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Review Article

A Review of Fish Anomalies in Türkiye's Waters

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ABSTRACT

In recent years, anomaly studies have increased in number, covering both individual cases and their effects on natural populations and farmed species. However, in the literature review, no current study has been found to compile the types and cases of anomalies encountered in species found in Türkiye's waters. In the context of this review, 34 articles and symposium proceedings were found to belong to fish anomalies in Türkiye's waters. In these studies, 62 individuals from 38 species and 20 families from different water bodies were detected to have at least one anomaly type that is included in this review. According to the literature, possible factors causing anomalies can be discussed under four general headings; environmental (anthropogenic factors, industrial activities, industrial chemicals, trace elements, pollution, light intensity, pesticide usage), biological (endocrine system, genetic, teratological cases, epigenetic, nutritional problems, parasitic or physiologic reasons, oxidative stress, pigment deficiency), ecological (attacked by carnivores, competition, changes in water parameters), and fishery-related (ghost fishing). This review also presents some possible causes of particular anomaly types in detail. It is thought that with the information provided, this review may establish an up-to-date basis for future studies.

Keywords: Fish anomaly, environmental factors, genetics, nutrition

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INTRODUCTION

The deterioration of water resources due to urbanization and intensification of anthropogenic activities have raised global concerns regarding environmental sustainability (Giora et al., 2022). The health of the organisms in an ecological system typically determines the biotic entirety of the system. Species in aquatic ecosystems, particularly those at the top of the food chain, are often seen as representative indicators of the overall health of the ecosystem. Fish contribute to the nutrition of billions of consumers by providing rich sources of vitamins, minerals, fatty acids, and high-quality proteins (Belton et al., 2018).

In addition, because of their location in the food chain, fish combine the effects of many biotic and abiotic variables in the system and represent the secondary effects of chronic stress transferred through the food chain (Adams & McLean 1985). Unusual developmental disorders associated with deteriorating environmental conditions threaten the marine environment, fisheries, and community health (Mavruk et al., 2015).

Fish anomalies were identified and documented for the first time in a three-volume bibliography published by Dawson (1964; 1966; 1971 in Ugbomeh et al., 2022). There are two main types of anomalies in fish: severe, which can affect the condition of the animal, and minor anomalies, which have little or no effect on the survival of the fish (Jawad & Akyol, 2018). The dominant morphological abnormalities in fish may be divided into a few major classes, including the skeleton, body shape, scales, otoliths, and pigmentation (Uzer & Karakulak, 2022).

Aquaculture Anomalies

Morphological and skeletal abnormalities observed in aquaculture are the main problems because they affect the esthetic appeal of fish, reduce their market value by affecting their growth and survival, and decrease the performance of fish grown in hatcheries, such as swimming ability, feed consumption, and susceptibility to pathogens (Çoban et al., 2016). Malformations in fish are caused by environmental factors, nutritional deficiencies, livestock conditions, and genetic factors (Lewis et al., 2004).

The literature defines three primary spinal conditions: lordosis (dorsal deformity, V shape), scoliosis (lateral deformity, zig-zag shape), and kyphosis (ventral deformity, Λ shape) (Afonso et al., 2000). In reared fish, vertebral column deformity is an important factor in economic loss because it adversely affects the external morphology, growth, and survival of the fish, reducing the quality of the fish. The survival of most fish species is largely influenced by their swimming performances (Plaut, 2001). The relationship between lordosis severity and swimming performance in juvenile sea bass was investigated by Başaran et al. (2009), who demonstrated that spinal angles affect swimming performance in these species. Abnormal lordosis is frequently observed in dense cultures of *Sparus aurata*, and it affects biological functions such as swimming speed during feeding (Ortiz-Delgado et al., 2014). Scoliosis and lordosis are some of the most common problems in sea bass larvae and fry rearing in Türkiye (Tan et al., 2015). It has been reported that the prevalence of kyphosis is lower than that of lordosis (Jawad et al., 2017a).

