STUDY ON WATER QUALITY AND *Chattonella* RED TIDE IN THE ARIAKE SEA

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1. Introduction

The Ariake Sea is a semi-closed sea located in the west of Kyushu Island. It is not yet clear exactly what has caused red tide and poor water qualities in the Ariake Sea. During winter of 2000, *Rhizosolenia* red tide occurred in wide area of the Ariake Sea and damaged seaweed production. Aim of this study is to investigate occurrence of red tide and poor water quality in the Ariake Sea. From this study, it has been revealed that bottom sediment resuspension influences the behavior of *Chattonella* red tide in the Ariake Sea. That is, it can be concluded that one of the regular bloom of red tides in the Ariake Sea is caused by *Chattonella* with resuspension process.

2. Water quality model

Two-dimensional water quality model in the Ariake Sea is developed based on the finite volume model as shown in Fig. 1. In this model, the Ariake Sea is divided into 11 elements; each divided element is considered to be in complete mixing state. In this study, Isahaya water quality model is combined with the Ariake Sea model. Water quality parameters in this model are chlorophyll a (Chl-a), chemical oxygen demand (COD), suspended solids (SS), dissolved inorganic nitrogen (DIN), orthophosphate phosphorus (PO_4) and chloride ion (Cl^-).With given boundary conditions, a net flow rate between two adjacent elements can be obtained from the continuity equation in Eq.(1) (Vongthanasunthorn et al. 2004). Basic equation in each element of the finite volume model (Rich 1973) is described in Eq. (2).The reaction terms of DIN and PO_4 of element n are described as S_N and S_P in Eqs. (3) and (4). The substantial biomass change of algae (*AG*) is shown in Eq. (5). The reaction term of suspended solids (S_S) in element *n* is expressed in Eq. (7). The reaction term of particulate COD (S_{CP}) and dissolved COD (S_{CD}) are described in Eqs. (8) and (10), respectively. The simulation period is from 1997 to 2000.

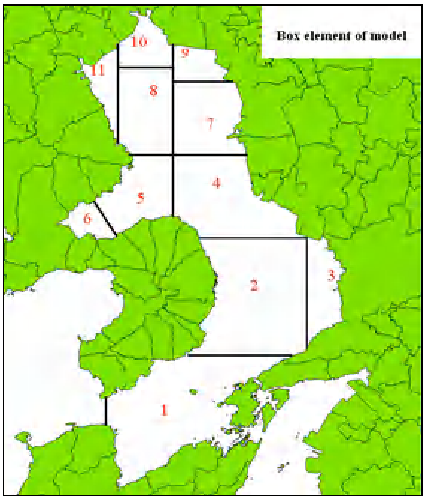

Fig. 1 The Ariake Sea and divided elements

$$\frac{dV_n}{dt} = \sum Q_{nm} + Q_{B(n)} \quad (1)$$

$$\frac{dc_{(n)} \cdot V_{(n)}}{dt} = \sum\left\{Q_{nm}\left[\delta_{nm} \cdot c_{(m)} + (1-\delta_{nm})c_{(n)}\right] + E'_{nm}(c_{(m)} - c_{(n)})\right\} \pm S_{(n)} \quad (2)$$

$$S_N = -\sum_{x=1}^{5} Y_{N(x)} \cdot AG_{(x)} + K_{RN} \cdot DIN_B \cdot R_M \cdot A \quad (3)$$

$$S_P = -\sum_{x=1}^{5} Y_{P(x)} \cdot AG_{(x)} + K_{RP} \cdot PO4_B \cdot R_M \cdot A \quad (4)$$

$$AG_{(x)} = \left(\mu_{(x)} - K_{D(x)} \cdot \theta_{(x)}^{(T-T_{D(x)})}\right) CH_{(x)} \cdot V \quad (5)$$

$$\mu_{(x)} = \mu_{MAX(x)} \cdot T_{G(x)} \cdot \frac{DIN}{(K_{N(x)} + DIN)} \cdot \frac{PO4}{(K_{P(x)} + PO4)} \cdot CH_{(x)} \cdot V \cdot \left(1 - \alpha \frac{Cl}{Cl_S}\right) \quad (6)$$

$$S_S = SS_{RS} - K_{SS} \cdot B_S \cdot SS \cdot A \quad (7)$$

$$S_{CP} = Y_{SC} \cdot SS_{RS} - (K_{SC} \cdot PCOD + SCOD_{ALGAE}) \cdot A + \sum_{x=1}^{5} Y_{C(x)} \cdot AG_{(x)} \quad (8)$$

$$SCOD_{ALGAE} = \sum_{x=1}^{5} Y_{C(x)} \cdot K_{SA(x)} \cdot CH_{(x)} \quad (9)$$

$$S_{CD} = K_{RC} \cdot DCOD_B \cdot R_M \cdot A \quad (10)$$

V = water volume of element (m^3)
Q_{nm} = net flow rate between element n and m (m^3/s)
Q_B = boundary condition of flow rate of the element (m^3/s)
c = average concentration in the element (g/m^3)
δ_{nm} = net advection factor between element n and m (-)
E'_{nm} = mixing coefficient between element n and m (m^3/s)
S = reaction term (g/s)

Subscripts n and m denote the considered element and the adjacent element, respectively.

