Appendix V

APPENDIX V

Appendix V-1

List of Utility Sponsored Studies

I. **Impingement**

A. **Indian Point Monitoring**

Hudson River Ecological Study in the Area of Indian Point. 1990 Annual Report. Lawler, Matusky & Skelly Engineers, October 1991.

Hudson River Ecological Study in the Area of Indian Point. 1989 Annual Report. Lawler, Matusky & Skelly Engineers, July 1990.

Hudson River Ecological Study in the Area of Indian Point. 1988 Annual Report. EA Engineering, Science, and Technology, November 1989.

Hudson River Ecological Study in the Area of Indian Point. 1987 Annual Report. EA Engineering, Science, and Technology, July 1988.

Hudson River Ecological Study in the Area of Indian Point. 1986 Annual Report. Normandeau Associates, Inc., August 1987.

Hudson River Ecological Study in the Area of Indian Point. 1985 Annual Report. Normandeau Associates, Inc., September 1986.

Hudson River Ecological Study in the Area of Indian Point. 1984 Annual Report. Martin Marietta Environmental Systems, July 1985.

Hudson River Ecological Study in the Area of Indian Point. 1983 Annual Report. Normandeau Associates, Inc., June 1984.

Hudson River Ecological Study in the Area of Indian Point. 1982 Annual Report. Consolidated Edison Company of New York, Inc., November 1983.

Hudson River Ecological Study in the Area of Indian Point. 1981 Annual Report. Consolidated Edison Company of New York, Inc., August 1982.

B. **Bowline Point Monitoring**

Bowline Point Generating Station 1997 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1998.

Bowline Point Generating Station 1996 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1997.

Bowline Point Generating Station 1995 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1996.

Bowline Point Generating Station 1994 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1995.

Bowline Point Generating Station 1993 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1994

Bowline Point Generating Station. 1991 Impingement Studies. Normandeau Associates, Inc., July 1992.

1990 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, May 1991.

1989 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, May 1990

1988 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, May 1989.

1987 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, June 1988.

1986 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, June 1987.

1985 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, May 1986.

1984 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, May 1985.

1983 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, June 1984.

1982 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, June 1983.

1981 Impingement Studies at the Bowline Point Generating Station. Lawler, Matusky & Skelly Engineers, June 1982.

C. **Lovett Point Monitoring**

Lovett Generating Station 1997 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1998.

Lovett Generating Station 1996 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1997.

Lovett Generating Station 1995 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1996.

Lovett Generating Station 1994 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1995.

Lovett Generating Station 1993 Impingement Studies. Prepared for Orange and Rockland Utilities, Incorporated. Normandeau Associates Inc. 1994

D. **Roseton and Danskammer Point Monitoring**

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1997 Annual Progress Report. Normandeau Associates. 1998.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1996 Annual Progress Report. Normandeau Associates. 1997.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1995 Annual Progress Report. Normandeau Associates. 1997.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1994 Annual Progress Report. Normandeau Associates. 1996.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1993 Annual Progress Report. Normandeau Associates. 1996.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1990 Annual Progress Report. Normandeau Associates, Inc., January 1992.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1989 Annual Progress Report. Normandeau Associates, Inc., August 1990.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1992 Annual Progress Report. Lawler, Matusky & Skelly Engineers. 1994.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1991 Annual Progress Report. Lawler, Matusky & Skelly Engineers. 1993.

Impingement Monitoring Program at the Roseton and Danskammer Point Generating Stations. 1988 Annual Progress Report. Lawler, Matusky & Skelly Engineers, June 1989.

Impingement Monitoring Program at the Roseton and Danskammer Point Generating Stations. 1987 Annual Progress Report. Lawler, Matusky & Skelly Engineers, June 1988.

Impingement Monitoring Program at the Roseton and Danskammer Point Generating Stations. 1986 Annual Progress Report. Lawler, Matusky & Skelly Engineers, June 1987.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Programs. 1985 Annual Progress Report. EA Engineering, Science, and Technology, June 1986.

Roseton and Danskammer Point Generating Stations Impingement Monitoring Program. 1984 Annual Progress Report. EA Engineering, Science, and Technology, June 1985.

Impingement Monitoring at Roseton and Danskammer. 1983 Annual Progress Report. Lawler, Matusky & Skelly Engineers, May 1984.

Impingement Abundance Sampling at Roseton and Danskammer Point Generating Stations. Annual Progress Report 1982. Lawler, Matusky & Skelly Engineers, June 1983.

Impingement Abundance Sampling at Roseton and Danskammer Point Generating Stations. Annual Progress Report 1981. Lawler, Matusky & Skelly Engineers, June 1982.

E. **Impingement Special Studies**

Precision and Accuracy of Stratified Sampling To Estimate Fish Impingement at Indian Point Units Nos. 2 and 3. Normandeau Associates, Inc., November 1984.

Biological Evaluation of 0.95 cm Mesh Barrier Net Deployed To Mitigate Fish Impingement at the Bowline Point Generating Station Cooling Water Intake. Lawler, Matusky & Skelly Engineers, August 1983.

Bowline Point Generating Station Entrainment Abundance and Impingement Survival Studies. 1981 Annual Report. EA Engineering, Science, and Technology, July 1982.

II. Entrainment

A. Indian Point Monitoring

Indian Point Generating Station Entrainment Abundance Program. 1987 Annual Report. Normandeau Associates, Inc., May 1988.

Indian Point Generating Station Entrainment Abundance Program. 1986 Annual Report. Normandeau Associates, Inc., June 1987.

Indian Point Generating Station Entrainment Abundance Program. 1985 Annual Report. Normandeau Associates, Inc., April 1987.

Indian Point Generating Station Entrainment Abundance and Outage Evaluation. 1984 Annual Report. EA Engineering, Science, and Technology, July 1985.

Indian Point Generating Station Entrainment Abundance and Outage Evaluation. 1983 Annual Report. EA Engineering, Science, and Technology, September 1984.

Hudson River Ecological Study in the Area of Indian Point. 1981 Annual Report. Consolidated Edison Company of New York, Inc., August 1982.

B. Bowline Point Monitoring

1987 Annual Report. Entrainment Abundance and Unit Outage Evaluation for. Bowline Point Generating Station. EA Engineering, Science, and Technology, April 1989.

Bowline Point Generating Station Entrainment Abundance and Unit Outage Evaluation. 1986 Annual Report. EA Engineering, Science, and Technology, September 1987.

Bowline Point Generating Station Entrainment Abundance and Unit Outage Evaluation. 1985 Annual Report. EA Engineering, Science, and Technology, June 1986.

Bowline Point Generating Station Entrainment Abundance and Unit Outage Evaluation. 1984 Annual Report. EA Engineering, Science, and Technology, July 1985.

Bowline Entrainment Abundance and Unit Outage Evaluation. 1983 Annual Report. EA Engineering, Science, and Technology, June 1984.

Bowline Point Generating Station Entrainment Abundance and Unit Outage Evaluation. 1982 Annual Report. EA Engineering, Science, and Technology, September 1983.

Bowline Point Generating Station Entrainment Abundance and Impingement Survival Studies. 1981 Annual Report. EA Engineering, Science, and Technology, July 1982.

C. **Lovett Point Monitoring**

EA Engineering, Science, and Technology. 1998. 1997 Ichthyoplankton Entrainment Monitoring Study at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Incorporated.

D. Roseton and Danskammer Point Monitoring

Roseton and Danskammer Point Generating Stations Entrainment Abundance Studies. 1987 Report. EA Engineering, Science, and Technology, June 1988.

Roseton and Danskammer Point Generating Stations Entrainment Abundance Studies. 1986 Report. EA Engineering, Science, and Technology, May 1987.

Entrainment Abundance Monitoring Program at the Roseton and Danskammer Point Generating Stations. 1985 Progress Report. Lawler, Matusky & Skelly Engineers, May 1986.

Entrainment Abundance Monitoring Program at the Roseton and Danskammer Point Generating Station. 1984 Progress Report. Lawler, Matusky & Skelly Engineers, June 1985.

Roseton and Danskammer Point Generating Stations Entrainment Abundance Studies. 1983 Report. EA Engineering, Science, and Technology, June 1984.

Roseton and Danskammer Point Generating Stations Entrainment Abundance Studies. 1982 report. EA Engineering, Science, and Technology, June 1983.

Roseton Generating Station Entrainment Abundance Studies. 1981 Report. EA Engineering, Science, and Technology, July 1982.

E. Entrainment Special Studies

Ichythoplankton Monitoring Study, Deployment of a Gunderboom System at Lovett Generating Station Unit 3, 1998. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Incorporated, New York Power Authority, Niagara Mohawk Power Corporation, Orange and Rockland Utilities, Incorporated. Applied Science Associates. 1999.

Lovett Generating Station Gunderboom Evaluation Program 1997. Prepare for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Incorporated, New York Power Authority, Niagara Mohawk Power Corporation, Orange and Rockland Utilities, Incorporated. Lawler, Matusky & Skelly Engineers LLP. 1998.

Lovett Generating Station Gunderboom Evaluation Program 1996. Prepared for Orange and Rockland Utilities, Incorporated. Lawler, Matusky & Skelly Engineers LLP. 1997.

Lovett Generating Station Gunderboom Evaluation Program 1995. Prepared for Orange and Rockland Utilities, Incorporated. Lawler, Matusky & Skelly Engineers LLP. 1996.

Effectiveness Evaluation of a Fine Mesh Barrier Net Located at the Cooling Water Intake of the Bowline Point Generating Station. 1994. Prepared for Orange and Rockland Utilities, Incorporated. Lawler, Matusky & Skelly Engineers LLP. 1996

Effectiveness Evaluation of a Fine Mesh Barrier net located at the Cooling Water Intake of the Bowline Point Generating Station. 1993. Prepared for Orange and Rockland Utilities, Incorporated. Lawler, Matusky & Skelly Engineers LLP. 1994.

Addendum To Evaluation of Entrainment Abundance Sampling Designs. Schwager, S.J., G. Casella, D.S. Robson, W.D. Youngs, February 1990.

Indian Point Generating Station 1988 Entrainment Survival Study. EA Engineering, Science, and Technology, August 1989.

1986 Winter-Spring Entrainment Abundance Program. Indian Point Generating Station Final Report. EA Engineering, Science, and Technology, May 1987.

Evaluation of Entrainment Abundance Sampling Designs. Casella, G., D.S. Robson, S.J. Schwager, W.D. Youngs, July 1986.

Indian Point Generating Station Entrainment Survival Study. 1985 Annual Report. EA Engineering, Science, and Technology, July 1986.

A Critical Review of Thermal Modeling Studies. Lawler, Matusky & Skelly Engineers, July 1985.

Roseton Generating Station Entrainment Survival Studies. 1980 Annual Report. EA Engineering, Science, and Technology, April 1983.

Gear Comparability Study for Entrainment Sampling of Juvenile Fish at the Indian Point Station, 1981. Normandeau Associates, Inc., June 1982.

III. Fish Stock Assessment

A. General

1995 Year Class Report for the Hudson River Estuary Monitoring Program, Newburgh, NY. EA Engineering, Science, and Technology. 1997.

1994 Year Class Report for the Hudson River Estuary Monitoring Program, Newburgh, NY. Consolidated Edison Company of New York, Inc. 1997b.

1993 Year Class Report for the Hudson River Estuary Monitoring Program, Newburgh, NY. Consolidated Edison Company of New York, Inc. 1997a.

1990 Year Class Report for the Hudson River Estuary Monitoring Program. Lawler, Matusky & Skelly Engineers, January 1992.

1989 Year Class Report for the Hudson River Estuary Monitoring Program. EA Engineering, Science, and Technology, March 1991.

1988 Year Class Report for the Hudson River Estuary Monitoring Program. EA Engineering, Science, and Technology, August 1990.

1986 and 1987 Year Class Report for the Hudson River Estuary Monitoring Program. Lawler, Matusky & Skelly Engineers, June 1989.

1985 Year Class Report for the Hudson River Estuary Monitoring Program. Versar, Inc., October 1987.

1984 Year Class Report for the Hudson River Estuary Monitoring Program. Martin Marietta Environmental Systems, May 1986.

1983 Year Class Report for the Hudson River Estuary Monitoring Program. Normandeau Associates, Inc., April 1985.

1982 Year Class Report for the Hudson River Estuary Monitoring Program. Normandeau Associates, Inc., February 1985.

1980-1981 Year Class Report for the Hudson River Estuary Monitoring Program. Battelle New England Marine Research Laboratory, December 1983.

B. **Striped Bass**

Lawler, Matusky & Skelly Engineers LLP. 1999. Hudson River Striped Bass Stock Assessment Program November 1994 – April 1995. Prepared for New York Power Authority.

Lawler, Matusky & Skelly Engineers LLP. 1999. Hudson River Striped Bass Stock Assessment Program November 1995 – April 1996. Prepared for New York Power Authority.

Lawler, Matusky & Skelly Engineers LLP. 1999. Hudson River Striped Bass Stock Assessment Program November 1996 – April 1997. Prepared for New York Power Authority.

Robustness of the Hudson River Striped Bass Autoregressive Model and Hudson River Striped Bass Indices of Abundance. Coastal Environmental Sciences, Inc., July 1991.

Hudson River Striped Bass Tag Recovery Program. March 1987 - February 1988. Hudson River Foundation, October 1989.

Hudson River Striped Bass Stock Assessment Workshop Final Report. Volume 1 and Volume 2. Coastal Environmental Services, Inc., March 1989.

1986 Hudson River Striped Bass Tag Recovery Program. Hudson River Foundation, April 1988.

1985 Hudson River Striped Bass Tagging Program. Hudson River Foundation, May 1986.

1984 Hudson River Striped Bass Tagging Program. Hudson River Foundation, November 1985.

Relative Sensitivity of Hudson River Striped Bass To Competing Source Of Mortality and the Implications for Monitoring Programs. Applied Biomathematics, July 1983.

C. **White Perch**

Hudson River Estuary White Perch Adult and Subadult Stock Assessment Study. Fall 1988. Lawler, Matusky & Skelly Engineers, October 1989.

Hudson River Estuary White Perch Adult and Subadult Stock Assessment Study. Fall 1987. Lawler, Matusky & Skelly Engineers, August 1988.

Hudson River Estuary White Perch Adult and Subadult Stock Assessment Study. Fall 1986. Lawler, Matusky & Skelly Engineers, June 1987.

Hudson River Estuary White Perch Adult and Sub-Adult Stock Assessment Study, Fall 1985. Lawler, Matusky & Skelly Engineers, November 1986.

Final Report for the 1983-1984 Hudson River White Perch Stock Assessment Study. Normandeau Associates, Inc., July 1985.

Age, Growth, and Population Dynamics of White Perch in Haverstraw Bay. Lawler, Matusky & Skelly Engineers, July 1984.

Age, Growth and Population Dynamics of White Perch in Haverstraw Bay. Lawler, Matusky & Skelly Engineers, 1982.

D. **Atlantic Tomcod**

Abundance and Stock Characteristics of the Atlantic Tomcod Spawning Population in the Hudson River, Winter 1989-90. Normandeau Associates, Inc., May 1991.

Abundance and Stock Characteristics of the Atlantic Tomcod Spawning Population in the Hudson River, Winter 1988-89. Normandeau Associates, Inc., November 1990.

Abundance and Stock Characteristics of the Atlantic Tomcod (*Microgadus tomcod*) Spawning Population in the Hudson River, Winter 1987-1988. Normandeau Associates, Inc., September 1988.

Abundance and Stock Characteristics of the Atlantic Tomcod (*Microgadus tomcod*) Spawning Population in the Hudson River, Winter 1985-1986. Normandeau Associates, Inc., September 1987.

Abundance and Stock Characteristics of the Atlantic Tomcod (*Microgadus tomcod*) Spawning Population in the Hudson River, Winter 1983-1984. Normandeau Associates, Inc., September 1984.

Abundance and Stock Characteristics of the Atlantic Tomcod Spawning Population in the Hudson River, Winter 1982-83. Normandeau Associates, Inc., January 1984.

Stock Characteristics of the Hudson River Atlantic Tomcod Population During the 1980-81 & 1981-82 Spawning Seasons. EA Engineering, Science, and Technology, January 1983.

E. **Gear Evaluation**

Evaluation of Hudson River Beach Seine Programs Conducted By the New York State Utilities and the New York Department of Environmental Conservation. Versar, Inc., February 1988.

Size Selectivity and Relative Catch Efficiency of a 3 Meter Beam Trawl and a 1 Square Meter Epibenthic Sled for Sampling Young of the Year Striped Bass and Other Fishes in the Hudson River Estuary. Normandeau Associates, Inc., January 1986.

Striped Bass Tag Loss and Mortality in Holding Pools. New York Power Authority, May 1985.

Ichthyoplankton Gear Evaluation Studies. 1984. Lawler, Matusky & Skelly Engineers, March 1985.

Relative Catch Efficiency of a 3-m Beam Trawl and a 6.2-m High Rise Trawl and a 1.0-m^2 Epibenthic Sled for Sampling Y.0.Y. Striped Bass and Other Fishes in the Hudson River Estuary.

Optimum Deployment & Relative Catch Efficiency of a 3-m Beam Trawl for Quantitative Fisheries Sampling in the Hudson River Estuary. New York Power Authority, November 1982.

IV. Striped Bass Hatchery

A. Hatchery Production

Hudson River Striped Bass Hatchery. 1990 Overview. EA Engineering, Science, and Technology, May 1991.

Hudson River Striped Bass Hatchery. 1989 Overview. EA Engineering, Science, and Technology, April 1990.

Hudson River Striped Bass Hatchery. 1988 Overview. EA Engineering, Science, and Technology, April 1989.

Hudson River Striped Bass Hatchery. 1987 Overview. EA Engineering, Science, and Technology, January 1988.

Hudson River Striped Bass Hatchery. 1986 Overview. EA Engineering, Science, and Technology, June 1987.

Hudson River Striped Bass Hatchery. 1985 Overview. EA Engineering, Science, and Technology, November 1986.

Hudson River Striped Bass Hatchery. 1984 Overview. EA Engineering, Science, and Technology, February 1985.

Hudson River Striped Bass Hatchery. Design Through First Year of Operation. EA Engineering, Science, and Technology, February 1984.

B. **Hatchery Evaluation**

1988-89 Hudson River Striped Bass Hatchery Evaluation. Normandeau Associates, Inc., January 1990.

Distribution of Hatchery Striped Bass in the Hudson River, 1987. Lawler, Matusky & Skelly Engineers, June 1989.

Distribution of Hatchery Striped Bass in the Hudson River. Lawler, Matusky & Skelly Engineers, October 1988.

1987-88 Hudson River Striped Bass Hatchery Evaluation. Normandeau Associates, Inc., July 1988.

1986-1987 Hudson River Striped Bass Hatchery Evaluation. Normandeau Associates, Inc., September 1987.

1985-86 Hudson River Striped Bass Program. Normandeau Associates, Inc., December 1986.

An Overall Study Design for a Hatchery Evaluation and Population Assessment for Hudson River Striped Bass. Martin Marietta Environmental Systems, July 1986.

Adult Striped Bass Tagging Program. Spring 1984 - January 1985. Normandeau Associates, Inc., 1985.

Final Report On Review and Evaluation of Fish Marking Techniques. Battelle New England Marine Research Laboratory, April 14 1983.

V. **Outage and Flow Restriction Evaluation**

Assessment of Mitigation Value of Outage and Flow Reduction. Phase IV Final Report. Coastal Environmental Services, Inc., April 1991.

ETM/EIM Applications for Outage Evaluation at Three Hudson River Generating Stations. Lawler, Matusky & Skelly Engineers, February 1988.

Evaluating the Effectiveness of Outages: Phase III Report. Versar, Inc., November 1987.

Evaluating the Effectiveness of Outages - Objective II: Adequacy of Experimental Designs for the Long River, Fall Juvenile, and In-Plant Entrainment Programs. Martin Marietta Environmental Systems, April 1986.

Evaluating the Effectiveness of Outages Objective I: Enumeration And Review of Statistical Estimators for Biological Parameters. Martin Marietta Environmental Systems, March 1986.

Methods for Defining and Evaluating Assessment Levels To Determine Outage Effectiveness for Entrainment Reduction. Martin Marietta Environmental Systems, March 1984.

VI. **Cooling Water System Evaluations**

Central Hudson Gas & Electric Corporation, Roseton Steam Electric Station Cooling Tower Installation Study, February 1978.

Cooling Tower Study, Bowline Point Station, Units 1 and 2, June 1977.

Economic and Environmental Impacts of Alternative Closed-Cycle Systems for Indian Point Unit 2, December 1, 1974.

Economic and Environmental Impacts of Alternative Closed-Cycle Systems for Indian Point Unit 3, January 1976.

Environmental Analysis of Natural Draft Cooling Towers for Bowline Generating Station, January 1977.

Report on Cost-Benefit Analysis of Operation of Hudson River Steam Electric Units With Once-Through and Closed-Cycle Cooling Systems, July 1, 1977.

Roseton Generating Station Engineering, Environmental (Non-biological), and Economic Aspects of a Closed-Cycle Cooling System, July 1977.

VII. **Miscellaneous**

Workplans for Projecting Ecological Consequences and Assessing Economic Benefits and Costs of Potential Alternative Actions to Mitigate Power Plant Impacts on Hudson River Fish Populations. Coastal Environmental Services, Inc., July 1991.

1979 and 1980 Data Analysis and Application of Empirical Models of Hudson River Fish Populations. Lawler, Matusky & Skelly Engineers, August 1983.

Appendix V-2

Indices of Abundance Based on data from the Utilities Longitudinal River Survey, Fall shoals Survey, and Beach Seine Survey

Indices of Abundance Based on Data from the Utilities' Longitudinal River Survey, Fall Shoals Survey, and Beach Seine Survey

Introduction

Annual indices of abundance for 13 species of finfish that are presented in the DEIS are based on data from the utilities' Longitudinal River Survey (LRS), Fall Shoals Survey (FSS) and Beach Seine Survey (BSS). For some of these species, indices of abundance based on other sampling programs (e.g., the striped bass mark-recapture program and the Atlantic tomcod mark-recapture program) are also presented in the DEIS and are documented in other Appendices. This appendix documents the methods used to calculate the indices of abundance that are based on the LRS, FSS and BSS.

