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Viruses and Virus Diseases of Salmonid Fishes

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Four viral agents—infectious pancreatic necrosis (IPN) virus, infectious hematopoietic necrosis (IHN) virus, viral hemorrhagic septicemia (VHS) virus, and *Herpesvirus salmonis*—cause disease among salmonid fishes. In addition, a virus may be the cause of erythrocytic necrosis in salmon.

INFECTIOUS PANCREATIC NECROSIS VIRUS

The IPN virus infects fry and fingerlings of several species, and mortality is generally heavy during epizootics. Shipment of infected eggs and fish has contributed to worldwide dissemination of the virus. Clinical manifestations include exophthalmia, darkened color, fecal pseudocasts, erratic swimming, and mucoid accumulations in the otherwise vacuous alimentary tract. Histopathological examination reveals necrosis of the pancreas and in some cases slight renal or hepatic necrosis (Kudo et al., 1973; McKnight and Roberts, 1976; Yasutake, 1970). Neither the clinical nor histopathologic changes clearly differentiate IPN from other salmonid virus diseases.

The IPN virus can be recovered from internal organs, sex products, feces, and peritoneal washings (Billi and Wolf, 1969; Frantsi and Savan, 1971a). Neutralization and complement fixation tests have demonstrated multiple, cross-reacting serotypes (Finlay and Hill, 1975; Lientz and Springer, 1973). Mortality is generally higher at 15°-16°C than at lower temperatures (Frantsi and Savan, 1971b; Sano, 1973). Survivors of epizootics may become carriers and shed virus with feces and sex products, thus permitting both horizontal and vertical transmission (Bullock et al., 1976; Wolf et al., 1963; Wolf et al., 1968; Yamamoto, 1975). An agent that is morphologically and serologically related to IPN virus has been recovered from several genera of marine invertebrates (Hill, 1976; Underwood et al., 1977).

The IPN virus is an unenveloped, icosahedral particle 55-65 nm in diameter (Moss and Gravell, 1969). The virion contains at least four structural proteins. These polypeptides are grouped in three general size classes, designated α, β, and γ, having approximate molecular weights of 100,000, 58,000, and 32,000 daltons, respectively (Dobos, 1977; Dobos et al., 1977). The viral genome consists of two segments of double-stranded RNA (Dobos, 1976; Macdonald and Yamamoto, 1977), which are transcribed by a virion-associated RNA polymerase (Cohen, 1975). Reaction temperatures of 24°-29°C favor continued, linear in vitro enzyme activity; reaction products have yet to be characterized. The capsid structure and nucleic acid content differentiate IPN virus from the recognized virus groups.

INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS AND VIRAL HEMORRHAGIC SEPTICEMIA VIRUS

Two rhabdoviruses, IHN virus and VHS virus, produce acute disease in salmonid fry and fingerlings; VHS virus also causes epizootics and mortality in older fish. The IHN virus has attained global distribution whereas VHS virus has thus far been isolated only in Europe. Clinical manifestations of IHN and VHS are similar to those of IPN, but also include petechial hemorrhages at the anus and bases of the pectoral and pelvic fins. In fish with VHS, hemorrhages may be evident throughout the viscera and musculature. Histopathological examination reveals necrosis of liver, kidneys, spleen, and pancreas. In IHN, but not in VHS, necrosis of the granular cells of the stratum compactum and stratum granulosum is evident (Yasutake, 1970). Both the clinical and histopathological manifestations of VHS may vary during the course of the disease (Ghittino, 1973).

Either IHN or VHS virus can be recovered from internal organs, feces, and sex products, and VHS virus may also be recovered from skeletal muscle. A pH of 7.6-7.8 is required for VHS virus to induce cytopathic effects in cell culture (Campbell and Wolf, 1969). One IHN virus serotype (McCain et al., 1971) and two VHS virus serotypes (Jørgensen, 1972) are recognized. The optimum temperature for promoting IHN mortality is 12°C and for VHS is about 10°C. The severity of infection with these two viruses generally decreases at temperatures above 15°C (Amend, 1970, 1976), but some survivors become carriers (Amend et al., 1973; Ghittino, 1973). Transmission occurs horizontally and possibly vertically with IHN virus, but apparently only horizontally with VHS virus.

