FISHERIES & AQUATIC LIFE (2024) 32: 227 - 234
Archives of Polish Fisheries
DOI 10.2478/aopf-2024-0020

RESEARCH ARTICLE

Incidences of taillessness in *Acanthopagrus arabicus* and *Oreochromis niloticus* collected from the Shatt al-Arab River, Basrah, Iraq

Jassim M. Abed, Laith A. Jawad, Mujtaba A. Ankush

Received – 13 March 2024/Accepted – 16 December 2024. Published online: 30 December 2024; ©National Inland Fisheries Research Institute in Olsztyn, Poland
Citation: Abed, J. M., Laith A. Jawad, L. A., Ankush, M. A. (2024). Incidences of taillessness in *Acanthopagrus arabicus* and *Oreochromis niloticus* collected from the Shatt al-Arab River, Basrah, Iraq. Fisheries & Aquatic Life 32, 227-234.

Abstract. Taillessness (the absence of the caudal fin and some of the caudal peduncle) is described in *Acanthopagrus arabicus* Iwatsuki and *Oreochromis niloticus* (L.) specimens collected from the Shatt al-Arab River, Basrah, Iraq. The abnormal specimens completely lacked caudal fins and peduncles. The last remaining caudal vertebra was turned downward in *A. arabicus*, whereas the remaining parts of the caudal fin skeleton were turned upward in *O. niloticus*. The abnormalities were assessed by morphological diagnosis. None of the cases was fatal as they occurred in adult individuals. The likely reasons for these abnormalities and the appropriateness of this case study for environmental monitoring are discussed. Additional studies should be conducted from the viewpoint of pollution.

Keywords: *Acanthopagrus arabicus*, *Oreochromis niloticus*, Sparidae, Cichlidae, deformity, malformation

J. M. Abed, M. A. Ankush
Department of Fisheries and Marine Resources,
College of Agriculture, University of Basrah, Basrah, Iraq

L. A. Jawad [✉]
School of Environmental and Animal Sciences,
Unitec Institute of Technology, Auckland, New Zealand
E-mail: laith_jawad@hotmail.com

Introduction

The high diversity of skeletal anomalies has been described in marine fishes. Genetic and ecological influences incorporating pollution from human sources and climate change are regularly named as likely contributing drivers (von Westernhagen and Dethlefsen 1997, Jawad et al. 2018a, 2018b). Such reports contain instances of fin deformities relating to individuals losing their caudal fins and portions of their caudal peduncles (taillessness): white spotted pygmy filefish, *Rudarius ercodes* Jordan & Fowler (Honma 1994); longhorn cowfish, *Lactoria cornuta* (L.) (Tyler et al. 2014); Richardson's ray, *Bathyraja richardsoni* (Garrick) (Orlov 2011); and striped piggy, *Pomadasys stridens* (Forsskål) (Alavi-Yeganeh et al. 2019). Environmental circumstances, such as water temperature and salinity that are above or below specific levels (Dunham et al. 1991, Kurokawa et al. 2008, Okamoto et al. 2009, Georgakopoulou et al. 2010) and complexes that are common water pollutants, such as polycyclic aromatic hydrocarbons (Heintz et al. 1999) and heavy metals (e.g., cadmium, nickel, and lead (Sfakianakis et al. 2015)), are recognized as causal agents of skeletal anomaly and taillessness in captive fishes. The causes of taillessness in wild fishes are challenging to verify categorically, but ecological influences have been implicated in a range of skeletal abnormalities (Bengtsson et al. 1988, Wassenberg et al. 2005, Kessabi et al. 2013).

There is continuing concern about recording anomalies in wild fishes since abnormalities can be used as biomarkers to inspect ecosystem categories (Vethaak and Ap Rheinallt 1992, Sun et al. 2009). Fishes are valued biomarker species in aquatic ecosystems because they are susceptible to several impurities, can be examined in the field and freed without lethal sampling, and inhabit a range of niches and trophic levels (Whitfield and Elliott 2002). Studies that have used fish anomaly positively for environmental monitoring have engaged in thorough study design with large sample sizes of fishes and temporal or spatial factors (e.g., sampling before and after a pollution event or sampling in unpolluted versus polluted areas; Sun et al. 2009). Nevertheless, several such investigations were at least moderately inspired by reports from anglers or publications describing deformity in fishes collected deviously.

