td colspan="7">1-2-2</td><td colspan="7">1-3-2</td><td colspan="7">Not used</td></tr>
<tr><td rowspan="2">Distribution pattern of the participating laboratories coded A, B, C, D, E, F and G</td><td colspan="4">A</td><td colspan="4">B</td><td colspan="4">C</td><td colspan="4">D</td><td colspan="4">E</td><td colspan="4">F</td><td colspan="4">G</td></tr>
<tr><td colspan="4">1-1-1</td><td colspan="4">1-2-1</td><td colspan="4">1-3-1</td><td colspan="4">1-4-1</td><td colspan="4">1-1-2</td><td colspan="4">1-2-2</td><td colspan="4">1-3-2</td></tr>
</table>

2.3. SEDIMENT

Sediment samples were collected using a grab sampler between 4 and 6 November 2020 offshore from the Fukushima Daiichi Nuclear Power Station at locations F-P04, T-S3 and T-S8 (Fig. 1 and Table 3). The samples were subsequently oven-dried at 105 °C on large stainless-steel trays, crushed using stainless-steel spatulae, and sieved through a 2-mm mesh sieve at the KANSO laboratory. No grinding was required prior to sieving due to the sandy nature of the sediments. The fraction with grain size <2 mm was ground using a rotary ball mill, sieved to ≤250 µm, then placed in a plastic bag and mixed thoroughly to ensure homogeneity. An incremental division method was used for sample splitting. Each sample was split into two aliquots using a splitter; one aliquot was archived and the second one was further split until the required sample weight for each laboratory was attained. The sequence of splitting of each sample depended on the total weight of the sieved and sample. The samples were then bottled in 500 mL plastic bottles and shipped to the IAEA Environment Laboratories in Monaco where their

^{137}Cs homogeneity was checked using γ-ray spectrometry with high purity germanium (HPGe) detectors. Approximately 300 g of homogeneous dried sediment from each location was then shipped to each participating laboratory analysing for all radionuclides of interest (^{134,137}Cs, ^{238}Pu, ^{239,240}Pu). For those analysing only for either Cs or Pu isotopes, approximately 150 g was provided.

2.4. FISH

In 2020, six batches of freshly landed fish samples, one each of olive flounder (*Paralichthys olivaceus*), stone founder (*Kareius flounder*), crimson sea bream (*Evynnis tumifrons*), redwing sea robin (*Lepidotrigla microptera*), whitespotted conger (*Conger myriaster*) and shotted halibut (*Eopsetta grigorjewi*), were collected from the port of Numanouchi on 16 November 2020. The fish species were caught by bottom trawling and gill net on 15 and 16 November 2020 in the vicinity of the Fukushima Daiichi Nuclear Power Station at the locations and depths shown in Table 8.

TABLE 8. COORDINATES AND DEPTHS OF THE CATCH LOCATIONS FOR ILC 2020

Sample: Species	Latitude (N)	Longitude (E)	Depth (m)
20FA0001: Olive flounder	36°55′54″	140°55′52″	21
20FA0002: Stone flounder	37°01′51″	140°59′15″	11
20FA0003: Crimson sea bream	36°54′41″	140°59′44″	66
20FA0004: Redwing sea robin	37°04′43″	141°06′16″	87
20FA0005: Whitespotted conger	37°04′43″	141°06′16″	87
20FA0006: Shotted halibut	37°04′43″	141°06′16″	87

Each fish sample was prepared by homogenising the muscle tissue and then splitting into two separate sub-samples at MERI (Onjuku) on 20 November 2020. One set of sub-samples, each of mass approximately 2.4 kg, were analysed in turn by the three participating Japanese laboratories. The second set, each of mass 1.2 kg, were frozen and shipped to the IAEA Environment Laboratories in Monaco for analysis.

The fish samples were analysed for ^{134}Cs and ^{137}Cs by gamma-ray spectrometry in each participating laboratory. In a change to previous ILCs, two sets of measurement results for the fish samples were requested. The first were for measurement times per sample of 1 hour. Such measurements comply with procedures set out in a testing manual for radioactive substances in food for emergencies published by the Ministry of Health, Labour and Welfare and are thus consistent with those routinely conducted by Japanese laboratories participating in the Sea Area Monitoring Plan.

The second set of measurement results requested were for measurement times per sample of 24 hours. These were intended to facilitate effective intercomparison of the results from each laboratory by reducing detection limits and counting uncertainties, particularly for ^{134}Cs.

The first set of sub-samples were analysed between 20 November and 1 December, then shipped to JFRL (Tama) on between 23 November and 3 December and, in turn to SKC (Fujieda) on between 23 November and 1 December for the same analyses. The set of sub-samples that were frozen and shipped to the IAEA were analysed in February 2021.

3. METHODOLOGY OF RADIONUCLIDE DETERMINATION

3.1. SEAWATER

Radionuclides of interest in seawater were determined by seven laboratories participating in ILC 2020: FP, GSL, JCAC, KANSO, KEEA and TPT, all participating on behalf of the Nuclear Regulation Authority, Japan, and IAEA (see Tables 1 and 2).

3.1.1. FP methodology for seawater

3.1.1.1. ^{90}Sr analysis

A cation exchange resin column was used for pre-concentration of strontium from each seawater sample, followed by precipitation of carbonates and an additional cation exchange resin column for separation of calcium. ^{90}Y was removed by scavenging and, once the sample reached secular equilibrium, ^{90}Y was co-precipitated with iron hydroxide and then measured using a low background β counter.

3.1.1.2. ^{134}Cs and ^{137}Cs analysis

Chemical separation of caesium by ammonium molybdophosphate (AMP) and manganese dioxide (MnO_2), followed by γ-ray spectrometry with a HPGe detector.

3.1.2. IAEA methodology for seawater

3.1.2.1. ^{3}H analysis

The samples were measured by liquid scintillation counting after double vacuum distillation (at 35°C) and electrolytic enrichment followed by a second vacuum distillation. An ultra-low level liquid scintillation counter was used for the counting of an aliquot of the enriched and distilled sample mixed with a scintillation cocktail.

3.1.2.2. ^{90}Sr analysis

Liquid-liquid extraction with di-(2-ethylhexyl)phosphoric acid (HDEHP) was used for the separation of yttrium from seawater samples, while caesium was precipitated from the same sample by using ammonium molybdophosphate (AMP). The ^{90}Sr activity concentration was calculated based on the measurement of ^{90}Y (yttrium oxalate source) β activity using a proportional counter with an efficiency of up to 44%.

3.1.2.3. ^{134}Cs and ^{137}Cs analysis

Caesium was separated with AMP, followed by γ-ray spectrometry using a HPGe detector.

3.1.3. JCAC methodology for seawater

3.1.3.1. ^{3}H analysis

The seawater samples were distilled, followed by electrolytic enrichment (500 mL reduced to 55 mL). 50 mL of the purified sample was mixed with 50 mL of liquid scintillation fluid and measured with a liquid scintillation counter.

3.1.3.2. ^{90}Sr analysis

A cation exchange resin column was used for pre-concentration of strontium from each seawater sample, followed by precipitation of carbonates and an additional cation exchange resin column for separation of calcium. ^{90}Y was removed by scavenging and, once the sample reached secular equilibrium, ^{90}Y was co-precipitated with iron hydroxide and then was measured using a low background β counter.

3.1.3.3. ^{134}Cs and ^{137}Cs analysis

Chemical separation of radiocaesium was undertaken using AMP and followed by γ-ray spectrometry using a HPGe detector.

3.1.4. KANSO methodology for seawater

3.1.4.1. ^{3}H analysis

The samples were first purified by distillation in glass. Then, 1 L of the resultant material was electrolytically concentrated using a solid polymer electrolytic film. 50 mL of the purified sample was mixed with 50 mL of Ultima Gold LLT scintillant and then counted for 1000 minutes using a liquid scintillation counter.

3.1.4.2. ^{90}Sr analysis

An ion exchange resin was used for pre-concentration of strontium in each seawater sample, followed by precipitation of carbonates and barium chromate. After secular equilibrium was attained, ^{90}Y was separated using a ferric hydroxide co-precipitation technique and measured by a gas-flow counter.

3.1.4.3. ^{134}Cs and ^{137}Cs analysis

Chemical separation of radiocaesium was undertaken using AMP and followed by γ-ray spectrometry with a HPGe detector.

3.1.5. KEEA methodology for seawater

3.1.5.1. ^{3}H analysis

Each seawater sample was distilled and electrically enriched about 50 times. The enriched sample was neutralised and distilled. 10 mL of the enriched sample was mixed with 10 mL of scintillation cocktail in a 20mL low diffusion polyethylene vial and counted for 1100 min using a low background liquid scintillation counter.

3.1.6. MERI methodology for seawater

3.1.6.1. ^{3}H analysis

Each seawater sample was first purified by distillation. Then, ^{3}H was concentrated by electrolysis (a sample volume of 500 mL was reduced to 50 mL). This enriched sample was further purified by distillation. 50 mL of the distillate was mixed with 50 mL of Ultima Gold uLLT scintillation cocktail to prepare a sample for measurement, then measured using a low background liquid scintillation counter.

