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# Heart and skeletal muscle inflammation (HSMI) of farmed Atlantic salmon (*Salmo salar* L.) and the associated *Piscine reovirus* (PRV)

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## Susceptible species

Heart and skeletal muscle inflammation (HSMI) has only been recorded in farmed Atlantic salmon (*Salmo salar* L.) after sea transfer and in freshwater hatcheries that use seawater in their production (Johansen *et al.*, 2008). *Piscine reovirus* (PRV) seems to be ubiquitous in Norwegian salmon farms, but viral loads and tissue distribution support a causal relationship between the virus and disease (Løvoll *et al.*, 2012). PRV has also been found in wild Atlantic salmon and in anadromous brown trout (sea-trout; *Salmo trutta* L.) without clinical signs (Garseth *et al.*, 2012). PCR-screening of marine fish caught along the Norwegian coast revealed PRV in great silver smelt (*Argentina silus* Ascanius), capelin (*Mallotus villosus* Muller), Atlantic horse mackerel (*Trachurus trachurus* L.), and Atlantic herring (*Clupea harengus* L.; Wiik-Nielsen *et al.*, 2012). The significance of these findings is unknown.

## Disease name

Heart and skeletal muscle inflammation (HSMI).

## Aetiological agent (suspected)

An infectious aetiology was suspected since the recognition of HSMI disease outbreaks and this has since been supported by experimental transmission trials (Kongtorp *et al.*, 2004a; Kongtorp and Taksdal, 2009). Virus-like particles have been associated with HSMI (Watanabe *et al.*, 2006), but a causal relationship between these findings and the disease was not established. In 2010, a reovirus with the proposed name *Piscine reovirus* (PRV) was linked to HSMI. The titre of PRV as measured by real-time PCR correlated with disease development (Palacios *et al.*, 2010). This link has been further strengthened as virus detection by immunohistochemistry also seems to follow progression of clinical signs (Finstad *et al.*, 2012). However, it is also clear that PRV can be present in salmon at relatively high titres without typical HSMI pathology (Garseth *et al.*, 2012).

PRV is described as equally distant to *orthoreovirus* and *aquareovirus* genera in the *Spinareovirinae* sub family (Palacios *et al.*, 2010). Reoviruses are icosahedral and non-enveloped, with double-stranded RNA genomes with 10–12 segments. The *Reoviridae* family is divided in two subfamilies, *Spinareovirinae* and *Sedovirinae*, with altogether fifteen genera (Carstens and Ball, 2009). The host range of *Reoviridae* extends from insects, fungi and plants to fish, molluscs, reptiles birds and mammals (Fenner *et al.*, 1993).

## Geographical distribution

HSMI has so far been diagnosed in farmed Atlantic salmon in Norway and Scotland (Ferguson *et al.*, 2005), and PRV has been detected by PCR on some marine salmon sites in Ireland without an HSMI diagnosis (Neil Ruane, pers. com.). Outside Europe,

a technical report claims that HSMI has been diagnosed and PRV been found in farmed Atlantic salmon in Chile (Bustos *et al.*, 2011) and unconfirmed reports claim that PRV has been found in both farmed Atlantic salmon and wild cutthroat trout (*Oncorhynchus clarkii* Richardson) in British Columbia.

### **Associated environmental conditions**

HSMI is usually diagnosed during the first year at sea, and on average 6 months after sea-transfer. There have also been a few cases in freshwater hatcheries that use seawater in their production. Mortality in affected cages may be negligible but can reach approximately 20%. HSMI is increasingly diagnosed in association with outbreaks of other diseases or following grading, movement or other management events which may induce stress. In particular, this represents a challenge in relation to treatment against the salmon louse.

### **Significance**

HSMI is commonly diagnosed in Norwegian aquaculture. In 2011, the disease was diagnosed in a total of 162 sites, most of them in seawater. This was an increase of approximately 20% in registered cases compared to 2010. In 2011, HSMI outbreaks were also diagnosed in two juvenile production units with seawater intake. PRV has also been detected in wild salmon in 31 of 36 examined rivers in Norway (Garseth *et al.*, 2012).

### **Gross clinical signs**

Characteristic features of HSMI are onset of clinical signs 5–9 months after sea-transfer with abnormal swimming behaviour, anorexia and up to 20% mortality. Autopsy findings point towards circulatory failure, and blood clots in the heart cavity are the most common finding. There may also be ascites, yellowish or blood-filled liver, splenomegaly and pin-prick haemorrhages in the adipose tissue.

### **Control measures and legislation**

No control measures are currently available, but vaccine development is ongoing. HSMI is a notifiable disease in Norway (List 3, national diseases), but this has been debated due to the widespread occurrence in farmed salmon. The ubiquitous occurrence of PRV in farmed salmon and its high prevalence also in wild salmon will be relevant in this discussion. HSMI is not listed by OIE.

