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Seasonal Variation of Epilithic Diatom Community and an Assessment of Water Quality by DAIpo in the Water System of Ulleung Island

Choi, Jae Sin, Jung Won Park, Kyung Lak Lee, Myoung Sook Yang[1] and Han Soon Kim*

(*Department of Biology, Kyungpook National University, Daegu 702-701, Korea*
[1]*Middle school of Ulleung, Ulleung Island, Korea*)

We investigated the variations of epilithic diatom community and assessed water quality of the water system of Ulleung Island by DAIpo in April, May, July, August, October, and November of 2003, and January and February of 2004. Samples were collected from four sampling stations. Total 95 taxa were identified from this study and dominant species were *Nitzschia inconspicua, Achnanthes minutissima, Gomphonema angustum* and *Cocconeis placentula* var. *lineata*. The variation of DAIpo values was ranged from 51.14 to 77.77 and the water quality by DAIpo was estimated between α-oligosaprobic and β-oligosaprobic states.

Key words: epilithic diatom, water quality, DAIpo

INTRODUCTION

The individuals of epilithic diatom can be accurately counted due to their shorter life cycle and more distinct individuality than other algae or benthic insects. Also diatoms show the highest confidence when relative frequency of appearance in a community is calculated. Diatoms inhabit in water with wide ranges of organic pollution. The epilithic diatom assemblage has been used as an excellent biological indicator to assess water quality (Watanabe *et al*., 1986, 1988, 1990) since it displays the accumulative value of average changes of water quality over a certain period of time.

In Korea, there has been only a few reports about the diatoms in the water system of Ulleung Island. The first report (Kang, 1973) described several diatom species and later Chung (1981) reported approximately 30 species of diatoms found in Ulleung Island. In this paper, we report the investigation of the variation of epilithic diatom community and the assessment of water quality of the water system of Ulleung Island.

MATERIALS AND METHODS

For the diatom analyses, samplings were made at four different stations of Ulleung Island in April, May, July, August, October, and November of 2003, and January and February of 2004 (Fig. 1). Samples were collected from the surface of stones located approximately 10 to 30 cm under water. Samples were cleaned by the Permanganat method (Hendey, 1974) and mounted in Pleurax. Slides were examined using a Nikon Apophoto microscope and the relative abundances of diatom taxa occurred in each station were obtained by counting the number of individuals in randomly selected view fields. At least 500 individuals were counted in each analysis.

Diatom taxa were identified based on the des-

* Corresponding Author: Tel: 053-950-5344, Fax: 053-953-3066, E-mail: kimhsu@knu.ac.kr

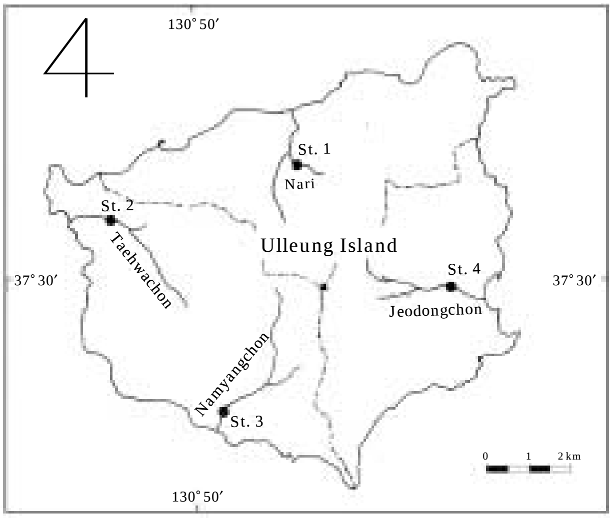

Fig. 1. Sampling stations in Ulleung Island.

cription of Krammer and Lange-Bertalot (1986, 1988, 1991a, b), and classified by the diatom system of Simonsen (1979). According to the tolerance level to organic pollution, all the occurring diatom taxa were classified into the three ecological groups : saprophilous taxa, indifferent taxa and saproxenous taxa. The water quality was assessed by diatom assemblage index to organic water pollution (DAIpo). The relationship of DAIpo, BOD_5 and conventional saprobic levels is given below for reference (Table 1).

Table 1. Relationship among DAIpo, BOD_5 and saprobic degrees (from Watanabe and Asai, 1990).

DAIpo	BOD_5	Saprobic level
0-15	>-10.0	polysaprobic
15-30	10.0-5.00	α-mesosaprobic
30-50	5.00-2.50	β-mesosaprobic
50-70	2.50-1.25	α-oligosaprobic
70-85	1.25-0.625	β-oligosaprobic
85-100	0.625-<	xenosaprobic

RESULTS AND DISCUSSION

Physicochemical factors

The physicochemical factors of the water system are shown in Table 2.

