academicJournals

Vol. 11(22), pp. 287-295, 30 November, 2016
DOI: 10.5897/IJPS2016.4503
Article Number: 4A74A9E61631
ISSN 1992 - 1950

http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

Some fish species in offshore Fukushima, Japan have the ability to accumulate a specific nuclide (radioisotope)

Katsura Hidemitsu[1,2,3]

[1]Coimbatore Institute of Technology (CIT), Coimbatore, Tamil Nadu 641014, India.
[2]Department of Ocean Sciences, Faculty of Marine Science, Tokyo University of Marine Science and Technology, Konan 4-Chome, Minato-Ku, Tokyo 108-8477, Japan.
[3]Institute of Product Design and Manufacturing (IPROM), Universiti Kuala Lumpur (Uni.KL), 119 Jalan 7/91, Taman Shamelin Perkasa, 3.5 Miles Cheras, 56100 Kuala Lumpur, Malaysia.

Received 1 May, 2016; Accepted 30 September, 2016

The Tokyo Electric Power Company's, Fukushima Dai-ichi nuclear power plant in Fukushima-Ken (Fukushima Prefecture), Japan, was destroyed in March 2011 by a massive magnitude 9 earthquake (centred offshore to the northeast of Honshu Island) and by the subsequent historic Tsunami of March 11, 2011. Because of the nuclear meltdown, hydrogen-explosion damage to the buildings that housed the reactors, and the contamination of the cooling water from the reactor cores, large quantities of radioisotopes were emitted into the atmosphere and adjacent seawater. The Tokyo University of Marine Science and Technology has measured radioisotope levels in fishery species off Iwaki-Shi(Iwaki City), Fukushima-Ken (located south of the former nuclear power plant); these data could be used to understand the relationship between the accumulation of specific nuclides (radioisotopes) and certain species of fish, as follows: [1] It is possible to accumulate or separate specific nuclides (134Cs and 137Cs) by combining *Sebastes cheni (Japanese rockfish; SHIROMEBARU)* and *Kareius bicoloratus* (Stone flounder; ISHIGAREI), and *Ditrema temmincki temmincki* (Surfperch; UMITANAGO) and *Cynoglossus joyneri* (Red tongue sole; AKASHITA BIRAME). [2] There are differences in 134Cs and 137Cs accumulation between adult fish and fry of *Paralichthys oli*vaceus (Bastard halibut; HIRAME). Therefore, some fish species have the ability to accumulate a specific nuclide (radioisotope). To date, ultra-centrifugation and diffusion methods have been used to accumulate specific nuclides for atomic fuel. However, if we could use the ability of some fish species to accumulate specific nuclides, we would have additional methods to concentrate nuclides.

Key Words: Nuclide, Accumulate, Fukushima, Fish.

INTRODUCTION

The Tokyo Electric Power Company's, Fukushima Dai-ichi nuclear power plant (37.4212°:N, 141.0334°:E), located in Futaba-Gun (Futaba County), Fukushima-Ken (Fukushima Prefecture), Japan, was destroyed in March

E-mail: hi@katsura.dk Tel: +81-467-54-5869. Fax: +81-467-54-1383.

Table 1. Total fish collection area on 22 to 23 November, 2012.

		Yotsukura	Yotsukura	Ena	Ena (Land Side)	
		Trawl (Net) [Dragneta Trawlnet] (HIKIAMI)	Gill Net (SASHIAMI)	Trawl (Net) [Dragneta Trawlnet] (HIKIAMI) (2 Times)	Gill Net (SASHIAMI)	
	Sampling date for weght of fishes	22-Nov-12	22 to 23 NOV-2012	22-Nov-12	22 to 23 NOV-2012	Total Fish Collecting Area in 22 to 23 NOV-2012 [m^2] = [TFCA]
Area [m^2]		9450	28900	9775	50141	98266

2011 by a massive magnitude 9 earthquake (centred offshore to the northeast of Honshu Island) and by the subsequent historic tsunami of March 11, 2011. Because of the resulting nuclear meltdown, the hydrogen-explosion damage to the buildings that housed the reactors, and the contamination of the cooling water from the reactor cores, large quantities of radioisotopes were emitted into the atmosphere and adjacent seawater. From November 22 to 23, 2012, the Tokyo University of Marine Science and Technology independently sampled radioisotope levels in fishery species off Iwaki-Shi (Iwaki City), Fukushima-Ken, just south of the former nuclear power plant. These data included detailed measurements of individual fish such as weight, sex, length, and collection site, which can be used to better understand the accumulation of radioisotopes in fishes. This report shows new insights into the relationship between the accumulation of specific nuclides (radioisotopes) by specific fish species based on this sampling after Katsura's report (Katsura, 2013a; Gerhard et al., 1998; Hellstrom and Brune, 1964; Kalmun, 1982; Murray, 1962; Wolfson, 1956) (Figure 1).

