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Cultivation of *Undaria pinnatifida* (Harv.) Sur. (WAKAME)

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Cultivation of Undaria pinnatifida

(Harv.) Sur. (Wakame)

Yunosuke Saito

(Revised Edition)

INTRODUCTION

<u>Undaria pinnatifida</u> is one of the original seaweeds of Japan. It grows in coastal waters of the greater part of the Japanese islands and it has been a popular sea-food for Japanese people from old times. Of late years, the demand for <u>Undaria pinnatifida</u> has increased, because its nutritive value such as vitamines, minerals, and protein (Table 1) are thought much of and because of its low price.

Table 1. Nutritive Value of <u>Undaria pinnatifida</u>

Components		Dry Products	Wet Products
calorie	cal	75	4
water	g	17.41	96.73
protein	g	12.45	0.65
fat	g	0.88	0.03
sugariness	g	4.42	0.25
cellurose	g	4.15	0.20
ash	g	19.70	0.55
calcium	mg	389	18
phosphorous	mg	636	24
table salt	mg	5.737	33
vitamine A	IU	400	-
vitamine B_1	mg	0.10	-
vitamine B_2	mg	0.15	-
vitamine C	mg	15	-

After "Shokuhin Eiyoka Yoran," (Handbook of Nutritive Value of Food), Kokuritsu Eiyo Kenkyusho and Kokumin Eiyo Kyokai edi., 1956.

Concerning the production of *Undaria pinnatifida*, it is a very important resource for fisheries propagation industries because of its wide occurrence and the higher rank among seaweeds resources of our country. The importance of *Undaria pinnatifida* is followed by those of seatang (*Laminaria*), purple laver (*Porphyra*), and agar-agar (*Gelidium* and allied species). Recent production of *Undaria pinnatifida*, including *Undaria undarioides* and *Undaria peterseniana*, is shown in Table 2 after "The statistical table of fisheries, cultivation industries and fisheries catch." This table shows how the harvest of *Undaria pinnatifida* varies from year to year. There are several reasons ~~on~~ for the variation ~~of the produce~~ in production; the most important reason is the variation in amount of resources, which is controlled by natural conditions.

Fisheries propagation industry had been practiced by setting stones on the sea bottom from the Meiji era (1968-1912). Since 1952 the industry 4
has being studied based on a long-term and large-size project as one of the government supported inshore (and off shore) fisheries industries. However, the propagation techniques and the plans practiced currently can not control the harverst of *Undaria pinnatifida*. In addition to that, they are not effective enough for the larger production. There are several reasons for the ~~u~~ineffective culture practice; among them the lack of research and effort to unveil the ecology of *Undaria pinnatifida* may be responsible. The ecology of *Undaria pinnatifida*, however, has ~~being~~ been revealed, so ~~in~~ the future propagation plan studies the natural contions of the shore where *Undaria pinnatifida* will be propagated and applies proper methods to the conditions. Thus, "fields in sea" will be developed and improved.

Table 2. Fiscal year produce of <u>Undaria pinnatifida</u>*
(Weight in raw or wet, metric ton)

Sea District	District or state	Fiscal Year Produce '53	'54	'55	'56	'57	'58	'59	'60	'61
Hokkaido	North east	622	820	1,004	929	1,315	722	601	1,296	723
	South	5,176	3,521	2,730	2,449	4,322	3,168	3,869	7,313	4,458
	West	4,375	2,989	3,397	3,738	6,097	4,364	4,897	8,471	5,134
	Total	10,173	7,330	7,131	7,116	11,734	8.255	9,368	17,081	10,317
Pacific Ocean	Aomori	1,255	1,180	1,112	1,794	1,521	1,639	3,319	3,148	2,104
	Iwate	12,876	5,846	12,210	10,674	12,974	14,137	15,239	16,080	13,480
	Miyagi	9,075	1,607	6,150	7,262	6,801	5,444	10,450	10,089	7,576
	Fukushima	146	34	112	52	82	111	63	132	186
	Ibaragi	828	45	464	288	419	219	171	216	447
	Chiba	236	71	206	307	614	613	433	664	777
	Tokyo	—	—	4	187	150	172	6	1	—
	Kanagawa	434	423	517	288	816	598	166	546	569
	Shizuoka	236	333	1,315	1,386	614	167	20	85	246
	Aichi	408	255	232	277	318	234	56	561	419
	Mie	1,887	146	356	419	311	339	122	507	907
	Wakayama	165	56	206	255	15	12	4	20	62
	Tokushima	7	0	7	0	4	10	10	10	47
	Kohchi	—	—	—	—	—	—	—	—	—
	Ehime	0	15	—	4	30	46	38	12	8
	Ooita	0	4	0	4	11	3	6	2	5
	Miyazaki	—	—	—	—	—	0	0	—	—
	Total	27,553	10,015	22,891	23,197	24,680	23,751	30,109	32,080	26,838

* "Gyogyo, Yoshoku-gyo, Gyokaku Tokei-hyo (The statistical table of fisheries and cultivation industries and fisheries catch)," edited by Nohrin-sho Nohrin Keizai-kyoku Tokei Chosa-bu (The Department of Statistical Study, Bureau of Agriculture and Forestry Economics, Ministry of Agriculture and Forestry).

Table 2. (Continued)

Sea District	District or state	'53	'54	'55	'56	'57	'58	'59	'60	'61
Sea of Japan	Aomori	318	528	419	270	258	630	25	666	213
	Akita	64	112	97	41	67	187	195	348	141
	Yamagata	330	513	592	285	760	600	442	46	520
	Niigata	210	809	393	288	719	1, 096	281	446	141
	Toyama	22	49	71	22	71	27	46	230	26
	Ishikawa	333	468	670	251	513	463	341	201	213
	Fukui	408	423	449	236	367	464	460	514	514
	Kyoto	311	303	303	258	479	449	289	221	696
	Hyogo	187	199	442	281	393	681	1, 029	494	418
	Tottori	67	49	82	90	202	267	147	144	173
	Shimane	2, 094	2, 903	4, 247	2, 461	4, 240	2, 781	3, 019	4, 282	4, 892
	Yamaguchi	517	708	1, 169	1, 419	1, 506	834	465	616	1, 166
	Total	4, 861	7, 064	8, 934	5, 902	9, 575	8, 483	6, 739	8, 215	9, 120
East China Sea	Fukuoka	843	551	993	985	1, 127	848	597	648	894
	Saga	71	26	45	112	157	82	131	90	249
	Nagasaki	3, 449	2, 925	2, 899	3, 232	3, 131	2, 873	1, 589	2, 695	8, 090
	Kumamoto	416	929	513	674	524	1, 191	1, 125	711	1, 604
	Kagoshima	22	0	30	157	97	72	6	1	355
	Total	4, 801	4, 431	4, 480	5, 160	5, 036	5, 068	3, 450	4, 148	11, 194
Seto-naikai Inland Sea	Wakayama	206	400	288	185	101	202	173	187	91
	Oosaka	0	0	0	4	0	39	49	14	108
	Hyogo	303	348	487	400	161	286	280	447	377
	Okayama	4	7	11	76	76	34	18	33	116
	Hiroshima	7	4	11	7	19	22	21	14	17
	Yamaguchi	41	60	30	176	86	44	73	116	126
	Tokushima	236	206	408	292	199	197	303	244	248
	Kagawa	0	4	0	79	79	58	29	17	75
	Ehime	26	53	202	52	37	81	78	45	62
	Fukuoka	—	0	—	0	—	—	—	—	—
	Ooita	0	0	4	11	22	16	7	15	56
	Total	823	1, 085	1, 441	1, 282	780	983	1, 031	1, 137	1, 281
	Sum Total	48, 211	29, 925	44, 877	42, 657	51, 805	46, 542	50, 711	62, 664	58, 752

Note: the produce of 1953 - 1957 was converted to metric ton from an unit used in the statistical table.

Recently the cultivation industry of Undaria pinnatifida becomes important as one of the projects for intensive fisheries and for stabilizing the fisheries management. Artificial ~~sporing~~ sporulation and cultivation of Undaria pinnatifida have been studied since the beginning of the Showa era (1926-): Messrs. Toraichiro Kinoshita (Hokkaido) and Yojiro Ootsuki (Kanto-shu) primarily established the techniques in 1942-1943, following the research by Mr. Toshizo Sudo. As a result of their studies, ~~manufacture~~ production of seedling became possible in sea or indoor at many culture stations. And the cultivation of Undaria pinnatifida is spreading over the country after the successful industrialization ~~in~~ on the ~~sea~~shores of Tohoku district. The figures of cultivation of Undaria pinnatifida are shown in Table 3 for the fiscal years of 1962 and 1963.

In the following chapters the cultivation of Undaria pinnatifida will be described. ~~To be~~ For successful ~~for the~~ cultivation, first we must know the ecology of the seaweed. The ecology of Undaria pinnatifida and the techniques of its cultivation will be described in details in separate chapters.

Table 3. The present figure of cultivation industry of Undaria pinnatifida

Sea District	State	Fiscal year 1962: Number of seedlings culture station	Fiscal year 1962: Amount of seedlings cultured (m)	Fiscal year 1962: Number of cultivation rafts	Fiscal year 1962: Produce in weight (raw, kg)	Fiscal year 1962: Produce in price (¥1000)	Fiscal year 1963: Number of seedlings culture station	Fiscal year 1963: Amount of seedlings cultured (m)	Fiscal year 1963: (Prescribed) Number of cultivation rafts
Hokkaido	Hokkaido	7	(25,000)	370	6,000	(480)	7	(21,000)	300
Pacific Ocean	Aomori*	2	3,200	108	22,000	(1,760)	7	22,500	120
	Iwate	46	176,545	673	(185,540)	(37,770)	58	2,785.344	1,262
	Miyagi	183	235,310	2,127	(1,654,900)	(50,000)	454	327,430	5,120
	Fukushima	0	0	2	200	10	3	1,000	4
	Ibaragi	0	0	2	—	—	0	0	0
	Chiba	3	1,100	2	0	0	2	1,500	1
	Tokyo	—	—	—	—	—	—	—	—
	Kanagawa	36	14,000	175	16,500	1,140	24	19,000	400
	Shizuoka	3	4,400	4	(300)	(50)	2	3,200	4
	Aichi	4	60,800	366	(37,500)	(2,300)	34	72,140	506
	Mie	12	82,000	250	50,000	2,500	14	39,000	130
	Miyazaki	0	0	1	—	—	0	0	3
Sea of Japan	Akita								
	Yamagata	1	50	1	0	0	4	150	2
	Niigata	11	5,000	56	22,300	(200)	23	38,200	222
	Toyama	1	1,000	1	100	(10)	2	2,000	—
	Ishikawa	1	4,500	16	—	—	2	7,200	20
	Fukui	2	3,200	16	22	20	3	6,950	35
	Kyoto	2	4,000	2	(300)	—	2	8,000	4
	Tottori	0	0	0	0	0	1	700	1
	Shimane	0	0	3	—	—	2	600	10
	Yamaguchi	1	15,000	60	3,000	500	1	15,000	175

Table 3. (Continued)

Sea District	State	Fiscal year 1962: Number of seedlings culture station	Fiscal year 1962: Amount of seedlings cultured (m)	Fiscal year 1962: Number of cultivation rafts	Fiscal year 1962: Produce in weight (raw, kg)	Fiscal year 1962: Produce in price (¥1000)	Fiscal year 1963: Number of seedlings culture station	Fiscal year 1963: Amount of seedlings cultured (m)	Fiscal year 1963: (Prescribed) Number of cultivation rafts
East China Sea	Fukuoka*	4	2,500	3	57	6	3	2,100	—
	Saga	4	17,000	2	—	30	5	20,500	20
	Nagasaki	135	57,950	268	18,000	1,800	184	255,935	1,185
	Kumamoto	3	25,000	28	(8,000)	(400)	5	30,000	35
	Kagoshima	2	32,350	(100)	—	—	5	88,780	(250)
Seto-naikai Inland Sea	Wakayama*								
	Oosaka	—	—	—	—	—	—	—	—
	Hyogo*	3	9,160	68	(3,000)	198	17	49,090	200
	Okayama	—	—	—	—	—	—	—	—
	Hiroshima	5	5,750	13	4,000	320	23	48,000	200
	Yamaguchi	2	15,500	70	1,540	250	1	95,000	100
	Tokushima*	15	31,700	115	25,840	3,869	74	202,775	350
	Kagawa	1	200	2	100	7	7	3,100	27
	Ehime*	1	100	2	100	10	2	800	120
	Ooita*	2	1,500	30	36,000	(3,000)	3	5,000	150
Sum Total		492	833,815	4,936	2,095,299	106,630	974	4,171,994	10,956

Note:
1. The data are based on study by the fisheries laboratory in each state (ken).
2. The states (ken) marked with * have more than one sea district and their data indicate total amount.
3. One cultivation raft is equivalent to 200 m of main rope.
4. Amount in parentheses include an estimation.

Ecology of Undaria pinnatifida

Undaria pinnatifida grows on reefs and stones in coastal waters faced to or close to a warm open sea. Along the west coast of Kyushu and the Sea of Japan, Undaria pinnatifida occurs in the coastal waters of Tozakibana, Kagoshima-ken, Kyushu and northward, all coasts of the Sea of Japan, west coast of Hokkaido, Rishiri island, and Rebun island. The straits of Sohya is the north limit. And also the seaweed occurs in the coastal waters of the Pacific Ocean: Yamakawa in Kagoshima Bay (very small amount), north of Kadokawa Bay, Miyazaki-ken, eastern coast of Kyushu, all coasts of the Seto-naikai inland sea, most Pacific coasts of Honshu, and east of Muroran, Hokkaido. Along the coast of Shikoku, the seaweed occurs in the coastal waters of Yurazaki (western coast) and northward and Hiwasa, Tokushima-ken (eastern coast) and northward, but not of Kohchi-ken. Along the coast of Kii Peninsula, the seaweed occurs in the north of Sakaiura, Wakayama-ken (west coast) and of Mugizaki, Mie-ken (east coast), but not in the Sea of Kumano-nada. Generally, Undaria pinnatifida does not occur in the deep inside of a bay nor around the mouth of a river where the bottom of the sea is sandy or muddy. The seaweed occurs in the coastal water of Korean Peninsula: south; east (south of Zozan Bay); and west coasts (south of Daisei Island).

Undaria pinnatifida can be classified into the following two types based on the shape of frond and its occurrence (another classification shows three types: the following two types and Naruto wakame).

Southern wakame (wakame) --- generally smaller in size, short stem, shallower emarginated frond, too many leaflets for the frond length. The reproduction frond has few waves (2 to 4 waves). The reproduction fronds and the nutritive fronds are often continuous, and sometimes small tongue-like fronds can be seen on the edge of the reproduction frond. This type of Undaria pinnatifida grows mostly in the coastal waters of the middle-south of Honshu Island (Pacific coast) and of the Sea of Japan, especially in the shallow places.

Northern wakame (Nanbu wakame) --- larger in size , longer stem, 7
deeper emarginated frond, few leaflets for the frond length. The reproduction frond has many waves (6 to 20 waves). This Undaria pinnatifida grows in the coastal waters of Sanriku coast of the north of Inubo-zaki and of Hokkaido. This also grows in other coastal waters, where is deep and strong current.

