Atlas of marine bony fish otoliths (*sagittae*) of Southeastern-Southern Brazil Part III: Clupeiformes (Clupeidae, Engraulidae, Pristigasteridae)

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Abstract

This publication is the second in a series that will together constitute an Atlas of Teleostei Otoliths for the Southeastern-Southern Brazilian area. Here we present results of morphologic and morphometric analyses of 12 Clupeiform species (3 Clupeidae, 7 Engraulidae and 2 Pristigasteridae) by means of the most commonly used features, measurements and indices. Three otoliths of each species have been illustrated and photographed whenever possible. The frequency of occurrence has been calculated for each characteristic by total length class (TL), and the ontogenetic differences have been analyzed (multiple χ^2 test; significance 0.05).

Descriptors: Otoliths, Morphology, Morphometry, Southwestern Atlantic, Brazil, Clupeiformes.

Resumo

Esta publicação é a segunda de uma série que constituirá um Atlas de Otólitos para os Teleostei da região Sudeste-Sul brasileira. Nela são apresentados os resultados de análises morfológicas e morfométricas de 12 espécies de Clupeiformes (3 Clupeidae, 7 Engraulidae e 2 Pristigasteridae) através de feições, medidas e índices usualmente utilizados. Três otólitos de cada espécie foram desenhados e fotografados, sempre que possível. A frequência de ocorrência foi calculada para cada característica por classes de comprimento total dos peixes (CT) e as diferenças ontogenéticas foram analisadas (Teste χ^2 múltiplo; significância 0,05).

Descritores: Otólitos, Morfologia, Morfometria, Atlântico Sudoeste, Brasil, Clupeiformes.

INTRODUCTION

Otolith size and shape differ among species, among populations and within each species. These variations are influenced during development by both genetic and environmental factors. Due to their intra and interspecific variation in shape, otoliths are useful in many studies: taxonomy, phylogeny, archeology, paleontology, species' geographical variation, stock identification, food webs and others.

Many papers have been published since the 1980s showing the value of photographs and drawings in the analysis of otolith features. Parallel to this development, otolith collections have proved to be useful in the analysis of past populations' genetics and populations' structure, growth dynamics and environmental conditions.

Recently, during the 5th International Otolith Symposium, held in Palma de Mallorca, between 20 and 24 October 2014, the latest developments in otolith analytical techniques and novel applications were presented. A special workshop on otolith shape analysis was held focusing on these structures as indicators for community, population and individual analysis, and environmental events.

The Collection of Teleostei Fish Otoliths of the Southeastern-Southern Brazilian region (COSS-Brasil) held at the Instituto Oceanográfico - USP, (IOUSP) contains around 45,000 pairs of otoliths from 210 species.

Following ROSSI-WONGTSCHOWSKI et al. (2014), in this second publication (PART III) of a series that will together constitute an Atlas of Otoliths of the Southeastern-southern Brazilian region we present the results of the morphologic and morphometric analyses of Clupeiformes species (3 Clupeidae, 7 Engraulidae and 2 Pristigasteridae), by means of the most commonly used features, measurements and indices.

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MATERIAL AND METHODS

The sampling area and the methodology followed those presented in ROSSI-WONGTSCHOWSKI et al. (2014).

The acronyms in the shape indices tables represent: TL = total fish length, OL = otolith length, OH = otolith height and OT = otolith thickness.

RESULTS

Family CLUPEIDAE

Otolith shape tends to be rectangular, the anterior region is clearly peaked to lanceolated, the *rostrum* and *antirostrum* being well developed and the *pseudorostrum* and *pseudoantirostrum* always absent.

Harengula clupeola (Cuvier 1829) - **Plate 1**

Maximum Size:	170-180 mm (TL) (FIGUEIREDO; MENEZES, 1978; FROESE; PAULY, 2014), but attaining 212 mm in our collection.
Distribution:	Western Atlantic from Florida to the Southern Brazilian coast (FIGUEIREDO; MENEZES, 1978; MENEZES et al., 2003).
Habitat:	Coastal waters (brackish and marine) and estuaries. Forms schools of small individuals, often along sandy beaches (FIGUEIREDO; MENEZES, 1978; ESCHEMEYER, 2014).
Diet:	Planktonic organisms, mainly zooplankton (FROESE; PAULY, 2014).
Collection:	1544 pairs of otoliths (TL ranging from 38 to 212 mm).
Sample:	86 left otoliths divided into ten 20 mm classes (20 to 200 mm).

Shape: elliptic to rectangular (52.33%), rectangular, elliptic. ***Anterior region:*** peaked (97.67%), peaked-round. ***Posterior region:*** round (86.05%), angled-round. ***Dorsal edge:*** sinuate to entire (75.58%), entire, lobed to sinuate. ***Ventral edge:*** lobed to sinuate (44.19%), dentate to sinuate, sinuate to entire. ***Profile:*** concave-convex (88.37%), plane. ***Rostrum and antirostrum orientation:*** in agreement (88.37%), in disagreement. ***Rostrum:*** developed. ***Antirostrum:*** developed. ***Sulcus acusticus:*** *position:* median; *orientation:* slightly ascending (52.33%), horizontal (47.67%); *opening:* ostial; *morphology:* heterosulcoid (88.37%), pseudo-archaesulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like; *cauda:* elliptic (50%), oval, tubular slightly curved.

Significant differences ($p < 0.05$) were found within some length classes for otolith shape, anterior and posterior regions, dorsal and ventral edges, *sulcus acusticus* and *cauda* morphology, otolith profile, *rostrum* and *antirostrum* orientation. Over the period of the fishes' development differences were found in otolith shape, anterior and posterior regions, dorsal edge, *sulcus acusticus* orientation and morphology, *cauda* morphology, profile and *rostrum* and *antirostrum* orientation.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	2.30 ± 0.33	1.66	3.11
OH/OL (%)	57.15 ± 3.06	51.41	66.67
OT/OL (%)	21.03 ± 2.38	15.53	30.11
OT/OH (%)	36.77 ± 3.34	29.60	46.55
Circularity	21.85 ± 2.36	16.36	27.38
Rectangularity	0.71 ± 0.02	0.67	0.75

Opisthonema oglinum (Lesueur 1818) - **Plate 2**

Maximum Size:	300 mm (TL) (FIGUEIREDO; MENEZES, 1978).
Distribution:	Gulf of Maine to Argentina (FIGUEIREDO; MENEZES, 1978; MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Shallow and coastal waters (brackish and marine). Forms shoals (FIGUEIREDO; MENEZES, 1978; ESCHEMEYER, 2014).
Diet:	Filtering plankton (copepods) and also small fishes, crabs and shrimps (FURTADO-OGAWA, 1970; FROESE; PAULY, 2014).
Collection:	439 pairs of otoliths (TL ranging from 85 to 312 mm).
Sample:	88 left otoliths divided into eleven 20 mm classes (100 to 300 mm).

Shape: rectangular to lanceolated (97.73%), rectangular. ***Anterior region:*** lanceolated (97.73%), peaked. ***Posterior region:*** round. ***Dorsal edge:*** sinuate to entire (55.68%), sinuate, entire, lobed to entire. ***Ventral edge:*** dentate to entire (46.59%), dentate to sinuate, lobed to sinuate, sinuate to entire. ***Profile:*** concave-convex (94.32%), flattened. ***Rostrum and antirostrum orientation:*** in agreement (68.18%), in disagreement. ***Rostrum:*** developed. ***Antirostrum:*** developed. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal (92.05%), slightly ascending; *opening:* ostial; *morphology:* pseudo-archaesulcoid (65.91%), heterosulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like; *cauda:* elliptic (97.73%), tubular slightly curved.

Significant differences ($p < 0.05$) were found inside some length classes for otolith shape, anterior region, dorsal and ventral edges, *sulcus acusticus* morphology and orientation, *cauda* morphology, otolith profile and *rostrum* and *antirostrum* orientation. Over the period of the fishes' development significant differences were obtained in otolith shape, anterior region, dorsal and ventral edge, *sulcus acusticus* morphology and orientation, *cauda* orientation, *rostrum* and *antirostrum* orientation.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	1.79 ± 0.23	1.29	2.73
OH/OL (%)	49.16 ± 2.65	44.04	54.98
OT/OL (%)	14.78 ± 1.42	9.36	18.93
OT/OH (%)	30.07 ± 2.51	18.39	36.06
Circularity	27.23 ± 3.60	20.84	37.76
Rectangularity	0.71 ± 0.02	0.65	0.75

Sardinella brasiliensis (Steindachner 1879) - **Plate 3**

Maximum Size:	240-250 mm (TL) (FIGUEIREDO; MENEZES, 1978; FROESE; PAULY, 2014).
Distribution:	Southwestern Atlantic from Rio de Janeiro to Argentina (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Surface coastal waters. Forms large and compact shoals (FIGUEIREDO; MENEZES, 1978; BERNARDES et al., 2005).
Diet:	Zooplankton (FROESE; PAULY, 2014).
Collection:	301 pairs of otoliths (TL ranging from 45 to 264 mm).
Sample:	77 left otoliths divided into eleven 20 mm classes (40 to 240 mm).

Shape: rectangular to lanceolated (90.91%), elliptic rectangular, rectangular. ***Anterior region:*** lanceolated (90.91%), peaked. ***Posterior region:*** oblique-round (87.19%), round, blunt-round. ***Dorsal edge:*** sinuate to entire (58.44%), lobed to sinuate, entire. ***Ventral edge:*** lobed to entire (49.35%), dentate to sinuate, dentate to lobed, sinuate to entire. ***Profile:*** concave-convex (71.43%), plane. ***Rostrum and antirostrum orientation:*** *in agreement* (62.34%), in disagreement. ***Rostrum:*** developed. ***Antirostrum:*** developed. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal (72.73%), slightly ascending; *opening:* ostial; *morphology:* pseudo-archaesulcoid (68.83%), heterosulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like; *cauda:* elliptic (71.43%), oval.

