J. Fish. Sci. Tech.. 6(2), 66-73, 2003

JOURNAL OF
FISHERIES SCIENCE
AND TECHNOLOGY

Filtration of Red Tide Dinoflagellates by an Intertidal Bivalve, *Glauconome chinensis* Gray: An Implication for the Potentials of Bivalves in Tidal Flats

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To understand the physiology of a suspension-feeding bivalve and its potential impacts on the dynamics of red tides on tidal flats, rates of clearance and ingestion of *Glauconome chinensis* were measured as a function of algal concentration, when the bivalve was fed on a nontoxic strain of red tide dinoflagellate *Prorocentrum minimum*, *Cochlodinium polykrikoides* or *Scrippsiella trochoidea*. With increasing algal concentration, weight-specific clearance rate increased rapidly at lower concentrations and after reaching the maximum at ca. 0.2 to 1.0 mgC/L, it decreased at higher concentrations. Maximum clearance rate was nearly equal for different algal species and ranged between 2.1 and 2.6 L/g/hr. Weight-specific ingestion rate also increased at lower algal concentrations but saturated at higher concentrations. Maximum ingestion rate was 2 to 10 fold different with different algal species: *S. trochoidea* (10.1 mgC/g/hr), *P. minimum* (3.9 mgC/g/hr), and *C. polykrikoides* (0.99 mgC/g/hr). Nitrogen and protein content showed that *S. trochoidea* is the best among the tested three red tide dinoflagellates. The maximum filtration capacity, calculated by combining the data on ingestion rate from laboratory experiments and those from the field for the density of the bivalve and the red tide dinoflagellates was 4.7, 1.4, and 25.3 tons/m^2/day for *P. minimum*, *C. polykrikoides*, and *S. trochoidea*, respectively. It is hypothesized that the abundant suspension-feeding bivalves in tidal flats can effectively mitigate the outbreak of red tides.

Key words: *Glauconome chinensis*, Red tide dinoflagellates, Clearance rate, Ingestion rate, Chemical composition, Tidal flat

Introduction

In tidal flat communities, suspension-feeding bivalves are one of the most dominant taxonomic invertebrate groups. Their major role is to filter suspended particles from the water column. Therefore, a dense population of bivalves can influence the structure of the pelagic community (Cloern, 1982; Officer et al., 1982). Several studies have emphasized that bivalves can effectively control and reduce phytoplankton biomass (Carlson et al., 1984; Gerritsen et al., 1994). Inversely, the phytoplankton community in the water column also can influence the structure of the benthic community. In general, high algal production is beneficial to suspension-feeding bivalves. However, some extreme algal blooms, especially dominated by the so called red tide dinoflagellates, are harmful. Depending on the algal species and its concentration, an algal bloom can be either beneficial or harmful to bivalve populations.

Many studies on the interactions between suspension-feeding bivalves and red tide dinoflagellates (Lesser and Shumway, 1993; Luckenbach et al., 1993; Matsuyama et al., 1997; Li et al., 2001) have focused on the adverse effects of toxic red tide dinoflagellates on commercially important bivalves. However, red tides are not always dominated by toxic algal species alone. A large number of nontoxic dinoflagellates may also abound during the red tides (Kim et al., 1997). The adverse effect of red tides is not restricted to only commercially important bivalves, and in many

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cases the occurrence of red tide resulted in little or no damage to bivalve populations.

Nontoxic red tide dinoflagellates can apparently serve as food for suspension-feeding bivalves, and the bivalves can effectively mitigate the red tides by their filtering activities. Hence, the purpose of this study is to determine how much of the nontoxic red tide dinoflagellates can be filtered by suspension-feeding bivalves. We selected a small intertidal bivalve, *Glauconome chinensis* Gray (Glauconomidae) and three nontoxic strains of dinoflagellates *Prorocentrum minimum*, *Cochlodinium polykrikoides*, and *Scrippsiella trochoidea* as the test organisms. *G. chinensis* is not commercially important but is one of the most abundant species on the upper zone of tidal flats near Kunsan (Lee et al., unpublished data). Therefore, their ecological role in the dynamics of tidal flat community cannot be ignored. Hitherto, there were no studies on functional aspects of this bivalve on the tidal flats of Korea. Rates of clearance and ingestion of *G. chinensis* were measured as a function of algal concentration, when the bivalve was fed a unialgal diet of the red tide dinoflagellates. Nutritional quality of algal species was also assessed by measuring the carbon, nitrogen, and protein contents. Using the results and field data from relevant literature, we assessed the cumulative filtration capacity of *G. chinensis* in a tidal flat. Thus, this study provides an insight into the feeding aspects of a bivalve and its role in mitigating red tides in a tidal flat community.

