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by K. Kawamura

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Ecological Studies and Some Discussions about the Methods of Conservation of the Sea Urchin, *Strongylocentrotus nudus*, on the Coast of Urakawa, Hokkaido.

Kazuhiro KAWAMURA

The author carried out ecological studies on the living environment, growth, distribution, gonad development and food conditions of the sea urchin, *Strongylocentrotus nudus*, on the coast of Urakawa. He discussed the methods of their conservation on the basis of the results obtained.

The specimens were collected by diving from 4 m² areas at 126 places in May, 1965. The results are as follows :

1) The habitats of the sea urchins are rocky or stony bottoms, and are separated into seven localities : Sanbetsu, Shiroizumi, Tsukisappu, Urakawa, Ikantai, Toe, and Ogifushi by sandy zone. The production of seaweed is different in these localities. They are best in Toe, somewhat good in Shiroizumi, Ikantai and Ogifushi, but bad in other localities.

2) In Toe, the ages of the sea urchin are represented by the diameter as follows :

one year and 8 months ····· 3.21 cm
2 years and 8 months····· 4.18 ± 0.31 cm
3 years and 8 months····· 5.18 ± 0.28 cm
4 years and 8 months····· 6.11 ± 0.27 cm
5 years and 8 months····· 6.94 ± 0.35 cm
6 years and 8 months····· 7.55 ± 0.21 cm

3) In all localities, specimens having a test diameter of 6 cm or so are most abundant, and the larger or smaller the diameter becomes, the fewer the number. In adult urchins, there are some differences of their habitats according to their size group. There is a tendency for 4 and 5 years old sea urchins to crowd together in special places, but the older sea urchins disperse. The density of the sea urchins is varied with the locality and collection point.

4) Gonad development is the best in Toe, somewhat good in Shiroizumi, Ikantai and Ogifushi, but bad in other localities. The growth stage of the gonads is generally a "*Growing* stage" in both the female and male.

5) The amount of seaweed found in the gut is closely related to the habitat. Of the sea urchins having a gonad index larger than 1.0, the rates are more than 80%. There is no clear relation between the food conditions and distribution of sea urchins.

6) The author discussed the fishing season, the fishing grounds, transplantation, and other problems related to the methods of conservation of these resources.

Strongylocentrotus nudus and Strongylocentrotus intermedius are p. 7
the centre of Hokkaido sea urchin fishery. The state of ecological studies on S. nudus is behind that of S. intermedius. Up to now there have only been Fuji's (1960 a, b, c) clarification of the reproductive cell formation process, of the biological minimal shape and of the yearly cycle of gonad p. 8
development; and the author's report (1966) on the effects of transplantation. The author's report (1964, b) on sea urchins at Toe in Urakawa-cho was the first of its kind relating to ecology in fishing grounds.

The author in May of 1964 carried out fishing ground research on S. nudus in Toe. Having investigated the size, distribution, food conditions, and gonad development conditions, the author reported on methods of fishery resource management, including his own evaluation of resource conditions. From the results of this report a further investigation was planned for 1965, because the recovery of resources at Toe were insufficient, and because there appeared to be an instability in the conditions of stock replenishment. Later, in 1965 the investigation plan was enlarged, and it was decided to carry out a fishing ground investigation including the entire Urakawa-cho coast, as a joint undertaking of Urakawa-cho, the Urakawa Fishermen's Cooperative Association and the Ogifushi Fishermen's Cooperative Association. The purpose of this investigation was to obtain the basic information necessary for joint management of S. nudus fisheries under the guidance of the cooperative associations. The investigation was carried out between the 13th and 25th of May, 1965. Here is the report on the information obtained from this investigation.

The report contains a summary of fishing grounds and fisheries; living environment; age and size of sea urchins; distribution; contents of

digestive tract; gonad development conditions; and methods of fishery resource management.

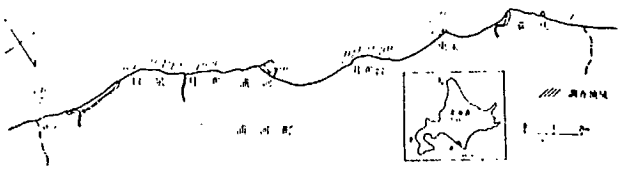
Before entering the text of the report, I wish first of all to express my appreciation to Urakawa-cho, to the Urakawa Fishermen's Cooperative Association, and to the Ogifushi Fishermen's Cooperative Association which provided the opportunity for this investigation, and to Mr. ONO Katsuyoshi, Urakawa-cho Fisheries techniques extension member, to Mr. UMETSU Hideo, diver, to Skipper HIDA Ryukichi, to Mr. NOUSHI Choji, engineer and rigger, who all gave me their cooperation from beginning to end in the investigation. And also to the local association employees, together with all the association members, I express my gratitude.

Summary of fishing grounds and fisheries.

Urakawa-cho is located on the Hidaka coast on the Pacific Ocean side of Hokkaido. The Urakawa-cho coast alternates between sandy and rocky or stony zones. The rocky or stony zones are at the same time fishing grounds for Laminaria angustata Kjellman (mitsuishi konbu) and the habitat of sea urchins, inhabited by S. nudus and S. intermedius. The rocky or stony zones going from east to west in Sanbetsu, Shiroizumi, Tsukisappu, Urakawa and Ikantai districts are within the jurisdiction of the Urakawa Fishermen's Cooperative Association; and the Toe and Ogifushi districts are within the jurisdiction of the Ogifushi Fishermen's Cooperative Association (Fig. 1).

The beginning of S. nudus fishery at Urakawa-cho is comparatively recent. Based on the Cooperative records and on inquiries, in 1958 there was harvesting by divers at Shiroizumi; this appears to be the first. After

Figure 1. p. 8



第 1 図　調 査 場 所

The map of coastal line in Urakawa. Showing each place where sea urchins were sampled.

that, businessmen paid concession money to the Cooperatives and carried on operations, or the district kelp association became the nucleus of business and carried on operations. Due to the low degree of transparency of the sea on the Urakawa Coast, S. nudus harvesting is done by diving.

The years of operation in each district are: Sanbetsu and Shiroizumi, 1958, 1959, 1961, 1963, 1965; Tsukisappu and Urakawa, 1959, 1961, 1964; Ikantai, 1962, 1963; Toe, 1960, 1961; and Ogifushi 1960, 1962. In 1965 operations were carried out in Sanbetsu and Shiroizumi only.

Although accurate records on the catch are often unobtainable, there seems to be in Sanbetsu and Shiroizumi districts an annual catch at the 20 - 30 ton level (weight including shells). In 1963 there were around 15 tons caught at Ikantai. Based on records of the Ogifushi Fishermen's Cooperative Association, there were 167 tons caught at Toe during 9 months in 1960 - 1961, and there were 39 tons caught at Ogifushi in 1962.

At Ikantai and Toe small scale harvesting of chiefly S. intermedius p.9 is carried out in very shallow sea by dip net harvesting or dotsuki*. Dip net harvesting is carried out as a business, but dotsuki harvesting is carried out at low tide by fishermen's wives as a part time job. Both seem to be sources of substantial income.

*Translator's note: Gathering by waders using underwater observation glass.

Materials and method.

Present fishery areas and major habitats were roughly mapped out and divided into 200 m x 200 m sampling stations. The number of investigation sites is as follows: Sanbetsu 12, Shiroizumi 23, Tsukisappu 7, Urakawa 7, Ikantai 23, Toe 19, Ogifushi 35; a total of 126 (Figures 2 a, b, c).

Figure 2.

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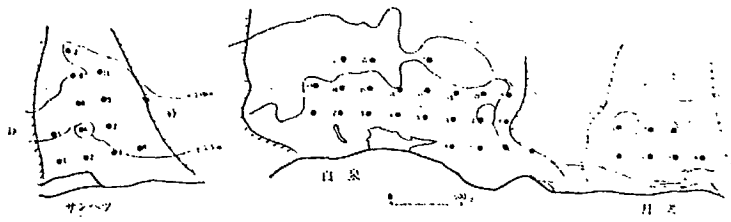
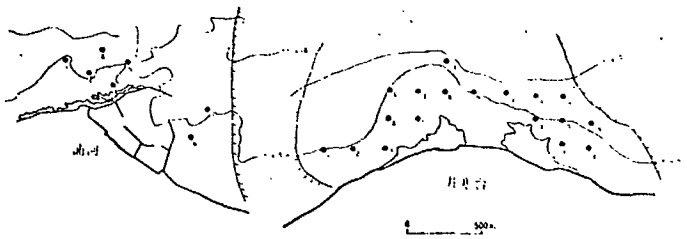


第2図—a 調 査 地 点 図

The details of sampling stations at Sanbetsu, Shiroizumi and Tsukisappu respectively.



第2図—b 調 査 地 点 図

The details of sampling stations at Urakawa and Ikantai respectively.

第2図—c 調 査 地 点 図

The details of sampling stations at Toe and Ogifushi respectively.

At each sampling station, collection was carried out by divers, after 2 m x 2 m frames had been positioned in areas which were thought to have the highest density of distribution. The adoption of this investigatory method was based on the following considerations:

a) As there were many sampling stations, the collection time in each of the districts had to be as short as possible because of the large number of specimens to be collected. With this method many samples could be collected in a short time.

b) If a fixed condition (in this case high density areas) is decided upon for the sampling method, it becomes comparatively easy to judge the yearly change in distribution conditions (The same method was used at Toe last year). p. 10

c) Wherever possible an investigation method should be established which accurately reflects the distribution and actual living conditions of sea urchins. However, with the present lack of information, time to study other methods was limited in this investigation.

In locations that were dived, observation of seaweeds growing and collection of seaweeds within the frames (including floating seaweeds which had sunk to the sea bottom) were carried out.

The shell diameter and weight of each of S. nudus collected were measured. The weight of the gonads was measured and the maturity was determined in 10 sea urchins from each of the sampling stations. For classification of maturity, the method of Fuji (1960, a) was followed. The contents of the gut were observed with the naked eye and were divided into seaweed, sand, etc. Coefficients for the inclusion of seaweed were divided into 11 degrees with 0 for absolutely no inclusion and 10 for cases with seaweeds only. These

were recorded. Using the method of Moore (1935) on 98 S. nudus from Toe, the relationship between age and size was studied from the number of pigmented rings on the genital plate. From hereon "sea urchin" means in all cases Strongylocentrotus nudus.

Results and discussion

1. Habitat

The depths of the waters investigated in all the districts range from about 3 to 10 m. With the exception of Toe, depths of 10 m are often reached in off-shore areas within 1000 m (Figure 2 a, b, c). While in all localities bottoms were rocky or stony, some areas close to beaches are rocky covered with sand. Generally in rocky areas there are reefs close to the shore that appear at ebb tide. These areas are frequently inhabited by young S. intermedius. In depths deeper than 5 m the rocky areas become very uneven, and areas with the so-called peaks are numerous. In Toe, as the 1964 investigation took place at high tide and that of 1965 at low tide, the depths at each sampling site for 1965 are shallower than those for 1964.