Otoliths are required for hearing and hydro-dynamic balance (Popper et al., 2005). The otolith morphology, especially the sagittal otolith, is genus- and species-specific. It is widely used in taxonomic research and for the formation of phylogenetic relationships among different fish groups (Teimori et al., 2012). Abnormal otoliths have been reported in various fish from both marine and freshwater ecosystems (Sweeting et al., 2004). Manizadeh et al. (2018) examined fish samples from 83 species and 33 families from the Persian Gulf and the Gulf of Oman and found that 4.8% of the fish had abnormal otoliths. Ecologically, the Persian Gulf has been recognized as one of the most stressful environments in terms of salinity fluctuation (>39‰), acidification, and water temperature (12 to 38°C) (Bauman et al., 2013). These stressors likely affect otolith formation during the larval stages of these fish and have been accepted as possible causes of the abnormalities observed in the study.

Another anomaly observed in fish concerns pigmentation. The role of skin pigmentation is significant in camouflage, thermoregulation, photoprotection, and mate selection; nonetheless, it is one of the quality criteria that determines its market value for both human consumption and ornamental use (Cal et al., 2017). The pigmentation pattern of fish can be altered by nutritional quality, UV light incidence, light intensity, and social interactions (Kumar et al., 2023). The first documented abnormal pigmentation in the Aegean Sea was reported by Akyol and Şen (2012).

İlkyaz and Tosunoğlu (2019) reported findings of partial albinism observed in a blue crab sampled at Köyceğiz Lagoon (Muğla, Türkiye). The authors mentioned that the underlying cause of the incident might be genetic, leading to the absence of pigments.

It is unclear why pigment abnormalities occur, but the most likely cause is the interaction between genetic and environmental factors (Kumar et al., 2023).

It has been indicated that abnormalities in some fish species can be reduced through rearing practices, such as the application of appropriate feeding regimes and optimization of environmental conditions (Fjelldal et al., 2006). It is emphasized that developing protocols for the early identification of this ailment will enhance quality monitoring in commercial hatcheries because the majority of skeletal malformations occur in the larval and juvenile stages (Çolak & Çanak 2020).

Anomalies in Natural Environments

Natural aquatic environments pose various conditions (temperature fluctuations, decrease in the amount of dissolved oxygen, food shortage, etc.) that can challenge fish. The presence of anomalies in fish has been a source of interest for researchers since the sixteenth century, and since then, several studies have documented the presence of different types of anomalies in wild fish (Rutkayová et al., 2016). Abnormalities in wild fish are usually encountered because of fishing activities and scientific research. The high incidence of abnormal fish in polluted areas can serve as a sign of water pollution (Jawad et al., 2018a).

Dağlı (2008) reported that the ventral fin of *Capoeta damascina* from the family Cyprinidae is reduced and this region is completely covered with scales. In addition, in *Garra variabilis* belonging to the same family, he determined that while the rays of the left ventral fin developed in the form of protrusions, those of the right ventral fin were underdeveloped and completely covered with scales. It is thought that the underdevelopment of the ventral fins and arches of *C. damascina* may be due to mutations, whereas the partial underdevelopment of the ventral fins of *G. variabilis* may be due to parasitic or physical causes.

İnnal et al. (2019) aimed to determine skeletal deformations in natural populations of *Barbus pergamonensis* inhabiting the Dalaman Stream. According to the study, kyphosis can be induced in natural populations of *B. pergamonensis* by exposure to environmental pollutants.

Heavy metals are considered the main cause of many fish anomalies (Jawad & Ibrahim, 2021). The aquatic environment and its inhabitants are threatened when heavy metal concentrations exceed safe limits. Heavy metal toxicity has been linked to decreased gonadosomatic index values, fertility, hatchability, fertilization success, abnormal reproductive organ shape, and reproductive failure in fish (Taslima et al., 2022).

The aforementioned deformities are linked to genetic and epigenetic factors (Nguyen et al., 2016). Environmental parameters such as salinity, fluctuations in water temperature, organic compounds, oxygen, radiation, heavy metals, wastes of industrial origin, stress, food deficiency, parasitism, and other pollutants are among the remarkable epigenetic factors (Kolarevic et al., 2013). Moreover, pollution is a valuable indicator of the frequency of deformities in fish (Boglione et al., 2013).

The cited literature contains many terms (anomaly, abnormality, aberration, malfunction, malformation, etc.) that can be confusing for readers in certain situations. To prevent term chaos and make it easier to read the text, these terms were grouped together as "anomaly" in the entire text. In this study, we reviewed studies on fish anomalies and the causes of anomalies in Türkiye's marine, fresh, and brackish waters. To understand the diverse fish anomalies that can be encountered in Türkiye's waters and their differences from healthy individuals, visual materials from the literature were collected.