3.1.6.2. ^{134}Cs and ^{137}Cs analysis

Chemical separation of radiocaesium was undertaken using AMP and followed by γ-ray spectrometry using a HPGe detector.

3.1.7. TPT methodology for seawater

3.1.7.1. ^{3}H analysis

Each seawater sample was first purified by distillation. The distilled seawater was then mixed with a scintillation cocktail to prepare a sample for measurement using a low background liquid scintillation counter.

3.1.7.2. ^{90}Sr analysis

Strontium was first separated from seawater by alkaline precipitation with sodium carbonate (Na_2CO_3), further separated using cation exchange chromatography and then reprecipitated as strontium carbonate ($SrCO_3$). After attaining secular equilibrium between ^{90}Y and ^{90}Sr, ^{90}Y was separated using an iron hydroxide coprecipitation method and measured with a gas flow counter.

3.1.7.3. ^{134}Cs and ^{137}Cs analysis

Caesium was separated with AMP, followed by γ-ray spectrometry using a HPGe detector.

3.2. SEDIMENT

Radionuclides of interest in sediment samples were determined by five laboratories participating in ILC 2020: FP, JCAC, KEEA and TPT, participating on behalf of the Nuclear Regulation Authority, Japan, and IAEA (see Tables 1 and 2).

3.2.1. FP methodology for sediment

3.2.1.1. ^{134}Cs and ^{137}Cs analysis

γ-ray spectrometry using a HPGe detector.

3.2.1.2. ^{238}Pu and ^{239,240}Pu analysis

α-particle spectrometry with a Si detector after leaching, radiochemical separation and purification of plutonium by using an anion exchange resin column followed by electrodeposition from the purified solution.

3.2.2. IAEA methodology for sediment

3.2.2.1. ^{134}Cs and ^{137}Cs analysis

γ-ray spectrometry using a p-type coaxial HPGe detector.

3.2.2.2. ^{238}Pu and ^{239,240}Pu analysis

Classical digestion followed by ion exchange, electrodeposition and counting by α-particle spectrometry. An aliquot of 5 g of sediment sample was ashed and spiked with a ^{242}Pu tracer. The sample was totally dissolved by using concentrated acids. After $Fe(OH)_3$ precipitation and plutonium oxidation state adjustment, double ion exchange (DOWEX 1×4) was used for Pu purification. Plutonium was electrodeposited from Na_2SO_4/H_2SO_4 electrolyte solution on stainless-steel discs and counted by α-particle spectrometry.

3.2.3. JCAC methodology for sediment

3.2.3.1. ^{134}Cs and ^{137}Cs analysis

Direct counting on a p-type coaxial HPGe detector with a relative efficiency 31%.

3.2.3.2. ^{238}Pu and ^{239,240}Pu analysis

Plutonium isotopes were measured with a Si semiconductor detector after leaching, radiochemical separation and purification of plutonium by using an anion exchange resin column followed by electrodeposition from the purified solution.

3.2.4. KEEA methodology for sediment

3.2.4.1. ^{238}Pu and ^{239,240}Pu analysis

Dried sediment samples were first heated to 450 °C. Then a ^{242}Pu isotope dilution tracer was added to each sample, and the plutonium in the sediment was extracted with 8M HNO_3. This extracted solution was heated, concentrated and adjusted to 8M HNO3. This material had the plutonium oxidation state adjusted with sodium nitrate(III) ($NaNO_2$). Plutonium was then separated and purified using a Dowex 1x8 (100-200 mesh) anion exchange resin. Plutonium was electrodeposited onto a stainless-steel plate and measured by a silicon semiconductor detector.

3.2.5. TPT methodology for sediment

3.2.5.1. ^{134}Cs and ^{137}Cs analysis

γ-ray spectrometry using a p-type coaxial HPGe detector.

3.3. FISH

Radionuclides of interest in fish samples were determined by four laboratories participating in ILC 2020: FRA, MERI, and TRK, all participating on behalf of the Japan Fisheries Agency, and the IAEA (see Tables 1 and 2).

3.3.1. IAEA methodology for fish

3.3.1.1. ^{134}Cs and ^{137}Cs analysis

Direct counting by coaxial HPGe detectors with relative efficiencies of 35% and 48%. The samples were prepared in 1 L Marinelli beakers and measured for 24 hours. Two spectra were saved for each sample, after 1 hour and after 24 hours.

3.3.2. JFRL methodology for fish

3.3.2.1. ^{134}Cs and ^{137}Cs analysis

Direct counting by p-type coaxial HPGe detectors with relative efficiencies between 38% and 39%. The samples were prepared in 2 L Marinelli beakers and measured for 24 hours. Two spectra were saved for each sample, after 1 hour and after 24 hours.

3.3.3. MERI methodology for fish

3.3.3.1. ^{134}Cs and ^{137}Cs analysis

Direct counting by a p-type coaxial HPGe detector of relative efficiency 46%. The samples were prepared in 2 L Marinelli beakers and measured for 24 hours. Two spectra were saved for each sample, after 1 hour and after 24 hours.

3.3.4. SKC methodology for fish

3.3.4.1. ^{134}Cs and ^{137}Cs analysis

Direct counting by a p-type coaxial HPGe detector with relative efficiency of 45%. The samples were prepared in 2 L Marinelli beakers and measured for 24 hours. Two spectra were saved for each sample, after 1 hour and after 24 hours.

4. STATISTICAL EVALUATION OF THE RESULTS

The IAEA collected and evaluated the results reported by all ILC participants. The method used for the statistical evaluation depended on the number of results received for each sampling location, sample type and radionuclide.

If two or three measurement results above the detection limit were received, then one or three zeta tests [2] were performed. The zeta $\zeta_{i,j}$ test is defined as:

$$\zeta_{i,j} = \left| \frac{x_i - x_j}{\sqrt{u_i^2 + u_j^2}} \right| \tag{1}$$

where:

x_i is the value of laboratory i [Bq $unit^{-1}$];
x_j is the value of laboratory j [Bq $unit^{-1}$];
u_i is the standard uncertainty for the value of laboratory i [Bq $unit^{-1}$];
u_j is the standard uncertainty for the value of laboratory j [Bq $unit^{-1}$]; and
$unit$ is the unit of volume of mass, L or kg, as appropriate for the particular sample type.

If two results were received, $\zeta_{1,2}$ was calculated, while for three received results $\zeta_{1,2}$, $\zeta_{1,3}$ and $\zeta_{2,3}$ were calculated.

If the value of the zeta test exceeded 2.58, the results were evaluated as being significantly different (at a 99% confidence level).

If the data set contained four or more results, the statistical evaluation consisted of a method for calculating a comparison reference value as a power-moderated mean of the combined results [3]. After calculating a reference value, a relative degree of equivalence (DoE) was calculated for each submitted result and if this relative DoE was significantly different from zero, the corresponding result was evaluated as being discrepant. The relative DoE (%) was calculated according to:

$$\text{DoE (\%)} = \frac{x_{\text{lab}} - X_{\text{ref}}}{X_{\text{ref}}} 100 \tag{2}$$

where:

x_{lab} is the individual laboratory result; and
x_{ref} is the reference value calculated as the power-moderated mean of the combined results.

The standard uncertainty of the relative DoE, u_{DoE}, was calculated according to reference [2]. If the absolute value of the relative DoE exceeded 2.58 times u_{DoE}, the corresponding result was evaluated as being discrepant (at a 99% confidence level), as the relative DoE in this case would be significantly different from zero.

5. RESULTS

5.1. GENERAL

The results are presented in Tables 9 – 14 and Figures 2 – 12.

5.1.1. Uncertainties

In this report, the numerical result of an activity concentration measurement is stated in the format x ± y, where the number following the symbol ± is the numerical value of the combined standard uncertainty, i.e. with a coverage factor of $k = 1$.

Relative degrees of equivalence are also quoted in the format x ± y. In this case, the number following the symbol ± is the 99% confidence interval.

5.1.2. Reference time

All activity concentrations for seawater and sediment were reported at a reference time of 4 November 2020 12:00 UTC. All activity concentrations for fish were reported at a reference time of 16 November 2020 12:00 UTC.

5.2. SEAWATER

Table 9 contains the results reported by the participating laboratories (FP, JCAC, KANSO, KEEA, MERI, TPT and the IAEA) for the activity concentrations of ^{3}H, ^{90}Sr, ^{134}Cs and ^{137}Cs in the seawater samples. Figures 2 to 5 show the activity concentrations of these radionuclides in the seawater samples.

