LIFE HISTORIES OF SEVEN FISH SPECIES THAT INHABIT THE HUDSON RIVER ESTUARY

Testimony of

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ABSTRACT

The fish species discussed in this exhibit are striped bass, white perch, blueback herring, alewife, American shad, Atlantic tomcod, and bay anchovy. For each species, the discussion includes: (1) spawning, ichthyoplankton, and juvenile spatial and temporal distributions during 1974 and/or 1975; (2) coastal movements of juveniles and adults; (3) past and present fisheries, if any; and (4) trophic relationships among members of each species and other populations of the Hudson River aquatic community. The life histories are confined to information related specifically to the populations in the Hudson River. However, this information is sometimes supplemented by data reported for other populations of the same species.

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INTRODUCTION

The intent of this exhibit is to present the biological basis for subsequent analyses of power plant impacts on selected Hudson River fish species. The life histories included here are confined to information related specifically to the populations in the Hudson River. However, this information sometimes is supplemented by data reported for other populations of the same species.

The fish populations inhabiting the Hudson River discussed in this exhibit are striped bass, white perch, blueback herring, alewife, American shad, Atlantic tomcod, and bay anchovy. For each population, the discussion includes: (1) spawning, ichthyoplankton, and juvenile spatial and temporal distributions during 1974 and/or 1975; (2) coastal movements of juveniles and adults; (3) past and present fisheries, if any; and (4) trophic relationships among members of each population and other populations of the Hudson River aquatic community.

The spatial and temporal distributions of each population were derived from data collected during the Texas Instruments, Inc. (TI) Long River, beach seine, and fall shoals sampling programs. The spatial distributions of each life stage of each population represent the proportions of the average weekly standing crop of that life stage present in each region of the estuary during a given year. Life stage standing crops were derived by multiplying the average regional densities of each life stage during each sample week by the total regional water volume (for Long River Survey data), the shorezone water volume (for beach seine data), or the shoal water volume (for fall shoals survey data). The average regional density of each life stage of each fish population, as well as water volumes for the depth strata of each region, were provided to the Environmental Protection Agency (EPA) by the utilities (Marcellus 1977a, 1978a, 1978b, 1978d, 1979a).

The temporal distributions of each life stage of each species are based on the proportion of the sum of the estimated weekly standing crops of that life stage present in the estuary during a specified week. The temporal distributions of life stages for which data are available that relate life stage duration to water temperatures are adjusted to account for the possibility that capture depends on the length of time a member of a given life stage is present in the water body. This adjustment is accomplished by dividing the proportion of the total estimated standing crop present during a specified week by the duration of that life stage, based on the average river temperature recorded for that week. The resultant proportions are then normalized to unity. Weekly average water temperatures are based on measurements at the City of Poughkeepsie Water Works, which were supplied to EPA by the utilities (Marcellus 1978c).

STRIPED BASS

Goodyear (1978) reported that the striped bass (Morone saxatilis) is perhaps the most sought after and most studied sport fish taken by the small boat livery and trailer fisheries on the Atlantic coast. The 1965 Salt-Water Angling Survey (Deuel and Clark 1968) revealed sport fishermen landed an estimated 57 million pounds of striped bass along the Atlantic coast that year; Koo (Table 2, 1970) indicated another 8 million pounds were landed in 1965 by commercial fishermen along the Atlantic coast. In 1970, sport fishermen along the Atlantic coast landed an estimated 73 million pounds (Deuel 1973) and commercial fishermen accounted for an additional 11 million pounds (Westin and Rogers 1978). Thus, within five years (1965-1970) landings of striped bass increased approximately 1.3 times along the Atlantic coast. This value to sport and commercial fishing, as well as its vulnerability to power plant impacts, has caused the striped bass to be a principal concern in this case.

SPAWNING

Striped bass spawn in the Hudson River from early May through June. Peak spawning activity occurs in mid-May (p. 6.6, Exhibit UT-4). Based on 1974 and 1975 TI Long River Survey collections of striped bass eggs (figures 1 and 2), spawning activity was concentrated between the Croton-Haverstraw and West Point regions (RM 34-55).

Fecundity of Hudson River striped bass ranges from approximately 400,000 to 2,600,000 ova per female (Table 2-VIII-1, Exhibit UT-3). A few female striped bass are mature at age 3; all are mature by age 9 (Table 2-VIII-1, Exhibit UT-3). However, determination of the overall age composition of the spawning stock in the Hudson is hampered by the size selectivity of gill nets for smaller striped bass (p. 2-VII-9, Exhibit UT-3).

EGGS

The spatial distribution of striped bass eggs within the Hudson River during 1974 and 1975 are shown in figures 1 and 2. The peak estimated weekly standing crop occurred in the West Point region (RM 47-55) during both years. The overall distribution of eggs was slightly more downriver in 1975 than in 1974.

Documented durations of the incubation period of striped bass eggs at different water temperatures are listed in Table 1. Based on these data, egg incubation periods range from 48-72 hours. Rogers et al. (1977) developed a regression equation for calculating the duration of the egg incubation period based on water temperature. Their equation was as follows:

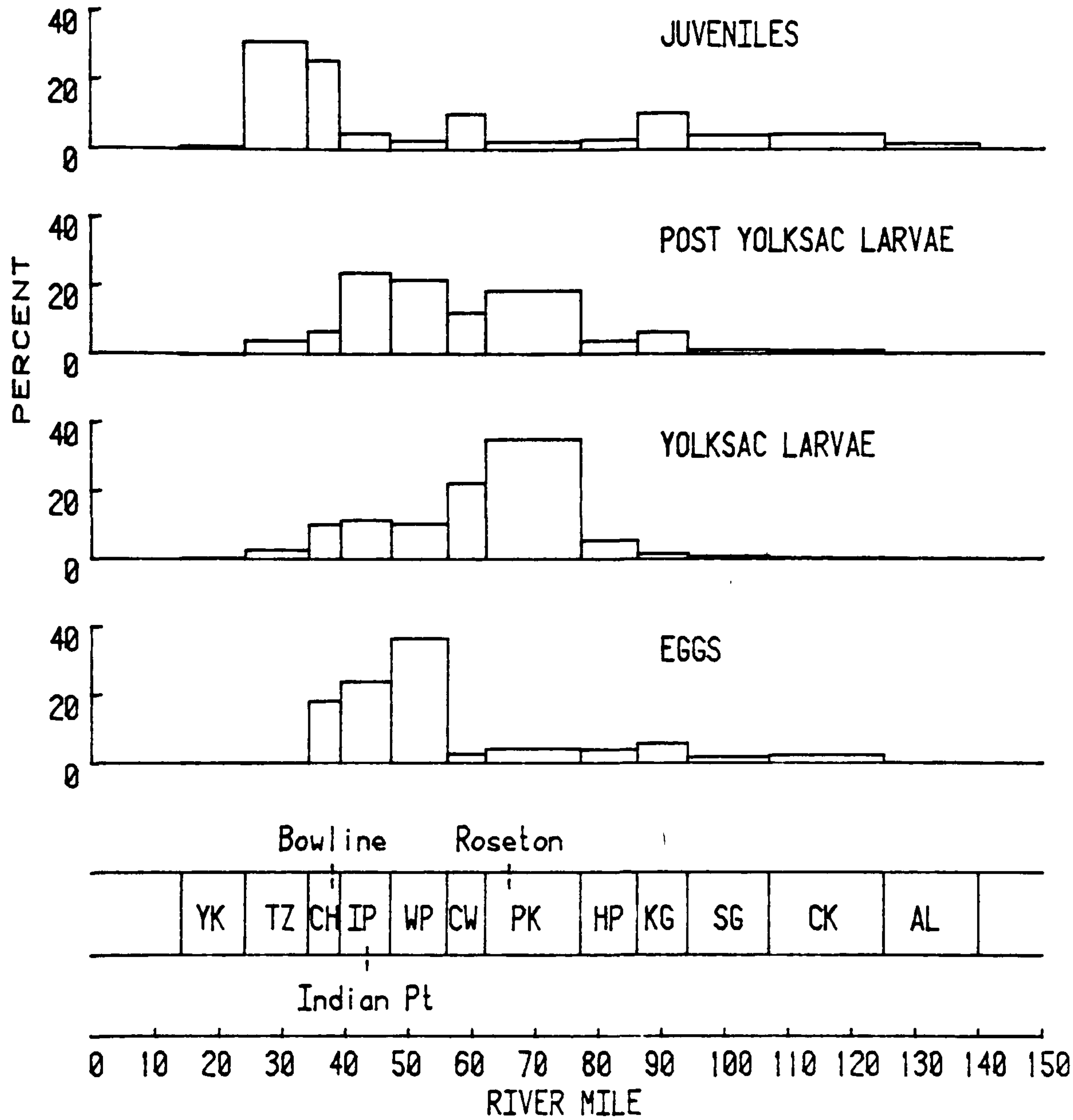

Figure 1. Proportional distributions, expressed as percentages, of early life stages of striped bass during 1974, based on TI Long River Survey data supplied to EPA (Marcellus 1977b).

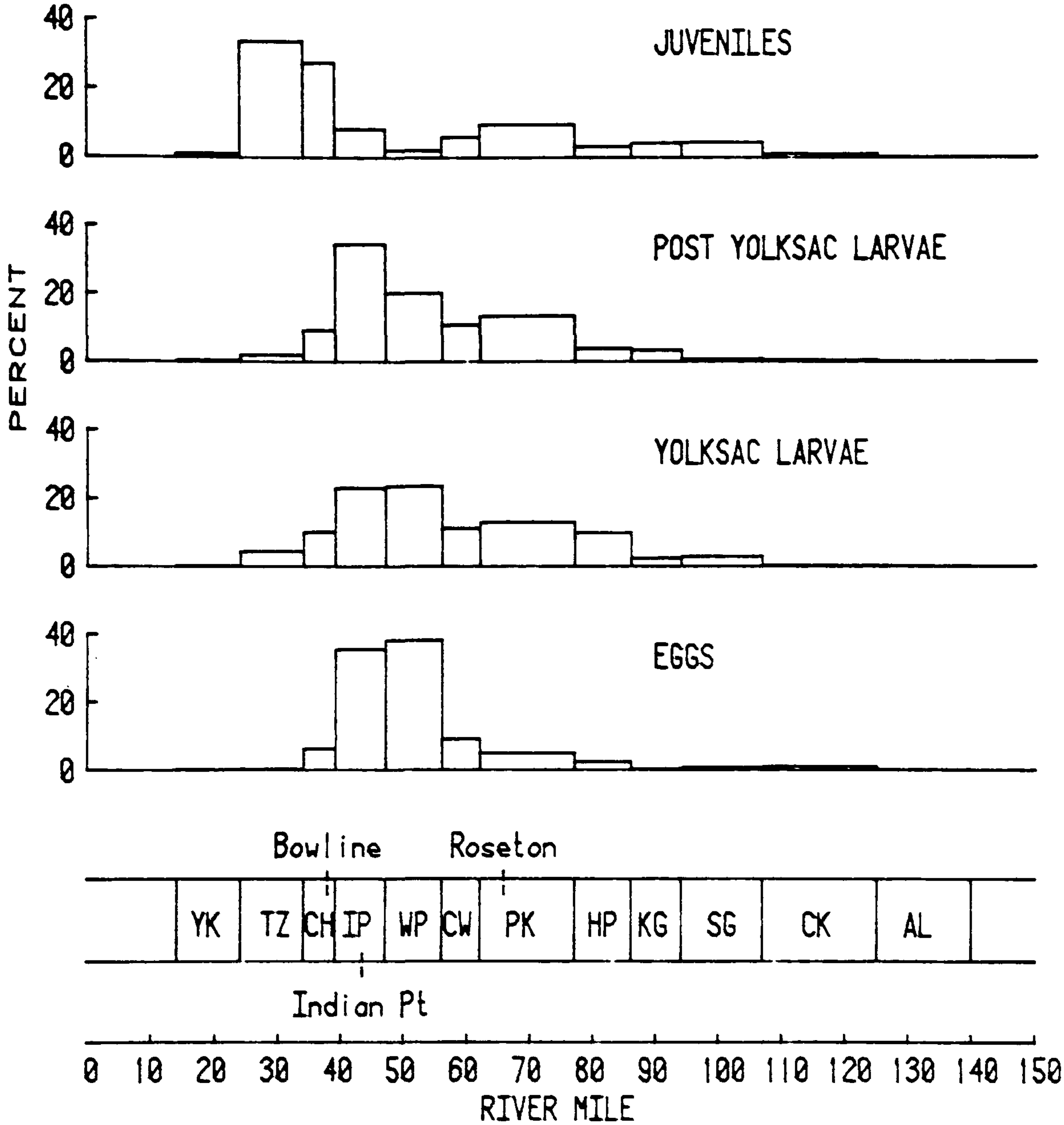

Figure 2. Proportional distributions, expressed as percentages, of early life stages of striped bass during 1975, based on TI Long River Survey data supplied to EPA (Marcellus 1977b).

Documented Durations of Early Life Stages of Striped Bass

	Temperature(°C)	Duration	Source
	16.7-17.2	48 hr	Mansueti 1958
	17.9	48 hr	Pearson 1938
	14-18	48-70 hr	Rogers et al. 1977
	16-20	40-58 hr	"
	18.3	48 hr	p. 7.45, Exhibit UT-4
	16.6	56 hr	"
	-	48 hr	NRC 1975
larva	12	9 days	Rogers et al. 1977
	15	8.3 days	"
	18	7.75 days	"
	21	5.1 days	"
	24	3.8 days	"
	-	4-6 days	p. 8.3, Exhibit UT-4
	-	12 days	p. 12.6, Exhibit UT-4
	-	4-10 days	Hardy 1978
	-	6 days	NRC 1975
yolksac larva	15	67.66 days	Rogers et al. 1977
	18	33 days	"
	21	23.9 days	"
	24	22.66 days	"
	-	20 days	p. 12.6, Exhibit UT-4
	-	20-30 days	p. 8.3, Exhibit UT-4
	-	22 days	NRC 1975
trainable juvenile	-	30 days	p. 12.6, Exhibit UT-4
	-	20-30 days	p. 8.3, Exhibit UT-4

$$\text{duration(hr)} = 258.5e^{-0.09341(°C)} \qquad (1)$$

The regression of the linear form of this model has an r^2-value of 0.93 (n=42).

Equation 1 was used to estimate the average durations of the striped bass egg incubation periods during 1974 and 1975 in the Hudson River, as well as to adjust the 1974 and 1975 temporal distributions to account for the relationship between the duration of the life stage and the probability of capture of the life stage in the weekly sampling. Table 2 lists the temporal distributions of egg standing crops based on data collected during the TI Long River surveys, the average weekly water temperatures recorded at Poughkeepsie, the associated egg incubation periods based on equation 1, and the resultant adjusted temporal distributions of egg standing crops. The average incubation periods, derived by weighting the durations by the adjusted standing crop proportions they represent, were 2.5 days and 2 days for 1974 and 1975, respectively.

LARVAE

Figures 1 and 2 show that the average weekly standing crops of yolksac and post yolksac larvae were more upriver in 1974 than in 1975. The peak average weekly standing crop of yolksac larvae occurred in the Poughkeepsie region (RM 62-76) in 1974 and the West Point region (RM 47-55) in 1975. The peak average weekly standing crop of post yolksac larvae occurred in the Indian Point region (RM 39-46) in both 1974 and 1975. However, regions upriver from Indian Point contained higher proportions of the average weekly river-wide standing crop in 1974 than in 1975. A higher freshwater discharge during June, 1975 (Table 2.2-1, Exhibit UT-4), which coincides with the period of egg and larval occurrence in field collections, may have caused the concentrations of these life stages further downriver during that year.

Documented durations of the yolksac larval stage of striped bass in relation to water temperature are listed in Table 1. Based on these data yolksac larva life stage durations range from 4 to 12 days. Durations of the yolksac larval life stage in the Hudson River during 1974 and 1975 and temporal distribution among sample weeks can be derived by the same method used to determine the egg incubation periods and temporal distributions for those years. Based on data presented by Rogers et al. (1977), the following regression equation was developed:

$$\text{duration (days)} = 24.34e^{-0.0737(°C)} \qquad (2)$$

The r^2-value of the linearized form of this equation is 0.85 (n=5).

Applying the same method used for derivation of the average striped bass egg incubation periods to derive the average durations of the yolksac larval life stage results in average durations of approximately 7 and 5.5 days for 1974 and 1975, respectively (Table 3). Table 3 also lists the temporal distributions of yolksac larvae standing crops during 1974 and 1975, adjusted for weekly water temperatures.

Table 2. Temporal Distributions, Expressed as Percentages of Striped Bass Egg Standing Crops during 1974 and 1975, Adjusted for Weekly Water Temperatures

Year	Week	Proportion[a]	Ave. Temp.[b] (°C)	Duration[c] (hr)	Adjusted proportion
1974	4/29 - 5/5	0.30	12.8	78.2	0.25
	5/6 - 5/12	13.75	13.5	73.3	12.26
	5/13 - 5/19	45.25	13.9	70.6	41.89
	5/20 - 5/26	35.04	15.8	59.1	38.75
	5/27 - 6/2	4.76	16.8	57.5	5.41
	6/3 - 6/9	0.38	16.9	53.3	0.47
	6/10 - 6/16	0.31	18.8	44.7	0.46
	6/17 - 6/23	0.20	20.5	38.1	0.34
	6/24 - 6/30	0.10	20.5	38.1	0.17
1975	5/11 - 5/17	4.61	13.5	73.2	3.09
	5/18 - 5/24	55.35	16.6	54.8	49.52
	5/25 - 5/31	35.42	19.4	42.2	41.15
	6/1 - 6/7	3.55	20.8	37.0	4.70
	6/8 - 6/14	0.06	20.5	38.1	0.08
	6/15 - 6/21	0.40	20.6	37.7	0.52
	6/22 - 6/28	0.61	22.4	31.9	0.94

[a] based on TI Long River surveys (Marcellus 1977b)
[b] from Poughkeepsie Water Works (Marcellus 1978c)
[c] based on equation 1 in text

Table 3. Temporal Distributions, Expressed as Percentages, of Striped Bass Yolksac Larvae Standing Crops during 1974 and 1975, Adjusted for Weekly Water Temperatures

Year	Week	Proportion[a]	Ave. Temp.[b] (°C)	Duration[c] (days)	Adjusted proportion
1974	5/6 - 5/12	1.44	13.5	9.0	1.11
	5/13 - 5/19	0.83	13.9	8.7	0.66
	5/20 - 5/26	15.33	15.8	7.6	13.97
	5/27 - 6/2	43.27	16.8	7.1	42.20
	6/3 - 6/9	18.35	16.9	7.0	18.15
	6/10 - 6/16	18.49	18.8	6.1	20.99
	6/17 - 6/23	1.99	20.5	5.4	2.55
	6/24 - 6/30	0.28	20.5	5.4	0.36
	7/1 - 7/7	0.01	21.4	5.0	0.01
1975	5/11 - 5/17	0.05	13.5	9.0	0.03
	5/18 - 5/24	4.44	16.6	7.2	3.47
	5/25 - 5/31	52.21	19.4	5.8	50.60
	6/1 - 6/7	42.20	20.8	5.3	44.76
	6/8 - 6/14	0.88	20.5	5.4	0.92
	6/15 - 6/21	0.14	20.6	5.3	0.15
	6/22 - 6/28	0.07	22.4	4.7	0.08

[a]based on TI Long River surveys (Marcellus 1977b)
[b]from Poughkeepsie Water Works (Marcellus 1978c)
[c]based on equation 2 in text

Documented durations of the post yolksac larval life stages are listed in Table 1. Rogers et al. (1977) presented data from which a regression equation for the duration of the post yolksac larval life stage versus water temperature (can be developed.) Their equation is as follows:

$$\text{duration(days)} = 345.2e^{-0.120T(^{\circ}C)} \qquad (3)$$

The linearized form of this equation has an r^2-value of 0.86 (n=4).

Using the same method applied to eggs and yolksac larvae, the average life stage durations for the post yolksac larvae of striped bass during 1974 and 1975 are approximately 33 days and 28 days, respectively (Table 4). Table 4 lists the temporal distributions of post yolksac larvae standing crops during 1974 and 1975, adjusted for weekly water temperatures. Since the fish are actively seeking food by this stage, duration of the post yolksac larval life stage is influenced by more than water temperature. Life stage durations based solely on studies conducted under controlled laboratory conditions are probably not truly representative of the actual situation in the Hudson River, which could generally be expected to be somewhat longer because of increased activity due to predator avoidance and searching for food.

An alternative approach to derivation of the life stage durations of striped bass post yolksac larvae during 1974 and 1975 is examination of the temporal distributions of this and the following life stage (juveniles) in field collections. The life stage duration of post yolksac larvae is approximately equal to the time period between peak weekly standing crops of post yolksac larvae and juveniles or the time period between the first appearance of post yolksac larvae and the first appearance of juveniles in field samples. These approaches to estimating life stage durations are influenced by differential recruitment to the life stages as well as differential mortality of cohorts within each life stage.

The difference between the estimated peak weekly standing crops of post yolksac larvae and juveniles was five weeks in 1974 (which corresponds closely to the 33 day duration estimated using equation 3), and six to seven weeks in 1975 (which is greater than the 28 days estimated by using equation 3). The periods between the first appearance of striped bass post yolksac larvae and juveniles in field collections were four weeks in 1974 and five weeks in 1975. Combining the information derived from the temporal distribution and laboratory temperature study approaches, a four week duration for post yolksac larvae during 1974 and 1975 is a minimum value for the Hudson River striped bass population.

JUVENILES

Juveniles are defined as the life stage of striped bass (and all other populations discussed in this testimony) following post yolksac larvae. For discussion, juvenile life stage of striped bass is divided into two categories: early juveniles (through mid-August) and fall juveniles (mid-August through December). The basis of the mid-August cut-off is a change in sampling programs by TI at this time during both 1974 and 1975; the Long River Survey was completed and the fall shoals survey was initiated.

Early juveniles

In figures 3 and 4, the average weekly distributions of early juveniles, based on the 1974 and 1975 TI Long River surveys, are compared to the average weekly distributions of early juveniles based on the 1974 and 1975 TI beachseine surveys (before mid-August). The distributions based on the beach seine surveys represent the standing crops of juveniles in the shorezone (<10 ft in depth) only. The beach seine data reflect a higher abundance of juveniles further upriver during 1974 and 1975 than the Long River Survey data. This may have resulted from movement of early juvenile striped bass out of the depth strata sampled by the Long River Survey (> 10 ft in depth) and into the shorezone, or from avoidance of Long River Survey gear by larger fish. Both surveys indicate juveniles were more dispersed in the estuary than earlier life stages. This apparent dispersion could have been caused by movement and/or differential spatial mortality.

Juvenile striped bass first appeared in field samples during mid-June of both 1974 and 1975 (Table 5). Peak abundance of this life stage occurred in mid-July during both years, according to the Long River Survey data, and late-July to early-August, according to the beach seine data. No data are available to relate growth in the early juvenile life stage to water temperatures in the Hudson River. Length data collected by the TI beach seine, bottom trawl, and fall shoals surveys during 1974 and 1975 are presented in tables 6 and 7. These data indicate that juvenile striped bass in the Hudson River began to attain a length of 50 mm (considered maximum entrainable size in this testimony) by mid-July. The minimum recorded lengths began to surpass 50 mm by late September in 1974 and by late August in 1975. Since post yolksac larvae disappeared from field collections during late July in 1974 and 1975 (Table 4), a life stage duration of four to six weeks for entrainable juveniles is probably appropriate for 1974. Four weeks is a minimum value for 1975.

Fall juveniles

Figures 5 and 6 show the distributions of fall juvenile striped bass in the Hudson River during 1974 and 1975, respectively. These distributions are based on the TI beach seine (after mid-August) and fall shoals surveys. The fall shoals survey distributions represent standing crops estimated only for the shoal habitat (<20 ft in depth, Tr. 6853-6854) of the Hudson River. Figures 5 and 6 indicate a distinct downriver shift in the distribution of fall juveniles as compared to earlier life stages. However, the observation by TI of bi-directional movement of fin-clipped striped bass released during the fall contradicts the hypothesis of continuous downriver displacement of the entire juvenile population during fall and early winter (p. V-84, Volume I, TI 1977).

Table 4. Temporal Distributions, Expressed as Percentages, of Striped Bass Post Yolksac Larvae Standing Crops during 1974 and 1975 Adjusted for Weekly Water Temperatures

Year	Week	Proportion[a]	Ave. Temp.[b] (°C)	Duration[c] (days)	Adjusted proportion
1974	5/13 - 5/19	0.01	13.9	65.0	0.01
	5/20 - 5/26	0.12	15.8	51.8	0.08
	5/27 - 6/2	6.00	16.8	45.9	4.28
	6/3 - 6/9	10.04	16.9	45.4	7.24
	6/10 - 6/16	29.63	18.8	36.1	26.89
	6/17 - 6/23	36.71	20.5	29.4	40.89
	6/24 - 6/30	12.94	20.5	29.4	14.42
	7/1 - 7/7	2.44	21.4	26.4	3.03
	7/8 - 7/14	1.19	22.3	23.7	1.64
	7/15 - 7/21	0.86	23.9	19.6	1.44
	7/22 - 7/28	0.05	23.6	20.3	0.08
1975	5/18 - 5/24	0.01	16.6	47.0	0.01
	5/25 - 5/31	1.30	19.4	33.6	1.10
	6/1 - 6/7	50.75	20.8	28.4	50.86
	6/14 - 6/21	40.59	20.5	29.4	39.30
	6/15 - 6/28	3.06	20.6	29.1	2.99
	6/29 - 7/5	2.26	22.4	23.4	2.75
	7/6 - 7/12	1.01	24.5	18.2	1.58
	7/13 - 7/19	0.11	25.3	16.5	0.19
	7/20 - 7/26	0.01	25.5	16.1	0.02

[a] based on TI Long River surveys (Marcellus 1977b)
[b] from Poughkeepsie Water Works (Marcellus 1978c)
[c] based on equation 3 in text

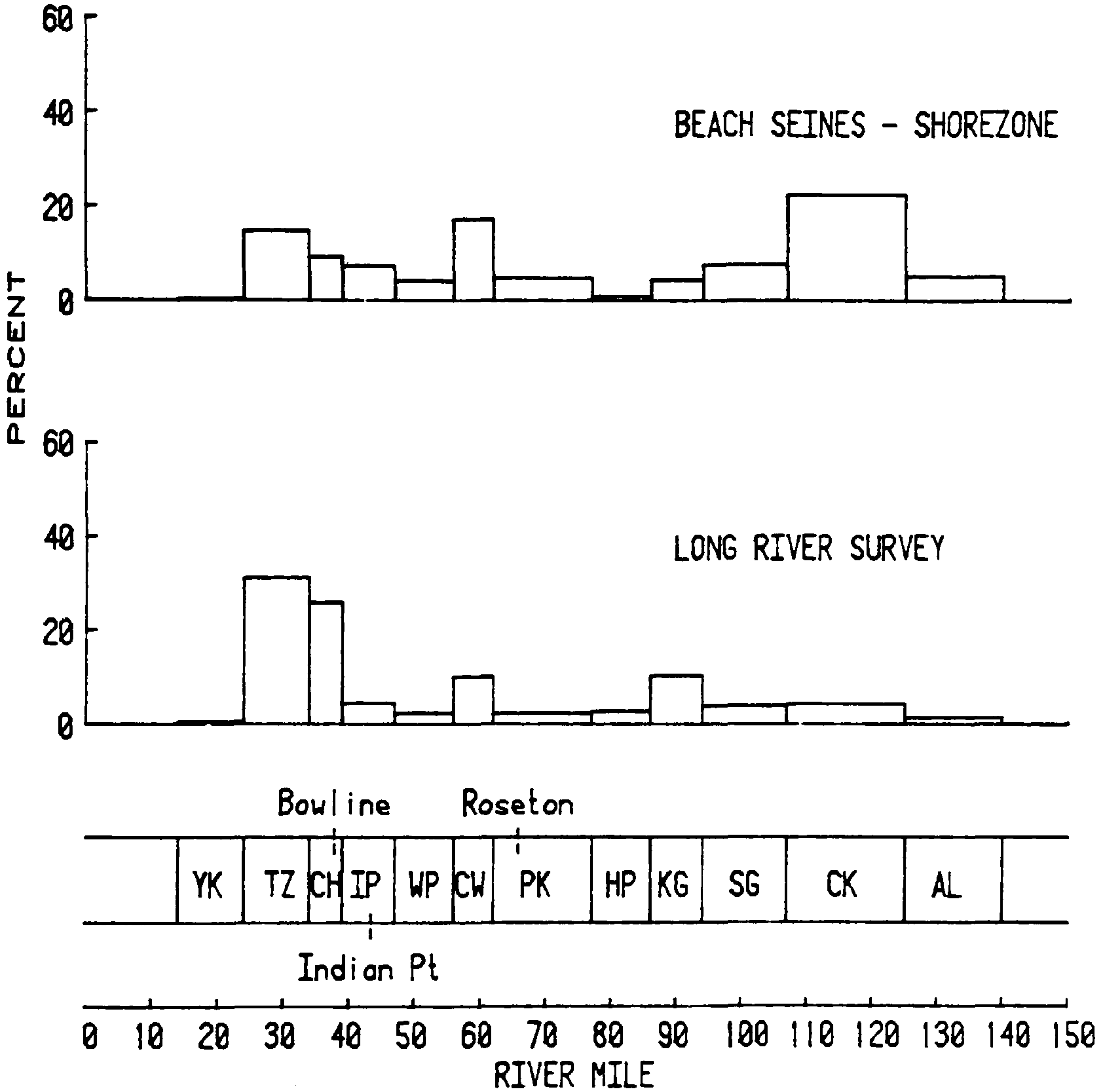

Figure 3. Proportional distributions, expressed as percentages, of early juvenile striped bass during 1974, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1977b).

