



MORPHOLOGY AND PHYSIOLOGY

## The adductor pectoral fin muscle of *Micropogonias furnieri* (Perciformes: Sciaenidae): a morphological and histochemical study

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**ABSTRACT.** The adductor pectoral fin muscle in post-spawning females of the white croaker *Micropogonias furnieri* (Desmarest, 1823) is described from a morphological, histochemical and morphometric perspectives. A description of the morphological characteristics was conducted after dissections in different layers, down to the deep layer. Five muscles were found: superficial, medial, radial and deep adductors, and dorsal arrector. Their fibers were studied after applying histochemical techniques: succinic dehydrogenase (SDH) to reveal mitochondria, periodic acid-Schiff (PAS) for glycogen, Sudan black for lipids, myosin adenosinetriphosphatase (mATPase) to reveal the types of fibers, and modified mATPase to evidence the capillaries. Fiber diameters were measured and the number of capillaries was counted. Fiber subtypes named small, medium and large were found within red, pink and white fibers, the latter prevailing. Staining homogeneity was observed in white fibers after alkaline pre-incubations. The number of capillaries decreased from red to white fibers. Due to the prevalence of white fibers, the adductor muscle of the pectoral fins appears to be capable of rapid and discontinuous movements, which are important to body stabilization during subcarangiform swimming. The homogenous staining of white fibers observed in this research corresponds to the post-spawning gonad stage studied.

**KEY WORDS.** fin musculature, histochemistry, morphology, morphometry, white croaker.

The myotomal and pectoral fin musculature of teleost fish has three different types of muscle fibers: red, white and pink. Differences in the histochemical, biochemical and ultrastructural features of fiber types have been found between species (DEVINCENTI et al. 2000a, b, 2009).

Enzyme histochemistry provides useful information for the classification of the different fiber types of vertebrates and invertebrates (OGATA 1988, ALVAREZ et al. 2012). Specifically, there are tests that measure the activity of the enzyme myosin adenosinetriphosphatase (mATPase) and the oxidative capacity of fibers. Slow and rapid contraction fibers can be differentiated with the mATPase technique. Rapidly contracting fibers stain more intensely than slowly contracting fibers. In turn, pre incubations at different pH's as well as changes in the incubation temperature, allow the detection of a great variety of muscular fiber types. The speed of contraction and the oxidative capacity of fibers tend to vary inversely (JOHNSTON 1981, BIEWENER 2003).

Environmental factors have a variable impact on the skeletal musculature of fish. For instance, hyperplasic annual growth phases have been observed in the white musculature of mugilids (CARPENÉ & VEGGETTI 1981). Furthermore, seasonal his-

tochemical and immunochemical variations have been observed in the muscle fibers of the pectoral fins of flatfish (CHAYEN et al. 1993). Beside environmental (extrinsic) factors, intrinsic factors such as gonad stage also influence the properties of muscular fibers. For instance, modifications of the ratio myosin/actin and changes in the biochemical and physicochemical features of actomyosin were observed in the myotomal muscle of hakes (CRUPKIN et al. 1988, ROURA et al. 1990). Additionally, a variation of the histochemical activity of the mATPase of myotomal white fibers, which correlate with the gonad stage, has been observed in scienid species (DEVINCENTI et al. 2000a).

The pectoral fins, which some fish species use for their primary propulsion, are modified in some other species for different functions (WALKER & WESTNEAT 2002). The swimming modes of fish species can be varied, but there are two main modes: labriform and subcarangiform. In the first, the fins are used for locomotion, while the miotomal musculature gives rigidity to the body. In the second, the pectoral fins are used to stabilize and to maneuver the body, while undulations from the back of the body generate the movement (JOHNSTON 1989, WARDLE et al. 1995, FERNÁNDEZ & CALVO 2009). Diverse studies have been

conducted on the pectoral muscles of Antarctic labriform fishes (JOHNSTON 1989, FERNÁNDEZ & CALVO 2009) and on subcarangiform fishes (CHAYEN et al. 1987, 1993, PATTERSON et al. 2008, DEVINCENTI et al. 2009, 2015).

The pectoral fins of teleost fishes are formed by abductor or extensor muscles, and adductor or flexor muscles. The number of pectoral muscles varies greatly among species. In highly derived fish species, the pectoral fins are located closer to the dorsum than to the venter and are actively used for swimming (COUSSEAU 2010).

The Whitemouth Croaker, *Micropogonias furnieri* (Desmarest, 1823), is a teleost fish that inhabits marine, brackish and fresh water environments. It has a wide distribution, from the Yucatán Peninsula (Mexico) to 41°S (Argentina), and a subcarangiform type of swimming (COUSSEAU & PERROTTA 2013). Adults usually develop in the shallow waters of the continental platform, on muddy and sandy substrates (BERMARDES et al. 2005). The Whitemouth Croaker is one of the most important demersal fishes of the South American estuaries, and is widely used for commercial and recreational purposes in Brazil, Argentina and Uruguay (MANICKCHAND-HEILEMAN & KENNY 1990, MACCHI et al. 2011, VIEIRA et al. 1998, CHAO 2002). In terms of biomass, it is the dominant species of the Río de la Plata's estuary (JAUREGUIZAR et al. 2003).

After conducting preliminary morphological and histochemical studies on the pectoral fin muscles of *M. furnieri*, we encountered three fiber types at the muscle insertion zone of the fin: superficial red, deep white and intermediate pink (DEVINCENTI et al. 2009). No studies have yet analyzed in a more detailed way the morphology and composition of the fiber types of the adductor pectoral fin muscle of this Sciaenidae species. With this in mind, we provide a morphological, histochemical and morphometric characterization of the adductor pectoral fin muscle of post-spawning females of *M. furnieri*. Our goal was to relate the characteristics of the muscle fibers with the way of swimming and the gonad stages of the species.

