Impact of Bryozoan, *Bantariella* sp., on Black Corals at Munseom in Jejudo Island

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Abstract - **In 2005, an unrecorded bryozoan, *Bantariella* sp., invading on black corals was observed at Munseom in Jejudo Island. An intensive study was performed in the portion of 180 m width and 10 ~ 30 m deep of Hangae-chang at Munseom during the period from Jan. to Nov. 2006. The following two black corals, *Antipathes japonica* and *A. lata* are occurring in this area. To investigate the quantitative change of invasion rates, 26 colonies with initial invasion rate of 0%, 30%, 70% and 100% respectively were individually tagged at the beginning of this study. After that, the change of reinvasion rates was monitored in a timely manner with the pictures taken by underwater camera and onsite observation. These data were analyzed as to host species, depth and initial invasion rates. According to host species, the removal effect was higher in *A. lata* than *A. japonica*. The reinvasion rate of black corals showed a maximal effect at 20 ~ 30 m deep, and the most successful removal effect appeared in the colonies of initial invasion rates of 30 ~ 70%. Especially, the invasion of *Bantariella* sp. on black corals is related to seawater temperature in seasonal manner and this appearance was limitedly observed at Munseom. This study is to document the impact by bryozoan proposing removal methods and its proper time of removal. It could contribute to the conservation of black corals and furthermore help to predict the change of marine environments.**

Key words : Bryozoa, *Bantariella* sp., invasion, black corals, *Antipathes japonica*, *Antipathes lata*

INTRODUCTION

Black corals have been commercially harvested for jewelry and an ancient belief that wearing pieces of its skeleton benefits the health. They have got damaged by fishing nets, net waste and diverse biological invasion including thoughtless overfishing. They were determined by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) as a trade regulation species for protection worldwide (Kang *et al.* 2005). Korea appointed *Antipathes japonica* as a wildlife species needs protection by the Ministry of Environment in 1998 and designated soft corals communities on Jejudo Is. coast where generally black corals habitat as a No. 442 precious natural monument by Cultural Properties Administration in 2004. And, *A. japonica* and *A. lata* were especially protected as respectively No. 456, No. 457 of natural treasure in 2005. Even in these circumstances, studies on the ecology of black corals are very scarce in Korea.

In Hawaii, the black coral fishery has continued over past 40 years. That was accepted on the basis of experience that the overfishing has not violated black coral's recruitment (Grigg 2004). However, it is hard to keep up using resources, since not only the biomass gradually decreased over a long period of harvesting, but also a introduction of an invasive alien octocoral, *Carijia riisei* (Duchassaing and Michelotti 1860) into Pearl Harbor to black corals since 1972. Therefore, they tried to provide new measures preserving black corals after quantitative survey with submersible

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dives since 2001 about damage of black corals by alien species and the degree of biomass reduction (Grigg 2004).

In the beginning of 20th century, the biological invasion of alien species was emerged as an international issue. It is told the most significant reasons are ballast water carried by ocean-going ships making cases such as releasing living organisms of specific region to other area and moving planktonic larvae swept by ocean current settling down other place (Coles *et al.* 1999). Also during the 20th century, as plenty of harbors were constructed and the coastlines were urbanized in Pearl Harbor, many habitats of marine organisms disappeared, and some areas were dominated by alien species in accordance with low quality of water consequently. As of this, the invasion of ecosystems by alien species becomes one of the greatest threats to biodiversity and community structure (Laura 2006).

A newspaper reported that soft corals communities located around construction area were destroyed by gravels and the decreasing of tide speed, since the authority built a west-bulwark extension work at the Port of Seogwipo, Jejudo Island in 2005 (Dong-a newspaper Dec. 7, 2005).

Furthermore, there is bryozoan like a wad of cotton invading on black corals around Munseom in Jejudo Is. (Yonhapnews Dec. 7, 2005). So preliminary inspection is started and we get down to a study for the purpose of understanding what species the bryozoan, how these impacts occur and how to minimize the impacts on black corals.

This study compares the control group with artificially *Bantariella* sp. removing group by monitoring recovery rates, after classifying black coral colonies depending on initial invasion rates. Two groups were compared to host species of black corals, depth of habitat, and difference by initial invasion rate. We tried to observe the change of the *Bantariella* sp., because there is no known biological study about *Bantariella* sp. species, itself which impacts black corals. Based on this, environmental changes in this area and finding out the factors of biological invasion should be investigated.

MATERIALS AND METHODS

1. Hosts and symbionts (Fig. 1)

There are two kinds of black corals (two host species; Family Antipathdae, Order Antipatharia) distributed in this area, *Antipathes japonica* Brook, 1889 and *A. lata* Silberfeld, 1909 with a preliminary research on 6 Nov. 2005 (Song 1987). And, the bryozoan invading on black corals is *Bantariella* sp. (ectosymbiont; Family Mimosellidae, Order Ctenostomata), which is undetermined to Korean fauna by a bryozoan taxonomist, Dr. Ji-Eun Seo.