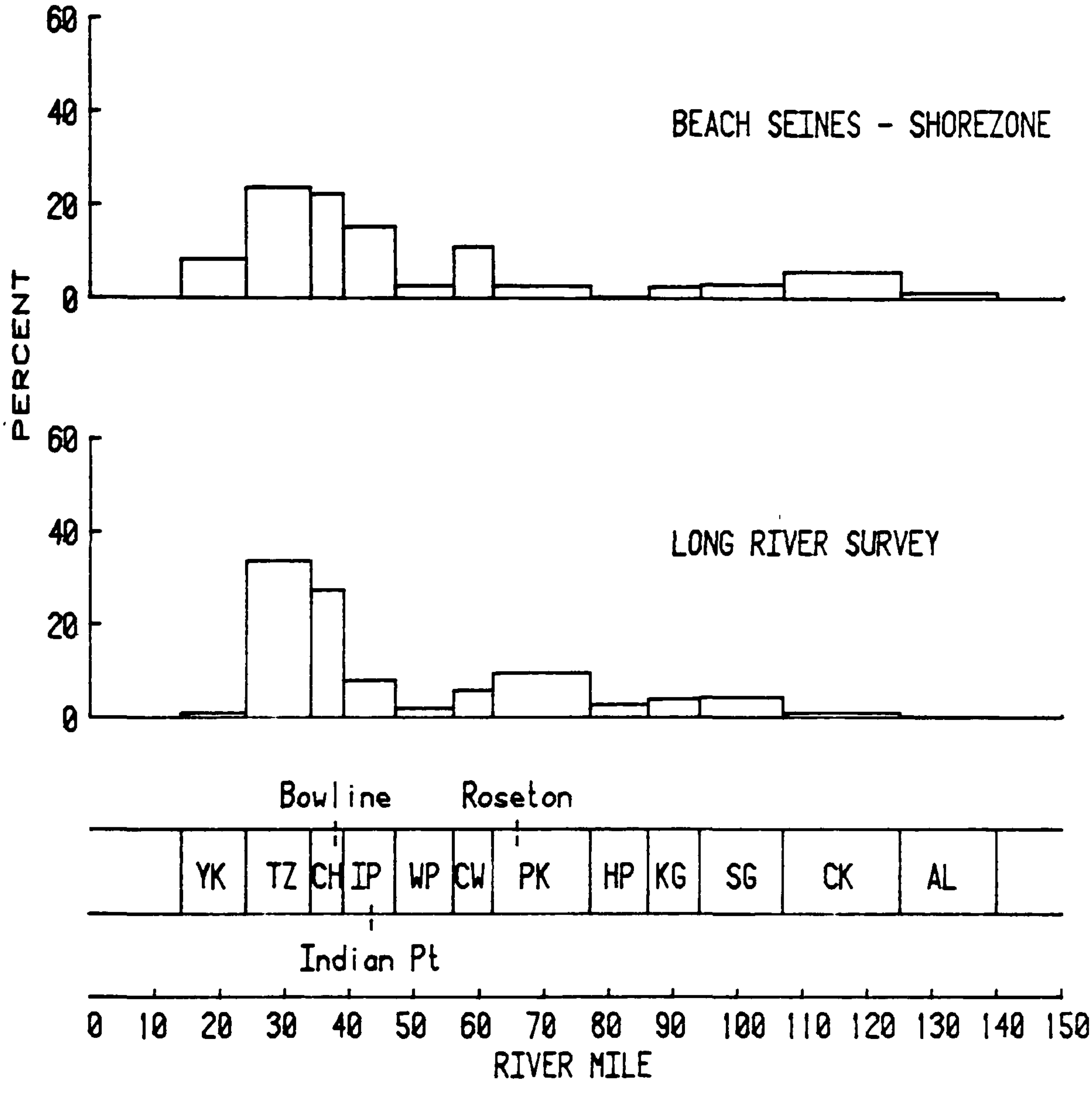

Figure 4. Proportional distributions, expressed as percentages, of early juvenile striped bass during 1975, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1977b).

Table 5. Temporal Distributions, Expressed as Percentages, of Striped Bass Juvenile Standing Crops during 1974 and 1975, Based on the TI Long River Surveys[a]

Year	Week	Proportion
1974	6/10 - 6/16	0.19
	6/17 - 6/23	0.20
	6/24 - 6/30	0
	7/1 - 7/7	3.63
	7/8 - 7/14	15.62
	7/15 - 7/21	20.69
	7/22 - 7/28	25.40
	7/29 - 8/4	17.25
	8/5 - 8/11	7.27
	8/12 - 8/18	9.76
1975	6/22 - 6/28	1.78
	6/29 - 7/5	9.68
	7/6 - 7/12	18.72
	7/13 - 7/19	21.13
	7/20 - 7/26	21.98
	7/27 - 8/2	17.57
	8/3 - 8/9	-[b]
	8/10 - 8/16	9.13

[a]Marcellus (1977b)
[b]no sampling conducted

Table 6. Average Lengths and Size Ranges Recorded for Juvenile Striped Bass Sampled in the Hudson River by TI during 1974[a]

Week	Average length (mm)	Range (mm)
6/23 - 6/29	24	18 - 30
6/30 - 7/6	28	21 - 35
7/7 - 7/13	33	22 - 45
7/14 - 7/20	41	28 - 63
7/21 - 7/27	34	20 - 70
7/28 - 8/3	51	23 - 75
8/4 - 8/10	59	24 - 75
8/11 - 8/17	63	44 - 85
8/18 - 8/24	68	41 - 118
8/25 - 8/31	57	34 - 119
9/1 - 9/7	80	32 - 120
9/8 - 9/14	78	31 - 119
9/15 - 9/21	82	47 - 129
9/22 - 9/28	85	57 - 130
9/29 - 10/5	86	54 - 130
10/6 - 10/12	98	49 - 130

[a]based on Tables A-85 to A-88 in TI (1977) averaged for all gear each week

Table 7. Average Lengths and Size Ranges Recorded for Juvenile Striped Bass Sampled in the Hudson River by TI during 1975[a]

Week	Average length (mm)	Range (mm)
6/15 - 6/21	20	13 - 25
6/22 - 6/28	26	14 - 28
6/29 - 7/5	32	19 - 52
7/6 - 7/12	44	25 - 63
7/13 - 7/19	44	17 - 74
7/20 - 7/26	55	28 - 86
7/27 - 8/2	60	29 - 83
8/3 - 8/9	67	27 - 90
8/10 - 8/16	71	32 - 101
8/17 - 8/23	76	44 - 110
8/24 - 8/30	81	48 - 110
8/31 - 9/6	83	53 - 127
9/7 - 9/13	85	21 - 120
9/14 - 9/20	88	53 - 130
9/21 - 9/27	90	28 - 128
9/28 - 10/4	92	7 - 133
10/5 - 10/11	95	37 - 148

[a]based on Table B-71 in TI (1978) averaged for all gear each week

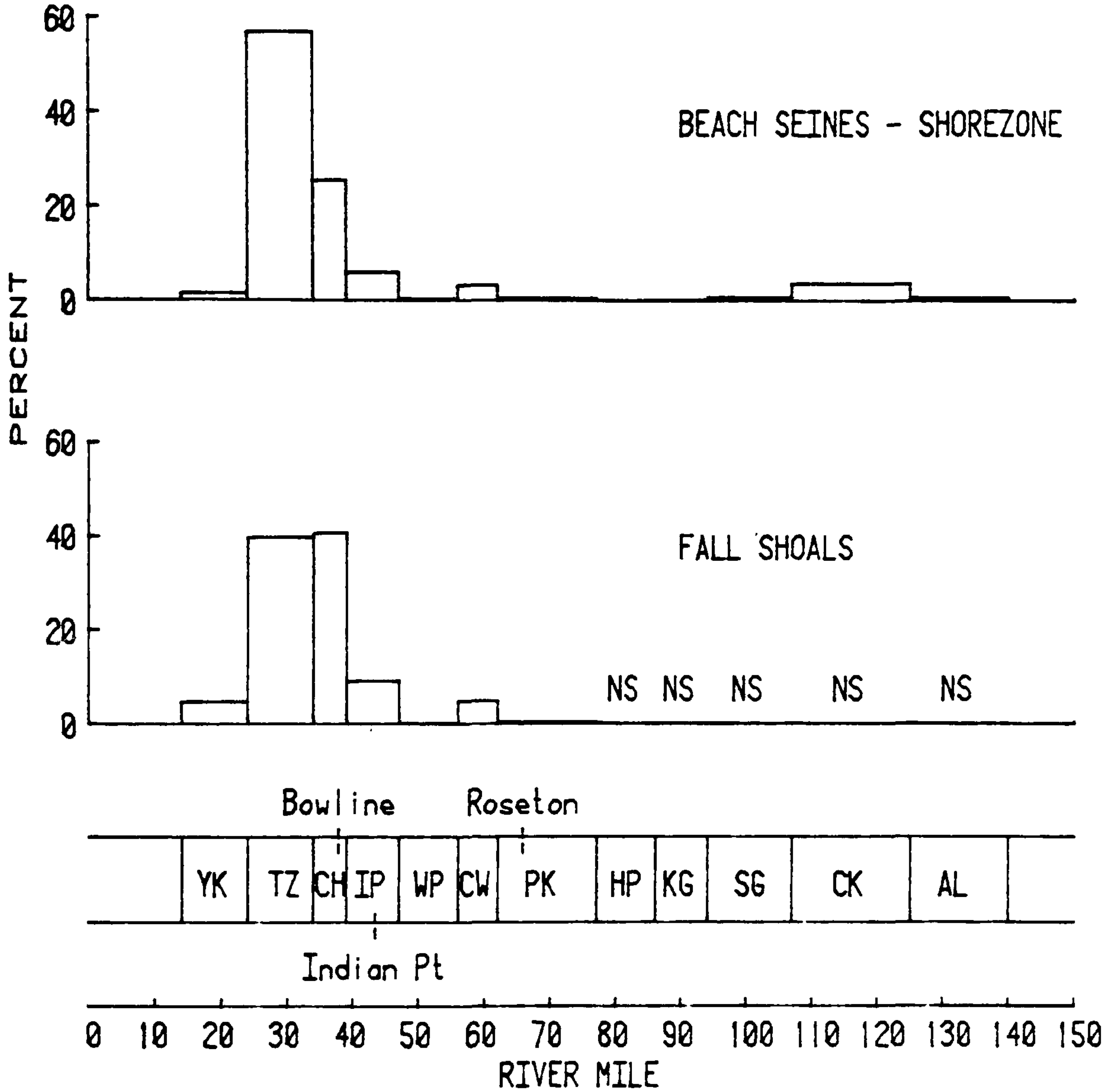

Figure 5. Proportional distributions, expressed as percentages, of fall juvenile striped bass during 1974, based on TI fall shoals data (Table A-3, Volume II, TI 1977) and beach seine data supplied to EPA (Marcellus 1977b).

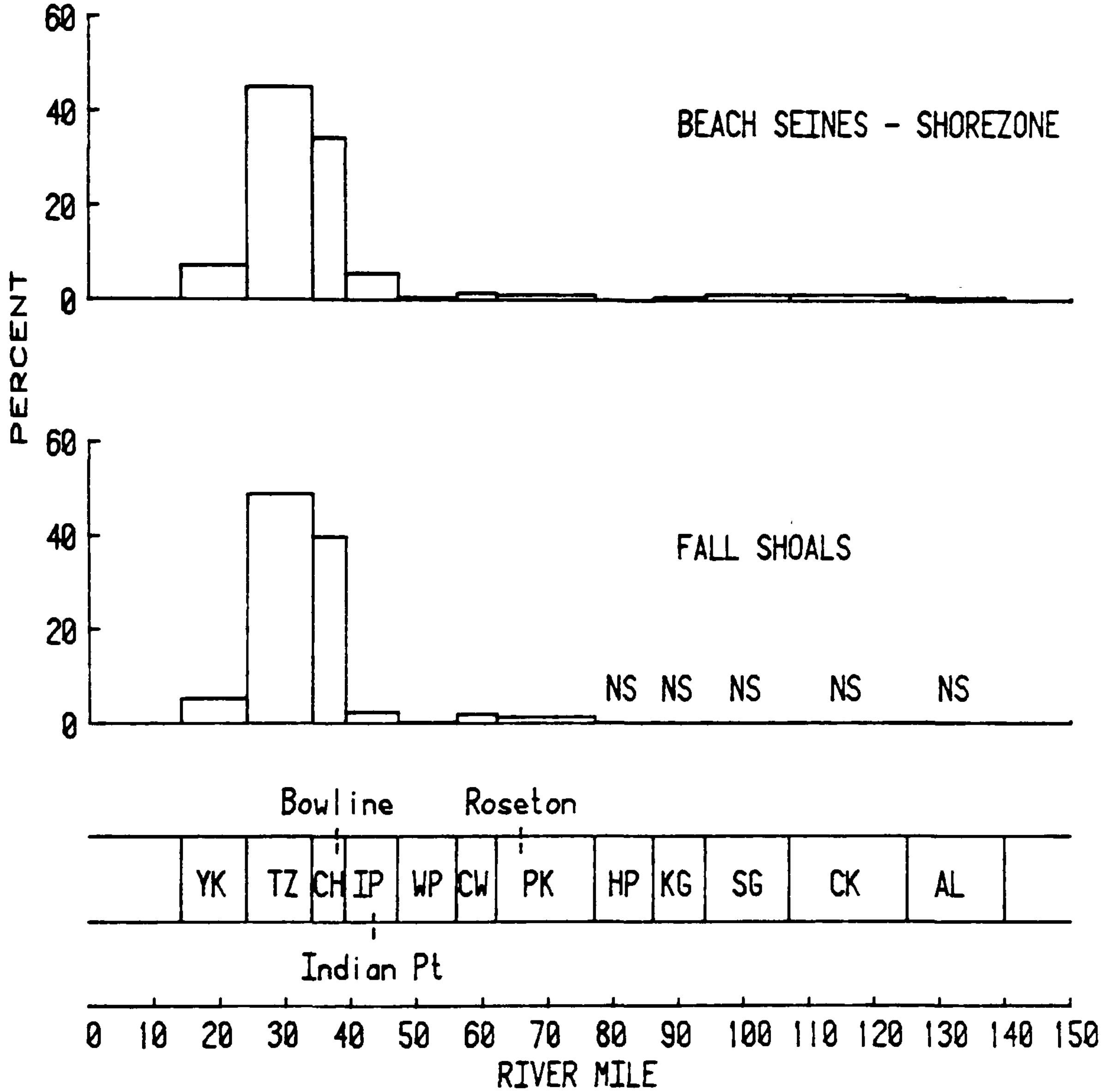

Figure 6. Proportional distributions, expressed as percentages, of fall juvenile striped bass during 1975, based on TI fall shoals data (Table B-23, TI 1978) and beach seine survey data supplied to EPA (Marcellus 1977b).

Mark-recapture data suggest that yearlings present in the lower bays in the Hudson River vicinity do not move back into the river but remain in the lower bays or continue emigration to the marine environment (p. 7.119, Exhibit UT-4). Some members of the juvenile population that do remain in the lower river to overwinter may actually move back upriver to the Indian Point region (RM 39-46) by the following spring (p. V-84, Volume I, TI 1977).

ADULTS

Coastal movement of striped bass tagged in the Hudson River and its vicinity is quite extensive. Adult striped bass released by TI in Manhassett and Little Neck bays (western Long Island Sound) were captured by sport fishermen as far away as Chincoteague, Virginia, and Falmouth, Maine (p. IV-24, Volume III, TI 1977). Adult striped bass tagged by TI in the Hudson River during 1976 were recaptured from Chatham, Massachusetts, to Cape May, New Jersey (Marcellus 1977a). Alperin (1966) tagged over 1,900 predominately two and three year old striped bass in Great South Bay, Long Island. Of the total number recaptured (281), 11 percent were recaptured in New England waters (Connecticut to Maine); 26 percent were recaptured in waters south of New York (New Jersey to Virginia). The remaining recaptures were in the Hudson River and Long Island waters. Tagging studies reported by Clark (1968) support the extensive movement patterns shown by Alperin (1966) and TI (1977).

FISHERIES - PAST AND PRESENT

Reported commercial landings of striped bass in the Hudson River during 1931-1975 ranged from 4,500 lb to 133,100 lb (Table 7.2-1, Exhibit UT-4). A peak in landings was reached in the 1940's coinciding with the large number of gill nets licensed during World War II (p. IV-12, Volume I, TI 1977). The largest peak, however, occurred during the late 1950's subsequent to a change from linen to more efficient nylon gill nets (Klauda et al. 1976). The accuracy of these data in reflecting actual landings is unknown. Due to PCB contamination the commercial fishery for striped bass in the Hudson River has been closed since 1976.

The sport fishery for Hudson River striped bass is of undetermined size, but it appears presently to be much larger than the commercial fishery. Based on recapture data pertaining to striped bass tagged in the Hudson River during 1972-1974 (Table 7.8-10, Exhibit UT-4), the ratio of tags returned by sport fishermen to tags returned by commercial fishermen was 7.3:1. Of the 34 tags returned by sport fishermen, 10 were recaptured in the Hudson River, as far as 320 miles from the tagging site. Of the 146 tags returned by fishermen who caught striped bass tagged in the Hudson River during 1976 (Marcellus 1977a), 84 percent were returned by sport fishermen and the remaining 16 percent by commercial fishermen for a ratio of 5.3:1. Despite PCB contamination, sport fishing for striped bass in the Hudson River is not restricted.

TROPHIC RELATIONSHIPS

Food preference studies conducted by TI during 1972-1974 (p. V-16, TI 1976b) indicate that during the first year of life striped bass fed primarily on harpacticoid, calanoid, and cyclopoid copepods; Gammarus spp.; and chironomid larvae. As striped bass increased in total length, they progressed from copepods to chironomid larvae to Gammarus spp. to fish. Striped bass greater than 75 mm fed on bay anchovies. Those greater than 116 mm fed on clupeids, Atlantic tomcod, mummichogs, Morone spp. and banded killifish.

Studies conducted by Lawler, Matusky, and Skelly Engineers, Inc. (LMS 1975) indicated that smaller striped bass selected amphipods during summer and fall, and copepods during late fall and spring. Larger juvenile striped bass also selected copepods during the winter and spring, while tomcod and clupeids comprised a large part of their diet in summer and fall. Dew and Hecht (1976) stated it is possible that tomcod are "a critical link in the food chain necessary to perpetuate a viable stock of Hudson River striped bass."

Reported predators upon striped bass in the Hudson River are bluefish (TI 1976a), older striped bass, white perch, and tomcod (Table 10.1, Exhibit UT-4). Predation on striped bass by American eels has also been suggested (Tr. 4109-4110).

WHITE PERCH

The white perch (Morone americana) is distributed along the Atlantic coast from Nova Scotia to South Carolina (Woolcott 1955). It is one of the more common teleost food fishes in estuarine waters along the Atlantic coast and, wherever the white perch is found, it has brought about an intensive sport fishery (Mansueti 1961).

SPAWNING

The spawning season for the Hudson River population of white perch lasts from April to July (p. 5.15, Exhibit UT-4; Tr. 10816). Based on TI Long River Survey collections of white perch eggs during 1974 (Figure 7), the peak spawning activity for that year was concentrated in the Croton-Haverstraw region (RM 34-38), although eggs were found in all river regions except Yonkers (RM 14-23). In 1975, spawning activity was less concentrated in any single region (Figure 8); peak egg collections occurred in the Tappan Zee (RM 24-33), Poughkeepsie (RM 62-76), and Catskill (RM 107-124) regions.

Sexual maturation begins for both sexes at two years of age. All males and females are mature by three and four years of age, respectively (p. 5.15, Exhibit UT-4). Fecundity of Hudson River white perch ranges from 10,000 to 70,000 ova per female (p. 5.17, Exhibit UT-4). Fecundities of over 200,000 ova per female have been reported for other populations (Sheri and Power 1968; Taub 1969).

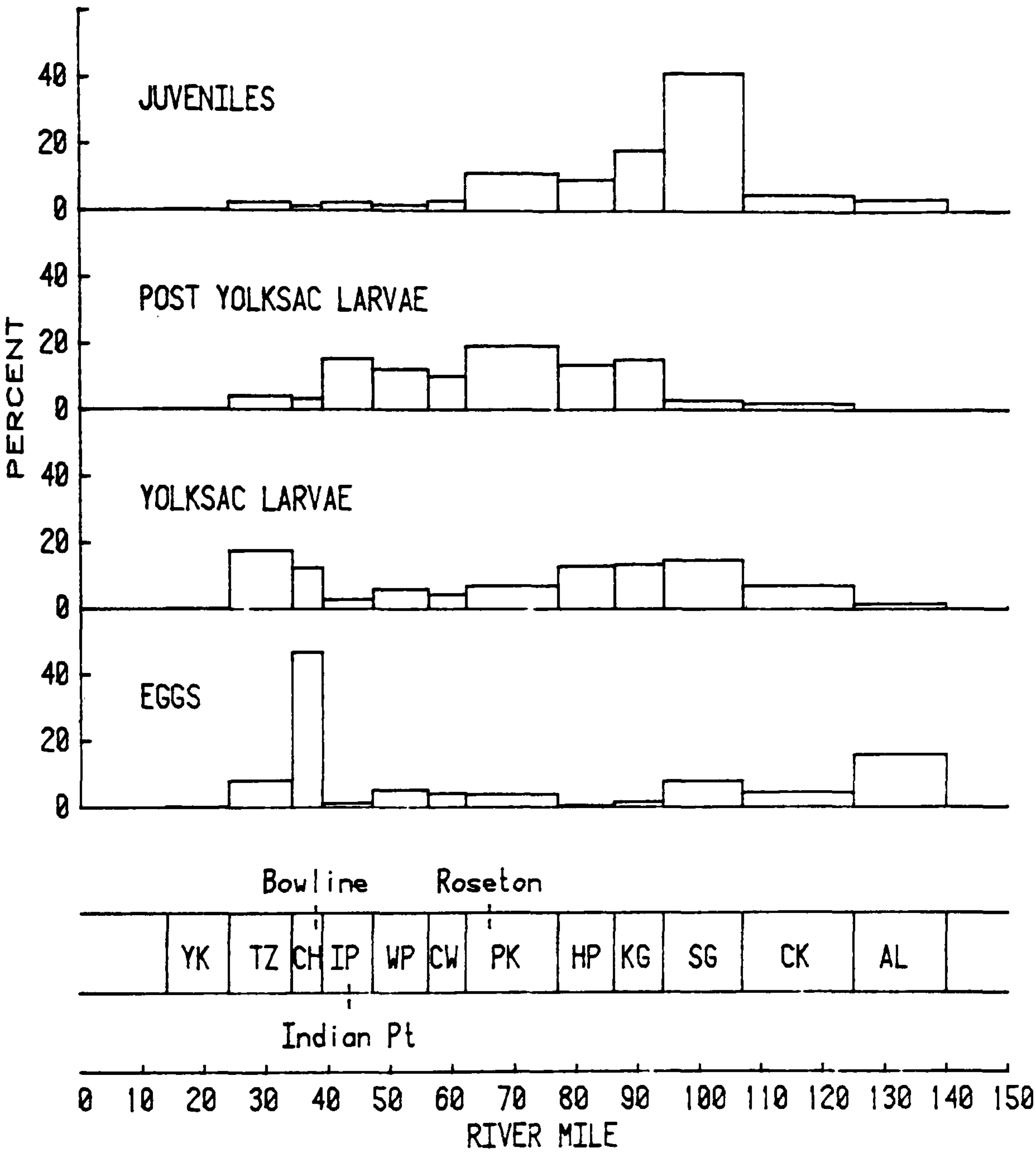

Figure 7. Proportional distributions, expressed as percentages, of early life stages of white perch during 1974, based on TI Long River Survey data supplied to EPA (Marcellus 1977b).

