TABLE 2-9 SPECIFICATIONS OF SAMPLING GEAR USED DURING THE 1997 BEACH SEINE SURVEY

30.5-m Beach Seine	
Number of wings	2
Length of wings	12.0 m
Depth of wings	2.4 m
Wing mesh (bar)	1.0 cm
Length of bag	6.1 m
Depth of bag	3.0 m
Bag mesh (bar)	0.5 cm
Sampling area	450 m^2

TABLE 2-10 SUMMARY OF 1997 SAMPLE COLLECTION BY RIVER REGION FOR THE BEACH SEINE SURVEY

Region	5-Week Period from 16 JUN to 18 JUL	13-Week Period from 28 JUL to 24 OCT	Total
Yonkers	9	35	44
Tappan Zee	33	168	201
Croton-Haverstraw	21	98	119
Indian Point	9	35	44
West Point	9	35	44
Cornwall	9	42	51
Poughkeepsie	24	35	59
Hyde Park	24	35	59
Kingston	24	35	59
Saugerties	45	63	108
Catskill	57	70	127
Albany	36	49	85
Total	300	700	1,000

W_{irw} = Physical/chemical measurement for location i at river mile r during biweek w.

n_{rw} = Number of physical/chemical measurements taken at river mile r during biweek w.

$$\text{Salinity} = -100\, ln\left(1 - C_{25}/178.5\right) \quad (3)$$

where

C_{25} = Conductivity (millisieman/cm at 25°C).

2.5.2 Spatiotemporal Distribution Indices

2.5.2.1 Density and Catch-Per-Unit-Effort Estimates

Estimates of population densities were made for the LRS and FSS. For these two surveys the number of fish (by species and life stage) in individual samples was first converted to density (no./m^3 of water sampled) using Equation 4. The mean density and the standard error of the mean were calculated for each stratum, region, and sampling week using Equations 5 and 6. To obtain a mean density and standard error for each region during each sampling week, the stratum densities were weighted by the proportion of the regional river volume found in the stratum (Equations 7 and 8). If a stratum was not sampled, its volume was added to the volume of an adjacent stratum that was sampled. Stratum volume adjustments were made according to the following rules:

If This Stratum Was Not Sampled	Its Volume Was Added To This Stratum
Shoal	Bottom
Bottom	Channel
Channel	Bottom

$$D_{ikrw} = \frac{C_{ikrw}}{V_{ikrw}} \quad (4)$$

where

D_{ikrw} = Density (for a life stage and species)/m^3 for sample i in stratum k in region r during week w.

C_{ikrw} = Number of fish caught in sample i in stratum k in region r during week w.

V_{ikrw} = Volume sampled (m^3) by sample i in stratum k in region r during week w.

$$D_{krw} = \frac{1}{n_{krw}} \sum_{i=1}^{n_{krw}} D_{ikrw} \quad (5)$$

where

D_{krw} = Average density in stratum k in region r during week w.

D_{ikrw} = Sample density calculated in Equation 4.

n_{krw} = Number of samples taken in stratum k in region r during week w.

$$SE(D_{krw}) = \sqrt{\frac{\sum_{i=1}^{n_{krw}} (D_{ikrw} - D_{krw})^2}{(n_{krw})(n_{krw} - 1)}} \quad (6)$$

where

$SE(D_{krw})$ = Standard error of the average density in stratum k in region r during week w.

D_{ikrw} = Sample density calculated in Equation 4.

D_{krw} = Average stratum density calculated in Equation 5.

$$D_{rw} = \sum_{k=1}^{n_{rw}} (D_{krw})(P_k) \quad (7)$$

where

D_{rw} = Average density in region r during week w.

D_{krw} = Average stratum density calculated in Equation 5.

P_k* = Proportion of the regional river volume found in stratum k (Table 2-11).

n_{rw} = Number of strata sampled in region r during week w.

* When a stratum is missing, P_k for the sampled stratum is equal to the sum of the P_k for the sampled stratum and the P_k for the unsampled stratum.

$$SE(D_{rw}) = \sqrt{\sum_{k=1}^{n_{rw}} \left[SE(D_{krw})^2 (P_k)^2 \right]} \quad (8)$$

where

$SE(D_{rw})$ = Standard error of average density in region r during week w.

$SE(D_{krw})$ = Standard error of the average stratum density calculated in Equation 6.

Catches from the BSS were reported as number caught per seine haul (catch-per-unit-effort [CPUE]) by life stage and species. The average CPUE for a region and its standard error were calculated using Equations 9 and 10:

$$C_{rw} = \frac{1}{n_{rw}} \sum_{i=1}^{n_{rw}} C_{irw} \quad (9)$$

where

C_{rw} = Average CPUE in region r during week w.

C_{irw} = CPUE for sample i in region r during week w.

n_{rw} = Number of samples taken in region r during week w.

$$SE(C_{rw}) = \frac{\sum_{i=1}^{n_{rw}} (C_{irw} - C_{rw})^2}{n_{rw}(n_{rw} - 1)} \quad (10)$$

where

$SE(C_{rw})$ = Standard error of average CPUE in region r during week w.

C_{rw} = Average regional CPUE calculated in Equation 9.

