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Growth Analysis of *Microlepidotus brevipinnis* from the Pacific Coast of Jalisco, Mexico

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Abstract: Thirteen age groups were identified for *Microlepidotus brevipinnis* (Pisces: Haemulidae). Otoliths sagittae gave a better fit between observed and calculated data than scales, but both methods are considered valid for age determination. The constants of Von Bertalanffy´s growth equation calculated through sagittae analysis were: L_∞ = 388.68 mm, W_∞ = 829.741 g, K = 0.207, t_0 = -0.718 and $A_{0.95}$ = 14 years. Differences in growth between sexes were found; females show higher values of L_∞ and longevity than males. *Microlepidotus brevipinnis* reaches its sexual maturity at age four. The gonadosomatic index presented higher values during December and March. The periods of more intensive feeding and fatty acids accumulation in liver are from May to October. With other researcher data, growth parameters of species from the same family were calculated in order to compare them with the one obtained in the present study. *Microlepidotus brevipinnis* has an intermediate size among other species of the same family.

Key words: Fish ecology, fisheries, population dynamic, Von Bertalanffy's equation, resource management

INTRODUCTION

Microlepidotus brevipinnis (Pisces: Haemulidae) or brassy grunt (Fig. 1) is a demersal and coastal species of the continental shelf from Baja California and the Gulf of California to Chiapas, Mexico (Allen and Robertson, 1994; Fischer *et al*., 1995; Nelson *et al*., 2004). It

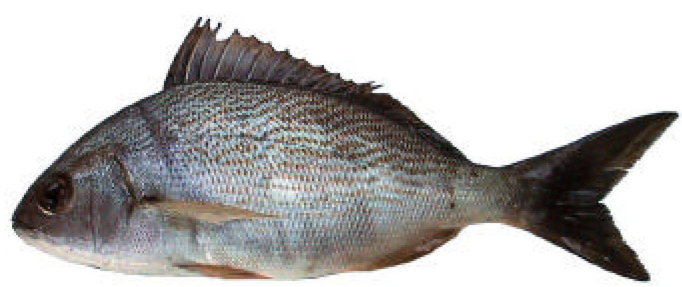

Fig. 1: Brassy grunt *Microlepidotus brevipinnis*

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is commonly fished during the whole year by artisanal fishers off the coast of Jalisco, México. Its capture volumes constitute about 10% of total annual average catch (Cruz-Romero *et al*., 1993).

This species is considered a second class commercial product; its price is from 20 to 30 pesos on the beach or from 30 to 40 pesos per kg in the market ($2.15 to $2.85 USD). Analysis on its taxonomic description has been made by Castro-Aguirre *et al*. (1999), Van der Heiden (1985) and Chávez-Ramos *et al*. (1994). Its fishery has been described by Ramírez-Granados (1977), Cruz-Romero *et al*. (1989, 1993, 1996) and Espino-Barr *et al*. (2003, 2004a) analyzed age and growth of this species using and indirect method of length frequency. Granados-Flores *et al*. (2010) determined the average length for each age with the analysis of the sagittae and scales.

Age and growth studies are necessary to understand the behavior of the fish population in time and space (Lucano-Ramírez *et al*., 2006). Analysis of age through direct methods based on hard structures as otoliths and scales are good instruments to estimate age groups and obtain growth Von Bertalanffy parameters (Espino-Barr *et al*., 2008; Gallardo-Cabello *et al*., 2006).

Analysis of the weight-length relation is very important to obtain the condition factor which explains yearly weight variations related to food availability (Safran, 1992). Calculations of the gonadosomatic index and the hepatosomatic index help to understand the growth through fish life span, the gonadic maturity and spawning phenomena, the fatty acid accumulation in the liver and the trophic dynamics of the populations (Saucedo-Lozano *et al*., 1999; Rojas-Herrera *et al*., 2004; Espino-Barr *et al*., 2004b, 2008; Rojas *et al*., 2004; Aguirre-León and Díaz-Ruiz, 2006).

In this study, the growth constants by Von Bertalanffy´s (1938) equation were calculated from the observed data obtained by the analysis of otoliths and scales. Differences between sexes were also analyzed. Longevity and values of the condition factor, gonadosomatic and hepatosomatic indexes were calculated.