Materials and Methods

Test organisms

Approximately 500 individuals of *G. chinensis* were collected from Sura tidal flat near Kunsan (35° 55' 59" N, 126° 36' 56" E), west coast of Korea. They were separated from sediments by sieving with a 2-mm mesh screen and transported to the laboratory within 1 hr of collection. They were then rinsed with 5 μm filtered seawater and acclimated to the experimental temperature (20℃) without feeding for 1 day. They were maintained in a 20-liter aquarium with filtered seawater in a calm place under dim light (5 $\mu E/m^2/sec$). Only individuals of shell length 12 ± 1 mm were used for experiments.

The red tide dinoflagellates *P. minimum*, *C. polykrikoides*, and *S. trochoidea* were grown at 20℃ in enriched f/2 seawater medium (Guillard and Ryther, 1962) without silicate under continuous illumination of 100 $\mu E/m^2/sec$ provided by cool-white fluorescent light. Only cultures in exponential growth phase were used for experiments.

Feeding experiments

Experiments were designed to measure the rates of clearance and ingestion of *G. chinensis* as a function of algal concentration, when fed on a unialgal diet of red tide dinoflagellate (Table 1). Using an autopipette to deliver the predetermined volume of known concentration to the bottle, the desired initial concentrations of algae was established. Triplicate 270 mL polycarbonate bottles (Nalgene Co.) were used as feeding chambers. They were filled with 250 mL of algal suspension, and then 4 individuals of *G. chinensis* were transferred to each bottle. Triplicate control bottles with the highest concentration of algae alone (without *G. chinensis*) were also set up. The control was used to check changes in algal concentration due to growth, death, or attachment of the cells to the bottle. Bottles were maintained in a calm place at 20℃ under 5 $\mu E/m^2/sec$ of cool-white fluorescent light for 4 hr. To determine the actual concentrations of algae at the beginning and the end of experiments, an aliquot of 5 mL algal suspension was subsampled from each bottle and fixed with 5%

Table 1. Initial concentration and carbon content of three species of red tide dinoflagellates used in feeding experiments for the measurements of the clearance rate and ingestion rate of an intertidal bivalve, *Glauconome chinensis*

Algal species	Initial concentration (cells/mL)	Carbon content (mgC/L)
Prorocentrum minimum	2.0×10^3	0.4
	4.9×10^3	1.0
	1.3×10^4	2.7
	3.0×10^4	6.3
	6.5×10^4	13.6
Cochlodinium polykrikoides	3.3×10^2	0.3
	6.9×10^2	0.5
	1.5×10^3	1.2
	3.0×10^3	2.4
	5.6×10^3	4.5
Scrippsiella trochoidea	8.8×10^2	0.6
	1.9×10^3	1.3
	3.4×10^3	2.3
	8.0×10^3	5.5
	1.3×10^4	9.1

Lugol's solution; >400 algal cells were counted in an 1-mL Sedgwick-Rafter Chamber (SRC). If cell concentration was less than 400 cells/mL, all the cells in SRC were counted. Counting was triplicated for each sample. At the end of the experiment, pseudofeces were transferred by a Pasteur pipette into vials with 20 mL of filtered seawater. Vials were shaken vigorously to disperse all the cells into suspension and cell concentration was determined. After the experiment, dry weight of the flesh of each bivalve was measured. Soft tissue was removed from the shells, dried in an oven at 90℃ for 48 hr, then weighed on an electronic microbalance (Sartorius Co.) to the nearest 0.001 mg.

