Population Trends Among Smallmouth Bass in the Eastern Basin of Lake Ontario, 1976-1997.

J.R. Chrisman and T.H. Eckert

New York Department of Environmental Conservation
Cape Vincent, New York 13618

Smallmouth bass (*Micropterus dolomieui*) have provided an important sport fishery in the eastern basin of Lake Ontario for decades (Jolliff and LeTendre 1967, Panek 1981, NYDEC 1984). Stone et al. (1954) describes eastern basin fishing grounds as "probably [the] most productive for smallmouth bass in the State". The importance of maintaining a good fishery in the basin was realized as early as the late 1930s, (NY Conservation Department 1941) and since the 1940s, creel and netting surveys have monitored warm water fish populations (Stone et al. 1951, Stone et al. 1954, Panek 1981, Schiavone 1989, Eckert 1997).

In recent years, many changes have occurred in the eastern basin, including reduced lake productivity, the introduction and proliferation of Dreissenid mussels, increased water clarity, and increased abundance of two piscivores, double-crested cormorants (*Phalacocorax auritus*) and walleye (*Stizostedion vitreum*) (Ross and Johnson 1997, Eckert 1997). Little is known about possible impacts of these changes on smallmouth bass population dynamics. The objective of this study was to examine population trends, including recent changes in abundance, recruitment, growth, and survival of eastern basin smallmouth bass.

Methods

Field and Laboratory Procedures

Annual assessments of the warm water fish community in New York waters of Lake Ontario's eastern basin have been conducted by the New York Department of Environmental Conservation (DEC) each August from 1976-1997. Standard sinking gill net gangs were set overnight on the bottom, parallel to depth contours at predetermined randomly selected sample locations. Each net gang consisted of nine equal length net panels, 2.4 m deep, and ranging in size from 51-152 mm stretch mesh by 12.7 mm size increments. From 1976-1979, the sampling utilized 274 m multifilament net gangs (each net panel 30 m long), half set at the 9 m contour, and half set in deeper water between the 9 m contour and the top of the thermocline. The 1976-1979 sampling excluded Chaumont, Black River and Henderson Bays. In 1980, the sampling switched to shorter 137 m net gangs (each net panel 15 m long with all other specifications remaining the same); included Chaumont, Black River and Henderson Bays; and was conducted according to a stratified random sampling design. This new design used three depth strata (stratum 1, 4-9 m; stratum 2, 10-15 m; stratum 3, 16-30 m), plus five area strata. Emphasis was placed on the sampling in depth strata 1 and 2 with 10 and 9 net gangs, respectively, scheduled each year. The area strata were used primarily to ensure that all major geographic areas within depth strata 1 and 2 were sampled each year in proportion to their surface areas. In 1993, multifilament nets were replaced with monofilament mesh gill nets. This latest change was implemented in part due to problems and costs of obtaining multifilament netting with proper specifications.

Biological Data Collected

Measurements of total length, weight, sex and stage of maturity were recorded for each smallmouth bass netted. Scales were removed from the left side of each fish, below the lateral line and near the end of the pectoral fin as it lay flat against the fish. Scales were later pressed

onto acetate slides. The scale impressions were viewed through a compound microscope and annuli were counted to determine the age of each fish.

Data Corrections and Calculation of Mean Catch per Net Gang (CPUE)

Corrections for changes in the sampling design that occurred between 1979 and 1980 have been described previously (Eckert 1986), while corrections for the change from multifilament to monofilament gill nets are described in Eckert (1998). Correction factors were applied to the 1976-1992 multifilament catch data, and "monofilament equivalents" were calculated. Mean CPUE estimates for all years were calculated from untransformed monofilament catch data using standard formulas for stratified random samples (Cochran 1977). The CPUE estimates for each age class were calculated by proportionately dividing the mean CPUE of a given year by the relative age composition of the bass sampled that year.

Year Class Strength

An index of year class strength was determined by summing CPUE estimates of age 2-4 smallmouth bass from each year class. Ages 2-4 were chosen since the majority of these fish are less than the legally harvestable length of 12 inches and should be relatively unaffected by the fishery. It was assumed that summing across three years (ages 2-4) would reduce errors due to yearly sampling variability, and that relative vulnerability had changed significantly over the years sampled. Age 2 and age 4 CPUE values were not available for the 1973-1976 and 1994 year classes, respectively. Estimated CPUEs for these missing age classes were calculated by applying the average percent increases in CPUE (from age 2 to 3, 1977-1994 year classes; and age 3 to 4, 1973-1993 year classes) to the catch data for the 1973-1976 and 1994 year classes. CPUE estimates for these year classes were calculated by summing the age 3&4 (1973-1976) and age 2&3 (1994) CPUE values with the estimated CPUE of missing age classes.

Growth Rate: To examine differences in growth rate between year classes, slopes were calculated for the linear regression through natural log transformed mean length and weight values (age groups 2-10, 2-5 and 6-10). The slopes are a direct measure of growth rate.

Survival Rate

Survival rates of smallmouth bass were calculated using two different methods to make comparisons between year classes and between years sampled. Comparisons were limited to bass age 6-12 to avoid biases due to incomplete recruitment of smaller bass to the gear used, and small sample sizes among older fish. Annual survival rates were estimated by taking the antilog of the slopes for linear regressions through natural log transformed mean CPUE values for each year class (Ricker 1975). Survival rates between years sampled were calculated using the ratio of the sum of CPUE for fish ages 7-12 in the second sample year to the sum of CPUE for fish ages 6-11 in the first sample year (Everhart and Youngs 1981). Both methods of estimating survival were affected by yearly variations in catchability. However, the impacts on survival comparisons between years were more evident, both in the amount of variation between years and in the estimation of impossibly high survival rates (greater than 100%). Although these variations in catchability do increase variability in and interpretation of the survival estimates, there is no evidence of a systematic change which would invalidate general trends or multiple averages .

Maturity

Maturity of smallmouth bass was determined by visual inspection of the gonads. Fish were considered to be sexually mature only if they had previously spawned. Since sampling occurred at least one month after spawning, the gonads of mature fish had begun to shrink from the spawning state. Medium sized (8-12") fish often had intermediate sized gonads that could not give a clear indication of previous spawning. Such fish were classified as unknown maturity, and the August gill net samples are therefore not

considered a good source of material to determine the initial age of spawning.