Table 1 shows seaweed, including floating seaweeds, growing at each sampling station and its vicinity. Generally seaweed is scarce at Sanbetsu; at st. 6 (depth 4.5 m) one variety of Endarachne Binghamiae J. Agardh (habanori), and at st. 10 (depth 10.5 m) Desmarestia ligulata Lamouroux (urushigusa) only were observed. Although there are areas where kelp is growing at Shiroizumi, these growing areas are limited to part of the fishing grounds. Moreover, because kelp are often growing only on the upper portions of peaks, locations within the sea urchin sampling areas where kelp was sampled did not surpass four in number. At Tsukisappu, p. 12

Table 1. The seaweeds found in each sampling station. p.10

x floating seaweeds

district	sampling station	seaweeds within sampling frames	seaweeds in vicinity of sampling stations
Sanbetsu	6	a variety of Endarachne Binghamine J. Agardh (habanori)	a variety of Endarachne Binghamine J. Agardh (habanori)
	10	Desmarestia ligulata Lamouroux (urushigusa)	Desmarestia ligulata Lamouroux (urushigusa)
Shiroizumi	3		Laminaria angustata Kjellman (mitsuishikonbu) on the top of high reefs
	4	x Laminaria angustata Kjellman (mitsuishikonbu)	
	5		Laminaria angustata Kjellman on the top of high reefs
	7		same as above
	9		same as above
	11	Laminaria angustata Kjellman	Laminaria angustata Kjellman
	13	x "aname"	same as above
	14	x Laminaria angustata Kjellman	same as above
	22	"oobaokitsubara"	"oobaokitsubara"
Tsukisappu	1	"aname"	"aname"
	2		"aname" on the top of high reefs
	3		same as above
	6		same as above
	7		same as above
Urakawa	1	x "aname"	"aname"
	2	x "aname", "numehanori", x Phyllospadix iwatensis Makino (sugamo)	"aname" on the top of high reefs

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district	sampling station	seaweeds within sampling frames	seaweeds in vicinity of sampling stations
Urakawa (cont'd)	3	x Laminaria angustata Kjellman, "aname", x Sargassum fulvellum (hondawara)	
	6	x Sargassum fulvellum, x Ulva pertusa Kjellman (anaaosa)	Laminaria angustata Kjellman and Sargassum fulvellum on the top of high reefs
Ikantai	1	x Laminaria angustata Kjellman	Laminaria angustata Kjellman on the top of high reefs
	3	"oobaokitsubara"	"oobaokitsubara"
	4	same as above	same as above
	7	Laminaria angustata Kjellman	Laminaria angustata Kjellman
	9	same as above	same as above
	10	same as above	same as above
	11	"oobaokitsubara"	"oobaokitsubara"
	19		"aname" on the top of high reefs
	20	Laminaria angustata Kjellman	Laminaria angustata Kjellman
Toe	2	x "nokogirihiba", x Coelarthrrum muelleri (darush), x Costaria costata Saunders (sujime), x Phyllospadix iwatensis Makino (sugamo)	
	3	x Laminaria angustata Kjellman, x Coelarthrrum muelleri, x Phyllospadix iwatensis Makino, x "nokogirihiba"	
	4	"oobaokitsubara"	"oobaokitsubara"
	5	x Laminaria angustata Kjellman	Laminaria angustata Kjellman of the top of high reefs

district	sampling station	seaweeds within sampling frames	seaweeds in vicinity of sampling stations
Toe (cont'd)	6	x Laminaria angustata Kjellman, x Coelarthrrum muelleri	same as above
	7	x Ulva pertusa Kjellman, x Alaria crassifolia Kjellman, x "soso", x Laminaria angustata Kjellman, x Phyllospadix iwatensis Makino	
	8	x Alaria crassifolia Kjellman	"oobaokitsubara"
	10	x Laminaria angustata Kjellman, x Alaria crassifolia Kjellman, x Ulva pertusa Kjellman, x Phyllospadix iwatensis Makino	Laminaria angustata Kjellman, Sargassum fulvellum
	11	x Laminaria angustata Kjellman, x "nokogirihiba", x Phyllospadix iwatensis Makino	
	13	x Alaria crassifolia Kjellman, x Costaria costata Saunders, x "nokogirihiba", x Laminaria angustata Kjellman, x Phyllospadix iwatensis Makino	Laminaria angustata Kjellman, Sargassum fulvellum
	15		Laminaria angustata Kjellman
	16	x Laminaria angustata Kjellman, x "nokogirihiba"	same as above
	17		same as above
	18		same as above
	19		same as above
Ogifushi	1		Laminaria angustata Kjellman on the top of high reefs
	3		Laminaria angustata Kjellman
	11		Laminaria angustata Kjellman on the top of high reefs

district	sampling station	seaweeds within sampling frames	seaweeds in vicinity of sampling stations
Ogifushi (cont'd)	15	x Laminaria angustata Kjellman	
	24	x Laminaria angustata Kjellman	Laminaria angustata Kjellman
	25	"oobaokitsubara"	"oobaokitsubara"
	26		Laminaria angustata Kjellman on the top of high reefs
	27	"oobaokitsubara"	"oobaokitsubara"
	30		Laminaria angustata Kjellman on the top of high reefs
	32		Laminaria angustata Kjellman
	33	x Laminaria angustata Kjellman	Laminaria angustata Kjellman on the top of high reefs

p.11

there is a lot of "aname", and it grew almost entirely on the top of peaks. There are places in Urakawa where there are several varieties of floating seaweeds. These are thought to originate from the breakwater of Urakawa Bay and nearby shallow rocky areas where many seaweeds are growing. In Ikantai there are areas at sts. 7, 9, and 10 (depths 4.0-4.5 m) where kelp is very abundant; and at sts. 3, 4 (depths 3.0-4.0 m) "oobaosatsubara" is growing. There are small numbers of seaweeds at other stations. At the majority of the sampling stations in Toe either kelp and other seaweeds are growing or there are floating seaweeds. Seaweed is most abundant in Urakawa-cho. Even when compared with the previous year, conditions were good. Growing grounds of kelp in Ogifushi showed the same tendencies as those of Shiroizumi; and there were only a few places among the sampling stations where kelp could be collected (the depths at all locations: 4.0-4.5 m). Further, "oobaokitsubara" was growing at sts. 25, 27.

Table 2.

第 2 表　浦河町コンブ生産高の年変化

The annual variations of the yield of *Laminaria Angustata* in Urakawa. (kg)

district / year	Sanbetsu Shiroizumi	Tsukisappu Urakawa	Ikantai	Toe	Ogifushi
1961	150,299	75,240	301,882	70,770	102,330
1962	143,689	76,860	95,733	17,490	55,470
1963	116,668	39,360	211,081	57,600	79,920
1964	90,435	46,370	95,149	5,990	19,050
1965	64,756	34,492	223,390	59,760	161,460

Table 2 shows amounts of kelp produced for the past 5 years in each district. The annual variations in yield in each of the districts were great. Yield also showed variations dependent on the district. In 1965 the yields in Shiroizumi and Urakawa were the lowest in the past 5 years,

64,756 kg and 34,492 kg respectively; in Ikantai and Toe they were the second largest, 223,390 kg and 59,760 kg respectively; and in Ogifushi they were the greatest, 161,460 kg. It is thought that such variations in production of kelp reflect to a certain degree variations in the growth amount of kelp. It is conjectured that there is as well a considerable yearly variation in growth amounts of seaweeds (including floating seaweeds) in each district.

The varieties of bottom animals collected together with S. nudus are as follows: one variety of Coelenterata; one variety of Crustacea (crab); Cryptochiton stelleri Middendorff(oobanhizaragai); one variety of mollusk; hard shell mussel (one variety was probably Stavelia subdisorta Récley (ezoigai)); sea cucumber and starfish (chiefly Asterina pectinifera Kuller et Troschel (itomakihitode)) more than two varieties; and S. intermedius. These were all few in number with the exceptions of hard shell mussels and S. intermedius. Hard shell mussels were found only in sts. 3, 5 in Ogifushi. S. intermedius is growing in each sector and tends to be abundant in water depths 5-6 m and shallower. Depending on the location, there were cases of more than 100 S. intermedius in 4 m^2. Within the range of depths investigated, there were many sea urchins with large shell diameters of 5.0-7.0 cm. Gonad development, however, was very poor. Furthermore, the author (1964, a) observed reddish black spots on the gonads which had been reported on S. intermedius in Funadomari. Their state is such as to be almost valueless as finished goods.

2. Age and size of sea urchins

The author (in an unpublished report) has observed in S. nudus as well the pigmented rings visible on the genital plate that were first

discovered by Moore (1935) in Echinus esculentus. The use of these as annual rings has probably been made indisputable by the research on sea urchins from Yoichi. The author plans to report on the formative process of these pigmented rings on another occasion.

The ring count was two or more for sea urchins from Toe with shell diameters ranging from 2.81 to 8.62 cm. One-year-old sea urchins were not collected. The ages shown in Table 3 are based on the number of rings. At one full year, with the development period in October (based on research by Fuji (1960, c)), 2 years become 1 year 8 months, and 3 years become 2 years 8 months. The average size for each year is as follows: 2nd year, 3.21 cm; 3rd year, 4.18 cm; 4th year, 5.18 cm; 5th year, 6.11 cm; 6th year, 6.94 cm; 7th year, 7.55 cm (Table 3). The number of rings were difficult to decipher in the 8th year and over. p.13

Table 3.

第 3 表　東楽キタムラサキウニの年令と大きさ
The size of each age group of *Strongylocentrotus nudus* in Toe.

Age	Numbers	Shell diam. range (cm)	Shell diam. (cm)	Weight (g)
2	3	2.81 ~ 3.53	3.21	14
3	8	3.49 ~ 4.65	4.18 ± 0.31	31 ± 6
4	14	4.72 ~ 5.50	5.18 ± 0.28	57 ± 10
5	29	5.63 ~ 6.60	6.11 ± 0.27	97 ± 14
6	25	6.40 ~ 7.41	6.94 ± 0.35	143 ± 22
7	12	7.30 ~ 7.87	7.55 ± 0.21	186 ± 20
8以上	7	8.05 ~ 8.62	—	—

Between the 2nd and 5th years growth is roughly 1 cm each year, and slows down after the 6th year. However, it may be questioned whether these age figures are representative of the age groups, given the fact that in the investigation there were only a few sample sea urchins in their 2nd and 3rd years. Each of the habitats of sea urchins within the jurisdiction

of Urakawa-cho is independent of the others, and as the living conditions are different, it can naturally be presumed that growth too will be different. It is, therefore, unreasonable to make these figures representative of the relationships between age and size of all the sea urchins in Urakawa-cho. However, given the lack of other data, this time sea urchins were divided into groups with shell diameters of 2.80-3.59 cm, 3.60-4.59 cm, 4.60-5.59 cm, 5.60-6.59 cm, 6.60-7.29 cm, 7.30-7.79 cm, and 7.80 cm and over; and were dealt with as representative of a measure of age. The division of the groups also closely resembles the change in the mode of shell size-frequency distribution in last year's Toe sea urchins. p.14

Table 4.

