Journal of the Oceanographical Society of Japan
Vol. 41, pp. 235 to 243, 1985

Temporal Fluctuations of Water Temperature in a *Sargassum* Forest*

Teruhisa Komatsu†

Abstract: This paper examines the influence of a *Sargassum* forest on temporal fluctuations in temperatures of surrounding water in relation to the thermal structure of water in and above the *Sargassum* forest. Water temperature records were obtained at about one-minute intervals for almost two days in May 1977 during the season of luxuriant seaweed growth, and in August 1977 during the season of little growth. The fluctuations were divided into two types. (1) A diurnal fluctuation under the forest with about a three hour lag behind that above the forest during the season of luxuriant growth but with about a 30 min lag during the season of little growth. (2) Sharp spike-like fluctuations with periods shorter than five minutes appearing only in the dense canopy or floating seaweeds in the surface and subsurface layers during the period of luxuriant growth.

The luxuriant forest of *Sargassum* seems to influence the spatial distribution of water temperature and consequently seems to induce the fluctuations mentioned above. The relationship between short period fluctuations and behaviours of larval fishes are discussed.

1. Introduction

Seaweed forests have been regarded as very important nursery grounds for fishes (Ohshima, 1954), but their physical environment has scarcely been investigated (Ohno, 1981). In a previous report (Komatsu *et al.*, 1982), the authors examined the influence of a *Sargassum* forest on spatial and temporal distributions of surrounding water temperature in a small cove on a time scale of the order of hours. They revealed that the forest delayed the diurnal fluctuation of temperature during the season of luxuriant seaweed growth, but did not refer to the time lag in diurnal fluctuation between the upper and lower layers of the forest. It seems that the forest influences not only diurnal fluctuations but also fluctuations on a shorter time scale, but this has not yet been reported elsewhere. The present paper aims to clarify the characteristics of temperature fluctuations with periods not exceeding a day influenced by the *Sargassum* forest, by analyzing the data reported in the previous paper (Komatsu *et al.*, 1982). This paper examines how fluctuations in water temperature between upper and lower layers of the forest are asynchronized and how fluctuations with periods shorter than a day occur in the sea, and also analyses these problems in relation to the spatial structure of water temperature distribution.

2. Location and methods of observation

The observations were made at Kodomari Cove, a small-sized and open-shaped inlet, located on the west coast of Takahama Bay in Wakasa

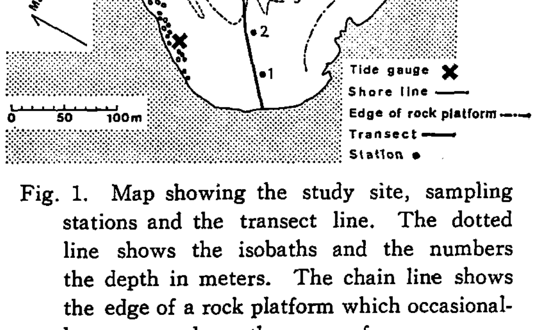

Fig. 1. Map showing the study site, sampling stations and the transect line. The dotted line shows the isobaths and the numbers the depth in meters. The chain line shows the edge of a rock platform which occasionally emerges above the sea surface.

* Received 8 June 1984; in revised form 31 October 1985; accepted 12 March 1985.

† Department of Fisheries, Faculty of Agriculture, Kyoto University, Sakyo-ku, Kyoto 606, Japan

Bay (Fig. 1). The methods of observation were described in detail in a previous paper (Komatsu *et al.*, 1982), and so only an outline of the observation made are given here. Water temperature was taken every 64.54 sec from 13:20 hr on 17 to 10:19 hr on 19 May 1977 during the season of luxuriant growth of the *Sargassum* forest, and every 60.50 sec from 15:54 hr on 5 to 03:53 hr on 7 August 1977 during the season of little growth. Cross-sectional positions of water temperature measurements are shown with dots in Figs. 9a and b. A portable tide gauge was set at the place marked on Fig. 1 to obtain sea-level data. A single, fixed transect line was set from the west shore to the bay mouth (Fig. 1) in order to investigate the growth condition of the seaweed forest.

Analytical Methods

In order to inspect time lags of the diurnal fluctuations among different positions on a vertical section along the transect line, the original time series of water temperature by station and by depth are shown in Figs. 2 and 4. Since detailed inspections of these figures are tedious, cross-correlation coefficients are calculated to detect statistically the time lag between two series of data taken at neighbouring points vertically or horizontally. The maximum lag for computation is 450 sampling-intervals. The computation is based on nine series of data in May and seven series in August.

