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# 316(b) and Quad Cities Station, Commonwealth Edison Company

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**Abstract**

Quad Cities Station is a 1630 $MW_e$ dual reactor facility located on the Upper Mississippi River approximately 30 miles north of Davenport, Iowa and Rock Island, Illinois. As designed, the Station utilizes river water at the rate of 2270 cfs in an open-cycle mode of operation. From the 316(b) perspective, numerous agencies and intervenors expressed major concern regarding the potential adverse impacts of open-cycle entrainment and impingement effects on the River's highly valued and diverse fishery. As a result, the fishery has been monitored continuously since 1971 through field surveys directed at measurements of community composition and relative abundance, as well as fish impingement surveys of the Station's intake. From 1972 to 1983 the Station operated in a closed-cycle or partial closed-cycle mode.

Regulatory relief and intervenor approval for open-cycle operation were not granted until 1984, following several years of intensive studies directed at entrainment/impingement and methods to reduce impingement. Beginning in 1978, the freshwater drum was selected as the indicator species most likely to manifest changes in population characteristics potentially resulting from open-cycle operation. Population levels (numbers and biomass), growth, fecundity, sex ratios and survival were all monitored to determine if compensatory responses occurred within the population following increases in impingement under open-cycle operation. Included in the agreement that allowed the return to open-cycle operation was a commitment to construct and operate a fish production facility to mitigate for potential impacts.

After 14 years of monitoring under open-cycle operation, there have been no measurable changes in the local fishery and, specifically, none within the freshwater drum population. Naturally occurring environmental conditions have more profound influences on this dynamic and resilient fishery than operation of a large generation facility. Station operation is relatively constant from year to year and impingement monitoring may actually be the most accurate monitoring activity. Fluctuations in annual impingement projections are reflections of conditions within the river and the fishery's response to them. Increases or decreases in fish numbers impinged at the Station in any given year are primarily due to fluctuations in the fishery and the effects of existing environmental variables and not to Station operation. The fishery fluctuations are reflections of conditions within the river and the fishery's response to them. 

*Keywords:* Power plant; Fish entrainment; Fish impingement; Ichthyoplankton; Survival; Population estimates

## 1. Introduction

Aquatic biological monitoring of Pool 14 of the Upper Mississippi River (UMR) in the vicinity of Quad Cities Station has been conducted continuously from 1971 to the present. Throughout the history of Quad Cities Station, the design, objectives and interpretation of results from monitoring efforts, as well as special investigations, have been a collaborative effort involving ComEd, consultants, regulatory agencies, resource managers and intervenors. A Steering Committee, comprised of representatives from all the sectors listed above, meets annually to review study results from the previous year and to formulate new direction for ongoing work. During this period of time the Station has operated in both open- and

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closed-cycle modes. The purpose for these investigations has been to determine if there have been any measurable adverse impacts to the local biota attributable to Station operation, from either thermal discharge [316(a)] or entrainment/impingement [316(b)]. Early investigations (1971–1977) addressed all major trophic levels; however, since 1978 studies have focused on monitoring of the River's highly valued and diverse fishery. 316 (a) and (b) demonstrations were first submitted to USEPA in 1975 (Commonwealth Edison Company, 1975) followed by supplemental demonstrations in 1981 (Commonwealth Edison Company, 1981). An initial account of fish impingement and impact assessment was prepared by Latvaitis et al. (1976). More recently, a 24-year synopsis of major survey findings relative to the local fishery was developed by Bowzer and Lippincott (1995).

Quad Cities Station has commissioned many more aquatic studies than any other facility in the ComEd system and we are not aware of any other generating facilities in the Midwest with as extensive a data base. We have conducted more monitoring than is typical due to major design changes (closed-cycle, spray canal) and because of serious questions raised about possible effects on the resource. Monitoring programs were developed by a consensus of stakeholders. The extensive monitoring that has been performed has successfully resolved many issues. Ongoing monitoring to date continues to confirm earlier results of no measurable effects of Station operation on the River's fish community. For all intents and purposes, ComEd's resolution of issues related to 316(b) at Quad Cities Station were satisfactorily completed in late 1983 with the issuance of a new NPDES permit allowing open-cycle operation. The Illinois Environmental Protection Agency (IEPA) revisits issues related to 316(b) during NPDES permit renewals. IEPA is a participant in the Steering Committee.

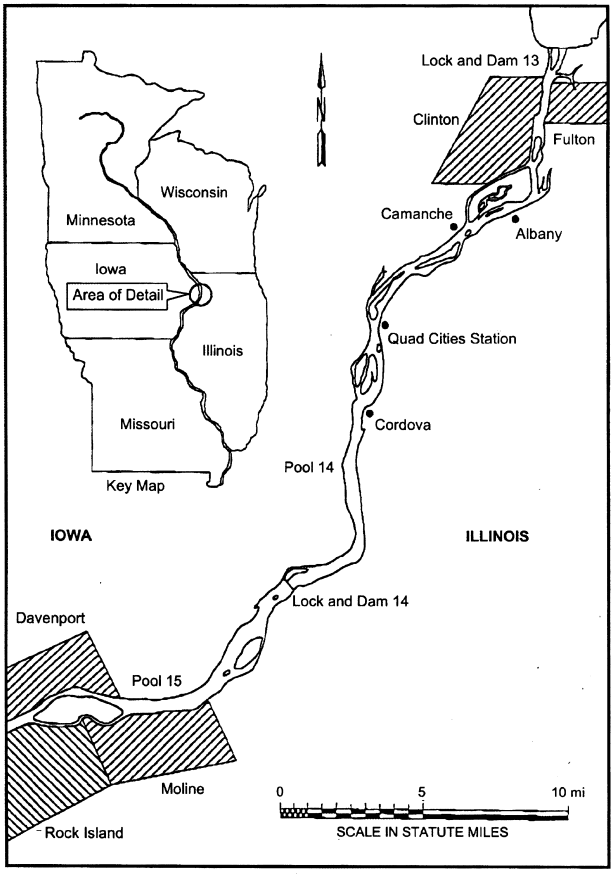



Fig. 1. Pool 14 of the Upper Mississippi River near Quad Cities Station.