For each of the 13 species, one or more sampling programs was selected to be the basis for the index of abundance. The selections considered when and where each species was expected to be present in the Hudson River based on life-history characteristics of each species in relation to the times and places sampling gear is deployed by each program. The selections were also based on observed catch rates from each of the three sampling programs.

The sampling programs on which the indices of abundance are based are summarized in Table 1. The statistical methods used to estimated the annual indices of abundance are described in the following sections. Summaries of the indices of annual abundance for the 13 species are presented in Tables 2 through 14.

Beach Seine Survey

Indices of abundance using data from the utilities' Beach Seine Survey (BSS) were calculated for striped bass, white perch, American shad, bluefish, and spottail shiner juveniles, and for yearling and older white catfish. Weeks 33 to 40 were selected as the only period consistently sampled in the BSS in those years. The Beach Seine Survey Index of abundance (*B*) for each year and species is a measure of catch per haul and is calculated according to the following formula:

$$B = \frac{1}{n} \sum_{w=33}^{40} \left[\frac{\sum_{i=1}^{12} W_i \left(\frac{\sum_j Ct_{jiw}}{h_{iw}} \right)}{\sum_{i=1}^{12} W_i} \right] X_w ,$$

where

B	=	the BSS index for a species in a year;
Ct_{jiw}	=	the count of a species in sample *j*, region *i*, and week *w*;
X_w	=	1 if week *w* was sampled during the year, 0 otherwise;
n	=	the number of weeks sampled in the year,
	=	$\sum_{w=33}^{40} X_w$;
h_{iw}	=	the number of seine hauls in region *i* and week *w*; and
W_i	=	the number of beaches in the sampling design in river region *i*.

The above equation can be expressed in terms of a weighted average catch per haul (CPH) as follows:

$$B = \frac{1}{n} \sum_{w=33}^{40} \bar{Y}_w X_w = \frac{1}{n} \sum_{w=33}^{40} \left[\frac{\sum_{i=1}^{12} W_i \bar{Y}_{wi}}{\sum_{i=1}^{12} W_i} \right] X_w ,$$

where

$\bar{Y}_{wi}$	=	the average CPH in week *w* and region *i* and
$\bar{Y}_w$	=	the weighted average CPH in week *w*.

Because not all weeks within the period of week 33 to 40 were sampled by the BSS in each year, the variance of the BSS index in any year is calculated as a two-stage variance. The primary sampling unit in the first stage is weeks, and the design is assumed to be simple random sampling (i.e., weeks of sampling are construed to be a random sample of weeks within the period from week 33 through week 40). The sampling units in the second stage are regions, and the design is stratified random where regions are the statistical strata. The variance is calculated using a two-stage estimator based on equation 11.24 in Cochran (1977, p. 303):

$$\mathrm{var}(B) = \frac{\left(1 - \frac{n}{N}\right)}{n} S_1^2 + \frac{1}{Nn} \sum_w S_{2,w}^2 ,$$

where

S_1^2	=	the first stage variance (temporal, among weeks),
$S_{2,w}^2$	=	the second stage variance (spatial) in week w, and
N	=	the number of weeks (8) within the selected period, i.e., weeks 33 through 40.

The first stage variance component is estimated as

$$S_1^2 = \frac{1}{n-1} \sum_{w=33}^{40} \left(\bar{Y}_w - B\right)^2 .$$

The second stage variance component is estimated as

$$S_{2,w}^2 = \frac{\sum_{i=1}^{12} W_i^2 \left[\frac{\sum_j \left(Ct_{jiw} - \frac{1}{h_{iw}} \sum_j Ct_{jiw} \right)^2}{(h_{iw})(h_{iw}-1)} \right]}{\left(\sum_{i=1}^{12} W_i \right)^2} .$$

Then std. err.$(B) = (\mathrm{var}(B))^{1/2}$.

Fall Shoals Survey

Indices of abundance using data from channel sampling by the Fall Shoals Survey (FSS) were calculated for juvenile blueback herring, alewife, bay anchovy, weakfish, and rainbow smelt for the years 1979 through 1997, the years that the channel was sampled. In addition, indices of abundance based on bottom sampling by the FSS were calculated for juvenile hogchoker. Weeks 33 to 40 were selected as the only period consistently sampled in the FSS in those years. The Fall Shoals Survey Index of abundance (*F*) for each year and species sampled in gear specific for either the channel or the bottom is a measure of average density and is calculated according to the following formula:

$$F_g = \frac{1}{n}\sum_{w=33}^{40}\left[\frac{\sum_{i=1}^{12}\sum_{s=1}^{3} V_{is}\left(\frac{\sum_j Ct_{jiswg}}{\sum_j v_{jiswg}}\right)}{\sum_{i=1}^{12}\sum_{s=1}^{3} V_{is}}\right] X_w,$$

where

F_g	=	the FSS index (for gear *g*) for a species in a year;
Ct_{jiswg}	=	the count of a species in sample *j* from gear *g*, region *i*, stratum *s*, and week *w*;
X_w	=	1 if week *w* was sampled during the year, 0 otherwise;
n	=	the number of weeks sampled in the year,
	=	$\sum_{w=33}^{40} X_w$;
v_{jiswg}	=	the volume of sample *j* from gear *g* in region *i* , stratum *s*, and week *w*; and
V_{isg}	=	the volume of stratum *s*, sampled by gear $_g$, in river region *i*.

The above equation can be expressed in terms of weighted average sample densities as follows:

$$F_g = \frac{1}{n}\sum_{w=33}^{40}\bar{Y}_{wg}X_w = \frac{1}{n}\sum_{w=33}^{40}\left[\frac{\sum_{i=1}^{12}\sum_{s=1}^{3} V_{si}\bar{Y}_{iswg}}{\sum_{i=1}^{12}\sum_{s=1}^{3} V_{si}}\right] X_w,$$

where

$\bar{Y}_{iswg}$	=	the average density of a species in samples from region *i*, stratum *s*, week *w*, and gear *g* and

$\bar{Y}_{wg}$ = the weighted average density of a species in samples from week w, and gear g.

Because not all weeks within the period of week 33 to 40 were sampled by the FSS in each year, the variance of the FSS index of abundance in any year is calculated as the sum of two components. The primary unit in the first stage is weeks, and the design is assumed to be simple random sampling (i.e., weeks of sampling are construed to be a random sample of weeks within the period from week 33 through week 40). The sampling units in the second stage are region-(habitat) strata, and the design is stratified random where region-(habitat) strata are the statistical strata. The variance is calculated using a two-stage estimator based on equation 11.24 in Cochran (1977, p. 303):

$$\operatorname{var}(F_g) = \frac{\left(1 - \frac{n}{N}\right)}{n} S^2_{1,g} + \frac{1}{Nn} \sum_w S^2_{2,gw} ,$$

where

$S^2_{1,g}$ = the first stage variance (temporal, among weeks),

$S^2_{2,gw}$ = the second stage variance (spatial) in week w, and

N = the number of weeks (8) within the selected period, i.e., weeks 33 through 40.

The first stage variance component is calculated as

$$S^2_{1,g} = \frac{1}{n-1} \sum_{w=33}^{40} \left(\bar{Y}_{wg} - F_g\right)^2 .$$

The second stage variance is calculated as

$$S^2_{2,gw} = \frac{\sum_{i=1}^{12} \sum_{s=1}^{3} \left[V^2_{isg} \frac{\left(\frac{h_{iswg} \sum_j \left(Ct_{jiswg} - \bar{C}t_{iswg}\right)^2}{h_{iswg} - 1} \right)}{\left(\sum_j v_{ijswg} \right)^2} \right]}{\left(\sum_{i=1}^{12} \sum_{s=1}^{3} V_{isg} \right)^2},$$

where

V_{isg} = the total volume of (habitat) stratum, s, and region, i, sampled by gear g.

Then std. err. $(F_g) = (\mathrm{var}(F_g))^{1/2}$.

3. Long River Survey

Indices of abundance using data from the utilities' Long River Survey (LRS) were calculated for striped bass, white perch, American shad, Atlantic tomcod and rainbow smelt. For striped bass, white perch and American shad, the indices are based on the post-yolk sac larvae (PYSL) life stage. For Atlantic tomcod and rainbow smelt, the indices are based on the juvenile life stage. The Long River Survey Index of abundance (L) for each year and species is a measure of average density and is calculated according to the following formula:

$$L = \sum_{w=firstwk}^{lastwk} \left[\frac{\sum_{i=1}^{12}\sum_{s=1}^{5} V_{is} \left(\dfrac{\sum_{j} Ct_{jisw}}{\sum_{j} v_{jisw}} \right)}{\sum_{i=1}^{12}\sum_{s=1}^{5} V_{is}} \right],$$

where

L	=	the LRS index for any species in any year;
Ct_{jisw}	=	the count of a species in sample j, region i, stratum s, and week w;
v_{jisw}	=	the volume of sample j from in region i , stratum s, and week w;
V_{is}	=	the volume of stratum s in river region i; and
firstwk	=	the first week included in the annual index of abundance:

striped bass, American shad, and white perch PYSL -- the first week of the year in which the sum of weekly density estimates (from the initial week of sampling in the year through the current week) exceeds 5% of the sum of densities over all weeks of sampling,
Atlantic tomcod juveniles -- week 19, and
rainbow smelt juveniles -- week 20;

lastwk = the last week included in the annual index of abundance:

striped bass, American shad, and white perch PYSL -- *firstwk* +7,
Atlantic tomcod juveniles -- week 22, and
rainbow smelt juveniles -- week 27.

The above equation can be expressed in terms of average sample density as follows:

$$L = \sum_{w=firtswk}^{lastwk} \overline{Y}_w = \sum_{w=firstwk}^{lastwk} \left[\frac{\sum_{i=1}^{12} \sum_{s=1}^{5} V_{si} \overline{Y}_{isw}}{\sum_{i=1}^{12} \sum_{s=1}^{5} V_{si}} \right],$$

where

$\overline{Y}_{isw}$ = the average density of a species in samples from region i, stratum s, and week w [Note: for strata and regions that were not sampled, predicted densities (based on regression predictors and densities in adjacent strata) were used] and

$\overline{Y}_w$ = the weighted average density of a species in samples collected during week w.

Variance of the index was estimated using the following equation:

$$\operatorname{var}(L) = \sum_{w=firstwk}^{lastwk} \left[\frac{\sum_s \sum_i V_{is}^2 \left(\frac{n_{si} \left(\sum_j \frac{\left(Ct_{jisw} - \overline{Ct}_{isw}\right)^2}{n_{si} - 1} \right)}{\left(\sum_j v_{jisw} \right)^2} \right)}{\left(\sum_s \sum_i V_{is} \right)^2} \right],$$

where

V_{is} = the total volume in region i and stratum s.

Then std. err.$(L) = (\operatorname{var}(L))^{1/2}$.

Literature Cited

Cochran, W.G. 1977. Sampling techniques, 3rd edition. Wiley, New York.

Table 1. Summary of indices of annual abundance presented in the DEIS that are based on data from the utilities' Beach Seine Survey (BSS), Fall Shoals Survey (FSS), and Longitudinal River Survey (LRS),.

Species	Sampling Program		
	BSS	FSS	LRS
Striped Bass	▼		●
White Perch	▼		●
Atlantic Tomcod			▼
American Shad	▼		●
Blueback Herring		▼ (Channel)	
Alewife		▼ (Channel)	
Bay Anchovy		▼ (Channel)	
Bluefish	▼		
Hogchoker		▼ (Bottom)	
Weakfish		▼ (Channel)	
Rainbow Smelt		▼ (Channel)	▼
Spottail Shiner	▼		
White Catfish	❑		

● Post yolk-sac larvae
▼ Juveniles
❑ Yearlings and older

Table 2. Striped bass indices of annual abundance based on the Utilities' LRS and BSS.

Year	LRS		BSS	
	PYSL Index	Std. Err. PYSL Index	Juvenile Index	Std. Err. Juv. Index
74	0.42	0.03	5.65	0.87
75	0.69	0.04	4.56	0.30
76	0.27	0.02	3.44	0.39
77	0.61	0.04	5.92	0.41
78	0.54	0.04	9.11	1.88
79	0.47	0.03	3.76	0.76
80	0.83	0.06	5.60	0.83
81	2.48	0.12	6.61	0.91
82	0.82	0.06	3.83	0.54
83	0.59	0.03	6.58	1.25
84	0.87	0.10	5.06	1.01
85	0.41	0.03	1.07	0.24
86	0.72	0.04	1.62	0.39
87	1.70	0.07	12.82	2.25
88	1.48	0.14	4.91	0.61
89	4.54	0.34	5.66	0.90
90	5.64	0.54	6.41	0.70
91	8.01	0.77	5.03	1.07
92	6.38	0.43	3.68	0.58
93	8.25	0.73	7.50	1.63
94	8.45	0.80	5.88	1.06
95	3.94	0.39	6.04	0.90
96	15.40	1.46	1.25	0.33
97	4.89	0.74	9.18	0.83

Table 3. White perch indices of annual abundance based on the Utilities' LRS and BSS.

Year	LRS		BSS	
	PYSL Index	**Std. Err. PYSL Index**	**Juvenile Index**	**Std. Err. Juv. Index**
74	0.46	0.04	4.09	0.56
75	1.78	0.15	8.04	1.95
76	2.21	0.24	9.54	1.34
77	2.43	0.13	6.78	1.11
78	3.44	0.19	13.93	2.84
79	3.57	0.10	17.03	2.75
80	2.95	0.11	10.68	2.31
81	3.47	0.17	10.30	1.29
82	5.76	0.22	9.99	1.14
83	2.98	0.10	10.36	2.02
84	2.75	0.12	4.17	0.68
85	5.64	0.21	4.35	1.08
86	8.11	0.38	5.60	1.13
87	3.97	0.12	8.88	1.68
88	2.91	0.15	7.61	1.30
89	4.06	0.37	6.28	1.72
90	2.92	0.26	3.84	0.42
91	3.64	0.24	4.03	0.75
92	4.92	0.20	3.68	0.65
93	4.96	0.18	5.84	0.95
94	4.11	0.17	2.84	0.58
95	2.51	0.11	3.21	0.48
96	6.12	0.27	0.31	0.13
97	1.46	0.07	3.91	0.56

Table 4. Atlantic tomcod indices of annual abundance based on the Utilities' LRS.

Year	Juvenile Index	Std. Err. Juv. Index
74	0.093	0.015
75	0.035	0.009
76	0.010	0.003
77	0.407	0.265
78	0.105	0.031
79	0.017	0.005
80	0.129	0.035
81	0.149	0.037
82	0.061	0.023
83	0.035	0.012
84	0.142	0.068
85	0.147	0.027
86	0.077	0.010
87	0.318	0.049
88	0.142	0.033
89	0.326	0.086
90	0.293	0.133
91	0.193	0.029
92	0.061	0.018
93	0.203	0.048
94	0.082	0.021
95	0.146	0.024
96	0.093	0.014
97	0.049	0.011

Table 5. American shad indices of annual abundance based on the Utilities' LRS and BSS.

Year	LRS		BSS	
	PYSL Index	Std. Err. PYSL Index	Juvenile Index	Std. Err. Juv. Index
74	0.171	0.065	11.50	0.82
75	0.276	0.176	10.63	1.43
76	0.155	0.049	13.32	0.87
77	0.170	0.033	13.70	1.39
78	0.092	0.031	23.67	2.66
79	0.492	0.069	11.65	1.74
80	0.479	0.216	10.75	2.46
81	0.777	0.309	17.62	2.17
82	0.586	0.120	16.31	1.92
83	0.573	0.092	19.68	3.89
84	0.376	0.168	8.69	1.84
85	0.672	0.165	8.08	1.30
86	1.054	0.150	19.06	3.74
87	0.177	0.077	13.47	2.28
88	0.729	0.344	7.72	1.01
89	1.040	0.794	22.05	2.41
90	1.170	0.733	18.67	1.74
91	0.320	0.116	11.97	3.16
92	0.622	0.213	13.92	1.05
93	0.228	0.116	7.07	0.87
94	0.366	0.126	17.56	3.28
95	0.191	0.060	3.79	0.43
96	0.260	0.061	11.77	1.93
97	0.153	0.033	12.54	2.04

Table 6. Blueback herring indices of annual abundance based on the Utilities' FSS.

Year	Juvenile Index	Std. Err. Juv. Index
79	3.70	0.75
80	2.61	0.75
81	21.20	5.86
82	10.33	2.06
83	6.08	1.07
84	20.38	3.67
85	17.42	4.58
86	6.48	1.38
87	25.61	12.36
88	26.69	4.30
89	16.83	5.41
90	29.69	10.64
91	12.65	4.47
92	15.52	3.87
93	7.72	1.59
94	5.77	1.90
95	1.27	0.42
96	50.16	15.89
97	7.30	1.43

Table 7. Alewife indices of annual abundance based on the Utilities' FSS.

Year	Juvenile Index	Std. Err. Juv. Index
79	0.199	0.077
80	0.686	0.354
81	0.634	0.214
82	0.275	0.084
83	0.188	0.067
84	0.213	0.125
85	0.930	0.407
86	0.263	0.079
87	0.524	0.268
88	0.268	0.129
89	0.227	0.068
90	0.350	0.137
91	0.328	0.115
92	0.165	0.084
93	0.234	0.083
94	0.120	0.063
95	0.113	0.034
96	0.489	0.146
97	0.319	0.101

Table 8. Bay anchovy indices of annual abundance based on the Utilities' FSS.

Year	Juvenile Index	Std. Err. Juv. Index
79	63.4	10.4
80	215.9	53.2
81	149.4	23.7
82	196.6	25.2
83	115.0	32.4
84	160.0	33.1
85	152.7	16.3
86	109.3	15.8
87	196.0	42.2
88	340.7	50.6
89	288.9	40.2
90	110.4	11.7
91	110.7	8.4
92	146.7	35.0
93	161.0	20.1
94	138.4	32.8
95	266.0	44.1
96	76.2	20.2
97	147.8	26.6

Table 9. Bluefish indices of annual abundance based on the Utilities' BSS.

Year	Juvenile Index	Std. Err. Juv. Index
74	0.712	0.210
75	0.283	0.074
76	0.189	0.028
77	0.325	0.097
78	0.350	0.075
79	0.217	0.054
80	0.303	0.053
81	0.464	0.119
82	0.296	0.059
83	0.320	0.101
84	0.153	0.034
85	0.245	0.068
86	0.128	0.054
87	0.173	0.049
88	0.176	0.027
89	0.177	0.043
90	0.238	0.053
91	0.156	0.043
92	0.133	0.050
93	0.099	0.033
94	0.058	0.017
95	0.182	0.043
96	0.036	0.012
97	0.185	0.028

Table 10. Hogchoker indices of annual abundance based on the Utilities' FSS.

Year	Juvenile Index	Std. Err. Juv. Index
74	0.15	0.03
75	2.75	1.91
76	0.02	0.02
77	2.09	1.39
78	1.93	0.81
79	0.79	0.17
80	0.62	0.18
81	2.73	0.78
82	0.98	
83	6.79	4.52
84	1.77	0.43
85	1.40	0.26
86	3.30	1.59
87	2.23	0.57
88	7.83	0.91
89	1.32	0.41
90	1.73	1.02
91	6.77	4.73
92	0.50	0.23
93	1.19	0.31
94	10.08	1.42
95	0.88	0.33
96	0.30	0.07
97	0.03	0.03

Table 11. Weakfish indices of annual abundance based on the Utilities' FSS.

Year	Juvenile Index	Std. Err. Juv. Index
79	0.133	0.070
80	0.599	0.285
81	0.215	0.125
82	0.663	0.306
83	0.125	0.088
84	1.588	0.633
85	0.977	0.481
86	0.295	0.105
87	0.253	0.180
88	1.444	0.599
89	0.763	0.248
90	0.149	0.090
91	0.100	0.061
92	0.025	0.017
93	0.252	0.149
94	0.130	0.058
95	0.229	0.128
96	0.213	0.160
97	0.156	0.053

Table 12. Rainbow smelt indices of annual abundance based on the Utilities' FSS and LRS.

Year	FSS		LRS	
	Juvenile Index	Std. Err. Juv. Index	Juvenile Index	Std. Err. Juv. Index
74			0.020	0.004
75			0.001	0.000
76			0.001	0.000
77			0.006	0.002
78			0.069	0.006
79	0.226	0.092	0.020	0.003
80	0.099	0.088	0.031	0.002
81	0.000	0.000	0.001	0.000
82	0.129	0.055	0.003	0.001
83	0.000	0.000	0.000	0.000
84	0.419	0.165	0.003	0.001
85	0.074	0.057	0.002	0.000
86	0.959	0.165	0.016	0.002
87	0.122	0.066	0.006	0.001
88	0.041	0.027	0.051	0.008
89	0.000	0.000	0.000	0.000
90	1.140	0.341	0.027	0.002
91	0.000	0.000	0.010	0.003
92	6.721	2.340	0.045	0.005
93	1.190	0.563	0.011	0.003
94	0.105	0.105	0.008	0.002
95	0.000	0.000	0.010	0.002
96	0.000	0.000	0.000	0.000
97	0.000	0.000	0.000	0.000

Table 13. Spottail shiner indices of annual abundance based on the Utilities' BSS.

Year	Juvenile Index	Std. Err. Juv. Index
74	6.41	1.42
75	13.65	3.19
76	9.21	1.45
77	4.86	1.11
78	12.23	1.72
79	8.56	1.36
80	6.79	1.28
81	19.13	3.98
82	4.99	0.82
83	11.89	3.01
84	8.20	1.94
85	4.92	0.78
86	4.63	1.16
87	5.87	1.40
88	4.66	0.72
89	6.63	1.47
90	9.10	1.51
91	11.22	1.88
92	6.99	1.07
93	6.38	0.80
94	14.68	2.02
95	4.88	0.70
96	1.68	0.63
97	11.88	1.74

Table 14. White catfish indices of annual abundance based on the Utilities' BSS.

