

# Systematic Studies on the Bagrid Catfish (Siluriformes: Bagridae) from Korea III. Multivariate Analysis of Osteological Characters

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The five species of family Bagridae in Korea were analyzed by numerical taxonomic method based on the twelve osteological characters of 110 cleared specimens. Family Bagridae of Korea was classified into genera *Pseudobagrus* and *Leiocassis*. Genus *Pseudobagrus* has *P. fulvidraco*, *Pseudobagrus* sp. and *P. brevicorpus*, and *Leiocassis* also has *L. nitidus* and *L. ussuriensis*. *P. brevicorpus* represented more closely relationships to *P. fulvidraco* rather than *Pseudobagrus* sp. in the morphological features of skeleton.

**KEY WORDS:** Systematics, Multivariate analysis, Bagridae

Family Bagridae living in south-western rivers of Korea has classified into 8 species and 5 genera based on the shape of the caudal fin and the length of body (Kim *et al.*, 1981). But Son (1987) transferred *Liobagrus andersoni* and *L. mediadiposalis* to family Amblycipitidae from family Bagridae. For that reason family Bagridae from Korea has described as 6 species and 4 genera. Lee (1988), however, identified into 6 species and 2 genera—*Pseudobagrus fulvidraco*, *Pseudobagrus* sp., *P. brevicorpus*, *Leiocassis nitidus*, *L. ussuriensis* and *L. longirostris*—based on the osteological characters and exomorphological features except the shape of the caudal fin used previously as the taxonomic characters.

The most taxonomic studies on the fishes were mainly description based on the exomorphological characters. Sneath and Sokal (1973), Wiley (1981) and Koh (1985, 1987), however, are utilizing various characters by numerical taxonomic method for systematic studies on the vertebrates.

In this paper, the systematic position and relationships of family Bagridae from Korea were made a review around osteological characters by numerical taxonomic method.

## Materials and Methods

### Materials

Specimens (Taylor, 1967; Dingerkus and Uhler, 1977) of one hundred and ten cleared specimens of family Bagridae from Korea were analyzed statistically. All scientific name of specimens, standard length, individual numbers, localities, rivers and date are as follows.

*Pseudobagrus fulvidraco*: 48.8-73.7 mm, 4 individuals, Kanggyöng, Namhan River, Jun. 20, 1984; 45.1-92.7 mm, 5 indiv., Kanggyöng, Küm R., Jul. 1, 1984; 22.3-39.0 mm, 11 indiv., Kunsan, Miryong Reservoir, Sept. 27, 1987; 58.9-141.0 mm, 5 indiv., Munsan, Imjin R., Dec. 20, 1987.

*Pseudobagrus* sp.: 40.3-101.0 mm, 5 indiv., Imshil, Sömjin R., May 30, 1981; 62.2-84.9 mm, 4 indiv., Nonsan, Küm R., Aug. 10, 1983; 35.9-97.0 mm, 6 indiv., Munsan, Imjin R., Apr. 20, 1985; 76.7-105.6 mm, 6 indiv., Yangpyöng, Namhan R., Dec. 30, 1987.

*Pseudobagrus brevicorpus*: 47.5-73.4 mm, 5 indiv., Hamyang, Naktong R., Jun. 9, 1985;

46.0-62.3 mm, 3 indiv., Hamyang, Naktong R., May 27, 1985; 50.8-74.0 mm, 7 indiv., Hamyang, Naktong R., Jul. 20, 1985; 38.2-105.4 mm, 8 indiv., Hamyang, Naktong R., Sept. 3, 1987.

*Leiocassis nitidus*: 88.4-89.2 mm, 5 indiv., Kanggyöng, Küm R., Jul. 1, 1984; 104.4-122.8 mm, 4 indiv., Kanggyöng, Küm R., Aug. 17, 1984; 88.4-140.7 mm, 5 indiv., Munsan, Imjin R., May 5, 1985; 82.4-131.5 mm, 6 indiv., Papyöng, Imjin R., Apr. 13, 1986; 105.0-153.4 mm, Munsan, Imjin R., Dec. 20, 1987.

*Leiocassis ussuriensis*: 80.9-126.6 mm, 4 indiv., Yangpyöng, Namhan R., Apr. 5, 1985; 91.4-144.9 mm, 4 indiv., Yangpyöng, Namhan R., Jul 2, 1985; 109.2-183.6 mm, 6 indiv., Yöju, Namhan R., Dec. 20, 1987.