## MATERIAL AND METHODS

Females of *M. furnieri* ( $n = 10$ , length  $38.25 \pm 4.65$  cm, weight  $629 \pm 219.77$  g), obtained from sport and commercial fishing at the municipality of Mar del Plata (Argentina), were used in this study. The animals were sacrificed by cervical dislocation, following the guidelines of the American Fisheries Society (AFS 2004). The pectoral fins and gonads of every individual were removed. The gonads were processed for their inclusion in paraffin, and the scale proposed by BROWN-PETERSEN et al. (2011) was used to determine the gonad stage. Only the post-spawning stage was observed. The pectoral fins were used both for the morphological description of the muscle and the histochemical techniques.

Fresh samples, and specimens fixed in formaldehyde buffer were dissected from the superficial to the deep plane of the muscle. Photographs of the different muscle layers were

taken with an Olympus SP-350 digital camera. The morphology, origin and insertion of every muscle were macroscopically observed, and the orientation and fiber types were determined (COUSSEAU 2010).

The adductor pectoral fin muscle was removed and fixed in liquid nitrogen. Approximately 15  $\mu\text{m}$ -thick seriated cryostat cuts were made on the entire muscular mass; the muscles were not separated because they are very fragile, and excessive manipulation makes them unsuitable for the rapid freezing fixation required to perform the histochemical techniques. The hematoxylin-eosin technique (H-E) was used to verify the transversal orientation of the fibers, and the histochemical techniques were performed as follows:

1. Succinic dehydrogenase (SDH) (DEFENDI & PEARSON 1955, DEVINCENTI et al. 2015): to evidence the oxidative capacity of the fiber. The activity of this enzyme was demonstrated using the nitroblue tetrazolium technique. In the control, sodium succinate was replaced by sodium malonate.
2. Periodic acid Schiff (PAS) (HOTCHKISS 1948): to evidence glycogen. Samples were treated with periodic acid and colored with Schiff's reagent. Controls were made with  $\alpha$ -amylase prior to the treatment with periodic acid.
3. Sudan Black (CHAYEN et al. 1973): to evidence neutral lipids. Sections were stained in a saturated solution of color in 70% ethyl alcohol. In the controls the sections were treated with acetone half an hour before staining.
4. Myosin adenosinetriphosphatase (mATPase): to identify different fiber types based on the contraction speed. The GUTH & SAMAHA (1970) method adapted for fish (JOHNSTON & TOTA 1974) was used. The modifications proposed by DEVINCENTI (1998) and LONGO & DÍAZ (2013) were implemented: sections were pre-incubated in buffered glycine/NaOH at pH's 9.8, 10.4 and 10.6, and with acetate buffer at pH's 4.6 and 4.3. Controls were prepared by replacing ATP with sodium glycerophosphate.
5. Modified mATPase to evidence capillaries and fiber diversity, applying the original ROSENBLATT et al. (1987) technique with the following modifications: the material was fixed in 5% formaldehyde, sucrose 0.36 M and  $\text{Cl}_2\text{Ca}$  0.068 M at ambient temperature and at 4°C from one to five minutes; incubation at ambient temperature.

In order to determine mean fiber diameter, 100 red, pink and white fibers per animal ( $n = 5$ ) were measured with the technique developed by TE KRONNIE et al. (1983). From the mean diameter, the fiber area was obtained with the following formula (ALNAQEEB & GOLDSPINK 1986):  $A = (D/2)^2 \times \pi$ , where A = area of a fiber type, and D = mean diameter of a fiber type.

To determine the number of capillaries vascularizing the red, pink and white muscle fibers, 100 fibers of each type were analyzed in five specimens. For each fiber type, the percentage of fibers surrounded by 0, 1, 2, 3, 4 and 5 capillaries was calculated. The average number of peripheral capillaries (PC) per fiber type was also obtained. With the PC and the area of each fiber

type, the fiber area per peripheral capillary (APC) was calculated (MOSSE 1978):  $APC = A/PC$ .

Statistical analysis was performed with the SigmaPlot 12.0 program. Mean diameters and the number of capillaries between different fibers types were compared using the Kruskal-Wallis (ZAR 2010) test. The frequency histograms for the mean diameter of every fiber were obtained with the Minitab 16 program.

## RESULTS

### Morphology

The adductor pectoral fin muscle in post-spawning females of *M. furnieri* is composed of five different muscles, distributed in two layers: a more superficial layer, attached to the skin, and a deeper layer, attached to the skeletal elements.

The superficial musculature consists of: the superficial adductor, the medial adductor and the radial adductor. The superficial adductor, with pink and white fibers, elongated and rectangular in shape, originates in the cleithrum and the scapula, and is inserted on the medium surface of the fin rays by tendons (Fig. 1). The medial adductor, triangular in shape and composed of white fibers, comes from the cleithrum and is inserted on the medium rays of the fin, through tendons (Figs. 1, 2). The slender and elongated radial adductor is composed of white fibers, and connects the radials and the coracoid with the ventral rays of the fin (Figs. 1, 2).

In the deep plane, below the superficial adductor, the triangle-shaped dorsal arrector, composed of pink and white fibers, was found. Its origin comes from the cleithrum, coracoid and scapula, and it is inserted on the upper rays of the fin by tendons (Figs. 2, 3). Ventral to the radial adductor, the rounded deep adductor, comprising red, pink and white fibers, is found; its origin comes from the coracoid and the cleithrum. It inserts through tendons on the base of the inferior rays of the fin (Figs. 2, 3).

