Aspects of the Sea Urchin Fishery in Japan

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ABSTRACT

Supported by heavy demand for hard roe by the Japanese people, the sea urchin fishery produces annually more than 25,000 tons from domestic littoral waters. This large harvest makes the fishery of considerable significance amongst Japanese artisanal fisheries, especially on the coasts of Hokkaido, Sanriku and Kyushu Districts. The rich resources of Japanese sea urchins consist of 8 echinoid species, though three predominate: Hemicentrotus pulcherrimus (bafun-uni), Pseudocentrotus depressus (aka-uni) and Anthocidaris crassispina (murasaki-uni). The best seasons for ripe sea urchins of these species are February-April, August-October and June-August, respectively.

Processed roe, or seasoned and aged ones, are still in good demand. Annual amounts of these processed products are estimated to be about 4,000 tons per year. Recently, however, fresh roe has become more favored by the Japanese people. To supply the market demand for fresh roe, 14% of which are steamed, imports recently reached 2,700 tons per year. Imports coming from North and South American countries account for 33% of the total. These imports are expected to compensate for the lack of supplies of fresh roe during the poor winter season in the domestic fishery.

The unstable or decreasing domestic production has resulted in measures being considered for increasing supplies. Both mariculture and new food processing technologies are being developed. The mariculture technology principally relates to fishery biological (control) methods for propagation in the field. The food processing technology is mainly devoted to the quality control of fresh roe as raw material. In this connection, freezing techniques for preservation, partly protected by a Japanese patent, will help to secure increased domestic supplies and international imports.

SEA URCHIN FISHERY PRODUCTION IN JAPAN

The traditional heavy demands of hard roe (gonads), by the Japanese people over some hundreds of years of their history, has meant that the sea urchin populations are an important part of the resources for the Japanese artisanal fisheries in littoral waters. The sea urchin fisheries in Japan produced an average of 25,000 tons (range 24-27,000 t) over the 5 years, 1978-82, in western Kyushu (Nagasaki Prefecture), Sanriku or eastern Tohoku (Iwate Prefecture) and Hokkaido (Soya Province)

Table 1. Fluctuations of sea urchin catches (tons, total weight with shell) in important regions of Japan, 1978-1982. (D = District; Pref. = Prefecture; Prov. = Province; R = Region). Source: Japanese Government Statistics.

Item	1978	1979	1980	1981	1982	Average
All Japan	25930	26500	24158	23984	25975	25309.4
Hokkaido R	9764	10221	10866	9517	10639	10201.4
Soya Prov	2599	2905	2780	2558	3387	2845.8
Nemuro Prov	2040	2019	2001	1961	1908	1985.8
Oshima Prov	1186	1314	1594	1374	1612	1416.0
Sum	5825	6238	6375	5893	6907	6247.6
N Pacific R	7236	7361	4317	5395	6954	6252.6
Aomori Pref	1436	1638	1043	1480	2029	1525.2
Iwate Pref	2942	3201	1963	1779	2286	2434.2
Miyagi Pref	2578	2399	1236	2047	2536	2195.2
Sum	7136	7238	4242	5306	6851	6154.6
W Japan Sea R	1497	1238	1291	1420	1296	1343.0
Yamaguchi Pref	1118	842	887	958	786	918.2
E China Sea R	6017	6086	5944	5993	5558	5919.6
Nagasaki Pref	3659	3616	3733	4041	3455	3700.8

Districts (the dominant production region in each district is in parentheses). Almost 90% of the total domestic production is from these three districts, with 23.4, 24.7 and 40.3% of the total catch, respectively (Table 1, Fig. 1).

JAPANESE SEA URCHIN RESOURCES

The rich sea urchin resources in Japanese waters are composed of 8 echinoidean camarodont species (Tables 2), three of which are of major and five of minor importance. The major species are Hemicentrotus pulcherrimus, Pseudocentrotus depressus and Anthocidaris crassispina and the minor ones are Strogylocentrotus intermedius, S. nudus, Tripneustes gratilla, Mespilia globulus and Temnopleurus toreumaticus. The three major species are found in southern Japanese waters (mid-Honshu to Kyushu). Among the minor species, Strongylocentrotus species, represented mainly by S. intermedius, are principally found on the coasts of Hokkaido, while the other species are seen on shores in southern Japan. About 13% of the common echinoideans of Japan are regarded as edible by the Japanese public.

