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Hermaphroditism in the Lantern Shark *Etmopterus unicolor* (Squalidae, Chondrichthyes)

Kazunari Yano and Sho Tanaka

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Abstract Of the 70 specimens of the lantern shark, *Etmopterus unicolor*, collected in Suruga Bay and adjacent waters 22.9% were abnormal hermaphrodites, 30.0% normal males, and 47.1% normal females. Fifteen hermaphrodites had female reproductive organs composed of normal ovaries, oviducts, nidamental glands and uteri as well as claspers. The clasper lengths of these hermaphrodites increased rapidly after the sharks reached 510 mm TL, the length about equal to the size at maturity for normal females. The ovary and uterus of abnormal females became mature at a total length greater than 500 mm, whereas the size at maturity was about 500 mm TL for normal females compared to 460 mm TL for normal males. In one specimen, the left gonad contained both ovarian and testicular tissues, the bulk of which was testicular.

The lantern shark, *Etmopterus unicolor*, belongs to the family Squalidae. Although this species has usually been recorded from waters deeper than 800 m (Yano and Tanaka, 1983) there is little other information on its biology (Compagno, 1984). Hermaphroditism in *E. unicolor* has not been previously mentioned in the literature and is apparently rare in other elasmobranchs (Atz, 1964; Pratt, 1979). However, of the 70 specimens of *E. unicolor* collected in Suruga Bay and adjacent waters, 22.9% (16 specimens) were abnormal hermaphrodites.

Materials and methods

Specimens were caught with bottom drop lines, bottom longlines, and bottom trawl nets in water depths between 250 m and 1,270 m in Suruga Bay and Enshu-nada, during the period from June, 1980 to October, 1985 (Fig. 1). Six additional specimens were caught with bottom longlines and bottom trawl nets from Kumano-nada (34°00′N, 136°20′E, 600–700 m in depth), off Choshi (35°30′N, 141°20′E, 350–450 m in depth) and off Oshima Island (34°28′N, 139°38′E, 897–904 m in depth) from May, 1977 to February, 1985 (Fig. 1). The specimens examined included one abnormal male, 15 abnormal females, 21 normal males, and 33 normal females. For size frequency analysis the specimens were grouped by size at 10 mm intervals. We considered females to be immature if they possessed ova less than 10 mm in diameter and threadlike uteri. Mature females either had ova larger than 10 mm in diameter or expanded uteri greater than 10 mm in width, or contained embryos or fertilized ova in the uteri (i.e., were pregnant). We considered males to be mature if they possessed sperm in seminal vesicles and sperm sac, and calcified claspers with spurs. Identification of males was possible in embryos over 60 mm TL because of the presence of claspers observable with the naked eye.

Clasper length was measured from the anterior end of the cloaca to the distal tip of the clasper. Length of the siphon sac was measured from the anterior end of the clasper groove to the proximal end of the sac. Clasper elements were cleared and stained following the method of Dingerkus and Uhler (1977). Terminology of the clasper elements followed Gilbert and Heath (1974) with the addition of the term accessory cartilage. The ovary of normal and abnormal females was observed with the naked eye, but the testis was cut into 6 μm paraffin sections and stained with Mayer's hematoxylin and eosin by routine procedure. The spermatogenic cells were divided into four types: spermatogonia, spermatocytes, spermatids, and spermatozoa (Yano and Tanaka, 1987).

Results and discussion

Fifteen hermaphroditic specimens of *E. unicolor* had normal female reproductive organs composed

