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Diatom assemblages in a high moor: an observed correlation between species composition and pool size

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The species composition of periphytic diatom assemblages collected from Kinunuma Moor, an high moor at an altitude of about 2000 m, was analyzed. A correlation between the species composition and pool size was observed. *Eunotia* species, such as *E. curvata* (Kütz.) Lagerst., *E. curvata* v. *subarcuata* (Kütz.) Woodhead et Tweed, *E. pectinalis* v. *minor* (Kütz.) Rabh., *E. tenelloides* H. Kob. *et al.*, were dominant in large pools (more than 10 m across), whereas *Frustulia rhomboides* v. *saxonica* (Rabh.) De Toni was dominant in smaller pools (less than 1 m across). In medium sized pools the relative abundance of *Eunotia* species and *Frustulia* species was almost equal, but *Asterionella ralfsii* W. Sm. was sometimes dominant. The water temperature was likely to be higher in smaller pools than in larger pools. Therefore, water temperature, its stability, or the stability of total environment is assumed to have some relation to the observed variation in species composition.

Key Index Words: Asterionella ralfsii—*diatoms—ecological stress*—Eunotia curvata—Frustulia rhomboides *v.* saxonica—*high moor—water temperature.*

Diatom assemblages in moors have been surveyed by some diatomists (e.g. Hirano 1976, 1977). But there are few reports about the relation between environmental conditions except for pH and species composition of diatom assemblages in moors: the pH preference of diatom species was analyzed by many authors (e.g. Van Dam *et al.* 1981, Watanabe and Yasuda 1982).

The species composition of diatom assemblages is influenced by conditions other than pH. Van Dam *et al.* (1981) showed that the abundance of *Eunotia exigua* (Bréb.) Rabh. increases with the concentration of sulfate. Scherer (1988) discussed the importance of local variation in trophic status and some restrictive conditions, such as occasional desiccation, to species composition. Van Dam (1988) also suggested the importance of desiccation to species composition.

In high moors smaller pools often dry up whereas larger pools always contain water. Considering the results of the works mentioned above, it appears that species composition of diatom assemblage has some relation to pool size. The aim of this study is mainly to analyze the relation between the species composition of diatom assemblages and pool size.

Materials and Methods

Kinunuma Moor was selected as the study field. The moor is located on the mountain ridge on the border of Tochigi Prefecture and Gunma Prefecture, at an altitude of about 2000 m (Fig. 1), and the latitude and longitude of the moor are 36°52.5′N and 139°22.5′E, respectively. The area of this moor is almost 800 m (north to south) × 400 m (east to west). There are about 50 pools in it. The largest one is "Kin-Numa" (Kin pool) with dimension of about 80 m × 40 m, and small pools are less than 1 m across.

Field surveys were made on 29 June, 21 July and 29 September in 1986. Eleven sampling stations were set in ten pools and one

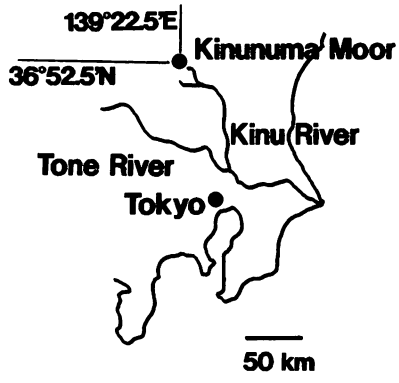

Fig. 1. The location of Kinunuma Moor.

brooklet which issued from a large pool. As the flow of the brooklet stopped before the third survey (29 September) because of a drop in the water level of the source, a sample was collected from a puddle which was a remnant of the brooklet.

At the second and the third surveys, water temperature (WT) and pH were measured by alcohol thermometer and test papers (Toyo Roshi Co. Ltd.), respectively. Electric conductivity (EC) was measured at the second survey by portable conductivity meter (TOA model CM-1K). Pool size was recorded in three ranks, large (more than 10 m across), medium (from 1 m to 10 m across) and small (less than 1 m across). Usually, pool area and pool depth were positively correlated although the depth of some small or medium sized pools was almost equal to that of the large pools. Station 9 was located at such a medium sized and deep pool.

Diatoms were collected from the surface of dead grasses in water. Samples were cleaned with H_2SO_4 and mounted in Pleurax. The relative abundance of diatom taxa occurring in each sample was obtained by counting the number of valves; more than 400 valves were counted for each sample.

