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An Approach to Environmental Evaluation using Binary Data of the Butterfly Community on Environment Preservation Areas and Natural Parks in Kagawa Prefecture

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香川県の環境保全地域と自然公園におけるチョウ類のバイナリーデータを用いた環境評価の試み　中村寛志（信州大学農学部）

本研究はチョウ類群集の存在・不在２元データ（binary data）を利用して，クラスター分析と数量化Ⅳ類による環境評価を試みたものである．香川県にある９つの環境保全地域，１つの町立森林公園および県立自然公園内の３地域で，1992年から1996年の間に採集と目視による調査を行い，生息チョウ類の目録が作成された．調査した13地域で確認できたチョウ類は，８科74種であった．調査地域の平均標高および面積と種数との間には明瞭な相関関係は見られなかった．目録は存在・不在の２元データなので，SørensenのCs係数を１から減じた 1-Cs 係数と不一致係数（いずれか一方の地域で確認された種数／全調査地域で確認された種数）を，種構成の重複度を表す非類似度行列として多変量解析をおこなった．クラスター分析と数量化Ⅳ類のいずれの手法でも，13の調査地域は３つのグループに分類することができ，グループの構成地域もほぼ同じ結果であった．調査地域の植生と多変量解析による分類結果を比較して，本評価手法の妥当性を検討した．

An approach to evaluate the environment using cluster analysis and quantification theory type Ⅳbased on the binary data of a butterfly community was tried. The investigation to make an inventory of butterflies was done at 9 environment preservation areas, one forest park, and 3 survey areas in the natural parks in Kagawa Prefecture from 1992 to 1996 by collecting and observation methods. The number of butterfly species found in this investigation was 74 species belonging to 8 families. The number of species found in each survey area was not related to either the altitude or the area. The Sørensen coefficient (Cs) and disagreement coefficient (the number of species found in either area)／(the number of all species found in 13 survey areas) was used to compare the community composition between 2 areas by the number of species. Thirteen survey areas were classified into three groups by cluster analysis using the dissimilarity matrix of the 1-Cs coefficient and disagreement coefficient. The grouping by quantification theory type Ⅳ agreed with the result of cluster analysis. The validity of application of these multivariate analyses for the structural analysis of butterfly communities is discussed by comparing with the grouping from the flora of survey areas.

Key words : Environmental evaluation, Butterfly community, Binary data, Cluster analysis, Quantification theory type Ⅳ, Kagawa Prefecture

Introduction

Studies on environmental evaluation by the community structure of insects, especially butterflies, have often been tried (Tashita & Ichimura, 1997 ; Yoshida, 1997). In such research, insect communities are analyzed by indexes that express species diversity (e. g. λ of Simpson (1949)) and similarity, the degree of overlap of the species composition (e. g. α of Pianka (1973)). Also, the index added to the evaluation value of species such as the existence ratio of the environmental stage (ER) (Tanaka, 1988) was developed. Recently, Hori *et al.* (1994) analyzed the environmental structure using cluster analysis of a ground beetle community.

The natural environment in Kagawa Prefecture has been so rapidly developed since the 1970's that the fauna and flora have become poor. However, there have been few studies to try environmental evaluation from the changes of such insect fauna in Kagawa Prefecture. One of the causes was that quantitative data on changes of insect fauna were not accumulated. And so Nakamura *et al.* (1995, 1999) proposed on RI index to deal with the ordinal scale data and tried to evaluate the environment in Kagawa Prefecture based on the unquantitative data of butterfly communities.

This investigation was done as a survey project for the preservation area of the natural environment and a fundamental survey for the display plan at the Natural Park Center in Kagawa Prefecture. The purpose of these investigations was to make an inventory of insects, so that the scale of data was binary, that is, existence or absence. Therefore, the above-mentioned analysis methods based on the quantitative data can not be used in this study.

However, there are some indexes which reflect the similarity in species between two habitats using qualitative investigation data such as the inventory of the inhabitant species. The Czekanowski or Sørensen Cs coefficient (Sørensen, 1948 ; Southwood, 1978) and the Nomura and Simpson index (NSC) show the degree of overlap of the species composition (Kimoto and Takeda, 1989). In this study, the author analyzed 13 butterfly communities in Kagawa Prefecture using only the binary data of existence or absence. Based on a (dis) similarity matrix calculated from the 1-Cs coefficient and disagreement coefficient (Fujisawa, 1985), cluster analysis and quantification theory type Ⅳ were used.

Survey areas and methods

Survey areas

This investigation was done out at 9 environment preservation areas, one forest park, and 3 survey areas in the natural park (13 areas in all). In Kagawa Prefecture, preservation areas of 4 natural environments and 5 green environments were designated based on "the regulation about the preservation of the natural environment and the promotion of planting trees". The environments consisted of the characteristic ecosystem of animals and plants have been preserved there.

・ The forest park was designated by Ayauta Town. Ohtaki-Ohkawa Prefectural Natural Park is situated in the center of the Sanuki mountains, on the border with Tokushima Prefecture, and its area is 2363 ha. In this natural park, the *Fagus crenata* forest on Mt. Ohtaki, the *Carpinus tschonoskii* forest on Mt. Ohkawa, and the mountaintop of Mt. Ryuou, which is the highest peak in Kagawa Prefecture, were chosen as the survey areas.

