Korean J. Ichthyol. 17(3), 159~166, 2005

Karyotypes of Three Species of *Gobiobotia* (Pisces: Cyprinidae) in Korea

Ho-Bok Song[1] and Gab-Man Park*

[1]Division of Life Sciences, College of Natural Sciences, Kangwon National University, Chunchon 200-701, Korea
Department of Parasitology, Kwandong University College of Medicine, Gangneung 210-701, Korea

The karyotypes of three species of *Gobiobotia* in Korea were investigated: *G. macrocephala*, *G. brevibarba*, and *G. nakdongensis*. In these species, the mitotic chromosomes from 25 groups with two chromosomes each indicated that it is a diploid. The karyotypes of *Gobiobotia macrocephala* are 2n = 50 (9M+7SM+9ST) with NF = 100, *G. brevibarba* 2n = 50 (10M+7SM+4ST+4T) with NF = 92, and *G. nakdongensis* 2n = 50 (5M+9SM+9ST+2T) with NF = 96. Chromosome sizes ranged from 3.3 to 7.5 μm, 2.7 to 6.3 μm and 3.5 to 7.3 μm in length, respectively. This is the first report on the chromosomes of *G. macrocephala* and *G. nakdongensis*.

Key words : Chromosome, Cyprinidae, *Gobiobotia macrocephala*, *G. brevibarba*, *G. nakdongensis*, Korea

Introduction

The Cyprinid fishes represent the world's largest primary freshwater fish family (more than 2,000 species; Nelson, 1994), and also an important element in the Korean ichthyofauna. In Korea, 65 species of Cyprinidae are recognized (Kim, 1997). In the Korean Peninsula, the genus *Gobiobotia* Kreyenberg, 1911 has been reported by three species: *G. macrocephala* Mori 1935, *G. brevibarba* Mori, 1935 and *G. nakdongensis* Mori, 1935 (Mori, 1935; Uchida, 1939). They are endemic and endangered species of Korea. There have been a few previous studies on the feeding habit and reproductive ecology in these species (Choi and Baek, 1972; Choi *et al*., 2001, 2004).

Cytogenetic studies of fishes have been important in aspects of phylogenetics and cytogenetic relationships among the species (Ozouf-Costaz and Foresti, 1992; Collares-Pereira *et al*., 1998; Gozukara and Cavas, 2004). The chromosome numbers of animal species are, in general, uniform and constant, each species having a characteristic chromosome number. The chromosome numbers of about 50 species belonging to the Korean Cyprinidae family have been reported previously (Table 1). And the chromosome numbers of these species range from 2n = 44 to 2n = 76 (Lee *et al*., 1982; Lee *et al*., 1983; Lee, 1984; Lee *et al*., 1984b; Ueno and Ojima, 1984; Kim *et al*., 2004). Ueno and Ojima (1984) reported the chromosome numbers of *G. brevibarba*. However, cytogenetic studies of *G. macrocephala* and *G. nakdongensis* have not been examined.

This paper presents the chromosome numbers and the karyotypes of *G. macrocephala*, *G. brevibarba* and *G. nakdongensis* in Korea.

Materials and Methods

The specimens used in this study were collected in Korea from July 2004 to January 2005, and examined shortly after collection. Fifteen specimens of *G. brevibarba* were collected in the Geoun-ri, Yeongwol-eup, Yeongwol-gun, Gang-

