PERENNIAL OCCURRENCE AND FAST GROWTH RATES BY CREVALLE JACKS (CARANGIDAE: Caranx hippos) IN THE HUDSON RIVER ESTUARY.

Richard S. McBride, Ph.D.[1]
Polgar Fellow
Rutgers University, Marine Field Station
Institute of Marine and Coastal Sciences
800 Great Bay Blvd.
Tuckerton, NJ 08087

[1]Present address:
Florida Marine Research Institute
100 Eighth Avenue S.E.
St. Petersburg, FL 33701-5095

McBride, R.S. 1995. Perennial occurrence and fast growth rates by crevalle jacks (Carangidae: Caranx hippos) in the Hudson River estuary. Section VI: pp: 34 . In E.A. Blair and J.R. Waldman (Eds.). Final Reports of the Tibor T. Polgar Fellowship Program, 1994. Hudson River Foundation, NY

Advisor

Kenneth W. Able
Rutgers University, Marine Field Station
Tuckerton, NJ 08087

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Crevalle jacks, Caranx hippos (Linnaeus), are considered a 'southern' species in the western Atlantic and are distributed worldwide, but principally at subtropical and tropical latitudes (Briggs 1960; Grosslein and Azarovitz 1982). Caranx hippos is important to recreational fisheries in the southeastern U.S. and the Gulf of Mexico, but it is only incidentally caught north of Cape Hatteras (Alperin 1967; Palko 1984; U.S. Dept. of Commerce 1986). Young-of-the-year C. hippos occur at small sizes (21-50 mm standard length) in subtropical estuaries of the western Atlantic, and appear to use these habitats as nurseries (Berry 1959).

Young-of-the-year Caranx hippos are, however, also reported for many temperate estuaries, north of Cape Hatteras (Moore, 1894; Nichols 1921; Nichols and Breder 1926; Hildebrand and Schroeder 1928; Vladykov 1935; de Sylva et al. 1962; Schaefer 1967; Marcellus 1972; Gordon 1974; Vouglitois 1983; Tatham et al. 1984; Scott and Scott 1988; Fletcher 1990), but the ecological consequences of their presence there has not been evaluated. In the western Atlantic, C. hippos larvae are known only from the Straits of Florida, therefore the individuals found at temperate latitudes are presumed to be dispersed from subtropical spawning grounds. Comparative data for both southern and northern estuaries are scarce, but such data do not indicate notably higher abundances of YOY C. hippos at subtropical versus temperate latitudes. This suggests that northerly transport of individuals constitutes a significant portion of the population. Thus, the fate of those individuals arriving to the Hudson River and other northern estuaries (i.e., whether these fish become expatriates or not) may be relevant to the population regulation of this species.

Despite this historic occurrence across a broad geographic area and the potential significance for its population regulation, there is little known about Caranx hippos' early life history at any latitude. Herein, I report on the variability of abundance, length-frequencies, and growth rates of C. hippos for the Hudson River estuary (Fig. 1). The data are synthesized to consider the potential importance of the Hudson River as nursery habitat for C. hippos and the implications for their population regulation.

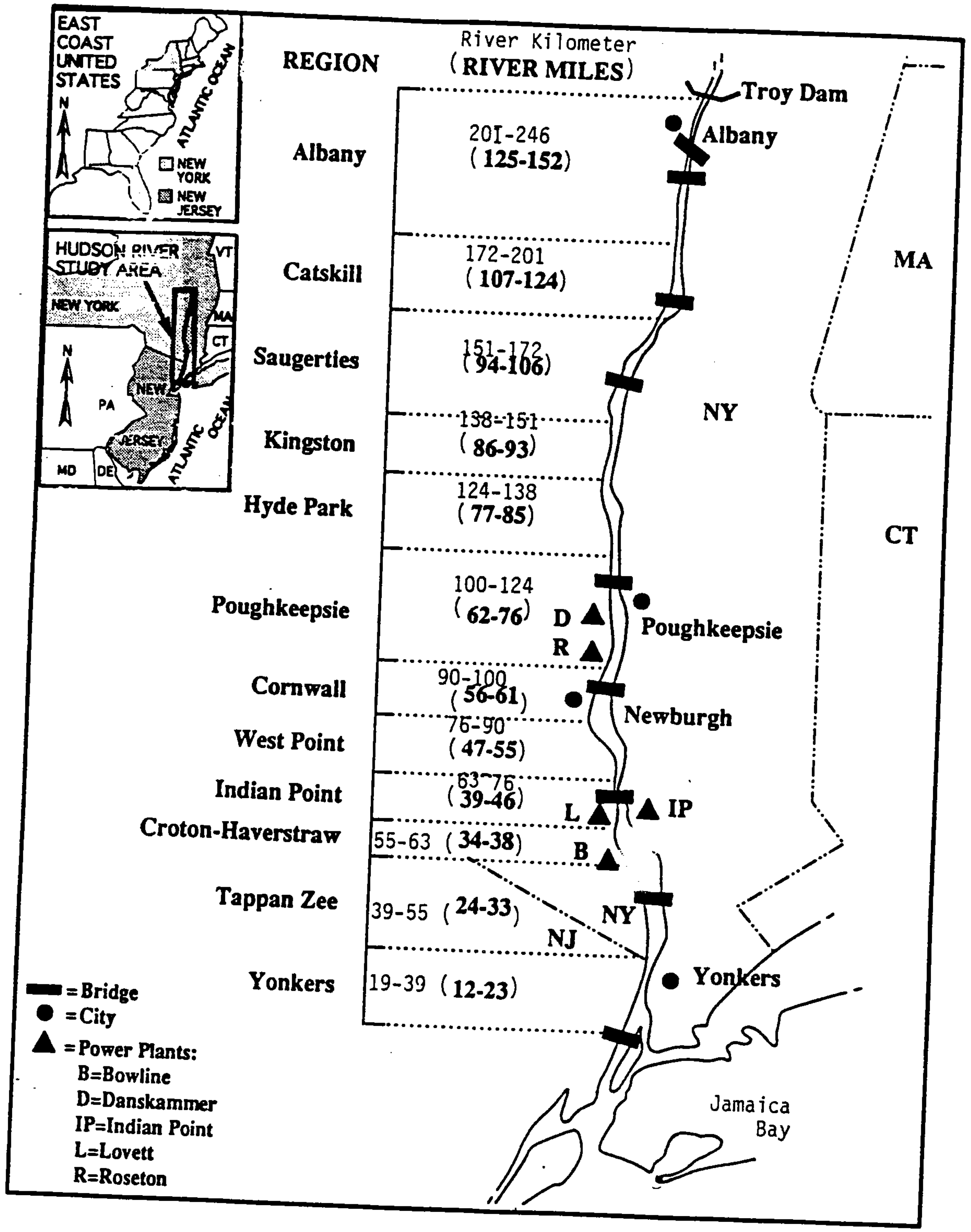

Figure 1 - Area map of the Hudson River, Haverstraw Bay, Jamaica Bay, and other landmarks mentioned in the text. The strata used for sampling the length of the Hudson River are also indicated.

MATERIALS AND METHODS

Historical Review

As general background, both the literature and museum sources were reviewed for data about collection location, collection dates, fish size, and relative abundance of Caranx hippos. Various published sources were tabulated for locations along the U.S. east coast to represent the widest possible latitudinal range of occurrences. A published account of collections from the southeastern U.S. (from various museums and tabulated by Berry 1959) was compared to collections from the New York Bight. These temperate latitude collections were accessed from the New York State Museum, the American Museum of Natural History, and the Academy of Natural Sciences at Philadelphia.

Field sampling of the entire Hudson River

Recent data were analyzed from an ongoing (since 1974) seine survey by Consolidated Edison (ConEd) of the entire Hudson River (data source: John Young and Gene Sentell, Consolidated Edison Company of New York, Inc., 4 Irving Place, New York, New York 10003). Only data for the eight year period, 1986-1993, were analyzed for this study. Fish were collected during daylight over a one week period, every other week between mid-June and mid-November. During each week a 30.5 X 2.4 m beach seine was set in a simple arc from a boat at approximately 100 stations. Station locations were selected in a stratified, random manner using 12 strata in a series from Manhattan to Albany, New York (from river kilometer 19 to 246). The length of each stratum varied from 8-44 km (5-27 miles) and typically 5-20 hauls were completed in each stratum at each biweekly interval. Further details of sampling design, procedures, and history can be found in annual 'year class reports' prepared for Consolidated Edison (e.g., EA Engineering, Science, and Technology 1990).

