

Fukushima Daiichi Nuclear Power Station Status of Progress of the Marine Organisms Rearing Test



May 25, 2023
Tokyo Electric Power Company Holdings, Inc

1. Marine organisms rearing status to date



- No flounders have died or have experience abnormalities since February 11, in both series of tanks of normal seawater and tanks of ALPS treated water diluted with seawater. Current survival rate^{※1} continues to be high at over 90% (Survival rate for tanks of normal seawater: 99%; Survival rate for tanks of ALPS treated water diluted with seawater: 99%)(as of May 18).
- Since this test began on October 25, the survival rate for abalone has been approximately 70% (Survival rate for tanks of normal seawater: 75%; Survival rate for tanks of ALPS treated water diluted with seawater: 68%)(as of May 25).
- On May 9, gulfweed (seaweed) was sampled and tritium concentration testing began.
- Professor Kato from Aquaculture Research Institute, Kindai University came to the Fukushima Daiichi Nuclear Power Station to assess the rearing status of flounder, abalone and gulfweed currently being tested, and made the following comments.

"I can see no difference in the specimens reared in tanks to which ALPS treated water has been added, and tanks of normal seawater, all specimens are in good health and are comparable to my findings."

Size of flounder(at December) : 【 Tanks of normal seawater 】 Weight: 116±31g; Length: 22±2cm
 : 【 Water tank to which ALPS treated water has been added 】 Weight: 121±31g; Length: 22±2cm
 Size of abalone(at December) : 【 Tanks of normal seawater 】 Shell length: 5.8±0.3cm
 : 【 Water tank to which ALPS treated water has been added 】 Shell Length: 5.8±0.3cm

Abalones have not been weighed because weighing them would require removal from the water tank which could result in possible injury.

Tank series	Classification	Number of marine organisms in each tank (as of May 18, 2023)		
		Flounder	Abalone	Seaweed
Series 1	Normal seawater (around 0.1~1 Bq/L)	115	120	-
Series 2	Normal seawater (around 0.1~1 Bq/L)	125	117	-
Series 3	Less than 1,500Bq/L ^{※2}	148	123	-
Series 4	Less than 1,500Bq/L ^{※2}	149	107	-
Series 5	Around 30Bq/L ^{※3}	10	-	-

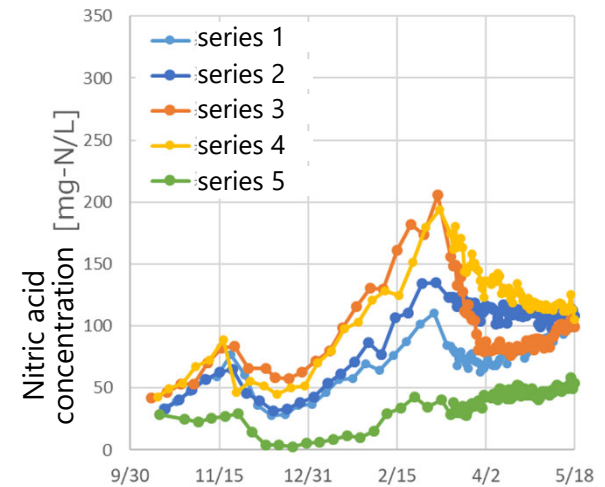
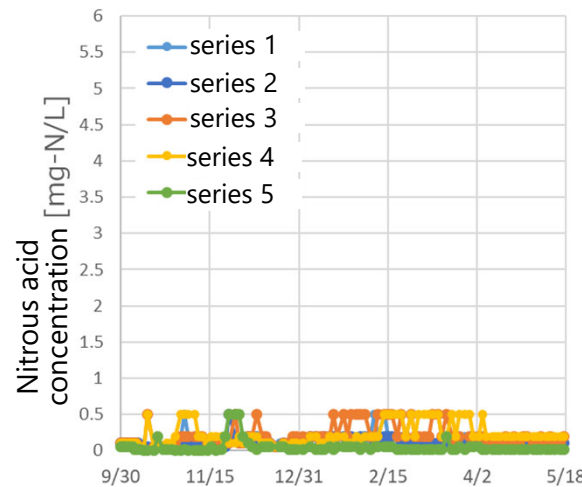
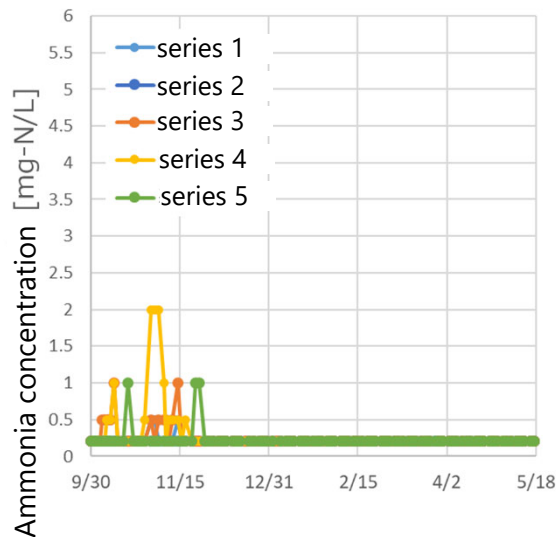
※1 Survival rate has been calculated after excluding the number of specimens removed for investigations or other testing.
 ※2 Measurement as of the end of April: approx. 1283Bq/L (no large change from the last measurement taken)
 ※3 Measurement as of the end of April: approx. 35Bq/L (no large change from the last measurement taken)

2. Water quality of rearing tanks to date



- While there have been some fluctuations in figures, water quality has been kept generally in the range suited to rearing marine organisms.

Item	Minimum to maximum in series 1 through 5 (September 30, 2022 to May 18, 2023)	Explanation for the measurement values
Water temperature (°C)	16.2~19.7	Kept around 18.0°C
Ammonia (mg-N/L)	0.2 ~2	We have seen temporary spikes in ammonia, but ammonia levels have generally kept below 0.5mg-N/L, in a range that doesn't impact most marine organisms.
Nitrous acid (mg-N/L)	0.005~0.5	Generally kept below 0.5mg-N/L, in a range that doesn't impact most marine organisms
Nitric acid (mg-N/L)	2.5~206	An increase was seen at the beginning of rearing. Denitrification equipment was put into use on November 14, 2022, and levels fell during 2022. Thereafter, we saw another increase at the beginning of 2023, so heaters and carbon sources were added, and after that we saw a gradual increase, then a leveling flat, then a decrease, and then another gradual increase.

