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BILATERAL ASYMMETRY IN OTOLITH SIZE OF *Pampus argenteus* (OSTEICHTHYES: STROMATIDAE) FROM IRAQI MARINE WATERS

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ABSTRACT

Bilateral asymmetry is presumed to reveal the developmental variability of the fish in polluted aquatic environments. In these habitats, high-level asymmetry develops, and these fish expend more energy to balance their growth than fish that are not under an impact. A total of 121 specimens of *Pampus argenteus* were collected from Khor Abdulla located in the northwest part of the Arabian Gulf. The asymmetry of two otolith parameters of the marine fish species *Pampus argenteus*, length and width, was calculated. The results demonstrated that the level of asymmetry was highest for otolith width. The level of asymmetry in both otolith parameters was lowest in fish length ranging between 70-100 mm and the highest in fish ranging between 281-310 mm.

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INTRODUCTION

Three pairs of otoliths (asteriscus, lapillus and sagitta) are found inside the inner ear of fish. The sagittae are generally the largest otoliths in most teleosts. Otoliths are composed of calcium carbonate and are involved in hearing and balance functions. Otolith growth is accomplished by the continuous deposition of calcium carbonate layers on an organic matrix. In contrast to bones and scales, otoliths are metabolically passive, and the deposited material remains unchanged and cannot be resorbed (Campana and Neilson, 1985). Otoliths represent important structures that can be used to document life history events in fish (Lecomte-Finiger, 1999).

Otolith shape is genetically determined (L'Abée-Lund, 1988) and is extremely species-specific and therefore useful in studying phylogenetic relationships between species (Lombarte and Lleonart, 1993). However, environmental conditions may affect the metabolism of fish, which in turn disturbs somatic growth and accordingly the amount of material deposited in otoliths (Cardinale et al., 2004, Galley et al., 2006; Stransky et al., 2008). Other factors, such as ontogenetic stage as represented by size (Hüssy, 2008), age (Castonguay et al., 1991) and/or sexual maturity status (Mérigot et al., 2007), may also impact the shape of otoliths.

Over the last few decades, the majority of studies exploring the causes of variation in otolith shape have focused on the effect of extrinsic factors, such as environmental conditions, or individual characteristics, such as genotype or state (Mille et al., 2015). However, only a few studies have investigated the possible reasons for intra-individual variation in otolith shape. For example, the difference between otolith shape in the right and left inner ears (referred to as otolith location side). The position of the otolith in the inner ear structure of the fish showed that the two divisions of the vestibular system are exactly the same with three orthogonal semicircular canals that permit perceiving angular accelerations and three otolithic organs devoted to hearing and balance (Panfili et al., 2002). Although there are some interspecific alterations in the size and shape of these features, otoliths are bilaterally symmetrical in roundfishes (Popper and Lu, 2000).

Any changes in the lateralization of the fish body will lead to variation in otolith biomineralization. Accordingly, the deposition of carbonate accretion will be different on both sides of the fish head resulting in asymmetry of otolith mass (Helling et al., 2005), which may induce asymmetry in otolith shape.

Somarakis et al. (1997a) proposed that measurements of fluctuating otolith asymmetry may be a useful indicator of fish condition. Indeed, Clark (1992) revealed that it is a tremendously subtle indicator of stress. The otolith characters examined by Somarakis et al. (1997a) did not show any size or age-related changes. The study of otolith asymmetry is a low-cost, simple measurement that does not need any special handling or facilities in the field and is not affected by damage during net capture or shrinkage. Fluctuating otolith asymmetry also serves as a potentially useful bioindicator of the health status of different fish populations (Somarakis et al., 1997a, 1997b; Grønkjaer and Sand, 2003), possibly revealing the impact of pollution (Hardersen, 2000), temperature (Lu and Bernatchez, 1999) or parasitism (Sasal and Pampoulie 2000; Reimchen and Nosil, 2001).