*Corresponding author: gmpark@kd.ac.kr

Table 1. Chromosome number of Korean Cyprinid fishes by references

Classification	Chromosome No. (2n)	References
Acheilognathinae		
Rhodeus ocellatus	48	Lee *et al*., 1982; Lee, 1983
R. uyekii	46, 48	Lee *et al*., 1982; Lee, 1982; Lee *et al*., 1983
R. notatus	46	Lee, 1982; Lee *et al*., 1982; Lee, 1983
Acheilognathus lanceolatus	48	Lee *et al*., 1982; Lee, 1983; Kim, 1991
A. signifier	48	Lee *et al*., 1983; Kim, 1991
A. koreensis	48	Lee, 1982; Lee *et al*., 1982; Kim, 1991; Yang, 2004
A. somjinensis	48	Kim, 1991; Yang, 2004
A. yamatsutae	44, 48	Lee *et al*., 1982; Lee, 1983; Lee *et al*., 1983; Kim, 1991
A. rhombeus	44	Lee *et al*., 1982; Lee, 1983; Kim, 1991
A. macropterus	44	Lee *et al*., 1982; Lee, 1983
A. gracilis	44	Lee *et al*., 1982; Lee, 1983
Gobioninae		
Pseudorasbora parva	50	Lee *et al*., 1983
Pungtungia herzi	50	Lee *et al*., 1983; Lee, 1984
Pseudopungtungia nigra	50	Lee *et al*., 1983; Kim and Shim, 1991
P. tenuicorpa	50	Kim and Shim, 1991
Coreoleuciscus splendidus	50	Lee *et al*., 1983; Lee, 1984
Sarcocheilichthys variegatus wakiyae	50	Lee *et al*., 1984a
S. nigripinnis morii	50	Lee, 1984
Ganthopogon strigatus	50	Lee, 1984
Squalidus gracilis majimae	50	Lee, 1984
S. japonicus coreanus	50	Lee *et al*., 1984a
S. chankaensis tsuchigae	50	Kim *et al*., 2004
S. multimaculatus	50	Kim *et al*., 2004
Hemibarbus labeo	50	Kang and Park, 1973; Lee *et al*., 1984a
H. longirostris	50	Lee *et al*., 1983
H. mylodon	50	Ueno and Ojima, 1984
Pseudogobio esocinus	50	Lee *et al*., 1984a; Lee, 1984
Gobiobotia macrocephala	50	Present study
G. brevibarba	50	Ueno and Ojima, 1984; Present study
G. nakdongensis	50	Present study
Microphysogobio yaluensis	50	Lee *et al*., 1983
M. jeoni	50	Lee *et al*., 1983
M. longidorsalis	50	Lee *et al*., 1983; Im *et al*., 2004
Leuciscinae		
Tribolodon hakonensis	50	Lee *et al*., 1984b; Lee *et al*., 1986
T. brandti	50	Lee *et al*., 1984b; Lee *et al*., 1986
Phoxinus phoxinus	50	Lee *et al*., 1984b; Lee *et al*., 1986
Rhynchocypris oxycephalus	48, 50	Kang and Park, 1973; Lee *et al*., 1983; Lee *et al*., 1984b; Lee *et al*., 1986; Lee *et al*., 1987
R. steindachneri	50	Kang and Park, 1973; Lee *et al*., 1984a; Lee *et al*., 1984b; Lee *et al*., 1986; Lee *et al*., 1987
R. kumgangensis	50	Lee *et al*., 1983; Lee *et al*., 1984b; Lee *et al*., 1986
R. semotilus	50	Lee *et al*., 1984b
Danioninae		
Aphyocypris chinensis	48	Lee *et al*., 1984a; Lee *et al*., 1986
Zacco temmincki	48	Lee *et al*., 1983; Lee *et al*., 1986
Z. platypus	48	Lee *et al*., 1983; Lee *et al*., 1986
Opsariichthys uncirostris amurensis	76	Lee *et al*., 1983; Lee *et al*., 1986

weon−do, Korea, twelve specimens of *G. macrocephala* in Boktan−ri, Sotae−myeon, Chungju−si, Chungcheongbuk−do, Korea and five specimens of *G. nakdongensis* in Seoktap−ri, Andong−si, Gyeongsangbuk−do, Korea. Chromosome preparations were made from gill tissues by the

Table 2. Karyotypes of the three species in the genus *Gobiobotia* (Cyprinidae) of Korea

Species	No. of chromosome	Karyotype*	NF value	Locality
Gobiobotia macrocephala	2n = 50	9M+7SM+9ST	100	Han river
Gobiobotia brevibarba	2n = 50	10M+7SM+4ST+4T	92	Han river
Gobiabotia nakdongensis	2n = 50	5M+9SM+9ST+2T	96	Nakdong river

*M: metacentric chromosome; SM: submetacentric chromosome; ST: subtelocentric chromosome; T: telocentric chromosome

Table 3. Relative lengths and total lengths (μm) of chromosomes of *Gobiobotia macrocephala**

Chromosome	RL±SE (%)	TL±SE	Type
1	5.62±1.04	7.5±0.37	ST
2	5.57±0.80	7.4±0.21	M
3	4.97±0.76	6.6±0.16	ST
4	87±0.72	6.5±0.15	ST
5	4.77±0.67	6.3±0.12	ST
6	4.72±0.67	6.3±0.12	M
7	4.62±0.43	6.1±0.19	SM
8	4.52±0.39	6.0±0.17	M
9	4.42±0.39	5.9±0.17	SM
10	4.31±0.34	5.7±0.14	M
11	4.22±0.84	5.6±0.19	ST
12	4.12±0.79	5.5±0.17	M
13	4.01±0.73	5.3±0.16	M
14	3.82±0.66	5.1±0.10	M
15	3.67±0.39	4.9±0.12	SM
16	3.61±0.35	4.8±0.09	SM
17	3.52±0.35	4.7±0.09	ST
18	3.46±0.33	4.6±0.08	ST
19	3.41±0.57	4.5±0.15	SM
20	3.31±0.33	4.4±0.14	SM
21	3.22±0.25	4.3±0.16	ST
22	3.11±0.29	4.1±0.14	SM
23	2.91±0.24	3.9±0.15	M
24	2.71±0.74	3.6±0.16	M
25	2.51±0.69	3.3±0.15	ST

