Studies on the Relationship Between the Respiration and the Changes in Salinity in Some Marine Plants in Japan*

By

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Notwithstanding the fact that many works have been done on the respiration of marine algae affected by salinity change, some disagreements among the results, for instance, those obtained by INMAN (1921), FROMAGEOT (1923), HOFFMANN (1929) and OGATA (1963) remained unsettled. HOFFMANN (1929) first advocated that several algal species would be divided into two groups from view point of the changes in respiration with changes in salinity by his precise investigation : One group showed no remarkable change in respiration rate with salinity change, and on the other hand, the other group showed considerably increased respiration with decreased salinity. According to his opinion, *Enteromorpha*, *Fucus vesiculosus*, and *Porphra laciniata* belong to the former group, but *Fucus serratus* and *Laminaria digitata* to the latter. Although the respiratory trend of *Enteromorpha* obtained by HOFFMANN (1929) was similar to that in *Ulva* by FROMAGEOT (1923), INMAN (1921) had formerly found that the rate of carbon dioxide output of the respiration in *Ulva* and *Laminaria* were always suppressed by hypo- and hypertonicity of artificial sea water.

By manometric technique, OGATA (1963) recently worked the respiration of *Porphyra tenera*, economically important species in Japan, with salinity change, and found that the respiration increased in diluted sea water to half strength, and decreased under extreme hypo- and hypertonic conditions, and that it steadly increased with rising temperature up to 30°C irrespective of salinity change.

In order to avoid such confusion as mentioned above, the following work was undertaken to substantiate the changes in the respiration rate with changes in tonicity under more strict conditions.

The experimental materials were obtained from coastal zone in Japan and some marine higher plants such as *Zostera marina* were also chosen, because they are sometimes exposed to a drastic change in salinity by heavy rainfall in rainy season. We have carefully chosen and treated the samples. For the measurement of respiration rate, Warburg's manometric method was used as previously mentioned by OGATA

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(1963), because one of the causes of disagreement of the data obtained by each of workers was attributed to the different techniques to determine the respiration rate.

Materials and Methods

Fresh materials of more than 10 species of marine plants growing in the coastal region near Shimonoseki in Japan, were used.

Name of material in two series of experiment in 1958 and 1963 is arranged systematically in Tables 1 and 3, as green, brown, and marine or fresh water phanerogams.

Table 1. Names of materials arranged systematically and experimental conditions in the experimental series in 1958.

No.	Date	Species	Classification	Fresh wt. in mg for experimental use	Bath-temperature	Qo_2 in normal sea water
1	June, 13	*Ulva pertusa*	Chlorophyta	300	30	3.54
2	〃 19	*Undaria pinnatifida*	Phaeophyta	500	〃	1.45
3	〃 19	*Sargassum thunbergii*	〃	〃	〃	1.59
4	〃 6	*Gloiopeltis furcata*	Rhodophyta	〃	〃	1.16
5	〃 11	*Gracilaria verrucosa*	〃	〃	〃	1.60
6	〃 19	*Gloiopeltis tenax*	〃	〃	〃	0.86
7	July, 10	*Ceramium* sp.	〃	300	〃	—
8a	〃 28	*Polysiphonia urceolata*	〃	500	〃	—
8b	〃 30	〃 〃	〃	300	〃	—
9a	〃 9	*Zostera marina*	Angiospermae	500	〃	1.89
9b	〃 19	〃 〃	〃	〃	〃	2.47
10	〃 19	*Zostera nana*	〃	300	〃	3.70
11	Aug., 6	*Ulva pertusa*	Chlorophyta	〃	〃	2.57
12	July, 28	*Polysiphonia urceolata*	Rhodophyta	〃	〃	—

Table 2. The chlorinity at various concentration of sea water as experimental medium in the experimental series in 1958.

Concentration of sea water	1/8	1/4	1/2	1	2
Chlorinity in ‰	2.76	5.14	11.44	21.37	38.80
pH	7.0	7.2	7.4	7.7	7.6

Hypotonic and hypertonic media were made by diluting the natural sea water with distilled water or by evaporating it to one-half or two-thirds of original volume, respectively. Solutions of diluted or concentraed sea water were designated as 0

(zero), 1/8, 1/4, 1/2, 3/4, or 3/2, 2 and so on, respectively. After the preparation of medium at a given concentration, all media were once boiled to sterilize. The concentrations of such prepared media and their chlorinities are presented in Tables 2 and 4, respectively.

Fresh plant materials were all collected from their habitats just before experimental use, and were brought into the reaction flasks containing a media at a given concentration, and after quick treatments of sweeping off the water on the surface of material, cutting into several pieces and weighing were made.

To determine the respiration rate by means of the ordinary manometric technique in darkness (UMBREIT et al, 1957) readings were taken for one hour after 15-min. pre-shaking at the bath-temperature in Tables 1 and 3. The endogenous oxygen

Table 3. Names of materials arranged systematically and experimental conditions in the experimental series in 1963.

No.	Date	Species	Classification	Fresh wt. in mg for experimental use	Bath-temperature	Qo_2 in normal sea water
13	June, 29	*Ulva pertusa*	Chlorophyta	100	25	2.57
14	July, 7	*Enteromorpha linza*	〃	〃	〃	2.50
15	〃 7	*Sargassum thunbergii*	Phaeophyta	300	〃	1.58
16	〃 10	*Ishige okamurai*	〃	〃	〃	0.75
17	June, 24	*Gracilaria verrucosa*	Rhodophyta	〃	〃	1.18
18	〃 25	*Gloiopeltis tenax*	〃	〃	〃	0.58
19	July, 21	*Gelidium amansii*	〃	200	〃	1.99
20	〃 7	*Laurencia okamurai*	〃	300	〃	1.28
21	〃 3	*Zostera marina*	Angiospermae	〃	〃	1.07
22	〃 2	*Zostera nana*	〃	〃	〃	1.53
23a	〃 23	*Potamogeton crispus*	〃	200	27	2.35
23b	〃 24	*Ceratophyllum demersum*	〃	〃	〃	1.76

Table 4. The chlorinity at various concentration of sea water as experimental medium in the experimental series in 1963.