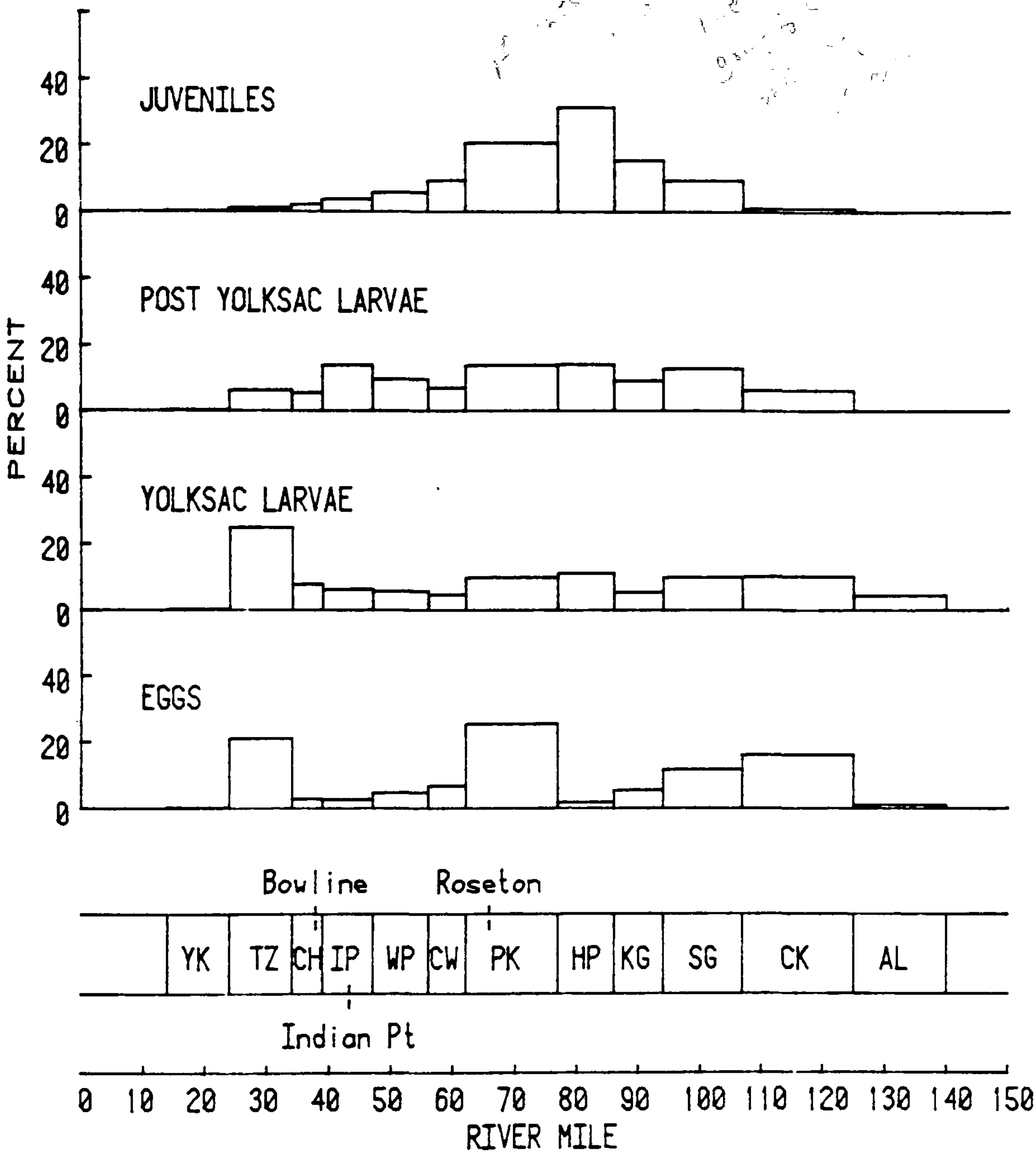

Figure 8. Proportional distributions, expressed as percentages, of early life stages of white perch during 1975, based on TI Long River Survey data supplied to EPA (Marcellus 1977b).

EGGS

Spatial distributions of white perch eggs in the Hudson River during 1974 and 1975 are shown in figures 7 and 8. As previously mentioned, egg deposition appears to have been more widespread in 1975.

Documented egg incubation periods for white perch are listed in Table 8. The average incubation period for white perch eggs in the Hudson River, as well as the temporal distribution of egg standing crops adjusted for weekly water temperatures, were derived by the same method used for striped bass (Table 9). The resultant average egg incubation periods are approximately 2 days for 1974 and 1.5 days for 1975.

LARVAE

Both the yolksac and post yolksac larval stages of white perch were somewhat evenly distributed from the Tappan Zee through Catskill regions (RM 24-124) during both 1974 and 1975 (figures 7 and 8). The highest average weekly standing crop of yolksac larvae occurred in the Tappan Zee region both years. Post yolksac larvae peak standing crops were evenly spread among regions bounded by Indian Point and Kingston (RM 39-93) in 1974 and Indian Point and Saugerties (RM 39-106) in 1975.

Durations of the yolksac larval life stage of white perch obtained from the literature are listed in Table 8. No life stage durations for white perch post yolksac larvae were found in the literature. Temporal distributions of post yolksac larvae and early juvenile white perch collected in the TI Long River surveys (tables 10 and 11) indicate the time period between the estimated peak weekly standing crop of these life stages was seven weeks in 1974 and ten weeks in 1975.

JUVENILES

For purposes of this discussion, juvenile white perch are divided into two categories: early juveniles (prior to mid-August) and fall juveniles (mid-August through December). As explained earlier, the mid-August cut-off is based on a change in TI sampling programs at that time.

Early juveniles

Juvenile white perch collected in the 1974 and 1975 TI Long River surveys exhibited almost bell-shaped distributions within the Hudson River estuary (figures 7 and 8). In 1974, the estimated peak average weekly standing crop was in the Saugerties region (RM 94-106), while in 1975 the Hyde Park region (RM 77-85) had the highest estimated average weekly standing crop.

The 1974 and 1975 distributions of early juvenile white perch based on TI Long River Survey data are compared to distributions of this life stage based on TI beach seine data (before mid-August) in figures 9 and 10. The distributions based on beach seine data represent estimated

Table 8. Documented Durations of Early Life Stages of White Perch

Life stage	Temperature (°C)	Duration	Source(s)
Egg	8.9-20	51-58 hr	Taub 1966
	10.6-11.7	6 days	AuClair 1956
			Ryder 1887
			Tracy 1910
	11.1	6 days	Conover 1958
			Raney 1959
	11.1-21.7	70-73 hr	Taub 1966
	14.4	3-4.5 days	AuClair 1956
			Foster 1919
			Nichols and Breder 1927
			Richards 1960
			Thoits and Mullan 1958
	15.6	24-30 hr	AuClair 1956
			Lagler 1961
		48-52 hr	Richards 1960
			Titcomb 1910
		72 hr	Schwartz 1960
	17.2	48 hr	Raney 1965
	18.3	44-50 hr	Raney 1965
	20.0	30 hr	Richards 1960
			Thoits and Mullan 1958
	21.2-25.0	34-42 hr	Taub 1966
Yolksac larva	-	4 days	Hildebrand and Schroeder 1958
	-	13 days	Mansueti and Mansueti 1955
	-	3-5 days	p. 5.17, Exhibit UT-4

Table 9. Temporal Distributions, Expressed as Percentages, of White Perch Egg Standing Crops during 1974 and 1975 Adjusted for Weekly Water Temperatures

Year	Week	Proportion[a]	Ave. Temp. (°C)[b]	Duration[c] (days)	Adjusted proportion
1974	5/6 - 5/12	0.02	13.5	3	0.01
	5/13 - 5/19	5.92	13.9	3	4.33
	5/20 - 5/26	22.21	15.8	3	16.26
	5/27 - 6/2	8.65	16.8	2	9.50
	6/3 - 6/9	33.09	16.9	2	36.33
	6/10 - 6/16	28.72	18.8	2	31.53
	6/17 - 6/23	0.72	20.5	1.5	1.06
	6/24 - 6/30	0.62	20.5	1.5	0.91
	7/1 - 7/5	0.05	21.4	1.5	0.07
1975	5/4 - 5/10	0.44	10.6	6	0.12
	5/11 - 5/17	6.99	13.5	3	3.82
	5/18 - 5/24	19.09	16.6	2	15.67
	5/25 - 5/31	56.20	19.4	1.5	61.49
	6/1 - 6/7	8.38	20.8	1.5	9.17
	6/8 - 6/14	1.46	20.5	1.5	1.60
	6/15 - 6/21	6.74	20.6	1.5	7.37
	6/22 - 6/28	0.67	22.4	1.5	0.73
	6/29 - 7/5	0.03	23.1	1.5	0.03

[a]based on TI Long River surveys (Marcellus 1977b)
[b]from Poughkeepsie Water Works (Marcellus 1978c)
[c]based on Table 8

Table 10. Temporal Distributions Expressed as Percentages, of Early Life Stages of White Perch Sampled by the TI Long River Survey during 1974[a]

	Yolksac larvae	Post yolksac larvae	Early juveniles
5/6 - 5/12	1.38	0	0
5/13 - 5/19	4.47	0.18	0
5/20 - 5/26	45.49	2.49	0
5/27 - 6/2	21.59	7.26	0
6/3 - 6/9	8.90	9.63	0
6/10 - 6/16	15.50	33.51	0.31
6/17 - 6/23	1.42	28.33	0.15
6/24 - 6/30	0.62	12.58	0.33
7/1 - 7/7	0.61	2.30	5.17
7/8 - 7/14	0	2.19	3.83
7/15 - 7/21	0	0.68	5.89
7/22 - 7/28	0	0.69	11.55
7/29 - 8/4	0	0.13	47.01
8/5 - 8/11	0	0.02	8.59
8/12 - 8/18	0	0	17.17

[a]Marcellus (1977b)

Table 11. Temporal Distributions, Expressed as Percentages, of Early Life Stages of White Perch Sampled by the TI Long River Survey during 1975[a]

Week	Yolksac larvae	Post yolksac larvae	Early juveniles
5/4 - 5/10	0.01	0	0
5/11 - 5/17	1.62	0	0
5/18 - 5/24	43.57	0.36	0
5/25 - 5/31	37.86	21.68	0
6/1 - 6/7	6.71	35.89	0
6/8 - 6/14	4.39	20.76	0
6/15 - 6/21	3.70	4.64	0
6/22 - 6/28	2.12	8.85	0.12
6/29 - 7/5	0.01	5.83	10.35
7/6 - 7/12	0	1.48	11.46
7/13 - 7/19	0	0.41	15.13
7/20 - 7/26	0	0.06	9.79
7/27 - 8/2	0	0.03	18.56
8/3 - 8/9[b]	-[b]	-	-
8/10 - 8/16	0	0	34.60

[a] Marcellus (1977b)
[b] no sampling conducted

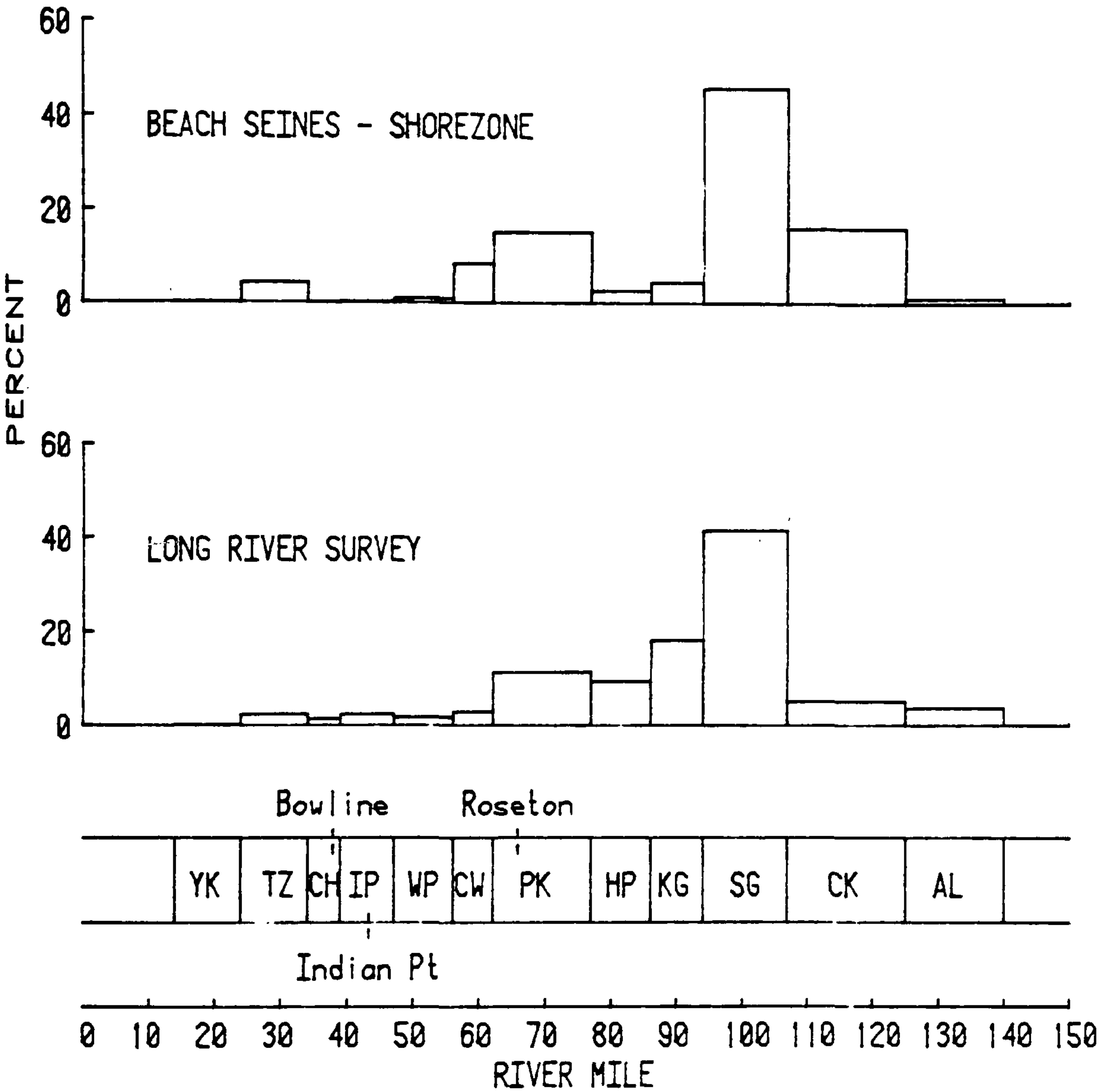

Figure 9. Proportional distributions, expressed as percentages, of early juvenile white perch during 1974, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1977b).

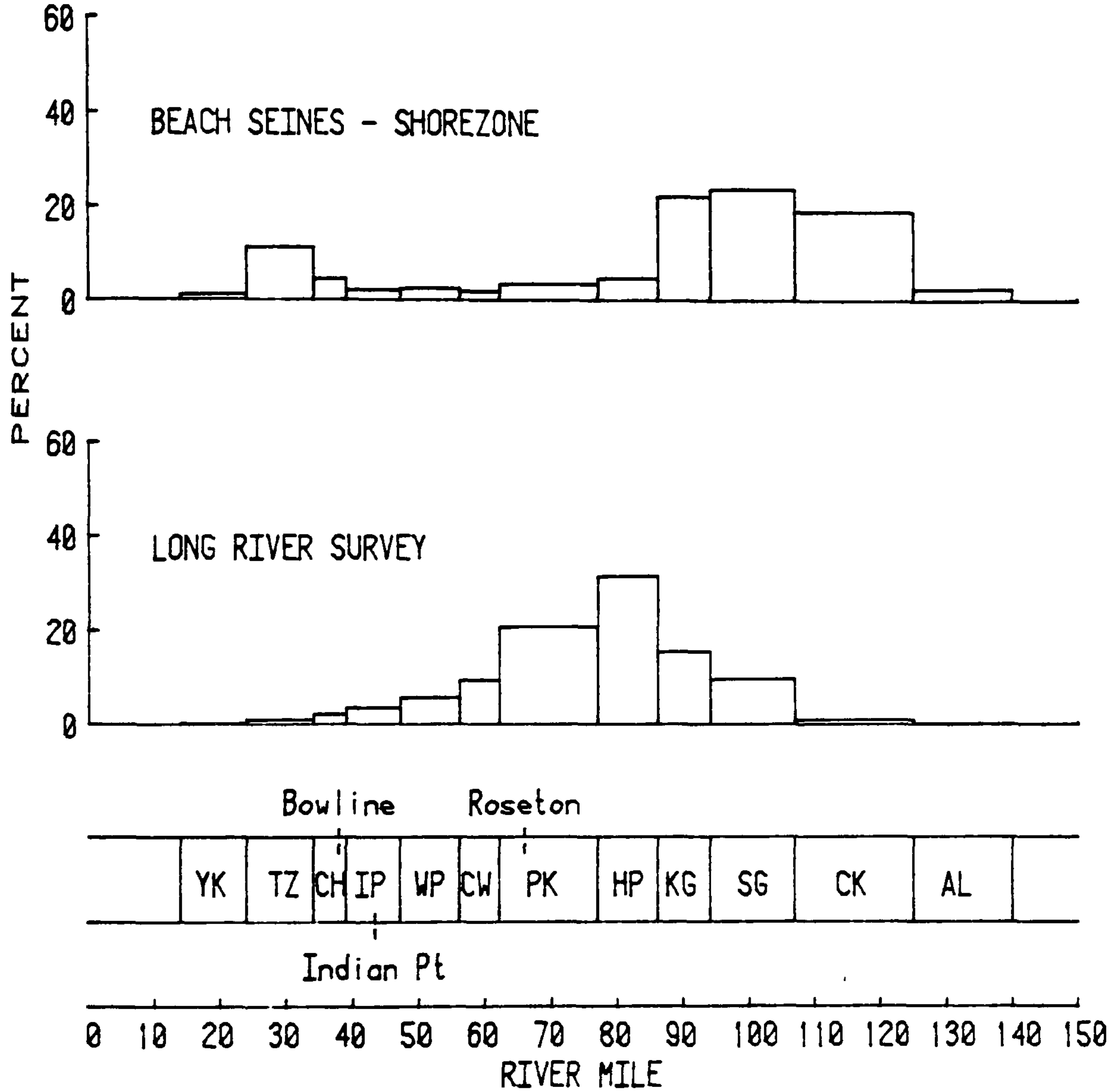

Figure 10. Proportional distributions, expressed as percentages, of early juvenile white perch during 1975, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1977b).

standing crops for the shorezone (< 10 ft in depth) of each region. In 1974 distributions derived from the two survey programs were quite similar. However, in 1975 the distribution derived from beach seine data showed higher relative abundances of early juveniles both upriver and downriver from the distribution based on Long River Survey data. Movement of fish into the shorezone or avoidance of Long River Survey sampling gear by larger fish may have caused the differences in the observed distributions during 1975. These factors may also have occurred during 1974, however, their operation was not reflected in the 1974 data base used in this analysis.

Length data collected on juvenile white perch during 1974 and 1975 are presented in tables 12 and 13. Average lengths surpassed 50 mm (considered maximum entrainable size in this testimony) by early to mid-August each year. The minimum recorded lengths remained below 50 mm until late September in both 1974 and 1975. Since post yolksac larvae disappeared from Long River Survey collections in early August each year, the time period juveniles less than 50 mm were present in the river was at least four weeks in 1974 and 1975.

Fall juveniles

The distributions of fall juvenile white perch, based on the TI fall shoals (epibenthic sled) and beach seine surveys after mid-August are shown in figures 11 and 12 for 1974 and 1975. The 1974 and 1975 distributions based on beach seine data indicated fall juvenile white perch were abundant in regions (Hyde Park to Albany) not sampled by the fall shoals surveys.

Fin-clipped juvenile white perch moved considerable distances in both directions in the Hudson River from their point of release during August-December 1974 (p. V-84, Volume I, TI 1977). Tagged juvenile white perch apparently moved to deep water off Indian Point for overwintering (p. V-88, Volume I, TI 1977).

ADULTS

Tagging studies conducted by TI from 1973 to 1975 indicated no movement of white perch out of the Hudson River (Table A-101, Volume II, TI 1977). Of the 349 tags recovered, 33 were returned by sports fishermen, while 88 were recovered from white perch impinged at the Indian Point, Lovett, Bowline, and Roseton power plants. These data indicate that most, if not all, Hudson River white perch probably remain in the river throughout their entire life cycle.

FISHERIES - PAST AND PRESENT

Reported commercial landings of white perch in the Hudson River peaked during the mid-1930's to early 1940's and dwindled to almost non-existance by the 1970's (Table IV-2, TI 1977). This decline has been

Table 12. Average Lengths and Size Ranges Recorded for Juvenile White Perch Sampled in the Hudson River by TI during 1974[a]

Week	Average length (mm)	Range (mm)
7/7 - 7/13	21	13 - 41
7/14 - 7/20	28	20 - 50
7/21 - 7/27	32	20 - 48
7/28 - 8/3	37	22 - 50
8/4 - 8/10	44	19 - 57
8/11 - 8/17	50	24 - 74
8/18 - 8/24	55	29 - 75
8/25 - 8/31	59	25 - 86
9/1 - 9/7	62	36 - 80
9/8 - 9/14	62	32 - 80
9/15 - 9/21	63	42 - 89
9/22 - 9/28	67	37 - 90
9/29 - 10/5	68	43 - 90
10/6 - 10/12	70	51 - 85
10/13 - 10/19	70	46 - 89
10/20 - 10/26	71	43 - 92
10/27 - 11/2	71	44 - 95
11/3 - 11/9	70	45 - 94
11/10 - 11/16	70	47 - 95
11/17 - 11/23	72	48 - 95
11/24 - 11/30	72	43 - 91
12/1 - 12/7	71	47 - 95
12/8 - 12/14	74	46 - 95

[a]based on tables A-89 to A-92 in TI (1977) averaged for all gear each week

verage Lengths and Size Ranges Recorded for Juvenile White
erch Sampled in the Hudson River by TI during 1975[a]

	Average length (mm)	Range (mm)
/21	16	13 - 20
,/28	22	15 - 32
/5	24	17 - 30
7/12	31	19 - 47
7/19	35	12 - 55
7/26	39	17 - 68
8/2	44	20 - 72
8/9	53	23 - 79
8/16	58	12 - 83
· 8/23	60	26 - 91
- 8/30	68	34 - 93
- 9/6	72	43 - 94
- 9/13	71	39 - 100
- 9/20	72	41 - 99
- 9/27	74	51 - 96
- 10/4	75	48 - 100
- 10/11	75	51 - 102
2 - 10/18	77	51 - 115
9 - 10/25	80	45 - 104
6 - 11/1	78	52 - 111
! - 11/8	74	49 - 101
9 - 11/15	75	32 - 105
16 - 11/22	76	54 - 93
23 - 11/29	74	53 - 98
'30 - 12/6	81	55 - 104
/7 - 12/13	74	51 - 103
/14 - 12/20	74	53 - 97

based on Table B-75 in TI (1978) averaged for all gear each week

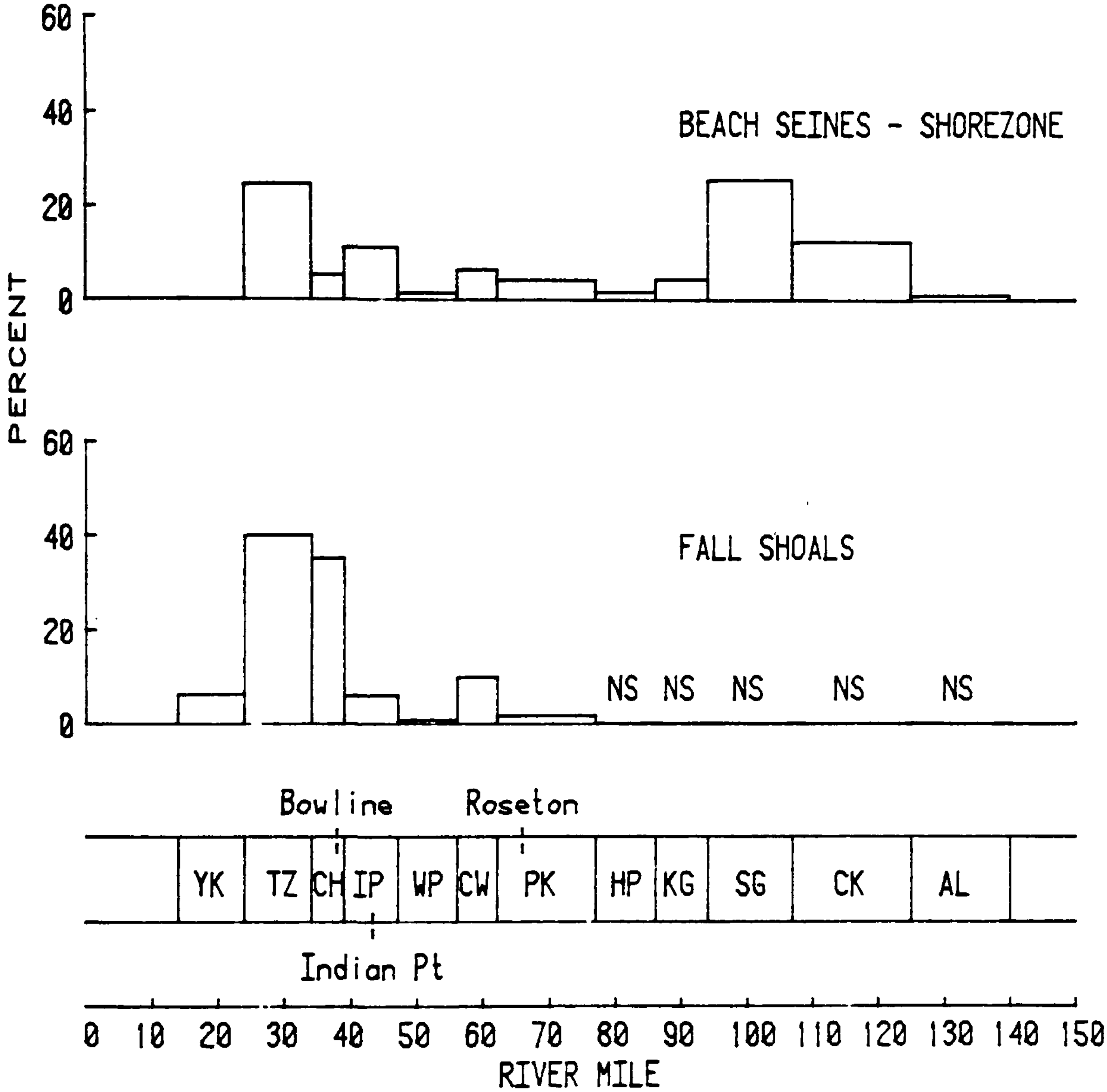

Figure 11. Proportional distributions, expressed as percentages, of fall juvenile white perch during 1974, based on TI fall shoals data (Table A-15, Volume II, TI 1977) and beach seine survey data supplied to EPA (Marcellus 1977b).

