Morphological and osteological malformations in hatchery bred redline torpedo fish, *Sahyadria denisonii* (Day 1865) (*Cyprinidae*)

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**Abstract**

This is the first published report on morphological and osteological malformations in hatchery produced *Sahyadria denisonii*. Morphological abnormalities were photographed with a digital camera and digital X-ray. In present study, out of 950 larvae produced only 12 individuals (1.26%) were found to have any type of abnormality, including lordosis, scoliosis, kyphosis, semi-operculum, fin deformity, mouth deformity, head deformity and multiple type deformities. The exact cause of abnormalities could not be definitively determined, but the possible aetiologies are discussed. The present record is, nevertheless, significant owing to the occurrence of deformity in hatchery produced young ones of a freshwater ornamental fish for which induced breeding is considered to be the key to conservation.

**Key words:** Deformity, Induced breeding, Radiography, Western Ghats.

**Resumen**

Malformaciones morfológicas y oseas en ejemplares de criadero de barbo de línea roja, *Sahyadria denisonii* (Day 1865) (*Cyprinidae*)

Se publican, por primera vez, malformaciones morfológicas y osteológicas de *Sahyadria denisonii* producidas en criadero. Se fotografiaron anomalías morfológicas con cámara digital y de rayos X digital. De 950 larvas producidas, sólo 12 individuos (1,26 %) presentaron algún tipo de anomalía, incluyendo lordosis, escoliosis, cifosis, semi-opérculo, deformidad de la aleta, deformidad de la boca, deformación de la cabeza y deformidades múltiples. La causa exacta de anomalías no se pudo determinar, pero se discuten las posibles etiologías. Sin embargo, el registro actual es significativo debido a la aparición de deformidades en peces ornamentales de agua dulce de criadero, para los que se considera la reproducción inducida como la clave de su conservación.

**Palabras clave:** Deformidad, Reproducción inducida, Radiografía, Ghats Occidentales.
Introduction

Deformities in fish are relatively well described with a higher frequency of occurrence reported in hatchery produced individuals than wild (Sennar 1980, Hosoya & Kawamura 1998, Ma et al. 2014). Deformities in fishes are known to be caused as a result of environmental contaminants, scarcity of nutrients, oxygen deficiency, sudden changes in temperature, water current, mutation, inbreeding, parasitic infestation, mechanic trauma, and attack from predators (Fagbua 2009, Amittabh & Firoz 2010, Tave et al. 2011, Malekpouri et al. 2015). Numerous reports are available regarding abnormalities associated with both freshwater and marine fish species (Poynton 1987, Ayle et al. 1989, Panday & Awasthi 1994, Madhavan & Dalsgard 1999, Raj et al. 2004, Olatunji-Akioye et al. 2010, Dutta et al. 2011, Jaward & Mamry 2012, Ma et al. 2014, Sajan et al. 2014, Malekpouri et al. 2015). Sahyadria denisonii (Day 1865), is popularly known as Redline torpedo fish or Miss Kerala and is endemic to the fourteen rivers flowing through the Western Ghats of India (Mercy et al. 2013a, Sajan 2015). This species is much sought after in the international ornamental fish trade (Raghavan et al. 2007, Mercy et al. 2010, Mercy et al. 2015) and it contributes the major share of India’s ornamental fish exports during 2005-2012 (Raghavan et al. 2013). As a result of targeted and indiscriminate exploitation of this species for aquarium trade from wild listed those into endangered group. To the best of our knowledge, occurrence of any kind of deformities in hatchery produced S. denisonii has not yet been reported. This paper documents for the first time different types of deformities recorded in hatchery produced S. denisonii.

Material and methods

Induced breeding and larval rearing

Ripe S. denisonii were anaesthetised to minimise handling stress (Sajan et al. 2012) and induced bred at fish hatchery of College of Fisheries, Kerala, India (Mercy et al. 2015). The newly hatched larvae (Average size=3.50±0.20mm) consume its yolk up to 4 days of post hatch, and then paramecium culture was given as the first exogenous feed. After a week of larval husbandry, they were weaned with live micro worms (Panagrellus redivirus (Goodey, 1945)) and followed by Artemia Flakes (OSI feeds, U.S.A) and commercial formulated diet (HiHalsi Aqua feeds Pvt. Ltd) with crude protein (38 %), crude fat (4 %), crude fibre (3 %), ash (16 %) and moisture (11 %). The formulated feed was given twice a day ad libitum throughout the study period, the unconsumed feeds and excrements were siphoned out from the tanks and 1/3 portion of the water in each tanks was exchanged before next feeding (Mercy & Sajan 2014). Water quality parameters such as temperature, dissolved oxygen, pH, alkalinity, hardness and ammonia were daily monitored by following standard procedures (APHA 1992) and maintained within optimum ranges.