In general, the relationship between fish morphology and fluctuating asymmetry has been examined for adult fishes and a number of characters have been surveyed, including the number of gill rakers, pectoral fin rays, fish body proportions, eyespot area, and otolith size and shape (Al-Hassan et al., 1990; Al-Hassan and Hassan, 1994; Somarakis et al., 1997; Jawad, 2001; Øxnevad et al., 2002; Jawad 2003, 2004).

Pampus argenteus is a marine species that prefers to live in the benthopelagic habitats (Riede, 2004) at depths of 5-110 m (Pauly et al., 1996). Individuals of this species are distributed in the Indo-West Pacific region from the Persian Gulf to Indonesia, north of Hokkaido, Japan. They are also reported from the Adriatic (Piper, 2010). This species reaches a maximum total length of 600 mm, with a common length of 300 mm SL (Last, 1997).

Fluctuating asymmetry is usually used to test the health of the environment in which the fish lives (Palmer, 1994). Despite the high commercial value of *P. argenteus*, such a study has never been conducted on this species anywhere within its distributional range to assess the environmental effect on the life of this species.

Assessment of the extent of fluctuating asymmetry has not been performed on the otolith widths or lengths of *Pampus argenteus* examined in the present study. Therefore, the aim of this study is to provide such a study on highly commercially important species like *P. argenteus*.

The aim of the present study was to determine the level of bilateral asymmetry in both the length and width of *Pampus argenteus* otoliths collected from Iraqi marine waters.

MATERIALS AND METHODS

Study area

Khor Abdulla is one of several marine areas of Iraq that includes the estuary of the Shatt AlArab River at the city of Fao, in the Khor alZubair and Um Qasar regions (Fig. 1). The marine biodiversity of Iraq has gone through several changes related to its geological history, its temporal and geographical positions at the top of the Arabian Gulf, and its physiographical complexity (Jawad, 2016). The climate and hydrology of the lower Mesopotamian plain including its coastal area were fully described by Purser et al. (1982) and AlAzzawi (1986).

