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A COMPARISON OF THE TECHNIQUES USED FOR SAMPLING  
JUVENILE AND ADULT FISHES IN THE ENVIRONMENTAL  
MONITORING PROGRAMS AT THREE RIVERINE  
NUCLEAR POWER PLANTS

by

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## ABSTRACT

As a first step in developing concise guidelines for fish sampling programs on large rivers, the juvenile and adult fish sampling data from the monitoring programs at Susquehanna, Quad Cities, and Prairie Island nuclear power plants was analyzed to determine the effectiveness and variability of electrofishing, trapnetting, trawling, and seining on carp, channel catfish, bluegill, white crappie, and walleye. The four sampling methods were also compared to determine if the techniques provided similar information about population abundance, and the potential for using seasonal fluctuations in CPUE or habitat preferences of fish to reduce sampling variability or sampling effort was explored.

Both effectiveness and variability changed among sites, species, and years so that none of the sampling methods consistently produced the greatest CPUE or least variability for all species at all times. The yearly population trends detected by the four techniques were also different, so it is uncertain which, if any, of the sampling methods monitored the real population abundance for the five species.

Electrofishing seems to be the most useful sampling technique because it captured adequate numbers of each species except channel catfish, it generally had a low variability, and it captured the widest size range of fish. There are also indications that its effectiveness can be further increased by switching from A.C. to D.C. electrofishing gear and by sampling at night.

Trawling and seining are also useful because they sample different habitats than electrofishing. However, these techniques are only effective

for small fishes. In addition, trawling is limited to relatively clean, smooth channel areas and seining is largely a qualitative technique.

Trapnetting does not seem to be as useful as the other methods because it samples the same habitat as electrofishing, it generally has a lower CPUE and a higher variance than electrofishing, and it only captures the larger fishes.

Seasonal fluctuations in CPUE and habitat preferences by the individual species both appeared in the data, but they were inconsistent so that sampling only during one season or in one habitat did not provide a reliable index of annual abundance for any of the five species. Sampling variability was also not decreased by grouping sampling stations by habitat.

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## INTRODUCTION

For many years, regulatory agencies such as the Nuclear Regulatory Commission have required industries to conduct fish monitoring programs to assess the impacts of various construction and operational activities on the fisheries communities of large rivers. However, the lack of knowledge on what is needed to determine impact and the lack of accessible data on the efficiency and applicability of the various fish sampling methods in large rivers have resulted in vague monitoring requirements and the consequent use of a large variety of fish sampling techniques. This variety, in turn, has added to the difficulty of analyzing monitoring data because each technique has a different selectivity and efficiency for the various species, and the results depend on the sampling methods used as well as the actual populations.

Many studies have been done on the selectivity and effectiveness of fish sampling methods in lakes and reservoirs (Hansen, 1953; Moyle, 1950; Powell et al., 1971, Walburg, 1969), but these are not directly applicable to river sampling because many of the standing water methods such as gillnetting and trammel netting are not feasible in moving water. In addition, large rivers present more difficult sampling problems because they have variable parameters such as river level and current and they have indefinite boundaries and open, migratory populations. Many rivers, such as the Mississippi, also have a number of different habitats which are interconnected, but which may have different populations and sampling problems.

As a first step in developing guidelines for improved fish monitor-

ing programs on large rivers, the data on juvenile and adult fishes from monitoring programs at three riverine nuclear power plants has been analyzed to obtain a general understanding of the effectiveness, selectivity, and variability of present fish sampling methods. Specific objectives of the study were to:

1. Compare the common methods of sampling fish in terms of their effectiveness (catch per unit effort) and variability (coefficient of variation) for five species of fish.
2. Examine any variations in sampling methods to determine if they increase effectiveness and/or decrease sampling variability.
3. Compare the sampling methods to determine if each technique provides similar information about population abundance.
4. Examine seasonal trends in CPUE and variability to determine if there are short sampling periods which will indicate yearly abundance as well as year-round sampling.
5. Determine whether the populations in the sampling area are homogeneous and mobile so that population changes are reflected in the same way in every habitat, or whether different habitats contain discrete populations so that all habitats on the site must be sampled to obtain a true index of relative abundance.
6. Determine if grouping stations by habitat will reduce sampling variance.

## METHODS

Site Descriptions

After reviewing the fish monitoring programs at riverine nuclear power plants throughout the United States, the programs at the Susquehanna Steam Electric Station, the Quad Cities Station, and the Prairie Island Nuclear Generating Plant were selected for the analysis of sampling methods. These studies each used a variety of sampling techniques and each was intensive in terms of sampling frequency or number of sampling stations over a long period (5 to 8 years). In addition, the three study areas all had different characteristics so that generalizations between sites could be investigated.

The Susquehanna site is located on the North Branch of the Susquehanna River near Berwick, Pennsylvania. At this point, the river is relatively small, with an average flow of 13,300 cfs and maximum and minimum flows of 239,000 cfs and 540 cfs, respectively (U.S.A.E.C., 1973). It flows in a well-defined channel 100 to 480 meters wide and during the summer low-flow period averages only 1 to 3 meters deep (Ichthyological Associates, 1973).

The river bottom is scoured during periods of high water and consists of gravel, large rocks, and bedrock, with some silt in the larger eddies. There is relatively little vegetative cover in the water or along the shore except during high water, and there are no discrete habitats other than the riffles, pools, and eddies created by variations in gradient and current.

The Quad Cities site, on the Mississippi River above Cordova, Illinois,

is very different from the Susquehanna site because the river is larger, the current is slower, and the habitats are more diverse. This change in character is caused largely by the river's greater volume (average flow 47,000 cfs) (Commonwealth Edison, 1971) and lesser gradient, but it is also due to the series of low head navigation dams which have converted the Mississippi River into a chain of long flowing pools.

Approximately midway along the 29-mile long Pool No. 14, the site has at least three distinct habitats--main channel, side channel, and slough. The main channel averages 375 to 750 meters wide and is 6 to 9 meters deep with a bottom of scoured sand. The shoreline is relatively barren with few submerged stumps and very little overhanging brush or other cover. In the side channels, the current is much less noticeable and the shorelines are less scoured, with more overhanging vegetation, submerged trees, and other cover. Sloughs or backwaters have no current and they are generally shallow with many submerged stumps and other forms of vegetation over bottoms of mud or fine sand.

The Prairie Island site is also on the Mississippi River, approximately 300 miles above Quad Cities near Red Wing, Minnesota. With much less volume (15,000 cfs average) (U.S.A.E.C., 1973b), the river is smaller than at Quad Cities, but the sampling site is more complex because it includes the swift tailwaters below Lock and Dam No. 3 as well as the deep flowing pool and shallow slough areas above it.

Four habitats are evident in the area--main channel, slough, river-lake, and tailwater. Of these, only the North Lake slough is comparable to the Quad Cities habitats. The main channel overlaps Quad Cities classifications, having both the scoured gravel, sand, and mud substrate

of the main channel and the stumps and overhanging brush characteristic of a side channel. In addition, the Prairie Island main channel has a number of rock wing dams and riprap sections which are not present at the Quad Cities site.

Sturgeon Lake, the Prairie Island river-lake, is a large, shallow, stump-filled body with a number of connections to the main channel. It is similar to a slough but it has a greater flushing rate and a perceptible current, especially during high water. The tailwaters of Lock and Dam No. 3 have strong currents and are fairly deep, with riprap and steep drop-offs in most areas. However, they do not extend downstream very far before the river regains the "typical" main-channel character.

#### Monitoring Data

In order to compute CPUE and variability for individual species, sampling dates, sampling stations, and replicates, detailed data was necessary from each of the three power plant monitoring programs. For Susquehanna, most of this information was available from the annual environmental monitoring reports. For the Prairie Island and Quad Cities monitoring programs, the summarized results in the annual and semiannual reports were unsuitable for analysis and copies of the original field data sheets were obtained from the utilities' consultants.

At least five years of data were analyzed for each site, with six and eight years used for Susquehanna and Quad Cities, respectively. As Table 1 shows, both the sampling frequency and the number of sampling stations varied from site to site, method to method, and year to year, ranging from three samples per year to twice per month and from four sampling stations up to fifty. This provided a data base of approximately

5,200 separate samples.

### Species Selection

Because of the great diversity at the three sites, it was not feasible to analyze the sampling methods for each species. Therefore, five species which were at least common or abundant at all three sites and which exhibited different life histories and habitat preferences were selected for intensive study. These included carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), bluegill (*Lepomis macrochirus*), white crappie (*Pomoxis annularis*), and walleye (*Stizostedion vitreum*).

Of these, the carp was selected primarily because of its importance in both numbers and biomass at all sites. The other species all represent popular sport fishes which were present in varying abundances at each site (Table 2).

### Sampling Methods

Although eight different fish sampling methods were used at various times in one or more of the monitoring programs, only electrofishing, trapnetting, trawling, and seining were analyzed in this study. Gillnetting, drifting trammel nets, setlining, and midriver seining were not included because they are unsuitable for generalized riverine monitoring programs. They are either unusable in current (gillnets), they snag and are lost easily (drifted trammel nets), they have extremely low CPUE (midriver seine), or they are too species-selective to be used in generalized programs (setlines).

Electrofishing utilizes an electric field to immobilize the fish until they can be captured with dip nets. Either A.C. or D.C. current

can be used, but A.C. electrofishing is generally more popular and this was used at all three sites. The equipment was similar among sites with the basic unit consisting of a 230-volt A.C. generator mounted on a 16 to 18 foot flatbottom boat with the booms and electrodes extending from the bow. Each unit also had a voltage regulating mechanism to control current and power. D.C. electrofishing was used at Susquehanna after 1974. This utilized the same boat and generator as the A.C. unit, but the current was run through a rectifier to transform it to pulsed D.C. and the electrode configuration was changed to permit effective use of D.C. current (see Novotony and Priegel, 1974, for design specifications).

At each site, the boat was driven slowly along the shoreline and one or two men in the bow dipped the stunned fish. Effort, which was reported as minutes spent shocking, and/or length of shoreline travelled, varied from year to year and site to site. To make the results uniform, the data was converted to catch per 15 min. "run."

The data should still not be considered as directly comparable among sites because electrofishing effectiveness is affected by the electrode configuration, the conductivity of the water, and the nature of the river bottom as well as the size and species of the fish (Novotony and Priegel, 1974). Each of these varied from site to site. Each site also used different current regulating mechanisms so electrical power and current of the various units was probably different.

Trapnets were also used at each site. This is a more-or-less generic term for any fish trap which uses blocking nets and/or a series of net funnels to guide fish into a central bag or box from which it is diffi-

cult to escape. They are generally set in 3 to 10 feet of water with the large funnel opening facing downstream or perpendicular to the current, depending on the design of the net.

The framenets used at the Susquehanna and Prairie Island sites were similar. They consisted of a 3 x 6 ft. frame opening and two series of mesh funnels to direct the fish into a mesh bag. A 50 ft. lead net was stretched from the mouth of the framenet to divert fish into the trap.

The Susquehanna monitoring program also used an oneida net. This net, which is harder to set because of its larger size and more complex construction, has a 6 x 6 ft. opening and three series of funnels. It also has two wing nets extending from the mouth of the net at 45° angles, with floor and ceiling netting between them to prevent the fish from swimming over or under the oneida net once they have been diverted toward the trap by the barrier and wing nets.

A wing net-hoop net combination was used in the Quad Cities monitoring program. It was similar to a framenet except the funnel openings were circular instead of rectangular and the trap had two wing nets extending from the mouth at 45° angles instead of the framenet's perpendicular barrier net. In addition, the hoops also had a slightly larger mesh (1 inch square mesh) than the framenets (1/2 inch square mesh).

For convenience, most of the trapnets were fished for 24 hours before the catch was removed. However, a few sets were much shorter. Because there is evidence that trapnet catch is not linear with time (Hansen, 1944; Kennedy, 1951), any sets less than 10 hours long were discarded from the analysis. All other sets were adjusted to a 24-hour unit of effort.

Otter trawling was used to sample midchannel fishes at Prairie Island and Quad Cities. Both programs used a small trawl (16 ft. head-rope) with a 1/4 inch square mesh cod end which was towed behind a single boat. At Quad Cities the river channel was fairly clean so that 7-minute downstream tows could be taken consistently. However, the Prairie Island trawling stations contained many rocks, stumps, and other snags which made hang-ups frequent and trawling time for individual runs varied considerably. To make the values for the two sites comparable, a seven-minute tow was selected as the standard unit of effort and all individual trawling runs were adjusted to this value.