*Based on measurement of six karyotyped cells. RL±SE, relative length of the chromosome (percentage of the total length of the autosomes in diploid); TL, total length of the autosomes in diploid; SE, standard error.

air-dry method with minor modification (Collares-Pereira, 1992; Park, 1994). Specimens were treated with 0.1 mL of 0.05% colchicine solution to intra-abdominal injected to fishes and set aside for 10 hours in an aquarium at room temperature. The treated gill tissues were dissected and minced with needles in a hypotonic 0.01% NaCl solution. Separated cells were collected by centrifugation at 1,000 rpm, for 10 mins. These cells were fixed in freshly mixed modified Carnoy's fixative (three parts of methanol and one part of glacial acetic acid). The supernatant was replaced by fresh fixative. The centrifugation (1,000 rpm, 10 mins) was repeated two more times. A drop of the cell suspension was then pipetted by a microhematocrit capillary tube and dropped onto a clean slideglass pre-cooled at 4°C. The cells left on the slide were air-dried and then stained for 10 minutes with 4% Giemsa (Gurr's R66) solution made up in 0.1 M phosphate buffer, pH 7.0. The prepared slides were observed under an Olympus (VANOX, Japan) microscope with a 100× (n.a. 1.25) oil immersion objective and a 10× ocular.

Morphological features of the chromosomes used to compare karyotypes were the total lengths and the relative lengths of the chromosomes, as well as the positions of their centromeres (primary constrictions). Nomenclature of chromosome morphological types follows Levan *et al.* (1964). To estimate the NF value, the chromosomes of the group meta- and submetacentrics were scored as bi-armed and the chromosomes of the group acrocentrics as uni-armed. For sex chromosomes, males and females of three species were separately observed.

Voucher specimens of the three species used in this investigation have been placed in the Department of Parasitology, Kwandong University College of Medicine, Korea.

Results

1. *Gobiobotia macrocephala*

In 25 cells, 50 chromosomes were observed (NF = 100). The karyotype of this species consists of nine pairs of metacentric chromosomes, seven pairs of submetacentric chromosomes and nine pairs of subtelocentric chromosomes (Table 2, Fig. 1). Table 3 shows the mean lengths and relative lengths of each chromosome as examined in six cells. Observed chromosomes ranged from 3.3 to 7.5 μm. The mean total chromosome length based on the measurements of six cells was 132.9 ±3.85 μm. Fig. 1B is the karyotype constructed from the chromosomes shown in Fig. 1A, which

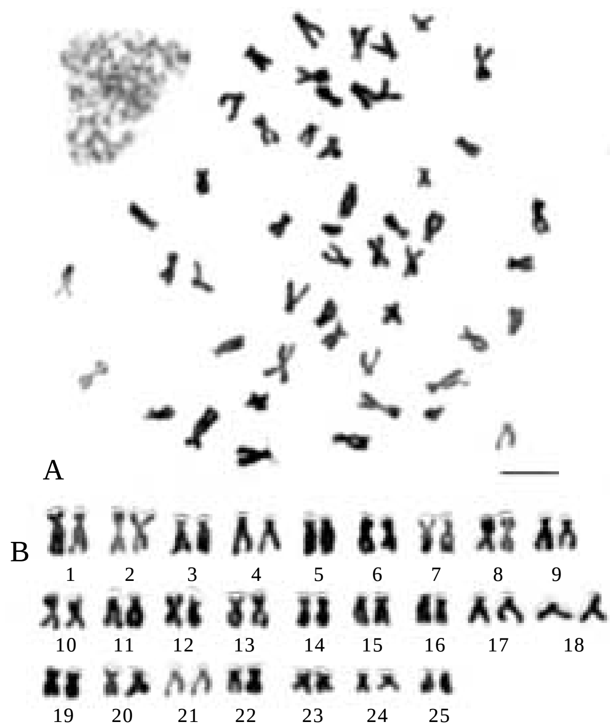

Fig. 1. A, Metaphase chromosome of *Gobiobotia macrocephala*; B, Karyotype constructed from A. Scale bar indicates 5 μm.