At some stations, sampling or measurement was not possible due to mechanical troubles or unfavorable situations. The highest water temperature was recorded as 21.5°C at station 3 on August 2003, and the lowest was 5.0°C at station 2 and 4 on January 2004. Average water temperature of all stations except station 1 showed the seasonal variation such as 11.5°C in spring, 15.7°C in summer, 12.6°C in autumn and 6.4°C in winter. pH was ranged between 7.0 and 8.6.

Table 2. Physicochemical factors at each sampling station in the water system of Ulleung Island during the survey period.

Station	Factor	2003						2004	
		Apr.	May	Jul.	Aug.	Oct.	Nov.	Jan.	Feb.
1	WT	-	10.0	10.0	11.3	10.0	9.0	-	-
	pH	8.2	-	8.3	7.5	8.5	8.6	-	-
2	WT	8.5	11.5	15.0	19.1	13.0	12.5	5.0	7.0
	pH	7.8	-	8.1	8.0	8.6	8.3	8.6	8.6
3	WT	10.0	14.0	16.0	21.5	15.0	12.0	5.1	9.0
	pH	8.0	-	7.0	7.4	8.2	8.3	8.5	8.4
4	WT	10.0	15.0	15.0	18.1	13.0	10.0	5.0	7.0
	pH	7.8	-	8.3	7.7	8.2	8.0	8.4	8.2

Table 3. Summary of epilithic diatoms in the water system of Ulleung Island.

	Order	Subord.	Fam.	Gen.	Sp.	Var.	Total
Centrales	1	1	2	4	7		7
Pennales	1	2	7	24	77	11	88
Total	2	3	9	28	84	11	95

Table 4. Species number of the diatom community at each station in the water system of Ulleung Island.

Station	2003						2004	
	Apr.	May	Jul.	Aug.	Oct.	Nov.	Jan.	Feb.
1	36	19	33	19	24	-	-	-
2	28	44	40	29	35	27	42	21
3	24	27	25	36	38	42	32	36
4	34	30	34	27	14	-	32	33

Epilithic diatom community

Total 95 taxa were identified in this study and classified into 84 species and 11 varieties belonging to 28 genera, 9 families, 3 suborders and 2 orders (Table 3).

The species numbers at each station are shown in Table 4. The highest number of taxa (44) appeared at station 2 in May, and the lowest number of taxa (14) was at station 4 in October 2003.

The diversity index of station 1 was between 0.69

Table 5. Diversity and dominance index of the epilithic diatom communities at each sampling station in the water system of Ulleung Island.

Station	Index \ Month	2003 Apr.	2003 May	2003 Jul.	2003 Aug.	2003 Oct.	2003 Nov.	2004 Jan.	2004 Feb.
1	Diversity	1.56	1.23	2.11	0.69	1.91	–	–	–
	Dominance	1.04	1.04	0.45	1.76	0.47	–	–	–
2	Diversity	0.79	2.20	2.09	1.82	1.70	1.74	2.28	2.23
	Dominance	1.65	0.60	0.71	0.80	0.88	0.73	0.50	0.40
3	Diversity	1.62	1.12	1.22	1.82	2.00	1.81	1.95	2.28
	Dominance	0.71	1.35	1.29	0.72	0.56	0.83	0.59	0.38
4	Diversity	1.56	1.90	2.37	1.56	1.27	–	1.74	2.40
	Dominance	1.00	0.66	0.50	0.97	1.07	–	0.82	0.36