### Histochemistry

Red, pink and white fibers were found in the adductor muscle. Three fiber subtypes were categorized: small, medium and large fibers, each with their own histochemical properties.

The PAS and SDH techniques resulted in a strong reaction from the small red fibers, while medium and large fibers displayed a moderate reaction (Figs. 4, 5). The mATPase activity of the three red fiber types was strong and stable at pH 9.8, and light at pHs 10.4 (Fig. 8) and 10.6. As for the acid pre-incubation, red fiber activity was strong and stable, and the fibers deactivated only after long pre-incubation periods (Table 1).

Small and medium pink fibers reacted moderately to SDH and PAS, while large fibers reacted only slightly (Figs. 4, 5). The mATPase activity on small and medium pink fibers was moderate at pH 9.8, losing its activity at pH's 10.4 (Figs. 8, 9) and 10.6. On the other hand, the mATPase activity of large pink fibers was stable and strong after alkaline pre-incubation and

for long periods (Table 1). The activity after acid pre-incubation was moderate to strong for all three fiber subtypes at different pH's (Fig. 10) and pre-incubation times (Table 1).

Table 1. Histochemistry of the adductor pectoral fin muscle of *Micropogonias furnieri*.

	Red Fibers			Pink Fibers			White Fibers		
	s	m	l	s	m	l	s	m	l
SDH	3/4	2	1/2	2	2	1	p 1	1	0
							d 0/1	0	0
PAS	4	3/4	2/3	2/3	2	1/2	p 0/1	1	0
							d 0	0	0
mATPase	4	4	3/4	2/3	3	2	p 2	2	3
S/P							d 2	2	2
mATPase	1/4	1/3	2/3	1/2	1/2	4	p 1/2	2	2/3
9.8							d 1/2	1/2	2
mATPase	1	1	1	1	1/2	3/4	p 1/2	2	2
10.4							d 1	2	2
mATPase	1	1	1	1	1/2	3/4	p 1/2	2	2
10.6							d 1/2	2	2
mATPase	1/3	1/2	2/3	2/3	2/3	2/3	p 1/2	1/2	1/2
4.6							d 1/2	1/2	1/2
mATPase	0/1	0	0	3	2/3	2/3	p 3	2/3	1
4.3							d 3	1	1

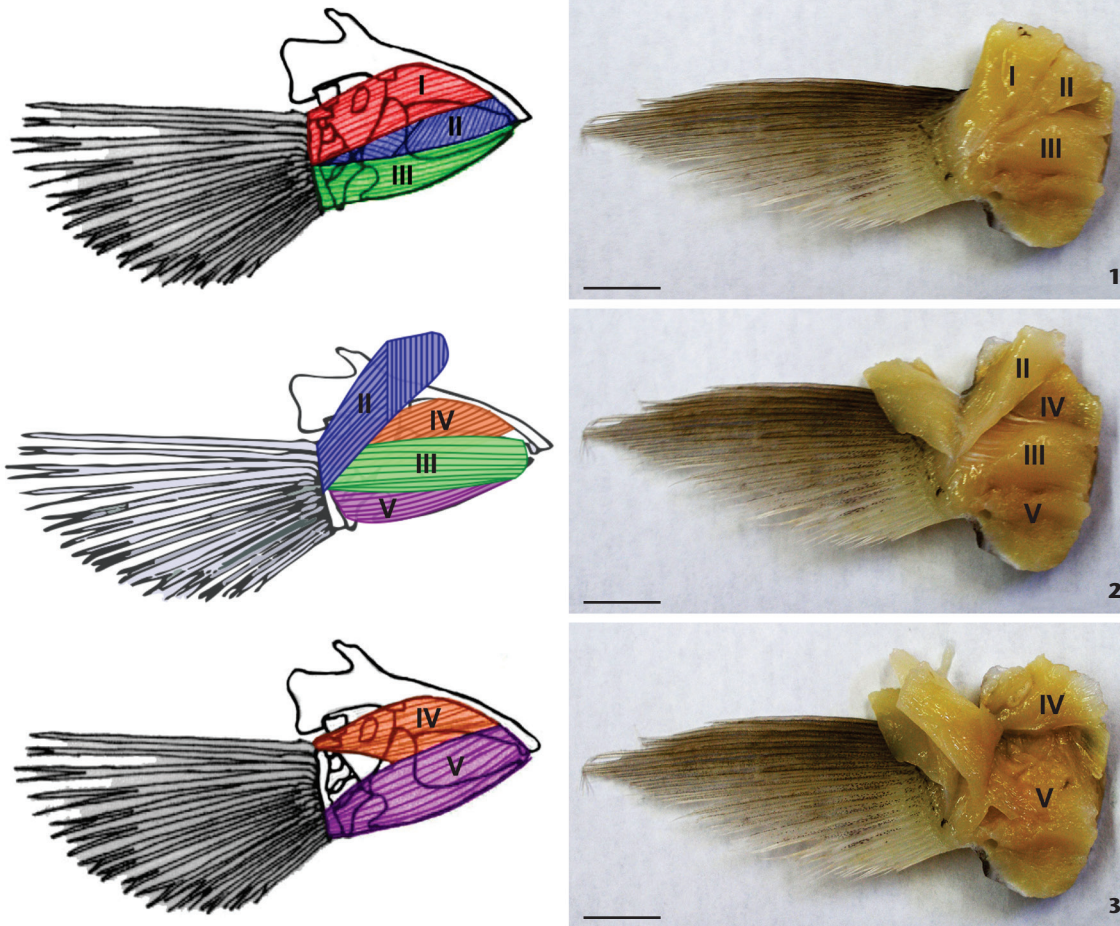
Reactivities: negative (0); weak (1); moderate (2); strong (3); very strong (4). Distal (d) zone; large (l); medium (m); myosin-adenosinotriphosphatase (mATPase); Periodic Acid-Schiff (PAS); proximal (p) zone; small (s); succinate dehydrogenase (SDH).

