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Accumulation of a Specific Nuclide by Female Common Skete (Feminam *Okamejei kenojei* spp.)

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Tokyo Electric Power Fukushima Dai-Ichi Nuclear Power Station in Fukushima-Ken, Japan was destroyed due to a magnitude 9 earthquakes in the ocean north east of the Island of Honshu in Japan that produced a historical Tsunami on 11 March 2011. Due to a nuclear meltdown, hydrogen explosions damaged buildings housing reactors, cooling water from the reactor core was contaminated and huge amounts of radioisotopes were released into the atmosphere and marine waters. Currently, offshore fishing in Fukushima-Ken, Japan is prohibited because the majority of fish still contain excessive amounts of radioisotopes. Tokyo University of Marine Science and Technology measured the amounts of radioisotopes found in fishes offshore of Iwaki-shi, located south of the destroyed Nuclear Power Station in Fukushima-Ken, Japan. Some of these data indicated that feminam *Okamejei kenojei* spp. (English Name: Female Common skete; Japanese Name: KOMON KASUBE NO MESU) had a negative linear relationship between fish weight and $^{137}Cs/^{134}Cs$ ratio . Therefore, feminam *Okamejei kenojei* spp. have the ability to accumulate a specific nuclide (radioisotope). To date, ultracentrifugation and diffusion methods have been used to accumulate specific nuclides for atomic fuel. However, if we could utilize the ability of *Okamejei kenojei* spp. to accumulate a specific nuclide, we would have an additional method to obtain specific nuclides.

Key Words: Accumulation, Nuclide, *Okamejei kenojei* spp.

INTRODUCTION

Tokyo Electric Power Fukushima Dai-Ichi Nuclear Power Station in Futaba-Gun, Fukushima-Ken, Japan was destroyed due to a magnitude 9 earthquake in the ocean northeast of the Island of Honshu in Japan that produced a historical Tsunami on 11 March 2011. Due to a nuclear meltdown, hydrogen explosions damaged buildings housing reactors, cooling water from the reactor core was contaminated and huge amounts of radioisotopes were released into the atmosphere and marine waters. Currently, offshore fishing in Fukushima-ken, Japan is prohibited because the majority of fish still contain amounts of radioisotopes that exceed the Japanese Standard Value[1-4]. Therefore, the Japanese Government has measured the amounts of radioisotopes in fish offshore the neighbouring regions around the destroyed reactor and across the Exclusive Economic Zone (EEZ) of Japan. Some of these measured data are frequently released to the public on a website by the Japanese Government. However, these data do not contain individual fish data, including fish weight, sex, length and collecting detail position. However, Tokyo University of Marine Science and Technology independently measured the amounts of radioisotopes found in fish offshore of Iwaki-Shi, located south of the destroyed Nuclear Power Station in Fukushima-Ken, Japan in September and November 2012. The data collected by Tokyo University of Marine Science and Technology included detailed individual fish data, such as fish weight, sex, length and collecting detail position. Using the original data collected in September and November 2012, a negative linear relationship between fish weight and $^{137}Cs/^{134}Cs$ ratio was found in feminam *Okamejei kenojei* spp.

EXPERIMENTAL

Okamejei kenojei spp. (English Name: Common skete; Japanese Name: Komon Kasube) fish were caught by Trawl Net on 19 September 2012 and 22 Novemeber 2012 offshore of Iwaki-Shi, Fukushima-Ken, Japan. The edible parts of the fish were minced and packed into a 100 mL U-8 container. The concentrations of radioisotopes ^{134}Cs and ^{137}Cs in the fish meat were measured using a germanium semiconductor detector (SEIKO EG & G, model GEM20-70) by IDEA Consultants Inc., Tokyo, Japan[5].

RESULTS AND DISCUSSION

Japanese Government revealed that fallout amounts of ^{134}Cs and ^{137}Cs radioisotopes in Futaba-Gun, Fukushima-Ken, Japan in March 2011 were 3100000 MBq/km^2 and 3340000 MBq/km^2, respectively, due to the destruction of the Tokyo Electric Power Fukushima Dai-Ichi Nuclear Power Station in Futaba-Gun, Fukushima-Ken, Japan on 11 March 2011[6]. The half-life of ^{134}Cs is 2.0648 years (754.17 days) and the half-life of ^{137}Cs is 30.1671 years (11018.5 days). Therefore, if contaminated fish directly accumulated ^{134}Cs and ^{137}Cs without any physiological effects or environmental factors, the ^{137}Cs/^{134}Cs ratio in the bodies of all fish offshore of Fukushima-Ken should be similar to the ratios in Table-1 and Fig. 1. The ^{137}Cs/^{134}Cs ratio in all contaminated fish offshore of Fukushima-Ken on 19 September 2012 should be 1.73727244219614 and the ^{137}Cs/^{134}Cs ratio on 22 November 2012 should be 1.8351234381334. However, the measured ^{137}Cs/^{134}Cs ratio in contaminated fish was very different, indicating variation in the ^{137}Cs/^{134}Cs ratio in fish.

