CHAPTER 10

Macroinvertebrates

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Macroinvertebrates discussed here comprise a wide range of river fauna, including insects (adult and immature forms), worms, some crustaceans, and some mollusks. Macro here refers to creatures smaller than large freshwater mussels but large enough to be captured by screens used to filter samples as opposed to microscopic plankton (see Chapter 11). Macroinvertebrates inhabit all aquatic areas of the river, including the water column, soft substrates (sand and mud), and surfaces of aquatic plants, rocks, woody debris, and mussel shells. Because macroinvertebrates are distributed widely and can exhibit dramatic community changes when exposed to water and sediment pollution, they frequently are used as indicators of environmental quality (Fremling 1964, 1973, 1989; Rosenberg and Resh 1993).

Most investigations of the Upper Mississippi River System (UMRS) invertebrate communities have focused on bottom-dwelling macroinvertebrates that live in and on soft substrates. These animals, collectively called benthos, make a good subject for study because of their wide distribution throughout the system, sensitivity to human activity, and food value for fish and wildlife. Fingernail clams and burrowing mayflies (Figure 10-1) are the target organisms of most studies, but the equally important macroinvertebrates that inhabit aquatic plants and hard substrates like riprap also have been investigated (Figure 10-2, following page).

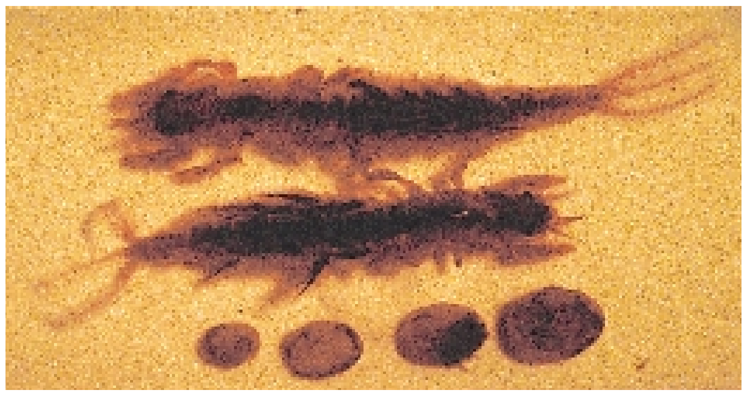


Figure 10-1. **Immature burrowing mayflies (top) and fingernail clams (bottom), though small, can occur in dense aggregates and provide a major portion of the diet for some fish and bird species. Pollution and sedimentation have caused macroinvertebrate populations to decline in the Upper Mississippi River System, especially the Illinois River. They are valuable as indicator species used to assess water quality.**

The importance of mayflies and fingernail clams as components of the river's aquatic food web is well known. Thompson (1973) found that during fall migration, lesser scaup diets included 76 percent fingernail clams and about 13 percent mayflies and that both organisms were important to canvasback ducks, ring-necked ducks, and American coots. Many river fishes, including commercial and recreational species, also consume large numbers of mayflies and fingernail clams (Hoopes 1960; Jude 1968; Ranthum 1969). Over a 22-year period on Pool 19, fingernail clams and mayflies accounted for 86 percent of the total benthic macroinvertebrate community biomass (Richard Anderson, Western Illinois University, Macomb, Illinois, personal communication).

Figure 10-2. **Caddis flies sometimes are present in high densities on rocks (above) and other hard substrates. On surfaces exposed to flow, they build nets (inset) to intercept and then graze on drifting organic material. The entire rock- or riprap-dwelling invertebrate community is little-studied on the river (Source: Brian Johnson, U.S. Army Corps of Engineers, St. Louis, Missouri [main photo]; Mike Higgins, Michigan State University, East Lansing, Michigan [inset photo]).**

Long-term widespread declines in benthic macroinvertebrates have had adverse effects on river fishes and birds. Mills et al. (1966) and Sparks (1980, 1984) described the mid-1950s decline of diving-duck migrations through the Illinois River Valley and suggested that the loss of the fingernail clam community was a principal causal factor (see Chapter 14). Sparks (1984) also attributes a decline in carp condition (or fitness) in the Illinois River to the loss of fingernail clams and other benthos.

Present Status

Macroinvertebrates are laborious to sample, identify, and count. Most studies of river macroinvertebrates therefore have been limited to small areas or short time frames. Since 1992, more widespread sampling in the six Long Term Resource Monitoring Program (LTRMP) study reaches has been used to assess spatial differences in burrowing mayflies and fingernail clams. One of the longest monitoring programs, conducted by Western Illinois University, has been ongoing in Pool 19 for 22 years.

