Karyotypes of Two Species in the Order Torpediniformes

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About thirty species of elasmobranchs have been studied for their karyotypes. Elasmobranchs are various in the number of chromosomes and show a complicated composition of chromosome shape and size. A detailed comparison of karyotypes of the group was made by Stingo (1979).

Karyotypes of three species in the order Torpediniformes have been observed (Donahue, 1974; Stingo, 1979). The results were rather interesting because two species of the genus *Torpedo* have about 80 diploid chromosomes while a species of the genus *Narcine* has only 28, which is the smallest count among the elasmobranchs so far as reported.

We analyzed karyotypes of the two torpediniform species, *Narke japonica* and *Torpedo californica*. The karyotype of *Narke japonica* is intermediate between those of *Torpedo* and *Narcine* in the diploid number and shapes of chromosomes, providing some clues for karyological relationships of the Torpediniformes. Details are described below.

Materials and methods

Materials used in the present study are as follows: *Narke japonica* (female, 193 mm in total length [TL], 96 mm disc length [DL], 140 g BW) was hand-netted using SCUBA at Futo, Izu Peninsula, on April 5th, 1981. *Torpedo californica* (female, 103 cm TL, 53 cm DL, 18.8 kg BW) was collected by a set net at Sanriku-cho, Iwate Prefecture, on November 19th, 1981. Additional samples of *Narcine maculata* and *N. timlei*, collected from the South China Sea by a trawl net, were also used for comparison of meristic characters. Counts for the vertebrae and fin supporting elements were based on X-ray photographs. Vertebrae anterior to the anus were regarded as abdominal ones. For the observation on chromosomes, the conventional air drying method was used for *Narke japonica*. The *in vitro* method (Ida *et al.*, 1978) was adopted for *Torpedo californica* due to its large size. Classification of chromosomes followed Levan *et al.* (1964). Meta- and submetacentric chromosomes are treated as two-arm ones and subtelocentric and acrocentrics as one-arm ones.

Torpedo californica was recorded for the first time from Japanese waters. Another female specimen, 127 cm TL, was also captured from the same locality with the specimen used for chromosome observations on May 20th, 1983. The diagnostic characters of this species are shown below.

Torpedo californica Ayers

(New Japanese name: Gomafu-shibire-ei)
(Fig. 1)

Diagnosis. Body width about 1.4 times its length (1.1 to 1.2 times in *T. tokionis*); anterior half of the first dorsal base over base of pelvic (first dorsal over middle of pelvic); dorsal bluish-grey, lighter posteriorly with numerous black spots of various sizes, belly milky white with sparse black spots (dorsal dark blue without any speckle, belly whitish); posterior margin of caudal vertical (distinctly emarginate).

Description. Disc oval, wider than long. Dorsal and belly perfectly smooth, without any tubercles nor ridges. A ventro-lateral skinfold developed from before origin of 2nd dorsal to caudal base. Eye small, about 1/6 interorbital. Interorbital slightly shorter than snout. Spiracle about twice of eye diameter, distance between two spiracles equal to interorbital width. Mouth small, width about 1/8 disc length. Teeth on jaws minute, about 6 rows in longitudinal and 10 in oblique series, each

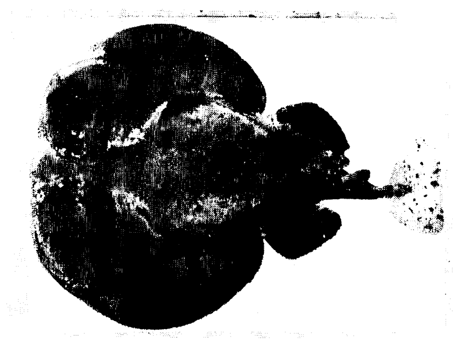

Fig. 1. Dorsal view of *Torpedo californica*, 103 cm TL, from Sanriku-cho, Iwate Prefecture.

Table 1. Distribution of chromosome counts for two species of the order Torpediniformes.

Species	Chromosome count											Number of cells observed
	36	37	38	42	47	48	50	51	52	53	54	
Narke japonica	3	2	1	1	1	1	1			2	6	18
Torpedo californica	<74	75	76	77	78	79	80	81	82	83	84	
	4	1	1				1		4	1	1	13