MATERIAL AND METHODS

The literature was separated into three sections by marine, freshwater, and brackish water and scanned with keywords such as fish anomaly, abnormality, aberration, malfunction, malformation, Türkiye, Anatolia, Black Sea, Aegean Sea, Sea of Marmara, and Mediterranean. References from the literature were also sought. Species, anomalies, possible causes, regions, and fishing gear in the papers were detected and ordered.

RESULTS AND DISCUSSION

In the literature, 34 articles and symposium proceedings were found relating to fish anomalies in Türkiye's waters. According to studies, 38 species, 20 families, and 62 individuals from different water bodies were detected (Table 1).

In these articles, 62 anomaly records were provided by researchers from Türkiye's marine, freshwater, and brackish waters. The Aegean Sea was considered the location of most detected anomalies (20 records). The Black Sea (5 records), Mediterranean (5 records), and Sea of Marmara (4 records) also had certain cases of fish anomalies. On the other hand, while 12 records concerning freshwater species have been found that belong to 7 studies, only one crustacean (*Callinectes sapidus*) has been reported from brackish water (Figure 1).

According to the literature, Soleidae had the most anomaly (12 records) records among marine fish families. On the other hand, in freshwater, Cyprinidae dominated (9 records) the other freshwater families in terms of anomalies presence (Figure 2).

According to the literature, the most anomalous finding was found in *Solea solea* (8 records). Additionally, *Barbus xanthos* has the most anomaly studies in Türkiye's freshwater (Figure 3).

In addition, 10 different anomaly types were determined. The most frequently observed anomaly type is an otolith anomaly (12 records). It was followed by skeletal (11 records), pigmentation anomalies (8 records), and head (7 records) (Figure 4).

Studies have shown that trawling and trammel nets are the most common methods to come across individuals with anomalies, respectively (Figure 5).

Fish can be affected by different diseases and disorders caused by either living or non-living agents. Infectious organisms that are both communicable and pathogenic are among the living agents of diseases. Bacterial, fungal, viral, and parasitic organisms commonly cause diseases in fish. Fish health can be negatively impacted by non-living agents that may come from the fish's interior or exterior. Normal physiological processes can be

Table 1. Literature summary of anomalies in fish species and their regions.

The order of studies in Figure 1	Species	Types of anomalies/ abnormalities/ deformities	Possible causes	Region	Fishing gear	Researcher(s)
			Marine			
1	*Solea solea*	Abnormal pigmentation (Ambicoloration)	Light intensity, Feeding during the larval stages Neurological aspects such as hormones (i.e. endocrine system) Genetic factors Environmental stressors Environmental contamination of sediments (Anthropogenic and industrial activities)	İzmir Bay, Aegean Sea	Trammel net	Akyol and Şen (2012)
2	*Raja clavata*	Nose and tail deformation	Ghost fishing	Çandarlı Bay, Aegean Sea	Trawl	Akyol and Aydın (2018)
3	*Liza ramada*	Hermaphroditism	Industrialization Pesticide usage Environmental pollution (effect on hormonal balance)	İzmir Bay, Aegean Sea	Gillnet	Bayhan and Acarlı (2006)
4	*Liza ramada*	Caudal fin anomaly	Domestic and industrial chemicals	İzmir Bay, Aegean Sea	Gillnet	Bayhan et al. (2010)

Table 1. Continue.