TABLE 9. ACTIVITY CONCENTRATIONS (mBq L^{-1}) IN SEAWATER

Nuclide	Sample	IAEA	FP	JCAC	KANSO	KEEA	MERI	TPT	Reference value
^{3}H	M-101	114 ± 14	–	126 ± 17	120 ± 14	108 ± 8	108 ± 20	–	114 ± 6
	M-102	90 ± 13	–	81 ± 15	63 ± 13	81 ± 8	100 ± 20	–	81 ± 6
	M-103	50 ± 11	–	58 ± 14	56 ± 13	67 ± 8	87 ± 20	–	61 ± 6
	M-104	63 ± 11	–	94 ± 16	63 ± 13	69 ± 8	81 ± 20	–	71 ± 6
	T-D1	70 ± 12	–	107 ± 16	48 ± 13	75 ± 8	108 ± 20	<340	80 ± 12
^{90}Sr	M-101	1.166 ± 0.067	1.12 ± 0.22	0.98 ± 0.14	0.93 ± 0.17	–	–	–	1.08 ± 0.06
	M-102	0.67 ± 0.041	<0.5	0.82 ± 0.13	0.75 ± 0.17	–	–	–	–
	M-103	0.889 ± 0.052	0.63 ± 0.19	0.63 ± 0.11	0.69 ± 0.16	–	–	–	0.74 ± 0.08
	M-104	0.633 ± 0.040	<0.5	0.76 ± 0.13	0.98 ± 0.18	–	–	–	–
	T-D1	0.708 ± 0.043	0.71 ± 0.20	0.94 ± 0.13	0.77 ± 0.17	–	–	1.46 ± 0.21	0.90 ± 0.14
^{134}Cs	M-101	1.037 ± 0.086	<2.0	<0.98	1.00 ± 0.24	–	<0.9	–	–
	M-102	<0.24	<2.2	<0.91	<0.7	–	<0.8	–	–
	M-103	0.301 ± 0.054	<1.7	<0.97	<0.7	–	<0.8	–	–
	M-104	0.201 ± 0.029	<2.0	<0.94	<0.7	–	<0.8	–	–
	T-D1	<0.26	<2.2	<0.96	<0.7	–	<0.9	<0.9	–
^{137}Cs	M-101	20.2 ± 1.2	19.96 ± 0.84	22.5 ± 1.2	20 ± 0.72	–	24.4 ± 1.8	–	21.1 ± 0.9
	M-102	4.57 ± 0.23	4.65 ± 0.54	4.91 ± 0.34	4.3 ± 0.24	–	5.7 ± 0.5	–	4.7 ± 0. 3
	M-103	6.52 ± 0.39	7.64 ± 0.62	6.72 ± 0.42	6.8 ± 0.32	–	8.6 ± 0.7	–	7.1 ± 0.4
	M-104	4.55 ± 0.22	4.26 ± 0.60	5.05 ± 0.35	4.1 ± 0.23	–	4.8 ± 0.4	–	4.5 ± 0.2
	T-D1	3.2 ± 0.18	3.73 ± 0.52	3.69 ± 0.28	2.9 ± 0.20	–	3.1 ± 0.3	4.50 ± 0.37	3.5 ± 0.3

Table 10 contains the degrees of relative equivalence for the activity concentrations of ^{3}H, ^{90}Sr, ^{134}Cs and ^{137}Cs in the seawater samples.

TABLE 10. DEGREES OF EQUIVALENCE (%) IN SEAWATER SAMPLES

Nuclide	Sample	IAEA	FP	JCAC	KANSO	KEEA	MERI	TPT
^{3}H	M-101	0 ± 28	–	11 ± 35	5 ± 29	-5 ± 16	-5 ± 43	–
	M-102	10 ± 35	–	-1 ± 43	-23 ± 38	0 ± 23	23 ± 60	–
	M-103	-19 ± 41	–	-6 ± 53	-9 ± 51	9 ± 31	42 ± 80	–
	M-104	-12 ± 36	–	32 ± 51	-12 ± 43	-3 ± 26	13 ± 68	–
	T-D1	-13 ± 47	–	34 ± 54	-40 ± 49	-6 ± 41	36 ± 65	DL
^{90}Sr	M-101	8 ± 14	3 ± 48	-10 ± 30	-14 ± 36	–	–	–
	M-102	Note 1	DL	Note 1	Note 1	–	–	–
	M-103	20 ± 27	-15 ± 60	-16 ± 37	-7 ± 49	–	–	–
	M-104	Note 2	DL	Note 2	Note 2	–	–	–
	T-D1	-21 ± 40	-21 ± 60	4 ± 49	-14 ± 54	–	–	**63 ± 63**
^{134}Cs	M-101	Note 3	DL	DL	Note 3	–	DL	–
	M-102	DL	DL	DL	DL	–	DL	–
	M-103	Note 4	DL	DL	DL	–	DL	–
	M-104	Note 4	DL	DL	DL	–	DL	–
	T-D1	DL	DL	DL	DL	–	DL	DL
^{137}Cs	M-101	-4 ± 16	-6 ± 13	6 ± 16	-5 ± 12	–	15 ± 22	–
	M-102	-4 ± 15	-2 ± 28	3 ± 19	-9 ± 16	–	20 ± 26	–
	M-103	-9 ± 17	7 ± 23	-6 ± 18	-5 ± 16	–	20 ± 25	–
	M-104	0 ± 13	-6 ± 33	11 ± 19	-10 ± 14	–	6 ± 22	–
	T-D1	-8 ± 21	7 ± 38	6 ± 25	-16 ± 21	–	-11 ± 26	**30 ± 29**

Note 1: Values of -1.09, -0.46 and 0.32 for $\zeta_{1,3}$, $\zeta_{1,4}$ and $\zeta_{3,4}$, respectively.

Note 2: Values of -0.94, -1.97 and -1.02 for $\zeta_{1,3}$, $\zeta_{1,4}$ and $\zeta_{3,4}$, respectively.

Note 3: Value of 0.15 for $\zeta_{1,4}$.

Note 4: No evaluation was possible as only one value above the detection limit was submitted.

DL: As a value less than the detection limit was submitted, no evaluation was performed.

$\zeta_{i,j}$ indexes: number 1 refers to IAEA, number 2 refers to FP, number 3 refers to JCAC, number 4 refers to KANSO, number 5 refers to KEEA, number 6 refers to MERI and number 7 refers to TPT.

5.3. SEDIMENT

Table 11 contains the results reported by the five participating laboratories (FP, JCAC, KEEA, TPT and the IAEA) for the activity concentrations of radionuclides in the sediment samples. Figures 6 to 9 show the activity concentrations of ^{134}Cs, ^{137}Cs and ^{239,240}Pu in the sediment samples.

TABLE 11. ACTIVITY CONCENTRATIONS (Bq kg$^{–1}$-dry) IN SEDIMENT

Nuclide	Sample	IAEA	FP	JCAC	KEEA	TPT	Reference value
^{134}Cs	F-P04	2.5 ± 0.22	1.97 ± 0.41	2.90 ± 0.32	–	2.81 ± 0.29	2.57 ± 0.20
	T-S3	1.93 ± 0.12	2.25 ± 0.33	2.48 ± 0.27	–	1.83 ± 0.31	2.09 ± 0.15
	T-S8	3.48 ± 0.18	4.08 ± 0.43	3.49 ± 0.31	–	3.70 ± 0.44	3.61 ± 0.15
^{137}Cs	F-P04	55.7 ± 1.8	54.3 ± 3.1	58.4 ± 3.0	–	56.8 ± 1.8	56.3 ± 1.1
	T-S3	41.8 ± 1.4	46.7 ± 2.6	46.6 ± 2.4	–	46.3 ± 1.5	45.1 ± 1.3
	T-S8	75.7 ± 2.5	75.1 ± 4.2	75.8 ± 3.8	–	83.7 ± 2.5	77.9 ± 2.2
^{238}Pu	F-P04	0.0086 ± 0.0020	<0.010	0.0047 ± 0.0012	0.005 ± 0.001	–	–
	T-S3	0.0051 ± 0.0024	<0.014	0.0037 ± 0.0011	0.005 ± 0.002	–	–
	T-S8	0.0066 ± 0.0021	<0.011	0.0084 ± 0.0016	0.009 ± 0.002	–	–
^{239,240}Pu	F-P04	0.414 ± 0.020	0.389 ± 0.032	0.379 ± 0.012	0.410 ± 0.020	–	0.396 ± 0.010
	T-S3	0.393 ± 0.020	0.372 ± 0.035	0.384 ± 0.012	0.391 ± 0.019	–	0.386 ± 0.009
	T-S8	0.556 ± 0.023	0.549 ± 0.040	0.529 ± 0.015	0.530 ± 0.023	–	0.538 ± 0.011

Table 12 contains the degrees of relative equivalence for the activity concentrations of ^{134}Cs, ^{137}Cs, ^{238}Pu and ^{239,240}Pu in the sediment samples.

