SEXUAL AND GEOGRAPHICAL VARIATION OF MORPHOMETRICS IN THE BLUE SHARK (*Prionace glauca*)

Jefferson F. A. Legat
Empresa Brasileira de Pesquisa Agropecuária, Embrapa Meio-Norte.
BR 343, km 35, Caixa Postal 341, Parnaíba-PI. CEP 64200-970. Brazil.
e-mail: legat@cpamn.embrapa.br

Carolus M. Vooren
Fundação Universidade Federal do Rio Grande, Laboratório de Elasmobrânquios e Aves Marinhas, Caixa Postal 474, Rio Grande-RS.
CEP 96201-900. Brazil. e-mail: doccmv@furg.br

Abstract

Specimens of *Prionace glauca* were collected from November 1996 to April 1998 by pelagic longline on the continental slope of southern Brazil between latitudes 27°S and 35°S. Forty body measurements were taken from 35 females with total length from 148.5 to 294.5 cm, and 78 males with total length from 135 to 292 cm. The sexes differed significantly in six body proportions. The female had a broader pectoral fin, a greater pectoral-pelvic space and a shorter tail than the male. These differences may be a secondary sexual characteristics related to reproduction and to the hydrodynamics of swimming. Thirty-four body proportions were compared with published data from northeastern Brazil: 8 differed in both sexes, 5 in males only, and 5 in females only. In *P. glauca*, geographical variation of body proportions exists and can be measured. Morphometrics may be useful for identifying unit stocks of this species.

Introduction

Throughout its area of distribution, the blue shark has been caught in increasing numbers since the early 1960's as bycatch or target species in pelagic longline fisheries, and in recent years the catch per unit effort has declined in several fishing areas. The species is classified as especially vulnerable to overfishing (Castro *et al.*, 1999). One of the requirements for fishery management is to define unit stocks and their distribution in space. In the case of *P. glauca*, unit stocks have not been recognized yet.

Morphometry is often applied in the taxonomical study of sharks and can be used to separate species which are otherwise very similar in morphology (Compagno, 1984). Therefore, unit stocks, of a species may differ from each other in their typical body proportions. Morphometric measurements are easily made with simple equipment. If morphometrics could separate unit stocks of *P. glauca*, a useful tool for fisheries management would become available. This possibility can be explored through study of geographic variation of morphometrics of the species. For the Atlantic Ocean, there are published data on morphometrics of *P. glauca* from northeastern Brazil and the Atlantic coast of Canada (Mckenzie and Tibbo, 1964; Hazin, 1991). In the present study, the morphometrics of *P. glauca* from southern Brazil are presented, and are compared with data from Northeastern Brazil.

Material and methods

This study was conducted at the "Laboratório de Elamobrânquios e Aves Marinhas da Universidade Federal do Rio Grande". The study area was the continental slope of Southern Brazil, between latitudes 27°S and 35°S, longitudes 46°W and 51°W (Figure 1). The samples were taken by R. V. "Atlântico Sul", using tuna longline as follows: mainline monofilament Ø 3.5 mm; buoy line monofilament Ø 3.5 mm and length 16 m; gangion monofilament Ø 1.8 mm and length 7 m, with steel wire tracer Ø 1.4 mm and length 3 m; tuna hook Mustad 9202 SKR 8/0; baskets of 6 hooks with 60 m between gangions; longline of 50 baskets and 300 hooks. Longline was baited with squid, set at 5 pm, and retrieved at 9 am of the next day.

Longline sets were distributed randomly over depths from 200 to 1000 m, with few samples over greater depths: 7 sets in November and December 1996, 11 sets in July 1997, and 10 sets in March and April 1998.

Fishing depth was monitored with depth recorders mounted in hook position, and varied between 30 and 80 m. Morphometrics were measured immediately after capture. Specimens caught alive were immobilized by cutting the spinal cord behind the head, and passing a steel wire through the neural arches. Complete sets of measurements were obtained from 113 specimens, 35 females and 78 males.

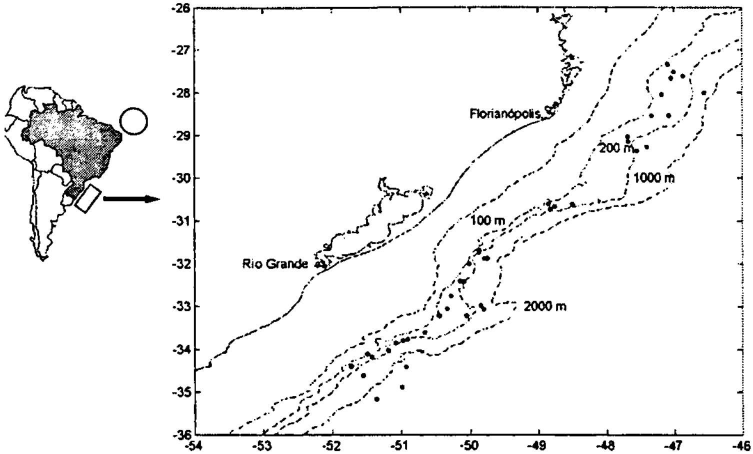

Figure 1. Location of the study area ( ) and positions of the longline sets (•) made by R.V. "Atlantico Sul" from November 1996 to April 1998. The circle (o) represents the study area of Hazin (1991).

