

# Effect of salinity on vertical migration of green *Noctiluca* under laboratory conditions

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»» Received 14 December 2009; accepted 16 September 2011

**Abstract**—Field studies in the Upper Gulf of Thailand and Manila Bay on red tides of green *Noctiluca scintillans* with the photosynthetic symbiont *Pedinomonas noctilucae* showed that vertical maximum of *N. scintillans* often occurred below halocline at 10 to 15 meter depths, suggesting that salinity influenced the vertical distribution of this organism. Then, we examined the influence of salinity on the vertical distribution of *N. scintillans* under laboratory conditions. A three layer system with varying salinity of 10, 20 and 31 was produced in the black polyethylene tubes of 20 cm in diameter and 1.5 m long. Tubes were exposed to a 12:12 LD cycle under the light intensity of  $70 \mu\text{mol m}^{-2} \text{s}^{-1}$  provided at the top. Two set of experiments were conducted to observe behaviors of *N. scintillans* for a week: in the first set *N. scintillans* cells were added at the surface of the tubes while in the second one cells were added at the bottom. In the stratified tubes, all cells released at the surface died immediately at the beginning of the experiment, while cells released at the bottom slowly migrated toward the upper layer, and uniformly distributed throughout the column within 24 h. In the control tubes with a uniform salinity of 28, it took shorter (3 h) for cells released from the bottom to attain the uniform distribution. During the latter half of the experiment most cells stayed at the surface. These results indicate that *N. scintillans* is able to tolerate a wide range of salinity, and that an acclimation period is needed to adapt to low salinity conditions; this adaptive feature may be an important factor to maintain its population and to form red tide in the river mouth areas.

**Key words:** salinity, vertical migration, green *Noctiluca*

## Introduction

The vertical migration (VM) in dinoflagellates is one of the adaptive features that allow them to survive, reproduce and form dense blooms. There are some factors involved with this mechanism such as light cycle, pycnocline, and nitricline. The study on diurnal migration through temperature gradients in *Prorocentrum micans* Ehrenberg showed that this species exhibited the complex changes in swimming speed that depended on the light cycle, but not to the cross-thermocline temperature differential (Kamykowski 1981). Doblin et al. (2006) investigated the behavior of VM in *Gymnodinium catenatum* Graham using vertically-stratified laboratory columns. In their experiments, VM was observed only in the stratified columns with surface nutrient depletion. In the columns, downward VM starts at 3 h before the end of the light period and upwards migration begins at 3 h before the light period. Cells in nutrient-replete columns showed no VM, but they were more dispersed in the upper layer during the dark compared to the light period. Townsend et al. (2005) found that *Alexandrium fundyense* Balech exhibits double

peak of vertical distribution with relatively high cell densities in the Gulf of Maine. A shallow peak was located near the surface (<15 m depth), and a deeper peak at depths between 25 and 40 m, each coincident with the depth of the pycnocline and nitricline, respectively. The low-frequency internal tidal wave of greater than 20 m amplitude was considered to control the vertical distribution of the deep population. The field studies on red tides of green *Noctiluca scintillans* (Macartney) Ehrenberg in the Upper Gulf of Thailand and Manila Bay showed that vertical maximum of this species occasionally occur below halocline 10 to 15 meter depths where salinity was in the range of 26 to 28. Bloom occasionally occurs even in the water of lower salinity near the river mouth (Lirdwitayaprasit et al. 2006). These observations suggest that salinity may influence the vertical distribution of this organism. However, the study on VM in this species is quite rare. The present study examined this possibility by laboratory experiments.

## Materials and Methods

To determine the size of experimental tubes, 2 two-layer columns both with salinity of 10 and 31 were prepared using a siphon in transparent acrylic tubes, one with diameter of 5 cm and the other 20 cm, and diffusion of salinity was observed. During a 10-d observation, a mixing layer between salinity 10 and 31 developed at increasing thickness of  $0.5 \text{ cm d}^{-1}$ , and there was no difference between the two tubes.

Since the diameter of tubes did not affect vertical diffusion of salinity in the preliminary experiment, we used black polyethylene tubes of 20 cm in diameter and 150 cm long.