In order to examine the short-period fluctuations, the original data were processed as follows. For the purpose of eliminating the diurnal fluctuations, the original time series are smoothed by a three-hour-moving-average method, and the smoothed series are subtracted from the original series. The residual time series comprise only fluctuations with periods shorter than three hours.

The sea-level data include both semi-diurnal and short-period fluctuations. In order to compare the short-period fluctuations of temperature and sea-level, the same processing procedure was used for both parameters.

Standard deviations of the residual time series of water temperature are computed to examine how widely the individual water temperature scatters around the mean value. The deviations are calculated on two kinds of residual time series; one is the residual series in which fluctuations with periods longer than three hours have been eliminated from the original series, and the other is that in which fluctuations with periods longer than five minutes have been eliminated. Standard deviations of the time series processed as above represent the intensity of short-period fluctuations of water temperature.

Growth conditions of the *Sargassum* forest along the transect line are shown in Fig. 9. Though detached floating seaweeds consisting mainly of *Sargassum horneri* are not included in this figure for the May observations, they covered the sea surface at Station 2 where seaweed grew most luxuriantly.

3. Results

3.1. *Time lag of diurnal fluctuation of water temperature*

(1) May (Figs. 2 and 3)

At Station 2, the maximum and minimum of the bottom temperature at a depth of 3.0 m

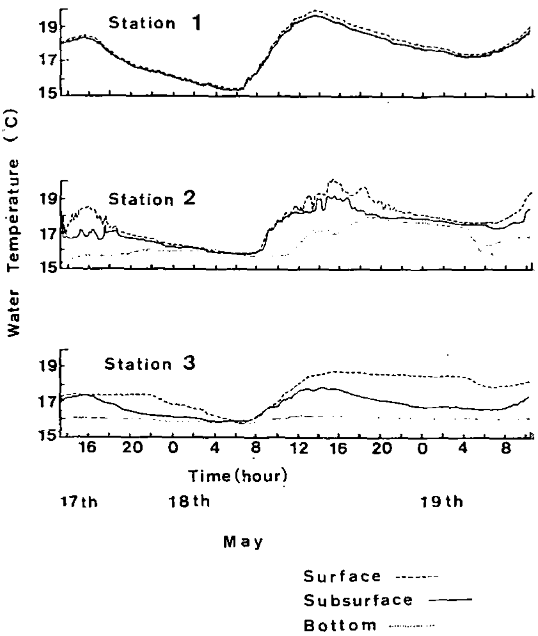

Fig. 2. Raw records of water temperature at three depths at three stations from 13:20 hr on 17 to 10:19 hr on 19 May 1977. Surface indicates the records measured at 0 m depth. Subsurface indicates the records at 0.5 m depth at Station 1 and 1.0 m depth at Stations 2 and 3. Bottom indicates the records 0.5 m above the bottom, meaning that probes were fixed at 0.8 m depth at Station 1, at 3.0 m depth at Station 2 and at 7.0 m depth at Station 3.

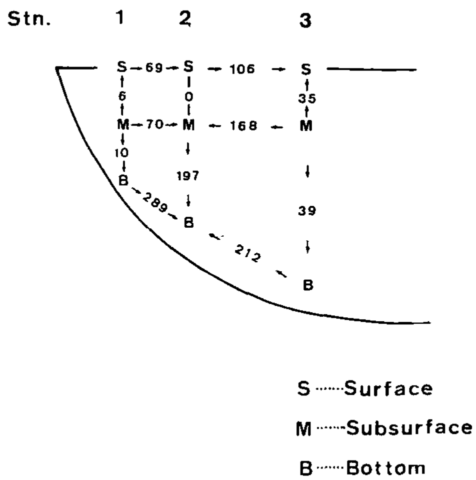

Fig. 3. Typical cross-section showing the time lags with the maximum value of coefficient calculated by cross-correlation analysis for the raw time series of water temperature during May. Arrows represent the direction of the delay. Numbers between arrows represent the minutes of time lag.

appeared about three or four hours behind the surface and subsurface temperature at depths of 0 m and 1.0 m, respectively, on 18 May. The vertical thermal gradient was larger before 20:00 hr on 17 and from 08:00 hr to 22:00 hr on 18 May. The surface (0 m depth) temperature at Station 1 fluctuated one hour ahead of that at Station 2. The rise of water temperature at Station 2 started about one hour and a half ahead of that at Station 3.