Table 1 shows the name, code name, the area, the

Table 1 Overview of survey areas and survey year

Code name	Name	Area / Altitude / Survey year[1)] / Vegetation
A	Iyadaniyama	33.96 ha 140-381.5 m 1992 (2), 1993 (1) Forest of Iyadani temple, Shikoku sacred place No. 71 Evergreen broadleaf trees (*Quercus glauca* Thumb, *Quercus salicina* Blume), deciduous trees (*Carpinus tschonoskii* Maxin)
B	Shippouzan	50.98 ha 120-389.8 m 1992 (3) Fudo fall *Pinus densiflora* Sieb. et Zucc. and deciduous trees (*Quercus acutissima* Carr., *Quercus variabilis* Blume)
C	Fujiosan	37.27 ha 80-166 m 1993 (9) Forest of Fujio shrine Evergreen broadleaf trees (mainly *Q. glauca, Castanopsis cuspidata* Schottky) and deciduous trees
D	Makawa	4.24 ha 50-100 m 1993 (8) Changing from *P. densiflora* trees to deciduous trees (*Q. variabilis, Quercus serrata* Thumb) and *Q. glauca* trees
E	Mizushi	4.41 ha 40-100 m 1994 (8) Forest of Mizushi shrine Evergreen broadleaf trees (*C. cuspidata, Lithocarpus glabra* Nakai) and afforested *Chamaecyparis obtusa* Endl trees
F	Nyotaisan	12.38 ha 430-702.5 m 1994 (8) Mountain located Ohkubo temple, Shikoku sacred place No. 88 *P. densiflora, Machilus japonica* Sieb. et Zucc., afforested *C. obtusa* and deciduous broadleaf trees
G	Ohminakami	6.51 ha 50-103 m 1995 (10) Forest of Ohminakami shrine Evergreen broadleaf trees (mainly *C. cuspidata, L. glabra*)
H	Komatsuoyama	2.99 ha 50-80 m 1995 (10) Forest of Komatsuo temple, Shikoku sacred place No. 68 Evergreen broadleaf trees (mainly *C. cuspidata, Q. glauca*)
I	Ohtakanbou	124.1 ha 200-504.1 m 1996 (7) Forest of Ohtakanbou shvine Changing from *P. densiflora* trees to *Q. serrata, Litsea coreana* H. Lev. and afforested *C. obtusa* trees
J	Ayauta	253 ha 100-468 m 1996 (8) Forest park of Ayauta Town *P. densiflora*, afforested *C. obtusa* and deciduous broadleaf trees (*Q. serrata*)
K	Ohtakisan	about 300 ha 480-946 m 1993 (11) Northern side of Mt. Ohtaki (946m) in prefectural natural park *Fagus crenata* Blume and *Zelkova serrata* Makino trees, *Q. salicina* and *Quercus acuta* Thunb. et Murray trees, afforested trees (*C. obtusa, Cryptomeria japonica D. Don*)
L	Ryuousan	about 90 ha 700-1060 m 1993 (6) Mountain top of Mt. Ryuou (1060 m) in prefectural natural park *F. crenata, C. tschonoskii* and *Alnus hirsuta* Turcz. trees, evergreen trees and afforested *C. obtusa* trees
M	Ohkawayama	18ha 950-1043m 1993 (4) Mountain top of Mt. Ohkawa (1043 m) in prefectural natural park Climax forest consisted of *C. tschonoskii* and *Acer Mono* Maxim.

1) Figure in parenthesis shows the number of survey in that year.

altitude, the overview of vegetation, and survey year for each survey area. Also, the positions of 13 survey areas in Kagawa Prefecture are shown in **Fig. 1.** Hereafter, the name of the survey area is expressed by the code name as shown in **Table 1.**

Investigation methods

This investigation was for the purpose of making an inventory of insects that inhabited in a survey area. Adults of butterflis in each area were surveyed several times per year from 1992 to 1996 by collecting and observation methods (**Table 1**).

Analysis methods

Methods to analyze the butterfly community are the following. First, a dissimilarity matrix among survey areas was made from the inventory of butterflies. Dissimilarity between two survey areas was expressed by the 1-Cs coefficient and disagreement coefficient. Then 13 butterfly communities were classified into groups by cluster analysis and quantification theory type Ⅳ based on this matrix.

1・Cs coefficient

The data of this investigation was binary data (presence or absence data) which showed whether a species inhabits in the area or not. So in this study, the Sørensen coefficient (Cs) (quotient of similarity QS) was used to compare the community composition between 2 areas by the number of species.

Assuming that S_A and S_B are the number of the species in A and B area respectively, and S_C is the number of species common to the two areas, the Cs coefficient is calculated by the following formula.

$$Cs = 2S_C/(S_A+S_B)$$

Where, the species compositions of 2 areas agree precisely for Cs = 1, and are completely different for Cs = 0. The value (1-Cs) subtracted Cs coefficient from 1 was used as a dissimilarity matrix for the

