山口県西部吉見湾の波止場における付着生物の調査 稚ナマコApposichopus japonicusの探索

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Assessment of attached organisms on a jetty in Yoshimi Bay, western Yamaguchi Prefecture, Japan − Search for juvenile sea cucumber *Apostichopus japonicus* (Stichopodidae)

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Abstract : In order to search for juvenile *Apostichopus japonicus*, the attached organisms were detached from every 30 cm depth of two steel sheet piles in the framework of a jetty in 3 m depth of water in a shallow harbor area in Yoshimi Bay. A total of 103 species of benthic animals were observed attached to the whole surface of the two steel sheets, and the most numerous 48 species of them were observed in the section of 60−90 cm below the top of the sheet. The total amount of attached organisms was largest in this section, where the oyster *Crassostrea gigas* was dominant. Two juveniles of *A. japonicus* of the green colored type were separately collected from the section of 210−240 cm and 240−270 cm, where the bivalve *Chama japonica* was dominant. They were very hidden in the attached organisms and were considered to belong to 1-year age group settled on the sheet piles.

Key words : Benthos, Distribution, Echinoderm fisheries, Ecology, Growth

Introduction

The Japanese sea cucumber *Apostichopus japonicus* (Selenka, 1867) is distributed widely throughout Japan from Hokkaido to Kagoshima.[1)] Although it is a commercially important species, information on its basic ecology is rare, and it is difficult to make an effective strategy for conservation and propagation of its resources. Especially, information on the population growth is required. However, in the investigation of the population growth and the distribution pattern, preliminary research on juvenile habitat requirements is essential. Recently, and the juvenile distribution on rocky shores has been partially clarified since there are some reports of juvenile habitats.[2,3)] On the other hand, in Japan there usually can be observed few or many individuals of adult *A. japonicus* on the sea bed and structures of artificial ports and harbors, where no information on juveniles has been reported. In the present study, to clarify whether the juvenile *A. japonicus* distributed or not on the structure of artificial ports, and to investigate the benthic biota of the habitat that may be important factors for the local distribution of juvenile *A. japonicus*, we conducted a survey by detaching the biota attached to steel sheet piles in a small harbor in Yoshimi Bay, western Yamaguchi Prefecture.

Materials and methods

Study site

Present study was carried out in the small harbor near the front gate of National Fisheries University in Nagata-Honmachi located at Yoshimi Bay, western Yamaguchi Prefecture (Fig. 1). There are many adult *Apostichopus japonicus* around the harbor, where sediment conditions are not rocky bottom but mainly sandy to soft muddy bottom, however that is considered not to be the preferred

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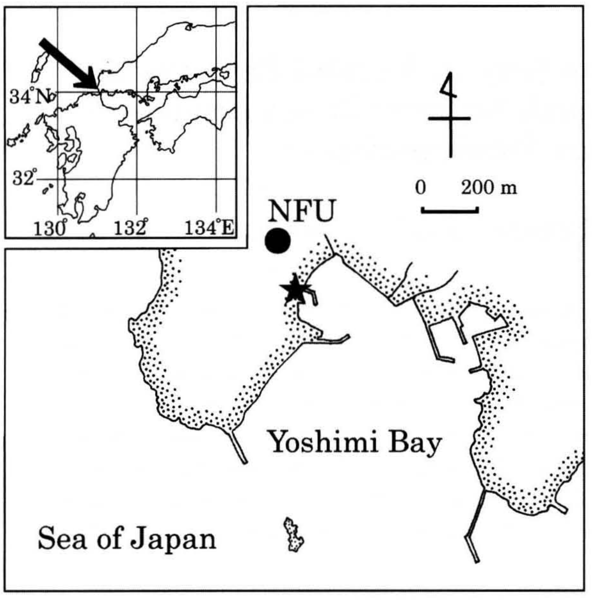

Fig. 1. Location of Yoshimi Bay. Star denotes the study site. NFU, National Fisheries University.

