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Community Analysis of the Moths in the Gotjawal Terrains of Jeju Island, Korea

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ABSTRACT: Collection of moths in four Gotjawal terrains of Jeju Island was conducted using black light trap, beginning July through September 2005. The insects investigated were classified into 146 species, 15 families and 7 superfamilies, and Noctuoidea appeared to have accounted for 41.1%, or 60 species, which was the largest number among them, followed by Geometroidea. *Ercheia niveostrigata* was found to have been the dominant species over the entire area. The diversity index showed the highest at Aewol Gotjawal and the lowest at Hangyeong-Andeog Gotjawal. Aewol Gotjawal formed a cluster with Gujwa- Sungsan Gotjawal at the lowest chord distance (0.75). At the higher chord distance of 0.82, Jocheon- Hamdeog Gotjawal fused the cluster of Aewol Gotjawal and Gujwa-Sungsan Gotjawal. Hangyeong-Andeog Gotjawal fused with the rest three terrains, forming a single cluster at the highest chord distance of 0.89.

Key words: Black light trap, Cluster analysis, Gotjawal Terrain, Jeju Island, Species diversity index

INTRODUCTION

Gotjawal, named in Jeju dialect, where the trees, vines, and rocks are jumbled and tangled an together, represents the unique topographic features of rough lava bed created by volcanic activity (Song 2003a, 2003b, 2003c). Song (2000) named the Gotjawal lava terrain, depending on their own name, as Hangyeong-Andeog and Aewol Gotjawal Terrain in the west, and Jocheon-Hamdeog and Gujwa-Sungsan Gotjawal Terrain in the east.

Thanks to high permeability of the ground, with rainfall that tends to directly penetrates into the ground, Gotjawal terrain recently was found to have been rich in ground water resource, coupled with the heat and moisture-retaining geographic condition, which prompted the government to refrain from building the structures in the area (Song 2003a, 2003b, 2003c). However, this area has been in danger of losing its very unique ecological value because many golf courses are being constructed and some area is reclaimed for garbage in this area.

So far there has been no biological report on Gotjawal except Yang et al. (2006), which dealt with the insect community without Lepidoptera. This study focused on identifying the fauna of moths as well as analyzing their community in Gotjawal terrain, which was aimed at obtaining the basic data to better understand the ecological features of Gotjawal terrain from biological standpoint.

MATERIALS AND METHODS

The investigation was conducted from July through September 2005. The locations determined include Jocheon-Hamdeog, Hangyeong-Andeog, Aewol and Gujwa-Sungsan Gotjawal Terrain (Fig. 1). Sampling was alternately carried out at two sites per each terrain. The sample collection was conducted at nighttime (21:00~23:00) twice a month at designated points, collecting the moths using mercury lamps (300W, KP Electric Co., H300). The collection activity was mostly done in calm and fine days. Given the moonlight might affect the activities of the moth (Choi and Na 2005), a full-moon night was excluded, as far as possible. The insects collected were processed with ethyl acetate and kept in a freezer after finishing the treatment for stuffed specimen monitoring.

The relative abundances of component species were evaluated into three classes, abundant, common and rare, in the following way. The 95% confidence limits of relative percentage are given by Sakuma's (1964) formula.

$$(n/N \pm \sqrt{n(N-n)/N^3}) \times 100$$

where N=total individual number and n=individual number of a specie. Next, the limits of the mean percentage can be calculated in the same way by using the mean individual number ($n=N/S$, where S=total species number) instead of n. In comparison between the percentage range of each species and that of the mean, the species is regarded to be abundant when the lower limit of the former exceeds the higher one of the latter, common when the two ranges overlap, and rare when opposite to the case of "abundant."

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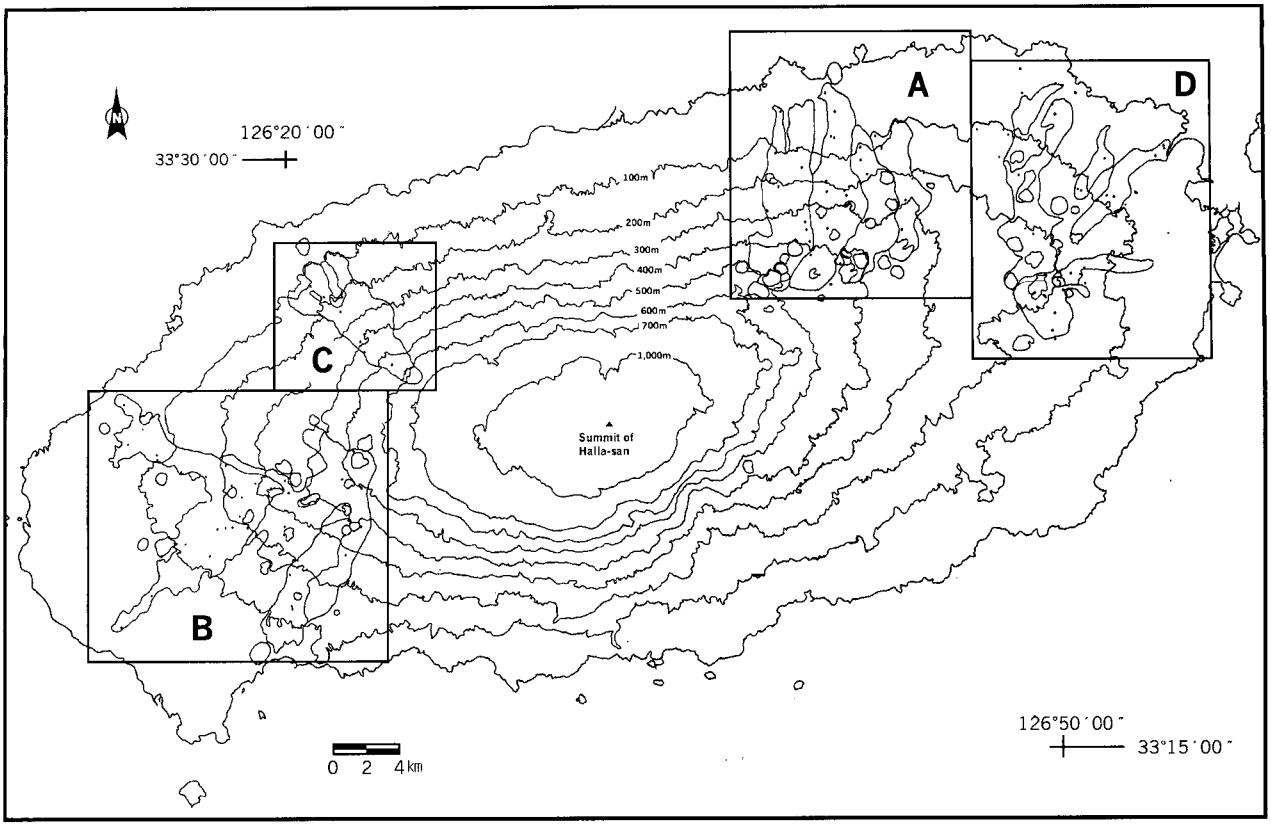

