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FLUCTUATING ASYMMETRY IN THE OTOLITH LENGTH, WIDTH AND THICKNESS IN TWO PELAGIC FISH SPECIES COLLECTED FROM THE PERSIAN GULF NEAR BANDAR ABBAS

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ABSTRACT

Asymmetry was calculated for the otolith length, width, and thickness of two pelagic fish species, Sardinella sindensis *(Clupeidae) and* Sillago sihama *(Sillaginidae). The results showed that the level of asymmetry of the otolith width was the highest among the two asymmetry values obtained for the otolith of* S. sindensis. *For* S. sihama*, otolith thickness showed the highest value among the three otolith measurements. The asymmetry value was zero for the otolith thickness in* S. sindensis. *The lowest and highest values of asymmetry for the three otolith measurements are recorded in the following fish size classes of* S. sindensis*: for otolith length, 9.0-9.9 mm and 14.0-14.9 mm respectively; for otolith width, 9.0-9.9 mm, 14.0-14.9 mm respectively. In* S. sihama*, for otolith length, 19.0-20.9 mm. and 21.0-22.9 mm. respectively, for otolith width, 15.0-16.9 mm and 25.0-26.9 mm respectively; for otolith thickness, 17.0-18.9 mm and 19.0-20.9 mm respectively. The possible cause of asymmetry in these two species has been discussed in relation to different pollutants and their presence in the area. The trend of an increase in the asymmetry value with the fish length was noticed in the width of the otolith of the two species studied.*

Key words: asymmetry, otolith, *Sardinella, Sillago*, Persian Gulf, Iran

ASIMMETRIA FLUTTUANTE IN LUNGHEZZA, LARGHEZZA E SPESSORE DI OTOLITE IN DUE SPECIE DI PESCI PELAGICI DEL GOLFO PERSICO, VICINO A BANDAR ABBAS

SINTESI

L'asimmetria è stata calcolata per lunghezza, larghezza e spessore degli otoliti di due specie di pesci pelagici, Sardinella sindensis *(Clupeidae) e* Sillago sihama *(Sillaginidae). I risultati hanno evidenziato che per l'otolite di* S. sindensis*, l'asimmetria era presente per due parametri, e il livello di asimmetria è risultato massimo per la larghezza dell'otolite. Per* S. sihama*, il valore più alto di assimetria si è registrato per lo spessore dell'otolite. Per* S. sindensis *invece, il valore dell'asimmetria per lo spessore degli otoliti era pari a zero. Sempre per* S. sindensis*, i valori minimo e massimo di asimmetria si sono registrati nelle seguenti classi di grandezza: per la lunghezza degli otoliti pari a 9,0-9,9 mm e 14,0-14,9 mm rispettivamente, e per la larghezza degli otoliti pari a 9,0-9,9 mm e 14,0-14,9 mm rispettivamente. Per* S. sihama*, i valori minimo e massimo di asimmetria si sono registrati per la lunghezza degli otoliti pari a 19,0-20,9 mm e 21,0-22,9 mm rispettivamente, per la larghezza degli otoliti pari a 15,0-16,9 mm e 25,0-26,9 mm rispettivamente, nonché per lo spessore degli otoliti pari a 17,0-18,9 mm e 19,0-20,9 mm rispettivamente. La possibile causa di asimmetria in queste due specie è stata messa in relazione a diverse sostanze inquinanti e alla loro presenza nella zona. Per entrambe le specie, gli autori hanno registrato una tendenza all'aumento del valore di asimmetria in relazione alla lunghezza del pesce.*

Parole chiave: asimmetria, otolite, *Sardinella, Sillago*, Golfo Persico, Iran

INTRODUCTION

Asymmetry is the differential development of a bilateral character between the sides of an organism (Van Valeen, 1962; Palmer & Strobeck, 1986; Leary & Allendorf, 1989). In many instances, developmental instability, which is the inability of an organism to compensate for disturbances during development (Zakharov, 1992), can be reflected by fluctuation asymmetry which is a random deviation from a perfect bilateral system (Palmer, 1994; Fey & Hare, 2008). Developmental instability ia affected by stress related to environmental or genetic conditions. Taking into consideration environmental stress which causes developmental instabilities; high fluctuating asymmetry could indicate the lower condition of larvae which experienced unfavourable environments. Thus, the method could show the specific environmental effects on the condition of the organism.

