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著者	Nishihira Moritaka
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DISTRIBUTION PATTERN OF HYDROZOA ON THE BROAD-LEAVED EELGRASS AND NARROW-LEAVED EELGRASS[1)]

By

MORITAKA NISHIHIRA[2)]

西 平 守 孝

Biological Institute, Tôhoku University, Sendai, Japan

The well developed marine plant community composed of *Sargassum* spp. is found on the rocky shore and that composed of *Zostera* in the sandy and/or muddy bottoms around Asamushi. There are various epiphytic organisms on these plants. Among them, the Hydrozoa are abundant, and in each vegetation type, there are observed characteristic Hydrozoa population (Nishihira, 1966). In the *Sargassum* belt, *Sertularella miurensis*, *Orthopyxis platycarpa* and some other species colonize a certain species of *Sargassum* abundantly, while in the *Zostera* belt *Clytia edwardsi* is dominant on the blades of *Zostera marina*.

Katô *et al.* (1961) reported on the distribution pattern of several Hydrozoa on the thallus of *Sargassum* species and suggested that the coaction between hydrozoan species modified the normal distribution pattern when two species settled together on a branch. But they did not analyze the normal distribution pattern.

The present article is concerned with the distribution pattern of hydrozoan colonies of three species on the blades of two genera of eelgrass.

I wish to express my thanks to Prof. Mutsuo Katô of the Tôhoku University, for his guidance during the course of the present work and for reading the manuscript. Thanks are also due to the staff members of the Marine Biological Station of Asamushi for providing me with the facilities. I am indebted to Prof. Mayumi Yamada of the Hokkaido University for the identification of *Plumularia undulata*.

HYDROZOA AS EPIPHYTES ON THE EELGRASSES

The 8 or 9 hydrozoans which have been reported on *Zostera marina* are shown in Table 1 together with several other Hydrozoa. At one extreme, there are hydroids characteristic of *Zostera marina*, e.g., *Tubularia radiata* (Uchida *et al.*, 1963) and *Clytia edwardsi* (Nishihira, 1965), and at the other there are indifferent

1) Contributions from the Marine Biological Station of Asamushi Aomori Ken, No. 355
2) Present address: Marine Biological Station of Asamushi, Tôhoku University, Aomori City, Japan

Table 1.
Hydrozoa associating with narrow- and broad-leaved eelgasses.

Hydrozoa	*Zostera marina*	*Phyllospadix iwatensis*	Locality	Author
Tubularia radiata	○		Hokkaido	Uchida *et al.*
T. mesembryanthemum	○		Matsushima	
Orhopyxis platycarpa	○	○	Asamushi	
			Hokkaido	Uchida *et al.*
Obelia plana		○	Hokkaido	Uchida *et al.*
Obelia dichotoma		○	Hokkaido	Uchida *et al.*
Obelia geniculata	○		Asamushi	
Campanularia sp.	○		Asamushi	
Clytia edwardsi	○		Asamushi	
Clytia volubilis	○		Asamushi	Katô *et al.*
Sertularella miurensis	○		Asamushi	
Dynamena hozawai		○	Asamushi	
Plumularia strictocarpa	○		Asamushi	
Plumularia undulata		○	Matsushima	
Number of species on this plant	9	5		

species, e.g., *Orthopyxis platycarpa* which occurs on various substrata. It is interesting that *Tubularia mesembryanthemum*, which is commonly observed in Matsushima Bay and Hokkaido, has not been collected at Asamushi and its vicinity. The submerged vegetation such as *Sargassum* spp. and *Zostera marina* also supports small sedentary and crawling organisms, which constitute the epiphytic community, or aufwuchs, their composition and quantity varying according to the locality in which they are found, the depth, seasson, the algal species on which they are attached or crawling, the age of the individual blade of the weed, and the existence of other organisms.

DISTRIBUTION PATTERN OF *Clytia edwardsi* ON *Zostera marina*

Twenty-five plants of *Zostera marina* were collected at random from the uniform forest of *Zostera marina* at the deeper part (3 m) of the *Zostera* belt at Ôura in August 1963. The number of blades were counted, the length of each blade was measured to the nearest millimeter and the length of each blade where hydrozoa were attached was measured. Measurements were taken at the inner and outer surfaces of each blade and of the attachment positions on each blade. The plants were grouped on the basis of the number of blades, into 6-bladed plants (designated as group VI), 5-bladed plants (group V), and so on; and blades were named from the outermost inwards, in group VI for example, 1st blade, 2nd blade,.., and 6th blade, and the position on the blade was shown as the distance from the tip of the blade.