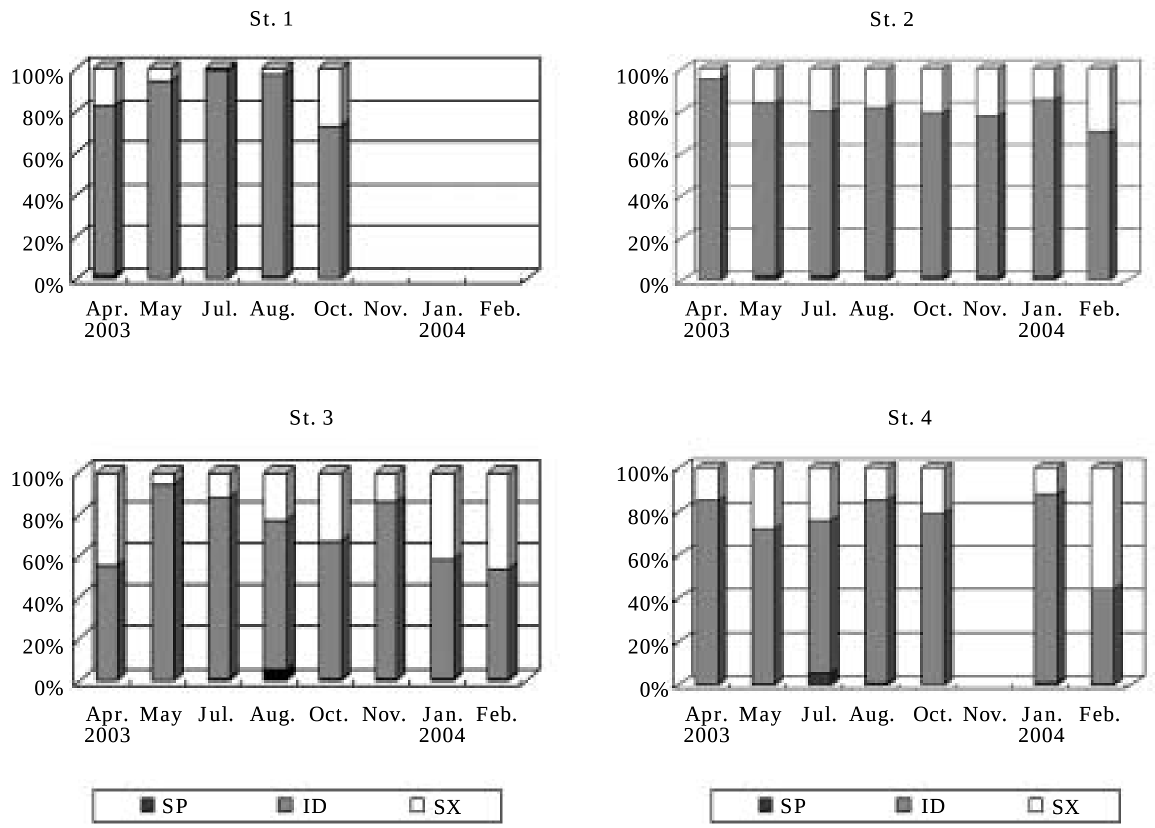

Fig. 2. Comparison with three taxa based on pollution tolerance at each station during the surveyed period (SP: Saprophilous taxa, ID : Indifferent Taxa, SX : Saproxenous taxa).

and 2.11. The dominance index was high values to 1.76 in August at station 1 because *Achnanthes minutissima* appeared hyper dominant (87.61%). At station 2, the diversity index was between 0.79 and 2.28 showing the lowest in April(0.79). However the dominance index in April was high (1.65) due to the 84.69% dominance of *Nitzschia inconspicua*. The diversity index was ranged 1.12 and 2.28 at station 3, and between 1.27 and 2.40 at station 4. We did not find correlative regularity between the indices of species diversity and dominance at stations and seasons (Table 5).

Nitzschia inconspicua was the only taxon that appeared at all stations and seasons. Following 18 taxa appeared only once : *Aulacoseria ambigua*, *Cyclotella comta*, *Cyclotella stelligera*, *Cycloste-*

Table 6. Dominant species of epilithic diatom at each sampling station in the water system of Ulleung Island.