Calculation of clearance rate and ingestion rate

The clearance rate (CR, mL/ind./hr) was calculated as:

$$CR=V\,[\ln (C^*_t/C^*_0) - \ln (C_t/C_0)] / (N \cdot t) \qquad (1)$$

where, V is the volume of algal suspension (mL); C^*_0 and C^*_t are initial and final concentration of algae in control bottle (cells/mL); C_0 and C_t are initial and final concentration of algae in experimental bottle (cells/mL); N is the number of *G. chinensis* in experimental bottle (ind.); t is incubation time (hr). Algal concentrations were converted from cell number (cells/mL) to carbon equivalent (mgC/L) to facilitate interspecific comparison. Weight-specific clearance rate was calculated by standardizing clearance rate to flesh dry weight of the tested bivalve and expressed in L/g/hr. To determine the functional response of *G. chinensis* to algal concentration, data on clearance rate were fitted to an exponential equation (Riisgård, 1988):

$$CR=a/\langle C\rangle \cdot e^{-b/\langle C\rangle} \qquad (2)$$

where, <C> is the mean algal concentration during incubation period (Frost, 1972); a and b are parameters estimated by curve-fitting. Parameter a explains the magnitude of the clearance rate and parameter b denotes the algal concentration at which the clearance rate is maximal. The maximum clearance rate (C_{max}) was calculated by substituting the algal concentration with estimated b value to the above equation.

The ingestion rate (IR) was calculated as:

$$IR=[\langle C\rangle \cdot CR] - PS \qquad (3)$$

where, PS is the rate of pseudofeces production. Weight-specific ingestion rate was calculated the same as the clearance rate and expressed in mgC/g/hr. To determine the functional response of *G. chinensis* to algal concentration, data on ingestion rates were fitted to a Michaelis-Menten equation:

$$IR=I_{max} \cdot C/(K_{IR}+C) \qquad (4)$$

where, I_{max} is the maximum ingestion rate; C is algal concentration; K_{IR} is the algal concentration sustaining 50% of I_{max}.

Biochemical composition of red tide dinoflagellates

Biochemical composition was analyzed to compare the nutritional value of the three dinoflagellates. To determine carbon and nitrogen contents, the algal cultures were filtered on GF/C filters (Whatman Ltd.) and the filters were dried in an oven at 90℃ for 48 hr; subsequently, the carbon and nitrogen contents were analyzed in a CHN analyzer (Carlo Erba, EA-1110).

Total protein content of the dinoflagellates was determined by the micro Lowry method modified by Peterson (1977), with a protein assay kit (Sigma Co.). One mL of concentrated algal suspension was transferred to a test tube, to which 1 mL of Lowry reagent was added. After 20 min, 0.5 mL of Folin and Ciocalteu's phenol reagent was added and mixed immediately. After 30 min, the optical density was read at 750 nm on a spectrophotometer (Shimadzu, UV-160A) with bovine serum albumin as standard.

Statistical analyses

Data on the rates of clearance and ingestion at the tested concentrations for each algal species were compared by one-way ANOVA on SPSS program. Multiple comparisons were conducted using Tukey's HSD (Zar, 1984). Before statistical analyses, data on the rates of clearance and ingestion were tested for normality (Shapiro-Wilk's test) and homogeneity of variance (Bartlett's test). If at least one of the above ANOVA requirements was not met, the data were $\log_{10}$ transformed, and then ANOVA was repeated. For all analyses, a significance level of $\alpha=0.05$ was used.

Results

Clearance rate

In general, the weight-specific clearance rate of *G. chinensis* feeding on one of the tested algae rapidly increased with increasing algal concentration and after reaching a peak, the rate decreased with further increase in algal concentration. The rapidly increasing phase was observed at algal concentrations ranging from 0.29 to 0.54 mgC/L for *P. minimum* (Fig. 1), 0.16 to 0.31 mgC/L for *C. polykrikoides* (Fig. 2) and 0.39 to 1.25 mgC/L for *S. trochoidea* (Fig. 3). For these tested algae, the rate was minimal at the concentration of 12.76, 4.12 and 6.98 mgC/L, respectively. When the clearance rate data were fitted to eq. (2), the maximum clearance rate (C_{max}) was estimated as 2.61, 2.21 and 2.38 L/g/hr for *P. minimum*, *C. polykrikoides* and *S. trochoidea*, respectively (Table 2).