TABLE 12. DEGREES OF EQUIVALENCE (%) IN SEDIMENT SAMPLES

Nuclide	Sample	IAEA	FP	JCAC	KEEA	TPT
^{134}Cs	F-P04	-3 ± 24	-24 ± 38	13 ± 31	–	9 ± 28
	T-S3	-8 ± 19	8 ± 38	19 ± 31	–	-12 ± 35
	T-S8	-3 ± 11	13 ± 28	-3 ± 20	–	3 ± 29
^{137}Cs	F-P04	-1.1 ± 7.0	-4 ± 13	4 ± 13	–	0.9 ± 6.7
	T-S3	-7.3 ± 8.9	4 ± 14	3 ± 13	–	2.7 ± 9.1
	T-S8	-2.8 ± 8.9	-4 ± 13	-3 ± 12	–	7.4 ± 9.0
^{238}Pu	F-P04	Note 1	DL	Note 1	Note 1	–
	T-S3	Note 2	DL	Note 2	Note 2	–
	T-S8	Note 3	DL	Note 3	Note 3	–
^{239,240}Pu	F-P04	5 ± 12	-2 ± 19	-4.2 ± 7.1	4 ± 12	–
	T-S3	2 ± 12	-4 ± 22	-0.6 ± 6.8	1 ± 11	–
	T-S8	3.3 ± 9.2	2 ± 18	-1.7 ± 6.1	-1.5 ± 9.6	–

Note 1: Values of 1.68, 1.61 and -0.20 for $\zeta_{1,3}$, $\zeta_{1,4}$ and $\zeta_{3,4}$, respectively.

Note 2: Values of 0.54, 0.03 and -0.57 for $\zeta_{1,3}$, $\zeta_{1,4}$ and $\zeta_{3,4}$, respectively.

Note 3: Values of -0.69, -0.84 and -0.24 for $\zeta_{1,3}$, $\zeta_{1,4}$ and $\zeta_{3,4}$, respectively.

DL: As a value less than the detection limit was submitted, no evaluation was performed.

$\zeta_{i,j}$ indexes: number 1 refers to IAEA, number 2 refers to FP, number 3 refers to JCAC, number 4 refers to KEEA and number 5 refers to TPT.

5.4. FISH

Table 13 contains the results reported by the four participating laboratories (JFRL, MERI, SKC and the IAEA) for the activity concentrations of radionuclides in the fish samples. Figures 10 and 11 show the activity concentrations of ^{134}Cs and ^{137}Cs in the fish samples.

TABLE 13. ACTIVITY CONCENTRATIONS (Bq kg^{-1}-wet) IN FISH

Nuclide	Sample number: Species	IAEA	JFRL	MERI	SKC	Reference value
^{134}Cs (1h)	20FA0001: Olive flounder	<0.79	<0.33	<0.28	<0.42	–
	20FA0002: Stone flounder	<0.77	<0.36	<0.30	<0.40	–
	20FA0003: Crimson sea bream	<0.76	<0.39	<0.30	<0.41	–
	20FA0004: Redwing sea robin	<0.63	<0.42	<0.27	<0.41	–
	20FA0005: Whitespotted conger	<0.72	<0.37	<0.25	<0.38	–
	20FA0006: Shotted halibut	<0.82	<0.35	<0.30	<0.43	–
^{134}Cs (24h)	20FA0001: Olive flounder	<0.12	<0.064	<0.056	<0.072	–
	20FA0002: Stone flounder	<0.14	<0.064	0.055 ± 0.012	<0.065	–
	20FA0003: Crimson sea bream	<0.12	<0.059	<0.049	<0.071	–
	20FA0004: Redwing sea robin	<0.13	<0.064	<0.046	<0.067	–
	20FA0005: Whitespotted conger	<0.11	<0.059	<0.047	<0.062	–
	20FA0006: Shotted halibut	<0.14	0.066 ± 0.019	0.066 ± 0.014	<0.074	–
^{137}Cs (1h)	20FA0001: Olive flounder	0.76 ± 0.18	0.99 ± 0.16	0.99 ± 0.14	0.82 ± 0.14	0.90 ± 0.08
	20FA0002: Stone flounder	<0.98	1.10 ± 0.16	1.04 ± 0.14	1.06 ± 0.15	–
	20FA0003: Crimson sea bream	0.77 ± 0.16	0.78 ± 0.16	0.85 ± 0.12	0.47 ± 0.16	0.73 ± 0.09
	20FA0004: Redwing sea robin	0.53 ± 0.18	0.74 ± 0.15	0.74 ± 0.13	0.57 ± 0.15	0.66 ± 0.08
	20FA0005: Whitespotted conger	<0.66	0.37 ± 0.12	0.545 ± 0.092	0.49 ± 0.13	–
	20FA0006: Shotted halibut	0.69 ± 0.20	0.97 ± 0.15	0.90 ± 0.13	1.19 ± 0.15	0.95 ± 0.10
^{137}Cs (24h)	20FA0001: Olive flounder	0.886 ± 0.052	0.943 ± 0.041	0.905 ± 0.035	0.904 ± 0.029	0.910 ± 0.019
	20FA0002: Stone flounder	1.054 ± 0.075	1.029 ± 0.043	0.983 ± 0.037	1.020 ± 0.030	1.016 ± 0.020
	20FA0003: Crimson sea bream	0.749 ± 0.046	0.772 ± 0.037	0.751 ± 0.031	0.751 ± 0.027	0.755 ± 0.017
	20FA0004: Redwing sea robin	0.674 ± 0.061	0.734 ± 0.036	0.758 ± 0.031	0.763 ± 0.027	0.743 ± 0.019
	20FA0005: Whitespotted conger	0.386 ± 0.031	0.415 ± 0.028	0.439 ± 0.022	0.418 ± 0.023	0.415 ± 0.037
	20FA0006: Shotted halibut	1.060 ± 0.069	0.942 ± 0.041	0.924 ± 0.036	0.937 ± 0.029	0.951 ± 0.026

Table 14 contains the degrees of relative equivalence for the activity concentrations of ^{134}Cs and ^{137}Cs in the fish samples.

TABLE 14. DEGREES OF EQUIVALENCE (%) IN FISH SAMPLES

Nuclide	Sample: Species	IAEA	JFRL	MERI	SKC
^{134}Cs (1h)	20FA0001: Olive flounder	DL	DL	DL	DL
	20FA0002: Stone flounder	DL	DL	DL	DL
	20FA0003: Crimson sea bream	DL	DL	DL	DL
	20FA0004: Redwing sea robin	DL	DL	DL	DL
	20FA0005: Whitespotted conger	DL	DL	DL	DL
	20FA0006: Shotted halibut	DL	DL	DL	DL
^{134}Cs (24h)	20FA0001: Olive flounder	DL	DL	DL	DL
	20FA0002: Stone flounder	DL	DL	Note 1	DL
	20FA0003: Crimson sea bream	DL	DL	DL	DL
	20FA0004: Redwing sea robin	DL	DL	DL	DL
	20FA0005: Whitespotted conger	DL	DL	DL	DL
	20FA0006: Shotted halibut	DL	Note 2	Note 2	DL
^{137}Cs (1h)	20FA0001: Olive flounder	-15 ± 45	10 ± 40	11 ± 33	-9 ± 33
	20FA0002: Stone flounder	DL	Note 3	Note 3	Note 3
	20FA0003: Crimson sea bream	5 ± 52	8 ± 51	18 ± 41	-35 ± 50
	20FA0004: Redwing sea robin	-19 ± 60	12 ± 50	13 ± 42	-13 ± 50
	20FA0005: Whitespotted conger	DL	Note 4	Note 4	Note 4
	20FA0006: Shotted halibut	-27 ± 49	2 ± 40	-5 ± 35	25 ± 39
^{137}Cs (24h)	20FA0001: Olive flounder	-3 ± 14	4 ± 11	-0.5 ± 8.5	-0.7 ± 6.9
	20FA0002: Stone flounder	4 ± 18	1.3 ± 9.4	-3.2 ± 8.0	0.4 ± 6.4
	20FA0003: Crimson sea bream	-1 ± 14	2 ± 12	-0.6 ± 9.0	-0.6 ± 7.8
	20FA0004: Redwing sea robin	-9 ± 20	-1 ± 12	2 ± 9.5	2.6 ± 8.3
	20FA0005: Whitespotted conger	-7 ± 27	0 ± 26	6 ± 25	1 ± 25
	20FA0006: Shotted halibut	11 ± 18	-1 ± 11	-2.9 ± 9.3	-1.5 ± 8.2

Note 1: No evaluation was possible as only one value above the detection limit was submitted.

Note 2: Value of 0.21 for $\zeta_{2,3}$.

Note 3: Values of -0.47, -0.17, and 0.26 for $\zeta_{2,3}$, $\zeta_{2,4}$ and $\zeta_{3,4}$, respectively.

Note 4: Values of 0.01, 0.29 and 0.18 for $\zeta_{2,3}$, $\zeta_{2,4}$ and $\zeta_{3,4}$, respectively.

DL: As a value less than the detection limit was submitted, no evaluation was performed.

