# *Aquatic Invaders of the Delaware Estuary Symposium*

***May 20, 2003***
***Penn State Great Valley Campus***
***Malvern, Pennsylvania***

# *Proceedings*

Partnership for the Delaware Estuary

DELAWARE ESTUARY PROGRAM

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Sea Grant Pennsylvania

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***Prepared by: Kirstin Wakefield and Ann Faulds***
***Penn State University, Pennsylvania Sea Grant***

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DEP

Sea Grant
Pennsylvania

# *Executive Summary*

Aquatic Invaders of the Delaware Estuary is the first symposium to comprehensively review the status and identify gaps in aquatic invasive species management in the Delaware Estuary watershed. Sponsored jointly by Pennsylvania Sea Grant, DEP's Coastal Zone Management Program, the Partnership for the Delaware Estuary, NOAA, and the EPA's Delaware Estuary Program, the symposium addressed both economic and ecological impacts, identified key pathways for introduction, and highlighted regional and local management successes.

The diversity of presentations gave a broad overview of invasive species issues across the watershed. Keynote speaker, Dr. David Pimentel discussed the economic costs and the human health risks associated with nonindigenous species. Dr. Paul Fofonoff highlighted similarities between Chesapeake and Delaware Bay invaders and environmental conditions, identifying a need for a targeted survey of invasive species in the Delaware Estuary. Dr. Kristin Saltonstall enlightened participants on the debate over native versus foreign strains of *Phragmites* and management implications. Poster topics ranged from oyster restoration in the Delaware Bay, to larval transport dynamics of invasive marine crabs, to modeling *Phragmites* infestations with GIS, to the effects of UV radiation on zebra mussel larvae.

The symposium facilitated dialogue between state and federal policymakers, natural resource managers, non-governmental organizations, environmental professionals, and scientists; over 75 participants attended from the tri-state area. With some of the "worst" invasive species in the US (i.e. zebra mussels) not yet present in the Delaware Estuary, participants clearly saw the need for a proactive management approach for this emerging problem. When asked to rank the value of federal, state, estuary-wide or local coordination to address AIS issues in the Delaware Estuary, participants ranked regional, estuary-wide coordination the highest. Active prevention and early detection, enhanced public awareness, and regional coordination will be the keys to minimizing the innumerable ecological and economic impacts of aquatic invasive species. Building on this dialogue and the frameworks of the Delaware Invasive Species Council, Pennsylvania's interagency invasive species workgroup, and the anticipated Mid-Atlantic Regional ANS Panel, we hope the lessons learned from this symposium will foster collaboration to prevent the introduction and control the spread of aquatic invasive species in the Delaware Estuary watershed.

# *Acknowledgements*

The design and organization of the symposium was guided by a steering committee composed of the following members:

- Debbie Carr, Fairmount Park Commission
- Ann Faulds, Pennsylvania Sea Grant
- Betsy Lyman, The Nature Conservancy
- Joe Matassino, Partnership for the Delaware Estuary
- Martha Maxwell-Doyle, Delaware Estuary Program
- Chari Towne, Schuylkill Riverkeeper Network
- Edward Santoro, Delaware River Basin Commission
- Joanne Steinhart, Delaware River Invasive Plant Partnership
- Carrie Szalay, Academy of Natural Sciences of Philadelphia
- Kirstin Wakefield, Pennsylvania Coastal Zone Management Program

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# *Table of Contents*

# *Symposium Agenda*

## ***Welcome***

Peter Evans, Director, Delaware Estuary Program

## ***Session 1***

*Economic and Ecological Costs Associated with Aquatic Invasive Species*
David Pimentel, Cornell University

*Biological Invasions in the Chesapeake and Delaware Bays - Patterns and Impacts*
Paul W. Fofonoff and Gregory M. Ruiz, Smithsonian Environmental Research Center

## ***Sesson 2, Pathways for Aquatic Invasive Species Introductions***

*PLNA- How Can We Make a Difference?*
Gregg Robertson, Pennsylvania Landscape and Nursery Association

*Preventing Aquatic Non-indigenous Species in the United States Through Regulation and Management*
Bivan R. Patnaik, United States Coast Guard Aquatic Nuisance Species Program

*The Native/ Non-native Oyster Situation: an Overview*
Frederick G. Kern, NOAA/NOS Cooperative Oxford Laboratory

*Bait Shop Introductions of Aquatic Invaders: Revelations from a Crayfish Survey*
John R. Wallace, Millersville University

## ***Session 3***

*Recent Research on Phragmites australis in North America: Implications for Management*
Kristin Saltonstall, Horn Point Laboratory, University of Maryland Center for Environmental Science

## ***Session 4, Regional and Local Management Initiatitives***

*Community-based Invasive Species Removal and Monitoring*
Thomas Dougherty, Fairmount Park Commission

*Ongoing Research on the Ecology and Control of Invasive Japanese Knotweed in Urban Parks of Philadelphia*
James N. McNair, Patrick Center for Environmental Research, Academy of Natural Sciences of Philadelphia

*Lessons Learned from Pennsylvania's Zebra Mussel Monitoring Program*
Tony Shaw, Pennsylvania Department of Environmental Protection

*Delaware Invasive Species Council (DISC); a Multi-tiered Collaborative Approach to Managing Invasive Species*
Bruce A. Richards, Center for the Inland Bays

*Pennsylvania's Invasive Species Initiatives at the State and Regional Level*
Leo Dunn, Pennsylvania Department of Agriculture

## ***Concluding Remarks and What's Next***

Ann Faulds, Pennsylvania Sea Grant

## ***Economic and Ecological Costs Associated with Aquatic Invasive Species***

Keynote Speaker, Dr. David Pimentel

*Abstract: More than 50,000 non-indigenous species have invaded the United States and their ecological damages and control costs total more than $137 billion/yr. The most serious aquatic invading species based on damages and control in terms of millions of dollars per year are fishes ($5400); zebra and quagga mussels ($500); others ($3000). One of the most serious ecological costs of biological invading species is the extinction of native species caused by non-native species. Approximately 40% of the species forced to extinction in aquatic ecosystems are due to predation, parasitism, and competition from biological invaders.*

A significant driving force to fuel the increased pace of invasive species introductions worldwide has been the dramatic increase in human population movements and foreign imports of food products. The United States population is growing by 3.3 million each year and the present population of 285 million is expected to double in the next 70 years. Most foodstuffs are introduced; the average American consumes 2,200 lbs/ yr. or about 3,600 cal/ day. Not all introduced species are invasive. For example, 99% of crops and 100% of livestock have been introduced to the United States. Ninety percent of world food, including the United States, relies on 15 plant and 8 livestock species.

However, a major effect of human driven invasive species introductions is a loss of biodiversity. It is estimated that exotic species have contributed to 40% of species extinctions in the United States. Florida alone now has 25,000 exotic plant species and only 2,500 native plant species. Nationwide there are about 18,000 native species while 50,000 exotic species are now established. Over 128 species of agricultural plants have become serious weeds including Johnson grass and purple loosestrife.

Over fifty thousand species have been introduced in the United States, causing $137 billion in damages each year. Below is a breakdown of these introductions:

| Taxa | Number of Species Introduced |
|---|---|
| Plants | 25,000 |
| Mammals | 20 |
| Birds | 97 |
| Mollusks | 88 |
| Arthropods | 4,500 |
| Microbes | 20,000 |

Annual exotic mammal pest damage in millions of dollars includes:

| | |
|---|---|
| Mongoose | $50 |
| Pigs | $800 |
| Cats | $17 |
| Rats | $19 |

The mongoose is a classic example of a biological control disaster. The mongoose was introduced in the West Indian Islands (including Puerto Rico) and Hawaii to control tree rats and Norway rats that were decimating sugar cane crops. Unfortunately, it only preyed on the Norway rat. As the Norway rat population declined, the tree rat populations flourished, and sugar cane crop damage continued. The mongoose itself has been responsible for the extinction of 12 species of birds and lizards in addition to harboring rabies and *Strongyloides* which both present a risk to human health.

About 4,500 species of exotic arthropods are present in the United States including gypsy moths and fire ants (that have attacked birds, snakes, chicks and killed 2 people in Mississippi). About 40% of our insect pests in the United States are exotic, costing $14.5 billion annually in damage and pesticide applications. The United States applies 1 billion of the 5 billion lbs of pesticide sprayed yearly, which in turn, has significant ecological impacts.

Exotic microbes comprise the highest percentage (65%) of crop pathogens (e.g. Dutch elm, and American chestnut blight). Damage and control associated with these pathogens costs nearly $23 billion/yr, discounting the environmental impact of associated pesticide applications.

***Aquatic Invaders***

Associated damages and costs of controlling aquatic invaders in the United States are estimated to be $9 billion annually:

| | |
|---|---|
| Fish | $5.4 billion |
| Zebra and quagga mussels | $1 billion |
| Asiatic clam | $1 billion |
| West Nile Virus (WNV) | $1 billion |
| Aquatic plants | $500 million |

(Cost of mechanical and chemical aquatic weed control ranges from $2,000 to $6,000/ hectare/ yr; once established, removal is very difficult.)

| | |
|---|---|
| Shipworm | $205 million |
| Green Crab | $100 million |

Exotic diseases including those associated with waterborne vectors, such as West Nile Virus (WNV), which affects 4,200 people annually, are extremely hard to combat. Mosquito spraying for WNV costs $15/ person/ yr in affected communities. Public education and screening programs for United States ports of entry can minimize exotic disease transmission. Better risk communication among federal agencies such as the USDA and health services is also needed. An example of an extremely invaded aquatic system is San Francisco Bay, host to 234 alien species. There, 90% of the species and 99% of the biomass are composed of introduced species. From 1851 to 1960, 117 new species were introduced to the Bay. From 1960 to 1995, an additional 117 species were introduced. The pace of introductions has accelerated, a national trend that is expected to continue.

Discussion Questions:

Q – What are your data sources?
A – Lots of places, for example, there are 63 million cats in the United States. How many birds does each cat kill? By looking at the literature we estimate about 13 birds/cat/yr, which totals 500 million birds. What's the value of a bird? Birders spend $0.40/bird/year while hunters spend $260/bird shot. Exxon paid $800 to replace each bird that died in the Valdez oil spill. We used a figure of $30/bird although some ornithologists were not happy with our figure. It's a difficult thing to determine, however, decision makers are more likely to listen to you if you speak numbers.

Q – The number of species coming in is daunting. Is there any hope?
A – We shouldn't give up, although I know of only 2 successful exterminations; the Mediterranean fruit fly and the citrus canker. Human and livestock diseases alone are major problems.

Q – What do you think about the intentional introduction of the Asian oyster in the Chesapeake?
A – I think we should proceed very, very cautiously. The problem is that once released, it cannot be taken back.

## *Biological Invasions in the Chesapeake and Delaware Bays - Patterns and Impacts*

Paul W. Fofonoff and Gregory M. Ruiz
Smithsonian Environmental Research Center

*Abstract: Since the beginning of European settlement in the 17th century, estuaries of the mid-Atlantic region have been invaded by non-indigenous organisms. Invaders, which range from protozoans to mammals to birds, occur along the whole salinity gradient from freshwater to the ocean, and occur in every habitat. We have documented at least 160 non-native species, with established populations in tidal waters and wetlands of Chesapeake Bay, and in a preliminary assessment, at least 70 species in the Delaware Bay-River estuary. Many species of invaders are shared between the two estuaries, and the actual total of invaders in Delaware Bay probably approaches that in the Chesapeake. More extensive surveys would be needed to fully assess the extent of invasions in the Delaware Bay system. An analysis of shipping arrivals in Delaware Bay indicates that many ships arriving at the ports of Wilmington, Camden, and Philadelphia come from European ports invaded by fresh and brackish-water species from the Black Sea-Caspian basin, home region of the zebra mussel. It is likely that many invaders from this region, such as mysids, amphipods, and other invertebrates would not be detected without targeted surveys. The known economic and ecological impacts of biological invasions in Chesapeake and Delaware Bays will be discussed. However, very few quantitative studies of impacts of introduced species are available, and much information consists of subjective impressions. Consequently, the impacts of invasions in the region may be underestimated.*

Invasions by nonindigenous species (NIS) are a major force of global change, resulting in significant ecological, economic, and human health impacts. For the United States alone, aquatic invasive species cost an estimated $10 billion/yr. The transfer and introduction of NIS by human activities has increased dramatically over the past century and continues to do so.

While the size varies considerably between the Chesapeake and Delaware Bays, there are many similarities. Both estuaries have extensive tidal freshwater regions, wetlands, a long, gradual salinity gradient, large cities in the upper reaches, and support major seaports.

The Smithsonian Marine Invasions Lab is developing a relational database, NEMESIS, the National Exotic Marine and Estuarine Invasive Species Information System (http://invasions.si.edu/nemesis), to compile information on marine invasions. NEMESIS houses comprehensive records from 1998 to present, covering multiple coasts, regions, and bays. Chesapeake Bay data from 1994 to present will soon be available.

Within the database, information sources for Delaware Bay invasions came primarily from published literature. For Chesapeake Bay invasions, data sources included gray literature, museum collections, and interviews with local scientists. In addition, field surveys of fouling organisms were conducted for both the Chesapeake and Delaware Bays.

Following review of the NEMESIS database, we found that a high number of species (63) were shared between both bays. Some species in the Chesapeake Bay appeared to be limited by climate; however, environmental changes such as global warming may expand their ranges northward. Only two species present in the Delaware Bay have not been found in the Chesapeake, Chinese lobelia and an isopod from the Pacific Ocean.

NIS in the Delaware Bay originated from other regions in the United States (freshwater fish introductions) as well Eurasia (flowering plants). Surprisingly, however, a higher percentage of NIS are native to the Western Pacific. This may be in part because the climates of the Pacific Northwest, China and Japan are similar to the Eastern Atlantic Coast.