MATERIALS AND METHODS

To sample local fish, trawl (dragnet) fishing was conducted on the November 22, 2012, off Yotsukura and Ena, Iwaki-Shi, Fukushima-Ken, Japan, in a total fishing area of 9,450 and 9,775 m^2, respectively (Atkins and Warren, 1953). Gill-net fishing was conducted from November 22-23, 2012 in the same location, with a total fishing area of 28,900 and 50,141 m^2 off Yotsukura and Ena, respectively (Buscaino et al., 2009). The edible portion of sampled fish was minced and placed into 100 ml plastic containers (U-8 containers). The concentration of Cs-134 and Cs-137 radioisotopes in the fish biomass were measured by IDEA Consultants Inc. (Tokyo, Japan) using a germanium semiconductor detector (Seiko EG&G Co.Model:GEM20-70) (Inazu et al., 2011; Minatani et al., 2012).

RESULTS AND DISCUSSION

The total fish-collection area for November 22-23, 2012 as shown in Table 1 was calculated as follows (Katsura, 2013b):

$$9{,}450+28{,}900+9{,}775+50{,}141= 98{,}266\ m^2$$

Table 2 shows the following:

i) [Percentage of Total Fish Weight] = [%TFW] is the percentage that each species of fish has with respect to the total fish weight sampled.

ii) ([134Cs per Fish Species] / [Total 134Cs for All Species]) × 100

= ([134Cs] / [T134Cs]) × 100=[134Cs%]

is the percentage of 134Cs becquerel that each fish species has of the total 134Cs becquerel for all fish species (Bq is the symbol for "becquerel", an SI derived unit of radioactivity; One Bq is defined as the activity of a quantity of radioactive material in which one nucleus decays per second) (Choppin et al., 2002).

iii) ([137Cs per Fish Species]/[Total 137Cs All Species]) x 100 =([137Cs]/[T137Cs])x100=[137Cs%]

is the percentage of 137Cs becquerel that each fish species has of the total 137Cs becquerel for all fish species sampled.

iv) Tables 3 and 4 show the proportion of 134Cs and 137Cs accumulated by each fish species according to their percentage of the total fish weight in descending order, as follows:

[134Cs%]/[%TFW] × 100

[137Cs%]/[%TFW] × 100

If there was a proportional relationship between the amount of 134Cs or 137Cs Bq (that is, quantity of 134Cs or 137Cs radioactive material) in sampled fish body weight regardless of species, all percentages of 134Cs or 137Cs Bq per percentage of total fish weight should be 100% (Table 5).

Table 2. Amount of fishery resources and the total amount of cesium radioisotopes in fish bodies in offshore Fukushima-Ken, Japan in Nov. 2012.