## 2. The station and its environmental setting

The UMR segment that extends from St Anthony Falls, Minnesota to Alton, Illinois is divided into numbered navigation pools each separated by a lock and dam.

Quad Cities Station is located near the mid-point of this system on Pool 14 of the UMR, approximately 30 miles north of Davenport, Iowa and Rock Island, Illinois (Fig. 1). The Station is a 1630 $MW_e$ dual reactor facility which began commercial operation in 1972. As designed, the Station utilizes river water at the rate of 2270 cfs in an open-cycle mode of operation. Condenser cooling water is warmed a maximum of 12.8°C (23°F) above ambient before being discharged to the river.

The original discharge design for Quad Cities Station was an on-shore side-jet discharge along the Illinois bank of the river. This design was utilized for only 8 months when a thermal-hydraulic study determined that this type of discharge would violate the State of Illinois thermal criterium, which limits the maximum temperature rise to 2.8°C (5°F) above ambient at the edge of the 600 ft radius mixing zone.

The Station discharge design was then modified into a multi-port diffuser pipe system, which transports heated condenser water out to the main channel of the river through two 16 ft diameter pipes. Condenser water is discharged through a series of 29-in diameter diffuser ports across the top of each pipe. With this system, heated condenser water is completely mixed with river water and meets the 2.8°C criterion within 500 ft downstream of the diffuser pipes. The Station operated in an open-cycle mode on this diffuser system from August 1972 to May 1974.

In resolution of a lawsuit brought by the Attorney General of Illinois, the Izaak Walton League and the United AutoWorkers, ComEd constructed an off-stream spray canal system for cooling the condenser discharge water from the Station. The Station operated

in a closed-cycle or partial closed-cycle mode from May 1974 to December 1983. However, the cooling capacity of the spray canal system was inadequate to allow normal plant operation, particularly during the summer months. Substantial generation deratings occurred that resulted in the use of generation from elsewhere in the ComEd system to supplement lost production.

Concurrent with the history of the Station, extensive monitoring of the river's fishery has been conducted each year to assess the impacts of Station operation. Results of these studies have not demonstrated any measurable effects of Station operation on the aquatic communities of the river under either closed-cycle or open-cycle operation. The results have been and continue to be reviewed and approved by independent reviewers.

In the early 1980s, in consideration of the findings to date, ComEd petitioned the regulatory agencies and intervenors to allow Quad Cities Station to return to open-cycle cooling and to discontinue further use of the spray canal for cooling purposes. A new agreement was reached with the intervenors allowing open-cycle cooling using the diffuser pipe system, contingent upon continued monitoring of the fish community. This agreement became effective in late-1983 and the Station continues to operate in accordance with the agreement.

As previously mentioned, maximum cooling water flow for the Station under open-cycle operation is 2270 cfs. At low river flow (16,000 cfs), mean intake velocity with all pumps operating is approximately 1.5 ft/s at the traveling screens. Intake velocity measurements taken at the entrance to the intake forebay averaged less than 1.0 ft/s at a river flow of 30,000 cfs. At average river flows (54,000 cfs), intake velocities are lower. When ambient river water temperature falls below 4.4°C (40°F) in the late autumn, cooling water requirements for the Station can be reduced by one half. This is accomplished by opening the ice-melt recirculation line and by idling one condenser circulating water pump from each unit. During this period, current velocities at the forebay entrance and traveling screens are also reduced by approximately 50%.