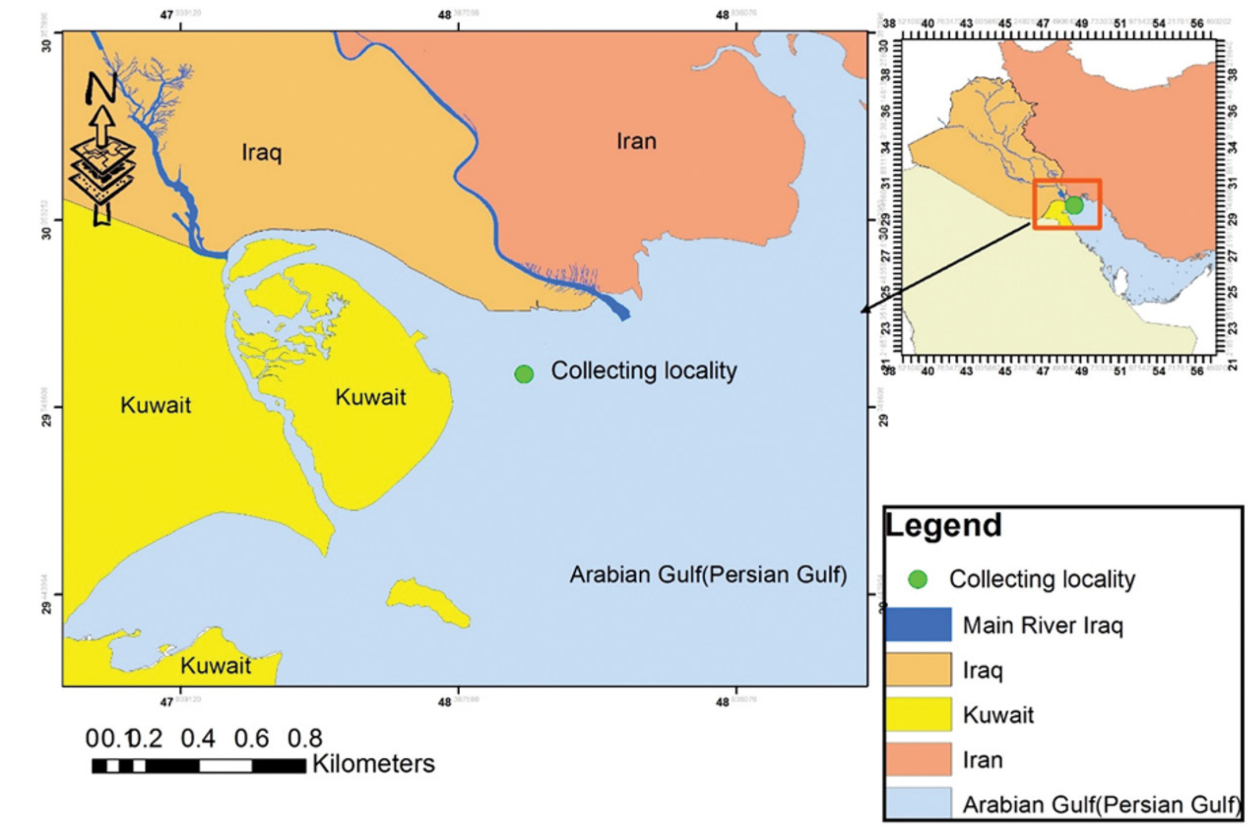

Fig 1. Map showing the sampling area of *Pampus argenteus*

Fish specimens

Specimens of *P. argenteus* (121) (Fig. 2) were collected from small commercial trawlers (21 m length x 3.5 m width), fishing with nets of mesh size 2.5 cm off Khor Abdullah at the southern extent of Iraqi marine waters. The sampling area was chosen as it represents one of the main fishing grounds for the species in Iraq.

The specimens were caught in the period February-September 2019 at depths of 10-25 m. Sagittae from both sides of the fish head were extracted from the sacculus part of the fish inner ear. The standard length (SL) of the fish samples ranged from 78 to 293 mm. Otolith length and width were measured to the nearest millimetre under a dissecting microscope (Fig. 3). The features chosen for bilateral asymmetry analysis were previously used in fish studies (Al-Rasady et al., 2010; El-Regal et al., 2016).

Data analysis

Statistical analysis was based on the squared coefficient of asymmetry variation (CV^2_a) for the two otolith dimensions according to Valentine et al. (1973):

$$CV^2_a = (S_{r-1} \text{ X } 100 / X_{r+1})^2$$

where S_{r-1} is the standard deviation of signed differences and X_{r+1} is the mean of the character, which was calculated by adding the absolute scores for both sides and dividing by the sample size. Bilateral asymmetry values and measurement errors were small and normally distributed around a mean of zero (Merilä and Bjöklund, 1995). Individual inaccuracies in taking measurements can disturb the results of bilateral asymmetry analysis, rendering it vague (Palmer, 1994). Therefore, in the present study all measurements were carried out in duplicate by only one person in order to reduce any unsolicited errors (Lee, 1990). Coefficients of asymmetry were compared between the different SL classes using ANOVA.

RESULTS

The results of the asymmetry analysis of the data of otolith length and width are summarized in Table 1. The results indicated that the level of asymmetry was highest for otolith width.

Table 1. Squared coefficient of asymmetry (CV^2_a) value and character means (X_{r+1}) of *P. argenteus* collected from the marine waters of Iraq

Character	CV^2_a	N	Character mean ± SD	% of individuals with asymmetry
Otolith length	41.55	121	7.93 ± 3.1	80
Otolith width	89.56	121	3.86 ± 2.3	99

Furthermore, the lowest and highest levels of asymmetry were recorded in fish ranging in length between 70-100 mm and 281-310 mm, respectively (Table 2).

