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Natural Substrata of Marine Fouling Animals

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(With 3 Text-figures and 2 Tables)

海産付着動物の自然基盤について

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海中の人造基盤上に出現しおびただしく繁殖する付着動物については すでに多くの報告があるが，それらの自然環境下の分布・生態に関してはほとんど何も知られていない。ここでは油壺湾周辺の海下の種々の自然基盤，すなわち海藻，海草，岩盤，転石，砂底などにおける付着動物の分布が，人造基盤特にプラスチックス製の人工海藻上の動物相と比較して調べられた結果について論じられた。

黒色のポリエチレンフィルムから成る人工海藻の表面には，いわゆる汚損付着動物として知られたほとんどすべてのものが付着した。その動物相は幼生の付着量の季節的な変動にしたがって変化し，フジツボ類，カンザシゴカイ類そしてコケムシ類の一部のものは季節的な消長が著しかったがその他のものは個体数あるいは群体数が周年，比較的一定な水準に保たれた。後者のグループでは繁殖がほぼ一年中行なわれて幼生が絶えず付着し続けるためであったことが，イタボヤの例からも明らかであった。

天然の海藻あるいはアマモのような 海草の葉体の上にも人工海藻上のものと同じ種の動物が見られたが，その種数も個体数も限られていた。ただし，ウズマキゴカイだけは多量に付着しておりしかも葉体上で繁殖を続けることができた。これはこの動物の繁殖周期が短かったため葉体の寿命の間に成熟することができたことによるものであろう。岩盤や転石などの表面では，外部に向かって露出し，容易に魚などによって摂食されるような場所には付着動物は少なく，岩の割れ目や転石の積み重ねられた下向面などにだけ限られていた。また砂底に分布していたシロボヤとカイメンの一種は人工基盤上の付着動物群集の中に多数の個体や群体が出現した。

人工基盤上の付着動物は一般に低潮線以深の陰影部となった基盤の動物相の中から 選び出されたもので，特に成長が早く繁殖力の旺盛な種が，付着後の摂食や激しい成長の競争に耐えて生残ることが条件となっているように思われた。したがって，自然環境下では適当な基盤の分布が限定されていて付着動物の多くのものは目立った存在ではないにもかかわらず，人工基盤上には良く適応しおびただしい数量にのぼる群集を形成するのが見られた。またその動物相の構成も自然基盤上のものとは大きく異なっており，その差異の生じた原因や過程を解析するのが付着動物群集についての理解を深めるのに良い方法であると思われた。

Introduction

The phenomenon of marine fouling by various invertebrates on the surfaces of objects submerged in the sea happens as a matter of course because there are so many sessile animal-forms that settle on the natural underwater objects. The biological aspects of this problem have been studied extensively, especially in cases of fouling of ships-bottoms and light-buoys (See Anon. 1952 for the review). The problem is important also in the salt-water cultivation of edible oysters, pearl oysters and other organisms which are economically important in Japan. These suffer a great deal from the overgrowth of fouling animals settling not only on the surface of the shells but also on the rafts, buoys, cages, anchor ropes or chains and other materials submerged in the sea for cultivation. It is said that the cleaning of shells and cages is one of the most laborious works in pearl oyster cultivation.

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Many authors have dealt with this matter from the fisheries or biological point of view (MIYAZAKI 1938, TANITA and KIKUCHI 1953, MAWATARI and KOBAYASHI 1954, KAWAHARA 1961 and KAZIHARA 1964). Their observations are limited to the fouling animals appearing on cultivating farms or the artificially settled substrata such as test-collectors for oyster-spats. Ecological observations of marine fouling animals in their natural habitat are lacking in spite of many works on the phenomena of artificial substrata or on the natural sedentary communities on rocky substrata.

The field of cultivation of marine organisms is restricted to shallow and less exposed waters such as coves or sheltered bays. In such places sessile animals are abundant and most of them are, like oysters, filter-feeders. There are so many kinds of organisms in the fouling communities that a complete list of fauna and flora in such communities cannot be compiled.

