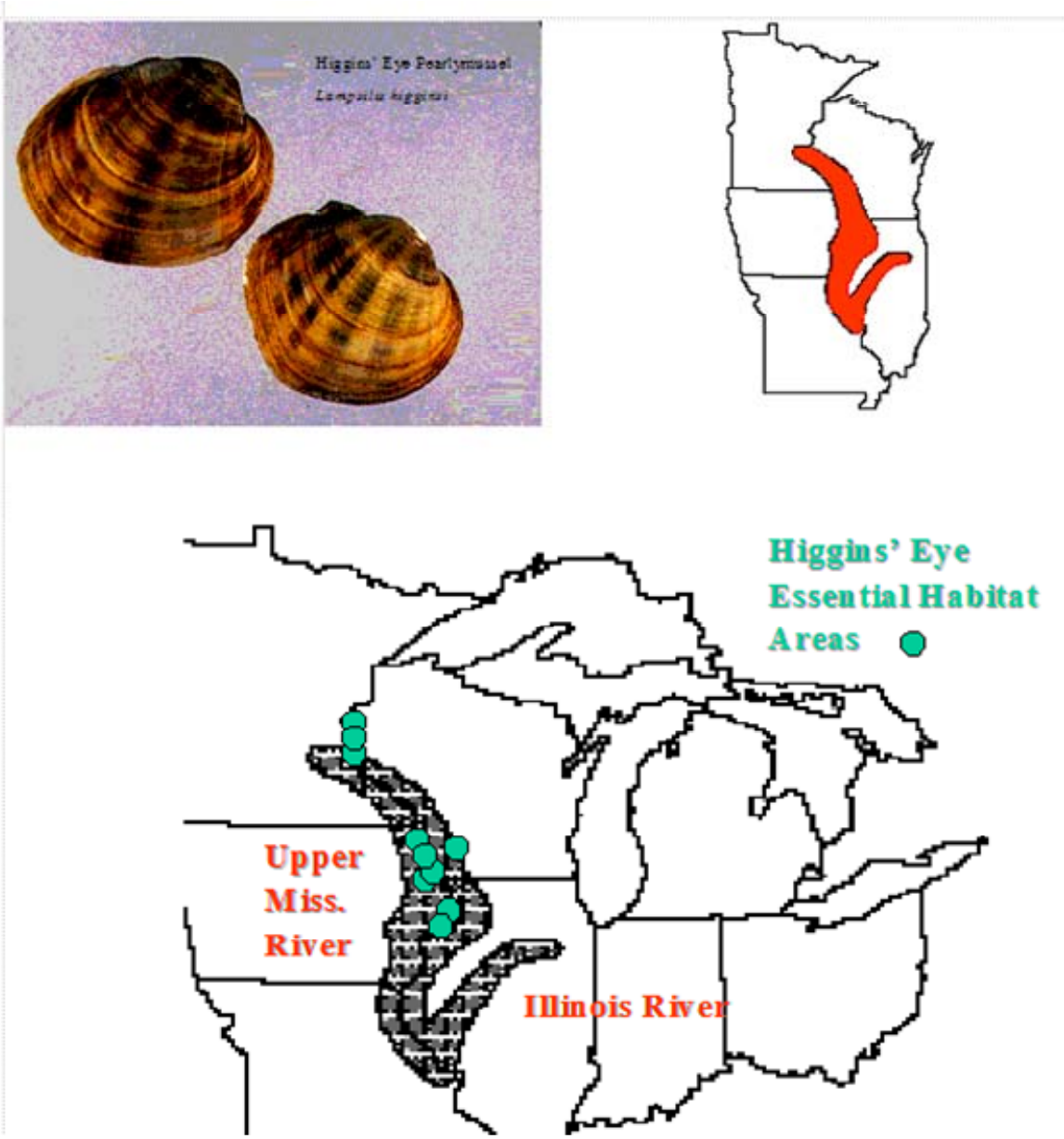


Figure 1. The federally endangered Higgins eye (*Lampsilis higginsii*); male on left, female on right. The historic range of Higgins eye is shown in red. Ten Essential Habitat Areas (green dots) were identified in the 2004 revised recovery plan (U.S. Fish and Wildlife Service 2004. (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

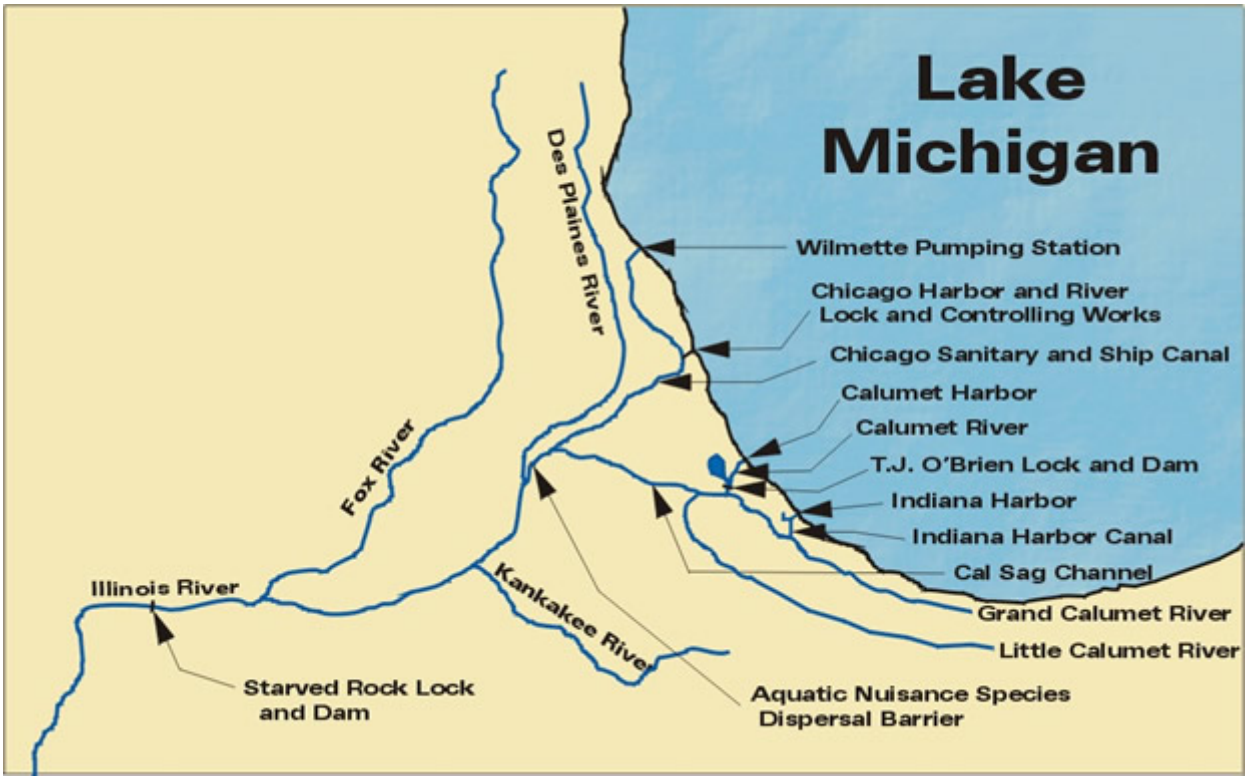


Figure 2. Connecting the Mississippi River and Great Lakes Watersheds. Before these connections, the Mississippi River and Great Lakes were separate watersheds. A series of connections were made between Lake Michigan and the Illinois River in Chicago to reroute sewage and provide commercial navigation. These connections provided a pathway for introduction of exotic species between the Great Lakes and Mississippi River basins. (Graphic by Jerry Rasmussen, U.S. Fish and Wildlife Service)

Figure 3. Top photos show the distribution of zebra mussels (*Driessena polymorpha*) between 1988 and 2007. (Graphics by the U.S. Geological Survey). The middle photos show zebra mussels attached to a barge in the Twin Cities, Minnesota, and a houseboat in La Crosse, Wisconsin. The bottom photos show zebra mussels scooped from the bottom of Lake Pepin by a diver; they formed a "carpet" on the bottom. They also covered individual mussels; this fat mucket (*Lampsilis siliquoidea*) was removed from the bottom sediment by divers. All exposed areas were covered by zebra mussels. (Photos by Mike Davis, Minnesota Department of Natural Resources)

MUSSEL COORDINATION TEAM

Upper Mississippi River and Tributaries

PARTNERING AGREEMENT

We, the partners involved in the management of native unionid mussel fauna on the Upper Mississippi River and tributaries, are committed to working together as a trusting, cooperative team to coordinate planned mussel studies and projects and share information on the management of native mussel resources and the control of invasive non-indigenous mussel species.

GOALS

I. We will actively work to foster confidence and mutual trust by discussing issues openly and respecting differences if they arise.

II. Consistent with our own programs, authorities, and funding limitations, we will work jointly towards our objectives of conserving native mussels and controlling non-indigenous mussels.

III. We will encourage interagency and public communications about our ongoing studies and plans to maximize public awareness of and involvement in our mussel conservation and control activities.

IV. We will coordinate our activities to avoid duplication of efforts and administrative delays.

V. We will share information on mussel conservation and non-indigenous mussel control activities.

MEMBERS

U.S. Army Corps of Engineers - St. Paul District

U.S. Army Corps of Engineers - Rock Island District

U.S. Fish and Wildlife Service - Region 3

U.S. Geological Survey - UMESC

National Park Service - Regional Office

U.S. Coast Guard

Iowa Department of Natural Resources

Science Museum of Minnesota - SC WRS

Illinois Department of Natural Resources

Minnesota Department of Natural Resources

Wisconsin Department of Natural Resources

Figure 4. Partnering Agreement establishing the interagency Mussel Coordination Team (MCT). (Graphic by Dennis Anderson, U.S. Army Corps of Engineers)

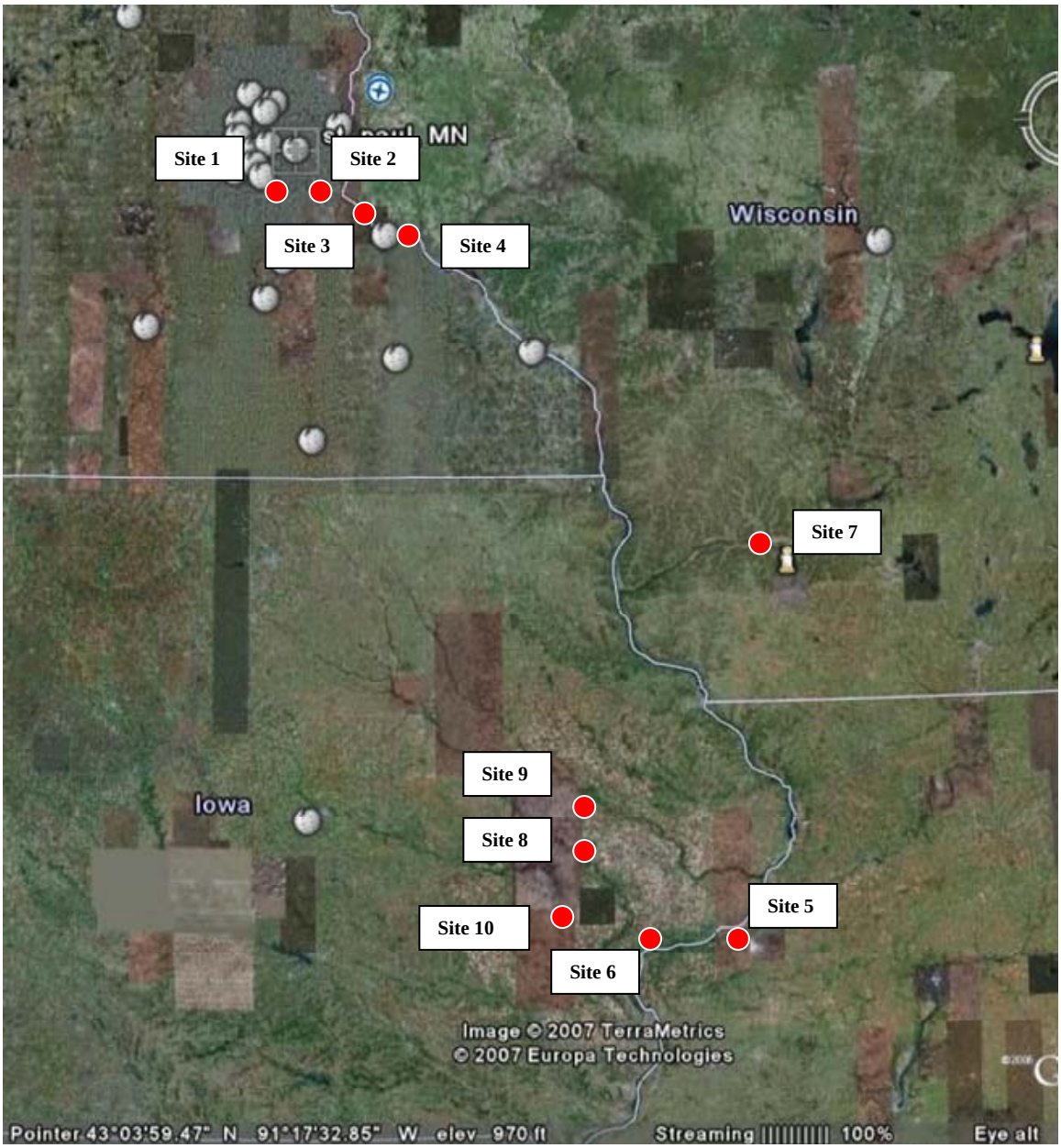


Figure 5. Ten population establishment sites for Higgins eye (*Lampsilis higginsii*) on the upper Mississippi River and tributaries. (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

Site 1, UMR, Upper Pool 2, St. Paul, MN, adults and subadults
Site 2, UMR, Lower Pool 2, Hastings, MN, subadults
Site 3, UMR, Pool 3, Hastings, MN & Diamond Bluff, WI, adults and subadults
Site 4, UMR Pool 4, Red Wing, MN, subadults
Site 5, Rock River, Rock Island, IL, subadults
Site 6, UMR, Pool 16, Fairport, IA, subadults
Site 7, lower Wisconsin River, Prairie du Sac & Orion, WI, juveniles and subadults
Site 8, Iowa River, Iowa City, IA, juveniles
Site 9, Cedar River, Palisades-Kepler State Park, IA, juveniles
Site 10, Wapsipinicon River, Central City & Anamosa, IA, juveniles

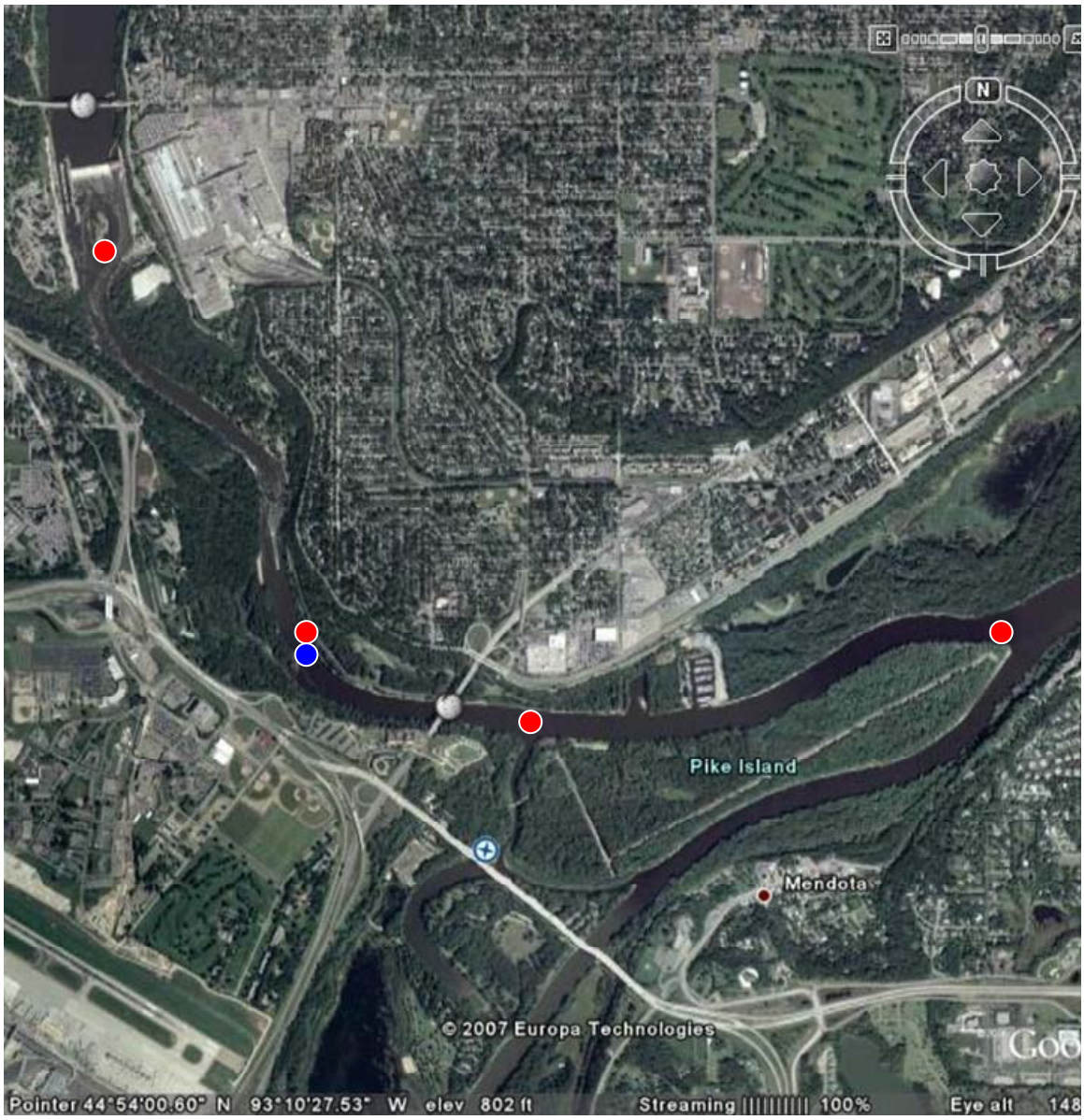


Figure 6. Population Establishment Site 1, upper Mississippi River, Pool 2, St. Paul, Minnesota. Site 1 was stocked with adult ● and subadult ● Higgins eye (*Lampsilis higginsii*). (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

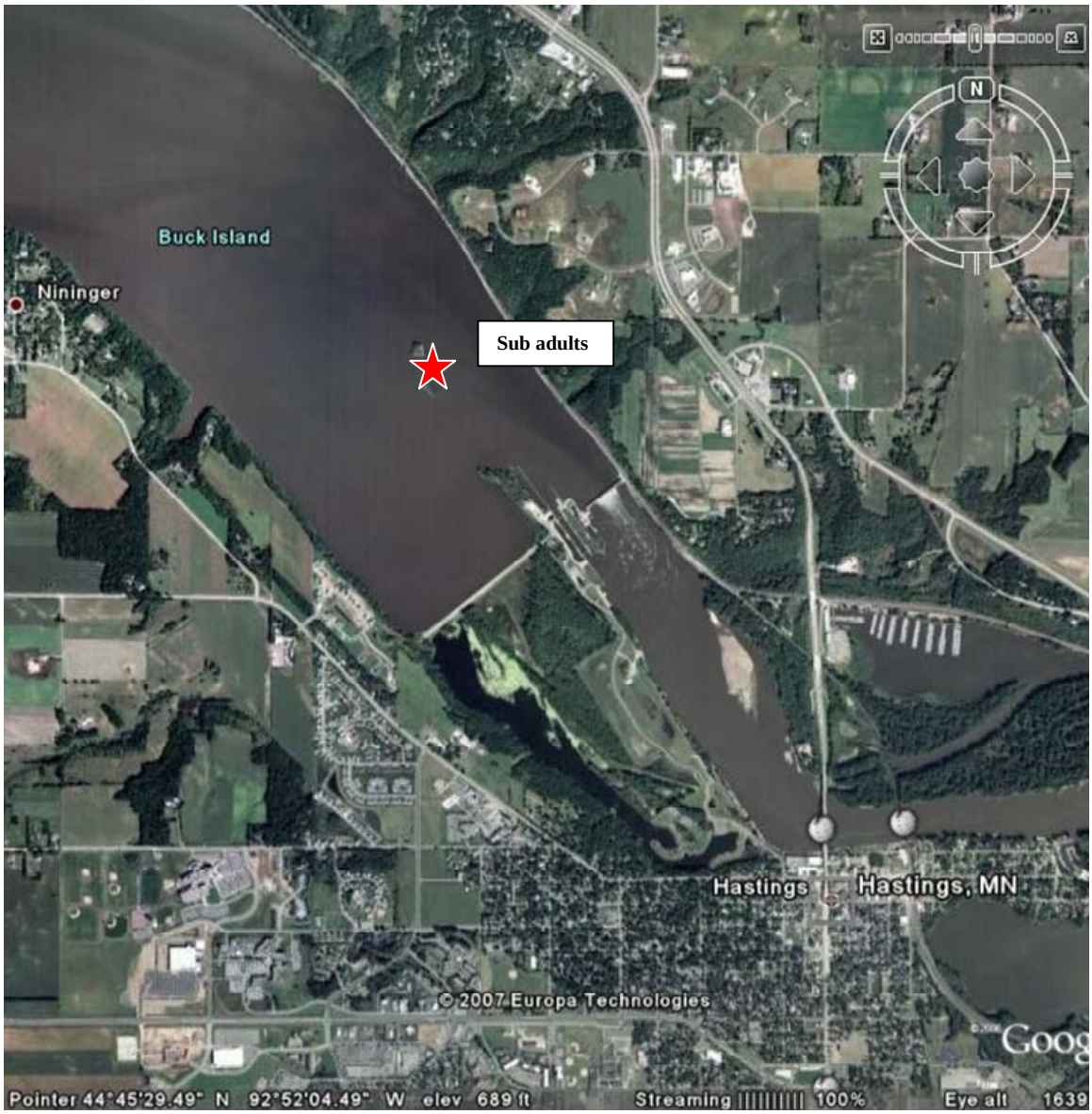


Figure 7. Population Establishment Site 2, upper Mississippi River, Pool 2, Hastings, Minnesota. Site 2 was stocked with subadult Higgins eye (*Lampsilis higginsii*). (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

Figure 8. Population Establishment Site 3, upper Mississippi River, Pool 3, Hastings, Minnesota and Diamond Bluff, Wisconsin. Site 3 was stocked with adult and subadult Higgins eye (*Lampsilis higginsii*). (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

Figure 9. Population Establishment Site 4, Pool 4, upper Mississippi River, Red Wing, Minnesota. Subadult Higgins eye (*Lampsilis higginsii*) were stocked at Goose Lake (top) and 4th Cut (bottom). (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