第 4 表　大きさ別，個体数百分率

The percentage of number in each size-group. (%)

shell diameter (cm) / district	2.00~3.49	3.50~4.59	4.60~5.59	5.60~6.59	6.60~7.29	7.30~7.79	7.80 or more
Sanbetsu	3.0	8.2	17.0	39.6	19.0	8.0	5.2
Shiroizumi	0.5	5.4	10.3	42.5	26.6	12.3	2.1
Tsukisappu	2.8	2.8	9.8	50.8	19.8	12.6	1.4
Urakawa	0	5.8	11.4	22.6	26.8	15.6	17.4
Ikantai	1.8	5.4	22.9	33.3	17.4	10.3	8.2
Toe	1.3	3.7	10.8	35.5	28.1	12.6	8.0
Ogifushi	1.0	5.4	19.0	42.7	19.2	8.4	4.3
Toe 1964	1.4	4.4	20.2	42.8	17.8	8.6	4.8

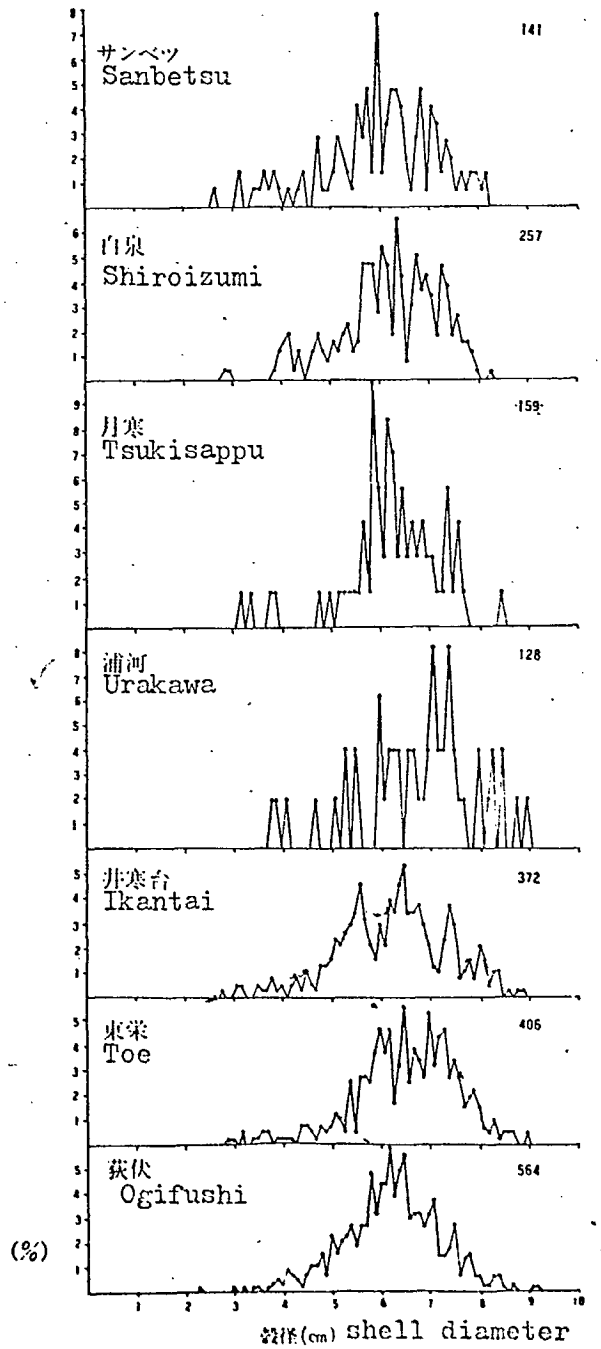
第 5 表　大きさ別，重量百分率

The percentage of weight in each size-group. (%)

shell diameter (cm) / district	2.00~3.49	3.50~4.59	4.60~5.59	5.60~6.59	6.60~7.29	7.30~7.79	7.80 or more
Sanbetsu	0.5	2.3	10.2	36.9	25.6	13.9	10.6
Shiroizumi	0.1	1.6	6.0	35.5	33.4	19.4	4.1
Tsukisappu	0.4	0.7	5.6	46.1	24.5	19.3	3.4
Urakawa	0	1.2	5.3	14.9	28.5	19.7	30.4
Ikantai	0.2	2.1	12.9	29.7	21.9	16.5	16.8
Toe	0.3	1.2	3.1	27.9	33.4	18.7	15.2
Ogifushi	0.0	1.4	10.6	38.5	25.0	14.5	10.0
Toe 1964	0.2	1.5	11.7	39.1	23.5	13.8	10.2

The average weights for each age are: 2nd year, 14 g; 3rd year, 31 g; 4th year, 57 g; 5th year, 97 g; 6th year, 143 g; 7th year, 186 g.

Figure 3. p.14



第 3 図　地域別殻径組成

The local variations of the size-frequency distributions.

Percentages of growth during the year become: 2nd to 3rd year, 121%; 3rd to 4th year, 84%; 4th to 5th year, 70%; 5th to 6th year, 49%; 6th to 7th year, 30%.

3. Size and distribution of sea urchins.

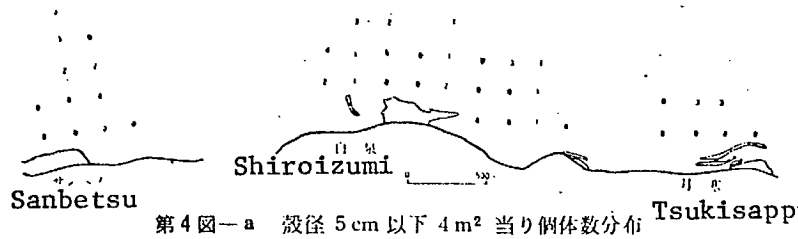
(1) Sea urchin size, sample numbers, and weight ratios.

The shell size-frequency variations for each district are shown in Figure 3, and the percentages of numbers in each size-group and of weight in each size group are shown in Tables 4 and 5 respectively. In each district the mode centres on ± 6 cm shell diameter. The smaller they get and also the larger they get, the smaller [the percentage] becomes. This tendency is the same as last year's results in Toe. Looking at the percentages of sample numbers in each size group, with the exception of Urakawa, sea urchins in the 5.60-6.59 cm group are, at 30-50%, the largest in number in all districts. In Urakawa the 6.60-7.29 cm group at 26.8% was the largest and on the whole when compared with other districts Urakawa had the highest ratio of large sea urchins. The 4.60-5.59 cm shell diameter group is present in each district in the 10-20% range, but is large in Ikantai and Ogifushi. Sea urchins with shell diameters of less than 4.60 cm were less than 10% in all districts. The percentage of weight tends to be naturally slightly larger than percentage of number.

(2) Individual distributions of the sea urchins smaller than 5 cm.

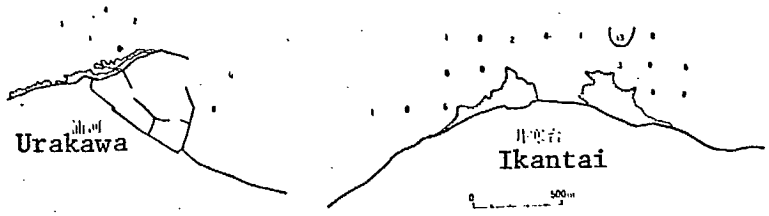
As shown in Figures 4a, b, c, in most cases the individual distribution of diameters smaller than 5 cm in each district was less than 10 sea urchins in each 4 m^2. However, in Ikantai and Ogifushi there were three locations where more than 10 sea urchins were found. The locations where many sea urchins appeared had depths of 7-10 m. p.16

Figure 4.



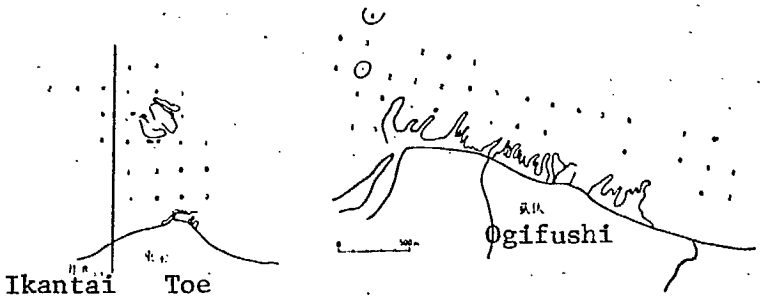
第4図—a　殻径 5 cm 以下 4 m² 当り個体数分布

The individual distributions of the sea urchins smaller than 5 cm in test diameter, in each 4 m² square (at Sanbetsu, Shiroizumi and Tsukisappu).



第4図—b　殻径 5 cm 以下 4 m² 当り個体数分布

The individual distributions of the sea urchins smaller than 5 cm in test diameter, in each 4 m² square (at Urakawa and Ikantai).



第4図－c　殻径 5 cm 以下 4 m² 当り個体数分布

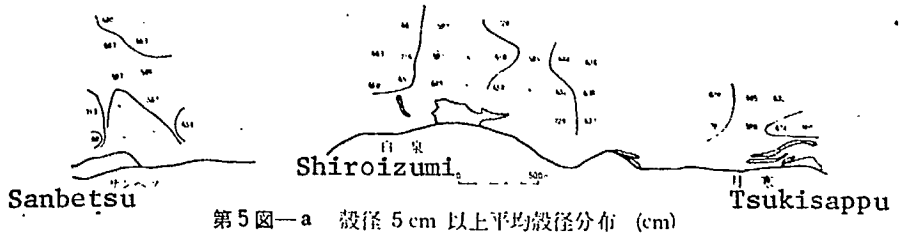
The individual distributions of the sea urchins smaller than 5 cm in test diameter, in each 4 m² square (at Toe and Ogifushi).

(3) Distribution of average shell diameter of sea urchins larger than 5 cm.

Figures 5 a, b, c show the distributions of average shell diameters of sea urchins over 5 cm at each sampling station. In the central part of Sanbetsu and Tsukisappu where the fishing grounds are small there were locations with sea urchins at the 5 cm diameter level. Going towards the periphery a tendency to gradually become larger was observed. In Shiroizumi,

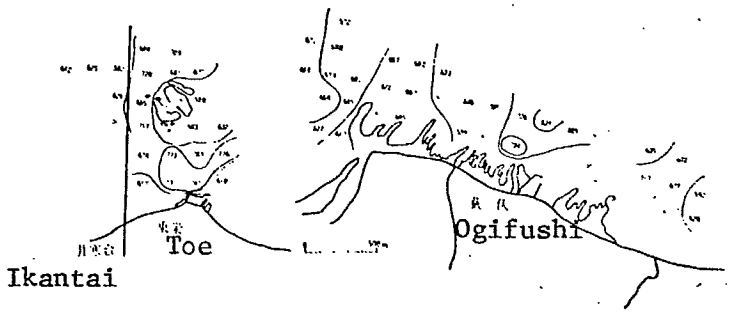
Figure 5.

p.16



第5図—a　殻径 5 cm 以上平均殻径分布 (cm)

The distributions of the average test diameter of the sea urchins larger than 5 cm in it (at Sanbetsu, Shiroizumi and Tsukisappu).