The order of studies in Figure 1	Species	Types of anomalies/ abnormalities/ deformities	Possible causes	Region	Fishing gear	Researcher(s)
			Marine			
5	*Raja clavata* *Raja clavata*	Disc asymmetry Caudal fin anomaly	Fishery related Trace elements Teratological cases Accidental (in early life stages)	İzmir Bay, Aegean Sea	Trawl Trawl	Capapé et al. (2018)
6	*Solea solea* *Solea solea*	Hypomelanosis Dorsal fin anomaly	Environmental and/or anthropogenic causes	Güllük Bay, Aegean Sea	Trammel net Trammel net	Cerim et al. (2016)
7	*Pagellus erythrinus*	Saddleback syndrome Pughead	Environmentally induced stress	Gerence Bay, Aegean Sea	Trawl	Jawad et al. (2017b)
8	*Atherina boyeri*	Lordosis Kyphosis	Genetics	İzmir Bay, Aegean Sea	Beach seine	Jawad et al. (2017a)
9	*Conger conger*	Caudal fin deformity	Viral, bacterial, or environmental pollution	Çandarlı Bay, Aegean Sea	Trawl	Jawad et al. (2018a)
10	*Mullus barbatus*	Vertebral coalescence Vertebral deformity Hyperostosis	Environmental and genetic factors	İzmir Bay, Aegean Sea	Trammel net	Jawad and Akyol (2018)
11	*Trachurus mediterraneus*	Conjoined twinning	Pollution	Bandırma Bay, Sea of Marmara	Hensen Net (500µm)	Mavruk et al. (2015)
12	*Raja polystigma*	Morphologic deformation (head)	?	İzmir Bay, Aegean Sea	Trawl	Metin et al. (2009)
13	*Lophius budegassa*	One-eyed	Environmental or genetic factors Attacked by other carnivores (in early life stages)	Karaburun offshore, Aegean Sea	Trawl	Şenbahar and Özaydın (2019)
14	*Mullus surmuletus*	Abnormal pigmentation	Environmental contamination of sediments (Anthropogenic and industrial activities)	İzmir Bay, Aegean Sea	Trawl	Tokaç et al. (2013)
15	*Dicologolossa cuneata* *Scophthalmus maeoticus*	Albinism Xanthochroism Ambicoloration	? ? ?	İzmir Bay, Aegean Sea Black Sea coast of Istanbul	Trammel net Trawl Gillnet	Ulutürk et al. (2015)
16	*Merluccius merluccius*	One-eyed	Fishery related Competition during the early life stages Genetics Pollution	İzmit Bay, Sea of Marmara	Gillnet	Uzer and Karakulak (2022)
17	*Lophius budegassa*	Aberrant otolith morphology	Changing water parameters Pollution	Sea of Marmara	Angling	Yedier and Bostanci (2019)

Table 1. Continue.

The order of studies in Figure 1	Species	Types of anomalies/ abnormalities/ deformities	Possible causes	Region	Fishing gear	Researcher(s)
			Marine			
18	*Pagellus acarne*	Aberrant otolith morphology	Pollution	Sea of Marmara	Angling	Yedier and Bostanci (2020)
	Trachurus mediterraneus			Black Sea	Angling	
	Diplodus puntazzo			Aegean Sea	Angling	
	Merlangius merlangus			Black Sea	Angling	
19	*Dicentrarchus labrax*	Gonadal anomaly	Environmental pollution Genetics	Güllük Bay, Aegean Sea	Trammel net	Cerim et al. (2018)
	Solea solea				Trammel net	
20	*Solea solea*	Lateral line anomaly	?	Güllük Bay, Aegean Sea	Trammel net	Cerim et al. (2021)
	Solea solea	Caudal fin anomaly			Trammel net	
21	*Microchirus ocellatus*	Otolith deformation	Environmental and/or anthropogenic causes	Güllük Bay, Aegean Sea	Trawl	Cerim et al. (2019)
	Solea solea				Trawl	
28	*Merluccius merluccius*	Pughead deformity	Genetic and epigenetic causes		Trawl	Jawad et al. (2018b)
32	*Serranus hepatus*	Pugheadedness and ankylosis	Environmental factors	Sea of Marmara	Trawl	Jawad et al. (2022a)
	Mullus surmuletus	Lordosis-kyphosis			Trawl	
	Merluccius merluccius	Pugheadedness			Trawl	
	Trachurus trachurus	Abnormal body			Trawl	
	Trachurus trachurus	lordosis-kyphosis			Trawl	
	Trachurus trachurus	Pugheadedness			Trawl	
33	*Lepidorhombus boscii*	Abnormal otoliths	Pollution, nutritional problems, stress, and environmental factors	Aegean Sea	Trawl	Yedier et al., (2023)
	Platichthys flesus			Black Sea	Trawl	
	Solea solea			Mediterra-nean Sea	Trawl	
	Pegusa lascaris			Black Sea	Trawl	
29	*Champsodon nudivittis*	Otolith anomaly	Environmental factors	Aegean Sea	Trawl	Cerim et al., (2022)
	Mullus surmuletus	Skeletal anomaly	Environmental factors		Trawl	
34	*Chelon auratus*	Otolith asymmetry	Ecological issues, like water temperature, salinity, and pollut-ants.	Köyceğiz Lagoon, Muğla	Fish bar-riers	Reis et al. (2023)
	Chelon labrosus					
	Chelon saliens					
	Mugil cephalus					

Table 1. Continue.

