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FLUCTUATING ASYMMETRY IN *CHELON AURATUS* FROM THE LIBYAN MEDITERRANEAN COAST AND THE AIN ZIANA LAGOON

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ABSTRACT

The present study represents the first research of morphological asymmetry in the eye lens diameter and three otolith features (otolith length, width, and weight) examined in the mullet species Chelon auratus *collected from the Mediterranean coast and the Ain Ziana Lagoon, Libya. The asymmetry value for the eye lens diameter was the highest among the four morphological characters studied, and higher for the Ain Ziana Lagoon than for the Mediterranean coast of Libya. The study also showed that the asymmetry value increased with the fish's total length. Plausible reasons for asymmetry in the four morphological traits examined are discussed in relation to the inconstancy in growth induced by ecological factors, including differences in water temperature, salinity, depth, and contaminants present in the marine waters of Libya and the Ain Ziana Lagoon.*

Key words: *Chelon auratus,* ecological factors, Mugilidae, pollution, otolith, morphology

ASIMMETRIA FLUTTUANTE IN *CHELON AURATUS* LUNGO LA COSTA MEDITERRANEA LIBICA E NELLA LAGUNA DI AIN ZIANA

SINTESI

Il presente studio rappresenta la prima ricerca di asimmetria morfologica nel diametro della lente oculare e nei tre caratteri otolitici (lunghezza, larghezza e peso dell'otolito) esaminati nel cefalo dorato Chelon auratus, *pescato lungo la costa mediterranea e nella laguna di Ain Ziana, in Libia. Il valore di asimmetria per il diametro della lente oculare è stato il più alto tra i quattro caratteri morfologici studiati, e più alto per la laguna di Ain Ziana rispetto alla costa mediterranea della Libia. Lo studio ha anche mostrato che il valore di asimmetria aumenta con la lunghezza totale degli esemplari. Le ragioni plausibili dell'asimmetria nei quattro caratteri morfologici esaminati sono discusse in relazione all'incostanza della crescita indotta da fattori ecologici, tra cui le differenze di temperatura dell'acqua, salinità, profondità e contaminanti presenti nelle acque marine della Libia e nella laguna di Ain Ziana.*

Parole chiave: *Chelon auratus*, fattori ecologici, Mugilidae, inquinamento, otoliti, morfologia

INTRODUCTION

Otoliths are the bony structures located in the inner ear cavity of all teleost fish, which function as a balance organ in addition to supporting hearing. For years, otoliths have been used to gather evidence related to taxonomy, age, and fish size (Mendoza, 2006). In addition, otoliths have been studied extensively in various aspects of fish biology (hearing and balance in fish), larval fish ecology, species identification, fish stock identification, and environmental reconstruction of fish habitats (Mendoza, 2006). Over recent periods, otolith morphological features, mainly shape, length, width, area, thickness, and weight, have been studied to assess genetic and environmental impacts and as biomarkers (Jawad *et al*., 2010, 2011, 2012a, 2012b, 2012c, 2016, 2020; Jawad, 2012, 2013; Abu El-Regal *et al*., 2016; Al-Busaidi *et al*., 2017; Mejri *et al*., 2018; 2020; Ben Labidi *et al*., 2020a, 2020b; Osman *et al*., 2020; Khedher *et al*., 2021; Mejri *et al*., 2022a, 2022b; Ben Mohamed *et al*., 2023; Bouriga *et al*., 2023; Adjibayo Houeto *et al*., 2024). These investigations have revealed that otolith shape is species specific (Sadighzadeh *et al*., 2014) and that variations in otolith shape, structure, and development may be affected by ontogenetic, genetic, and environmental factors (Ider *et al*., 2017; Fashandi *et al*., 2019), including sex, growth, maturity, and patterns of fishery exploitation (Begg & Brown, 2000), or by individual characteristics, such as genotype (Jawad *et al*., 2020) or physiological state (Campana & Neilson, 1985). Nonetheless, the potential reasons for the intra-individual variation, chiefly asymmetry in shape between the right and left otoliths, have been insufficiently studied (Mille *et al*., 2015). In a healthy environment, the otoliths on both sides of the head are morphologically symmetrical (Panfili *et al*., 2002), even though there can be some interspecific variations in size and shape (Popper & Lu, 2000). Where a weight difference (i.e., mass asymmetry) between the masses of the left and right otoliths is observed (Ambuali *et al*., 2011; Jawad & Sadighzadeh, 2013; Al Balushi *et al*., 2017; Yedier *et al*., 2018), it may be an indication of previous developmental disturbances in fish caused by different types of impact, such as genetic or environmental stress (Valentine *et al*., 1973; Grønkjaer & Sand, 2003). While these can be either substantial (Scherer *et al*., 2001) or minor (Takabayashi & Ohmura-Iwasaki, 2003), any asymmetrical increase or decrease in otolith mass can harmfully affect critical life functions in fish, particularly the sense of hearing, balance, and linear acceleration (Popper & Lue, 2000; Panfili *et al*., 2005).