Okamejei kenojei spp. was the major fish species offshore of Fukushima-Ken, Japan, in September and November 2012. The concentrations of ^{134}Cs and ^{137}Cs and the $^{137/134}$Cs ratio of *Okamejei kenojei* spp. offshore of Iwaki-Shi, Fukushima-Ken is shown in Table-2 for September 2012 and Table-3 for November 2012.

Okamejei kenojei spp. body weight *vs.* concentrations of ^{134}Cs, ^{137}Cs and the ^{137}Cs/^{134}Cs ratio is shown in Fig. 2 for September 2012 and Fig. 5 for November 2012. However, no correlations were found between fish body weight and concentrations of ^{134}Cs, ^{137}Cs and the ^{137}Cs/^{134}Cs ratio.

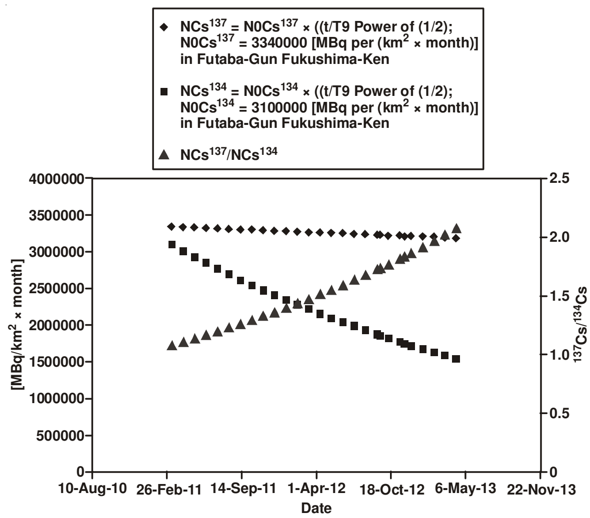

Fig. 1. Ratios ^{137}Cs/^{134}Cs from 11-March-2011 in Futaba-Gun, Fukushima-ken, Japan

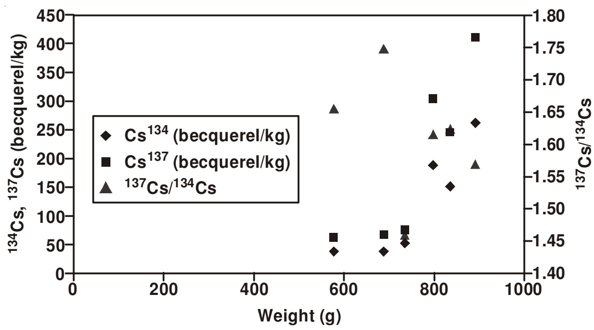

Fig. 2. *Okamejei kenojei* spp. [Common Skete spp.] fish body weight *vs.* concentration of ^{134}Cs, ^{137}Cs and ^{137}Cs/^{134}Cs in September 2012

