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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Grading the Occurrence of Scoliosis Seen in Siberian Sturgeon (*Acipenser baerii* Brandt, 1869)

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Abstract: Scoliosis (lateral curvature of the spine) is a health problem that is encountered in fish. Swimming ability of fishes diagnosed with scoliosis is limited and therefore malnutrition occurs. Consequently, some health problems may encounter in these fishes. The aim of this study was to determine to what extent fishes diagnosed with scoliosis are affected from this disease by developing a grading method that can conduct physical measurements of scoliosis detected in Siberian sturgeon (*Acipenser baerii* Brandt, 1869). Our study was carried out on 34 scoliotic Siberian sturgeon individuals obtained from a commercial fish farm, 61.3±9.7 cm in length and 694.9±15.2 g in weight. According to this method that we have created to measure the degree of scoliosis in Siberian sturgeon, 1.0-18.9° was defined as the presence of scoliosis, 19° and above was defined as severe scoliosis. In the measured scoliotic fishes, were detected the presence of scoliosis in 14 fishes (41.18%) and severe scoliosis in 20 fishes (58.82%).

Keywords: *Acipenser baerii*, grading method, scoliosis, sturgeon.

Sibirya Mersin Balığı (*Acipenser baerii* Brandt, 1869)'ında Rastlanılan Skolyoz'un Derecelendirilmesi

Öz: Skolyoz (lateral omurga eğriliği) balıklarda rastlanılan bir sağlık sorunudur. Skolyoz gelişen balıkların fonksiyonel yüzme yetileri kısıtlanır ve bu nedenle beslenme yetersizliği oluşur. Bunun sonucunda ise balık sağlığında olumsuzluklar meydana gelmeye başlar. Bu çalışma ile Sibirya mersin balığı (*Acipenser baerii* Brandt, 1869) 'nda rastlanılan skolyoz'un fiziksel ölçümünün yapılabileceği bir derecelendirme metodu geliştirildi ve skolyozlu balıkların sağlıklarının ne oranda etkilendiği ortaya konuldu. Çalışmamız, ticari bir balık çiftliğinden elde edilen 61,3±9,7 cm uzunluğunda ve 694,9±15,2 g ağırlığında 34 skolyotik Sibirya mersin balığı üzerinde gerçekleştirildi. Sibirya mersin balığında skolyoz derecesini belirlemek için oluşturduğumuz bu yönteme göre; 1–18,9° arası skolyoz varlığı olarak tanımlandı, 19° ve üstü ise şiddetli skolyoz olarak tanımlandı. Derecesi ölçülen skolyotik 14 balıkta (% 41,18) skolyoz varlığı, 20 balıkta ise (% 58,82) şiddetli skolyoz olduğu tespit edildi.

Anahtar sözcükler: *Acipenser baerii*, derecelendirme yöntemi, skolyoz, mersin balığı.

INTRODUCTION

Due to the production of caviar, which is a luxury consumption material, natural stocks have started to decrease due to reasons such as overfishing and natural habitat destruction in sturgeons caught from nature. Sturgeon farming has been increasing in recent years to meet the present demand in the world (Bronzi et al., 2011). Scoliosis (lateral spine curvature) is a health problem that commonly seen in fishes due to intensive aquaculture conditions in fish farms and causes economic loss (Negrín-Báez et al., 2015). In fish, scoliosis can be caused by nutritional deficiencies, genetic factors, diseases, parasitism, vitamin and mineral deficiency, hypoxia, thermal shock, traumatic injuries during early development, stock intensity, and some environmental factors such as chemicals and pollutants (Silverstone & Hammell, 2002; Arbuatti et al., 2013; Baker et al., 2014; Hayes et al., 2014; Tomasiewicz et al., 2014). In recent years, due to the developing industry, water resources such as seas, lakes, and streams are polluted (Verep et al., 2017). Developing of scoliosis in the fishes restricts the ability of fish to functionally swimming and therefore occur malnutrition (Afonso et al., 2000). As nutritional deficiency also increases spinal deformities, an unwanted vicious cycle occurs. As a result of this, there may happen negativities in fish health and an increase in existing health problems start to come out. In aquaculture, lack of vitamin C causes spinal deformities (scoliosis, kyphosis, lordosis) and decreased growth rate (Cahu et al., 2003). To detect different skeletal patterns, spinal deformities in rainbow trout collected from fish farms were clinically diagnosed with radiographic and histopathological evaluations. Various fish skeletal deformities, including lordosis, kyphosis, scoliosis, vertebral fusion, with the inclusion of mandibular joint, have been reported in the examined fishes (Yadegari et al., 2011). In aquaculture the effects of the breeding conditions on the shape of the fishes are important. Altered outer morphology of the fish may affect the aquaculture, and the perception of the fish as a product can easily be rejected by the consumer (Losada et al., 2014). The maintenance of normal spine formation depends on the symmetry and balance of the muscles, the shapely spinal development, and the compatible functioning of functional feedback pathways. Failure any of these factors causes spinal deformities (Grimmett et al., 2011).