Although each program used 1/4 inch mesh seines to sample juvenile and young of the year fishes along the shoreline, the means and variances of the samples are not directly comparable because each site used different nets and techniques. The Susquehanna program used a 10 ft. common seine from 1971 to 1974 when they switched to a 25 ft. bag seine. The sampling times and effort per station varied from daytime only with 3 hauls/station (1971-72) to day and night with 1 haul/station (1973-74) to nighttime sampling only with 2 hauls/station (after 1974) (Ichthyological Associates, 1972, 1973, 1974, 1976a, 1976b, 1977). The Prairie Island program conducted sampling during the day by making 1 haul/station with a 50 x 4 ft. bag seine. A 100 x 8 ft. bag seine was used in 1973, but this was discontinued because it was too large to effectively sample a number of stations (Northern States Power Co., 1975). The Quad Cities program also conducted daylight sampling, but they made 2 hauls/station with a 25 x 6 ft. common seine (Industrial Biotest, Inc., 1973).

Because of the variety of seines and techniques, no attempt was made to adjust the results to a single unit of effort. Instead, the results were simply adjusted to catch/haul for whatever seine or method was being used.

#### Procedure for Analysis

To meet the objectives of the study, CPUE, variance, and coefficient of variation were computed by month for each of the five species by sampling method at each of the three sites. Monthly periods were used for these initial calculations because the fish populations were assumed to change over time, and months were the shortest periods which gave sufficient samples to allow realistic estimates of CPUE and variance. Had longer periods been used, the possibility of combining different populations would have been increased and the variance estimates might have been unrealistically high.

From these calculations, a series of graphs plotting average monthly CPUE over time was developed for each sampling method and species. The first of these plotted CPUE by replicate for methods with consecutive hauls or sets such as trawling at Quad Cities and framenetting at Prairie Island. Pseudo-replicates such as day and night electrofishing at Susquehanna were also plotted. These graphs were evaluated by inspection to determine if the samples which were considered "replicates" on the monitoring programs were actually replicates or if there was a bias in the results indicating that different populations were sampled. The graphs were also used to establish the relative effectiveness of method variations, such as day vs. night sampling, and to determine how well the

results of these variations corresponded on a monthly basis.

Additional graphs were developed for CPUE/month by method and species for all replicates and all stations combined. These were used to determine if there were any seasonal trends in abundance and whether short periods such as spring or fall could give realistic indications of yearly abundance.

To compare average CPUE and coefficients of variation for the various methods and to determine whether observed population changes in the five target species were consistent among the different methods, yearly averages for CPUE and coefficient of variation were developed. For CPUE this was done by averaging the monthly values for each month in which sampling was attempted, including months in which no fish were caught. This did not give the true yearly grand means because the calculation was not weighted for differences in sampling effort between months; however, this computation gave an average value for the many different populations throughout the year and it avoided the problem of differing sample sizes. The only assumption the computation required was that the same months were sampled each year by each method. Since sampling dates did change between years, this was not strictly true, but the error should have been insignificant if there were no consistent seasonal patterns of abundance.

Average yearly coefficients of variation (C.V.) were computed in the same manner as the yearly CPUE except only non-zero monthly values were included in the averages. This avoided distortion of the coefficient of variation when many months had zero CPUE and therefore had an undefined C.V. It was assumed that the coefficients of months with zero CPUE would be similar to the coefficients of variation of other months with greater CPUE since seasonal trends in C.V. were not expected for either species

or methods.

To evaluate the five species' habitat preferences and their effect on sampling variance, additional variance tables were developed by grouping the sampling stations at each site into habitat types before computing average CPUE, variance, and coefficient of variation. The primary groupings for the Quad Cities site included main channel stations, side channel stations, and slough or backwater stations. These were based on a combination of substrate, current, and cover differences as explained in the site description. There were five habitat groupings at Prairie Island: main channel--silt, main channel--riprap, tailwater, river-lake, and slough. In addition, a sixth group was established to include the probable impacted sites in the immediate plant area.

At Susquehanna there were no distinct habitats other than riffle and pool, so the stations were grouped by substrate as either fine-coarse sand, coarse sand-pebble, pebble-cobble, or cobble and boulder. This was felt to be a more realistic classification than current velocity because the current fluctuates considerably with river level, while substrate composition is more stable and should reflect the relative velocity over a long period.

The potential for reducing sampling variability by grouping sampling stations according to habitat was investigated by comparing the range of coefficients of variation for the station groups against the coefficients of variation for all stations (all habitats) combined. In addition, the station group CPUEs were compared to determine if the different habitat groups corresponded with each other on a monthly or yearly basis so the necessity of sampling all of the habitats to obtain an accurate index

of relative abundance for the five species could be examined.

## RESULTS AND DISCUSSION

### Trapnet Replicates

Although most monitoring programs routinely combine consecutive trapnet sets or "replicates," two factors may potentially bias the replicate results and should be considered before the data is lumped. First, the initial set or sets may catch enough fish to significantly reduce the populations sampled in subsequent sets and result in reduced CPUE for the later replicates. This would be particularly important for small, nonmobile populations where the fish are released at different points than they are captured. Even releasing the fish at the same sites cannot guarantee that the catchable populations will remain the same for subsequent samples, because the fish may exhibit an increased avoidance response after being captured once.

There is also some evidence that acclimation to the presence of the trap will increase some fishes' tendency to enter it (McCammon and LaFaunce, 1961). This, in effect, would increase the efficiency in the later replicates and give a trend of increasing CPUE through time.

Neither of these factors seemed to be active in the trapnet catches at either Susquehanna or Prairie Island, because no consistent trends of increasing or decreasing CPUE by replicates were observed in either the monthly or yearly averages for any of the five species at either site. As figures 1 and 2 show, there were large differences in replicate CPUE values at both Susquehanna and Prairie Island, but since trapnets are

passive sampling devices depending upon both the population size and the activity of the fish for CPUE, these differences can probably be explained by changes in the activity levels of the fishes, i.e., a heavy rain would be likely to cause a strong feeding response and more fish would encounter the net than during the day before when the fish were not as active.

Sampling variability did not seem to be significantly increased by combining the trapnet replicates, since the coefficients of variation for all replicates combined were well within the range of the coefficients for the four individual replicates for each species at Prairie Island except the channel catfish, which had a very low CPUE. The Susquehanna data was inconsistent in that it did show an increase in variability, with the combined coefficients generally being larger than either of the individual replicate coefficients of variation; however, this was probably an artifact of the low number of replicates taken per sampling station (only 2) and the relatively low framenet CPUE for all species at Susquehanna.

With no evidence of CPUE trends between replicates and only weak, inconsistent evidence of increased variability with combined replicates, it seems valid to combine all of the trapnet replicates. This was done for the remainder of the analysis.

#### Trapnet Variations

Although the monthly CPUE values for framenet and oneida net showed little correspondence for the three years in which they were used concurrently at Susquehanna (fig. 3), the average yearly CPUE trends for the two methods corresponded very well. This suggests that both methods can detect the same long-term population changes; however, the oneida net seems to be a more useful fish monitoring technique because it was more

effective than the framenet in capturing all five species. The increases in average yearly CPUE of the oneida net over the framenet were consistent, ranging from 1.2 - 3.5 times for bluegills and white crappies to greater than 30 times more efficient for channel catfish. Carp and walleye were also affected significantly, with CPUE increases of from 3 to 16 times (Table 3).

The variability of the oneida net catches was also consistently less than that of the framenets, with the coefficients of variation varying between .75 - 2.96 and 1.56 - 3.61, respectively.

These differences in the effectiveness and variability of the two methods are undoubtedly related to the larger size and more complex construction of the oneida net, but the exact causes of the differences are uncertain. One possibility is that the oneida net, with its larger size, wing nets, and ceiling and floor netting, covered more area and diverted the fish into the trap more efficiently than the framenet. Another possibility is that the addition of another web funnel leading into the central bag of the oneida net made it more difficult for the fish to escape once they were inside the net. However, studies have shown that bluegills can swim in and out of a framenet freely (Hansen, 1944) so the addition of one more funnel should not make a great deal of difference to every species. If most fish can leave the trap at will, then the larger holding area of the oneida net may also be partially responsible for increasing CPUE by increasing the number of fish which can stay in the trap without becoming crowded.

Electrofishing VariationsA.C. vs. D.C.

Although much research has been done on electrofishing boat designs and a number of authors have compared the effectiveness of alternating current (A.C.) and direct current (D.C.) electrofishing (Frankenberger, 1960; Novotony and Priegel, 1974; Vincent, 1971), there still seems to be some confusion over the two methods. A.C. electrofishing is the most commonly used type. Its major advantage over D.C. is that it gives the greatest effective sampling area for a given power or voltage. This is important in clear, shallow, or cover-free areas where the fish are frightened easily by the electrofishing boat and must be stunned before they can escape. It is also useful for very fast swimming fishes such as northern pike and muskellunge which may pass through small electrical fields without being completely stunned. Unfortunately, high turbidity or large amounts of cover severely restrict the effectiveness of A.C. because they make the stunned fish difficult to see and capture.

D.C. electrofishing gear samples a smaller area than A.C. for a given generator output, so it is less effective in large clear water systems, but it has the advantage of causing a forced swimming reaction toward the negative electrode in fish (galvanotaxis). This makes D.C. effective in turbid water or dense cover because it can draw the fish to the surface where they can be seen and captured.

Both A.C. and D.C. electrofishing were used at the Susquehanna site, but no direct comparisons of efficiency or variability could be made because the two techniques were not used concurrently. Indirect comparisons of CPUE between A.C. and D.C. were also thwarted because of large year-to-

year fluctuations and a lack of correlation between electrofishing CPUE and other methods such as trapnetting or seining. However, indirect comparisons of variation between A.C. and D.C. electrofishing were made by comparing the average yearly coefficients of variation for the two techniques. Because the two methods were used at different times, the annual values for three years were averaged for each method so that unusual occurrences such as low water or high temperatures during a single year would not affect the results (A.C. 1972-74, D.C. 1975-77).

As table 4 demonstrates, D.C. electrofishing was consistently less variable than A.C. for all five species in the turbid Susquehanna River. The decreases in the coefficients of variation occurred during both day and night sampling and ranged from 4% for nighttime carp samples to 46% for daytime white crappies. The average decrease in the coefficient of variation was about 28% for both day and night, with walleye, white crappie, and channel catfish having the greatest reductions.

Assuming that the fish populations sampled by the two methods are similar, this information is enough to recommend the use of D.C. instead of A.C. for monitoring turbid rivers such as the Susquehanna and Mississippi.

#### Day vs. Night Sampling

With the evidence for increased fish movements during the night (Bailey and Harrison, 1948; Hansen, 1951; Morgan, 1954) and life history information on fish such as channel catfish and walleye indicating movements from deep water to shallow water at night (Carlander and Clearly, 1949; Davis, 1959), it seems reasonable that night electrofishing would be more effective than daytime sampling because the fish would be more

available to the gear. In addition, fish in the shallows are probably frightened less easily by the boat in the dark than they are during daylight so that fewer fish flee before they encounter the electric field and are stunned. These hypotheses were investigated at Susquehanna where day and night sampling were conducted concurrently from 1974 to 1977.

The results, which are compiled in table 5, indicate that night shocking is at least as effective as day shocking for all five species, and that it is much more effective and less variable than day shocking for walleye, channel catfish, and bluegill. These increases in efficiency (annual CPUE) over daytime values ranged up to 2.9 times for bluegill, 3.5 times for channel catfish, and 13.0 times for walleye. At the same time, the annual average coefficients of variation for the three species decreased by as much as 18% for bluegill, 32% for channel catfish and 41% for walleye.

Carp and white crappie results were inconsistent, exhibiting no trends in either CPUE or variability between day and night electrofishing. Carlander (1953) found the same lack of diel differences for carp and white crappie using gillnets, so it seems unlikely that there is an advantage or disadvantage to sampling for these species at night.

Although the monthly CPUE trends for daytime and nighttime electrofishing may not correspond well (fig. 4, 5), the annual trends generally follow each other for all five species. This indicates that either sampling period can be used for monitoring the fish populations. However, the increases in effectiveness and the decreases in variability observed during night sampling for three of the five species in this study strongly encourage the use of nighttime sampling in future monitoring programs.

Seasonal Fluctuations in CPUE

Most fishes exhibit some type of seasonal variation of CPUE in response to their yearly spawning cycles or environmental variables such as temperature or water level. These fluctuations may reflect real population changes which occur from migration or mortality. They may also be apparent population changes caused by changes in the catchability of the species. These can occur because behavioral factors such as periods of spawning, intensive feeding activity, or movements from deep to shallow water alter the effectiveness of the various gears. They are also caused by the growth of the fishes as they first become catchable to a gear and then become large enough to avoid it. Apparent population changes can also be produced by variations in environmental parameters such as water level, velocity, or turbidity because they affect the accessibility of the gears to the fish and alter catchability.

Regardless of the cause of the CPUE variations, a number of studies have shown these annual cycles to be consistent for various species in specific locations (Hansen, 1953; Kelly, 1953; Morgan, 1951; Morgan, 1954; Muncy, 1957; Scott and Crossman, 1973). If this is true, then comparing two yearly CPUEs may give unrealistic results if the samples were taken at different times of the year. It also suggests that sampling over an entire year may be unnecessary because a single season of sampling may give an adequate indication of yearly abundance if the samples are taken at the same time each year.