2.5.2.2 Standing Crop Estimates

An index of standing crop (the number of fish in an area at a particular time) was estimated by life stage and species for each of the three surveys. Standing crop indices and the associated standard errors were calculated for each stratum in a region by taking the product of the average stratum density (or the standard error) and the volume of water contained in that stratum (Equations 11 and 12 for the LRS and FSS) (Table 2-11). The regional standing crop index was then estimated as the sum of the stratum index values (Equations 13 and 14). Similarly, an estimate of the standing crop index for the Hudson River estuary for each week was calculated by summing the standing crops for the 13 (12 for the BSS) river regions

TABLE 2-11 STRATUM AND REGION VOLUMES (m^3) AND SURFACE AREAS (m^2) USED IN ANALYSIS OF 1997 HUDSON RIVER ESTUARY DATA

Geographic Region	Channel Volume	Bottom Volume	Shoal Volume	Region Volume	Shorezone Surface Area
Battery	141,809,822	48,455,129	18,747,833	209,012,784	(a)
Yonkers	143,452,543	59,312,978	26,654,767	229,420,288	3,389,000
Tappan Zee	138,000,768	62,125,705	121,684,992	321,811,465	20,446,000
Croton-Haverstraw	61,309,016	32,517,633	53,910,105	147,736,754	12,101,000
Indian Point	162,269,471	33,418,632	12,648,163	208,336,266	4,147,000
West Point	178,830,022	25,977,862	2,647,885	207,455,769	1,186,000
Cornwall	94,882,267	36,768,629	8,140,123	139,791,019	4,793,000
Poughkeepsie	228,975,052	63,168,132	5,990,260	298,133,444	3,193,000
Hyde Park	131,165,041	32,012,000	2,307,625	165,484,666	558,000
Kingston	93,657,021	35,479,990	12,332,868	141,469,879	3,874,000
Saugerties	113,143,296	42,845,077	20,307,338	176,295,711	7,900,000
Catskill	83,924,081	42,281,206	34,526,456	160,731,743	8,854,000
Albany	32,025,080	13,517,183	25,606,842	71,149,105	6,114,000
Total	1,603,443,480	527,880,156	345,505,257	2,476,828,893	76,555,000

a. Shorezone surface area is unknown and not used in data analysis as no beach seine sampling is performed in the Battery region. Estimation of strata volumes for the Battery Region is described in the 1989 Year Class Report (EA 1990).

(Equations 15 and 16). This value is an index rather than an absolute standing crop value because no adjustment was applied for collection efficiency.

$$SC_{krw} = (V_{kr})(D_{krw}) \qquad (11)$$

where

SC_{krw} = Standing crop index for stratum k in region r during week w.

V_{kr} = River volume contained by stratum k in region r.

D_{krw} = Average stratum density calculated in Equation 5.

$$SE(SC_{krw}) = (V_{kr})[SE(D_{krw})] \qquad (12)$$

where

$SE(SC_{krw})$ = Standard error of the standing crop index for stratum k in region r during week w.

$SE(D_{krw})$ = Standard error of average stratum density calculated in Equation 6.

$$SC_{rw}^{**} = \sum_{k=1}^{3} SC_{krw} \qquad (13)$$

where

SC_{rw} = Standing crop index for region r during week w.

SC_{krw} = Stratum standing crop index calculated in Equation 11.

$$SE(SC)_{rw}^{**} = \sqrt{\sum_{k=1}^{3}[SE(SC_{krw})]^2} \qquad (14)$$

where

** Volumes of unsampled strata were added to the volumes of an adjacent stratum according to the rules for stratum volumes in Section 2.5.2.

$SE(SC_{rw})$ = Standard error of standing crop index for region r during week w.

$SE(SC_{krw})$ = Standard error of stratum standing crop index calculated in Equation 12.

$$SC_w = \sum_{r=1}^{12} SC_{rw} \qquad (15)$$

where

SC_w = Standing crop index for week w. For the LRS and FSS, regional standing crop indices include the Battery Region (r=0).

SC_{rw} = Regional standing crop index calculated in Equations 13 or 17.

$$SE(SC_w) = \sqrt{\sum_{r=1}^{12} [SE(SC_{rw})]^2} \qquad (16)$$

where

$SE(SC_w)$ = Standard error of standing crop index for week w. For the LRS and FSS, regional standing crop indices include the Battery Region (r=0).

$SE(SC_{rw})$ = Standard error of regional standing crop index calculated in Equations 14 or 18.

An index of regional standing crop (and standard error) for the BSS was obtained by multiplying CPUE and the surface area of the shorezone and dividing by the empirically derived estimate of the area sampled by the 30.5-m beach seine (Equations 17 and 18). The weekly index of standing crop for the shorezone was calculated as the sum of the 12 regional standing crops (Equations 15 and 16).

$$SC_{rw} = (C_{rw} A_r) / A \qquad (17)$$

where

SC_{rw} = Standing crop index for the shorezone in region r during week w.

C_{rw} = Average regional CPUE calculated in Equation 9.

A_r = Surface area (m^2) of the shorezone in region r.

A = Surface area (m^2) sampled by the beach seine (450 m^2) (TI 1981).

$$SE(SC_{rw}) = \frac{[SE(C_{rw})]\,(A_r)}{A} \quad (18)$$

where

$SE(SC_{rw})$ = Standard error of standing crop index for the shorezone in region r during week w.

$SE(C_{rw})$ = Standard error of average regional CPUE calculated in Equation 10.

2.5.2.3 Temporal and Geographic Distribution Indices

Distribution indices were computed to facilitate presentation of changes in distribution of selected species and life stages through time and space. To allow comparisons of 1997 data with historical data, only data from samples collected from Weeks 18 to 27 (where Week 1 begins with the first Monday in January) were used for LRS (except for bay anchovy which used Weeks 18-40); data from Weeks 33 to 40 were used for the FSS and BSS. In all cases, data were used only when Regions 1-12 were sampled (except for bay anchovy which included Region 0).

