Marine Pollution Bulletin 156 (2020) 111177

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Asymmetry in the otolith length and width of three sparid fish species collected from Iraqi waters

Saad M.S. Abdulsamad[a], Laith A. Jawad[b,*], Azal N.B. Al-Nusear[c], Baradi Waryani[d], Jitka Rutkayová[e]

[a] University of Basrah, College of Education for Pure Sciences, Department of Biology, Basrah, Iraq
[b] Pokeno, Auckland 2417, New Zealand
[c] University of Basrah, College of Veterinary Medicine, Department of Anatomy and Histology, Basrah, Iraq
[d] Department of Fresh Water Biology and Fisheries, University of Sindh, Jamshoro, Sindh, Pakistan
[e] University of South Bohemia, Faculty of Agriculture, Department of Animal Science, České Budějovice, Czech Republic

ARTICLE INFO

Keywords:
Bilateral asymmetry
Otolith
Sparidae
Acanthopagrus
Basrah

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 210 specimens of *Acanthopagrus bifasciatus*, *A. latus* and *Sparidentex hasta* were collected from the marine waters of Iraq in the northwest part of the Arabian Gulf. The asymmetry was calculated for the sagittal otolith characters of length and width. Otolith width has lower asymmetry than otolith length for the three sparid fish species investigated. An increase in the value of fluctuating asymmetry with fish length was observed. This could be a pertinent indicator of pollution in the habitat.

The discrepancy in development of a bilateral trait between the left and right sides of an organism is recognised as asymmetry (Van Vallen, 1962; Palmer and Strobeck, 1986; Leary and Allendrof, 1989). Fluctuating asymmetry which is a random deviation from perfect bilateral system reflects variable growth during development (Palmer, 1994; Fey and Hare, 2008) and is thought to reflect the genetic and environmental pressures experienced throughout development,

Asymmetry of otoliths has been suggested as a valuable index of body condition and health (Grønkjaer and Sand, 2003; Allenbach, 2011) during the early development and growth of fish (Gagliano and McCormick, 2004). Fluctuating asymmetry denotes a specific pattern of bilateral difference in a particular character showed by a sample of individuals, i.e. a frequency distribution of right minus left (R _ L) whose mean is zero and whose shape does not depart from normal (Somarakis et al., 1997b).

Fish otoliths are a very important structure in the fish body and perform vital functions such as recognition of sound and balance. Asymmetric otoliths may negatively affect the sensory accurateness of the inner ear (Lychakov and Rebane, 2005; Gagliano et al., 2008). Notwithstanding the prevalence of the use of fish otoliths for age and growth studies, few studies have examined fluctuating asymmetry in otoliths. Earlier studies have concentrated mostly on the larval stage (Panfili et al., 2005).

Some investigations have shown that increased fish otolith fluctuating asymmetry can happen due to stressful conditions caused by pollution (Franco et al., 2002), parasitism (Escós et al., 1995) and poor feeding conditions (Somarakis et al., 1997a, 1997b). However, other studies have not detected any strong relation between stress and fluctuating asymmetry in otolith (Folkvord, 2005; Panfili et al., 2005; Fey and Hare, 2008).

Assessment of the extent of fluctuating asymmetry has not been performed on the otolith widths or lengths of the three sparid fish species examined in the present study. Fish were collected from the marine waters of Iraq and the study is the first in its kind for the Arabian Gulf area in general and the Iraqi marine waters in particular.

A total of 210 specimens of the three members of the family Sparidae, *Acanthopagrus bifasciatus* (80), *A. latus* (80) and *Sparidentex hasta* (50) were collected from Khor Abdullah at the southern extent of the marine waters of Iraq using small trawler (21 m length x 3.5 m width), which was equipped with net of mesh size 2.5 cm. Khor Abdullah in southern part of the Iraqi marine waters is one of the main fishing grounds for the three sparid species in Iraq. Fish specimens were caught in the in the period January 2017 to March 2018 and at depth of 10–25 m. Sagittae from both sides of the fish head were removed from the sacculus part of the fish inner ear. Fish samples ranged from 204 to 330, 101–235 and 170–252 mm TL for *A. bifasciatus*, *A. latus* and *S.*