Year	Yearling and Older Index	Std. Err. Yearling and Older Index
74	0.034	0.020
75	0.021	0.011
76	0.030	0.010
77	0.072	0.022
78	0.069	0.030
79	0.054	0.028
80	0.023	0.008
81	0.050	0.029
82	0.048	0.026
83	0.064	0.044
84	0.019	0.006
85	0.010	0.005
86	0.026	0.012
87	0.031	0.015
88	0.050	0.018
89	0.123	0.056
90	0.010	0.005
91	0.016	0.008
92	0.005	0.004
93	0.013	0.009
94	0.003	0.002
95	0.012	0.008
96	0.028	0.016
97	0.002	0.001

Appendix V-3

Sampling Programs and Data Evaluations

APPENDIX V-3

SAMPLING PROGRAMS AND DATA EVALUATION

1. DESCRIPTION AND OBJECTIVES OF SAMPLING PROGRAMS

A. Utility Surveys

Several surveys are currently being conducted to obtain information on the distribution and abundance (relative and absolute) of fish eggs, larvae, young-of-year (YOY), subadults and adults in the Hudson River estuary. All reflect the evolution of programs initiated in 1973 or 1974 and have been jointly sponsored by Central Hudson Gas & Electric, Consolidated Edison, the New York Power Authority, Niagara Mohawk Power Corp., and Orange Rockland Utilities. A full description of the methods and materials employed in these surveys and a summary of changes since program inception can be found in the individual reports listed in Appendix V-1.

The size of fish and their ability to actively avoid or escape from sampling gear vary tremendously by life stage. As a result, different surveys were developed in order to sample various life stages. Thus the following discussion of surveys has been organized by life stage.

Eggs and Larvae

Longitudinal River Ichthyoplankton Survey (LRS)

The Longitudinal River Ichthyoplankton Survey (LRS) is conducted between the Hudson River estuary from the Battery (RM) to the Federal Dam at Troy (RM 152) to provide abundance estimates for eggs, larvae and early juvenile fish; however, prior to 1986 sampling did not extend above RM 140 and prior to 1988 did not extend below RM 14. Sampling generally occurs from April through July according to a stratified random design. The period and extent of sampling have varied in some years, as illustrated in the following table. The 152-mile stretch of the estuary is divided into 13 regions (Figure 1) and each region further divided into strata according to river depth (Figure 2). During weeks when the entire estuary is sampled, approximately 200 samples are collected each week; of these about 120 are routinely analyzed and the others are stored for use if needed. Early and late in the sampling season, the spatial extent and sampling intensity are somewhat reduced (Table 1).

Two gear types have been used to sample three river strata: a 1m^2 Tucker trawl for the channel stratum; an epibenthic sled with a 1m^2 net similar to that of the Tucker trawl for the bottom stratum; and both gear for the shoal stratum. Gear are towed for 5 min against the prevailing current at about 1m/s. An electronic flowmeter mounted along the side of the research vessel and equipped with an on-deck readout display is used to establish and

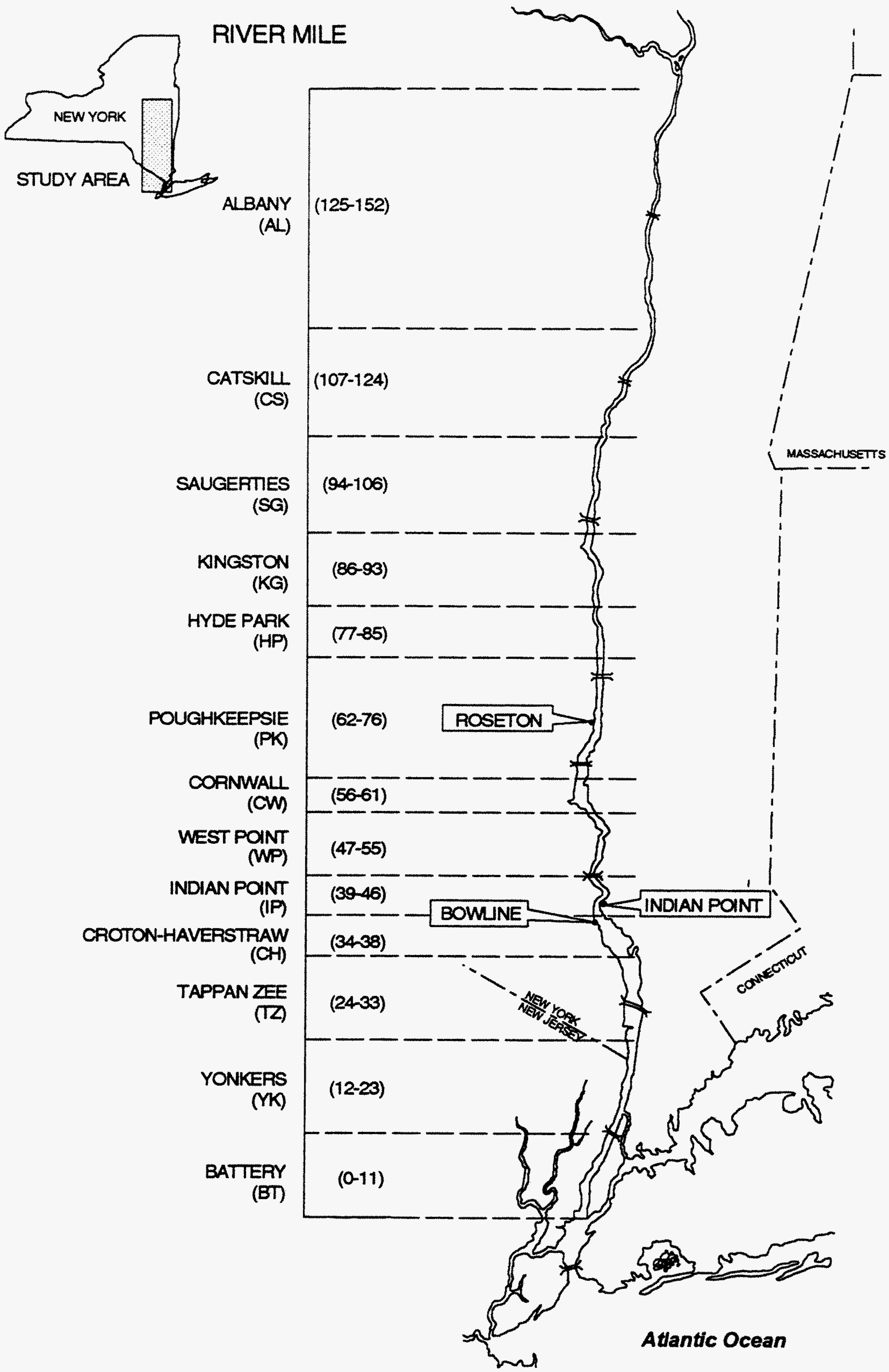
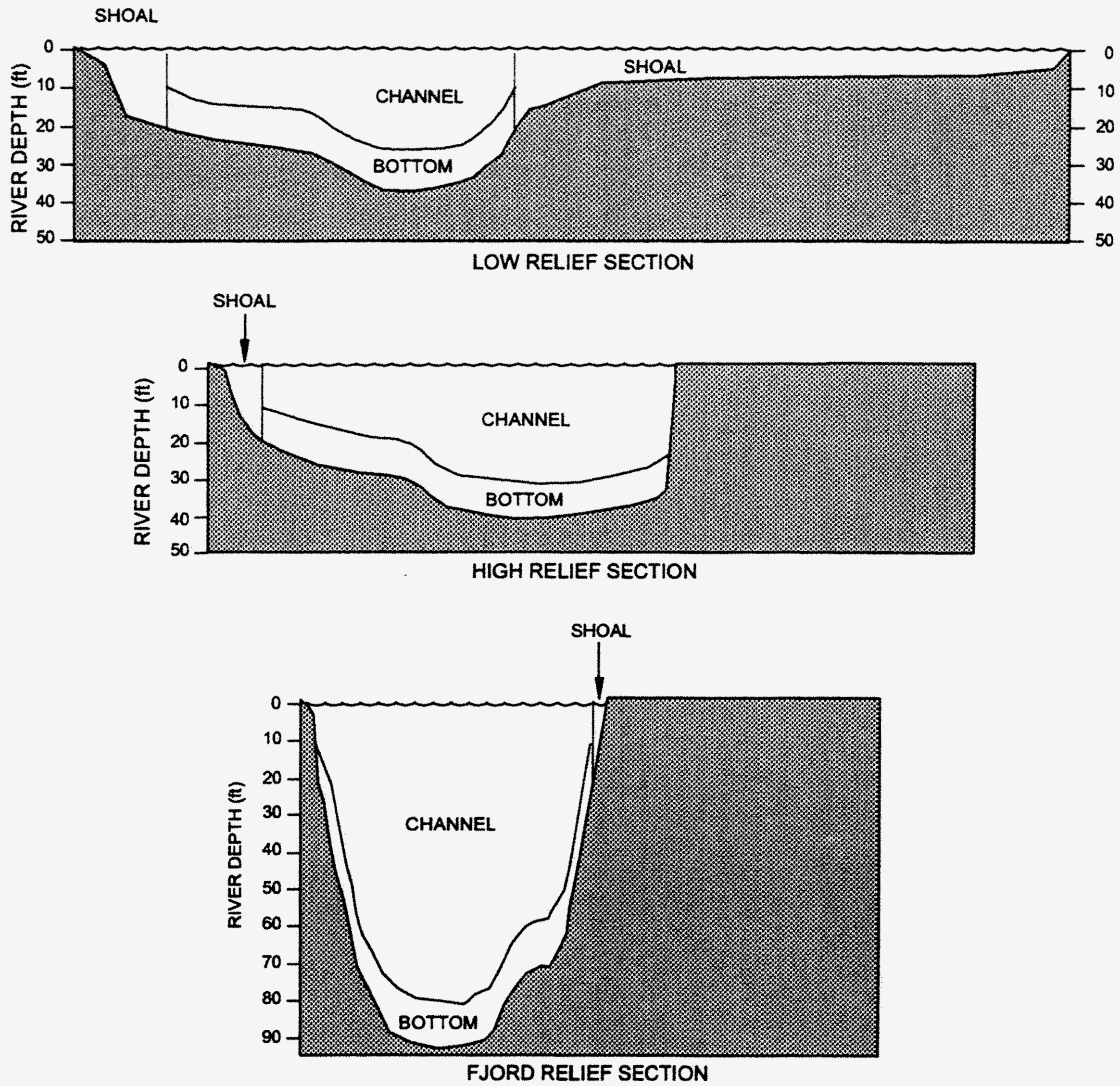


Figure 1. The lower Hudson River estuary.



STRATA DEFINITIONS

SHOAL	Water of 20 ft (6 m) or less.
BOTTOM	Water within 10 ft (3 m) of the river bottom in more than 20 ft (6 m) depth.
CHANNEL	Water more than 10 ft (3 m) from the river bottom in more than 20 ft depth.

Figure 2. Cross sections of the Hudson River showing locations and typical proportional relationships of shoal, bottom, and channel strata.

Table 1

Summary of Long River Survey (LRS)

YEAR OF DATA COLLECTION	Start Date	End Date	Minimum River Mile	Maximum River Mile	Number of River Runs	Mean Number of Samples Collected per Run	Mean Number of Samples Analyzed per Run
74	16APR74	15AUG74	12	143	23	115	115
75	11MAR75	14AUG75	14	139	18	142	142
76	23FEB76	13AUG76	14	140	20	184	184
77	21FEB77	12AUG77	14	139	20	178	145
78	28MAR78	18AUG78	14	139	20	188	150
79	19MAR79	17AUG79	14	138	23	189	150
80	17MAR80	04JUL80	14	139	14	169	139
81	04MAY81	10JUL81	14	139	10	201	157
82	10MAY82	09JUL82	14	138	10	188	188
83	02MAY83	09JUL83	14	139	10	189	189
84	08MAY84	12JUL84	14	139	11	188	188
85	29APR85	11JUL85	14	138	11	189	188
86	29APR86	10JUL86	14	139	11	211	198
87	14APR87	09JUL87	12	152	13	201	190
88	18APR88	08SEP88	1	151	17	175	98
89	17APR89	23AUG89	1	151	16	180	103
90	19APR90	16AUG90	1	151	15	179	104
91	15APR91	17OCT91	1	150	20	167	100
92	13APR92	14OCT92	1	151	20	167	99
93	12APR93	05OCT93	5	150	20	167	99
94	11APR94	05OCT94	3	150	20	167	99
95	06MAR95	12OCT95	1	152	23	159	106
96	12MAR96	09OCT96	1	151	23	162	107
97	11MAR97	09OCT97	1	151	23	162	108

maintain tow speed. A calibrated digital flowmeter mounted in the center of the net mouth is used to calculate the volume of water filtered for each sample. During the weeks when substantial numbers of free-swimming larvae are present, sampling has been conducted during nighttime hours to reduce gear avoidance.

In situ measurements of water temperature, dissolved oxygen, and specific conductance are taken in each region at fixed river miles in conjunction with field sampling. The measurements are taken at the surface, mid-water, and bottom in the channel and at the surface and bottom in the shoal.

Ichthyoplankton samples are returned to the laboratory where random subsets are selected for identification of all fish life stages. Length and weight are recorded for subsamples of selected species. Data, generally available as river region and stratum densities, are variously used to describe distribution, estimate annual abundance and as input for models of population dynamics and power station effects. Details of each year's sampling program and its results are reported in an Annual Year Class Report.

Young-of-the Year Fish

Beach Seine Survey (BSS)

The Beach Seine Survey (BSS) is generally conducted on alternate weeks from mid-June through early October between the George Washington Bridge and the dam at Troy (Figure 1). Data are used to estimate the abundance of juvenile fish, also called young-of-the-year (YOY), and older fish in the shore-zone (extending from the shore to a depth of 10 ft). In the BSS a 100-ft bag beach seine is used to collect one hundred samples during each sampling week from beaches selected according to a stratified random design. One end of the net is held on shore; the other is towed perpendicularly away from shore by boat and then returned in a semicircular path toward shore. When completed, a tow sweeps an area of approximately 450 m^2. Water temperature, dissolved oxygen, and specific conductance are measured 1 ft below the water surface and approximately 50 ft from the shoreline with each beach seine sample.

Fish are ordinarily identified in the field and returned to the river. Selected samples are returned to the laboratory for length and weight measurements on species of interest. Data, generally converted to shore zone densities or catch per unit effort (CPUE), are used for the same purposes as those from the LRS. Details of each year's sampling program, which are summarized in Table 2, and its results are reported in an annual Year Class Report.

Fall Shoals Survey (FSS)

The Fall Shoals Survey (FSS) is conducted on alternate weeks from the Beach Seine Survey between Manhattan and the Troy Dam. Data are used to estimate the abundance of YOY and older fish in offshore habitats. Approximately 200 samples are collected each week

TABLE 2

SUMMARY OF BEACH SEINE SURVEY

YEAR OF DATA COLLECTION	START DATE	END DATE	MINIMUM RIVER MILE	MAXIMUM RIVER MILE	NUMBER OF RIVER RUNS	MEAN NUMBER OF SAMPLES COLLECTED PER RUN
74	10 Apr	18 Dec	12	152	37	63
75	02 Apr	16 Dec	12	152	38	86
76	31 Mar	10 Dec	12	152	37	93
77	04 Apr	16 Dec	12	151	37	97
78	03 Apr	22 Dec	12	152	38	96
79	02 Apr	14 Dec	12	151	37	97
80	31 Mar	03 Dec	12	151	29	92
81	03 Aug	28 Oct	12	151	7	100
82	16 Aug	14 Oct	14	151	5	100
83	01 Aug	13 Oct	12	148	6	101
84	24 Jul	01 Nov	12	145	8	100
85	16 Jul	21 Nov	12	145	10	100
86	15 Jul	21 Nov	12	151	10	100
87	24 Jun	13 Nov	12	151	11	100
88	14 Jun	03 Nov	14	149	11	100
89	13 Jun	02 Nov	12	151	11	100
90	18 Jun	24 Oct	12	152	10	100
91	24 Jun	01 Nov	15	151	10	100
92	23 Jun	28 Oct	12	151	10	100
93	01 Jul	04 Nov	14	149	10	100
94	27 Jun	02 Nov	14	149	10	100
95	19 Jun	26 Oct	14	151	10	100
96	18 Jun	23 Oct	14	151	10	100
97	16 Jun	23 Oct	14	151	10	100

according to a stratified random design. A 1-m^2 Tucker trawl is used to sample the channel strata. A 3-m beam trawl is used in the shoal and bottom strata to collect YOY fish in offshore habitats. The 3-m beam trawl was first used in the FSS during 1985; prior to 1985 an epibenthic sled was used. Gear are towed against the prevailing current for 5 min at 1.5 m/sec, unless consistently large numbers of fish are caught, in which case tows may be reduced in duration. A calibrated digital flowmeter mounted in the center of the net mouth is used to calculate the volume of water filtered for each sample. Measurements of physical and chemical parameters are taken at the surface, mid-water and bottom in the channel and at the surface and bottom in the shoals.

Fish from most samples are identified in the field and returned to the river. Selected samples are returned to the laboratory for length and weight measurement on species of interest. Data, generally converted to densities or CPUE, are used for the same purposes as those from the LRS. Details of each year's sampling program, which are summarized in Table 3, and its results are reported in an annual Year Class Report.

Age 1^+ and Older Fish

White Perch Stock Assessment (WPSA)

The White Perch Stock Assessment Program (WPSA) was conducted annually from 1971-1988. Bottom samples were collected biweekly during the day from September through mid-December, using a 30-ft flat otter trawl. The trawl was towed for 10 min against the prevailing current at an adjusted speed (corrected for surface tidal current) over the bottom of approximately 1.5 m/s. From 1971 through 1977, sampling was confined to three stations in the vicinity of the Bowline Point plant. From 1978 through 1982, sampling was extended to additional shallow and deepwater stations in Haverstraw Bay. From 1983 through 1988, sampling was extended to additional sites in the middle and upper parts of the estuary. Water temperature, specific conductance, and dissolved oxygen were measured at the bottom immediately after each tow.

White perch were identified and counted, and substantial information on age composition and growth was also collected. Details of each year's sampling program and its results were reported in an Annual White Perch Stock Assessment Report.

Atlantic Tomcod Mark-Recapture Program (ATMR)

The Atlantic Tomcod Mark-Recapture Program (ATMR) has been conducted in most years since 1974 to generate estimates of the number of tomcod in the winter spawning population. This program uses box traps and bottom trawls to collect fish for marking and recapture.

From early December through mid-February, box traps are set in 1 to 12 m of water at 17 sites along the east and west banks of the Hudson River. The similar box trap sampling

TABLE 3

SUMMARY OF FALL SHOALS SURVEY

YEAR OF DATA COLLECTION	START DATE	END DATE	MINIMUM RIVER MILE	MAXIMUM RIVER MILE	NUMBER OF RIVER RUNS	MEAN NUMBER OF SAMPLES COLLECTED PER RUN
74	19 Aug	12 Dec	14	76	17	99
75	18 Aug	11 Dec	14	76	9	100
76	16 Aug	08 Dec	14	76	9	98
77	15 Aug	06 Dec	14	75	9	92
78	21 Aug	14 Dec	14	74	9	100
79	09 Jul	13 Dec	14	138	12	199
80	07 Jul	10 Dec	14	139	12	175
81	10 Aug	23 Oct	14	139	6	200
82	12 Aug	09 Oct	14	139	5	200
83	08 Aug	20 Oct	14	136	6	200
84	16 Jul	25 Oct	14	139	8	200
85	22 Jul	14 Nov	14	138	9	200
86	21 Jul	02 Dec	14	151	10	210
87	13 Jul	05 Nov	12	151	9	218
88	18 Jul	28 Oct	12	151	8	210
89	17 Jul	26 Oct	12	150	8	210
90	09 Jul	17 Oct	14	151	8	210
91	15 Jul	25 Oct	12	147	8	210
92	13 Jul	23 Oct	12	144	8	210
93	19 Jul	29 Oct	12	144	8	210
94	18 Jul	27 Oct	13	144	8	210
95	10 Jul	20 Oct	13	150	8	210
96	10 Jul	17 Oct	1	146	8	209
97	07 Jul	23 Nov	1	146	11	183

sites have been used in annual surveys since the winter of 1974-75. The traps are attached by wire cable to a solid shore structure (e.g. dock, pier, bulkhead). They are generally checked and repositioned daily, Monday through Friday. Atlantic tomcod caught in the traps between Yonkers and Poughkeepsie are finclipped using codes reflecting area and period of release. Once a week from December through February, an entire day's Atlantic tomcod catch from each of the six standard box trap sites is taken in fresh condition to the laboratory and each fish is examined for selected biocharacteristics; these include age, length, weight, sex, and reproductive condition.

Since the winter of 1984-1985 the Hudson River south of the George Washington Bridge and a portion of upper New York Harbor between Battery Park and Liberty Island has been sampled by a 9-m high-rise trawl. The program was added to the existing tomcod box trap program to increase the number of marked (finclipped) tomcod recaptured. Sampling is carried out weekdays from early November through early April. Approximately 8 tows, each intended to last 10 minutes, are made daily against the current at a boat speed (through water) of between 1.2 and 1.7 m per second. All Atlantic tomcod collected in the trawls are examined for clipped fins, sorted and counted by length groups, and released.

Conductivity and water temperature are measured in situ, after each box trap or trawl sample. Measurements are made at the water surface and bottom at box trap sites, and at the surface and bottom immediately after the completion of each 9-m trawl tow.

Data from the Atlantic tomcod mark/recapture program are used to estimate the size of the Hudson River population, describe its biology and provide input into a population model. A detailed description of the program and its results appear in a year-specific series entitled "Abundance and Stock Characteristics of the Atlantic Tomcod Spawning Population in the Hudson River".

