The Potential Distribution and Abundance of Zebra Mussels in California

Investigators: Anna Weinstein and Andrew N. Cohen, San Francisco Estuary Institute, Richmond, California

Zebra mussels have not yet been found west of the Continental Divide, and the nearest established populations are nearly 2000 miles away, in the Oklahoma River. However, they have been found on several occasions on trailered boats entering California, which alarmed natural resource managers in the state and precipitated this study. Other potential means of introduction include the bait fish and aquarium plant trade, ships’ ballast water, and any number of other routes such as for novelty or for algae control.

Potential impacts of a zebra mussel invasion in California

The zebra mussel could have very significant economic and ecological impacts in California, potentially even more serious than in the American Midwest. In the Midwest, the densest concentrations of zebra mussels are found within the plumbing of water delivery systems and in the cooling water systems for power plants. Should zebra mussels be introduced into California, hundreds of reservoirs and thousands of miles of steel and concrete pipes, water gates, fish screens, water intakes, filter plants, agricultural irrigation systems, and many other water system components could be at risk. The State Water Project and the Central Valley Project alone have over 1600 miles of aqueducts and canals. Virtually every citizen and agency in California is directly or indirectly dependent upon these systems to provide water for households, businesses, and agriculture.

Abundant zebra mussel populations in California could reduce or eliminate populations of rare species, change the composition of biotic communities, and alter the physical and chemical conditions of aquatic habitats. For example, in the San Francisco Estuary, a recently introduced Asian clam (Potamocorbula amurensis) has eliminated phytoplankton blooms in the northern part of the estuary, so that many zooplankton and bentthic organisms in this region now survive on organic matter carried in from the Sacramento-San Joaquin Delta. If zebra mussels were to become abundant in the Delta and Central Valley rivers, and efficiently filter the organic material out of these waters as they have in parts of the Great Lakes, there might be little left for organisms in the northern Estuary to feed on.

Method of analysis

In this study we analyzed and mapped the colonization potential of zebra mussels at 160 sites around the state, based on a selected set of environmental variables. We also considered how additional factors may affect colonization potential and abundance.

We based our analysis on five environmental variables for which tolerance limits are well-studied and data are available: salinity, dissolved calcium, pH, temperature, and dissolved oxygen. For most variables, we used averaged data for April to September to capture conditions during the zebra mussel’s spawning and growth period. We classified waters as having high, moderate, or low-to-no colonization potential based on their habitat suitability across all five variables, giving greater weight to calcium and pH, and mapped the results. In some cases we incorporated other information, such as records of periodic desiccation of shallow lakes, in our assessment.

We chose the sites for analysis to cover most of the state, capture a wide range of water quality conditions, show elevational changes along rivers, and include the large water delivery systems. The primary source of data was STORET, the U.S. Environmental Protection Agency’s (EPA) Water Quality Data Clearinghouse, which consolidates and organizes water quality data from federal, state, and local agencies. Eric Wilson, the STORET manager for EPA Region IX, extracted and tabulated the data for this study. We also obtained data from eight other state agencies. [See Cohen and Weinstein 1998b for a detailed description of methods and data used in this study].

Results

1. Potential Distribution

The zebra mussel has a wide but not comprehensive potential range in California. Of the 160 sites that we assessed, 54% ranked as having low or no potential for colonization by zebra mussels, 2% ranked as having moderate potential, and 44% ranked as having high. Most of the coastal watersheds, the west side of the Sacramento Valley, and the San Joaquin River and southern Delta, provide suitable water chemistry and temperature for colonization. Suitable waters include many important facilities such as the Delta-Mendota Canal, the California and South Bay aqueducts, the Los Angeles Aqueduct, the Colorado River Aqueduct, the All American Canal, and their associated reservoirs.