Results of cross-correlation analysis show that there is a tendency for the fluctuations in surface temperature to be delayed as one goes offshore (Fig. 3). The subsurface temperature at Station 2 fluctuated behind those at Stations 1 and 3. At Station 2, the time lag between 0 m and 1.0 m depths is 0 min, but about 197 min between the subsurface and the bottom temperature. At the bottom, the time lag is about 289 min between Stations 1 and 2.

(2) August (Figs. 4 and 5)

At Station 2, the diurnal fluctuation was only observed at the subsurface (1.0 m depth), since no data were taken at the surface (0 m depth). The rise of the surface temperature tends to slow down as one moves offshore from Station 1 to Station 3. The subsurface temperature at Station 2 rose about 40 min ahead of that at

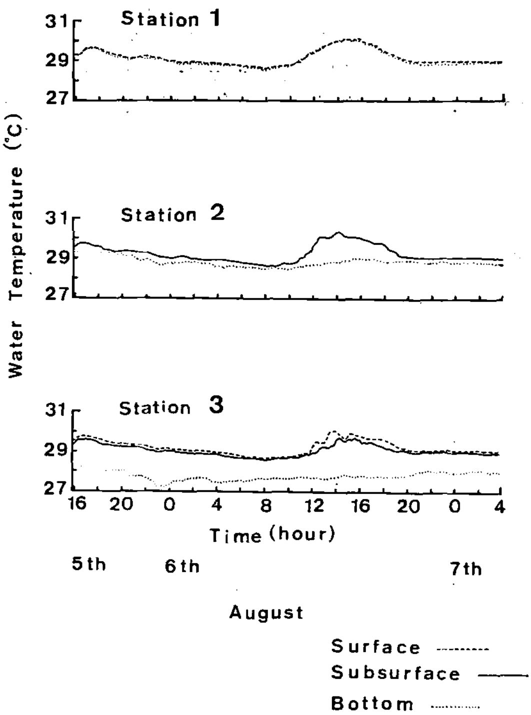

Fig. 4. Raw records of water temperature at three depths at three stations from 15:54 hr on 5 to 03:53 hr on 7 August 1977. The records were obtained at the same depths as the May observations.

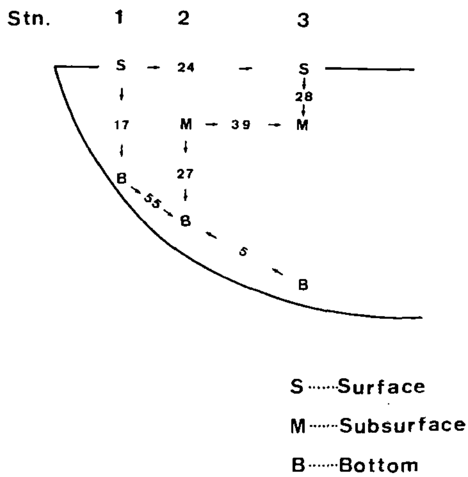

Fig. 5. Typical cross-section showing the time lags with the maximum value of coefficient calculated by cross-correlation analysis of the raw time series of water temperature during August. Arrows indicate the direction of the delay. Numbers between arrows represent the minutes of time lag.

Station 3. The bottom temperature at Stations 2 (3 m depth) and 3 (7.0 m depth) were almost constant, and did not fluctuate with a diurnal period. A vertical thermal gradient was formed from 12:00 hr to 20:00 hr on 6 August at Stations 2 and 3.

Results of cross-correlation analysis show that the surface and subsurface temperature fluctuations are delayed as one goes offshore (Fig. 5). However, the time lag is as short as about 24 min at the surface and about 39 min in the subsurface layer. The water temperature fluctuations are delayed as one goes from the surface down to the subsurface or the bottom, or from the subsurface to the bottom at all the stations. The time lags in temperature fluctuations in August do not exceed about 28 min, and are shorter than in May.

3.2. Comparison of fluctuations of water temperature with periods shorter than three hours

(1) May (Fig. 6)

The fluctuations are divided into two patterns. One pattern consists of abrupt spike-like changes of water temperature with a period shorter than five minutes and with a range of about 0.4°C. This type of fluctuation appeared only at depths of 0 m and 1.0 m at Station 2. The other pattern observed is a slow fluctuation with a period of about two hours, appearing at the surface and subsurface depths at Station 2. The range of the slow fluctuation is about 1.0°C, and is the largest range of all fluctuations of water temperature with periods shorter than three hours. The former fluctuation overlapped with the latter one at depths of 0 m and 1.0 m at Station 2, and appeared before 19:00 hr on 17 May and from 11:00 hr to 21:00 hr on 18 May. The latter occurred before 19:00 hr on 17 May and from 08:00 hr to 21:00 hr on 18 May. At all the stations, the ranges of fluctuation of the bottom temperature are smallest even during the daytime. The thermistor probes at the bottom were in the luxuriant *Sargassum* forest (see Fig. 9a).