It is noteworthy that only a few species of animals in the fouling communities are large enoughor abundant enough to be a nuisance in salt-water cultivation. There are some differences in the composition of fouling communities according to the localities or to the degree of "exposure" to use a term suggested by MUUS (1968). But the most conspicuous fouling animals are limited to the following groups; sponges, hydrozoans, bryozoans, serpulid annelids, bivalved molluscs, barnacles and ascidians. The most important fouling animals in Aburatsubo-Moroiso Inlet, near Misaki Marine Biological Station, are listed in Table 1. Their occurrences on the artificial and natural substrata are discussed in the present paper.

Table 1. Common fouling animals in Aburatsubo-Moroiso Inlet.

Porifera	Halichondria japonica
	Grantia sp.
Coelenterata	
Hydrozoa	Obelia spp.
	Clytia spp.
Actiniaria	Haliplannella luciae
Bryozoa	Bugula neritina
	Tricellaria occidentalis
	Zoobotryon pellucidum
	Dakaria subovoidea
	Shizoporella sp.
	Microporella orientalis
	Celleporina costazii
	Mucropetraliella watersi
	Membranipora sp.
Mollusca	
Pelecypoda	Mytilus edulis
Annelida	
Polychaeta	Hydroides norvegica
	Dexiospira foraminosus
Arthropoda	
Cirripedia	Balanus trigonus
	Balanus amphitrite hawaiiensis
	Balanus amphitrite albicostatus
Chordata	
Urochordata	Leptoclinum mitsukurii
	Botrylloides violaceus
	Ciona intestinalis
	Styela plicata

Observations

1. Fouling animals on eel-grass and algae in comparison with those on artificial seaweed.

1–1. Fouling animals on the eel-grass, *Zostera marina*.

Aburatuso-Moroiso Inlet opens westward into Sagami Bay and has two coves each about one half kilo-meter long. The prevailing coast is rocky and there are very few sandy beaches in the inlet. The rocky coastal slope falls rapidly and is soon replaced by sandy or muddy bottom. The deepest part of the inlet is located where the two coves, Aburatsbo and Moroiso, join together and the depth varies between 5.5 and 7.0 meters according to the tidal rhythm.

The distribution of a bed of eel-grass, *Zostera marina*, was determined from the observations from boat through the clear water which prevails there in autumn and winter. Several bundles of eel-grass were collected at twelve sites in the shallow zones in the inlet in August, 1965 (Fig. 1). The Leaves of *Zostera* were about one centimeter in width and one or one and a half meters long. One bundle of the eel-grass had several fully-grown leaves that gathered not only fouling animals but coraline algae and other small seaweeds on their surfaces. Old leaves were reddish in color due to the tints of these algae. It was not clear how fast the leaves grow or how long each of them remained attached to the rhizomes. However, it was assumed that the period of one cycle of leaf-turnover, i. e. the longivity of a leaf, might be about several weeks in summer because a tubeworm, *Dexiospira* (=*Spirorbis*) *foraminosus*, could grow to the adult state on a leaf of the eel-grass. Old leaves were easily detached from the rhizomes and decomposed after drifting and dropping to the bottom.

The flower of the eel-grass develops in early summer. The eel-grass beds expand in spring and