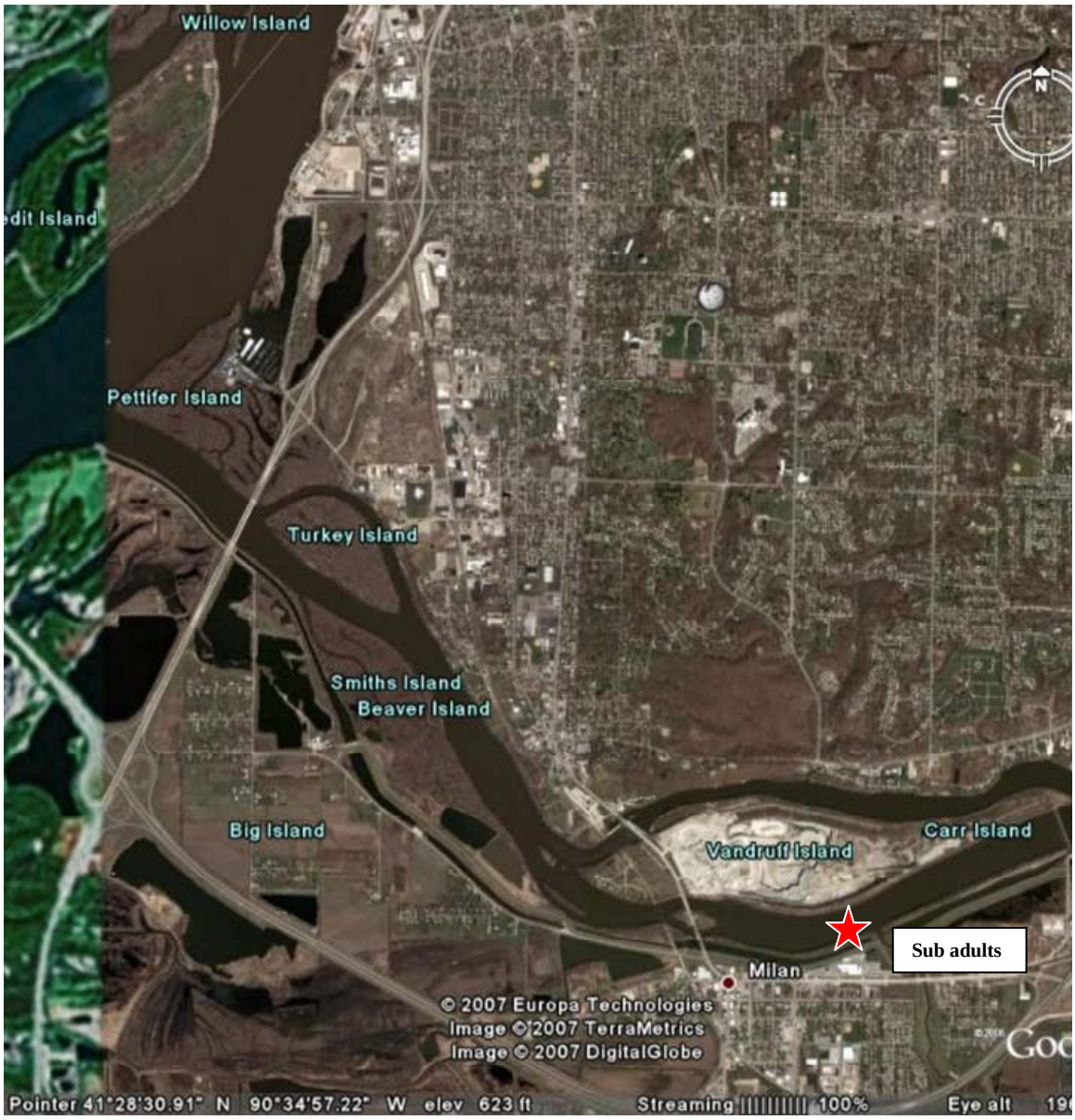


Figure 10. Population Establishment Site 5, Rock River, Rock Island, Illinois. Site 5 was stocked with subadult Higgins eye (*Lampsilis higginsii*). (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

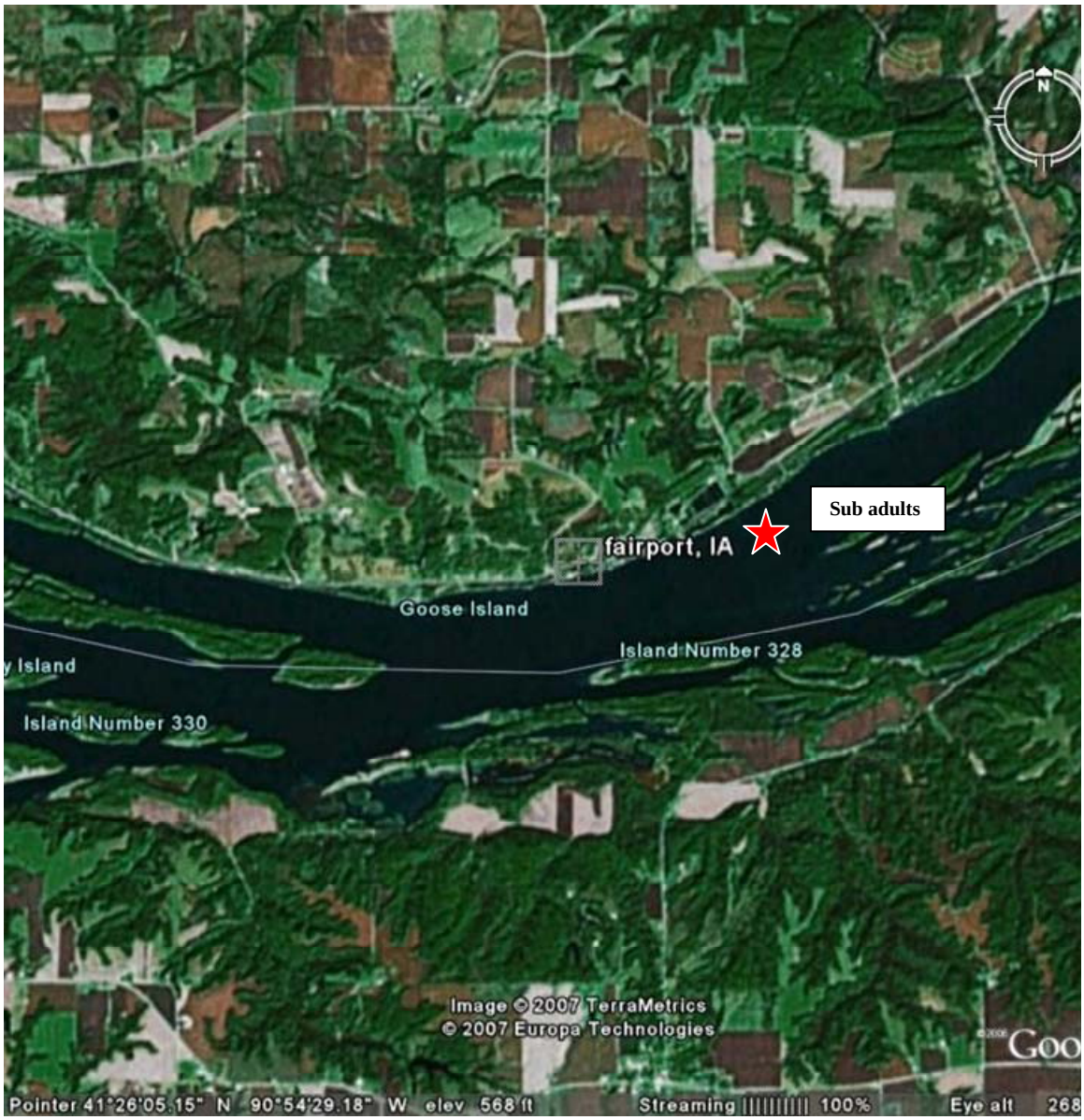


Figure 11. Population Establishment Site 6, upper Mississippi River, Pool 16, Fairport, Iowa. Site 6 will be stocked with subadult Higgins eye (*Lampsilis higginsii*). (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

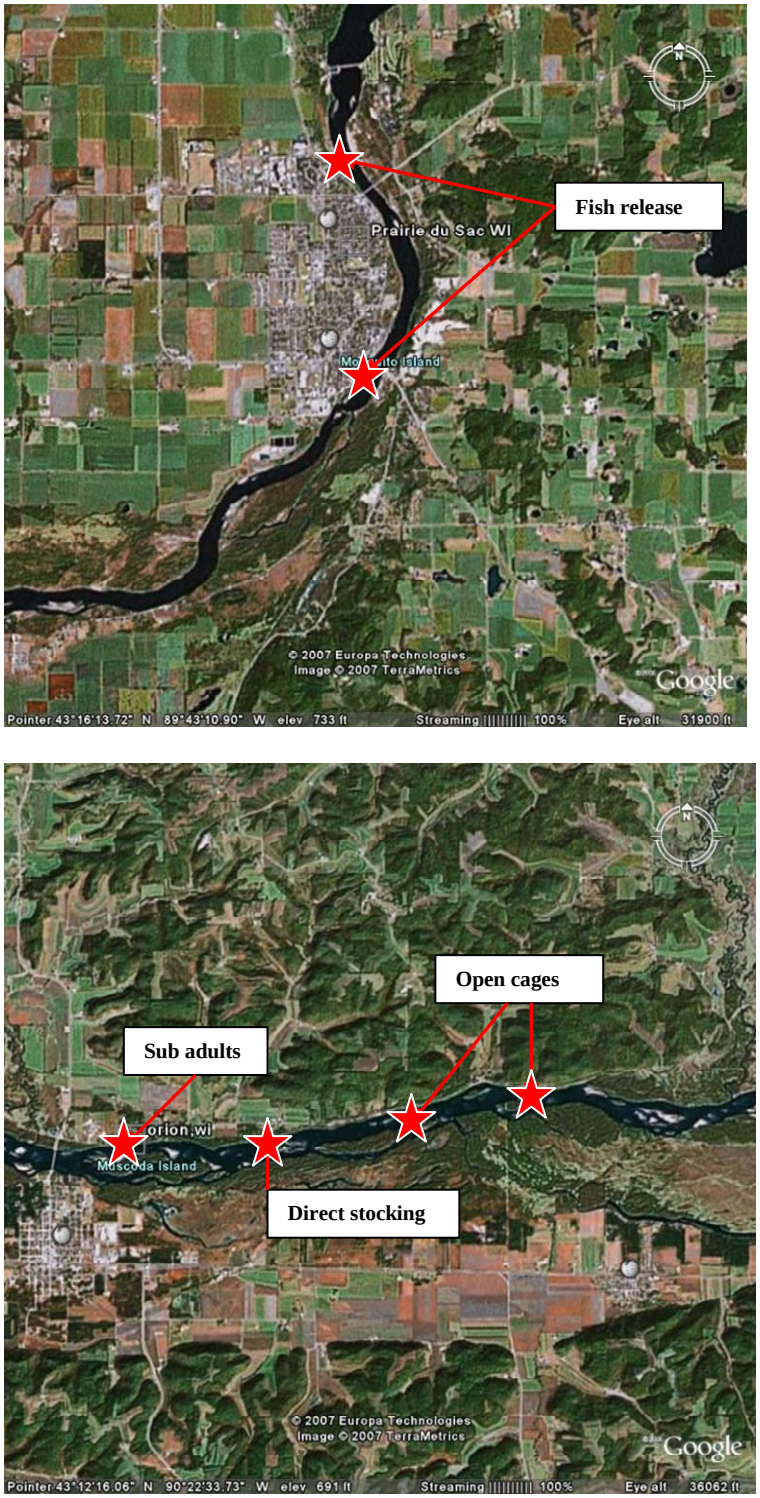


Figure 12. Population Establishment Site 7, lower Wisconsin River, Prairie du Sac and Orion, Wisconsin. Site 7 was stocked with juvenile (open cages, direct stocking and releasing glochidia-infested host fish) and subadult Higgins eye (*Lampsilis higginsii*). (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

Figure 13. Population Establishment Site 8, Iowa River, Iowa City, Iowa. Juvenile Higgins eye (*Lampsilis higginsii*) were stocked at Site 8 by releasing host fish that were infested with glochidia. (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

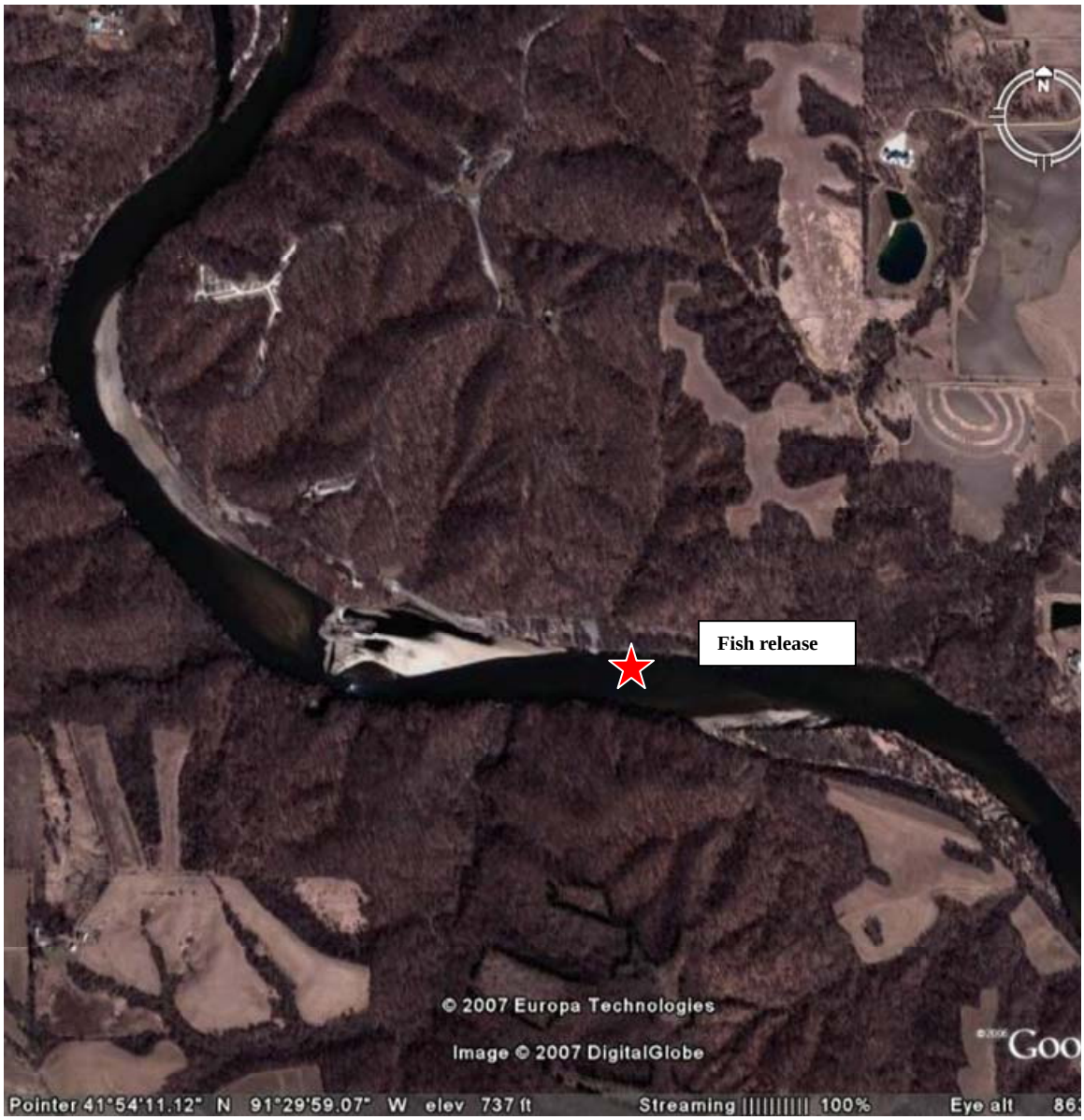
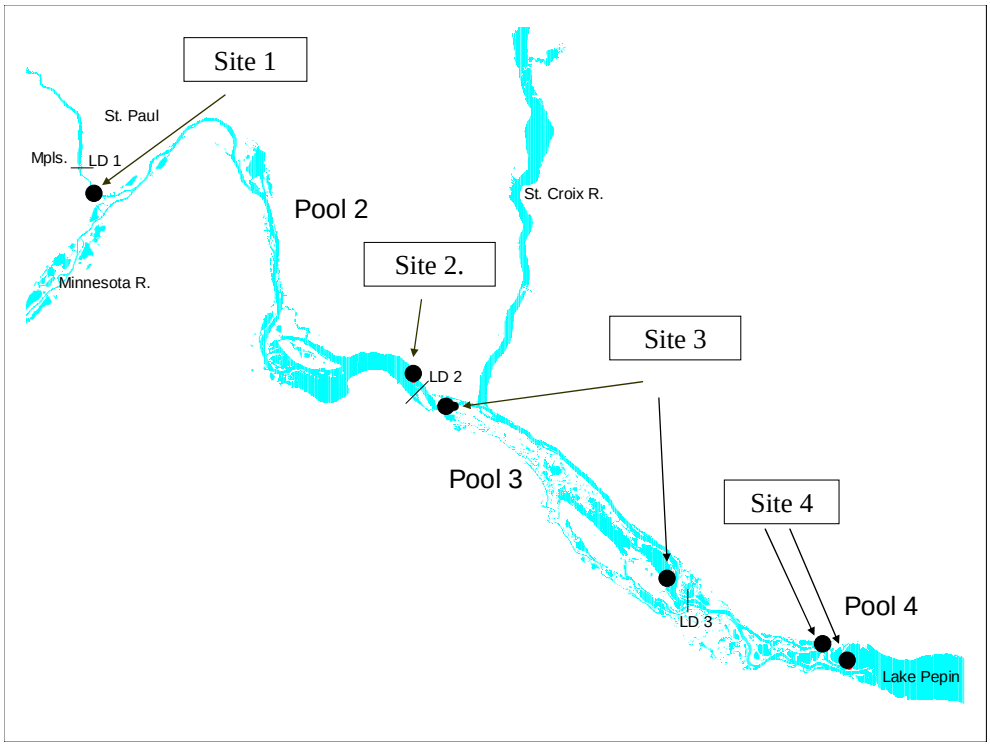


Figure 14. Population Establishment Site 9, Cedar River, Palisades-Kepler State Park, Iowa. Juvenile Higgins eye (*Lampsilis higginsii*) were stocked at Site 9 by releasing host fish that were infested with glochidia. (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

Figure 15. Population Establishment Site 10, Wapsipinicon River, Central City and Anamosa, Iowa. Juvenile Higgins eye (*Lampsilis higginsii*) were stocked at Site 10 by releasing host fish that were infested with glochidia. (Graphic by Gary Wege, U.S. Fish and Wildlife Service)



Upper Pool 2 Sub-Adult Placement Sites, 2006

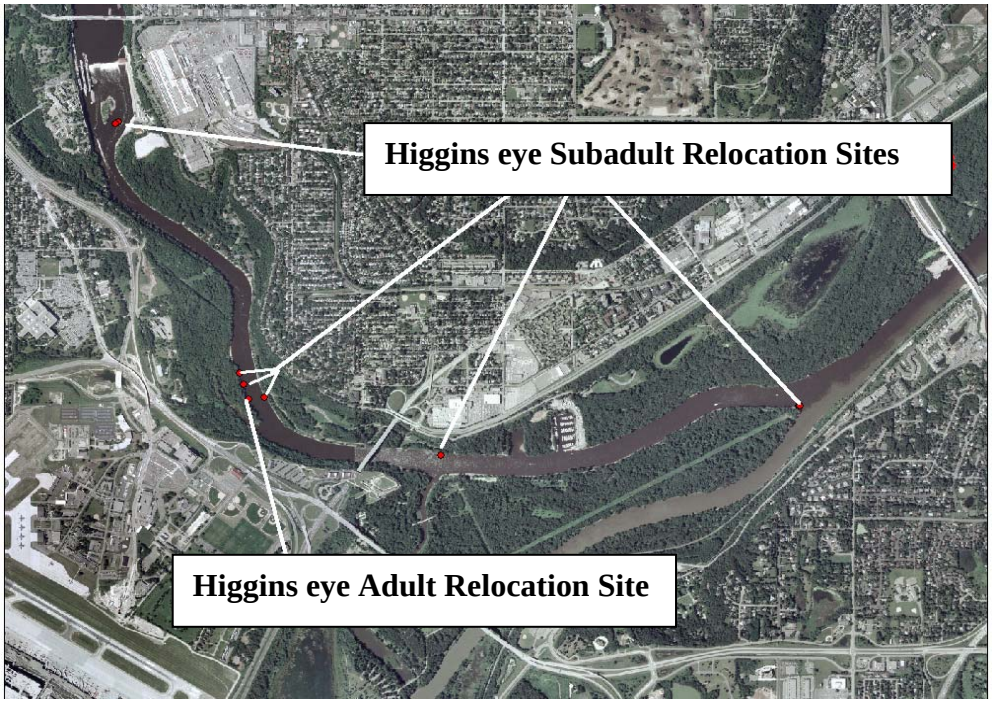


Figure 16. Population establishment sites for Higgins eye (*Lampsilis higginsii*) in the Twin Cities Metro Area, Pools 2, 3 and 4, upper Mississippi River, Minnesota - Wisconsin. Bottom photo shows location of subadult stockings at Site 1 in 2006. (Graphics by Dan Kelner, U.S. Army Corps of Engineers)

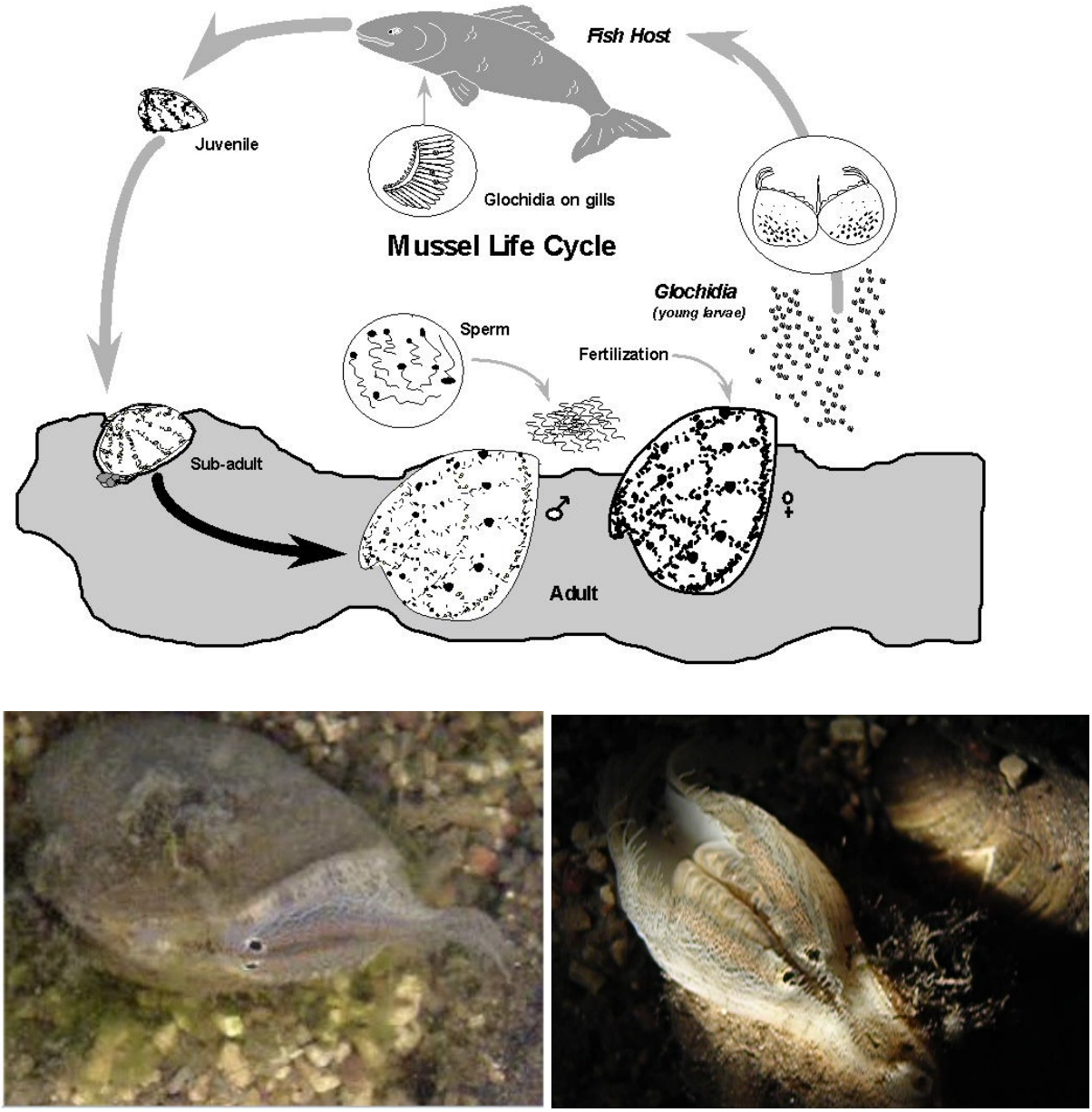


Figure 17. Life history of freshwater mussels. The bottom photos shows the fish "lure" displayed by a gravid female Higgins eye (*Lampsilis higginsii*). (Photos by Mike Davis, Minnesota Department of Natural Resources)

Figure 18. Gravid plain pocketbook (*Lampsilis cardium*) displaying its damaged lure (scarred mantle tissue) suggesting injury from host fish like walleye or smallmouth bass during glochidia infestation. Mussel was collected in 2005 on the lower St. Croix River near Hudson, Wisconsin. (Photo by Mike Davis, Minnesota Department of Natural Resources).

