The Thermal Effects on the Mortalities in Several Marine Invertebrates in the Air

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海產 無脊椎動物의 致死率에 對한 溫度의 影響

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摘　　要

本 實驗은 몇가지 海產 無脊椎動物, *Crassostrea gigas* (THUNBERG), *Musculus senhousia* (BENSON), *Adula atrata* (LISCHKE), *Littorina brevicula* (PHILIPPI) 그리고 *Balanus amphitrite communis* (DARWIN)의 致死率에 對한 溫度의 影響을 밝히고저 實施한 것이다.

1. 溫度 35°C 와 −5°C 는 上記한 五種의 動物에 對하여 致命的이 아니었다.
2. 本 實驗에서 五種의 致死率은 −20°C 에서 가장 높았다.
3. 同一 溫度일 경우 水中에서 보다는 空氣 中에서 굴의 生存能力이 더 높았다.
4. 溫度가 매우 높거나 낮지 않더라도 反復해서 處理하는 것은 海產 動物에 보다 致命的인 影響을 준다. 그 理由는 그들이 먼저번의 傷害를 회복할만한 充分한 時間을 가질 수 없기 때문이다.
5. *M. senhousia* 는 처음에는 *B. amphitrite* 보다 抵抗力이 强하지만 다음에는 *B. amphitrite* 보다 빨리 抵抗力을 잃는다.
6. 本 實驗에서 얻은 致死率의 系列은 다음과 같다.

M. senhousia〉 *B. amphitrite*〉 *C. gigas*〉 *L. brevicula*〉 *A. atrata*.

INTRODUCTION

It is well known that higher and lower lethal temperatures are important factors on the mortality of animals, especially on that of aquatic forms. The ability of organisms to be acclimated to seasonal changes of temperature or to new conditions is considered as an economical problem. When the seed-animals of oysters or clams are transplanted from one place to another or when they are exposed in the air by the ebb and flow, the influence of thermal changes reveals increasing mortality of them.

Henderson (1929) reported that 48.5°C is lethal temperature for oysters. Davis (1955) pointed out that the *Olympia* oysters left in tank during winter showed 100 per cent mortality at −0.7°C. Fingerman and Fairbanks (1957) showed that 50 per cent of oysters, *Crassostrea virginica*, were killed in 117 minutes at 42°C; 50 per cent mortality in 25 mintues at 45°C and complete mortality occurred with additional 5 minutes at 45°C of water temperature.

It has been found that young and adult bivalves, *Tapes philippinarum*, lost ability to regulate the metabolism at temperatures higher or lower than at normal temperatures by studying ciliary activity (Choi and Lee, 1961). Several investigators studied on the thermsl effects upon bivalves but there are few reports on the other marine invertebrates.

It happened that we observed some of *Musculus senhousia* died at below zero 12°C of air temperature at Inchon Bay in 1964. This led to our research on the thermal effects on mortality of several invertebrates.

MATERIALS and METHODS

The materials used in this experiment were *Crassostrea gigas* (THUNBURG), *Musculus (Musculista) senhousia* (BENSON), *Adula atrata* (LISCHKE), *Littorina brevicula* (PHILIPPI) and *Balanus amphitrite communis* (DARWIN), which were attached on rocks on intertidal zone. They were collected from intertidal zone at Wolmi Island, Inchon Bay, Korea, during the low ebb, and brought to the laboratory in Seoul. Fresh materials were maintained in aquaria containing sea water filtered and aerated. Sea water was changed once a day during the work.

Each species of sample animals were divided into 23 groups which composed of 20 to 33 animals. In the first series of higher thermal experiments, 15 groups of each species were exposed to higher temperatures of 35°C, 40°C and 45°C in the air for 1/2, 1, 2, 4 and 6 hours respectively in the incubators (Table 1). In the second series of lower one, 4 groups of eash species were treated by the temperatures of —5°C, —12°C, —15°C and —20°C in the air for 2 hours a day in the refrigerators (Table 1). Each treatment was repeated with the same temperature once a day for 5 days. After treatment all samples were transferred into aquaria filled with fresh sea water. The temperature of laboratory was approximately 10°C.

The mortality rate was determined in the following morning by the per centage of dead animals to the total samples.