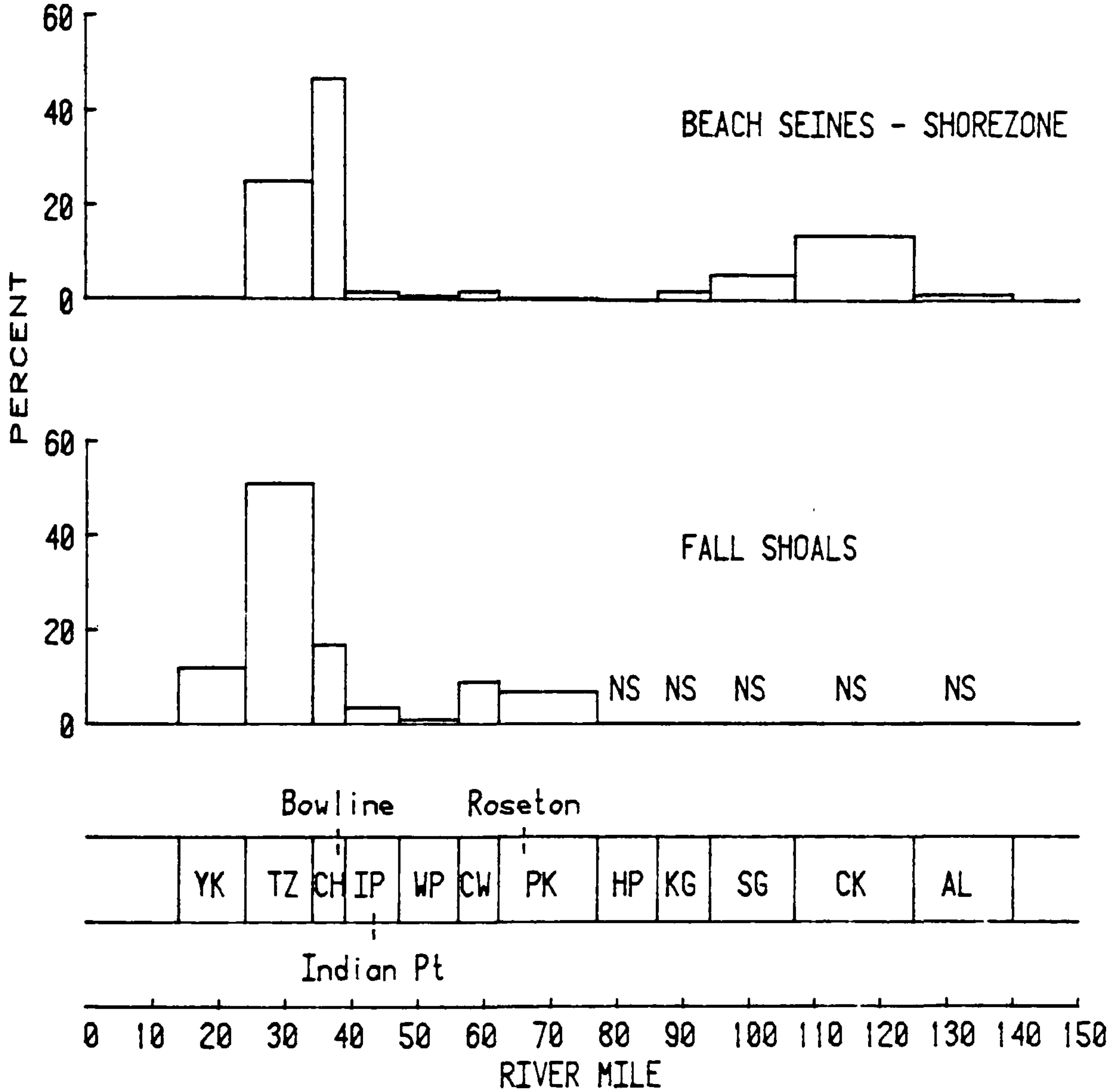

Figure 12. Proportional distributions, expressed as percentages, of fall juvenile white perch during 1975, based on TI fall shoals data (Table B-24, TI 1978) and beach seine survey data supplied to EPA (Marcellus 1977b).

attributed to a loss of interest by commercial fishermen in white perch rather than a decline in the Hudson River population level (Tr. 6622-6625). White perch landings from 1931 to 1944 also include yellow perch landings, making these data unreliable (p. IV-12, Volume I, TI 1977).

The sport fishery for white perch in the Hudson River is still viable, though unquantifiable, as evidenced by the number of tags placed on Hudson River white perch that were returned by sport fishermen (Table A-101, Volume II, TI 1977).

TROPHIC RELATIONSHIPS

Based on stomach analyses of the Hudson River white perch population conducted by TI (TI 1976b), juvenile white perch initially preyed on copepods and gradually changed to larger amphipods, isopods, and chironomid larvae as their total lengths increased to approximately 100 mm. The importance of *Gammarus* spp. as a primary food item fluctuated in response to its density in the river and the seasonal addition of new food to the system. *Gammarus* spp., polychaetes, and calanoid copepods were of major importance to yearling white perch. LMS found that oligochaetes comprised a large proportion of the diet of large white perch (>170 mm) based on numbers and percent of total volume (p. 10.1-88, Exhibit UT-6). Both TI and LMS found unidentifiable fish eggs made up a large percentage of the spring diet in some years (p. V-27, TI 1976b; p. 10.1-88, Exhibit UT-6). Reported predators of white perch in the Hudson River are bluefish (TI 1976a) and striped bass (TI 1976b).

BLUEBACK HERRING AND ALEWIFE

The blueback herring (*Alosa aestivalis*) and alewife (*Alosa pseudoharengus*) are members of the family Clupeidae, which also includes the American shad. These species are difficult to separate due to their similar external appearance (Leim and Scott 1966), especially in the early life stages (Dovel 1971). This difficulty has caused TI to combine early life stage collections of the two species and to assess their distribution and vulnerability to power plants jointly (p. 6.47, Exhibit UT-4). LMS chose not to distinguish American shad from these two species at early life stages (p. 9.1-50, Exhibit UT-6).

Both species are anadromous, although landlocked populations of alewives do exist in many lakes (Scott and Crossman 1973). The range of the blueback herring is from Nova Scotia to St. John River, Florida (Hildebrand 1963). The range of the alewife is farther north, from Newfoundland (Winters et al. 1973) to South Carolina (Berry 1964).

SPAWNING

The alewife spawns earlier in the year than the blueback herring; generally preceding the blueback herring by 3-4 weeks (Hildebrand and Schroeder 1928). *Alosa* spp. eggs were collected in the TI Long River surveys from late April through mid-June during 1974 and 1975, with peak egg collections occurring during late May each year. Based on these egg collections, peak spawning activity occurred in the uppermost regions of the estuary (figures 13 and 14), although Alosa spp. eggs were collected throughout the river during both years. (Table III-3 , Boreman 1979)

Fecundities of alewives and blueback herring are similar. Each female produces from 60,000 to over 100,000 eggs (Leim and Scott 1963). Most male blueback herring spawn at three and four years of age. Most females spawn at four years of age. Most male alewives spawn at four years, and most females at five years (Marcy 1968).

EGGS

As previously mentioned, Alosa spp. eggs were collected by TI between late April and mid-June during 1974 and 1975, with peak collections in late May (Table 14). The occurrence of only a single peak in the temporal distributions of egg standing crops during both years indicated either substantial overlap in the spawning seasons of the two species in the Hudson River or a much higher egg production by one of the two species. The latter, more plausible explanation is favored by the utilities' consultants (p. 6.47, Exhibit UT-4).

Based on the method used for determining the average egg incubation period for striped bass in the Hudson River, the average incubation period for Alosa spp. eggs during both 1974 and 1975 was approximately four days (Table 14). The weekly egg incubation periods used in Table 14 were derived from documented relationships between the durations of the egg life stages of alewives and blueback herring listed in Table 15. Table 14 also lists the temporal distributions of Alosa spp. egg standing crops during 1974 and 1975, adjusted for weekly water temperatures.

LARVAE

Alosa spp. yolksac larvae were collected by TI in all regions of the river except Yonkers (RM 14-23) during both 1974 and 1975. The estimated average weekly standing crop of yolksac larvae was highest in the Saugerties through Albany regions (RM 94-140) each year (figures 13 and 14). Post yolksac larvae were collected in all regions of the river, but their distributions in both 1974 and 1975 were more downriver than the earlier life stages (figures 13 and 14).

Yolksac larvae were collected during May and June of 1974 (Table 16) and 1975 (Table 17). The week of the estimated peak standing crop of yolksac larvae occurred simultaneously with the estimated peak standing crop of eggs during both years. Documented yolksac larval life stage durations range from 2-5 days for the two Alosa spp. (Table 14), which explains the one-week difference in peak standing crops of yolksac larvae and post yolksac larvae during both years.

Post yolksac larvae of Alosa spp. were collected from early May

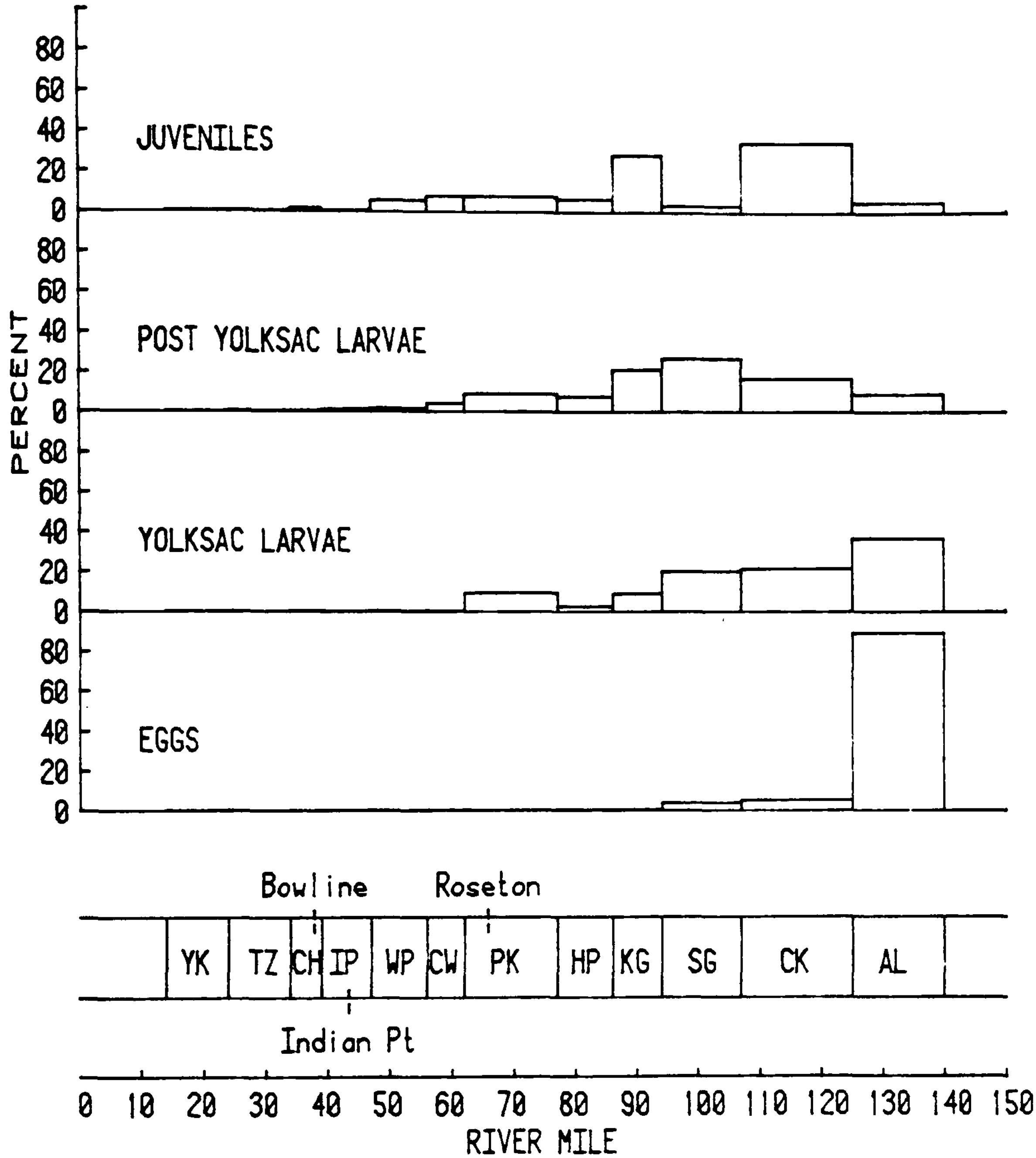

Figure 13. Proportional distributions, expressed as percentages, of early life stages of *Alosa* spp. (blueback herring and alewives) during 1974, based on TI Long River Survey data supplied to EPA (Marcellus 1977b).

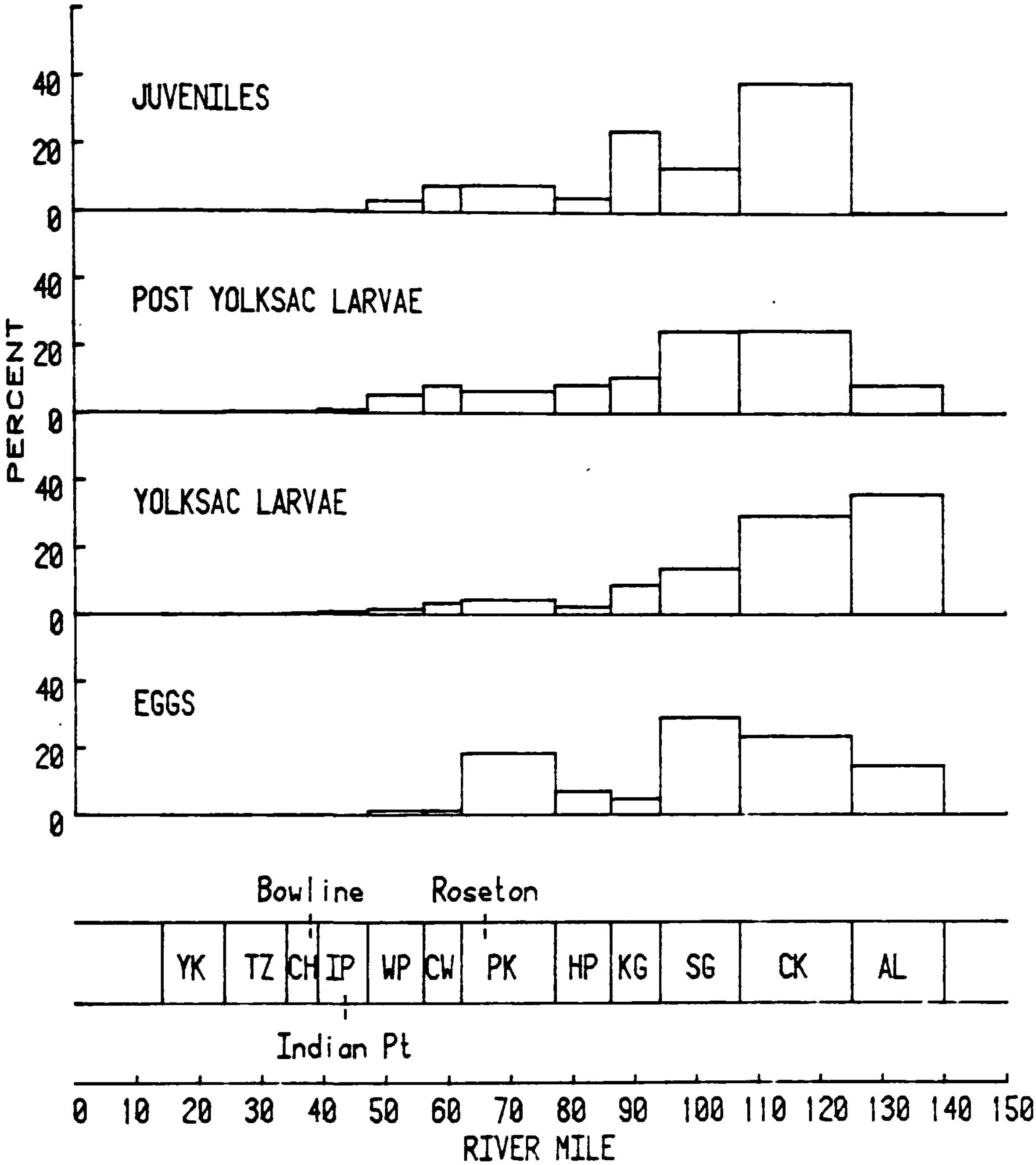

Figure 14. Proportional distributions, expressed as percentages, of early life stages of *Alosa* spp. (blueback herring and alewives) during 1975, based on TI Long River Survey data supplied to EPA (Marcellus 1977b).

Table 14. Temporal Distributions, Expressed as Percentages, of *Alosa* spp. (Blueback Herring and Alewife) Egg Standing Crops during 1974 and 1975 Adjusted for Weekly Water Temperatures

Year	Week	Proportion[a]	Ave. Temp.[b] (°C)	Duration[c] (days)	Adjusted proportion
1974	4/29 - 5/5	0.64	12.8	5	0.52
	5/5 - 5/12	1.64	13.5	5	1.34
	5/13 - 5/19	7.34	13.9	5	5.98
	5/20 - 5/26	82.13	15.8	4	83.70
	5/27 - 6/2	2.38	16.8	4	2.43
	6/3 - 6/9	5.72	16.9	4	5.83
	6/10 - 6/16	0.15	18.8	3	0.20
1975	4/21 - 4/27	0.30	-	10[d]	0.12
	4/28 - 5/3	0	10.0	10	0
	5/4 - 5/10	15.42	10.6	5	12.37
	5/11 - 5/17	20.32	13.5	5	16.31
	5/18 - 5/24	42.87	16.6	4	43.00
	5/25 - 5/31	20.78	19.4	3	27.79
	6/1 - 6/7	0.17	20.8	3	0.23
	6/8 - 6/14	0.01	20.5	3	0.01
	6/15 - 6/21	0.13	20.6	3	0.17

[a] based on TI Long River surveys (Marcellus 1977b)
[b] from Poughkeepsie Water Works (Marcellus 1978c)
[c] based on Table 15 in this testimony
[d] ten days used due to lack of temperature data for this week

Table 15. Documented Durations of Early Life Stages of Blueback Herring and Alewife

Life stage	Temperature(°C)	Duration	Source
Blueback Herring:			
Eggs	20-21	80-94 hr	Morgan and Prince 1976
	22	50 hr	Bigelow and Schroeder 1953
	22.2-23.7	50-58 hr	Cianci 1969
	22-24	2-3 days	p. 5.30, Exhibit UT-4
Yolksac larvae	-	2-3 days	Jones et al. 1978
		4 days	p. 5.30, Exhibit UT-4
Alewife:			
Eggs	7.2	15 days	Edsall 1970
	15.6	6 days	Hildebrand 1963
	10-12.2	3.4-5 days	Cianci 1969
	20	3-5 days	Jones et al. 1978
	21.1	3.7 days	Edsall 1970
	28.9	2.1 days	Jones et al. 1970
	15.5-22	3-6 days	Leim and Scott 1966
Yolksac larvae	-	2 days	Cianci 1969
	-	5 days	Jones et al. 1978

Table 16. Temporal Distributions, Expressed as Percentages, of Early Life Stages of _Alosa_ spp. (Blueback Herring and Alewife) Sampled by TI during the 1974 Long River Survey[a]

	Yolksac larvae	Post yolksac larvae	Early juveniles
4/29 - 5/5	0.19	0.01	0
5/6 - 5/12	3.71	0.47	0
5/13 - 5/19	15.28	1.98	0
5/20 - 5/26	55.98	7.40	0
5/27 - 6/2	22.48	21.53	1.61
6/3 - 6/9	2.16	27.36	0
6/10 - 6/16	0.19	17.13	0
6/17 - 6/23	0	13.98	0.30
6/24 - 6/30	0	6.53	0.09
7/1 - 7/7	0	0.87	0
7/8 - 7/14	0	1.18	32.83
7/15 - 7/21	0	0.31	0.52
7/22 - 7/28	0	0.76	47.23
7/29 - 8/4	0	0.33	14.54
8/5 - 8/11	0	0.07	0.06
8/12 - 8/18	0	0.09	2.82

[a]Marcellus (1978a)

Table 17. Temporal Distributions, Expressed as Percentages, of Early Life Stages of <u>Alosa</u> spp. (Blueback Herring and Alewife) Sampled by II during the 1975 Long River Survey[a]

Week	Yolksac larvae	Post yolksac larvae	Early juveniles
5/4 - 5/10	0.62	0	0
5/11 - 5/17	4.71	0.23	0.01
5/18 - 5/24	70.80	1.76	0
5/25 - 5/31	14.02	31.21	0
6/1 - 6/7	4.98	36.07	0
6/8 - 6/14	0.95	11.60	0.06
6/15 - 6/21	3.78	6.85	0.83
6/22 - 6/28	0.13	5.16	3.52
6/29 - 7/5	0	3.40	20.08
7/6 - 7/12	0	2.53	14.35
7/13 - 7/19	0	0.77	16.07
7/20 - 7/26	0	0.25	13.17
7/27 - 8/2	0	0.16	31.82
8/3 - 8/9[b]	-	-	-
8/10 - 8/16	0	0.01	0.08

[a]Marcellus (1978a)
[b]no sampling conducted

through early August each year (tables 16 and 17). The peak estimated weekly river-wide standing crop of post yolksac larvae occurred in early June of both years, while the peak standing crop of juveniles occurred 7 weeks later in 1974 and 8 weeks later in 1975. The first appearance of post yolksac larvae preceded the first appearance of juveniles by four weeks each year (tables 16 and 17). Therefore, the duration of the post yolksac larval life stage of <u>Alosa</u> spp. was 4-7 weeks in 1974 and 4-8 weeks in 1975. This wide range during both years may be a result of the difference in spawning periods for the two species of concern.

JUVENILES

For purposes of this discussion, juvenile <u>Alosa</u> spp. are divided into early juveniles (before mid-August) and fall juveniles (mid-August through December). As explained earlier, the mid-August cut-off was based on a change in TI sampling programs at that time. Since fall juveniles were distinguishable to the species level by the utilities' consultants (p. 6.47, Exhibit UT-4), blueback herring and alewives are discussed separately under that category.

<u>Early juveniles</u>

Early juvenile <u>Alosa</u> spp. showed similar distribution patterns to post yolksac larvae during 1974 and 1975 (figures 13 and 14). The peak estimated average regional standing crop of early juveniles, based on the TI Long River Survey collections, was in the Catskill region (RM 107-124) during both years. TI beach seine collections of early juveniles (prior to mid-August) indicated a slightly greater abundance upriver during 1974 when compared to the Long River Survey data (Figure 15). Beach seine collections during 1975 indicated similar shorezone distribution patterns of early juveniles when compared to the distributions derived from the Long River Survey collections (Figure 16).

Length data for <u>Alosa</u> spp. collected by TI during their 1974 and 1975 beach seine and bottom trawl surveys (Table 18) indicated blueback herring surpassed an average length of 50 mm (considered maximum entrainable size in this testimony) by early August each year. Alewives surpassed an average length of 50 mm by late July of 1974 and by mid-July of 1975. Since post yolksac larvae peaked in abundance during early June each year, and the duration of the post yolksac larval stage was at least four weeks, the duration of the entrainable juvenile life stage of blueback herring and alewives was at least four weeks during both 1974 and 1975.

<u>Fall juveniles</u>

Beach seine data collected by TI after mid-August of 1974 and 1975 indicate blueback herring were distributed more upriver than alewives during those years (figures 17 and 18). Peak average weekly standing crops of blueback herring occurred in the Indian Point region (RM 39-46) during 1974 and the Tappan Zee region (RM 24-33) during 1975. The peak

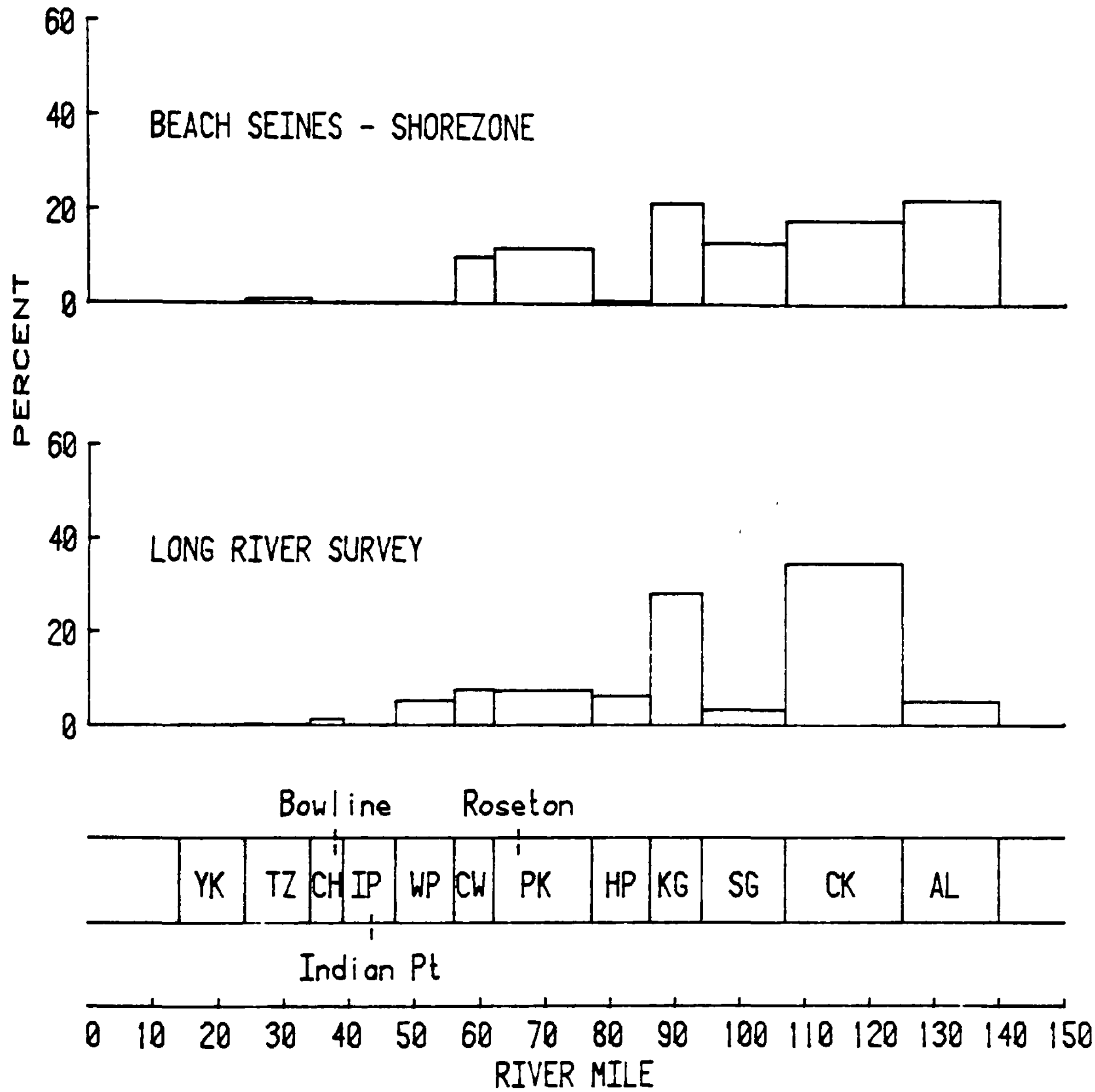

Figure 15. Proportional distributions, expressed as percentages, of early juvenile *Alosa* spp. (blueback herring and alewives) during 1974, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1977b, 1979).