### Characters

Analyses were based on 12 osteological characters as follows (Fig. 1): 1. length of skull, 2. width of supraethmoid, 3. width of lateral ethmoid, 4. width of frontal, 5. length of premaxilla, 6. length of prevomer, 7. length of

madibular, 8. length of supraoccipital process, 9. length of cleithrum process, 10. length of pectoral spine, 11. number of abdominal vertebrae, 12. number of ribs.

### OTU designation

Sufficiently many samples were available for analyses, and each species was grouped as Operational Taxonomic Units (OTU's).

In the phenetic analyses with the five species of the family Bagridae from Korea, OTU 1 is *Pseudobagrus fulvidraco*, OTU 2 *Leiocassis nitidus*, OTU 3 *L. ussuriensis*, OTU 4 *Pseudobagrus* sp., OTU 5 *P. brevicorpus*.

### Phenetic analysis.

All computations were made using the HP-3000 computer, Chungbuk University. Principal component analysis of 12 characters of 5 OTU's was carried out by PCAS program of Interactive statistical package program (ISP: Seal, 1964), discriminant function analysis was also accomplished by DISCRIM program of statistical package for the social science (SPSS: Nie *et al.*,

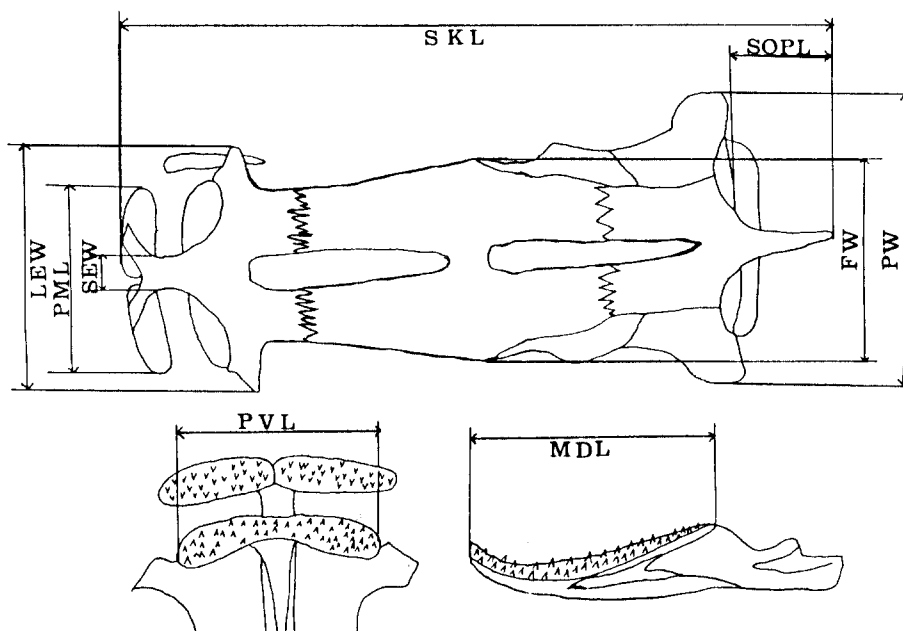


Fig. 1. Diagram showing the method of measuring skull part of the bagrid catfish. SKL, skull length; LEW, lateral ethmoid width; SEW, supraethmoid width; PML, premaxillary length; FW, frontal width; PW, posterior skull width; SOPL, supraoccipital process length; PVL, prevomer length; MDL, mandibular dental length.

1975) and phenogram was constructed with the average taxonomic distance matrix of 5 OTU's by UPGMA (Sneath and Sokal, 1973).

## Results

Two dimensional configuration from principal component analysis with 110 samples are shown in Fig. 2 and 3 (Arabic numerals indicate OTU numbers of each species). The correlations between original characters and the principal component are given in table 1 (factor I, II and III represented 50, 20 and 14 per cent of the variance, respectively). The first principal component axis scores of 110 samples from the 5 OTU's are summarized as a histogram (Fig. 4). The five OTU's were divided into two large groups in principal component analysis and first principal component axis scores (Fig. 2,3 and 4): OTU's 1, 4 and 5 (*Pseudobagrus fulvidraco*, *Pseudobagrus* sp. and *P. brevicorpus*); OTU's 2 and 3 (*Leiocassis nitidus* and *L. ussuriensis*).

The highest coefficients in the first axis were

shown in the width of supraethmoid, the width of lateral ethmoid, the length of premaxilla, the length of prevomer, the length of mandibular and the length of supraoccipital process, as shown in table 1.

The correlations between original characters and the canonical discriminant function are given in table 2 (function I, II and III represented 63.7, 26.4 and 6.7 percent of the variance, respectively).