Y_N = DIN: Chl-a (mg DIN/μg Chl-a)
Y_P = DIP: Chl-a (mg DIP/μg Chl-a)
K_{RN} , K_{RP} = release rate of DIN and DIP (g/m^2-d)
DIN_B , $PO4_B$ = DIN and DIP in mud bed (g/m^3)
R_M = ration of mud bed area in the element (-)
A = element area (m^2)
K_D = specific decay rate (1/d)
θ = temperature coefficient for decay (-)
T_D = critical temperature for decay (℃)
T = water temperature (℃)
μ_{MAX} = maximum specific growth rate (1/d)
T_G = temperature coefficient for algae growth (-)
K_N , K_P = saturation constant of DIN and DIP (g/m^3)
CH = Chlorophyll a (mg/m^3)
DIN = dissolved inorganic nitrogen (g/m^3)
$PO4$ = orthophosphate phosphorus (g/m^3)
SS_{RS} = resuspension suspended solids (m/d)
α = Salinity coefficient (-)
Cl = Salinity concentration (mg/l)
Cl_S = Salinity concentration of open sea (mg/l)
K_{SS} = settling velocity of SS (m/d)
B_S = settling coefficient (-)
SS = suspended solids (g/m^3)
A = element area (m^2)
Y_{SC} = PCOD content of particulate materials in mud bed (mg COD/ mg SS)
K_{SC} = settling velocity of PCOD (m/d)
$PCOD$ = particulate COD (g/m^3)
Y_C = PCOD: Chl-a (mg COD / μg Chl-a)
K_{SA} = settling velocity of algae (g/m^2-d)
K_{RC} = release rate of DCOD (g/m^2-d)
$DCOD_B$ = DCOD in mud bed (g/m^3)

3. *Chattonella* life cycle

In this study, there are 4 kinds of algae concerned, namely, diatom, green algae, blue green algae, and *Chattonella*. It is well known that *Chattonella* forms cysts in their life cycles and overwinter via this form in the bottom sediments. When the resuspension process occurs, *Chattonella* cysts lying in the bottom sediments are resuspended to water column. This resuspension processes occur as same as the resuspension of SS by tides and winds. Similar to other phytoplankton, the appropriate conditions for growth are sunlight, nutrients, water temperature and other limiting factor. When these environmental conditions reach to the optimum for photosynthesis, *Chattonella* is blooming. According to this hypothesis, the resuspension of *Chattonella* is included into the water quality model in this study.

Keyword: Water quality, *Chattonella* red tide, Ariake Sea
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4. Results and discussion

From salinity simulation results, fluctuated salinity concentration can often be seen at element 9 as shown in Fig. 2, indicating that the influence of Chikugo River is often greater than the discharge flow from other watersheds such as element 5. Results of Chlorophyll a simulation shown in Fig. 3 reveal that high *Chattonella* occurs at the same time when high SS concentration occurs (Fig.5). That is, occurrences of *Chattonella* may be affected by high SS concentration from high resuspended after high rainfall period. Furthermore, the simulation results are almost happened in the same time with observed data, occurring periods of *Chattonella* bloom, as shown in the shade columns in Fig. 3. From this agreement, it can be verified that this water quality model can simulate the periods of *Chattonella* bloom in the Ariake Sea. In addition, it is clearly seen that *Chattonella* is resuspended from the bottom and agrees with the hypothesis mentioned in the *Chattonella* life cycle section. Simulation results of COD are shown in Fig. 4. COD simulation results have fairly good agreement with observed data only in some period. In the future study, to provide better agreement of COD simulation results with observed data, Chlorophyll a simulation results should be concerned more in detail. However, these simulation results suggest that high COD occurs during high algal productivity. Simulation results of DIN and PO_4 are illustrated in Fig. 6 and Fig. 7, respectively. Both nutrients simulation results in element 11 are higher than simulation results in element 5. It means the influence of discharge loading from land area and mud bed are greater than water movement in the central part and result in the nutrient-rich waters in the innermost part of the Ariake Sea.