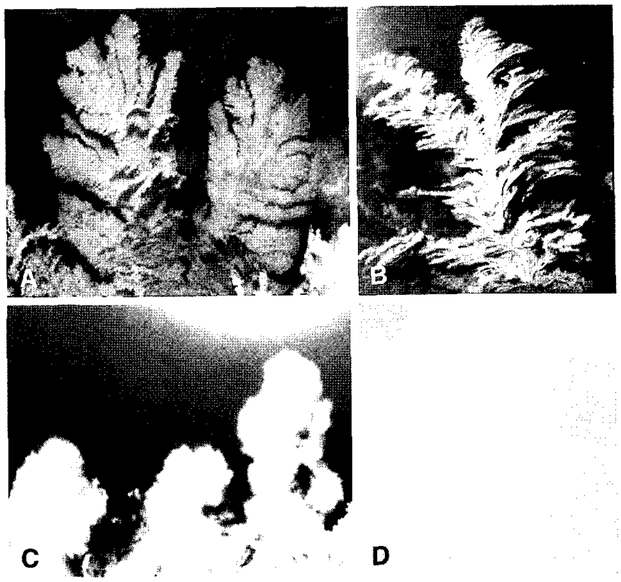

Fig. 1. Impact of the bryozoans on black corals. A-B. Healthy black corals. A. **Antipathes japonica*; B. ***Antipathes lata*; C. Invaded black corals by *Bantariella* sp.; D. Zooids of ****Bantariella* sp.

2. Study site (Fig. 2)

The Munseom (33° 13′25″N, 126° 33′58″E) located at about 1 km away from the southern coast of Seogwipo is influenced directly by the Tsushima warm current, the branch of Kuroshio current. This area belongs to the temperate region and shows a range of water temperature from 14°C to 26°C depending on the seasons and the change of salinity goes 32.2 ~ 34.4 psu (Kang *et al.* 2005) up and down. This water factors cause the diversity of marine organisms in the southern coast of the Jejudo Island. In 130 m width portion of northern part of Munseom, the underwater tour via submarine has been being operated since 1989 and that area is directly affected by surroundings due to the port extension works of Seogwipo. Especially, some areas where impacted by *Bantariella* sp. are restricted over

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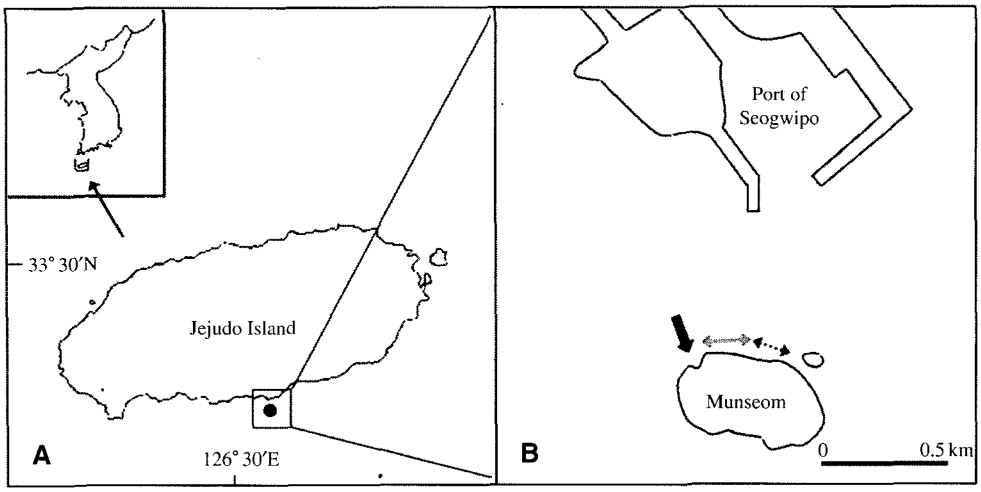

Fig. 2. Location of the study area. A. Jejudo Is.; B. Munseom (arrow: Hangae-chang, ◄—► : impact area, ◄--► : a submarine service).

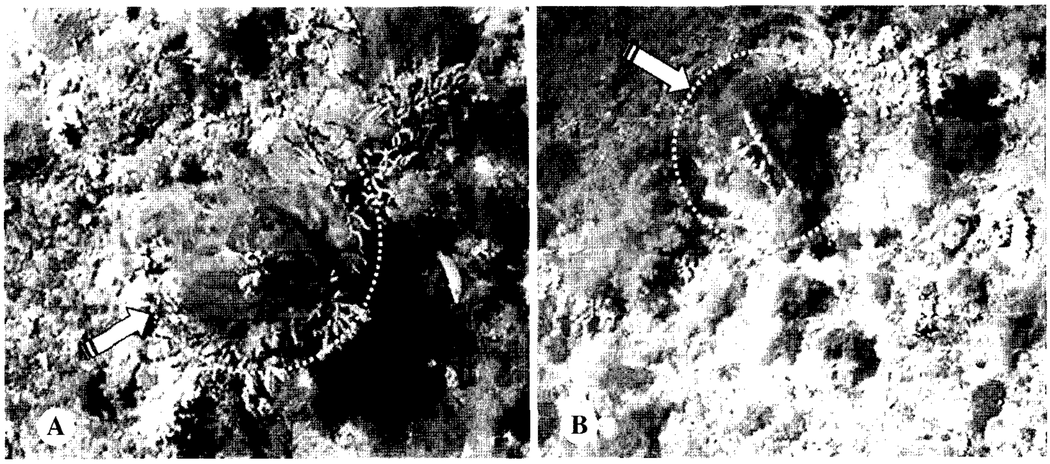

Fig. 3. Substrates of the bryozoan, *Bantariella* sp.. A. Gorgonians; B. Gorgonians and others.

the Hangae-chang eastern cliff and steep rock wall of 180 m width, gradient 70° located in west northern side of Munseom and out of submarine tour area as well. This impact prominently occurs in the west northern side of Hangae-chang at Munseom while few are observed in the east southern side.