C. auratus is a marine species, but sometimes enters fresh and brackish water niches (Riede, 2004). It typically inhabits depth ranges of 10–20 m (Thomson, 1990). The maximum fork length *C. auratus* can reach is 610 mm, with the common fork length being 300 mm (Thomson, 1990). The largest recorded weight for this species is 2.5 kg (Fazli *et al*., 2008). The golden grey mullet is distributed in the eastern Atlantic region, spanning from Scotland to Cape Verde, and is also present in the Mediterranean and Black Seas. Similarly, it is reported from coastal waters ranging from southern Norway to Morocco, and is rare off Mauritania (Thomson, 1986). This species is neritic and frequently forms schools, typically inhabiting lagoons and lower estuaries (Thomson, 1990). Young juveniles disperse to coastal lagoons and estuaries primarily during winter and spring (Kottelat & Freyhof, 2007). *C. auratus* feeds on small benthic organisms and detritus, occasionally consuming insects and plankton (Ben-Tuvia, 1986). Reproduction occurs at sea from July to November. The females are oviparous, producing pelagic, non-adhesive eggs (Breder & Rosen, 1966).

In the context of differences in otolith shape among conspecific individuals, numerous researchers have suggested that these may be influenced by ecological factors, primarily water temperature, salinity, food availability, depth, and substrate features (Hüssy, 2008; Morat *et al*., 2012). Studies investigating the effects of environmental factors on otolith shape in Libyan waters are exceedingly rare. The first to study asymmetry in the external morphology of fish from Libyan waters was Jawad (2000, 2003), who suggested that environmental factors contribute to variations in fish body shape. Furthermore, there are only two studies examining asymmetry in the eye lens diameter of certain fish species collected from Libyan waters, but none addressing asymmetry in otolith features. Hence, it is imperative to employ scientific methods to assess the health of both the environment and its organisms. Accordingly, the current investigation was undertaken to determine, for the first time, the level of asymmetry in the golden grey mullet collected from the Mediterranean Sea coasts of Libya and the Ain Ziana Lagoon. This study examines otolith features, including length, width, and weight, as well as the eye lens diameter. The results are significant given the ongoing expansion of anthropogenic impacts on the environment, which may further affect the condition of the fish habitat.

MATERIAL AND METHODS

Study area

The present study was performed on specimens collected from the Mediterranean coasts of Libya (32°14′56″ N, 19°56′42″ E) and from the Ain Ziana Lagoon (32°12′56″ N, 20°09′16″ E). Libya is situated in the southern Mediterranean, and its coastline, a

