Elements in Gonad of the Sea Urchin *Strongylocentrotus nudus*

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As one of serial studies on the variation of elemental concentrations in marine organisms, major elements (Ca, K, Mg, Na, P) and trace elements (Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Sr and Zn) in 263 specimens of gonad of the sea urchin *Strongylocentrotus nudus* were determined by inductively coupled plasma atomic emission spectrometry.

The differences of the elemental concentrations in gonad were not significant among three sampling years of 1984, 1985 and 1986, although annual differences of gonad indexes were observed. Seasonal variation in the elemental concentrations was observed on magnesium, sodium, phosphorus and zinc. Furthermore, magnesium, phosphorus and zinc indicated clear differences by sex. For example, the concentration of zinc in ovary was several times higher than that in testis. On the contrary, the concentrations of magnesium and phosphorus in testis were higher than those in ovary.

It is well known that elemental concentrations in marine organisms are affected by biological and environmental factors.^{1,2} The relationship between elemental concentrations and influencing factors has been examined for many species of marine organisms.³⁻⁶ However, hitherto, little information was reported on the relationship for sea urchin, which is regarded as one of important sea foods in Japan.

In order to clarify the annual, seasonal and sexual variation of elemental concentrations, fifteen elements (Al, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Sr and Zn) in 263 specimens of gonad of *Strongylocentrotus nudus* were determined by inductively coupled plasma atomic emission spectrometry.

Material and Methods

Material

Sea urchin *Strongylocentrotus nudus* were collected off the coast of Nakaminato City, the Pacific coast of mid Japan, from June 1984 to September 1986.

The body weight and shell diameter of 263 in-

dividuals of sea urchins used for analysis were in the range of 43.8-187.7 g and 46-78 mm, respectively.

Then gonad was taken out and sex was checked with a microscope magnifying 50 times. The sex of specimens in February was histologically determined because of there being no movement of sperm under microscope in this season. The wet weight of specimens ranged from 3.7 to 28.4 g depending on season. Twenty specimens collected at each sampling time were dried at 110°C for 24 hours and ashed in an electric muffle furnace at 450°C for 48 hours.

Measurement of the Elemental Concentrations

Ashed sample was dissolved in 0.5 N HNO₃ solution, and then filled up to 50 ml after filtration with a filter paper (Toyo No. 5C). The elemental concentrations in the solution were determined with an inductively coupled plasma atomic emission spectrometer (Shimadzu ICPQ-1012W). The applicability of inductively coupled plasma atomic emission spectrometry to multielement analysis of marine organisms was previously examined by us.^{9,10}

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Results and Discussion

Difference of Gonad Indexes among Sea Urchins Collected from Three Sampling Stations

The representability of samples of sea urchins in the sampling stations was checked. Sea urchins were collected from three neighboring sampling stations (A, B, and C) in August 1985 and gonad indexes (weight ratio of gonad to whole body) were calculated (see Table 1). Average gonad index of testis from three sampling stations was 14.7 ± 6.3 and that of ovary was 18.1 ± 6.7 . Differences in gonad indexes were not significant between sea urchin from three sampling stations.

Difference of Gonad Indexes among Three Sampling Years

The change of gonad indexes of sea urchins from June 1984 to September 1986 is illustrated in Fig. 1, with seawater temperature of the

Table 2. The comparison of gonad index (%) for three sampling years

Gonad	1984 (N=76)	1985 (N=107)	1986 (N=80)
Testis	17.2 ± 8.4	11.6 ± 6.1	13.1 ± 3.9
Ovary	20.6 ± 13.2	13.2 ± 4.8	10.2 ± 3.5
av $\pm$ sd*	19.3 ± 11.1	12.5 ± 5.4	11.6 ± 3.7

* average and standard deviation for the total number of each sampling year.

Table 1. The gonad index (weight ratio of gonad to whole body) of *S. nudus* collected from three sampling stations

Sampling station	Gonad	No. of sample	Shell diameter (mm)	Whole body weight (g)	Gonad weight (g)	Gonad index (%)
A	Testis	8	62.0 ± 6.9	102.1 ± 29.5	12.9 ± 4.4	12.6 ± 4.3
	Ovary	12	58.2 ± 4.0	85.7 ± 16.9	14.8 ± 4.2	17.3 ± 4.9
B	Testis	9	61.0 ± 9.9	98.3 ± 37.5	15.6 ± 7.5	15.9 ± 7.6
	Ovary	11	59.8 ± 7.1	89.7 ± 26.2	18.4 ± 7.5	20.5 ± 8.4
C	Testis	10	62.9 ± 5.9	111.2 ± 29.5	17.3 ± 7.5	15.6 ± 6.7
	Ovary	10	60.7 ± 6.0	99.1 ± 24.9	16.4 ± 6.8	16.5 ± 6.9