Fig. 1. Index map of Gotjawal Terrains, Jeju Island. A: Jocheon-Hamdeog Gotjawal Terrain, B: Hangyeong-Andeog Gotjawal Terrain, C: Aeweol Gotjawal Terrain, and D: Gujwa-Sungsan Gotjawal Terrain (Adapted from Song, 2000).

In a bid to identify the differences in diversity index among the groups of Lepidoptera in the area, a Shannon-Weaver function (1963) was adopted.

$$H' = -\sum pi \log pi$$

where, P_i = the ratio of i species to the total number (n_i/N), n_i = the number of i species, and N= total number of individuals.

The BASIC program CLUSTER.BAS was used for a cluster analysis on the insect data of four Gotjawal terrains, and chord distance (see below) was the resemblance function used along with the flexible clustering strategy (Ludwig and Reynold 1988). Chord distance is given by

$$CRD_{jk} = \sqrt{2(1 - ccos_{jk})}$$

where the chord cosine (ccos) is computed from

$$ccos_{jk} = \frac{\sum(X_{ij}X_{ik})}{\sum X_{ij}^2 \sum X_{ik}^2}$$

RESULTS AND DISCUSSION

The dominant vegetative species were described in Table 1. The fauna of the moths collected and identified in Gotjawal terrain in Jeju Island was finally found to be 146 species, belonged to 15 families and 7 superfamilies (Fig. 2).

Noctuoidea and Geometroidea were found to have the most diversified species with 4 families, accounting for 26.7% of the total. These two groups, also in terms of species, demonstrated more diversified species with 60 (41.4%) and 44 (30.3%), respectively, which were significantly higher than other groups.

Species Composition of Jocheon-Hamdeog Gotjawal Terrain

The Lepidoptera inhabiting in Jocheon-Hamdeog Gotjawal Terrain were found to have totaled 91 species, 14 families and 6 superfamilies (Table 2). Noctuidae had the largest number of species with 32 (35.2%), followed by Geometridae (19.8%), Pyralidae (12.1 %), Arctiidae (9.9%), Sphingidae (7.7%), Lymantriidae (3.3%), Drepanidae (2.2%), Thyatiridae (2.2%), Saturniidae (2.2%), Cyclidiidae (1.1%), Bombycidae (1.1%), Lasiocampidae (1.1%), Notodontidae

Table 1. Frequency and relative abundance of the insects collected from Jocheon-Hamdeog Gotjawal Terrain

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
Pyraloidea	Pyralidae	*Herpetogramma luctuosalis* (Guenee)	0.84	1.54	2.24	19(+)
		Hymenia recurvalis (Fabricius)	0.65	1.29	1.94	16(+)
		Locastra muscosalis (Walker)	−0.07	0.16	0.39	2(±)
		Maruca testulalis Geyer	−0.08	0.08	0.24	1(±)
		Oncocera semirubella (Scopoli)	1.16	1.94	2.73	24(+)
		Orthaga euadrusalis Walker	1.16	1.94	2.73	24(+)
		Palpita nigropunctalis (Bremer)	6.02	7.52	9.02	93(++)
		Pleuroptya balteata (Fabricius)	−0.08	0.08	0.24	1(±)
		Scirpophaga praelata Scopoli	−0.07	0.16	0.39	2(±)
		Tamraca torridalis (Lederer)	−0.04	0.24	0.52	3(+)
		Tyspanodes hypsalis Warren	2.71	3.80	4.89	47(++)
Geometroidea	Drepanidae	*Agnidra scabiosa* (Butler)	−0.08	0.08	0.24	1(±)
		Oreta pulchripes Butler	−0.07	0.16	0.39	2(±)
	Cyclidiidae	*Cyclidia substigmaria* (Hubner)	−0.08	0.08	0.24	1(±)
	Thyatiridae	*Habrossyne pyritoides* (Hufnagel)	0.14	0.57	0.99	7(+)
		Thyatira batis (Linne)	−0.08	0.08	0.24	1(±)
	Geometridae	*Abraxas niphonibia* Wehrli	−0.04	0.24	0.52	3(+)
		Chiasmia defixaria (Walker)	−0.08	0.08	0.24	1(±)
		C. hebesata (Walker)	−0.08	0.08	0.24	1(±)
		Chloromachia infracta (Wileman)	0.04	0.40	0.77	5(+)
		Comibaena procumbaria (Pryer)	−0.07	0.16	0.39	2(±)
		Deileptenia ribeata (Clerck)	2.23	3.24	4.24	40(++)
		Ectropis excellens (Butler)	2.16	3.16	4.15	39(++)
		Euryobeidia languidata (Walker)	−0.07	0.16	0.39	2(±)
		Fascellina chromataria Walker	3.92	5.18	6.44	64(++)
		Hypomecis roboraria (Denis et Schiffermuller)	−0.07	0.16	0.39	2(±)
		Menophra harutai (Inoue)	−0.07	0.16	0.39	2(±)
		M. senilis (Butler)	−0.07	0.16	0.39	2(±)
		Odontopera arida (Butler)	−0.07	0.16	0.39	2(±)
		Ophthalmitis albosignaria (Bremer et Grey)	−0.08	0.08	0.24	1(±)
		Ourapteryx maculicaudaria (Motschulsky)	−0.07	0.16	0.39	2(±)
		Pareclipsis gracilis (Butler)	−0.04	0.24	0.52	3(+)
		Scopula superciliata (Prout)	2.09	3.07	4.06	38(++)
		Xandrames dholaria Moore	0.09	0.49	0.88	6(+)