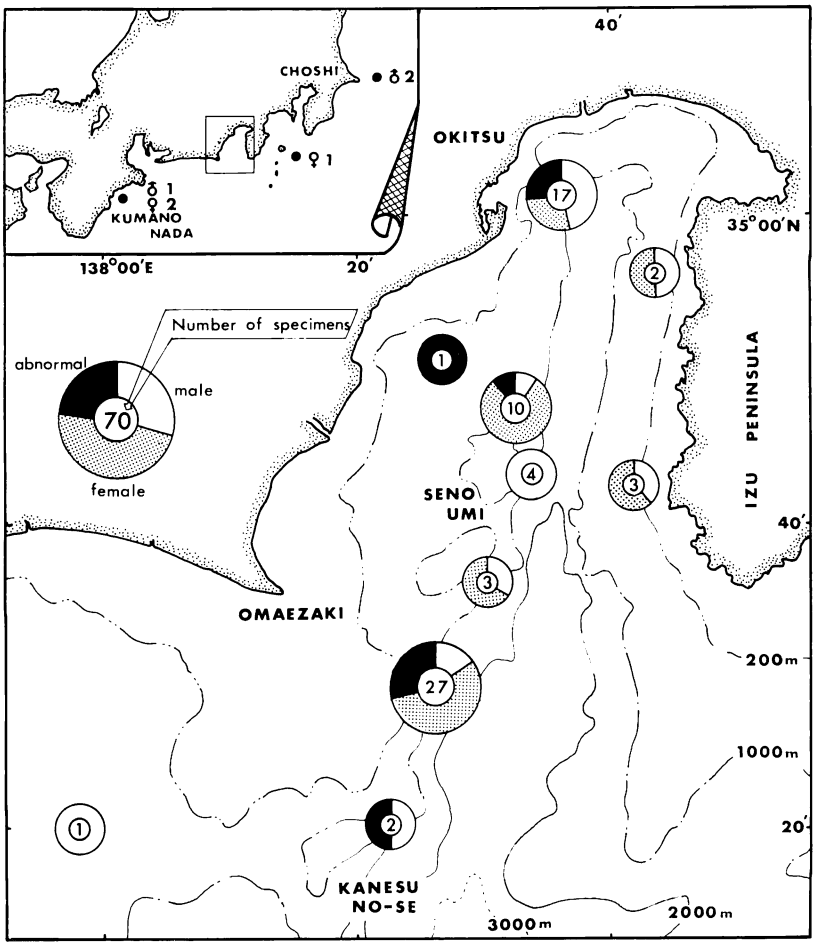

Fig. 1. Catch localities of *Etmopterus unicolor* in Suruga Bay and adjacent regions and the proportions of abnormal individuals (filled), normal males (open) and normal females (stippled) from each locality.

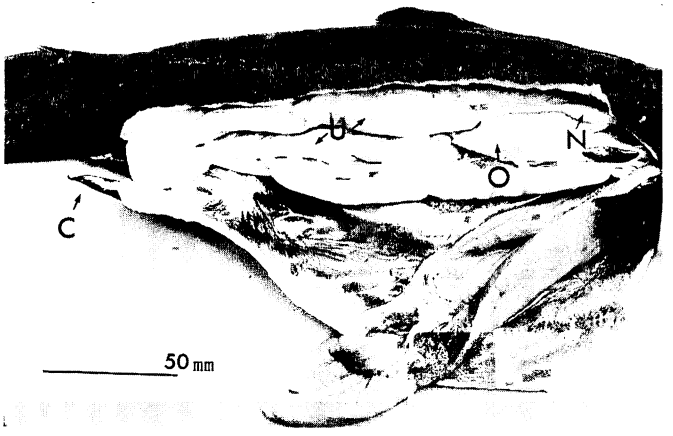

Fig. 2. An abnormal hermaphrodite with normal female reproductive organs and claspers. C, clasper; N, nidamental gland; O, ovary; U, uterus.

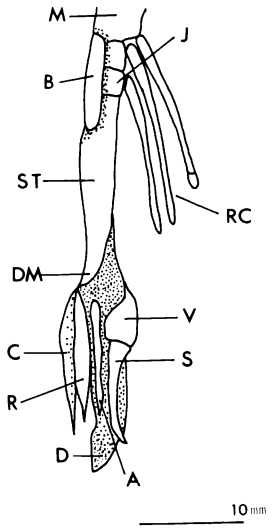

Fig. 3. Skeleton of the clasper of an abnormal hermaphrodite of *Etmopterus unicolor* (specimen No. 6 in Table 1). A, accessory cartilage; B, beta cartilage; C, claw; D, distal basal; DM, dorsal marginal cartilage; J, joint cartilage; M, metapterygium; R, rhipidion; RC, radial cartilage; S, spur; ST, stem cartilage; V, ventral marginal cartilage.