Of the 86 sites we ranked as having low or no colonization potential, low calcium was the critical factor in 65% of the sites, a combination of low calcium and low pH in 17% of the sites, high temperature in 12% of the sites, periodic desiccation in 5% of the sites, and low temperature or high salinity at the remaining 1% of the sites. Low calcium, sometimes combined with low pH, will prevent significant zebra mussel colonization in most of the Sierra Nevada and the upper Sacramento River watershed. Warm summer temperatures will prevent colonization at several southern California sites. Freezing, which is thought to limit zebra mussels’ range in parts of Europe, may prevent establishment in small or shallow lakes in California that freeze solid in the winter, though no such lakes were included in this assessment.
Periodic desiccation, possibly combined with high or fluctuating salinities, will prevent establishment in some northeast lakes. Zebra mussels can tolerate salinities up to about 8 parts per thousand as long as changes in salinity are gradual, so they may be allowed to colonize some inland brackish waters, although others, such as Mono Lake and the Salton Sea, are clearly too salty. Zebra mussels’ low tolerance for rapidly changing salinities would limit their seaward distribution in estuaries and coastal lagoons. They are abundant in some slightly brackish water portions of estuaries in Europe, but seldom persist where salinity exceeds 2 parts per thousand. We therefore estimate that zebra mussels could colonize in the Bay/Delta Estuary downstream to a tidally averaged, near-bottom salinity of 2 ppt. Here and throughout coastal California, rapidly fluctuating salinity levels would make many tidal regions very unstable habitats for zebra mussels, and their present likely depend on a upstream source of larvae to reestablish extirpated colonies.

Several cautions apply to these results:

- Additional factors may limit colonization. For example, zebra mussels are usually not found in very productive (that is, having high levels of phytoplankton) or very unproductive waters. Young zebra mussels also need a hard surface on which to settle when moving from the floating larval to the attached adult stage, so waters with mud, clay, or fine sand bottoms may not support zebra mussels. Also, young zebra mussels cannot settle in fast currents.

- The average values for some variables at some sites were just under or just over the tolerance limits used in the analysis. Where these average values were based on a small number of sampling events, especially for calcium or pH, this could have produced a misclassification.

- Interactions of some of the variables may limit colonization. For example, zebra mussels’ salt tolerance and metabolic efficiency decrease as temperatures rise beyond 25-28°C; therefore, zebra mussel distribution may be more restricted in the warm southern areas of the state than indicated by our analysis, which did not take such interactions into account.

- Confounding factors in studies of existing zebra mussel distributions may have given us an unrealistically narrow impression of their environmental tolerances; and introduced populations may become adapted, through natural selection and genetic change, to conditions that earlier generations could not tolerate. These issues could lead to waters being judged environmentally unsuitable which latter support thriving populations of zebra mussels, as has happened on occasion.

Finally, our preliminary assessment of some data on zebra mussel distribution that we acquired late in this study suggests that the calcium levels required for reproduction or early development may be greater than the threshold levels cited by most of the literature and researchers, and which we used in this analysis. Should this turn out to be the case, a number of the sites that we classified as suitable habitat may in fact not be able to support in situ reproducing populations. Some of these sites, however, may still be subjected to dense accumulations of zebra mussels resulting from the settlement of larvae produced by upstream populations. We hope to sort this issue out with further analysis.

2. Potential abundance

The aqueducts and many of the reservoirs of California’s State Water Project and the Central Valley Project provide optimal chemical and physical conditions for zebra mussels, and thus may support abundances approaching those seen in the Great Lakes. The California Aqueduct, the Los Angeles Aqueduct, and the Colorado River Aqueduct have concrete or steel substrates and flow rates under 1.5 m/sec. Even waters with soft substrates could potentially support high densities of mussels after initially settling on vegetation, sticks, or trash, and then on each other, to form large aggregations. However, flowing water may depress abundance in rivers and streams relative to lakes and reservoirs, and in smaller rivers relative to larger (and generally slower) ones. In Europe, zebra mussels are seldom found in rivers less than 30 meters wide and are generally at least an order of magnitude more abundant in lakes and reservoirs than in large rivers.

Abundance could also be affected by the presence or absence of upstream sources of larvae. Larvae from upstream sources can supplement resident populations and serve to re-inoculate an area should an environmental perturbation, such as a winter die-off, depress or exterminate a population. It is also possible that the settlement of larvae from upstream
has created some dense populations in waters that are unsuitable for reproduction.

