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TWO *Caranx caninus* (CARANGIDAE, PERCIFORMES) SPECIMENS WITH PUG-HEADED, EXOPHTHALMOS, OPERCLE, AND ANAL FIN ABNORMALITIES; FIRST RECORD FOR THE EASTERN PACIFIC

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ABSTRACT. The Pacific crevalle jack, *Caranx caninus* Günther, 1867, is a marine pelagic migratory fish species that usually inhabit shallow coastal water, including brackish and estuarine areas. The "pug-headed" abnormality in teleost fishes is characterized by an abnormal skeletal formation of the head, affected by an anteroposterior compression of the upper jaw, resulting in an abnormally shorter upper jaw concerning its lower jaw. In October 2016, an artisanal fisherman from Puerto Chale (Eastern Pacific, Mexico) captured a shoal of Pacific crevalle jack, where two of them presented morphological anomalies of pug-head, exophthalmos, opercle and anal fin. Both specimens' size and weight were 69.9 and 59.3 cm fork length and 3200 and 2550 g, respectively. One of the individuals was a six-year-old female. A list of 58 cases of pug-headed marine fishes worldwide is provided and reviewed in this article. This study is the first report for the Eastern Pacific and also for wild specimens of Carangidae species. The causes of this abnormality remain uncertain and the main hypotheses were reviewed in this study. However, factors such as temperature, nutrition, salinity, oxygen dissolved, pressure, unspecified pollutants are not discarded. More studies in the future, including new techniques, must be done to clarify the causes of this abnormality..

Keywords: America, Crevalle Jack, deformity, fish, Mexico.

Dos especímenes de *Caranx caninus* (Carangidae, Perciformes) con anormalidades de cabeza de pug, exoftalmia, opérculo y aleta anal; primer reporte para el Pacífico Oriental

RESUMEN. El jurel del Pacífico, *Caranx caninus* Günther, 1867, es una especie de pez migratorio pelágico marino que habitualmente habita en aguas costeras poco profundas, incluyendo zonas salobres y estuarinas. La anomalía de la "cabeza de pug" en los peces teleósteos se caracteriza por una formación esquelética anómala de la cabeza, afectada por una compresión anteroposterior de la mandíbula superior, lo que resulta en una mandíbula superior anormalmente más corta en relación con su mandíbula inferior. En octubre de 2016, un pescador artesanal de Puerto Chale (Pacífico Oriental, México) capturó un cardumen de jurel del Pacífico, donde dos de ellos presentaban anomalías morfológicas de cabeza de pug, exoftalmia, opérculo y aleta anal. El tamaño y peso de ambos ejemplares fueron 69,9 y 59,3 cm de longitud furcal y 3200 y 2550 g, respectivamente. Uno de los individuos era una hembra de seis años. En este artículo se proporciona y revisa una lista de 58 casos de peces marinos con cabeza de pug en todo el mundo. Este estudio es el primer informe para el Pacífico Oriental, y también para especímenes silvestres de una especie de Carangidae. Las causas de estas anomalías siguen siendo inciertas y se revisaron en este estudio. Sin embargo, no se descartan factores como temperatura, nutrición, salinidad, oxígeno disuelto, presión, contaminantes no especificados. Se deben realizar más estudios en el futuro, incluidas nuevas técnicas, para aclarar las causas de este tipo de enfermedad.

Palabras claves: América, Deformidad, Jurel toro, Pez, México.

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INTRODUCTION

The Pacific crevalle jack, *Caranx caninus* Günther, 1867, is a marine pelagic migratory species that usually occurs on shallow coastal water, including brackish, estuarine areas (Froese & Pauly, 2019) and occasionally ascend rivers (Smith-Vaniz, 1995). It has a geographical distribution between California (USA) to Peru, including the Gulf of California and the Galapagos Islands (Chirichigno & Cornejo, 2001; Miller & Curtis, 2008), being an important species in the Gulf of California for local consumption (Sánchez-García *et al*., 2017). This species has been previously reported to reach a maximum length of over 100 cm (Smith-Vaniz, 1995). Its longevity has been estimated between six to nine years (Torres-Aguilar, 2002; Espino-Barr *et al*., 2008). The species is considered a piscivorous predator and specialist due to its preference for *Anchoa* species (Sánchez-García *et al*., 2017).