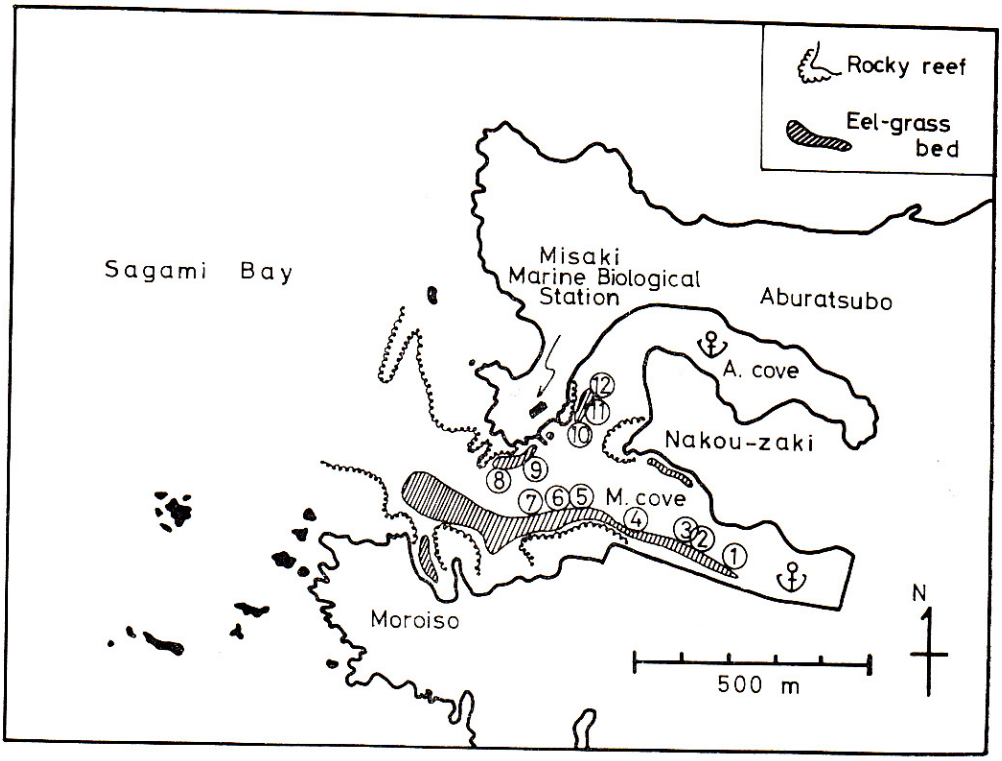

Fig. 1. Aburatsubo-Moroiso Inlet.

decrease in summer after flowering. The fouling communities on the eel-grass might change seasonally in their abundance and composition. However, fouling animals thrive mostly in summer and the results of this observation was thought to represent the fouling characteristics on the leaves of the eel-grass.

The tubeworm, *Dexiospira foraminosus*, was dominant on the leaves of the eel-grass but the other common fouling tubeworm, *Hydroides norvegica*, many kinds of bryozoans and two common fouling compound ascidians, *Leptoclinum* (=*Diplosoma*) *mitsukurii* and *Botrylloides violaceus*, also appeared. Barnacles were very rare on the leaves. The solitary ascidians, bivalved molluscs, hydrozoans and sponges were not found in the samples. The densities of these animals varied markedly among the twelve sampling sites. That of *Dexiospira* was very high at the middle parts of the eel-grass beds, both on the northern and southern coasts. The bushy bryozoans, *Bugula neritina* and *Tricellaria occidentalis*, occured only in the beds of the southern coast. The above results are summarized in Table 2.

Table 2. Fouling animals on the leaves of the eel-grass.

SPECIES \ STATIONS	1	2	3	4	5	6	7	8	9	10	11	12
Dexiospira foraminosus	R	R	+	C	CC	+	+	+	+	C	+	R
Hydroides norvegica	RR		RR	RR		R				RR	RR	RR
Microporella orientalis	R	R	+		R	R	RR	C	+	R	R	R
Mucropetraliella watersi	+	R	+	+	R	R	RR			R	R	R
Celleporina costazii			+				RR	R		R		R
Dakaria subovoidea												RR
Schizoporella sp.	RR											
Bugula neritina	+	R	+	+	+	R						
Tricellaria occidentalis	+		C	C	C	C	C					
Leptoclinum mitsukurii	RR		R	R		RR	RR			R	R	R
Botrylloides violaceus								RR		RR	RR	
Balanus amphitrite								RR			RR	

CC: very common
C: common
+: present
R: rare
RR: very rare

1–2. Fouling animals on algae.

The fronds of algae are generally poor substrata for the marine fouling animals. Only a few larger brown algae, i.e. laminarians and sargassums, can be the substrata for sedentary animals. The small hydrozoans *Obelia* and *Clytia* frequently appeared on the edges of the fronds of laminarians. They are a nuisance in the cultivation of the edible laminarian, *Undaria pinnatifida*. Several kinds of bryozoans encrust on the fronds and stipes of laminarians. Large thin colonies of a bryozoan, *Membranipora sp.*, are common on two dominant laminarians, *Eisenia bicyclis* and *Ecklonia cava*, in the waters adjacent to the Aburatsubo-Moroiso Inlet. The gall-shaped bryozoan, *Celleporina costazii*, is abundant on a laminarian, *Eckloniopsis sp.*, which thrives along the inner rocky shores in the inlet.