Table 2.
The number of blades colonized by hydrozoa. In *Clytia* for example, each of nine of 16 plants of V-plants have 3 blades supporting *Clytia edwardsi* and the rest seven have two blades supporting hydrozoa.

Hydrozoa	Plant	Case	No. of blades colonized					
			5	4	3	2	1	0
Clytia	II	1						1
	III	3						3
	IV	7				4	3	
	V	16			9	7		
	VI	2			2			
Tubularia	IV	2			1	1		
	V	5		3	2			
	VI	3	1		2			
Plumularia	III	14				4	10	
	IV	8				3	5	
	V	3				1	2	

Small plants with less than 4 blades, which were examined in addition to the 25 plants, carried no hydrozoan epiphytes as shown in Table 2, which shows that most plants have 4 to 6 blades, one to three of which carry hydrozoa, and that the number of blades colonized by *Clytia edwardsi* increases with an increase in the number of blades on the plant. In general, it may be said that an older plant has more blades, and thus has more blades supporting Hydrozoa.

Fig. 1 shows the distribution pattern of *Clytia edwardsi* according to blade group and to plant group. Younger blades, 4th to 6th, do not carry any hydrozoa, in other words, at least the inner (younger) two blades of each group are free from Hydrozoa. All of the 1st blades have colonies, those of group VI have the largest colonies, and group IV the smallest. These figures are also seen in the 2nd baldes, in which some blades of group IV do not carry Hydrozoa. The number of blades colonized is 25 (100%) in the 1st blades, 21 (84%) in the 2nd, 11 (44%) in the 3rd baldes (Table 3). The younger the blades, the smaller the hydrozoan colonies on them. Thus the attachment of Hydrozoa is heavier on the outer blades than on the inner ones, and the degree of attachment increases towards the tip of the blades.

The colonization ratio of the blade, expressed as the percentage of the total (viz., inner surface plus outer surface of the blade) length of the blade occupied by the hydrozoan colonies, is shown graphically in Fig. 2. In all of the three groups of blades, 1st to 3rd, it is obvious that the blades of group VI plants have large values, which means that the blades support large colonies, and that the blades of the plants with fewer blades, e.g., group IV, carry smaller colonies. It shows further that in a given group of plants the colonization ratio is smaller for the

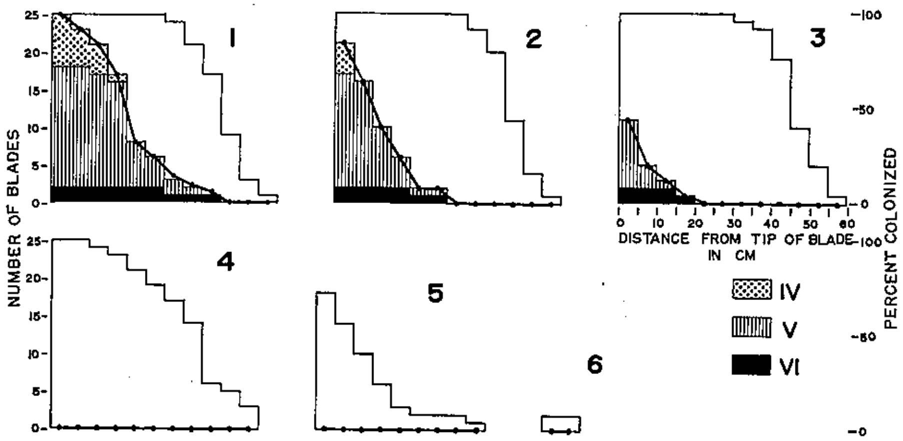


Fig. 1. Distribution pattern of *Clytia edwardsi* on *Zostera marina*. The number of blades epiphytized is shown in each group of blades (1 to 6) in 3 groups of plants (IV to VI). '1' represents the outermost blade (that is the oldest one) of a plant and '6' the innermost and so the youngest. The position on the blade is expressed as the distance from the tip of the blades. In a single blade the distal part is more aged than the basal part, from which the blade grows.

Table 3.
Frequency of blades colonized by each Hydrozoa.