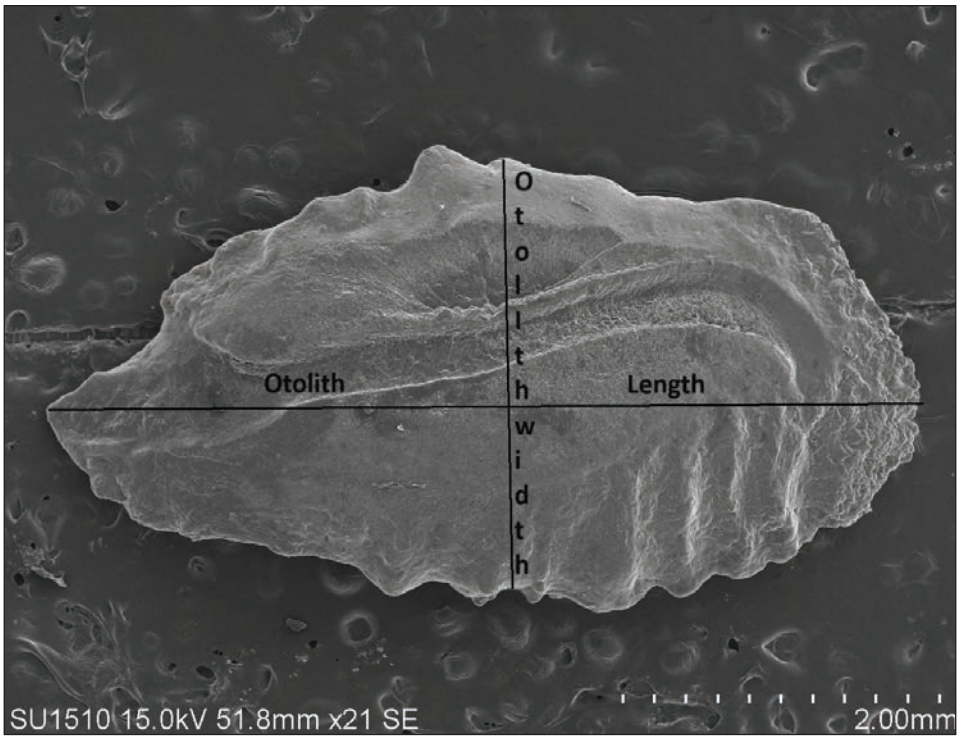

Fig. 1: SEM image of an otolith of** C. auratus**, 159 mm TL (total length), showing otolith length and width.
Sl. 1: SEM posnetek otolita vrste** C. auratus **(159 mm totalne dolžine), ki kaže dolžino in širino otolita.

segment of the North African coast spanning approximately 2000 km, is characterised by diverse topography and a wide range of niches (Wikipedia, 2023). Libyan marine waters cover an area of 350,000 km^2 (Wikipedia, 2023), which is bordered by the Levantine Sea to the east, the Strait of Sicily to the west, and the Ionian Sea, including the island of Crete, to the north (Wikipedia, 2023).

Lagoon habitats are a common feature of the southern Mediterranean coast regions. Aside from other topographies, the Libyan coast is home to four important coastal lagoon environments: Farwa in the west, and Ain Zayanah, the Khalige Al-Bomba Lagoon, and the Ain Al-Ghazalah Cove in the east (UNESCO, 1986), with Ain Zayanah being the largest (Guerre, 1980). Ain Zayanah is a brackish water lagoon located about 15 km east of Benghazi city, spanning an area of 50 ha. It is 5 km long and several hundred meters wide, with an average depth of 2 m; it is linked to the sea by a canal created by the overflow of water from underground springs (Amer & El-Toumi, 2018). These springs discharge brackish water with a salinity of 10‰ into the lagoon at a rate of 4.5 m3/sec (Guerre, 1980; UNESCO, 1986; Azafzaf *et al*., 2006), reducing the lagoon's water salt content to 16–28‰. The lagoon water has a temperature ranging from 14°C to 28°C and a pH of 7.8 (Guerre, 1980; Reynolds *et al*., 1995). Fish specimens collected from the two investigated localities were classified into three length groups: 200–300 mm, 301–400 mm, and 401–500 mm.

Sample collection

A total of 275 adult specimens of *C. auratus* were collected, consisting of 119 from Libyan Mediterranean waters (60 females, 59 males) and 156 from the Ain Ziana Lagoon (83 females, 73 males). The total length (TL) of the specimens ranged from 203 to 496 mm in females and 203 to 465 mm in males from the Libyan Mediterranean coast, and from 208 to 496 mm in females and 208 to 499 mm in males from the Ain Ziana Lagoon. All specimens were caught aboard coastal boats using gillnets ranging 5–13 m in length, during the period from 18 April 2019 to 7 January 2020. The sex of the individuals was determined by microscopic examination of the gonads.

Otolith extraction

The right and left otoliths were removed from all fish samples collected from the two locations, rinsed with distilled water, stored in Eppendorf tubes, and kept in dry storage for 24 hours to eliminate

moisture. The fish's total length was measured using an electronic board, and total weight (TW) was recorded using a Sartorius TE 313S analytical balance with an accuracy of 0.0001 g. The maximum otolith length (OL) and width (OW) (both measured to an accuracy of 0.1 mm) were determined using image analysis software (Digimizer 5.7.2) (Fig. 1).

Statistical analyses

The t-test was used to confirm the differences in length, width, and weight between the left and right otoliths for each specimen. The variation in otolith weight between males and females was also validated using the t-test.