MATERIALS AND METHODS

From January 2005 to June 2006, 1050 specimens of *Microlepidotus brevipinnis* (Pisces: Haemulidae) were obtained from the commercial catch in Melaque, coast of Jalisco (104°40'30" to 104°43'30"W and 19°12'00" to 19°13'30"N) (Fig. 2).

Standard (Ls, cm) and total length (Lt, cm), total (Wt, g) and eviscerated weight (We, g), gonad (Wg, g) and liver weight (Wl, g) were recorded for each individual. Sex was determined for 480 individuals; the other 570 were eviscerated by fishers before landing. For age study two structures were obtained from 353 individuals: otoliths (sagittae) and scales.

The average length of the fish at age groups determined by the analysis of the otoliths sagittae and scales by Granados-Flores *et al*. (2010) were used to obtain the constants by Von Bertalanffy´s (1938) growth equation. The observed values determined by sagittae were: for age 1 = 125.0 mm; age 2 = 141.72 mm; age 3 = 222.32 mm; age 4 = 246.46 mm; age 5 = 283.37 mm; age 6 = 291.76 mm; age 7 = 304.09 mm; age 8 = 318.44 mm; age 9 = 335.19 mm; age 10 = 340.46 mm; age 11 = 349.54 mm; age 12 = 367.24 mm and age 13 = 372.68 mm. The observed values determined by scales were: for age 1 = 125.0 mm, age 2 = 138.80 mm; age 3 = 220.00 mm; age 4 = 243.80 mm; age 5 = 281.50 mm; age 6 = 285.60 mm; age 7 = 295.20 mm; age 8 = 307.10 mm; age 9 = 315.60 mm; age 10 = 331.10 mm, age 11 = 346.40 mm; age 12 = 354.00 mm and age 13 = 360.50 mm.

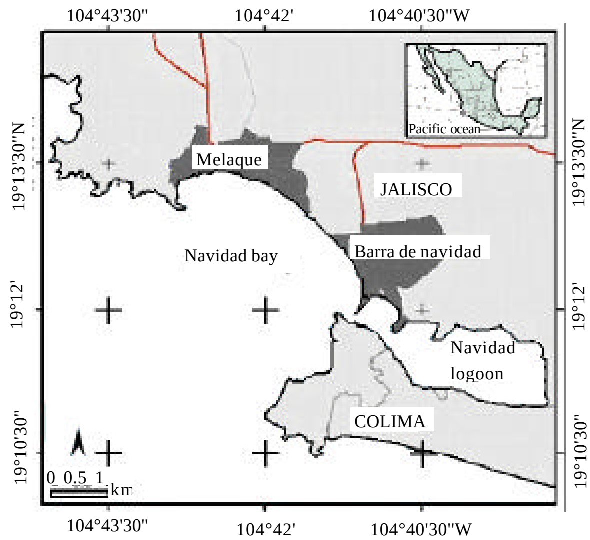

Fig. 2: Map of the study area, San Patricio Melaque, Jalisco, Mexico

The time of formation of slow or fast growth bands in sagittae, as well as the time of ring formation in scales was one year. The growth of otoliths and scales was proportional to the growth of the fish. There were growth differences between sexes (Granados-Flores *et al*., 2010).

The constants L_∞, K and t_0 of Von Bertalanffy´s (1938) equation were obtained with Ford (1933), Walford´s (1946) and Gulland´s method and were adjusted by convergent iterations of Newton´s algorithm with the Solver program in Excel software (Microsoft, 1992).

Weight-length relationship was calculated with the function $W = a * L^b$ (Mendenhall, 1987; Zar, 1996). Weight for every age was obtained with the growth data in length and the weight-length function. Weight growth was obtained substituting Lt and L_∞ for Wt and W_∞, in Von Bertalanffy´s (1938) equation. Age limit or longevity (95% of L_∞) was determined by Taylor (1958, 1960) equation:

$$A_{0.95} = \frac{\ln(1-0.95)}{K+t_0}$$

Monthly values of the condition factor, equivalent to the a parameter of weight-length equation, were obtained for total and eviscerated weight (Safran, 1992) and compared with the confidence interval, to explain changes in the gonad and liver throughout the year.

The gonadosomatic index (GSI) was determined with the equation described by Rodríguez-Gutiérrez (1992): GSI = Wg/Wt*100, where Wg is gonad weight and Wt is the total weight of the individual.