Acanthopagrus arabicus, is a marine species inhabiting the pelagic-neritic region at a depth range from the water surface to 50 m (Randall 1995). Specimens of this species reach a maximum standard length of 345 mm (Hussain and Abdullah 1977) with a common length of 300 mm (Bauchot and Smith 1984). This species is distributed in the Western Indian Ocean from Duqum, southern Oman to Qatar, off the coasts of Kuwait and Iraq, to Thiruvananthapuram, southwestern India (Bauchot and Smith 1984). It feeds mostly on echinoderms, worms, crustaceans, and molluscs.

Oreochromis niloticus, is a freshwater species that sometimes enters brackish waters (Riede 2004). It inhabits a depth range of 0–20 m (Wudneh 1998), but it is usually found from the water surface to 20 m (van Oijen 1995). Specimens of this species reach a maximum standard length of 600 mm (Eccles 1992). The maximum reported weight of this species is 4.3 kg (IGFA 2001) and the maximum recorded age is nine years (Noakes and Balon 1982). This species is widely distributed in Africa (Trewavas and Teugels 1991), the Nile basin, and in many lakes in Africa (Trewavas 1983). It is widely introduced for aquaculture with many existing strains around the world, including Iraq (Trewavas and Teugels 1991). Specimens of this species inhabit several freshwater habitats such as rivers, lakes, and canals (Bailey 1994). This species is diurnal and feeds primarily on phytoplankton or benthic algae. The females are oviparous (Breder and Rosen 1966) and ovophilic (Lamboj 2004). The species matures early (about 11 cm TL females, 14 cm TL males) (Bailey 1994). Temperature tolerance range from 8 to 42°C and a natural temperature range of 13.5-33°C (Philippart and Ruwet 1982). It is marketed fresh and frozen (Frimodt 1995).

The present study describes two cases of taillessness in specimens of *A. arabicus* and *O. niloticus* from the Shatt al-Arab River, Basrah, southern Iraq, which is an area with huge fluctuations in water temperature and salinity and elevated levels of hydrocarbon and heavy metal pollution (Al-Aboodi et al. 2018, Allafta and Opp 2020). This is the first report of taillessness in both *A. arabicus* and *O. niloticus* collected from Iraqi waters. This study adds to the growing literature documenting the deformity of fishes in the wild (Almatar and Chen 2010, Jawad et al. 2018b).

Materials and Methods

Two abnormal specimens of *A. arabicus* and *O. niloticus* (Fig. 1) were obtained from a fisherman operating in Shatt al-Arab River in the Abu al-Khaseeb area (Fig. 2) on September 4, 2018. The specimens were collected at a depth of 4 m using a gillnet with a mesh size of 40 mm. The specimens were deposited in the fish collection of the College of Agriculture and Marine Resources, University of Basrah, Basrah, Iraq. Since the abnormal specimens had incomplete bodies, neither total nor standard length could be measured. Instead, the term “body length” refers to the body length measurement taken. Body measurements were made with a dial caliper to the nearest