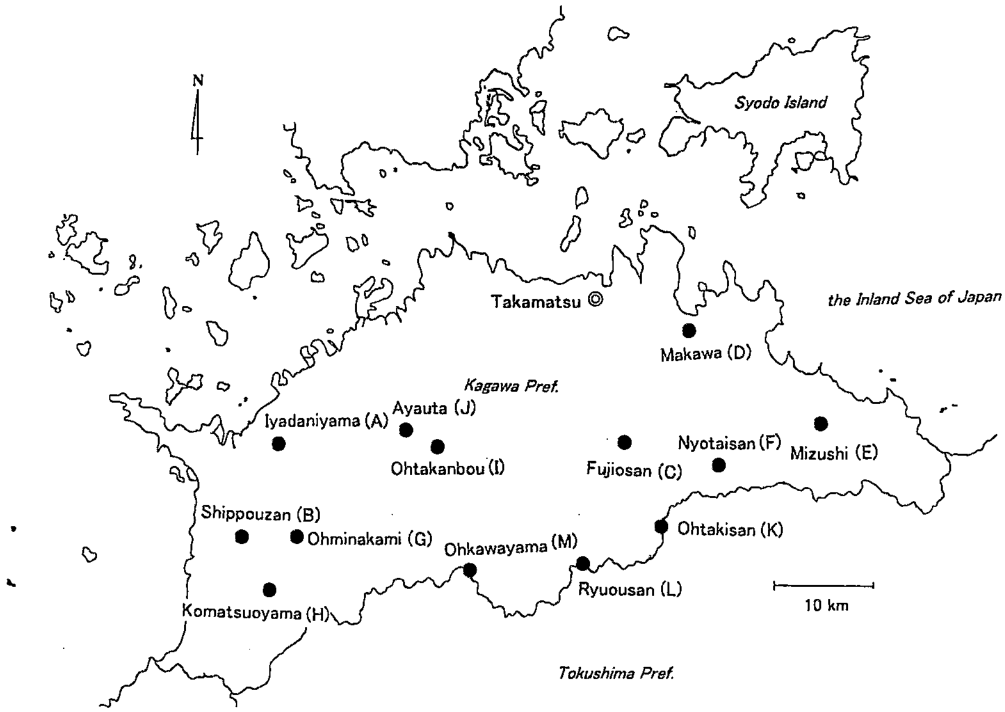


Fig. 1 Map of 13 survey areas in Kagawa Prefecture.

multivariate analysis.

Disagreement coefficient

This coefficient is often used to measure the similarity of preference by the questionnaire survey. The taste of two persons (A and B) was asked about the m kinds of foods. The disagreement coefficient is given "{the number of (○, ×) or (×, ○) combination}/m", where ○ and × show the answer of liking and disliking, respectively. Therefore, A and B precisely differ in the taste of the food on disagreement coefficient = 1, and the taste of two agrees precisely on disagreement coefficient = 0 .

Applying to the survey data of butterflies, the disagreement coefficient between two areas can be obtained by the following formula.

Disagreement coefficient = (the number of species found in either area)/(the number of investigated species)

Where, the number of investigated species is the number of all species found in 13 survey areas.

These coefficients obtained for each pair of areas were used as the dissimilarity matrix for cluster analysis and quantification theory type Ⅳ. The software of statistical analysis handbook for Win-multivariate analysis- Ver. 1. 01 (Kyoritsu publishing) was used for calculation. Also, the way of hierarchical cluster analysis was the Ward method.

Results

Species found in survey areas

The number of butterfly species found in this investigation was 74 species belonged to 8 families. The number of species in each family and its ratio are shown in **Table 2.** Half of the total species belonged to only 2 families, Nymphalidae (28.4 % of total species) and Lycaenidae (20.3 %), but the ratio of lycaenid species was lower at 3 survey areas in the prefectural natural park than other areas. On the other hand, the ratio of hesperiid and pierid species depended on the survey area. However, about the relative frequency of family size, there was no significant difference between any two areas (χ^2-test, $P > 0.543$).

The species that are characteristic of the butterfly fauna in Kagawa Prefecture are below. *Cyrestis thyodamas* Boisduval inhabited almost all survey areas and *Papilio memnon* Linnaeus and *Narathura japonica* (Murray) were found in a lot of areas. *Narathura bazalus* (Hewitson) was collected in the shrine precincts near the town. Also, *Celastrina albocaerulea* (Moore), *Tongeia fischeri* (Eversmann), and *Thymelicus sylvaticus* (Bremer), were uncommon species in Kagawa Prefecture. Especially, *C. albocaerulea* was first found in Kagawa Prefecture in 1995 (Nakamura, 1998).

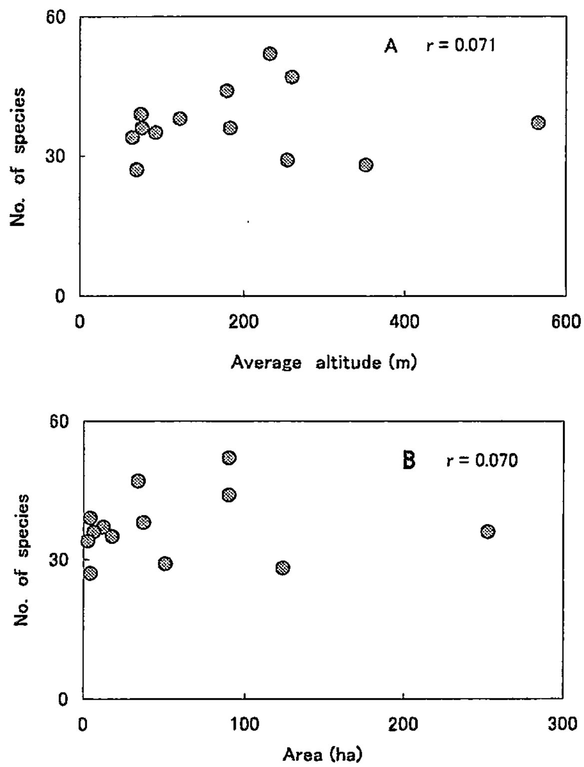


Fig. 2 Relationship between the number of species and the altitude (A) and the area (B).