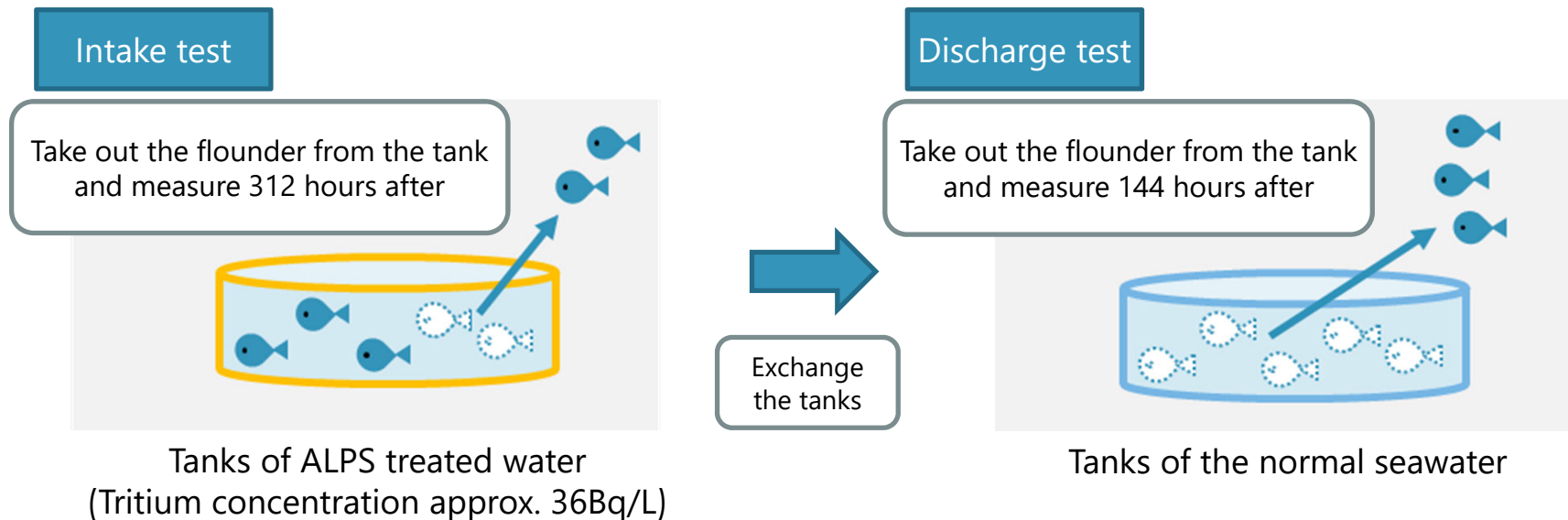


3. Results and insights of tritium concentrations (1/7)

Measurement of tritium concentrations in flounder (tritium concentration of approx. 30Bq/L)

- We have obtained the tritium concentration measurement results for flounder reared in ALPS treated water diluted with seawater (of approx. 30Bq/L) since November, 2022.
 - The number of flounders used for measurements: 4 for intake test, 6 for discharge test
- In order to demonstrate that the tritium concentration in the flounders reach equilibrium at the concentration lower than the environment where they are living after a certain period of time during which the flounders ingest the tritium, an <intake test> was conducted measuring the tritium concentration in the flounders 312 hours after the flounders were put into ALPS treated water.
- Subsequently, in order to demonstrate that the tritium concentration in the flounders decreases as the flounders excrete the tritium after moving the flounders from tanks of ALPS treated water to the tanks of normal seawater, a <discharge test> was conducted by measuring the tritium concentration in the flounders 144 hours after the flounders were moved.

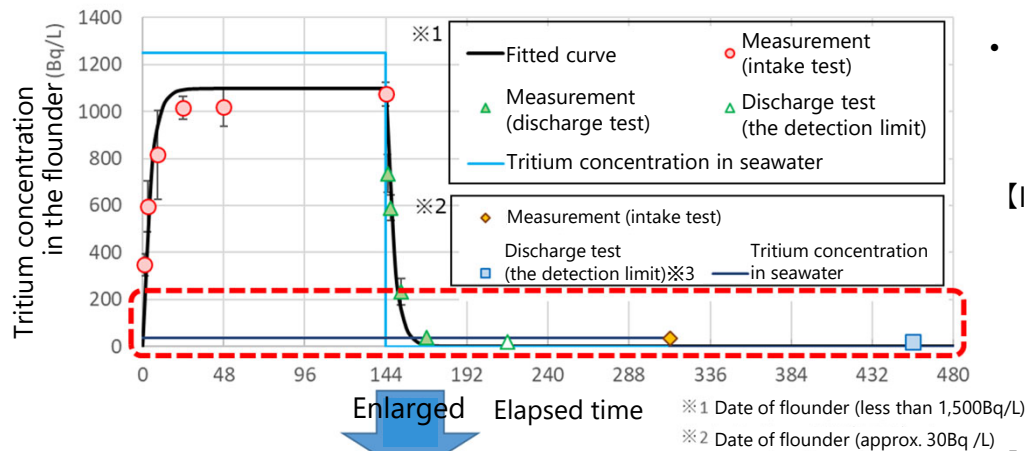
※Based on previous knowledge and flounder tests (less than 1,500Bq/L), we have been able to observe that the tritium concentration in flounders reach equilibrium approximately 24 hours during intake tests, and decrease and stabilize approximately 24 hours during discharge tests. Therefore, for the other tests, samples were taken after more than 24 hours had passed in consideration of this fact.



3. Results and insights of tritium concentrations (2/7)

Results and insights of tritium concentrations in flounder (tritium concentration of approx. 30Bq /L)

- During each of intake and discharge tests, the tritium concentration in the flounders was measured more than 24 hours after the start of the tests.
- As a result, the tritium concentration changed in both test.



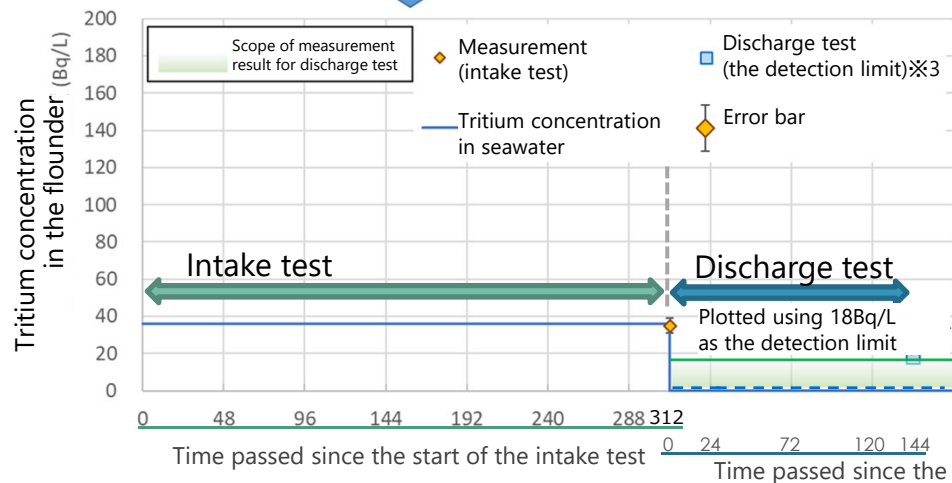
- We have been able to observe the following, which are consistent with previous knowledge and tritium concentration measurements for flounders (tritium concentration: less than 1,500Bq/L).