$\zeta_{i,j}$ indexes: number 1 refers to IAEA, number 2 refers to JFRL, number 3 refers to MERI and number 4 refers to SKC.

6. CONCLUSION

A detailed data analysis was performed on the activity concentrations reported for ^{3}H, ^{90}Sr, ^{134}Cs and ^{137}Cs in five seawater samples, for ^{134}Cs, ^{137}Cs, ^{238}Pu and ^{239,240}Pu in three sediment samples and for ^{134}Cs and ^{137}Cs in six fish samples. All samples were collected offshore the Fukushima Daiichi Nuclear Power Station in November 2020. The samples were shared between nine laboratories: FP (Japan), IAEA (Monaco), JCAC (Japan), JFRL (Japan), KANSO (Japan), KEEA (Japan), MERI (Japan), SKC (Japan) and TPT (Japan).

From this analysis it can be concluded that the overwhelming majority of results are not significantly different from each other. A global analysis of the whole data set demonstrated just two discrepant values from the 163 statistical tests applied to the data, i.e. over 98% were passed with a high level of confidence (99%). The exceptions were the following cases where the relative DoE was significantly different from zero:

- DoE (%) = 63 ± 63 for the ^{90}Sr activity concentration in the seawater sample from T-D1 submitted by TPT.
- DoE (%) = 30 ± 29 for the ^{137}Cs activity concentration in the seawater sample from T-D1 submitted by TPT.

Given the small number of cases where discrepant or significantly different results were reported (less than 2%), it can be said with confidence that the laboratories are reporting reliable and comparable results for the tested radionuclides in seawater, sediment and fish samples prepared and analysed according to each laboratory's regularly used methods.

Following this sampling mission, the IAEA can confidently report that Japan's sample collection procedures follow the appropriate methodological standards required to obtain representative samples. The results obtained in ILC 2020 demonstrate a continued high level of accuracy and competence on the part of the Japanese laboratories involved in the analyses of radionuclides in marine samples for the Sea Area Monitoring programme.

REFERENCES

[1] INTERNATIONAL ORGANISATION FOR STANDARDISATION, Conformity assessment — General requirements for proficiency testing. Geneva, ISO/IEC 17043:2010.

[2] INTERNATIONAL ORGANISATION FOR STANDARDISATION, Statistical methods for use in proficiency testing by interlaboratory comparisons. Geneva, ISO 13528:2015.

[3] POMMÉ, S. and KEIGHTLEY, J.D. 2015. Determination of a reference value and its uncertainty through a power-moderated mean. Metrologia **52**, S200-S212.

APPENDIX: FIGURES

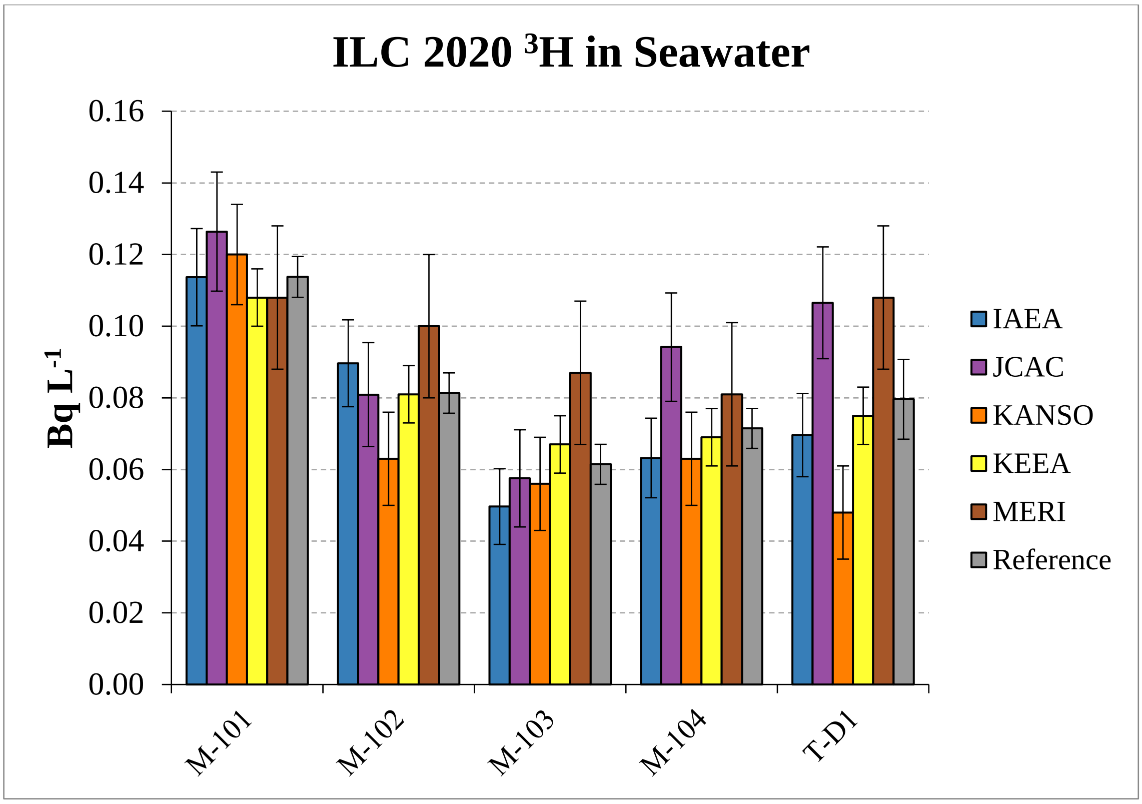

FIG. 2. Activity concentrations of ^{3}H in seawater samples.

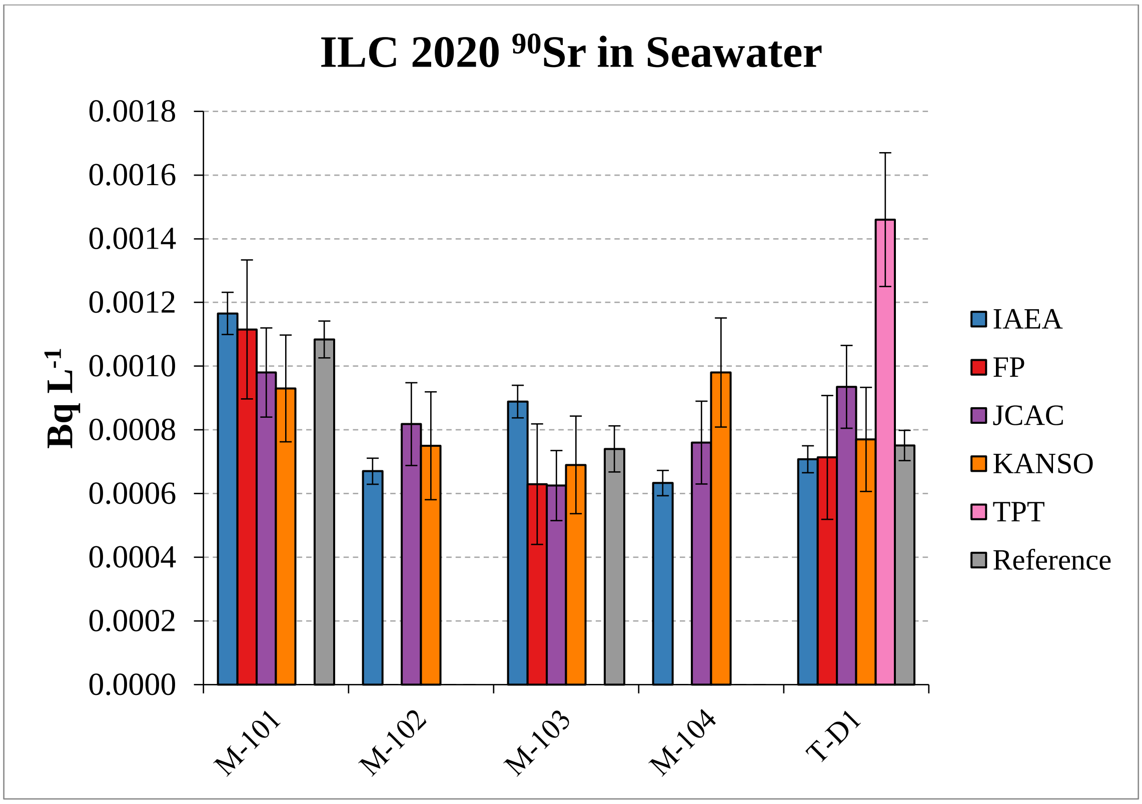

FIG. 3. Activity concentrations of ^{90}Sr in seawater samples.