Finally, abundance may be affected by predation. While it is clear that predation has in some cases significantly depressed the local abundance of zebra mussels, it is not known whether predation could control populations in an entire region and over the long term.

References:
A.N. Cohen and A. Weinstein. 1998 [a]. The potential distribution and abundance of zebra mussels in California. San Francisco Estuary Institute, Richmond, CA.
A.N. Cohen and A. Weinstein. 1998 [b]. Methods and Data for analysis of potential distribution and abundance of zebra mussels in California. San Francisco Estuary Institute, Richmond, CA.

There are also indications that public domestic water supplies are being affected. There is also the fear that the mussel will have negative impacts on the Lough Derg spawning grounds of the endangered pollan (Coregonus autummalis).

An international workshop "Zebra Mussels in Ireland," was held on 19 - 21 February 1998 in Connemara, Galway, sponsored by ESB, the Ir-Am-Aqua Initiative (an Irish-American aquaculture initiative between Ireland, Northern Ireland, and the Northeast Sea Grant Network), Connecticut and New York Sea Grant, the Marine Institute of Ireland, the Irish EPA, Duchas (the Irish Heritage Service), the Northern Ireland Environment and Heritage Service, the Shannon and Western Regional Fisheries Boards, and the National University of Ireland. More than 120 government, academic, and private sector attendees learned about the zebra mussel, its impacts, and control from a conference faculty made up of North America, Irish, and European researchers. North American presenters included: Ellen Marsden (University of Vermont), Robert McMahon (University of Texas-Arlington), Chuck O'Neill (New York Sea Grant), Nancy Balkom (Connecticut Sea Grant), and Ladd Johnson (Laval University).

Two of the abstracts from the workshop are presented below. More detailed articles by Irish researchers regarding the invasion will be published in Vol. 9 No. 3 of this newsletter. In the meantime, two main contacts regarding zebra mussels in Ireland are Dr. T.K. McCarthy (tk.mccarthy@ucc.ie) and Dr. D. Minchin (dmchin@rcf.ie). [Chuck O'Neill, Editor.]

Dispersal of Zebra Mussels in Ireland
Investigator: Dan Minchin, Marine Institute, Fisheries Research Centre, Abbotstown, Dublin 15

Zebra mussels Dreissena polymorpha were found for the first time in Ireland during 1997 naturalized in the lower region of the River Shannon between Limerick Dock and the northern end of Lough Derg, a linear distance of about 70 km. The first observation of zebra mussels was from the Limerick Dock in March 1995. This suggests that they had become established in 1994. The zebra mussel has been established in lower Lough Derg at least since 1995. This has been deduced from polymodal frequencies verified from known dates of immersion of boats from which samples have been obtained. Zebra mussels may have come from the UK on the bottom of second-hand boats imported on trailers and were found on one recently imported barge. It is possible that there has been more than one introduction with a further population introduced with discharged ballast, used as trim, from boats carrying timber from the Baltic Sea. It is likely that within a few years boats on the Shannon will extend the present range of zebra mussels to the navigable waterway network to include Lough Erne and the Barrow navigation via the Grand Canal. Leaflets have been distributed to advise boatowners, lock-keepers, anglers and public bodies as to how movements may take place and what measures to avoid range extensions.

The Zebra Mussel in Ireland
Investigator: T.K. McCarthy, National University of Ireland, Galway

Ireland’s fauna exhibits mainly “island” features, with reduced species richness and disjunctive structure being evident in respect of several taxonomic groups. Equilibrium models of island biogeography and knowledge of the effects of the Pleistocene glaciations can assist understanding of the relative importance of environmental condition and barriers to dispersal as determinants of the present day species composition of the Irish aquatic fauna. Species introductions, deliberate or accidental, by man are occurring at a greatly increased rate. The introduction of zebra mussels to Ireland reflects this trend.

