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Methods for increasing production of edible seaweeds

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Methods for Increasing Production of Edible Seaweeds (2)

I. Propagation of Edible Seaweeds

1) Foreword

Table 1 shows the changes in the production of seaweeds over the years. The amount of cultured laver has shown favourable growth except during the war years. Cultured Undaria pinnatifida and in China cultured Laminaria have also increased rapidly, whereas the increase of Laminaria, which has been one of the items in the propagation programme in Japan, has been slow and the production of Gloiopeltis furcata has decreased. From the local point of view, the production of Laminaria japonica and Laminaria angustata has either remained unchanged or has decreased. The increase in overall production has been made possible mainly by the

Table 1 Change in Production of Seaweeds

(5 years average; unit: raw ton; Norin statistics)

	1913	1918	1923	1928	1933	1938	1943	1948	1953	1958	1961-1962
Propagation:											
Laminaria	48	88	150	252	227	305	132	139	148	142	151
Undaria pinnatifida	-	-	15	19	26	37	31	-	48	51	61
Gelidium amansii	5.0	5.5	5.4	8.0	10.7	12.3	-	-	16.6	15.3	11.5
Gloiopeltis furucata	2.5	3.1	3.2	3.8	4.4	4.7	3.7	-	-	2.2	1.9
Culture:											
laver	8	10	18	23	27	33	36	18	45	81	139

exploitation of the Laminaria angustata var.longissima belt along Nemuro and Kushiro. As for Gelidium amansii, the production in traditional places such as Shirahama of the Shizuoka prefecture (illust. 5) and Susaki has remained static. The increase has been achieved by the exploitation of new places such as Onbase of Kamitsushima and by the intensification of the catch, but the overall effect of propagation has not been clear in our statistics. Since the choice of the particular kinds of seaweed to be cultured is made according to the possibility of economic success in connection with supply and demand (whereas in China the Laminaria culture is promoted because it is considered necessary for the health of the people) and the profit is returned to the people, the investment of capital and labour is encouraged and technical improvement is also demanded. Since it is only a matter of speeding up the growth with the use of the water surface, place and technique are not restricted.

The investment for the propagation of seaweeds is under the present system made by the union. In general this has discouraged investment and as a result the development of techniques has not been fast. The place chosen for the propagation is a shore reef and hence the growth of seawood is restricted by the geographical formation. For economic reasons the effect of propagation must be long and stable and this prohibits the freedom of technical experiments.

2) The Amount of Investment and the Result (3)

Some people used to believe that the whole investment would be redeemed within a year after throwing rocks into the water, but the results of recent investigations on the subject have disproved this idea. Take Gelidium amansii, for example: if we want to double the production of, say, 30,000 dollars a year, we need 100,000 dollars capital for rocks in an excellent spot such as Izu, and for a middle class place we need 200,000 to 270,000 dollars capital. # The same idea is applicable to porphyra growing on rocks.

The production of seaweeds, excluding laver, amounts to 17 to 20 million dollars a year and the propagation business capital for 1963 was 0.7 to 1 million dollars. # Even if we assume that the business capital is redeemed in 3 to 6 years, which is the minimum range, the yearly increase in capital is about one percent, which is not large enough to show up clearly in the statistics. It is hoped to have a great increase in capital which, in turn, requires a greater effort to put it to good use.

3) How Do Seaweeds Grow?

The differences in seaweeds in the Hokkaido and Kyushu areas are caused by differences in water temperature,

calculated as 300 yen to 1 dollar

in the nourishment provided by the warm and cold currents, and in the strength of the light. But even in a small area which seems to have uniform natural conditions, seaweeds vary in kind and in the quantity of growth. This variation is caused by the land formation at the bottom of the sea, the angles of the light coming to the area, the depth of the sea, the quantity of fresh water from rivers, etc. These conditions are not easily changed.

After scraping the rock surfaces or throwing rocks into the water we observed that seaweeds grow in the following order.

a) Diatomaceae and Cyanophyceae

b) (2-3 months) plants: Porphyra growing on rocks, Endarachne binghamiae, Enteromorpha and Melobesioideae.

c) Small annual plants- Gracilaria verrucosa, and Meristotheca populosa;
Large annual plants- Undaria pinnatifida and Akamoku;
Melobesioideae.

d) 2-3 years plants: large- Laminaria and Sargassum ringgoldianum.
2-3 years plants: small- Gloiopeltis furcata, Iridophycus cornucopiae, and Chondrus ocellatus.

e) Perennial plants: large- Sargassum bacciferum, Eckloris bicyclis, Cystophyllum fusi-forme, Phyllospadix iwatensis and Ecklonia cava.

Perennial plants: small- Gelidium amansii and
Corallinoideae;
Melobesioideae (perennial).

This order does not necessarily hold everywhere. Sometimes the development stops after the first few stages. The kind of plant which grows at each stage and where the process stops depends upon the conditions of the spot. The time of year when the rocks should be thrown in is considered to be a problem. Surely the particular plant that will grow at the B stage will depend upon the time that the rocks are thrown in the water, but the growth process will still reach the D and E stages. The plants to be cultured are those in the B stage and sometimes those in the C stage. Utilizing the surface of the water it is possible to obtain wave conditions according to our set-up. Since the purpose of propagation is to obtain a stable effect on the rock surface over many years, this restricts the freedom.

Propagation is described as follows: (4)

1) In order to change the stable stratification (usually D or E) of the spot, the geographical formation must be changed. On a small scale, overhanging rocks can be exploded or crevices can be cut into rock slabs which are too high. These things change the seaweeds. If the geographic formation is not changed, but Corallinaceae is eliminated, there will be no permanent improvement.

In short, throwing in rocks has the effect of enlarging the area under the same geographic conditions. It is not possible to grow Gelidium amansii by throwing rocks in the midst of Corallinaceae.

In Izu if you throw rocks into the place where Gelidium amansii grows 5 kg/m^2 the same amount of Gelidium amansii will also grow on the rocks. If you throw rocks under high rocks where Undaria pinnatifida grows it would not grow on these rocks. As exception, if you throw in a different type of rock above the low tide line you will get a different result. For example, if you throw in andesite in the Miura Peninsula area which is clayey, Gloiopeltis furcata grows better on the rocks than on the surrounding area. In the case where rocks are thrown in under the low tide line, the kind of rock does not make much difference, except for especially fragile rock. It seems that some structures such as iron and expand metal when put into the water have the same effect as changing the geographical formation.

2) For the propagation of seaweeds at the B and C stages it is better to choose places where the A to E process stops at B or C. Otherwise the effect

of propagation would not last. An example is the shore reef where Porphyra grows.

In many places other weeds grow gradually and the A - E process is apt to move to the D, E stages. In this case, it is recommended to clean the rocks by removing these weeds. In the places where the A - E process progresses very rapidly it is necessary to remove the weeds quite often, which is a disadvantage.

3) From one Undaria pinnatifida or Laminaria plant several hundred million spores are created. Even one Gelidium amancii plant creates several million spores. Hence the shortage of spores could not be the reason for limited germination. Even if there is a lean year and the production is cut down to one-tenth that of an average year, this would not influence the production of the next year. The quantity of germination mainly depends upon the yield of spores. That is to say, it depends upon the conditions of the location. Even if young plants are put in a place where the growth of Gelidium amancii is scarce, there will not be satisfactory propagation.

As for Porphyra on rocks . the yield of the filaments is small in summer, but if cultured filaments are used germination increases. In the case of Undaria pinnatifida also the yielding of filaments in summer is small. Hence, when the planting is done in autumn, which is the germination season, production increases. In short, what must be done is protect the plants during the period when the yield is small and plant later when the the yield is large. If this is done, we can grow plants for one year even outside the growing area.

4) Over-harvesting seldom affects the next year's production. Resuscitation of the remaining plants and spores makes up for it. You can take as much as you can. Exceptions are the following perennial plants which do not have a strong resuscitation ability: Ecklonia cava, Eckloris bicyclis, Gelidium subcostatum and Acanthopeltis japonica. In these cases over-harvesting affects the production of the next year.

The year's production often depends upon the method of harvesting. If Gelidium amancii, Undaria pinnafitida, Laminaria and Porphyra on rocks (5) grow densely, thinning out encourages the growth of the rest and brings about increased production.

5) It is expected that the introduction of foreign species brings about abnormal propagation.

II Porphyra Growing on Shore Reefs (Rocks)

1) Foreword

It is rather difficult to estimate the annual production of Porphyra growing on shore reefs since these seaweeds are mainly consumed locally. Table 2, however, gives a rough idea.

Table 2 Production of Porphyra growing on Rocks (Average of 1957 - 1960, Norin Statistics)

National	17.02	Shimane	2.75
Hokkaido	4.22	Nagasaki	0.86
Yamagata	1.41	Iwate	0.25
Ishikawa	0.87	Miyagi	0.75
Kyoto	0.59		

unit: 10 million sheets

2) Species and their Ecology

The important seweeds in this category are: long and narrow Porphyra pseudolinearis and Porphyra dentata which are both hermaphrodite; and wide Porphyra yezoensis, Porphyra okamurai and Porphyra suborbiculata which are hermaphrodite.

The distribution is shown in Illustration 1. The shape varies to a great extent even among the same kind. If they grow densely in a place where there are good conditions they tend to become long and narrow.

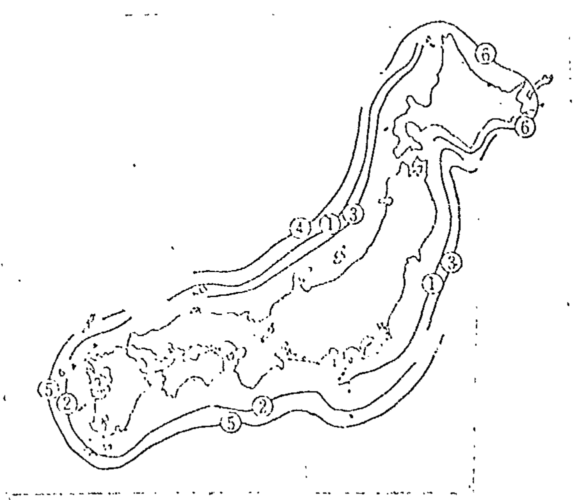


Illustration 1

Distribution of Porphyra on Rocks

(1) Porphyra pseudolinearis

(2) Porphyra dentata

(3) Porphyra yezoensis

(4) Porphyra okamurai

(5) Porphyra suborbiculata

(6) Porphyra umbilicalis

In general, they germinate around autumn when the (6)
water temperature drops down to 20° C., grow to their full size during winter to early spring, and disappear when the water temperature is 15 - 16° C.

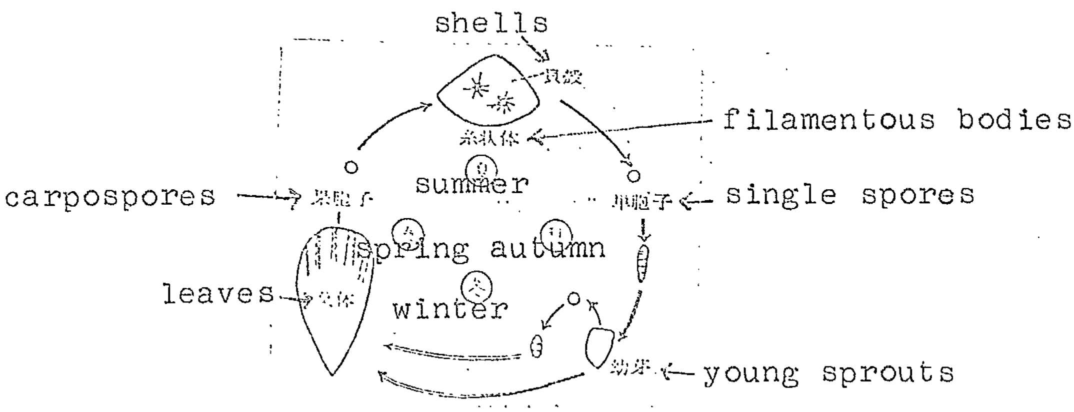
They grow in wavy places. Since on the coast of the Sea of Japan the difference between high and low tide is small and the water is calm in the summer and rough in the winter, the seaweeds grow in the autumn on rocks above the low water line where the waves wash over them. When the sea calms down in the spring they disappear. On the other hand, on the Pacific Ocean coast the wave conditions do not differ to a great extent in summer and winter and the difference between high and low tides is large. Hence, the place where the seaweeds grow is only a little above the average water level where they are properly exposed to the air.

