Fishes Spawning in Non-tidal Portions of Hudson River Tributaries

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INTRODUCTION

One of the perceived values of estuaries in general and the Hudson River in particular is the presence of abundant anadromous fishes. The river herrings (Alosa pseudoharengus and A. aestivalis) and the rainbow smelt (Osmerus mordax) are commercially and recreationally significant species as well as playing a significant (and essentially unknown) ecological role in the Hudson. One poorly known aspect of the life history of these organisms is the role that tributaries play in reproduction. The purpose of this study was to evaluate the non-tidal portions of tributaries as spawning areas for anadromous fishes and to observe spawning of resident species as well. Of interest is which physico-chemical, anthropogenic, and possibly biological factors serve as controls on the process of larval fish production in tributaries. We report here on our attempts to evaluate the effects of geography, physiography, water quality, and land use on this process.

Generally, the interactions between the mainstem of the Hudson and its tributaries are poorly understood, particularly with regard to biological processes. Some new estimates of carbon and nutrient loadings from the watershed to the tidal freshwater portion of the mainstem have been made (R. Howarth, pers. comm.). In his study, urbanized parts of the watershed were found to contribute a disproportionately large share of material to the Hudson, presumably because of increased runoff and less sorption. This suggests that land use in different watersheds can be an important ecological factor to consider.

The tributaries draining the Hudson basin span a number of stream orders (sensu Horton 1945: a stream with no tributaries is first order, one with only first-order tributaries is second order, etc.). Can we expect that size (scale) plays a role in dictating the magnitude of various physical and ecological processes? Little work has been done on habitat scale in relation to fishes. Rozas and Odum (1987) found greatest utilization of second and third order streams by fish and macroinvertebrates in a freshwater tidal marsh system. There, availability of protective habitat (submersed macrophytes) was suggested as the main control on fish abundance. We proposed that spawning activity might also be a function of stream size, and designed the study in part to address this question.

Finally, we proposed that spawning activity would proceed temporally from south to north, as water temperatures rose; thus, position of a tributary along the estuary might be an important factor to consider as well.

Larval drift-

Downstream drift is a well documented phenomenon for invertebrates (Waters 1965, 1972; Hynes 1970; Muller 1974). Several basic questions of why drift occurs remain unanswered but invertebrate drift is strongly tied to light levels with drift beginning after sunset and often peaking within a few hours. Kotila (1988) showed that diurnal drift is more likely to occur in streams where there are no fish, suggesting that predation by sight feeders is minimized by nocturnally drifting organisms.

Fish larvae drift synchronously with invertebrates (Armstrong and Brown 1983, Elliott 1967, Clifford 1972, Reisen 1972, Griffith 1974, Mancini et al. 1979). These authors document a bigeminous pattern (Waters 1962, 1965) for larval fishes: a peak of drift approximately 2 hr after sunset and a smaller peak about 2-3 hr before sunrise.

Drift of fish larvae is also a behavior clearly tied to light levels (Muller 1978) and has been documented in many families (Manteifel et al. 1978). Most of the observations of larval fish drift have been in north temperate lotic systems, but this phenomenon occurs in tropical rivers as well (Elouard and Leveque 1977). Thus it appears that drift is a phenomenon common to most lotic fishes although there is specific variation in respect to thresholds of light level that they may respond to. Manteifel et al. (1978) suggested that smaller fishes will drift at higher light levels.

A number of studies have been done on larval fish drift in North America. Although methods differ in detail, many authors estimated larval transport by sampling drift with static nets over a period of time and estimating flow of the system. Clifford (1972) found that white sucker fry had pronounced nocturnal drift and drifted in higher densities than invertebrates. Mansfield (1984) found that small tributaries of Lake Michigan were important spawning areas for spottail shiners, white suckers, and alewives. Catfish alevins were observed in the nocturnal drift (Armstrong and Brown 1983) but could not be considered feeding. In larger rivers, drift sampling of fish larvae has become a significant part of impact assessment: Gale and Mohr (1978), Clark and Pearson (1980), Potter et al. (1978), Hess and Winger (1976), Harvey (1987), Carter et al. (1986), and Muth and Schmulbach (1984).

METHODS

Study Area

The unimpounded tidal Hudson estuary extends 243 km from the Federal Lock and Dam at Troy, NY to the Battery in Manhatten. There are 198 streams tributary to the estuary ranging from 1st to 9th order (NYSDEC 1988).

