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Potential of Using Oribatid mites(Acari: Oribatida) as Biological Indicators of Forest Soil Acidification

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산림토양 산성화의 생물지표로써 날개응애(Acari: Oribatida) 이용 가능성

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ABSTRACT

The use of biological indicator for environmental monitoring has suddenly become popular in many international organizations as well as domestic ones. Since the biological indicator species should be well responsive to native environmental change, development of native indicator species is prerequisite for environmental assessment and restoration program. Through regression analysis of mean density and pH, potential indicator species were screened from Namsan and Kwangreung where differential environmental stresses are influenced; *Lasiobelba remota, Ceratozetes* sp. *Tectocepheus velatus, Neogymnobates* sp. and *Oppia* sp.3. Also keystone species in two study area were *Lohmannia coreana, Ceratozetes* sp., *Rostrozetes pulcherrimus,* and *Lasiobelba remota* in Namsan Deciduous forest and *Neogymnobates* sp., *Neogymnobates donghaksaensis,* and *Cultroribula tridentata* in Kwangreung. Advantages and disadvantages of using biological indicator for environmental monitoring were further discussed.

Key words* : *acid rain, biological indicator, environmental monitoring, restoration

I. INTRODUCTION

Potential disastrous impacts by environmental degradation have been proposed and detailed stories enumerate the need of improvement of natural and anthropogenic habitat conditions. Furthermore, recently, continuous and consistent environmental monitoring and impact assessment attract more interests in administrative parties, and research and civilian groups as well (Min. Environ., 1994). Core component of environmental monitoring is survey of fluctuation or movement of biological indicator species (Kari and Rauno, 1993). The simplest indication is presence/ absence of certain organism that well respond to a given chemical/physical stimuli. It becomes ideal if this organism responses in terms of density fluctuation or quantitative relationship between pollution level and accumulation in its body (van Straalen, 1996).

The environmental impacts of the deposition of acidifying substances from the atmosphere, popularly

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known as "acid rain", are currently a high profile issue in both scientific and public sectors (Freedman, 1986; Min. Environ., 1994). The acidification of ecosystem is considered as anthropogenic, and problems caused by acidification are realized by the "person-on-the-street". The important causal substances are known as sulfuric and nitric acids in wet and dry forms; precipitation and gaseous deposition. Studies of biological effects of acidification have been largely focused on terrestrial vegetation and aquatic system (Tamm and Cowling, 1976; Abrahamsen and Stuanes, 1980; Yu, 1994), but rare on terrestrial arthropods. Jung *et al.* (1998) reported higher atmospheric pollutant deposition and less primary production in Namsan compared to Kwangreung and consequently low species diversity and abundance of soil-inhabiting oribatid mites (Jung *et al.,* 1998; Park, 1998; Park and Lee, 2000). Also environmental data on soil, litter and precipitation pH were generally lower in Namsan than in Kwangreung indicating more acidification stress in Namsan. Correlation analysis showed a close relationship between soil and litter layer acidity to oribatid mite abundance (Jung *et al.,* 1998).

Here we report the selected biological indicator candidates of forest soil acidity by regression analysis of soil and litter pH and species abundance of oribatid mite. Oribatid mites are well suited for indicator of soil conditions because they occur in most terrestrial soil habitats, are easy to sample with high diversity and abundance, show a variety of adaptations and have short generation times with low mobility.

II. MATERIALS AND METHOD

2.1. Sampling Oribatid mites

The oribatid mite is one of the richest soil arthropod groups relative to diversity and abundance in forest soil habitat. Sampling site and procedure, methods for extraction of mites from the soil and litter layer were described in detail in Jung *et al.* (1998) and Jung and Lee (2001). In short, oribatid mites were sampled from 6 plots each from Namsan and Kwangreung deciduous forests from 1993 to 1994, 3 times per year (early May, mid August and early October, respectively). Firstly, we uncovered the fresh litters and took decomposing litters for litter layer sample, and then soil samples beneath the litter layer. In Namsan sampling plots, *Quercus mongolica*, *Sorbus alnifolia* and *Acer* spp. were dominant and *Carpinus laxiflora*, *Q. aliena*, *Q. mongolica* and *Acer* spp. were dominant in Kwangreung.

2.2. Environmental data

From each sampling plot, subsamples of soil and litter were taken for chemical analysis. Acidity of soil, litter layer, total nitrate and sulfate were measured. Data on acidity of precipitation were adopted from Min. Environ. (1994). Standard methods were used for environmental chemical analysis (RDA 1988). The pH of soil and litter samples was measured following Carter (1993) and RDA (1988) with 1:10 dilution.