【Intake test】

- The tritium concentration in the organisms does not exceed the tritium concentration in the environment where the organisms are living (for this test, this means that the tritium concentration in the organisms does not exceed the tritium concentration in ALPS treated water diluted with seawater)

【Discharge test】

- The tritium concentration in the flounders decreases over time when the flounders, the tritium concentration has reached equilibrium in higher than that of normal seawater, are returned to normal seawater.



※"More than 24 hours"

Based on previous knowledge and flounder tests (less than 1,500Bq/L), we have been able to observe that the tritium concentration in flounders reach equilibrium approximately 24 hours during intake tests, and decrease and stabilize approximately 24 hours during discharge tests. Therefore, for the other tests, samples were taken after more than 24 hours had passed in consideration of this fact.

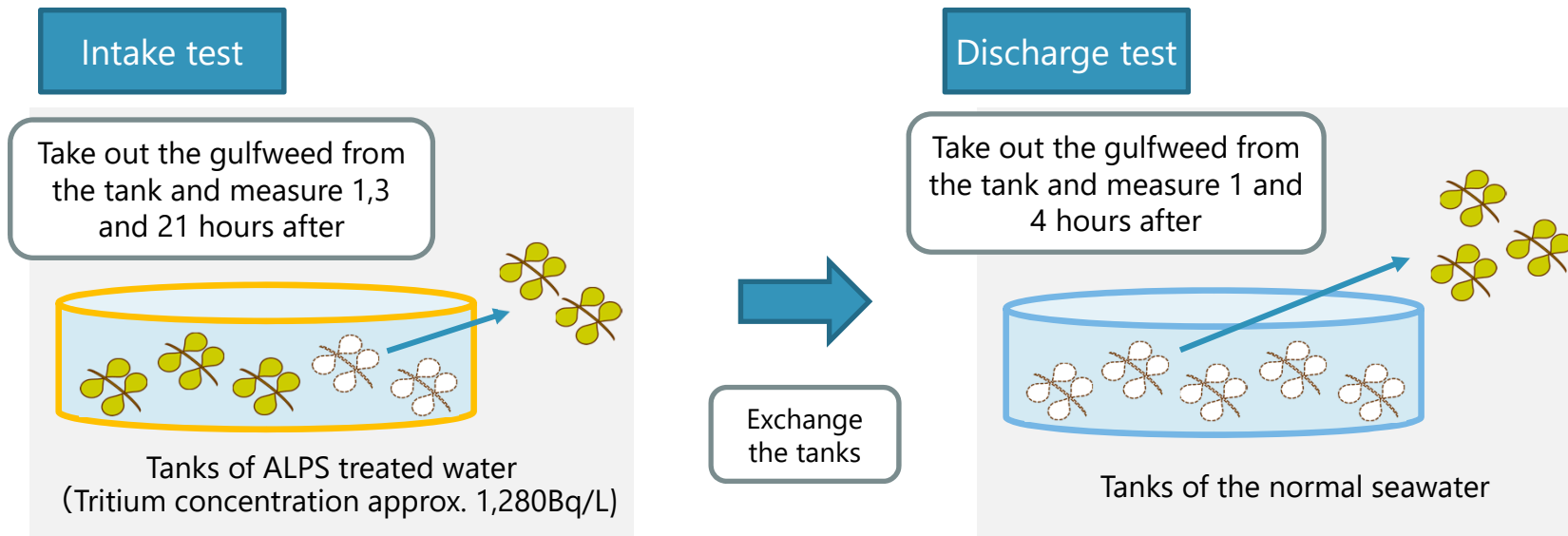
※ Tritium concentrations are higher than normal seawater as a result of the discharge test

※3 Analysis results for the discharge test were all below the detection limits

3. Results and insights of tritium concentrations (3/7)

Measurement of tritium concentrations in gulfweed (tritium concentration of less than 1,500Bq/L)

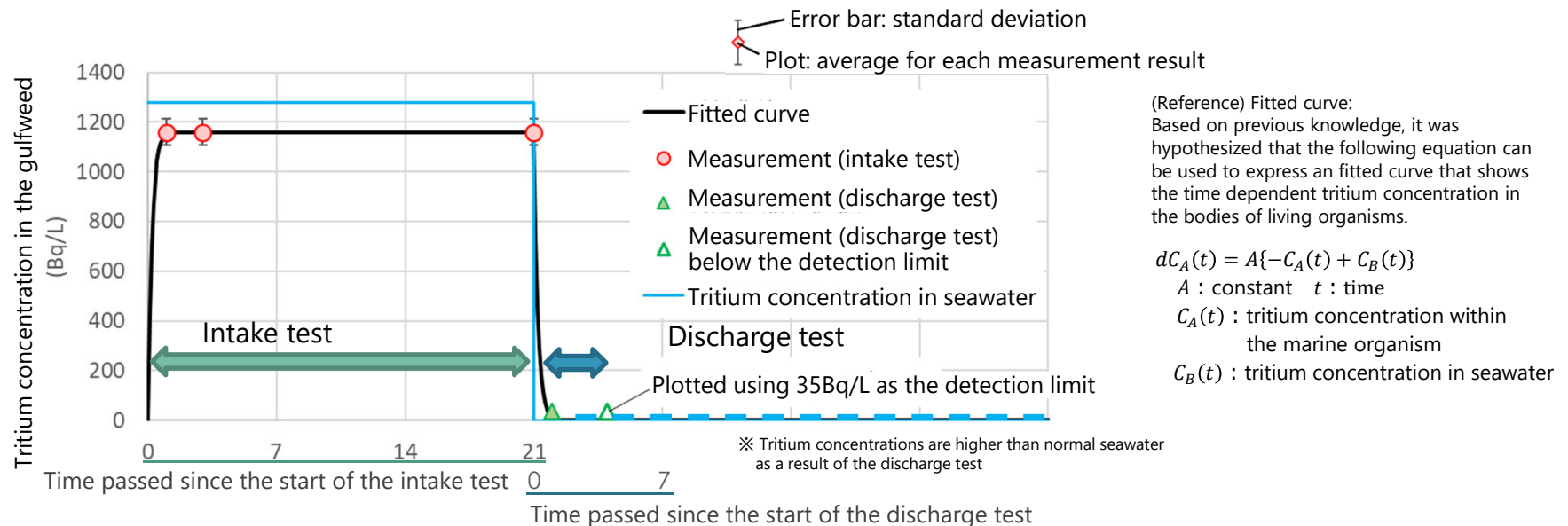
- We have obtained the tritium concentration measurement results for gulfweed reared in ALPS treated water diluted with seawater (less than 1,500Bq/L) in May, 2023.
 - The amount of gulfweed used for measurements: about 3 kilogram
- In order to demonstrate that the tritium concentration in the gulfweeds reaches equilibrium at the concentration lower than the environment where they are living after a certain period of time during which the gulfweeds ingest the tritium, an <intake test> was conducted measuring the tritium concentration in the gulfweeds 1, 3 and 21 hours after the gulfweeds were put into ALPS treated water.
- Subsequently, in order to demonstrate that the tritium concentration in the gulfweeds decreases as the gulfweeds excrete the tritium after moving the gulfweeds from tanks of ALPS treated water to the tanks of normal seawater, a <discharge test> was conducted by measuring the tritium concentration in the gulfweeds 1 and 4 hours after the gulfweeds were moved.



