Transmission of Exotic Fish Viruses: The Relative Risks of Wild and Cultured Bait

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The movement of hatchery-reared sportfish to new watersheds has long been an important concern for fish health managers. To reduce the risk of disease transfer, the movement of many sportfish species, especially salmonids, is subject to numerous state and federal fish health regulations. The health status of fish used for bait is regulated by state laws that often fail to recognize the diversity of the baitfish industry. Many of the freshwater baitfish used in the United States are supplied by farms that utilize biosecurity practices including the use of well water, captive brood stock, and semi-annual farm inspections for significant diseases. However, anglers also purchase significant numbers of live and frozen baitfish that are captured from the wild, moved long distances to new regions or watersheds, and sold without any regard for their health status. These wild marine and freshwater fish have the potential to move viruses from endemic regions where fish populations have co-evolved with the pathogen, to new regions with naïve hosts that may have little innate resistance.

Viruses in frozen marine baitfish

Most finfish used as live bait in marine ecosystems are caught and sold locally, a practice that has little potential to move pathogens to new areas. However, thousands of tons of marine baitfish are captured from the wild, frozen, and shipped interstate and internationally each year. In Florida alone, the wild marine baitfish harvest is more than 500 metric tons/year (Florida Fish and Wildlife Conservation Commission 2000). These frozen fish that travel long distances may be a significant disease risk.

Viral hemorrhagic septicemia virus (VHSV) is a pathogen of particular concern. The European strain of VHSV has caused serious mortality in rainbow trout (*Oncorhynchus mykiss*) populations and major economic losses in Europe (Wolf 1988). The North American strain of this virus was first detected in adult coho salmon (*Oncorhynchus kisutch*) and Chinook salmon (*Oncorhynchus tshawytscha*) returning to Washington state hatcheries in 1989 (Winton et al. 1991). Since then, research has shown the North American VHSV to be marine in origin and of low pathogenicity or apathogenic to trout and salmon (Follett et al. 1997). However, this VHSV strain is a serious pathogen for marine fish species (Meyers et al. 1999) including juvenile Pacific herring (*Clupea pallasi*; Meyers et al. 1994; Kocan et al. 1997). In fact, VHSV is indigenous to several baitfish species in waters off the Pacific coast of North America: Pacific herring from Prince William Sound (Marty et al. 1998) and other waters in Alaska; Pacific herring, Pacific sardine or pilchard (*Sardinops sagax*; Traxler and Kieser 1994; Traxler et al. 1999), shiner perch (*Cymatogaster aggregata*), and threespine stickleback (*Gasterosteus aculeatus*; Kent et al. 1998) from British Columbia, Canada; Pacific herring and sand lance (*Ammodytes hexapterus*) from Puget Sound, Washington (Kocan et al. 2001); Columbia River smelt (*Thaleichthys pacificus*) from Oregon (Kaufman and Holt 2001; Hedrick et al. 2003); and Pacific sardines and Pacific mackerel (*Scomber japonicus*) off the coast of Southern California (Hedrick et al. 2003). Baitfish harvested from these waters are likely to have been exposed to this virus and may be carriers of VHSV.

The North American strain of VHSV has been recovered by cell culture from frozen Pacific herring even after two freeze/thaw cycles at conventional freezer temperatures (Meyers et al. 1994). These fish showed clinical signs of disease and probably carried high loads of virus particles. Subclinically infected or asymptomatic fish that are more likely to be used as bait will have lower virus loads making virus recovery and infection of receiving fish populations less likely because one freeze thaw cycle can reduce the number of surviving North American VHSV particles by 99.9% (Meyers et al. 1999).

In addition to well-described pathogens like VHSV, there may be other viruses present in frozen marine baitfish. Recent attempts to assess the risk of viral transfer via baitfish by fish health agencies in several states have resulted in the detection of other viruses. For example, frozen surf smelt (*Hypomesus pretiosus*), sold as bait, were procured from a local food store by staff from Montana Fish, Wildlife and Parks. A frozen sample was submitted for virus testing to the Washington Animal Disease Diagnostic Laboratory (WADDL) at Washington State University. An aquareovirus was isolated from these fish (J. Peterson, unpublished data). The Colorado Division of Wildlife conducted a similar screening on frozen rainbow smelt (*Osmerus mordax*). The smelt, packaged for use as baitfish, were purchased and sent to the WADDL lab for testing. An aquareovirus was also isolated from these fish (Walker 2001). In a third case, staff from the Alaska Department of Fish and Game (T. Meyers, unpublished data) examined frozen Atlantic herring (*Clupea harengus*) collected from New England waters and sold as bait in Alaska to determine if VHSV was present but instead isolated an aquareovirus. While most aquareoviruses are not considered to be pathogenic, these isolations demonstrate that fish viruses may routinely survive in frozen baitfish and may be disseminated to the watersheds by anglers.