Zebra mussels were first recorded scientifically in Ireland in May 1997 during studies in unionidacean mussels in Lough Derg, though subsequent enquiries revealed that lock gate operatives on the lower River Shannon had noted them in the previous year. Length frequency analysis of the initial samples indicated that the species had been established for at least two years. Questionnaires were issued to anglers, commercial eel fishermen, boat marinas and a field-sampling programme was undertaken. The results of this study, sum-
Asian clam, spartina, and purple loosestrife now threaten western waters. Problems that are caused by exotics in fresh and marine waters include:

a. The Central Arizona Project estimates zebra mussels will increase operations and maintenance costs between $4 - 5 million annually. This figure does not reflect cost to customers, farmers and water treatment plants. Great Lakes water users spend millions of dollars annually to monitor and control zebra mussels.

b. The Japanese oyster drill Ceratostoma inornatum has decreased aquaculture net profits by 55%, increased production costs by 17% and caused a 25% mortality in outplanted oyster seed.

c. The invasion of the Asian clam, Potamocorbula amurensis has affected food webs in San Francisco Bay by depleting phytoplankton stocks.

d. A 1996 report issued by the Nature Conservancy states that invasive non-native species are one of the leading threats to the ecological integrity of our nation’s forests, grasslands, and waterways.

The West has an opportunity to protect its financial and ecological resources from the damage caused by these nuisance species. A rapid and coordinated rapid response on the part of the public and private sector will ensure that the spread of aquatic nuisance species is limited. Research has indicated that most of these species be introduced into the west through recreational boating and angling activity, aquaculture and ballast water.

On November 20, 1997, representatives from resource agencies in CA, CO, KS, ND, NE, OK, TX, WA, WY and Manitoba, the U.S. Fish and Wildlife Service, Bureau of Reclamation, U.S. Army Corps of Engineers, Sea Grant and private industries met to discuss the 100th Meridian Initiative to Prevent the Western Spread of Zebra Mussels and other Nuisance Aquatic Exotics. The program outlined in the 100th Meridian initiative is aimed at preventing or slowing the spread of zebra mussels and aquatic vegetation into the western United States.

**Zebra Mussels: A Case In Point**

The zebra mussel, *Dreissena polymorpha* has rapidly spread across much of the eastern United States and Canada. This nuisance exotic has cost municipal and industrial water facilities millions of dollars to control. Native freshwater mussel populations are being decimated by zebra mussels (Biggins 1992), (Haag, et al., 1993). Their cumulative impact on aquatic ecosystems has yet to be quantified. Most experts believe that in the absence of effective preventative measures, the zebra mussel may spread throughout North America. With the exception of Oklahoma, States and Provinces west of Minnesota, Iowa, Missouri, and Arkansas have not been impacted by the zebra mussel invasion. The scarcity of water in the west makes water delivery systems and aquatic systems particularly vulnerable to zebra mussel fouling. For example, many westerners rely on canals, diversion systems, and dams built by the Bureau of Reclamation to deliver water for a variety of needs. Tens of thousands of miles of canals provide an ideal habitat for zebra mussel colonization. In the event that zebra mussels establish themselves, the probability of reducing the quality or quantity of limited water resources could be devastating to agricultural, industrial and recreational interests.

(F. Nibing, Bureau of Reclamation, Personal Communication 1995).

In 1994, the U.S. Fish and Wildlife Service (Service) conducted a study to determine the feasibility of preventing or reducing the further western spread of zebra mussel (Tyus et al., 1994). The study determined that the primary method of zebra mussel transport across the Continental Divide is by recreational boating activity. Many people trailer boats and motors across the country for fishing tournaments, recreational fishing, and pleasure boating. Adult zebra mussels may attach to hulls, motors, or in motor compartments. Larvae can survive in wells, bilge water, or in the internal parts of motors and trailers. Secondary methods for spreading zebra mussel veligers include the use of tank trucks and equipment by bait dealers, State and Federal fish distributors, the aquaculture industry, and the aquarium trade. Zebra mussels can also spread in irrigation water, introduced with hatchery bait or aquarium fish, or attached to or on various items that are used by anglers, the aquarium trade, and the aquaculture industry.