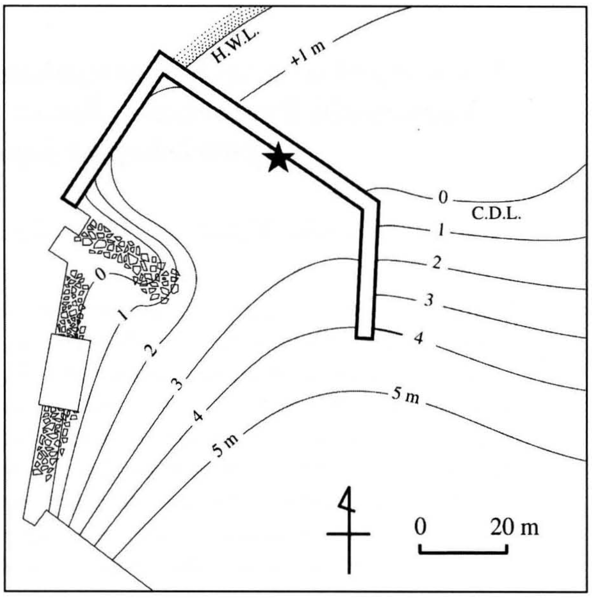

Fig. 2. Map showing the study site. Star denotes the position of sheet piles used for the detaching survey. H.W.L., the mean monthly-highest water level; C.D.L., the chart datum level.

habitat for juveniles.[3] The harbor has the distance round of approximately 230 m and the water depth 0−4 m under the chart datum level. It is composed of a quay excavated parallel to coastline and a jetty projected perpendicularly from the quay (Fig. 2), and constructed by double sheet pile quay wall in which the framework of steel sheet piles supports the concrete blocks (Fig. 3). In the quay, the concrete block is extends out over the water by about 40 cm from the steel sheet pile and forms an overhang, and the top of the framework is in about 0.5 m below the chart datum level. In the jetty, such a structure of overhang was not used, and the top of the framework is in about 1.0 m above the chart datum level (Fig. 3). In all year round, every steel sheet pile in either part are covered with common oyster *Crassostrea gigas* and other attached organisms, and seasonally covered with the annual kelp *Undaria pinnatifida* (Phaeophyceae) from January to June.

Methods

To search for juvenile *Apostichopus japonicus* and to investigate the benthic biota, the attached organisms were detached from the steel sheet pile in the framework by using SCUBA within five days from September 23 to 27, 2004. This period was selected as it is the aestivating season in which the dynamics of *A. japonicus* show minimal activity and the survey was considered not to significantly affect them. In the aestivating season, *A. japonicus* is at excessively low activity condition and stops eating with its digestive tract involuted,[4] then the effects of detaching a part of habitat in this season was seemingly low upon *A. japonicus* in the growth. We selected a site for detaching the biota in consideration of a site where waves action was minimal and the turbid water followed by detaching easily decreased, thus enabling the divers' work to be carried out more easily and safely (Fig. 2). At the present study site, the framework was designed so that its cross section may represents a waveform by combining the U-shaped steel sheet pile, therefore two adjacent sheets were chosen as the subject of the survey (Fig. 4). The detaching was carried out every 30 cm depth on the procedure that one surveyor detached the attached organisms by using stripping knife and the other one positioned below hold a filter bag with mesh size 1 mm and caught the falling organisms. In addition to this, we collected the surface sediment, which were approximately 5 cm in thickness and contained organisms, at the foot of the two sheets by using a dustpan and a filter bag with mesh size 1 mm. The collected organisms were sorted in the living condition or after being fixed in

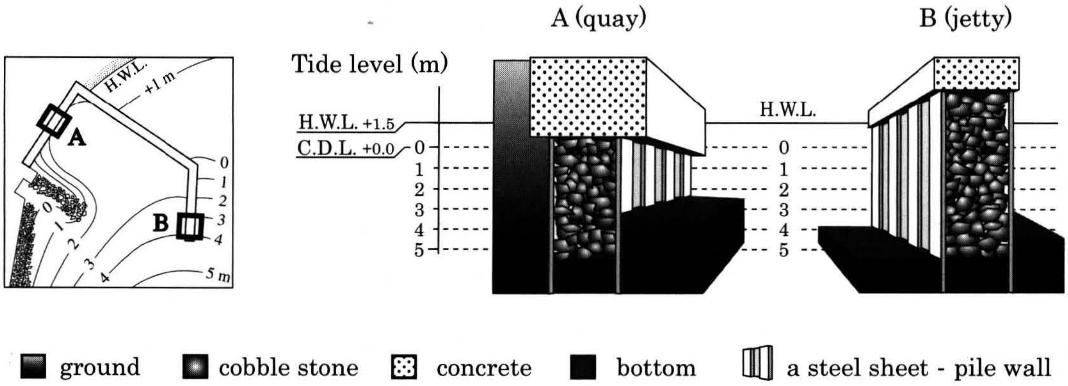

Fig. 3. Cross-section of A (quay) and B (jetty). H.W.L., the mean monthly-highest water level ; C.D.L., the chart datum level.