Following Valentine *et al*. (1973), asymmetry in otolith length, width, weight, and eye diameter was calculated using the squared coefficient of asymmetry variation (CV^2_a) for the two otolith dimensions:

$CV^2_a = (S_{r-1}\ X100/X_{r+1})^2$

where S_{r-1} is the standard deviation of signed changes and X_{r+1} is the mean of the feature, which is calculated by adding the absolute scores for both sides and dividing them by sample size. The study of asymmetry in this commercially valuable species is important for understanding its impact on the settlement of fish larvae in the fishing grounds. Although bilateral asymmetry values and measurement errors are typically small and normally distributed around a mean of zero (Merilä & Björklund, 1995), individual variations in measurement-taking can still influence the analysis (Palmer, 1994). Therefore, in the present study, all measurements were performed by a single person to minimise potential errors (Lee & Lysak, 1990; StatSoft, Inc., 1991) and were repeated twice. Coefficients of asymmetry were compared across the total length classes using ANOVA test. Additionally, Tukey's HSD post hoc test was employed to assess significant differences in pairwise comparisons of length classes (StatSoft, Inc., 1991).

RESULTS

The asymmetry values for otolith length (OL), width (OW), and weight (OWe) in the *C. auratus* collected from the Mediterranean Sea and the Ain Ziana Lagoon, Libya, are presented in Table 1. Among all the features examined, the eye diameter exhibited the highest asymmetry value (91.74), with otolith length showing the highest asymmetry value among otolith features alone (88.82) (Tab. 1).

The study revealed an increase in asymmetry levels for the three otolith characteristics (length, width, and weight), as well as for the eye diameter, correlating with increasing fish size (Tab. 2).

The highest percentage of asymmetry among the characteristics examined in *C. auratus* from both locations was observed in the eye diameter of female specimens (86%) (Tab. 1). The percentage of individuals with asymmetry increased with the fish size (Tab. 2).

The divergence coefficients of the different length groups in the *C. auratus* collected from the Mediterranean Sea and the Ain Ziana Lagoon, Libya, were found to be not significant ($P > 0.5$).

DISCUSSION

The present investigation aimed to assess bilateral asymmetry in three otolith features and one body morphometric character of *C. auratus*. Any irregularity in the four morphological features of this mullet species may decrease the capability of young individuals to orient themselves in their habitats and cause them to disperse to other niches (Gagliano *et al*., 2008).

Asymmetry in the eye diameter has previously also been detected and reported in *Coptodon zillii* (Jawad, 2000), which might suggest that this morphological feature may be more susceptible to environmental changes compared to the other three features examined in this study. Consequently, notable variance in eye lens diameter values can be taken as an indicator of environmental stress in the Ain Ziana Lagoon habitat. In contrast, the lowest bilateral asymmetry in both populations investigated was found in otolith weight, which suggests that this feature is less susceptible to environmental factors such as contamination or adverse environmental events (Jawad, 2003). As previously noted by Helling *et al*. (2003), bilateral asymmetry in fish otoliths may result in irregular swimming movements and interference with accurate sound reception, ultimately affecting the fish's ability to navigate its habitat (Lychakov & Rebane, 2005).

Similar findings to those obtained in the present study have been reported by several authors investigating various fish species across different geographical regions. For instance, Mejri *et al*. (2020) examined asymmetry in otolith shape, length, width, and area in *Pagellus erythrinus* from the Gulf of Tunis. They observed intra- and inter-population asymmetry in these features and proposed an explanation within the context of developmental instability induced by genetic and environmental stress. In study of specimens of *Lutjanus bengalensis* collected off Muscat in the Arabian Sea, Jawad (2012) reported higher levels of asymmetry in otolith width compared to length. They observed a tendency of asymmetry in both width and length to increase with fish size and attributed this phenomenon to the presence of numerous pollutants

Tab. 1: Squared coefficient of asymmetry (CV^2a) values and character means (X_{r-l}) of** C. auratus **sampled from the Mediterranean Sea coast and the Ain Ziana Lagoon, Libya.
Tab. 1: Vrednosti kvadratnega koeficienta asimetrije (CV^2a) in značilnih povprečij (X_{r-l}) pri primerkih vrste** C. auratus**, vzorčenih na sredozemski obali Libije in v laguni Ain Ziana.

