

Grazing pressure by amphipods on microalgae in Gamo Lagoon, Japan

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ABSTRACT: Grazing effects of amphipods were examined for 3 groups of diatoms (loosely attached cells, moderately attached cells and strongly attached cells) in Gamo Lagoon, Miyagi Prefecture, Japan. Diatom species with filamentous forms or low adhesive strength were susceptible to grazing, while those with stronger adhesion were less affected by grazing pressure. Seasonal trends for both amphipods and microalgae found on the macroalgae *Gracilaria vermiculophylla* showed high densities of amphipods and low densities of microalgae during warmer months (June to September) and vice versa in colder months (December to March). This inverse relationship between densities of amphipods and diatoms suggests a causal relationship and that effects of grazing pressure by amphipods on epiphytic diatom communities seem to be strong in Gamo Lagoon. A manipulative experiment (feeding pressure experiment) revealed that *Melosira* sp. and *Nitzschia* sp. were mostly selected by tube-dwelling species (*Corophium uenoi* and *Grandidierella japonica*), whilst *Gyrosigma* sp. and *Melosira* sp. were mostly selected by free-living species (*Eogammarus possjeticus* and *Melita setiflagella*).

KEY WORDS: Grazing pressure · Amphipods · Diatom · Algae · Gamo Lagoon

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INTRODUCTION

The presence of epiphytes on aquatic macrophytes has been noted in communities worldwide, but their role has often been difficult to assess. In aquatic environments, epiphytes have been found to contribute to the primary productivity of the ecosystem (Brock 1970, Finke 1978, Jones 1980) and also supply food for grazers (Randall 1964, Reyes-Vasquez 1970, Berg 1974, Zimmermann et al. 1979, Morgan 1980, Brawley & Adey 1981). Therefore epiphytes are important components of food webs in an aquatic ecosystem.

Grazing pressure of epifauna on periphyton has been reported by D'Antonio (1985) to cause significant periphyton biomass reductions. Previous studies by Zimmerman et al. (1979) revealed the capacity of amphipods to reduce periphyton biomass. Admiraal (1977) reported that the benthic microflora contributes considerably to the primary production in the Ems-

Dollard estuary and consists largely of diatoms. Many laboratory and field experiments have shown that the standing crop and species composition of benthic diatoms are influenced by grazing pressure (Hickman & Round 1970, Nicotri 1977, Kawamura & Hirano 1992). Reduction of microalgae biomass on macroalgae has been observed in Gamo Lagoon, especially during summer. Considering the important position of microalgae in the aquatic food chain, studies of prey choice among estuarine omnivores feeding on epiphytic microalgae are very necessary. For the epibenthic diatom community, grazing pressure can have a determinant effect on species composition and diversity (Sumner & McIntire 1982), biomass (Castenholz 1961, Calow 1973) and vertical development (Nicotri 1977, Kesler 1981). In Gamo Lagoon, grazing pressure exerted by amphipods on microalgae was investigated after observation of an increase in attached material during the winter months that disappears in summer. The aim of this work is to elucidate some of the factors causing this seasonal variation in attached material.

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Many amphipods are known to assimilate microscopic flora (bacteria, fungi and diatoms) more efficiently than the organic substratum on which they grow (detritus, macroalgae and vascular plants) (Zimmerman et al. 1979, Morrison & White 1980). In the present investigation, we examined the role of the strength of adhesion of microalgae to surfaces in their susceptibility to grazing by amphipods. Grazing effects were examined for 3 groups of diatoms: loosely, moderately and strongly attached cells. In order to examine the grazing effects of amphipods on microalgae, seasonal trends of both amphipods and microalgae were determined. To obtain a detailed picture of the relationship between amphipods and microalgae, a manipulative experiment was carried out in Gamo Lagoon to assess the feeding preferences of several amphipod species.

MATERIALS AND METHODS

Study site and sampling of macroalgae. Field investigations and experiments were carried out in the estuarine environment of Gamo Lagoon (Fig. 1), a small brackish lagoon at the mouth of the Nanakita River running through the northern part of Sendai City, NE Japan ($38^{\circ}15'N$, $141^{\circ}00'E$), that covers a total area of about 10 ha. A stone levee with 3 rectangular entry channels forms a gateway through which lagoon water is exchanged via tidal movement. Salinity varies from 5 to 30‰ at the center of Gamo Lagoon according to tidal state (Kurihara et al. 1997). Average daily water temperatures were maximum during July and August (25 and 30°C), and minimum during January and February (3 and 6°C) (Kurihara et al. 1997). During low tides, sandy mud flats appear in the outer and central parts of the lagoon and outside the levee, whereas the innermost part of the lagoon remains covered by water (Kikuchi et al. 1980).

Samples of the macroalga *Gracilaria vermiculophylla* (Ohmi) Papenfuss were collected monthly from 2 stations (Stn 1 and Stn 2; Fig. 1) located approximately 200 and 800 m from the levee of Gamo Lagoon, respectively. Stn 1 was located in a backwater of the lagoon near the seaward end, and Stn 2 in the innermost reaches of the lagoon. *G. vermiculophylla* was found at both stations. Monthly samples were taken from January to December 1999 using a 0.25 m² quadrat placed randomly at algal sites at both stations. Four replicates were sampled at both stations per visit on the same day per month. *G. vermiculophylla* was gently pulled from the sediment by hand and placed in polyethylene bags. Chilled samples (in icebox filled with ice blocks) were then transported to the laboratory for further treatment.