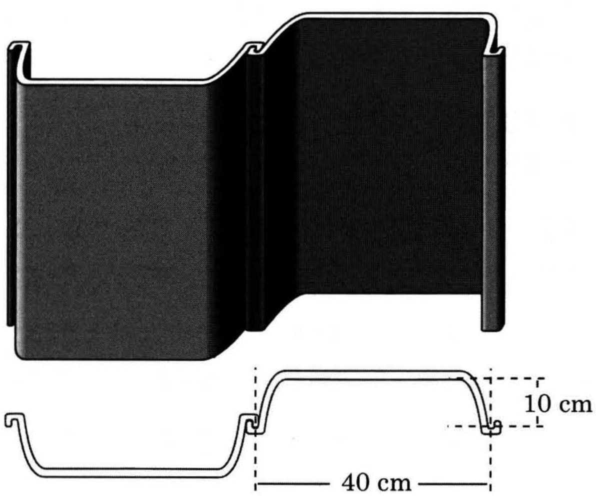

Fig. 4. Form and dimensions of the steel sheet-pile.

70% alcohol, and then all the species were counted by number and weighed the total wet weight. If *A. japonicus* was collected, the body size was calculated from measurement of simultaneous body length and breadth by using the formula of Yamana & Hamano,[5] and it was dissected after the fixing. The diversity index of the collected organisms in every water depth ranges were calculated as the Morisita modified Shannon-Wiener's H^*.[6] And the similarities in the species composition of the collected organisms in every water depth ranges were calculated as Pianka's α-index, that were applied for cluster analysis by using nearest neighbor method.

In the present study site for detaching, the tidal range was about 1.5 m, the water depth was about 2 m below the chart datum level, and the height of the steel sheet pile was just 3 m except for the foot buried in the ground. The sections of 0−30 cm, 30−60 cm, and 60−90 cm below the top of the pile were in the intertidal zone, and from 90−120 cm to the sediment were in subtidal zone. The area of two steel sheet piles was about $110 \times 300 = 33{,}000\ cm^2$, and the area of each 30 cm depth sections was about $3{,}300\ cm^2$.

Results

We observed 103 species sampled from the whole surface of the two sheets, and the most numerous 48 species of them were observed in the section of 60−90 cm below the top of the sheet (Table 1). On the other hand, we observed the least numerous 12 species in both the section of 0−30 cm and in the sediment. The diversity index of the collected organisms took the lowest value in the section of 0−30 cm ($H^* = 0.3$) and the highest value in the sediment ($H^* = 1.8$). The similarities in the species composition were calculated from the list of the collected organisms in every water depth ranges, and applied for cluster analysis. When the standard for judgment $\alpha = 0.7$ was chosen, the analysis shows that there were four groups in these sections (Table 1, Fig. 5); 0−60 cm where the barnacles were dominant, 60−90 cm where *Crassostrea gigas* was dominant, 90−300 cm where the bivalve *Chama japonica* was dominant, and the sediment. The total amount of attached organisms was largest in the section of 60−90 cm, where *C. gigas* was dominant, and reached 4,483 g (13,585 g/m^2) including the amount of dead shells of *C. gigas* etc. On the contrary in the section of 90−120 cm just below

Table 1 . The benthic biota of attached organism on the steel sheet-pile wall consisting the jetty

