

STURGEON DISEASES IN AQUACULTURE

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Abstract

Sturgeon aquaculture is economically important in many countries, for both meat and caviar production. Sturgeon is the common name for 27 species of fish belonging to the family Acipenseridae. Among them, only the sterlet (*Acipenser ruthenus*) and the Siberian sturgeon (*Acipenser baerii*) completes the lifecycle in fresh water. In Serbia, in the last few years, aquaculture enterprises have shown more interest in farming these fish species. Also, the importance of sturgeon aquaculture grows due to the rapid decrease of wild populations caused by overfishing, water pollution and destruction of habitat. The development of sturgeon aquaculture activities has been accompanied by the disease outbreaks, and possibility of the emergence and rapid dissemination of several infectious disease agents may represent serious problem in sturgeon aquaculture. Several viral, bacterial, fungal and parasitic diseases have been reported worldwide. Due to the limited knowledge about epizootiology and disease control methods, infectious diseases may represent a major challenge in sturgeon aquaculture. Moreover, none of the diseases reported in sturgeon are regulated in the World Organization for Animal Health (OIE) or European Union (EU) legislations. Due to the increasing interest in sturgeon aquaculture in Serbia present study is focused on the most important pathogens that may represent a threat to sturgeon aquaculture in Serbia.

Key words: sturgeon, Acipenseridae, aquaculture, diseases

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BOLESTI JESETRE U AKVAKULTURI

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Kratak sadržaj

Akvakultura jesetre ima veliki ekonomski značaj u brojnim zemljama, kako za dobijanje mesa tako i za proizvodnju kavijara. Jesetra je uobičajeno ime za 27 vrsta riba koje pripadaju porodici Acipenseridae. Među njima, samo kečiga (*Acipenser ruthenus*) i sibirska jesetra (*Acipenser baerii*) pro- vode ceo životni ciklus u slatkoj vodi. Poslednjih godina, u Srbiji postoji veća zainteresovanost za uzgoj ovih vrsta riba. Značaj akvakulture jese- tre raste zbog brzog opadanja njihovog broja u prirodi, izazvanog pre- komernim izlovom, zagađenjem voda i uništavanjem staništa. Razvoj ak- vakulture jesetre je praćen pojavom bolesti, a mogućnost pojave i brzog širenja uzročnika zaraznih bolesti može predstavljati ozbiljan problem. Više virusnih, bakterijskih, gljivičnih i parazitskih bolesti je uočeno širom sveta. Zbog ograničenih podataka o epizootiologiji i metodama kontrole bolesti, zarazne bolesti mogu predstavljati veliki izazov u akvakulturi jesetri. Šta više, nijedna od bolesti utvrđenih kod jesetri nije regulisana od strane Svet- ske organizacije za zdravlje životinja (OIE) niti zakonodavstva Evropske unije (EU). Zbog sve većeg interesovanja za akvakulturu jesetre u Srbiji, u ovom radu je ukazano na najvažnije patogene koji mogu predstavljati pret- nju za zapate jesetre u akvakulturi.

Ključne reči: jesetra, *Acipenseridae*, akvakultura, bolesti

INTRODUCTION

Sturgeon farming has become an important and rapidly expanding sector of aquaculture worldwide. In the last decade, the farming of sturgeon in West- ern Europe has increased exponentially. The annual world production is al- located among 4 species: White sturgeon (*Acipenser transmontanus*), Siberian

sturgeon (*Acipenser baerii*), Adriatic sturgeon (*Acipenser naccarii*) and Russian sturgeon (*A. gueldenstaedtii*). This applies to both the growing of fry and fingerlings for restocking natural reservoirs as well as the production of table sized fish and caviar for the market. Sturgeon farming has become increasingly important worldwide for the production of caviar and fish flesh, as well as for restoration programmes set up to save endangered wild populations (Bronzi and Rosenthal, 2014). Several species are farmed, among which the most desirable are Russian (otherwise known as Danube) (*Acipenser gueldenstaedtii*) and Siberian (*Acipenser baerii*) sturgeons due to their short reproductive cycles and desired products (caviar and meat) (Williot et al., 2001). However, the success of sturgeon farming is heavily restricted due to the paucity of information related to sturgeon diseases and related control methods. It is believed that sturgeons are comparatively more resistant to fish diseases; nevertheless, many studies have shown that their diseases are idiopathic and involve different pathogens. Intensive culture exposes the fish to several sources of stress, such as high stock densities and manipulations that predispose animals to a number of infectious diseases associated with viral or bacterial pathogens (Georgiadis et al., 2000). As in the culture of other fish species, diseases are a principal limiting factor in sturgeon farming. Among them, viral diseases often cause major damage to the industry. Disease control in sturgeon farming is difficult due to lack of knowledge about disease epidemiology and control methods (Ciulli et al., 2016). As a result of more intensive sturgeon aquaculture, infectious diseases that affect the species have emerged.