Table 1. Interrelations in species, animal groups, different temperature degrees and regular intervals during the treatment. A group, small squares numbered, was treated with the same codnition every day.

Temp. °C / Time in hours / Species	First Day (First Treatment)																						
	35±1						40±1						45±1							-5	-12	-15	-20
	Control	1/2	1	2	4	6	Control	1/2	1	2	4	6	Control	1/2	1	2	4	6	Control	2	2	2	2
C. gigas	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
M. senhousia	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A. atrata	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
L. brevicula	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
B. amphitrite	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

RESULTS

The mortalities of 5 species treated with 35°C temperature are shown in Fig. 1—A,B,C,D and E. In Fig. 1—A, all of *C. gigas, M. senhousia A. atrata* and *L. brevicula* survived after first treatment, but *B. amphitrite communis* registered the mortality rate of 45.5 per cent by the first 6-hour treatment. Throughout 2nd, 3rd and 4th treatments, mortalities of *M. senhousia* and *B. amphitrite* were increased gradually up to 75 per cent (Fig. 1—B, C and D). Mortalities of *M. senhousia* and *B. amphitrite* were 100 per cent and 90.9 per cent respectively at the 5th 6-hour treatment (Fig. 1-E), but all of *A. atrata* and *L. brevicula* survived in all treatments through these experiments (Fig. 1-A, B, C, D and E).

In the groups treated with 40°C temperature, mortalities increased apparently (Fig. 2-A, B, C, D and E). All of *M. senhousia* were killed by the 2nd 4-hour treatment (Fig. 2-B), and all groups of 5 species showed from 62 per cent to 100 per cent of mortalities at the 5th 6-hour treatment (Fig. 2-E). When *M. senhousia* were exposed to 40°C temperature, they showed more higher resistabilities than *B. amphitrite* at 2nd, 3rd, 4th and 5th 2-hour treatment, but their resistabilities decreased than *B. amphitrite* by 2nd, 3rd, 4th and 5th 4-hour treatments (Fig. 2-B, C, D and E). Animals of all species began to die after 3rd treatment at 40°C (Fig. 2-C, D and E).

As shown in Fig. 3-A, B, C, D and E), mortalities of *M. senhousia* and *B. amphitrite* were 100 per cent by 2-hour treament and 81.3 per cent by 6-hour treatment respecitively at the first treatment of 45°C (Fig. 3-A), and that of all species extremely increased by 4th and 5th treatments (Fig. 3-D and E). It is interesting to know that all five species showed 100 per cent mortalities after 4th treatment at 45°C (Fig. 3-D), and that the curves of mortality moved to left side, especially in *M. senhousia* and *B. amphitrite* (Fig. 3-D and E). There are quite similar results between Fig 1 and 2. *M. senhousia* was stronger than *B. amphitrite* at 1/2-hour treatment, but *M. senhousia* showed greater mortality than *B. amphitrite* after 1-hour treatment (Fig. 3-A, B, C, D and E).

Effects of lower temperatures on the mortality of sample animals are similar to those of higher one. *C. gigas, M. senhousia, A. atrata* and *L. brevicula* were not greatly affected by the cold treatment of -5°C except 5 per cent of mortality of *B. amphitrite* (Fig. 4-A). *B. amphitrite* showed greater mortality than other 4 species at -5°C at the higher treatment.

The mortalities of *M. senhousia* and *B. amphitrite* were 100 per cent and 95.5 per cent at first 2-hour treatment of -12°C, but *C. gigas, A. atrata* and *L. brevicula* showed only about 20 per cent mortality by 2nd treatment, and 41 to 99 per cent mortalities by 4th treatment of -12°C (Fig. 4-B).

The mortalities of all species increased extremely at -15°C and -20°C (Fig. 4-C and D). When samples of 5 species