* Corresponding author.
E-mail address: laith_jawad@hotmail.com (L.A. Jawad).

https://doi.org/10.1016/j.marpolbul.2020.111177
Received 7 March 2020; Received in revised form 7 April 2020; Accepted 14 April 2020

hasta respectively. Otolith length and width was measured to the nearest millimetre under dissecting microscope. These measurements have been used in our studies of the bilateral asymmetry analysis of other fish (Al-Rasady et al., 2010; Jawad et al., 2012d; El-Regal et al., 2016).

Asymmetry was calculated as the squared coefficient of asymmetry variation (CV_a^2) for the two otolith dimensions according to Valentine et al. (1973):

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

where S_{r-1} is the standard deviation of signed changes and X_{r+1} is the mean of the trait, which is computed by adding the absolute scores for both sides and dividing by the sample size. The asymmetry study for these species is significant to the effect of this trait on the settlement of the larvae of these commercially important species in the fishing ground. Bilateral asymmetry estimates and measurement errors are in general small and normally distributed around a mean of zero (Merilä and Bjöklund, 1995). Individual differences in taking measurements can affect the results of bilateral asymmetry analysis (Palmer, 1994). Consequently, in the present study, all the measurements were reached by only one person to exclude any unwanted error (Lee and Lysak, 1990; StatSoft, Inc., 1991), and were repeated twice. Coefficients of asymmetry were compared between the different total length classes using ANOVA test. In addition to the ANOVA test, Tukey HSD post hoc test were conducted to assess whether the differences were significant between pairwise comparisons of length classes (StatSoft, Inc., 1991).

The results of asymmetry examination of the data of the otolith length and width of the three sparid species are shown in Table 1. The level of asymmetry of the otolith width was greater than that of otolith length for all three species. Also, the asymmetry values of length classes were significantly different ($P < .05$). For the two otolith traits investigated in the present work, the results exhibited that the level of asymmetry at its lowest and highest values in fish ranging in length between 200 and 340, 100–240 and 170–250 for *A. bifasciatus*, *A. latus* and *S. hasta* respectively.

The percentage of the individuals showing asymmetry in the otolith length traits was the highest between the percentages calculated for the two otolith characters of the three species in question (Table 1). Individuals of *A. bifasciatus*, *A. latus* and *S. hasta* were grouped into length classes (Tables 2–4). A tendency for the asymmetry value to increase with fish length was noted in both the length and width of the otolith.

There is some inconsistency in the degree of asymmetry between the two otolith measurements of the three sparid fish species in the present study. It is hard to assess the value of asymmetry of those characters and to decide if they are higher or lower than the usual owing to the lack of data regarding natural asymmetry in this part of the world. Even so, traits like otolith width showed bigger asymmetry level than the otolith length feature (Tables 2–4). The high asymmetry value of the otolith width could indicate the susceptibility of this character to the direct disparities in the habitats that fish living in. It is not conceivable at the moment to upkeep such result as the correlation between varied environmental pollution and the morphology of the fish species in question is not accessible. Nonetheless, based on previous surveys in this field, it is likely to achieve that there is a clear-cut relationship between environmental influence due to pollution and asymmetry in these species. These environmental impacts are present in the marine

Table 1
Squared coefficient of asymmetry (CV_a^2) value and character means (X_{r+1}) of *three* sparid fish species collected from the marine waters of Iraq.

Character	CV_a^2	N	Character mean (mm) ± SD	% of individuals with asymmetry
Acanthopagrus bifasciatus				
Otolith length	45.74	80	8.0830	69
Otolith width	85.57	80	4.5880	96
Acanthopagrus latus				
Otolith length	44.98	80	7.4600	75
Otolith width	88.65	80	4.9785	98
Sparidentex hasta				
Otolith length	41.87	50	7.6315	65
Otolith width	87.3	50	4.9915	91

Table 2
Squared coefficient of asymmetry and character means by size class of *Acanthopagrus bifasciatus* fish species collected from the marine waters of Iraq.