Among the white fibers, two different histochemical zones were determined: a proximal zone, following the pink fibers in the insertion region of the muscle on the fin rays, and a distal one, in the region of the bone origin. The small and medium white fibers of the proximal zone slightly reacted to SDH and PAS, while the large failed to react to either technique (Figs. 6, 7). In the distal zone, white small fibers presented a very slight activity for SDH, and both medium and large fibers showed no reaction; the PAS-activity was negative for all three fiber types (Fig. 7). In relation to the mATPase, the activity of the three fiber types was moderate and stable in both zones after alkaline pre-incubations (Fig. 9). The activity of white fibers from the proximal zone at pH's 4.6 and 4.3 was variable, as the pre-incubation times increased, and a mosaic pattern was observed (Fig. 10). On the other hand, fibers at the distal zone, at pH 4.6, had moderate activity during short pre-incubation periods; after longer periods the activity decreased (Table 1). At pH 4.3, after 5 min pre-incubation, the small white fibers had a strong reaction, and the medium and large fibers had a weak reaction (Fig. 11).

For the Sudan Black technique, red, pink and white fibers of both zones had no reaction.

The modified mATPase technique for capillaries (one-minute formaldehyde fixation) allowed evidencing both fibers and capillaries. Red fibers showed no activity, pink fibers gave moderate activity and white fibers revealed moderate to weak activity (Figs. 12-14).





Figures 1-3. Diagram of the adductor pectoral fin muscles of *Micropogonias furnieri*. (1). Superficial view showing the adductor superficialis (I), adductor medialis (II) and adductor radialis (III), (bar = 1 cm). (2). Superficial view showing adductor medialis (II), adductor radialis (III), adductor profundus (V) and arrector dorsalis (IV); no adductor superficialis is evidenced, (bar = 1 cm). (3). Superficial view showing adductor profundus (V) and arrector dorsalis (IV); no adductor medialis is evidenced, (bar = 1 cm).

## Morphometry

Red fibers had an average mean of  $39.33 \pm 14.31 \mu\text{m}$  (range 16.2-75.51  $\mu\text{m}$ ) and a round appearance. They were the least abundant of all fiber types, and were only present below the tissue and intermingled with some pink fibers.

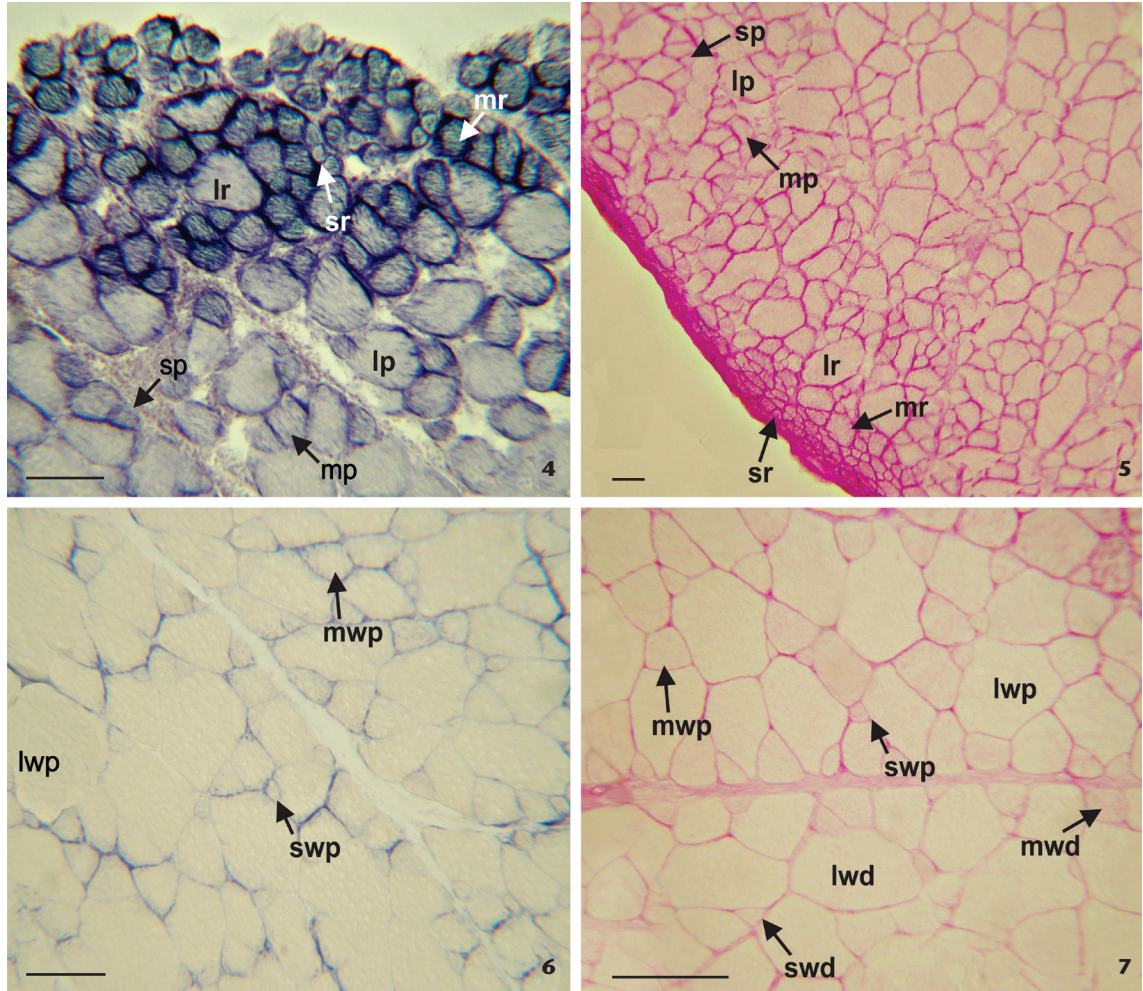
Pink fibers, polyhedral in shape, presented an average diameter of  $48.11 \pm 21.19 \mu\text{m}$  (range 14.63-110.71  $\mu\text{m}$ ) and were found among the red and white fibers.

