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Progrès récents dans les repeuplements marins

Recent progress in marine restocking

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Restocking of fry of useful marine animals has been conducted in various parts of Japan. In 1980, about 283 million penaeid shrimp postlarvae, 10 million red sea bream fry 750 million chum salmon fry and 10 million abalone seed were released into the coastal areas. These fry were produced under controlled condition in various hatcheries. Restocking of chum salmon and abalone is considered reasonable because of returning to its home stream for the former and settling on rocky shore for the latter. Due to lack of such ecological or physiological character, significance of restocking has not been clear for penaeid shrimp and red sea bream, which are the most important marine product in Japan.

Both species has been considered as migratory species in the coasts of several neighbouring prefectures. Migration, growth and survival have been investigated by many Prefectural Fisheries Experimental Stations. Monitoring is possible for red sea bream with marks by tagging or by cutting fin. It is not applicable for penaeid shrimp because they are released at postlarval stage and molt for the growth. Although the large scale production method for marine seedling was firstly established for penaeid shrimp and recent marine restocking has been developed with penaeid shrimp, gratification of recovery seems to be less compared to other species.

In this paper, first,results of restocking of penaeid shrimp in Panama City, Florida from 1970 to 1973 is reported and discussion is made on the penaeid shrimp restocking in Japan since 1966. Second, progress of red sea bream restocking since 1972 is reviewed and comparison is made with the penaeid shrimp. Third, introduction of lobster in Japan since 1975 is reviewed and furture problem on crustacean restocking is discussed. Last, marine ranching of chum salmon will be supplementally introduced. Althogh it was conducted based on the traditional method, recent drastic increase of amount of catch will give suggestion on marine restocking.

I. Penaeid shrimp

I-1. Preparatory release experiment .

Hatchery production has drastically increased since the community culture method was developed at Aio along Seto Inland Sea coast in 1964[5]. An excess of postlarval shrimp Penaeus japonicus over the required number for pond culture was experimentally release at Ucinoura Bay, Fukui prefecture, along Japan Sea coast in 1966[8]. The experimental site is shown in Fig.1 The site was selected in expectation to increase catch due to restocking because general oceano-graphic condition was not unsuitable but distribution of shrimp was scarece. Total 3,514,000 postlarval shrimp (20-30mg in body weight) were transported from Aio during the period from July 26 to October 23, 1966. The postlarvae were temporarily released in pen or cage for a few days before release into the sea. The shrimp were caught near release site after October, 1966. The number of the shrimp caught was 96. Recovery rate was 0.003%. This suggests that application of a suitable intermediate rearing method is necessary to increase survival rate after release.

I-2. Restocking of postlarval shrimp in West Bay, Panama City, Florida .

Sucess of the large scale production for penaeid shrimp larvae drew attention in many countries. A shrimp farming company was established in Panama City, Florida in 1970. The company condducted research and development work on penaeid shrimp culture in Gulf of Mexico. Several hundred million postlarval penaeid shrimp, brown shrimp Penaeus aztecus, white ahrimp Penaeus setiferus, and pink shrimp Penaeus duorarum were

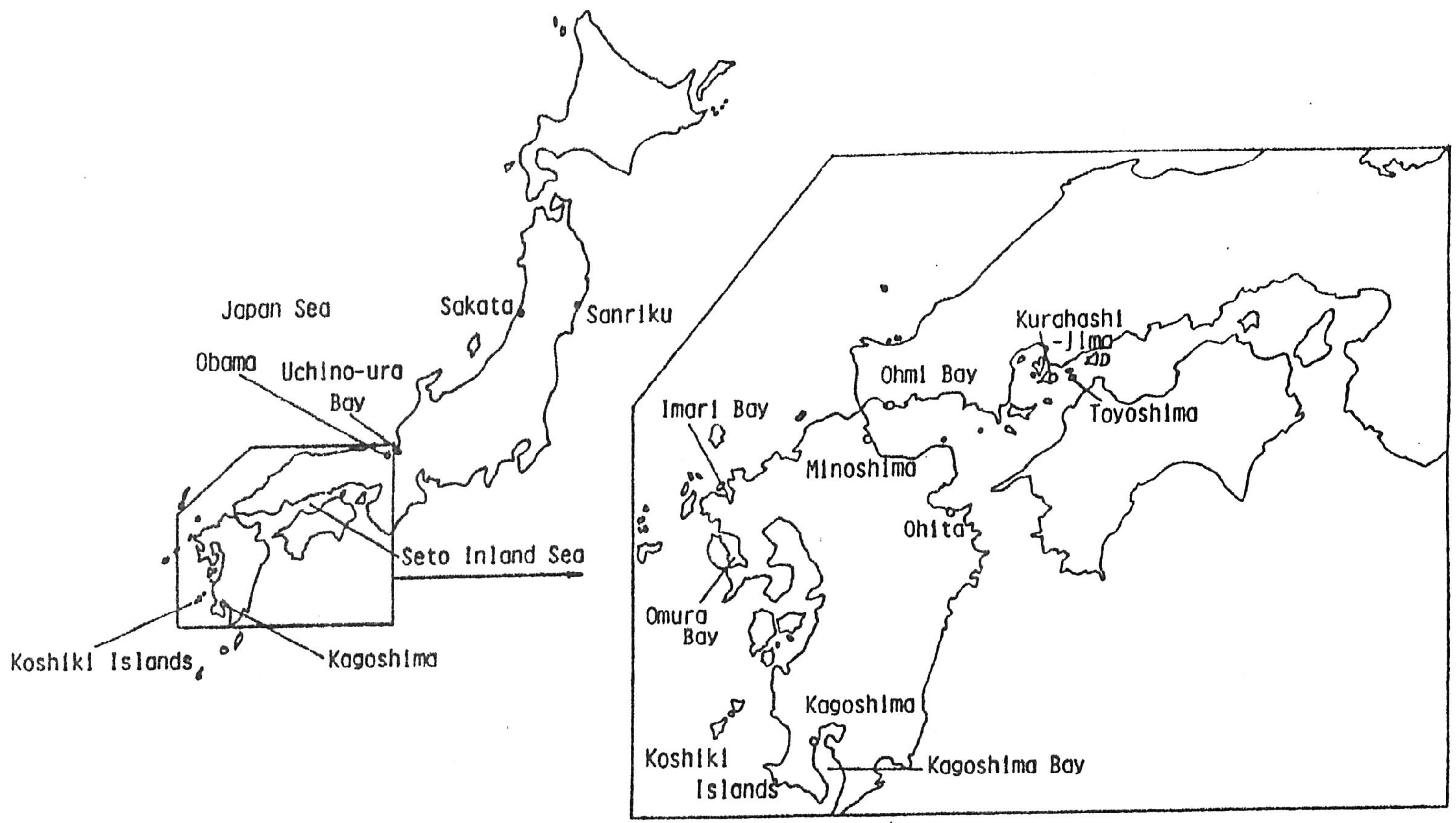

Fig.1. Map showing localities where restocking experiments for penaeid shrimp and red sea bream were conducted.

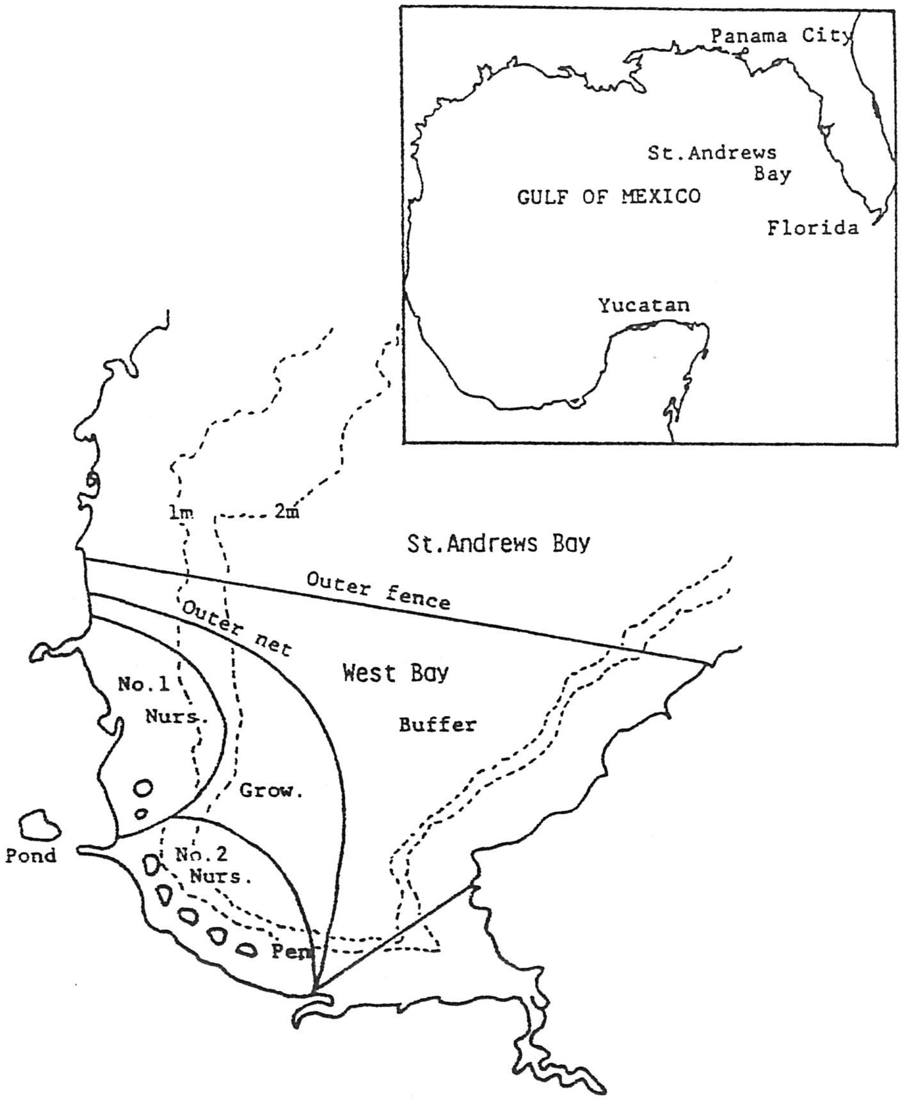

Fig. 2. Map showing the netted-off portion of West Bay in 1973.
Pen No. 1 : 2 acres (0.8 ha) in nursery and No. 2 : 5 acres (2.0 ha) in nursery, Nursery No. 1 : 300 acres (121.4 ha) and No. 2 : 350 acres (141.6 ha), Growing area : 700 acres (283.3 ha), Buffer area : 900 acres (364.2 ha).