Data were analyzed using multivariate analysis. Hierarchical cluster analysis and principal component analysis (PCA) were carried out for the classification and ordination of the samples and species. Bray-Curtis similarity index (Bray and Curtis 1957) was used in cluster analysis. It is known by a variety of names such as Czekanowski's index, Least Common Percentage Index, is said to be robust, and reflects accurately true similarity (Bloom 1981, Faith *et al.* 1987). In PCA each sample and taxon become "variable" and "sample" of the data matrix, respectively. Based on the result, the effect of pool size and other environmental factors were analyzed.

Results

The measured parameters of the pool water are listed in Table 1. Water temperature had

Table 1. Characters of water at stations 1–11.

Station No.	Area	pH (July)	EC (μS/cm) (July)	WT (°C) (July)	WT (°C) (Sept.)
1	(brooklet)	5.4	8.4	15.1	10.4
2	small	—[1]	4.2	—	*[2]
3	("Kin-numa") large	5.4	7.5	15.1	11.0
4	small	5.2	6.7	18.1	11.0
5	medium	5.2	11.2	16.5	13.5
6	small	—	—	—	14.0
7	medium	5.2	8.6	16.5	—
8	medium	5.6	7.9	17.2	12.0
9	medium[3]	—	—	*	11.0
10	small	—	—	*	14.0
11	large	—	—	*	*

[1] "—" indicates that the parameter was not measured whereas diatom sampling was carried out.
[2] "*" indicates that no work was done at the station.
[3] Deeper than the other medium sized pools (see text).

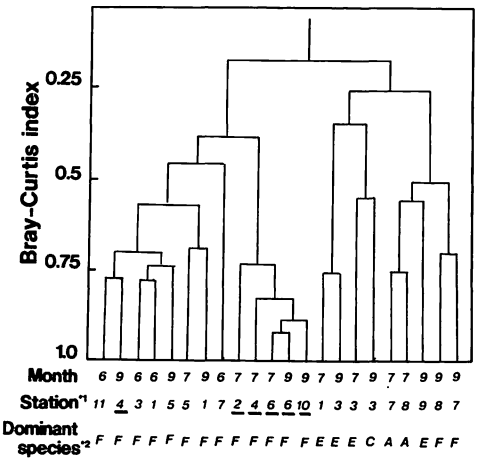

Fig. 2. The result of the cluster analysis (furthest neighbor method). *1: The underlined stations are for small pools. *2: "F", "E", "C" and "A" are for *Frustulia rhomboides* v. *saxonica, Eunotia curvata* or its varieties, *Fragilaria construens* v. *bidens*, and *Asterionella ralfsii*, respectively.

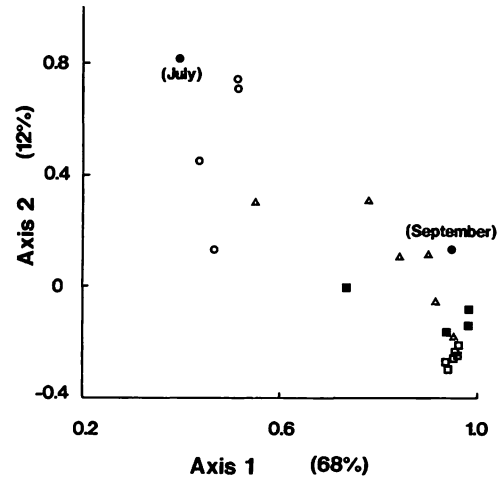

Fig. 3. Factor loadings of the principal component analysis. The parenthesized values beside the axis number are proportions of the eigenvalue of each axis (i.e. principal component). Small, medium and large pools are indicated by squares, triangles and circles, respectively. The samples collected in June are indicated by solid squares. The samples collected from Station 1 (brooklet) are indicated by solid circles with the sampling month parenthesized.

a tendency to increase in small pools, though the number of samples was small. In the brooklet and larger pools WT was relatively low.

Figure 2 gives the result of the cluster analysis. The samples were classified into three categories and the classification was correlated with pool size. This correlation suggested that pool size was an index of the most important environmental factor affecting the species composition of diatom assemblages.

The first category is the group of samples in which *Eunotia curvata* (Kütz.) Lagerst. and its varieties were dominant. The samples from larger pools tend to belong to this category. Station 9 was a medium sized pool but deeper than any other medium sized pools. Samples of the second category contained *Asterionella ralfsii* W. Sm. as the foremost or secondmost abundant taxon. All samples belonging to this category were collected from medium sized pools. Samples in which *Frustulia rhomboides* v. *saxonica* (Rabh.) De Toni was the most dominant belong to the third category. All the samples from small pools belonged to this category. In the brooklet (Station 1) diatom assemblage was similar to that in large pools as long as the flow did not stop. In the samples collected on 29 June, *Frustulia rhomboides* v. *saxonica* was the most dominant and the samples belonged to the third category.