Fig. 1. The variation of gonad indexes of *S. nudus* from June 1984 to September 1986

- ◆: averaged value and standard deviation of testis
- : averaged value and standard deviation of ovary
- ×: water temperature (W.T.).

sampling station monitored by Ibaraki Prefectural Fisheries Station. Although the low gonad index of testis was observed in July 1985, generally gonad indexes increased in spawning season in summer and decreased in autumn corresponding to the falling of the water temperature.

Average gonad indexes for each sampling year are shown in Table 2. The gonad index in 1984 was higher than that in 1985 or in 1986. From these figures in Table 2, the maximum annual difference of gonad indexes could be considered as being double. High gonad index in 1984 is probably attributable to the abundance of brown algae like *Eisenia bicyclis* and *Undaria pinnatifida* as food for sea urchins.

Annual Difference of the Elemental Concentrations

The difference of the elemental concentrations in gonad of sea urchins collected in 1984, 1985 and 1986 is shown in Table 3. Although the difference of gonad indexes among three years was about two times as described above, the average concentrations of each element in gonad of sea urchins were similar among three years, as shown in Table 3.

Seasonal Variation of the Elemental Concentrations

Seasonal variation of the elemental concentrations in gonad was observed on Mg, Na, P and Zn. The concentrations of Mg (Fig. 2, (3)) and Na (Fig. 2, (4)) in gonad were low in summer and

rose in autumn. On the contrary, the P concentration (Fig. 2, (5)) was high in summer and then decreased. Although the Zn concentration in testis is constant through the year, the Zn concentration in ovary, shows the highest value in summer, as shown in Fig. 2, (15). Both P and Zn seem to have a particular role in the maturation of ovary of sea urchins.

There was no seasonal variation in concentrations of other elements, as shown in Fig. 2, (1-2 and 6-14).

Difference of the Elemental Concentrations due to Sex

The differences of the elemental concentrations between testis and ovary were statistically examined. As shown in Table 4, the significant differences were observed on Mg, P and Zn. The concentrations of Mg and P in testis were higher than those in ovary. Although the Zn concentration in ovary showed a clear seasonal variation as in Fig. 2, (15), the average value (54.9 $\mu\text{g/g}$ wet wt) of Zn in ovary was much higher than that (7.9 $\mu\text{g/g}$ wet wt) in testis. As to Ca, K, Al, Cd and Co, there was no difference of the concentrations between testis and ovary, but concerning other ten elements the differences were obscure.

In conclusion, the fluctuation of the elemental concentrations in sea urchins can be generally considered to be less than three times among years or seasons. Furthermore, it is found that

Table 3. The annual difference of the elemental concentrations ($\mu\text{g/g}$ wet wt) in gonad of *S. nudus*

Element	1984 (N=76)	1985 (N=107)	1986 (N=80)
Ca	390 $\pm$ 190*	330 $\pm$ 430	350 $\pm$ 240
K	2750 $\pm$ 870	3000 $\pm$ 580	3100 $\pm$ 830
Mg	590 $\pm$ 210	670 $\pm$ 460	710 $\pm$ 190
Na	2600 $\pm$ 860	2850 $\pm$ 1140	2640 $\pm$ 640
P	2170 $\pm$ 790	2470 $\pm$ 650	2480 $\pm$ 780
Al	3.0 $\pm$ 1.7	4.2 $\pm$ 3.8	3.6 $\pm$ 2.6
Cd	0.04 $\pm$ 0.04	0.06 $\pm$ 0.05	0.04 $\pm$ 0.03
Co	0.11 $\pm$ 0.04	0.12 $\pm$ 0.06	0.09 $\pm$ 0.04
Cr	0.14 $\pm$ 0.07	0.18 $\pm$ 0.11	0.14 $\pm$ 0.06
Cu	0.92 $\pm$ 0.55	0.73 $\pm$ 0.24	0.49 $\pm$ 0.15
Fe	9.4 $\pm$ 3.8	11.9 $\pm$ 6.0	9.7 $\pm$ 4.2
Mn	0.22 $\pm$ 0.09	0.25 $\pm$ 0.15	0.24 $\pm$ 0.06
Ni	0.13 $\pm$ 0.07	0.19 $\pm$ 0.14	0.14 $\pm$ 0.06
Sr	3.5 $\pm$ 1.3	4.0 $\pm$ 2.7	3.3 $\pm$ 1.8
Zn	33.7 $\pm$ 23.8	36.4 $\pm$ 31.0	30.9 $\pm$ 22.9

* average and standard deviation.