Because the estimated number of aquatic invasive species in Delaware Bay depends on the quality of information available, the frequency of invertebrate and algal invasions has been underestimated. Although data has been compiled from local sources, a targeted survey of Delaware Bay's aquatic invasive species is needed. Based on the distribution of species in northern bays, e.g. Long Island Sound, we anticipate an increase in the number of documented invasive species. Fishes, vascular plants, and mollusks are the most abundant nonindigenous species; however no tunicate surveys have been conducted. Some examples of Delaware Bay invaders include: the protozoan MSX introduced in 1957 via oysters; *Hydrilla* discovered in the Delaware River near Philadelphia in 1990's; *Hydroid sp*. near Philadelphia; the Asiatic clam in the Delaware River, Chesapeake Bay and freshwater tributaries; and the green crab in Lower Delaware Bay and the mouth of the Chesapeake.

Biologists from VIMS, University of Delaware, and Smithsonian Environmental Research Center provided much of the early data and drove much of the Chesapeake Bay data collection efforts. Despite the growing popularity of water gardens, few aquatic plants have been introduced since 1950. However, the rates of algae and invertebrates introductions appear to be increasing, with shipping being the dominant vector.

Ballast water introductions continue to be a threat to mid-Atlantic estuaries, particularly species originating from the Ponto-Caspian region. Many Ponto-Caspian species, such as zebra mussels, round gobies, and spiny waterfleas are tolerant of mid-Atlantic estuary conditions - salinities ranging from 0-18 ppt and temperatures between 0-30°C. The ports of Wilmington, Delaware and Philadelphia received the highest number of cargo ships from the Baltic seas between 1997-1999. Further surveys are necessary to evaluate organisms present in ballast water and assess the estuaries for Ponto-Caspian species. Although pollution monitoring occurs at all ports, port employees are generally not trained to identify invasive species. A targeted survey conducted by scientists would provide the best database of potential Delaware Bay invaders.

Discussion Questions:

Q – Its not always clear whether a species is a native or exotic. How can you tell?
A – It's sometimes a debatable process, but we have a set of criteria. We look at the geography of the species including the previously known range and if its been found in previous surveys of an area. So we see how closely the species fits the criteria. Some species are easy to tell, others fall into a grey area.

Q – Have there been studies on the positive effects of introduced filter feeders on water quality?
A – Zebra mussels may be a case where increases in filtering caused negative impacts (such as a proliferation of nuisance aquatic plants) and a beneficial impact on native freshwater sponges. A study of *Corbicula* in the Potomac indicates the clams have probably increased water clarity. Improvements to sewage treatment plants have also increased water clarity, so it's hard to know the relative role. *Corbicula* also provides food for fish. Other negative impacts of *Corbicula* in the Potomac may include an increased the growth of *Hydrilla* and native aquatic plants, clogging of power plant intakes, and competition with native mussels.

Q – Did you mention invasive *Phragmites* insects?
A – There may be as many as 18 introduced arthropods in the northeast that feed on *Phragmites*. We don't know how this will ultimately impact *Phragmites*. Invaders often exhibit an initial period of rapid growth followed by a population drop as native species learn how to eat them or introduced pests manage to impact populations. We may be seeing that with *Phragmites*, but it's too soon to tell.

Q – In Lake Erie, doesn't the round goby feed on zebra mussels?
A – Yes, they do. They're neighbors in the Caspian and Black Seas. Now they're back together again in the Great Lakes.

Q – Do you have a sense of how well or poorly we're addressing the situation in the Chesapeake and Delaware Bays?
A – I think there's a need for increased monitoring to find new arrivals. Once a species becomes established, it's a lot harder to do something about it. Science is limited in time and space, so in many cases, some described impacts are just that; subjective impressions. We need to know if the benefit of management actions outweighs the damage done by the invader. It might be more

productive to focus on prevention, monitoring and rapid action than to combat well established invaders.

Q – Have you looked at cruise ships as vectors of invasives?
A – We haven't sampled cruse ships but they present a potential fouling problem. In many ways, fouling is more difficult to deal with than ballast water, which is relatively easy to tackle with technology. Fouling can be prevented with toxic paints, the more effective the paint more deadly. With an aging shipping fleet we can expect to see a growing fouling problem. I personally think it deserves a lot more attention in American ports, but I can't offer an easy solution.

## *PLNA- How Can We Make a Difference?*

Gregg Robertson
Pennsylvania Landscape and Nursery Association

*Abstract: The Pennsylvania Landscape and Nursery Association (PLNA) is helping the Pennsylvania green industry (nurseries, garden centers and landscape contractors) and the gardening public understand the impact of invasive plants on Pennsylvania's ecosystems. Having adopted the American Nursery and Landscape Association (St. Louis) Code of Conduct in 2002, PLNA is now implementing this code by posting a list of invasive plants and native alternatives for Pennsylvania gardeners on their website; evaluating plant invasiveness ranking systems for use by Pennsylvania's nursery industry; and incorporating invasive plants education into PLNA's professional certification programs.*

The PLNA represents 750 companies in Pennsylvania's Green Industry, including production nurseries, garden centers, landscape contractors, arborists, irrigation contractors, turf farms, seed companies, power equipment dealers, hardscaping manufacturers and others, however, the primary focus is terrestrial plants. Non-native plants are cultured to grow in manicured or urban landscapes, which are often inhospitable for native Pennsylvania plants, and therefore, susceptible to weed invaders. In addition, the nursery industry is increasingly becoming a global trade. Pennsylvania growers and distributors import plants and cuttings from foreign countries, where warm climates alleviate the costs associated with raising plants in greenhouses. This practice can lead to the introduction of agricultural plant pests and diseases, for example, geranium cuttings from Kenya were riddled with a virus that attacks the roots of important food crops like peppers and potatoes.

PLNA is proactively limiting the use of invasive plants through the nursery and landscape industry. They are developing a comprehensive invasive plants action plan based on the St. Louis Code of Conduct. To date, they have collaborated with DCNR on a list of Pennsylvania's invasive plants and are creating a database of invasive plants and native alternatives that will be posted on their website www.plna.org. In addition, PLNA is evaluating scientific protocols for assessing the invasiveness of plant species sold and propagated in Pennsylvania's nursery industry.

Discussion Question:

Q - What percentage of plants propagated in Pennsylvania are sold outside?

A - Most plants propagated by the Pennsylvania nursery industry are purchased from other states or countries. Many are imported from Oregon and North Carolina. Some are imported from foreign countries with warmer climates, like geranium cuttings from Kenya, where propagation costs are reduced compared to raising plants in greenhouses.

## *Preventing Aquatic Non-indigenous Species in the United States Through Regulation and Management*

Bivan R. Patnaik
US Coast Guard Aquatic Nuisance Species Program

*Abstract: Invasive aquatic non-indigenous species (NIS), transported by ballast water, are one of the greatest threats to U.S. waters. To address the ecological, economic, and health issues caused by NIS, Congress enacted the Non-indigenous Aquatic Nuisance Prevention and Control Act and reauthorized it with the National Invasive Species Act. These acts authorized the U.S. Coast Guard to develop regulations to prevent and control the spread of NIS in U.S. waters via ballast water discharge. The U.S. Coast Guard has several regulations in place and is currently working on future regulations. We are at the early stages of these efforts and are optimistic that they will be beneficial in protecting our waters.*

Impetus for Coast Guard Ballast Water Regulations:
The zebra mussel invasion in the Great Lakes led to the National Aquatic Nuisance Prevention and Control Act (NANCPA) of 1990. Specific ballast water regulations were created for the Great Lakes in 1993 and extended to the Hudson River in 1994. The Great Lakes Ballast Water Program recommended management actions to reduce the introduction of aquatic invaders through ballast water. Foreign vessels could: a) exchange ballast water 200 m offshore at a minimum depth of 2000 m (CFR 33); b) retain ballast water on board, or c) utilize another environmentally sound ballast water management method approved by the US Coast Guard.

Concern over ballast water exchange in the San Francisco Bay prompted the revision of NANCPA, and in 1996, the National Invasive Species Act (NISA), was passed into legislation. In addition to the three options for ballast water treatments listed above, NISA recommended ships could also discharge ballast water to an approved reception facility, or under extraordinary conditions could conduct ballast water exchange in an area designated by the Captain of the Port (COPT). However, vessels could be granted exemptions for the following reasons; the vessel is a crude oil tanker engaged in coastwise trade; the vessel is a passenger vessel (i.e. cruise ship) with a functioning treatment system; the vessel is owned and operated by DOD or USCG; the vessel discharges at the origin of the ballast water; the vessel travels through United States waters without entering or departing a United States port; or if there is a safety concern for the vessel.

Under NISA, Congress also required the Coast Guard to develop national voluntary guidelines for ballast water management. Created in 1999, the national voluntary guidelines require vessels to file Ballast Water Management (BWM) reports. These reports are entered in the National Ballast Water Clearinghouse (http://invasions.si.edu/NBIC/ballast.html). USCG reported to Congress in 2002 on the efficacy of the National Voluntary guidelines, and found them to be ineffective in ballast water management. The two-year compliance with BWM reports was only 30%. Of those vessels submitting BWM reports, only half were conducting ballast water management. So, of the 50,000 to 70,000 vessels entering United States ports per year, only 7,500 to 10,500 complied with BWM guidelines.

The USCG is currently developing a suite of regulations to strengthen BWM in the United States. Anticipated regulations include: Civil penalties ($25K fine) for failure to submit BWM reports; a National Mandatory Ballast Water Management Program; creation of an experimental approval program for environmentally sound BWM methods where vessel owners are exempted from regulations until experiments are completed; and development of a ballast water discharge standard based on size exclusion that will help drive technological advances in BWM. These regulations, in concert with proposed NAISA legislation (introduced to Congress in March 2003), should strengthen BWM practices in United States ports and minimize the risk of this vector for introducing new invasive species.

For more information, visit: www.uscg.mil/hq/g-m/mso/mso4/ans.html.

## *The Native/ Non-native Oyster Situation: an Overview*

Frederick G. Kern
NOAA/NOS Cooperative Oxford Laboratory

*Abstract: Continued declines in native oyster populations in Delaware and Chesapeake Bays have led biologists and managers to investigate alternative management practices to enhance oyster production. Native oyster populations have declined due to many factors including environmental changes, over-harvesting and sustained disease mortalities. Approaches to rebuild native oyster populations include: shellfish bed restoration, the use of selected disease resistant oysters, and protecting natural brood stock reserve areas. Recently, investigators have examined non-native oyster species, Crassostrea gigas, the Pacific Oyster, and Crassostrea ariakensis, the Chinese river oyster. The controversy surrounding these issues will be discussed.*

The oyster industry in the Delaware and Chesapeake Bays has been plagued since the 1950's introduction of the parasite, MSX. Just when native oyster populations began to recover, drought conditions leading to higher temperatures and salinities and the spread of Dermo disease (*Perkinsus marinus)* dealt another blow to the oyster industry in the 1980's.

A traditional fishery, the oyster fishery impacts the economy off-dock as well as dockside. A wealth of shucking houses and boat construction facilities appeared around the Bays, but within the last 10 years, the number of shucking houses has decreased from 50 to 2.

The decline of the oyster fishery and associated industries led to examination of alternative species to propagate. In particular, the Pacific oyster, *Crassostrea gigas*, was examined for introduction on the east coast.

In 1997, Virginia proposed to introduce *C. gigas* as an alternative to aquaculture with native *C. virginica*. They instituted a shellfish recovery program and genetic research to investigate natural disease resistance in *C. gigas*. In 2000, they began investigating the Chinese River Oyster (*C. ariakensis*) as a second alternative. *C. ariakensis* is disease resistant, has no known pathogens, and grows rapidly. However, triploid sterility is not 100% reliable; in a large population some oysters would revert to a reproducing state. The ecological impact of non-native oysters on hard clams and other organisms is currently uncertain.

In 1993, EPA's Chesapeake Bay Program instituted a policy for the introduction of non-indigenous aquatic species, signed by the governors of PA, MD, VA, and DC. Under this policy, all proposed new introductions are subject to scientific review, and monitoring must be conducted to reduce the risk of escape and disease transmission. In 2002, the Virginia Seafood Council proposed to introduce 1 million *C. ariakensis* into the Chesapeake Bay for aquaculture. The National Academy of Sciences Ocean Studies Board convened a panel to review the proposal. The proposal also triggered permit review by the Army Corps of Engineers, who regulate any offshore activity (i.e. aquaculture) that interferes with shipping. The ACOE formed an ad hoc panel to review the permit, and issued the permit with the following recommendations:

The Virginia seafood council must develop an emergency contingency plan; conduct inventory control and gather economic data; develop a disease monitoring program; archive tissue samples to identify escapees with DNA analysis; provide for Quality Assurance and Quality Control; and must remove oysters from the Bay by June 2004.

For more information about current status and trends see:

Rickards, William and Paul Ticco. 2002. *The Suminoe Oyster, Crassostrea ariakensis, in the Chesapeake Bay*. Virginia Sea Grant Publication VSG-02-23.
http://www.virginia.edu/virginia-sea-grant/pdf/ariakensis.pdf

Leffler, Merrill. 2002. *Crisis and Controversy. Does the Bay Need a New Oyster?* Chesapeake Quarterly 1:3. http://www.mdsg.umd.edu/CQ/V01N3/main.html

## ***Bait Shop Introductions of Aquatic Invaders: Revelations from a Crayfish Survey***

John R. Wallace
Millersville University

*Abstract: Many ecologists have noted that besides alterations to land use, the introduction of non-indigenous species (NIS) is probably one of the greatest threats to freshwater biodiversity in the 21st century. In North America, several vectors or methods of introduction are of increasing importance, such as aquaculture, aquarium/pond trade, live food trade as well as the biological supply trade. Of special concern in Pennsylvania and many other states is the problem of the live bait trade. Dr. Wallace discussed how a county crayfish survey revealed such a problem and how bait shops and state regulations can be improved to eliminate the threat on native aquatic faunal diversity.*

The distribution of live bait is a potential vector for new introductions in Pennsylvania. Although data is available through unpublished studies, it is difficult to gather bait shop data from interviews and surveys. Dr. Wallace presented two case studies on the rusty crayfish (*Orconectes rusticus*) and the nuclear worm (*Namalcystis aluna*).