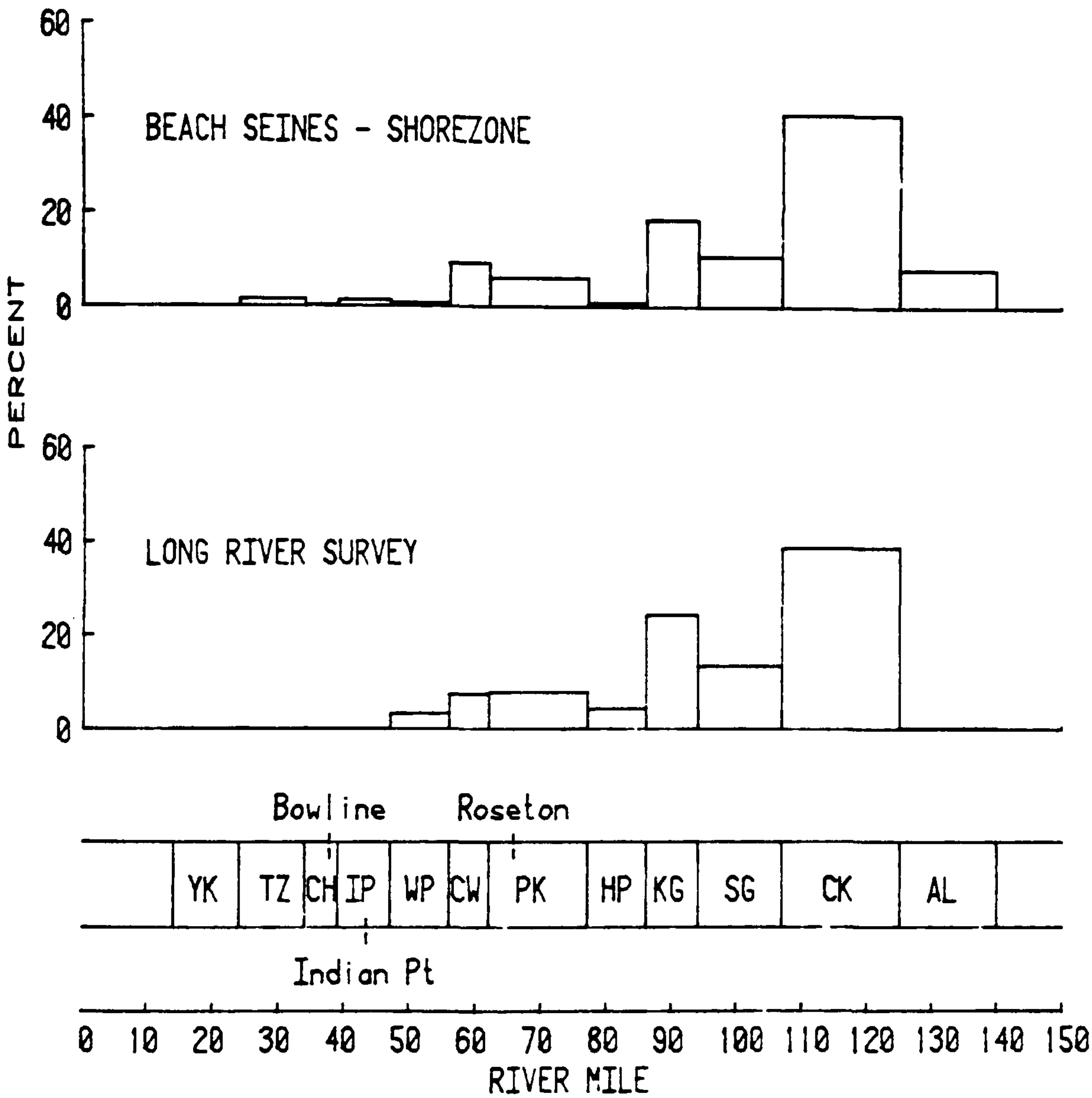

Figure 16. Proportional distributions, expressed as percentages, of early juvenile Alosa spp. (blueback herring and alewives) during 1975, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1977b, 1979).

Table 18. Average Lengths of Blueback Herring and Alewives Sampled during the 1974 and 1975 TI Beach Seine and Bottom Trawl Surveys[a]

Species	Interval	1974	1975
Blueback herring	6/1 - 6/14	33.2	-[b]
	6/15 - 6/28	34.6	37.0
	6/29 - 7/12	33.6	42.7
	7/13 - 7/26	40.2	47.6
	7/27 - 8/9	52.4	57.4
	8/10 - 8/23	55.2	49.0
	8/24 - 9/6	65.9	63.9
	9/7 - 9/20	65.5	62.4
	9/21 - 10/4	68.2	68.4
	10/5 - 10/18	76.8	68.5
	10/19 - 11/1	74.4	68.1
	11/2 - 11/15	75.0	67.5
	11/16 - 11/29	71.3	70.9
	11/30 - 12/13	-	69.2
Alewife	6/1 - 6/14	36.0	-
	6/15 - 6/28	32.8	38.9
	6/29 - 7/12	42.7	52.0
	7/13 - 7/26	50.8	66.0
	7/27 - 8/9	55.3	73.0
	8/10 - 8/23	71.1	77.6
	8/24 - 9/6	76.1	84.0
	9/7 - 9/20	80.6	83.1
	9/21 - 10/4	83.3	87.6
	10/5 - 10/18	87.2	89.2
	10/19 - 11/1	86.9	91.2
	11/2 - 11/5	93.8	97.0
	11/16 - 11/29	81.2	94.8
	11/30 - 12/13	-	91.4

[a] Marcellus (1978a)
[b] none sampled during interval

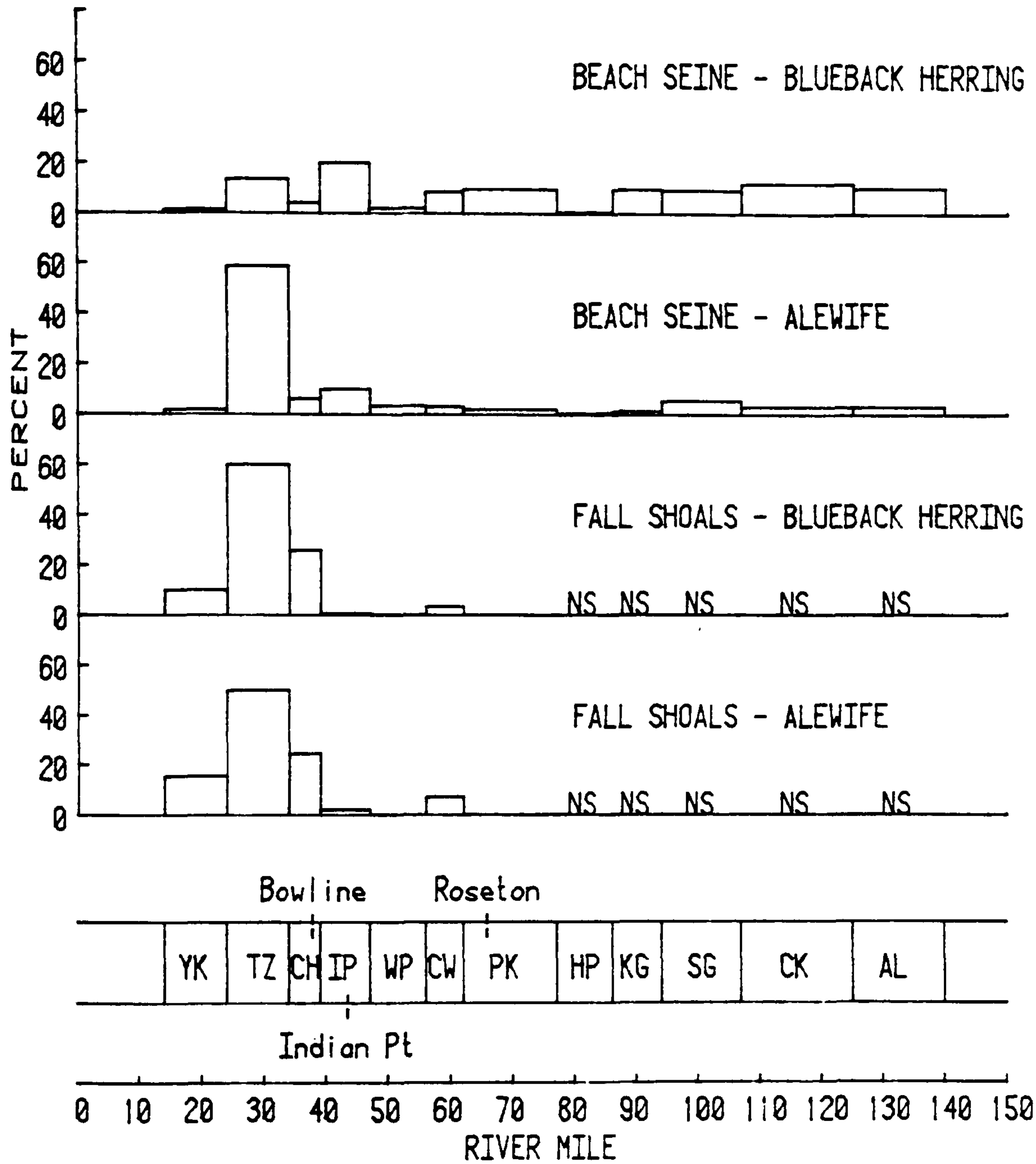

Figure 17. Proportional distributions, expressed as percentages, of fall juvenile *Alosa* spp. (blueback herring and alewives) during 1974, based on TI beach seine and fall shoals survey data supplied to EPA (Marcellus 1977b, 1979).

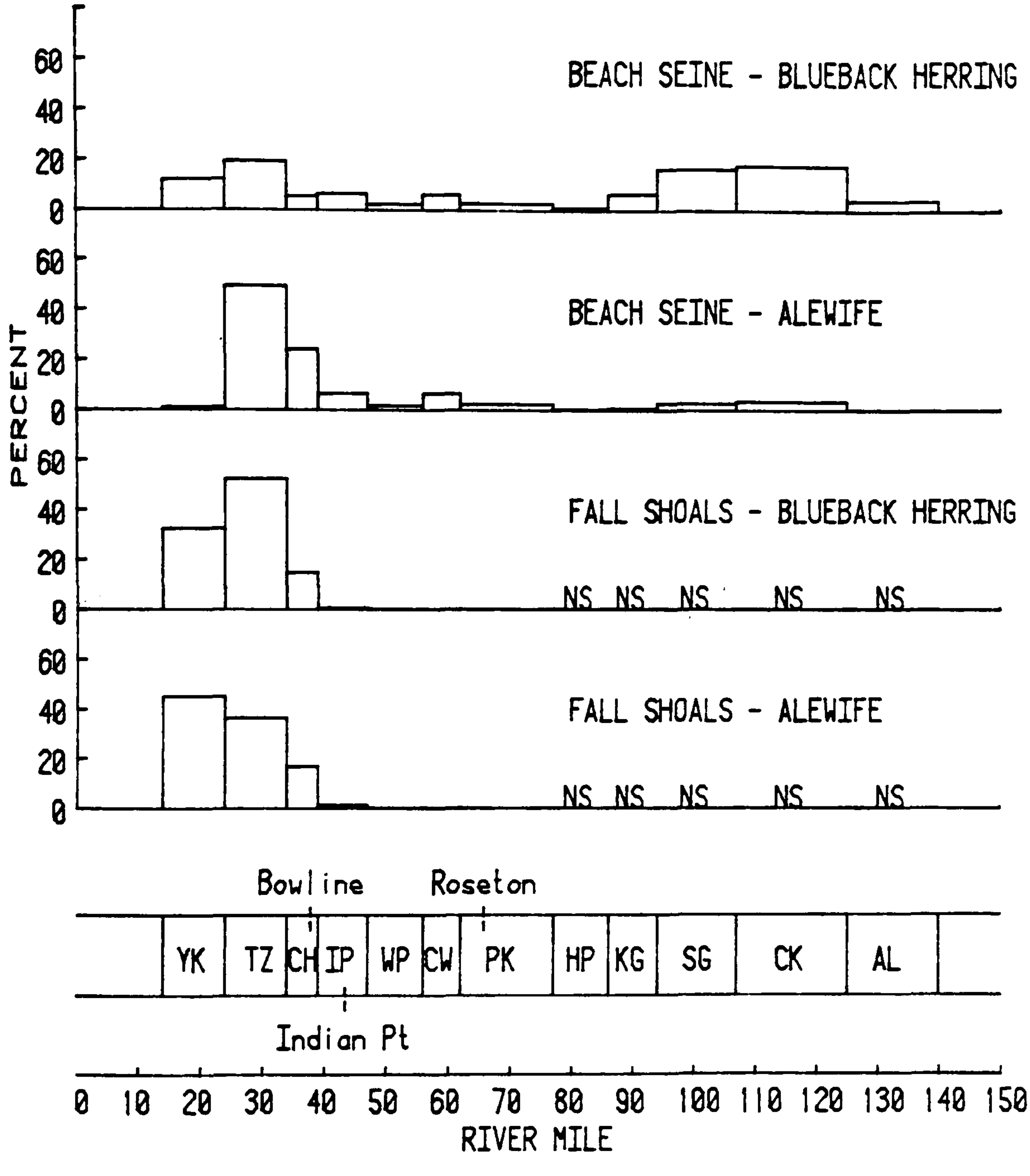

Figure 18. Proportional distributions, expressed as percentages, of fall juvenile <u>Alosa</u> spp. (blueback herring and alewives) during 1975, based on TI beach seine and Fall shoals survey data supplied to EPA (Marcellus 1977b, 1979).

average standing crop of alewives occurred in the Tappan Zee region (RM 24-33) during both years. The data presented in figures 17 and 18 imply that alewives probably move downriver earlier than blueback herring probably due to their larger size (Table 18) and probable older age. The TI fall shoals surveys indicate similar distributions of alewives and blueback herring during 1974 and a more upriver distribution of blueback herring than alewives in 1975 (figures 17 and 18).

ADULTS

No tagging studies have been reported for the Hudson River populations of blueback herring and alewives. However, capture of yearling blueback herring and alewives by the utilities' consultants in the Hudson River indicates that at least part of the populations overwinter in the estuary during their first year of life. Adults of both species exhibit schooling behavior and inhabit a narrow band of coastal water close to shore (Bigelow and Schroeder 1928).

FISHERIES - PAST AND PRESENT

A commercial fishery for blueback herring and alewives exists along the Atlantic coast. Commercial landings along the Atlantic coast reported for the two species from 1965-1975 are listed in Table 5.5-3 of Exhibit UT-4. According to this table, the total pounds landed by commercial fishermen declined from approximately 64 million pounds in 1965 to approximately 23.5 million pounds in 1975. The extent of the sport fishery for the two species in the Hudson is unknown, although both species are seined by fishermen to serve as bait fish for other species (Boyce Thompson Institute for Plant Research 1977).

TROPHIC RELATIONSHIPS

Food habits studies of the Hudson River populations of blueback herring and alewives have not been documented by the utilities' consultants. Studies elsewhere indicate that the food of blueback herring consists of plankton, copepods, pelagic shrimp, and early life stages of small fishes (Scott and Crossman 1973). Alewives feed chiefly on plankton, amphipods, mysids, copepods, small fish, and fish eggs (Leim and Scott 1963).

Reported predators of blueback herring and alewives in the Hudson River include bluefish (Table II-2, TI 1976a), striped bass (p. V-17, TI 1976b), and white perch (p. V-28, TI 1976b).

AMERICAN SHAD

The American shad (Alosa sapidissima) is a member of the family Clupeidae (herrings). Other members of this family that are found in the Hudson River are alewife, blueback herring, gizzard shad, Atlantic menhaden, Atlantic herring, round herring, and hickory shad (Table 5.6-1, Exhibit UT-4). Of these species, the American shad adult is the largest. Leim (1924) reported American shad attaining a size of over 70 cm and a weight of over 6.5 lb. Weights up to 12-14 lb have been reported by McDonald (1884) and Worth (1898).

SPAWNING

Based on the periods of commercial catch and presence of eggs in field samples, the spawning season of American shad in the Hudson River begins in late March to early April and is over by the end of June. Egg collections by TI in 1974 indicate that the major spawning activity is concentrated between RM 62 and 140 (Figure 19), although some spawning probably does occur in the Indian Point region (Rm 39-46) (Table III-4, Boreman 1979).

Table 19 presents the age composition as read by scale samples of 2,424 American shad caught in the Hudson River by commercial fishing gear during the 1950 and 1951 fishing seasons (Talbot 1954). Ages are weighted to catch by sex, gear, and year. More recent age composition studies of the commercial catch of American shad in the Hudson River are not available. The highest percentage of the adult shad caught in 1950 and 1951 were entering the river to spawn for the first time. Ninety-three percent of this group of maiden spawners were 4-6 years of age; 88 percent of all the fish captured were 4-7 years of age (Table 19).

According to Lehman (1953), the fecundity of 22 female American shad collected in the Hudson River during 1951 ranged from 116,000 to 468,000 ova per female, with an average fecundity of 273,000 ova. These fish represented an age range of 3-9 years. More recent fecundity data on the Hudson River American shad population are not available.

EGGS

The majority of eggs of American shad were collected by TI in the upper half of the Hudson River estuary (RM 62-140) during their 1974 Long River Survey (Figure 19). The highest abundances of shad eggs were recorded in the Saugerties and Catskill regions (RM 94-124) where almost 90 percent of the estimated average weekly standing crop of eggs occurred. Some eggs were collected in the Indian Point region (RM 39-46) (Table III-4, Boreman 1979).

American shad eggs hatch in 2-17 days depending on water temperature (Table 20). Temperatures in the Hudson River during the period of shad egg collections (late April - mid-June, Table 21) averaged close to 16°C; this temperature corresponds to a seven day average egg incubation period for American shad eggs. This value is also supported by the observed one week difference between the disappearance of eggs and disappearance of yolksac larvae from field samples (Table 21).

LARVAE

Yolksac and post yolksac larvae were principally collected by TI in

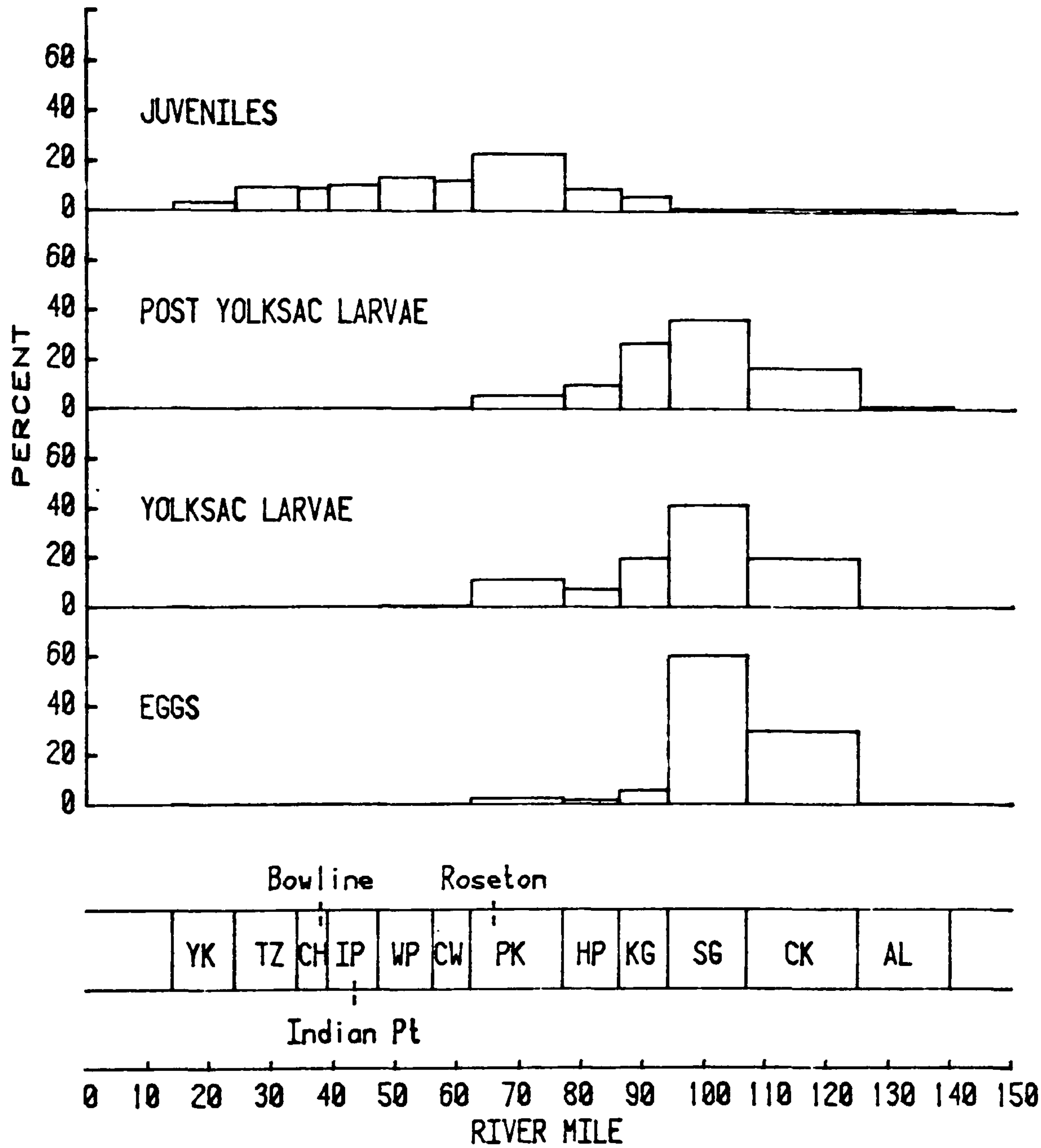

Figure 19. Proportional distributions, expressed as percentages, of early life stages of American shad during 1974, based on TI Long River Survey data supplied to EPA (Marcellus 1977b).

Table 19. Percentage Distribution of American shad in the Hudson River at Capture, Age at First Spawning, and Number of Times Previously Spawned[a]

Group	Percentage in group
Total age at capture:	
3 years	2
4 years	23
5 years	29
6 years	22
7 years	14
8 years	6
9 years	2
over 9 years	2
Age at first spawning:	
2 years	-
3 years	6
4 years	47
5 years	36
6 years	10
over 6 years	1
Number of times previously spawned:	
None	49
1 time	19
2 times	18
3 times	10
4 times	2
5 times	2
6 times	-
7 times	-

[a]based on Table 10 in Talbot (1954)

Table 20. Documented Durations of Early Life Stages of American Shad

Life Stage	Temperature (°C)	Duration (days)	Source
Egg	12	12-15	Leim 1924
	12	17	Ryder 1887
	17	6-8	Leim 1924
	27	2	Rice 1878
Yolksac larva	12	7	Jones et al. 1978
	17	4-5	Jones et al. 1978
	-	7	p. 5.27, Exhibit UT-4
Post yolksac larva	-	21-28	Ryder 1887
	-	30	p. 5.27, Exhibit UT-4

Table 21. Temporal Distributions, Expressed as Percentages of Early Life Stages of American Shad Samples by TI during the 1974 Long River Survey[a]

Week	Eggs	Yolksac larvae	Post yolksac larvae	Early juveniles
4/22 - 4/28	5.77	0	0	0
4/29 - 5/5	16.92	0	0	0
5/6 - 5/12	8.26	0	0	0
5/13 - 5/19	7.22	14.74	1.83	0
5/20 - 5/26	16.87	25.74	9.49	0.24
5/27 - 6/2	38.62	31.71	13.22	0.27
6/3 - 6/9	5.52	26.74	12.98	0.03
6/10 - 6/16	0.80	0.58	13.95	0.18
6/17 - 6/23	0.02	0.16	36.60	0.03
6/24 - 6/30	0	0.32	7.21	0.65
7/1 - 7/7	0	0	3.89	12.55
7/8 - 7/14	0	0	0.62	27.70
7/15 - 7/21	0	0	0.18	18.35
7/22 - 7/28	0	0	0.02	15.18
7/29 - 8/4	0	0	0	9.26
8/5 - 8/11	0	0	0	8.85
8/12 - 8/18	0	0	0	6.70

[a]Marcellus (1977b)

their Long River Survey in the Poughkeepsie through Catskill regions (RM 62-124) during 1974 (Figure 19). The region of estimated peak abundance was Saugerties (RM 94-106) for both larval life stages. Stira and Smith (1976) presented a similar distribution pattern of American shad larvae in the Hudson River during 1973.

Yolksac larvae were collected in the 1974 Long River Survey from mid-May through June (Table 21); peak abundance occurred in late May. Shad absorb their yolksacs in 4-5 days at a water temperature of 17°C (Table 20). Based on water temperatures recorded at the Poughkeepsie Water Works during 1974, the average temperature from mid-May through June was 17.6°C. Therefore, an average life stage duration of 4 days is probably a minimum value for shad yolksac larvae in the Hudson River during 1974.

Post yolksac larvae of American shad were collected from mid-May through July of 1974 (Table 21). Peak abundance occurred in mid-June. The peak estimated standing crop of juvenile shad, based on Long River Survey data, occurred three weeks after the peak estimated standing crop of post yolksac larvae, which implies at least a three week life stage duration of post yolksac larvae during 1974.

JUVENILES

The discussion of juvenile American shad is divided into two categories: early juveniles (prior to mid-August) and fall juveniles (mid-August through December). As mentioned earlier, the mid-August cut-off corresponds to a change in sampling programs by TI.

Early juveniles

Juvenile American shad collected in the 1974 TI Long River Survey showed a distinctive downstream shift in distribution from the distributions of earlier life stages (Figure 19). Juveniles were found in all 12 regions; almost 93 percent of the average weekly standing crop occurred between the Tappan Zee and Kingston regions (RM 24 to RM 93).

Beach seine collections performed by TI prior to mid-August support the downstream shift of this life stage (Figure 20). This rather abrupt downstream shift in distribution was also evident in 1973 TI ichthyoplankton collections (Stira and Smith 1976). Leim (1924) noted a similar sudden downstream shift in distribution of early life stages of American shad in the Shobenacadie River (New Brunswick). He attributed this shift to the pelagic nature of shad larvae; most of his specimens were collected in surface tows, indicating they could have easily been carried downstream by water currents.