Striped Bass Mark-Recapture Program (SBMR)

The Striped Bass Mark-Recapture Program (SBMR) began in 1984 and from 1984 through 1987 evaluated the most efficient and effective gear and techniques to catch, handle and tag striped bass. Survival was greatest when water temperatures were low (November through March). Age 1^+ and age 2^+ striped bass provided the greatest total catch and catch per unit effort (CPUE) and the catches were high enough to satisfy the statistical assumptions underlying estimates of the proportion of hatchery-reared striped bass in the Hudson River striped bass population, the primary objective of the SBMR program. The 9-m trawl was the most effective gear for capturing age 1^+ and age 2^+ striped bass. The Battery region of the Hudson River adjacent to Manhattan, and upper New York Harbor in the vicinity of Liberty Island provided the most consistent catches of these age groups during the November through March period. Between 1986 and 1989, the design of the internal anchor-external streamer tag used in this program was modified to improve the legibility of recovered tags (abrasion reduced the legibility of the tags that were recovered during the early years of the program) and to reduce irritation and infection at the insertion site for the tags. Since 1990, tagged striped bass have been released into a recovery pen alongside the tagging vessel in order to provide a refuge where fish can recover from processing without being preyed on by gulls.

All striped bass from each sample are measured, and examined for the presence of either external body tags or internal magnetic coded-wire tags. The latter, applied to fish produced at the utilities' hatchery in Verplanck, require the use of a magnetic field detector. All striped bass over 150 mm in good condition and not already marked are tagged with an anchor tag and released. Fish that die during sampling are returned to the laboratory for determination of length, weight, sex, reproductive state and stomachs contents.

Data from the winter striped bass program are used to estimate the numbers of striped bass >150 mm overwintering in the lower estuary (See Appendix VI.2-B); evaluate biological characteristics such as growth and survival; estimate the proportion of fish that are of hatchery origin; and as input into population models. A detailed description of the program and its results appear in a year-specific report series entitled "Hudson River Striped Bass Hatchery Evaluation/Monitoring Program".

B. New York State Department of Environmental Conservation Surveys

Young-of-the Year Fish

Juvenile Striped Bass Seine Survey (JSB)

The NYSDEC-Division of Marine Resources (DMR) has conducted a beach seine survey in the lower Hudson River estuary (Tappan Zee - Haverstraw Bay area) since 1976. The objective of this study is to provide an annual index of relative abundance for young-of-the-year (YOY) striped bass. In addition, the catches of YOY bluefish provide information on their use of the Hudson River estuary.

The beach seine survey uses a 61 m x 3 m x 13 mm stretched mesh (200 ft x 10 ft by 0.5 in stretched mesh) beach seine set by boat at standard sites. Twenty-five of 36 sites located between RM 25 and RM 40 are sampled bi-weekly. The beach seine survey was initiated in 1976 stating in late August and continuing through early November, six bi-weekly runs were conducted. The survey was expanded in 1985 to nine bi-weekly runs starting in mid-July through early November.

Bottom Trawl Survey (BTS)

The NYSDEC-Division of Fish and Wildlife (DFW) sampled the lower estuary between RM 25-43 with a 26 ft Carolina wing bottom trawl from July through early November. The program began in 1981 and continued through 1990. The objective of the program was to develop an annual abundance index for YOY striped bass and other juvenile fishes of the lower estuary.

Sampling was conducted biweekly at standard sites located in the off-shore shoal area of Haverstraw Bay and the Tappan Zee. All fish were counted by life stage (YOY and older); age was verified by scale samples. Data were typically expressed as mean number per 5-minute tow.

Juvenile Alosid Survey (JAS)

The NYSDEC-DFW conducts a beach seine survey in the middle and upper regions of the estuary (> RM 55) to estimate the relative abundance of YOY American shad and other juvenile fishes. The biweekly sampling, which began in 1980 and continues to present, occurs from mid-June through late October or early November in two primary areas: RM 55-77 and RM 121-140. The sampling gear is a 100 ft x 12 ft, 1/4 in mesh beach seine. Sampling is conducted during the daytime at approximately 30 standard sites. All species are identified to life stage (YOY or older) and counted. Data are expressed as mean number of fish per seine haul.

Yearling and Older Fish

Western Long Island Survey (WLIS)

The NYSDEC conducts a survey for subadult striped bass in the bays around western Long Island Sound. The survey was initiated to provide an index of relative abundance for age one (yearling) striped bass. This index was used to validate the Hudson River YOY striped bass indices. The objective of the survey has been modified to tag subadult striped bass to determine migration patterns and mortality rates.

The NYSDEC-DMR western Long Island beach seine survey collects striped bass primarily from the bays around WLI from 1984 through present using a 61 m x 3 m x 13 mm stretched mesh (200 ft x 10 ft by 0.5 in stretched mesh) beach seine set by boat at standard stations. In addition a 152 m x 3.7 m (500 ft x 12 ft) beach seine with 76 mm (3 in) stretched mesh wings and 51 mm (2 in) stretched mesh bag was used once each year in each of the bays during the spring. The bays sampled in WLIS include: Little Neck Bay, Manhasset Bay, Hempstead Harbor, Staten Island, Jamaica Bay, and South Oyster Bay. The bays are sampled twice a month from April through June, and then once a month from July through October or November.

Spawning Stock Assessment (SSA)

NYSDEC-DFW conducts a haul seine survey in the Hudson River in order to provide information on length, age and sex distribution, and mortality rates for adult American shad and striped bass. The program, which began in 1982 and continues to present, uses large haul seines, either 500 or 1000 ft in length to sample between Kingston (RM 91) and Athens (RM 116). The net is fished with the tide, set by boat and hauled in by hand. Crews of up to eight people are required. Captured fish are held in a floating net pen before processing. Fish are measured to the nearest mm total length, weighed to the nearest 10 gm and sampled for scales. Scale impressions are examined by two individuals to determine age.

Commercial Fishery Monitoring (CFM)

To determine relative abundance, through catch-per-unit-effort, and age structure of the total commercial catch of American shad and striped bass by-catch, the NYSDEC-DFW monitors the success of the commercial gill net fishery. Onboard observers record data on fish caught in the commercial fishery from April through May, including catch of each sex, fishing time, location, and gear type. A subsample of the catch is measured to the nearest mm total length, weighed to the nearest 10 gm, and sampled for scales. Scale impressions are examined by two individuals to determine age. The program began in 1980 and has continued annually.

2. METHOD OF EVALUATION

Each of the surveys was evaluated for its suitability for producing valid indices of abundance for the various life stages of the 15 species to be considered in the Environmental Impact Statement. The criteria used in the evaluation were:

Criteria	Description
Record Duration -	The number of years that the survey has been conducted in a consistent manner and for which information is available. Longer time series are more useful for describing temporal abundance trends than are shorter series.
Temporal Coverage -	The degree of temporal overlap of the survey with the occurrence of the target life stage(s). Surveys that overlap a life stage completely are generally more useful than those that cover only a portion of a life stage.
Spatial Coverage -	The degree of spatial overlap of the survey with the spatial distribution of the life stage(s). Again, surveys that completely overlap the spatial distribution of a life stage are generally more useful than those that cover only a portion of the spatial distribution. For estuarine species, habitats outside the estuary must also be considered.

Sampling Design -	The method used to select sampling stations. For abundance surveys, randomized sampling locations are preferred. Fixed stations are less desirable but may be acceptable, and sampling directed at concentrations of the target species is least desirable, unless it is a mark-recapture program.
Sampling Intensity -	The frequency of sampling intervals and number of samples taken during each interval. The sampling interval should be shorter than the duration of the life stage being studied. With regard to sample numbers, a larger number of samples is generally better than a smaller number of samples.

For each criterion, the survey was evaluated and assigned a numerical score of 1, 2, or 3:

Score	Interpretation
1	The characteristics of the survey match well with the life stage; the data should be useful for assessing abundance.
2	The characteristics of the survey match reasonably well with the life stage; the data may be useful for assessing abundance with due consideration of limitations.
3	The characteristics of the survey do not match well with the life stage; data are likely to be of limited use for assessing abundance.

3. SPECIES DATA SETS AND EVALUATIONS

A. STRIPED BASS

Adults

Sampling program evaluation for striped bass is summarized in Table 4 and data sets are provided in Table 5.

The CFM program provides the only data suitable for an index of adult abundance. The entire spawning stock moves through the area of the estuary that is worked by the commercial gill net fishery. Therefore, this program provides a consistent measure of relative striped bass abundance for fish of the size selected by gill nets. Due to the narrow range of mesh sizes used in the Hudson River fishery, 5.5 to 7 in (Kahnle and Stang 1988), and to the size selectivity of the gill net fishery (Dew 1988), fish older than about age 7 are likely to be undersampled.

TABLE 4

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF STRIPED BASS FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

STRIPED BASS																		
SURVEY	SELECTION CRITERIA FOR ABUNDANCE INDICES												USE OF DATA FOR ABUNDANCE INDICES (BY LIFE STAGE)					
	RECORD DURATION		TEMPORAL COVERAGE		SPATIAL COVERAGE (RM)		GEAR		SAMPLING DESIGN		SAMPLING INTENSITY		EGG	YSL	PYSL	JUV	YRL	ADULT
LRS	1974-97	1	May-Jul	1	14-140	1	1 m^2 nets 505μ mesh 1 m/sec night	1	Stratified Random	1	110-210 weekly	1	5 5A	5 5A	5 5A 6A	NU	NU	NS
BSS	1974-97	1	Aug-Oct	1	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5 5A 6A	NU	NS
FSS	1979-97	2	Aug-Oct	1	14-140	2	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	NU	NU	NS
JSB	1976-97	1	Jul-Nov	1	23-42	2	200' seine 1/2" mesh day	1	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	5 5A 6A	NU	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NU	NU	NS
BTS	1981-90	2	Aug-Nov	2	24-43	2	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NU	NU	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NU	5A 6A	NS
SBMR	1984-97	2	Nov-Apr	1	NY harbor - 12	2	30' trawl day	1	Directed	2	25-60 Weekly	2	NS	NS	NS	NU	5 5A 6A	NS
SSA	1985-97	2	Apr-Jun	1	91-116	2	500' or 1000' haul seine day	1	Directed	3	Variable	3	NS	NS	NS	NS	NS	6A

TABLE 5

ESTIMATES OF RELATIVE AND ABSOLUTE ABUNDANCE OF DIFFERENT LIFE STAGES OF STRIPED BASS (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/".)

	ADULT	EGG	YSL	PYSL	JUVENILE				YEARLING+[h]	
YEAR	CFM[a]	LRS[b]	LRS[b]	LRS[b]	BSS[c]	JSB[d]	BTS[e]	JSB/BTS[f]	SBMR[i]	WLIS[j]
1974		0.006/0.04	0.08/0.02	0.42/0.03	5.65/0.87					
1975		0.08/0.01	0.49/0.03	0.69/0.04	4.56/0.30					
1976		0.10/0.01	0.25/0.01	0.26/0.02	3.45/0.39	16.3				
1977		0.19/0.02	0.57/0.03	0.60/0.04	5.92/0.41	39.7/7.80				
1978		0.08/0.01	0.31/0.02	0.54/0.04	9.11/1.88	41.8/9.70				
1979		0.08/0.01	0.36/0.02	0.47/0.03	3.76/0.76	5.0/0.74				
1980	1.25	0.07/0.01	0.32/0.02	0.83/0.06	5.60/0.83	24.1/4.70				
1981	1.45	0.14/0.02	0.49/0.06	2.48/0.12	6.61/0.91	21.6/3.72	5.2	1.0		
1982	0.93	0.07/0.01	0.74/0.08	0.82/0.06	3.83/0.54	30.5/4.01	6.2	1.4		
1983	1.38	0.28/0.19	0.39/0.03	0.59/0.03	6.58/1.25	48.1/9.10	7.5	1.7		
1984	4.78	0.15/0.02	0.36/0.03	0.87/0.10	5.06/1.01	37.1/7.44	5.6	1.4	821/152	
1985	9.97	0.05/0.00	0.20/0.02	0.40/0.03	1.07/0.24	3.9/0.48	1.5	0.2	342/74	0
1986	7.82	0.06/0.01	0.42/0.03	0.72/0.04	1.62/0.39	6.1/0.74	7.3	0.8	282/64	0
1987	7.28	0.06/0.01	1.45/0.08	1.70/0.07	12.82/2.24	60.7/12.88	15.9	2.3	1336/194	0.26
1988	11.39	0.02/0.01	0.71/0.07	1.48/0.14	4.91/0.61	52.3/3.75	45.8	5.8	1128/89	2.46
1989	15.99	0.59/0.27	2.94/0.28	4.54/0.34	5.66/0.90	41.9/4.72	10.5	2.2	908/153	1.58
1990	13.95	1.22/0.18	3.27/0.29	5.64/0.54	6.41/0.70	38.0/3.65	23.9	3.1	817/109	0.76
1991	13.06	0.36/0.06	2.85/0.26	8.00/0.77	5.03/1.07	6.9/0.67	NA	NA	1017/139	3.7
1992	24.93	0.87/0.15	3.88/0.22	6.38/0.42	3.68/0.58	17.3/1.28	NA	NA	895/246	3.7
1993	31.05	0.63/0.12	4.81/0.97	8.25/0.73	7.50/1.63	26.5/2.80			996/497	14.07
1994	35.29	9.83/1.87	3.68/0.53	8.45/0.80	5.88/1.06	28.5/2.63			1140/276	1.98
1995	17.09	6.27/1.01	1.31/0.20	3.94/0.39	6.04/0.90	27.4/3.72			971/174	1.23
1996	36.53	4.50/0.65	12.74/1.80	15.40/1.46	1.25/0.33	14.7/1.59				34.76
1997	10.01	1.03/0.19	1.80/0.30	4.89/0.74	9.18/0.83	50.3/5.39				0.26

a Catch per 1000 yd^2 hr in fixed nets. Data from NYSDEC data file CFBASSCF.WK1
b Sum of weighted average number per m^3 for 7 consecutive sampling weeks over period of peak abundance.
c Average number per 100' seine haul for sampling from mid-August to early October (weeks 33-40).
d Geometric mean number per 200' seine haul for 6 week sampling period. Data from Table 4 of McKowan 1994a
e Geometric mean number per two in bottom trawl survey.
f Index based on combined seine and trawl data.
g Estimated absolute number of juveniles on September 1, in millions. Estimation methods described in Appendix VI-2.
h. Applied to the year in which the cohort was spawned.
i. Estimated number of age 1+ fish during second winter of life, in 1000s.
j Geometric number per 200' seine haul in Little Neck Bay, Manhasset Bay, and Jamaica Bay.

The utilities do not conduct sampling for adult fish and the Spawning Stock Assessment conducted by DFW using haul seines, due to the nature of how sampling sites are selected and dual species focus, does not provide a reliable measure of relative abundance. The primary objective of the DFW haul seine program is to estimate the population's age structure.

Egg and Larval Stages

The LRS conducted by the utilities was designed to provide complete spatial and temporal coverage for early life stages of striped bass. The PYSL index (Heimbuch et al. 1992) is the preferred measure of relative abundance during the egg and larval period. The duration of this life stage is 6 weeks long, which is considerably longer than the period between sampling events (one week). Although indices were also calculated for the egg and YSL stages, the durations of these stages are shorter than the one-week interval between sampling events and the abundance may, therefore, be measured less accurately than that for PYSL. Nevertheless, egg and YSL indices were generated for comparison with the PYSL index because of the possibility that the PYSL index was biased by the misidentification of striped bass and white perch PYSL (See Appendix VI.1-B). The YSL and PYSL indices were highly correlated ($r = 0.94$), demonstrating that misidentification did not bias the preferred measure of relative abundance. The PYSL index also had a high correlation with the CFM index of adults ($r = 0.86$), indicating that PYSL abundance is closely related to adult abundance.

Juvenile Stage

Juvenile striped bass are captured frequently in the beach seine surveys. Although beach seines are limited to shore zones suitable for seining, they are commonly used to estimate relative abundance of striped bass populations (e.g., Maryland DNR striped bass index). The utility BSS data and the NYSDEC JSB data were highly correlated with each other ($r=0.76$), and with the SBMR index of the same year classes at Age 1+. Correlation for BSS and SBMR Age 1+ index was 0.81 and for JSB and SBMR it was 0.70. However, in spite of the higher correlation of the BSS data with SBMR, the JSB index was ultimately selected as the preferred index for juvenile abundance due to the extremely close agreement of the JSB index and SBMR from 1984 through 1990. During these years, the normalized values of these indices were nearly identical (Figure 3), indicating that recruitment was being measured accurately with the JSB index. The divergence of both BSS and JSB indices from the SBMR values after 1990 could indicate that there are additional sources of juvenile production outside the habitats sampled by the Hudson River beach seining programs. The improvements in water quality in NY harbor at this same time suggest that young striped bass may have begun successfully emigrating from the Hudson River in late summer and then were returning to contribute to the Age 1+ population a year later. Support for this possibility is provided by the increase in young-of-year catches in the WLIS program that also occurred after 1990. This potential emigration suggests that the BSS and JSB beach seine programs may be best interpreted as in-river juvenile production. Prior to

1991 the in-river production was the entire production for the stock, but since 1991 it represents only a fraction of the production.

Although data from the BTS and WLIS surveys were not used for the depiction of abundance trends, they were considered in interpreting the life history data.

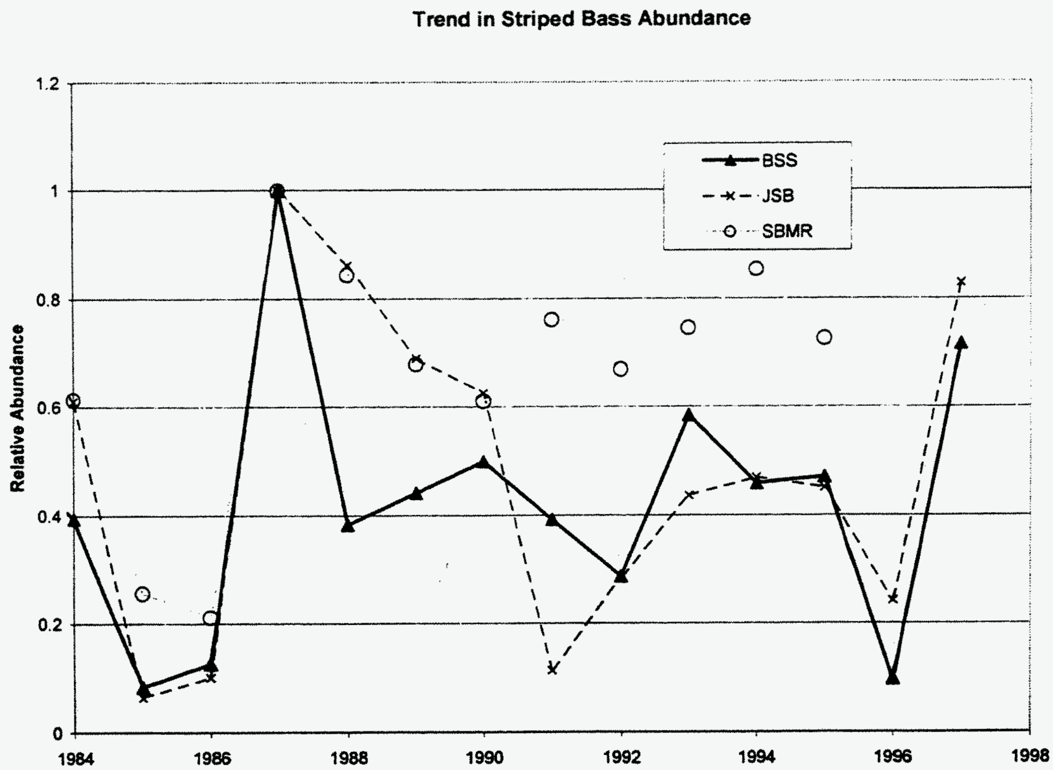


Figure 3. Abundance trends in striped bass year classes estimated from the BSS, JSB, and SBMR sampling programs from 1984-1997. Abundances for each program have been normalized to the largest value in the time series.

Yearling and sub-adults

The SBMR program provides estimates of absolute abundance at age 1+ and 2+. The WLIS program provides estimates of relative abundance at age 1^+. The WLIS program involves sampling with a limited spatial extent at a time of year (summer) when age 1^+ fish are spread out over a wide area, both within and outside of the Hudson River estuary. The SBMR program also involves sampling with a limited spatial extent but deliberately in an area where age 1^+ striped bass are known to be concentrated during the sampling period. The sampling intensity was also greater in the SBMR program than in the WLIS program. Thus, the SBMR abundance estimates are probably more reliable than the WLIS abundance estimates and the SBMR estimates were selected as the preferred measure of abundance for age 1^+ striped bass.

WHITE PERCH

Adults

Sampling program evaluation for white perch is summarized in Table 6 and data sets are provided in Table 7.

The White Perch Stock Assessment Program (WPSA) was the only program directed at adult white perch. Although only the lower estuary was sampled in each year of the 18-year program, this sampling may provide a valid measure of abundance because adult white perch are generally found in the lower estuary during the fall. The average catch per 10 min tow from the samples taken from the lower estuary for age 3 fish was examined as a potential index of relative abundance of fish entering the spawning stock because over 80% of both male and female white perch are mature by age 3 (Klauda et al. 1988). However, due to the fact that the program ended in 1988, prior to the large increase in striped bass abundance and improvement in lower estuary water quality, the value of these data in assessing recent or future abundance trends is severely compromised.

Egg and Larval Stages

The LRS conducted by the utilities was designed to provide indices of abundance for early life stages of striped bass. However, the sampling also covers the time and extent of the egg and larval stages for white perch in the estuary. The program is probably less efficient in capturing white perch eggs and yolk-sac larvae than those of striped bass because white perch spawn in shallow water. However, as white perch become more active during the PYSL stage, the efficiency of the program increases and the PYSL data were used to develop a relative measure of abundance (Heimbuch et al. 1992). This life stage is also sampled better than either of the earlier life stages because the stage duration is considerably longer than the period between sampling events. Indices of egg and YSL abundance were generated in order to compare with abundance of PYSL and to evaluate the effect of misidentification of striped bass and white perch PYSL on the relative abundance index for white perch. The YSL and PYSL indices were significantly correlated ($r = 0.83$), demonstrating that misidentification did not substantially bias the measure of relative abundance derived from the PYSL data.

Juvenile Stage

Most juvenile white perch appear in the upper and middle estuary in July and disperse downriver and shoreward by August. The juvenile population is concentrated in the shore zone during August and September. In mid to late October, juveniles begin moving offshore and by early December, they are in water deeper than 20 ft (Klauda et al 1988).