The hepatosomatic index (HSI) was calculated by Rodríguez-Gutiérrez (1992) as:

$$HSI = \frac{Wl}{Wt} \times 100$$

where, Wl is the liver weight and Wt is the total weight of the individual.

RESULTS AND DISCUSSION

Growth in Length

Analysis of the sagittae and scales permitted to identify thirteen age groups. Growth parameters for the total length determined through sagittae were: L_∞ = 388.68 mm, K = 0.207 years^{-1}, t_0 = -0.718 and for scales were L_∞ = 368.66 mm, K = 0.226 years^{-1}, t_0 = -0.724.

Estimated length for each age for otoliths and scales are shown in Table 1. Sum Square Error (SSE) shows that otoliths gave a better fit between observed and calculated data than scales. So, the sagittae can be considered a better structure for age determination of *M. brevipinnis*. Instantaneous growth rate is also shown in Table 1. During the first year of age *M. brevipinnis* reaches 116.52 mm of length after which growth rate decreases to 51 mm between ages 1 and 2 and 5.2 mm in ages 12 and 13 years.

Growth in Weight

The allometric growth index value of the total weight-length equation was isometric: b = 3.042. For eviscerated specimens, b = 2.954, which shows a tendency to negative allometric growth (Fig. 3a, b).

Table 1: Total length values for each age estimated with the Von Bertalanffy (1938) growth equation and fitted with solver program for *M. brevipinnis*

Age	Scales	SSE	Otoliths	SSE	Otolith rate
1	118.83	5.43	116.52	71.84	51.00
2	169.31	1164.17	167.52	665.69	41.44
3	209.59	737.85	208.96	178.48	33.68
4	241.73	9.42	242.64	14.60	27.37
5	267.38	250.86	270.00	178.65	22.24
6	287.84	0.38	292.24	0.23	18.07
7	304.17	59.04	310.31	38.75	14.69
8	317.20	90.76	325.00	42.95	11.93
9	327.60	151.12	336.93	3.01	9.70
10	335.90	35.86	346.63	37.98	7.88
11	342.52	3.38	354.51	24.67	6.40
12	347.80	10.56	360.91	40.07	5.20
13	352.01	22.18	366.11	43.17	
		2541.03		1340.09	

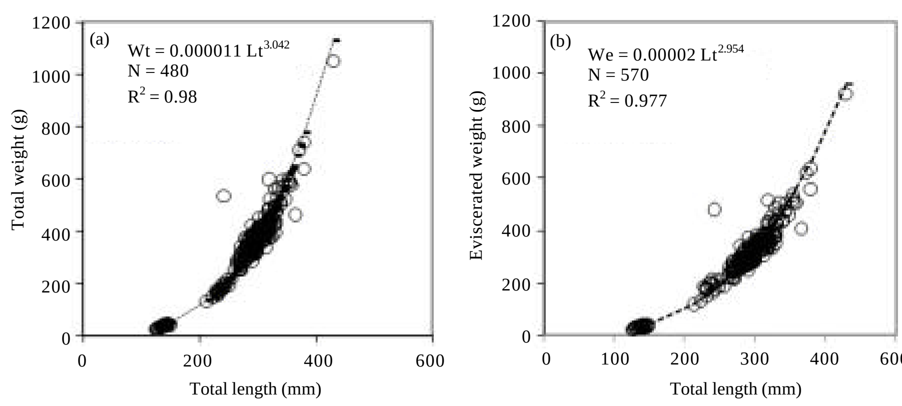

Fig. 3: Weight (g) and length (mm) relationship of *M. brevipinnis*: (a) total weight and (b) eviscerated weight

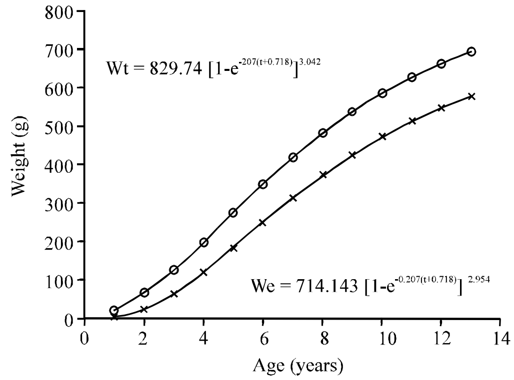

Fig. 4: Von Bertalanffy's growth curve in weight (g) of *M. brevipinnis*

Table 2: Estimated length (Lt) and weight: total (Wt) and eviscerated (We) of each age of *M. brevipinnis*