Table 1. Continued

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
Bombycoidea	Lasiocampidae	*Paralebeda plagiata* (Menetries)	−0.08	0.08	0.24	1(±)
	Bombycidae	*Bombyx mandarina* (Moore)	0.04	0.40	0.77	5(+)
	Saturniidae	*Antheraea yamamai* (Guerin-Meneville)	−0.07	0.16	0.39	2(±)
		Samia cynthia (Drury)	0.53	1.13	1.73	14(+)
Sphingoidea	Sphingidae	*Ambulyx ochracea* (Butler)	−0.07	0.16	0.39	2(±)
		Ampelophaga rubiginosa Bremer et Grey	−0.07	0.16	0.39	2(±)
		Deilephila elpenor (Linne)	−0.08	0.08	0.24	1(±)
		Dolbina tancrei Staudinger	−0.07	0.16	0.39	2(±)
		Marumba spectabilis (Butler)	−0.07	0.16	0.39	2(±)
		Rhagastis mongoliana (Butler)	0.04	0.40	0.77	5(+)
		Theretra nessus (Drury)	0.14	0.57	0.99	7(+)
Notodontoidea	Notodontidae	*Dudusa sphigiformis* Moore	−0.07	0.16	0.39	2(±)
Noctuoidea	Lymantriidae	*Arctornis kumatai* Inoue	0.00	0.32	0.65	4(+)
		Euproctis piperita Oberthur	−0.08	0.08	0.24	1(±)
		E. subflava (Bremer)	−0.08	0.08	0.24	1(±)
	Arctiidae	*Cyana hamata* Walker	4.28	5.58	6.89	69(++)
		Miltochrista pulchera Butler	−0.04	0.24	0.52	3(+)
		M. striata (Bremer et Grey)	1.16	1.94	2.73	24(+)
		Rhyparioides metelkana (Lederer)	0.04	0.40	0.77	5(+)
		Spilosoma punctaria (Stoll)	−0.08	0.08	0.24	1(±)
		Spilarctia seriatopunctata Motschulsky	1.96	2.91	3.87	36(++)
		S. imparilis (Butler)	−0.04	0.24	0.52	3(+)
		S. lubricipeda (Linne)	0.04	0.57	0.99	7(+)
		Stigmatophora flava (Bremer et Grey)	−0.04	0.24	0.52	3(+)
	Noctuidae	*Acanthoplusia agnata* (Staudinger)	−0.07	0.16	0.39	2(±)
		Aedia leucomelas (Linne)	0.04	0.40	0.77	5(+)
		Amphipyra livida (Denis et Schiffermuller)	−0.08	0.08	0.24	1(±)
		Anomis mesogona (Walker)	−0.07	0.16	0.39	2(±)
		Artena dotata (Fabricius)	−0.08	0.08	0.24	1(±)
		Atrachea nitens (Butler)	0.71	1.38	2.04	17(+)
		Callopistria juventina (Stoll)	2.37	3.40	4.43	42(++)
		Chrysodeixis eriosoma (Doubleday)	1.96	2.91	3.87	36(++)
		Cucullia fraterna Butler	−0.08	0.08	0.24	1(±)
		Cymatophoropsis trimaculata (Bremer)	−0.08	0.08	0.24	1(±)

Table 1. Continued

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
		Dysgonia arctotaenia (Guenee)	−0.07	0.16	0.39	2(±)
		Ercheia niveostrigata Warren	11.19	13.11	15.03	162(++)
		Hypena amica (Butler)	3.49	4.69	5.90	58(++)
		Hypopyra vespertilio Fabricius	−0.08	0.08	0.24	1(±)
		Lagoptera juno (Dalman)	−0.08	0.08	0.24	1(±)
		Lygephila maxima (Bremer)	5.58	7.04	8.48	87(++)
		Mamestra brassicae (Linne)	1.16	1.94	2.73	24(+)
		Mecodina cineracea (Butler)	−0.08	0.08	0.24	1(±)
		M. nubiferalis (Leech)	−0.08	0.08	0.24	1(±)
		Metopta rectifasciata (Menetries)	−0.08	0.08	0.24	1(±)
		Mocis ancilla (Warren)	−0.08	0.08	0.24	1(±)
		Oraesia excavata (Butler)	0.77	1.46	2.14	18(+)
		Orthogonia sera Felder et Felder	−0.08	0.08	0.24	1(±)
		Pangrapta trimantesalis (Walker)	2.37	3.40	4.43	42(++)
		Pseudoips sylpha (Butler)	−0.08	0.08	0.24	1(±)
		Spirama helicina (Hubner)	−0.04	0.24	0.52	3(+)
		Simplicia niphona (Butler)	1.09	1.86	2.63	23(+)
		S. retorta (Clerck)	−0.08	0.08	0.24	1(±)
		Spodoptera litura (Fabricius)	1.89	2.83	3.78	35(++)
		Trichoplusia intermixta (Warren)	−0.08	0.08	0.24	1(±)
		Xestia stupenda (Butler)	−0.08	0.08	0.24	1(±)
		Xylena formosa (Butler)	−0.08	0.08	0.24	1(±)
	Agaristidae	*Sarbanissa subflava* (Moore)	−0.08	0.08	0.24	1(±)
TOTAL	S = 91	Mean=13.58	0.51		1.69	

* Relative abundance.