TABLE 6

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF WHITE PERCH FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS.

WHITE PERCH																		
SURVEY	SELECTION CRITERIA FOR ABUNDANCE INDICES												USE OF DATA FOR ABUNDANCE INDICES (BY LIFE STAGE)					
	RECORD DURATION		TEMPORAL COVERAGE		SPATIAL COVERAGE (RM)		GEAR		SAMPLING DESIGN		SAMPLING INTENSITY		EGG	YSL	PYSL	JUV	YRL	ADULT
LRS	1974-97	1	MMay-eJul	1	14-140	1	1 m^2 nets 505µ mesh 1 m/sec night	1	Stratified Random	1	110-210 weekly	1	5A	5A	5 5A 6A	NU	NU	NS
BSS	1974-97	1	MAug-eOct	1	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5 5A	5 5A	NS
FSS	1979-97	2	MAug-eOct	1	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	NU	NU	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine 1/2" mesh day	1	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NU	NU	NS
JAS	1980-97	2	Jun-Oct	1	55-140	2	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NU	NU	NS
BTS	1981-90	2	LAug-eNov	2	24-43	3	26' trawl day	2	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NU	NU	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NS	NS	NS
WPSA	1972-88	2	Sep-Dec	1	26-38	3	30' trawl day	2	Fixed Stations	2	3-20 bi-weekly	2	NS	NS	NS	NU	5A	NS
SSA	1985-97	2	LApr-eJun	1	91-116	2	500' or 1000' haul seine day	1	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends
e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 7

ESTIMATES OF RELATIVE AND ABSOLUTE ABUNDANCE OF DIFFERENT LIFE STAGES OF WHITE PERCH. (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/".)

	EGG	YSL	PYSL	JUVENILE		Age 1[e]	ADULT
YEAR	LRS[b]	LRS[a]	LRS[a]	BSS[b]	JAS[c]	BSS[b]	WPSA[f]
1968							0.48
1969							2.15
1970							8.57
1971							5.31
1972							5.91
1973						9.57/2.24	5.11
1974	0.12/.05	0.04/0.01	0.46/0.04	4.09/0.56		2.68/1.41	10.02
1975	0.33/.05	0.20/0.02	1.78/0.15	8.04/1.95		3.31/0.43	10.38
1976	0.48/.09	0.39/0.02	2.21/0.24	9.54/1.34		0.45/0.07	10.45
1977	0.11/.02	0.26/0.01	2.43/0.13	6.78/1.11		4.92/2.37	3.73
1978	0.69/0.08	0.26/0.02	3.43/0.19	13.93/2.84		5.31/1.63	18.16
1979	0.53/0.07	0.34/0.02	3.57/0.10	17.03/2.75		3.24/0.94	16.53
1980	0.41/.04	0.33/0.01	2.95/0.11	10.68/2.31	11.9	3.22/0.62	14.02
1981	1.28/.08	0.36/0.03	3.47/0.17	10.30/1.29	11.7	4.31/0.80	12.91
1982	1.37/0.16	0.99/0.05	5.76/0.22	9.99/1.14	13.0	4.08/1.60	27.79
1983	1.09/0.08	0.78/0.04	2.98/0.10	10.36/2.02	8.1	4.31/1.11	39.37
1984	2.69/0.66	0.31/0.02	2.75/0.12	4.17/0.68	2.6	1.47/0.53	37.17
1985	1.04/0.12	0.46/0.04	5.64/0.21	4.35/1.08	8.7	1.71/0.43	10.55
1986	2.31/0.34	1.37/0.08	8.11/0.38	5.60/1.13	8.9	2.21/0.26	
1987	0.53/0.06	0.48/0.02	3.97/0.12	8.88/1.68	12.5	1.23/0.25	
1988	0.780.10	0.38/0.04	2.91/0.15	7.61/1.30	16.4	2.84/0.51	
1989	0.17/0.01	0.57/0.05	4.06/0.37	6.28/1.72	3.6	2.25/0.59	
1990	1.63/0.35	0.46/0.03	2.92/0.26	3.84/0.42	6.8	1.57/0.43	
1991	0.44/0.06	0.24/0.02	3.64/0.24	4.03/0.75	11.3	1.34/0.18	
1992	0.66/0.06	1.05/0.06	4.92/0.20	3.68/0.65	11.5	1.89/0.55	
1993	0.43/0.06	0.79/0.04	4.96/0.18	5.84/0.95		0.65/0.19	
1994	0.38/0.04	0.81/0.04	4.11/0.17	2.84/0.58		1.14/0.34	
1995	0.45/0.07	0.43/0.02	2.51/0.11	3.21/0.48		0.29/0.10	
1996	1.07/0.13	0.72/0.05	6.12/0.27	0.31/0.13		0.45/0.07	
1997	0.26/0.05	0.13/0.01	1.46/0.07	3.91/0.56			

a Sum of weighted average number per m^3 for 7 consecutive sampling weeks over period of peak abundance.
b Average number per 100' seine haul for sampling from mid-August to early October (weeks 33-40).
c Arithmetic mean number per 100' seine haul.
d Estimated absolute number of juveniles on September 1, in millions. Estimation methods described in Appendix VI-2.
e Applied to the year in which the cohort was spawned.
f Average number of age 3 fish per 10 min tow in lower estuary samples, applied to the year in which the cohort was spawned. Data rom LMS 1989, Table 5-31.

The BSS covers a much greater spatial extent of the river than either the JAS or JSB programs although the JAS does cover the upriver areas where juvenile perch are more prevalent. The sampling is substantially more intense in the BSS relative to the two DEC surveys (100 samples bi-weekly vs 25 samples bi-weekly). The BSS also employs a randomized design for its sample allocation rather than the fixed design used in the JAS and JSB. Thus, an index of relative abundance derived from the BSS is probably more as a measure of relative abundance for the juvenile stage.

Yearling and sub-adults

Age 1^+ white perch remain in the estuary and were commonly caught during the BSS. Thus, the relative abundance of age 1^+ fish was also derived from the BSS data.

C. ATLANTIC TOMCOD

Adults

Sampling program evaluation for Atlantic tomcod is summarized in Table 8 and data sets are provided in Table 9.

The absolute abundances of age-1 and age-2 fish were estimated from the ATMR program. In the ATMR, Atlantic tomcod spawning within the Hudson River estuary were marked on the spawning grounds in the middle of the estuary and recaptured after spawning near the mouth of the estuary using bottom trawls. Information on the age structure, sex ratio by age, and fecundity by age in the spawning population was also collected during the winter surveys. The mark-recapture information was used to generate an absolute estimate of total abundance for the spawning population. The estimate of total abundance was then combined with the age-specific biological information to generate an estimate of the total number of eggs deposited by the spawning population.

Although mark-recapture estimates from 1974-75 through 1978-79 calculated by McLaren et al. (1988) used different sampling methods, they have been included in the data series for describing absolute abundance of the spawning stock. These estimates could contain a positive bias due to inclusion of box trap sampling from the lower river regions in the recapture effort (since these samples contained few fish marked in primary spawning regions), however the estimates probably do reflect major patterns of abundance changes among years.

The egg deposition estimates, like the population estimates on which they depend, are most reliable for the period from 1988 through 1997.

TABLE 8

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF ATLANTIC TOMCOD FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS.

ATLANTIC TOMCOD																	
	SELECTION CRITERIA FOR ABUNDANCE INDICES												USE OF DATA FOR ABUNDANCE INDICES (BY LIFE STAGE)				
SURVEY	RECORD DURATION		TEMPORAL COVERAGE		SPATIAL COVERAGE (RM)		GEAR		SAMPLING DESIGN		SAMPLING INTENSITY		EGG	YSL	PYSL	JUV	ADULT
LRS	1974-97	1	MMay-eJul	2	14-140	2	1 m^2 nets 505µ mesh 1 m/sec night	1	Stratified Random	1	110-210 weekly	1	NS	NU	5 5A 6A	5 5A 6A	NS
BSS	1974-97	1	MAug-eOct	3	12-152	2	100' seine 3/8" mesh day	3	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5 5A 6A	NS
FSS	1979-97	2	MAug-eOct	2	14-140	2	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2/1	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	NU	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine 1/2" mesh day	3	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NS	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	3	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NS	NS
BTS	1981-90	3	LAug-eNov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NU	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	3	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NS	NS
ATMR	1974-97	1	Nov-Apr	1	12-76 0-12	2 2	Box traps 30' trawl	1 1	Fixed Sites	2	17 daily Variable	2 2	NS	NS	NS	NS	5 5A 6A

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends
e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 9

ESTIMATES OF RELATIVE AND ABSOLUTE ABUNDANCE OF DIFFERENT LIFE STAGES OF ATLANTIC TOMCOD. (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/".)

	EGG	PYSL/ JUVENILE	ADULT	
YEAR	ATMR[a]	LRS[b]	Age 1-ATMR[c]	Age 2-ATMR[c]
1974		0.09		0.1[d]
1975		0.04/0.86	3.65[d]	0.7[d]
1976	22	0.01/0.00	9.72[d]	0.1[d]
1977	65	0.41/0.27	2.44[d]	0.1[d]
1978	21	0.11/0.03	5.98[d]	0.3[d]
1979	51	0.03/0.01	8.86[d]	e
1980	57	0.23/0.04	e	e
1981	e	0.15/0.04	e	1.9
1982	e	0.06/0.02	10.6	0.8
1983	98	0.03/0.01	5.88	f
1984	76	0.15/0.07	F	0.1
1985	f	0.15/0.03	2.0	f
1986	26	0.08/0.01	F	0.4
1987	f	0.32/0.05	3.1	0.6
1988	41	0.15/0.03	5.3	2.0
1989	41	0.36/0.08	4.8	0.6
1990	87	0.31/0.13	2.6	0.1
1991	52	0.19/0.03	0.3	0.4
1992	7	0.06/0.02	2.2	0.2
1993	30	0.21/0.05	0.5	0.3
1994	7	0.11/0.02	2.1	0.03
1995	32	0.15/0.02	0.06	0.9
1996	2	0.09/0.01	2.4	0.6
1997	47	0.05/0.01	0.7	

a Estimated number of eggs spawned in billions determined from average age-specific fecundity and estimated populations. Estimate applied to the year that began during the winter the eggs were spawned.
b Weighted average number per m^3 for 4 consecutive sampling weeks in May (weeks 19-22).
c Estimated population size in millions applied to the year that began in the winter the cohort was spawned.
d Population estimates and age composition from McLaren et al. 1988. Sampling conducted entirely above RM 12.
e Insufficient number of fish recaptured to calculate an estimate.
f No sampling program conducted.

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

Egg, Larval, and Juvenile Stages

The Ichthyoplankton surveys (LRS) generally began too late to sample eggs and yolk-sac larvae (YSL) adequately and no abundance estimate was generated for these life stages. The LRS surveys started soon enough to capture post yolk-sac larvae (PYSL) but often missed the period of peak abundance for this life stage. They also did not sample below the George Washington Bridge in March and April (when and where high densities of small larvae may occur) until 1995. However, tomcod larvae move up river during the spring as they grow and the distribution of samples in the LRS program was adequate when abundance peaked during the juvenile stage in late May and early June. A combined PYSL-juvenile index was used to describe cohort abundance at this time.

During the summer and the beginning of the fall, the majority of the young-of-the-year population is located in deeper waters in upper New York Harbor and the lower portion of the estuary. As a result, the population is not adequately sampled by the BSS, JSB, or JAS. Although the FSS at least samples in correct habitat, an unknown and probably variable fraction of the population may not have been sampled for most of the years of the survey since prior to 1996, no samples were collected below River Mile 12. The BTS program also missed fish in the lower part of the river, and only comprised less than a 10-year time series.

Thus, the winter surveys conducted during the period from 1988 through 1997 provide the most reliable estimates of absolute abundance for age 1 and age 2 Atlantic tomcod and of the number of eggs deposited by the spawning population. The late spring YOY index appears to be a reliable measure of abundance in the YOY population before the summer shifts in the distribution and abundance of this species occur.

D. AMERICAN SHAD

Adults

Sampling program evaluation for American shad is summarized in Table 10 and data sets are provided in Table 11.

As a valuable commercial species, American shad have been a focal species for the Hudson River Fisheries Unit of NYSDEC. They have monitored the commercial fishery since 1980, and have conducted a spawning stock assessment effort since 1985. The commercial fixed gill net fishery for American shad in the Hudson River is highly selective for age-5 to age-7 fish thus the CPUE values developed from the CFM program should provide an index of relative abundance for these newly recruited age groups. The Spawning Stock Assessment (SSA) sampling is conducted with haul seines and is less selective; therefore, it provides a better measure of age structure of the spawning stock.

In addition to the data sets useful for relative abundance information, there are long data series of landings data for American shad that may be useful for modeling the population

TABLE 10

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF AMERICAN SHAD FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS.

AMERICAN SHAD																			
SURVEY	SELECTION CRITERIA FOR ABUNDANCE INDICES													USE OF DATA FOR ABUNDANCE INDICES (BY LIFE STAGE)					
	RECORD DURATION		TEMPORAL COVERAGE		SPATIAL COVERAGE (RM)		GEAR		SAMPLING DESIGN		SAMPLING INTENSITY		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	May-Jul	1	14-140	2	1 m^2 nets 505μ mesh 1 m/sec night	1	Stratified Random	1	110-210 weekly	1	NU	NU	5 5A 6A	NU	NS	NS
BSS	1974-97	1	Aug-Oct	2	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5 5A	NS	NS
FSS	1979-97	2	Aug-Oct	2	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	NU	NS	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine 1/2" mesh day	1	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	5A	NS	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	5 5A 6A	NS	NS
BTS	1981-90	3	Aug-Nov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NU	NS	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	Apr-Jun	1	91-116	3	500' or 1000' haul seine day	1	Directed	3	Variable	3	NS	NS	NS	NS	NS	6A
CFM	1980-97	2	Apr-May	1	23-55	3	Commercial gill nets	1	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	5 5A 6A
Landings	1970-1997	3	Annual	1														6A

dynamics of the stock. Landings data exist for the Hudson River, for New York state, and for the Atlantic coast, which would contain a component due to the Hudson River population.

Egg and Larval Stages

The egg life stage has a duration less than the interval between sampling events and occurs primarily in upriver shoal habitats which are not well-sampled by the LRS. The YSL stage may begin in the shoal habitat and is also short in comparison to the interval between sampling events. As a result, these life stages may not have been sampled consistently from year to year, especially since the duration of these life stages varies with temperature. The PYSL life stage occurs in pelagic habitats and is much longer in duration than the egg and larval stages; therefore it should have been sampled more consistently across the years and the PYSL data were used generate an index of relative American shad spawning effort.

Juvenile Stage

Due to the pelagic nature of juvenile American shad, channel FSS catches may provide a useful index of juvenile abundance for this species. However, sampling of the channel stratum in the upper estuary did not begin until 1979, which limits the number of years available for a juvenile index. Because juvenile American shad move into shallow water during the day, BSS and JAS surveys potentially provide a good index of relative abundance. Although the abundance indices generated from the BSS and FSS surveys did depict similar patterns in abundance from 1979 through 1997 ($r = 0.$___), the JAS data exhibited the highest correlation with the PYSL data ($r = 0.76$). The geometric mean annual abundance, which is the preferred measure of shad abundance for the ASMFC, was selected as the best measure of juvenile American shad over the period from 1974 through 1997.

E. **BLUEBACK HERRING**

Adults

Sampling program evaluation for blueback herring is summarized in Table 12 and data sets are provided in Table 13.

The life history of blueback herring makes it difficult to accurately measure their relative abundance. Adults are in the estuary only a short time during and after the spawning season. The Ichthyoplankton gear used in the LRS program are not efficient for sampling the adults (they are large enough to easily avoid and escape from the Tucker trawl and epibenthic sled). The haul seine and gill net sampling for American shad and striped bass are also not effective because the meshes are too coarse for the smaller blueback herring or alewife, therefore no index of adult abundance was available.

TABLE 11

ESTIMATES OF RELATIVE AND ABSOLUTE ABUNDANCE OF DIFFERENT LIFE STAGES OF AMERICAN SHAD. (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/")

	ADULT		PYSL	JUVENILE		
YEAR	CFM-males[a]	CFM-females[a]	LRS[b]	BSS[c]	JAS[d]	FSS[e]
1974			0.17/0.06	11.50/0.82		
1975			0.28/0.18	10.63/1.43		
1976			0.16/0.05	13.32/0.87		
1977			0.17/0.03	13.70/1.39		
1978			0.09/0.03	23.67/2.66		
1979			0.49/0.07	11.64/1.74		0.10/0.04
1980	4.28	19.11	0.48/0.22	10.75/2.46	23.87	0.22/0.12
1981	6.17	14.47	0.78/0.31	17.62/2.17	19.12	0.48/0.20
1982	3.04	8.02	0.59/0.12	16.31/1.92	12.17	0.46/0.08
1983	5.65	9.16	0.57/0.09	19.68/3.89	18.24	0.79/0.48
1984	3.42	9.49	0.38/0.17	8.69/1.84	7.79	0.40/0.09
1985	10.66	26.65	0.67/0.17	8.08/1.30	26.65	0.43/0.20
1986	24.54	52.09	1.05/0.15	19.06/3.74	46.32	1.51/0.51
1987	13.00	47.34	0.18/0.08	13.47/2.28	20.20	0.37/0.15
1988	19.40	42.22	0.73/0.34	7.72/1.01	27.59	0.29/0.13
1989	9.30	33.79	1.04/0.79	22.05/2.41	47.30	0.62/0.20
1990	3.53	16.61	1.17/0.73	18.67/1.74	41.24	0.31/0.15
1991	2.32	18.31	0.32/0.12	11.96/3.16	24.05	0.14/0.05
1992	1.32	14.61	0.62/0.21	13.92/1.05	35.17	0.38/0.11
1993	0.91	13.02	0.23/0.12	7.07/0.87	11.64	0.05/0.04
1994	0.86	24.35	0.37/0.13	17.56/3.28	26.09	0.07/0.04
1995	1.40	11.49	0.19/0.06	3.79/0.43	5.74	0.08/0.04
1996	2.19	20.25	0.26/0.06	11.77/1.93	30.89	1.37/0.72
1997	0.91	7.11	0.15/0.03	12.54/2.04	9.51	0.18/0.09

a Catch per 1000 yd^2 hr in fixed nets.
b Sum of weighted average number per m^3 for 7 consecutive sampling weeks over period of peak abundance.
c Average number per 100' seine haul for sampling from mid-August to early October (weeks 33-40).
d Geometric mean number per 100' seine haul.
e Average number per 1000 m^3 in channel sampling from mid-August to early October (weeks 33-40).

TABLE 13

ESTIMATES OF RELATIVE AND ABSOLUTE ABUNDANCE OF DIFFERENT LIFE STAGES OF BLUEBACK HERRING (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/".)

Error! Bookmark not defined.	JUVENILE		
YEAR	JAS[a]	BSS[b]	FSS[c]
1974		23.51/ 3.39	
1975		69.66/ 9.49	
1976		155.55/23.84	
1977		219.36/26.38	
1978		229.19/44.49	
1979		54.45/ 8.32	3.70/ 0.75
1980	64.6	100.84/53.80	2.61/ 0.75
1981	69.5	181.93/72.90	21.2/ 5.86
1982	91.4	121.72/31.43	10.33/ 2.06
1983	152.1	190.86/41.85	6.08/ 1.07
1984	75.8	22.55/ 5.43	20.38/ 3.67
1985	150.7	18.82/ 3.90	17.24/ 4.58
1986	101.9	14.10/ 4.41	6.48/ 1.38
1987	138.8	69.80/15.69	25.61/12.36
1988	245.6	47.41/14.02	26.69/ 4.30
1989	100.7	35.88/ 8.09	16.83/ 5.41
1990	334.3	97.85/13.97	29.69/10.64
1991	290.7	47.44/11.06	12.65/ 4.47
1992	187.3	31.10/ 6.53	15.62/ 3.87
1993		35.28/5.52	7.72/1.59
1994		88.83/13.78	5.77/1.90
1995		38.18/23.30	1.27/0.42
1996		35.87/17.65	50.16/15.89
1997		162.11/35.44	7.30/1.43

a Average number per 100' seine haul.
b Average number per 100' seine haul for sampling from mid-August to early October (weeks 33-40).
c Average number per 1000 m^3 for channel sampling from mid-August to early October (weeks 33-40).
d Estimated absolute number of juveniles on September 1, in billions. Estimation methods described in Appendix VI-2.

TABLE 12

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF BLUEBACK HERRING FROM

BLUEBACK HERRING																		
SURVEY	SELECTION CRITERIA FOR ABUNDANCE INDICES												USE OF DATA FOR ABUNDANCE INDICES (BY LIFE STAGE)					
	RECORD DURATION		TEMPORAL COVERAGE		SPATIAL COVERAGE (RM)		GEAR		SAMPLING DESIGN		SAMPLING INTENSITY		EGG	YSL	PYSL	JUV	YRL	ADULT
LRS	1974-97	1	May-Jul	1	14-140	2	1 m^2 nets 505μ mesh 1 m/sec night	1	Stratified Random	1	110-210 weekly	1	NU	NU	NU	NU	NU	NS
BSS	1974-97	1	Aug-Oct	2	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5 5A 6	NU	NS
FSS	1979-97	2	Aug-Oct	2	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	5 5A 6	NU	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine 1/2" mesh day	1	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NU	NU	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	5A	NU	NS
BTS	1981-90	3	Aug-Nov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NU	NU	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	ApreJun	1	91-116	3	500' or 1000' haul seine day	1	Directed	3	Variable	3	NS	NS	NS	NS	NS	NU
CFM	1980-97	2	Apr-May	1	23-55	3	Commercial gill nets	1	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 14

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF ALEWIFE FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

Alewife																			
Survey	Selection Criteria for Abundance Indices													Use of Data for Abundance Indices (by Life Stage)					
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	MMay-eJul	1	14-140	2	1 m^2 nets 505μ mesh 1 m/sec night	1	Stratified Random	1	110-210 weekly	1	NU	NU	NU	NU	NU	NS
BSS	1974-97	1	MAug-eOct	2	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5A	NU	NS
FSS	1979-97	2	MAug-eOct	2	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	5 5A 6	NU	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine 1/2" mesh day	1	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NU	NU	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NU	NU	NS
BTS	1981-90	3	LAug-eNov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NU	NU	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NU	NS	NS
SSA	1985-97	2	LApr-eJun	1	91-116	3	500' or 1000' haul seine day	3	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	1	23-55	3	Commercial gill nets	3	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

Egg and Larval Stages

Eggs and larvae of the river herrings, except for American shad, are not distinguished from each other in the laboratory. Therefore, an index of eggs or larvae would represent an unknown mix of alewifeand blueback herring. In addition, blueback herring spawn outside the river proper, in tributaries and in the Mohawk River. The fraction of the stock spawning outside of the Hudson River is not known. Therefore, sampling of the early life stages within the Hudson may underestimate the true abundance of eggs and larvae.