One of the common characteristics of humans and fish is that they have a vertebra that gives the name to this group. From the early embryonic period, the vertebral column sequences of these two groups show similarity. In addition, similar mechanical problems such as vertebral fusion, lordosis, kyphosis, and scoliosis can be seen in both groups (Schünke et al., 2007). Scoliosis is the deformity that occurs as a result of the deviation in the normal sequence of the spinal column. Although scoliosis is defined as a coronal plane deformity, rotation in a transverse plane, pathological lordosis and kyphosis are seen (Shaffrey et al., 2005). The most important obstacle to scoliosis-related animal studies is that an entirely appropriate model has not yet been found (Milcan, 2009).

The aim of this study was to determine to what extent fish diagnosed with scoliosis are affected from this disease by developing a grading method that could conduct physical measurements of scoliosis detected in Siberian sturgeon (*Acipenser baerii* Brandt, 1869).

MATERIAL and METHOD

Fish material: The study was carried out on 34 scoliotic Siberian sturgeon (*Acipenser baerii*) obtained from a commercial sturgeon farm, 61.3±9.7 cm in length and 694.9±15.2 g in weight. After the length and weight measurements were made, the fishes were brought as alive to the laboratory in Fish Diseases Department of Faculty of Aquaculture, Çukurova University for examination. Fishes were anesthetized with MS-222 for physical measurement and clinical examination (Imanpoor et al., 2010). In this study, the principles of local ethics committee were complied with.

Physical measurement: There are physical evaluation methods to measure scoliosis in the people beings. Cobb and Ferguson are the most frequently used methods (Pruijs et al., 1994). In these methods, often C or S (having 1 or 2 apexes) type scoliosis is defined (Cobb, 1948; Ferguson, 1930; Stokes et al., 1993). Multiple scoliosis is more frequently seen in the fishes (Yadegari et al., 2011). Therefore, one major and single apex is accepted as a reference in the grading system that we had been created. In our grading system, in which physical measurements can be conducted, a line connecting two points by marking neurocranium and scoliosis regions have created. The point on the neurocranium on the dorsal direction of the Siberian sturgeon is referred to as reference 1, also the midpoint of the area where the curvature is most severe in the medial region is marked as the apex. In addition, in a sub-segment following the apex, the midpoint of the curvature in the caudal region is marked as reference 2 (Figure 1). The degree of scoliosis is determined by measuring the angle formed by the intersection of these three points. According to this method that we have created to measure the degree of scoliosis in Siberian sturgeon, 1.0-18.9° was defined as the presence of scoliosis, 19° and above was defined as severe scoliosis. The spine in Siberian sturgeon (*Acipenser baerii*) was divided into three parts according to Leprévost et al., (2017). These were the cranial region enclosing the first 15 vertebrae, the medial region enclosing the 16^{th}-30^{th} vertebrae and the caudal region after the 31st vertebrae. If the apex was in the cranial region the right or left cranial scoliosis if the apex was in the medial region the right or left medial

scoliosis if the apex was in the caudal region the right or left caudal scoliosis were named.

Statistical analyses: Scoliosis measurements in the Siberian sturgeon were evaluated by using one-sample t-test analysis of variance (Düzgüneş et al., 1983).