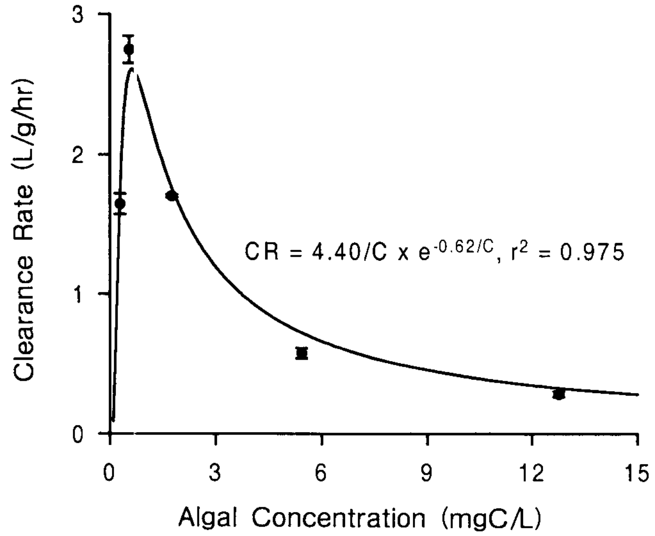

Fig. 1. Weight-specific clearance rate (L/g/hr) of *Glauconome chinensis* as a function of mean algal concentration (mgC/L), when fed on *Prorocentrum minimum*. Symbols represent treatment means ± 1 SE. The curve was fitted by an exponential equation [eq. (2)] using all treatments.

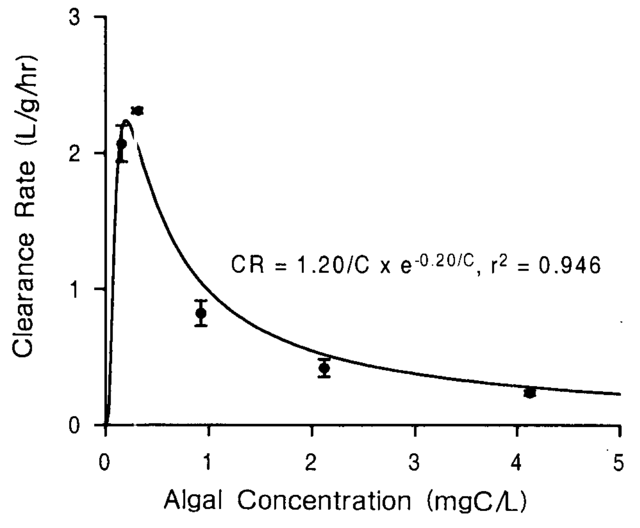

Fig. 2. Weight-specific clearance rate (L/g/hr) of *Glauconome chinensis* as a function of mean algal concentration (mgC/L), when fed on *Cochlodinium polykrikoides*. Symbols represent treatment means ± 1 SE. The curve was fitted as in Fig. 1.

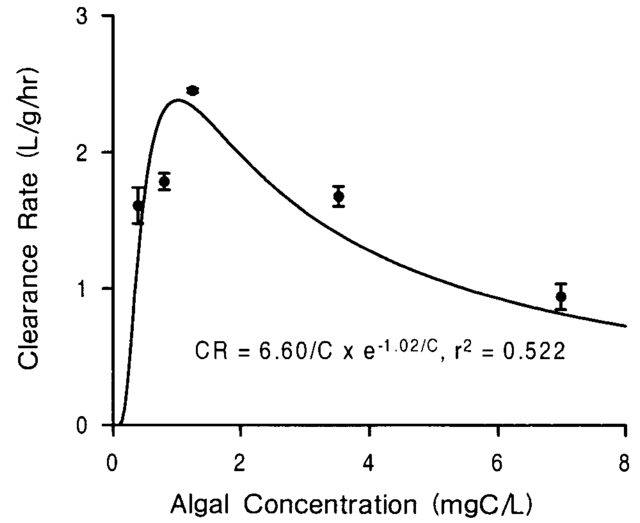

Fig. 3. Weight-specific clearance rate (L/g/hr) of *Glauconome chinensis* as a function of mean algal concentration (mgC/L), when fed on *Scrippsiella trochoidea*. Symbols represent treatment means ± 1 SE. The curve was fitted as in Fig. 1.