Both IHN and VHS viruses contain five structural proteins, designated L, G, N, M_1, and M_2, having approximate molecular weights of 157,000, 73,000, 41,000, 23,000, and 19,000 daltons, respectively (Hill et al., 1975; Lenoir and de Kinkelin, 1975; McAllister and

Wagner, 1975). Glycosylation of the G protein of both viruses has been demonstrated, as well as phosphorylation of the N protein of VHS virus and the N and M_1 proteins of IHN virus (McAllister and Wagner, 1975). Both IHN and VHS virions possess an endogenous RNA-dependent RNA polymerase which transcribes the single-stranded RNA viral genome (McAllister and Wagner, 1977). The optimal temperature for in vitro transcription is about 18°C for IHN virus and about 15°C for VHS virus; these optimal temperatures closely approximate growth of IHN and VHS viruses in salmonid cell cultures. The mRNA species synthesized in vitro have been analyzed by cross-hybridization to single-stranded IHN and VHS virion RNA. The transcription products hybridize completely to the homologous genome but not at all to the heterologous genome, indicating no detectable complementarity between the IHN and VHS viral RNA templates. These data support earlier cross-neutralization studies which suggest that IHN and VHS viruses are unrelated agents (McAllister et al., 1974).

HERPESVIRUS SALMONIS

The isolation of *Herpesvirus salmonis* from moribund, post-spawning rainbow trout, *Salmo gairdneri*, was confirmed in 1975 (Wolf, 1976). A similar, if not identical, agent has been recovered from moribund fry of kokanee salmon, *Oncorhynchus nerka* (Sano, 1976). At present, *H. salmonis* is known to occur only in Washington State and Japan. It produces mortality in fry, but a causal relationship to the adult mortality has not been proved. Experimentally infected fish appear lethargic, but are intermittently hyperactive, exophthalmic, and darker in color. The abdomen is distended with ascitic fluid, and the musculature and internal organs are edematous. A marked anemia exists, and pathologic changes occur in the hepatic, hematopoietic, and pancreatic tissues. Since the virus has been recovered from both kidney tissue and ovarian fluid, it is assumed (but has not been experimentally demonstrated) that the virus can be transmitted horizontally and vertically.

Classification in the herpesvirus group is based on electron microscopy and cytopathic effects in cell culture. The enveloped *H. salmonis* particle is estimated to be 175 nm in diameter and to have a 95-nm icosahedral capsid (Wolf et al., 1978). The optimum temperature for virus replication in cell culture is about 10°C, and the cytopathic effect is characterized by the production of syncytia and Cowdry Type A inclusions (Wolf, 1976). The virus replicates only in the salmonid cell lines (RTG-2, RTF-1, CHSE-214, KF-1). Further biophysical and biochemical characterization of *H. salmonis* has yet to be accomplished.

VIRAL ERYTHROCYTIC NECROSIS

Recently, a condition designated viral erythrocytic necrosis (VEN) has been recognized in chum salmon, *Oncorhynchus keta*, and pink salmon, *O. gorbuscha* (Evelyn and Traxler, 1978). The disease is similar, if not identical, to piscine erythrocytic necrosis reported in several nonsalmonid marine species (Appy et al., 1976; Walker, 1971). Infected erythrocytes become rounded and undergo degenerative nuclear changes. Severe anemia results and thus may predispose the host to secondary infection.

Infected erythrocytes generally contain a single, round cytoplasmic inclusion. Although a virus has not been isolated, putative viral etiology has been supported by electron micrographs of infected erythrocytes and by efforts to transmit the disease (Evelyn and Traxler, 1978). Thin-section electron micrographs reveal seemingly enveloped particles 174 nm in diameter, with a 120-nm icosahedral capsid. On the basis of morphology, the agent has been tentatively assigned to the icosahedral deoxyribovirus group. The disease has been transmitted in chum and pink salmon by using filtered tissue extracts. Continued research is necessary to delineate the effects of VEN on fishes.

CONTROL OF VIRUS DISEASES OF FISH

Present efforts to control the spread of virus diseases include avoidance, disinfection of eggs and holding facilities, environmental manipulation, surveillance of hatcheries and their classification by disease status, and legislation to prevent the transportation of diseased fish (Amend, 1976). Iodophor disinfection of eggs shows potential for controlling IHN and VHS (Amend and Pietsch, 1972), but appears less effective for controlling IPN (Bullock et al., 1976). Immunization is a possible method for controlling IHN, VHS, and IPN (Amend, 1976; Fryer et al., 1976; Jorgensen, 1976). Additional outbreaks of *H. salmonis* have not occurred, but monitoring continues. Methods for control of VEN have not been investigated.

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