The order of studies in Figure 1	Species	Types of anomalies/ abnormalities/ deformities	Possible causes	Region	Fishing gear	Researcher(s)
			Freshwater			
22	*Garra variabilis* *Capoeta damascina*	Ventral fin anomaly	Genetics Parasitic or physical reasons	Balıksuyu creek, Kilis Afrin creek, Kilis	? ?	Dağlı (2008)
23	*Barbus pergamonensis*	Kyphosis	Environmental pollutants	Dalaman Stream, Burdur	Electro-fishing	İnnal et al. (2019)
24	*Alburnus tarichi*	Abnormal ovary	Oxidative stress	Lake Van	Cast nets	Özok et al. (2017)
25	*Chalcalburnus tarichi*	Abnormal gonads	Polluting chemicals or other unknown factors (such as global warming)	Karasu river and Lake Van	?	Ünal et al. (2007)
30	*Salaria fluviatilis (3 specimens)*	Pectoral and pelvic fin deformity	Environmental factors	Kızılırmak River	Electro-fishing	Jawad et al., (2022b)
31	*Barbus xanthos (4 specimens)*	Skeletal deformities	Environmental factors	Dalaman River	Electro-fishing	Jawad and Güçlü (2022)
			Crustacea			
26	*Callinectes sapidus*	Albinism	Pigment deficiency, genetic origin, or both.	Köyceğiz Lagoon, Muğla	Trap	İlkyaz and Tosunoğlu (2019)
27	*Pontastacus leptodactylus*	Albinism	Genetics	Atikhisar Reservoir, Çanakkale	Fyke net	Kale et al. (2020)

affected by external factors, such as environmental conditions, resulting in disease. Endogenous factors, like their genetic composition, may have an impact on fish's susceptibility to less-optimal environmental conditions or infectious agents. different fish species, as well as specific strains within a particular species, exhibit diverse tolerance to different environmental conditions and pathogens (Wiegertjes et al., 1996).

The changes in biology/physiology of fish due to the effectors briefly mentioned above may reflect on the phenotype of fish either as an unusual appearance or an altered behaviour. As a very well-established example, disorders affecting the coloration of fish and other water-related species can be described. Coloration plays a crucial role in the connection between an organism and its environment. It serves as a means of communication, protection from predators, defense against parasites, regulation of body temperature, and protection against UV light, bacteria, and physical damage (Cuthill et al., 2017). The cases included in the current study display various types of coloration-related anomalies, such as ambicoloration (*S. solea*, *Scophthalmus maeoticus*), albinism (*Dicologolossa cuneata*), xanthochroism (*D. cuneata*), and abnormal pigmentation (*Mullus surmuletus*). Disorders involving the melanin pigmentary system are often linked to genetic abnormalities (Muto et al., 2013), specifically arising from mutations in the tyrosinase gene family. These mutations can affect the enzymes responsible for the production of melanin, leading to an imbalance in the body's pigment metabolism (Wang et al., 2007).

Champsodon nudivittis, *Chelon auratus*, *Chelon labrosus*, *Chelon saliens*, *Mugil cephalus*, *Lepidorhombus boscii*, *Platichthys flesus*, *S. solea*, *Microchirus ocellatus*, *Lophius budegassa*, *Pagellus acarne*, *Trachurus mediterraneus*, *Diplodus puntazzo*, *Merlangius merlangus*, and *Pegusa lascaris* are species with otolith anomalies (most of which being otolith asymmetry) cases covered in the context of this study. The formation of otoliths in embryos occurs as a cluster of precursor particles attached to saccular epithelial tissue (Riley et al., 1997). The cumulative nature of the increment bands can be used to determine the age and changes in somatic growth of individual fish using increment numbers and widths (Campana & Neilson, 1985). The process of validating the deposition of annual and daily increments is a fundamental component of effective fisheries management, as well as age and growth studies (Devries & Frie, 1996). The expression of otolith proteins and increment growth are influenced by thyroid hormone activity, as shown in numerous studies (Coffin et al., 2012). On the other hand, carbonic anhydrase activity is considered to have a regulatory function in otolith growth in terms of both size and symmetry (Thomas & Swearer, 2019). Trace and minor elements as constituents of their aquatic environment also form the inorganic part of the otoliths, and these components may hint at the physicochemical nature of the organism's surroundings (Campana & Thorrold, 2001).

