

Abnormal hermaphroditism in the multispine skate *Bathyraja multispinis* (Chondrichthyes, Rajidae)

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A hermaphroditic individual of the multispine skate, *Bathyraja multispinis*, caught on the Argentinean continental shelf, is described. This is the first record of hermaphroditism in the genus *Bathyraja* and one of the very few hermaphroditic specimens reported in the Rajidae.

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Hermaphroditism is defined as the presence of both the male and female sex organs in a single individual (Atz, 1964). Normal hermaphroditism is considered when all or many members of a species exhibit hermaphroditism at some time of their ontogeny. All other forms of hermaphroditism are abnormal by definition (Atz, 1964).

All chondrichthyans are considered gonochoristic (*i.e.* the existence of a single sex in the individual), with internal fertilization through the agency of paired copulatory organs (claspers) on the pelvic fins of males (Compagno, 1990). Iglésias *et al.* (2005), however, recently reported a normal hermaphroditic chondrichthyan species (*Apristurus longicephalus* Nakaya). These hermaphroditic sharks possessed claspers and internal reproductive organs of both sexes simultaneously, with the morphologically dominant gonad considered to be the functional sex. In addition, cases of abnormal hermaphroditism have been occasionally documented in cartilaginous fishes. Some abnormal hermaphrodites have a normal male genital apparatus but also possess ovarian tissue (Yano & Tanaka, 1989; Yano, 1995). Other hermaphrodites possess claspers

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and both female and male internal reproductive organs (Capapé, 1974; Capapé & Zahnd, 1974; Capapé & Desoutter, 1979; Capapé *et al.*, 1979; Pratt, 1979; Jones *et al.*, 2005). Within the Rajidae, hermaphroditic specimens have been reported rarely (Atz, 1964; Quignard & Capapé, 1972). Hermaphroditic skates have been reported with both female and male internal reproductive organs in different degrees of development, with at least one clasper.

The multispine skate *Bathyraja multispinis* (Norman) is one of the eight species of *Bathyraja* occurring on the Argentinean continental shelf (Cousseau *et al.*, 2000; Díaz de Astarloa & Mabrugaña, 2004). Although this species appears to have a wide distribution on the upper slope of the south-west Atlantic, it is less frequent on the Argentinean shelf (Cousseau *et al.*, 2000). The multispine skate has also been caught in Uruguayan and Chilean waters, around the Falkland (Malvinas) Islands and over the Burdwood Bank (Bellisio *et al.*, 1979; Pequeño & Lamilla, 1993). Maximum total lengths (L_T) observed were 1040 and 1020 mm for male and female, respectively (Cousseau *et al.*, 2000).

A total of 333 specimens of *Bathyraja* spp. were caught as by-catch during a research cruise on board the R.V. 'Dr Eduardo L. Holmberg' of the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP, Mar del Plata, Argentina), in September 2005. The cruise was conducted on the Argentinean continental shelf, between 41 and 45° S. The L_T , disc width, total body mass, eviscerated body mass and gonad mass were measured on board for all species of *Bathyraja*. Furthermore, uterus width (W_U), oviducal gland width (W_{OG}), number of vitellogenic (yellow) ovarian follicles, maximum diameter of ovarian follicles (D_M), inner clasper length and number of rows in the alar thorn patch were recorded for different sexes. Maturity stages in both sexes were determined following Mabrugaña *et al.* (2002) and Stehmann (2002). Males were considered mature when they had long fully calcified claspers, a fully developed alar thorn patch, enlarged testes and highly coiled sperm ducts. Females were mature when they had enlarged ovaries with large vitellogenic ovarian follicles, widened uteri along their entire length and widened oviducal glands. The total number of specimens of *B. multispinis* captured in the cruise was 10 including one hermaphrodite, two mature males and five immature males (Table I). The hermaphrodite was caught from 78 m depth at 41°32' S and 59°41' W. This eviscerated hermaphroditic individual is deposited in the fish collection of the Instituto Nacional de Investigación y Desarrollo Pesquero as INIDEP 781.