2.3. Selection of biological indicators

From the soil and litter sampling, total 89 and 114 species of oribatid mite were reported from Namsan and Kwangreung, respectively (Jung *et al.,* 1998). Among those, species with >5% of total abundance were screened if any has a relation to soil and litter pH, firstly by visual graphing and secondly by regression analysis. First order and exponential curves were fitted to the abundance data relative to pH. For some species that was not abundant in our study or in Korea but reported to respond to soil acidity, e.g., *Tectocepheus velatus*, were also considered for bioindicator selection if shows any relationship. Also, keystone species (Price, 1984; Mayer *et al.,* 1992; Bond, 1993) were identified as the best representatives to Namsan and Kwangreung deciduous forests. Feeding characteristics were further discussed on their function in decomposition food chain.

III. RESULTS AND DISCUSSION

3.1. Biological indicator of acidification

Overall soil and litter layer in Namsan was more

Table 1. Chemical properties related to acidity of soil and litter layer in Namsan and Kwangreung deciduous forests (condensed from Jung *et al.* 1998)

		Namsan	Kwangreung
pH	Soil	4.423 ± 0.08	4.824 ± 0.056*
	Litter	5.049 ± 0.135	5.215 ± 0.056*
	Rain water[a]	5.24 ± 0.14	5.48 ± 0.19
Total nitrate (%)	Soil	0.258 ± 0.019	0.245 ± 0.028
	Litter	0.751 ± 0.049	0.643 ± 0.058
Total sulfate (ppm)	Soil	132.67 ± 44.37	129.92 ± 12.35*
(%)	litter	0.135 ± 0.018	0.098 ± 0.008

*t-test, $p<0.05$
[a]source (Min. Environ. 1994)

Table 2. Acidity (pH) of soil and litter layer in six plots of Namsan and Kwangreung deciduous forests in 1995

Plot number	Namsan		Kwangreung	
	Soil layer	Litter layer	Soil layer	Litter layer
1	4.51± 0.023	5.55± 0.102	4.93± 0.061	5.07± 0.045
2	4.52± 0.031	5.25± 0.082	4.72± 0.072	5.22± 0.121
3	4.27± 0.072	5.04± 0.124	4.61± 0.094	5.04± 0.063
4	4.17± 0.029	4.79± 0.302	4.97± 0.204	5.3± 0.078
5	4.34± 0.041	5.04± 0.524	4.89± 0.182	5.4± 0.055
6	4.72± 0.50	4.62± 0.328	4.82± 0.751	5.26± 0.125
Average	4.423c*	5.049ab	4.824b	5.521a