of ovaries, oviducts, nidamental glands and uteri, but they also possessed claspers (Fig. 2). One (No. 6 in Table 1) had large claspers complete with clasper grooves and siphon sacs. The clasper was attached to the metapterygium of the pelvic fin by means of the intermediate elements. The cleasper skeleton (Fig. 3) was composed of three intermediate elements (i.e., two joint cartilages and one beta cartilage), one main stem cartilage, two marginal (i.e., dorsal and ventral) cartilages, and five terminal cartilages. The two marginal cartilages were fused to the stem cartilage. The five terminal cartilages which were located distal to the stem cartilage, consisted of a claw, rhipidion, distal basal, spur, and an accessory cartilage (Fig. 3). The claw and spur were hard and well calcified. The above-mentioned structure appeared to be normal and complete. The clasper lengths of one abnormal specimen (No. 6 in Table 1) were 42 mm (left) and 43 mm (right) (Table 1). Five specimens (Nos. 4, 8, 9, 11 and 15) had a pair of similar-sized claspers (31–45 mm) complete with clasper grooves and siphon sacs, and three (Nos. 1, 5, and 10) had a pair of similar-sized claspers

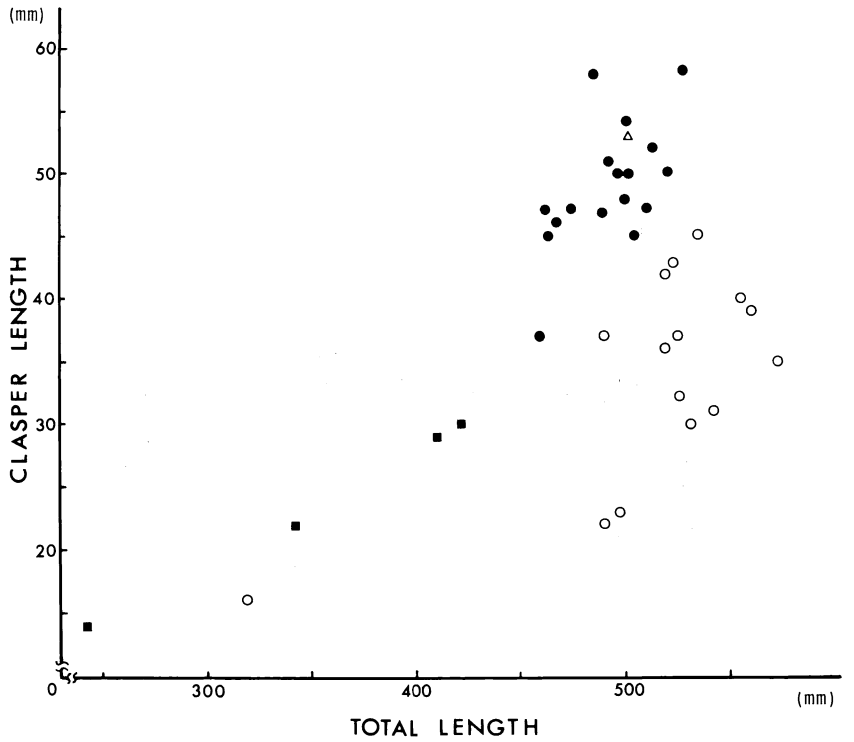

Fig. 4. Relationship between clasper length and total length of abnormal and normal *Etmopterus unicolor*. ○, abnormal females; △, abnormal males; ●, normal mature male; ■, normal immature male.

Table 1. Capture data and condition of reproductive organs of abnormal hermaphroditism in *Etmopterus unicolor*. long, bottom longline; drop, bottom drop line; L, left; R, right; +, present; −, absent