Rusty Crayfish

Lodge et al. examined vectors for rusty crayfish introductions (Fisheries 25: 7-20). In Pennsylvania, there are three primary vectors: legal stocking in natural waters, aquarium supply trade, and live bait introductions. Of these vectors, only the first is regulated in Pennsylvania. However, a permit is also required to sell approved species in bait vending machines found at gas stations, boat launches, and recreational fishing areas.

The rusty crayfish competes with native crayfish species. In a survey of Midwestern lakes, ecological impacts of rusty crayfish included disease, competition, fish predation interactions, reproductive interference, and hybridization with native species. They have also been known to reduce macrophyte and algal cover and reduce macroinvertebrate abundance (especially snails).

Nuclear Worm

The nuclear worm was introduced to the West Coast from Vietnam. In the Chesapeake and Delaware Bays, anglers use nuclear worms as bait for stripers and white perch. The worm is an excellent bait because it requires no refrigeration and the cost is relatively low. At $6-7 apiece, one worm can be diced into multiple pieces. In general, the import of live worms for bait is a profitable business. Between 1998-2000, imports were valued at $70 million/yr. Live worms are widely sold over the Internet and potential impacts arising from their import and distribution include:

- The risk of introducing other species attached in the seaweed packaging
- Transfer of disease-causing bacteria
- Ecological or genetic displacement of native species.

## *Recent Research on <u>Phragmites</u> <u>australis</u> in North America: Implications for Management*

Kristin Saltonstall
Horn Point Laboratory, University of Maryland Center for Environmental Science

*Abstract: Dr. Saltonstall presented a summary of recent <u>Phragmites</u> research with a focus on issues relevant to the Atlantic coast region. This included a discussion of causes and impacts of the invasion as well as background on native populations which persist.*

Historical evidence of *Phragmites* in the United States:

- 40,000 years ago: Scientists examined sloth caves from the Pleistocene period in Southwestern United States. Examination of dung samples illustrated that *Phragmites* composed 60% of sloth diets.
- 3,500 - 4,000 years ago: *Phragmites* was present in New England coastal marshes. Peat core analysis in Connecticut marshes indicated presence of *Phragmites* rhizomes.
- 600 – 1,400 AD: *Phragmites* was integral to Anasazi culture. Archeaological findings in cliff dwellings indicated *Phragmites* was used for arrowshafts, cigaretts, prayer sticks, mats, flutes, etc.

Although historically present in the United States, *Phragmites* did not seem to grow as a monoculture. During peat core analysis, it was often found in mixed communities of sedges and forbs. Botanical records indicate that *Phragmites* was uncommon or rare in the 1800's, however by 1975, it was recorded across all of the lower 48 states.

How did it arrive in the United States and rapidly spread? Packing material on ships and ballast from Europe containing peat and sediments was frequently dumped in coastal marshes bordering ports. Human–mediated transport, associated with *Phragmites* genetic traits, facilitated rapid range expansion.

Characterisitics of *Phragmites*

- Generalist; wide habitat range; brackish and freshwater conditions
- Reproduces through wind dispersal of seeds, and vegetatively through rhizomes
- Expands clonally through underground runners at a rate of several meters per year

Anthropogenic sources affecting *Phragmites* distribution

- Habitat manipulation and disturbance
- Tidal restrictions, flood control, and resulting changes in salinity
- Pollution
- Introduction of new genetic strain. The aggressive nature of *Phragmites* is likely the result of cryptogenic invasion, where the introduced species enters a lag phase, then undergoes rapid population expansion.

Several factors may also serve to limit the spread of *Phragmites*. They include:

- Salinity (optimal range 0-15ppt)
- Sulfides – clonal expansion enables *Phragmites* to escape high sulfide concentrations
- Wave action
- Reduced disturbance
- Chemical and physical controls with repeated applications
- Competition with other plants?
- Nutrients?

*Phragmites* infestations affect whole ecosystems, in addition to individual plant and animal species. However, not all impacts are negative.

Positive impacts of *Phragmites:*

- Sediment accretion; *Phragmites* is highly productive, creating nutrient-rich litter, and high inorganic sediment loading
- Stabilizes soil, preventing erosion. In the 1940's-1950's, *Phragmites* was widely used in marsh restoration projects.
- Pollution-tolerant; can concentrate pollutants, such as heavy metals, in roots and rhizomes.
- Provides habitat

Negative Impacts

- Alters marsh topography through accretion, filling in channels and tidal creeks
- Ties up nutrients in biomass, not released as quickly as native vegetation
- Alters light and temperature dynamics in the marsh; freezing occurs earlier in fall, thaws later in spring
- Forms monoculture, has secondary impact on nutrient export
- Changes marsh structure. Plant communities shift from mixed to monoculture in freshwater marshes; short grasses shift to tall grasses in saltwater marshes.
- Alters animal communities? Impacts to marsh residents are largely anecdotal and are influenced by the stage of the invasion. In the early stages, fish and invertebrate communities are rarely impacted. In a late stage invasion, sediments accrete and fish habitat deteriorates.

Despite the common perception that all *Phragmites* is bad, recent research by Saltonstall demonstrates that *Phragmites* is native to the United States. Native populations are found primarily in tidal freshwater oligohaline marshes, along creeks, and near uplands. They occur in mixed communities and typically exhibit lower stem densities than non-native strains. Native populations have been confirmed in Maryland, Delaware, and Virginia, due in part to the vigilance of natural resource managers in conducting field studies. Plant samples can be analyzed through a free diagnostic service at Cornell University (www.invasiveplants.net).

*Phragmites* exhibits morphological variation. Although several characteristics can be used to differentiate between strains, no single "key" can be used in the field to label a plant native or non-native. A future goal for Saltonstall is to identify morphological characteristics that can be used to identify *Phragmites* in the field. Finally, as natural resource managers consider *Phragmites* control strategies, Saltonstall posed several questions that should be addressed when native populations are present:

- Should we preserve native strains of *Phragmites*?
- Are attempts to restore native *Phragmites* populations worthwhile?
- Do native strains have similar impacts to the invasive strains on the environment and other species?

Discussion Questions:

Q - *Phragmites* populations are declining in Europe. Can any lessons be applied to control in the United States?
A - Not likely, because *Phragmites* is commercially harvested for thatching and there are multiple native herbivores that feed on *Phragmites* in Europe.

Q - When you're restoring an unvegetated site, how do you prevent invasion by *Phragmites*?
A - The key is vigilance. By removing individual plants early (through digging or Rodeo application) before they send out shoots, you have a chance at preventing an infestation. Once native grasses and perennials become established, *Phragmites* is much less capable of invading. Ongoing monitoring is required.

Q - Are there ecological differences between the strains that affect competition?
A - This is the focus of Dr. Saltonstall's future research; to examine competition among populations ranging from Maryland to Southern Canada along nutrient and salinity gradients.

Q - Is *Phragmites* being used for bioremediation of contaminated sites?
A - It has been used for wastewater treatment by local municipalities.

## *Community-based Invasive Species Removal and Monitoring*

Thomas Dougherty
Fairmount Park Commission

*Abstract: Fairmount Park, one of the largest municipal parks in the world, is engaging citizens of all ages in our award-winning "Preserve-Your-Park" program. Stewards adopt a small section of the 5,400 acres of natural lands, learn to identify problems, actively remove invasives, replant natives, control stormwater runoff, and monitor the success of their efforts - all under the direction of park staff.*

More than half of the park property managed by the Fairmount Park Commission (FPC) in Philadelphia is considered to be natural lands. The Academy of Natural Sciences conducted a study of the resources in these natural areas and developed a master plan and suite of restoration goals. Through GIS mapping, FPC identified 450 high priority sites for restoration. Not having enough staff to adequately address habitat restoration, they created a volunteer program, the Natural Lands Restoration and Environmental Education Program (NLREEP) to assist with restoration goals. Each year, NLREEP recruits about 10,000 volunteers to improve Park sites through the control and removal of invasive plants, including purple loosestrife and Japanese knotweed. For more information: http://www.nlreep.org

## *Ongoing Research on the Ecology and Control of Invasive Japanese Knotweed in Urban Parks of Philadelphia*

James N. McNair
Patrick Center for Environmental Research, Academy of Natural Sciences of Philadelphia

*Abstract: Ongoing research at the Academy of Natural Sciences of Philadelphia addresses several aspects of the ecology and control of Japanese knotweed in urban parks of Philadelphia. Field experiments have been conducted to assess the effectiveness of alternative methods for controlling this invasive plant. Field and growth-chamber experiments are being conducted to assess seed germination rates and seedling survival. Additional projects are underway to assess morphological and genetic variation among populations in order to assess the importance of sexual reproduction and hybridization.*

Knotweed is known by several names: *Polygonum cuspidatum* (US), *Fallopia japonica* (British Isles), and *Reynoutria japonica*. In the United States, knotweed is a riparian invader, but in Japan, it is the first species to colonize high elevation volcanic deposits on Mount Fuji.

The goals of this study were to assess alternative management of Japanese knotweed in urban Philadelphia parks and to fill basic scientific data gaps on the reproductive and hybridization potential of Japanese knotweed.

Control technique study

The first set of experiments investigated the effectiveness of various management practices on controlling the spread of Japanese knotweed. Four treatments were tested: glyphosate-based herbicide, tilling, tilling and herbicide, and no treatment. Following two years of treatments, the number of stems and clumps of knotweed increased, but the stem diameter and height decreased across all treatments. Short-term, treatments reduced plant vigor, but in order to eradicate plants, successive treatments are necessary.

Seed germination study

Knotweed fruits, or achenes, encase the seeds. One stem can produce 100,000 achenes, and on average, there are 10 stems per plant. About 90% of seeds collected from study sites germinated. Based on laboratory experiments, there is a 3-week window between September and October where seed production can successfully be controlled.

Dr. McNair also conducted studies on genotypic and phenotypic variability among Japanese knotweed plants collected from different sites. For genetic variability, he analyzed variation in chromosome numbers via DNA microsatellite loci. For phenotypic variability, McNair compared leaf shape within and among knotweed infested sites. Based on the high degree of variation within and among sites, development of a taxonomic key would assist with proper identification of Japanese knotweed.

## *Lessons Learned from Pennsylvania's Zebra Mussel Monitoring Program*

Tony Shaw
Pennsylvania Department of Environmental Protection

*Abstract: A brief history of Pennsylvania's Zebra Mussel Monitoring Program will be presented emphasizing its original vision to how it functions today. From initial enthusiasm through waves of apathy, the Program has had its ups and downs. With renewed regional interest concerning the spread of zebra mussels and other aquatic invasive species, Pennsylvania is an active state participant in mid-Atlantic regional efforts to increase monitoring and awareness of these undesirable exotic organisms.*

Although PA DEP's scope is limited to environmental quality regulation and we have no legal authority to control invasive species, the zebra mussel invasion of the Great Lakes in the late 1980's prompted the creation of a volunteer monitoring network for zebra mussels. A one-time grant was provided to initiate the network, the main purpose of which was to detect and track the spread of zebra mussels in Pennsylvania's waters and alert downstream water users of zebra mussel presence.

The monitoring protocol used both plankton nets and Plexiglas multiplate samplers to detect the presence of zebra mussel veligers. However, the multiplate samplers were not effective sampling devices. They broke easily and required frequent surveillance.

During the first three years of the program, about 200 locations were surveyed, in each of the six river basins, major tributaries, state park and inland lakes. Initially, about 60 monitors participated. Most were trained state field biologists or consultants. Of those, about 20 are still actively monitoring today. Attrition of volunteers was probably due to the low frequency of sightings. In the mid 1990's, few zebra mussels or veligers were detected in inland lakes and waterways. Between 2000-2002, however, sightings rapidly increased. Quagga mussels were found at quarries in several counties and zebra mussels were found in several inland lakes and NY's headwaters to the Susquehanna River.

Lessons learned from DEP's zebra mussel monitoring program include:

- Protocols were too labor intensive and sampling frequency was too high
- Veliger identification required expertise and associated costs
- Early stage veliger identification was subject to error
- Plexiglass samplers were easily damaged, cheaper substitutes can be made
- Continuous funding was needed to maintain supplies
- Plankton tows required too much boat and staff time
- Private lakes were also subject to invasion, but not monitored
- Transport mechanisms were underemphasized, i.e. recreational dive sites and quarries
- Public education and awareness needs rejuvenation
- Volunteers need incentives for long-term participation in monitoring network

DEP is serving on the Chesapeake Bay Program's ad hoc zebra mussel panel to develop a zebra mussel management plan for the Chesapeake Bay Watershed. The plan focuses on early detection and rapid response and will incorporate and enhance DEP's existing volunteer monitoring network.

## *Delaware Invasive Species Council (DISC); a Multi-tiered Collaborative Approach to Managing Invasive Species*

Bruce A. Richards
Center for the Inland Bays

*Abstract: Formed in the late 1990's, the Delaware Invasive Species Council (DISC) has become a non-profit education, research and organism tracking organization active in a wide variety of Delaware's terrestrial and aquatic environments. One of DISC's newest initiative is the development of a statewide invasive species management plan.*

Formation of Delaware's invasive species council was stimulated by agricultural concerns in the late 1990's. Initiated by the Delaware Department of Agriculture, the council is incorporated as a 501-C3 nonprofit organization. A partnership between government, public, and private organizations, members include the Department of Agriculture, the Department of Natural Resources and Environmental Control (DNREC), the Delaware Nature Society, the University of Delaware, Delaware State College, the Center for the Inland Bays, and various landscaping and business interests.