Mean abundance, by month or stratum, was calculated from transformed values of number of fish in each seine haul ($\log_{10}$ [n+1]) and expressed as geometric means (antilogged mean values - 1; see also Sokal and Rohlf 1981). Annual abundances were also calculated as geometric means, but only for data from the months July-October (when C. hippos was consistently collected).

Sampling in Haverstraw and Jamaica Bays

Further analyses of the ecology of Caranx hippos in the Hudson River was explored using data from an independent seining survey by the New York State Department of Conservation (NYSDEC) (data source: Kim McKown and Byron Young, NYSDEC, Division of Marine Resources, Building 40, SUNY, Stony Brook NY 11790-2356). The data analyzed were for the same eight-year period (1986-1993) as the ConEd program. The NYSDEC survey focused on two subregions of the estuary (Fig. 1): Haverstraw Bay (river kilometer 39 - 63) and Jamaica Bay (a satellite embayment at the mouth of the river). Haverstraw Bay is of particular interest because it corresponded to the ConEd strata numbers 2 & 3, while Jamaica Bay was well outside the range of ConEd sampling strata but was close to the mouth of the Hudson River (Fig. 1).

Seining in Haverstraw Bay occurred biweekly from July to November. Typically, 25 stations were sampled during daylight over a two-day period, each station with a single haul using a 60 X 3 m beach seine set in an arc from a boat. This seine was used similarly in Jamaica Bay from May to November, but sample frequency was generally monthly and 4-5 stations per bay were sampled each time. The abiotic parameters of temperature, salinity, and dissolved oxygen were measured at time of each collection from bottom water samples with a hand-held thermometer, refractometer, and by Winkler titration, respectively. Annual abundance of C. hippos was calculated as geometric means using only data from July-October for each bay. Further details about sampling can be found in McKown and Young (1992).

Data for size-structure and estimations of growth rates were available from the NYSDEC survey. At the time of collection, fish were measured to the nearest mm fork length (FL) (or converted from total length [TL] measurements using the linear equation FL=2.58 + 0.842 [TL]) before being released alive. Growth rate was estimated using least square regression of FL (y) on day of the year (x) using a variety of linear models:

(1) $y = a + bx$,

(2) $y = a + bx + b(x*x)$,

(3) $\ln(y) = \ln(a) + x*\ln(b)$,

(4) $\ln(y) = \ln(a) + b*\ln(x)$.

These models were evaluated based on statistical significance of the product-moment correlation coefficient and plots of residuals against the predicted values. All fish measured were used in these growth models except for a single fish (113 mm FL) collected 2 July 1991 in Jamaica Bay, which was considered an outlier.

RESULTS

Historical review

Based on published records, Caranx hippos ranged widely in the northwestern Atlantic, from at least Cape Kennedy (Florida) northward to Cape Cod (Massachusetts; Table 1). During this project, dozens of specimens were located from three local museums (Tables 2-4) to demonstrate that small C. hippos occur in many different years and widely in the New York Bight (the coastline from Montauk Point to Cape May, for which the Hudson River is the apex). Berry (1959) lists the locations of capture for 112 specimens from Plantation Key (Cape Sable, Florida) to Woods Hole (Cape Cod, Massachusetts), but only 3 (2%) of these specimens were from the Middle Atlantic (Cape Hatteras [North Carolina] to Cape Cod). Berry's focus on southeast waters overlooks a large number of collections from middle Atlantic localities (although not all those listed in Tables 2-4 were available at the time of Berry's research). Similar to Berry's findings, a wide size range of juveniles (2-20 cm) were represented. In contrast to Berry's account of juveniles occurring from April to November, records for the New York Bight were found only from July to November.

Table 1. Reports of young-of- the- year Caranx hippos collected along the U.S. east coast, based on seine surveys from estuarine, shore-zone, or coastal surf zone habitats. Several states are indicated as: Connecticut (CT), New York (NY), New Jersey (NJ), Delaware (DE), North Carolina (NC), South Carolina (SC), and Florida (FL). [SL=standard length, FL=fork length, TL=total length: * = not indicated in source]

SAMPLE AREA	SAMPLE PERIOD	GEAR	ABUNDANCE	AUTHOR (DATE)
Long Island Sound, CT	biweekly; Jul 1942-Jun 1943	9.1 m seine	Aug; n=5, 34-42 mm FL	Wargel & Merriman 1944
Long Island Sound, NY	monthly; Sep 1971-Oct 1972	396 m seine	Sep-Oct; n=4, 120-150 mm FL	Zawacki & Briggs 1976
Long Island Sound, NY	monthly; Mar-Oct 1972	91 m seine	none	Zawacki & Briggs 1976
Long Island, NY	Jul-Aug; 1938	10.6 m seine	none	Greeley 1939
Fire Island, NY	monthly; May-Nov 1961-63	400 m seine	Jul-Oct; n=39, 20-200 mm FL	Schaefer 1967
Great South Bay, NY	monthly; Jul-Oct 1967-68	91 m seine	none	Briggs & O'Connor 1971
Fire Island Inlet, NY	Jul-Nov 1970-71	91 m seine	n=20	Briggs 1975
Barnegat Bay, NJ	monthly; 1966-70	10.6 m seine	Jul-Oct; n=148, 42-142 mm TL	Marcellus 1972
Barnegat Bay, NJ	monthly; 1975-78	45.7 m seine	Jul-Oct; n=88	Tatham et al. 1984
Absecon Inlet, NJ	monthly; 1973-74	76.2 m seine	Aug-Sep; n=10	Thomas et al. 1974 & 1975
Delaware Bay, DE	monthly; Jun-Oct 1958-60	18 m seine	Jun-Oct; n=82, 2-16 cm*	de Sylva et al. 1962
Indian River, DE	weekly; 1957	7.5 m seine	Jul-Oct; n=22, 42-107 mm FL	Pacheco & Grant 1965
Coastal Virginia	biweekly; 1965-66	15.2 m seine	Jul; n=1, 66 mm FL	Richards & Castagna 1970
Cape Lookout, NC	biweekly; 1957-60	21 m seine	Jun-Oct; n=22, 24-158 mm FL	Tagatz & Dudley 1961
Folly Beach, SC	biweekly; 1969-71	19.8 m seine	Jul-Aug; n=2, 28-34 mm SL	Anderson et al. 1977
North Inlet, SC	biweekly, 1981-84	15.2 m seine	'spring-summer'; n=21, 11-140 mm SL	Ogburn et al. 1988
Coastal Georgia	biweekly; 1953-61	12 & 21 m seine	Jun-Nov; n=84, 21-115 mm FL	Miller & Jorgenson 1969
Hutchinson Island, FL	bimont'.y 1971-73	15 m seine	Nov; n=1, 135 mm SL	Futch & Dwinell 1977

Table 2. Caranx hippos specimens collected from the New Jersey coast and housed in the Academy of Natural Science in Philadelphia. Date, location, number of fish (N) and museum catologue number is given for each collection.

DATE	LOCATION	N	MUS. CAT. NUMB.
07 SEP 13	Corson's Inlet	1	40068
08 SEP 13	Corson's Inlet	1	40067
23 OCT 27	Atlantic City, Young's Pier	1	126907
18 AUG 28	Longport Bridge	1	86875
21 AUG 28	Ventnor	1	80703
09 SEP 28	Atlantic City	1	121280
30 SEP 28	Cohansey Creek	1	51399
31 OCT 28	Longport	3	81017
10 JUN 30	Maurice River near Mauricetown	1	126464
24 OCT 30	Maurice River near Mauricetown	1	130047
07 JUL 31	Ocean City, mouth of Forked River	1	126463
15 AUG 31	Toms River	1	127200
07 JUL 54	Atlantic Ocean off New Jersey	3	169367
12 SEP 72	Absecon Bay in Absecon	2	165914
04 OCT 72	Brigantine on Intercoastal Waterway	1	165917
03 AUG 73	Newbold Island	28	165919
30 AUG 73	Mullica River at Clark's Landing	6	165912
31 AUG 73	Great Bay, mouth of Broad Creek	2	165916
18 SEP 73	Great Egg Harbor, Beasley's Point	4	165915
19 SEP 73	Brigantine at Absecon Inlet	1	165918
26 SEP 73	Brigantine at Absecon Inlet	2	152727
05 OCT 73	Mullica River near Garden State Parkway bridge	1	165913
12 SEP 74	Reed's Bay in Brigantine Wildlife Refuge	1	165911
03 AUG 76	Great Channel Bridge	1	138857
12 SEP 78	Horseshoe Cove at Sandy Hook	4	169475

Table 3. Caranx hippos specimens from locations in the New York Bight and housed at the American Museum of Natural History. Date, location, number of fish, fork length in millimeters and museum catalogue number is given for each collection.