*ANOVA, Tukey studentized range test

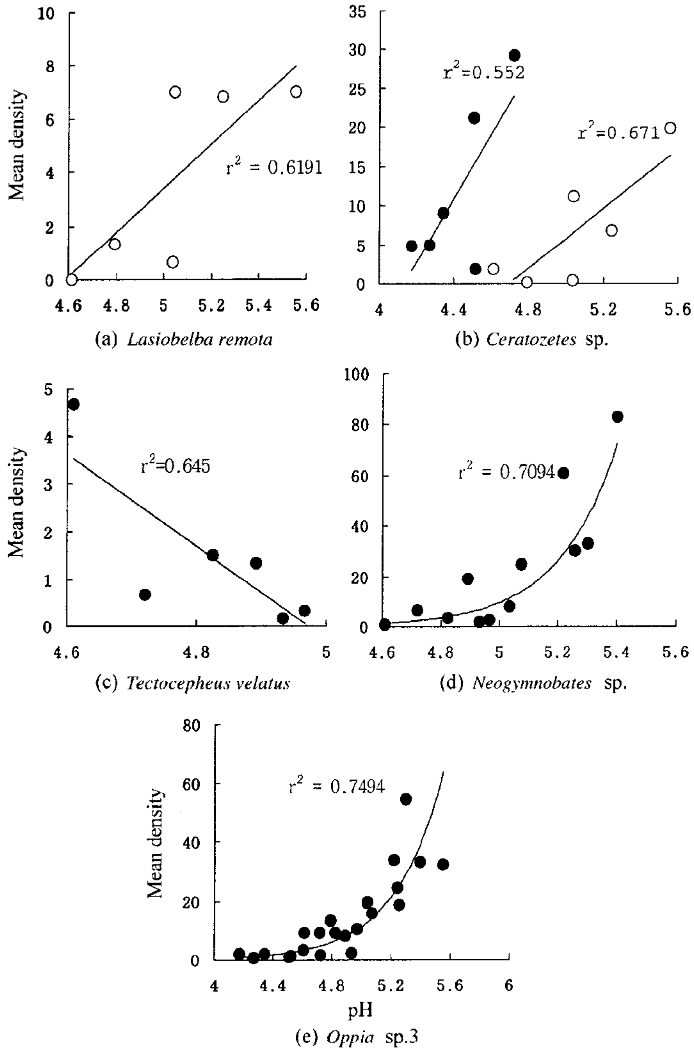

Fig. 1. Relationships between abundance of selected species and soil and/or litter layer pH. a) *Lasiobelba remota* in Namsan litter layer, b) *Ceratozetes* sp. in Namsan soil and litter layer, c) *Tectocepheus velatus* in Kwangreung soil layer, d) *Neogymnobates* sp. in Kwangreung soil and litter layer, and e) *Oppia* sp.3 in Namsan and Kwangreung soil and litter layers.

acidic than in Kwangreung. This was further supported by lower precipitation pH and higher sulfate and nitrate concentration in Namsan soil and litter layer, respectively (Table 1). Table 2 shows the acidity data measured from each sampling plot. Acidity was significantly different among study area, and soil-litter layer (ANOVA, df=3, 23, $P<0.001$). The value of pH was highest in Kwangreung litter layer followed by Namsan litter layer and Kwangreung soil layer, and lowest in Namsan soil layer.

Out of total species of oribatid mits surveyed, five species were identified having correlation with habitat acidity (Fig. 1). *Lasiobelba remota* was mostly found in Namsan, thus the mean density of this species at each plot was related to pH measured only at each plot in Namsan soil and litter layer (Fig. 1a). Although a positive linear relation was described in the graph (Fig. 1a), its abundance drastically increased around pH 5.03. *Ceratozetes* sp. was found mostly in Namsan soil and litter layer, but not in Kwangreung. This species showed two distinctive relationships relative to its habitats, soil and litter layer. Two separate linear relationships were found in soil and litter layer, respectively. As shown in Fig. 1b, in soil layer, mean density increased as the pH increased, and the distribution was shifted rightward according to pH in litter layer. Although *Tectocepheus velatus* is relatively not abundant in Namsan and Kwangreung deciduous forests (Jung *et al.* 1998), this species, however was reported highly abundant in sandy soil, coniferous forests, and very sensitive to soil pH in eastern Europe (Schenker, 1984). *T. velatus* was mostly found from Kwangreung soil and showed negative relationship to soil pH, meaning preference to acidic soil (Fig. 1c). *Neogymnobates* sp. was mostly found in Kwangreung soil and litter layer. Abundance of *Neogymnobates* sp. was positively related to soil and litter layer pH (Fig. 1d). The pattern of association with soil and litter layer pH of *Neogymnobates* sp. was different to that of *Ceratozetes* sp. Since those two species occupy the similar habitat (soil and litter) with similar feeding preference (microphytophage), the differential association reqiures further population level study. *Oppia* sp.3 was the most abundant in both study area regardless of layer. Its abundance was consistently related to soil and litter pH (Fig. 1e).

3.2. Keystone species in Namsan and Kwangreung

Another category of indicator species, keystone species were selected by the importance in the community. Thus, if something such as destructive environmental change results in reduction or extinction of keystone species, overall structure and function of the community can be seriously damaged (Price, 1984; Mayer *et al.* 1992). Species in this criteria were listed in Table 3; *Lohmannia coreana, Ceratozetes* sp., *Rostrozetes pulcherrimus, Lasiobelba remota* in Nsmsan Deciduous forest and *Neogymnobates* sp., *Neogymnobates donghaksaensis, Cultroribula tridentata* in Kwangreung. Also, *Oppia* sp.3 may be used as deciduous forest indicator since this was found to be one of the most dominant species particularly in deciduous forests, but not in coniferous forests in the same study area (Park *et al.,* 1998). Many representatives of Namsan deciduous forest are soil inhibitors and pan/macrophytophagous while those of Kwangreung are litter layer inhibitors and microphytophagous (Table 3). It was formerly noted that many oribatids are principally fungivorous while a number of species are comsuming the decaying leaves of higher plants (Wallwork 1983). Since oribatid mites play important roles in decomposition process in forest soil system, we carefully conclude that the keystone species in Kwangreung deciduous forest function in decomposition process as regulators of microfauna such as bacteria and fungi while keystone species in Namsan function as direct feeder of decaying plant residue. This was partly explained that reduced microfaunal activity slowed down the decomposition process indicated by depth of fresh litter layer in Namsan (Jung *et al.,* 1998).