The tubeworm *Dexiospira* was aboundant on the fronds of laminarians and sargassums as on the eel-grass. Most of the common fouling animals appeared on these algae, especially on the stipes and rhizoids. Encrusting animals such as bryozoans and compound ascidians were found frequently not only on the fronds of laminarians but also on those of sargassums, *Sargassum serratifolium* and *S. ringgoldianum*. However, the fronds of sargassums are short-lived and become detached from the rocky substrata in summer. There seems to be no persistent substrata for the fouling animals to reproduce on.

1–3. Seasonal changes in the fouling animal communities on artificial seaweed.

An artificial seaweed was devised for the purpose of making shelters in the artificial reefs. This was made of a plastic, polyethelene, imitating laminarians in its shape; sixteen sheets of black film (15 cm wide, 1.5 m long and 0.05 mm thick) were attached to six arms of a float (500 grams in buoyancy). It resembled very closely a large laminarian in the sea because the specific gravity of the material was a little less than unity (=0.95). But the fouling animals increased the weight of the film and its leaves drooped after a short period.

The artificial seaweed was submerged at the depth of between two and four meters on the anchor chain of a test-raft settled at the place where the two coves meet in the Aburatsubo-Moroiso Inlet. One of the sixteen leaves of the artificial seaweed was cut at interval of three or four weeks soon after the submersion in August 3, 1964. Then the intervals were changed to about six weeks and the sampling continued until August, 1965. One more series of the artificial seaweed was submerged in September 19, 1964 and the films were cut one by one at the same intervals of the first series. The plastic films were collected in the sea by diving and they were fixed in formalin immediately after collection.

The fauna and flora on the artificial seaweed were rich and complicated but only those fouling animals that adhered firmly to the films were counted in this study. The results of these observations are shown in Fig. 2. Occasional species were excluded from the figure. The counting of numbers of individuals or colonies of the fouling animals was limited to those visible to the naked eye. The numbers were calculated in the densities per square meter and then the exponent (base=10) of the numbers of density were plotted in the figure. The enormous fluctuations of the population densities of fouling animals seem to be reduced in the figure by these procedures. But the changes in the number of exponent showed the patterns of succession of fouling animals very well in the figure, being comparable between different species at the same time. The exponent of zero means one as the number of the density, but the density was calculated from about a half square meter (multiplied about double) and there were no numbers of one per square meter in the data. In short, the number of zero in the figure means absence of the animals in the samples.

The latter series showed the same patterns of succession as the former except for a bryozoan, *Zoobotryon pellucidum*, and the barnacles. It was apparent that these animals recuced their reproductive activities distinctly during the six weeks between the two series of submersions of the artificial seaweeds.

The film was not a stable substratum for animals with calcareous shells or tubes. Serpulids and barnacles were easily detached from the surface of the artificial seaweed and their number decreased rapidly after they stopped reproducing in the seasons of lower water temperature. However, most bryozoans and ascidians showed rather constant population densities on the substratum. They

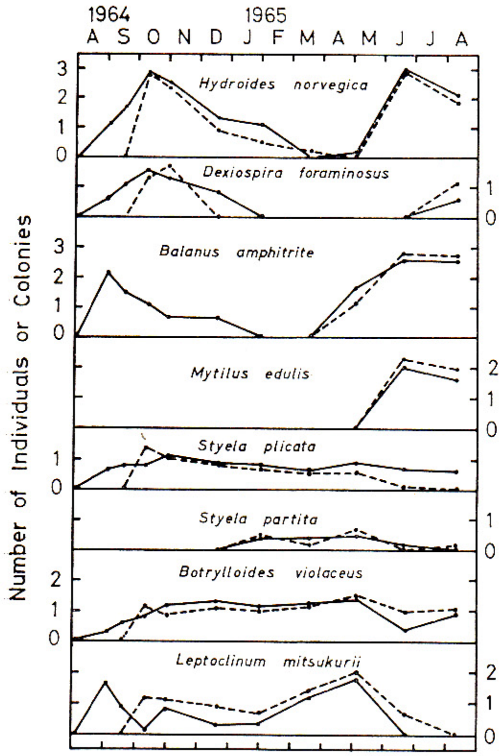

Fig. 2a. Succession of fouling animals on the artificial seaweed.