Bantariella sp. most likely invades on black corals intensively. It is rarely observed that it adheres to other gorgonians and algae (Fig. 3).

At 10~20 m deep of eastern cliff of Hangae-chang, where is mainly dominated by *Scleronepthya gracillimum*, the low density of *Bantariella* sp. appeared depending on the low black coral density. However, at 15~30 m deep, black corals were distributed densely, and more than 70% of them were faced with death.

3. Experimental procedure for monitoring black corals

After the reports of impact about black corals in Dec. 2005, we carefully analyzed such things as invasion rates, host species and the depth of habitat and also researched the specimens of black corals which were deposited in the Natural History Museum, Ewha Womans University to see a damage record by bryozoan. After setting up methods for research, we divided invaded colonies into two groups as *Bantariella* sp. removing group and leaving group by initial invasion rates, and tagged them all. We classified invaded black corals by invasion rates, and compared the control with both artificially *Bantariella* sp. removing group and leaving group by monitoring them. This study was started on 4 Jan. 2006 and ended on Nov. 2006, namely observation was performed carefully every twice a month before May 2006 when the seawater temperature starts going up, every once a month until Jun. 2006, and irregularly for the rest of the period. Monitoring was done in the level of individual and group separately by SCUBA diving, taking digital photographs through transect line for analyzing images and onsite observation was done.

As for quantitative investigation on change of invasion rates, 26 colonies with initial invasion rates of 0%, 30%, 70%, 100% respectively were individually tagged at the area of A (10~20 m deep) and B (20~30 m deep), and removed all bryozoans within the area of 3 m in diameter from the colonies to prevent an inflow from surroundings. To compare the effect of removal, all bryozoans attached to the 13 colonies of test group were removed while the other 13 colonies of control group were leaved, and then invasion rates of each colony were monitored twice a month until late Apr. with underwater camera (NIKON F5) and once a month in May to Jun. as *Bantariella* sp.'s natural decrease goes on in May when the seawater temperature hits over 17°C (Table 1). Onsite observation was also performed until Nov. 2006 in order to check out the seasonal changes.

4. Image analyzing and statistical process

Using digital image analysis program (Motic images plus 2.0 ML), the parts invaded by *Bantariella* sp. were calculated by the percentage of invasion rate against the whole colony. Statistical analysis was performed by the linear regression model to examine the significance over the change of invasion rates versus physical and environmental variables including host species, depth of habitat, initial invasion rates and seawater temperature with statistic program (SPSS).

RESULTS AND DISCUSSION

1. Initial situation before experiment

Among the 26 tagged colonies, 9 were *Antipathes japonica* and 17 were *A. lata*. Therefore, *A. lata* was more domi-

Table 1. Reinvasion rates on the antipatharians by *Bantariella* sp.

No.	Species	Size (cm)	Color	Depth (m)	Removal of *B.* sp.	Invasion rate (%)							
						Jan/04 (T_0)	Jan/27	Feb/10	Feb/25	Mar/10	Mar/24	Apr/14	Apr/28
1	*A. lata*	48	white	31.5	+	30	29	0	1	0	0	0	0
2	*A. japonica*	55	maroon	25.6	−	30	30	35	30	38	16	2	2
3	*A. lata*	62	white	26.7	+	70	9	21	19	24	12	15	14
4	*A. lata*	60	white	30.1	−	70	80	73	75	82	73	58	50
5	*A. lata*	71	white	23.2	+	30	24	38	43	39	17	25	22
6	*A. lata*	66	white	29.9	−	30	10	17	36	40	20	15	12
7	*A. lata*	82	white	23.8	+	70	7	12	12	13	9	2	1
8	*A. lata*	45	white	23.4	−	0	5	11	5	4	0	0	0
9	*A. lata*	42	white	22.2	+	0	3	2	2	0	0	0	0
10	*A. lata*	66	white	20.8	+	30	0	1	2	2	0	0	0
11	*A. lata*	70	green	19.9	+	70	70	43	53	56	62	62	74
12	*A. lata*	31	green	17.9	−	0	0	0	0	0	0	0	0
13	*A. lata*	36	white	18.8	+	70	3	17	8	10	3	3	2
14	*A. lata*	38	brown	19.7	+	0	2	2	2	2	0	0	0
15	*A. lata*	39	white	17.7	−	0	0	0	2	0	2	0	0
16	*A. lata*	78	white	17.7	−	30	13	32	34	30	18	8	5
17	*A. lata*	43	white	16.7	−	30	8	1	1	17	18	20	13
18	*A. japonica*	44	maroon	16.5	−	70	72	79	79	74	77	79	80
19	*A. lata*	63	pink	19.2	+	30	1	1	2	3	2	0	0
20	*A. japonica*	47	maroon	19.7	+	100	74	84	75	72	61	59	47
21	*A. japonica*	65	maroon	18.2	−	70	80	65	69	72	56	64	38
22	*A. japonica*	42	maroon	18.4	+	70	40	67	61	64	56	49	44
23	*A. japonica*	46	maroon	19.1	+	70	26	37	30	16	22	17	13
24	*A. japonica*	74	maroon	16.7	−	100	70	80	86	77	73	68	74
25	*A. japonica*	38	maroon	24.8	−	100	100	100	100	100	100	100	100
26	*A. japonica*	35	maroon	23.1	+	100	70	89	89	72	62	79	64

