Record of morphological abnormality in embryos of Caribbean sharpnose shark, *Rhizoprionodon porosus* (Elasmobranchii, Carcharhinidae), from the south coast of São Paulo State, Brazil

Registro de anomalia em embriões de cação frango – *Rhizoprionodon Porosus* na região sul de São Paulo (Elasmobranchii carcharhinidae) no Brasil

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**ABSTRACT**

The subclass Elasmobranchii aggregate the sharks and rays that are cartilaginous fish present on the planet millions of years ago. Sharks are efficient predators that occupy all oceans, being important in the balance of the marine ecosystem. There are not many reports of a morphological abnormality for the group, but the cases increase gradually. Most of the reported morphological abnormalities are cases of bicephaly or albinism. Factors such as parasitic infection, mechanical lesions, congenital abnormality and environmental conditions are pointed as possible causes of deformities, as well as anthropic activities such as pollution and excised fishing. Neonates of *Rhizoprionodon porosus*
evaled in the present study have a deformity in the caudal fin region. The 8 individuals were delivered to the Institute of Marine Biology and Environment in 2016 for research and better understanding of the case. The reports of anomalies found are of great importance to understand the functioning of the group and to have control of the cases, thus verifying if there is an increase in the number of animals presenting anomalies in the last decades.

Keywords: anomaly, embryo, shark.

RESUMO
A subclasse Elasmobranchii agrega os tubarões e raias que são peixes cartilaginosos presentes no planeta há milhões de anos. Os tubarões são predadores eficientes que ocupam todos os oceanos, sendo importantes no equilíbrio do ecossistema marinho. Não há muitos relatos de anormalidades morfológicas para o grupo, mas os casos aumentam gradualmente. A maioria das anormalidades morfológicas relatadas são casos de bicefalia ou albinismo. Fatores como infecção parasitária, lesões mecânicas, anormalidades congênitas e condições ambientais são apontados como possíveis causas de deformidades, além de atividades antrópicas como poluição e pesca extirpada. Os neonatos de Rhizoprionodon porosus avaliados no presente estudo apresentam uma deformidade na região da nadadeira caudal. Os oito indivíduos foram entregues ao Instituto de Biologia Marinha e Meio Ambiente em 2016 para pesquisa e melhor entendimento do caso. Os relatos de anomalias encontradas são de grande importância para entender o funcionamento do grupo e controlar os casos, verificando se há um aumento no número de animais apresentando anomalias nas últimas décadas.

Palavras-chave: anomalia, embrião, tubarão.

1 INTRODUCTION

According to Stearns (1) mutations are inherited changes in the DNA sequence or in the structure and shape of chromosomes, which can be induced or spontaneous. Gene mutations can happen in any living organism, being an important speciation mechanism and one of the main reasons for having a great diversity of life on Earth (2), being related to evolution and genetic variability. However, its results are not always advantageous and, in many cases, are treated as anomalies (1).

Sharks belong to the Chondrichthyes Class (which includes the Sharks and rays in the Elasmobranchii Subclass and the Chimeras in the Holocephali Subclass) (3). They are cartilaginous fish, efficient predators that occupy all the oceans, being important in the balance of the marine ecosystem. Its evolutionary success was due to several morphological changes, many of them resulting from innumerable mutations (3).

In recent years, changes in their habitat and constant fishing have brought negative results for the group, threatening their survival (4). Human activities have been growing in recent years, increasing the emission of gases and technological disasters such as contamination and leakage (3) leading to an increase pollution and global warming rates. These factors can contribute to mutations and anomalies.
There are few studies addressing the anomalies in Elasmobranchii, however the cases have been gradually increasing. Dicephaly, cephalic malformation and albinism are some published reports for sharks (5,6,7,8). Little is known about the reasons that could lead to these deformities and further research is needed leading to a better understanding of the cases.

This research aims to report the case of anomalies, for the first time, in the species Rhizoprionodon porosus (9) and to analyze whether the observed genetic mutation resembles the cases already reported in the literature for the class Chondrichthyes.

2 THEORETICAL REFERENCE

Sharks are great predators, responsible for maintaining the balance of marine life. Its morphological characteristics, especially the sensorial ones like lateral line and Lorenzini ampoules, in addition to the serrated teeth arranged in restorative rows, and the changes in the feeding structures, made this animal a versatile and effective predator. habitats have been threatening the number of species in this class (3). Finning is the most worrying practice, as it consists of removing the fins and disposing of the animals still alive in the sea (4), aiming to get the largest number of fins, quickly and with little cost, thus maintaining the consumption of the so-called “fin soup”, mainly in Asian countries (10).