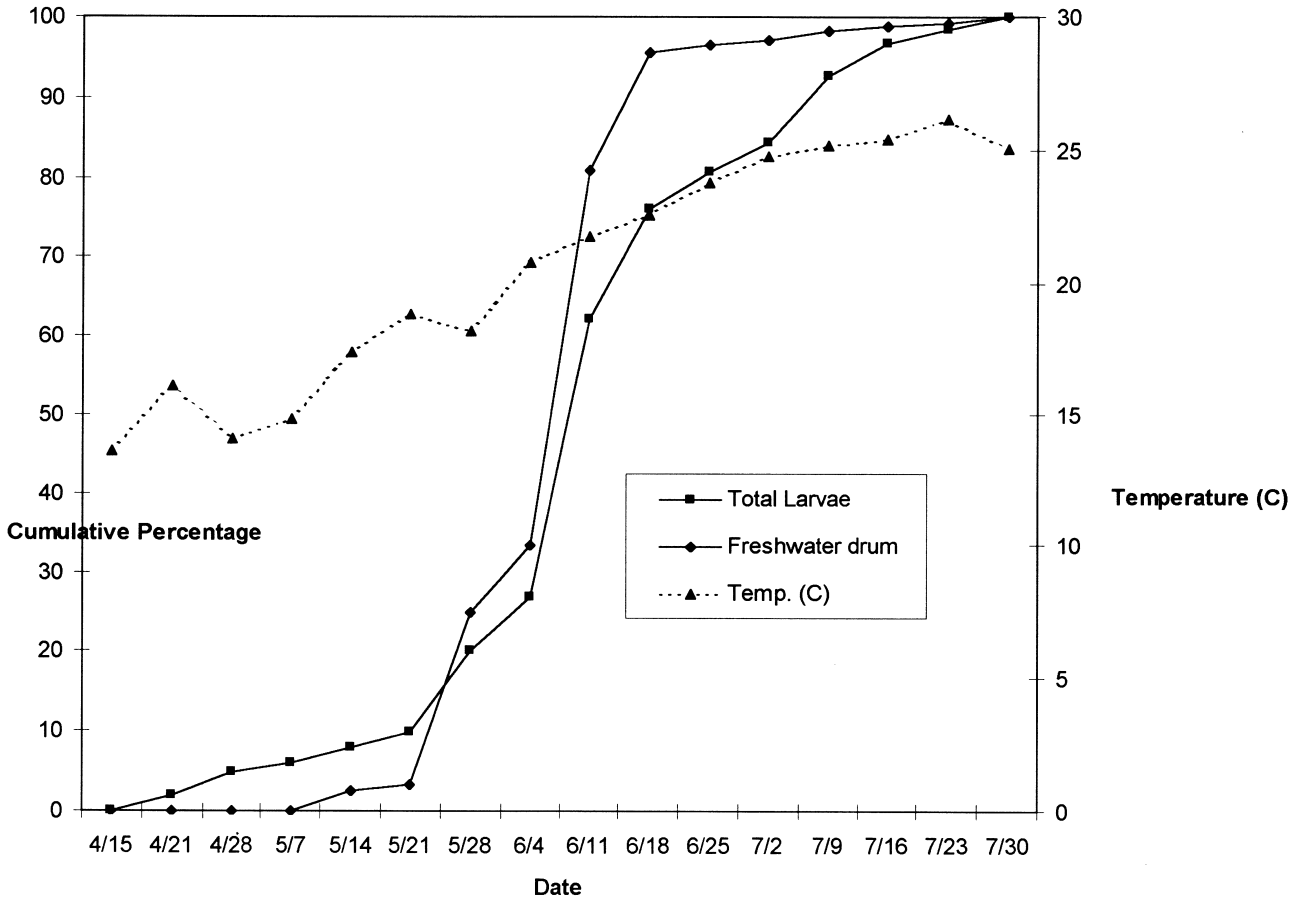



Fig. 2. Cumulative passages of total larvae and freshwater drum larvae, and mean water temperature in Pool 14, Quad Cities Station, 1984–1985 (data are mean of 2 years).

## 3. Monitoring efforts

Monitoring the potential impacts of Station operation on the fish community of Pool 14 has occurred continuously from 1971 to date using a variety of traditional collection techniques and sampling strategies. Detailed descriptions of sampling methodologies, locations and equipment are not included in this paper, but can be found in annual reports submitted to ComEd. The objectives of these efforts were directed at measurements of community composition and relative abundance.

More direct approximations of potential Station impacts were developed through ichthyoplankton drift/entrainment surveys and impingement monitoring. Fish impingement at Quad Cities Station has been monitored from 1973 to date and annual projections of total impingement are reported to IEPA. Ichthyoplankton drift and entrainment have been monitored at varying levels of intensity from 1975 to 1985.

Shortly after the spray canal became operational in mid-1975 and the Station changed from open-cycle operation to closed-cycle operation, it became apparent that its cooling performance was unacceptable. Power production was far below capacity and the Station could not operate either efficiently or economically. Before any modifications to existing NPDES permits or intervenor agreements could be considered; however, specific questions and concerns regarding operational impacts on the fish community had to be addressed. Consequently, in 1978 some monitoring program elements were intensified and additional special studies were developed.

Ichthyoplankton drift/entrainment sampling was greatly expanded in 1978 and supplemented with an intensive study on entrainment survival (Restaino et al., 1979). This effort was essentially duplicated again in 1984, the Station's first year of returning to open-cycle operation (Lawler, Matusky & Skelly Engineers (LMS), 1985). In 1979, experimentation began with a net barrier system across the entrance of the intake forebay in an effort to reduce fish impingement losses (Commonwealth Edison Company, 1981). Backwater rotenone surveys and sampling with haul seines were also added in 1978 to estimate the standing crop of certain fish species within Pool 14. Results of these efforts were then compared with impingement estimates to provide some approximation of cropping effects on population levels.

While no list of 'representative important species' had been formulated to address 316(b) issues, dialog between ComEd, regulatory agencies and intervenors identified the need to study the potential impacts of open-cycle Station operation on the population dynamics and various life history parameters of a fish species most likely to be affected. The freshwater drum was selected for these special studies based on its overall abundance throughout Pool 14, the vulnerability of planktonic early life stages to entrainment, and the high numbers routinely encountered in impingement collections. A series of special studies began in 1978 whose focus was to monitor population levels (numbers and biomass), growth, fecundity, sex ratios and survival of freshwater drum to determine if compensatory responses occurred within the population following increases in impingement under open-cycle operation. The relatively high numbers of freshwater drum impinged during the winter also was of particular concern, so a special research project was commissioned to try and determine the cause (Lewis and Bodensteiner, 1985). Many of these special program elements remain active monitoring efforts today as part of the Station's commitment for continued monitoring.

## 4. Results and discussion

Assessing the potential impacts of ichthyoplankton

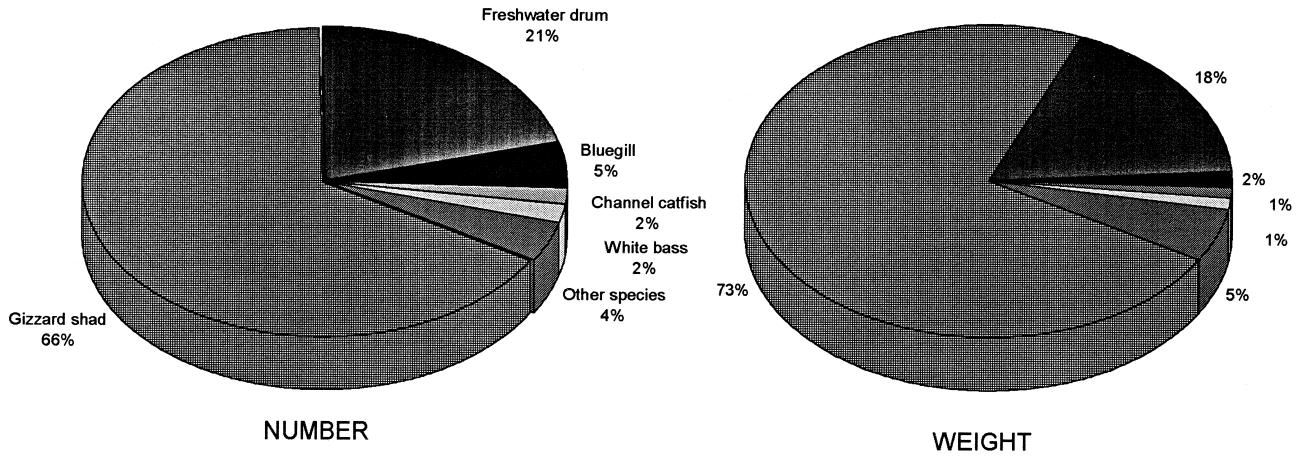



Fig. 3. Mean annual impingement composition at Quad Cities Station during open-cycle operation, 1984–1994.

