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Araştırma Makalesi
Research Article

The Comparison of The Genus *Alburnus* (Cyprinidae) Species with Karyotype Symmetry/Asymmetry Index (S/A_I)

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Abstract

The S/A_I is a new formula for the measurement of the karyotype symmetry/asymmetry in animals. The symmetry/asymmetry index is applied to the *Alburnus* (Cyprinidae) species. After a comprehensive literature search, karyotype formulae, S/A_I values and karyotype types of seven species were determined. According to the S/A_I values, a phylogenetic trees were drawn showing relationships among the species of the genus *Alburnus*. The karyotype symmetry/asymmetry values are 1.6400–2.1600. The karyotype types of *Alburnus alburnus*, *Alburnus arborella*, *Alburnus filippii* and *Alburnus heckeli* are between symmetric and asymmetric. The karyotype types of *Alburnus akili*, *Alburnus albidus* and *Alburnus doriae* are symmetric.

***Keywords*:** *Alburnus*, Cyprinidae, phylogeny, symmetry/asymmetry index.

Öz

Alburnus (Cyprinidae) Türlerinin Karyotip Simetri/Asimetri İndeksi (S/AI) ile Karşılaştırılması

S/A_I hayvanlarda karyotip simetri/asimetrisinin ölçülmesi için kullanılan yeni bir formüldür. Simetri/asimetri indeksi *Alburnus* (Cyprinidae) türlerine uygulandı. Kapsamlı bir literatür taramasından sonra, yedi türün karyotip formülleri, S/A_I değerleri ve karyotip tipleri belirlendi. S/A_I değerlerine göre, *Alburnus* cinsinin türleri arasındaki ilişkileri gösteren bir filogenetik ağaç çizildi. Karyotip simetri/asimetri değerleri 1.6400–2.1600 arasındadır. *Alburnus alburnus*, *Alburnus arborella*, *Alburnus filippii* ve *Alburnus heckeli*'nin karyotip tipleri simetrik ve asimetrik arasındadır. *Alburnus akili*, *Alburnus albidus* ve *Alburnus doriae*'nin karyotip tipleri simetriktir.

***Anahtar Kelimeler*:** *Alburnus*, Cyprinidae, filogeni, simetri/asimetri indeksi.

Introduction

The genus *Alburnus* Rafinesque, 1820 is placed in the family Cyprinidae. The genus described from the bleak, shemaya and kuli (Table 1) consists of approximately 39 species found in Europe and Asia (IUCN, 2015).

According to the International Union for the Conservation of Nature Red List, 8 species are categorized as Endangered (EN) and four species are categorized as Critically Endangered (CR). *Alburnus akili* and *Alburnus nicaeensis* are categorized as Extinct (EX) (IUCN, 2015).