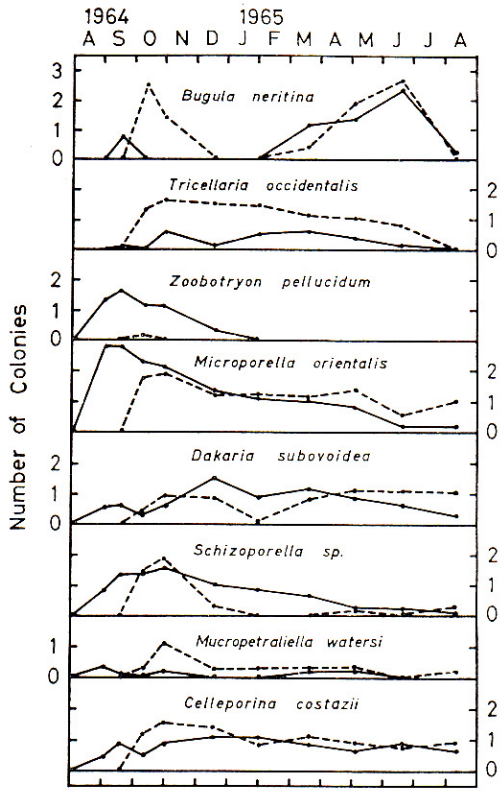

Fig. 2b. Succession of fouling animals on the artificial seaweed.

Number of individuals or colonies was plotted as the exponent (base=10) of population densities per sq. meter.

seemed to be mostly continuous breeders because the younger forms appeared in every sample. For example, the size distribution of a compound ascidian, *Botrylloides violaceus*, is shown in Fig. 3. This animal increased its numbers of zooids asexually by budding. Its colony grows exponentially in its area, expanding on the flat surfaces (Yamaguchi in press). Then the area of the colonies in the figure three was divided in the intervals of multiple sizes for the purpose of showing the grades of age groups. The youngest group of this ascidian was the chief component of these populations in most samples.

The patterns of the succession of fouling animals on the artificial seaweed seemed to represent their patterns of seasonal reproduction. They grow very rapidly and their reproductive cycles were thought to be very short. Some of these bryozoans were studied by Mawatari (1951a, 1951b and 1952) in central Japan and their reproductive cycles were observed to be one or two months in summer. The breeding of the individual colonies of these bryozoans continued for several months after they were sexually mature. Therefore, they could reproduce several overlapped generations in a year during the warmer seasons. The growth rate of a barnacle, *Balanus amphitrite hawaiiensis*, was determined by Hirano and Okushi (1952) at the same site as the present study. The acorn barnacle also reached sexual maturity in a month in summer.

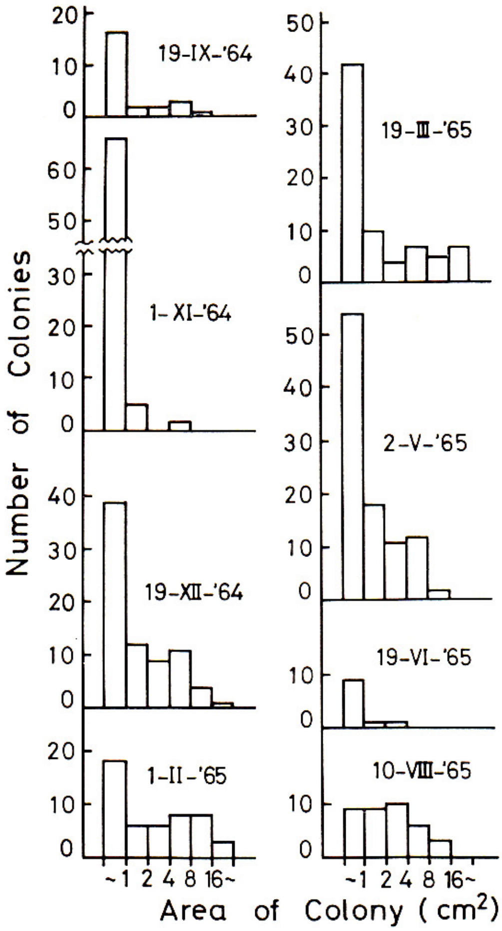

Fig. 3. Size distribution of *Botrylloides violaceus* on artificial seaweed. The youngest group was dominant all year around.