Between 1992 and 1996, average fingernail clam densities in the LTRMP study reaches were 0–2,511 per square yard (0–3,013 per square meter; Figure 10-3). Mayfly densities were 0–237 per square yard (0–289 per square meter; Figure 10-4). Most samples contained no mayflies or fingernail clams and low densities were common. Total densities greater than 321 per square yard (385 per square meter) occurred in fewer than 15 percent of the samples. The high-density areas appear clumped in relation to environmental conditions (Figure 10-5).

The Pool 13 study reach consistently contained the highest densities of fingernail clams and mayflies. One possible explanation for this pattern is that Pool 13 is outside of a pollution gradient that extends downstream from Minneapolis-St. Paul, Minnesota (Wilson et al. 1995; Wiener et al. 1998). Another is that the substrates of the impounded area of Pool 13 are especially suitable to mayflies and fingernail clams.

Nonchannel aquatic areas of the Upper Mississippi River consistently support more benthic macroinvertebrates than channel areas. This pattern was anticipated, as the instability and sandy content of channel substrates make them a less-suitable habitat for most macroinvertebrate species than the muddier substrates of nonchannel areas. However, densities of fingernail clams in the Illinois River were higher in channel areas than in nonchannel areas. This exception may result from the finer-grained substrates of the Illinois River