entrainment first required a characterization of the composition, distribution and duration of the 'drift'. In Pool 14, the ichthyoplankton drift season typically runs from mid-April through late-July, although a few 'straggler' larvae can still be found in August. There is minimal to no difference in density between day vs night collections nor in depth within the water column. Ichthyoplankton density typically is higher along the Illinois bank (Station side) than along the Iowa bank or in mid channel, but not for all taxa. Freshwater drum dominate the drift assemblage, comprising over 80% of the eggs collected and 57% of all larvae. Other common species are emerald shiner and common carp. Lesser contributions come from sunfishes, gizzard shad and buffaloes.

Though the drift season extends from mid-April to July, the peak period of larval drift occurs from late-May to early-July, which coincides with the peak in freshwater drum abundance (Fig. 2). During this period, water temperatures range from 18 to 24°C (64–75°F). By early-July, almost 85% of all larvae and up to 97% of freshwater drum larvae have passed the Station. These observations are integral in evaluating the magnitude of entrainment impacts.

Under open-cycle operation, assuming the worst case scenario of total mortality of all entrained ichthyoplankton, it is a simple matter to estimate the numbers of ichthyoplankton entrained compared to the total flux of ichthyoplankton passing the Station and calculate a percentage of loss. Under these conditions, projected entrainment losses could have been reported as high as 5.4% of total ichthyoplankton (Commonwealth Edison Company, 1981). However, a number of studies at other stations have shown that the assumption of 100% mortality is not valid (Ecological Analysts, Inc., 1977; Cada, 1977; King, 1978; Stevens and Finlayson, 1978). Entrainment survival studies conducted at Quad Cities Station in 1978 (Restaino et al., 1979) and again in 1984 and 1985 (Lawler, Matusky & Skelly Engineers, 1985, 1986) demonstrated that substantial percentages of entrained ichthyoplankton do survive condenser and diffuser passage depending on Station operating capacity and intake water temperature. At discharge temperatures of up to 33°C (91.4°F), Restaino estimated larval survival of up to 70%. LMS reported similar results in 1984. As long as discharge temperatures do not exceed 37.8°C (100°F), some entrainment survival does occur.

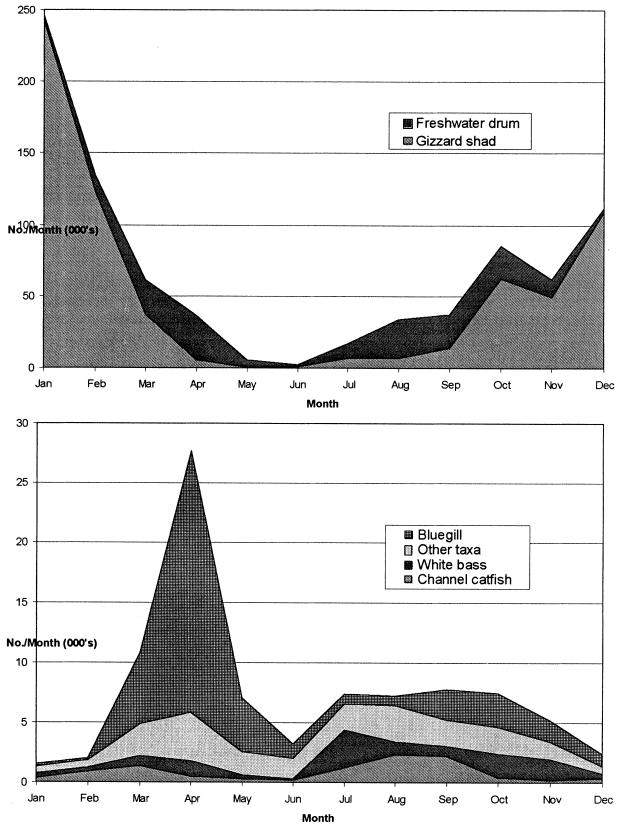



Fig. 4. Mean monthly impingement estimates of dominant fish species at Quad Cities Station under open-cycle operation, 1984–1994.

Applying these survival data in reference to Fig. 2, 84% of all larvae and 97% of freshwater drum larvae will have passed Quad Cities Station before discharge water temperatures become too warm to expect some level of entrainment survival. In 1984, LMS (1985) estimated that Station impact on total larvae, assuming 100% mortality, ranged from 0.1 to 0.7%, depending on taxon. However, after applying entrainment survival data to freshwater drum, common carp and buffalo species, the range of impact on these species were 0.0006–0.10%, 0.0000–0.0055%, and 0.000–0.004%, respectively. These projections of cropping are not considered to adversely affect the fish community of Pool 14.