Figure 19. Collecting glochidia from a gravid female Higgins eye (*Lampsilis higginsii*) at Genoa National Fish Hatchery, Wisconsin. Glochidia are collected by injecting water into the gills with a syringe. Glochidia (middle left) are flushed into a collecting dish, tested for viability with salt, and a measured quantity placed in a bucket containing host fish. Contents of the bucket are mixed for a period of time. The gills of an individual host fish is examined under a microscope to estimate the number of attached glochidia. When a suitable number of glochidia are attached, host fish are placed into a concrete holding tank. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

Figure 20. Host fish produced at Genoa National Fish Hatchery for glochidia infestation include largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), and walleye (*Stizostedion vitreum vitreum*). Bottom right photo shows host fish (largemouth bass) in a bucket ready for addition of Higgins eye (*Lampsilis higginsii*) glochidia. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

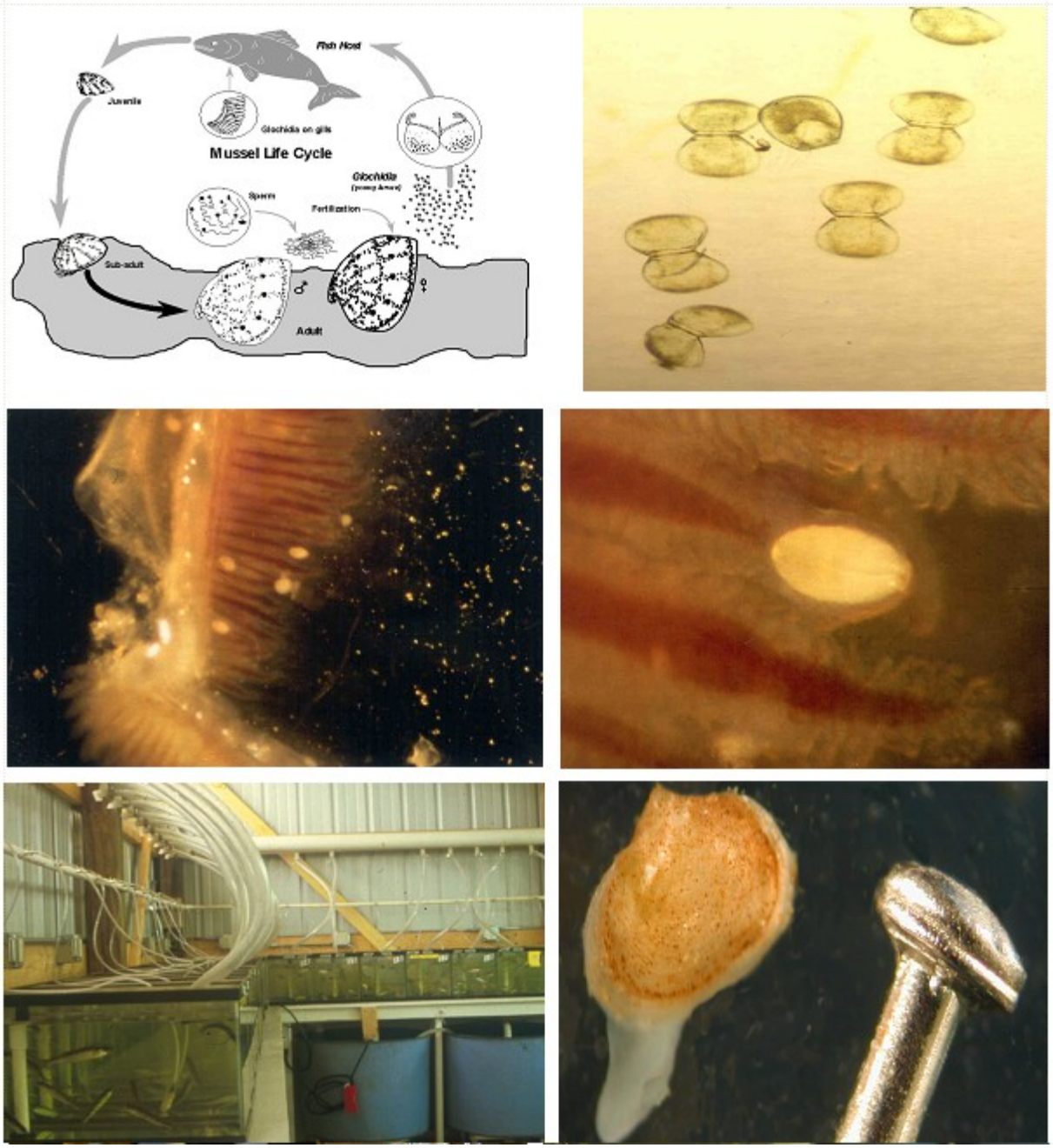


Figure 21. Transformation of glochidia from Higgins eye (*Lampsilis higginsii*) at Genoa National Fish Hatchery, Wisconsin. In mixing buckets, glochidia (top right) attach to the gills of host fish (middle left) and encyst (middle right). Host fish are placed in aquariums and glochidia transform, fall of the gills and settle to the bottom as juveniles. The juvenile shown in the lower right photo is approximately 0.75 millimeters long; it is shown next to the head of a pin for size comparison. (Photos by Roger Gordon, U.S. Fish and Wildlife Service)

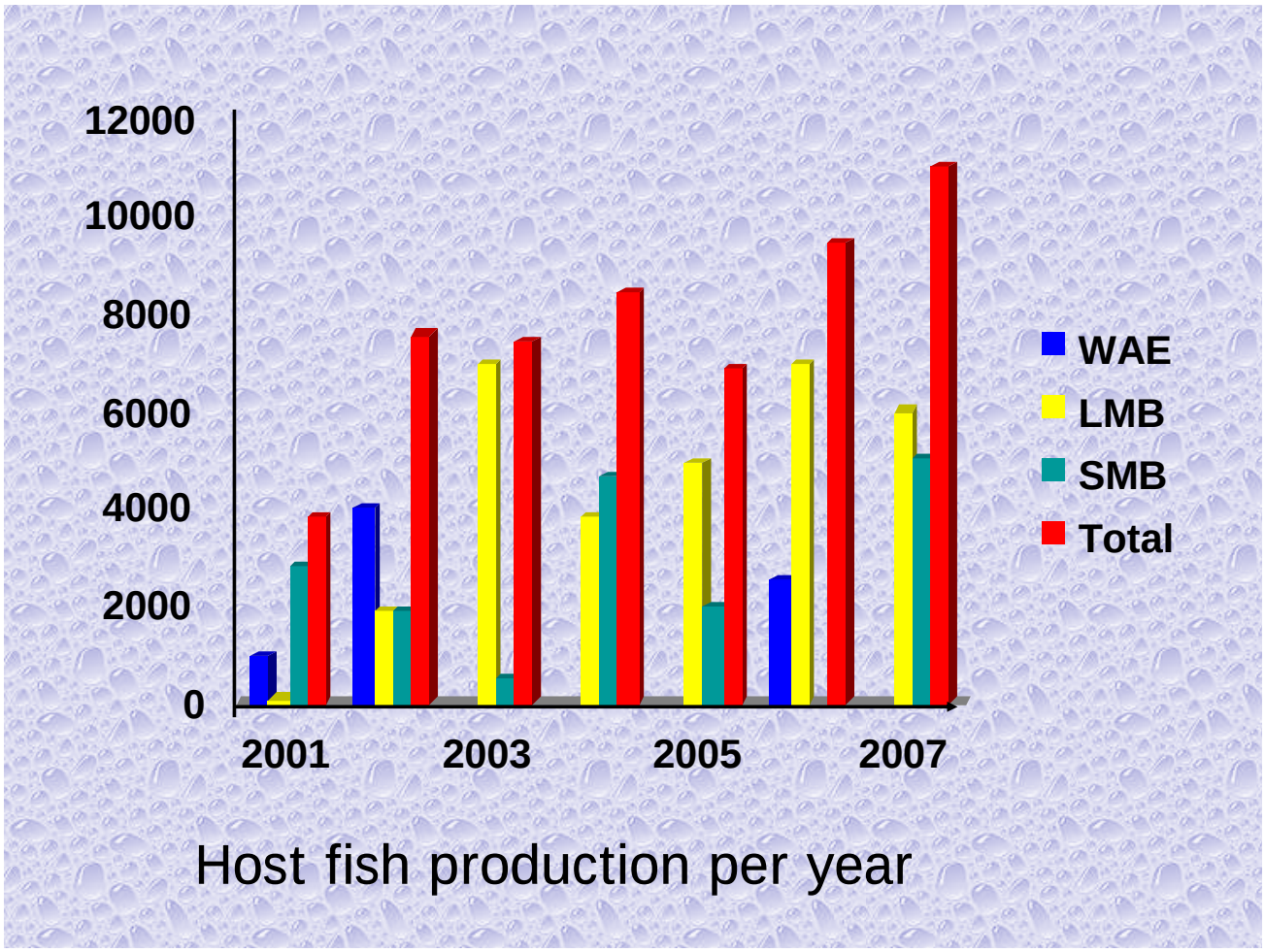


Figure 22. Annual production of host fish for Higgins eye (*Lampsilis higginsii*) propagation at Genoa National Fish Hatchery, Wisconsin. WAE = walleye; LMB = largemouth bass; SMB = smallmouth bass. (Graphic by Tony Brady, U.S. Fish and Wildlife Service)

Figure 23. Stocking juvenile Higgins eye (*Lampsilis higginsii*) into the lower Wisconsin River, Wisconsin. Juveniles were produced at Genoa National Fish Hatchery, Wisconsin. The diver is submerging a wooden tray containing approximately 3,700 juveniles. The juvenile in the photo is less than one millimeter long and is shown next to the head of a pin for size comparison. The bottom photo shows a small cage placed in the Lower St. Croix River in 2001. (Photos by the Minnesota Department of Natural Resources and U.S. Fish and Wildlife Service)

Figure 24. Cages used to propagate Higgins eye (*Lampsilis higginsii*) on the upper Mississippi River. Cages are constructed of aluminum sides, base and ½-inch screen. The top left photo shows two types of cages; the cage on the left is used in low current areas and the right one in higher velocity areas. These are open cages with no bottoms; closed cages have a 3/8-inch plywood bottom to collect transformed mussels (top right photo). The middle and bottom photos show the process of transporting closed cages to the relocation site, adding substrate and host fish, and placing them on the river bottom. The middle right photo shows a cage holder attached to a boat; depending on water depth, cages can be placed by diving or wading from shore. (Photos by the Minnesota Department of Natural Resources and U.S. Fish and Wildlife Service)

Figure 25. Stocking glochidia infested host fish into the Iowa River, Iowa. Host fish are obtained from a fish hatchery or collected in the wild from the Iowa River. Laboratory equipment is set up in the field and glochidia collected from female Higgins eye (*Lampsilis higginsii*). Glochidia are inserted into the gills of larger host fish with a pipette; smaller host fish are inoculated in a bucket containing glochidia and water. Host fish are released into the Iowa River and in approximately 2 - 4 weeks glochidia transform, fall off the gills of the host fish, and settle to the river bottom as juveniles. (Photos by the U.S. Fish and Wildlife Service)

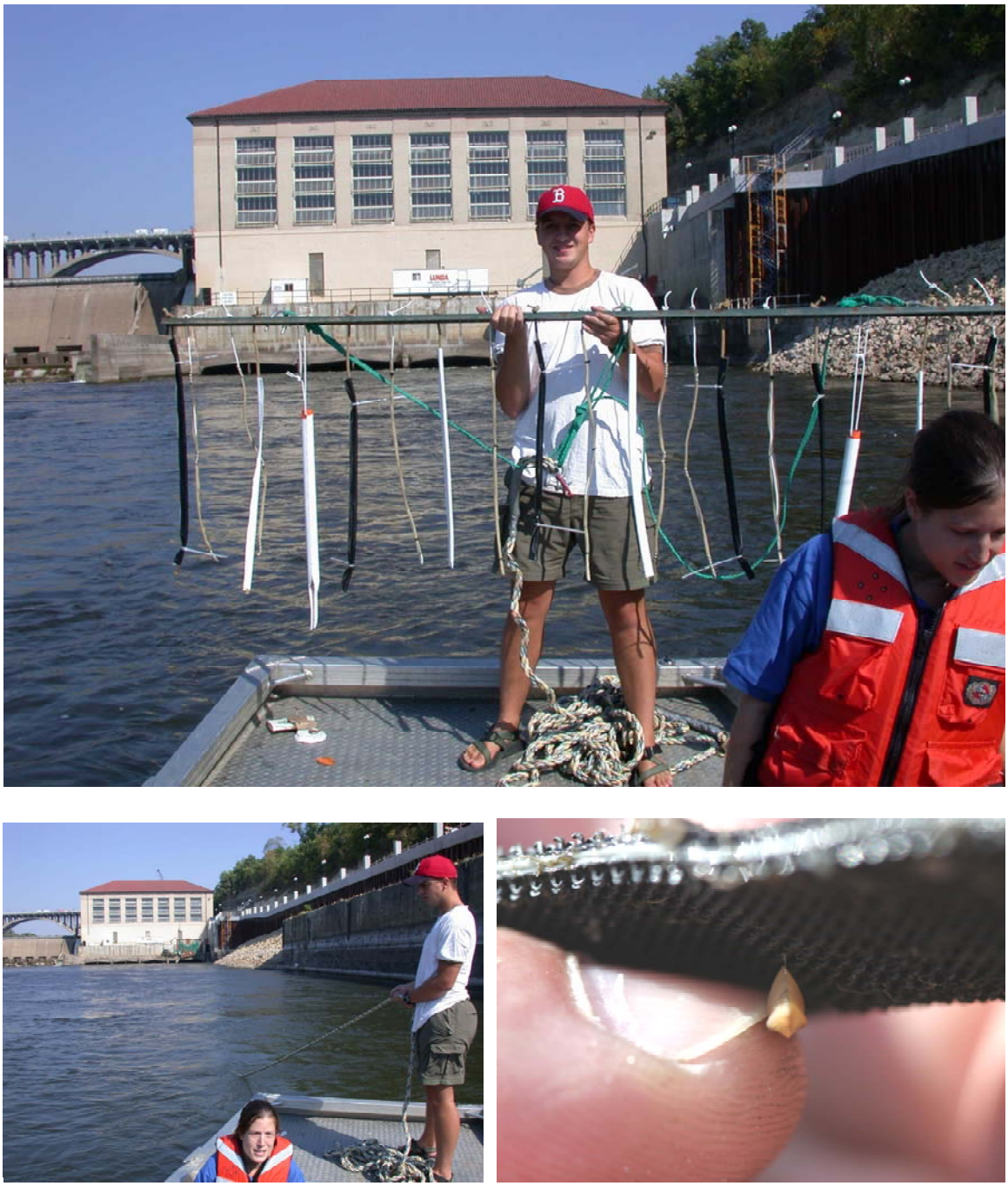


Figure 26. Bar for collecting juvenile mussels by their byssal threads. Velcro (hook side) is attached to weighted pipe and metal bars and dragged along the bottom by boat. Byssal threads become attached/entangled with the Velcro material and pull juveniles from the substrate (bottom right photo). (Photos by Gary Wege, U.S. Fish and Wildlife Service)

Figure 27. Two of four juvenile Higgins eye (*Lampsilis higginsii*) collected downstream of open propagation cages in the lower Wisconsin River, Wisconsin. Juveniles were collected during monitoring activities in 2005. (Photos by Dave Heath, Wisconsin Department of Natural Resources)

Figure 28. Subadult Higgins eye (*Lampsilis higginsii*) collected in 2005 and 2006 from the Wapsipinicon River, Iowa. (Photos by Tony Brady, U.S. Fish and Wildlife Service)

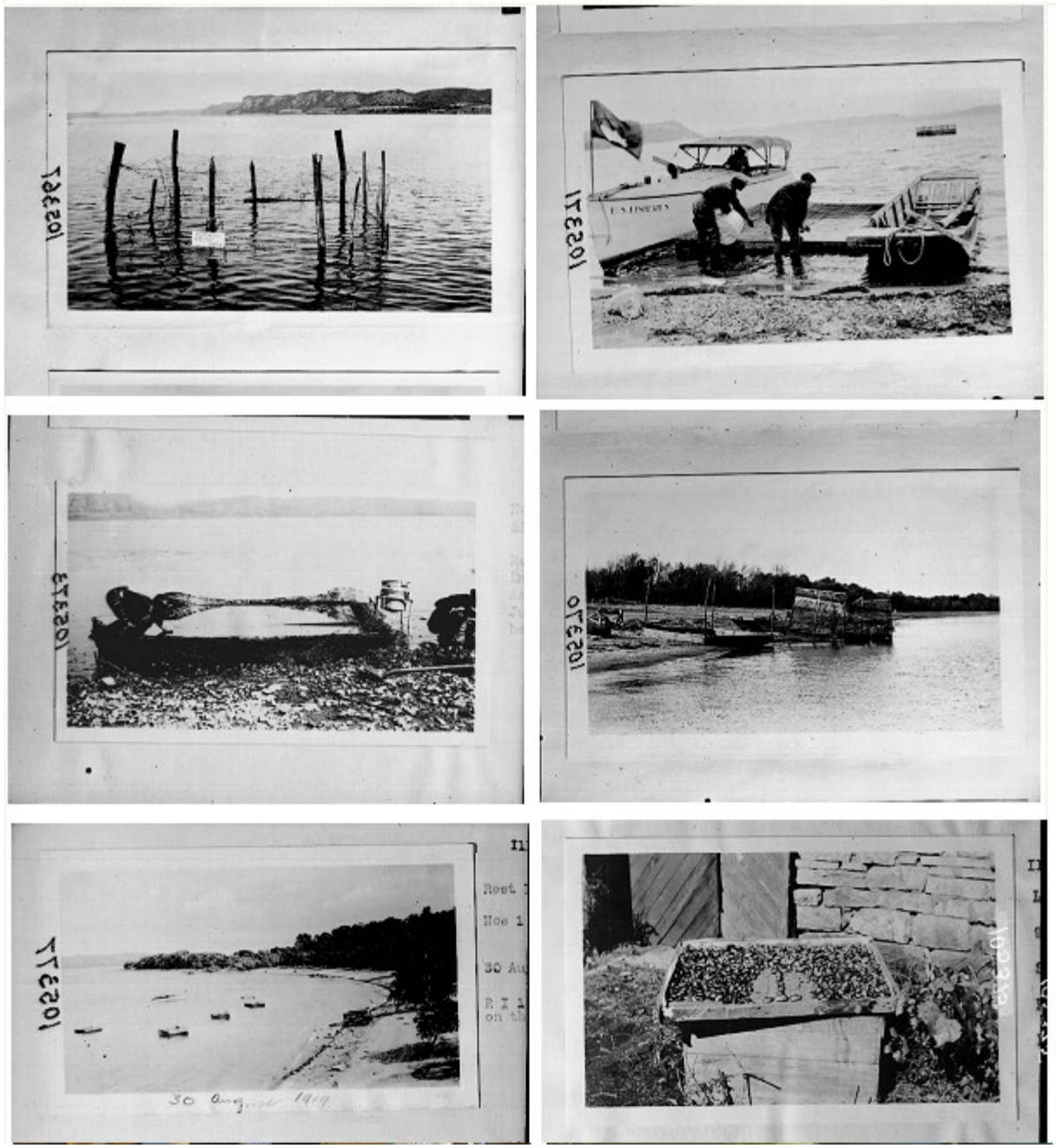


Figure 29. Historic photos of mussel propagation in wooden “corrals” in Lake Pepin, Pool 4, near Lake City, Minnesota. (Photos taken by R. Corwin around 1916 and are courtesy of the Milwaukee Public Museum)

Figure 30. Propagation of native mussels in Lake Pepin, Pool 4, upper Mississippi River. Top two photos are from around 1919 (Photos by R. Corwin courtesy of the Milwaukee Public Museum). Bottom two photos are from 2003 (Photos by Gary Wege, U.S. Fish and Wildlife Service)

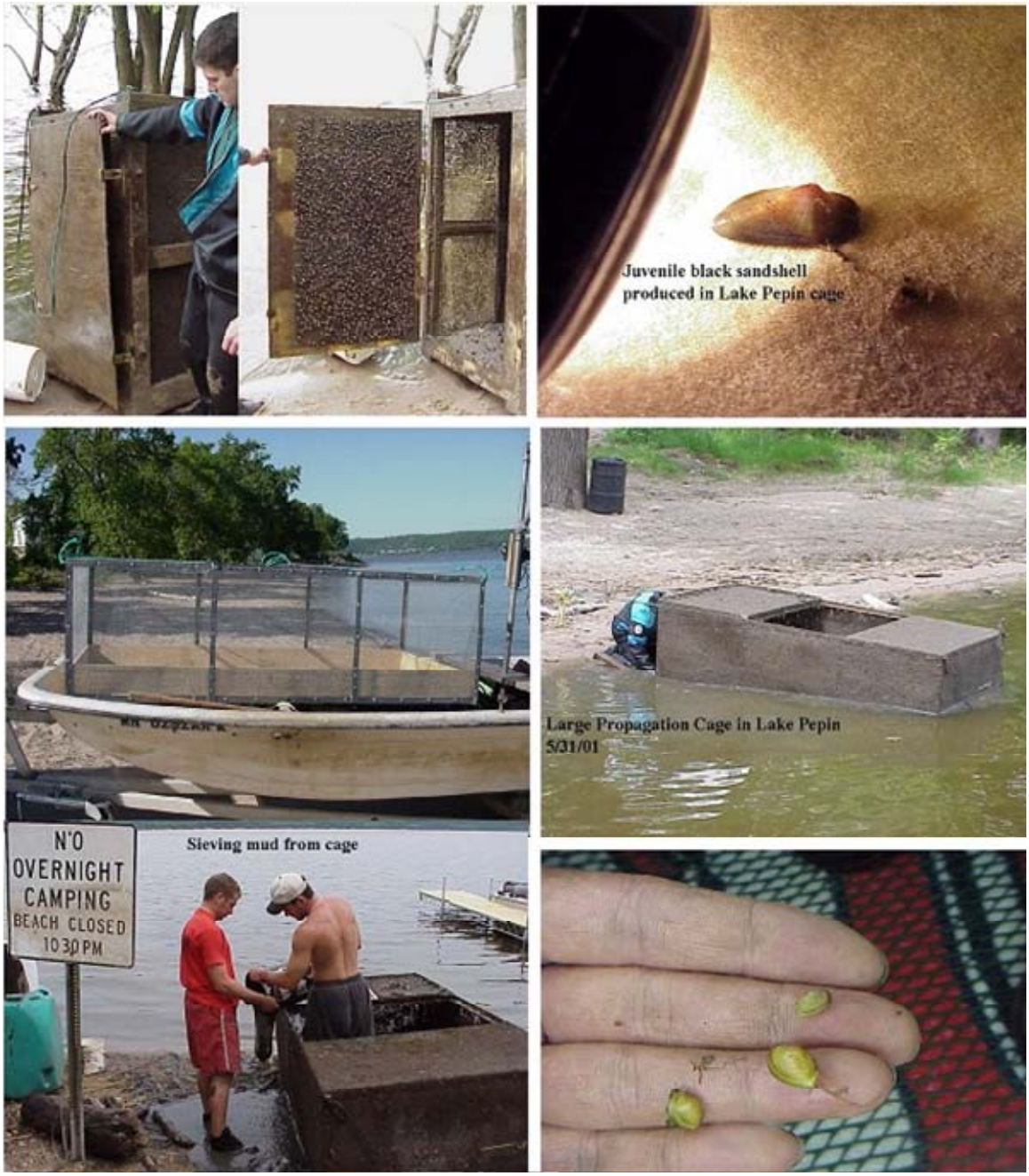


Figure 31. Two propagation cages placed in Lake Pepin (Pool 4) in June 2000. Zebra mussels (*Driessena polymorpha*) are shown attached to the inside of the wooden cage; one subadult black sandshell (*Ligumia recta*) was found in June, 2001. The middle and bottom photos show installation of a metal frame cage and subsequent monitoring. The cage filled with sediments and was difficult to monitor; three subadult Higgins eye (*Lampsilis higginsii*) were collected in June 2001. (Photos by Mike Davis, Minnesota Department of Natural Resources)