Although there were obvious differences between months, the adult fish sampling methods (electrofishing and trapnetting) showed no consistent seasonal fluctuations in CPUE for any species at any of the three

sites in this study. Some species, such as bluegill and white crappie, did seem to have definite peaks of abundance in most years, but as figures 6 and 7 show, the timing and shape of the yearly curves varied a great deal from year to year so that no single sampling period could accurately represent the abundance of the species. This more or less mandates that adult fish sampling be conducted as many times and over as many months as possible in order to truly represent the yearly populations. However, the possibility of consistent yearly CPUE cycles at other sites also demands that yearly comparisons be made only with similar months so that biases are not introduced into the yearly values.

Sampling methods for young of the year fishes (seining and trawling) showed more consistent yearly cycles for many of the species; however, there was still enough variability that sampling only one or two months would not be sufficient to determine yearly population trends (fig. 8). Therefore, sampling the young of the year fishes throughout the time they are present (approximately May through October) would be recommended.

Unfortunately, even this type of sampling may misrepresent the yearly abundance of young fishes if there are large fluctuations in the growth rate between years, because catchability for seines and trawls decreases as the fish become large enough to avoid the gears. In years with slow growth rates, the gears may take fish efficiently until sampling is concluded for the year, but in years with faster growth the fish may become large enough to avoid the net, thus giving a lower CPUE and indicating a smaller population than is actually present. To avoid this problem and reduce variations in apparent population size caused by different growth rates, a "stopping rule" should be developed so that

seine and trawl samples would not be counted in the yearly total averages for a specific species after a given proportion of that species in the catch reaches a specified size.

#### Habitat Groupings

The preference of various fishes for certain substrates, current velocities, or cover characteristics has been well documented. In a river, this is translated into a preference for particular types of habitat, such as shallow weedy slough areas or relatively swift deep mainstream channels. Within the four major riverine habitats (slough, side channel, main channel border, and main channel bottom) there may also be gradients of "preference" as factors such as substrate change from mud to gravel or rip rap.

The combination of species habitat preferences and the large number of habitats available to the fish in large rivers generally increases the difficulty of obtaining a representative index of yearly abundance for a species because it induces a high degree of patchiness in the populations. However, the presence of a species specific habitat preference in fishes also holds a potential for reducing the difficulty and the amount of effort necessary to obtain representative indexes of yearly abundance if one can assume that the preference is consistent so that the proportion of the catch from each habitat type over the total catch for that species remains constant from year to year. If this is true, then sampling any one habitat should give an indication of yearly population trends for any species present as long as the same habitat is sampled each year. Sampling one habitat should also give less variability than combining all of the sampling stations in the different habitats.

No evidence to support these hypotheses was found in this study because the habitat preferences of each of the five species were extremely variable and inconsistent within the broad habitat categories which were used (i.e., slough, side channel, main channel border). This can be seen in the four examples presented in tables 6 and 7 and figures 9 and 10. Less than 25% of all of the annual averages for samples which could be broken down into habitat groups exhibited a consistent difference with the same two habitat types having the greatest and least CPUE for all years of sampling. An additional 25% of the yearly averages had one habitat group which was consistently either highest or lowest in CPUE. The remaining samples had no consistent differences in CPUE between habitat groups, indicating that the proportions of the species in each habitat changed between years.

This lack of consistent habitat selection within the five species may have been caused by actual changes in the preference for particular substrates, current velocities or covers, but it is more likely that consistent habitat preferences were modified by additional environmental factors such as river level, temperature, or oxygen. Environmental variables, specifically river level and turbidity, can also affect the efficiency of sampling gears in the various habitats differently in different years, i.e., high water may make electrofishing along the river channels more difficult but it may make the sloughs more accessible. This may cause apparent differences in habitat selection rather than real changes.

Along with the lack of consistent habitat preferences within the five species, there is a lack of correspondence between the average

yearly CPUE trends for all stations (habitats) combined and the average yearly CPUE trends for the individual habitat groups (tables 6 and 7, figures 9 and 10). Only about 50% of the samples had habitat groups where more than half of the groups followed the combined total CPUE trends. Less than 30% of the samples had all habitat groups corresponding with the combined trends, but even this is unrealistically high since each of these samples included only two habitat groupings while the other samples which did not correspond had up to six groups. The lack of correspondence of yearly CPUE trends between habitats may be caused by the same factors that seem to alter habitat selection, but it indicates that sampling a single habitat will not provide an adequate index of species abundance for any of the species in this study.

As the two examples in tables 8 and 9 show, the potential for reducing the coefficients of variation of the sampling methods by using habitat groups instead of all stations combined was also variable and inconsistent between methods, sites, and species. Of the approximately 60 yearly sample points for electrofishing and trapnetting and the 20 points for trawling, the proportions of the coefficients of variation for all stations combined which exceeded the range of the coefficients for the individual habitat groups for that year were 54%, 40%, and 59%, respectively. Many of the combined coefficients were rather large (up to 1.90 greater than the individual groups); however, the inconsistencies between years, the need to sample all of the habitats, and the reduction in sample sizes which would result from computing each habitat separately would seem to nullify any advantages there are to analyzing individual habitat groups instead of combined totals for these methods.

The seining results are much more consistent, with 88% of the combined coefficients of variation exceeding the ranges of the individual habitat groups. Many of these differences are also large, so that there is a good potential for decreasing the variability of seine results by using habitat groups instead of combined totals even though the sample sizes for the individual habitats will be reduced.

#### Sampling Method - Habitat Interactions

Each fish sampling method is designed for particular habitats such as shorelines, shallow areas, or midchannel bottoms and there are obvious problems with applicability and effectiveness if the methods are used in other areas, i.e., if electrofishing is used out in the middle of a deep river. There are also differences in the effectiveness of the methods within the broad habitat categories for which they were designed.

Trapnetting and electrofishing sampled similar habitats, so the habitat preferences which they detected for the various species should have been similar. However, the data showed that the relative abundance of each species in the various habitat groups was unrelated between the two methods (tables 6 and 7). In three instances (carp at Susquehanna, bluegill at Prairie Island, and white crappie at Quad Cities) the trapnet and electrofishing results were consistently opposite, with the habitat groups with the greatest CPUE for trapnet having the least CPUE for electrofishing or vice versa.

Even between the frame and oneida nets, which are variations of the same basic method, the relative efficiency changed between habitats so that the coarse sand-pebble substrate at Susquehanna consistently produced a higher white crappie CPUE for the oneida net than for the framenet,

while the framenet consistently had a larger CPUE than the oneida net over the fine-coarse sand substrates. The data for the other species was inconsistent and generally showed no habitat correspondence between the two methods even though the total monthly CPUE trends corresponded very well for some of the species, especially bluegill.

These differences, which indicate a high degree of method-habitat interaction, can be caused by a number of factors such as sampling efficiency differences caused by habitat, fish behavioral differences caused by habitat, and sampling differences caused by varying environmental factors.

Small changes in the habitat of a sampling site such as the presence or absence of a submerged brushpile, large rock, or deep hole can change the efficiency of a sampling method by making it easier or more difficult to sample. This is especially evident with a seine, which is most effective in a shallow, barren area, because any snags, large rocks, or unevenness on the river bottom may allow the fish to escape by going under or around the net. The presence of even minimal cover may also affect the efficiency of electrofishing in shallow water because it would give fish frightened by the electrofishing boat a place to hide until they could be stunned and collected. If there is no cover, the frightened fish would be more likely to flee the area completely and escape before they come within range of the electric field.

Differences in habitat may also cause differences in the behavior of some species. This is a possible explanation for the greater trapnet catches of bluegills and white crappies in barren habitats than in habitats with cover because the fish may actually perceive the nets as cover

and enter them for protection. Another possibility is that fish in areas of cover do not move around as much as fish in the open so they are less vulnerable to capture by the nets than fish in the barren areas.

Environmental variables such as river level, turbidity, and temperature affect the efficiency of all fish sampling methods, but they may affect each method differently. For example, river level, which is probably the most important variable in terms of sampling effectiveness, may cause either increased or decreased seining efficiency by increasing or decreasing the seinable area at various water levels. Small increases in river level may not affect trapnets, but they may decrease electroshocking efficiency because of increased current and water depth. They may also increase efficiency by increasing the accessibility of various areas. Large increases in river level generally decrease the efficiency of both trapnetting and electrofishing because the fish move up onto the flood plain where they are inaccessible.

#### Comparison of Sampling Methods

The ranges of annual CPUE and coefficients of variation for electrofishing, trapnetting, trawling, and seining for the five species at each of the three sites are shown in table 10. As was generally expected, there were large differences in CPUE and coefficient of variation between the various sampling methods. However, the differences were variable and inconsistent so that no sampling method produced the greatest CPUE nor the smallest coefficient of variation for all species at all sites. In general, carp, bluegill, and walleye were most vulnerable to electrofishing at each of the three sites. Electrofishing also produced the least variability for these species. Channel catfish, especially young

of the year fish, were taken most effectively by trawling at both sites where the method was used. For white crappie, the most effective and least variable sampling method changed from electrofishing at Susquehanna, to trawling at Prairie Island, and trapnetting at Quad Cities.

The annual population trends detected for the various species by the different sampling methods were also inconsistent. There were a few instances where methods followed each other for short periods for certain species at a single site, or where one method such as seining or trawling which collected young of the year fish predicted the following year's results for electrofishing or trapnetting which picked up adults, but these were rare. In general, the annual CPUE trends detected by the various sampling methods showed very little or no correspondence for any of the species in the study. Two examples are shown in figures 11 and 12.

The inconsistency of the methods in terms of CPUE, variability, and population trends suggests that the various methods are obtaining different information about the same overall populations. This is not unexpected since, as table 11 indicates, each method has a unique set of advantages and disadvantages and each method is applicable in different situations. Because of this, the observed differences may represent real differences in catchable populations caused by the varying areas sampled or the size selectivity of each method. They may also be apparent population differences caused by differing modes of capture or responses to environmental variables.

Although there do not seem to be consistent population differences within the habitat category which each method was designed to sample

(i.e. shorelines, mid-depth, or mid-channel bottom)(see table 11), the possibility of consistent population differences between the habitats sampled by the various gears is still great because of the large differences between these habitats. This would create real differences in the catchable populations available to the sampling methods, especially for seining and trawling which sample shallow shoreline and mid-channel bottom areas, respectively. Electrofishing and trapnetting comparisons should not be affected by this factor because the two methods sample roughly similar, midwater depth habitats.

Each of the sampling methods examined also exhibited a different size selectivity so that the catchable populations for each method were actually different. The Prairie Island data, which is also representative of the other sites, is given in table 12. In general, the trapnets caught adult fishes over about 10-15 cm. while electrofishing gear picked up young fish as well (down to 2 cm.). Seines and trawls also caught fish over a large size range, but their problems of gear avoidance by adult fishes generally limited their usefulness to the capture of young of the year and other small fishes.

Size selectivity may also produce inconsistencies in the yearly CPUE trends between methods because the fish are recruited by the gears at different sizes and a successful spawning may yield an increase in CPUE for a seine or trawl, but it would not affect the trapnet catch during that year. These discrepancies could be increased if growth rates, mortality rates, or migrations fluctuate so that, even when the methods are adjusted for differences in recruitment time, the annual population changes may not be similar for the different sampling methods.

Apparent rather than real population differences between the methods may be caused by the different modes of action of the sampling techniques. The CPUE of active sampling methods such as electrofishing, seining, and trawling depends primarily on the catchable populations present. The catch of passive methods such as trapnetting, in which the fish must swim into the gear to be caught, also depends in part on the catchable populations present, but the activity of the fish is equally important because it is an index of how likely the fish are to encounter the nets (Moyle, 1950). This can create inconsistencies between the results of various methods as activity (and therefore catch) fluctuates in response to spawning behavior, water level, or temperature. A large portion of the differences between the electrofishing and trapnetting results might be explained by this factor.

Fluctuations in environmental variables such as river level, turbidity, and temperature can also create inconsistencies between methods because the sampling methods respond differently. These factors were discussed in the previous section on sampling method-habitat interactions.

## CONCLUSIONS

Through the analysis of three riverine fish monitoring programs, a number of factors have come to light which can aid in developing or evaluating fish sampling programs. Among these, the most surprising, but also one of the most solidly supported findings, is that seasonal fluctuations in CPUE, although present, are not consistent enough to allow sampling during a single month or season to give an accurate index of yearly abundance for any of the species which were considered. This mandates a year-round sampling program and encourages frequent sampling.

Within the broad habitat categories sampled by each method, habitat preferences for the various species were also inconsistent between years so that no single habitat type could be used to obtain realistic indexes of annual population abundance. At the same time, sampling stations could not be changed indiscriminately between years because there were marked differences between habitats in many cases, and including or deleting a sampling station would significantly alter the results. Evidence for decreased sampling variability by grouping the sampling stations by habitat was both inconclusive and contradictory, so that combining all sampling stations, regardless of habitat, is recommended to increase the sample size for each method.