In the laboratory, attached materials were scraped from the macroalgae. Identification and cell counts of sub-sampled diatoms fixed in 2.5% glutaraldehyde solution were done under a light microscope. For each replicate, 6 sub-samples of 0.1 ml were further sampled for counting. Algal samples were treated in 3 ways to remove all attached material: (1) loosely attached material was rinsed off each sample with 200 ml distilled water into a plastic tray; (2) moderately attached material was washed vigorously from each sample with 200 ml distilled water into a second tray; (3) strongly attached material was removed completely from thalli with a nail brush and placed into a third tray. The algal samples were drained for ca. 30 min and oven-dried for 48 h; dry weight was then determined to the nearest 0.05 g.

Macrofauna were identified to species under a stereoscopic microscope. Each species was stored in a separate sampling bottle containing 70% ethanol and counted to determine density. Chlorophyll *a* and *c* contents were determined for all 3 groups of attached material from the macroalgae by the acetone extraction method of Lorenzen (1967).

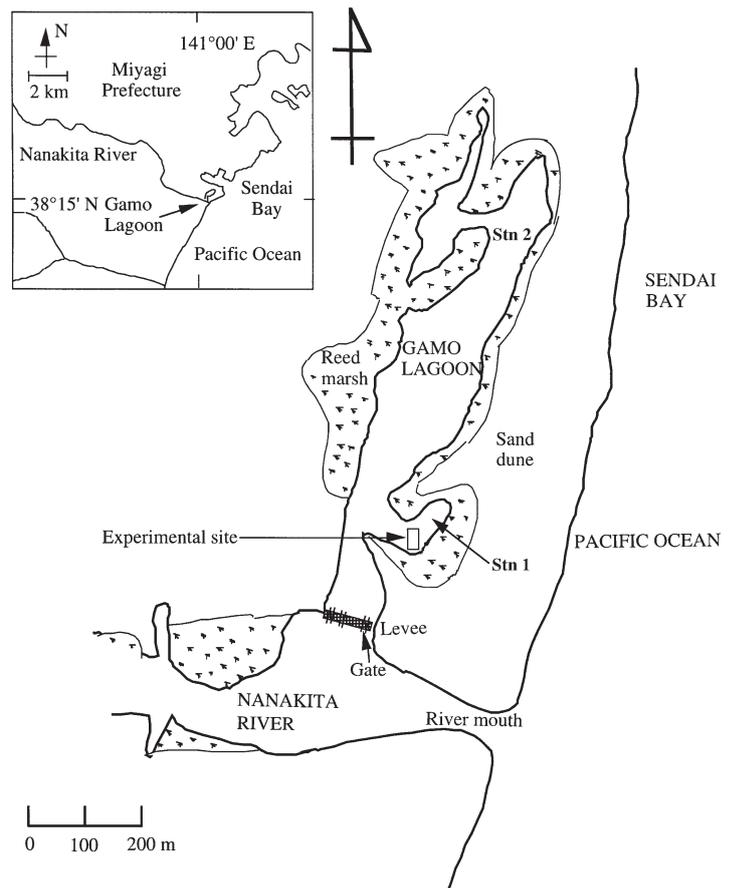


Fig. 1. Study sites in Gamo Lagoon, Japan

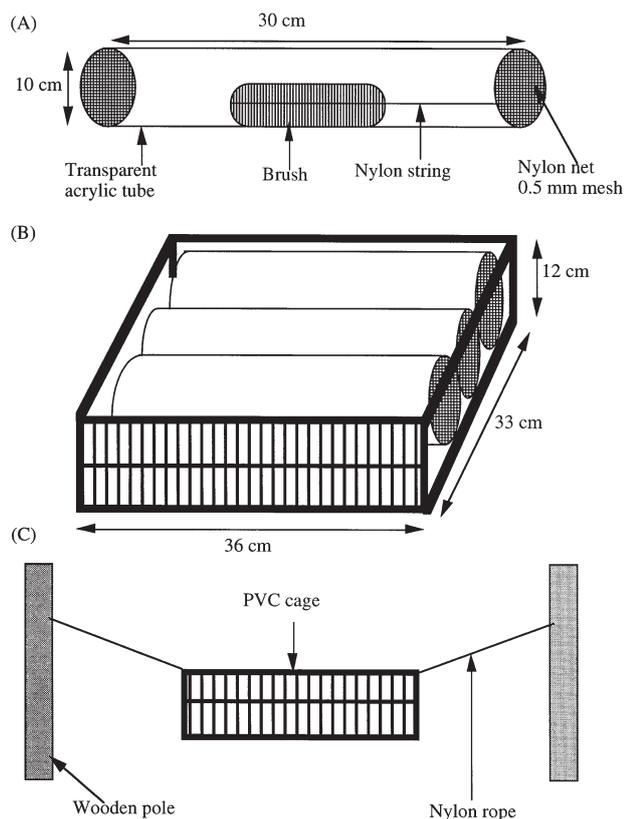


Fig. 2. Experimental design and setup in Gamo Lagoon. (A) Acrylic tube with inserted brush; (B) PVC cage with 3 tubes; (C) PVC cage setup

Feeding pressure experiment. A manipulative experiment was set up in August 2000 inside the lagoon approximately 200 m from the levee, near Stn 1 (Fig. 1), and was sampled after 2 wk. For the feeding pressure experiment, we used 4 species of amphipods (*Corophium uenoi*, *Eogammarus possjeticus*, *Melita setiflagella* and *Grandidierella japonica*) from Gamo Lagoon. These species are dominant and widely distributed on natural and artificial substrates in Gamo Lagoon (Aikins & Kikuchi 2001). Cultures of 50 adults of each species were inoculated into separate tubes of almost 0.25 m², corresponding to the minimum density of *M. setiflagella* (198 ind. m⁻²) in August in the field.

