Thalassia Salentina
Thalassia Sal. 41 (2019), 33-46
ISSN 0563-3745, e-ISSN 1591-0725

DOI 10.1285/i15910725v41p33
http: siba-ese.unisalento.it - © 2019 Università del Salento

LAITH A. JAWAD[1], PIERRE GNOHOSSOU[2]

[1] Flat Bush, Manukau, Auckland, New Zealand
[2] Département d'Aménagement et Gestion de Ressources Naturelles, Faculté d"Agronomie, University of Parakou, BP 123 Parakou, Republic of Benin
Corresponding author: laith_jawad@hotmail.com; Telephone: +6492715165

ASYMMETRY IN *CHRYSICHTHYS AURATUS* (GEOFFROY SAINT-HILAIRE, 1809) (SILURIDAE) AND *MUGIL CEPHALUS* LINNAEUS, 1857 (MUGILIDAE) FROM LAKE AHÉMÉ (BÉNIN, WEST AFRICA)

SUMMARY

Asymmetry study was performed for four bilateral characters of *Chrysichthys auratus* (Geoffroy Saint-Hilaire, 1809) (Siluridae) and *Mugil cephalus* Linnaeus, 1857 (Mugilidae) collected from Guézin and Akodéha-Kpodji localities at Lake Ahémé, Republic of Bénin, West Africa. For both *C. auratus* and *M. cephalus* the four morphometric and one meristic characters, bilateral asymmetry was higher in the fish specimens collected from Guézin compared with that of specimens from Akodéha-Kpodji localities within Lake Ahémé. Bilateral asymmetry in *C. auratus* and *M. cephalus* increased with the fish size at both localities. The conceivable reasons of bilateral asymmetry in the two fish species are deliberated in relative to diverse pollutants in Lake Ahémé.

INTRODUCTION

The aquatic environments adjacent to large cities are subjected to a wide range of anthropogenic events. Organisms living in these ranges are exposed to several deviations such as agricultural, industrial and engineering projects, and other human-related functions related with growth and industrialization (Haedrich, 1983).

Knowing the forthcoming status of biological systems rely on knowing the significance of the biological consequence of pollution at the level of organisms, populations and communities, and to visualize their responses to changes in the environment (Lajus *et al*. 2015). The valuation of such influences can be in several types depending on the type of biological system and parameter, and on the focus of the particular research (Newman, 2014).

To understand specific developmental trails, the organism must have developmental constancy. In case of any fault in such instability, the organism becomes unable to adapt to its environment (Zakharov, 1989). Fluctuating asymmetry is deemed among the best measures of the developmental instability, which is a divergence from accurate morphological symmetry. Consequently, the fluctuating asymmetry index has a cumulative attraction as a substitute of fitness and a measure of the effect of various environmental pressures since the late 1980s-early 1990s (Palmer and Strobeck, 1986; Zakharov, 1989; Parsons, 1990; Graham *et al.*, 1993). A considerable rise in bilateral asymmetry levels within a population may specify that individuals are facing greater difficulty holding precise development which may result in on future generations of the species (Markov, 1995).

While biodiversity inquiries and monitoring methods are capable to disclose changes in both community structures and species levels, they usually require a noteworthy time frame and huge input of efforts. Otherwise, the analysis of bilateral asymmetry has a number of benefits over more traditional environmental monitoring methods; it is modest, inexpensive and needs no skilled labour to achieve. The latter advantages are particularly suitable for environmental monitoring programs in Benin where financial and scientific skills are limited (Mabrouk *et al.*, 2014; Elie and Girard, 2014).

Chrysichthys auratus has well known distribution in the West African water bodies, except in the coastal areas between Gambia and Liberia, where it is replaced by *Chrysichthys maurus* (Risch, 1992, 2003). It is widespread throughout Lower Guinea (Geerinckx *et al.*, 2007) and also reported from the Chad and Nile basins (Risch, 1986). On the other hand, M. cephalus has a cosmopolitan distribution in the coastal waters of the tropical, subtropical and temperate zones of all seas (Lalèyè *et al.*, 2003; Durand *et al.*, 2012).