Plant	*Zostera*				*Phyllospadix*	
Hydrozoa	*Clytia*		*Tubularia*		*Plumularia*	
Blade	No.	%	No.	%	No.	%
1	25/25	100	10/10	100	25/25	100
2	21/25	84	9/ 9	100	8/25	32
3	11/25	44	10/10	100	0/25	0
4	0/25	0	5/10	50	0/11	0
5	0/18	0	1/ 8	13	0/ 3	0
6	0/ 2	0	0/ 3	0		

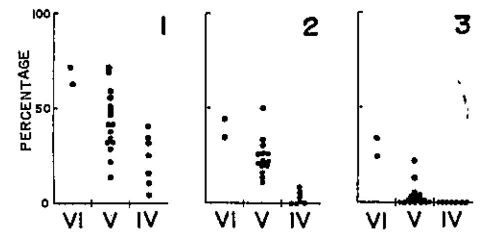


Fig. 2. Colonization ratio of *Clytia edwardsi* on the blades of *Zostera marina*.

inner (younger) blades. This decrease of ratio according to the decrease in age of blade in any group of plants is the result of the smaller extent of downward growth of the colony from the tip of the blade in the younger blades (Fig. 1). It is quite natural because the colony is small on the inner blade and always starts from the tip of the blade. The figures show, consequently, that all the blades in a single plant do not afford similar substrates for the attachment of Hydrozoa in terms of the colonization ratio.

This suggests that, on a single blade, there may be some differences in the colonization ratio on the outer and inner surfaces. As shown in Fig. 3, however, the difference is so small as to be negligible. So it may be said that the surface

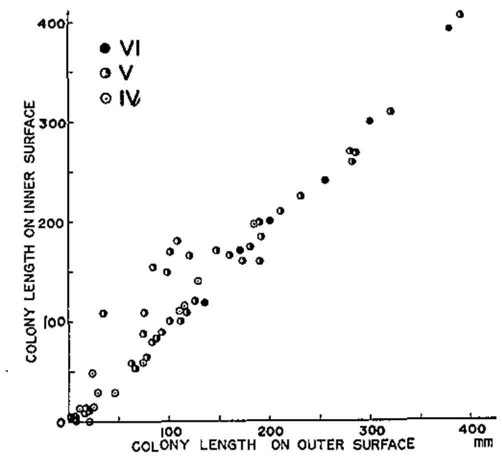


Fig. 3. Relation between the attachment (or colony length) of *Clytia edwardsi* on outer surface and on inner surface of a blade of *Zostera marina*.

differences of a blade do not show remarkable differences in attached hydrozoa compared with the age of the blades.

The simple conclusion derived from the observations mentioned above may be as follows: the degree of attachment or colonization ratio of the Hydrozoa, *Clytia edwardsi*, on *Zostera marina* is a reflection of the age of the blade. It means that the outer blades are much more heavily colonized than the inner ones and that the colonization ratio or degree of attachment of the organisms increases towards the tip of the blade.

Additional observations on the same association at the same locality in the summer of 1964 gave the same results. This characteristic distribution pattern appears to be constant in *Clytia edwardsi* which is attached to *Zostera marina* at Ôura in the summer. It is important to compare the distribution of other Hydrozoa attached to the same and also to different kinds of plants in different localities.

For this purpose, *Zostera marina* carrying *Tubularia mesembryanthemum*, and *Phyllospadix iwatensis* colonized by *Plumularia undulata* were observed in Matsushima Bay, Miyagi Prefecture, in October 1963.

DISTRIBUTION PATTERN OF *Tubularia mesembryanthemum* ON *Zostera marina*

In the *Zostera* belts at Katsura-jima, Matsushima Bay, a quantity of (about 200 plants) *Zostera marina* were collected but none of them carried Hydrozoa though several Bryozoa including *Amathia* and *Barentsia* were abundant.

Floating *Zostera* occasionally carries colonies of *Tubularia mesembryanthemum* in the Bay, so those plants which had drifted ashore were collected at Katsura-jima, and 10 specimens of *Zostera* were examined in the laboratory. The same information for *Clytia* was obtained and the number and height of the stems of the hydrozoans were also measured. Table 2 shows the number of blades of a plant bearing epiphytes, classified by the blade number. In the 10 plants examined the innermost blades are free from Hydrozoa. Here again the general tendency described in *Clytia* can be noted. The older plant has more blades, and thus more blades bearing colonies.