Significant differences ($p < 0.05$) were found within some length classes in otolith shape, anterior and posterior regions, dorsal and ventral edges, morphology and orientation of the *sulcus acusticus*, *cauda* morphology and otolith profile. During the fishes' development differences were found in otolith shape, anterior and posterior regions, and *sulcus acusticus* morphology and orientation.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	2.04 ± 0.29	1.58	2.75
OH/OL (%)	45.08 ± 5.18	36.10	65.22
OT/OL (%)	14.14 ± 3.29	8.10	25.22
OT/OH (%)	31.11 ± 4.73	20.94	43.33
Circularity	26.31 ± 3.24	17.29	33.04
Rectangularity	0.69 ± 0.02	0.65	0.73

Family ENGRAULIDAE

The shape is elliptic, the anterior region is peaked-round, the *antirostrum* is undeveloped and *pseudorostrum* and *pseudoantirostrum* always absent.

Anchoa filifera (Fowler 1915) - **Plate 4**

Maximum Size:	120 mm (FROESE; PAULY, 2014).
Distribution:	Western Atlantic from the Caribbean to southeastern Brazil (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Shallow and coastal waters (brackish and marine) forming shoals (FIGUEIREDO; MENEZES, 1978; ESCHEMEYER, 2014).
Diet:	Phyto, zooplankton, small fishes, annelids and insects (MUTO et al., 2014).
Collection:	8 pairs of otoliths (TL ranging from 85 to 201 mm).
Sample:	6 left otoliths divided into five 20 mm classes (80 to 200 mm).

Shape: elliptic. ***Anterior region:*** peaked. ***Posterior region:*** round (33.33%), angled (33.33%), peaked-angled (33.33%). ***Dorsal edge:*** sinuate to entire (66.67%), sinuate. ***Ventral edge:*** sinuate to serrate (83.33%), lobed to sinuate. ***Profile:*** plane-convex (66.67%), concave-convex. ***Rostrum and antirostrum orientation:*** in agreement. ***Rostrum:*** developed. ***Antirostrum:*** developed (66.67%), undeveloped. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal; *opening:* ostial; *morphology:* heterosulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like; *cauda:* elliptic.

The small number of otoliths examined did not permit statistical analysis of the data but their morphometric characteristics are shown below:

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	2.82 ± 0.67	2.03	3.56
OH/OL (%)	57.36 ± 3.80	52.08	61.39
OT/OL (%)	18.85 ± 2.29	15.80	21.19
OT/OH (%)	32.80 ± 2.61	29.36	36.16
Circularity	17.46 ± 1.15	16.50	19.14
Rectangularity	0.69 ± 0.02	0.67	0.72

Anchoa lyolepis (Evermann & Marsh 1900) - **Plate 5**

Maximum Size:	120 mm (FROESE; PAULY, 2014).
Distribution:	Western Atlantic from Florida to southeastern Brazilian coast (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Coastal waters (ESCHEMEYER, 2014). Forms shoals. Depth range: 1 - 54 m (FROESE; PAULY, 2014).
Diet:	Plankton (FROESE; PAULY, 2014).
Collection:	17 pairs of otoliths (TL ranging from 59 to 93 mm).
Sample:	4 left otoliths divided into three 20 mm classes (40 to 80 mm).

Shape: elliptic. ***Anterior region:*** peaked. ***Posterior region:*** round. ***Dorsal edge:*** sinuate to entire (50%), sinuate, entire. ***Ventral edge:*** sinuate to entire (50%), sinuate to serrate (50%). ***Profile:*** plane-convex (75%), concave-convex. ***Rostrum and antirostrum orientation:*** in agreement. ***Rostrum:*** developed. ***Antirostrum:*** undeveloped (75%), absent. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal; o*pening:* ostial; *morphology:* heterosulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like; *cauda:* elliptic.

The small number of otoliths examined did not permit the statistical analysis of the data but their morphometric characteristics are shown below:

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	3.04 ± 0.18	2.91	3.30
OH/OL (%)	53.23 ± 2.88	50.64	56.07
OT/OL (%)	20.95 ± 0.95	20.09	22.03
OT/OH (%)	39.44 ± 2.58	36.08	42.37
Circularity	16.62 ± 0.50	16.04	17.24
Rectangularity	0.72 ± 0.01	0.70	0.74

Anchoa tricolor (Spix & Agassiz 1829) - **Plate 6**

Maximum Size:	120 mm (FROESE; PAULY, 2014).
Distribution:	Western Atlantic from northeastern to southeastern Brazilian coast (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Marine; brackish; pelagic-neritic. Depth range of 0-50 m (ESCHEMEYER, 2014; FROESE; PAULY, 2014).
Diet:	Plankton (FIGUEIREDO; MENEZES, 1978).
Collection:	214 pairs of otoliths (TL ranging from 43 to 129 mm).
Sample:	32 left otoliths divided into five 20 mm classes (40 to 120 mm).

Shape: elliptic. ***Anterior region:*** peaked (78.13%), peaked-round, angled. ***Posterior region:*** round (65.63%), angled-round. ***Dorsal edge:*** entire (56.25%), sinuate. ***Ventral edge:*** sinuate to entire (34.38%), sinuate to serrate, sinuate, entire to serrate. ***Profile:*** flattened (40.63%), concave-convex, plane-convex. ***Rostrum and antirostrum orientation:*** in agreement (84.38%), except when the *antirostrum* is undeveloped or absent. ***Rostrum:*** developed. ***Antirostrum:*** developed (56.25%), undeveloped, absent. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal; *opening:* ostial; *morphology:* heterosulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like; *cauda:* elliptic.

Significant differences ($p < 0.05$) were found within some length classes in anterior and posterior regions, dorsal edge, otolith profile, *rostrum* and *antirostrum* orientation and *antirostrum* development. Over the period of the fishes' development differences were found only in the posterior region of the otoliths.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	2.75 ± 0.28	2.17	3.52
OH/OL (%)	59.81 ± 4.43	49.39	67.27
OT/OL (%)	20.22 ± 1.92	16.36	24.55
OT/OH (%)	33.79 ± 1.74	29.93	36.99
Circularity	17.48 ± 1.43	15.10	21.82
Rectangularity	0.70 ± 0.02	0.66	0.74

Anchovia clupeoides (Swainson 1839) - **Plate 7**

Maximum Size:	300 mm (FROESE; PAULY, 2014).
Distribution:	Western Atlantic from the Caribbean to São Paulo state, Brazil (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Marine; brackish; benthopelagic (ESCHEMEYER, 2014; FROESE; PAULY, 2014).
Diet:	Plankton (CARPENTER, 2002).
Collection:	23 pairs of otoliths (TL ranging from 55 to 80 mm).
Sample:	10 left otoliths divided into two 20 mm classes (40 to 60 mm).

Shape: elliptic. ***Anterior region:*** peaked. ***Posterior region:*** round (90%), oblique-round. ***Dorsal edge:*** sinuate to entire. ***Ventral edge:*** sinuate to serrate (70%), lobed to sinuate, sinuate. ***Profile:*** biconvex. ***Rostrum and antirostrum orientation:*** in agreement. ***Rostrum:*** developed. ***Antirostrum:*** developed (50%), undeveloped (50%). ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal; *opening:* ostial; *morphology:* heterosulcoid (80%), pseudo-archaesulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like; *cauda:* elliptic.

Significant differences ($p < 0.05$) were observed in some length classes in the anterior region, ventral edge and *sulcus acusticus* morphology. During the fishes' development differences were observed only for the anterior region of these structures.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	3.67 ± 0.28	3.26	4.27
OH/OL (%)	61.30 ± 1.66	58.76	64.36
OT/OL (%)	23.23 ± 1.88	19.71	26.32
OT/OH (%)	37.91 ± 3.23	31.95	44.30
Circularity	16.61 ± 0.82	15.78	18.36
Rectangularity	0.70 ± 0.02	0.68	0.74

Anchoviella lepidentostole (Fowler 1911) - **Plate 8**

Maximum Size:	120 mm (FROESE; PAULY, 2014).
Distribution:	Western Atlantic from the Guianas to the southeastern Brazilian coast (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Freshwater, brackish, marine. Depth range of 0 - 50 m (ESCHEMEYER, 2014; FROESE; PAULY, 2014).
Diet:	Crustacean larvae or small invertebrates (FROESE; PAULY, 2014).
Collection:	54 pairs of otoliths (TL ranging from 72 to 126 mm).
Sample:	17 left otoliths divided into four 20 mm classes (60 to 120 mm).

Shape: elliptic. ***Anterior region:*** peaked (76.47%), peaked-round. ***Posterior region:*** angled-round (47.06%), peaked, round, angled. ***Dorsal edge:*** sinuate to entire (52.94%), entire, sinuate. ***Ventral edge:*** entire to serrate (88.24%), sinuate to serrate. ***Profile:*** concave-convex (70.59%), plane-convex. ***Rostrum and antirostrum orientation:*** in agreement. ***Rostrum:*** developed. ***Antirostrum:*** developed (70.59%), undeveloped. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal; *opening:* ostial; *morphology:* heterosulcoid (94.12%), pseudo-archaesulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like; *cauda:* elliptic.

Significant differences ($p < 0.05$) were observed in some length classes in the dorsal edge and the *sulcus acusticus* morphology. No differences were found during the fishes' development.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	2.72 ± 0.12	2.51	2.93
OH/OL (%)	58.03 ± 3.41	52.26	62.46
OT/OL (%)	18.89 ± 1.08	16.73	20.74
OT/OH (%)	32.60 ± 1.61	30.05	35.48
Circularity	18.08 ± 0.59	16.94	19.37
Rectangularity	0.67 ± 0.01	0.65	0.69

Cetengraulis edentulus (Cuvier 1829) - **Plate 9**

Maximum Size:	150 mm (FROESE; PAULY, 2014).
Distribution:	Central and Southwestern Atlantic along the entire Brazilian coast (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Occurs inshore and forms quite large schools. Enters brackish waters of lagoons and estuaries (ESCHEMEYER, 2014; FROESE; PAULY, 2014).
Diet:	Filter-feeder presumably on both phytoplankton and zooplankton (FROESE; PAULY, 2014).
Collection:	38 pairs of otoliths (TL ranging from 78 to 93 mm).
Sample:	32 left otoliths divided into two 20 mm classes (60 to 80 mm).