+: removal. −: leaving, T_0: beginning of the study (%)

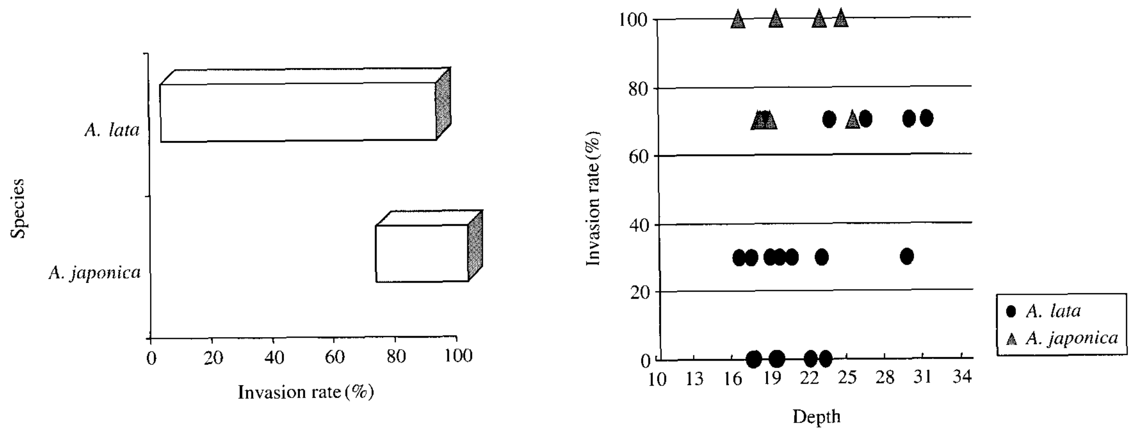

Fig. 4. Invasion rates on antipatharians by *Bantariella* sp. at the beginning of study (Jan/04, 2006: T_0).

nant at almost the rate of 2 : 1 than *Antipathes japonica*. The initial invasion rate of *A. japonica* was very high reaching 70~100% while it showed wider range of 0~90% with *A. lata* (Fig. 4).

The vertical distribution of *Bantariella* sp. in this area was 8~32 m deep usually but they were mainly distributed at 15~30 m deep in related to the density of black corals. The vertical distribution of black corals showed a difference depending on species. *A. japonica* of 9 colonies was observed at 16.2~25.6 m deep and *A. lata* of 17 colonies was observed at 16.7~31.5 m deep, meaning that *A. japonica* inhabits in upper part of less than 26 m deep and *A. lata* inhabits up to 31.5 m deep.

In order to examine the relationship between invasion rates and colony height, the survey on invasion rates according to the height of black coral colonies showed that black corals inhabiting in this area were mainly 30~80 cm (n=30) in height and non-invaded colonies were limited within 50 cm in height. But we could presume that other causes rather than size of colonies played an important role because of the research result that the colonies with invasion rates of 100%, leaving only thick branches, were also 20~50 cm (n=10) in height.

In the case of *C. riisei*, alien species in Hawaii, the invasion rates vary most likely depending on the size of black coral colonies. For examples, the small colonies about 40 cm in height were invaded less than 20%, the mature colonies about 40~75 cm in height were invaded over 60% and the colonies larger than 75 cm in height were invaded more than 60%. It reveals that the size and exposure time get the cumulative probability of *C. riisei* settlement (Kahng and Grigg 2005) increased.

Bryozoans directly influenced by environmental changes could play an important role in ecological investigations (Kelmo *et al.* 2004). The survey result of black coral specimens collected in the past showed that a few bryozoans were found in the specimen collected from this area on Jan. 22, 1998.

And they are seldom observed in the southeast of Munseom but recently their expansion seems to end up with gradual impact on black corals in near future. The surrounding of Munseom is quite turbulent by environmental variability such as the changes of tide current and turbidity caused by a port extension construction at Seogwipo and submarine tour which is still ongoing over past 15 years.

The impact of *Bantariella* sp. was restrictively observed only along the specific area within 180 m width between submarine service area of northwestern side and Hangaechang at Munseom. Geographically, this area keeps water current from flowing well and whirlpool occurs. In addition, the construction of breakwater is accelerating irregular tide current. But in the underwater touring service area, submarine screw creates artificial water current hence disturbs *Bantariella* sp. in settling down. On the other hand, non-service area just neighboring service area gives a better condition for *Bantariella* sp. to adhere on black corals due to floating particles by means of submarine.

