FISH ENTRAINMENT AT BROWNS FERRY NUCLEAR PLANT, WHEELER RESERVOIR, ALABAMA, FOR THE YEARS 1978 and 1979

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INTRODUCTION

Fish eggs and larvae entrained in cooling water may suffer mortality from one or more physical effects of passage through the plant. As a consequence, in conjunction with the construction of Browns Ferry Nuclear Plant (BFNP), TVA investigated the preoperational characteristics and dynamics of the annual ichthyoplankton populations in Wheeler Reservoir (1971-1973) (reported in Chapter 7 in BFNP Preoperational Fisheries Resources Report, TVA 1978a). This investigation was continued through initiation of commercial operation in 1974, and six years of operational monitoring data have been collected. The 1971-1977 data are available in Volume 4: Effects of the Browns Ferry Nuclear Plant Cooling Water Intake on the Fish Populations of Wheeler Reservoir (1978b). This report augments this data base with the results of the 1978 and 1979 investigations and provides a reassessment of the 1977 entrainment estimates.

Specific objectives as presented in the previous description of larval fish entrainment at BFNP (1978b) were:

1. To define the annual patterns and fluctuations in density of the ichthyoplankton community near and/or transported past the plant.
2. To determine the species composition and relative abundance of the various taxa comprising the ichthyoplankton.
3. To define temporal distribution of fish eggs and larvae in order to determine periods of greatest plant entrainment.
4. To describe spatial distribution of ichthyoplankton near the plant in relation to the normal zone of influence of

the cooling water intake and relative vulnerability of the various taxa to entrainment.

5. To estimate numbers and relative abundance of the various taxa entrained during plant operation.
6. To relate periodic densities and relative abundance of ichthyoplankton estimated to be entrained with those occurring in the reservoir in order to determine and assess the impact of this entrainment on the fish community of Wheeler Reservoir.

MATERIALS AND METHODS

Reservoir Sampling

Ichthyoplankton sampling was incorporated in the overall Browns Ferry fisheries monitoring program in 1971. Sampling gear and technique for estimating the abundance of ichthyoplankton were modified in 1978 to better sample deeper strata. Concurrently, the primary transect sampled to measure seasonal transport of ichthyoplankton past BFNP was relocated at TRM 294.5 (Figure 1). The transect at TRM 293.0, referred to as the plant transect, and utilized since 1971, was maintained for comparison with TRM 294.5. Each year samples were collected weekly during both day and night. Sample periods and corresponding dates for each year of full (three-unit) plant operation are listed in Table 1.

Sample gear used in 1978 and 1979 consisted of a square 0.5 m (flow meter equipped) side-towed net (0.505 mm mesh). This net was capable of sampling the water column (except the lowest 0.5 m) in a stair-step, oblique fashion. At a towing speed of 1 m/sec, 10-minute samples filtered approximately 150 m^3 of water. This net replaced the 1 m diameter stern-towed net (0.79 mm mesh) used from 1971-1977 because it increased the effectiveness in sampling more than one or two discrete strata and boat propwash could be avoided.

Transport Estimation Techniques

The method of estimating total numbers of eggs and larvae annually transported past BFNP from 1974-1977 utilized a cross-sectional depth profile of the river at TRM 293. The profile was subdivided into compartments to determine the ratio of overbank ($\leq$ 3 m depth) area to open water (> 3 m depth) area. Compartment weighting factors (0.22-shoreline, 0.78-channel) were multiplied by corresponding larval fish densities

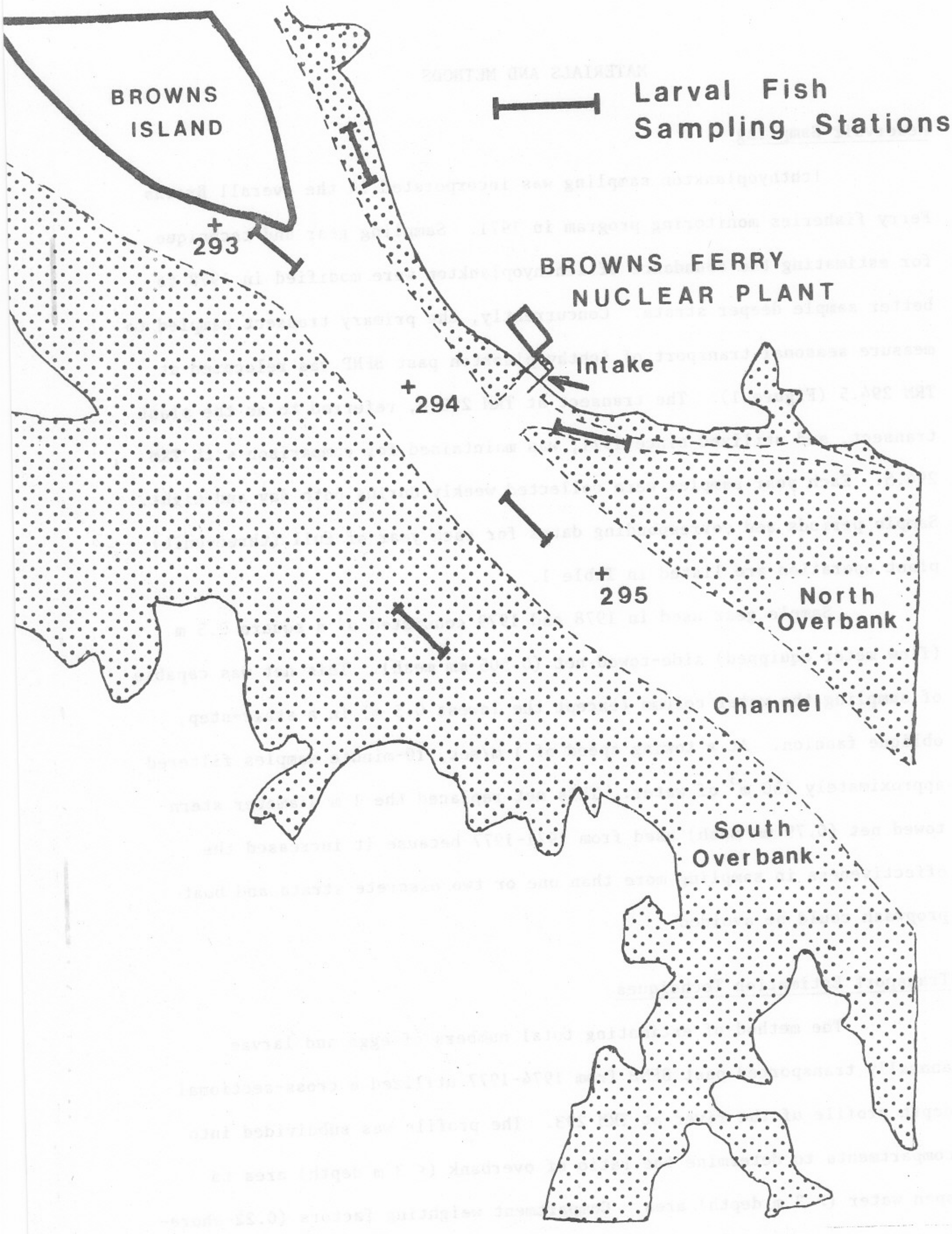

Figure 1: Location of larval fish sample stations (reservoir and intake) at Browns Ferry Nuclear Plant in 1978 and 1979.

Table 1. Larval fish sample dates for reservoir and plant intake stations at Browns Ferry Nuclear Plant during 1977-1979.

Sample Period	Sample Date 1977	1978	1979
1	3-16	3-27	3-13
2	3-23	4-03	3-19
3	3-30	4-10	3-27
4	4-06	4-20	4-02
5	4-13	4-24	4-10
6	4-19	5-01	4-17
7	4-27	5-08	4-26
8	5-04	5-16	4-30
9	5-11	5-22	5-07
10	5-18	5-30	5-14
11	5-26	6-05	5-21
12	6-02	6-12	5-31
13	6-09	6-19	6-04
14	6-15	6-26	6-12
15	6-22	7-03	6-19
16	6-29*	7-10	6-27
17	7-07*	7-17	7-02
18	7-13	7-24	7-10
19	7-20	7-31	7-16
20	7-27	8-07	7-25
21	8-03	8-14	7-30
22	8-10	8-21	8-13
23	8-17	8-28	8-06
24	8-24		8-20
25			8-27

*No intake samples taken

to obtain a weighted mean transect density for each sample period. Data from both channel strata (surface and 5 m) were combined to calculate the weighted density for the channel or open water station.

The initial assumption of uniform water velocities across both main channel and overbank areas was in error according to estimates of flow in the transect compartments at both TRM 293.0 and 294.5 supplied by the TVA Water Systems Development Branch. Velocity measurements on which these estimates are based were taken by the TVA Hydraulic Data Branch on August 1, 1969, at TRM 291.8 and 294.0 when the average river flow was 39,000 cfs. The flows in each transect compartment (TRM 293.0 and 294.5) were calculated by multiplying the average velocity in each sample compartment by its cross-sectional area. Flow volumes were calculated for total overbank area and upper and lower strata of the channel or open water area corresponding to the sections sampled for ichthyoplankton. Figure 2 shows the depth profiles of the two sample transects with the proportionate river flow for each sample compartment. These flow estimates were used as weighting factors to calculate the total number of fish eggs and larvae transported past BFNP during 1978 and 1979. This was an improvement over the previous method which was based on the simple assumption of uniform transect velocity.

Intake Samples

Ichthyoplankton densities in the intake basin at Browns Ferry Nuclear Plant were sampled from 1974-1977 with a 3 x 3 array of 0.5 m diameter (0.79 mm mesh) stationary nets. In accordance with the change to 0.5 m square nets in the reservoir in 1978, intake nets were also changed to 0.5 m square with 0.505 mm mesh; the 3 x 3 array was retained. The three rows of nets were fished at 0.5 m, middepth, and

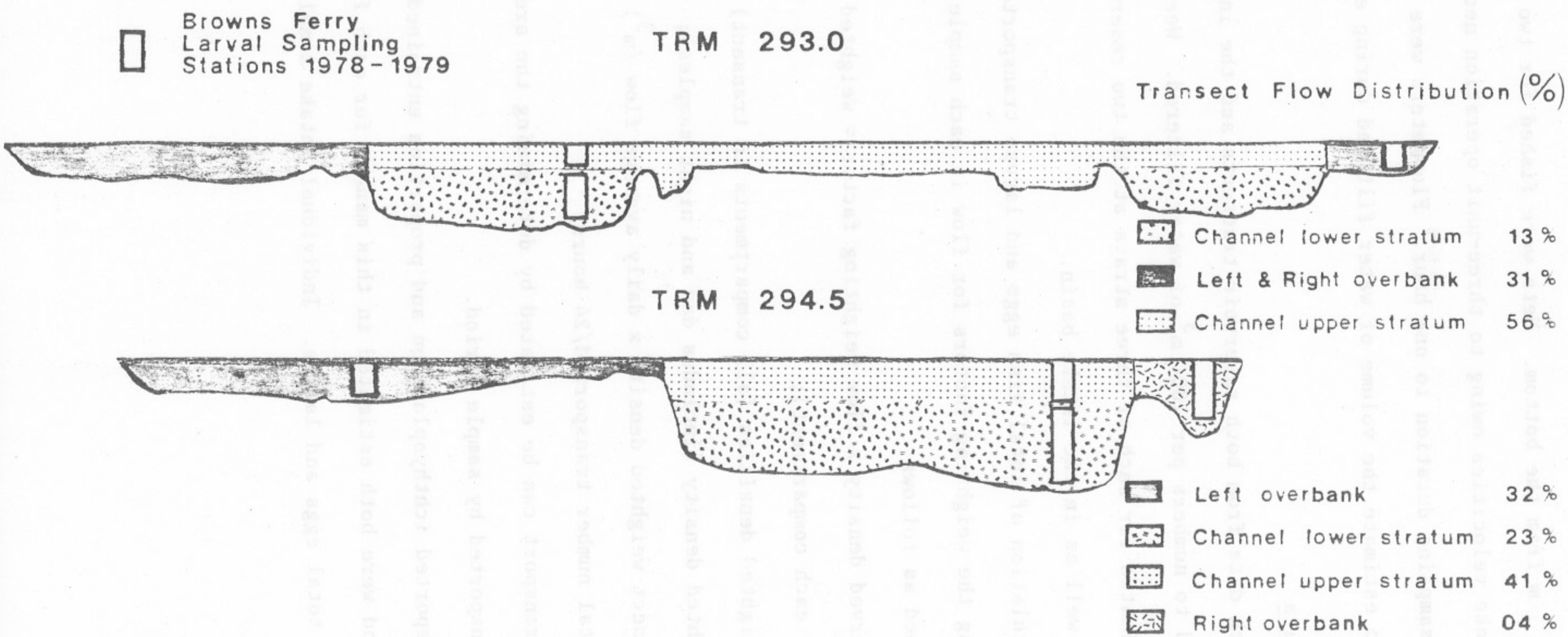

Figure 2: Cross-section profiles of reservoir transects at TRM 293.0 and 294.5 including locations of sample compartments and percentages of river flow calculated for each stratum sampled.

approximately 1 m from the bottom. Nets were fished for two hours except when high intake velocities owing to three-unit operation necessitated reduction in sampling duration to one hour. Flowmeters were mounted in intake nets to estimate the volume of water filtered during each sample.

Analysis of Data

Catch data from both reservoir transects and the intake basin were converted to numbers per 1000 m^3 of water filtered. Weekly densities were thus estimated for each of three strata at the two reservoir transects, as well as in the intake basin.

Calculation of total fish eggs and larvae transported past the plant utilizing the weighting factors for flow in each sample compartment was accomplished as follows:

Observed density x flow weighting factor = weighted density (for each compartment);

Σ weighted densities (all compartments in transect) = transect weighted density (includes day and night samples);

transect weighted density x daily average flow (m^3) past plant = total number transported/24 hours.

Total annual transport can be estimated by determining the area under a graph of numbers transported by sample period.

Transported ichthyoplankton and proportion entrained by the plant by sample period were both estimated in this manner for each family collected, as well as for total eggs and larvae. Individual intake samples were averaged to provide overall intake densities for each sample period. Plant entrainment rate was estimated by the following equation:

$$\frac{Di}{Dr} \times \frac{Qi}{Qr} \times 100$$

where Di = mean density (No./1,000 m^3) of eggs or larvae in intake samples;
Dr = weighted mean density (No./1,000 m^3) of eggs or larvae in the reservoir (transect);
Qi = intake water demand (m^3/day);
Qr = reservoir flow (m^3/day).

Reservoir flows past the plant for each sample period were estimated based on the upstream and downstream hydroelectric releases and tributary inflow (provided by TVA Hydraulic Data Branch). Intake water demand was calculated from known rating (833 m^3/minute each) of condenser circulating pumps. The number of pumps operating during each sample period was recorded. Table 2 lists 24-hour reservoir (Qr) and intake (Qi) flows ($m^3 \times 10^6$) and proportion hydraulic plant entrainment (Qi/Qr) for 1977-1979 by sample period.

Table 2. Reservoir (Q_r) and intake (Q_i) flows ($m^3 \times 10^6$) at Browns Ferry Nuclear Plant, 1977-1979. Flows are 24-hour totals. (Q_i/Q_r) = proportion hydraulic entrainment.