Results

Abundance

Smallmouth bass abundance per standard gang varied in a cyclic pattern over the 22 years sampled with high mean CPUEs in 1979-1980 and 1989-1991, and low mean CPUEs in 1984-1986 and 1995-1997 (Figure 1). The mean CPUE from 1995-1997 (6.0 bass per net gang)

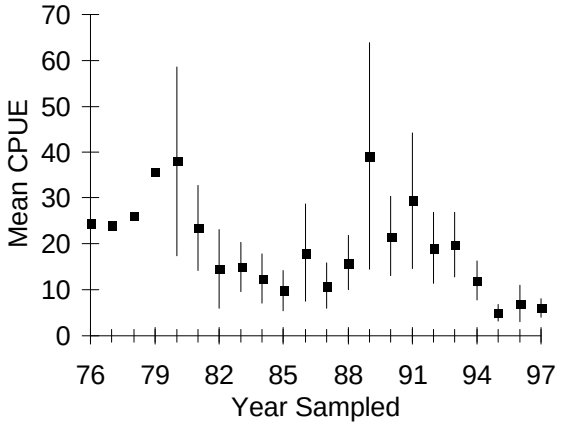

Figure 1. Mean CPUE (with 95% confidence intervals) of smallmouth bass in the eastern basin of Lake Ontario.

was more than 50% lower than the mean CPUE from 1984-1986 (13.5 bass per net gang). This coincides with anecdotal reports that smallmouth bass fishing in the eastern basin was extremely poor throughout the 1997 fishing season. Despite recent increases in water clarity, changes in the smallmouth bass depth distribution were not detected. Relative catches among depth strata 1-3 varied without trend between years and between different size classes throughout the 22 year data series.

Recruitment and Year Class Strength

The mean CPUE of sub-legal, age 2-5 smallmouth bass fluctuated over time with the lowest occurring in 1995 and 1997 (Figure 2). The relative abundance of sub-legal bass from 1988-1993 was high; however, these did not contribute significantly to the fishery in 1994-1997. The proportion of legally harvestable fish in the population declined significantly since 1980 to the lowest percentage in the 22 year data series in 1996 (linear regression, p=.0001, Figure 3).

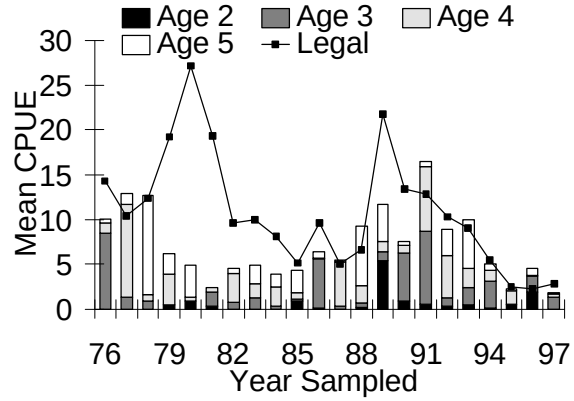

Figure 2. Mean CPUE of sub-legal (age 2-5) and legal smallmouth bass in the eastern basin of Lake Ontario

Length frequency distributions of gill net catches reflected the declining proportion of legal sized smallmouth bass relative to sub-legal bass (Figure A1). From 1976-1992, these distributions were bi-modal or normally distributed. After 1992, the length frequency distribution skewed toward the left each year and by 1996 and 1997 52.9% and 39.6% of all bass sampled were <260 mm, respectively. Most of these smallmouth bass were age 2 (1996, mean CPUE=1.9; 1997, mean CPUE=1.2) and 3 (1996, mean CPUE=1.7; 1997, mean CPUE=1.4).

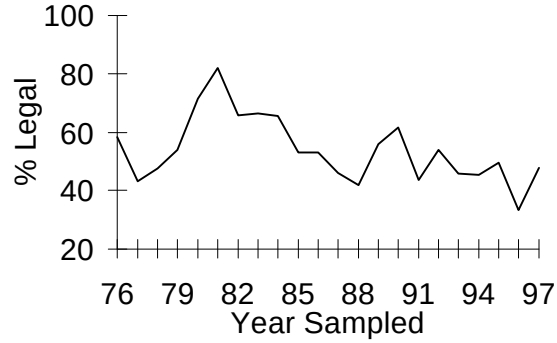

Figure 3. Proportion of legally harvestable smallmouth bass in the eastern basin of Lake Ontario.

The four strongest year classes observed over the 22 year sampling period were from 1973, 1983, 1987, and 1988 (Figure 4, Figure A2). The 1973 year class represented 81% of the legal sized smallmouth bass in 1980 (age 7) (Table 1, Figure 2). The proportion of legally harvestable bass declined until the strong 1983 year class began recruiting into the fishery in 1988 and 1989 (Figure 2, Figure 3). CPUE in 1989 indicated the 2nd highest abundance of legally harvestable fish since 1980 with 58% from the 1983 year class (age 6) (Table 1). In 1990, 61% of the legal smallmouth bass were from the 1983 year class (age 7). The strong 1987 and 1988 year classes began recruiting into the fishery at age 4, and by age 6 only represented 37% and 32% of harvestable fish, respectively. Despite being the 2nd (1988) and 3rd (1987) strongest year classes, recruitment of smallmouth bass into the fishery was poor compared to the strong 1973 and 1983 year classes. By age 8 the mean CPUEs of the 1987 and 1988 year classes were reduced to 0.41 and 0.49, respectively (Figure A3). By 1996 and 1997, sub-legal age 2 and 3 smallmouth bass represented 55 and 50% of the bass sampled, respectively; yet the mean CPUE of all age 2 and 3 smallmouth bass did not exceed 4.0 fish per net gang (Figure 2, Figure A2). The lack of strong year classes in recent years and a low CPUE of all ages of sub-legal bass in 1997 suggest poor recruitment to the fishery for the next 2 or 3 years (Figure 2, Figure 4).

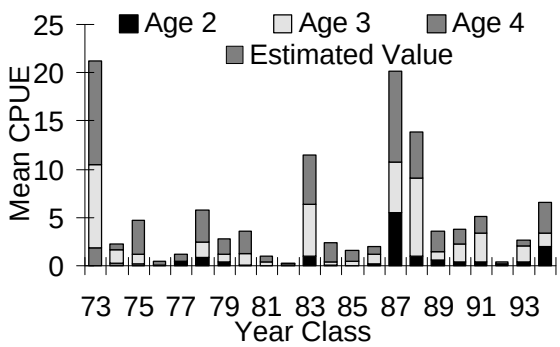

Figure 4. Mean CPUE of age 2-4 smallmouth bass by year class, in the eastern basin of Lake Ontario.