Table 3. Keystone species of oribatid mites in Namsan and Kwangreung deciduous forest and their biological characteristics

	Habitat	Feeding preference
Namsan		
Lohmannia coreana	Soil	Panphytophage
Ceratozetes sp.	Soil, litter	Microphytophage
Rostrozetes pulcherrimus	Soil	Panphytophage
Lasiobelba remota	Soil, litter	Macrophytophage
Oppia sp.3	Soil, litter	Microphytophage
Kwangreung		
Neogymnobates donghaksaensis	Litter	Microphytophage
Neogymnobates sp.	Litter	Microphytophage
Cultroribula tridentata	Litter	Microphytophage
Oppia sp.3	Soil, Litter	Microphytophage

3.3. Use of biological indicator for environmental monitoring

Here we reported that the possibility of using soil oribatid mites as biological indicator of forest acidification. Some species of oribatid mite distribution are clearly correlated to pH positively or negatively, while some of them have a distinct preference for a certain range (Wallwork, 1983). This was exemplified by the relationship between *Lasiobelba remota* abundance and Namsan soil pH. Also van Straalen *et al.* (1988) proposed whole microarthropod community as indicator of soil acidification from their simulated study. Current debates on the necessity of indicator species and species-level resolution in applied research in aquatic system has relevance to the soil invertebrate system where the taxonomic impediments are much more severe (Paoletti *et al.*, 1991). Butcher *et al.*(1971) warned that it would be misleading to correlate density of mites and pH, if sampling and chemical measures were done in a short period of time, especially in summer when temperature, humidity and animal respiration combined acidity of the substrates. Our sampling period was 2 years covering three seasons each year, representation of the relationship between mean density of certain oribatid mite species and pH is realistic. However, because this study was carried out in field survey type, detailed toxicological study is required in population level for practical applications in environmental monitoring and restoration program. Also site-specificity is to be overcome through extensive survey program under varying environmental gradient. For example, *Neogymnobates* sp. and *Ceratozetes* sp. are well responsive to soil and litter layer, but, this analysis was limited to each study area since its restricted distribution either to Namsan or Kwangreung. Most selected species are indigenous species in Korea and information on their individual/population level is limited. Further ecological studies such as distribution, habitat microenvironment, feeding habits, and ecotoxicological aspects are suggested.

With mounting limitations, however, using biological indicator to monitor environmental quality has some clear advantages against physico-chemical study. First, biological study can measure the cumulative impacts on organism rather than temporary snap-shot status of environmental pollutants. Second, indicator organism can detect even lower level of toxicant that can not be detected with physico-chemical instruments. Third, bioindiator can measure the environmental quality with least human interception. Fourth, bioindicator can react as well to complex factors as to individual factors. And bioindicator also can be useful to assess the specific effect to invaluable components of the system without removal or damaging those components. Thus, it is important to start with right species that is sensitive and responsive coherently to particular stimulus (Harrison, 1990; Curry and Good, 1992).

적 요

국제 기구 뿐만 아니라 우리나라에서도 생물 지표를 이용한 환경 모니터링에 관한 관심이 증대하고 있다. 생물 지표는 자극의 국지환경 변화에 잘 반응해야 하므로, 토착 생물지표의 개발은 생태계 복원 및 평가에서 매우 중요한 시발점이다. 환경 스트레스를 달리 받고 있는 남산과 광릉 활엽수림 지역에서 조사된 날개응애 중에서 토양 및 부엽 산도(pH)와 밀접한 관계를 보이는 종을 회귀분석을 통하여 잠재적 생물 지표종으로 선발하였다. 선발된 종은 다음과 같다; *Lasiobelba remota*, *Ceratozetes* sp. *Tectocepheus velatus*, *Neogymnobates* sp. and *Oppia* sp.3. 또한 군집구성 및 기능에 매우 중요한 역할을 하는 핵심종(keystone species)으로는, 남산 활엽수림지역에서는 *Lohmannia coreana*, *Ceratozetes* sp., *Rostrozetes pulcherrimus*, *Lasiobelba remota* 그리고 광릉지역에서는 *Neogymnobates* sp., *Neogymnobates donghaksaensis*, *Cultroribula tridentata*로 나타났다. 생물지표를 이용한 환경 모니터링의 장단점에 대해 고찰하였다.