As exceptions, Utasutsunori of the west coast of Hokkaido grows several metres beneath the water surface and Scytosiphon lomentarius also grows beneath the water surface above the Chorda filum species. Porphyra onoi and Porphyra variegata grow above some other seaweeds.

Growing periods are different according to the species. In general, long and narrow Porphyra pseudolinearis and Porphyra dentata grow fast . Popphyra okamurai, porphyra yezoensis and porphyra suborbiculata which perform secondary propagation by single spores grow slowly. Porphyra are small and annual plants. They grow on new rock surfaces first. If the rock surface is covered by some other seaweeds or Diatomaceae, then fewer seaweeds will be found to grow there. The difference between a good harvest and a poor harvest year is great. The cause is not fully understood. It is known by experience that we will have a good harvest year if the water temperature is lower and the waves are strong in winter.

3) <u>Life History</u> (Illustration 2)

When the plants mature they create carpospores. The carpospores are released into the sea and lodge themselves in shells or barnacles. They spend the summer in the form of filamentous bodies. In autumn they become spores, leave the shells and fasten themselves onto rocks to become seaweeds. In the case of Porphyra yezoensis and others the cells around the rim of young sprouts in autumn become spores (single spores or neutral spores) and detach themselves, germinate into seaweeds, and thus increase their numbers. In the case of Porphyra dentata this type of propagation occurs when the sprouts are even younger. In the case of Porphyra pseudolinearis and Porphyra umbilicalis there is no such propagation.



<u>Illustration 2</u> Life History of Porphyra yezoensis

= on shore reefs

- in sea water

Porphyra umbilicalis growing in cold current belts around Hokkaido flourish from spring to autumn and spend the winter in the form of filamentous bodies.

Several hundred thousand carpospores are made in one seaweed plant but they decrease to a great extent by autumn. After germination in autumn the yield is large. Our guess is more than one-tenth. The seaweeds which germinate through single spores even increase their number. In culturing seaweeds it has become common to culture filamentous bodies during the summer, ensuring the highest possible yield, and then to plant them in the autumn. This method has increased production to a great extent. We expect that the same method can be applied to Porphyra growing on rocks. In culturing seaweeds, secondary germination is effectively utilized. We think the same thing can be done with Porphyra on rocks. Although it is not satisfactory, Table 3 shows examples of times and temperatures for the release of spores from filamentous bodies and from young sprouts. (7)

Table 3 Proper Temperatures for the Formation and Release of Spores of Porphyra on rocks

Species	Spores from filamentous bodies	Spores from young sprouts
Porphyra pseudolinearis	24 - 15°C Sept-Nov (Tohoku, Japan Sea)	?
Porphyra yezoensis	22 - 10°C Oct-Dec (central mainland)	18 - 16°C Nov-Jan (central mainland)
Porphyra umbilicalis	3 - 15°C April-May (Nemuro)	-

4) Propagation (artificial)

The central method is to make concrete surfaces to increase the productivity of the places where seaweeds grow, but they do not build the concrete surface in the places where the production is scarce or non-existant. The method of exploding to create an entirely new place for seaweed to grow is not popular. Throwing rocks into the water is not generally useful because of the rough waves. When we use a breakwater or tetrapod we design them so that other seaweeds can grow there as well. Cleaning the breakwater from time to time is very effective. The method of dispersing spores from filamentous bodies and nourishing them will be used in the future.

The net culture method for culturing seaweeds is not effective for Porphyra since the waves are too rough, but the floating culture method will be introduced and developed very much in the future.

(1) Building Concrete Surfaces: This is done in the places where rock surfaces are very irregular and seaweeds are therefore hard to collect. This method increases the efficiency of collecting seaweeds. This concrete surface must be built during the time when the sea is calm, preferably in August or September, which is close to the time when spores attach themselves to the rocks. First the rock surface must be made smooth and then the concrete is poured over. Customarily, the mixture is 1:3-6. If it is made substantial it will last

six to seven years or longer. In one case in Tottori prefecture, however, it has lasted fifteen years and is still productive.

The economic effect of using concrete surfaces has often been exaggerated. Since in general the construction of concrete surfaces is done in flourishing places we have to carefully examine the difference in production before and after the construction, but this is difficult. Hence, the comparison is made between the production of a concrete surface and that of an adjoining rock not covered by concrete. However, since Porphyra grow densely in some areas and sparsely in some adjoining areas in the same region, if the comparison is made to a rock where the growth is sparce the difference will be exaggerated. The following is a reliable investigation.

Furuhata et al. (1957) experimentally collected (8) seaweeds from natural and concrete surfaces each 2 m^2 which seemed to have the same growth conditions. The results are shown in Table 4. As shown, on the natural surface 34% remained

Table 4 Experimental Collection from 2 m^2

(Furuhata et al. 1957, Kyoto)

Area	Quantity Collected		Time of Collection		Quantity coll. in 10 min.	
	concrete surface	natural surface	concrete surface	natural surface	concrete surface	natural surface
	kg	kg	min	min	kg	kg
1	2.6	2.0	20	60	1.3	0.34
2	5.6	3.8	35	50	1.6	0.75
3	3.8	2.0	15	30	2.5	0.65
Ratio	1:0.66		1:2.0		1:0.33	

uncollected. On the concrete surface the quantity collected per unit time was three times as much as on the natural surface. Katada (1962) also investigated the quantity collected by one person in one day (3 hours) at four fishery unions of the Ishikawa prefecture, and showed that when the quantity collected on the concrete surface is represented as 1, the quantity collected on the natural surface is 0.23 - 0.42, an average of 0.34, which shows that the harvest efficiency on concrete surfaces is three times as much.

Katada et al. (1962) made many collections on 2 m^2 on concrete surfaces and on natural surfaces which have the same natural conditions in 1959 in Kyoto. The collection per 1 m^2 was 744 gm and 429 gm on concrete surfaces and natural surfaces respectively. The yearly harvest was 33.4 sheets and 18.4 sheets respectively, which shows the increase caused by concretizing surfaces was 15 sheets, i.e. $.50 (unit price 3.3 ¢). The investment was $1.30 per m^2, which would be redeemed in 2.6 years. The area he investigated mainly produces Porphyra pseudolinearis. The concrete surface must be durable in order to make a profit.

The productivity from concrete surfaces in above-mentioned Kyoto during 1951-1960 was an average of 40.8 sheets per m^2 but it varied to a great extent from year to year. The maximum production of any year was 63.9 sheets per m^2; the minimum was 19.5 sheets per m^2. The record of four fishery unions of Ishikawa prefecture shows the productivity of

17.6 - 62.0 sheets per m^2. With reference to other records we can say that 50 sheets per m^2 per year (1 sheet equals 3.75 gm) is above average.

Cleaning - If Diatomaceae, disc-type Phaeophyceae, etc. grow densely on concrete surfaces the number of seaweeds attaching themselves to the surface will be decreased. In the worst event sodium hydroxide is used on the concrete surface. It is recommended to use wire brushes or to pour gasoline over the concrete to be burned. 10% sodium hydroxide was used on the concrete surface in Watarujima , Hokkaido where the weeds were dense. The production in March of the next year was 24.5 gm per m^2 (dry quantity) from the uncleaned surface, whereas the production of June was 33.5 gm per m^2, July 36.5 gm, August 75.5 gm, September 50.5 gm, and October 43.5 gm from the cleaned surface. (Tokida et al.1961)

(2) <u>Explosion of Shore Reefs</u>: The result and expense of cutting rocks at the height of 3 meters in Kyogasaki, Kyoto are the following: Expense - $1400, Area- 350 m^2, Production - 49 gm per 0.5 m^2 and assumed production at a time was 3,570 sheets. Since we have four harvests a year, if we assume the price per sheet to be 3.3 ¢, the annual production would be 3.3 x 4 x 3,570 or $470. This indicates that the capital would be redeemed in three years. The assumed (9)
production might be a little exaggerated.

(3) Planting Young Seaweeds Utilizing Filamentous Bodies

In 1960 Hyogo Water Research Institute made a hole of 15-18 cm in diameter and 20-25 cm in depth per 15 m^2 in concrete surfaces. Four or five filamentous bodies were placed in the hole and then rocks were placed at the entrance of the hole in order to prevent the filamentous bodies from washing away. This was done on October 22nd. One month later germination took place around the hole. Two months later the first harvest occurred, and later during the year there were four subsequent harvests. The total production was 2,300 sheets for 90 m^2, which was twice as many as in the average year (1 sheet; 5-6 gm, 33.5 x 22.5 cm). There are many cases of failure - in some cases the filamentous bodies are washed away and in other cases they dry out and die. Hyogo Water Research Institute used rocks and was successful but it also recommended to wrap the filamentous bodies and small stones with metal nets when placing them in the holes. This method is recommended for places where the seaweeds do not grow densely. This method is also used for transplanting seaweeds in order to improve the species.

III Gelidium amansii

1) Foreword

Table 5 shows the amount of domestic production and imports of seaweed materials for vegetable gelatin. The main imports are as follows: Gelidium amansii - 1,500 tons from Portugal, 1,300 tons from Chile; Graciliara - 1,270 tons from

Argentina, 890 tons from the Union of South Africa; amounting to approximately 2 million dollars in total. Imported seaweeds are not good quality but they are less expensive and hence the price of foreign seaweeds has been influencing the domestic price.

Table 5 The Supply of Seaweed Materials for Vegetable Gelatin (unit: dry ton; Shizuoka Water Research Institute)

Years	Domestic Production			Imports			Total		
	Gelidium amansii	Gracilaria	Total	Gelidium amansii	Gracilaria	Total	Gelidium amansii	Gracilaria	Total
1958-1960	3,327	2,812	6,139	1,680	1,187	2,867	5,007	3,999	9,006
1961-1963	3,158	3,498	6,656	2,653	2,861	5,514	5,811	6,359	12,170

In 1963, Gelidium amansii produced in Shizuoka prefecture was priced at about $1.50 per kg, whereas the same from Portugal was $0.50 per kg and Gracilaria from Argentina was about $0.30.

The demand for seaweed materials besides for manufacturing vegetable gelatin is little and is only 1,000 tons.

Table 6 shows the production of vegetable gelatin. Industrially produced vegetable gelatin for which the principal raw material is Gracilaria has developed very rapidly.

Table 6 Production of Vegetable Gelatin (unit: 1,000 lb., Shizuoka Water Research Institute)

Years	Natural	Industrial	Total
1956 - 1959	3,679	713	4,392
1960 - 1963	3,669	1,714	5,383

Table 7 Production of Domestic Seaweed Material for Vegetable Gelatin (10)
(1956-1957; unit: 1000 kg equals 8270 lb, Yamazuki)

Gelidium amansii	713	Acanthopetis japonica	45
Gelidium japonicum	75	Gelidium subcostatum	151
Dorakusa	36	Egonori	44
Igisu	21		
Gracilaria verrucosa	480		
Others	34		

Table 8 Prefectural Production of Gelidium amansii (1958 - 1962; unit: raw ton; Forestry Statistics)

Nation	13,149	Tokyo	3,259	Wakayama	451
Hokkaido	924	Kanagawa	445	Shimane	379
Chiba	521	Shizuoka	3,295	Nagasaki	424

The yield of vegetable gelatin from domestic Gelidium amansii is said to be 28% and from Gracilaria 19%. Although we do not know the details, Korea, which supplied seaweed material for vegetable gelatin before World War II, has been producing vegetable gelatin and exporting it to compete against the Japanese product.

The production of domestic seaweed material for vegetable gelatin is shown in Table 7 and the prefectural production of Gelidium amansii is shown in Table 8.

2) Species

Gelidium amansii is the most important and makes the better quality of vegetable gelatin. It grows below the low-water line down to 20 - 30 m. deep in the Izu district. Gelidium subcostatum grows below the low water line down to 40 m. at the deepest spot and the quality is

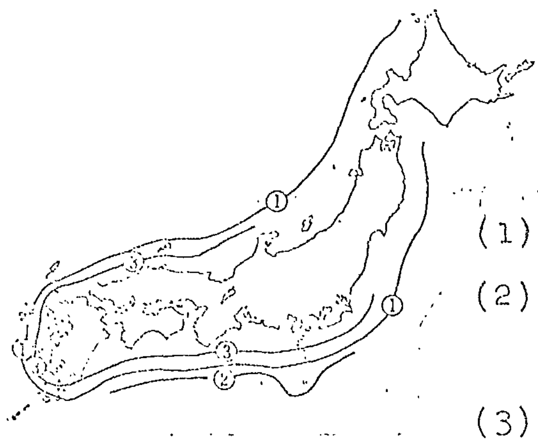


Illustration 3

Distribution of Gelidium amansii

(1) Gelidium amansii, Pterocladia tenuis
(2) Gelidium subcostatum, Gelidium pacificum, Acanthopeltis japonica
(3) Gelidium japonicum

is inferior to that of Gelidium amansii. Gelidium pacificum and Gelidium japonicum grow down to 4 - 5 m. where the water

is rough. The product made from them is of good quality. Pterocladia tenuis grows in shallow places and Acanthopeltis japonica grows in deeper places. Both produce inferior gelatin. The production of these species is shown in Table 7 and the distribution is shown in Table 8 and Illustration 3. The areas in which they grow are under the influence of warm currents and the water temperature never drops below 2°C. The main reason that more than 60% of national production is produced in the area of Izu peninsula and the seven Izu islands seem to be that the rocks are of the andesite type and that the water is highly transparent because of the Black Current so that (11)
the seaweeds flourish even in the deeper areas.