Scientific name	Japanese Name	Weight [g]	Weight %	Weight [g]	Weight %	Weight [g]	Weight %	Weight [g]	Weight %	Weight [g]	Weight %	Each species of total fish weight [g]	[%TFW]	[134Cs]	[134Cs%]	[137Cs]	[137Cs%]
		Yotsukura				Ena		Ena (Land Side)		Ena (Offshore Side)							
		By Trawl (Net)		By Gill Net		By Trawl (Net) (2 times)		By Gill Net		By Gill Net							
Acanthopagrus schlegeli	Kurodai	2000	1.456261195	0	0	0	0	0	0	0	0	2000	0.743555235	0	0	0	0
Chelidonichthys spinosus	Houbou	0	0	1170	3.549757282	0	0	0	0	0	0	1170	0.434979812	7.015	0.057003374	10.085	0.047709706
Clupea pallasii Vakenciennes	Nishin	23	0.016747004	0	0	0	0	0	0	0	0	23	0.008550885	0	0	0	0
Cynoglossus joyneri	Akashita Birame	600	0.436878359	0	0	1810	4.815110402	300	2.284843869	0	0	2710	1.007517343	14.1	0.265384423	22.25	0.243805938
Ditrema temminkii	Umi Tanago	0	0	0	0	0	0	210	1.599390708	2960	6.171809842	3170	1.178535047	12.445	0.273994086	22.3	0.285830849
Engraulis japonica	Katakuchi Iwashi	88	0.064075493	0	0	0	0	0	0	0	0	88	0.03271643	0	0	0	0
Hexagrammos otakii	Ainame	0	0	2130	6.462378641	0	0	1060	8.073115004	1810	3.773978315	5000	1.858888088	52.19230769	1.812439544	88.01538462	1.779399929
Hexagrammos stelleri	Ezo Iso Ainame	0	0	0	0	0	0	330	2.513328256	940	1.959966639	1270	0.472157574	21.9	0.193167857	37.36666667	0.191881477
Kareius bicoloratus	Ishi Garei	0	0	750	2.275485437	920	2.447459431	0	0	0	0	1670	0.620868621	130	1.507810796	213	1.438272074
Lateolabrax japonicus	Suzuki	0	0	0	0	1300	3.458366587	0	0	0	0	1300	0.483310903	53.9	0.486652706	98.6	0.518280944
Lepidotrigla microptena Gunther	Kana Gashira	280	0.203876567	0	0	0	0	0	0	0	0	280	0.104097733	0	0	0	0
Liparis tanakai	Kusauo	310	0.225720485	0	0	0	0	0	0	0	0	310	0.115251061	0	0	0	0
Mlicrostomus achn	Baba Garei	0	0	2600	7.888349515	0	0	0	0	850	1.772310259	3450	1.28263278	107.8333333	2.583801526	187.3333333	2.61323899
Mustelus manazo	Hoshi Zame	50500	36.77059517	0	0	11100	29.52913009	0	0	0	0	61600	22.90150124	0	0	0	0
Nibea mitsukurii	Nibe	0	0	0	0		0	1140	8.682406702	1040	2.168473728	2180	0.810475206	16.66	0.252242647	29.9	0.263555847
Okamejei kenojei	Komon Kasube (Tsumari Kasube)	56900	41.430631	1390	4.21723301	13480	35.86060122	0	0	0	0	71770	26.68247961	98.95	49.32257817	173.95	50.47918713
Oncorhynchus keta	Sake	0	0	0	0	0	0	0	0	500	1.042535446	500	0.185888809	0	0	0	0
Oplegnathus punctatus	Ishigaki Dai	0	0	640	1.941747573	0	0	0	0	0	0	640	0.237937675	0	0	0	0
Pagrus major	Madai	0	0	0	0	0	0	0	0	290	0.604670559	290	0.107815509	0	0	0	0
Pagrus major (Fry)	Madai (Chigyo)	322	0.234458052	0	0	0	0	0	0	0	0	322	0.119712393	0	0	0	0
Paralichthys olivaceus	Hirame	1600	1.165008956	6280	19.05339806	5340	14.20590583	0	0	2500	5.212677231	15720	5.844344147	14.98	1.635503132	25.74727273	1.636548003
Paralichthys olivaceus (Fry)	Hirame (Chigyo)	34	0.02475644	0	0	0	0	0	0	0	0	34	0.012640439	0	0	0	0
Platycephalus sp.2	Magochi	580	0.422315747	0	0	450	1.197126895	0	0	0	0	1030	0.382930946	0	0	0	0
Platycephalus sp.2 (fry)	Magochi (Chigyo)	10	0.007281306	0	0	0	0	0	0	0	0	10	0.003717776	0	0	0	0
Scyliorhinus torazame	Tora Zame	5200	3.786279107	250	0.758495146	3190	8.486299548	0	0	0	0	8640	3.212158615	27.00583333	1.620534759	47.58	1.662199524
Sebastes cheni	Shiro Mebaru	0	0	200	0.606796117	0	0	8890	67.70753998	27760	57.88156797	36850	13.7000052	129.0857143	33.03715945	213.2857143	31.77929316
Sebastes inermis	Aka Mebaru	0	0	0	0	0	0	0	0	1020	2.12677231	1020	0.37921317	96.175	0.681317261	160.15	0.660498884
Sebastes pachycephalus pachycephalus	Murasoi	0	0	0	0	0	0	330	2.513328256	1760	3.669724771	2090	0.777015221	40.175	0.583161973	70.65	0.597039996
Sebastes vulpes	Kitsune Mebaru	0	0	1260	3.822815534	0	0	590	4.493526276	6530	13.61551293	8380	3.115496435	32.4	1.885714992	59.068	2.001433931
Sebastiscus marmoratus	Kasago	0	0	0	0	0	0	280	2.132520944	0	0	280	0.104097733	38.3	0.074480714	67.1	0.075967096
Seriola quinqueradiata	Buri	0	0	1670	5.066747573	0	0	0	0	0	0	1670	0.620868621	4.03	0.046742135	5.09	0.034369976
Takifugu poecilonotus	Komon Fugu	70	0.050969142	0	0	0	0	0	0	0	0	70	0.026024433	0	0	0	0
Takifugu rubipes	Tora Fugu	1610	1.172290262	0	0	0	0	0	0	0	0	1610	0.598561964	83.9	0.938155571	135	0.878829483
Takifugu snyderi	Shousai Fugu	16200	11.79571568	0	0	0	0	0	0	0	0	16200	6.022797404	0	0	0	0
Takifugu stictonotus	Goma Fugu	120	0.087375672	0	0	0	0	0	0	0	0	120	0.044613314	0	0	0	0
Trachurus japonicus	Ma Aji	887	0.64585184	0	0	0	0	0	0	0	0	887	0.329766747	0	0	0	0

Table 2. Contd.