The "pug-headed" condition in teleost fishes is characterized by an abnormal skeletal formation of the head, affected by an anteroposterior compression of the upper jaw, resulting in an abnormally shorter upper jaw concerning the lower jaw (Gudger & Miller, 1929; Jawad *et al*., 2014; Bueno *et al*., 2015). This rare disease in fishes is documented and reviewed, mostly for freshwater species in Europe and North America (Gemmill, 1912; Dawson 1964, 1966, 1971; Dawson & Heal, 1971). Worldwide reports on marine fishes having this abnormality are less frequent; however, it can be traced back to 1885, including different species (Table 1).

Other anatomical and morphological abnormalities, particularly eye diseases, operculum complex, spine (e.g., scoliosis, lordosis), ventral and dorsal fin (Saddleback syndrome) in marine and freshwater fish species, are well documented and reviewed worldwide (see Mansueti, 1960; Engelman *et al*.,

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Table 1. Worldwide records of marine fishes documenting Pug-headed abnormality arranged in chronological order. Question sign (?) is referred to doubts with the information provided in the record or article consulted.

Species	Year	Country	Type of case	Reference
Salmo salar Linnaeus, 1758	1885	Netherland	Wild-Caught	Gudger & Miller (1929).
Chelidonichthys lucerna (Linnaeus, 1758)	1897	England	Wild-Caught	Gudger & Miller (1929).
Lumpenus lampretaeformis (Walbaum, 1792)	1907?	Denmark	Wild-Caught	Dawson (1964).
Salmo trutta Linnaeus, 1758	190?	Scotland?	Wild-Caught	Gemmill (1912).
Salmo trutta Linnaeus, 1758	190?	Scotland?	Wild-Caught	Gemmill (1912).
Trout spp.	1910	Scotland	Wild-Caught	Gudger & Miller (1929).
Salmo salar Linnaeus, 1758	1912	Scotland	Wild-Caught	Gudger & Miller (1929).
Gadus morrhua Linnaeus, 1758	1919?	Germany	Wild-Caught	Dawson (1964).
Lumpenus lampretaeformis (Walbaum, 1792)	1919?	Germany	Wild-Caught	Dawson (1964).
Lepidopsetta bilineata (Ayres, 1855)	1926	USA	Wild-Caught	Gudger *et al*. (1937).
Mystus gulio (Hamilton, 1822)	1927	India	Wild-Caught	Mukerji (1927).
Morone saxatilis (Walbaum, 1792)	1929?	USA	Wild-Caught	Dawson (1964).
Haemulon plumieri (Lacepède, 1801)	1930?	USA	Wild-Caught	Dawson (1964).
Bairdiella chrysoura (Lacepède, 1802)	1933	USA?	Wild-Caught	Gudger & Nichols (1933).
Morone saxatilis (Walbaum, 1792)	1948	USA	Wild-Caught	Lyman (1961).
Oncorhynchus keta (Walbaum, 1792)	1954	Japan	Reared?	Hikita (1955).
Muraenesox cinereus (Forsskål, 1775)	1954	Japan	Wild- Landed	Hotta & Honma (1958).
Evynnis tumifrons (Temminck & Schlegel 1843)	1958	Japan	Wild-Caught	Akazaki (1963).
Oncorhynchus nerka (Walbaum, 1792)	1958	Japan	Reared?	Sano (1958).
Morone saxatilis (Walbaum, 1792)	1960	USA	Wild-Caught	Mansueti (1960).
Morone saxatilis (Walbaum, 1792)	1961	USA	Wild-Caught	Dawson (1964).
Sebastes oblongus Günther, 1877	1962	Japan	Wild-Caught	Okiyama (1965).
Brevoortia tyrannus (Latrobe, 1802)	196?	USA	Wild-Caught	Schwartz (1965).
Brevoortia tyrannus (Latrobe, 1802)	1965	USA	Wild-Caught	Dahlberg (1970).
Brevoortia tyrannus (Latrobe, 1802)	1966	USA	Wild-Caught	Warlen (1969).
Etropus crossotus Jordan & Gilbert, 1882	1967	USA	Wild-Caught	Dalhberg (1970).
Cynoscion regalis (Bloch & Schneider, 1801)	1967	USA	Wild-Caught	Dalhberg (1970).
Rhomboplites aurorubens (Cuvier, 1829)	1969	USA	Wild-Caught	Bortone (1971).
Acanthopagrus schlegelii (Bleeker, 1854)	1970	Japan	Wild-Caught	Honma & Ikeda (1971).
Brevoortia patronus Goode, 1878	1971	USA	Wild-Caught	Kroger & Guthrie (1973).
Thunnus thynnus (Linnaeus 1758)	1974	Japan	Wild-Caught	Nakamura (1977).
Sebastes auriculatus Girard, 1854	1977	USA	Wild-Caught	Adams (1982).
Gymnothorax sp.	1989	USA	Wild-Caught	Browder *et al*. (1992).
Lutjanus synagris (Linnaeus, 1758)	1989	USA	Wild-Caught	Browder *et al*. (1992).
Haemulon parra (Desmarest, 1823)	1989	USA	Wild-Caught	Browder *et al*. (1992).
Lagodon rhomboides (Linnaeus, 1766)	1989	USA	Wild-Caught	Browder *et al*. (1992).
Rachycentron canadum (Linnaeus, 1766)	1991	USA	Wild-Caught	Franks (1995).
Latris lineata (Forster, 1801)	1998	Tasmania	Reared	Cobcroft *et al*. (2001).
Pagrus auratus (Forster, 1801)	2005	New Zealand	Wild-Caught	Jawad & Hosie (2007)
Bodianus rufus (Linnaeus, 1758)	2006	Brazil	Wild-Caught	Macieira & Joyeux (2007).