Table 1. Relation between mesh of net and size of shrimp retained

Mesh of net box	At the beginning		At the end			
	No. of shrimp put in the box	Body weight (g)	No. of shrimp retained inside the box	Body weight (g)	No. of shrimp moved outside the box	Body weight (g)
18.8 mm (1/16 ")	17	0.18-1.38	5	1.09-1.38	12	0.18-1.02
	30	0.26-1.90	8	0.92-1.90	19	0.26-0.87
	30	0.32-1.88	10	0.40-1.88	20	0.32-0.89
	31	0.30-1.31	6	0.57-1.31	25	0.30-0.92
12.5 mm (1/2 ")	30	0.20-1.29	24	0.26-1.29	3	0.20-0.29
	30	0.12-0.49	16	0.21-0.49	13	0.12-0.27
9.4 mm (3/8 ")	33	0.18-1.84	33	0.18-1.84	0	
	30	0.17-0.38	29	0.17-0.38	0	
	30	0.05-0.18	11	0.07-0.18	16	0.05-0.15
	30	0.03-0.18	7	0.12-0.18	14	0.03-0.16
6.3 mm (1/4 ")	35	0.28-2.13	35	0.28-2.13	0	
	50	0.01-0.41	11	0.02-0.41	26	0.01-0.02
	30	0.02-0.20	30	0.02-0.20	0	
	50	0.004-0.163	23	0.008-0.163	22	0.004-0.024
	30	0.009-0.153	12	0.028-0.153	12	0.009-0.028
1.6 mm (1/16 ")	60	0.001-0.500	27	0.009-0.500	27	0.001
	30	0.011-0.020	19	0.011-0.020	0	
	50	0.001-0.050	36	0.007-0.050	1	0.001
	30	0.004-0.0008	25	0.0008-0.004	5	0.001-0.0027

Kind of shrimp : white shrimp *Penaeus setiferus*.

Dimensions of net box : 30 cm x 30 cm x 30 cm.

Experimental hour : 24 hours.

Water temperature : 23 - 26 °C.

released annually in a 10,000,000 m^2 netted-off portion of West Bay.[6,10] Although the details of the work has not been fully disclosed because of unsuccess from commercial viewpoint, it seems to be the most comprehensive and basic experiments for marine restocking ever made.

(1) Netting system for nursery. Postlarval shrimp are usually released into an enclosed area with netting installed at the release site. They are reared for a few days or weeks before release into the open area. Predators in the enclosed area are controlled by seining or treatment with chemicals. Upon opening the netting enclosures, shrimp are will be exposed to predators outside. To reduce mortality due to predation, another larger netting has been installed. The layout of the netting system - pen, nursery, abd growing area - is shown in Fig. 2.[8,12]

(2) Relation between mesh of net and size of shrimp retained with netting. Penaeid shrimp of the body weight ranged from 0.01 to 2.0 g and net of mesh 1.6, 6.3, 9.4, 12.5 and 18.8 mm (1/16, 1/4, 3/8, 1/2 and 3/4 inch) were used for the experiment. The shrimp were enclosed in a netting cage with the net as above mentioned. The netting cage was submerged in a tank in various combination of size of shrimp and mesh of net. After 24 hours, shrimp retained in the cage and escaped outside the cage were measured separately. The results are summerized in Table 1.

The size of shrimp retained by the above mentioned mesh was 0.01, 0.03, 0.2, 0.3 and 1.1 g, respectively. After checking the material and strength of the net, 1.6, 12.5 and 18.8 mm mesh nets were selected as the netting for pen, nursery and growing area, respectively. This indicates that the timing of opening pen and nursery should be at 0.3 and 1.1 g body weight, respectively. Combination of floats and sinkers is shown in Table 2.

Table 2. Floatation of netting

Dimension of cork		Spacing	Floatation
Diameter (cm)	Length (cm)	No. of cork (/m)	(kg/m)
15	21	6.6	6.65
15	9	3.3	5.44
10	7.5	6.6	6.50
7.5	14 *	3.3	4.08

Weight of chain: 9.07 kg/m.

* in combination with another cork of 7.5 cm in diameter.

(3) Survival and growth of shrimp inside netting fence. Shrimp were fed pelletized food as supplemental feed. The daily feeding rate was maximum 2% of the estimated weight of shrimp daily. Survival rate during the pen stage was estimated by random sampling with a scoop net (dimensions: 30cm x 20cm x 10cm, scooping distance 1.2m, and scooping efficiency:0.9).[10] Growth and distribution of the shrimp in the nursery were estimated by drag with a semi-circular frame net (width:60cm, height:90cm, and mesh:12.5mm) or a 16-foot try net (mesh of bag:28.1mm) weekly. After shrimp were dispersed in the growing area, commercial trawl was employed.

i) Survival of brown and white shrimp in the pen.[10] Survival rate was 75% for brown shrimp (stage at the release:P15-P45, duration at the pen:23-25 days) and 64% for white shrimp (P10-P17, 19-23 days). Survival was 72% for shrimp released in pen and 99% for those in restocking pond. Survival rate is relatively higher in the pond compared to the pen in the bay. This means no escape and less predation in the pond.

ii) Survival and growth of brown shrimp in the nursery. 13.800,000 and 12,500,000 postlarval brown shrimp were released into pens in the bay and into pond near the nursery in the early part of May and the early part of June, 1973, respectively. Estimated number of 11,000,000 shrimp was moved from the pens and the pond by scheduled opening from the end of May to the middle part of June. Additional 7,500,000 shrimp were moved from the pond at the end of June.

The results of drags with the frame net are shown in Table 3. The number of brown shrimp caught per minute drag in the nursery showed an increase to the early part of July. A linear relation was found between the density of shrimp (number of shrimp released/1,200,000 m) and the number of shrimp caught per minute drag during the period from the early part of May to the middle part of June as shown in Fig. 3.

A decreasing tendency in number of shrimp caught per minute drag was found after the end of June and it became remarkable after July. The average number of the shrimp during the middle part of August was 35.4. It is about 33% of the maximum number observed on July 10, 1973. This means dispersion of shrimp from the nursery.

Growth rate of these shrimp is shown in Table 4. About 97% shrimp grew larger than 1.1g on July 10. They should be retained inside the nursery if the net fence was stable. However, it was often found that the shrimp escaped through holes and breaks which were accidentally formed on the net fence.

iii) Survival and growth of white shrimp in the nursery. 46,800,000 and 59,000,000 postlarval white shrimp were released into the pond located near the nursery (No. 1 Nursery) and the pens installed in another nursery (No.2 Nursery) in July, 1973, respectively. The pond and pens were opened on August 8 and 9. Total number of shrimp moved from the pond and the pens was estimated as follows:

46,800,000 x 0.70 x (1-0.05) = 31,122,000 --- to No.1 Nursery from the pond, where 0.70:estimated survival rate at the pond and 0.05:estimated mortality during transfer from the pond to the nursery and

59,000,000 x 0.40 = 23,600,000 --- to No.2 Nursery from the pens, where 0.40:estimated survival rate at the pens.

Table 3. Results of drags with a frame net for brown shrimp *Penaeus aztecus* in No. 1 Nursery of West Bay in 1973

Date	Total No. of shrimp in pens (million)	Total No. of shrimp in No.1 Nursery (million)	Average number of shrimp caught per minute drag		
			Shallower area	Deeper area	Average
5/9	2.7	0	5.71	0	2.86
5/15	2.7	0	10.0	0	5.00
5/25	4.9	0	6.91	0	3.46
5/31	10.0	2.4	90.8	0.85	45.82
6/5	10.0	4.2	90.0	1.95	45.98
6/13	13.8*	8.0	147.8	8.35	78.08
6/20		11.0**	108.3	4.00	56.15
6/25			172.6	6.75	89.68
7/2		18.5***	77.1	89.1	83.10
7/10			155.7	59.8	107.75
7/17			145.6	53.0	99.3
7/27			82.3	15.5	48.9
8/3			92.0	28.2	60.1
8/9			40.6	15.3	28.0
8/16			67.6	18.0	42.8

* Total number of brown shrimp released into pens.

** Total number of brown shrimp moved from pens to the nursery.

*** Additional 7.5 million shrimp were released from the pond.

Frame net : semicircular, width: 60 cm, height: 90 cm, mesh: 12.5 mm.