Like above, the influence of water current changes and the increment of floating particles is continuing. Furthermore, this area showing less various organisms comparing to other areas around Munseom has been conspicuously dominated by *Scleronephya gracilimum*, and the experiment result of soft corals' survival rate during the construction of breakwater shows the highest survival rate of *S. gracilimum* among dominant soft coral species in this area

Considering the environmental changes as a one of factors influencing benthos' inhabitation and distribution like above, the impact by bryozoan which limitedly occurs in this area seems to be related with this fact.

2. Observations of change after experiment

1) Comparison of antipatharian host species

70 ~ 100% were recorded in initial invasion rates of *A. japonica* by *Bantariella* sp.. Although the most of *Bantariella* sp. was removed, it was impossible to remove completely with removal rates less than 30%, because of branching mode and shape of branchlets. After four months, invasion rates of *A. japonica* were decreased to more than 40% of initial's. However, when the *Bantariella* sp. was leaved, initial invasion rates maintained until mid-March and later decreased.

Meanwhile, 0 ~ 70% were recorded in initial invasion rates of *A. lata* by *Bantariella* sp.. When the *Bantariella* sp. was removed, it is possible to remove completely. After four months, invasion rates of most colonies were decreased to more than 95% of initial's except for two colonies. However, when the *Bantariella* sp. was leaved, initial invasion rates maintained until mid-March and later decreased naturally to more than 50% of initial's.

The observations of change of the invasion rate showed clear difference between the two host species. *A. japonica* facilitates to attaching for the substrate of *Bantariella* sp., because it has lots of short and compact branchlets, so it was difficult to remove completely as well as colonies were reinvaded easily after removal. While *Bantariella* sp. attached on *A. lata* could be departed away naturally by external circumstances such as strong current because of long and smooth branchlets. Therefore, once *Bantariella* sp. was removed, *A. lata* has a better effect than *A. japonica* and can be cured completely. It is assumed that the physical shape plays a good substrate for *Bantariella* sp. to attach, not by chemical process. In case of the *C. riisei*, alien

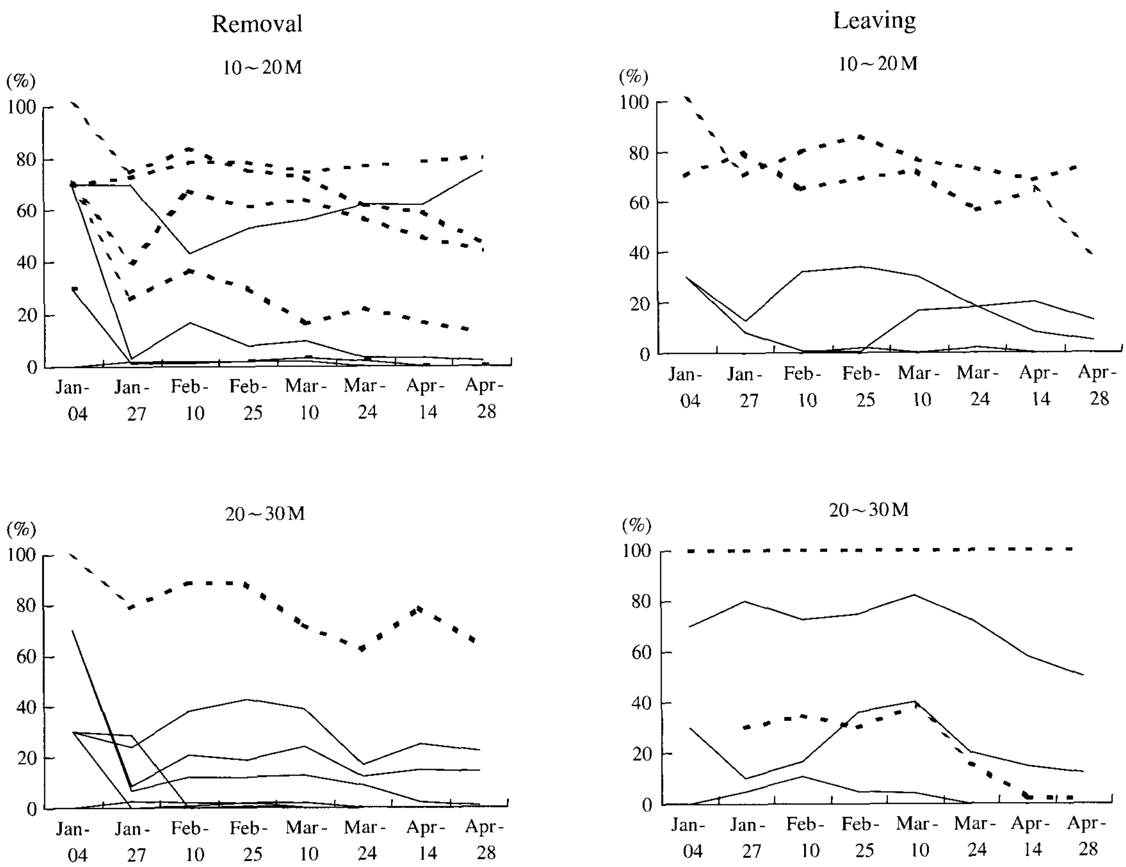

Fig. 5. Change of invasion rates on species and depth (dotted line : *A. japonica*, solid line : *A. lata*).