Table 2 The number of butterfly species found in each survey area

Code name	Survey area		Hesperiidae	Papilionidae	Pieridae	Lycaenidae	Danaidae	Libytheidae	Nymphalidae	Satyridae	Total
A	Iyadaniyama	No. of species	4	7	5	11	0	1	13	6	47
		%	8.5	14.9	10.6	23.4	0.0	2.1	27.7	12.8	100
B	Shippouzan	No. of species	4	6	2	6	0	1	6	4	29
		%	13.8	20.7	6.9	20.7	0.0	3.4	20.7	13.8	100
C	Fujiosan	No. of species	3	9	3	7	0	1	9	6	38
		%	7.9	23.7	7.9	18.4	0.0	2.6	23.7	15.8	100
D	Makawa	No. of species	5	6	4	8	0	1	9	6	39
		%	12.8	15.4	10.3	20.5	0.0	2.6	23.1	15.4	100
E	Mizushi	No. of species	1	4	5	6	0	1	7	3	27
		%	3.7	14.8	18.5	22.2	0.0	3.7	25.9	11.1	100
F	Nyotaisan	No. of species	3	6	3	6	0	1	13	5	37
		%	8.1	16.2	8.1	16.2	0.0	2.7	35.1	13.5	100
G	Ohminakam	No. of species	2	6	5	8	0	1	8	6	36
		%	5.6	16.7	13.9	22.2	0.0	2.8	22.2	16.7	100
H	Komatsuoyama	No. of species	5	6	5	7	0	1	5	5	34
		%	14.7	17.6	14.7	20.6	0.0	2.9	14.7	14.7	100
I	Ohtakanbou	No. of species	2	5	4	5	0	1	7	4	28
		%	7.1	17.9	14.3	17.9	0.0	3.6	25.0	14.3	100
J	Ayauta	No. of species	3	6	5	9	0	1	8	4	36
		%	8.3	16.7	13.9	25.0	0.0	2.8	22.2	11.1	100
K	Ohtakisan	No. of species	6	9	5	6	1	1	18	6	52
		%	11.5	17.3	9.6	11.5	1.9	1.9	34.6	11.5	100
L	Ryuousan	No. of species	6	7	5	5	1	1	13	6	44
		%	13.6	15.9	11.4	11.4	2.3	2.3	29.5	13.6	100
M	Ohkawayama	No. of species	4	6	4	6	1	1	9	4	35
		%	11.4	17.1	11.4	17.1	2.9	2.9	25.7	11.4	100
	Total areas	No. of species	10	11	5	15	1	1	21	10	74
		%	13.5	14.9	6.8	20.3	1.4	1.4	28.4	13.5	100

Relation between the number of species, and the altitude and the area

Figure 2 shows the relationship between the number of species and the average altitude (**Fig. 2 A**) and between the number of species and the area (**Fig. 2 B**). The number of species found in each survey area was not related to either the altitude ($r = 0.071$) or the area ($r = 0.070$).

Comparison among survey areas by similarity index

The similarity of the butterfly community among survey areas is shown in **Table 3.** Cs coefficients in B and E were smaller. This showed that the composition of the butterfly community in these two areas was different from the other survey areas. On the other hand, the similarity of the butterfly communities at K, L, and M in the prefectural natural park was supposed to be high because Cs coefficients among these 3 areas was large. Also, Cs coefficient between A and D, D and G, F and I, and G and H showed a high value, more than 0.77.

The disagreement coefficient showed almost the same tendency in the large value of the Cs coefficient and also large disagreement coefficients of 3 areas in the prefectural natural park showed that the

Table 3 The similarity of butterfly communities among 13 survey areas. Values at the upper right half are disagreement coefficients and those of the lower left half are Cs coefficients

		A	B	C	D	E	F	G	H	I	J	K	L	M
A	Iyadaniyama		0.297	0.284	0.243	0.324	0.378	0.284	0.284	0.311	0.284	**0.446**	**0.419**	**0.432**
B	Shippouzan	0.711		0.284	0.270	0.351	0.378	0.311	0.284	0.257	0.311	**0.554**	**0.446**	0.378
C	Fujiosan	0.753	0.687		0.257	0.311	0.284	0.297	0.270	0.270	0.297	0.378	**0.405**	**0.446**
D	Makawa	**0.791**[1)]	0.706	0.753		0.324	0.351	**0.230**	**0.230**	0.284	0.284	**0.419**	0.338	0.351
E	Mizushi	0.676	**0.536**	0.646	0.636		0.270	0.311	0.257	**0.176**	0.257	**0.419**	**0.392**	0.324
F	Nyotaisan	0.667	**0.576**	0.720	0.658	0.688		0.365	0.365	**0.176**	0.284	0.311	0.284	0.297
G	Ohminakami	0.747	0.646	0.703	**0.773**	0.635	0.630		**0.216**	0.243	0.351	**0.459**	**0.405**	**0.392**
H	Komatsuoyama	0.741	0.667	0.722	0.767	0.689	0.620	**0.771**		0.270	0.270	**0.459**	0.378	0.365
I	Ohtakanbou	0.693	0.667	0.697	0.687	0.764	**0.800**	0.719	0.677		0.243	0.351	0.324	0.257
J	Ayauta	0.747	0.646	0.703	0.720	0.698	0.712	0.639	0.714	0.719		0.324	0.297	**0.230**
K	Ohtakisan	0.667	**0.494**	0.689	0.659	**0.608**	0.742	0.614	**0.605**	0.675	0.727		**0.135**	0.257
L	Ryuousan	0.659	**0.548**	0.634	0.699	**0.592**	0.741	0.625	0.641	0.667	0.725	**0.896**		**0.176**
M	Ohkawayama	**0.610**[2)]	**0.563**	**0.548**	0.649	0.613	0.694	**0.592**	**0.609**	0.698	0.761	**0.782**	**0.835**	

1) Bold figures with mesh indicate Cs coefficient more than 0.77 or disagreement coefficient less than 0.23.
2) Bold figures with double underline indicate Cs coefficient less than 0.61 or disagreement coefficient more than 0.38.

composition of these butterfly communities was different from the other areas.