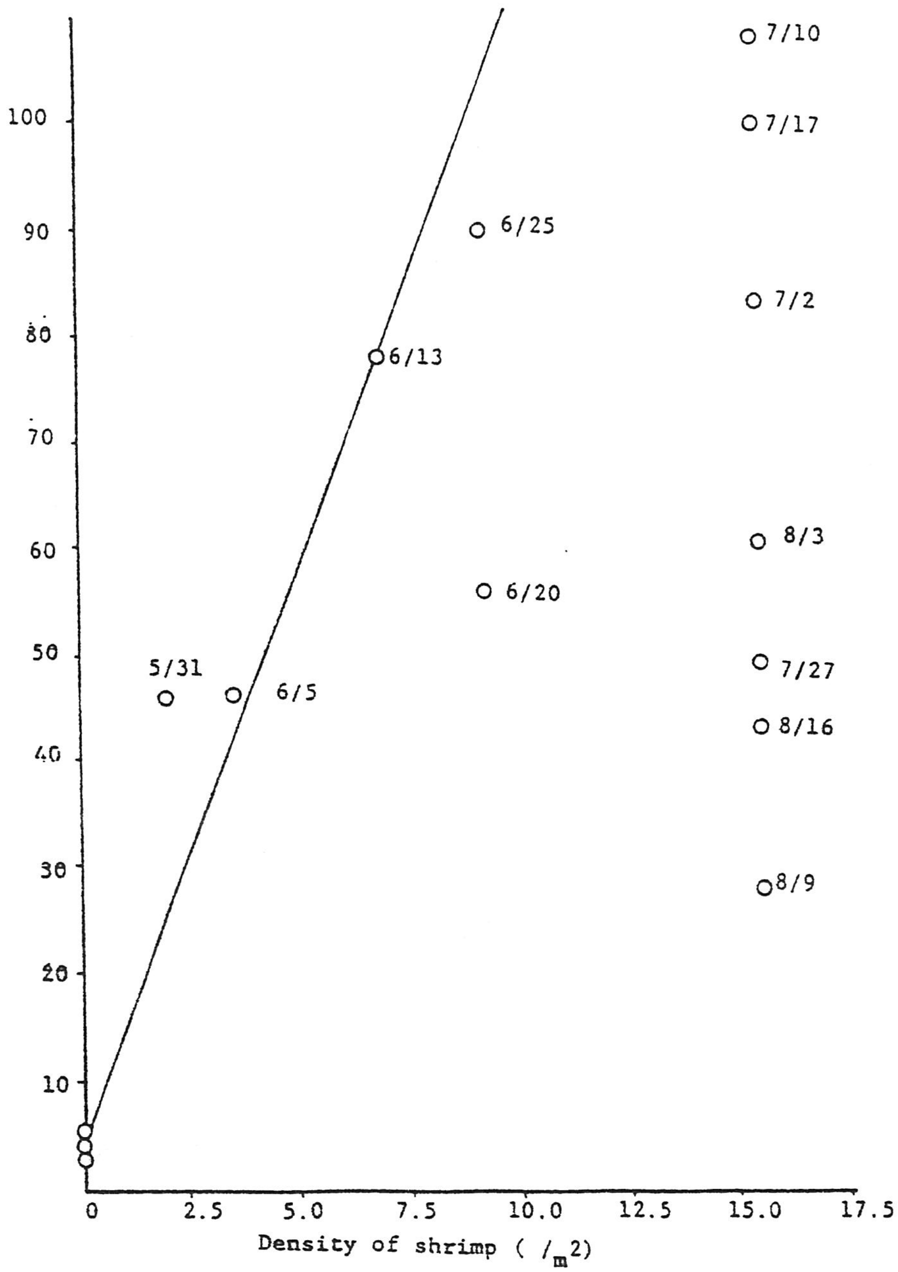

Fig.3. Relation between densty and number caught per minute drag. Drag was dona with a semi-circular frame net (width:60cm, hight:90cm, mesh of net:12.5mm.).

Table 4. Growth rate of brown shrimp *Penaeus aatecus* in No.1 Nursery of West Bay in 1973

Date	Number of shrimp (%) Range of body weight			Average body weight (g)	Note*
	0.3 g	0.3 - 1.1 g	1.1 g		
5/9	100	0	0	0.15	No.1 Pen
5/15	89	11	0	0.18	"
5/25	39	58	3	0.36	"
5/31	11	85	4	0.50	"
6/5	3	39	58	1.20	No.1,2 Pen
6/13	7	38	55	1.40	"
6/20	8	54	38	1.18	No.1,2,3 Pen
6/25	12	50	38	1.00	No.1,2,3,4 Pen
6/25	55	45	0	0.28	Pond**
7/2	32	45	23	0.31	
7/10	3	49	48	1.29	
7/17	1	52	47	1.22	
7/27	0	18	82	1.66	
8/3	0	4	96	2.32	
8/9	0	1	99	3.45	
8/16	0	0	100	4.32	

* The pen indicated in the column was opened.

** Shrimp in the pond just before release into the nursery

Table 5. Average number of white shrimp *Penaeus setiferus* caught with try net drag in No.1 and 2 Nursery of West Bay in 1973

Date	Number of shrimp caught per minute No.1 Nursery	No.2 Nursery	Average
8/8	46.8	0	23.4
8/10	91.3	0.7	46.0
8/15	246.3	0	123.2
8/22	327.0	26.1	176.6
8/29	170.4	54.2	112.3
9/10	55.6	30.5	43.1
9/27	47.0	25.6	36.3
10/4	40.8	29.3	35.1
10/12	2.4	57.0	29.7

Try net : 16-foot, 28.1 mm mesh of bag.

Area of No.1 and 2 Nursery : 1,200,000 m^2 each.

Table 6. Average number of white shrimp *Penaeus setiferus* caught with try net drag in Central Pond in 1973

Date	Number of shrimp caught		
	Nursery area (per 10 sec.)	Growing area (per 10 sec.)	Average (per min.)
6/26	120.0	0	72.0
7/9	475.0	0	285.0
7/18	135.4	25.5	219.0
7/23	19.9	15.5	95.4
7/31	22.9	23.0	142.2
8/7	195.6	78.1	539.4
8/13	48.8	27.0	175.2
8/21	35.7	43.3	255.0
8/28	49.3	25.9	169.2
9/5	17.3	21.7	127.8
9/11	41.1	32.8	201.6
9/18	13.2	64.9	358.2
9/25	50.5	30.0	192.6
10/2	30.0	36.2	213.6
10/9	54.8	48.8	296.4
10/16	26.5	25.0	151.2

Try net : 16-foot, 28.1 mm mesh bag.

Acrage of nursery area: 120,000 m^2.

Acrage of growing area: 1,080,000 m^2.

Owing to schooling behaviour of white shrimp, a 16-foot try net drag was applied. Average number of shrimp caught per minute drag is shown in Table 5. It showed a remarkable decrease after the end of August. Growth rate of the white shrimp is shown in Table 6. They probably grew to the size retained in the growing area after September. There would be a gap in timing of movement from the nursery and the growth rate of the shrimp.

An interesting results obtained with the same try net drag in another isolated growing pond (Central Pond). The acrage of the growing pond, No.1 Nursery and No.2 Nursery was the same, that is, 1,200,000 m^2 ,each. Number of shrimp caught per minute drag was 220 in September and October as shown in Table 7. Total number of shrimp harvested in Central Pond in 1973 was 19,220,000. One shrimp caught per minute with a 16-foot try net drag is roughly equivalent to 87,360 shrimp harvested in a 1,200,000 m area.

Table 7. Growth rate of white shrimp Penaeus setiferus in No. 1 and 2 Nursery of West Bay in 1973

Date	Average body weight (g) No.1 Nursery	Average body weight (g) No.2 Nursery	Note
7/5	0.004*	0.005**	
7/12	0.012*	0.010**	
7/19	0.053*	0.014**	
7/26	0.050*	0.073**	
8/2	0.106*	0.073**	
8/8	0.050*	0.143**	Release into the nursery
8/10	0.14	0.24	
8/15	0.32		
8/22	0.76	0.44	
8/29	0.91	0.43	
9/10	0.90	1.87	
9/27	0.90	2.82	
10/4	1.80	1.34	
10/12	1.78	1.88	

* Body weight of shrimp sampled in the pond.

** Body weight of shrimp sampled in the pen.

Table 8. Recovery rate of shrimp in West Bay

Area	Kind	Year	Total number released (million)	Total harvest (ton)	Average body weight (g)	Total number recovered (million)	Recovery rate (%)
West Bay	Brown shrimp	1971	24.95	0		0	0
		1972	16.32	15.84	10.48	1.51	9.2
		1973	52.1	8.93	10.76	0.83	1.6
		1974	40.1	31.95	8.24	3.87	9.6
	White shrimp	1971	101.4	112.46	8.54	13.17	13.0
		1972	137.3	26.17	10.20	2.56	1.8
		1973	105.8	36.27	4.91	7.38	7.0
		1974	135.0	95.85	6.51	10.90	10.9
Central Pond	Brown	1971	24.05	43.96	8.70	5.05	21.0
	White shrimp	1972	15.7	40.90	9.49	4.31	27.4
		1973	43.5	95.04	4.95	19.22	44.2
		1974	38.0	133.65	6.90	19.36	50.9
North Pond	Brown	1971	16.85	10.78	3.52	3.06	18.1
	White shrimp	1971	3.4	21.52	12.22	1.76	51.7
		1972	12.2	44.17	7.99	5.53	45.3
		1973	43.5	46.35	3.36	13.77	31.7
		1974	37.0	95.40	6.20	15.39	41.6

West Bay : 5,200,000 m^2.