The relationship between fish condition and fluctuating asymmetry has been studied for adult fishes, and a number of measurements have been analysed, including the number of gill rakers, pectoral fin rays, fish body proportions, eye spot area, or otolith size and shape (Al--Hassan *et al.,* 1990; Al-Hassan & Hassan,1994; Escós *et al.,*1995; Somarakis *et al.,* 1997a, b; Jawad, 2001; Gonçalves *et al.,* 2002; Øxnevad *et al.,* 2002; Jawad, 2003, 2004).

This work studied fluctuating asymmetry in the otolith length, width, and thickness of the teleost fish *Sillago sihama* and otolith length and width of *Sardinella sindensis* collected from the Persian Gulf near Bandar Abbas as such studies were never performed on fish from Iranian waters. The Bandar Abbas locality was chosen as it considered among the important fishing grounds for the species in question (Al-Alawi, 2002). An asymmetry study of these two species is important in order to know the effects of this phenomenon on the settlement of the larvae of these species in this important fishing ground.

MATERIAL AND METHODS

Description of the sampling area

Bandar Abbas City, Iran (27° 03′ 46.43″ N, 56° 54′52.29″ E), capital of Hormozgan province is located in the middle of the strait of Hormoz. The port of Bandar Abbas links the Persian Gulf to the Sea of Oman and is located 1.501 km southwest of the capital, Tehran City. The fish sample was obtained from an area southwest of the Bandar Abbas Port (26° 46′ 52.18″ N, 56 ° 35′ 44.04″ E).

The characteristic features of the climate in Bandar Abbas in the summer are heat and humidity. Winters are moderate. The maximum temperature in summer can reach up to 49 °C while in winter the minimum temperature drops to about 5 °C. The annual rainfall is around 251 mm and the relative humidity is 66 %. The movement of sea currents, as in the other part of the Persian Gulf, is anticlockwise.

The annual average surface temperature of the water is 26.5 °C with a maximum temperature of more than 50 °C and a minimum temperature in winter of 3 °C. Fluctuations in the temperature at/near shore areas are higher, exceeding 20 °C (16-36 °C) than at the open Gulf areas (17-34 °C). Salinity varies between 36.5-37.

Sample collection

Samples were collected with a gill net on 13 July 2007 from the waters at Badar Abbas. A total of 130 specimens of adult *S. sidensis* and 120 specimens of *S. sihama* were examined. Fish total length was measured to nearest mm using a measuring board. Species were identified according to Randall (1995). Using digital callipers, otoliths were measured to the nearest mm. Otolith length, width and thickness were used to study the asymmetry level in the fish species.

Tab. 1: Squared coefficient of asymmetry (CV^2_a) value and character means (X_{r+l}) of** S. sindensis **and** S. sihama**.
Tab. 1: Vrednost kvadrata koeficienta asimetrije (CV^2_a) in srednja vrednost lastnosti (X_{r+l}) pri vrstah** S. sindensis **in** S. sihama**.

Character	CV^2_a	X_{r+l}	N	% of individuals with asymmetry
Sardinella sindensis				
Otolith length	2.1	2.1	130	13.3
Otolith width	9.0	0.9	130	10.0
Otolith thickness	0	0.3	130	0
Sillago sihama				
Otolith length	2.9	7.7	120	59.3
Otolith width	21.6	3.9	120	66.7
Otolith thickness	66.7	1.8	120	33.3

Statistical analysis

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

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

where S_{r-l} is the standard deviation of signed differences and X_{r+l} is the mean of the character, which is calculated by adding the absolute scores for both sides and dividing by the sample size.

RESULTS

In the present study, fluctuating asymmetry was not correlated with sex asymmetries developed in the early stages of fish life where larvae are not recognizable sex-wise and any compensational growth during the larval stage cannot correct it. This is because such anomalies persist and became a source of stress to the individual further on in its life.

The results of asymmetry data analysis of the otolith length, width and thickness of *S. sindensis* and *S. sihama* collected from the waters around Badar Abbas, Persian Gulf are shown in Table 1. The results showed that the level of asymmetry was high for the otolith width and absent for the thickness of *S. sindensis*. As for *S. sihama*, the asymmetry value of the otolith thickness was the highest among the three otoliths measurements investigated. The asymmetry value was zero for the otolith thickness of *S. sindensis*.

