Scientific Name: *Novirhabdovirus sp.*

Discovered by: Jensen

Year Named: 1963

Common Name: Viral Hemorrhagic Septicemia (VHS). Also known as 'Egtved virus' in Europe.

Taxonomy: Available through ITIS.

Identification: VHS is an RNA virus with a bullet-shaped morphology typical of rhabdoviruses and a 11–12 kb nucleotide genome encoding five structural proteins. Viral particles are 170-180 nm in length and 60-70 nm in width (Skall et al. 2005; Elsayad et al. 2006). A classification based on sequences of N- and G-genes reveals four major genotypic groups that correspond to the geographical distribution of the virus: one group includes isolates from European inland waters and northern marine coastal areas, a second group is composed of marine isolates from the Baltic Sea, a third group comprises isolates from the North Sea, and a fourth group comprises North American isolates. Thus far, the virus has been found in Europe, North America, Japan and Korea (Nishizawa et al. 2002; Skall et al. 2005). Based on a comparison of the gene sequences of all North American VHS isolates, Elsayad et al. (2006) propose that the VHS isolate obtained from a muskellunge in Lake St. Clair constitutes a distinct sublineage of the North American genotype that likely originated on the east coast of North America.

The clinical signs of VHS differ depending on the course of infection. In the latent manifestation of the disease, some mortality may occur and fish become hyperactive, sometimes displaying nervous symptoms such as twisting of the body and behavior that involves swimming erratically in circles or in a corkscrew pattern (CFSPH 2003). Conversely, some carriers of the virus may show no symptoms at all (Dopazo et al. 2002). Histopathological changes occur in the liver, kidneys, spleen and skeletal muscle (McAllister 1990); the kidney and spleen appear to be the organs most often targeted by VHS virus (Brudeseth et al. 2002). In the acute form of the disease, fish become lethargic, dark and anemic, with bulging eyes, congested kidneys, mottled liver, and with hemorrhage in the eyes, skin, gills, fin bases, skeletal muscle and viscera (McAllister 1990). Mortality is very high and the disease is short-lived (CFSPH 2003). In the chronic form of the disease, mortality is low and all the symptoms are similar to the acute form, except that hemorrhaging is not common; instead, the liver, spleen and kidneys experience an accumulation of fluid such that the body becomes bloated and the liver and kidneys become very light in color (McAllister 1990). Survivors of infection can be carriers of the virus throughout the rest of their lives.

Size: The VHS virus is approximately 170–180 nm long and 60–70 nm wide (Elsayad et al. 2006; McAllister 1990).

Native Range: VHS is indigenous to eastern and western Europe, Japan, and the Pacific coast (from California to Alaska) and Atlantic coast of North America. Some evidence suggests that the European strains of VHS are native to the Atlantic Ocean. It is generally believed that all strains of VHS are derived from a common marine ancestor (Skall et al. 2005).

Nonindigenous Occurrences: VHS virus has been present in the Great Lakes since at least 2003. The North American strain of the virus was first isolated from muskellunge *Esox masquinongy* caught in the northwest part of Lake St. Clair, Michigan (Elsayad et al. 2006). In 2005, infected freshwater drum *Aplodinotus grunniens* and round goby *Neogobius melanostomus* were captured in the Bay of Quinte, Lake Ontario (Wren and Lee 2006). In the spring and summer of 2006, VHS was detected in fishes in the Thousands Islands area of the St. Lawrence River (Wren and Lee 2006) and in Lake St. Clair, Lake Erie and Lake Ontario (USDA 2006). All isolates from these areas belong to the same sublineage of the North American genotype (M. Faisal, personal communication, November 2006).

Means of Introduction: It is not known how VHS was initially introduced to the Great Lakes–St. Lawrence River system; however, genetic evidence suggests that the virus originated from the Atlantic coast of North America, possibly via transport in ballast water or infected migratory fishes (Elsayad et al. 2006). Aquaculture activities are implicated in the spread of the virus (Skall et al. 2005; Fisheries Research Services 2006). The potential for transport with bait fish (reviewed by Goodwin et al. 2004) is demonstrated by the virus' recovery in cell culture from frozen Pacific herring *Clupea pallasi* after two freeze/thaw cycles in a conventional freezer (Meyers et al. 1994). Waterfowl might also play a role in transmitting the virus (Peters & Neukirch 1986).