3) Life History and Propagation (Illustration 4)

Each species has male, female and non-sexual plants which look alike. Antherozoids are produced on the small branches of male plants, carpospores are produced on the small branches of female plants, and tetraspores are produced on the first layer of the small branches of the non-sexual plants.

Carpospores and tetraspores are spherical and germinate soon after they lodge themselves on rocks. Sometimes they grow straight to become Gelidium amansii and sometimes they make stolones and then grow Gelidium amansii. The first case seems to occur when it is brighter.

Gelidium amansii grows about 10 cm in a year and about 20 cm in two years. It is said that the tetraspore grows into a male or a female plant and the carpospore into a non-sexual one. The number of non-sexual plants is predominant and the male and female plants occupy only 20%. The reason for this seems to be the shorter life of male and female plants. The number of male and female plants is said to be more during 1 - 2 years after throwing in rocks.

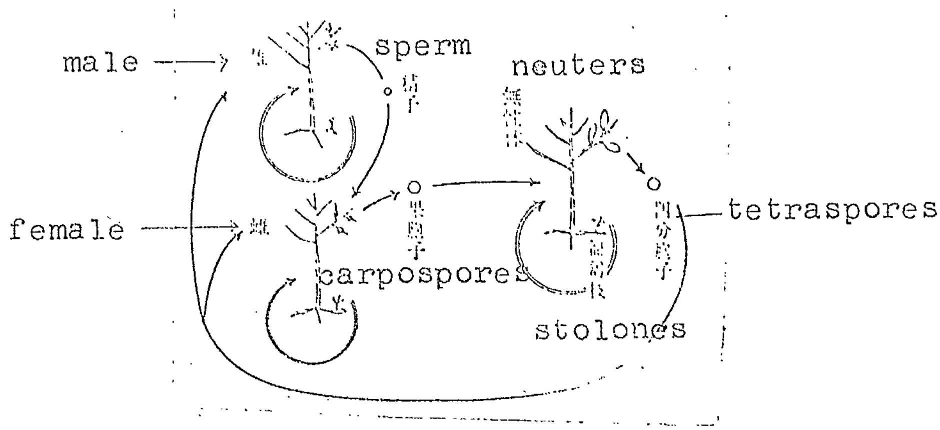


Illustration 4 Life History of Gelidium amansii

Gelidium amansii seems to live about two years but it grows stolones from its base and new plants grow from the stolones. Through this process the stubs gradually become larger. Such stubs live at least several years. Most of the harvest consists of Gelidium amansii plants which grow from stolones and hence the amount of this type of germination and growth control the size of the harvest. On the other hand, propagation through spores is not strong. It has been observed that cut branches lodge on some rocks and develop roots to settle, but this would not happen very often in the sea.

4) Ecology

(1) Maturity : Tetraspores tend to mature when the water is about 20°C about June to September in northern areas and about April to October in southern areas. Carpospores tend to mature when the water is 24-25°C. or more about July to August in northern areas and about June to September in southern areas. If mother-bodies are dried or soaked in sea water whose density is less than 1.020, the release of spores is hindered.

(2) Young Sprouts : The proper temperature for the occurrence of spores of Gelidium amansii is 24-25°C. If it is 28°C. this causes abnormalities. 30°C. means death and growth is hindered when the temperature falls below 20°C. If 20% of fresh water is mixed with sea water they tend to die. The germination from stolones takes place when the temperature is 15-25°C.

(3) Plant Bodies : As the temperature approaches (12) 25°C. the better the immature plants grow. The growth slows down, however, when the spores they produce mature. If they are thinned out in spring then the remaining immature plants grow fast at high temperatures. The growth is hindered if the temperature falls to 2°C. or lower. The growth takes place only at the tips of the branches. In flat areas they grow above the level where the water has a certain transparency, that is

16 - 17% of the surface brightness. They concentrate from this level up to 2/3 of the distance to the surface. In shallow areas they grow in the shadow of rocks or the shadow of the other weeds where the water brightness is about the same. On the Kanagawa prefecture coast, they flourish in areas where the brightness is 15 - 30% of that at the surface in around May to June. If the brightness is more than 60% then they lose their colour and die of too much light. If it is less than 5% then they grow very slowly and the branches will not be well developed.

Lack of N often seems to hinder the growth of the seaweeds. B_{12} is found to be essential for the growth of plants in the laboratory but it is not certain if an insufficiency of B_{12} occurs in the sea. It is also found that proper movement of water currents or waves is needed for growth.

(4) Harvesting area : Gelidium amansii grows towards the inside of the bay where the water is not very rough, whereas Gelidium japonicum and Gelidium pacificum grow toward the outside of the bay where the water is rough. The main reason that around the seven Izu islands less seaweeds grow in the south-western area where the Black Current hits and more grow on the other side of the island seems to be that there is less nutritious salt on the south-western side of the island. In the Hokkaido area where the temperature is low they grow mostly to a depth of 1.8 - 3.6 m below the surface. Along the coast of the Middle-South of the main island of Japan

seaweeds grow in flat areas above the level where the water has a certain transparency, that is 16-17% of the surface brightness. They flourish from this level up to 2/3 of the distance to the surface. In shallow areas they grow in the shadow of rocks or of other weeds. In places where other seaweeds grow densely they do not grow since the brightness drops down below 1/20 of the surface brightness. They grow less in places where the water is turbid or the rock surfaces are dirty. They grow well on rocks lying on a sandy bottom.

(5) Production : Around the Izu Peninsula the productivity is 1 kg (raw) per m^2. Around Joga shima of Kanagawa Peninsula the productivity is about 0.3 kg, which makes it a middle-class harvesting place.

In Izu 0.2 kg of the seaweeds remains after harvesting. The rate of increase through growth is rapid when the plants are scarce. Hence, in summer the rate of increase is almost 5% a day, but the rate decreases as the number of plants increases and finally the rate drops down below 1%. Since within two months after harvesting the productivity returns to normal, it is recommended to harvest the seaweeds every two months during the season, or three times. In this case, the harvest of the fishermen is at a maximum, that is, more than 2 kg per m^2 per season. In winter the growth is very slow, however the productivity of the area becomes normal again in four to five months, that is, by the next spring. When we talk of growth in terms of the height of the plants, the plants grow fastest when they are several cm high and they almost stop growing when they are 15 - 20 cm high.

Production
(unit: 10,000 kan
= 37,600 kg)

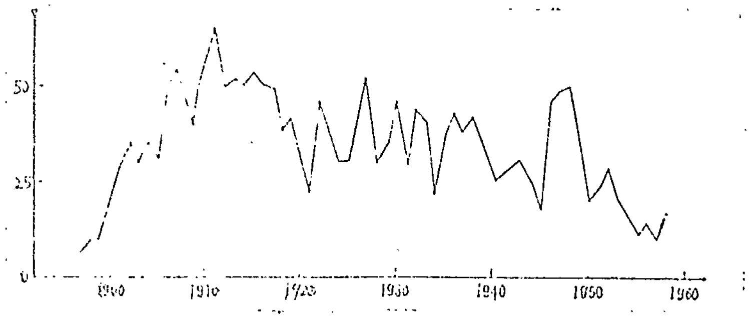


Illustration 5 Production of Gelidium amansii in Shirahama, Shizuoka prefecture

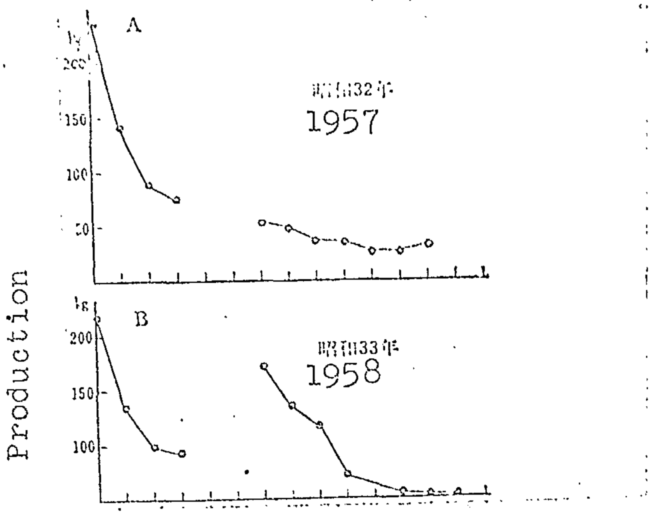
(6) Rich and Poor Harvests : The amount of the (13)
harvest changes very much from year to year. Illustration 5 shows the change in the harvest in Shirahama of Shizuoka prefecture over the years. Rich or poor harvests are decided by the following factors, 1) the development of stolones in autumn to winter and the following germination, that is to say the quantity of stubs of the plants, 2) the growth of the plants; the growth in spring to summer in such places as Izu, where the harvesting period is long,or the growth by the harvesting period in places where the plants are not dense and the harvesting period is shorter.

Table 9 Correlation between Water Temperature of the Previous Autumn and Productivity (Yamazaki, 1963)

	Sept.	Oct.	Nov.
Nishina	- 0.811	- 0.886	- 0.824
Shirahama	- 0.464	- 0.814	- 0.294

In Shirahama and Nishina of Izu, the correlation between the water temperatures of the previous autumn (Sept. - Nov.) and the harvest of the next year is negative. The water temperature was low because of the approach of a cold stream in 1947, 1948 and 1962 and in each case in the following year, that is, in 1948, 1949, and 1963 there was a rich harvest. The low temperatures in autumn seem to encourage germination from stolones.

<u>Illustration 6</u>
Average Production per Boat per Day (Shirahama; <u>Manga</u> Method) Yamazaki, 1963.



May June Jul Aug Sept
(beginning, middle and end of each month)

<u>Illustration 6</u> Average Harvest per Boat per Day (Shirahama; Yamazaki 1963)

In Izu the correlation between the temperature of the water during June to July and the harvest is positive. It seems that high temperatures encourage the growth of the remaining plants. In Izu the harvest usually increases after the period of prohibition of catching seaweed which occurs during June to July, but this increase did not take place in in 1957 when the water temperature was low (Illustration 6).

The low temperatures of winter (below 4 - 5°C.) cause poor harvests.

(7) Coastal Wasteland : Sometimes almost none of the seaweeds except Sargassum bacciferum are found in wider coastal areas and only Melobesioideae covers the rocks. This phenomenon is called "coastal wasteland" (Isoyake) and causes disaster. The coastal wasteland which occurred continuously during and after the war in Southern Hokkaido and Aomori prefecture is said to be caused by the accumulation of volcanic ashes of Mount Komagatake, but in many such cases the causes are not known. The case of Mie and Shizuoka prefectures is said to be caused by the approach of water (14) from far out in the ocean. Usually it lasts for a few years. There is no damage in the area close to the surface of the water. Agar-agar could survive as stolones among Melobesioideae but it cannot grow after germination. The methods of throwing stones and transplanting in order to recover the coast from the coastal wasteland situation seldom succeeded. During the recovery period agar-agar germinates from stolones which survived the disaster. If you transplant at this time or if you throw rocks with seed plants into the water the recovery seems to be encouraged.

5) Propagation (artificial)

Agar-agar is a perennial plant and grows slowly. The areas where it grows are severely restricted by the kind of geographic formation, but once it grows it settles down in the place. The most important thing is the adjustment and arranging of the harvests. The main method of propagation is to enlarge the suitable area by throwing rocks into the area, but it is not easy to change a naturally poor area into a prosperous area, except when recovering an area from the coastal wasteland situation or when the rocks in the area are inferior. Elimination of other seaweeds is useful for one or two years if they grow among other seaweeds.

Usually it is difficult from the economic point of view to change the geographic formations on a large scale, but it is possible to create suitable areas free from the restrictions of the geographic formation of the bottom if we use iron structures or expand metal.