Table 1. Percent contribution to the fishery of the 1973, 1983, 1987, and 1988 year classes by successive ages.

	Year Class			
Age	1973	1983	1987	1988
4	4.7	3.1	16.3	0.8
5	31.1	30.3	31.9	12.5
6	72.0	58.3	37.3	31.9
7	81.0	60.8	31.4	25.5
8	47.9	33.7	16.4	21.2
9	28.8	23.4	8.2	18.9
10	35.2	10.0	5.4	
11	20.2	7.3		
12	18.8	7.3		
13	12.5	3.5		
14	7.0	1.8		

Growth

Mean lengths of smallmouth bass showed annual fluctuations over the 22 year sampling period with some interesting trends in recent years (Figure A4). Age 1 smallmouth bass appear for the first time in 1994, 1995, and 1997 with lengths comparable to the length at age 2 in previous years. Mean lengths of age 2 and age 3 bass were above their 22 year averages each year since 1991 and 1989, respectively. There were no trends in length at age for age 4-6 smallmouth bass, but since approximately 1990, the mean lengths at age for fish ages 7 and older were above 22 year averages (Figure A4). In 1997, 6 of 12 ages had the longest mean length at age in the data series. Mean lengths of male bass were generally longer than female bass of the same age (Figure A5); however, the rate of growth from age 2-10 (as measured by slopes of linear regression) were not significantly different between males and females (Figure 5).

There was no significant trend in growth rates in length for smallmouth bass ages 2-10; however, growth rates in weight for the 1983-1987 year classes were above average (Figure 6). There was a significantly increasing trend (linear regression, p=.0112) in growth rate in weight for age 2-10 smallmouth bass.

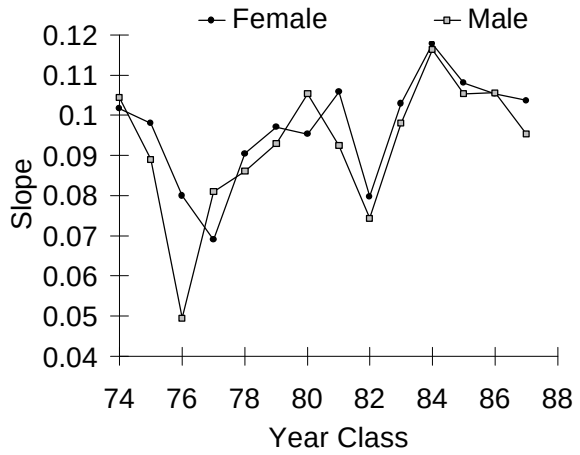

Figure 5. Slopes of linear regressions through natural log transformed length data (age 2-10) for male and female smallmouth bass, 1974-1987 year classes.

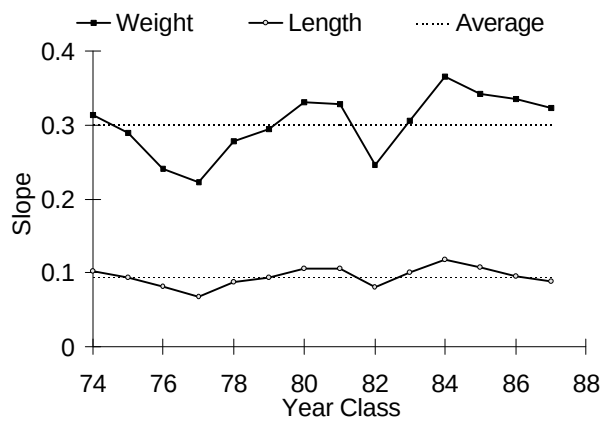

Figure 6. Slopes of linear regressions through natural log transformed weight and length data (age 2-10) for smallmouth bass, 1974-1987 year classes.

Dividing the range of ages into two age groups showed more differences in growth. Younger bass (ages 2-5) had faster growth rates than older bass (ages 6-10) as would be expected, and showed no significant trends in growth rate (Figure 7). In contrast, there was a significantly increasing trend in growth rates in weight and length for bass ages 6-10 (linear regression, weight p=.0002; length p=.0004). Increased growth rates for bass age 6-10 agrees with the observed increases in length at age for bass age 7 and older since 1990 (Figure A4). Increased growth suggests that older smallmouth bass in the eastern basin of Lake Ontario are currently not resource limited, despite declines in lake productivity.

There was no apparent correlation between smallmouth bass abundance and growth (Figure 1, Figure 7). Smallmouth bass growth during periods of low abundance (1978-1981 year class growth during 1982-1988 sample years; and 1988 year class growth during 1994-1997 sample years) was both below and above average. Growth during periods of high abundance (1974-1975 year class growth during 1976-1981 sample years; and 1985-1986 year class growth during 1989-1993 sample years) was near or above average.

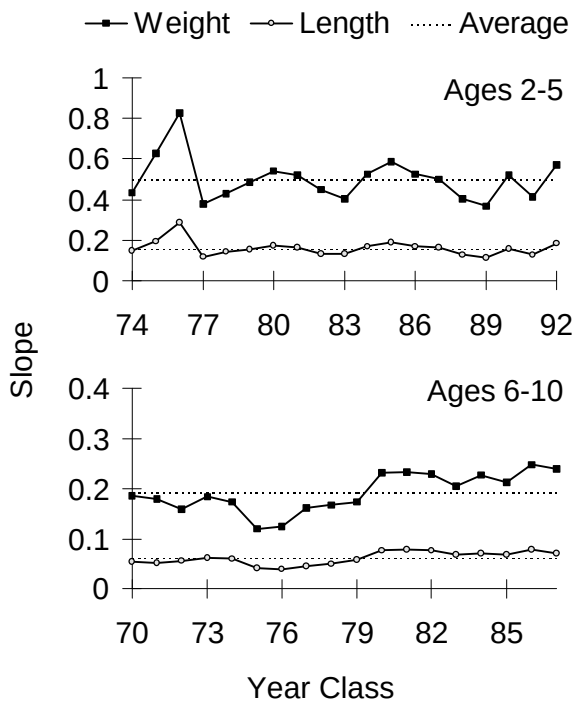

Figure 7. Slopes of linear regressions through natural log transformed weight and length data (ages 2-5 and 6-10) for smallmouth bass, by year class.