Triakis scyllium	Dochi Zame	0	0	14620	44.35679612	0	0	0	0	0	0	14620	5.435388768	27.00583333	2.742154881	47.58	2.812657065
Zeus faber Linnaeus	Matou Dai	4	0.002912522	0	0	0	0	0	0	0	0	4	0.00148711	0	0	0	0
	Total Fish Weight	137338	100	32960	100	37590	100	13130	100	47960	100	268978					

The percentage that each species of fish has with respect to the total fish sampled = [%TFW]; (134Cs per Fish Species) [becquerel]/[kg] = [134Cs]; ([134Cs per Fish Species]/[Total 134Cs for All Species])x100 [%] = [134Cs%]; (137Cs per Fish Species) [becquerel]/[kg] = [137Cs]; ([137Cs per Fish Species]/[Total 134Cs for All Species])x100 [%] = [137Cs%].

However, these percentages vary depending on fish species from 0 to 242.855% for 134Cs and from 0 to 231.9655554% for 137Cs.

The values of

[134Cs%] / [%TFW] × 100

and

[137Cs%] / [%TFW] × 100

for the following species are 0%: *Acanthopagrus schlegeli* (Japanese black seabream; KURODAI), *Clupea pallasii Vakenciennes* (Pacific herring; NISHIN), *Engraulis japonica* (Japanese anchovy; KATAKUCHI IWASHI), *Lepidotrigla microptena Gunther* (Gurnard, Sea-robin; KANAGASHIRA), *Liparis tanakai* (English Name: Not-Available=N/A; KUSAUO), *Mustelus manazo* (Starspotted smooth hound; HOSHI-ZAME), *Oncorhynchus keta* (Chum salmon, Salmon; SAKE), *Oplegnathus punctatus* (Spotted Knifejaw; ISHIGAKIDAI), *Pagrus major* (Red seabream; MADAI (SEIGYO)), *P. major (fry)* (Redseabream (Fry); MADAI (CHIGYO)), *Paralichthys olivaceus (fry)* (Bastard halibut (Fry); HIRAME (CHIGYO)), *Platycephalus sp.* (Flathead; MAGOCHI), *Platycephalus sp. (fry)* (Flathead (Fry); MAGOCHI (CHIGYO)), *Takifugu poecilonotus* (Pufferfish; Name: KOMON FUGU), *Takifugu snyderi* (Globefish, Blowfish, Puffer; SHOUSAI FUGU), *Takifugu stictonotus* (Globefish, Blowfish, Puffer; GOMA FUGU), *Trachurus japonicas* (Japanese jack mackerel. Japanese horse mackerel, Japanese scad; MAAJI) and *Zeus faber Linnaeus* (John dory; MATOU DAI). These findings indicate that these fish species do not have the ability to accumulate 134Cs and 137Cs radioisotopes. In other words, these species eliminate 134Cs and 137Cs radioisotopes from their bodies.

iv) Tables 3 and 4 show the differences in the 134Cs and 137Cs accumulation ratio depending on fish species; some species accumulate more 134Cs whereas other species accumulate more 137Cs.

Thus, the order values of

([134Cs%] / [%TFW]) × 100% and ([137Cs%] / [%TFW]) × 100%

are reversed. In detail, it has the following features.

a) The order value of

([137Cs%] / [%TFW]) × 100%

of *Sebastes cheni* (Japanese rockfish, Japanese sea perch; SHIRO MEBARU) is higher than that of *Kareius bicoloratus* (Stone flounder; ISHIGAREI). However, the order value of ([134Cs%] / [%TFW]) × 100% of *Kareius bicoloratus* is higher than that of *Sebastes cheni*. Therefore, it may be possible to use *Sebastes cheni* and *Kareius bicoloratus* for the separation or accumulation of nuclide 134CS and 137Cs. *Sebastes cheni* shows

((231.965554-231.6548179) / 231.6548179) × 100=0.13413755 Weight%

higher accumulation than *Kareius bicoloratus* for 137Cs.

However, *Kareius bicoloratus* shows

((242.85505-241.14706) / 241.14706) × 100=0.708277347 Weight%

higher accumulation than *Sebastes cheni* for 134Cs.

Therefore, it may be possible to use *Sebastes cheni* and *Kareius bicoloratus* for the accumulation or separation for specific nuclides 134Cs and 137Cs.

b) The order value of

([137Cs%] / [%TFW]) × 100%

of *Ditrema temminkii* (Surfperch; Japanese Name: UMITANAGO) is higher than that of *Cynoglossus joyneri* (Red tongue sole; AKASHITA BIRAME) (Figure 4) and the order value of:

Table 3. The order value of ([134Cs%]/[%TFW])x100%.

