Category III
Living Resources

THEN ~ "The extensive commercial fishery of the 19th century in the Delaware River and Bay declined in the 1920s, due to deterioration of water quality and over-harvesting. Fishery conditions have improved in the last several years. An objective now must be to maintain and continue the improvement, with traces of toxic substances."

Level B Study, May 1981, p 19
DRBC

Now

The past history of the river's anoxic (zero dissolved oxygen) zone, the introduction of water quality regulations, and subsequent improvements in water quality is recounted the Water Quality section of this report. The success of years of management and change is most dramatically evident in the restoration of living resources, especially fin fish populations and most notably shad.

Water quality criteria for the support of aquatic life have been adopted for a number of parameters, and are being considered for more. All of the waters of the basin are designated for the support of aquatic life. The key water parameter of concern has been dissolved oxygen (DO) because it is necessary for nearly every aquatic resource and is essential for overall ecosystem health. Aside from water quality, there are many other aspects affecting living resource condition. These include, but are not limited to, flows, temperature, natural predation, harvesting by humans, disease, and habitat loss.

Context and Linkage

As food and as habitat, healthy aquatic resources are linked to terrestrial and avian populations. The story of living resources in the basin is one of food webs, competition, interconnections, and water. Clean water is a requisite for fish and shellfish, which are principal foods for birds and mammals. Shellfish are filter feeders and help to absorb nutrients that can result in low DO levels that impair fish survival.

One example of an interconnection is the horseshoe crab and red knot. Horseshoe crabs, a key crustacean of Delaware Bay, lay eggs on bayshore beaches at exactly the right time for them to nourish migrating red knots on their annual journey to nesting grounds in the arctic. Without sufficient food, many birds cannot complete the trip and species survival may be in jeopardy. The infringement of rising sea levels and human settlement on bay beaches, the commercial harvesting of crabs, the earlier onset of spring with changes in global climate, and other unknown impacts

Table 3.1. **Environmental Factors Highly Related to Impairment of Aquatic Communities Along An Urban Land-Use Gradient.**
Green shading indicates factors that were more favorable to healthy aquatic communities and red shading indicates factors that were less favorable.
[NS= No statistically significant effect on aquatic community]

Watershed Characteristic	Fish	Aquatic invertebrates	Algae
Area of forest and wetlands	NS	Positive	NS
Ability to maintain base flow	NS	Positive	NS
Percentage of cobble substrate	Positive	Positive	NS
Median sulfate concentration	NS	Positive	Positive
Median total phosphorus concentration	Negative	NS	Positive
Mean annual flood	Negative	Negative	Negative
Flashiness of streamflow	Negative	NS	NS
Impervious area, road area only	Negative	Negative	Negative
Impervious area, nonroad area only	NS	Negative	NS
Population density	Negative	Negative	Negative
Total urban area in 1986	Negative	NS	NS
Urban area growth from 1986 to 1995	NS	Negative	NS
Commercial and industrial area in 1986	NS	Negative	Negative
Total point-source flow	NS	Negative	NS

Source: Ayers, M , J Kennen, P Stackelberg 2000. *Water Quality in Long Island-New Jersey Coastal Drainages 1996-98.* USGS Circular 1201. http:/nj.usgs.gov/nawqa/linj.ntml.

1896
Nearly 20 million pounds of American shad, celebrated as America's founding fish by author John McPhee, are caught in the Delaware River.

1910
The value of the NJ oyster harvest in Delaware Bay exceeds the state's wheat harvest by $1 million.

1914
Area of leased oyster grounds at 30,000 acres, up from 12,000 acres in 1900.

1940s
Shad and herring, unable to migrate through zero oxygen barrier at Philadelphia, cannot swim to upriver spawning grounds.

Late 1950s
MSX disease devastates oyster stocks in the Delaware Bay.

1981
Sole surviving commercial shad fishery on the non-tidal river nets 6,392 shad—the biggest catch since 1896.

1987
Over 56,000 shad, worth about $1.6 M recreational dollars are landed in 9 weeks between Hancock NY and Yardley PA.

beyond the basin all have the potential to affect the success of migrating red knot populations.

Not all links among living resources are this dramatic or international. Aquatic invertebrates, like freshwater mussels, are or become sedentary species and therefore are excellent indicators of local water quality and watershed condition. Aquatic invertebrates are especially sensitive to landscape changes related to development (Table 3.1).

Getting Personal

The health of living resources is not just important to maintaining the natural ecology of basin and estuary. Humans are an integral part of the web, linked by economic, recreational, and health interests. Fishing, for example, is both a commercial and recreational enterprise, highly valued throughout the basin. World-class trout fishing in the cold waters of the basin is an economically important enterprise that lures thousands of fisherfolk each year. The importance of oysters, crabs and other species of the Bay have been the foundation of commercial enterprises – harvesting, canning and shipping – for many generations. Threats to the living resource base may also be threats to the survival of basin and bayshore towns.

Monitoring living resources is important not only for ecosystem condition assessment, but also for understanding threats to human health and wellbeing. Toxic substances and diseases in water and sediment can be accumulated in fish tissue and shellfish. When consumed, that burden is passed on to other animals, including humans. As our knowledge of living resources improves, so may our ability to protect human health. (See *Fish Consumption* in the Water Quality section.)

Reporting

More than any other category of indicators, living resources are the most problematic to measure and report. Living resources tend to move about, change size and form, alternate food preferences, alter habits, and even their habitat, as they pass through their life cycles. Determining which species to evaluate in a community, what parameter to measure, and how to account for the effects of natural and imposed stressors is daunting. Moreover, although a wealth of information may exist; centralized clearinghouses for the information generally do not.

This section on living resources reports the condition status and observed trends for only a few of the thousands of species that call the basin home for all or part of the year. Some were chosen for their economic benefits, others were chosen because of their ecological significance, several are critical species that need to be protected from extirpation or extinction, and some were chosen for their ability to be monitored and serve as a representative indicator of other living resources.

Living resource indicators included in this report are:

- Benthic macroinvertebrates
- Freshwater mussels
- Oysters
- Horseshoe crabs
- Birds: Red knot, Louisiana water thrush, and American bald eagle
- Finfish: Weakfish and Striped bass, Atlantic sturgeon, American shad, and Brook trout.

A feature on invasive species concludes the Living Resource section.

1987 New Jersey and Delaware Shellfish Councils close Delaware Bay oyster seed beds to dredging.

1989 Landing of a 53 lb. 13 oz. striped bass from the Delaware River near Chester breaks PA record.

1991 The economic value of recreational fishing in Delaware Bay is estimated at $25 million per year.

1995 Over a half million shad swim up the Delaware to spawn.

1996 Over 90 percent of the Delaware Estuary meets fishable and swimmable goals of the Clean Water Act.

1998 Striped bass fishery declared "Restored" by ASMFC.

1999 Red knot listed as "threatened" by NJ.

2007 DE and ASFMC limit harvesting of male horseshoe crabs.

2008 NJ bans harvesting of all horseshoe crabs.

Indicator • Benthic Macroinvertebrates

Indicator Description

Benthic macroinvertebrates—mainly insects but also snails, worms, crayfish, and other fauna without back bones—are considered one of the nation's top biological indicators of environmental conditions in freshwater systems. In a pristine stream, aquatic invertebrates are typically diverse and abundant, consisting of many species from a wide variety of invertebrate groups. Because most invertebrates have limited movement, they typically spend their life in a short segment of stream and thus reflect the local conditions. In addition, many species live in the stream for a year or more, long enough to experience the full range of environmental conditions at a site but short enough so that they reflect the present and recent conditions.