Concentration of sea water	(1/8)*	1/4	1/2	3/4	1	3/2	2
Chlorinity in ‰	(2.58)*	5.79	10.36	14.84	19.79	27.90	36.30

* Only used in the case with fresh water phanerogams

uptake was expressed as μl/net fresh weight·hour in the early series in 1958, but as μl/mg dry wt. hour (Qo_2) in the latter case in 1963.

In order to estimate the resistibility of samples to salinity change for somewhat prolonged period after the pre-acclimatization which was prepared by pre-immersion to different media at a respecitive concentration for 24 hours, the respiration was

also examined in normal sea water.

Results

I. Respiration in the drastic salinity change

The results obtained under the experimental condition, as shown in Tables 1 and 2, are presented in Figs 1~12.

In *Ulva pertusa*, two layered leafy green alga, the respiration was slightly enhanced at 1/2 sea water, and then reduced gradually with decrease in concentration of medium as seen in Fig. 1. Hypertonic medium suppressed the respiration to some extent.

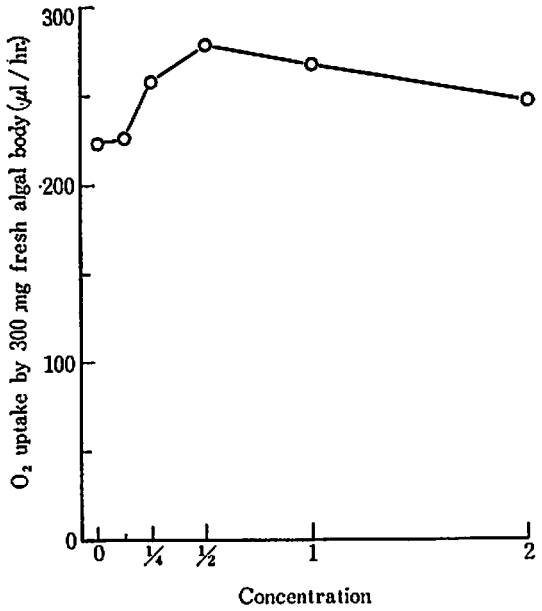

Fig. 1. Respiration rate of *Ulva pertusa* affected by hypo- and hypertonicity of sea water.

Respiration rate of brown alga *Undaria pinnatifida*, useful seaweed as food in Japan, at 1/2 concentration was, however, scarcely enhanced as seen in Fig. 2, and it was more remarkably suppressed than in the case of the former sepcies in more dilutied medium.

Respiration rate of *Sargassum thunbergii*, thick brown alga, was gradualy suppressed in both sides of hypo- and hypertonic conditions as presented in Fig. 3.

Somewhat particular trend was found in the case of a red alga *Gloiopeltis furcata*

as presented in Fig. 4. Hypotonicity gradually made to increase the respiration rate with somewhat remarkable enhancement at 1/8 concentration. Extreme hypotonicity, namely 0 (zero) concentration, however, rapidly suppressed the rate.

A similar trend to the above case was also observed in a parenchymatous red alga *Gracilaria verrucosa* which is an important material as the source of agar industry. The enhancement of respiration rate in hypotonicity was, however, not so remarkable as in the above species, but in hypertonicity it was also suppressed as presented in Fig. 5.

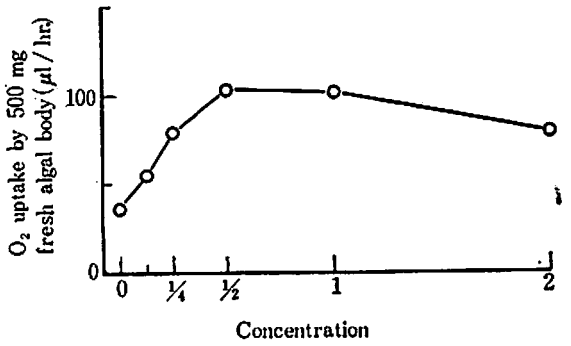

Fig. 2. Respiration rate of *Undaria pinnatifida* affected by hypo- and hypertonicity of sea water.

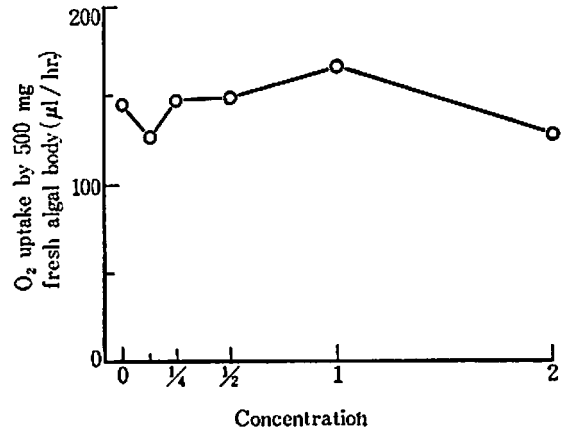

Fig. 3. Respiration rate of *Sargassum thunbergii* affected by hypo- and hypertonicity of sea water.

In *Gloiopeltis tenax*, (Fig. 6) no remarkable changes in the respiratory rate with changes in tonicity of medium was found with rather broad plateau regardless of systematic proximity to *G. furcata* (Fig.4).

The respiration rate of a red alga *Ceramium* sp. having the fine and delicate thallus structure, was very sensitive to changes in the environmental tonicity, especially in hypotonicity as seen in Fig. 7. In an extreme hypotonicity as pure water, a part of cells appeared to be damaged by significance of red-coloured clute from the cells into medium, and the respiration rate was suppressed to about one-half of it in normal sea water.

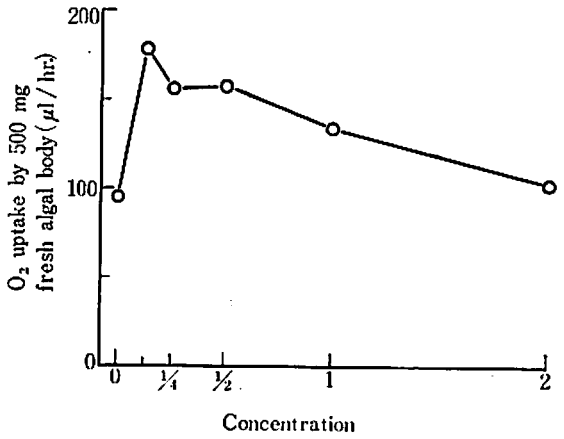

Fig. 4. Respiration rate of *Gloiopeltis furcata* affected by hypo- and hypertonicity of sea water.