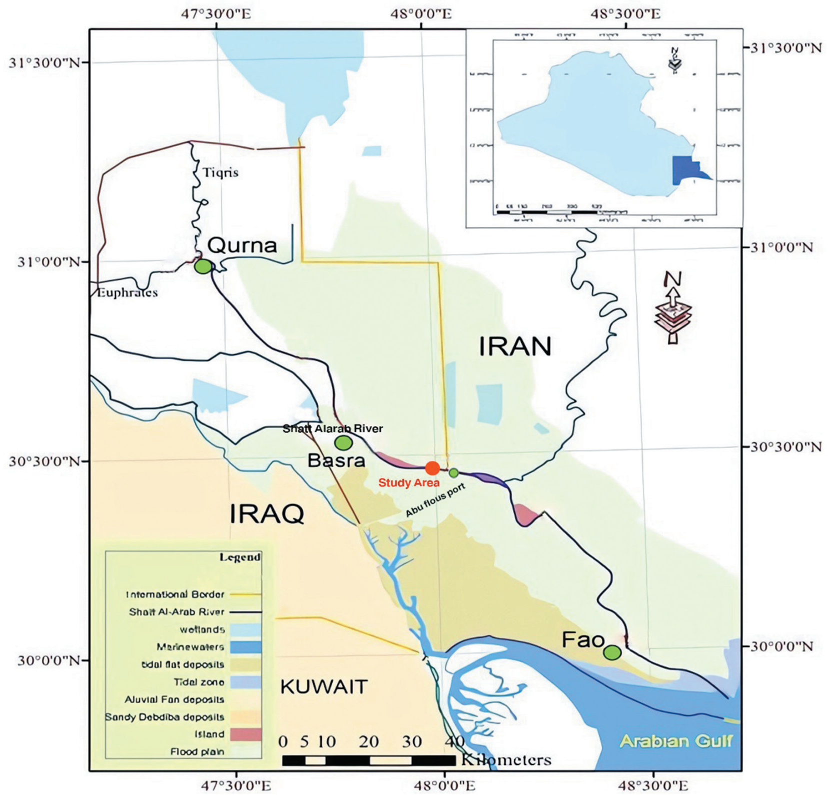

Figure 1. Map showing the sampling location.

0.02 mm. Normal specimens were obtained from the same sample for comparison (Fig. 3). Both abnormal specimens of *A. arabicus* and *O. niloticus* were radiographed to visualize their internal anatomy (Fig. 4). Radiographs of the normal specimens of *A. arabicus* and *O. niloticus* were obtained for comparison (Fig. 5). The bodies and fins of both abnormal specimens were examined carefully for external parasites, malformations, amputations, and any other morphological anomalies.

Results

The body length of the abnormal specimens of *A. arabicus* and *O. niloticus* were 150.5 and 150.2 mm, respectively (Fig. 2). For comparison, the normal specimens of these two species measured 180 and 172 mm respectively (Fig. 3). The abnormal specimens of *A. arabicus* and *O. niloticus* had lost their caudal fins completely. In the specimens of both species, the soft part of the dorsal and the anal fins were not affected by the absence of the caudal fin. In addition to the absence of caudal fins, the complete absence of caudal peduncles were also observed in the abnormal specimens of *A. arabicus* and *O. niloticus*. The wounds were entirely healed and grown over with scales.

The radiograph of the abnormal specimens of the two species examined showed that the thoracic vertebrae of *A. arabicus* were normal, while there was slight lordosis and kyphosis in the 8–11th thoracic vertebrae of *O. niloticus*. In *A. arabicus*, the results showed that the caudal region had 11 vertebrae, with 10 of them normal and one deformed. In the abnormal specimen of *O. niloticus*, the caudal region had 11 vertebrae, with abnormal 10th and 11th vertebrae.

Figure 2. Abnormal specimens of *Acanthopagrus arabicus* (above), 150 mm body length; *Oreochromis niloticus* (below), 150.2 mm body length.

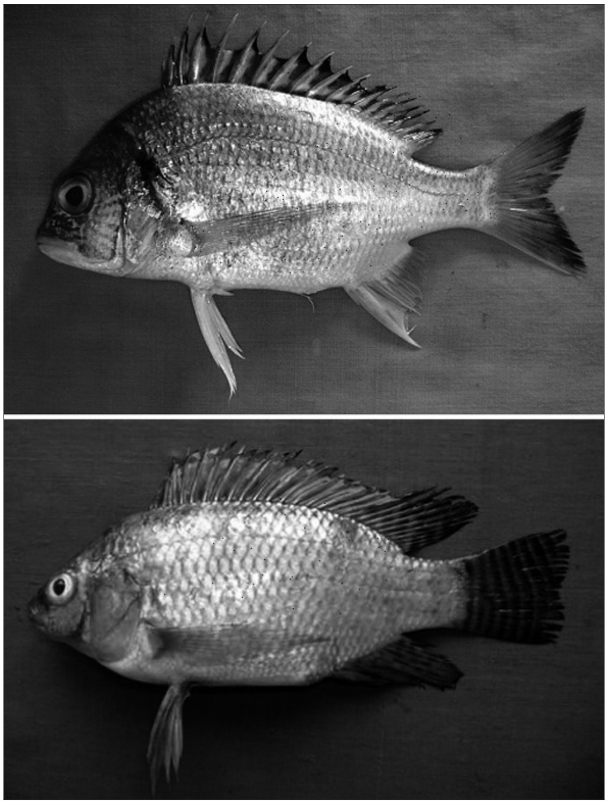

Figure 3. Normal specimens of *Acanthopagrus arabicus* (above), 150 mm body length; *Oreochromis niloticus* (below), 150.2 mm body length.