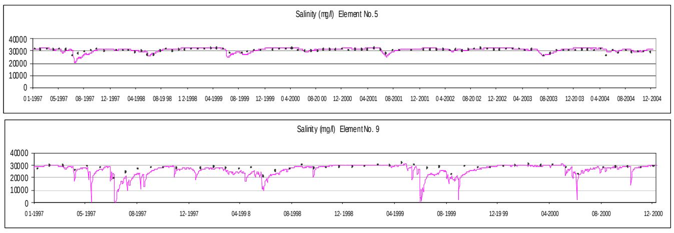

Fig. 2 Salinity concentration (mg/l) in element 5 and 9

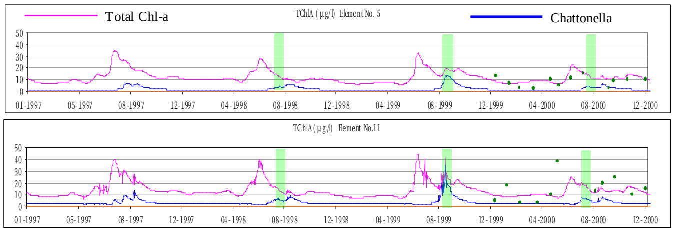

Fig. 3 Chl a concentration (mg/l) in element 5 and element 11

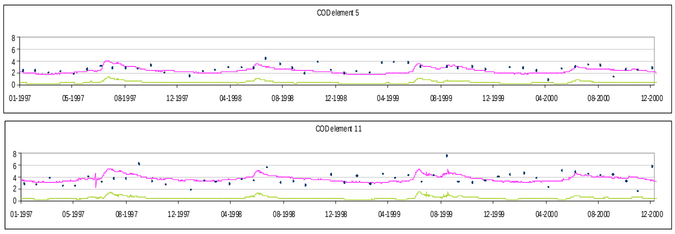

Fig. 4 COD concentration (mg/l) in element 5 and element 11

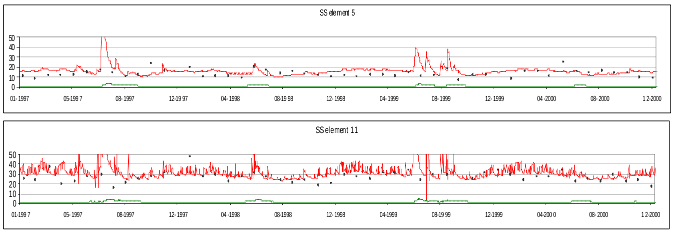

Fig. 5 SS concentration (mg/l) in element 5 and element 11

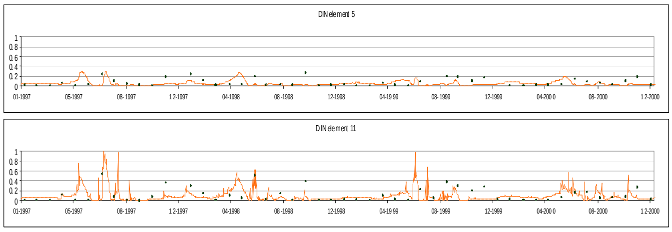

Fig. 6 DIN concentration (mg/l) in element 5 and element 11

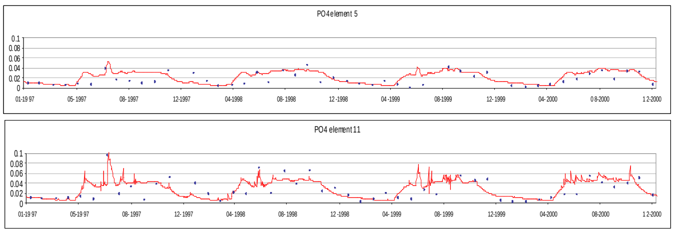

Fig. 7 PO_4 concentration (mg/l) in element 5 and element 11

5. Conclusions

From this study, it can be said that occurring of *Chattonella* red tide phenomenon in the Ariake Sea is the effect of the bottom resuspension process. In the other words, without this resuspension process *Chattonella* red tide will not be occurred. Poor water quality in the Ariake Sea is caused by rapid growth of algae during high nutrients discharge loading period. It means, *Chattonella* productivity can be caused by high resuspension rate which represented by high SS concentration. In order to control *Chattonella* red tide blooms in the Ariake Sea, management of water quality especially SS is very important issue. Form this study, it can be concluded that the *Chattonella* is one of significant red tide species in the Ariake Sea and the behavior of *Chattonella* should be concerned in the water quality model of the Ariake Sea.

6. Acknowledgement

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7. References

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