The LRS was used for calculating the temporal and geographic indices for early life stages of striped bass, white perch, Atlantic tomcod, bay anchovy, American shad, *Alosa* spp., and rainbow smelt. The FSS was used to calculate geographical distribution indices for hogchoker, white catfish, and weakfish. The BSS was used to calculate geographical distribution indices for striped bass, white perch, bay anchovy, American shad, alewife, blueback herring, gizzard shad, spottail shiner, and bluefish.

The periods used for the LRS and BSS spanned 1974-1997, whereas the time period for the FSS extended from 1979 (when the FSS sampled the river from RM 12 to RM 152) through 1997. Temporal and geographic indices for bay anchovy from the LRS used the period from 1988 to 1997, when the sampling design included the Battery region.

A geographic index that collapses data over weeks was calculated for LRS, FSS, and BSS data as the relative standing crop in each region. This geographic index was calculated as follows:

$$G_{ry} = \frac{\sum_{w=1}^{n_y} SC_{rwy}}{\sum_{r=1}^{12} \sum_{w=1}^{n_y} SC_{rwy}} \quad (19)$$

where

G_{ry} = Geographic index for region r in year y.

SC_{rwy} = Regional standing crop index for region r in week w in year y calculated in Equations 13 or 17.

n_y = Number of weeks sampled in year y.

A temporal index that collapses data for the entire Hudson River estuary was computed for early life stages from LRS standing crop indices (Equation 20):

$$T_{wy} = \frac{SC_{wy}}{\sum_{w=1}^{n_y} SC_{wy}} \qquad (20)$$

where

T_{wy} = Temporal index for week w in year y.

SC_{wy} = Weekly standing crop index in year y calculated in Equation 15.

n_y = Number of weeks sampled in year y.

CHAPTER 3
PHYSICAL/CHEMICAL PARAMETERS

This chapter provides information on the parameters of temperature, salinity, and dissolved oxygen as measured during the 1997 surveys. Although parameters were measured with the BSS, emphasis will be placed on data from the LRS/FSS because these surveys encompassed the entire fish sampling period. In addition, freshwater flow data obtained from the U.S. Geological Survey for the Green Island Dam near Troy, New York, and daily water temperature data from the Poughkeepsie Waterworks are discussed. Physical and chemical parameters are presented in Appendix B.

3.1 GREEN ISLAND DAM FLOWS

During 1997, daily freshwater flow for Green Island, New York was estimated from discharge data provided by the U.S. Geological Survey for the Hudson River above Lock 1, the Mohawk River at Cohoes, and the Mohawk River diversion at Crescent Dam. The daily flow in 1997 ranged from approximately 96 to 1,477 m^3/sec/day (Figure 3-1). The primary peaks in daily flows occurred in March, April, and May with flows reaching 1,000 to 1,400 m^3/sec/day. Periods of low daily flows of 100-200 m^3/sec/day began in June and continued through October (Figure 3-1, Appendix Table B-1). The 1997 monthly freshwater flow rates were very similar to the long-term (1947-1996) monthly average flow rates, with flows in the second half of the year slightly lower than normal (Figure 3-1, Appendix Table B-2). This was also true of the second half of 1997 when compared to monthly average flow rates since the Hudson River surveys began in 1974 (Appendix Table B-3).

3.2 POUGHKEEPSIE WATERWORKS TEMPERATURES

Long-term (1951-1997) daily temperature records are available from the Poughkeepsie Waterworks, located just north of the City of Poughkeepsie, New York, at RM 76. The lowest recorded temperature in 1997 was 0.6°C in January (Appendix Table B-4). Water temperatures in 1997 remained relatively low (<4°C) through March, then began increasing in April and reached a high of 26.1°C in late July/early August. Temperatures started to decline in September (Figure 3-2).

The 1997 mean water temperature profile generally resembled the long-term (1951-1996) pattern with the exceptions that water temperatures were cooler than normal during the spring of 1997 and slightly warmer than normal during the early summer of 1997 (Figure 3-2).

3.3 HUDSON RIVER SURVEYS

3.3.1 Spatiotemporal Pattern in Temperature

Average weekly water temperature measured during the 1997 LRS/FSS increased from the beginning of sampling in March until mid-June, remained relatively constant until mid-August, and then decreased steadily until the end of the sampling program in October (Figure 3-3). This temporal pattern observed throughout the Hudson River estuary closely reflected that recorded at Poughkeepsie Waterworks. Average weekly temperatures measured during the LRS/FSS were similar to concurrent Poughkeepsie Waterworks temperatures. Peak river temperatures occurred during August when the river-wide mean temperature was 25.5°C and regional mean values were between 23.2 and 26.4°C (Appendix Table B-5).