Undaria pinnatifida is an annual seaweed and its life cycle is shown in Fig. 1. The full-grown Undaria pinnatifida gets, at the lower part of

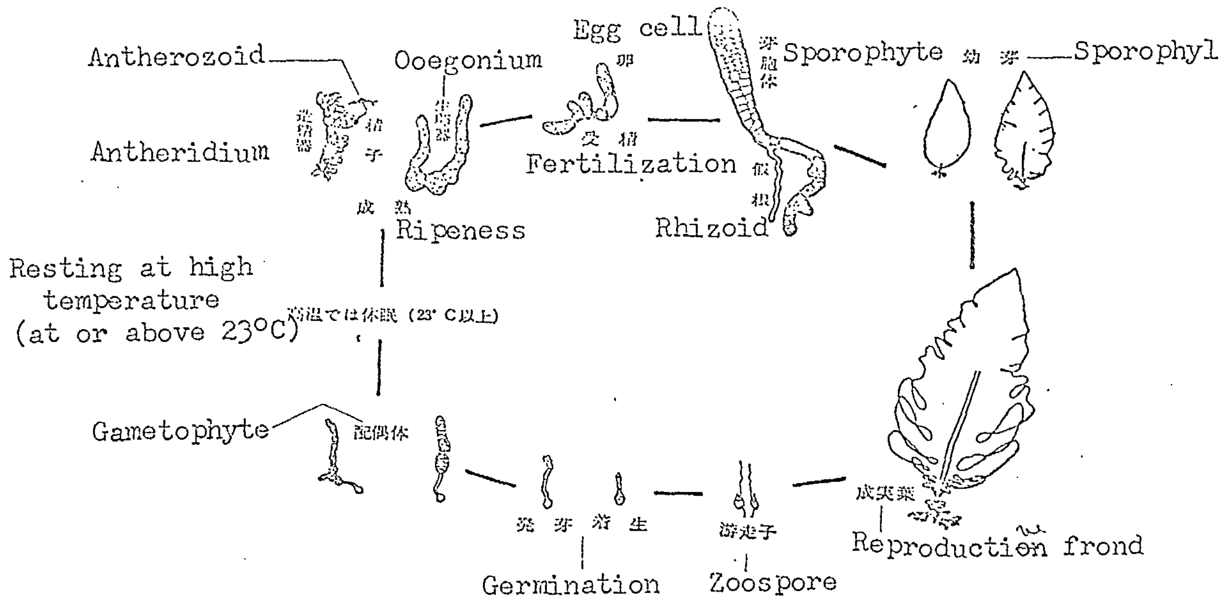


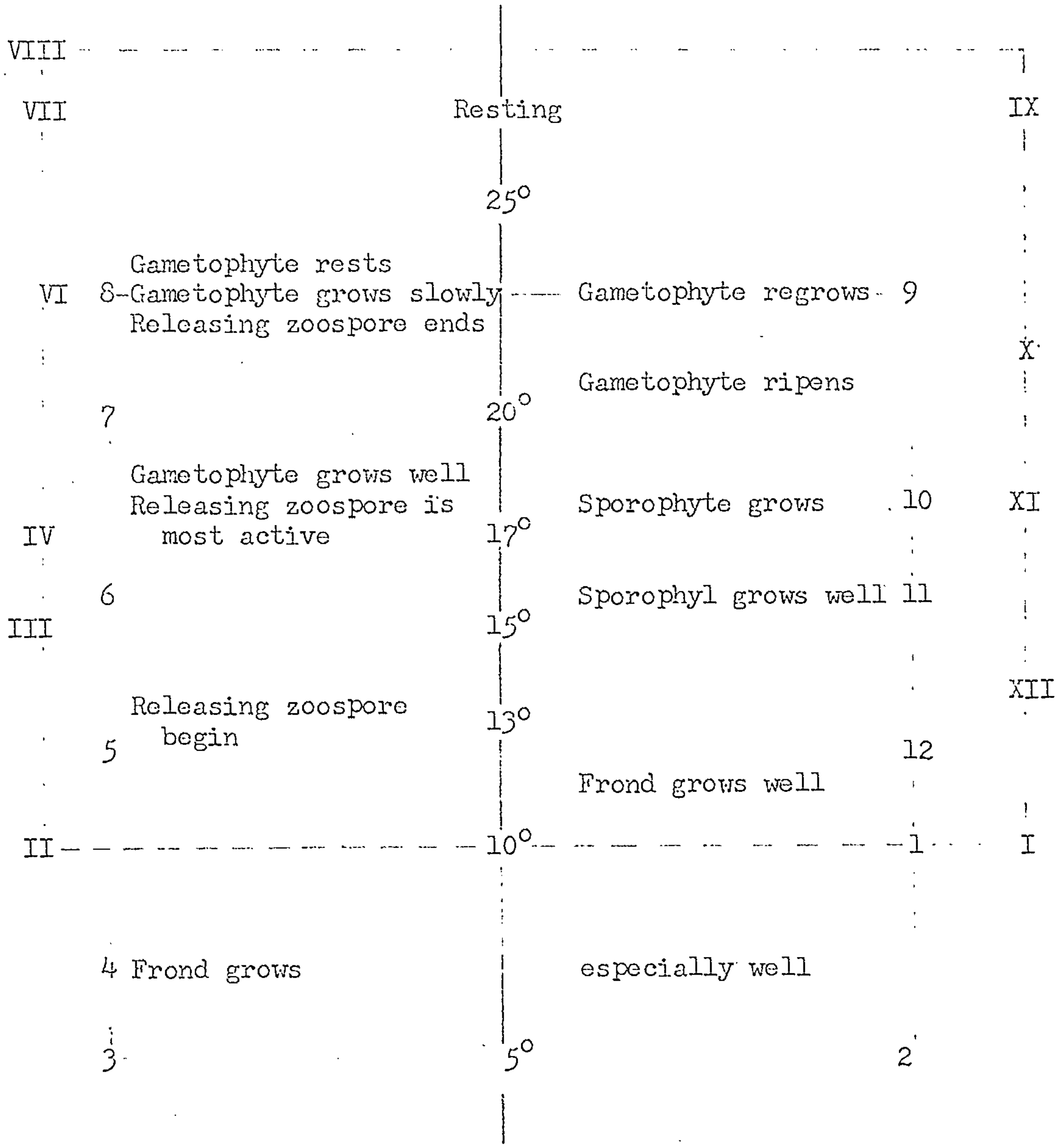
Fig. 1. Life cycle of Undaria pinnatifida

its stem, the pleats called reproduction fronds which shapes are different from those of a nutritive frond. Zoosporangia are formed on the reproduction fronds and when time comes, the cusp of the zoosporangium is broken and zoospores produced in the zoosporangium come into the sea water with a viscous liquid in it. The zoospore, about 9 micron long, is pear-shaped with two hairlines on its side and can swim by waving the hairlines. As the hairlines reach to a foundation in the sea water, germination of the zoospore occurs. The zoospore, thus, looses the hairlines and becomes round; after this, it grows a pipe-like process (germination organ) into where the contents of the zoospore body moves, then a new cell will be formed at the point of the process. As the result of the division of the new cell, the cells called gametophytes successively (sometimes branched) grow forming a thready body (its size is generally microscopic, but in some cases it grows to a large size to be observed with naked eyes). There are two types of gametophyte: male gametophyte having thinner, longer, and more cells and female gametophyte having fatter, shorter, and less cells. When they ripen, the former will have an antheridium and the latter an ooegonium. One male gametophyte produces numerous antheridia on it, which are seen as a racemose shape sometimes; each antheridium produces one antherozoid, which has a similar shape to that 8
of zoospore. The ooegonium is formed at the point of the female gametophyte or by extending newly divided cells to a bat-like form; each ooegonium has one egg. Staying in the female gametophyte, the egg is fertilized with an antherozoid which is swimming in the sea water and germinates (a sporophyl is called a sporophyte when it is microscopic size and consists of a single layer of cells). At the beginning, the sporophyl stays on the foundation

by means of a rhizoid which is an extension of cells at the base of sporophyl, then it grows a stem; subsequently the cells of the sporophyl become multi-layer around the border of their stem and frond. The sporophyl becomes a lanceolate or oval single young-frond with a complete histology until the sporophyl grows to several centimeters length. Around this time the stem of the sporophyl also has a complete histology and the sporophyl grows fibriform roots around its base so that it sticks to the foundation (Refer to Plate I). Then the sporophyl grows at its growing region at the boundary of stem and frond; the growing region will have comb-like leaves on both sides; the comb-like leaves grow to the grown fronds as the body length of the sporophyl grows. The grown frond ripens to have the reproduction fronds, dispaches zoospores, falls, and ends its life. Undaria pinnatifida has this life history, however, time of the ripeness and growth differ in each sea district because of its wide occurrence. Nevertheless, according to the detail studies by the fisheries experiment stations in each state (ken), water temperatures are about same at the time of releasing zoospore, the appearance of sporophyl, and growing. The relation among the ecology, water temperature, and time(month) is diagramatically shown in Table 4 for northern and middle-southern sea districts, respectively.

The reproduction fronds start to grow without the relation to the water temperature, however, releasing zoospores begins above 14°C of the 10-day average temperature, continues up to about 22°C, and is most active between 17 and 22°C. Experimental results in an indoor water current shows that releasing zoospores has a clear-peak once a day and in other time the number of zoospores released is small. The number of zoospores released in one

Table 4. Ecology of Undaria pinnatifida



Arabic on a loop indicates a month in the northern sea district;
Roman in the middle-southern sea district.

peak is 100,000 to 1,000,000 per one gram of ripe part of the reproduction frond; only one day per three days or more, one to ten millions are released. The peak frequently appears between 9 a.m. and 4 p.m., but not between 0 a.m. and 9 a.m. The time of appearance of the peak changes from sample to sample; 9
generally the peak disappears within two hours. The direct observation on the release of zoospores has not been reported in the natural sea; however, a similar phenomenon is supposed and a large quantity release (one to ten millions) is expected at a four- to five-day period. The large quantity release has not been observed in two- to three-days after bad weather; releasing period of one reproduction frond is 20 to 40 days. When released zoospores contact with a foundation in the sea water, most of them swim along the surface of the foundation and move against the water current. Along a glass surface they can stand up to 8 cm/sec of a water current; some of them are washed down above 8 cm/sec; all of them are completely washed down at 14 cm/sec. On the other hand, when the zoospores have no chance to contact with a foundation, they swim continuously for a long time (1 - 2 days). However, their swimming area is small; their swimming directions are at random; they don't have any light tendency. Therefore, zoospores are accidentally flown to neighbour of a foundation by the water current, then they swim to germinate on it. The swimming hour and the efficiency of germination depend upon the temperature, the specific gravity, and pH of the sea water: generally at a higher water temperature and in the sea water with lower specific gravity, the swimming hour is short; a good efficiency of germination is observed at or below 20°C of water temperature and in the sea water with 20 or more of specific gravity (at 15°C); an extremely weak efficiency at or above 25°C and with or lower than 10.

Zoospores germinated become gametophytes. The germination and the growth of the gametophytes are best at 17 - 20°C, but above 27°C the germination doesn't occur. The gametophytes grow at a temperature of up to 23°C; at above 23°C they stop to grow; their cells become round and cell skins become thick; they get into resting stage. The resting gametophytes can bear a high water temperature like 30°C (See Plate I. B and C). Concerning the specific gravity of the sea water, the germination and the growth of zoospores are active in the sea water with 22 - 24 of specific gravity; those are extremely poor with lower than 12; at higher water temperatures those are poor with 20 or below. The effect of light on the germination and the growth of zoospores also depend upon water temperature: at or below 20°C the growth is better in brighter days (clear, daylight average 2,000 - 6,000 luxes); at a higher water temperature the germination prefers weaker light (below 1,000 luxes around 28°C).

The ripeness of gametophytes and the germination of sporophytes occur below 20°C and the growth of sporophyte is good below 17°C. Under a bright light, the ripeness of gametophytes, the germination and the growth of sporophytes are active, but under a dark light (below 150 lux) even the ripeness doesn't occur. In the sea water with below 20 of a specific gravity, the ripeness, the germination, and the growth become slow. Moreover, the ripeness of gametophytes is likely relating to the length of daylight, probably a short daylight (8 - 12 hours) affects the ripeness.

According to the results of an indoor culture, an egg cell moves to a pointed edge of an ooegonium and is fertilized; the egg cell germinates to sporophyte as staying on the pointed edge (Plate I, D); cells at the

base of sporophyte grow to be a rhizoid; the sporophyte sticks to a foundation by means of the rhizoid. The egg cell so seldom germinates away from its ooegonium. Although the reproduction of Undaria pinnatifida has been supposed to be proceeded only by its zoospores, the effect-determination- 10
study of the fisheries propagation industry or other experimental results show that Undaria pinnatifida occurs in the growing period of the following year on the stones and on the foundations which were thrown into the sea 11
and the place where reef-blastings were performed, when the time is not a zoospore releasing period. This indicates that the reproduction of Undaria pinnatifida is proceeded by something rather than zoospores. The result of an indoor experiments revealed that the gametophytes in a resting stage are easily removed from a foundation and they hardly germinate on it again without any conditional change. At a lower water temperature the gametophytes are not removed easily; very few gametophytes are removed by the water current of 3 cm/sec. On the contrary, the gametophytes removed artificially germinate easily again and also the gametophytes, which removed naturally from the foundation at a higher water temperature and are floating, can easily germinate again when the water temperature comes down. Fertilized egg cells and sporophytes which do not have rhizoids yet are hardly removed from the pointed edges of their ooegonium by a weak water current, however, when some of them are removed, they germinate well. It is hard to conclude that the results of these indoor experiments are quite similar to the situation of the reproduction of Undaria pinnatifida in the natural sea, but these phenomena might occur in nature.

As for the growth of the frond of Undaria pinnatifida, its natural condition has not yet been revealed because of few observation reports,

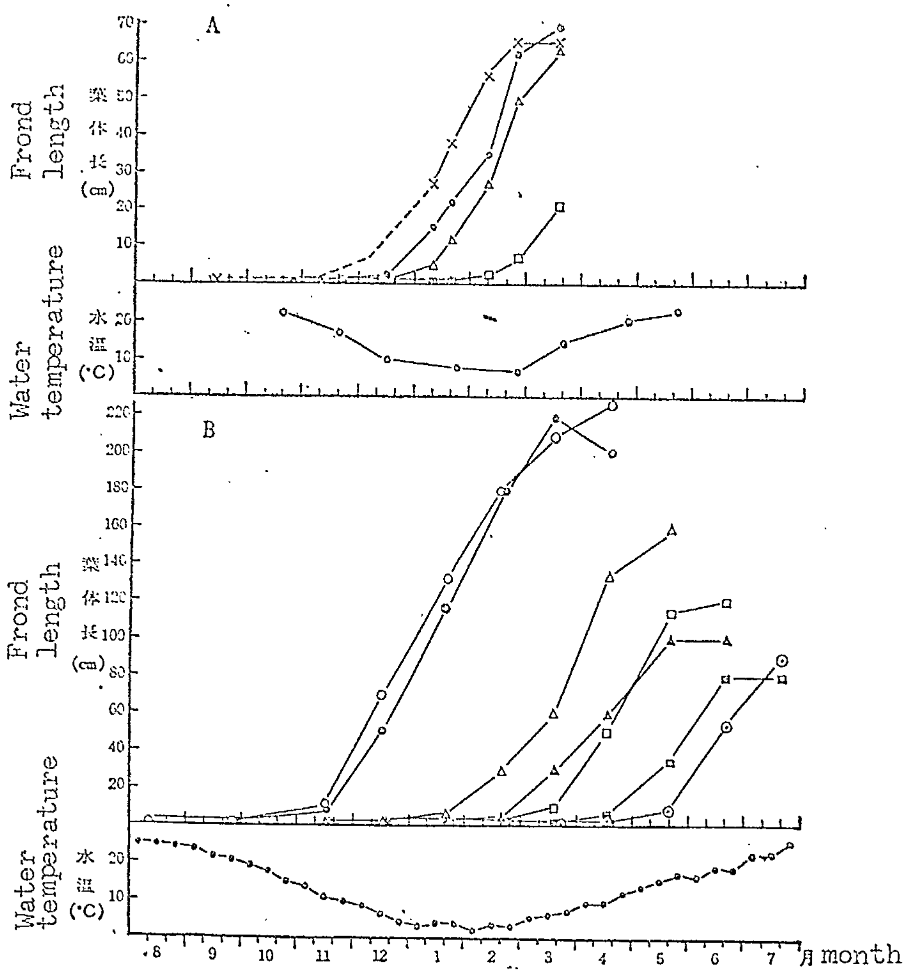


Fig. 2. Relation among time, water temperature, and growth of <u>Undaria pinnatifida</u>

A. Cultivated in Toyohama Port, Aichi-ken (1956 - 1957). Frond length is an average value among well grown fronds.
Date cultivation began: X - Sept. 14; ◎- Oct. 25; △- Nov. 21; □- Dec. 14, 1956.