Cluster analysis

Classification results of 13 survey areas by cluster analysis using 1-Cs coefficient and disagreement coefficient as the dissimilarity matrix are shown in **Fig. 3.** In the dendrogram used 1-Cs coefficient (Fig. 3 I), 13 survey areas were classified into three groups at dissimilarity = 0.4. The first group was composed of 3 areas (M, L, K) in the prefectural natural park, the second of 4 areas (J, I, F, E), and the third of the other 6 areas.

As for the dendrogram that used a disagreement coefficient (**Fig. 3** II), 13 survey areas were classified into three groups like the result of the 1-Cs coefficient at dissimilarity = 0.4, too. These three groups were composed of the same areas as **Fig. 3** I except for J.

Grouping by quantification theory type IV

Quantification theory type IV is an analysis method which composes eigenvector space of 13 survey areas based on the similarity of the species composition of butterflies. And so it is possible that survey areas are grouped together from the coordinates position on the scatter plot. 1-Cs coefficient, and the disagreement coefficient were used as a dissimilarity matrix of the species composition of butterflies as cluster analysis.

The eigenvalue from λ_1 of the 1st axis to λ_5 of the 5th axis and the eigenvector are shown in **Table 4** on the 1-Cs coefficient and disagreement coefficient. The eigenvalue below the 6th axis was near the constant. The cumulative variances to λ_5 in both cases were about 45%.

The components of the 1st axis and the 2nd axis of the eigenvector in **Table 4** were plotted in **Fig. 4.** The similarity of the species composition of butterfly at 13 survey areas was expressed on two-dimensional coordinates. In **Fig. 4** I on the 1-Cs coefficient, E and B were plotted at different positions from other areas. However, it was possible from the position of the coordinates to divide the 13 areas into three groups, that is, the first group composed of K, M, and L whose components of the first axis were less than -0.223, the second of F, I, J, and E having component values from -0.152 to -0.033, and the third of the other 6 areas having positive component values (**Table 4**). Although the

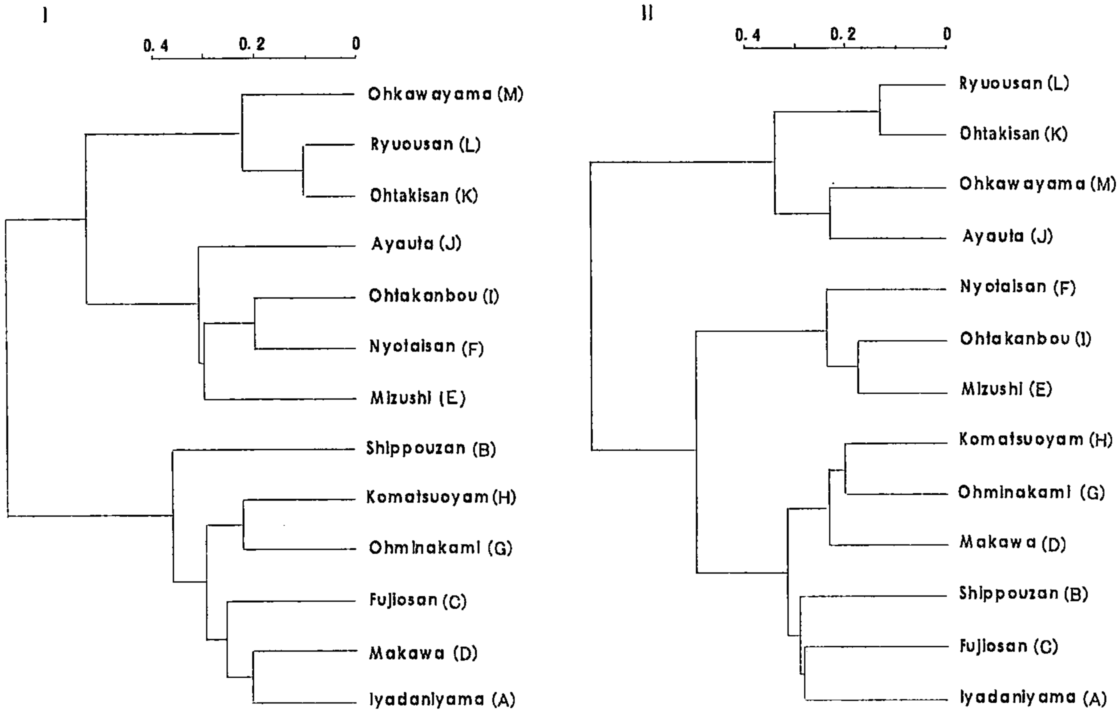
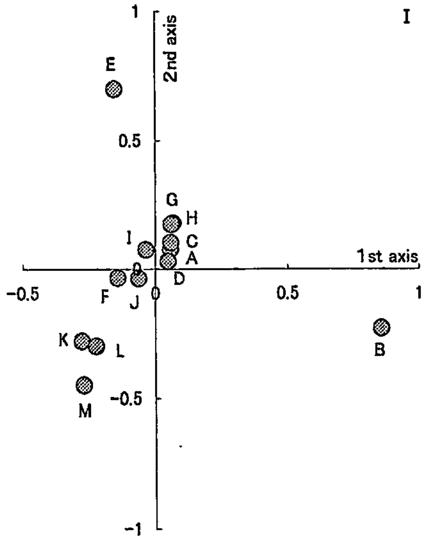


Fig. 3 Dendrogram of the clustering of 13 survey shown in areas by cluster analysis (the Ward method) on 1-Cs coefficient (I) and disagreement coefficient (II) as the dissimilarity matrix. Letter in parenthesis indicates code name of survey area shown in Table 1.