We selected 16 tributaries for this study (Table 1) based on tributary size, geographic location, our familiarity with the stream, known presence of anadromous fishes, correlation with other studies, and/or accessability (not necessarily in that order of priority). For analysis, tributaries were grouped into four geographic areas (Table 1) and a range of stream sizes were

Table 1. Tributaries sampled in the larval fish study. Watershed was estimated by digitizing 1:250,000 scale topographic maps.

Tributary Name	Location	Watershed Size km^2	River Reach
Sparkill	Piermont, Rockland Co.	20	I
Pocantico R.	Tarrytown, Westchester Co.	37	I
Unnamed	Ossining, Westchester Co.	8	I
Peekskill Hollow	N. of Peekskill, Westchester Co.	184	I
Moodna Crk.	New Windsor, Orange Co.	416	II
Quassaick Crk.	Newburgh, Orange Co.	36	II
Unnamed	N. edge Newburgh, Orange Co.	4	II
Fishkill Crk.	Beacon, Dutchess Co.	521	II
Black Crk.	Port Ewen, Ulster Co.	79	III
Rondout Crk.	Eddyville, Ulster Co.	3082	III
Crum Elbow Crk.	Hyde Park, Dutchess Co.	61	III
Saw Kill	Annandale, Dutchess Co.	55	III
Catskill Crk.	Catskill, Greene Co.	1030	IV
Hannacroix Crk.	N. of Albany Co. line	129	IV
Mill Crk.	N. of Hudson, Columbia Co.	10	IV
Vlockiekill	Castleton, Rensselaer Co.	31	IV

River reaches are: I= south of the Hudson Highlands (RM 24-44), II= north of but close to the Hudson Highlands (RM 58-63), III= Approximately between Poughkeepsie and Kingston (RM 82-98), and IV= between Hudson and Albany (RM 113-136).

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selected within each of the areas. The total area drained by these watersheds is approximately 5700 km^2, or 42% of the lower Hudson drainage (Limburg et al. 1986).

<u>Procedure</u>

1. <u>Field and Laboratory</u>

Efforts were made to sample each stream near the mouth but above the influence of the tide. This was not possible in every stream for every sample. The physiography and access to some of the streams (ie Pocantico and Sparkill) made it necessary to sample within tidal influence most of the time. Also, in many of the streams, high spring tides did reach our sampling stations at least once during the study.

Each stream was sampled weekly from March 15 through the end of June, 1988, for a total of 15 weeks. Four teams did the sampling so that all tributaries were sampled within a 24 hr period of each other (barring accidents and weather). Sampling was done after sundown but within 3 hr of sundown to catch the theoretical maximum drift of organisms.

Drift was sampled in one of two ways. In shallow streams (up to about 0.5 m deep), rectangular standard drift nets with 303 micron mesh as described by Waters (1962) were staked into the stream bed. In deeper streams, or in the same streams at high flows, 0.5 m circular plankton nets (500 micron mesh) were suspended from bridges. In some streams, where volume of flow changed drastically over the study period or during storm events, the sampling device was chosen on the spot and is not necessarily consistant from sample to sample or stream to stream in a given week. Three nets (either drift or plankton) were fished for each sample.

Nets were to be deployed for about 20 min, a time that the literature suggested was reasonable for sampling fishes. Each team, however, could reduce the time nets were fished if water velocities were high and/or large amounts of debris were present. (During the height of alewife spawning in Crum Elbow Creek, nets held in place for 30 sec caught several thousand eggs.) Times that nets were put in and taken out were recorded so we could calculate actual fishing time for each net.

When nets were retrieved, contents (fishes, invertebrates, detritus) were emptied and backwashed into glass jars and formaldehyde was added to approximate a 10% solution in the field. Those preserved samples were returned to the laboratory.

While nets were fishing, estimates of flow were made in order to calculate volume of water sampled by the nets. Water velocities were estimated by timing the drift of a stick over a measured distance. Measurements were in triplicate. If velocities were obviously different at the different nets, velocities were measured near each net. Thus, knowing the surface area of the net mouth and velocity, we could calculate volume of water sampled. If nets were not totally submerged, the field teams measured the distance from the water surface to the top of the drift net opening with a meter stick or visually estimated the percent of the plankton net that was submerged. The area of the net mouth actually fishing was calculated accordingly.