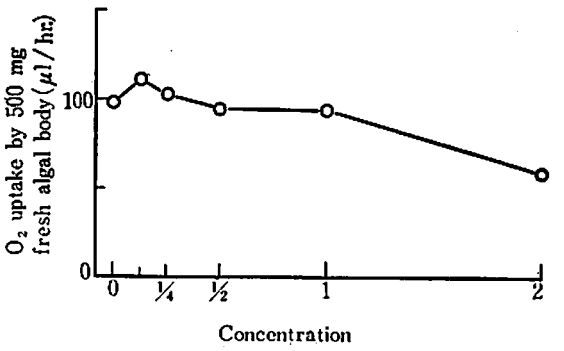

Fig. 5. Respiration rate of *Gracilaria verrucosa* affected by hypo- and hypertonicity of sea water.

In the case of a red alga *Polysiphonia urceolata* which is the most delicate among examined ones, two separated estimations were made in the materials with each 300 and 500 mg fresh weight. It was clearly indicated that this species was the most sensitive to hypotonicity. The respiration in more than 1/4 diluted medium was

completely suppressed and the tissue came to bleach lethally. In two separated examinations, however, the results of the respiration rate somewhat differed from each other. The rate obtained at 1/2 concentration was greater than that in normal

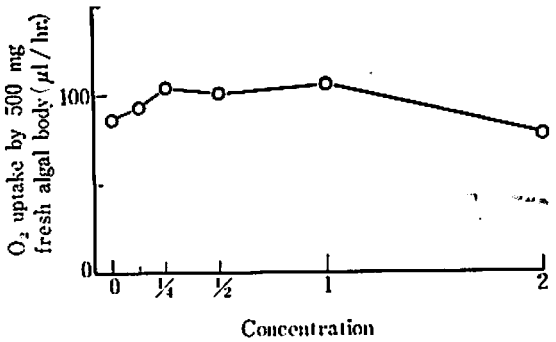

Fig. 6. Respiration rate of *Gloiopeltis tenax* affected by hypo- and hypertonicity of sea water.

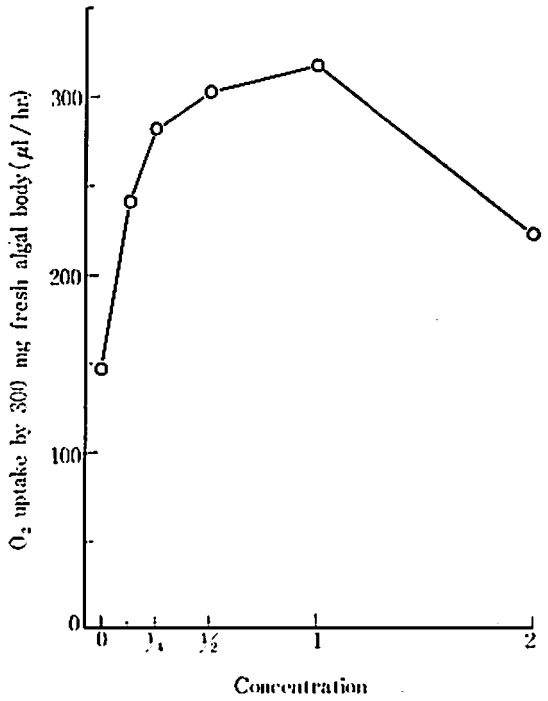

Fig. 7. Respiration rate of *Ceramium* sp. affected by hypo- and hypertonicity of sea water.

medium (open circles), but on the other hand it was lessend (closed circles), as presented in Fig. 8.

On marine phanerogam *Zostera marina*, two lots of result obtained under the entirely identical condition in separated experiments were essentially identical with each other as seen in Fig. 9.

The rate of respiration was enhanced more or less at 1/2 concentration in both cases, and the somewhat significant depression was observed in hypertonicity such as 2-fold concentration.

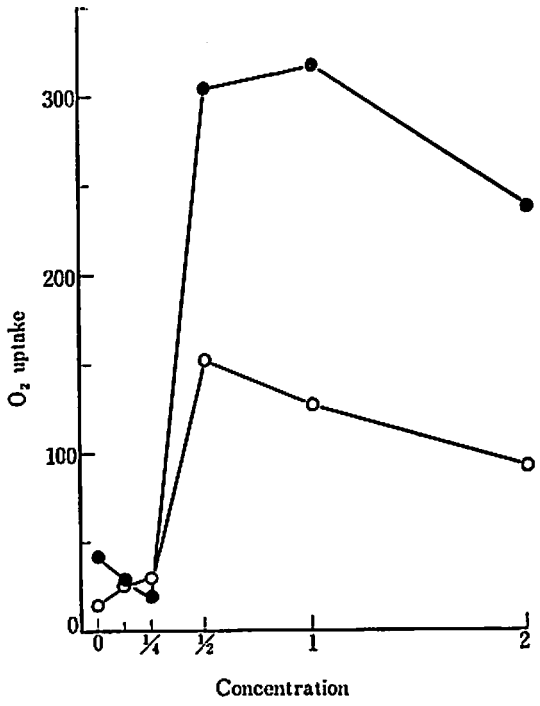

Fig. 8. Respiration rate of *Polysiphonia urceolata* affected by hypo- and hypertonicity of sea water. Two sets of measurements with different raw weights, 300 mg (open circles) and 500 mg (closed circles) are presented.

The similar sensitivity to hypertonicity was also found in the case of *Zostera nana* which is another common marine phanerogam in Japan, but the enhanced rate in hypotonicity was not found (Fig. 10).