The objective of the present study is to examine common fish species in Lake Ahémé, Bénin, West Africa to reveal the level of bilateral asymmetry in six morphological characters and to afterward utilize those characters showing the highest levels of bilateral asymmetry in more unconventional studies. The only study on the bilateral asymmetry of fishes from Lake Ahémé was that of Jawad *et al*. (2016) in which the level of asymmetry was investigated in 3 morphometric characters of two cichlid fish species, *Sarotherodon melanotheron* and *Coptodon guineensis*. Therefore, the present study provides the second data on the bilateral asymmetry in freshwater fishes of Benin.

MATERIAL AND METHODS

The sampling locations were nominated since they are heavily populated and are influenced by enormous anthropogenic waste disposal. Lake Ahémé is located in the southern area of Benin between 6.20° and 6.40°N and between 1.55°and 2°E) (Fig. 1). The lake obtains its main freshwater source from the Couffo River at its northern part. The surface area of the lake is 78 km2 during low water level and 100 km2 during floods (Dissou, 1986). The lake is 24 km long and the northern part is deeper than the southern. The lake is connected to the sea by the Aho channel, 10 km long. During the dry season the sea water flows into this channel and causes an upsurge in water salinity in the southern part of the lake (Niyonkuru and Lalèyè, 2012). Fish samples were obtained from fishermen operating in the sampling sites of Guézin and Akodeha Kpodji located at the south of the lake. Gillnets (200 m × 1.30 m, 25, 40 and 50 mm mesh) and cast nets (6 diameter, 20 mm mesh) were used by the fishermen to catch the fish. Fish samples were collected in August 2016. The depth at the two sampling sites ranged from 0.5 to 2.4 m. Two species of fish were chosen for the study: *C. auratus* (Guézin, n = 120, range = 80–300 mm; Akodeha Kpodji, n=50, range=50–280 mm) and the mullet species *M. cephalus* (Guézin, n = 110, range = 120–450 mm; Akodeha Kpodji, n=60, range=110–460 mm). The characters selected for bilateral asymmetry analysis were formerly used in fish studies (Hechter *et al.*, 2000; Lucentini *et al.*, 2002; Jawad *et al.*, 2010, 2016), including four metric and two meristic characters as follows: (1) head length (HL), measured from the tip of the mouth to the posterior edge of the operculum; (2) snout length (SnL), measured from the tip of the mouth to the anterior edge of the orbit; (3) eye diameter (ED),measured from the anterior edge of the orbit to the posterior edge of the orbit; (4) prepectoral fin length (PPFL); and (5) pectoral fin ray count (PFC). Characters were measured to the nearest 0.1 cm using digital calipers. Bilateral asymmetry values and measurement errors are in best cases small and normally distributed around a mean of zero (Merilä and Bjöklund, 1995). Personal error in taking measurements can disturb the results of bilateral asymmetry analysis, leaving it undistinguishable (Palmer, 1994). Therefore, in the current study, all the measurements were performed by only one person to evade any undesirable error (Lee, 1990), and were repeated twice. In the statistical analysis, the square coefficient of asymmetry variation (CV^2_a) for meristic and morphometric characters was calculated according to Valentine *et al.* (1973) as:

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

where S_{l-r} is the standard deviation of the signed difference, and X_{l+r} is the mean of the character, which is calculated by adding the absolute marks for both sides and dividing by the sample size. To eradicate scaling difficulties linked with growth in morphometric characters (non-discrete, measurable), each measurement was divided by a conventional standardizing measurement (e.g. head length, from the tip of the mouth to the posterior edge of operculum, was used in the present study). Each morphometric measurement was handled in a similar means and the squared coefficient of asymmetry was determined as before. Coefficient of asymmetry was calculated both for individuals within each locality and across all individuals. For each locality, sampled individuals were classified into classes based on their total length. Coefficients of asymmetry were compared between the two fish populations within Lake Ahémé using ANOVA tests.

RESULTS

The results of the bilateral asymmetry analysis of four morphological and one meristic characters of *C. auratus* and *M. cephalus* are shown in Tables 1, 2 and 3. For both species, the asymmetry values of the morphological characters examined were higher in Guézin than in Akodéha-Kpodji. In both locations investigated, the asymmetry values for *C. auratus* were lowest for eye diameter and highest for head length. Conversely, the asymmetry values for *M. cephalus* were highest for eye diameter and lowest for head length in both Guézin and Akodéha-Kpodji (Table 1).

Table 1. Squared coefficient asymmetry (CV^2_a) values and character means (X_{r+1}) of *Chrysichthys auratus* and *Mugil cephalus* collected from two localities at Lake Ahémé, Benin, West Africa.