Viral Diseases

The intensive breeding of sturgeon has facilitated the emergence and the spread of diseases. To date, several specific viruses have been found in sturgeons. Almost all of them were discovered in sturgeons native to North America, both in the USA and Canada, as well as in Europe, where these fish species were introduced (Raverty et al., 2003, Kelley et al., 2005). Viruses of the *Herpesviridae* and *Iridoviridae* families are the major threats for the sturgeon aquaculture and presents the most reported causes of mortality outbreaks in sturgeons (Raverty et al., 2003; Shchelkunov et al., 2009; LaPatra et al., 2014). Among them, the white sturgeon (*A. transmontanus*) iridovirus (WSIV) and white sturgeon herpesvirus type 2 (WSHV-2, later renamed to Acipenserid herpesvirus 2, AciHV-2) are economically the most significant pathogens, causing up to 95% mortality in cultured young sturgeon (Watson et al., 1995, Georgiadis et al., 2001, Kelley et al., 2005).

Herpesviral diseases

Herpesviral diseases in sturgeons are caused by three viruses, the Acipenserid herpesvirus-1 (AciHV-1), Acipenserid herpesvirus-2 (AciHV-2), and Siberian sturgeon herpesvirus (SbSHV) (Kurobe et al., 2008; Shchelkunov et al., 2009).

Acipenserid herpesvirus 1 (AciHV-1) disease

Acipenserid herpesvirus 1 (AciHV-1), also known as a white sturgeon herpesvirus 1 (WSHV-1), was initially isolated in 1991, from cultured juvenile white sturgeon (*Acipenser transmontanus*), in California (USA) hatcheries. Mortality was result of the severe infection of the integument and oropharyngeal mucosa (Hedrick et al., 1991). Histopathologically, the virus causes epidermal lesions and diffused dermatitis. AciHV-1 appears to be less virulent under experimental conditions than is AciHV-2 (Plumb and Hanson, 2011).

Acipenserid herpesvirus 2 (AciHV-2) disease

Acipenserid herpesvirus 2 (AciHV-2) also known as a white sturgeon herpesvirus 2 (WSHV-2), was first isolated from ovarian fluid of an adult sturgeon and was a cause of mortality in farmed juvenile white sturgeon in North America in the mid-1990s (Watson et al., 1995). Later, a closely related virus was isolated in Russia, suggesting that the Russian isolates may have originated from North America. Mortality in adult fish infected with AciHV-2 was generally less than 10%. Experimentally, the shovelnose and pallid sturgeon were susceptible to AciHV-2 but other species were refractive (Mao et al., 1999). White sturgeon herpesvirus-2 occurs in older sturgeon with small white blisters which develop into the open lesions on the body surface. These lesions are frequently infected with secondary bacteria and/or ectoparasites. Internally, the stomach and intestines are filled with fluid but other tissues appear normal. Wild white sturgeon which was infected with AciHV-2 became listless and stopped eating. Current management strategies for controlling AciHV-1 and AciHV-2 are avoidance of the agent and inspection of potential carrier fish via cell culture assay. Sturgeon infected with AciHV-2 could be prophylactically treated with salt and parasiticides to reduce secondary infections in open ulcers.

Siberian sturgeon herpesvirus (SbSHV) disease

Siberian sturgeon herpesvirus (SbSHV) was isolated in Russia for the first time in 2006 from moribund Siberian sturgeon (*Acipenser baerii*) and bester (beluga *Huso huso* × sterlet *Acipenser ruthenus* hybrid) fingerlings during acute outbreak of disease on a fish farm (Shchelkunov et al., 2009). The infection has been found widespread in cultured sturgeon species in Russia. It is the cause of an acute necrohaemorrhagic skin syndrome complicated by secondary opportunistic infections (fungal, myxobacterial or protozoan) (Shchelkunov et al., 2009). Based on sequence analysis of the viral genome, it is determined that the SbSHV is a potential member of the genus Ictalurivirus within the family *Alloherpesviridae* under the order *Herpesvirales* (Dospoly and Shchelkunov, 2010). Two Russian types of SbSHV (I and II) were isolated, and they differ from each other in four principal marker traits and each of the two has close genetic relationship with one or another strain of North American AciHV-2 species. It was hypothesized that the Russian type I and type II SbSHV may represent two different strains or genotypes of the Acipenserid herpesvirus 2 species (Dospoly and Shchelkunov, 2010).