B. Cultivated in Matsushima Bay, Miyagi-ken (1952 - 1953), after Kuroki and Akiyama, Tohoku Sea District Fisheries Experiment Station (cf. Bibliography).
Date cultivation began: ○- Aug. 12; ◌- Sept. 27; △- Nov. 14; ▲-Dec. 16, 1952; □- Jan. 19; ▣- Feb. 19; ◎- Mar. 17, 1953.

nevertheless, the following phenomena are known by cultivation experiments. Two examples of the relation among growth, water temperature, and time are shown in Fig. 2. The young fronds (sporophyl) at the stage of sporophytes and a single leaf grow over entire fronds; this growth is good in the water temperature range of 15 - 17°C, slow below the temperature range, and extremely slow below 10°C. The growing region of the young frond moves to tho boundary between its stem and frond and the young frond has a midrib and comb-like leaf. The growth of the young *Undaria pinnatifida* is good below 12 - 13°C; the growth is comparatively good up to 15°C; the rate of growth becomes very slow above 15°C; the growth is extremely little but still exists at about 20°C. Lightness in the sea water, which depends upon the insolation, the transparency of the sea water, and the depth of the sea also governs the growth of *Undaria pinnatifida*. Probably, not only lightness but also period of sun shine affects the growth. The lightness and the water temperature correlate on the growth of *Undaria pinnatifida*: it grows well at less-lighted area (deeper area) when the water temperature is high, or at well-lighted area (shallow area) when the temperature is low. Fig. 3 shows the relation between the water depth where *Undaria pinnatifida* is caltivated and the growth of *Undaria pinnatifida* which are germinated in different times (seedlings whose growth were controlled to a similar degree were transplanted from a pilot plant to the sea to be cultivated). The figure shows the correlation of the lightness and the water temperature, mentioned above.

When the upper part of the frond of *Undaria pinnatifida* is cut off leaving the main growing region at the boundary between the stem and the

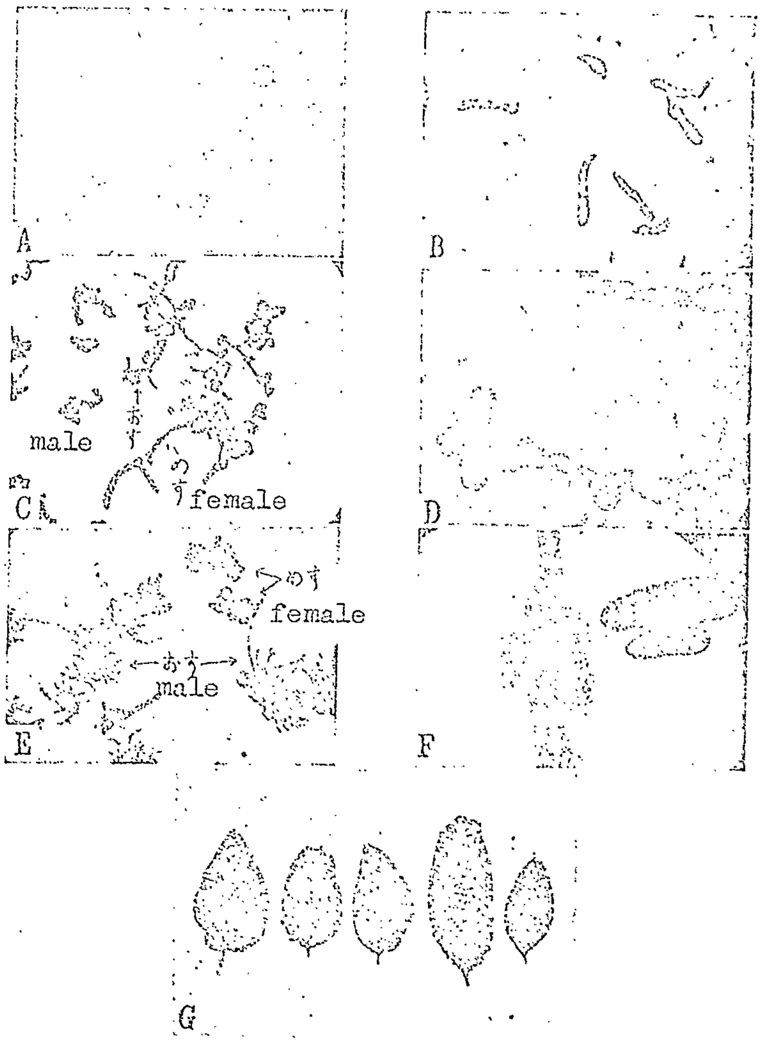


Plate I

A. Gametophyte immediately after the germination. x 600.

B. Growing gametophyte (at 21°C; after 10-day culture). x 600.

C. Resting gametophyte at a higher water temperature. x 150.

D. ibid, enlarged. x 600.

E. Gametophytes which start to re-grow as the water temperature goes down. x 150.

F. Sporophyte germinated on the seedling rope (Kuremona fiber: polyvinyl alcohol). x 600

G. Young fronds. Origin: Toyohama, Aichi-ken.

Plate II

A. Seedling device (screen made of palm rope) and culture tank (under ground type made of tufa. Mr. Ryuzo Tsuji, Oginohama, Ishinomaki-shi, Miyagi-ken.

B. Seedling device (palm rope, culturing in the sea). At Miyako Bay, Iwate-ken. Division of Fisheries, Miyako-shi.

C. Undaria pinnatifida grown on oyster shells (hanging from a raft). At Toyohame Port, Chita peninsula, Aichi-ken.

D. Frond cut at lower part of the frond (the frond length 36 cm, stump length 7 cm, March 10, 1958).

D. Re-growth of the stump D (frond length 17 cm, March 25, 1958).

frond to its stump and when the stump is large enough to grow, it re-grows well. The relation among the re-growth, water temperature, and lightness in the sea is similar to that of the initial growth of the frond. This can be seen in Plat II. D and E.

Undaria pinnatifida occurs forming a sheaf (several fronds grows at a point) or a group. When Undaria pinnatifida grows in a small area, several groups are formed according to the different growth: a group showing the best and fastest growth grows well without any relation to the growth density in the area; a group showing slower growth is affected by the growth density and the group always has many small fronds. This phenomenon can be seen when it is observed in a very small area. On the contrary, if it is observed in a large area the growth density affects the water current and other circumstances and the growth of Undaria pinnatifida will be different 14
in each area (c.f. Fig. 7).

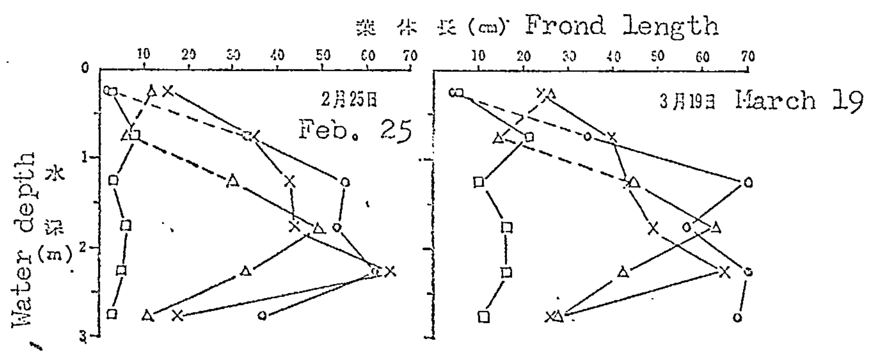


Figure 3. Relation among the growth of Undaria pinnatifida, the water depth, and the germination time. (Designations and the water temperature are referred to Fig. 2, A)

Broken lines indicate the unusual growth, which are caused by the mechanical interference or by the extremely delayed germination time, in those water depth.

As mentioned previously, the frond shape of Undaria pinnatifida is briefly classified into northern and southern types, besides other characteristic shapes in different areas. Not only the frond shape but also the degree of growth, a color, and the softness of frond show characteristics in each area. These properties, naturally, would be altered with the circumstances in the area, where Undaria pinnatifida grows. However, some properties show little change when circumstances are largely changed. Experimental results which Undaria pinnatifida from different origins are cultivated in a station are shown in Table 5-1. In Table 5-2, the comparison between natural and cultivated Undaria pinnatifida, which are obtained from the same origin, is shown. The tables indicate that the shape of a 15
young frond, a stem length to a frond length, and the degree of growth show characteristics of the originals. This observation does not change until at least the third generation in cultivation; these properties are thought hereditary. Quality of Undaria pinnatifida are not yet clear because of few experimental data, however, they seem to have a tendency that the thickness and the softness of a frond vary little but the color of a frond varies greatly in the different circumstances.

Table 5-2. Comparison of forms of natural and cultivated *Undaria pinnatifida* from the same origin

Origin	Cultivation station (Investigator)	Sample	Stem length / Frond length	Cut-in depth of frond / Frond width	Distance between nutritive and reproduction frond / Frond length	Number of measurement
Toyohama, Aichi-ken	Toyohama Port, Chita Peninsula, Aichi-ken	Cultivated	0.08 ± 0.04	0.41 ± 0.25		7
		Natural	0.07 ± 0.01	0.33 ± 0.02		141
Oono, Tokoname-shi Aichi-ken		Cultivated	0.20 ± 0.05	0.34 ± 0.07		11
		Natural	0.14 ± 0.04	0.37 ± 0.04		6
Mie-mura Nishisonogi-gun Nagasaki-ken	Kugajima, Fukue-shi, Nagasaki-ken (Goto)	Cultivated	0.13 ± 0.03	0.32 ± 0.01	0.05 ± 0.01	30
		Natural	0.19 ± 0.08	0.34 ± 0.06	0.09 ± 0.07	8

Table 5-1. Comparison of the forms of *Undaria pinnatifida* when the species of the different origins are cultivated in a station

Cultivation station (Investigator)	Items studied	Miyagi-ken origin Northern type	Aichi-ken origin Southern type	Tokushima-ken origin Naruto type
Toyohama Port Chita Peninsula Aichi-ken (Saito)	Shape of a young frond	Peach-like shape	Peach-like shape	Ellipse
	Comparison of stem length to frond length	Too long stem for the frond	Too short stem for the frond	Too short stem for the frond
	Season of the appearance of comb-like leaf	Late	Early	Late
	Frond length to form reproduction frond	40 - 60 cm	30 - 50 cm	----
Ooisozaki Naruto-shi Tokushima-ken (Kato et al.)	Shape of a young frond	Peach-like shape	----	Ellipse
	Comparison of stem length to frond length	Too long stem for the frond	----	Too short stem for the frond
	Season of the appearance of comb-like leaf	Early	----	Late
	Frond length to form reproduction frond	36 - 60 cm	----	40 - 70 cm

Cultivation

The purpose of the cultivation of Undaria pinnatifida is to intensify fishery and to stabilize its management. The cultivation cannot take the place of harvesting the natural Undaria pinnatifida, because the natural produce is very huge, therefore, to practice the cultivation industry one should work for stabilizing his management by clarifying the purpose and the goal of the cultivation. When the cultivation is performed with an industrial size, the goal of the cultivation will be changed according to the circumstances: the cultivation as a seasonal principal occupation or the cultivation as a side occupation, and the areal special problems as to the different locations. In case of the principal occupation or very close to the principal occupation, generally it is necessary to aim the following things for the cultivation of Undaria pinnatifida:

(1) Early harvest --- Prices of Undaria pinnatifida greatly differ from early season to late. In the early season the quality is excellent and the production is small, so the price is high. Afterwards, the price, which is quite changeable by the quality and quantity of the produce, generally decreases. Therefore, the cultivation of Undaria pinnatifida should be cultured early and harvested early so that the cultivated produce can be harvested before or in the early season of the natural production, when the price is not governed by the natural rich or poor harvest.

(2) Mass cultivation and improvement of the quality --- The growth and the quality of Undaria pinnatifida are affected by the environment conditions at the cultivation ground. As mentioned in the previous chapter,

the shape and the quality of the original species are kept well, therefore, 16

the cultivation should use good original species having the good growth and the good quality which are proper to the secondary use so that the high earnings may be expected. For that purpose, it is necessary to cross or transplant the proper Undaria pinnatifida to the environment of the cultivation ground.

(3) Marketing --- If the cultivated Undaria pinnatifida is utilized to manufacture products which is similar to the products made of natural Undaria pinnatifida and if the products made of cultivated Undaria pinnatifida are sold on the same market route with those made of the natural products, excepting the early harvest, caltivated products are overwhelmed by the natural products and cannot make good earnings. Even if the special market such as selling the raw or wet produce is opened, when the amount of the cultivated products exceeds a definitequantity, an expected earnings cannot always be obtained. Therefore, a cultivator should always try to make new secondary products and to open the new market. He must also try to cultivate Undaria pinnatifida with proper quality for his purposes.

In case the cultivation is taken up as a side occupation, a cultivator must consider the ecology of Undaria pinnatifida as well as the changes of the environment conditions of the cultivation ground. what is more, he should consider the allocation of the labor for the principal occupation in an effort to perform the reasonable management. The techniques of the cultivation are described below. In any case, the most important thing is to understand the relation between the ecology of Undaria pinnatifida and the varieties of the environment conditions of the cultivation ground.

1) Sporing (seeding)

In the northern sea coast the sporing of Undaria pinnatifida is sometimes operated directly on cultivation beds, however, in most cases the sporing is done on proper seedling beds which are convenient to culture seedlings. Materials for the beds are as follows:

For cultivation by direct sporing --- timbers of pine, Japanese oak, etc., ropes (2 cm or more in diameter) made of wisteria vines, palms, or rice straws, split bamboo.

For seedling; outdoor culture --- palm ropes, coil- yarns (3 - 5 mm in diameter).

For seedling; indoor culture --- fiber yarn made of Vinylon or its family: polyvinyl alcohol, (No. 20 count, 36 to 45 yarns in a three-plying thread, etc.), porous tubings or plates, shell.