The culturing method is difficult since it takes more than two years to raise plants from spores. If you insert young plants into rope and hang it down into the water they grow very well, but since these seed plants are expensive and it takes too much labour this operation is not profitable.

(1) Throwing in Rocks : This is practised in flourishing sandy areas in order to have more area. Various types of rocks can be used if they are not brittle. River rocks and coastal rocks whose surfaces are smooth are not suitable. Rocks with a weight of 20 - 100 kg are used. The rocks should be large

and heavy in order not to be buried in the sand or moved from place to place by the waves. The time at which rocks are thrown into the water is not very important. Melobesioideae starts to grow soon. On the top of this the agar-agar spores lodge themselves. The best time to throw in the rocks is about one month before the release of the agar-agar spores to let Melobesioideae grow. It is said that the best time in the

Table 10 Economic Effect of Throwing in Rocks (Shizuoka Water Research Institute; with corrections)

Year	Quantity per Harvest Raw kg/m2	Annual Production* Raw kg/m2	Annual Production* Dry kg/m2	Annual** Income $	Cumulative Annual income $	Investment for throwing in rocks $
1st	0.28	0.56	0.112	0.10	0.10	1.11
2nd	0.79	1.58	0.316	0.29	0.39	
3rd	1.15	2.30	0.460	0.42	0.81	
4th	1.30	2.60	0.520	0.48	1.29	
5th	1.50	3.00	0.600	0.55	1.84	
6th	1.50	3.00	0.600	0.55	2.39	

Calculated as 300 yen = $ 1.00

* assuming that the annual production is twice as much as the lodging quantity

** assuming an average price of $0.92 per kg during 1957 and 1958

Izu area is in March to April and in other places in May (15) to July. However, throwing in rocks at the proper time only means that the flourishing season will come one year earlier.

The most important thing in this operation is the choice of location.

In the Izu area where the natural productivity is 1 - 2 kg/m^2, the investment for throwing in rocks is redeemed after four years as seen in Table 10. In Jogashima of Kanagawa prefecture the natural productivity is 0.3-0.4 kg/m^2 and it takes seven to eight years to redeem the investment. The productivity from rocks thrown in becomes the same as the natural productivity after three years. The investment of throwing in rocks is not recommended for areas where the natural productivity is less than that of Jogashima.

Instead of throwing in rocks concrete discs and old rubber tires (rubber is suitable for lodging) have been tried. These are picked up, relieved of the seaweeds and cleaned. Since they are not heavy enough to hold themselves against the waves, they are used in the places where there are strong currents but no rough waves. The main weakness in using these materials is the length of time it takes to pull them up and put them back into the water. Another experiment has been conducted to find materials to paint on the rocks to encourage the lodging of seaweeds. Seed plants have also been tried. Three dimensional structures such as iron structures or expand metal are hoped to create flourishing areas out of naturally poorly productive areas, improving on the restrictions of the natural geographic formation of the bottom of the sea, but this is still at the experimental stage.

(2) Elimination of Other Seaweeds : In Jogashima and other areas Ecklonia cava and Eckloris bicyclis are mowed down during autumn to winter and this is effective for one or two years in areas where agar-agar suffers from the shadow of the other seaweeds. If the mowing is done in summer the light would be too bright for the seaweeds. The elimination of Melobesioideae has almost no effect.

(3) Transplanting of Seed Plants : This is expected to be effective for artificially created suitable areas next to flourishing areas or for areas which are in a recovery period from coastal wasteland. Transplanting in unsuitable areas would not be successful even if the plants germinate. Avoid letting them dry out in transport. When they are put into the sea, they should be wrapped in weighted nets in small quantities in order to avoid loss through floating away.

(4) Regulating the Harvests : In the places where the harvesting season is longer than three months temporary prohibition in the middle of the season saves labour and increases income. Illustration 6B shows the example of Shirahama of Izu. This temporary prohibition is effective in a better year but it brings about a decrease in income in a poor year as shown in Illustration 6A. In areas where the daily harvest does not decrease rapidly from day to day temporary prohibition is not

necessary since the growth of the seaweeds compensates for the harvest. It is therefore recommended to encourage the harvest instead.

The quantity of the remaining seaweed at the end of the season has no relationship to the productivity of the next year. In other words, you can take as much as you can.

(5) Nourishment : Shizuoka Water Research Institute scattered fertilizer chunks which dissolve very slowly in the harvesting area and found that it was effective for the growth and recovery of the colour. It is not yet clear about the absorption rate of the fertilizer and the economic effects.

6) Harvest

In Izu if the harvest of fisherwomen is represented as 1, then that of Giri boats is 3 - 6 , of Manga boats is 5 - 7, and of submarines is 6 - 7. (16).

As mentioned before, as far as agar-agar is concerned, it is recommended to investigate and to adjust the methods of harvesting, the harvest seasons, prohibition periods, the amount of seaweeds in the area and the rate of growth before trying propagation methods.

IV Gracilaria verrucosa

1) Foreword

This seaweed is mixed with agar-agar in order to make vegetable gelatin. Recently the strength of the gelatin has been improved by the alkali process, which made it possible to use Gracilaria verrucosa alone as raw material for "chemical gelatin". Since this improvement this seaweed has begun to be used in large quantities. Domestic production is 2,500 dry tons. In addition, about 2,000 tons are imported from Argentina at $0.30 per kg. (Table 4).

They grow in calm water in bays. Since it takes a short time (about 3 months) from germination to the harvesting season, propagation and culturing methods can be used, but it is difficult to industrialize because of the competition from the natural product and imports, and because of the extreme fluctuations in the price during good and poor harvest years. Table 11 shows the natural production of Gracilaria verrucosa of various areas.

Table 11 Production of Gracilaria verrucosa (average of 1954 - 1956; unit: dry ton; Okazaki)

National	2,520	Miyagi	220	Okayama	86	Shizuoka	52
Chiba	1,310	Oita	110	Aichi	71	Kumamoto	34
Hokkaido	410	Shimane	94	Saga	56	Fukushima	33

2) Life History and Propagation

Gracilaria verrucosa produces spores from May to June (July to August in northern areas). They germinate and make disc-like sheets from which the plants grow. They grow to their full size from the end of autumn to the spring, but if the spores are put on oyster shells and thrown into the sea they grow faster. The young sprouts appear in twenty days and grow large enough to be harvested in two to three months. When they reach their full size, they detach themselves from the rocks and float along the bottom of the sea. In this stage the growth rate is rather good. The cut branches also grow very well. Gracilaria verrucosa, which is produced in large quantities in Hokkaido, Lake Agichi, grows among Zostera marina 1 - 2 m below the low water line and grows very well. It seems that the seaweeds reproduce through cut branches. They produce almost no spores.

3) Ecology

Gracilaria verrucosa has a strong resistance to changes in water temperature and salt content. They grow all over Japan and also grow in the Java area. They grow all year round. Although they grow in the open sea, they are concentrated in inlets with sandy, muddy bottoms and with calm water. They grow from the low water line down to 1 m below. The plants do not easily survive lack of water, but can survive one day under this condition. They grow in temperatures from (17) $5^{\circ} - 30^{\circ}C$. but grow better when the temperature is above $20^{\circ}C$. The water density required for growth is from 1.005 - 1.025 . Dry exposure is not good for growth. The spores are released when the tide is rising after the low noon tide. The plants can be collected and dried and will live till the next day. When they are thrown back into the sea within this time they will also release spores.

4) Harvesting

The seaweeds are pulled out of the sea with a pole with a hook from winter to spring (early summer in northern areas) or collected with a net.

5) Propagation and Culturing

The harvesting of the seaweeds takes place three months after the spore stage. It seems to be better to make use of the resuscitation process, but as there are many problems to be solved they are not yet industrialized.

(1) Propagation and Culturing : Suitable places are shoaling beaches with calm water and sandy, muddy bottoms. The best places are pools in tidelands. The depth at which they grow is from the low tide line down to 50 cm below.

(2) Culturing by Resuscitation of small branches : The seaweeds are cut into lengths of 10 - 20 cm and are inserted into ropes. Instead of ropes seaweed nets, synthetic fibres or bamboo whose tip is thin cut have been tried. Table 12 presents the findings as to the cost of this type of culturing of the experiment conducted by the Kumamoto Water Research Institute. They used twenty-two 36-meter palm ropes and planted the 10 - 20 cm lengths of Gracilaria verrucosa in the rope 10 cm apart. They placed the ropes in an area 240 m^2.

Old seaweed nets (3.6 x 7.2 m) were used and the result was an increase in raw material seaweed from 2.1 kg to 9.2 kg (1.8 kg dry weight) in one month from the end of January.

Table 12 An Example of Resuscitation Culturing
(Kumamoto Water Research Institute)

Period	Raw material Seaweed	Harvest					Expense			
		June 4	June 18	Total	Dry weight	Profit	Rope	Labour	Stakes	Total
May 1-June 18, 1954	20.6 kg	146.2 kg	182.8 kg	329.0 kg	39.5 kg	$8.90	$2.20	$3.30	$0.70	$6.20

The ropes must be stretched out across the bottom of the sea. If they are more than 15 cm above the bottom, production decreases. The lengths of seaweed should be about 10 cm apart. If they are too close together the increase rate goes down.

One problem is the loss suffered when the lengths of seaweed planted in the ropes fall off. If the ropes are shaken the branches planted into the bottom side of the ropes tend to get buried in the bottom of the sea. It also takes a whole day for one person to complete 100 m of rope. The operation must be done from January to August when the water is not rough.

(3) Culturing from Spores : Young plants attach themselves to almost anything such as ropes, shells, rocks, stones, and concrete. Placing the young plants takes place from May to June (June to August in the north). In the places where the production of Gracilaria verrucosa is low, seed plants

are transported still partly wet and planted within a day. If nets are used they must be made of synthetic fibres to prevent rotting. Longer fibres are preferable in order to prevent the penetration of dirt.

(18)

Chiba Marine Institute placed a 1.2 m x 18 m net (I8) in May or June and found that the plant grew 30 - 40 cm in three months to produce 20 - 30 kg. After the first harvest 15 - 20 kg of the seaweed was produced every two months from the same net. 0.4 - 0.8 kg of young seed plants are said to be needed for the above net.

One problem is that the harvest coincides with the typhoon season of autumn and the seasonal winds of winter. The data on gains are not sufficient to permit a definite conclusion, but it seems that this method is far less efficient than the inserting method mentioned in the previous chapter.

(4) Propagation Based Upon Regeneration: As far as the growth rate is concerned, the seaweed which is cut off from its base and is floating in the water is far greater than the one which is attached to the base. With the inserting method if the net is made to float the seaweed grows faster. Kumamoto Marine Institute experimented on this principle. Young plants of 50 kg were cut into 10 cm lengths and sowed in 100 m^2 of calm water on May 27, 1955. The seaweed was harvested at every tide and the young branch cut off and thrown back into the water. 400 dry kg ($83.00) were harvested by October 25. Fishermen in Kumamoto prefecture used this method thereafter, but had to abandon it because of a decrease in price.

(5) The culture and propagation of Gracilaria verrucosa has not been industrialized since the price is too ~~cheap~~ low and moreover, it fluctuates because the natural product is abundant and the imported one is inexpensive. However, if more than several tons of the seaweed are produced at a time and sold directly to the Japanese gelatine manufacturers, the price can be doubled.

So far the method described in (4) is most promising. In the places where floating loss is expected, a net can be used to surround the area. The inserting method needs a reduction in labour for planting the young plants. If this is operated on a large scale in such places as abandoned salt ponds and electric power is used to keep the net suitably moving, this method is feasible.

In the middle-southern part of Honshu on the Pacific Ocean side where the water is rougher, the closely related Tsurushiramo seems to be suitable for culture because it grows fast and the consistency of the jelly is strong.

V Gloiopeltis furcata

1) Foreword

The simple-dried seaweed is exposed under the sun as it is watered from time to time and it is made into Barafunori and Sukifunori which are used for silk weaving or hair washing. However, both the prices and production have gone down due to the decline of the silk industry and the development of alginic acid (Table 1).

2) Species and Ecology

Fukuro (Baggy) Gloiopeltis furcata grows everywhere a little below the surface of the water and produces well. Ma (True) Gloiopeltis furcata grows only in the south of Mie and Nagasaki prefectures. It grows a little deeper in the sea than the former (the baggy one) and the quality is better and more valuable, but it does not produce as much.