Sex Ratio

Smallmouth bass, ages 1-4, were predominately male, with a 22 year average of 53.7% male (Figure A6). As age increased, the proportion of males decreased, with 22 year averages of 43.4% and 40.2% male at ages 5-7 and 8-10, respectively. Most smallmouth bass ages 11 and

older were female for all but two of the years sampled, with a 22 year average of 75.3% female (Figure A6). Stone et al. (1954) also found that females dominated the older age classes with some males that lived just as long as females though in smaller numbers.

Maturity

According to Stone et al. (1954), male and female smallmouth bass typically "begin to reach maturity" at the end of their 4th and 5th years of life, respectively; however, in this study some smallmouth bass were considered mature at age 2 (male) and 3 (females) (Table 2). Since males began maturing younger than females and females dominated the catch of older ages, the calculated mean age of mature females was older than males for all years sampled (Figure 8).

Throughout the 22 year data set, 99.2% of the smallmouth bass were mature by 12" in length with a mean age ranging from 4 to 7 years (Figure 9). Males were 12" in length at a younger age than females for most years sampled. In 1997, the mean age of mature, 12" smallmouth bass was the youngest (4.2) in the 22 year data series (Figure 9).

Table 2. Youngest age of mature male and female smallmouth bass collected in August warm water assessments in the eastern basin of Lake Ontario.

Year Sampled	Age Male	Age Female
1976	3	3
1977	3	3
1978	3	5
1979	4	4
1980	4	3
1981	3	3
1982	3	4
1983	4	5
1984	4	4
1985	4	4
1986	3	4
1987	4	4
1988	4	4
1989	2	4
1990	3	3
1991	3	3
1992	3	4
1993	3	3
1994	3	3
1995	4	4
1996	2	4
1997	3	3

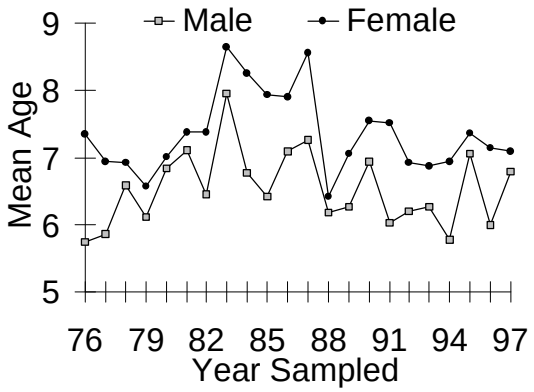

Figure 8. Mean age of mature male and female smallmouth bass in the eastern basin of Lake Ontario.

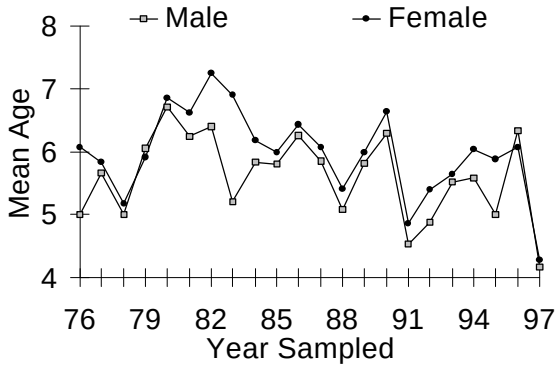

Figure 9. Mean age of 12 inch female and male smallmouth bass in the eastern basin of Lake Ontario.

Survival Rate and Catch Curves

Mean annual survival rate for smallmouth bass from age 6-12 averaged 65.7% for the 1970-1985 year classes, and fluctuated without trend between 41.1 and 90.1% (Figure 10). Survival rates of individual year classes tended to be below average when fish were age 6-12 during periods of low abundance and above average during periods of high abundance.

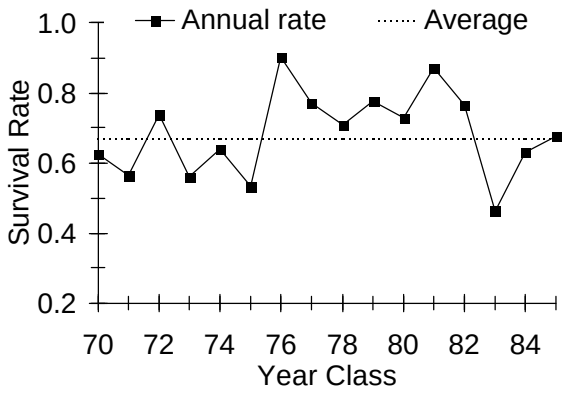

Figure 10. Annual survival rate for age 6-12 smallmouth bass, 1970-1985 year classes.

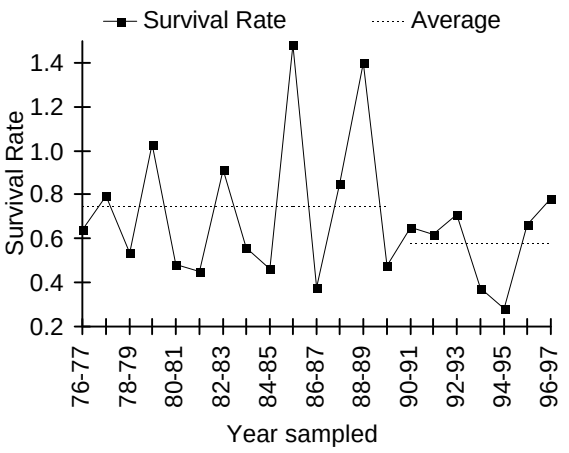

Figure 11. Survival rate between years sampled for age 6-12 smallmouth bass.

Though annual survival rates were not significantly different over time, the modal age and size of the catch curves declined dramatically since the 1985 year class (Figure A3). The modal age of cohort catch curves was 6 or 7 for the 1969-1984 year classes. After the 1984 year class, the mode in CPUE shifted progressively towards younger (age 3) and smaller (8.5") fish.

Survival rates between sample years for age 6-12 smallmouth bass was obviously affected by yearly variations in catchability (Figure 11). Overall, the annual estimates varied about an average of 69.2%. From 1976-1990, annual survival rates showed an alternating high/low pattern with a 14 year average of 74.6%. Since 1991, survival rates were lower and fluctuated less with a 6 year average of only 58.3%.