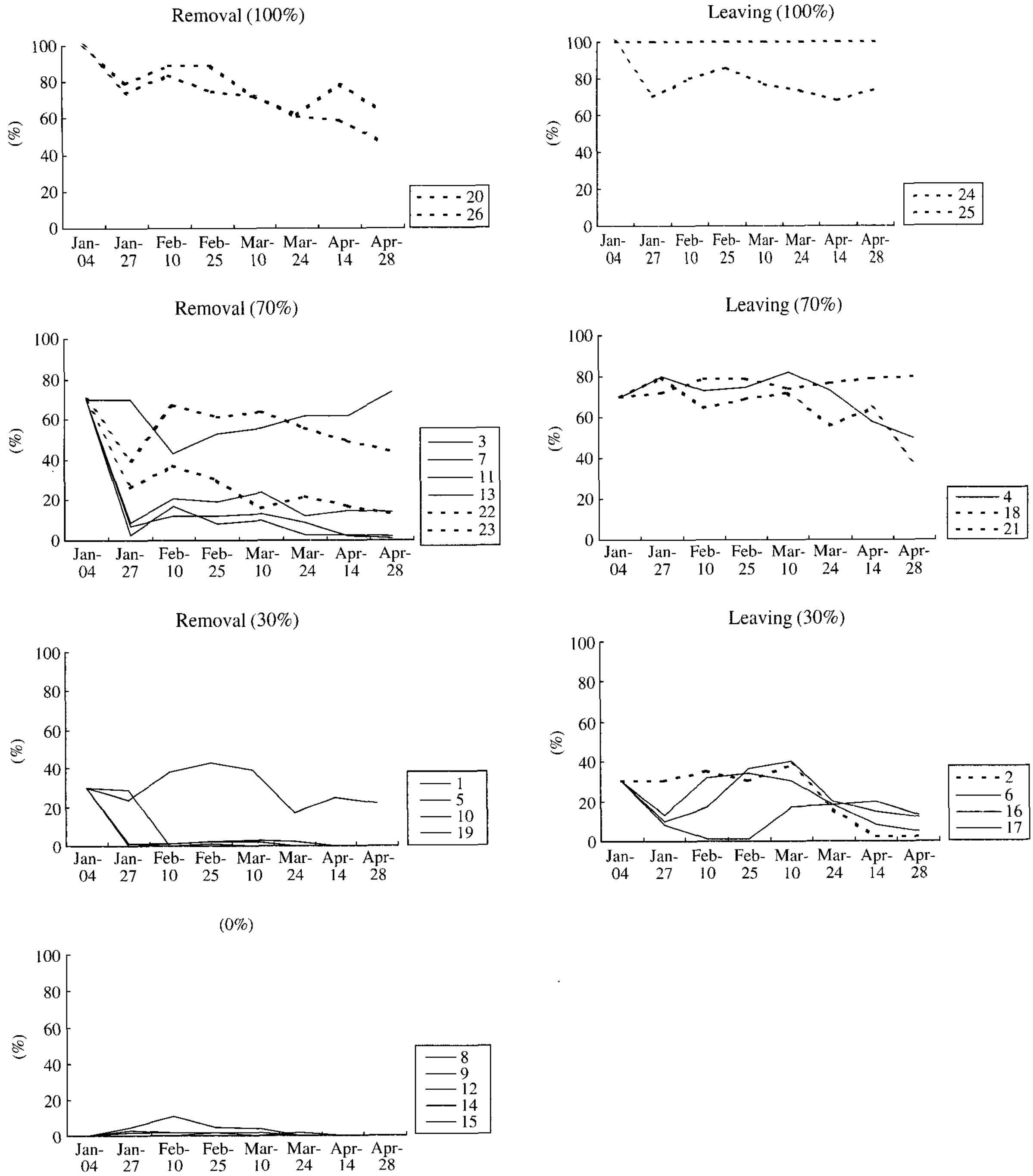

Fig. 6. Change of invasion rates on early invasion rates (dotted line : *A. japonica*, solid line : *A. lata*).

species in Hawaii, feed on zooplankton in the 200~1,200 μm ranges which overlaps with the size class of black coral prey and suggests the potential for competition for food. Polyps of black corals may also be influenced by an axis of the *C. riisei* because the external surface of *C. riisei* colonies covered by tough interlocking calcite spicules while the living tissue of a black coral forms a fragile, gelatinous layer. So they are always susceptible to damage (Kahng and Grigg 2005). But it remains unclear in the relation of *Bantariella* sp. and black corals, so the continuous study is needed.

2) Depth of habitat

At 10~20 m deep, when *Bantariella* sp. was removed, invasion rates of black corals were decreased to more than 55 ~ 100% of initial's. When *Bantariella* sp. was leaved, invasion rates of black corals were decreased to more than 40 ~ 70% of initial's (Fig. 5). At 20 ~ 30 m deep, when *Bantariella* sp. was removed, invasion rates of black corals were decreased to more than 40 ~ 90% of initial's. When *Bantariella* sp. was leaved, invasion rates of black corals were decreased up to 40% of initial's.

This result showed that there is also difference on depth of habitat. At 10 ~ 20 m deep, the inflow of *Bantariella* sp. was limited because of rare distribution of black corals. Since *A. japonica* was recorded a great damage compared with *A. lata*, and mainly distributed at this depth, the colonies of *A. japonica* could be faced with death. Therefore, when *Bantariella* sp. is removed, it is effective to focus on *A. japonica*.