Edad	Lt	Wt	Annual instant growth rate in total weight	We	Annual instant growth rate in eviscerated weight
1	116.52	21.253		20.338	
2	167.52	64.121	42.868	59.431	39.093
3	208.96	125.611	61.490	114.180	54.749
4	242.64	197.892	72.281	177.533	63.353
5	270.00	273.912	76.020	243.432	65.899
6	292.24	348.475	74.564	307.549	64.117
7	310.31	418.254	69.778	367.188	59.639
8	325.00	481.422	63.168	420.928	53.740
9	336.93	537.237	55.816	468.242	47.314
10	346.63	585.670	48.433	509.182	40.940
11	354.51	627.122	41.451	544.142	34.960
12	360.91	662.221	35.100	573.693	29.551
13	366.11	691.697	29.476	598.474	24.781

Table 3: Length values of otoliths for each age estimated by sexes with the von Bertalanffy (1938) growth equation for *M. brevipinnis*

	Males		Females	
Age	Observed	Calculated	Observed	Calculated
1		157.62		167.04
2		193.51		193.98
3	220.00	223.84	220.00	218.47
4	251.11	249.48	237.33	240.75
5	280.36	271.14	261.60	261.00
6	288.11	289.45	282.21	279.43
7	297.66	304.93	294.47	296.18
8	320.00	318.01	312.04	311.41
9	329.50	329.06	325.51	325.27
10	334.02	338.40	336.54	337.87
11	345.00	346.29	350.00	349.33
12	357.80	352.96		359.75
13		358.60		369.22

Theoretical growth in weight: Table 2 and Fig. 4 show the values of theoretical growth for total and eviscerated weight at each age. The asymptotic total weight was Wt_∞ = 829.741 g and the eviscerated asymptotic weight, We = 714.143 g.

Differences Between Sexes

Growth parameters values from otoliths by sexes of *M. brevipinnis* for males were: L_∞ = 381.81 mm, K = 0.197 years^{-1}, t_0 = -1.122 and L_∞ = 489.05 mm, K = 0.082 years^{-1}; t_0 = -4.251 (Fig. 5a, b) for females. Table 3 shows length values of otoliths for each age by sexes.

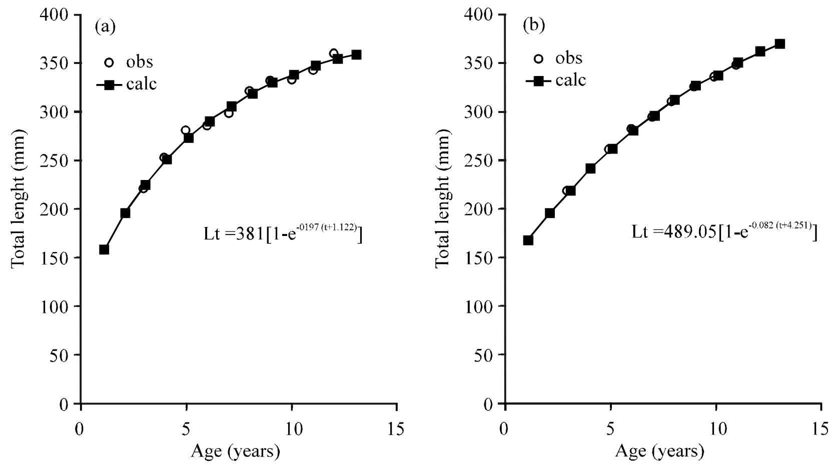

Fig. 5: Von Bertalanffy's growth curve in length (mm) with otoliths by sexes of *M. brevipinnis:* (a) males and (b) females

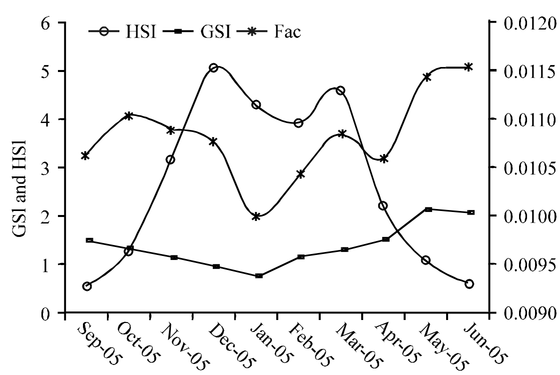

Fig. 6: Monthly variations of the gonadosomatic (GSI) and hepatosomatic (HSI) index and condition factor in *M. brevipinnis*

Longevity (Age $A_{0.95}$)

Microlepidotus brevipinnis reached 95% of its infinite length L_∞ at 14 years. Differences between sexes are: males 14 years and females 32 years.