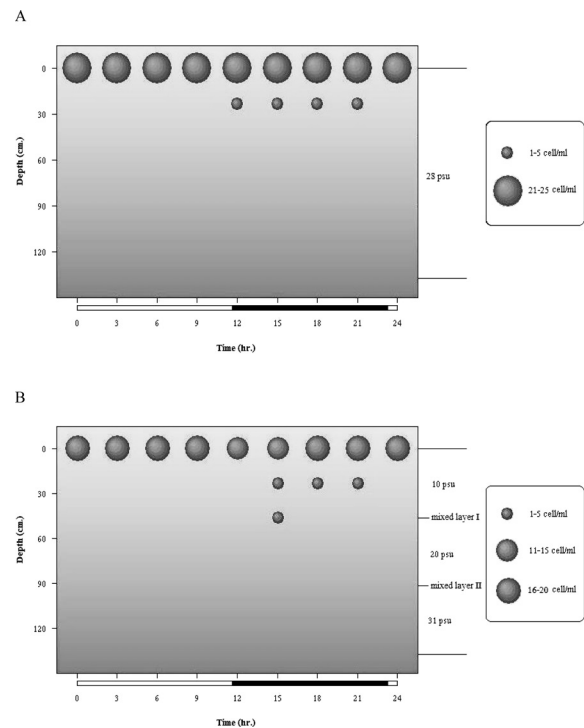
Tubes with layers of 3 different autoclaved filtered seawater with salinity of 10, 20 and 31 were prepared, with which sampling valves were fitted at 0.5, 23, 46, 69, 92, 115 and 138 cm below the water surface, each corresponding to the surface, salinity 10, a mixing layer between salinity 10 and 20, salinity 20, a mixing layer between salinity 20 and 31, salinity 31 and the bottom layer. Tubes with vertically uniform salinity of 28 were prepared as control.

Each run of the experiment was made using 2 control and 2 stratified water tubes. About 104,400 cells of *Noctiluca* were added at the surface of one control tube, and at the bottom of the other control tube. About 102,500 *N. scintillans* cells were added at the surface of one stratified tube, and at the bottom of the other stratified tube. Behavior of *N. scintillans* cells was observed for 7 d, during which cell density, cell size and salinity were measured every three hours for the first, fourth and seventh days of a run. All tubes were exposed to a 12:12 LD cycle under the light intensity of  $70 \mu\text{mol m}^{-2} \text{ s}^{-1}$  provided at the top.

## Results and Discussion

Salinity fields in both control and stratified tubes were stable throughout the experiment (Table 1).

In the control tubes, cells released at the surface and bottom became distributed throughout the water column within 3 h after the release. In the stratified water tubes, all cells added at the surface immediately died at the beginning of the experiment. In contrast, cells added at the bottom slowly moved upward and became uniformly distributed throughout the column within 24 h. On day 4 and 7, most of cells in all the tubes aggregated at the surface layer throughout the day. A minor portion of cells moved downward during the dark period but not deeper than 60 cm (Fig. 1). Cells located near the surface of the stratified tubes were about 20% bigger in cell size than those in the control tubes, and remained large throughout the experiment. They appeared unhealthy and most of cells died after day 7. Therefore, *Noc-*



**Fig. 1.** Vertical distribution of *Noctiluca* on day 4 in the control tube (A) and in the stratified water tube (B).

**Table 1.** Salinity (psu) of water in control and stratified tubes at the 1st, 4th and 7th day.

	Day1	Day4	Day7
Control tubes	28	28	28
Stratified tubes (depth from surface: cm)			
0.5	10	10	10
23	10	10	10
46	16	16	16
69	20	20	20
92	26.5	26.5	26
115	31	31	31
138	31	31	31

*tiluca* could temporally adapt to survive in such a low salinity condition.

These observations suggested that this species was not an active vertical migrator. This is consistent with the fact that, unlike other dinoflagellate species, *N. scintillans* has only a rudimentary transverse flagellum and it may not be used for swimming. As for upward movement, a buoyancy role of low molecular weight solutes, especially ammonium ( $\text{NH}_4^+$ ) has been described for certain squids, tunicate eggs and *N. miliaris* (Goethard and Heinsius 1892, cited by Krogh 1939). Body fluids can be lighter than seawater by placement of high molecular mass solutes with those of lower molecular, that is,  $\text{NH}_4^+$  replacement of  $\text{Na}^+$  reduces solution density in marine animals (Lambert and Lambert 1978, Voight et al.

1994).

In the Upper Gulf of Thailand, red tides of this species often occur two or three days after the rain and their horizontal distribution extends toward the river. Lirdwitayaprasit et al. (2006) showed that the blooms of this species were often found when salinity was in the range of 22–33 and occasionally 10–15. These observations, together with our experiments, wherein all cells added at the surface (0 psu) immediately died, suggest that the *Noctiluca* populations in the surface layer of the field suddenly died after being exposed to low salinity water from the rain or river run off. On the other hand, the populations in deeper layers were able to gradually acclimate to the low-salinity water during their ascent to the surface where they formed a red tide after a certain period. For a better understanding of the mechanism controlling the vertical migration in this species, further studies should be focused on the influence of prey, light intensity and temperature gradients.

### Acknowledgements

We thank to Senior Project Program for undergraduate student of the Faculty of Science, Chulalongkorn University and NRCT-JSPS joint research program for the research fund and also thank to PHETSAM PE PIPE OO., LTD. for supporting the materials to make the experimental tubes.

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