	Locality	Characters				
		Head length	Snout length	Eye diameter	Prepectoral fin length	Pectoral fin ray count
Chrysichthys auratus						
CV^2_a	Guézin	62.8	61.3	60.4	60.9	62.1
	Akodéha-Kpodji	59.6	59.3	55.7	56.7	58.9
N	Guézin	120	120	120	120	120
	Akodéha-Kpodji	50	50	50	50	50
Character mean (X_{r+1})	Guézin	9.5	2.4	0.9	5.4	9
	Akodéha-Kpodji	9.3	2.1	0.9	5.1	9
% of individuals with asymmetry	Guézin	80	82	89	91	98
	Akodéha-Kpodji	75	77	78	80	81
Mugil cephalus						
CV^2_a	Guézin	58.4	62.2	59.6	59.7	60.1

	Akodéha-Kpodji	57.9	58.2	58.1	58.6	56.1
N	Guézin	110	110	110	110	110
	Akodéha-Kpodji	60	60	60	60	60
Character mean (X_{r+1})	Guézin	5.6	3.5	1.2	8.4	17
	Akodéha-Kpodji	5.2	3.3	1.1	8.5	17
% of individuals with asymmetry	Guézin	85	87	91	93	98
	Akodéha-Kpodji	80	81	82	84	91

Table 2. Squared coefficient asymmetry (CV^2_a) values and character means (X_{r+1}) of *Chrysichthys auratus* collected from two localities at Lake Ahémé, Benin, West Africa.

Character	CV^2_a	N	Character mean	% of individuals with asymmetry
Guézin				
Head length				
80-120	63.8	20	9.3	78
121-160	64.1	30	9.1	88
161-200	64.9	30	9.2	90
201-240	65.2	20	9.4	95
241-280	65.9	10	9.5	98
281-320	66.3	10	9.3	99
Snout length				
80-120	61.3	20	2.4	65
121-160	61.9	30	2.2	72
161-200	62.1	30	2.1	79
201-240	62.8	20	2.0	82
241-280	63.5	10	2.3	89
281-320	64.7	10	2.3	96
Eye diameter				
80-120	61.4	20	0.9	75
121-160	63.5	30	0.8	79
161-200	63.9	30	0.7	82
201-240	64.3	20	0.9	89
241-280	65.9	10	0.8	93
281-320	66.2	10	0.7	97
Prepectoral fin length				

80-120	61.9	20	5.4	54
121-160	62.5	30	5.2	65
161-200	62.8	30	5.0	78
201-240	63.3	20	5.0	89
241-280	64.7	10	5.3	92
281-320	65,5	10	5.1	97
Pectoral fin ray count				
80-120	62.9	20	9	66
121-160	63.5	30	8	69
161-200	64.2	30	7	72
201-240	64.9	20	8	76
241-280	65.7	10	7	84
281-320	66.8	10	9	94
Akodéha-Kpodji				
Head length				
50-100	59.9	20	9.2	76
101-250	60.8	20	9.3	79
251-300	61.6	10	9.0	82
Snout length				
50-100	59.9	20	2.0	74
101-250	60.5	20	2.2	83
251-300	62.3	10	2.3	97
Eye diameter				
50-100	59.1	20	0.9	65
101-250	60.4	20	0.8	77
251-300	62.8	10	0.7	89
Prepectoral fin length				
50-100	60.8	20	5.3	75
101-250	62.4	20	5.5	85
251-300	63.7	10	5.2	94
Pectoral fin ray count				
50-100	59.7	20	9	87
101-250	60.5	20	8	90
251-300	62.7	10	8	94

Table 3. Squared coefficient asymmetry (CV^2_a) values and character means (X_{r+1}) of *Mugil cephalus* collected from two localities at Lake Ahémé, Benin, West Africa.