There are male, female and non-sexual plants. The carpospore is produced in the knob of the female plant. The tetraspore is produced on the smooth surface of the non-sexual plant. The release of spores in the baggy Gloiopeltis furcata takes place in spring with a water temperature of 15 - 20°. In the true Gloiopeltis furcata, the release occurs during the (I9) rising noon tide with a water temperature of 19 - 22°C. The spores are spherical and attach themselves to rocks. They form disk-like bases from which one or two shoots come out in autumn and they grow from winter to spring. After releasing spores the plant is washed away except for the root, which develops into a new base which produces sprouts again in autumn. The diameter of the base is about several mm and it lasts for 2 - 3 years in the case of true Gloiopeltis furcata and several years in the case of the baggy one. The plant is fairly small in the first year and hence the main part of the harvest is the second year plant. In the case of baggy Gloiopeltis furcata, Kaneko reported that until the sixth year the older the base is the more sprouts grow from it. However, this seems to vary by species.

The seaweed grows close to the shore where the broken waves from the open sea arrive. It is not likely to grow on clayey rocks or soft sandy rocks. If there are enemies such as acorn barnacles or some perennial plants in the area, the whole stratification is gradually pushed up toward the area where such enemies are scarce.

3) Propagation

This is mainly to protect the bases of the plants by eliminating noxious weeds. This is also to clean the rocks to revive the productivity when the area gets old and the productivity of the seaweed decreases. The area in which Gloiopeltis furcata is not abundant can be turned into a prosperous area and perhaps it will stay prosperous for some time if it is taken proper care of.

(1) Cleaning the Shore: This is done when acorn barnacles or other noxious weeds come into the area. The harmful weeds must be eliminated carefully not to damage the bases of Gloiopeltis furcata. If the bases are

old and the noxious weeds are plentiful, the area is washed with sodium hydroxide. Or gasoline is used to burn the whole area, and it will be recovered in one or two years. The important thing is to choose the right time for eliminating noxious weeds, which is just before the release of the spores. If it is not done at the proper time, it encourages the flourishing of noxious weeds.

(2) Throwing in Rocks: This is effective to create a prosperous area. In northern areas it is allright to throw in small size rocks (5 - 10 kg) in the inlets. Rocks which easily absorb water are not suitable for this. A concrete surface alone is not suitable either. It must be combined with suitable rocks. It is also important when the rocks are thrown in.

(3) Transplant: When floating loss is prevented by some facilities, scattering the spores in the area is effective and is commonly done. For example, a metal cage was used and produced good results (Nagasaki Marine Institute). The mother plant stays alive for 2 - 3 days while it is dry-transported. A rock with the plant can be transported and fixed with cement in a new environment to test if the new area is suitable. Throwing in rocks and seeding can be effectively combined. If the mother plant is soaked in sea water just before the rising tide, it releases spores in ten minutes. This water with spores is sprinkled over rocks to the extent that the rock is not dried until the rising tide.

(4) Nourishing: In the growing period, if the thin nourishing liquid is sprinkled every day at low tide, the productivity and the quality of the seaweed are known to rise. However, there is not enough data concerning economic gain.

VI Rhodoglossum pulcherum, Iridophycus Cornucopiae, and Chondrus ocellatus (20)

1) Foreword :

The gelatin quality of these seaweeds is low. They are used for making plaster and for food. Recently the seaweed product used in making plaster has come in a powdered form. Seaweeds from Korea have been used to a great extent for this purpose. The seaweed product for food is an industrially extracted glue-like substance which is used for making ice cream, soup cubes, or stabilizers. In Europe and the United States more than 10,000 tons of these seaweeds are consumed. Table 13 shows the production of these seaweeds in Japan.

Table 13 Production of Seaweed Material for Glue Extraction (1952-1961; unit: 1000 dry kan = 3,759 dry kg; Okazaki, 1957)

Rhodoglossum pulcherum & Iridophycus cornucopiae		Chondrus ocellatus		Gratelupia turuturu & others	
National	207	National	147	National	131
Hokkaido	200	Chiba	57	Ibaragi	40
Aomori	5	Kanagawa	15	Aomori	30
Iwate	2	Iwate	10	Chiba	26
		Miyagi	10	Hokkaido	15
		Kagoshima	7	Tokyo	5
		Tokyo	6		

2) Rhodoglossum pulcherum and Iridophycus cornucopiae :

These seaweeds grow in the area north of Iwate, especially around Hokkaido. They tend to concentrate around the low tide line on the shore reefs of the open sea. The spores form a disc-like base from which 2 - 10 plants grow. The plants die in one year but the base is perennial. More spores are produced from July to August. Throwing in rocks and cleaning the shore are effective for the increase of production but the price of the seaweeds is not high enough to warrant investment in throwing in rocks.

3) Chondrus ocellatus

Several species are in this category. They concentrate in the area a little below the low tide line. Their propagation and base are similar to that of above species. The propagation period is Spring to early Summer (summer in northern areas). The elimination of other seaweeds is effective but is not practised very much since the price of the seaweed is too low. Throwing in rocks is also unprofitable judged from the fact that in Ibaragi prefecture it takes twenty years to redeem the investment.

VII Undaria pinnatifida

1) Foreword

Japan (and Korea) produce approximately 60,000 tons (about 1,000 dry tons) annually, as shown in Tables 1 & 14. Culturing has been industrialized recently around Tohoku area (north-eastern part of Japan) and has been spreading to various areas of Japan but the production by culturing in 1963 was (21) still only 3,000 tons (for Culturing, see Vol. II).

Table 14 Prefectural Production of Undaria Pinnatifida
(1960; unit: 1,000 raw tons; Norin Statistics)

National	62.7	Miyagi	10.1	Kumamoto	0.7
Hokkaido	17.1	Shimane	4.3	Tokushima	0.2
Aomori	3.8	Hyogo	0.5		
Iwate	16.1	Nagasaki	2.7		

2) Species

Undaria pinnatifida f. distans is produced in the Tohoku - Hokkaido area. It has a long stem and the cuts in the leaves are deep. It is hereditarily different from Undaria pinnatifida of the middle-southern part of Japan, but the appearance of the plant changes to a certain extent according to the growing conditions. Undaria undarioides, which does not have cuts in the leaves, grows in higher temperatures than Undaria pinnatifida. Undaria peterseniana without cuts grows at a deeper level south of Chiba. Production of these two species is small. Undaria pinnatifida and these latter two species combine to produce hybrids.

3) Life History and Propagation (Illustration 7)

The seaweeds flourish from winter to spring and release spores and die. They produce spore cases on the surface of so-called ears. The spores are zoospores with two tails and they are released in the quantity of several hundred millions in 20 - 40 days from one stub. The zoospores germinate soon and become microscopic filamentous bodies. In the south the cells of the filamentous bodies swell in the summer and become inactive. In autumn when the water temperature falls below 20^{o}C. eggs and sperms are produced and the fertilized eggs germinate on the filamentous bodies and then they grow into Undaria pinnatifida. Under the proper conditions they become several millimeters long in one month, 10 cm in two months, and 1 - 2 m in 3 - 4 months.

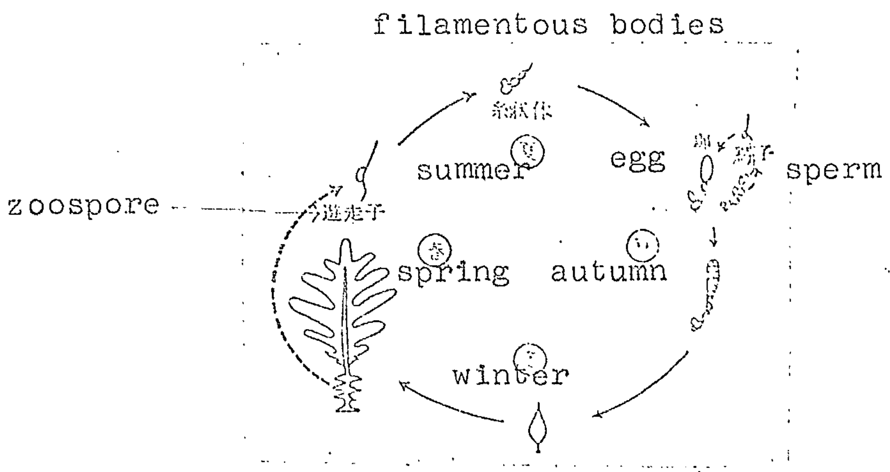


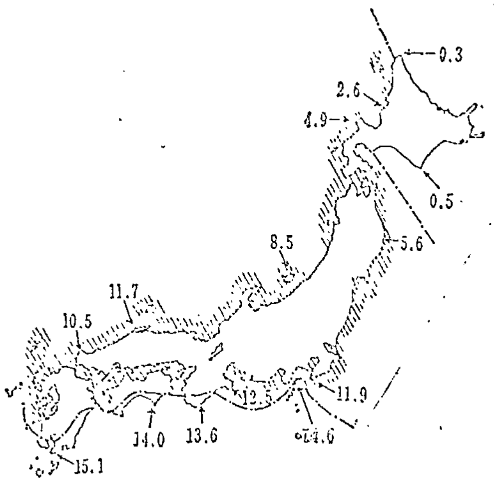
Illustration 7 Life History of Undaria Pinnatifida (release of zoospores in the north occurs during July to August)

4) Ecology

(1) Distribution : The northern limit is where the

water temperature in winter is a minimum of 2°C. The southern limit is where the water temperature in winter is a maximum of 14°C. (Illustration 8). On the west coast of Hokkaido the water temperature increased recently and at the same time the northern boundary for Undaria pinnatifida was driven further north and the production was increased. Although more of them grow in the open sea they also grow in Haneda (Tokyo Bay), Yokkaichi (Ise Bay) and various inlets. The depth at which they grow is 0 - 2 m. in the north and 10 - 15 m. in the south.

(22)



//// area where Undaria pinnatifida grows

—.—. boundaries for growth

(numbers) indicate water temperature in winter (February)

Illustration 8 Distribution and Water Temperature of Undaria Pinnatifida

Good harvesting areas are in the middle-south. They are located at the mouth of bays where the current is fast and the waves are calm and the bottom of the sea is flat and gravelled and the depth is several meters. In these areas variations in the water temperature and salt content are slightly larger than in the open sea, other seaweeds do not grow much, and Undaria pinnatifida stratification is stable. (Katada)

Table 15 Growth Conditions of Various Stages of Undaria pinnatifida

	Water temperature (°C)	Light (lux)
Zoospore; release and lodging	14 - 20°C; > 25°C is too high	
Filamentous body; growth	17 - 20°C; if > 23°C stop growing	2000 - 6000
inactivity	25 - 30°C; if > 30°C dies	less than 500
maturity and fertilization	less than 20°C	greater than 1000
Young sprout; growth	less than 17°C if less than 10°C, slow	
Mature leaf; growth	less than 12°C 5 - 10°C are too low greater than 15°C is too high	

(2) Table 15 shows the suitable conditions under which Undaria pinnatifida grows at each stage of its life history. In summer the water temperature is high and the light is strong in the sea but filamentous bodies prefer weak light. Several hundred millions zoospores are produced from one stub but only about one-hundred of them germinate; that is, the yield is one out of several million. It seems that they only survive if they lodge themselves in shadowy places with especially

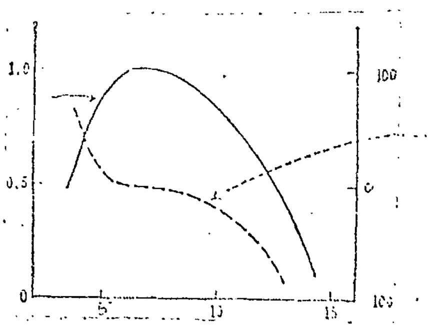
good conditions. This seems to be the reason why Undaria pinnatifida does not grow easily when rocks are thrown into the water, even if spores are attached to them. The yield after germination in the autumn is good in comparison since about 10 out of 100 become full grown and are harvested. Hence in culturing in which young sprouts just after germination are used a certain amount of production is always guaranteed. In shallower areas in the sea the seaweeds grow faster and die faster. In the deeper areas they grow and die more slowly. In culturing the depth at which they grow is adjusted so that they germinate faster and grow faster.

The faster the current the better they grow. Nourishing salt is important too and hence in Tohoku production decreases when the Tsushima warm current, which does not contain enough nourishing salt, strongly flows southward through Tsugaru Channel. It seems that Vitamin B_{12} also influences the growth of the (23) seaweeds besides N and P.