DATE	LOCATION	N	FORK LENGTH (mm)	MUS. CAT. NUMB.
late AUG 31	Ossining on Hudson River	2	55 & 59	11677
26 JUL 34	Moriches Bay	2	34 & 39	12511
16 JUL 48	Coney Island	2	18 & 27	18230
24 JUL 48	Coney Island	1	29	18238
07 AUG 48	Coney Island	1	42	18249
21 AUG 48	Coney Island	1	43	18269
12 SEP 62	Shinnecock Bay	4	81, 85, 93 & 98	64419
07 SEP 66	Shinnecock Bay	5	46, 48, 49, 60 & 72	28540
12 SEP 66	Shinnecock Bay	1	83	28557
15 OCT 66	Hudson River at Croton	1	123	50141
02 AUG 75	Hudson River, River Mile 39	5	74, 78, 79, 90 & 93	37291
10 JUL 77	Rockaway	1	46	40695
22 AUG 84	Hudson River, River Mile 59	3	54, 57 & 64	55607

Table 4. Caranx hippos specimens from locations in the New York Bight and housed at the Academy of Natural Sciences in Philadelphia. Date, location, number of fish (N), fork length in millimeters (when available) and museum catalogue number is given for each collection.

DATE	LOCATION	N	FORK LENGTH (mm)	MUS. CAT.NUMB
03 AUG 1898	Atlantic Ocean off Southhampton	1		11950
13 AUG 1898	Great South Bay at Blue Point	1		11951
29 AUG 1898	Duncan Creek	1		11952
30 OCT 16	Atlantic Ocean off Orient	1		11955
30 OCT 22	Atlantic Ocean off Orient	1		11956
17 OCT 23	Atlantic Ocean off Orient	1		12335
25 AUG 36	Hudson River at Snedeckers Landing	1	60	37720
25 JUL 38	Moriches Bay at Seatuck Cove	3	52-67	37726
02 AUG 38	Long Island Sound, Horton Point to Gull Island	1	109	26503
02 AUG 38	Great South Bay , 2 m southwest of Babylon	1	36	37721
02 AUG 38	Great South Bay at mouth of Moby Creek	2	47 & 73	37728
04 AUG 38	Great South Bay, 1.5 m south of Blue Point	2	42 & 55	37724
04 AUG 38	Moriches Bay at Seatuck Cove	7	37-68	37727
08 AUG 38	Fire Island Inlet at Captree State Park	11	38-43	37725
10 AUG 38	Patchogue Bay, 2 m southeast of Patchogue	1	39	37723
11 AUG 38	Fire Island Inlet at Captree State Park	2	34 & 37	37722
11 NOV 39	Atlantic Ocean off Orient Point	1	200	39688
16 JUL 53	Basket NK Bay at Remsenburg	2		11957
08 SEP 75	Hudson River, River Mile 38-1	1		11954
13 SEP 76	Hudson River, River Mile 36-1	2		11953

Table 4 (cont.)

04 AUG 77	Hudson River, River Mile 42-3	1		14376
24 AUG 77	Hudson River, Bowline Bay north	1		20111
27 SEP 78	Hudson River, 0.5 m northeast of Haverstraw	2		7314
17 OCT 78	Hudson River, Bowline Gen. Station intake	1		9970
19 OCT 78	Hudson River, Lovett Gen. Station intake	3		11237
25 OCT 78	Hudson River, Bowline Bay north	1		7513
07 NOV 78	Hudson River, River Mile 42-3	3		14332
07 NOV 78	Hudson River, Lovett Gen. Station intake	2		11233
10 NOV 78	Hudson River, Lovett Gen. Station intake	3		11236
16 NOV 78	Hudson River, Lovett Gen. Station intake	5		11239
23 NOV 78	Hudson River, Lovett Gen. Station intake	5		11240
25 OCT 79	Hudson River, Bowline Gen. Station control	1		8430
26 OCT 79	Hudson River, Lovett Gen. Station intake	1		6322
22 NOV 79	Hudson River, Lovett Gen. Station intake	1		19871
22 NOV 79	Hudson River, Lovett Gen. Station intake	1		20496
24 OCT 80	Hudson River, Lovett Gen. Station intake	68		10509
01 NOV 80	Hudson River, Lovett Gen. Station intake	12		11253
07 NOV 80	Hudson River, Lovett Gen. Station intake	16		11252
SEP 84	Moriches Bay	1		14752
05 SEP 85	Bay at Middle Pond Inlet, Southampton	11		17690
01 SEP 87	Cold Spring Inlet, under Rte. 585 bridge	10		39423
Summer 88	Hudson River, River Mile 24-43	7		30050 & 30054
12 SEP 90	Hudson River at Danskammer Cove	4	69-73	28837

Field sampling of the entire Hudson River

Based on the Consolidated Edison (ConEd) survey, Caranx hippos occurred commonly in the lower portion of the estuary during seasonally warm months. A total of 248 C. hippos was collected in 91 of 8301 seine hauls during 1986-1993 (Table 5). Caranx hippos was found between river kilometer (RK) 19 and 102 and was most concentrated from RK 63 to 76 (Stratum 4; Fig. 2). They were present from July to October, but the month of greatest abundance was not consistent between years (Fig. 3). They were never collected in June and were only once collected in November. Annual abundance varied by an order of magnitude (geometric means: 0.00199-0.1934 fish $haul^{-1}$) based on data from all stations (Table 5).

TABLE 5 - Basic catch statistics for the survey by Consolidated Edison (using a 30.5 m seine) based on data from all sampling strata (Left) and from the Haverstraw Bay strata only (Right). Data tabulated are total number of hauls (F), the number of hauls collecting Caranx hippos (f), the total number of C. hippos collected (C), and the geometric mean based on collections from Jul-Oct only.

	All Sampling Strata				**Haverstraw Bay Strata only**			
Year	F	f	C	GM	F	f	C	GM
1986	1000	6	10	0.00462	303	3	7	0.0076
1987	1101	2	3	0.00199	342	2	3	0.0053
1988	1100	12	22	0.01402	295	5	11	0.0151
1989	1100	15	40	0.01765	322	13	21	0.0341
1990	1000	19	32	0.01934	302	11	21	0.0315
1991	1000	11	58	0.01331	290	6	9	0.0177
1992	1000	9	53	0.01344	302	4	4	0.0092
1993	1000	17	30	0.01778	282	11	18	0.0350
Total	8301	91	248		2438	55	94	