Character	CV^2_a	N	Character mean	% of individuals with asymmetry
Guézin				
Head length				
120-180	63.7	30	5.4	69
181-240	66.5	25	5.3	74
241-300	69.3	30	5.5	83
301-420	79.2	25	5.1	98
Snout length				
120-180	65.9	30	3.4	65
181-240	69.9	25	3.3	76
241-300	73.2	30	3.1	86
301-420	79.9	25	3.0	98
Eye diameter				
120-180	60.2	30	1.2	54
181-240	68.9	25	1.1	67
241-300	72.3	30	1.0	78
301-420	78.8	25	1.1	98
Prepectoral fin length				
120-180	62.9	30	8.2	65
181-240	66.3	25	8.1	78
241-300	70.4	30	8.0	88
301-420	78.4	25	8.5	97
Pectoral fin ray count				
120-180	63.5	30	17	54
181-240	65.3	25	16	56
241-300	66.8	30	18	67
301-420	76.9	25	17	89
Akodéha-Kpodji				
Head length				
110-180	59.9	10	5.1	45

181-150	63.2	10	5.0	56
151-220	69.0	10	5.5	67
221-290	73.2	10	5.3	78
291-360	79.8	5	5.2	82
361-430	81.2	10	5.0	89
431-500	88.6	5	5.1	94
Snout length				
110-180	64.3	10	3.2	56
181-150	76.7	10	3.1	68
151-220	78.0	10	3.3	76
221-290	83.2	10	3.0	87
291-360	88.9	5	3.1	89
361-430	90.1	10	3.4	92
431-500	96.5	5	3.4	98
Eye diameter				
110-180	60.8	10	1.1	54
181-150	66.8	10	1.0	59
151-220	72.3	10	1.0	63
221-290	74.9	10	0.9	67
291-360	79.9	5	1.1	78
361-430	81.2	10	1.2	85
431-500	88.4	5	1.0	98
Prepectoral fin length				
110-180	89.7	10	8.7	67
181-150	93.8	10	8.5	78
151-220	96.3	10	8.1	83
221-290	97.8	10	8.0	87
291-360	98.0	5	8.4	91
361-430	98.4	10	8.3	94
431-500	98.9	5	8.5	97
Pectoral fin ray count				
110-180	64.5	10	17	65
181-150	69.8	10	16	69

151-220	73.2	10	17	73
221-290	78.6	10	18	78
291-360	79.9	5	17	82
361-430	82.3	10	17	85
431-500	86.7	5	16	98

Analysis of variance showed that the values of asymmetry for the four morphological and one meristic characters differed between the populations of the two species inhabiting Guézin and Akodéha-Kpodji within Lake Ahémé ($P < 0.001$).

Individuals of *C. auratus* and *M. cephalus* from the two localities were grouped into length classes (Tables 2 and 3). An increasing fashion in asymmetry values was distinguished for each of the four morphological and one meristic characters.

DISCUSSION

High bilateral asymmetry values for eye lens diameter and head length have earlier been documented in numerous freshwater and marine fish species (Al-Hassan *et al.*, 1990; Al-Hassan and Hassan, 1994; Jawad *et al.*, 2012a, 2012b, 2016; Jawad 2013; Mabrouk *et al.*, 2014). Such conformities in results of bilateral asymmetry might indicate the vulnerability of these two characters to instant changes in the environment. Therefore, they could be used as an operative biomarkers of strain in the environment. Moreover, the lower asymmetry values of morphometric characters in the two species examined could suggest that these character may be less sensitive to environmental pressure factors comprising pollution. Jawad (2003) suggested that the lower bilateral asymmetry values attained for such morphometric characters might be elucidated on the basis that the developmental period of these characters may not concur with the occurrence of opposing environmental actions. On the other hand, slight modifications throughout development can diverge from normal developmental courses (Palmer and Strobeck, 1992). These indiscretions may be owing to the quality and quantity of food, extreme temperatures, parasites, disease and behavioral pressure forced by interactions with the related species living in the same environment (Markov, 1995).

Analysis of variance showed that bilateral asymmetry values for the four morphological and one meristic characters studied differed significantly between *C. auratus* and *M. cephalus* collected from two localities at Lake Ahémé ($P < 0.001$). There is a substantial source of contamination by diverse types of pollutants such as organic pollutants and heavy metals in the areas where fishes were collected at both sites (Soclo *et al*., 2000; Yèhouénou *et al*., 2006a, 2006b, 2013). It is likely that pollution may account for the high bilateral asymmetry values in these areas. Jawad *et al*. (2016) have shown that level of asymmetry in three morphological characters of *Sarotherodon melanotheron* and *Coptodon guineensis* collected from Lake Ahémé was lower than that of Porto-Novo lagoon. In the present study, the level of asymmetry in the two species examined from Lake Ahémé showed ⅓ higher value than that obtained for fish species collected from the same localities of the Lake Ahémé by Jawad *et al.* (2016). Such increase occurred within only two years. This signify the quick deterioration of the environment during this short period of time.