Character	CV_a^2	N	Character mean (mm) ± SD	% of individuals with asymmetry
Acanthopagrus bifasciatus				
Otolith length				
200–220	33.5	5	8.0734 ± 1.2	76
221–240	47.9	13	7.8531 ± 2.2	89
241–260	59.9	10	8.0652 ± 2.4	69
261–280	63.5	21	8.1367 ± 1.3	98
281–300	78.7	10	7.8541 ± 1.6	99
301–320	91.6	11	8.0952 ± 1.5	98
321–340	109.9	10	8.0833 ± 1.9	97
Otolith width				
200–220	28.2	5	4.5881 ± 1.7	90
221–240	39.9	13	4.2742 ± 1.2	97
241–260	53.6	10	4.3652 ± 1.1	89
261–280	79.9	21	4.4352 ± 1.4	98
281–300	95.6	10	4.3672 ± 1.7	87
301–320	110.9	11	4.2678 ± 1.5	89
321–340	120.1	10	4.3342 ± 1.8	87

Table 3
Squared coefficient of asymmetry and character means by size class of *Acanthopagrus latus* fish species collected from the marine waters of Iraq.

Character	CV_a^2	N	Character mean (mm) ± SD	% of individuals with asymmetry
Acanthopagrus latus				
Otolith length				
100–120	43.5	4	7.4501 ± 1.1	86
121–140	57.9	14	7.3872 ± 2.4	89
141–160	79.9	9	7.4286 ± 2.7	89
161–180	93.5	22	7.3274 ± 1.9	98
181–200	105.7	8	7.4541 ± 1.5	99
201–220	120.6	13	7.3895 ± 1.8	97
221–240	134.9	10	7.4411 ± 1.7	96
Otolith width				
100–120	38.2	4	4.9883 ± 1.4	90
121–140	59.9	14	4.8973 ± 1.5	97
141–160	73.8	9	4.9042 ± 1.4	89
161–180	89.9	22	4.8762 ± 1.3	98
181–200	105.6	8	4.9775 ± 1.6	87
201–220	119.9	13	4.9742 ± 1.4	89
221–240	127.1	10	4.9342 ± 1.9	87

Table 4
Squared coefficient of asymmetry and character means by size class of *Sparidentex hasta* fish species collected from the marine waters of Iraq.

Character	CV_a^2	N	Character mean (mm) ± SD	% of individuals with asymmetry
Sparidentex hasta				
Otolith length				
170–190	53.5	4	7.6353 ± 1.2	96
191–210	67.9	14	7.6431 ± 2.5	89
211–230	89.9	10	7.6386 ± 2.5	87
231–250	103.5	22	7.6474 ± 1.8	98
Otolith width				
170–190	58.2	4	4.9916 ± 1.5	92
191–210	75.9	14	4.9851 ± 1.7	96
211–230	93.8	10	4.9786 ± 1.5	88
231–250	119.9	22	4.9702 ± 1.4	97

waters of Iraq (DouAbul et al., 2009; Abdulnabi, 2016; AL-Khion et al., 2016). Otherwise, the small asymmetry value exhibited by the otolith length feature might be elucidated on the basis that this characteristic is less susceptible to environmental effect. Jawad (2003, 2004) advocated that the lower bilateral asymmetry level attained for otolith length may be designated on the basis that the developmental period of this trait may not coincide with the presence of contrasting environmental events. Noticeably, minor variations during the growth of the fish can depart from normal developmental characters (Palmer and Strobeck, 1992). These indiscretions may be due to the state and quantity of food, extreme temperatures, parasites, disease and behavioral burden imposed by interactions with the related species living in the same environment (Markov, 1995).

On the basis that fish under poor environmental conditions have high levels of asymmetry, evaluation of whether a value of the fluctuating asymmetry is high or low (Valentine et al. (1973), requires comparison with samples of fishes collected from a known polluted area,.. The other option is to compare the results of the fluctuating asymmetry of a species with those obtained from other localities for the same species. However no such comparative data exists for this species. Nevertheless, the present results will be a base line for further studies on fluctuating asymmetry in fishes in the Arabian Gulf area.