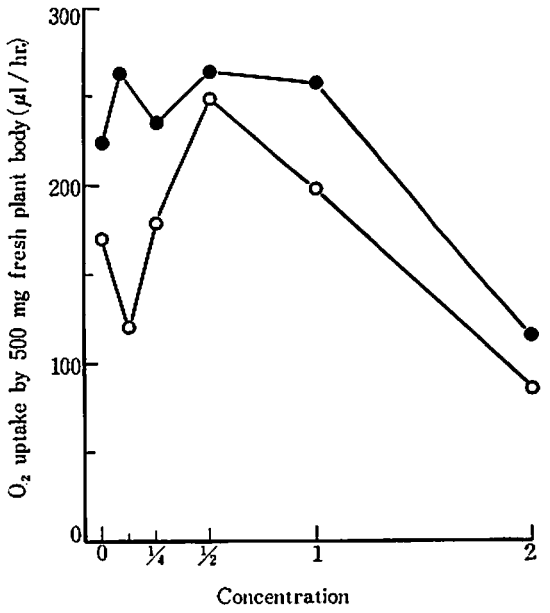

Fig. 9. Respiration rate of *Zostera marina* affected by hypo- and hypertonicity of sea water. Two sets of measurements at different date were presented.

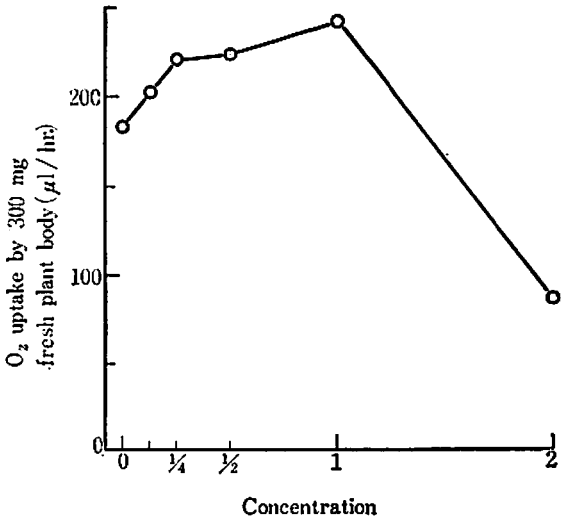

Fig. 10. Respiration rate of *Zostera nana* affected by hypo- and hypertonicity of sea water.

II. Respiration rate affected by the prolonged immersion period under hypo- and hypertonicity.

After immersing the sample in hypo- or hypertonic medium for more prolonged period, the subsequent changes in respiration rate were examined. The materials were immersed in 1/2 or 2-fold concentrated media during 1, 2, and 3 hours before the determination of respiration rate.

Ulva pertusa indicated rather lower sensitivity at both sides of hypo- or hypertonicity, and the rates in 1/2 (open circles in Fig. 11) and in 2 sea water (closed circles in Fig. 11) were kept almost unchangeable after the pre-imersion in the respective medium for 1 hour, but the rate was enhanced in the sample acclimatized to 1/2 sea water for 2 hours, and the more prolonged acclimatization for 3 hours remarkably suppressed in both hypo- and hypertonicities.

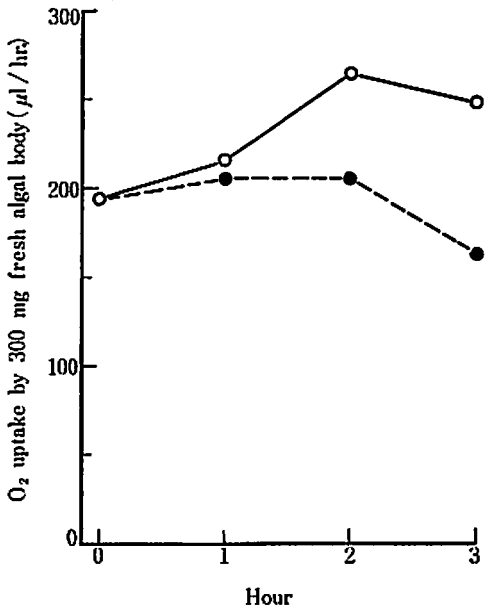

Fig. 11. Respiration rate of *Ulva pertusa* affected by duration of pre-immersion in hypo- and hypertonicity of sea water. Open circles : 1/2 concentration, closed circles : 2.0 concentration.

A sensitive rate of red alga *Polysiphonia urceolata* came to be enhanced or suppressed by only 1-hour pre-immersion under hypo- (open circles) or hypertonicities (closed circles) respectively, as shown in Fig. 12 and the once elevated rate came to be suppressed in hypotonicity by only 2-hour pre-immersion.

The varied grade of the respiratory rate of *Polysiphonia* with 1 hour pre-immersion under hypo- and hypertonicities coincided with those in respective medium presented by each curve with open circles in Fig. 8. Q_{O_2} values in normal sea water obtained in each species are also presented in Table 1.

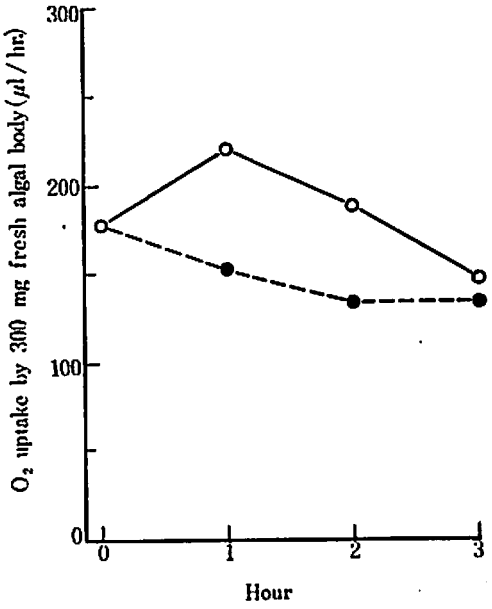

Fig. 12. Respiration rate of *Polysiphonia urceolata* affected by duration of pre-immersion in hypo- and hypertonicity of sea water. Open circles : 1/2 concentration, closed circles : 2.0 concentration.

III. Recovery and resistibility from the depressed respiration by drastic changes in salinity after prolonged pre-acclimatization.

The varied respiration rate by drastic salinity change under the experimental conditions in Table 3 and 4, is expressed as Q_{O_2} on dry weight base instead of fresh weight in the previous experimental series in 1958. The results are shown by solid lines with the open circles in Figs. 13~23.

Resistibility of samples to salinity change after prolonged acclimatization period were shown in terms of the respiration rate in normal medium after pre-immersion for 24 hours into a given concentrated medium (closed circles).