3. Results and insights of tritium concentrations (4/7)

Results and insights of tritium concentrations in gulfweed (tritium concentration of less than 1,500Bq/L)

- In both tests, changes were seen in tritium concentrations over time. The relationship between the fitted curve from this data drawn based on the comparison with the fitted curve drawn based on previous knowledge, and the measurement values is as follows:



- Referring the data from the graph above, we have been able to observe the following, which are consistent with previous knowledge and tritium concentration measurements for flounders and abalones (tritium concentration: less than 1,500Bq/L).

【Intake test】

- The tritium concentration does not exceed the tritium concentration in the environment where the organisms are living (for this test, this means that the tritium concentration in the organisms does not exceed the tritium concentration in ALPS treated water diluted with seawater)
- Tritium concentration reaches equilibrium after a certain period of time

【Discharge test】

- The tritium concentration in gulfweed decreases over time when the gulfweeds, which the tritium concentration has reached equilibrium in higher than that of normal seawater, are returned to normal seawater

3. Results and insights of tritium concentrations (5/7)



Referring the data from each tritium concentration tests, we have been able to observe the following, which are consistent with previous knowledge.

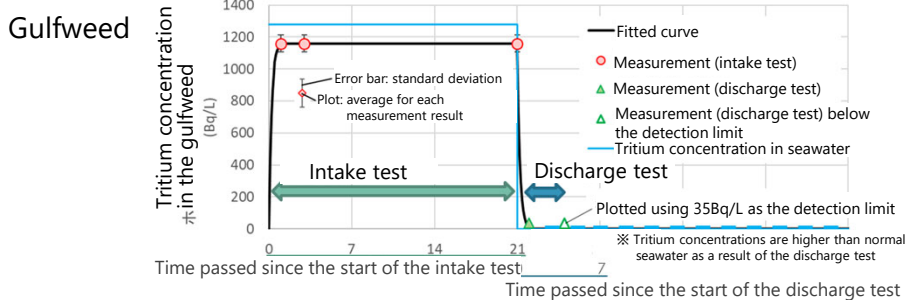
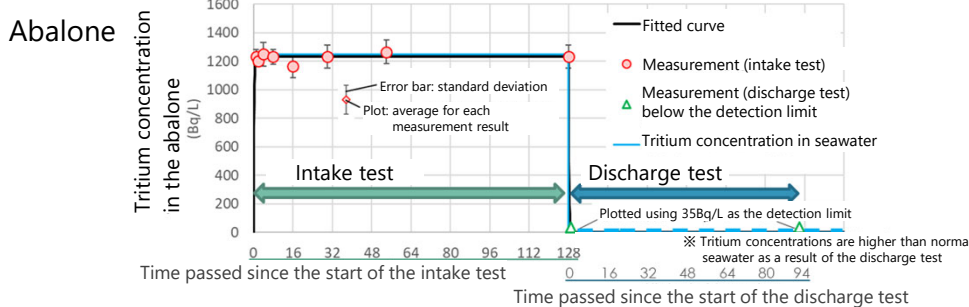
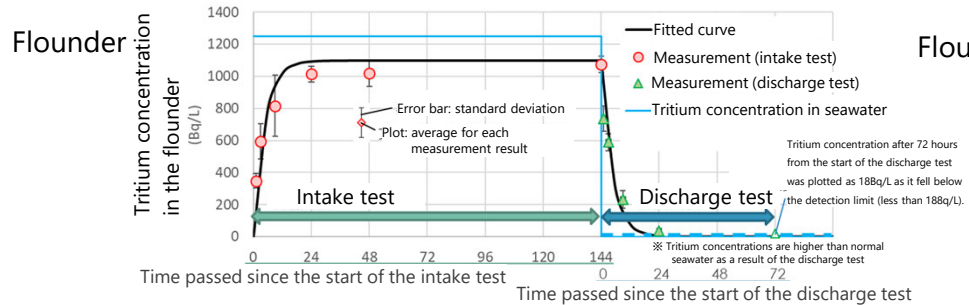
[Intake test]

- The tritium concentration in the organisms does not exceed the tritium concentration in the environment where the organisms are living (for this test, this means that the tritium concentration in the organisms does not exceed the tritium concentration in ALPS treated water diluted with seawater)
- Tritium concentrations reach equilibrium after a certain period of time

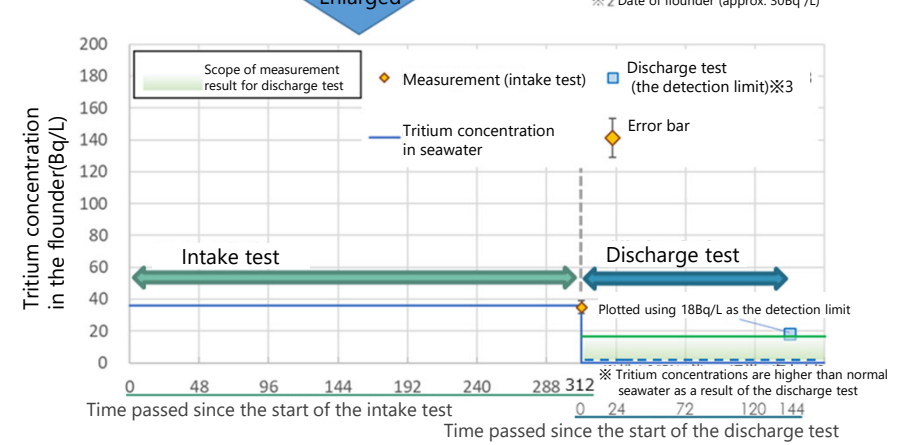
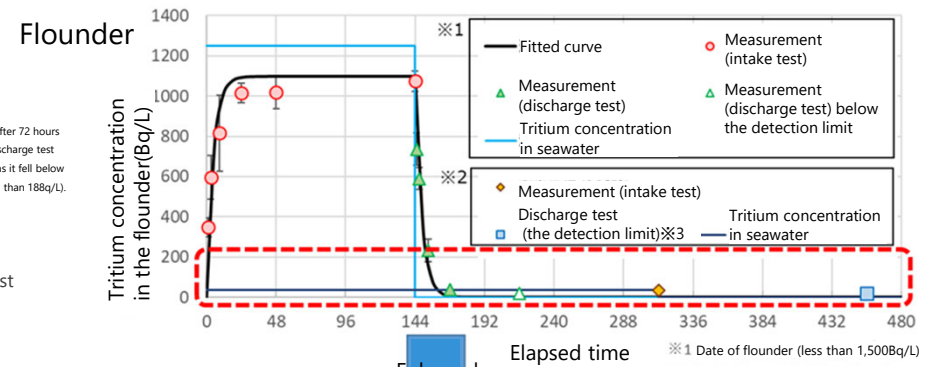
[Discharge]

- The tritium concentration decreases over time when the flounders, the tritium concentration has reached equilibrium in higher than that of normal seawater, are returned to normal seawater