Table 2. Feeding parameters of *Glauconome chinensis* fed on red tide dinoflagellates. Parameters are maximum clearance rate (C_{max}), maximum ingestion rate (I_{max}) and algal concentration sustaining 50% of I_{max} (K_{IR})

Algal species	C_{max} (L/g/hr)	I_{max} (mgC/g/hr)	K_{IR} (mgC/L)
Prorocentrum miinimum	2.61	3.90	0.92
Cochlodinium polykrikoides	2.21	0.99	0.22
Scrippsiella trochoidea	2.38	10.13	3.26

Ingestion rate

Weight-specific ingestion rate of *G. chinensis* fed on *P. minimum* rapidly increased ($p<0.001$), with increasing concentration from 0.29 to 1.76 mgC/L (Fig. 4). As the concentration increased further, the ingestion rate did not increase significantly ($p=0.062$). When data on the ingestion rate were fitted to eq. (4), the maximum ingestion rate (I_{max}) and the algal

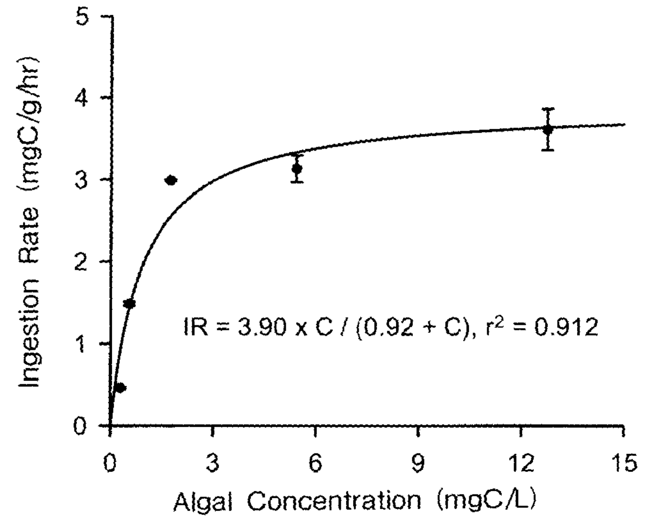

Fig. 4. Weight-specific ingestion rate (mgC/g/hr) of *Glauconome chinensis* as a function of mean algal concentration (mgC/L), when fed on *Prorocentrum minimum*. Symbols represent treatment means ± 1 SE. The curve was fitted by a Michaelis-Menten equation [eq. (4)] using all treatments.

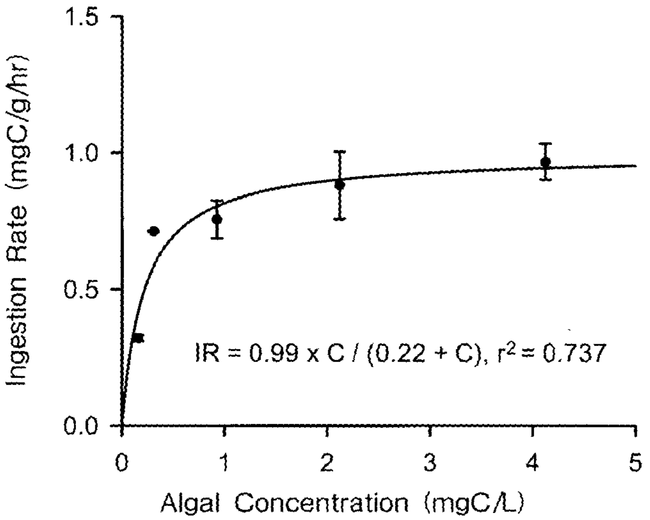

Fig. 5. Weight-specific ingestion rate (mgC/g/hr) of *Glauconome chinensis* as a function of mean algal concentration (mgC/L), when fed on *Cochlodinium polykrikoides*. Symbols represent treatment means ± 1 SE. The curve was fitted as in Fig. 4.

concentration sustaining 50% of I_{max} (K_{IR}) were estimated as 3.90 mgC/g/hr and 0.92 mgC/L, respectively (Table 2). The trends for the weight-specific ingestion rates of other algae, namely *C. polykrikoides* and *S. trochoidea* were similar (Figs. 5, 6). When data on ingestion rates were fitted to eq. (4), the I_{max} and K_{IR} were estimated as 0.99 mgC/g/hr and 0.22 mgC/L for *C. polykrikoides*, and 10.13 mgC/g/hr and 3.26 mgC/L for *S. trochoidea*.