Bioecologic Considerations

Figure 6 shows the trends of the monthly average data of the indexes of condition factor (a), gonadosomatic (GSI) and hepatosomatic (HSI). Massive spawning period occurs from December to March with two important pulses and two less abundant (January and February). The most active feeding season represented as condition factor (Fac) is from May to October. The hepatosomatic index (HSI) reaches its highest values in May and June and decreases abruptly in December and January.

Growth Parameters of Members of the Haemulidae Family

Table 4 shows growth parameters L_8 and K of 23 species of the Haemulidae family around the world.

Table 4: Values of the growth parameters for different species of the Haemulidae family

Place and researchers	Species	L_∞	K
Manzanillo, Colima (Cruz-Romero *et al.*, 1993)	*Anisotremus interruptus*	482.00	0.130
Manzanillo, Colima (Espino-Barr *et al.*, 2004b)	*A. interruptus*	505.90	0.147
Togo (Beck, 1974)	*Brachydeuterus auritus*	247.00	0.300
Jamaica (Gaut and Munro, 1983)	*Haemulon album*	650.00	0.200
Bank of Campeche (Sokolova, 1965)	*H. aurolineatum*	247.25*	0.249*
Bank of Campeche (Sauskan and Olayechea, 1974)	*H. aurolineatum*	200.36*	0.664
Campeche Bank (Olaechea and Hernández, 1976)	*H. aurolineatum*	271.30	0.184
Southeastern US (Manooch and Barans, 1979)	*H. aurolineatum*	310.00	0.220
Campeche, México (Claro and García-Arteaga, 1994)	*H. aurolineatum*	271.00	0.200
Manzanillo, Colima (Cruz-Romero *et al.*, 1993)	*H. flavigutattum*	424.00	0.115
Jamaica (Billings and Munro, 1974a)	*H. flavolineatum*	269.00	0.179
Manzanillo, Colima (Cruz-Romero *et al.*, 1993)	*H. maculicauda*	309.00	0.123
Cuba (Valle *et al.*, 1997)	*H. parra*	388.00	0.200
Jamaica (Billings and Munro, 1974b)	*H. plumieri*	420.00	0.710
North and South Carolina (Manooch, 1976)	*H. plumieri*	640.00	0.108
Puerto Rico (Appeldoorn, 1992)	*H. sciurus*	371.00	0.300
Manzanillo, Colima (Cruz-Romero *et al.*, 1993)	*H. sexfasciatum*	490.00	0.132
Brasil (Vianna and Verani, 2002)	*Orthopristis ruber*	410.00	0.350
Japan (Kimura, 1987)	*Parapristipoma trilineatum*	358.00	0.286
Papua New Guinea (Munro and Williams, 1985)	*Plectorhinchus lineatus*	630.00	0.300
Papua New Guinea (Baillon, 1991)	*P. nigrus*	865.00	0.200
Gulf of Aden, Yemen (Munro and Williams, 1985)	*P. picus*	816.00	0.180
Philippines (Ingles and Pauly, 1984)	*Pomadasys argyreus*	142.00	0.800
Gulf of Aden (Oven and Salekhova, 1970)	*P. hasta* (males)	220.62*	0.614*
Western India (Deshmukh, 1973)	*P. hasta*	742.70*	0.264*
Northwest Africa (Pajuelo *et al.*, 2003)	*P. incisus*	315.00	0.217
Nothern Arabian Sea, Pakistan (Iqbal, 1988)	*P. kaakan*	625.00	0.570
Gulf of Suez (Latif and Shenouda, 1972)	*P. striatum*	176.92*	0.312*
Gulf of Suez, Egypt (Pauly, 1978)	*P. striatus*	180.00	0.300
Manzanillo, Colima (Cruz-Romero *et al.*, 1993)	*Microlepidotus brevipinnis*	368.00	0.134
Jalisco, present study (scales)	*M. brevipinnis*	368.66	0.226
Jalisco, present study (otoliths)	*M. brevipinnis*	388.68	0.207

*Calculated by the researchers of this study

In this study, the values of growth obtained by the identification of growth rings in the sagittae were very similar to those found with scales analysis which rendered age determination in *M. brevipinnis* valid with both methods and validating them both.