Figure 32. Juvenile Higgins eye (*Lampsilis higginsii*) collected from propagation cages in the upper Mississippi River. Juveniles were trapped between the wire mesh and plywood bottom of the cage (1/4-inch space). Some larger individuals died because they could not open their shells. These individuals grew through the wire mesh as indicated by the indentations in their shells. To eliminate this problem, we removed the wire mesh bottom. (Photo by Mike Davis, Minnesota Department of Natural Resources)

Figure 33. One of two mussel "sleds" used for propagation of Higgins eye (*Lampsilis higginsii*) in the upper Mississippi River. The sled was constructed of a 4x8-foot sheet of ½- inch plywood, wire mesh and has a hinged top. The sides and ends are 2x12-inch pine. The ends of the sled are angled upward and a rope attached to both ends to facilitate dragging underwater to the placement site. To improve water circulation for growing juveniles and subadults, the sleds were later modified by cutting out sections of the wooden sides and ends (bottom left photo). (Photos by Gary Wege, U.S. Fish and Wildlife Service)

Figure 34. Tags used to identify closed propagation cages on the upper Mississippi River. The yellow tag is an ear tag for marking livestock; although made of a rubber/plastic compound the area where it attaches to a plastic base deteriorated within a year underwater and sometimes became detached from the cage. We used different colored tags over the years and all tended to foul and make color identification difficult. Our newest tag (light green) is also a livestock ear tag but we now attach it to cages with plastic zip ties. We also write information on the tag with a permanent marker and etch this information on the tag with a Dremel tool. This particular tag indicates that the cage contains a consolidation of Cassville Strain Higgins eye, 2005 Cohort, that was placed into the river in August, 2006. (Photo by Gary Wege, U.S. Fish and Wildlife Service)

Figure 35. Monitoring propagation cages in the upper Mississippi River. Cages are brought to the surface and placed in the boat or on shore. Water is used to wash contents; benthic sampling trays are used to screen sediment and small mussels. Larger mussels and sediment can be washed using the cage as a screen. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

Figure 36. Underwater communication system used during mussel propagation activities on the upper Mississippi River. The system provides voice communication between divers, and between divers and shore attendants. This system is very useful in waters like the Mississippi River that have limited visibility. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

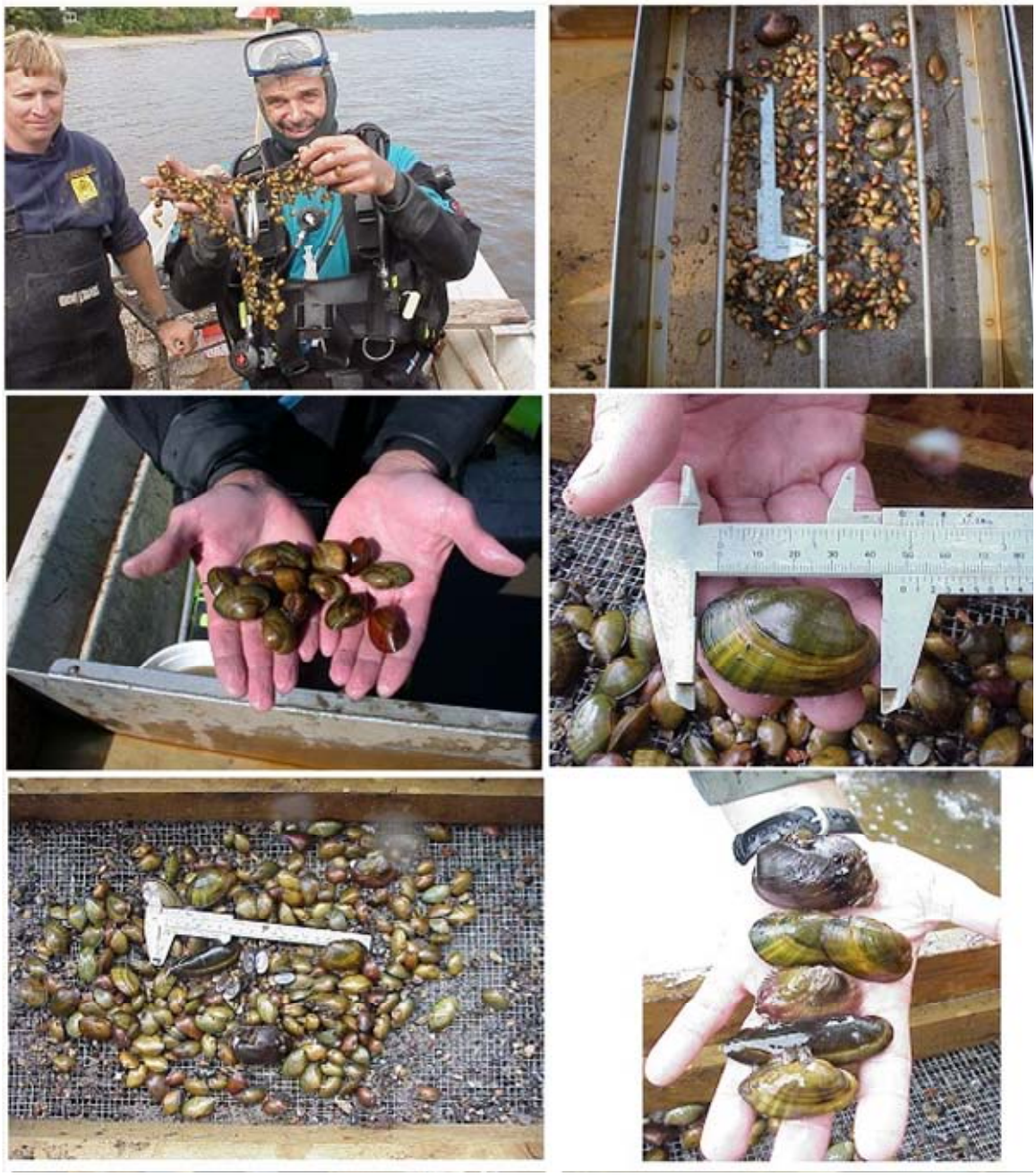
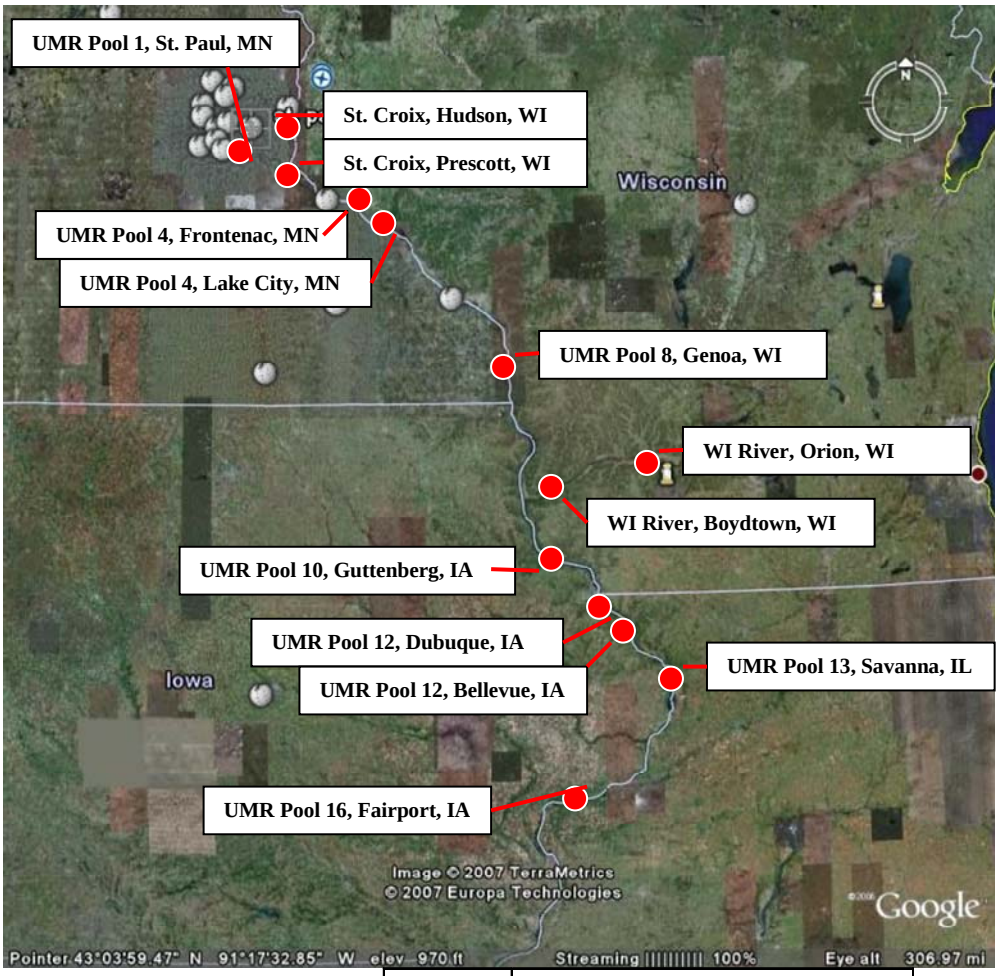


Figure 37. Higgins eye (*Lampsilis higginsii*) produced in cages in the upper Mississippi and lower St. Croix Rivers. The diver is holding 3-month old Higgins eye by their byssal threads. The top tray contains approximately 562 mussels (547 are 3 months old and 9 - 22 mm long). The middle left photo shows 15 individuals from this tray that are 15 months old and 25 - 35 mm long. The 28-month old individual in the middle right photo is approximately 48 mm long. The bottom photos show a variety of age groups and species; the right photo shows 3 Higgins eye and a rock pocketbook, monkeyface and black sandshell. (Photos by Mike Davis, Minnesota Department of Natural Resources and Gary Wege, U.S. Fish and Wildlife Service)



Propagation Site	Cages Placed	Monitoring		
		Mussels	Cages	No./Cage
St. Croix, Hudson	6	215	6	36
St. Croix, Prescott (upper)	6	317	6	53
St. Croix, Prescott (lower)	5	9	4	2
UMR Pool 1, St. Paul	27	8	16	0.5
UMR Pool 4, Frontenac	275	12,209	59	208
UMR Pool 4, Lake City	48	910	48	19
UMR Pool 8, Genoa	1	0	1	0
UMR Pool 10, Guttenberg	1	11	1	11
UMR Pool 12, Dubuque	19	5,370	19	283
UMR Pool 12, Bellevue	30	0	30	0
UMR Pool 13, Savanna	30	0	30	0
UMR Pool 16, Fairport	30	0	30	0
WI River, Boydtown	7	375	7	54
WI River, Orion	6	0	6	0

Figure 38. Fourteen experimental closed-cage propagation sites for Higgins eye (*Lampsilis higginsii*) on the upper Mississippi and lower St. Croix Rivers. (Graphic by Gary Wege, U.S. Fish and Wildlife Service)

Figure 39. Fredericks Point and Methodist Camp in relation to the existing Frontenac mussel propagation site in Pool 4, upper Mississippi River. Fredericks Point and Methodist Camp were evaluated as potential replacement sites for Frontenac which has an increasing abundance of zebra mussels inside propagation cages. However, we found that density of zebra and native mussels, species abundance, and evidence of ongoing native mussel recruitment was similar among all three sites. Consequently, we continue to use the Frontenac Site which has easy access. (Graphic by Mike Davis, Minnesota Department of Natural Resources)

Figure 40. Three color phases of the federally endangered Higgins eye pearlymussel (*Lampsilis higginsii*) observed during propagation activities on the upper Mississippi River. Subadult mussels are in their third growing season. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

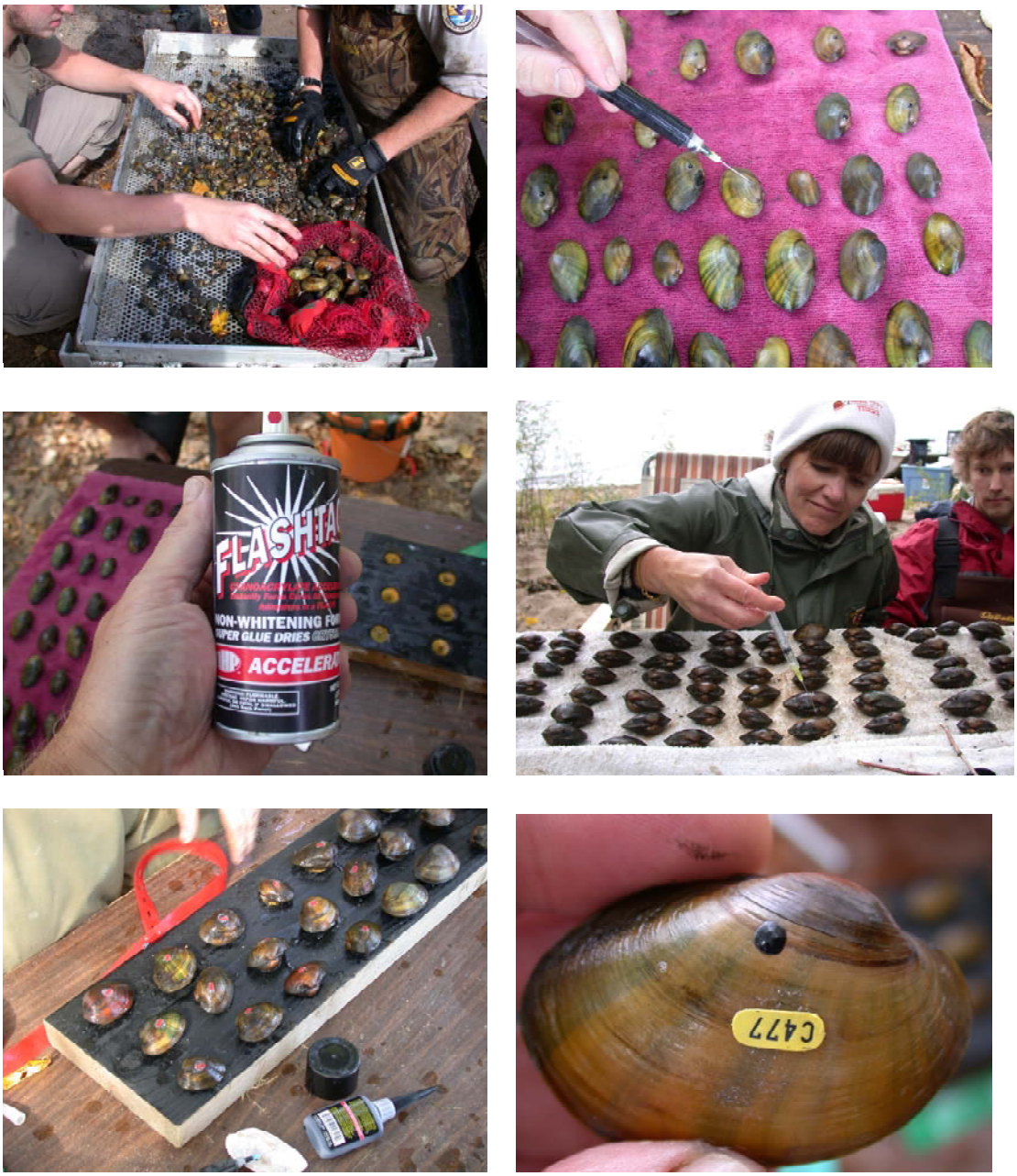
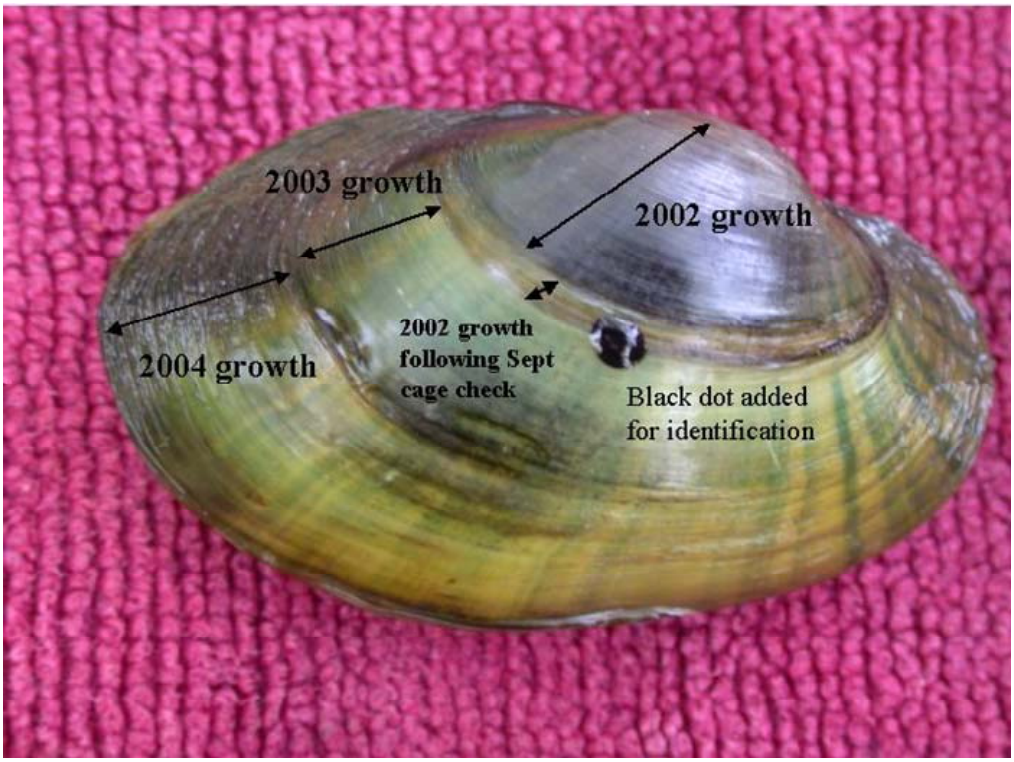


Figure 41. Marking subadult Higgins eye (*Lampsilis higginsii*) prior to stocking in the upper Mississippi River and tributaries. Mussels of the same age are marked with an identifying black dot (black super glue). To speed the drying process, an accelerant is sprayed or applied with a syringe (middle photos). All mussels are measured for total shell length; a subset are individually marked with plastic oyster tags attached with clear super glue. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

Figure 42. Sign used to identify mussel cage propagation sites in Minnesota. (Graphic by Mike Davis, Minnesota Department of Natural Resources)



2003 Cohort				
	Female	Male	Unknown	All
Average	45.1	45.1	35.9	43.9
Min	33	34	26	26
Max	59	66	54	66
Median	45	43.5	35	43
N	118	142	40	300
2002 Cohort				
	Female	Male	Unknown	All
Average	53.5	54.3	42.9	53.8
Min	34	39	30	30
Max	72	76	58	76
Median	53	54	42.5	53
N	433	419	16	867

Figure 43. Growth of subadult Higgins eye (*Lampsilis higginsii*) in cages in the upper Mississippi River. Top photo shows growth annuli on a subadult from the 2002 cohort. Tables show data from 2002 and 2003 cohorts. (Photo and data from Mike Davis, Minnesota Department of Natural Resources)

Figure 44. Gravid female Higgins eye (*Lampsilis higginsii*) from a propagation sled in the upper Mississippi River. The photo was taken in September, 2006. Mussels in the sled are from the 2003 cohort and have completed four growing seasons. The gill chambers seen in the photo are filled with glochidia. (Photo by Mike Davis, Minnesota Department of Natural Resources)

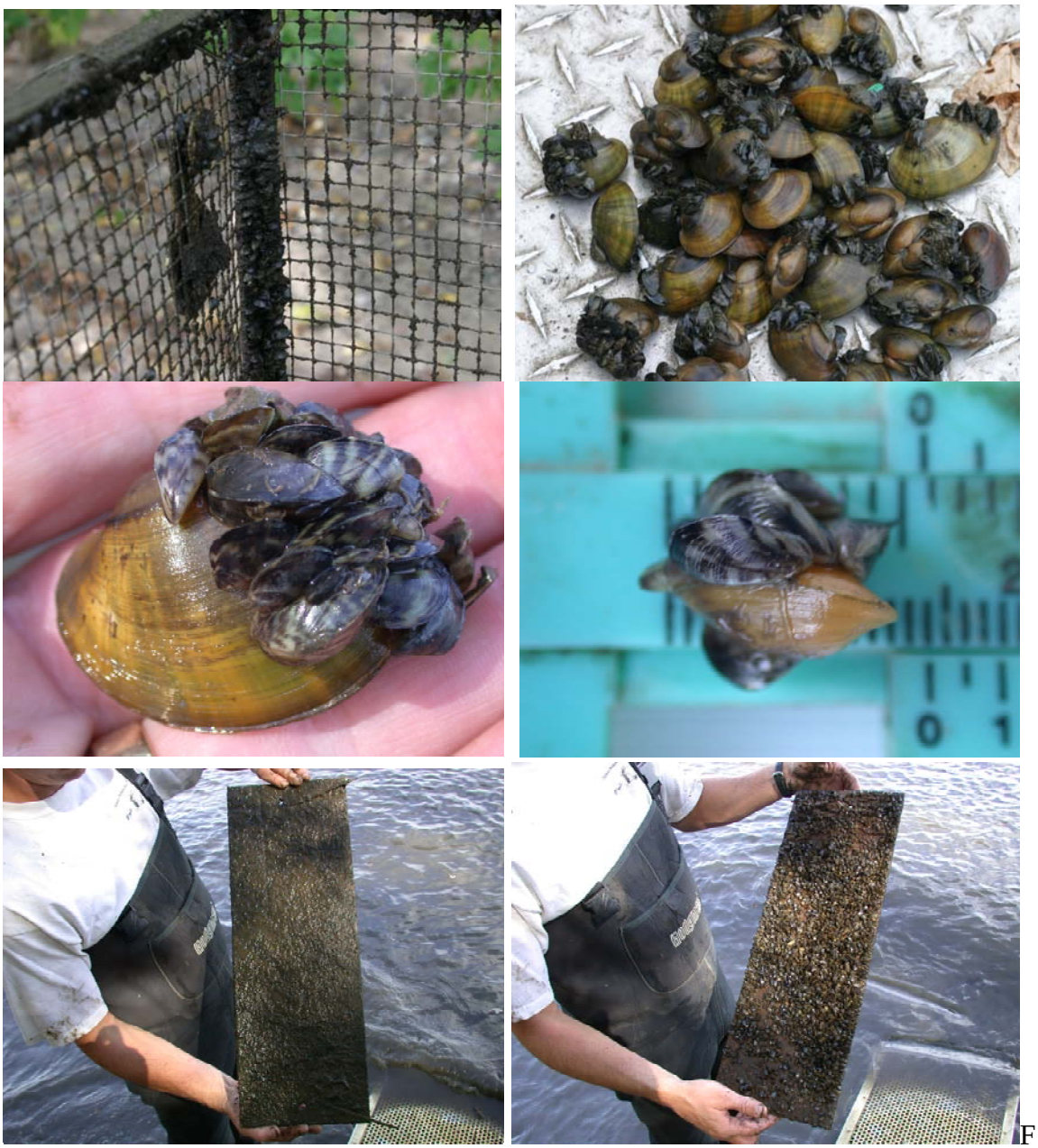


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Figure 45. Zebra mussels (*Driessena polymorpha*) attached to juvenile Higgins eye (*Lampsilis higginsii*) in closed propagation cages in the upper Mississippi River. Zebra mussels are often abundant inside cages (top left photo) but absent/at low densities on outside surfaces. Mussels in the top right photo were cleaned of zebra mussels one year earlier before being put in their cage. The bottom photos show a wooden board that is attached to the outside of a propagation cage to provide a current break for host fish inside. The left photo shows the surface of the board that was exposed to the river; it has very few zebra mussels. Conversely, the right photo shows the surface of the board attached to the metal cage that is not exposed to the river; it is covered with zebra mussels. We believe that fish or other predators actively feed on zebra mussels if they are exposed and available to them. (Photos by Mike Davis, Minnesota Department of Natural Resources, and Gary Wege, U.S. Fish and Wildlife Service)