(2) August (Fig. 7)

The slow fluctuation mentioned above appeared at the surface and at the subsurface depth at Station 3 and at the subsurface depth at Station 2, and continued from 09:00 hr to 20:00 hr on 6 August. Abrupt spike-like changes of water

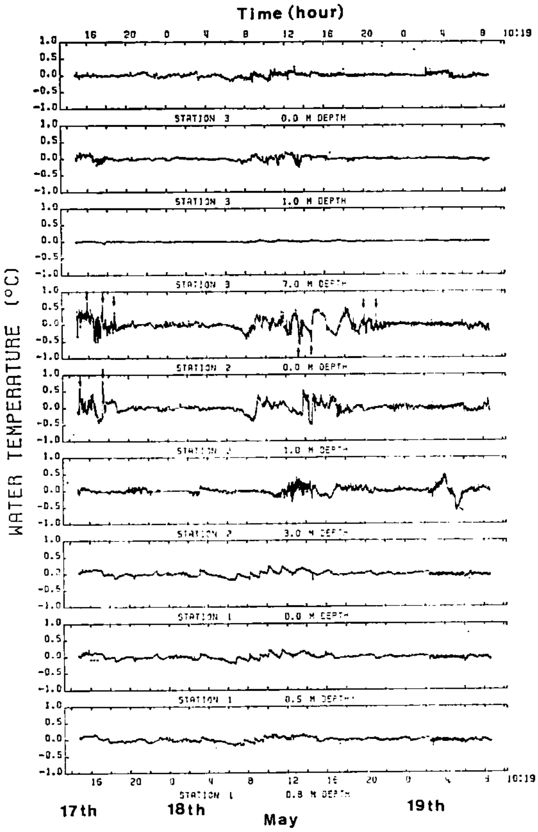

Fig. 6. Time series of water temperature with periods shorter than three hours during May. Arrows indicate abrupt temperature fluctuations.

temperature did not occur in August.

3.3. Sea-level fluctuation (Fig. 8)

In the original data of sea-level measurement, the semi-diurnal fluctuation appeared during the observational periods both in May and August. The range of sea-level fluctuation was 34.0 cm in the former and 34.9 cm in the latter. A fluctuation having a period of about two hours, and with a range of 4.0 cm to 8.0 cm, overlapped the semi-diurnal one.

In the residual data that included only fluctuations with periods shorter than three hours, the fluctuation with a period of about two hours also appeared in both sets of observations.

3.4. Cross-sectional distributions of standard deviation of water temperature fluctuations

(1) Standard deviations of the residual data of water temperature by three-hour-moving average

i) May (Fig. 9a)

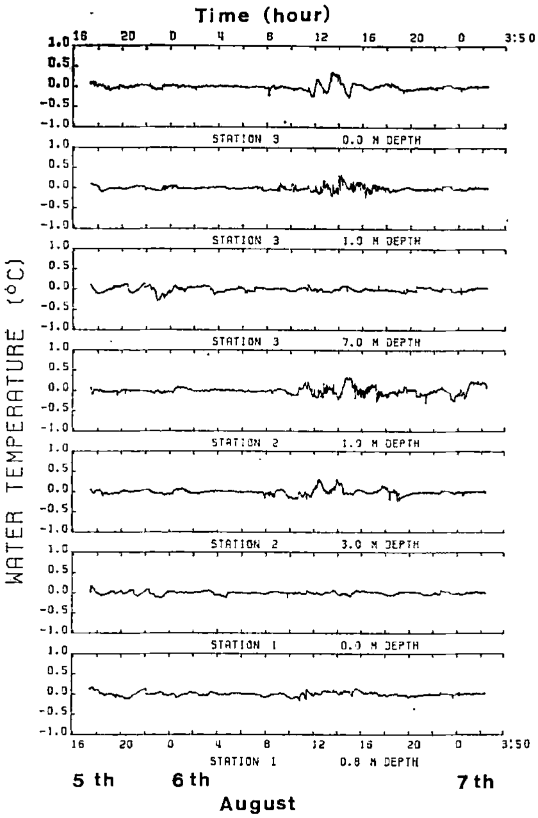

Fig. 7 Time series of water temperature with periods shorter than three hours during August.