Table 2. Japanese Echinoideans: systematic composition in number of biologically important species with number of important edible species in parentheses (after Utinomi, 1965).

Class Echinoidea			
Cidaroidea	9	Holectypoida	1
Lepidocentroida	5	Cassiduloida	1
Stirodonta	3	Clypeastroida	11
Aulodonta	4	Spatangoida	9
Camarodonta	20(8)		

The ripe season of the important species are summarized as Spring or Summer to Autumn (Table 3). The species are found in shallow waters where they are taken by diving or on rocky shores where they are taken by hand.

Table 3. Important edible sea urchins in Japan with their distribution (range), habitat and ripe season (after Utinomi 1965, and Shiino 1969).

Species/Japanese Name	Range/Habitat	Ripe Season
Hemicentrotus pulcherrimus (A. Agassiz), Bafun-uni	endemic, N Honshu to Kyushu/gravelly shores	March-April
Pseudocentrotus depressus (A. Agassiz), Aka-uni	endemic, Tokyo Bay to Kyushu/shallow waters (0-5m depth)	October-November
Anthocidaris crassispina (A. Agassiz), Murasaki-uni	mid-Honshu to Kyushu/rocky shores	June-August
Strongylocentrotus intermedius (Agassiz), Ezo-bafun-uni	Tohoku to Hokkaido/neritic (0-35m depth)	July-August or September-mid-October
Strongylocentrotus nudus (A. Agassiz), Kita-murasaki-uni	Sagami Bay and Tsushima Is to Hokkaido/neritic (0-180m depth)	September-November
Tripneustes gratilla (Linnaeus) Shirahige-uni	Indo-Pacific, Kii Peninsula to southern waters/ shallow waters	early July-August
Mespilia globulus (Linnaeus), Koshidaka-uni	Sagami Bay to Kyushu/gravelly shores	July-August
Temnopleurus toreumaticus (Leske), Sansho-uni	mid-Honshu to southern waters/ shallow sandy bottoms in inlets	late June-July

Of these exploited species, Hemicentrotus pulcherrimus has the highest esteem in Japan, because the color of its roe is most appetizing, while Anthocidaris crassispina is dominant from both the view point of biological distribution as well as actual consumption.

SEA URCHIN CONSUMPTION AND IMPORT OF MATERIALS

For a long time, sea urchin roe principally has been utilized in Japan as processed roe, or seasoned and aged ones. Recently, there has been a shift from them to fresh roe, including simply steamed or gilled, though the processed roe is still in good demand. It is provisionally estimated that the fresh roe in markets represents about 80% of total production. The main market for the fresh roe is apparently the Japanese sushi restaurant. The annual total production of processed roe may be about 4,000 tons, including secondary roe products (Table 4).

Table 4. Processed products (tons) of sea urchin roe in Japan for 1978-1982. Content is expressed as net weight (%) of salted roe, standardized by JAS and producers. Secondary products include mixtures of fish (jellyfishes, scallops, abalones, squids, crab meat, herring roe, etc.) or farm products (Cortinellus mushrooms, etc.) dressed with salted roe. Source: Japanese Government Statistics, modified.

Item	Content	1978	1979	1980	1981	1982	Average
Total	--	4172	4383	4640	4379	3225	4195.8
Seasoned and Aged	65-90	1319	1309	1398	1372	1225	1324.6
Secondary Products	20-25	2853	3074	3242	3007	2000	2835.2

To satisfy the main markets because of the increasing fresh roe consumption, the hard roe has been imported from overseas, especially since 1972, and recently reached a total of 2,700 tons per year, 14% of which is in the form of steamed roe (Table 5). The overseas products come from 12-14 countries in Asia, North and South America, U.S.S.R., as well as Norway and Austalia. The North and South American exports (Table 6), from Canada, U.S.A., Mexico, Peru and Chile, represent 33% of the total quantity mentioned above; at present, the U.S.A. (southern Pacific coasts), Canada and Chile are the major exporters to Japan. They are expected to supply the total need for raw material during the winter or poor season in the domestic sea urchin fishery.