White fibers prevailed over the other two types: the ones in the proximal zone, with a mean diameter of  $73.68 \pm 28.44 \mu\text{m}$  (range 21.5-152.16  $\mu\text{m}$ ) and those in the distal zone, with a mean diameter of  $77.34 \pm 31.32 \mu\text{m}$  (range 27.61-162.16  $\mu\text{m}$ ) and polyhedral in shape.

Significant differences in diameter were observed between: a) red and pink fibers ( $p < 0.05$ ) (Fig. 15); b) red and proximal

zone white fibers ( $p < 0.05$ ) (Fig. 16); c) red and distal zone white fibers ( $p < 0.05$ ) (Fig. 17); d) pink and proximal zone white fibers ( $p < 0.05$ ) (Fig. 18) and e) pink and distal zone white fibers ( $p < 0.05$ ) (Fig. 19). No significant differences were found between the white fibers of both zones ( $p < 0.05$ ) (Fig. 20).

The average number of capillaries surrounding red fibers was 1.51 and the percentage of fibers surrounded by no capillaries was 16%. In the proximal zone, the average number of capillaries surrounding pink and white fibers was less than the average number of capillaries surrounding red fibers. The percentage of fibers not surrounded by capillaries was as follows: 44% for pink fibers, 33% for proximal zone white fibers and 52% for distal zone white fibers. White fibers of the distal zone had a maximum of three capillaries per fiber, while white fibers of the proximal zone had a maximum number of four (Table 2). The APC increased from red to white fibers in the proximal zone (Table 3).



Figures 4-7. Histochemical staining of red, pink and white fibers from the adductor fin muscle of *Micropogonias furnieri*. (4). Red fibers showing strong staining (SDH technique); pink fibers showing weak reaction to SDH (lp: large pink, lr: large red, mp: medium pink, mr: medium red, sp: small pink, sr: small red), (bar = 100  $\mu$ m). (5). Periodic acid-Schiff (PAS) showing small red fibers (sr) with very strong stain intensity, and small pink (sp) fibers with moderate activity; medium and large fibers react weakly to PAS (lp: large pink, lr: large red, mp: medium pink, mr: medium red), (bar = 50  $\mu$ m). (6). The small (swp) and medium (mwp) white fibers of the proximal zone show a weak reaction to SDH; large fibers (lwp) have no reaction, (bar = 100  $\mu$ m). (7). White fibers of the proximal zone react weakly to PAS; white fibers of the distal zone have no reaction (lwd: large white distal, lwp: large white proximal, mwd: medium white distal, mwp: medium white proximal, swd: small white distal, swp: small white proximal), (bar = 150  $\mu$ m).

Table 2. Capillary supply of the adductor pectoral fin muscle of *Micropogonias furnieri*.

Fibre	Percentage of fibers surrounded by 0-5 capillaries					PC
	0	1	2	3	4	
Red	16	37	28	18	1	1.51 <sup>a</sup>
Pink	44	30	22	4		0.86 <sup>bc</sup>
White proximal zone	33	46	15	4	2	0.96 <sup>b</sup>
White distal zone	52	37	10	1		0.60 <sup>c</sup>