Other viruses of concern that are known or suspected to be present in baitfish species include viral erythrocytic necrosis virus (VENV) that commonly infects asymptomatic Pacific herring (Meyers et al. 1986) and is experimentally transmissible to certain salmonids (Evelyn and Traxler 1978; MacMillan and Mulcahy 1979). Little is known about the ability of VENV to survive in frozen tissues and its transmissibility from herring to salmonids in freshwater has not been established. Another serious pathogen is the infectious salmon anemia virus (ISAV) that has recently been reported from several new locations, including the northeastern seaboard of the United States and Canada (Miller and Cipriano 2003), where it has been responsible for devastating economic losses in the Atlantic salmon (*Salmo salar*) farming industry. Given the spread of ISAV in Norway and the new isolations in the United States and Canada, some have speculated that natural reservoirs of infection may include fish present in coastal waters. A recent study in Norway demonstrated that herring challenged by immersion became infected with ISAV and the re-isolated virus was able to infect and cause mortality in Atlantic salmon (Nylund et al. 2002). Until proven otherwise, marine forage fish species should be highly suspect as potential sources of the virus and frozen Atlantic herring baitfish from these enzootic areas should be treated as a serious fish health concern.

Viruses from live freshwater baitfish

The freshwater baitfish industry has sales of more than $170 million per year. The most important species are the golden shiner (*Notemigonius crysoleucas*) and the fathead minnow (*Pimephales promelas*), but a variety of other wild and farmed species are sold in significant numbers. More than 80% of all baitfish are farm raised, but there is a very significant trade in wild-caught fish (Stone et al. 1997). The baitfish industry ships more than 10 billion fish per year, frequently across state lines and often cross country. These fish are distributed through wholesale and retail networks to anglers who take the live baitfish to rivers and lakes where they may be consumed by predators or escape into the wild. There is almost no commerce in frozen freshwater baitfish.

The recent discovery of spring viremia of carp (SVC) virus in the United States has raised new questions about the safety of live freshwater baitfish. The SVC virus is recognized as one of the most significant fish pathogens by the World Organization for Animal Health (OIE) and is common in Europe but never previously found in North America. In the spring of 2002, SVC virus was discovered in koi (*Cyprinus carpio*) grown by a major koi dealer in North Carolina (Goodwin 2002). At about the same time, it was reported in several lakes and rivers in Wisconsin including the Mississippi River (Marcquenski et al. 2003). The SVC virus infects a broad range of fish species (primarily cyprinids) and causes high mortality in susceptible hosts in cold water where the fish immune response is impaired (Ahne et al. 2002). Due to the pathogenicity, host diversity, and regulatory status of the SVC virus, the discovery of SVC in the United States caused state wildlife agencies to become concerned about the potential of baitfish to move the disease.

In order to assess the potential of baitfish to spread SVC, wild and cultured baitfish must be considered separately. Wild baitfish caught and sold in the same body of water pose no risk of disease movement, however, sellers of wild baitfish commonly move these wild fish long distances from watershed to watershed and frequently interstate. Fish health certification for non-salmonids is regulated only on the state level and there are few or no requirements for health inspection of these wild fish prior to distribution and sale.

The wild baitfish business is primarily located in the north-central United States and includes the SVC virus-positive regions of Wisconsin. Until the identification of SVC virus in July 2002, wild cyprinid baitfish, including fathead minnows, common carp, and native fish species were being captured and sold from a region now definitively identified as SVC virus positive. Because of the historically European distribution of the virus, little is known about its impact on North American fishes. The susceptibility of most North American cyprinids to SVC virus is unknown, but in Europe the virus does naturally produce disease in common carp, Asian carps, tench (*Tinca tinca*), and even rarely in more distant species like the wels catfish (*Siluris glanis*). In laboratory bath exposures, the virus also produces disease in roach (*Rutilus rutilus*), zebra danio (*Danio rerio*), golden shiners, and even non-cyprinids such as guppies (*Lebistes reticulatus*) and northern pike (*Esox lucius*). Thus, it seems likely that wild baitfish are susceptible to SVC virus and that they may pose a serious risk for the spread of SVC virus to other species and regions (Ahne et al. 2002).

There has also been concern about the potential spread of SVC virus by cultured baitfish. The majority of U.S. baitfish production is located in the delta region of Arkansas. Large farms, some with nearly 2,000 ha in production, produce golden shiners, fathead minnows, and other fish species that are distributed throughout the lower 48 states. If one or more of those farms were infected, the SVC virus might be distributed nationwide in the same manner as seems likely with wild fish. Fortunately, the controlled culture conditions and health monitoring of most commercial baitfish aquaculture make these disease risks much easier to assess. For 5 years prior to the discovery of SVC in 2002, the Arkansas aquaculture industry was already participating in a voluntary farm-wide disease inspection program that included protocols specifically designed to detect SVC virus. This program requires a semi-annual sample of at least 150 fish collected under the direct supervision of an Animal and Plant Health Inspection Service (APHIS)-approved veterinarian. The sample is shipped to an APHIS-approved laboratory that uses APHIS-approved protocols to inspect the fish for disease. If SVCV was found during one of these inspections, reporting of the result to APHIS and state authorities is mandated.