A Canadian boater survey and California Agricultural Check Stations inspections provide evidence supporting the conclusion that zebra mussels will be transported into the west via recreational boats. During the summer of 1994, Youth Service Canada students, under the supervision of Fish Futures, Inc.,
and with the cooperation and assistance of Canada Customs, Ontario Ministry of Natural Resources, and Manitoba Environment, conducted interviews and boat inspections at border crossings located between the United States and Canada as well as other key sites. All interviews and inspections were carried out in watersheds that contribute surface water to Manitoba. Major findings included: 93% of the boats originated from jurisdictions that have waters with zebra mussels, 5% had been in waters with zebra mussels in the last 5 days, 60% had been drained since being in zebra mussel-infested waters, and 32% had been cleaned since being in zebra mussel-infested waters (Fish Futures, Inc. 1994).

The California Department of Food and Agriculture inspects boats entering California at border agricultural inspection stations for the presence of zebra mussels. These exotic species have been declared injurious species by California law. Since the inception of the inspection program in early October 1993, there have been fourteen records of boats with zebra mussels being stopped at border agricultural inspection stations. Michigan was the point of origin in three cases and these mussels were dead (D.F. Peterson, California Department of Water Resources, Written Communication, 1995).

Despite this evidence of zebra mussels being carried into the west, there are still opportunities to preclude the extensive colonization that has occurred in the east. In the east, barges, large recreational boats and downstream colonization are considered the primary reasons for the rapid spread of zebra mussels. In the west there are a limited number of land and water pathways through which zebra mussels may colonize western waters. The large, relatively unpopulated arid and semiarid territories of western North America may provide the first realistic opportunity to slow or stop the further spread of the zebra mussel.

Goals and Strategies

The goal of the 100th Meridian Initiative is to prevent or slow the spread of zebra mussels and aquatic species west of the 100th Meridian. To determine and reduce the risk of zebra mussel infestation, a comprehensive prevention-exclusion program will be supported by the Service in the six States and Manitoba that straddle the 100th Meridian. Components of this proposed program include; information/education campaigns, strategic placement of voluntary inspection stations and monitoring programs.

Strategy I. Information and Education

The main aspect of an information and education program is to educate the public, particularly boaters and anglers, on what they can do to prevent the further spread of zebra mussels. Information and education programs will be developed by each state in order to meet its individual circumstances. Commercial haulers, recreational boaters and anglers and aquaculturists will be encouraged to utilize techniques that reduce the likelihood of zebra mussels being transported during their respective activities.

Actions

1. Develop a single theme public information campaign targeted at western boaters and anglers. Create templates of educational posters, pamphlets, and billboards for use throughout the western United States. [Lead Agencies: USF&WS, SG]
2. Contact long distance boat transport companies regarding 100th meridian exclusion initiative to request their participation. [Lead Agencies: USF&WS, MA]
3. Post exotics prevention (including voluntary inspection procedures) literature in conjunction with low power radio stations at interstate visitors centers, weigh stations, and rest areas in KS, NE, ND, OK, SD, TX. [Lead Agencies: States]
5. Post zebra mussel advisory signs at public boat access sites in KS, NE, ND, OK, SD, TX. [Lead Agencies: States, SG]
6. Create TV and radio public information spots on prevention message. Distribute these spots throughout States. [Lead Agencies: USF&WS, SG]
7. Contact state and local boat shows and request information be distributed that USF&WS Western Spread Display be used. [Lead Agency: USF&WS]
8. States will identify fishing tournaments requiring zebra mussel prevention conditions. [Lead Agencies: States]
9. Zebra mussel prevention information will be placed in state boater registration packets or fishing regulations when feasible. [Lead Agencies: States]
10. Aquatic exotic curricula including videos will be developed for elementary and secondary school. [Lead Agencies: USF&WS, SG, States]
11. Contact state Departments of Transportation to determine feasibility of placing low/high power radio stations at selected visitor centers, rest areas or weigh stations in states along the 100th Meridian Highways. These radio stations will be used to notify travelers and commercial haulers of the need to inspect for zebra mussels and other aquatic exotics. The radio spots will identify the closest voluntary inspection station. [Lead Agencies: States]

Strategy II. Inspection and Access Management

This strategy is intended to take management actions which will prevent the inadvertent spread of zebra mussels into the Western United States.