The highest coefficients in the first axis were shown in the length of skull and the length of premaxilla, and those in the second axis were shown the length of skull and the width of frontal, as shown table 2.

In two dimensional configuration of discriminant analysis with twelve osteological characters, the five OTU's were divided into five groups, respectively (Fig. 5). These also were in accord with the result of classification of family Bagridae in Korea (Lee, 1988).

The five OTU's were divided into two large groups by UPGMA cluster analysis, as shown in Fig. 6 (1) OTU's 1, 4 and 5;(2) OTU's 2 and 3.

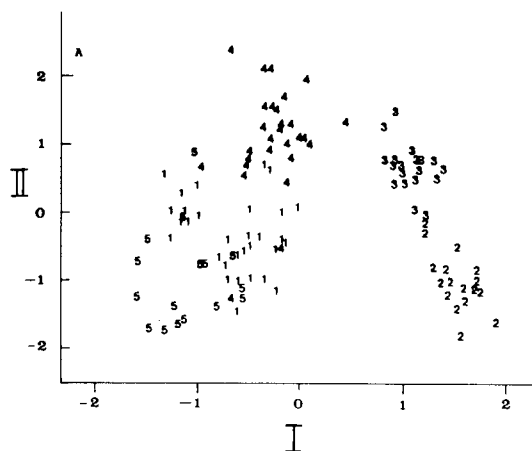


Fig. 2. Projection of 110 individuals of 5 OTU's of the family Bagridae based on principal component analysis in three dimension using 12 skeletal characters. Factor I, II and III represented 50, 20 and 14 percent of the variance, respectively. Numerals indicate the each species: 1, *Pseudobagrus fulvidraco*; 2, *Leiocassis nitidus*; 3, *L. ussuriensis*; 4, *Pseudobagrus* sp.; *P. brevicorpus*. A, ordination with factor I vs II. B, ordination with factor I vs III.

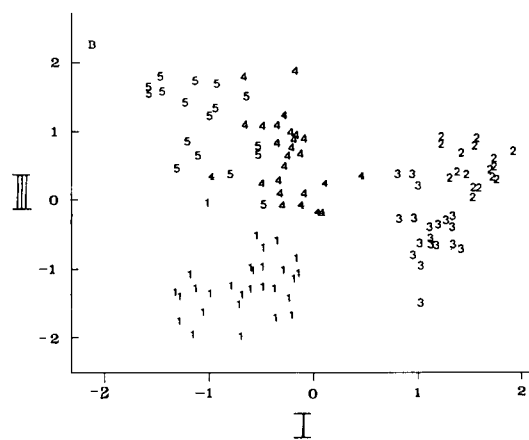


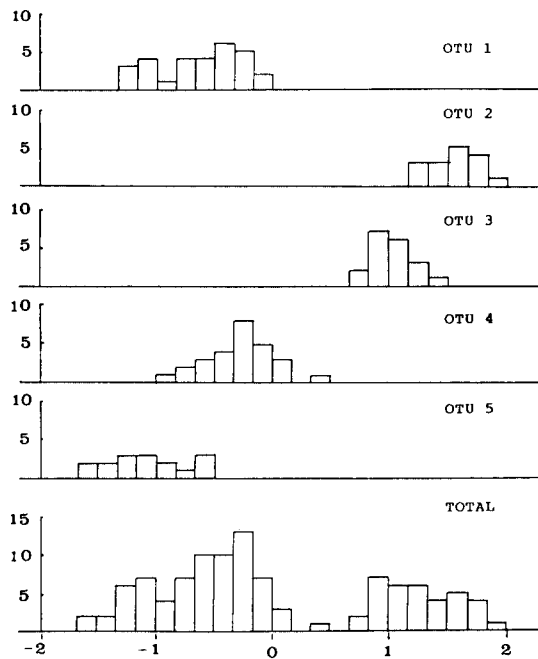
Fig. 3. Projection of 110 individuals of 5 OTU's of the family Bagridae based on principal component analysis in three dimension using 12 skeletal characters. Factor I, II and III represented 50, 20 and 14 percent of the variance, respectively. Numerals indicate the each species: 1, *Pseudobagrus fulvidraco*; 2, *Leiocassis nitidus*; 3, *L. ussuriensis*; 4, *Pseudobagrus* sp.; 5, *P. brevicorpus*. A, ordination with factor I vs II. B, ordination with factor I vs III.