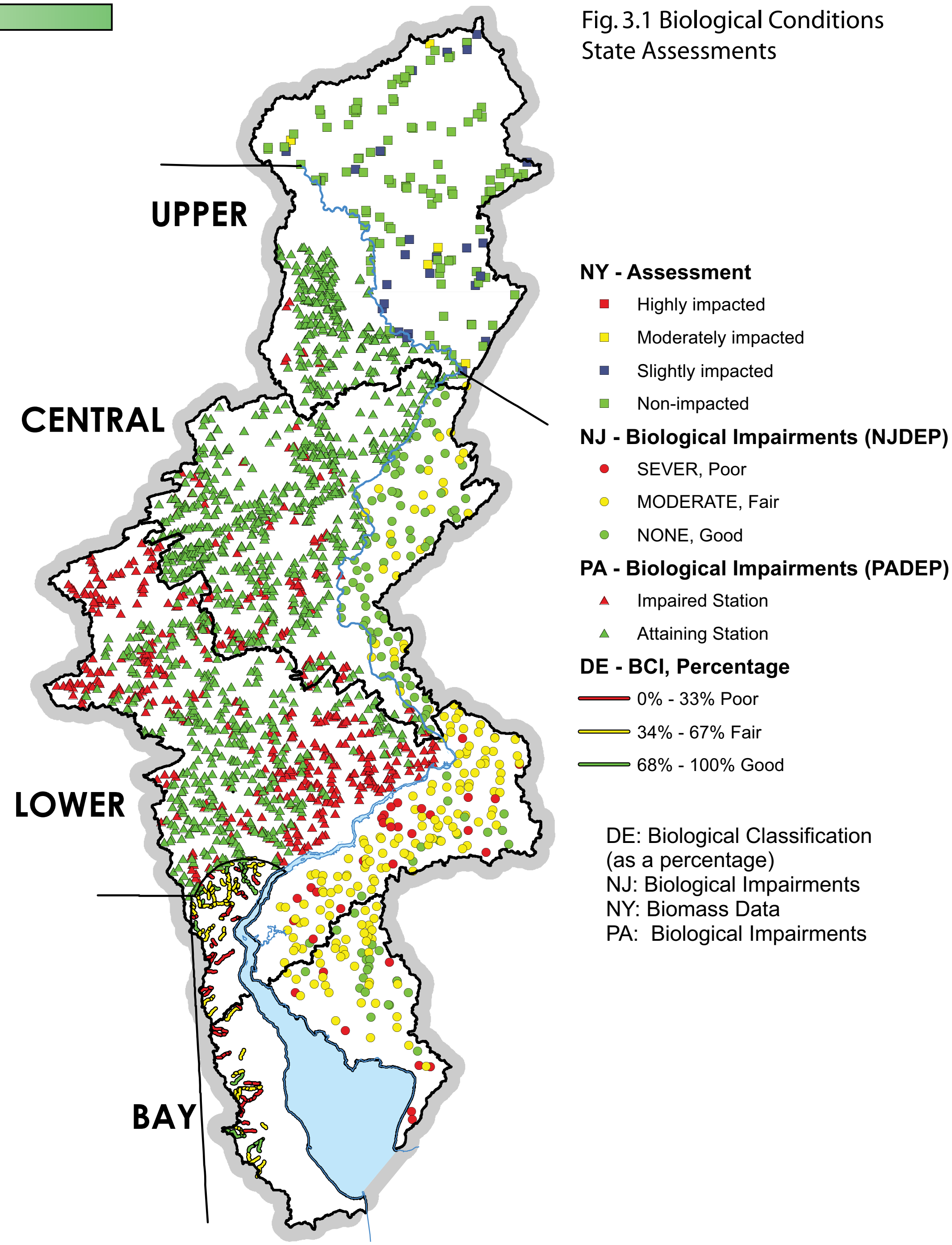
Among the invertebrates most commonly encountered in streams are species of mayflies, caddisflies, stoneflies, and true flies. Many of the midges (true fly family *Chironomidae*) can tolerate high levels of pollution and low dissolved oxygen, whereas the mayflies (e.g., *Drunella, Epeorus*), caddisflies (e.g. *Rhyacophila*) and stoneflies (e.g., *Acroneuria, Paragnetina*) typically require clean water and suitable habitats. Scientists continue to learn more about these species, and their requirements and sensitivities to environmental pollutants. Taken together with information from longer-lived invertebrates such as crayfish and freshwater mussels, the invertebrate fauna can tell us a lot about conditions at the base of the food chain.

Many government agencies center their stream assessment programs around collections of aquatic invertebrates. It is relatively easy and inexpensive to collect these aquatic invertebrates, and many statistical tools exist for converting data from an aquatic invertebrate sample into recognizable elements of ecological health.

Desired Condition

Diverse and abundant species of aquatic invertebrates indicative of high water quality (BP 1.2, 2.3; CCMP Action H5).

Fig. 3.1 Biological Conditions State Assessments



Status

Fair: Ranges from poor to very good; all regions show impacts.

Based on macroinvertebrate diversity, water quality and environmental conditions vary widely across the watershed. The most broadly impaired waters are in the urbanized area of the Lower Region, and in watersheds with a legacy of mining activity. Some level of impairment is found in almost all watershed regions. The best condition is represented in the uppermost portion of the basin where population density is low and a greater proportion of land remains in natural landscapes.

Trends

Trend data are not uniformly available. The frequency of macroinvertebrate sampling in the basin ranges from one to 5 years and may or may not include recurrent sampling. Differences among streams (temperature, flow regimes, chemistry and physical attributes) make application of a single index inappropriate. For example, a species index for the low-gradient and low-pH waters of the New Jersey Pinelands is very different from that of the coldwater streams of northeastern PA and NY. Furthermore, the basin states have developed dissimilar scoring systems that confound the comparison of conditions.

Scientific studies suggest that macroinvertebrate condition can be expected to decline in watersheds with greater point source flows, urban development, population and greater areas of impervious cover – especially associated with roads. Watersheds with greater areas of forests and wetlands, more cobble substrate, and maintained base flows have heathier macroinvertebrate communities (Table 3.1). Thus, watersheds that are undergoing development are at risk of degraded conditions for macroinvertebrates. Riparian corridor and wetland restoration efforts should improve macroinvertebrate health.

Actions and Needs

- Macroinvertebrate studies for the entire Delaware River Basin need to be conducted on a regular basis to facilitate trend analyses.
- In addition, the four states should consider standardized methods for reporting macroinvertebrate data to enable interstate comparisons and watershed-based reporting like that attempted here.
- Integration between estuarine and freshwater biological monitoring programs would facilitate a watershed approach to ecosystem monitoring.


G. SMITH, DRBC

Rhyacophila (*Rhyacophilidae*) caddisfly. Free-living predatory caddisfly are a strong indicator of clean water and a healthy aquatic ecosystem.


G. SMITH, DRBC

Chironomidae midges. Although varying in their tolerance to pollution, midge larvae are a vital component of all aquatic ecosystems yet can become dominant as water quality and ecological condition deteriorate.


G. SMITH, DRBC

Mayfly nymph (*Attenella*). Mayflies constitute one of the most important groups of bottom-dwelling animals in streams, rivers and lakes.


PHOTO: HTTP://WWW.CIRRUSIMAGE.COM

Mayfly adult. Mayflies are routinely used for monitoring water quality because their presence and diversity can be valuable indicators of the health of their aquatic environment. Many mayfly species are among the most sensitive to pollution.

Indicator • Freshwater Mussels

Indicator Description

Freshwater mussels are filter feeding bivalve mollusks that live in lakes, rivers, and streams. Unlike marine species, freshwater mussels grow more slowly, live longer (50 years or more), and have complicated reproduction strategies dependent on fish hosts. Because of their long and complex life-cycle, freshwater mussels provide different environmental information than benthic macroinvertebrates, which are good indicators for shorter-term changes in conditions. The health, reproductive status, population abundance, and species diversity of the mussel assemblage represents an excellent indicator of watershed conditions over long time scales. Unfortunately, they also lay claim to being the most imperiled taxonomic group in the nation.

Desired Condition

Water quality and flow conditions to support diverse aquatic communities (BP 1.2, 2.3; CCMP Action H5).

Status

Very poor: More than 75% of species have special conservation status.

North America has the world's greatest diversity of native freshwater mussels (more than 300 species); however, more than 75 percent have special conservation status. The leading causes of mussel decline are habitat and water quality degradation. For example, dams that block fish passage can affect reproduction, gene flow, and prevent re-colonization from adjacent tributaries following disturbance. Of the 12 or more native species in the Delaware basin, even the most common mussel is irregular in abundance and may not be successfully reproducing across much of its range. See Table 3.2.

Trend

The most recent comprehensive mussel survey in the region was conducted in Pennsylvania between 1909 and 1919. Even at that early date, dams and poor water quality may have diminished mussel communities. Nevertheless, the study provides a benchmark for gauging mussel status over nearly one hundred years. State surveys and recent anecdotal information suggest that all native mussel species in the region are impaired to some degree, with most being severely depressed or extirpated altogether.