Among these bed materials, most kinds of ropes are used for the seedling culture. The ropes are popular as "seedling ropes." As for the seedling culture techniques the seedling ropes will be described in detail. For convenience of care requirement the seedling ropes are prepared in the seedling devices as shown in Fig. 4. A frame type (1) is common, but for outdoor culture types (2) and (3) are better because of the large amount of miscellaneous germinations. In case of the small amount of culture, hanks of ropes, only by decreasing the overlaps of the ropes, can be used for the sporing and the culture.

When a ten-day average water temperature is 14 to 22°C which is the zoospore releasing temperature, the sporeling may be performed any time, however, for the best result for the shortening of the culture period and also for the growth of gametophytes, the water temperature 20°C, the most active zoospore releasing time, should be choosen.

The selection and the amount of the reproduction frond of <u>Undaria pinnatifida</u> should be carefully prepared. At the time mentioned above most of the reproduction frondsis well ripe, but it is not known whether the release of the huge amount of zoospores occurs on that day when the seedling ropes 17 are set. Avoiding the time just after the bad weather, a cultivator should selects the reproduction fronds which are larger, thicker, brown or dark brown, especially dark-colored edges, softer, and rich with a viscous liquid in order to expect the huge amount of release (about ½ to 1/3 of the reproduction fronds prepared will release a huge amount of zoospores). The reproduction fronds which are yellow-brown, hard, and poor with the viscous liquid finished their zoospore release. The number of the reproduction fronds prepared can be determined by using the following equation:

$$A \times B \times \frac{1}{10^6} \times \frac{2 \sim 3}{10} = N$$

where N: number of reproduction frond to be prepared

A: number of zoospores germinated per 1 cm of a seedling rope

B: length of a seedling rope (cm).

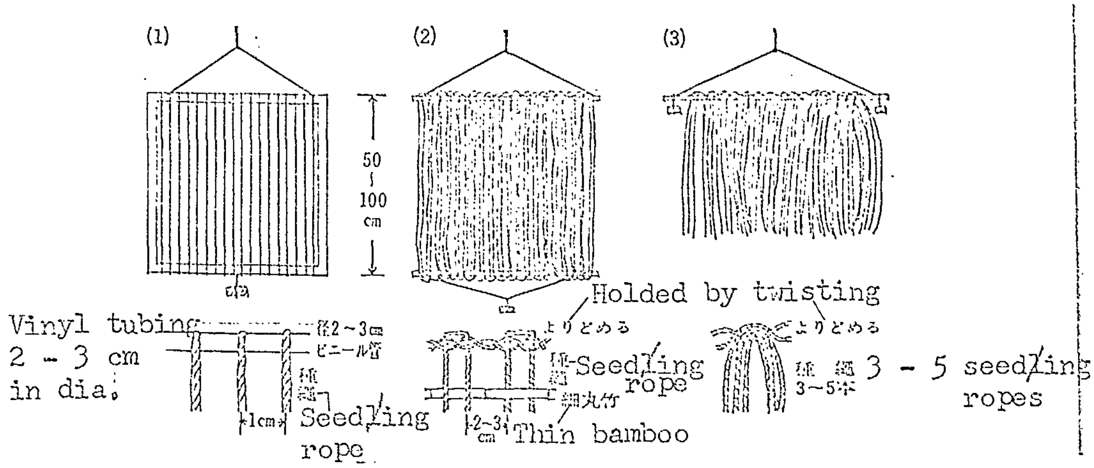


Fig. 4. Seedling devices for <u>Undaria pinnatifida</u>

According to the above equation, when A is 1000, several reproduction fronds per 100 m of B are enough to prepare and if the culture is in a good condition, at least ten germinations are observed per 1 cm of a seedling rope. 18

Upon the sporing of <u>Undaria pinnatifida</u> the important thing is to prepare the sea water with a dense liquid of zoospores. To do this, it is recommended to minimize the quantity of sea water to be used and to let the reproduction fronds release their zoospores at one time by drying the reproduction fronds in the shade in advance. Time for the drying, which depends on weather, is about one to several hours, which are just enough to dry up water on the surfaces of the reproduction fronds by spreading them flatly in the airy and cool shade. If the reproduction fronds change their color to green or droop, they are over dried.

Procedure of the sporing is as follows. A proper quantity of sea water is poured into a container so that the materials may be just covered with the sea water when the materials for the sporing bed (seedling rope) is dipped into the container (the materials may be placed in the container first and then sea water can be poured into the container as an alternate way). The sea water should be clean and fresh. Its density should be 20 or more. The temperature is preferably 20°C or lower and should not be 23°C or more during the sporing. The place for the sporing is preferably the light place but not under the direct sun light. Reproduction fronds dried in a shade in advance are dipped into the sea water for a quick wash and immersed into the container. Zoospores begin to be released into the sea water around five minutes after the immersion. As the releasing zoospores becomes active, (ten to fifteen minutes later) the sea water turns pale brown or yellow brown. At this time, if the small amount of the sea water is examined microscopically, actively swimming zoospores can be observed. Then the materials for the sporing bed are immersed into the container. By slowly stirring them occasionally or by turning over the materials, the zoospores are uniformly attached to the material. In 20 to 30 minutes after the immersion of the reproduction fronds into the sea water, the reproduction fronds finish the release of their zoospores for that day and afterwards they deteriorates the quality of the sea water by pouring out a viscous liquid from their breaks. The reproduction fronds should be taken out of the container at 30 minutes after their immersion. The materials for the sporing keep immersed in the container for a while so that the enough amount of zoospores germinate on them. In 40 to 60 minutes after the beginning of the sporing, the sea water is slowly changed with fresh one, or the materials is replaced into another container filled with fresh sea water, or the material is dipped into sea. The sporing of Undaria pinnatifida ends. In case the seedling device is left in the sea water where the sporing was done, the zoospores germinated in the device will be weaken, because the sea water contains a viscous liquid bearing tannin, dirt, and improper components. For the reason mentioned above the seedling device must be removed into a fresh sea water after the sporing. When a glass plate is immersed into the container where sporing is progressing, the glass plate will help observing the germination and the growth of zoospores.

In case of a direct sporing on cultivation materials, the timing of sporing and the selection of reproduction fronds (larger number is better) are similar to the previous method. The procodure is as follows. Reproduction fronds are directly inserted into cultivation ropes, which are called main ropes, with 30 cm spacing and the cultivation ropes are set in the sea. An alternate way is that the reproduction fronds which are inserted into ropes made of rice-straw are set in the sea along with materials for the cultivation. Drying the reproduction fronds in the shade is thought to be effective, however, if a release of zoospores occurs before the cultivation materials becomes dirty, all requirements for the sporing are satisfied, therefore the drying is unlikely to be effective.

2) Culture of seedling

There are two methods of the culture of Undaria pinnatifida seedlings: the sea culture (outdoor) which set the seedling ropes in the sea, and the indoor culture which are performed in a tank or in a proper container. The former has several merits such as simple facilities and utilizing the seedling ropes made of low priced natural fiber, on the contrary, this method has a couple of weak points such as the risk of washed-away and germination of the miscellaneous livings and the dirt on the seedling ropes. This method is improper in the middle southern Honshu, where its water temperatures are comparatively high and the period of the seedling is long, and many miscellaneous germinations exist; this method is practiced only in the northern area. However, even in the middle southern Honshu the former method is not impossible by preventing the attachings of miscellaneous germination 19
on the seedling rope. For example by sealing the seedling ropes, the filtered sea water, and the air in a strong polyethylene bag (the amount of air is adjusted to float the bag), the miscellaneous germinations can be prevented. The bags are hanged from a raft by means of a rope; the water depth for the bag is adjusted by a weight balance.

The latter requires facilities in most cases. Another weak point of this method is the seedling ropes made of natural fiber cannot be used, because the culture of Undaria pinnatifida seedlings is performed with a small quantity of sea water. The several merits of this method are the water temperature, the light, and the nutrients are controlled artificially; the method can be practiced in any area and is especially good in the middle southern Honshu. In some cases a culture room is specially built as one of the facilities. The lighting and the ventilation of the room should be carefully considered; the lighting should avoid the direct sun light (a semitransparent glass or a plastics plate are used to shade); the lighting is similar to the light at the sea surface during the daytime of a fine day and should be adjustable over the range of 300 to 10,000 luxes according to the time. A water tank for the culture is made of wood or concrete, which must not contaminate the sea water in it. The depth of the water tank is preferably up to 80 cm to decrease difference in the light at the top and the bottom of the sea water in the tank. Moreover, a skylight is preferably installed above the water tank (despite of the skylight, difference in the growth of seedlings exists, therefore, the interchange of the sporing devices resting the top and the bottom of the tank is necessary). The maximum water temperature in the water tank is preferably up to 28°C with a good ventilation. A sea water flow or circulation device or a water temperature regulator is not necessary, but if the water tank is equipped with them, it is very favourable. For a small quantity of culture, a small water tank made of glass or wood (a polyethylene sheet is placed in it for better results) is used; the small water tank is moved to proper places to adjust the conditions for the culture depending on the time; in some stations ditches are used to place the small water tank.

The stage of culture is classified into three, the initial, the middle, and the final, according to the degree of the growth of Undaria pinnatifida; each stage has its own method to control the culture.

The initial stage is about 10 to 20 days after the sporing; this stage is the period to grow zoospores germinated on seedling ropes to the gametophytes. The water temperature in this period is preferably 20°C or lower and should not be 23°C or higher. The light, 2000 to 6000 luxes, is needed. Accordingly, in case of the indoor culture, the water temperature should be minded, the direct sun light should be avoided, but the room kept lighted, and the seedling devices should be interchanged up and down occasionally. In some cases, 0.1 g of sodium nitrate and 0.02 g of sodium phosphate per one liter of the sea water are added as nutritive salts into the culture tank. In case of the sea culture (outdoor), the seedling devices are generally set in a shallow sea water. After 10 to 20 days under these conditions a male gametophyte will be 5 to 10 cells, female 3 to 5, thus the initial stage of the culture is over. However, if the gametophytes are left under the good conditions, they grow long and in some cases they will ripen to grow sporophytes. These gametophytes often result useless, because the longer gametophytes easily drop off from their seedling ropes in the middle stage. When the good conditions still continue, it is better to depress the growth of the gametophytes by reducing the light. For the seedling, the gametophyte may be only one cell, but judging from the experiments, to grow a gametophyte to the size mentioned above is recommended.

The middle stage is the period of high water temperature; the stage requires a good control to keep a high survival ratio of seedlings of Undaria pinnatifida. Accordingly, the stage does not exist in the northern sea district where the water temperature is low or even if it exists, it's out of consideration for the very short period of time. On getting the stage, the light must be reduced in proportion to the increase of the water temperature. Gametophytes rest at about 24°C or higher of the water temperature and some of them will die at about 28°C or higher, therefore, keeping the water temperature between 25 and 26°C is ideal. The light for the good survival ratio is 1000 luxes or less at 25 to 26°C and 200 to 500 luxes at 27°C or higher. The density of the water largely affects on the growth of the gametophytes at the high water temperature; the density is preferably kept at 20 or more. Concerning to the sea water change of the indoor culture at the middle stage, it may be better that the sea water change is not performed unless the quality of the sea water has been deteriorated, because the resting gametophytes easily drop off from the seedling ropes. If the dropping-off is few, changing a whole or one-third of the sea water per day by the water-flow or circulation device prevents the increase of the water temperature and likely results in a high survival ratio. In the sea culture (outdoor), the seedling devices are set in a deep place at the initial stage and the depth is not definite. They are depending on the conditions of the culture ground. The middle stage is the period which gets many miscellaneous livings on the seedling ropes, the light as well as the water depth which gets least miscellaneous livings must be determined. The kind and the amount of the livings germinated on the seedling ropes are different in each area, seasons, and the water depth: in the northern area they are mussels, Mytilus edulis, and Polyzoa or Bryozoa; in the middle southern area barnacles, ascidians, and Polyzoa or Bryozoa. The livings which cover tightly and perfectly the surfaces of the seedling devices kill the seedlings; they should be kept away from the seedling devices.

The final stage is the period which gametophytes ripen and grow sporophytes and the seedlings of Undaria pinnatifida are completed. If the cultivation of Undaria pinnatifida is begun and developed at the progressing stage of the seedlings, the fertilization ratio decreases and the growth of sporophyls are often unsatisfactory. The finished seedlings are those which at least grow sporophytes or sporophyls which can be observed by the naked eyes. The first step for the control of the seedlings at this stage is to increase the light gradually from 2000 to 4000 luxes when the water temperature reaches to about 23°C or lower. Under these conditions the resting gametophytes begin their re-growth and ripen at about 20°C, and grow to sporophyls. While the sporophytes are seen the light should be increased again to 4000 to 10000 luxes. At the beginning of the final stage of the indoor culture that the sea water change has not been performed through the summer, ripeness of the gametophytes and the growth to sporophytes can be promoted by performing the sea water change or circulation, or by adding the nutritive salt (same to those for the initial stage). Despite of an adequate sea water temperature for the cultivation, if decreasing the water temperature of culture tank delays and if the ripeness of the gametophytes and the growth to sporophytes delay, the water temperature must be artificially lowered to about 20°C to pro- 21
mote the growth of seedlings. The ripeness of the gametophytes and the growth to sporophytes are retarred sometimes in spite of these controls. In this case, if the water temperature in the sea is about 22°C or lower,

the ripeness and the growth are promoted by setting a bandle of the seedling devices in the shallow sea. (This procedure is called a ripeness operation or a sporophyte operation). In the indoor culture, when the sporophytes grow about 100 to 1000 micron, their growth terminates in most cases. In the northern area the sporophytes easily grow to sporophyls observable by the naked eyes in a culture tank; in the middle southern area this is difficult. If the water temperature in the sea is 20°C or lower at this time, the seedling devices are preferably set in the sea. The seedlings which have been cultured in the sea (outdoor culture) are reset in shallower depth according to the decreasing of the water temperature in the sea. The seedlings which have been cultured in a polyethylene bag are taken out of the bag and are reset directly in the sea when the water temperature reached to 20 to 22°C.

Timing to start the cultivation and the degree of growth of the seedlings will be mentioned later.

In any case the seedlings which fit to the water temperature of the beginning of cultivation should have been cultured.

3) Cultivation

(a) Selection of the cultivation ground. The cultivation ground may be the places where *Undaria pinnatifida* grows naturally, or any other places where it does not grow naturally, but the reasons why it doesn't are clear and they can be removed artificially. There are several limits for the effective cultivation.

(1) Water temperature. *Undaria pinnatifida* grows even at 15°C or higher of the water temperature; the seaweed grows well below that temperature,

especially at 10°C or lower (c.f. the chapter of the ecology; the minimum of the adequate water temperature is about 5°C for ten-day average). The longer the period at 15°C or lower, the more effective for the cultivation. Where the low temperature period is long Undaria pinnatifida grows well. Thinning and cut harvests are possible and a larger produce can be expected.

(2) Water density. The fronds of Undaria pinnatifida can bear with a very decreased specific gravity of the sea water, but the place where it is always or for a long period 15 or lower is inadequate.

(3) Nutritive substances. Nutritive substances for the growth of the seaweed may be very little. The concentrations of the nutritive salts, which are the necessities for the better growth and the better quality of the fronds of the seaweed, are hardly determined. Generally speaking, the good concentrations can be found where the ocean water and the bay water meet rather than the cultivation ground where the ocean water washes directly.