The species R. porosus is part of the family Carcharhinidae, with (21) species, the most numerous in Brazil (11). This family has as main characteristic the well-developed upper lip groove and pre-caudal grooves positioned in the upper portion (12). Popularly known as cation - chicken, is a coastal shark, found on the South American continental shelf, reaching depths of 500 m (13).

These animals are relatively small compared to other shark species, and can reach a maximum size of 110 cm as adults. The development is classified as viviparous with placenta (viviparous placenta) of yolk sac and its pups (2 to 6 in R. porosus) can be born with about 31 to 39 cm. Its diet basically consists of bony fish, cephalopod molluscs and crustaceans (13). As it does not have great commercial and economic interest, it has been little studied as to its biology (14).

Morphological anomalies are relatively common and can be observed in different species of vertebrates such as horses, calves and dogs (15,16,17). Reports of the most diverse deformities are published, for example, animals with two heads (18). The first works related to elasmobranchs were published before the 2000s (7). Some examples of anomalies recorded are albinism, deformities in the pectoral development, dicephaly (19), fusion between the pectoral fins and the head (20) and deformity in the spine classified as kyphoscoliosis (21).
Anthropic activities lead to the emission of gases such as carbon dioxide (CO2), methane (CH4) and ozone (O3) due to the burning of fossil fuels and vegetation. These gases cause an increase in the greenhouse effect (22). When CO2 is absorbed by the oceans, the formation of carbonic acid occurs, leading to acidification of the same (23). In addition, the waste generated by society increases the pollution indexes, with the consequence of increasing the number of plastics and the growth in the concentration of chemical elements in the water, such as copper sulfate (CuSO4) and aluminum hydroxide (Al(OH)3). This results in damage to several marine organisms (23). Intensive fishing can reduce genetic diversity in shark populations due to large exploitation leading to loss of reproductive stock (7). Other factors are also pointed out as the causes of deformities, such as parasitic infection, injuries mechanical, congenital abnormality and environmental conditions, although they are not conclusive in all cases (7).

This study intends to describe for the first time an anomaly in the species *R. porosus*, found in the city of Peruíbe, located on the south coast of the State of São Paulo, Brazil.

3 MATERIAL AND METHODS

Eight specimens of *R. porosus* sharks were used, which were caught by artisanal fishermen from the city of Peruíbe, south coast of the State of São Paulo, Brazil (24°22’38.78” S and 47°01’12.15” W) (Figure 1). The specimens were donated to IBIMM (Institute of Marine Biology and Environment) in April 2016. The institution develops the SOS sharks project, which aims to work with the conservation of elasmobranchs in the region and normally receives donations from fishermen.

The animals were fixed in 4% formalin, then placed in a 70% alcohol solution. Currently, they are deposited in the collection of the Museum of the Sea, under number 0007/2016 of IBIMM and approval under number 007/2018, of the Bioceua Ethics Committee-IBIMM scientific.
The newborns of *R. porosus*, had tail deformities and after very detailed examinations with a NIKON stereoscopic magnifier in 100X magnification, it was possible to detect anomalies in the caudal region. Biometrics was performed with the aid of a tape measure and a caliper, according to the methodology by Compagno (13).

4 RESULTS

Identification

The identification of the newborns was possible through the morphological characteristics, based on the data presented by Figueiredo (24) and Compagno (13), in which the standard measures were found (table 1), making it impossible to count the vertebrae and not evaluate the dermal denticles, as they are still neonates and do not present differentiation, according to figure 2.

The genus Rhizoprionodon has two species in Brazil, namely *R. lalandii* and *R. porosus*. According to Figueiredo (24), identification by external characteristics is not easy and the number of pre-caudal vertebrae is the safest character for separation. In addition, the length of the first dorsal fin is greater than the anterior margin of the pectoral fin in *R. lalandii*, differentiating it from *R. porosus* (figure 2), which has the length of the first dorsal fin less than the anterior margin of the pectoral fin,
and which when pressed, the pectoral fin exceeds half of the base of the 1st dorsal fin (13). The species *R. lalandii* has a more slender body, tapered snout and labial grooves smaller than that of *R. porosus* (25).

The use of dermal denticles for taxonomic purposes is another form of identification little known and already used by researchers to determine species within the same genus that are morphologically similar (26). Another form of identification is by molecular analysis, which was not applied in the present study.