Biochemical composition of the red tide dinoflagellates

Carbon and nitrogen contents of the tested red tide dinoflagellates were in the range of 0.21-0.79 and 0.03-0.14 ng/cell, respectively (Table 3). *P. minimum* showed the highest C:N ratio (8.6) and *S. trochoidea* the lowest (5.6). Protein content was highest in *S. trochoidea* (69.1%) and lowest in *C. polykrikoides* (34.7%).

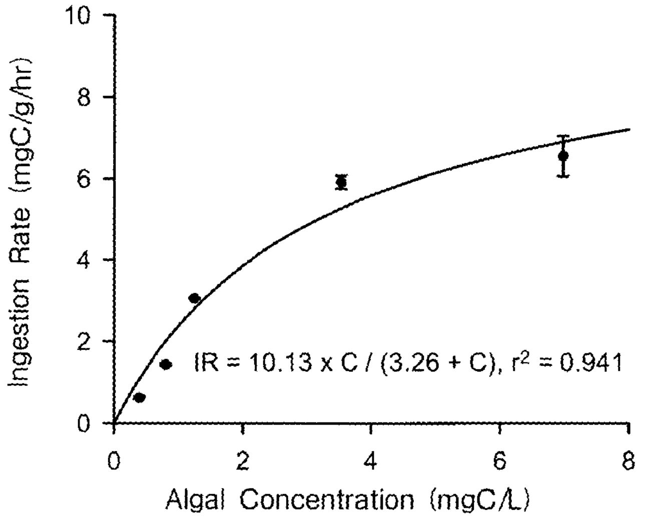

Fig. 6. Weight-specific ingestion rate (mgC/g/hr) of *Glauconome chinensis* as a function of mean algal concentration (mgC/L), when fed on *Scrippsiella trochoidea*. Symbols represent treatment means ± 1 SE. The curve was fitted as in Fig. 4.

Discussion

The clearance rate of *G. chinensis* was highest at low algal concentration (Figs. 1-3). Reduction in clearance rate with increasing algal concentration is known as a general phenomenon (Bayne et al., 1976). The C_{max} of *G. chinensis* (2.21-2.61 L/g/hr; Table 3) is lower than those of *Potamocorbula amurensis* (4.97-17.8 L/g/hr, Werner and Hollibaugh, 1993), and the mussel *Mytilus edulis* (18 L/g/hr, Clausen and Riisgård, 1996), and spats of scallop *Argopecten ventricosus-circularis* (8.7- 17.8 L/g/hr, Sicard et al., 1999). The C_{max} values of *G. chinensis* on three different red tide dinoflagellates (RTDs) are almost

Table 3. Size (length×width), dry weight and biochemical composition of three species of red tide dinoflagellates chosen as the food for the intertidal bivalve, *Glauconome chinensis*

Algal species	Size (μm)	Dry weight (ng/cell)	C (ng/cell)	N (ng/cell)	C:N ratio	Protein (%)
Prorocentrum minimum	17.0×12.6	0.37	0.21	0.03	8.6	44.0
Cochlodinium polykrikoides	27.8×21.2	3.01	0.79	0.12	7.7	34.7
Scrippsiella trochoidea	24.2×20.6	1.92	0.68	0.14	5.6	69.1