第5図—b　殻径 5 cm 以上ウニ平均殻径分布 (cm)

The distributions of the average test diameter of the sea urchins larger than 5 cm in it (at Urakawa and Ikantai)*

第5図—c　殻径 5 cm 以上平均殻径分布 (cm)

The distributions of the average test diameter of the sea urchins larger than 5 cm in it (at Toe and Ogifushi).*

Ikantai and Ogifushi distribution belts of comparatively small-sized sea urchins and of large-sized sea urchins were observed alternatively along the coast line. Toe shows a mixed type of the above mentioned two types. Comparatively small-sized sea urchins were found at both the east and west ends of the Toe coast, in the northwest part of Rebunbira reef and in the Ikantai area. Large sized sea urchins were found in the belt between Rebunbira reef and the Toe coast. They were also found extending over from the east side to the south side of Rebunbira reef. While

this distribution in Toe is basically the same as that of last

*Translator's note: The English captions for Fig. 5b and Fig. 5c have apparently been switched in the text.

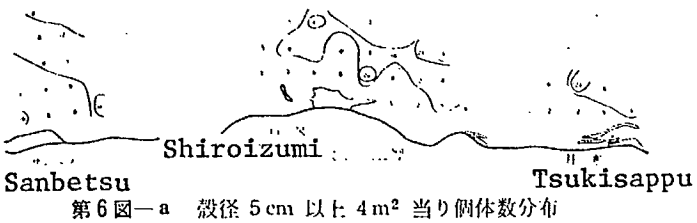
year's investigation, sea urchins have generally become larger.

(4) Individual distributions of sea urchins larger than 5 cm in diameter in each 4 m^2 square.

Figures 6 a, b, c show the individual distributions of sea urchins larger than 5 cm in diameter in each 4 m^2 square.

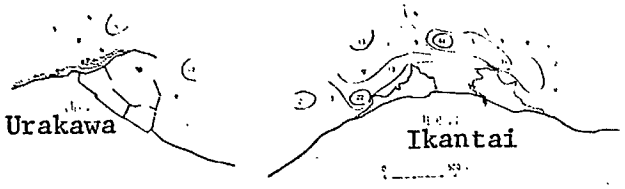
Figure 6.

p.17



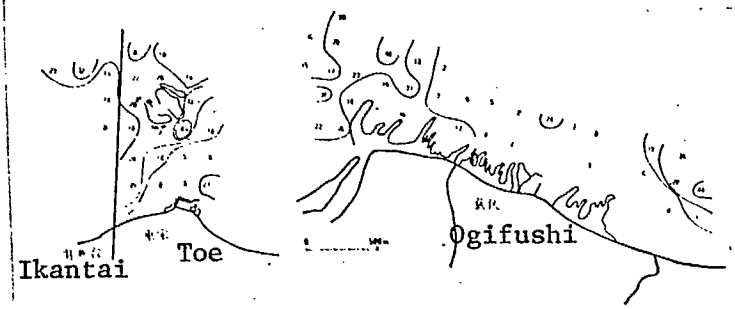
第6図—a 殻径 5cm 以上 4m² 当り個体数分布

The individual distributions of the sea urchins larger than 5 cm in test diameter, in each 4 m² square (at Sanbetsu, Shiroizumi and Tsukisappu).



第6図—b 殻径 5cm 以上 4m² 当り個体数分布

The individual distributions of the sea urchins larger than 5 cm in test diameter, in each 4 m² square (at Urakawa and Ikantai).



第6図—c 殻径 5cm 以上ウニの 4m² 当り個体分布

The individual distributions of the sea urchins larger than 5 cm in test diameter, in each 4 m² square (at Toe and Ogifushi).

Although at one place in Sanbetsu's st. 4 (depth 4.5 m) there were 33 sea urchins, on the whole in other locations they were scarce with ± 10 sea urchins. There were no sea urchins at sts. 2 or 3 (depths 4.5-4.8 m),

while at st. 6 (depth 4.5 m) only sea urchins with diameters of less than 5 cm were collected.

In Shiroizumi locations having 10-20 sea urchins were found in a long, narrow strip; with the exception of st. 11 (depth 3.5 m) the number of sea urchins was small on the shore side. At sts. 4, 16 no sea urchins were collected. Generally it was found that as sizes tended to be small where sea urchins were numerous.

In Tsukisappu, sts. 4, 6, 7 (depths 5.0-10.0 m) had distributions of 10-20 sea urchins; yet other stations had only small numbers.

In Urakawa, at sts. 5 and 7 (depths 9.0-4.0 m)*, 15 and 17 sea urchins were observed respectively; yet generally numbers were small.

In Ikantai there were areas in the central part (depths 4.0-5.5 m) where there were very large numbers (30-40) of sea urchins; these sea urchins were large as well. In the eastern end (depths 3.0-3.5 m) there were spots where around 20 sea urchins were found, but the sea urchins were small in size. In areas touching on the Toe district (depths 5.0-7.5 m) distribution was from 10-30 sea urchins of small size.

In Toe 20-40 sea urchins were found in the vicinity of Rebunbira reef (depths 2.5-6.0 m). There were also over 20 sea urchins at sts. 1, 4 and 5. In the central area (depths 5.0-8.0 m) between Rebunbira reef and the Toe coast, locations with less than 10 sea urchins were frequent. While the state of distribution of these shows roughly the same tendencies as last year, there were many areas where, when compared to last year, there was somewhat of an increase in the numbers of sea urchins. However, there were in the central area between Rebunbira reef and the Toe coast some areas that even showed somewhat of a decrease. In Ogifushi, distribution was p.18

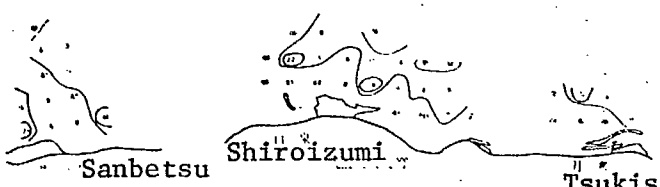
*Translator's note: sic.

large with 20–40 sea urchins in spots near both the east (depths 3.0–10 m) and west (depths 4.0–4.5 m) ends of the Ogifushi coast. But in the central part, with the exception of st. 20, it was small with less than 10 sea urchins.

In areas surrounding the sampling stations in each district there are locations where sea urchins are numerous. There is a strong possibility that sea urchins may be found outside the sampling stations as well.

(5) Weight distributions of sea urchins larger than 5 cm in diameter in each 4 m^2 square.

Figure 7. p.18

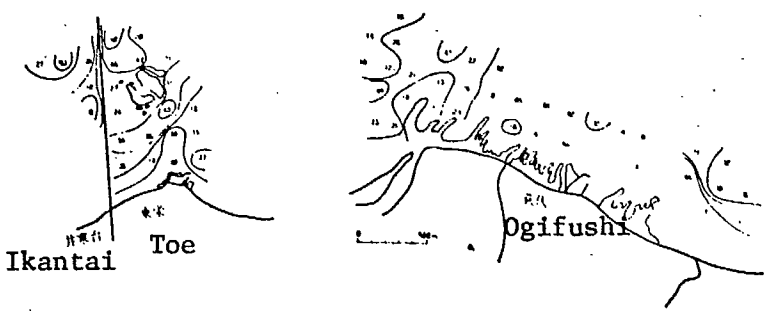


第7図—a 殻径 5 cm 以上ウニの 4 m² 当り重量分布 (kg)

The quantitative distributions of the sea urchins larger than 5 cm in test diameter, in each 4 m² square (at Sanbetsu, Shiroizumi and Tsukisappu).

第7図—b 殻径 5 cm 以上ウニの 4 m² 当り重量分布 (kg)

The quantitative distributions of the sea urchins larger than 5 cm in test diameter, in each 4 m² square (at Urakawa and Ikantai).



第7図—c 殻径 5 cm 以上ウニの 4 m² 当り重量分布 (kg)

The quantitative distributions of the sea urchins larger than 5 cm in test diameter, in each 4 m² square (at Toe and Ogifushi).

Figures 7a, b, c are shown weight distributions for each 4 m^2 square in each district. The weight distributions roughly conform to the quantitative distributions, but there is some variation according to size of the sea urchin.

In Sanbetsu, while st. 1 had a weight of 2.1 kg and st. 4, one of 4.4 kg, the heaviest in other stations was 1.6 kg, with most weights around 1.0 kg.

In Shiroizumi there were weights of over 3.0 kg in sts. 19, 20 on the west side offshore. In the long narrow strip sea urchins weighing 1.0-2.4 kg were found in some locations.

In Tsukisappu, the heaviest sea urchin was 2.2 kg found at st. 6. p.19

In Urakawa, sts. 5 and 7 had 1.8 kg and 2.7 kg respectively, but other stations were below 1.0 kg.

In Ikantai, there were spots in the central part where sea urchins with weights of 3.5-7.3 kg were very numerous. As for the other locations, a sea urchin weighing 2.8 kg was found in one location on the east side, while in only a few locations in the area bordering on Toe were found sea urchins of 2.3-3.3 kg. In the remaining areas sea urchins were few in number.

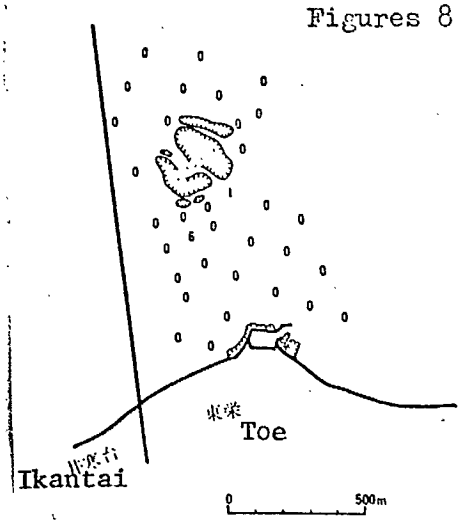
In Toe, with the exception of the central part between the Toe coast and Rebunbira reef, the standard was over 2.0 kg. It had more than any other district and more than last year, too.

In Ogifushi, sea urchins weighing over 2.0 kg were found in spots near the east and west ends of the coast. In the central area, however, sea urchins on the whole weighed under 1.0 kg.