Table 4 Eigenvalue and eigenvector by quantification theory type IV using 1-Cs coefficient and disagreement coefficient as the dissimilarity matrix

		Components of eigenvector by 1-Cs coefficient					Components of eigenvector by disagreement coefficient				
		1st axis	2nd axis	3rd axis	4th axis	5th axis	1st axis	2nd axis	3rd axis	4th axis	5th axis
A	Iyadaniyama	0.058	0.077	0.165	-0.119	0.064	-0.215	0.413	-0.215	-0.318	-0.137
B	Shippouzan	0.858	-0.232	-0.321	0.010	-0.135	-0.348	-0.068	0.870	0.018	0.008
C	Fujiosan	0.059	0.102	0.254	-0.097	0.322	-0.129	0.239	-0.028	-0.159	0.453
D	Makawa	0.050	0.029	0.197	-0.117	0.054	-0.129	0.063	-0.057	0.158	0.057
E	Mizushi	-0.152	0.699	-0.582	-0.085	-0.193	-0.092	-0.076	-0.202	-0.254	-0.205
F	Nyotaisan	-0.140	-0.035	-0.048	0.569	0.303	0.054	-0.150	-0.123	-0.395	0.216
G	Ohminakami	0.068	0.180	0.484	0.448	-0.459	-0.198	0.141	-0.227	0.720	-0.131
H	Komatsuoyama	0.062	0.173	0.272	-0.486	0.288	-0.168	0.039	-0.117	0.189	-0.042
I	Ohtakanbou	-0.033	0.075	-0.049	0.311	0.121	-0.046	-0.062	-0.035	-0.067	-0.036
J	Ayauta	-0.061	-0.038	-0.024	-0.115	0.156	-0.005	-0.079	-0.039	-0.127	-0.081
K	Ohtakisan	-0.277	-0.281	0.009	-0.229	-0.501	0.759	0.491	0.252	0.055	-0.156
L	Ryuousan	-0.223	-0.299	-0.020	-0.166	-0.291	0.327	-0.408	-0.068	0.220	0.589
M	Ohkawayama	-0.270	-0.449	-0.337	0.075	0.273	0.189	-0.545	-0.009	-0.040	-0.534
	Eigenvalue	10.106	9.380	8.987	8.203	8.172	10.360	8.922	8.759	8.396	8.306
	Percent of variance	0.102	0.094	0.090	0.086	0.083	0.105	0.090	0.089	0.086	0.085
	Cumulative variance	0.102	0.196	0.287	0.372	0.455	0.105	0.195	0.283	0.370	0.454



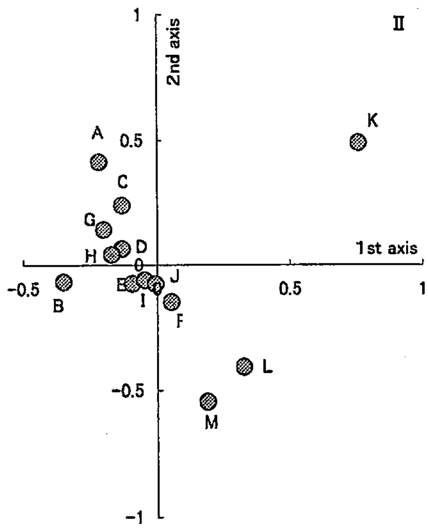


Fig. 4 Scatter plot of the components of the 1st and the 2nd axis of the eigenvector caluculated by quantification theory type Ⅳ on 1-Cs coefficient (I) and disagreement coefficient (Ⅱ) as the dissimilarity matrix. Letter with each plot indicates code name of survey area shown in Table 1.

coordinates positions of 13 survey areas in **Fig. 4** Ⅱ on disagreement coefficient were in the direction opposite to those in **Fig. 4** I , they were also divided into three groups composed of the entirely same areas.

Discussion

The number of species found in the investigation is influenced by survey efforts (time, area, and the number of surveys), and also biased by season or year. On the moth community in the same survey areas as in this study, there was a high correlation between the number of moth species and the number of light trap surveys ($r = 0.725$) (Nakamura and Masui, 1999). In this study, 13 survey areas differ in the number and year of survey (**Table 1**). However, the number of species in each area was not corrected in any way when comparing the butterfly communities of 13 areas for the following reasons. First, the number of species in each area was not related to the number of surveys (r=0.138) and area (r=0.070). Secondly, only about 90 butterfly species inhabit Kagawa Prefecture (Nakamura, 1998) and so it can be considered that there is a small effect of the differences on the number of surveys, if happened.