Figure 2 - In A, registered the standard measurement for identification, based on Compagno (13) and Figueiredo (24) for *Rhizoprionodon lalandii*. In B and C, the standard measurement for identification, based on Compagno (13) and Figueiredo (24), for *Rhizoprionodon porosus* is observed.
Table 1 - Evaluation of comparative fins data to identify Rhizoprionodon species, according to Figueiredo (24) and Compagno (13).

| ANIMAL (N) | PECTORAL SWIMMER | 1st DORSAL SWIMMER |
|------------|------------------|--------------------|
| 1          | 2.2              | 2.5                |
| 2          | 2.8              | 3.2                |
| 3          | 2.2              | 2.3                |
| 4          | 2.7              | 2.8                |
| 5          | 2.6              | 3                  |
| 6          | 2.4              | 2.5                |
| 7          | 2.9              | 3.2                |
| 8          | 3                | 3.2                |

Description of anomalies

The puppies of R. porosus have a deformity in the region of the caudal fin and each individual has a particularity in relation to the anomaly presented (figure 3). It was not possible to measure the total length of the animals' size due to the fin roll. This anomaly caused the entire cartilaginous skeleton of the caudal fin region to become rigid, thus preventing the tail from stretching, making it impossible to obtain exact measurements. It is also possible to observe a difference in the development of the mouth extension.

Figure 3 - Individuals identified with scoliosis in the caudal fin region.
Individual I presents the caudal curl, leaving the lower part of the tail in the pectoral region. Individual II presents winding in the extreme region of the caudal fin, taking the region of the caudal fin down. Individual III presents its winding similar to individual II. Individual IV has less wrapping leaving the lower part of the caudal fin in the pectoral region. Individuals V, VI and VII have a curling pattern similar to individual II, with the bottom of the caudal fin down. Individual VIII presents a less curled pattern with the lower part of the tail looser.

**Specimen measurement**

Table 2 shows details of the information presented in figure 3, after performing biometrics based on Compagno (13), no individual underwent an autopsy.

**Table 2 - Standard measures for elasmobranchs according to Compagno (13).**

| NORMAL | AN 1 | AN 2 | AN 3 | AN 4 | AN 5 | AN 6 | AN 7 | AN 8 |
|--------|------|------|------|------|------|------|------|------|
| TL[cm] | 31   | 27   | 25   | 26   | 0    | 0    | 23   | 21   | 0    |
| PCL    | 22   | 22   | 20   | 20   | 23   | 21   | 16   | 14   | 17   |
| CDM    | 9    | 7    | 9    | 8    | 7    | 7    | 8    |      |      |
| HDL    | 7    | 7    | 6.2  | 6.5  | 6.3  | 6.5  | 5.5  | 4.8  | 5.4  |
| GS1    | 0.5  | 0.5  | 0.4  | 0.3  | 0.4  | 0.4  | 0.3  | 0.2  | 0.3  |
| P1A    | 4    | 3    | 3    | 3.2  | 3.3  | 3.1  | 2.1  | 2.5  | 2.5  |
| D1L    | 3    | 3.2  | 3.8  | 3.5  | 4    | 3.7  | 3.1  | 2.9  | 3.2  |
| D1H    | 2    | 1.5  | 1.8  | 1.6  | 2    | 1.6  | 0.6  | 1.2  | 1.7  |
| D1I    | 1    | 1    | 1    | 1    | 1    | 1    | 0.7  | 1    | 1    |
| D1B    | 3    | 2.2  | 2.3  | 2.1  | 2.7  | 2.3  | 2.1  | 2    | 2.2  |
| D2B    | 1    | 1    | 0.5  | 0.5  | 0.5  | 0.5  | 0.5  | 0.3  | 0.4  |
| P2B    | 2    | 0    | 0.7  | 0.5  | 0    | 0    | 0    | 0    | 0    |
| CTR    | 2    | 1.7  | 1.7  | 1.7  | 1.6  | 1.6  | 1.5  | 1.3  | 1.1  |

**Legend:** AN: anomaly; TL: Total length; PCL: Pre-flow length; CDM: Caudal fin length; HDL: Head length; GS1: Height of first gill; P1A: Pectoral fin anterior margin; D1L: Length of the first dorsal fin; D1H: Height of the first dorsal fin; D1I: Length of the inner margin of the first dorsal ridge; D1B: Base of the first dorsal ridge; D2B: Base of the second dorsal fin; P2B: Pelvic fin base; CTR: Tail fin end margin

**5 DISCUSSION**

Studies with elasmobranchs have been increasing in recent years, but there are still few studies on anomalies that affect the group. Due to the difficulties in carrying out the research, it is not known, for sure, which aspects are directly influencing the reported cases (7).

