Lessons from the mollusk that made headlines

ZEBRA MUSSELS (*DREISSENA POLYMORPHA*) APPEARED in North America in 1988, and the invasion has been well documented; for example, the U.S. Geological Survey (USGS) posts daily updates of sightings in Google Maps (Benson 2009; see fig. 1). Models show that zebra mussels spread by both natural process and human transport. According to Strayer (2009), colonization of North America has proceeded through a combination of long-distance leaps, medium-distance jumps, and short hops. Long-distance leaps include downstream transport through the Mississippi River basin and overland into Lake Mead (Nevada and Arizona). Medium-distance jumps include movement from the Great Lakes to inland lakes, and short hops include the movement between lakes within a regional lake district. Because the most vulnerable bodies of water have already been colonized, spread has slowed in recent years but will presumably continue until the entire potential range is filled (Strayer 2009). Extreme temperatures and inadequate calcium concentrations are the limiting factors to zebra mussel colonization. Hence, zebra mussels are unlikely to spread to the calcium-poor waters found in most of New England and the Pacific Northwest, the very cold waters of northern Canada, or the very warm waters in much of the U.S. Southwest.

Lessons learned for science

Appearance of the zebra mussel, which has become an icon for invasive species study and policy, helped give birth to invasion ecology, now a major part of general ecology. Moreover, as evidenced by the USGS zebra and quagga mussel information resource page (see Benson 2009), much is known about its spread. Furthermore, scientists have identified many ecological impacts of the invasion, most basically the withering of planktonic food webs and the thriving of littoral ones (i.e., organisms that live on, in, or near the seabed or lakebed). The following have decreased as a result of the spread of zebra mussels: phytoplankton and small zooplankton, benthic animals and large zooplankton, native bivalves (some to the point of local extinctions), dissolved oxygen in the water column, and calcium concentrations in freshwater bodies; water clarity, soluble nitrogen and phosphorus, bacteria, and local benthic animal populations have increased. In addition, the zebra mussel invasion has altered the pathways of contaminant cycling. In short, this species has transformed the food webs and biogeochemistry of freshwater habitats throughout North America. Seemingly significant yet unknown impacts include difficult-to-measure (or analyze) responses to the invasion (e.g., fish populations) and the outcome of transforming sediment from mud and sand to shell. Moreover, impacts to large-scale processes and systems are unknown. Strayer (2009) concludes that "scientists and funders working on alien species have preferred to

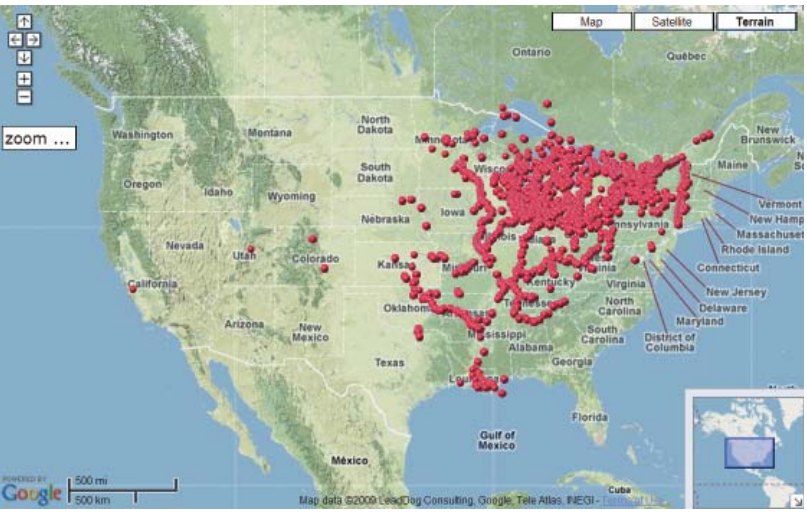

Figure 1. Updated daily on the U.S. Geological Survey's Web site, this map is a compilation of confirmed sightings of zebra mussels (red dots) in the United States and Canada from 1988 through 2009 (Benson 2009). The data shown here are as of 8 December 2009 [see note with Benson (2009) reference]. Each dot does not necessarily represent an established population, but for most locations it does. Reported sightings come from a variety of federal, state, and municipal agencies as well as universities, public utilities, and engineering and private consulting firms.

seek precise answers to small questions, rather than approximate answers to large questions" (p. 138).

Lessons learned for policy

Alarm associated with the appearance of zebra mussels drove advances in control technologies and policies for better prevention and management of species invasions in the United States (Strayer 2009). For instance, the U.S. government passed the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 and its reauthorization as the National Invasive Species Act of 1996, and set up the Aquatic Nuisance Species Task Force (1990) and National Invasive Species Council (1999). In addition, the Lacey Act (1900, amended in 1998) lists zebra mussels as "injurious." However, much remains to be done before the United States has a coordinated and effective policy (Strayer 2009). According to Strayer (2009), even after 20 years, the approach to alien species prevention and control in the United States is a patchwork of inadequate policies that are poorly coordinated, focused on species rather than vectors, slow, and largely reactive rather than proactive. Furthermore, the current approach "does not meet the recommendations of experts on invasive species ecology and management" (Strayer 2009, p. 140).

Lessons learned for economics

Except for rare examples, economic impacts of the zebra mussel invasion are poorly documented at best. Impacts to recreation, commercial fisheries, and commercial shipping seem not to have been studied at all (Strayer 2009). The documented cost to power plants and municipal drinking water plants in North America from 1989 to 2004 was $267 million, which is perhaps surprising, yet according to Strayer, "we are far from having a full appreciation of the economic effects of the zebra mussel invasion, even though this was articulated as an important question at the very beginning of the invasion" (p. 138).

Lessons learned for outreach

Outreach efforts via Web sites, brochures, wallet cards, lectures, and newspaper articles, for example, have resulted in the zebra mussel being the freshwater invertebrate with the highest public profile in North America. As a result, recreationists often provide the first report of spread to new areas. However, the lack of evaluation mechanisms built into outreach efforts has resulted in a lack of understanding of which tools actually work to increase public awareness and change damaging behaviors. Strayer (2009) identifies two challenges to successful public education: (1) overcoming public misconceptions and (2) overcoming the public tendency to see the spread of zebra mussels (and other invasive species) as random, unconnected problems. A primary misconception is that zebra mussels "improve" water clarity (without any acknowledgment of the dangers of moving this species into uninfested waters). For example, in order to improve water clarity, recreational divers likely introduced zebra mussels into two lakes in New Jersey, which had been far outside their established range (Strayer 2009). Zebra mussels are still touted as "the best thing that ever happened" to Dutch Springs, one of these lakes (http://njscuba.net/reefs/chart_pa_dutch_springs.html; accessed 3 December 2009). This example illustrates the deleterious outcome of the public harboring naive ideas about the benefits of zebra mussels (and other invasive species); it also illustrates that although invasions may be inevitable, they are also predictable and potentially controllable consequences of specific human behaviors.

Reference

Benson, A. J. 2009. Zebra mussel sightings distribution. http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/zebramusseldistribution.asp (data retrieved 8 December 2009).

Strayer, D. L. 2009. Twenty years of zebra mussels: Lessons from the mollusk that made headlines. Frontiers in Ecology and the Environment 7(3):135–141.

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