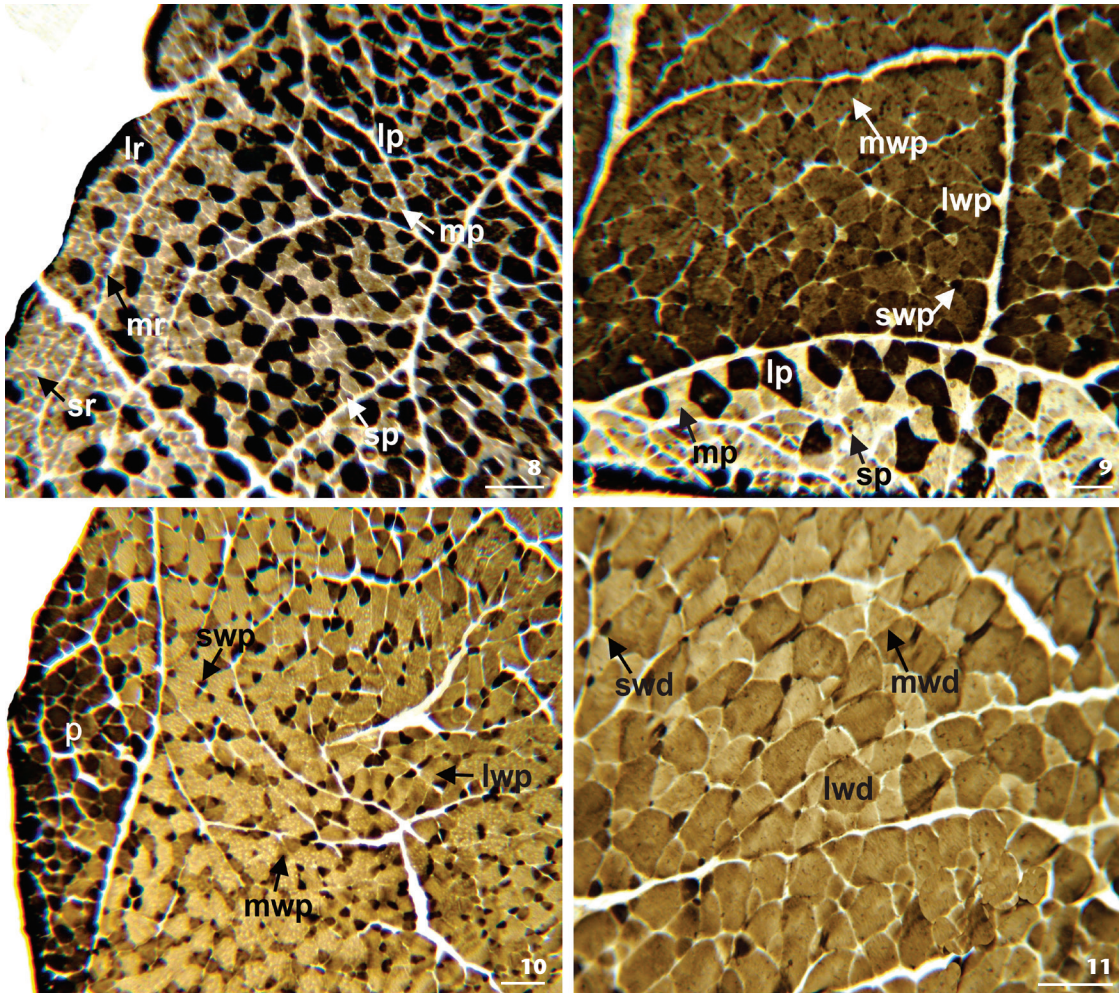
References: peripheral capillary average (PC). Similar superscripts express no statistically significant differences. Different superscripts indicate statistically significant differences ( $p < 0.05$ ).

Table 3. Standardized data of capillarization for the mean transverse area of each muscle fiber type in the adductor pectoral fin muscle of *Micropogonias furnieri*.

Fibre	D ( $\mu$ m)	A ( $\mu$ m <sup>2</sup> )	PC	APC ( $\mu$ m <sup>2</sup> )
Red	39.33 $\pm$ 14.310 <sup>a</sup>	1214.27	1.51	804.15
Pink	48.11 $\pm$ 21.19 <sup>b</sup>	1816.94	0.86	2112.72
White proximal zone	73.68 $\pm$ 28.44 <sup>c</sup>	4261.56	0.96	4439.12
White distal zone	77.34 $\pm$ 31.26 <sup>c</sup>	4695.46	0.60	7825.76

References: area per muscle fiber type (A); area per peripheral capillary (APC); mean diameter (D); peripheral capillary average (PC). Similar superscripts express no statistically significant differences. Different superscripts indicate statistically significant differences ( $p < 0.05$ ).





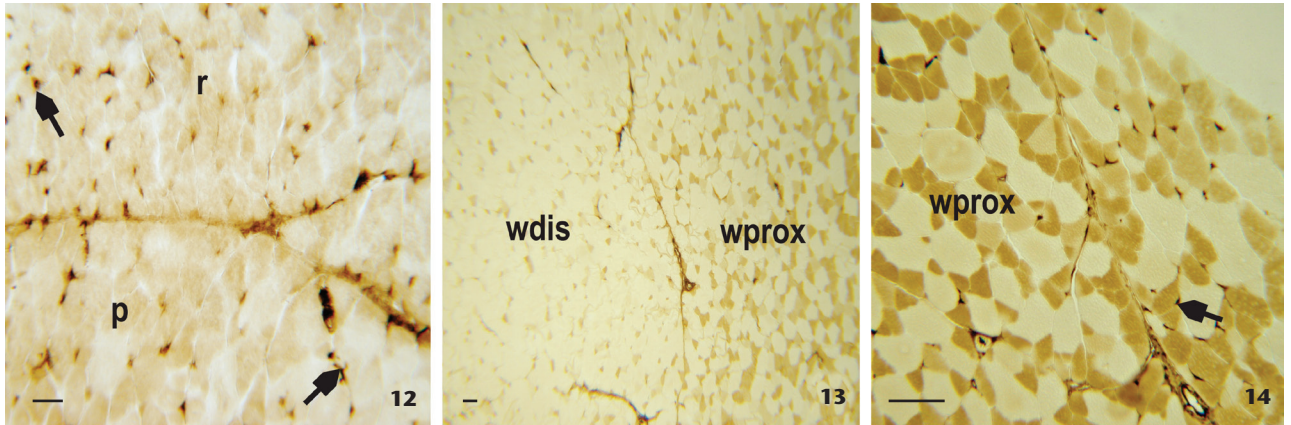
Figures 8-11. Histochemical staining of mATPase activity in the adductor fin muscle of *Micropogonias furnieri*. (8). mATPase activity with pre-incubation at pH 10.4 showing red and pink fibers; small and medium fibers lose their activity; large fibers show a strong reaction (lp: large pink, lr: large red, mp: medium pink, mr: medium red, sp: small pink, sr: small red), (bar = 100  $\mu$ m). (9). mATPase activity with pre-incubation at pH 10.4. A homogeneous staining of white fibers of the proximal zone is shown (lp: large pink, lwp: large white proximal, mp: medium pink, mwp: medium white proximal, sp: small pink, swp: small white proximal), (bar = 120  $\mu$ m). (10). mATPase activity with pre-incubation at pH 4.3; white fibers of the proximal zone showing a mosaic pattern of staining (lwp: large white proximal, mwp: medium white proximal, p: pink, swp: small white proximal), (bar = 120  $\mu$ m). (11). mATPase with pre-incubation at pH 4.3 showing white fibers of distal zone; small white fibers (swd) exhibit a strong reaction; medium (mwd) and large (lwd) fibers show a moderate reaction, (bar = 80  $\mu$ m).