Table 1. Continued.

Species	Year	Country	Type of case	Reference
Salmo salar Linnaeus, 1758	2008	Norway	Reared	Jawad *et al*. (2014).
Epinephelus itajara (Lichtenstein, 1822)	2011	USA	Wild-Caught	Bueno *et al*. (2015).
Rhizoprionodon oligolinx Springer, 1964	2011	Kuwait	Wild-Caught	Moore (2015).
Epinephelus itajara (Lichtenstein, 1822)	2012	Brazil	Wild-Caught	Bueno *et al*. (2015).
Holocanthus ciliaris (Linnaeus, 1758)	2011	Brazil	Wild-Caught	Francini-Filho y Amado-Filho (2012).
Holocanthus ciliaris (Linnaeus, 1758)	2011	Brazil	Wild-Caught	Francini-Filho y Amado-Filho (2012).
Epinephelus itajara (Lichtenstein, 1822)	2012	USA	Wild-Caught	Bueno *et al*. (2015).
Cynoscion nebulosus (Cuvier, 1830)	2013	USA	Wild-Caught	Schwartz & Jones (2013).
Myrichthys ocellatus (Lesueur, 1825).	2014	Brazil	Wild record	Grimaldi & Bertoncini (2021).
Nemipterus randalli Russell, 1986	2015	Turkey	Wild-Caught	Jawad *et al*. (2017b).
Pagellus erythrinus (Linnaeus, 1758)	2016	Turkey	Wild-Caught	Jawad *et al*. (2017a).
Bodianus macrognathos (Morris, 1974)	2016	Saudi Arabia	Wild-Caught	Jawad & Ibrahim (2017).
Caranx caninus Günther, 1867	2016	Mexico	Wild-Caught	This study.
Caranx caninus Günther, 1867	2016	Mexico	Wild-Caught	This study.
Oreochromis mossambicus (Peters, 1852)	2017	Oman	Wild-Caught	Jawad & Ibrahim (2019).
Epinephelus diacanthus (Valenciennes, 1828)	2017	Oman	Wild-Caught	Jawad & Ibrahim (2019).
Epinephelus marginatus (Lowe, 1834)	2018	Brazil	Wild-Caught	Grimaldi & Bertoncini (2021).
Epinephelus marginatus (Lowe, 1834)	2020	Brazil	Wild-Caught	Grimaldi & Bertoncini (2021).

1984; Hickey, 1972; Hargis, 1991; Galeotti *et al*., 2000; Stephens *et al*., 2001; Beraldo *et al*., 2003; Boglione *et al*., 2013; Campbell & Landers, 2013; Fragkoulis *et al*., 2017; Gao *et al*. 2018; Jawad & Ibrahim, 2018; Jawad *et al*., 2019; Feng *et al*., 2020). Abnormal specimens have been reported on reared and natural (wild) fish populations (Barahona-Fernandes, 1982; Eissa *et al*., 2009), even showing a combination of these diseases on the same specimen, including pug-headedness.

As far as it is known, this study is the first record of a pug-headed deformity along the Eastern Pacific. Simultaneously, this report constitutes the first evidence of several morphological and anatomic anomalies (*i.e*., pug-headed, opercular series, exophthalmia, and anal fin abnormalities) recorded jointly in a single specimen, reaching the adult size in a natural population.