Since the population trends detected by the four fish sampling techniques were all inconsistent between sites and/or species and the actual populations were unknown, it is uncertain which of the sampling methods, if any, detected the correct population fluctuations. However, in these systems electrofishing seemed to be the most satisfactory sampling method

because it generally provided an adequate CPUE and a low variance for all species except channel catfish. Electrofishing also collected the best size distribution of any technique, capturing both small young of the year and large adult fishes. Although most of the sampling in these studies was done with A.C. equipment during the day, there are strong indications that the effectiveness can be further increased and the variability decreased by using properly designed D.C. electrofishing gear and by sampling at night.

Trawling was also a useful technique where it could be applied, because it sampled a habitat which was inaccessible to electrofishing. Trawling also sampled the small young of the year fishes, so it should be able to detect significant population changes sooner than the adult sampling methods. Unfortunately, the applicability of this method is greatly limited by the need for relatively smooth unobstructed river bottoms so it cannot be used at many sites.

Seining also captures young of the year fishes, but being more or less qualitative, the technique is not as useful as electrofishing or trawling. The major difficulty lies in quantifying the effort, because the width of the haul and its effectiveness change radically with river level. The length of a seine haul also varies from sample to sample in many programs. In addition to the quantitative problems, the seine samples in these three studies also exhibited a generally low CPUE and a high variance so that no population decrease could be proven statistically significant.

Of the four sampling techniques used in these studies, trapnetting seems to be the least useful in programs of this type. It essentially samples the same habitat as electrofishing, but it generally has a lower

CPUE and a higher variance. Part of this may be caused by the trapnet's dependence on fish activity as well as population size to determine CPUE. In addition, trapnetting is a less effective monitoring technique than electrofishing because it does not sample small fishes, so any population changes would have to manifest themselves in the adult populations before they could be detected.

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TABLE 1. Fish sampling methods, frequencies, and numbers of stations used in the Susquehanna, Prairie Island, and Quad Cities monitoring programs.

METHOD	Susquehanna	Prairie Island	Quad Cities
Electrofishing	A.C. 1972-74 1972 - 14 stations frequency varied 1973-74 - 10 stations monthly D.C. 1975-77 4 stations monthly	A.C. 1973-77 up to 50 stations 3/year	A.C. 1973-78 12 stations twice/monthly
Trapnet	Framenet 1972-75 1972 - 26 stations frequency varied 1973 - 5 stations monthly 1974 - 4 stations monthly 1975 - 7 stations monthly All years had 2 consecutive sets Oneida Net 1972-74 1972 - 5 stations frequency varied 1973-74 - 4 stations monthly All years had 2 consecutive sets	Framenet 1973-77 1973-74 - up to 37 stations 3/year 1975-77 - up to 24 stations 4 consecutive sets, 3/year	Wingnet 1971-72 11 stations twice/month
Trawl		Otter Trawl 1974-77 4 stations 3/year	Otter Trawl 1971-78 3 stations twice/month
Seine	Common Seine 1972-73 11 stations monthly  Bag Seine 1974-77 4 stations monthly	Bag Seine 1974-77 up to 18 stations 3/year	Common Seine 1971-77 6 stations twice/month

TABLE 2. Checklist of common fishes at two or more sampling sites.  
A = abundant, P = present, R = rare

SPECIES		Susquehanna	Quad Cities	Prairie Island
LEPISOSTEIDAE				
<i>Lepisosteus osseus</i>	- Longnose gar		P	P
<i>L. platostomus</i>	- Shortnose gar		P	P
CLUPCIDAE				
<i>Dorosoma cepedianum</i>	- Gizzard shad		A	A
ESOSCIDAE				
<i>Esox lucius</i>	- Northern pike	P	P	P
CYPRINIDAE				
<i>Cyprinus carpio</i>	- Carp	A	A	A
<i>Hybopsis aestivalis</i>	- Speckled chub		P	R
<i>H. storeriana</i>	- Silver chub		A	P
<i>Notemigonus crysoleucas</i>	- Golden shiner	P	P	
<i>Notropis antherinoides</i>	- Emerald shiner		A	A
<i>N. blennius</i>	- River shiner		A	P
<i>N. hudsonius</i>	- Spottail shiner	A	P	A
<i>N. spilopterus</i>	- Spotfin shiner	A	A	A
<i>Pimephales notatus</i>	- Bluntnose minnow	P	P	P
<i>P. vigilax</i>	- Bullhead minnow		P	P
CATOSTOMIDAE				
<i>Carpoides carpio</i>	- River carpsucker		A	P
<i>C. cyprinus</i>	- Quillback	A	P	P
<i>Catostomus commersoni</i>	- White sucker	A	P	P
<i>Hypentelium nigricans</i>	- Northern hogsucker	P		R
<i>Ictiobus bubalus</i>	- Smallmouth buffalo		P	P
<i>I. cyprinellus</i>	- Largemouth buffalo		A	P
<i>Minytrema melanops</i>	- Spotted sucker		P	P
<i>Moxostoma anisuras</i>	- Silver redhorse		P	P
<i>M. macrolepidotum</i>	- Shorthead redhorse	A	A	A

Table 2 - Continued

SPECIES		Susquehanna	Quad Cities	Prairie Island
ICTALURIDAE				
<i>Ictalurus melas</i>	- Black bullhead		P	P
<i>I. natalis</i>	- Yellow bullhead	P	P	P
<i>I. nebulosus</i>	- Brown bullhead	A		P
<i>I. punctatus</i>	- Channel catfish	P	A	A
<i>Pylodictis olivaris</i>	- Flathead catfish		P	P
PERCICHTHYIDAE				
<i>Morone chrysops</i>	- White bass		P	A
CENTRARCHIDAE				
<i>Ambloplites rupestris</i>	- Rock bass	P	P	P
<i>Lepomis cyanellus</i>	- Green sunfish	P	P	P
<i>L. gibbosus</i>	- Pumpkinseed	P	P	P
<i>L. macrochirus</i>	- Bluegill	A	A	A
<i>Micropterus dolomieu</i>	- Smallmouth bass	P		P
<i>M. salmoides</i>	- Largemouth bass	A	P	P
<i>Pomoxis annularis</i>	- White crappie	A	A	P
<i>P. nigromaculatus</i>	- Black crappie	A	P	A
PERCIDAE				
<i>Etheostoma nigrum</i>	- Johnny darter		P	P
<i>Perca flavescens</i>	- Yellow perch	P	P	P
<i>Percina caprodes</i>	- Logperch		P	P
<i>Stizostedion canadense</i>	- Sauger		P	P
<i>S. vitreum</i>	- Walleye	A	P	P
SCIAENIDAE				
<i>Aplodinotus grunniens</i>	- Freshwater drum		A	A

TABLE 3. Ranges of average yearly CPUE and Coefficient of Variation for framenets and oneida nets at Susquehanna, 1972-74.

	Framenet		Oneida Net	
	<u>CPUE</u>	<u>C.V.</u>	<u>CPUE</u>	<u>C.V.</u>
Carp	.12 - .41	2.24 - 2.75	.47 - 3.20	1.09 - 1.89
Channel Catfish	.00 - .06	2.65 - 3.10	.43 - 1.76	1.22 - 1.98
Bluegill	.47 -1.93	1.87 - 2.28	.84 - 7.13	.88 - 1.65
White Crappie	.16 -3.26	1.56 - 2.73	.22 -11.80	1.21 - 2.96
Walleye	.01 - .15	1.88 - 3.61	.09 - 1.96	.75 - 1.99

TABLE 4. Average yearly coefficient of variation for daytime and nighttime sampling with A.C. and D.C. electrofishing at Susquehanna Steam Electric Station (A.C. - 1972-74, D.C. - 1975-77).

	<u>Day</u>		<u>Night</u>	
	<u>A.C.</u>	<u>D.C.</u>	<u>A.C.</u>	<u>D.C.</u>
Carp	1.41	1.05	1.07	1.03
Channel Catfish	2.76	1.55	2.57	2.27
Bluegill	2.15	1.59	1.77	1.31
White Crappie	2.98	1.60	1.90	1.66
Walleye	2.29	1.35	1.66	.97

TABLE 5. Range in average yearly CPUE and coefficient of variation for day and night electrofishing at Susquehanna, 1974-1977.

	<u>Day</u>		<u>Night</u>	
	<u>CPUE</u>	<u>C.V.</u>	<u>CPUE</u>	<u>C.V.</u>
Carp	.53 - 2.63	.65 - 1.51	.36 - 4.16	.67 - 1.47
Channel Catfish	.00 - .07	2.27 - 2.90	.05 - .30	1.55 - 2.76
Bluegill	.11 - 1.82	1.59 - 1.93	.16 - 2.09	1.31 - 1.77
White Crappie	.03 - 4.35	1.60 - 2.00	.00 - 5.21	1.66 - 1.90
Walleye	.09 - 1.74	1.35 - 2.82	1.22 - 3.51	.97 - 1.66

Table 6. Average yearly bluegill CPUE for electrofishing (15 min. run) and trapnetting (24 hr. set) from five habitats at Prairie Island

	1973		1974		1975		1976		1977	
	Trap.	Electro	Trap.	Electro	Trap.	Electro	Trap.	Electro	Trap.	Electro
All stations combined	.34	2.71	.58	7.43	.29	2.60	.43	3.50	4.36	6.10
Slough (North lake)	.45	1.50	.40	2.03	.38	3.06	.28	2.46	.24	3.74
River-lake	.00	.25	1.22	.66	.27	.44	.27	.73	.72	3.61
Main channel - silt, sand	.63	.00	1.27	.51	.29	.15	.73	.34	6.11	1.33
Main channel - rip rap	.25		.60	5.02	.13	1.67	.22	1.98	2.00	1.67
Tail waters	.58	8.83	.00	28.00	.19	10.60	.08	16.30	.00	27.30

Table 7. Average yearly walleye CPUE for electrofishing (15 min. run) and trapnetting (24 hr. set) from five habitats at Prairie Island

	1973		1974		1975		1976		1977	
	Trap.	Electro	Trap.	Electro	Trap.	Electro	Trap.	Electro	Trap.	Electro
All stations combined	.47	.41	.28	.86	.18	1.38	.41	1.35	.39	.38
Slough (North Lake)	.70	.33	.67	.27	.20	.90	.55	.38	.22	.18
River-lake	.28	.13	.29	.31	.38	.69	.44	.55	.44	.26
Main channel - silt, sand	.00	1.00	.15	.63	.04	.93	.13	.76	.72	.23
Main channel - rip rap	.70		.07	1.40	.12	2.22	.56	3.33	.25	1.27
Tail waters	.42	.17	.56	.92	.60	1.56	.50	4.11	.42	1.00

Table 8. Average yearly coefficients of variation for bluegill from electro-fishing and trapnetting in five habitats at Prairie Island

	1973		1974		1975		1976		1977	
	Trap.	Electro	Trap.	Electro	Trap.	Electro	Trap.	Electro	Trap.	Electro
All stations combined	2.19	1.12	2.35	2.44	2.23	2.22	2.73	2.21	1.92	2.32
Range of individual habitat values	1.41-1.73	.75-1.17	1.10-2.24	.80-1.92	1.15-2.49	.34-1.95	1.73-2.98	.99-2.15	1.02-1.85	1.19-1.87
Slough (North Lake)	1.73	.94	2.24	1.48	1.93	1.95	1.96	1.50	1.85	1.87
River-lake	--	1.00	1.30	1.92	2.49	1.56	2.98	1.60	1.52	1.70
Main channel - silt, sand	1.51	--	1.10	1.84	1.26	1.97	1.95	2.15	1.02	1.65
Main channel - rip rap	1.41		1.77	1.25	1.15	.91	1.73	1.01	1.06	1.41
Tail waters	1.57	.75	--	1.24	1.28	.63	2.00	.99	--	1.19

Table 9. Average yearly coefficients of variation for walleye from electro-fishing and trapnetting in five habitats at Prairie Island

	1973		1974		1975		1976		1977	
	Trap.	Electro	Trap.	Electro	Trap.	Electro	Trap.	Electro	Trap.	Electro
All stations combined	1.66	1.67	2.01	1.79	2.41	1.40	2.25	1.80	1.91	2.35
Range of individual habitat values	1.39-2.64	1.00-2.69	1.37-2.24	1.36-2.16	.81-2.59	1.11-1.70	.80-1.73	.83-1.90	1.44-2.00	1.54-2.00
Slough (North Lake)	1.41	1.66	1.37	1.84	2.07	1.32	1.54	1.80	2.00	2.55
River-lake	2.64	2.35	2.20	2.16	2.59	1.70	1.63	1.90	1.65	2.25
Main channel - silt, sand	--	1.00	1.87	2.05	2.65	1.24	1.38	1.63	1.72	2.35
Main channel - rip rap	1.39	--	2.24	1.36	1.15	1.11	1.73	1.04	1.58	1.54
Tail waters	1.57	2.69	1.73	1.44	.81	1.28	1.41	.83	1.44	1.60