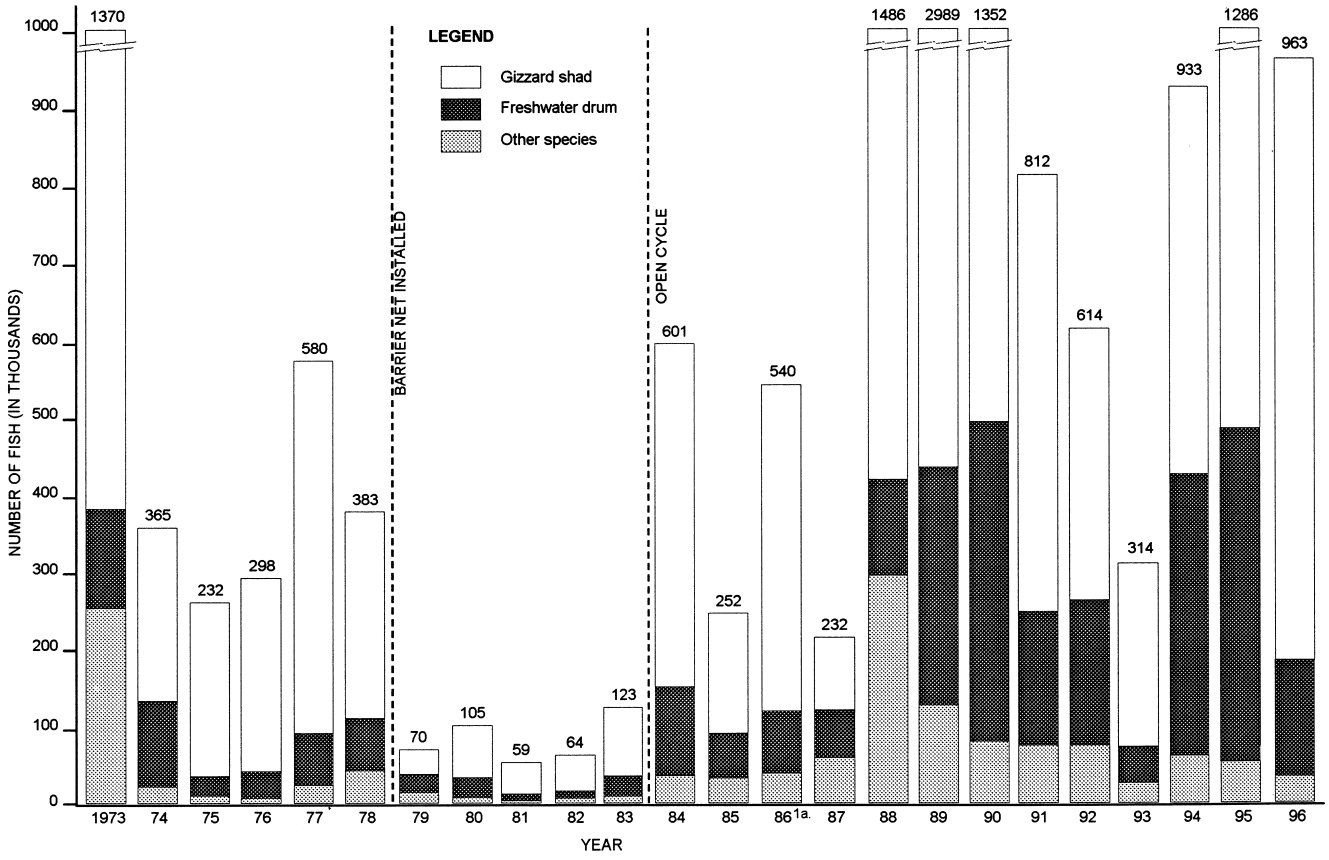
The issue of fish losses due to impingement was of greater concern to the stakeholders, particularly regarding the return to open-cycle operation in 1984. Resource management agencies and intervenors recognized that impingement numbers would probably increase under open-cycle operation and, as a mitigative action, secured a commitment from ComEd to convert the inactive cooling canal into a game fish rearing facility. Fish produced in the canal are earmarked for stocking Pool 14 as a means of increasing game fish populations and improving sport fishing opportunities in the area.

Fish impingement has been highly variable over the history of the Station due to three different modes of operation, experimentation with a net barrier system, natural fluctuations in fish abundance and major perturbations affecting the environment. Assessing the impact of impingement on 91 fish species known to occur in Pool 14 of the UMR is

simplified by the fact that only a few species are impinged in high enough numbers to warrant a detailed discussion. Gizzard shad and freshwater drum dominate annual impingement projections (Fig. 3). Collectively, these two species account for almost 90% of the numbers and biomass of all fish impinged. Far lower contributions are made by bluegill (5% by number, 1.6% by weight), white bass (1.9% by number, 1.2% by weight) and channel catfish (1.7% by number, 1.1% by weight). The remaining 86 species typically account for 4% by number and 5.5% by weight.

In most years, impingement increases during the autumn and remains high throughout the winter and spring regardless of Station operational mode (Fig. 4). The greatest number of fish typically are impinged during the winter months, with fewer fish being impinged during the May to August period. Gizzard shad impingement usually peaks in January and February coincident with the stresses of freezing or near-freezing water temperatures. As gizzard shad numbers decline, freshwater drum numbers increase and peak in March or April. Impingement of bluegill, white bass and channel catfish peak in April, July, and August–September, respectively. Impingement is primarily comprised of young fish (young-of-year or yearlings) which, particularly in the case of gizzard shad and freshwater drum, cannot tolerate the near-freezing water temperatures that occur in the main channel and side channels during the winter months (Bodensteiner and Lewis, 1992, 1994).

Figs. 5 and 6 illustrate annual impingement projections from 1973 to 1996. Projections made from 1974 to 1978 (closed-cycle or partial closed-cycle) are similar to projections from 1984 to 1987 (open-cycle with net barrier system). Low impingement projections from 1979 to 1983 represent a period of partial closed-cycle operation with the net barrier system. While the net barrier system effectively reduced impingement under partial closed-cycle Station operation, it could not function effectively under the increased intake flows of open-cycle operation. Debris and fish accumulated on the nets so quickly that an effective barrier to the intake forebay could not be maintained. Attempts to utilize the net barrier system under open-cycle conditions continued until 1990 when the Station's NPDES permit was amended to remove that special condition as a requirement. Projections for 1988 and 1989 were the highest impingement estimates in the Station's history, both years in which the net barrier




1a. Impingement samples were not collected during 1 July through 31 August.

