70. Karyotypic Studies of Five Species of *Anguilliformes* (Pisces)

By Akinori TAKAI and Yoshio OJIMA

Department of Biology, Faculty of Science,
Kwansei Gakuin University, Nishinomiya 662

(Communicated by Sajiyo MAKINO, M. J. A., June 11, 1985)

Only ten of approximately six hundred known species of *Anguilliformes* (Nelson, 1984), have been cytogenetically studied (Ojima, 1985, Fish CDR List). The cytogenetical results have suggested some attractive problems related to the karyotype evolution and the sex chromosome differentiation in this order. The present paper deals with karyotypic studies in two species of the Congridae, *Conger japonicus* "Kuro-anago" and *Alloconger anagoides* "Hana-anago", and three species of the Muraenidae, *Muraena pardalis* "Tora-utsubo", *Gymnothorax kidako* "Utsubo", and *G. eurostus* "Waka-utsubo".

Materials and methods. The five species used in the present study are given in Table I. The chromosome preparations were made according to the kidney culture method after Yamamoto and Ojima (1973) and the direct method with the kidney tissue (Ojima, 1982). The BSG method after Sumner (1972) was also employed for C-banding analysis.

Table I. The karyotype constitution of the five species studied

species	CN	NF	Karyotype	No. of specimens
Congridae				
<i>Conger japonicus</i>	38	58	10M+10SM+18A	♀2
<i>Alloconger anagoides</i>	34	52	10M+8SM+6ST+10A	♀1
Muraenidae				
<i>Muraena pardalis</i>	42	52	8M+2SM+32A	1
<i>Gymnothorax kidako</i>	36	60	16M+8SM+12A	2
<i>Gymnothorax eurostus</i>	42	54	12M, SM+30A	♂3, ♀1

CN, chromosome number; NF, fundamental number; M, metacentrics; SM, submetacentrics; ST, subtelocentrics; A, acrocentrics. Only *G. eurostus* was collected at Kuro-shima, Yaeyama Islands, Okinawa Prefecture, and the other four species were obtained at Kushimoto, Wakayama Prefecture.

Results and discussion. Figs. 1–5 show the karyotypes of the five species and their chromosomal constitutions are summarized in Table I. In *Conger japonicus* and *Alloconger anagoides*, the second largest submetacentric pair commonly showed heteromorphism characterized by a slight difference in the centromeric position (Figs. 1 and 2, arrows). In the heteromorphic pair of *A. anagoides*, only the member with the larger short arm displayed an intensely stained C-band at the centromeric region (Fig. 2C). Also in *G. eurostus*, a pair of the heteromorphic chromosomes was present in the males (Fig. 5, arrow), but not in the female. No characteristic C-banding pattern was found in this heteromorphic pair (Fig. 5C).

Figs. 1-5. 1-2: The female karyotypes of *Conger japonicus* (1) and *Alloconger anagoides* (2). Arrows show the heteromorphic pairs. 3-4: The karyotypes of *Muraena pardalis* (3) and *Gymnothorax kidako* (4). 5: The male karyotype of *G. eurostus*. An arrow shows the heteromorphic sex chromosome complements comprized X and Y. C in Figs. 2 and 5 indicates the C-banding patterns of the heteromorphic pairs.

The karyotypic studies have been carried out in about ten species of Anguilliformes (Table II). It is clear from these results that the diploid chromosome number of most species is 38 or near to 38. The same was also found in the five new species reported in this study. This feature was quite different from that found in the majority of fish orders. A marked similarity of the karyotype was observed among the species of the Anguillidae and the Congridae. The karyotype of *C. japonicus* in this study resembled these species and was nearly identical with that of *C. myriaster* reported by Park and Kang (1979). This karyotypic similarity may reflect the close relationship between these two families. The karyotype of *A. anagoides* seems to be more differ-

Table II. The chromosome number (CN) and fundamental number (NF) of anguilliform fishes reported so far