Figure 46. A new floating cage system installed in the upper Mississippi River, Pool 12, at Dubuque, Iowa (Ice Harbor). This system is used to float standard closed propagation cages. The bottom photo shows the system floating after individual cages have been placed on the underwater rack system. (Photos by Tony Brady, U.S. Fish and Wildlife Service)

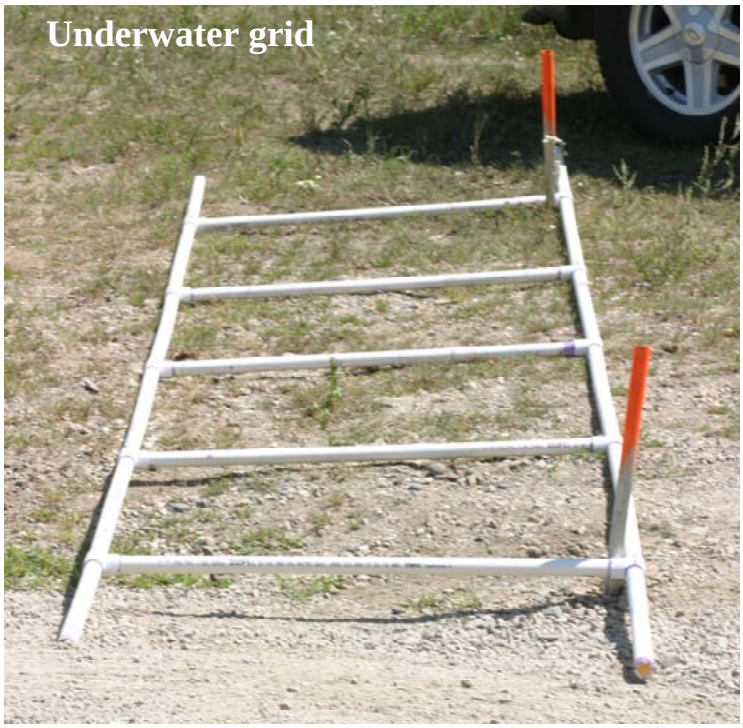
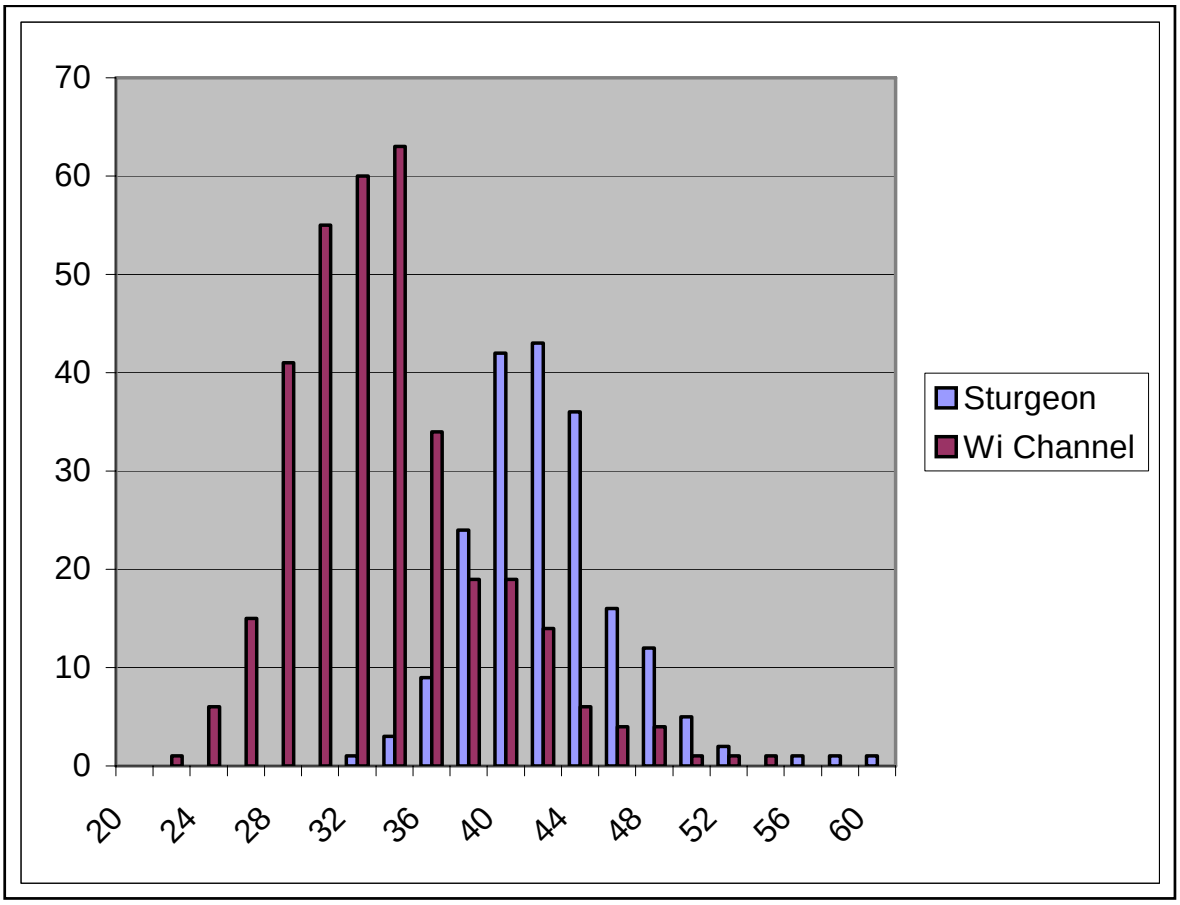


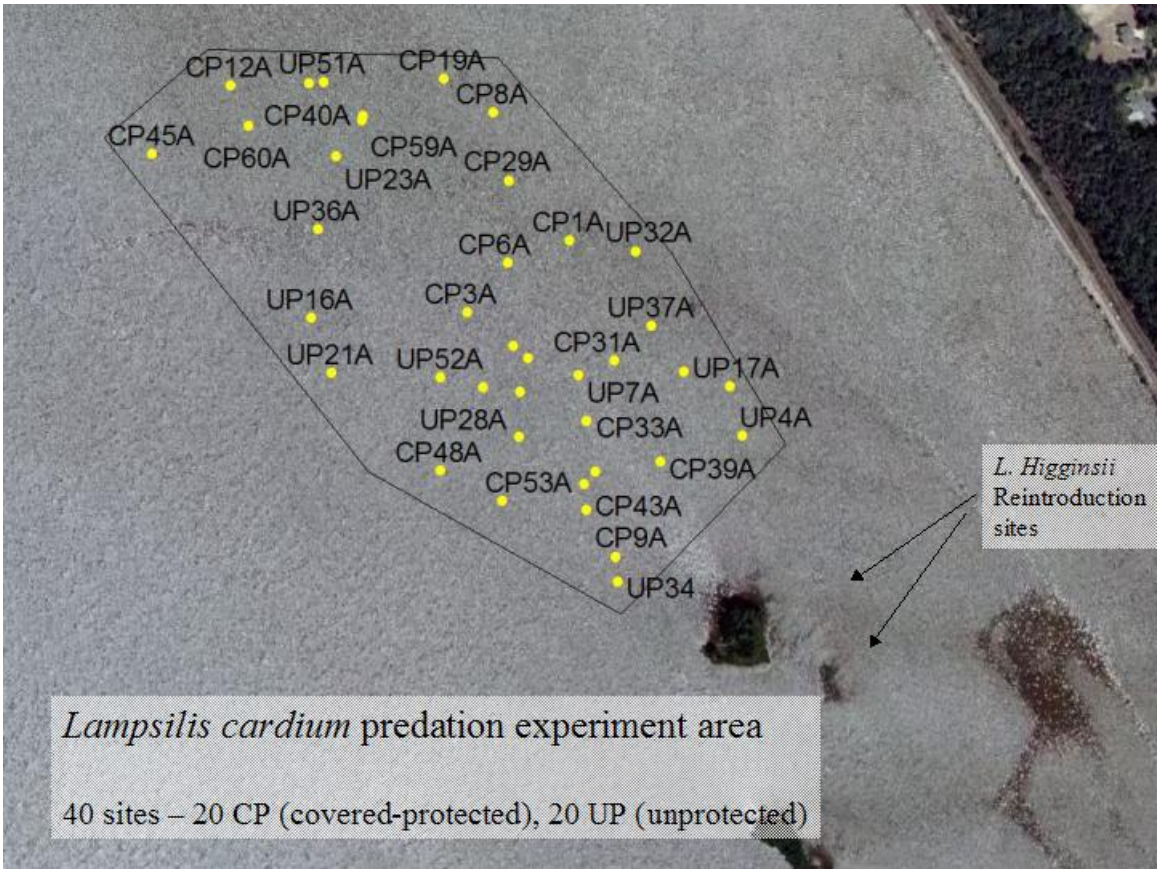
Figure 47. Top photo shows the underwater grid system used in stocking subadult Higgins eye (*Lampsilis higginsii*) at population establishment sites on the upper Mississippi River. The bottom photo shows the underwater blanket (upside down) which is placed over stocked subadults to protect them from large predators. (Photos by Gary Wege, U.S. Fish and Wildlife Service)



	Population Establishment Site 3 Sturgeon Lake (lower Pool 3)[1]	Population Establishment Site 4 Wisconsin Channel (upper Pool 4)[2]
Date	7/29/2003	8/6/2003
Strain	St. Croix River	St. Croix River
Source (reared in cages)	St. Croix River at Hudson	St. Croix River at Prescott
Stock (year dropped from fish)	2001	2001 (3 from 2000)
Total relocated	195	346
Average length (mm)	41.7	33.0
Minimum length (mm)	32	22
Maximum length (mm)	59	54
Current velocity	Very minimal	Very minimal
Substrate	Sand/gravel	Sand w/ some woody debris

Figure 48. Size distribution of subadult Higgins eye (*Lampsilis higginsii*) stocked at two population establishment sites on the upper Mississippi River. Subadults were larger at Site 3 (41.7 mm) than Site 4 (33.0 mm) which may have contributed to higher survival. (Data from Mike Davis, Minnesota Department of Natural Resources)

Figure 49. Evidence of predation on stocked subadult Higgins eye (*Lampsilis higginsii*) in the upper Mississippi River. Top left photo shows subadult Higgins eye that were protected under a large wire mesh blanket. Top right and bottom left photos show broken shells collected from stocking site. We presume that mussel predators are large common carp, freshwater drum or other large fish. Bottom right photo shows pharyngeal teeth from a black carp (*Mylopharyngodon piceus*) on the left and a common carp (*Cyprinus carpio*) on the right. (Photos by Gary Wege, U.S. Fish and Wildlife Service)



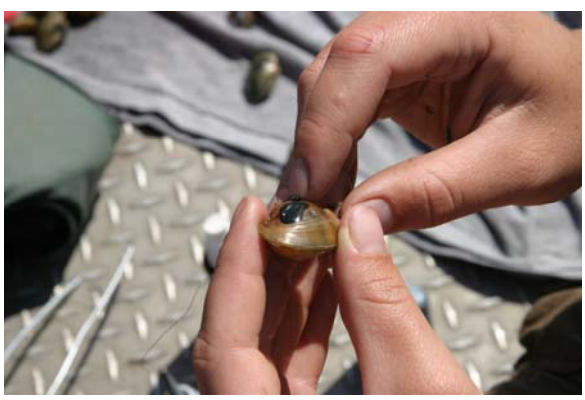


Figure 50. Preparing plain pocketbook (*Lampsilis cardium*) to test fish predation at population establishment Site 2, Pool 2, upper Mississippi River. Mussels were glued to fishing line and tethered to a metal rod which is placed in the river bottom at locations shown in the top graphic. (Graphic and photos by Mike Davis, Minnesota Department of Natural Resources)

Figure 51. Attaching monofilament fishing line and hooks to subadult plain pockbook (*Lampsilis cardium*). These mussels are surrogates for Higgins eye (*Lampsilis higginsii*) subadults and were placed in Pool 8, upper Mississippi River, to catch large fish or other predators. (Photos by Tony Brady, U.S. Fish and Wildlife Service)

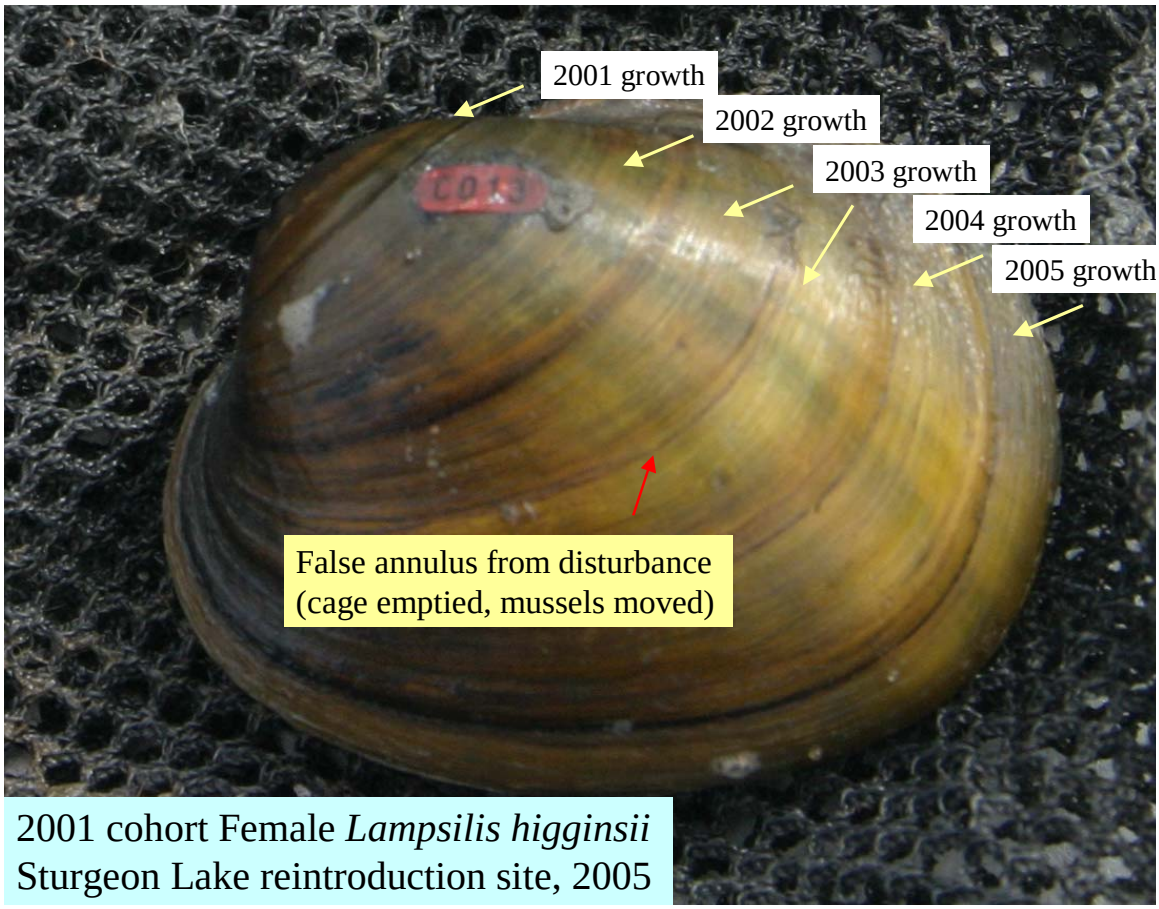


Figure 52. Growth of Higgins eye (*Lampsilis higginsii*) propagated in cages and stocked at population establishment Site 3, Pool 3, upper Mississippi River. The photo was taken in September, 2005. This individual is from the 2001 cohort and shows its growth annuli. (Photo by Mike Davis, Minnesota Department of Natural Resources)

Figure 53. Subadult Higgins eye (*Lampsilis higginsii*) stocked in the upper Mississippi River at population establishment Sites 2 and 3 (Pools 2 and 3). Top left photo shows Age 1 mussels. Top right photo shows Age 2 mussels that are marked and ready for stocking. Middle photos show Higgins eye collected during monitoring. Bottom left photo shows sexually mature (gravid) female from 2001 cohort; right photo shows her viable glochidia. (Photos by Gary Wege, U.S. Fish and Wildlife Service and Mike Davis, Minnesota Department of Natural Resources)

Figure 54. Adult Higgins eye (*Lampsilis higginsii*) cleaned of zebra mussels (*Driessena polymorpha*) and relocated to population establishment Sites 1 and 3 on the upper Mississippi River. 370 adults were relocated to Site 1 in upper Pool 2, and 101 relocated to Site 3 in upper Pool 3. The bottom left photo shows a gravid female collected in September, 2002 at the Pool 3 Site. The bottom right photo shows unusual growth along the ventral margin of the shell perhaps due to cleaning methods used to remove zebra mussels. (Photos by Mike Davis, Minnesota Department of Natural Resources and Gary Wege, U.S. Fish and Wildlife Service)

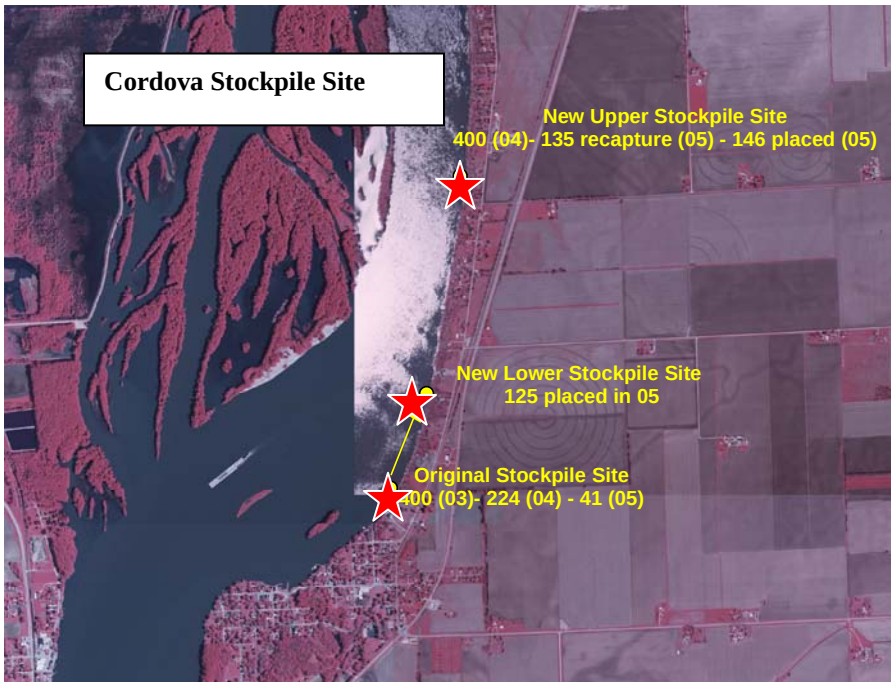


Figure 55. Clean and stockpile sites on the upper Mississippi River for adult Higgins eye (*Lampsilis higginsii*). Higgins eye are cleaned of zebra mussels (*Driessena polymorpha*) and returned to the river. Sites are in Pool 11 (top photo) at Cassville, Wisconsin, and Pool 14 (bottom photo) at Cordova, Illinois. (Graphics by Dan Kelner, U.S. Army Corps of Engineers)

Figure 56. Cleaning and stockpiling adult Higgins eye (*Lampsilis higginsii*) in the upper Mississippi River. Adults were collected by diving and wading, brought to shore, and cleaned of zebra mussels (*Driessena polymorpha*) with a brush. The lower left photo shows byssal threads from attached zebra mussels that are nearly impossible to remove. Mussels were measured, sexed, marked, photographed and hand placed by divers into the river bottom at a known location where they will be monitored and recleaned, if necessary. (Photos by Mike Davis, Minnesota Department of Natural Resources and Gary Wege, U.S. Fish and Wildlife Service).