Table 1. The species list of genus *Alburnus*

No	Scientific name	Common name
1	*Alburnus akili* (Battalgil, 1942)	Beyşehir bleak
2	*Alburnus albidus* (Costa, 1838)	Italian bleak
3	*Alburnus alburnus* (Linnaeus, 1758)	Bleak
4	*Alburnus arborella* (Bonaparte, 1841)	
5	*Alburnus attalus* (Özuluğ & Freyhof, 2007)	Bakır shemaya
6	*Alburnus baliki* (Bogutskaya, Küçük & Ünlü, 2000)	Antalya bleak
7	*Alburnus battalgilae* (Özuluğ & Freyhof, 2007)	Gediz shemaya
8	*Alburnus belvica* (Karaman, 1924)	
9	*Alburnus caeruleus* (Heckel, 1843)	Black spotted bleak
10	*Alburnus carinatus* (Battalgil, 1941)	Manyas shemaya
11	*Alburnus chalcoides* (Güldenstädt, 1772)	
12	*Alburnus demiri* (Özuluğ & Freyhof, 2008)	Eastern Aegean bleak
13	*Alburnus derjugini* (Berg, 1923)	Georgian shemaya
14	*Alburnus doriae* (De Filippi, 1865)	
15	*Alburnus escherichii* (Steindachner, 1897)	Sakarya bleak
16	*Alburnus filippii* (Kessler, 1877)	Kura bleak
17	*Alburnus heckeli* (Battalgil, 1943)	Hazer shah kuli
18	*Alburnus hohenackeri* (Kessler, 1877)	
19	*Alburnus istanbulensis* (Battalgil, 1941)	Istanbul bleak
20	*Alburnus kotschyi* (Steindachner, 1863)	Iskenderun shah kuli
21	*Alburnus leobergi* (Freyhof & Kottelat, 2007)	
22	*Alburnus macedonicus* (Karaman, 1928)	Macedonia bleak
23	*Alburnus mandrensis* (Drensky, 1943)	
24	*Alburnus mento* (Heckel, 1837)	
25	*Alburnus mentoides* (Kessler, 1859)	
26	*Alburnus nasreddini* (Battalgil, 1943)	Central Anatolian bleak
27	*Alburnus neretvae* (Buj, Šanda & Perea, 2010)	Neretva bleak
28	*Alburnus nicaeensis* (Battalgil, 1941)	Iznik shemaya
29	*Alburnus orontis* (Sauvage, 1882)	Orontes spotted bleak
30	*Alburnus qalilus* (Krupp, 1992)	Syrian spotted bleak
31	*Alburnus sarmaticus* (Freyhof & Kottelat, 2007)	
32	*Alburnus schischkovi* (Drensky, 1943)	
33	*Alburnus scoranza* (Bonaparte, 1845)	
34	*Alburnus sellal* (Heckel, 1843)	Shah kuli
35	*Alburnus tarichi* (Güldenstädt, 1814)	Van shah kuli
36	*Alburnus thessalicus* (Stephanidis, 1950)	
37	*Alburnus timarensis* (Kuru, 1980)	Karasu sha kuli
38	*Alburnus vistonicus* (Freyhof & Kottelat, 2007)	
39	*Alburnus volviticus* (Freyhof & Kottelat, 2007)	

The *Alburnus* species are excellent examples for endemism and high diversity in the western Palaearctic freshwater fishes. Turkey and especially Anatolia are centers of diversity of the genus *Alburnus* (Mohammadian-kalat *et al.,* 2015).

The diploid chromosome numbers in genus *Alburnus* are $2n = 50$ (Arkhipchuk, 1999; Bianco *et al*., 2004; Cataudella et al., 1977; Gül *et al.,* 2004; Klinkhardt *et al*., 1995; Nazari

et al., 2009; Schmid *et al*., 2006; Vasil'ev, 1980). The S/A_I is a new formula for the measurement of the karyotype symmetry/asymmetry index in higher animals. The formula uses centromeric position and chromosomal type. A symmetric karyotype occurs from metacentric and submetacentric chromosomes. Unlike an asymmetric karyotype occurs from telocentric or subtelocentric/acrocentric chromosomes (Eroğlu, 2015). The objective of this study is to determine the S/A_I of the *Alburnus* species according to the chromosome types and centromeric position.

Materials and Methods

The karyotype symmetry/asymmetry index formula (S/A_I);

The formula was given below.

$S/A_I = (1 \times M) + (2 \times SM) + (3 \times A) + (4 \times T) / 2n$ or

$S/A_I = (1 \times M) + (2 \times SM) + (3 \times ST) + (4 \times T) / 2n$

In these equations, M = metacentric chromosome number; SM = submetacentric chromosome number; A = acrocentric chromosome number; ST = subtelocentric chromosome number; T = telocentric chromosome number; *2n* = diploid chromosome number (Eroğlu, 2015).

Eroğlu (2015) showed the new classification model with 5 types of karyotype symmetry/asymmetry. They are full asymmetric, asymmetric, between symmetric and asymmetric, symmetric and full symmetric. A full asymmetric karyotype is characterized by completely telocentric chromosomes and the S/A_I value is 4.0000. In contrast, a full symmetric karyotype consists of a complete set of median chromosomes and the S/A_I value is 1.0000 (Eroğlu, 2015).

Sample application of symmetry / asymmetry on species;

The karyotypes of the genus *Alburnus* were used for the example application. After a comprehensive literature search, the diploid chromosome number of 16 species and karyotype formulae, index values, karyotype types of 7 species have been identified (Table 2). The chromosome formulae of 9 species were unknown. The scientific names were checked from IUCN Red List (IUCN, 2015).