No.	TL (mm)	BW (g)	Date	Fishing depth (m)	Fishing gear	Clasper length (mm)		Siphon sac length (mm)		Clasper groove		Max. width of uterus (mm)		Max. diameter of ovum (mm)		Appearance	Maturity or stage
						L	R	L	R	L	R	L	R	L	R		
1	319	140	9/11/1982	450–950	long	16	16	—	—	—	—	1	1	1	1	female	immature
2	490	630	3/ 6/1981	1120	drop	37	—	—	—	—	—	5	5	5	5	female	immature
3	490	495	9/11/1982	450–950	long	—	22	—	—	—	—	2	2	1	1	female	immature
4	542	720	8/11/1984	870–960	long	31	31	9	10	+	+	6	7	5	5	female	immature
5	498	710	9/11/1982	450–950	long	22	23	—	—	—	—	9	9	10	11	female	mature
6	523	530	9/11/1982	450–950	long	42	43	31	35	+	+	22	21	2	3	female	mature
7	528	520	9/11/1982	450–950	long	32	—	—	—	—	—	25	25	5	5	female	mature
8	555	820	9/11/1982	450–950	long	38	40	—	14	—	+	12	12	15	15	female	mature
9	560	620	9/11/1982	450–950	long	39	34	6	—	+	—	15	10	5	5	female	mature
10	573	850	7/11/1984	1200–1270	long	32	35	—	—	—	—	18	18	10	10	female	mature
11	519	750	17/ 7/1980	665–720	long	41	42	19	19	+	+	28	28	5	5	female	pregnant
12	519	800	19/10/1985	760–780	long	—	36	—	—	—	—	50	50	3	3	female	pregnant
13	525	860	7/11/1980	525–860	long	—	37	—	—	—	—	35	30	5	5	female	pregnant
14	532	—	29/ 7/1981	630–645	long	—	30	—	—	—	—	35	45	3	3	female	pregnant
15	535	935	5/ 6/1980	690–790	long	45	45	24	24	+	+	45	45	1	1	female	pregnant
16	501	590	22/12/1981	1200	drop	53	53	46	46	+	+	—	—	—	15	male	mature

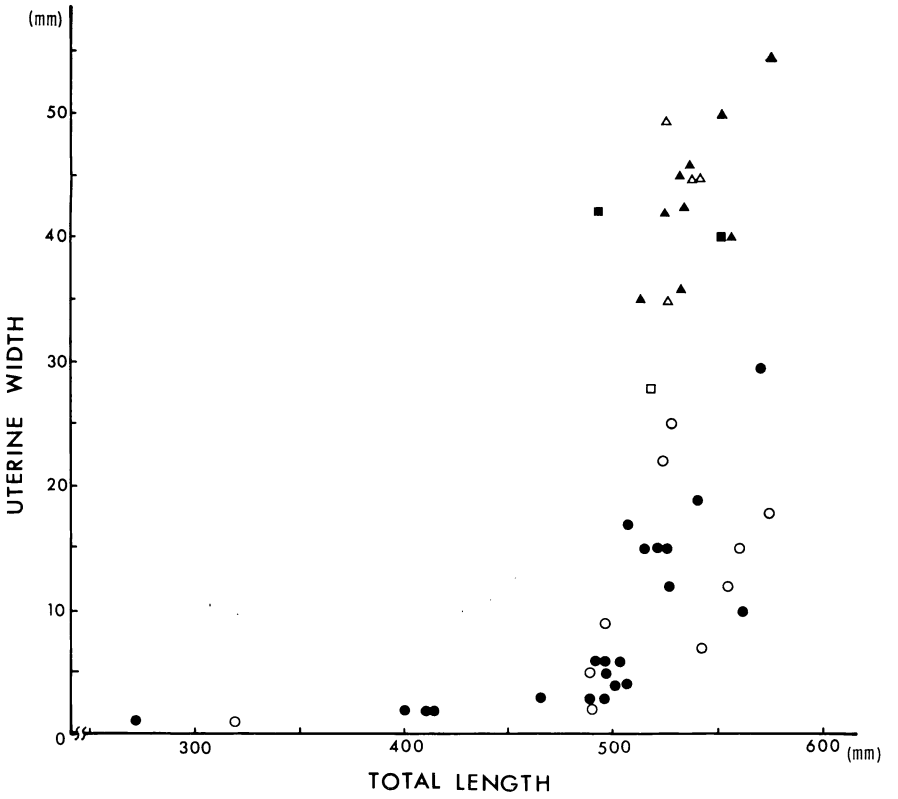

Fig. 5. Relationship between uterine width and total length of abnormal and normal *Etmopterus unicolor*. ○, abnormal female; □, recently ovulated abnormal female; △, abnormal pregnant female; ●, normal female; ■, recently ovulated normal female; ▲ normal pregnant female.

but lacked clasper grooves and siphon sacs. The claspers of these eight specimens were soft and uncalcified. The remaining six specimens (Nos. 2, 3, 7, 12, 13 and 14) possessed a single short clasper which was uncalcified and lacked clasper grooves as well as terminal cartilages.