1. Determine existing state and federal laws, regulations and policies governing exclusion of aquatic exotics. [Lead Agencies: USF&WS, States]
2. Identify key east west interstate highways in 100th Meridian states. Locate all visitor centers, weigh stations and rest areas on these highways.(NE: I-80, ND; I-94, KS; I-70, OK; I-40, TX; Dallas Ft. Worth). [Lead Agencies: USF&WS, SG]
3. Identify strategic visitor centers, rest areas and weigh stations for use as voluntary boat inspection sites. Determine strategic times to ensure maximum visitation at boat inspection sites. [Lead Agencies: States]
4. Utilize low/high power radio stations to notify travelers and commercial haulers of the need to inspect for zebra mussels and other aquatic exotics. The radio spots will identify the closest voluntary inspection station. [Lead Agencies: States]
5. Identify strategic marinas and access sites for location of boat wash/inspection sites. [Lead Agencies: States, USACE, BOR]

Strategy III. Monitoring for Zebra Mussels and Exotic Aquatic Vegetation

This strategy will identify areas at specific risk to infestation as well as allow for a rapid response to initial infestation.

1. Develop and conduct assessment of 100th Meridian Initiative efforts including; effectiveness of educational/inspection/monitoring program. [Lead Agencies: USF&WS, BOR, USACE, SG, States]
North American Range of the Zebra Mussel
as of 1 May 1998

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Sightings: No new sightings

North American Range of the Quagga Mussel
as of 1 May 1998

Sightings: No new sightings

KEY
- Confirmed point sighting
- Area colonization
- Velder only sighting
WHAT’S NEW

**DPIC242** Allen, Y. 1997. Sampling for zebra mussels in industrial facilities. Louisiana Sea Grant College Program. (available from Louisiana Sea Grant College Program)


**DPTX100** Dauberschmidt, C., Dietrich, D.R., & Schlatter, C. 1997. Organophosphates in the zebra mussel *Dreissena polymorpha*: Subacute exposure, body burdens, and organ concentrations. *Archives of Environmental Contamination and Toxicology*, 33(1): 42-46. ($0.60)


**DPEC200** Kastner, R., Lutz, G., & Barrett-O’Leary, M. 1997. The zebra mussel and bait fish aquaculture. (available from Louisiana Sea Grant College Program)

**DPEC201** Kastner, R., Lutz, G., & Barrett-O’Leary, M. 1997. The zebra mussel and catfish aquaculture. (available from Louisiana Sea Grant College Program)


**DPEC203** Kastner, R., Lutz, G., & Barrett-O’Leary, M. 1997. The zebra mussel and hybrid striped bass aquaculture. (available from Louisiana Sea Grant College Program)

**DPEC204** Kastner, R., Lutz, G., & Barrett-O’Leary, M. 1997. The zebra mussel and tilapia aquaculture. (available from Louisiana Sea Grant College Program)


Filtration rates during chronic exposure trials were comparable to short-term trials after 48 hours, but mortality increased sharply at higher acridine concentrations. In the chronic trials, a degradation metabolite, 9(10H)-acridone, appeared in the medium after 4 weeks with concomitant cessation of mussel mortality. Indications of enhanced metabolic degradation of acridine over time by mussels, periphyton and bacteria in the aquaria were observed. (bib:fig:tab)

Klers, P.L. & Fraleigh, P.C. 1997. Uptake of nickel and zinc by the zebra mussel Dreissena polymorpha. Archives of Environmental Contamination and Toxicology, 32:191-197. ($0.84) DPTX093