In *Ulva pertusa* in Fig. 13, the respiration was markedly enhanced at 3/4, 1/2 concentrations and then was gradually suppressed at 1/4 and 0 concentrations. These

data did never conflict with those irrespective of some difference from those in hypotonicity in Fig. 1. In the present results, hypertonicity at 3/2 and 2 concentrations increased the rate to some extent.

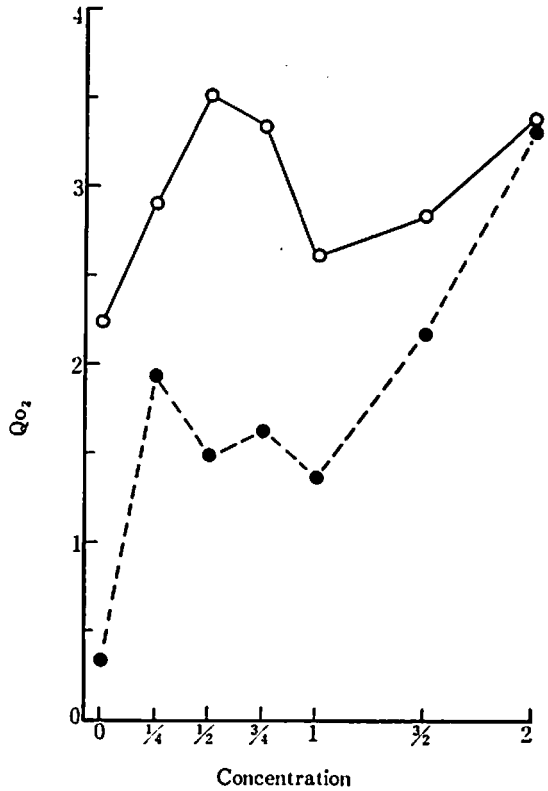

Fig. 13. Respiration rate of *Ulva pertusa* affected by hypo- and hypertonicity of sea water (open circles), and recovery or decrease in respiration rate (resistibility for prolonged salinity change) measured in normal sea water after pre-acclimatization for 24 hours (closed circles).

Rates of respiration in normal medium in *Ulva* were lessened by pre-acclimatization under extreme hypotonicity such as 1~1/4 concentration for 24 hours considerably but the one pretreated at 2 concentration kept almost unchangeable in normal medium as control did. These results are presented by the curve with closed circles in Fig. 13.

Fig. 14 indicated the corresponding results of a green alga *Enteromopha linza* being closely related to *Ulva*. The respiration of this alga was remarkably enhanced at 3/4 and 1/2 concentrations, and was hardly suppressed even at 1/4 and O concentrations.

Hypertonicity suppressed the rate slightly. Transfer of algal body from 24-hour pre-acclimatization at 2 concentration medium to normal one markedly enhanced the rate beyond the one before transfer. Rates affected by pre-acclimatization at 1/2 and 1/4 concentrations were kept almost unchanged, but those in 3/4 and even normal concentrations fell slightly as well as in 0 concentration.

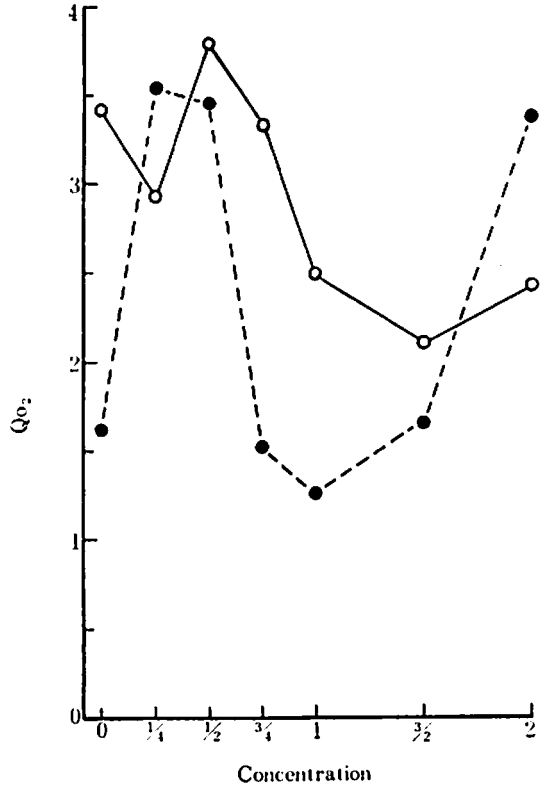

Fig. 14. Respiration rate of *Enteromorpha linza* affected by hypo- and hypertonicity of sea water (open circles), and its recovery or decrease in respiration rate after pre-acclimatization for 24 hours (closed circles).

Although the results of *Sargassum thunbergii* in Fig. 15 may be corresponded to those in Fig. 3, the rate of the respiration was markedly enhanced at some hypotonicity at from 1 to 1/4 concentrations as seen in Fig. 15, without gradual decline as seen in Fig. 3. At this time, the resistibility could not be examined because of damage of a thallus by immersing in the medium for long period.

Rigid brown alga *Ishige okamurai* was slightly affected by hypotonicity with the gradually increased rate of respiration as decreased concentrations.

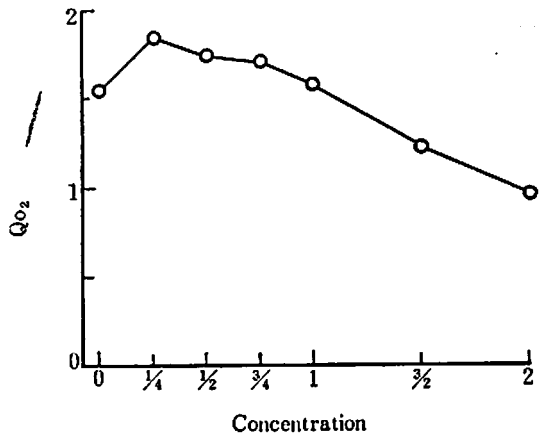

Fig. 15. Respiration rate of *Sargassum thunbergii* affected by hypo- and hypertonicity of sea water.

This alga showed stable resistance to salinity change, hence the examined rate after the prolonged pre-acclimatization period up to 24 hours indicated almost constant rate of respiration as seen in Fig. 16.