Shape: elliptic. ***Anterior region:*** peaked round (63.64%), angled-round. ***Posterior region:*** angled (54.55%), angled-round, peaked, round. ***Dorsal edge:*** sinuate to entire (45%), sinuate (45%), entire. ***Ventral edge:*** entire to serrate (63.64%), sinuate to serrate. ***Profile:*** plane-convex (90.91%), concave-convex. ***Rostrum and antirostrum orientation:*** in agreement. ***Rostrum:*** developed. ***Antirostrum:*** developed (90.91%), undeveloped. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal; *opening:* ostial; *morphology:* heterosulcoid (90.91%), pseudo-archaesulcoid; *colliculum:* heteromorphic; *ostium:* elliptic; *cauda:* elliptic.

Significant differences ($p < 0.05$) were found in some length classes in the posterior region of the otolith, in the *sulcus acusticus* morphology and the *antirostrum* development. During the fishes' development differences were present only in the anterior region of these structures.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	2.85 ± 0.25	2.46	3.35
OH/OL (%)	67.24 ± 2.55	63.49	70.54
OT/OL (%)	20.88 ± 1.77	18.01	23.36
OT/OH (%)	31.03 ± 2.14	26.86	34.97
Circularity	17.04 ± 0.56	16.20	18.31
Rectangularity	0.68 ± 0.01	0.66	0.70

Engraulis anchoita Hubbs & Marini 1935 - **Plate 10**

Maximum Size:	170 mm (SL) (FROESE; PAULY, 2014).
Distribution:	Southwestern Atlantic from Rio de Janeiro (Brazil) to Argentina (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Marine. Dense shoals at 30 to 200m deep (ESCHEMEYER, 2014). Exhibits north-south and near shore-offshore migrations (FROESE; PAULY, 2014).
Diet:	Juveniles feed on phytoplankton but zooplankton become increasingly important as fish grow (FROESE; PAULY, 2014).
Collection:	3444 pairs of otoliths (TL ranging from 38 to 165 mm).
Sample:	62 left otoliths divided into seven 20 mm classes (40 to 160 mm).

Shape: elliptic (69.35%), fusiform, discoidal, discoidal to elliptic. ***Anterior region:*** peaked (91.94%), angled-round, peaked-round. ***Posterior region:*** angled-round (41.94%), round, peaked, peaked-round, angled-round. ***Dorsal edge:*** entire (48.39%), sinuate, sinuate to entire. ***Ventral edge:*** entire to serrate (69.35%), sinuate to serrate, sinuate to entire, lobed to entire. ***Profile:*** concave-convex (67.74%), plane-convex, flattened, biconvex. ***Rostrum and antirostrum orientation:*** in agreement (87.10%). ***Rostrum:*** developed. ***Antirostrum:*** developed (59.68%), undeveloped, absent. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal; *opening:* ostial; *morphology:* heterosulcoid; *colliculum:* heteromorphic; *ostium:* funnel-like (77.42%), elliptic; *cauda:* elliptic.

In some length classes significant differences ($p < 0.05$) were observed for the otolith shape, anterior and posterior regions, ventral edge, *ostium* morphology, otolith profile, *rostrum* and *antirostrum* orientation and *antirostrum* development. During the fishes' development differences were found in the posterior region and in the ventral edge of the otoliths.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	2.73 ± 0.47	1.65	4.56
OH/OL (%)	55.60 ± 7.35	45.80	84.51
OT/OL (%)	18.40 ± 2.77	13.49	29.58
OT/OH (%)	33.10 ± 2.56	29.14	40.54
Circularity	18.14 ± 1.33	14.42	22.43
Rectangularity	0.68 ± 0.02	0.64	0.74

Family PRISTIGASTERIDADE

The anterior region is peaked. The *ostium* and *cauda* are always elliptic, and in most otoliths the *sulcus acusticus* is *pseudo-archaesulcoid,* and *pseudorostrum and pseudoantirostrum:* always absent.

Chirocentrodon bleekerianus (Poey 1867) - **Plate 11**

Maximum Size:	110 mm (TL) (FIGUEIREDO; MENEZES, 1978; FROESE; PAULY, 2014).
Distribution:	Western Atlantic from Panama to São Paulo, Brazil (MENEZES et al., 2003; ESCHEMEYER, 2014).
Habitat:	Marine; brackish; pelagic-neritic; depth range 20-60 m (ESCHEMEYER, 2014; FROESE; PAULY, 2014).
Diet:	Zooplankton and small fishes (MUTO et al., 2008).
Collection:	330 pairs of otoliths (TL ranging from 65 to 128 mm).
Sample:	30 left otoliths divided into three 20 mm classes (60 to 100 mm).

Shape: elliptic. ***Anterior region:*** peaked. ***Posterior region:*** round. ***Dorsal edge:*** sinuate to entire (70%), entire, sinuate. ***Ventral edge:*** serrate to entire. ***Profile:*** biconvex. ***Rostrum and antirostrum orientation:*** in agreement. ***Rostrum:*** developed. ***Antirostrum:*** underdeveloped. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal (93.33%), slightly ascending; *opening:* ostial (73.33%), pseudo-ostial; *morphology:* pseudo-archaesulcoid; *colliculum:* heteromorphic; *ostium:* elliptic; *cauda:* elliptic.

Significant differences ($p < 0.05$) were found in some length classes for the posterior region, dorsal edge, *sulcus acusticus* orientation and opening, and *antirostrum* development. During the fishes' ontogeny significant differences were observed for the posterior region, *sulcus acusticus* orientation and opening and *antirostrum* development.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	2.38 ± 0.35	1.98	3.49
OH/OL (%)	69.96 ± 4.44	61.99	77.01
OT/OL (%)	20.23 ± 1.79	16.87	24.62
OT/OH (%)	29.01 ± 2.94	24.44	35.76
Circularity	17.66 ± 0.95	15.85	19.39
Rectangularity	0.69 ± 0.02	0.62	0.72

Pellona harroweri (Fowler 1917) - **Plate 12**

Maximum Size:	180 mm (TL) (FIGUEIREDO; MENEZES, 1978; FROESE; PAULY, 2014).
Distribution:	Western Atlantic from Panama to Rio Grande do Sul State, Brazil (FIGUEIREDO; MENEZES, 1978; ESCHEMEYER, 2014).
Habitat:	Shallow waters and estuaries (FIGUEIREDO; MENEZES, 1978; ESCHEMEYER, 2014). Depth range of 5 - 36 m (FROESE; PAULY, 2014).
Diet:	Shrimps, copepods and small fishes (CRIÁLES-HERNÁNDEZ, 2003; MUTO et al., 2008; SOARES et al., 2008).
Collection:	756 pairs of otoliths (TL ranging from 65 to 160 mm).
Sample:	33 left otoliths divided into four 20 mm classes (80 to 140 mm).

Shape: elliptic. ***Anterior region:*** peaked. ***Posterior region:*** round. ***Dorsal edge:*** sinuate to entire (93.94%), lobed. ***Ventral edge:*** dentate to entire (90.91%), dentate to sinuate. ***Profile:*** concave-convex. ***Rostrum and antirostrum orientation:*** in agreement. ***Rostrum:*** developed. ***Antirostrum:*** developed. ***Sulcus acusticus:*** *position:* median; *orientation:* horizontal; *opening:* ostial (93.94%), pseudo-ostial; *morphology:* pseudo-archaesulcoid (63.64%), heterosulcoid; *colliculum:* heteromorphic; *ostium:* elliptic; *cauda:* elliptic.

Significant differences ($p < 0.05$) were found in some total length classes for the dorsal and ventral edges, and *sulcus acusticus* morphology and opening. No differences were observed during the fishes' development.

Shape indices	Mean ± SD	Minimum	Maximum
OL/TL (%)	3.22 ± 0.27	2.74	3.74
OH/OL (%)	66.92 ± 2.93	61.96	77.17
OT/OL (%)	19.89 ± 1.59	17.06	24.76
OT/OH (%)	29.72 ± 2.08	25.97	34.22
Circularity	19.52 ± 1.09	17.84	21.99
Rectangularity	0.69 ± 0.01	0.66	0.72

ACKNOWLEDGMENTS

The organization of the collection and the analysis of the otoliths began five years ago when substantial financial support was received from the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP Processes -2010/51631-2 and 2014/03764-4) which permitted the improvement of the laboratory and its equipment and the addition of human resources to the LABIC. The authors wish to express their gratitude to everyone who participated in this long process. In relation to this volume special thanks are due to Silvia de Almeida Gonsales, Marcella Bockis Giaretta and Alexandre Y. Gomes Arackawa for their drawings, measurements of the otoliths and organization of the collection.

