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Accumulation mechanism of "red tide" plankton in Lake Biwa, Japan

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With 5 figures in the text

Introduction

The red tide, having been seen generated in Lake Biwa for the first time in May, 1977, is regularly observed from May on to June every year. The red tide is the concurrent mass of plankton, *Uroglena americana*, its density frequently amounting to 1,000 colonies/ml in the red tide zone. The development of red tide can be divided into two principal mechanisms, one being the mechanism which renders a bloom of plankton possible within such a short period of time and the other, the mechanism whereby multiplied planktons localize the formation of increasing mass concentration. The authors have contiuned the study on the latter mechanism since 1978. The movement of water, the diffusion of water and the behaviour of plankton are what significantly influences the distribution of plankton.

The prominent development of red tides in Lake Biwa is frequently seen immediately after several successive days of fair and calm weather, when the temporary thermocline is formed in the surface layer or the gentle lake breeze blows landwards from the offshore. It is, therefore, considered of utmost significance to clarify the actual circumstances of the convergence in the surface layer under such weather. In view of the above, the authors have followed observational investigation on the current velocity distribution and its time variation in the area off Kitakomatsu located on the west coast of the northern basin of Lake Biwa.

Observations

In order to directly observe the convergence or divergence in the surface layer, the LAGRANGIAN method was adopted for the measurement of water movement. Several drogues were simultaneously released into the water and tracked by means of several transits set in advance at several spots on the shore, with which the trajectory was traced every 5 minutes. In consideration of the temperature structure varying in accordance with the convergence or divergence in the surface layer, the temperature was recorded with an automatic temperature recorder provided to the anchored buoys, and repeated at the same time temperature soundings with bathythermograph casting at many fixed stations every half day. Furthermore, the automatic recording of temperature in double water layers (0.3 m and 1.3 m depth) was continued while cruising on the water, from all of which the precise distribution of water tempeature and its time variation were obtained. On the other hand, an aerial survey was performed on the microstructure of current movement by photographing at a fixed time interval approximately 50 drifters released beforehand in a grid pattern on the water. And a camera attached to a balloon was used to take photographs from an altitude of about 400 m above the lake level. Although there was an influence of wind on the longshore current, it was overcome by making use of the continuous record of wind velocity.

Results and considerations

Red tides are frequently occasioned along the west shore of Lake Biwa, mostly forming belts in parallel with the coastal line, although assuming on rare occassions

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irregularly gathered mass in the offing. Fig. 1 consists of maps illustrating the location of red tides and their shapes for 4 years since 1977, which suggests a tendency of convergence in the surface layer taking the shape of belt inshore in parallel with the coastal line, and most of the belt extending over a length of a few thousand meters in a breadth of a few hundred meters.

Now the description on the typical example of the convergence in the surface layer off Kitakomatsu (Refer to Fig. 1) as observed on May 29, 1979 is to follow. Trajectories of 10 drogues released into the water, 5 drogues (X_1—X_5) in parallel with the depth contour and other 5 (Y_1—Y_5) in perpendicular direction crossing the line X_1 to X_5, respectively, are shown in Fig. 2, which verifies the horizontal convergence in an area some hundred meters offshore, drogues being drifted southwest or west southwest. This also suggests that such inshore current pattern was caused by the easterly or northeasterly lake breeze that had been blowing since before the observation.

The behaviour of horizontal convergence can be learned by Fig. 3 which shows the time changes in 4 triangular (A, B, C and D) areas that are formed by 5 re-