MATERIALS AND METHODS

In October 2016, a fisherman from Puerto Chale (24º25'20''N – 111º33'15''W), using artisanal gear, captured a Pacific crevalle jack shoal in the Almeja-Magdalena Bay Complex (Baja California Sur, México). Within this shoal, two specimens were observed with a bilateral pug head condition (Fig. 1). Additionally, exophthalmic, opercle and anal fin abnormalities were also noticed (Fig. 1). For species identification, taxonomic literature was used (Smith-Vaniz, 1995). Biometric information was made using a metric rule and an analog balance. Photos were also made for digital morphometric records using the software Image-Pro Plus. Specimen 1 was dissected to evaluate stomach contents, sex, maturation stage. The postcranial vertebra was used for age estimation. Sex was determined based on macroscopic characteristics, according to (Gillanders *et al*. 1999). The tie bow of vertebrae was obtained using a low revolution cutter saw (BUEHLER®). Vertebrae were photographed with a video camera (Sony CCD-IRIS-RGB) adapted to a microscope (Olympus SZX9). Fixation using Formaldehyde 10% and preservation in Ethanol 70% were performed on the head (specimen 1) and the whole specimen 2. Both preserved individuals were donated to the ichthyological collection CICIMAR-IPN and cataloged under the code number (CICIMAR-CI-8331). The morphometric and meristic information were contrasted with a normal adult *C. caninus* specimen preserved in the Ichthyological Collection CICIMAR-IPN (CI-2800) (Table 2).

An X-ray plate to determine the anatomical degree of severity of the deformation of the bones (Al-Mamry *et al*., 2010; Jawad *et al*., 2013; Shwartz & Jones, 2013; Jawad *et al*., 2017a,b) could not be performed in this study due to the logistic and pandemic COVID-19 restriction protocols. The data matrix of Table 1 was elaborated with the available worldwide information of pug-headed condition in marine fishes, using only those articles with detailed information (*e.g.,* species, collection place, year, and photographic or schematics evidence). The spe-