Actions and Needs

- Additional monitoring is needed to assess species presence and the health of freshwater mussel populations across the Delaware River Basin.
- Improved coordination and data sharing among state and regional agencies, environmental groups and researchers would facilitate condition assessment.
- Standardized terminology would be helpful for comparing assessments.

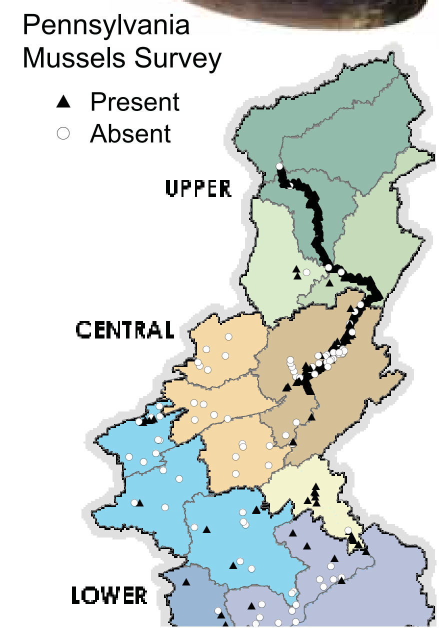


Fig. 3.2. Presence of Freshwater Mussels. From stream and snorkel surveys 1998-2004, The Nature Conservancy.

Table: 3.2 Freshwater Mussels - State Conservation Status

Common Name	Scientific Name	State Conservation Status			
		DE	NJ	PA	NY
Dwarf Wedgemussel	*Alasmidonta heterodon*	Endangered	Endangered	Critically Imperiled	Endangered
Triangle Floater	*Alasmidonta undulata*	Extirpated	Threatened	Vulnerable	Common
Brook Floater	*Alasmidonta varicose*	Endangered	Endangered	Imperiled	Endangered
Alewife Floater	*Anodonta implicata*	Extremely Rare	Not Listed*	Vulnerable	Uncommon; not protected
Eastern Elliptio	*Elliptio complanata*	Common	Common	Secure	Abundant
Yellow Lampmussel	*Lampsilis cariosa*	Endangered	Threatened	Vulnerable	Rare; not protected
Eastern Lampmussel	*Lampsilis radiata*	Endangered	Threatened	Imperiled	Common
Green Floater	*Lasmigona subviridis*	Not Listed*	Endangered	Imperiled	Threatened
Tidewater Mucket	*Leptodea ochracea*	Endangered	Threatened	Critically Imperiled	Rare; not protected
Eastern Pondmussel	*Ligumia nasuta*	Endangered	Threatened	Critically Imperiled	Uncommon; not protected
Eastern Pearlshell	*Margaritifera margaritifera*	Not Listed*	Not Listed*	Critically Imperiled	Rare; not protected
Eastern Floater	*Pyganodon cataracta*	Not Listed*	Not Listed*	Secure	Abundant
Squawfoot	*Strophitus undulatus*	Extremely Rare	Special Concern	Apparently Secure	Common to Abundant

*These mussels may never have been found in that state.

Indicator • Oysters - *Crassostrea virginica*

Indicator Description

American oysters are a nutritious food and an important fishery in the Delaware Bay. In 1887, about 1,400 sailing vessels harvested approximately 1.5 million bushels, or 22 million pounds of oysters. Today, harvests deliver about 100,000 bushels with a dockside value of $3 to $5 million, but efforts are under way to boost those numbers.

Oysters also provide important ecosystem services by creating reef habitats for fish and other organisms, filtering water, recycling nutrients, and stabilizing sediments. However, these filter-feeders can be sensitive to degraded water conditions. Like other bivalve mollusks, oysters are world-renowned as excellent "bioindicators" of environmental conditions.

Desired Condition

Water quality and habitat conditions to support oyster communities (BP 2.3, CCMP Action H5.8).

Status

Poor: Populations are low but carefully managed and stabilizing.

Although only a fraction of their historic size, today's oyster populations are carefully managed to maintain and increase abundance through the interplay of harvest, oyster disease mortality, and recruitment. Fortunately, oysters in Delaware Bay have developed some resistance to MSX disease, which devastated the population from 1957 to 1986. However, Dermo disease has been a persistent problem since 1990, especially in the lower bay's high-salinity waters. After an unprecedented seven years of low "recruitment" by juvenile oysters (a.k.a., spat), 2007 marked a return to average levels (Fig. 3.3).

Trends

Oyster abundance was not accurately assessed before the 1950s, but landings data suggest that populations are a fraction of their historic size in the 19th and early 20th centuries. Seed bed data indicate that current abundance is 39 percent of the 1953 to 2007 long-term average and 78 percent of the 1989 to 2007 (short-term) average. While recruitment in 2007 was 54 percent of the long-term average, it represents 135 percent of the short-term average. In fact, populations in Upper Delaware Bay remain relatively robust. Therefore, it is likely the oyster population will continue to support commercial harvests. Oyster population health and recruitment are presently monitored at seed beds by Delaware's Department of Natural Resources (DNREC) and Haskin Shellfish Lab of Rutgers University (Fig. 3.4).

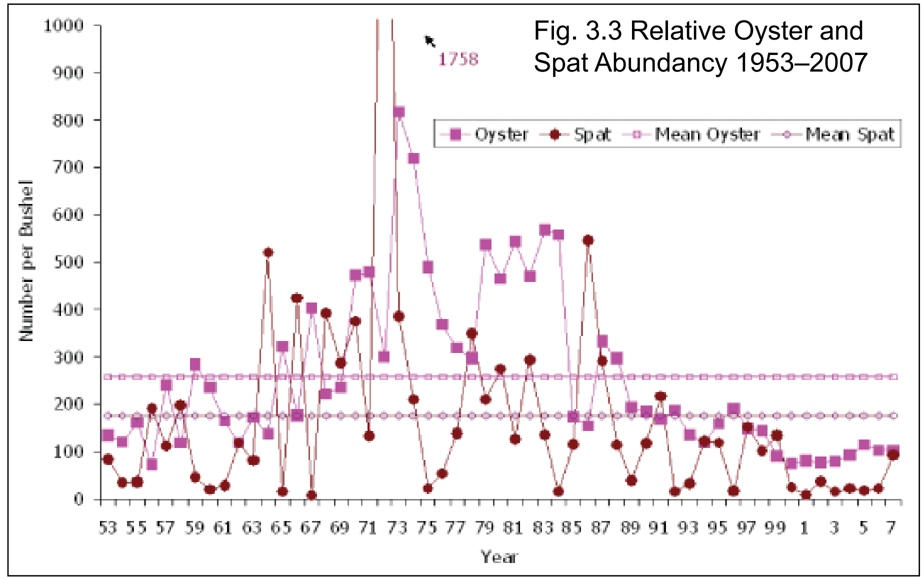
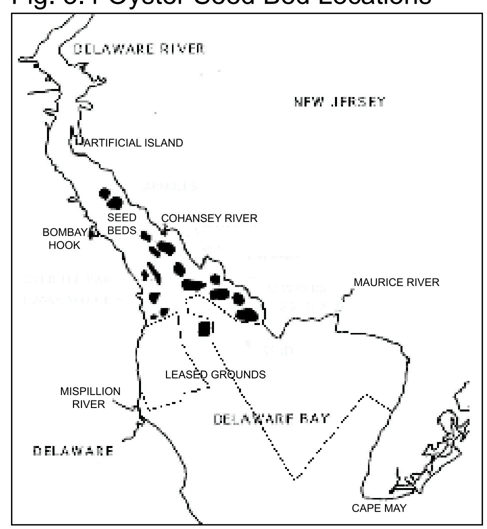


Fig. 3.3 Relative Oyster and Spat Abundancy 1953–2007

Actions and Needs

- A more comprehensive monitoring program to provide additional information about fresh water flow requirements, along with continued study of both oyster biology and food supplies.
- Attention should be paid to the effects of human activity and climate change on oyster habitat and life cycle.
- Shell-planting activities are crucial to maintaining and enhancing the oyster resource.

