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Successful mitigation of viral disease based on a delayed exposure rearing strategy at a large-scale steelhead trout conservation hatchery

Rachel Breyta [a,b,*], Corie Samson [c], Marilyn Blair [c], Allison Black [a,d], Gael Kurath [a]

[a] U.S. Geological Survey, Western Fisheries Research Center, 6505 NE 65th St., Seattle, WA 98115, United States
[b] School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195-5020, United States
[c] US Fish and Wildlife Service, Idaho Fish Health Center, 276 Dworshak Complex Drive, Orofino, ID 83544, United States
[d] Institute for Public Health Genetics, University of Washington, Box 353410; Raitt Hall, Seattle, WA 98195-3410, United States

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ABSTRACT

In 2009, the largest steelhead trout conservation hatchery in the state of Idaho, Dworshak National Fish Hatchery (NFH), lost over 50% of the juvenile steelhead trout (*Oncorhynchus mykiss*) population being reared for release. The causative agent of this high mortality was the viral pathogen infectious hematopoietic necrosis virus (IHNV). This was neither the first nor the worst epidemic of IHNV to occur at the hatchery, but it was the worst in over a decade. Genetic analysis of IHNV isolates taken from juveniles suffering epidemic IHN disease in 2009 revealed that the virus was of the M group of IHNV viruses, known to have high virulence for trout. The water supply for steelhead trout rearing at Dworshak NFH is untreated water taken directly from the Clearwater River. Further genetic analysis of IHNV isolates from adults spawned in 2009 indicated that adult steelhead trout in the river (in the hatchery water supply) were the most probable transmission source for the epidemic IHN disease in the juvenile fish. Previously, Dworshak NFH had been able to gain access to reservoir water from behind the Dworshak Dam for nursery egg incubation and the earliest stage of fry rearing, which nearly eliminated incidence of IHN disease in that stage of rearing. Additionally, the nearby Clearwater State Fish Hatchery (SFH), which operates entirely with reservoir water, has never had a case of IHN disease in juvenile steelhead trout. Therefore, staff at Dworshak NFH sought and obtained access to a limited supply of reservoir water for the first few months of outdoor rearing of juvenile steelhead trout, beginning in 2010. This strategy delayed the exposure of juvenile steelhead trout to river water for several months. The effects of this program change were: drastic reduction in IHN disease in juvenile steelhead trout; interruption in the transmission of highly virulent M group IHNV from adult steelhead trout; no interruption in the transmission of low virulent U group IHNV from adult Chinook salmon; and a shift of IHNV types in adult fish spawned at Dworshak NFH in subsequent years from M to U group viruses. While juvenile steelhead trout may still be infected via exposure to IHNV in river water, the disruption of virulent M group IHNV has been successful in dramatically reducing IHN disease in steelhead trout every year since 2010.

Statement of relevance: Effective reduction of severe mortality due to IHNV.

1. Introduction

Dworshak National Fish Hatchery is the largest steelhead trout conservation hatchery in Idaho. The US Army Corps of Engineers built it in 1969, before many important fish health pathogen control standards were developed. Juvenile steelhead trout at this facility suffered extremely high mortality in 2008 and 2009 when over 50% of the population was lost each year. Diagnostic tests revealed that the cause of the high mortality was infectious hematopoietic necrosis virus (IHNV), which had repeatedly caused disease outbreaks at the hatchery over the past 35 years, although not in every year. In response to these dramatic losses, hatchery staff designed a significant change to their rearing strategy for steelhead trout juveniles.

IHNV is a rhabdoviral pathogen that causes acute disease and mortality in salmonid fishes. It is endemic in western North America where it is a significant burden on hatchery-based salmon and trout conservation programs. IHN disease pathology is observed in the hematopoietic kidney and spleen tissues; disease occurs primarily in juvenile fish where it can cause mortality as high as 90%. Asymptomatic adult fish can have high viral loads at or near the time of spawning. Both adults and juveniles can transmit their infection (Arkush et al., 2004; Mulcahy and Bauersfeld, 1983; Mulcahy et al., 1983a,b; Traxler et al., 1993). The primary route of IHNV transmission is horizontal, via waterborne virus, between fish of any age (Bootland and Leong, 1999;

* Corresponding author at: U.S. Geological Survey, Western Fisheries Research Center, 6505 NE 65th St., Seattle, WA 98115, United States.
E-mail address: rbjmax@uw.edu (R. Breyta).

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Mulcahy et al., 1983b). Spawning adult fish may transmit IHNV to their offspring via egg-associated virus, but in hatcheries this route is usually blocked by egg disinfection, so hatchery fish generally start life free of IHNV infection (McDaniel et al., 1994).

Previous studies comparing genetic sequences of many isolates of IHNV from North America have revealed three distinct viral genetic groups (Kurath et al., 2003a). The M genogroup is found primarily in steelhead and rainbow trout (migratory and residential forms of *Oncorhynchus mykiss*, respectively) in Washington, Oregon, and Idaho, especially in the Columbia River Basin (Fig. 1). The U genogroup of IHNV is found primarily in sockeye salmon (*Oncorhynchus nerka*) in Alaska, British Columbia, Washington, Oregon and Idaho, but also to a significant degree in Columbia River Basin Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout. The L genogroup is found in Chinook salmon of southern Oregon and northern California. Genetic typing of IHNV isolates based on sequence data from a variable 303 nucleotide segment of the virus glycoprotein gene, called the midG region, has been used for phylogeographic analyses. Each unique midG genetic sequence is called a 'type' and denoted by a universal sequence designator (USD) in the format mG###U/M/L, e.g., type mG001U. Many isolates may have the same type, and a single cohort of fish may have more than one type circulating among infected fish. When these midG types are combined with case-detection details like location, age, and species of the infected fish, IHNV transmission pathways can be inferred retrospectively (Breyta et al., 2013).