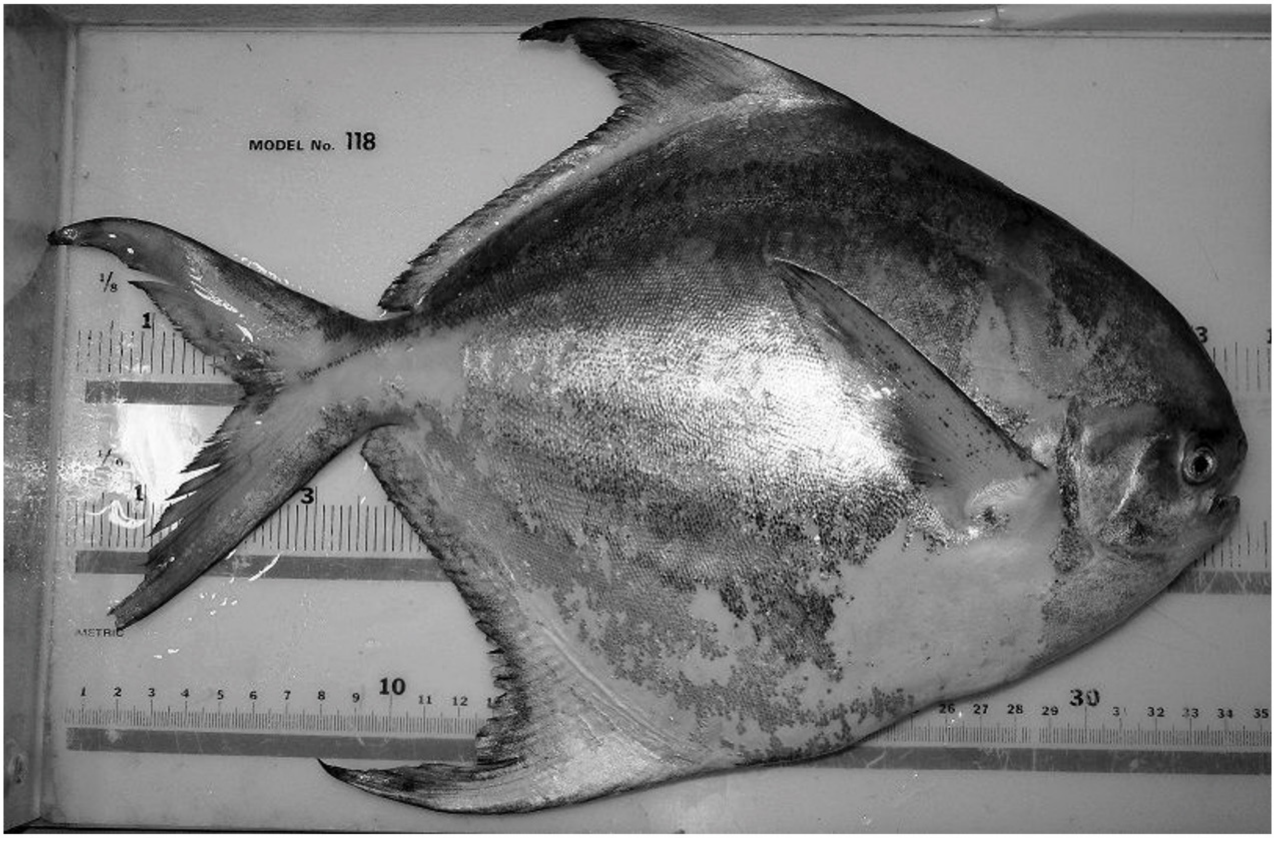

Fig 2. Specimen of *Pampus argenteus*, 260 mm SL, collected from the marine waters of Iraq