Fig. 3.4 Oyster Seed Bed Locations



Indicator • Horseshoe Crabs - *Limulus polyphemus*

Indicator Description

Delaware Bay is the principal breeding location for horseshoe crabs on the east coast. More closely related to spiders than crabs, they have seen few physical changes in the past 350 million years. The arthropod's hard, curved shell defends a soft underbelly and protects a body able to survive for up to a year without eating. Economically viable, they are used as bait by watermen and their blue blood has important pharmaceutical uses for testing medications and biomedical devices. Horseshoe crabs are also the State of Delaware's official marine animal.

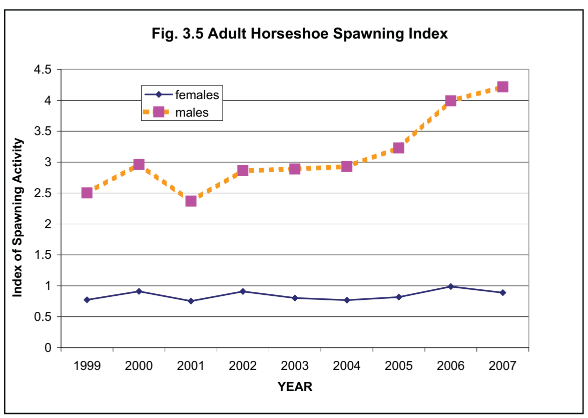
The horseshoe crab's greatest importance, however, is ecological. Their sheer abundance makes them an important consumer along the bottom where they prey on marine worms, bivalves and other fauna. Their eggs, deposited on beaches, are a critical food source for migrating shorebirds, including the red knot, listed as a *threatened* species by NJ (see facing page). Horseshoe crabs also appear to be an important part of the diet of sea turtles and many other animals. The Delaware estuary's signature commercial and ecological resource is the horseshoe crab, and the health of this population is one of our region's most important environmental indicators.

Desired Condition

Water quality and habitat conditions to support horseshoe crab populations (BP 1.2, 2.3; CCMP Action H5)

Status

Fair: Breeding populations are reduced but show improvement.



Source: *State of the Delaware Estuary 2008*, PDE.

The horseshoe crab population appears to be stable, but greatly reduced in number from historic levels. However, current population levels are not high enough to support historic levels of shorebirds during the spring stopover. There are indications that management actions to limit harvests combined with voluntary reductions in bait use by watermen are allowing the population to increase. Because horseshoe crabs are long-lived and do not reproduce until at least 8-to-12 years old, it can take a decade or more for management actions to result in a measurable increase in the spawning population.

Trends

Little data are available for measuring trends prior to 1990, but the population probably declined in the early 1900s due to overharvest and then increased through the 1970s. Bait overharvest led to another decline in the 1990s, followed by stability and recovery in the late 1990s and early 2000s. Baywide female spawning activity has remained stable since 1999, whereas male spawning activity has significantly increased for the same period (Fig. 3.5). Since males mature earlier, this increase in males may signal an increase in females to come. New Jersey currently has a harvest moratorium; Delaware allows only limited harvests of males.

Actions and Needs

- Continued monitoring and management are needed to benefit horseshoe crab populations.

- Habitat restoration projects would also benefit horseshoe crab spawning and could potentially increase the number of eggs available for shorebirds.

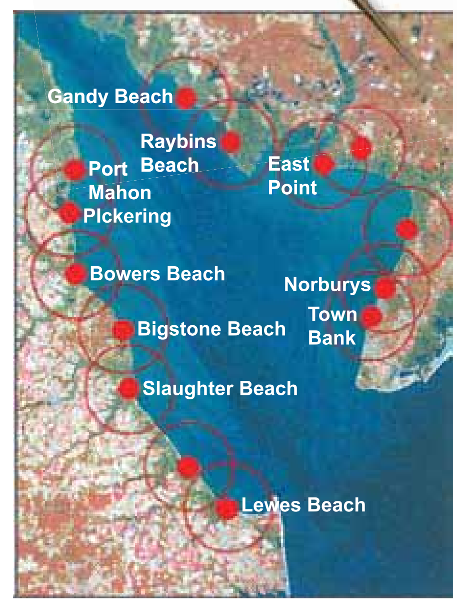


Fig. 3.6. Almost 30 beaches are included in the Delaware Bay Horseshoe Crab Spawning Survey, which is undertaken annually. Radio transmitters aid in this research by monitoring beaches throughout the Delaware Bay and signals often overlap. Source: *State of the Delaware Estuary 2008*, PDE.

Indicator • Red Knot *(Calidris canutus rufa)*

Indicator description

The red knot (*Calidris canutus rufa*) is one of many species of migratory shorebird that relies on the resources of the Delaware estuary for rest and nutrition to complete its spring flight. Listed as a "Species of High Concern" in the *US Shorebird Conservation Plan*, the red knot is of special interest because its survival is linked to the health of the horseshoe crabs populations of Delaware Bay. In 1999, NJ listed the red knot as a "threatened" species.

Desired Condition

Sufficient habitat and forage for migrating shorebirds along the Atlantic flyway to support robust and diverse populations, (BP 1.2, 2.3; CCMP Action H5).

Status and Trend

Very poor: Populations may be crashing.

The Delaware Estuary is the largest stop-over for shorebirds in the Atlantic flyway and is the second largest staging site in North America. Close to a million migratory shorebirds converge on the Delaware Bay to feed and build energy reserves prior to completing their migrations. The red knots are perhaps the best know migratory shorebirds, described by the National Audubon Society as champion, long-distance migrants.

Aerial surveys conducted in Delaware Bay and South America, along with counts in Canada, show that shorebird populations, particularly the red knot, have declined over the past 30 years (Fig. 3.7). In the 1980s for example, up to 100,000 red knots descended on Delaware Bay, but in 2006 they numbered less than 13,500. At the current rate of decline, biologists fear that the red knot could become extinct by the end of this decade.

Factors affecting shore bird survival include delayed migration, die-offs in other parts of their ranges, habitat suitability, and abundance of food at critical stopover points. While there is uncertainty concerning the risk each factor is contributing, the most important factor related to Delaware Bay is food supply, since weight gain at stopover points affects breeding success and survival. In the 1990s the horseshoe crab spawning population declined due to over-harvesting, which in turn reduced the Bay's available egg supply for migrating shorebirds. Current surface densities of horseshoe crab eggs may be insufficient to support the recovery of migrant shorebirds.

In addition to harvesting, horseshoe crab populations are adversely affected by sea level rise and coastal development, both of which infringe on the sandy shore environments essential for egg laying. See the *Horseshoe Crab* and *Coastal Wetland Buffer* indicators for more information.

Since 2000, horseshoe crab harvest restrictions have been imposed, a sanctuary has been established, and watermen have reduced their use of horseshoe crabs as bait. The success of these measures may take years to measure. It takes 9 to 12 years for horseshoe crabs to reach spawning age and for measurable changes to be seen in the abundance of eggs for the red knots in the spring.

Actions and Needs

- Continued vigilance in monitoring red knot populations and efforts to increase the abundance of horseshoe crab breeding populations and egg densities.

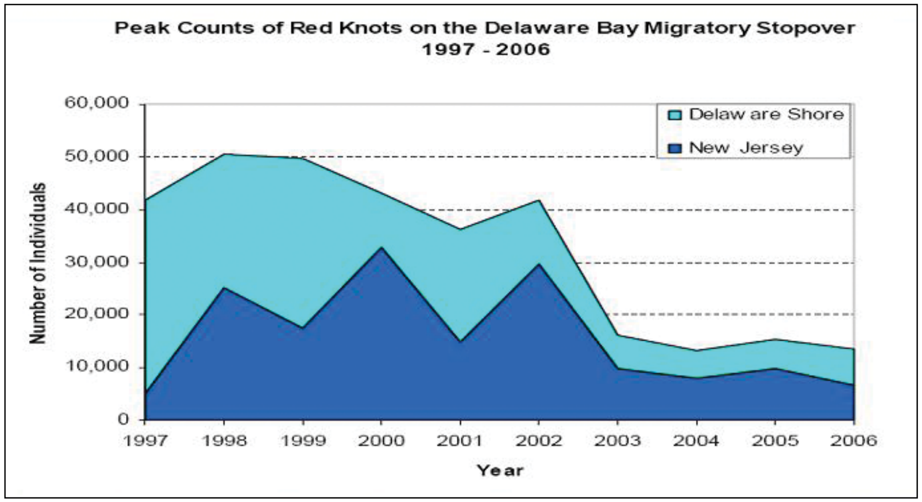


Fig. 3.7. The number of red knots (Calidris canutus rufa) migrating to the Delaware Bay declined during the period 1997 to 2006. Source: *State of the Delaware Estuary 2008*, PDE.