Central Pond : 1,200,000 m^2.

North Pond : 1,200,000 m^2.

Therefore, number of the white shrimp distributed in the nursery in West Bay was estimated at

87,360 × (123.2+176.6+112.3)/3 × 2,400,000/1,200,000=24,000,000

in August, and

87,360 × (35.1+29.7)/2 × 2,400,000/1,200,000 = 5,461,000 in

October. Total number of white shrimp harvested in West Bay in November and December, 1973 was 7,380,000. From these figures it will be pointed out that shrimp in the nursery decreased from August to October due to dispersion from the nursery.

iv) Recovery rate of released shrimp. Recovery rate of the released shrimp in West Bay and the ponds (Central Pond and North Pond) is shown in Table 8. Better recovery rate was shown for both species in the ponds compared to the bay. Average recovery rate in the bay was 5.1% for brown shrimp and 8.2% for white shrimp, respectively. Average recovery rate in the ponds was 19.6% for brown shrimp and 41.8% for white shrimp respectively. Predators were controlled repeatedly in the bay prior to release. Therefore, lower recovery rate in the bay is considered due to dispersion of shrimp through netting fence.

I-3. Restocking postlarval shrimp in Japan

Almost 10 years after the success of postlarval production in commercial scale, restocking shrimp larvae has been conducted as the policy in many prefectures in Japan as shown in Fig. 4. Research has been made to find relationship between release and increase of catch of the shrimp. There has been two approaches; one is how to improvesurvival for postlarval stage and the other is how to monitor released shrimp in wild population. The former developed construction of netting enclosures, artificial tideland or restocking pond. The latter developed method of release with marking and analysis of body length composition of shrimp caught. However, there is no assurance that the released shrimp are directly monitored by these method because shrimping starts one or two month after the release from these intermediate rearing facilities.

(1) Release at Minoshima, Fukuoka Prefecture , along the coast of Seto Inland Sea[2] 360,000 postlarval shrimp (20-45mm in body length) and 700,000 postlarval shrimp (11-21mm) were released on July 4 and August 4, 1966, respectively. Samples were taken with a pump-net for juvenile stage

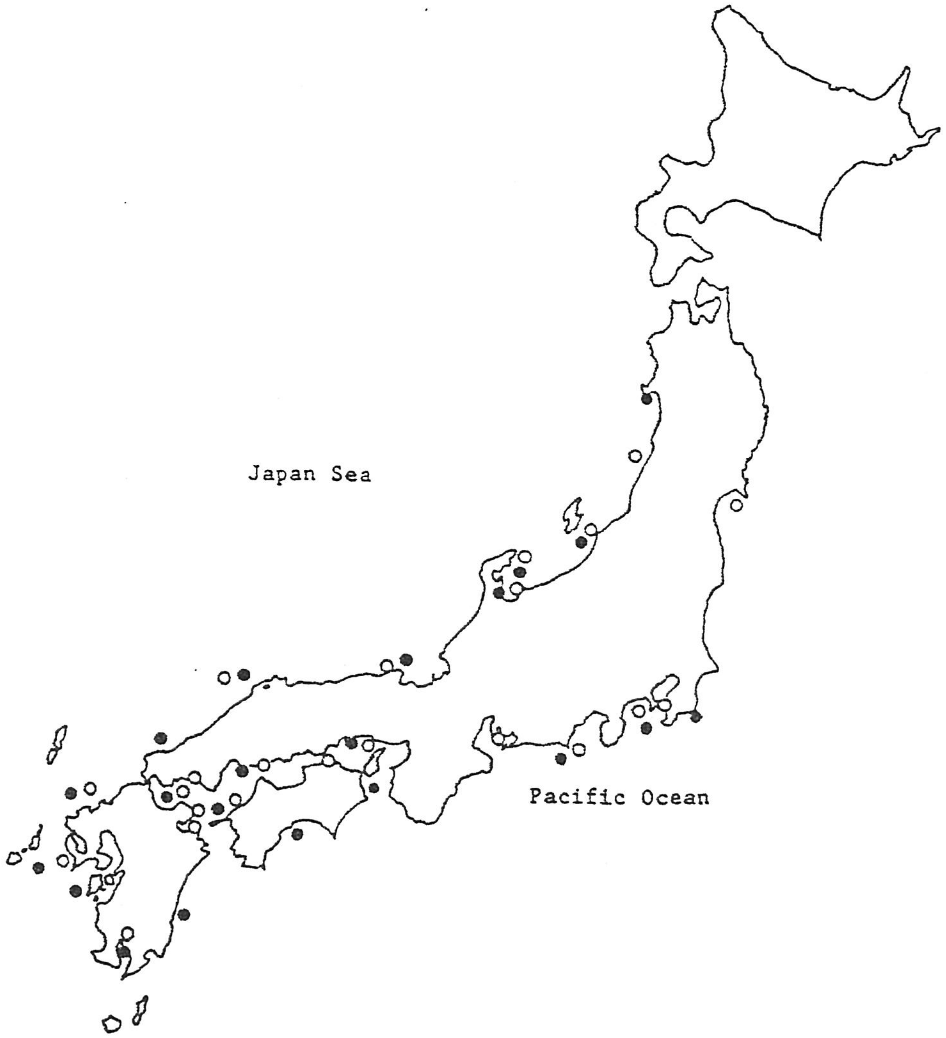

Fig.4. Map showing the prefectures where hatcheries for penaeid shrimp and red sea bream were established.
o:kuruma shrimp. •:Red sea bream

at tideland and from the catch by fishermen for marketable stage, respectively. For 5 days after the release the population density decreased to 3% of that just after the release. The released shrimp of August 4 was traced on the growth curve. The number of the recovered shrimp was about 140,000 by analysing the body length composition of shrimp caught. Recovery rate was estimated at about 20%. This value seems to be much higher compared to those obtained later.

(2) Release at Omi Bay near Aio, Yamaguchi Prefecture, along the coast of Seto Inland Sea.[3] Spawning season of <u>Penaeus japonicus</u> is in July and August. About one month after the spawning postlarvae of the wild stock appear on tideland in August or September. Therefore, when postl-

arval shrimp were released in June or July, they would be distinguishable on the size composition of histograms from the wild shrimp. Total 27,000,000 postlarval shrimp were released into natural tideland from 1972 to 1974. Total 430,000 marketable shrimp were recovered. Recovery rate was 1.6%. Number of the postlarvae settled on the natural tideland after the release was estimated at 4.5-9.0%. Recovery rate to the postlarval shrimp settled on the natural tideland ranged from 10 to 20%. From these results, effect-ualness of artificial tideland was recognized.

(3) Artificial tide land.[15] Survival rate of postlarval shrimp just after release was improved with netting enclosures installed on tideland However, to maintain such netting enclosures in natural tideland and to controll fish inside the enclosures are rather difficult problem. Preliminary experiments showed that the initial survival of the released postlarvae was better in tidepools at higher elevation compared to those at lower elevation. The difference of the survival rate is considered due to less predation during exposure time which is shorter at higher elevation.

An artificial tideland was constructed at Omi Bay in 1973. It was composed of stocking area (50 x 200 m) and nursery (70m x 200m). The former was divided into 32 blocks (unit block: 12.5m x 25.0m) at Mean High Water Level of Neap Tide with concrete hedge of 5cm height above sand bottom. It had a slope of 1/200 seawards. The latter was divided into 4 blocks (unit block: 50m x 70m) at Mean Sea Level with concrete hedge. The water depth was kept at about 5cm deep by pumping sea water during low tide. It was possible to release postlarvae at high density (about $100/m^2$) and to make settle at better survival. On July 22 and 30, 1975, a total 2,400,000 postlarvae was released in the stocking area. Estimated number of postlarvae settled in the area was about 800,000. Two or three week after the restocking, the postlarvae moved to deeper area from the stocking area and grew to marketable shrimp in deeper waters. Recovery of shrimp during the autumn was 139,000. Recovery rate was 5.8% for the total number of shrimp released and 17.4% for the number of shrimp settled on the stocking area.

Recovery rate of shrimp released into natural tideland in Omi Bay with a netting enclosures was 1.4% for initial number of postlarvae and 7.5% for the postlarvae settled in the enclosures. Recovery rate was much higher when postlarvae were released in artificial tideland.

(4) Release into restocking pond. As seen in West Bay, the stocking pond connected to the nursery with a canal showed a better survival because of no predators. Similiar idea has been applied in release program at Obama Bay, Fukui Prefecture since 1980.[14)]

The pond was digged in sand beach close to shore line. Total area of the pond was 2,660m^2 and the water depth was 0.8-0.9m. The water was exchanged with pipes (diameter:0.5m, length:20m) installed at 2 sites by tidal difference. Screen nettings were installed around both end of pipes.

1,314,000 postlarval shrimp (23mg in body weight) were released into the pond on July 20 and 21, 1980. Survival and growth were examined with a scoop net. The survival rate showed a decrease on the following day of the release. After that, it was stable and final rate was 83% for 20 days after release. Final body weight was 135mg.