Immediately after the discovery of SVC in North Carolina, the Arkansas Bait and Ornamental Fish Growers Association met to develop a plan that would ensure the safety and marketability of their product. The association developed a Hazards Analysis Critical Control Points (HACCP) program that addresses infectious disease, farm biosecurity, and aquatic nuisance species. In the late fall of 2002 when water temperatures had cooled into the range where SVC virus replication is active in fish, samples were collected and submitted to the University of Arkansas Pine Bluff Fish Disease Diagnostic Laboratory (UAPB) according to APHIS-approved protocols. Samples were repeated in the spring and fall of 2003 and included an even larger group of farms; more than 75% of the baitfish production acreage in Arkansas was inspected for SVC and found negative for the virus. Equally important is that throughout the 6-year history of the program, not even one virus has been detected in tissue cultures of some 15,000 baitfish. The culture methods employed would be expected to detect not only SVC virus, but any culturable virus that replicates in cyprinid or salmonid cell lines.

The low prevalence of viruses in general and absence of SVC virus in Arkansas probably result from culture practices common in the state. Baitfish are produced in well water in levee-type ponds that are drained and dried between crops. New hatchery technology is widely employed to hatch fish indoors by using methods that make it possible to disinfect the outside of eggs thus preventing the transmission of most viruses from parents to progeny. New farm biosecurity measures greatly reduce the risk of disease movements between farms or from wholesalers back to producers.

Of course, SVC is not the only viral disease that could be transferred with cultured baitfish. The golden shiner virus (GSV) is an aquareovirus that has been reported to kill golden shiners stressed by heat or handling (Plumb et al. 1979). While it has been detected sporadically in sick fish (most recently in two cases at UAPB in 2000), it has not been detected in a farm inspection. The virus itself has not been shown to produce disease in any native North American fish other than golden shiners and is of a family generally regarded as being of very low pathogenicity. It was discovered in 1979 and, despite the wide distribution of cultured golden shiners, has never been reported in wild fish.

The only other virus of concern reported in cultured baitfish is the fathead minnow rhabdovirus. This virus was cultured in 1991 from fathead minnows that were returned to a farmer by an out-of-state wholesaler that dealt in both wild and cultured fish. Shortly after the fish were unloaded at the farm, they began to die of a previously-undescribed rhabdovirus. The farmer quickly quarantined the pond and submitted samples for diagnosis. On first report of a positive tissue culture, the farmer destroyed the fish and disinfected the pond. In the 6 years since that discovery, the virus has not been detected in Arkansas. The Arkansas fish were most likely infected at the dealer and quick action by the farmer prevented the establishment of the virus on his farm (Iwanowicz and Goodwin 2002).

The prevalence of viruses other than SVC virus in wild baitfish is unknown. The U.S. Fish and Wildlife Service National Wild Fish Survey has identified only one virus in wild cyprinids (a picornavirus from an apparently healthy sandbar shiner *Notropis scepticus;* Iwanowicz and Goodwin 2000). Recent survey work on wild fish in North Carolina

(Robert Bakal, USFWS, Warm Springs, GA; pers. comm.) has detected a virus that produces syncytia in tissue cultures and that appears to be an aquareovirus. The Koi Herpes Virus (KHV) is an exotic pathogen that only affects common carp and koi (both *C. carpio*) and is currently widespread in the United States causing heavy losses to ornamental fish dealers and hobbyists. Due to its species specificity, KHV is of little concern to fisheries managers who usually regard common carp as an exotic nuisance species.

Reducing the risk of epizootics resulting from the movement of baitfish

A few states ban the importation of live baitfish, whether they are from farmed sources or the wild, but there are few if any fish health regulations restricting the movement of frozen wild-caught baitfish. On the other hand, many jurisdictions do regulate the importation of farmed baitfish. Those limitations have provided strong motivation for the industry to eradicate known diseases and to prevent the introduction of new pathogens. Recent advancements in hatchery technology have recently made it possible for the cyprinid baitfish industry to use the same biosecurity arrangements that are successful in salmonids. Golden shiner eggs are now hatched indoors in well water under controlled conditions. Disinfection of the eggs and stocking into treated levee ponds using only well-water has enabled farmers to break the re-infection cycle and to work toward the production of specific pathogen free baitfish. This, along with a HAACP program covering aquatic nuisance species, should allay most concerns about the safety of cultured baitfish.

Given the current structure and poor regulation of the wild-caught baitfish industry, there seems little opportunity to decrease disease risks associated with the movement of fish obtained from the wild. Resource managers must recognize that imported wild baitfish can pose a threat of disease introduction even if the fish are frozen. In addition, the movement of live freshwater baitfish, especially susceptible species imported from regions known to harbor significant viral pathogens, should be of concern to agencies responsible for the health of these ecosystems.

Live fish are popular baits in many areas across the country. Reasonable attention to the source, handling, and health status of fish intended for use as bait will effectively reduce disease risks to acceptable levels. However, the harvest of fish from the wild and movement of them to new regions, along with their associated nuisance species and pathogens, is a practice that deserves a higher level of scrutiny by resource managers and the public.

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