Sampling Period	1977 Q_r	1977 Q_i	1977 Q_i/Q_r	1978 Q_r	1978 Q_i	1978 Q_i/Q_r	1979 Q_r	1979 Q_i	1979 Q_i/Q_r
1	296.06	7.19	0.024	86.12	7.19	0.083	303.37	10.79	0.035
2	95.91	8.39	0.087	64.10	7.19	0.112	139.21	10.79	0.077
3	87.10	10.79	0.123	64.59	7.19	0.111	128.44	10.79	0.084
4	511.88	10.79	0.021	39.15	7.19	0.184	111.56	10.79	0.096
5	189.87	9.59	0.050	45.51	7.19	0.158	100.30	10.79	0.107
6	119.65	8.39	0.070	60.92	7.19	0.118	224.84	10.79	0.047
7	118.76	9.59	0.081	143.37	7.19	0.050	92.48	10.79	0.116
8	98.85	9.59	0.097	103.49	9.59	0.093	98.84	9.59	0.097
9	95.91	10.79	0.112	77.80	7.19	0.092	79.51	9.59	0.120
10	77.56	10.79	0.139	47.95	9.59	0.200	80.73	9.59	0.118
11	82.54	10.79	0.130	57.25	8.99	0.157	75.35	7.19	0.095
12	76.83	10.79	0.140	100.80	9.59	0.095	179.08	9.59	0.053
13	73.65	10.79	0.146	56.52	8.99	0.159	213.09	10.79	0.050
14	92.98	9.59	0.103	76.09	8.39	0.110	106.91	10.79	0.100
15	88.08	7.19	0.081	92.97	8.39	0.090	83.67	10.79	0.128
16	66.06	-[1]	-	70.46	8.39	0.119	83.18	10.79	0.129
17	78.05	-[1]	-	63.37	8.39	0.132	85.87	10.79	0.125
18	60.68	7.19	0.118	96.40	8.39	0.087	87.09	10.79	0.123
19	70.71	9.59	0.135	33.52	8.39	0.250	108.38	10.79	0.099
20	73.40	9.59	0.130	43.67	8.39	0.192	221.65	10.79	0.048
21	48.93	10.79	0.220	59.33	8.39	0.141	185.69	10.79	0.058
22	48.44	9.59	0.197	57.98	8.39	0.145	117.43	10.79	0.091
23	62.39	9.59	0.153	50.89	9.59	0.188	110.82	10.79	0.097
24	39.15	10.79	0.275				94.92	9.59	0.101
25							119.39	7.79	0.065
Mean Seasonal hyd. ent.			0.12			0.133			0.09

1. Data are not available due to plant operational characteristics.

RESULTS

Seasonal occurrence and relative abundance of major taxa of fish eggs and larvae collected in 1978 and 1979 were determined for the reservoir transects (TRM 293.0 and 294.5) and intake basin. Temporal distribution of larval populations in relation to seasonal transport and entrainment was also determined. Because this report serves to update the results of larval entrainment at Browns Ferry from 1974-1977 (TVA 1978b), results were compared with those reported for 1977, the first year of full (three-unit) plant operation. In addition to use for estimating egg and larval entrainment in 1978 and 1979, the modified weighting factors (based on flow) for TRM 293.0 were applied to the 1977 data, and the results compared to the earlier estimate.

Occurrence and Relative Abundance of Eggs and Larvae

Eggs

1978

Planktonic fish eggs were most abundant at TRM 293.0 in 1978 (Appendix B1) and were virtually all sciaenid (drum) eggs (Appendix A1). Highest densities of eggs at all three transects (Appendix B1) occurred on May 22. This was similar to the period of greatest egg density ($3,500/1,000\ m^3$) in 1977, which was May 18 (TVA 1978b).

1979

Egg densities in 1979 were again greater (7 times) at TRM 293.0 than at TRM 294.5. The peak density in 1979 ($5,500/1,000\ m^3$) was similar to the peak in 1978, ($6,500/1,000\ m^3$) but occurred four weeks later on

June 19 (Appendix B2). Greatest densities observed at both TRM 294.5 and in the intake basin were approximately 700/1,000 m^3 on May 21 and June 12, respectively.

Larvae

1978

Larval fish from 14 families were collected in 1978 (Appendix A1); two of these (Lepisostiidae and Poeciliidae) had not been collected in earlier years. Five families were represented by only one specimen each (Appendix A1). As in previous years, the family Clupeidae was the most abundant, composing a high of 95.5 percent of all larvae collected at TRM 294.5 and a low of 93.8 percent at the TRM 293.0 transect (Appendix A1). Intake samples contained 94.7 percent clupeids. Percichthyidae and Centrarchidae were second and third in abundance at the reservoir transects.

Temporal distributions of total larval fish by transect for each sample period during 1978 and 1979 are shown in Appendix B. Larval densities in the reservoir and intake were highest during the month of May (Appendix B3). The greatest density (36,400/1,000 m^3) was observed at TRM 294.5 on May 22. Larval density in the plant intake was highest (16,800/1,000 m^3) a week earlier (May 16). Downstream, at TRM 293.0, a peak larval density of 17,700/1,000 m^3 was recorded on May 30. Appendix C contains densities by sample period and transect for the major families of larval fish collected in 1978 and 1979.

1979

Twelve families of fish larvae were collected in the 1979 samples, including one family (one specimen) Petromyzontidae (lampreys), not previously observed in BFNP larval samples. Relative abundance of clupeids was lower at all transects than in previous years, ranging from 87.8 percent in the intake to 91.7 percent at TRM 294.5 (Appendix A2). Percichthyids (white and yellow bass) and sciaenids (drum) were second and third in abundance, respectively, and each composed from two to four percent of the catch at all three transects.

As observed in 1978, greatest larval densities occurred during May (Appendix B4). Intake larval densities were highest on May 7 and 14 at 3,100/1,000 m^3. Reservoir densities of 10,100 and 7,700/1,000 m^3 were observed at TRM 294.5 (May 14) and TRM 293.0 (May 7), respectively.

Entrainment

Eggs

1977

The previous (TVA 1978b) estimate for entrainment of fish eggs by BFNP was 2.3 percent. This estimate (as described in methods section) was derived by weighting egg densities by only the cross-sectional area in each compartment sampled. Application of the weighting factors based on volume flow in each compartment (Figure 2) to the 1977 data resulted in an increase in estimated egg entrainment to 2.7 percent. This resulted from a lower estimate (4.76×10^9) of transported eggs than was estimated by the previous method (6.44×10^9). Table 3 shows egg and larval entrainment by year (1977-1979) both by family and for total eggs and larvae. For 1977, the previous entrainment estimates (TVA 1978b) are given in parentheses for comparison with current estimates.

Table 3. Annual entrainment (percent) of fish eggs and larvae by family at Browns Ferry Nuclear Plant from 1977-1979.

Family	Estimated Entrainment (percent) 1977*	1978**	1979**
Unidentifiable eggs	0.7 (0.3)	5.9	114.9†
Clupeidae eggs	I	NC	NC
Sciaenidae eggs	2.7 (2.3)	3.6	8.0
Unidentifiable eggs	12.1 (10.3)	5.9	5.5
Petromyzontidae	NC	NC	I
Lepisosteidae	NC	I	NC
Clupeidae	9.1 (12.1)	5.3	4.3
Hiodontidae	1.2 (1.2)	2.1	4.5
Cyprinidae	2.9 (4.8)	2.3	7.8
Catostomidae	4.1 (4.5)	19.2	3.1
Ictaluridae	31.5 (29.0)	16.4	6.4
Cyprinodontidae	NC	I	25.9
Poeciliidae	NC	I	NC
Percichthyidae	11.8 (15.6)	14.7	5.3
Centrarchidae	3.5 (4.8)	2.2	3.6
Percidae	12.7 (14.6)	14.7	13.8
Sciaenidae	6.3 (6.1)	4.4	8.5
Atherinidae	R	R	I
Total eggs	2.7 (2.3)	3.6	8.1
Total fish	9.0 (11.7)	5.4	4.5
Mean hydraulic entrainment (see Table 2)	12.0	13.3	9.0

*Based on densities and weighting factors from TRM 293.0 - values in parentheses are previous entrainment estimates weighted by cross-sectional area only.

**Based on densities and weighting factors from TRM 294.5.

†Seventy-six specimens collected in intake basin, six collected in reservoir sampling; thus high entrainment estimate.

I - Collected in intake samples but not in reservoir (TRM 293.0-1977; TRM 294.5-1978-1979) samples, entrainment estimate not possible.

R - Collected in reservoir samples but not in intake samples, entrainment estimates effectively zero.

NC - None collected in either reservoir or intake samples.

Mean hydraulic entrainment (percent of river flow entrained by the plant) is shown in Table 3 and was calculated by averaging the 24-hour hydraulic entrainment estimates from recorded plant-intake volumes during each sample period. During the period of March 16-August 24, 1977, 12 percent of the flow past BFNP was entrained. This was an increase of 3.6 percent over hydraulic entrainment in 1976 (TVA 1978b) due to initial three-unit plant operation in 1977.

1978

Samples from the transect at TRM 294.5 in 1978 contained lower densities of fish eggs than observed at TRM 293.0 (Appendix B1). Calculated total eggs transported (using densities from TRM 294.5) in 1978 were 1.37×10^9. Estimated entrainment of fish eggs was 5.00×10^7, yielding an entrainment estimate of 3.6 percent (Table 3). Mean hydraulic entrainment in 1978 was 13.3 percent, again higher than the previous year.

1979

Due to increased river flow in 1979 (Table 2), mean hydraulic entrainment was 9.0 percent, a decrease of 4.3 percent from 1978. Total egg transport for 1979 was 2.30×10^9; total egg entrainment by the plant was 1.88×10^8, resulting in an entrainment estimate of 8.1 percent.

Larvae

1977

Total larval entrainment for 1977, based on cross-sectional transect weighting factors was estimated to be 11.7 percent (TVA 1978b). Utilizing the same densities from the plant transect (TRM 293.0), the weighting factors based on flow were applied, and the refined estimate for larval entrainment in 1977 was 9.0 percent (Table 3). Entrainment of the most abundant family, Clupeidae, decreased from 12.1 to 9.4 percent using this method. Conversely, entrainment of Ictaluridae increased from 29.0 to 32.9 percent. Estimates for Percichthyidae and Percidae decreased from 15.6 and 14.6 to 11.7 and 12.6 percent, respectively (Table 3). Entrainment of drum larvae (Sciaenidae) increased from 6.1 to 6.6 percent based on the refined estimates weighted by compartmental volumes.

1978

In 1978, an estimated 5.35×10^{10} fish larvae were transported past the plant with 2.92×10^{9} of these entrained, yielding an annual estimated entrainment of 5.4 percent (Table 3). Again, total entrainment paralleled that of the dominant clupeids (5.3 percent). The two families with the highest estimated entrainment were Catostomidae and Ictaluridae at 19.2 and 16.5 percent, respectively. Two other families, Percichthyidae and Percidae, were estimated to be entrained at rates of 14.8 and 14.5 percent, respectively.

1979

Total larval transport in 1979 was estimated to be 2.97×10^{10}, lower than for either of the two previous years. Larval entrainment in 1979 was estimated to be 1.34×10^{9}, less than one-half the estimated numbers entrained in 1978. Entrainment for total fish larvae transported in 1979 was estimated to be 4.5 percent. Entrainment of clupeids was 4.4 percent. Cyprinodontidae (topminnow) showed the highest entrainment rate (26.0 percent), but this was based on only two specimens (one each from TRM 294.5 and the intake). Percidae, at 13.9 percent, was the only other family with estimated entrainment greater than 10 percent. Larval drum (Sciaenidae) at 8.6 percent, ranked highest of the remaining families (Table 3).

DISCUSSION

Hydraulic entrainment at BFNP during ichthyoplankton sample periods for the first three years of three-unit operation, has been 12.0, 13.3, and 9.0 percent for 1977, 1978, and 1979, respectively (Table 3). Entrainment estimates for fish eggs and larvae prior to 1978 were derived from reservoir density measurements immediately downstream of the plant at TRM 293.0 (Figure 1). Beginning in 1978, ichthyoplankton transport was calculated from samples collected at TRM 294.5, immediately upstream of the BFNP intake. This transect should more accurately depict egg and larval populations subjected to entrainment. The addition of the sampling station on the south overbank or left shoreline (Figure 1) at TRM 294.5 should further improve estimates of ichthyoplankton transported past the plant.

The availability of velocity profile data from both transects (Figure 2) has rectified the overly simplistic assumption of uniform velocities in both the channel and overbank areas. The horizontal and vertical compartments of the transect were found to have varying water velocities (Figure 2), which required a new estimate for transported eggs and larvae. The refined weighting factors derived from this data resulted in an estimated increase of 0.4 percent for entrainment of fish eggs in 1977; estimated larval entrainment, however, decreased 2.7 percent (Table 3). These variations are due to nonuniform distribution of eggs and larvae between overbank and channel as well as between the upper and lower strata of the channel.

Entrainment estimates of 3.6 and 8.1 percent for fish eggs in 1978 and 1979 respectively, represent a progressive increase over the estimate for 1977. This increase is attributed to the observed difference in abundance of (drum) eggs between the two reservoir transects (Appendix A1 and A2). Densities more than an order of magnitude lower at TRM 294.5 than at TRM 293.0 (Appendix B1 and B2) resulted in a significantly lower estimate of numbers transported and, thus, a greater proportion entrained. It appears that in 1978 and 1979, intensive spawning by drum occurred adjacent to or immediately below BFNP. Since large numbers of drum eggs appear to be spawned below the plant, it is concluded that estimated entrainment of 8.1 percent of eggs (highest of three years discussed) transported past BFNP in 1979 is not a significant adverse impact to the Wheeler Reservoir fish community. In support of this hypothesis, if 1978 data from the TRM 293.0 transect are employed to estimate egg entrainment, only 0.5 percent of the total transported eggs are estimated to be entrained.

Entrainment of fish larvae, unlike that observed for eggs, showed a decreasing trend for the three years of full (three-unit) operation at BFNP. Even though the highest hydraulic entrainment (13.3 percent) occurred in 1978, larval entrainment (5.4 percent) showed a decrease of 60 percent from the highest observed entrainment of 9.0 percent (in 1977). For comparison, since entrainment was estimated from a different transect (TRM 294.5) beginning in 1978, data from TRM 293.0 analyzed by the same method yielded an estimate of 6.1 percent entrainment for transported fish larvae. In 1979, hydraulic entrainment (9.0 percent) as well as larval entrainment (4.5 percent) decreased from levels observed in 1978.

The four families with estimated entrainment of greater than 10 percent in 1978 all had lower entrainment estimates in 1979 (Table 3). Among the four, only Percidae (logperch and sauger) continued to be entrained at greater than 10 (13.8) percent. Percids frequently were collected in greater densities in the BFNP intake than at either of the two reservoir transects (Appendix C 13 and 14), which accounts for entrainment estimates ranging from 12.7 to 14.7 percent during 1977-1979. These data suggest that some percid spawning (probably logperch) may be occurring in or near the intake basin. Ictalurids (catfishes) were similarly collected in the intake in densities often greater than those observed in the reservoir and are also suspected to spawn in the basin. Catostomids (buffalo and suckers) were estimated to be entrained at rates (Table 3) lower than those for total larvae in 1977 (4.1 vs 9.0) and 1979 (3.1 vs 4.5). In 1978, estimated entrainment of catostomids was a surprising 19.2 percent. However, on April 20 when catostomids were at peak density (Appendix C5) in both intake and reservoir samples, hydraulic entrainment by BFNP was 18.4 percent. Percichthyid (white and yellow bass) entrainment in 1977 (11.8 percent) and 1978 (14.7 percent) closely paralleled hydraulic entrainment (Table 3), but was considerably lower (5.3 percent) in 1979. Percichthyids are the only family of the four discussed above which consistently compose greater than 1 percent of total larvae collected in BFNP larval samples. In 1978 and 1979, percichthyids ranked second only to clupeids in relative abundance at all transects and comprised a larger percentage of larvae collected in intake samples (1977-1979) than at either reservoir transect (Appendix A).

SUMMARY

In summary, entrainment estimates for total fish larvae in 1978 (5.4 percent) and 1979 (4.5 percent) were considerably lower than those calculated for 1977 (9.0 percent), the initial year of full plant operation. Sampling procedures and weighting factors for estimating numbers of fish eggs and larvae transported past the plant have both improved since the earlier report on entrainment at BFNP (TVA 1978b). Samples from the transect added at TRM 294.5 should more accurately reflect those eggs and larvae most susceptible to plant entrainment.

Since ichthyoplankton in Wheeler Reservoir are produced above and below BFNP, it can be concluded that estimated plant entrainment, as given here, would not add significantly to expected natural mortality of fish eggs and larvae in the reservoir.

REFERENCES

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APPENDIX A

TOTAL NUMBERS COLLECTED AND RELATIVE ABUNDANCE OF FISH/EGGS AND LARVAE BY FAMILY AND TRANSECT IN 1978 AND 1979

Key to common names of families

Family Name	Common Name*
Petromyzontidae	lampreys
Polyodontidae	paddlefish
Lepisosteidae	gar
Clupeidae	shad and skipjack
Hiodontidae	mooneye
Cyprinidae	minnows and carp
Catostomidae	buffalo and suckers
Ictaluridae	catfishes
Cyprinodontidae	topminnows
Poeciliidae	mosquito fish
Percichthyidae	white and yellow bass
Centrarchidae	crappie and sunfishes
Percidae	sauger and logperch
Sciaenidae	freshwater drum
Atherinidae	brook silversides

*Most common taxa of family occurring in Wheeler Reservoir fish larvae samples.