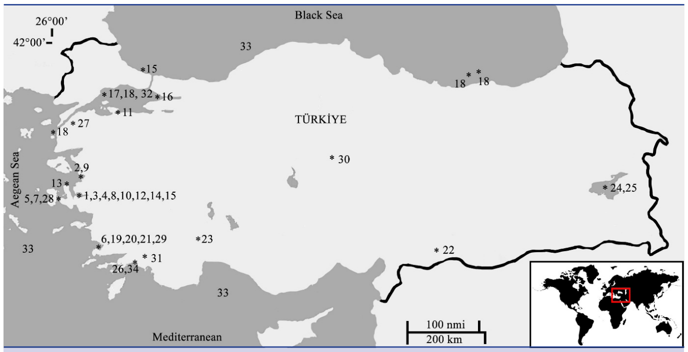

Figure 1. Anomaly studies in Türkiye 1- Akyol and Şen (2012), 2- Akyol and Aydın (2018), 3- Bayhan and Acarlı (2006), 4- Bayhan et al. (2010), 5- Capapé et al. (2018), 6- Cerim et al. (2016), 7- Jawad et al. (2017b), 8- Jawad et al. (2017a), 9- Jawad et al. (2018a), 10- Jawad and Akyol (2018), 11- Mavruk et al. (2015), 12- Metin et al. (2009), 13- Şenbahar and Özaydın (2019), 14- Tokaç et al. (2013), 15- Ulutürk et al. (2015), 16- Uzer and Karakulak (2022), 17- Yedier and Bostanci (2019), 18- Yedier and Bostanci (2020), 19- Cerim et al. (2018), 20- Cerim et al. (2021), 21- Cerim et al. (2019), 22- Dağlı (2008), 23- İnnal et al. (2019), 24- Özok et al. (2017), 25-Ünal et al. (2007), 26- İlkyaz and Tosunoğlu (2019), 27- Kale et al. (2020), 28- Jawad et al. (2018b), 29- Cerim et al. (2022), 30- Jawad et al. (2022b), 31-Jawad and Güçlü (2022), 32- Jawad et al. (2022a), 33- Yedier et al., (2023), 34- Reis et al. (2023).

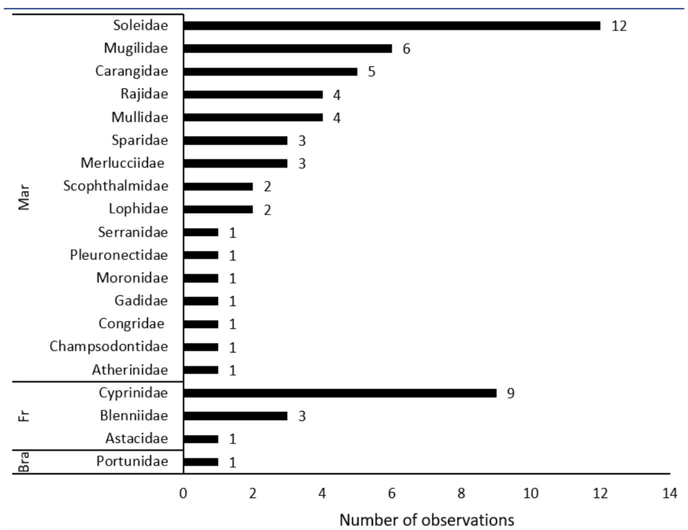

Figure 2. Number of anomaly studies in Türkiye's waters by family (Mar; Marine, Fr; Freshwater, Bra; Brackish water).