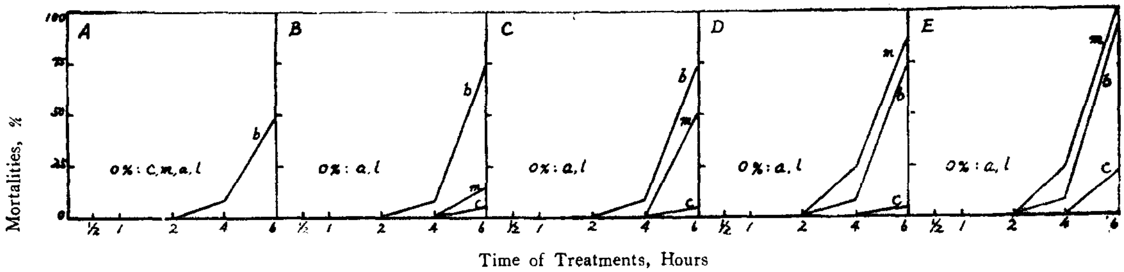

Fig 1. Relations of the mortalities to the time of treatments and the regular intervals in five marine species exposed in the air at 35°C

SYMBOLS: Materials: c, *C. gigas;* m, *M. senhousia;* a, *A. atrata;* l, *L. brevicula;* b, *B. amphitrite* (through all figures). Treatments: A, First; B, 2nd; C, 3rd; D, 4th and E, 5th treatment (in Fig. 1, 2 and 3).

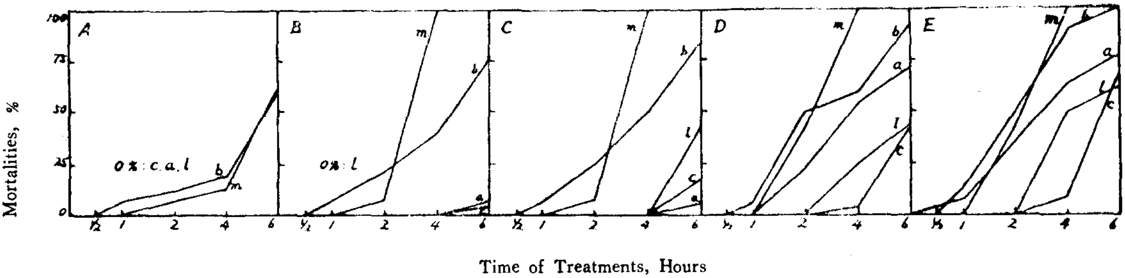

Fig. 2. Relations of the mortalities to the time of treatments and the regular intervals in five marine species exposed in the air at 40°C.

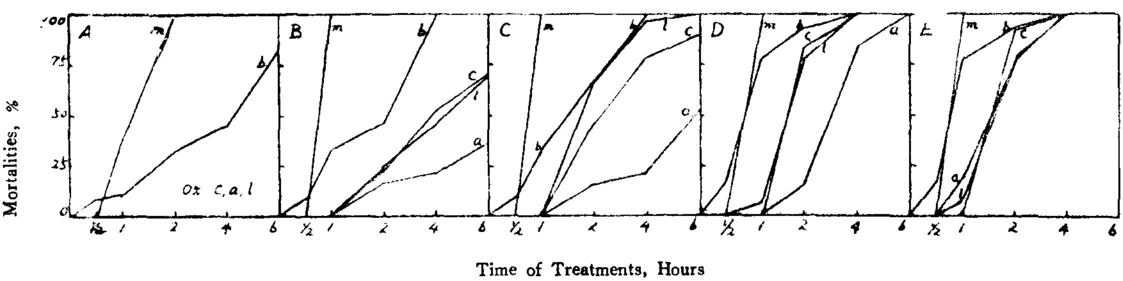

Fig. 3. Relations of the mortalities of the time of treatments and the regular intervals in five marine species exposed in the air at 45°C.

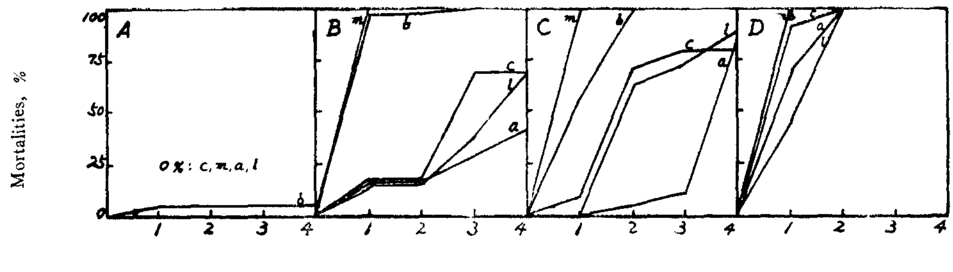

Fig. 4. Relations of the mortalities to the regular intervals in five marine species exposed in the air at -5°C, A; -12°C, B; -15°C, C; -20°C, D.

were exposed to -20°C in the air, all of *M. senhousia* and *B. amphitrite* were killed at first 2-hour treatment, and all sample animals of 5 species including *M. senhousia* and *B. amphitrite* were killed completely at the 2nd treatment (Fig. 4-D).