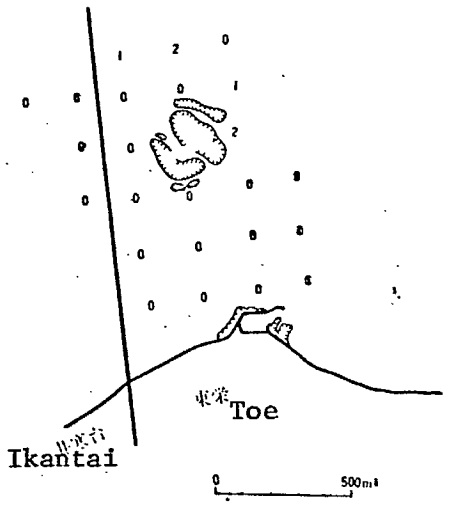
(6) Age distribution in Toe.

Shown in Figures 8-21 are the individual distributions for each 4 m^2 square of each age group of sea urchins in Toe during the years 1964-65. The ages are divided according to the diameter size groups mentioned before. In both years not even one one-year-old sea urchin was collected.

Figures 8 and 9. p.19



第8図 4 m² 当り2年ウニ個体数分布 (1964)
The individual distribution of two years old sea urchins in each 4 m² square at Toe, in 1964.



第9図 4 m² 当り2年ウニ個体数分布 (1965.
The individual distribution of two years old sea urchins in each 4 m² square at Toe, in 1965.

Two-year-old sea urchins. In 1964, 6 sea urchins were observed on the north side of Rebunbira reef (depth 5.5 m), but other than that only one location had 1 two-year-old sea urchin (Fig. 8). In 1965, 1 to 2 sea urchins were observed on the south and west sides of Rebunbira reef (depths 2.5-6.0 m) (Figure 9).

Three-year-old sea urchins. In 1964 many spots on the north side of Rebunbira (depths 5.5-9.5 m) had 2 to 5 sea urchins. In other locations as well 1-2 sea urchins were found sporadically (Figure 10). In 1965 were observed 2-4 sea urchins on the west side (depths 2.5-3.5 m) and 2-3 sea urchins on the south side (depths 5.0-6.0 m) of Rebunbira (Figure 11).

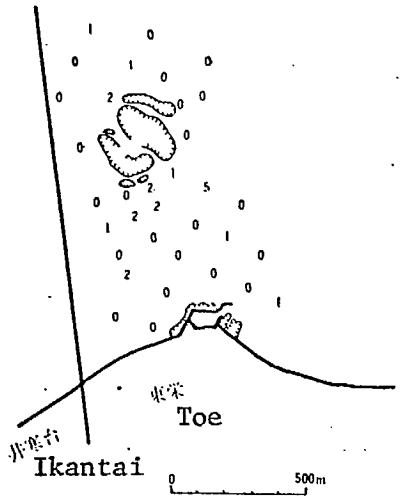
Hardly any relation between these and the two-year-old sea urchins in 1964 was seen.

Four-year-old sea urchins. In 1964, sea urchins were clustered together in numbers of 10 to 24 in spots on the north (depth 4.5 m) and west (depths 5.5-9.5 m) sides of Rebunbira reef. On the west side (depth 4 m) of Toe Harbour as well 8 sea urchins were observed; but there were few on the east and south sides of Rebunbira reef (Figure 12). In 1965 on the west side of Rebunbira (depth 2.5 m), the west side of Toe Harbour (depth 3.0 m) and offshore from the east side of Toe Harbour (depth 3 m) there were 10 or more sea urchins each. On the Ikantai side (depths 5-6 m) some spots had 5-8 sea urchins (Figure 13). Like the previous year there were few on the east and south sides of Rebunbira reef; and the patterns of distribution for the two years resemble each other.

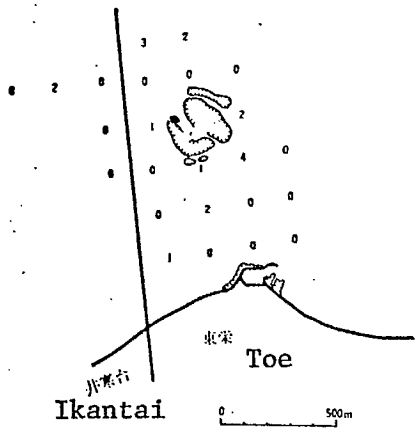
However, compared to 1964, in 1965 there were fewer sea urchins p.20
on Rebunbira's north side and more in the area offshore from the east side of Toe Harbour. While the connection with the 1964 three-year-old sea urchins is not too clear, there is a similar tendency towards large numbers of sea urchin on the shore side of Rebunbira reef. However, in numbers, there seem to be more four-year-old sea urchins.

Five-year-old sea urchins. In 1964 there were spots with 10 or more sea urchins each on the north (depths 5.5-7.0 m) and west (depths 4.5-9.5 m) sides of Rebunbira reef, on the west side of Toe Harbour (depth 5.0 m), and on the southeast side of Rebunbira reef (depth 6.0 m). If the south-
east side of Rebunbira is excluded the distribution pattern resembles that p. 21
of the four-year-old sea urchins; the numbers and range, however, are more and wider (Figure 14). In 1965, too, 10 sea urchins or more each were

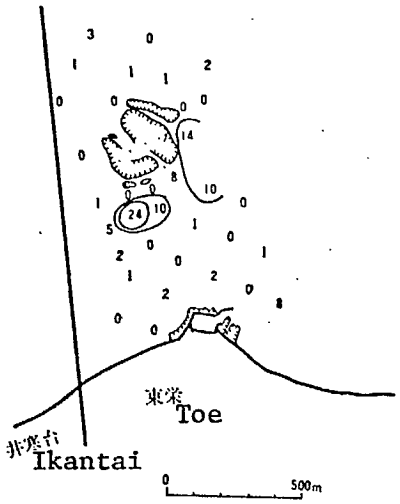
Figures 10, 11, 12 and 13. p.20



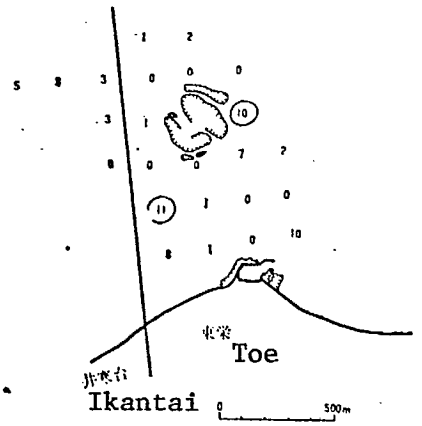
第10図　4 m² 当り 3 年ウニ個体数分布 (1964)
The individual distribution of three years old sea urchins in each 4 m² square at Toe, in 1964.



第11図　4 m² 当り 3 年ウニ個体数分布 (1965)
The individual distribution of three years old sea urchins in 4 m² square at Toe in 1965.



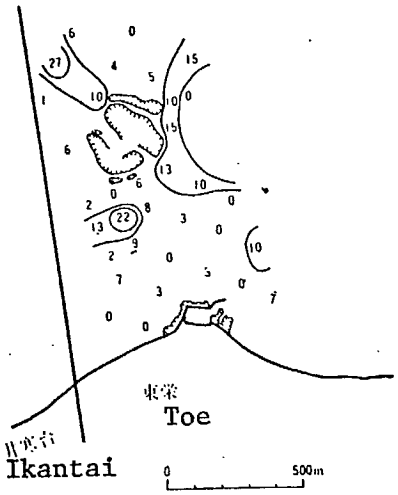
第12図　4 m² 当り 4 年ウニ個体数分布 (1964)
The individual distribution of four years old sea urchins in each 4 m² square at Toe, in 1964.



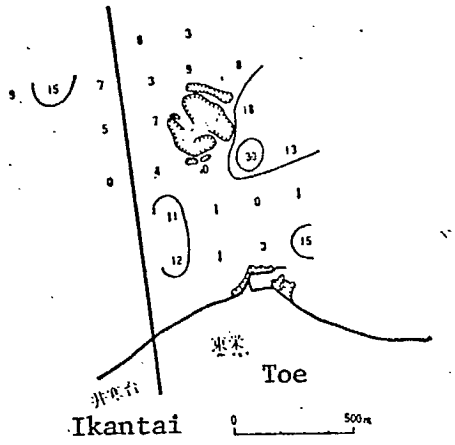
第13図　4 m² 当り 4 年ウニ個体数分布 (1965)
The individual distribution of four years old sea urchins in each 4 m² square at Toe, in 1965.

observed on the west side (depths 2.5-6.5 m) of Rebunbira reef, the east side (depths 3.0-5.5 m) and offshore area on the west side (depth 3.0 m) of Toe Harbour, and on the Ikantai side (depth 5.0 m). While they show

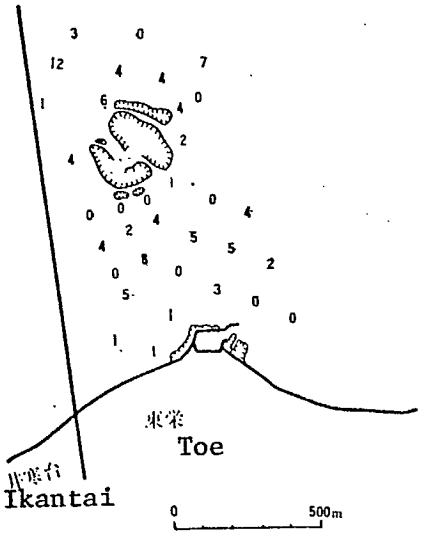
Figures 14, 15, 16 and 17.



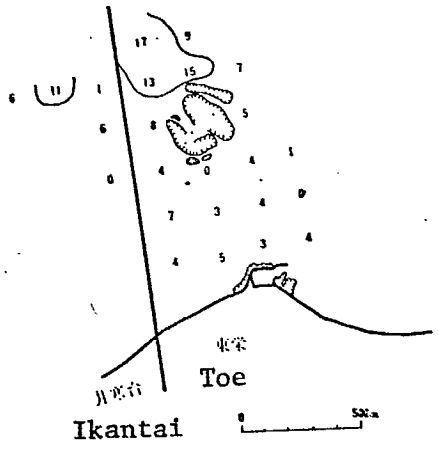
第14図　4 m² 当り 5 年ウニ個体数分布 (1964)
The individual distribution of five years old sea urchins in each 4 m² square at Toe, in 1964.



第15図　4 m² 当り 5 年ウニ個体数分布 (1965)
The individual distribution of five years old sea urchins in each 4 m² square at Toe, in 1965.



第16図　4 m² 当り 6 年ウニ個体数分布 (1964)
The individual distribution of six years old sea urchins in each 4 m² square at Toe, in 1964.



第17図　4 m² 当り 6 年ウニ個体数分布 (1965)
The individual distribution of six years old sea urchins in each 4 m² square, in 1965.