A1. Total number and relative abundance (percent) of fish eggs and larvae collected at Browns Ferry Nuclear Plant in 1978.

Fish Eggs and Larvae	TRM 294.5		Intake Basin		Plant Transect (TRM 293)	
	Total Collected	Relative Abundance	Total Collected	Relative Abundance	Total Collected	Relative Abundance
Sciaenid eggs (drum)	2,601	92.93	4,087	98.55	18,658	99.97
Unidentifiable fish eggs	198	7.07	60	1.45	5	0.03
<u>Family</u>						
Clupeidae	155,702	95.52	213,043	94.70	83,894	93.76
Percichthyidae	2,404	1.47	6,581	2.93	2,527	2.82
Centrarchidae	2,192	1.34	1,283	0.57	1,070	1.20
Sciaenidae	1,191	0.73	2,147	0.95	865	0.97
Catostomidae	746	0.46	1,152	0.51	662	0.74
Cyprinidae	564	0.35	249	0.11	366	0.41
Percidae	117	0.07	289	0.13	62	0.07
Unidentifiable fish larvae	67	0.04	167	0.07	13	0.01
Ictaluridae	12	0.01	56	0.02	18	0.02
Hiodontidae	3	<0.01	3	<0.01	4	<0.01
Atherinidae	1	<0.01	0	0.00	0	0.00
Lepisosteidae	0	0.00	1	<0.01	0	0.00
Cyprinodontidae	0	0.00	1	<0.01	0	0.00
Poeciliidae	0	0.00	1	<0.01	0	0.00
Polyodontidae	0	0.00	0	0.00	1	<0.01

A2. Total number and relative abundance (percent) of fish eggs and larvae collected at Browns Ferry Nuclear Plant in 1979.

Fish Eggs and Larvae	TRM 294.5		Intake Basin		Plant Transect (TRM 293)	
	Total Collected	Relative Abundance	Total Collected	Relative Abundance	Total Collected	Relative Abundance
Sciaenid Eggs (drum)	2,883	99.93	9,589	99.21	12,128	99.97
Unidentifiable fish eggs	2	0.07	76	0.79	4	0.03
Family						
Clupeidae	46,068	91.70	62,206	87.76	37,828	90.39
Percichthyidae	1,721	3.43	3,022	4.26	1,560	3.73
Sciaenidae	963	1.92	2,823	3.98	981	2.34
Cyprinidae	468	0.93	1,160	1.64	818	1.95
Catostomidae	525	1.04	864	1.22	340	0.81
Centrarchidae	303	0.60	396	0.56	167	0.40
Percidae	104	0.21	255	0.36	63	0.15
Unidentifiable fish larvae	63	0.13	84	0.12	66	0.16
Ictaluridae	16	0.03	54	0.08	19	0.05
Hiodontidae	8	0.02	11	0.02	9	0.02
Petromyzontidae	0	0.00	1	0.00	0	0.00
Cyprinodontidae	1	0.00	1	0.00	0	0.00
Atherinidae	0	0.00	1	0.00	0	0.00

APPENDIX B

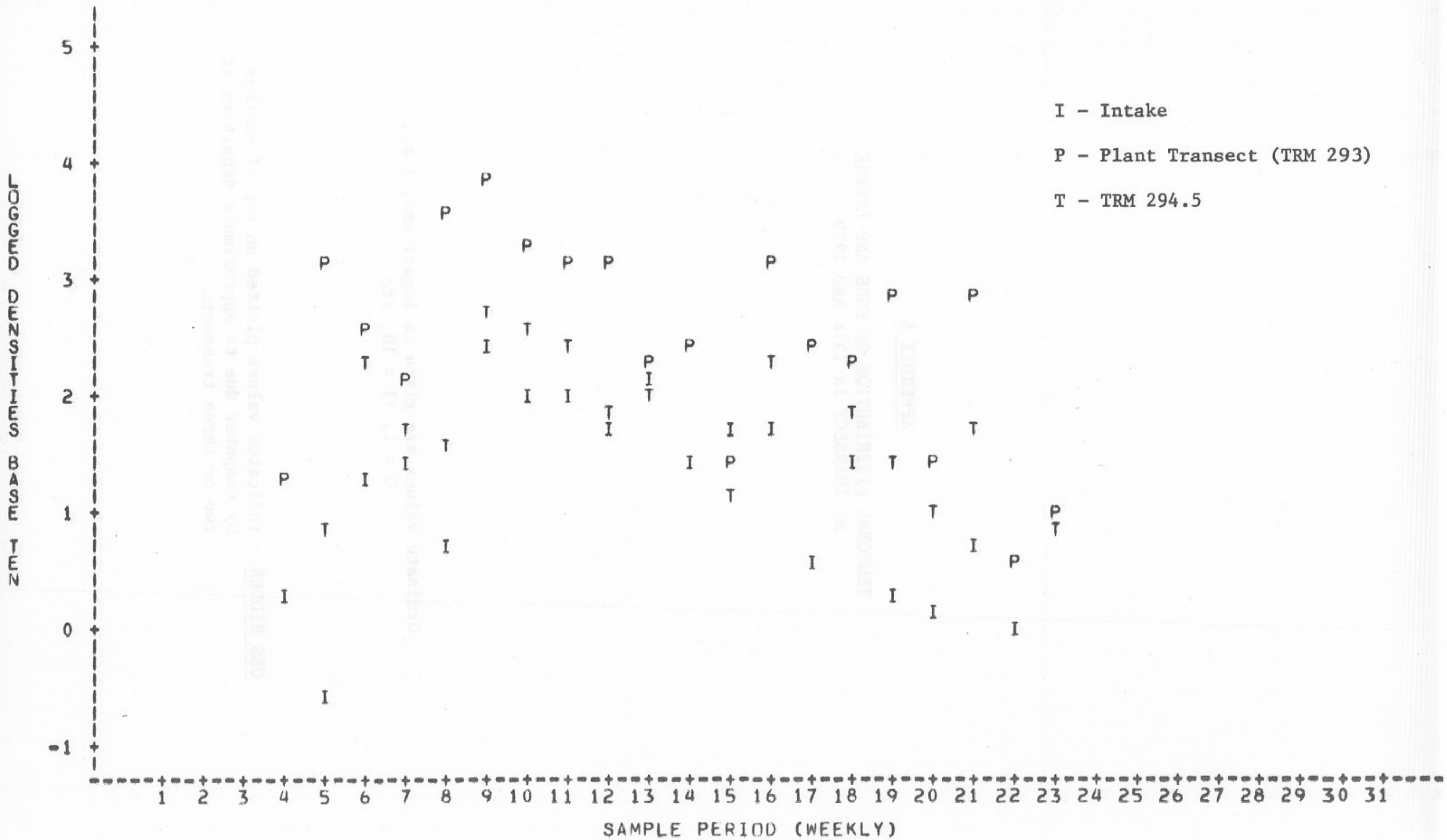
TEMPORAL DISTRIBUTION OF EGGS AND LARVAE
BY TRANSECT IN 1978 AND 1979

Ordinate values are given in logarithms, i.e.,
0 = 1, +1 = 10, etc.

OBS HIDDEN - indicates values plotted on top of another by computer due to approximate densities at two or three transects

B1. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
TAXATYPE=FISH EGGS YEAR=1978

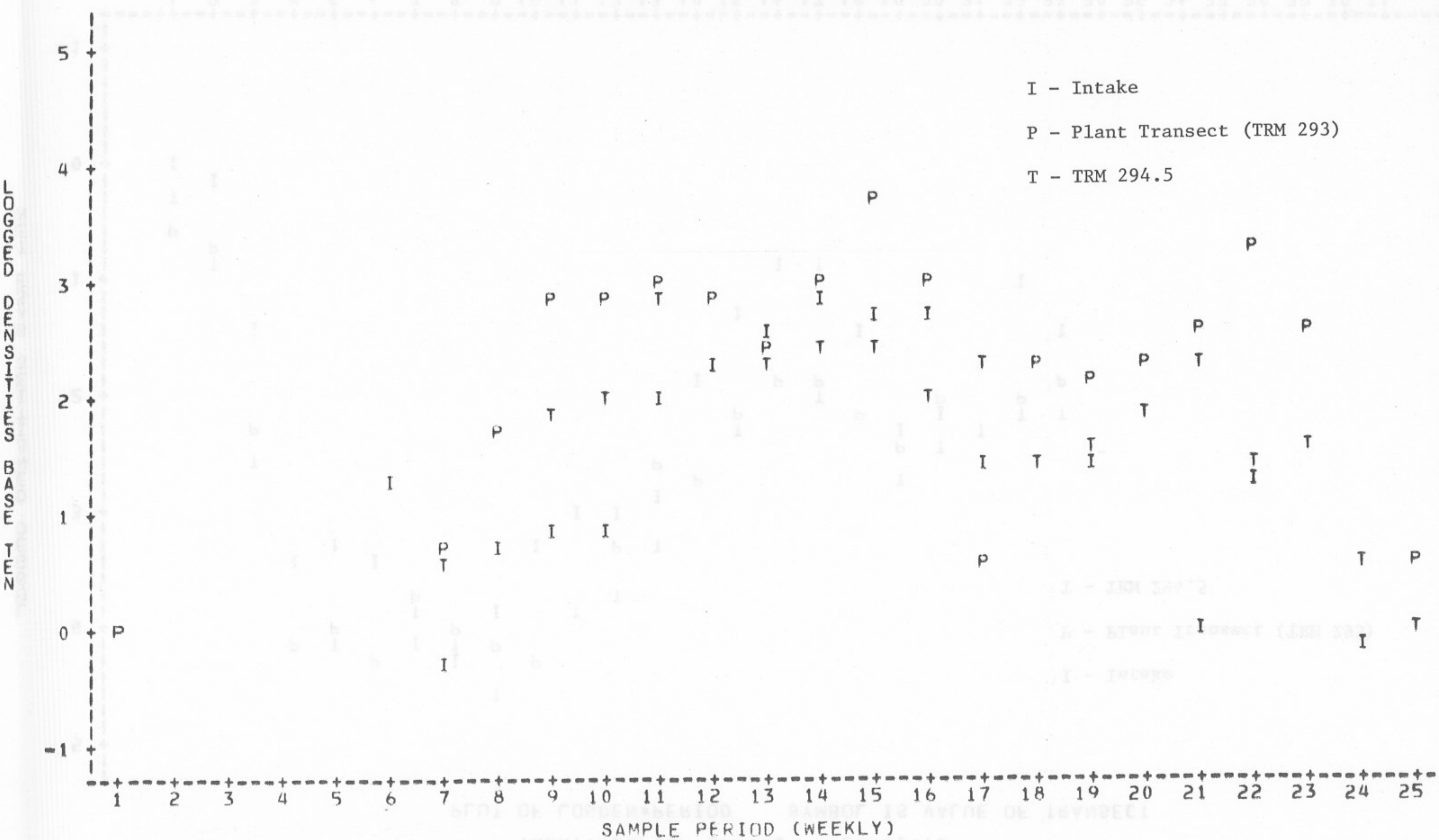
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 3 OBS HIDDEN

B2. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1979
TAXATYPE=FISH EGGS YEAR=1979

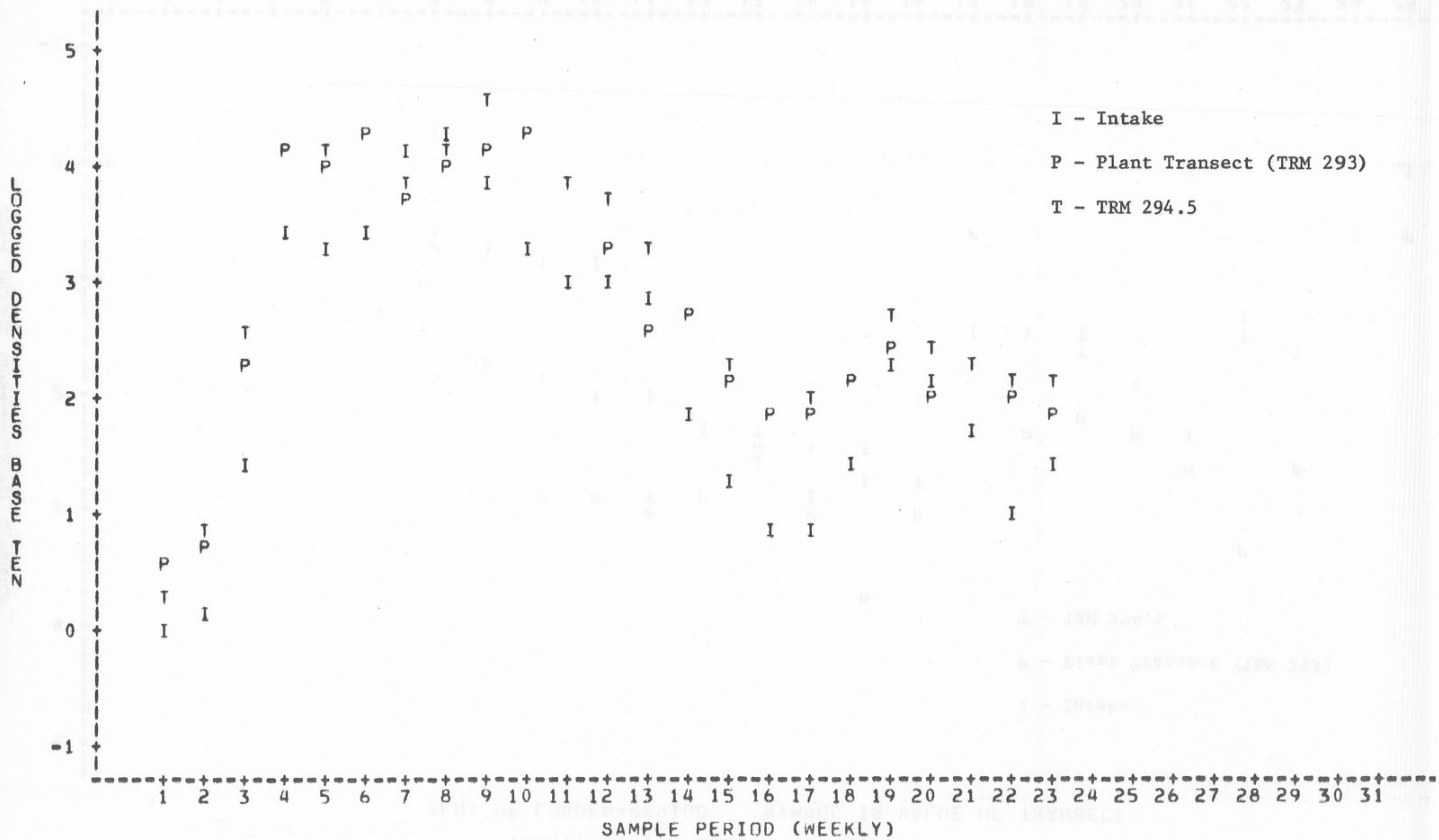
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 2 OBS HIDDEN

B3. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
TAXATYPE=FISH LARVAE YEAR=1978