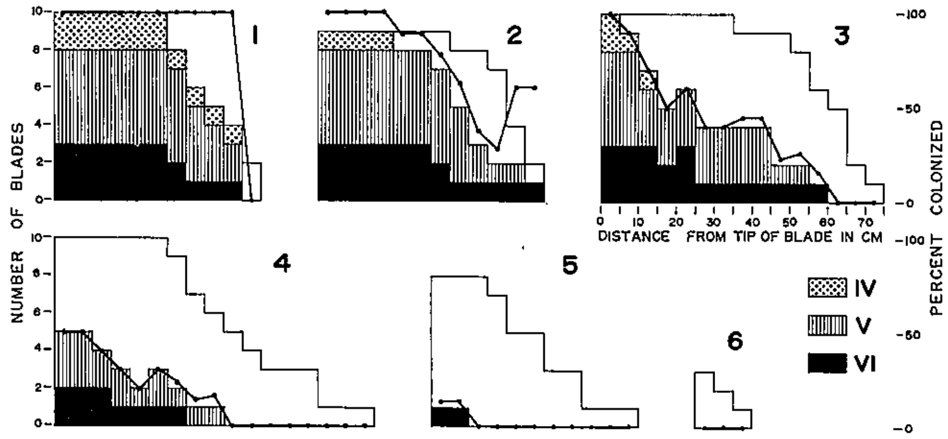


Fig. 4. Distribution pattern of *Tubularia mesembryanthemum* on *Zostera marina*.

The outermost blades in the three plant groups have *Tubularia* on almost the whole length of their blades (Fig. 4). The distribution range of *Tubularia* decreases gradually on the 2nd, 3rd, 4th and 5th blades, and the 6th blades are free from epiphytization as with *Clytia*. The percentage of the blades colonized in each of 1st to 6th blades is 100, 100, 100, 50, 13 and 0 percent respectively (Table 3). It is interesting to note that the percentage of the blade occupied decreased towards

the base of the blade, which means that the attachment of Hydrozoa, as seen in the case of *Clytia*, is highly restricted to the distal part of the blades. This is most clearly shown on the blades with lower percentage values. In the figure for the 2nd blades, the number of blades is reduced to 9, since the 2nd blade of one of the group IV plants was detached.

It is not safe to derive from Fig. 4 that the blades of older plants have a wide range of attachment surface, viz., a large value of colonization ratio, because the real length both of the actual range utilized by hydrozoa and the blade itself is not shown in the figures. But it is true in most of the cases as is shown clearly in Table 4. The values are largest in the 1st blade and gradually decrease to the

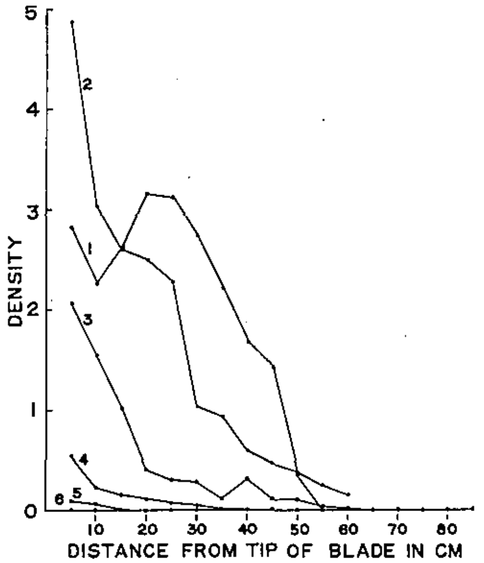
Table 4.
Colonization ratio of *Tubularia mesembryanthemum* on the blades of *Zostera marina*.

Plant	Blade					
	1	2	3	4	5	6
IV	65.5	33.3	14.6	0		
V	100	82.6	51.2	25.2	0	
VI	97.0	86.1	67.9	31.0	18.2	0

inner baldes in all of the three groups of plants, and on a given blade the largest value appears in the plants with the largest number of blades and the smallest one in the plants with the fewest blades.

In *Clytia* a single colony almost always occupies the whole surface of a blade (though it is uncertain whether it is derivative from a single planula or is the outcome of fusion of several colonies), but in *Tubularia* the many independent colonies have obviously started from the attachment of many actinula larvae, and the various colony sizes ranging from several millimeters to several centimeters are found. Consequently it is possible to take the density of stem as the representative of colony number at least in the early phase of colony growth. Fig. 5 shows that the outer blades and also the distal parts of them have the highest density though there appeared to be a slight discrepancy on the distal part of the outermost blades. This may show that the attachment of actinula larvae is heavy on the distal part of the outer blades though the colony bears more than one stem as it continues to grow.