(4) Water current. As the water current in the cultivation ground affects the supply of nutritive substances and the gas exchanges by the assimilation and the respiration, the water current is a very important factor for the growth and the quality of Undaria pinnatifida. The water current relates to many other condtions. As it has not been studied so much, a proper velocity of the water current is still unknown. With the exception of the place like a strait where the water current is extremely fast, generally, the places with a moderate fast water current are preferred. The current is commonly obtainable in a bay or at a coast. The velocity of the water current and the waving are not only the factors for the selection of the cultivation ground but also the factors for the determination of the method, the size, and the density of the cultivation.

(5) Water depth and sea bottom. The water depth in the cultivation ground 22
will be discussed in detail later. Although the water depth depends upon the cultivation method and the sea bottom, it is preferred to measure more than one meter from an adequate depth for the cultivation to the sea bottom. In some cases the quality of the sea bottom limits the cultivation facilities. Gnerally it has no relation to the cultivation.

(b) Cultivation facilities. The cultivation facilities for *Undaria pinnatifida* are devised in many forms at each cultivation ground all over the country. Here, the major methods are taken up and explained briefly (Structures and specifications of the facilities shown in the following figures are only standard. Actually there are too many ways. It is necessary to devise proper ways for the circumstances of each cultivation ground).

(1) Preparation of main ropes. *Undaria pinnatifida* grows as it holds the foundation with its fibriform roots. When the base of the frond of the seaweed is not firm because of the improper holding of the foundation, the growth of the seaweed is poor. The cultivation requires the foundation that the roots hold well and the fronds become stable. Accordingly, the direct sporing culture method performs the cultivation by sporing on a larger gauge rope. For the seedling method, the seedling ropes with a smaller gauge are mostly employed for the conveniences. Therefore, the seedling ropes must be set on the ropes with larger gauge, stones, or concrete blocks to give the seedlings a sound foundation. The ropes with a large gauge are usually employed; they are called the main ropes. The main ropes are 10 to 30 mm in diameter and are made of rice strows, manila (these two are dyed with coal tar in some cases), hemp palms, palms, or

synthetic fibers. There are two ways, winding and inserting, to attach the seedling ropes to the main ropes as shown in Fig. 5.

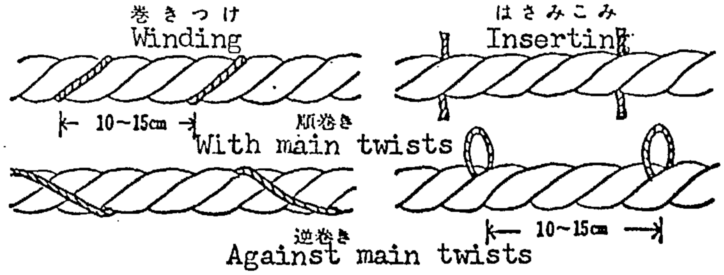


Fig. 5. The methods to attach the seedling ropes to the main ropes.

Winding --- This method winds the seedling ropes around the main ropes with or against the twists of the main ropes. The winding interval is commonly one wind of the seedling rope per 10 to 15 cm of the main rope. This method gets <u>Undaria pinnatifida</u> on the main rope continuously. When a number of ~~the~~ germination is small on the seedling rope, the winding method is ~~proper~~. When a number of ~~the~~ germination is large, this method causes a waste of the seedlings because of the high density ~~of the seedlings~~. The winding method also requires long seedling ropes (the length depends on the ~~way~~ of winding. The length of the seedling rope is required 1.1 to 1.2 times that of the main rope). The method is not suited to begin ~~an~~ early cultivation at a cultivation ground where ~~the dirt is~~ much and 23
the water current and waving are less. The germination of sporophytes sometimes is impeded when the water temperature is too high or the growth of the seedlings is delayed, or much dirt attaches to the main ropes.

Inserting --- The seedling rope is cut at the length of about 2 cm longer than the diameter of the main rope to be used; the cut is commonly 3 to 5 cm; the cuts are inserted in the main rope at the intervals of about 15 cm. The ways of inserting are shown in Fig. 5. The merits of inserting are that less amounts of the seedling rope is required (25 to 30 m per 100 m of the main rope) and that the germination of sporophytes is favorable even at a dirty cultivation ground. A low labour efficiency is the weak point of the method. When the cuts of the seedling rope are too long, <u>Undaria pinnatifida</u> will not be firmly holded on the main rope. The seedlings are scratched off from the seedling rope during the insertion, so the special cautions are needed for the inserting.

In either ways, the seedlings are very weak against dryness (under the direct sun light, they die 5 to 6 minutes after drying). To prevent this, devices and tools for these procedures should be made to improve the labour efficiency. And the main rope should be set in the sea one by one right after the attaching of the seedling rope.

(2) Cultivation facilities (methods). As shown in Fig. 6, there are many ways in the cultivation facilities. They can be classified briefly into two groups: horizontal and vertical methods. The former sets the main ropes (or other materials) horizontally; the latter sets them vertically by hanging them down or by floating one end of the main rope with a float and the other end set near the sea bottom. Another classification is raft-, rope-, lattice-, laver rack-type, etc. One type from each classification is combined to other types for a practical use. Generally, the horizontal method can be set in the right water-depth for the growing <u>Undaria pinnatifida</u> so that the growth will be uniform. At a cultivation ground where

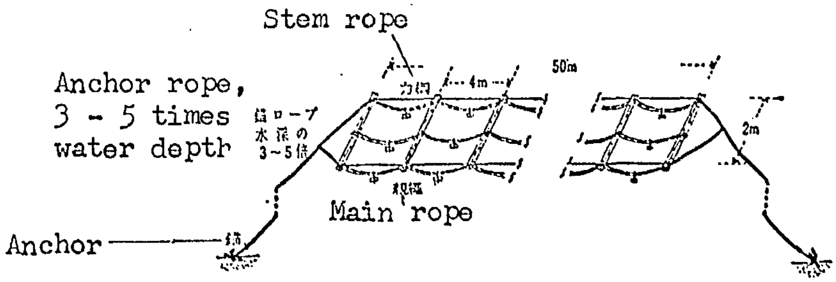
its circumstances are changeable from time to time, the main ropes can be conveniently reset in the best water-depth for the time. The vertical method ~~has a~~ difficulty in the adjustment of the water-depth for the cultivation; the growth of Undaria pinnatifida shows difference at the top and the bottom of the main rope. The vertical method is useful to ~~know~~ the best water-depth for the cultivation and shows better ~~germination to~~ sporophytes and better growth of Undaria pinnatifida than those by the horizontal method at a cultivation ground where the water current and waving are weak.

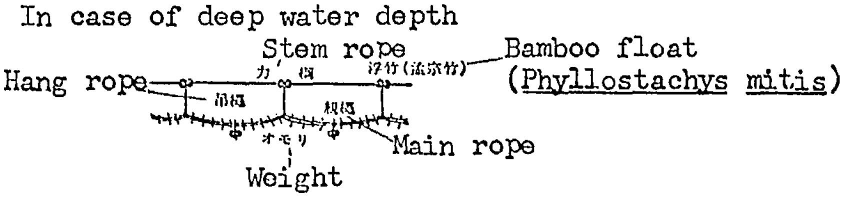
i. Raft type --- The raft type has a slightly large resistance ~~against~~ waves. This is good in a bay where waving is less. Any number of rafts may be connected parallel to the direction of the water current. It is not preferable to connect perpendicular to the direction; a proper interval should be set for the connection.

Horizontal method. The rafts (called simple rafts) are made of bamboo or strong ropes; the main ropes are stretched horizontally, using bamboo floats (this is practiced all over the country, especially in Tohoku district). The interval of main ropes is commonly one meter; at a cultivation ground where the water current and the waving are strong, the interval may be 0.75 m. The size of the raft is 1.5 m wide and 100 m (or 50 m) long for two lines of the main rope, 2 m wide and 50 to 60 m long for three lines, or 2.5 m wide and 50 m long for four lines. This is standard and the line is reduced ~~at a place~~ with a weak water current and ~~less waving~~. The horizontal method is desirable in a ~~sea~~ district where the water-depth ~~of the cultivation~~ is shallow. On the contrary, in a sea district with

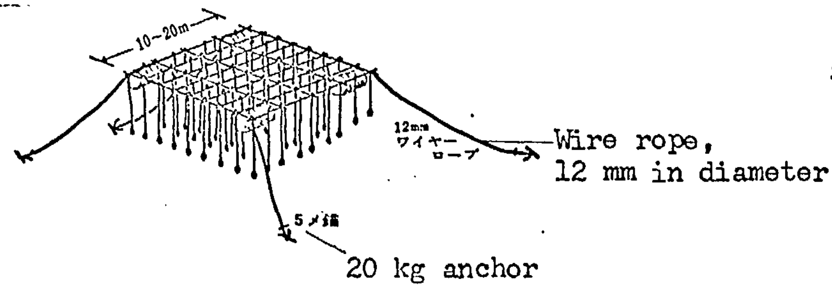
Fig. 6. Cultivation facilites for <u>Undaria pinnatifida</u>

A. 1. Raft (simple)-horizontal type (three lines of the main rope) --- Iwate-, Miyagi-ken, etc.

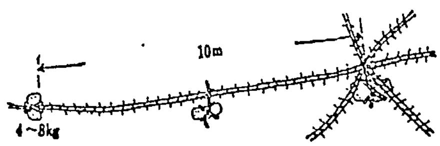




2. Raft-vertical (hanging) type --- Mie-, Hyogo-ken, etc.



B. 1. Rope type (sinking, radially stretched) --- Tokushima-ken.



2. Rope (vertical-horizontal combined) type

a. Floating rope type --- Mie- and Hyogo-ken.

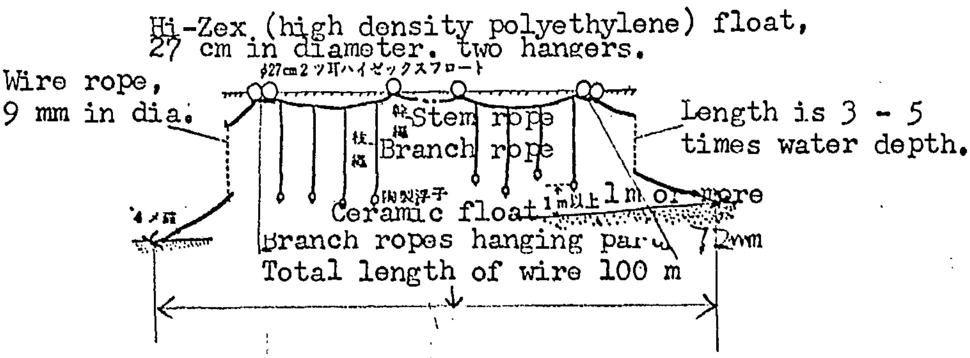
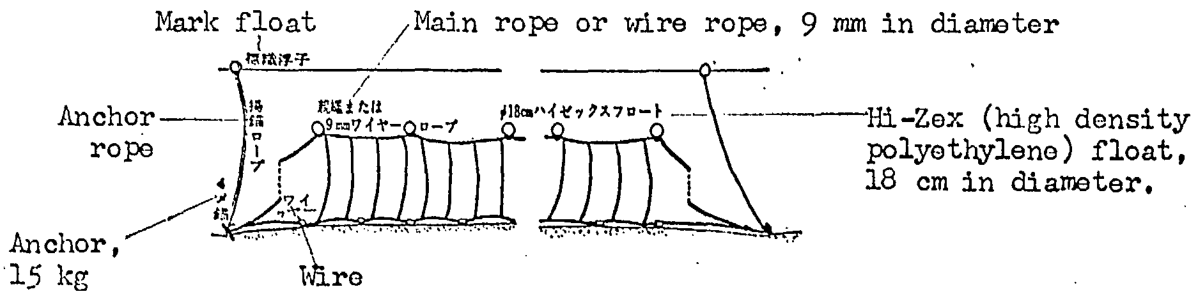
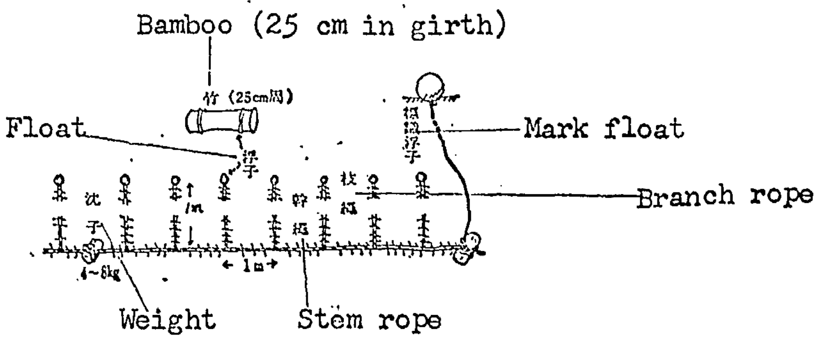


Fig. 6 (Continued)

b. Sinking rope type --- Hyogo-ken



c. Sinking rope type (improved) --- Tokushima-ken.



C. Square type (10 m square) --- Aichi-ken

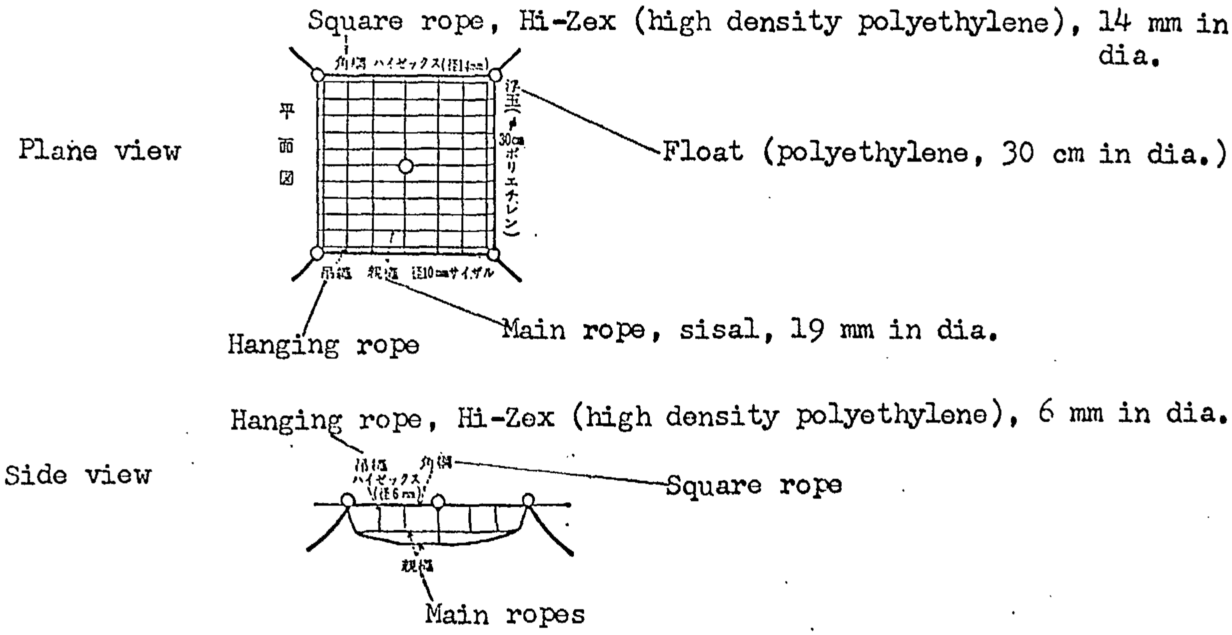
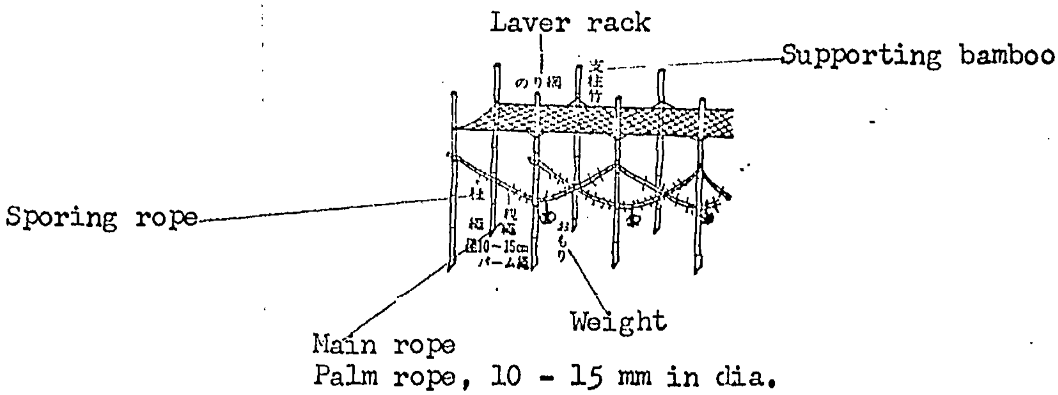