For the experimental set up, one end of a transparent acrylic tube (30 cm length, 10 cm diameter) was sealed with a nylon plankton net (0.5 mm mesh) (Fig. 2). Brushes were used as a substrate substitute for natural algae, since they support a diatom species composition similar to that of *Gracilaria vermiculophylla* (see Table 2). The brushes were made of polypropylene strings and were cylindrical in shape (10.5 cm length, 5.0 cm diameter); their filamentous nature is similar to that of natural substrate (macro-

algae), and they provide a suitable habitat for the amphipods (Aikins & Kikuchi 2001). Brush substrates were inserted into tubes by nylon strings, the various amphipod species were inoculated into the tubes and the open end was sealed with nylon plankton net (0.5 mm mesh).

Three sealed transparent acrylic tubes, each containing different amphipod species, were placed together in a PVC (polyvinyl chloride) cage (36 × 33 × 12 cm). The cages were suspended in the lagoon water on nylon ropes (Fig. 2). Control tubes (without amphipods) were placed randomly among inoculated tubes. Five replicates of each amphipod species in tubes and 7 control tubes were set and sampled 2 wk later. In all, 9 PVC cages containing a total of 27 tubes were set up.

Samples were transported on ice to the laboratory for further treatment. Attached materials removed from brush substrates were fixed in 2.5% glutaraldehyde solution for identification, cell counts and species composition. TWINSpan (Hill 1979, Jongman et al. 1987) was carried out using PC-ORD for Windows (Version 3.2.0). Cluster analysis (single linkage method) was used to reveal the similarities in diatom selection by the 4 species of amphipods.

RESULTS

Monthly changes in *Gracilaria vermiculophylla* biomass and amphipods

Maximum and minimum dry biomasses (g m⁻²) of *Gracilaria vermiculophylla* at Stns 1 and 2 were recorded in the warmer (June to September) and colder (December to March) months, respectively (Fig. 3). At Stn 1, dry biomass increased from March, reached a peak of about 600 g m⁻² in July, and declined steadily to a minimum of 120 g m⁻² in February. A similar trend occurred at Stn 2: dry biomasses of 810 and 75 g m⁻² were recorded in July and February, respectively.

For all species of amphipods, high and low densities were found in the warmer and colder months, respectively (Fig. 4). The amphipods have 2 kinds of lifestyles: the tube-dwelling species *Corophium uenoi* and *Grandidierella japonica* construct and live in tubes; the free-living species *Eogammarus possjeticus* and *Melita setiflagella* cling to or crawl over algae without constructing tubes (Table 1). There was a clear positive correlation between tube-dwellers and macroalgal biomass at both stations: correlation at Stns 1 and 2 was significant at the 5 and 1% levels, respectively (Table 1). Of the free-living species, *M. setiflagella* showed a positive correlation ($p < 0.01$) at Stn 1,

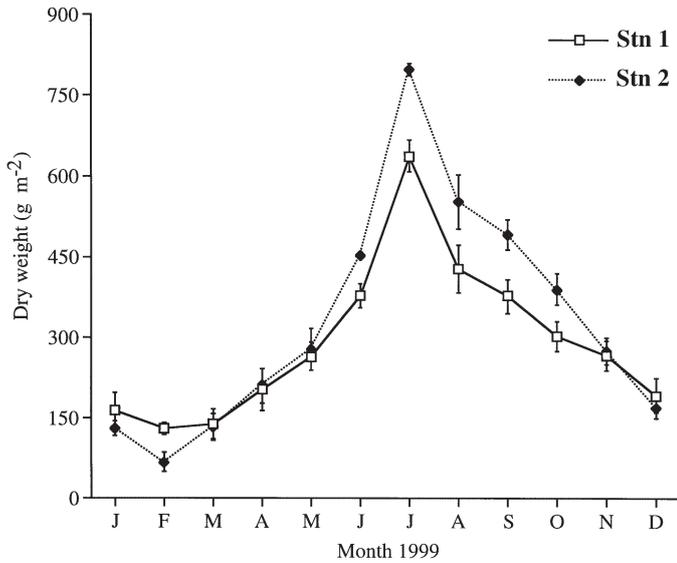


Fig. 3. *Gracilaria vermiculophylla*. Monthly changes in biomass (dry wt, g m⁻²) at Stns 1 and 2 in Gamo Lagoon. Bars indicate SD, n = 4

while *E. possjeticus* did not show any significant correlation with macroalgal biomass at either station. This suggests that tube-dwelling species are dependent on algal biomass whilst free-living species have only a partial dependency.

Total attached material (microalgae and detritus) on *Gracilaria vermiculophylla*

Both stations had maximum attached material loads of 1.5 and 3.5 g g⁻¹ in February with a minimum of 0.2 g g⁻¹ in September and July for Stns 1 and 2, respectively (Fig. 5). Between April and November, <1.0 g g⁻¹ mo⁻¹ was recorded at both stations. Attached material began increasing after November and attained a peak in February. There were more attached materials at Stn 2 than at Stn 1.

Table 1. Relationship between densities of 4 amphipod species and dry algal biomass at Stns 1 and 2 in Gamo Lagoon, Japan. Values are correlation coefficient (r). *p < 0.05, **p < 0.01

Amphipod species	Stn 1 (n = 30)	Stn 2 (n = 30)
Tube-dwellers:		
<i>Corophium uenoi</i>	0.566*	0.682**
<i>Grandidierella japonica</i>	0.599*	0.683**
Free-living:		
<i>Eogammarus possjeticus</i>	0.474	0.525
<i>Melita setiflagella</i>	0.534*	0.521

Density of 3 groups of diatom cells on *Gracilaria vermiculophylla*

High densities of diatom cells (nos. g⁻¹) were found during the colder months, while low densities occurred during warmer months at both stations. Considering the total number of diatom cells irrespective of these categories, more diatom cells were found at Stn 1 than at Stn 2 (Fig. 6).