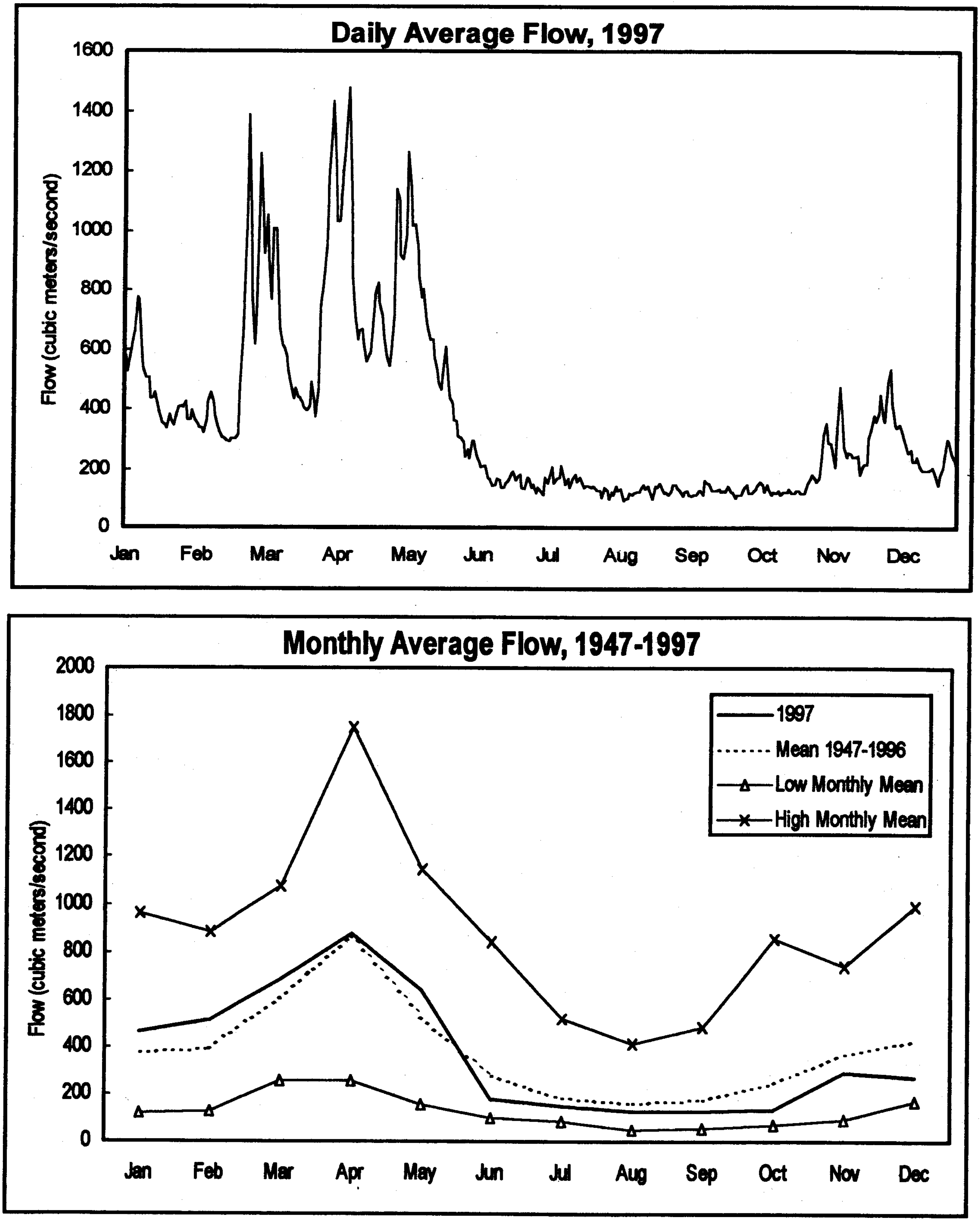


Figure 3-1. Hudson River daily average flow rate in 1997 and monthly average flow rates from 1947 to 1997, Green Island, New York.