Raja clavata, *Liza ramada*, *S. solea*, *Pagellus erythrinus*, *Atherina boyeri*, *Conger conger*, *Mullus barbatus*, *Raja polystigma*, *Merluccius merluccius*, *Serranus hepatus*, *M. surmuletus*, *Trachurus trachurus*, *G. variabilis*, *C. damascina*, *B. pergamonensis*, *Salaria fluviatilis* (3 specimens), and *B. xanthos* (4 specimens) are speci-

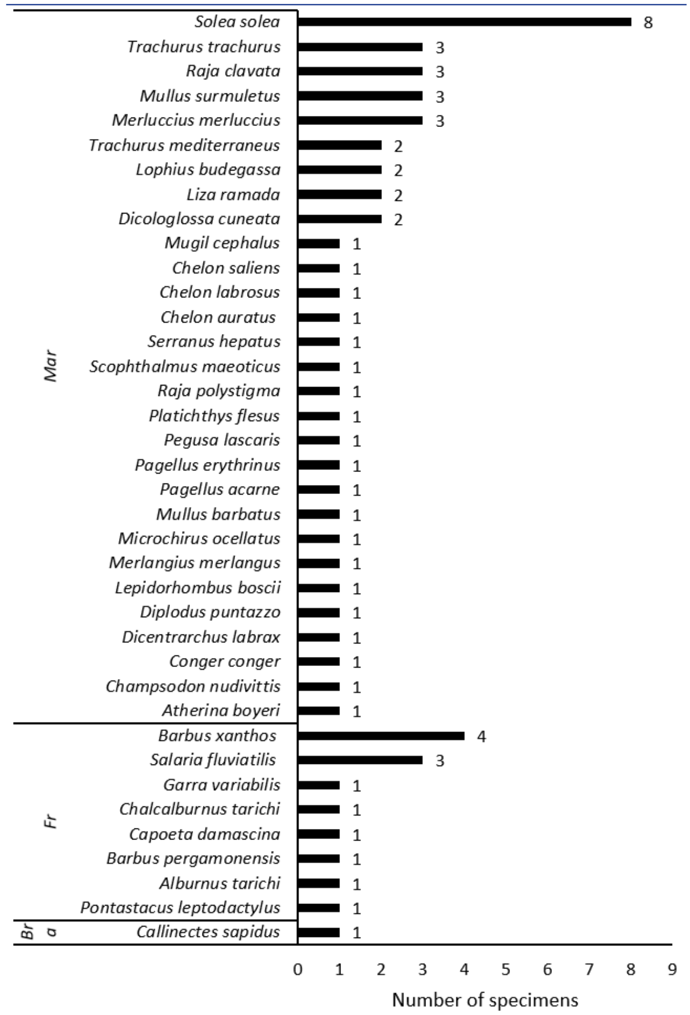

Figure 3. Number of anomaly studies in Türkiye's waters by species (Mar; Marine, Fr; Freshwater, Bra; Brackish water).

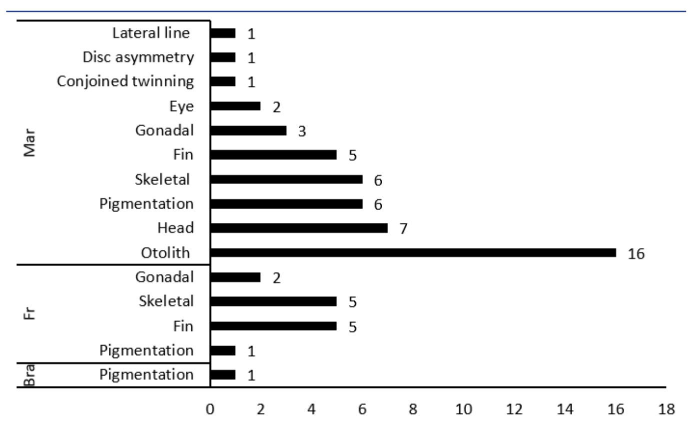

Figure 4. Anomaly types in Türkiye's waters (Mar; Marine, Fr; Freshwater, Bra; Brackish water).