Indicator • Louisiana Waterthrush - *Seiurus motacilla*

SOURCE: C. CONRAD, FLICKER 2007

Indicator description

The Louisiana waterthrush, *Seiurus motacilla*, is the only obligate headwater riparian songbird in the Delaware River Basin and the eastern United States. It is a biological indicator both of riparian songbird population and fresh water wetland habitat condition, correlating to healthy land and water environments throughout the Basin. It is a widespread species with breeding populations recorded in nearly all of the hydrologic regions in the basin Data are compiled semi-annually as part of a national Breeding Bird Survey (BBS).

Desired Condition

Robust breeding communities of songbirds indicating adequate habitat of suitable quality for forage and propagation (BP 1.2, 2.3, CCMP Action H5).

Status

Fair: Very sensitive to polluted waters and loss of forested riparian habitat.

The status of songbirds generally can be examined by assessing the breeding abundance of the Louisiana waterthrush, which correlates positively with riparian tree density and continuity. However, breeding success, in terms of nest density, is very closely tied to the bird's reliance on aquatic macroinvertebrates. A paired watershed study of pristine watersheds and polluted watersheds impacted by acid atmospheric deposition and abandoned mine drainage in Pennsylvania, more than double the number of nests per kilometer of streams were found in unpolluted streams versus acidified streams with much lower abundance and diversity of macroinvertebrates.

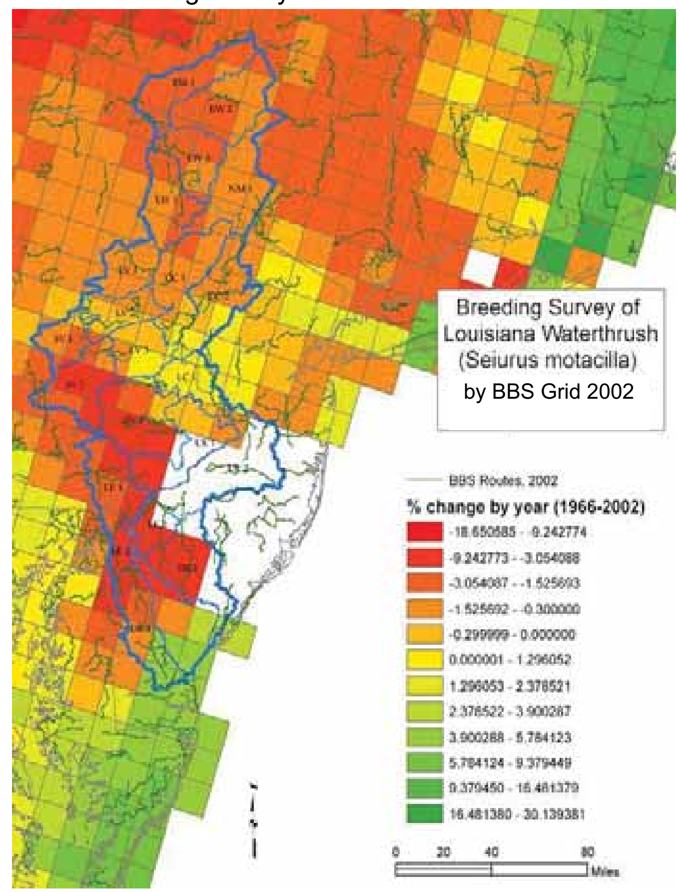
Trend

As of 2002, the abundance of Louisiana water thrush appears to be decreasing in much of the Basin (Fig. 3.8). Changes seem to coincide with development patterns and change. Decreases are greatest in the more heavily developed bayshore, estuary and Schuylkill valley watersheds, while the less developed reaches of the southern bayshore and lower central basin show modest increases.

Actions and Needs

- Maintaining natural vegetative cover and tree canopy on riparian headwaters is critical for the Louisiana waterthrush and many other riparian species, including amphibians and reptiles.
- Measurements of riparian and wetland habitat integrity would enhance assessment and reporting.
- Identification, tracking and assessment of additional species related to the water-related habitats of the basin, especially amphibians, is recommended.

Fig. 3.8 Louisiana Waterthrush Breeding Survey



Indicator • Bald Eagle - *Haliaeetus leucocephalus*

Indicator description
The bald eagle (*Haliaeetus leucocephalus*) is the only eagle unique to North America. Fish are an important food source for all bald eagles.

Desired Condition
Continued protection and expansion of bald eagle nesting and foraging habitat, and continued monitoring programs.

Status
Good and generally improving.

Bald eagle populations are currently in good condition in the Delaware Basin watersheds. Sightings along the non-tidal Delaware River have generally increased annually since 1998. In 2007, a pair of bald eagles established a nest near the confluence of the Schuylkill and Delaware Rivers at the Navy Yard in south Philadelphia, which may be the first nesting pair within the city limits since Colonial times. Since the main diet of the eagles are fish, it is thought that the birds are returning in nests near the Delaware River in greater numbers due to a greater abundance of fish and cleaner water.

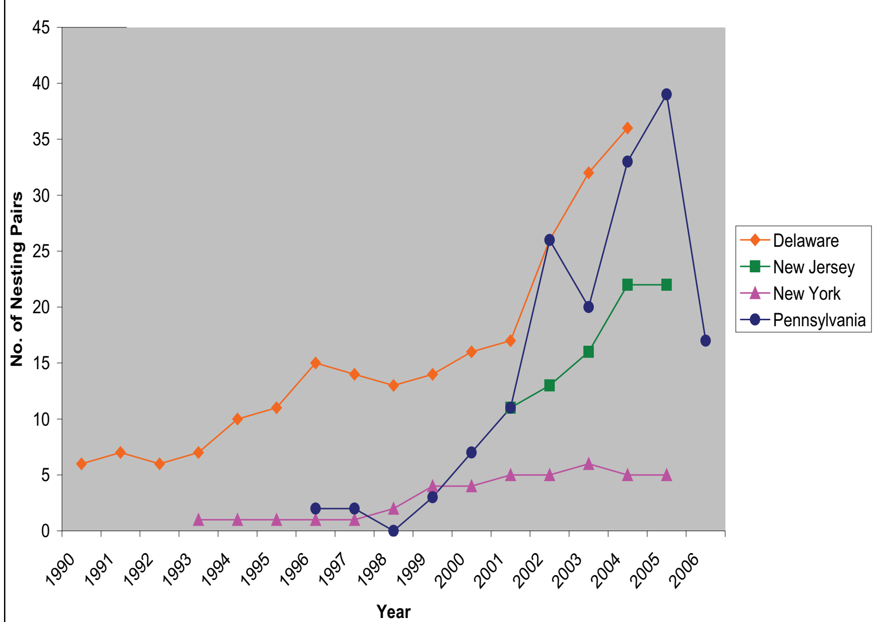
The return of the bald eagle to Delaware basin watersheds is an astonishing success story. Bald eagle nests have increased significantly. In 2004 for example, 96 nests were spotted in the basin, up from 44 in 2001.

Trend
The Bald Eagle Protection Act of 1940 prohibited shooting or otherwise harming the birds in the US, but this protection did not prevent damage from pesticides that harm their eggs. By the 1960s only about 400 breeding pairs of bald eagles remained in the lower 48 states and they were declared an endangered species in 1967. The banning of DDT in 1972 and other measures launched an amazing comeback for eagles, and by 1995 their status was upgraded from endangered to threatened. Today, with more than 6,000 breeding pairs, the US Fish and Wildlife Service proposes to remove eagles from the nation's Endangered Species list later in 2007.

Actions and Needs
- Continued vigilance to monitor water quality, especially emerging contaminants with the capacity to disrupt reproduction cycles in living resources.
- Continued monitoring of eagles and other mammals dependent on aquatic resources and associated habitat in order to determine population health and protect it from reversals.