Certainly, several studies have confirmed that pollution was accountable for circumstances linking high bilateral asymmetry values (e.g. Franco *et al*., 2002; Romanov and Kovalov 2004; Mabrouk *et al*., 2014; Elie and Girard, 2014). In general, the toxicity of some trace metals and other chemicals is revealed to upsurge with the increase in both temperature and salinity (Sogorb *et al*., 1988; Wright, 1995; Rainbow, 1997; Kwok and Leung, 2005; Elie and Girard, 2014). The similarity in the average water temperature of both water bodies (28 °C) will undervalue the role of water temperature in increasing harmfulness. On the other hand, the salinity as a factor enhancing the toxicity to pollutants can be taken into consideration in this case, because the salinity level of water of Lake Ahémé ranges 5-28 g/l (Gnohossou, 2006; Niyonkuru, 2007).

Developmental illnesses resulting from chemical and organic pollution can direct to severe morphological deformities (Bengtsson *et al*., 1988; Elie and Girard, 2014). In the two localities studied, fish abnormalities were reported which were connected to heavy metal and organic pollution.

As confirmed in preceding investigations (Al-Mamry *et al*., 2011a,b; Jawad *et al*., 2012a, 2012b, 2012c; Mabrouk *et al*., 2014), Anova test analysis in the current study revealed that large size specimens of *C. auratus* and *M. cephalus* from the two localities studied had higher bilateral asymmetry values than smaller young specimens ($P < 0.001$). It was obvious that the values of fluctuating bilateral asymmetry of the four morphological and one meristic characters increased with fish size in both species (Tables 2 and 3). This tendency is maybe the consequence of imperfect development; character means are always the lowest in smaller size classes (Valentine *et al*., 1973). Similar results were gained by Valentine *et al*. (1973) in nominated fish species collected from California, U.S.A. They recommended two possible theories that may responsible for such a style; ontogenetic variations linked to an increase in bilateral asymmetry with size (age), and possible historical procedures which results in a secular increase in bilateral asymmetry. On the other hand, Thiam (2004) recommended that an increasing tendency in bilateral asymmetry values with fish size could be due to the fact that the large size individuals had longer periods of contact to opposing environmental circumstances and hence lose their steadiness in such environments.

An administration plan is immediately compulsory in order to reinstate a healthy environment in Lake Ahémé. Numerous aquatic plant and animal species within this water body have previously been unfavourably affected (Gnohossou, 2006).

REFERENCES

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

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. *Revista de Idrobiologia*, **29**: 775-780.

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

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

Bengtsson Å.B., Bengtsson E., Lithner G., 1988. Vertebral defects in four horn sculpin, Myoxocephalus quadricornis L., exposed to heavy metal pollution in the Gulf of Bothnia. *Journal of Fish Biology*, **33**: 517-529.

Dissou M., 1986. La republique Populaire du Bénin: Milieux naturels, régions, économie agricole régionale. Première Partie: le Bas-Bénin. Project UNB/UVA/ER, Abomey-Calavi (Bénin), 1986.

Durand J.D., Shen K.N., Chen W.J., Jamandre B.W., Blel H., Diop K., Nirchio M., De León F.G., Whitfield A.K., Chang C.W., Borsa P., 2012. Systematics of the grey mullets (Teleostei: Mugiliformes: Mugilidae): molecular phylogenetic evidence challenges two centuries of morphology-based taxonomy. *Molecular and Phylogenetic Evolution*, **64**: 73-92.

Elie P., Girard P., 2014. La santé des poissons sauvages: les codes pathologie, un outil d'évaluation. Association Santé Poissons Sauvages. Achevé d'imprimer sur les Presses d'AVL diffusion, Montpellier (France) (Pages: 286 pp.).

Franco A., Malavasi S., Pranovi F., Nasci C., Torricelli P., 2002. *Ethoxyresorufin odeethylase* (EROD) activity and fluctuating asymmetry (FA) in *Zosterisessor ophiocephalus* (Teleostei, Gobiidae) as indicators of environmental stress in the Venice lagoon. *Journal of Aquatic Ecosystem and Stress Recovery,* **9**: 239-247.

Geerinckx T., Risch L., Vreven E.J., Adriaens D., Teugels G.G., Claroteidae C., 2007. In M.L.J. Stiassny, G.G. Teugels and C.D. Hopkins (eds.) The fresh and brackish water fishes of Lower Guinea, West-Central Africa. Volume I. Collection Faune et Flore tropicales 42. Institut de Recherche pour le Développement, Paris, France, Muséum National d'Histoire Naturelle, Paris, France, and Musée Royal de l'Afrique Centrale, Tervuren, Belgium. 800 pp.