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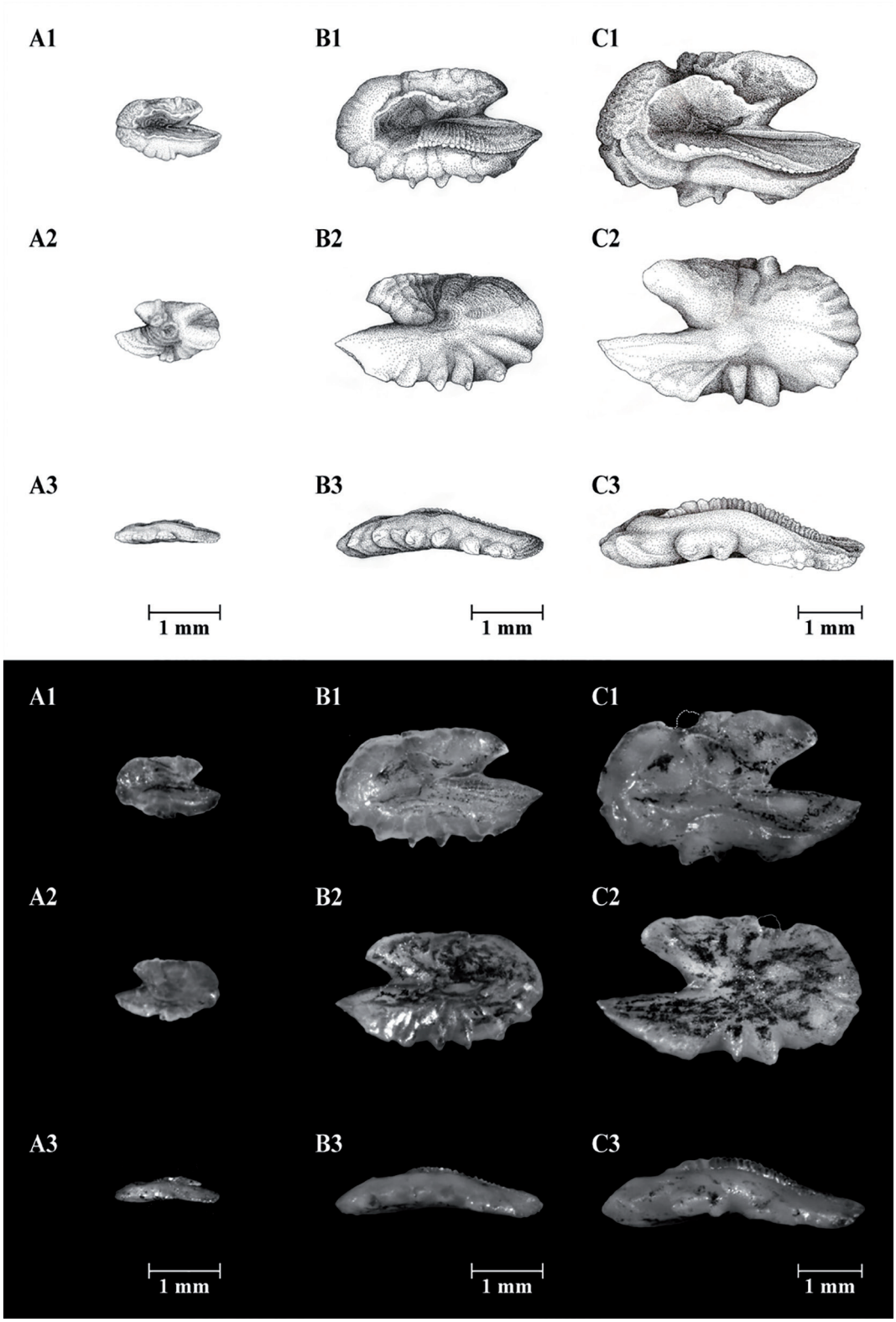

Plate 1. Illustrations (above) and photographs (below) of *Harengula clupeola* otoliths from fishes with total lengths: A. 65 mm; B. 128 mm; C. 190 mm. The medial face is shown in A1, B1, C1; the lateral face in A2, B2, C2; and the ventral profile in A3, B3, C3 (Illustration: Silvia de Almeida Gonsales; Photos: Cesar Santificetur).

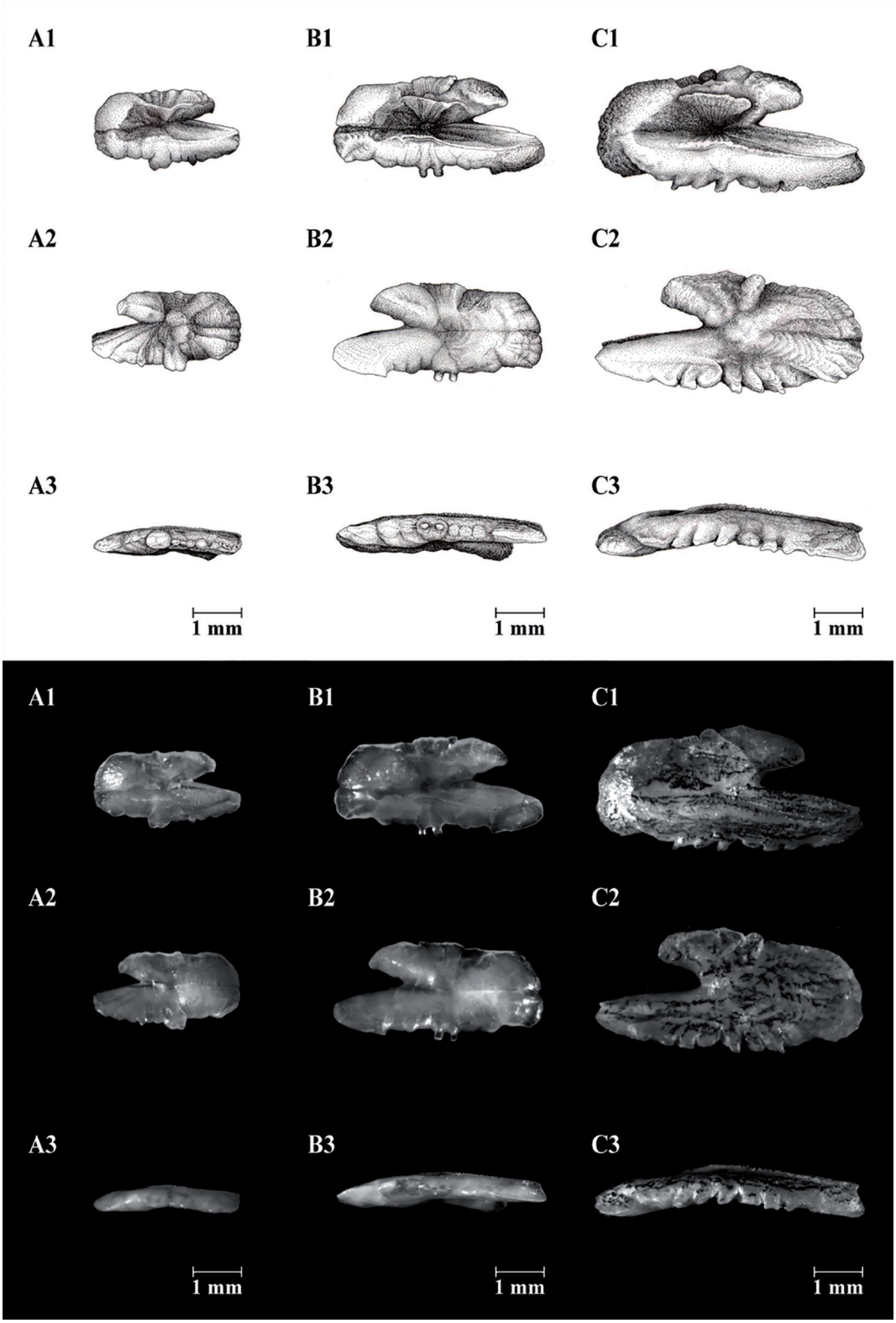

Plate 2. Illustrations (above) and photographs (below) of *Opisthonema oglinum* otoliths from fishes with total lengths: A. 130 mm; B. 224 mm; C. 312 mm. The medial face is shown in A1, B1, C1; the lateral face in A2, B2, C2; and the ventral profile in A3, B3, C3 (Ilustration: Silvia de Almeida Gonsales; Photos: Cesar Santificetur).