Juvenile Stage

Like juvenile shad, juvenile blueback herring were caught in significant numbers in the BSS but the diel behavior of the two species is quite different. Blueback herring exhibit diel changes in their distributions but it is not onshore and offshore. They move up in the water column at night and down during the day (Schmidt 1988). As a result, the BSS catches are probably not a reliable index of their relative abundance because during the day blueback herring are near the bottom in deep water. The index of juvenile abundance was generated from FSS Tucker trawl catches from the channel stratum. The FSS shoal catches were not used because of the change in the sampling gear in 1985.

F. **ALEWIFE**

Adults

Sampling program evaluation for alewife is summarized in Table 14 and data sets are provided in Table 15.

The life history of alewife makes it difficult to accurately measure the relative abundance of adults because they are in the estuary only a short time during and after the spawning season. In addition, the Ichthyoplankton gear used in the LRS do not capture adult fish very efficiently (they easily avoid or escape from these nets). The haul seine and gill net sampling for American shad and striped bass are also not effective because the meshes are too coarse to effectively collect alewife or blueback herring.

Egg and Larval Stages

Eggs and larvae of the river herrings, except for American shad, are not distinguished from each other in the laboratory. Therefore, an index of eggs or larvae would represent an unknown mix of alewifeand blueback herring. In addition, alewife spawn outside the river proper, in tributaries and in the Mohawk River. The fraction of the stock spawning outside of the Hudson River is not known. Therefore, sampling of the early life stages within the Hudson may underestimate the true abundance of eggs and larvae.

Juvenile Stage

Alewives move inshore at night and offshore during the day. Night seine tows produce higher catches than day seine tows (TI 1976 - Fisheries Survey of the Hudson River, March-December 1973, Volume IV, Revised Edition). The BSS is conducted during the day and, consequently, not appropriate for this species. The FSS shoal catches are more appropriate for this species but the capture efficiency of the gear used in this survey changed significantly in 1985 when the 3-m beam trawl replaced the epibenthic sled (the netting used in the beam trawl is coarser than that used in the epibenthic sled and extrusion of small fish is greater after 1985). The FSS channel catches provide a longer time series than the shoal catches prior to 1985 and include the most recent years when the abundance of adult striped bass (predators on adult alewives) and zebra mussels (a species that could change the abundance of zooplankton prey for larval and juvenile alewives) changed dramatically. As a result, the relative abundance index for juvenile alewives was generated from the FSS channel catches.

G. **BAY ANCHOVY**

Adults

Sampling program evaluation for bay anchovy is summarized in Table 16 and data sets are provided in Table 17.

Bay anchovy is a marine species. Thus, none of the sampling programs are ideal for estimating relative abundance either of the population, or that component of the population within the Hudson River. Adult bay anchovy are caught in the LRS. However, due to the relatively small size of the gear (1 m^2 mouth opening) collection efficiency for adults is probably low. The LRS also does not cover the entire period when adult bay anchovy are in the river.

Egg and Larval Stages

No indices of abundance have been developed for bay anchovy eggs or YSL because the duration of these stages was short compared to the weekly sampling interval for the LRS program and because of the tendency of the eggs to sink to the bottom. In addition, YSL are small enough to pass easily through the 0.5 mm mesh of Ichthyoplankton nets. Although the temporal and spatial distribution of PYSL also extends substantially outside the spatial and temporal coverage of the LRS sampling, the life stage is caught in large numbers and densities probably represent the relative abundance of the life stage north of RM 12 during the LRS sampling period.

TABLE 15

ESTIMATES OF RELATIVE AND ABSOLUTE ABUNDANCE OF DIFFERENT LIFE STAGES OF ALEWIFE (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/".)

	JUVENILE	
YEAR	BSS[a]	FSS[b]
1974	2.92/0.44	
1975	2.47/0.40	
1976	2.40/0.63	
1977	4.18/0.60	
1978	5.48/0.97	
1979	1.35/0.23	0.20/0.08
1980	0.50/0.16	0.69/0.35
1981	4.15/0.94	0.63/0.21
1982	0.79/0.24	0.27/0.08
1983	1.79/0.27	0.19/0.07
1984	0.49/0.14	0.21/0.13
1985	0.74/0.17	0.93/0.41
1986	0.83/0.50	0.26/0.08
1987	0.65/0.12	0.52/0.27
1988	0.42/0.09	0.27/0.13
1989	0.16/0.04	0.23/0.07
1990	1.05/0.17	0.35/0.14
1991	3.47/0.57	0.33/0.12
1992	0.30/0.12	0.17/0.08
1993	0.54/0.16	0.23/0.08
1994	1.40/0.34	0.12/0.06
1995	1.14/0.35	0.11/0.03
1996	0.10/0.04	0.49/0.15
1997	2.26/0.44	0.32/0.10

a Average number per 100' seine haul for sampling from mid-August to early October (weeks 33-40).
b Average number per 1000 m^3 for channel sampling from mid-August to early October (weeks 33-40).
c Estimated absolute number of juveniles on September 1, in millions. Estimation methods described in Appendix VI-2.

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends

e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 17

ESTIMATES OF RELATIVE AND ABSOLUTE ABUNDANCE OF DIFFERENT LIFE STAGES OF BAY ANCHOVY (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/")

	PYSL	JUVENILE
YEAR	LRS[a]	FSS[b]
1974	5.99/0.40	
1975	7.67/0.69	
1976	3.84/0.64	
1977	5.13/0.37	
1978	2.28/0.14	
1979	1.50/0.09	63.35/10.36
1980	1.20/0.19	215.91/53.15
1981	2.19/0.17	149.45/23.70
1982	0.10/0.01	196.61/25.20
1983	1.90/0.59	114.99/32.41
1984	2.61/0.39	159.99/33.09
1985	1.96/0.13	152.68/16.31
1986	0.68/0.05	109.35/15.80
1987	1.53/0.09	196.01/42.21
1988	15.71/1.72	340.70/50.62
1989	8.95/1.21	288.92/40.24
1990	4.70/0.43	110.38/11.75
1991	26.47/2.27	110.74/8.44
1992	4.72/0.43	146.69/35.02
1993	10.26/0.62	161.0/20.1
1994	24.34/1.56	138.4/32.8
1995	9.59/0.46	266.0/44.1
1996	3.95/0.31	76.2/20.2
1997	8.13/0.92	147.8/26.6

a Weighted average number per m^3 for 7 consecutive sampling weeks over period of peak abundance.
b Weighted average number per 1000 m^3 for sampling from mid-August to early October (weeks 33-40).

TABLE 16

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF BAY ANCHOVY FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS.

Bay Anchovy																		
Survey	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)					
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	May-Jul	3	14-140	2	1 m^2 nets 505µ mesh 1 m/sec night	1	Stratified Random	1	110-210 weekly	1	NU	NU	5 5A 6A	NU	NU	NS
BSS	1974-97	1	Aug-Oct	2	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	NU	NU	NS
FSS	1979-97	2	Aug-Oct	2	14-140	2	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	5 5A 6A	NU	NS
JSB	1976-97	1	Jul-Nov	1	23-42	2	200' seine ½" mesh day	2	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NU	NU	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine ¼" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NU	NU	NS
BTS	1981-90	3	Aug-Nov	2	24-43	2	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NU	NU	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	2	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NU	NU	NS
SSA	1985-97	2	Apr-Jun	3	91-116	3	500' or 1000' haul seine day	3	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	3	23-55	3	Commercial gill nets	3	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends
e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 18

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF ATLANTIC AND SHORTNOSE STURGEON FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

ATLANTIC AND SHORTNOSE STURGEON																			
SURVEY	SELECTION CRITERIA FOR ABUNDANCE INDICES													USE OF DATA FOR ABUNDANCE INDICES (BY LIFE STAGE)					
	RECORD DURATION		TEMPORAL COVERAGE		SPATIAL COVERAGE (RM)		GEAR		SAMPLING DESIGN		SAMPLING INTENSITY		EGG	YSL	PYSL	JUV	SUB ADULT	ADULT
LRS	1974-97	1	May-Jul	1	14-140	1	1 m^2 nets 505µ mesh 1 m/sec night	31	Stratified Random	1	110-210 weekly	1	NS	NU	NU	NU	NU	NS
BSS	1974-97	1	Aug-Oct	1	12-152	1	100' seine 3/8" mesh day	3	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	NS	NS	NS
FSS	19785-97	2	Aug-Oct	1	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	1	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	5 5A	5 5A	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine 1/2" mesh day	2	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NS	NS	NS
JAS	1980-97	2	Jun-Oct	1	55-140	2	100' seine 1/4" mesh	3	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NS	NS	NS
BTS	1981-90	2	Aug-Nov	2	24-43	3	26' trawl day	2	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	5A	NU	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NS	NS	NS
SBMR	1984-97	2	Nov-Apr	1	NY harbor - 12	3	30' trawl day	1	Directed	2	25-60 Weekly	2	NS	NS	NS	NS	NS	NS
WPSA	1972-88	2	Sep-Dec	1	26-38	3	30' trawl day	2	Fixed Stations	2	3-20 bi-weekly	2	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	Apr-Jun	1	91-116	2	500' or 1000' haul seine day	1	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	1	23-55	2	Gill nets	1	"Fixed"	2	Variable	2	NS	NS	NS	NS	5A	NU

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends
e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

Juvenile Stage

Although bay anchovy juveniles are caught in the utilities' BSS program and the NYSDEC-DMR beach seine programs (JSB and WLIS), bay anchovy are primarily pelagic and offshore sampling is more appropriate for this species. The FSS shoal data are probably the most appropriate for generating an index of relative abundance for this species but the capture efficiency of the gear used in this survey changed significantly in 1985 when the 3-m beam trawl replaced the epibenthic sled (the netting used in the beam trawl is coarser than that used in the epibenthic sled and extrusion of small fish is greater after 1985). The FSS channel catches provide a longer time series than the shoal catches prior to 1985 and include the most recent years when the abundance of PYSL striped bass, which may compete with or feed upon larval bay anchovy, increased dramatically. As a result, the relative abundance index for juvenile alewives was generated from the FSS channel catches.

H. ATLANTIC STURGEON

Adults

Sampling program evaluation for Atlantic sturgeon is summarized in Table 18 and data sets are provided in Table 19.

Adult Atlantic sturgeon were not effectively sampled in either the utility or DEC monitoring programs.

Sub-Adults

Sub-adult Atlantic sturgeon are caught in the commercial shad fishery and the average catch rate estimates are available from 1980 through 1997. Juvenile and sub-adult Atlantic sturgeon are also caught in the 3-m beam trawl of the FSS and in the NYSDEC-DFW bottom trawl program (BTS). The catch rates are low and neither the Utility nor DEC monitoring programs provide precise estimates of relative abundance. However, the total annual catches from the 3-m beam trawl and the average catch per tow estimates from the bottom trawl generally support the population trends suggested by the CFM catch rates.

Egg and Larval Stages

The catches of egg and larval stages are so low that abundance indices cannot be generated for Atlantic sturgeon.

I. SHORTNOSE STURGEON

Adult and Sub-Adult Stages

Sampling program evaluation for shortnose sturgeon is summarized in Table 18 and data sets are provided in Table 20.

Adult shortnose sturgeon are caught in the commercial shad fishery, although the major portion of the adult shortnose sturgeon population should be in the upper estuary spawning during most of the period when fixed gill nets are fished for shad in the lower estuary. The total annual catches from the 3-m beam trawl used in the FSS program, and the average catch per tow estimates from the bottom trawl program (BTS) generally reflect the same population trends suggested by the CFM catch rates.

Egg and Larval Stages

The catches of egg and larval stages are so low that abundance indices cannot be generated for shortnose sturgeon.

J. BLUEFISH

Adults

Sampling program evaluation for bluefish is summarized in Table 21 and data sets are provided in Table 22.

Adult bluefish are not caught in any of the Hudson River sampling programs.

Egg and Larval Stages

Bluefish spawn at offshore in the marine environment; therefore, eggs and larvae are generally not found in the Hudson River.

Juvenile Stage

Juvenile bluefish are sampled in coastal waters by the National Marine Fisheries Service offshore trawl survey. Juvenile bluefish that enter the estuary are sampled by the utilities' BSS and FSS programs, and by the NYSDEC-DMR JSB seine survey and the DFS bottom trawl program (BTS). The JSB and BTS programs do not cover the spatial distribution of bluefish within the estuary as well as the BSS and FSS programs and the sampling intensity is also greater in the BSS and FSS programs. A comparison of the BSS and FSS catches demonstrates that bluefish are caught more consistently in BSS program than in the FSS program, and catches in the bottom and shoal strata show a definite effect of the change to the 3-m beam trawl in 1985. The time series for the BSS program is therefore longer than

TABLE 19

ESTIMATES OF RELATIVE ABUNDANCE OF DIFFERENT LIFE STAGES OF ATLANTIC STURGEON (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/")

	SUBADULT	JUVENILE & SUBADULT	
YEAR	CFM[a]	FSS[b]	FSS[c]
1974			
1975			
1976			
1977			
1978			
1979			
1980	0.230		
1981	0.161		0.10
1982	0.090		0.27
1983	0.025		0.13
1984	0.035		0.07
1985	0.055	96	0.04
1986	0.022	184	0.09
1987	0.033	149	0.06
1988	0.043	117	0.08
1989	0.006	63	0.02
1990	0.024	6	0.00
1991	0.011	10	
1992	0.007	11	
1993		7	
1994		15	
1995		15	
1996		14	
1997		34	

a Catch per 1000 yd^2 hr in fixed nets.
b Total annual catch in 3 m beam trawl.
c Average catch per tow in bottom trawl survey.

TABLE 21

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF BLUEFISH FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS.

Bluefish																		
	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)					
Survey	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	May-Jul	2	14-140	2	1 m^2 nets 505µ mesh 1 m/sec night	3	Stratified Random	1	110-210 weekly	1	NU	NS	NS	NS	NS	NS
BSS	1974-97	1	Aug-Oct	2	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5 5A	NS	NS
FSS	1979-97	2	Aug-Oct	2	14-140	2	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	5A	NS	NS
JSB	1976-97	1	Jul-Nov	1	23-42	2	200' seine 1/2" mesh day	1	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	5A	NU	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NS	NS	NS
BTS	1981-90	3	Aug-Nov	2	24-43	2	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	5A	NS	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NU	NU	NS
SBMR	1984-97	2	Nov-Apr	3	NY harbor - 12	3	30' trawl day	1	Directed	2	25-60 Weekly	2	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	Apr-Jun	3	91-116	3	500' or 1000' haul seine day	1	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	3	23-55	2	Commercial gill nets	3	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends
e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 20

ESTIMATES OF RELATIVE ABUNDANCE OF DIFFERENT LIFE STAGES OF SHORTNOSE STURGEON (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/".)

	ADULT	JUVENILES & ADULTS	
YEAR	CFM[a]	FSS[b]	BTS[c]
1974			
1975			
1976			
1977			
1978			
1979			
1980	0.007		
1981	0.008		
1982	0.001		
1983	0.001		
1984	0.000		
1985	0.003	0.0025/0.0025	16
1986	0.003	0.0031/0.0031	8
1987	0.002	0.0000/0.0000	11
1988	0.001	0.0024/0.0024	20
1989	0.000	0.0206/0.0122	12
1990	0.004	0.0000/0.0000	2
1991	0.004	0.0044/0.0044	18
1992	0.009	0.0041/0.0041	76
1993		0.0109/0.0086	82
1994		0.0069/0.0057	56
1995		0.0215/0.0126	36
1996		0.0112/0.0060	40
1997		0.0235/0.0076	26

a Catch per 1000 yd^2 hr in fixed nets.
b Total annual catch in 3 m beam trawl.
c Average catch per tow.

that for any of the other survey programs. The BSS data are not correlated (r=0.01) with the NMFS data, which suggests that changes in abundance within the estuary may not accurately reflect changes in the coastal juvenile population.

K. HOGCHOKER

Adults

Sampling program evaluation for hogchoker is summarized in Table 23 and data sets are provided in Table 24.

Adult hogchokers tend to be found in more saline waters and spawn in the lower regions of estuaries and offshore from estuary mouths during spring and summer. The spatial extent of the Hudson River surveys probably does not encompass that of the adult population generating the juvenile population sampled within the estuary and no index was generated for this life stage.

Egg and Larval Stages

The spatial distributions for these life stages indicate that the LRS program does not extend far enough into the lower estuary to sample the entire egg and larval populations and no abundance indices were generated for these life stages.

Juvenile Stage

The center of the spatial distribution for juveniles is in the middle estuary and they are most abundant during late September and early October. Thus, the spatial and temporal extent of the BSS and FSS programs are appropriate for this life stage. Hogchokers are a bottom-dwelling species and the FSS bottom gear should provide the more reliable abundance estimates for juvenile hogchokers than either the FSS channel gear or the BSS seines. Juvenile and older life stages were not differentiated in the BTS program and these data could not be used to generate a juvenile abundance index. The change in the gear used to sample the bottom stratum in the FSS in 1985, when the epibenthic sled was replaced with the 3-m beam trawl, did not appear to have affected catches of juvenile hogchokers and probably reflects the bottom-oriented, sedentary nature of this species. As a result, the entire FSS bottom time series (1974-1997) was used in the assessment of changes in the relative abundance of hogchokers.

Yearling and Older

The FSS samples from the bottom strata were also used to assess the changes in the relative abundance of yearling and older (primarily yearling) hogchokers.

TABLE 22

ESTIMATES OF RELATIVE ABUNDANCE OF DIFFERENT LIFE STAGES OF BLUEFISH (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/".)

	JUVENILE			
YEAR	BSS[a]	JSB[b]	FSS[c]	NMFS[e]
1974	0.71/0.02			1.484
1975	0.28/0.07			5.587
1976	0.19/0.03			5.572
1977	0.33/0.10			6.546
1978	0.35/0.08			5.875
1979	0.22/0.05		0.00/0.00	7.443
1980	0.30/0.05	2.05	0.03/0.03	7.031
1981	0.46/0.12	2.86	0.00/0.00	13.183
1982	0.30/0.06	2.99	0.02/0.02	4.823
1983	0.32/0.10	2.45	0.04/0.02	3.958
1984	0.15/0.03	1.20	0.15/0.07	7.682
1985	0.24/0.07	2.36	0.03/0.03	3.451
1986	0.13/0.05	2.15	0.03/0.03	3.913
1987	0.17/0.05	0.95	0.15/0.07	2.703
1988	0.18/0.03	3.59	0.05/0.02	1.982
1989	0.18/0.04	1.33	0.00/0.00	9.132
1990	0.24/0.05	1.46	0.18/0.07	2.513
1991	0.16/0.04	0.56	0.02/0.02	2.063
1992	0.13/0.05	0.71	0.05/0.03	1.363
1993	0.10/0.03	0.67	0.01/0.01	0.736
1994	0.06/0.02	0.81	0.07/0.04	1.673
1995	0.18/0.04	1.56	0.13/0.07	2.054
1996	0.04/0.01	0.43	0.01/0.01	2.264
1997	0.19/0.03	1.35	0.01/0.01	1.367

a Average number per 100' seine haul for sampling from mid-August to early October (weeks 33-40).
b Arithmetic mean number per 200' seine haul for 6-week sampling period.
c Average number per 1000 m^3 in channel stratum sampling from mid-August to early October (weeks 33-40) of the FSS
d Arithmetic mean number per tow in bottom trawl survey.
e Mean kg/tow for the NEFSC fall inshore index reported in Gibson, M. R. and N. Lazar. 1998. Assessment and Projection of the Atlantic coast bluefish stock using a biomass dynamic model. Report to the ASMFC Bluefish Technical Committee and MAFMC Statistics and Science Committee

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends
e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 23

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF HOGCHOKER FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

Bluefish																			
	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)						
Survey	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	May-Jul	2	14-140	2	1 m^2 nets 505μ mesh 1 m/sec night	2	Stratified Random	1	110-210 weekly	1	NU	NU	NU	NU	NS	NS
BSS	1974-97	1	Aug-Oct	2	12-152	2	100' seine 3/8" mesh day	3	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	NS	NS	NS
FSS	1979-97	2	Aug-Oct	2	14-140	2	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2/1	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	5 5A	NU	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine 1/2" mesh day	3	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NS	NS	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	3	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NS	NS	NS
BTS	1981-90	2	Aug-Nov	2	24-43	2	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	5A	5A	5A
WLIS	1984-97	2	May-Oct	1	WLI	3	200' seine 1/2" mesh day	3	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NS	NS	NS
SBMR	1984-97	2	Nov-Apr	3	NY harbor - 12	3	30' trawl day	1	Directed	2	25-60 Weekly	2	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	Apr-Jun	3	91-116	3	500' or 1000' haul seine day	3	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	3	23-55	2	Commercial gill nets	3	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends
e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 24

ESTIMATES OF RELATIVE ABUNDANCE OF DIFFERENT LIFE STAGES OF HOGCHOKER (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/")

YEAR	JUVENILE FSS[a]	YEARLING AND OLDER FSS	JUVENILE AND OLDER[b] BTS[c]
1974	0.15/0.03	7.26/0.80	
1975	2.75/1.91	4.81/0.69	
1976	0.02/0.02	2.55/0.36	
1977	2.09/1.39	2.18/0.32	
1978	1.93/0.81	4.69/0.59	
1979	0.79/0.17	3.11/0.68	
1980	0.62/0.18	2.92/0.46	
1981	2.73/0.78	5.99/0.90	264.9
1982	0.98/NA	3.90/0.58	128.3
1983	6.79/4.52	2.34/0.58	206.8
1984	1.77/0.43	6.60/0.84	93.9
1985	1.40/0.26	16.36/0.93	64.7
1986	3.30/1.59	17.17/1.13	144.2
1987	2.23/0.57	14.06/0.78	60.1
1988	7.83/0.91	15.20/0.99	45.4
1989	1.32/0.41	17.53/1.06	169.4
1990	1.73/1.02	5.62/1.02	101.9
1991	6.77/4.73	7.65/0.62	
1992	0.50/0.23	12.39/0.99	
1993	1.19/0.31	8.36/0.69	
1994	10.08/1.42	1.75/0.12	
1995	0.88/0.33	4.44/0.31	
1996	0.30/0.07	4.17/0.39	
1997	0.03/0.03	0.62/0.05	

a. Mean number per 1000 m^3 in bottom samples. Gear used were an epibenthic sled from 1974-1984, and a beam trawl from 1985-1997.
b. Life stages not differentiated.
c. Arithmetic mean number per tow in bottom trawl survey.