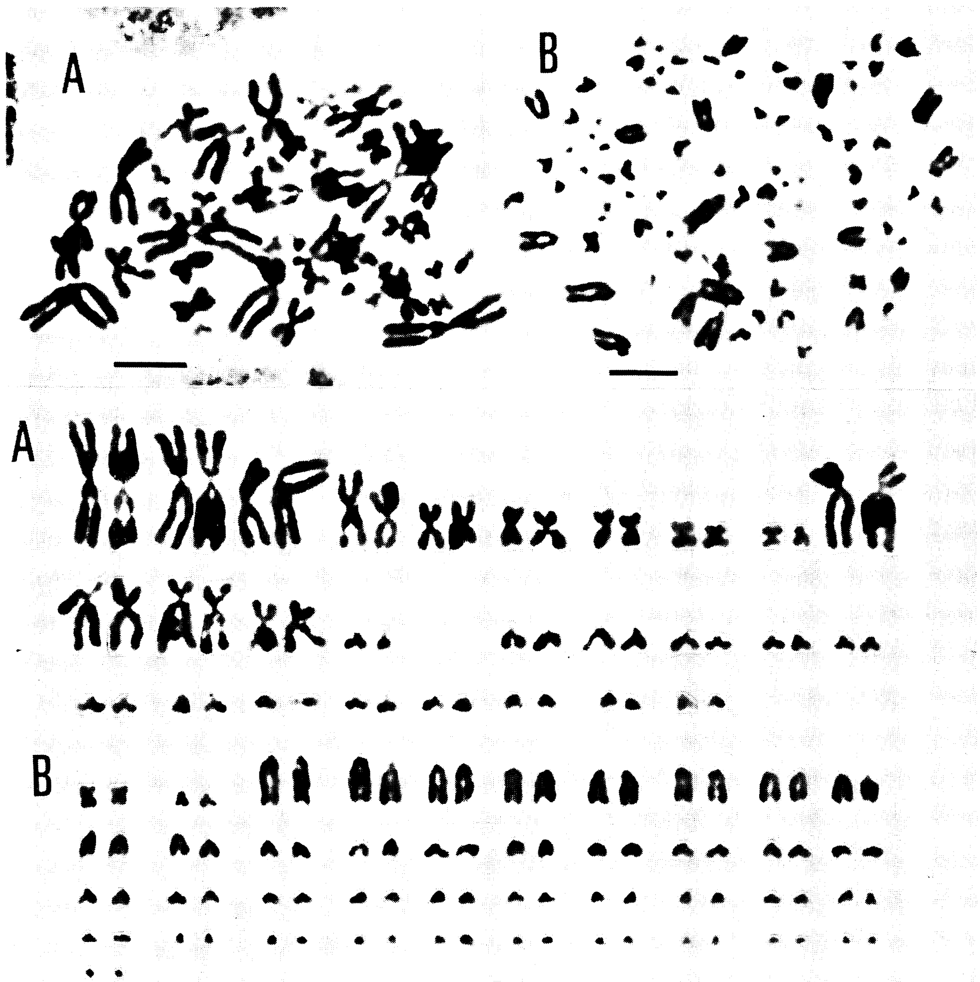

Fig. 2. Chromosome spreads and karyotypes of two species of torpedinids. A, *Narke japonica.* B, *Torpedo californica.* Bars indicate 10 μm.

tooth with a sharp point. About 30 papillae present behind toothbands of jaws. Nasal with 26 outer and 24 inner olfactory lamellae. Second dorsal small, its height about 1/2 of that of the 1st. Interspace between 1st and 2nd dorsal fins about 3/4 of base of 1st dorsal. Caudal fin large, as wide as pelvic, its height larger than distance between caudal base and 1st dorsal origin.

Results

The numbers of chromosome figures gained for each species are shown in Table 1. Details of their karyotypes are as follows.

Narke japonica (Fig. 2A). Several female specimens were sacrificed for chromosome observations, but only one individual provided good chromosome figures for the analysis. The overall karyotype of the species is similar to the usual selachian type in having numerous large to medium-sized metacentric chromosomes and the absence of large acrocentric or subtelocentric chromosomes. The karyotype consists of 28 meta- or submetacentric and 26 acrocentric or subtelocentric chromosomes. The fundamental number is 82.

Torpedo californica (Fig. 2B). Two specimens were available for chromosome observations but a single individual offered chromosome figures for the analysis. The overall feature of the karyotype resembles that of *Raja* spp. in numerousity of acrocentric chromosomes of various sizes and absence of large metacentric chromosomes. The karyotype consists of four small metacentric and 78 acrocentric chromosomes. The acrocentrics change their sizes gradually from 0.82 to 7.3 μm. The fundamental number is 86.

The vertebral composition and the numbers of supporting elements of fins were selected as the meristic characters (Table 2). Most elements showed rather wide variations and there were no apparent features specific to these genera.

Discussion

The karyotype and DNA content of the torpedinids are summarized in Table 3. Data are not available for genome size of the genus *Narke*. The most salient feature of the karyotypes in the torpedinids is diversity of the number of chromosomes. The highest chromosome count among this group was observed in *Torpedo marmorata* having only acrocentric chromosomes (2n=86, Stingo, 1979), while the smallest count was observed in *Narcine brasiliensis* (2n=28, Donahue, 1974) showing only metacentrics.

The genome sizes of *Torpedo* and *Narcine* are 14.0 to 15.0 pg and 8.4 pg respectively. These values suggest the tetraploid origin of *Torpedo* from an ancestral form having about 8 pg in genome size.

Recently, Olmo *et al.* (1982) analyzed the DNA reassociation kinetics in six species of four genera, viz. *Raja*, *Torpedo*, *Dasyatis* and *Oxynotus*, and suggested the polyploid origin of *Torpedo* and *Oxynotus* on the basis of high concentration of repeated DNA sequences.