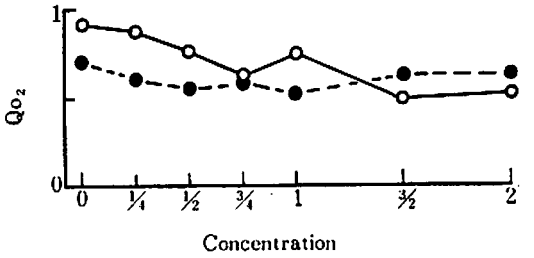

Fig. 16. Respiration rate of *Ishige okamurai* affected by hypo- and hypertonicity of sea water (open circles), and its recovery or decrease in respiration after pre-acclimatization for 24 hours (closed circles).

In a red alga *Gracilaria verrucosa*, the enhancement in hypotonicity was also observed in both present (Fig. 17 open circles) and the former (Fig. 5). The enhancement of the rate at 1/4 concentration in the present series was remarkably higher than in the former case.

The once suppressed rate by pre-acclimatization in hypertonicity rapidly recovered over the rate of control, but once enhanced rate in hypotonicity was depressed still original value at standard concentration and the rate retained in O concentration decreased considerably by returning back the material to standard medium.

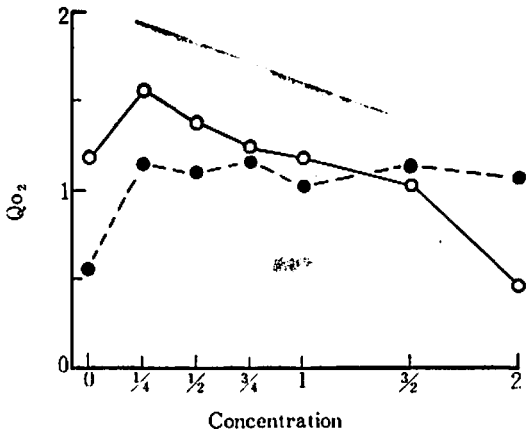

Fig. 17. Respiration rate of *Gracilaria verrucosa* affected by hypo- and hypertonicity of sea water (open circles), and its recovery or decrease in respiration after pre-acclimatization for 24 hours (closed circles).

The data in Fig. 18 corresponds to those in Fig. 6 in a red alga *Gloiopeltis tenax*. Respiration rate affected by drastic change to low salinity was slightly enhanced in the present mesurements (Fig.18, open circles) but was kept almost unchanged in the former case (Fig. 6) with only meagre deviations in both cases. Resistibility of this species after 24 hour pre-acclimatization was weak at low salinity such as 1/4 or 0 concentration as shown by curves with closed circles in Fig. 18.

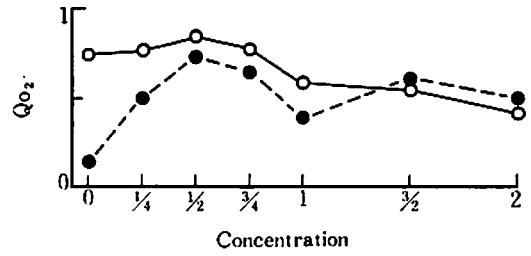

Fig. 18. Respiration rate of *Gloiopeltis tenax* affected by hypo- and hypertonicity of sea water (open circles), and its recovery or decrease in respiration after pre-acclimatization for 24 hours (closed circles).

Deep sea red alga, *Gelidium amansii*, being important material for agar industry, showed rather sensitive to both hypo- and hypertonicities, because, as seen in Fig. 19,

the respiration was markedly increased by hypotonicity, especially at 1/2 concentration, but was markedly suppressed by hypertonicity.

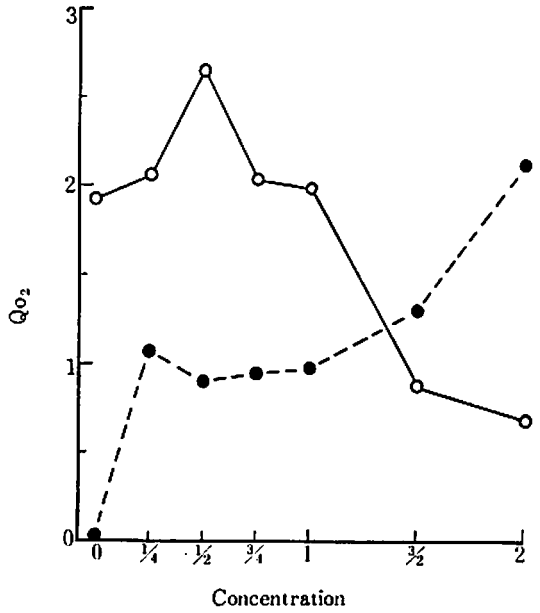

Fig. 19. Respiration rate of *Gelidium amansii* affected by hypo- and hypertonicity of sea water (open circles), and its recovery or decrease in respiration after pre-acclimatization for 24 hours (closed circles).

The resistibility of this species to hypotonicity for long period such as 24 hours was not so strong, and the respiration affected by pre-acclimatization at O concentration was completely undetectable. This species, therefore, was proved to be the most sensitive one to extreme low salinity. On the other hand, once suppressed respiratory rate by pre-immersion in hypertonicity recovered when the samples were transferred from 2 to normal concentration.

Fig. 20 presents the results obtained in *Laurencia okamurai*, which is delicate and fragile red alga. This species reacted sensitively to drastic salinity change and also to prolonged pre-acclimatization in hypotonicity. The respiration rate was tremendously enhanced at 1/2 and 1/4 concentrations, showing maximum at 1/4 concentration.

The rate retained after pretreatment at 1/4 concentration for 24 hours was, however, drastically suppressed, and this became more conspicuous in 0 concentration. Once elvated rate at 1/2 concentration by drastic salinity change was on the other hand, remained almost unchanged even after prolonged pre-acclimatization in

1/2 concentration. According to these results, it clearly proved that this delicate and fragile red alga was most sensitive species among those examined.