1–4. Fouling animals on the eel-grass and algae in comparison with those on the artificial seaweed.

The fauna on the artificial seaweed was typical of marine fouling animals. They covered the whole submerged surface of the black plastic film which simulated as the fronds of the large algae. The artificial seaweed were covered by the overgrowth of fouling animals while the fronds of some of the true seaweeds were only partly covered with these animals while the fouling animals themselves seemed to be little different from those on artificial substrata. Some of the natural seaweeds such as laminarians make good substrata for the animals because their fronds live long enough for the animals to grow and reproduce on them. However, the fouling animals on the fronds of laminarians were considerably limited.

The reason why marine algae collect fewer fouling animals on their surfaces may be that they generally excrete mucous substances and also that they are very flexible. It is known that sargassums excrete tannin and that this substance repels, the larvae of fouling animals (SIEBURTH and CONOVER 1965). It is true that some sedentary animals are closely associated with certain algae (RYLAND 1962 and NISHIHIRA 1965), and this is explained by chemical stimulants secreted by algae to promote the settlement of larvae (CRISP and WILLIAMS 1960 and GEE 1965). However, most fouling animals can not expect to find a stable habitat on natural seaweeds.

Leaves of the eel-grass, *Zostera*, were colonized by fouling animals as they grew older. But their longivity was rather short and only a few animals such as a tubeworm, *Dexiospira*, could reproduce on the substratum. A solitary ascidian, *Ciona intestinalis*, a social ascidian, *Clavelina lepadiformis*, and a compound ascidian, *Botrylloides leachi*, were common on the leaves of *Zostera* on the west coast of Norway (DYBERN 1969). However, ascidians were scarce on the leaves of *Zostera* in Aburatsubo-Moroiso Inlet. The compound ascidians appeared there occasionally, but never *Ciona*.

Larvae of *Ciona* were common in plankton and they settled on the glass surfaces of test collectors submerged in Aburatsubo-Moroiso Inlet. They were thought to attach to the eel-grass there. However, they might have been eaten by fishes such as *Rudarius ercodes* or by shrimps, *Heptacarps* and others, which inhabit the eel-grass bed. These animals were observed feeding on young ascidians in the laboratory. Therefore, *Ciona* could not survive on the eel-grass to grow to a visible form. Thus the fauna on the eel-grass is limited by predation as well as by the short longivity of the leaves.

2. **Fouling animals on the hard bottoms.**

2–1. Under stones.

There are overlapping round stones from ten to forty centimeters indiameter just beneath the low water level on the rocky slopes at some parts in Aburatsubo-Moroiso Inlet. They are covered with muddy detritus on the upper surfaces and are colonized by green algae in the season of lower water temperature. However, rich animal communities are found throughout the year under these stones.

Most fouling animals common on the artificial substrata were recognized in these fauna but many other sedentary animals were also found. The communities under the stones were dominated by the encrusting forms of bryozoans and compound ascidians. Some stones were completely covered on their undersurfaces by a compound ascidian, *Leptoclinum mitsukurii*. Another common fouling compound ascidian, *Botrylloides violaceus*, occurred very commonly, but the number of colonies decreased in early summer as the result of predation by a freeliving flatworm, *Cycloporus japonicus*. The flatworm sucks the body fluid of the ascidian by attaching to the common test of the host. Its breeding seemed to be very active in summer, producing vast numbers of larvae hatched in the sea from the egg-masses layed under stones.

Solitary ascidians, *Ciona intestinalis, Ascidia zara, Pyura mirabilis* and *Styela partita*, were common among the sedentary animals in this habitat. The most conspicuous fouling ascidian on artificial substrata in the inlet was *Styela plicata* but it rarely occurred under stones.

Encrusting bryozoans, *Microporella orientalis, Dakaria subovoidea, Shizoporella sp., Mucropetraliella watersi* and *Celleporina costazii*, were common under the stones. On the contrary, bushy colonies of *Bugula neritina, Tricellaria occidentalis* and *Zoobotryon pellucidum* were scarce in this habitat. They appeared occasionally on the side surfaces of the stones.

Sponges, dwarf hydrozoans, acorn barnacles and serpulid polychaetes were the major sedentary animals in addition to the bryozoans and ascidians mentioned above. The fouling tubeworms *Dexiospira foraminosus* and *Hydroides norvegica* were very common among them.