Character	CV2a + S.D.	N	Character means (mm) ± S.D.	% of individuals with asymmetry
Mediterranean coast of Libya				
Otolith length				
Females	88.82 ± 0.524	60	7.35 ± 0.242	68
Males	86.74 ± 0.165	59	7.96 ± 0.219	67
Otolith width				
Females	84.55 ± 0.219	60	5.22 ± 0.218	79
Males	84.95 ± 0.218	59	6.35 ± 0.223	78
Otolith weight				
Females	67.54 ± 0.146	60	0.0449 ± 0.176	83
Males	66.78 ± 0.149	59	0.0689 ± 0.177	81
Eye diameter				
Females	91.82 ± 0.211	60	13.1 ± 0.173	86
Males	91.74 ± 0.218	59	8.06 ± 0.169	85
Ain Ziana Lagoon				
Otolith length				
Females	89.92 ± 0.553	83	7.84 ± 0.265	74
Males	89.64 ± 0.145	73	7.36 ± 0.239	73
Otolith width				
Females	85.35 ± 0.220	83	4.1 ± 0.234	55
Males	85.75 ± 0.215	73	4.09 ± 0.262	54
Otolith weight				
Females	67.99 ± 0.148	83	0.0333 ± 0.266	44
Males	68.01 ± 0.136	73	0.0333 ± 0.195	43
Eye diameter				
Females	92.42 ± 0.218	83	12.45 ± 0.182	86
Males	92.53 ± 0.217	73	7.33 ± 0.143	85

in the area. Similar findings were reported by Jawad (2012) and Jawad *et al*. (2012a) for *Sardinella sindensis* and *Sillago sihama* from the Persian Gulf near Bandar Abbas, and by Jawad *et al*. (2020) in studies of *Sarotherodon melanotheron* and *Coptodon guineensis* from Lake Ahémé and the Porto-Novo Lagoon, in Bénin. Here, however, the trend of asymmetry increasing with fish length was observed only in otolith width. Conversely, Al-Busaidi *et al*. (2017) reported that both the length and width measurements of otoliths in *Lutjanus ehrenbergii* from the Arabian Sea off Muscat city were well correlated with fish length, and they also found symmetry between the left and right otoliths. Kontaş *et al*. (2018), on the other hand, studied fluctuating asymmetry of otolith area, length, perimeter, and width in four groups of *Merlangius merlangus* collected from the Middle Black Sea, finding the highest degree of asymmetry in otolith area and lowest in otolith length. They noted no significant association between the asymmetry values of the four otolith features and total fish length, suggesting that asymmetry in these characteristics might be a result of pressure from various contaminants in the Black Sea. Chakour & Elouizgani (2018) observed substantial asymmetry in otolith length, perimeter, and width in three groups of *Solea lascaris* from three main harbours along the central Atlantic coast of Morocco and concluded that the variations in these features are likely associated with environmental characteristics and adaptations of each fish group to their habitats. Finally, Abu El-Regal

Tab. 2: Squared coefficient of asymmetry (CV^2_a) and mean values of otolith length and width (in mm), and weight (in g) by size classes of* C. auratus *from the Mediterranean Sea coast and the Ain Ziana Lagoon, Libya.
Tab. 2: Vrednosti kvadratnega koeficienta asimetrije (CV^2_a) in srednje vrednosti dolžine in širine otolita (v mm), ter mase (v g) velikostnih razredov pri primerkih vrste* C. auratus, *vzorčenih na sredozemski obali Libije in v laguni Ain Ziana.