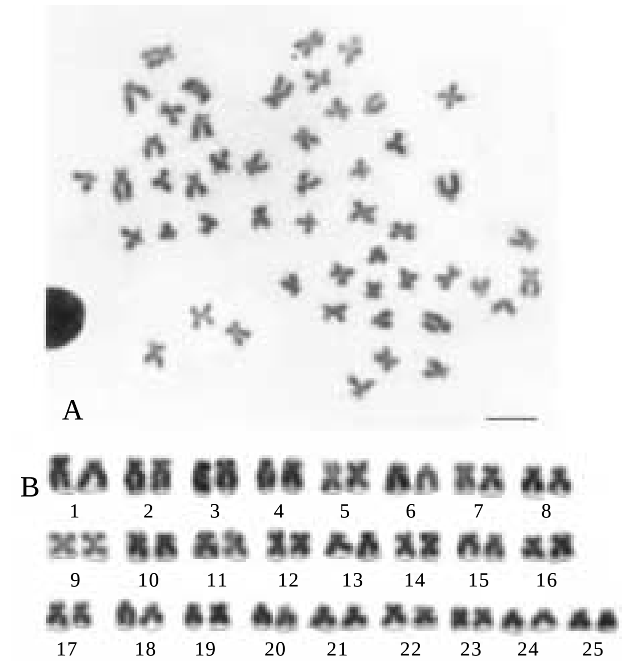

Fig. 2. A, Metaphase chromosome of *Gobiobotia brevibarba*; B, Karyotype constructed from A. Scale bar indicates 5 μm.

was one of the good prepared complements. The chromosomes were arranged by size. This is the first report on the chromosomes of *G. macrocephala*.

2. *Gobiobotia brevibarba*

Chromosomes in 28 cells were observed and the chromosome number is 50 (NF = 92). The karyotype of this species consists of 10 pairs of metacentric chromosomes, seven pairs of submetacentric chromosomes, four pairs of subtelocentric chromosomes and four pairs of telocentric chromosomes (Table 2, Fig. 2). Table 4 shows the mean lengths and relative lengths of each chromosome as examined in five cells. Observed chromosomes ranged from 2.7 to 6.3 μm. The mean total chromosome length based on the measurements of six cells was 112.5±4.28 μm. Fig. 2B is the karyotype constructed from the chromosomes shown in Fig. 2A, which was one of the good prepared complements. The karyotypes of this species arranged by size.

3. *Gobiobotia nakdongensis*

Chromosomes in 21 cells were observed and the

Table 4. Relative lengths and total lengths (μm) of chromosomes of *Gobiobotia brevibarba**

Chromosome	RL±SE (%)	TL±SE	Type
1	5.48±0.77	6.3±0.35	ST
2	5.30±0.68	6.1±0.24	SM
3	5.25±0.38	6.1±0.27	SM
4	5.13±0.46	5.9±0.19	SM
5	5.02±0.47	5.8±0.18	M
6	4.91±0.44	5.7±0.17	ST
7	4.73±0.52	5.5±0.20	M
8	4.50±0.53	5.2±0.18	SM
9	4.33±0.51	5.0±0.17	M
10	4.21±0.41	4.9±0.14	M
11	4.15±0.38	4.8±0.16	M
12	4.09±0.26	4.7±0.14	M
13	3.87±0.32	4.5±0.13	SM
14	3.75±0.36	4.3±0.11	M
15	3.69±0.33	4.3±0.09	ST
16	3.57±0.31	4.1±0.17	M
17	3.46±0.34	4.0±0.17	M
18	3.40±0.32	3.9±0.15	T
19	3.29±0.33	3.4±0.18	SM
20	3.23±0.31	3.3±0.17	T
21	3.18±0.46	3.2±0.14	T
22	3.05±0.32	3.1±0.15	SM
23	2.88±0.45	2.9±0.13	M
24	2.83±0.26	2.8±0.16	T
25	2.71±0.35	2.7±0.14	ST

*Based on measurements of five karyotyped cells.