The caudal fin skeleton was completely absent in *A. arabicus*, while two hypural bones were noted and directed upward in *O. niloticus* (Fig. 4).

Discussion

This is the first investigation of taillessness in wild adult *A. arabicus* and *O. niloticus* collected from the inland waters of Iraq. The objective was to identify teratogenic caudal fins in the specimens of the species studied and to identify a possible relationship between these anomalies and several kinds of environmental issues such as pollutants. Numerous fish species from a broad taxonomic spectrum that showed caudal fin deformity and were collected from the same geographical area could justify the proposal put forth by Browder et al. (1993).

Even though there are numerous investigations on fin abnormalities worldwide, no percentages of

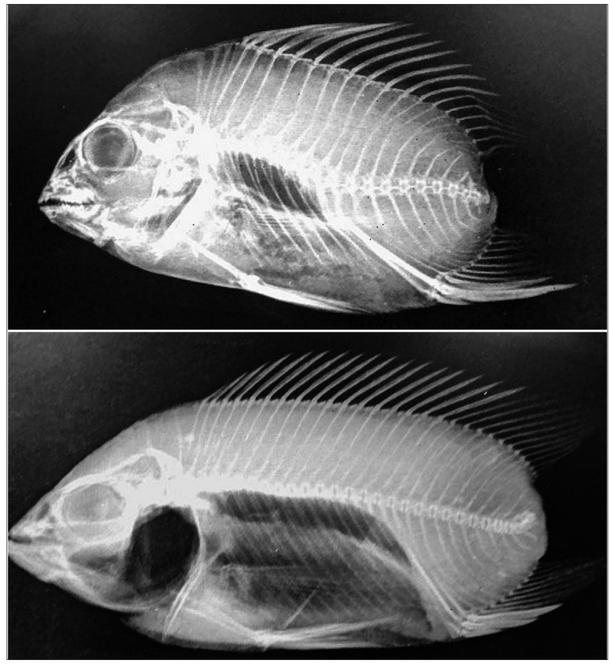

Figure 4. Radiograph of *Acanthopagrus arabicus* (above), 150 mm body length; *Oreochromis niloticus* (below), 150.2 mm body length.

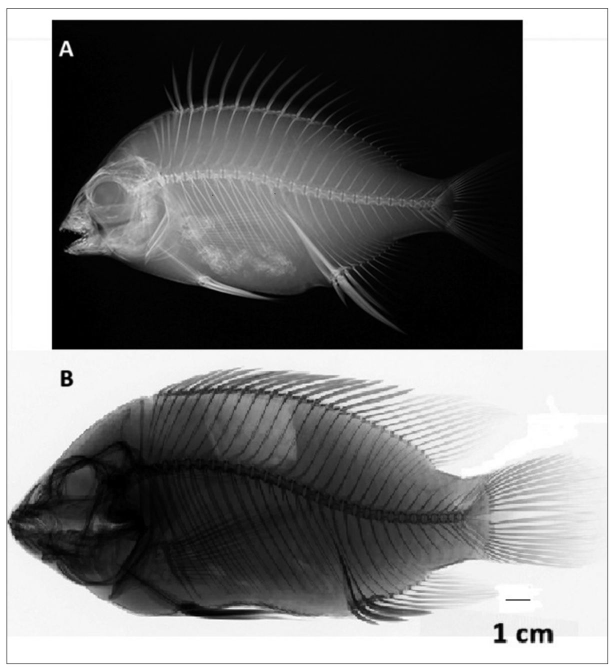

Figure 5. Radiograph of A, *Acanthopagrus arabicus*, MCZ145-604_17612, Museum of Comparative Zoology, Cambridge, Massachusetts, USA; B, *Oreochromis niloticus*, ASIZP0055460, Taiwan Fish Data Base.

deformity in specific fins is available. Generally, the dispersal of fin abnormalities is second to vertebral column deformities in fishes, which encompass 13%

of malformed vertebral columns described (Galván-Magańa et al. 1994). Some of the factors responsible for the development of morpho-anatomical abnormalities in aquaculture can be hypothesized (Koumoundouros 2010).