Fig. 6. (Continued)

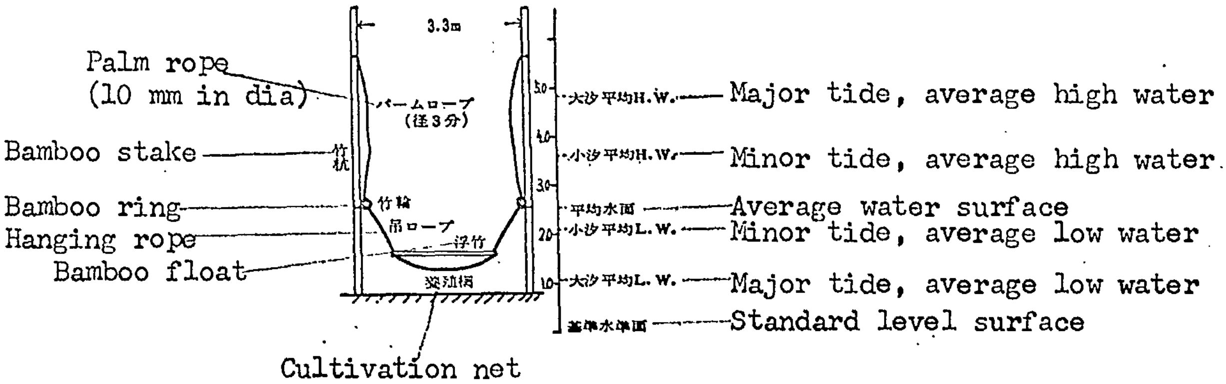
D. Laver rack utilization type

1. Horizontal type --- Tokyo and Aichi-ken



2. Floating net type --- Nagasaki-ken

Side view (tide-net relation is shown)



Plane view

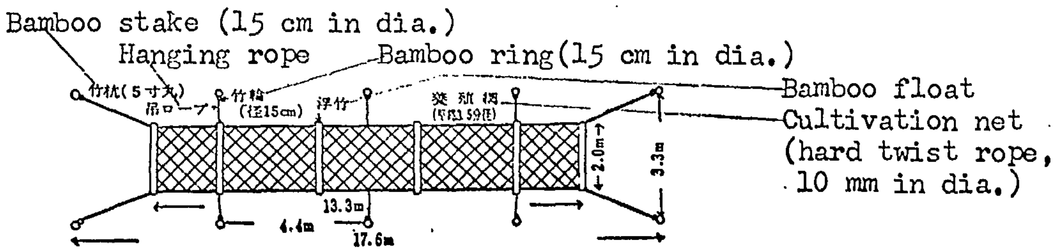
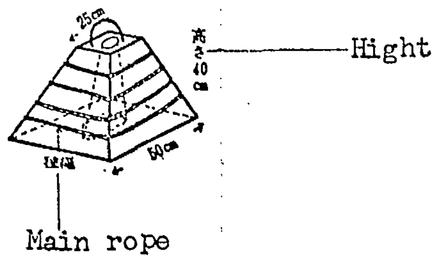


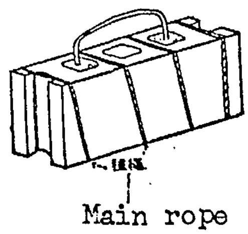
Fig. 6. (Continued)

E. Others (concrete block)

1. Stool --- Mie-ken



2. Building block --- Hyogo-ken



the deep water-depth this is not suitable, because hangers are needed between the main ropes and the bamboo floats. The main ropes also could contact each other because of a large slack ~~of~~ in the main rope. The horizontal method uses a net which is directly spored or tied with the main ropes on each knot of the net (Toba-shi, Mie-ken).

Vertical method. The raft may be a simple type~~, the raft is~~ made of bamboo or timbers and drum cans as the floats in most cases. The main ropes are cut to fit the best water-depth of the cultivation and are hung with a weight at one end and about one meter apart each other (the interval should be changed depending on the water current and the wav~~ing~~es at the cultivation ground). The sporing of Undaria pinnatifida is done on shells or porous ceramic plates. The shells or the plates are tied in series with a No. 8 gauge wire by spacing with the bamboo or ~~the~~ vinyl tubing~~s~~ of 15 to 20 cm ~~long.~~ length.

ii. Rope type --- This has a small resistance against waves and is ~~proper~~ useful for a cultivation ground with ~~a~~ high waves ~~faced to an~~ from the ocean. The ropes with the main ropes can be parallelled 10 m apart, ~~each other~~.

Horizontal method. Commonly one line (rarely two lines) of the main rope is set near to the sea surface or at the middle between the sea surface and the bottom with vinyl floats or drum cans as floats (Miyagi-ken, etc.). This is similar to the simple raft-horizontal method. ~~At the~~ On the rocky cultivation ground a large anchor (stone, etc.) is placed at the center of the main ropes, which are extended radially (B. 1., Fig. 6). The main ropes are set along the sea bottom by means of the smaller anchors which are tied at the middle and the end of each main rope (~~cautions~~ care should be taken to avoid the contact between the main ropes and the bottom rock). To avoid the contact the main ropes are floated in the middle water by floats in some cultivation grounds (Naruto-shi, Tokushima-ken, Hyogo-ken, etc.).

Vertical-horizontal combined method. There are two ways: floating rope type (B. 2. a, b, Fig. 6, Hamajima-cho, Mie-ken, Hyogo-ken, Iwate-ken, etc.) and sinking rope type (B. 2. C, Fig. 6, Tokushima-ken etc.). Branch ropes (made of the main rope) which are vertically hung down with the weights or hung up by the floats from a stem rope, are major part of this method. The stem rope extended horizontally is only ulizized as the main rope in some cases, or the wire rope is employed instead. The stem rope is usually set near the sea surface; it is seldom set in the middle water. The length of the branch rope depends upon the conditions of the cultivation ground as described in the raft-vertical method. The branch ropes are tied to the stem rope at intervals of about one meter; too narrow intervals or too long branch ropes causes a contact or an entanglement each other. In case of the floating rope type which is set at a very windy cultivation ground the branch ropes sometimes entangle the stem rope; this can be prevented by attaching heavier weights to the branch ropes so that one end of the branch rope, which is longer than the usual length, may be reached to the sea bottom or by setting the stem rope in the middle water rather than close to the sea surface. In case of the sinking rope type, where the sea bottom is not rocky, the stem rope and the part of the branch rope (up to one meter from the sea bottom) cannot be utilized as the main rope. In other word, those parts cannot be utilized as the main rope. The former is proper at a cultivation ground where the wind and the wave are not strong; the latter is proper where the sea bottom is rocky even if the wind and the wave are strong.

iii. Square type (C, Fig. 6) --- This is a method which employs the merits of the raft-horizontal and the floating rope types and makes up the weak points of those types; this is proper at a cultivation ground where the sea bottom is not rocky (Aichi-ken). A rope makes a square (standard, 10 m square) with floats such as glass balls, wooden barrel, or vinyl products on the four corners. Each corner is anchored. The main ropes are horizontally set in the square so that they make a net of 1 m x 1 m or 1 m x 2 m mesh. There are two ways to set the net in the square: tieing the 27
main ropes to the square rope and hanging the net previously made of the main rope from the square rope (the latter is convenient to adjust the water-depth for the cultivation). One float on each corner or one more at the center of the net is enough in the beginning of the cultivation. The number of floats is increased to prevent sinking of the net with the growth of Undaria pinnatifida on the main ropes. An alternate method of this type is as follows: the main ropes are set to make a net of 2.5 m x 2.5 m mesh and about 1.5 m long branch ropes are hung from the net at intervals of 0.5 m. This is a vertical-horizontal combination. By connecting several these nets in series the cost of the cultivation can be cut down.

iv. Laver rack utilization type --- This method utilizes the lower part of a supporting pole type laver rack. The main ropes are horizontally set among the poles of the laver rack at the lowest level of the tide. At a cultivation ground where the sea bottom is muddy or sandy, the main ropes are preferably set at more than 0.5 m above the sea bottom (D. 1., Fig. 6, Aichi-ken, Tokyo-to, etc.). In the Sea of Ariake, Nagasaki-ken, a net with 40 to 50 cm mesh is made of the ropes with 10.6 mm in diameter and with a hard twist; the main ropes are tied to each knot of the net; the net will be set so that the net can be movedup and down with the tide. The cultivation is done successfully at the water depth where the net can be seen above the sea surface only at the night of a major tide (D. 2., Fig. 6).

v. Others --- None of previously mentioned cultivation methods can be practiced at some cultivation grounds for their own special circumstances. If they have the rocky sea bottom, the cultivation of Undaria pinnatifida is possible by the methods mentioned below. These methods are somewhat inconvenient to controll and cannot be said to be the perfect cultivation. The cultivation facilities cannot be taken out from the water and are not adequate for a midterm harvest. In some area, these methods can still get the better harvest than the cutting the natural Undaria pinnatifida; these are desirable for an union-unit management rather than private ones.

Net type. Sporing is applied directly to an old net of the laver cultivation; the net is set on the rock so that Undaria pinnatifida can grow on the rock and the net. The method has been practiced in Aichi-ken. Recently, the method is improved: 10 m x 10 m or 10 m x 5 m of net with a large mesh (0.6 to 0.9 m) is made of a large gauge rope (4, 6, or 9 mm in diameter) similar to that of the square type (the net made of 9 mm in diameter rope may be used for the square type cultivation); sporing is practiced directly on the net, or tieing the main ropes to each knot of the net, then, the net is set on the rock for the cultivation. Nets for this purpose are commercially availabel.

Concrete block type (E. 1, 2, Fig. 6). The main ropes are wound around the concrete blocks of many different shapes and sizes (cautions should be taken to prevent damage of the main rope from the abrasion or the dropping of seedlings). The concrete blocks should be between the rocks so that they may not be moved. This method is not impossible even at the place where the sea bottom is sandy or mud-sandy by taking the devices so that the concrete blocks may not be barried in the sand or so that the germination of sporophytes may not be disturbed with the sand or the mud.

(c) Water depth of cultivation. As mentioned in the chapter of the ecology of Undaria pinnatifida, the growth of the seaweed depends upon the water temperature, the light in the water, and other environment conditions of the cultivation ground and also the best condition depends upon the age of the seaweed. Accordingly, the water depth of cultivation will have been changed with the environment conditions of the cultivation ground, the degree of growth of the seedlings and/or the state of growth of Undaria pinnatifida. 28
Stricly speaking, since the environment conditions differ from time, the best water depth for the growth vary from time. However, the water depth of the cultivation has no need to be the best always. To aim the cultivation with a least labor, the best water layer through the entire period of the cultivation should be found; it is taken up as the water depth of the cultivation. From this point of view the water depth of the cultivation in each area is shown in Table 6 by the experimental results. In Hokuriku-, Sanin-district, etc, where the amount of the sun light is largely changeable with the season, the water depth of cultivation should be changed according to the season. In case the cultivation starts with the seedlings which degree

of growth does not fit the water temperature at that time or starts under the special circumstances or at the time ~~such as~~ when the water surface is always low, a different water depth from the standard ones as listed in Table 6 must be considered. To study the best water depth of a cultivation ground, the cultivation experiments should be done by means of a vertical type or a horizontal type at several depths. The results from only one experiment does not always show the best water depth of the cultivation ground. The environmental conditions differ from each year. The best water depth of cultivation depends upon the water temperature at the beginning of the cultivation and the state of the seedlings. By examining the all ~~changeable~~ variable factors the standard water depth of the cultivation ~~should~~ may be determined.

(d) <u>Time for the beginning of cultivation and seedlings</u>. For an early harvest the cultivation should begin early. If the seedlings of <u>Undaria pinnatifida</u> have grown to a proper degree to ~~fit~~ suit the water temperature at the cultivation ground, the beginning of the cultivation may be delayed a little. Commonly, at a cultivation ground where miscellaneous germinations 29
are few, the cultivation is preferably begun at about 20°C of water temperature with the seedlings grown to sporophytes. On the other hand, at a cultivation ground where miscellaneous germinations are many, the cultivation is desirably begun at 17 to 18°C with the seedlings grown to sporophyls of 1 to 3 cm long. The cultivation begun with the latter case will not fail ~~at~~ on any cultivation ground. As it is after the state of the germination of the seedlings on the main rope is examined, the following advantages can be observed: there will be no main ropes that the germination and the growth of <u>Undaria pinnatifida</u> do not occur; an uniform growth can be expected; the

Table 6. Proper Water Depth of Cultivation for Each Area

State (Place experiments done)	Proper water depth of cultivation	Note
Iwate-ken (Miyako Bay, at the mouth of the bay)	2 m	Raft-horizontal type
ibid (ibid, in the bay)	1 m	ibid
ibid (Oofunato)	0.5 - 1.5m	ibid
Miyagi-ken (Ayukawa)	0.5 - 1 m	ibid
ibid (Onagawa)	0.5 - 1 m	ibid
Shizuoka-ken (Shirahama, Izu)	Deepest 3 m	ibid
Aichi-ken (Toyohama, Minami-chita)	1.5 - 2 m	Raft-vertical(hanging)type
Tokushima-ken (Naruto)	2.0 - 3.5 m	ibid
ibid (ibid)	3 - 5 m	Sinking-rope type
Ooita-ken (Usuki)	3 m	Raft-horizontal type
Saga-ken (Karatsu Bay)	2 - 3 m	ibid
Yamaguchi-ken (Senzaki)	2 - 3 m	ibid
Kyoto-fu (miyatsu)	0.5 - 1 m 2 - 3 m	ibid, March or before ibid, March or after
Niigata-ken (Sado)	3.5 - 4.5 m	Raft-vertical(hanging)type

loss of the main ropes is little. On the other hand, the seedlings grown to the large sporophyls are not suitable because the seedlings may be mechanically injured during the cultivation operations or the edge of the frond may be dried up and the seedlings may die.