The anomaly found in the present study corresponds to scoliosis in the caudal fin. The same type of deformity was identified in the species *R. lalandii* in the coastal city of Praia Grande, in the State of São Paulo, by Santos (7). Three individuals were registered who, in addition to vertebral
deformity, also had kyphosis, which is the abnormal curvature of the spine and lordosis which refers to the excessive curving of the lower part of the spine. In the same study it was presented the internal anatomy where it was possible to count the vertebrae having the individual A 83 vertebrae and the individuals B and C 86 vertebrae. However, they did not present caudal fin winding as the neonates observed in this study. A case of dicephaly in the species *R. porosus* has also been reported, the first case recorded in Brazil, where the newborn infant has two heads, each containing a mouth, pair of eyes and nostrils having its bifurcation up to the height of the pectoral fins. Dicephaly has already been found in other shark species such as *Galeorhinus galeus* (27) and *Carcharhinus leucas* (9), but the possible causes of deformities have not been presented in the reported cases.

According to Santos (7), the survival of newborns with caudal anomalies has already been recorded in nature. However, the difficulty in swimming leaves them vulnerable to predation, environmental conditions and the search for food and partners.

Many authors such as Clarke (4) and Muñoz-Osorio (5) believe that human activities may be associated with anomalies found in these animals, such as high levels of pollutants in the seas (for example, mercury, lead and others), degradation of the marine environment and fishing excessive, which contributes to decrease genetic variability between individuals. Therefore, scientific studies regarding these occurrences of anomalous animals are important. In addition to anthropic aspects, genetic mutations (such as deletion and addition of nucleotides) can occur spontaneously or from the interaction of genetic material with environmental elements (for example, radiation) (1).

Another aspect to be considered in cases of anomaly is reproduction. The females of the species generate, on average, litters of 2 to 6 young. However, the shark analyzed in the present study had 8 young. This fact may have represented excess intrauterine pressure (20), causing difficulty in the development of the embryos and leading to spinal deformity in the region of the caudal fin.

6 CONCLUSION

Anomaly cases must be reported so that future studies can be carried out in more depth, in addition to helping other researchers to discover what factors may be related to the development of deformities. Many hypotheses have already been raised, but there are no concrete data. It is of great importance to report the events, in order to have control of the cases, thus checking if there is an increase in the number of animals presenting anomalies in the last decades, if there is a relationship between the anthropic actions, if there is a relationship between the deformities and the species or if they are random facts. Thus, this work reports the first case of caudal anomaly in the species *Rhizoprionodon porosus* found on the south coast of São Paulo.
REFERENCES

1- Stearns. S. C., Hoekstra. R. F. Evolution an introduction. Sao Paulo. Atheneu: 2003.

2- Ribeiro. L. R., Salvadori. D.M. F., Marques. E. K., Environmental Mutagenesis. Canoas (RS). Ulbra, 2003.

3- Pugh., F. H. Heiser. J. B., Janis. C. M. The Life of Vertebrates. 3rd ed. Sao Paulo. Atheneu: 2003.

4- Clarke. S. C. McAllister. M. K. Milner-Gulland. E. J. Kirkwood. G. P. Michielsens C. G. J. Agnew. D. J. et al. Global estimates of shark catches using trade records from commercial markets. Ecology Letters. 2006; 9: 1115–1126.

5- Muñoz-Osorio. L. A., Mejía-Falla P. A., Navia A. F. First record of a bicephalic embryo of smalltail shark *Carcharhinus porosus*. Journal of Fish Biology. 2013; 82 (5): 1753-1757.

6- Wagner. C. M. Rice. P. H. Pease. A. P. First record of dicephalia in a bull shark *Carcharhinus leucas* (Chondrichthyes: Carcharhinidae) foetus from the Gulf of Mexico, U.S.A. Journal of Fish Biology. 2013; 82 (4): 1419-1422.

7- Santos. C. M. H., Gadig. O. B. F. Abnormal embryos of sharpnose sharks, *Rhizoprionodon porosus* and *Rhizoprionodon lalandii* (Elasmobranchii: Carcharhinidae), from Brazilian coast, western South Atlantic. Marine Biodiversity Records. 2014; 7 (55): 1-6.

8- Escobar-Sánchez, X. G. Moreno-Sánchez, C. A. Aguilar-Cruz, L. A. Abitia-Cárdenas. First case of synophthalmia and albinism in the Pacific angel shark *Squatina californica*. Journal of Fish Biology. March 2014. 85 (2): 1-8.