Fig. 5. Estimated number of fish impinged at Quad Cities Station from 1973 to 1996.

system was still in use. Observations on the condition of fish entrapped on the barrier net aided in the decision to abandon this requirement. During the 4 months that the net was deployed in 1984 (January, February, November, December), over 90% of all fish entrapped on the net were either dead or moribund, as confirmed by monitoring efforts that collected and analyzed fish from the net, after it had been cleaned, over two 2-h collection periods weekly (Lawler, Matusky & Skelly Engineers, 1985). Fish impingement at Quad Cities Station, though relatively high, does not represent a direct impact on the fish community because the vast majority of fish impinged by the Station are dead or moribund upon their arrival in the intake forebay. These individuals are essentially lost from the fishery, whether or not they become impinged.

In reviewing the long-term data base developed from the in-stream monitoring program and population studies, there have been wide fluctuations in abundance among principal species, but community composition has remained relatively stable (Lawler, Matusky & Skelly Engineers, 1995). The fish community remains dominated by gizzard shad and freshwater drum, with emerald shiner, river shiner, bullhead minnow, common carp and bluegill also abundant. Paddlefish and white crappie have declined in abundance, but modest numbers of lake sturgeon have been collected in recent years. Channel catfish have greatly increased in abundance due primarily to major changes in commercial harvest regulations that have benefited reproductive potential. Bertrand (1997) reported similar changes in the fish community throughout the Illinois portion of the UMR and attributed these changes to the decline in quality backwater habitat as a result of siltation. Walleye abundance has increased measurably in recent years as a result of stocking fingerling fish reared in the inactive cooling canal at Quad Cities Station. Conservatively, the adult walleye population in Pool 14 is presently comprised of 30% stocked fish, with lesser, yet measurable, contributions to downstream pools.

Life history studies of freshwater drum have shown wide fluctuations in population levels, standing crop and catch rates, but surprisingly little variation in most other parameters measured. There have been no notable changes in linear growth, fecundity, sex ratios or survival estimates that can be attributed to Station operation. However, there is one period of record worthy of discussion, a prolonged drought that

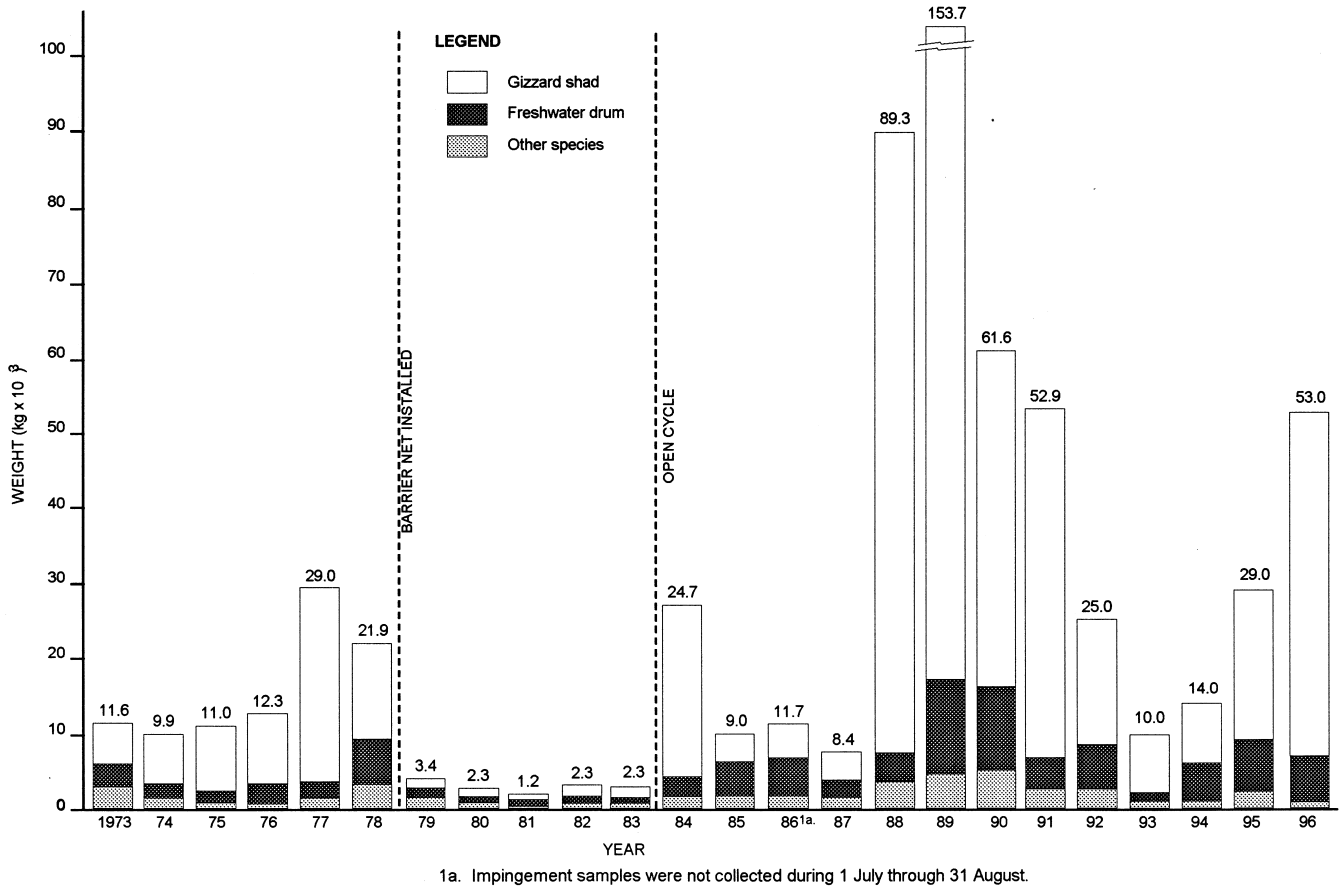



Fig. 6. Estimated weight of fish impinged at Quad Cities Station from 1973 to 1996.