TABLE 10. Range of average annual CPUE and coefficients of variation (in parentheses) for daytime electrofishing (15 min. run), trapnetting (24 hr. set), trawling (7 min. tow), and seining (1 haul) at Susquehanna, Prairie Island, and Quad Cities

	Electrofishing				Trapnet				Seine				Trawl			
	Susq.	P. I.	Quad	Susq.	P. I.	Quad	Susq.	P. I.	Quad	Susq.	P. I.	Quad	Susq.	P. I.	Quad	
Carp	2.41-5.09 (.89-1.57)	3.75-7.72 (.72-.94)	1.80-4.35 (.87-1.69)	.10-.41 (2.24-2.75)	3.44-6.04 (.80-1.12)	.04-.06 (2.93-3.01)	.00-.11 (3.32)	.13-.32 (2.37-3.01)	.00-.30 (1.63-2.84)		.64-3.24 (1.04-1.88)	.03-.20				
Channel Catfish	.00-.04 (2.24-2.90)	.00-.87 (2.94-3.79)	.32-.91 (2.38-3.73)	.00-.33 (2.48-3.10)	.06-.24 (2.16-6.25)	.04-.09 (3.43-3.62)	.00 (---)	.25-1.23 (2.55-3.14)	.00-1.36 (1.76-2.76)		.25-11.90 (1.28-3.22)	2.80-18.40				
Bluegill Sunfish	.67-1.82 (1.64-2.43)	2.59-7.43 (1.12-2.44)	.48-4.81 (1.74-2.34)	.47-4.46 (1.51-2.28)	.29-4.36 (1.92-2.73)	.22-.31 (3.07-3.38)	.64-4.57 (1.26-2.59)	.41-4.14 (1.62-2.48)	.37-5.55 (1.65-2.28)		.00-1.66 (1.16-3.49)	.00 (---)				
White Crappie	.00-4.41 (1.56-3.64)	.04-.69 (1.55-4.68)	.15-1.79 (1.38-3.88)	.16-3.61 (1.18-2.73)	.12-7.53 (1.54-3.14)	1.74-2.27 (1.34-1.77)	.00-.22 (2.00-3.32)	.37-2.09 (1.79-2.21)	.02-.79 (1.15-2.65)		.34-16.20 (1.20-1.75)	.00 (---)				
Walleye	.09-.68 (1.65-2.82)	.38-1.38 (1.40-2.35)	.09-.82 (1.57-3.01)	.00-.15 (1.88-3.61)	.18-.47 (1.66-2.41)	.00 (---)	.00 (---)	.00-.45 (1.90-2.53)	.00-.21 (1.14-2.45)		.04-.58 (1.41-2.30)	.00-.03				

Table 11. Summary of juvenile and adult fish sampling methods for riverine sites.

Method	Advantages	Disadvantages	Applicability
A.C. Electro-fishing	Greatest range for given power (voltage) Non-destructive sampling	Difficult to dip stunned fish from bottom or cover, especially in turbid water Causes more tissue damage than D.C. Size selective for larger fish	Useful for sampling most adult fish in water up to 6 ft. deep although turbidity and cover reduce its effectiveness Works well in shallow stump strewn or rocky areas
D.C. Electro-fishing	Causes forced swimming (galvanotaxis) of fish toward anode (+) so fish can be drawn from cover or bottom before they are stunned	Less range than A.C. Ineffective in highly conductive water Size selective for larger fish Some species selectivity by pulse rate	Useful for sampling most adult fish in water up to about 6 ft. deep, especially in dense cover or high turbidity
Trapnet	Samples over time Non-destructive	Cannot be used in fast current Catch depends upon activity or movement of fish in addition to population High species selectivity Unknown area sampled Can be time-consuming to set and remove trap Smaller nets generally less effective than larger, more complicated nets	Samples many species of adult fishes in water from 3-10 ft. deep in slow to moderate currents
Trawl	Samples different habitat than other methods Quantitative technique - samples a known area	Cannot be used on most sites because of snags on the river bottom Obvious gear avoidance by adult fishes Often destructive sampling	Samples benthic fish in areas with clean, uniform bottoms Primarily used to sample young of the year fishes

Table 11. (continued)

Method	Advantages	Disadvantages	Applicability
Seine	<p>Samples smaller fish which escape through meshes of other gears</p> <p>Can sample shallow areas and shorelines which are inaccessible to other gears</p>	<p>Large gear avoidance problems</p> <p>Need shallow, snag-free sampling sites</p> <p>Sampling sites and sampling efficiency change with water level</p>	<p>Samples young of the year fishes and minnows along shorelines</p>

TABLE 12. Size ranges (in cm.) of fish caught by trapnet, electrofishing gear, trawl, and seine at Prairie Island.

	<u>Trapnet</u>	<u>Electrofishing</u>	<u>Trawl</u>	<u>Seine</u>
Carp	16 - 80	2 - 80	2 - 70	2 - 65
Channel Catfish	24 - 65	4 - 70	1 - 12	2 - 12
Bluegill Sunfish	10 - 30	2 - 28	1 - 22	2 - 20
White Crappie	10 - 34	6 - 34	1 - 30	2 - 26
Walleye	24 - 75	4 - 75	6 - 55	4 - 16

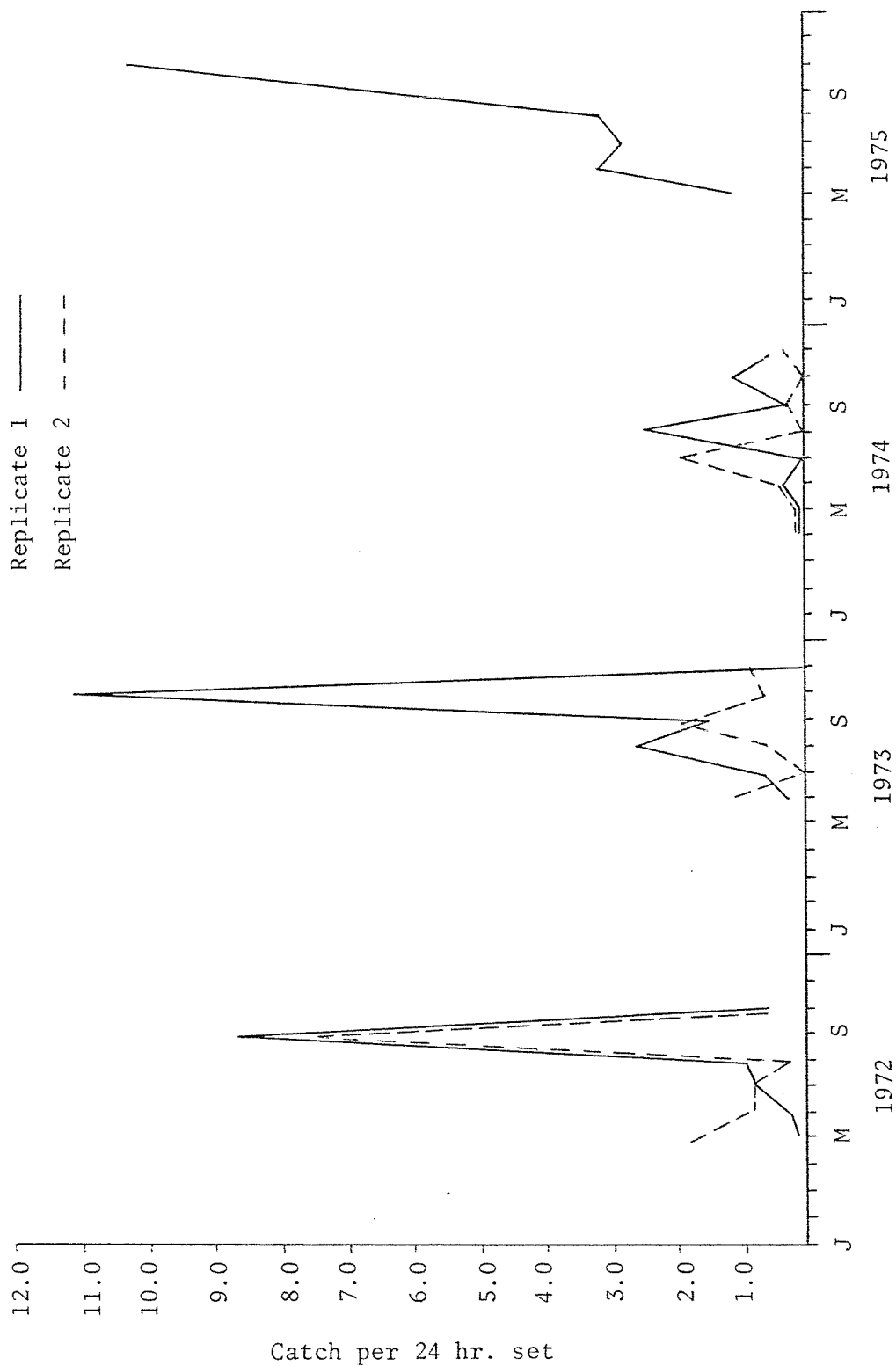


Figure 1. Monthly CPUE of two consecutive frame net sets for bluegill sunfish as Susquehanna.

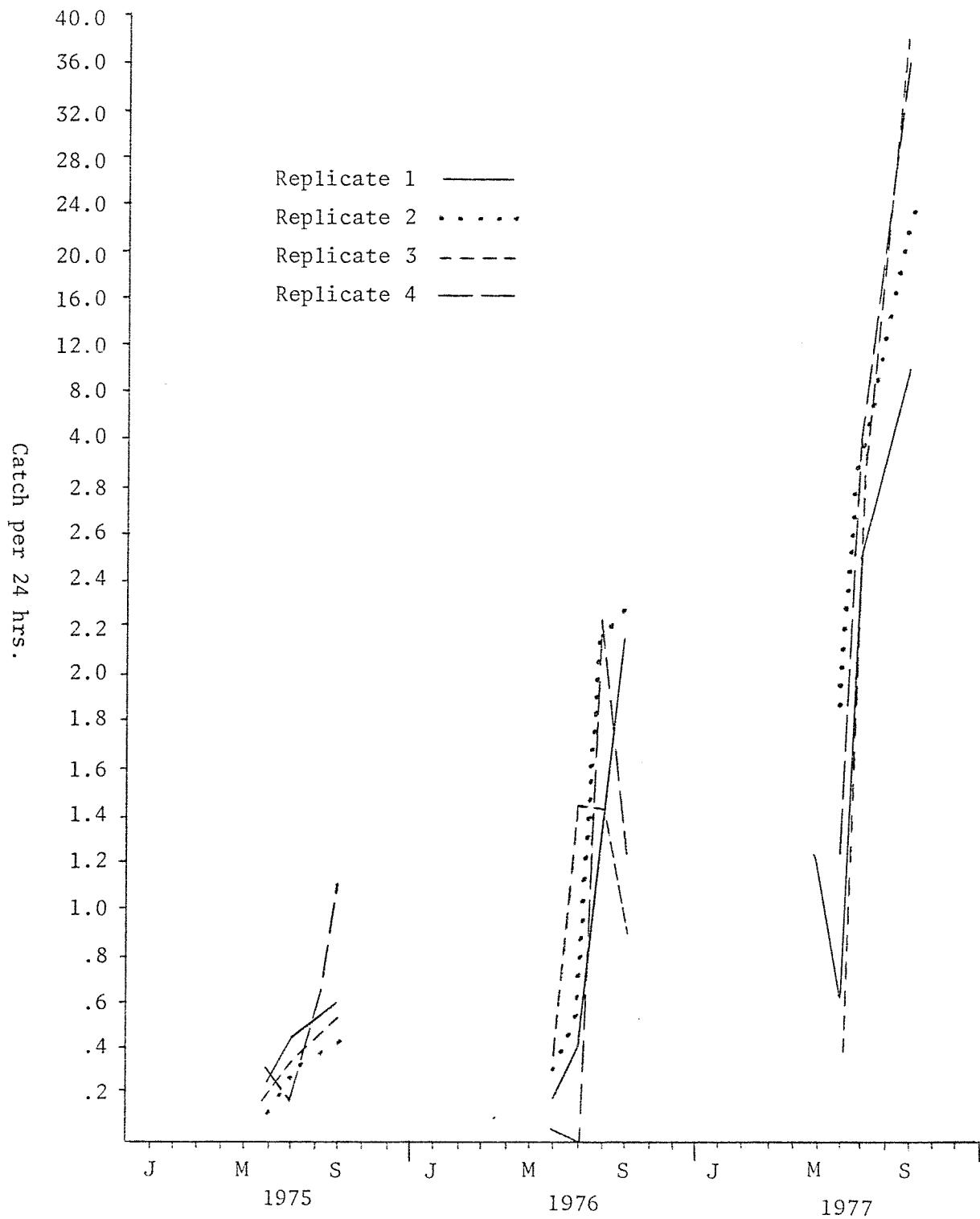


Figure 2. Monthly CPUE of four consecutive trapnet sets for white crappie at Prairie Island.