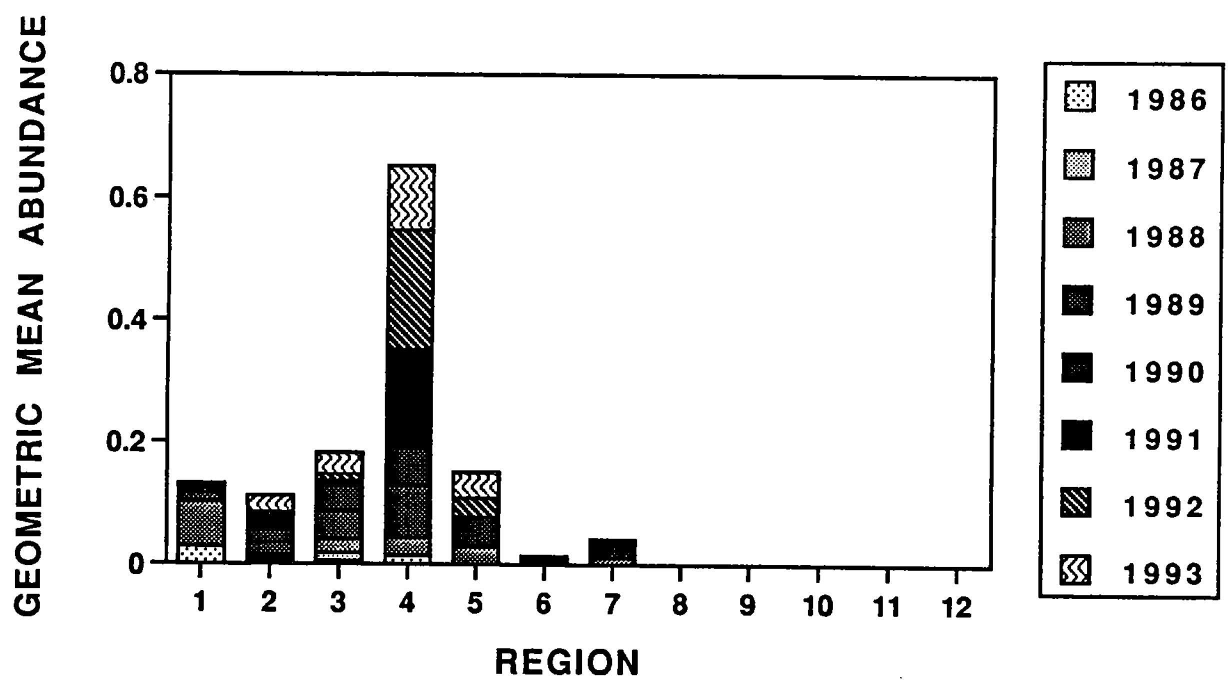

Figure 2 - Geometric mean abundance of Caranx hippos , by sampling strata and year, based on collections in the ConEd sampling program (1986-1993) using a 30.5 m seine. Seining occurred between River Kilometer (RK) 19 and 240.

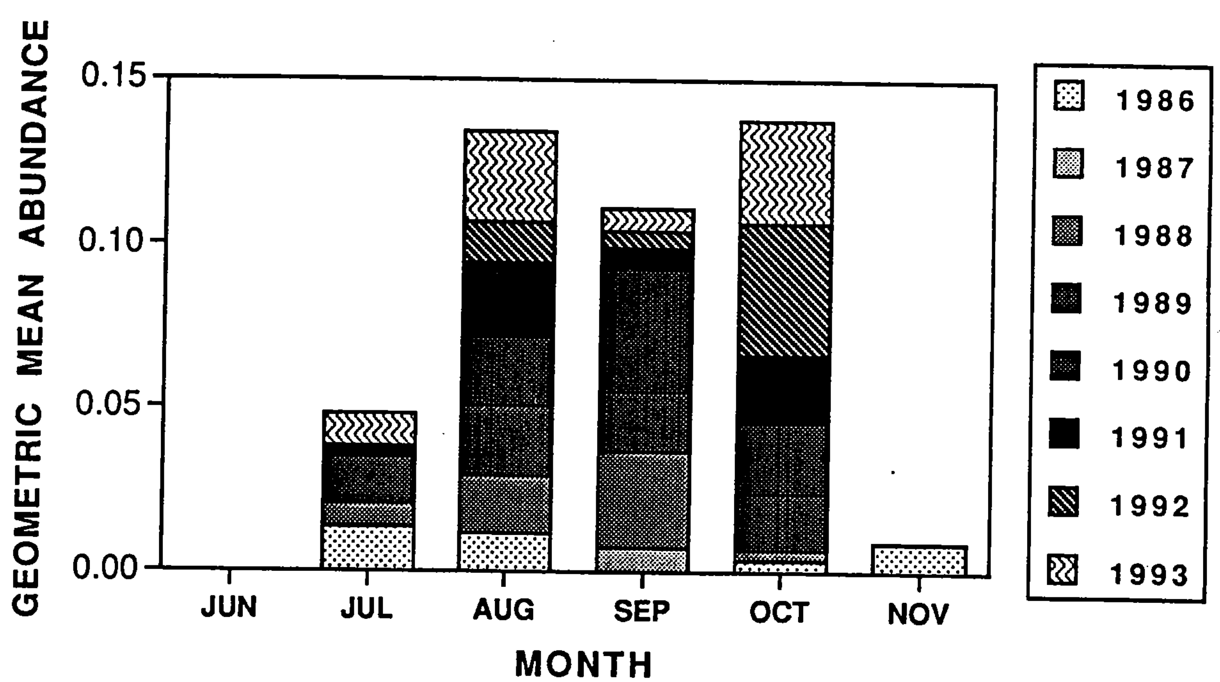

Figure 3 - Geometric mean abundance of Caranx hippos, by month and year, based on collections in the ConEd sampling program (1986-1993) using a 30.5 m seine. Seining occurred from late June to early November.

Sampling in Haverstraw and Jamaica Bays

Caranx hippos was found in both Haverstraw and Jamaica Bays in all years (1986-1993) of the NYSDEC survey (Table 6). Annual abundances varied by an order of magnitude. Annual abundance was not significantly correlated between Jamaica Bay and Haverstraw Bay (based on the NYSDEC survey; r=0.63; p=0.091) or between the ConEd and the NYSDEC survey (based on Haverstraw Bay data only; r=0.61; p=0.109).

Caranx hippos occurred seasonally as early as July and as late as November (i.e., the range of sampling months) in Haverstraw Bay, but they were never collected in May, June, or November in Jamaica Bay where sampling occurred from May to November. Most hauls collecting fish were from waters warmer than 25°C in Haverstraw Bay and 23°C in Jamaica Bay (Fig. 4a). Caranx hippos invaded nearly freshwater regions of the river (Fig. 4b). Fish were collected at various DO concentrations, from 2.0 - 13.6 ppm (Fig. 4c).

TABLE 6 - Catch statistics for survey by NYSDEC (61 m seine) for Haverstraw Bay (Left) and Jamaica Bay (Right). Data are for total number of hauls (F), number of hauls collecting Caranx hippos (f), total number of C. hippos collected (C), and geometric mean based on collections from Jul-Oct only.

	Haverstraw Bay				Jamaica Bay			
Year	F	f	C	GM	F	f	C	GM
1986	222	6	21	0.02870	38	2	10	0.1894
1987	225	7	9	0.02871	56	4	14	0.1712
1988	220	21	45	0.11410	42	4	54	0.9419
1989	225	17	64	0.09923	49	2	2	0.0757
1990	217	16	39	0.09131	48	7	11	0.3741
1991	215	9	20	0.05509	58	4	6	0.1269
1992	221	5	5	0.01396	44	2	3	0.0848
1993	225	11	20	0.05577	43	3	11	0.2480
Total	1770	92	223		378	28	111	