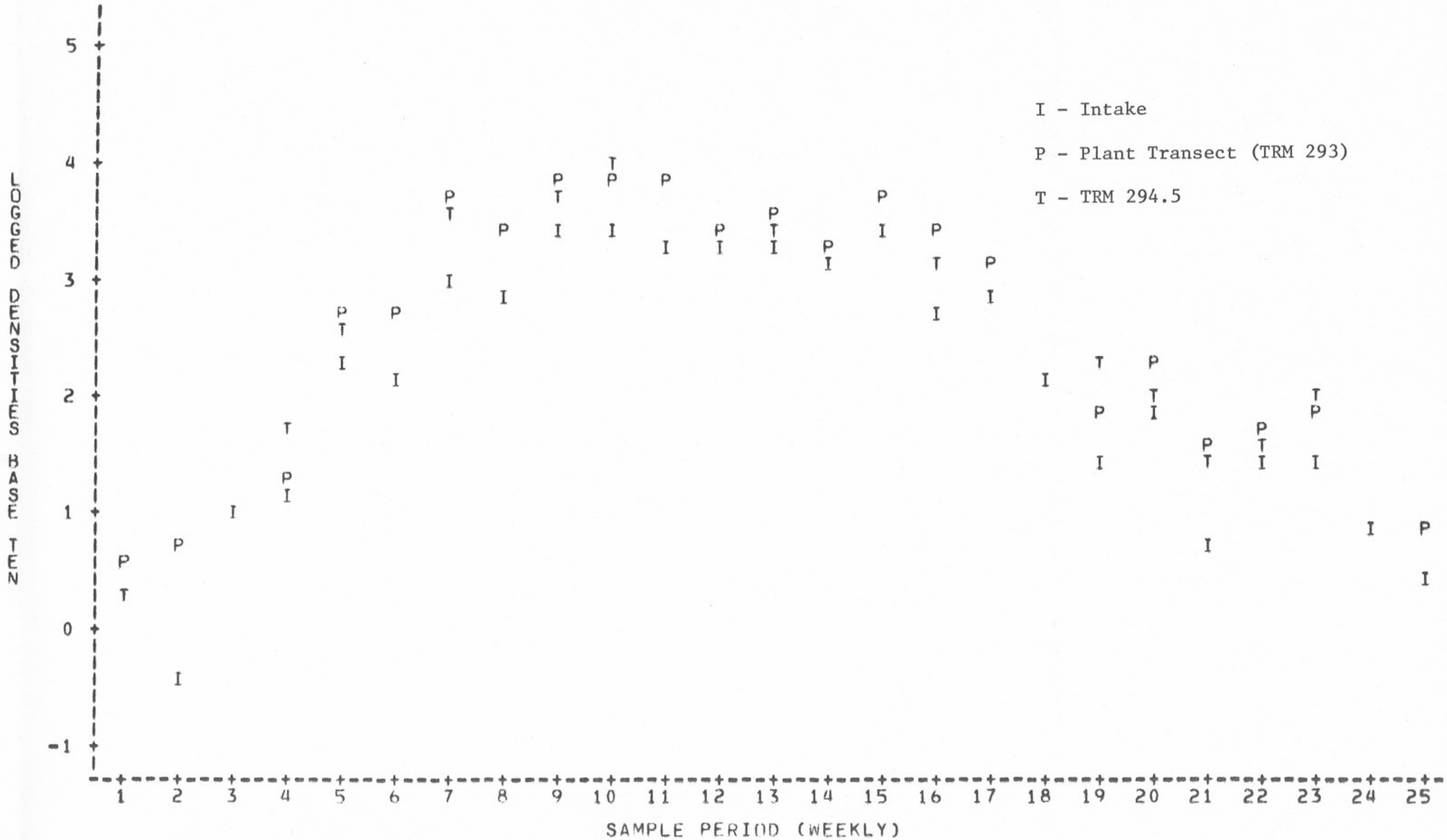
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 8 OBS HIDDEN

B4. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1979
TAXATYPE=FISH LARVAE YEAR=1979

PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 15 OBS HIDDEN

APPENDIX C

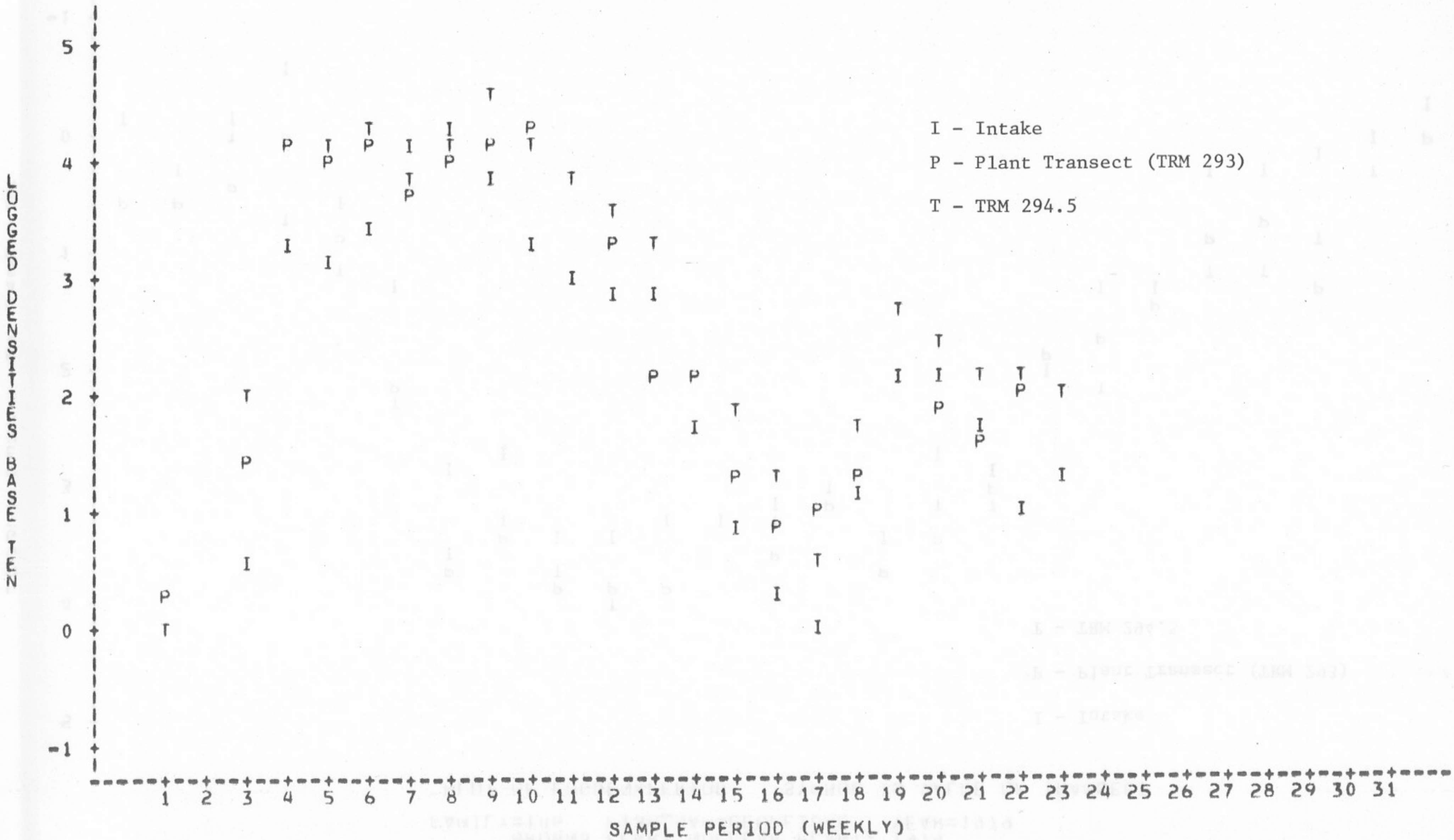
LARVAL FISH DENSITIES FOR MAJOR FAMILIES BY TRANSECT AND SAMPLE PERIOD IN 1978 AND 1979

Ordinate values are given in logarithms, i.e., 0 = 1, +1 = 10, etc.

OBS HIDDEN - indicates values plotted on top of another by computer due to approximate densities at two or three transects

C1. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
FAMILY=106 FISH_NAM=CLUPEIDAE YEAR=1978

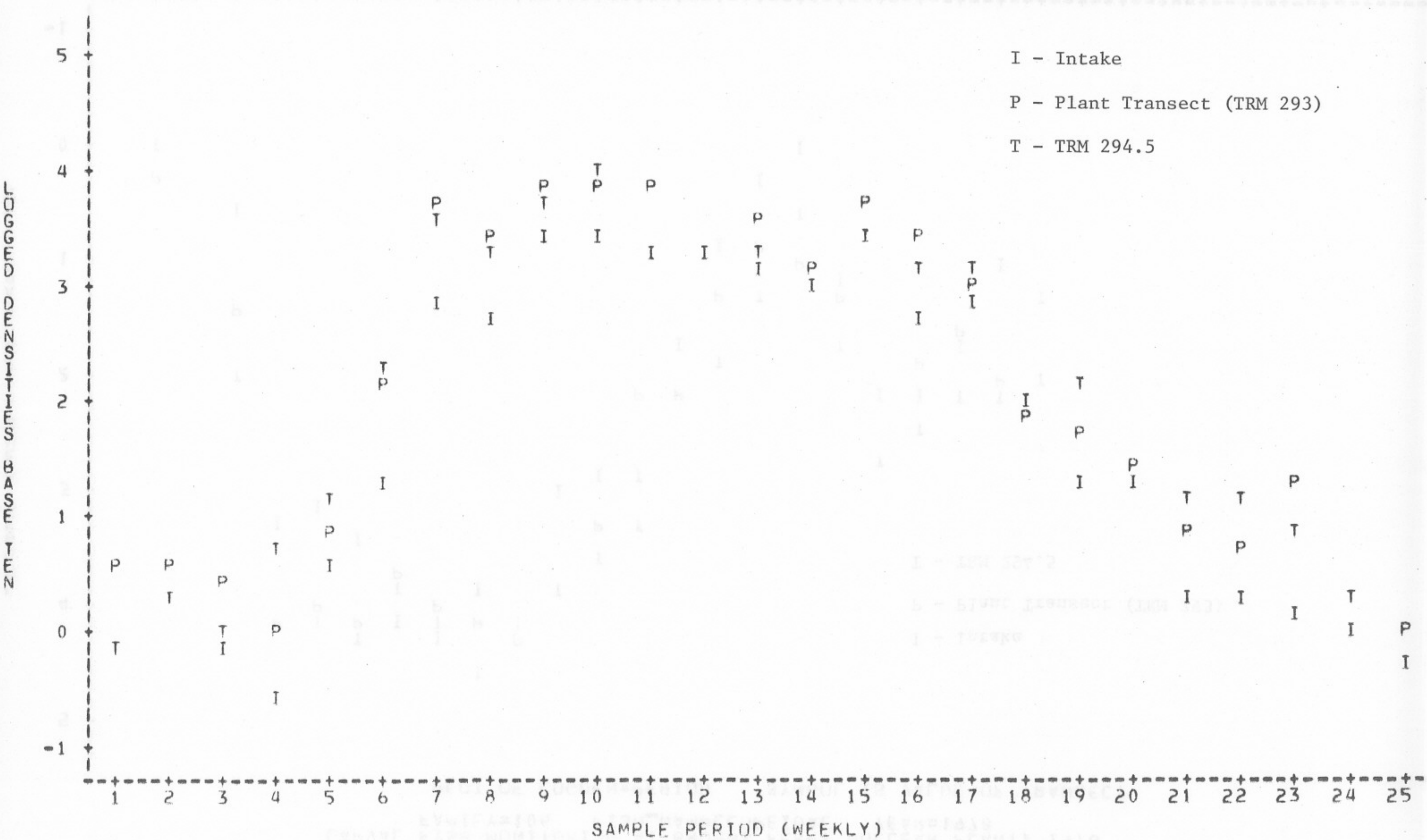
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 5 OBS HIDDEN

C2. DENSITIES OF LARVAL FISHES COLLECTED AT
BROWNS FERRY NUCLEAR PLANT, 1979
FAMILY=106 FISH_NAM=CLUPEIDAE YEAR=1979

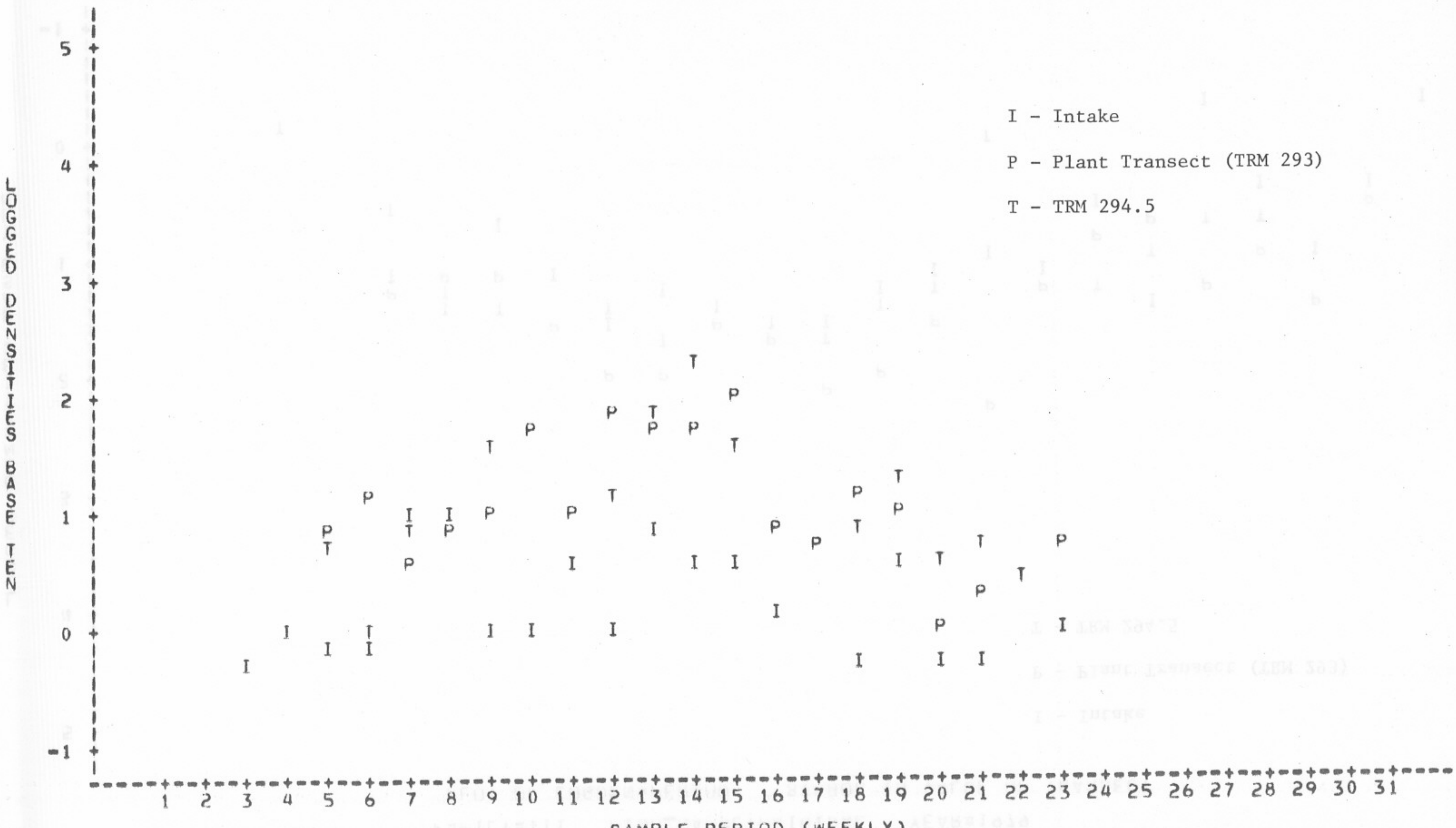
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 9 OBS HIDDEN

C3. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
FAMILY=111 FISH_NAM=CYPRINIDAE YEAR=1978