(e) Transplantation. Transplantation of Undaria pinnatifida is practiced not only for the transfer and the distribution of the seedlings but also for the cultivation of the seaweed, having a good degree of growth, or an excellent quality, or the proper qualities for its use (c.f. the chapter of the ecology of Undaria pinnatifida). There are two ways of transplantation: the first, transplanting the original Undaria pinnatifida, then sporing and culturing the seedlings, and the second, transplanting the seedlings (main ropes). In the former method the reproduction fronds are cut off from the well ripe original seaweed in the sea, taken out of the sea, then transferred avoiding a extreme dryness and a temperature rise. The reproduction fronds are packed in open boxes and preferably transferred during the night. A three- to four-day postal delivery has been successfully reported with this method. The method is generally suitable for the area where it can be reached by a 12- to 24-hour delivery under the conditions mentioned above. A long distance or a long ~~hour~~ delivery prefers the latter. Seedlings can transplanted almost any time with the following precautions; an allowable water temperature range depends upon the degree of growth of the seedlings, 30
so an adjustment of the water temperature is needed; large seedlings have some difficulties such as the mechanical injuries. The safer and the simpler transplantation would prefer ~~the cultivation ground to~~ be transplanted with the proper facilities for the ~~culture of~~ gametophytes. The reasons are that the gametophytes have a wide allowable temperature range and can be conveniently

transferred in a saturated water vapour immediately after taking out of the sea. In case the facilities are not available, of course depending upon the season, the transplantation should be done just before the beginning of the cultivation while the seedlings are sporophytes or sporophyls (up to 2 cm long). In this case, adjustment of ~~a~~ water temperature is especially important. When the amount of transplantation is small, a Dewar jar can be used for transfer.

(f) Harvest. As mentioned in the chapter of the ecology of Undaria pinnatifida, the seaweed does not always germinate and grow all at once, according to the experimental observations on the growth of the seaweed on a main rope (seed rope; the seaweed as an example observed at a certain time shown in Fig. 7, grows by forming the several groups varying in their degree of growth. The reasons are that the fertilizations and the germination

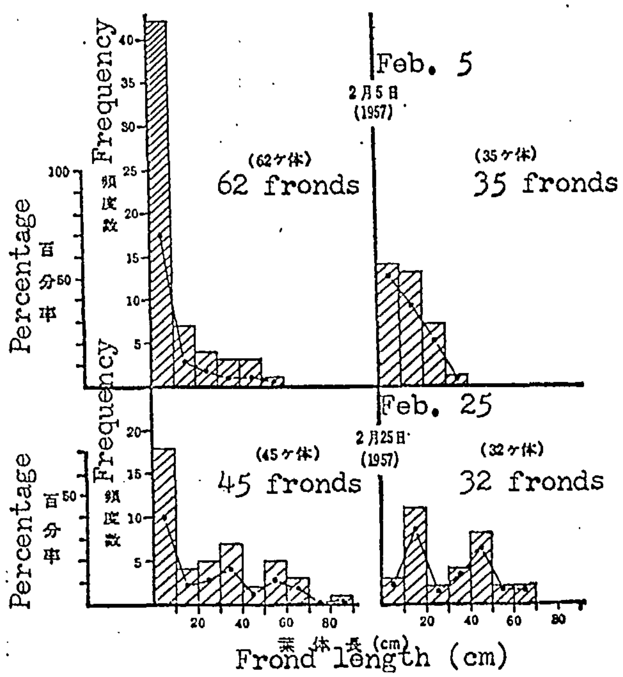


Fig. 7. Structure of the growth of Undaria pinnatifida grown on each oyster shell (30 cm^2): left --- higher growth density, right --- lower growth density.
Date of the beginning of cultivation: October 25, 1956.

to sporophytes last for a fairly long time at 20°C or lower water temperature; the seedlings which germinated to sporophytes at 15°C or lower have a long period as sporophyls; and even if the germinations occur at the same time, the difference in growth happens for some reason and the seedlings growing slowly are checked to grow by the ones growing quickly. However, these phenomena depend upon the sea conditions such as the water temperature at the cultivation ground and the growth density of sporophytes. The seedlings germinated late do not grow well enough at a cultivation ground where its water temperature is slightly high (the period at 15°C or lower is short). For that reason the growth of Undaria pinnatifida which are objects of harvest tends to uniform. At a low-water temperature, number of groups being different in growth tends high. The low growth density of the seedlings has a tendency to grow uniform and the high density to grow un-uniform. When the upper part of the fronds of Undaria pinnatifida are cut off leaving the main growing area between the stem and the frond to its stubbles, the remainders can grow again. Accordingly, there are three ways of harvests of Undaria pinnatifida:

i. Simultaneous harvest --- when most of the Undaria pinnatifida grows enough to harvest at a cultivation ground, they are harvested all at once by cutting their stems. This is mainly practiced when the growth density is low or where the water temperature at a cultivation ground is comparatively high.

ii. Cut harvest --- the fronds are cut at the upper part of the growing area leaving about 5 cm of comb-like leaves to its stubbles. The remainder will be harvested later when re-grows. This can be practiced when the growth density of seedlings is low, or where the period of low water temperature is long, and where the water temperature stays at 15°C or lower at the time of cut and after (at least about one month).

iii. Thinning harvest --- fast growing Undaria pinnatifida are harvested by thinning to promote the growth of slow ones. The harvests are repeated by thinning. This can be practiced when the growth density of the seedlings is high, and where the period of the low water temperature is long, and also the water temperature is at 15°C or lower for a long period after the thinning, and the growth of the slow ones is good.

The method chosen among those three must be determined by the growth density of the seedlings and by the sea conditions at the cultivation ground. When the seaweeds become old, their weight increases, and their quality degradates because of the harder fronds, the top withering, or the decoloration. Moreover, the consideration should be taken on the changes of the market price and the uses (selling fresh (raw) or secondary products) for the best harvest method. The comparison tests considered all those factors have not yet been reported, but a comparison test clearly indicating the number of the seedlings and the changes of the water temperature has been reported by Izu Branch, Shizuoka-ken Fisheries Experiment Station. According to the report, when average 20 to 30 seedlings per 10 cm of a main rope germinate and grow (the main ropes are inserted at intervals of 15 cm and cultivated by a raft-horizontal type), the produce ratios of simultaneous to thinning harvest are as follows: the simultaneous harvest (harvested fronds of 40 cm or longer on March 28 or on April 11) to the thinning harvests (case 1: thinned fronds of 40 cm or longer on February 20 and 28 and simultaneously harvested fronds of 40 cm or longer on March 28, case 2: thinned on March 7 and harvested the remainder on April 11, case 3: thinned

on March 16 and the remainder on April 11) are 1 : 0.37, 1 : 0.69, and 1 : 0.88, respectively. As for the quantity of the produce is concerned, the highest merit can be obtained by a simultaneous harvest at their season. If thinning is practiced, it should be done around at their season. In this case, the number of the seedlings is comparatively small, and the growth is very well, and the ratio of the number of the grown-up weeds into good size to the total number of the weeds is high, and the water temperature is comparatively high (the last ten days of February 13.3°C, the first ten days of March 13.9°C, the second ten days 14.3°C, the last ten days 14.7°C, and the first ten days of April 14.4°C). The experimental results indicate the reasons mentioned above. Generally speaking, if the degradation of the quality of the produce is not considered, the highest quantity of the products will be expected by the simultaneous harvest at their season. According to the author's experimental result, when 14 seedlings of Undaria pinnatifida grow per about 50 cm of a main rope (the main rope is wound around a rope and adjustments were made so that the seweeds in the same length grow uniformly on the main rope), the three methods of the harvest 32
are compared as shown in Table 7. The number of seedlings was small and the simultaneous harvest was done at the time when the growth reached to the maximum and while the degradation of the quality did not occur. In addition to that, the thinning harvest was done based on the same conditions. As a result, these results were obtained. If the timing of the simultaneous and the thinning harvests is delayed, the differences between the produce of those two and that of the cut harvest would be smaller or might be reverse. Considering the change of the market prices, it can be said that the cut harvest is more effective than others when the number of seedlings

Table 7. Comparison of produce by the harvest methods

(Results of cultivation in Toyohama Port, Aichi-ken, 1960)

A: Frond length B: Stump length C: Produce

Method	Feb. 18 A	B	C	Mar. 12 A	B	C	Apr. 14 A	B	C	May 6 A	C	Total
	cm	cm	kg	cm	cm	kg	cm	cm	kg	cm	kg	kg
Simultaneous harvest	32~168 77.7			84~226		2030						2030
Thinning harvest	32~168 77.7	32~72 (10) 47	840 (4)	72~112 95.2	72~99 (5) 85	590 (5)	85~117 100.0		1300 (5)			2730
Cut harvest	51~121 83.5	20	1075	29~70 56.7	20	1553	26~52 36.1	20	1309	21~49 260	547	4484

The second number for each frond length indicates an average.
The figure in the parentheses indicates the number of weeds.

are small and the water temperature is low as in this case. As seen in the examples above, the best method of the harvest could be determined by the length of the low temperature period, 15°C or lower. However, it would be hardly determined by the number of the seedlings. Although there are some differences in each case, in case of the inserting, the number of Undaria pinnatifida which grows very well and fast does not depend much upon that of the seedlings and is likely about 5 to 10 per main rope (in case of winding, per 15 to 20 cm of a main rope). Therefore, if more than 10 seedlings exist, it is preferable to thin the weeds until the number reaches to 5 to 10 as far as the water temperature stays in a proper range. If the number of the weeds is less than that, depending upon the water temperature, the simultaneous or the cut harvest is considered as the better.

Table 8. Standard Produce of Each State
(Per 1 m of main rope or per a net; weight in wet (raw))

State	Production	Cultivation method employed
	kg	
Iwate-ken	10	Raft-horizontal
Miyagi-ken	7.5 - 15	Raft-horizontal
Tokyo	0.4 - 1.2	Transplantation experiment by the Miyagi-ken origin seedlings.
Shizuoka-ken	7.5	Raft-horizontal
Aichi-ken	5 - 10	Square
Tokushima-ken	2 - 3	Transplantation of the Miyagi-ken origin seedlings, rope and vertical (hanging)
Tokushima-ken	2 - 17	The Naruto origin seedlings, rope and vertical (hanging)
Kumamoto	2.2 - 3.9	
Nagasaki-ken	4.1 - 5.7	Vertical (hanging)
Nagasaki-ken	5.8 - 9.2	Horizontal
Nagasaki-ken	180	Per a net (laver rack)

Note: the number of the germination on a main rope depends upon the state of the culture. The number of the seedlings changes as it grows. According to the reports by the several fisheries experiment stations, the average number of the seedlings per 1 cm of a main rope after immersing into sea, are 16, 2 to 3, 2 to 3, 1 to 2, and 30 to 10 for Tokushima-, Shizuoka-, Miyagi-, Gotoh, Kumamoto-, and the Sea of Ariake, Kumamoto-ken, respectively. The last case, the Sea of Ariake, indicates that one month after the immersion the number was 30, but three months after decreased to 10.

The produce of Undaria pinnatifida per an unit length of the main rope for the cultivation quite differ from case to case. Table 8 shows the produce, based on the report submitted by each state.

(g) Commercialization (Calculation of profit). It is diffucult to 33
set the standard for the expenditures, becase the cultivation facilities vary in types, methods, and in sizes, besides the price of seedlings is variable in each state. As for the expenditures (excluding the labour) for each method reported, Table 9 can be a standard.

The standard income for each cultivation method or for each sea district is also difficult to be determined, because the produce by the same cultivation method and in the same size is variable in each sea district (or at each cultivation ground). In addition to that, the price of the produce is variable in each sea district and also in the season.

Accordingly, to discuss the possibility of the commercialization by a profit calculation is good only for each case. The summary of the profit calculations reported up to date and estimated possible profit calculations for each cultivation method are listed in Table 10. According

to the examples reported and estimated, in most cases, the profit rates are 2 to 7 or 1 to 5, excluding or including labour, respectively. This indicates that the cultivation of Undaria pinnatifida is profitable enough. Depending upon the method and the size employed, the profit is about 30,000 to 40,000 yen per 200 m of main rope (1,000 yen = $3.00). Therefore, with ~~the~~ family labour and the cultivation of 1500 to 2000 m of main ropes, a 36
seasonal professional management can be established. However, the examples in the table are ~~the~~ cases in which Undaria pinnatifida germinated uniformly on a main rope and grew very well. Taking some negative factors for the seedlings and the harvest into account, more facilities should be ~~considered to be~~ set out for a practical management.

Table 9. Material cost for cultivation facilities

1. Simple raft-horizontal type
(1.5 m wide, 30 m long, 3 lines of main rope, Iwate-ken)

Item	Quantity	Unit price yen	Price yen	Durable years	Annual cost yen	Remarks*
Rope (used)	37 kg		2,500	1	2,500	A
Hard twist rope	90 kg		1,200	1	1,200	B
Palm string	5 kg		950	1	950	C
Phyllostachys mitis	6	300	1,800	2	900	D
Empty straw-bag	50	35	1,750	1	1,750	E
Coal tar	60 l		1,000	1	1,000	
Glass ball	4	300	1,200	3	400	F
Miscellaneous			1,000		1,000	G
Total			11,400		9,700	

* Remarks: A - anchor rope and stem rope, 18 to 24 mm in diameter; B - main rope 120 m, 9 mm in diameter dyed with coal tar; C - sporing rope; D - for float, 1.5 m long 16 sets; E - for anchor bag filing with sand, clay, stone, etc.; F - for water mark 24 cm in diameter; G - for tieing rope or wire, etc.

2. Raft-vertical type
(for actual length 210 m of main rope, pearl raft type, Hyogo-ken)

Item	Qunatity	Unit price yen	Price yen	Durable years	Annual cost yen	Remarks*
Timber	17	850	14,450	3	4,817	A
Drum can	4	1,700	6,800	2	3,400	B
Stationary anchor	4	2,500	10,000	5	2,000	C
Anchor rope	a half hank	1,6000	8,000	5	1,600	D
Main rope	7 hanks	200	1,400	1	1,400	E
Weight for main rope	70	25	1,750	3	583	F
Metal hardwares			720	1	720	G
Tieing string	1.5 kg	800	1,200	1	1,200	H
Miscellaneous			2,000		2,000	I
Total			46,320		17,720	

* Remarks: A - scaffolding-pole, 6 cm in diameter at smaller end; B - attached several rings for rope, painted for rust prevention; C - 20 kg each; D - wire rope, 12 mm in diameter, 25 m x 4; E - rice straw rope, 22 mm in diameter 5 m x 70; F - ceramic weight, No. 13 (490 g); G - wiro course, 8; shackle, 4; H - Kuremona (polyvinyl alcohol), soft twist, 200 ply; I - wire rope rust prevention, etc.