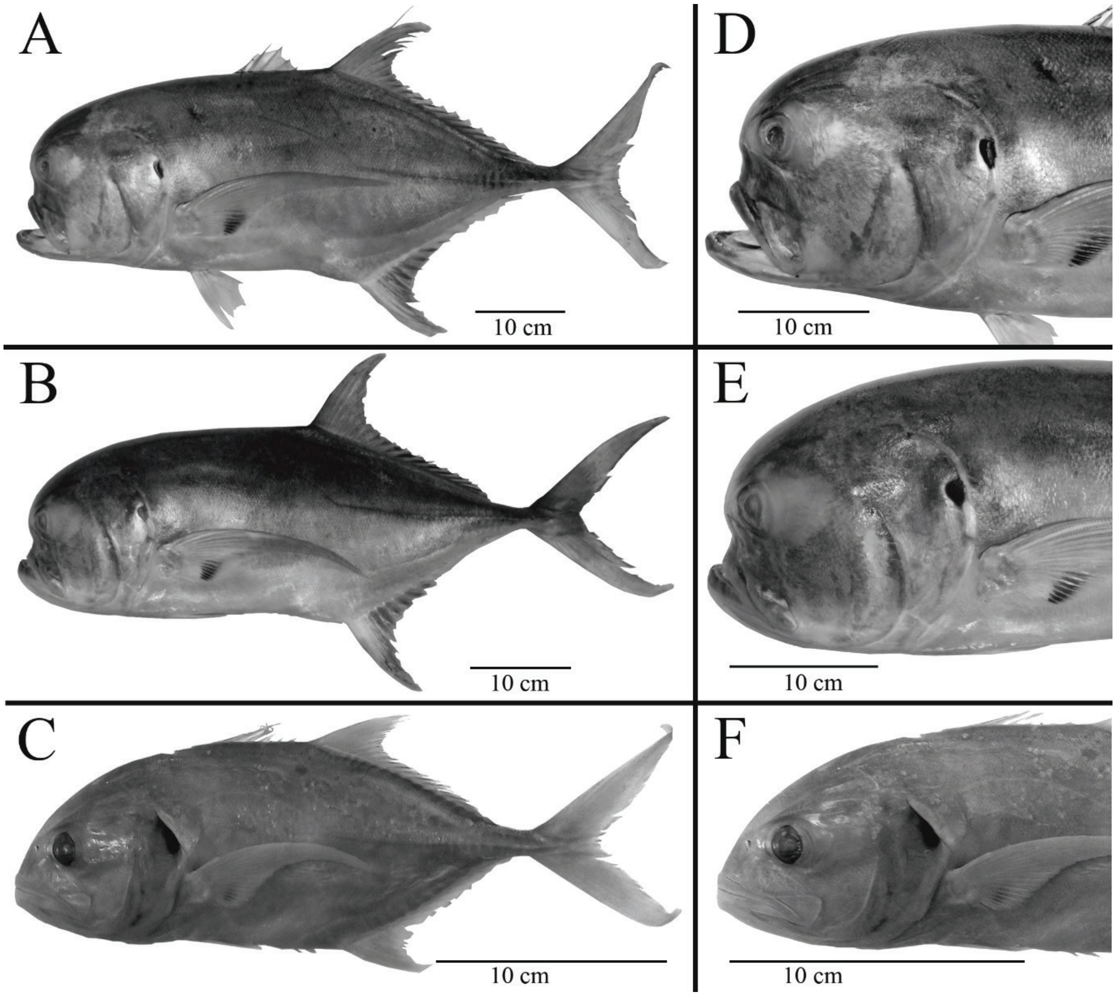

Figure 1. Pug-headed *Caranx caninus* (CICIMAR-CI-8331) specimen 1 (A, D); specimen 2 (B, E); normal specimen CICIMAR-CI-2800 (C, F).

cies validity (Table 1) was verified and actualized according to the information provided in Eschmeyer's Catalog of Fishes (Fricke *et al*., 2020).

RESULTS

Both individuals were identified as *Caranx caninus*. The Furcal Length (FL) for the CICIMAR-CI-8331 specimen number one and specimen number two was 69.9 and 59.3 cm (Fig. 1), weighing 3200 g and 2550 g, respectively. Complemental biometric and meristic information are provided in Table 2.

Additionally, both specimens showed an ocular disease (i.e., exophthalmic) and lacked the two most anterior spines of the anal fin (Fig. 1). The dissected specimen presented an empty stomach. Despite the bad initial preservation, this specimen was sexed as a female by its pale-orange mass. Nevertheless, a microscopic analysis could not be performed. The age of the dissected specimen was estimated at six years (Fig. 2).

A total of 58 available worldwide reports of marine pug-headed fishes were gathered in the present study (Table 1). All records except for the Grey sharp-nosed shark (*Rhizoprionodon oligolinx*: Carcharinidae: Cacahriniformes: Chondrichthyes) belonged to the Superclass Osteichthyes. Pug-headed in bony fish was recorded on nine orders and 25 Families: Perciformes (15 Families total cases: 35), Salmoniformes (Salmonidae, total cases: eight), Clupeiformes (Clupeidae, total cases: four), Anguilliformes (Muraenidae, Muraenesocidae and Ophicthidae, total cases: three), Scorpaeniformes (Sebastidae and Triglidae, total cases: three), Pleuronectiformes (Cyclopsettidae and Pleuronectidae, total cases: two), Gadiformes (Gadidae, total cases: one) and Siluriformes (Bagridae, total cases: one).

Of the 58 records, only three occurred on reared conditions. Marine fishes having this abnormality were recorded in 16 countries worldwide (Table 1). The USA showed the highest frequency with 23 cases, followed by Brazil (7), Japan (7), Scotland (4),

Table 2. Morphometric characteres (expressed in cm) of the two pug-headed *Caranx caninus* specimens caught in Puerto Chale, Baja California Sur, Mexico. The comparison between abnormal specimens and the normal specimen is expressed with the fork length percentage (%FL). Pre-anal fin distance measured until isolated spines (*). Meristic characters are expressed according to Cervigón (1991), roman numbers are for spines, and Arabic numbers represent the soft-rays; the comma symbol (,) represents a separation between fins and the hyphen (-) represent followed by the soft-rays.

		Pug-Headed Specimens				Normal Specimen	
		#1	%FL	#2	%FL	Unique	%FL
Morphometrics	Total Length	76.2		68.6		27.5	
	Fork Length	69.9		59.3		25.0	
	Standard Length	67.2	96.1	56.5	95.3	23.2	92.8
	Pre-orbital length	2.5	3.6	0.9	1.5	1.8	7.2
	Eye Diameter	2.2	3.1	1.8	3	1.5	6.0
	Mouth length	6.9	9.9	5.42	9.1	3.1	12.4
	Head length	17.8	25.5	13.8	23.3	6.9	27.6
	Pre-pectoral fin distance	18.7	26.8	14.3	24.1	7.0	28
	Pre-2ºdorsal fin distance	36.2	51.8	30	50.6	11.9	47.6
	Pre-anal fin distance	39.3	56.2	34.3	57.8	11.4	45.6*
	High of the body	21.6	30.9	17.1	28.8	7.7	30.8
Meristic	Dorsal fin	VII, I-19		VII, I-19		VII, I-19	
	Pectoral fin	16		17		16	
	Pelvic fin	I, 5		I, 5		I, 5	
	Anal fin	I-17		I-17		II, I-17	

Germany (2), Mexico (2 this study), Oman (2), Turkey (2), Denmark (1), England (1), India (1), Kuwait (1), Netherland (1), New Zealand (1), Norway (1), Saudi Arabia (1), and Tasmania (1).