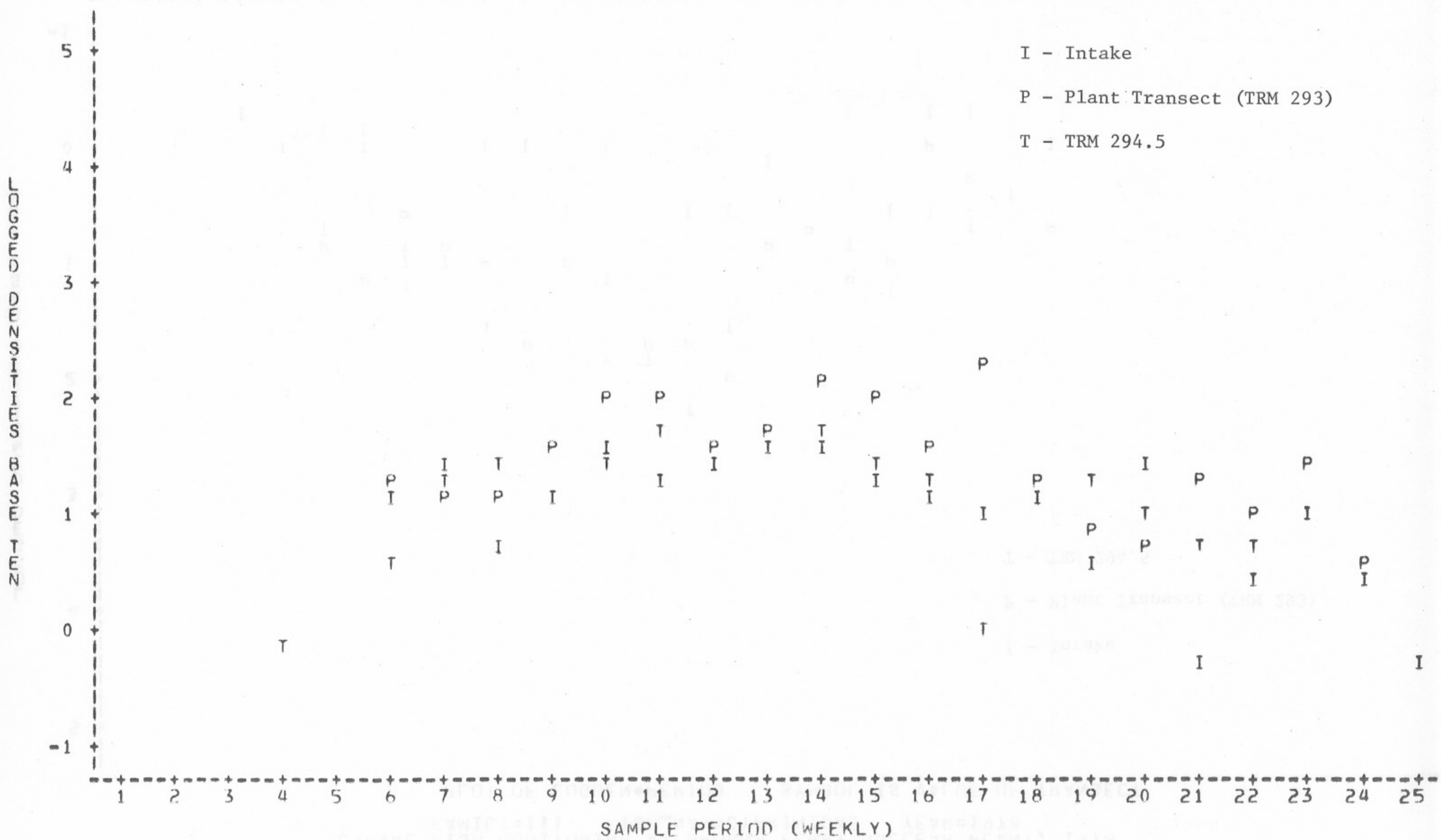
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 6 OBS HIDDEN

C4. DENSITIES OF LARVAL FISHES COLLECTED AT
BROWNS FERRY NUCLEAR PLANT, 1979
FAMILY=111 FISH_NAM=CYPRINIDAE YEAR=1979

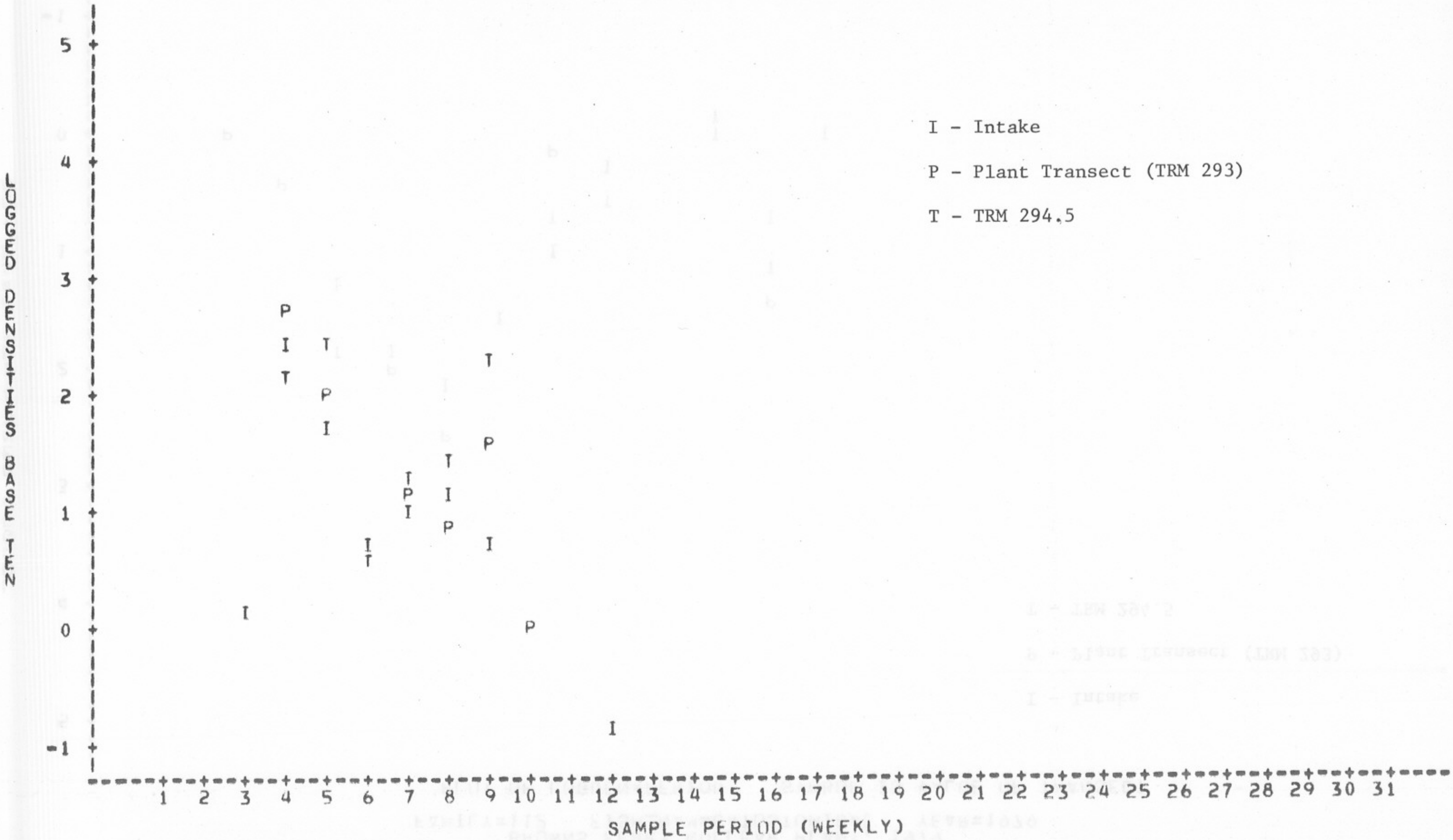
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 6 OBS HIDDEN

C5. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
FAMILY=112 FISH_NAM=CATOSTOMIDAE YEAR=1978

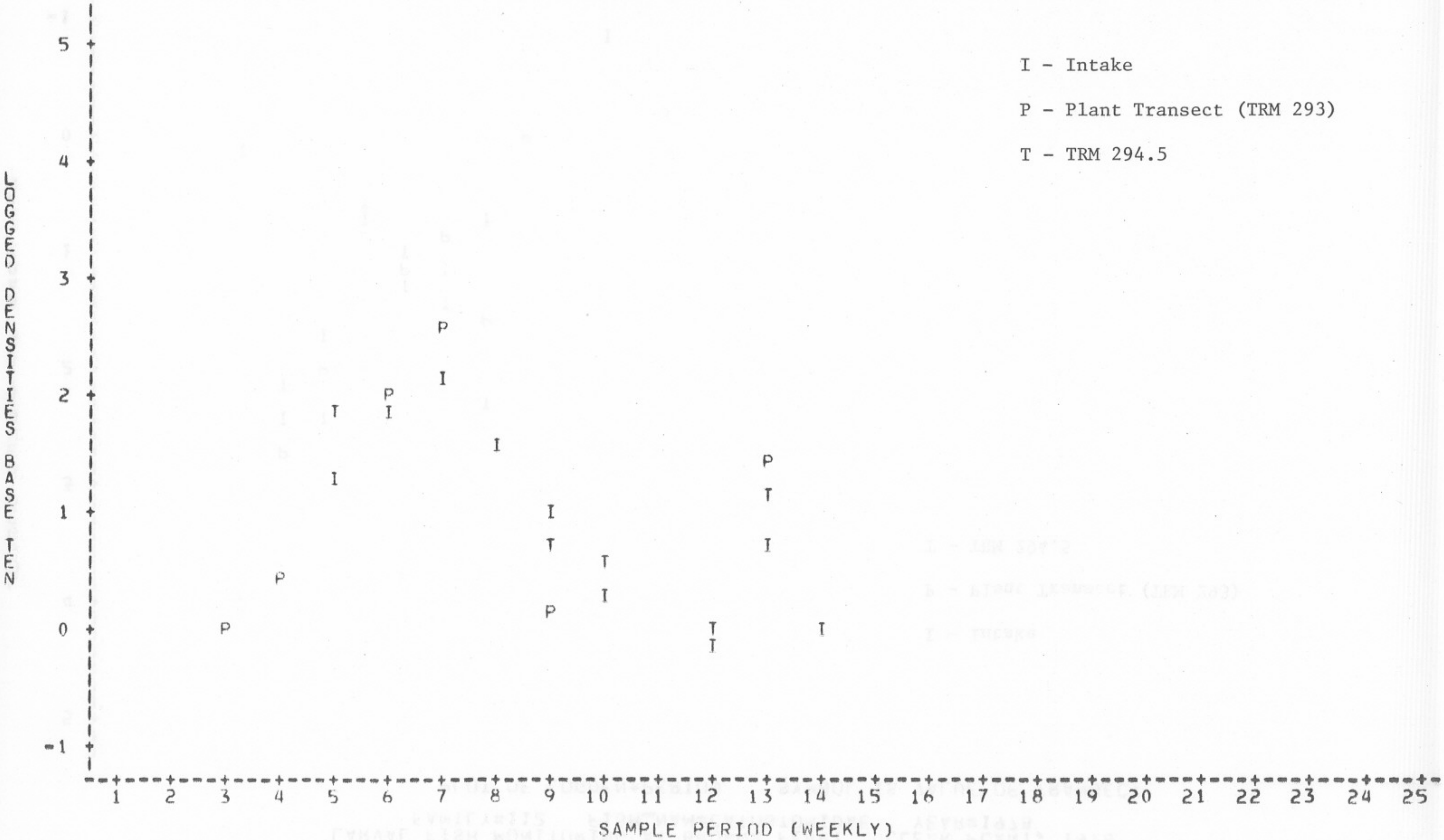
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 2 OBS HIDDEN

C6. DENSITIES OF LARVAL FISHES COLLECTED AT
BROWNS FERRY NUCLEAR PLANT, 1979
FAMILY=112 FISH_NAM=CATOSTOMIDAE YEAR=1979

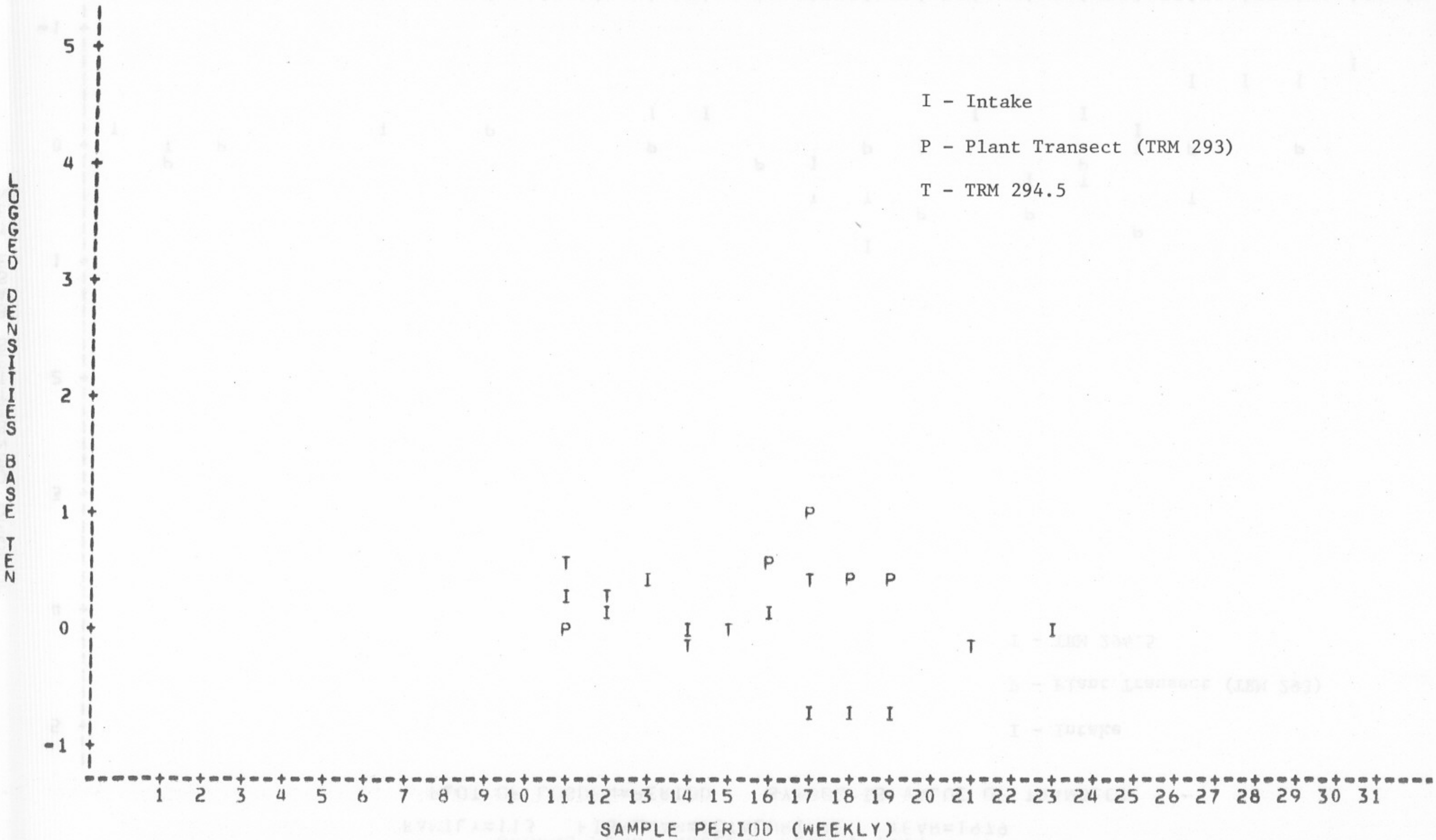
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 5 OBS HIDDEN

C7. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
FAMILY=113 FISH_NAM=ICTALURIDAE YEAR=1978

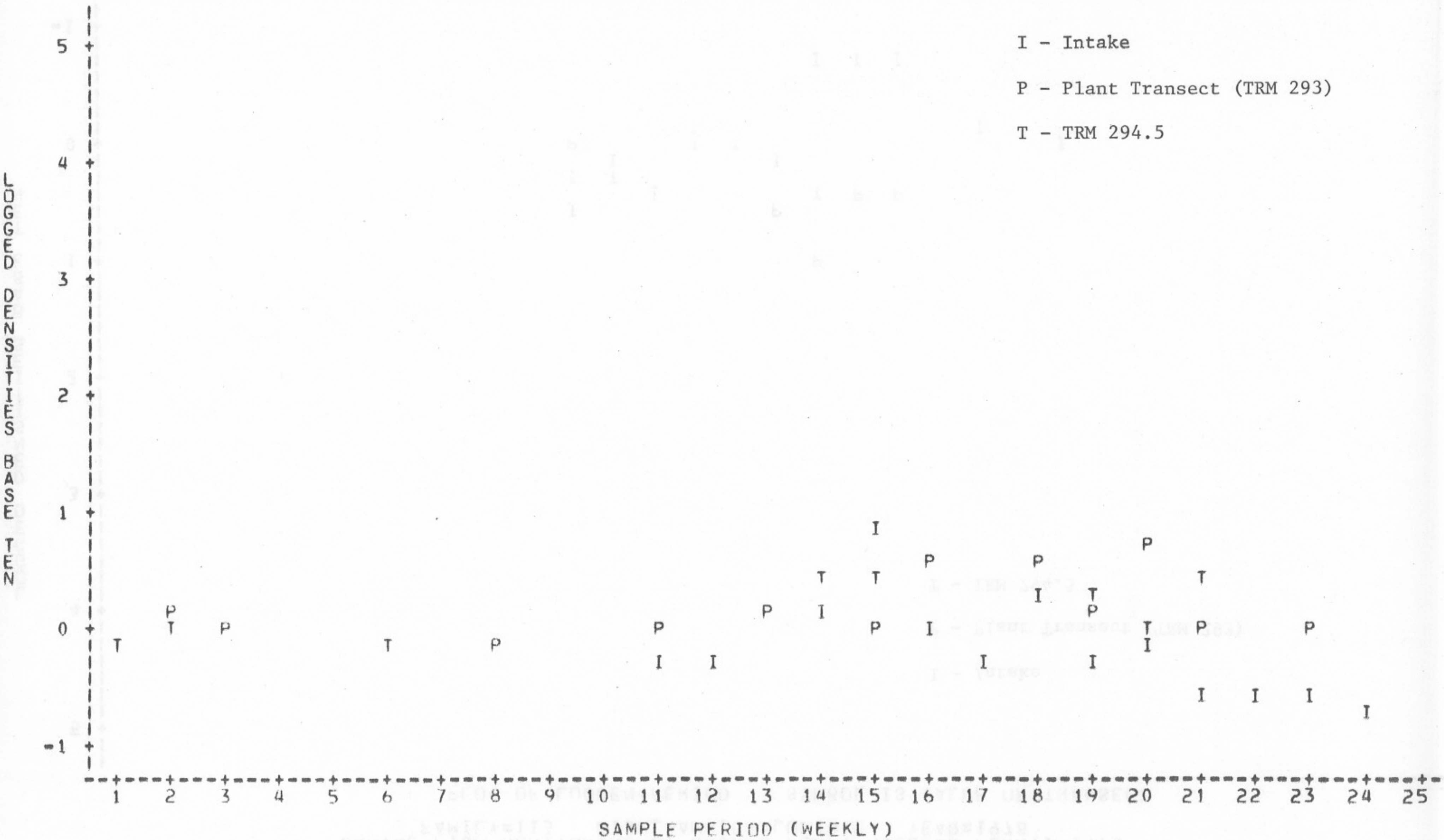
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 2 OBS HIDDEN