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REFERENCES

Abrahamsen, G. and A. O. Stuanes, 1980: Effects of simulated rain on the effluent from lysimeters with acid, shallow soil rich in organic matter. *Ecological impact of acid precipitation*, D. Drablos and A. Tollan (Eds.), SNSF project, Oslo, Norway, 152-153.

Bond, W. J., 1993: Keystone species. *Biodiversity and ecosystem function*, E. D. Schulze and H. A. Mooney (Eds.), Springer-Verlag, Hongkong, 237-253.

Butcher, J. W., R. Snider and R. J. Snider, 1971: Bioecology of edaphic collembola and acarina. *Annual Review of Entomology,* **16**, 249-288.

Carter, M. R., 1993: *Soil sampling and methods of analysis.* Lewis publishers, London, 822p.

Curry, J. P. and J. A. Good, 1992: Soil fauna degradation and restoration. *Advances in Soil Science,* **17**, 171-215.

Harrison, R. M., 1990: *Pollutions: causes, effects and control.* Royal Society of Chemistry, 399pp.

Freedman, B., 1986: *Environmental ecology: The impacts of pollution and other stresses on ecosystem structure and function*, Academic Press, New York, 424pp.

Jung, C., J.-H. Lee, Y.-H. Bae, and S.-S. Choi, 1998: Diversity of oribatid mites (Acari: Oribatida) in Namsan and Kwangreung deciduous forests. *Korean Journal of Soil Zoology,* **3**, 91-105.

Jung, C. and J.-H. Lee, 2001: Stability analysis of soil oribatid mite communities (Acari: Oribatida) from Na, san and Kwangreung deciduous forests, Korea. *Korean Journal of Ecology,* **24**, 239-243.

Kari, H. and V. Rauno, 1993: *Insects and pollution.* CRC Press, Londodn, 393pp.

Mayer, F. L., D. J. Versteeg, M. J. Mckee, L. C. Folmar, R. L. Graney, D. C. McCume, and B. A. Rattner, 1992: Physiological and nonspecific biomarkers. *Biomarkers,* R. J. Huggett, R. A. Kimerle, P. M. Mehrle, Jr, and H. L. Bergman (Eds.), 5-85.

Ministry of Environment., 1994: *Assessment and restoration of biodiversity in a degraded ecosystem.* 359pp.

Paoletti, M. G., M. R. Favretto, B. R. Stinner, F. F. Purrington and J. E. Bater, 1991: Invertebrates as bioindicators of soil use. *Agriculture, Ecosystem and Environment,* **34**, 341-362.

Park, H.-H. J.-H. Lee, Y.-H. Bae, and S.-S. Choi, 1998: Diversity of oribatid mites (Acari: Oribatida) in Namsan and Kwangreung coniferous forests. *Korean Journal of Soil Zoology,* **3**, 78-90.

Park, H.-H. and J.-H. Lee, 2000: Community analysis of oribatid mites (Acari: Oribatida) in Namsan and Kwangreung coniferous forests. *Korean Journal of Applied Entomology,* **39**, 31-41.

Price, P. W., 1984: *Insect ecology* (2nd ed.), John Willey & Sons, New York, 606pp.

RDA, 1988: *Standard methods for soil chemical analysis.* 350pp.

Schenker, R., 1984: The ecological significance of the abundance and distribution pattern of *Tectocepheus velatus* (Acari: Oribatei) in a temperate mixed forest. *Acarology VI. Vol. 1*, D. A. Griffiths and C. E. Bowman (Eds.), Ellis Horwood, Chichester. 519-527.

Tamm, C. O. and E. B. Cowling, 1976: *Acidic precipitation and forest vegetation.* USDA rep. NE-23. NorthEast Forest Experimental Station, Broomall, Pennsylvania. 845-855.

van Straalen, N. M., 1996: Critical body concentration: their use in bioindication. *Bioindicator systems for soil pollution.* N. M. van Straalen and D. A. Krivolutsky (Eds.), Kluwer Academic Publishers, Amsterdam, 5-16.

Wallwork, J. A., 1983: Oribatids in forest ecosystems. *Annual Review of Entomology,* **28**, 109-130.