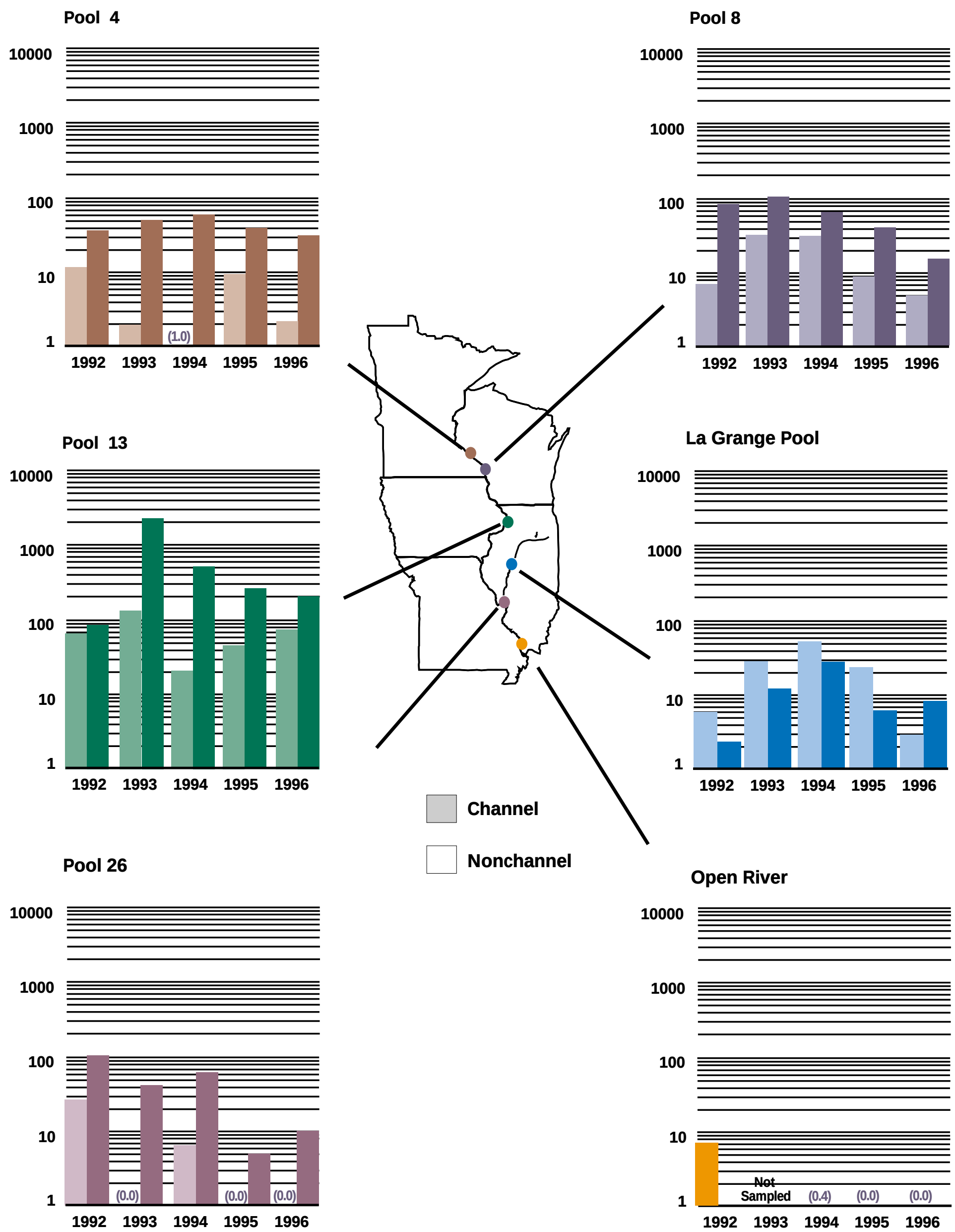


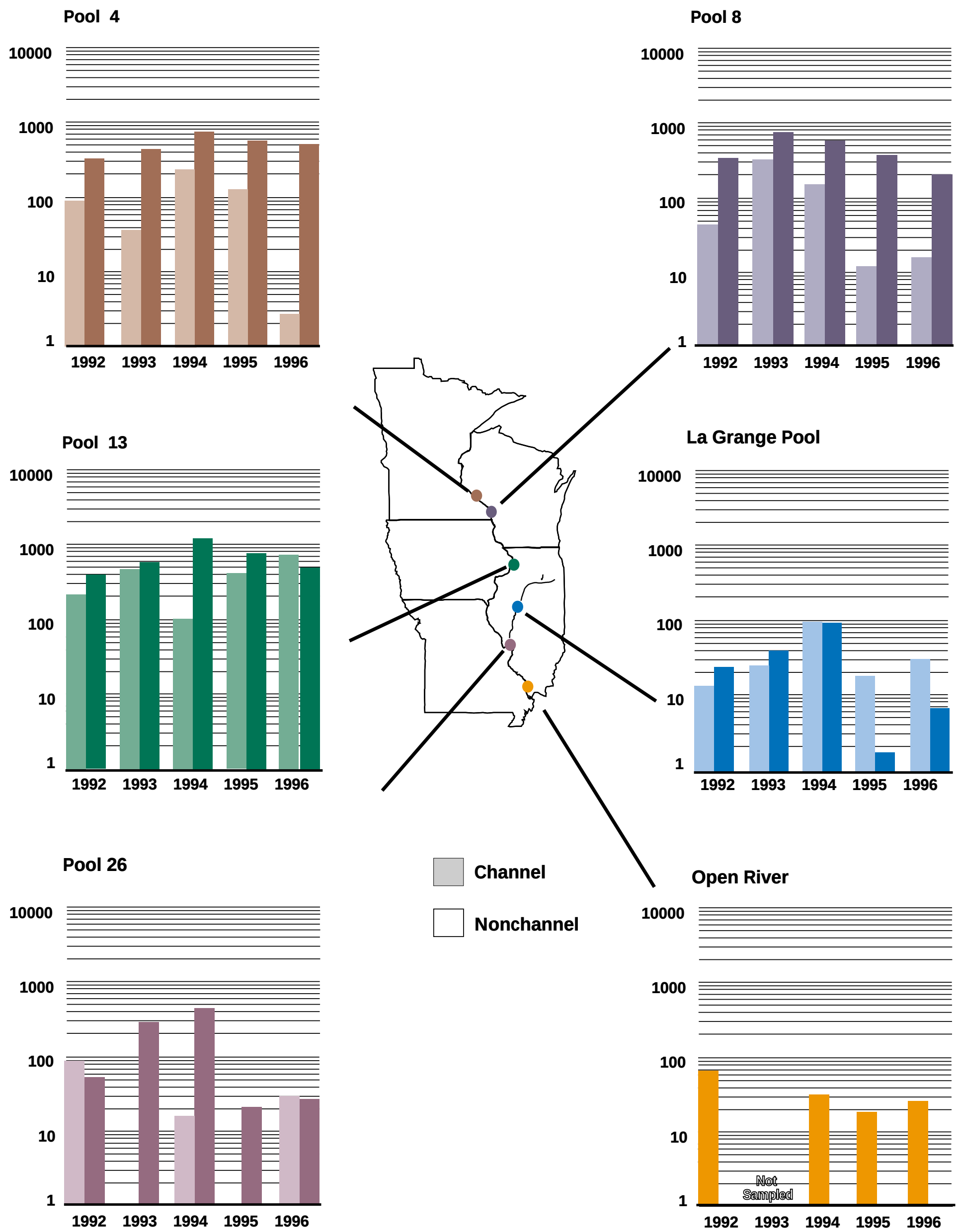
Figure 10-3. **Data collected in the Long Term Resource Monitoring Program study reaches over a 5-year period show that average finger-nail clam densities in numbers per square meter are consistently higher in nonchannel areas. Densities are lower in the Open River (Unimpounded) Reach because little nonchannel habitat exists. These macroinvertebrates are more abundant in the Illinois River channel because backwater sediments are silty. The Pool 13 impounded area con-sistently supported the highest density of fingernail clams. Note the logarithmic scale on the left axis of each graph.**

channel, the relative lack of channel border areas, and water and sediment quality problems in the river's shallow backwaters.