Character	CV2a + S.D.	N	Character means (mm) ± S.D.	% of individuals with asymmetry
Mediterranean coast of Libya				
Otolith length				
Females				
200 – 300	88.82 ± 0.524	15	7.31 ± 0.242	76
301 – 400	88.92 ± 0.514	25	7.32 ± 0.231	78
401 - 500	91.24 ± 0.514	19	7.36 ± 0.167	81
Males				
200 – 300	86.94 ± 0.135	14	7.92 ± 0.223	75
301 – 400	87.89 ± 0.223	26	7.94 ± 0.215	77
401 - 500	87.99 ± 0.322	20	7.96 ± 0.218	80
Otolith width				
Females				
200 – 300	83.85 ± 0.317	15	5.12 ± 0.209	65
301 – 400	84.87 ± 0.219	25	5.14 ± 0.211	67
401 - 500	85.67 ± 0.334	19	5.17 ± 0.220	73
Males				
200 – 300	83.95 ± 0.328	14	6.32 ± 0.218	64
301 – 400	84.23 ± 0.255	26	6.33 ± 0.217	65
401 - 500	84.76 ± 0.277	20	6.34 ± 0.232	71
Otolith weight				
Females				
200 – 300	68.34 ± 0.126	15	0.0442 ± 0.165	83
301 – 400	68.89 ± 0.154	25	0.0444 ± 0.172	89
401 - 500	69.05 ± 0.239	19	0.0447 ± 0.185	93
Males				
200 – 300	68.78 ± 0.139	14	0.0676 ± 0.166	80
301 – 400	68.88 ± 0.219	26	0.0678 ± 0.154	86
401 - 500	69.08 ± 0.122	20	0.0681 ± 0.164	90
Eye diameter				
Females				
200 – 300	91.99 ± 0.127	15	13.23 ± 0.153	45
301 – 400	92.52 ± 0.178	25	13.87 ± 0.169	57
401 - 500	92.82 ± 0.244	19	13.99 ± 0.188	79
Males				
200 – 300	91.89 ± 0.222	14	8.36 ± 0.178	42
301 – 400	91.95 ± 0.229	26	8.84 ± 0.193	55
401 - 500	92.17 ± 0.222	20	8.89 ± 0.173	73
Ain Ziana Lagoon				
Otolith length				
Females				
200 – 300	91.32 ± 0.523	23	7.89 ± 0.252	86
301 – 400	91.82 ± 0.433	42	7.91 ± 0.250	89
401 - 500	92.72 ± 0.233	18	7.93 ± 0.276	92
Males				
200 – 300	89.99 ± 0.123	15	7.39 ± 0.253	84
301 – 400	90.19 ± 0.224	44	7.41 ± 0.282	86
401 - 500	90.79 ± 0.256	14	7.49 ± 0.276	90
Otolith width				
Females				
200 – 300	85.95 ± 0.232	23	4.13 ± 0.228	43
301 – 400	86.25 ± 0.240	42	4.29 ± 0.217	54
401 - 500	86.95 ± 0.251	18	4.31 ± 0.223	73
Males				
200 – 300	85.95 ± 0.219	15	4.12 ± 0.234	41
301 – 400	86.25 ± 0.223	44	4.19 ± 0.274	50
401 - 500	86.75 ± 0.286	14	4.21 ± 0.282	70
Otolith weight				
Females				
200 – 300	68.49 ± 0.163	23	0.0335 ± 0.248	82
301 – 400	68.79 ± 0.123	42	0.0339 ± 0.265	89
401 - 500	68.99 ± 0.176	18	0.0343 ± 0.232	94
Males				
200 – 300	68.78 ± 0.226	15	0.0336 ± 0.187	80
301 – 400	68.88 ± 0.281	44	0.0339 ± 0.193	87
401 - 500	68.99 ± 0.271	14	0.0341 ± 0.184	92
Eye diameter				
Females				
200 – 300	92.72 ± 0.139	23	12.54 ± 0.154	45
301 – 400	92.83 ± 0.182	42	12.59 ± 0.184	58
401 - 500	92.97 ± 0.191	18	12.68 ± 0.224	72
Males				
200 – 300	92.73 ± 0.220	15	7.38 ± 0.164	42
301 – 400	92.84 ± 0.234	44	7.78 ± 0.194	53
401 - 500	92.95 ± 0.229	14	7.98 ± 0.171	69

et al. (2016) discovered asymmetry in the length and width of otoliths in *Chlorurus sordidus* and *Hipposcarus harid* from Hurghada on the Red Sea coast of Egypt, observing the asymmetry increased with the fish's length (age) and attributing the changes to the presence of contaminants in the region.

Previous studies of asymmetry in fishes collected from the Mediterranean Sea coasts of Libya and the Ain Ziana Lagoon (Jawad, 2000, 2001) revealed significant pollution levels. The Libyan coasts along the Mediterranean Sea have a long history of pollution from various sources (Hamouda & Wilson, 1989; Soliman *et al*., 2015; Obeidat, 2016; Bago *et al*., 2018; Bonsignore *et al*., 2018; Omar, 2022). Additionally, the topography of the Ain Ziana Lagoon allows for water exchange between the Libyan coastal waters and the lagoon itself, facilitating the transport of pollutants into the lagoon.