The sand dike of the pond was cut on August 10. The shrimp moved to the sea were sampled in front of the pond (1,000m along the shoreline x 1,000m Offshore) with a drag net equiped with electric shocker. On the fllowing day of the release relatively dense distribution was found within 300m offshore. The distribution density decreased to 20, 6, and 1.2 % for 2, 6 and 15 days after opening the pond, respectively.

Another interesting observation was done on August 20. 261,000 postlarval shrimp were released at another station along the beach in the bay. Sampling was done in front of the release station (135m along the shoreline x 15m offshore) with quadrate method. Number of the shrimp distributed just after the release was estimated at 21,241, namely, 8.1% of the total number released. This means the shrimp dispersed further offshore from the releaseg site. Thus, the pattern of dispersion was not the same as observed in tideland in Seto Inland Sea area.

(5) Restocking in the north of Japan. Penaeid shrimp distribute along Japan Sea coast of the main island of Japan because the warm current wash the coast. Although the shrimping has been made at a very small scale, there will be capacity to grow more shrimp. Intermediate rearing of shrimp in the digged pond is a very effective method in this coast. However, quick dispersion after the release from the pond makes it difficult to trace shrimp after release. To develope a method of monitoring will be an important problem.

A restocking program has begun near Sakata, Yamagata Prefecture since 1983.[1)] A restocking pond (70 x 30m) was digged in the sand beach. The pond divided into two small ponds (north pond and south pond;total area: 1,880m) with sandy dike. During construction fresh water welled up at 0.7m high over the sea level. Pumping became necessary because the tidal difference was smaller than 0.3m. Pipes (diameter: 350mm) were installed for pumping, connecting both ponds and draining. 900,000 postlarval shrimp (24mm in body length and 148mg in body weight) were released on September 14, 1983. Initial density was 479 postlarval shrimp/m . The dike was cut at the south pond on September 21 and at the north pond on September 22. Estimated survival rate was 75%. Monitoring was done in front of the pond (260m along shoreline and 20m offshore) during releasing time of September 22. Distribution of shrimp and occurence of fish were observed at 226 stations by diving. The results are shown illustratively in Fig. 5.

Number of the shrimp counted in the south side and north side by diving was 11 and 27, respectively. Because almost the same number of shrimp moved from each pond to the sea, less number in the south side indicates decrease of the shrimp for one day after the release. The survival rate is roughly 11/27 = 41%. About 60% decreasing rate for one day is considered due to dispersion or predation. 7 mortality was found on the north beach, but no mortality was found in the sea. This means mortality due to mechanical shock during the release is presumably very low.

Number of fish counted by diving for 3 days was about 130 (18 species). Among them predacious fish was about 90 (15 species); about 49 (10 species) were found on sandy bottom, about 35 (3 species) near tetrapots and 6 (2 species) in both area. A higher distribution of fish was found in the south area compared to the north area. This may have relation with the fact that first release was done from the south pond.

Although predation of fish is well recognized as an important factor on the survival of the penaeid shrimp, the degree of the predation pressure has not yet been studied well. It had been shown that Tridentiger obscurus , most popular predator fish in shrimp pond, preyed on average 1.7 postlarval shrimp (50mg) daily by Hudinaga and Kittaka. An experiment has been done with predator fish found in Sanriku coast. The results are summerized in Table 9. It is interesting to note that the number of shrimp preyed by swimming fish decreased remarkably with sandy bottom but not in the case of benthic fish.

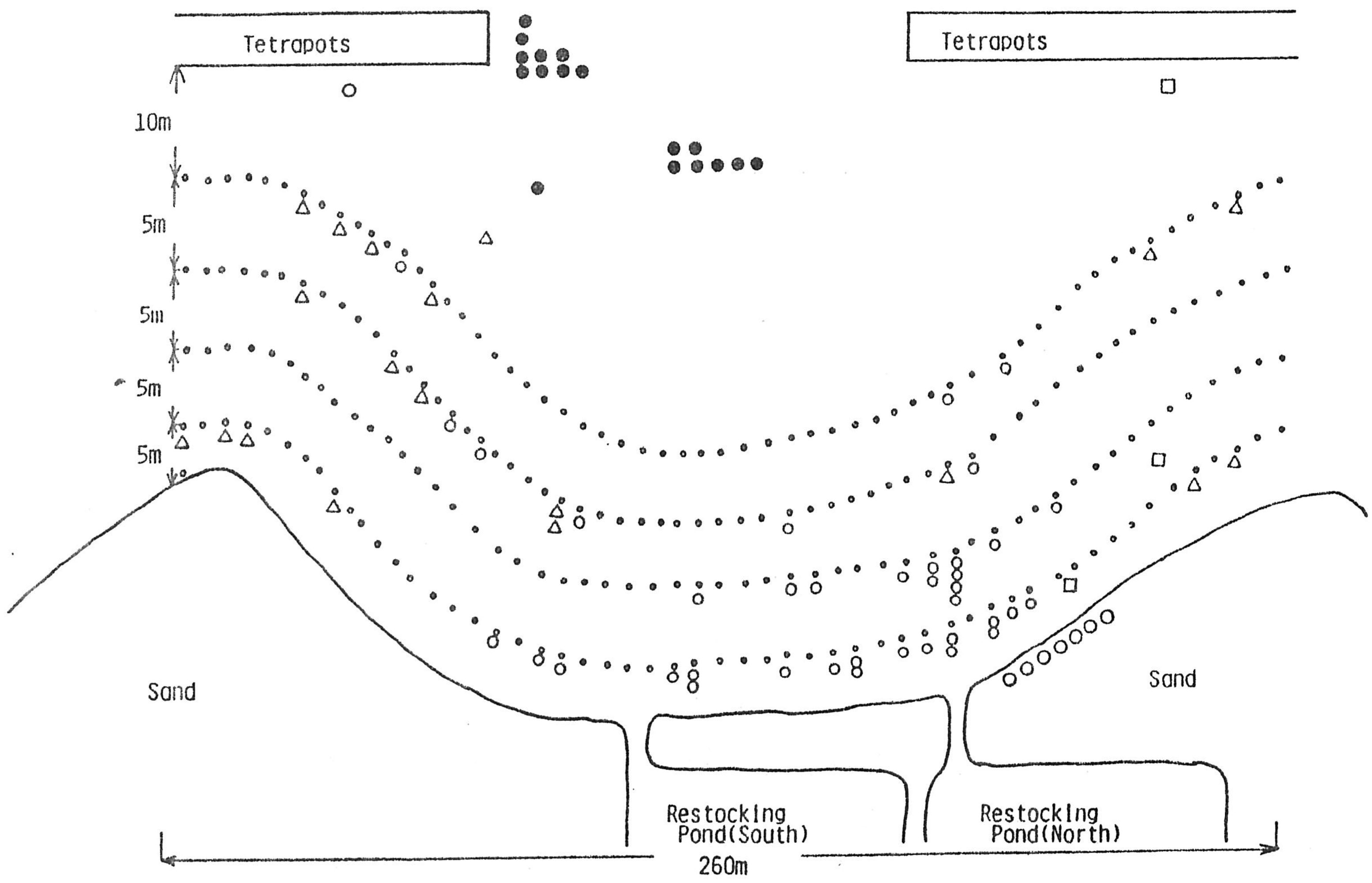

Fig.5. Distribution of Kuruma shrimp and predator fishes found at the releasing site at Sakata.
Penod of observation: September 21-23, 1983.
•: Station for diving observation.
○: Kuruma shrinp (one individual) found by diving on September 22.
●,△,□,: Predator fish (one individual) found by diving on September 21 (first release),22 (second release), and 23, respectively.

Table 9. Number of Kuruma shrimp fry eaten by predator fishes found commonly along Sanriku coast

English name	Scientific name	Body length (cm)	Body weight (g)	No. of fry eaten without sand (/day/fish)	No. of fry eaten with sand (/day/fish)
Striped beak perch	*Oplegnathus fasciatus*	11.8	42	74	28
Girella	*Girella punctata*	7.9	12.5	4	5
Beauty goby	*Ptelogobius zacallus*	13.5	29	19	5
Common brackish goby	*Acanthogobius flavimanus*	8.2	10	2	0
Temmink's surfperch	*Ditrema temmincki*	12.6	30	85	9
Sculpin	*Alcichtys* sp.	11.8	16	10	7
Fat greenling	*Hexagrammos otakii*	17.8	60	19	24
Marbled sole	*Limanda yokohamae*	16.8	65	13	3

Kuruma shrimp *Penaeus japonicus* of 33 mm in total length and 0.200 g in body weight wereeused for the experiment. Shrimp fry were placed in an aquarium of 60 l and fish were introduced in the aquarium individually for 24 hrs.

Dispersion of shrimp after release was remarkable in Japan Sea coast. Once the shrimp were moved into deeper waters, they may expose to heavy predation pressure. Only one solution is considered to install a nursery connected with the restocking pond.

II. Red sea bream

Restocking program for red sea bream Chrysophrys major is more complicated compared to the case for penaeid shrimp because red sea bream live for several years and they gain better commercial value with their size increase. Although it is still difficult to produce a large number of their fry[9] as already done in the case of penaeid shrimp, it has been common practice to grow them to juvenile stage and then to release with marking. Red sea bream was considered to be a migratory species. However, marking experiment has shown that their migration is of rather small scale especially at young stage. Environments, fisheries and population of red sea bream are different depending on locality. Restocking has been done experimentally to establish a method suitable to the locality. The experimental sites are shown in Fig. 1.