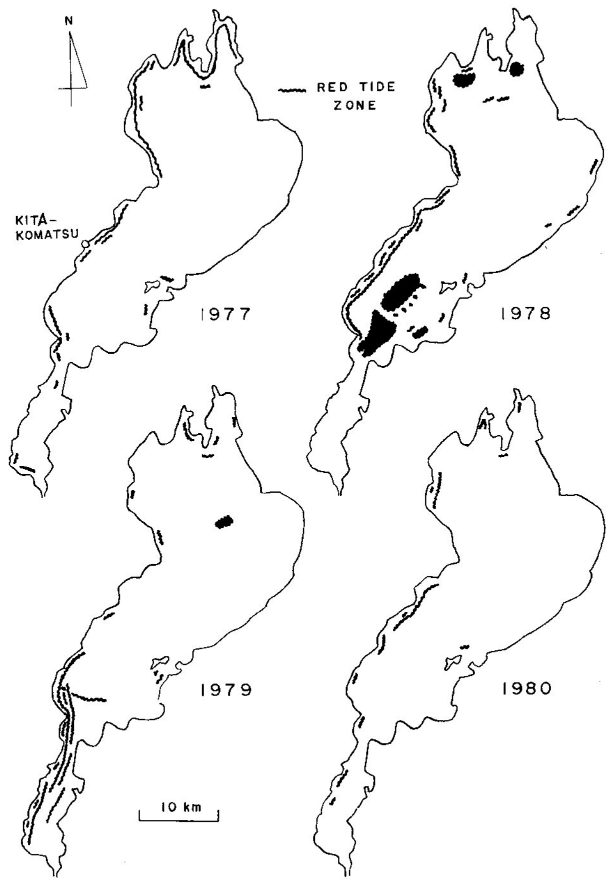

Fig. 1. Appearance of red tides in Lake Biwa in recent years (after Shiga Prefectural Government).

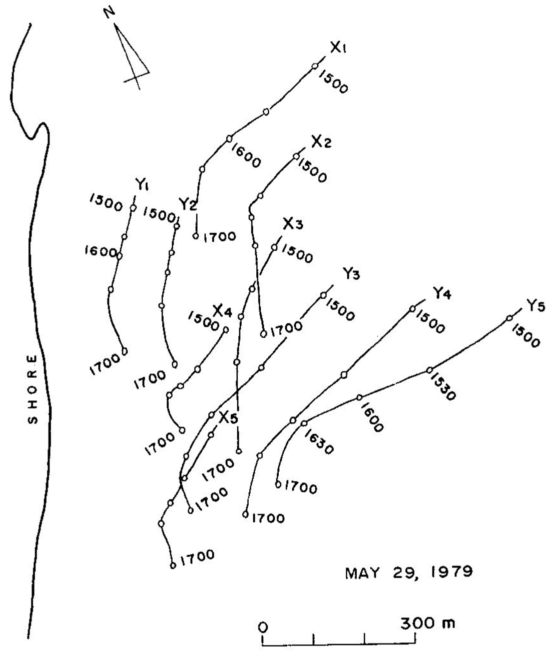

Fig. 2. Trajectory of drogues traced every 5 minutes. Drogues drifted southwestward in the layer 1 m below the lake surface, showing a tendency to gather. The numerals show the time of observation.

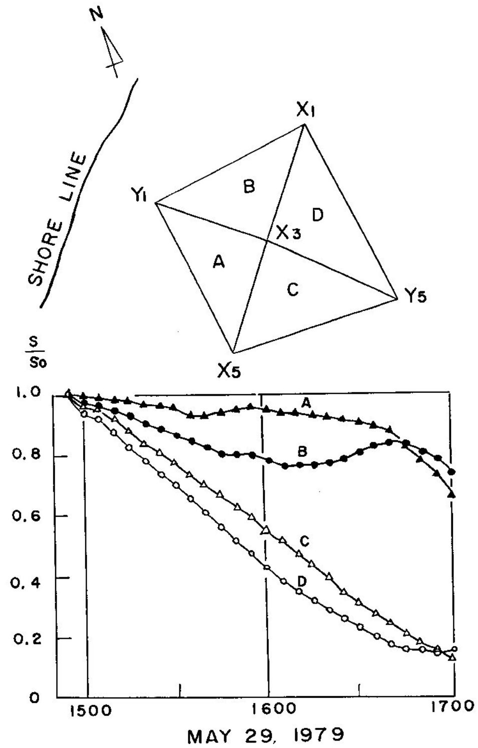

Fig. 3. Time change in triangular areas by water surface convergence. 2 triangles (C and D) formed with offshore drogues rapidly became smaller. The ordinate indicates the ratio of area to the initial area. (Refer to Fig. 2.)

presentative drogues (X_1, X_5, Y_1, Y_5 and X_3). While two triangles A and B at the coastal side did not much lose their areas, triangles C and D at the offing side reduced to less than 20 % of initial area in 2 hours. The horizontal convergence is then estimated at $1 \times 10^{-4} \cdot sec^{-1}$. This observation result shows that even within such a limited water area of less than 1 km^2, the convergence is not homogeneous but highly localized. On the assumption that the planktons cling to the water surface without being sunk into depth as the drifters do, the planktons would gain the high density of 5 times as much as they were initially in the regions C and D after a lapse of only 2 hours.

Observing the above mentioned convergence from a different point of view, Fig. 4 shows how the velocity component perpendicular to the shore line varied in accordance with the distance from the shore. Velocity component heading for the shore decreased as the drouges approached closer to the shore finally diminishing to zero at approximately 300 m off the shore. (A current heading for offshore was caused by a shift of wind immediately before the observation was finished.) In this instance, therefore, it is presumed that the convergence zone is to be formed in the shape of a belt approximately 300 m off the shore in parallel with the coastal line.