DISCUSSION

According to the information provided for *C. caninus* by Smith-Vaniz (1995), both specimens reported in this study were adults. An upper jaw distal end located at the same vertical line (or farter) than the distal part of the eye orbit is a diagnostic condition of a mature specimen of this species (Smith-Vaniz, 1995). Additionally, a distinctive black spot in the pectoral fin and the operculum (visible on both specimens) is also characteristic in this species for mature specimens. Reaching adult size for pug-headed specimens is uncommon (Gudger *et al*., 1937; Mansueti, 1960; Dahlberg, 1970). However, the record of mature specimens showing this abnormality has been increasing in the last decade, being reported for *Morone saxatilis* (Mansueti, 1960), *Micropterus salmoides* (Bunckley-Williams & Williams, 1998), *Bodianus rufus* (Macieira & Joyeux, 2007), *Salmo salar* (Jawad *et al*. 2014), *S. trutta* (Gudger & Miller, 1929), *Epinephelus itajara* (Bueno *et al*., 2015), *Ephinephelus marginatus* and *Myrichthys ocellatus* (Grimaldi & Bertoncini, 2021).

In this study, both specimens had a total weight of almost 50% lower than normal specimens with similar sizes captured on the coast of Colima, Mexico (Espino-Barr *et al*., 2008). This finding is not surprising, as pug-headed specimens usually had significantly lower weights than typical fish (Shariff *et al*. 1986; Schmitt & Orth, 2015). Pug-headed and normal individuals in some species may have similar feeding behavior and efficiency in the earliest life stage (Mansueti, 1958). However, this deformity has been demonstrated to negatively affect foraging ability and efficiency, particularly in larger sizes or mature specimens (Mansuati, 1960; Noble *et al*., 2012). This agreement could explain the disadvantage of these abnormal specimens, resulting in lower weight, which can be more evident in piscivorous predator species such as *C. caninus* (Sánchez-García *et al.*, 2017). Latitudinal and geographic bias affecting prey richness and abundance in highly marine migratory species (Ferreira *et al*., 2004; Sánchez-García *et al*., 2017; Ehemann *et al*., 2019) are not discarded.

Fish having the pug-head condition has slower growth rates than normal individuals (Shariff *et al*. 1986), being congruent with the present results, considering the age estimated for the specimen in this study and bibliographic references. The standard length of specimen 1 (SL=67.2 cm and six years) differs from the results obtained by Torres-Aguilar