To assess the values of the fluctuating asymmetry obtained for both length and width of otolith of the three sparid species, a comparison was made between the present study and the values of the fluctuating asymmetry of otolith sizes of some fish species collected from the same area (Arabian Gulf), from a neighbouring areas (Sea of Oman, Red Sea) and other areas (Black Sea) (Table 5). Fluctuating asymmetry values of the otolith length in the compared species ranges between 2.1 in *Sardinella sindensis* Jawad et al. (2012) collected from the Arabian Gulf and 88.71 in *Rastrelliger kanagurta* collected from the Omani coasts of Sea of Oman Al-Mamry et al., 2011. On the other hand, fluctuating asymmetry in the otolith width varies between 4.59 in *Sargocentron spiniferum* from the Egyptian coasts of the Red Sea (El-Mahdy et al., 2019) and 117.60 in *Rhynchorhamphus georgi* collected from the Omani coasts of Sea of Oman (Al-Rasady et al., 2010). For the otolith length, the values of the fluctuating asymmetry of the sparid species range between 41.87 and 45.74. This is close to the mid-point of the maximum value of 88.71 obtained for *Rastrelliger kanagurta* collected from the Omani coasts of Sea of Oman (Al-Mamry et al. (2011). For the otolith width, the values of the fluctuating asymmetry ranges between 85.57 and 88.65 near the top value of fluctuating asymmetry (117.60) obtained for *Rhynchorhamphus georgi* collected from the Omani coasts of Sea of Oman. The result of such comparison indicates that the level of asymmetry in both length and width of the otolith of the three sparid fishes examined in the present study are high and that of the otolith width is particularly high. Although the species of fish taken from different areas used in this comparison are not the same, but they show the degree of influence of the environment of the otolith characteristics, i.e., characters of the otolith either they vulnerable or resistance to the unfavorable conditions of the environment (Fey and Hare, 2008).

Table 5
Comparison of the Coefficient of asymmetry (CV_a^2) of otolith sizes of the three sparid species examined in the present study with those of other fish species collected from neighbouring localities.

Species	Coefficient of asymmetry (CV_a^2)		Reference
	OL	OW	
Acanthopagrus bifasciatus	45.74	85.57	Present study
Acanthopagrus latus	44.98	88.65	Present study
Beryx splendens	41.87	87.30	
Carangoides caeruleopinnatus	28.43	54.05	Jawad et al. (2012c)
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 et al. (2012a)
Merlangius merlangus	4.710	4.772	Kontaş et al. (2018)
Rastrelliger kanagurta	88.71	41.75	Al-Mamry et al. (2011)
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. (2012b)
Sillago sihama	2.9	21.6	Jawad et al. (2011b)
Sparidentex hasta	41.87	87.30	Present study

The effect of measurement error in determining the degree of fluctuating asymmetry t has been considered in the last few decades (Palmer and Strobeck, 1986). Since variation in values of bilateral traits are usually small in relation to the total variation in a given trait (Palmer, 1996) and are by definition random, fluctuating asymmetry values are likely to be especially liable to measurement error.

The generation asymmetry in fish otoliths can be ascribed to genetic and environmental factors. The relationship between genetic factors and the asymmetry in these two traits has yet to be explored due to the lack of genetic data on the marine ichthyofauna of Iraq. The other feasible reason is sub lethal environmental impacts which gives rise to an increased degree of asymmetry (Bengtsson and Hindberg, 1985).

Pollution of sea water and sediments by hydrocarbons, heavy metals, pesticides and organic matter are deliberated the chief causes of environmental pressures in marine ecosystems The marine environments of Iraq have been impacted by a range of pollutants for at least in the last twenty years (Al-Imarah et al., 2007; Zuhkair et al., 2007; Al-Jaberi and Al-Dabbas, 2014).

Other environmental stressors could be natural events that reduced food availability as well as disease (Bengtsson and Hindberg, 1985.