Figure 3 shows the factor loadings of the variables (=diatom samples) of the PCA. This figure shows that, according to the samples collected, a predictable difference is always found in the species composition of

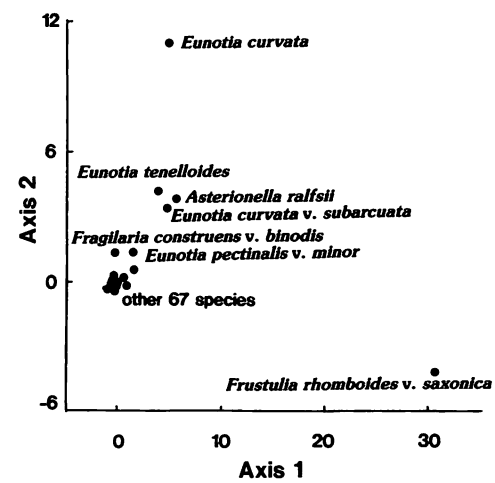

Fig. 4. Principal component scores of the principal component analysis.

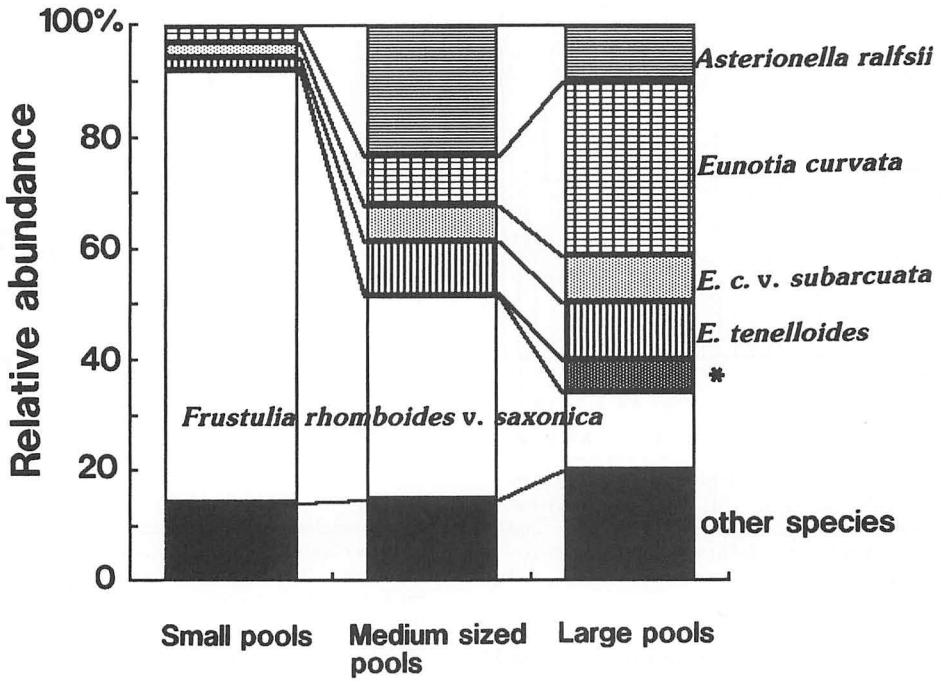

Fig. 5. Average species composition of the diatom assemblages in the small, medium and large pools. *: *Fragilaria construens* v. *binodis*.

small and large pools. This difference seems to be proportional to the size of the pools as the medium pool samples range between the small and large samples. This figure also shows that the samples collected in June were similar to the samples collected from small pools or the samples collected from some of the medium sized pools.

Figure 4 shows the principal component score of each taxon. The preference of each taxon for a particular pool size is understood by Figures 3 and 4. *Eunotia curvata, E. curvata* v. *subarcuata* (Kütz.) Woodhead *et* Tweed, *E. pectinalis* v. *minor* (Kütz.) Rabh., *E. tenelloides* H. Kob. *et al., Fragilaria construens* v. *binodis* (Ehr.) Grun. and *Asterionella ralfsii* each had large second principal component score. It appears that these taxa prefer larger pools to smaller ones. This preference was confirmed by the average relative abundance of diatoms in small, medium and large pools (Fig. 5).