Now, since the stem length is considered to be related with the age, it is possible to discover the sequence of attachment by estimating the length of stems on the assumption that the growth rate of the colony is not dependent on the attachment position on the blades or the season of attachment. The results of this treatment of group VI plant are shown in Fig. 6. Where the density was high the longest 10 stems were measured and the average length was plotted against the



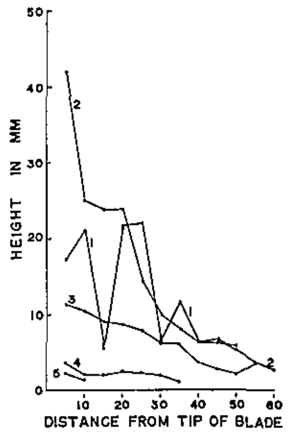


Fig. 5 Fig. 6

Fig. 5. Density of the *Tubularia* stems on the blades of *Zostera marina*. Density is expressed as the number of stems per 1 cm blade.

Fig. 6. Height of *Tubularia* stems on a 6-bladed plant of *Zostera marina*. The longest 10 stems on each position on the blade were averaged.

Table 5.
Density of the *Tubularia* stems on the blades of *Zostera marina*.

Plant	Blade					
	1	2	3	4	5	6
IV	1.76	0.33	0.11	—		
V	2.89	1.56	0.33	0.11	—	
VI	2.49	3.19	1.40	0.18	0.02	—

position on the blade. The outer blades have the longer and consequently older stems and the stems on the distal parts are longer, although there are considerable fluctuations on the outermost blade. This suggests that the attachment of actinula larvae started first on the older parts on the older blades and then gradually spread to the other younger parts. The length of the blade bearing settled hydrozoans in the 4th balde is only 35 cm although the blade is 70 cm long, and all stems are young and less than 5 mm long. The 5th blade is 55 cm long and the distal 10 cm bear hydrozoa and the stems are shorter than those on the 4th blade. The attachment on the inner and outer surfaces of a blade does not differ markedly though it is somewhat heavier on the outer surface.

These figures generally suggest, as in *Clytia*, that the more blades a plant has, the more blades are occupied by *Tubularia*, and that in a single plant, the outer blades and the distal parts of a blade have heavier colonization. Thus the age of the blades has a great influence upon the attachment and consequently the distribution pattern of the Hydrozoa on *Zostera*.

DISTRIBUTION PATTERN OF *Plumularia undulata* ON *Phyllospadix iwatensis*

At the sandy part of the rocky shore of Katsura-jima, a well developed *Phyllospadix* belt was recognized. Twenty five plants were collected and the same information was recorded as in the case of *Clytia*. The general figures for the colonization of *Plumularia undulata* are similar to those of the species described above.

The number of colonized blades of *Phyllospadix* is not always large in the plants with more blades as is shown in Table 2. But the distribution pattern of the Hydrozoa on this plant is not different from that of the two examples already shown.

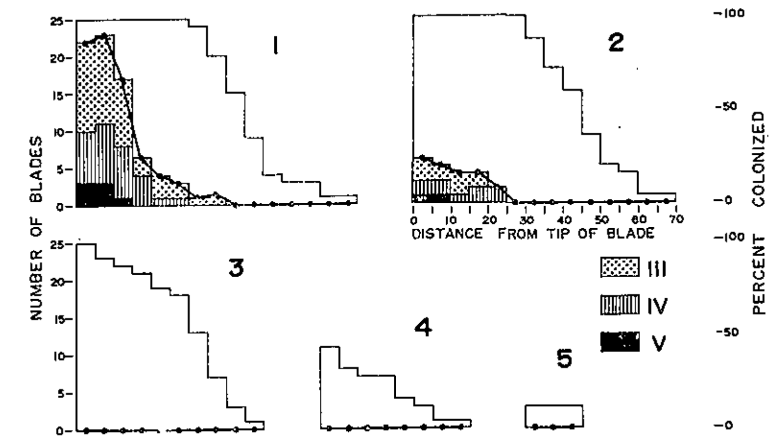


Fig. 7. Distribution pattern of *Plumularia undulata* on *Phyllospadix iwatensis*.