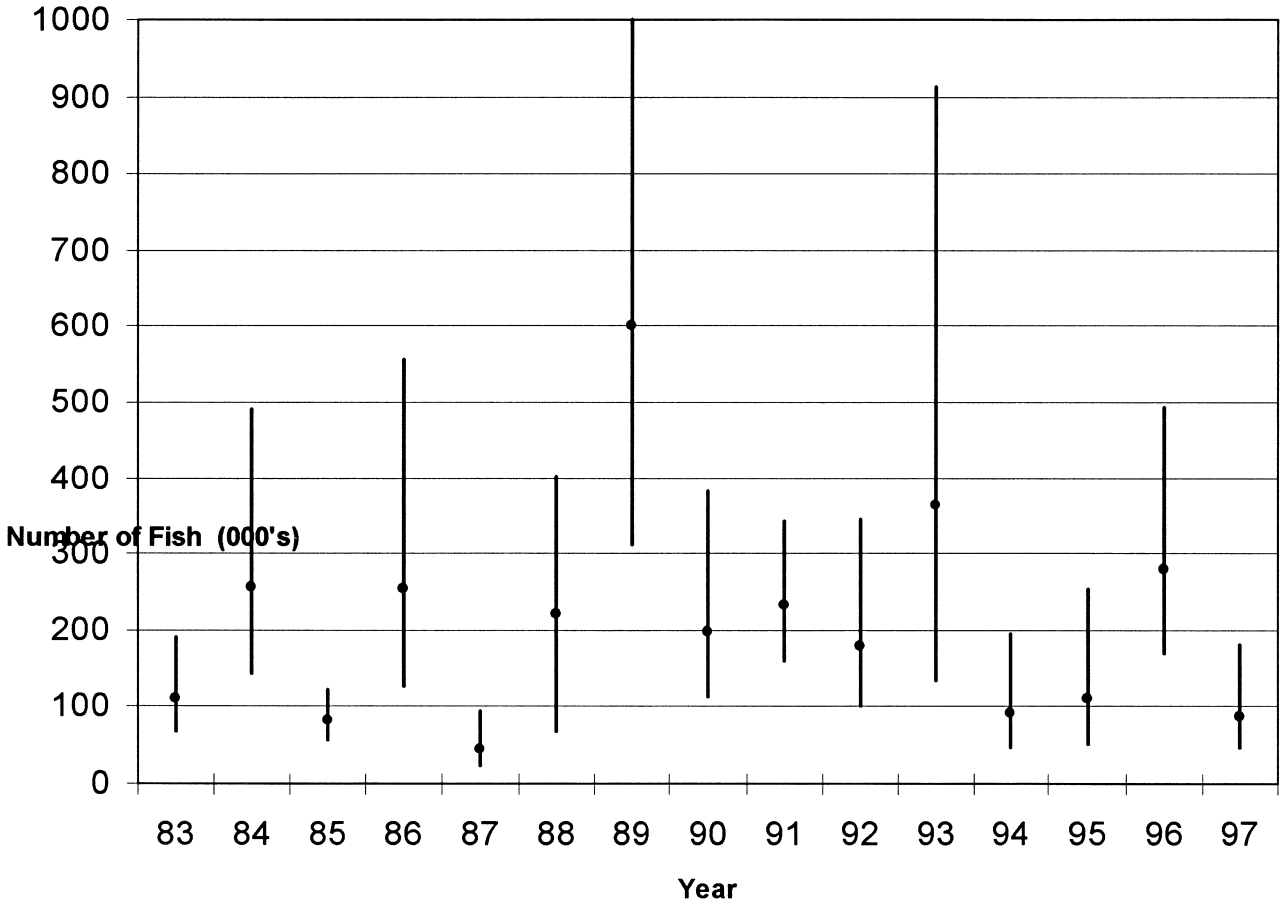



Fig. 7. Freshwater drum population estimates from long-term sampling areas in Pool 14, 1983–1997.

extended from 1987 to 1989. In 1987, adult population levels were the lowest ever calculated (Fig. 7). Low, stable water levels that followed over the next 2 years resulted in high recruitment and good survival, which in turn resulted in the highest population estimate ever calculated. Between 1989 and 1990 the drum population exhibited clear signs of stress through competition for available resources. Average weight of adult fish declined dramatically (Fig. 8), and mean fecundity (no. ova/100 g body weight) declined by almost 20%. Survival, which averages 71% by the catch curve method, also declined to 47% and 52% in 1989 and 1990, respectively. Thin, emaciated fish were common and impingement estimates rose accordingly. The return to a more normal water year in 1991, preceded by 2 years of relatively high mortality, resulted in substantial increases in average weight, increased fecundity, average survival and a marked decline in impingement. It would appear that natural mechanisms of compensation were functioning.

Several program elements have been sufficiently sensitive to document changes for several species following major hydrologic events. Electrofishing catches and impingement monitoring detected increased recruitment and abundance of largemouth bass, bluegill and gizzard shad during the same prolonged drought of 1987–1989. These same program elements detected very poor recruitment among several fish species during the prolonged record flood of 1993. A record fall flood during October 1986 greatly influenced impingement collections. During that event, large numbers of young-of-year common carp and largemouth bass were impinged. Neither species has ever comprised more than a small fraction of impingement collections throughout the entire 25-year monitoring program, except during this period. There was no evidence in subsequent years that this event had an adverse impact on the populations of either species. These young fish were washed out of protected habitats where they would have overwintered.