While at 20 ~ 30 m deep, black corals showed a maximal impact by *Bantariella* sp., because they were distributed densely. According to this distribution pattern, black corals were reinvaded easily at this depth. Therefore, when *Bantariella* sp. is removed, it is effective to designate the maximal impact area and remove as a group.

The depth distribution of *C. riisei*, alien species in Hawaii, relative to black corals showed a maximal impact between 80 m and 105 m depth. The decrease in abundance of *C. riisei* at depths greater than 105 m coincides with the top of the thermocline where temperature begin to decrease *C. riisei* was not observed on black corals or on the substrata deeper than 115 m. The thermocline may also account for the diminishing abundance of host species, *Antipathes dichotoma* and A. grandis, at the same depth. After all, the distribution of *C. riisei* showed a direct influence by seawater temperature (Kahng and Grigg 2005).

3) Initial invasion rates (Fig. 6)

Most of colonies with initial invasion rates of 100% were *A. japonica*. When *Bantariella* sp. was removed, invasion rates of black corals were decreased to more than 50% of initial's. But, when *Bantariella* sp. was leaved, invasion rates of black corals maintained more than 80% of initial's. Colonies with initial invasion rates of 70% showed a significant difference depending on species. Namely when *Bantariella* sp. was removed, invasion rates of black corals were decreased to more than 80% of initial's. When *Bantariella* sp. was leaved, invasion rates of black corals maintained more than 40% of initial's.

Most of colonies with initial invasion rates of 30% were *A. lata*, when *Bantariella* sp. was removed, invasion rates of black corals were decreased to more than 90% of initial's and they were no longer reinvaded. When *Bantariella* sp. was leaved, invasion rates of black corals were repeatedly increased and decreased until mid-March and decreased to more than 70% of initial's. All colonies with initial invasion rates of 0% were *A. lata*, which showed a little increase or decreased in early season but they were no longer reinvaded since mid-March.

Considering this result, colonies with initial invasion rates of 100% could lead to death because of high invasion rate by *Bantariella* sp. and when *Bantariella* sp. was leaved, it is impossible to natural recovery so that it should be removed certainly. In case of colonies with initial invasion rates of 30 ~ 70%, the recovery rate varies according to attaching parts of *Bantariella* sp.. It doesn't matters because *Bantariella* sp. decreases naturally with passage of time when *Bantariella* sp. was attached to the whole colony scatteredly, but the removal is necessary to prevent partial death when *Bantariella* sp. was attached on small part of the colony densely. The most successful effect by removal was appeared in colonies of initial invasion rates, 30 ~ 70%. In case of colonies with initial invasion rates of 0 ~ 30%, *Bantariella* sp. naturally disappears with passage of time and does no harm to the colonies. So it is not necessary to remove. *Bantariella* sp. is found on the complete dead black corals, but the *C. riisei*, alien species in Hawaii, is known to keep away from dead black corals (Kahng and Grigg 2005).

4) Correlation between seawater temperature and invasion rates

Colonies which have the same initial invasion rate show that similar patterns in a change of invasion rate as time goes on. As a result of monitoring leaving colonies as a control group for clear understanding, the change of invasion rate is in inverse proportion to seawater temperature (Fig. 7). In the middle of March, the seawater temperature went down to the lowest point around 14°C, it may lead to the highest invasion rates by *Bantariella* sp..

On the basis of seasonal limitation, the change of *Bantariella* sp. was looked over from Nov. 2005 to Nov. 2006. As the seawater temperature hit the peak point during

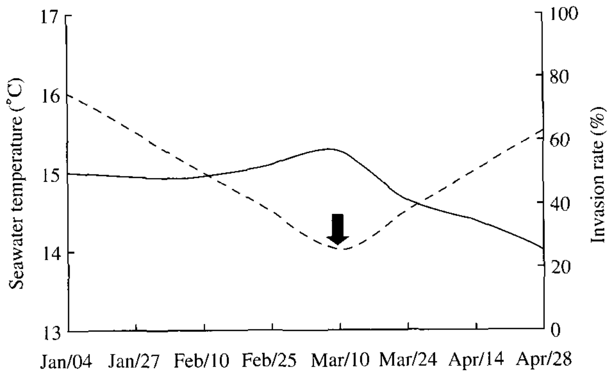

Fig. 7. Correlation between seawater temperature and invasion rates (dotted line: seawater temperature (°C), solid line: invasion rate, arrow: the lowest seawater temperature).

summer and started falling down to 24°C in Sep. 2006, *Bantariella* sp. begun to increase gradually. And it eventually reached its peak in the middle of October covering whole colonies of black corals in November with partly dead colonies on excessively invaded parts.

This observation ensures that *Bantariella* sp. starts increasing at the middle of September when the seawater temperature begins to fall down from its highest, following the highest invasion rates by *Bantariella* sp. in the middle of March and starts disappearing naturally in spring when the seawater temperature goes up. However, it does not disappear completely during summer season and increases again in autumn. Therefore, it seems that it is proper to remove *Bantariella* sp. in October, before *Bantariella* sp. increasing dramatically.