## DISCUSSION

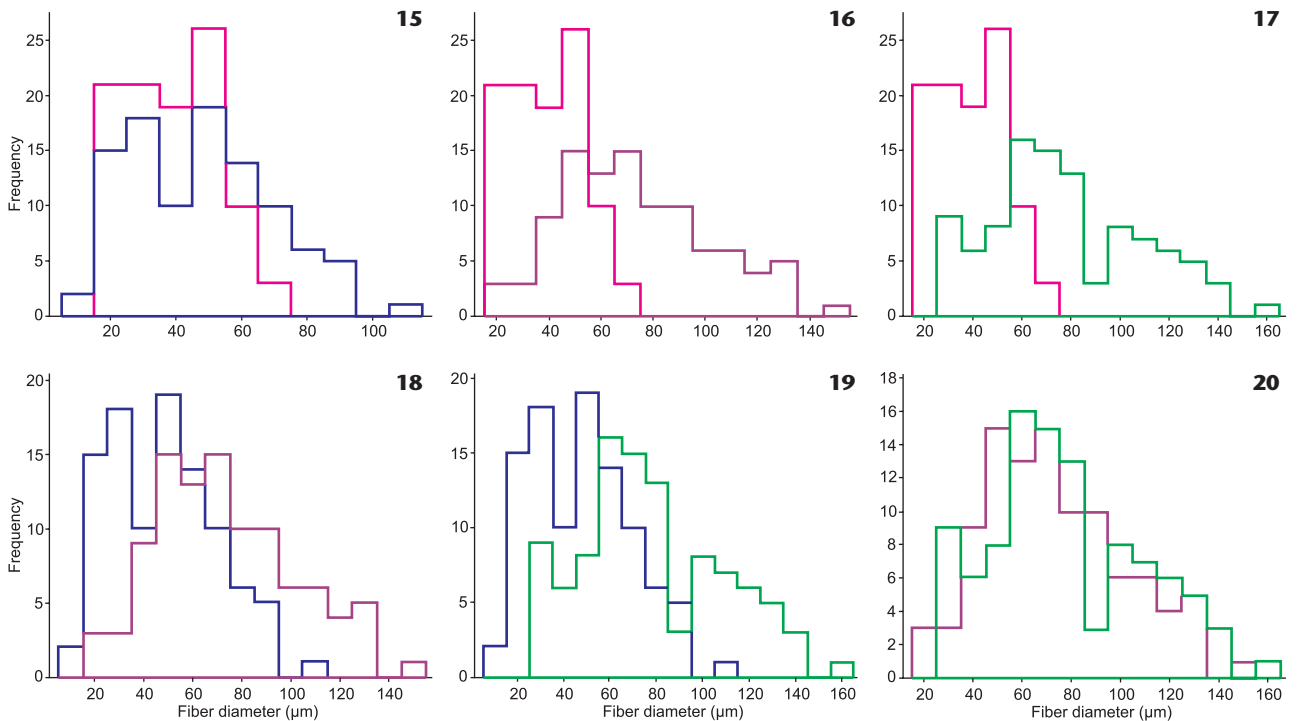
The composition of the adductor pectoral fin muscle of *M. furnieri*, in our data, is consistent with the findings of other investigations on teleost fish in general (WINTERBOTTOM 1974, THORSEN & WESTNEAT 2005, COUSSEAU 2010). However, the presence and morphology of these muscles vary among species (THORSEN & HALE 2005, MIANO et al. 2013). For instance, according to DIOGO & ABDALA (2007) in *Danio rerio* (Hamilton, 1822) the superficial

and deep adductor muscles are not individualized, but comprise a single entity. In *M. furnieri*, on the other hand, these muscles are separated by connective tissue into two fascicles, and are thus considered individual muscles.

The adductor muscle of the pectoral fins of *M. furnieri* is mainly composed of white fibers and, to a lesser extent, red and pink fibers, just as in the myotomal musculature and the abductor muscle of the species (DEVINCENTI et al. 2000a, 2009). The anatomy of the abductor muscle of the striped weakfish



Figures 12-14. Histochemical staining of mATPase for capillaries from the adductor fin muscle of *Micropogonias furnieri*. (12). The number of capillaries (black arrow) in red fibers (r) is greater than those found in the other fiber types; pink fibers (p) have an intermediate irrigation, (bar = 150  $\mu$ m). (13). The technique shows two different white fibers zones: proximal (wprox) and distal (wdis), (bar = 50  $\mu$ m). (14). The white fibers proximal (wprox) zone exhibits more irrigation than the distal zone (black arrow: capillaries), (bar = 130  $\mu$ m).



Figures 15-20. Frequency histogram of fiber diameters of the adductor fin muscle of *Micropogonias furnieri*. (15). Red and pink fibers. (16). Red and white fibers from the proximal zone. (17). Red fibers and white fibers from the distal zone. (18). Pink and white fibers from the proximal zone. (19). Pink and white fibers from the distal zone. (20). White fibers from the proximal and distal zones. Pink line, red fibers; blue line, pink fibers; purple line, proximal zone white fibers; green line, distal zone white fibers.