The council is organized into four committees: bylaws, data management, research, and education and outreach. The council meets annually as a whole, convening around 100 people. Within the next 12-18 months, completion of a comprehensive state management plan is anticipated. The management plan is being drafted by a panel of experts and will blend both species and process-oriented approaches. Upon completion, the plan will position Delaware for federal funding and establishment as a government commission.

## *Pennsylvania's Invasive Species Initiatives at the State and Regional Level*

Leo Dunn
Pennsylvania Department of Agriculture

*Abstract: An update on the progress towards creating a Pennsylvania Invasive Species Council, State Management Plan, and a mid-Atlantic regional aquatic nuisance species panel through the Chesapeake Bay Program.*

Invasive species are a statewide concern in Pennsylvania. In light of historical data, there has been a real increase in the incidence and extent of invasive species related impacts. Coordination of control and management will increase the effectiveness of tackling our invasive species problems and a coordinated management plan will leverage federal funding to address priorities.

To date, Pennsylvania has established an ad hoc interagency working group to coordinate invasive species efforts. The group has met several times, and is currently drafting a recommendation to the governor to endorse formation of an invasive species council. We anticipate the council will be created in July 2002. The goals of the council are to develop a management plan that will a) prevent, contain, and eradicate invasive species as appropriate, b) develop rapid response protocols, and c) coordinate funding requests and projects across state agencies and organizations.

Statewide invasive species initiatives will be integrated into regional strategies for the Chesapeake Bay and mid-Atlantic States. The Chesapeake Bay is creating six priority species management plans for the watershed, of which several address Pennsylvania species of concern: mute swan, *Phragmites*, purple loosestrife, and zebra mussels. Each of the plans will be finalized by December 2003. Building on the efforts of the Chesapeake Bay Invasive Species workgroup, which is scheduled to sunset this year, the Chesapeake Bay Program is exploring formation of a mid-Atlantic Aquatic Nuisance Species Panel for regional coordination between PA, MD, NY, NJ, DE, VA, WV, and DC. They anticipate approval from each of the member states by July 2003 and will seek approval from the ANS Task Force in the spring of 2004.

# *Appendices*

# *Poster Presentations*

Delaware Bay Oyster Management Program
*Russell Babbs, New Jersey Division of Fish and Wildlife*

Smithsonian Environmental Research Laboratory: Quantifying Invasion Patterns and Processes
*Esther Collinetti, A. Whitman Miller, Gregory M. Ruiz, Brian Steves, Paul Fofonoff, Smithsonian Environmental Research Center*

Use of GIS in Description and Modeling of *Phragmites* Colonial Expansion
*Richard Field, University of Delaware*

Effects of UVR on Invasive Mussel Larvae in a High-UV Lake
*Shawna Gilroy, Lehigh University*

Early-life-history Traits and Range Expansion of the Invasive Marine Crab *Hemigrapsus sanguineus*
*Susan Park, University of Delaware Graduate College of Marine Studies*

Invasive Species: A Blight on Biodiversity
*Kirstin Wakefield, Pennsylvania DEP Coastal Zone Management Program*

Delaware Estuary Aquatic Supertramps: Asian Carp, Eurasian Watermilfoil, Flathead Catfish, *Hydrilla*, Japanese Knotweed, Nutria, *Phragmites*, Purple Loosestrife, Resident Canada Goose, Zebra Mussel
*Pennsylvania Sea Grant*

# *Participant Feedback*

<table>
<tr><th><u>Before</u> attending this Symposium, how important did you think it was to stop the spread of aquatic invasive species (AIS)?</th><th colspan="2"><u>After</u> attending this Symposium, how important do you now think it is to stop the spread of aquatic invasive species (AIS)?</th></tr>
<tr><td rowspan="3">Important (6)</td><td>Important</td><td>2</td></tr>
<tr><td>Very Important</td><td>3</td></tr>
<tr><td>Extremely Important</td><td>1</td></tr>
<tr><td rowspan="3">Very Important (12)</td><td>Somewhat Important</td><td>1</td></tr>
<tr><td>Very Important</td><td>8</td></tr>
<tr><td>Extremely Important</td><td>3</td></tr>
<tr><td>Extremely Important (25)</td><td>Extremely Important</td><td>25</td></tr>
<tr><td colspan="2">Total Count</td><td>43</td></tr>
</table>

**How has this program benefited you? (Summary of comments from participants)**

- Increased awareness and provided new information on Delaware Bay issues, invasive species, and organizations engaged in management
- Will incorporate information into jobs, research, and educational workshops
- Provided opportunities for networking
- Provided a better understanding of the cost to society
- Magnitude of the problem provides strong argument for decision makers

**Please rank the value of the following approaches to address AIS issues in the Delaware Estuary (sum of participant ranks using 1=highest and 4=lowest):**

64- Delaware Watershed Coordination (highest rated approach)
83- State Coordination
91- Mid-Atlantic Coordination
107- Local Coordination (lowest rated approach)

**Which type of organization(s) should be represented as part of an effective aquatic invasive species working group? (Check all that apply.)**

0- Environmental Consultants
1- Water Utilities
3- Interstate Commissions
3- City, County and Local Government
4- Non-profit Conservation and Watershed Groups
5- Colleges, Universities and Research Groups
6- State Agencies
6- Federal Agencies
37- All of the Above

**Would you be interested in subscribing to a Delaware Estuary and Watershed listserv?**

28- Yes, 5- No

# *Participants*

| *Name* | *Organization* | *Address* | *E-mail* |
|---|---|---|---|
| Olin Allen | Delaware Natural Heritage Program | 4867 Haypoint Landing Road, Smyrna, DE 19709 | olin.allen@state.de.us |
| Daniel Barringer | Natural Lands Trust | Crow's Nest Preserve, 201 Piersol Rd. Elverson, PA 19520 | dbarringer@natlands.org |
| Jessie L. Benjamin | Taproot Native Design | 366 Chatham Rd., West Grove, PA 19390 | jessie@taprootnativedesign.com |
| Jill Benowitz | Pennsylvania Sea Grant | 4601 Market Street, Philadelphia, PA 19139 | jebby1er@cs.com |
| Jill Brown | University of Delaware | 16010 Bowman Drive, Lewes, DE 19958 | jrbrown@udel.edu |
| Debbie Carr | Fairmount Park Commission | 4231 North Concourse Drive, Philadelphia, PA 19131 | debbie.carr@phila.gov |
| John Christmas | George Mason University | 680 South Hills Drive, Arnold, MD | johnchristmas@aol.com |
| James Cramer | US Fish & Wildlife, NJ | 928 North Main Street, Pleasantville, NJ 08320 | james_cramer@fws.gov |
| Megan D'Arcy | University of Pennsylvania | 4632 Chester Avenue, Philadelphia, PA 19143 | mdarcy@sas.upenn.edu |
| Clifford Day | US Fish & Wildlife, NJ | 927 North Main Street, Pleasantville, NJ 08320 | clifford_day@fws.gov |
| Gregory DeCowsky | DNREC/DAWM/SIRB | 391 Lukens Drive, New Castle, DE 19720 | gregory.decowsky@state.de.us |
| Charles Dilks | | 215 West Willow Grove Avenue, Philadelphia, PA 19118 | |
| Thomas Dougherty | Fairmount Park Commission | 4231 N. Concourse Drive, Memorial Hall, Philadelphia, PA 19131 | thomas.dougherty@phila.gov |

| *Name* | *Organization* | *Address* | *E-mail* |
|---|---|---|---|
| Leo Dunn | PA Dept of Agriculture | 2301 North Cameron Street, Harrisburg, PA 17100 | ledeunn@state.pa.us |
| Joan Egerton | Fairfield Township | 74 Fairton Gouldtown Rd., Fairton, NJ 08320 | |
| Bill Ettinger | Normandeau Associates | 87 Woods Drive, Lewes, DE 19958 | wettinger@normandeau.com |
| Peter Evans | Delaware Estuary Program | P.O. Box 7360, W. Trenton, NJ 08628 | pevans@drbc.state.nj.us |
| G. Winfield Fairchild | West Chester University | Department of Biology, West Chester, PA 19383 | wfairchild@wcupa.edu |
| Jack Farster | PA DEP | 400 Market Street, 1st Floor, Harrisburg, PA 17105 | jfarster@state.pa.us |
| Ann Faulds | Pennsylvania Sea Grant | 4601 Market Street, Philadelphia, PA 19136-4616 | afaulds@psu.edu |
| Richard Field | University of Delaware College of Marine Studies | Newark, DE 19716 | rtfield@triton.cms.udel.edu |
| Paul Fofonoff | Smithsonian Institute Marine Invasions lab | P.O. Box 28, Edgewater, MD 21037 | fofonoff@si.edu |
| Shawna Gilroy | Lehigh University | 31 William Drive, Bethlehem, PA 18015 | slg4@lehigh.edu |
| Jim Grabusky | PA DEP Southeast Regional Office | Lee Park, Suite 6010, 555 North Lane, Conshohocken, PA 19428 | jgrabusky@state.pa.us |
| Michael Grove | Rowan University, Dept. of Biology | 201 Mullica Hill Road, Glassboro, NJ 08028 | grove@rowan.edu |
| Beth Hass | Partnership for Delaware Estuary | 400 W. 9th Street, Wilmington, DE 19801 | bhaas@delawareestuary.org |
| Bill Hall | University of Delaware, Delaware Sea Grant | 700 Pilottown Road, Lewes, DE 19958 | bhall@udel.edu |
| Job Heintz | Mid-Atlantic Environmental Law Center | 4601 Concord Pike, Wilmington, DE 19803-0474 | jch0301@mail.widener.edu |

| *Name* | *Organization* | *Address* | *E-mail* |
|---|---|---|---|
| Kevin Hess | PA DEP Coastal Zone Management Program | 400 Market Street, 15th Floor, Harrisburg, PA 17105-2063 | khess@state.pa.us |
| Marilyn Katz | US EPA | EPA West (4504T) 1200 Penn Avenue, NW, Washington, DC 20460 | katz.marilyn@epa.gov |
| Jeff Keller | Habitat by Design | 74 Stagecoach Rd., Pipersville, PA 18947 | habitat@epix.net |
| John Kennel | DNREC | 89 Kings Highway, Dover, DE 19808 | john.kennel@state.de.us |
| Fred Kern | NOAA | 904 South Morris Street, Oxford, MD 21645 | Fred.Kern@NOAA.gov |
| Kathy Klein | Partnership for Delaware Estuary | 400 W. 9th Street, Wilmington, DE 19801 | kklein@delawareestuary.org |
| Robert Lonsdorf | Brandywine Conservancy | P.O. Box 141, Chadds Ford, PA 19317 | rlansdorf@brandywine.org |
| Bob Limbeck | DRBC | P.O. Box 7360, W. Trenton, NJ 08628-0360 | rlimbeck@drbc.state.us.nj |
| Joseph Lomax | Lomax Morey Consulting | P.O. Box 9, Cape May Court House, NJ 08210 | |
| Betsy Lyman | The Nature Conservancy | 301 Merkle Road, Boyertown, PA 19512 | blyman@TNC.org |
| Joe Matassino | Partnership for Delaware Estuary | 400 W. 9th Street, Wilmington, DE 19801 | jmatassino@delawareestuary.org |
| Martha Maxwell-Doyle | Delaware Estuary Program | P.O. Box 7360, W. Trenton, NJ 08628 | mmaxwell@drbc.state.nj.us |
| Derrick McDonald | PA DEP Coastal Zone Management Program | 400 Market Street, 15th Floor, Harrisburg, PA 17105-2063 | emcdonald@state.pa.us |
| Jim McNair | Academy of Natural Sciences | 1900 Benjamin Franklin Parkway, Philadelphia, PA 19103 | |
| Bob Meadows | US Fish & Wildlife, DE | 2430 Old Co. Rd., Newark, DE 19702 | robert.meadows@state.de.us |

| *Name* | *Organization* | *Address* | *E-mail* |
|---|---|---|---|
| Gene Nieminen | US Fish & Wildlife, NJ | 929 North Main Street, Pleasantville, NJ 08320 | gene_nieminen@fws.gov |
| Mary Ellen Noble | Delaware Riverkeeper Network | 20 Sandy Ridge Drive, Doylestown, PA 18901 | noble.me@verizon.net |
| Jane Nogaki | NJ Environmental Federation | 223 Park Avenue, Marlton, NJ 08053 | janogaki@eticomm.net |
| Susan Park | University of Delaware College of Marine Studies | 700 Pilottown Road, Lewes, DE 19958 | spark@udel.edu |
| Bivan Patnaik | US Coast Guard Headquarters | 2100 2nd Street, SW, Washington, DC 20593 | Bpatnaik@comdt.uscg.mil |
| Kurt Philipp | Wetlands Research Services | P.O. Box 156, Newark, DE 19715 | krphilipp@aol.com |
| David Pimentel | Cornell University | 5126 Constock Hall, Ithaca, NY 14853-0901 | dp18@cornell.edu |
| Pat Pingel | PA DEP | P.O. Box 8555, Harrisburg, PA 17105-8555 | ppingel@state.pa.us |
| Carlo Popolizio | US Fish & Wildlife, NJ | 930 North Main Street, Pleasantville, NJ 08320 | carlo_popolizio@fws.gov |
| Jenn Porter | Partnership for Delaware Estuary | 400 W. 9th Street, Wilmington, DE 19801 | jporter@delawareestuary.org |
| Ingrid Ratsep | The Ratsep Group, Inc. | 4 Chester County Commons, Malvern, PA 19355 | ingrid.ratsep@ratsepgroup.com |
| Bruce Richards | Center for Inland Bays | 467 Highway One, Lewes, DE 19958 | brichard@udel.edu |
| Gregg Robertson | PA Landscape & Nursery Association | 1707 South Cameron Street, Harrisburg, PA 17104 | frobertson@pina.com |
| Barbara Root | USEPA | 1650 Arch Street, Philadelphia, PA 19103 | okorm.barbara@epa.gov |
| Clark Rupert | DRBC | P.O. Box 7360, W. Trenton, NJ 08628 | crupert@drbc.state.nj.us |