II-1. Restocking of red sea bream in Imari Bay and Omura Bay, Nagasaki Prefecture.[18]

2,490 artificial fry (37mm in body length) and 2,899 wild fry (42mm in released into Imari Bay on June 18, 1973. 9,227 artificial fry (35mm in body length) were also released into Omura Bay on June 26,1973. These fry were marked with cutting ventral fin. Fishing was done 3 and 13 days after release in Imari Bay and Omura Bay, respectively. Difference of growth was observed between the artificial fry and the wild ones. The former showed a retarded growth (daily body length increase:0.75mm) compared to the latter (0.95mm). The former had a tendency to stay near the releasing site(200-400m offshore from shoreline) , while the latter dispersed in the entire fishing ground (200-1,000m offshore). Thus, less activity of feeding and swimming was observed for the artificial fry. Almost 40 days was necesary for them to gain same behaviour with the wild fry.

Red sea bream fry become benthic at about 20mm in total length about 40 days after hatching. Body length of the fry released in Omura Bay ranged from 20 to 48mm. Higher mortality was observed for the fry of smaller size by monitor ing the body length composition of fry. Judging from these results, suitable size for releasing is considered at about 40mm in total length about 20 days after entering to benthic stage.

II-2. Restocking of red sea bream in combination with sound acclimatization.[19]

In Seto Inland Sea area, juvenile red sea bream (60-120mm in total length) are often cauht with a small-scale drag net for shrimping. It is obvious that this depress the red sea bream restocking. Although, size limit regulation has be been applied for red sea bream, it is not efficient way to save released fish at young stage. In order to save the red sea bream from the fishing, an experiment with sound acclimatization was done at Kurahashi Island by Hiroshima Fisheries Experimental Station. The fish were acclimatized in combination with sound of 200 Hz and feeding with pelletized food.

10,000 and 24,965 acclimatized fish were marked with tag-pin and abbreviation of pectral fin,respectively. 10,000 non-acclimatized fish were used as controll. These fish were released in September 2 weeks after marking. Total number of the recovered fish with the mark was 1,955 (recovery rate:5.6%) for a 2 months period after the release. Rate of the acclimatized fish to the total number of the fish caught was 78.8%. This fact shows the acclimatized fish with sound distribute near the restocking site after the release.

II-3. Restocking of red sea bream in combination with artificial reef.[19]

The main purpose of artificial reef is to attract fish. The function will be applicable for constructing sanctuary for juvenile fish. Artificial reefs combined with plastic frame were installed at a site of 17 -24m in water depth around Toyoshima Island in 1974 by Hiroshima Prefectural Fisheries Experimental Station. Dimensions of a unit reef was $20m^3$(2.6m x 5.5m x 1.8m) or $50m^3$(4.3m x 5.5m x 2.6m). The former was equipped with a bag of about 1 m^3 oyster shell to promote propagation of living organisms. The scale of a whole reef was $300m^3$ in about $15,000m^2$ fishing ground.

50,000 fry were released at artificial reefs in September and October. Number of fish habitant was estimated at 90-100%, 60-70% and 20-40% on 0, 4 and 50 days after the first release, respectively. Census of angling showed that 0 year fish were caught in October and November and 1 year ones from May to September of the following year. Rate of the marked fish for 1980 and 1981 year class in the total catch was 29.3% in 1981. Recovery rate was estimated at 0.2-2.2 %.

II-4. Restocking with a netting system.[16)]

Postlarvae of red sea bream (about 12mm in total length) reared at hatchery are transferred into a netting cage and reared to about 27mm for about 25 days. The size and activity of these fry is not satisfactory for release to the open sea although they have acquired the benthic habitat. Rearing in pen and nursery after the cage stage has been applied at several sites along the coast of Oita Prefecture since 1975 by Oita Prefectural Fisheries Experimental Station.

A pen was installed inside the nursery with 2.14mm mesh net. The dimension was 20m x 20m x 10m. The nursery was constructed with 1.76cm mesh net. Its area was about $10,000m^2$. The fry were reared in the pen up to about 60mm in total length, which are the suitable size for releasing, for about 30 days. They were moved to the nursery and reared to 9-14 cm in total length for about 3 months. Survival rate during pen and nursery stage was about 70-76%. Average 15,000 juveniles were released from a nursery to the sea. Acclimatization with sound and feeding with automatic feeder were applied for the pen and nursery system. Advantage of the nursery system is that the fry grow healthily because of abundant natural food and wide space availability. 4,083 and 10,100 fish with marking were released into the sea in 1975 and 1976, respectively. Recovery rate was 14.7% for a 3 years' period for the former and 12.4% for 2 years' for the latter. Before using the nursery system, recovery rate was 1.7 and 6.0% for the fish released in 1973 and 1974, respectively. Thus, recovery rate was improved by the nursery system.

From the marking release, it was shown that the recovery rate was higher for 1 and 2 years fish compared to 0 year fish and that 99% recovered fish were caught within 10km from the releasing site. These findings will encourage restoking program of red sea bream.

II-4. Restocking of red sea bream in Kagoshima Bay.[17)]

Kagoshima Bay has 80km in length, 20km in width and maximum 200m in depth. Its total area is about 1,130 km^2. Whether red sea bream restocking will be successful or not through entire life cycle in such a large-scale semi-enclosed bay has been an interesting problem. Restocking program has been begun since 1974 by Kagoshima Prefectural Fisheries Experimental Station. Number of red sea bream released annually increased from 5,500 in 1974 to 240,900 in 1979. Average total length of the fry at the releasing time was 6.3 - 11.6cm. 100 - 50% fish were released with marking. Maximum recovery rate was 4.1% for the fish released in 1977. The fish released in the innermost part of the bay distributed within 5-10km from the releasing site for 2 years. Growth rate of the fish was 200-250g and 700-800g at 1 and 2 years after the release, respectively. It is noticiable that fish with marking are caught at 4 and 5 years old in the innermost part of the bay. Rate of the released fish in the annual catch of 1977 and 1978 was 30.3 and 13.2% in the total number and 8.6 and 6.8% in the total weight. Spawning and larval recruitment from the released red sea bream will be expected in Kagoshima Bay.

III. Lobster

Although lobster Homarus americanus and H. gammarus does not distribute around Japan, a trial to intro-duce them to Japan was initiated in 1915 at Karakuwa, Miyagi Prefecture. The trial was not successful because seedling technology was not yet developed as of today Because important indigenous crustacean species are very scarce in the north of Japan, research on introduction of lobster into Sanriku coast has newly begun at Kitasato University in cooperation with French and U.S. scientists with the scientific research fund from the Japan Promotion for Scientific Research and the Ministry of Education, Culture and Scieces, Japan, since 1975. Thorough culture of lobster has been demonstrated at Sanriku in 1981.[11)]

The research has been carried out on two lines. One is to establish culture method for lobster and the other is to develope restocking programme. Along the former line, controlled reproduction is most important

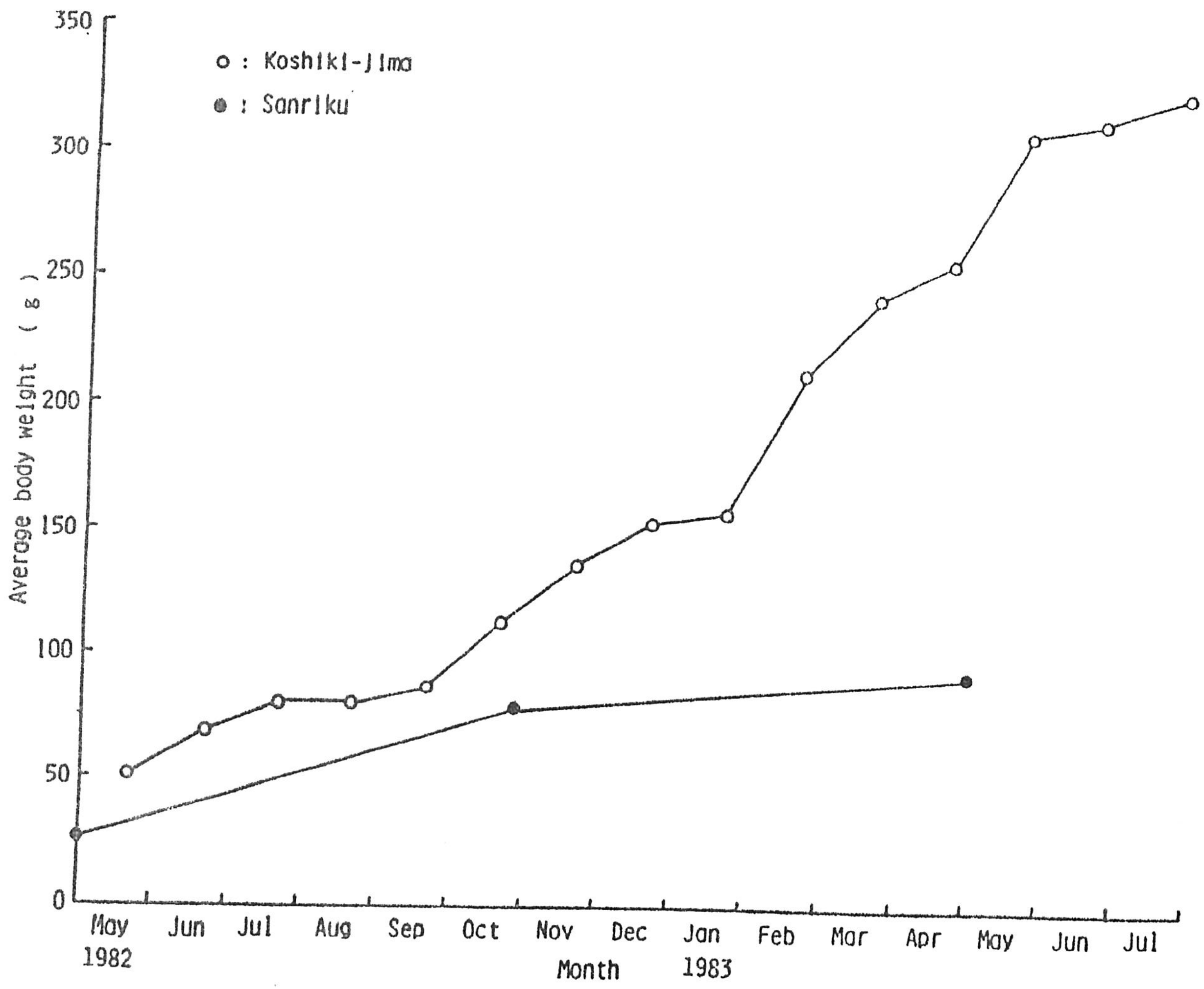

Fig.7. Comparison of growth for lobster between Koshiki-Jima and Sanriku.