At Stn 1, as many as 275 × 10³ strongly attached cells g⁻¹ macroalga were recorded in February 1999. Densities of diatom cells declined after March through April and were lowest in June. Fairly constant densities were recorded from June until September, and these began to increase after October for all groups of diatoms.

At Stn 2, a maximum density of about 200 × 10³ moderately attached cells g⁻¹ was recorded in February. As at Stn 1, densities of diatom cells declined after March, reaching a minimum in July and beginning to increase again after October. With respect to the 3 attachment categories, moderately attached cells recorded maximum and strongly attached cells displayed minimum densities at most times during the entire sampling period. Density of all diatom groups decreased in the warmer season, while that of amphipods increased during the same period.

Monthly changes in chlorophyll a and c concentrations of attached material

Both Stns 1 and 2 had higher concentrations of chlorophyll c than chlorophyll a (Fig. 7). At Stn 1, moderately and strongly attached materials had higher concentrations of chlorophyll a and c than loosely attached materials.

At Stn 2, loosely attached materials had high concentrations of chlorophyll a and c compared to moderately and strongly attached materials. High and low concentrations of chlorophyll a and c were recorded in colder and warmer months, respectively, at both stations for all treatments.

Monthly variations in diatom species on *Gracilaria vermiculophylla*

Most diatom species had maximum and minimum densities in the colder and warmer months, respectively (Fig. 8). Nine diatom species (*Gyrosigma* sp., *Nitzschia* sp., *Navicula* sp., *Melosira* sp., *Synedra* sp., *Triblionella* sp., *Surirella* sp., *Amphora* sp. and *Amphiprora* sp.) were found on *Gracilaria vermiculophylla* at both stations, with *Navicula* sp., *Melosira* sp.

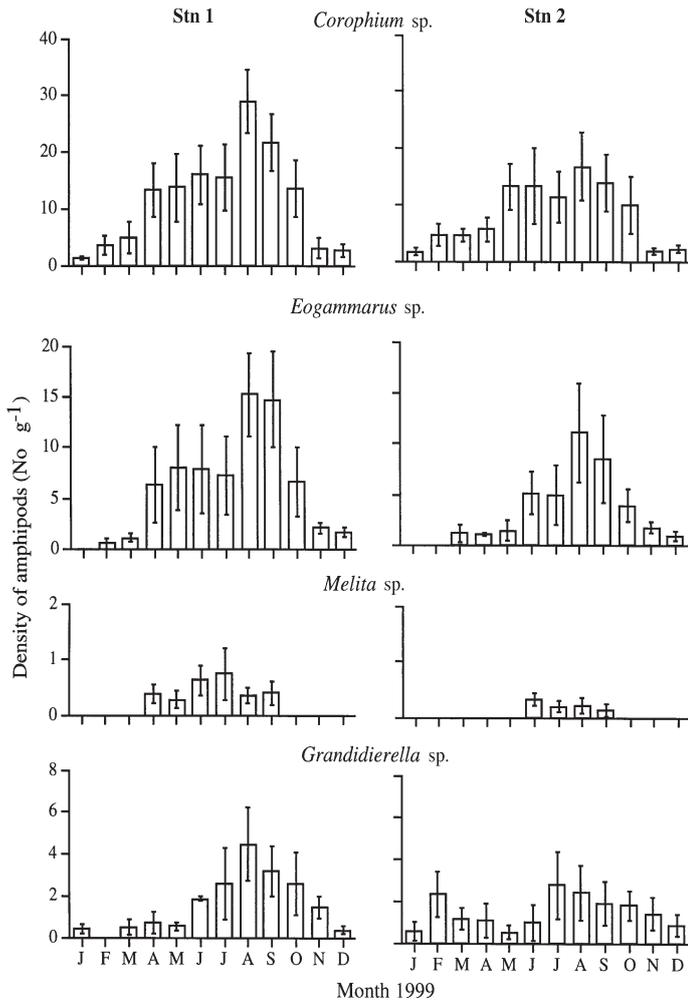


Fig. 4. *Gracilaria vermiculophylla*. Monthly changes in amphipod densities per gram algal biomass at Stns 1 and 2 in Gamo Lagoon. Bars indicate SD, $n = 4$

and *Synedra* sp. occurring in especially high densities. High densities of *Synedra* sp. occurred in strongly attached material. *Navicula* sp. tend to be dominant in warmer months.

Feeding-pressure experiment

Eight diatom species (*Navicula* sp., *Nitzschia* sp., *Gyrosigma* sp., *Melosira* sp., *Synedra* sp., *Triblinella* sp., *Surirella* sp., and *Amphora* sp.) were found on the brush substrate used for the feeding pressure experiment (Fig. 9). An analysis of the similarities between the selection of diatoms revealed 2 primary clusters (Fig. 10). Tubes inoculated with amphipod species formed one cluster (CL 1), tubes without amphipods (control) formed another cluster (CL 2). CL 1 was further divided into 2 subgroups: CL 1-1 with tubes

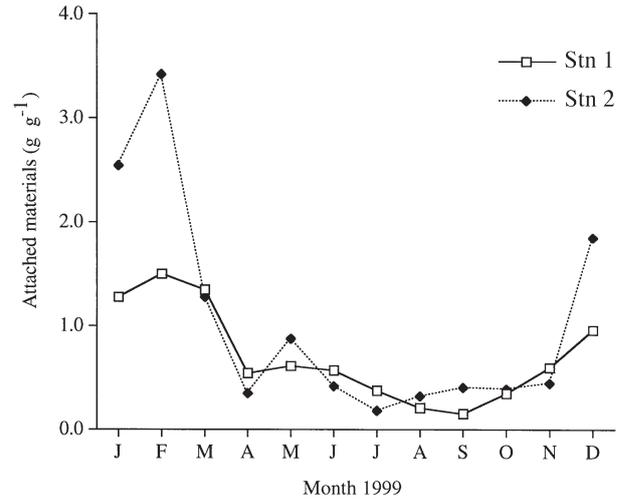


Fig. 5. *Gracilaria vermiculophylla*. Total attached material (including microalgae and detritus) per gram algal biomass at Stns 1 and 2 in Gamo Lagoon. Bars indicate SD, $n = 4$