Examination of deformities

950 hatchery bred larvae were examined and abnormal specimens were anaesthetized by using MS-222 (Mercy et al. 2013b). Morphological abnormalities were photographed with a digital camera (Nikon Coolpix L22) and it was further examined with digital X-ray system (Fujifilm FCR Capsula XL II Reader). Morphological, anatomical terminologies relating to the fish abnormality were used by following Al-Harbi (2001). We selected all the deformed fish that could be observed in that particular breeding batch. For the comparison of abnormality, a normal specimen was also radiographed. The deformed specimens were preserved in 4% formaldehyde solution and deposited in the Museum of Department of Fishery Biology, College of Fisheries, KUFOS, Panangad, Kerala, India (FRM-SAH-DEN/2013-2).

Results

In present study, out of 950 larvae produced only 12 individuals (1.26 %) were found to have any type of abnormality. These abnormal fishes were grown up to an average length of 5.60 ± 0.84 cm in the hatchery compared to normal specimen (6.40 ± 0.53 cm), before they were sampled for the study (4-6 month of age). Length and weight of deformed specimens except those affected semi-operculum were measured. The water quality parameters were recorded as temperature (27.0 ± 0.50 °C), pH (7.0±0.3), dissolved oxygen (5.29 ± 0.24 ppm), alkalinity (35.6 ± 6.0 ppm), hardness (55.46 ± 10.28 ppm) and ammonia (<0.02 ppm). Different types of morphological as well as osteo-
logical malformations recorded in *S. denisonii* were listed in Table. 1. In present study, malformations were externally apparent compared to normal specimens (Figs. 1, 2) and observed deformities include semi-operculum, vertebral deformity, head deformity, mouth deformity, fin deformity and also multiple deformities.

<table>
<thead>
<tr>
<th>Type of deformity</th>
<th>Occurrence (%)</th>
</tr>
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<tbody>
<tr>
<td>Lordosis</td>
<td>12.9</td>
</tr>
<tr>
<td>Scoliosis</td>
<td>9.68</td>
</tr>
<tr>
<td>Kyphosis</td>
<td>3.23</td>
</tr>
<tr>
<td>Semi-operculum</td>
<td>6.45</td>
</tr>
<tr>
<td>Fin deformity</td>
<td>22.6</td>
</tr>
<tr>
<td>Mouth deformity</td>
<td>9.68</td>
</tr>
<tr>
<td>Head deformity</td>
<td>9.68</td>
</tr>
<tr>
<td>Multiple deformity</td>
<td>25.8</td>
</tr>
</tbody>
</table>

Tabla 1. Porcentaje de ocurrencia de diferentes tipos de deformidad en *S. denisonii*.

Table 1. Percentage of occurrence of different types of deformity in *S. denisonii*.

Vertebral malformations were recorded by the presence of excessive inward curvature and abnormal lateral curvature respectively (Fig. 3). Scoliosis was affected the vertebral column at the post dorsal fin region of *S. denisonii* (Fig. 4) had total length of 5.8 cm (Body weight of 2.16 g.) compared to normal fish had total length of 6.2 cm (Body weight of 2.15 g.). In the present study, vertebral deformities were frequently affected in the posterior half of the spinal column (Figs. 3c, 3d). Meanwhile one abnormal fish was noticed with lordosis and kyphosis (Fig. 3c). Abnormal fishes had functional double chambered swim-bladder (Figs. 3e, 3d), similar to normal specimen (Fig. 2b).