2–2. Overhanging rock walls.

Diving observations were carried out directly by the author frequently at every spot in the inlet. Overhanging rock walls usually had the richest fauna of sedentary animals as was mentioned by FORSTER (1958). The faunas of this habitat varied according to the location probably because of the degree of "exposure". Overhanging rock walls were usually densely covered by a bryozoan, *Dakaria subovoidea* (=*Watersipora cucullata*), at the most sheltered sites. Some oysters (not identified) and a solitary ascidian, *Pyura vitata*, were found associating there, but the so-called "fouling animals" which are common on artificial substrata were found only rarely on the rock walls with the exception of the bryozoan, *Dakaria*. A beautiful soft coral, *Bellonella sp.*, was found colonizing the overhanging rock wall at the point of Nakou-zaki where the two coves branch off. Gorgonians also appeared at the mouth of the inlet.

Rock crevices may be important habitats of fouling animals, but they were very hard to study by underwater observations. A horned turban shell, *Turbo cornutus*, was common in the crevices of shallow rock walls around the inlet. The serpulid worm, *Hydroides*, and acron barnacles, usually gathered densely on the surface of the shells of this species.

2–3. Mussel and oyster beds.

The mussel, *Mytilus edulis*, is a famous fouling animal of pipes and ducts for cooling water in maritime power stations. It also appears abundantly in oyster farms. It is one of the most important fouling animals in an economical sense.

On artificial seaweed, the spats of this mussel settled densely in spring and grew very rapidly in summer, at the same time decreasing in number. The primary settlement of *Mytilus* larvae in Aburatsubo-Moroiso Inlet was observed on the colonies of bushy bryozoans, such as *Bugula* and *Tricellaria*. The spats of *Mytilus* were observed to move from these bryozoan colonies just as they did in the observations by BAYNE (1964) at Menai Straits, North Wales, from the filamentous algae on which they settled primarily. This was a dominant animal along with the acorn barnacles, *Balanus tintinnabulum* and *B. trigonus*, on the buoys of set-nets at the outer part of the inlet. However, the mussel-beds of this species were very limited in number and size. Only two small communities of the mussel were found on the rock wall beside small islands outside of the inlet by the author during his diving observations from 1965 to 1969. Numbers of a starfish, *Coscinasterias acutispina*, were feeding on these mussels just as *Asterias amurensis* does on the mussel beds in Tokyo Bay. The *O. acutispina* usually occurs under stones in the tidal zones and rarely comes out in zones which the mussel has colonized below the low water level and on the open surface of rocky substrata. *A. amurensis* does not occur in the neighborhood of the inlet and its ecological niche is occupied by *O. acutispina*. A settlement of young *Asterias amurensis* was observed in the inlet in spring. Young starfishes were abundant everywhere until summer but they disappeared from the inlet as the water temperature became higher. Larvae of *Asterias* were transported from Tokyo Bay but they could not survive in Aburatsubo-Moroiso Inlet. The planktonic larvae of the mussel also seemed to be carried from Tokyo Bay where a vast population is established on the coast. Both species, *Asterias* and *Mytilus*, are animals that occur in northern districts. They breed in winter in central Japan. It was interesting to see that these animals could survive and colonize successfully in Tokyo Bay where the temperature falls greatly in winter while they survived poorly in Aburatsubo-Moroiso Inlet where the water temperature is kept higher by the effect of the Kuroshio Current.

An oyster, *Saxostrea echinata*, formed a bed on the rock in the lower tidal zone in the inlet. However, it was not a component of fouling animal communities.

2–4. Intertidal fauna on the rocky coast.

The surface of the rocky coast in the inlet was covered mostly by small acorn barnacles, *Chthamalus challengeri*. Another larger acorn barnacle, *Tetraclita squamosa japonica*, and a goose-barnacle, *Mitella mitella*, were associated on rock exposed to the outer bay. On the other hand, a tubeworm, *Pomatoleios kraussii*, and a solitary ascidian, *Pyura michaelseni*, appeared on the overhanging rock wall of the lower intertidal zone in more sheltered parts of the inlet. Among these animals mentioned above, there were sponges, *Halichondria japonica* and *H. okadai*, and sea-anemones, *Haliplannella luciae, Anthopleura japonica* and *A. stella*. These sedentary animals appeared occasionally in the fouling communities but never established themselves as the major fouling constituents.