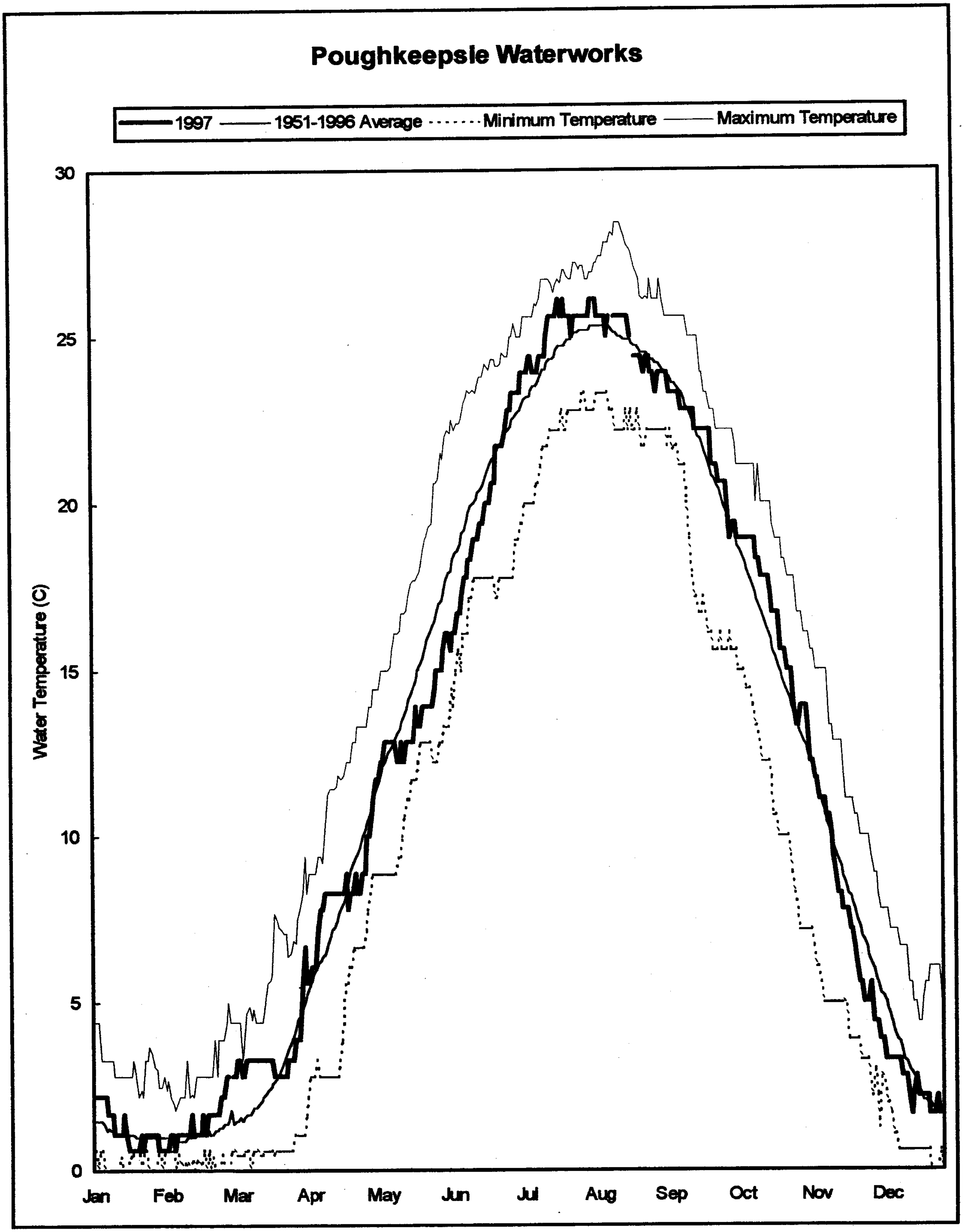
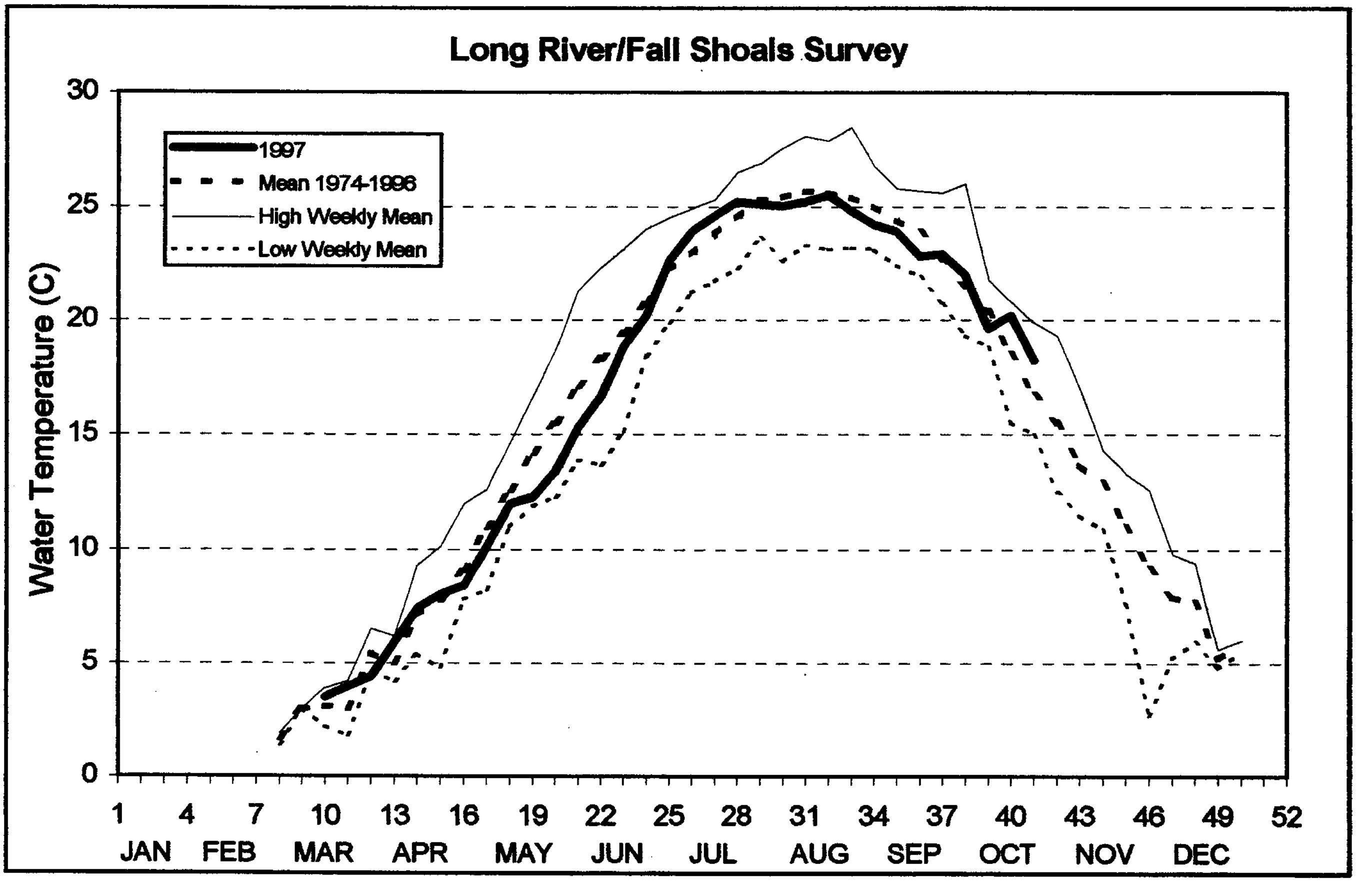


Figure 3-2. Seasonal variations in water temperature from 1951 to 1997 as measured at Poughkeepsie Waterworks.