An investigation of fingernail clam distribution related to flow patterns around islands in Lake Onalaska (Pool 7) provided some insight into the clams' environmental preferences. The animals were most abundant in areas surrounding the islands which experienced low flow (2.4 inches [6 cm] per second) and were less than 6 feet (2 m) deep. Substrate preference was variable, but clay and silt composites tended to support higher population densities than sand or silt (Randy Burkhardt, USGS Environmental Management Technical Center, Onalaska, Wisconsin, personal communication).

Studies of macroinvertebrate communities other than bottom dwellers are limited in the UMRS, but the few studies conducted illustrate the importance of epiphytic (plant

Figure 10-4.
Burrowing mayfly populations in numbers per square meter in the six Long Term Resource Monitoring Program study reaches are variable between nonchannel and channel areas, with the exception of the (Unimpounded) Open River reach which has little non-channel habitat. Mayfly density has been similar in the three upstream reaches during the last five years. Except for 1993 and 1994 in Pool 26 the two downstream Mississippi River reaches and the Illinois River reaches have far fewer burrowing mayflies. Note the logarithmic scale on the left axis of each graph.



dwelling) and epilithic (rock dwelling) macroinvertebrate communities. Epiphytic macroinvertebrate studies have been conducted in the Finger Lakes Habitat Rehabilitation and Enhancement Project monitoring studies (Barko et al. 1994), Lake Onalaska (Pool 7; Chilton 1990); and Swan Lake (Lower Illinois River; Charles Theiling, USGS Environmental Management Technical Center, unpublished data). Consistent among all the studies was high species diversity and density but low biomass compared to other habitats (see also Anderson and Day 1986). In the Finger Lakes, macroinvertebrate biomass, density, and species diversity also were higher in sediments underlying plants than in open-water sediments. The diverse epiphytic macroinvertebrate community typically supports more species of predaceous macroinvertebrates (i.e., dragonfly nymphs, beetles, etc.; Chilton 1990) than do open-water sediments.

Epilithic communities in the UMRS now are confined mostly to wing dams, revetted banks, and other channel-training structures made of limestone rock. In the unmodified river they would have been found on woody debris, on boulders in rapids, and on cobble sediments of the river bed. Recent studies have been completed in Pool 8 (William Richardson, USGS Upper Mississippi Science Center, La Crosse, Wisconsin, unpublished data), Pool 24 (ESI 1995, 1996) and Pool 26 (Seagle et al. 1982). Several more studies are ongoing in the Middle Mississippi and lower-pooled reaches. These studies consistently find high densities of hydropsychid caddis flies (Figure 10-2), exceeding 16,670 per square yard (20,000 per square meter), with the remaining community being quite diverse—94 taxa in Pool 24 (ESI 1995). The community composition associated with rock substrates also is interesting to note because the dominant taxa, (hydropsychid caddis flies) are indicators of good water quality.

The open-water invertebrate community consists of animals that are free-swimming (e.g., water boatmen, beetles), those that float in the water column (e.g., zooplankton), or live on the surface of the water (e.g., whirligig beetles, water striders). The open-water community usually is most abundant in aquatic plant beds and flooded terrestrial vegetation. Although intensely studied in many wetlands and waterfowl management areas because of their importance as waterfowl food (see Reid et al. 1989 for review), this community has been unstudied in the Upper Mississippi River. These invertebrates also are important for fish populations, especially the zooplankton eaten by larval fish. Theiling et al. (1994) studied the nekton during extreme flooding in 1993 and found about 9,600 animals per cubic yard (11,500 per cubic meter) at the rising edge of the flood (mostly water boatmen) and only 54 per cubic yard (65 per cubic meter) on the falling flood. Nekton densities were much lower in open water compared to the shoreline. Anecdotal observations indicate that zooplankton and other nekton are distributed unevenly and may be present in high densities under some conditions.