This relationship with seawater temperature would be known through the study for life cycle of *Bantariella* sp. later. Based on such evidence, it suggests that the propagation of *Bantariella* sp. is closely related to the seawater temperature in a seasonal manner.

There are some reports saying the seawater temperature influences the biological invasion regardless of season. Black coral colonies inhabiting in relatively greater depths than those in shallow water are known that they are easy to be impacted by adhesion of sponges, oysters, bryozoans since colder temperature get them grow steadily (Kahng and Grigg 2005).

Also, an alien bryozoan, *Bantariella* sp. prefers to settle down on the injured or dead parts of some black coral colonies and it shows maximum invasion rates in the middle of March. After that, *Bantariella* sp. was affected by filiform diatoms which used to be propagated excessively in spring, and also this phenomenon limitedly occurred at the depth of less than 23 m. It is known that diatoms can be played an important role as bryozoan epibionts (Wuchter *et al.* 2003). However, such relationship between diatom and bryozoan was yet not fully investigated and would need continuing study.

Table 2. Parameter estimates by Linear regression analysis

Variable	B	S.E.	t	P-value
(constant)	105.359	18.531	5.686	0.000
Species	−20.633	3.799	−5.43	0.000*
Depth	2.455	2.756	0.891	0.374
Initial invasion rates	0.513	0.053	9.674	0.000*
Seawater temperature	−5.851	1.174	−4.984	0.000*

Dependent variable: change of invasion rates, B: Regression coefficient, S.E.: Standard error, t: t-statistic, *P-value <0.05: statistically significant

5) Statistical analysis of the environmental parameters

Physical and environmental data were analyzed using a linear regression model (Table 2). Under the given outcome, the three among the four variables influenced the change of invasion rates by *Bantariella* sp. and they are species, initial invasion rates and seawater temperature.

Species on the change of invasion rates was highly significant (p-value <0.01). It indicates the difference of two host species is obviously related to the observed result. On the other hand, the depth of habitat seemed not to be statistically significant (p-value >0.05), consequently this is not that much important factor. The initial invasion rates also show high significance (p-value <0.01) upon the change of invasion rates. Especially it brought up a number of interesting effects on each initial invasion rate. Finally, the linear regression relationship between the change of invasion rates and the seawater temperature demonstrates that the propagation of *Bantariella* sp. is significantly (p-value <0.01) correlated with the environmental variable.

A statistical analysis reveals that all factors except for the depth of habitat significantly affect the change of invasion rates. Correlation of this model is $R^2=0.843$ and p-value <0.01. Therefore, the estimated model meets the experimental data.

CONCLUSION

Considering the result of this study, the increasing and decreasing of *Bantariella* sp. in natural condition is closely related to the change of seawater temperature. And this biological invasion can be directly influenced by environmental condition. As the seawater temperature goes down in September, *Bantariella* sp. begins to increase and eventually over proliferate in November and start decreasing in March, therefore, it seems that it is proper to remove *Bantariella* sp. in October, before the *Bantariella* sp. increases dramatically. Besides, the difference of external feature in terms of host species influences adhesion of *Bantariella* sp. and most likely, the appearance of colonies could be the most important factor in the change of invasion and recovery rates. Hence *A. japonica* might be harder than *A. lata* to conserve the species.

Likewise, providing both removal methods and the proper time of *Bantariella* sp. in terms of host species it could contribute to the conservation and restoration of black corals at Munseom by minimizing the impact. But we should continuously study that life cycle of *Bantariella* sp., and keep trying to identify the root cause of black coral's death and the changes of marine environments which influence to black corals directly or indirectly.

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REFERENCES

Coles SL, RC Defelice, LG Eldredge and JT Carlton. 1999. Historical and recent introductions of non-indigenous marine species into Pearl Harbor, Oahu, Hawaiian Islands. Mar. Biol. 135:147-158.

Grigg RW. 2004. Harvesting impacts and invasion by alien species decrease estimates of black coral yield off Maui, Hawaii. Pacific Sci. 58:1-6.

Kahng SE and RW Grigg. 2005. Impact of an alien octocoral, *Carijoa riisei*, on black corals in Hawaii. Coral Reefs. 24:556-562.

Kang DH, JI Song and KS Choi. 2005. Image analysis of typhoon impacts on soft coral community at Munseom in Jeju, Korea. Ocean Polar Res. 27:25-34.

Kelmo F, MJ Attrill, CT Rilza, Gomes and MB Jones. 2004. El Nino induced local extinction of coral reef bryozoan species from Northern Bahia, Brazil. Biol. Conserv. 118:609-617.

Laura FR. 2006. Can invasive species facilitate native species? Evidence of how, when, and why these impacts occur. Biol. Invasions 8:927-939.

Song JI. 1987. A systematic study on the Korean Anthozoa 10. Antipatharia (Haxacorallia). Korean J. Syst. Zool. 3:63-73.

Song JI, SH Kim and KS Choi. 2006. Ecological environment of corals (class Anthozoa) in relation to the establishment of South Breakwater in the natural protected area of Natural Monument No. 421. Research Report. Seogwipo City. pp. 107 (in Korean).

Wuchter C, J Marquardt and WE Krumbein. 2003. The epizoic diatom community on four bryozoan species from Helgoland (German Bight, North Sea). Helgol. Mar. Res. 57:13-19.

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