TABLE 25

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF WEAKFISH FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

Weakfish																		
	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)					
Survey	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	May-Jul	2	14-140	2	1 m² nets 505µ mesh 1 m/sec night	3	Stratified Random	1	110-210 weekly	1	NU	NS	NS	NS	NS	NS
BSS	1974-97	1	Aug-Oct	2	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5 5A	NS	NS
FSS	1979-97	2	Aug-Oct	2	14-140	2	1 m² nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	5 5A	NS	NS
JSB	1976-97	1	Jul-Nov	1	23-42	2	200' seine 1/2" mesh day	1	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NS	NU	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NS	NS	NS
BTS	1981-90	3	Aug-Nov	2	24-43	2	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	5A	NS	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NU	NU	NS
SBMR	1984-97	2	Nov-Apr	3	NY harbor - 12	3	30' trawl day	1	Directed	2	25-60 Weekly	2	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	Apr-Jun	3	91-116	3	500' or 1000' haul seine day	1	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	3	23-55	2	Commercial gill nets	3	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends

e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

L. **WEAKFISH**

Adults

Sampling program evaluation for weakfish is summarized in Table 25 and data sets are provided in Table 26.

Adult weakfish are not caught in any of the Hudson River sampling programs.

Egg and Larval Stages

Weakfish spawn at the mouths of estuaries and many of the eggs and larvae are outside of the geographic range of the LRS program.

Juvenile Stage

Juvenile weakfish enter the areas north of George Washington Bridge during July and emigrate from the estuary during late August. The abundance of juvenile weakfish increases downriver which indicates that juveniles are more abundant in areas of the estuary south of the George Washington Bridge, a pattern consistent with that observed in other estuarine systems. Juvenile weakfish were consistently caught in the FSS channel samples and a juvenile index was generated from this program because it had a greater spatial extent and sampling intensity than the other (BTS) trawl program.

M. **RAINBOW SMELT**

Adults

Sampling program evaluation for rainbow smelt is summarized in Table 27 and data sets are provided in Table 28.

Rainbow smelt spawn earlier than many other Hudson River species and the adults have not been sampled consistently in the LRS program.

Egg and Larval Stages

Rainbow smelt spawn in tributaries and the eggs are adhesive. Thus, LRS egg catches may not be representative of the total spawn. Newly hatched larvae are carried downstream and out of the tributaries by current flows. Larval smelt are very slender and the catch efficiency during the PYSL stage is probably better than that during the YSL stage. However, PYSL abundance can be estimated only for the years of extended LRS sampling, 1975 to 1980, which does not provide an adequate time series and no abundance index was generated for egg or larval stages.

TABLE 27

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF RAINBOW SMELT FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

Rainbow Smelt																		
Survey	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)					
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	MMay-eJul	2	14-140	2	1 m^2 nets 505µ mesh 1 m/sec night	1	Stratified Random	1	110-210 weekly	1	NS	NS	NS	5A	NS	NS
BSS	1974-97	1	MAug-eOct	2	12-152	2	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	NS	NS	NS
FSS	1979-97	2	MAug-eOct	2	14-140	2	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	5 5A	NS	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine ½" mesh day	2	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NS	NS	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NS	NS	NS
BTS	1981-90	3	LAug-eNov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NS	NS	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	2	Fixed Stations	2	5-40 monthly	3	NS	NS	NS	NS	NS	NS
SBMR	1984-97	2	Nov-Apr	3	NY harbor - 12	3	30' trawl day	3	Directed	2	25-60 Weekly	2	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	LApr-eJun	3	91-116	3	500' or 1000' haul seine day	3	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	3	23-55	3	Commercial gill nets	3	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends
e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 26

ESTIMATES OF RELATIVE ABUNDANCE OF DIFFERENT LIFE STAGES OF WEAKFISH (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/")

	JUVENILE		
YEAR	FSS[a]	BTS[b]	NMFS[c]
1974	/		
1975	/		
1976	/		
1977	/		
1978	/		263.3
1979	0.13/0.07		
1980	0.60/0.28		
1981	0.22/0.12	6.2	
1982	0.66/0.30	13.3	29.6
1983	0.12/0.09	24.4	
1984	1.59/0.63	9.7	
1985	0.98/0.48	8.1	
1986	0.29/0.11	7.0	
1987	0.25/0.18	1.9	
1988	1.44/0.60	6.6	
1989	0.76/0.24	14.0	
1990	0.15/0.09	7.2	
1991	0.10/0.06		
1992	0.03/0.02		
1993	0.25/0.15		
1994	0.13/0.06		
1995	0.23/0.13		
1996	0.21/0.16		
1997	0.16/0.05		

a. Weighted mean number per 1000 m^3 in channel sampling from mid-August to early October (weeks 33-40).
b. Mean catch per tow.
c. NMFS bottom trawl index.

Juvenile Stage

Juvenile rainbow smelt remain in deep channels during the day and move into shallow water at night. As a result, the BSS catches are not a reliable index of their relative abundance. Juvenile rainbow smelt were caught during the LRS program but the catches are very low, probably because the juvenile rainbow smelt can detect the Ichthyoplankton net and avoid it. The catches from the FSS Tucker trawl in the channel stratum were much higher and the index of juvenile abundance was generated from these data. The FSS shoal data were not used because of the change in the sampling gear in 1985.

N. GIZZARD SHAD

Adults

Sampling program evaluation for gizzard shad is summarized in Table 29 and data sets are provided in Table 30.

Adult gizzard shad are impinged at the Hudson River power plants during the winter months. The impingement rate over the period from November through January (the number impinged per million gallons of water withdrawn from the river) at the Roseton generating station was selected as an index of abundance because this generating station operated more consistently during the November through January period than Indian Point and Lovett generating stations did.

Egg, Larval, and Juvenile Stages

No abundance indices were developed for these life stages because extremely low catch rates were observed in all sampling programs.

O. SPOTTAIL SHINER

Adults

Sampling program evaluation for spottail shiner is summarized in Table 31 and data sets are provided in Table 32.

Adult spottail shiners were caught during the LRS program. However, this species spawns in shallow water habitats that are not sampled efficiently during the LRS program and no abundance index was developed for the adult stage.

TABLE 28

ESTIMATES OF RELATIVE ABUNDANCE OF DIFFERENT LIFE STAGES OF RAINBOW SMELT (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/")

	JUVENILE	
YEAR	LRS[a]	FSS[b]
1974	0.02/0.00	
1975	0.00/0.00	
1976	0.00/0.00	
1977	0.01/0.00	
1978	0.07/0.01	
1979	0.02/0.00	0.23/0.09
1980	0.03/0.00	0.10/0.09
1981	0.00/0.00	0.00/0.00
1982	0.00/0.00	0.13/0.03
1983	0.00/0.00	0.00/0.00
1984	0.00/0.00	0.42/0.14
1985	0.00/0.00	0.07/0.04
1986	0.02/0.00	0.96/0.07
1987	0.01/0.00	0.12/0.06
1988	0.05/0.01	0.04/0.02
1989	0.00/0.00	0.00/0.00
1990	0.03/0.00	1.14/0.27
1991	0.01/0.00	0.00/0.00
1992	0.04/0.00	6.72/1.84
1993	0.01/0.00	1.19/0.56
1994	0.01/0.00	0.11/0.11
1995	0.01/0.00	0.00/0.00
1996	0.00/0.00	0.00/0.00
1997	0.00/0.00	0.00/0.00

a Weighted average number per m^3 for 8 consecutive sampling weeks from mid-May to early July (weeks 20-27).

b Weighted mean number per 1000 m^3 for sampling from mid-August to early October (weeks 33-40).

TABLE 29

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF GIZZARD SHAD FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

Gizzard Shad																		
Survey	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)					
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	May-Jul	1	14-140	1	1 m^2 nets 505μ mesh 1 m/sec night	3	Stratified Random	1	110-210 weekly	1	NS	NS	NS	NS	NS	NS
BSS	1974-97	1	Aug-Oct	2	12-152	1	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	NS	NS	NS
FSS	1979-97	2	Aug-Oct	2	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	NS	NS	NS
JSB	1976-97	1	Jul-Nov	2	23-42	3	200' seine ½" mesh day	2	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NS	NS	NS
JAS	1980-97	2	Jun-Oct	2	55-140	2	100' seine 1/4" mesh	3	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NS	NS	NS
BTS	1981-90	3	Aug-Nov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NS	NS	NS
WLIS	1984-97	2	May-Oct	3	WLI	3	200' seine 1/2" mesh day	2	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NS	NS	NS
SBMR	1984-97	2	Nov-Apr	2	NY harbor - 12	3	30' trawl day	1	Directed	2	25-60 Weekly	2	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	Apr-Jun	3	91-116	2	500' or 1000' haul seine day	1	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	3	23-55	3	Gill nets	2	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS
Impingement	1974-1997	1	Jan-Dec	1	37, 40,65,66	2	Intake Screens	2	Fixed single site	2	Variable	2	NS	NS	NS	NS	NS	5 5A

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends

e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 30

THE RELATIVE ABUNDANCE (NUMBER IMPINGED PER MILLION GALLONS OF COOLING WATER WITHDRAWN) OF ADULT GIZZARD SHAD AT THE ROSETON GENERATING STATION DURING THE WINTER

Error! Bookmark not defined.YEAR[A]	NUMBER/10^6 GAL
1974	
1975	
1976	0.010
1977	0.035
1978	0.043
1979	0.016
1980	0.099
1981	0.206
1982	0.022
1983	0.060
1984	0.005
1985	0.030
1986	0.027
1987	0.082
1988	0.216
1989	0.160
1990	0.111
1991	
1992	
1993	
1994	
1995	
1996	
1997	

a Includes months of November and December of the year indicated and January of the following year.

TABLE 31

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF SPOTTAIL SHINER FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

Spottail Shiner																		
Survey	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)					
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	May-Jul	1	14-140	1	1 m^2 nets 505µ mesh 1 m/sec night	3	Stratified Random	1	110-210 weekly	1	NS	NS	NS	NS	NS	NS
BSS	1974-97	1	Aug-Oct	2	12-152	1	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	5 5A	NS	NS
FSS	1979-97	2	Aug-Oct	2	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	NU	NS	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine ½" mesh day	1	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NS	NS	NS
JAS	1980-97	2	Jun-Oct	1	55-140	2	100' seine ¼" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	5A	NS	NS
BTS	1981-90	3	Aug-Nov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NS	NS	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	2	Fixed Stations	3	5-40 monthly	3	NS	NS	NS	NS	NS	NS
SBMR	1984-97	2	Nov-Apr	3	NY harbor - 12	3	30' trawl day	3	Directed	2	25-60 Weekly	2	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	Apr-Jun	3	91-116	3	500' or 1000' haul seine day	3	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	3	23-55	3	Commercial gill nets	3	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends

e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 32

ESTIMATES OF RELATIVE AND ABSOLUTE ABUNDANCE OF DIFFERENT LIFE STAGES OF SPOTTAIL SHINERS (STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/")

	JUVENILE		
YEAR	BSS[a]	JAS[b]	Estimated Number[c]
1974	6.41/1.42		
1975	13.65/3.19		
1976	9.21/1.45		
1977	4.86/1.11		
1978	12.23/1.72		
1979	8.56/1.35		29.2
1980	6.79/1.28	1.3	24.6
1981	19.13/3.98	1.1	65.8
1982	4.99/0.82	0.3	17.1
1983	11.89/3.01	0.8	40.5
1984	8.20/1.94	5.4	28.2
1985	4.92/0.78	15.6	17.4
1986	4.63/1.16	20.3	15.9
1987	5.87/1.40	66.1	20.1
1988	4.66/0.72	29.3	16.0
1989	6.63/1.47	10.5	22.5
1990	9.10/1.51	32.0	30.9
1991	11.22/1.88	36.8	38.7
1992	6.97/1.07	12.5	
1993	6.38/0.80		
1994	14.68/2.02		
1995	4.88/0.70		
1996	1.68/0.63		
1997	11.88/1.74		

a Average number per 100' seine haul for sampling from mid-August to early October (weeks 33-40).
b Average number per 100' seine haul.
c Estimated absolute number of juveniles on September 1, in millions. Estimation methods described in Appendix VI-2.

Egg and Larval Stages

The catch rates from the LRS program for eggs and larvae were very low, probably because this species spawns in shallow water habitats that are not sampled efficiently during the LRS program. No abundance indices were developed for these life stages.

Juvenile Stage

Both the BSS and JAS programs sampled the proper habitat for juvenile spottail shiners. The BSS program had a greater spatial coverage and sampling intensity than the JAS program and an abundance index for the juvenile stage was generated from the BSS catches.

P. **WHITE CATFISH**

Adults

Sampling program evaluation for white catfish is summarized in Table 33 and data sets are provided in Table 34.

Yearling and older white catfish were consistently caught in the lower portion of the estuary during the BSS and JSB programs. Abundance indices for these combined life stages was generated from both data sets.

Egg and Larval Stages

White catfish eggs and larvae were not captured in the LRS program because white catfish build nests in shallow water and these life stages are not vulnerable to the sampling gear used in this program.

Juvenile Stage

Catches of juvenile white catfish were low in both the FSS or BSS programs and no abundance index was generated for this life stage.

Q. **BLUE CRAB**

Adults

Sampling program evaluation for blue crab is summarized in Table 35 and data sets are provided in Table 36.

Adult blue crabs move about extensively within the lower and middle regions of the Hudson River estuary and fish impinged on the intake screens of the Hudson River power

TABLE 33

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF WHITE CATFISH FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

White Catfish																		
Survey	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)					
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	YSL	PYSL	JUV	YRL	Adult
LRS	1974-97	1	May-Jul	2	14-140	1	1 m^2 nets 505µ mesh 1 m/sec night	3	Stratified Random	1	110-210 weekly	1	NS	NS	NS	NS	NS	NS
BSS	1974-97	1	Aug-Oct	2	12-152	1	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1	NS	NS	NS	NS	5 5A	NS
FSS	1979-97	2	Aug-Oct	2	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1	NS	NS	NS	NS	NS	NS
JSB	1976-97	1	Jul-Nov	1	23-42	3	200' seine ½" mesh day	2	Fixed Station	2	25 bi-weekly	2	NS	NS	NS	NS	NS	NS
JAS	1980-97	2	Jun-Oct	1	55-140	3	100' seine 1/4" mesh	2	Fixed Stations	2	28 bi-weekly	2	NS	NS	NS	NS	NS	NS
BTS	1981-90	3	Aug-Nov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2	NS	NS	NS	NS	NS	NS
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	2	Fixed Stations	2	5-40 monthly	3	NS	NS	NS	NS	NS	NS
SBMR	1984-97	2	Nov-Apr	3	NY harbor - 12	3	30' trawl day	3	Directed	2	25-60 Weekly	2	NS	NS	NS	NS	NS	NS
SSA	1985-97	2	Apr-Jun	3	91-116	3	500' or 1000' haul seine day	3	Directed	3	Variable	3	NS	NS	NS	NS	NS	NS
CFM	1980-97	2	Apr-May	3	23-55	3	Commercial gill nets	3	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	NS

1 = Data should be useful for assessing abundance trends
2 = Data may be useful for assessing abundance trends
3 = Data are likely to be of limited use for assessing abundance trends

e, m, l = early, middle, or late

NS = Not effectively sampled
NU = Not used
Numbers 5 and 6 indicate the chapter of the DEIS, or appendix indicated by "A", in which the survey was used for information on abundance trends.

TABLE 34

ESTIMATES OF RELATIVE ABUNDANCE OF DIFFERENT LIFE STAGES OF WHITE CATFISH
STANDARD ERRORS, WHERE AVAILABLE, ARE GIVEN AFTER "/")

	YEARLING & OLDER	YEARLING & OLDER
YEAR	JSB[a]	BSS[b]
1974		0.03/0.02
1975		0.02/0.01
1976		0.03/0.01
1977		0.07/0.02
1978		0.07/0.03
1979		0.05/0.03
1980	0.05	0.02/0.01
1981	0.06	0.05/0.03
1982	0.16	0.05/0.03
1983	0.77	0.06/0.04
1984	0.09	0.02/0.01
1985	0.02	0.01/0.00
1986	0.05	0.03/0.01
1987	0.15	0.03/0.02
1988	0.06	0.05/0.02
1989	0.13	0.12/0.06
1990	0.04	0.01/0.01
1991	0.04	0.02/0.01
1992	0.02	0.00/0.00
1993	0.03	0.01/0.01
1994	0.01	0.00/0.00
1995	0.02	0.01/0.01
1996	0.01	0.03/0.02
1997	0.01	0.00/0.00

a. Average number per 100' seine haul for sampling from mid-August to early October (weeks 33-40)

TABLE 35

DATA SELECTION MATRIX FOR ABUNDANCE INDICES OF BLUE CRAB FROM POTENTIALLY USEFUL HUDSON RIVER SAMPLING PROGRAMS

Blue Crab															
Survey	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)		
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGG	JUVENILES	Adult
LRS	1974-97	1	May-Jul	1	14-140	1	1 m^2 nets 505μ mesh 1 m/sec night	3	Stratified Random	1	110-210 weekly	1			
BSS	1974-97	1	Aug-Oct	2	12-152	1	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1			
FSS	1979-97	2	Aug-Oct	2	14-140	1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1			
JSB	1976-97	1	Jul-Nov	2	23-42	3	200' seine ½" mesh day	2	Fixed Station	2	25 bi-weekly	2			
JAS	1980-97	2	Jun-Oct	2	55-140	2	100' seine 1/4" mesh	3	Fixed Stations	2	28 bi-weekly	2		Not Recorded	
BTS	1981-90	3	Aug-Nov	2	24-43	3	26' trawl day	1	Fixed Stations	2	20 bi-weekly	2			
WLIS	1984-97	2	May-Oct	3	WLI	3	200' seine 1/2" mesh day	2	Fixed Stations	3	5-40 monthly	3			
SBMR	1984-97	2	Nov-Apr	2	NY harbor - 12	3	30' trawl day	1	Directed	2	25-60 Weekly	2			
SSA	1985-97	2	Apr-Jun	3	91-116	2	500' or 1000' haul seine day	1	Directed	3	Variable	3			
CFM	1980-97	2	Apr-May	3	23-55	3	Commercial gill nets	2	"Fixed"	2	Variable	2			
Landingss	1986-1997	2	Jan-Dec	1	NY	2	All	2	Directed	2	Variable	2	NS	NS	5 5A
Impingement	1974-1997	1	Jan-Dec	1	37, 40,65,66	2	Intake Screens	2	Fixed single site	2	Variable	2	NS	NS	5 5A

TABLE 36 (Page 1 of 2)

Data selection matrix for abundance indices of blue crab from Hudson River sampling programs.

Blue crab																
Survey	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)			
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGGS	LARVAE	JUV	Adults
LRS	1974-97	1 3 3	lApr-eJul	1	14-140	1 1 1	1 m^2 nets 505µ mesh 1 m/sec night	3	Stratified Random	1	110-210 weekly	1				
BSS	1974-97	1	mAug-eOct	1 2	12-152	1	100' seine 3/8" mesh day	2	Stratified Random	1	100 bi-weekly	1				
FSS	1979-97	1 2 3	mAug-eOct	1 2	14-140	2 1	1 m^2 nets 3 mm mesh 1.5 m/sec 3 m trawl night	2	Stratified Random	1	200 bi-weekly	1				
JSB	1976-97 1985-97	1 2	Aug-Nov Jul-Nov	2 1	23-42	3	200' seine 1/2" mesh day	1	Fixed Station	2	25 bi-weekly	2				
JAS	1980-97	2	Jun-Oct	1	55-140	2	100' seine 1/4" mesh day	2	Fixed Stations	2	28 bi-weekly	2	Not evaluated in samples.			
BTS	1981-90 1982-90 1985-90	2 2 3	lAug-eNov eAug-eNov mJul-eNov	2 1 1	24-43	3	26' trawl day	2	Fixed Stations	2	20 bi-weekly	2				
WLIS	1984-97	2	May-Oct	2	WLI	3	200' seine 1/2" mesh day	1	Fixed Stations; only 3 stations sample consistently	3	5-40 monthly	3				

TABLE 36 (Page 2 of 2)

Data selection matrix for abundance indices of blue crab from Hudson River sampling programs.