because no wild stock is available in Japan. Large scale larval rearing and communal rearing are also essential to establish lobster culture as in the case of penaeid shrimp culture. Along the latter line, assessment of the possible ecological effects is most important because impact on useful marine organisms is not fully known. Both culture experiment and experimental release have been done at Sato-mura, Kamikoshiki Island, Kagoshima Prefecture since 1982.

III-1. Growth and survival of lobster in the north of Japan.

Lobsters were cultured communally in a concrete tank at Sanriku. IV stage lobsters were introduced into the tank (10m x 6m x o.6m) with oyster shell as the bottom. Alive mussles or pelletized shrimp feed were used for the experiments. The growth of 1975 year class lobster was 7.4, 37.9, 143.2, 312.7, and 453.6g for 0, 1, 2, 3, and 4 years group, respectively as shown in Fig.6. Survival rate was 1.9, 66.3, 87.5, 88.2, and 89.5% for 0,1, 2, 3, and 4 years group, respectively. Although survival rate was very low for o year group, it was shown to be improved to about 60% in the following years' experiments.

III-2. Growth and survival of lobster in the south of Japan.

Lobster were cultured individually in a plastic netting case placed in a tank at Koshiki Islands. The most important matter for successful culture in southern area is how to control temperature increase of the tank water. The tank water was changed several times daily and black fine mesh net was streched over the tank in the daytime to controll sunshine.

A remarkable difference of growth for lobster was found betwen the north and the south of Japan as shown in Fig. 7. Water temperature was higher than 25°C during the period from the early part of August to the early part of September at Koshiki Islands as shown in Fig 8. Water temperature decreased lower than 10°C during the period from the last part of November to the last part of March at Sanriku. No molting was found during these periods. While the water temperature was maintained at minimum 15°C in February at Koshiki Islands. The tempeature was suitable for growth of lobster all year round except summer season at Koshiki

Islands.

Individually reared lobster at Koshiki Islands molted 4 or 5 times per year (average 4.25 per year) and they grew from the initial average body weight 50 g to the final body weight 308g. While those reared communally at Sanriku grew 28g to 90g in the same year. Although both were not strictly comparable because of difference of the rearing method, it will be estmated that the period required for the growth of lobster is shortened to almost 1/2 in the south of Japan compared to the north of Japan.

III-3. Release experiments in the south of Japan.[13)]

Lobsters of IV-V stage (1.5-2.0 cm in total length) and XI-XV stage (5-9 cm in total length) were used for the experiments in 1982. The formers were introduced in a net cage without bottom installed in sandy substrate. The latters were introduced one by one under concrete blocks laid on sandy bottom in 4 parallel lines with a 2m space between each block. One end of the lines was close to the stony-coral substrate. Monitering was carried out for 11 days by diving. Experimental site is shown in Fig. 8.

Survival rate was 68% just after release and 25% 9 days after release for IV-V stage lobster. Survival rate was 2.7% and 25.0% after 11 days for XI-XV stage lobsters released close to the stony-coral substrate and the others respectively. Under the concrete blocks about 20-40% lobsters disappeared and 10-15% new ones appeared daily. Thus, movement of lobster between blocks was rather frequent. Fishes of Pomacentridae and Gobiidae were observed frequently around the blocks digging in sand. Although fish predation was never observed on XI-XV stage lobsters, the lobsters were forced to move between shelters rather frequently if they were exposed to predators. This may result in dispersion and mortality after release. For IV-V stage lobsters, the use of cage seems to be esential. Without such a protection system, they will hardly settle.

Discussion

This paper dealt with restocking program of three kinds of important marine fish and shellfish. All of them has been produced under controlled condition in the hatcheries.[5,6,9)] Although their phisiological and ecological

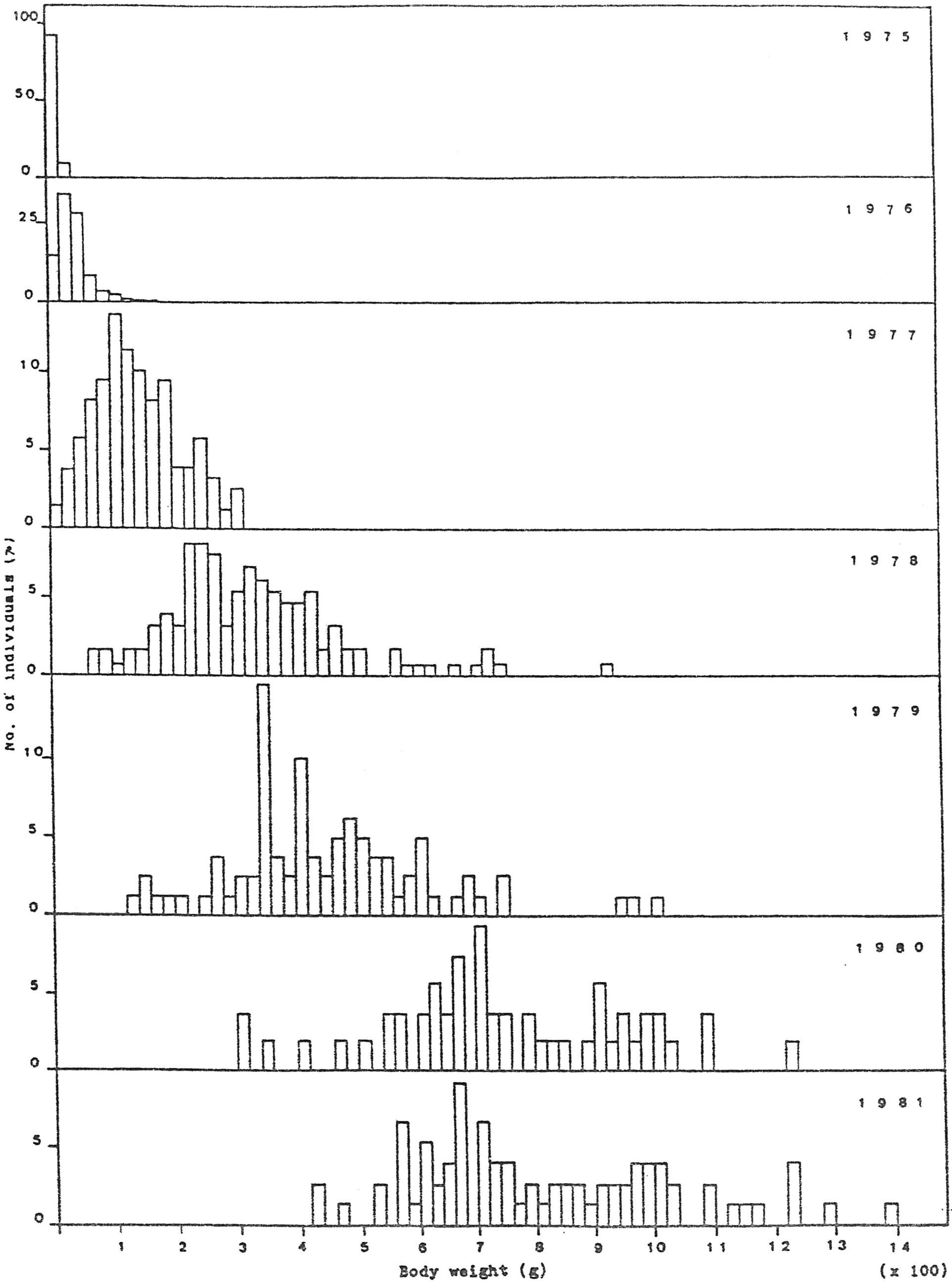

Fig. 6. Growth of 1975 year class lobster Homarus americanus at Sanriku.