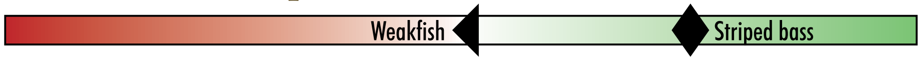
SOURCE: PENNSYLVANIA GAME COMMISSION

Fig. 3.9 Population of Bald Eagle Nesting Pairs in Delaware River Basin



Source: Technical Summary of the State of the Delaware River Basin, Water Resources Agency, University of Delaware 2008.

Indicator • Striped bass and Weakfish - *Morone saxatilis* and *Cynoscion regalis*



SOURCE: PHILADELPHIA WATER DEPARTMENT

Indicator Description

As a premiere sport fish and a top predator in the aquatic food web, striped bass is economically and ecologically important in the Delaware basin. Striped bass is a large anadromous species of finfish that live mostly in the ocean and bay but spawn in freshwater. Found throughout the tidal ecosystem from spring to fall, striped bass are much sought after as game fish. Weakfish, a smaller finfish and the state fish of Delaware, show a more compressed range, spawning in the lower reaches of the Bay and migrating nearer offshore. Both species are important economic and recreational species.

Desired Condition

Water quality and habitat conditions to support healthy and diverse finfish populations (BP 1.2, 2.3; CCMP Action H5).

Status

Good: Striped bass restored.
Fair: Weakfish declining.

Substantial populations of striped bass indicate a true success story in fishery restoration credited to water quality improvements and constraints on striped bass harvests until 1998. Water quality improvements also benefited weakfish, whose numbers increased and peaked in 1996. A decline in abundance of both species in the last decade requires additional investigation.

Trends

Striped bass were nearly eliminated from the Delaware estuary by the 1960s. Low dissolved oxygen levels in the River created a barrier that prevented fish from migrating to their spawning grounds. Weakfish which generally stay further south in the river were not as affected by this, although their population numbers were also depressed. A further dramatic decline in stripers in the late 1970s led to harvest moratoria in 1985–89 followed by harvest restrictions until 1995.

Survival of weakfish and striped bass increased with improved water quality, and reduced harvesting of stripers meant that more adults were present to spawn. In 1998 the Atlantic States Marine Fisheries Commission officially declared the striped bass fishery "restored."

In contrast, weakfish populations have declined in recent years following improved abundance between 1994 and 2002. The decrease may be related to the increase in striped bass and perhaps predation of weakfish by stripers.

The age structure of populations as well as physical variations in temperature and salinity affect spawning stock. Entrainment and impingement in large water intake structures affect larval and juvenile populations and also is a factor in population survival.

Actions and Needs

- A more detailed investigation of the dynamic interactions among finfish population would help in the prediction of future status and trends, and may suggest management options.

- The emergence of an apparent bottleneck to yearling survival for striped bass is worthy of investigation, as is the cumulative impact of entrainment and impingement on fish populations.

Fig. 3.10 Mean Weakfish Abundance 1990-2005 Delaware Estuary

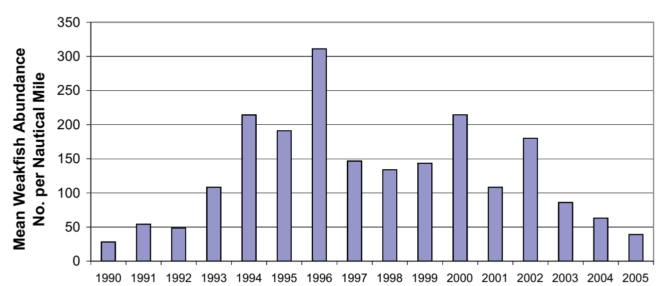
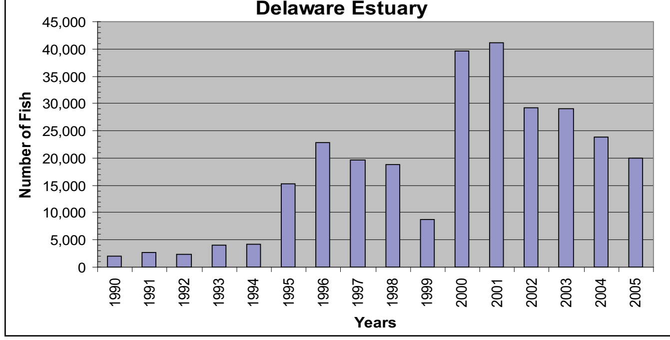


Fig. 3.11 Delaware Recreational Striped Bass Harvest Delaware Estuary



Indicator • Atlantic Sturgeon - *Acipenser oxyrhynus*

Indicator Description

The shortnose and Atlantic sturgeon are long-lived species that spend at least part of their life cycle in the Delaware Estuary. The shortnose is currently a federal endangered species, but the Atlantic sturgeon may be even more imperiled. The Atlantic sturgeon is an ancient fish that, when abundant, can represent an important bottom consumer in large eastern rivers.

Desired Condition

Water quality and habitat conditions to support diverse fish populations (BP 1.2, 2.3; CCMP Action H5).

Status

Poor and getting worse.

The population of shortnose sturgeon in the Delaware Estuary currently appears stable at about 13,000 fish, despite being listed as an endangered species. Today's numbers of Atlantic sturgeon, on the other hand, are estimated to be less than 1,000 and probably less than 100 across the Estuary. The Atlantic sturgeon is on the endangered species list in Delaware and it may be a good candidate for federal listing.

Trends

The Delaware estuary was once the hub of American sturgeon fishery, having the largest population of Atlantic sturgeon in the world. Record harvests and virtual elimination of spawning and nursery habitat, combined with poor water quality and low reproduction, likely caused the population collapse during the late 1800s.

Nearly fished to extinction over a century ago, they have not yet rebounded despite increasing management attention and harvest restrictions. In 1991, a seven-foot size minimum was adopted, and by 1998 a complete harvest moratorium was imposed. As recently as 1986 an adult female sturgeon was valued at $3,000 per fish for its caviar.

Scientists have stepped up studies of sturgeon population dynamics and ecology. Telemetry indicates that sturgeon use main channel habitats; large alterations such as dredging may have changed salinity and bottom habitats causing sturgeon to now spawn further upstream from their historic reaches. This, coupled with boat strikes and by-catch by large mesh gill nets are thought to be impeding their recovery.

Actions and Needs

- A better understanding of sturgeon habitat requirements and improvements in reporting.
- A better understanding of the impacts of human actions on sturgeon populations and habitat to inform management strategies.

Fig. 3.12 Tracking Locations of Atlantic Sturgen, 2006

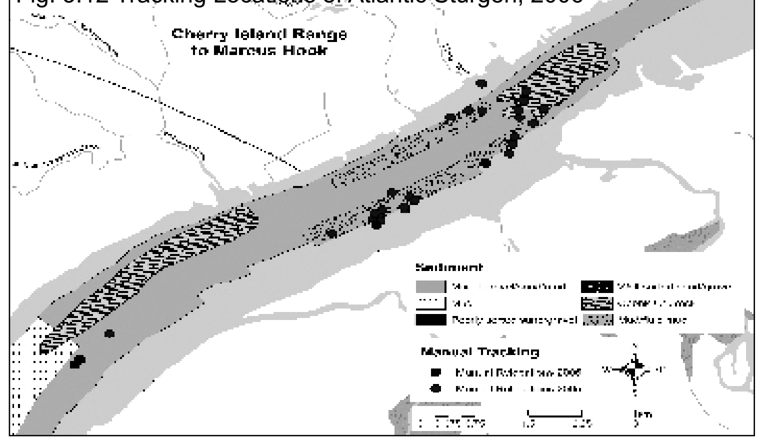
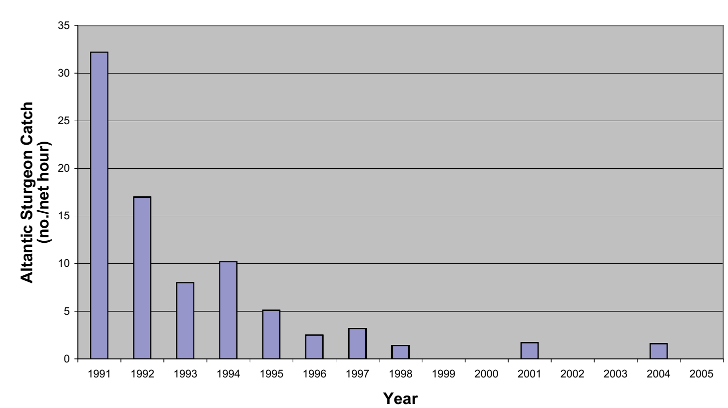