Growth of juvenile shad, based on TI beach seine, bottom trawls, and epibenthic sled collections during 1974, is shown in Table 22. Shad surpassed an average length of 50 mm (considered maximum entrainable size in this testimony) by mid-July and minimum recorded lengths surpassed 50 mm for the first time by the end of August. Since post yolksac

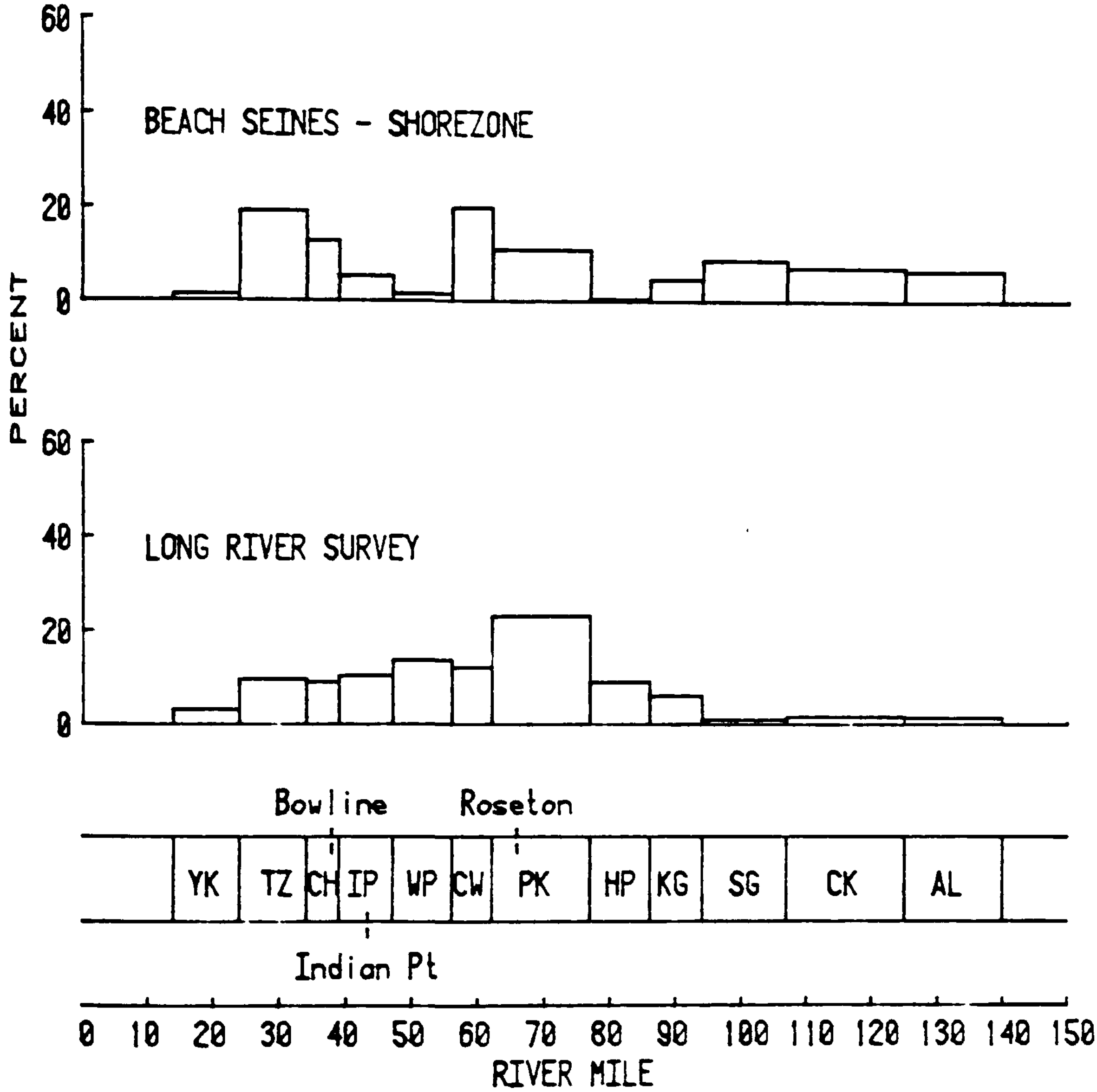

Figure 20. Proportional distributions, expressed as percentages, of early juvenile American shad during 1974, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1977b).

Table 22. Average Lengths and Size Ranges Recorded for Juveniles American Shad Sampled in the Hudson River by TI during 1974[a]

Week	Average length (mm)	Range (mm)
6/9 - 6/15	33	31 - 36
6/16 - 6/22	25	19 - 31
6/23 - 6/29	30	18 - 40
6/30 - 7/6	39	28 - 73
7/7 - 7/13	42	25 - 67
7/14 - 7/20	51	30 - 70
7/21 - 7/27	56	27 - 83
7/28 - 8/3	58	30 - 82
8/4 - 8/10	63	42 - 85
8/11 - 8/17	64	39 - 82
8/18 - 8/24	70	47 - 90
8/25 - 8/31	73	50 - 89
9/1 - 9/7	73	53 - 99
9/8 - 9/14	75	42 - 95
9/15 - 9/21	75	52 - 108
9/22 - 9/28	78	33 - 110
9/29 - 10/5	79	53 - 104
10/6 - 10/12	81	61 - 104
10/13 - 10/19	85	67 - 110
10/20 - 10/26	83	65 - 107
10/27 - 11/2	86	25 - 120
11/3 - 11/9	89	65 - 119
11/10 - 11/16	91	67 - 119
11/17 - 11/23	88	42 - 117

[a]based on tables A-97 to A-100 in TI (1977) averaged for all gear each week

larvae reached a peak abundance in mid-June and disappeared from collections in late July (Table 21). a four week average life stage duration of entrainable juveniles American shad in the Hudson River during 1974 is appropriate.

Fall juveniles

Based on TI beach seine data after mid-August, juvenile American shad were most abundant in the Tappan Zee (RM 24-33). Cornwall (RM 56-61), and Catskill (RM 107-124) regions (Figure 21). Epibenthic sled (fall shoals survey) data indicated a peak abundance in the Tappan Zee region; however this survey was limited to the lowermost seven sampling regions (RM 14-76).

Disappearance of juvenile shad from TI river collections in November indicated a probable movement into coastal waters (p. V-22, Volume I, TI 1977). Chittenden and Westman (1967) and Leggett and Whitney (1972) noted a coincidence between peak downstream migration of juvenile shad and decline of water temperature to below 15.5°C in other river systems. The Hudson River water temperature declines below 15.5° by the end of October (Figure 2.2-8, Exhibit UT-4), a decline which corresponds with the observed downstream migration of juvenile shad. Most juveniles migrate to coastal waters by their first winter (p. V-16, TI 1977).

ADULTS

Talbot and Sykes (1958) found that after spawning adult shad tagged in estuaries from the Chesapeake to the Connecticut River migrate to the Gulf of Maine to spend the summer and fall. Evidence also indicated that adult shad overwintered in the deep waters along the middle Atlantic coast, moving closer to their natal streams as spawning season approached. Observations by Talbot and Sykes (1958) on the coastal migration behavior of American shad were confirmed by Leggett and Whitney (1972), who noted that migration paths followed the 13-18°C isotherm northward to the Gulf of Maine in summer and southward to the middle Atlantic region in winter. Most of the shad south of North Carolina die after spawning, which Leggett (1972) attributed to increased use of fat reserves during spawning in the warmer climate. Shad have a strong homing tendancy, as noted in studies by Hollis (1948), Nichols (1960), and Dodson and Leggett (1973).

FISHERIES - PAST AND PRESENT

Several early papers describe the condition of the Hudson River American shad fishery prior to 1900. Over 250,000 shad were taken annually in New York Harbor with stake and drift gill nets, which caused McDonald (1887) to consider the Hudson River shad fishery equal in monetary value to the American shad fisheries of the Potomac River, Susquehanna River, or Albermarle Sound. As early as 1896, overfishing was considered a threat to the continued well-being of shad stocks in the Hudson River (Cheney 1896), and in the early 1900's over-harvest was being cited as a cause for observed declines in fishery landings (Blackford 1916).

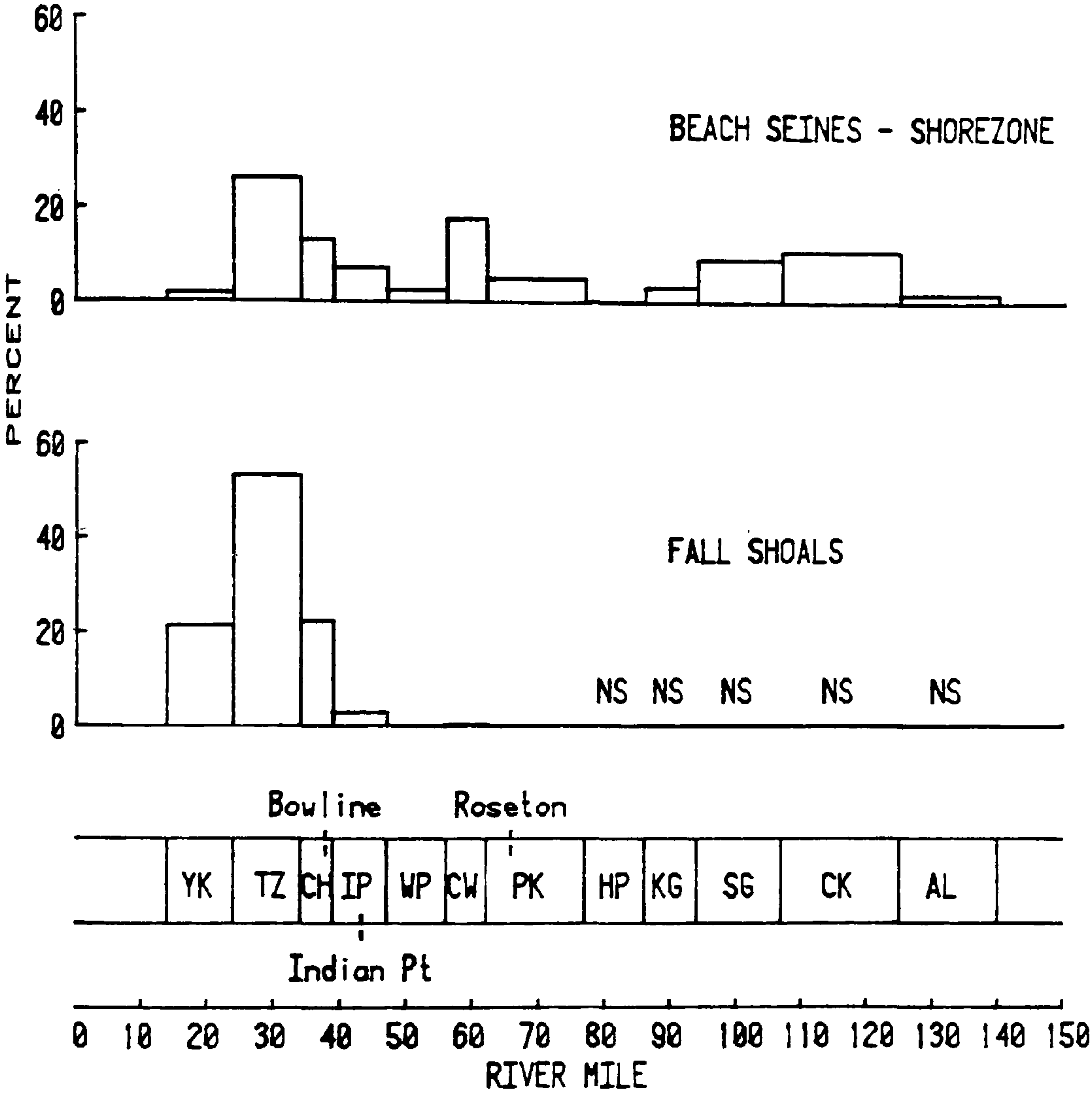

Figure 21. Proportional distributions, expressed as percentages, of fall juvenile American shad during 1974, based on TI fall shoals and beach seine survey data supplied to EPA (Marcellus 1977b).

Historical landings data for Hudson River shad were presented for 1915-1949 by Talbot (1954) and are reproduced with an update to 1975 (from Klauda et al. 1976) in Figure 22. Shad landings remained below 750,000 pounds per year until the late 1930's when landings suddenly increased to 2-3 million pounds per year. In the mid-1940's to 1960's landings began to decline to about 250,000 pounds per year by the 1970's, although they increased slightly in the mid-1950's. The decline after the mid-1940's was attributed to low escapement of spawners due to intense fishing pressure (Talbot 1954; Burdick 1954). This is also the major factor given for declines in landings from other systems (Connecticut River: Fredin 1954, Walburg 1963; Maryland: Walburg 1955; St. Johns River, Florida: Williams and Bruger 1972; North Carolina: Sholar 1976). The decline in landings since the 1950's has been attributed to reduced fishing effort (Medeiros 1974) or the changeover in the mid-1950's to more efficient nylon nets (Klauda et al. 1976) which allow less spawner escapement for the same unit of effort expended with linen nets. The Susquehanna, Delaware, and New England rivers experienced declines due to or attributed to physical obstructions (dams) and pollution (Walburg and Nichols 1967). Attempts to relate the declines in Hudson River shad landings to factors other than spawner escapement, such as natural population cycles or environmental factors, have not been successful (Talbot 1954).

TROPHIC RELATIONSHIPS

Juvenile American shad feed mostly on crustaceans and aquatic and terrestrial insects (Walburg 1956; Massman 1963; Davis and Cheek 1966; Levesque and Reed 1972). Some freshwater feeding by adult shad has also been noted (Hatton 1941; Atkinson 1951; and Chittenden 1976). Hatton (1941) found that shad collected by commercial fishermen in California fed mainly on mysid shrimp and other crustaceans. Predators on juvenile shad in the Hudson River include bluefish (TI 1976) and probably any predator larger than the shad (Table 5.3-1, Exhibit UT-4).

ATLANTIC TOMCOD

The Atlantic tomcod (Microgadus tomcod) is a relatively small member of the cod family (Gadidae), seldom exceeding a length of 12 inches (Nichols and Breder 1927). ~~It inhabits northern boreal estuaries and nearby coastal waters~~ from Virginia to Labrador (Hardy 1978), although no accounts of tomcod spawning in estuaries south of the Hudson River have been reported (p. 10.1-182, Exhibit UT-7). The southern limit of the tomcod's range is apparently influenced by water temperature. Tomcod are most active inshore during the period of lowest water temperature and probably have a low optimum temperature (Howe 1971). Warm summer temperatures in the Hudson River could potentially stress juvenile tomcod (Grabe 1978), particularly if dissolved oxygen levels are low (p. V-75, Volume I, TI 1977), as evidenced by reduced summer growth and feeding activity (p. 10. 221, Exhibit UT-7).

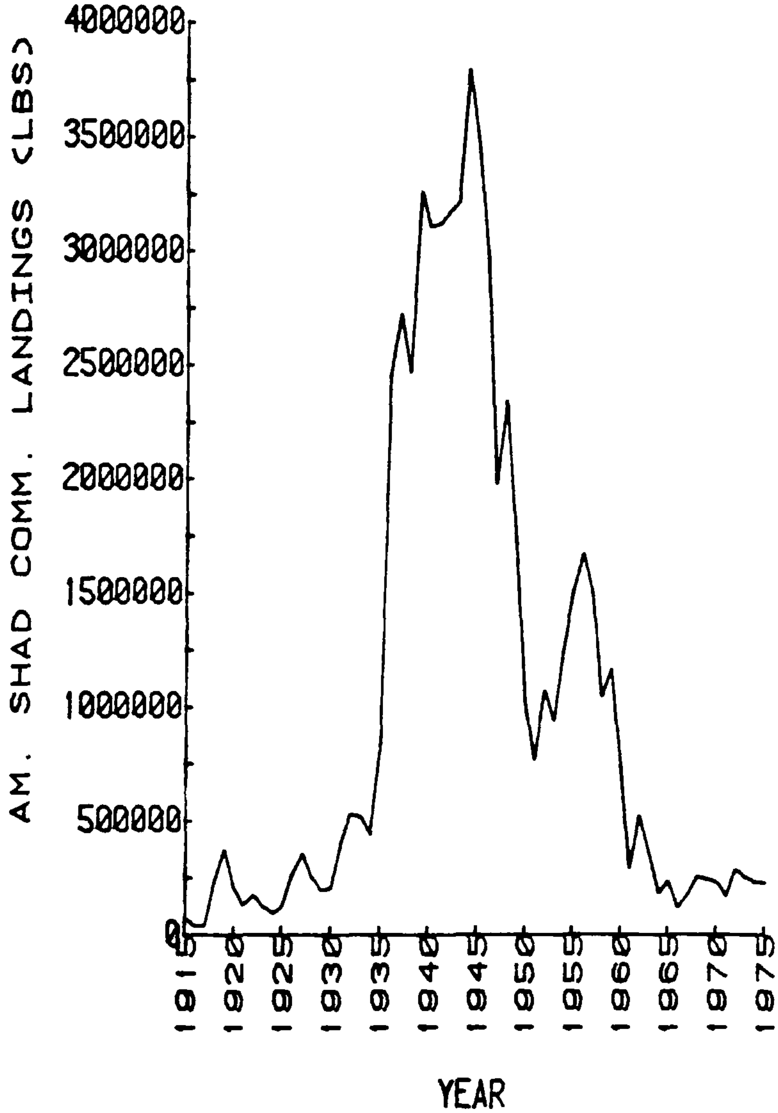

Figure 22. Commercial landings of American shad in the Hudson River, 1915-1975 (from Table 10, Talbot 1954; and Table IV-3, TI 1977).

SPAWNING

The tomcod spawns during the winter months in ice-covered fresh or brackish water (Booth 1967; Scott and Crossman 1973). Although eggs have not been sampled in the Hudson, tomcod in spawning condition (ripe and spent gonads) have been collected at least as far north as RM 94 (p. 5.20, Exhibit UT-4). Based on box trap sampling conducted by TI (Tables A-82 and A-83, Volume II, TI 1977), spawning activity appears to be concentrated in the Indian Point to Cornwall regions of the estuary (Table 23 and Figure 23).

Apparently, the majority of spawners are 11 to 13 months of age, i.e., they are members of the preceding year class (p. 5.20, Exhibit UT-4). Egg production of the Hudson River tomcod population is almost entirely dependent on this age group (p. 10.1-182, Exhibit UT-7). This conclusion is supported by length-frequency data collected during the TI box trap sampling program (Table V-13, TI 1976). The average length (158.4 mm) of tomcod caught in the box traps (which were presumed to be spawners) during December 1975, corresponded to the average length attained by the end of their first year of life, as shown in Table 24.

Average fecundities of tomcod for December 1973 and December 1974 were an estimated 20,260 and 11,640 ova per female, respectively (p. V-42, TI 1976). The estimated mean fecundity of tomcod during 1972 was approximately 15,000 ova for age 1 females and 55,000 ova for age 2 females (p. 10.1-194, Exhibit UT-7). These estimates are within the range of published fecundity estimates (5,075-75,000) reported by Hardy (1978) for the species in general.

EGGS

Tomcod eggs are demersal and non-adhesive, although their adhesiveness is a point of controversy (Booth 1967). The demersal nature of tomcod eggs, as well as the time of the year when they were present in the estuary, precluded their collection by the utilities consultants (p. 9.1-38, Exhibit UT-7; p. VI-41, TI 1975; p. IV-60, TI 1978). Workers in other estuaries have also had difficulty in sampling tomcod eggs (Booth 1967; Howe 1971).

Egg incubation periods for Atlantic tomcod are listed in Table 25. Water temperatures in the Hudson River, based on average USGS monthly temperatures, 1959-1969, taken at Indian Point, are generally less than 4°C during the incubation period of tomcod eggs. December, January, February, and March temperatures averaged 5°C, 1.11°C, 0.56°C, and 1.67°C, respectively. Therefore, the incubation period for tomcod eggs in the Hudson River probably ranges from 22-70 days.

LARVAE

The 1974 Long River Survey conducted by TI began too late (April

Table 23. Estimated Relative Distributions of Spawning Atlantic Tomcod, Expressed as Percentages[a]

Region	December - March 1973-1974	1974-1975
YK	NS[b]	NS
TZ	NS	0.8
CH	0.4	0.6
IP	51.9	2.9
WP	34.6	64.8
CW	6.9	29.9
PK	NS	1.0
HP	3.6	NS
KG	NS	NS
SG	2.6	0
CK	NS	NS
AL	NS	NS

[a]determined from TI box trap collections, December to March 1973-1974 and 1974-1975 (tables A-82 and A-83, TI 1977).
[b]NS = no sampling in region

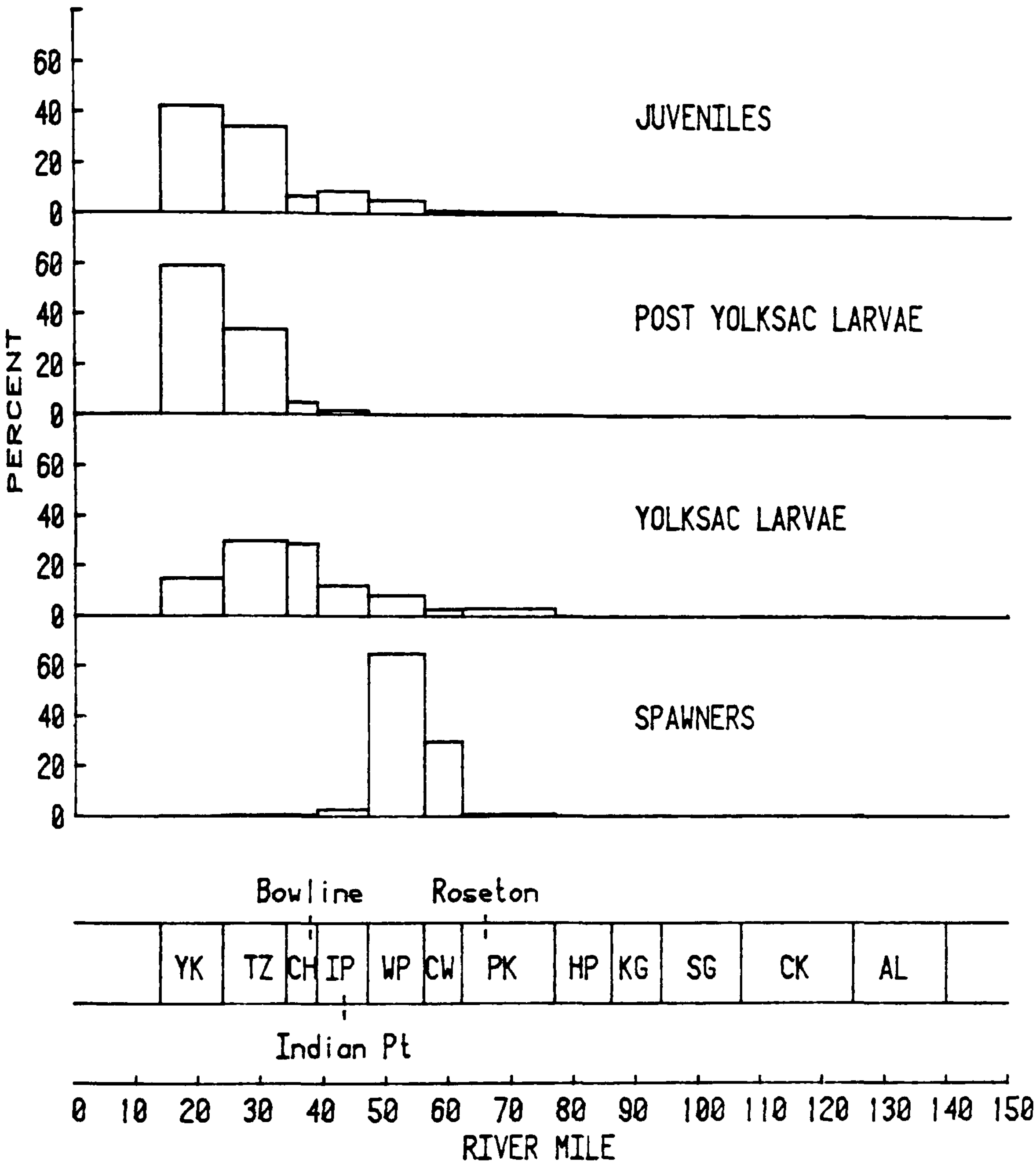

Figure 23. Proportional distributions, expressed as percentages, of spawning Atlantic tomcod during the winter of 1974-1975, and early life stages of Atlantic tomcod during 1975, based on TI box trap data (Table A-83, Volume II, TI 1977) and Long River Survey data supplied to EPA (Marcellus 1977b).

Table 24. Average Lengths and Size Ranges Recorded for Juvenile Atlantic Tomcod Sampled in the Hudson River by TI during 1975[a]

Week	Average length (mm)	Range (mm)
4/6 - 4/12	14	11 - 18
4/27 - 5/3	27	-
5/4 - 5/10	28	17 - 41
5/11 - 5/17	36	26 - 48
5/18 - 5/24	41	27 - 57
5/25 - 5/31	50	42 - 65
6/1 - 6/7	54	27 - 75
6/8 - 6/14	61	46 - 85
6/15 - 6/21	65	28 - 93
6/22 - 6/28	69	63 - 77
6/29 - 7/5	72	60 - 93
7/6 - 7/12	74	59 - 94
7/13 - 7/19	79	36 - 104
7/20 - 7/26	71	-
7/27 - 8/2	78	57 - 106
8/10 - 8/16	82	60 - 116
8/17 - 8/23	84	50 - 117
8/24 - 8/30	85	66 - 114
8/31 - 9/6	83	57 - 119
9/7 - 9/13	84	64 - 112
9/14 - 9/20	90	64 - 123
9/21 - 9/27	95	69 - 134
9/28 - 10/4	95	65 - 129
10/5 - 10/11	102	77 - 129
10/12 - 10/18	107	81 - 135
10/19 - 10/25	113	90 - 138
10/26 - 11/1	118	92 - 152
11/2 - 11/8	118	71 - 136
11/9 - 11/15	132	85 - 160
11/16 - 11/22	141	115 - 155
11/23 - 11/29	143	97 - 180

[a]based on Table B-79 in TI (1978) averaged for all gear each week

Table 25. Documented Life Stage Durations for Atlantic Tomcod

Life stage	Temperature (°C)	Duration (days)	Source
Egg	0	44-70	Leim and Scott 1966
	1-4.5	36-42	Hardy and Hudson 1975
	2.2-7.8	25	Baird 1887 Mather 1887
	4.4	30	Bigelow and Schroeder 1953 Vladykov 1955
		22-35	Leim and Scott 1966
		35	Nichols and Breder 1927 Tracy 1910
	4.5	30	Svetovidov 1962
	6	24	Svetovidov 1962
	6.1	24 25	Bigelow and Schroeder 1953 Vladykov 1955
	-	30	p. 5.20, Exhibit UT-4
Yolksac larva	-	4 6	Nichols and Breder 1927 Tracy 1910 Mather 1900
	-	30	p. 5.20, Exhibit UT-4

29) to sample tomcod yolksac larvae, as evidenced by the Long River Survey data (Marcellus 1977). Yolksac larvae were present in the Hudson River during the first Long River Survey sampling period of 1975, which began on or about March 6. Further discussion of abundance, distribution, and duration of ichthyoplankton life stages of Atlantic tomcod in the Hudson River will focus on the 1975 year class.

Since the estimated weekly standing crop of yolksac larvae was highest during the initial sampling period in 1975 (Table 26), this life stage was probably present in the estuary prior to March. The time difference between the weeks of peak yolksac and peak post yolksac standing crops suggests at least a four week life stage duration for yolk-sac larvae. This duration is comparable to the one month duration estimate presented by the utilities (p. 5.20, Exhibit UT-4), and contradicts the estimated range of 4-6 days reported by Mather (1900), Tracy (1910), and Nichols and Breder (1927).