(3) Rich and Poor Harvests : The production of the seaweeds fluctuates very much from year to year and the major cause is said to be the water temperature. In Hokkaido, where the northern boundary is located, low temperatures during the growing period; that is, winter to spring, brings about poor harvests. So do high temperatures in Nagasaki, Chiba, etc. where the southern boundary is located. It seems, however, that in the latter case the quality of the water

which is mixed with the water from warm currents may influence the productivity. Illustration 9 explains the relationship between water temperature in winter (February) and the productivity ratio. It is not clear what the correlation between the flourishing period of the previous year and the water temperature in the summer of the previous year is. Low temperatures during the harvesting season have the effect of prolonging the growing period and cause rich harvests. In Naruto district the water temperature in spring does not rise fast, hence the harvesting season is long. Other causes besides water temperature are not clearly defined.

Productivity Ratio



% Increase in Production due to 1°C. Increase in Water temperature

Water temperature in February

Illustration 9 Production of Undaria Pinnatifida and Water Temperature in February

5) Propagation (artificial)

While the elimination of other seaweeds is effective there is no successful example of creating a permanent effective new area by the method of throwing in rocks. The areas where Undaria pinnatifida grows are those with [ ] special conditions because of which the succession of growth as a group stops in the middle and remains static. It is difficult to create these conditions by throwing in rocks. Referring to the life history, when the survivors of filamentous bodies created in summer encounter good conditions for germination in autumn they grow. It is difficult to provide these conditions on the surface of rocks thrown into the water.

(1) Throwing in Rocks : The purpose is to create permanent areas for growth and hence it is necessary to provide similar conditions as those in naturally productive places. If rocks are thrown in areas where Undaria pinnatifida grows sparsely or where the geographic formation is different from that of the naturally productive spot, they do not grow on rocks. The flourishing areas of middle-southern Japan are mentioned in section 4) (1).and in those places throwing in rocks is effective in enlarging the area...

(2) Elimination of Other Seaweeds : The geographic conditions under which Undaria pinnatifida grows are not suitable for the growth of many other weeds, except perennial weeds, which are to be eliminated to maintain the standard of growth of Undaria pinnatifida. The main perennial weeds are Phyllospadix iwatensis (North), Ecklonia cava, and Sargassum bacciferum (South).

Submerging, mowing and explosion of rock surfaces are effective but these means are not effective in an economic sense in the areas where these weeds are predominant because Undaria pinnatifida will be outnumbered by the weeds very soon even if they grow temporarily after the elimination of the weeds.

In Chiba prefecture the explosion of rock surfaces in September and October brought about flourishing Undaria pinnatifida the next spring. Rocks can also be thrown in in September and October to make the seaweeds grow the next year. The reason for this seems to be that the maturing filamentous bodies detach themselves from rocks in autumn and lodge somewhere else. (In culturing, germination takes place just outside the area where the culturing is actually conducted.) This fact can be made use of for propagation. (24)

(3) Throwing in Seed Plants : Aichi Water Research Institute attached zoospores to seaweed nets, placed them at the bottom of the sea and found much germination to have taken place in the area in autumn, but it has been reported that the effect of this operation varies from year to year. As in the culturing method, if the filamentous bodies are cultured and spend the summer in artificial conditions on land and if a method of planting them on rocks in autumn were devised, we would have an effective method of propagation. For example, if the filamentous bodies are attached to nets and placed across the bottom of the sea in autumn, they seem to be scattered around the area. This method is hoped to be used widely in the areas where filamentous bodies cannot survive through summer and hence there is no Undaria pinnatifida. The effect of this operation lasts only for one year. In other

words, seed plants must be thrown in every year.

(4) Protection for Propagation : Care is taken during the harvest to leave some seaweed plants, especially the female stubs to carry on the next year's propagation. It is of concern to some people that female stubs are collected for culturing purposes because the result of this might be a poor harvest in the next year. The harvest of Undaria pinnatifida fluctuates to a great extent from year to year and if we investigate whether a poor harvest influences the production in the next year we find that that there is no influence whatsoever, even if the production in the previous year was only 10% of that of an average year. On the other hand, a rich harvest year does not influence the next year's production either. From these facts it can be said that protecting the female stubs has no effect on the next year's production. One exception is when the production of the seaweeds dropped to 1/20 of the average year in Aichi prefecture, the following year was also a poor harvest year.

(5) Effect : The correlation between the amount of production of Undaria pinnatifida in the following year and methods, operation period, and areas have been investigated. In areas where the seaweeds do not naturally grow almost every method failed, except for a few cases in which the method of attaching spores was used. In the areas where the maturing period of filamentous bodies in autumn as well as the period of releasing zoospores can be effectively used, the method

of attaching spores has little effect. We do not have enough data on the effect of propagation operations for periods longer than two years, but there are cases in which the effect lasted for a few years. The economic effects have not been calculated but in general the investment for throwing in rocks is only redeemed after many years, and hence this method is not recommended for economic reasons. The elimination of other seaweeds by such methods as the explosion of rock surfaces is profitable in many cases.

6) Collection

Since the young soft early in the season are high priced they are thinned out and collected as they grow. The price goes down at the end of a certain period. The result of an investigation of prices and production in Aichi prefecture shows that it is profitable to harvest after the seaweeds become full grown, especially when the harvest is poor.

VIII Laminaria

1) Foreword

Table 16 shows the production of recent years and Table 17 shows detailed production of Hokkaido, which is the main productive area.

Table 16 Production of Laminaria

(Unit: raw ton; Norin Statistics)

Year	National	Hokkaido	Aomori	Iwate	Miyagi
1956	31,140	29,444	281	924	491
1957	36,641	34,741	377	657	867
1958	31,140	28,836	1,202	712	391
1959	30,256	27,614	1,119	1,011	511
1960	31,295	28,355	772	1,361	804
Average	32,094	29,798	750	933	613

Table 17 Production of Laminaria in Hokkaido

(1961, Hasegawa)

Species	Area	Production (tons)	of the area: of all seaweeds %	of the area: of total harvest %
Laminaria religiosa	Ishikari · Goshi, Hiyama, Rumoi	1,452	57	0.8
Laminaria japonica	Watarigima · Tanshin	3,484	67	2.6
Laminaria japonica var. ochotensis	Abashiri · Soya	3,935	94	0.8
Laminaria angustata	Hidaka · Tokatsu	5,958	92	15
Laminaria angustata var. longissima	Kushiro · Nemuro	11,915	97	3.3

2) Species and distribution

Important seaweeds here are Laminaria japonica (and its district variations: Laminaria japonica var. ochotensis, Laminaria diabolica, Laminaria religiosa) and Laminaria angustata (and its district variation: Laminaria angustata var. longissima). Their distribution is observed in Table 17. Laminaria angustata var. longissima is about one half of the total production in Hokkaido. Laminaria japonica is of superior quality but is not produced in great quantity.

3) Life History and Ecology

In general these seaweeds mature from Autumn to winter. When they reach maturity, dull specks appear on the surface of the leaves from which zoospores with two tails are released in quantities of several hundred million per stub. As in the case of Undaria pinnatifida, the zoospores germinate and become microscopic filamentous bodies which produce eggs and sperms in one half to one month's time when the water temperature is below 10°C. Fertilized egges, as attached to the filamentous bodies, germinate and grow into Laminaria.

An experiment on culturing filamentous bodies under various temperatures (Kinoshita, 1947) proves that the filamentous bodies do not mature when the water temperature is above 10°C. and hence that no Laminaria is produced.

Table 18 Suitable temperatures for filamentous bodies of Laminaria japonica (Kinoshita)

water temperature °C.	0.8	3.8-8.5	above 18.5
maturation	44 days	37 days	die

The southern limit of Laminaria distribution is around Kinkazan, which also proves that the seaweeds do not grow if the water temperature exceeds 10°C. (26)

We begin to see young sprouts in early spring. They grow rapidly up to the maximum rate of 2 cm per day. Laminaria religiosa is an annual plant and matures in summer, but many others of this species start to die from the tips of the leaves in autumn but not entirely to the base; for example, in the case of Laminaria angustata, a part about one meter from the base remains alive and in the case of Laminaria japonica the base survives. Since the growth points of the plants, which are located on the edge of the stems and leaves, remain, they grow again in the next summer to become so-called second year Laminaria. The main object of harvesting is the second year Laminaria since the first year Laminaria is thinner and is inferior in quality.

They grow satisfactorily in spring when the water temperature is 5-15°C. and stop growing when the temperature exceeds 20°C. in summer. Even in the south of Kinkazan where the southern limit is located if young Laminaria sprouts are

are put into the sea in winter they grow in spring but they cannot survive through the summer.

4) Propagation (artificial)

The harvesting season is from July to August. The object is a full grown second year Laminaria. One problem in Hokkaido is the process of drying the seaweeds. If the weather is not good then the seaweeds are not dried in one day and the quality becomes inferior. The seaweeds are usually laid down on rocks on the beach or hung from crossbars, but the weather is often foggy and the areas for drying are not sufficient. These conditions often cause degradation in the quality and even force a stop to the harvesting. It is therefore more important in some areas to construct drying areas or to build artificial driers for increasing production and improving the quality than to try the propagation methods.

In 1718 Saint Shinder is said to have thrown rocks into the sea in Imabetsu in Aomori prefecture to propagate Laminaria. Lately a considerable sum of money with a national subsidy has been invested annually in the areas at the centre of which lies Hokkaido.

(1) Throwing in Rocks : This method has been practised for a long time. There are many successful cases but on the other hand quite a few unsuccessful cases have been reported. The production per square meter on rocks thrown in is similar to the natural production of the adjoining area. The most important factor is the selection of area. It is recommended

to choose areas between naturally productive areas or the adjacent areas, which serves to enlarge the productive areas. It is better to avoid the areas where the natural growth is scarce or the areas where the mobility of the sand at the bottom of the sea is great and the sand would therefore bury the rocks thrown in. Any kind of rocks can be used except the brittle kinds. Concrete blocks are also used but there is no authoritative theory as to the shape of the blocks. Short cylindrical blocks were used for the grand-scale operation off the Nemuro shore.

(2) Explosion of shore reefs : This operation sometimes substitutes for throwing in rocks by cracking the shore rocks at their roots. This is also used to cut down shore reefs which are too high for the seaweeds or to cut a crevice into flat reefs to create the proper depth for them to grow. This is useful to exfoliate the surface of the rocks in order to get rid of harmful weeds, especially when Phyllospadix iwatensis starts to settle in the area. An explosive is laid on the rocks and a weight is put on top in order to prevent loss from floating away. More weight than this is not required. The explosion area of an explosive powder of 150-300 gm is $2m^2$ at a depth of 0.5-1 m. Since the roots of Phyllospadix iwatensis 2 m^2 around the area are loosened and the plants soon drift away and are lost, the effective area of the explosion is about 4 m^2. If such an explosion is set off

at 2 meter intervals, the whole area can be covered. It is not economically advisable to increase the amount of explosive powder for each explosion since the effective area does not increase proportionately. (27)

5) Culture

In China the culturing of Laminaria has recently developed rapidly and production is said to have reached 30,000 tons annually. China does not produce natural Laminaria and imports from Japan have stopped. Since Laminaria is regarded as essential for the health of the people, the culturing of the seaweeds is strongly promoted. In Japan, however, the production of natural Laminaria is large and a little culturing has been tried in such areas as Shimokita in Aomori prefecture, Funka-wan in Hokkaido, and in Hiroshima prefecture. The method is similar to that used for Undaria pinnatifida. The culturing of Undaria pinnatifida has been industrialized in Miyagi and Iwate prefectures, but there are some problems in culturing Laminaria: it takes two years to produce good quality Laminaria; especially in the area south of Kinkazan the seaweeds do not survive under normal conditions; a special demand for cultured Laminaria must be created in order to make profits. It is said that cultured Laminaria is popular for making marinated Laminaria in Hiroshima.

The concrete method of culturing Laminaria is the same as that for Undaria pinnatifida. Please refer to volume 2 of this series. The only difference is that in the case of Laminaria the culturing of filamentous bodies takes place in the winter and for a shorter period. In Tohoku and Hokkaido districts they only need to hang down into the sea and in the middle-south districts where the water temperature is above 10^{o}C., a water tank on the land is used. In the middle-south districts, if first year Laminaria is to be harvested, germination should be encouraged to take place as soon as possible in autumn so that the low temperature period of winter is fully used for growth. It is recommended to use fertilizer for growth. The problem of surviving the summer arises if second year Laminaria is to be harvested. The problem may be solved by delaying the beginning of growth of the first year Laminaria plants so that they are very small when the summer comes (perhaps 1-2 cm) and they can then be put into water tanks with cooling systems during the summer, or placed on the proper place in the deep area of the sea (5-10 m).