Normal specimen of *S. denisonii* has mouth at sub-terminal position (Figs. 2a, 2b), while malformed specimens had depressed lower and upper jaw (Fig. 5b). Head of deformed specimen appeared as laterally compressed and shortened (Fig. 5a) compared to normal specimen (Figs. 2a, 2b). Type of head deformities like beak-head, inward bending of the lower jaw and shortening of the neurocranium were also noticed in *S. den-
isonii (Figs. 5c, 5d). A case of unilateral semi-operculum was observed in *S. denisonii* by the shortening of the posterior part of operculum (Figs. 6a, 6b). Fin abnormalities were mainly affect the dorsal-caudal fins (Fig. 7a) and abnormal caudal fin observed as truncated towards the posterior side (Figs. 7a, 7b). More than one deformities (Multiple deformity) were recorded in eight abnormal specimens like semi-operculum, spinal deformity, head deformity, mouth deformity or fin deformity in one sample itself (Figs. 1, 6b).

**Discussion**

Information’s on body malformation is an important biological aspect in hatchery production of fish larvae. Larvae of several freshwater fish produced through induced breeding exhibit morphological abnormalities that adversely affect their survival rate (Daoulas *et al.* 1991, Gavaia *et al.* 2002, Sahoo *et al.* 2004, Sahoo *et al.* 2007, Boglione *et al.* 2013). Available evidence suggests that abnormalities are induced during the embryonic and post-embryonic periods of life (Al-Harbi 2001). In present study, we describes different abnormalities have been recorded in hatchery produced *S. denisonii*.

Occurrence of vertebral deformities are more common in early stages as compared to adults, which may be attributed to that deformed fish at early stages were more prone to mortality (Amitabh & Firoz 2010). Vertebral deformities like lordosis and scoliosis was recorded in *S. denisonii* by the presence of excessive inward curvature and abnormal lateral curvature respectively. According to Boglione *et al.* (1993), scoliosis is the lateral bending of the vertebral axis, it is the most easily distinguishable abnormality in live fishes. *S. denisonii* with scoliosis had two curvatures in the vertebral column at the post dorsal region, one below the dorsal fin region and second at the caudal peduncle region. In present study, vertebral deformities were more affected generally at the posterior half of the vertebral column. Similar types of vertebral deformities were reported in *Fundulus heteroclitus* (L., 1766) (Gabriel 1944) and *Esox lucius* L., 1758 (Orska 1962). Recently, wild caught specimen of *S. denisonii* from River Valapattanam, Kerala was also recorded with vertebral deformity (Sajan *et al.* 2014).

Spinal deformities were found to be associated with the absence of a functional swim-bladder (Iseda *et al.* 1979, Kitajima *et al.* 1981, Daoulas *et al.* 1991, Chatain 1994, Andrades *et al.* 1996). In the present study, deformed fish had normal
double chambered swim-bladder similar to Cypri
inus carpio L., 1758 (Al-Harbi 2001) and Labeo
rohita (Hamilton, 1822) (Dutta et al. 2013). Fluc
tuation in water temperature is considered to be
one of the causes of the spinal deformities,
because by the sudden change in water tempera
ture may lead to abnormal muscle growth and
spinal deformity (Al-Hassan 1982, Wang & Tsai
2000, Davidson et al. 2011). Low dissolved oxy
gen content in the water during spawning and
developmental stages may also responsible for
vertebral deformity (Al-Hassan 1982). But in the
present study, dissolved oxygen content may
never a limiting factor, because continuous aera
tion was provided in the hatching and rearing
tanks to maintain dissolved oxygen level. The
water quality parameters were maintained at
optimum level, so in present study it is unable to
correlate deformities with water quality param
eters.

In present study, average length and weight of
ten abnormal fish have been found to be substan
tially lower than that of normal fishes, probably
due to their inability to feed normally and com
pete with the normal ones for food (Al-Harbi
2001). Dabrowski et al. (1988) and Frischkenecht
et al. (1994) reported vitamin-C deficiency in the
diet also leads to vertebral deformities. Finally, a
genetic basis has also been proposed for spinal
deformations (Fagbuaro 2009, Arbuatti et al.
2013), vertebral deformities are known to be
hereditary and non-hereditary (Yamamoto et al.
1963). Vertebral abnormalities are also known to
occur in Cirrhinus mirgala (Hamilton, 1822) and
Hypothalmichthys motitrix (Valenciennes, 1844)
(Raj et al. 2004) and Poecilia wingei Poeser,
Kempkes & Isbrücker, 2005 (Arbuatti et al. 2013)
due to inbreeding depression. In present study
deformed fishes were not analysed genetically,
hence it could not be ascertained whether the
anomalies were hereditary or non-hereditary.
Mouth abnormalities of various types have been
reported in Dicentrarchus labrax (L., 1792)
(Barahona-Fernades 1982) and C. carpio (Al-
Harbi 2001). The mouth position of normal spec
imen of S. denisonii is sub-terminal, but the
deformed specimens had depression on their lower and upper jaw of the mouth. Jaw deformity
is known to be caused by many factors such as
mechanical injury, nutritional deficiency, environ
mental condition, parasitism or genetic aberration
(Quigley 1995). Beak like appearance of head,
inward bending of the lower jaw and shortening
of the neurocranium were also noticed in mal
formed S. denisonii. According to Al-Harabi
(2001) distended or compressed head of deformed
fishes may be due to the ossification or compres
sion of bones.