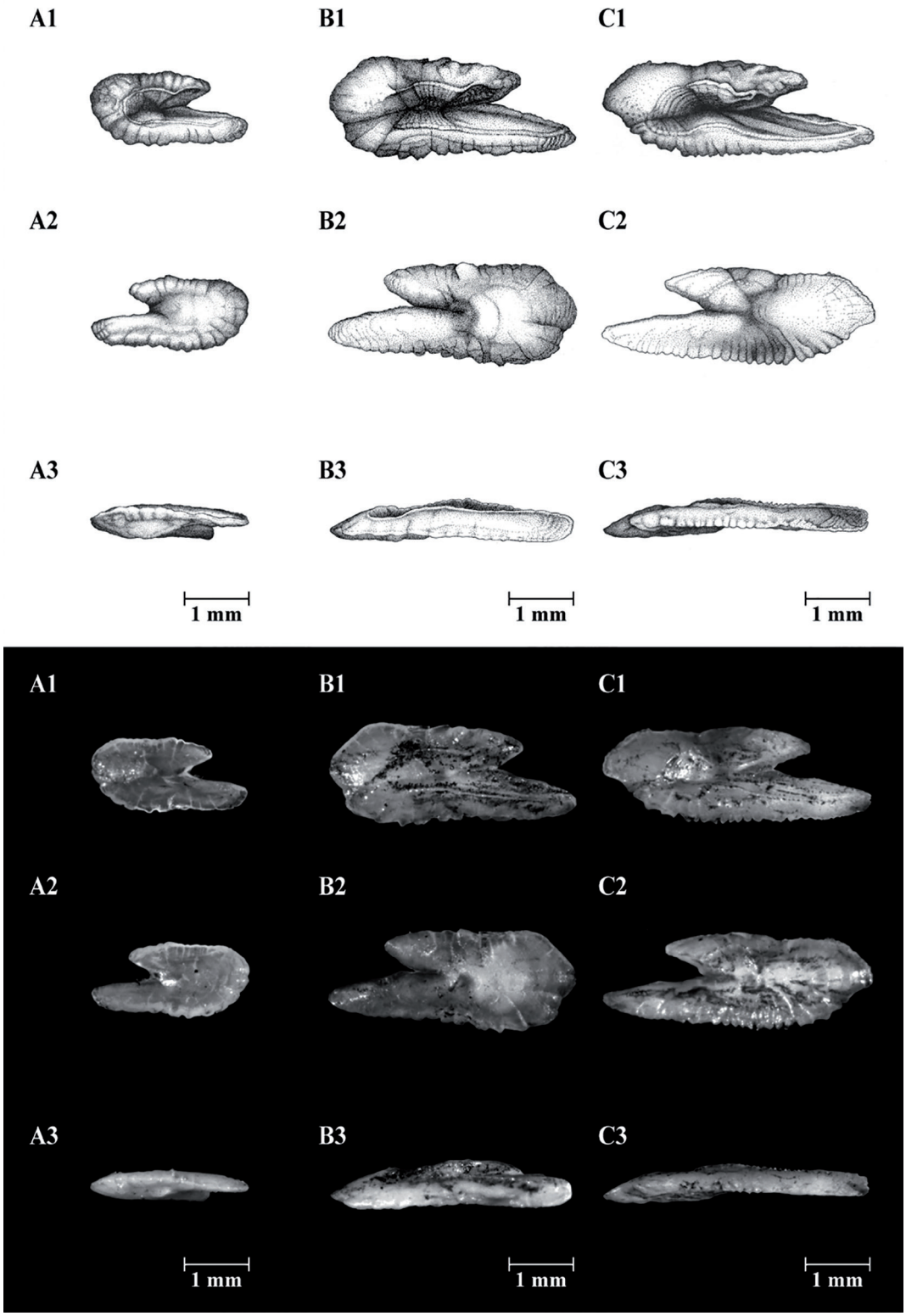

Plate 3. Illustrations (above) and photographs (below) of *Sardinella brasiliensis* otoliths from fishes with total lengths: A. 93 mm; B. 170 mm; C. 234 mm. The medial face is shown in A1, B1, C1; the lateral face in A2, B2, C2; and the ventral profile in A3, B3, C3 (Illustration: Alexandre Arackawa; Photos: Cesar Santificetur).

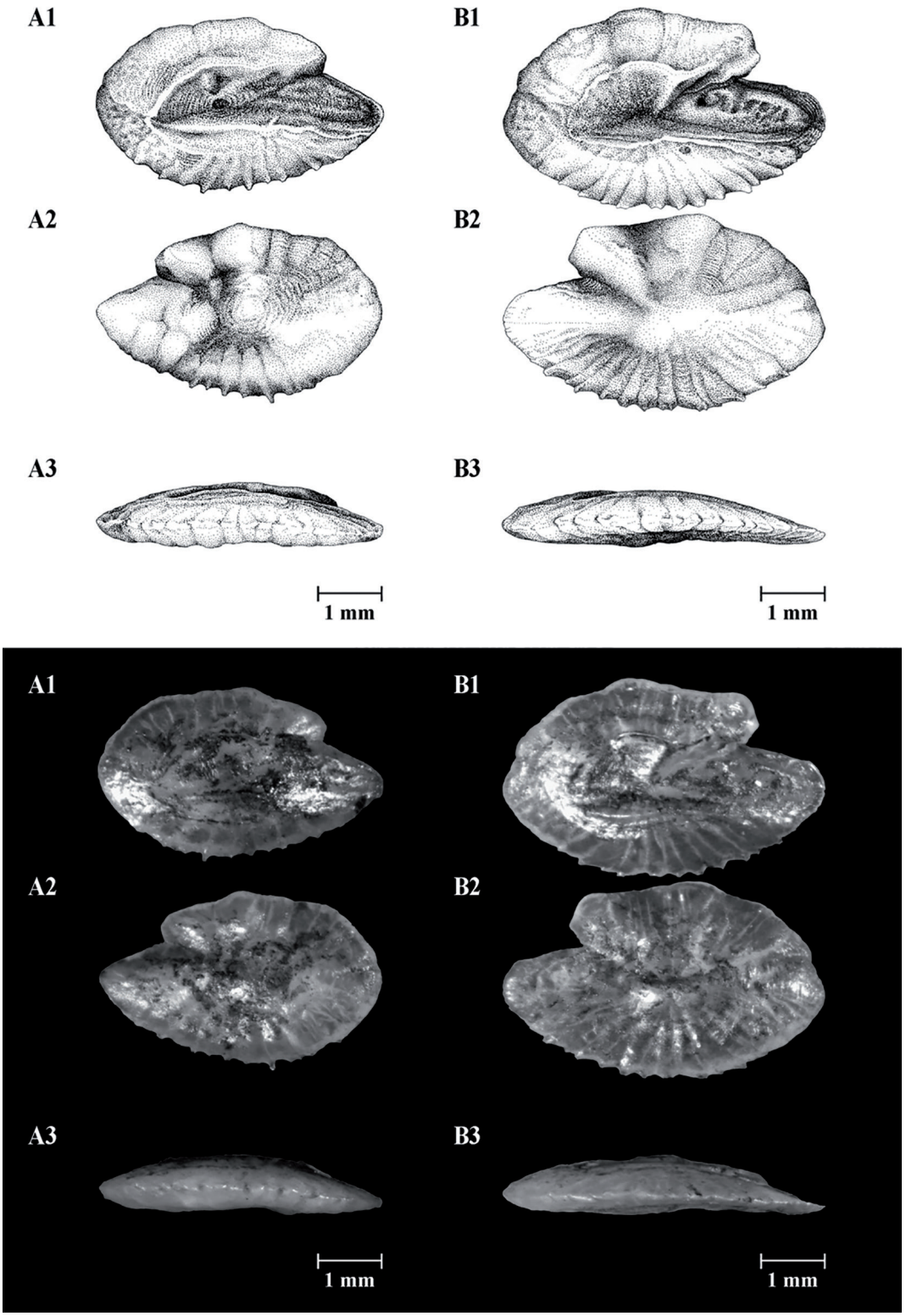

Plate 4. Illustrations (above) and photographs (below) of *Anchoa filifera* otoliths from fishes with total lengths: A. 85 mm; B. 135 mm. The medial face is shown in A1, B1; the lateral face in A2, B2; and the ventral profile in A3, B3 (Illustration: Silvia de Almeida Gonsales; Photos: Alexandre Arackawa).

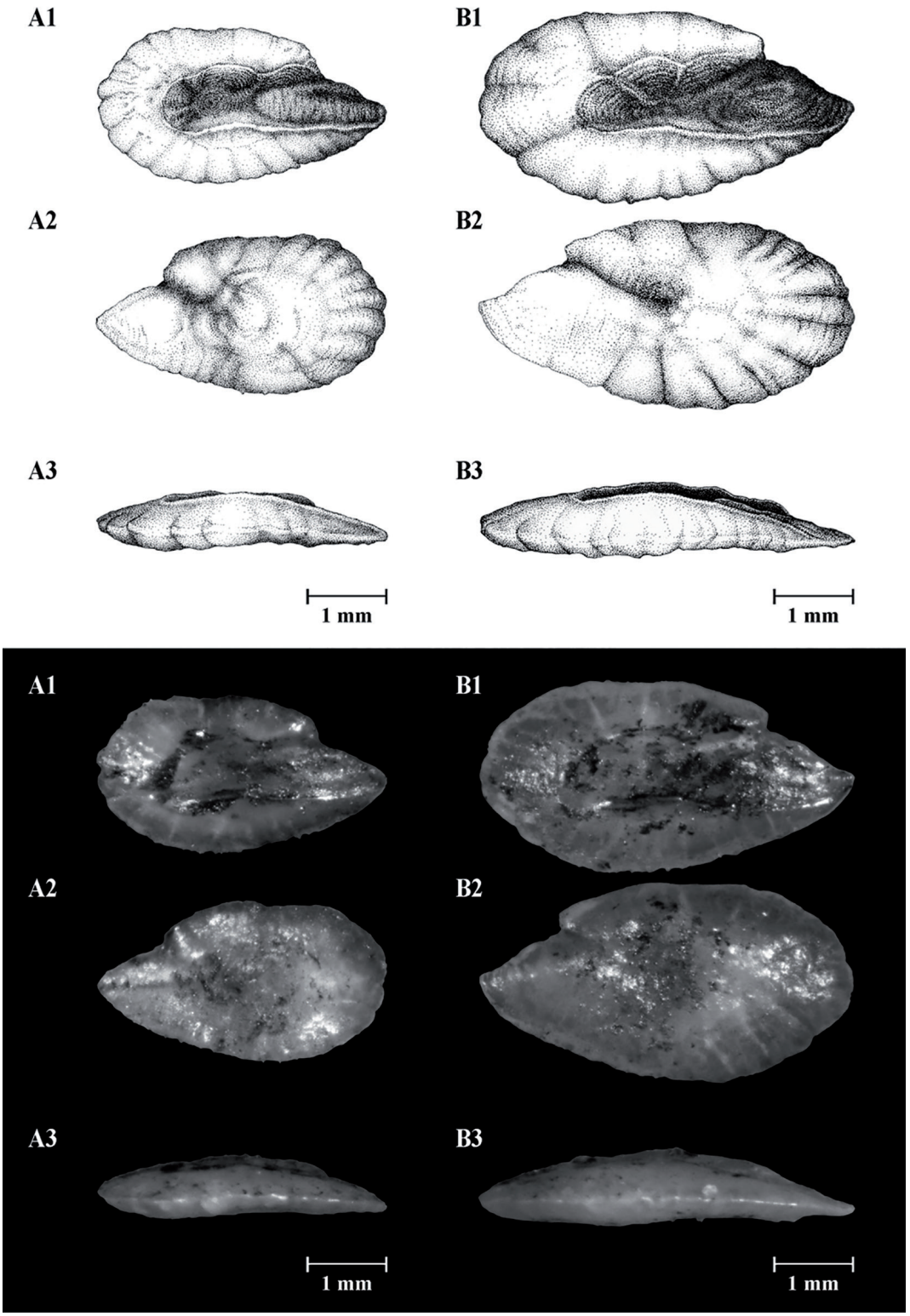

Plate 5. Illustrations (above) and photographs (below) of *Anchoa lyoleps* otoliths from fishes with total lengths: A. 59 mm; B. 80 mm. The medial face is shown in A1, B1; the lateral face in A2, B2; the ventral profile in A3, B3 (Illustration: Alexandre Arackawa; Photos: Alexandre Arackawa).