Using the index values in Table 2, a phylogenetic tree was drawn showing relationships among the species of the genus *Alburnus* (Figure 1).

Results

In Table 2 the chromosome numbers are *2n* = 50 and the karyotype symmetry / asymmetry values are 1.6400–2.1600. In Figure 1 the karyotype types are between symmetric and asymmetric in the four species and symmetric in the three species. Although the karyotype types of *Alburnus alburnus*, *Alburnus arborella*, *Alburnus filippii* and *Alburnus heckeli* are between symmetric and asymmetric, there are symmetric karyotype in *Alburnus akili*, *Alburnus albidus* and *Alburnus doriae*.

Discussion

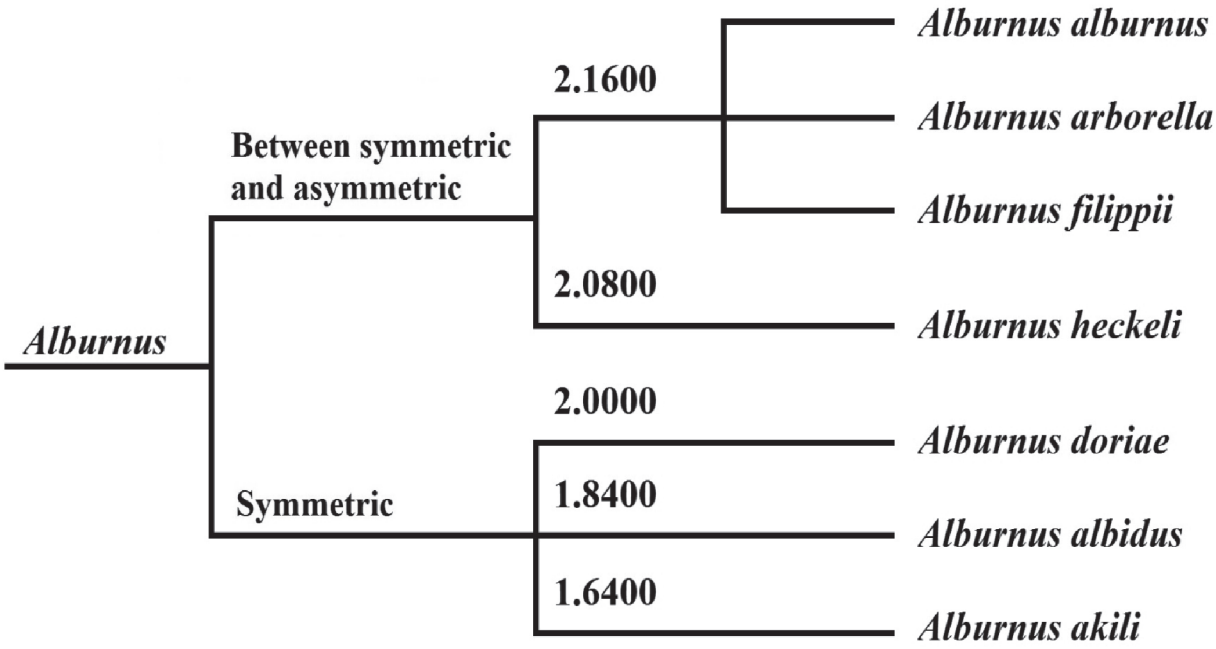
In Table 2 the diploid chromosome number of all *Alburnus* species is *2n* = 50. This number is most commonly found in Cyprinidae species (Collares-Pereira, 1989). However, it is reported that there are four different models of chromosomes including tetraploidy *2n* = 100, hexaploidy *2n* = 150 and octaploidy *2n* = 200 (Nahavandi et al., 2001). Also, the sex chromosomes could not be identified.