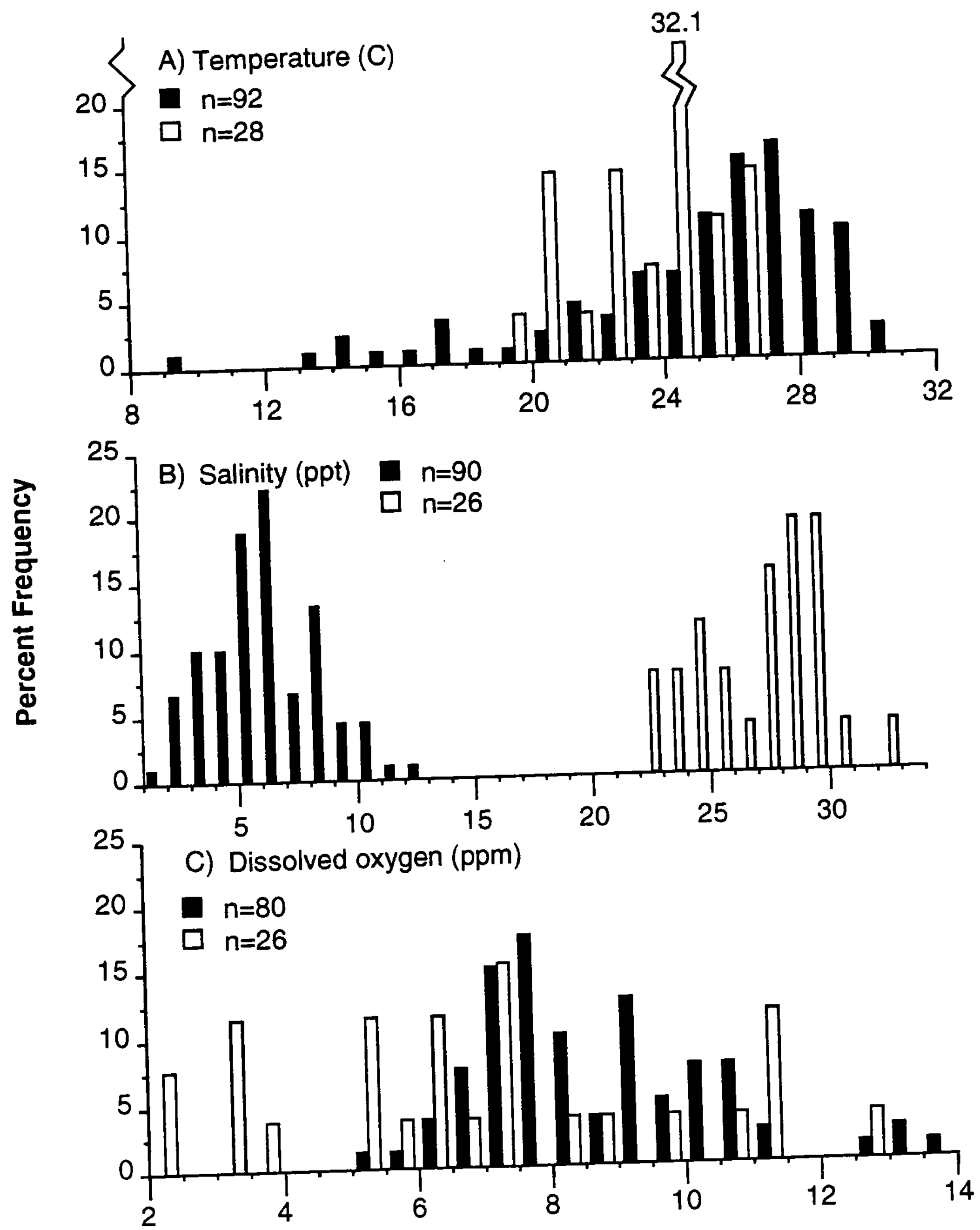

Figure 4 - Frequency of occurrence of temperature (A), salinity (B), and dissolved oxygen (C) based on data from Haverstraw (solid bars) and Jamaica (open bars) bays surveyed by the New York State Department of Environmental Conservation. Data is pooled for all years, 1986-1993. Number of occurrences for which each parameter was measured = n.

Fork length ranged from 29 to 176 mm, in all years and for both bays, suggesting that only YOY fish were present. Changes in size were similar between Haverstraw Bay and Jamaica Bay (Fig. 5), particularly in the following aspects: length-frequency was fairly unimodal in July (mean FL = 48 vs. 40 mm in each respective bay); mean length increased only slightly in August (64 vs. 47 mm FL) while the variance increased more rapidly; the most rapid increases were not clearly evident until September (mean FL = 120 vs 119 mm).

Growth was modeled using least squares regression of FL on day of the year. The linear form of the exponential growth model (i.e., ln[Y] = ln[a] + X*ln[b]) provided the best fit to the data, based on consistently significant correlation coefficients and plots of residuals that appeared unbiased against the predicted values. Instantaneous (or specific) growth rates in Haverstraw Bay were fairly consistent between years (0.5 - 2.2 % FL d^{-1}; Table 7; Fig. 6). Size structure and growth rates appeared similar in Jamaica Bay, but reduced sampling effort there precluded detailed comparisons.

TABLE 7 - Specific growth rates (G) of Caranx hippos representing the rate of growth (% fork length per day) in Haverstraw Bay and Jamaica Bay, based on survey by NYSDEC (61 m seine). Coefficient of determination is also provided as these growth rates were modeled using least squares methods of the linear model lnFL=ln(a)+x*ln(b). Significance of the coefficient of determination is indicated as *P<0.05, **P<0.01, and *P<0.001. Number of fish measured (n) is also indicated. Missing data indicates that C. hippos was not collected on more than two separate dates.

	Haverstraw Bay			Jamaica Bay		
Year	G	r^2	n	G	r^2	n
1986	0.49	0.49**	20	1.0	0.80**	10
1987	2.0	0.46*	9	3.6	0.73***	15
1988	1.8	0.84***	45	0.8	0.16*	54
1989	1.0	0.24***	62	--	--	--
1990	1.4	0.51***	39	1.9	0.78**	11
1991	2.3	0.96***	19	--	--	--
1992	1.6	0.82*	5	--	--	--
1993	1.4	0.86***	20	--	--	--

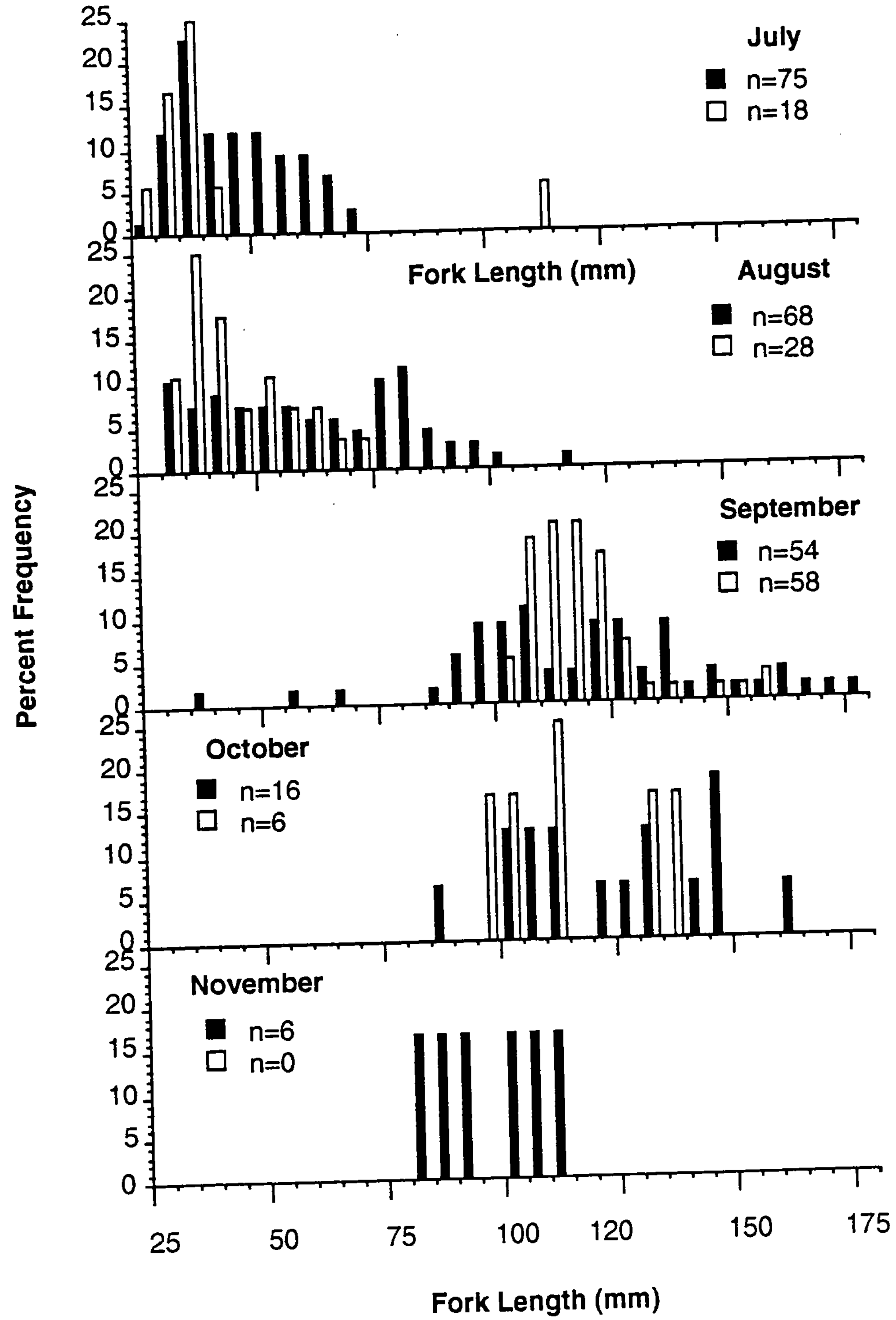

Figure 5 - Monthly length-frequency of Caranx hippos based on data from Haverstraw Bay (solid bars) and Jamaica Bay (open bars) surveyed by the New York State Department of Environmental Conservation. Data is pooled for all years, 1986-1993. Number of fish measured = n.