Gnohossou P., 2006. La faune benthique d'une lagune Ouest Africaine le lac Nokoué au Bénin, diversité, abondance, variations temporelles et spatiales, place dans la chaîne trophique (PhD thesis) Institut National Polytechnique/Ecole Nationale Supérieure Agronomique, Toulouse, France.

Graham J.H., Freeman D.C., Emlen J.M., 1993. Developmental stability: a sensitive indicator of populations under stress. Pages 136-158 in Landis, WG, Hughes, J.S., Lewis, M.A., eds. Environmental toxicology and risk assessment. Philadelphia (PA): American Society for Testing and Materials.

Haedrich R.L., 1983. Estuarine Fishes. In: Ketchum B (ed.) Ecosystems of the world. 26. Estuaries and Enclosed Seas. Elsevier, Amsterdam 183-207.

Hechter R.P., Moodie P.F., Moodie G.E.E., 2000. Pectoral fin asymmetry, dimorphism and fecundity in brook stickleback, *Culaea inionstans*. Behavior 137, 999-1009.

Jawad L.A., 2003 Asymmetry in some morphological characters of four sparid fishes from Benghazi, Libya. *Oceanological and Hydrobiological Studies*, **32**: 83-88.

Jawad L.A., Al-Mamry J.M., Al-Kharusi L.A., Al-Habsi S.H., 2010. Asymmetry in some morphological characters of the carangid species, *Decapterus russelli* collected from Lema coastal area, north of the Sea of Oman. *Oceanological and Hydrobiological Studies*, **39**: 55-62.

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

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

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

Jawad L.A., 2013. On the asymmetry of some morphological characters of the silvercheeked toadfish *Lagocephalus sceleratus* (Gmelin, 1789) collected from the Sea of Oman. *Water Research Management*, **3**: 25-30.

Jawad L.A., Gnohossou P., Tossou A.G., 2016. Bilateral asymmetry in certain morphological characters of *Sarotherodon melanotheron* Rüppell 1852 and *Coptodon guineensis* (Günther 1862) collected from Lake Ahémé and Porto-Novo Lagoon Bénin, West Africa. *Marine Pollution Bulletin*, **103**: 39-44.

Kwok K.W.H., Leung K.M.Y., 2005. Toxicity of antifouling biocides to the intertidal harpacticoid copepod *Tigriopus japonicus* (Crustacea, Copepoda): effects of temperature and salinity. *Marine Pollution Bulletin*, **51**: 830-837.

Lajus D., Yurtseva A., Birch G., Booth D.J., 2015. Fluctuating asymmetry as a pollution monitor: The Australian estuarine smooth toadfish *Tetractenos glaber* (Teleostei: Tetraodontidae). *Marine Pollution Bulletin*, **101**: 758-767.

Lalèyè P., Niyonkuru C., Moreau J., Teugels G.G., 2003. Spatial and seasonal distribution of the ichthyofauna of Lake Nokoué, Benin, West Africa. *African Journal of Aquatic Science*, **28**: 151-161.

Lee J.C., 1990. Sources of extraneous variation in the study of meristic characters: the effect of size and inter-observer variability. *Systematic Zoology*, **39**: 31-39.

Lucentini L., Lorenzoni M., Panara F., Mearelli M., 2002. Effects of short term and long term thermal stress in perch (*Perca fluviatilis*) determined through fluctuating asymmetry and HSP70 expression. *Italian Journal of Zoology*, **69**: 13-17.

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. *Marine Pollution Bulletin*, **85**: 248-251.

Markov T.A., 1995. Evolutionary ecology and developmental instability. *Annual Review of Entomology*, **40**: 105-120.

Merilä J., Björklund M., 1995. Fluctuating asymmetry and measurement error. *Systematic Biology*, **44**: 97-101.

Newman M.C., 2014. The Science of Pollution. Fourth ed. Taylor and Francis, Inc., Boca Raton 253-259.

Niyonkuru C., Lalèyè P., 2012. A comparative ecological approach of the length–weight relationships and condition factor of *Sarotherodon melanotheron* Rüppell, 1852 and *Tilapia Guineensis* (Bleeker 1862) in Lakes Nokoué and Ahémé (Bénin, West Africa). *International Journal of Business, Humanities and Technology*, **2**: 41.