Tritium concentration of less than 1,500Bq/L



Tritium concentration of approx. 30Bq/L



※3 Analysis results for the discharge test were all below the detection limits

3. Results and insights of tritium concentrations (6/7)

Measurement of the concentration of organically bound tritium (OBT) in flounder (tritium concentration of less than 1,500Bq/L)

- We have been analyzing the concentration of organically bound tritium (hereinafter referred to as, "OBT") in flounder that have been reared in ALPS treated water (less than 1,500Bq/L) since October 2022. As follows, from previous knowledge, we have learned that OBT behaves the same as the free water tritium (hereinafter referred to as, "FWT").
 - The number of flounders used for measurements: 23 for intake test

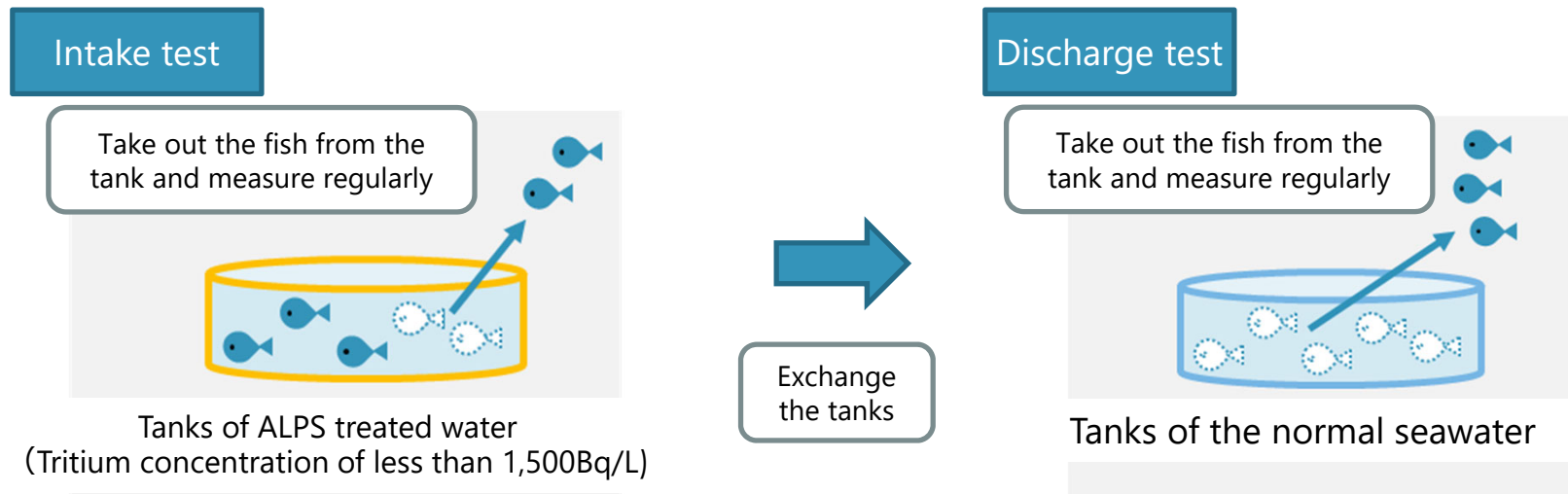
【Intake test】

- OBT concentration does not exceed the tritium concentration in the environment where the organisms are living (for this test, this means that the tritium concentration in the organisms does not exceed the tritium concentration in ALPS treated water diluted with seawater)
- OBT concentration reaches equilibrium after a certain period of time※

※Based on previous knowledge we have learned that compared to FWT, more time is required for this to happen

【Discharge test】

- OBT concentration decreases over time when the flounders, which the OBT concentration has reached equilibrium in higher than that of normal seawater, are returned to normal seawater

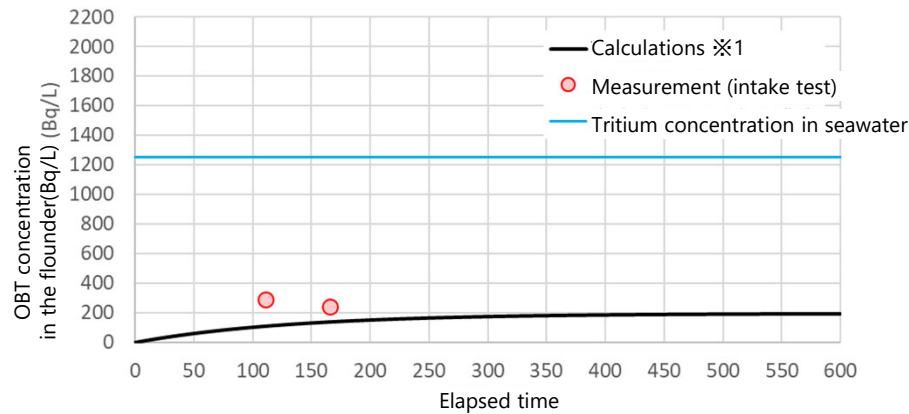


Specimens sampled in January and March for intake test were analyzed at this time. We will continue with intake tests and plan to perform discharge tests thereafter.

3. Results and insights about tritium concentrations (7/7) TEPCO

Results and insights of organically bound tritium (OBT) concentration in flounder (tritium concentration of less than 1500Bq/L)

- The relationship between the calculated values from this data drawn based on the comparison with the fitted curve drawn based on previous knowledge, and the measurement values is as follows:

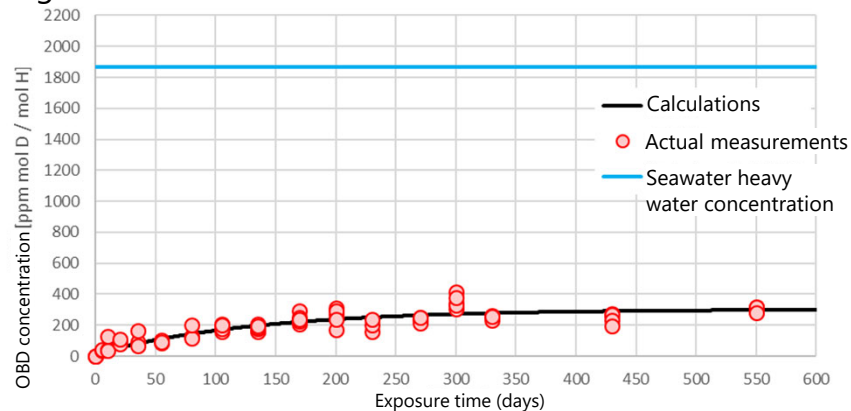


- OBT concentration at equilibrium predicted from existing research is approximately less than 20% that of the tritium concentration in the seawater. The following was confirmed and is consistent with previous knowledge.

[Intake test]

- It's been approximately six months since OBT intake tests began, and OBT concentration in flounder is less than 20% that of the tritium concentration in the seawater, so it is assumed that equilibrium has been reached

[Reference] Example of experiment data for organically bound hydrogen^{※2} in the muscles of flounder



Created based on Chart 2-1 from the General Experiments on the Transference of Excreted Tritium to Living Organisms (The amount of naturally occurring heavy water has been subtracted from calculations, actual measurements, and seawater heavy tritium concentrations shown in the graph)

※2 Has the same chemical composition as tritium

We will continue to take samples and perform analysis.