Macroinvertebrate data are commonly reported according to density (number for a given area); however, biomass (weight of invertebrates per unit area) or productivity (total biomass produced for a given time span) may be better measures of the contribution of the macroinvertebrate community as food value to fish and wildlife. Annual productivity estimates can provide an assessment of the amount of invertebrate food resources available to fish and wildlife because many invertebrate species produce

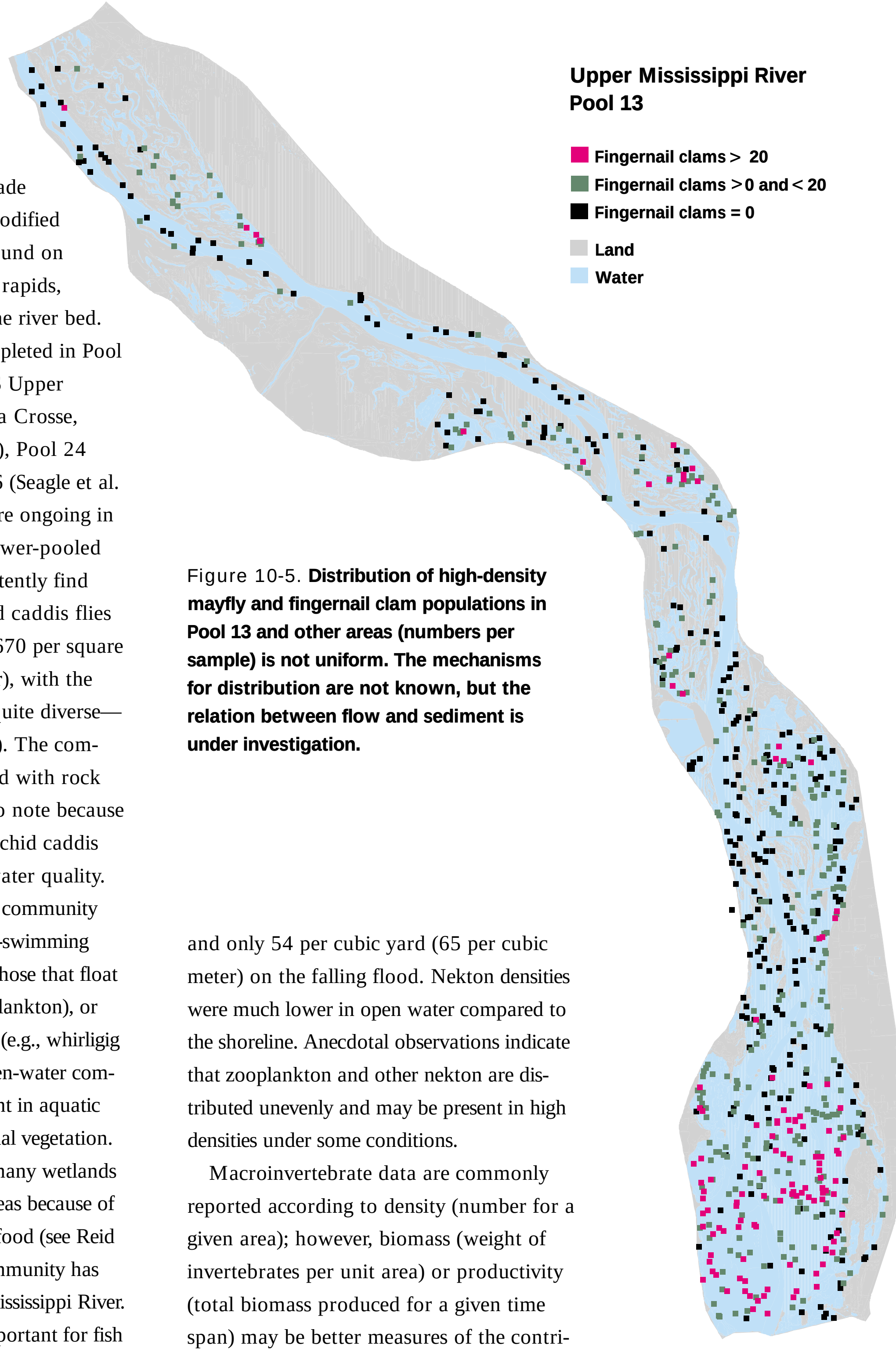


Figure 10-5. **Distribution of high-density mayfly and fingernail clam populations in Pool 13 and other areas (numbers per sample) is not uniform. The mechanisms for distribution are not known, but the relation between flow and sediment is under investigation.**