Table 2. Frequency and relative abundance of the insects collected from Hangyeong-Andeog Gotjawal Terrain

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
Pyraloidea	Pyralidae	*Botyodes principalis* Leech	0.00	0.33	0.67	4(±)
		Dichocrocis punctiferalis (Guenee)	−0.08	0.08	0.25	1(±)
		Goniorhynchus butyrosa (Butler)	1.13	1.92	2.71	23(+)
		Herpetogramma luctuosalis (Guenee)	4.64	6.01	7.38	72(++)

Table 2. Continued

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
		Hymenia recurvalis (Fabricius)	−0.07	0.17	0.40	2(±)
		Maruca testulalis Geyer	−0.08	0.08	0.25	1(±)
		Palpita indica (Saunder)	−0.08	0.08	0.25	1(±)
		P. nigropunctalis (Bremer)	4.04	5.34	6.64	64(++)
		Tamraca torridalis (Lederer)	−0.07	0.17	0.40	2(±)
Geometroidea	Drepanidae	*Oreta pulchripes* Butler	−0.07	0.17	0.40	2(±)
	Thyatiridae	*Thyatira batis* (Linne)	−0.08	0.08	0.25	1(±)
	Geometridae	*Agathia carissima* Butler	0.74	1.42	2.10	17(+)
		Amraica superans (Butler)	−0.08	0.08	0.25	1(±)
		Carige cruciplaga (Walker)	−0.07	0.17	0.40	2(±)
		Ectropis excellens (Butler)	−0.04	0.25	0.54	3(±)
		Fascellina chromataria Walker	0.67	1.34	2.00	16(+)
		Gandaritis fixseni (Bremer)	−0.08	0.08	0.25	1(±)
		Geometra dieckmanni Graeser	−0.08	0.08	0.25	1(±)
		G. valida Felder et Rogenhofer	−0.07	0.17	0.40	2(±)
		Heterolocha aristonaria (Walker)	−0.04	0.25	0.54	3(±)
		Hirasa paupera (Butler)	−0.08	0.08	0.25	1(±)
		Hypephyra terrosa Butler	−0.07	0.17	0.40	2(±)
		Hypomecis punctinalis (Scopoli)	−0.07	0.17	0.40	2(±)
		Menophra harutai (Inoue)	−0.08	0.08	0.25	1(±)
		M. senilis (Butler)	−0.07	0.17	0.40	2(±)
		Odontopera arida (Butler)	0.09	0.50	0.91	6(+)
		Ophthalmitis albosignaria (Bremer et Grey)	−0.07	0.17	0.40	2(±)
		Ourapteryx maculicaudaria (Motschulsky)	0.09	0.50	0.91	6(+)
		Pareclipsis gracilis (Butler)	−0.08	0.08	0.25	1(±)
		Somatina indicataria (Walker)	−0.08	0.08	0.25	1(±)
		Tephrina vapulata (Butler)	−0.08	0.08	0.25	1(±)
		Trigonoptila latimarginaria (Leech)	3.97	5.26	6.55	63(++)
Bombycoidea	Lasiocampidae	*Dendrolimus spectabilis* (Butler)	−0.07	0.17	0.40	2(±)
		Paralebeda plagiata (Menetries)	−0.08	0.08	0.25	1(±)
	Bombycidae	*Bombyx mandarina* (Moore)	2.80	3.92	5.05	47(++)
Sphingoidea	Sphingidae	*Ambulyx japonica* (Rothschild)	−0.08	0.08	0.25	1(±)
		Ampelophaga rubiginosa Bremer et Grey	0.09	0.50	0.91	6(+)
		Marumba gaschkewitschii (Bremer et Grey)	−0.08	0.08	0.25	1(±)
		Rhagastis mongoliana (Butler)	0.43	1.00	1.58	12(+)
		Theretra nessus (Drury)	0.43	1.00	1.58	12(+)

Table 2. Continued

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
Notodontoidea	Notodontidae	*Phalera flavescens* (Bremer et Grey)	0.00	0.33	0.67	4(±)
Noctuoidea	Lymantriidae	*Arctornis kumatai* Inoue	−0.08	0.08	0.25	1(±)
		Euproctis subflava (Bremer)	0.00	0.33	0.67	4(±)
	Arctiidae	*Cyana hamata* Walker	−0.04	0.25	0.54	3(±)
		Miltochrista striata (Bremer et Grey)	1.74	2.67	3.60	32(+)
		Spilarctia seriatopunctata Motschulsky	9.21	11.02	12.83	132(++)
		Spilosoma imparilis (Butler)	5.91	7.43	8.94	89(++)
		S. lubricipeda (Linne)	2.23	3.26	4.28	39(++)
		Stigmatophora flava (Bremer et Grey)	−0.04	0.25	0.54	3(±)
	Noctuidae	*Aedia leucomelas* (Linne)	0.00	0.33	0.67	4(±)
		Anomis mesogona (Walker)	−0.07	0.17	0.40	2(±)
		Axylia putris (Linne)	−0.08	0.88	0.25	1(±)
		Callopistria juventina (Stoll)	−0.07	0.17	0.40	2(±)
		Chrysodeixis eriosoma (Doubleday)	1.06	1.84	2.61	22(+)
		Cosmia achatina Butler	0.86	1.59	2.31	19(+)
		Dictyestra dissectus (Walker)	−0.08	0.08	0.25	1(±)
		Ercheia niveostrigata Warren	14.30	16.44	18.59	197(++)
		Hypena amica (Butler)	6.22	7.76	9.31	93(++)
		Lagoptera juno (Dalman)	−0.04	0.25	0.54	3(±)
		Lygephila maxima (Bremer)	−0.08	0.08	0.25	1(±)
		Mecodina nubiferalis (Leech)	1.46	2.34	3.21	28(+)
		Metopta rectifasciata (Menetries)	−0.08	0.08	0.25	1(±)
		Oraesia excavata (Butler)	2.30	3.34	4.38	40(++)
		Pangrapta trimantesalis (Walker)	4.64	6.01	7.38	72(++)
		Phytometra amata (Butler)	−0.08	0.08	0.25	1(±)
		Simplicia niphona (Butler)	0.04	0.42	0.79	5(+)
		Spirama helicina (Hubner)	−0.04	0.25	0.54	3(±)
		Spodoptera litura (Fabricius)	−0.08	0.08	0.25	1(±)
		Xestia stupenda (Butler)	−0.08	0.08	0.25	1(±)
		Xylena formosa (Butler)	−0.04	0.25	0.54	3(±)
	Agaristidae	*Sarbanissa subflava* (Moore)	−0.07	0.17	0.40	2(±)
TOTAL	S = 71	Mean=16.87	0.73		2.09	

* Relative abundance.