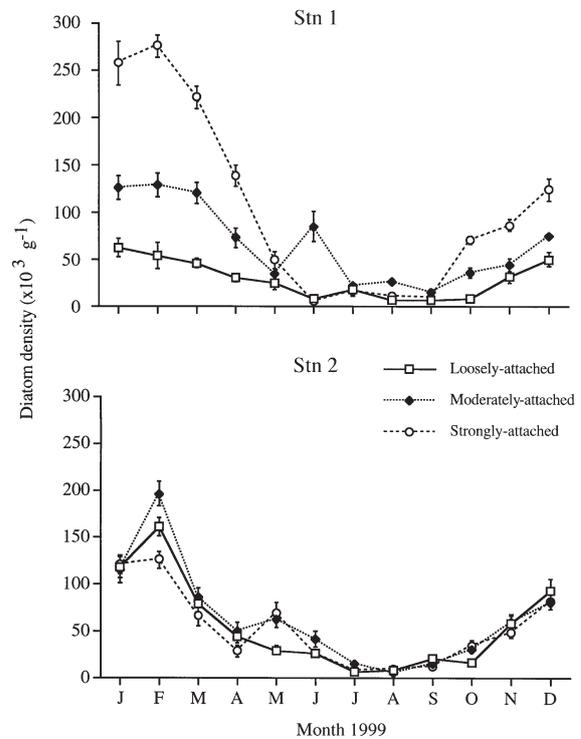


Fig. 6. *Gracilaria vermiculophylla*. Density of diatom cells per gram algal biomass ($\times 10^3 \text{ g}^{-1}$) in Gamo Lagoon at Stns 1 and 2. Grazing effects for 3 groups of diatoms (loosely, moderately and strongly attached cells). Bars indicate SD, $n = 4$

inoculated with *Eogammarus possjeticus* and *Melita setiflagella* (free-living species); CL 1-2 with tubes inoculated with *Corophium uenoi* and *Grandidierella japonica* (tube-dwelling species) (Fig. 10). The diatom species composition on *Gracilaria vermiculophylla* in

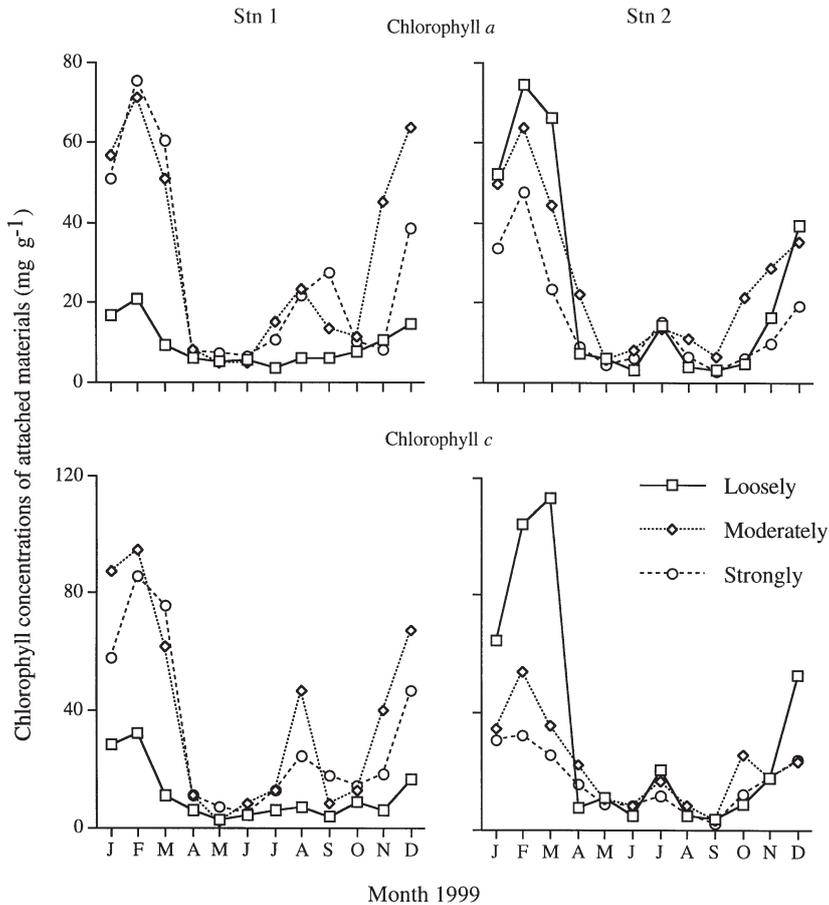


Fig. 7. *Gracilaria vermiculophylla*. Concentrations of chl a and c of attached materials per gram algal biomass (mg g^{-1}) in Gamo Lagoon at Stns 1 and 2 from January to December 1999

February (Table 2) was similar to that on the brushes within control tubes. Eight diatom species appeared on the brush substrate in control tubes, but were less dense within inoculated tubes. In inoculated tubes, *Melosira* sp. were not found (Student's *t*-test, $p < 0.001$) (Fig. 9). As for *G. japonica* tubes, *Nitzschia* sp. and *Melosira* sp. were absent from tubes inoculated with *Corophium uenoii*. Low densities of *Navicula* sp., *Gyrosigma* sp., *Synedra* sp. and *Triblinella* sp. were recorded in *C. uenoii* and *G. japonica* tubes. *Surirella* sp. showed no significant change within *C. uenoii* and *G. japonica* tubes, whilst the decrease in densities of *Amphora* sp. was significant. Very few *Gyrosigma* sp., *Melosira* sp. and *Surirella* sp. were found in *E. possjeticus* tubes, and *M. setiflagella* tubes had low densities of *Gyrosigma* sp., *Melosira* sp. and *Synedra* sp. The effects of *C. uenoii* and *G. japonica* on diatoms were similar, whilst the effects of *E. possjeticus* and *M. setiflagella* on diatoms were also similar (Fig. 10). On the whole, all species of diatoms decreased in all tubes containing amphipods.