		Amount of attached organisms (g) on each section of the sheet pile from top to bottom (cm)																					
		0-30		30-60		60-90		90-120		120-150		150-180		180-210		210-240		240-270		270-300		Bottom	
Scientific name	Japanese name	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Gastropoda																							
Peasiella habei	KOBITOURAUZUGAI	204	0	107	0																		
Littorina brevicula	TAMAKIBIGAI	79	0.3	4	0	1	0																
Cellana nigrolineata	MATSUBAGAI	2	0.1	3	0	3	0.1																
Mitrella bicincta	MUGIGAI			6	0.1	141	15.4	56	6.6	21	1.8	13	1.4	13	1.2	1	0.1	1	0	8	0.9	5	0.7
Thaisiella (*Reishia*) *clavigera*	IBONISHI			4	0.4	10	13.5							1	0.9								
Patelloida pygmaea signata	SHIBORIGAI			1	0.5	1	0																
Batillaria cumingii	HOSOUMININA			1	0																		
Omphalius rusticus rusticus	KOSHIDAKAGANGARA					2	18.5																
Monodonta (*Monodonta*) *labio confusa*	ISHIDATAMIGAI					1	1																
Reticunassa japonica	KINUBORA					1	0																
Nipponacmaea schrenckii schrenckii	AOGAI							1	0														
Ergalatax contracta contracta	HIMEYOHRAKUGAI							1	1.8	4	5.7	6	3.9	6	2.9	18	19.1	14	15.5	12	13.5	1	1.6
Haloa (*Haloa*) *japonica*	BUDOHGAI											3	0									1	0.2
Proterato (*Sulcerato*) *callosa*	ZAKUROGAI											2	0	1	0	3	0.3			2	0.1		
Purpuradusta (*Purpuradusta*) *gracilis*	MEDAKARAGAI															1	1.7						
Litharium sp.	FUTASUJIKIRIORE-ZOKU sp.																	1	0	2	0.1	1	0
Diodora (*Diodora*) *sieboldii*	KUZUYAGAI																			1	0.7		
Bivalvia																							
Xenostrobus atratus	KUROGUCHIGAI	242	7.4	285	9.1	40	1.3																
Saccostrea kegaki	KEGAKI	48	46	322	270	288	225	2	2.8														
Crassostrea gigas	MAGAKI	30	273	136	1505	187	2129	72	638	40	220	14	46	6	116								
Irus (*Irus*) *mitis*	MATSUKAZEGAI			15	9.1	12	2.8			3	0.2					1	0						
Hormomya mutabilis	HIBARIGAIMODOKI			4	0	10	0.8	1	0.4														
Barbatia (*Abarbatia*) *decussata*	EGAI			3	0.8	8	27.7	14	72.9	4	24	6	28.2	2	11.9	4	13.7	3	7.3	2	3		
Septifer (*Mytilisepta*) *virgatus*	MURASAKIINKOGAI					37	39	6	1.3														
Mytilus galloprovincialis	MURASAKIIGAI					28	1.2	14	1.4	1	0	1	0										
Modiolus (*Modiolus*) *agripetus*	HIBARIGAI					5	2.8	15	22.1	5	26.9	18	46	6	13.8	8	27.5	1	0.3	2	4.4	2	1.9
Kellia porculus	KOHAKUNOTSUYUGAI					3	0.3									2	0.5						
Chama japonica	KIKUZARUGAI					1	2.1	1	4.2	7	108	16	157	18	92	19	242	20	129	21	146	1	4.2
Arca boucardi	KOBERUTOFUNEGAI							5	6.4			5	5.1	12	11	12	10	7	8.4	2	0.8		
Septifer (*Mytilisepta*) *keeni*	HIMEIGAI									10	28	16	27.7	13	22.4	5	6.6	1	1.3	2	1.2		
Musculus cupreus	TAMAEGAI									2	0.2	2	0.7			2	1.9	8	2.2				
Chlamys sp.	KAMIONISHIKI-ZOKU sp.									2	22.5			1	7.9	1	4			1	36		
Spondylus barbatus barbatus	UMIGIKUGAI													6	57	10	143	12	78	6	39	1	2.2
Dead shells			50		385		1850		994		746		680		762		393		292		273		
Nudibranchia																							
Halgerda japonica	NIKUIROUMIUSHI			1	2.0			2	0.9							1	0.2	1	0.2				
Phyllidia ocellata	IBOUMIUSHI							1	0.2							1	0.2						
Dendrodoris rubra nigromaculata	MADARAUMIUSHI									1	0	1	0.1			1	0.2						
Polyplacophora																							
Acanthopleura japonica	HIZARAGAI	2	5.0	21	148	9	28																
Acanthochitona sp.	KEHADAHIZARAGAI-ZOKU sp.			8	1.6	44	7.5	3	0														
Rhyssoplax kurodai	KUSAZURIGAI			1	0.6	8	1.8	11	0.9	2	0.2			5	0.3					2	0.5		
Cryptoplax japonica	KEMUSHIHIZARAGAI							1	0.1	1	0.1							1	0.1				
Mopalia (*Mopalia*) *retifera*	HIGEHIZARAGAI									6	0.2	1	0	2	0								
Acanthochitona achates	KOKEHADAHIZARAGAI											2	0.3	2	0	2	0.1	2	0.1				
Crustacea																							
Chthamalus challengeri	IWAFUJITSUBO	4624	73	1078	9.9	383	5.3																
Balanus albicostatus	SHIROSUJIFUJITSUBO	39	2.5	20	0.1	135	11																
Hemigrapsus penicillatus	KEFUSAISOGANI	17	0.5	268	39	443	11.1	63	1.3	10	0.2												
Balanus amphitrite	TATEJIMAFUJITSUBO	11	0.3	26	0.3	25	0.8	4	0.1														
Pinnotheres sinensis	OHSHIROPINNO	1	1.0	3	0.6	1	0																
Hyalidae sp.	MOKUZUYOKOEBI-KA sp.			7	0																		
Pagurus lanuginosus	KEASHIHONYADOKARI			1	0																		
Pagurus minutus	YUBINAGAHONYADOKARI			1	0	32	2.5	8	0.8					1	0.2								
Pagurus sp.	HONYADOKARI-ZOKU sp.					3	0.1																
Balanus trigonus	SANKAKUFUJITSUBO					28	0.8	275	51.6	71	14.5	26	6.2	32	2.4	3	0.5			1	0.4		
Leptodius exaratus	OHGIGANI					15	10.1	16	4.6			3	0.7			4	0.9	3	0.6	4	0.7		