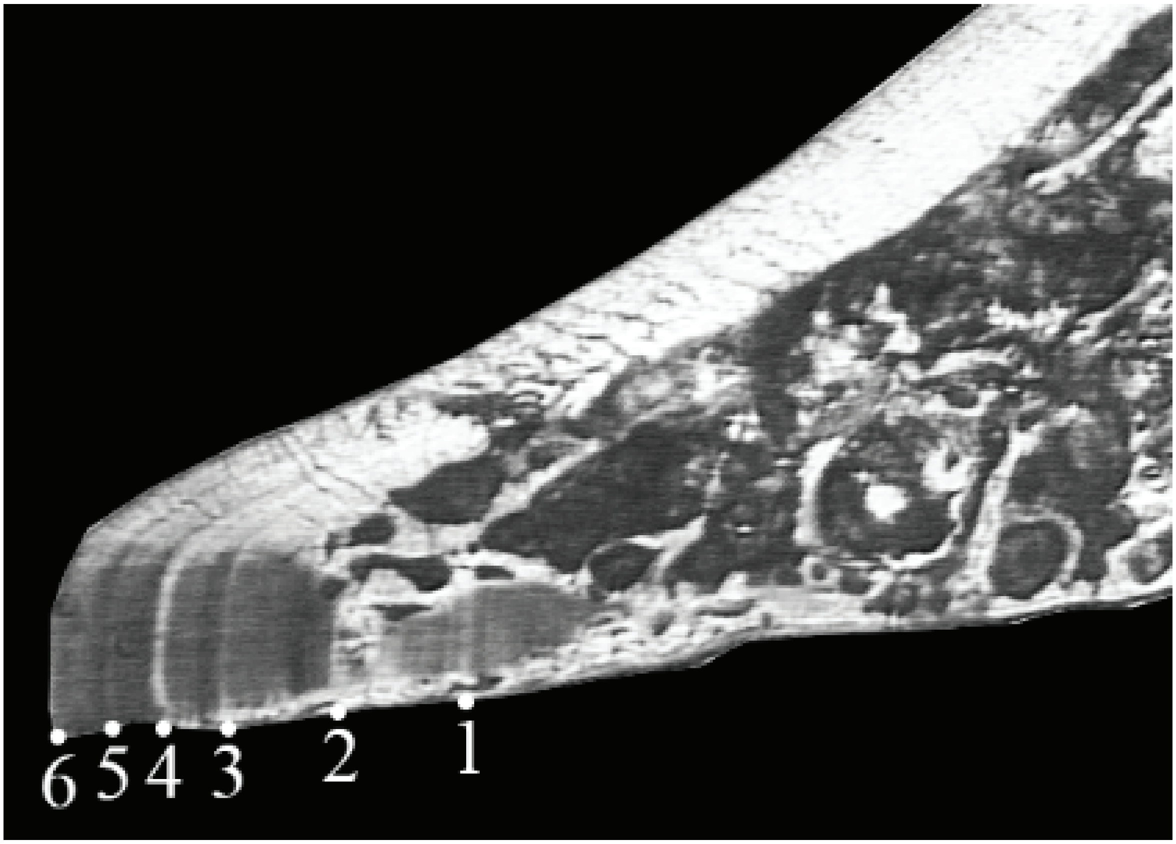

Figure 2. Age estimated for the pug-headed (CICIMAR-CI-8331) specimen 1. Age mark counts were performed on the vertebrae distal part due to the vascularization process along the vertebrae.

(2002) with 68.54 cm and nine years (using the vertebrae). Also, the age of this pug-headed specimen differs from the average SL size (59-60 cm) of the groupage of six years estimated by Cruz-Romero *et al*. (1993) (using ELEFAN method) and Espino-Barr *et al*. (2008) using otoliths. However, in this result, a sub-estimation of the age due to the vertebrae's vascularization process is not discarded.

More than one hundred records worldwide of pug-headed fish cases have been documented (Gudger, 1930; Dawson 1964, 1966, 1971; Dawson & Heal, 1971; Cobcroft *et al*., 2001; Jawad & Hosie 2007; Porta & Snow, 2015; Catelani *et al*., 2017). The areas and cranial bones affected by this anomaly are well described and documented (Okiyama, 1965; Dawson 1971; Al-Mamry *et al*., 2010; Schwartz & Jones, 2013. Jawad *et al*., 2017; Ma *et al*., 2016). The upper jaw (premaxilla and maxilla); suspensorium (palatine); neurocranium (vomer, ethmoid, nasal, parasphenoid, frontal); infraorbital series (lacrimal, infraorbital 2-6) and the opercular series (preopercle, opercle, subopercle, and interopercle) are affected -in different degrees- by this abnormality (Schaeperclaus, 1954, Bortone, 1971, 1972; Jawad & Hosie, 2007; Jawad *et al*. 2017a). In this study, all preopercular measures evidenced a pug-headed affection due to its abnormal skull and head bones compared to the ordinary individuals.

The pug-headed condition does not exclusively affect foraging ability reverberating on the size, weight, growth rates, and head skull as detailed before. This anomaly also has been documented to have consequences on other systems such as visual, digestive, locomotion and respiratory (Isaacson, 1965; Okiyama, 1965; Dawson & Heal, 1971; Hickey, 1972; Jawad *et al*., 2013). Eye diseases on reared fishes have increased worldwide, caused by bacterial and viral pathogens, exposition to toxic environments, and barotrauma (Austin, 2005; Fajer-Ávila *et al*., 2003; Baeck *et al*., 2006; Humborstad *et al*., 2016). However, this condition on wild population specimens might be due to the abnormal infraorbital series bones arrangements. Beraldo *et al*. (2003) reviewed the effects and causes (discussed below) of the unnormal opercular complex. The main disadvantages are reducing the gill arches protection and mechanic efficiency, reverberating its respiratory system.