For measuring, the specimen was placed outstretched on a measuring board. Thirty-seven measurements were taken as defined by Compagno (1984), whose terms are used here (Tables 1 and 2). Total length and fork length were measured on the measuring board. All other measurements were taken with a builder's measuring tape made of plastic-coated glass fibre. All distances from the snout to body points were taken in a straight line parallel to the body axis. All other distances were measured in a straight line, point to point.

The total length (TL) ranged from 148 to 294 cm in the females and from 135 to 292 cm in the males. In the analysis, the measurements were transformed into percent of TL. Differences between sexes, for each body proportion, were tested by analysis of variance using the Tukey's significant difference method (Sokal and Rohlf, 1969). The variables which differed significantly between sexes ($p<0.5$), were used to compute the discriminant function for sexes according to Johnson and Wichern (1992).

For northeastern Brazil (latitudes 2°S to 7°S, longitudes 32°W to 38°W), Hazin (1991) presents means, standard deviations, range and sample sizes, for males and females, of 34 body proportions measured in the same way as in the present study, but given as proportions of fork length (FL), of 20 specimens with FL from 166 to 227 cm in the males and from 162 to 208 cm in the females. For comparison, all 81 specimens within this range of FL were selected from the present data, and their body proportions were expressed as percent of FL. The differences between the means within sexes were tested by t-test according to StatSoft Inc. (1993), with $p<0.05$ being significant.

Results and Discussion

Four variables differed between sexes with probability <0.01, and two variables differed with probability <0.05 (Tables 1 and 2). The female had the following body proportions greater than male: prenarial length, posterior margin of pelvic fin, and distance between pectoral and pelvic fins. The following body proportions were greater in the male: upper lobe of caudal fn, and distance between pelvic and anal fins.

The following discriminant function was found, with Z being the discriminant score: (Z) = -5.31189 – 0.54827 (pelvic-anal space) + 0.827511 (pelvic posterior margim) + 0.252561 (pectoral-pelvic space) + 0.889528 (prenarial length) – 0.2642(dorsal caudal margin) + 0.413261 (pectoral base). The frequency distribution of Z consisted of two overlapping curves, the centroids being Z= -0.47 for the males and Z= 1.04 for the females (Figures 2 and 3). The critical value of Z was 0.21. The discriminant function classified 82% of the specimens correctly as to sex.

Table 1. Mean, range, standard deviation(SD), of proportional body dimensions of males and females of *Prionace glauca* from Southern Brazil in % of total body length. Total length from 135.0 to 292.0 cm in the males, n = 78, and from 148.5 to 294.5 cm in the females, n = 35. Variables marked with # differ significantly between sexes with p<0.01, variables marked with * differ with p<0.05. Morphometric measurements taken in the present study according to Compagno (1984).

	Males			Females		
Body proportion	Mean	Range	SD	Mean	Range	SD
Fork length	81.54	75.34 – 88.59	1.74	81.68	79.10– 89.24	1.82
Precaudal length	74.55	71.14 – 79.17	1.23	74.78	70.99– 81.17	1.67
Pre-first dorsal length	37.16	33.64 – 41.67	1.46	37.30	33.97– 39.61	1.17
Pre-second dorsal length	64.02	59.09 – 68.75	1.51	64.55	61.80– 69.93	1.56
Prepectoral length	22.12	17.94 – 28.60	1.57	21.84	18.68– 26.67	1.73
Prebranchial length	22.45	18.39 – 26.74	1.35	22.39	18.08– 25.15	1.65
Head length	22.95	19.97 – 25.51	1.25	23.29	20.70– 26.46	1.52
Preorbital length	7.75	5.85 – 9.17	0.84	7.79	5.29– 9.18	0.90
Prenarial length *	4.87	3.18 – 6.08	0.44	5.09	4.29– 5.77	0.38
Eye height	1.44	1.15 – 2.11	0.17	1.48	0.99– 1.85	0.18
Eye length	1.43	1.15 – 1.84	0.18	1.43	1.12– 1.73	0.13
First gill slit height	2.66	1.92 – 3.67	0.38	2.58	1.87– 3.20	0.38
Fifth gill slit height	1.99	1.02 – 3.23	0.36	1.92	1.43– 2.42	0.24
Interdorsal space	20.24	17.77 – 22.55	1.00	20.33	19.06– 22.49	0.83
First dorsal anterior margin	10.07	7.35 – 11.72	0.94	9.86	8.19– 12.22	0.91
First dorsal posterior margin	8.19	6.58 – 10.07	0.87	7.94	6.90– 9.29	0.67
First dorsal base	7.08	5.00 – 8.25	0.62	7.11	5.95– 8.56	0.59
First dorsal height	7.36	5.59 – 9.13	0.81	7.36	6.17– 9.36	0.88