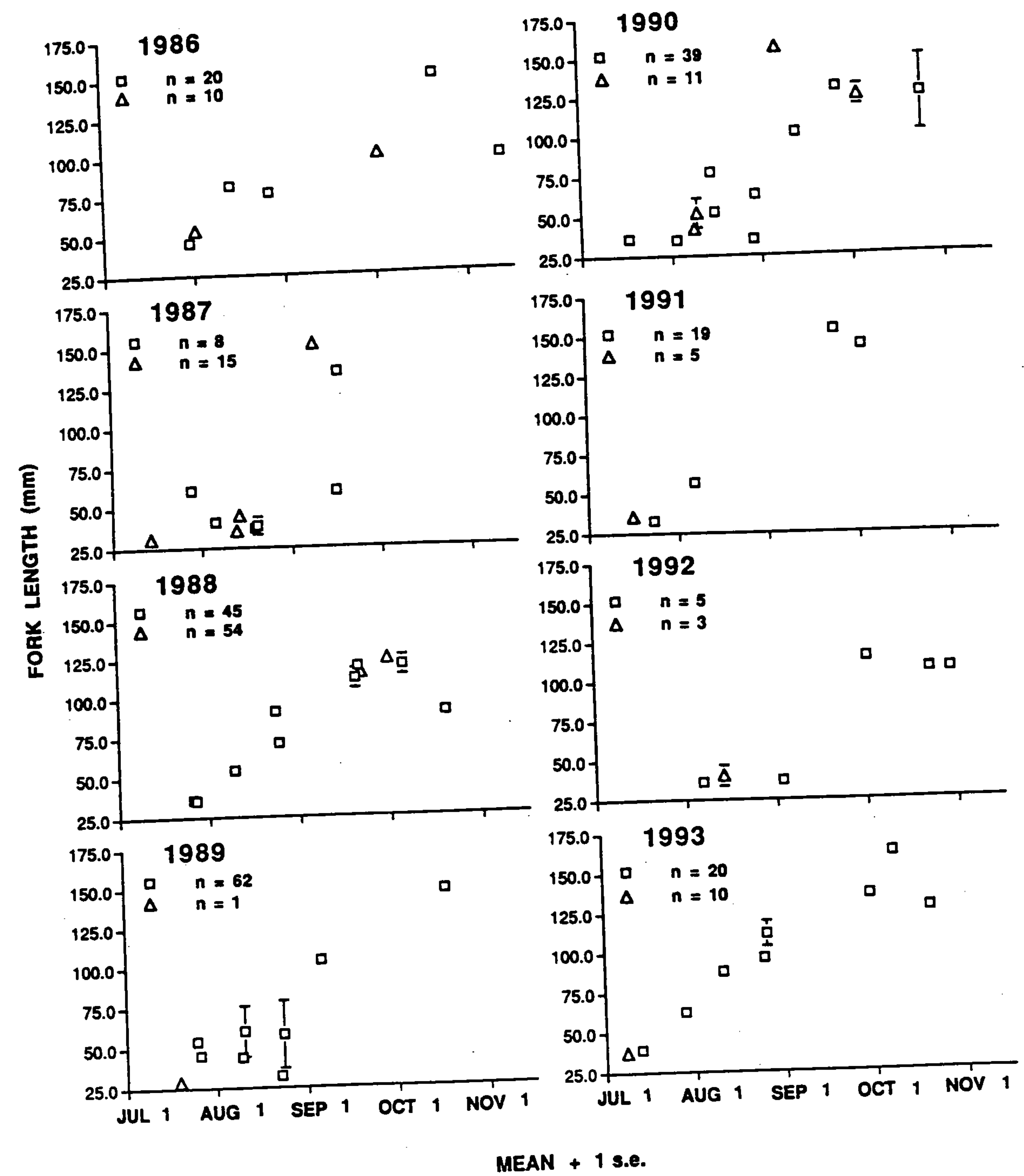

Figure 6 - Mean fork length (± 1 s.e.) plotted by day of the year for Caranx hippos during 1986-1993 in Haverstraw Bay (squares) and Jamaica Bay (triangles) as surveyed by the New York State Department of Environmental Conservation. Number of fish measured = n.

DISCUSSION

Distribution and Abundance

Historically, young-of-the-year (YOY) Caranx hippos occur seasonally and are broadly distributed throughout the New York Bight. They were widely distributed throughout the lower Hudson River estuary during this study. These findings are more consistent with the conclusions of Smith (1985) who referred to C. hippos as a "common summer resident", than with Greeley's (1937) reference to C. hippos as "rare" or Nichols' (1918) vague categorization for C. hippos as "tolerably common". The absence of C. hippos in some previous surveys (Table 1) is quite likely the result of low sampling frequency (usually monthly) by many studies, since even in this investigation the vast majority of seine hauls collected no C. hippos. There was a positive relationship between independent measures of annual abundance (i.e., in Haverstraw Bay as measured by ConEd and NYSDEC surveys and between Haverstraw and Jamaica Bays for the NYSDEC survey), but the lack of a significant correlation was unexpected. This may be related to a low sample size (n=8 years). Small sample sizes are less likely to detect a relationship even if one exists (i.e., Type II error).

Despite their broad distribution in the lower estuary, Caranx hippos exhibited some level of habitat selection. Their distribution was strongly associated with temperature, which may have important consequences for the ecology of this species. This may, for example, explain the concentration of fish in and near the Haverstraw Bay region versus other parts of the river. Haverstraw Bay is the warmest part of the river because of its broad, shallow areas that maintain slow water movements and large surface:volume ratios for transmission of solar radiation (EA Engineering 1990). Temperatures in the Hudson River are generally rising from June to August and falling from August to November (EA Engineering 1990). Three power plants are also located in strata 3 & 4 (Fig. 1), each of which may elevate further the temperatures of local areas. Winter temperatures become low enough to be lethal to this species and no specimen has been collected in the Hudson River after November or before July in any year. Daily water temperature maxima do not exceed 10°C for the four-month period, December-March (as observed during 1951-1987 at the Poughkeepsie Water Works near river kilometer 110; EA Engineering 1990). Hypothermal mortality of C.

hippos was suggested by Hoff (1971), when he documented a fish kill of over 200 C. hippos in an upstream portion of a Massachusetts river during October at temperatures of 7.4-9.0°C. The influence of warm temperatures has been noted at southern latitudes as well. Tagatz and Dudley (1961) collected C. hippos at temperatures between 24-32°C, near Cape Lookout, North Carolina, and Gilmore et al. (1978) noted cold-induced mortality of C. hippos during January, 1977, when temperatures dropped to 6°C in Florida. It is necessary, then, that YOY C. hippos migrate out of the Hudson River, and well south, if they are to survive the winter.

Caranx hippos was distributed up to freshwater portions of the Hudson River estuary and several others have collected C. hippos from a wide range of salinities. Caranx hippos was collected in 2-3°/₀₀ in Delaware Bay (de Sylva et al. 1962), 8-36°/₀₀ near Cape Lookout (Tagatz and Dudley 1961), and generally above 30°/₀₀ near North Inlet (Ogburn et al. 1988). Smith (1985) also reported C. hippos in the Hudson River as far upstream as river kilometer 110 in October and early November, so it would appear that salinity only affects the distribution of C. hippos at the freshwater edge. Bottom salinity in the Hudson River varies with respect to season (low in spring and autumn due to freshwater discharges; EA Engineering 1990). During July-October freshwater (<0.3 ppt) is generally found only north of river kilometer 90-100 (EA Engineering 1990).

Caranx hippos was collected in a broad range of dissolved oxygen concentrations and, although oxygen concentrations measured in Jamaica Bay were generally lower than in Haverstraw Bay, none were particularly stressful (i.e., < 2 ppm). Dissolved oxygen in the Hudson River decreases from July to August and increases from August to October, but there is no regular trend with respect to river kilometer (EA Engineering 1990). It is likely that only extremely low concentrations of dissolved oxygen would affect the distribution of C. hippos, but these were not observed in this study.

Dovel (1981) considered Haverstraw Bay as a 'critical zone' that acts as a primary nursery area in the Hudson River. Thus, aside from the abiotic variables already discussed, there is also a good forage base (i.e., Anchoa; Dovel 1981) which may attract this species. Thus, YOY Caranx hippos are tolerant to a wide range habitats within the Hudson River, and its particularly high abundance in the Haverstraw region is consistent with the distribution of many regional, estuarine species.