Previous studies have reported water temperatures along the Libyan coast of the Mediterranean Sea and in the Ain Ziana Lagoon to range from 16 to 17°C, with salinity standing at 38.5‰ (Shaltout & Omstedt, 2014; Al-Asadi, 2015). Fablet *et al*. (2009) speculated that temperature might be the primary environmental factor affecting otolith growth. This is because fish are highly sensitive to temperature fluctuations, with some reacting to changes as small as 0.03°C (Trojette *et al*., 2015). Salinity can also directly influence marine habitats, potentially altering the chemical composition and shape of otoliths in fish (Rebaya *et al*., 2017). Martin & Wuenschel (2006) suggested that differences in the chemical composition of otoliths may be associated with variations in individual responses to the combined effects of salinity, temperature, and concentrations of common elements such as Cl, Mg, K, Na, and Ca. Consequently, it is conceivable that the differences in otolith shape observed in the present study can be explained by fluctuations in environmental factors such as water temperature and salinity (Cañás *et al*., 2012). Other contributing factors may include life-history features associated with otolith shape (Mérigot *et al*., 2007), as well as biological and behavioural traits, such as swimming activity (Lord *et al*., 2012).

Comparing our findings with those of Reis *et al*. (2023) on asymmetry in otoliths of four mullet species, including *C. auratus*, from the Aegean Sea, Turkey, we observe similar levels of asymmetry in otolith length and width, with Reis *et al*. (2023) reporting values of 89.82 and 87.65 for these categories, respectively. This similarity may reflect common environmental factors affecting otolith features in both the Aegean Sea and the Mediterranean coast of Libya. Additionally, the absence of topographical barriers between the two seas could facilitate the dispersion of pollutants.

Some researchers have suggested that genetic factors may be responsible for asymmetry observed on both sides of the otoliths (Panfili *et al*., 2005). However, the present study cannot address this issue due to the lack of genetic information available for the *C. auratus* mullet species that was examined.

This study contributes additional data on otolith morphology and morphometry, as well as on body morphometrics, specifically the eye lens diameter, which serve as effective indicators for discriminating and detecting fluctuating asymmetry between the right and left sides in the mullet species selected for this study. The observed asymmetry in these morphometric features can be associated with ecological factors such as water temperature, salinity, and pollutants.

CONCLUSIONS

In the present study, three otolith features and one morphological character were investigated in the *C. auratus* mullet species. The fish specimens were collected from two locations in Libya, the Mediterranean Sea coast and the Ain Ziana Lagoon. The four studied characters showed different levels of asymmetry, with the highest observed in the eye diameter. The asymmetry values in fish specimens collected from the Ain Ziana Lagoon were higher than in those from the Mediterranean Sea coast. Moreover, asymmetry seems to be linked to fish length, with larger fish length groups exhibiting higher degrees of asymmetry in both localities. The differing levels of asymmetry observed in relation to the four characteristics examined in *C. auratus* appear to be attributable to the variation in growth processes during fish development.

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NIHAJOČA ASIMETRIJA PRI ZLATEM CIPLJU IZ LIBIJSKE SREDOZEMSKE OBALE IN LAGUNE AIN ZIANA

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POVZETEK

*Avtorja predstavljata prvo raziskavo morfološke asimetrije v premeru očesne leče in treh lastnostih otolita (dolžina, širina in masa otolita) pri zlatih cipljih (*Chelon auratus*), zbranih na sredozemski obali in laguni Ain Ziana v Libiji. Vrednost asimetrije v premeru očesne leče je bila med najvišjimi med štirimi morfološkimi znaki in višja za laguno Ain Ziana kot za sredozemsko obalo Libije. Poleg tega se je asimetrija povečevala s totalno dolžino ribe. Avtorja razpravljata o možnih razlogih za asimetrijo v štirih raziskanih morfoloških lastnostih, ki jo povezujeta z nekonstantno rastjo, ki jo povzročajo ekološki dejavniki kot so razlike v temperature vode, slanosti, globini in prisotnimi onesnaževali v morskih vodah Libije in lagune Ain Ziana.*

Ključne besede: *Chelon auratus,* ekološki dejavniki, Mugilidae, onesnaževanje, otolit, morfologija

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