**Table 1.** Principal components I, II and III expressed as correlations between characters and individual component from an analysis of five species of the family Bagridae. Individual measurement of 12 skeletal characters from 110 cleared specimens were used

Characters	Fac. I	Fac. II	Fac. III
SKL/SL	-0.12	-0.63	-0.60
SEW/SKL	-0.92	-0.20	-0.18
LEW/SKL	-0.94	0.05	0.01
FW/SKL	-0.73	-0.41	0.26
PML/SKL	-0.92	0.11	-0.26
PVL/SKL	-0.93	0.20	-0.16
MDL/SKL	-0.88	0.21	-0.29
SOPL/SKL	0.83	-0.34	0.04
CLL/SKL	-0.13	0.70	0.42
PSL/SKL	-0.20	0.96	0.34
No. of Abd. Vert.	0.53	0.54	-0.59
No. of Rbs	0.39	0.59	-0.65
% of trace	50%	20%	14%

**Table 2.** Canonical discriminant function I, II and III expressed as correlations between characters and individual function from an analysis of the family Bagridae from Korea. 12 skeletal characters from 110 cleared specimens were used

Characters	Func. I	Func. II	Func. III
SKL/SL	0.56	0.66	-0.18
SEW/SKL	0.35	0.32	-0.12
LEW/SKL	0.30	0.07	-0.18
FW/SKL	-0.14	-0.62	-0.06
PML/SKL	0.41	-0.29	0.17
PVL/SKL	0.31	0.09	0.14
MDL/SKL	-0.28	0.15	0.34
SOPL/SKL	-0.18	0.38	-0.46
CLL/SKL	-0.11	-0.06	0.22
PSL/SKL	-0.25	-0.21	0.03
No. of Abd. Vrt.	-0.16	0.20	0.08
No. of Rbs.	-0.16	0.48	0.54
% of trace	47.5%	31.3%	19.3%



**Fig. 4.** Frequency distribution of the first principal component axis scores of 110 samples from 5 OTU's of the family Bagridae. The species of OTU's 1, *Pseudobagrus fulvidraco*; 2, *Leiocassis nitidus*; 3, *L. ussuriensis*; 4, *Pseudobagrus* sp.; 5, *P. brevicarpus*.

## Discussion

In the analyses based on the osteological characters with the five species of family Bagridae of Korea, five OTU's were divided into two large groups (Fig. 2,3 and 4): (1) OTU's 1, 4 and 5; (2) OTU's 2 and 3. These were in accord with the results of the morphological analysis of their skeleton by Lee(1988), because OTU's 1, 4 and 5 belong to genus *Pseudobagrus* and OTU's 2 and 3, also genus *Leiocassis*.

Sneath and Sokal (1973) stated that the processes of numerical taxonomic include the decisions about the selections of organisms, taxonomic characters, similarity coefficients and clustering method, and that it is possible to obtain different results even if the same data. One of important questions in numerical taxonomic study is what the number of characters is required to obtain stable classification (Koh, 1987).

Clifford and Stephenson (1975) stated that principal component analysis make no assumption about the existence or otherwise of grouping among the entities, but analyses of family Bagridae from Korea were well divided into two large groups (Fig. 2,3 and 4). That is, in this