equal. This indicates that the filtration potential of *G. chinensis* is not affected by the algal species. Matsuyama et al. (1997) reported that there was no significant difference in clearance rate of *M. galloprovincialis* fed on *Isochrysis galbana* (non-RTD), *S. trochoidea* (nontoxic RTD), or *Heterocapsa triquetra* (nontoxic RTD). They found a reduction in clearance rate only when the algal species was a toxic RTD (*H. circularisquama*). Li et al. (2001) stated that the filtration process of *Ruditapes philippinarum* and *Chlamys nobilis* did not distinguish *Alexandrium tamarense* (toxic RTD) from *Thalassiosira pseudonana* (diatom), as there was no significant difference in clearance rate between these species offered in different algal mixtures. In another experiment, C_{max} of *G. chinensis* fed on a non-RTD (*I. galbana*) was 2.56 L/g/hr (Lee et al., 2002) and lies in the same range as that obtained for the RTDs tested in this study. Therefore, the C_{max} of 2.21-2.61 L/g/hr can be regarded as the maximum filtration potential of *G. chinensis*, irrespective of algal species.

However, the algal concentrations at which C_{max} was found [parameter b in eq. (2)] were not the same among three red tide dinoflagellates. C_{max} for *P. minimum* and *C. polykrikoides* were found at relatively low concentrations (0.62 and 0.20 mgC/L, respectively), as compared to relatively higher concentration (1.02 mgC/L) for *S. trochoidea*. This indicates that *G. chinensis* can filter more *S. trochoidea* than *P. minimum* or *C. polykrikoides*, if the given alga is equal in amount at high concentration. At algal concentrations over 2 mgC/L, clearance rate is in the following order: *S. trochoidea*, *P. minimum*, and *C. polykrikoides*. Similarly, the I_{max} for *S. trochoidea* (10.13 mgC/g/hr) is ca. 3 and 10 times higher than that for *P. minimum* (3.90 mgC/g/hr) and *C. polykrikoides* (0.99 mgC/ g/hr), respectively.

Several explanations are possible for the differences in the rates of clearance and ingestion of *G. chinensis* fed on different algal species. Shumway et al. (1997) found that clearance rate of three species of scallops was higher (within the range of 3-13 μm) for larger particles. In contrast, Li et al. (2001) reported that the clearance rate of *R. philippinarum* and *C. nobilis* was equal for larger (30-40 μm) and smaller (5-6 μm) particles. According to Shumway et al. (1997), the differences in clearance rate between *S. trochoidea* (24 μm) and *P. minimum* (17 μm) can easily be explained. However, the lowest clearance rate for *C. polykrikoides* (28 μm) cannot be explained.

The low rates of clearance and ingestion obtained for *C. polykrikoides* seem to be related to its swimming speed, morphology, and extracellular metabolites. Measuring the swimming speed of various dinoflagellate species, Jeong et al. (1999) noted that *C. polykrikoides* swam much faster (1,063 μm/sec) than *P. minimum* (157 μm/sec) and *S. trochoidea* (304 μm/sec). They also found that the mixotrophic dinoflagellate *Fragilidium* cf. *mexicanum* could not catch only *C. polykrikoides* due to its high swimming speed.

In addition, *C. polykrikoides* is a chain-forming dinoflagellate with up to 8 cells in a chain, but *S. trochoidea* and *P. minimum* are solitary. In this study, only 14% of *C. polykrikoides* existed as single cells, while 55% had 2 cells and 31% more than 3 cells. Therefore, even though the size of a single cell of *C. polykrikoides* is similar to *S. trochoidea*, the average size of *C. polykrikoides* actually contacted by *G. chinensis* was much larger (and longer), perhaps resulting in difficulty filtering the long-chained cells. Lee (1996) reported that extract from *C. polykrikoides* cells was not toxic to fishes and mice, and no toxin was detected from its extracts by HPLC analyses. Evidently, *C. polykrikoides* may not produce toxins as products of intracellular metabolism. However, Kim et al. (1999) noted that in its exponential growth phase, *C. polykrikoides* produced hydrogen peroxide, which can induce oxidative damage to gill tissues of fishes and eventually lead to death. Kim et al. (2000) found that flounder (*Paralichthys olivaceus*) and red sea bream (*Pagrus major*) succumbed to the oxidative damage of *C. polykrikoides* at the concentration of 2.4 mgC/L (ca. 3000 cells/mL).