※1 Calculated values:

Based on previous knowledge, a concentration curve that represents the changes in OBT concentrations in the muscle tissue of a living organism can be expressed by the following equation. Calculated values in the graph have been generated based on the assumption that tritium concentrations in the seawater are 1,250Bq/liter.

$$\frac{dC_1(t)}{dt} = \left(\frac{E_1 \cdot m_0(t) \cdot C_0(t) \cdot dt + M_1 \cdot C_1(t)}{E_1 \cdot m_0(t) \cdot dt + M_1} - C_1(t) \right) / dt + k_{31} \cdot C_w - k_{13} \cdot C_1(t)$$

E1, M1, k13, k31, Cw : Constant t : Time

C₀(t) : OBT concentrations during feeding ("0" on the graph)

C₁(t) : OBT concentrations in the body of the flounder (muscle tissue)

m₀(t) : Hydrogen ingestion from food over a period of time

4. Conclusions and future plans

Conclusions

【Rearing status】

- Flounder and abalone have been reared since September 30, 2022 and October 25, 2022, respectively, and we have been able to observe that there are no discrepancies in rearing status between specimens reared in tanks of normal seawater and those reared in tanks of ALPS treated water. External experts have concurred with our results.

【Tritium concentration tests】

- In FWT concentration tests on flounder, abalone and gulfweed, the results obtained for each marine organism and tritium concentrations are consistent with previous knowledge.
 - FWT concentration does not exceed the tritium concentration in the environment where the organisms are living (for this test, this means that the tritium concentration in the organisms does not exceed the tritium concentration in ALPS treated water diluted with seawater)
 - FWT concentration reaches equilibrium after a certain period of time
 - FWT concentration decreases over time when the flounders, which the tritium concentration has reached equilibrium in higher than that of normal seawater, are returned to normal seawater.
- OBT concentration at equilibrium in flounder predicted from existing research is approximately less than 20% that of the tritium concentration in the seawater. The following was confirmed and is consistent with previous knowledge.
 - It's been approximately six months since OBT intake tests began, and OBT concentration in flounder is less than 20% that of the tritium concentration in the seawater, so it is assumed that equilibrium has been reached.

Rearing plan

- We will continue to rear flounder in ALPS treated water that has been diluted (Tritium concentration: Less than 1,500Bq/L).

Future plan

- We will continue to measure OBT concentration in flounder (Tritium concentration: less than 1,500Bq/L).

【Reference】

Previously reported tritium concentration test (1/4)

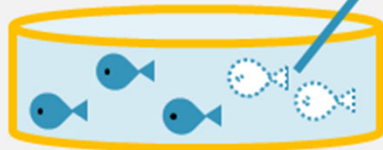
110th meeting of the Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water Fukushima Daiichi Nuclear Power Station Start of Marine Organisms Rearing Tests (December 22, 2022 Excerpts from documents)

Measuring the tritium concentration in flounder (tritium concentration of less than 1500Bq/L)

- The result of tritium concentration measurements taken on October 2022 from flounder reared in diluted ALPS treated water (less than 1500Bq/L) was disclosed (the part analyzed by TEPCO).
 - Number of flounder measured
 - 33 flounder for the intake test
 - 25 flounder for the discharge test
- To verify that after a certain period of time the tritium in flounder reaches equilibrium at a lower concentration than the rearing environment, an *intake test* was conducted measuring tritium concentrations in flounder at 0, 1, 3, 9, 24, 48 and 144 hours after the flounder is brought into the ALPS treated water.
- Afterward, to verify that the tritium concentration in the flounder will be reduced by discharging the tritium from the flounder that had been moved from ALPS treated water tanks to normal seawater tanks, a *discharge test* was conducted measuring tritium concentrations in flounder at 0 hours (the 144-hour point in the intake test) after the flounder is placed in the normal seawater tank, and 1, 3, 9, 24, 72 hours afterward.

Intake test

Measure the fish taken out from the tank 0, 1, 3, 9, 24, 48, 144 hours later.



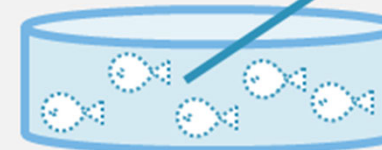
ALPS treated water tank
(tritium concentration of approx.
1250 Bq/L)



Exchange
the tanks

Discharge test

Measure the fish taken out from the tank 1, 3, 9, 24, 72 hours later.



Normal seawater

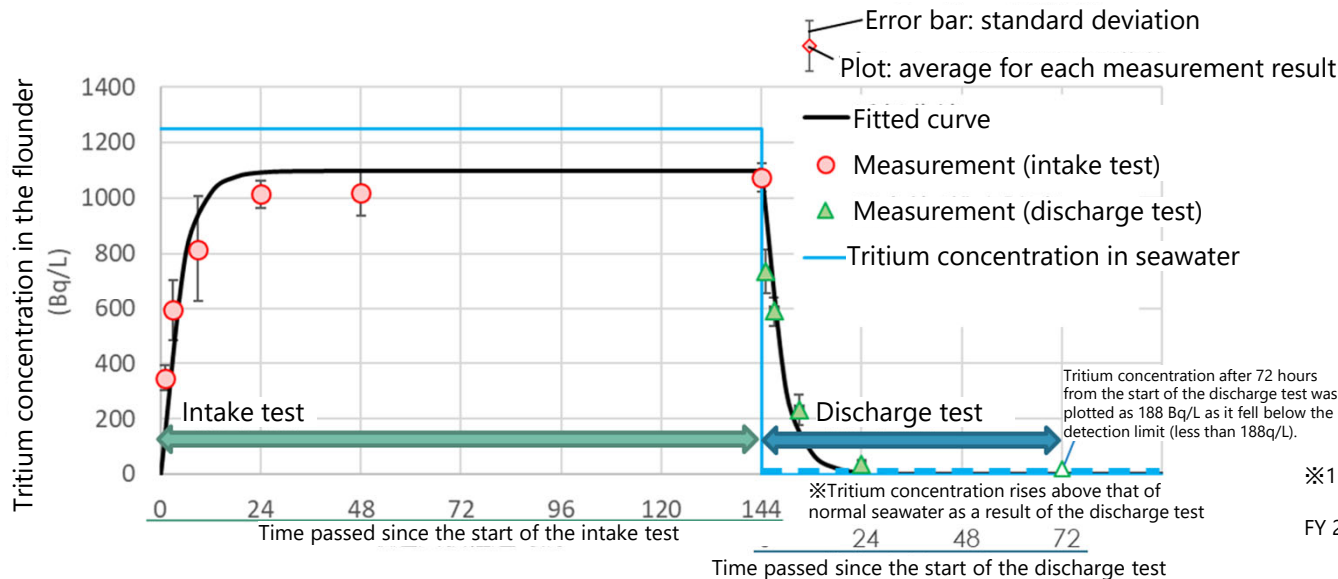
【Reference】

Previously reported tritium concentration test (2/4)

110th meeting of the Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water Fukushima Daiichi Nuclear Power Station Start of Marine Organisms Rearing Tests (December 22, 2022 Excerpts from documents)

Results of tritium concentrations in flounder (tritium concentration of less than 1500Bq/L) and insights

- Tritium concentrations changed with time in both intake and discharge tests. The relationship between the measurement values and the fitted curve for the data drawn based on the approach to fitted curve developed based on past data is as follows.