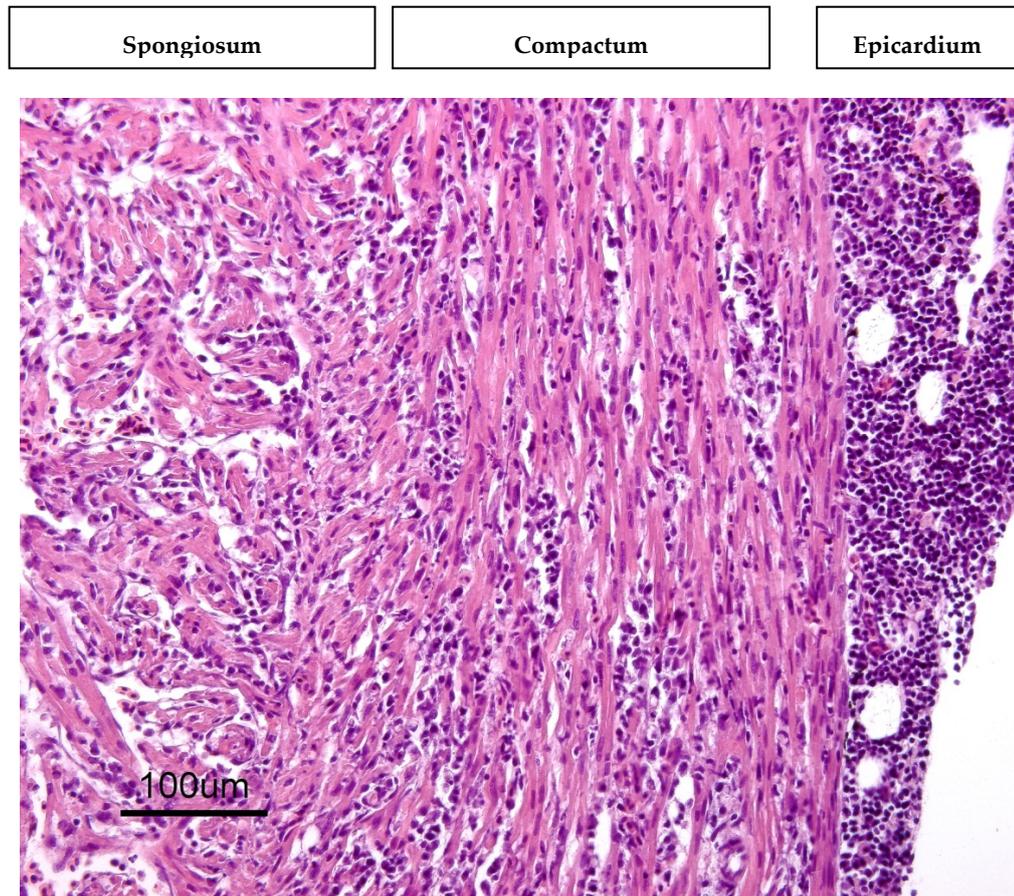
### **Diagnostic methods**

The diagnosis of HSMI is based on histological examination of changes in heart and skeletal muscle. Histological findings are myocarditis affecting the epi- and endocardium, myocardial necrosis, myositis and necrosis of red skeletal muscle (Kongtorp *et al.*, 2004b). So far, PRV has not been grown in cell culture, but the virus can be detected by PCR (Palacios *et al.*, 2010) or by immunohistochemistry (Finstad *et al.*, 2012). HSMI is an important differential diagnosis for pancreas disease (PD) and cardiomyopathy syndrome (CMS).

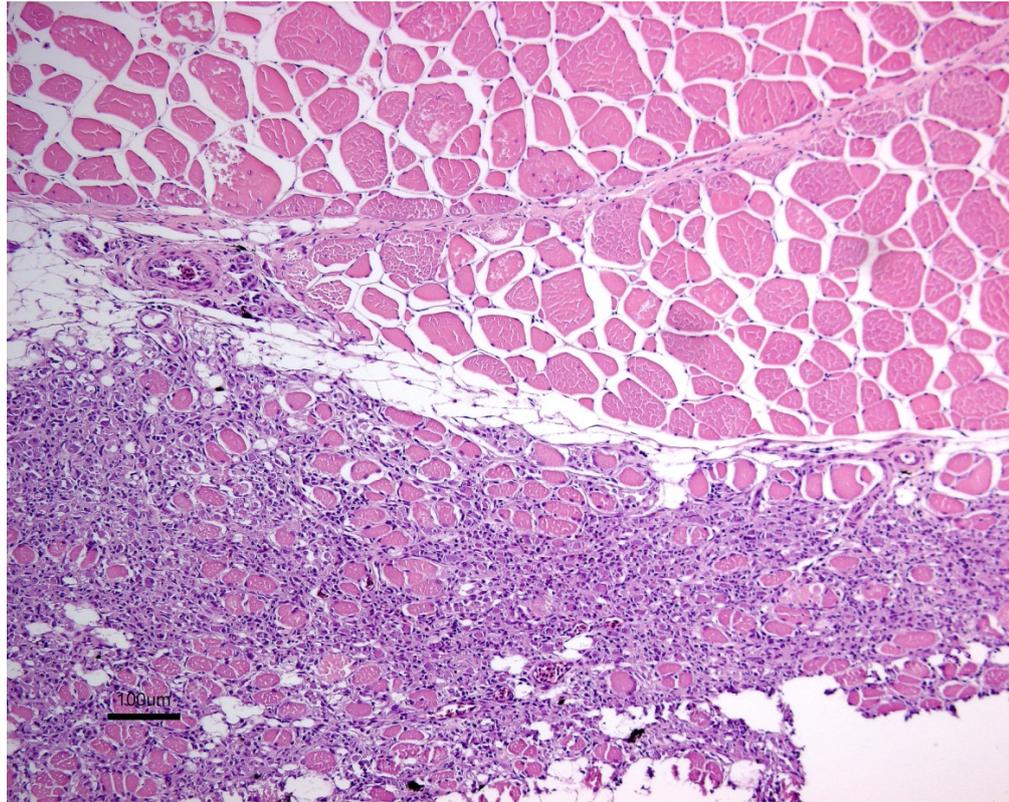
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Histological section of heart ventricle from Atlantic salmon with HSMI. Inflammation of spongiosum, compactum and epicardium, (Photo: Torunn Taksdal, Norwegian Veterinary Institute).



White  
muscle

Red  
muscle

Histological section of skeletal muscle from Atlantic salmon with HSMI. Severe inflammation of red muscle (below) and normal white muscle above. (Photo: Torunn Taksdal, Norwegian Veterinary Institute).

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