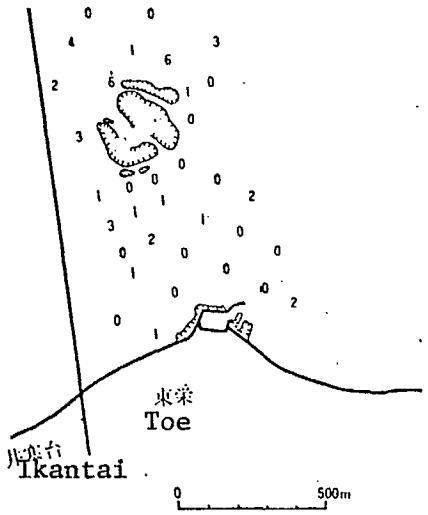
the same distribution tendencies as the four-year-old sea urchins, their numbers have increased. Further, on the south side (depths 4.0-6.0 m) of Rebunbira reef, as well, nearly 10 sea urchins were observed (Figure 15). The distribution patterns for five-year-old sea urchins for both years

closely resemble each other. Sea urchins on the north side of Rebunbira reef, however, moved over to the shore side in 1965, and there are fewer sea urchins on Rebunbira's southeast side. Looking at the distri- p. 22 butions of 1964 four-year-old sea urchins and 1965 five-year-old sea urchins, hardly any changes in locations having large numbers are evident; but on the whole five-year-old sea urchins increased in numbers. On the east and south sides of Rebunbira reef as well their numbers increased.

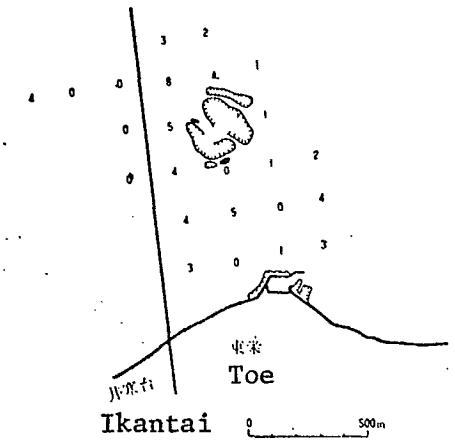
Six-year-old sea urchins. In 1964 only one location on the southeast part of Rebunbira reef (depth 6.0 m) had 10 or more sea urchins. In all other areas 10 sea urchins or less were found. However, there were even fewer sea urchins in the shallow areas on the north side of Rebunbira reef and the Toe Coast (Figure 16). Comparatively, locations which had a high density of five-year-old sea urchins have a lesser number of six-year-old sea urchins. Distribution has become more even and a tendency for the number of sea urchins to increase in somewhat deeper depths is evident. In 1965, some locations on the south side (depths 4.0-6.0 m) of Rebunbira reef had more than 10 six-year-old sea urchins, but on the north side there were less than 10 (Fig. 17). Contrasted to 1964, sea urchins had increased on the south side of Rebunbira reef. When compared to the distribution of five-year-olds in 1964, the same tendencies are evident. Looking at the relationship with 1964 five-year-old sea urchins, these 1965 six-year-old sea urchins, too, are lower in density and more scattered. It was discerned that they tend to decrease to the north and west of Rebunbira reef, and to increase somewhat to the east and south of it, and in the central part between it and the Toe Coast.

Seven-year-old sea urchins. Although in 1964 there were no spots

Figures 18 and 19. p.22



第18図 4 m² 当り7年ウニ個体数分布 (1964)
The individual distribution of seven years old sea urchins in each 4 m² square at Toe, in 1964.



第19図 4 m² 当り7年ウニ個体数分布 (1965)
The individual distribution of seven years old sea urchins in each 4 m² square at Toe, in 1965.

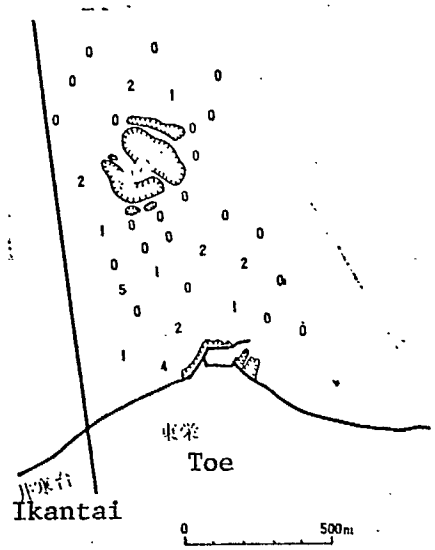
having over 10 sea urchins, sea urchins were numerous on the south side (depths 3.0-8.5 m) of Rebunbira reef (Figure 18). In 1965 there were also no locations with over 10 sea urchins. A tendency to be slightly more numerous on the east and south sides (depths 3.5-5.5 m) of Rebunbira reef was observed. Densities were lower than those of six-year-old sea urchins (Figure 19). The relationship is also the same as that with 1964 six-year-old sea urchins.

Eight-year-old and older sea urchins. In 1964 sea urchins were on the whole few in number, with 5 being the highest in any one spot. Many spots had 1 or 2 sea urchins, but in nearly 2/3rds of the locations there were no eight-year-old sea urchins to be collected (Figure 20). In areas where four-and five-year old sea urchins were numerous there were hardly any eight-year-olds observed at all. In 1965, while there were spots with 9 and 6 sea urchins, on the whole the same tendencies as in 1964 were

evident (Figure 21). When both years are compared to the seven-year-old sea urchins there is a decrease in numbers.

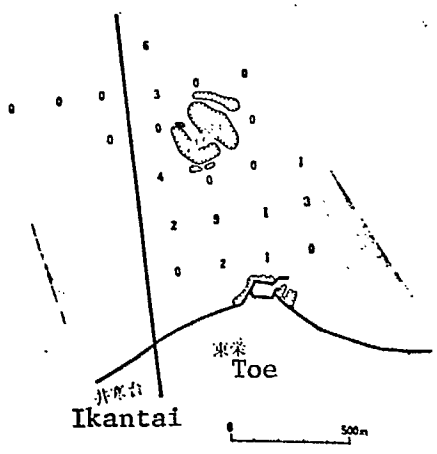
Figure 20.

p.23



第20図 4 m² 当り 8 年ウニ個体数分布 (1964)
The individual distribution of older than eight years oldsea urchins in each 4 m² square at Toe, in 1964.

Figure 21.



第21図 4 m² 当り 8 年以上ウニ個体数分布 (1965)
The individual distribution of older than eight years old sea urchin in each 4 m² square at Toe, in 1965.

Tables 6 and 7. p.23

第 6 表　東栄における1964年，1965年の年令別推定生息個体数と重量

The annual variation of estimated number and weight of the sea urchin in each age-group, within the experimental area in Toe.

	age / year	2	3	4	5	6	7	8 or more	Total
number	1964	16,400	51,700	236,300	502,000	209,000	100,700	56,200	1,172,300
	1965	23,200	65,900	192,300	632,300	500,500	224,400	142,500	1,781,100
weight(kg.	1964	200	1,900	14,600	49,600	29,300	17,200	12,700	125,500
	1965	700	2,600	6,700	60,600	72,500	40,600	33,000	216,700

第 7 表　1964年を 100 とした1965年における各年級の変化率

The rate of variation of number and weight in each age-group during one year.

age	2→3yrs	3→4yrs	4→5yrs	5→6yrs	6→7yrs	7→8 yrs or more	Total
number	400	340	267	97	107	91	152
weight	1,300	352	415	147	139	111	173

Tables 6 and 7 give the rate of variation of estimated number and weight in each age group during one year in the years 1964 and 1965 at Toe. (More will be explained about these tables later.) While the number of sea urchins increased 52% in one year, the increase was among sea urchins in the 1965 five-year-old group or younger. The change for six-year and older was less than 10%. Because a decrease of close to 10% was observed in eight-year and older, it is thought that the natural decrease has probably become more pronounced. Among the five-year and older the rate of weight variation corresponds closely with the rate of weight increase in each age-group.

The author (1964, b) stated that from the results of the 1964 Toe investigation it was unclear whether the number of young sea urchin inhabitants was in fact small or the inability to collect samples was due to a shortcoming in the investigation methodology. Upon consideration of the results of this 1965 investigation, the author feels that this present investigative method reflects for the most part distribution conditions of five-year and older sea urchins. This conclusion was based on the following facts: (a) in all areas of Urakawa-cho only small numbers of young sea urchins were collected; (b) a disparity was observed in the habitats of small sea urchins and large sea urchins of four years and older; (c) the four-and five-year-old sea urchins in Toe are concentrated into high densities in 3 or 4 spots as seen from the makeup of distribution by age; and (d) the variation in the estimated number of five-year and older sea urchin inhabitants is low, while (e) in the 4th year there is a rapid increase. For sea urchins of four-years and younger, however, the makeup of their distribution is not reflected by the method. For ages of three- and younger the actual conditions of distribution are especially unclear. p.24 When considering the way four-and five-year-old sea urchins are distributed, it is thought that the habitats in which three-year and younger sea urchins are clustered together might probably be near high density areas of four- and five-year-olds. And regarding this point it is conjectured that post-metamorphosis sea urchins converge and adhere to specific locations which have certain conditions at the time of benthic migration of floating larvae. Further study is necessary on these points.

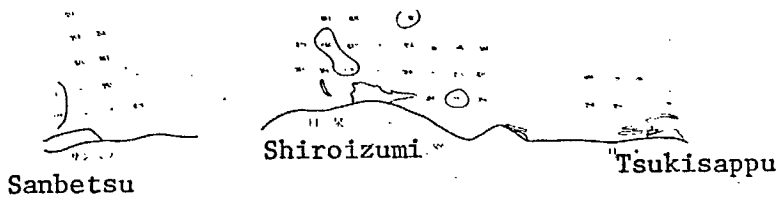
It is notable that with S. intermedius small ones tend to be widespread in very shallow areas, and as they grow larger to spread deeper

(Kawamura 1960, 1964 a, 1965 a, Kawamura, Taki 1965). As the distribution of young S. nudus is not apparent, it is difficult to be exact, but within the sphere of this investigation, it seems that the relationship between its size and water depth is more complicated than that with S. intermedius. However, it is almost certain that definite movement and dispersion can be observed according to the growth stage. The gregarious life accompanying growth stages and the life cycle of S. nudus are subjects for further concrete study.

4. Development conditions of gonads.

Figures 22 a, b, c show the distributions of the average gonad

Figure 22. p.24

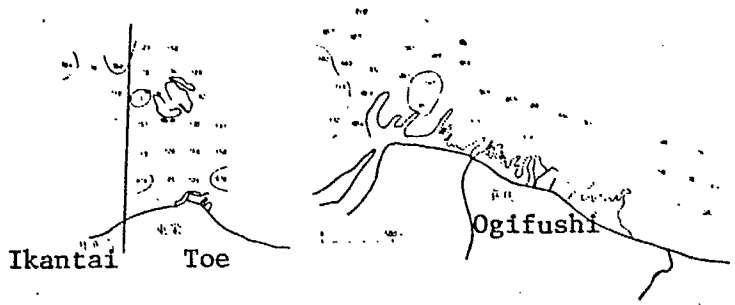


第22図—a 生殖巣指数分布

The distributions of the gonad index of the sea urchins in each different station (at Sanbetsu, Shiroizumi and Tsukisappu).