Impingement monitoring has been one of the most informative and sensitive of all data gathering techniques used at Quad Cities. Nuclear stations operate as 'base load' facilities. Consequently, there is only minor variation in cooling water usage between years and their influence remains relatively stable. Wide annual fluctuations in the numbers of fish impinged reflect actual changes in fish abundance in the pool,

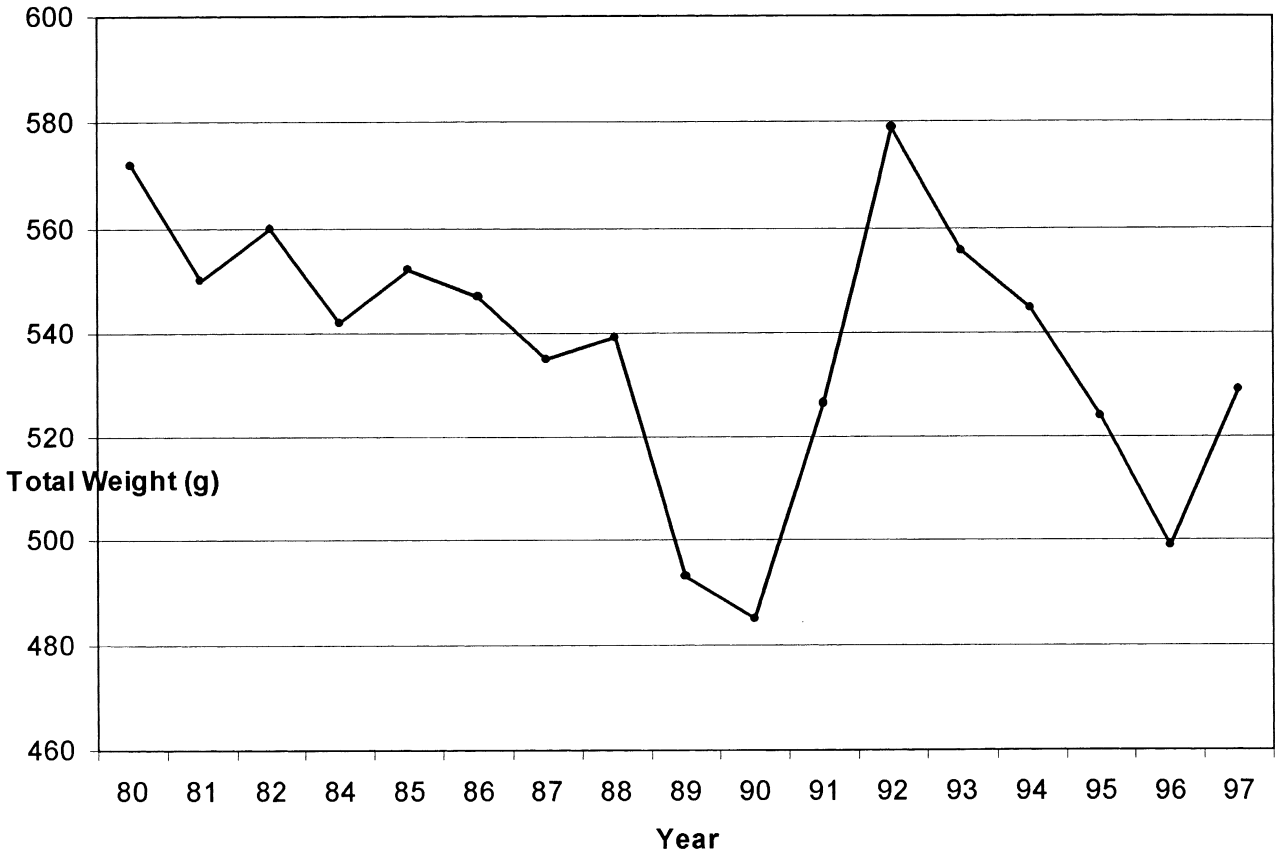



Fig. 8. Freshwater drum average weight at 350 mm total length, 1980–1997.

and measure climatic and hydrologic effects on fish survival.

## 5. Summary

Twenty-seven years of fisheries monitoring in Pool 14 of the UMR have been conducted in an effort to determine whether operation of Quad Cities Station has had a measurable impact on fish populations in the pool. Over the past 14 years, efforts have been directed at evaluating possible effects of open-cycle operation, which include discharge effects as well as entrainment/impingement. A review of this long-term data base has led to the conclusion that the UMR is an extremely dynamic ecosystem, which is influenced by many natural variables that affect the entire ecosystem. These variables may operate independently or in consort with one another, and similar environmental conditions seldom, if ever, occur during consecutive years. The fact that individual organisms are lost due to entrainment and impingement by the Station is not disputed. In estimating the number of fish lost to the river by impingement, the direct impact is confounded by the observation that the majority of these fish are either dead or moribund prior to their arrival on the Station's intake screens. These long-term studies have not identified any measurable adverse impact of open-cycle operation on the fish community of Pool 14.

One major advantage of this long-term data base has been the opportunity to observe several periods of cyclic fluctuations within the fish community, and the high degree of variability within the freshwater drum population. The influences of naturally occurring environmental perturbations (floods, drought, and severe winter) may have more profound effects on the fish community than operation of a large generation facility.

Because Station operation is relatively constant from year to year, impingement monitoring may be the most sensitive assessment tool of all. Fluctuations in annual impingement estimates are reflections of environmental conditions within the river and the fishery's response to them. Increases or decreases in fish numbers impinged at the Station in any given year are primarily due to fluctuations in the fishery and the effects of prevailing environmental variables and not to Station operation.

Conversion of the inactive cooling canal into a game fish rearing facility and the subsequent supplemental

stocking of game fish into Pool 14 following the return to open cycle operation has resulted in a 'win–win' situation for all parties involved. Regulatory agencies, intervenors and ComEd view this mitigation as a fair and equitable solution to an arguable issue. Recreational angling opportunities have greatly improved in Pool 14 and several other navigation pools as a result of this commitment.

In summary, the fish population of Pool 14 of the UMR is extremely dynamic and resilient. Individual species and the overall fishery have exhibited both long-term and short-term fluctuations in response to a wide range of environmental influences. This long-term data base affords the opportunity to observe multiple occurrences of short-term cycles, overcoming a problem with short-term investigations, i.e., the investigator cannot fully interpret at which point the cycle was entered without additional information.

We do not advocate or believe that every facility needs to compile such a lengthy record of documentation. However, when and where recent historical fishery data are available, they should be reviewed to aid in evaluating the current status of the fish community. Regulators and resource managers, who must base decisions and actions on short-term investigations of aquatic ecosystems, are urged to balance the desire for extensive site specific data with the utility of that data.

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