Month	Station	Dominant species (relative abundance)	Subdominant species (relative abundance)
2003 Apr.	1	*Nitzschia inconspicua* (66.67)	
	2	*Nitzschia inconspicua* (84.69)	
	3	*Nitzschia inconspicua* (40.93)	*Rhoicosphenia abbreviata* (37.19)
	4	*Nitzschia inconspicua* (65.30)	
May	1	*Achnanthes minutissima* (63.95)	*Nitzschia inconspicua* (20.72)
	2	*Nitzschia inconspicua* (49.69)	
	3	*Nitzschia inconspicua* (76.09)	
	4	*Nitzschia inconspicua* (51.16)	*Achnanthes lanceolata* (10.89)
Jul.	1	*Nitzschia inconspicua* (36.97)	*Achnanthes lanceolata* (15.76) *Amphora pediculus* (14.75)
	2	*Nitzschia inconspicua* (54.93)	
	3	*Nitzschia inconspicua* (74.80)	
	4	*Nitzschia inconspicua* (44.95)	
Aug.	1	*Achnanthes minutissima* (87.61)	
	2	*Nitzschia inconspicua* (57.87)	
	3	*Nitzschia inconspicua* (52.33)	*Cocconeis placentula* var. *lineata* (19.38)
	4	*Nitzschia inconspicua* (64.06)	
Oct.	1	*Navicula* sp. 2 (33.78)	*Achnanthes lanceolata* (23.31) *Achnanthes minutissima* (14.19) *Navicula lacunolaciniata* (11.99)
	2	*Nitzschia inconspicua* (60.69)	*Rhoicosphenia abbreviata* (10.98)
	3	*Nitzschia inconspicua* (40.85)	*Cocconeis placentula* var. *lineata* (26.99)
	4	*Gomphonema angustum* (66.36)	*Cocconeis placentula* var. *lineata* (15.21)
Nov.	1	–	
	2	*Nitzschia inconspicua* (52.22)	*Cocconeis placentula* var. *lineata* (12.87) *Navicula lacunolaciniata* (11.93)
	3	*Nitzschia inconspicua* (58.43)	*Nitzschia fonticola* (10.08)
	4	–	
2004 Jan.	1	–	
	2	*Nitzschia inconspicua* (43.77)	
	3	*Nitzschia inconspicua* (39.77)	*Cocconeis placentula* var. *lineata* (30.68)
	4	*Achnanthes minutissima* (57.40)	*Nitzschia inconspicua* (15.79)
Feb.	1	–	
	2	*Nitzschia inconspicua* (36.48)	*Achnanthes lanceolata* (13.70)
	3	*Nitzschia inconspicua* (31.20)	*Fragilaria vaucheriae* (18.43) *Cocconeis placentula* var. *lineata* (15.69)
	4	*Cocconeis placentula* var. *lineata* (33.60)	*Nitzschia inconspicua* (10.03)

phanos dubius, *Achnanthes montana*, *Diploneis subovalis*, *Diploneis elliptica*, *Frustulia rhomboides* var. *viridula*, *Gomphonema augur*, *Navicula confervacea*, *Navicula decussis*, *Navicula minuscula*, *Navicula charlatii*, *Navicula menisculus*, *Stauroneis anceps* var. *siberica*, *Nitzschia debilis*, *Nitzschia levidenssis* var. *victoriae*, *Surirella tenera*.

Dominant species were *Nitzschia inconspicua*, *Achnanthes minutissima*, *Gomphonema angustum*, *Cocconeis placentula* var. *lineata*, and *Navicula* sp. 2. *Nitzschia inconspicua* was dominated at most stations and seasons. Notably, *Nitzschia inconspicua* was dominated the whole seasons at station 2 and 3. At station 1, the dominant species was *Achnanthes minutissima* in May and August, *Navicula* sp. 2 in October. These dominant species were different from station 2 and 3. At station 4, the dominant species was *Nitzschia inconspicua* in April, May, July and August, *Gomphonema angustum* in October, *Achnanthes minutissima* in January, and *Cocconeis placentula* var. *lineata* in February. Following 6 taxa appeared more than 10% of relative abundance : *Rhoicosphenia*

Table 7. Percentage of ecological diatom groups divided by degress of pollution tolerance in epilithic diatom communities at each sampling station in the water system of Ulleung Island.

Station	Group \ Month	2003 Apr.	May	Jul.	Aug.	Oct.	Nov.	2004 Jan.	Feb.
1	Saproxeous	17.26	5.89	27.47	2.96	27.19	–	–	–
	Saprophilous	1.78	0.16	1.61	0.69	0.34	–	–	–
	Indifferent	80.96	93.95	70.92	96.35	72.47	–	–	–
2	Saproxeous	4.79	15.63	20.10	18.44	20.82	22.58	14.57	30.07
	Saprophilous	0.48	2.30	2.12	1.62	1.74	1.85	1.55	0.36
	Indifferent	94.73	82.07	77.78	79.94	77.44	75.57	83.88	69.57
3	Saproxeous	44.46	5.60	12.20	23.14	32.51	14.33	41.87	46.14
	Saprophilous	0	0.36	1.14	5.30	1.10	0.63	0.95	0.91
	Indifferent	55.54	94.04	86.66	71.56	66.39	85.04	57.18	52.95
4	Saproxeous	14.99	28.07	24.16	14.72	20.97	–	12.18	55.81
	Saprophilous	0.16	0.34	5.32	0.75	0	–	0.99	0.27
	Indifferent	84.85	71.59	70.52	84.53	79.03	–	86.83	43.92

abbreviata, *Achnanthes lanceolata*, *Amphora pediculus*, *Navicula* sp. 1, *Nitzschia fonticola*, *Fragilaria vaucheriae*. *Achnanthes minutissima* was dominated and subdominated mostly at station 1. *Rhoicosphenia abbreviata* and *Cocconeis placentula* var. *lineata* were subdominated at station 2 and 3 which were dominated mostly by *Nitzschia inconspicua*. At station 1 in October, dominant species was *Navicula* sp. 2 (Table 6).