IX <u>Ecklonia cava and Eckloris bicyclis</u>

1) <u>Foreword</u>

Ecklonia cava grows in the middle-south districts of the Pacific coast and Eckloris bicyclis grows in various areas except Hokkaido. They are perennial and make stable groups. Of Eckloris bicyclis, one species which grows in the south of Omaezaki in Shizuoka prefecture is tastier and has been used as food for a long time. Since the seaweeds contain 4-9% of K and 0.2-0.4 of I when dried, they are also used for potassic manure and during the war for extracting K and I. (21,600 dry tons in 1943; 29,400 in 1944). This caused a decrease in the

Table 19 Production of Ecklonia cava and Eckloris bicyclis in 1944 (Unit: dry ton)

National	29,400	Chiba	1,960
Nie	10,300	Kanagawa	1,890
Yamaguchi	4,200	Tokushima	1,710
Shimane	2,760	Ibaragi	1,150

natural resource all over Japan. After the war these demands (28) have died down since imported minerals took the place of seaweeds. However, the seaweeds have been used to extract alginic acid, since they contain 20-30% of the acid. The amount consumed annually is 7000 tons.

2) Propagation and Ecology

Both Ecklonia cava and Eckloris byciclis grow in the band from the low water line down to the depth of 20 m. These and Sargassum bacciferum are the main plants of the sea forest in the middle-south districts of Japan. They are perennial plants and grow to 1-2 m in 2-3 years. The age of Eckloris bicyclis can be acknowledged by the tips of the forked stem where marks are left by fallen leaves. Most of them are three to five years old. They can live five to six years and one stub weighs as much as 1-2 kg (raw). The dry yield is 20-25 %. In the areas where both Ecklonia cava and Eckloris bicyclis grow, the former occupies the deeper and rougher part. If Ecklonia cava is not present then Eckloris bicyclis grows also in the deeper areas.

The flourishing and propagation period of Ecklonia cava is from August to September and that of Eckloris bicyclis is from September to October (in Tohoku districts from August to September). Then dark spots appear on the leaves and on the spots spore cases are produced. After releasing spores the leaves die and new leaves grow from spring to summer. The spores and their development are similar to those of Undaria pinnatifida. The spores turn into filamentous bodies which produce eggs and sperms in one to two months. The fertilized eggs germinate into young sprouts which become of visual size during winter to early spring. The first year plants are small and in the case of Eckloris bicyclis the stems do not acquire their forked shape yet.

3) Propagation (artificial)

It is not encouraging to culture or to propagate Ecklonia cava or Eckloris bicyclis for alginic acid material since the price has become too low (1.7 - 2.7¢ per dry kg) to compete with Macrocystis which is mass produced in Europe and America. The natural resource, however, can be maintained be regulating the amount of the harvest. So far an annual harvest of 7000 dry tons does not affect the resource, but it is to thin out the seaweeds rather than collecting them at random, since it takes 2-3 years for them to grow back.

It is also important to remember that these seaweeds form sea-forests which attract fish and provide living quarters especially for the young ones, and that they are the food of abalones and trochoids. It is said that 15 kg of Eckloris bicyclis is needed in order to increase the weight of abalones by 1 kg. A considerable amount of the seaweeds are needed to support 4,000 tons of abalones and 5,000 tons of trochoids which are our annual national production.

Decrease in the natural resource by over-harvesting can be recovered simply by discontinuing harvesting for 1-2 years in the shallower areas and for 3-4 years in the deeper areas, but if the decrease was brought about by the coastal wasteland phenomenon it is not recovered easily. The annual production of abalones in Ibaragi dropped from 75,000 - 113,000 kg before the war to 11,300 kg after the war and this decrease was parallel to the decrease of Eckloris bicyclis by the coastal wasteland phenomenon. The cause of the phenomenon is as yet unknown, but in the cases where Ecklonia cava died suddenly in 1959 in Hayama of Kanagawa prefecture and in 1962 in Omaezaki, the cause seemes to be the quality of the water of the current passing through the area since the damage was done where the current passed.

There is no effective method for recovering the coastal wasteland phenomenon. Most of the attempts of throwing in rocks and seed plants achieved nothing. Usually plants in the area of 2-3 m. depth survive and hence there is a sufficient supply of spores, but even if germination takes place they do not grow into plants. The elimination of Melobesioideae does not work either. However, when the are starts to recover itself and the distribution of the seaweeds begins to spread from the shallower areas to the deeper areas, the methods of propagation will help to speed up the process. Mass throwing in of mother plants and young sprouts attached to rocks would help the recovery. If the quantity is small, the seaweeds will be consumed by hungry abalones and trochoids. It is easy to create a large quantity of young sprouts in one or two months, as in the case of Undaria pinnatifida, by culturing zoospores in water tanks. If a method of attaching the young sprouts is devised, this will help to develop effective peopagation.

X Cystophyllum fusi-forme

1) Foreword

Cystophyllum fusi-forme is produced anywhere south of Hokkaido and in the south-western coast of Hokkaido. The seaweeds are dried, boiled for a day, and then dried again before going on the market. The annual production of the dried Cystophyllum fusi-forme was about 1,500 tons (Table 20) during 1956 to 1960. The demand seems to be decreasing.

Table 20 Production of dried Cystophyllum fusi-forme

(Unit: ton; Norin Statistics)

National	1,560	Mie	262
Miyagi	95	Ehime	70
Chiba	124	Nagasaki	363
Kanagawa	103	Kumamoto	192

2) Propagation and Ecology

Cystophyllum fusi-forme grow a little below the average water surface on shore reefs with gradual slopes facing toward the open sea. They prefer soft rocks and hence they do not grow on granite or concrete blocks.

The propagation period is from June to July. Eggs are produced on special branches of rice grain size which grow at the root of small branches. The eggs are fertilized on the special branches. The fertilized egges detach themselves from the branches the next day when the tide rises and settle onto some rocks to germinate. They grow slowly during autumn to winter, suddenly grow rapidly in spring, reach maturity, and die. Before they die, the seaweeds extend stolones from their roots. New sprouts spring from the stolones (Illustration 10). The seaweeds are small in their first year but in three years the stubs become large and stable and they live for 7-8 years. (Table 21). Propagation by stolones is predominant, which makes the annual production stable, but on the other hand the survival rate of the eggs is small and hence once they disappear from the area it takes a few years to recover them.

Table 21 Growth of the stubs of Cystophyllum fusi - forme

Year	No. of plants in one stub	Length (m)	Weight (raw kg)	Spread of root (cm)
1	1	0.1	0.01	5 - 6
2	3 - 4	0.2-0.6	0.05-0.2	10
over 3	4 -20	0.3-1.0	0.1-0.6	15 - 20

The greatest part of the harvest is plants grown from the roots.

In productive areas, 10 - 16 kg (Chiba), 6 - 11 kg (Kanagawa), and 7 - 10 kg (Hokkaido) per m^2 are produced. (30) The density is about 1000 plants per m^2, that is, about 100 stubs per m^2.

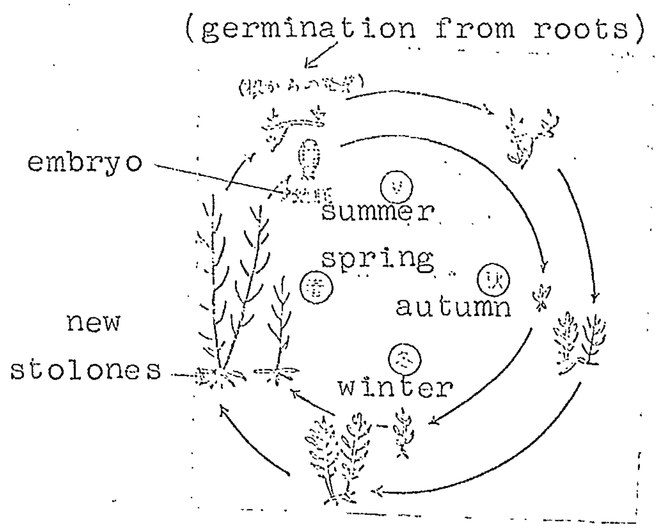


Illustration 10 Life History of Cystophyllum fusi - forme

3) Propagation (artificial)

(1) In areas where the water is calm, Sargassum thunbergii grows among Cystophyllum fusi-forme. This causes a decrease in the production of the latter (Illustration 11). In these mixed areas elimination of Sargassum thunbergii

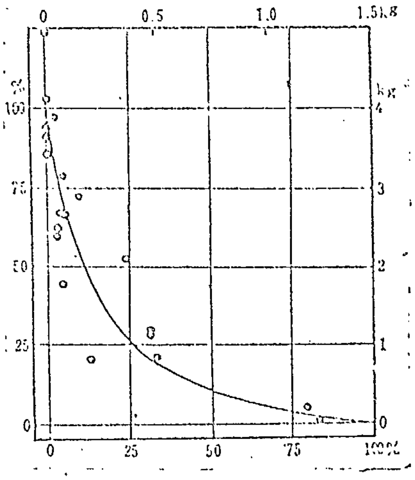


Illustration 11

Relationship in coexistence of Cystophyllum fusi - forme (vertical axis) and Sargassum thumbergii (Katada, 1941)

is very effective. The suitable time for the elimination starts around April or May when stolones begin to extend and ends before August when the propagation period of Sargassum thunbergii starts. Sargassum thunbergii is also perennial and it takes 2 years to establish stubs. Hence the elimination is needed only every other year or every third year.

(2) Transplanting of Seed Plants : When the production in productive areas decreases, transplanting of mother plants is effective. For example, when Cystophyllum fusi-forme died out completely in Nagao village in Chiba prefecture because

of the rise of the ground by 2 m caused by the earthquakes in 1923, rocks with mother plants were put in the sea and fastened by cement in May and June and harvesting was prohibited. In three years plants became visible and in seven years the seaweeds flourished again in the area. Since the propagation by eggs is not strong, and it takes three years for stubs to become full grown, the recovery of productivity takes several years. One of the methods of transplanting is the following: tear off only the roots of plants from the rocks in July to September ; make a paste with cement, plaster (ratio 2:1) and fresh water (sea water makes the paste solid too fast); pour the paste into small holes in the rocks; and press the roots on the paste. This method is handy since collection and transportation of the rootsare not difficult.

XI Hornwort, Nemacystus desipiens, Endarachne binghamiae and Sargassum bacciferum (31)

1) Hornwort

Hornwort is an annual plant which belongs to Phaeophyceae, Chordariaceae and grows north of Chiba and Ishikawa prefectures. The main producing areas are the Sanriku coast and Hokkaido. The product is either salted or dried on boards and is very tasty. The seaweeds grow on shore reefs facing the open sea and the centre of the band in which they grow is just above the low tide line. They germinate in autumn and grow in the winter and spring. They die after producing spores in May to June (in Tohoku districts) and in June to August (Hokkaido). The spores are zoospores which lodge themselves on rocks, germinate and become microscopic filamentous bodies. In autumn male and female spores are produced and they swim into the sea to fertilize. The fertilized spores attach themselves to rocks, germinate, and become Hornworts. It seems to be easy to culture zoospores, to make them form autumn spores, and attach them to pieces of rope and stones, but this process is not used yet.

2) Nemacystus desipiens

Nemacystus desipiens is an annual plant which belongs to Phaeophyceae, Spermatochnaceae and grows in various inlets in the south of the south-western part of Hokkaido. The seaweeds grow below the low tide line and on Chorda filum and Sargassum bacciferum. The seaweeds are collected in February and March and are salted before being sold.

The growth period is winter to early summer. The seaweeds produce zoospores in spring which survive the summer in the form of filamentous bodies. In autumn the filamentous bodies produce male and female spores which are fertilized, lodge themselves on Chorda filum or Sargassum bacciferum, and germinate. It seems to be easy to culture the spring zoospores using a similar method to that used for culturing Undaria pinnatifida, and to obtain autumn spores. It is quite possible to attach the autumn spores to Sargassum bacciferum or Chorda filum to make them grow, or to devise ways to use pieces of rope instead of the seaweeds. These methods have, however, not been used yet.

3) Endarachne binghamiae

Endarachne binghamiae is an annual plant and belongs to Phaeophyceae, Punctariaceae. The seaweeds grow in the area south of Kinkazan and Sado. They are used to put into Miso (bean) soup either raw or dried. The young sprouts are used as bait for fishing fish such as sea breams.

They grow between the low-tide and high-tide lines and flourish from winter to spring. They produce male and female spores during the flourishing period. After fertilization the spores form disc-like bodies. It is assumed that these disc-like bodies produce spores in autumn to propagate. If the rocks are cleaned in the autumn when the water temperature is about 20°C. the rocks are well covered by spores. It should not be difficult to culture the winter-spring spores through the summer to obtain the autumn spores. They germinate well on bamboos thrown into the water when the water temperature is about 20°C. Since the growth of spores into young sprouts is fast, this method can be used in areas where the sprouts flor bait are sold at a good price.