| Name | Organization | Address | E-mail |
|---|---|---|---|
| Kristin Saltonstall | U of MD Center for Environmental Science, Horn Point Lab | P.O. Box 775, Cambridge, MD 21613 | ksalton@hpl.umces.edu |
| Edward Santoro | DRBC | P.O. Box 7360, W. Trenton, NJ 08628 | esantoro@drbc.state.nj.us |
| Tony Shaw | PA DEP | 400 Market Street, Harrisburg, PA 17105-8467 | tshaw@state.pa.us |
| Laurel Standley | University of Delaware | 109-I Chestnut Crossing Drive, Newark, DE 19713 | standleylaurel@hotmail.com |
| Jamie Stark-Davis | USEPA, Region 3 | 3ES10, 1650 Arch Street, Philadelphia, PA 19103-2029 | davis.jamie@epa.gov |
| Joanne Steinhart | The Nature Conservancy | P.O. Box 55, Long Pond, PA 18347 | jsteinhart@tnc.org |
| Donna Suevo | PA DEP Southeast Regional Office | Lee Park, Suite 6010, 555 North Lane, Conshohocken, PA 19428 | dsuevo@state.pa.us |
| Jil Swearingen | National Park Service | 4598 McArthur Blvd., Washington, DC 20007 | jil-swearingen@nps.gov |
| Carie Szalay | The Academy of Natural Sciences of Philadelphia | 1900 Benjamin Franklin Parkway, Philadelphia, PA 19103 | szalay@acnatsci.org |
| Chari Towne | Delaware Riverkeeper Network | P.O. Box 459, Saint Peters, PA 19470-0459 | Srk2@worldlynx.net |
| Maria Trabka | Delaware Bayshores Program, The Nature Conservancy | 210 Union Street, Milton, DE 19968 | mtrabka@tnc.org |
| John Wallace | Millersville University | Department of Biology, Millersville, PA 17551 | john.wallace@millersville.edu |
| Kirstin Wakefield | PA DEP Coastal Zone Management Program | 400 Market Street, 15th Floor, Harrisburg, PA 17105-2063 | c-kwakefie@stata.pa.us |
| Dana Walker | The Schuylkill Center for Environmental Education | 8480 Hagy's Mill Road, Philadelphia, PA 19128 | dwalker@schuylkillcenter.org |

| ***Name*** | ***Organization*** | ***Address*** | ***E-mail*** |
|---|---|---|---|
| Vivian Williams | Stroud Water Research Center | 970 Spencer Rd., Avondale, PA 19311 | vwilliams@stroudcenter.org |
| Floyd Yoder | NJ Dept of Agriculture | NJDA Division of Plant Industry P.O. Box 330, Trenton, NJ 08625-0330 | floyd.yoder@ag.state.nj.us |

## Biological invasions in Chesapeake and Delaware Bays- Patterns and Impacts

Paul W. Fofonoff and Gregory M. Ruiz

Smithsonian Environmental Research Center, Edgewater MD.

## Outline

- Features of the Bays
- Databases
- Invasion Patterns in the Bays- Taxa, Origins, Timing, Vectors
- Potential for Ponto-Caspian invasions
- Impacts of invaders
- Overall Conclusions

## Effects of Invasions

- Invasions by **Nonindigenous Species (NIS)** are a major force of global change, resulting in significant ecological, economic, and human health impacts.
- For the U.S. alone, the economic cost of aquatic invasions was recently estimated at > $10 billion per year (Pimentel, this forum).
- All available evidence indicates the transfer and introduction of NIS by human activities has increased dramatically over the past century and continues to do so.

## Chesapeake and Delaware Bays


U.S. EPA http://www.epa.gov/maia/html/globwarm.html

## Chesapeake and Delaware Bays- Similarities and Differences

- **Chesapeake Bay is bigger, bay area= 115,000 $km^2$; watershed area= 306,300 $km^2$, compared to 1940 and 35,000 for Delaware Bays.**
- **Chesapeake Bay has six major tributaries; Delaware Bay has one.**
- **But both estuaries:**
- **have extensive tidal freshwater regions, extensive wetlands, and a long, gradual salinity gradient.**
- **have large cities along their upper estuaries.**
- **have major seaports.**

## SERC's Marine Invasion Research Laboratory's **National Exotic Marine and Estuarine Species Information System (NEMESIS)-** Brian Steves, database designer.

- Relational databases in Microsoft "Access"
- Chesapeake Bay (1994 to present), soon to be accessible at: http://invasions.si.edu/nemesis
- National Database (1998 to present), multiple coasts, regions and bays (e.g. Delaware Bay)
- Soon to be merged with Global Database, map-based system (2000 to present)

## Information Sources on nonindigenous species

- Published literature (CB and DB)
- Gray literature (mostly CB)
- Museum collections (mostly CB)
- Interviews with local scientists (CB only)
- Field surveys- fouling communities (CB only), *Hemigrapsus*, *Carcinus* (CB and DB, unpublished).

## Both estuaries have been extensively invaded. (#'s are for regular residents.)

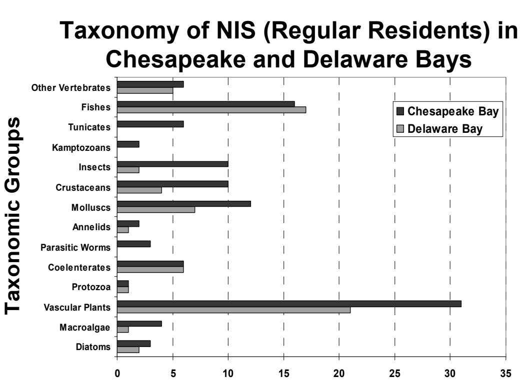
| Groups | Delaware | Chesa-peake | Shared Spp. |
|---|---|---|---|
| Algae | 3 | 7 | 3 |
| Flowering Plants | 21 | 31 | 20 |
| Marine Inverts | 14 | 35 | 13 |
| FW Inverts | 7 | 17 | 7 |
| Fishes | 17 | 16 | 14 |
| Other Vertebrates | 5 | 6 | 5 |
| Total | 67 | 112 | 63 |

## CB vs DB: Some comparisons

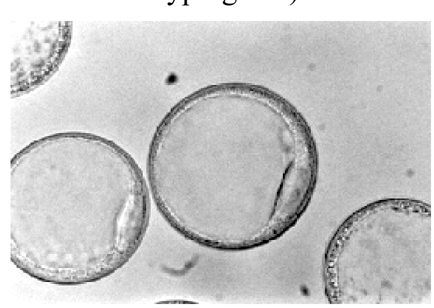
- 43 species found in Chesapeake Bay, but absent in Delaware Bay.
- However, 21 of these species are present in bays to the north, and are probably present in DB.
- Some CB species may be limited by climate (e.g. Alligatorweed, *Murdannia keisak*, Threadfin Shad, Nutria), all confined to southern CB.
- In our database, only 2 DB species are absent from CB (Chinese Lobelia and an isopod- *Synidotea* sp.)

## Our estimates are dependent on the information available.

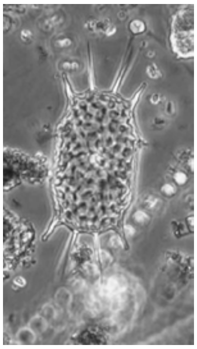
- Smaller number of known invaders in Delaware Bay is probably somewhat influenced by estuary-watershed size.
- But the major factor is local sources of information.
- Field surveys in Delaware Bay, especially of marine invertebrates and algae, will probably greatly increase the known number of invaders.




## *Perkinsus marinus* (Dermo, cryptogenic)

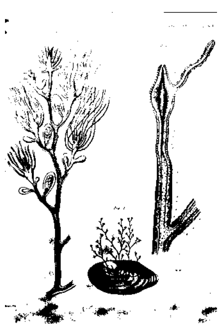


*Odontella sinensis*, diatom



*Hydrilla verticillata*

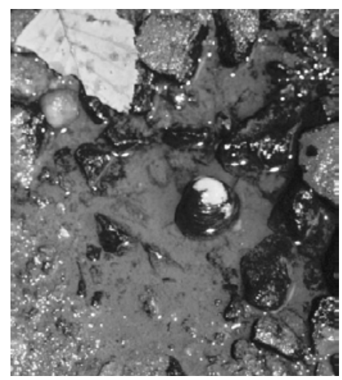
*Cordylophora caspia* (Pallas 1771)



- Described from Caspian Sea
- Spread through European canals in early 19th century
- Found in Ireland (as *C.lacustris)* by 1844.
- Found in North America (Newport RI, Philadelphia PA) by 1865.
- Now found on 6 continents

Allman 1853

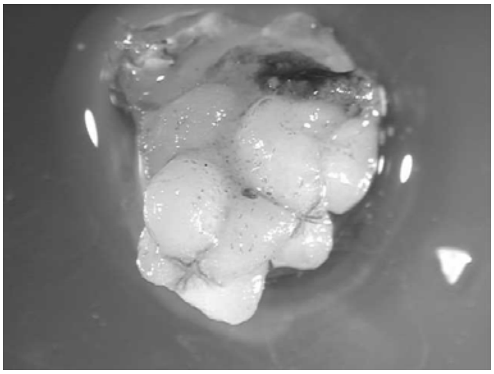
*Corbicula fluminea*- Asian Freshwater Clam



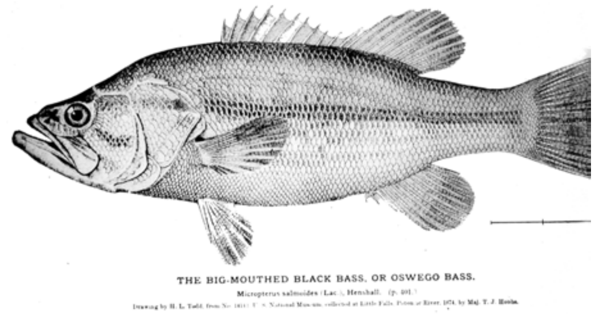
*Carcinus maenas* (Green Crab)

*Loxosomatoides laevis*
(Entoproct=Kamptozoan)

## *Styela plicata*- Pleated Tunicate



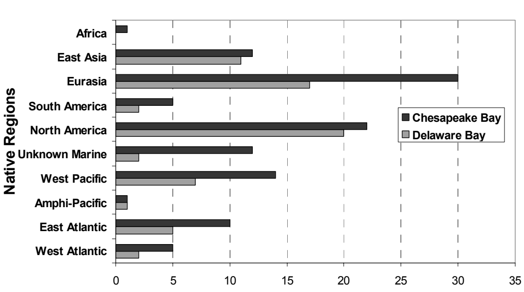
## *Micropterus salmoides* (Largemouth Bass)



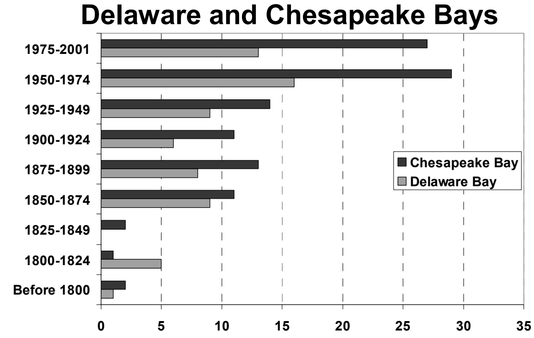

## *Cygnus olor*- Mute Swan

## *Myocastor coypus*- Nutria

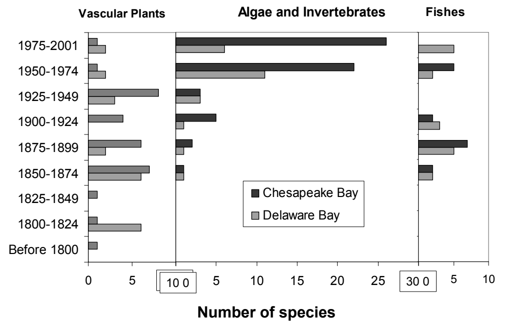
## Origins of Aquatic NIS in Delaware and Chesapeake Bays



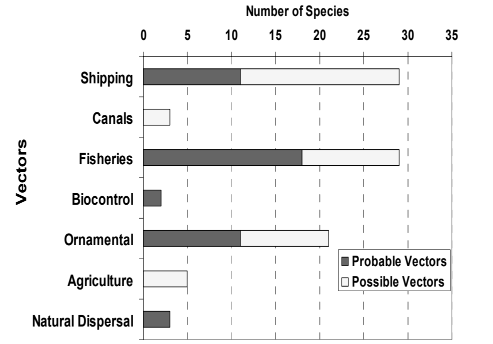

## Dates of first record of aquatic NIS in Delaware and Chesapeake Bays



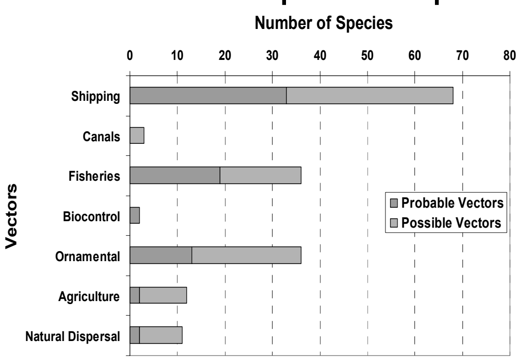
## Dates of 1st record, by taxonomic group




## Vectors of NIS transport- Delaware Bay




## Vectors of NIS Transport- Chesapeake Bay

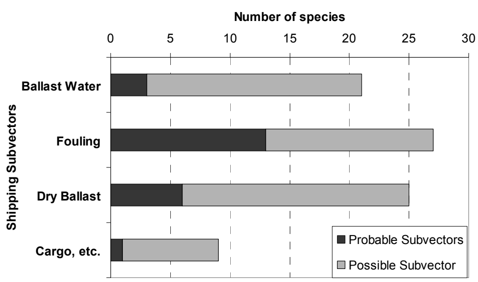



*Ship in dry dock with fouled hull.*

Replica Viking Ship with rock ballast, Rosskilde, Denmark

**Bulk carrier, discharging ballast water, Chesapeake Bay**

## Modes of shipping transport of known NIS in Chesapeake Bay




## Chesapeake & Delaware Bay Invasion Patterns-Summary (1)

- Invaders in CB and DB are taxonomically and biogeographically diverse.
- 3 Major groups, (1) vascular plants (mostly Eurasian), (2) algae/invertebrates (most numerous origins-Pacific, unknown regions, East Atlantic), (3) freshwater fishes (mostly North American).
- Rates of discoveries of algae/invertebrates appear to be increasing.
- Other groups show varying temporal patterns-

## Chesapeake & Delaware Bay Invasion Patterns-Summary (2)

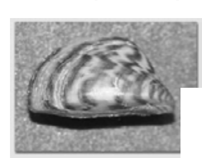
- Vectors vary greatly among taxonomic groups.
- For marine algae/invertebrates, shipping is the dominant vector.
- However, the relative importance of ballast water and fouling is difficult to determine.
- We have underestimated the frequency of NIS in the Delaware estuary.
- Biological surveys are needed to determine the full extent of invasions in the estuary.