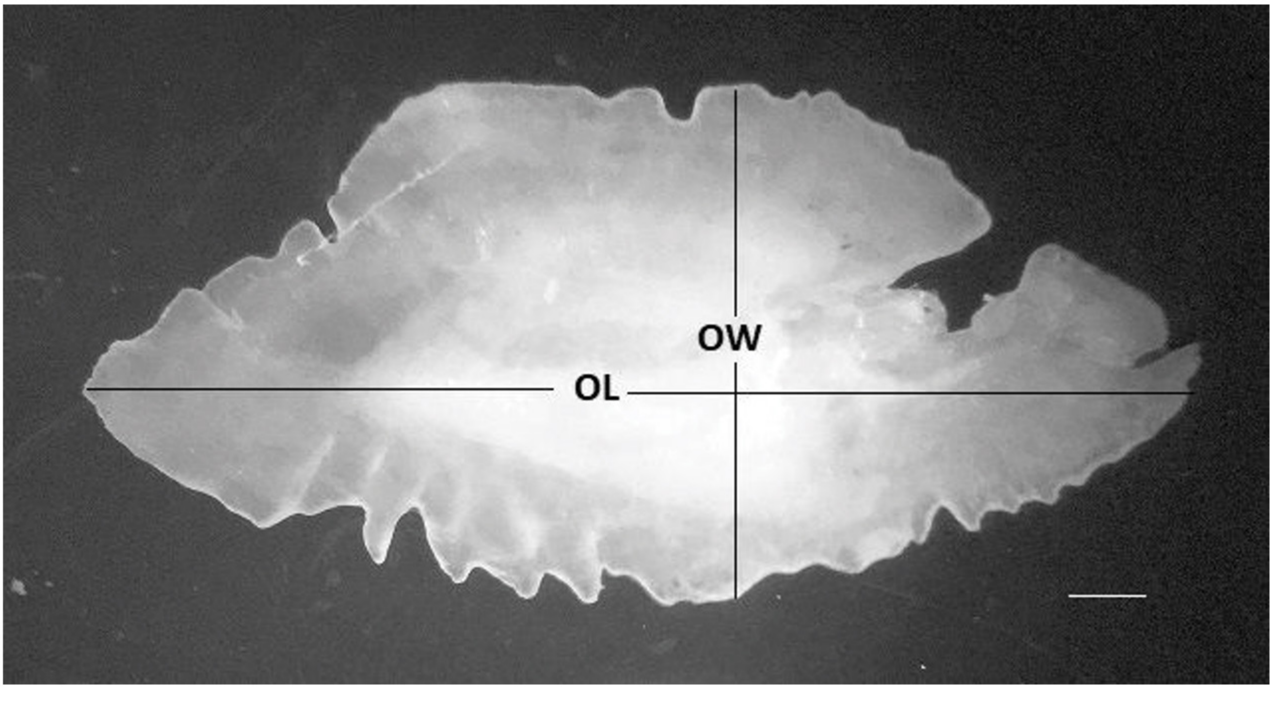

Fig 3. Otolith of *Pampus argenteus*, 326 mm TL, showing the length and width of the otolith. Scale bar = 10 mm.

Table 2. Squared coefficient of asymmetry and character means by size class of *P. argenteus* collected from the marine waters of Iraq

Character	CV^2_a	N	Character mean ± SD	% of individuals with asymmetry
Otolith length				
Fish standard length mm				
70-100	24.6	4	3.34 ± 1.2	100
101-130	29.9	10	5.23 ± 2.2	100
131-160	30.3	9	6.22 ± 2.4	79
161-190	35.7	20	10.93 ± 1.3	98
191-220	39.9	10	11.98 ± 1.6	89
221-250	42.6	49	11.41 ± 1.9	99
251-280	48.7	10	12.74 ± 1.3	100
281-310	50.9	8	12.56 ± 2.5	94
Otolith width				
Fish standard length mm				
70-100	18.1	4	2.1	99
101-130	19.9	10	2.5	100
131-160	19.9	9	3.1	79
161-190	21.9	20	3.7	99
191-220	22.3	10	4.1	100
221-250	22.9	49	4.8	99
251-280	23.1	10	5.2	97
281-310	23.5	8	5.3	98

DISCUSSION

Due to the deficiency of data regarding natural otolith asymmetry in this part of the world, it is difficult to evaluate whether or not they are typical for *P. argenteus*. Although it is possible that the relatively high level of asymmetry in otolith width may be related to environmental factors, it is not possible to support this hypothesis at this stage. The relatively small level of asymmetry observed in otolith length suggests that this parameter may be less vulnerable to environmental impact. In a previous study, Jawad (2003) suggested that the lower level of bilateral asymmetry observed in otolith length of sparid fishes off Libya may be due to the fact that the developmental period of these features may not agree with the existence of opposing environmental events. Palmer and Strobeck (1992) noted that slight changes throughout the growth of the fish can result in a move from normal developmental trails. These irregularities may be due to the state and quantity of food, excessive temperatures, parasites, disease and/or behavioral burdens imposed by interactions with related species living in the same environment (Markov, 1995).