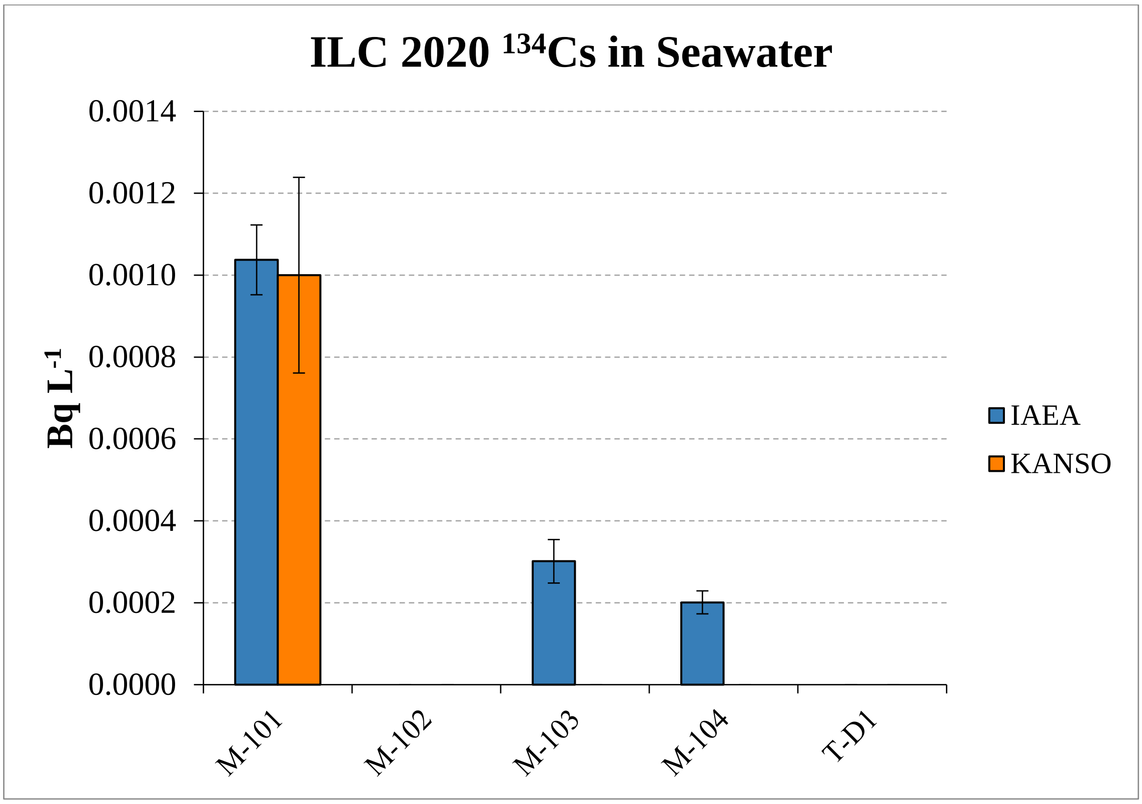

FIG. 4. Activity concentrations of ^{134}*Cs in seawater samples.*

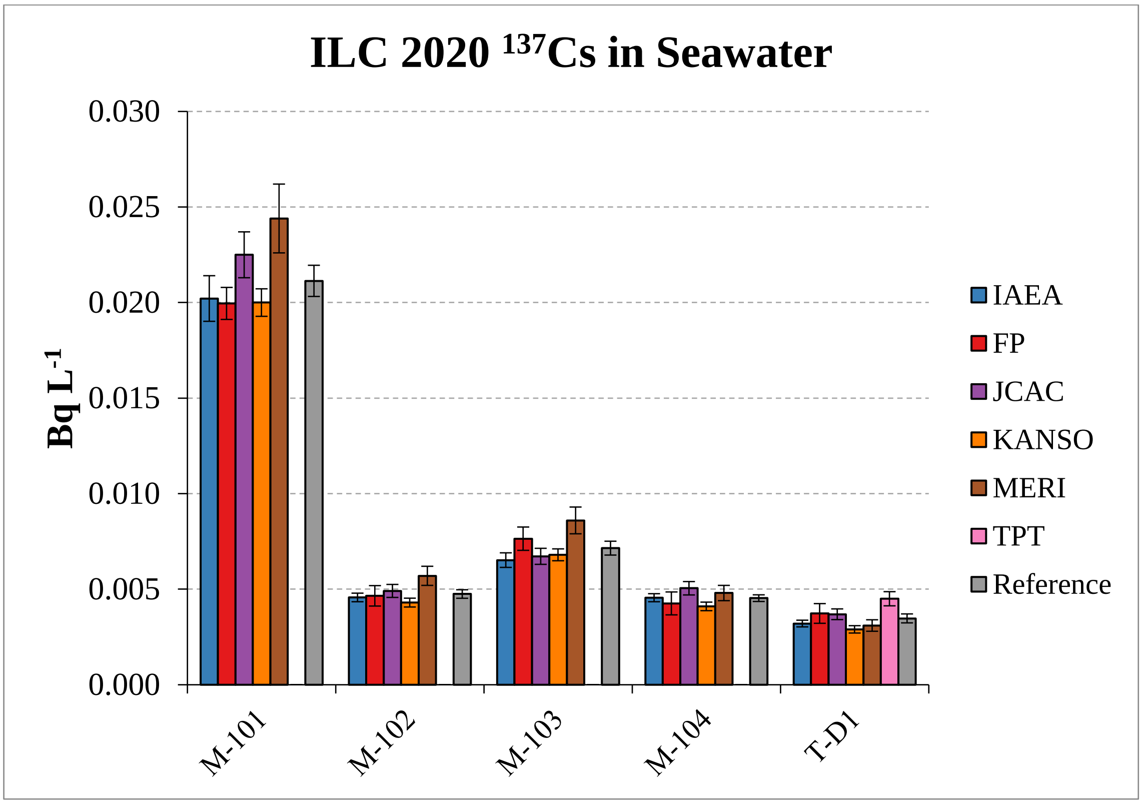

FIG. 5 Activity concentrations of ^{137}*Cs in seawater samples.*

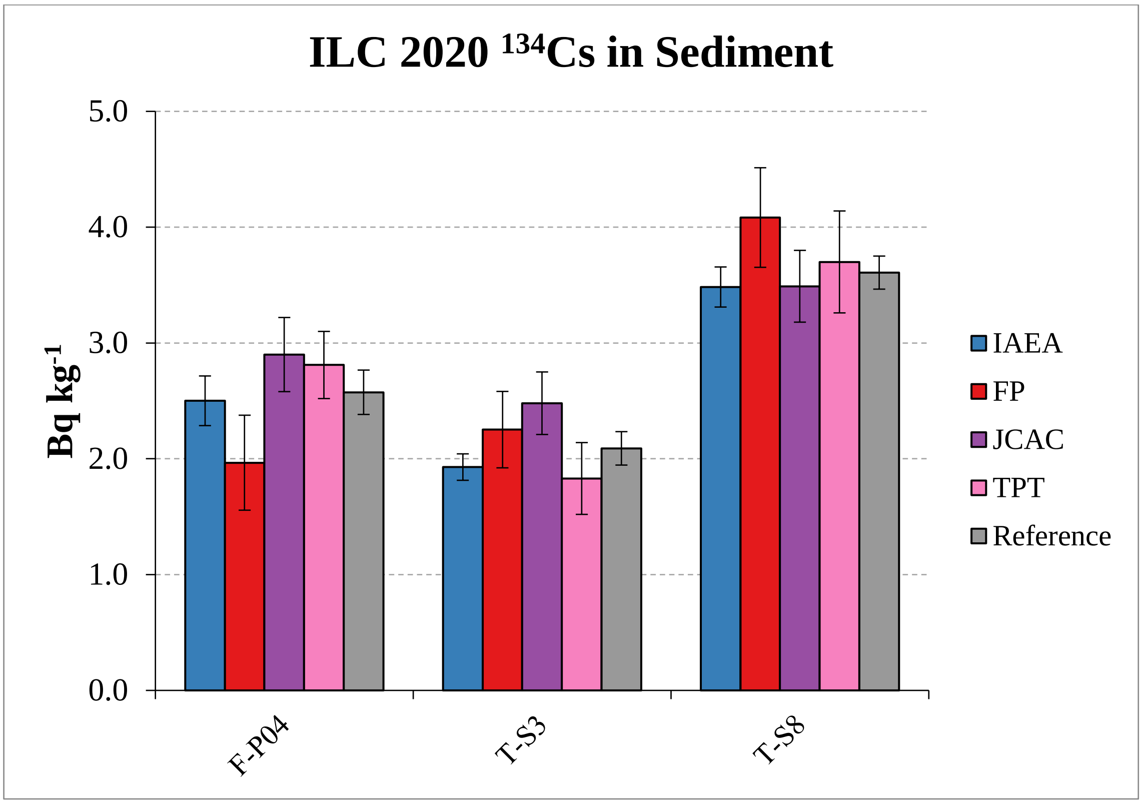

FIG. 6. Activity concentrations of ^{134}*Cs in sediment samples.*

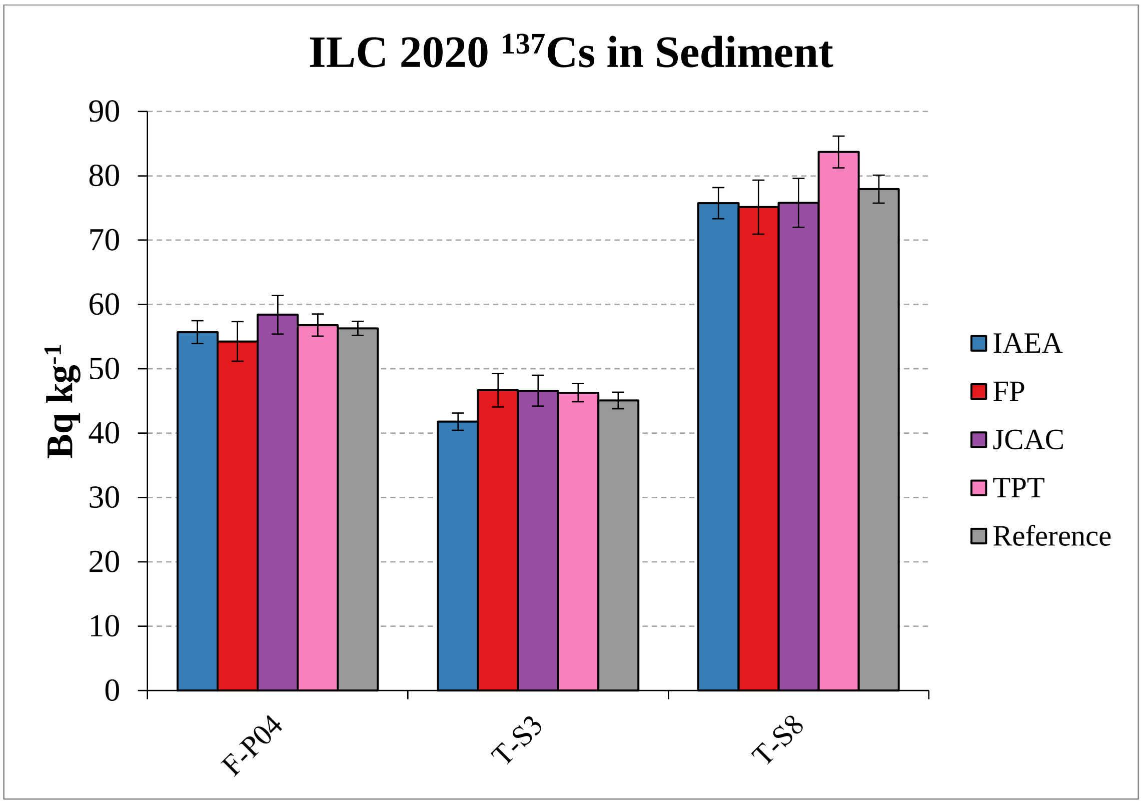