Niyonkuru C., 2007. Etude comparée de l'exploitation et de la démographie des poissons Cichlidés dans les lacs Nokoué et Ahémé au Bénin (Thèse de Doctorat en Gestion de l'Environnement) Université d'Abomey-Calavi, Bénin, pp. 199.

Palmer A.R., Strobeck C., 1986. Fluctuating asymmetry: measurement, analysis, patterns. *Annual Review of Ecology and Systematics*, **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 Zoologica Fennica*, **191**: 57-72.

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.

Parsons P.A., 1990. Fluctuating asymmetry: an epigenetic measure of stress. *Biological Review*, **65**: 131-145.

Rainbow P.S., 1997. Trace metal accumulation in marine invertebrates: marine biology or marine chemistry? *Journal of the Marine Biological Association of United Kingdom*, **77**: 195-210.

Risch L.M., Bagridae B., 1986. In: J. Daget, J.-P. Gosse and D. F. E. Thys van den Audenaerde (eds.) Check-list of the freshwater fishes of Africa (CLOFFA). ISNB, Brussels; MRAC, Tervuren; and ORSTOM, Paris. **2**: 2-35.

Risch L.M., Bagridae B., 1992. In: C. Lévêque, D. Paugy and GG Teugels (eds.) Fauna of freshwater and brackish fishes of West Africa. Volume 2. Coll. Tropical Fauna N ° XXVIII. Royal Museum of Central Africa, Tervuren, Belgium and ORSTOM, Paris, France, pp. 395-431.

Risch L.M., 2003. Claroteidae. In: C. Lévêque, D. Paugy and GG Teugels (eds.), pp. 60-96. Fauna of freshwater and brackish fish of West Africa, Volume 2. Coll. Tropical Fauna and Flora 40. Royal Museum of Central Africa, Tervuren, Belgium, National Naturalle History Museum, Paris, France and Research Institute for Development, Paris, France.

Romanov N.S., Kovalov M.Y., 2004. Fluctuating asymmetry in goldfish, *Carassius auratus gibelio* (Cyprinidae) from water bodies of the Far East. *Journal of Ichthyology*, **44**: 101-108.

Soclo H.H., Garrigues P.H., Ewald M., 2000. Origin of polycyclic aromatic hydrocarbons (PAHs) in coastal marine sediments: case studies in Cotonou (Bénin) and Aquitaine (France) areas. *Marine Pollution Bulletin*, **40**: 387-396.

Sogorb A., Andreu-Moliner E.S., Almar M.M., Del Rame J., Múňez A., 1988. Temperaturetoxocity relationship of fluvalinate (synthetic pyrenthroid) on *Procambarus clarkii* (girard) under laboratory conditions. *Bulletin of Environmental Contamination and Toxicology*, **40**: 13-17.

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, p. 190.

Valentine D.W., Soul M.E., Samollow P., 1973. Asymmetry in fishes: a possible statistical indicator of environmental stress. *Fishery Bulletin*, **71**: 357-370.

Wright D.A., 1955. Trace metal and major ion interactions in aquatic organisms. *Marine Pollution Bulletin*, **31**: 8-18.

YÈhouénou A., Pazou E., Boko M., Van Gestel C.A.M., Ahissou H., Lalèyè P., Akpona S., Van Hattum B., Swart K., Van Straalen N.M., 2006a. Contamination of fish by organochlorine pesticide residues in the Ouémé River catchment in the Republic of Bénin. *Environment International*, **32**: 594-598.

Yèhouénou A., Pazou E., Lalèyè P., Boko M., Van Gestel C.A.M., Ahissou H., Akpona S., Van Hattum B., Swart K., Van Straalen N.M., 2006b. Organochlorine and organophosphorus pesticide residues in the Ouémé River catchment in the Republic of Bénin. *Environment International*, **32**: 616-623.

Yèhouénou A., Azéhoun R., Edorh P.A., Ahoyo T., 2013. Monitoring of heavy metals in the complex "Nokoué lake - Cotonou and Porto-Novo lagoon" ecosystem during three years in the Republic of Benin. *Research Journal of Chemical Science*, **3**: 12-18.

Zakharov V.M., 1989. Future prospects for population phenogenetics. *Soviet Science Review Section F*, **4**: 1-79.