Average Weekly Water Temperature



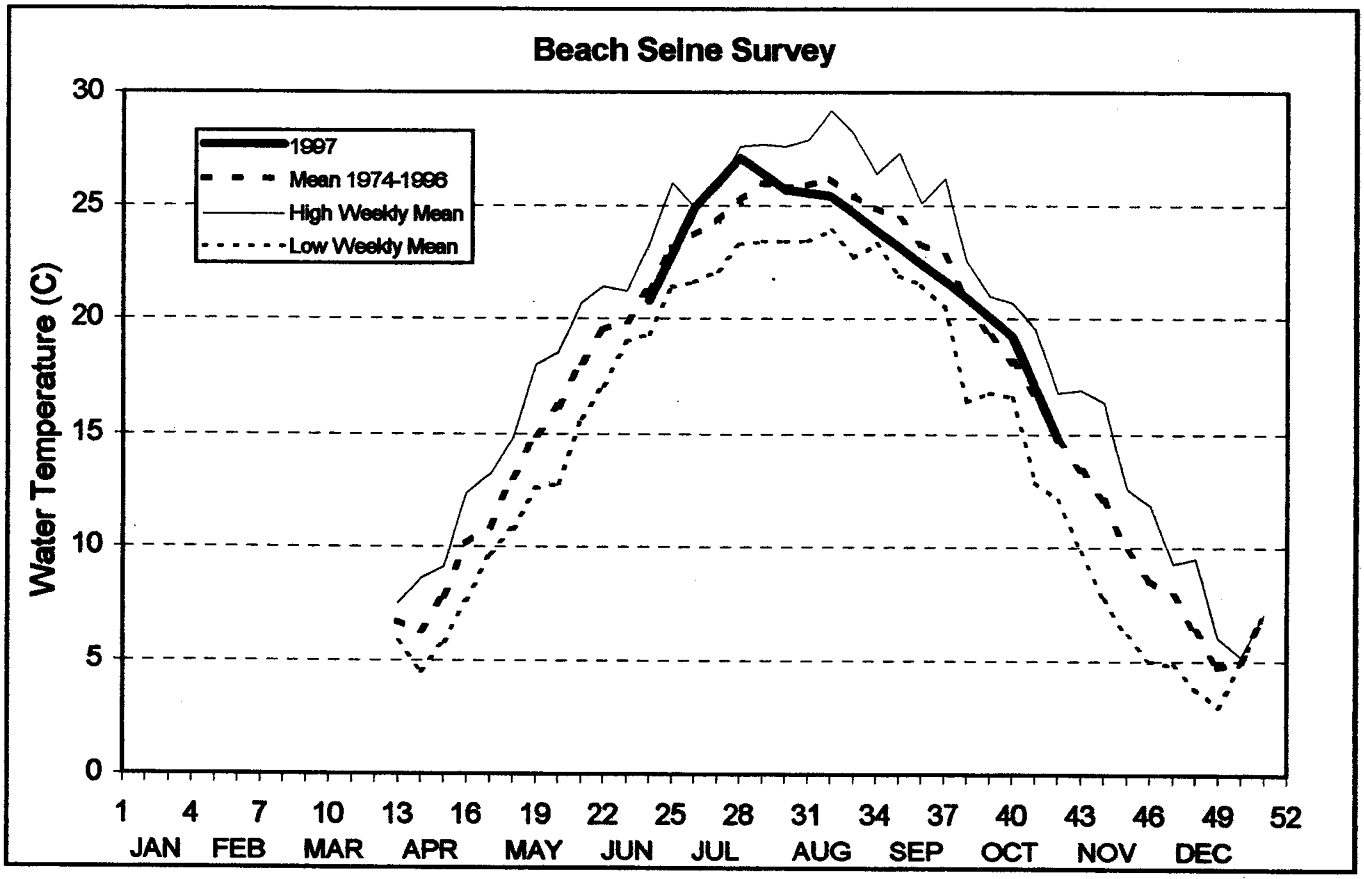


Figure 3-3. Seasonal variations in water temperature from the Hudson River surveys, 1974-1997.

Lowest values occurred during the week of 10 March when the mean temperature in the lower river was 3.5°C and regional mean temperatures from Battery to Cornwall ranged from 3.0 to 4.6°C (Poughkeepsie Waterworks daily temperatures were 3.3°C for this week). Spring temperatures in 1997 were slightly cooler than the long-term (1974-1996) average temperatures observed in previous Hudson River surveys, but generally 1997 temperatures fit the long-term average temperature curve (Figure 3-3).

Temporal patterns in the 1997 BSS temperature data resembled the pattern observed with LRS/FSS measurements except that summer peak temperatures were achieved in early July (Figure 3-3). Mean weekly regional temperatures at the peak were 26.2 to 28.5°C (Appendix Table B-6). BSS mean temperatures in 1997 decreased steadily from the summer peak into fall and were slightly cooler than the long-term (1974-1996) average temperatures in the late summer (Figure 3-3). Minimum mean temperatures of 13-16°C were recorded during the last week of sampling that began on 20 October.