The unstable or decreasing supply from domestic sources since 1970, has resulted in measures being considered for increasing production and both the mariculture and food processing technology sector are interested in the problem.

Table 5. Quantities of sea urchin hard roe (tons) imported into Japan, 1978-1983. Crude items are, fresh materials, including frozen, salted and alcohol-added ones and prepared ones are steamed materials (listed only for 1982-1983). Source: Japanese Government Statistics, modified.

Item	1978	1979	19890	1981	1982	1983	Average
Crude	2314.7	2505.5	2206.8	2425.9	2396.9	2321.1	2361.3
Prepared	———	———	———	———	———	———	———
Number of exporting countries	13	14	13	12	12	13	———

Table 6. North and South American exports (tons) of sea urchin raw material (crude and prepared, cf. Table 5) to Japan, 1978-1983. Source: Japanese Government Statistics.

Item	1978	1979	1980	1981	1982	1983	Average
Total	778.4	1196.6	736.4	927.0	598.9	571.3	801.5
Percent of total Japanese imports*	33.6	47.8	33.4	38.2	25.0	24.6	33.9
Canada	0.3	19.7	26.6	14.9	23.9 ———	69.1 ———	25.8
U.S.A.	485.9	759.0	590.3	637.4	497.5 (6.7)	411.2	563.6 ———
Mexico	44.6	25.7	14.1	15.1	4.6 ———	4.0 ———	18.0
Peru	———	22.4	16.4	21.3	13.7 ———	2.0 ———	15.2
Chile	247.6	370.1	89.0	238.3	59.2 (259.4)	85.0 ———	181.5 (373.5)

* Only in reference to crude items.

MARICULTURE AND BIOLOGICAL CONTROLS IN SEA URCHIN FISHERY

Mariculture or biological control technology is focused on: 1) recruitment control, or repopulation, by artificial seed; 2) quality control by hybridization; 3) environmental control in the micro-ecosystem; and 4) fishery control through regulations. Further details are given in some case studies which follow.

(1) Recruitment an quality controls by artificial seeds: the case in Yagamuchi Prefecture.--Yamaguchi Prefecture has been for a long time an important center of the sea urchin fishery, especially processing industries, in Japan and regional catches reached a maximum of 2,065 tons in 1970, but have decreased annually since then to less than a half that total (Kakuda 1983). According to the annual reports of the Prefectural Fisheries Experimental Station (Inoue 1982), basic biological studies began in 1958 for the rehabilitation of the sea urchin fishery on the coasts of the Japan Sea. First developed were artificial breeding techniques for Hemicentrotus pulcherrimus, Pseudocentrotus depressus and then, since 1964 Anthocidaris crassispina, as well as hybridizing techniques for H. pulcherrimus and P. depressus. During these studies, it was recognized that the phytoplanktonic Chaetoceros gracillis is the preferred food for the planktonic echinopluteus stage. The hybrids grow up intermediate between the parents, and their gonads develop (1.2-1.3 in gonad index) and appear in color (orange) better than in Hemicentrotus pulcherrimus, the favorite species. Since 1974, stocking was tested with the artificially produced seeds of Hemicentrotus pulcherrimus, Pseudocentrotus depressus and their hybrids. The habitats (communities of Sargassum fluvellus, Eisenia byciclis, Ecklonia cava, etc.) are considered as ideal for the sea urchin species as they are rich in their food.

In the case of the above experiment (Kakuda 1983), gravel beds were suggested to be better than rocky substrates for stocking, probably because of the higher carrying capacity, even if the rocky substrates have much more (3-6 times) food available than the gravel beds. On the gravel beds survival for about one year is estimated to be much higher (65-76%) than on the rocky substrates (38%) in the case of Pseudocentrotus depressus, regarded as the best species for stocking.