※ In graphing the measurements, points below the detection limit and suspected adulteration were removed

(Reference) On the fitted curve: Based on previous findings, the changes in tritium concentration within marine organisms were represented by the following formula.

$$dC_A(t) = A\{-C_A(t) + C_B(t)\}$$

A : constant t : time
 $C_A(t)$: tritium concentration within the marine organism
 $C_B(t)$: tritium concentration in seawater

※1 Similar analysis results have been reported in the following literature in the past.
 FY 2009 Experimental Study on Carbon Transfer in Land and Aquatic Ecosystems, Research Institute of Environmental Science and Technology

- Referring the data from graph above, the following results are confirmed same as previous findings. ※1
 - 【Intake test】
 - The tritium concentration in living bodies does not exceed that of the environment which it was reared in (i.e., does not exceed the tritium concentration in ALPS treated water diluted with seawater in this test).
 - The tritium concentration reaches an equilibrium after a certain period of time.
 - 【Discharge test】
 - The tritium concentration in the flounder will be reduced as time passes after the flounder, which has reached equilibrium in higher tritium concentrations than that of normal seawater, is returned to normal seawater.

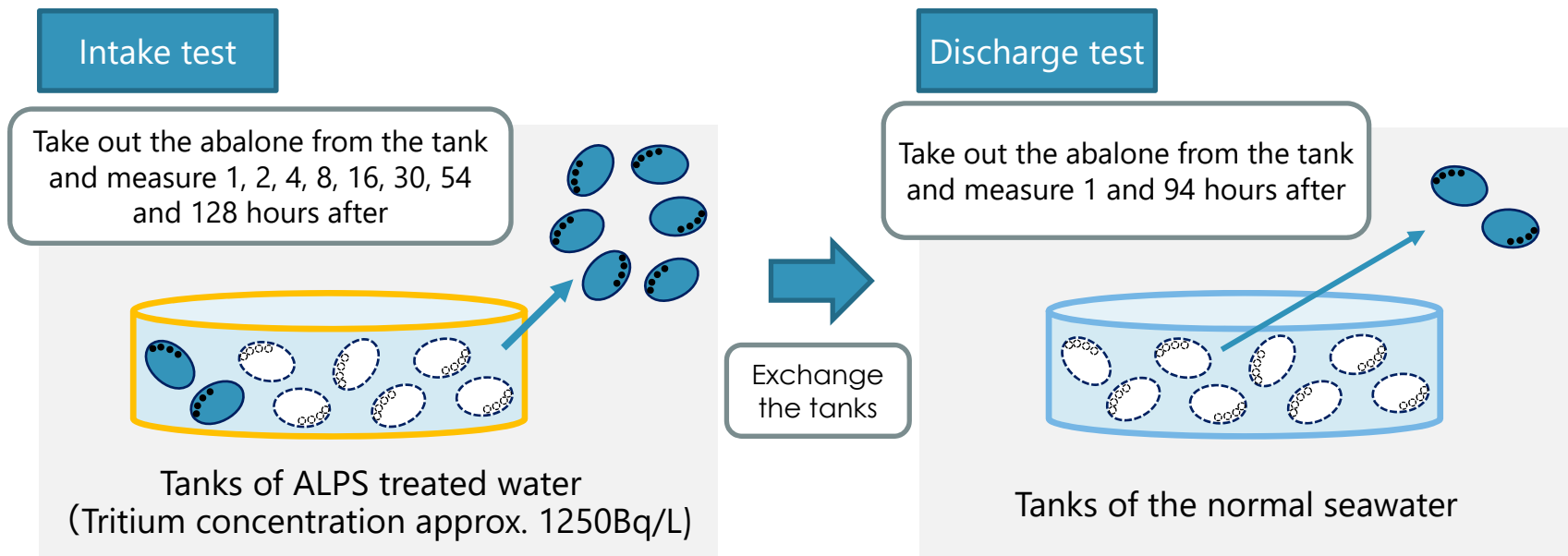
【Reference】

Previously reported tritium concentration test (3/4)

113th meeting of the Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water
Fukushima Daiichi Nuclear Power Station Start of Marine Organisms Rearing Tests
(April 27, 2023 Excerpts from documents)

Measurement of tritium concentrations in abalone (tritium concentration of less than 1500Bq/L)

- We have obtained the tritium concentration measurement results for abalone reared in ALPS treated water diluted with seawater (less than 1,500Bq/L) since October 26, 2022.
 - The number of abalones used for measurements: 48 for intake test, 12 for discharge test
- In order to demonstrate that the tritium concentration in the abalones does not exceed the tritium concentration of the environment where they are living after a certain period of time during which the abalones ingest the tritium, an *intake test* was conducted by measuring the tritium concentration of the abalones 1, 2, 4, 8, 16, 30, 54 and 128 hours after the abalones were put in the tanks of ALPS treated water.
- Subsequently, in order to demonstrate that the tritium concentration in the abalones decreases as the abalones excrete the tritium after moving the abalones from tanks of ALPS treated water to the tanks of normal seawater, a *discharge test* was conducted by measuring the tritium concentration of the abalones 1 and 94 hours after the abalones were moved.