Cluster analysis has been often used as an available method of the classification of animal or plant community. Hori *et al.* (1994) on the ground beetle community and Nakamura (2000) on the moth community captured by light traps tried to analyze the environmental structure of investigation areas using cluster analysis. On the other hand, the method of quantification theory type Ⅳbased on the questionnaire investigation has been used to analyze the preference for food or to construct a concept structure in the fields of psychology and education. However, this method was seldom used for analysis of the community structure of animals or plants. In the following, the validity of application of cluster analysis and quantification theory type Ⅳ to the structural analysis of the butterfly community is considered.

Thirteen survey areas in this study are divided into three groups from the overview of their flora. It is the first group (B, D, F, I, J) that their trees are mainly composed of *Pinus densiflora,* and deciduous secondary (*Quercus acutissima* and *Quercus variabilis*) or afforested (*Chamaecyparis obtusa*) trees are mixed in these areas. Five environment preservation areas (A, C, E, G, H) belong to the 2nd group, the flora of which is mainly composed of evergreen broadleaf trees. Moreover, it is possible to classify into *Castanopsis cuspidata* forest (E, G, H) and *Quercus glauca* forest (A, C). Three survey areas in the prefectural park located in the Sanuki mountains belong to the 3rd group (K, L, M) which has many tree species including *F. crenata* and *Carpinus tschonoskii* trees at the mountaintop.

The altitude of the 3rd group is the highest (near 1000 m). Next, the altitude at F is more than 700 m. In the other area, the altitudes of 5 areas (I, B, A, C, J) are 100-500 m and those of the remainder 4 area are less than 100 m (**Table 1**).

The grouping from the flora and the altitude is compared with the classification by cluster analysis. Thirteen areas were divided into three groups by cluster analysis (**Fig. 3**) and quantification theory type IV (**Fig. 4**) using the dissimilarity of the butterfly community. One group was composed of the 3 highest altitude areas (K, L, and M), which was the same result grouped by the flora. Although G and H composed of *C. cuspidata* forest were classified into the very near group (**Fig. 3**), E of the same forest was classified into the group which was mainly composed of *P. densiflora.* On the other hand, B and D which were composed of *P. densiflora* trees were classified into the group of evergreen broadleaf forest.

Although the grouping of 3 ares (B, D, E) was different from the result by the flora, the classification in this study may reflect more or less the environmental condition of the survey area. The grouping by quantification theory type IV agreed with the result of cluster analysis. From these results, it may be possible to say that the differences in the butterfly community could be evaluated using these two analysis methods. It is considered that the same result would be obtained whether the 1-Cs coefficient or the disagreement coefficient is used as the dissimilarity index.

On the moth community, Nakamura (2000) evaluated 9 preservation areas (A, C, E, G, H, B, D, F, I) using cluster analysis based on the same similarity index. As a result, E and I were classified into one group, because the number of moth species in these 2 areas was fewer than the other areas. The number of butterfly species in E and I was also fewer than the others in this investigation. This result is more clearly expressed in the dendrogram of cluster analysis based on the disagreement coefficient (**Fig. 3 B**). This may be related to the properties of the disagreement coefficient. In this study, the denominator of the disagreement coefficient was defined as the number of all species which were found at the whole survey area. Therefore, the agreement data of (×, ×) increases among the areas of less abundance of species, so that the disagreement coefficient becomes smaller and consequently, E and I were classified into a very near group as expressed in the dendrogram in **Fig. 3 B.**

The coordinate axis of eigenvalue, especially λ_1 and λ_2, in quantification theory type IV should be given the ecological meaning about the butterfly community, and then the plotted data in scatter plot would be interpreted. Nakamura and Toshima (1999) reported in grouping of butterflies in Kagawa Prefecture that the coordinate axis of λ_1 and λ_2 in factor analysis would reflect the abundance and location of a species. In this study, the correlation coefficients between the number of species and the component of the 1st axis in each area were -0.382 on the 1-Cs coefficient and 0.616 on the disagreement coefficient. From this result, it may be said that the 1st axis of λ_1 is related to species abundance or species diversity in the survey area. However, in this study, the concrete meaning could not be given to the coordinate axis any longer.

There is a criticism that quantification theory type IV is not an objective analysis method because the subjectivity and knowledge of a researcher influences the result. However, this is an effective method to use binary data for the multivariate analysis. It will be necessary in the future to show a lot of analysis examples using quantification theory type IVand to examine the validity of their results.

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Appendix List of butterfly species found at each survey area. * indicates that the species found at the area.