3.3.2 Spatiotemporal Pattern in Salinity

Seasonal variations in salinity in 1997 generally resembled the pattern observed in previous years of the Hudson River surveys: decreased salinity in the spring in response to increased freshwater flows, increasing summer levels as freshwater input slows, and finally, decreased salinity in the fall as freshwater discharges increase again. In 1997, salinity values measured during the LRS/FSS were lowest in early April with salinity levels about 1 ppt in the Yonkers region (Figure 3-4). Salinity values fluctuated until late May, rose gradually to peak values in August, and remained relatively uniform through the end of sampling in October (Figure 3-4, Appendix Table B-7). The typical fall decrease in salinity was not observed in 1997 even though freshwater flows were near normal for this time of year (Figure 3-1). The northernmost edge of the salt front (i.e., salinity greater than 0.3 ppt) in the Hudson River estuary remained in the Poughkeepsie region in 1997.

The spatiotemporal pattern of salinity observed during the BSS typically resembles that observed during the LRS/FSS: increasing salinity during the summer and decreasing levels in the fall. Actual salinity measured during the BSS was lower than during the LRS/FSS because of the tendency for the denser, saline water to follow the deeper channel rather than the shorezone area. In the 1997 BSS, salinity was relatively uniform throughout the summer and fall (Appendix Table B-8). Salinity levels reached a summer peak during the week of 11 August (9.3-1.2 ppt from Yonkers to Cornwall) (Appendix Table B-8). Mean weekly regional salinity was highest in the Yonkers region and decreased upstream.

3.3.3 Spatiotemporal Pattern in Dissolved Oxygen

Dissolved oxygen concentration changes inversely with changes in temperature and salinity. The seasonal pattern of dissolved oxygen typically observed during the Hudson River surveys consists of high concentrations in the spring, declining to minimum values in the summer, and increasing levels in the fall. As temperatures rose in the Spring and Summer of 1997, dissolved oxygen, as recorded in the LRS/FSS, declined from peak mean weekly regional values of 10.5-12.8 mg/L on 10 March to minimum mean levels of 4.9-7.6 mg/L on 4 August when temperatures and salinity were elevated (Figure 3-5, Appendix Table B-9). Dissolved oxygen concentrations in 1997 followed the general pattern of the long-term (1974-1996) mean values (Figure 3-5).

Percent oxygen saturation relates the theoretical limit of oxygen saturation, based on temperature and salinity, to the observed dissolved oxygen concentrations. Mean weekly regional percent saturation based on measurements taken during the LRS/FSS was usually above 85 percent for most of the sampling season

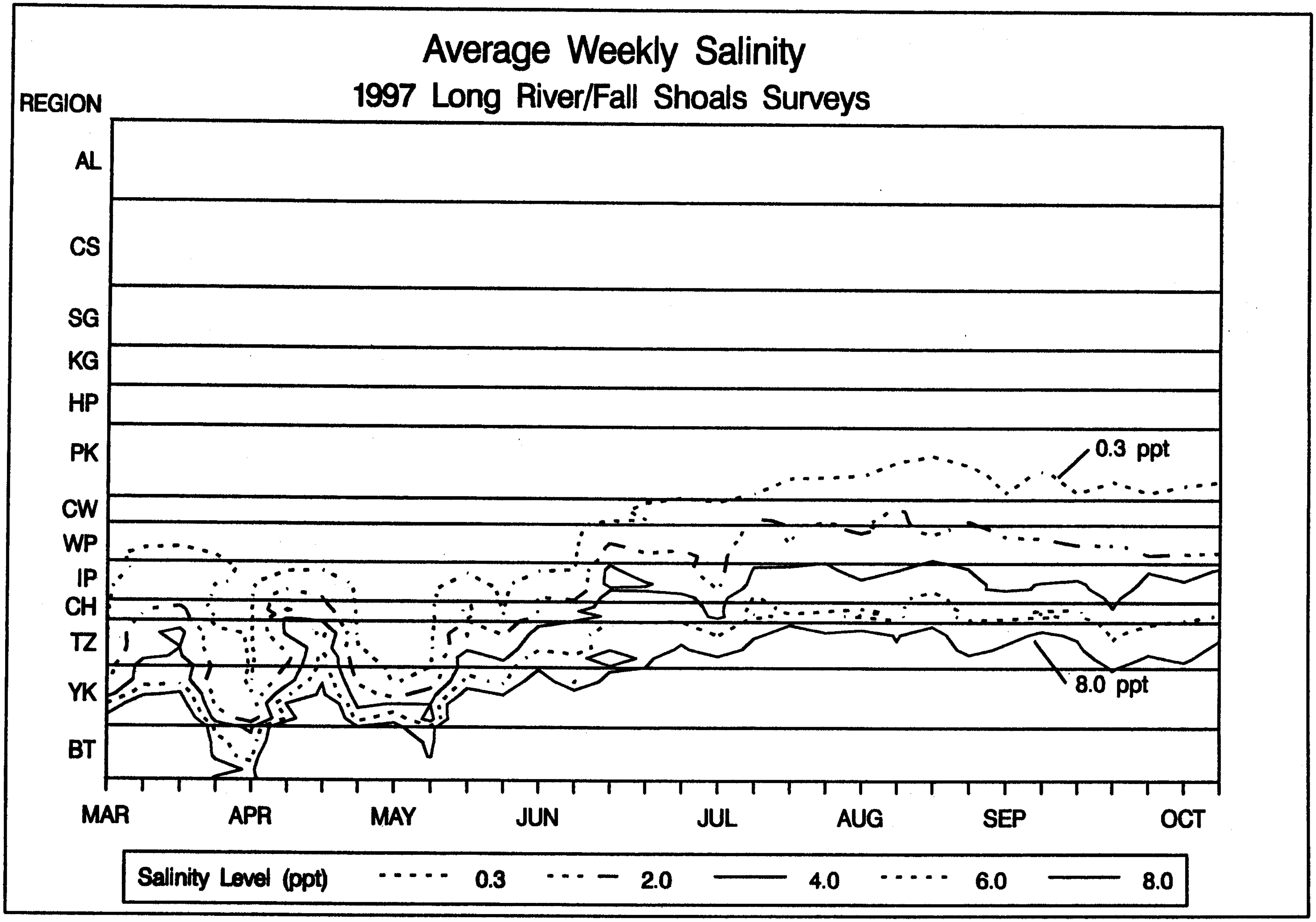


Figure 3-4. Seasonal variations in salinity from the 1997 Long River/Fall Shoals surveys, average weekly values.