Size and Growth

The most rapid changes in size occurred in August-September, which suggested non-linear growth, possibly as a result of the high temperatures during this period. Growth rates were high relative to other YOY estuarine fish species in the New York Bight (Rountree and Able 1992). This indicates that Caranx hippos uses northern estuaries, such as the Hudson River, profitably for growth.

In general, treating fish from each year as a single 'cohort' appeared justifiable for the purpose of modeling growth rates. The prolonged appearance of small fish (30-50 mm FL) during August and occasionally in September suggests, however, that a series of young fish may be new arrivals to the Hudson River estuary.

CONCLUSIONS

Caranx hippos is seasonally common and grows fast in the Hudson River estuary. Latitudinal comparisons of C. hippos abundance is hindered by a lack of data and potential changes in catchability in smaller versus larger seines. For example, C. hippos is a fast-swimming, shoaling species (Kwei 1978) and likely to be capable of outswimming smaller seines. Nonetheless, I have attempted to evaluate geographic variation in abundance of YOY C. hippos based on the sparse data available. Keeping in mind that YOY C. hippos are rarely captured in smaller seines and trawls after a few weeks of arriving into estuaries (Ogburn et al. 1988), then the seines used in the Hudson River (30.5 and 61 m) were well suited for collecting C. hippos because they captured fish for a 4-5 month period. Since I am unaware of any studies south of Cape May, New Jersey (Table 1), using a seine net larger than 21 m, my interpretations may be biased, but I conclude that YOY C. hippos density is as high or higher in temperate estuaries than in subtropical estuaries, although for a shorter period of time (Jul-Nov versus Apr-Nov).

Growth rates observed for C. hippos could not be contrasted between latitudes, since no comparable information was found. Based on available size data, it is also postulated that YOY C. hippos grow at similar rates in both temperate and subtropical estuaries.

A diverse assemblage of subtropically-spawned fishes occurs in northern estuaries during the late summer and some species, such as C. hippos, are numerous in selected habitats (Sumner et al. 1913; Alperin and Schaefer 1965; Milstein 1976). It has long been assumed that these fish are expatriates (i.e., they can not survive their first winter once they recruit to northern latitudes; Gill 1904), and the disjunct distribution of many faunal and floral species at Cape Hatteras and Cape Cod (Parr 1933; Bliss 1982) support this view. If YOY C. hippos remained at temperate latitudes then these individuals would not survive the ambient temperatures, but it is worthy of further consideration that these fish may be capable of migrating to southerly overwintering areas.

Few coastal species are known to exploit habitats on both sides of Cape Hatteras within their first year of life. One well documented exception to this paradigm is that of spring-spawned bluefish, Pomatomus saltatrix (Kendall and Walford 1979; McBride and Conover 1991; Hare and Cowen 1993). McBride et al. (1993) discuss the evidence that YOY P. saltatrix use habitats at both temperate and subtropical latitudes. Regardless of whether YOY Caranx hippos can or can not survive the overwintering period, if such a large proportion of offspring are annually exported away from subtropical spawning grounds, then estuaries of the Mid-Atlantic region (such as the Hudson River) represent either a major sink or source of nursery habitats for this species and may influence population size.

RECOMMENDATIONS

Dispersal of Caranx hippos to northern estuaries may be important for their population regulation, for the reason discussed above, and is worth further research. More information about the early life history of coastal marine species across wide latitudinal ranges is likely to challenge the static paradigm of faunal breaks and lead to more dynamic views of life history circuits for northwestern Atlantic fishes. Beyond this ecological perspective, there are applications for such research as well. Examples such as Pomatomus saltatrix show how environmental conservation of the Hudson River ecosystem is an investment for both local fishes, as well as for fish that move along routes beyond local (and certainly political) boundaries. The findings of this research project suggests that Caranx hippos is also such an example for fish ecologists and fishery managers to keep in mind.

ACKNOWLEDGEMENTS

Much of this project originates from the enthusiastic support of K. McKown of the New York State Department of Environmental Conservation (NYSDEC), Division of Marine Resources. K. McKown, B. Young, L. Pasciutti, M. Penski, and other NYSDEC biologists collected the data for Haverstraw Bay and Jamaica Bay. J. Young and G. Sentell provided data from the Consolidated Edison sampling program. C.L. Smith provided access to the collections at the American Museum of Natural History; W. Saul provided printouts of material at Academy of Natural Sciences at Philadelphia; R. Daniels provided printouts of material at the New York State Museum. My advisors in graduate studies, D. Conover and K. Able, were helpful in letting me pursue this investigation while at State University of New York and Rutgers, The State University of New Jersey. An earlier version of this manuscript was submitted to K. Able and R. Loveland as part of an estuarine ecology course at Rutgers University. This research was further assisted through sponsorship of a Polgar Fellowship from the Hudson River Foundation (HRF), a program administered by J. Waldman (HRF) and B. Blair (NYSDEC). I am grateful to all of the above.

LITERATURE CITED

Alperin, I.M. 1967. Notes on the carangid fishes of Long Island. New York Fish and Game J. 14(1): 82-85.

Alperin, I.M., and R.H. Schaefer. 1965. Marine fishes new or uncommon to Long Island, New York. New York Fish and Game J. 12(1): 1-16.

Anderson, W.D.Jr., J.K. Dias, R.K. Dias, D.M.Cupka, and N.A. Chamberlain. 1977. The macrofauna of the surf zone off Folly Beach, South Carolina. U.S. Fish and Wildlife Spec. Rep. 23pp.

Berry, F.H. 1959. Young jack crevalles (Caranx species) off the southeastern Atlantic Coast of the United States. Fish. Bull. 59:417-535.

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishery Bull. Fish and Wldl. Ser. 53: 1-577.

Bliss, D.E. 1982. Shrimps, lobsters and crabs: their fascinating life story. Piscataway, New Jersey: New Century Publ.

Briggs, J.C. 1960. Fishes of worldwide (Circumtropical) distribution. Copeia. 1960(3): 171-180.

Briggs, P.T. 1975. Shore-zone fishes of the vicinity of Fire Island Inlet, Great South Bay, New York. New York Fish and Game J. 22(1): 1-12.

Briggs, P.T., and J.S. O'Connor. 1971. Comparison of shore-zone fishes over naturally vegetated and sand-filled bottoms in Great South Bay. New York Fish and Game Journal. 18(1): 16-41.

de Sylva, D.P., F.A. Kalber, and C.N. Shuster. 1962. Fishes and ecological conditions in the shore zone of the Delaware River Estuary, with notes on other species collected in deeper water. University of Delaware Marine Lab. Information Series Publication no. 5. Tech. Rep. to Delaware Board of Game and Fish Commissioners under Dingell-Johnson Federal Aid in Fish and Wildlife Restoration. Delaware Project F-13-R-1-2-3. pp. 38-39.

Dovel, W.L. 1981. Ichthyoplankton of the lower Hudson estuary, New York. New York Fish and Game Journal. 28(1): 21-39.

EA Engineering, Science, and Technology. 1990. 1988 Year Class Report for the Hudson River Estuary Monitoring Program. EA Report No. 11432.01. Prepared for Consolidated Edison Company of New York, Inc.

Fahay, M.P. 1975. An annotated list of larval and juvenile fishes captured with surface-towed meter net in the South Atlantic Bight during four RV Dolphin Cruises between May 1967

and February 1968. NOAA Tech. Rep. NMFS-SSRF-685. 39pp.

Festa, P.J. 1979. The fish forage base of the Little Egg Harbor Estuary. New Jersey Department of Environmental Protection. Division of Fish, Game and Shellfisheries. Bureau of Fisheries. Nacote Creek Research Station. Technical Report No. 24 M.

Fletcher, R.I. 1990. Flow dynamics and fish recovery experiments: water intake systems. Trans. Am. Fish. Soc. 119(3): 393-415.

Fowler, H.W. 1945. A study of the fishes of the southern Piedmont and coastal plain. Philadelphia: The Acad. Nat. Sci. Phil. Monographs No. 7.

Futch, C.R., and S.E. Dwinell. 1977. Nearshore marine ecology at Hutchinson Island, Florida: 1971-1974. IV. Lancelets and Fishes. Fla. Mar. Res. Publ. No. 24. 23pp.

Gill, T. 1904. State ichthyology of Massachusetts. Science N.S. 20(506): 321-338.

Gilmore, R.G., L.H. Bullock, and F.H. Berry. 1978. Hypothermal mortality in marine fishes, south-central Florida, January, 1977. Northeast Gulf Sci. 2(2): 77-97.