For the specimens examined of *S.sindensis*, the lowest value of asymmetry was noticed in fish ranging in length between 9.0-9.9 mm and the highest level was showed in specimens in length ranging between 14.0-14.9 mm. While to *S. sihama*, the lowest and highest asymmetry values were reported for fish length groups 19.0-20.9 mm and 25.0-26.9 mm respectively. However, no asymmetry of the three otolith parameters was observed in the several size classes examined for both species.

The percentage of the individuals showing asymmetry in the otolith width was the highest among the percentages obtained for the three otolith characters studied of the two species in question (Tab.1). Individuals of *S. sindensis* and *S. sihama* were grouped into size classes (Tab. 2). The trend of an increase in the asymmetry value of the fish length was noticed in the width of the otolith of the two species studied.

DISCUSSION

Animal fitness is negatively correlated with asymmetry of morphological character in a large number of animal taxa (*e.g.* Møller & Nielsen, 1997; Martin & Lopez, 2001; Bergstrom & Reimchen, 2003). So far, there is a lack of information on the possible effects of asymmetry on the dispersal and recruitment of individuals (Matessi, 1997; Breuker *et al*., 2007). In fishes, the individual loses the ability to integrate with the habitat they are living in when they experience abnormal swimming activity (Helling *et al.,* 2003) and interference with correct sound localization (Lychakov & Rebane, 2005) as a result of the bilateral asymmetry in the otolith mass.

The results of this study present basic information about the variations in the dimensions of the otoliths of *S. sindensis* and *S. sihama,* such variations no matter how small, can affect the capability of young individuals to locate and settle in their suitable habitats (Gagliano & McCormick, 2004; Gagliano *et al*., 2008). Due to the asymmetry observed in the width of the otolith of *S. sindensis* and the otolith thickness of *S. sihama*, the settlement of those larvae might have been affected. Both *S. sindensis* and *S. sihama* are considered among the most commercial species in Iran, thus, further studies on these two species has to follow the variation of the asymmetry in the otolith of the larvae and its relation to the settlement process in their environment.

The high asymmetry value of the otolith width and thickness might indicate the vulnerability of the individual that, under conditions of stress, may develop an asymmetry in these two otolith characters. However, based on previous studies in this field, it is possible to conclude that there is a direct correlation between environmental stress due to pollution and asymmetry in the morphology of this species. Such environmental factors are present in the Persian Gulf waters in general (De Mora *et al.,* 2004) and the Iranian coasts of the Persian Gulf in particular (Fowler, 1993; Zahed, 2002; Pourebrahim & Yavari, 2003; Vossoughi *et al.,* 2005; Haapkylä *et al.,* 2007; Zahed *et al.,* 2010). On the other hand, the low asymmetry value displayed by the otolith characters studied in this work might be explained on the basis that these characters are less vulnerable to environmental stresses.

The origin and cause of asymmetry in fishes can depend on several factors, one of which is genetic factors which might be responsible for the asymmetry in these two characters, but these cannot be discussed at this stage due to the lack of genetic data on the ichthyofauna of Iran. The other possible factor is the environmental stress which leads to an increased level of asymmetry, but which might occur at low levels before causing wide spread death (Bengtsson & Hindberg, 1985).

Environmental stress can originate from pollution of sea water and sediments by hydrocarbons, heavy metals, pesticides and organic matter. Such a state of pollution became a usual event for the environment of the Persian Gulf coasts of Iran where different pollutants were reported to affect its water for at least the last twenty years (Fowler, 1993; Zahed, 2002; Pourebrahim & Yavari, 2003; Vossughi *et al.,* 2005; Haapkylä *et al.,* 2007; Zahed *et al.,* 2010).

Environmental causes might be natural and various pathogens and various population phenomena appeared to be producing nutritional deficiencies (Bengtsson

Tab. 2: Squared coefficient of asymmetry (CV^2_a) value and character means (X_{r+l}) by size class (in mm) of** S. sindensis **and** S. sihama**.
Tab. 2: Kvadrat koeficienta asimimetrije (CV^2_a) in srednja vrednost lastnosti (X_{r+l}) glede na velikostni razred (v mm) pri vrstah** S. sindensis **in** S. sihama**.