In the early life history of fishes, any twisting in the posterior end of the notochord can cause a deformity in the caudal fin (Koumoundouros et al. 1997). Consequently, the fish specimens investigated in this study might have been living for several years with these deformities, and this type of defect would not have affected biological aspects of the fishes such as feeding (Ribeiro-Prado et al. 2008). These caudal fin deformities were not lethal, but we do not know if they influenced the movement of the fish in some way.

The vital parts of maneuvering and steering in fishes are in the caudal fin. Thus, it must be built to manage the hydrodynamic pressures with the least possible outlay of energy (Boglione et al. 1993, Lauder 2000). Any anomaly in the caudal fin will hinder the elasticity of the tail, consequently damaging the performance of the fish including the capacity to evade predators. Weihs (1972) and Webb (1977) reported that neither metabolic rates nor metabolic scope were influenced by the elimination or absence of part of the caudal fin in fishes. Thus, the metabolic power existing in the muscular system will be the same in normal and deformed specimens. Also, these authors realized that serious speed was not significantly decreased by the partial or complete absence of the caudal fin, but it was lessened extremely when the caudal fin was completely absent. Schäperclaus et al. (1992) proposed that there are five main categories of conceivable reasons for fish defects: hereditary issues, damage during embryonic development, wounds, diseases, and damage stemming from environmental influences. In the present investigation, the specimens presenting with no caudal fin could have been attacked by predators during the juvenile stage because of the well-cured tip of the posterior end of the vertebral column, but without further information we are unable to sustain this hypothesis. Normally, fish that survive injuries confront numerous other difficulties such as blood loss, overcoming osmotic disorders, infections, slow healing, escaping predators, hunger, and great changes in the ability to swim (Gunter and Ward 1961). Accordingly, the condition of such fish deformities in the Shatt al-Arab River area needs to be assessed repeatedly and precisely.

Instabilities in environments fishes usually inhabit can be located and supervised through the development of different fish anomalies that can signal the presence of ecosystem disruptions. Hence, it is vital to alert people and ensure they know how healthy the environment is in which they live. Numerous possible issues can give rise to caudal fin anomalies including the influence of light and heat exposure during reproduction (Koo and Johnston 1978) and heavy metal pollution (Slooff 1982). Water temperatures in the Shatt al-Arab River region vary widely during the year, which causes variations in water oxygen levels, which is very clear during the summer when temperatures are at their highest (Mohamed et al. 2015, Moyel and Hussain 2015, Al-Asadi et al. 2020). Further studies should focus on pollution. Moyle and Hussain (2015) and Abdullah et al. (2015) suggested that the Shatt al-Arab River is polluted with heavy metals, and their results signaled that the chief sources of rivers contaminated with heavy metals were the atmospheric deposit of gaseous emissions from oil production and electric generators and surface runoff from agricultural areas after rainfall. In addition, the tide greatly controls the distribution of heavy metals in this river. The adverse effects of this level of pollutants in the water of the Shatt al-Arab River have changed it into a heavily polluted habitat.

From a commercial perspective, morphological anomalies can adversely affect economic outcomes from decreased fish weight, and, more significantly, from a much lower value per kg of the fishes caught. Hence, fisheries management must discover the several etiological reasons for these anomalies before measure can be undertaken to address this problem.

Acknowledgments. We would like to thank Dr. Andrew Williams, Museum of Comparative Zoology, Cambridge, Massachusetts, USA for providing the

X-ray of the normal *O. niloticus* and Taiwan Fish Data Base for using the X-ray of *Acanthopagrus arabicus*.

Ethical statement. This work is based on commercial fish species, and the specimens were collected from a commercial catch. Therefore, ethical aspects are not applicable.

Conflicts of interest. The authors declare that they have no conflicts of interest.

Author contributions. L.A.J. developed the research idea and wrote the manuscript with input from all authors; J.M.A. collected the samples and partially analyzed data; and M. A. A. assisted in specimen collection and data analysis.

Data availability statement. The data underlying this article will be shared upon reasonable request to the corresponding author.

ORCID iD

Laith Jawad https://orcid.org/0000-0002-8294-2944

Jassim M. Abed https://orcid.org/0000-0002-5458-0421

Mujtaba Ankush https://orcid.org/0000-0002-4703-2224

References

Abdullah, A.D., Masih, I., van der Zaag, P., Karim, U.F., Popescu, I., Al Suhail, Q. (2015). Shatt al Arab River system under escalating pressure: a preliminary exploration of the issues and options for mitigation. International Journal of River Basin Management, 13(2), 215-227.