Some authors have shown a relationship between the coefficient of asymmetry and fish length (Al-Hassan et al., 1990; Al-Hassan and Hassan, 1994; Al-Mamry et al., 2011; Al-Hassan and Shwafi, 1997; Jawad, 2001) and in particular that there is a rise in the asymmetry values with the increase in fish length. As documented in previous studies (Al-Mamry et al., 2011a, 2011b; Jawad et al., 2012a, 2012b, 2012c, 2012d, 2012e, 2012f; Mabrouk et al., 2014), our study has shown that large size specimens of three sparid fish species had higher bilateral asymmetry estimates than smaller young specimens ($P < .001$). It was clear that the degrees of fluctuating bilateral asymmetry of the length and width of the otolith increased with fish size (Tables 2). This link is possibly the result of missing fish growth; trait means are continually be the lowest in smaller size classes (Valentine et al., 1973). Similar results were obtained by Valentine et al. (1973) in chosen fish species collected from California, U.S.A. They suggested that the ontogenetic variations linked to an increase in bilateral asymmetry with size (age). Elsewhere, Thiam (2004) commented that an increase in bilateral asymmetry levels with fish size could be due to the fact that the large size individuals had longer periods of contact with unsuitable environmental conditions and therefore should greater degree of asymmetry than younger fish.

Quick management intervention is required to restore a healthy environment in the marine waters of Iraq. Numerous aquatic organisms within this water body have formerly been reported (Saeed et al., 1999; Zukhair et al., 2008).

Funding

The study was completed without external funding.

CRediT authorship contribution statement

Saad M.S. Abdulsamad:Validation, Formal analysis, Investigation, Resources, Data curation.**Laith A. Jawad**: Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration.**Azal N.B. Al-nusear**:Validation, Formal analysis, Investigation, Resources, Data curation.**Baradi Waryani**:Validation, Data curation.**Jitka Rutkayová:**Validation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank Nigel Adams, Environmental and Animal Sciences, Unitec, Auckland, New Zealand for reading the manuscript.

References

Abdulnabi, Z.A., 2016. Assessment of some toxic elements levels in Iraqi marine water. Mesopotamian J. Mar. Sci. 31, 85–94.

Al-Hassan, L.A.J., Hassan, S.S., 1994. Asymmetry study in *Mystus pelusius* collected from Shatt al-Arab River, Basrah, Iraq. Pakistan J. Zool. 26, 276–278.

Al-Hassan, L. A. J., Shwafi, N. A. A., 1997. Asymmetry analysis in two marine teleost fishes collected from the Red Sea coast of Yemen. Ocean. Lit. Rev. 10, 1205.

Al-Hassan, L.A.J., Al-Doubaikel, A.Y., Wahab, N.K., Al-Daham, N.K., 1990. Asymmetry analysis in the catfish, *Heteropneustes fossilis* collected from Shatt al-Arab River, Basrah. Iraq. Riv. Idrobiol 29, 775–780.

Al-Imarah, F.J., Hantoosh, A.A., Nasir, A.M., 2007. Petroleum hydrocarbons in water and sediments of northwest Arabian Gulf 1980–2005. Aqu. Ecosy. Health Manag. 10, 335–340.

Al-Jaberi, M.H., Al-Dabbas, M.A., 2014. Assessment of heavy metals pollution in the sediments of Iraqi coastlines. Science 3, 9.

AL-Khion, D.D., Al-Ali, B.S., Al-Nagar, G., Al-Saad, H.T., Al-Anber, L.J., 2016. Polycyclic aromatic hydrocarbons in some fishes from the Iraqi marine waters. Intern. J. Sci. Res. 7, 1911–1917.

Allenbach, D.M., 2011. Fluctuating asymmetry and exogenous stress in fishes: a review. Rev. Fish Biol. Fish. 21, 355–376.

Al-Mamry, J.M., Jawad, L., Ambuali, A., 2011. Fluctuating asymmetry in the otolith length and width of adult Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817) collected from Muscat waters at the Sea of Oman. J. Black Sea/Med. Environ. 17, 254–259.