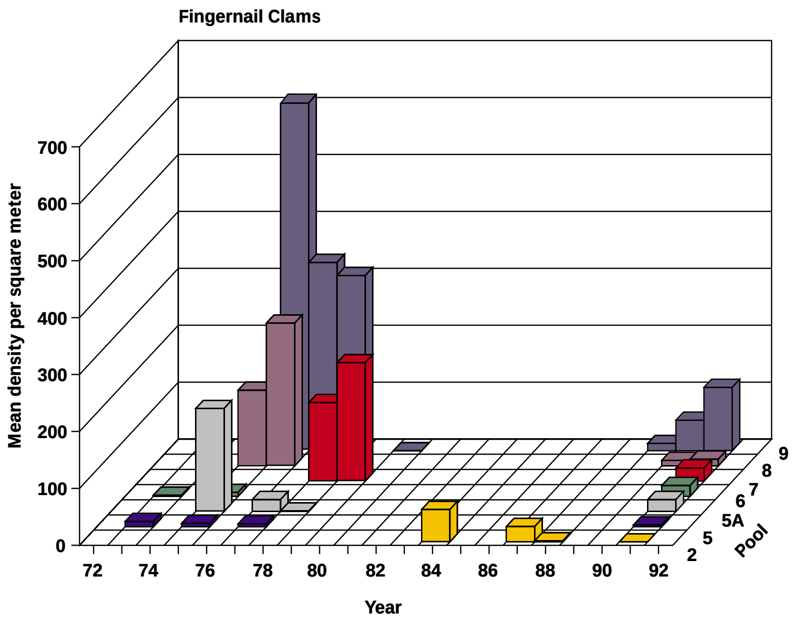


Figure 10-6. **A compilation of available data for fingernail clams in Pools 2 and 5 through 9 documents a decline in density (numbers per square meter) in Pools 5A, 7, 8, and 9. The compilation also reveals a large gap in data collection between 1978 and 1988. Domestic and industrial pollution are believed responsible for the population changes (Source: Wilson et al. 1995).**

multiple generations per year and a one-time sampling cannot account for the total energy available. However, the process to determine productivity is laborious and costly.

Change Over Time

Wilson et al. (1995) recently compiled and compared studies of fingernail clams between Pools 2 and 9. The results (Figure 10-6) highlight site-specific declines, but also indicate large gaps in the database. Wilson et al. (1995) discussed a variety of potential causal factors related to the observed changes. They hypothesized that population declines in the late 1980s were linked to domestic and industrial pollution originating in the Minneapolis-St. Paul area, rather than dredging or commercial traffic activity. Metal-contaminated sediments and ammonia were suspected as causal factors.

Contrasting with the decline of fingernail clams described by Wilson et al. (1995) is the recovery of mayflies between Pool 2 of the Upper Mississippi River and Lake Pepin (Pool 4; Fremling 1989). Recovery is attributed to improved waste treatment in the Twin Cities area and resultant higher dissolved oxygen concentrations (see Chapter 7). Wilson et al. (1995) suggest that the surface-water filtering behavior of mayflies (similar to caddis flies on rocks) has allowed them to recover faster than fingernail clams, which probably filter more heavily contaminated sediment pore water.

Since the compilation of Wilson et al. (1995), James Eckblad of Luther College in Decorah, Iowa (personal communication), repeated his collections of fingernail clams in seven backwater lakes in Pool 9 (Figure 10-7). His 1995 results indicated a return to high densities more typical of the mid-1970s. Increases in fingernail clam densities during 1995 in the impounded area of Pool 9 also were observed by staff members of the Upper Mississippi River Wildlife and Fish Refuge (Eric Nelson, U.S. Fish and Wildlife Service, Winona, Minnesota, personal communication).

The most consistent data records for Upper Mississippi River benthic macroinvertebrates have been compiled on Pool 19 and on the Illinois River (see Chapter 14). On Pool 19, annual observations between 1972 and 1992 (Wilson et al. 1995) indicated a major decline in biomass (Figure 10-8). Densities often higher than 8,400 per square yard (10,033 per square meter) through the 1970s and 1980s dropped to below 15 per square yard (18 per square meter) between 1989 and 1991 (Wilson et al. 1995). Densities in this same location were more than 83,000 per square yard (100,000 per square meter) in 1967 (Gale 1975). However, continued monitoring during 1994 and 1995 indicates a strong recovery in the fingernail clam population (Richard Anderson, Western Illinois University, Macomb, Illinois, personal communication). The study area in Pool 19 is noteworthy because data has been collected here longer than in any other UMRS pool. It also has the oldest dam on the river. The