DISCUSSION

Grazing pressure effects have been reported to influence diatom densities (Hickman & Round 1970, Kawamura & Hirano 1992). The effect of grazing on epiphytic diatom communities seems to be strong in Gamo Lagoon. Our results revealed that diatom densities were highest in winter when amphipod densities were lowest, suggesting that amphipod grazing may have suppressed the diatoms when they might otherwise have been expected to be most abundant.

Two types of feeding, representing high and low feeding pressure, were observed in Gamo Lagoon. A rapid increase in the density of amphipods (Fig. 4) during spring resulted in a corresponding decrease in diatoms (Fig. 8), signifying a higher feeding pressure at this time. However, the inverse relationship that occurred in the colder months could have been due to low densities of invertebrates and/or low water temperature effects on their digestive efficiency, or slower physiological activities, which would result in lower feeding pressure.

Although amphipods are not the only invertebrates in Gamo Lagoon, they are known to be important grazers of diatoms and to have a great impact. According to Moore (1975), diatoms form a regular and relatively important part of the diet of *Gammarus pulex* living among *Cladophora glomerata* in Wellow Brook, England. In the present study high chlorophyll a and c concentrations of attached material (Fig. 7) indicate the presence of diatoms. The similar trends of seasonal changes in attached material

Table 2. *Gracilaria vermiculophylla*. Density of diatoms as a function of algal biomass (nos. g^{-1}) and brush substrates ($\times 10^2$ cell brush $^{-1}$) in Gamo Lagoon in February and August 2000. Values are mean \pm 1 SD, $n = 4$

Diatoms	Macroalgae		Brush August
	February	August	
<i>Melosira</i> sp.	9652 \pm 543.6	151 \pm 12.5	644 \pm 105.3
<i>Synedra</i> sp.	7617 \pm 367.4	210 \pm 10.4	642 \pm 97.8
<i>Navicula</i> sp.	6709 \pm 346.2	454 \pm 53.6	1683 \pm 231.5
<i>Nitzschia</i> sp.	1743 \pm 167.9	278 \pm 31.4	484 \pm 44.9
<i>Triblinella</i> sp.	1458 \pm 211.9	44 \pm 3.8	407 \pm 59.5
<i>Gyrosigma</i> sp.	1024 \pm 203.8	28 \pm 4.6	561 \pm 16.3
<i>Amphora</i> sp.	597 \pm 45.7	26 \pm 4.6	486 \pm 66.7
<i>Surirella</i> sp.	362 \pm 43.6	28 \pm 5.9	328 \pm 41.1
<i>Amphiprora</i> sp.	43 \pm 6.8	4 \pm 1.7	Not found