## Potential for ballast-water mediated invasions of Ponto-Caspian fauna in Mid-Atlantic Estuaries

- The Black Sea-Caspian Sea Basin has become a major source of biological invaders to European fresh and brackish waters (via canals), and the Laurentian Great Lakes (via ballast water).
- Major invaders now in the Great Lakes include the Zebra and Quagga Mussels (*Dreissena polymorpha, D. bugensis*), the Fish-hook Water Flea (*Cercopagis pengoi*), and the Round Goby (*Neogobius melanostomus*)
- Ponto-Caspian invaders are tolerant of Mid-Atlantic estuarine conditions (0 to 5-18 ppt, 0 to 25-30ºC).

## Ponto-Caspian Invaders in the Great Lakes

**Zebra Mussel**
***Dreissena polymorpha***



**Round Goby *Neogpbius melanostomus***

**Fish-Hook Water-Flea**
***Cercopagis pengoi***

## Some Ponto-Caspian invaders spreading in European estuaries

Tube-building Amphipod- *Corophium curvispinum*

"killer" amphipod- *Dikerogammarus villosus*

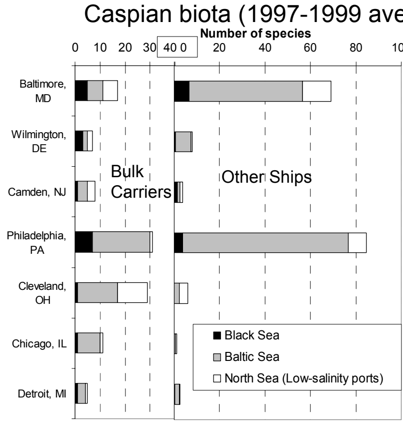
Mysid- *Hemimysis anomala*

## Potential sources of Ponto-Caspian Invaders in European Waters (MARAD* ports of origin)

- Native- Black Sea estuarine ports (Romania; Ukraine), Constantinople, Turkey).
- Invaded- Baltic Sea ports (Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Russia, Sweden.
- Invaded- North Sea river delta ports (Rhine, Elbe, etc.– Belgium, Germany, Netherlands)

*U.S. Maritime Adminsitration

Arrivals of cargo ships from sites of Ponto-Caspian biota (1997-1999 averaged)




## Potential for Ponto-Caspian invasions in Mid-Atlantic Estuaries

- Arrivals of ships from regions inhabited by these invaders exceed those in U.S. Great Lakes ports, which has been heavily invaded by PC species.
- Many of these invaders, such as amphipods, isopods, mysids, etc. may not be detected by existing monitoring programs.

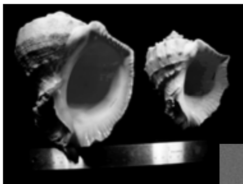
## Impacts of invasions- Chesapeake Bay

- Of **112** regular residents:
- **36 (32%)** have reported impacts of varying information quality and magnitude in CB.
- **28 (25%)** have reported ecological impacts.
- **25 (23%)** have reported economic impacts.

## Trying to define perceptions (admittedly subjective)

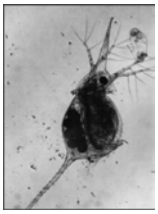
- **Negative- 17** (few or no positive, e.g, Purple Loosestrife, *Phragmites*, MSX, Nutria)
- **Mixed- 17** (substantial negative & positive, e.g., Hydrilla, *Corbicula*, Blue Catfish, Mute Swan)
- **Positive- 2** (few or no negatives reported locally- Red Swamp Crayfish, Black Crappie –negative impacts noted elsewhere)

## Recent Chesapeake invaders with potential impacts



*Rapana venosa*
*Veined Rapa Whelk*

*Galerucella pusilla*
*Purple Loosestrife* **Leaf Beetle**



*Daphnia lumholtzi*
*African water-flea*

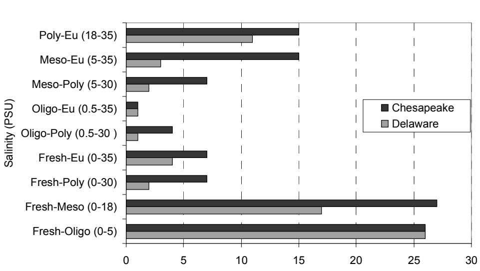
## Recent Chesapeake invaders with potential impacts

- *Gyrodactylus anguillae, Pseudodactylogyrus anguillae, Anguillicola crassus*- eel parasites
- *Rapana venosa*- Veined Rapa Whelk, Shellfish predator
- *Daphnia lumholtzi*- African Water-flea, avoided by juvenile fishes?, replacing native prey?
- *Botrylloides violaceus, Diplosoma listerianum*- Tunicates, hull foulers
- *Galerucella calmariensis, G. pusilla*- Purple Loosestrife biocontrol herbivores
- *Chaetococcus phragmitis, Lasioptera hungarica, Lipara rufitarsis, Tetramesa phragmitis*- *Phragmites* insect herbivores

## Overall conclusions

- Chesapeake and Delaware Bays are heavily invaded,.
- Invasions by marine algae and invertebrates, mostly shipping-related, appear to be increasing..
- We have under-estimated the number of invertebrate and algal NIS in Delaware Bay.
- Ballast-water introductions of Ponto-Caspian animals are a threat to Mid-Atlantic estuaries.
- NIS impacts vary greatly in type and magnitude; many species may have a mixture of perceived costs and benefits.

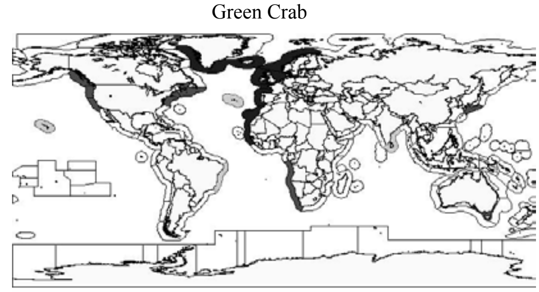
## Salinity ranges (by Venice salinity zones) of NIS in Chesapeake and Delaware Bays




Smithsonian Environmental Research Center

Native range
Introduced range
Not established

*Carcinus maenas* (Linnaeus, 1758)
Green Crab



Occurrences are plotted using standard IUCN marine bioregions. (Note: A species may occupy only a small portion of a region.)

# How Can We Make a Difference?

Gregg E. Robertson

President PLNA

## Who are we?

- Founded in 1904
- Represent 750 companies in Pa.'s Green Industry
- Includes production nurseries, garden centers, landscape contractors, arborists, irrigation contractors, turf farms, seed companies, power equipment dealers, hardscaping manufacturers, etc.

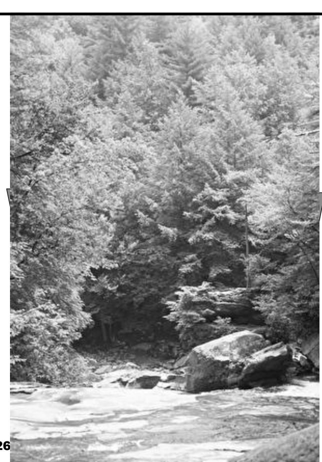


## Reality

- We have irreversibly changed the character of the land and ecosystems
- Increasing world trade geometrically increases the potential for introduction of problematic alien species
- Solutions will require widespread understanding and acceptance by US public and trading partners











2003

# attack of the aliens

*by Caroline Glassic, PLNA*

*It sounds like the making of some low-budget, sci-fi thriller – more laughable than real. "Attack of the Alien Species," "Nightmare on Elm Trees," or "Invasion of the Plant Snatchers."*

But, unfortunately, it's not fiction. And, it's not funny. Alien species are landing on American soil, courtesy of a host of international sources. And it could cost the green industry some real "green." Just ask Michigan, whose nursery industry lost $8 million to its No. 1 enemy, the Emerald Ash Borer, last year.

To manage the threat here in Pennsylvania, the state Department of Agriculture (PDA) has identified 10 top threats that are on the move; some are already in the state, others are riding the wind. Keeping the threat minimized, though, is as much the responsibility of each nursery grower as it is the wide network of survey scouts, according to a PDA official.

"It has to be understood that there is natural spread here; the wind is going to blow where the wind is going to blow and bugs are going to fly where bugs are going to fly," said Walt Blosser, plant inspection specialist with the PDA Bureau of Plant Industry. Plant pest laws can only attempt to regulate "artificial" movement that occurs through trade.

> "Growers have to become familiar with these pests. They have to be proactive."

"Unfortunately, growers often only get involved when pests become problems—when they start costing them money. Growers have to become familiar with these pests. They have to be proactive," stressed Blosser. Blosser said growers can choose to employ Integrated Pest Management (IPM) systems, which include pest scouting, and use pest-resistant varieties when they are available.

For invasives like plum pox and giant hogweed, eradication programs are underway. "We hope eradication means just that—that eventually, through survey, we won't find them anymore," said Blosser. The U.S. Cooperative Agriculture Pest Survey provides monetary assistance for this kind of survey work.

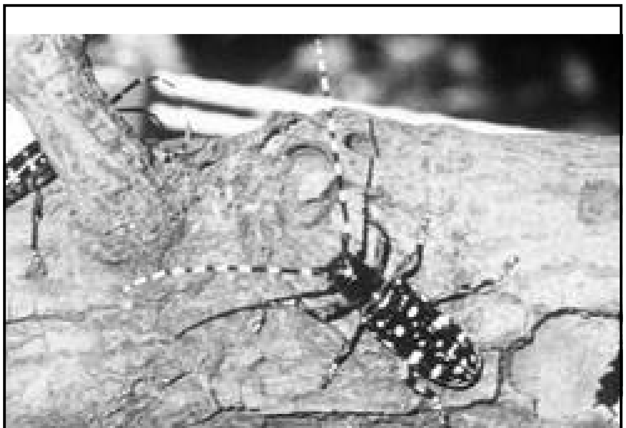
When eradication fails, pests-



September 2003

14

2003



2003


2003

# PLNA Invasive Plants Action Plan

- Adopted St. Louis Code Of Conduct
- Incorporated invasive plant information into certification programs
- Invasive plant alternative database
- Evaluating scientific protocol for evaluating the invasive tendencies of plant species

# Preventing Aquatic Nonindigenous Species in the U. S. by Regulation and Management

May 20, 2003

Mr. Bivan R. Patnaik
USCG Headquarters
Washington DC

# Presentation Overview

**Background**

- Problems caused by NIS
- Role of ships

**U.S. Coast Guard Responds**

- Current regulatory activities
- Future (regulations, legislation)

# Problems Caused by Aquatic NIS

# How Ships Introduce NIS into the U.S.

# Initial Legislation/Regulations

- Nonindigenous Aquatic Nuisance Prevention Control Act 1990 (NANPCA)
- Regulations established for the Great Lakes in 1993
- Extended to the Hudson River in 1994

# Great Lakes Program

- Conduct ballast water exchange;
- Retain ballast on board your vessel; or
- Use an alternative environmentally sound method of ballast water management

## National Invasive Species Act 1996 (NISA)

- Regulations for a National Voluntary Guidelines developed in 1999
- "Required" to file Ballast Water Management Report
- Report to Congress

## National Voluntary Guidelines

- Conduct ballast water exchange;
- Retain the ballast on board your vessel;
- Use an alternative environmentally sound method of ballast water management;
- Discharge ballast water to an approved reception facility; or
- Under extraordinary conditions, conduct a ballast water exchange in an area agreed to by the COTP.