*Cynoscion guatucupa* (Cuvier, 1830) (Sciaenidae) (DEVINCENTI et al. 2015), which also presents a subcarangiform mode of swimming, is also consistent with this model.

The arrangement of the small red fiber in the adductor muscle of the pectoral fin of *M. furnieri* is not consistent with the arrangement of the small red fiber in the corresponding



myotomal muscle (DEVINCENTI et al. 2000a). In the fins, the red fibers are round, and are located below the connective tissue, while in the myotomal musculature they form spherical groups within the red musculature. This small red fiber subtype was also found in the abductor of *M. furnieri* and *C. guatucupa* (DEVINCENTI et al. 2009, 2015).

Medium red fibers had a mATPase activity that agrees with the description of IBABE MARTINEZ et al. (2000) of “typical red fibers” of species like *Seriola dumerili* (Risso, 1810), *Diplodus vulgaris* (Geoffroy Saint Hilaire, 1817), *Trachinus draco* Linnaeus, 1758 and *Liza aurata* (Risso, 1810). It also agrees with the description of DEVINCENTI (1998) of the myotomal musculature of *M. furnieri*.

The large red fibers of the adductor pectoral fin muscle of *M. furnieri* presented the same metabolic features described for the “other red” fiber type of the myotomal musculature of this species, and species such as *Oreochromis niloticus* (Linnaeus, 1758) and *Thunnus orientalis* (Temminck & Schlegel, 1844) (DAL PAI-SILVA et al. 2003, ROY et al. 2012). On the other hand, the activity of the mATPase exhibited a pattern opposite to the one found in the myotomal and abductor muscles (DEVINCENTI et al. 2000a, 2009). IBABE MARTINEZ et al. 2000, described this type of fiber like “infiltrated pink fibers”.

Pink fibers were consistent with those of the abductor muscle with regards to the mATPase activity after alkaline treatments, while activity in both muscles was different for acid treatments. Moreover, the oxidative activity and the glycogen content of pink fibers in the adductor muscle were higher than in the abductor muscle (DEVINCENTI et al. 2009). This is no surprise since the adductor muscle is involved in slower and continuous movement during fin upstrokes (THORSEN & WESTNEAT 2005).

The distribution of the white fibers of the adductor pectoral fin muscle of *M. furnieri* was consistent with that found in the abductor muscle of *C. guatucupa* (DEVINCENTI et al. 2015): a proximal zone with a mosaic of white fibers, and a distal zone with more homogeneous staining fibers. However, while the mean diameters of white fibers in both zones had significant differences in *C. guatucupa* (DEVINCENTI et al. 2015), they were similar in *M. furnieri*.

Differences have been found in the histochemical profile of the white fibers of the myotomal musculature of *M. furnieri* and *C. guatucupa*, according to the gonad stage. In females of *M. furnieri*, white muscles at post-spawning and/or resting stages presented great resistance to alkaline and acid treatments, with a homogeneous mATPase activity. However, in maturation and pre-spawning stages the white muscle was less resistant to those treatments, resulting in a mosaic of white fibers (DEVINCENTI et al. 2000a). In the white muscle of the pre-spawning hake a change in the ratio myosin/actin was found (CRUPKIN et al. 1988). The contractile properties of the white muscle of *Myoxocephalus scorpius* (Linnaeus, 1758) vary according to the reproductive cycle (JAMES & JOHNSTON 1998). According to our work, the staining homogeneity of white fibers to the mATPase technique at different pHs agree with the post-spawning gonad stage of the individuals under study.

The technique used to determine capillaries also allowed the identification of fiber types. Nevertheless, the fixation time influenced their expression: long fixation periods determined the total loss of fiber activity, and only the capillaries became evident. Short fixation periods allowed the observation of fibers and capillaries. With this same technique, red fibers gave low activity, and white and pink fibers gave from moderate to high. Opposite results were found in the myotomal muscle of *M. furnieri*, *C. guatucupa* and *Engraulis anchoita* Hubbs & Marini, 1935 (DEVINCENTI et al. 2000a, b, 2015). In mammals, prolonged fixation stained the capillaries and, in turn, the reaction was more intense in type II (rapid) fibers than in type I (slow) fibers (ROSENBLATT et al. 1987). In bird muscles, however, this technique permitted the detection of capillaries only (FOUCES et al. 1993).

The distribution of capillaries in fibers of the adductor pectoral fin muscle of *M. furnieri* was coincident with that of the teleost fish musculature (MOSSE 1978, DEVINCENTI et al. 2000b). The two white muscle zones presented differences in relation to the number of capillaries supplying them, decreasing from the proximal to the distal region. A positive correlation exists between the blood supply and the oxidative capacity of fibers in every white muscle zone. Similar results were found (DEVINCENTI et al. 2015) for the abductor muscle of *C. guatucupa*. The greater vascularization of the continually active red muscle offer the potential needed to guarantee an adequate transport of substances to and from the muscular fibers. On the contrary, the dependence of the white muscle on the anaerobic metabolism seems to be a consequence of low vascularization (MOSSE 1978).

According to the results of this study, we highlight the dominance of white fibers in the pectoral fins of *M. furnieri*. This fact, undoubtedly, is correlated with the subcarangiform way of swimming, where the pectoral fin is involved in the execution of fast and discontinuous movements in order to stabilize and maneuver the body. Moreover, the homogenous staining of the white muscle would be related with the gonadal stage here studied.

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