Number (Order value of the right is less)	([134Cs%]/[%TFW%]) x100 [%]	Scientific Name	Species Japanese Name
1	0	*Acanthopagrus schlegeli*	Kurodai
2	0	*Clupea pallasii Vakenciennes*	Nishin
3	0	*Engraulis japonica*	Katakuchi Iwashi
4	0	*Lepidotrigla microptena Gunther*	Kana Gashira
5	0	*Liparis tanakai*	Kusauo
6	0	*Mustelus manazo*	Hoshi Zame
7	0	*Oncorhynchus keta*	Sake
8	0	*Oplegnathus punctatus*	Ishigaki Dai
9	0	*Pagrus major*	Madai
10	0	*Pagrus major (Fry)*	Madai (Chigyo)
11	0	*Paralichthys olivaceus (Fry)*	Hirame (Chigyo)
12	0	*Platycephalus sp.2*	Magochi
13	0	*Platycephalus sp.2 (fry)*	Magochi (Chigyo)
14	0	*Takifugu poecilonotus*	Komon Fugu
15	0	*Takifugu snyderi*	Shousai Fugu
16	0	*Takifugu stictonotus*	Goma Fugu
17	0	*Trachurus japonicus*	Ma Aji
18	0	*Zeus faber Linnaeus*	Matou Dai
19	7.5285065	*Seriola quinqueradiata*	Buri
20	13.104832	*Chelidonichthys spinosus*	Houbou
21	23.248701	*Ditrema temminkii*	Umi Tanago
22	26.340432	*Cynoglossus joyneri*	Akashita Birame
23	27.984374	*Paralichthys olivaceus*	Hirame
24	31.122809	*Nibea mitsukurii*	Nibe
25	40.911735	*Hexagrammos stelleri*	Ezo Iso Ainame
26	50.450023	*Scyliorhinus torazame*	Tora Zame
27	50.450023	*Triakis scyllium*	Dochi Zame
28	60.526951	*Sebastes vulpes*	Kitsune Mebaru
29	71.548834	*Sebastiscus marmoratus*	Kasago
30	75.051551	*Sebastes pachycephalus pachycephalus*	Murasoi
31	97.501273	*Hexagrammos otakii*	Ainame
32	100.69144	*Lateolabrax japonicus*	Suzuki
33	156.73491	*Takifugu rubipes*	Tora Fugu
34	179.66603	*Sebastes inermis*	Aka Mebaru
35	184.85005	*Okamejei kenojei*	Komon Kasube
36	201.44515	*Mlicrostomus achn*	Baba Garei
37	241.14706	*Sebastes cheni*	Shiro Mebaru
38	242.85505	*Kareius bicoloratus*	Ishi Garei

([134Cs%] / [%TFW]) x 100%

of *Cynoglossus joyneri* is higher than that of *Ditrema temminkii.* Therefore, it may be possible to use *Ditrema temminkii* and *Cynoglossus joyneri* for the separation or accumulation of nuclide 134CS and 137Cs. *Ditrema temminkii* shows

((24.2530309-24.19868403) / 24.19868403) × 100=0.224719079 Weight%

higher accumulation than *Cynoglossus joyneri* for 137Cs. However, *Cynoglossus joyneri* shows

((26.340432-23.248701) / 23.278701) × 100=13.29851074 Weight%

higher accumulation than *Ditrema temminkii* for 134Cs. Therefore, it may be possible to use *Ditrema temminkii* and *Cynoglossus joyneri* for the accumulation or

Table 4. The order value of ([137Cs%]/[%TFW])x100%.