## Vessels that are Exempt

- A crude oil tanker engaged in coastwise trade
- A passenger vessel (cruise ship) equipped with a functioning treatment system
- A Department of Defense or Coast Guard vessel

## Vessels that are Exempt (cont'd)

- A vessel that will discharge its ballast water at the same location the ballast water originated from
- A vessel merely traversing U.S. waters without entering or departing a U.S. port
- Safety exemption

## Report to Congress 2002

- Assessed the adequacy and effectiveness of the guidelines
- Assessed compliance with the guidelines
- Proceed with future regulations

## Anticipated Regulations

- Civil Penalties for Non-submission of Ballast Water Reports
- National Mandatory BWM Program
- Experimental Approval Program
- Development of Ballast Water Discharge Standards

## Possible New Legislation

- Reauthorization of NISA
- National Aquatic Invasive Species Act
- Introduced into Congress on March 2003

Further information on the U.S. Coast Guard's Program can be found at:
http://www.uscg.mil/hq/g-m/mso/mso4/ans.html

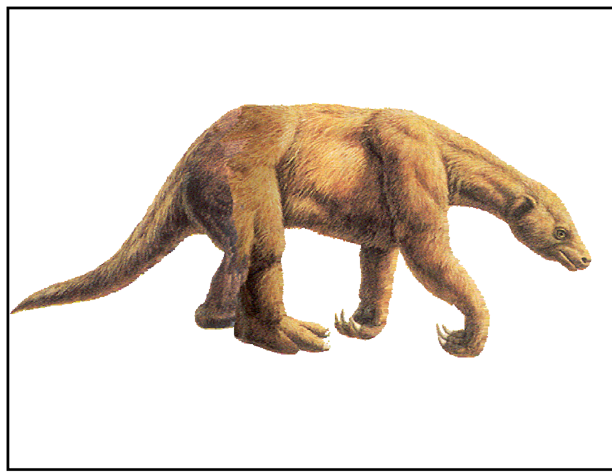
Recent research on *Phragmites australis* in North America: Implications for Management

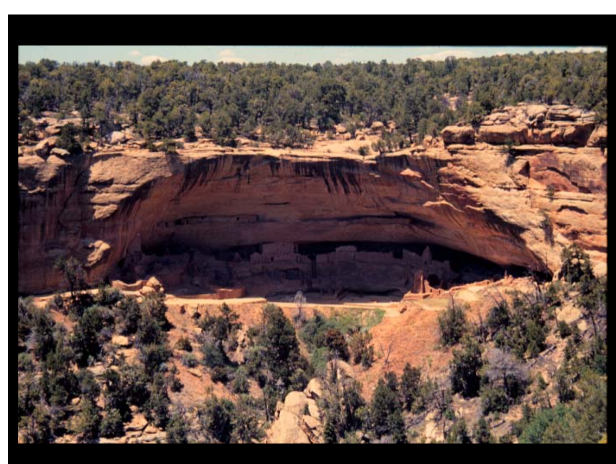
Kristin Saltonstall

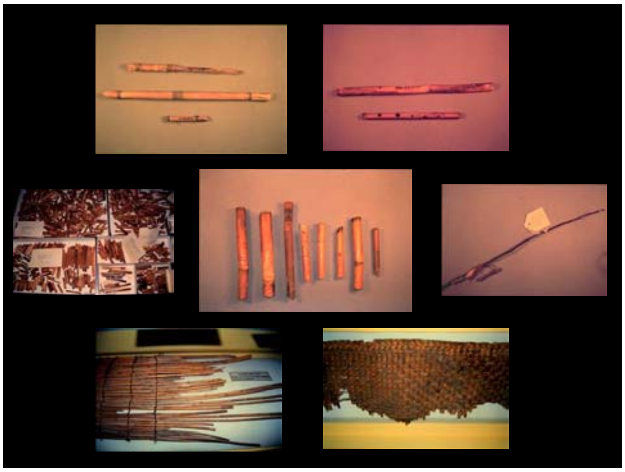
Horn Point Laboratory

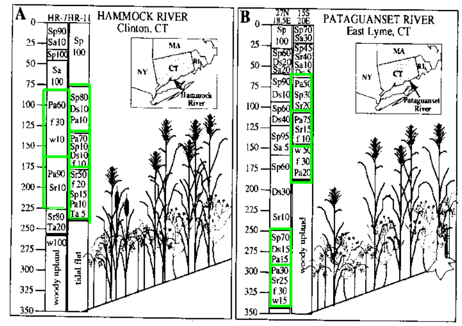
UMCES

- History of *Phragmites* in North America
- Causes of spread
- Impacts of *Phragmites* invasions
- Native *Phragmites* – Management Issues







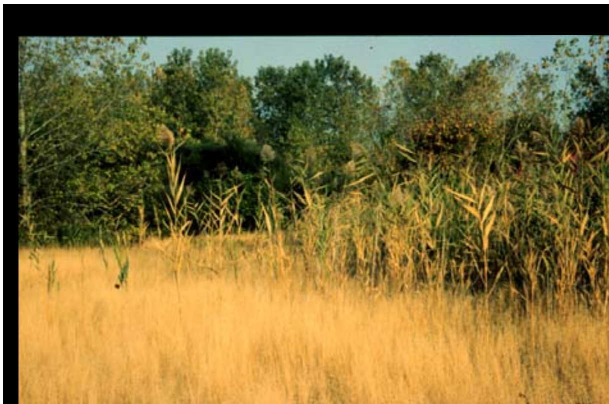



From Orson 1999

## Botanical Records

- 1843 **Not common**, along borders of ponds and swamps in NY (Torrey)
- 1874 **Rare** in NJ (Willis)
- 1888 **Not common** in MA (Dame & Collins)
- 1910 **Rare** inland, **occasional** along the CT coast; becoming more frequent (Graves et al.)
- 1975 Recorded in all of the lower 48 states

Why is *Phragmites* such a good invader?



## Anthropogenic causes of *Phragmites* spread

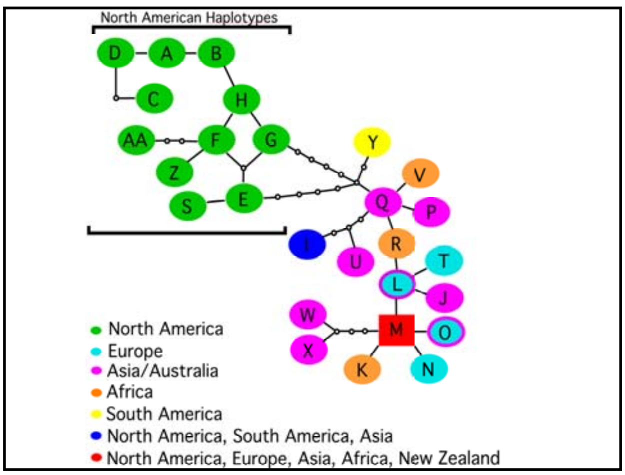
- Habitat manipulation/disturbance
  - Tidal restrictions
  - Substrate disturbance
    - Mosquito ditching
    - Railroad and road construction
    - Development along marsh borders
    - Altered hydrology

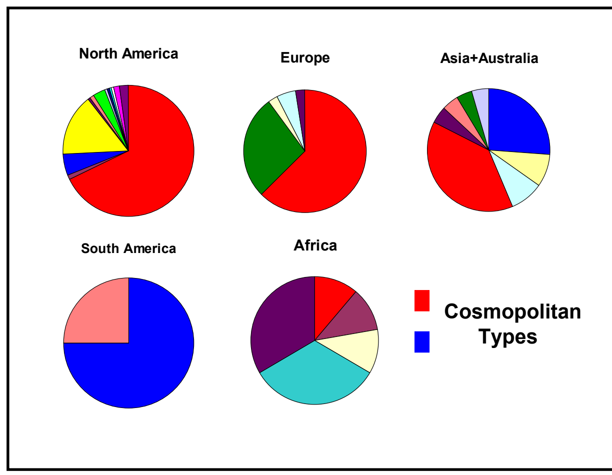
## Causes of *Phragmites* spread

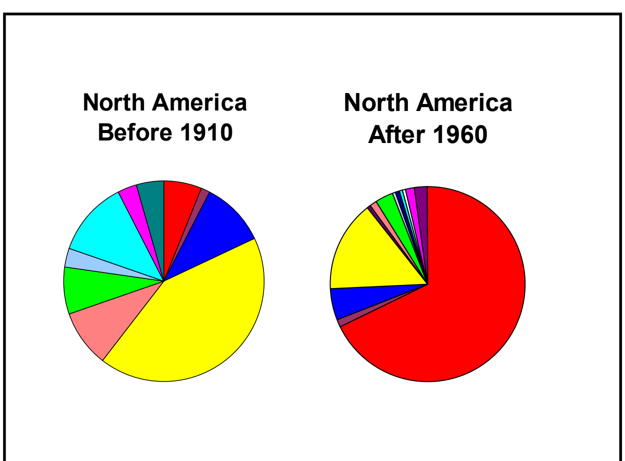
- Habitat manipulation/disturbance
  - Tidal restrictions
  - Substrate disturbance
- Pollution
  - Increased nutrient runoff
    - Both industrial and residential development
  - Increased soil salinity
    - Atmospheric inputs
    - Road salt

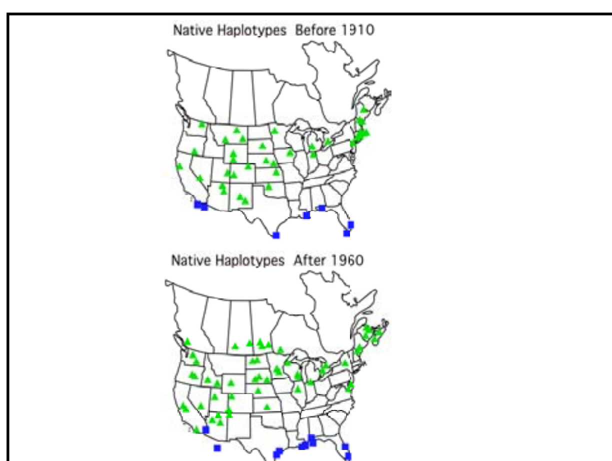
## Causes of *Phragmites* spread

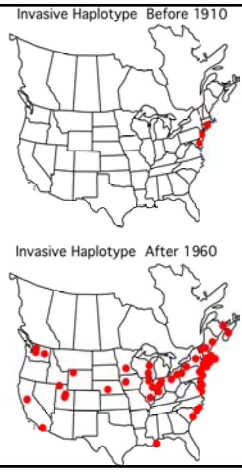
- Habitat manipulation/disturbance
  - Tidal restrictions
  - Substrate disturbance
- Pollution
  - Increased nutrient runoff
  - Increased soil salinity
- Introduction of a new genetic strain

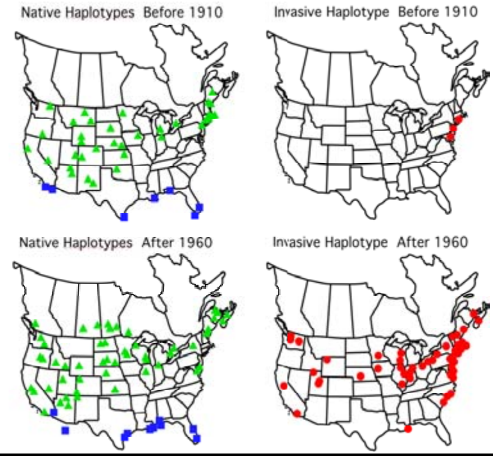





## Positive Impacts

- Sediment accretion
  - High productivity →lots of litter
  - High inorganic sediment loading
- Stabilizes soil, prevents erosion
- Tolerates pollutants
- Provides habitat

## Impacts – Ecosystem

- Topography of the marsh is altered
- More nutrients locked up in biomass
- Light/temperature dynamics change
- Decomposition rates change
  - More standing dead material
  - Influences nutrient export

## Impacts: Plants

- Forms monoculture – excludes other plants
- Changes the structure of a marsh
  - Go from mixed communities to monoculture
  - Or short grass salt marsh to tall grass

## Impacts: Animals

- Fish, invertebrates – may or may not affect marsh usage
- Amphibians – may influence breeding
- Birds – marsh specialists may be affected
- Mammals – not good forage but used for other purposes

➡ In general, large monotypic stands have less value for wildlife than those interspersed with other vegetation and creeks and pools

## What factors limit *Phragmites* spread?

- Salinity, sulfides
- Wave action
- Reduced disturbance
- Chemical controls/Fire/Mowing
- Other plants?
- Nutrients?

## Where do we find native *Phragmites*?

- Tidal freshwater/oligohaline marshes
  - Both along creeks and near uplands
- Known sites:
  - Tuckahoe River, Choptank River, Wicomico Creek (MD)
  - Appoquinimink River, St. Johns River, Indian River, Love Creek (DE)
  - Rappahannock River (VA)

## Management Issues

- Should we try to preserve native *Phragmites*?
  - Since we don't know much about it, how do we do this?
- Does native *Phragmites* have the same kinds of impacts on other species and the environment as invasive *Phragmites*?
- Are attempts to restore native *Phragmites* populations worthwhile?


## Acknowledgements

- Collectors
- Yale Herbarium, CT Botanical Society, Harvard Herbarium, NE Botanical Club, UCONN Herbarium, US National Herbarium
- US EPA STAR Fellowship, TNC-CT chapter, CT DEP License Plate Fund, MERP/NJ Sea Grant

***Lessons Learned from Pennsylvania's Zebra Mussel Monitoring Program***

***Tony Shaw***
Water Supply & Wastewater Management
**Pennsylvania Department of Environmental Protection**

***tshaw@state.pa.us*** **717-787-9637**

- Few Laws Existed To Address Invasive Species Issues
- DEP Scope - Limited To Environmental Quality Regulation
- DEP Has No Legal Authority To Control Invasive Species.

A Monitoring Strategy Was Developed With Two Main Objectives:

- Detect and track the spread of ZMs in PA waters
- Alert local and downstream water users when they are found in their area.