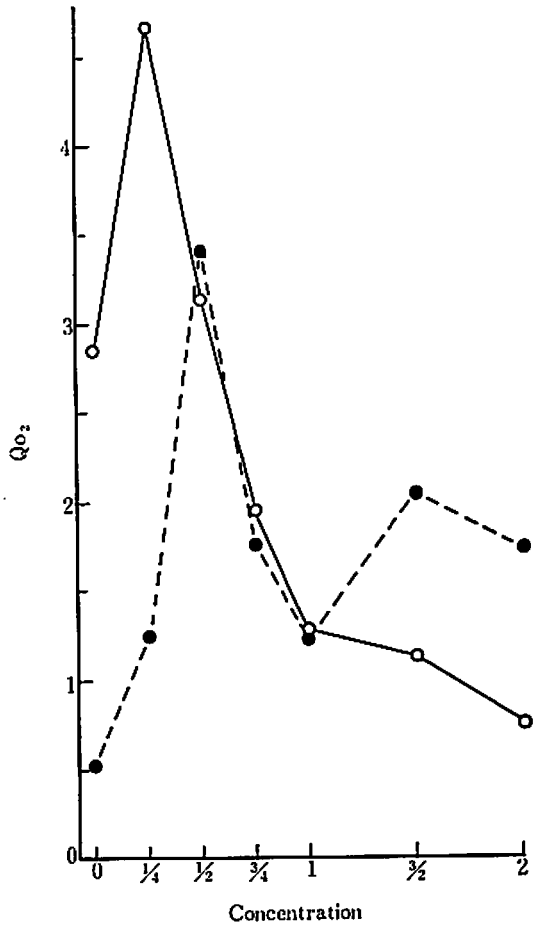

Fig. 20. Respiration rate of *Laurencia okamurai* affected by hypo- and hypertonicity of sea water (open circles), and its recovery or decrease in respiration after pre-acclimatization for 24 hours (closed circles).

Next, the similar rates of respiration of *Zostera marina* which have been shown in Figs. 9 and 21, were found between the data in Fig. 21 and the data shown by the curves with closed circles in Fig. 9.

That is, hypotonicity even at extreme low salinity scarcely suppressed the rate despite of suppression presented in another survey at extreme low salinity with open circles in Fig. 9.

After the pre-acclimatization at low salinity for 24 hours. the rates did not decrease, and on the other hand those affected by hypertonicity markedly rose.

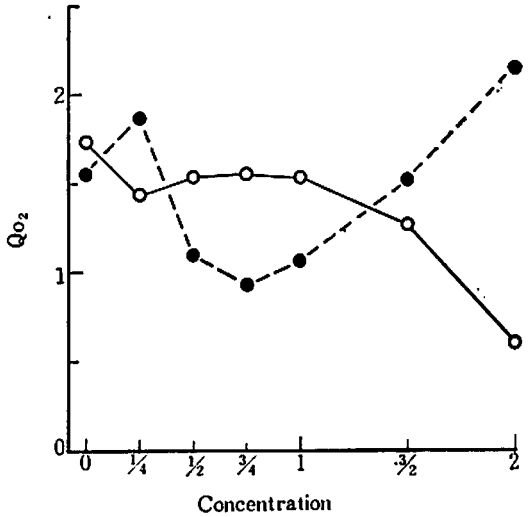

Fig. 21. Respiration rate of *Zostera marina* affected by hypo- and hypertonicity of sea water (open circles), and its recovery or decrease in respiration after pre-acclimatization for 24 hours (closed circles).

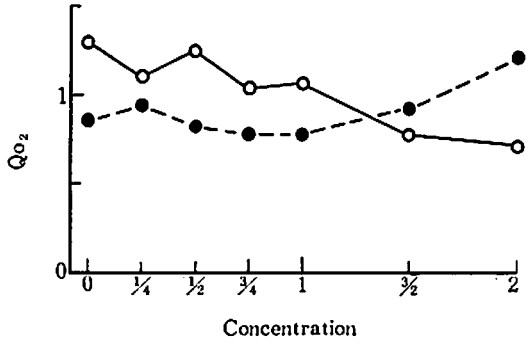

Fig. 22. Respiration rate of *Zostera nana* affected by hypo- and hypertonicity of sea water (open circles), and its recovery or decrease in respiration after pre-acclimatization for 24 hours (closed circles).

The results from *Zostera nana* were shown in Fig. 22 as well as Fig. 10. The hypotonicity rather enhanced the respiration in the series in Fig. 22, but it was suppres-

sive in the former case. Amplitudes of deviation from the rate in standard medium in both cases were, however, not so wide that this confliction might not essential. This species was also resistant to prolonged hypotonic condition as seen well recognizable in the data with closed circles in Fig. 22,

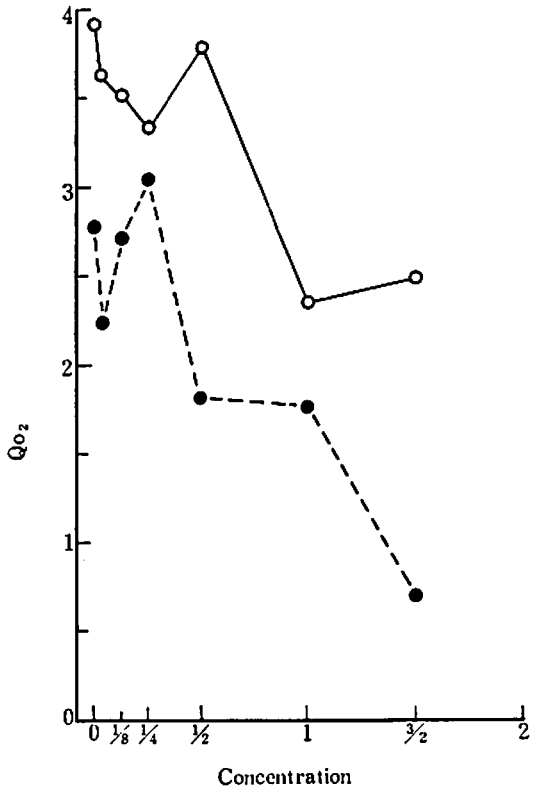

Fig. 23. Respiration rate of fresh water phanerogam affected by hypo- and hypertonicity of sea water. Open circles : *Potamogeton crispus*, closed circles : *Ceratophyllum dmersum*.

Some attempts to survey the influence of drastic osmotic changes on the respiration of fresh water phanerogams was made with *Potamogeton crispus* and *Ceratophyllum demersum* by using the same medium as shown in the case of marine plants (Fig. 23). It was a very interesting fact that the respiration was enhanced temporalily by both hypotonic (0 concentration) and hypertonic condition.