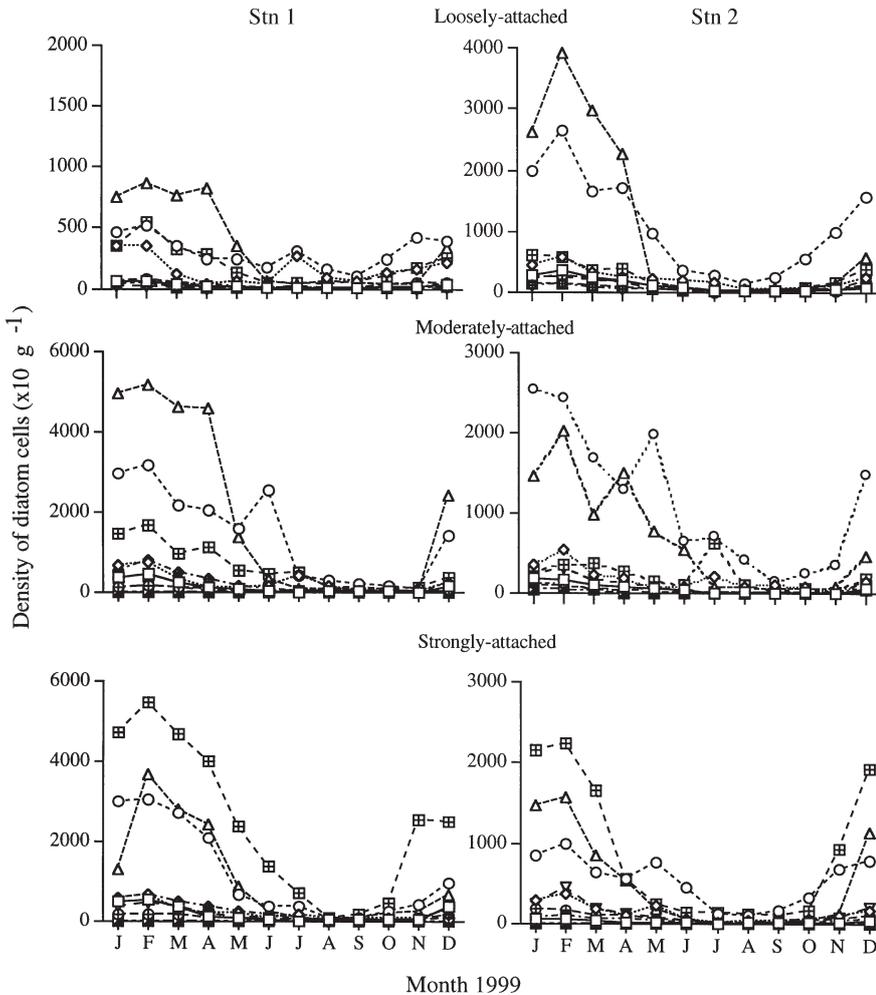


Fig. 8. Monthly density of diatom cells on *Gracilaria vermiculophylla* in Gamo Lagoon at Stns 1 and 2. \square : *Gyrosigma* sp.; \diamond : *Nitzschia* sp.; \circ : *Navicula* sp.; Δ : *Melosira* sp.; \boxtimes : *Synechococcus* sp.; \diamond : *Triblionella* sp.; \ominus : *Suriella* sp.; ∇ : *Amphora* sp.; \blacksquare : *Amphiprora* sp.

(Fig. 5) to those in concentrations of chlorophyll *a* and *c* suggest that diatoms contributed to changes in the attached material. The results of experiments in Gamo Lagoon also indicated that amphipods selected and fed on diatoms (Fig. 9). The disappearance of some diatom species from amphipod-inoculated tubes and their occurrence in control tubes suggests grazing of diatoms by amphipods in the experimental tubes (Fig. 10). Even though the density of the diatoms in the tubes might depend on their growth rate, any density difference between control and inoculated tubes would be a result of amphipod feeding, since diatom growth rate would not differ. The use of a brush substrate as a substitute of *Gracilaria vermiculophylla* was validated by the similarity in species composition (Table 2) on both substrates. Brush substrates provided exact replicates of conditioned substrates.

In general, species of filamentous form or with low adhesive strength are apt to be more heavily grazed, while species with stronger adhesion are less affected by grazing pressure (Moore 1975, Nicotri 1977, Hudon 1983, Suzuki et al. 1987, Steinman et al. 1989). Moore (1975) reported that *Melosira varians* and *Diatoma vulgare*, diatoms forming long filamentous colonies, were ingested in disproportionately large quantities by amphipods, whereas *Cocconeis* sp., a highly adhesive prostrate forms, was rarely eaten. The results of our feeding-pressure experiment in Gamo Lagoon showed that all amphipod species selected *Melosira* sp. (Fig. 9), a colony enclosed in a filamentous, arborescent, mucous tube, emphasizing the importance of diatom morphology in amphipod feeding. In general, larger varieties of grazers prefer arborescent and filamentous colonial diatoms over small, prostrate forms (Hudon 1983). Similarly, *Synechococcus* sp., which is a non-motile, fan-shaped colony standing upright on macroalgae, occurred in higher densities among strongly attached cells (Fig. 8). This may be partially due to its mode of attachment, but the experimental results suggest that this species was ingested fairly efficiently by the amphipods (Fig. 9).

Our results show that almost all diatom species found were ingested by the amphipods (Fig. 9). However, total ingestion of *Melosira* sp. and *Nitzschia* sp. was recorded for the tube-dwelling amphipods *Corophium uenoi* and *Grandidierella japonica*, whilst total ingestion of *Gyrosigma* sp. and *Melosira* sp. were common to the free-living species *Eogammarus possjeticus* and *Melita setiflagella* (Student's *t*-test, $p < 0.001$). *Suriella* sp. seems to be ingested mainly by free-living species and not by tube-dwellers. Diatom selection, therefore, was similar among free-living amphipods and similar among tube-dwellers, but it differed between the 2 groups (Fig. 10). This suggests that life form and lifestyle of diatoms influence the degree of grazing effect exerted by amphipods.

Hudon (1983) reported that larger diatoms were not selected by the amphipod *Calliopius laeviusculus*. Smaller and medium-sized diatoms may be preferred over larger cell diatoms. However a larger diatom, *Gy-*