FIG. 7. Activity concentrations of ^{137}*Cs in sediment samples.*

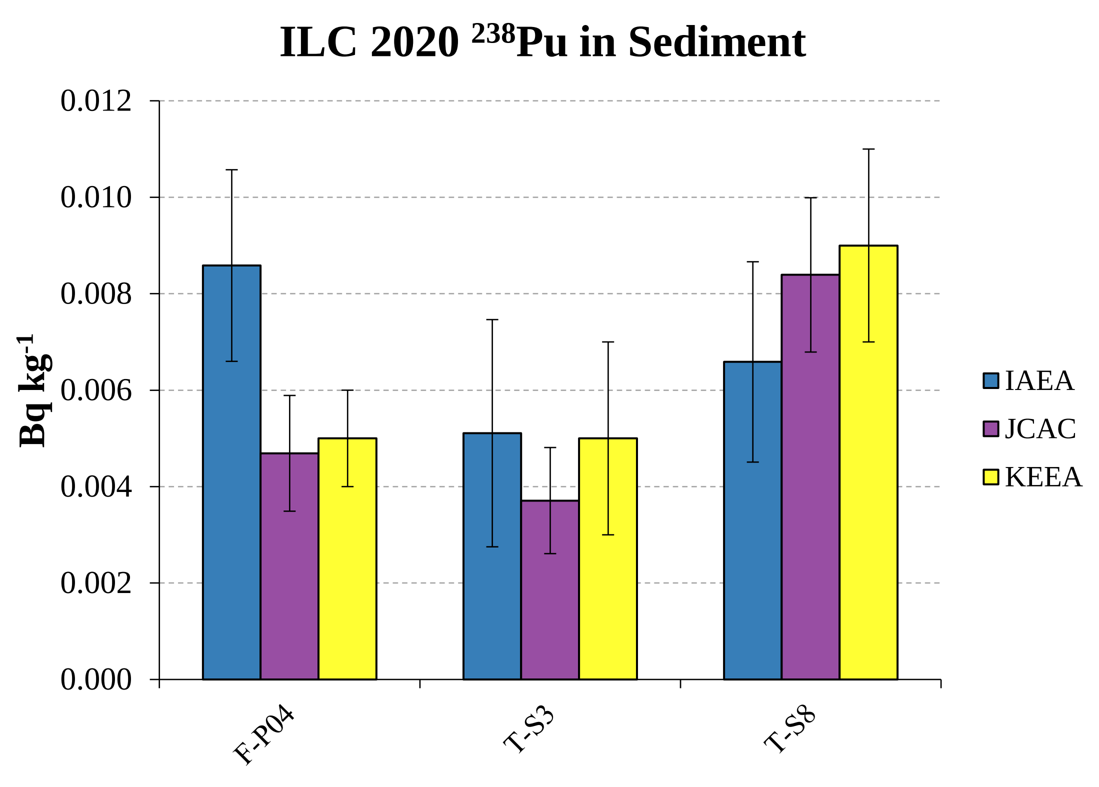

FIG. 8. Activity concentrations of ^{238}*Pu in sediment samples.*

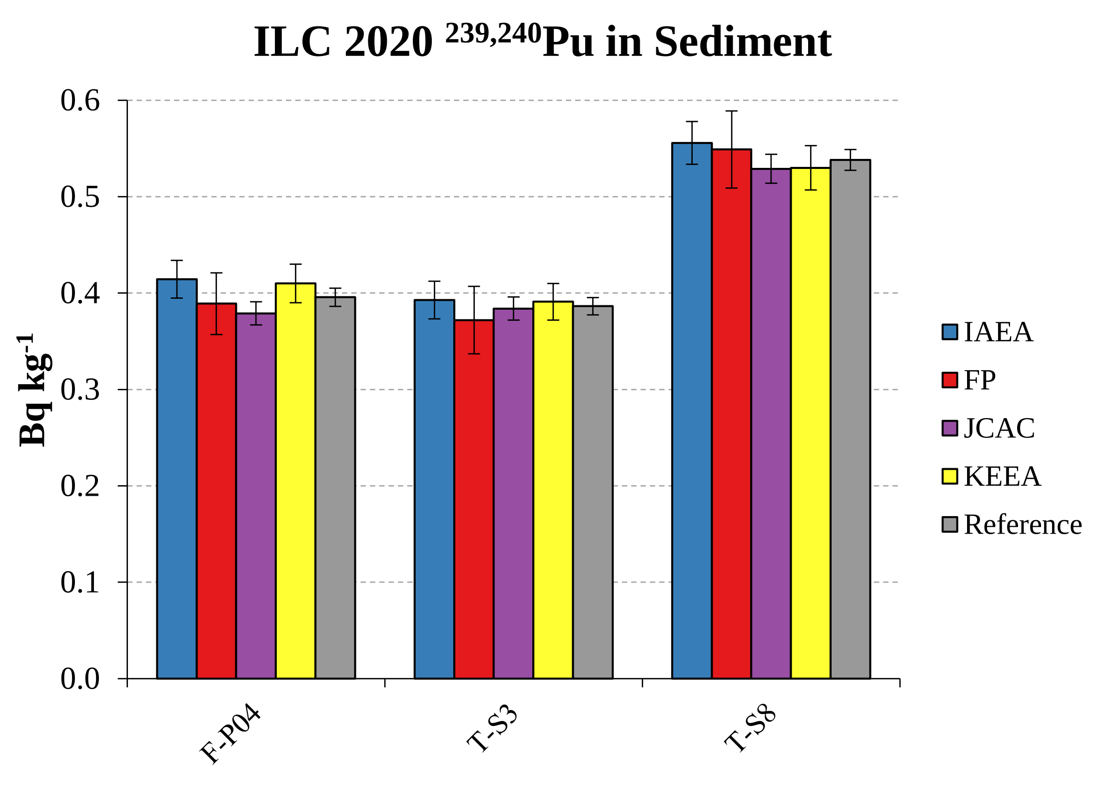

FIG. 9. Activity concentrations of ^{239,240}*Pu in sediment samples.*

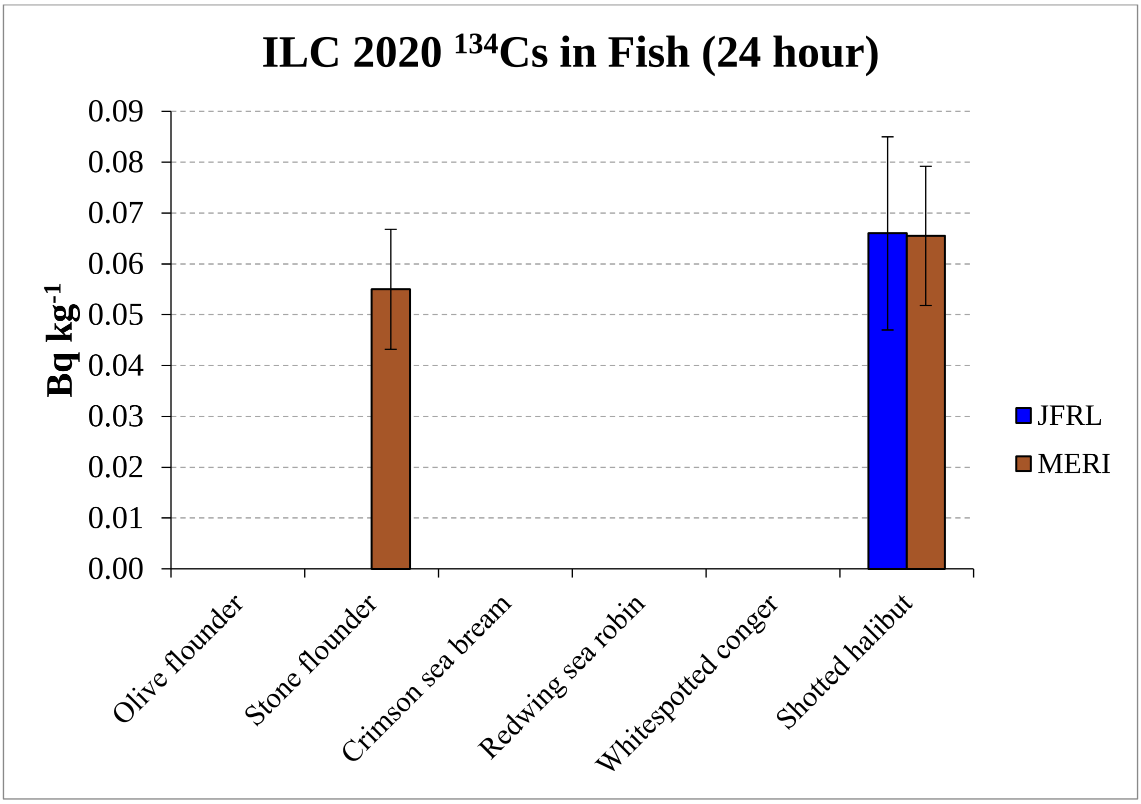