3. Fouling animals from the soft bottom.

The fouling ascidian, *Styela plicata*, was commonly observed on the soft bottoms in the inlet. It was noted that this ascidian was collected in vast quantities by dredge net for bottom organisms and this caused serious trouble in this type of fishing at Omura Bay, Kyushu (Kazihara 1964).

The ascidian attached to firm surfaces such as gravel-stones, tubes of polychaetes or the upper exposed surface of shells of *Pinna bicolor* which acorn barnacles also covered at the same time. However, many individuals were found not attaching but burying the lower parts of their tests in the sand bottom like the sponge, *Tetilla serica*, in beds on the shallow bottoms of the inlet. A large finger-shaped sponge (not identified) was common on the sand bottom of the inner part of the inlet and it appeared among the fouling communities in considerable numbers.

Discussion

The origins of the fouling animals on the artificial substrata in the sea are, without doubt, larvae being discharged or hatching from eggs spawned by the animals on the natural substrata. If the artificial substrata were settled to the extent of supporting large numbers of animals on them such as the farms of oysters or pearl oysters, the fauna could be sustained by themselves, reproducing their larvae in the established communities. They could establish their own eco-system. The communities were very different from those of natural substrata in many aspects. The artificial substrata had selected animals from various habitats in nature as the components. These animals adapted to the artificial substrata in various ways according to their abilities or morphological characters. Most of them are cosmopolitan because they have been carried on the ship bottoms throughout the world. It is well known that the mixing process of fouling animals is still going on.

Most of the marked fouling animals were thought to be selected from subtidal and shaded habitats such as under stones or in crevices of the rocky substrata. Only one fouling ascidian, *Styela plicata*, and a sponge came from soft bottoms. Many of the conspicuous sedentary animals on the natural substrata did not appear in the fouling communities in spite of their abundance. The process of the selection could be variable according to the specific animals. Larval behavior to select suitable substrata may be of much value in that respect. Lack of intertidal inhabitants in the faunas of fouling animals on the artificial substrata could be explained partly by this fact. The intertidal animals rarely settled on the collectors submerged continuously in the sea. The intertidal acorn barnacle, *Chthamalus*, settled on rather shaded surfaces of intertidal rocky slopes, probably avoiding competetion with algae. The tubeworm, *Pomatoleios*, prefered more shaded parts in the intertidal zone than *Chthamalus*. However, their larvae might settle only in the tidal zones and were rarely found on subtidal fouling communities. Most larvae of typical fouling animals prefered strongly shaded substrata for settlement on both artificial and natural substrata. Their rheo-taxis, photo-taxis and geo-taxis should be adjusted to do so in the course of the history in adaptation.

Smaller animals such as *Dexiospira*, *Microporella* and dwarf hydrozoans, *Obelia* and *Clytia*, showed extremely short reproductive cycles of about several weeks. They are not rich on the old artificial substrata covered by larger animals. But they are very abundant on surfaces newly submerged in the sea. They are inhabitants of algal fronds or leaves of eel-grass in nature. Algae and eel-grass provide short-lived substrata suitable only for these smaller fouling animals.

The competetion on the artificial substrata is known to be very severe because fouling animals grow very rapidly and they have short reproductive cycles and continuous settlement of larvae. The continuous breeding could be an adaptition for the settlement of new surfaces of the artificial substrata. The primary settlers of the larger fouling animals usually established dense communities dominated by single species on the newly appeared substrata until the sudden extinction of the communities at their end of their lives. This phenomenon is well known in *Styela plicata* and *Bugula neritina* as described by KAWAHARA (1960).

Most animals dominating the artificial substrata were not abunant in the natural habitats and their populations were limited because their natural habitats were not so plentiful in the sea. It was difficult to recognize the distribution of bushy bryozoans in natural habitats. They appeared sometimes on the over hanging rock walls, but only in small numbers. However, they did succeed in colonizing artificial substrata very abundantly. The causes of such a phenomenon, i.e. the difference of the faunas on the artificial and natural substrata, should be studied in order to understand the fouling characteristics in the sea.

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