Table 1 . Continued

Heptacarpus rectirostris	ASHINAGAMOEBI					14	1.2					1	0	1	0								
Alpheus sp.	TEPPOHEBI-ZOKU sp.					6	0.5	29	3.4	10	0.8	6	0.5	11	1	3	0.4	2	0.2	2	0.1	1	1.8
Paguristes ortmanni	KEBUKAHIMEYOKOBASAMI					1	0.4	2	0.5	1	0.3	4	10.4			2	0.2						
Pugettia quadridens quadridens	YOTSUHAMOGANI					1	1.5			3	0.4	3	0.3	4	0.2	4	0.3	1	0.2	1	0.1		
Charybdis japonica	ISHIGANI					1	1.5					4	0.4	4	0.2	4	0.3	6	1.8	6	1.2		
Pilodius nigrocrinitus	TOGEOHGIGANI							13	0.3	8	1.2	11	0.4	19	0.9	9	0.3	4	0.2	6	0.4		
Athanas japonicus	SEJIROMURASAKIEBI							2	0	1	0												
Petrolisthes japonicus	ISOKANIDAMASHI									5	0.1									1	0		
Paguristes sp.	HIMEYOKOBASAMI-ZOKU sp.									3	1.4												
Actaea semblatae	SAMEHADAOHGIGANI									1	2.5					1	1						
Abludomelita japonica	-											3	0.2										
Paratymolus pubescens	MAMETSUBUGANI															2	0						
Pilumnus sp.	KEBUKAGANI-ZOKU sp.															1	0						
Menaethius monoceros	IKKAKUGANI															1	0	1	0				
Munida sp.	CHUKOSHIORIEBI-ZOKU sp.																			1	0		
Anthozoa																							
Anthopleura fuscoviridis	MIDORIISOGINCHAKU			2	0	3	0.2																
Ascidiacea																							
Styela plicata	SHIROBOYA			1	0	3	1.2			2	2.5	11	23.2	21	20.8	21	26						
Pyura vittata	KARASUBOYA							22	24.7	10	15	3	20.1	1	3.5	6	22	11	15.1	3	13.7	2	13.4
Halocynthia hispida	IGABOYA													3	10	4	9						
Aplidium pliciferum	MANJUBOYA													2	2	3	3.4	1	2.3				
Polychaeta																							
Lepidonotus sp.	-			22	0.7	35	1.1	9	0.3	6	0.2	2	0.2	3	0.2	1	0	2	0.2	5	0.2		
Pomatoleios kraussii	YAKKOKANZASHIGOKAI			15	0.2	627	7.8	6	0.1														
Eulalia sp.	-			6	0.3	4	0.1																
Perinereis sp. (1)	-			4	0.2	47	2.1	7	0.4	15	0.5	7	0.5	2	0.1	1	0	1	0	2	0.1		
Perinereis sp. (2)	-							10	0.8														
Tharyx sp.	-			4	0.4	5	0.2	4	0.2					1	0.1								
Genetyllis sp. (1)	-					1	0																
Genetyllis sp. (2)	-							3	0.2					1	0								
Lysidice collaris	SHIBORIISOME					1	0			6	0.2	1	0	2	0.2	1	0.1	1	0.1				
Halosydna sp.	-							2	0											1	0		
Cirriformia sp.	-									2	0.3	1	0.1									3	0.4
Neanthes sp.	GOKAI-ZOKU sp.													2	0.1	1	0	6	0.6				