Gordon, B.L. 1974. The marine fishes of Rhode Island, RI: The Book and Tackle Shop. 136pp.

Greeley, J.R. 1937. Survey of the lower Hudson Watershed. II. Fishes of the area with annotated List. Albany: State of New York Conservation Department. pp: 45-103.

Greeley, J.R. 1939. A biological survey of the salt waters of Long Island, 1938. XV. Fishes of the area with annotated List. Albany: State of New York Conservation Department. pp: 72-91.

Grosslein, M.D., and T.R. Azarovitz. 1982. Fish distribution. MESA New York Bight Atlas Monograph No. 15. Albany: New York Sea Grant Institute. 182 pp.

Hare, J.A., and R.K. Cowen. 1993. Ecological and evolutionary implications of the larval transport and reproductive strategy of bluefish Pomatomus saltatrix. Mar. Ecol. Prog. Ser. 98: 1-16.

Hildebrand, S.F., and W.C. Schroeder. 1928. Fishes of Chesapeake Bay. U.S. Bur. Fish. Bull. 43 (pt. 1).

Hoff, J.G. 1971. Mass mortality of the crevalle jack, Caranx hippos (Linnaeus) on the Atlantic Coast of Massachusetts. Chesapeake Science. 12: 49.

Kendall, A.W., and L.A. Walford. 1979. Sources and distribution of bluefish Pomatomus saltatrix, larvae and juveniles off the east coast of the United States. Fish. Bull., U.S. 73: 453-462.

Kwei, E.A. 1978. Food and spawning activity of Caranx hippos (L.) off the coast of Ghana. J.

Nat. Hist. 12: 195-215.

Latham, R. 1918. Notes on fishes at Orient, Long Island in 1917. Copeia. 1918 (57): 53-56.

Marcellus, K.L. 1972. Fishes of Barnegat Bay, NJ with particular reference to seasonal influence and the possible effect of thermal discharge. Ph.D. dissertation. New Jersey: Rutgers University. p. 103.

McBride, R.S., and D.O. Conover. 1991. Recruitment of young-of-the-year bluefish (Pomatomus saltatrix) to the New York Bight: Variation in abundance and growth of spring- and summer-spawned cohorts. Mar. Ecol. Prog. Ser. 78: 205-216.

McBride, R.S., J.L. Ross, and D.O. Conover. 1993. Recruitment of bluefish (Pomatomus saltatrix) to estuaries of the South Atlantic Bight, U.S.A. Fish. Bull., U.S. 91: 389-395.

McKown, K.A. and B.H. Young. 1992. Effects of year class strength on size of young-of-the-year striped bass. IN: Estuarine Research in the 1980's. (Ed.) C.L. Smith. Albany: State Univ. of New York Press. pp: 265-276.

Miller, G.L., and S.C. Jorgenson. 1969. Seasonal abundance and length frequency distribution of some marine fishes in coastal Georgia. U.S. Fish Widl. Serv. Data Rep. 35. 103 pp. on 2 microfische.

Milstein, C.B. 1976. Fishes new or uncommon to the New Jersey Coast. Chesapeake Science. 17(3): 198-204.

Moore, H.F. 1894. List of fishes collected at Sea Isle City, New Jersey, during the summer of 1892. Bulletin of the United States Fishery Commission. 12: 357-364.

Nichols, J.T. 1918. Fishes of the vicinity of New York City. New York: The Am. Mus. Nat. Hist. Handbook Series. No. 7. p. 112.

Nichols, J.T. 1920. On the range and geographic variation of Caranx hippos. Copeia 1920(83): 44-45.

Nichols, J.T. 1921. Species of northwest and Atlantic Caranx. Copeia. 1921(98): 45-51.

Nichols, J.T. 1937. Notes on carangid fishes. I. On young Caranx hippos (Linnaeus). Am. Mus. Novitates. No. 967. pp: 1-6.

Nichols, J.T. 1939. Young Caranx in the western North Atlantic. Bull. Bingham Ocean. Coll. 7(2): 1-9.

Nichols, J.T., and C.M. Breder. 1926. The marine fishes of New York and southern New England. Zoologica. IX(1): 112-113.

Ogburn, M.V., D.M. Allen, and W.K. Michener. 1988. Fishes, shrimps, and crabs of the North Inlet Estuary, SC: A four-year seine and trawl survey. Baruch Institute Technical Report. No. 88-1. Columbia: University of South Carolina. 299 pp.

Pacheco, A.L., and G.C. Grant. 1965. Studies of the early life history of Atlantic menhaden in estuarine nurseries. Part 1. Seasonal occurrence of juvenile menhaden and other small fishes in a tributary creek of Indian River, Delaware, 1957-58. U.S. Fish and Wildlife Service. Sep. Sci. Rep. 504. 32pp.

Palko, B.J. 1984. An evaluation of hard parts for age determination of pompano, ladyfish, crevalle jack, gulf flounder, and southern flounder. NOAA Tech. Memo. NMFS-SEFC-132. 11pp.

Parr, A.E. 1933. A geographic-ecological analysis of the seasonal changes in temperature conditions in shallow water along the Atlantic coasts of the Unites States. Bull. Bingham Ocean. Coll. 4(3): 1-90.

Richards, C.E., and M. Castagna. 1970. Marine fishes of Virginia's eastern shore (Inlet and marsh, seaside waters). Chesapeake Sci. 11(4): 235-248.

Rountree, R.A., and K.W. Able. 1992. Fauna of polyhaline subtidal marsh creeks in southern New Jersey: composition, abundance, and biomass. Estuaries. 15(2): 178-220.

Schaefer, R.H. 1967. Species composition, size and seasonal abundance of fish in the surf waters of Long Island. New York Fish and Game J. 14(1): 1-46.

Scott, W.B., and M.G. Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. No. 219. 731 pp.

Smith, C.L. 1985. The inland fishes of New York State. Albany: The New York State Department of Environmental Conservation. 522 pp.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. Second Edition. New York: W.H. Freeman and Co.

Sumner, F.B., R.D. Osborn, and L.I. Cole. 1913. A catalogue of the marine fauna of Woods Hole and vicinity. Bull. Bur. Fish. XXXI (2):

Tagatz, M.E. and D.L. Dudley. 1961. Seasonal occurrence of marine fishes in four shore habitats near Beaufort, N.C., 1957-60. U.S. Fish and Wildlife Spec. Rep. 19pp.

Tatham, T.R., D.L. Thomas, and D.J. Danila. 1984. Fishes of Barnegat Bay, New Jersey. In: Ecology of Barnegat Bay, New Jersey: Lecture notes on coastal and estuarine studies. M.J. Kennish, M.J. and R.A. Lutz (Eds.) New York: Springer-Verlag. pp. 241-280.

Thomas, D.L., Milstein, C.B., Tatham, T.R, Bieder, R.C, Margraf, F.J, Danila, D.J, Hoff, H.K, Illjes, E.A, McCullough, M.M, and Swiecicki, F.A. 1974. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic generating station, NJ. Progress Report for January-December, 1973. Volume One: Fishes. Ichthyological Associates, Inc.

Thomas, D.L., Milstein, C.B., Tatham, T.R, Bieder, R.C, Danila, D.J, Hoff, H.K, Swiecicki, D.P, Smith, R.P, Miller, G.J, Gift, J.J, and Wyllie, M.C. 1975. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic generating station, NJ. Progress Report for January-December, 1974. Volume One: Fishes. Ichthyological Associates, Inc.

U.S. Department of Commerce. 1986. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1985. Current Fishery Statistics No. 8327. Washington, D.C.: NOAA, NMFS.

Vladykov, V.D. 1935. Some unreported and rare fishes for the coast of Nova Scotia. Proc. Nova Scotian Inst. Sci. XIX(1): 1-8.

Vouglitois, J.J. 1983. The ichthyofauna of Barnegat Bay, New Jersey - relationships between long term temperature fluctuations and the population dynamics and life history of temperature estuarine fishes during a five year period, 1976-1980. M.Sc. thesis. New Brunswick: Rutgers University.

Warfel, H.E. and D. Merriman. 1944. Studies of marine resources of southern New England. I. An analysis of the fish population of the shore zone. Bull. Bingham. Ocean. Coll. IX(1): 1-91.

Zawacki, C.S. and P.T. Briggs. 1976. Fish investigations in Long Island Sound at a nuclear power station site at shoreham, New York. New York Fish and Game J. 23(1): 35-50.