C8. DENSITIES OF LARVAL FISHES COLLECTED AT
BROWNS FERRY NUCLEAR PLANT, 1979
FAMILY=113 FISH_NAM=ICTALURIDAE YEAR=1979

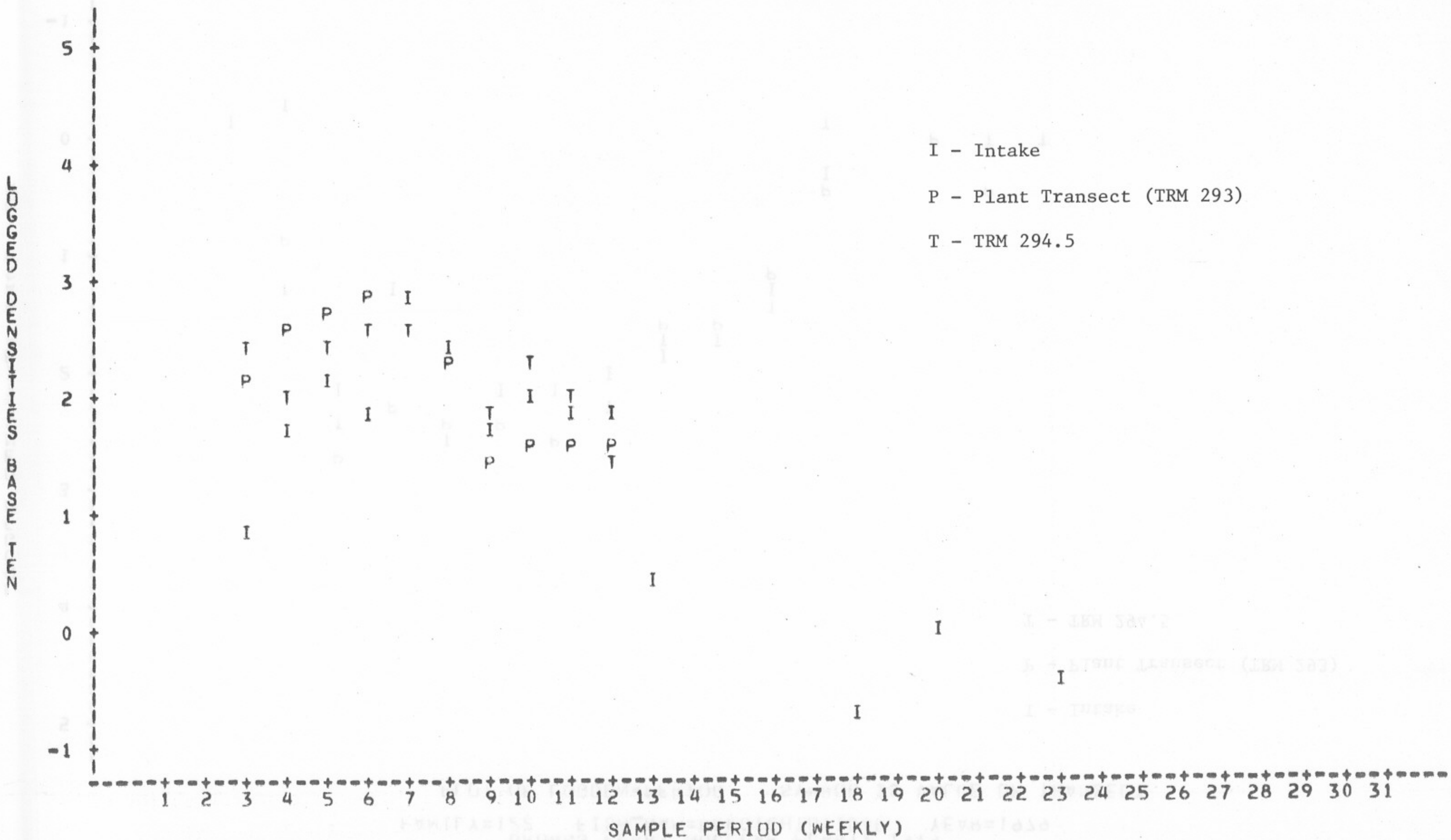
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 1 OBS HIDDEN

C9. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
FAMILY=122 FISH_NAM=PERCICHTHYIDAE YEAR=1978

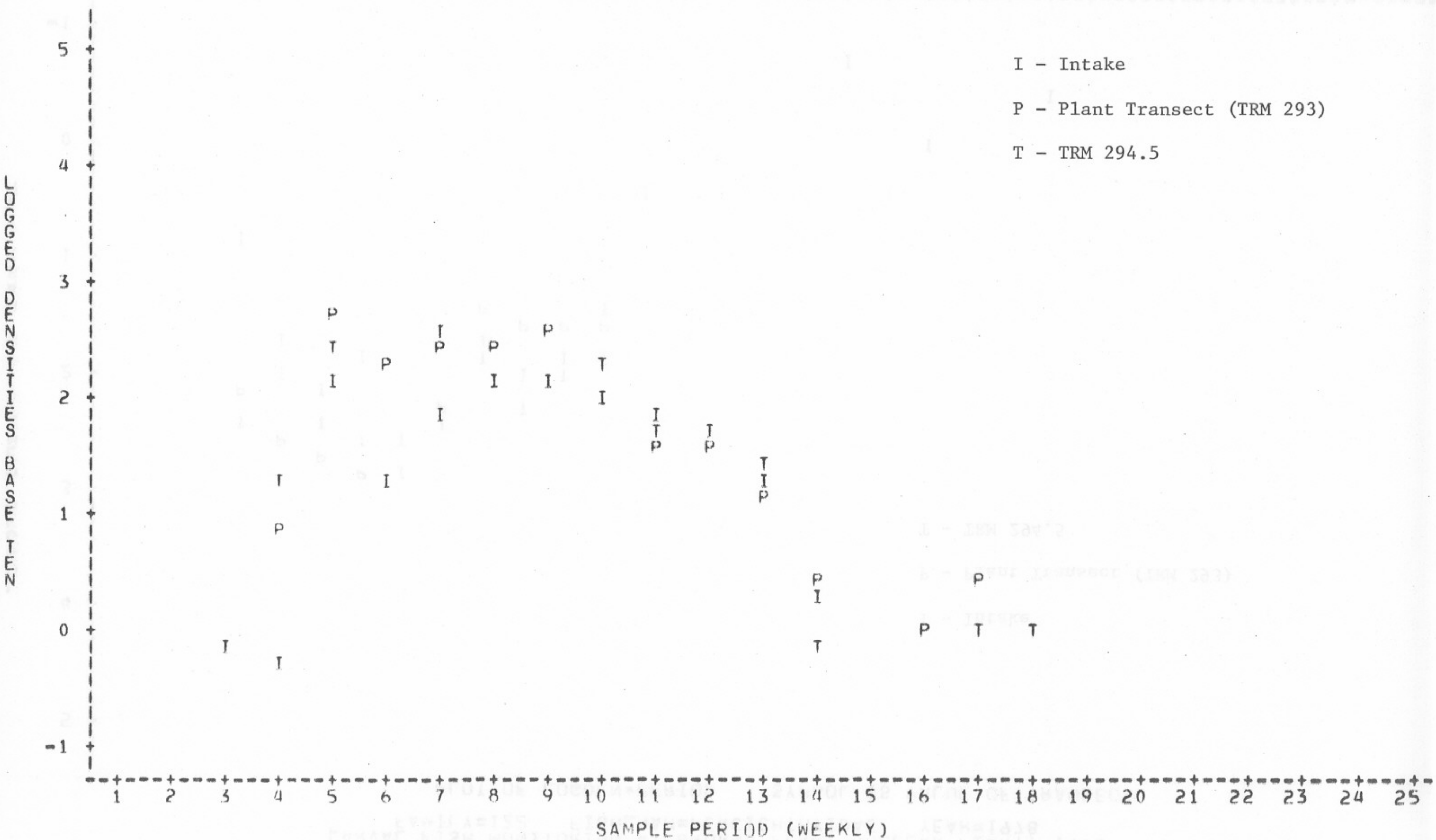
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 3 OBS HIDDEN

C10. DENSITIES OF LARVAL FISHES COLLECTED AT
BROWNS FERRY NUCLEAR PLANT, 1979
FAMILY=122 FISH_NAM=PERCICHTHYIDAE YEAR=1979

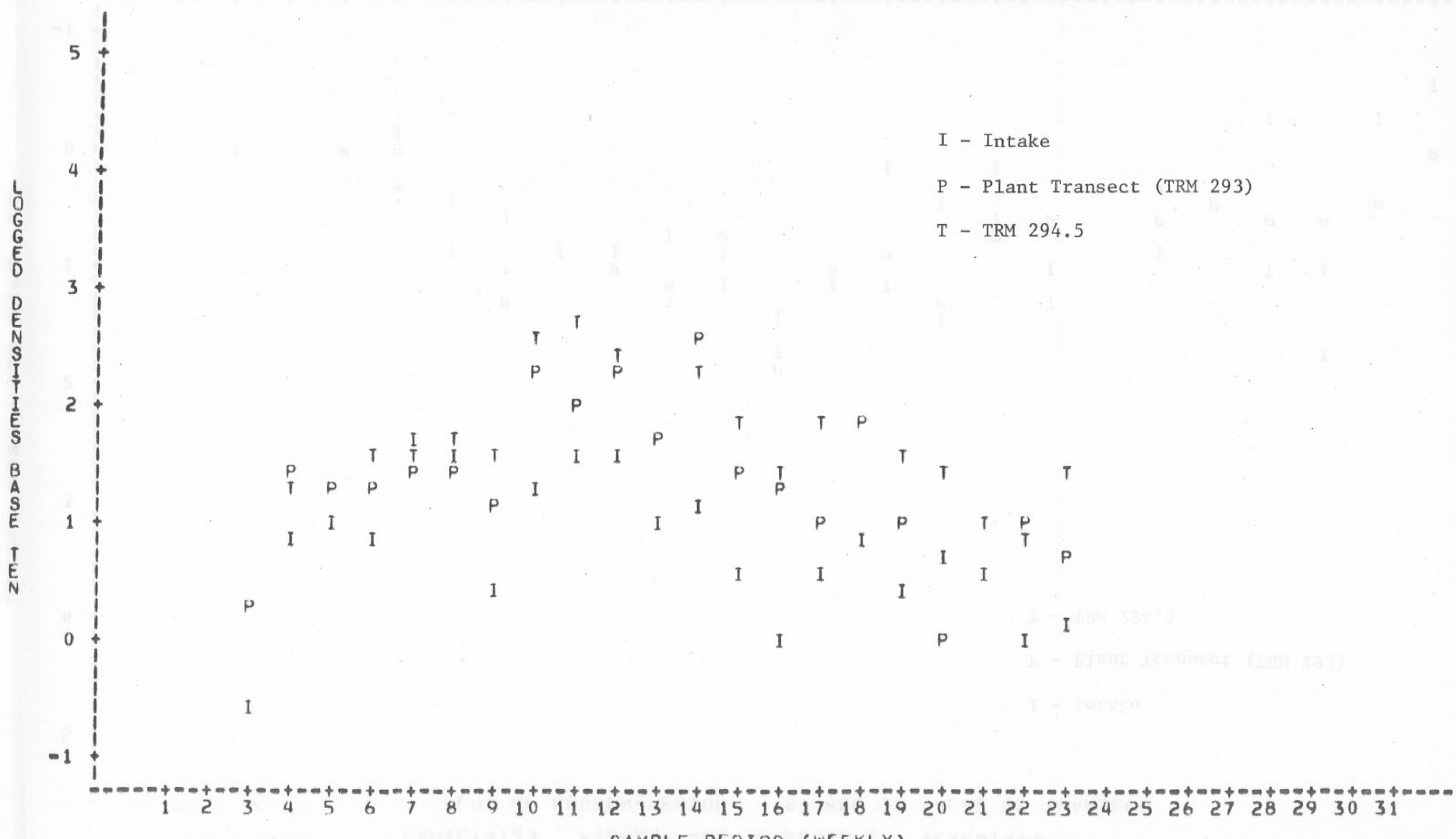
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 5 OBS HIDDEN

C11. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
FAMILY=123 FISH_NAM=CENTRARCHIDAE YEAR=1978

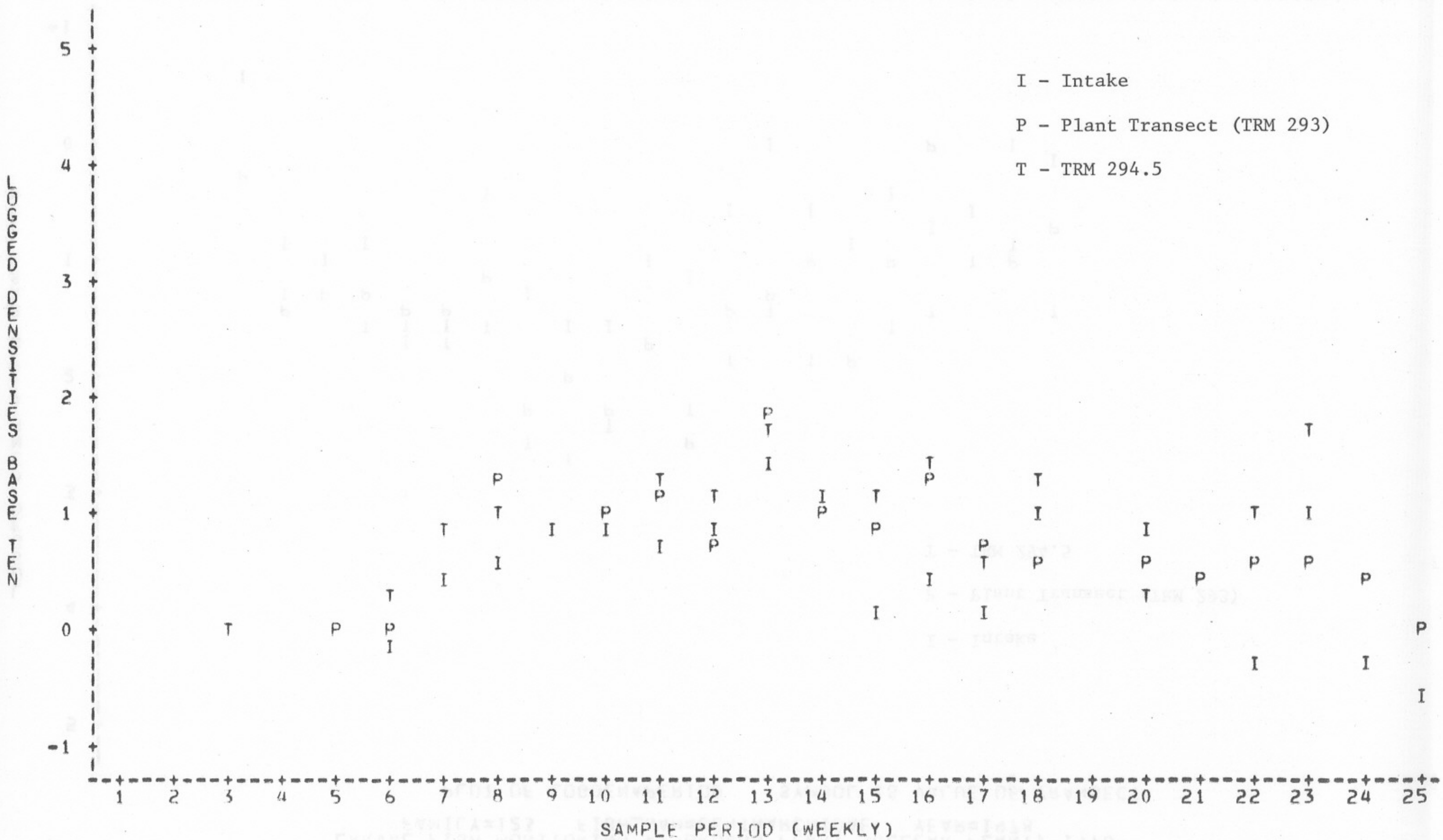
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 4 OBS HIDDEN