Fig. 2. A number of species in the investigated areas. The abbreviated letters in the abscissa are same as represented in Fig. 1.

(1.1%) and Agaristidae (1.1%). As shown in the table, fifteen species were regarded to be abundant, corresponding 16.5% of the total species number, twenty seven species were common (29.7%), and the remaining forty nine species rare (53.8%).

Samia cynthia was the species, which of 14 individuals was only collected in this terrain but not found in any other place. This result seemed to have been closely connected to the stand of *Phellodendron amurense* and *Styrax japonica* in the region. Because *Samia cynthia* was known as the species having host plants such as *Cinnamomun camphora*, *Phellodendron amurense*, *Styrax japonica*, *Picrasma quassioides*, and *Ailanthus altissima* (Park and Kwon 2001).

Species Composition of Hangyeong-Andeog Gotjawal Terrain

The Lepidoptera inhabiting in Hangyeong-Andeog Gotjawal Terrain were found to have totaled 71 species, 12 families and 6 superfamilies (Table 3). Geometridae had the largest number of species with 22(31.0%), followed by Noctuidae (28.2%), Pyralidae (12.7%), Arctiidae (8.2%), Sphingidae (7.0%), Lasiocampidae (2.8%), Lymantriidae (2.8%), Drepanidae (1.4%), Thyatiridae (1.4%), Bombycidae (1.4%), Notodontidae (1.4%) and Agaristidae (1.4%). As shown in the table, eleven species were regarded to be abundant, corresponding to 15.5% of the total species number, thirteen species were com-

Table 3. Frequency and relative abundance of the insects collected from Aeweol Gotjawal Terrain

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
Pyraloidea	Pyralidae	*Botyodes principalis* Leech	−0.10	0.25	0.61	2(+)
		Cirrhochrista brizoalis (Walker)	−0.13	0.13	0.38	1(+)
		Goniorhynchus butyrosa (Butler)	5.27	7.10	8.93	56(++)
		Herpetogramma luctuosalis (Guenee)	1.82	3.04	4.26	24(+)
		Oncocera semirubella (Scopoli)	−0.03	0.13	0.38	1(+)
		Palpita indica (Saunder)	−0.03	0.13	0.38	1(+)
		P. nigropunctalis (Bremer)	2.97	4.44	5.90	35(++)
		Tyspanodes hypsalis Warren	−0.10	0.25	0.61	2(+)
Zygaenoidea	Limacodidae	*Latoia sinica* (Moore)	−0.06	0.38	0.82	3(+)
Geometroidea	Drepanidae	*Agnidra scabiosa* (Butler)	−0.13	0.13	0.38	1(+)
		Hypsomadius insignis Butler	−0.13	0.13	0.38	1(+)
	Thyatiridae	*Habrosyne pyritoides* (Hufnagel)	0.10	0.25	0.61	2(+)
		Thyatira batis (Linne)	0.65	1.52	2.39	12(+)
	Geometridae	*Abraxas niphonibia* Wehrli	−0.06	0.38	0.82	3(+)
		Agathia carissima Butler	−0.13	0.13	0.38	1(+)
		Biston regalis (Moore)	−0.13	0.13	0.38	1(+)
		Chiasmia defixaria (Walker)	3.40	4.94	6.49	39(++)
		C. hebesata (Walker)	−0.13	0.13	0.38	1(+)
		Deileptenia ribeata (Clerck)	−0.13	0.13	0.38	1(+)

Table 3. Continued

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
		Ectropis excellens (Butler)	1.52	2.66	3.81	21(+)
		Fascellina chromataria Walker	−0.13	0.13	0.38	1(+)
		Gandaritis fixseni (Bremer)	−0.13	0.13	0.38	1(+)
		Menophra harutai (Inoue)	4.05	5.70	7.35	45(++)
		M. senilis (Butler)	−0.10	0.25	0.61	2(+)
		Odontopera arida (Butler)	−0.13	0.13	0.38	1(+)
		Ourapteryx maculicaudaria (Motschulsky)	0.65	1.52	2.39	12(+)
		O. persica Menetries	−0.06	0.38	0.82	3(+)
		Pareclipsis gracilis (Butler)	−0.13	0.33	0.38	1(+)
		Phthonosema invenustaria (Leech)	−0.13	0.33	0.38	1(+)
		Problepsis minuta Inoue	−0.06	0.38	0.82	3(+)
		Scopula superciliata (Prout)	−0.10	0.25	0.61	2(+)
		Thinopteryx crocoptera (Kollar)	−0.10	0.25	0.61	2(+)
Bombycoidea	Lasiocampidae	*Dendrolimus spectabilis* (Butler)	−0.13	0.13	0.38	1(+)
		Paralebeda plagiata (Menetries)	0.07	0.63	1.20	5(+)
	Bombycidae	*Bombyx mandarina* (Moore)	1.22	2.28	3.34	18(+)
Sphingoidea	Sphingidae	*Agrius convolvuli* (Linne)	−0.13	0.13	0.38	1(+)
		Ampelophaga rubiginosa Bremer et Grey	−0.13	0.13	0.38	1(+)
		Aspledon himachala (Butler)	−0.10	0.25	0.61	2(+)
		Callambulyx tatarinovii (Bremer et Grey)	−0.01	0.25	0.61	2(+)
		Clanis bilineata (Walker)	−0.13	0.13	0.38	1(+)
		Dolbina tancrei Staudinger	0.00	0.51	1.01	4(+)
		Marumba gaschkewitschii (Bremer et Grey)	−0.10	0.25	0.61	2(+)
		M. spectabilis (Butler)	0.30	1.01	1.73	8(+)
		M. sperchius (Menetries)	−0.13	0.13	0.38	1(+)
		Rhagastis mongoliana (Butler)	−0.13	0.13	0.38	1(+)
		Theretra nessus (Drury)	0.65	1.52	2.39	12(+)
Notodontoidea	Notodontidae	*Phalera flavescens* (Bremer et Grey)	−0.13	0.13	0.38	1(+)
Noctuoidea	Lymantriidae	*Arctornis kumatai* Inoue	−0.13	0.13	0.38	1(+)
		Euproctis pulverea (Leech)	−0.13	0.13	0.38	1(+)
		Neocifuna eurydice (Butler)	1.92	3.17	4.42	25(++)
	Arctiidae	*Chionarctia nivea* (Menetries)	−0.10	0.25	0.61	2(+)
		Cyana hamata Walker	1.32	2.41	3.50	19(+)
		Miltochrista pulchera Butler	−0.13	0.13	0.38	1(+)
		Spilarctia seriatopunctata Motschulsky	3.72	5.32	6.92	42(++)
		Spilosoma imparilis (Butler)	−0.13	0.13	0.38	1(+)