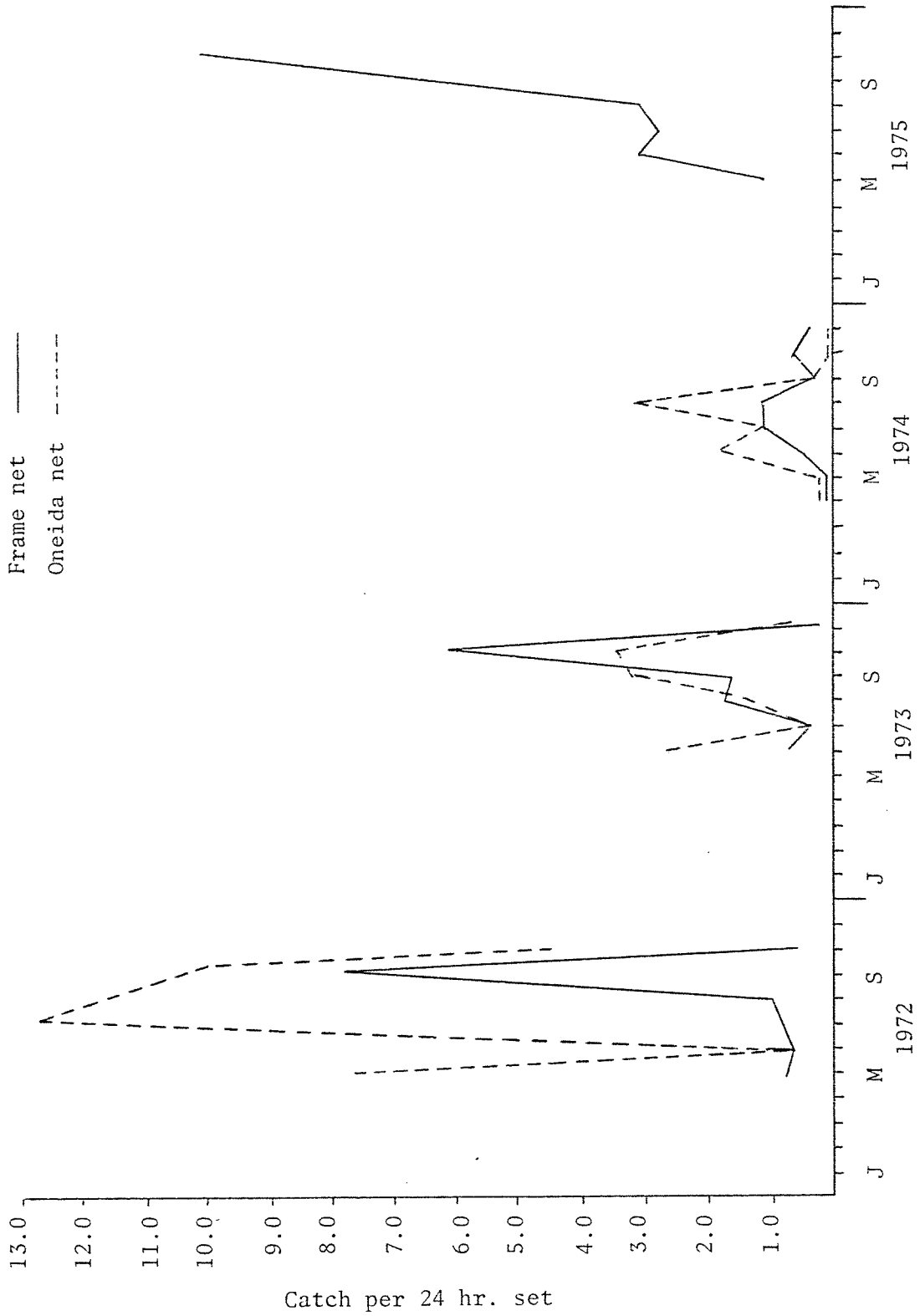


Figure 3. Monthly CPUE of two types of trapnets for bluegill sunfish at Susquehanna.

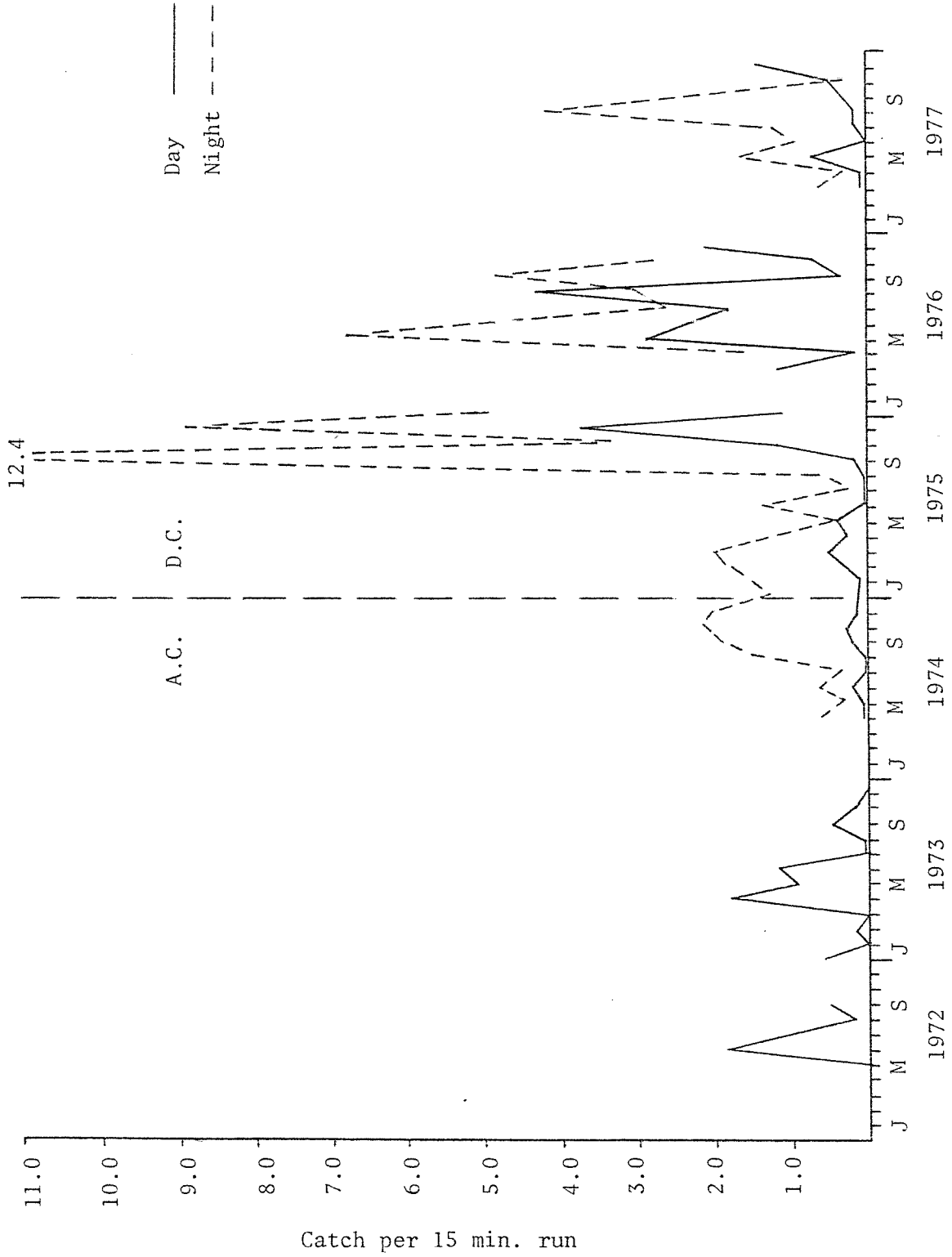


Figure 4. Monthly CPUE for day and night electrofishing for walleye at Susquehanna.

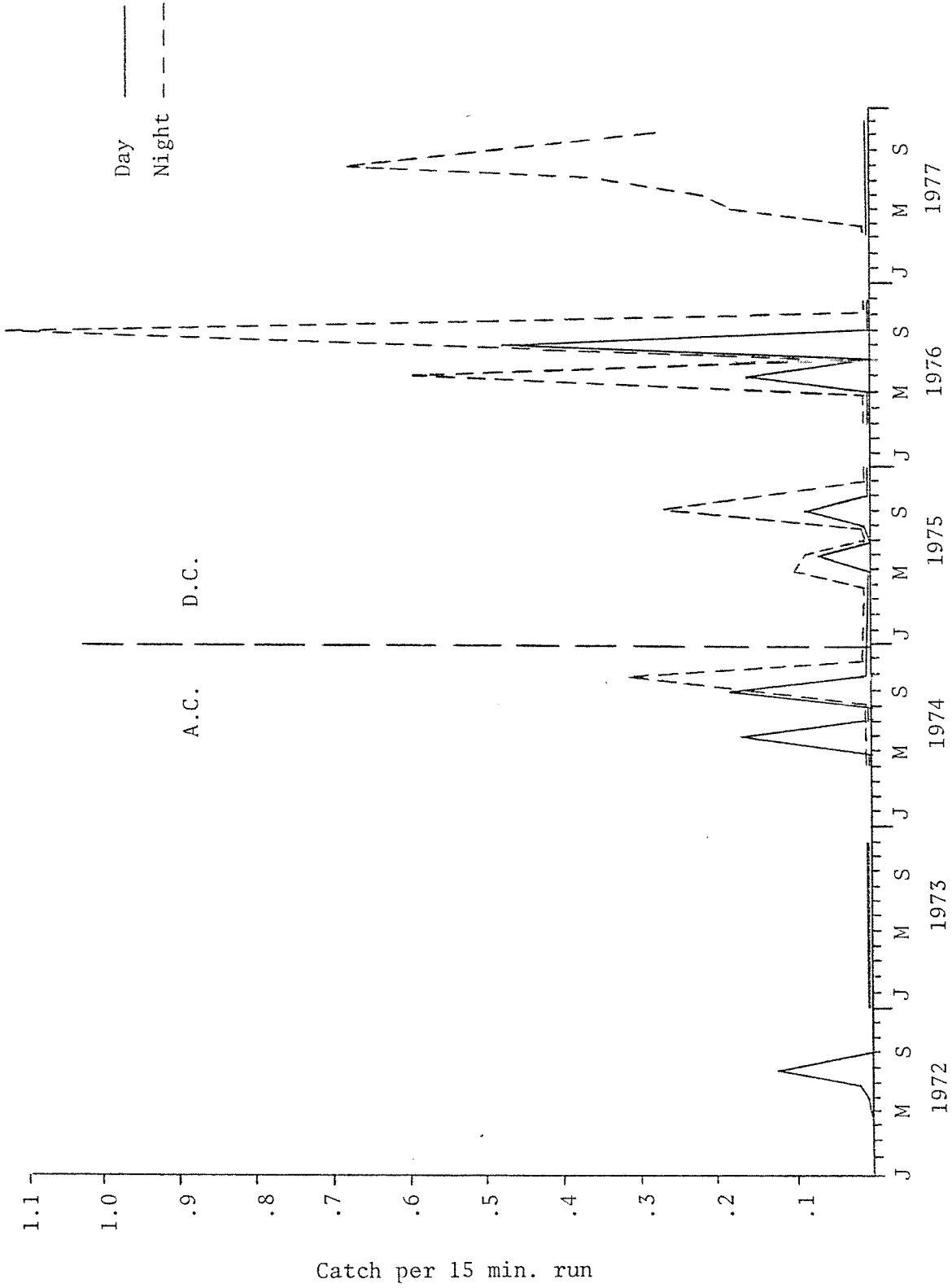


Figure 5. Monthly CPUE for day and night electrofishing for channel catfish at Susquehanna.