In comparison with the respiratory changes with saline condition as described above, the some experiments were made to see those of fresh water phanerogams.

At only 0.05 ‰ chlorinity of pond water at natural habitat, the respiration rate

of *Potamogeton* was lowest at some point between 0 and 5.79 ‰ (1/4) and in *Ceratophyllum* it was lowest at some point between 0 and 2.59 ‰ (1/8). Hypetonicity above 5.79 and 2.59 ‰ both suppressed the rate in both species, respectively.

Discussion

According to the results obtained in the present work, some definite conclusions may be abstracted. First, hypertonicity always suppresses the respiration of marine plants with the exception as *Ulva pertusa*. On the other hand, without attention to the effect of hypertonic condition, somewhat different effects of hypotonic condition on the rate of algal respiration were often found in different species and among these examined at different data on the same species. In the experimental series in 1958, for example, enhanced respiration rates were found in *Ulva* at 1/2 concentration, in *Gloiopeltis furcaua*, and *Gracilaria* at 1/8 concentration and other examples in *Polysiphonia* and *Zostera marina* at 1/2 concentration. We can show some examples which were more or less suppressed by hypotonicity, such as *Sargassum*, *Ceramium*, *Zostera nana* and *polysiphonia*, among aboves, *Polysiphonia* being the most sensitive species. In *Undaria* and *Z. marina* the rates at 1/2 concentration were kept almost unchanged, but was suppressed under more heavy hypotonicity.

In the experimental series in 1963, however, the rates of the respiration of all species were enhanced more or less under hypotonic condition. For instance, in *Ulva*, *Enteromorpha*, *Gloiopeltis tenax* and *Gelidium*, the rates of the respiration were enhanced at 1/2 concentration, in *Sargassum*, *Gracilara* and *Laurencia* at 1/4 concentration, and in *Ishige*, *Zostera marina*, *Z. nana* with gradual increase as decreasing salinities.

Some conflictions were, therefore, found among the results obtained in 1958 and in 1963 in same species such as *Sargassum thunbergii*, *Gloiopeltis tenax*, *Zostera marina*, and *Z. nana* respectively. The hypotonicity acted somewhat suppressively in the 1958, but somewhat enhancingly in 1963 on one species. Good coincidence was found only in the case of *Gracilaria verrucosa*, in both years, and on the other hand in *Polysiphonia* and *Zostera marina*, the results obtained on different days were conflicted each other.

The fact that the effect of hypotonicity on the respiration is not always constant but labile according to the undetectable and unavoidable deviation in the materials, despite of the precise experimental technique and of careful attention which may ellucidate enough the conflictions among the above results and those by above noted workers.

However, over such conflictions, it may be noted as common trend that the enhancement of respiration by hypotonicity is in general more significant in finely or delicately constructed or thin leafy species such as *Polysiphonia*, *Ceramium*, *Laurencia* or *Ulva* and *Enteromorpha* than in rigidly constructed species such as *Ishige*, *Gloiopeltis*, *Gracilaria* or *Zostera*.

According to above reason, the responses of the rate of respiration to low salinity resulted in the structural rigidity of thallus rather than the characteristics of the

habitat. For example, such trends are observable in the thin two layered leafy green alga *Ulva*, and in delicate red alga *Laurencia*. In spite of its rigid construction, deep red alga *Gelidium amansii* are also very sensitive to prolonged acclimatization in extreme low salinity.

On the contrary, hypertonicity always suppress the respiration in marine plants with only one exception of the case in *Ulva* in Fig. 13. The grade of depression varies with different species case by case. In general the rate in deep sea algae or delicately and fragilely constructed species tend to be more remarkably suppressed than in rigidly and tightly constructed intertidal species.

Any explanation of the enhancement of the respiration in hypotonic side has not been found, but the elongation of algal body in hypotonicity as reported by OGATA and TAKADA (1955), seems to be one explanation because the elongation of algal body will give rise to considerable expantion of respiratory surface of plant cells. As another explanation the temporary elevation of respiration was also caused by slight injury (OGATA, unpublished data). The pretreatment may result in the changes in cellular respiratory material and then they affected the causal respiratory changes. The enhancement of the respiratory rate consumed rapidly the respiratory material such as carbohydrates.

It is very interesting that the respiration in fresh water higher plants affected by high osmotic condition temporarily rose to some extent. This has never been observed in marine plants.

Summary

In order to survey the respiration in marine plants affected by differently diluted or concetrated sea water, numerous and carefully selected fresh materials more than 10 species were chosen for respiration measurements by the manometric technique.

Two experimental series were repeated in 1958 and 1963. From the changes in the rate of respiration by transfer the thallus to low salinity, four types were observed as follows. 1 : An enhancement by hypotonicity at 1/2 concentration, 2 : An enhancement by hypotonicity at 1/8 concentration, 3 : Scarcely enhancement, 4 : Sensitive to hypotonicity. *Ulva*, *Enteromorpha*, *Gelidium*, and perhaps *Polysiphonia* and *Zostera marina* belong to type 1 ; *Gloiopeltis furcata*, *Gracilaria* and perhaps *Sargassum*, to type 2 ; *Ishige*, *Gloiopeltis tenax*, *Zostera nana*, and sometimes *Zostera marina*, to type 3 : *Polysiphonia* and *Ceramium* sp. to type 4.

The meaning of sensitivity to salinity change, however, varies according to two ways of pre-experimental conditions, namely the way the sensitivity to drastic salinity change as above described, and the way the prolonged acclimatization in hypo- or hypertonic medium.

After 24 hours, respiration in *Ulva*, *Gelidium*, *Laurencia* affected by extreme hypotonicity such as 0 hardly recovered even when they were returned in to normal medium. That is, these species were most sensitive to prolonged hypotonic condition.

and on the other hand *Ishige, Zostera marina, Z. nana* were proved to be more resistant. Above noted resistibility of marine plant to prolonged acclimatization also depended not only on the difference in their habitat but also on the difference in their construction.

In general, fine filamentous or thin leafy algae were easily affected by the salinity change, but rigid parenchymatous species were hardly affected during short as well as prolonged periods so far the respiration was concerned.

Some conflictions which were found in the identical species by different authors are probably due to the fact that the effect of hypotonicity is rather labile character depending on the minor undetectable deviation in the nature of materials.

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