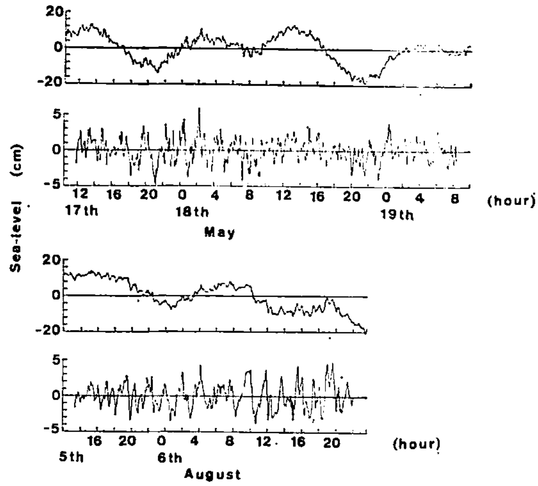

Fig. 8. Sea-level fluctuations at Kodomari Cove during the May and August observations. The upper graph is the raw time series of sea-level fluctuations and the lower one is time series with periods shorter than three hours in each observation. The mean sea-level is indicated by the 0 cm horizontal line.

The maximum value of standard deviation was distributed in a semi-circle around the surface at Station 2. Floating seaweeds existed in the same location. The distribution of high value corresponded with the place where the canopy of the *Sargassum* forest and the floating seaweeds occurred.

ii) August (Fig. 9b)

Slightly higher values of standard deviation were distributed in the surface layer above a depth of about 1.5 m from Station 2 to 3.

(2) Standard deviations of the residual data of water temperature by five-minute-moving average

i) May (Fig. 9c)

The maximum value of standard deviation appeared at the surface at Station 2. This tendency is the same as the case mentioned above, being more clear than that of Fig. 9a.

ii) August (Fig. 9d)

This figure represents a similar pattern as in Fig. 9b with slightly higher values of standard deviation in the surface layer.

4. Discussion

4.1. Time lag of diurnal fluctuation of water temperature

Komatsu *et al.* (1982) by analyzing the spatial distribution of water temperature revealed that a luxuriant *Sargassum* forest and its canopy delayed the ascent and descent of water temperature on a time scale of the order of hours. The present paper shows time lags of the diurnal fluctuation of water temperature that also appear in the time series data under the *Sargassum* forest during the season of luxuriant growth (Fig. 2). Results of the cross-correlation analysis and the comparison of the original time series suggest that the diurnal fluctuation of water temperature under the forest occurs three hours behind that of the surface and five hours behind that outside of the forest, *i. e.*, on the inshore side of the forest (Figs. 2 and 3). The thermal structure related to this fluctuation may be estimated to have a scale of about 3.0 m in height from the bottom and about 50 m in width under the luxuriant *Sargassum* forest around Station 2 (see Fig. 9 and Komatsu *et al.* (1982)). The lags of the diurnal fluctuation observed between

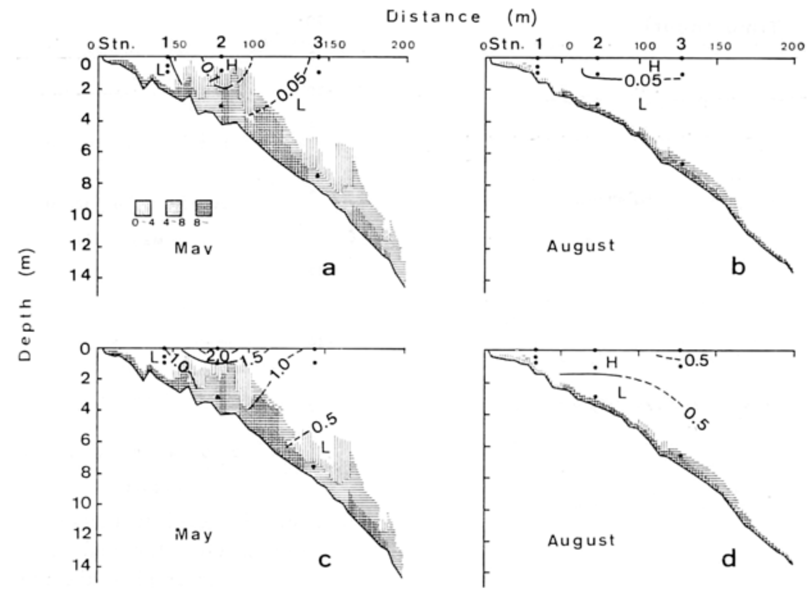

Fig. 9. Vertical profiles of standard deviation of water temperature fluctuations superimposed on cross-sections of growth condition during the seasons of luxuriant and little growth of the *Sargassum* forest. Figures a and b are from the time series of water temperature with periods shorter than three hours, and figures c and d are from the time series with periods shorter than five minutes. The contours of standard deviation are indicated with solid lines. When their locations are uncertain, the contours are indicated with broken lines. Dots show the water temperature observation points.

vertically neighbouring points are short and about 30 min in the season of little growth of *Sargassum* forest (Figs. 4 and 5).