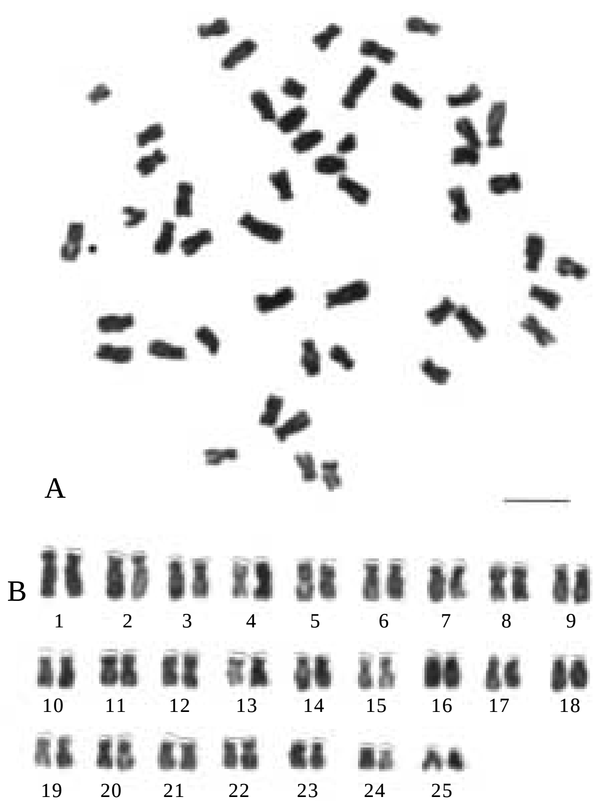

Fig. 3. A, Metaphase chromosome of *Gobiobotia nakdongensis*; B, Karyotype constructed from A. Scale bar indicates 10 μm.

Table 5. Relative lengths and total lengths (μm) of chromosomes of *Gobiobotia nakdongensis**

Chromosome	RL ± SE (%)	TL ± SE	Type
1	5.0 ± 0.55	7.31 ± 0.57	ST
2	4.9 ± 0.64	7.23 ± 0.48	ST
3	4.9 ± 0.57	7.21 ± 0.38	ST
4	4.9 ± 0.49	7.17 ± 0.36	M
5	4.8 ± 0.78	7.02 ± 0.27	M
6	4.7 ± 0.37	6.93 ± 0.54	ST
7	4.6 ± 0.29	6.77 ± 0.50	ST
8	4.6 ± 0.18	6.66 ± 0.33	M
9	4.5 ± 0.47	6.53 ± 0.21	ST
10	4.4 ± 0.34	6.47 ± 0.31	ST
11	4.3 ± 0.26	6.27 ± 0.30	M
12	4.2 ± 0.24	6.15 ± 0.21	M
13	3.9 ± 0.33	5.68 ± 0.22	SM
14	3.8 ± 0.21	5.61 ± 0.16	ST
15	3.8 ± 0.09	5.52 ± 0.23	SM
16	3.7 ± 0.57	5.45 ± 0.21	T
17	3.7 ± 0.37	5.36 ± 0.12	SM
18	3.6 ± 0.45	5.20 ± 0.12	ST
19	3.5 ± 0.28	5.15 ± 0.37	SM
20	3.5 ± 0.19	5.06 ± 0.51	SM
21	3.4 ± 0.24	4.93 ± 0.47	SM
22	3.3 ± 0.18	4.82 ± 0.32	SM
23	3.2 ± 0.23	4.68 ± 0.42	SM
24	2.6 ± 0.21	3.78 ± 0.36	SM
25	2.4 ± 0.14	3.51 ± 0.25	T

*Based on measurements of six karyotyped cells.

chromosome number is 50 (NF = 96). The karyotype of this species consists of five pairs of metacentric chromosomes, nine pairs of submetacentric chromosomes, nine pairs of subtelocentric chromosomes and two pairs of telocentric chromosomes (Table 2, Fig. 3). Table 5 shows the mean lengths and relative lengths of each chromosome as examined in six cells. Observed chromosomes ranged from 3.5 to 7.3 μm. Fig. 3B is the karyotype constructed from the chromosomes shown in Fig. 3A, which was one of the good prepared complements. The karyotypes of this species arranged by size. This species is the first report on the chromosomes. The mitotic metaphase chromosomes were observed in both sexes but sex chromosomes were not observed. Sex chromosomes were not determined in the studied species.

Discussion

An increase in the number of published works and laboratory techniques relevant to chromosome investigation in recent years has furthered our knowledge of chromosome number and morphology in many fish species. However, a taxonomic revision has been needed to enhance a thorough interpretation of the phylogenetic interrelationships between various groups. Levan *et al.* (1964) proposed the chromosomal classification. Considering the potential application of the cytological approach to cyprinid systematic (Buth *et al.*, 1991), this study provides also data for a correct specific definition, due to the relatively high conservative character of karyotypes in the family (Rab and Collares−Pereira, 1995).