TABLE-1
RATIOS ^{137}Cs/^{134}Cs FROM 11-MARCH-2011 IN FUTABA-GUN, FUKUSHIMA-KEN, JAPAN

1	2	3	4	5	6	7	8	9	10	11
11-Mar-11	–	11018.5	–	–	3340000	754.17	–	–	3100000	1.077419355
11-Apr-11	31	11018.5	0.002813450	0.998051765	3333492.896	754.17	0.041104791	0.971910390	3012922.210	1.106398594
11-May-11	61	11018.5	0.005536144	0.996169991	3327207.769	754.17	0.080883620	0.945478384	2930982.989	1.135184947
11-Jun-11	92	11018.5	0.008349594	0.994229218	3320725.588	754.17	0.121988411	0.918920265	2848652.821	1.165717901
11-Jul-11	122	11018.5	0.011072288	0.992354651	3314464.533	754.17	0.161767241	0.893929374	2771181.060	1.196047628
11-Aug-11	153	11018.5	0.013885738	0.990421311	3308007.178	754.17	0.202872032	0.868819247	2693339.665	1.228217599
11-Sep-11	184	11018.5	0.016699188	0.988491738	3301562.404	754.17	0.243976822	0.844414453	2617684.805	1.261252843
11-Oct-11	214	11018.5	0.019421881	0.986627988	3295337.480	754.17	0.283755652	0.821449817	2546494.434	1.294068205
11-Nov-11	245	11018.5	0.022235331	0.984705805	3288917.389	754.17	0.324860443	0.798375613	2474964.399	1.328874626
11-Dec-11	275	11018.5	0.024958025	0.982849194	3282716.308	754.17	0.364639272	0.776663046	2407655.441	1.363449375
11-Jan-12	306	11018.5	0.027771475	0.980934373	3276320.806	754.17	0.405744063	0.754846884	2340025.340	1.400121935
11-Feb-12	337	11018.5	0.030584925	0.979023283	3269937.764	754.17	0.446848854	0.733643529	2274294.941	1.437780872
11-Mar-12	366	11018.5	0.033216863	0.977238859	3263977.789	754.17	0.485301722	0.714347657	2214477.737	1.473926667
11-Apr-12	397	11018.5	0.036030313	0.975334968	3257618.795	754.17	0.526406513	0.694281910	2152273.921	1.513570723
11-May-12	427	11018.5	0.038753006	0.973496025	3251476.725	754.17	0.566185343	0.675400268	2093740.831	1.552950908
11-Jun-12	458	11018.5	0.041566456	0.971599427	3245142.085	754.17	0.607290134	0.656428538	2034928.468	1.594720470
11-Jul-12	488	11018.5	0.044289150	0.969767527	3239023.539	754.17	0.647068963	0.638576354	1979586.697	1.636212015
11-Aug-12	519	11018.5	0.047102600	0.967878192	3232713.161	754.17	0.688173754	0.620638993	1923980.879	1.680221043
11-Sep-12	550	11018.5	0.049916050	0.965992538	3226415.077	754.17	0.729278545	0.603205486	1869937.007	1.725413778
19-Sep-12	558	11018.5	0.050642102	0.965506514	3224791.757	754.17	0.739886233	0.598786569	1856238.365	1.737272442
20-Sep-12	559	11018.5	0.050732858	0.965445778	3224588.900	754.17	0.741212194	0.598236486	1854533.106	1.738760495
11-Oct-12	580	11018.5	0.052638744	0.964171209	3220331.840	754.17	0.769057374	0.586800752	1819082.332	1.770305710
11-Nov-12	611	11018.5	0.055452194	0.962292778	3214057.877	754.17	0.810162165	0.570317748	1767985.019	1.817921443
22-Nov-12	622	11018.5	0.056450515	0.961627117	3211834.572	754.17	0.824747736	0.564580914	1750200.834	1.835123438
23-Nov-12	623	11018.5	0.056541271	0.961566626	3211632.530	754.17	0.826073697	0.564062254	1748592.988	1.836695304

1: Date; **2:** Days = t; **3:** ^{137}Cs Half Days = T; **4:** tCs^{137}/TCs^{137}; **5:** (tCs^{137}/TCs^{137}) Power of (1/2); **6:** NCs^{137} = N0Cs^{137} × ((t/T) Power of (1/2)); N0Cs^{137}=3340000 [MBq per (km^2 × month)] in Futaba-Gun Fukushima-Ken; **7:** ^{134}Cs Half Days = T; **8:** tCs^{134}/TCs^{134}; **9:** (tCs^{134}/TCs^{134}) Power of (1/2); **10:** NCs^{134} = N0Cs^{134} × ((t/T) Power of (1/2)); N0Cs^{134}=3100000 [MBq per (km^2 × month)] in Futaba-Gun Fukushima-Ken; **11:** NCs^{137}/NCs^{134}

TABLE-2
CONCENTRATION OF ^{134}Cs AND ^{137}Cs AND RATIOS $^{137/134}$Cs OF *Okamejei kenojei* spp.
IN SEPTEMBER 2012 IN OFFSHORE IWAKI-SHI, FUKUSHIMA-KEN

Sampling date	Way of sampling	Size (cm^2) (Vertical × Horizontal)	Weight (g)	Remarks	^{134}Cs (becquerel/kg)	^{137}Cs (becquerel/kg)	^{137}Cs/^{134}Cs
19-Sep-2012	Trawl (Net) [Dragneta Trawlnet]	49.0 × 34.0	797.3	Female	189	305	1.613756614
19-Sep-2012	Trawl (Net) [Dragneta Trawlnet]	41.0 × 29.0	577.3	Male	36.8	60.9	1.654891304
19-Sep-2012	Trawl (Net) [Dragneta Trawlnet]	49.0 × 34.0	891.1	Female	262	411	1.568702290
19-Sep-2012	Trawl (Net) [Dragneta Trawlnet]	42.0 × 32.0	734.5	Male	50.9	74.2	1.457760314
19-Sep-2012	Trawl (Net) [Dragneta Trawlnet]	52.5 × 35.5	835.4	Male	151	245	1.622516556
19-Sep-2012	Trawl (Net) [Dragneta Trawlnet]	44.0 × 32.0	688.2	Female	37.5	65.5	1.746666667