4.2. Vertical thermal diffusivity in the Sargassum forest

Water temperature data expressed as a function of time and depth allow one to approximate diffusion properties after making certain assumptions concerning the nature of the diffusion process. Let us assume that the process by which heat is transferred vertically downward can be described by the Fourier heat equation for one-dimensional heat flow in a solid, that is

$$\frac{\partial T}{\partial t}=K_z\frac{\partial^2 T}{\partial z^2}, \qquad (1)$$

where T is temperature, t time and K_z a vertical thermal diffusivity assumed to be constant with depth z. The solution to Eq. (1) must fit a boundary condition that

$$T=T_0 \sin\omega t, \quad \text{at } z=0, \qquad (2)$$

where T_0 is the amplitude of temperature fluctuation at the surface, and ω its frequency. The solution to Eq. (1) satisfying Eq. (2) is

$$T=T_0 \exp[-z(\omega/2K_z)^{1/2}] \sin[\omega t-z(\omega/2K_z)^{1/2}]. \qquad (3)$$

Determining the lag of the maximum temperatures between depths of z_1 and z_2, where they appear respectively at t_1 and t_2, we obtain thermal diffusivity by the conventional method (*e.g.*, Dutton and Bryson, 1962) as follows,

$$K_z=\frac{(z_2-z_1)^2}{(t_2-t_1)^2}\cdot\frac{1}{2\omega} \qquad (4)$$

Values of K_z are calculated from Eq. (4) for the lags of diurnal fluctuation in Figs. 3 and 5 instead of the lags when maximum temperature appeared, where ω equals $2\pi/24\,\mathrm{hr}^{-1}$ ($7.3\times10^{-5}\,\mathrm{sec}^{-1}$). The value of K_z between depths of 1 m and 3 m at Station 2 under the luxuriant seaweed forest is $2\,\mathrm{cm}^2\,\mathrm{sec}^{-1}$ in the May observations, and that between the same depths without a canopy is $100\,\mathrm{cm}^2\mathrm{sec}^{-1}$ in August. The vertical stability near Station 2 was about $10^{-6}\mathrm{cm}^{-1}$ from 7:00 hr to 16:00 hr on 18 May, and about $0.7\times10^{-6}\mathrm{cm}^{-1}$ from 9.00 hr to 18:00 hr on 6 August (Komatsu, unpublished). Though the difference in vertical stability between May and August observations is small, there is a tendency that the K_z value becomes lower under the canopy in the season of luxuriant growth than at the same place in the season of little growth.

4.3. *Possible cause of the abrupt temperature change*

The analysis of time series data of water temperature shows that the exuberant *Sargassum* forest influences not only the diurnal fluctuation of water temperature but also shorter period fluctuations. The spike-like fluctuation with periods shorter than five minutes occurred peculiarly at depths of 0 m and 1.0 m at Station 2 in the season of luxuriant growth of the forest and only in the daytime and in the evening (Fig. 6). During May observations, surface and subsurface waters at Station 2 were covered with floating seaweed and canopies of the *Sargassum* forest, which might produce a strong vertical gradient of temperature in the daytime lasting even several hours after sunset. Vertical displacement of the thermocline is considered to be one of the possible causes of this fluctuation. Another possible cause is horizontal displacement of a thermal front. Gessner (1955) observed that the horizontal difference of surface temperature was 1.5°C between the place with dense floating weeds and that without them in the daytime in a shallow lagoon. This fact suggests the existence of a horizontal thermal gradient on a scale of several meters that depends on the distributions of floating seaweed and seaweed canopies. Komatsu *et al.* (1982) mentioned that water temperature in a canopy or upper part of a *Sargassum* forest was, in the daytime, warmer than that in other places without algae. Judging from the reports of Gessner (1955) and Komatsu *et al.* (1982), the warmer water in the canopy or floating seaweed and the cooler water in the places without algae may be distributed on a horizontal scale of several meters according to the growth condition of the seaweed forest. When the water mass, which has the above-mentioned thermal structure, moves back and forth with the canopy or the floating seaweeds and the thermal gradient accompanying them passes the thermistor probes, abrupt changes of water temperature are recorded on a time scale of the order of several minutes. The area covered by the thermal structure related to this fluctuation may correspond to places in the dense canopy or floating seaweeds in the surface and the subsurface around Station 2 (see Fig. 9 and Komatsu *et al.* (1982)). The scale of the distribution is about 5 to 10 m length and 1.0 m depth.