As shown in Fig. 7, group III to V plants have the outer two blades colonized by *Plumularia*, and the outer blades and the distal part of a blade bear large colonies. Though all of the 1st blades carry Hydrozoa the percentage colonization of the blades is not 100 per cent even on the uppermost part of the blade. This is because the colony of *Plumularia* is not so large as *Clytia* and not all of them are initiated from the tips of the blades. The degree of colonization is shown in Fig. 8, which shows that the outer blades have large values among which those of the plants with more blades are slightly larger. The comparison between the colonization of the outer and inner surfaces of the blade shows no differences as in both the species mentioned before. But the general trend in distribution pattern described

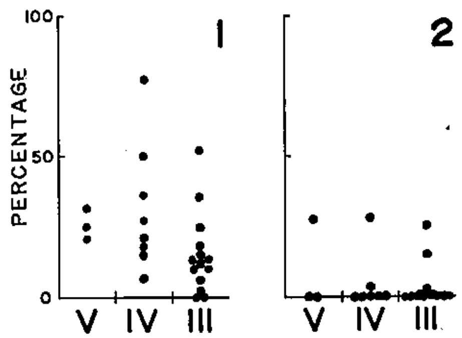


Fig. 8. Colonization ratio of *Plumularia undulata* on the blades of *Phyllospadix iwatensis*.

in the previous two examples is the same. The indistinct distribution pattern of *Plumularia* may be attributed to the variable ecological environment of *Phyllospadix* which grows on the sandy bottom of somewhat exposed rocky shores

DISCUSSION

The distribution pattern of three species of Hydrozoa, *Clytia edwardsi*, *Tubularia mesembryanthemum*, and *Plumularia undulata*, on two species of eelgrass, *Zostera marina* and *Phyllospadix iwatensis* were basically of the same pattern. Zhis was considered to be a reflection of the age of the given part of a blade, at least in the summer season. That the older plants with more blades such as group VI and V plants support more hydrozoan colonies, and the younger blades and the basal (younger) parts of blades are free from epiphytization of Hydrozoa was demsontrated. In *Zostera* the innermost two blades are free from *Clytia* and the youngest blade, at least, is free from colonies of *Tubularia*. *Plumularia* did not occur on the two innermost blades of *Phyllospadix*.

That the colonization ratio is larger on the older blades in *Clytia* and *Plumularia*, both of which usually occur as one large colony on a blade, and that the colonization ratio and the percentage of colonized blades is large on the old blades and plants, result from the fact that the colonies start from the older part of the blades and that on the older blades the colonies would be older. It is reasonable to consider that the large colony is formed by fusion in the process of the growth of many colonies originating from a number of planulae, though it is possible that fusion is not really occurring, but merely the intermingling of colonies occurs. In either case, the distribution pattern of these Hydrozoa may show a tendency towards heavier attachment of the planulae on the distal part of the blade. Thus it is possible to consider that the attachment of planulae occurred on the blades of suitable age and on the part of suitable oldness on a blade.

There may be serval possible reasons for the effect of the age of the blade on the settlement of the planulae. One of them is that the distal (older) part of the blade is illuminated more highly than the basal part and may influence the behaviour of larvae. The inner two blades of a plant, however, are always free from *Clytia* even if they are long enough to be illuminated as much as the outer older blades. Thus the observed pattern of settlement is not explained byreactions of the planulae to the light.

Another possibility is that the age of the blade has a very important influence on the settlement of the planulae though this does not necessarily deny the effects of the physical factors such as light intensity mentioned above. As has been mentioned by many authors, for example Kita and Harada (1962), a variety and quantity of diatoms and other micro-organisms occur on the blade and their distribution shows a tendency to be restricted to the distal part of the blades. They considered this was related to the high illumination, though it is not necessarily beneficial for the diatoms themselves, but they did not discuss the role of the age of the blades. Takano (1962, 1963) reported a variety of diatoms from various alage. On the other hand, Odum (1957) showed the successional series of the aufwuchs on the blades of *Sagittaria*, which has fundamentally the same pattern of growth as that of *Zostera marina* and *Phyllospadix iwatensis*, as follows:
Bacteria-cocconeis type diatom-larger diatoms-algal green and blue green filaments-herbivorous animals-carnivorous animals-breaking and bitten-off tips reaching the fishes. In addition to the above, a number of observations have been reported showing that the larvae of Bryozoa and serpulid polychaetes such as *Spirorbis*, prefer filmed surfaces (Knight-Jones, 1951, Wilson, 1955, Miller *et al.*, 1948). Maedows and Williams (1963) demonstrated that "larvae of *Spirorbis borealis* will settle more readily on a film developed in the presence of diatoms and their associated bacteria than on those developed in the presence of a green flagellate" and "it seems probable that similar variations in the constitutents of primary films will affect the settlement of *Spirorbis* under natural conditions in the sea". Kita and Harada (1962) observed that the diatoms grew luxuriantly on the *Zostera* leaves and the standing crop of diatoms increased twoards the tips of *Zostera* blades. Considering these facts collectively, it seems conceivable that when the blade reaches a certain age, it becomes suitable for the attachment of the planulae. Growth (in most cases towards the base) of the colonies after attachment resulted in the particular distribution pattern observed.