Table 2. Selected morphological characters of torpedinid fishes. Figures in parentheses show the modal counts.

Species	Vertebrae			Fin radials			
	Abdominal	Caudal	Total	P_1	P_2	D_1	D_2
Narcine timlei	36	76	112	25	19	5	8
Narcine maculata	45	73	117	29	15	7	9
Narke japonica	34–37 (35)	60–64 (62)	94–98 (97)	33–37 (35)	16–19 (18)	0	6–7 (6)
Torpedo californica	43	72	115	35	19	11	6

Table 3. Karyotypes and genome sizes of torpedinid fishes.

Species	2n	M	A	FN	DNA (pg)	Reference
Narcine brasiliensis	28	28	0	56	8.4**	Donahue (1974)
*Narke japonica**	54	28	26	82		Present study
Torpedo ocellata	66	12	54	78	11.0-15.0***	Stingo (1979)
Torpedo californica	82	4	78	86	14.6**	Present study
Torpedo marmorata	86	0	86	86	14.0***	Stingo (1979)

* Ida (1984) reported the karyotype of the species 2n=36 (M=20, A=1p), but his analysis was based on an improper chromosome figure.

** Hinegardner (1976).

*** Stingo (1980).

The karyotypes of *Torpedo ocellata* and *Narke japonica* include larger meta- or submetacentric chromosomes and their sizes apparently suggest their centric fusion origin. Fundamental numbers of the two species are 78 and 86 respectively. While fundamental numbers of *T. marmorata* and *T. californica* are both 86 and their karyotypes lack larger meta- or submetacentric chromosomes.

The karyotype of *Narcine brasiliensis* consists of 16 larger and 12 smaller metacentric chromosomes. Fission of the larger elements will result in 44 small to medium-sized chromosomes becoming close to the haploid number of *Torpedo* spp.

Thus fishes listed in the Table 3 may be divided into two groups, viz. a group with about 80 fundamental number and of 14–15 pg DNA, *Torpedo* and *Narke*, and the other with 56 fundamental number and of 8 pg, *Narcine*.

The systematic status of the Torpediniformes should be taken into consideration. In conventional way, classification of this group was based mainly on the number of dorsal fins but this character has been regarded as less important. Bigelow and Schroeder (1953) suggested the importance of jaw structure, e.g. mode of articulation and the absence or presence of labial cartilages. Compagno (1973) classified the group into two superfamilies, Torpedinoidea (including *Torpedo*, *Narke* and *Temera* etc.) and Narcinoidea (*Narcine*), with the skeletal characters and pointed out the peculiarity and primitiveness of the order Torpediniformes, e.g. the presence of a hyomandibula-ceratohyal connection in the order while all other sharks and rays lack the connection, and a well developed antorbital cartilage in the order. Tsumura (unpublished) also emphasized the peculiarity of the genus *Narke* among seven genera of batoids on the basis of the analysis of skeletal structures.

The meristic characters of the three genera of the order Torpediniformes shown in Table 2 provide little clue for the discrimination of a genus from the rest.

Fishes of the Torpedinoidea have the following features: labial cartilage and ceratohyal are present, rostrum is reduced, and jaws are reduced with weak dentition. On the other hand, in fishes of the Narcinoidea, these elements are present or not reduced. Thus the Torpedinoidea seem to have been derived from the Narcinoidea or a Narcinoidea-like ancestor.

In addition to these morphological characters, the polyploid origin suggested by Olmo *et al.* (1982) implies that its ancestor might have half amount of DNA at the level of *Torpedo* and so as for the number of chromosomes.

On the whole, the system proposed by Compagno (1973) seems in accordance with the karyological evidence mentioned above. And the following karyological change among the order Torpediniformes is suggested:

Suspected ancestral form, 2n=40–50 acrocentrics, ca 8 pg DNA/cell

A_1 Reduction of the diploid number by centric fusion. 2n=28 mostly metacentrics, 8.4 pg .... *Narcine*

A_2 Tetraploidization from the ancestral form.

B_1 Slight modification in karyotype by centric or tandem fusion. 2n≒80 mostly acrocentrics, 14–15 pg................*Torpedo*

B_2 Prominent reduction of diploid number by centric fusion. 2n=54, ca 15 pg?...*Narke*

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シビレエイとゴマフシビレエイ（新称）の核型

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シビレエイ類2種の核型を air-drying 法により分析した．シビレエイの核型は 2n=54, 中部～次中部着糸型染色体 (M～SM)=28, 端部～次端部着糸型染色体 (A～ST)=26, 腕数 (FN)=82 であり，ゴマフシビレエイでは 2n=82, M～SM=4, A～ST=78, FN=86 であった．

核型について分析されたシビレエイ類3属は腕数で約 80 (78～86) の *Torpedo, Narke* 群と 56 の *Narcine* 属の2群に分けられる．ゲノム量については *Torpedo* 属で 14.0～15.0 pg DNA/cell, *Narcine* 属で 8.4 pg の値が報告されており，核型の検討から *Torpedo, Narke* 群の倍数性起源が推定された．

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