Marphysa sanguinea	IWAMUSHI													2	0.4					2	0.8		
Serpula vermicularis	HITOEKANZASHIGOKAI																	3	0.2	3	1.1		
Hypsicomus sp.	-																	1	0.1				
Paralepidonotus ampulliferus	KOBUTSUKIUROKOMUSHI																					1	0.2
Gnathostomata																							
Tridentiger trigonocephalus	AKAOBISHIMAHAZE			1	1.7																		
Eviota abax	ISOHAZE					1	0.2					2	0.3										
Sipunculoidea																							
Golfingia margaritacea ikedai	IKEDAHOSHIMUSHI					1	0	9	0.6														
Phascolosoma scolops	SAMEHADAHOSHIMUSHI							6	0.3	9	0.3	15	0.7	20	0.8	16	0.8	9	0.3	7	0.3		
Demospongiea																							
Halichondria sp.	-						55.8		8.3														
Echinoidea																							
Temnopleurus toreumaticus	SANSHOUUNI							1	21											1	0.4		
Anopla																							
Unknown	UNKNOWN							2	0														
Florideophycea																							
Bossiella cretacea	ISOKIRI										3.4		2.5		5.5		5.8		1.1		5.5		
Ophiuroidea																							
Ophiothrix (*Ophiothrix*) *exigua*	NAGATOGEKUMOHITODE									3	0.2	4	0.7			6	1.3	14	1.1	8	0.9		
Amphiura vadicola	UDENAGAMEGANEKUMOHITODE																					2	3.7
Holothuroidea																							
Eupentacta chronhjelmi	ISHIKO											1	0.2										
Apostichopus japonicus	MANAMAKO															1	3.7	1	3.5				
Stolus sacellus	FUKURONAMAKO																			1	6.7		
Brachiopoda																							
Hemithyris sp.	-													1	1	1	0.9	1	3.9				
	Total	12	459	33	2386	47	4483	38	1874	33	1228	34	1064	35	1149	41	941	31	566	31	552	12	30.3

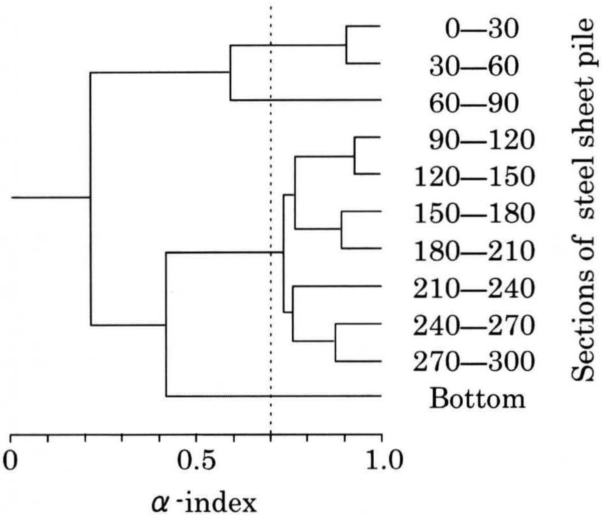

Fig. 5 . Dendrogram illustrating this similarity of biotic environment from the 11 sections of steel sheet-pile wall from top to bottom, using nearest neighbor method and Pianka's α-index. Each section is divided into an equal height of 30 cm.

this, where *C. japonica* was dominant, the amount was only 1,874 g (5,679 g/m^2) and it was less than half of that amount. Furthermore, in the section of 90−120 cm, there was a difference in the thickness of the attached organisms to approximately 10 cm thickness, as the masses of *C. gigas* were decreased sharply at the boundary of the low tide line.