In any case, if the seeds are large enough (more than 10 mm in shell diameter) and resistant to the mortality caused by such predators as starfishes and crabs in the same habitat, the stocking is remarkably effective, because the seeds grow up faster than the natural young.

(2) Recruitment control by preparing artificial beds: the case in Hokkaido District.--For the last 10 years, the sea urchin fishery in Hokkaido has had annual catches of 10,000 tons, with good increases since 1977. Because of the benthic or sessile nature of the animal, however, the fishing effort may easily become too large, and it is estimated that it is able to take 70% of the total local catchable stock in a single season (Kawamura 1983). This is the reason why artificial propagation techniques should be considered. In this district they are interested, therefore, in collecting natural seeds for stocking and preparing breeding and nursery beds for settlement of the seeds, mainly for Strongylocentrotus intermedius (Kawamura 1983).

Natural seeds are collected by constructing a reasonably large, artificial nursery bed, made of rocks and gravels, by picking up from kelp culture facilities, as well as by setting out special collectors, which are made of a 30 x 30 cm sized pieces of vinyl chloride plate (a unit plate) (Table 7). The efficiency of the operation may be shown by the annual 1.5 million seeds (maximum) from mariculture and 2 million seeds (1981) from collectors (Table 8).

Table 7. Typical composition of the natural seed collectors for Strongylocentrotus intermedius in Hokkaido (after Kawamura 1983).

Unit Plate	Transparent wavy plate (30 x 30 cm) made of vinyl chloride; three plates set in unit block
Unit Link of Blocks	Ten unit blocks connected on an hanging line 25 m long
Unit Set of Links	Assemblage of nine unit links (90 unit blocks)
Unit Set of Collectors	Four unit set of links (360 unit blocks) connected by the top end of the line to a supporting rope 100 m long

Table 8. Efficiency (density, range (mean)) of natural seed collection of Strongylocentrotus intermedius in Hokkaido facilities (after Kawamura 1983).

Facilities	Seed	Density	Survey Year
Artificial gravel beds	0 age	14-96 (47.6) individuals/m^2	1980
Natural seed collectors	Larvae	47-364 (173.0)x1000 individuals/m^2	1979-1981

The preparation of artificial nursery beds is necessary to accelerate growth of the young and to make them ripen properly. Nursery beds are regarded as especially appropriate for *Strongylocentrotus nudus* (Table 9), and may be more effective in considering them in combination with recruitment from breeding beds or by restocking of seeds (natural or artificial). Transplantation of young may be effective: (i) from areas with poor food supplies to areas with rich food supplies, and (ii) from areas of high temperatures inappropriate for survival to areas where the temperature is optimum for their growth. There are cases where the fishery may depend exclusively on annual transplantations. In these cases, the quantity transplanted may reach half of the amount of annual production.

Table 9. Efficiency of the artificial nursery beds for *Strongylocentrotus* species in a Hokkaido project. Efficiency is given in terms of number of individuals per m^2 in total base area of the beds/number of individuals per m^2 in natural fishery ground; the nursery beds, consisted of about 13,000 specially designed concrete blocks (1.5 x 1.5 x 0.6 m in size), set out in 1974 (after Kawamura 1983).

Species	1977	1978	1979	1980	1981
S. intermedius	3.7	0.9	0.7	1.1	5.3
S. nudus	7.9	19.0	8.2	5.5	62.0

(3) Environmental control of the micro-ecosystem: the case in Sanriku District.--Sankiru District, represented by Iwate Prefecture, is known as one of the mariculture centers of Japan. The fishermen are active in promoting this industry, and have produced a major part (24.7%) of the total sea urchin catch in Japan.