In order to calculate instantaneous transport from a given tributary, we also had to obtain an estimate of total flow for each stream. In small streams that were wadable, bank to bank depth transects were taken with a tape and a meter stick. In larger streams we used USGS flow data where available (Rondout Creek only in this study, most USGS stations are now inoperative in the Hudson Valley). For larger streams where no current USGS data were available, we derived regressions of watershed area vs stream flow from historic and 1988 USGS data and then used the

1988-based regressions to estimate flows in a stream from flows on the same date from current USGS stations.

Besides the above, we routinely measured three water quality parameters. Water temperature was measured with a hand-held thermometer. Dissolved oxygen was measured by the azide modification of the Winkler method (APHA et al. 1965). Water samples were fixed in BOD bottles in the field using prepackaged Hach chemicals, substituting sulfamic acid for sulfuric. Titrations were done within two days in the laboratory using PAO as the titrant. Additionally, a water sample was collected and pH was measured in the laboratory.

Fishes and macroinvertebrates were sorted from the samples by eye or with a low power stereo dissecting microscope. All organisms were stored in 70% ethanol following the suggested protocol for fish larvae (Lavenberg et al. 1987). Fishes were stored in 20 ml scintillation vials except for a few large samples.

Fishes were identified by sight or by referencing the following: Auer (1982), Fuiman et al. (1983), and Lippson and Moran (1974). Specimens were classified into one of four categories: Egg, Yolk-sac larvae, Post yolk-sac larvae (no yolk sac visible), or Other. The latter category included juveniles (full complement of fin rays), adults, elvers (American eel), and ammocoetes (sea lamprey). Specimens in each species and each category were counted by direct count with a few exceptions. Some samples contained large numbers of alewife eggs and numbers were derived by counting an aliquot and estimating the total numbers volumetrically.

Numbers were converted to densities (per cubic meter) for each sample which were then averaged for each river and date from the triplicate samples. Instantaneous transport (#/sec) was estimated by multiplying densities by the estimated total river flow (from regressions).

2. Geographic Analysis

Maps were used to evaluate geographic and anthropogenic influences. Geographic locations of tributary mouths were measured in river miles (RM) with RM=0 located by convention at the southern tip of Manhattan. Mylar land-use overlay maps (1:250,000 scale) were obtained from the USGS National Cartographic Information Center and were placed over corresponding topographic sheets to demarcate approximate watershed boundaries. Areas within watersheds were then grouped into seven land-use categories (barren, industrial & road, urban/suburban residential, agriculture and pasture, woodland, range & scrub, and open water) and areas were measured with a digitizer.

3. Data Analysis

Data were initially plotted as time-series for each tributary, and examined for patterns and trends. Correlations and both simple and multiple linear regressions were performed to explore relationships among the variables. Examination of residuals and other tests were performed to determine multicollinearity problems and violation of the assumption of normally distributed data. Dependent variables included: total numbers of eggs and larvae, anadromous species (eggs and larvae), and resident species (eggs and larvae). Analyses of individual species and lifestages are not included in this report.

RESULTS

Physico-Chemical

Data on temperature, dissolved oxygen (DO), and pH for each stream and sample event are included in Appendix 1. Summaries are presented in Figures 1-4. In Figures 1-3, tributaries have been grouped into four river reaches from south to north (See Table 1). Results in Figures 1-3 are means and standard deviations of the four tributaries in each reach.

Temperatures generally increased throughout the sampling period, although an early warming was followed by several cool weeks. Dissolved oxygen levels ranged from a high of 16.4 mg O_2/L (Peekskill Hollow Brook, March 19) to a low of 5.3 mg/L (Sparkill, May 20). Another way to view DO concentrations is percent of the saturation value at a given temperature; super-saturated values are typical of well-aerated streams, while undersaturation indicates an oxygen deficit created by an organic load in the water. Viewed this way, one pattern is apparent (Fig. 3): percent saturated DO among streams was most variable in