Discussion

Since the early 1990s, dramatic declines in smallmouth bass abundance have been reported in Ontario waters of the eastern basin of Lake Ontario (Hoyle 1997) and in the St. Lawrence River (LaPan and Klindt 1997, McCullough and Klindt 1997). New York waters in the eastern basin showed a similar trend. Abundance, recruitment, growth, and survival of smallmouth bass populations in the eastern basin of Lake Ontario are dependant on many factors including: water temperature, year class strength, time of spawning, food availability at the various life stages, competition, predation pressure, and fishing mortality. Since the mid- to late 1980s, changes have occurred in the eastern basin that have likely affected these factors in some way (Table 3).

Prior to the mid-1980s, surveys suggested that the fishery was maintaining stable and abundant stocks of smallmouth bass despite variations in year class strength (NY Conservation Department 1941, Panek 1981, Schiavone 1989). This study also showed that there were no significant changes in population parameters for this time period. Gill netting since the mid 1980s, however has indicated changes in abundance, recruitment, growth, cohort catch curves and survival.

In the past, strong year classes supported the smallmouth population for many years after they recruited to the fishery at approximately age 5 (e.g., 1973 and 1983 year classes during the 1980s). Therefore, recruitment of the two strong year classes in 1987 and 1988 should have made a pronounced contribution to the fishery beginning in 1992. Nevertheless, smallmouth bass relative abundances from 1995-97 were at record lows and the proportion of legally harvestable smallmouth bass has declined since 1980. Furthermore, there have been no strong year classes produced since 1988 and the CPUE of all ages of sub-legal bass was low in 1997,

Table 3. Recent ecological changes in the eastern basin of Lake Ontario and potential impacts on smallmouth bass populations.

Recent Change	Potential Impacts
Reduced Productivity in Lake Ontario	Reduced zooplankton production may affect growth and abundance of early lifestage of smallmouth bass.
Dreissenid Mussels	Zebra and quagga mussels redirect energy to the benthos, possibly increasing the benthic food supply (i.e. crayfish). Dreissenid mussels are responsible for increasing water clarity.
Increased Water Clarity	Increased water clarity may make smallmouth bass more vulnerable to predation and/or cause changes in distribution patterns.
Increase in Piscivores	Predation pressure on smallmouth bass will likely increase with higher numbers of double-crested cormorants and walleye.
Decrease in Competitors	Declines in rock bass and yellow perch abundance may reduce competition for food resources.

suggesting poor recruitment into the fishery for the next 2 or 3 years. Increased mean length at age for many ages and above average growth rate from ages 6-10 for recent year classes suggest that eastern basin smallmouth bass are not currently resource limited by reductions in nutrients.

One of the most noticeable changes in the population was the recent shift in both modal age and size groups of each year class toward younger and smaller fish (Figure A3). Smallmouth bass are not fully vulnerable to the standard gill net gangs until age 6. The fact that catch curves for the 1984-94 year classes have all peaked at ages younger than 6 (often age 3 or age 4), suggests that mortality of smallmouth bass ages 3-6 must have increased in recent years compared to earlier years (1969-83 year classes). Elrod et al. (1995) found an analogous, but opposite change in Lake Ontario lake trout. They concluded that the shift in the peak of cohort catch curves to larger, older fish was a result of improved survival of younger fish due to sea lamprey control and changes in harvest regulations. During the same period that mortality of younger bass appears to have increased, survival rates between sample years also suggest some increase in mortality among older bass (ages 6-12).

Increased mortality of smallmouth bass may have resulted from a number of recent changes in the eastern basin of Lake Ontario. Increases in mortality among younger bass may be especially important given the dramatic changes that have occurred in modal age and size of the year classes, and the fact that these younger smaller fish are relatively unaffected by mortality from sport fishing or spawning. Since the mid 1980s, two potential predators of young bass in the eastern basin, walleye and cormorants, have increased in abundance (Ross and Johnson 1997, Eckert 1997). The impact of walleye on bass populations is not known, but since 1992, smallmouth bass represented 0.7 - 2.1% of the cormorant diet items with an average estimated annual consumption of 650,000 smallmouth bass (Ross and Johnson 1997). Schneider et al. (1997) reviewed the potential consequences of this level of predation on the smallmouth bass population, and concluded that cormorants could be a major source of mortality.

To gain a better understanding of recent trends in eastern basin fish populations and the potential causes of these changes, additional surveys have been planned for the 1998 field season. The DEC in cooperation with USGS-BRD will conduct a more comprehensive assessment of cormorant diets. Cormorant pellets will be collected in 1998 from mid May through

September and examined to determine cormorant diets throughout the breeding and post-breeding periods and to provide more accurate estimates of annual consumption. In addition to pellet analysis, the DEC will analyze cormorant stomach samples from approximately 300 birds to determine the size and age structure of smallmouth bass consumed. Smallmouth bass otoliths from cormorant pellets collected in previous years will also be reexamined to determine the age of bass consumed. Additionally, the DEC will examine walleye stomachs and diet data available from the Province of Ontario waters in the eastern basin of Lake Ontario to document the importance of smallmouth bass in walleye diets. Finally, a creel census of the eastern basin of Lake Ontario will be conducted in 1998 to document fishing quality (i.e. harvest and catch rates) and the total number of smallmouth bass harvested by anglers.