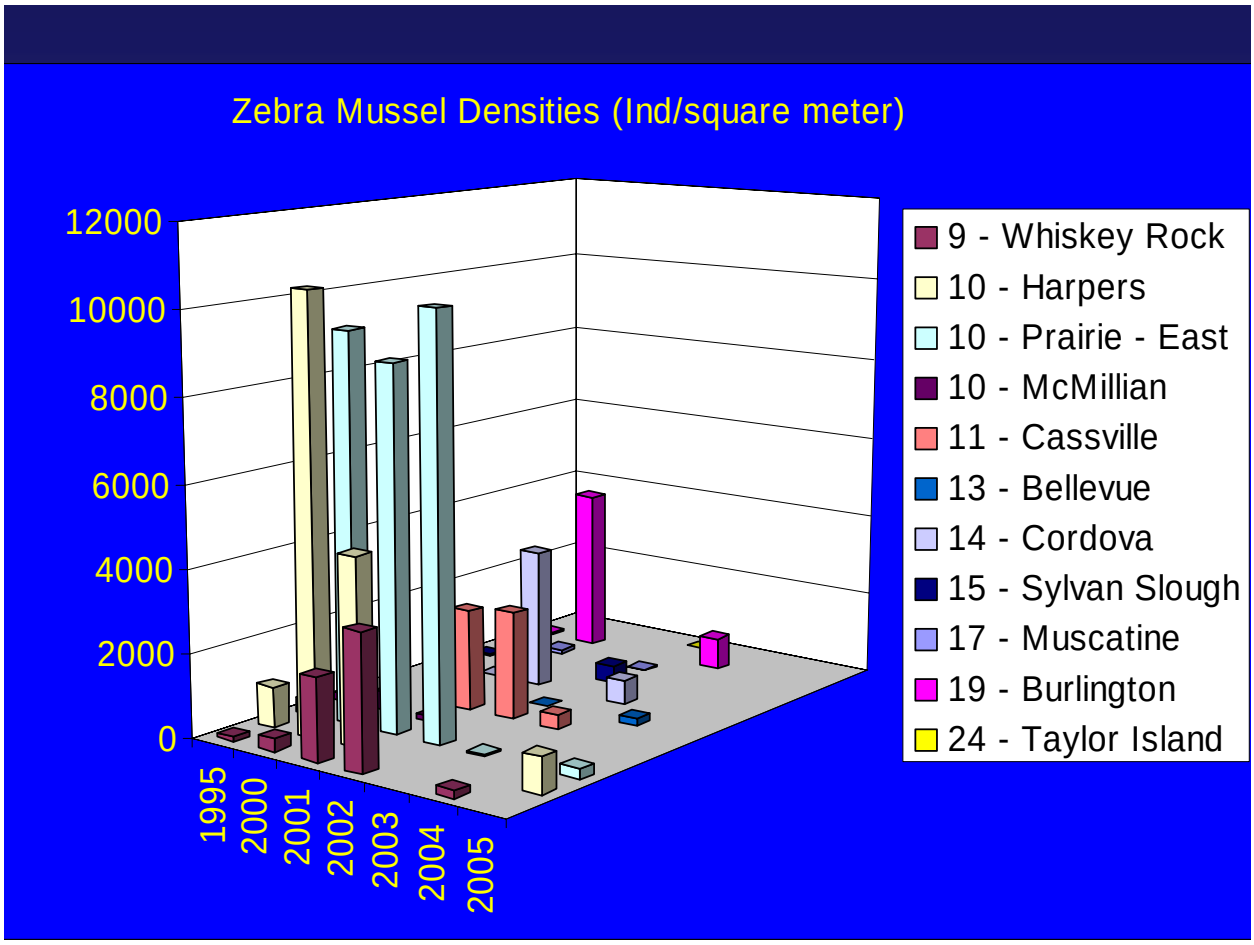
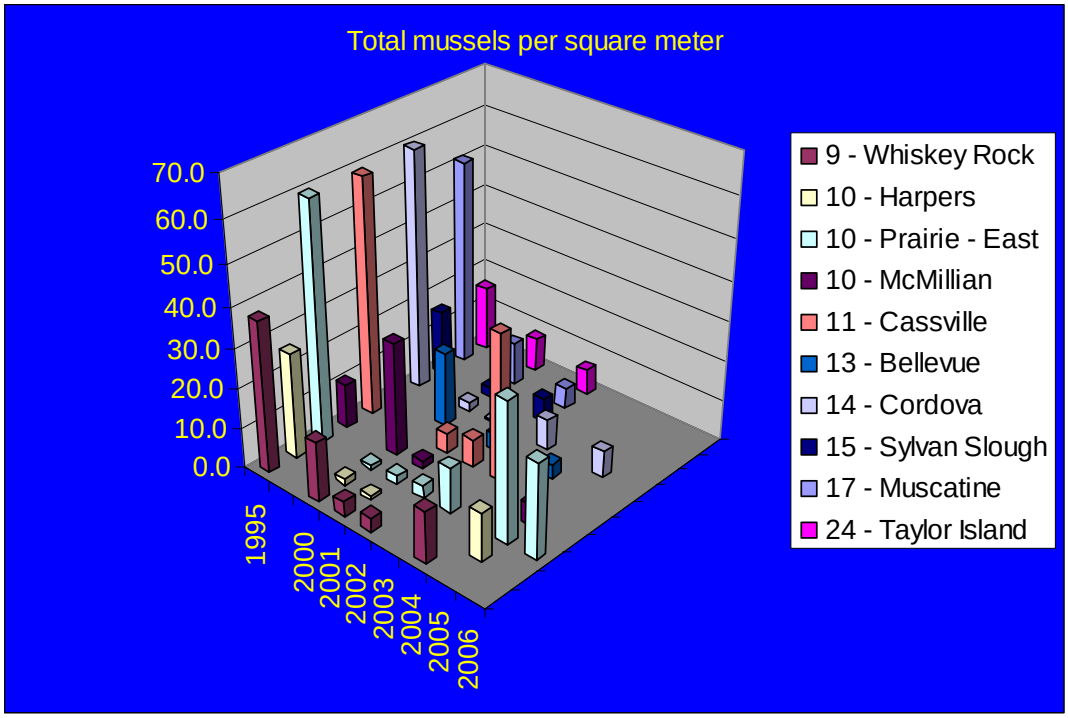


Figure 57. Abundance of zebra mussels (*Driessena polymorpha*) at selected sites on the upper Mississippi River. Numbers next to colored boxes identify navigation pools. (Graphic by Dan Kelner, U.S. Army Corps of Engineers)



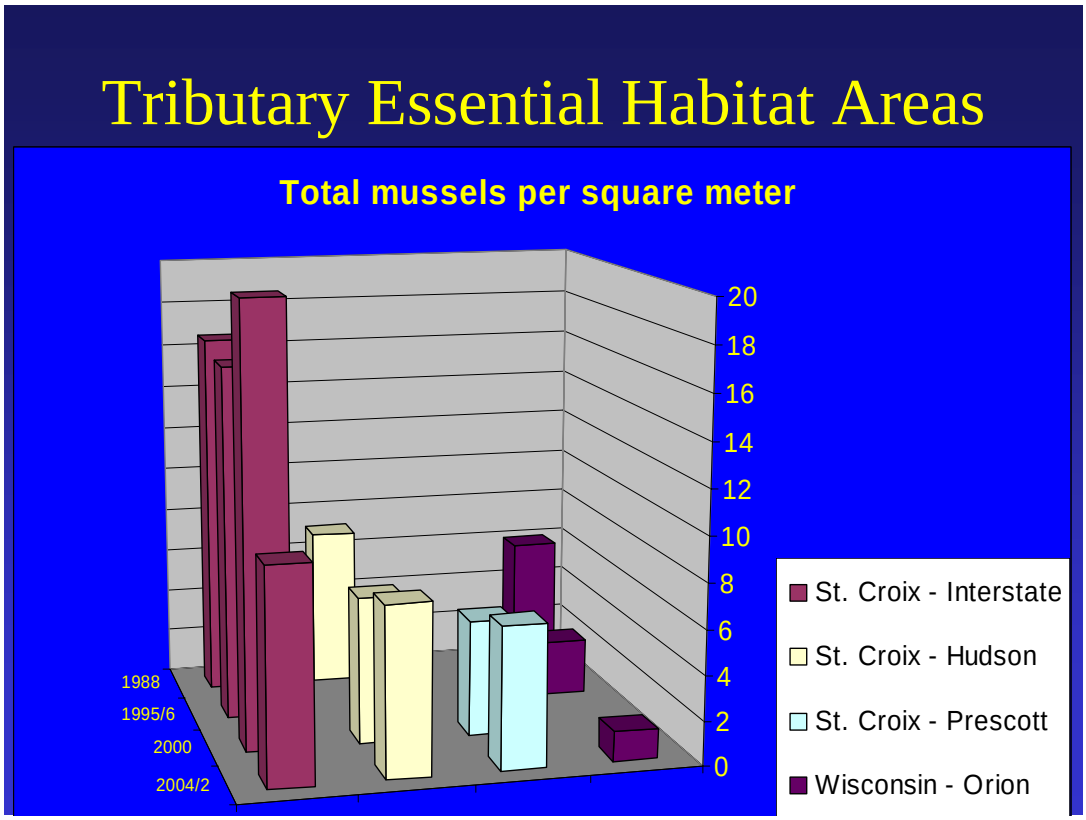


Figure 58. Abundance of native mussels at selected sites on the upper Mississippi River and tributaries. Numbers next to colored boxes in the top graph reference navigation pools. (Graphics by Dan Kelner and Dennis Anderson, U.S. Army Corps of Engineers)

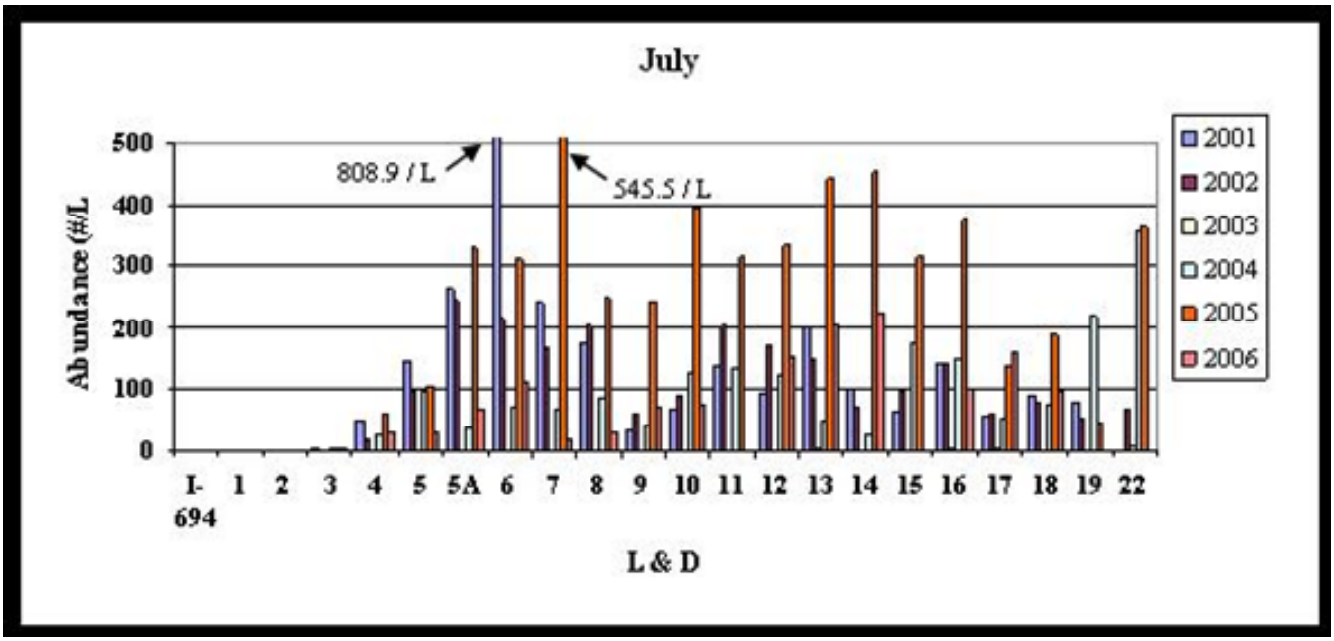
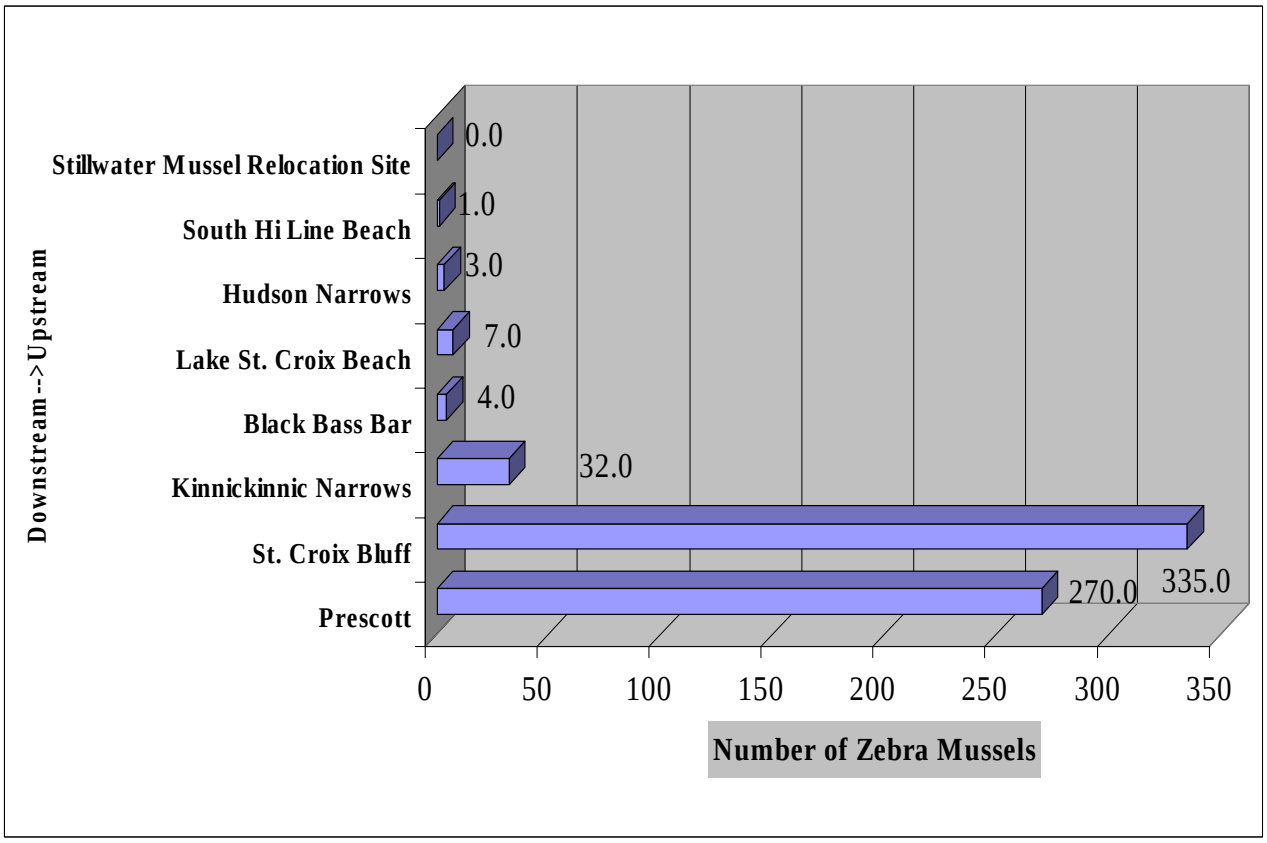


Figure 59. Abundance (number per liter) of zebra mussel veligers (*Driessena polymorpha*) on the upper Mississippi River, 2001 - 2006. (Graphic by Dennis Anderson, U.S. Army Corps of Engineers)



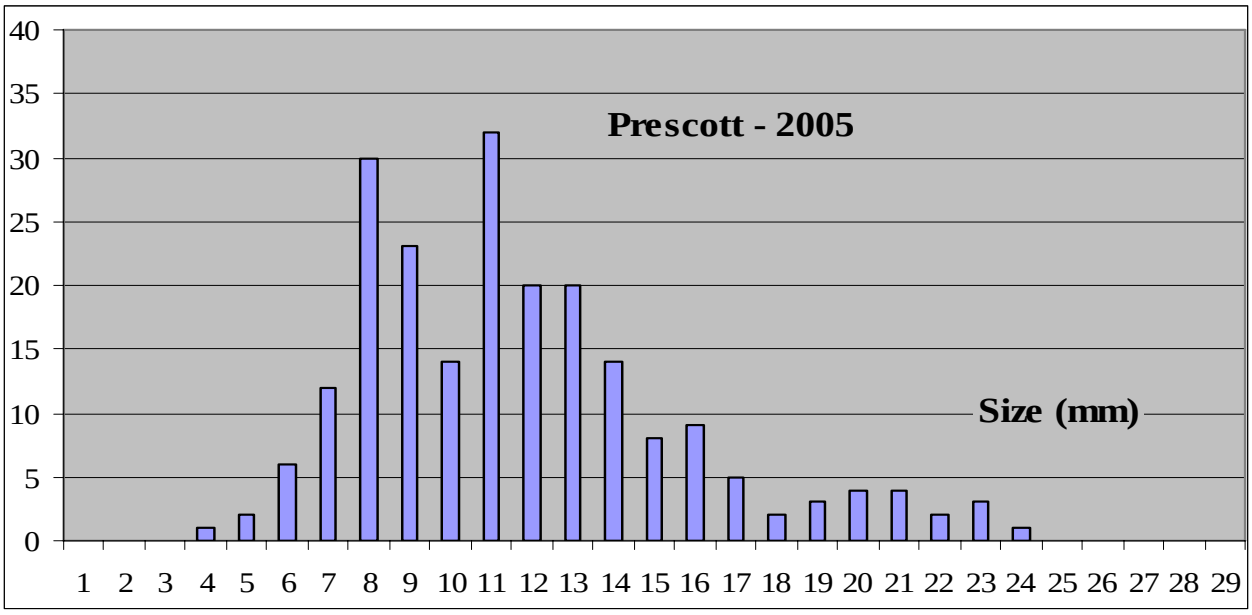


Figure 60. The top graph shows density of zebra mussels (*Driessena polymorpha*) at eight monitoring sites on the lower St. Croix River, Minnesota – Wisconsin. The bottom graph shows size distribution of zebra mussels at the Prescott Site, Wisconsin. (Graphics by Byron Karns, National Park Service)

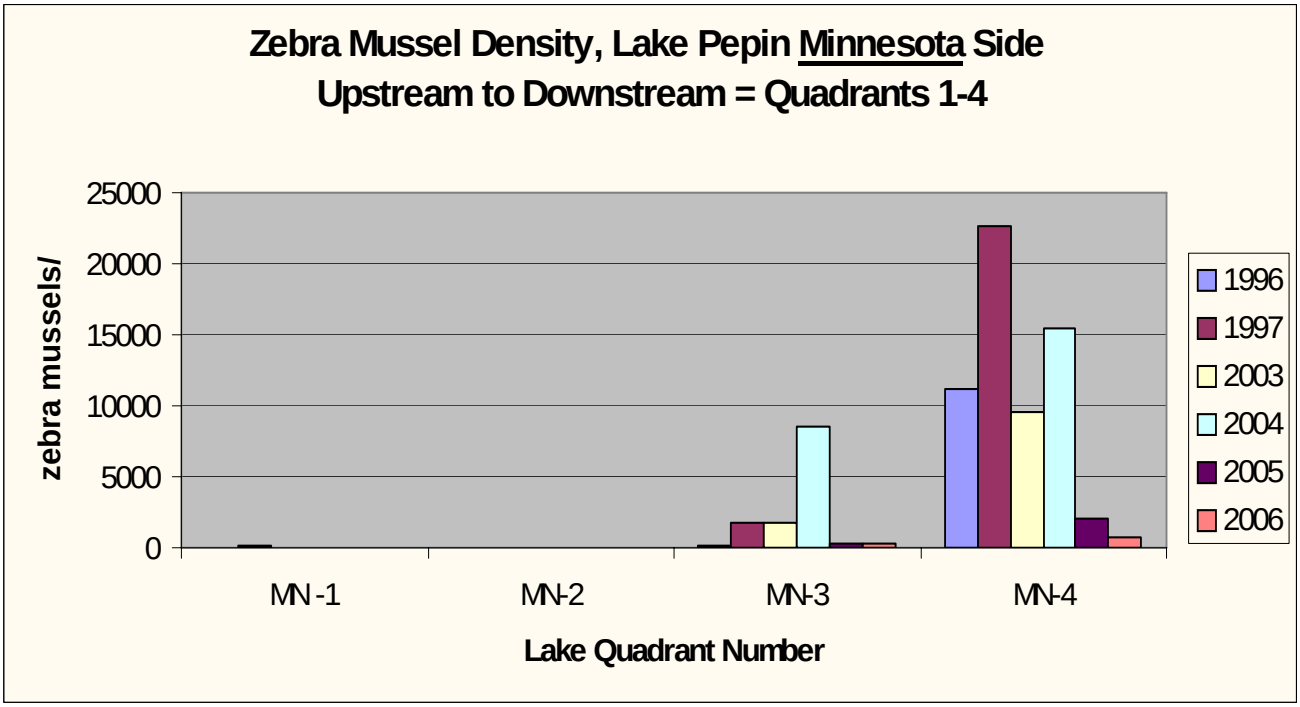
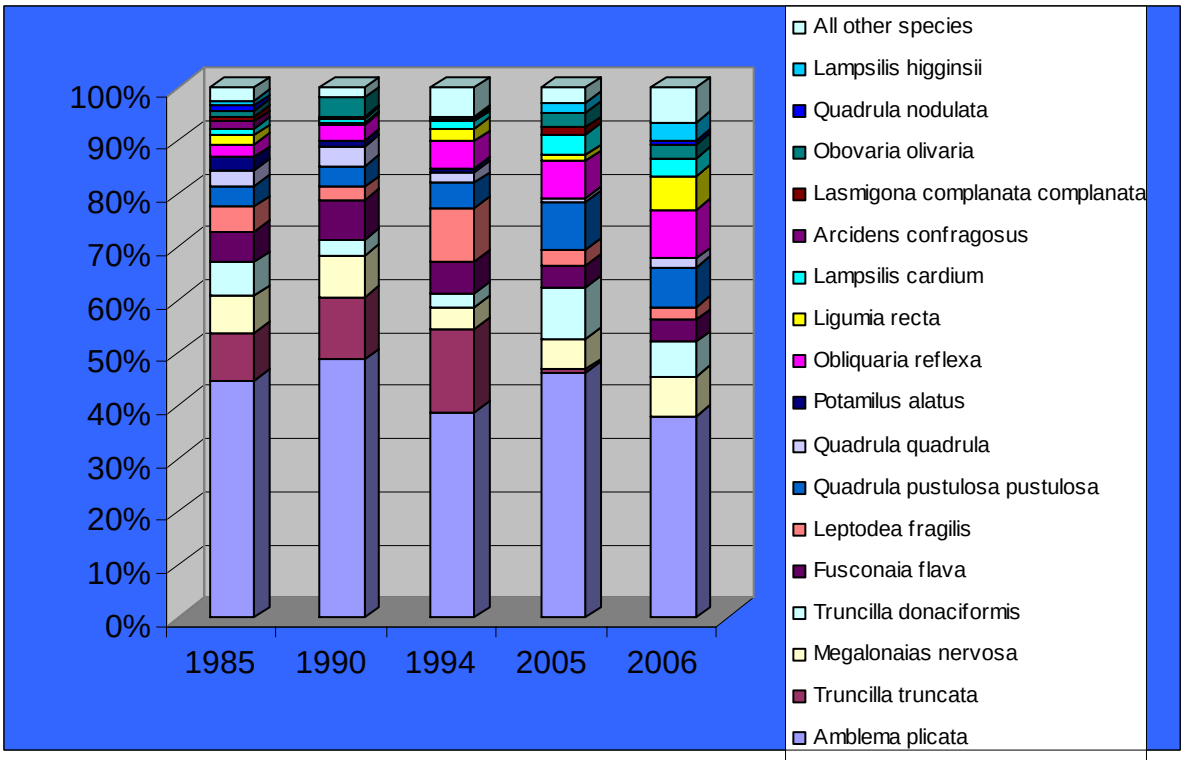


Figure 61. Density (number per square meter) of zebra mussels (*Driessena polymorpha*) at collection sites in Lake Pepin, Pool 4, upper Mississippi River. Photos show zebra mussels attached to native mussels collected in 2006. (Graphic and photos by Mike Davis, Minnesota Department of Natural Resources)



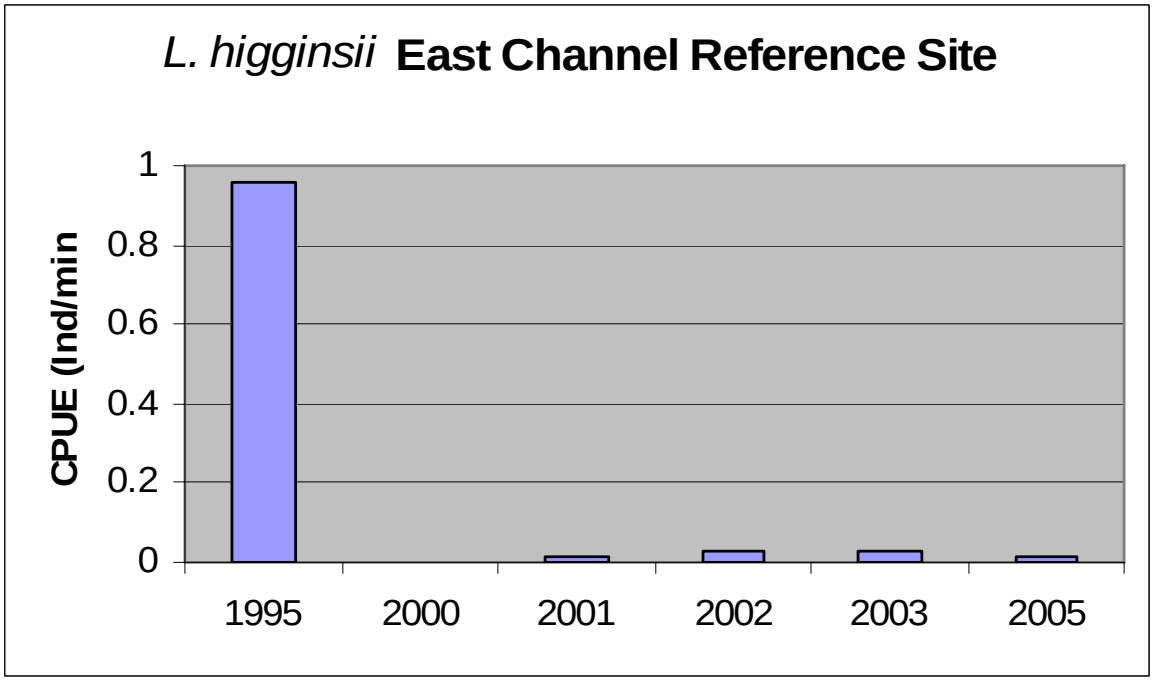
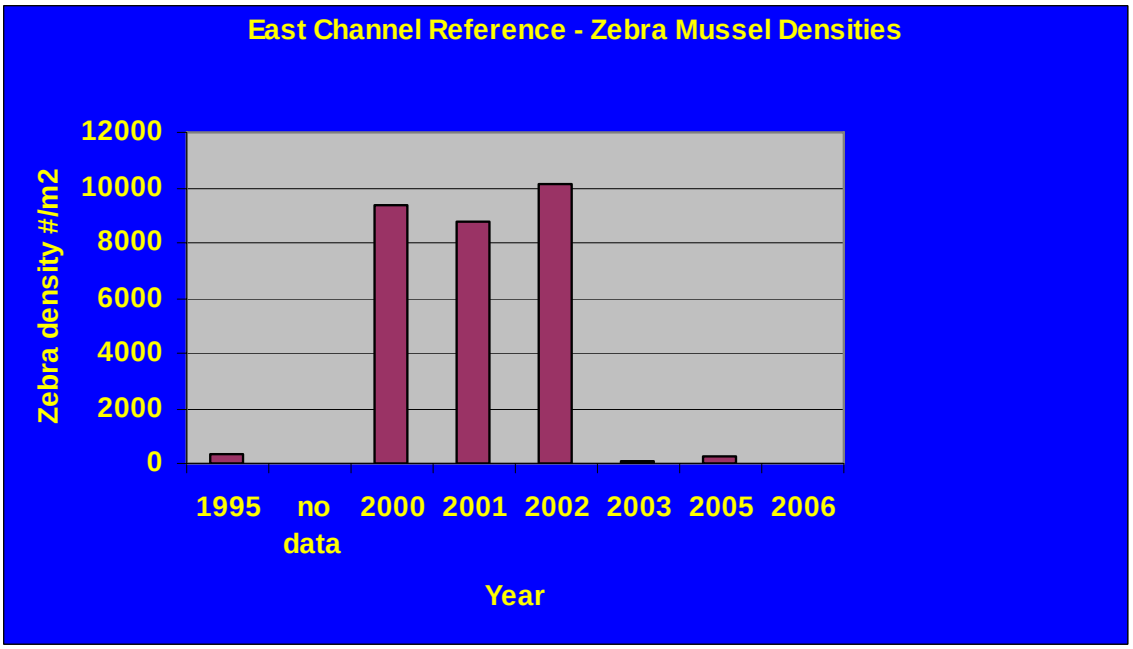


Figure 62. Top graph shows percent composition of mussel species collected at the East Channel Reference Site within the Prairie du Chien Essential Habitat Area, Pool 10, upper Mississippi River, Wisconsin, 1985 – 2006. The bottom graph shows catch-per-unit-effort (individuals per minute) of Higgins eye (*Lampsilis higginsii*) at this same location. (Graphics by Dan Kelner and Dennis Anderson, U.S. Army Corps of Engineers).