Table 4. The comparison of the elemental concentrations ($\mu\text{g/g}$ wet wt) between testis and ovary of *S. nudus*

Element	Testis (N=117)	Ovary (N=146)	Statistical significance
Ca	320 $\pm$ 210*	370 $\pm$ 180	no difference
K	2800 $\pm$ 640	3100 $\pm$ 720	no difference
Mg	800 $\pm$ 180	510 $\pm$ 100	$p < 0.001^{**}$
Na	2900 $\pm$ 1100	2600 $\pm$ 810	$p < 0.01$
P	3000 $\pm$ 550	1800 $\pm$ 300	$p < 0.001$
Al	3.6 $\pm$ 2.9	3.8 $\pm$ 4.1	no difference
Cd	0.05 $\pm$ 0.07	0.04 $\pm$ 0.02	no difference
Co	0.10 $\pm$ 0.05	0.11 $\pm$ 0.05	no difference
Cr	0.18 $\pm$ 0.08	0.14 $\pm$ 0.09	$p < 0.01$
Cu	0.64 $\pm$ 0.43	0.80 $\pm$ 0.32	$p < 0.01$
Fe	11.8 $\pm$ 5.9	8.8 $\pm$ 3.9	$p < 0.01$
Mn	0.19 $\pm$ 0.11	0.27 $\pm$ 0.15	$p < 0.01$
Ni	0.17 $\pm$ 0.13	0.14 $\pm$ 0.09	$p < 0.05$
Sr	3.4 $\pm$ 1.4	3.8 $\pm$ 1.4	$p < 0.05$
Zn	7.9 $\pm$ 2.9	54.9 $\pm$ 17.2	$p < 0.001$

* average and standard deviation.

** probability.

Fig. 2 (1)

Fig. 2 (2)

Fig. 2 (3)

Fig. 2 (4)

Fig. 2(5)

Fig. 2(6)

Fig. 2(7)

Fig. 2(8)

Ffig. 2(9)

Fig. 2(10)

Fig. 2(11)

Fig. 2(12)

Fig. 2(13)

Fig. 2(14)

Fig. 2(15)

Fig. 2. (1)-(15) The variation of the elemental concentrations ($\mu\text{g/g}$ wet wt) in gonad of *S. nudus*

♦ : averaged value and standard deviation of testis

◊ : averaged value and standard deviation of ovary.

the differences by sex are not significant except for Mg, P and Zn.

The concentration factor is a useful parameter for the internal dose estimation of human beings who consume sea foods contaminated by radionuclides.

In order to obtain the concentration factors, the elemental concentrations other than Mg, P and Zn were averaged on both testis and ovary because of no difference due to sex. In the cases of Mg, P and Zn indicating clear differences by

Table 5. The elemental concentrations and concentration factors (CF) by gonad of *S. nudus*

Element	Average conc. in gonad ($\mu\text{g/g}$ wet wt)	Conc. in seawater ¹¹⁾ ($\mu\text{g/ml}$)	CF
Ca	350	410	0.85
K	3000	391	7.7
Mg (testis)*	800	1290	0.62
Na	2700	10770	0.25
P (testis)*	3000	8.8×10^{-2}	3.4×10^4
Al	3.7	1.0×10^{-6}	3.7×10^6
Cd	0.044	1.1×10^{-4}	4.0×10^2
Co	0.11	3×10^{-5}	3.7×10^3
Cr	0.16	2×10^{-4}	8.0×10^2
Cu	0.72	9×10^{-4}	8.1×10^2
Fe	10.3	3×10^{-8}	3.4×10^3
Mn	0.23	4×10^{-4}	5.8×10^2
Ni	0.16	6.6×10^{-8}	2.3×10^3
Sr	3.6	8.1	0.41
Zn (ovary)*	54.9	5×10^{-8}	1.1×10^4

* Concentration factor was calculated for the gonad which showed higher concentration of the element for the security against the internal dose.

sex, the concentration factors were calculated using each higher elemental concentration for the conservative estimation of the internal dose of human beings. The elemental concentrations in seawater were cited from the data edited by Turekian.¹¹⁾ The values as seen in Table 5 were in accordance with previous data¹²⁾ except Cd. On the value of Cd, further investigation should be performed.

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