Assessment of water quality by DAIpo

According to the degree of tolerance to organic water pollution (Asai and Watanabe, 1995), the 95 species were divided into 8 saprophilous taxa, 67 indifferent taxa and 20 saproxenous taxa. Saproxenous taxa were appeared more than saprophilous taxa. Saprophilous taxa were *Navicula pupula*, *Navicula seminulum*, *Navicula subminuscula*, *Pinnularia microstaurion* and *Nitzschia palea*. Saproxenous taxa were *Achnanthes lanceolata*, *Diatoma mesodon*, *Fragilaria vaucheriae* and *Rhoicosphenia abbreviata*.

The component ratio of three ecological taxa were shown in Table 7. The ratio of saproxenous taxa was between 5.89 and 27.47% at station 1, 4.79 and 30.07% at station 2, 5.6 and 46.14% at station 3, and 12.18 and 55.81% at station 4. The ratio of saprophilous taxa was between 0.16 and 1.78% at station 1, 0.36 and 2.30% at station 2, 0 and 5.30% at station 3, and 0 and 5.32% at station 4. The component ratio of saprophilous taxa was lower than that of saproxenous taxa. The ratio of indifferent taxa was between 70.92 and

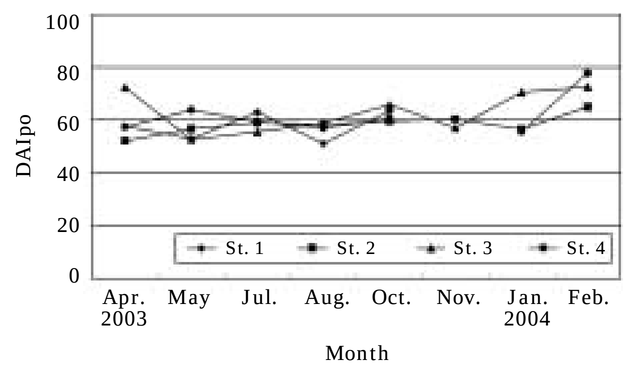

Fig. 3. Variations of DAIpo at each station in the Ulleung island.

96.35% at station 1, 69.57 and 94.73% at station 2, 55.54 and 94.04% at station 3, and 43.92 and 86.83% at station 4. The component ratio of indifferent taxa was mostly higher in the whole sampling seasons and stations (Fig. 2).

DAIpo was the highest at station 4 as 77.77 in February 2004, and the lowest at station 1 as 51.14 in August 2003. DAIpo values were between 51.14 and 62.93 at station 1, 52.17 and 64.86 at station 2, 52.62 and 72.62 at station 3, 55.60 and 77.77 at station 4. Average DAIpo values were 57.62 at station 1, 58.44 at station 2, 63.15 at station 3 and 61.65 at station 4 (Fig. 3). There were no distinguishable variations in the whole sampling seasons and stations. However the water quality was slightly improved in February 2004. The saprobic levels were estimated in the whole stations and seasons as α-oligosaprobic except station 3 in January, February and April, and station 4 in February which were β−oligosaprobic. There were a few reports that assessed the water quality by DAIpo in Korea : Kumho river (Chung *et al*., 1993), Pochun stream (Kim, 1999), Shinchon stream (Kim, 2001) and Nakdong river (Park *et al*., 2004). The water quality of Ulleung Island by DAIpo was oligosaprobic, between 51.14−77.77, and it was similar to that of upper stream of the Kumho river.

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<국문적요>

울릉도 수계의 부착규조군집의 계절적 변이와 DAIpo에 의한 수질평가

최재신 · 박정원 · 이경락 · 양명숙[1] · 김한순*

(경북대학교 자연과학대학 생물학과, [1]울릉중학교)

울릉도 수계의 부착규조군집의 계절적 변이와 DAIpo에 의한 수질평가를 조사하였다. 채집은 2003년 4월, 5월, 7월, 8월, 10월과 11월 그리고 2004년 1월과 2월에 4개의 정점에서 채집하였다. 총 95 분류군이 동정되었으며 우점종들은 *Nitzschia inconspicua, Achnanthes minutissima, Gomphonema angustum*과 *Cocconeis placentula* var. *lineata*였다. DAIpo는 51.15에서 77.77의 범위였고 울릉도 수계의 수질은 α-빈부수성에서 β-빈부수성이었다.