Table 4. Estimation of filtration capacity of *Glauconome chinensis* by combining filtration rate determined from laboratory experiments and the abundance data measured from the field for three red tide dinoflagellates

Algal species	Filtration rate[1] (10^9 cells/m^2/day)	Abundance[2] (cells/mL)	Filtration capacity (tons/m^2/day)
Prorocentrum minimum	18.90	4,000 - 35,000	0.54 - 4.72
Cochlodinium polykrikoides	1.28	920 - 8,700	0.15 - 1.39
Scrippsiella trochoidea	15.16	600	25.27

[1] Assuming the density of *G. chinensis* as 5000 ind./m^2 (Lee et al., unpublished data).
[2] Kim et al. (1997)

Though not lethal to *G. chinensis*, hydrogen peroxide released from *C. polykrikoides* might act as a feeding deterrent. Possibly, the low rates of clearance and ingestion observed for *G. chinensis* fed on *C. polykrikoides* are partly due to extracellular release of hydrogen peroxide.

Our data showed that *S. trochoidea* is the best food among three red tide dinoflagellates. The lowest C:N ratio and highest protein content also imply that *S. trochoidea* has the highest nutritional value (Table 3). Therefore, it is expected that the growth rate of *G. chinensis* feeding on *S. trochoidea* will be higher than those on *P. minimum* or *C. polykrikoides*. However, the biochemical composition of the algal species may also affect clearance rate and ingestion rate directly. For a better understanding of the response of bivalves to nutritional quality of the red tide dinoflagellates, measurements on growth efficiencies should be made in long-term experiments.

G. chinensis ingested all three red tide dinoflagellates and ingestion rate was not inhibited at high algal concentrations. The concentration ranges of the dinoflagellates in our experiments are similar to those found in the field at the time of red tides around Korean coasts (Kim et al. 1997). The maximum filtration capacity (the maximum volume of water that *G. chinensis* in 1 m^2 of a bottom can clear per day) calculated by combining the ingestion rate from laboratory experiments and the abundance data from fields for the bivalve and for the three dinoflagellates is as high as 4.7, 1.4, and 25.3 tons/m^2/day for *P. minimum*, *C. polykrikoides*, and *S. trochoidea*, respectively (Table 4). Hence, *G. chinensis* can remove substantial quantities of nontoxic red tide dinoflagellates from the water column. However, in extreme cases, the concentration of *C. polykrikoides* during the red tides in Korean coastal water reached up to 30,000 cells/mL which is much higher than the maximum concentration used in our experiments (5,600 cells/mL). We could not test with cultures of *C. polykrikoides* over 5,600 cells/mL because it was not easy to obtain higher concentrations in laboratory conditions. Thus, it remains still unknown how *G. chinensis* will respond to *C. polykrikoides* with concentrations ranging from 5,600 to 30,000 cells/mL.

The frequency and intensity of red tides along the western coast are lower than along the southern coast of Korea. The western coast of Korea has a macrotidal regime (tidal range of more than 4 m). Large tidal flats (up to several kilometers in distance between low and high tide lines) are well-developed along the coastline. Here, we suggest a hypothesis that the abundant suspension-feeding bivalves such as *G. chinensis* in tidal flats may mitigate the outbreak of red tides. The ecological impacts of the bivalve on red tide dinoflagellates may also be great. However, this study exhibited only the potentials of bivalves to remove red tide dinoflagellates in laboratory conditions. It is not sure that the bottom-dwelling bivalves actually remove red tide dinoflagellates from water column at all cases; it cannot be regarded as a general phenomenon. Rather, it can be applied to special cases such as shallow areas or tidal flats. To understand the potential of bivalves as grazers of red tide dinoflagellates and their role in tidal flat ecosystems, we need more detailed and systematic studies on the natural abundances and the ingestion rates of the other bivalves on the tidal flats of Korea.

Acknowledgements

The authors are grateful to Dr. T.J. Pandian of Madurai Kamaraj University of India and to the referees for helpful comments and corrections on the manuscript. The authors are also grateful to Mr. Yeong Tae Kim and Mr. Ki Hyun Kim of Kunsan National University, and Mr. Tae Seob Choi of Chonnam

National University for technical supports.

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(Received January 2002, Accepted June 2003)