Al-Mamry, J.M., Jawad, L.A., Al-Bimani, S.M.H., Al-Busaidi, H.K., Al- Marzouqi, M.S., Al-Habsi, S.H., 2011a. Asymmetry analysis study on *Callionymus margaretae* Regan, 1906 collected from the Arabian Sea coasts of Oman. Ribarstvo 69, 3–9.

Al-Mamry, J., Jawad, L.A., Al-Bimani, S., Al-Ghafari, F., Al-Mamry, D., Al-Marzouqi, M., 2011b. Asymmetry in some morphological characters of *Leiognathus equulus* (Forsskål) (Leiognathidae) collected from the Sea of Oman. Arch. Polish Fish. 19, 51–55.

Al-Rasady, I.H., Jawad, L.A., Al-Mamry, J.M., Al-Mamari, H.M., Al-Yarubi, M.M., Al-Mamary, D.S., 2010. Fluctuating asymmetry in the otolith length and width of *Rhynchorhamphus georgi* (Valenciennes, 1846) (family: Hemiramphidae) collected from the sea of Oman. Annals de Mus civi. Stor. nat. Ferrara 13, 85–89.

Bengtsson, B.E., Hindberg, M., 1985. Fish deformities and pollution in some Swedish waters. Ambio 14, 32–35.

DouAbul, A.A.Z., Al-Hello, M.A.R., Al-Taein, S.M., Al-Saad, H.T., 2009. Hydrocarbons and trace elements in the waters and sediments of the marshland of southern Iraq. Mesopotamian J. Mar. Sci. 24, 126–139.

El-Mahdy, S.M., Osman, Y.A., Mohammad, A.S., Mehanna, S.F., 2019. Fluctuating asymmetry in otolith morphology of sabre squirrelfish, Sargocentron spiniferum (Forsskål, 1775) from the red sea, Egypt. Int. J. Fish. Aquat. Stud. 7, 188–191.

Escós, J., Alados, C.L., Emlen, J.M., Alderstein, S., 1995. Development instability in the hake parasitized by myxosporeans Kudoa spp. Trans. Amer. Fish. Soc. 124, 943–945.

Fey, D.P., Hare, J.A., 2008. Fluctuating asymmetry in the otoliths of larval Atlantic menhaden Brevootita tyrannus (Latrobe) — a condition indicator? J. Fish Biol. 72, 121–130.

Folkvord, A., 2005. Comparison of size-at-age of larval Atlantic cod (Gadus morhua) from different populations based on size and temperature-dependent growth models. Cand. J. Fish. Aqua. Sci. 62, 1037_52.

Franco, A., Malavasi, S., Pravoni, F., Nasci, C., Torricelli, P., 2002. Ethoxyresorufin 0-deethylase (EROD) activity and fluctuating asymmetry (FA) in *Zosterisessor ophiocephalus* (Teleostei, Gobiidae) as indicators of environmental stress in the Venice lagoon. Journal of Aqua. Ecosy. Stress Rec. 9, 239–247.

Gagliano, M., McCormick, M.I., 2004. Feeding history influences otolith shape in tropical fish. Mar. Ecol. Prog. Ser. 278, 291–296.

Gagliano, M., Depczynski, M., Simpson, S.D., Moore, J.A.Y., 2008. Dispersal without errors: symmetrical ears tune into the right frequency for survival. Proc. Roy. Soc. B 275, 527–534.

Grønkjaer, P., Sand, M.K., 2003. Fluctuating asymmetry and nutritional condition of Baltic cod (*Gadus morhua*) larvae. Mar. Biol. 143, 191–197.

Jawad, L.A., 2001. Preliminary asymmetry analysis of some morphological characters of Tilapia zilli (Pisces: Cichlidae) collected from three localities in Libya. Boll. Mus. Region. Sci. Nat. Torino 18, 251–257.

Jawad, L.A., 2003. Asymmetry in some morphological characters of four sparid fishes from Benghazi, Libya. Oceanol. Hydrobiol. Stud. 32, 83–88.

Jawad, L.A., 2004. Asymmetry analysis in the mullet, Liza abu collected from Shatt al-Arab River, Basrah. Iraq. Boll. Mus. Region. Sci. Nat. Torino 21, 145–150.