Species	Family	Code name of the survey area													
		A	B	C	D	E	F	G	H	I	J	K	L	M	Total
Erynnis montanus (Bremer)	Hesperidae	*					*			*		*	*	*	6
Daimio tethys (Menetries)	Hesperidae			*	*		*		*		*	*	*	*	8
Choaspes benjaminii (Guerin-Meneville)	Hesperidae											*	*	*	3
Thymelicus sylvaticus (Bremer)	Hesperidae	*	*												2
Ochlodes ochraceus (Bremer)	Hesperidae							*				*	*		3
Thoressa varia (Murray)	Hesperidae				*				*		*	*	*	*	6
Isoteinon lamprospilus C. & R. Felder	Hesperidae				*										1
Potanthus flavum (Murray)	Hesperidae	*	*	*					*						4
Pelopidas mathias (Fabricius)	Hesperidae		*		*			*	*						4
Parnara guttata (Bremer & Grey)	Hesperidae	*	*	*	*	*	*		*	*	*	*	*		11
Parnassius glacialis Butler	Papilionidae													*	1
Byasa alcinous (Klug)	Papilionidae			*				*				*			3
Graphium sarpedon (Linnaeus)	Papilionidae	*	*	*	*			*	*	*	*	*	*	*	11
Papilio machaon Linnaeus	Papilionidae	*	*	*	*		*	*	*	*	*	*	*	*	12
Papilio xuthus Linnaeus	Papilionidae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Papilio helenus Linnaeus	Papilionidae	*		*	*	*	*			*	*	*			8
Papilio protenor Cramer	Papilionidae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Papilio macilentus Janson	Papilionidae			*			*					*	*		4
Papilio memnon Linnaeus	Papilionidae	*	*	*	*			*	*						6
Papilio bianor Cramer	Papilionidae	*	*	*		*	*		*		*	*	*	*	10
Papilio maackii Menetries	Papilionidae											*	*		2
Eurema hecabe (Linnaeus)	Pieridae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Colias erate (Esper)	Pieridae	*			*	*		*	*		*	*	*	*	9
Anthocharis scolymus Butler	Pieridae	*				*		*	*	*	*	*	*	*	9
Pieris rapae (Linnaeus)	Pieridae	*		*	*	*	*	*	*	*	*	*	*		11
Pieris melete (Menetries)	Pieridae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Narathura japonica (Murray)	Lycaenidae	*		*	*	*		*	*						6
Narathura bazalus (Hewitson)	Lycaenidae			*				*							2
Japonica lutea (Hewitson)	Lycaenidae	*		*			*		*		*				5
Antigius attilia (Bremer)	Lycaenidae	*			*										2
Rapala arata (Bremer)	Lycaenidae					*	*			*	*	*		*	6
Callophrys ferrea (Butler)	Lycaenidae	*									*	*	*	*	5
Lycaena phlaeas (Linnaeus)	Lycaenidae	*		*	*	*	*	*	*	*	*	*	*	*	12
Taraka hamada (H.Druce)	Lycaenidae	*													1
Lampides boeticus (Linnaeus)	Lycaenidae	*	*		*			*							4
Zizeeria maha (Kollar)	Lycaenidae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Celastrina argiolus (Linnaeus)	Lycaenidae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Celastrina albocaerulea (Moore)	Lycaenidae										*				1
Everes argiades (Pallas)	Lycaenidae	*	*		*			*	*		*				6
Tongeia fischeri (Eversmann)	Lycaenidae		*												1
Curetis acuta Moore	Lycaenidae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Parantica sita (Kollar)	Danaidae											*	*	*	3
Libythea celtis (Laicharting)	Libytheidae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Argynnis paphia (Linnaeus)	Nymphalidae						*	*	*	*		*	*	*	7
Nephargynnis anadyomene (C. & R. Felder)	Nymphalidae						*					*	*	*	4
Damore sagana (Doubleday)	Nymphalidae				*		*					*	*	*	5
Fabriciana adippe (Denis & Schiffermuller)	Nymphalidae						*					*	*		3
Argyreus hyperbius (Linnaeus)	Nymphalidae	*	*	*	*	*	*			*	*	*	*	*	11
Ladoga camilla (Linnaeus)	Nymphalidae	*	*	*	*	*	*	*		*	*	*	*	*	12
Neptis sappho (Pallas)	Nymphalidae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Neptis philyra Menetries	Nymphalidae											*			1
Neptis pryeri Butler	Nymphalidae	*	*												2
Araschnia burejana Bremer	Nymphalidae					*	*				*	*	*	*	6
Kaniska canace (Linnaeus)	Nymphalidae	*	*	*	*		*	*		*	*	*	*	*	11
Polygonia c-aureum (Linnaeus)	Nymphalidae	*				*	*	*	*	*		*			7
Polygonia c-album (Linnaeus)	Nymphalidae											*			1

Appendix List of butterfly species found at each survey area. * indicates that the species found at the area.

Species	Family	Code name of the survey area													
		A	B	C	D	E	F	G	H	I	J	K	L	M	Total
Nymphalis xanthomelas (Denis & Schiffermuller)	Nymphalidae	*			*							*	*	*	5
Cynthia cardui (Linnaeus)	Nymphalidae	*					*	*			*				4
Vanessa indica (Herbst)	Nymphalidae	*		*	*		*	*				*	*		7
Cyrestis thyodamas Boisduval	Nymphalidae	*		*	*	*	*	*	*	*		*	*		10
Dichorragia nesimachus (Doyere)	Nymphalidae			*								*			2
Apatura metis Freyer	Nymphalidae	*				*									2
Hestina japonica (C. & R.Felder)	Nymphalidae	*	*	*	*				*		*	*	*		8
Sasakia charonda (Hewitson)	Nymphalidae	*		*							*	*			4
Ypthima argus Butler	Satyridae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Minois dryas (Scopoli)	Satyridae						*								1
Lethe diana (Butler)	Satyridae	*	*	*	*		*	*		*	*	*	*	*	11
Lethe marginalis (Motschulsky)	Satyridae											*	*		2
Lethe sicelis (Hewitson)	Satyridae	*			*			*	*		*	*	*	*	8
Kirinia epaminondas (Staudinger)	Satyridae												*		1
Neope goschkevitshii (Menetries)	Satyridae	*	*	*	*		*	*	*	*					8
Mycalesis gotama Moore	Satyridae	*		*	*	*		*	*						6
Mycalesis francisca (Stoll)	Satyridae	*	*	*	*	*	*	*	*	*	*	*	*	*	13
Melanitis phedima (Cramer)	Satyridae			*								*			2
Total		47	29	38	39	27	37	36	34	28	36	52	44	35	