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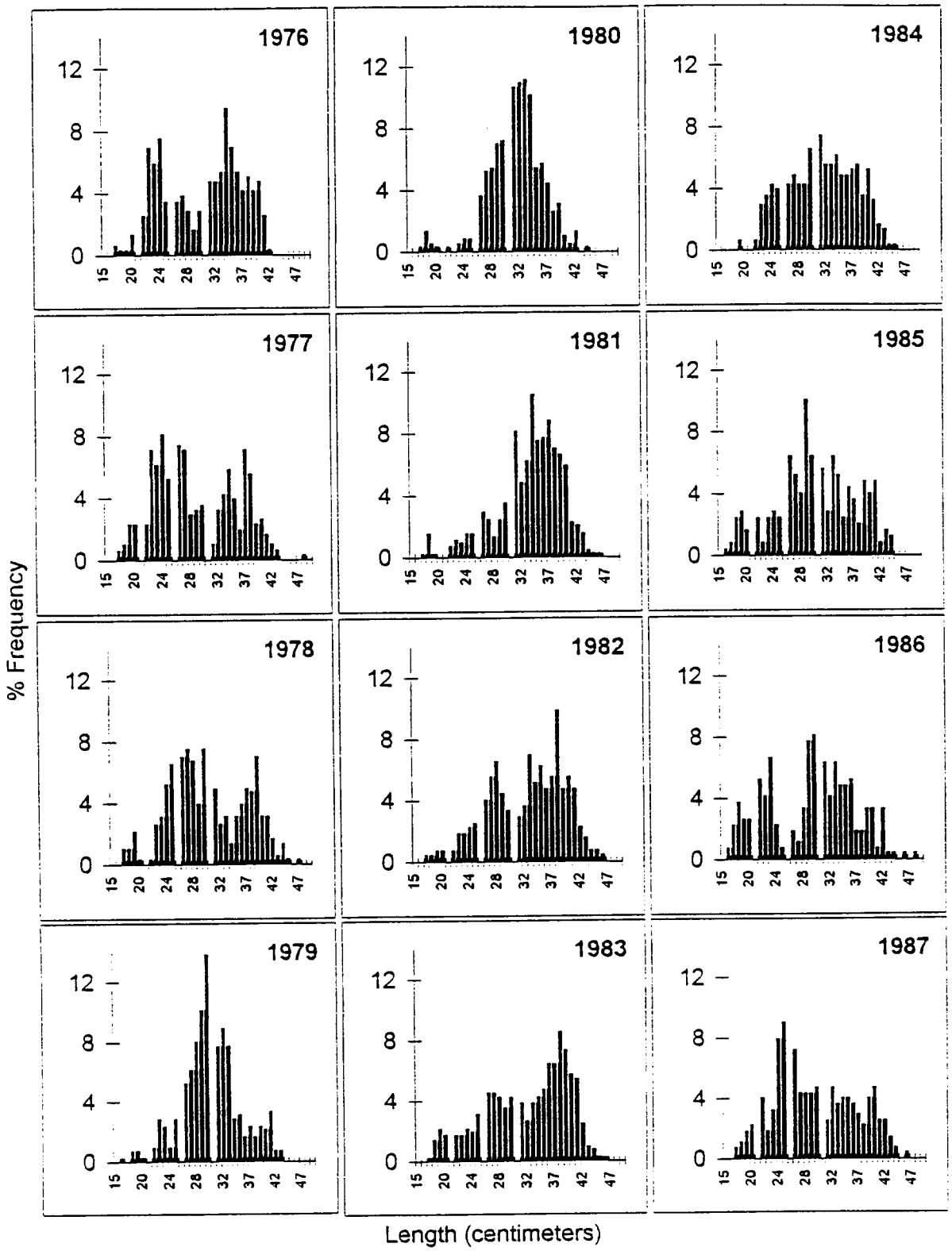

Figure A1. Length frequency distributions of smallmouth bass collected in August warm water assessments in the eastern basin of Lake Ontario, 1976-1997 sample years.

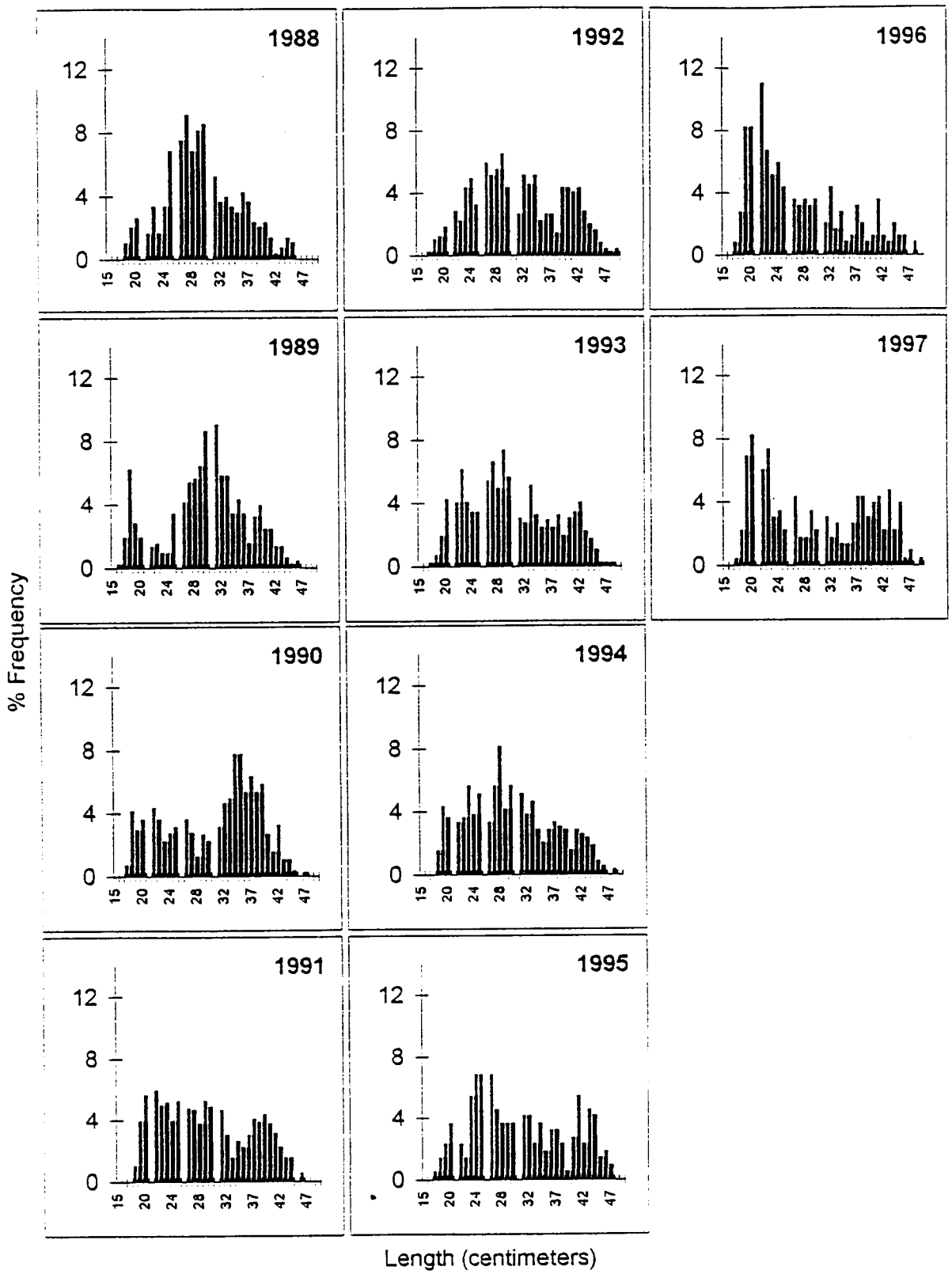

Figure A1 (con't). Length frequency distributions of smallmouth bass collected in August warm water assessments in the eastern basin of Lake Ontario,. 1976-1997 sample years.