C12. DENSITIES OF LARVAL FISHES COLLECTED AT
BROWNS FERRY NUCLEAR PLANT, 1979
FAMILY=123 FISH_NAM=CENTRARCHIDAE YEAR=1979

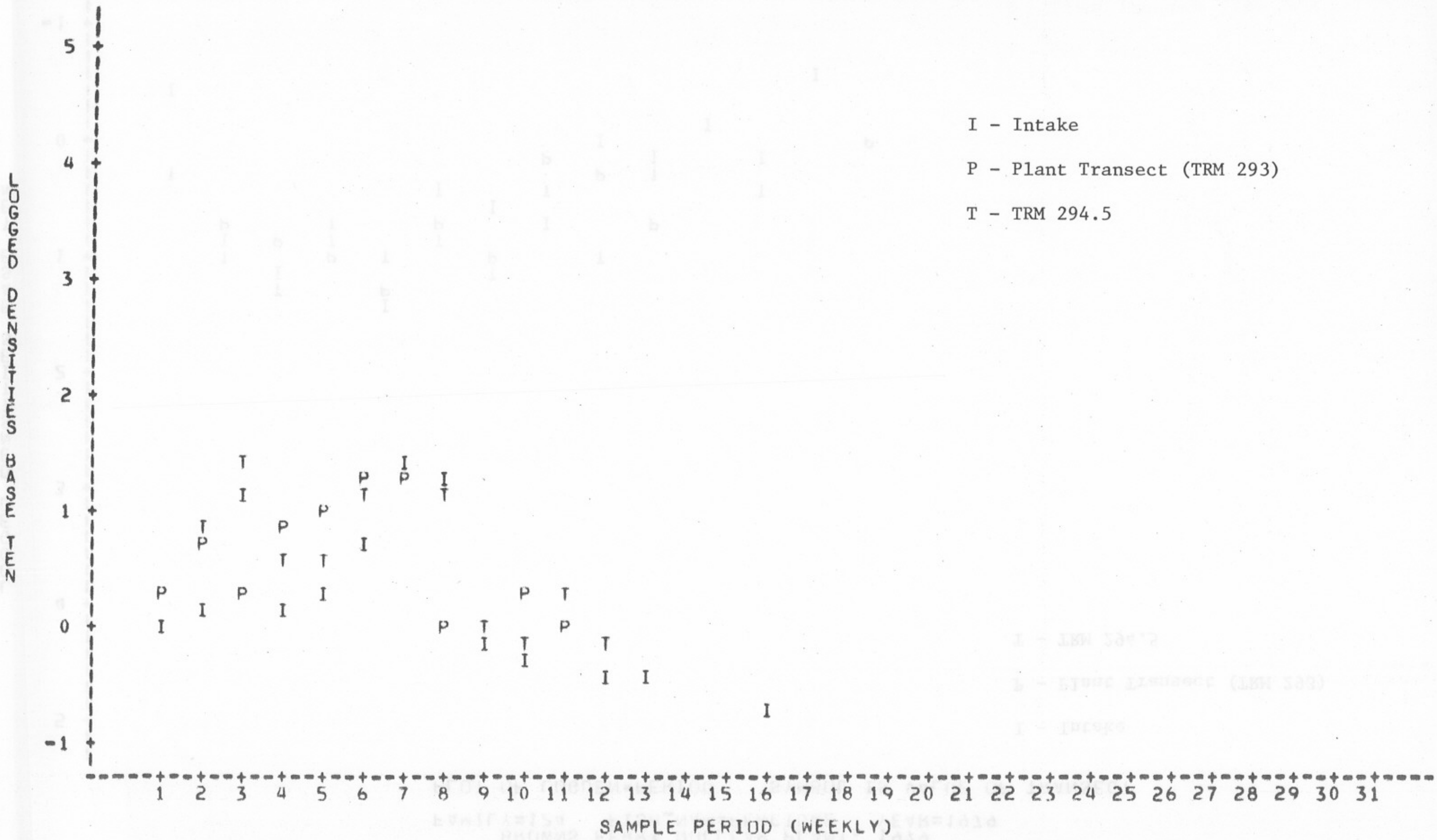
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 6 OBS HIDDEN

C13. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
FAMILY=124 FISH_NAM=PERCIDAE YEAR=1978

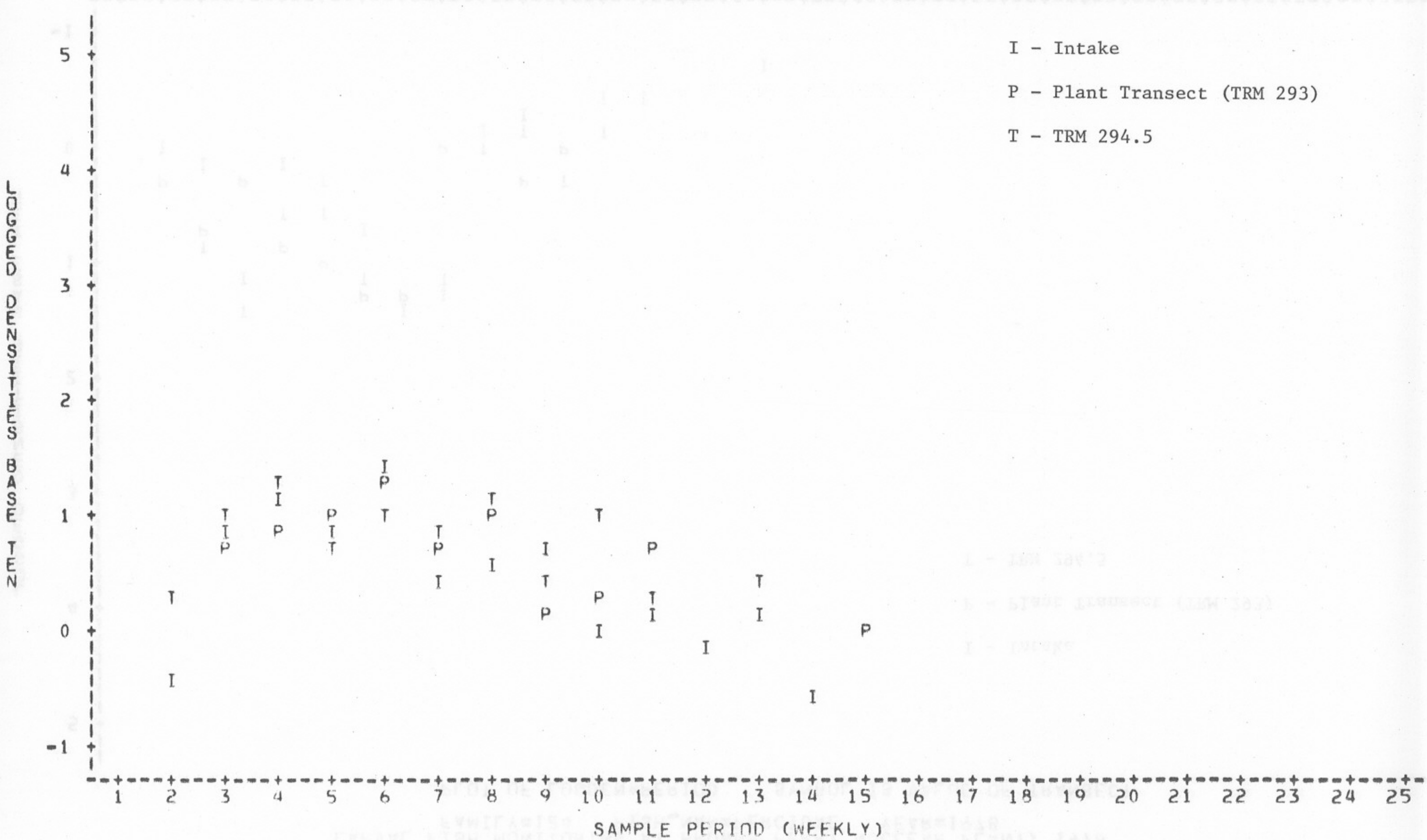
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 2 OBS HIDDEN

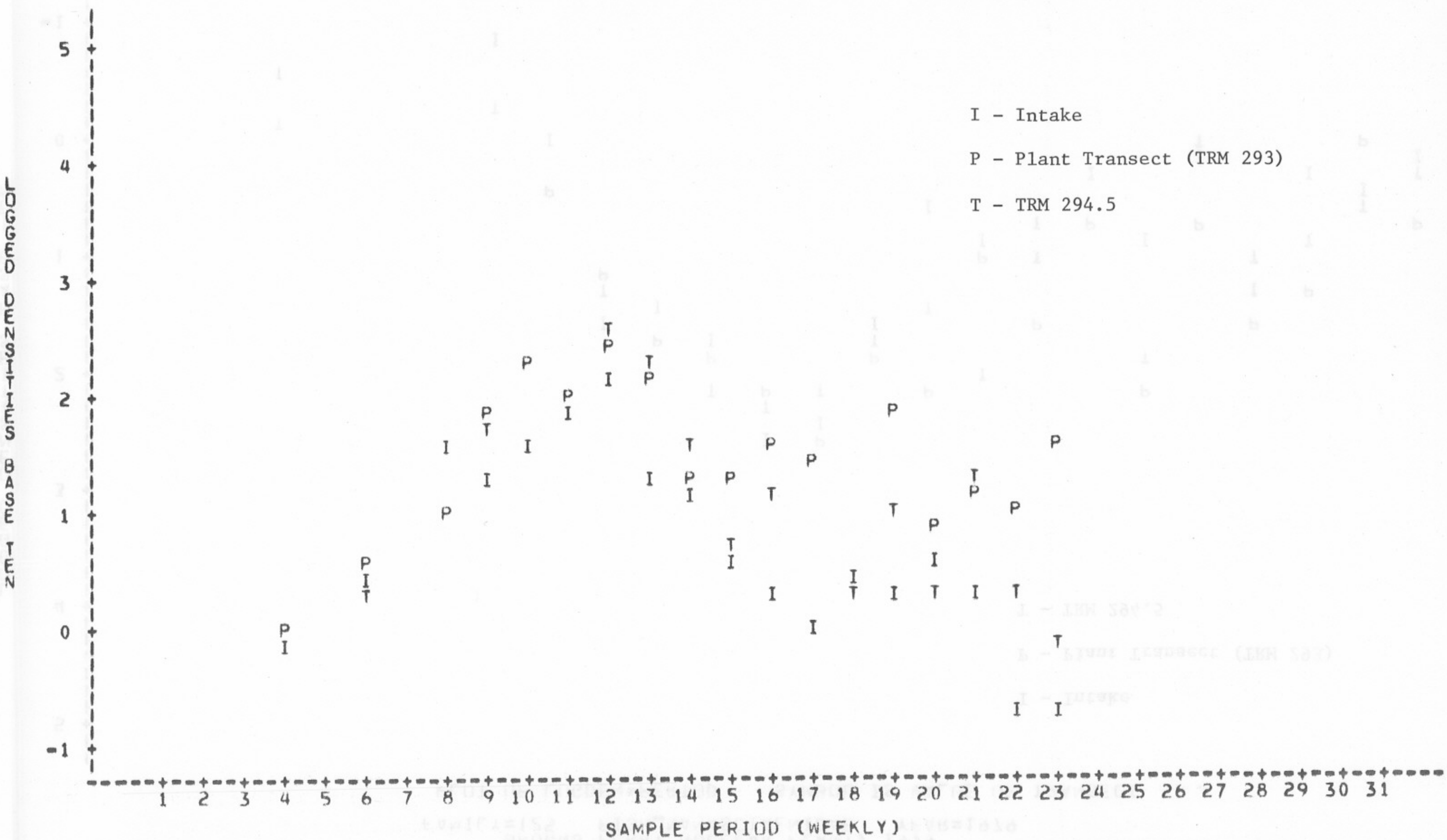
C14. DENSITIES OF LARVAL FISHES COLLECTED AT
BROWNS FERRY NUCLEAR PLANT, 1979
FAMILY=124 FISH_NAM=PERCIDAE YEAR=1979

PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



C15. DENSITIES OF LARVAL FISHES COLLECTED IN
LARVAL FISH MONITORING AT BROWNS FERRY NUCLEAR PLANT, 1978
FAMILY=125 FISH_NAM=SCIAENIDAE YEAR=1978

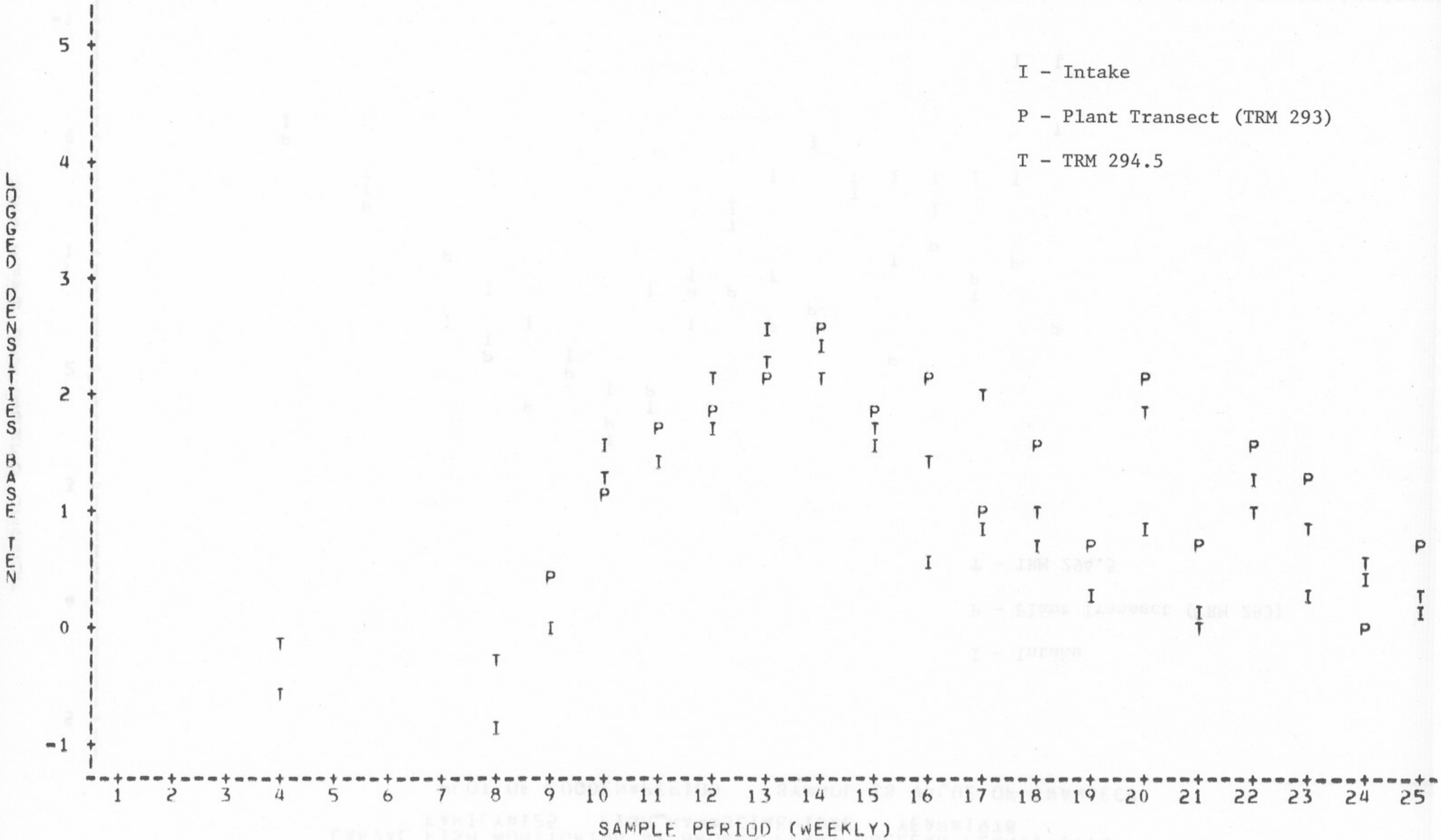
PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 5 OBS HIDDEN

C16. DENSITIES OF LARVAL FISHES COLLECTED AT
BROWNS FERRY NUCLEAR PLANT, 1979
FAMILY=125 FISH_NAM=SCIAENIDAE YEAR=1979

PLOT OF LOGDEN*PERIOD SYMBOL IS VALUE OF TRANSECT



NOTE: 3 OBS HIDDEN

FISH IMPINGEMENT AT BROWNS FERRY NUCLEAR PLANT, WHEELER RESERVOIR: SUPPLEMENT

March 1980

Prepared by
William C. Barr

Division of Water Resources
Fisheries and Aquatic Ecology Branch

Norris, Tennessee

INTRODUCTION

The nine BFNP cooling water circulators pump 124.9 m^3 sec^{-1} (1.98 million gpm) of water at full capacity. Fish are impinged as this water passes through 18 vertical traveling screens (9.5 mm mesh) at a velocity of 61.0 cm sec^{-1} (2.0 fps). Using procedures established as part of the requirements for the operating license (NRC) and described in environmental technical specifications for Browns Ferry Nuclear Plant, impingement monitoring studies commenced in February 1974 and have continued uninterrupted. Some observed deficiencies in the sample method required modification of sample design (BFNP Environmental Technical Specifications September 1976) to include a direct count of fish weekly from each screen during one 24-hour period.