Externally, the hermaphrodite possessed one fully developed alar thorn row on the right side together with two developing alar thorn rows, but claspers were absent. Internally, the specimen had normal male reproductive organs on the right side with an enlarged testis, developed and coiled epididymis and ductus deferens, and a poorly developed seminal vesicle without sperm (Fig. 1). Five normal immature and two normal mature males of the multispine skate were caught during the same research cruise and were compared with the hermaphroditic specimen (Table I). The hermaphrodite was the same size as one of the normal mature males but larger than the other mature males and immature males. The hermaphroditic specimen was heavier than normal males. Testis and sperm ducts were better developed in the two normal mature males

TABLE I. Measurements, masses and alar thorn rows recorded in the hermaphrodite, two normal mature males and five normal immature males of *Bathyraja multispinis* caught on the Argentinean continental shelf

	Hermaphro- dite		Mature males	Immature males				
L_T (mm)	1095	1095	1006	795	720	645	620	480
Disc width (mm)	720	705	700	530	515	410	415	325
Total body mass (g)	8800	7480	7500	3040	2240	1345	1375	630
Eviscerated body mass (g)	6305	5920	5600	2360	1810	1150	1150	510
Inner clasper length (mm)	—	268.5	270.2	47.6	47.3	30.0	29.6	21.9
Right testis mass (g)	47.53	52.52	56.82	5.20	4.70	3.15	2.32	2.58
Left testis mass (g)	—	54.55	52.33	5.38	3.77	2.54	2.30	2.30
Number of fully developed alar thorn rows	1	3	3–4	0	0	0	0	0

L_T , total length.

than in the hermaphrodite. The number of fully developed alar thorn rows was smaller in the hermaphrodite than that found in normal mature males.

Internally, normal female reproductive organs were found on the left side of the hermaphrodite characterized by an opened ostium, oviduct, well-developed and heart-shaped oviducal gland ($W_{OG} = 75.5$ mm), widened uterus along its entire length ($W_U = 21.4$ mm), enlarged ovary (ovary mass = 80.46 g) and enlarged urogenital sinus (Fig. 1). The ovary had seven large vitellogenic ovarian follicles ($D_M = 30.5$ mm), and some non-vitellogenic ovarian follicles ($D_M = 10.5$ mm) [Fig. 1(a)]. Two normal immature females of *B. multispinis* were collected during the research cruise, but no normal mature females were caught. The reproductive organs of the hermaphrodite individual were similar, however, to those of normal mature female skates (pers. obs.).

In skates, alar thorns are used by males to hold the female during copulation (Luer & Gilbert, 1985) and the number of alar thorn rows increases with male maturation (Mabragaña *et al.*, 2002). The hermaphroditic specimen of *B. multispinis* had alar thorns only on the right side of the disc, as was also found in a hermaphroditic individual of *Raja miraletus* L. (Quignard & Capapé, 1972). Claspers, however, were absent in the hermaphroditic specimen of *B. multispinis* as was recently reported in an hermaphrodite of the deep-water shark *Centroscymnus coelolepis* Barbosa du Bocage & de Brito Capello (Verissimo *et al.*, 2003). Abnormal hermaphroditic chondrichthyans with both ovarian and testicular tissues within the same gonad were observed in *R. miraletus* (Quignard & Capapé, 1972) and some sharks: *Scyliorhinus canicula* (L.), *Scyliorhinus stellaris* (L.), *Etmopterus unicolor* (Engelhardt) and *Centroscyllium fabricii* (Reinhardt) (Capapé & Zahnd, 1974; Capapé *et al.*, 1979; Yano & Tanaka, 1989; Yano, 1995). The simultaneous presence of separate male and female gonads was reported in abnormal hermaphroditic sharks (Pratt, 1979; Verissimo