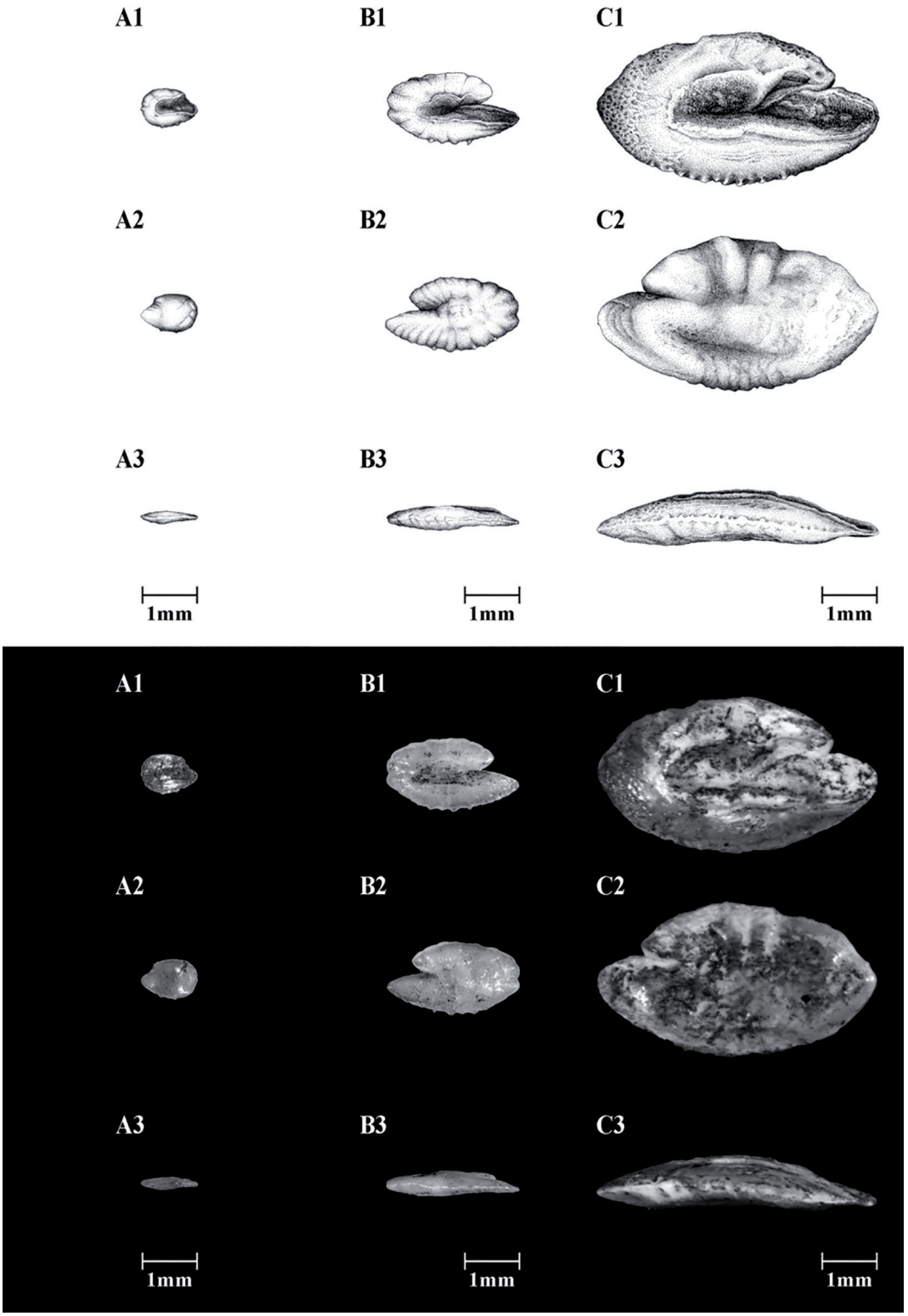

Plate 6. Illustrations (above) and photographs (below) of *Anchoa tricolor* from fishes with total lengths: A. 43 mm; B.86 mm; C. 129 mm. The medial face is shown in A1, B1, C1; the lateral face in A2, B2, C2; and the ventral profile in A3, B3, C3 (Illustration: Alexandre Arackawa; Photos: Cesar Santificetur).

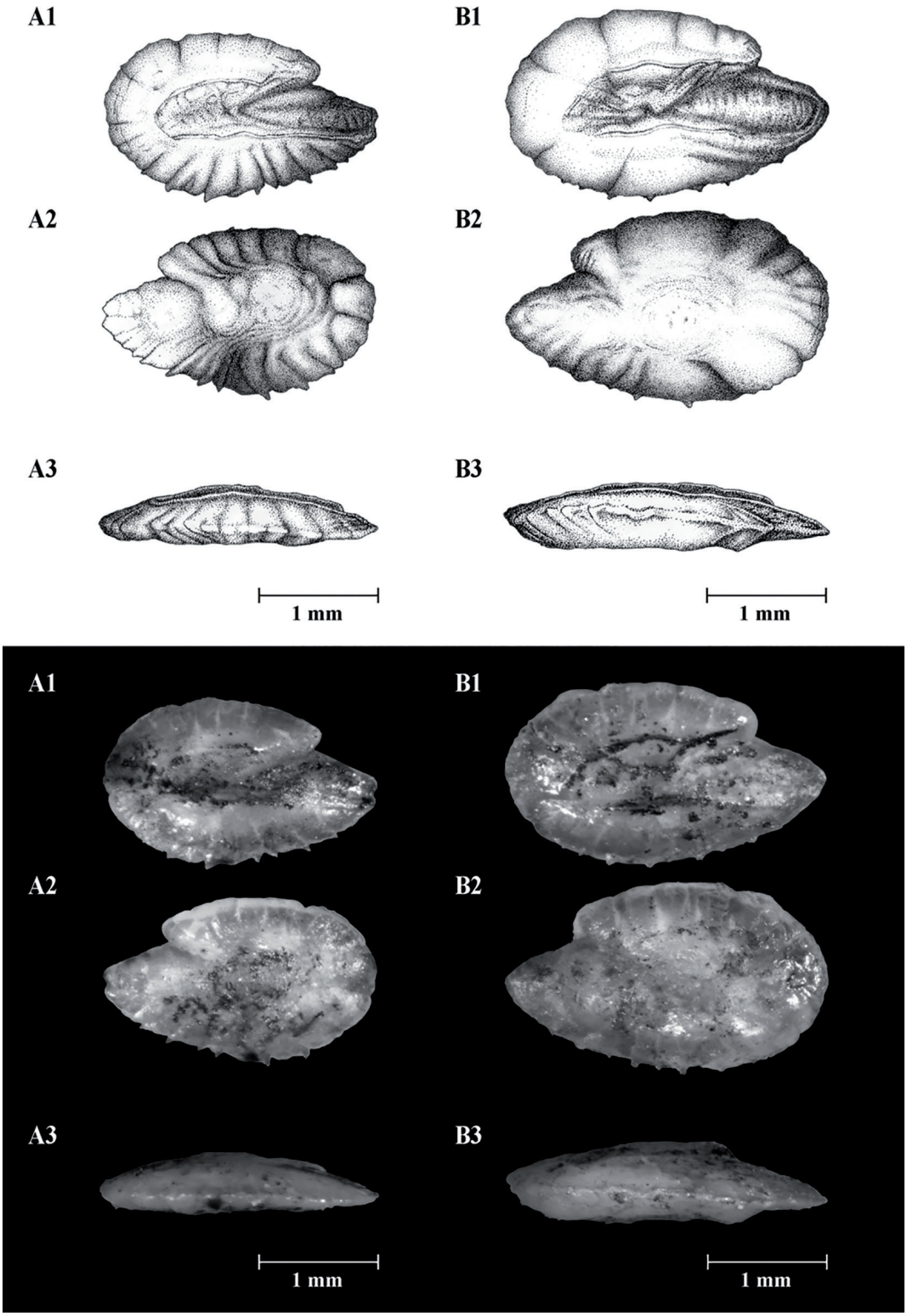

Plate 7. Illustrations (above) and photographs (below) of *Anchovia clupeoides* otoliths from fish with total lengths: A. 55 mm; B. 80 mm. The medial face is shown in A1, B1; the lateral face in A2, B2; and the ventral profile in A3, B3 (Illustration: Alexandre Arackawa; Photos: Alexandre Arackawa).