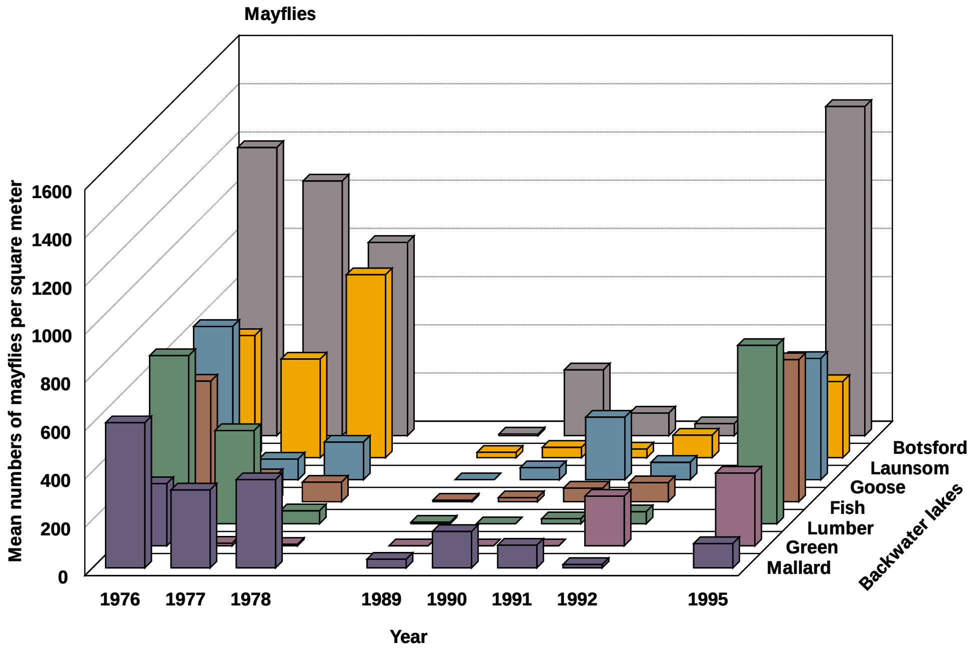


Figure 10-7. **Mayfly densities (numbers per square meter) during 1989 to 1992 in Pool 9 backwaters were lower than densities recorded in the late 1970s. When investigated again in 1995, most backwaters had recovered (Source: Jim Eckblad, Luther College, Decorah, Iowa).**

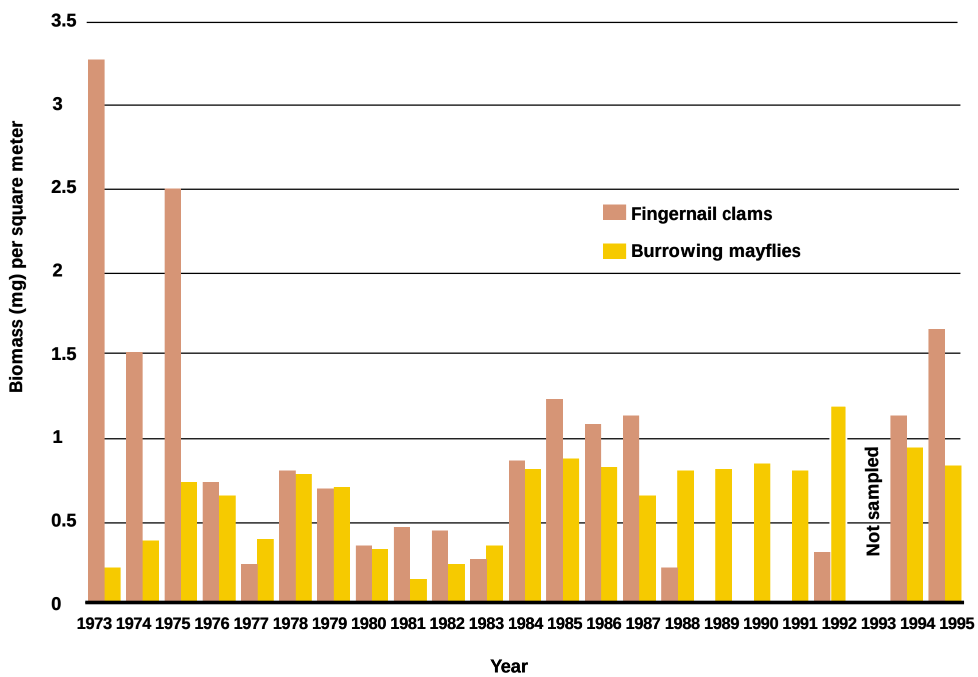


Figure 10-8. **Fingernail clam and mayfly populations (as measured by population biomass [milligrams ash-free dry weight per square meter]) have been tracked in Pool 19 continuously for more than two decades. Population biomass has been cyclical over this period—declines in the mid-1970s were followed by recovery in the mid-1980s, severe declines in the late-1980s, and recovery after the 1993 flood. One consequence of the flood was increased interest in the relation between benthic communities and flow. Mayfly biomass has remained generally stable for the last 10 years (Data provided by Rick Anderson, Western Illinois University, Macomb, Illinois).**

river bottom at the study site located upstream of the dam has been raised into the photic zone suitable for aquatic plants by excessive sedimentation and sediment trapping at the dam (see Chapter 4). Now moderate- to low-flow years favor the growth of aquatic plants in the area, whereas years of high flow limit the distribution of plants and make the greater surface area of the river bottom suitable for fingernail clams and burrowing mayflies.