4.4. *Possible cause of the fluctuation with a period of about two hours*

Another fluctuation of water temperature with a period of two hours was observed during the day and evening both in May and August.

Both in the May and August observations at Kodomari Cove, a period of about two hours is predominant in the sea-level fluctuations. Honda *et al.* (1908) have reported seiches with periods of 120–130 min and 150–180 min at eight points along the coast of the Japan Sea. Kawakami (1927) also observed seiches with periods from 100 to 130 min at two tide gauges in the western Japan Sea.

In the canopy or upper part of the forest, the range of the water temperature fluctuation with a period of about two hours is greater than those in other places during the season of luxuriant growth of *Sargassum* forest. It does not appear from midnight to early morning when convective motions predominate.

This fact suggests that the thermal gradient is related to the fluctuations of water temperature with a period of about two hours. The seiche with a period of about two hours associated with the sea-level fluctuation under a density stratification causes internal waves. As a result, isotherms may fluctuate with a period of about two hours in the daytime and in the evening. Consequently it can be considered that this fluctuation is caused not by the luxuriant *Sargassum* forest, but by the combination of the vertical thermal gradient and the sea-level fluctuations.

4.5. *Water temperature fluctuations and larval fishes*

I shall now present some ideas about the relationship between larval fishes and the fluctuations of water temperature with periods shorter than three hours in the *Sargassum* forest, since the forest has been regarded as a very important nursery ground of fishes. Several kinds of fishes, which live or spend part of their lives there, spawn in winter or early spring (Minami, 1977). In the season when larvae appear, many kinds

Table 1. Scales of water temperature fluctuations influenced by the *Sargassum* forest and those of related spatial distributions.

Scale of temporal fluctuation (period of fluctuation)	Length scale of water temperature distribution Place	Horizontal	Vertical
Day	under the forest	50 m	3 m (from the surface)
Less than five minutes	in the dense canopy or floating seaweeds	5-10 m	1 m (from the surface)

of *Sargassum* species reach their maximal heights at the study site (Umezaki and Ariyama, 1981).

The relationship between the behaviour of larval fishes and *Sargassum* forest has scarcely been reported. On the other hand, there are some reports on their behaviours relative to drifting seaweeds. In the Japan Sea, Yamada (1980) observed that larvae of *Sevastes thompsoni* less than 20 mm in total length were always present among floating seaweeds, and those from 20 to 30 mm in total length swam only under the shade of the seaweed in the day and slept amongst the seaweed at night. Hirosaki (1965) devided swimming patterns of larvae, juveniles and fishes connected closely with floating seaweeds into two types: one type swam among the bushy *Sargassum* leaves, and the other type swam under the floating seaweeds. These observations may be applicable to larvae appearing in the *Sargassum* forest.

The values of standard deviation due to fluctuations with periods shorter than five minutes are the highest in floating seaweeds or canopies of *Sargassum* forest, while values are lowest under the forest. As larval fishes have not fully developed their swimming ability yet, their horizontal positions in the sea are mainly dominated by the displacement of the water mass, surrounding them. When the water mass, which has a horizontal or vertical thermal gradient, passes the fixed thermistor probes, water temperature fluctuations are recorded as discussed above. However, the former type of larvae among the canopy or floating seaweeds in the water mass do not encounter such temperature fluctuations. It is also considered that the latter type of larvae stays under the canopy or floating seaweeds in the daytime to avoid these fluctuations, since they can regulate their buoyancy and decide their vertical position. The distributions of standard deviations due to fluctuations with periods shorter than three hours represent a pattern similar to those due to fluctuations with periods shorter than five minutes. The fluctuation, with a period of about two hours and an amplitude of about 0.5°C, contributes to the former standard deviations. This fluctuation does not seem to be a strong and quick stimulus, but, rather, a moderate and slow one for larval fishes. After all, luxuriant *Sargassum* forests provide larval fishes with controlled environmental conditions not only of water temperature but also of such thing as shade and currents, as do other seagrass beds (Kikuchi and Pérès, 1977).