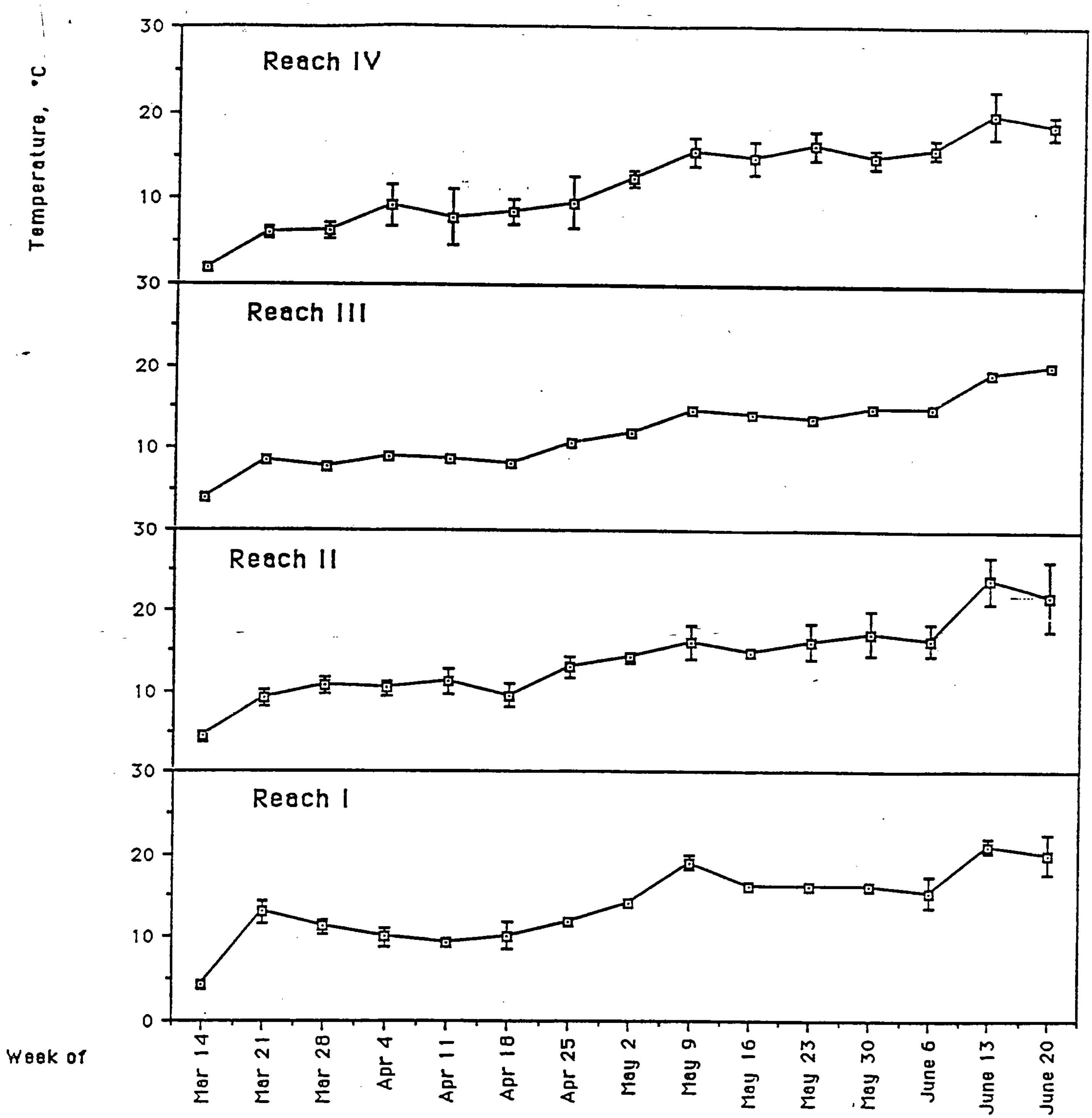

Figure 1. Average (open squares) and standard deviations (vertical lines) of temperatures in Hudson River tributaries, 1988. See Table 1 for definitions of Reaches.