Detailed studies of chromosome morphology and population cytology of the present fishes are very little on systematics based on the karyotypes other than chromosome numbers. In fact modern cytogenetic techniques have only recently been adopted for studies of fishes. These include application of special banding methods by Sumner (1972) and Howell and Black (1980). In the Korean cyprinid, about 50 species have been karyologically investigated; 2n range from 44 to 76: 2n =

44~48 of Acheilognathinae; 2n = 50 of Gobioninae and Leuciscinae; 2n = 48~76 of Danioninae (Lee *et al*., 1982; Lee *et al*., 1983; Lee, 1984; Lee *et al*., 1984a b; Ueno and Ojima, 1984; Kim *et al*., 2004). The most frequent chromosome number in the cyprinid fishes have been reported 2n = 50. For the present study, *G. macrocephala*, *G. brevibarba* and *G. nakdongensis* have 2n = 50 chromosomes. When the karyotypes of these three species are analyzed, *G. macrocephala* consists of nine pairs of metacentric chromosomes, seven pairs of submetacentric chromosomes and nine pairs of subtelocentric chromosomes, *G. brevibarba* has of 10 pairs of metacentric chromosomes, seven pairs of submetacentric chromosomes, four pairs of subtelocentric chromosomes and four pairs of telocentric chromosomes and *G. nakdongensis* has of five pairs of metacentric chromosomes, nine pairs of submetacentric chromosomes, nine pairs of subtelocentric chromosomes and two pairs of telocentric chromosomes. The chromosomes of *G. brevibarba* have already been revealed by Ueno and Ojima (1984). They reported the same chromosome numbers of 2n = 50. However, its karyotype is different from that of the present species. Ueno and Ojima (1984) reported that the karyotype were consists of six pairs of metacentric chromosomes, 15 pairs of submetacentric/ subtelocentric chromosomes and four pairs of telocentric chromosomes. These differences in the complements are probably due to a personal interpretation of the arm ratio. *G. macrocephala* and *G. nakdongensis* is the first report on the chromosomes. Karyotype evolution in bitterlings of cyprinid has been reported by John and Miklos (1979), Meyne *et al*. (1990) and Ueda *et al*. (2001). Most cyprinid fishes have karyotypes which are rich in M and SM (Lee *et al*., 1983, 1984a; Lee, 1984; Kim *et al*., 2004). Chromosome arm number is usually reported in addition to chromosome number. Species with vastly different chromosome numbers can have similar arm numbers, suggesting that Robertsonian fusions (creation of one metacentric by the centric fusion of two acrocentric chromosomes) occurred in evolution. Centric fission also may account for differences in chromosome number between species that have similar arm numbers (Ohno, 1974). Ohno (1974) and Arai (1983) have been reported that the archetypes have many more acrocentric chromosome and newly differentiated species have a large number of arm number. Chromosome numbers of three species are 2n = 50 in the present study. But NF of *G. macrocephala*, *G. brevibarba* and *G. nakdongensis* showed 100, 92 and 96 respectively. Further study will be need C- and Ag-banding analyses for the investigation of the karyotype evolution in *Gobiobotia*.

Koehler *et al*. (1995) have been reported that European cyprinid fish species *Scardinius erythrophthalmus* have sex determining chromosomes. This species was revealed to have 2n = 50 and karyotypes of all male were identical, consisting of 48 small meta- or submetacentric chromosomes and a pair of large metacentric chromosomes (ZZ males). On the other hand, in females, 16 had a karyotype similar to the males (ZW females) and 17 had a heteromorphic pair of chromosomes, including a large metacentric Z chromosome and a small acrocentric W chromosome (ZW females). In the present study, sex determining chromosomes are not observed from males and females in three specimens.

The genus *Gobiobotia* is well known for its intra- and inter-populational morphological variability (Ramaswami, 1955; Kim and Kang, 1989). The chromosome numbers are constant to a great extent at each of the various taxonomical levels, though some of the animals are geographically very widely separated. An especially valuable first step in such an endeavor is a cytogenetic one, as demonstrated here.

References

Arai, R. 1983. Karyological and osteological approach to phylogenetics of fishes. Bull. Nat. Sci. Mus., Tokyo. Ser. A., 9 : 175~210.

Buth, D.G., T.E. Dowling and J.R. Gold. 1991. Molecular and Cytological Investigations. In Cyprinid Fishes-Systematics, Biology and Exploitation (Winfield, I.J. & Nelson, J.E., eds.). Chapman & Hall, Fish and Fisheries Series, 3, London, pp. 83~126.

Choi, K.C. and Y.K. Baek. 1972. On the life-history of *Gobiobotia macrocephalus* Mori. Kor. J. Limnol., 5 : 45~57.

Choi, J.S., H.K. Byeon and O.K. Kwon. 2001. Reproductive ecology of *Gobiobotia brevibarba* (Cyprinidae). Kor. J. Ichthyol., 13 : 123~128.