第22図—b 生殖巣指数分布

The distributions of the gonad index of the sea urchins in each different station (at Urakawa and Ikantai).



第22図—c 生殖巣指数分布

The distributions of the gonad index of the sea urchins in each different station (at Toe and Ogifushi).

index (gonad weight/total weight x 10). In Sanbetsu the only locations with over 1.0 were sts. 1 and 5 (water depths 4.5-8.5 m). In Shiroizumi sts. 3, 10, 14 and 23 (water depths 3.5-7.0 m) had over 1.0, but on the whole development was not very good. In Tsukisappu, no location had over 1.0; and in Urakawa only st. 3 (water depth 6.5 m) had over 1.0. In Ikantai locations with over 1.0 were found in a long, narrow strip in the central part (water depths 2.5-5.5 m). There were also some in the area neighbouring on Toe (water depth 500 m)*. In Toe, with the exceptions of sts. 1 and 4 (water depths 5.5-3.0 m) all areas had over 1.0. Compared to last year development in the area around Rebunbira reef is somewhat poor, but between Rebunbira reef and the Toe coast there were several locations which showed improvement. In Ogifushi, there were locations in both the eastern and western ends (depths 3.0-5.0 m) with over 1.0; even in sts. 13 and 24 (water depths 4.0-5.5 m) 1.0 was exceeded. Other locations, however, were not good. p.25

Table 8. The percentage of sea urchin in each stage of gonad development. (%) p.25

♀ / ♂ 地域a / b熟度	c 回復期	d 成長期	e 成熟前期	f 成熟期	♀ / ♂ 地域a / b熟度	c 回復期	d 成長期	e 成熟前期	f 成熟期
Sanbetsu	16.7	83.3			サンベツ	11.1	61.1	27.8	
Shiroizumi	15.9	83.6	0.5		白泉	19.0	57.1	23.9	
Tsukisappu		100			月寒	12.0	80.0	8.0	
Urakawa		100			浦河	7.7	61.5	30.8	
Ikantai	23.3	70.9	5.8		井寒台	21.2	56.3	22.5	
Toe		85.6	14.4		東栄		17.1	82.9	
Ogifushi	28.4	71.6			荻伏	31.9	41.8	26.3	
Ogifushi 1964	3.0	85.0	11.0	1.0	東栄 '64年	0.5	30.0	69.0	0.5

a. District
b. Maturation
c. Recovery period
d. Growth period
e. Pre-maturation period
f. Maturation period

* Translator's note: This is probably a misprint for 5.0 m.

The maturation conditions of gonads are shown in Table 8. On the whole the majority of sea urchins, both male and female, were in the growth period. There were also many males which had reached the pre-maturation period. At the time of investigation, there was a strong connection between the progress of degree of maturation and the volume development of gonads. In locations with many in the recovery period [1st period] the volume development of gonads was extremely poor. In Toe the volume had developed more than at other areas; consequently, the stage of maturation was also advanced. Contrasted to last year, there were no male or female sea urchins in either the recovery or maturation periods. The absence of sea urchins in recovery stage is due to the fact that like last year there was not any district observed in which gonad development was extremely poor. And the absence of sea urchins in the maturation stage is probably due to the fact that they had not attained the level of last year although there were locations with good development.

Comparatively, the state of maturation of sea urchins at Urakawa generally resembles that of Ishiya and Shigoke* reported in a study by Fuji (1960 c). There seemed, however, to be somewhat fewer males in the maturation period.

5. Relationship between the contents of the digestive tract, seaweed growth conditions and distribution, and gonads.

Because there was a tendency observed last year for the development of gonads to improve as the percentage of seaweed in the gut increased, this time the percentages of seaweed and non-seaweed substances (calcareous seaweed is included among non-seaweed substances) were made the objects of

* Translator's note: This is probably a misprint for Shinori.

investigation. The numbers in Figures 23 a, b, and c show the percentage (%) of seaweed included in the guts of an average of 10 sea urchins in each location.

Figure 23. p. 25

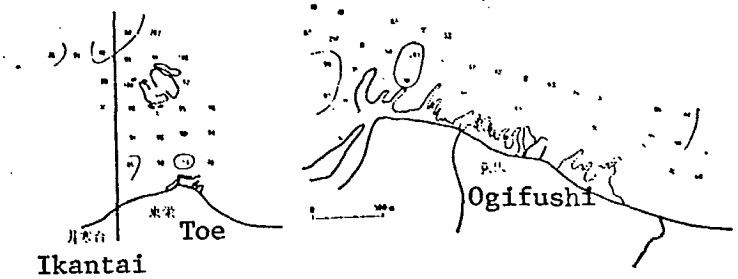
第23図-- a　消化管内容物に海藻の含まれる割合いの分布

The percentages of the seaweeds found in the gut contents in each different station (at Sanbetsu, Shiroizumi and Tsukisappu).

p. 26

第23図—b　消化管内容物に海藻の含まれる割合いの分布

The percentages of the seaweeds found in the gut contents in each different station (at Urakawa and Ikantai).



第23図—c　消化管内容物に海藻の含まれる割合いの分布

The percentages of the seaweeds found in the gut contents in each different station (at Toe and Ogifushi).

In Sanbetsu there was no location with over 50%. In Shiroizumi, while the majority of locations had under 50%, only sts. 14 and 23 (water depths 5.5-7.5 m) had over 80%. In Tsukisappu st. 1 (depth 5.5 m) had 80%, and sts. 2 and 3 (depth 6.5 m) had 65%, but the rest were all around 10%. p.26 In Urakawa, st. 3 (depth 6.5 m) had 80%, and sts. 4 and 5 (depth 9.0 m) had about 60-70%. In Ikantai the central part (depths 8.0-5.0 m)* and areas bordering on Toe (depth 5.0 m) had values centering in the 80-90% range; other locations all showed low values with the exception of st. 1 (depth 3.5 m) with 84%. In Toe, excepting sts. 1 and 4, all locations had above 85%. In Ogifushi, only values above 80% were observed at sts. 1, 3, 13, and 24 (depths 3.0-5.5 m) and in the western end (depths 4.0-5.0 m). In Toe the percentage of seaweed compared to last year has become higher in the region between Rebunbira reef and the Toe coast.

In all areas, the relationship seems to be not between the percentage of seaweed eaten by sea urchins and sea urchin distribution density, but rather whether seaweeds (both growing and floating) are present or not in the sea urchins' habitats. Even in cases where sea urchins inhabit the lower portion of a peak and kelp is on the upper, most likely the kelp is not eaten at all by the sea urchins. It seems that foraging actions of sea urchins are not very extensive.

Depending on the location the make up of food of sea urchins varies greatly. Considering the districts as units, Toe had the best conditions, while Sanbetsu and Tsukisappu could be said to not be that good. Further, in Shiroizumi, Ikantai and Ogifushi certain spots were good. In relation to water depths a tendency for good locations to be in the 3.0-6.0 m range was observed. It is thought that there is in each area a yearly

*Translator's note: sic.

variation in growth conditions of seaweed and food conditions attendant upon them. This consideration is based on the large variations of kelp produced in Urakawa-cho (Table 2) depending upon the year, on the larger amount of kelp produced in Toe compared to last year, and on the expansion of locations where seaweed is eaten. The food conditions in Toe are comparatively good. Moreover, they are regular, a fact which differs from other districts. This is probably due to the presence of the Rebunbira reef belt at sea and the constant supply of floating seaweeds originating from areas around the reef.

A close connection is evident between the state of development of the gonads and the percentage of seaweed contained in the gut. In locations showing a gonad index of 1.0 and above, the percentage of seaweed eaten is almost always over 80%, and in locations where development is especially good, the percentage is near 100%. Conversely, in locations where the percentage of seaweed is low the development of gonads as well becomes poor. Furthermore, in Toe last year where the percentage of seaweed was bad, development of gonads was also bad, but when the seaweed percentage rose the development of gonads improved.

Fuji (1965) reported that with S. intermedius such seaweeds as kelp, Ulva pertusa Kjellman (anaaosa), "kayamonori" and Alaria crassifalia Kjellman (chigaiso) were good for gonad development. The investigation p. 27
results of last year in Toe and this year show that in the kelp belt gonad development is good and that sea urchins who ate Ulva pertusa Kjellman, "habamodoki" and so forth were also good. However, with such seaweeds as "aname" and "oobaokitsubara" they did not appear to be that good.

The close connection between S. intermedius gonad development and

the amount of food intake from winter to spring has been confirmed (Fuji 1962, 1963, Kawamura, Hayashi 1965). Furthermore, the author (1966) has estimated that connection between food intake and gonad development of S. nudus is fundamentally almost the same as that for S. intermedius. In Toe gonad development generally tended to be somewhat slower when compared to the levels of last year. And in addition, according to reports from workers on operations in Sanbetsu and Shiroizumi gonad development was below normal. These facts, in light of the knowledge gained on S. intermedius, perhaps have a close connection with variations in seaweed growth conditions from winter into spring, the period of extensive feeding activity.

The authors (1965) pointed out that with S. intermedius in Rebun-to Funadomari there was a close relationship between the yearly fluctuations of kelp production and sea urchin food conditions which in turn affected the development of gonads. The more kelp there was available the better development conditions of gonads became. In Toe in 1965 there was ten times as much kelp as in 1964 and the gonad development which had been poor in 1964 was now improved; these results are the same as those of S. intermedius in Funadomari. Considering sea urchin food conditions from kelp output only, it can be said that in 1965 Ikantai, Toe and Ogifushi were better than normal, while Sanbetsu, Shiroizumi, Tsukisappu and Urakawa were poorer than normal. From the standpoint of gonad development conditions, these facts perhaps indicate that in the future locations in Sanbetsu, Shiroizumi, Tsukisappu and Urakawa where gonad development is good should be expanded. It would also be possible to limit them in Ikantai, Toe and Ogifushi.

In this investigation there does not appear to be any prima facie connection between sea urchin foraging activities and their distribution.

However, there is a need for further comprehensive research on such things as migration and density which go hand in hand with growth stages and the life cycle.

6. On management of fishery resources.

(1) Fishing grounds.

No matter how great a volume of sea urchins there may be, if gonad development conditions are poor they will have no value as a catch. Generally speaking, it is desirable that operations be carried out in areas with a minimum gonad index of 1.0 or above as long as resources are utilized effectively.

There is a close connection between gonad development and food conditions. Based on the relation between the development of seaweed growing conditions and the development of gonads, sea urchin distribution areas may be divided into the three following types:

A. Locations where seaweeds are stable and grow each year and where gonad development is good.

B. Locations where there are large yearly fluctuations in seaweed growing conditions and where there are annual changes in development conditions of gonads as well.