Pug-headed fishes specimens have been documented showing other anomalies such as eye diseases (*e.g*., exophthalmos), digestive or swimming locomotion (Isaacson 1965; Okiyama 1965, Dawson 1971; Francini-Filho & Amado-Filho Bueno *et al*., 2015; Catelani *et al*. 2017; Jawad *et al*., 2017).

These records usually reported two anomalies on a single specimen (*e.g*., pug headed and eye diseases, pug headed and skeletal deformity, pug headed and short tail). Although, as far as it knows, this study is the first to record at least four different morphological anomalies on a single specimen (*i.e*., pug head, exophthalmic, opercular complex, and anal fin abnormality) captured in a wild population.

The causes of pug-headed anomaly remain uncertain. Historically, several biotic and abiotic factors have been hypothesized and discussed as the causes or triggers of this particular aberration (see Gudger & Miller, 1929; Hickey, 1972; Bengston, 1979). Most of the hypotheses of this -and several other morphological anomalies- have been provided from the hatchery and reared conditions and extended on natural cases. Variation in water temperature, salinity, oxygen dissolved, nutrition, diet, solar radiation during the development of the embryo are the most mentioned variables to explain the origin of these conditions (Dahlberg 1970; Hickey *et al*., 1973; Shariff *et al*., 1986; Morrison & MacDonald, 1995; Divanach *et al*., 1996; Ottesen & Bolla, 1998; Georgakopoulou *et al*., 2010; Jawad *et al*., 2020; Sun *et al*., 2020).

In the last twenty years, several skeletal morphological anomalies (including pug-headedness) has been associated with nutritional factors such as insufficient phospholipid, highly unsaturated fatty acids, and vitamin C (Kanazawa *et al*., 1981; Gapasin *et al*., 1981; Beraldo *et al*., 2003; Fernandez *et al*., 2008; Darias *et al*., 2010, 2011). In larvae having a high vitamin A concentration, it negatively affects bone formation and skeletogenesis, mainly those from the cranial skeleton, vertebral centrum, and caudal fin complex (Fernández *et al*., 2008). Contrary, a low dose of vitamin D_3 (<38.4 IU of VD_3 per gram of diet) resulted in the appearance of malformations (Darias *et al*., 2010). Several authors agreed that vitamin pathways are crucial for bone formation and calcification during the first fish larval stage (Lall & Lewis-McCrea, 2007; Darias *et al*., 2010, 2011). Genetic anomalies, particularly triploidization, has been reported as the cause of pug-headedness and other several types of deformity in Atlantic salmon (Jawad *et al*., 2014).

Unspecified pollutants and radiation may have modulated gene expression (Koumoundouros *et al*., 1997). Slooff (1982) mentioned a higher incidence of fish skeletal anomalies (*e.g*., pelvic girdle, pug-headedness, fused and deformed vertebrae, and spinal curvatures) to the most polluted areas of the river Rhine compared to the control area. Glandular disturbance, probably in the pituitary, has also been mentioned as one of the causes (Gudger *et al*., 1937). Bacterial invasion of physically damaged oral membranes and parasitism is another credible source causing pug-headedness deformity (Gudger & Miller, 1929; Bolla & Holmefjord, 1988; Pitmann *et al*., 1989). It is noteworthy to mention that the majority of causes mentioned before are also the principal causes reported for other worldwide morphological abnormalities and aberration documented in teleost and chondrichthyan fishes (Kitajima *et al*., 1994; Beraldo *et al*., 2003; Bejarano-Álvarez & Galván-Magaña, 2013; Ehemann *et al*., 2016, 2018; Jawad *et al*., 2018). A combination of causes is more often the case of abnormalities and aberrations (Beraldo *et al*., 2003).

The Order Perciformes is the most diversified and largest among all vertebrates, containing two suborders, 62 families, about 36 genera, and more than 2240 species (Nelson *et al*., 2016), which explains the high frequency of pug-headed anomaly recorded in this order. Geographically, most records were documented in countries with the highest human population density globally, where information and communication technology in social networks is usual (Grimaldi & Bertoncini, 2021). Additionally, several of these countries have academic and research resources, equipment, and technology available for science.

The present study specimens reached adulthood, showing evidence of matured gonad (which has rare being reported in this anomaly) and such longevity, perhaps taking advantage and shelter of its shoal behavior (Espino-Barr *et al*., 2008). In the last decade, the number of pug-headedness in marine fishes has been considerably increased due to newly available technology to record this anomaly. Cases of morphological abnormalities in marine fish can be expected to increase due to citizen science data (Grimaldi & Bertoncini, 2021). However, more studies must be done and performed to clarify the causes of this particular disease.

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