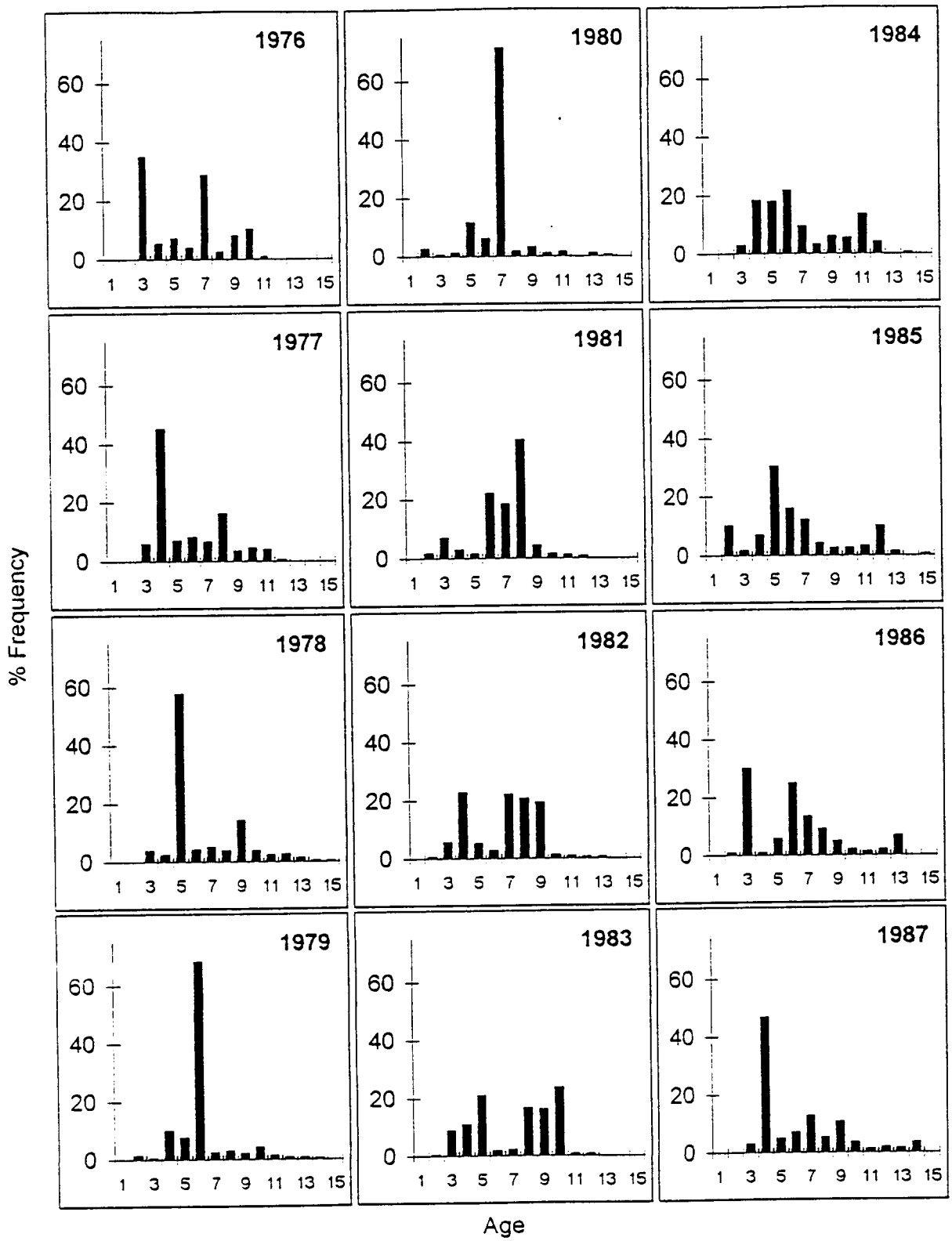

Figure A2. Age frequency distributions of smallmouth bass collected in August warm water assessments in the eastern basin of Lake Ontario, 1976-1997 sample years.