Number (Order value of the right is less)	([137Cs%]/[%TFW%]) x 100 [%]	Scientific Name	Species Japanese Name
1	0	*Acanthopagrus schlegeli*	Kurodai
2	0	*Clupea pallasii Vakenciennes*	Nishin
3	0	*Engraulis japonica*	Katakuchi Iwashi
4	0	*Lepidotrigla microptena* Gunther	Kana Gashira
5	0	*Liparis tanakai*	Kusauo
6	0	*Mustelus manazo*	Hoshi Zame
7	0	*Oncorhynchus keta*	Sake
8	0	*Oplegnathus punctatus*	Ishigaki Dai
9	0	*Pagrus major*	Madai
10	0	*Pagrus major (Fry)*	Madai (Chigyo)
11	0	*Paralichthys olivaceus (Fry)*	Hirame (Chigyo)
12	0	*Platycephalus sp.2*	Magochi
13	0	*Platycephalus sp.2 (fry)*	Makochi (Chigyo)
14	0	*Takifugu poecilonotus*	Komon Fugu
15	0	*Takifugu snyderi*	Shousai Fugu
16	0	*Takifugu stictonotus*	Goma Fugu
17	0	*Trachurus japonicus*	Ma Aji
18	0	*Zeus faber Linnaeus*	Matou Dai
19	5.53578884	*Seriola quinqueradiata*	Buri
20	10.96825746	*Chelidonichthys spinosus*	Houbou
21	24.19868403	*Cynoglossus joyneri*	Akashita Birame
22	24.25306309	*Ditrema temminkii*	Umi Tanago
23	28.00225246	*Paralichthys olivaceus*	Hirame
24	32.51868101	*Nibea mitsukurii*	Nibe
25	40.63928808	*Hexagrammos stelleri*	Ezo Iso Ainame
26	51.74711847	*Triakis scyllium*	Dochi Zame
27	51.74711847	*Scyliorhinus torazame*	Tora Zame
28	64.2412525	*Sebastes vulpes*	Kitsune Mebaru
29	72.97670554	*Sebastiscus marmoratus*	Kasago
30	76.83761917	*Sebastes pachycephalus pachycephalus*	Murasoi
31	95.72388683	*Hexagrammos otakii*	Ainame
32	107.2355166	*Lateolabrax japonicus*	Suzuki
33	146.8234761	*Takifugu rubipes*	Tora Fugu
34	174.1761459	*Sebastes inermis*	Aka Mebaru
35	189.1847679	*Okamejei kenojei*	Komon Kasube
36	203.7402311	*Mlicrostomus achn*	Baba Garei
37	231.6548179	*Kareius bicoloratus*	Ishi Garei
38	231.9655554	*Sebastes cheni*	Shiro Mebaru

separation of specific nuclides 134Cs and 137Cs.

v) Additionally, Tables 3 and 4 show accumulation ratio differences between adult fish and fry of the same species.

a) *Pagrus major* (Adult Fish) (Red seabream (Adult Fish); MADAI (SEIGYO)), *Pagrus major* (Fry) (Red seabream (Fry); MADAI (CHIGYO)), *Platycephalus* sp. (Adult Fish) (Flathead (Adult Fish); MAGOCHI (SEIGYO)) and *Platycephalus* sp.(fry) (Flathead (Fry); MAGOCHI (CHIGYO)) do not have the ability to accumulate both 134Cs and 137Cs. Additionally, there do not appear to be any differences between adult fish and fry for the accumulation 134Cs and 137Cs.

b) *Paralichthys olivaceus* (Adult Fish) (Bastard halibut (Adult Fish); HIRAME (SEIGYO)) has the ability to accumulate both134Cs and 137Cs; however, *Paralichthys*

Table 5. Total grand fish weight % [%TFW].

Number (Order value of the right is less)	Total Fish Weight %=[%TFW]	Scientific Name	Species Japanese Name
1	0.0014871	*Zeus faber* Linnaeus	Matou Dai
2	0.0037178	*Platycephalus sp.2 (fry)*	Makochi (Chigyo)
3	0.0085509	*Clupea pallasii Vakenciennes*	Nishin
4	0.0126404	*Paralichthys olivaceus (Fry)*	Hirame (Chigyo)
5	0.0260244	*Takifugu poecilonotus*	Komon Fugu
6	0.0327164	*Engraulis japonica*	Katakuchi Iwashi
7	0.0446133	*Takifugu stictonotus*	Goma Fugu
8	0.1040977	*Lepidotrigla microptena* Gunther	Kana Gashira
9	0.1040977	*Sebastiscus marmoratus*	Kasago
10	0.1078155	*Pagrus major*	Madai
11	0.1152511	*Liparis tanakai*	Kusauo
12	0.1197124	*Pagrus major (Fry)*	Madai (Chigyo)
13	0.1858888	*Oncorhynchus keta*	Sake
14	0.2379377	*Oplegnathus punctatus*	Ishigaki Dai
15	0.3297667	*Trachurus japonicus*	Ma Aji
16	0.3792132	*Sebastes inermis*	Aka Mebaru
17	0.3829309	*Platycephalus sp.2*	Magochi
18	0.4349798	*Chelidonichthys spinosus*	Houbou
19	0.4721576	*Hexagrammos stelleri*	Ezo Iso Ainame
20	0.4833109	*Lateolabrax japonicus*	Suzuki
21	0.598562	*Takifugu rubipes*	Tora Fugu
22	0.6208686	*Kareius bicoloratus*	Ishi Garei
23	0.6208686	*Seriola quinqueradiata*	Buri
24	0.7435552	*Acanthopagrus schlegeli*	Kurodai
25	0.7770152	*Sebastes pachycephalus pachycephalus*	Murasoi
26	0.8104752	*Nibea mitsukurii*	Nibe
27	1.0075173	*Cynoglossus joyneri*	Akashita Birame
28	1.178535	*Ditrema temminkii*	Umi Tanago
29	1.2826328	*Mlicrostomus achn*	Baba Garei
30	1.8588881	*Hexagrammos otakii*	Ainame
31	3.1154964	*Sebastes vulpes*	Kitsune Mebaru
32	3.2121586	*Scyliorhinus torazame*	Tora Zame
33	5.4353888	*Triakis scyllium*	Dochi Zame
34	5.8443441	*Paralichthys olivaceus*	Hirame
35	6.0227974	*Takifugu snyderi*	Shousai Fugu
36	13.700005	*Sebastes cheni*	Shiro Mebaru
37	22.901501	*Mustelus manazo*	Hoshi Zame
38	26.68248	*Okamejei kenojei*	Komon Kasube