FIG. 10. Activity concentrations of ^{134}Cs in fish samples (24 hour measurement time).

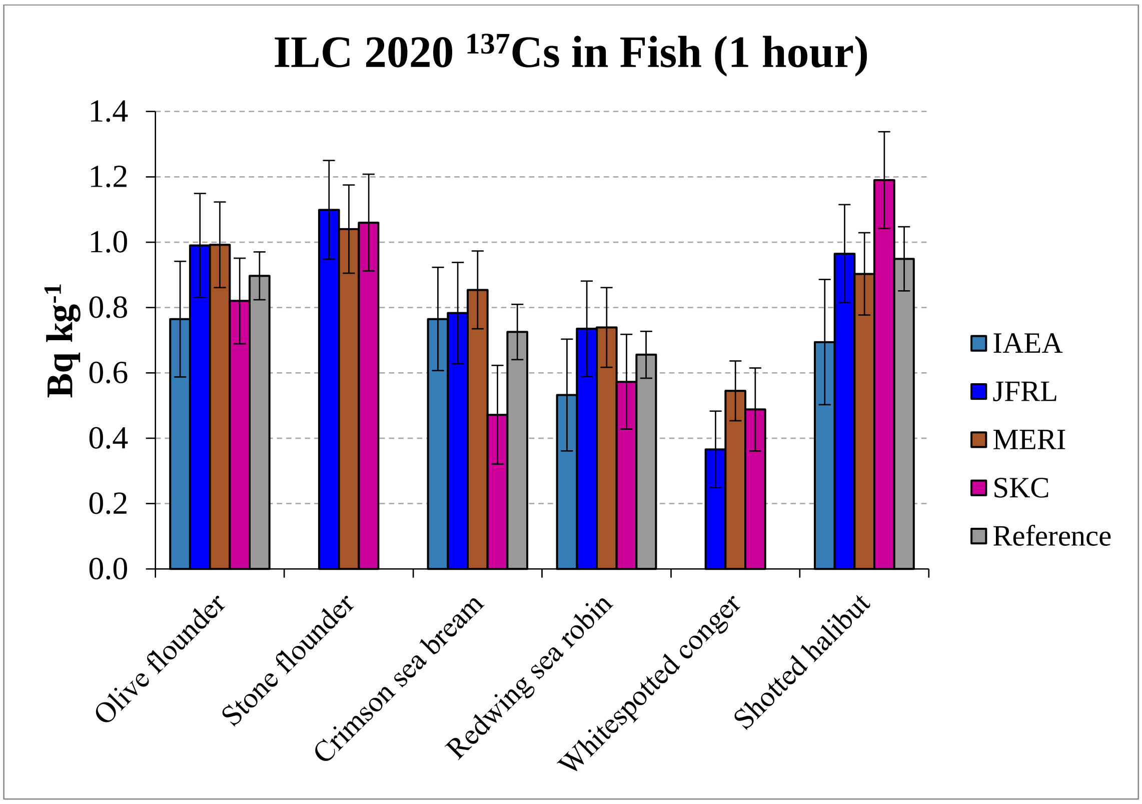

FIG. 11. Activity concentrations of ^{137}Cs in fish samples (1 hour measurement time).

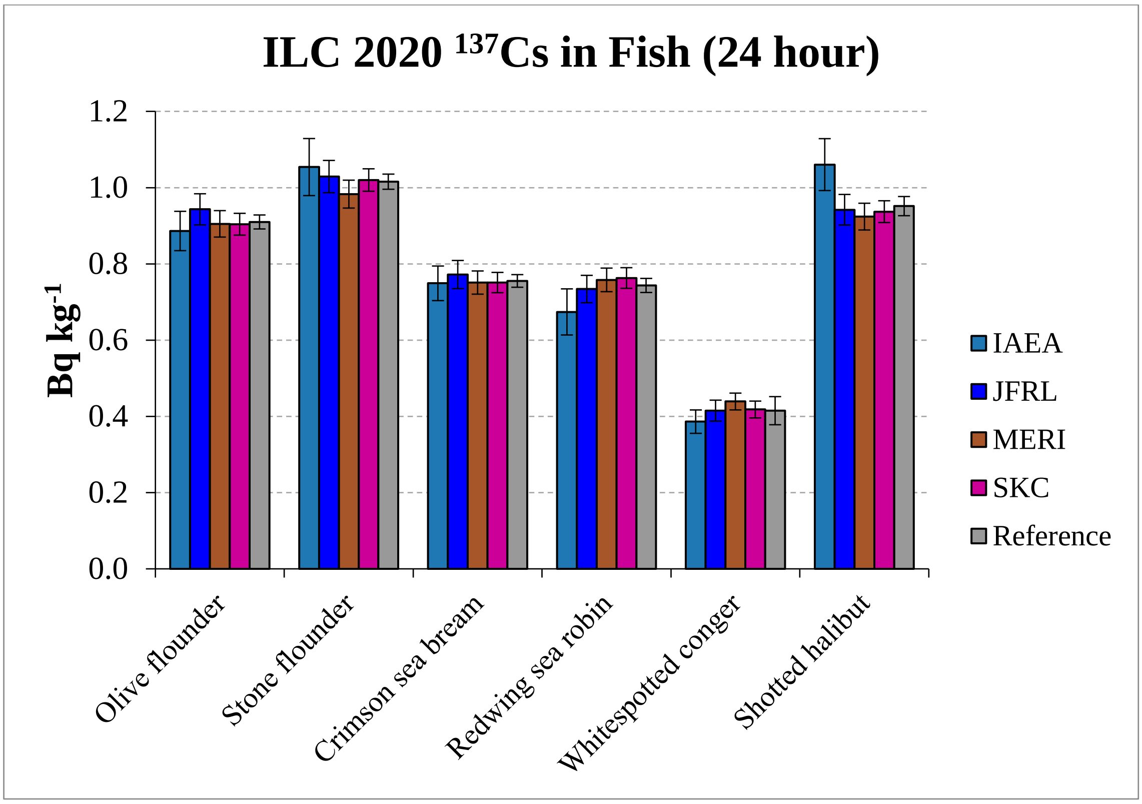

FIG. 12. Activity concentrations of ^{137}Cs in fish samples (24 hour measurement time).