Table 2. The karyotype formulae, index values and karyotype types of the species

No	Scientific name	*2n*	Chromosome formula	S/A_I	Karyotype type	References
1	*Alburnus akili*	50	18M + 32SM	1.6400	Symmetric	Arkhipchuk, 1999
2	*Alburnus albidus*	50	16M + 26SM + 8ST/A	1.8400	Symmetric	Bianco et al., 2004
3	*Alburnus alburnus*	50	14M + 14SM + 22ST/A	2.1600	Between symmetric and asymmetric	Schmid et al., 2006
4	*Alburnus arborella*	50	16M + 10SM + 24ST/A	2.1600	Between symmetric and asymmetric	Cataudella et al., 1977
5	*Alburnus doriae*	50	18M + 14SM + 18ST/A	2.0000	Symmetric	Arkhipchuk, 1999
6	*Alburnus filippii*	50	12M + 18SM + 20ST/A	2.1600	Between symmetric and asymmetric	Nazari et al., 2009
7	*Alburnus heckeli*	50	14M + 18SM + 18A	2.0800	Between symmetric and asymmetric	Gül et al., 2004
8	*Alburnus caeruleus*	50	Unknown			Klinkhardt et al., 1995
9	*Alburnus escherichii*	50	Unknown			Klinkhardt et al., 1995
10	*Alburnus hohenackeri*	50	Unknown			Klinkhardt et al., 1995
11	*Alburnus nasreddini*	50	Unknown			Vasil'ev, 1980
12	*Alburnus orontis*	50	Unknown			Vasil'ev, 1980
13	*Alburnus qalilus*	50	Unknown			Vasil'ev, 1980
14	*Alburnus scoranza*	50	Unknown			Vasil'ev, 1980
15	*Alburnus sellal*	50	Unknown			Klinkhardt et al., 1995
16	*Alburnus tarichi*	50	Unknown			Vasil'ev, 1980

Abbreviations: M, metacentric; SM, submetacentric; A, acrocentric; ST, subtelocentric.

Figure 1. Phylogenetic tree showing relationships of the index values among the genus *Alburnus*.



In Figure 1 the karyotype types of *Alburnus alburnus*, *Alburnus arborella*, *Alburnus filippii* and *Alburnus heckeli* are between symmetric and asymmetric. Although between symmetric and asymmetric, the index value (2.0800) of *Alburnus heckeli* is different from other *Alburnus* species (2.1600). Perea et al. (2010) reported that the phylogenetic trees presented by Bayesian analysis of the mitochondrial cytochrome b gene, mitochondrial cytochrome oxidase I gene, nuclear dataset (RAG1+S7 genes) and all genes data set (Cytochrome b, cytochrome oxidase I, RAG1+S7 genes). *Alburnus alburnus*, *Alburnus arborella* and *Alburnus filippii* are located close in all phylogenetic trees (Perea et al. 2010). These data are consistent with Figure 1. Durand et al. (2002) reported that a phylogenetic tree presented with cytochrome b sequences. *Alburnus alburnus*, *Alburnus escherichii* and *Alburnus hohenackeri* are located close in the phylogenetic tree (Durand et al., 2002). It is not known chromosome formula of *Alburnus escherichii* and *Alburnus hohenackeri* in Table 2.

Alburnus alburnus, *Alburnus arborella* and *Alburnus filippii* have the same index value, but the chromosome formulae are different. The chromosome formulae are 14M + 14SM + 22ST/A, 16M + 10SM + 24ST/A and 12M + 18SM + 20ST/A, respectively (Cataudella et al., 1977; Nazari et al., 2009; Schmid et al., 2006).

In Figure 1 the karyotypes types of *Alburnus akili*, *Alburnus albidus* and *Alburnus doriae* are symmetric. The symmetrical karyotypes are characterized by more metacentric and submetacentric chromosomes (Eroğlu, 2015). While *Alburnus doriae* has the highest index value with 2.000, *Alburnus akili* has the lowest index value with 1.6400 at symmetric type.

There is no data about these species in other phylogenetic trees (Durand et al., 2002; Perea et al. 2010).

As a result, the karyotypes of genus *Alburnus* were used for the comparison with karyotype symmetry/asymmetry index. However, more detailed karyotype researches are required in all *Alburnus* species to determine their intraspesific variation and role in evolution. The karyotype analysis is important for fish breeding from the viewpoint of genetic control, taxonomy and evolution studies.

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