Each species of fish has how much weight percent of total fish weight in this sampling in offshore Fukushima-ken, Japan in November 2012.

olivaceus (Fry) (Bastard halibut (Fry); HIRAME (CHIGYO)) does not have ability to accumulate both 134Cs and 137Cs. There are differences between adult fish and fry of *Paralichthys olivaceus* for the accumulation of 134Cs and 137Cs.

vi) It is currently known that specific fish species have the ability to accumulate specific elements, ions and molecules (Thompson et al., 1972). However, the accumulation of specific radioisotopes had not been reported until this and Katsura's research article (Katsura, 2013a). The disaster at Fukushima on March 11, 2011 provides the opportunity to gain new insight into the accumulation of specific radioisotopes by fishes. We must discover the theoretical reasons for these phenomena in order to use fishes as new methods for atomic fuel production and clean-up of specific radioisotope contamination.

Figure 1. Okamejei konojei.

Figure 2. *Sebastes cheni*.

Conclusion

1) This finding indicates that the following fishes do not have the ability to accumulate the 134Cs and 137Cs radioisotopes: *Acanthopagrus schlegeli* (Japanese black seabream; KURODAI), *Clupea pallasii Vakenciennes* (Pacific herring; NISHIN), *Engraulis japonica* (Japanese anchovy; KATAKUCHI IWASHI), *Lepidotrigla microptena Gunther* (Gurnard, Sea-robin; KANAGASHIRA), *Liparis tanakai* (English Name: Not Available=N/A; KUSAUO), *Mustelus manazo* (Starspotted smooth hound; HOSHIZAME), *Oncorhynchus keta* (Chum salmon, Salmon; SAKE), *Oplegnathus punctatus* (Spotted Knifejaw; ISHIGAKI DAI), *Pagrus major* (Red seabream; MADAI), *Pagrus major (Fry)* (Red seabream (Fry); MADAI (CHIGYO)), *Paralichthys olivaceus (Fry)* (Bastard halibut (Fry); HIRAME (CHIGYO)), *Platycephalus sp.* (Flathead; MAGOCHI), *Platycephalus sp. (fry)* (Flathead (Fry); MAGOCHI (CHIGYO)), *Takifugu poecilonotus* (Pufferfish; KOMON-FUGU), *Takifugu snyderi* (Globefish, Blowfish, Puffer; SHOUSAI-FUGU), *Takifugu stictonotus* (Globefish, Blowfish, Puffer; GOMA-FUGU), *Trachurus-japonicas* (Japanese jack mackerel. Japanese horse mackerel, Japanese scad; MAAJI) and *Zeus faber* Linnaeus (John-dory; MATOUDAI). Several fish species are able to eliminate 134Cs and 137Cs radioisotopes.

2) It is possible to accumulate or separate specific radioisotopes (134Cs or 137Cs) by combining the following fish species: *Sebastes cheni* (Japanese rockfish, Japanese sea perch; SHIRO-MEBARU) (Figure 2) and *Kareius bicoloratus* (Stone flounder; ISHIGAREI) (Figure 3); and *Ditrema temminkii* (Surfperch; UMITANAGO) (Figure 5) and *Cynoglossus joyneri* (Red tongue sole; AKASHITA BIRAME) (Figure 4).

3) Neither *Pagrus major* (Red seabream; MADAI) nor *Platycephalus* sp. (Flathead; MAGOCHI) adult fish and fry accumulated 134Cs and 137Cs. There were differences in the accumulation of 134Cs and 137Cs between adult fish and fry of *Paralichthys olivaceus* (Bastard halibut; HIRAME).

Figure 3. *Kareius bicoloratus.*

Figure 4. *Cynoglossus jpyneri*

Figure 5. *Ditrema temminkii.*

4) Physical methods such as ultra-centrifugation and diffusion have been used to obtain high concentrations of nuclides (e.g., 235 U). This study suggests that physical methods are not required to accumulate high concentrations of specific radioisotopes.

Conflict of interests

The author has not declared any conflict of interest.