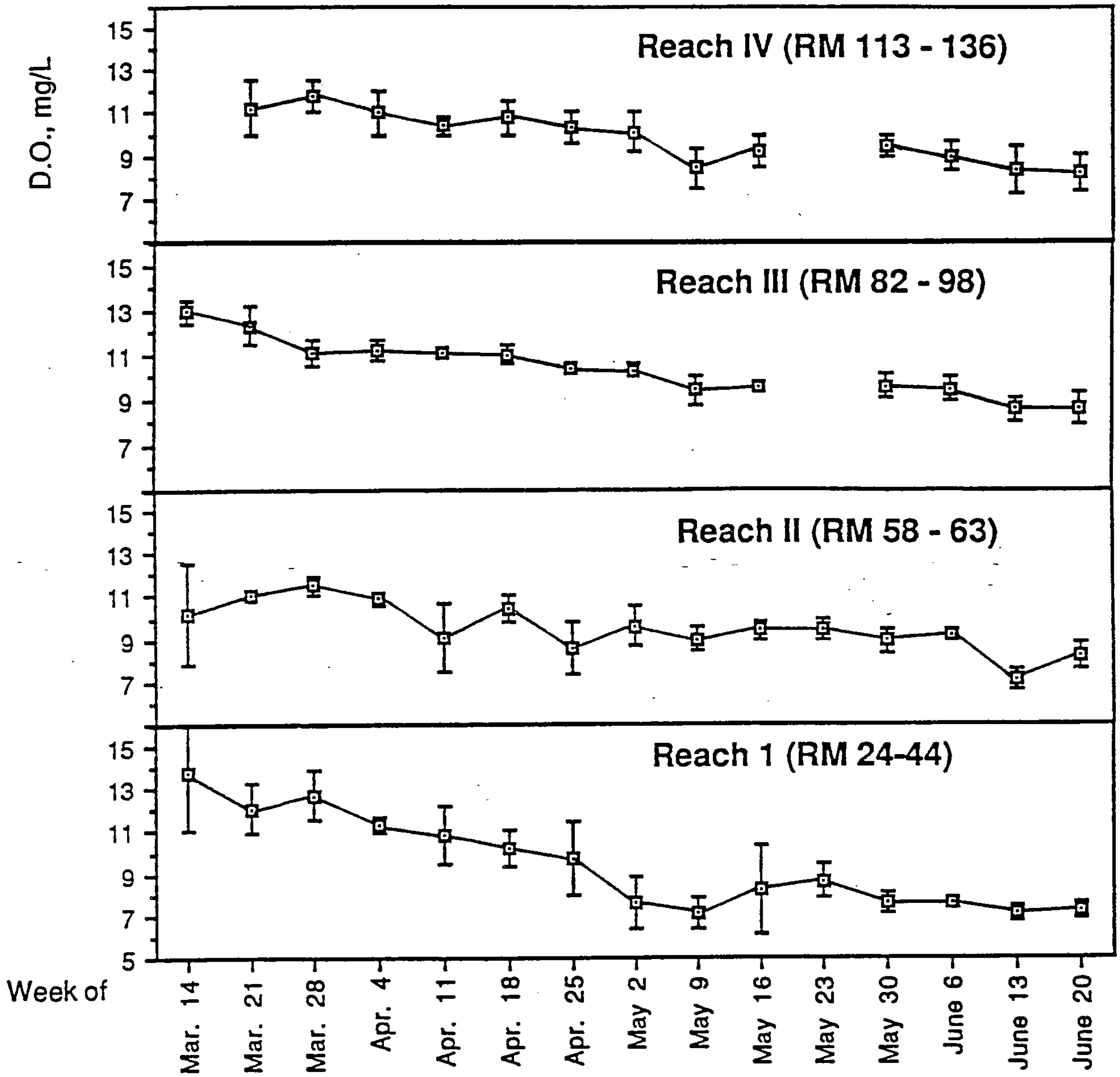

Figure 2. Average (open squares) and standard deviation (vertical lines) of dissolved oxygen from Hudson River tributaries, 1988. See Table 1 for definition of Reaches.