Al-Aboodi, A.H., Abbas, S.A., Ibrahim, H.T. (2018). Effect of Hartha and Najibia power plants on water quality indices of Shatt Al-Arab River, south of Iraq. Applied Water Science, 8, 1-10.

Al-Asadi, S.A., Al-Qurnawi, W.S., Al Hawash, A.B., Ghalib, H.B., Alkhlifa, N.H.A. (2020). Water quality and impacting factors on heavy metals levels in Shatt Al-Arab River, Basra, Iraq. Applied Water Science, 10(5), 1-15.

Alavi-Yeganeh, M.S., Razavi, S., Egan, J.P. (2019). Taillessness and skeletal deformity in striped piggy *Pomadasys stridens* (Osteichthyes: Haemulidae) from the Persian Gulf. Diseases of Aquatic Organisms, 132(3), 209-213.

Allafta, H., Opp, C. (2020). Spatio-temporal variability and pollution sources identification of the surface sediments of Shatt Al-Arab River, Southern Iraq. Scientific Reports, 10(1), 6979.

Almatar S., Chen W. (2010). Deformities in silver pomfret Pampus argenteus caught from Kuwait waters. Chinese Journal of Oceanology and Limnology, 28, 1227-1229.

Bailey, R.G. (1994). Guide to the fishes of the River Nile in the Republic of the Sudan. Journal of Natural History, 28 (4), 937-970.

Bauchot, M.-L., Smith, M.M. (1984). Sparidae. In: FAO species identification sheets for fishery purposes. Western Indian Ocean. Fishing Area 51 (Ed.) W. Fischer, G. Bianchi FAO Fisheries Department, Rome, Italy.

Bengtsson, A., Bengtsson, B.E., Lithner G. (1988). Vertebral defects in fourhorn sculpin, *Myoxocephalus quadricornis* L., exposed to heavy metal pollution in the Gulf of Bothnia. Journal of Fish Biology, 33(4), 517-529.

Boglione, C., Marino, G., Bertolini, B., Rossi, A., Ferreri, F., Cataudella, S. (1993). Larval and postlarval monitoring in sea bass: morphological approach to evaluate finfish seed quality. In: Production, Environment and Quality (Ed.) G. Bamabe, P. Kestemont, European Aquaculture Society. Special Publication No. 18, Ghent, Belgium: 189-204.

Breder, C.M., Rosen, D.E. (1966). Modes of reproduction in fishes. T.F.H. Publications, Neptune City, New Jersey, 941 p.

Browder, J.A., & McClellan, D. B., Harper, D.E., Kandrashoff M.G. (1993). A major developmental defect observed in several Biscayne Bay, Florida, fish species. Environmental Biology of Fishes, 371 (1), 181-188.

Dunham, R. A., Smitherman, R. O., Bondari, K. (1991). Lack of inheritance of stumpbody and taillessness in channel catfish. Progressive Fish Culturist, 53 (2), 101-105.

Eccles, D.H. (1992). FAO species identification sheets for fishery purposes. Field guide to the freshwater fishes of Tanzania. Prepared and published with the support of the United Nations Development Programme (project URT/87/016). FAO, Rome. 145 p.

Frimodt, C. (1995). Multilingual illustrated guide to the world's commercial warmwater fish. Fishing News Books, Osney Mead, Oxford, England. 215 p.

Galván-Magaña, F., Rodríguez-Romero, J., Abitia-Cárdenas, L.A. (1994). First record of abnormal vertebral column in the green bar snapper *Hoplopagrus guentheri* (Osteichthyes: Lutjanidae). Revista de Biología Tropical, 42(1-2), 388-389.

Georgakopoulou, E., Katharios, P., Divanach, P., Koumoundouros, G. (2010). Effect of temperature on the development of skeletal deformities in gilthead sea bream (*Sparus aurata* Linnaeus, 1758). Aquaculture, 308 (1), 13-19.

Gunter, G., Ward, J.W. (1961). Some fishes that survive extreme injuries, and some aspects of tenacity of life. Copeia, 4, 456-462.

Heintz, R. A., Short, J. W., Rice, S. D. (1999). Sensitivity of fish embryos to weathered crude oil. II. Increased mortality of pink salmon (*Oncorhynchus gorbuscha*) embryos incubating downstream from weathered Exxon Valdez crude oil. Environmental Toxicology and Chemistry, 18(3), 494-503.