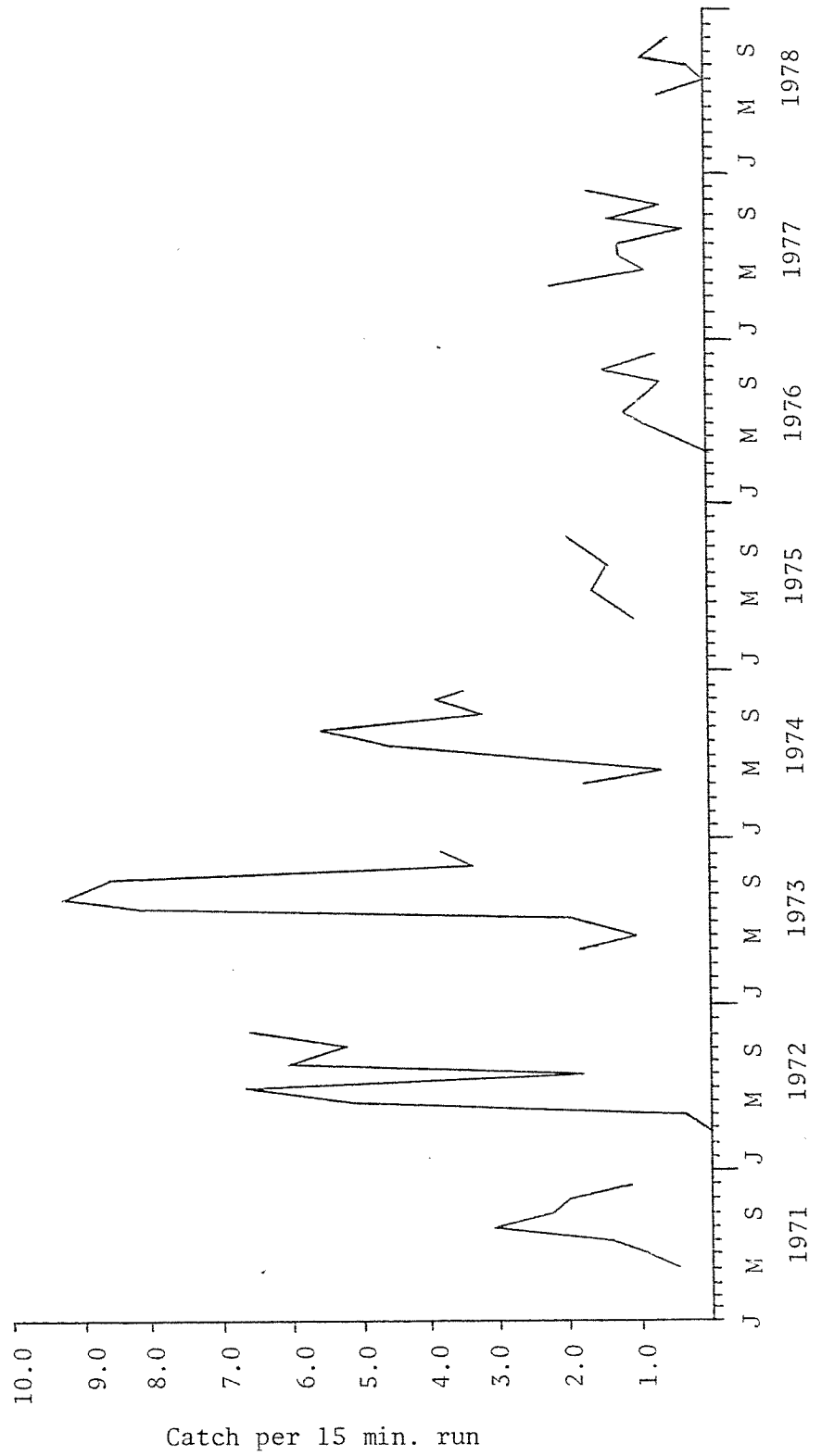


Figure 6. Seasonal change in electrofishing CPUE for bluegill sunfish at Quad Cities.

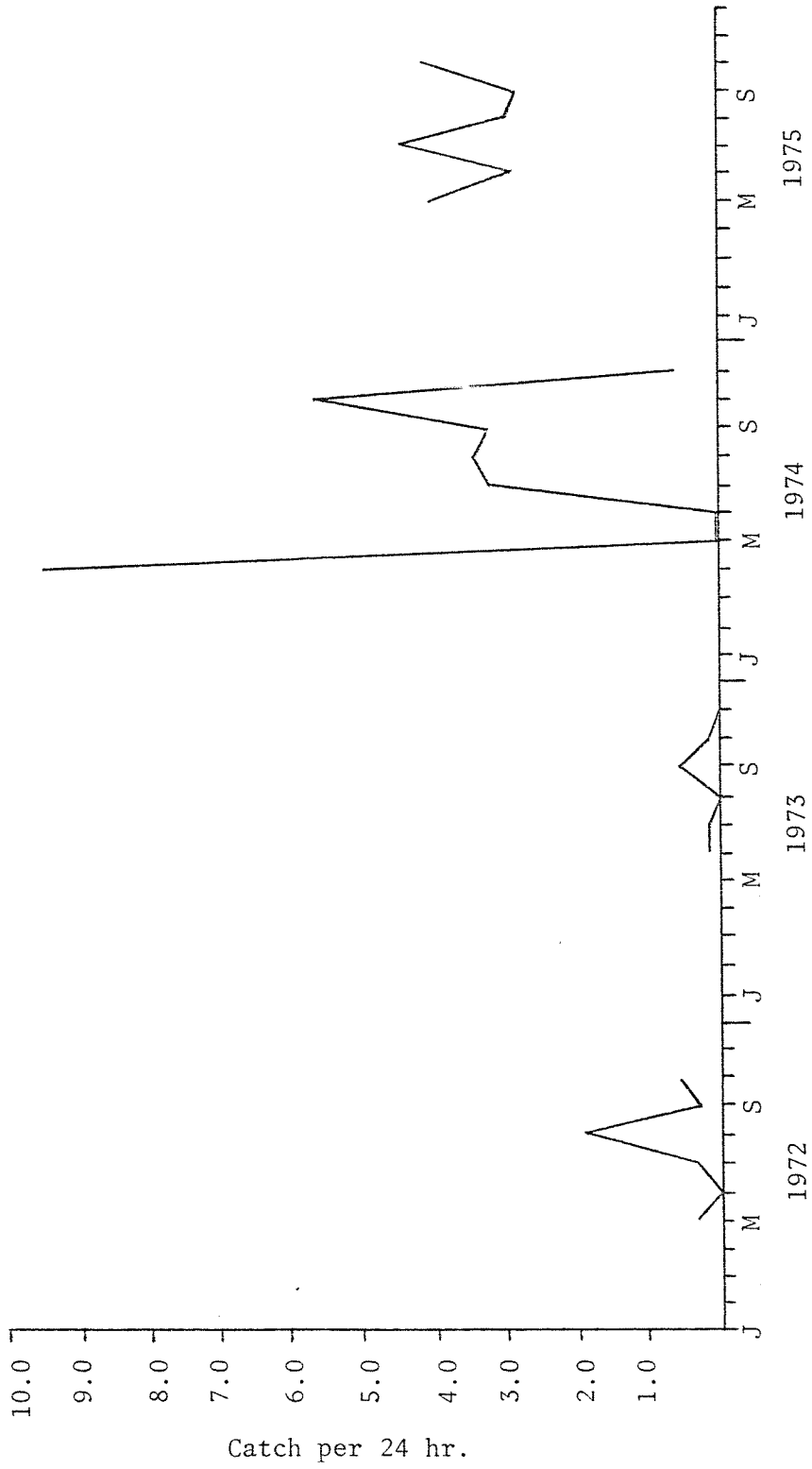


Figure 7. Seasonal change in trapnetting CPUE for white crappie at Susquehanna.

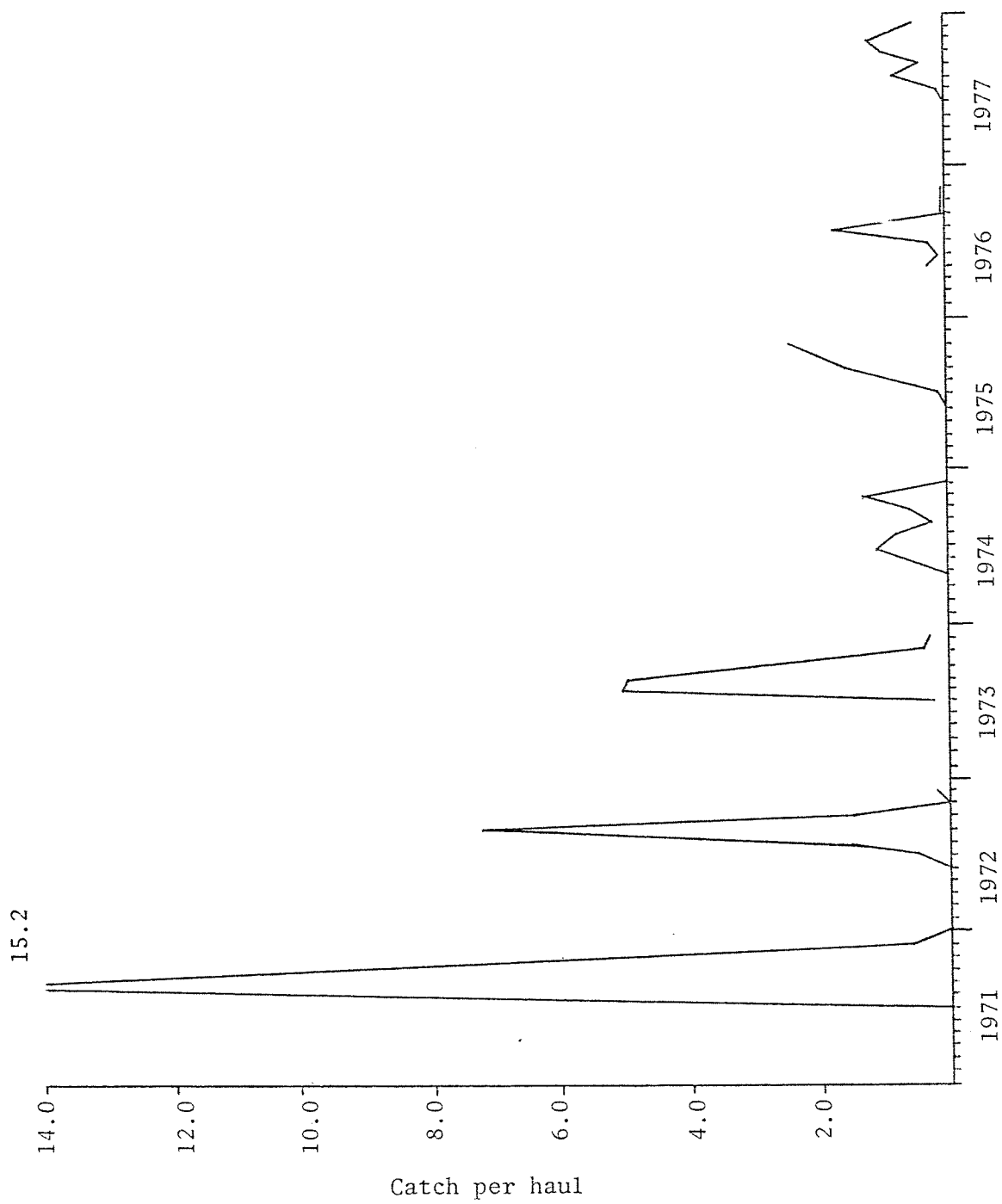


Figure 8. Seasonal change in seine CPUE for bluegill at Quad Cities.

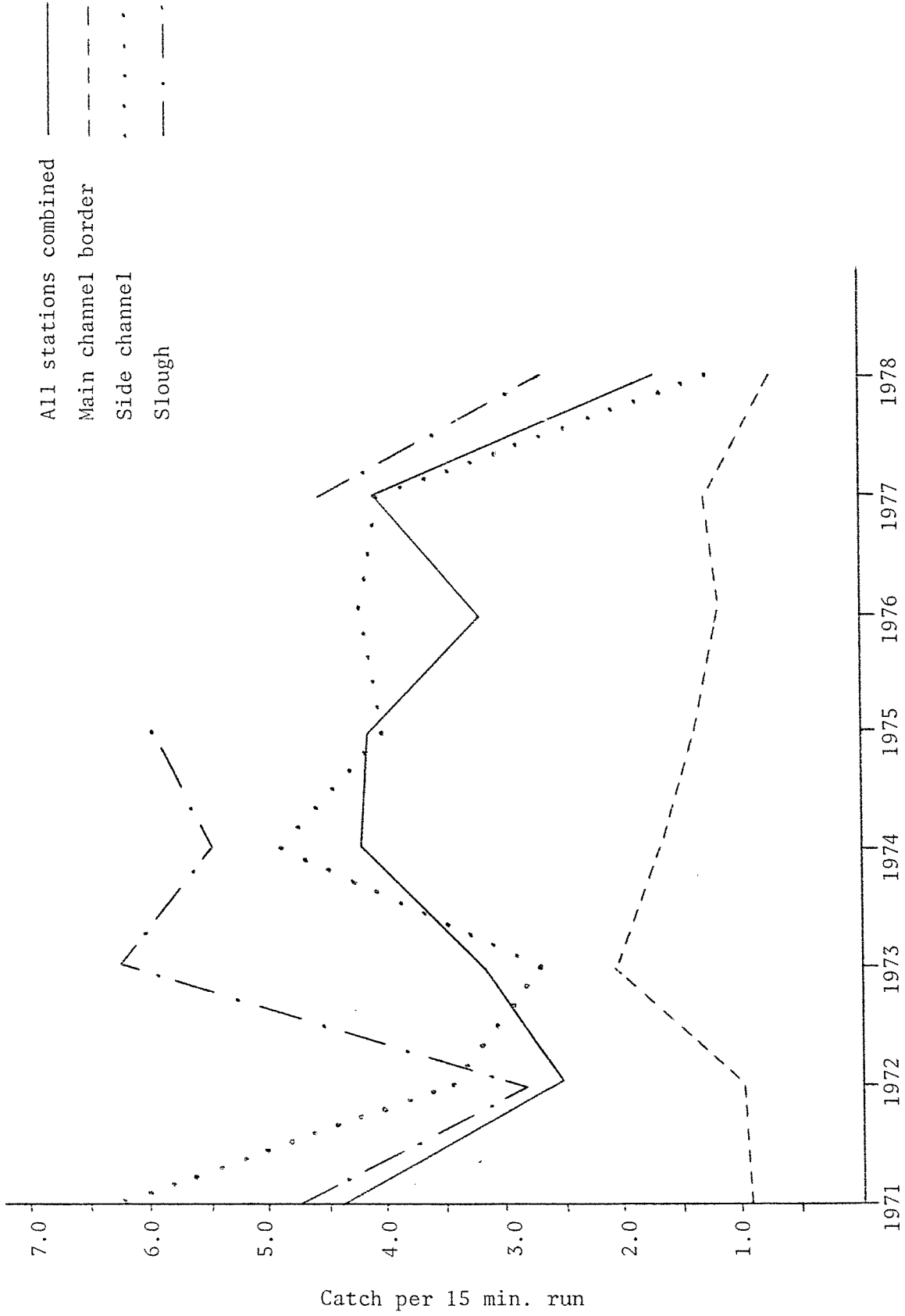


Figure 9. Average yearly electrofishing CPUE for carp from three habitats at Quad Cities.