Fig. 3.13 Annual Catch Rates of Atlantic Sturgeon Collected in the Delaware River



Indicator • Shad - *Alosa sapidissima*

Fig. 3.14. Shad Migration Routes

Indicator Description

The American shad is the largest North American member of the herring family. The shad is an anadromous fish that migrates each spring to the Delaware Estuary watershed to spawn. Between 1880 and 1890 fishermen in the Delaware River caught 10 to 20 million pounds of shad annually. Around 1910, shad numbers began to decline rapidly, and populations were so low by 1920 that shad fisheries were no long a viable industry. Overfishing, dammed spawning tributaries, and degraded water quality, such as low dissolved oxygen levels, were the principal factors in the shad's decline. As a once abundant fish that travels between tidal and non-tidal areas of the watershed (Fig. 3.15), shad represent a valuable indicator of environmental conditions in the Delaware Estuary and Basin.

Desired Condition

Water quality and habitat conditions to support healthy and diverse finfish populations (BP 1.2, 2.3; CCMP Action H5).

Status

Fair: Stable since improvements in dissolved oxygen and tributary fish passage, but recent reductions evident.

Today, the Delaware River supports a viable commercial and shad sport fishery, but harvests are small compared to historic benchmarks. In 1896 over 14 million pounds of shad were caught, having a value of $10 million in 2006. Although current populations cannot sustain that level of harvest, the economic value of today's recreational fishery is nearing levels reported more than 100 years ago. In 1996, for example, the economic value of the shad sport fishery in the Delaware was estimated at $3.2 million.

Trends

Once blocked by a lack of oxygen, shad now move more freely through the tidal freshwater zone during spawning runs. Sewage facility upgrades improved water quality and increased dissolved oxygen, which helped shad return to the Delaware. Still, shad abundance is low, even compared with numbers from the 1990s. Pennsylvania leads the nation in removing obsolete dams, and fish ladders are being installed in many areas of the basin. These efforts have reopened approximately 165 stream miles for shad migration.

Actions and Needs

Increases in the shad population in the Delaware Basin should continue if water quality and fish passage are continually maintained or improved (e.g., by removing dams and installing fish ladders). Habitat conditions in spawning reaches of tributaries must also be maintained and monitored.

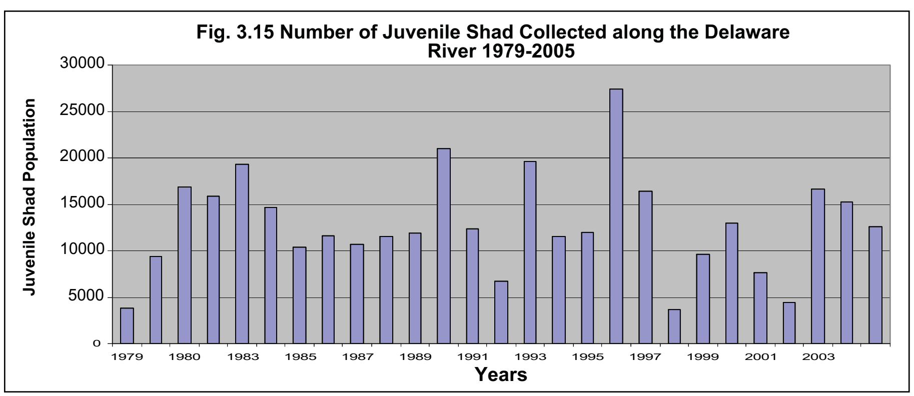


Fig. 3.15 Number of Juvenile Shad Collected along the Delaware River 1979-2005

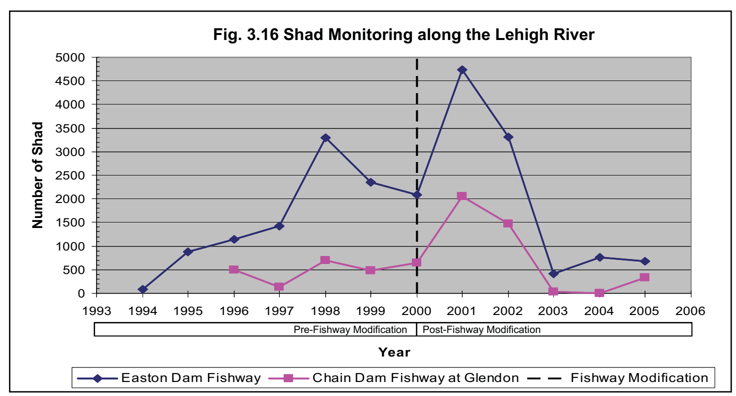


Fig. 3.16 Shad Monitoring along the Lehigh River

Indicator • Brook Trout - *Salvelinus fontinalis*

Indicator Description

Brook trout (*Salvelinus fontinalis*) are the only trout species native to streams in the Delaware River Basin. The brook trout thrives in cold water streams with heavily forested watersheds and low densities of human population; trout are extremely sensitive to temperature increases. As a once-abundant, native species that is relatively intolerant of degraded conditions, brook trout represent ideal biological indicators in the cold water streams of the Basin, particularly in headwater areas. It is also a fishery of significant economic importance for ecotourism. States often designate streams in part by their support of trout propagation or maintenance of adult populations.

Desired Condition

Sustained populations of native fish species (BP 1.2, 2.3, CCMP Action H5).

Status

Poor: Native trout populations have been extirpated or severely reduced in most of the basin's watersheds.

Former brook trout habitat has been virtually eliminated in urban corridors and greatly reduced in most of the rest of the basin. Temperature fluctuations from poor stormwater management practices, inadequacy of food sources, and changes in flow regimes may all have a role in reducing the extent and quality of trout habitat. Few areas remain that can support native brook trout, except those cold water streams that remain unaffected by development.

Trends

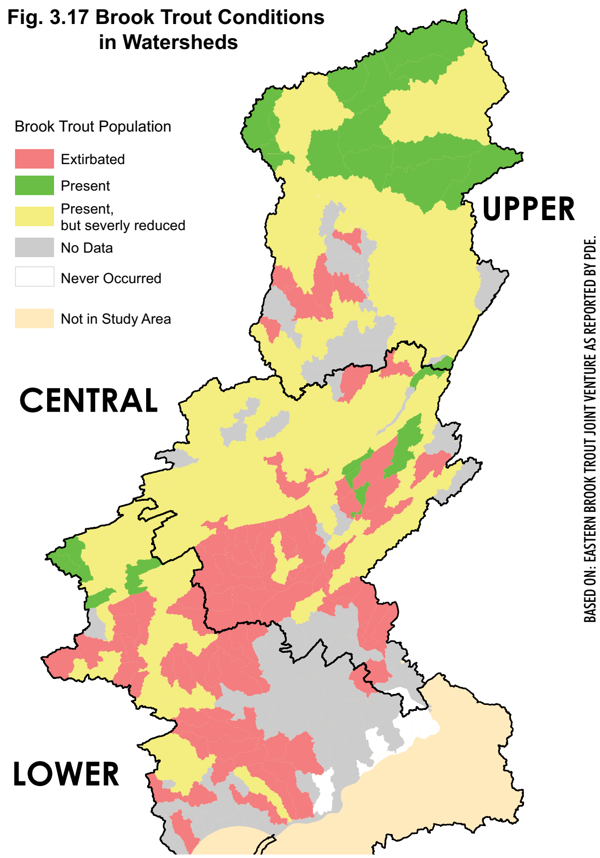
While actual brook trout population data and trends were not available for this report, a habitat-based analysis of their former and present range suggests that this native species has been either extirpated or severely reduced across most of its former range across the basin. Brook trout populations are in decline because of changes to water quality and temperature caused by acid deposition, deforestation, and other watershed changes caused by human development that increase sediment loads in spawning areas or otherwise impair water quality and trout habitat. Increasing temperatures and reduction in the timing and amount of snowmelt related to climate change may also be a factor.