Table 3. Continued

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
		S. lubricipeda (Linne)	−0.10	0.25	0.61	2(+)
		S. punctaria (Stoll)	−0.13	0.13	0.38	1(+)
	Noctuidae	*Aedia leucomelas* (Linne)	1.52	2.66	3.81	21(+)
		Amphipyra livida (Denis et Schiffermuller)	−0.06	0.38	0.82	3(+)
		Anomis mesogona (Walker)	1.02	2.03	3.03	16(+)
		Artena dotata (Fabricius)	−0.10	0.25	0.61	2(+)
		Atrachea nitens (Butler)	−0.10	0.25	0.61	2(+)
		Axylia putris (Linne)	1.82	3.04	4.26	24(+)
		Chrysodeixis eriosoma (Doubleday)	−0.10	0.25	0.61	2(+)
		Chrysorithrum amatum (Bremer et Grey)	−0.13	0.13	0.38	1(+)
		Craniophora ligustri (Denis et Schiffermuller)	−0.13	0.13	0.38	1(+)
		Ercheia niveostrigata Warren	5.05	6.84	8.64	54(++)
		Erygia apicalis Guenee	−0.10	0.25	0.61	2(+)
		Helicoverpa armigera (Hubner)	−0.13	0.13	0.38	1(+)
		Hypena amica (Butler)	3.40	4.94	6.49	39(++)
		Hypopyra vespertilio Fabricius	−0.13	0.13	0.38	1(+)
		Lagoptera juno (Dalman)	−0.06	0.38	0.82	3(+)
		Lygephila maxima (Bremer)	2.44	3.80	5.16	30(++)
		Mamestra brassicae (Linne)	−0.13	0.13	0.38	1(+)
		Mecodina cineracea (Butler)	−0.10	0.25	0.61	2(+)
		M. nubiferalis (Leech)	−0.13	0.13	0.38	1(+)
		Metopta rectifasciata (Menetries)	0.00	0.51	1.01	4(+)
		Mythimna turca (Linne)	−0.06	0.38	0.82	3(+)
		Oraesia excavata (Butler)	2.55	3.93	5.31	31(++)
		Orthogonia sera Felder et Felder	−0.13	0.13	0.38	1(+)
		Pangrapta trimantesalis (Walker)	2.02	3.30	4.57	26(++)
		Phytometra amata (Butler)	−0.13	0.13	0.38	1(+)
		Pseudoips fagana (Fabricius)	−0.13	0.13	0.38	1(+)
		P. sylpha (Butler)	−0.13	0.13	0.38	1(+)
		Simplicia niphona (Butler)	4.49	6.21	7.93	49(++)
		Spirama helicina (Hubner)	0.07	0.63	1.20	5(+)
		S. retorta (Clerck)	0.14	0.76	1.38	6(+)
		Xestia stupenda (Butler)	0.83	1.77	2.71	14(+)
		Xylena formosa (Butler)	0.00	0.51	1.01	4(+)
TOTAL	S = 89	Mean=8.87	0.37		1.87	

* Relative abundance.

mon (18.3%), and the remaining forty seven species rare (66.2 %). Unlike other regions, the species of Geometridae outnumbered the Noctuidae, which was deemed to be attributable to tangerine orchards occupying the southern and western region in Gotjawal terrain that favorably influenced the distribution of Geometridae. Geometridae has been reported as harmful insects, which have a host plant such as *Quercus serrata* and *Rubus crataegifolius* among the wild plants, and *Citus unshiu* and *Brassica fruticosa* among the cultivated plants (Kim and Beljaev 2001).

Forty-seven individuals of *Bombyx mandarina* were collected. The appearance of *Bombyx mandarina* seemed to have had a close connection with the flora in this area where a large community of *Morus alba* exists. It has been reported that *Morus alba*, *Broussonetia papyrifera*, *Diospyros kaki*, and *Quercus variabilis* were the host plants of this species (Park and Kwon 2001).

Species Composition of Aewol Gotjawa Terrain

The Lepidoptera inhabiting in Aewol Gotjawal Terrain were found to have totaled 89 species, 12 families and 7 superfamilies (Table 4). Noctuidae had the largest number of species with 32 (36.0%), followed by Geometridae (21.3%), Sphingidae (12.4%), Pyralidae (9.0%), Arctiidae (7.9%), Lymantriidae (3.4%), Drepanidae (2.2%), Thyatiridae (2.2%), Lasiocampidae (2.2%), Limacodidae (1.1%), Bombycidae (1.1%) and Notodontidae (1.1%) and Agaristidae (1.1 %). As shown in Table 4, twelve species were regarded to be abundant, corresponding to 13.5% of the total species number and the remaining seventy seven species were common (86.5).

Total 11 species of Sphingidae, more than any place else, were collected. Particularly, 2 individuals of *Aspledon himachala* and *Callambulyx tatarinovii*, respectively, and a single individual of *Marumba sperchius* were only found in this area, which was deemed

Table 4. Frequency and relative abundance of the insects collected from Gujwa-Sungsan Gotjawal Terrain