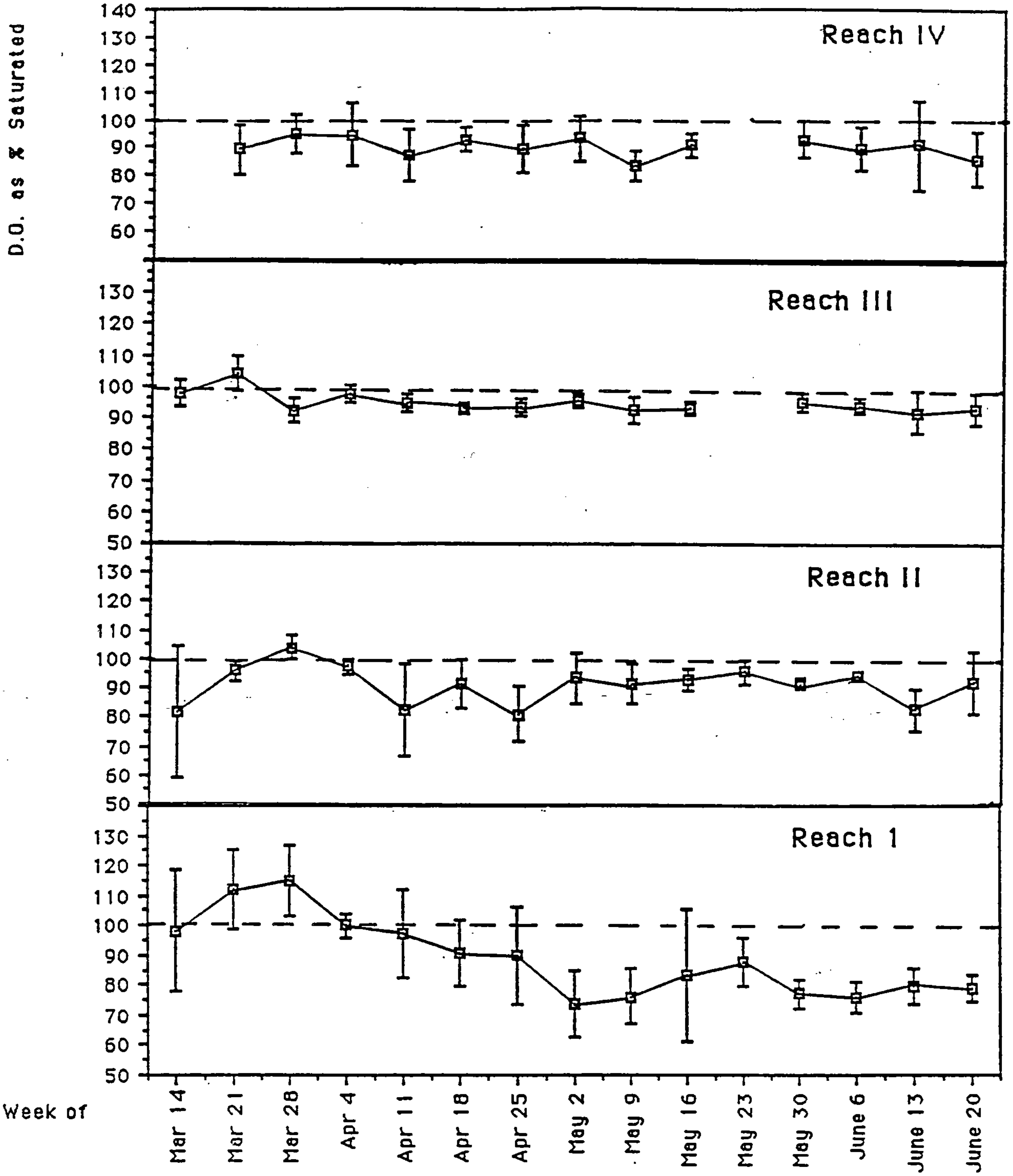

Figure 3. Average (open squares) and standard deviation (vertical lines) of dissolved oxygen as percent of saturation for Hudson River tributaries, 1988. See Table 1 for definition of Reaches.