Blue crab																		
Survey	Selection Criteria for Abundance Indices												Use of Data for Abundance Indices (by Life Stage)					
	Record Duration		Temporal Coverage		Spatial Coverage (RM)		Gear		Sampling Design		Sampling Intensity		EGGS	LARVAE		JUV	Adults	
WPSA	1972-88 1977-88 1983-88	1 2 3	Sep-Dec	1	33-34 26-38 26-107	3 3 2	30' trawl day	2	Fixed Stations	2	3-20 bi-weekly	2						
SBMR	1984-90	3	Nov-Apr	1	0-12	3	30' trawl day	2	Directed	3	Variable	3						
SSA	1985-97	3	lApr-eJun	1	91-116	2	500' or 1000' haul seine day	1	Directed	3	Variable	3						
CFM	1980-97	2	Apr-May	2	23-55	2	gill nets	2	"Fixed"	2	Variable	2	Not evaluated in samples.					
Landings	1986-92	2	Jan-Dec	1	NY	1	all	2	Directed	3	Variable	3	NS	NS	NS	NS	NS	5 5 A
Impingement	1980-97 1981-97 1983-90	2 2 3	Jan-Dec	1	65 37 41	2 2 2	intake screens	2	"Fixed"	2	Variable	2	NS	NS	NS	NS	NS	5 5 A

plants attract large numbers of blue crabs. Impingement data (annual rates) for adult crabs are available from 1980 (Roseton) and 1981 (Bowline) through 1991 and from 1983 through 1990 (Indian Point). The annual impingement rates at the three power plants increased in 1988. Impingement at Bowline should be less susceptible to changes in the salt front location during the fall months and probably provides a more accurate index of abundance than that at Roseton. New York State landings data supplied by fishermen with their license applications suggest that the adult blue crabs in New York waters began increasing in 1987. However, there is no way to verify the accuracy of these data or to estimate fishing effort associated with the annual harvest estimates.

Egg, Larval, and Juvenile Stages

Blue crab sampling has not been part of the river monitoring programs and there are no historical records for these life stages in the Hudson River estuary. However, larval development cannot proceed at salinities below 25 ppt, which means that only the juvenile stage enters the estuary. Within the estuary, the greatest concentrations of juveniles are found in heavily vegetated sites and this life stage does not appear to be adequately sampled by the power plants.

Temporal changes in abundance

The index of abundance for young-of-the-year (YOY) bay anchovy was developed from channel samples collected with a 1-m Tucker trawl during the Utilities' fall juvenile survey. Shoal and bottom samples were not included because of a change in sampling gear in 1985, when the 3-m beam trawl replaced the epibenthic sled. The 3-m trawl is more effective than the epibenthic sled for YOY striped bass and white perch. However, it is not as effective for YOY bay anchovy because the mesh of the netting used in the 3-m beam trawl is wider than that used in the 1-m Tucker trawl. The sampling in the channel in the upper portion of the estuary during the fall juvenile survey did not begin until 1979 and the time series for the YOY index runs from 1979 through 1997. The YOY index ranged from 63.3 to 340.7 and there was no time trend (Figure 1). Particularly high values occurred in 1988 (340.7), 1989 (288.9), and 1995 (266.0).

Potential influences on abundance

Bay anchovy are most abundant in the lower portion (regions 1-5) of the Hudson River estuary. They are unlikely to be affected by changes in invertebrate production in the upper portion of the estuary resulting from improvements in wastewater treatment or the invasion of zebra mussels. They are more likely to be affected by changes in invertebrate production in the lower portion of the estuary. The analysis of the variation in the abundance of age 1 tomcod suggested that recruitment to the Atlantic tomcod population in the Hudson River estuary was limited by food resources after 1990. If larval and YOY tomcod are resource limited and adult and larval bay anchovy utilize the same resources, the abundance of YOY bay anchovy should be affected by the number of eggs spawned by the tomcod population during the preceding winter.

Another factor likely to affect the abundance of YOY bay anchovy is the increase in the abundance of large striped bass during the late 1980s and throughout the 1990s. Bay anchovy spawn during June and July. PYSL bay anchovy appear in June and are most abundant during the first half of July. PYSL striped bass move down river into the lower portion of the estuary during June. YOY striped bass are most abundant during late June and early July. Both late PYSL and early YOY striped bass are capable of feeding upon smaller fish. The changes in the fishing regulations for striped bass generated peak standing crops of PYSL striped bass ranging from 2.9 to 25.1 billion during the period from 1989 through 1997. The survival of PYSL striped bass and white perch in the lower portion of the estuary decreased when the abundance of PYSL striped bass increased. It is hypothesized that some of the larger individuals within the population of PYSL striped bass become piscivorous as PYSL abundance increases and the frequency of encounter between large and small individuals rises. These piscivorous individuals then feed upon small striped bass and white perch until the small fish become scarce in July. The positive correlation between the abundance of PYSL striped bass and white perch

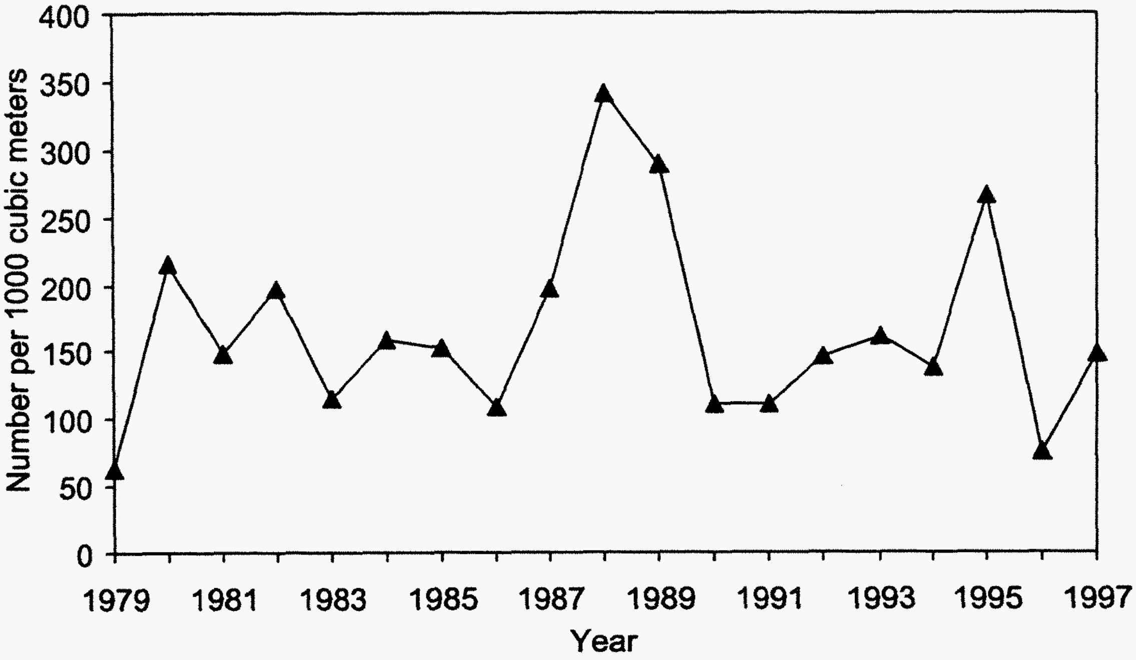


Figure 1. Bay anchovy: annual abundance indices for young-of-the-year (YOY) generated from channel samples collected during the Fall Shoals Surveys, 1979-1997.

suggests that the predation is non-selective; piscivorous striped bass feed upon smaller fish as they encounter them. Thus, as the abundance of small striped bass and white perch declines, the predation on larval and YOY bay anchovy should increase.

The first step in the analysis of the factors affecting the abundance of YOY bay anchovy is to determine the relationship between the abundance of YOY bay anchovy and PYSL striped bass during the period from 1988 through 1997. This is the period when the effects of both factors can be evaluated. Estimates of the number of eggs spawned by Atlantic tomcod are available from the Utilities' winter mark-recapture program and the peak standing crops of PYSL striped bass were high (greater than one billion). The regression of the YOY bay anchovy indices on the PYSL striped bass indices during this period was statistically significant ($p = 0.010$). However, the abundance of PYSL striped bass only explained a little more than half of the variation in the abundance of YOY bay anchovy ($R^2 = 0.580$), which indicates that the tomcod effect may also be important.

However, the effect of another factor has to be considered before the tomcod effect can be evaluated. Improvements in wastewater treatment decreased the amount of particulate organic carbon discharged charged into the lower portion of the Hudson River during the late 1980s and early 1990s (Brosnan and O'Shea 1996a, 1996b). YOY tomcod feed upon copepods and epibenthic invertebrates (Grabe 1978) and the production of these prey species depends upon particulate organic matter (Gladden et al. 1988). Total suspended solids in the discharge from the North River wastewater treatment plant declined significantly when it went to full secondary treatment in April 1991 and the production of age 1 tomcod appeared to be strongly density-dependent during the period from 1991 through 1997. If the change in the dynamics of the tomcod population is a reflection of a change in the carrying capacity for this species in the lower portion of the estuary, the effect of a given number of tomcod eggs on bay anchovy will also change after 1991. In order to isolate the effect of a change in carrying capacity, the time series was divided into two groups, 1988-1990 and 1991-1997, and the tomcod effect within each group was estimated.

Group 1 (Table 1)--The egg deposition estimates in 1988 and 1989 were very similar (43 and 41 billion eggs). Thus, the difference between the YOY bay anchovy indices for these two years (1989 minus 1988 = -51.8) should reflect the effect of the difference in the abundance of PYSL striped bass between these two years (1989 minus 1988 = +3.06). This comparison indicated that the abundance of YOY bay anchovy decreased 16.9 units when the PYSL index for striped bass increased one unit.

The egg deposition estimates were different in 1989 and 1990. Therefore, the difference in the abundance of PYSL striped bass between 1989 and 1990 (1990 minus 1989 = +1.1) was converted to YOY bay anchovy (by multiplying by -16.9) and subtracted from the difference in the abundance of YOY bay anchovy between the two years (1990 minus 1989 = -178.5). The adjusted YOY difference (-178.5 - (-18.6) = -159.9) was used to estimate the tomcod effect. The difference between the egg deposition estimates for these

Table 1. Young-of-the-year (YOY) indices for bay anchovy, post yolk-sac larval (PYSL) indices for striped bass, and egg deposition estimates for Atlantic tomcod: 1988-1997

Year	Bay Anchovy YOY	Striped Bass PYSL	Atlantic Tomcod Egg Deposition (billions)
Group 1:			
1988	340.7	1.48	43
1989	288.9	4.54	41
1990	110.4	5.64	87
Group 2:			
1991	110.7	8.01	52
1992	146.7	6.38	7
1993	161.0	8.25	30
1994	138.4	8.45	7
1995	266.0	3.94	32
1996	76.2	15.40	2
1997	147.8	4.89	47

two years (1990 minus 1989 = 46 billion) was divided into the adjusted YOY difference to estimate the tomcod effect (-159.9/46 = -3.48). Thus, the abundance of YOY bay anchovy decreased 3.48 units when tomcod egg deposition increased by a billion. If these two estimates are accurate, the variation in PYSL striped bass should account for 79.4% of the variation in the abundance of YOY bay anchovy.

Group 2 (Table 1)—In this group, there were four years (the odd numbered years) when the egg deposition by tomcod ranged from 30 to 52 billion eggs and three years (the even numbered years) when the egg deposition ranged from 2 to 7 billion eggs. The estimates of abundance for PYSL striped bass were very similar in 1991 (8.01) and 1993 (8.25) and the tomcod effect could be cleanly estimated. The abundance of YOY bay anchovy decreased 2.29 units per billion tomcod eggs. Thus, the effect of tomcod eggs on YOY bay anchovy did decrease after the North River wastewater treatment plant went to full secondary treatment in April 1991.

In 1992, 1994, and 1996, egg deposition was low, ranging from 2 to 7 billion. However, the production of age 1 tomcod appears to have been resource-limited during these three years, even though egg deposition was low. For example, the discharge of untreated sewage was high in 1976 and invertebrate production should have been high compared to that in 1992, 1994, and 1996. The fifteen billion eggs deposited in 1976 produced about 12 million age 1 tomcod. In 1992 and 1994, 7 billion eggs produced an average of 2.3 million age 1 tomcod, less than half of the 5.6 million age 1 tomcod predicted from the egg/recruit relationship observed in 1976. Thus, resources must have been limiting in these two years.

The similarity of the age 1 tomcod estimate in 1996 (2.4 million) to those 1992 (2.2 million) and 1994 (2.1 million) suggests that all three populations were limited by the improvements in sewage treatment. The effect of larval and YOY tomcod on the abundance of YOY bay anchovy during these three years was generated in the following way. The data from 1994 was selected for comparison with the data from 1991 and 1993 because the PYSL indices for striped bass were very similar across these three years (ranging from 8.01 to 8.45). This eliminated the striped bass effect from any differences in the abundance of YOY bay anchovy among these years. 1993 was selected as the reference year because its PYSL index was closest to that for 1994. The tomcod effect (the decrease in YOY bay anchovy per billion eggs) was assumed to be constant across these years. Therefore, the ratio of the difference in YOY abundance to the difference in egg deposition for 1991 and 1993 should be equal to the ratio of the difference in YOY abundance to the difference in egg deposition for 1994 and 1993. All of the terms in these two ratios are known except for the "relative egg deposition" in 1994. The "relative egg deposition" is the tomcod effect in the even numbered years expressed in terms of egg deposition in odd numbered years. The "relative egg deposition" for 1994 is 40 billion. The estimates of the number of age 1 tomcod produced in 1992 and 1996 were divided by the estimate for 1994 and multiplied times the "relative egg deposition" for

1994 to produce the "relative egg deposition" estimates for 1992 (42 billion) and 1996 (45 billion).

Standardization of tomcod effects within groups--The effects of the differences in tomcod egg deposition during the period from 1988 through 1997 were removed by standardizing all deposition estimates to the 1988 value according to the following procedure. The 1988 value (43 billion) was subtracted from each egg deposition estimate, except for 1992, 1994, and 1996 where the "relative egg deposition" estimates were used. The resulting differences were then multiplied by the appropriate tomcod effect to express the effect of the differences in egg deposition in terms of YOY abundance (Table 2). The egg effects were then added to or subtracted from (depending upon the sign of the difference) the observed YOY indices.

Standardization of tomcod effects across groups--the standardized YOY indices were adjusted again to remove the effect of the decrease in resources after 1990 (Table 3). This was done by adjusting the pre-1991 YOY indices downward, by dividing by the ratio of the tomcod effects (1.52).

Adjustment of the 1995 index value to reflect unusually low tomcod growth during the spring--The fully standardized YOY values were regressed on the PYSL indices for striped bass. There was a significant improvement in the goodness-of-fit ($R^2 = 0.796$; $p = 0.000$). However, 1995 value appeared to be unusually high (Figure 2). This year was also very different from the other years in the time series in that the production of age 1 tomcod was very low (0.06 million). If the unusually low production of age 1 tomcod in 1995 was associated with an unusually low utilization of resources, more resources may have been available for YOY bay anchovy, which would account for the unusually high YOY value in 1995.

The growth of larval tomcod during the spring should reflect the availability of resources. The measurement of tomcod larvae from the ichthyoplankton samples began in 1995 and it is only possible to compare larval growth in three years. The average lengths from samples of larval and YOY tomcod taken from the catches from the epibenthic sled during the 8-week period from the first week in April through the third week in May are plotted by week in Figure 3. The greatest growth occurred in 1996 and the lowest in 1995. The growth in 1997 was more similar to that in 1996 than it was to that in 1995. The length data from 1996 were used as the baseline. The increase in mean length over the 8-week period was 22 mm in 1995 and 43 mm in 1996. If the increase in mean length is a direct reflection of resource utilization, tomcod in 1995 used 0.51 of the resources used in 1996. The egg deposition estimate for 1995 was reduced (by multiplying by 0.51) to reflect the greater availability of resources for bay anchovy in 1995. The revised egg deposition estimate (16 billion) was used to generate a revised, standardized estimate of YOY abundance for bay anchovy. When the revised value (204.2) was substituted in the regression analysis, the goodness-of-fit improved significantly ($R^2 = 0.894$). The scatter around the regression line can be reduced further by regressing the natural

Table 2. Standardization of egg deposition and "relative* egg deposition" estimates for Atlantic tomcod in terms of young-of-the-year (YOY) bay anchovy: 1988-1997

Year	Egg Deposition Estimates (Billions)	Standardized Egg Deposition: (1988-Year)	YOY Conversion Factor (YOY/Egg)	YOY Adjustment
1988	43	0	-3.48	0.0
1989	41	+ 2	-3.48	- 7.0
1990	87	- 44	-3.48	+153.1
1991	52	- 9	-2.29	+ 20.6
1992	42*	+ 1	-2.29	- 2.3
1993	30	+ 13	-2.29	- 29.8
1994	40*	+ 3	-2.29	- 6.9
1995	32	+ 11	-2.29	- 25.2
1996	45*	- 2	-2.29	+ 4.6
1997	47	- 4	-2.29	+ 9.2

Table 3. Adjustment of standardized YOY indices to post-1990 resource levels.

Year	Standardized YOY Indices	Resource Adjustment	Adjusted, Standardized YOY Indices
1988	340.7	÷ 1.52	224.1
1989	281.9	÷ 1.52	185.5
1990	263.5	÷ 1.52	173.3
1991	131.3		131.3
1992	144.4		144.4
1993	131.2		131.2
1994	131.5		131.5
1995	240.8		240.8
1996	80.8		80.8
1997	157.0		157.0

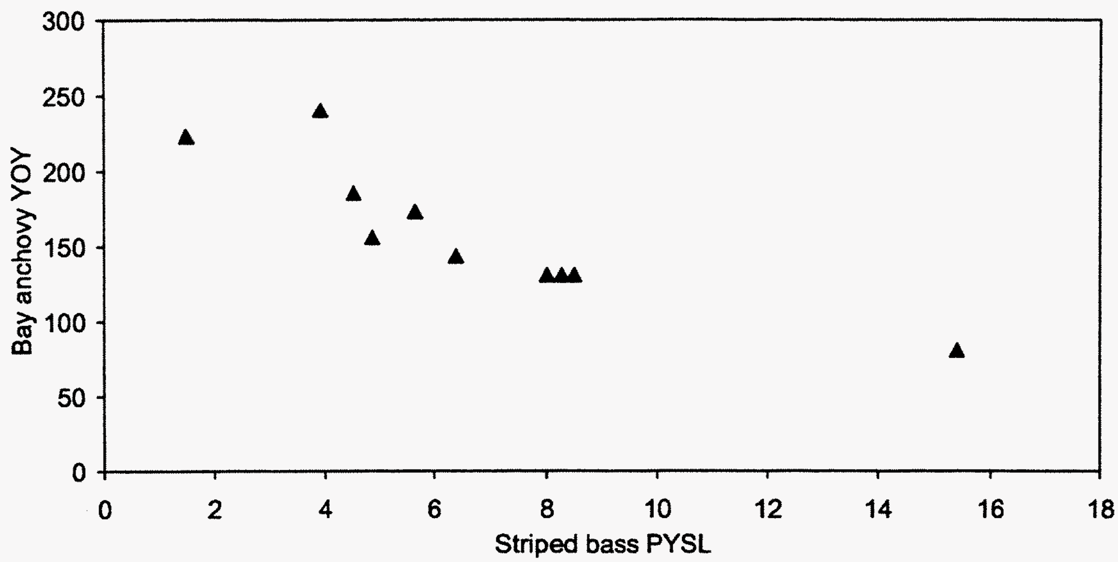


Figure 2. Bay anchovy: annual abundance indices for bay anchovy young-of-the-year (YOY) adjusted for differences in resource levels and tomcod abundance and regressed on striped bass post yolk-sac larvae (PYSL), 1988-1997.

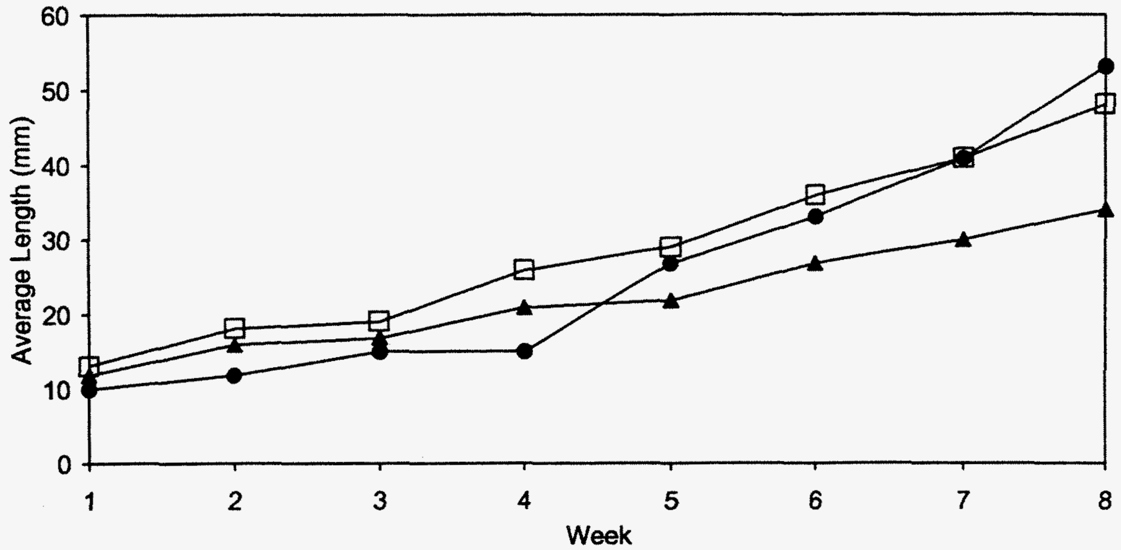


Figure 3. Bay anchovy: average length (in millimeters) of Atlantic tomcod by sampling week from first week in April through third week in May, 1995-1997.

logarithms of the standardized YOY values on the PYSL indices for striped bass (R^2 = 0.959).

The comparison between the total sum of squares from the analysis of the unadjusted data and the residual sums of squares from the analysis of the adjusted data provides another way to evaluate the effects of changes in ecosystem productivity and the abundance of Atlantic tomcod and striped bass. The total sum of squares in the analysis involving unadjusted YOY indices was 69,721. The residual sum of squares in the analysis involving adjusted YOY indices (including the further adjustment to the 1995 YOY index) was 1668. This residual sum of squares reflects the effects of all factors that were not included in the analysis. Thus, the adjustments for changes in resource availability and competition between Atlantic tomcod and bay anchovy in conjunction with the effect of PYSL striped bass explained all but 2% of the original variation in the abundance of YOY bay anchovy.