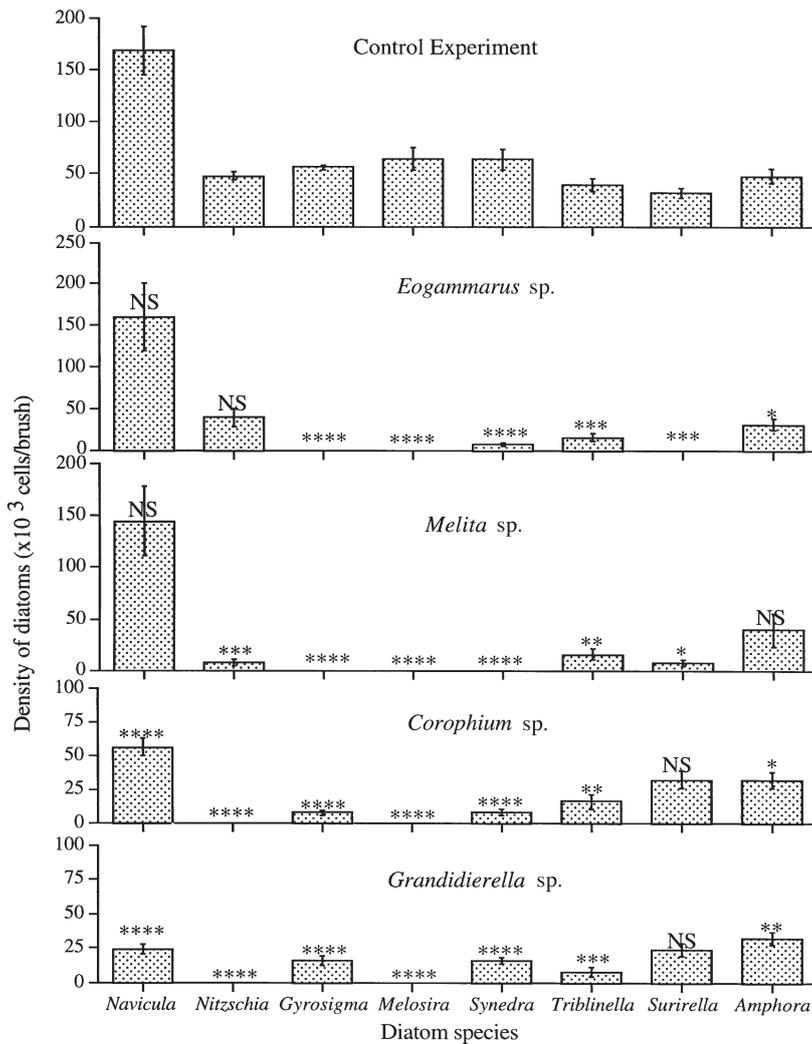


Fig. 9. Density of diatoms on brush substrate used for feeding-pressure experiment in Gamo Lagoon. Bars indicate SD, n = 5. p-values for unpaired t-test are shown —****: p < 0.001; ***: p < 0.005; **: p < 0.01; *: p < 0.05; ns: not significant

rosigma sp. (Table 3), was significantly (Student's *t*-test, $p < 0.001$) ingested by all 4 amphipods in the feeding experiment. Although *Gyrosigma* sp. is large in size, its slender and elongated form may contribute to its selection. In the feeding pressure experiment, densities of *Navicula* sp. changed little compared to control tubes, especially for free-living species. This was also reflected in the field survey of attached material. Although low diatom biomass occurred in the warmer months, *Navicula* sp. was dominant in most cases (Fig. 8). Kawamura & Hirano (1992) similarly reported that densities of *N. britannica* tended to be higher from summer to autumn. In the present study comparison of *Navicula* sp. densities in the tubes of tube-dwelling amphipods to densities in the controls revealed that *Navicula* sp. were ingested significantly (Student's *t*-test, $p < 0.001$), suggesting that their dominance in the warmer months may be due to a higher growth rate at that time. The high number of *Navicula* sp. in the control tubes confirms their higher growth rate. The results of the feeding experiment showed that *Amphora* sp., an adnate form (attached to the substrate along almost or all of its width), was selected less by the amphipods, and this may be attributable to its strength of adhesion. Kesler (1981) reported that adnate forms such as *Cocconeis* sp. and *Amphora* sp. have a low susceptibility to amphipod grazing pressure.

Although diatoms were categorized according to their strength of attachment, grazing pressure exerted was similar for all 3 attachment groups irrespective of adhesion strength (Fig. 8). This suggests that grazing pressure on diatoms in Gamo Lagoon may depend on other factors in addition to their strength of attachment. The results of the feeding experiment revealed that all diatom species were susceptible to feeding pressure from both tube-dwelling and free-living amphipod species, although grazing pressure on different diatom species varied, perhaps in relation to the different lifestyles and cell sizes of the various diatom and amphipod species.

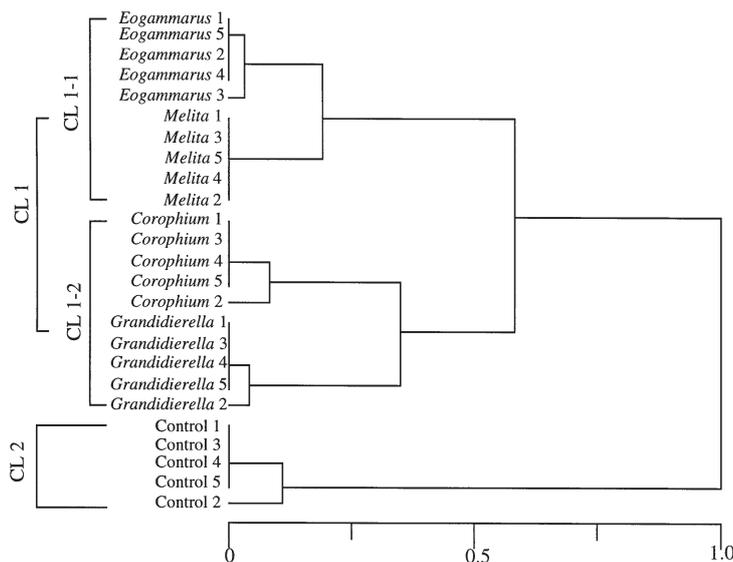


Fig. 10. Diatom assemblages exposed to grazing by each of 4 amphipod species in Gamo Lagoon. Analyses were carried out by single-linkage method based on similarities in their selection of diatom species; 25 tubes were classified into 3 main clusters: Class (CL) 1-1, 1-2 and 2

Table 3. Diatom species found on *Gracilaria vermiculophylla* in Gamo Lagoon, showing their life styles and sizes

Diatoms	Life style	Size (μm)
<i>Navicula</i> sp.	Solitary	Small (30–40)
<i>Nitzschia</i> sp.	Solitary	Medium (65–80)
<i>Gyrosigma</i> sp.	Solitary	Large (120–130)
<i>Melosira</i> sp.	Colonial	Small (15–25)
<i>Synedra</i> sp.	Colonial	Medium (70–85)
<i>Triblinella</i> sp.	Solitary	Small (20–30)
<i>Surirella</i> sp.	Solitary	Medium (60–90)
<i>Amphora</i> sp.	Solitary	Small (20–30)
<i>Amphiprora</i> sp.	Solitary	Large (120–150)

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