Iridoviral diseases

Iridoviruses have been associated with severe disease and economic loss in fish with more than 50% mortality. The first iridovirus associated with mortality outbreaks of sturgeon was the white sturgeon iridovirus (WSIV) (Hedrick et al., 1990). Other iridolike viruses have been detected in different sturgeon species in North America and Europe, namely white sturgeon iridovirus (WSIV) (Hedrick et al., 1990, Raverty et al., 2003), Missouri River sturgeon iridovirus (MRSIV) (Kurobe et al., 2010, 2011), shortnose sturgeon virus (SNSV) (LaPatra et al., 2014), British Columbia white sturgeon virus (BCWSV), Namao virus (NV) (Clouthier et al., 2013), and Russian sturgeon iridovirus (Adkison et al., 1998). They can cause a lethal disease of the integumentary system in infected sturgeon, resulting in > 90% mortality within captive populations. In other instances, they are associated with a chronic debilitating wasting syndrome, resulting in severely impaired growth and reduced survival of fry and fingerlings (Clouthier et al., 2018). In total, nine species of sturgeon in the genera *Acipenser* or *Scaphirhynchus* of the family *Acipenseridae* were found susceptible to one or another virus. Outbreaks of virus disease are associated with stress factors such as rearing density, handling, fluctuations in water temperature, levels, and flow rates (Watson et al., 1998, Georgiadis et al., 2000, 2001). The phylogenetic

studies revealed that these viruses are only distantly related to Iridoviridae, and are included in a group of sturgeon nucleo-cytoplasmic large DNA viruses (NCLDV). They do not form part of any currently recognized virus genera or family but do belong to the order *Megavirales* (Colson et al., 2013). NCLDV group has not formally been adopted by the International Committee for the Taxonomy of Viruses (Clouthier et al., 2015). The sturgeon NCLDVs are present in hatchery-reared and wild sturgeon found across North America and northern Europe (Clouthier et al., 2015), and pose a potential disease risk for strategies designed to aid the recovery of threatened and endangered sturgeon populations worldwide (Clouthier et al., 2018). Data on sturgeon iridolike viruses in Europe are limited despite the increasing importance of sturgeon aquaculture. Iridovirus-like infection has been reported in Northern Europe in Russian sturgeon (*Acipenser gueldenstaedtii*) associated with mortality (Adkison et al., 1998). NCLDVs outbreaks are frequently reported by sturgeon farmers, but only few thorough investigations have been conducted for these outbreaks. Sturgeon NCLDVs appear to be endemic in populations of *Acipenseridae* found throughout North America (Clouthier et al., 2015). At present, an accurate picture of the geographical distribution of sturgeon NCLDV infection in Europe is not available. Also, in 2009, frog iridovirus type 3 (FIV3), a well-known ranavirus provoked an outbreak on pallid sturgeon (*Scaphirhynchus albus*) in an American hatchery (Waltzek et al., 2014).

Recently, *Acipenser iridovirus* European (AcIV-E) has been detected in sturgeon populations in Europe. It appears that this virus is closely related to North American sturgeon iridoviruses, in particular with the white sturgeon iridovirus (WSIV) and the Namao virus (NV) (Axen et al., 2018). AcIV-E was detected and associated with clinical disease in different sturgeon species (*Acipenser baerii*, *Acipenser gueldenstaedtii*, *Acipenser naccari*, and *Huso huso*). Higher mortality due to AcIV-E was recorded in Russian sturgeon compared to Siberian sturgeon - 90% vs 50% - suggesting a lower susceptibility to the virus in Siberian sturgeon (Bigarré et al., 2017). Much important information, e.g., pathogenesis, transmission routes, and epidemiology of these viruses, is lacking, making virus and disease control extremely difficult (Axen et al., 2018).

Other sturgeon virus diseases

White sturgeon adenovirus (WSAV) disease

WSAV was identified in diseased juvenile white sturgeon between 1984 and 1986 (Hedrick et al., 1985) but the disease has not evolved into a serious

health problem, and there has not been any report on WSAV since then.