ACKNOWLEDGEMENTS

The author is grateful to Ms. Harriet Kim Anh Rodis, Graphic Artist in Angeles City, Philippines; Dr. Darulihsan Abdul Hamid, Associated Professor, Program Director for MJHEP, Institute of Product Design and Manufacturing (IPROM), Universiti Kuala Lumpur (UniKL); Dr. Adnan Bin Ibrahim, Associated Professor, Deputy Dean, IPROM, UniKL; Dr. Mohd Razif Idris, Associated Professor, Dean, IPROM, UniKL; Dr. Ahmad Zakaria, Professor, IPROM, UniKL; Ms. Ariki Mizuki, Ms. Gorai Myu, Ms. Henmi Chikako, Mr. Kase Ryota, Mr. Nakagawa Takuro and Mr. Myouse Hiroshi, undergraduate students at the Tokyo University of Marine Science and Technology (TUMST); Ms. Shimomura Yukiko, Mr. Hasegawa Kouhei, and Mr. Watanabe Hayato, graduate students at TUMST; Ph.D. Candidate Girault Mathias and Ph.D. Candidate Matsumoto Akira at TUMST; Mr. Sato Katsuhiro and Ms. Yoshizaki Kae, Research Scientists, TUMST; Ms. Honda Tomoko, Secretary to Professor Arakawa Hisayuki, TUMST; Dr. Wakabayashi Kaori, Doctoral Research Scientist, TUMST; Dr. Norman Chris, Adjunct Professor, TUMST; Dr. Akiyama Seiji, Assistant Professor, TUMST; Dr. Uchida Keiichi, Assistant Professor, TUMST; Dr. Arakawa Hisayuki, Professor, TUMST and Dr. Morinaga Tsutomu, Emeritus Professor TUMST and Ms. Katsura Sakie, Former Director General of the Nursing Department at Saiseikai Kanagawa-Ken Hospital by the Social Welfare Organization Saiseikai Imperial Gift Foundation Inc. in Japan for assisting with this study. This study was supported by the Research Trust Fund for fiscal year 2012 of the Ministry of the Environment, Japan for “Study of the diffusion process of radioisotope materials from the destroyed nuclear power plant in offshore ecosystems in Fukushima-Ken, Japan [HEISEI24NENDO KANKYOUSHOU SOUGOU KENKYUU SUISHINHI]”.

REFERENCES

Atkins WRG, Warren FJ (1953). The preservation of fishing nets, trawl twines, and fiber ropes for use in sea water. J. Mar. Biol. Assoc. UK. 31:509-513.

Buscaino G, Buffa G, Sara G, Bellante A, Tonello AJ Jr, Hardt FAS, Cremer MJ, Bonanno A, Cuttitta A, Mazzola S (2009). Pinger affects fish catch efficiency and damage to bottom gill nets related to bottlenose dolphins. Fish Sci. (Tokyo, Japan). 75(3):537-544.

Choppin GR, Liljenzin JO, Rydberg J (2002). Radiochemistry and Nuclear Chemistry, 3rd Ed., Butterworth-Heinemann (ISBN 978-0-7506-7463-8). 4(13).

Gerhard VDE, Stephen S, Leonel G, Ruben B, Kirsty G (1998). Electric fish measure distance in the dark. Nature 395:890-894.

Hellstrom S, Brune D (1964). Determination of the absolute disintegration rate of 137Cs sources by the tracer method. Nukleonik 6(4):174-178.

Inazu T, Tsunoda A, Ohnishi S, Matsubara Y (2011). Determination of radioactive substances in foods by Ge semiconductor detector. Kenkyu Hokoku - Kagawa-ken Sangyo Gijutsu Senta 12:67-68.

Katsura H (2013a). Accumulation of a specific nuclide by Female Common skete (Feminam Okamejei kenojei spp.). Asian J. Chem. 25(13):7613-7616.

Katsura H (2013b). The Total Quantity of Caesium Radioisotopes in Fish in the Fukushima-Ken Exclusive Economic Zone, Japan, in November 2012. Sci. Res. Essays. 8(26):1252-1257.

Kalmun ADJ (1982). Electric and Magnetic Field Detection in Elasmobranch Fishes. Science 218(26):916-918.

Minatani T, Nagai H, Nakamura M, Otsuka K, Sakai Y (2012). Radioactive cesium analysis in radiation-tainted beef by gamma-ray spectrometry with germanium semiconductor detector. Shokuhin eiseigaku zasshi. J. Food Hyg. Soc. Jpn. 53(4):177-82.

Murray RW (1962). The Response of the Ampullae of Lorenaini of Elasmobranchs to Electrical Stimulation. J. Exp. Biol. 39:119-128.

Thompson SE, Burton CA, Quinn DJ, Ng YC (1972). Concentration factors of chemical elements in edible aquatic organisms. California Univ., Livermore. Lawrence Livermore Lab. UCRL-50564 Rev.1.

Wolfson JL (1956). High-energy forbidden b-ray transitions from cesium-134 cobalt-60, scandium-46, and mercury-203. Can. J. Phys. 34:256-264.