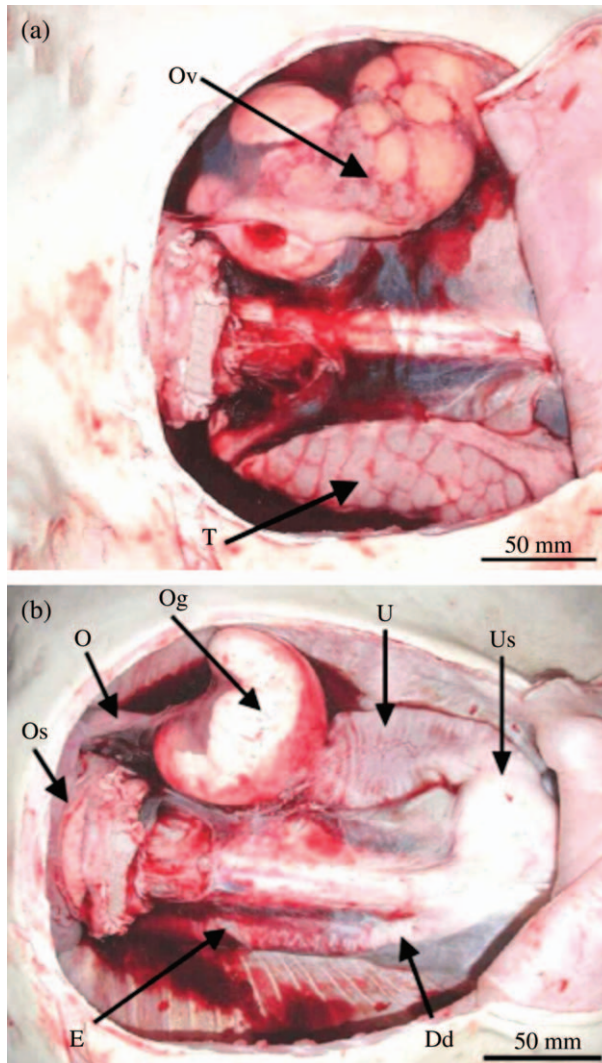


FIG. 1. Ventral view of internal reproductive organs in the hermaphroditic specimen of *Bathyraja multispinis* (a) showing ovary and testis and (b) with ovary and testis removed to show more dorsally positioned organs. Dd, duct deferens; E, epididymis; O, oviduct; Og, oviducal gland; Os, ostium; Ov, ovary; T, testis; U, uterus; Us, urogenital sinus.

et al., 2003; Jones *et al.*, 2005). In some of these shark species, abnormal hermaphroditic specimens had complete and separate female reproductive organs on both sides (Pratt, 1979; Jones *et al.*, 2005). In other species, complete and separate female reproductive organs were only found on one side (Veríssimo *et al.*, 2003) as was observed in the hermaphrodite of *B. multispinis*.

Although abnormal hermaphroditism is uncommon in chondrichthyans, it has been found in several bony fish species (Atz, 1964), but its cause remains unexplained. Environmental effects on species with labile sex-determination mechanisms may be responsible for some cases of abnormal hermaphroditism,

or normal variances that exist in endogenous sex-determination physiology may be also the cause of sexual ambiguity (Devlin & Nagahama, 2002). Yano & Tanaka (1989) suggested that the apparently abnormal hermaphroditism in *E. unicolor* probably resulted from environmental contamination (e.g. radio-activity).

This specimen of *B. multispinis* is the first record of hermaphroditism in the genus *Bathyraja* and one of the very few hermaphroditic specimens recorded and documented within the Rajidae. Despite the diversity and abundance of chondrichthyan species on the Argentinean continental shelf (c. 92 species; D. E. Figueroa, unpubl. data), this hermaphroditic specimen of *B. multispinis* represents the only reported example of hermaphroditism in cartilaginous fishes in these waters.