Observations of the Mississippi and Illinois Rivers provide additional cause for concern about the decline of benthic macroinvertebrate communities.

Sparks (1980) related the 1976–77 decline of fingernail clams in the area to drought. Borash and Anderson (1995) described how the Flood of 1993 scoured their study site and provided conditions more suitable for high fingernail clam and mayfly densities. Recent annual changes in the benthic macroinvertebrate community at this site relate to hydraulic patterns that affect particular aquatic areas, although long-term declines in benthos abundance likely are attributable to the development of silty substrates and toxic sediments. Sediment quality as a determinant of benthic communities has been examined extensively in the Illinois River where pollution and sedimentation nearly eliminated those communities (see Chapter 14).

Discussion

Are macroinvertebrate densities observed during the early years of the LTRMP low or average relative to long-term means and ranges? Our limited knowledge of annual and long-term changes and spatial patterns of macroinvertebrate density prevents us from answering this question definitively. Whereas LTRMP observations provide adequate mean estimates for broadly defined aquatic areas in the LTRMP study reaches, no similar comprehensive inventories were made in the past. This means that direct river-wide comparisons to pre-LTRMP time periods are impossible, with the notable exception of the Illinois River.

The combination of historic and current macroinvertebrate data sets available from the UMRS do, however, provide a baseline for evaluating the LTRMP study reaches and suggest important additional information needed in the future. Observations of the Mississippi (Wilson et al. 1995) and Illinois (see Chapter 14) Rivers provide additional cause for concern about the decline of benthic macroinvertebrate communities. Warning signals raised by these observations formed part of the initial justification for including benthic macroinvertebrates as a monitoring component of the LTRMP.

However, even the most intensive historic studies are limited either over space or time. These limitations require us to be conservative when speculating about what might be happening throughout the rest of the UMRS. In 1995, fingernail clam densities rose in Pools 9 and 19, but this may not have been typical of other areas. For example, mean densities of the clams in Pool 8 did not show a similar improvement.

Different annual patterns of a change in density among the study reaches and habitats suggest that macroinvertebrate community response often (if not frequently) is controlled by local conditions rather than “whole-river” factors. Our knowledge of long-term population cycles is poor, which makes it difficult to distinguish short-term changes influenced by human activities from those controlled by natural forces. Also, the past focus on benthic communities has created a large data gap for other macroinvertebrate communities that may serve as bioindicators of the health of the UMRS.

Information Needs

Additional information is necessary to evaluate the river macroinvertebrate community status and provide scientific data for management decisions necessary to maintain their densities at appropriate levels. For example, better estimates of macroinvertebrate community distribution are needed. Current LTRMP data suggest that benthic macroinvertebrate densities are low throughout the UMRS, but site-specific studies indicate that high densities occur in some areas. A review of benthological studies indicates that macroinvertebrate communities do not respond to natural factors or human activities as a single unit along the length of the UMRS, or perhaps even within a single pool reach.

We know that from one year to the next, spatial patterns of waterfowl use of river areas shifts, presumably in response to short-term changes in macroinvertebrate abundance and distribution. In the absence of pollution or large-scale flooding, local hydrology and its effect on substrate composition may be a primary controlling factor for soft-substrate-macroinvertebrate community development in any given year. This would explain why declines observed at some sites do not register at the broader spatial scales studied under the LTRMP. Greater knowledge of macroinvertebrate spatial-distribution patterns will allow us to develop a better hypotheses about the causal factors that control macroinvertebrates in a selected river reach and to identify appropriate spatial limits for management objectives.

We need to know what minimum level of macroinvertebrate density or biomass is needed to support viable fish and wildlife populations. For instance, what density of fingernail clams is needed to support migrating lesser scaup on a specific river reach and how many acres of open water are needed to meet this minimum level? Takekawa (1987) provided some of the limited knowledge we have in this area. He demonstrated that a diving duck needs to consume about five fingernail clams per dive to maintain its energy level during the fall migration. We do not know what density of fingernail clams is sufficient to support this level of grazing. Nor do we know how much aquatic area of suitable river bottom is necessary to support a population of migrating ducks.

Another advance would be standardization of data collection and reporting to compare the food value of one macroinvertebrate community over another, and to document fish and wildlife food habits in relation to the availability of macroinvertebrate resources. Progress in this area will provide the information needed to set practical management objectives for fingernail clams and mayflies and to ensure their future viability and the ecological services they provide.

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Current LTRMP data suggest that benthic macroinvertebrate densities are low throughout the UMRS, but site-specific studies indicate that high densities occur in some areas.

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