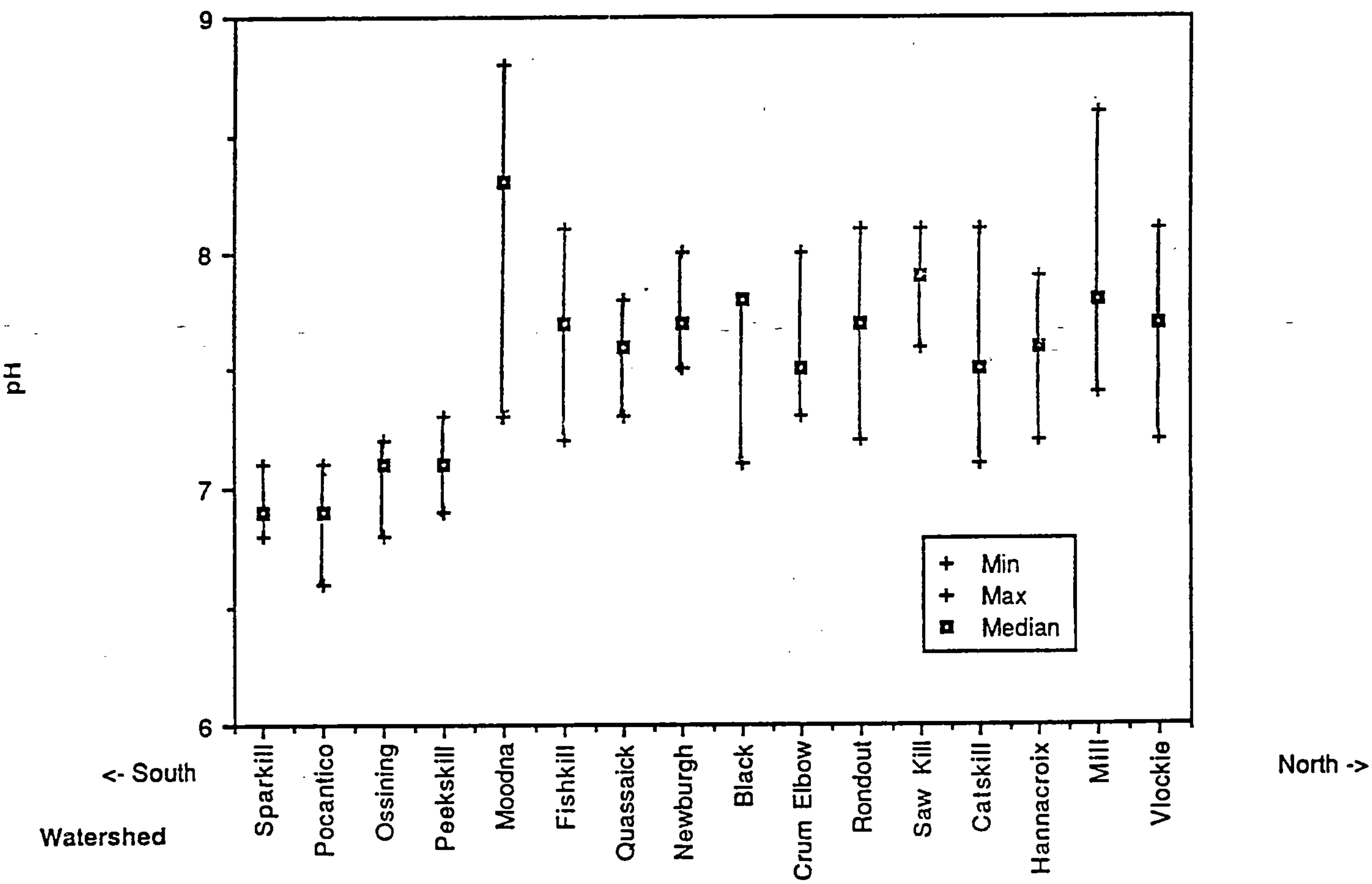

Figure 4. Median and range of pH values (standard units) for tributaries of the Hudson River, mid-March through the end of June, 1988.

Reach I, showing a general decline as temperatures increased, whereas lowest interstream variability was seen in Reach III, where DO values remained close to saturation.

Another pattern is seen in the pH data. Fig. 4 plots streams on the abcissa from south to north, and minimum, maximum, and median pH values on the ordinate. All four southern streams (Reach I) differ from the other 12 streams by over half a pH unit. Although this may be due to a consistent sampling error (there were different people measuring pH in the different reaches), this difference is more likely to be a function of local geological conditions. The geology of the lower Hudson valley up through the Hudson Highlands is a complex of various crystalline rock formations (Van Diver, 1985); from the Highlands north to Albany, soils are fairly well buffered by a mix of shale and limestone bedrock. Schmidt et al. (1978) observed significant pH depression in the upper Byram River during the winter. The Byram shares the same bedrock geology as our Reach I streams.

The high pH values in Moodna Creek are unexplained. These values are similar to pH values measured in Moodna Creek in an ongoing study of the water quality of this stream.

Fishes

Altogether more than 70,000 specimens of eggs and larvae were collected in the 15-week sampling period (Appendix 2); most of them originated from a subset of the tributaries in Reach III.