Character	CV^2_a	X_{r+l}	N	% of individuals with asymmetry
Sardinella sindensis				
Otolith length				
9.0-9.9	42.7	1.99	20	20
10.0-10.9	0	2.05	70	0
11.0-11.9	0	2.40	10	0
12.0-12.9	0	2.55	20	0
13.0-13.9	53.2	2.53	5	20
14.0-14.9	56.2	2.55	5	20
Otolith width				
9.0-9.9	3.60	0.93	20	10
10.0-10.9	14.5	0.95	70	0
11.0-11.9	35.7	1.0	10	0
12.0-12.9	46.8	1.1	20	50
13.0-13.9	57.9	1.0	5	30
14.0-14.9	68.3	1.2	5	20
Otolith thickness				
9.0-9.9	0	0.27	20	0
10.0-10.9	0	0.29	70	0
11.0-11.9	0	0.30	10	0
12.0-12.9	0	0.40	20	0
13.0-13.9	0	0.28	5	0
14.0-14.9	0	0.27	5	0
Sillago sihama				
Otolith length				
15.0-16.9	5.88	6.63	30	83.3
17.0-18.9	2.33	7.32	10	44.4
19.0-20.9	1.70	8.20	20	50
21.0-22.9	5.65	8.93	20	100
23.0-24.9	4.48	10.03	20	100
25.0-26.9	4.65	10.0	20	100
Otolith width				
15.0-16.9	6.47	3.51	30	66.7
17.0-18.9	17.78	3.75	10	33.3
19.0-20.9	19.78	4.13	20	87.5
21.0-22.9	22.35	4.18	20	100
23.0-24.9	29.4	4.85	20	100
25.0-26.9	34.7	4.87	20	100
Otolith thickness				
15.0-16.9	19.02	1.45	30	33.3
17.0-18.9	10.04	1.58	10	22.22
19.0-20.9	17.44	1.94	20	50
21.0-22.9	8.86	2.38	20	50
23.0-24.9	0	2.50	20	0
25.0-26.9	0	2.53	20	0

& Hindberg, 1985), and it is highly possible that these factors may be in action in the Sea of Oman as they seem to be common in the aquatic environment.

Several authors have shown a relationship between the coefficient of asymmetry and fish length (Al-Hassan *et al.,* 1990; Al-Hassan & Hassan, 1994; Al-Hassan & Shwafi, 1997; Jawad, 2001) where there was a trend of an increase in the asymmetry value with the increase in fish length. The otolith morphological characters studied were identical and showed an absence of asymmetry coefficient in several of the size classes studied. The results also show a trend of an increase in otolith width asymmetry value with fish length in the two species studied.

FLUKTUACIJSKA ASIMETRIJA V DOLŽINI, ŠIRINI IN DEBELINI OTOLITA PRI DVEH PELAGIČNIH RIBJIH VRSTAH, ULOVLJENIH V PERZIJSKEM ZALIVU BLIZU BANDAR ABBASA

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POVZETEK

V članku smo izračunali asimetrijo za dolžino, širino in debelino otolita pri dveh pelaških ribjih vrstah, in sicer vrsti Sardinella sindensis *(Clupeidae) in vrsti* Sillago sihama *(Sillaginidae). Rezultati so pokazali, da se pri otolitu* S. sindensis *asimetrija pojavi pri dveh parametrih, pri čemer je največja asimetrija značilna za širino otolita. Pri* S. sihama *je bila med tremi meritvami otolita najvišja vrednost asimetrije izmerjena pri debelini otolita. Pri* S. sindensis *je vrednost asimetrije v debelini otolita enaka nič. Pri* S. sindensis *so bile v okviru treh merjenj otolita najnižje in najvišje vrednosti asimetrije izmerjene pri naslednjih velikostnih razredih: dolžina otolita 9,0-9,9 mm oz. 14,0-14,9 mm; širina otolita 9,0-9,9 mm oz. 14,0-14,9 mm. Pri* S. sihama *se najnižje in najvišje vrednosti asimetrije pojavijo pri naslednjih velikostnih razredih: dolžina otolita 19,0-20,9 mm oz. 21,0-22,9 mm; širina otolita 15,0-16,9 mm oz. 25,0-26,9 mm; debelina otolita 17,0-18,9 mm oz. 19,0-20,9 mm. Možne vzroke za pojavljanje asimetrije pri omenjenih ribjih vrstah smo obravnavali v povezavi z različnimi onesnaževalci, prisotnimi na obravnavanem geografskem področju. Pri obeh ribjih vrstah smo pri širini otolita opazili trend povečevanja asimetrije glede na dolžino ribe.*

Ključne besede: asimetrija, otolit, *Sardinella, Sillago*, Perzijski zaliv, Iran

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