Environmental control relates to the food web complex, especially among sea urchins, abalones, kelps, and calcareous algae (corallinacean rhodophytes) in the District. To some extent, on Japanese rocky shores, we often recognize remarkably poor or damaged habitats in terms of utilizable sea weeds with instead, calcareous algae dominant. Rocky shore areas are usually a favorite habitat for sea urchins as well as abalones, because of the rich distribution of kelps. In fact, it is highly probable that seaweed predators such as sea urchins are a major factor in causing such undesirable changes in the habitat; when this happens, the animals may be damaged in turn, for it results in complete disturbance of their breeding areas, usually for several years. A survey in the region concerned revealed that sea urchins must cause considerable mortality to vegetation on the sea bed through having densities of more than 200 g/m^2. The problem is, then, for the establishment of conditions for a flourishing seaweed community. The algal succession in the ecosystem in Sanriku District and adjacent regions (Kanno, 1976), is summarized below.

The succession should move between the Laminaria japonica community and the calcareous algae community. The former climax community is distinguished by the Laminaria kelps, and the latter by the "poor" rocky shore conditions. In an ecological sense, the Laminaria kelps occur on the coasts with low water temperature in Hokkaido District, and the poor rocky shores on coasts with higher temperatures in Miyagi Prefecture. Control of the habitats should be considered through positive restocking of the predators, sea urchins and abalones, in the Laminaria climax community, or else by removing them from the calcareous algae climax community. It must be emphasized here that the problem is rather complicated in this case, because, as referred to already, the Laminaria kelps are a major food resource for the Japanese people - equally as much important as their predators; in addition young Laminaria buds are important food of the animals on the shore. Therefore, the kelps and animals in question must be maintained together at a reasonable population level. For this purpose, special plantation facilities are recognized as useful in the Sanriku and Hokkaido Districts.

(4) **Fishery control by regulation.**--As in all other marine fisheries, effective regulations may be good for development of the sea urchin fishery. In Japan (Kawaguchi 1983), some local governments have regulations for closed seasons (4 Prefectures) for minimum size (6 Prefectures).
In Hokkaido (Kawamura 1983), local government regulates the fishing operation by setting closed seasons during the peak ripe season by species and by region. The fishermen's associations in the districts are also very active in regulating their operations by themselves during the fishing season (2-3 months in most cases) and daily operation (2-4 hours in most cases).

QUALITY CONTROL OF ROE MATERIALS

Food processing technology has been developed mainly to control or improve the quality of fresh roe as a crude material. This relates to freezing techniques in order to secure materials from domestic sources as well as through international imports.

Freezing techniques are very important for preserving sea urchin roe, as it is already well known than the frozen roe can be frequently burned, or black-colored in tissues deteriorated after thawing. The developed techniques characteristically apply either a vacuum-freeze-dry method at thawing (Tanaka et al., 1970), or a low-level freezing method in the presence of a deoxygenizer (Uchiyama, et al., 1984) to prevent damage.