Choi, J.S., Y.S. Jang, K.Y. Lee and O.K. Kwon. 2004. Feeding habit of *Gobiobotia macrocephala* (Cyprinidae) from the Namhan River, Korea. Kor. J. Ichthyol., 16 : 165~172.

Collares-Pereira, M.J. 1992. In vivo direct chromosome preparation (protocol for air drying technique). First International Workshop on Fish Cytogenetic Techniques. Concarmeau, France.

Collares-Pereira, M.J., M.I. Prospero, R.I. Bileu and E.M.

Rodrigues. 1998. *Leuciscus* (Pisces, Cyprinidae) karyotypes: Transect of Portuguese populations. Genet. Mol. Biol., 21 : 63～69.

Gozukara, S.E. and T. Cavas. 2004. A karyological analysis of *Garra rufa* (Heckel, 1843) (Pisces, Cyprinidae) from the Eastern Mediterranean River basin in Turkey. Turk. J. Vet. Anim. Sci., 28 : 497～500.

Howell, W.M. and D.A. Black. 1980. Controlled silver staining of nucleolus organizer regions with a protective colloidal developer: a 1 step method. Experientia, 36 : 1014～1015.

Im, J.H., W.O. Lee, L. Peng, J.K. Noh, Y.K. Nam and D.S. Kim. 2004. Cytogenetic and molecular studies of endangered freshwater species from Korea I. *Microphysogobio longidorsalis* Mori (Cyprinidae: Gobioninae). Kor. J. Ichthyol., 16 : 189～200.

John, B. and G.L.G. Miklos. 1979. Functional aspects of satellite DNA and heterochromatin, Int. Tev. Cytol., 58 : 1～114.

Kang, Y.S. and E.H. Park. 1973. Studies on the karyotypes and DNA values in several Korean Cyprinidae fishes. Kor. J. Zool., 16 : 97～108.

Kim, C.H. 1991. Systematic studies on the bitterlings, genus *Acheilognathus* (Pisces: Cyprinidae) from Korea. Doctoral thesis in Chonbuk Nat. Univ., 132 pp.

Kim, I.S. 1997. Illustrated Encyclopedia of Fauna & Flora of Korea vol. 37 (Freshwater fishes). Ministry of Education, 1～629pp.

Kim, I.S. and E.J. Kang. 1989. Comparative study on the urohyal of the subfamily Gobioninae of Korea. Kor. J. Ichthyol., 1 : 35～41.

Kim, I.S., H. Yang, S.L. Lee and E.H. Lee. 2004. Karyotype analysis of the two species of the genus *Squalidus* (Pisces : Cyprinidae) in Korea. Kor. J. Ichthyol., 16 : 229～233.

Kim, I.S. and J.H. Shim. 1991. Karyptypes of the genus *Pseudopungtungia* (Pisces: Cyprinidae). Kor. J. Zool., 34 : 54～58.

Koehler, M.R., D. Neuhaus, W. Engel, M. Schartl and M. Schmid. 1995. Evidence for an unusual ZW/ZW'/ZZ sex-chromosome system in *Scardinius erythrophthalmus* (Pisces, Cyprinidae), as detected by cytogenetic and H-Y antigen analyses. Cytogenet Cell Genet. 71 : 356～362.

Lee, G.Y. 1982. Karyotypes of the Acheilognathinae fishes (Cyprinidae) in Korea (I). Ann. Rep. Biol. Res. (Jeonbug Nat. Univ), 3 : 19～24.

Lee, G.Y. 1983. Karyotypes of the Acheilognathinae fishes (Cyprinidae) in Korea (II). J. Chonbuk Nat. Univ., Natural Sciences, 25 : 411～418.

Lee, G.Y. 1984. Karyotype of seven species of the Gobioninae fishes (Cyprinidae) in Korea. Kor. J. Limnol., 17 : 81～88.

Lee, G.Y., J.N. So and S.Z. Kim. 1982. Chromosomes and arm number of the Acheilognathine fishes (Cyprinidae) in Korea. Basic. Sci. Rev. Jeonbug Nat. Univ., 5 : 61～69.

Lee, H.Y., H.Y. Chai, S.K. Jeon and H.S. Lee. 1983. The karyotype analysis on 29 species of fresh water fish in Korea. Bull. Inst. Basic., Inha Univ., Vol. 4 : 79～93.

Lee, H.Y., H.S. Lee, J.W. Cho and Y.O. Lee. 1984a. The karyotype ananysis on 21 species of fresh-water fish in Korea (ll). Bull. Inst. Basic., Inha Univ., Vol. 5 : 125～140.