The 1975 average weekly distribution of yolksac larvae, as determined from the TI Long River Survey, shows a downriver shift from the distribution of spawning adults (Figure 23). Ninety-four percent of the 1975 average weekly standing crop of yolksac larvae was collected in the Yonkers through West Point regions (RM 14-55). No yolksac larvae were collected above the Poughkeepsie region (RM 62-76); however, the first three surveys in 1975, during which all yolksac larvae collections were made, did not extend upriver past the Poughkeepsie region. The relatively low densities of yolksac larvae in the Cornwall and Poughkeepsie regions suggest very few, if any, members of this life stage were present in the river above RM 76.

Post yolksac larvae were found to be concentrated even further downriver than yolksac larvae by the 1975 Long River Survey (Figure 23). Ninety-three percent of the estimated average weekly river-wide standing crop of post yolksac larvae were sampled in the Yonkers and Tappen Zee regions. Since these regions are the two lowest regions in the Long River Survey, the data suggest a possible abundance of post yolksac larvae below RM 14. Dew and Hecht (1976) indicate, however, that the 1975 larval life stage of tomcod was most abundant above MP 11, and was present in relatively large numbers at MP 11 on only 3 of 12 sample dates (March 29, April 20, and May 10).

The estimated peak standing crop of post yolksac larvae occurred during the week beginning April 6, 1975. Based on the time interval between the peak standing crops of post yolksac larvae and juveniles (Table 26), the duration of the post yolksac larval stage of tomcod in 1975 was approximately 6 weeks. No estimates for the duration of this life stage have been found in the published literature.

JUVENILES

Tomcod transform to the juvenile life stage between 10-20 mm (Howe 1971). Early juveniles (prior to mid-August) were collected in the

Table 26. Temporal Distributions, Expressed as Percentages of Early Life Stages of Atlantic Tomcod Sampled by TI during the 1975 Long River Survey[a]

Week	Yolksac larvae	Post yolksac larvae	Early juveniles
3/9 - 3/15	78.51	14.17	0
3/16 - 3/22	-	-	-
3/23 - 3/29	21.48	27.91	0
3/30 - 4/5	-	-	-
4/16 - 4/12	0.02	46.98	0.16
4/13 - 4/19	-	-	-
4/20 - 4/26	0	9.63	0.94
4/27 - 5/3	-	-	-
5/4 - 5/10	0	1.19	6.65
5/11 - 5/17	0	0.12	17.82
5/18 - 5/24	0	0	25.75
5/25 - 5/31	0	0	5.18
6/1 - 6/7	0	0	6.05
6/8 - 6/14	0	0	11.51
6/5 - 6/21	0	0	2.34
6/22 - 6/28	0	0	2.58
6/29 - 7/5	0	0	6.55
7/6 - 7/12	0	0	4.16
7/13 - 7/19	0	0	3.87
7/20 - 7/26	0	0	2.42
7/27 - 8/2	0	0	1.27
8/3 - 8/9	-	-	-
8/10 - 8/16	0	0	1.75

[a]Marcellus (1977b)

Dashes indicate no sampling conducted.

Hudson River during the TI bottom trawl, beach seine, and Long River surveys of 1974 and 1975. After mid-August, juveniles were collected in the bottom trawl, beach seine, and epibenthic sled (fall shoals) surveys during both years.

Early juveniles

Based on beach seine and Long River survey data, early juveniles showed a similar distribution pattern among the 12 longitudinal regions of the Hudson River estuary during 1974 and 1975 (figures 24 and 25, respectively). Juveniles were most abundant in the two lowest regions of the estuary (Yonkers and Tappan Zee, RM 14-33). The relatively high abundance of early juveniles in the Yonkers region implies that some unknown fraction of this life stage might have been present in the estuary below RM 14. Lower estuary studies by TI (Volume III, TI 1977), which found juvenile tomcod in the lower estuary and nearby Long Island Sound in late May and early June, 1975, support this implication.

The bottom trawl data collected before mid-August, 1974 and 1975, show a markedly different distribution pattern of juvenile tomcod than the other two sampling programs, even though the bottom trawl survey did not encompass all 12 regions. According to this survey, early juveniles were most abundant in the Tappan Zee region (RM 24-33) in 1974 (Figure 24) and the Indian Point region (RM 39-46) in 1975 (Figure 25). The general distribution, based on bottom trawl data, was further up-river in 1975 than in 1974. Based on data presented in Table 24, it appears that the 1975 year class of tomcod attained an average length of 50 mm (considered to be maximum entrainable size in this testimony) by the end of May, which coincided with their period of peak abundance in 1975 Long River Survey samples (Table 26). If the peak standing crop of yolksac larvae was during the week beginning March 6, 1975, and the estimated durations of the yolksac and post yolksac larval stages were four and six weeks, then the duration of the entrainable juvenile stage was at least three weeks.

Fall juveniles

The 1974 and 1975 distribution patterns of juvenile tomcod in the Hudson River after mid-August are shown in Figures 26 and 27. The bottom trawl and epibenthic sled data showed similar fall juvenile distribution patterns for both years, with estimated peak abundances occurring in the Indian Point through Cornwall regions (RM 39-61). The estimated peak abundance of fall juveniles based on beach seine data occurred in the Tappan Zee region (RM 24-33) during both years. Since tomcod in this life stage are epibenthic and offshore (p. V-13, Volume I, TI 1977), the beach seine data are probably not as good an indicator of relative distribution as the other two data sources.

ADULTS

Few tomcod older than one year of age were found in the

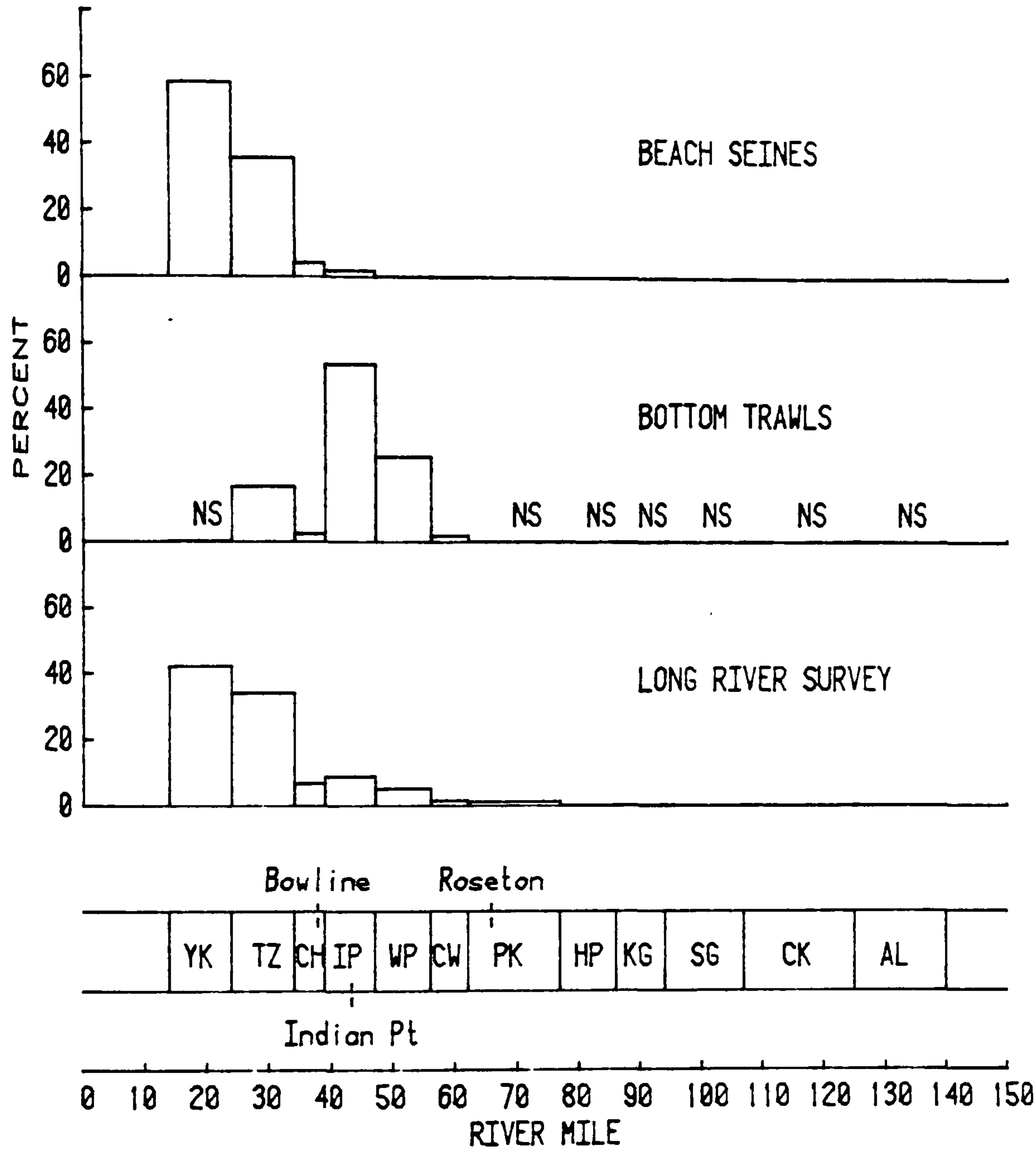

Figure 24. Proportional distributions, expressed as percentages, of early juvenile Atlantic tomcod during 1974, based on TI Long River, bottom trawl, and beach seine survey data supplied to EPA (Marcellus 1977b).

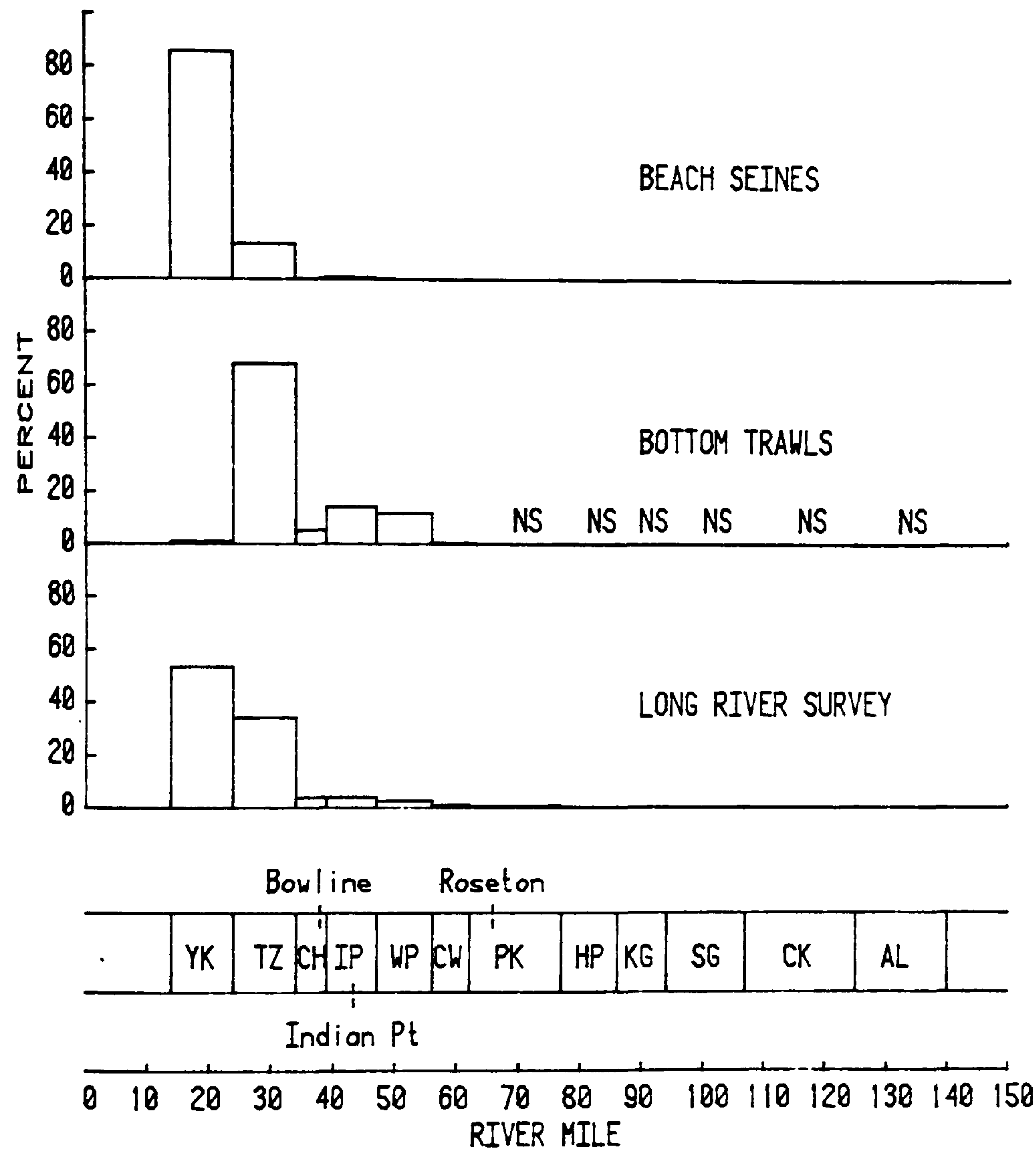

Figure 25. Proportional distributions, expressed as percentages, of early juvenile Atlantic tomcod during 1975, based on TI Long River, bottom trawl, and beach seine survey data supplied to EPA (Marcellus 1977b).

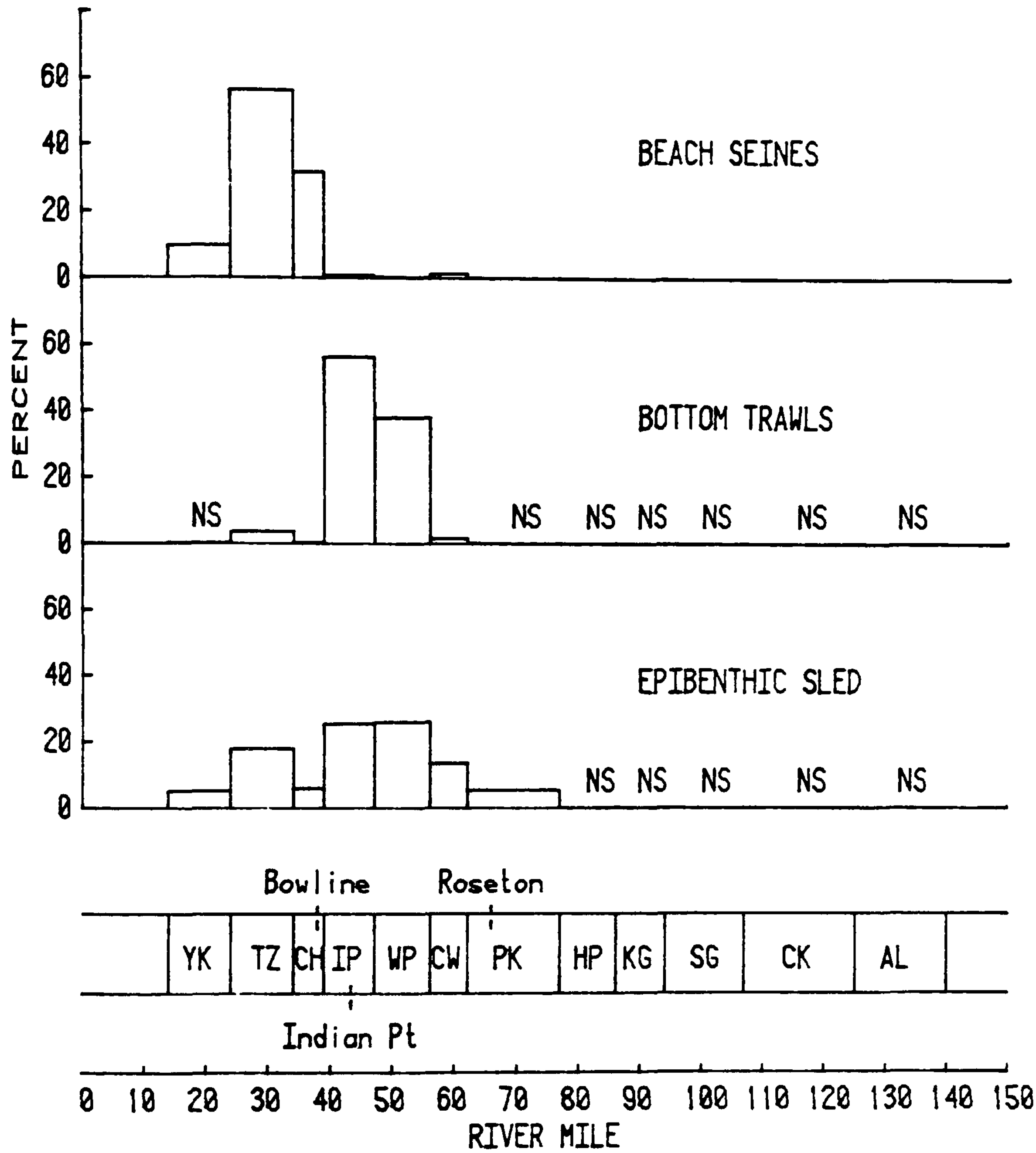

Figure 26. Proportional distributions, expressed as percentages, of fall juvenile Atlantic tomcod during 1974, based on TI fall shoals (epibenthic sled) data (Table A-27, Volume II, TI 1977) and bottom trawl and beach seine survey data supplied to EPA (Marcellus 1977b).

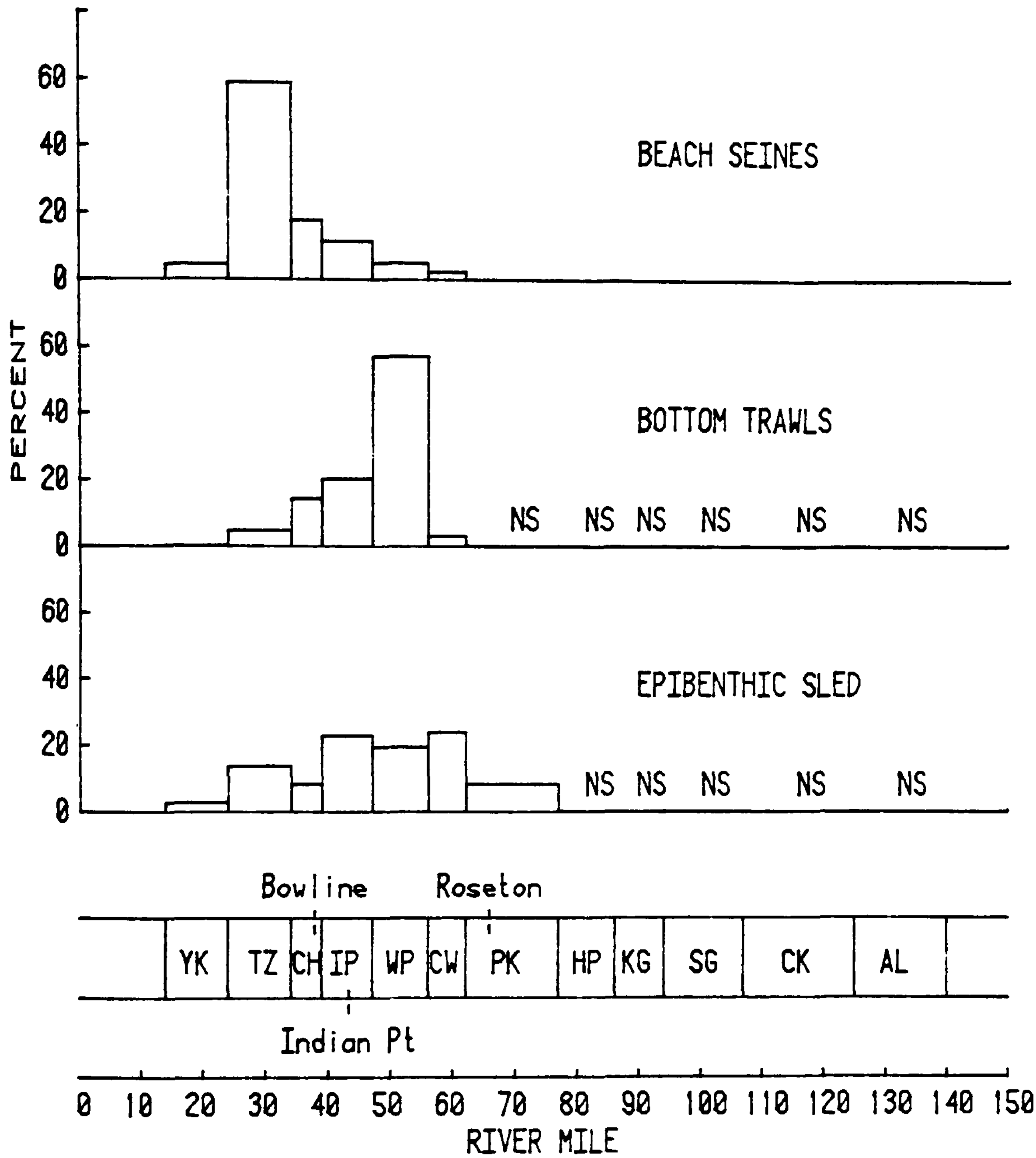

Figure 27. Proportional distributions, expressed as percentages, of fall juvenile Atlantic tomcod during 1975, based on TI fall shoals (epibenthic sled) data (Table B-79, TI 1978) and bottom trawl and beach seine survey data supplied to EPA (Marcellus 1977b).

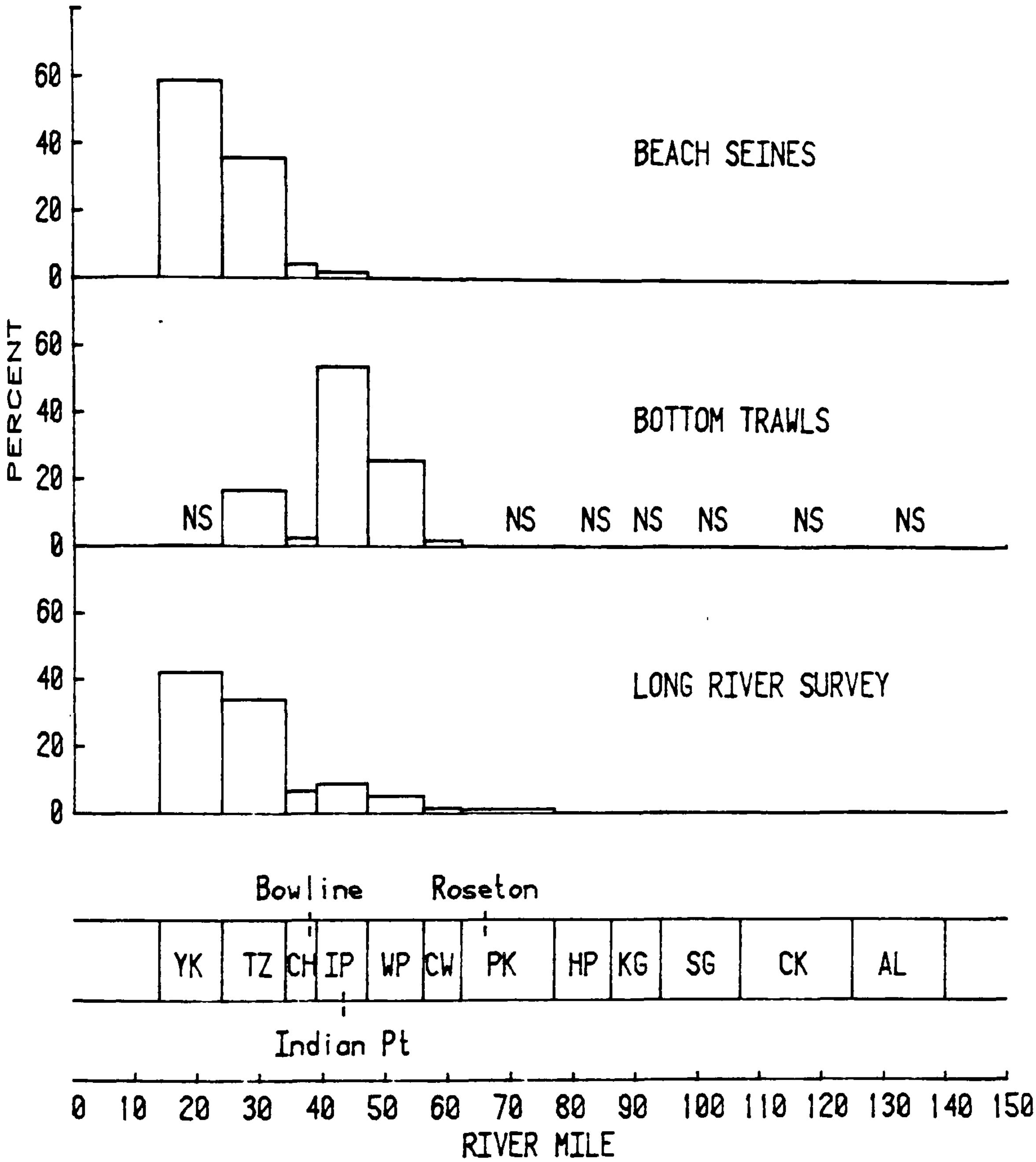

Figure 24. Proportional distributions, expressed as percentages, of early juvenile Atlantic tomcod during 1974, based on TI Long River, bottom trawl, and beach seine survey data supplied to EPA (Marcellus 1977b).

Hudson River during the utilities consultants' sampling programs (Marcellus 1977b). Six adult tomcod tagged during the 1974-1975 spawning season by TI were recovered in the lower estuary and Long Island Sound, one as late as July 1975 (Table A-102, Volume II, TI 1977). Based on the 153 tag recoveries, 66 tags or 43 percent were recaptured in box traps; 57 tags or 37 percent were recovered from impingement collections at the Bowline, Lovett, Indian Point, Roseton, and Danskammer Power plant facilities; and 29 tags or 19 percent were returned by sport fishermen.

FISHERIES - PAST AND PRESENT

According to Howe (1971), the commercial market for Atlantic tomcod has declined during the past century. The present fishery is essentially a sport fishery along the New England and New York coasts (Howe 1971), although it may extend as far south as Virginia (Massman 1958, 1962). Nichols and Breder (1927) described an extensive winter tomcod fishery in New York harbor waters. Greeley (1937) noted that tomcod had considerable commercial value to New York in the winter months. The importance of tomcod to New York fishermen at the turn of the century is evidenced by an extensive hatchery program at the time in Cold Spring Harbor, New York (Mather 1887, 1889).

Tag returns from sport fishermen during 1975, as discussed earlier, indicate that the sport fishery for Atlantic tomcod in the lower Hudson River and nearby Long Island Sound may be quite substantial. Unfortunately, no formal reporting procedure for tomcod sport fishermen exists, and the Salt-Water Angling surveys conducted by the National Marine Fisheries Service (Deuel and Clark 1968; Deuel 1973) lumped tomcod with other members of the cod family in their questionnaires.