While egg disinfection protects hatchery juvenile fish from infection by their parents, horizontal transmission of IHNV is still a serious risk, as many hatcheries' water supplies contain free-swimming and/or anadromous salmonids, which may be infected with IHNV. Resident, free-swimming fish like kokanee salmon or rainbow trout are less likely to become exposed to IHNV over their lifespan than anadromous fish, which may be exposed via numerous encounters with other salmonid populations during their lifespan. These unsecured water supplies have been described as likely sources of virus in juvenile IHN disease events (Wolf, 1988; Anderson et al., 2000; Bootland and Leong, 1999; Bootland et al., 1994; Breyta et al., 2013; Bendorf et al., 2007). Since the only truly 'secure' water supply is well or enclosed spring water, we define here alternative terms relative to the risk of IHNV in hatchery water supplies. The lowest IHNV-risk water supply is that with the lowest burden of IHNV infected fish, as defined by routine surveillance. A water supply with a low IHNV-risk includes surface water where migration of anadromous fish is prevented and resident fish are routinely tested and found negative for IHNV, as from behind a fish-impassable dam. Water supplies with a moderate IHNV-risk include those that lie upstream of fish barriers like weirs that can be breached occasionally by environmental conditions, or that use treatment systems that may fail, or those that alternate use of well and river water, for example. Alternating between water sources with different burdens of IHNV is usually the result of limited availability of the most secure water supply during summer and fall months. Unsecure water sources are those with the highest IHNV-risk such as surface water from lakes or rivers/creeks that can and frequently do contain migratory fish infected with IHNV. Correlations between water supplies with a high virus burden and IHN disease emergence have been described in steelhead trout in coastal Washington in 1997 and 2007–2011 (Breyta et al., 2013). These emergence events were caused by a new incidence of trout-adapted M genogroup IHNV in a region where this virus had not been previously observed; genetic epidemiological analysis revealed that the most likely source of the M virus was populations of steelhead trout in the Columbia River Basin, including the Snake River watershed in northern Idaho (Breyta et al., 2013).

The Snake River is the largest tributary of the Columbia River Basin, and the Clearwater River watershed in north Idaho is the largest tributary of the Snake River (Fig. 1). Ongoing IHNV surveillance (testing

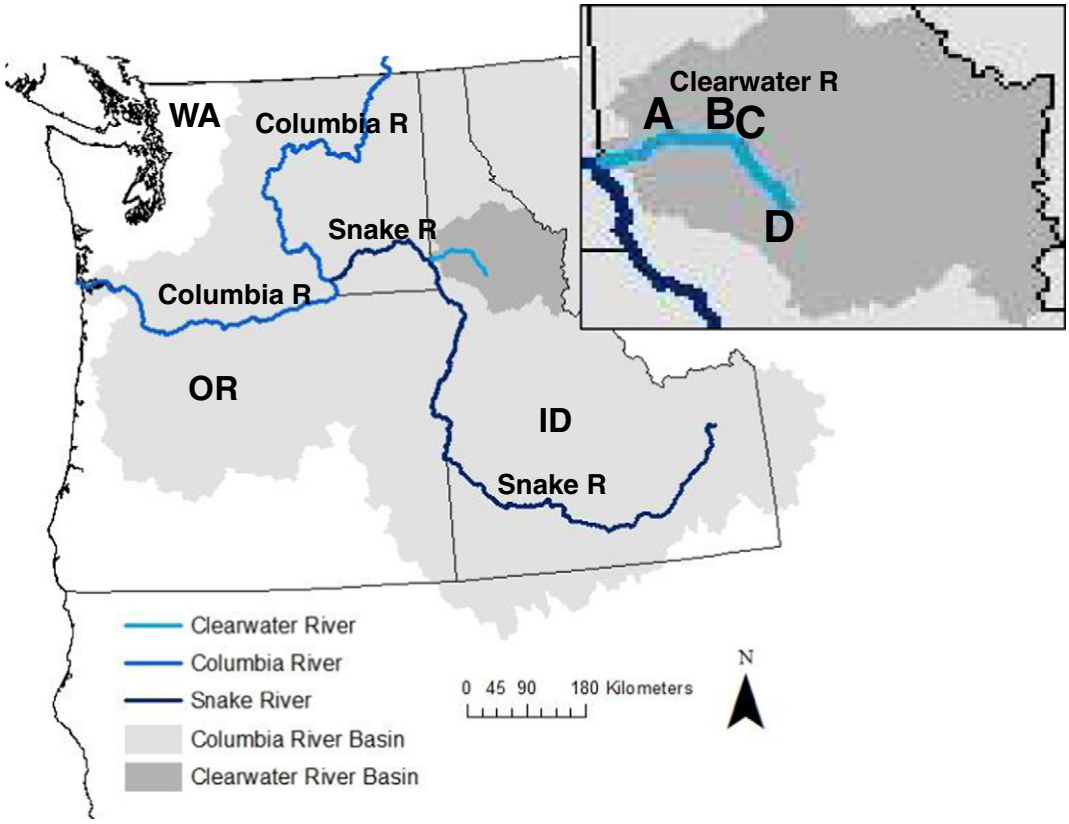

Fig. 1. Map of the Columbia River Basin in Washington, Oregon, and Idaho, showing the course and watershed of the Columbia, Snake, and Clearwater Rivers. Inset: Clearwater River and watershed with the approximate locations of the Nez Perce Tribal Fish Hatchery (A), Clearwater State Fish Hatchery (B), Dworshak National Fish Hatchery (C), and Kooskia National Fish Hatchery (D). The Columbia River Basin is 668,000 km^2, and the Clearwater River Basin is 24,980 km^2.