9- Mendoça F. F. Phylogeography of the genus *Rhizoprionodon* (Elasmobranchii, Carcharhiniformes) in the Western Atlantic using molecular markers of mitochondrial DNA. Botucatu Bioscience Institute. Botucatu. 2010.

10- Spiegel J. Even Jaws Deserves to Keep His Fins: Outlawing Shark Finning Throughout Global Waters. Boston College International and Comparative Law Review. 2001; 24 (2): 409-438.

11- Lessa R., Santana. F. M., Rincón. G., Gadig O. B. F., El-deir. A. C. A. Biodiversity of Elasmobranchs in Brazil. Recife (PE): Necton - Elasmobranchii: 1999.

12- Gomes U. L. Signori. C. N. Gadig. O. B. F. Santos.H. R. S. S. Guide for the identification of Rio de Janeiro sharks and rays. Rio de Janeiro: Technical Books; 2010.

13- Compagno L. J. V. FAO Species Catalog. Sharks of the world. An annotated and illustrated catalog of sharks species known to date. Part 2. FAO Fish. Synop, 1984; 125, (4) 251-655.

14- Ciena A. P. Rangel. B. S. Rangel. C. E. M. Miglino. M. A. Laranjeira M. E. Guimarães. J. P. Rotundo M. M. et al. Morphological Aspects of Oral Denticles in the Sharpnose Shark *Rhizoprionodon lalandii* (Muller and Henle, 1839) (Elasmobranchii, Carcharhinidae). Journal of Veterinary Medicine. March 2015; 45 (2016): 109-114.
15- Pinto A. C. B. C. F. Ferrigno, C. R. A. Matera J. M. Torres, L. N. Sinhorini, D. L. Cortopassi S. R. G. et al. Radiographic and tomographic aspects of meningeal hemangiosarcoma causing cauda equina syndrome in a German Shepherd. Rural Science, Santa Maria. 2017; 37 (2): 575-577.

16- Spadetto R. M. Dias, A.S. Diprosopia in calf - Case report. Acta Veterinaria Brasilia. 2012; 6 (4) 325-328.

17- Coelho E. G., Oliveira. D. A. A., Genetic testing in equideoculture. Revista Brasileira de Zootecnia. 2008; 37: 202-205.

18- Pacheco M. Addul Latif Hamzé. Bovine Dicephaly: Literature Review. Electronic Scientific Journal of Veterinary Medicine. January 2009; 5 (12): 1-4.

19- Sans-Coma V., Rodríguez C., López-Unzu MA, Lorenzale M., Fernández B., Vida L., Durán A. C. Dicephalous v. diprosopus sharks: record of a two-headed embryo of Galeus atlanticus and review of the literature. Journal of Fish Biology. 2016; 90 (1): 283-293.

20- Bonfil, R. S. An Abnormal Embryo of the Reef Shark, Carcharinhus perezi (Poey), from Yucatan, Mexico. Northeast Gulf Science. 1989; 10 (2): 1-3.

21- Tate E. E. Anderson P. A. Huber D. R. Berzins. I. K. Correlations of Swimming Patterns with Spinal Deformities in the Sand Tiger Shark, Carcharias taurus. International Journal of Comparative Psychology. 2013; 26 (1): 75-82.

22- Molion L. C. B. Global Warming, A Critical View. Brazilian Journal of Climatology. August 2008; 3: 1-18.

23- Hatje V. Costa M. F., Cunha L. C. Oceanography and Chemistry: Joining knowledge in favor of the oceans and society. Quim. Nova. September 18, 2013; 36 (10): 1497-1508.

24- Figueiredo J. L. Menezes N. A. Manual of marine fish from Southeast Brazil. University of São Paulo Museum of Zoology. 1977; Teleostei (4): 1-104.

25- Klein. R. Morphometric and Biological Aspects of Rhizoprionodon Sharks Captured by Fishing on the Brazilian Coast. UNIFIEO. 2011.

26- Rodrigues H. C. B., Dermal dentures of sharks from the Portuguese Coast: its use for the identification of different species. 2009.

27- Delpiani. S. M. Antoni. M. Y. D. Barbini. S. A. Figueroa. D. E. First record of a dicephalic specimen of tope Galeorhinus galeus (Linnaeus, 1758) (Elasmobranchii: Triakidae). Journal of Fish Biology. 2011; 78 (3): 941-944.