One question still remains. If the age of the blade is reflected in the succession of micro-organisms on the blades, the middle part of a given blade could have a similar aufwuchs as on the distal part of younger blades, and this in turn would show that the attachment figures on the middle part of a blade are similar to the distal part of a younger blade, and thus even the distal part of the younger blades may receive the settlement of planulae. Although the age and number of colonies could not be measured with *Clytia* and *Plumularia*, it is probable that a similar situation exists.

In *Tubularia*, in which the mode of colony formation is quite different from the previous two species of thecate hydroids, it is possible to count the colony number and to know the age by measuring the length of the stem and thus to discover the sequence of attachment of the actinula larvae on the blade. Table 6 shows the total number of stems and the number of stems less than 5 mm (which are thought to be yong recently-attached colonies) for every 5 cm from the tip of the blade, in one of group VI plants. From these figures, of the results on the 3rd to 5th blades,

Table 6.
The number of the *Tubularia* stems on every 5 cm of the blades of *Zostera marina*.
NT: Total number of stems, N5: Number of stems shorter than 5 mm.

Distance from tip of blade (cm)	Blade											
	1		2		3		4		5		6	
	NT	N5	NT	N5	NT	N5	NT	N5	NT	N5	NT	N5
5	21	0	46	0	37	0	19	19	6	6	0	
10	31	0	39	0	49	40	7	7	2	2	0	
15	2	1	27	0	31	22	6	6	0		0	
20	19	0	28	0	21	13	6	6	0			
25	34	0	25	0	19	12	4	4	0			
30	6	3	20	0	24	17	2	2	0			
35	15	6	22	15	10	6	1	1	0			
40	6	3	16	11	18	12	0		0			
45	12	6	22	16	6	6	0		0			
50	4	2	13	10	10	10	0		0			
55	0		8	7	1	1	0		0			
60			3	3	1	1	0					
65					0		0					
70							0					

it is considered that the degree of attachment of the larvae is correlated with the age of the blade and this results in the characteristic distribution pattern. On the basal part of the 1st and 2nd blades the same pattern of attachment is shown, though the figures on the whole length of the blades are not so clearly correlated with the age of the blades. It is conceivable that these two oldest blades of a plant may be too old and the innermost 6th blade too young for the attachment of larvae. The age of the blade and consequently the duration of its exposure to the attachment could be considered to affect greatly, in some manner, the settlement of the larvae.

With *Phyllaspadix* the distribution pattern of the surface filming calcareous red alga, *Fosliella zostericola*, shows a similar trend to that of *Clytia* and *Tubularia*. In the non-colonial sedentary forms such as *Spirorbis* and *Hydroides* a similar

pattern is seen. In conclusion the following may be said: The age of the *Zostera* blade may influence the attachment of the larvae and the subsequent growth of colonies determines the characteristic distribution pattern of Hydrozoa on the *Zostera* blade. The same may be true of *Phyllospadix*. About the influence of the age of blades on the larval settlement, more works are required.

SUMMARY

A total of 9 hydrozoan species was recorded on two species of Zosteraceae.

The distribution patterns of three hydrozoan species, *Clytia edwardsi*, *Tubularia mesembryanthemum* and *Plumularia undulata* on *Zostera marina* and *Phyllospadix iwatensis* were fundamentally similar. The degree of attachment or the colonization ratio of the Hydrozoa is considered to be a reflection of the age of the blades. This means that the more blades a plant has, the more blades will be occupied by Hydrozoa, that the outer and so older blades are much heavily colonized than the inner ones in a single plant and that colonization increases towards the tips of the blades.

It is suggested that the age may influence the settlement of the larvae in unknown manner and the subsequent growth of colonies determines the characteristic distribution pattern of Hydrozoa on these plants.

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