In this research, two *Apostichopus japonicus* of the green colored type were separately collected from the section of 210−240 cm and 240−270 cm. Their appearance was very similar, and both were measured as 54 mm and in the state of aestivating accompanied by the involution of their alimentary canals. When these individuals were sampled, they were very hidden in among the attached organisms (including many dead shells of *C. gigas etc.*), and then they were unexpectedly discovered during the sorting of organisms.

Discussion

Through the detaching survey, it was revealed that the benthic environment in the present study site changed in roughly four classes with the depth of water (Fig. 5). From the literatures, almost all the literatures in the studies of the habitats of *Apostichopus japonicus*, although they were very few, mentioned to the closely relation between the biotic environment and the density of sea cucumbers, and also noted the commonness of the attached positions among the individuals in these habitats, specifically among the juveniles.[2,3,7,8] When the information from these reports are put together, in the most cases juvenile individuals were found around the rhizoid of *Sargassum* species, under stones, and in cracks in rocks, and therefore it could be considered that the attachment positions of juvenile *A. japonicus* are affected by the substrate type, surface structure, and inclination, etc. In the present study site, the steel sheet pile was originally smooth over the whole surface structure, and the stratification of the attached organisms added the obvious change in structural differentiation to this structure. Furthermore, the amount of attached organisms suddenly decreased below the chart datum level, and it formed the difference in thickness of the attached organisms as large as approximately 10 cm thickness. Considering the body size of *A. japonicus*, the change was not simply in the surface structural scale. It is quite possible that such a change in the biotic and abiotic environment have some sort of effects upon the distribution of the sea cucumber in the present study site.

There, two individuals of the green colored type *A. japonicus* were collected. Both were measured as 54 mm and they were in the state of aestivating. These individuals are considered to be more than 1-year old, because this species dose not aestivate in 0-year.[4] In the study of population dynamics of juveniles *A. japonicus* in the Seto Inland Sea of eastern Yamaguchi Prefecture near the present study site,[8] the mode of 1-year age group was about 60 mm at the same season to the aestivating of present study. The present individuals were slightly smaller than this, and it seems to be the most probable that the two individuals belong to the 1-year age group. Considering the origin of these juveniles, the sediment condition of the harbor is not preferred as a juvenile distribution,[3] furthermore, there is a distance of about 80 m along the walls between the present study site and the nearest rocky shore, and it can be considered that these low-mobility juveniles are unlikely to have migrated this 80 m distance. It is therefore most probable that the present juveniles recruited onto the sheet piles as planktonic larvae.

Searching for small individuals was very difficult at the present study site because of the enormous amount of the attached organisms on the surface of the structure. Hamano *et al.*[9] reported that they could not collect all juvenile *A. japonicus* under 30 mm experimentally released in an intertidal tide pool, and presumed that the visible body size to reliably survey sea cucumbers would be even larger in subtidal diving due to greater restrictions related to working in the subtidal zone, as well as the greater abundance of attached organisms. In addition to such a difficulty, the green colored type of this species has the property that their body color is difficult to observe as it allows a degree of camouflage. It is difficult to research the juvenile *A. japonicus* in an enormous amount of attached organisms in artificial structure by using a diving survey, and it is advisable to conduct survey in intertidal habitats rich in juveniles such as the habitat in rocky shores reported by Yamana *et al.*[3]

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山口県西部吉見湾の波止場における付着生物の調査
ー稚ナマコ*Apostichopus japonicus*の探索

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稚ナマコ*Apostichopus japonicus*を探索するために，吉見湾の突堤の矢板上より，付着生物の剝ぎ取り調査を水深帯30 cm間隔でおこなった。矢板２枚分の付着生物より103種が見出され，水深帯別に最も種数が多かったのは矢板頂端から60－90 cmで48種が見出された。この水深帯ではマガキ*Crassostrea gigas*が優先し，付着生物の総重量もこの水深帯で最も多くなった。本調査の結果，２個体の青色型の稚ナマコが，それぞれ矢板頂端から210－240 cmと240－270 cmの水深帯より採集された。これらの水深帯では，キクザルガイ*Chama japonica*が優先し，稚ナマコは付着生物の隙間に非常に良く潜んでいた。これらの稚ナマコはいずれも，矢板上に着底し生残した１歳群に属すると考えられた。