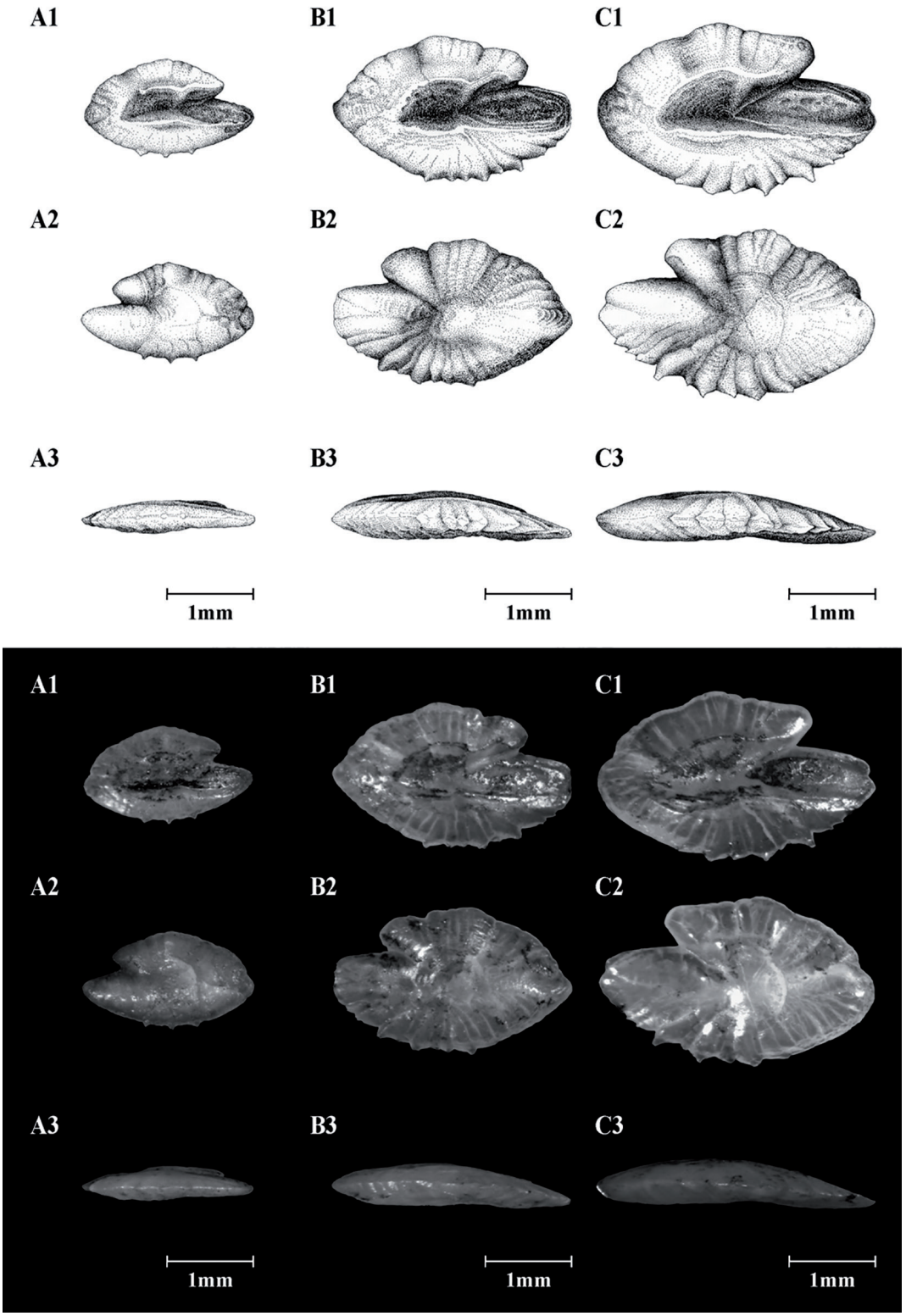

Plate 8. Illustrations (above) and photographs (below) of *Anchoviella lepidentostole* otoliths from fishes with total lengths: A. 75 mm; B. 102 mm; C. 126 mm. The medial face is shown in A1, B1, C1; the lateral face in A2, B2, C2; the ventral profile in A3, B3, C3 (Illustration: Silvia de Almeida Gonsales; Photos: Alexandre Arackawa).

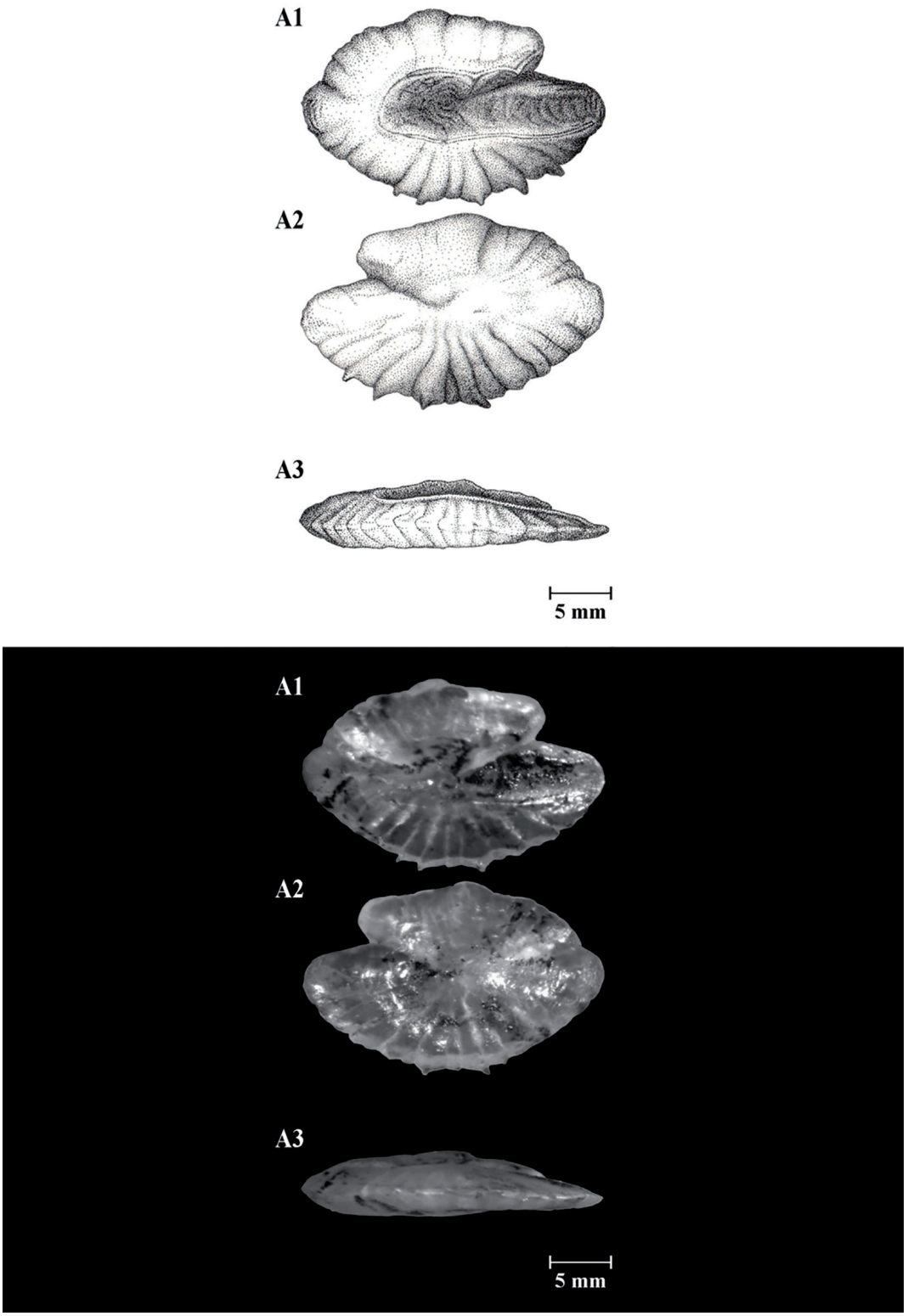

Plate 9. Illustrations (above) and photographs (below) of *Cetengraulis edentulus* otolith from a fish with total length of 93 mm. The medial face is shown in A1; the lateral face in A2; and the ventral profile in A3 (Illustration: Alexandre Arackawa; Photos: Alexandre Arackawa).