DISCUSSION

C. gigas, *A. atrata* and *L. brevicula* except *M. senhousia* and *B. amphitrite* were not greatly affected by 6-hour treatment of 35°C. This is similar to the results of *C. virginica* by Fingerman and Fairbanks (1957).

They also reported that 29 per cent of oysters immersed into water of 40°C for hours died. However, all samples of oysters exposed in the air of 40°C were not killed by the 3rd 4-hour treatment in this work. From these facts, it is considered that the oysters have a greater viability in the air than under water of the same temperature.

The mortality of *M. senhousia* was lower than that of *B. amphitrite* at the 2nd, 3rd, 4th and 5th 2-hour treatments of 40°C, and higher than *B. amphitrite* at the every 4-hour treatment. That is, the mortality curves of them crossed between the 2- and 4-hour treatments. This cross means that *M. senhousia* has more stronger tolerance than *B. amphitrite* when they are exposed in the air for a short time less than 2 hours. However, the tolerance of *M. senhousia* did not show higher resistability than *B. amphitrite* at the long exposure.

At the 45°C, the mortality curves of all species were moved to the left side day by day, and that of *M. senhousia* and *B. amphitrite* crossed between the 1/2- and 1-hour treatments (Fig. 3). This means that 45°C temperature is more lethal than 40°C to animals.

The low temperatures, -5°C and -12°C, were not found lethal to 3 species except *M. senhousia* and *B. amphitrite*, when they were treated for 2 hours a day in the air (Fig. 4-A and B). But Davis (1955) reported that 100 per cent of oysters were killed under water of -0.7°C during winter, and that the mortality was not caused by the tissue starvation because most of oysters died contained a considerable amounts of glycogen. Considering these facts, it is recognized that the immersion into water is more injurious to them than when they were exposed to the air.

From the Fig. 4-B of -12°C, it is apparent that the viability of *C. gigas*, *A. atrata* and *L. brevicula* are greater than that of *M. senhousia* and *B. amphirite*, therefore they can be divided into two groups, the strong; *C. gigas*, *A. atrata* and *L. brevicula*, and the weak; *M. senhousia*, *B. amphitrite*.

The authores observed some of dead *M. senhousia* animals attached on rocks, and obtained average 20.9 per cent mortality at Wolmi Island, Inchon Bay in February 1965. The temperature on the island at the time was -7°C highest -13.4°C lowest. This is an interesting datum in comparison with the experimental results.

The temperature of -15°C and -20°C under which laboratory treatments were made were found too low for all species to survive, even when they were exposed for only 2 hours a day (Fig 4-C and D).

It is true that the repetitious treatments are very injurious to marine animals of all five species because they can not have enough time for recovery from the injury of former treatment.

The authores obtained the order of mortality; *M. senhousia*> *B. amphitrite*> *C. gigas*> *L. brevicula*> *A. atrata*.

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SUMMARY

The experiment was performed to elucidate the thermal effects on mortality in several marine invertebrates, *Crassostrea gigas* (THUNBERG), *Musculus senhousia* (BENSON), *Adula atrata* (LISCHKE), *Littorina brevicula* (PHILIPPI) and *Balanus amphitrite communis* (DARWIN), in the air.

1. Tempertures of 35°C and -5°C were not lethal for all of five species.
2. The mortalities of five species were highest at -20°C in this survey.
3. It is found that the viability of oysters is higher in the air than under water of the same temperatures.
4. The repetitious treatments are very lethal to marine invertebrates, even if the temperature is neither the highest nor the lowest. This is because they can not have enough time for recovery from the injury of former treatment.
5. *M. senhousia* have higher tolerance than *B. amphitrite* at first, but *M. senhousia* lose their tolerance faster than *B. amphitrite*.
6. The following is the order of mortalities obtained: *M. senhousia*> *B. amphitrite*> *C. gigas*> *L. brevicula*> *A. atrata*.

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