C. Locations where each year food conditions are poor (no seaweeds growing; a paucity of floating seaweeds) and where gonad development is always bad.

"A" zones would be operation zones to begin with. Decisions whether "B" zones would be or not be used in operations would depend upon the state of gonad development for the year in question. "C" zones would not be used for operations.

In Toe last year fishing grounds were divided into an "A" zone (the periphery of Rebunbira reef) and a "B" zone (the Toe coast side) and operations were recommended for the "A" zone. This line of thinking probably need not be changed fundamentally. However, even in the "B" zone, depending on the year, the development of gonads may improve. Therefore, it is probably suitable to consider the "B" zone as being B-type locations as listed above. Moreover, because small sized sea urchins are appearing yearly in large numbers in the northern and western parts of Rebunbira reef, perhaps it would be better to make these into "fishing prohibited zones". Each of the A, B and C zones cannot be clearly indicated because in each area the actual conditions of annual fluctuation of growth locations and amounts of seaweed (with priority given to kelp) are not clearly defined.

(2) Fishing season

The season of operations at Urakawa-cho is limited almost entirely to January through March. Due to the fact that during this period there are no operations at all on the Japan Sea side of Hokkaido where the important fishing grounds of sea urchin fishing industry are located, it is advantageous in respect to prices of the product. However, it is an insatisfactory period for gonad development. Having sufficiently studied the development conditions of sea urchin gonads and socio-economic conditions, it is thought that it would be better to delay the fishing season as much as possible.

(3) Size of sea urchins for the catch.

Considering sea urchin age and size, it is the 4th year when sea urchins reach the catch qualification shell diameter of 5 cm according to the Hokkaido fisheries adjustment regulations. The percentages of weight

increase after the 4th year are: between 4th and 5th years, 70%; between 5th and 6th years, 49%; and between 6th and 7th years, 30%. Meanwhile, from shell diameter frequency and the variation in estimated numbers of sea urchins in each year of each age group at Toe, the natural decrease is thought to be greater after the age of 8 years and in shell diameters over 8 cm (see Figure 3, Tables 6, 7). From these facts it is considered that the catch of sea urchins in 6–7 cm shell diameter range and between 5 and 7 years old would be the most effective. However, as good locations for the development of gonads are narrow (Toe excepted), to restrict shell diameters to 6 cm and above would limit greatly the amounts of catch. Therefore, considered in connection with transplantation (discussed below), catches of sea urchins with shell diameters over 5 cm would probably be better.

(4) Transplantation

Because the growth stages of gonads are easily influenced by food conditions during the growth period, it is presumed that if sea urchins having poorly developing gonads are transplanted into areas with good food conditions, the gonad development will improve. There are a few reports on the effectiveness of S. intermedius transplantation (Kawamura 1963, Kawamura 1965 a, b, Kawamura, Taki 1965). Transplantations of S. nudus are also being carried out in various parts of the country. The author (1965) has carried out experiments on S. nudus at Iwanai and has generally confirmed its effectiveness. Each district is inhabited by large numbers of sea urchins with poor gonad development. If, after operations in areas of good gonad development, these sea urchins were transplanted, the resources of each and every area would be able to be utilized effectively.

(5) Estimated stocks and reasonable catch quantities.

Table 9 第 9 表 推 定 生 息 量 (殻径 5 cm 以上) p. 28
The estimated stocks of the sea urchins larger than 5 cm in test diameter.

District	Number of individuals	Weight (kg)
Sanbetsu	432,000 ± 213,000	49,500 ± 24,400
Shiroizumi	733,000 ± 301,000	83,800 ± 34,400
Tsukisappu	260,000 ± 123,000	27,500 ± 13,000
Urakawa	184,000 ± 158,000	26,800 ± 23,000
Ikantai	975,000 ± 341,000	118,200 ± 41,400
* U.F.C.A.	2,584,000 ± 1,136,000	301,800 ± 136,200
Toe	1,635,000 ± 434,000	212,600 ± 56,500
Ogifushi	1,670,000 ± 455,000	189,000 ± 51,600
** O.F.C.A.	3,305,000 ± 889,000	401,600 ± 108,100

* Urakawa Fishermen's Cooperative Association
** Ogifushi Fishermen's Cooperative Association

In Table 9 are shown the estimated stocks of sea urchins with shell diameters over 5 cm. The estimation method is the same as that the author (1964, b) used on sea urchins in Toe. The basic problem points of this method were reported on at that time. The average stocks by area are Sanbetsu 49.5 tons, Shiroizumi 83.8 tons, Tsukisappu 27.5 tons, Urakawa 26.8 tons, and Ikantai 118.2 tons; within this Urakawa Fisheries Cooperative Management area the figure becomes, therefore, about 300 tons. Within the Ogifushi Fisheries Cooperative Management area Toe had 212.6 tons, and Ogifushi 189 tons; reaching a total of roughly 400 tons. The calculated stock for Toe last year was 101 tons. But in last year's investigation the target area covered 640,000m^2, whereas this year it is 760,000m^2. For purposes here last year's values have been enlarged to correspond to 760,000m^2. Shown in Tables 6 and 7 are the estimated stocks by year and the rate of increase per 1 year. Numbers seem to vary only slightly among sea urchins five-years and older, but tend to decrease in eight-year and older. The rate of increase between the 4th year and 5th year is very high,

and on the whole shows a 52% increase over last year. Among last year's five-year and older sea urchins there was an increase in weight roughly proportional to the rate of increase per year of age; this year's five-year-old sea urchins are 4 times as many as last year owing to the increase in numbers. On the whole, the increase becomes 70%. The inclusive total of 212.6 tons demonstrates that resources are recovering to levels close to those of 1960-61 when the catch was 167 tons.

The results of calculations giving estimated stocks of sea urchins with gonad indices of 1.0 and over are shown in Table 10. In Sanbetsu 11 tons, Shiroizumi 12 tons, Tsukisappu 0, Urakawa 3.5 tons, Ikantai 74 tons; a total of about 100 tons for the Urakawa Fisheries Cooperative Management area. In Toe 190 tons, and Ogifushi 69 tons, a total reaching about 260 tons for the Ogifushi Fisheries Cooperative Management area. With the exception of Ikantai and Toe, the estimated stocks having gonad indices of over 1.0 are less than 30% of the whole. Assuming there would be transplantation, there doesn't appear to be any problem in taking all of these. In Ikantai the estimated stocks having gonad indices of over 1.0 reach 60%. It is thought that most of these sea urchins are six-and seven-years and older. Even if these were preserved there is the danger that the rate of natural decrease will become higher. A harvest of all these sea urchins,

Table 10　　第 10 表　生殖巣指数 1.0 以上のウニの推定生息量　　p.29

The estimated stocks of the sea urchins more than 1.0 in gonad index.

District	Numbers	Weight (kg)	District	Numbers	Weight (kg)
Sanbetsu	61,000	11,000	*U.F.C.A.	685,000	100,500
Shiroizumi	80,000	12,000	Toe	1,405,000	190,000
Tsukisappu	0	0	Ogifushi	536,000	69,000
Urakawa	24,000	3,500	**O.F.C.A.	1,942,000	259,000
Ikantai	520,000	74,000			

* Urakawa Fishermen's Cooperative Association
** Ogifushi Fishermen's Cooperative Association

therefore, appears justifiable. In Toe if all the sea urchins with gonad indices of 1.0 or over were taken, the resource would be at once completely exhausted. Although in the Toe "B" zone as well the meat was good this year, it is impossible to say what will happen next year. The northern and western parts of Rebunbira reef which are in an "A" zone were closed to fishing because of the comparatively small size of the ses urchins. It is estimated that the stock of this zone will be about 100 tons with operations on the eastern and southern sides only. Of this amount six-year and older sea urchins account for 50% of the numbers and 70% of the weight. If these sea urchins were caught one year later the catch would possibly be about 70 tons. And if in "B" zone the state of the meat is like this year's, a catch of 20-30 tons can be expected. The fishing season at Urakawa-cho starts in January. Yet as the sea urchins are expected to grow from May (the month of the investigation) until January of next year, we can anticipate to a certain extent an increase in weight.

Although it was pointed out in detail in last year's Toe investigation report, at present it is impossible to say how far the estimated values can be relied upon. The reasons for this lie in the fact that the stock estimation method is an expedient and is wanting in scientific support; and also that there has been no investigation based on actual practices in the fishing industry. It became clear during the 2 year investigation, as well, that the actual conditions of replenishment of sea urchins under four-years-old cannot be determined with the present investigation methodology.

Henceforth, together with taking accurate records of catches during operations, it will be necessary to carry out investigations after

operations, and to study both the accuracy of stock estimations and improvements in estimation methods. It is also important to define the living conditions of young sea urchins and to research the actual conditions of the replenishment group.

Summary

(1) From the 13th to the 26th of May, 1965 collection of S. nudus was carried out by divers in a total of 126 2 m x 2 m spots in the districts of Sanbetsu, Shiroizumi, Tsukisappu, Urakawa, Ikantai, Toe and Ogifushi along the Urakawa-cho coast. The habitat, age and size, size and distribution, development conditions of gonads, and gut contents of sea urchins were investigated. Further, based on the above results the management of fishery resources was studied.

(2) The habitat of S. nudus is characterized by rocky or stony bottoms. The growing conditions of seaweed vary greatly depending upon the locations. In Sanbetsu, Tsukisappu, and Urakawa they are small in numbers. Toe had the most of all including kelp. Only limited parts of Shiroizumi, Ikantai and Ogifushi were inhabited by seaweeds.

(3) The relationship between age and size (shell diameter) of sea urchins at Toe is as follows:

2 nd year--3.21 cm; 3rd year--4.18 cm; 4th year--5.18 cm; 5th year --6.11 cm; 6th year--6.94 cm; 7th year--7.55 cm.

(4) Throughout all the districts sea urchins having a shell diameter of about 6 cm were the most numerous. The more the shell diameter increased or decreased in size the fewer the numbers of sea urchins became. Among all sea urchins with shell diameters over 5 cm a slight difference was

observed between the habitats of the smaller ones and those of the bigger ones. There was a tendency among the four and five-year-old sea urchins to concentrate into special locations, but the tendency for six-year and older was to disperse. The distribution density of sea urchins varied from district to district and from spot to spot.

(5) The state of development of gonads was best in Toe; good in parts of Shiroizumi, Ikantai and Ogifushi; and bad in other locations. Gonads in both male and females were largely in the growth period of the maturation process.

(6) There was a close connection between the percentage of seaweed in the gut and seaweeds growing (including floating seaweeds) in sea urchin habitats. Further, cases where the percentage of seaweed in the gut reached over 80% were frequent among sea urchins having gonad indices of 1.0 and over. Just estimating from the appearance of gut contents it is impossible to establish a clear relationship between food conditions and distribution densities. p.30

(7) Fishing grounds, fishing seasons, size and transplantation, estimated stocks, and amounts suitable for the catch of sea urchins were discussed.

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