Data have been regularly summarized in preoperational and semi-annual and annual operational reports (TVA 1974a, 1974, 1975a, 1975b, 1976, 1978a, 1978b, 1978c, 1979) and have been examined in detail (February 1974-August 1977) in Biological Effects of Intake, Browns Ferry Nuclear Plant, Volume 4, January 1978. These documents indicate fish impingement at BFNP has little, if any, environmental impact on the fish community in Wheeler Reservoir. This report serves to supplement and update this earlier information.

RESULTS AND DISCUSSION

Data collected during operation of BFNP show similarities in species composition, relative abundance, and cycles of impingement susceptibility throughout the 1974-1979 operational period (Figure 1). Consistent increases and decreases in numbers of fish impinged annually,

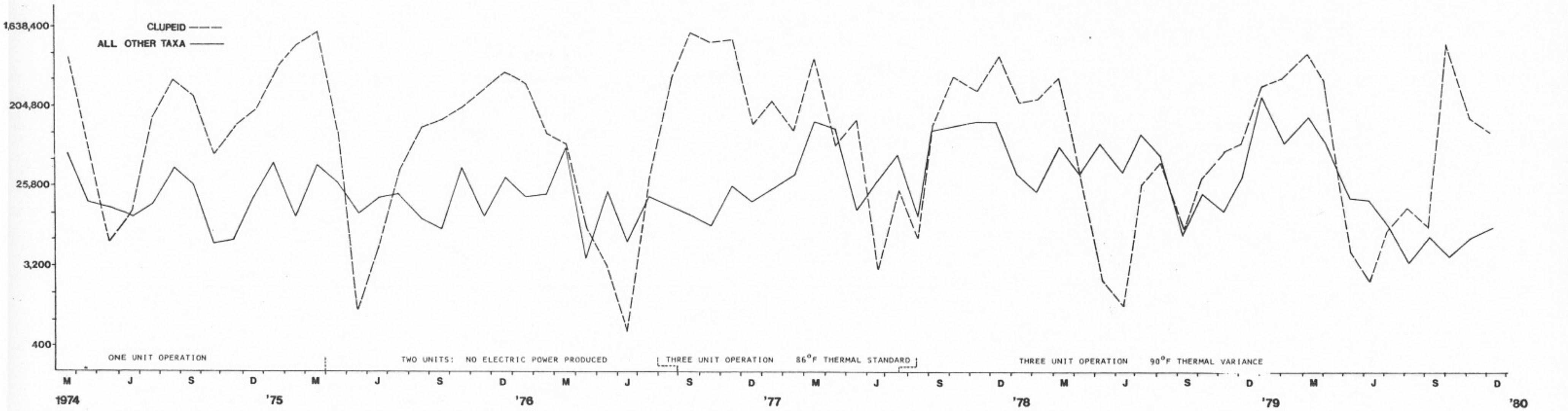


Figure 1. Estimated impingement at Browns Ferry Nuclear Plant by month for clupeids (shad) and all other taxa combined during the period March 1, 1974 through December 31, 1979. A geometric scale was used to show the large range in monthly values.

both clupeids and all other taxa combined show little, if any, effect of either changes in plant operating regime or increases in maximum mixed river temperatures ($30^{o}C$ to $32.2^{o}C$) to the fish community.

With the exception of sauger, the three "cool water" species are impinged in low numbers at BFNP. During 1974-1979 only five walleye were identified in the catch (two in 1977 and three in 1978). Sauger are regularly impinged at BFNP and since habitat requirements of walleye and sauger are generally similar (Pflieger 1975), the paucity of impinged walleye further corroborates the rarity of this species in Wheeler Reservoir and the low potential to be affected by operation of BFNP.

Smallmouth bass were impinged at an average rate of less than one fish per day throughout the operational period. This low rate of impingement suggests the BFNP intake area is not an attractive habitat for this species. Table 1 shows standing stock biomass for smallmouth bass well distributed between young-of-year, intermediate, and harvestable size classes. A healthy smallmouth bass population in Wheeler Reservoir indicates BFNP does not adversely affect this species.

The sauger population in Wheeler Reservoir shows fluctuations in estimated reproductive success (Table 2) and numbers (Table 3) that do not seem to be related to operation of the Browns Ferry Nuclear Plant. Comparison of the total number of sauger annually impinged by BFNP with annual estimated standing stock in Wheeler Reservoir (Table 4) shows large fluctuations but an impingement rate of less than one percent. Ichthyoplankton monitoring during plan operation also shows large fluctuations in larval sauger densities (Table 2). Interestingly, larval sauger densities are highly correlated ($r^2 = 0.840$) with total numbers of young-of-year sauger impinged during the same year (Figure 2).

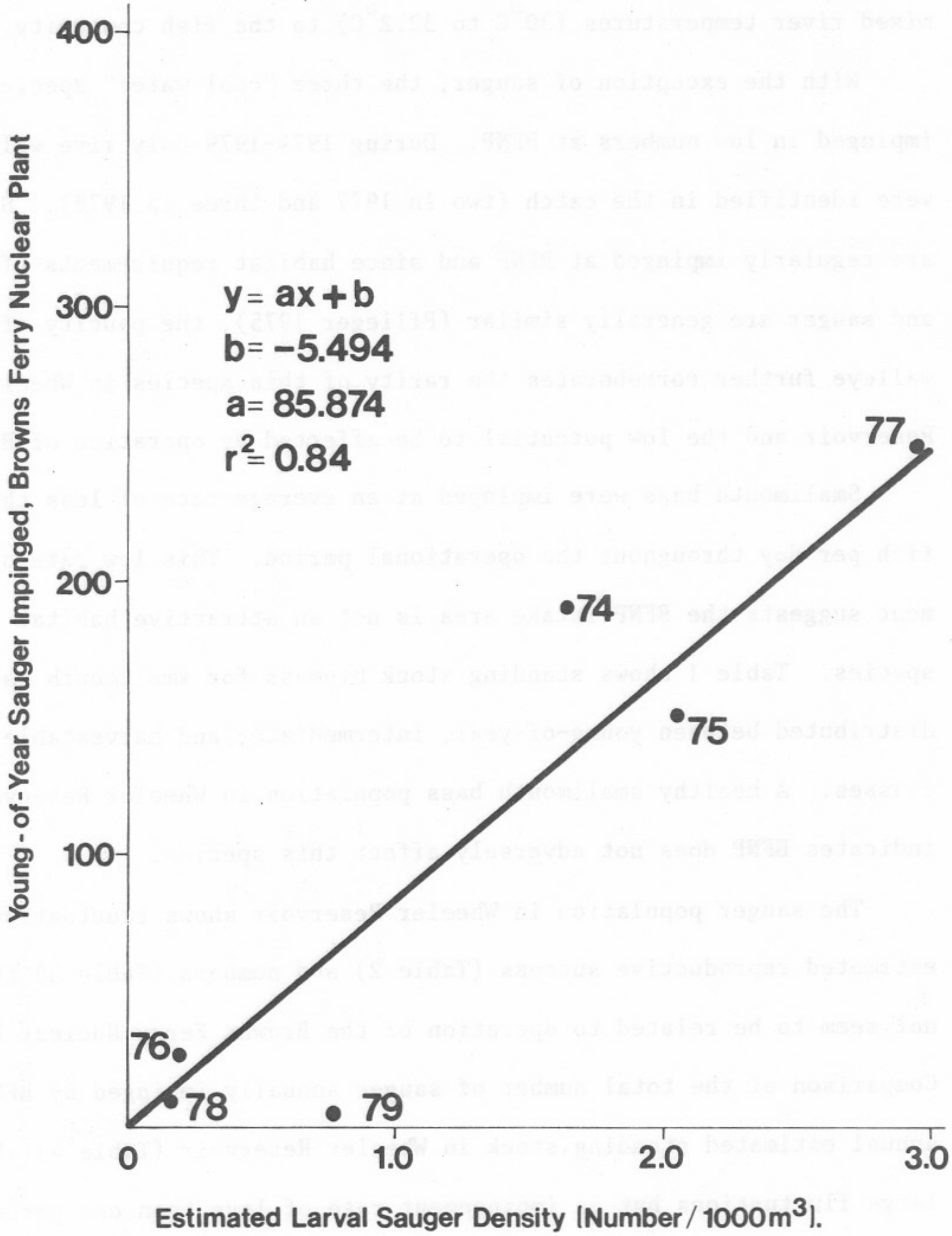


Figure 2. Relationships of young-of-year sauger impinged at Browns Ferry Nuclear Plant to the density of larval sauger (numbers/ 1000 m^3) in Wheeler Reservoir for the years 1974-1979.

Table 1. Number and biomass of smallmouth bass per hectare taken in cove-rotene samples, Wheeler Reservoir. YOY = young of year (<125 mm TL); I = intermediate (125-200 mm); H = harvestable (>200 mm). Coves at TRM 275, 286, and ERM (Elk River) 2.7 are preoperational and operational monitoring sites for BFNP.

Location	Year	YOY N	YOY kg	I N	I kg	H N	H kg
TRM 275	1970	95	0.36	19	1.02	12	4.66
	1971	85	0.86	32	1.35	32	18.69
	1972	80	0.64	31	2.56	17	3.39
	1973	36	0.41	7	0.57	8	1.34
	1974	146	0.87	11	0.69	6	0.85
	1975	84	0.68	11	0.67	3	0.87
	1976	108	1.46	19	0.91	24	3.35
	1977	71	0.29	25	1.26	23	4.77
	1978	153	0.72	39	0.97	9	1.24
	1979	48	0.31	40	1.03	14	2.37
TRM 286	1970	86	0.15	13	0.55	2	0.38
	1971	135	1.13	83	2.36	5	0.71
	1972	8	0.05	1	0.09	1	0.18
	1973	1	0.01	0		0	
	1974	1	0.01	0		0	
	1975	3	0.04	0		0	
	1976	7	0.10	1	0.03	7	1.13
	1977	40	0.15	11	0.51	11	0.47
	1978	45	0.23	5	0.11	0	
	1979	26	0.18	6	0.10	1	0.14
ERM 27	1970	20	0.21	2	0.23	0	
(Elk River)	1971	141	1.31	38	1.01	6	0.99
	1972	9	0.10	9	0.75	11	1.61
	1973	0		0		0	
	1974	16	0.13	0		0	
	1975	9	0.10	3	0.18	3	0.35
	1976	0		0		0	
	1977	2	0.01	10	0.23	5	1.18
	1978	9	0.06	5	0.11	5	1.11
	1979	0		0		0	

Table 2. Total numbers, density, latest occurrence, and temperature data for Stizostedion spp. (probably sauger) larvae collected from Wheeler Reservoir. 1971-1979.

Year	Total Number	Density (No./1000 m^3)	Latest Occurrence	Mean Temperature (C)
1971***	0	0		
1972***	0	0		
1973	93	2.14	May 15	19.3
1974	107	1.60	May 15	21.0
1975	112	2.09	May 21	22.0
1976	13	0.22	May 6	19.7
1977	225	2.96	May 11	21.9
1978	2	0.07	May 8	19.9
1979	25	0.85	April 30	20.9

* During period of occurrence.

** Mean of day-night water temperature on date of latest occurrence.

*** Sampling not begun until after the period of larval stizostedion spp. occurrence.

Table 3. Numbers and biomass of sauger per hectare taken in cove-rotene samples, Wheeler Reservoir. YOY = young of year (<200 mm TL); I = intermediate (200-300 mm); H = harvestable (>300 mm). Coves at TRM 275, 286, and ERM (Elk River) 2.7 are preoperational and operational monitoring sites for BFNP.

		Sauger - YOY		I		H	
Location	Year	N	kg	N	kg	N	kg
TRM 275	1970	5	0.13	0		0	
	1971	0		1	0.29	0	
	1972	5	0.35	0		0	
	1973	16	0.60	0		0	
	1974	5	0.15	0		1	0.21
	1975	14	0.37	5	0.62	1	0.11
	1976	6	0.31	5	0.88	0	
	1977	86	1.85	1	0.14	4	0.87
	1978	7	0.21	16	1.80	3	0.81
	1979	1	0.03	0		3	0.60
TRM 286	1970	18	0.69	0		0	
	1971	0		0		0	
	1972	1		1	0.05	0	
	1973	9	0.30	0		1	0.17
	1974	8	0.16	1	0.12	1	0.28
	1975	27	0.74	10	1.56	0	
	1976	21	0.99	24	2.48	7	2.45
	1977	124	2.76	0		14	4.38
	1978	4	0.07	8	0.66	1	0.29
	1979	9	0.21	6	0.60	0	
ERM 2.7	1974	5	0.17	0		0	
	1975	3	0.06	5	0.59		
	1976	0		8	0.77	2	0.60
	1977	3	0.09	0		0	
	1978	0	0.00	0		2	0.23
	1979	0	0.00	0		0	

Table 4. Estimated standing stock numbers (based on cove rotenone samples) for sauger in Wheeler Reservoir[1] compared with estimated total impingement of sauger during the period March 1, 1974, through December 31, 1979.

	Estimated Total Number Impinged	Estimated Standing Stock (No/ha) in Wheeler Reservoir	Percent impinged
1979	453	516,000	0.088
1978	2,985	1,113,000	0.268
1977	12,158	6,300,000	0.193
1976	837	2,009,000	0.042
1975	2,099	1,788,000	0.117
1974[2]	4,132	578,000	0.715
1973	None	715,000	-
1972	None	193,000	-

1. Based on a reservoir surface area of 27,154 hectares.
2. Impingement studies began March 1, 1974.

These data suggest the sauger population in Wheeler Reservoir is highly variable, but responds to factors unrelated to either the intake structure or thermal effluent from BFNP. Estimated numbers impinged were low compared to estimated reservoir standing stock and were highly coorelated with numbers of larvae present in the reservoir. Browns Ferry Nuclear Plant seems to be consistently sampling, but not adversely affecting, the sauger in Wheeler Reservoir.

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Pflieger, W. L., 1975. The Fishes of Missouri. Missouri Department of Conservation. 342 pp.

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