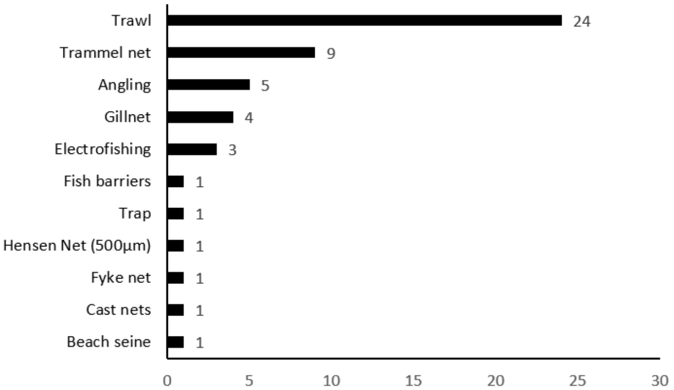

Figure 5. Number of capture methods used in the studies.

mens reported to have hard tissue deformities. These deformities are identified as nose and tail deformities, fin anomalies, vertebral deformities, pigheadedness, lordosis-kyphosis and hyperostosis. The etiology of skeletal anomalies, in general, is mentioned to have a relationship with incubation temperature (Sfakianakis et al., 2004), toxins like trifluralin (Wells & Cowan, 1982), treatment reagents like oxytetracycline (Toften and Jobling, 1996), infections (Madsen et al., 2001), deficiencies of or over-exposure to vitamins (vitamin C: Halver & Hardy, 1994) and minerals (selenomethionine: Kupsco & Schlenk, 2016), and genetic factors (Sadler et al., 2001).

Alburnus tarichi, *Chalcalburnus tarichi*, *T. trachurus*, *Dicentrarchus labrax*, *S. solea*, *M. merluccius*, *T. mediterraneus*, *R. polystigma*, *L. budegassa*, *and L. ramada* are reported to have various anomalies concerning the external and internal structures of specimens. Abnormal gonads and ovaries, abnormal body shape, lateral line anomaly, one-eyedness, conjoined twinning, head with morphological deformation, and hermaphroditism (intersex) are the deviations observed in these species. In the study of Jobling and Tyler (2003), the disruption of the endocrin system by chemicals, sub-optimal temperatures, food supply shortages, low pH, environmental pollutants, and parasites may alter the reproductive biology of fish. The masculinization of wild fish, meaning that female fish develop secondary sex characteristics to male fish, and other abnormal reproductive and developmental problems are some of the consequences of endocrine disorders in fish. The emergence of intersex cases throughout the fish populations is reported to alter sex steroid hormone profiles, thus affecting spawning times and resulting in reduced sperm production (Jobling et al., 2002). One-eyedness is also another case for the fish, and it is mentioned that in the development phase of fish embryos exposure to alkaloids might cause loss of eye(s) (McClendon, 1912). A more recent publication (Jones et al., 2017) on *Carcharhinus leucas* showed that postnatal trauma might be the background for lost eyes. Species' interactions with fishing gear or other sharks may also explain the loss of external structures.

The frequent occurrence of anomalies in certain families does not necessarily imply that the species are more exposed to the conditions that cause anomalies. According to the findings, a more logical explanation may be that species belonging to the Soleidae family (especially *S. solea*) have significant economic value, are constantly captured, and are thus seen in catch, and that many anomalies have been detected in these species. On the other hand, it can be said that species found in fresh water are exposed to more factors because they are found in perturbational, narrow, and specific water bodies, such as marine areas.

It can be seen that the majority of anomaly studies belong to studies conducted in the western regions of Türkiye (Figure 1). The reason for this may be more likely the capture method. Trawl nets allow for the catch of different sizes and larger amounts of fish compared to other fishing gear. For this reason, it is logical that in trawling, the number of individuals with anomalies in the trawl net coded is higher than that in other capture methods (i.e. mass capture of the species). Trawl nets and trammel nets are fishing gear generally used by commercial fishermen. Researchers either participate in fishing operations with commercial boats or perform these operations with their own research vessels on which trawl nets are generally used. On the other hand, although electrofishing and beach Seine are prohibited in Türkiye, researchers are allowed to do this for research projects with the permission of the Ministry of Agriculture and Forestry. In addition, Hansen net is also used for research.

CONCLUSION

According to the literature, possible factors causing anomalies can be discussed under four general headings; environmental (anthropogenic factors, industrial activities, industrial chemicals, trace elements, pollution, light intensity, pesticide usage), biological (endocrine system, genetic, teratological cases, epigenetic, nutritional problems, parasitic or physiologic reasons, oxidative stress, pigment deficiency), ecological (attacked by carnivores, competition, changes in water parameters), and fishery-related (ghost fishing). However, although the factors that cause anomalies are stated as is, further studies should be conducted with the mentioned factors to better understand their effects and consequences. If the origin of the factors is identified, some precautions can be taken to improve the health of the population.

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