Table 2. Mean, range, standard deviation(SD), of proportional body dimensions of males and females of *Prionace glauca* from Southern Brazil in % of total body length. Total length from 135.0 to 292.0 cm in the males, n = 78, and from 148.5 to 294.5 cm in the females, n = 35. Variables marked with # differ significantly between sexes with p<0.01, variables marked with * differ with p<0.05.

	Males			Females		
Body proportion	Mean	Range	SD	Mean	Range	SD
Second dorsal anterior margin	4.08	3.11 – 8.15	0.72	4.02	2.76– 5.48	0.48
Second dorsal posterior margin	4.53	3.64 – 7.93	0.54	4.36	2.93– 5.05	0.42
Second dorsal base	3.57	1.14 – 7.93	0.77	3.52	2.96– 4.39	0.29
Dorsal-caudal space	7.55	6.25 – 8.82	0.54	7.55	6.49– 8.61	0.55
Dorsal caudal margin *	25.61	23.76 – 35.05	1.34	25.06	22.02– 27.87	1.14
Preventral caudal. margin	11.94	8.89 – 14.17	1.03	12.02	10.49– 14.18	0.86
Anal-caudal space	7.34	6.08 – 8.82	0.54	7.32	5.97– 8.52	0.58
Anal anterior margin	5.28	4.35 – 6.49	0.44	5.42	3.88– 6.85	0.56
Anal posterior margin	3.78	2.37 – 5.63	0.63	3.65	2.49– 4.79	0.50
Anal base	3.79	3.01 – 4.72	0.38	3.88	3.17– 6.20	0.54
Pelvic-anal space #	9.49	6.64 – 12.34	1.13	8.53	5.83– 12.35	1.07
Pelvic anterior margin	5.90	3.80 – 9.04	0.68	5.89	4.14– 7.25	0.62
Pelvic posterior margin #	5.01	3.79 – 5.90	0.41	5.26	4.56– 6.36	0.41
Pelvic base	4.78	2.50 – 6.25	0.72	4.71	4.10– 5.38	0.30
Pectoral-pelvic space #	25.02	20.22 – 29.22	1.68	26.05	24.19– 28.52	0.96
Pectoral anterior margin	21.53	17.00 – 33.64	2.15	21.14	18.99– 26.41	1.40
Pectoral posterior margin	18.40	15.13 – 22.17	1.36	18.24	15.43– 23.41	1.76
Pectoral base #	4.89	3.55 – 6.36	0.65	5.31	4.01– 8.15	0.81

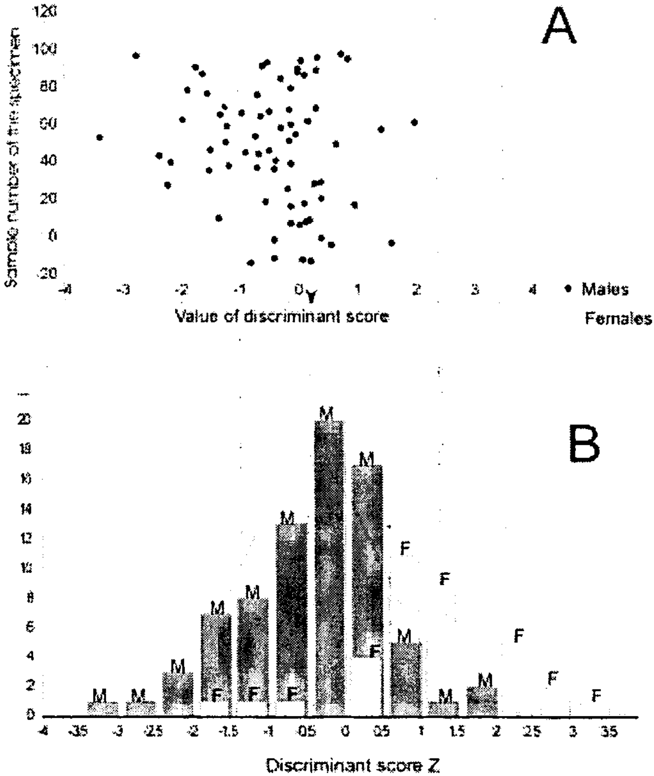

Figure 2. Morphometrics of *Prionace glauca* from southern Brazil A) Distribution of discriminant score values of each specimen. Arrow indicates limit value of separation. B) Frequency distribution of discriminant score Z, with. F = females, M = males