Jawad, L., Al-Mamry, J., Al-Mamary, D., 2012a. Fluctuating asymmetry in the otolith dimensions of *Lutjanus bengalensis* (Lutjanidae) collected from Muscat coast on the sea of Oman. Biol. J. Armenia 64, 117–121.

Jawad, L.A., Al-Mamry, J.M., Al-Hinai, A.M., Al-Rashidi, M.A., Al-Busaidi, H.K., 2011b. Preliminary study on asymmetry in morphological characters of Pentaprion longimanus (Osteichthyes: Gerridae) from the sea of Oman. Annales, Ser. Hist. Nat. 22, 1–6.

Jawad, L.A., Sadighzadeh, Z., Al-Mamary, D., 2012b. Fluctuating asymmetry in the otolith length, width and thickness in two pelagic fish species collected from the Persian Gulf near *Bandar abbas*. Annales: Ser. Hist. Nat. 22, 83.

Jawad, L., Al-Mamry, J., Al-Mamari, D., 2012c. Fluctuating asymmetry in the otolith width of *Carangoides caeruleopinnatus* (Carangidae) collected from Muscat City coast on the Sea of Oman. Croatian J. Fish. 70, 125–133.

Jawad, L.A., Al-Mamry, J.M., Al-Shuaily, S., 2012d. Bilateral asymmetry in some morphological characters of *Parapercis alboguttata* (Günther, 1872) (Family: Piguipedidae) collected from the Arabian Sea coasts of Oman. Romanian J. Biol. Zool. 57, 51–62.

Jawad, L., AL-Mamry, J., AL-Bimani, S., AL-Ghafri, F., AL-Marzouqi, M., 2012e. Asymmetry of some morphological characters of *Upeneus doriae* (Osteichthyes: Mullidae) collected from the sea of Oman. Thalassas Salentina 34, 3–10.

Jawad, L., Al-Mamry, J., Al-Busaidi, J., Al-Mamari, A., Al-Mamry, S., Al-Owisi, K., Al-Rubiey, M., 2012f. Asymmetry in some morphological characters of Indian oil sardine, *Sardinella longiceps* Valenciennes, 1847 collected from Muscat waters on the Sea of Oman. Water Res. Mang. 2, 61–64.

Jawad, Laith, Sadighzadeh, Zahra, Al-Mamary, Dawood, 2012. FLUCTUATING ASYMMETRY IN THE OTOLITH LENGTH, WIDTH AND THICKNESS IN TWO PELAGIC FISH SPECIES COLLECTED FROM THE PERSIAN GULF NEAR BANDAR ABBAS/ASIMMETRIA FLUTTUANTE IN LUNGHEZZA, LARGHEZZA E SPESSORE DI OTOLITE IN DUE SPECIE DI PESCI PELAGICI DEL GOLFO PERSICO, VICINO A BANDAR ABBAS. In: Annales: Series Historia Naturalis. 22 (1). Scientific and Research Center of the Republic of Slovenia, pp. 83.

Kontaş, S., Bostanci, D., Yedier, S., Kurucu, G., Polat, N., 2018. Investigation of fluctuating asymmetry in the four otolith characters of Merlangius merlangus collected from middle Black Sea. Türk Denizcilik ve Deniz Bilimleri Dergisi 4, 128–138.

Leary, A., Allendrof, F.W., 1989. Fluctuating asymmetry as an indicator of stress: implications for conservation biology. Trend Evol 4, 214–217.

Lee, D.H., Lysak, R.L., 1990. Effects of azimuthal asymmetry on ULF waves in the dipole magnetosphere. Geophys. Res. let. 17, 53–56.

Lychakov, D.V., Rebane, Y.T., 2005. Fish otolith mass asymmetry: morphometry and influence on acoustic functionality. Hearing Res 201, 55_69.

Mabrouk, L., Guarred, T., Hamza, A., Messaoudi, I., Hellal, A.N., 2014. Fluctuating asymmetry in grass goby, Zosterisessor ophiocephalus Pallas, 1811 inhabiting polluted and unpolluted area in Tunisia. Mar. Poll. Bull. 85, 248–251.