RESULTS and DISCUSSION

The scoliosis grade varies were between 8° and 31° in the fish examined by physical measurements. The average of the scoliosis grade of the fishes examined was 18,82° ± 6,55°. In the measured scoliotic fishes, were detected the presence of scoliosis (1°-18,9°) in 14 fishes (41.18%) and severe scoliosis (19° and above) in 20 fishes (58.82%) (Table 1).

Table 1. Scoliosis degrees in the measured Siberian sturgeon (*Acipenser baerii*).

Scoliosis degree	N (Number of fish)	% (Percent)
Presence of scoliosis (1-18.9°)	14	41.18
Severe scoliosis (19°+)	20	58.82

Also, the illustration of the method upon physically was shown in Figure 1, while the photograph of the scoliotic Siberian sturgeon had been shown in Figure 2.

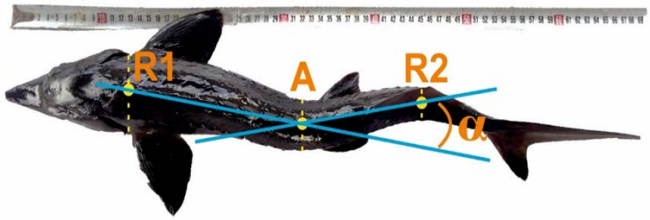

Figure 1. Illustration of the method upon physically (A: apex, R1: reference 1, R2: reference 2, α: angle of scoliosis)

Figure 2. Scoliotic Siberian sturgeon (*Acipenser baerii* Brandt, 1869)

Skeletal disorders of farm fish require a constant struggle for the aquaculture industry. Skeletal deformities affect the overall performance of the fish, its growth and cause problems with fish health. Irregularly shaped fish also cause commercial loss due to the visual evaluation and grading of the product (Karahan et al., 2013; Harris et al., 2014). There is evidence in the farm fishes that the etiology of skeletal malformations are different from the living in a marine environment. These deformities are less visible in marine fish. In the case of marine species, malformations are typically associated with early events of development, and malformations can be attributed to high larval mortality rates (Boglione et al., 2013). Fjelldal et al. (2012) explained the causes of many skeletal deformations in aquaculture conditions, as the abiotic, biotic, xenobiotic and genetic factors. However, if skeletal deformations are caused by mutational or genetic causes, they may become visible or measurable in later periods. Harris et al. (2014) reported that spine curvature in fish also occurred with mutational reasons. However, it is unknown whether vertebral development is directly affected in these mutants or whether the spinal curvature is indirectly caused by neuromuscular defects.

In relation to the subject, Losada et al. (2014) have identified and evaluated vertebral deformities by radiography in their research on the *Solea senegalensis*. They observed with the slight deterioration in a single spine to many different types of deformities as multiple scoliosis. They distinguished spinal deformities in fish between three divisions as minor malformations, major spinal deformities that do not alter body shapes, and more severe spinal curvatures that alter body shape. As a result, they stated that the highest deformity rate was in the caudal region. In another study of spinal deformity in fish, spinal deformities were studied radiographically in Atlantic salmon (*Salmo salar*) (Silverstone & Hammell, 2002). Also according to radiographic findings were detected spinal kyphosis and lordosis, shortened vertebra and pathologic fractures on the spine. Govett et al. (2004), performed radiological examinations on Cyprinus carpio, which developed scoliosis lesions. They detected left lateral deviation and mild scoliosis at the anal fin level of the tail also marked scoliosis in the right body. In another study on spinal deformity, Sullivan et al. (2007), have examined vertebral lesions that can be detected radiographically in commercially produced Atlantic salmon (*Salmo salar*). They have observed spinal deformities in the reviewed fish farms at varying rates between 3.8% and 8.8%. They have made a scoring system to describe the level of deformation. According to this; 1 = a single abnormal vertebra or narrowed intervertebral space; 2 = abnormal adjacent vertebrae or vertebra and space; 3 = single vertebrae affected at several sites; 4 = units of vertebrae (>2) affected or evidence of kyphosis or lordosis; 5 = several separate units of vertebrae affected or evidence of perivertebral soft tissue mineralization. In a different study on the subject, the relationship between spinal deformities including family structure and scoliosis was investigated in seabream (*Sparus aurata*) and skeletal deformities were reported to be a major problem in aquaculture. Skeletal malformations have been detected in 11600 fishes examined radiologically and thirty-nine different skeletal abnormalities have been determined in the examined fishes. In addition, new unusual complex spinal column deformities have been identified, including successive repetitions of lordosis, scoliosis, and kyphosis (LSK) from head to caudal fin. They have associated this syndrome with the family structure. They have said that these