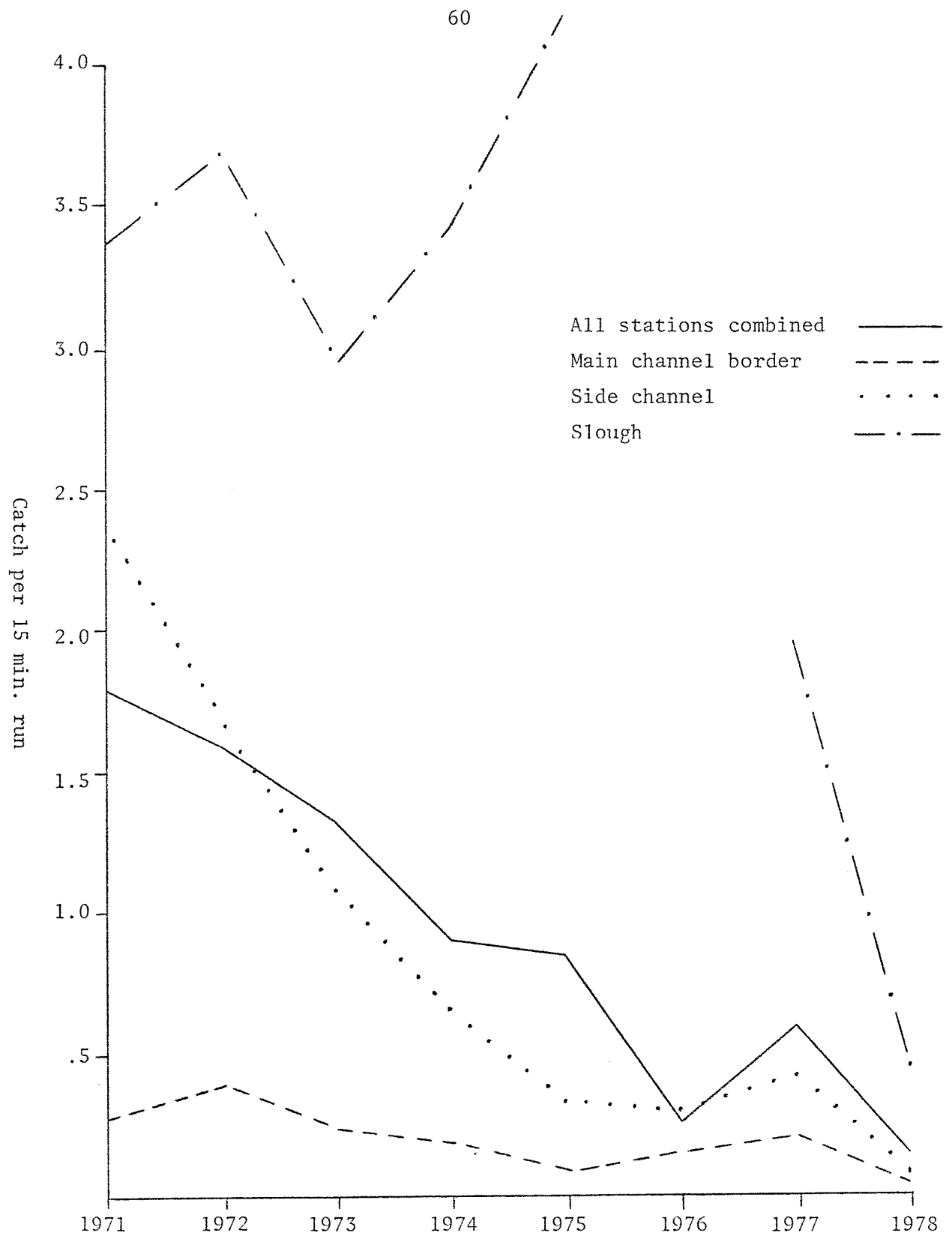


Figure 10. Average yearly electrofishing CPUE for white crappie from three habitats at Quad Cities.

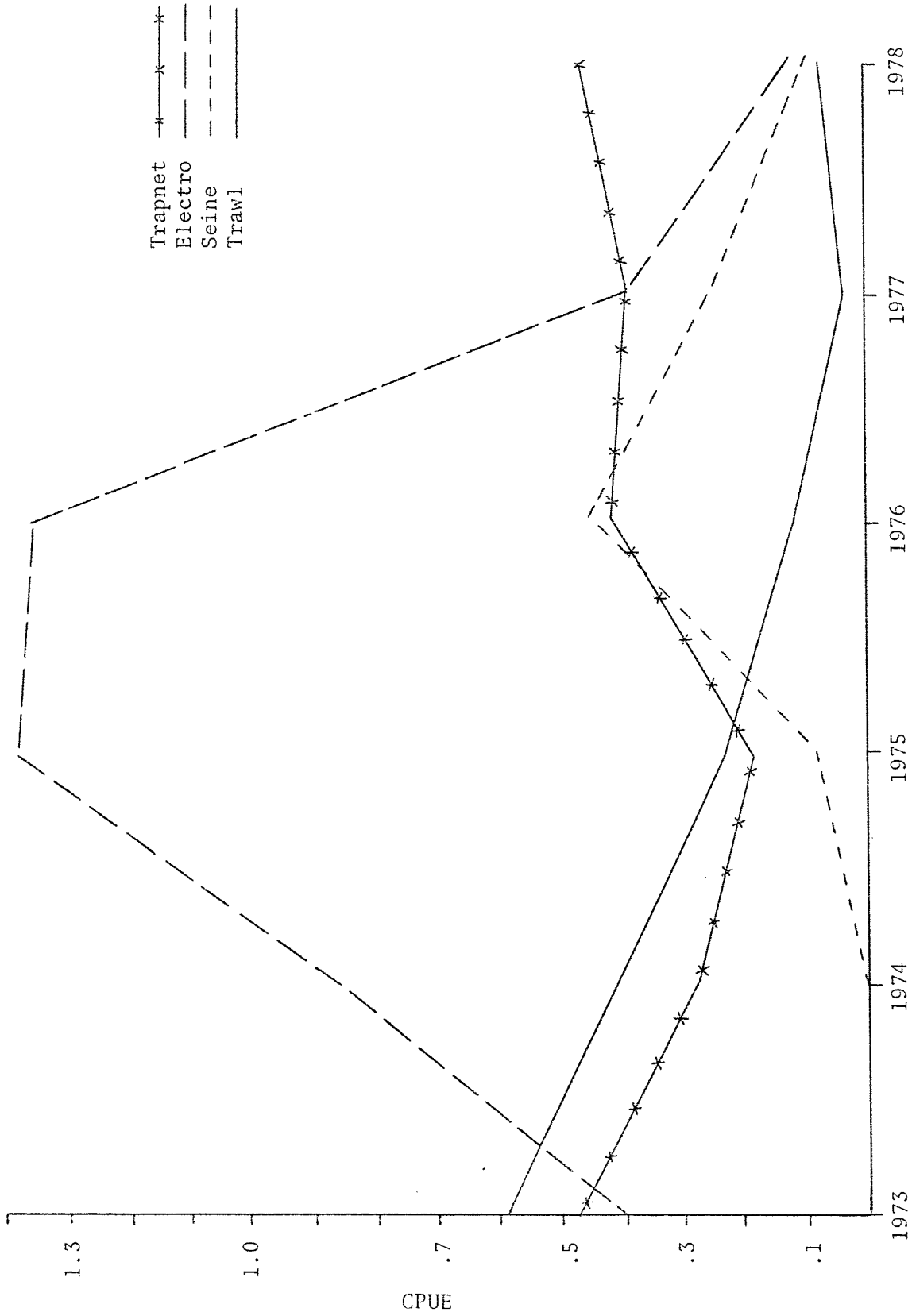


Figure 11. Average yearly CPUE for walleye at Prairie Island from A.C. electrofishing (15 min. run), trapnetting (24 hr. set), seining (1 haul), and trawling (7 min. tow).

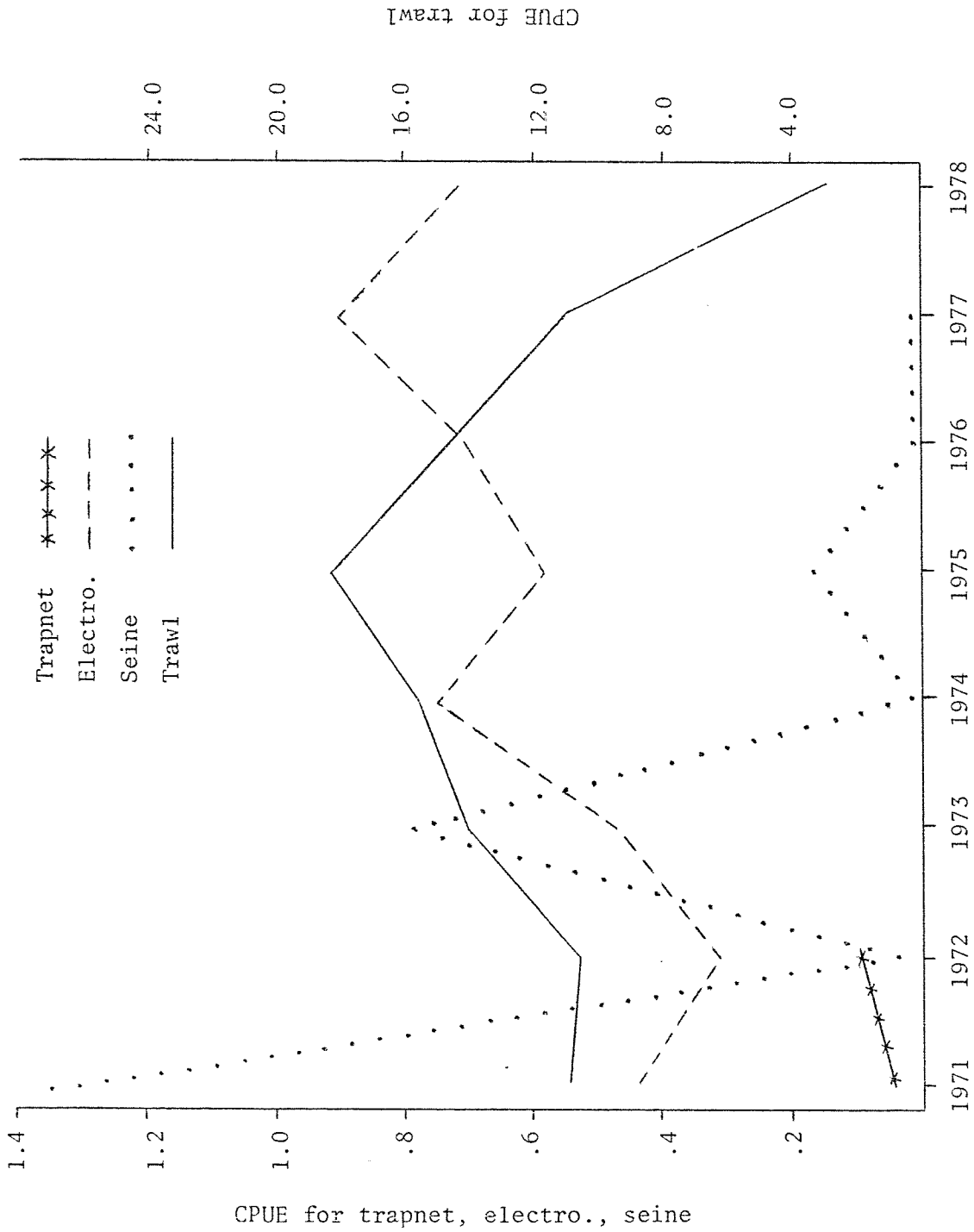


Figure 12. Average yearly CPUE for channel catfish at Quad Cities from A.C. electrofishing, trapnetting, seining, and trawling.