Atz (1964) reviewed the occurrence of hermaphroditism in elasmobranchs and documented its presence in two species, *Centrophorus lusitanicus* and *Squalus acanthias*, of the family Squalidae. He mentioned that one specimen of *C. lusitanicus* had normal female reproductive organs with claspers. Yano (1985) reported that one specimen of *Centroscymnus owstoni* from Suruga Bay had normal female reproductive organs and a single short, uncalcified clasper with a clasper groove. In other taxonomic groups, *Scyliorhinus caniculus* (Atz, 1964) and *Carcharhinus leucas* (Gruber and Morressey, per. comm.) had normal female reproductive organs and claspers. All these cases of hermaphroditism are similar to the present 15 specimens of *E. unicolor*.

The clasper lengths of 17 normal mature males with terminal cartilages varied from 37 mm to 63 mm, and those of 4 normal immatures without terminal cartilages varied from 14 mm to 30 mm (Fig. 4). The clasper lengths of 15 abnormal females varied from 16 mm to 45 mm (Fig. 4). The lengths of the siphon sacs of normal mature males were 37 mm to 52 mm, those of normal immature males 7 mm to 27 mm, and those of abnormal females 6 mm to 35 mm.

The clasper lengths of the normal males increased rapidly in sharks longer than 460 mm TL (Fig. 4). All normal males over 458 mm TL were completely mature. Therefore, normal males appear to reach maturity at about 460 mm TL (Fig. 4). The clasper lengths of the abnormal females increased rapidly after about 510 mm TL, the length about equal to the size at maturity of

Fig. 6. Gonad of an abnormal hermaphrodite, with an ovum (Ov) attached to the testicular region (T).

normal females. Eleven of the 12 abnormal females were mature in the size range of 498–573 mm TL (Table 1). One (542 mm TL) of these abnormal females was judged to be immature.

Uterine widths increased rapidly with the onset of maturity. The uterine widths of normal females increased at about 500 mm TL (Fig. 5). Proportions of maturity of normal females were 16.7% for 6 specimens of 490–499 mm TL, 20.0% for 5 specimens of 500–509 mm TL, and 100% for 17 specimens over 510 mm TL. The uterine widths of abnormal females also increased at about 500 mm TL. Proportions of maturity of abnormal females were 33.3% for 3 specimens of 490–499 mm TL and 90.9% for 11 specimens over 510 mm TL (one specimen of 542 mm TL was immature). These results suggest that the size at maturity in both normal and abnormal females is about 500-510 mm TL. It seems that an increase in clasper length of abnormal females is affected by the onset of maturity of the female reproductive organs (Fig. 5).

Nine normal pregnant females contained 9 to 18 embryos (average, A=12.4; standard deviation, SD=3.66). Two normal females had 12 and 17 fertilized ova, respectively, in their uteri. The number of male to female embryos in two normal pregnant females was 16: 12 (1.3: 1.0). Sex ratio (male/female) of embryos per litter of two normal females was 1.25 and 1.50. Four abnormal females were pregnant and contained 9 to 16 embryos (A=11.7, SD=3.09). Another abnormal female had 10 fertilized ova in her uteri. The number of male to female embryos in two pregnant abnormal females was 13: 10 (1.3: 1.0). Sex ratio (male/female) of embryos per litter of two abnormal females was 0.80 and 1.80. Statistically, there was no significant difference in the average number of embryos between normal and abnormal pregnant females based on the result of a significance test for the average ($P(t)=0.05$). χ^2 test did not reject the null hypothesis that the sex ratio of embryos of both normal and abnormal females was 1: 1 at the 5% significance level.

In one abnormal male specimen (No. 16), the left gonad contained both ovum and testis. The bulk of the tissue was testicular but attached to the anterior side was a distinct ovum, 15 mm in diameter (Fig. 6). Other reproductive structures of this shark appeared to be of the normal male type. No female reproductive organs (oviduct, nidamental grand, and uterus) could be recognized with the naked eye. The seminal vesicles and sperm sac were fully filled with sperm. Under the light microscope the spermatogonia, spermatocytes, spermatids and spermatozoa were observed in the testicular region and appeared to be normal. The structure of the testis was follicular and zonate. The structural arrangements of the cells were similar to those of other squaloid sharks, such as *Centroscymnus owstoni* and *C. coelolepis* (Yano and Tanaka, 1987).