The periodical water temperature fluctuations mentioned above are summarized in Table 1 in relation to the spatial scales of water temperature distribution in the *Sargassum* forest discussed in the previous paragraphs. These periodical fluctuations from several minutes to one day are related to spatial scales from several meters to a hundred meters and are under the influence of the *Sargassum* forest during its seaon of luxuriant growth.

Acknowledgement

I would like to express my appreciation to the students and staff of the Department of Fisheries and the Fisheries Research Station, University of Kyoto, especially, to Messrs. H. Ariyama and M. Ueno, and Drs. M. Kashiwai, T. Minami, H. Nakahara and W. Sakamoto for their help during the field work, suggestions and criticisms. I also wish to thank Mr. M. Kanamori, a member of the Otomi Fishermen's Cooperative, who kindly provided me with a boat. I am most grateful to Prof. Dr. H. Kawai, University of Kyoto, for his critical reading of the manuscript and his invaluable advice throughout my study.

References

Dutton, J. A. and R. A. Bryson (1962): Heat flux in Mendota. Limn. Oceanogr., **7**, 80-97.

Gessner, F. (1955): Die limnologischen Verhältnisse in den Seen und Flüssen von Venezuela. Verh. Int. Ver. Theor. Angew. Limnol., **12**, 284-295.

Hirosaki, Y. (1965): Ecological study on fishes with the driftng seaweeds VI. Observations, experiments and discussion. Miscel. Rep. Res. Ins. Nat. Resour., **65**, 1-16 (in Japanese).

Honda. K., T. Terada, Y. Yoshida and D. Ishitani (1908): An investigation on the secondary undulations of oceanic tides. J. Coll. Sci. Imp. Univ. Tokyo, **24**, 1-133.

Kawakami, N. (1927): Secondary undulations of the Sea of Japan. Umi to Sora, **7**, 91-94 (in Japanese).

Kikuchi, T. and J. M. Pérès (1977): Consumer ecology of seagrass beds. p. 147-193. In: Seagrass Ecosystems, ed. by C. P. McRoy and C. Helfferich, Marcel Dekker, New York.

Komatsu, T., H. Ariyama, H. Nakahara and W. Sakamoto (1982): Spatial and temporal distributions of water temperature in a *Sargassum* forest. J. Oceanogr. Soc. Japan, **38**, 63-72.

Minami, T. (1977): List of juvenile fishes appearing in Maizuru Bay. p. 62-64. In: List of Animals and Plants in Maizuru Bay, ed. by H. Kadota, Fish. Res. Sta. Kyoto Univ., Maizuru. (in Japanese).

Ohno, M. (1981): Environmental factors in *Sargassum* beds. p. 75-92. In: Seaweed beds. ed. by Japan Soc. Fish., Koseishakoseikaku, Tokyo. (in Japanese).

Ohshima, Y. (1954): On *Zostera* region and conservation of juvenile fishes. p. 128-181. In: Review of Fisheries Science in Japan, ed. by Japan Soc. Sci. Fish., Japan Soc. Promotion Sci., Tokyo. (in Japanese).

Umezaki, I. and H. Ariyama (1981): Vegetation and seasonal variation of *Sargassum* forest in Kodomari Cove, Fukui Pref. p. 2-7. In: Ecological Studies on the *Sargassum* Beds, Report on the Scientific Study Granted by the Ministry of Education, ed. by I. Umezaki, Kyoto Univ. (in Japanese).

Yamada, Y. (1980): Studies on the life histories of the rockfish, *Sebastes thompsoni*, found in waters around Noto Peninsula, the Japan Sea. Bull. Ishikawa Pref. Fish. Exp. Sta., **3**, 21-31 (in Japanese).

がら藻場における水温の時間的変動

小　松　輝　久*

要旨: がら藻場が環境水温の時間的変動に与える影響を藻場内外の水温構造との関連において検討した. 1977年の海藻の繁茂期の5月と衰退期の8月に, 約1分間間隔でほぼ2日間水温を測定した. 水温変動は, 次の2つの型に分けられた. (1) 上部の水温変動に比べて, 繁茂期には約3時間の遅れを, 衰退期には約30分の遅れを生じる群落下部の日周期変動. (2) 繁茂期には表層および次層内の密生したキャノピーや流れ藻の中にのみ現われる5分以下の周期の鋭いスパイク状の水温変動.

これらの水温変動は, 繁茂したホンダワラ林が水温の空間分布に影響を及ぼした結果引き起こされたと思われる. 短周期の水温変動と仔魚の行動の関係についても議論した.

* 京都大学農学部水産学科
〒606 京都市左京区北白川追分町