The contribution of the Hudson River population of Atlantic tomcod to the sport fishery in New York Bay and Long Island Sound may be significant, since no evidence exists that tomcod spawn in Long Island Sound (Richards 1959), although a spawning population was studied in the Mystic River in eastern Connecticut (Booth 1967). The fact that no tomcod spawning has been reported south of the Hudson River estuary means that catches by sport fishermen in Maryland (Schwartz 1964) and Virginia (Massman 1958, 1962) are likely to be at least partly of Hudson River origin (Dew and Hecht 1976).

TROPHIC RELATIONSHIPS

The Atlantic tomcod plays a dual role in the trophic structure of the Hudson River aquatic community. It is an opportunistic predator as well as a prey species. Food habit studies on adult and juvenile tomcod conducted by TI during 1975 (TI 1976b) concluded that fish constitute a very minor portion of their diet, and adults may be more piscivorous than juveniles. Among the adults, the percent frequency of occurrence in stomach samples was greatest for _Gammarus_ spp., _Neomysis_ spp., _Monoculodes_ spp., _Crangon_ spp., and _Chirodotea_ spp. (Table V-14, TI 1976b); _Morone_ spp. (white perch and possibly striped bass) constituted approximately 7 percent of the adult diet. Cannibalism of adults on tomcod eggs was also evident. Copepods were the major food items of juveniles during May-June, while the dietary regime switched to amphipods, mysids, and isopods from July-December (Grabe 1978). Prey density was not considered limiting during the summer slow-growth period (Grabe 1978), therefore, other factors (such as warmer water) probably induced the slower growth.

Stomach analyses conducted on juvenile tomcod in the Weweantic River (Howe 1971) indicated they fed mostly (73 percent of their diet) on the sand shrimp (Crangon septemspinosis), a species common in the Hudson River. Fish species preyed upon by tomcod in the Weweantic River included fry and juvenile life stages of alewife, white perch, cunner, toadfish, silversides, and sticklebacks. Howe (1971) concluded that tomcod feed predominately on sand shrimp but probably eat whatever is available in greatest numbers in their immediate environment.

Predators on tomcod include striped bass (TI 1976b) and bluefish (TI 1977a). Dew and Hecht (1976) stated that it is possible that tomcod are "a critical link in the food chain necessary to perpetuate a viable stock of Hudson River striped bass," especially in those years when bay anchovy abundance is low. They based this observation on stomach content data of juvenile striped bass that indicated selective predation on juvenile tomcod during July and August.

BAY ANCHOVY

The bay anchovy (Anchoa mitchelli) is a member of the family Engraulidae and a close relative of the herrings (Clupeidae). The range of the bay anchovy is from the Gulf of Maine to Yucatan, Mexico (Hildebrand 1963), primarily in estuarine and coastal waters (Jones et al. 1978). It is a relatively small species, seldom exceeding 85 mm in length in the Hudson River (Boyce Thompson Institute for Plant Research 1977).

SPAWNING

Based on egg collections during the 1974 and 1975 TI Long River surveys, spawning activity of the bay anchovy is concentrated in the lower part of the Hudson River estuary. The highest densities of bay anchovy eggs were recorded in the lowest sampling region (RM 14-23), indicating spawning probably occurred below this region.

The period of spawning activity during 1974 and 1975, based on the Long River surveys, was from early June through mid-August. Because the Long River surveys ended in mid-August, it is quite possible that spawning activity extended into September, especially since Richards (1959) noted a June-September spawning season for bay anchovies in nearby Long Island Sound.

The minimum age at maturity is approximately 2.5 months; the minumum length at maturity is 34-40 mm (Stevenson 1958). This information implies that anchovies spawned during June in the Hudson River may reach maturity and spawn themselves in late August or September of the same year. However, the minimum age and size at maturity noted by Stevenson is questioned by Jones et al. (1978).

EGGS

Almost all bay anchovy eggs were collected in the lowest five regions of the Hudson River (RM 14-55) during the TI Long River surveys (figures 28 and 29). In 1974, 71 percent of the estimated average weekly standing crop of bay anchovy eggs was in the Yonkers region (RM 14-23). In 1975, 49 percent was in the Yonkers region and 40 percent was in the Tappan Zee region (RM 24-33). The relatively high abundance of eggs in the lower sample regions indicates that an unknown proportion of the bay anchovy egg production was below RM 14 each year and, therefore, not vulnerable to collection by the Long River surveys.

The period of bay anchovy egg collection was from early June to mid-August during both 1974 and 1975 (tables 27 and 28), although, as previously mentioned, eggs could have been spawned in the Hudson River as late as September. Two peaks of egg abundance occurred during the collection period; one peak was in early to mid-June and a second peak was in early to mid-July. The one month separation between abundance peaks indicates a double spawning by adults (or the spawning of two adult cohorts), rather than spawning in July by young-of-the-year.

The duration of the egg incubation period for bay anchovies is relatively short. Kuntz (1914) found that bay anchovy eggs hatch in about 24 hr at temperatures between 27.2-27.8°C. Although these temperatures are slightly higher than temperatures in the Hudson River during the periods of egg collection, no data relating incubation periods of anchovy eggs to temperatures less than 27.2°C could be found in the literature. Therefore, an average egg incubation period of one day is assumed for bay anchovies in the Hudson River over the entire spawning period.

LARVAE

Samples of the yolksac larval life stage of bay anchovies were collected in the lower three regions of the Hudson River (RM 14-38) during 1974, and the Tappan Zee and Croton-Haverstraw regions (RM 24-38) during 1975 in the TI Long River surveys (figures 28 and 29). The short life stage duration of bay anchovy yolksac larvae (17-25 hr at 28°C, Houde 1974) is reflected in the low numbers collected in the Long River surveys compared to other life stages. The temporal distribution of yolksac larvae collections (tables 27 and 28) indicate that TI missed the first peak of yolksac larval abundance in 1974, probably due to the short life stage duration.

Post yolksac larvae were collected in all regions of the Hudson River except Albany (RM 125-140) during 1974 and 1975 (Marcellus 1978b). This information indicates substantial upriver movement by this life

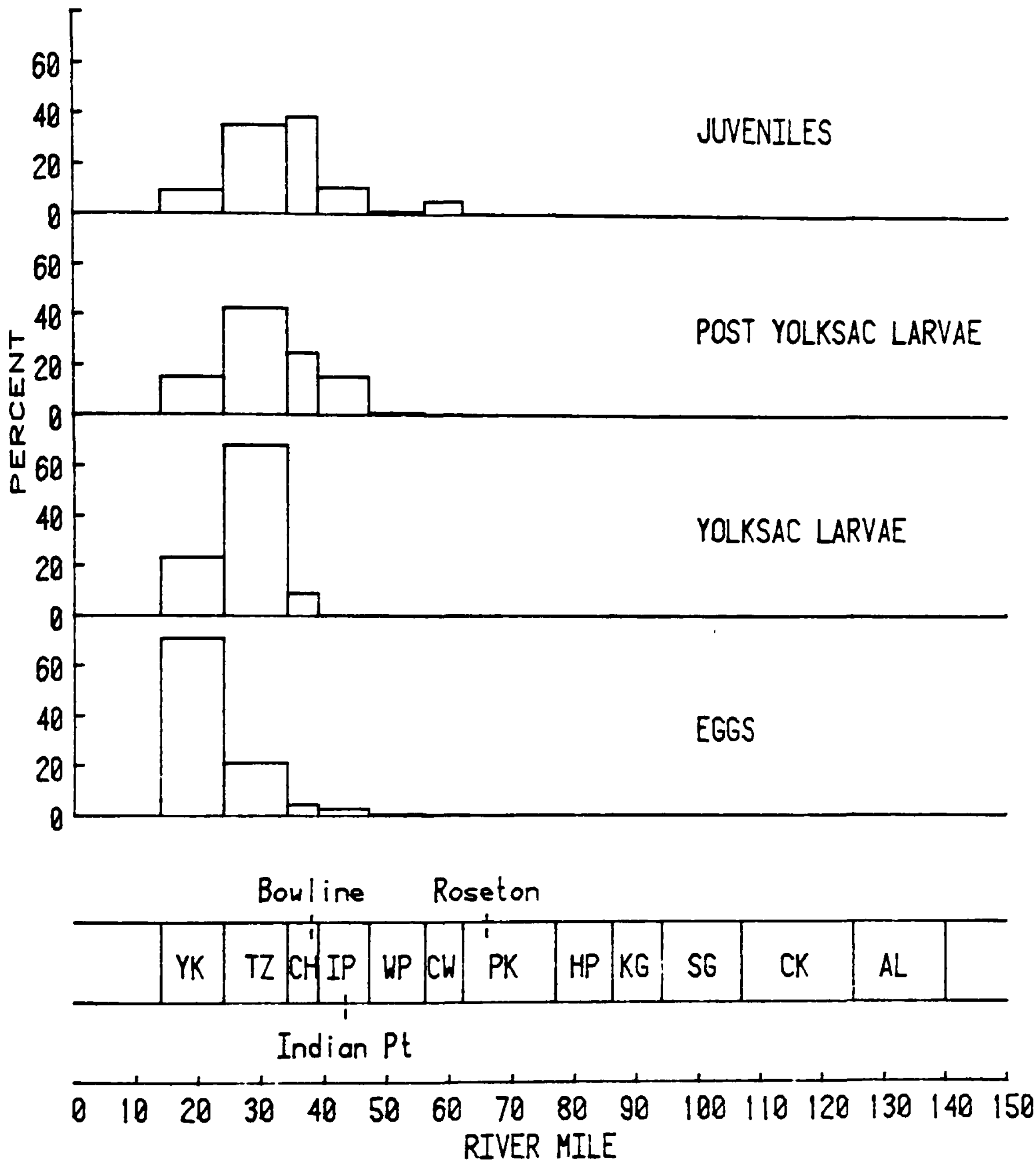

Figure 28. Proportional distributions, expressed as percentages, of early life stages of bay anchovies during 1974, based on TI Long River Survey data supplied to EPA (Marcellus 1978b).

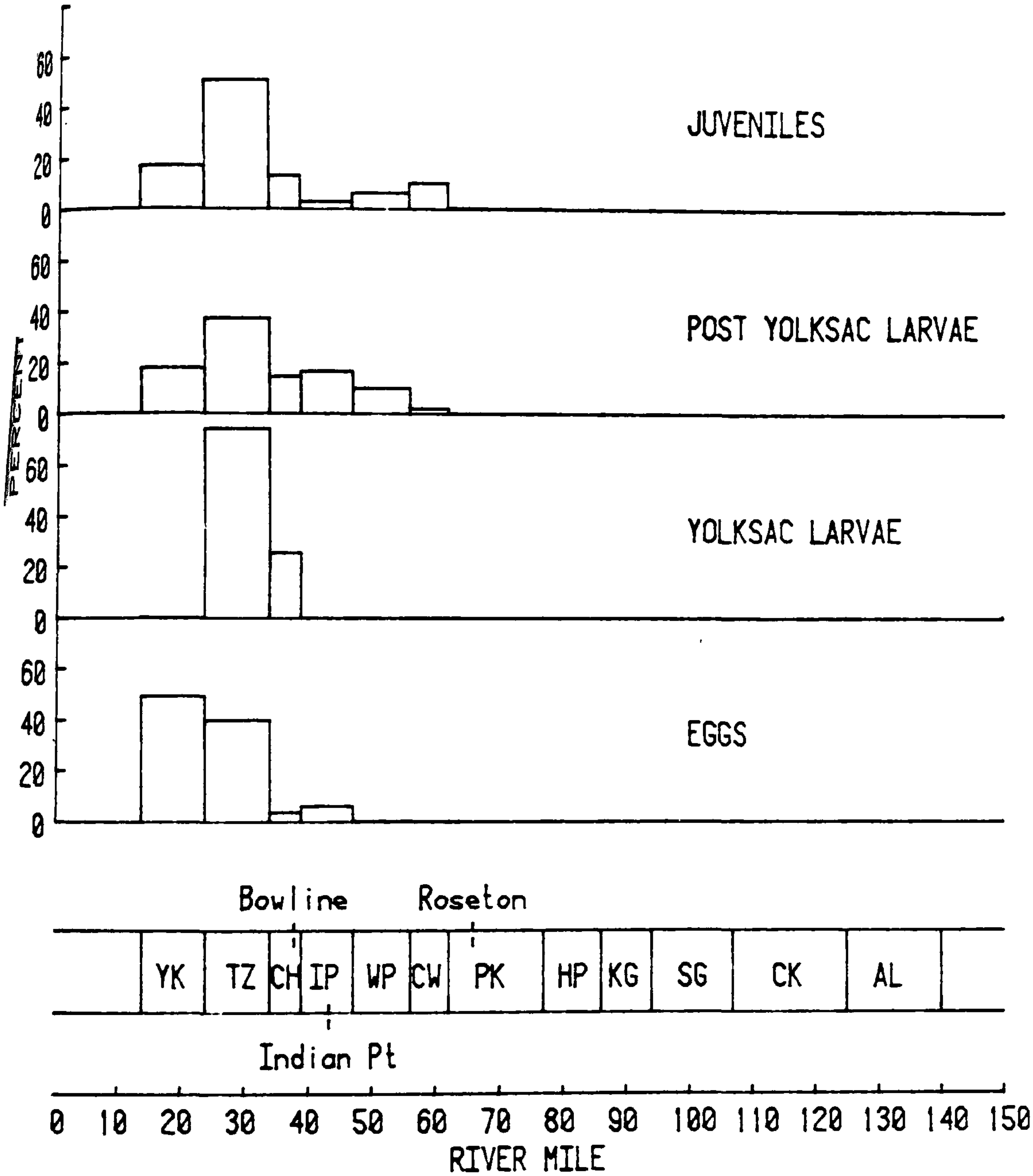

Figure 29. Proportional distributions, expressed as percentages, of early life stages of bay anchovies during 1975, based on TI Long River Survey data supplied to EPA (Marcellus 1978b).

Table 27. Proportional Distributions, Expressed as Percentages, of Early Life Stages of Bay Anchovy, Based on the 1974 TI Long River Survey[a]

Week	Eggs	Yolksac larvae	Post yolksac larvae	Early juveniles
6/3 - 6/9	0.78	0	0	0
6/10 - 6/16	52.54	0	0.01	0.25
6/17 - 6/23	14.86	0	0.30	5.01
6/24 - 6/30	0.47	0	2.22	3.64
7/1 - 7/7	0.35	0	2.50	0
7/8 - 7/14	5.69	0	2.53	2.67
7/15 - 7/21	12.79	8.97	16.58	2.13
7/22 - 7/28	6.27	0	22.10	0.83
7/29 - 8/4	3.26	32.44	22.15	25.03
8/5 - 8/11	1.18	58.58	14.79	27.63
8/12 - 8/18	1.81	0	16.72	32.81

[a]Marcellus (1978b)

Table 28. Proportional Distributions, Expressed as Percentages, of Early Life Stages of Bay Anchovy, Based on the 1975 TI Long River Survey[a]

Week	Eggs	Yolksac larvae	Post yolksac larvae	Early juveniles
6/1 - 6/7	27.84	10.33	0.06	0
6/8 - 6/14	4.63	18.91	2.53	0
6/15 - 6/21	0.96	0	0.53	0
6/22 - 6/28	0	0	3.04	0
6/29 - 7/5	30.12	0	2.49	0
7/6 - 7/12	28.38	70.76	34.05	2.66
7/13 - 7/19	6.89	0	20.45	0
7/20 - 7/26	0.98	0	20.42	11.67
7/27 - 8/2	0.20	0	10.62	20.66
8/3 - 8/9	-[b]	-	-	-
8/10 - 8/16	0	0	5.81	65.01

[a]Marcellus (1978b)
[b]no sampling conducted

stage. The estimated peak average weekly standing crop of post yolksac larvae occurred in the Tappan Zee region (RM 24-33) during both 1974 and 1975 (figures 28 and 29).

The period of collection of bay anchovy post yolksac larvae in the Long River surveys was from early to mid-June through at least mid-August each year (tables 27 and 28). Peak collections occurred in July of each year. The time period between peak collections of post yolksac larvae and juveniles in the Long River surveys was 2-3 weeks in 1974 and 4-5 weeks in 1975. Since peak juvenile abundance occurred during the last week of data collection each year (tables 27 and 28), peak abundance of this life stage may not have been reached by that time. Therefore, the duration of the post yolksac larval life stage is assumed to have been about one month (30 days) each year.

JUVENILES

Since growth data discussed in this section indicate bay anchovies remain an entrainable size through October, the term "early juveniles" will refer to juveniles prior to November and the term "fall juveniles" will refer to juveniles in November and December each year.

Early juveniles

Length data collected by LMS during 1974 and 1975 indicated juvenile bay anchovies in the Bowline region of the Hudson River, on the average, did not surpass 50 mm (considered maximum entrainable length in this testimony) until after October each year (Table 29). These data do not reflect slow growth of bay anchovy juveniles, but rather a continuous recruitment of fish into this life stage, as evidenced by the spawning season duration previously discussed. If bay anchovies do spawn in September in the Hudson River, as previously hypothesized, their offspring would reach the juvenile life stage in about one month or more.

TI beach seine collections of bay anchovy juveniles through the end of October 1974 and 1975, indicated a more downriver distribution than the Long River surveys (figures 30 and 31). The differences in distributions between the two surveys are probably due to the much later time period represented by the beach seine collections. Both surveys found peak abundances of early juveniles in the Tappan Zee region (RM 24-33) during 1975; the Long River Survey found a peak in the Croton-Haverstraw region (RM 34-38) in 1974.

Based on information previously discussed, the sum of bay anchovy life stage durations through the post yolksac larval life stage is approximately one month (32 days). Therefore, assuming the last cohort of bay anchovies is spawned in mid-August (tables 27 and 28), a six week life stage duration for entrainable juveniles would end the entrainment interval of this cohort at the end of October.

Fall juveniles

Based on beach seine collections past October, juvenile bay anchovies were almost entirely (100 percent in 1974 and 94 percent in 1975) concentrated

Table 29. Average Lengths of Bay Anchovies Sampled in the Bowline Region of the Hudson River during 1974 and 1975

Month	1974[a]	1975[b]
July	-	33
August	32	37
September	36	38
October	41	46
November	-	59

[a]from Table VII-37 of LMS (1975)

[b]from Table VII-39 of LMS (1976)

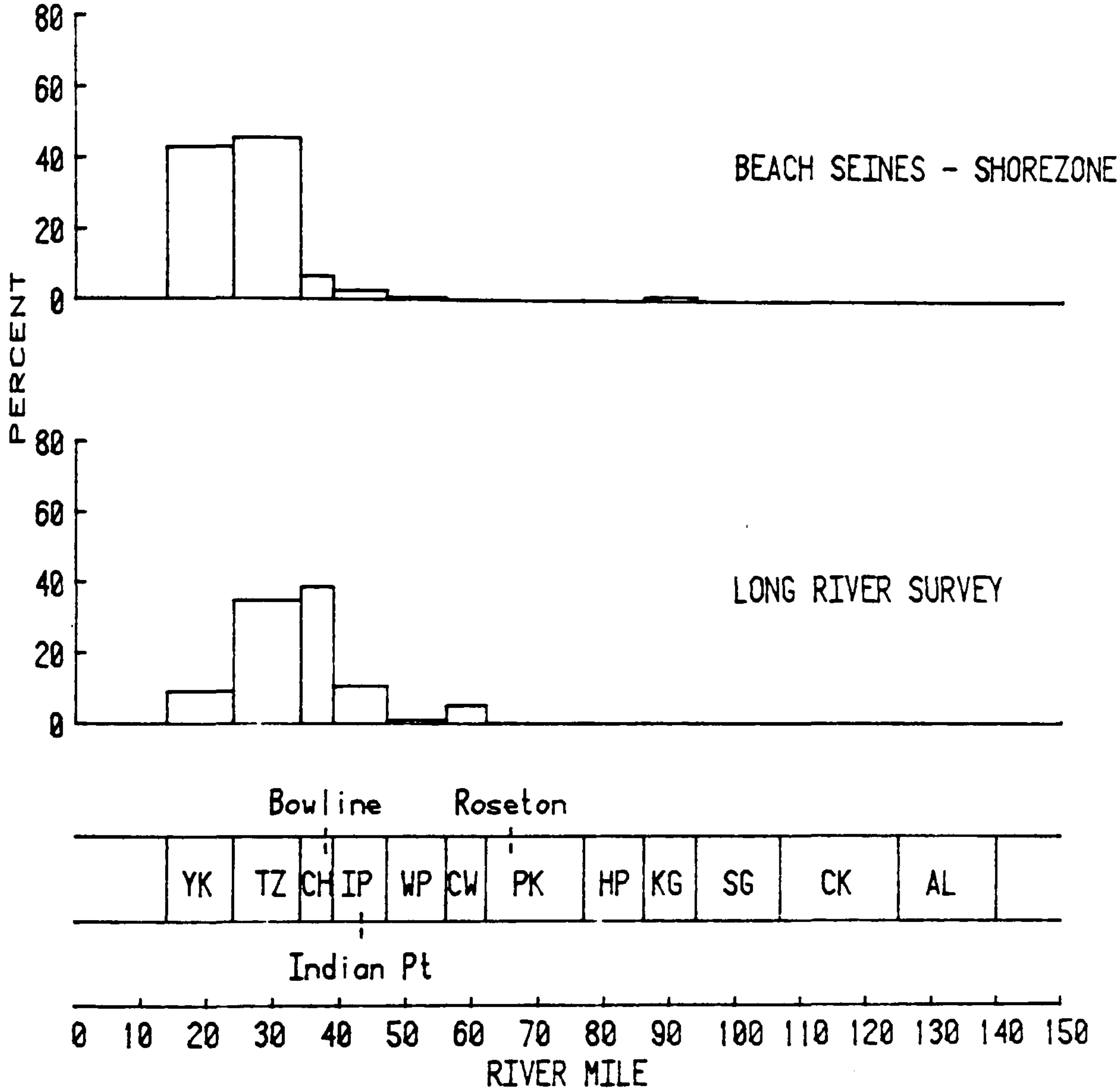

Figure 30. Proportional distributions, expressed as percentages, of early juvenile bay anchovies during 1974, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1978b).

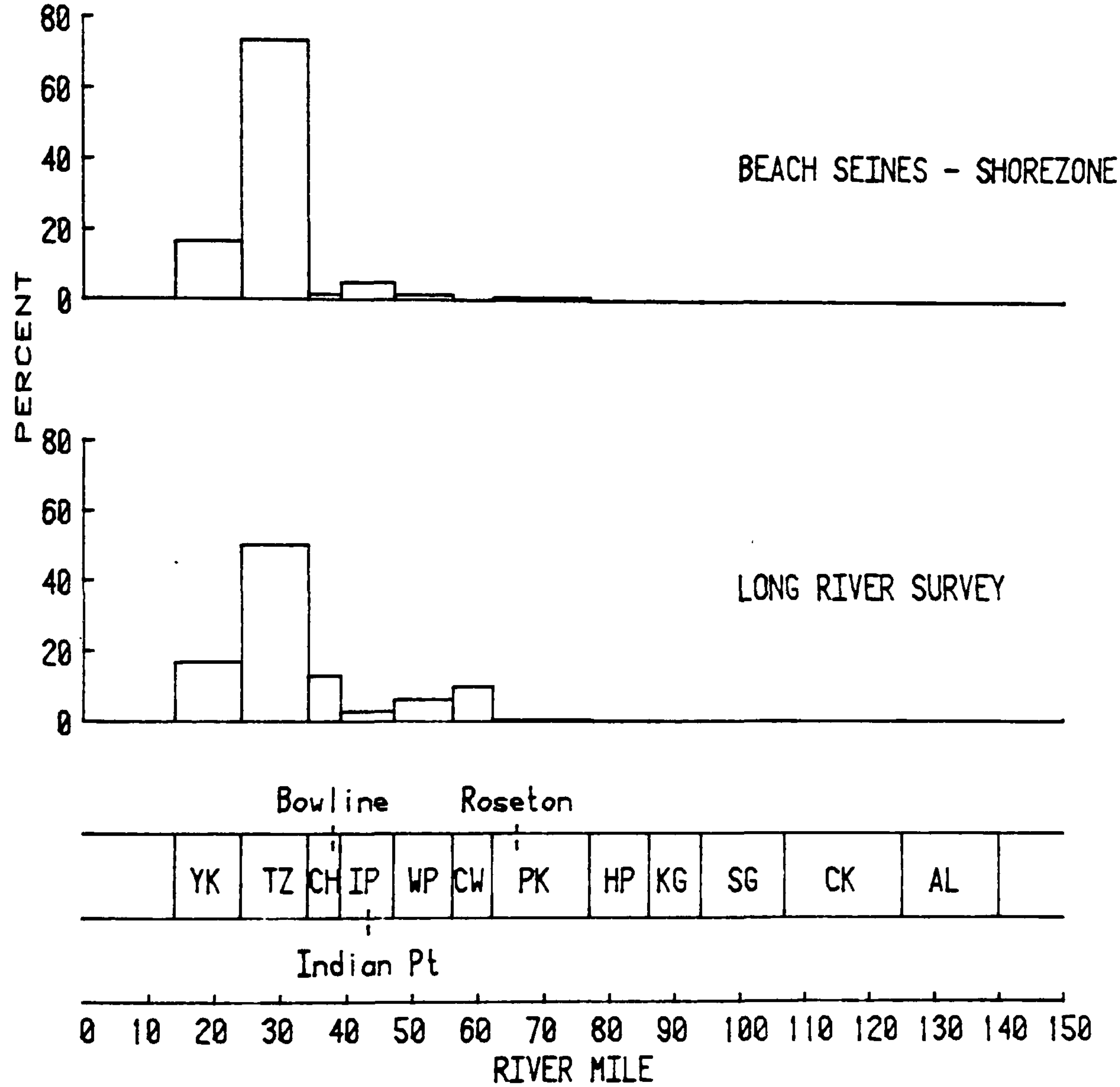

Figure 31. Proportional distributions, expressed as percentages, of early juvenile bay anchovies during 1975, based on TI Long River and beach seine survey data supplied to EPA (Marcellus 1978b).

in the lowermost region of the river (RM 14-23). This indicates a substantial proportion of the fall juvenile population of bay anchovies probably had moved below RM 14 by this time of the year.

ADULTS

No tagging studies have been conducted on the Hudson River population of bay anchovies. Studies elsewhere indicate that oceanic movements are apparently limited to localized inshore-offshore migrations (Hildebrand 1963).

FISHERIES - PAST AND PRESENT

In 1973, anchovies accounted for less than 500 lb or $500 in the New England commercial fisheries landings (NMFS 1975). No known sport fishery exists for the species in the Hudson River. However, they are probably used by sport fishermen as bait fish to catch other species.

TROPHIC RELATIONSHIPS

The bay anchovy feeds on small planktonic animals and detrital materials in the Hudson River (Boyce Thompson Institute for Plant Research 1977). The bay anchovy is the principal food source for bluefish in the Hudson River (p. II-4, TI 1976a). Striped bass also prey on bay anchovies (p. V-17, 1976b).

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