with occasional dips to 60 or 70 percent in the late summer especially in the downriver regions (Appendix Table B-11). Individual mean weekly regional values were never lower than 48 percent, the minimum recorded during the week of 18 August from the Yonkers region.

Data collected in the 1997 BSS (Figure 3-5, Appendix Tables B-10 and B-12) indicated slightly higher mean regional dissolved oxygen and percent oxygen saturation than recorded in the LRS/FSS during the early summer and fall. In many instances, mean regional percent oxygen saturation indicated supersaturated conditions. Turbulence from wave action and oxygen released as a by-product of photosynthesis could be two causes of this supersaturation. In 1997, percent oxygen saturation levels measured in the BSS were usually in the 80-100 percent range.

Average Weekly Dissolved Oxygen

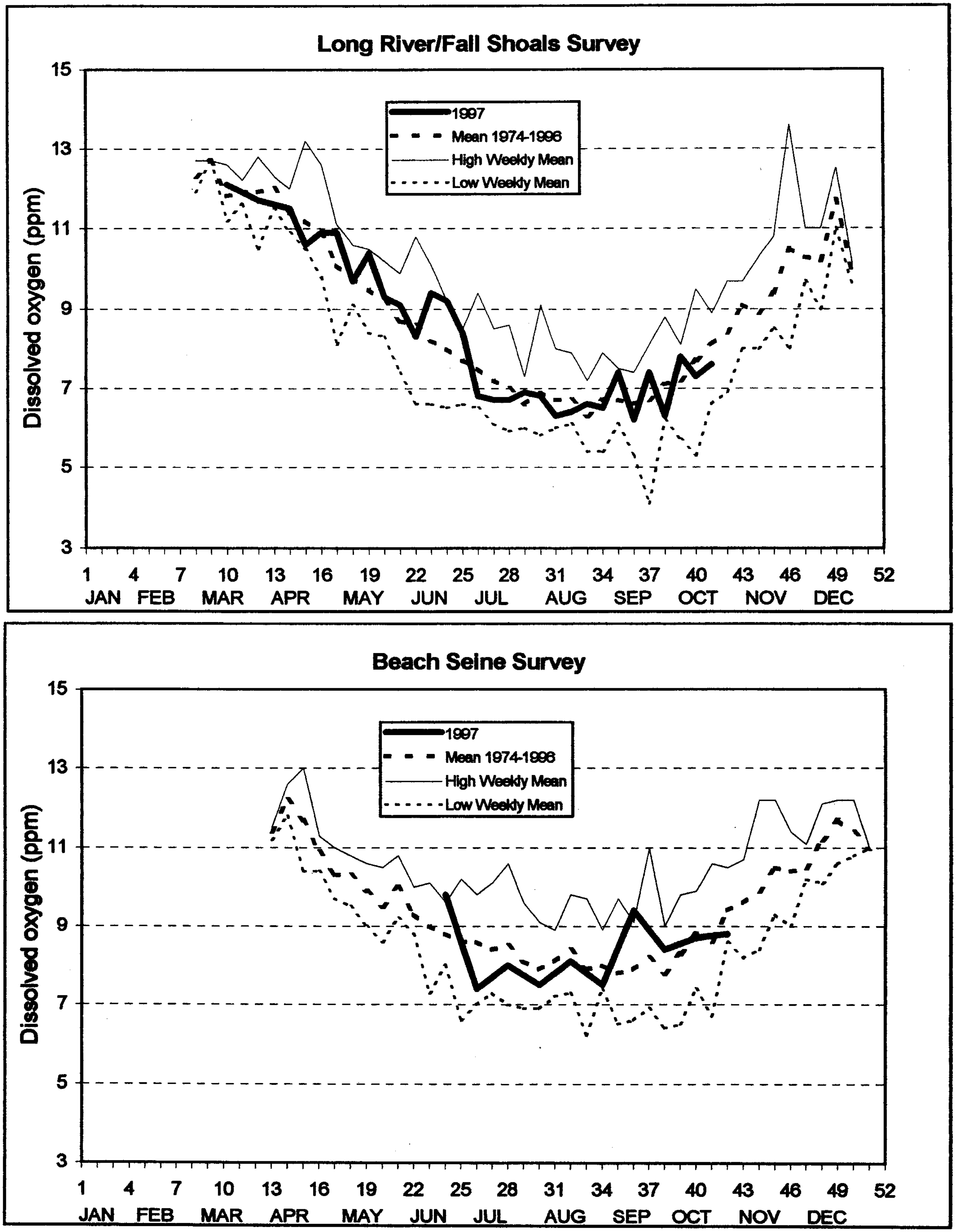


Figure 3-5. Seasonal variations in dissolved oxygen from the Hudson River surveys, 1974-1997.