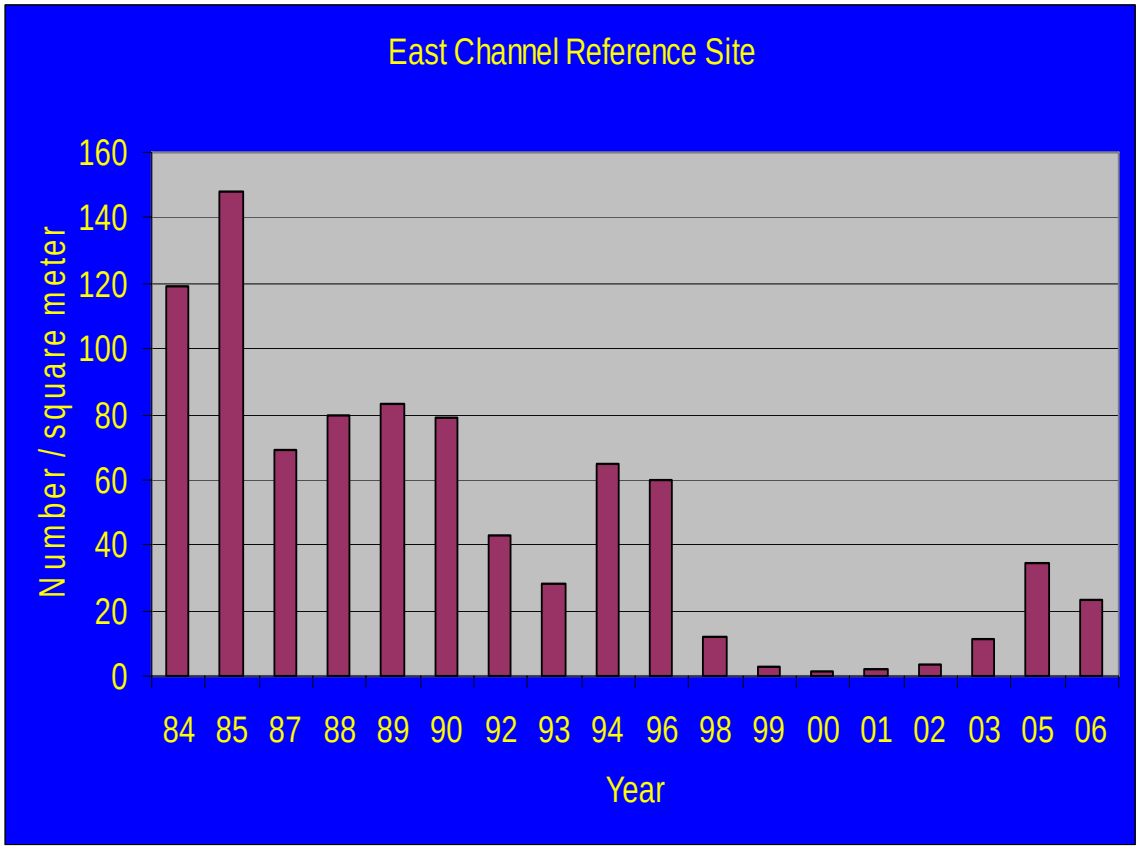
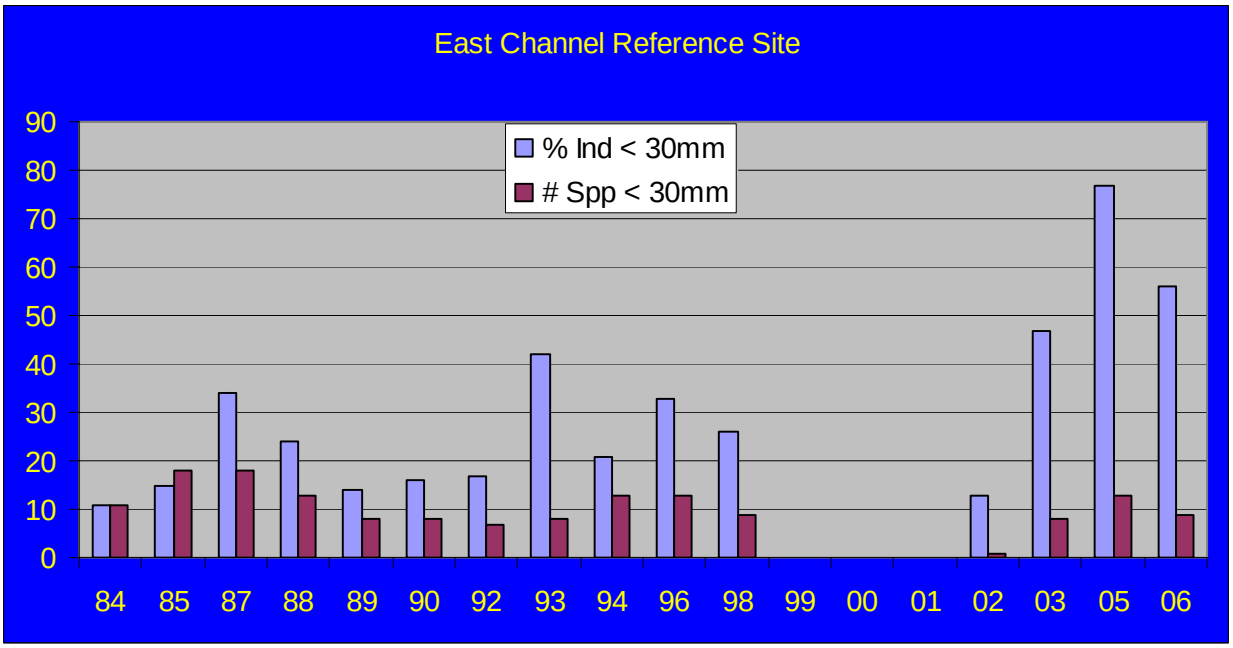


Figure 63. Abundance of zebra mussels (*Dreissena polymorpha*) and native mussels (bottom graph) at the East Channel Reference Site within the Prairie du Chien Essential Habitat Area, Pool 10, upper Mississippi River, Wisconsin. (Graphics by Dan Kelner and Dennis Anderson, U.S. Army Corps of Engineers)



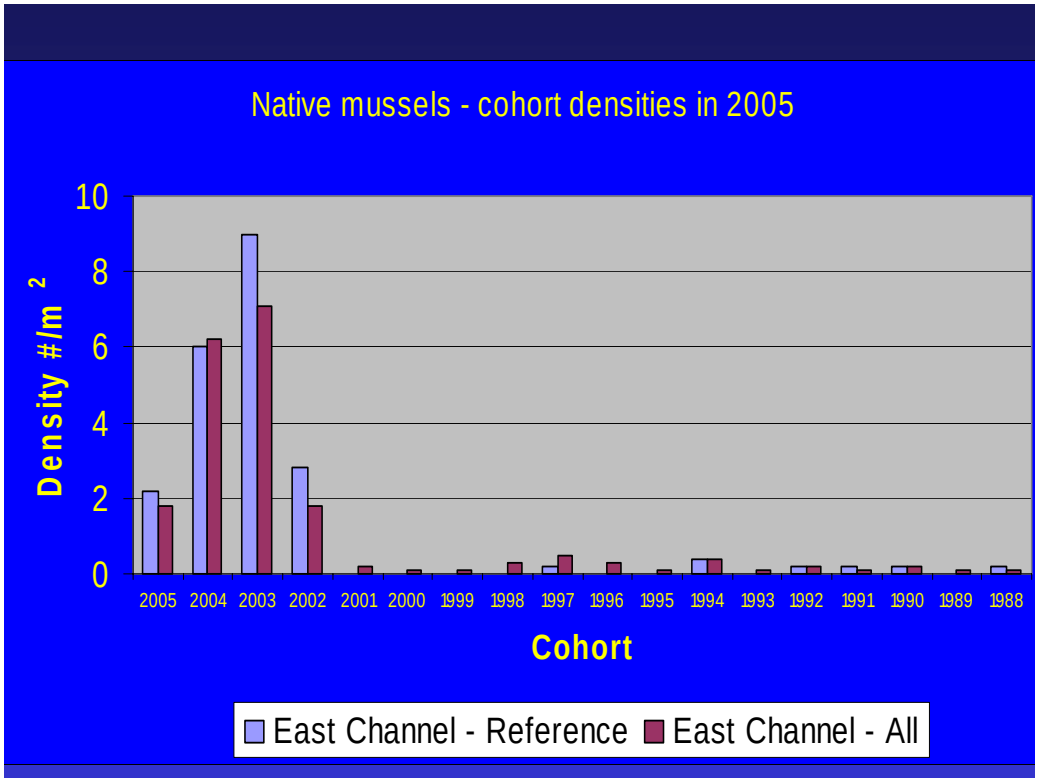
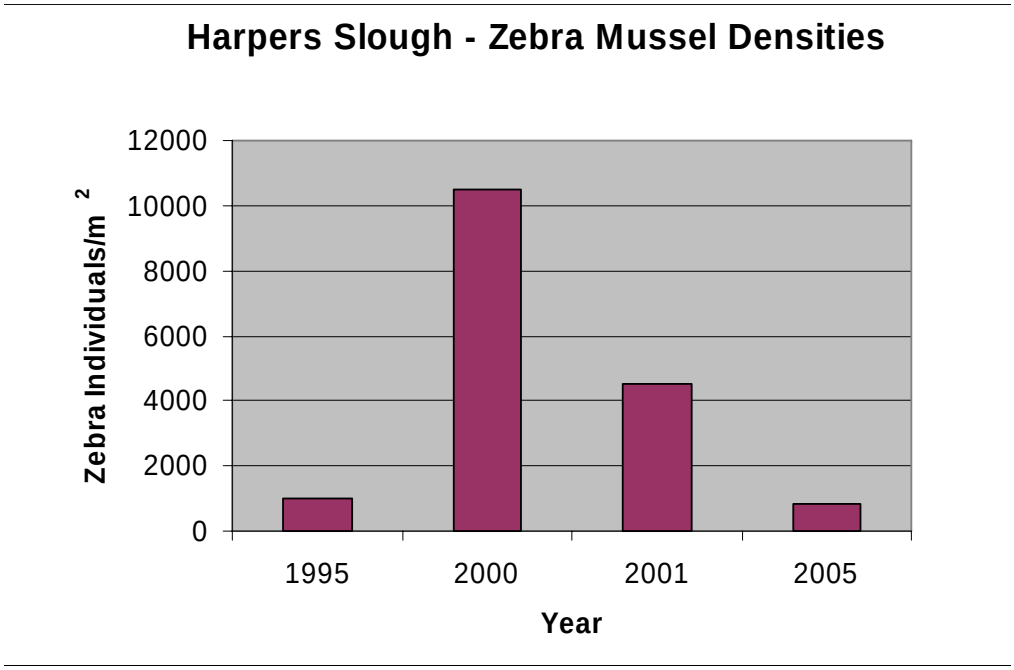


Figure 64. Native mussels in the East Channel Reference Site within the Prairie du Chien Essential Habitat Area, Pool 10, upper Mississippi River, Wisconsin. The top graph shows the trend in distribution of juveniles (<30 mm long) since 1984. The bottom graph shows the density of each cohort collected in 2005. (Graphics by Dan Kelner, U.S. Army Corps of Engineers)

Figure 65. Native and zebra mussels (*Driessena polymorpha*) collected in 2005 from the Prairie du Chien Essential Habitat Area, Pool 10, upper Mississippi River, Wisconsin. In the top left photo, the diver is indicating the depth of zebra mussel shell covering the former mussel bed. The top right photo shows zebra mussel shell collected in a ¼-meter quadrat sample. Live zebra mussels are attached to a giant floater (*Pyganodon grandis*) in the bottom left photo. Mussels shown in the bottom right photo were collected from shallow water along the shoreline. Included are 17 federally endangered Higgins eye (*Lampsilis higginsii*). (Photos by Gary Wege, U.S. Fish and Wildlife Service)



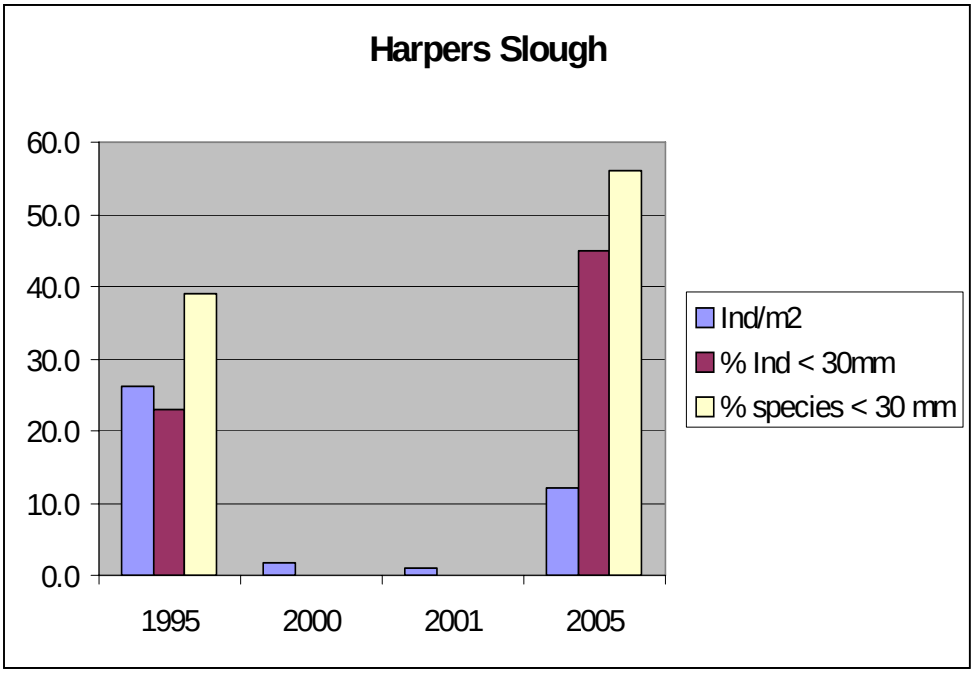


Figure 66. Abundance of zebra mussels (*Dreissena polymorpha*) and native mussels (bottom graph) at the Harpers Slough Essential Habitat Area, Pool 10, upper Mississippi River, Iowa. (Graphics by Dan Kelner, U.S. Army Corps of Engineers)

Figure 67. Native and zebra mussels (*Driessena polymorpha*) collected in 2005 at the Harpers Slough Essential Habitat Area, Pool 10, upper Mississippi River. Zebra mussel shell continues to be abundant at this site and traps fine sediment. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

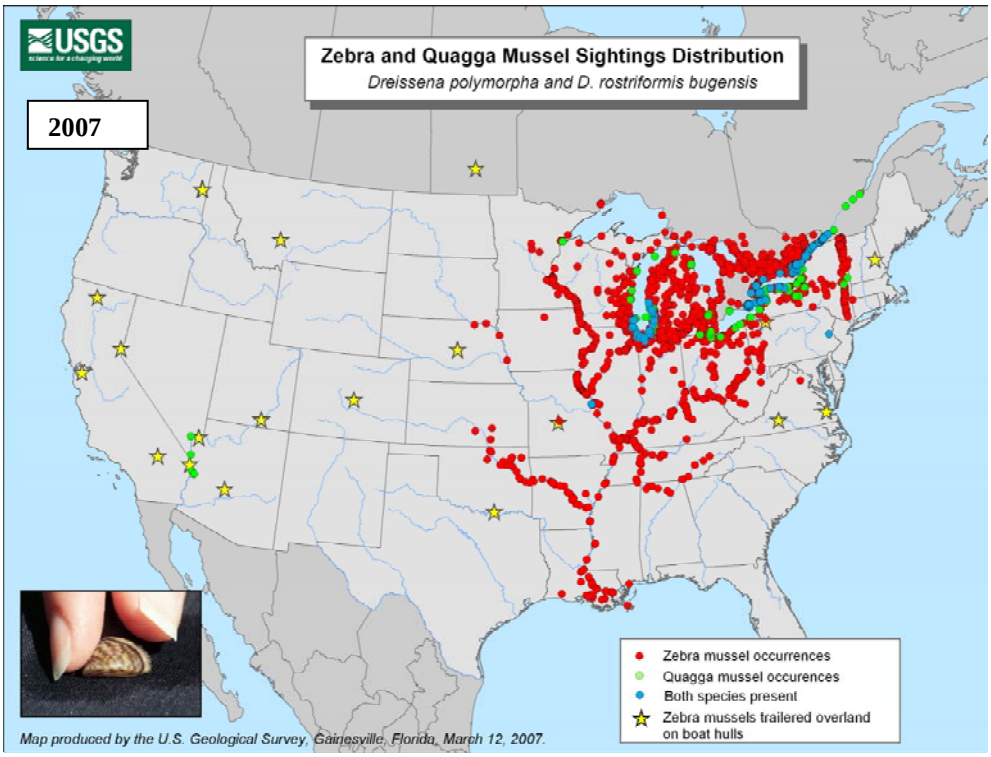


Figure 68. Current distribution of exotic zebra mussels (*Driessena polymorpha*) and quagga mussels (*Driessena bugensis*) (Graphic by the U.S. Geological Survey). Mussels in the photo were collected from Lake Michigan; a zebra mussel is on top and quagga mussels on the bottom. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

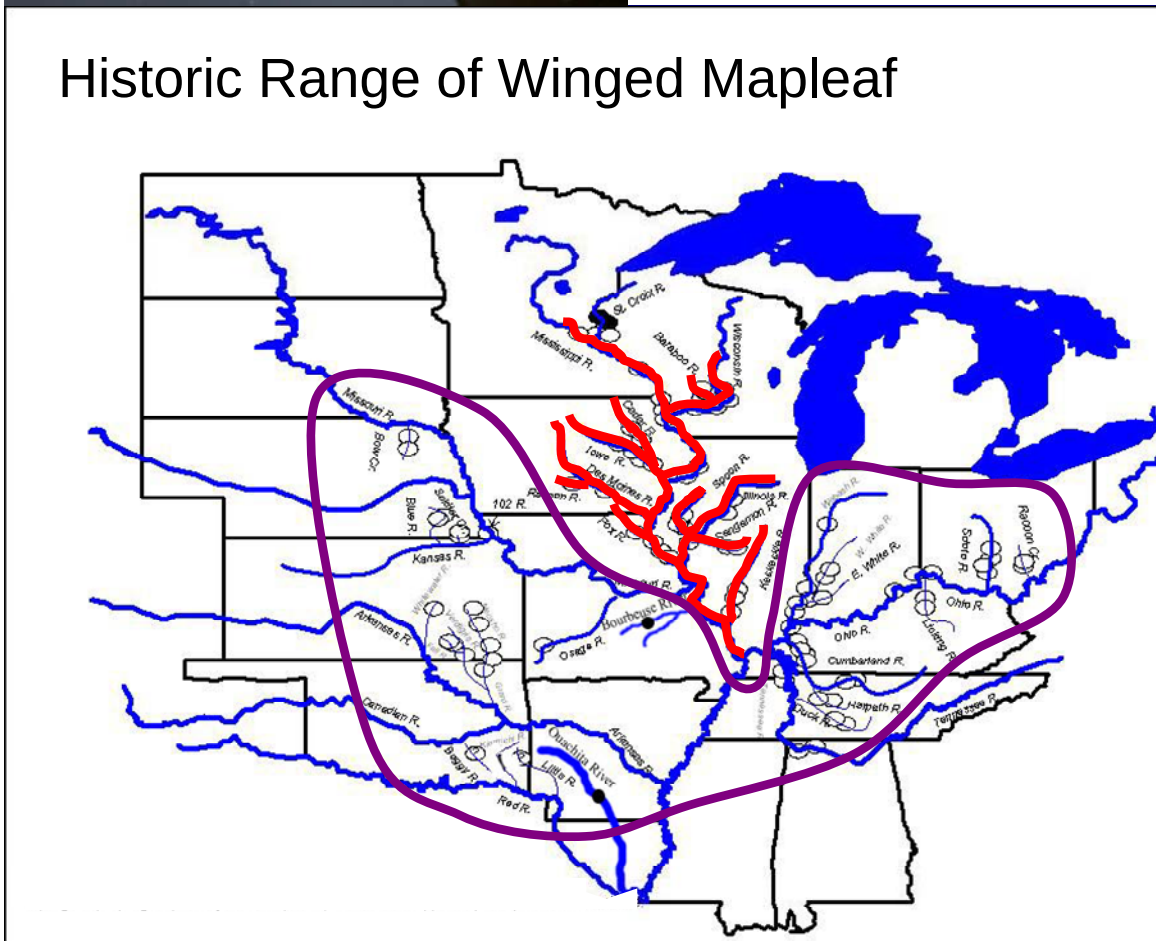


Figure 69. Historic range of the federally endangered winged mapleleaf (*Quadrula fragosa*). Red areas of the upper Mississippi River and tributaries will be evaluated by the Corps of Engineers in developing their relocation plan required by the April 2000 Biological Opinion. The U.S. Fish and Wildlife Service will be responsible for that portion within the purple area with respect to implementing their plan for controlled propagation, augmentation and reintroduction. (Photo by Gary Wege, U.S. Fish and Wildlife Service; graphic by Susan Rogers-Oetker, U.S. Fish and Wildife Service)