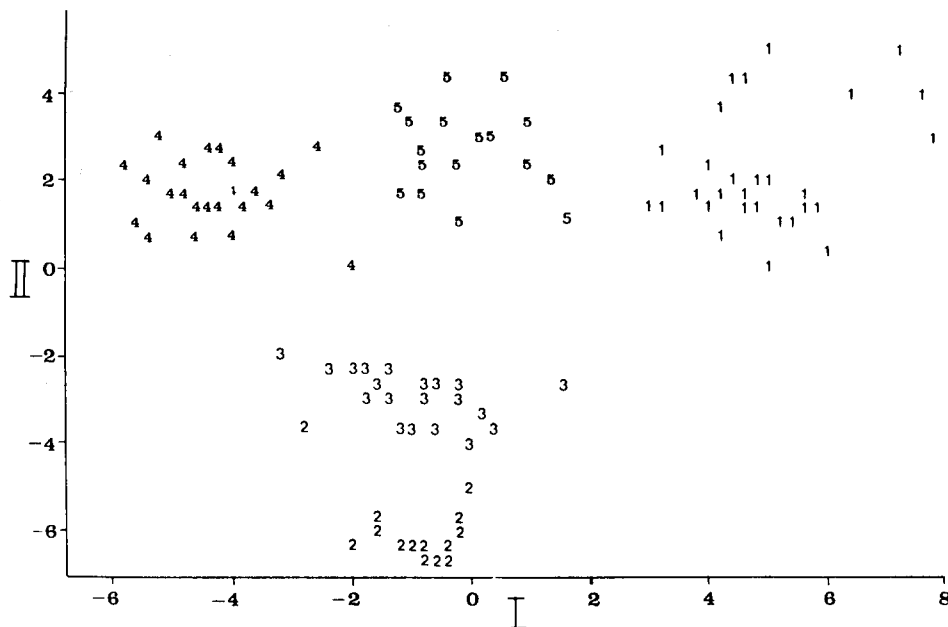


Fig. 5. Projection of 110 samples of family Bagridae based on discriminant analysis in three dimensions using individual of 12 skeletal characters grouped in to five OTU's. Function I, II and III represented 47.5, 31.3 and 19.3 percent of the variance, respectively. Numerals indicate the specimens of each species: 1, *P. fulvidraco*; 2, *L. nitidus*; 3, *L. ussuriensis*; 4, *Pseudobagrus* sp.; 5, *P. brevicorpus*.

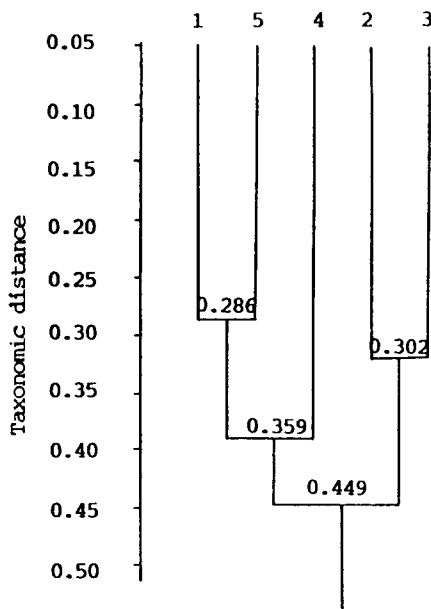


Fig. 6. Grouping of five OTU's of the family Bagridae based on UPGMA analysis average taxonomic distance matrix from standardized means of 12 skeletal characters. Numerals indicate the each species: 1, *P. fulvidraco*; 2, *L. nitidus*; 3, *L. ussuriensis*; 4, *Pseudobagrus* sp.; 5, *P. brevicorpus*.

paper, five species of Korean bagrid fishes showed two large groups divided into OTU's 1, 4 and 5, and OTU's 2 and 3. Two large groups were in accord with the criteria of genera *Pseudobagrus* and *Leiocassis* based on the osteological features (Lee, 1988). Family Bagridae from Korea, therefore, was divided into five species and two genera—*Pseudobagrus fulvidraco*, *Pseudobagrus* sp., *P. brevicorpus*, *Leiocassis nitidus* and *L. ussuriensis*—as the results of analysis based on the morphological characters of their skeleton by Lee (1988). Koh (1985) reported that Korean rodents were well grouped by UPGMA cluster analysis in their systematic studies. From UPGMA cluster analysis also Korean bagrid fishes formed two large groups (OTU's 1,4,5 and OTU's 2,3, Fig. 6), as shown in results (Fig. 2,3, and 4) of principal component analysis.

According to the results of principal component analysis, discriminant analysis, and UPGMA analysis based on the morphological characters of skeleton, the three OTU's (OTU's 1,4, and 5) were regarded as to become genus *Pseudobagrus*, and two OTU's (OTU's 2 and 3) also were

considered as genus *Leiocassis*.

*P. brevicorpus* has ordinarily known closely related to *Pseudobagrus* sp. in the exomorphological features until now, but the results of UPGMA cluster analysis based on osteological characters and morphological features of skeleton represented relationships more closed to *P. fulvidraco* rather than *Pseudobagrus* sp..

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### 한국산 동자개과 어류의 계통분류학적 연구 III. 골격형질의 다변량 분석 이충렬 (군산대학 생물학과)

우리 나라 서남해안에 유입되는 하천에 주로 서식하고 있는 동자개과 어류 110 개체의 골격표본을 중심으로 12개 골격형질을 추출하여 이들의 분류학적 위치와 계통관계를 조사하였다. 그 결과 한국산 동자개과 어류는 종전의 4속에서 2속으로 즉 *Pseudobagrus* 속과 *Leiocassis* 속으로 분류되었으며, *Pseudobagrus* 속에는 *P. fulvidraco*, *Pseudobagrus* sp., *P. brevicorpus* 이고 *Leiocassis* 속에는 *L. nitidus* 와 *L. ussuriensis* 가 해당 되었다. 또한 지금까지는 *P. brevicorpus* 는 *Pseudobagrus* sp. 와 가까운 관계로 알고 있었으나 그 보다는 오히려 *P. fulvidraco* 와 더욱 가까운 계통관계로 나타났다.