Introduction

As the largest and most productive estuary in North America, Chesapeake Bay is a vital ecological and economic resource. The bay and its watershed have been degraded, however, by poor water quality, loss of habitat, and overharvesting. The Chesapeake Bay Program, a cooperative program among several Federal and State agencies, is working to restore fish and wildlife in the bay watershed and the habitats and water quality on which they depend. The U.S. Geological Survey (USGS) provides the science that is needed to improve the understanding and management of the Chesapeake Bay ecosystem.

Fish skin lesions and fish kills have occurred in Chesapeake Bay and its watershed for many years. In some cases, specific pathogens or environmental factors (low dissolved-oxygen concentrations, rapid temperature changes, chemical spills) have been associated with these events. Often, however, the causes of fish mortality are not well understood. In 2002, many smallmouth bass (Micropterus dolomieu) and other freshwater fishes died in the South Branch Potomac River. In subsequent years, similar mortality occurred in the North Fork (2004) and South Fork (2005) of the Shenandoah River and in the Monocacy River (2009) (see fig. 1). These events primarily affected adult fishes during the spring and early summer.

Factors That Affect the Health of Aquatic Ecosystems

Although pathogens and parasites are an inherent and natural component of ecosystems, overt disease and mortality are generally considered indicators of degraded systems. The emergence of infections may be linked to environmental changes such as (1) poor water quality (overabundance of nutrients, sediment, and toxic contaminants); (2) degrading stream habitats (caused by changes in flow and temperature, for example); (3) introduction of non-native species; and (4) altered food webs. The complex interactions among these stressors and the sublethal effects of complex mixtures of chemicals are poorly understood. For example, exposure to atrazine, a commonly detected herbicide in the Chesapeake Bay watershed, has been shown to increase the susceptibility of silver catfish to Aeromonas hydrophila (this bacterium or other motile Aeromonads were cultured from diseased bass) at sublethal concentrations (Kreutz and others, 2010), and is also associated with increased trematode (a type of parasite commonly found in the tissues of bass) infections in some amphibians (Rohr and others, 2008). Arsenic (used in pesticides, used as an additive in poultry feed, and found naturally) has been reported to modulate the immune response of fishes (Hermann and Kim, 2005; Lage and others, 2006) and is also associated with skin lesions in humans (Kazi and others, 2009). Additionally, exposure to arsenic was shown to enhance the ability of A. hydrophila to colonize and disseminate within exposed catfish (Datta and others, 2009) and inhibit the ability of zebra danio to clear viral or bacterial infections (Nayak and others, 2007).
The USGS and its cooperators are monitoring the biological effects of contaminants on fishes, identifying parasites and pathogens involved in lesions and mortalities, and working to determine the causes of poor fish health and kills in the Chesapeake Bay watershed. This Science Summary is one in a series that is designed to facilitate the understanding and application of results of relevant USGS studies by Chesapeake Bay resource managers and policy makers. It provides a brief overview of the most recent published work by the USGS and collaborators on fish kills and fish lesions in the Chesapeake Bay watershed, an understanding of how this information can be used to develop effective management policies and practices, and a list of references for additional information.

Figure 1. Watersheds in the Chesapeake Bay region in which fish-health studies have been conducted. Significant fish mortalities have occurred in the South Branch Potomac River, North Fork Shenandoah River, South Fork Shenandoah River, and Monocacy River watersheds (modified from Blazer and others, 2010).

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The KEY FINDINGS and the IMPLICATIONS FOR MANAGEMENT POLICIES AND PRACTICES AND NEXT STEPS listed below are from Alvarez and others (2008; 2009), Iwanowicz and Ottinger (2009), Robertson and others (2009), Blazer and others (2010), and Walsh and others (2012).

Key Findings

- A variety of lesion types (ulcers/erosions, raised pale lesions, raised inflamed areas) and various external parasites (leeches, grubs) are observed on affected fishes (fig. 2). Microscopic examination and culture demonstrated bacterial infections (*Aeromonas hydrophila* and other...
motile Aeromonads, *Aeromonas salmonicida, Flavobacterium columnare*, largemouth bass virus, and heavy internal parasite loads (fig. 3), indicating mixed infections. No pathogen or parasite was consistently identified as a single cause of the mortalities at all sites (Blazer and others, 2010).

Pathological signs of environmental stress and contaminant exposure, including gill lesions, tissue damage, and a high prevalence of feminized male smallmouth bass [exhibiting intersex (testicular oocytes) and plasma vitellogenin] were also observed. The co-occurrence of skin lesions, mortalities, and signs of endocrine disruption provides additional evidence that exposure to chemical contaminants and other stressors may contribute to the reduced health of these populations (Blazer and others, 2010).

- Estrogenic contaminants, known to induce intersex and vitellogenin in male fishes, also modulate the immune response (Iwanowicz and Ottinger, 2009) and certain disease resistance factors, such as hepcidin (Robertson and others, 2009).

- Arsenic concentrations, particularly in the skin and anterior kidney, increased significantly from March to May, the time period when skin lesions and mortality of adult smallmouth bass occur (fig. 4).
The parasites most commonly observed in affected bass were trematodes and myxozoans (Blazer and others, 2010), two groups that have complex life cycles involving snails (trematodes) or benthic worms (myxozoans). Nutrients, estrogens, atrazine, and other contaminants can lead to increases in these intermediate hosts.

Two new species of myxozoan parasites, *Myxobolus branchiarum* and *M. micropterii*, from the gills of smallmouth bass were described (fig. 5). Cysts of *M. branchiarum* are observed during mortality events, as well as during other times of the year. Parasite intensities were greatest during the spring; this may be an additional stress to infected bass (Walsh and others, 2012).
Atrazine has been detected at sites where fish kills have occurred, with the highest concentrations detected in the spring (Alvarez and others, 2008; 2009).

**Implications for Management Policies and Practices and Next Steps**

- The understanding and management of infectious disease and parasite infections in wild fish populations will become increasingly important in the Chesapeake Bay watershed as land-use and climate changes impact stream quality and mixtures of toxic contaminants continue to enter the water, sediment, and food.

- Management practices and policies to reduce loads of nutrients to the bay may help to improve conditions for fish in the watershed. Lower nutrient loads can help decrease the amount of bacterial and fungal pathogens and intermediate hosts of parasites, such as snails and benthic worms.

- Actions to reduce toxic chemicals, which cause tissue damage and immunomodulation in the freshwater aquatic environment, should be considered in terms of their effects on fish health and disease.

- Current toxicity benchmarks do not address the sublethal effects of contaminants of emerging concern or the additive and (or) synergistic effects of complex mixtures. Additional field and laboratory studies are necessary to identify these chronic, sublethal effects and their influence on disease in wild fish populations.
Understanding and managing disease in the context of conservation and ecosystem services requires multidisciplinary approaches that focus on the individual pathogens and parasites as well as the environmental stressors that regulate these diseases.

References Cited


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