Uptake of both dissolved (<0.45 μm) and particulate fractions of zinc and nickel under laboratory conditions by Dreissena polymorpha is reported. Dissolved nickel uptake was twice that of particulate nickel uptake, although the latter was also significant. Zinc uptake was highly variable ranging from exclusively particulate uptake in highly turbid waters, to primarily dissolved zinc under less turbid conditions. Differential excretion rates were observed with over half the zinc eliminated within 24 hours of accumulation, compared to no detectable nickel excretion. Zinc removal from the water column exceeded that of nickel, with biodeposition of zinc as feces and pseudofeces and bioaccumulation of nickel. The results suggest element-specific decreases in metal concentrations in the water column with concomitant increases in metal bioaccumulation and bioexcretion, and that biomonitoring programs using mussels would reflect changes in both particulate and dissolved metal concentrations. (bib:fig)


Abundance of the zebra mussel (Dreissena polymorpha) in the Mississippi River four years after the initial reports of colonization is reported. Sampling took place from May to October, 1995 at locks and dam facilities in the upper Mississippi River from Minneapolis, Minnesota to Muscatine, Iowa.

Every lock and dam was colonized except the two sites furthest upstream at Minneapolis. The highest mussel density (11,432 m²) was observed at Fulton, Illinois. In general, sites 161 km or more downstream from Minneapolis had the greatest zebra mussel densities.


A series of descriptive and manipulative experiments were conducted in the Hudson River Estuary to quantify the abundance, natural mortality and effectiveness of predator control on the zebra mussel (Dreissena polymorpha). Measurements of the mussel population size structure and density on rocks collected along a depth gradient over a season were used to determine distribution and abundance. Natural mortality was examined using cages to exclude or allow access to local predators. Mortality on rocks of known mussel density presented to blue crabs (Callinectes sapidus) in field enclosures was compared with enclosed cages containing mussels alone to assess effectiveness of crab predation. Naturally occurring predators, as determined by underwater video observation, were primarily fish of the genus Lepomis. Mortality was an order of magnitude higher in enclosures containing crabs than those exposed to only the local predator guild and approached localized extinction at densities of 0.1 crab/m². It was suggested that in the southern portion of the mussel range, where blue crabs are more abundant, predation may serve to regulate zebra mussel populations. (bib:fig:tab)


Testing conducted on forty-seven chemicals with potential for preventing attachment of zebra mussels (Dreissena polymorpha) is reported. Mussels were exposed to candidate
chemicals for 48 hours followed by a 48 hour post exposure deparation period in untreated water. Eleven chemicals prevented reattachment during exposure and had sufficiently low effective concentrations to warrant further analysis. Of those, three chemicals were selected for toxicity testing on non-target fish (bluegill, Lepomis macrochirus; channel catfish, Ictalurus punctatus; rainbow trout, Oncorhynchus mykiss) following evaluation of chemical cost, aqueous solubility, anticipated treatment concentrations, and potential hazard to humans or the environment. The chemicals tested, all antioxidants (BHA, butylated hydroxyanisole; tert-butylated hydroxyquinone; tannic acid) were generally not toxic for Dreissena at concentrations necessary to prevent reattachment, but did affect non-target fish. Exploration of more selective formulations, such as in paints or coatings, was suggested.


Characterization and partial purification of metallothionein-like proteins from the zebra mussel (Dreissena polymorpha) was undertaken to assess the mechanism of heavy metal binding in the mussel. Metallothionein is a protein capable of binding heavy metals, such as copper (Cu), cadmium (Cd) and zinc (Zn). Dreissena were exposed to Cd to stimulate production of the metallothionein-like proteins for study, followed by extraction of the proteins. Two metallothionein-like proteins were identified. Evidence supporting the characterization of the proteins and data on the metal binding affinity of these proteins for Cd, Cu and Zn are presented. Characteristics of these proteins in mammals and other invertebrates are discussed. Wide distribution and large numbers of zebra mussels in the environment coupled with the characteristics of these proteins make them potentially useful biomarkers for heavy metal monitoring.