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
Pyraloidea	Pyralidae	*Botyodes principalis* Leech	−0.23	0.23	0.70	1(+)
		Cirrhochrista brizoalis (Walker)	−0.23	0.23	0.70	1(+)
		Goniorhynchus butyrosa (Butler)	1.72	3.49	5.26	15(+)
		Herpetogramma luctuosalis (Guenee)	−0.23	0.23	0.70	1(+)
		Hymenia recurvalis (Fabricius)	−0.11	0.70	1.50	3(+)
		Palpita nigropunctalis (Bremer)	2.62	4.65	6.68	20(+)
		Tamraca torridalis (Lederer)	−0.23	0.23	0.70	1(+)
Geometroidea	Drepanidae	*Oreta pulchripes* Butler	−0.23	0.23	0.70	1(+)
	Geometridae	*Abraxas niphonibia* Wehrli	−0.23	0.23	0.70	1(+)
		Agathia carissima Butler	−0.23	0.23	0.70	1(+)
		Amraica superans (Butler)	−0.23	0.23	0.70	1(+)
		Chiasmia defixaria (Walker)	0.00	0.93	1.86	4(+)
		Comibaena procumbaria (Pryer)	−0.23	0.23	0.70	1(+)
		Comostola subtiliaria (Bremer)	−0.19	0.47	1.12	2(+)
		Deileptenia ribeata (Clerck)	−0.23	0.23	0.70	1(+)
		Ectropis excellens (Butler)	3.94	6.28	8.62	27(++)
		Evecliptopera decurrens (Moore)	−0.23	0.23	0.70	1(+)
		Fascellina chromataria Walker	2.80	4.88	6.96	21(++)
		Gandaritis fixseni (Bremer)	−0.23	0.23	0.70	1(+)
		Heterolocha aristonaria (Walker)	−0.23	0.23	0.70	1(+)
		Menophra harutai (Inoue)	2.44	4.42	6.40	19(+)
		Odontopera arida (Butler)	3.75	6.05	8.35	26(++)

Table 4. Continued

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
		Tephrina vapulata (Butler)	−0.23	0.23	0.70	1(+)
Bombycoidea	Lasiocampidae	*Dendrolimus spectabilis* (Butler)	−0.23	0.23	0.70	1(+)
		D. superans (Butler)	−0.23	0.23	0.70	1(+)
	Bombycidae	*Bombyx mandarina* (Moore)	−0.19	0.47	1.12	2(+)
Sphingoidea	Sphingidae	*Agrius convolvuli* (Linne)	−0.11	0.70	1.50	3(+)
		Ampelophaga rubiginosa Bremer et Grey	−0.23	0.23	0.70	1(+)
		Clanis bilineata (Walker)	−0.23	0.23	0.70	1(+)
		Dolbina tancrei Staudinger	−0.23	0.23	0.70	1(+)
		Marumba gaschkewitschii (Bremer et Grey)	−0.19	0.47	1.12	2(+)
		Rhagastis mongoliana (Butler)	−0.23	0.23	0.70	1(+)
		Theretra japonica (Boisduval)	−0.23	0.23	0.70	1(+)
		T. nessus (Drury)	0.00	0.93	1.86	4(+)
Notodontoidea	Notodontidae	*Lophocosma atriplaga* (Staudinger)	−0.23	0.23	0.70	1(+)
Noctuoidea	Lymantriidae	*Euproctis subflava* (Bremer)	−0.23	0.23	0.70	1(+)
	Arctiidae	*Chionarctia nivea* (Menetries)	1.90	3.72	5.55	16(+)
		Cyana hamata Walker	−0.19	0.47	1.12	2(+)
		Rhyparioides metelkana (Lederer)	−0.19	0.47	1.12	2(+)
		Spilarctia seriatopunctata Motschulsky	6.90	9.77	12.63	42(++)
		Spilosoma lubricipeda (Linne)	−0.23	0.23	0.70	1(+)
		Stigmatophora flava (Bremer et Grey)	0.00	0.93	1.86	4(+)
	Noctuidae	*Aedia leucomelas* (Linne)	−0.23	0.23	0.70	1(+)
		Amphipyra livida (Denis et Schiffermuller)	0.13	1.16	2.20	5(+)
		Anomis mesogona (Walker)	−0.23	0.23	0.70	1(+)
		Brevipecten consanguis Leech	−0.23	0.23	0.70	1(+)
		Chrysodeixis eriosoma (Doubleday)	−0.19	0.47	1.12	2(+)
		Ercheia niveostrigata Warren	4.71	7.21	9.70	31(++)
		Helicoverpa armigera (Hubner)	−0.19	0.47	1.12	2(+)
		Hypena amica (Butler)	3.75	6.05	8.35	26(++)
		Hypopyra vespertilio Fabricius	−0.23	0.23	0.70	1(+)
		Lagoptera juno (Dalman)	0.00	0.93	1.86	4(+)
		Lygephila maxima (Bremer)	2.44	4.42	6.40	19(+)
		L. recta (Bremer)	−0.23	0.23	0.70	1(+)
		Mamestra brassicae (Linne)	1.90	3.72	5.55	16(+)
		Mecodina cineracea (Butler)	−0.23	0.23	0.70	1(+)

Table 4. Continued

Superfamily	Family	Scientific name	Relative percentage			Frequency (R.A.*)
			L. Limit	Observed	U. Limit	
		M. nubiferalis (Leech)	−0.23	0.23	0.70	1(+)
		Metopta rectifasciata (Menetries)	0.26	1.40	2.53	6(+)
		Mocis ancilla (Warren)	−0.23	0.23	0.70	1(+)
		Oraesia excavata (Butler)	−0.19	0.47	1.12	2(+)
		Pangrapta costinotata (Butler)	−0.23	0.23	0.70	1(+)
		P. trimantesalis (Walker)	−0.11	0.70	1.50	3(+)
		Simplicia niphona (Butler)	3.75	6.05	8.35	26(++)
		Spirama helicina (Hubner)	0.13	1.16	2.20	5(+)
		S. retorta (Clerck)	0.56	1.86	3.16	8(+)
		Spodoptera litura (Fabricius)	−0.23	0.23	0.70	1(+)
		Xestia stupenda (Butler)	3.37	5.58	7.80	24(++)
		Xylena formosa (Butler)	−0.11	0.70	1.50	3(+)
TOTAL	S = 68	Mean=6.32	0.31		2.63	

* Relative abundance

to be attributable to the community of *Quercus serrata* distributed in the area that favorably influenced the distribution of Sphingidae. This result seemed to reflect that the dispersed existence of *Quercus acutissima*, *Ulmus davidiana*, and *Euonymus sieboldianus*, which were reported as the host plants of Sphingidae (Park 2000).