Honma, Y. (1994). Droplets from the Sado Marine Biological Station, Niigata University-VII. Further notes on some anomalous fishes. Report of the Sado Marine Biological Station, Niigata University, 24 (1), 11-21.

Hussain, N.A., Abdullah, M.A.S. (1977). The length-weight relationship, spawning season and food habits of six commercial fishes in Kuwaiti waters. Indian Journal of Fisheries, 24(1/2), 181-194.

IGFA (2001). Database of IGFA angling records until 2001. IGFA, Fort Lauderdale, USA.

Jawad, L. A., Fjelldal, P. G., Hansen, T. (2018a). First report on vertebral abnormality in the fivebeard rockling *Ciliata mustela* (Linnaeus, 1758) (Osteichthyes: Lotidae) from Masfjorden, Western Norway. Marine Biodiversity, 48, 957-961.

Jawad, L. A., Ibrahim, M., Waryani, B. (2018b). Incidences of caudal fin malformation in fishes from Jubail City, Saudi Arabia, Arabian Gulf. Fisheries & Aquatic Life, 26(1), 65-71.

Kessabi, K., Annabi, A., Hassine, A. I. H., Bazin, I., Mnif, W., Said, K., Messaoudi, I. (2013). Possible chemical causes of skeletal deformities in natural populations of *Aphanius fasciatus* collected from the Tunisian coast. Chemosphere, 90 (11), 2683-2689.

Koo, T.S.T., Johnston, M.L. (1978). Larva deformity in striped bass, Morone *saxatilis* (Walbaum), and blueback herring, *Alosa aestialis* (Mitchell), due to heat shock treatment of developing eggs. Environmental Pollution, 16(2), 137-149

Koumoundouros, G. (2010). Morpho-anatomical abnormalities in Mediterranean marine aquaculture – In: Recent Advances in Aquaculture Research (Ed.) G Koumoundouros, Transworld Research Network, Kerala, India, 125-148.

Koumoundouros, G., Gagliardi, F., Divanach, P., Boglione, C., Cataudella, S., Kentouri, M. (1997). Normal and abnormal osteological development of caudal fin in *Sparus aurata* L. fry. Aquaculture, 149(2), 215-226

Kurokawa, T., Okamoto, T., Gen, K., Uji, S., Murashita, K., Unuma, T., Nomura, K., Matsubara, H., Kim, S.K., Ohta, H., Tanaka, H. (2008). Influence of water temperature on morphological deformities in cultured larvae of Japanese eel, *Anguilla japonica*, at completion of yolk resorption. Journal of the World Aquaculture Society, 39(6), 726-735.

Lamboj, A. (2004). The Cichlid Fishes of Western Africa. Birgit Schmettkamp Verlag, Bornheim, Germany. 255 p.

Lauder, G.V. (2000). Function of the caudal fin during locomotion in fishes: kinematics, flow visualization, and evolutionary patterns. American Zoologist, 40(1), 101-122.

Mohamed, A.R.M., Hussein, S.A., Lazem, L.F. (2015). Spatiotemporal variability of fish assemblage in the Shatt Al-Arab River, Iraq. Journal of Coastal Life Medicine, 3(1), 27-34.

Moyel, M.S., Hussain, N.A. (2015). Water quality assessment of the Shatt al-Arab river, Southern Iraq. Journal of Coastal Life Medicine, 3(6), 459-465.

Noakes, D.G.L., Balon, E. K. (1982). Life histories of tilapias: an evolutionary perspective. In: The biology and culture of tilapias (Ed.) R.S.V. Pullin, R.H. Lowe McConnell, ICLARM Conference Proceedings No. 7, 61-82.

Okamoto, T., Kurokawa, T., Gen, K., Murashita, K., Nomura, K., Kim, S.K., Matsubara, H., Ohta, H., Tanaka, H. (2009). Influence of salinity on morphological deformities in cultured larvae of Japanese eel, *Anguilla japonica*, at completion of yolk resorption. Aquaculture, 293(1-2), 113-118.

Orlov, A.M. (2011). Record of a tailless Richardson's ray *Bathyraja richardsoni* (Garrick, 1961) (Rajiformes: Arhynchobatidae) caught off the Mid-Atlantic ridge. Pan-American Journal of Aquatic Sciences, 6(3), 232-236.