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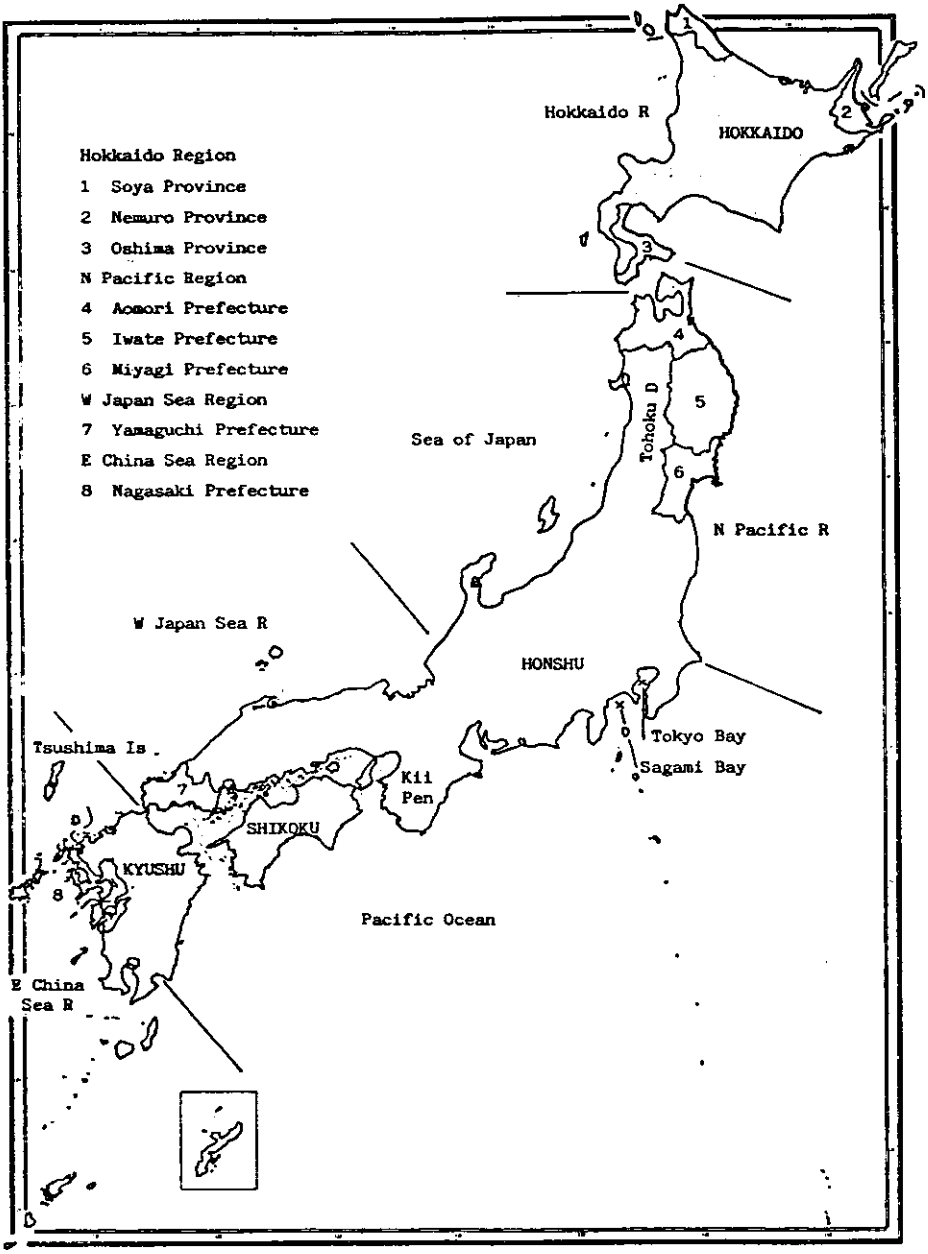

Figure 1. Main origin of sea urchin fishery production in Japan by fishing area (R) and by administrative section (1-8). For the biological distribution (Table 3), related locations are indicated.

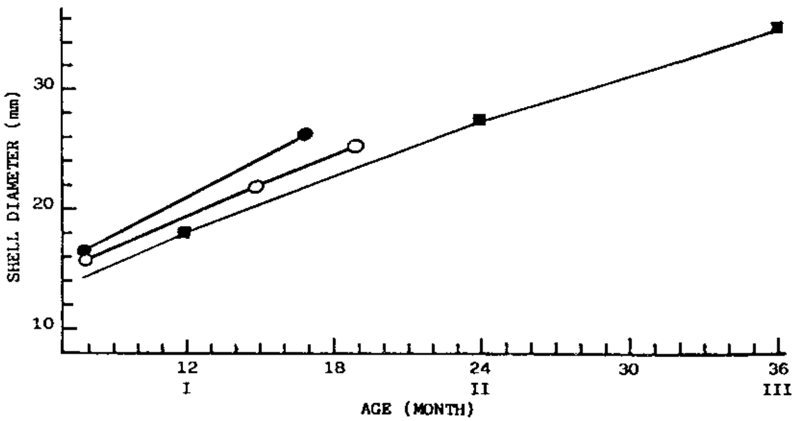

Figure 2. Growth trends of artificial seeds (Hemicentrotus pulcherrimus) repopulated by artificial gravel beds of 1 m depth in October 1978 (open circle) and September 1979 (closed circle). Growth of natural population (closed square) are estimated in the same location. Scale for growth begins at the hatching period (after Kakuda 1983).