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References

- Atz, J. W. (1964). Intersexuality in fishes. In *Intersexuality in Vertebrates Including Man* (Armstrong, C. N. & Marshall, A. J., eds), pp. 145–232. London and New York: Academic Press.
- Bellisio, N. B., López, R. B. & Torno, A. (1979). *Peces Marinos Patagónicos*. Buenos Aires: Codex S.A.
- Capapé, C. (1974). Anomalie de l'appareil urogénital chez *Torpedo* (*Torpedo*) *marmorata* Risso, 1810. *Archives de l'Institut Pasteur de Tunis* **51**, 321–328.
- Capapé, C. & Desoutter, M. (1979). Nouvelle description de *Aetomylaeus nichofii* (Bloch et Schneider, 1801) (Pises, Myliobatidae). Premières observations biologiques. *Cahiers de l'Indo-Pacifique* **1**, 305–322.
- Capapé, C. & Zahnd, J.-P. (1974). Cas d'hermaphrodisme chez *Scyliorhinus canicula* (Linné, 1758). *Bulletin de l'Institut National Scientifique et Technique d'Océanographie et de Pêche de Salammbô* **3**, 131–137.
- Capapé, C., Chadli, A. & Baouendi, A. (1979). Cas d'hermaphrodisme chez *Scyliorhinus stellaris* (Linné, 1758) (Pisces, Scyliorhinidae) étude morphologique et histologique. *Archives de l'Institut Pasteur de Tunis* **56**, 343–351.
- Compagno, L. J. V. (1990). Alternative life-history styles of cartilaginous fishes in time and space. *Environmental Biology of Fishes* **28**, 33–75.
- Cousseau, M. B., Figueroa, D. E. & Díaz de Astarloa, J. M. (2000). *Clave de identificación de las rayas del litoral marítimo de Argentina y Uruguay (Chondrichthyes, Familia Rajidae)*. Mar del Plata, Argentina: Publicaciones especiales, INIDEP.
- Devlin, R. H. & Nagahama, Y. (2002). Sex determination and sex differentiation in fish: an overview of genetic, physiological, and environmental influences. *Aquaculture* **208**, 191–364.
- Díaz de Astarloa, J. M. & Mabragna, E. (2004). *Bathyraja cousseauae* sp. n., a new softnose skate from the southwestern Atlantic (Rajiformes, Rajidae). *Copeia* **2004**, 326–335.
- Iglésias, S. P., Sellos, D. Y. & Nakaya, K. (2005). Discovery of a normal hermaphroditic chondrichthyan species: *Apisturus longicephalus*. *Journal of Fish Biology* **66**, 417–428. doi: 10.1111/j.1095-8649.2004.00607.x

- Jones, A. A., White, W. T. & Potter, I. C. (2005). A hermaphroditic Port Jackson shark, *Heterodontus portusjacksoni*, with complete and separate female and male reproductive tracts. *Journal of the Marine Biological Association of the United Kingdom* **85**, 1171–1172.
- Luer, C. A. & Gilbert, P. W. (1985). Mating behavior, egg deposition, incubation period, and hatching in the clearnose skate, *Raja eglanteria*. *Environmental Biology of Fishes* **13**, 161–171.
- Mabragaña, E., Lucifora, L. O. & Massa, A. M. (2002). The reproductive ecology and abundance of *Sympteria bonapartii* endemic to the south-west Atlantic. *Journal of Fish Biology* **60**, 951–967.
- Pequeño, G. R. & Lamilla, J. G. (1993). Batoideos comunes a las costas de Chile y Argentina-Uruguay (Pisces: Chondrichthyes). *Revista de Biología Marina* **28**, 203–217.
- Pratt, H. L. Jr (1979). Reproduction in the blue shark, *Prionace glauca*. *Fishery Bulletin* **77**, 445–470.
- Quignard, J. P. & Capapé, C. (1972). Cas d'hermaphroditisme chez *Raja miraletus* L. 1758. *Travaux du Laboratoire de Biologie Halieutique, Université de Rennes* **6**, 133–140.
- Stehmann, M. (2002). Proposal of a maturity stages scale for oviparous and viviparous cartilaginous fishes (Pisces, Chondrichthyes). *Archive of Fishery and Marine Research* **50**, 23–48.
- Veríssimo, A., Gordo, L. & Figueiredo, I. (2003). Reproductive biology and embryonic development of *Centroscyrmus coelolepis* in Portuguese mainland waters. *ICES Journal of Marine Science* **60**, 1335–1341.
- Yano, K. (1995). Reproductive biology of the Black dogfish, *Centroscyllium fabricii*, collected from waters off western Greenland. *Journal of the Marine Biological Association of the United Kingdom* **75**, 285–310.
- Yano, K. & Tanaka, S. (1989). Hermaphroditism in the Latern shark *Etmopterus unicolor* (Squalidae, Chondrichthyes). *Japanese Journal of Ichthyology* **36**, 338–345.