Figure 70. Current locations of the federally endangered winged mapleleaf (*Quadrula fragosa*). Top left photo shows a *Q. fragosa* from the lower St. Croix River, Minnesota. Top right photo was taken in April, 2007, and shows two *Q. fragosa* from the Saline River, Arkansas. (Photos by Gary Wege, U.S. Fish and Wildlife Service; graphic by Susan Rogers-Oetker, U.S. Fish and Wildlife Service)

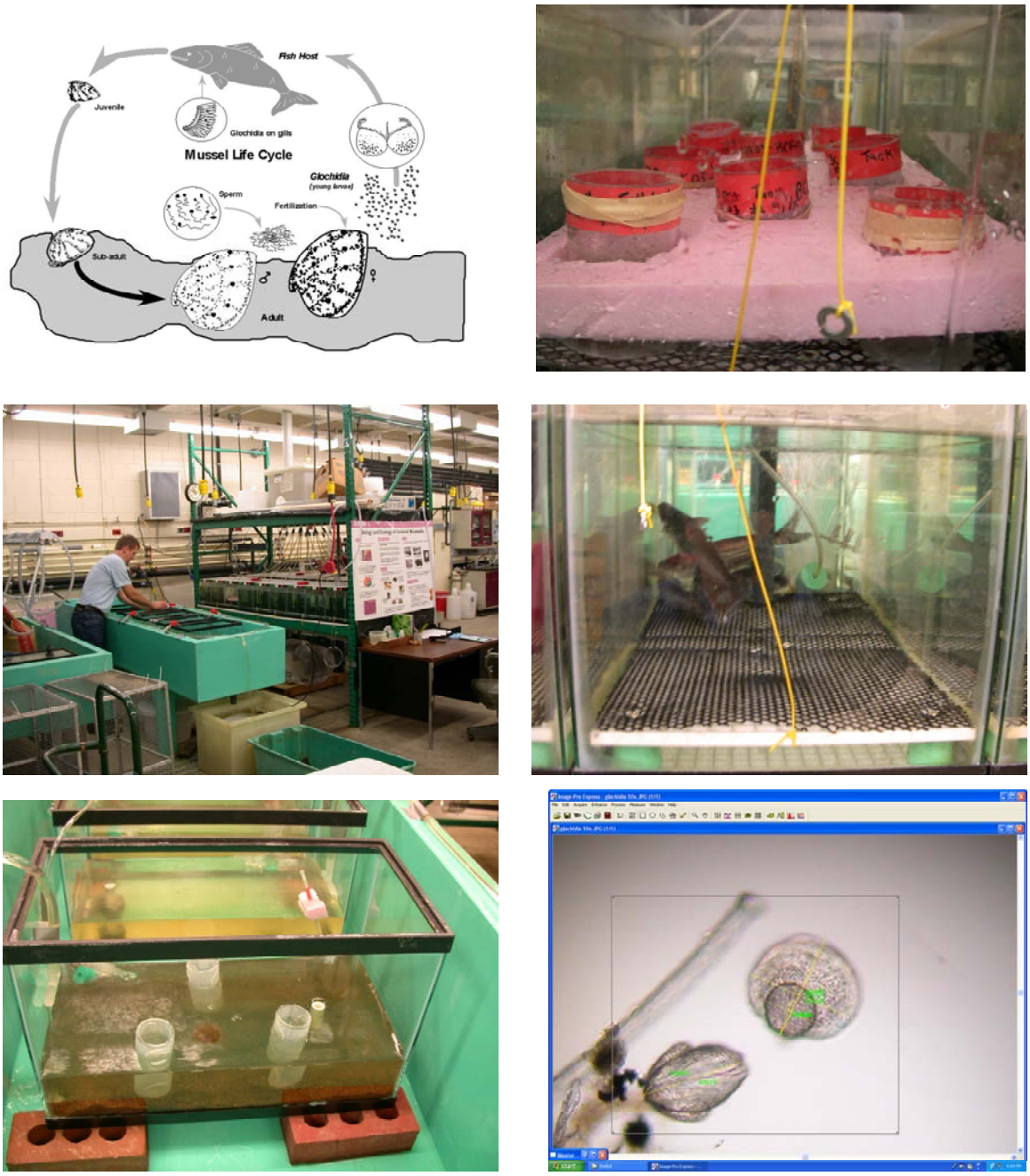


Figure 71. Identifying host fish for the federally endangered winged mapleleaf (*Quadrula fragosa*) at the U.S. Geological Survey facilities in La Crosse, Wisconsin. Host fish were identified as channel catfish (*Ictalurus punctatus*) and blue catfish (*Ictalurus furcatus*). Two juvenile winged mapleleaf are shown in the bottom right photo. (Photos by Gary Wege and Mark Steingraeber, U.S. Fish and Wildlife Service)

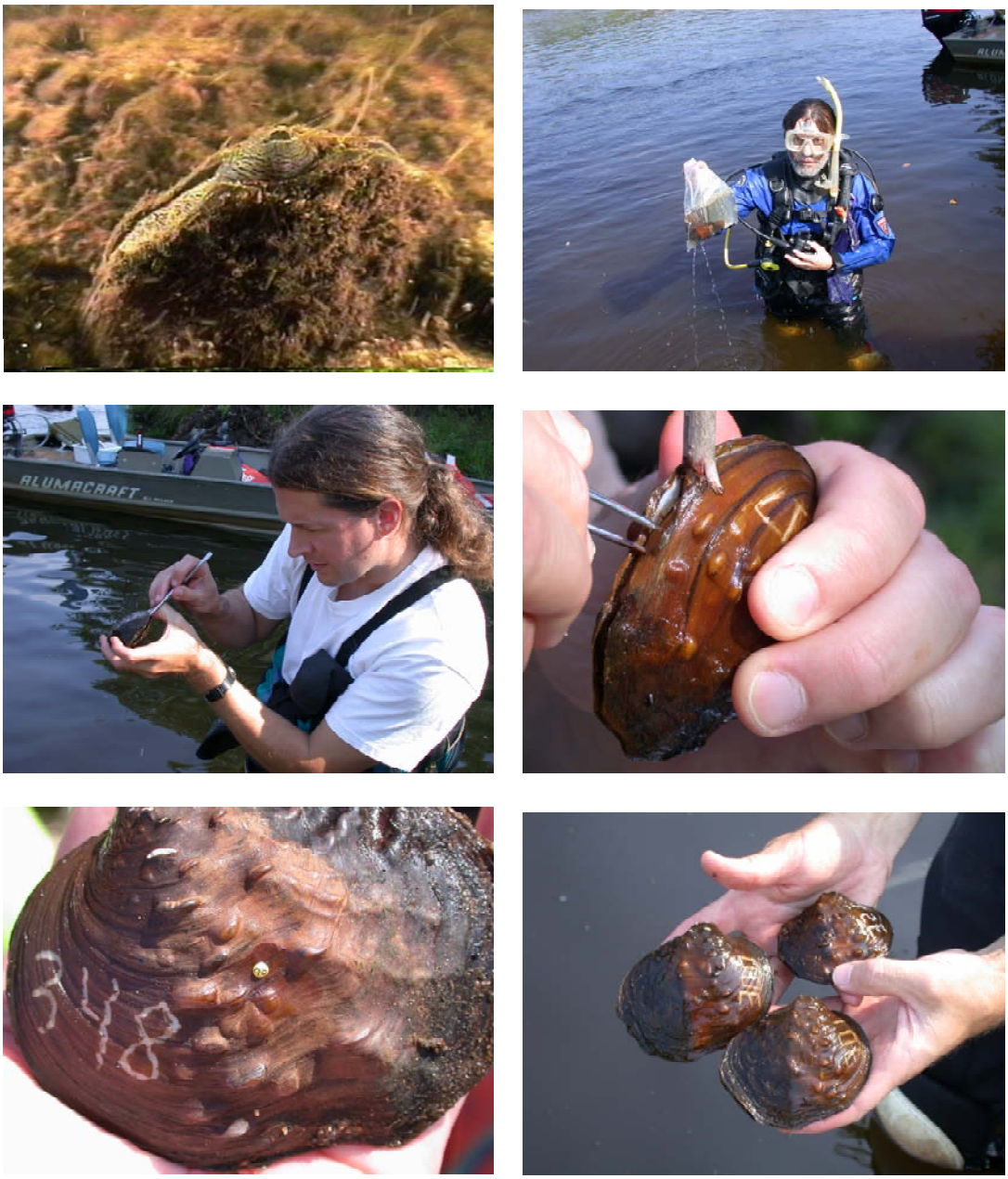


Figure 72. Collecting federally endangered winged mapleleaf (*Quadrula fragosa*) for propagation activities on the St. Croix River, Minnesota. The top left photo shows the display of a female winged mapleleaf. When collecting females in the fall for glochidia, divers will look for this display; if a displaying mussel is found, it is taken to the surface in a small plastic bag in case the female aborts her glochidia. In the middle photos, Mark Hove, University of Minnesota, is visually inspecting a female mussel to check her gravidity. Mussels collected for propagation and other research are marked by etching identification numbers on the shell and also using small bee tags; a yellow bee tag is shown in the bottom left photo. Mussels are returned to aggragation sites in the St. Croix River so researchers can find them in the future. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

Figure 73. Cage propagation sites for the federally endangered winged mapleleaf (*Quadrula fragosa*) in the lower St. Croix River, Minnesota. (Graphic by Susan Rogers-Oetker, U.S. Fish and Wildlife Service)

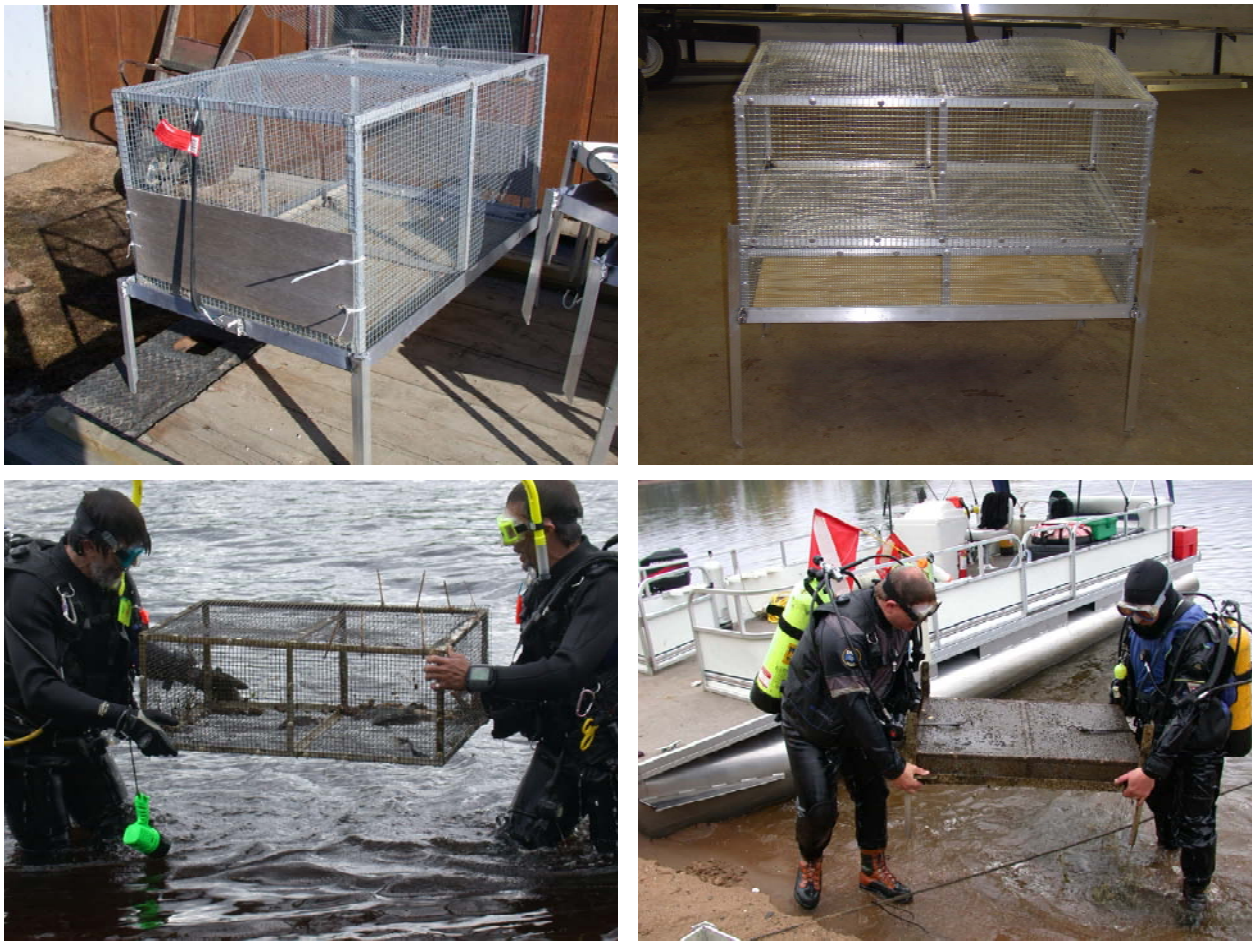


Figure 74. New closed cage ("cage-on-a-cage") for propagating winged mapleleaf (*Quadrula fragosa*) in the lower St. Croix River, Minnesota (top right photo). A standard closed cage is shown for comparison in the top left photo. The design allows for easy removal of host fish; in bottom left photo, divers are shown with the top portion of the cage containing host fish; they are bringing the lower cage containing juveniles and sediment to shore in the bottom right photo). (Photos by Gary Wege, U.S. Fish and Wildlife Service)

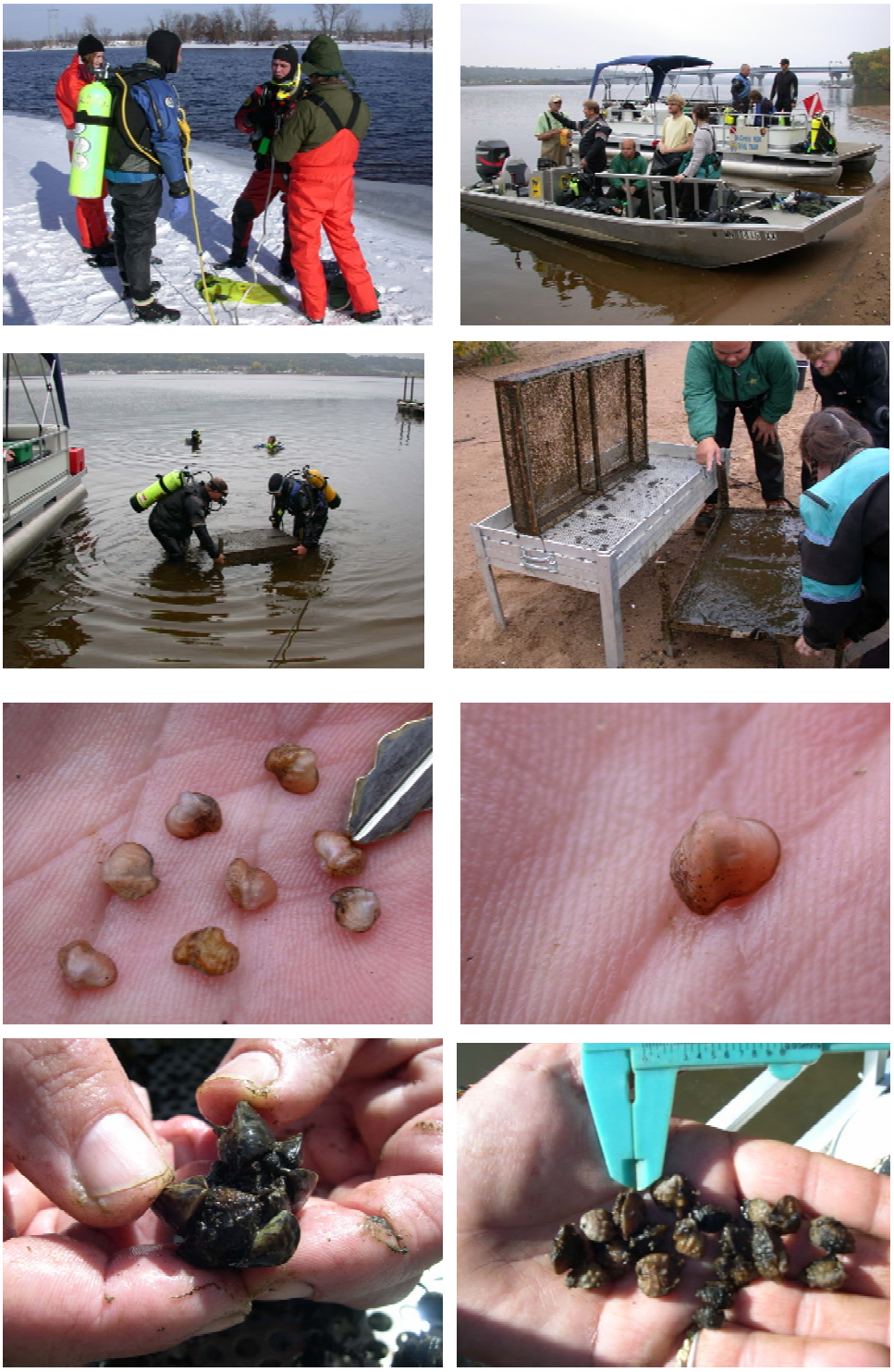


Figure 75. Propagation of federally endangered winged mapleleaf (*Quadrula fragosa*) in closed propagation cages in the lower St. Croix River, Minnesota. Juveniles in the third row of photos are 15 months old (Age 1) and approximately 3 - 5 millimeters long. Juveniles in the bottom row of photos are 27 months old (Age 2) and approximately 10 - 15 millimeters long; note attached zebra mussels (*Driessena polymorpha*). (Photos by Gary Wege, U.S. Fish and Wildlife Service and Byron Karns, National Park Service)

Figure 76. Portable hoist system installed in a pontoon boat for lifting mussel propagation cages. A 12-volt winch is attached to a steel A-frame with electricity supplied by a deep cycle battery. The system can be taken out of the boat, the floor cover reinstalled, and boat used for other purposes. A great addition is a 12-volt bilge pump that provides river water for washing cages on deck or on shore. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

Figure 77. Internet web site for mussels of the Upper Mississippi River System. Web address is www.midwest.fws.gov/mussel.

Figure 78. Live elephant ear (*Elliptio crassidens*) and ebonyshell (*Fusconaia ebena*) collected in 2003 in the lower St. Croix River near Prescott, Wisconsin. The host fish for both species is skipjack herring (*Alosa chrysochloris*) which no longer migrates to the St. Croix River due to hydropower and navigation locks and dams on the upper Mississippi River. (Photo by Gary Wege, U.S. Fish and Wildlife Servic).

Figure 79. Black sandshell (*Ligumia recta*) collected from closed propagation cages in the upper Mississippi River in Pool 4 near Frontenac, Minnesota. Juveniles in the top left photo are approximately 3 months old. The top right photo shows subadults approximately 15 months old. Black sandshell in the bottom photos were collected in August, 2006, and are three years old. (Photos by Gary Wege, U.S. Fish and Wildlife Service)

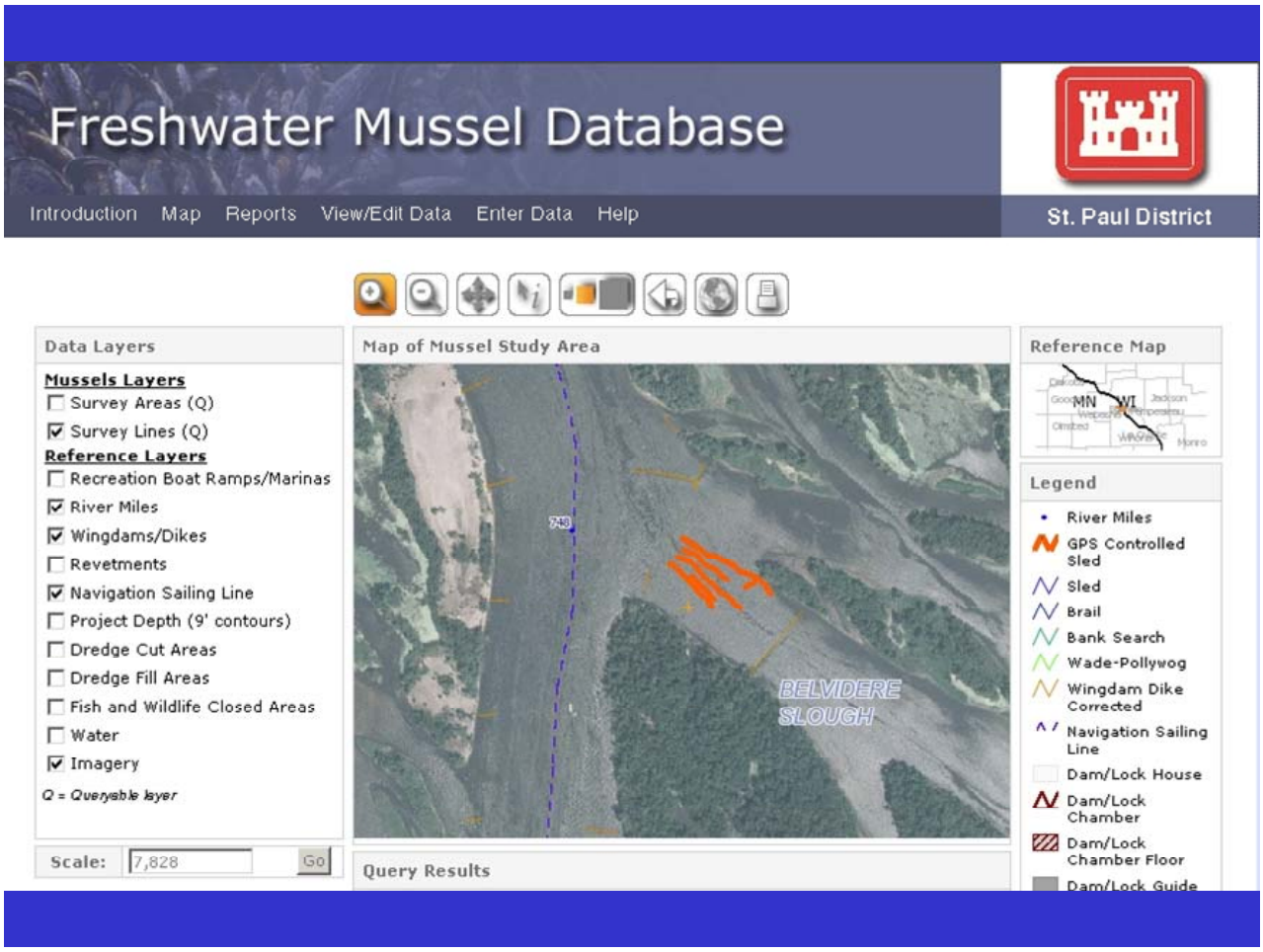


Figure 80. Template for new Geographic Information System (GIS) freshwater mussel database under construction by the U.S. Army Corps of Engineers (Corps). It is Internet web-based and will initially contain mussel survey data from the Corps and contractors (Graphic by Dan Kelner, U.S. Army Corps of Engineers)