Discussion

It is evident that the genera *Eunotia* and *Frustulia* were dominant in the pools of the Kinunuma Moor. This result coincides with those of other studies such as Hirano (1976, 1977). The genus *Pinnularia*, which is known as one of the popular genera in high pools (Hirano 1977, Hirano and Iwaki 1982), did not appear frequently, but more than a few taxa (10 species and 1 variety) of this genus were found. *Asterionella ralfsii* was dominant in some of the samples. This taxon prefers acidic and humic water (Patrick and Reimer 1966). It is concluded that the diatom assemblages in the pools of Kinunuma Moor were typical of high moors.

The water temperature was likely to be higher in small pools than in large pools (Table 1). A similar correlation between water temperature and pool size was observed at high moors in the Minamiaizu district, Fukushima Prefecture, Japan (Katoh, in printing). It is assumed that the heat capacity of water bodies affects the water temperature, and that water temperature is more stable in large pools than in small pools.

The correlation between species composi-

tion and pool size observed in the present study was also observed at 23 high moors (119 samples) in the Minamiaizu district (Katoh, in printing). Scherer (1988) states that the dominant species of diatom assemblage in marshes corresponds to the level of "ecological stress": *Eunotia exigua, Frustulia rhomboides* v. *saxonica* and *Asterionella ralfsii* correspond to quite severe, moderately severe and less severe "ecological stress", respectively. In the present study *E. exigua* was not dominant because no station was in an extremely severe environment: this species was often dominant in the samples collected from the wet ground of high moors but not dominant in pools (Katoh, in printing). As for *Frustulia rhomboides* v. *saxonica* and *Asterionella ralfsii* the result of the present study is similar to that of Scherer (1988), if "ecological stress" includes the instability of water temperature, or if "ecological stress" becomes more severe as the pool size decreases. Van Dam (1988) suggested the importance of desiccation to species composition, and it is reasonable that desiccation is more likely to occur in smaller pools than in larger pools. Therefore, it appears that the species composition of diatom assemblages in high moors has some association with pool size through environmental instability such as the instability of water temperature and occasional desiccation, or "ecological stress".

It is possible that an unstable environment itself limits the species composition. It is also possible that the development of diatom assemblages is disturbed and species which normally occur at later stages of this development can not dominate in an unstable environment. It was reported that *Eunotia curvata* and *E. pectinalis* are abundant at later stages of this development under acidic conditions (Planas *et al.*, 1989). Further studies are needed on the causes of different species composition in small and large pools.

Based on the results, one possible explanation is as below for the species composition of the samples collected from Station 1 or collected at the first survey. In the stable brooklet, environmental conditions were similar to those in large pools (in July). When the flow stopped (in September), its conditions became unstable like those in smaller pools. The environmental conditions of pools in the season of thaw (June) also seem to be unstable because of the irregular inflows from melting snow.

It is concluded that environmental instability (or "ecological stress") influences species composition: pool size is regarded as an index of environmental instability. Assemblages dominated by *E. exigua*, which were not dominant in the present study, are established in the most unstable habitat. Assemblages dominated by *F. rhomboides* v. *saxonica* develop under a moderately unstable environment. Assemblages dominated by *Asterionella ralfsii* occur when the environment becomes more stable. Assemblages in which *Eunotia curvata* and its varieties are dominant are found in quite stable habitats.

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加藤和弘：高層湿原の珪藻群集—種組成と池塘の大きさとの間に見られた関係

鬼怒沼湿原は標高約2000 mに位置する高層湿原である。同湿原で付着珪藻群集の調査を行った結果，群集の種組成と池塘の大きさとの間に関連がみられた。小型の池塘では *Frustulia rhomboides* v. *saxonica* (Rabh.) DeToni が優占し，大型の池塘では *Eunotia curvata* (Kütz.) Lagerst., *E. curvata* v. *subarcuata* (Kütz.) Woodhead et Tweed, *E. pectinalis* v. *minor* (Kütz.) Rabh., *E. tenelloides* H. Kob. *et al.* が優占した。中程度の大きさの池塘では，*Frusturia* 各種と *Eunotia* 各種はほぼ同じくらい出現したが，時に *Asterionella ralfsii* W. Sm. が優占した。大型の池塘でより低い水温が記録されたことから，水温またはその変わりやすさが種組成に関わるとも考えられるが，環境全般の安定性が関与した可能性もある。（153 東京都目黒区駒場3-8-1　東京大学教養学部生物学教室）