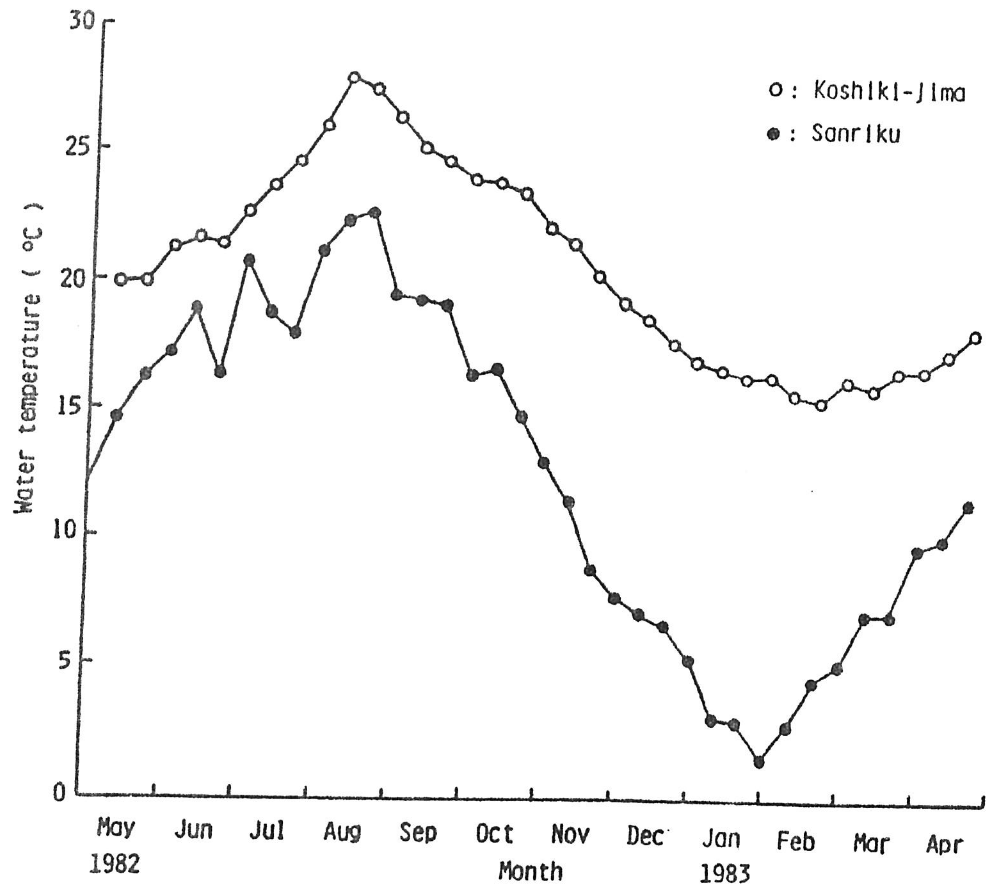

Fig.8. Average water temperature for a ten.day period at Koshiki-Jima and Sanriku.

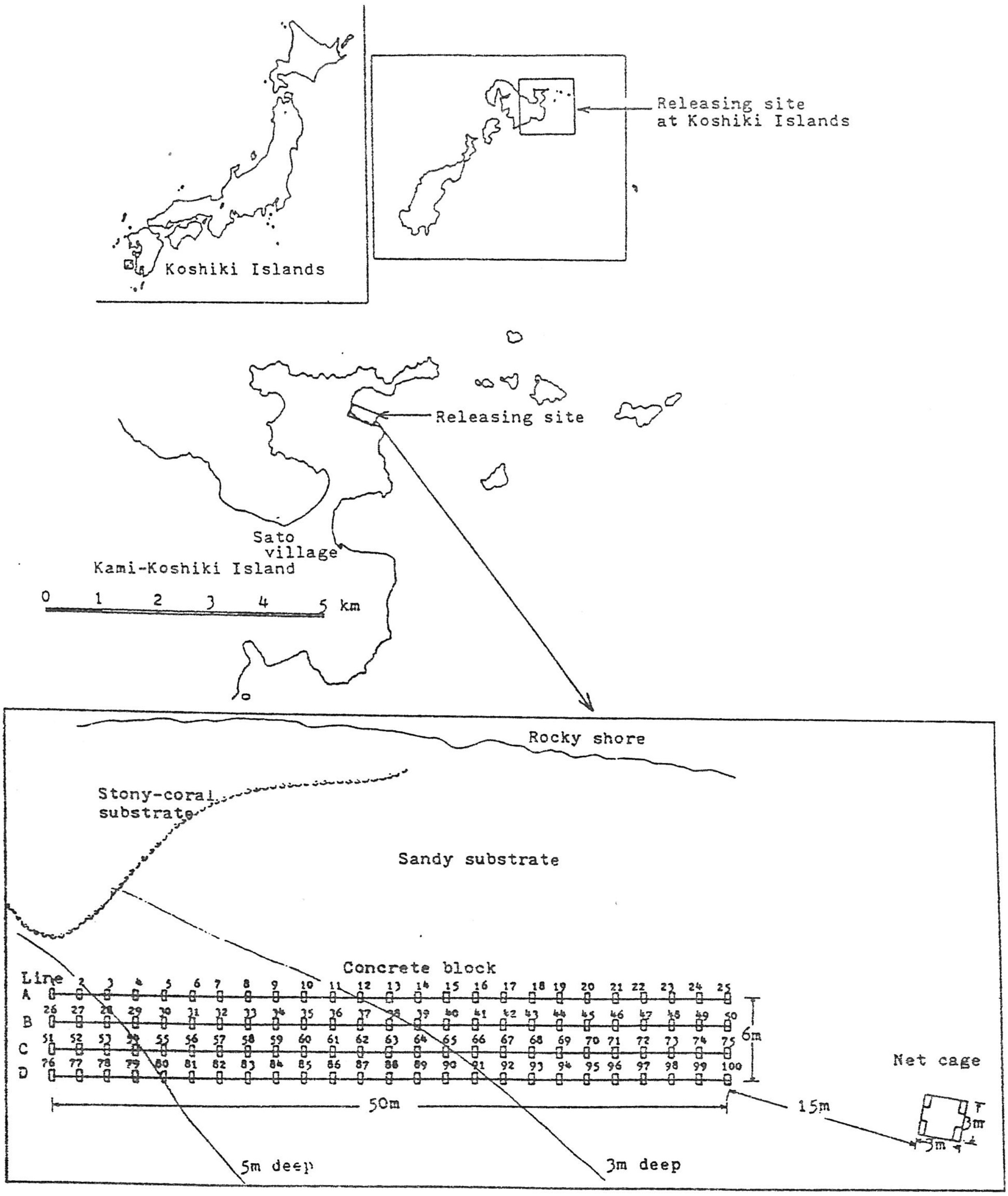

Fig. 9. Site of the experimental release of lobster at KOSHIKI ISLAND and arrangement of concrete block and a net cage. Modified from Kittaka, Henoque, Yamada and Tabata (1983).

character does not assure recovery after the release, the behavioral character of a small-scale migration reveals prospects for the restocking. Most important factor for the successful restocking will be selection of suitable site and species and application of suitable enclosing system after the release.

Good recovery rate has been shown for penaeid shrimp released in Seto-Inland Sea compared to those in Japan Sea.[3,14] A monotonous coastal line and a northeastward drift due to the current forms less sheltered area for the shrimp in the coast of Japan Sea. Topography is also important factor for red sea bream to settle near releasing site for a long period as shown in Kagoshima Bay.[17] From experimental culture and release for lobster at Koshiki Islands, it has been shown that the lobster are tolerable to high water temperature at 25-27°C but they can not compete with predator fish inhabited in coral-sandy substrate which is typical bottom condition in southern sea.[13]

Restocking was done in commercial scale for three species of penaeid shrimp in West Bay, Panama City, Florida.[10,12] White shrimp showed definitly better recovery rate compared to brown and pink shrimp. White shrimp which are belonging to the genus Litopenaeus are considered to be most primitive species in penaeid shrimp. Their environmental and nutritional requirements are not so severe as compared to other species. Both American lobster and European lobster have been reared individually or communally at Sanriku.[11] There has been no remarkable difference of growth between both in the case of individual culture. Difference of growth was remarkable in the case of communal culture, especially in the case of both species mixing in the same tank. Although no observation has been done to compare behavior of both species, these facts strongly suggest that European species is not so active as American one.

Body size and timing for restocking are different between the three kinds of animals. Regardless of the specific difference, it seems to be the most efficient method to apply a nursery system in order to obtain better recovery rate as shown in penaeid shrimp in Panama City, Florida[8,10,12] and red sea bream in Oita Prefecture.[16] Although single netting enclosure is not always complete in the natural environment, a pen-nursery system will minimize the risk of escape through the netting and predation by fishes in the netting. The artificial tideland seemed to have more stable structure and function than the nursery system.[15] However, the elevation of the artificial tideland was higher than that of the natural one. Apparently it was exposed to wave and current action, and it was very often buried with drift sand. Good growth and survival rate have been showen for both postlarval peaneid shrimp and red sea bream in digged pond along the seashore.[10,14] Provided with abundant propagation of food organisms and eradication of predators, these digged pond connected with a nursery system will improve the recovery rate after release.

Introduction of lobster into Japan is a unique experiment in marine restocking. Basically there is no significant limiting factor for the distribution of lobster around Japan. Lobster restocking will contribute not only to establish a new fisheries resource in Japan but also to reveal exact data on growth, survival, dispersion, and recovery rate of lobster after the release. These information will be also useful for the restocking program of lobster in the Atlantic coasts. Although there is a concern with ecological impact due to predation on indigenous marine life and burrowing behaviour, the results of the experimental release at Koshiki Islands may suggest that scale factor will be important for successful restocking and that the ecological impact would be future and not serious problem. One advantage of lobster restocking is that management of the population is not difficult by traditional catch method although it is new for Japanese fishermen. Pioneer work carried at Koshiki Islands will promote restocking trial of lobster in various part of Japan .

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