deformities correspond to 0.2% in the whole population and 6.5% in the affected family, besides they are effective in environmental and genetic factors (Afonso et al., 2000). Also, it has been reported by many fish farms that to increase skeletal deformities of the factors such as severe hydrodynamic conditions, vitamin deficiency or excess, nutritional imbalances and diseases (Athanassopoulou et al., 2004; Martens et al., 2012; Negrín-Báez et al., 2016). Gorman et al. (2012), have developed potential biomedical applications for the examination of idiopathic spinal curvatures in bony fish. In addition, they said that spinal curvature was a common deformity among the teleosts. They assumed that the genetic factors related to the curvatures found in humans and teleosts are shared with common biological routes. As a model curve back, is reported that teleosts are important not only for the basic biology of hereditary spinal curvatures but also for understanding phenotypic variation, a consequence of genotypic and environmental interactions. They reported that identification of genes associated with the idiopathic spine curves in guppy and medaka models and the examination of their expression and biochemical context will contribute to the understanding of the etiology of idiopathic spinal curvature in humans. The warming of ocean water due to global warming, additional high partial pressure of CO_2 conditions have increased the skeletal deformities of the *Solea senegalensis* larvae (Pimentel et al., 2014). They also said that water temperature and pH value for farm fishes could affect the frequency of skeletal deformities. Leprevost et al. (2017), have studied the development, structure, and mineralization of the vertebrae using X-rays and microtomography in the cultivated Siberian sturgeon (*Acipenser baerii*). Grimmett et al. (2011), have examined radiologically the triploid spinal deformity in grass carp (*Ctenopharyngodon idella*). In radiographic and computed tomography examinations, the deformities have found to be the bone origin and the levels of variable kyphosis, scoliosis and rotation of spinal deformities have determined. They said that it was not possible to determine the specific causes of the lesions, probably the observed pathology was a genetic component contributing to it.

Hu et al. (2009), determined that on studies of Chinese sturgeon (*Acipenser sinensis*), in 6.3% of larvae with nutritional deficiencies occurred skeletal deformities. Yadegari et al. (2011), reported that in their research 6.5% of skeletal deformities were located in the cranial region, 60.6% in the medial region and 32.9% in the caudal region. In our study, spinal deformities were observed in the cranial, medial and caudal regions of the spinal column. However, it was determined that the most affected area was the medial parts of the spinal column (Figure 2). This finding supports the study of Yadegari et al., (2011). In this fish species, the most mobile spine joints are located in the medial part of the vertebrae. So it is thought that the reason for the more exposure of the medial region to scoliosis. Kurtoğlu et al. (2015) reported that the qualitative and quantitative structure of the deformity which within the criteria determining the quality of larvae in Siberian sturgeon breeding, directly affected the survival rate and development performance. In addition, they have indicated that some anomalies such as caudal fin anomaly, lordosis, and kyphosis affect the survival rate in larvae to a limited extent. According to Hassantabar et al. (2016) the occurrence of skeletal anomalies may result in important, negative effects on animal welfare, product quality, and production costs.

CONCLUSIONS

Skeletal deformities are a problem in aquaculture. Functional swimming ability of fishes developing scoliosis is limited and accordingly, nutritional deficiencies occur. As a result of this malnutrition increases spinal deformities and an unwanted vicious cycle occurs. Additionally, the unwanted situation for fish health and rise in existing health problems start to come out. In the skewed shaped fish, the ability of the egg to fertilized and then transform into a normal embryo is reduced. At the same time, it causes commercial losses because of the visual evaluation and grading of the product. With our rating method, it can be done an easy physical measurement of scoliotic fish in the Siberian sturgeon farms. This measurement can provide a foresight us, such as breeding selection and estimate the performance of aquaculture achievements. It can be determined how the health of the detected scoliotic fishes is affected and thus necessary measures can be taken to reduce commercial losses. It is also suggested that this method is applicable to other fish species

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