A Sampling Protocol For Veliger Detection:

- Plankton tow nets
- Plexiglas multi-plate samplers

DEP distributed Plexiglas Multi-plate samplers

Deployed across the state:

- all of PA's large river basins,
- main tributaries,
- many larger State Park lakes,
- some other lakes with public access.

Original Zm Monitoring Participants Were Primarily:

- Pa Regional Biologist Staff
- Corps Of Engineer Maintained Facilities & Reservoirs
- Staff Or Consultants Power And Water Companies
- Some were Out-of-State Locations

Approximately 200 locations reported in during first 2-3 years.

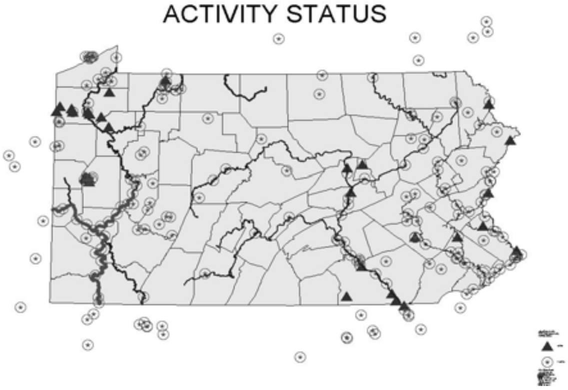
Early reports up to1993 documented spread of ZMs in:

- -Lake Erie tributaries
- - PA's Ohio River drainage: Larger main stems of Ohio, lower Allegheny, lower Monongahela Rivers

## ZEBRA MUSSEL DISTRIBUTION IN PENNSYLVANIA: EARLY 1990S

(data source from Pennsylvania Zebra Mussel Monitoring Program and cooperating adjacent state agencies) 10/15/02

## MONITORING STATION ACTIVITY STATUS



## Then In 2000, New Sighting Reports Started To Come In:

2000 – Quarry near Allentown PA

2000 – Edinboro Lake – Erie County PA (French Creek basin)

2001 – Sandy Lake – Mercer County PA

2001 - Canadohta Lake – Crawford County PA

2001 – Conewago Creek at NY State line – Warren CO.

2001 - Eaton Brook Reservoir, NY – *

2002 – Quarry in Lebanon Co.

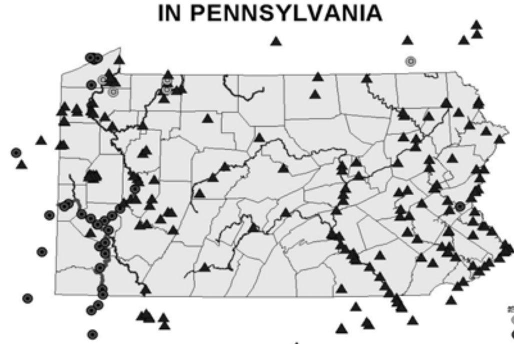
2002 - Canadarago Lake, NY – *

2002 – Lake LeBoeuf - Erie County PA

2002 – Millbrook Reservoir, Va

* In Susquehanna River headwaters

## ZEBRA MUSSEL DISTRIBUTION IN PENNSYLVANIA



(data source from Pennsylvania Zebra Mussel Monitoring Program and cooperating adjacent state agencies) 10/15/02

## Lessons Learned:

- Protocol's Original Monitoring Labor Efforts Were Burdensome.

- Sampling Frequency Was Excessive.

- Veliger Identification Required Expertise And Associated Costs.

- Early Veliger Identification may have been subject to error

- Plexiglas Samplers Subject To Damage, Vandalism, And Loss

- Other, cheaper monitoring devices were substituted

- Continuous $$$ Source Needed For Sampler Maintenance.

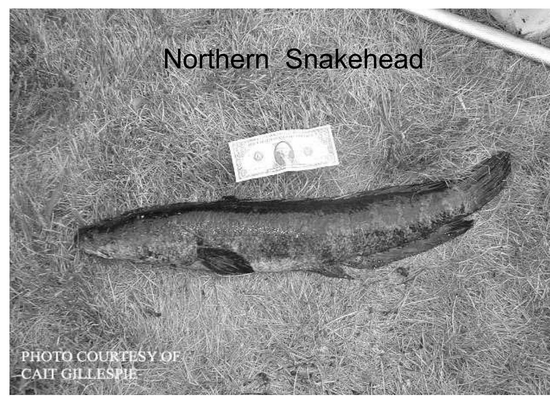
- Plankton Tow Net Sampling Required Major Effort.
  ***(Boats And Multiple Staff)***

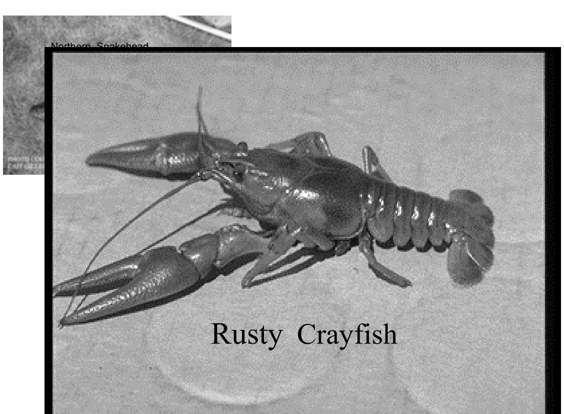
- Participants Had "Day Job" Responsibilities.

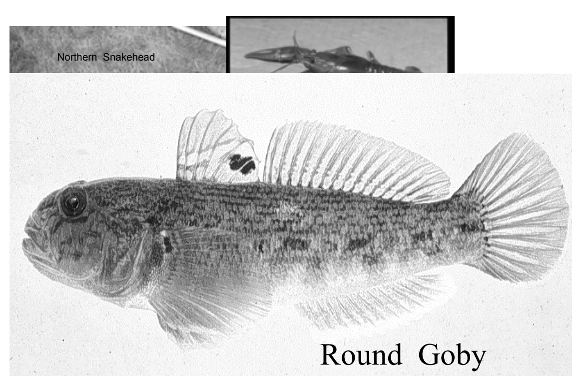
-More Obscure, Non-Public Lakes Were Also Vulnerable To ZM Infestation

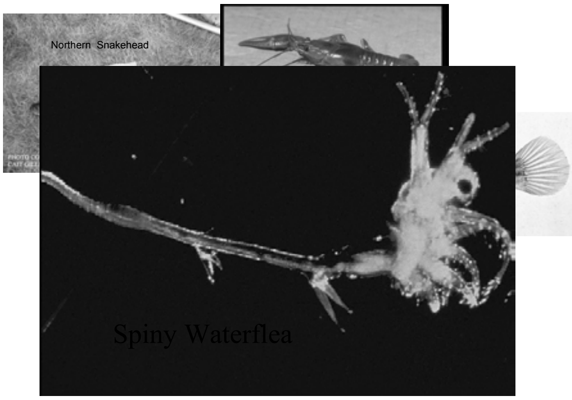
- Some ZM Transport Mechanisms Were Under-emphasized.

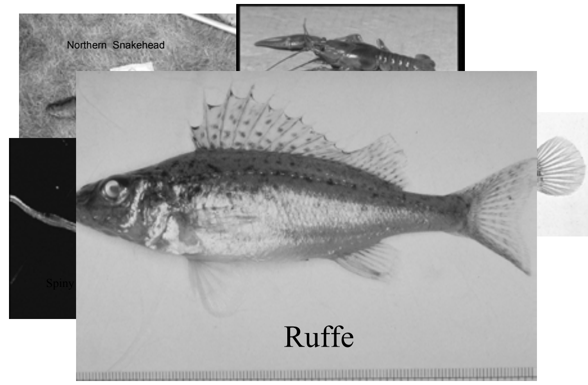
- Public Education & Awareness Programs Must Be Maintained And Refreshed Periodically.

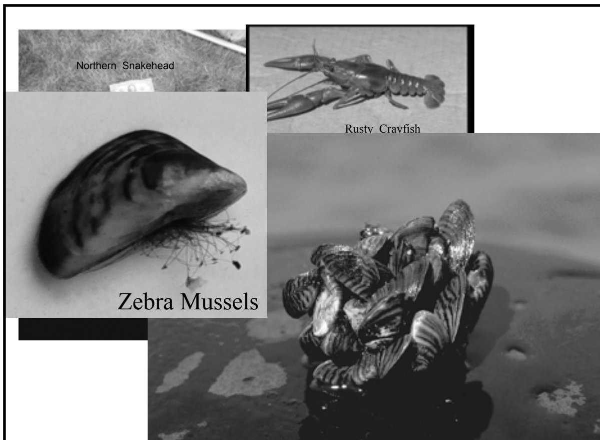





## Zebra Mussel Panel Management Plan

I. EXECUTIVE SUMMARY

II. INTRODUCTION
- Life History,
- Ecology & Economic Impact,
- Population Status & Distribution,
- Existing Research & Management Strategies

III. POLICY BACKGROUND – State & Federal legislation & policy overview

**IV. MANAGEMENT ACTION SECTION –**

**a. Leadership, Coordination, & Regulatory Authority**

**b. Prevention**

**c. Early Detection & Rapid Response**

**i. Review existing ZM monitoring programs**

**ii. Monitoring Stations Status**

**iii. Establish New ZM Stations**

**iv. Websites – Review and enhance.**

**d. Control & Management**

**e. Communication & Information Access**

I. IMPLEMENTATION SECTION

II. PROGRAM MONITORING & EVALUATION

III. GLOSSARY

IV. APPENDIX.

*Tony Shaw*

**tshaw@state.pa.us 717-787-9637**

## The Delaware Invasive Species Council

B.A. Richards, Ph.D.
Executive Director,
Delaware Center for the Inland Bays

## Partnerships

- DE Department of Agriculture
- DE Dept. of Nat. Res. & Envir. Control
- DE Nature Society
- The Nature Conservancy
- U of DE, DE State College
- Landscapers & Business Interests
- DE Center for the Inland Bays

## Formation of "DISC"

- Grew out of agricultural concerns, late 90's
- Developed By-Laws:
  - Public Policy
  - Education/Outreach
  - Scientific Research, data management, tracking
  - Organizational structure
- Developed Leadership Roles & Committees

## Committees

- By-Laws
- Data Management
- Education
- Research

## Activities

- Annual Meeting
- Field trips to problem sites
- web-site
- Educational displays & brochures
- State Management Plan

## Species Vs. Processes

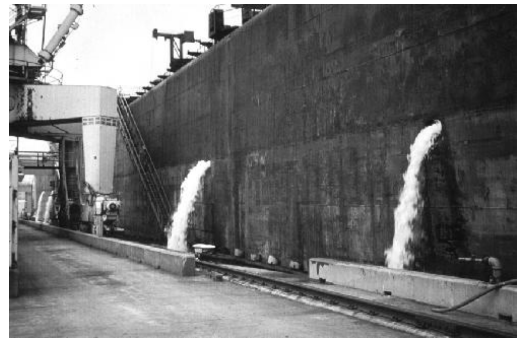
- Identify Species
- Learn Biology
- Develop Plan to Control, Eradicate
- Problems
  - limited # of experts
  - multiple # of species makes management nearly impossible

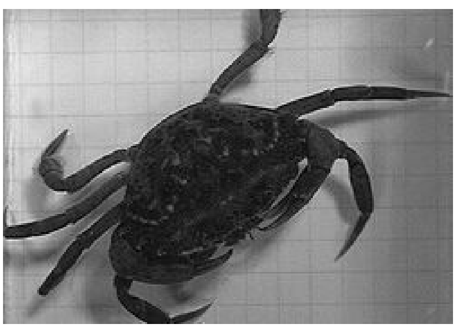
- Identify Processes
  - tropic dynamics
  - pathways for introduction
  - ecological systems
- Problems
  - one process works for one group, not another
  - processes are hard to identify at times

## DE Invasive Species Management Plan

- Comprehensive Plan for entire state
- Upland, Wetlands, Fresh & Salt Water Environments
- Panel of Experts
- Position DE for Federal Funding in Future
- Legitimate or Elevate DISC to Governor's Commission

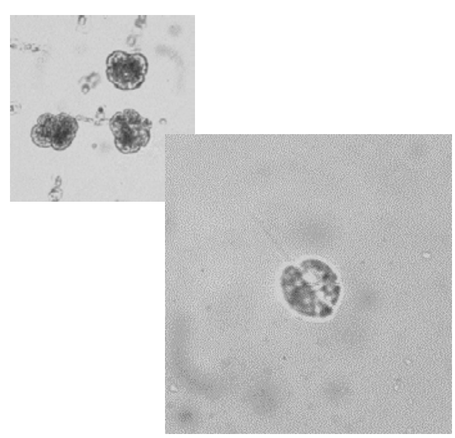
## Balast Water Release

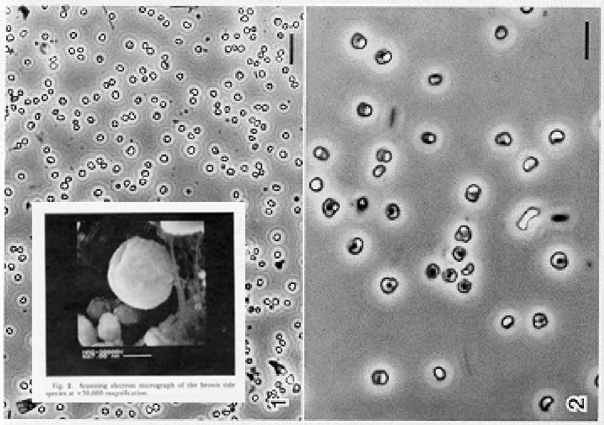




## *Hemigrapsus sanguineus*

## Codium






# Thank You

B. A. Richards
Executive Director
Center for the Inland Bays