Specimens with both testes and ovaries were reported by Atz (1964), King (1966), Capape (1974), Capape and Zahnd (1974), Capape et al. (1979), and Pratt (1979). These specimens had oviducts and uteri, as well as spermiducts, seminal vesicles, sperm sacs and claspers. In contrast, the present abnormal male primarily possessed testicular tissue with a small ovum attached to it and no other female reproductive organs.

The 21 normal males ranged from 242 mm to 527 mm TL, the 33 normal females from 271 mm to 575 mm TL, the abnormal male was 501 mm TL and the 15 abnormal females ranged from 319 mm to 573 mm TL. In size frequency analysis, the length of the abnormal male occurred in the range of 500–509 mm TL, which was the peak for normal males (Fig. 7). The length of the abnormal females included the range of length for normal

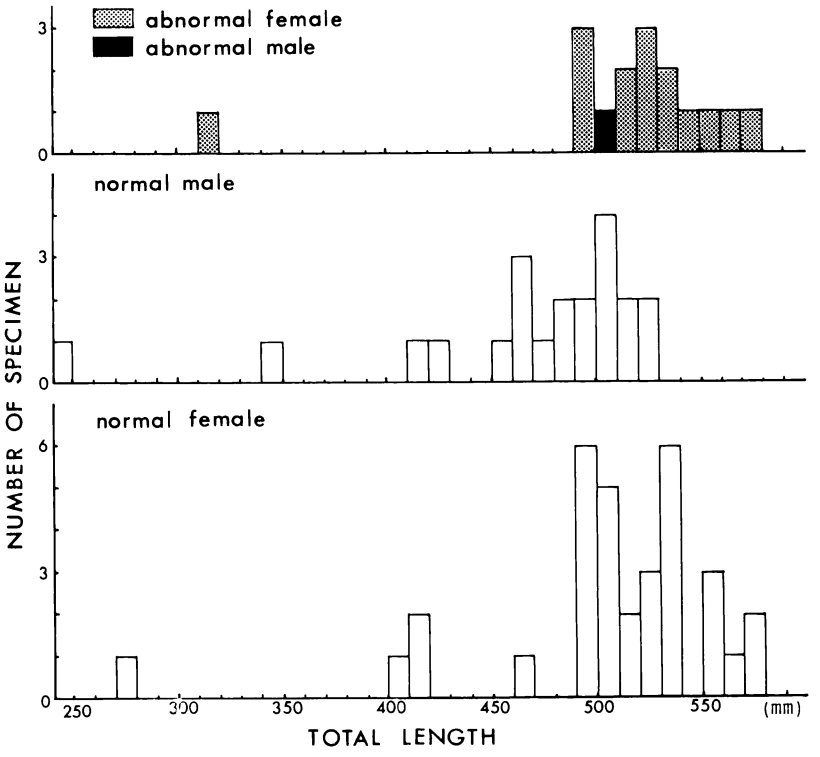

Fig. 7. Length-frequency of abnormal individuals, normal males and normal females of *Etmopterus unicolor* collected in Suruga Bay and adjacent regions. Specimens are grouped into 10 mm size classes.

females (Fig. 7).

Finally, of the 70 Suruga Bay specimens of *E. unicolor* we examined, 22.9% were abnormal, 30.0% normal males, and 47.1% normal females (Fig. 1). In addition, 29.6% of the specimens caught off Omaezaki were abnormal (Fig. 1). Six specimens collected from Choshi, Oshima, and Kumano-nada (Fig. 1) were normal with respect to their reproductive organs.

We examined 1,474 specimens of *Etmopterus brachyurus* collected from Suruga Bay, but no hermaphroditism was found in this species. Although about 2,000 specimens belonging to other squaloid genera (e.g., *Centroscymnus*, *Centrophorus*, *Deania* and *Squalus*) from Suruga Bay were also dissected, only one hermaphroditic specimen of *C. owstoni* (Yano, 1985) was encountered. Since other squaloid sharks inhabiting Suruga Bay were not commonly detected to be hermaphroditic, we suggest that the frequent occurrence of hermaphroditism in *E. unicolor* is a peculiarity for this species rather than a special phenomenon for this area. However, further collections are needed to elucidate the occurrence of hermaphroditism in this species by examining specimens from other areas. Because the incidence of hermaphroditism in *E. unicolor* is very high in Suruga Bay, it seems likely that it is a case of environmental contamination (e.g. radioactivity).