Infectious hematopoietic necrosis virus (IHN)

Sturgeon are often cultured on facilities that contain other fish species. LaPatra et al. (1995) demonstrated that white sturgeon fry were susceptible to IHNV and that white sturgeons cultured with IHNV-infected rainbow trout had neutralizing antibodies to the virus.

Viral nervous necrosis (VNN)

Betanodavirus within the family *Nodaviridae* is the etiological agent of viral nervous necrosis (VNN, also known as viral encephalopathy and retinopathy or VER). The virus infects a large range of host species in more than 50 species of marine and freshwater fish worldwide. Athanassopoulou et al. (2003) reported on the presence of a betanodavirus that infected sturgeon (*Acipenser gueldenstaedi*) in fresh water causing disease with neurological signs.

Spring viremia of carp (SVC)

Vicenova et al. (2011) reported isolation of the SVC virus in sturgeon with the clinical signs of the disease, which included internal haemorrhages, considerably enlarged bright-red spleen, and greyish-yellow liver showing tiny red spots. The sturgeon isolate was genetically identical to the isolate from clinically healthy koi carp collected from the same aquaculture site.

Infectious pancreatic necrosis (IPN)

Little scientific information is available to assess whether sturgeon can become infected and develop into potential carriers of IPNV. Only the report from France indicated that IPNV was isolated from 3% (1 of 34) of a group of Siberian Sturgeon *Acipenser baerii* (Nougayrede, 1988).

Aquareoviruses

Aquareoviruses are serious pathogens of aquatic animals. Reovirus particles were observed in diseased Chinese sturgeons, suggesting the existence of primary viral illness (Zhang and Gui, 2012).

Cyprinid herpesvirus-3 (CyHV-3)

According to Pospichal et al. (2016) the hybrid between sterlet and beluga seems to be susceptible to cyprinid herpesvirus 3, but the authors could not prove that they can transfer this virus to naïve koi. Also, Kempter et al. (2009) reported that Atlantic sturgeon and Russian sturgeon are susceptible to CyHV-3.

Bacterial diseases

Few mortality outbreaks have been reported in sturgeon associated with primary bacterial pathogens such as the case of lactococcosis in hybrid sturgeon, Bester (*Huso huso* x *Acipenser ruthenus*) (Chen et al., 2012). However, the isolation of bacteria from sturgeon was often reported as a secondary infection or as a consequence of severe stress and high stock densities. Motile *Aeromonas* infection (MAI) is one of the most common infection in sturgeon (Santi et al., 2019). MAI is usually associated with viral diseases in surviving sturgeon. Motile *Aeromonas* species have been isolated from sturgeon, generally as a consequence of severe stress and high stock densities or opportunistic, secondary to a primary viral infection. A motile *aeromonas* septicaemia caused by *Aeromonas hydrophila* frequently induced considerable losses in Persian sturgeon (*Acipenser persicus*) fingerlings in northern Iran (Soltani and Kalbassi, 2001) and also in the Harrison river sturgeon in Canada (Raverty and Nikl, 1999). *Aeromonas hydrophila* as a pathogenic agent has been isolated from Amur sturgeon (*Acipenser schrenckii*) in China (Meng et al., 2011). *Aeromonas hydrophila* and *Aeromonas veronii* were isolated during the outbreak of a disease characterized by haemorrhagic ascites and intestinal and renal haemorrhaging in cultured Chinese sturgeon (Di et al., 2018). In Turkey, *Aeromonas hydrophila* was detected in Russian sturgeon (*Acipenser gueldenstaedtii*) as the cause of bacterial haemorrhagic septicaemia and high rate of mortality (Timur et al., 2010). *Aeromonas veronii* was identified as a pathogen and cause of mortality of Siberian sturgeon (*Acipenser baerii*) (Ma et al., 2009). *Aeromonas veronii* was isolated from reared sturgeons in Iran (Gholamhosseini et al., 2018). *Aeromonas sobria* was isolated from *Acipenser gueldenstaedtii* and *Acipenser baerii* in Turkey (Kayis et al., 2017). *Pseudomonas* spp., particularly *Pseudomonas fluorescens*, are common worldwide and found mainly in cold freshwater. The infection was reported in *Acipenser baerii* by Brunetti et al. (2006) and in *Acipenser gueldenstaedtii* by Kayis et al. (2017). The pathogen *Pseudomonas alcaligenes* has been identified in Chinese sturgeon (Xu et al. 2015). *Streptococcus iniae* was isolated from liver, kidney and spleen of the dy-

ing sturgeons with clinical symptoms during an episode of continuous mortality of cultured hybrid sturgeons occurred on a farm in China in 2012 (Wang et al., 2014). *Yersinia ruckeri* was found responsible for 10% mortalities in cultured sturgeon (*Acipenser baerii*) in France (Vuillaume et al., 1987).