Markov, T.A., 1995. Evolutionary ecology and developmental instability. Annl. Rev. Entomol. 40, 105–120.

Merilä, J., Björklund, M., 1995. Fluctuating asymmetry and measurement error. Syst. Biol. 44, 97–101.

Palmer, A.R., 1994. Fluctuating asymmetry analyses: a premier. In: Markov, T.A. (Ed.), Developmental Instability: Its Origin and Evolutionary Implications. Kluwar, Dordrecht, Netherlands, pp. 335–364.

Palmer, A.R., 1996. Waltzing with asymmetry. Bioscience 46, 518–532.

Palmer, A.R., Strobeck, C., 1986. Fluctuating asymmetry: measurement, analysis, patterns. Annl Rev. Ecol. Syst. 17, 391–421.

Palmer, A.R., Strobeck, C., 1992. Fluctuating asymmetry as a measure of developmental stability: implications of non-normal distribution and power of stability tests. Acta Zool. Fenn. 191, 57–72.

Panfili, J., Durand, J., Diop, K., Gourène, B., Simier, M., 2005. Fluctuating asymmetry in fish otoliths and heterozygosity in stressful estuarine environments (West Africa). Mar. Fresh. Res. 56, 505–516.

Regal, E.L.–., A, M., Jawad, L., Mehanna, S., Ahmad, Y., 2016. Fluctuating asymmetry in the otolith of two parrotfish species, *Chlorurus sordidus* (Forsskål, 1775) and *Hipposcarus harid* (Forsskål, 1775) from Hurghada, Red Sea coast of Egypt. Intern. J. Mar. Sci. 6, 1–5.

Sadighzadeh, Z., Jawad, L., Al-Marzouqi, M., 2011. Fluctuating asymmetry in the otolith of the mugilid fish *Liza kluzingeri* (day, 1888) from Persian Gulf near Bandar Abbas. Thalassia Salentina 33, 95–102.

Saeed, T., Al-Ghadban, A.N., Al-Shemmari, H., Al-Mutairi, M., Al-Hashash, H., 1999. Preliminary assessment of the impact of draining of Iraqi marshes on Kuwait's northern marine environment. Part II. Sediment associated pollutants. Water Sci. Technol. 40, 89–98.

Somarakis, S., Kostikas, I., Tsimenides, N., 1997a. Fluctuating asymmetry in the otoliths of larval fish as an indicator of condition: conceptual and methodological aspects. J. Fish Biol. Suppl. A 51, 30–38.

Somarakis, S., Kostikas, I., Peristeraki, N., Tsimenides, N., 1997b. Fluctuating asymmetry in the otoliths of larval anchovy *Engraulis encrasicolus* and the use of developmental instability as an indicator of condition in larval fish. Mar. Ecol. Prog. Ser. 151, 191–203.

StatSoft, Inc., 1991. Complete Statistical System: Statistica, Version 3.0. StatSoft. Inc. Tulsa, pp. 237–270.

Thiam, N., 2004. Ecomorphologie de Trisopterus luscus (Linnaeus, 1758) tacaud, adaptation a la température at l'asymmétric fluctuante (Ph.D. Thesis). Faculté des

Sciences, Université de Vigo (190 pp.).
Valentine, D.W., Soule, M.E., Samollow, P., 1973. Asymmetry in fishes: a possible statistical indicator of environmental stress. Fish. Bull. 71, 357–370.
Van Vallen, L., 1962. A study of fluctuating asymmetry. Evolution 16, 125–142.
Zuhkair, M.K., Al-Hello, M.A., Abd, I.A., Al-Saad, H.T., 2007. Environmental assessment of trace metals pollution in sediment of Khor Al-Zubair, Iraq. Mesopotamian J. Mar. Sci. 22, 81–92.
Zukhair, M.K., Abd, I.M., DouAbul, A.A., Al-Saad, H.T., 2008. Uptake-release of pollutant by Hilsa shad Tenualosa ilisha (Hamilton-Buchanan) fish collected from southern Iraq. Mesopotamian J. Mar. Sci. 23, 237–255.