Acknowledgments

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Literature ctied

Atz, J. W. 1964. Intersexuality in fishes. Pages 145–232 *in* C. N. Armstrong and A. J. Marshall, eds. Intersexuality in vertebrates including man. Academic Press, London, 479 pp.

Capape, C. 1974. Anomalie de l'appareil urogenital chez *Torpedo* (*Torpedo*) *marmorata* Risso, 1810. Arch. Inst. Pasteur Tunis, 51 (4): 321–328.

Capape, C. and J. P. Zahnd. 1974. Cas d'herma-

phrodisme chez *Scyliorhinus canicula* (Linné, 1758). Bull. Inst. Oceanogr. Peche, Salammbo, 3(1/4): 131–137.

Capape, C., A. Chadli and A. Baouendi. 1979. Cas d'hermaphorodisme chez *Scyliorhinus stellaris* (Linné, 1758) (Pisces, Scyliorhinidae) etude morphologique et histologique. Arch. Inst. Pasteur Tunis, 56(3): 343–351.

Compagno, L.J.V. 1984. FAO species catalogue, vol. 4. Sharks of the world, part 1. FAO Fish. Synop. No. 125, Vol. 4, Pt. 1, viii+249 pp.

Dingerkus, G. and L. D. Uhler. 1977. Enzyme clearing of alcian blue stained whole small vertebrates for demonstration of cartilage. Stain Tech., 52(4): 229–232.

Gilbert, P. W. and G. W. Heath. 1974. The clasper-siphon sac mechanism in *Squalus acanthias* and *Mustelus canis*. Comp. Biochem. Physiol., 42A: 97–119.

King, A. D. 1966. Hermaphroditism in the common dogfish (*Scyliorhinus caniculus*). J. Zool., 148: 312–314.

Pratt, H. L., Jr. 1979. Reproduction in the blue shark, *Prionace glauca*. Fish. Bull., 77(2): 445–470.

Yano, K. 1985. Studies on morphology, phylogeny, taxonomy and biology of Japanese squaloid sharks, order Squaliformes. Unpubl. Ph. D. Thesis, Tokai Univ., 335 pp. (In Japanese.)

Yano, K. and S. Tanaka. 1983. Biological studies on squaloid sharks from Suruga Bay. Proc. North Pacific Aquacul. Symp., pp. 405–414.

Yano, K. and S. Tanaka. 1987. Reproductive organs of deep sea sharks, *Centroscymnus owstoni* and *C. coelolepis*. J. Fac. Mar. Sci. Tech., Tokai Univ., (25): 57–67.

(KY: Japan Marine Fishery Resource Research Center, 3–27 Kioicho, Chiyoda-ku, Tokyo 102, Japan; ST: Department of Fisheries, Faculty of Marine Science and Technology, Tokai University, 3–20–1, Orido, Shimizu 424, Japan)

ニセカラスザメの雌雄同体現象

矢野和成・田中　彰

駿河湾とその近海から採集されたニセカラスザメの70個体のうち 22.9% のものが雌雄同体，30% のものが雄，47.1% のものが雌であった．雌雄同体の 16 個体の内の 15 個体では雌の生殖器官である卵巣，輸卵管，卵殻腺，子宮が機能的であったが，それと同時に雄の生殖器官である交接器を持っていた．雌雄同体個体の交接器長は全長 510 mm 以上で急激に増加した．この時の全長は雌の成熟全長とほぼ同じであった．卵巣と子宮は雌雄同体個体では全長 500 mm 以上のもので成熟に達し，雌では全長 500 mm，雄では全長 460 mm 以上であった．雌雄同体のうちの 1 個体は，左側の精巣に直径 15 mm の卵 1 個が付着していたが，その他の器官は雄として機能していた．

(矢野: 102 千代田区紀尾井町 3–27 海洋水産資源開発センター; 田中: 424 清水市折戸 3–20–1 東海大学海洋学部水産学科)