As a result of the accumulation of warm surface water mentioned above, the water temperature was higher near the shore and there was brought about a sharp horizontal gradient of temperature 300 m away from the shore (Fig. 5). Incidentally the red tides were not seen, because the blooming of *Uroglena americana* had already been over at that time of the investigation.

Another mechanism for the development of red tide in a belt form in parallel with the shore line, the horizontal convergence which the coastal jet stream produces can be pointed out from our experience. In the case of coastal jet stream observed off the shore of Kitakomatsu, the jet stream was seen flowing inshore where the dip of lake bottom was steepest, the breadth of jet stream being approximately 200 m with current velocity of 30 cm/sec that amounted to almost

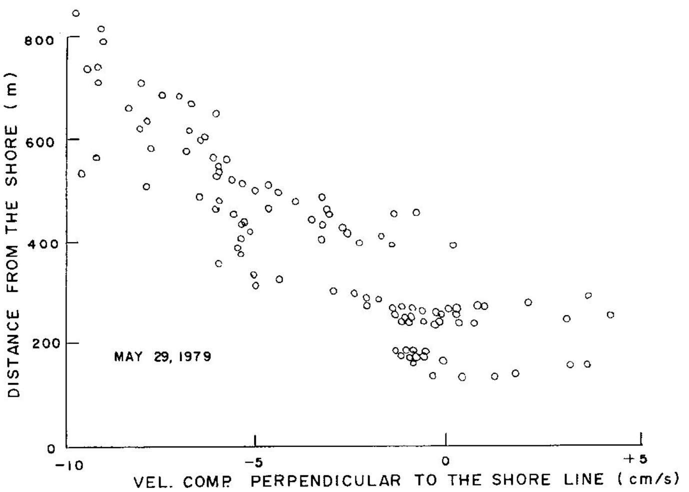

Fig. 4. Gradual decrease in velocity component heading for the lake shore, at water region closer to the shore. Positive: offshore; negative: inshore.

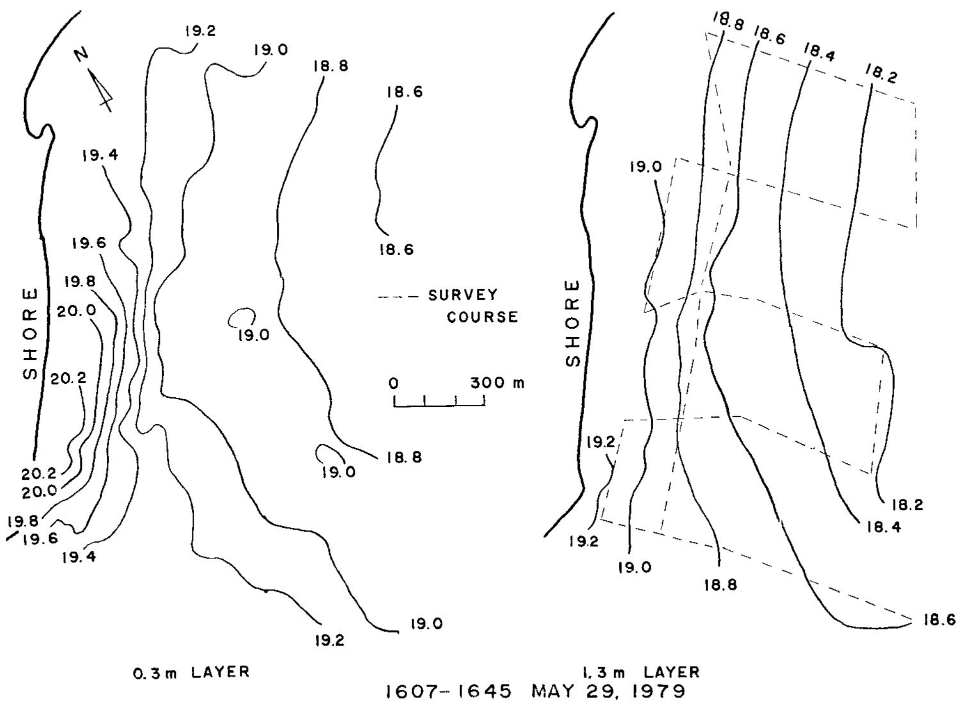

Fig. 5. Distribution of water temperature in the surface layer. As a result of accumulated warm surface water, temperature was higher near the lake shore.

three times as high as the current velocity in the vicinity. In this case a horizontal convergence was estimated at 10^{-3} sec^{-1} and velocity component downwards at 10^{-4} cm/sec.

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