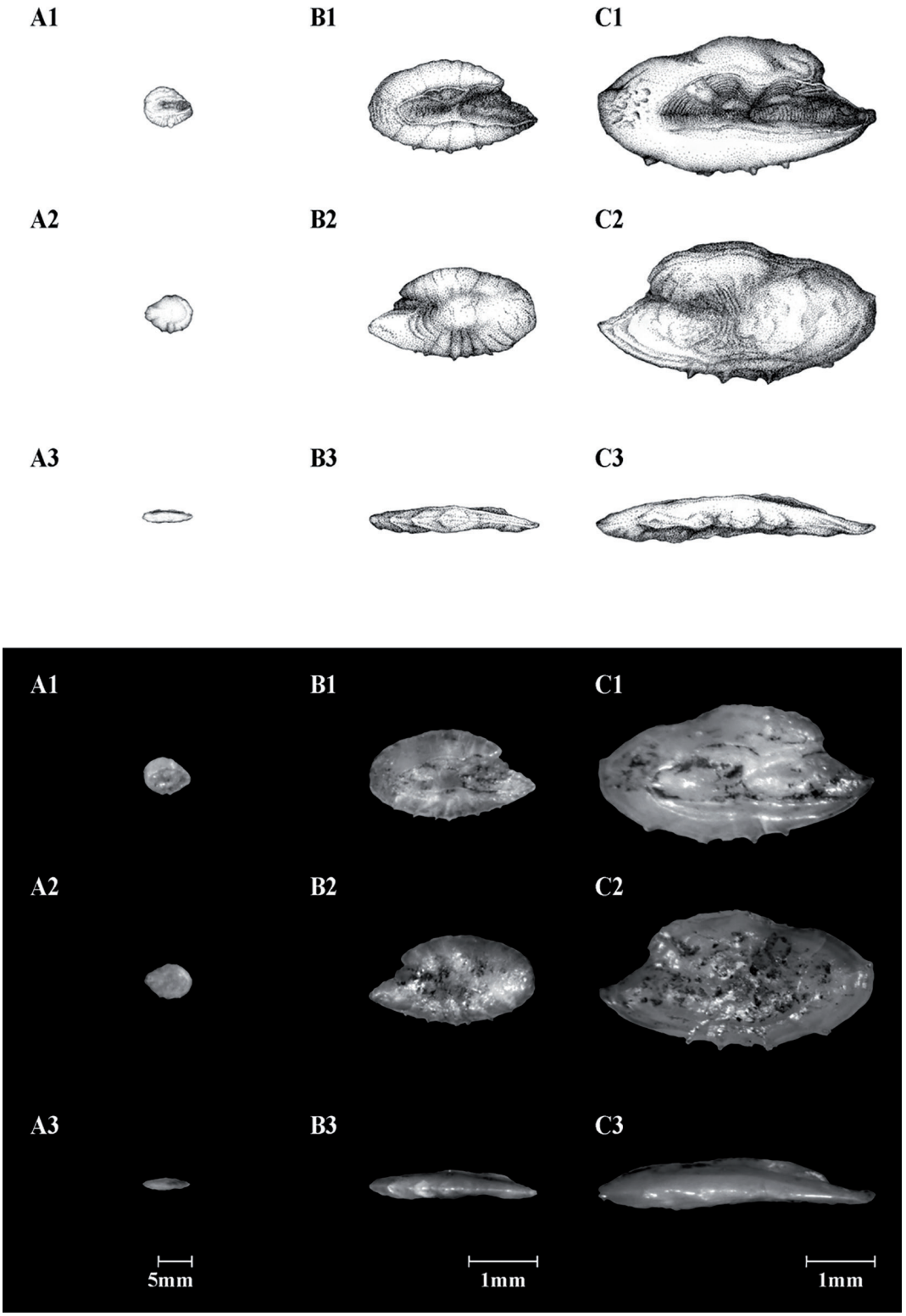

Plate 10. Illustrations (above) and photographs (below) of *Engraulis anchoita* otoliths from fishes with total lengths: A. 41 mm; B. 102 mm; C. 165 mm. The medial face is shown in A1, B1, C1; the lateral face in A2, B2, C2; the ventral profile in A3, B3, C3 (Illustration: Alexandre Arackawa; Photos: Alexandre Arackawa).

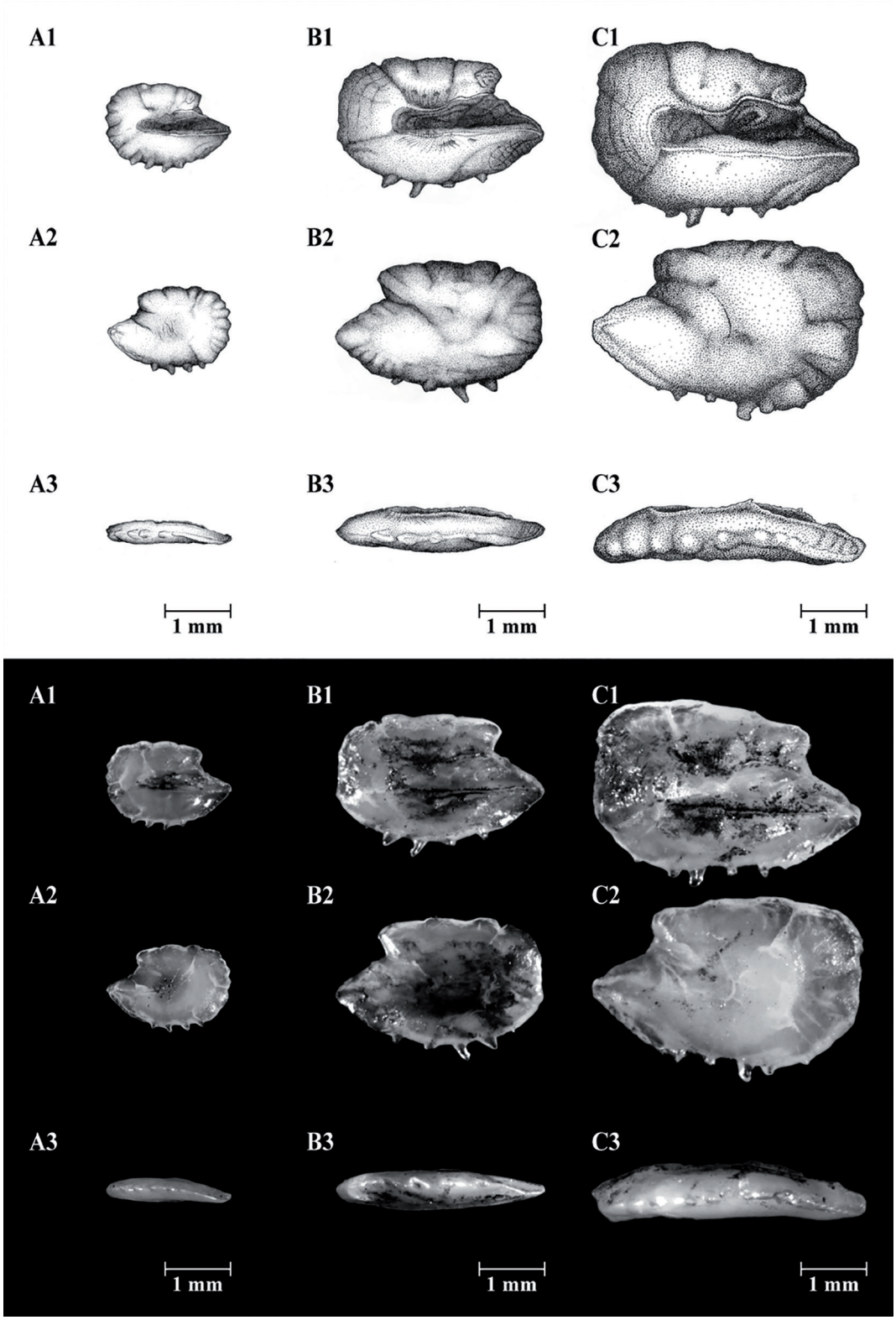

Plate 11. Illustrations (above) and photographs (below) of *Chirocentrodon bleekerianus* otoliths from fishes with total length: A. 65 mm; B. 92 mm; C. 116 mm. The medial face is shown in A1, B1, C1; the lateral face in A2, B2, C2; the ventral profile in A3, B3, C3 (Illustration: Alexandre Arackawa; Photos: Cesar Santificetur).

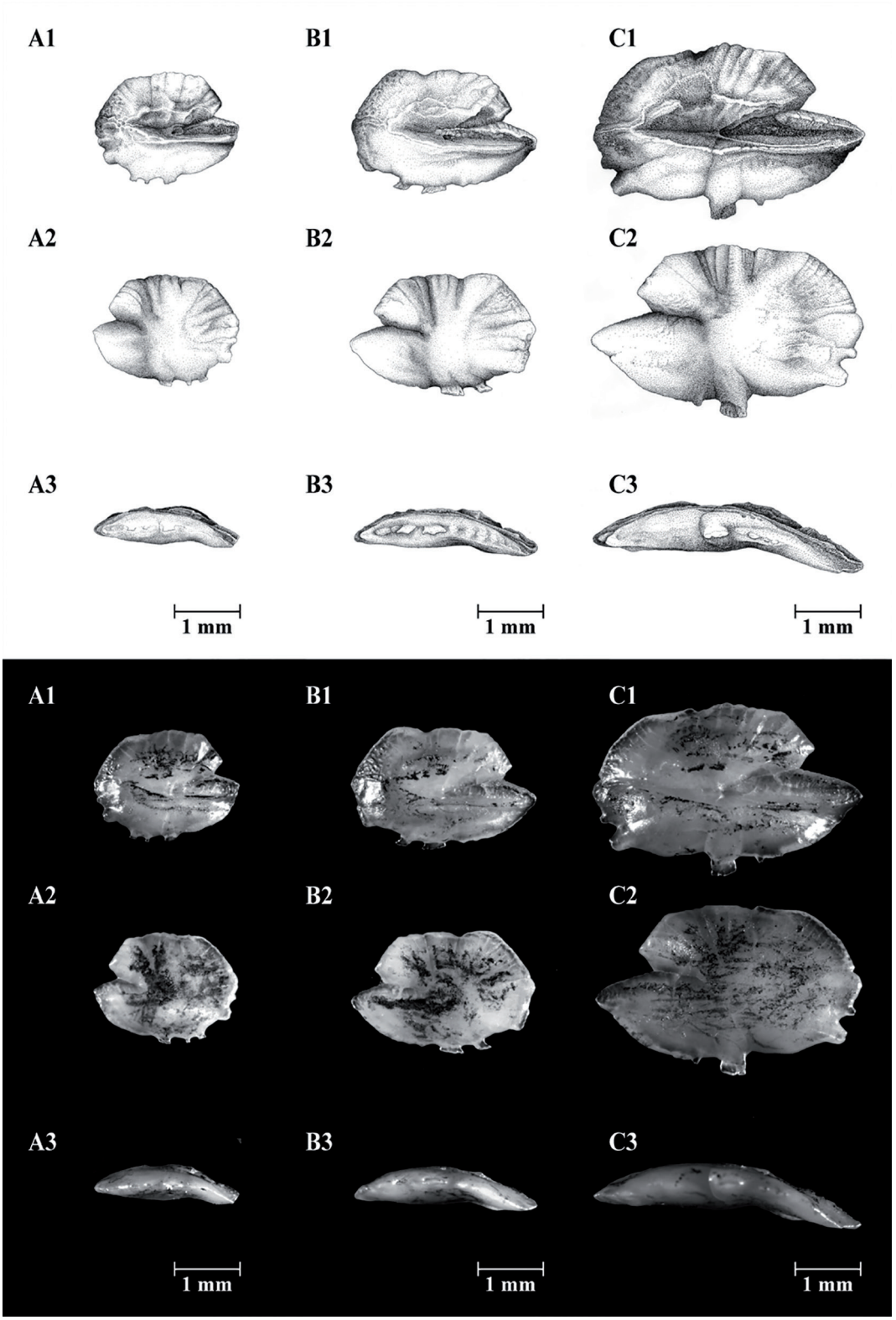

Plate 12. Illustrations (above) and photographs (below) of *Pellona harroweri* otoliths from fishes with total length: A. 93 mm; B. 123 mm; C. 154 mm. The medial face is shown in A1, B1, C1; the lateral face in A2, B2, C2; the ventral profile in A3, B3, C3 (Illustration: Silvia de Almeida Gonsales; Photos: Cesar Santificetur).