Status: The North American strain of VHS virus is present in Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River (Elsayad et al. 2006; USDA 2006).

Ecology: VHS occurs in both marine and freshwater environments. It requires an incubation period of approximately 7 to 15 days, depending on water temperature (CFSPH 2003). It becomes inactivated in ether, chloroform, glycerol, formalin, sodium hypochlorite, sodium hydroxide, iodophors, UV radiation, or by desiccation, or exposure to pH levels lower than 2.4 or higher than 12.2 (CFSPH 2003; McAllister 1990). VHS is still stable at a pH of 5.0, while the optimum replication pH is 7.4–7.8. The optimum replication temperature is 14–15ºC, whereas replication is low at 6ºC and almost non-existent at 20ºC (De Kinkelin et al. 1980; Bernard et al. 1983; McAllister 1990). The virus becomes inactive after 24 hours at 20ºC in water, but can persist for five days at 4ºC in water (CFSPH 2003). Consequently, fish mortality from VHS is greatest at 3–12ºC and is very rare above 15ºC (McAllister 1990).

Fishes are susceptible to infection at any age. VHS is transmitted to juvenile and adult fish most often via urine and sex products that enter a fish through secondary gill lamellae, or possibly through fin bases or via wounds; it cannot enter eggs and infect fish before hatching (McAllister 1990; Brudeseth et al. 2002; CFSPH 2003; Harmache et al. 2006). Juvenile fish are generally more susceptible than adults. Experiments have recorded infection after contact with infected fish and after immersion in infected water; the virus can remain activated in water for several days (McAllister 1990). The VHS virus can persist for long periods of time in the bottom of culture ponds, potentially in invertebrates (CFSPH 2003). There is evidence of infections transferred between farmed and free-living fishes in European inland waters and coastal areas (Stone et al. 1997; Skall et al. 2005). The mortality rate for infected fish varies between 20% and 80%, depending on environmental conditions, and has reached 100% in trout fry (CFSPH 2003).

Impact of Introduction

A) Realised: The North American VHS strain is less virulent to salmon and trout than the European strain (Follett et al. 1997) and has not caused large fish kills of these species in the Great Lakes to date (USDA 2006). However, mortality of other species has been documented. In 2005, VHS apparently caused large die-offs of freshwater drum *Aplodinotus grunniens* and round goby *Neogobius melanostomus* in eastern Lake Ontario and muskellunge *Esox masquinongy* in Lake St. Clair (Wren and Lee 2006). In the spring and summer of 2006, VHS was implicated as a cause of large die-offs of round goby and muskellunge in the Thousands Islands area of the St. Lawrence River (Wren and Lee 2006) and die-offs of muskellunge, northern pike *Esox lucius*, gizzard shad *Dorosoma cepedianum*, smallmouth bass *Micropterus dolomieui*, walleye *Sander vitreus* and yellow perch *Perca flavescens* in Lake St. Clair, Lake Erie and Lake Ontario (USDA 2006).

B) Potential: Nearly 50 species of fish are known to be susceptible to VHS. The virus was first isolated from most of these species only within the past two decades (Skall et al. 2005). Susceptible fishes include several species of commercial importance (e.g. lake trout *Salvelinus namaycush*, rainbow trout *Oncorhynchus mykiss*, brook trout *Salvelinus fontinalis*, and coregonids *Coregonus* spp.) that have not yet been killed by the virus in the Great Lakes basin. European freshwater-strain VHS infections usually manifest themselves in salmonids, particularly rainbow trout, which suffer high mortality rates. Although the North American strain appears to be of low pathogenicity to salmonids, it has caused mass mortality in a variety of other marine fishes (Kocan et al. 2003; Meyers and Winton 1995; Skall et al. 2005).

Remarks:

A U.S. Federal Order aims to prevent the spread of VHS into aquaculture facilities by restricting the interstate movement and importation of live fish of VHS-susceptible species: http://www.aphis.usda.gov/vs/aqua/pdf/vhs-fed-order_ogc-changes.pdf

Voucher Specimens:

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Group: Does not fit groups available

Lake(s): Lake Ontario, Lake Erie, Lake St. Clair

Genus: *Novirhabdovirus*

Species: Undescribed

Common Name: Viral Hemorrhagic Septicemia (VHS), Egtved disease.

Status: Reported

Freshwater/Marine: All

Pathway: Unknown

Exotic/Transplant: Native Transplant