Lee, K.Y., S.J. Kim, H.O. Kim and S.R. Jeon. 1984b. Karyotypes of the Leuciscinae fishes (Cyprinidae) in Korea and Japan. Kor. J. Limnol., 17 : 11～21.

Lee, G.Y., S.I. Jang and M.J. Yun. 1986. Karyotype of nine species in the family Cyprinidae fishes from Korea. Kor. J. Limnol, 19 : 59～69.

Lee, G.Y., S.I. Jang, M.J. Yun and J.N. So. 1987. Karyotype of four species in genus Moroco (Pisces: Cyprinidae) from Korea and Japan. Kor. J. Limnol, 20 : 49～60.

Levan, A., K. Fredga and A.A. Sandberg. 1964. Nomenclature for centromeric position on chromosomes. Hereditas, 52 : 201～220.

Meyne, J., R.J. Baker, H.H. Hobart, T.C. Hsu, O.A. Ryder, O.G. Ward, J.E. Wiley, D.H. Wurster-Hill, T.L. Yates and R.K. Moyzis. 1990. Distribution of non-teromeric sites of the (TTAGGG)n telomeric sequences in vertebrate chromosomes. Chromosoma., 99 : 3～10.

Mori, T. 1935. Description of two new genera and seven species of Cyprinidae from Korea. Ann. Zool. Japan., 15 : 161～166.

Nelson, J.S. 1994. Fishes of the World (3rd ed). John Wiley & Sons, New York, pp. 131～133.

Ohno, S. 1974. Animal Cytogenetics, Volum 4: Chordata 1. Protochordata, Cyclostomata and Pisces. Gebruder Borntraeger, Berlin.

Ozouf-Costaz, C. and F. Foresti. 1992. Fish cytogenetic research: Advances, applications and perspectives. Neth. J. Zool., 42 : 277～290.

Park, G.M. 1994. Cytotaxonomic studies of freshwater gastropods in Korea. Malacological review., 27 : 23～41.

Rab, P. and M.J. Collares-Pereira. 1995. Chromosomes of European cyprinid fishes (Cyprinidae, Cypriniformes): a review, Folia Zool., 44 : 193～214.

Ramaswami, J.S. 1955. Skeleton of cyprinoid fishes in relation to phylogenetic studies : 6. The skull and webrian apparatus of gobioninae (Cyprinidae). Acta Zoologica, Bd. 36 : 127～155.

Sumner, A.T. 1972. A simple technique for demonstrating centromeric heterochromatin. Exp. Cell. Res., 75 : 304～306.

Uchida, K. 1939. The fishes of Tyosen, Part I. Nematognathi, Eventognathi. Bull. Fish. Exp. Sta. Gov. Gener. Tyosen, 6, 1～458 pp.

Ueda, T., H. Naoi and R. Arai. 2001. Flexibility on the karyotype evolution in bitterlings (Pisces, Cyprinidae). Genetica, 111 : 423～432.

Ueno, K. and Y. Ojima. 1984. A chromosome study of nine species of Korean Cyprinid fish. Jap. J. Ichthyol., 31 : 338～344.

Yang, H. 2004. Ecology and speciation of two Korean bitterlings, *Acheilognathus koreensis* and *A. somjinensis* (Pisces: Cyprinidae) from Korea. Doctoral thesis in Chonbuk Nat. Univ, 100 pp.

Received: July 19, 2005
Accepted: September 1, 2005

한국산 꾸구리속, *Gobiobotia* (Pisces: Cyprinidae) 3종의 핵형

송 호 복[1] · 박 갑 만*

[1]강원대학교 자연과학대학 생명과학부, 관동대학교 의과대학 기생충학교실

한국산 꾸구리속 (*Gobiobotia*) 어류인 꾸구리 (*G. macrocephala*), 돌상어 (*G. brevibarba*) 및 흰수마자 (*G. nakdongensis*)의 핵형을 조사하였다. 연구 결과, 각각 25쌍의 배수체 염색체가 관찰되었다. 핵형은 꾸구리가 2n = 50 (9M+7SM+9ST), NF = 100, 염색체의 길이는 3.3~7.5 μm 크기였으며, 돌상어는 2n = 50 (10M+7SM+4ST+4T), NF = 92, 염색체의 길이는 2.7~6.3 μm의 크기였고, 흰수마자는 2n = 50 (5M+9SM+9ST+2T), NF = 96, 염색체의 길이는 3.5~7.3 μm였다. 본 연구 결과 꾸구리와 흰수마자의 핵형은 처음으로 보고되었다.