Flavobacterium johnsoniae was isolated from the diseased farmed young sturgeons (3-4 g) in Russia (Bauer et al., 2002). *Flavobacterium johnsoniae* and *Flavobacterium hydatis* isolates were associated with disease in cultured Russian sturgeon (*Acipenser gueldenstaedtii*) in Turkey (Karatas et al., 2010, Timur et al., 2010).

An outbreak of *Pseudomonas fluorescens* was reported in young (10 g in size) farmed Siberian sturgeon (*Acipenser baerii*) with high mortality (40%) in northern Italy (Brunetti et al., 2006).

Outbreaks of mycobacteriosis in reared sturgeons, including Chinese sturgeon (*Acipenser sinensis*), Russian sturgeon (*Acipenser gueldenstaedtii*) and Amur sturgeon (*Acipenser schrenckii*), were identified (Zhang et al., 2017, Antuofermo et al., 2014, Righetti et al., 2014).

Several *Acinetobacter* isolates were detected in both *Acipenser gueldenstaedtii* and *Acipenser baerii* involved in the mortality outbreaks caused by NCLDV (Ciuli et al., 2016).

Lesions in *Acipenser gueldenstaedtii* and *Acipenser baerii* have been described during natural and experimental infections with *Acinetobacter johnsonii* and *Acinetobacter baumannii* (Kozinska et al., 2014).

Streptococcus dysgalactiae, a Gram-positive bacterium, has been isolated from *Acipenser schrenckii* in China. Haemorrhages, abdominal swelling and ascites have also been reported in cultured sturgeons (Yang and Li, 2009).

Also, *Yersinia ruckeri*, *Flavobacterium columnare*, *Flavobacterium psychrophilum* and *Renibacterium salmoninarum* have been isolated from sturgeons reared in recirculating aquaculture system (Pelkola et al., 2012).

Parasitic diseases

Most common parasitic diseases are those in reared young sturgeons caused by ciliates of the genus *Trichodina* and other genera of the family *Urceolariidae*. Rarely occurs infections caused by *Ichthyophthirius multifiliis* and *Chilodonella cyprini* (Bauer et al., 2002). Helminthic diseases of reared sturgeons are very rare in fish farms, although representatives of several species of *Monogenea*, *Trematodes*, *Cestodes* and *Nematodes* are sometimes found in reared sturgeons (Bauer et al., 2002).

Other diseases

Fungal diseases caused by Saprolegniaceae are of great importance, especially during incubation of sturgeon eggs. Mortality of eggs during this period sometimes reaches 70-90%. Thirteen species of pathogens have been found, including *Saprolegnia* (seven species), *Achlia* (two species), *Aphanomyces* (one species), *Dactyulus* (two species) and *Zeptolagnia* (one species) (Bauer et al., 2002). Jalilpoor et al. (2006) also isolated *Penicillium spp.*, *Fusarium spp.*, *Mucor spp.* and *Saprolegnia sp.* from the eggs of *Acipenser persicus*.

CONCLUSIONS

The increasing importance of sturgeon farming and international trade in all species of sturgeon worldwide has increased the risk of disseminating specific pathogens and emphasizes the need for adequate diagnostics to prevent the spread of these pathogens. Most infections in natural conditions result in unapparent or mild disease, yet various pathogens can be highly pathogenic in sturgeon aquaculture where transfer of pathogens is facilitated by high densities of naïve hosts. As sturgeon is increasingly being farmed, a better understanding of the pathogens infecting this species is crucial to the development of a sustainable industry.

The majority of disease conditions on sturgeon farms could be significantly reduced if proper attention is paid to good husbandry and the maintenance of optimal environmental conditions, especially water quality.

In conclusion, the wide diversity of pathogens and the numerous movements of live fish and fish products have likely strongly contributed to the spread of infectious agents for years. The transfers of live material need to be better controlled in the future with an aim of improving fish health and hence their commercial and ecological value. Considering the potential of various infectious pathogens to cause severe disease in an aquaculture setting, additional studies are needed to increase the knowledge on the epidemiology of sturgeon diseases. This will help in controlling infections of managed stocks reared for food and also in conservation programs.

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