TABLE-3
CONCENTRATION OF ^{134}Cs AND ^{137}Cs AND ratios $^{137/134}$Cs OF *Okamejei kenojei* spp.
IN NOVEMBER 2012 IN OFFSHORE IWAKI-SHI, FUKUSHIMA-KEN

Sampling date	Way of sampling	Size (cm^2) (Vertical × Horizontal)	Weight (g)	Remarks	^{134}Cs (becquerel/kg)	^{137}Cs (becquerel/kg)	^{137}Cs/^{134}Cs
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	45.0 × 32.1	702.2	Male	36.6	66.6	0.54954955
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	56.1 × 39.5	1186.5	Female	59.2	96.2	0.615384615
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	49.5 × 35.0	980.5	Female	33.6	61.3	0.54812398
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	53.2 × 37.0	1025.9	Male	43.4	66.4	0.653614458
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	46.0 × 33.0	725.2	Female	49.9	72.8	0.68543956
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	43.7 × 32.7	742.3	Male	50.9	92.0	0.55326087
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	48.2 × 34.0	854.6	Female	50.3	79.0	0.636708861
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	43.6 × 31.0	624.0	Male	30.8	49.5	0.622222222
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	43.9 × 30.5	614.6	Female	25.3	47.5	0.532631579
22-Nov-2012	Trawl (Net) [Dragneta Trawlnet]	48.8 × 34.0	809.9	Male	26.9	47.0	0.572340426

Male *Okamejei kenojei* spp. body weight *vs.* ^{137}Cs/^{134}Cs ratio is shown in Fig. 3 for September 2012 and Fig. 6 for November 2012. However, no correlations were found between fish body weight and the ^{137}Cs/^{134}Cs ratio.

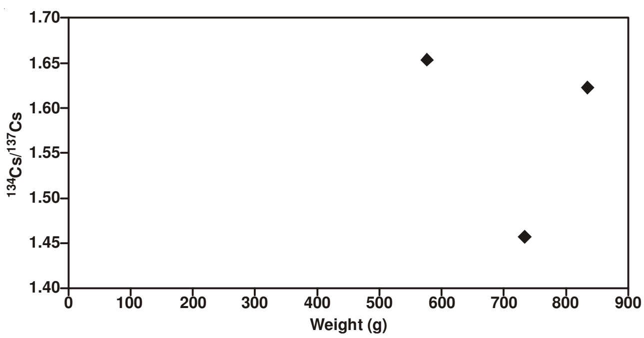

Fig. 3. Male *Okamejei kenojei* spp. [Common Skete spp.] fish body weight *vs.* ^{137}Cs/^{134}Cs in September 2012

Female *Okamejei kenojei* spp. body weight *vs.* ^{137}Cs/^{134}Cs ratio is shown in Fig. 4 for September 2012 and Fig. 7 for November 2012. A negative linear correlation between fish body weight and the ^{137}Cs/^{134}Cs ratio was found. Therefore, this result suggests that feminam *Okamejei kenojei* spp. have the ability to accumulate a specific nuclide.

Okamejei kenojei spp. have the ability to detect weak electric signals and they receive electrical information on the positions of their prey, the drift of ocean currents[7-9] and their magnetic compass headings. Radioisotopes ^{134}Cs and ^{137}Cs are β-emission nuclides and emit β-rays and γ-rays[10,11]. A β-ray is an electron beam or electric current and a γ-ray is a radio wave or electromagnetic wave of small wavelength. A major food source for *Okamejei kenojei* spp. is *Metapenaeopsis dalei* (Japanese Name: KISHI EBI)[12] and the radioisotope concentration in *Metapenaeopsis dalei* varied. The radioisotope concentration in *Metapenaeopsis dalei* depended on individual bodies