Hazin (1991) found the following morphometrics of *P. glauca* in northeastern Brazil: pectoral-pelvic space, 30.5 in males, and 31.5 in females; pelvic-anal space, 11.5 in males, and 10.7 in females (values in % of FL). The sample was small (only 10 specimens of each sex), and as a result the differences between sexes are not statistically significant. However, they are similar in sign and magnitude to those found in the present study. This is evidence that the morphometric differences between sexes found in the present study, may be a general feature of *P. glauca*.

In the male, the pelvic fin is situated nearer the pectoral fin, and further away from the anal fin, than in the female. Both sexes have the same value of anal-caudal space, and the male has a greater dorsal caudal margin; the male has a relatively longer tail. Summing the values of pelvic-anal space, anal base, anal-caudal space, and dorsal caudal margin in Table I, the male's tail is 1.44 % longer, a difference of 2.75 cm at TL of 210 cm. According to the values of pelvic-anal space in Table 1, in sexually mature (Pratt, 1979) specimens with TL of 215 cm, the space between the pelvic and anal fins is 19,5 cm in the male and 18 cm in the female. The functional aspect of this difference may be that the greater spacing of the pelvic and anal fins in the male results in the space necessary for the claspers to develop and move.

For any given value of TL, the distance between the pectoral and pelvic fins was 4% greater in the female than in the male (Table 1). If the distance between these fins is proportional to the size of the abdominal cavity of the fish, and if in fishes, body dimension scale approximately to the third power of volume or mass (Von Bertalanffy, 1977), then for any body size within the range of total length examined, the volume of the abdominal cavity of females approximately 13% larger than for male. *Prionace glauca* is viviparous and the greater abdominal cavity of the females may provide the space necessary for gestation. In conclusion, the morphometric differences between the sexes of *Prionace glauca* include secondary sexual characters, related to the functioning of reproductive organs.

Bass (1973) found that in 13 species of carcharhiniform sharks from South Africa of the genera *Mustelus*, *Sphyrna*, *Carcharhinus*, *Galeorcerdo*, *Cephaloscyllium*, *Halaelurus*, *Holohalaelurus* and *Rhizoprionodon*, the relative distance between the pectoral and pelvic fins was greater in the female than in the male. Thus, it seems that this morphometric feature occurs in carcharhiniform sharks in general.

The base of the pectoral fin was about 9% greater in the female than in the male (Table 1) but the anterior and posterior margin of the pectoral fin were not significantly different between the sexes. The broader pectoral fin and the shorter tail of the female of P. glauca are evidence of sexual differences in the hydrodynamics of swimming in this species. Bass (1973) found that the pectoral fin was greater in the female than in the male in carcharhiniform sharks from

South Africa. Therefore, such differences between the sexes may also be a general feature of these sharks.The morphometrics presented by Mckenzie and Tibbo (1964) for P. glauca from the Atlantic coast of Canada refer to a pooled sample of males and females. Therefore, comparing these data with the present results is difficult.

In the comparison of 34 morphometrics between the present data and those cited by Hazin (1991) for the northeast of Brazil, there are significant differences in 18 variables, 8 differing in both sexes, 5 in the males only, and 5 in the females only (Table 2). If such differences were due to methods, then they would always occur in both sexes, and in all or most of the morphometrics, but no difference occurred in 16 out of 34 variables. The close agreement in almost half of the variables is evidence that the observed differences in the remaining variables are real. The principal differences are that in both sexes, the specimens from southern Brazil have a longer head, smaller eyes, a lower first dorsal fin and a smaller pelvic fin. Between the two areas, the females differ in shape and relative size of the second dorsal fin, the anal fin and the lower caudal fin lobe, and the males differ in the shape of the pectoral fin. On the whole, the southern specimens have 11 body proportions smaller than the northern ones, but have a longer head.

These results are evidence that in *P. glauca* body proportions vary geographically. This could be further examined through discriminant function analysis of morphometrics from different ocean areas. In this way, unit stocks of *P. glauca* could be recognized, and their geographical range could be established. However, little can be done with the headed, gutted and finned carcass. Data for stock identification through morphometrics needs to be collected at sea by research vessels or on board of commercial vessels before the catch be processed.

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