4) Sargassum bacciferum (32)

Sargassum bacciferum is a perennial plant. The seaweeds grow mainly in shallower areas (depth up to several meters) of calm inlets. The larger ones exceed 5 m. The seaweeds as well as

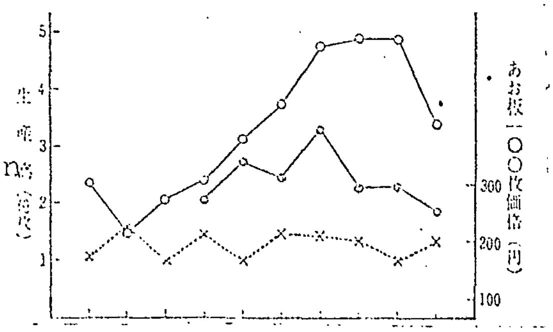
Ecklonia cava are the main plants of the sea forests in the southern part of Japan. Eggs and sperms are produced on small special branches from spring to summer where the tide is high. The fertilized eggs detach themselves from the mother plants in 1 - 2 days after fertilization and losge on rocks to grow. If the mother plants with fertilized eggs are collected at the time of high tide and then are floated on the surface of the water, the eggs easily settle on stones or pieces of rope at the bottom of the water and germinate. If the fertilized eggs are shaken off from the mother plants, the same effect is achieved. It is easy to culture such eggs for 1 - 2 months and after that the young sprouts can be released into the sea.

XII Monostroma nitidum

1) Foreword

Monostroma nitidum belongs to Chlorophyceae, Ulvaceae, Monostroma. This species and Enteromorpho are commonly called Aonori or this species is specially called Ginnori or Bekkoao in order to distinguish it from Enteromorpho. The seaweeds are used for Tsukudani (a preserved food boiled down in soya sauce). Table 22 shows the production statistics of Aonori (mainly Monostroma nitidum). Aonori is cultured in Mie and Aichi prefectures or grows naturally in various areas. The finished product ready for the market is either in the form of barbecued sheets (called Aoita) like laver or in the form of just loosely dried seaweeds (called Baraao). The price of the seaweeds is suppressed by the excess of production and by the fact that its use is limited to Tsukudani. (Illustration 12). Loose, raw, refrigerated Aonori is increasingly used lately for Tsukudani although this lowers the quality of Tsukudani slightly, since in this way the labour for drying or barbecuing is saved.

Production (unit: 100 million sheets)



Price in yen per 100 sheets of Aoita

1953 55 57 59 61

Illustration 12 Relationship between Production and Price of Aonori (mainly Monostroma nitidum) (Norin Statistics)

-O- Total production (3.75 kg of Baraao = 100 sheets)

-◎- Production of Aoita

--X-- Price per 100 sheets of Aoita

(33)

Table 22 Production of Aonori (1958-1962; Norin Statistics)

	Unit	National	Mie	Aichi	Ehime	Chiba	Toku-shima	Shizuoka
Sheet	million	240	61	89	20	19	9	8
Loose	dry ton	715	403	81	30			
Total	dry ton	1,350	566	415	105	71	34	31

2) Species, life history, and ecology

The most popular species for culturing is Monostroma latissimum which has fewer pleats around the edges of the leaves. The seaweeds flourish from February to May. Monostroma nitidum which has more pleats is also cultured and harvested in January and February although not in large quantities.

These seaweeds grow on stones lying on the bottom of the sea from the open sea to the inside of bays. They prefer shoaling beaches with calmer water with slightly higher salt content as compared with the preference of laver. They have a strong resistance to dryness and changes in the density of salt in the water, but they are not strong against low temperatures. Germination occurs in autumn and the plants flourish in spring and die in early summer.

The colour of the rims of the seaweeds becomes orange around the time of the spring tide. All the cells of the orange are of the plants become male or female spores and then swim into the sea. The male and female spores unite and attach themselves to various things. It is presumed that they attach themselves to shadowy places which would not be dried up in order to survive through the summer. Where the spores are cultured, they survive through summer in spherical form and produce zoospores in autumn which germinate to become Monostroma nitidum.

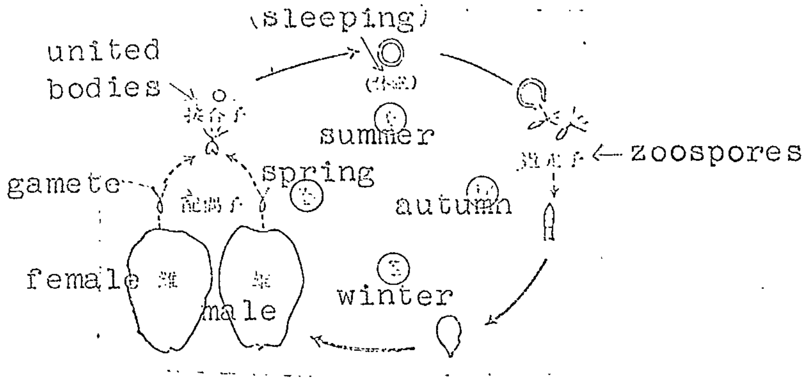


Illustration 13 Life History of Monostroma nitidum

=== growing on rocks period

— sleeping through summer period at the bottom of the sea

... swimming in the sea period

Lodging of the spores in the sea usually takes place just before the spring tide when the water temperature is about 25°C. They grow at the same depth or slightly shallower than laver. They grow gradually until winter and then increase their rate of growth suddenly from winter to spring. The harvesting season is from February to May.

3) Culture

The method of culturing is similar to that used for laver. Bamboo sticks and branches from trees used to be stuck into the sea but today nets are used. Sometimes an excess amount of nets are used, such as when the ratio area of the nets / area of the sea for culturing > 1/2 , in the hope of increasing production. Since a certain amount of waves and currents need go through the area, if need not be as much as for laver, the ratio must be kept at 1/4 - 1/3, otherwise the excess of density may cause some disease and degradation of quality and hence this may result in a decrease in income.

(1) Collection of plants : The natural collection (34) method is used. Nets are stretched across the "seeding area" in the sea and await the settling of the floating spores. Many spores appear from the middle to the end of September just before the major tide comes. The water temperature at this time of year is about 27 - 23°C. They gather around the mouth of rivers or near shores where the rising tide reaches. The preference of depth varies widely, as in the case of laver. In Ise Bay, the suitable depth is 40 cm below the average water surface. In general this method of collection is practised without much difficulty but it is also not rare that the germination of the collected spores is hindered by mud or Diatomaceae or that typhoons disturb the process.

It is not difficult to culture the spring spores and to make them survive through the summer, but techniques for releasing the spores at will in autumn have not been perfected, and hence the artificial collection method as opposed to the natural collection method has not yet been industrialized.

(2) Growth : The nets used for collecting spores are removed to the growth area in the sea after 20 - 30 days when the young sprouts become visible. They grow better if the position of the nets is a little lower in the growth area. Since they are not strong against the cold, the position of the nets should be deep enough so that they are not exposed to the air, but in March and May they should be exposed to the air for about 2 hours, otherwise Diatomaceae starts to live and lowers the quality of the seaweeds.

The harvesting season is from December to May, but the best season is March and April and they do not grow fast in January and February. In general the seaweeds are harvested 4 - 8 times during the season. The production per 1.2 x 18 m. net during the season is 5 - 15 kg. (about 800 sheets in terms of Aoita).

The harvested seaweeds are either made into barbecued sheets (Aoita) or loosely dried.

(3) In Matsuzaka district in Mie prefecture, laver culture was started but because of the low quality of the product and the fact that Monostroma nitidum grew well, the laver culture was switched to Monostroma nitidum culture. Recently this was switched to laver culture again and the income increased by more than three times. The main reason for this success is that the nutrition of the sea has increased through influx of the

used city water and that the number of nets have been decreased to 1/3 and have been rearranged.

XIII Enteromorpha prolifera

1) Foreword

Aonori is a general term for about twenty species which belong to Chlorophyceae, Ulvaceae, Enteromorpha and Ulvaceae. These seaweeds grow everywhere in shallow areas and they are regarded as harmful weeds for laver culture. The important species is Enteromorpha prolifera which is a branched, narrow, tube-like plant and grows to a height of more than 1 m. The seaweeds are used to make Kakeaonori or Momiaonori (dried seaweed to sprinkle on hot rice - tr. comment) The seaweeds are distributed in the south of Chiba and grow at the mouth of tidal rivers on stones which lie 1-2 m below the low tide line. In Shimato River (in Kochi prefecture) the annual production was about 70 - 80 dry tons, that is, about $70,000 (300 yen = $1) in 1959 and 1960. In Chiba and Tokushima the seaweeds are cultured. The total annual national production $330,000 - 660,000 (300 yen = $1).

Table 23 Production of Enteromorpha prolifera in Shimato River (Kochi prefecture) (35)

Year	1960					1961	1962
	Nov.	Dec.	Jan.	Feb.	Total		
Production (unit: dry ton)	4.7	25.2	34.6	22.8	87.3	73.0	28.0
Amount (unit:$3,300)					23.0	22.4	17.9

2) Life History, Propagation and Ecology

The seaweeds are either hermaphrodites or neuters. It is said that male and female spores from hermaphrodites are fertilized, germinate and grow into neuters and that zoospores from neuters germinate and grow into hermaphrodites. In Shimato River spores are formed during March to November. They attain full growth in 2 months after they settle on stones. The seaweeds are not large enough to be noticeable in the summer and then grow rapidly during October to the next April when the water temperature is below 15°C.

They do not have a great resistance to dryness, and hence those which grow above the low-tide line are small. Those which grow in the band from the low-tide line down to a depth of 2 m. are large. They prefer low density. In Shimato River the area in which the seaweeds grow is flooded with fresh water for 2-3 hours during low tide but the fresh water is replaced with the high tide by sea water with Cl more than 15%, except for the surface of the water of the area. In Tokushima prefecture, during the seeding period of September the area is flooded with fresh water for a short time during low tide and the density of the water becomes 1.015 to 1.020 during high tide.

If the areas are flooded with fresh water for 2-3 days by a heavy rain fall, the seaweeds tend to die. However, they seem to produce spores before they float away. The young sprouts in shallow water have greater resistance to fresh water.

3) Propagation (artificial)

Little artificial propagation is practised. One of the examples is the following: When most of the plants in Shiwato River were washed away by a flood in November 1962, the remaining young sprouts in the shallow area were removed with the small stones on which they grew into a depth of 1-2 m. The young sprouts successfully grew and were harvested after one month. It seems to be effective to throw small stones or shells into prosperous areas in autumn (September - October).

4) Culture

The culturing of the seaweeds is practised in Tokushima and Chiba prefectures. Nets are used. The nets are stretched a little above the low-tide line (where the nets are exposed in the air for 0-2 hours during the major tide) in autumn just before the major tide or after a rainfall when the water temperature is about 25 ^{o}C. The nets are lowered down to the low-tide line as the seaweeds grow. The seaweeds are harvested once or twice during November and December using this method. The production is about 4 kg (dry) per net.

It seems to be possible to obtain spores after floods until October. When the seaweeds are artificially soaked for half a day in water which is half fresh and half sea water with a temperature above 15 °C and are then put into sea water, they often release a great deal of spores 4 - 5 days later. There is a possibility that young sprouts can thus be cultured indoors.

5) Manufacturing (36)

The seaweed is washed and dried on a string. Then it is further dried by fire to make it into a powder which is called Furikake and sold. This product sells quite well. In Chiba prefecture the seaweed is also baked just like green laver. The harvest gathered and processed before the new year is sold at a good price for new year dishes.

XIV Zostera marina & Phyllospadix iwatensis

Several species are known. They grow in sandy and muddy areas in calm water. The areas are used for spawning and as a playground for fry. They are spermatophyte and bloom throughout the summer and release their seeds. They are also perennial and have subterranean stems.

Quite often the areas where this seaweed grows decline and become unsuitable. One known cause is harm by parasitic bacteria, but more often it seems to happen because the ground becomes hardened and worn out after a long time. It is considered good to dig out alternate narrow strips in the area and repeat this when the ground is again used up. It is also a good practice to transplant subterranean stems to recover the declining area.

Zostera marina and Phyllospadix iwatensis are closely related. They grow on shore reefs north of Chiba prefecture. They penetrate into the area of Undaria pinnatifida or Laminaria and are considered noxious weeds.

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