The drawback of measurement error in fluctuating asymmetry (FA) studies is not immaterial but has been given increasing consideration over the last few decades (Palmer and Strobeck, 1986). Since variations in values of bilateral characters are frequently small [<1-50/0 of the total variation in a given trait (Palmer, 1996)] and are by explanation random, FA indices are likely to be especially disposed to measurement error. It has been observed that measurement error in fluctuating asymmetry approximations can be high even when the measurement error of the original traits is very low. For example, Merilä and Bjöklund (1995) reported that measuring error in skeletal characters of greenfinches *Curduelis* sp. was 2.5 and 4.5% for the left and the right sides, respectively, while measuring error in fluctuating asymmetry was 98%.

The reason for this is that a large amount of the variation due to measuring error can occur as a result of either high levels of absolute measuring error or low levels of absolute asymmetry (Somarakis et al., 1997a).

Although there is no reference range for bilateral asymmetry levels in otolith dimensions to check the acuteness level of asymmetry, it is possible to assess the observed levels of otolith asymmetry dimensions of *P. argenteus* in the present study by comparing them with available published data on the same species studied in other countries and other fish species. The results obtained in the present study were compared with the values of fluctuating otolith asymmetry sizes in some fish species collected from the same area (Arabian Gulf), from neighbouring areas (Sea of Oman, Red Sea) and other areas (Black Sea) (Table 3).

Fluctuating asymmetry values in otolith length in the equated species ranged between 2.1 in *Sardinella sindensis* collected from the Arabian Gulf (Jawad et al., 2012d) and 88.71 in *Rastrelliger kanagurta* collected off the Omani coast of the Sea of Oman (Al-Mamry et al., 2011a). Fluctuating asymmetry in otolith width ranged between 4.59 in *Sargocentron spiniferum* off the Egyptian coast of the Red Sea (El-Mahdy et al., 2019) and 117.60 in *Rhynchorhamphus georgi* collected off the Omani coast of the Sea of Oman (Al-Rasady et al., 2010). The fluctuating asymmetry in otolith length in *P. argenteus* was 31.55, close to the mid-point of the maximum value of 88.71 obtained for *Rastrelliger kanagurta* collected off the Omani coast of the Sea of Oman (Al-Mamry et al., 2011a). For otolith width, the level of the fluctuating asymmetry in *P. argenteus* was 89.56, close to the highest value of fluctuating asymmetry (117.60) obtained for *Rhynchorhamphus georgi* collected off the Omani coast of the Sea of Oman (Al-Rasady et al., 2010). The comparative assessment indicates that the degree of asymmetry in both otolith length and width in *P. argenteus* is high and that otolith width is appreciably higher. While the species of fish included in the current comparison are not the same and are from diverse localities, they indicate some degree of environmental impact on otolith features, i.e. characters of the otolith that are either susceptible to or endure unsuitable environmental settings (Fey and Hare, 2008).

Table 3. Comparison of the Coefficient of asymmetry (CV^2_a) of otolith sizes of *P. argenteus* examined in the present study with those of other fish species collected from neighbouring localities

Species	Coefficient of asymmetry (CV^2_a)		Reference
	OL	OW	
Pampus argenteus	41.55	89.56	Present study
Acanthopagrus arabicus	47.74	88.65	Abdulsamad et al. (2020)
Acanthopagus latus	44.98	88.65	Abdulsamad et al. (2020)
Beryx splendens	41.87	87.30	Al-Busaidi et al. (2010)
Carangoides caeruleopinnatus	28.43	54.05	Jawad et al. (2012a)
Chlorurus sordidus	14.05	10.44	El-Regal et al. (2016)
Hipposcarus harid	15.19	11.90	El-Regal et al. (2016)
Liza Kluzingeri	4.23	14.06	Sadighzadeh et al. (2011)
Lutjanus bengalensis	5.06	10.29	Jawad (2012b)
Merlangius merlangus	4.710	4.772	Kontaş et al. (2018)
Rastrelliger kanagurta	88.71	41.75	Al-Mamry et al. (2011a)
Rhynchorhamphus georgi	66.70	117.60	Al-Rasady et al. (2010)
Sargocentron spiniferum	2.34	4.59	El-Mahdy et al. (2019)
Sardinella sindensis	2.10	9.00	Jawad et al. (2012d)
Sillago sihama	2.9	21.6	Jawad et al. (2012d)
Sparidentex hasta	41.87	87.30	Abdulsamad et al. (2020)
Engraulis australis	43.55	86.56	Jawad and Adams (2021)
Otolithes ruber	39.65	87.53	Jawad et al. (2021)