Operculum related malformations are attrib
uted to inside or outside folding, shortening or
abnormal positioning of the opercular and sub
opercular bones, bilaterally or unilaterally (Bogl
ione et al. 1993, Galeotti et al. 2000). In present
study, unilateral semi-operculum malformation
was observed in S. denisonii. Commonly abnor
mality is seen only on one side of the operculum
(unilateral), while some species had bilateral
semi-operculum (Al-Harbi 2001). Operculum
deformity has also been reported in hatchery
raised Oreochromis niloticus (L., 1758) (Mair
1992), Oreochromis mossambicus (Peters, 1852
(Handwerker & Tave 1994). Vitamin-C deficiency
related operculum deformity has been reported in
Onchorhynchus mykiss (Walbaum, 1792) (Frisch
knecht et al. 1994) and C. carpio (Dabrowski et
al. 1988). Fishes with such deformity can swim
normally, but their growth was less than that of
compared to the normal fish (Al-Harbi 2001).

Dorsal and caudal fin abnormalities were
recorded in deformed specimen of S. denisonii.
Similar types of fin disorders have also been ob
served in Pampus argenteus (Euphrasén, 1788
(Mamry et al. 2010), C. mrigala (Dutta et al.
2011) and Moolgarda pedaraki (Valenciennes,
1836) (Jaward & Mamry 2012). According to
Boglione et al. (1993), fin anomalies are fre
quently observed in hatchery reared fish, but their
frequency and severity vary according to the spe
cies, rearing condition or types of rearing tank.
Some of the deformed specimen of S. denisonii
had multiple deformities, such as semi-operculum,
spinal deformity, head deformity, mouth deform
ity and fin deformity in one fish, similar reports
by Tave et al. (1982) in Oreochromis aureus
(Steindachner, 1864) (= Sarotherodon aureus
(Steindachner, 1864)), Dabrowski et al. (1988)
in C. carpio, Wiegand et al. (1989) in Carassius
auratus L., 1758 and Frischknecht et al. (1994)
in O. mykiss.

Fish deformities have been also resulted from
nutritional deficiencies, unfavourable abiotic
factors, rearing conditions and genetic factors
(Yamamoto et al. 1963, Tave et al. 1982, Dab-
rowski et al. 1988, Boglione et al. 1993, Frischknecht et al. 1994, Wang & Tsai 2000, Fagbuar 2009, Amitabh & Firoz 2010, Arbuatti et al. 2013). However, earlier studies reported that the possible aetiologies and mechanisms responsible are not well understood (Koumoundouros et al. 1997, Gavaia et al. 2002). This study has attempted to provide insights into the morphological and osteological deformities in hatchery produced young ones of S. denisonii. We could not observe any deformed fish that died before we commenced our investigation. However, we are not sure whether we had overlooked any while in the larval stage. This is not a problem in the hatchery since we got good survival rate. This is reported as a case report as it is the first of its kind. S. denisonii is a difficult to breed fish and the captive breeding technology of the species has been developed first by the authors (Mercy et al. 2015).

The present study did not mean to discuss the causes of the abnormalities, but only to single out the fact that such deformities are recorded in the hatchery-reared S. denisonii. Even though the exact cause of deformity was not determined in the present study, unfavourable abiotic conditions, inappropriate nutrition, genetic defects, disruption of early developmental process or a combination of these factors could all have been involved in the malformations in S. denisonii. Therefore, more research is needed to exactly identify the factors causing such deformities. However, the present record is nevertheless significant owing to the occurrence of deformity in hatchery produced young ones of a highly sought after freshwater ornamental fish for which captive breeding is considered to be the key to conservation and sustainable use.

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