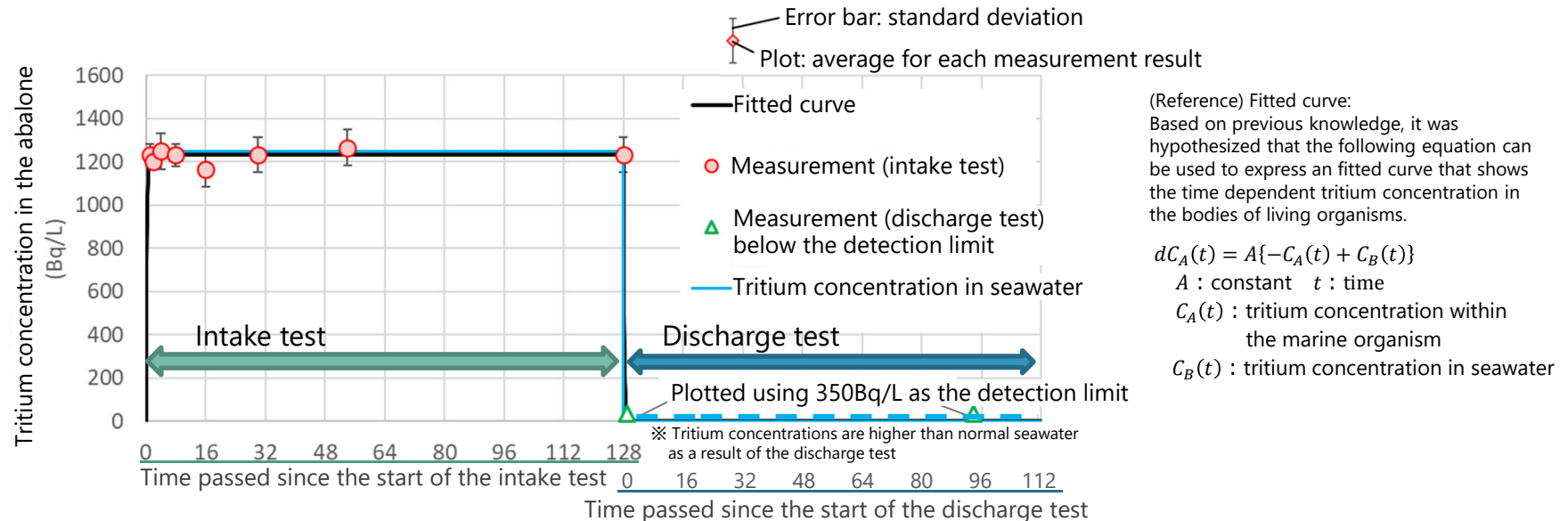
【Reference】

Previously reported tritium concentration test (4/4)

113th meeting of the Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water Fukushima Daiichi Nuclear Power Station Start of Marine Organisms Rearing Tests (April 27, 2023 Excerpts from documents)

Results and insights of tritium concentrations in abalone (tritium concentration of less than 1500Bq/L)

- In both tests, changes were seen in tritium concentrations over time. The relationship between the fitted curve from this data drawn based on the comparison with the fitted curve drawn based on previous knowledge, and the measurement values is as follows:



- Referring the data from the graph above, we have been able to observe the following, which are consistent with previous knowledge and tritium concentration measurements for flounders (tritium concentration: less than 1500Bq/L).

【Intake test】

- The tritium concentration in the organisms does not exceed the tritium concentration in the environment where the organisms are living (for this test, this means that the tritium concentration in the organisms does not exceed the tritium concentration in ALPS treated water diluted with seawater)
- Tritium concentrations reach equilibrium after a certain period of time

【Discharge test】

- The tritium concentration in the abalones decreases over time when the abalones, the tritium concentration has reached equilibrium in higher than that of normal seawater, are returned to normal seawater.

【Reference】

Fukushima Daiichi Nuclear Power Station Start of Marine Organisms Rearing Tests
(September 29, 2022 Excerpts from documents)

What We Hope to Prove with the Rearing Test (1/2)

- ① In order to alleviate people's concerns and to cultivate peace of mind, we will rear marine organisms in tanks of seawater containing ALPS treated water and compare them with organism reared in normal seawater and report the results carefully in an easy-to-understand manner.

To be confirmed in the test

- Marine organisms rearing tests will be conducted both in seawater and in ALPS treated water diluted with seawater. The marine organisms in these two environments will be compared via rearing data to confirm there are no significant differences between the two populations.

Information disclosure policy

- For ①, we will provide a live stream of the rearing tank and write about how the rearing test is going on in the observation diary on our website and on Japanese Twitter. The rearing environment (e.g., water quality, temperature of the water), state of organisms (e.g., changes in the number of organisms), analysis results (e.g., comparisons of the tritium concentration in the live organisms and in seawater) of the marine organisms reared in ALPS treated water diluted with seawater and organisms reared in normal seawater will be summarized and disclosed every month.
- In addition to having people from the local community and parties concerned visit the test site, we will also have biology experts check on the test as it is ongoing.



◀ Live stream of the seawater rearing test (for illustration purposes only)

- The normal seawater is in the blue tanks and the ALPS treated water diluted with seawater is in the yellow tanks.
- The layout of the tanks will be changed as needed based on feedback from relevant parties to ensure optimal visibility.

【Reference】

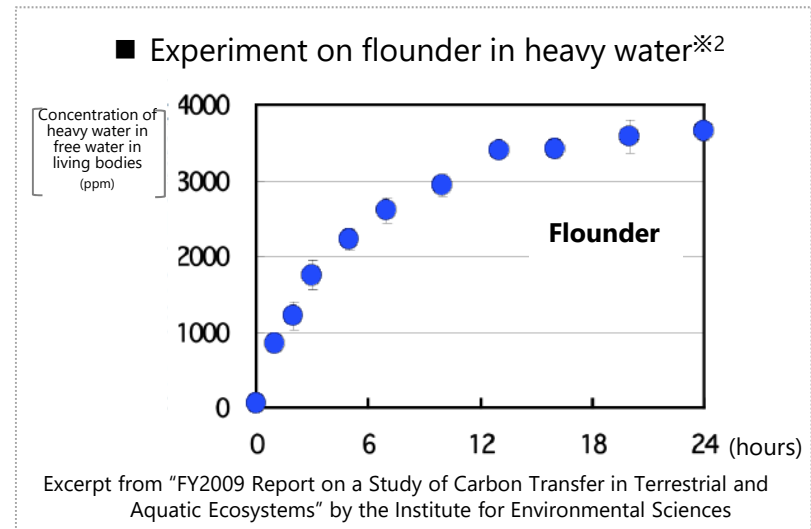
Fukushima Daiichi Nuclear Power Station Start of Marine Organisms Rearing Tests
(September 29, 2022 Excerpts from documents)

What We Hope to Prove with the Rearing Test (2/2)

- ② Based on the results of many studies domestic and abroad on the behavior of tritium, data for this test will first be gathered for 6 months to show that “tritium is not concentrated in the living bodies and that the concentration of tritium in living bodies does not exceed that of the rearing environment” as demonstrated in past tests results.

Results of experiments domestic and abroad

- The tritium concentration in a living bodies does not exceed that of the environment which it was reared in.
- The tritium concentration reached an equilibrium after a certain period of time.
 - ※1 Tritium in living bodies is either free water tritium (FWT) or organically bound tritium (OBT). Studies have been conducted domestically and abroad for both.
 - ※2 This experiment was conducted using heavy hydrogen (H-2) which has the same properties as tritium (H3) (The heavy hydrogen concentration in seawater is about 4000 ppm.)
 - Free water tritium (FWT): Tritium that exists in the form of water in living bodies
 - Organically bound tritium (OBT): Tritium that is organically bound with carbon and other molecules in living bodies



To be confirmed in the rearing test

- The tritium levels in the flounder, abalone and seaweed reared in the ALPS treated water diluted with seawater (tritium concentration of approx. 1500 Bq/L) will be analyzed and assessed* to confirm that tritium levels will reach equilibrium after a certain amount of time, and that the tritium concentration at equilibrium doesn't exceed that of the rearing environment.
 - It will also be confirmed that the tritium levels of marine organisms that have reached the tritium equilibrium will fall once they are moved to seawater only tanks .
- ※3 OBT data will be collected over 6 months and assessed for conformity with past data to confirm that OBT levels do not exceed that of the rearing environment.