The high growth rate in length during the first year of life shows *M. brevipinnis* reduction of natural mortality by avoiding depredation.

In the relationship of the standard length vs eviscerated weight, Cruz-Romero *et al.* (1993) found an allometric index of 2.45 which represent a thinner organism. This difference between years is closely related to environmental conditions and food availability (Safran, 1992).

Microlepidotus brevipinnis reaches reproduction maturity at age 4. From age 1 to age 4 growth curves for total and eviscerated organisms are equal. Both curves separate after age 4, probably because the weight of the reproductive organs has started to mature.

Females reach a lower catabolic index than males; therefore, their asymptotic length and longevity are higher than in males. After age 4 females use most of its energy to produce reproductive products (eggs).

The three indexes: condition factor (Fac), gonadosomatic (GSI) and hepatosomatic (HSI), show that the main spawning period occurs from December to March. During this period it was observed that the condition factor starts to reduce, individuals loose weight and the HSI reaches its lowest values due to loss of fatty acid reserves.

The period during which Fac increases (May to October) coincides with the rainy season and hurricanes, when food availability is higher, due to the delivery of nutriments by the rivers to the coastal zone and the removal of the bottom to the surface of the sea due to the winds (Manzanillo's Observatory, personal communication). This is a period in which specimens increase their individual weight, reserves of liver fatty acids and prepare for the next spawning season.

The value of L_∞ of Von Bertalanffy's (1938) growth equation of this study (368.66 mm with scales) in relation to the one found a decade ago (368.00 mm by length frequencies distribution) by Cruz-Romero *et al*. (1993) are almost the same suggesting certain stability in the population over the years in spite of environmental fluctuations and fishing pressure during the last 25 years; a reduction in length has not been observed, which could be considered as an overfishing symptom. Cruz-Romero *et al*. (1993) calculated a lower longevity (23 years) than the one found in the present study, which relates to a lower value of the catabolic index of K = 0.134.

Besides time periods, differences in the results of the study of Cruz-Romero *et al*. (1993) and ours can be due to the methods: they used an indirect method with size frequency analysis and we used two direct methods: scales and otoliths, which can be more accurate. Genus *Plectorhinchus* reaches the largest L_8 with the species *P. nigrus* (865 mm), *P. picus* (816 mm) and *P. lineatus* (639 mm). Other large Haemulidae species are *Pomadasys hasta* (742.7 mm), *Haemulon album* (650 mm), *H. plumieri* (640 mm), *P. kaakan* (625 mm) and *Anisotremus interruptus* (505.9 mm). Except for *H. plumieri,* most of these specimens are found in tropical areas where the temperature is higher. The smaller species of this family are the *Pomadasys* genus: *P. argyreus* (142 mm), *P. striatum* (176.9 mm) and *P. striatus* (180 mm). According to the value of L_8, *M. brevipinnis* has a middle size with respect to other members of the Haemulidae family.

Haemulon aurolineatum is the most studied species, five papers have been reported, the ones from the Bank of Campeche have lower L_8 than that of Southeastern US, which is in accordance with Taylor (1958, 1960), who established that there is a direct relation between L_8 and latitude and an inverse relation between the L_8 and temperature. This also occurs with *H. plumieri* in the areas of Jamaica and Carolina. In this case, it can also be observed that the catabolic index K is lower when the latitude increases and temperature decreases.

Values of the growth equation and other life parameters calculated in this study are important information for the management of the artisanal fishery in the Central Pacific coast of Mexico. Results have been compared with other species of the same family and *M. brevipinnis* of years ago, which validates and gives certainty to its use in future models.

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EEB, MGC, KGF, EGCS, AGB and MPG participated in the collection, sampling and analysis of the fish. We all also participated in the data analysis and growth parameters calculations. The MGC and EEB wrote the paper.

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