The effects of continued land use change in the basin is likely to spur further declines, although restoration projects may help brook trout survive and perhaps even increase in suitable areas, such as spring-fed creeks in headwaters.

Actions and Needs

- Conservation, restoration and management attention is needed, particularly in headwater areas, to safeguard and possibly reclaim the habitat and water quality necessary to sustain naturally-reproducing populations of brook trout.
- Efforts should be made to improve the monitoring and reporting of brook trout populations as harbingers of human-induced environmental degradation and climate change impacts.

Fig. 3.17 Brook Trout Conditions in Watersheds



Invasive Species

Description

Invasive species are those introduced from outside of an ecosystem with characteristics that allow them to dominate and limit the diversity of species within an invaded area. Invasive species can be plants or animals, terrestrial or aquatic. They gain advantage over native species by their capacity to reproduce, grow or expand their range faster than their native counterparts. A lack of natural predators or diseases often gives invasive species an advantage over local native species. Similarly, changes in temperature, precipitation, flow and chemistry can also exacerbate the establishment and success of invasives. While usually non-native, some native species can become invasive, especially in disturbed areas; an example is poison ivy (*Toxicodendron radicans*) that appears to be spreading and becoming more virulent in response to increased atmospheric carbon dioxide and global warming.

Invasive species causing the greatest impacts on water resources are directly associated with waterways and their adjacent riparian landscapes. In terms of potential loss of native biodiversity and ecological function, riparian zones are probably the landscape most vulnerable to severe impact by invasive species. As the margin or overlap between aquatic and terrestrial ecosystems, riparian zones have evolved a natural balance of richness, resilience and complexity that keeps any single species from becoming overly dominant. Invasive species can dangerously affect this balance. Furthermore, a watercourse provides the ideal conduit for the spread of invasive species by water, wind, and animals.

Desired Condition

The maintenance of healthy and biologically diverse riparian and aquatic ecosystems, and the implementation of invasive species detection and management plans (BP 2.3.E, CCMP Action H6).

Status

There are very few locations remaining in the Delaware River Basin that are undisturbed or sufficiently resilient to resist the establishment of invasive species. The Mid-Atlantic Exotic Pest Plant Council currently identifies 275 species of invasive plants in this region. The scale of economic and ecological damage is already significant; estimates of ecological damage and control costs top $137 billion/year nationwide. Table 3.3 shows a few of the many non-native invasive species that are established in or threatening forests, waterways, and riparian areas of the Delaware River Basin.

Trends

With increased global trade, the rate of species introductions in the US is high (Figure 3.19). The news is not all bad, however, as government agencies and other organizations have poured resources into planning and action. All Delaware Basin states have invasive species councils, rapid response teams are in action, and volunteers are very active in monitoring and control.

Actions and Needs

Where waterways and riparian lands are undisturbed, prevention of invasive species establishment is critical. Where invasive species have become established, the greatest practical effort should be made to eradicate those that pose the

Eurasian water-milfoil, *Myriophyllum spicatum*, infests the Lehigh and Lower Delaware Rivers.

Table 3.3 Invasive Species of Concern

Common Name	Scientific Name
FOREST	
Hemlock Woolly Adelgid	*Adelges tsugae*
Gypsy Moth	*Lymantria dispar*
Chestnut Blight	*Cryphonectria parasitica*
Dutch Elm Disease	*Ophiostoma ulmi*
AQUATIC	
Northern Snakehead	*Channa argus*
Flathead Catfish	*Pylodictus olivarus*
Common Carp	*Cyprinus carpio*
Chinese Mitten Crab	*Eriocheir sinensis*
Zebra Mussel	*Dreissena polymorpha*
Rusty Crayfish	*Orconectes rusticus*
Asiatic Clam	*Corbicula fluminea*
Rock Snot	*Didymosphenia geminata*
Eurasian Water-Milfoil	*Myriophyllum spicatum*
Curly Pondweed	*Potamogeton crispus*
Water Chestnut	*Trapa natans*
Hydrilla	*Hydrilla verticillata*
Yellow Floating Heart	*Nymphoides peltata*
RIPARIAN PLANTS	
Japanese Knotweed	*Fallopia japonica*
Purple Loosestrife	*Lythrum salicarium*
Poison Hemlock	*Conium maculatum*
Lesser Celandine	*Ranunculus ficaria*
Dames Rocket	*Hesperis matronalis*
Mile-a-Minute Weed	*Persicaria perfoliata*
Porcelainberry	*Ampelopsis brevipedunculata*
Japanese Hops	*Humulus japonicus*
Multiflora Rose	*Rosa multiflora*
Oriental Bittersweet	*Celastrus orbiculatus*
Burning Bush	*Euonymus alatus*
Amur Honeysuckle	*Lonicera maackii*
Reed Canary Grass	*Phalaris arundinacea*
Common Reed	*Phragmites australis*
Japanese Stiltgrass	*Microstegium vimineum*
Princess Tree	*Paulownia fomentosa*
Tree-of-Heaven	*Ailanthus altissima*

greatest risk to aquatic and riparian communities. Establishing appropriate metrics to track progress would be advantageous.

General actions for agencies and Institutions include:

- Prevention of additional introductions
- Early detection and eradication of new pests
- Control and management of established problem species
- Protection and recovery of native species and ecosystems
- Improved education of the general public regarding their role in invasive species introduction and control.

To learn more about invasive species:

Pennsylvania Field Guide: Common Invasive Plants in Riparian Areas. Alliance for Chesapeake Bay, Harrisburg PA 2004.

Economic and Ecological Costs Associated with Aquatic Invasive Species by D. Pimentel in Symposium Proceedings: Aquatic Invaders of the Delaware Estuary, May 20, 2003. Edited by L H Ziska, R C Sicher, K George & J E Mohan. Penn State University 2007.

America's Least Wanted: Alien Species Invasions of U.S. Ecosystems edited by B A Stein and S R Flack. The Nature Conservancy, Arlington VA 1996.

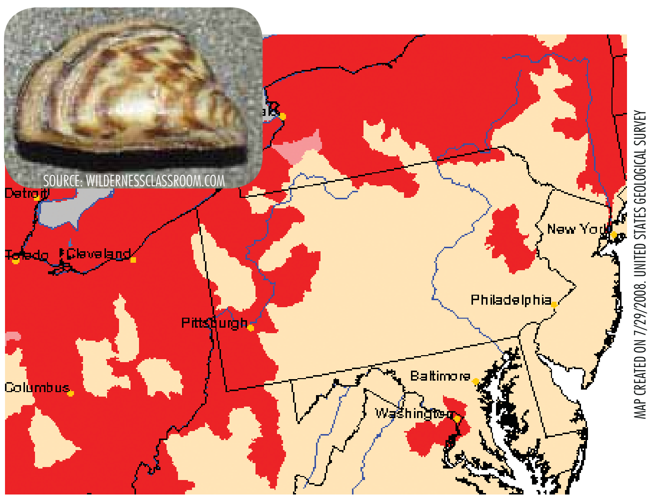


Fig. 3.18. Zebra Mussel Locations. The USGS reports that zebra mussels have been found in many areas surrounding the Basin. The areas in red on the map are hydrologic units (HUC 8s) where zebra mussels have established populations, competing with native mussel species. At this time, the only reported occurrence of zebra mussels in the Delaware River Basin is in Dutch Springs Reservoir, just north of Bethlehem, PA in Northampton County. The Lehigh River Watershed is of greatest risk of zebra mussels, where the reservoir is located, but precautions must be taken to ensure the invasive species is not introduced to any part of the basin.

Purple loosestrife, *Lythrum salicarium*, might be pretty but it competes with native plants for habitat all along the Delaware River.

Japanese knotweed (*Fallopia japonica*) is a large, herbaceous perennial plant, native to eastern Asia. In the US the species is very successful and has been classified as invasive. Tolerant of a wide range of temperature, soil types, pH and salinity, it readily colonizes riparian zones and sensitive wetlands, driving out native species. Its root system (rhizomes) can extend nearly 10 feet deep and 23 feet horizontally, making it difficult to eradicate and possibly exacerbating erosion along stream banks. Its flowers are valued as a nectar source by some beekeepers, and its young stems are edible.