Philippart, J.-C., Ruwet, J.-C. (1982). Ecology and distribution of tilapias. In: The biology and culture of tilapias (Ed.) R.S.V. Pullin, R.H. Lowe McConnell, ICLARM Conference Proceedings No. 7, 15-59.

Randall, J.E. (1995). Coastal fishes of Oman. University of Hawaii Press, Honolulu, Hawaii. 439 p.

Ribeiro-Prado, C.C.R., Oddone, M.C., Gonzalez, M.M.B., de Amorim, A.F., Capapé, C. (2008). Morphological abnormalities in skates and rays (Chondrichthyes) from off southeastern Brazil. Arquivos de Cięncias do Mar, 41(2), 21-28.

Riede, K. (2004). Global register of migratory species - from global to regional scales. Final Report of the R&D-Projekt 808 05 081. Federal Agency for Nature Conservation, Bonn, Germany. 329 p.

Schäperclaus, W., Kulow, H., Schreckenbach, K. (1992). Fish Disease. A.A. Balkema, Rotterdam, the Netherlands.

Sfakianakis, D. G., Renieri, E., Kentouri, M., Tsatsakis, A. M. (2015). Effect of heavy metals on fish larvae deformities: a review. Environmental Research, 137(1), 246-255.

Slooff, W. (1982). Skeletal anomalies in fish from polluted surface waters. Aquatic Toxicology, 2(3), 157-173.

Sun, P. L., Hawkins, W. E., Overstreet, R. M., Brown-Peterson, N. J. (2009). Morphological deformities as biomarkers in fish from contaminated rivers in Taiwan. International Journal of Environmental Research and Public Health, 6(8), 2307-2331.

Trewavas, E., Teugels, G. G. (1991). Oreochromis. In: Checklist of the freshwater fishes of Africa (CLOFFA) (Ed.) J.

Daget, J.-P. Gosse, G.G. Teugels, D.F.E. Thys van den Audenaerde (eds.). ISNB, Brussels; MRAC, Tervuren; and ORSTOM, Paris. Vol. 4, 307-346.

Trewavas, E. (1983). Tilapiine fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*. British Mus. Nat. Hist., London, UK. 583 p.

Tyler, J. C., Johnson, G. D., Jawad, L., Brothers, E. B. (2014). A developmentally 'tail-less' adult cowfish, *Lactoria cornuta*, from Oman (Ostraciidae, Tetraodontiformes). Proceedings of the Biological Society of Washington, 127(2), 311-322

van Oijen, M.J.P. (1995). Appendix I. Key to Lake Victoria fishes other than haplochromine cichlids. In: Fish stocks and fisheries of Lake Victoria. A handbook for field observations (Ed.) F. Witte, W.L.T. van Densen, Samara Publishing Limited, Dyfed, Great Britain, 209-300.

Vethaak, A.D., Ap Rheinallt, T. (1992). Fish disease as a monitor for marine pollution: the case of the North Sea. Reviews in Fish Biology and Fisheries, 2(1), 1-32.

Von Westernhagen, H., Dethlefsen, V. (1997). The use of malformations in pelagic fish embryos for pollution assessment. Hydrobiologia, 352(1), 241-250.

Wassenberg, D.M., Nerlinger, A.L., Battle, L. P., Di Giulio, R.T. (2005). Effects of the polycyclic aromatic hydrocarbon heterocycles, carbazole and dibenzothiophene, on in vivo and in vitro cypia activity and polycyclic aromatic hydrocarbon-derived embryonic deformities. Environmental Toxicology and Chemistry: An International Journal, 24(10), 2526-2532.

Webb, P.W. (1977). Effects of median-fin amputation on fast-start performance of rainbow trout (*Salmo gairdneri*). Journal of Experimental Biology, 68(1), 123-135.

Weihs, D. (1972). A hydrodynamical analysis of fish turning manoeuvres. Proceedings of the Royal Society of London. Series B. Biological Sciences, 182(1066), 59-72.

Whitfield, A.K., Elliott, M. (2002). Fishes as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future. Journal of Fish Biology, 61(1), 229-250.

Wudneh, T. (1998). Biology and management of fish stocks in Bahir Dar Gulf, Lake Tana, Ethiopia. Ph.D. thesis, Wageningen Agricultural University, The Netherlands, 144 p.