The sources and reasons for otolith asymmetry in fishes may be due to numerous factors. Although genetic factors might be responsible, they cannot be considered at this stage due to the lack of genetic data on the marine ichthyofauna of Iraq. Environmental factors might also lead to increased levels of asymmetry but may occur at low levels before producing widespread death (Bengtsson and Hindberg, 1985).

Pollution of seawater and marine sediments by hydrocarbons, heavy metals, pesticides and organic matter is considered the chief source of environmental impacts, particularly in the marine waters of Iraq where various pollutants have been noted over the last twenty years (Al-Imarah et al., 2007; Zuhkair et al., 2007; Al-Jaberi and Al-Dabbas, 2014). Chemical and organic pollution can lead to morphological deformities in fish (Elie and Girard, 2014). Indeed, fish deformities in Iraqi marine waters have been associated with heavy metal and organic pollution (Jawad and Bannai, 2014; Jawad et al. 2014, 2017). Other aquatic organisms within Iraqi waters have also been critically distressed due to environmental pollutants (Saeed et al., 1999; Zukhair et al., 2008). Environmental impacts may also be caused by natural events (Bengtsson and Hindberg, 1985), and it is feasible that in some cases they may also be impacting Iraqi marine waters.

Some authors have demonstrated a connection between the coefficient of asymmetry and fish length (Al-Hassan et al., 1990; Al-Hassan and Hassan, 1994; Al-Hassan and Shwafi, 1997; Jawad, 2001), characterized by increasing levels of asymmetry with fish length (Al-Mamry et al., 2011a, b, c; Jawad et al., 2012a, 2012b, 2012c; Mabrouk et al., 2014). In the current study, it was noted that the larger specimens of *P. argenteus* had higher levels of bilateral asymmetry than smaller specimens ($P < 0.001$). It is possible that the differences may be related to fish growth. Valentine et al. (1973) noted that trait means were always lower in smaller size classes, which may be related to ontogenetic variation and a subsequent increase in bilateral asymmetry with size (age), and/or possible historical events which result in a secular increase in bilateral asymmetry. Thiam (2004) suggested that increasing levels of bilateral asymmetry with fish size could be due to the fact that the larger individuals had longer periods of contact with unfavourable environmental scenarios.

A management policy is urgently required in order to reinstate a healthy environment in the marine waters of Iraq.

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BILATERALNA ASIMETRIJA VELIČINE OTOLITA KOD VRSTE *Pampus argenteus* (OSTEICHTHYES: STROMATIDAE) IZ IRAČKIH MORSKIH VODA

SAŽETAK

Pretpostavlja se da bilateralna asimetrija otkriva varijabilnost u razvoju riba u zagađenom vodenom okruženju. U tim se staništima razvija asimetrija visoke razine i te ribe troše više energije da uravnoteže svoj rast od riba koje nisu pod takvim utjecajima. Ukupno 121 primjerak vrste *Pampus argenteus* prikupljen je iz Khor Abdulle koji se nalazi u sjeverozapadnom dijelu Arapskog zaljeva. Izračunata je asimetrija dvaju parametara otolita morske vrste *Pampus argenteus*, duljine i širine. Rezultati su pokazali da je razina asimetrije najveća za širinu otolita. Razina asimetrije u oba parametra otolita najniža je pri duljini riba u rasponu od 70-100 mm, a najviša kod riba u rasponu između 281-310 mm.

Ključne riječi: Bilateralna asimetrija, otolit, Stromateidae, pomfret, Basrah

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