Species Composition of Gujwa-Sungsan Gotjawal Terrain

The Lepidoptera inhabiting in Gujwa-Sungsan Gotjawal Terrain were found to have totaled 68 species, 10 families and 6 superfamilies, which break down as follows (Table 5). Noctuidae had the largest number of species with 26 (38.2%), followed by Geometridae (22.1%), Sphingidae (11.8%), Pyralidae (10.3%), Arctiidae (8.8%), Lasiocampidae (2.9%), Drepanidae (1.5%), Bombycidae (1.5%), Notodontidae (1.5%), and Lymantriidae (1.5%). As shown in Table 5, eight species were regarded to be abundant, corresponding to 11.8% of the total species number and the remaining sixty species were common (88.2%).

A density of species appeared to be lower than other area, which deemed to be attributable to narrow land with larger cultivation area. However, *Metopta rectifasciata*, *Spirama helicina* and *Spirama retorta* appeared to have outnumbered the species in other area. Such a result was believed to be attributable to the *Albizzia julibrissin*, which was broadly distributed in the area as the host plant of the larva. The larva has been reported, which have a host plant such as *Albizzia julibrissin* (Shin 2001).

Diversity of Species

Shannon index (H'), which is based on information theory (Shannon and Weaver 1949), is the most widely used index in synecology. Species diversity index of the lepidopterous community for each Gotjawal terrain is illustrated in Fig. 3.

When it comes to species diversity index, Aewol Gotjawal indicated the highest figure, while Hangyeong-Andeog Gotjawal showed

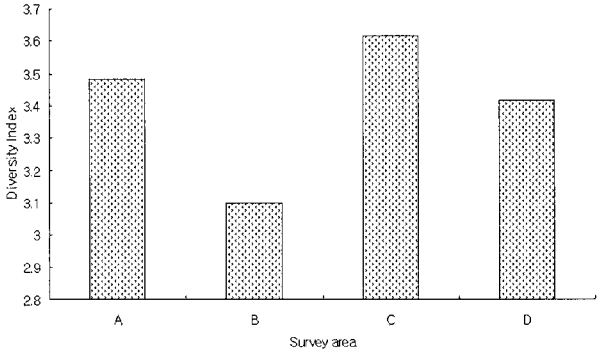

Fig. 3. Diversity indices of the surveyed areas. The abbreviation of the abscissa are same as represented in Fig. 1.

the lowest index. This appeared to have been caused by the fact that Aewol Gotjawal had abundance in 12 species including *Goniorhynchus butyrosa*, *Ercheia niveostrigata*, *Simplicia niphona*, *Menophra harutai* and *Spilarctia seriatopunctata*, despite of smaller number of individuals, while the abundance of *Ercheia niveostrigata* and *Spilarctia seriatopunctata*, among the 11 dominant species, was superior to other species in Hangyeong-Andeog Gotjawal Terrain. Remaining 2 Gotjawals showed a similar diversity level. Though the largest number totaled as many as 90 species were collected in Jocheon-Hamdeog Gotjawal, a diversity index was relatively lower because of the abundance of *Ercheia niveostrigata*, among the 15 dominant species, was too high. On the contrary, Gujwa-Sungsan Gotjawal, where the smallest number of species totaled 68 was collected, indicated higher figures due to relatively smaller number of 8 dominant species.

Clustering Analysis

The pattern of clustering for the four locations (communities) was summarized in the dendrogram in Fig. 4. The four communities formed a single cluster at the distance level of 0.39. This results disclosed that the four Gotjawal Terrains have ecological environment not so different from each other. Aewol Gotjawal (C) formed a cluster with Gujwa-Sungsan Gotjawal (D) at the lowest chord distance (0.75). Referring to Table 4 and 5, it can be seen that the two terrains were not only dominated by *Palpita nigropunctalis*, *Ercheia niveostrigata* and *Simplicia niphona* but also had the 48 common species. At the higher chord distance of 0.82, Jocheon-Hamdeog Gotjawal (A) fused the cluster of Aewol Gotjawal and Gujwa-Sungsan Gotjawal. The common species were numbered 37 in all three communities.

Finally, Hangyeong-Andeog Gotjawal (B) fused with the rest three terrains, forming a single cluster at the highest chord distance of 0.89. This was resulted from the fact that the diversity of species was comparatively low as well as only 27 species were collected commonly in this area.

The results obtained here did not coincide with the results of Yang et al. (2006), who have analyzed the communities of the same areas with the insect samples. The insect samples were collected by the same method but the lepidopterans were excluded. This deviation seemed to be derived from the qualitative difference of the samples, which were collected by same method at the same areas. The moth community (the species composition and the individual number) appeared to be mostly affected by the vegetational condition. Yang et al. (2006) reported that the species composition and the individual number of the insect community excluded lepidopterans were affected by the environmental conditions around Gotjawal, that is, pasture, agricultural land, or ponds, etc. Accordingly, it is very important thing to obtain representative sample for analysis of community.

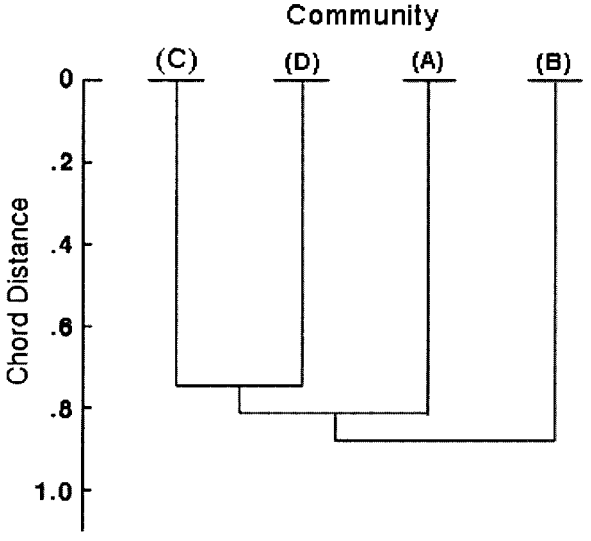

Fig. 4. Dendrogram for the cluster analysis of four Gotjawal terrains of Jeju Island using chord distance and the flexible strategy. The abbreviations of the communities are same as represented in Fig.1.

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