This review synthesizes information not generally available to the English-speaking scientific community because of language and political barriers. Over 60 years of research, conducted primarily in the former Soviet Union and Eastern Europe, describes the effects Dreissena polymorpha on taxonomy, biology, food web ecology, productivity and ecosystem function. The invasion of lakes often precipitates dramatic changes within a waterbody. Dreissena becomes quite abundant in a short period of time generally dominating the native benthic community and outcompeting native filter feeders. Native filter feeders decline, accompanied by an increase in the abundance of animals feeding in or on the sediments. Sharp declines are often seen in native unionids, followed by establishment of an equilibrium between unionids and Dreissena. Efficient filtration by Dreissena results in a loss in pelagic zoo- and phytoplankton productivity with a concomitant increase in benthic production causing a redistribution of resources from the pelagic to the benthic communities. Benthophage fish biomass increases, and a generally greater percentage of primary production is consumed by higher trophic levels than in systems lacking Dreissena. Comparisons to data generated in North America are discussed.


Heavy metal (cadmium, lead, zinc) accumulation three salinity levels (1.7, 2.7, 4.7 ppt (parts per thousand)) is reported in Dreissena polymorpha. Two experimental sequences were used. The first consisted of natural river water adjusted for salinity and the second, of river water at the same salinity levels enriched with a mixed solution of cadmium, lead, and zinc. Increasing salinity generally enhanced metal accumulation, possibly by increasing free ions in the water column. Cadmium accumulation was increased significantly (p < 0.05) at all salinity levels compared to controls, zinc accumulation increased significantly at salinities of 2.7 and 4.7 ppt, and lead at 4.7 ppt. Ecotoxicological effects of salinity on metal ion bioavailability are discussed.


An examination of the role of intrinsic gill muscles and associated connective tissue and their ability to control water flow by adjusting the size of water passageways in Dreissena polymorpha is reported. Two sets of muscles with a complementary orientation to each other, are located within the hemocoe and bathed in hemolymph. They function to reduce interfilament distances in the gill, regulating ostial size in both the inner and outer ostia. Interactions of these muscles with surrounding connective tissue are described in detail. The in vitro response of these muscles to exogenous application of acetylcholine and FMRFamide which stimulate muscle contraction, reducing ostial area, and serotonin which relaxes contraction, increasing ostial area are presented. Changes in gill dimensions observed during microscopic examination are consistent with a role in regulating water flow. Gill response to neurotransmitters in other bivalve species is discussed.


Elevated concentrations of polynuclear aromatic hydrocarbons (PAHs) and PCBs detected in zebra mussels (Dreissena polymorpha) collected in the Detroit River are compared to levels of PAH metabolites in the bile of gizzard shad (Dorosoma cepedianum) and freshwater drum (Aplodinotus grunniens) collected in the Detroit River and western Lake Erie. The purpose being to compare distribution of PAHs to PCBs from the upper Detroit
River down the eastern margin of the western Lake Erie basin to Point Pelee, and to determine whether benthic fish show signs of exposure to elevated levels of PAHs. Zebra mussel PCB concentrations are consistent with those reported in a moderately polluted rivers, and demonstrate the influence of the river contamination down the coastline. Both PAHs and PCBs were elevated in tissues of mussels from the heavily industrialized portions of the Detroit River, as were the PAH metabolite levels in the fish. No evidence of contamination by ingesting contaminated biota or exposure to sediments was observed in the fish from the Lake Erie basin.


Concentrations of cadmium and lead were determined for zebra mussels (*Dreissena polymorpha*), perch (*Perca fluviatilis*), and an acanthocephalan parasite (*Acanthocephalus lucii*) infesting the perch for a reference site and one contaminated by roadway runoff to investigate the potential advantages of using intestinal parasites as bioindicators of heavy metal contamination. Comparison of muscle, liver and intestinal tissues in the perch, total soft tissue in *Dreissena* and *A. lucii* demonstrated higher burdens in *A. lucii* of both cadmium (22-23 times) and lead (30-38 times) than the host intestinal wall, and 120-230 times the lead and 10-12 times the cadmium burden of *Dreissena*. Variability within the samples, however, was less for *Dreissena*. The levels of both cadmium and lead detected were significantly higher at the roadway site compared to the reference site. *Dreissena* was more suitable for detection of localized contamination than the fish or their endoparasites, possibly due to their lack of mobility. It was suggested that more sensitive detection of heavy metal contamination within an aquatic system may accomplished using acanthocephalans if host mobility is restricted due to their greater accumulation capacity.

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