	CN	NF		CN	NF
Anguillidae			Muraenidae		
<i>Anguilla anguilla</i>	38	60	<i>Sideria picta</i>	42	42
	38	58	Synaphobranchidae		
<i>A. rostrata</i>	38	60	<i>Synaphobranchus kaupii</i>	26	50
	38	58	Muraenesocidae		
<i>A. australis</i>	38	60	<i>Muraenesox cinereus</i>	38	54
	38	58	Ophichthidae		
<i>A. japonica</i>	38	58	<i>Muraenichthys gymnotus</i>	48	48
Congridae			<i>Ophisurus macrorhynchus</i>	38	76
<i>Conger myriaster</i>	38	58	<i>Pisoodonophis zophistius</i>	38	68
	38	56			

References are cited in "Fish CDR List" (Ojima, 1985).

entiated. The karyotypic comparison between *C. japonicus* and *A. anagoides* indicated that the two larger subtelocentric pairs in *A. anagoides* could have resulted from the tandem fusions between submetacentrics and acrocentrics, with a consequent decrease in the diploid chromosome number from 38 to 34. Furthermore, the comparison suggested that in addition to this tandem fusion the occurrence of the pericentric inversions in two small acrocentric pairs, can lead to the evolution of the karyotype of *A. anagoides* from that of *C. japonicus*. This means also that the chromosomes not involved in karyotype changes are homologous in the two species and therefore that the heteromorphic pairs are homologous. It is clear from the karyotypic comparisons among the species in Tables I and II that the diversity of these karyotypes has been brought about mainly by the pericentric inversions and Robertsonian rearrangements. The present investigation revealed that the tandem translocations as well as these chromosomal rearrangements also might have performed an important role throughout the karyotypic differentiation of eels. On the other hand, a noticeable fact emerging from the karyotypic comparison of the three muraenids was that the karyotype of *G. eurostus* resembled that of *M. pardalis* which belongs to the different genus, but was quite different from that of *G. kidako* in the same genus.

Ojima and Ueda (1982) reported that the second largest submetacentric pair in *C. myriaster* was the sex specific heteromorphic chromosomes of ZZ-ZW type characterized by a slight difference in the centromeric region which, on the basis of C-banding analysis, could have arisen by the pericentric inversion. This heteromorphic condition was very similar to those of *C. japonicus* and *A. anagoides*. The differences of the C-banding patterns of the heteromorphic pair in *A. anagoides* also could have resulted from the pericentric inversion. Ohno (1967) stated that the morphological differentiation by the pericentric inversion was one of the first steps toward the sex chromosome differentiation. Furthermore, the heteromorphic pair in these three species was usually in the second largest submetacentric pair, which seemed to be homologous in the three species as suggested above. So far as these findings were concerned, the heteromorphic pair in *C. japonicus* and *A. anagoides* seems to be sex specific and probably exists in an initial stage of the sex chromosome differentiation. On the other

hand, the heteromorphic pair in *G. eurostus* is considered to comprise the X and Y sex chromosome complements. This heteromorphism would have differentiated through over two steps of the structural rearrangements. However, no appearance of the heterochromatization related to the sex chromosome differentiation was found.

Acknowledgement. We are grateful to Dr. Sajiyo Makino, M. J. A., Professor Emeritus, Hokkaido University, for going over the manuscript with invaluable advice.

References

- Nelson, J. S. (1984): *Fishes of the World*. 2nd ed., John Wiley & Sons, New York, 523 pp.
- Ohno, S. (1967): *Sex Chromosomes and Sex-Linked Genes*. Springer-Verlag, New York, 192 pp.
- Ojima, Y. (1982): *The Nucleus*, **25**, 1-7.
- (1985): Fish CDR List. Dep. of Biol., Fac. of Sci., Kwansei Gakuin Univ.
- Ojima, Y., and Ueda, H. (1982): *Proc. Japan Acad.*, **58B**, 56-59.
- Park, E.-H., and Kang, Y. S. (1979): *Cytogenet. Cell Genet.*, **23**, 33-38.
- Sumner, A. T. (1972): *Exp. Cell Res.*, **75**, 304-306.
- Yamamoto, K., and Ojima, Y. (1973): *Jpn. J. Genet.*, **48**, 235-238.