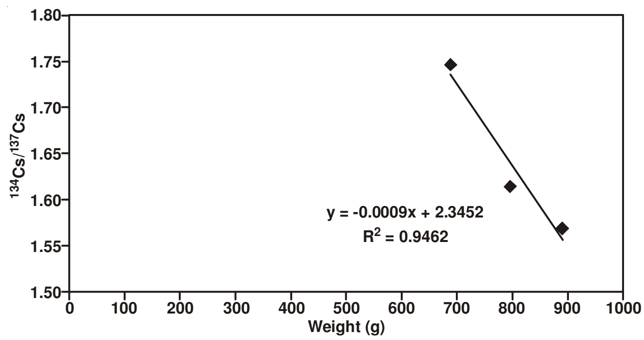

Fig. 4. Female *Okamejei kenojei* spp. [Common Skete spp.] fish body weight *vs.* ^{137}Cs/^{134}Cs in September 2012

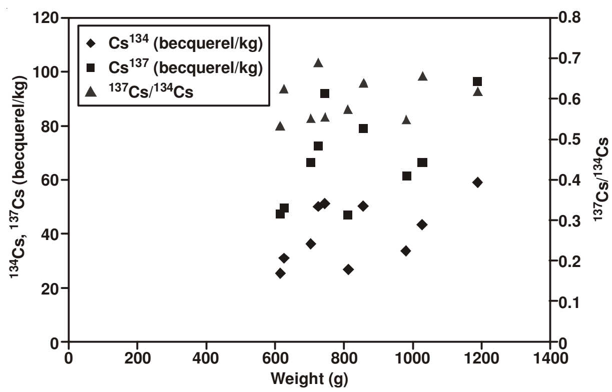

Fig. 5. *Okamejei kenojei* spp. [Common Skete spp.] fish body weight *vs.* concentration of ^{134}Cs, ^{137}Cs and ^{137}Cs/^{134}Cs in November 2012

and the average radioisotope concentration in individual bodies was not meaningful to this investigation[13,14]. If the *Metapenaeopsis dalei* radioisotope ratios changed depending on the body weight of feminam *Okamejei kenojei* spp., the negative linear correlation between *Okamejei kenojei* spp. body weight and the ^{137}Cs/^{134}Cs ratio could be explained by the ability of *Okamejei kenojei* spp. to detect weak electric signals.

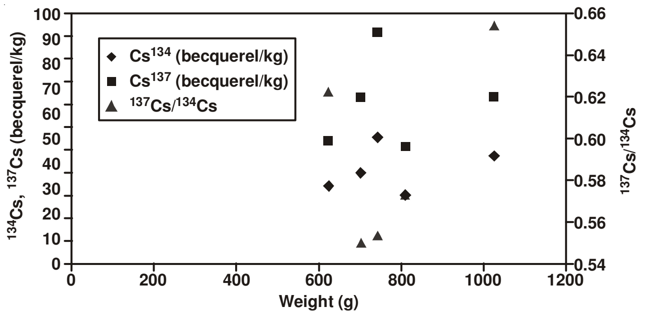

Fig. 6. Male *Okamejei kenojei* spp. [Common Skete spp.] fish body weight *vs.* $^{137}Cs/^{134}Cs$ in November 2012

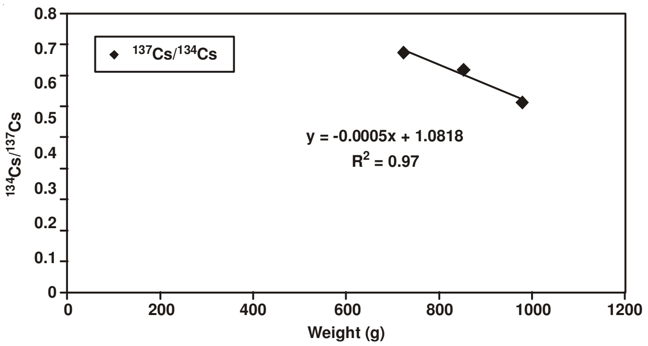

Fig. 7. Female *Okamejei kenojei* spp. [Common Skete spp.] fish body weight *vs.* $^{137}Cs/^{134}Cs$ in November 2012

Conclusion

• A negative linear correlation between feminam *Okamejei kenojei* spp. body weight and the $^{137}Cs/^{134}Cs$ ratio was identified (Fig. 4 and 7).

• The methodology in this study has the ability to detect specific β-ray emissions by feminam *Okamejei kenojei* spp. Furthermore, this methodology can be used to identify other species that accumulate specific radioisotopes.

• Physical methods such as ultracentrifugation and diffusion have been used to obtain higher concentration nuclides (*e.g.* ^{235}U). However, this study suggests that we do not need these physical methods to accumulate higher concentrations of specific radioisotopes[15].

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