3. Floating rope type (for actual length 216 m of main rope)

Item	Quantity	Unit price yen	Price yen	Durable years	Annual cost yen	Remarks*
Stem rope	a half hank	10,500	5,250	5	1,050	A
Anchor	2	2,000	4,000	5	800	B
Float for stem rope	21	530	11,130	5	2,226	C
Main rope	7 hanks	200	1,400	1	1,400	D
Weight for main rope	72	25	1,800	3	600	E
Tieing string	0.3 kg	800	240	1	240	F
Metal hardwares			1,730	1	1,730	G
Miscellaneous			2,000		2,000	H
Total			27,550		10,046	

* Remarks: A - wire rope, 9 mm in diameter, 100 m; B - 15 kg each; C - Hi-Zex (high density polyethylene) float, 27 cm in diameter, two hangers; D - rice straw rope, 22 mm in diameter, 5 m x 4 x 18, 5 kg/hank; E - ceramic weight, No. 13 (490 kg); F - Kuremona (polyvinyl alcohol) string; G - wire course, shackle, crip, etc.; H - wire rope

4. Square type(for actual length 180 m of main rope, Aichi-ken)

Item	Quantity	Unit price yen	Price yen	Durable years	Annual cost yen	Remarks*
Float	5	380	1,900	3	633	A
Anchor rope, square rope	140 m	25	3,500	3	1,167	B
Main rope	180 m	10	1,800	1	1,800	C
Anchor and metal hardwares	4 sets	1,500	6,000	5	1,200	D
Hanging rope	64 m	6	384	3	128	E
Total			13,584		4,928	

* Remarks: A - polyethylene, 30 cm in diameter; B - Hi-Zex (high density polyethylene) 14 mm in diameter; C - sisal, 10 mm in diameter; D - single fluke, steel, 15 kg each, shackle, crip, etc.; E - Hi-Zex (ibid), 6 mm in diameter.

5. Laver rack utilization type (2 x 18 m net, Nagasaki-ken)

Item	Quantity	Unit price yen	Price yen	Durable years	Annual cost yen	Remarks*
Long-jointed bamboo	12	70	840	2	420	A
Phyllostachys mitis	3	150	450	2	225	B
Palm rope (1)	4.4 kg	160	704	2	352	C
ibid (2)	0.15 kg	160	24	1	24	D
Hard twist rope	1.5	350	525	1	525	E
Total			2,543		1,546	

* Remarks: A - for supporting pole, 6 m long, 15 to 18 cm in diameter; B - for 8 floats, 21 to 24 cm in diameter; C - for floating rope, 9 mm in diameter 84 m; D - for tieing, 6 mm in diameter; E - for cultivation net 2 x 18 m.

Table 10. Profit calculation of cultivation (1000 yen = $3.00)

1. Examples reported

State	Iwate-ken	Iwate-ken	Aichi-ken	Nagasaki-ken
Type of cultivation	simple raft-horizontal	simple raft-horizontal	square	laver rack ulization-net
Size*	360 m	200 m	170 m	2 × 18m net
Cost (yen) A: total	12,800 円		19,992	2,763
B: annual	12,800 円	25,000	8,959	1,746
C: price at landing	70,000 円	50,000	54,850	12,300 ~13,500
D: profit(C - B)	57,200 円	25,000	45,891	10,600 ~11,800
Profit rate(D/B)x100	447 %	100 %	512 %	607~676 %

* Actual length of main rope except the net type.

2. Estimated

Type of cultivation	Simple raft-horizontal	Raft-vertical	Floating rope	Sunken rope	Square	Concrete block
Size*	200 m	200 m	200 m	300 m	180 m	(1000 m)
Cost (yen) A: total	20,000 円	54,000	35,000	24,000	15,400	80,000
B: annual	12,000 円	19,000	12,000	12,000	6,800	30,000
C: price at landing	60,000 円	50,000	60,000	60,000	45,000	200,000
D: profit(C - B)	48,000 円	31,000	48,000	48,000	38,200	170,000
Profit rate(D/B)x100	400 %	163 %	400 %	400 %	562 %	567 %
Remarks**	(1)	(2)	(3)	(4)	(5)	(6)

* The price of sporing rope is 10 yen per meter. Winding type is employed. The length of sporing rope is estimated to be needed as long as that of main rope.

** (1) Northern area: price of raw(wet) product, 10 kg/m at 30 yen/kg; middle and southern areas: 6 kg/m at 50 yen/kg. (2) Northern area: price, 8 kg/m at 30 yen/kg; middle and southern areas: 5 kg/m at 50 yen/kg. (3) The stem rope is made of wire rope and the branch rope is major for the cultivation. (4) ibid. (5) Price of raw(wet) product, 5 kg/m at 50 yen/kg. (6) Concrete block for building, 20 x 40 x 150 cm, 400 (converted to the length of main rope).

Conclusion

The cultivation of *Undaria pinnatifida* has not ~~come out of the region of~~ the experiment or has just been commercialized recently, except Tohoku district. The popularization and the development of the cultivation in future are expected; there are many problems to be solved or improved for ~~the development~~. The followings ~~are~~ the list of the problems which should be considered. They are summarized from the experimental results reported up to date. Solving these problems and putting the effort for the development of the cultivation industry of *Undaria pinnatifida* are urged in future.

(1) Culture of ~~excellent~~ seedlings --- to culture seedlings which germinate uniformly.

(2) Proper ground and proper species --- (a) to define the special properties of the *Undaria pinnatifida* in each sea district throughout the country and transplant them rationally. (b) to cultivate crossed species among *Undaria pinnatifida*, *Undaria undarioides*, and *Undaria peterseniana*, which belong to *Undaria pinnatifida* ~~family~~.

(3) Pioneering of market --- to aim ~~the~~ increase ~~of~~ the profit and prevention of ~~the~~ over-production by the proper sales for the conditions in each market.

(4) Fertilization --- to ~~intend~~ ~~the~~ improvement ~~of the~~ quality and ~~the~~ promotion ~~of~~ the growth by fertilization.

(5) Extermination of ~~noxious livings~~ --- to discover and exterminate ~~the livings~~ which harm sporophyls and to exterminate Amakusa seahares.

Bibliography

Aichi-ken Fisheries Experiment Station, Owari Branch, "Fiscal Showa 30 nen (1955) Operational Report," 1956.

Akira Ii, Lectures on Fisheries Culture, "Culture of Undaria pinnatifida," I & II in Takusui, May, 1963. Hyogo-ken Fisheries Union.

Chiyoichi Kanda, "On Gametophytes of a Couple of Seaweeds in Laminaria," Report II, Report of Laboratory of Seaweeds, University of Hokkaido, 1935.

Toraichiro Kinoshita, "Studies on Cultures of Laminaria and Undaria pinnatifida," 1947.

Toraichiro Kinoshita et al., "Study of New Culture Technique, Cut-Culture of Undaria pinnatifida," Research Report of Hokusuishi (Hokkaido Fisheries Experiment Station) No. 7, 1950.

Yoichi Kondo, "On the Culture of Undaria pinnatifida by Using a Laver Rack," in Study of Aichi Laver (a volume of papers presented), No. 2, 1959.

Kumamoto-ken and Ooita-ken Fisheries Experiment Stations, "Kyushu and Yamaguchi Districts Symposium on Techniques of Fisheries Culture," 1959 and 1961.

Munehisa Kuroki and Kazuo Akiyama, "Studies on Ecology and Culture of Undaria pinnatifida," Research Report of Tohoku Sea District Fisheries Laboratory, No. 10, 1957.

Takashi Kato and Yoshiaki Nakahisa, "Comparison of Forms of Miyagi and Naruto Undaria pinnatifidas Grown at a Fisheries Station," Bull. Scie. Fish. Japan, Vol. 28, No. 10, 1962.

Kumamoto-ken Fisheries Experiment Station, "Study on Culture of Undaria pinnatifida," (4), in the Operational Reports of the Station, Fiscal Showa 34 - 35, 1961.

Fujizo Komatsu, "Culture of Undaria pinnatifida at Kadonohama," in Abstracts of the Fourth Symposium of Agriculture, Forestry, and Fisheries Technologies, 1960.

Hiroshi Nishikawa, "Study on Culture of Undaria pinnatifida in Sea of Ariake (1), Floating Culture of Undaria pinnatifida by Using a Laver Rack," Suisan Zoshoku (Fisheries Cultivation), Vol. 11, No. 3, 1963.

Hiroshi Nishikawa, "On Growth, Productivity, and Forms of Undaria pinnatifida in the Westmost, Part of Kyushu (Goto Islands)," ibid, Vol. 10, No. 4, 1962.

Tadashi Nonaka and Yoshito Iwahashi, "On Growth and Harvesting of Undaria pinnatifida by a Raft Type Culture," ibid, Vol. 9, No. 4, 1962.

Yojiro Ootsuki, "Methods of Raft Type Cultures of Undaria pinnatifida and Laminaria," 1955.

Yunosuke Saito, "Fundamental Study on Culture of Undaria pinnatifida," Report of Fisheries Laboratory, Department of Agriculture, University of Tokyo, No. 3, 1962.

Hideyo Sakai, "On the Growth Depth of Undaria pinnatifida by Artificial Sporing," Suisan Zoshoku (Fisheries Cultivation), Vol. 9, No. 1, 1961.

Saga-ken Fisheries Experiment Station, "Experiments on Culture of Undaria pinnatifida," Operational Report of the Station, 1960.

Toshizo Sudo, "Release, Movement, and Germination of Zoospore of Seaweeds in Laminaria," Bull. Scientific Fish. Japan, Vol 13, No. 4, 1947.

Toshizo Sudo, "On the Release of Zoospores of Undaria pinnatifida, Ecklonia, and Eckloris bicyclis," Bull. Scientific Fish. Japan, Vol. 18, No. 1, 1952.

Tokyo Fisheries Experiment Station, Fiscal Showa 30 nen Operational Report, 1956.

Tokushima-ken Fisheries Experiment Station, "Study on Culture of Undaria pinnatifida," Research Report of the Station, No. 3, 1961.

Haruo Yoshinaga and Kenro Yatsuyanagi, "Cultural Study of Undaria pinnatifida," Research Report of Yamaguchi-ken Off-shore Fisheries Experiment Station, Vol. 3, No. 1, 1960.

Publication by Nippon Suisan Shigen Hogo Kyokai
(Japan Fisheries Resources Conservation Corporation)

Library of Fisheries Research

(1) "Resources of Yellow-tail, Seliola quinqueradiata, in Seas around Japan," Fumio Mitani, Nishi Sui Ken (West Sea District Fisheries Laboratory).

(2) "Study on Meshes of Dragnets," Tsuneo Aoyama, Nishi Sui Ken (ibid).

(3) "Resources of Bottom Fishes in the Yellow Sea and the East China Sea," Group of Bottom Fish, Nishi Sui Ken (ibid).

(4) "Resources of Mackerel Pike, Cololabis saira," Hideyuki Horita, Tohoku Sui Ken (Tohoku Sea District Fisheries Laboratory).

(5) "Ecology of Sardine," Keiichi Kondo, Tokai Sui Ken (Tokai Sea District Fisheries Laboratory).

(6-1) "Resources of Salmon and Trout in Northern Seas," I, Tomonari Matsushita, Suisan Cho (Fisheries Agency, Department of Agriculture and Forestry).

(6-2) "Recources of Salmon and Trout in Northern Seas," II, ibid.

(6-3) "Resources of Salmon and Trout in Northern Seas," III, ibid.

(7) "Preserving Freshness of Fisheries Catches," Eisaburo Noguchi, (Tokai Sea District Fisheries Laboratory).

(8-1) "Ecology and Resources of Bonito, Katsuwomus," I, Takeshi Kawasaki, Tokai Sui Ken (ibid).

(8-2) "Ecology and Resources of Bonito, Katsuwomus," II, ibid.

(9-1) "Nutrition and Food for Fishes, I, Yoshiro Hashimoto, University of Tokyo and Tomotoshi Okaichi, University of Kagawa.

(9-2) "Nutrition and Food for Fishes," II, ibid.

(10-1) "Resources of Horse Mackerel in the World," I, Hiroshi Nakamura, Minami Sui Ken (South Sea District Fisheries Laboratory. (In press).

(10-2) "Resources of Horse Mackerel in the World," II, ibid.

Library of Fisheries Culture and Progapation

(1) "Consideration on Construction of a Fisheries Culture and Progapation Plant from a Point of Civil Engineering View," Tokuichiro Tamura and Shigeki Yamada, Agricultural Civil Engineering Experiment Station.

(2) "Cultivation of Undaria pinnatifida," Yunosuke Saito, University of Tokyo.

(3) "Improved Construction of Laver Ground by Civil Engineering Methods," Tokeo Kurakake, Aichi-ken Fisheries Experiment Station.

(4) "Theory and Practice of Culture of Eel," Kai Matsui, Tokyo University of Fisheries.

(5) "Business of Artificial Incubation of Salmon and Trout," Takeo Mihara, Seizo Sano, and Hiroshi Eguchi, Hokkaido Sake Masu Fukajo (Hokkaido Salmon and Trout Hatchery).

(6) "Culture of Scallop in the Mutsu Bay," Moritaro Yamamoto, University of Yamagata.

(7) "Scallop Fishery in the Coastal Water of the Sea of Okhotsk," Shigeru Itoh, Department of Fisheries, Hokkaido.

(8) "Artificial Fish Reef," Yasuo Ooshima, University of Tokyo.

(9) "Propagation of Coastal Seaweeds," Toshizo Sudo, Tokai Sui Ken (Tokai Sea District Fisheries Laboratory).

Library of Foreign Fisheries 39

(1) "Artificial Reproduction of Salmon and Trout in U.S.S.R.," Translation Group for U.S.S.R. Literature, Suisan Cho (Fisheries Agency, Department of Agriculture and Forestry).

(2) "Ocean Fishery of Communist China," Shigeaki Mamichi, Nishi Sui Ken (West Sea-district Fisheries Laboratory).

(3) "Fishery Policies in England, West Germany, and Norway," Noboru Arimatsu, Suisan Cho (Fisheries Agency, Department of Agriculture and Forestry) and Bunji Ikejiri, Zen Gyo Ren (The National Federation of Fishermen's Unions).

(4) "Fishery in U.S.S.R.," Translation Group for U.S.S.R. Literature, Suisan Cho (Fisheries Agency, Department of Agriculture and Forestry).

(5) "Progress of the Establishment of the United States' Tunny Control Acts in 1962," Ryuzo Ooyama and Hiroya Mimura, Suisan Cho (Fisheries Agency, Department of Agriculture and Forestry).

(6) "Policy of the Recreational Fishing in the United States," Kazuo Miyazaki, Nippon Hogei Kyokai (Japan Whaling Corporation).

(7) "Situation of Conservation of Fresh Water Fishery Resources in North America," Yoshikazu Yamanaka, Suisan Cho (Fisheries Agency, Department of Agriculture and Forestry), Ryoichi Yagi, Zenkoku Naisuimen Gyoren (National Fresh Water Fishermen's Union), and Yorihide Tsuchida, Kaigai Gyogyoh Inc.

(8) "Preventive Measure of Water Polution in Western European Countries," Kazuo Inoue, Suisan Cho (Fisheries Agency, Department of Agriculture and Forestry).

(9) "Bartlett Act," Gonji Itano, Suisan Cho (ibid).

Library of Fishery Policy

(1) "Present Facts and Problems of Administration of Conserving Water Quality," Motokichi Morizawa, Suisan Cho (ibid).

(2) "Present Facts of the Project of Improvement and Popularization of Fisheries Industry," edited by Chosa Kenkyu Bu, Kenkyu Dai Ni Ka (Research Section No. 2, Division of Investigation and Research), Suisan Cho (ibid).

(3) "Off-shore Dragnet Fishery," Shinji Endo, Suisan Cho (ibid).

(4) "About Present Facts and Problems on Culture Industry of Hamachi in Seto Naikai Inland Sea and its Neighbor," Fumio Matsuo, Katsutoshi Yashiro, and Manzo Tachibana, Seto Naikai Gyogyoh Chosei Jimukyoku (Seto Naikai Fishery Control Office).

(5) "Reclamation of Ooita Foreshore Industrial Belt and Policy for Fishermen Changing Their Occupation," Tanaka, Department of Fisheries, Ooita-ken.

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