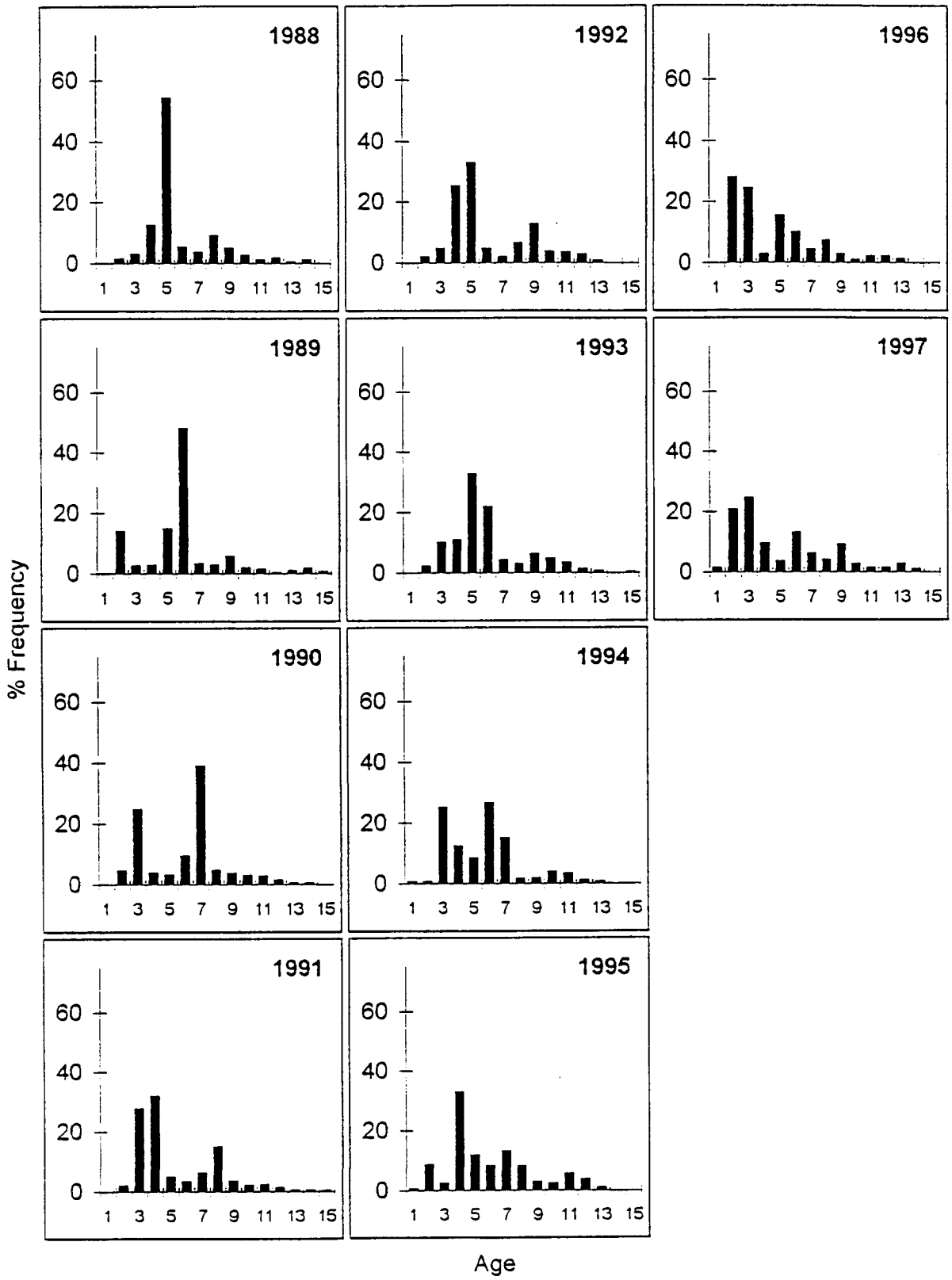

Figure A2 (con't). Age frequency distributions of smallmouth bass collected in August warm water assessments in the eastern basin of Lake Ontario, 1976-1997 sample years.

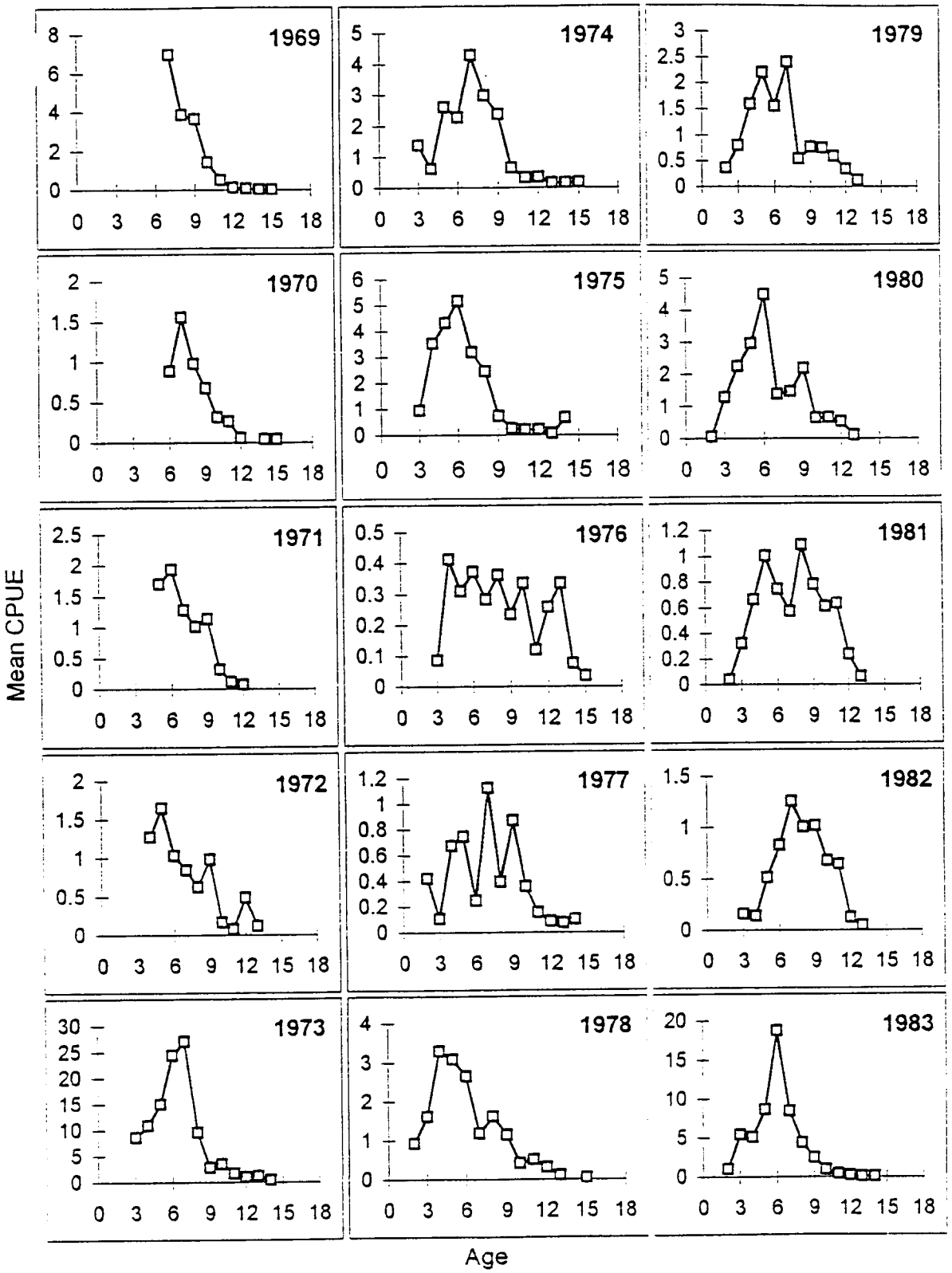

Figure A3. Catch curves of smallmouth bass as determined by mean CPUE at successive ages , 1969-1994 year classes.

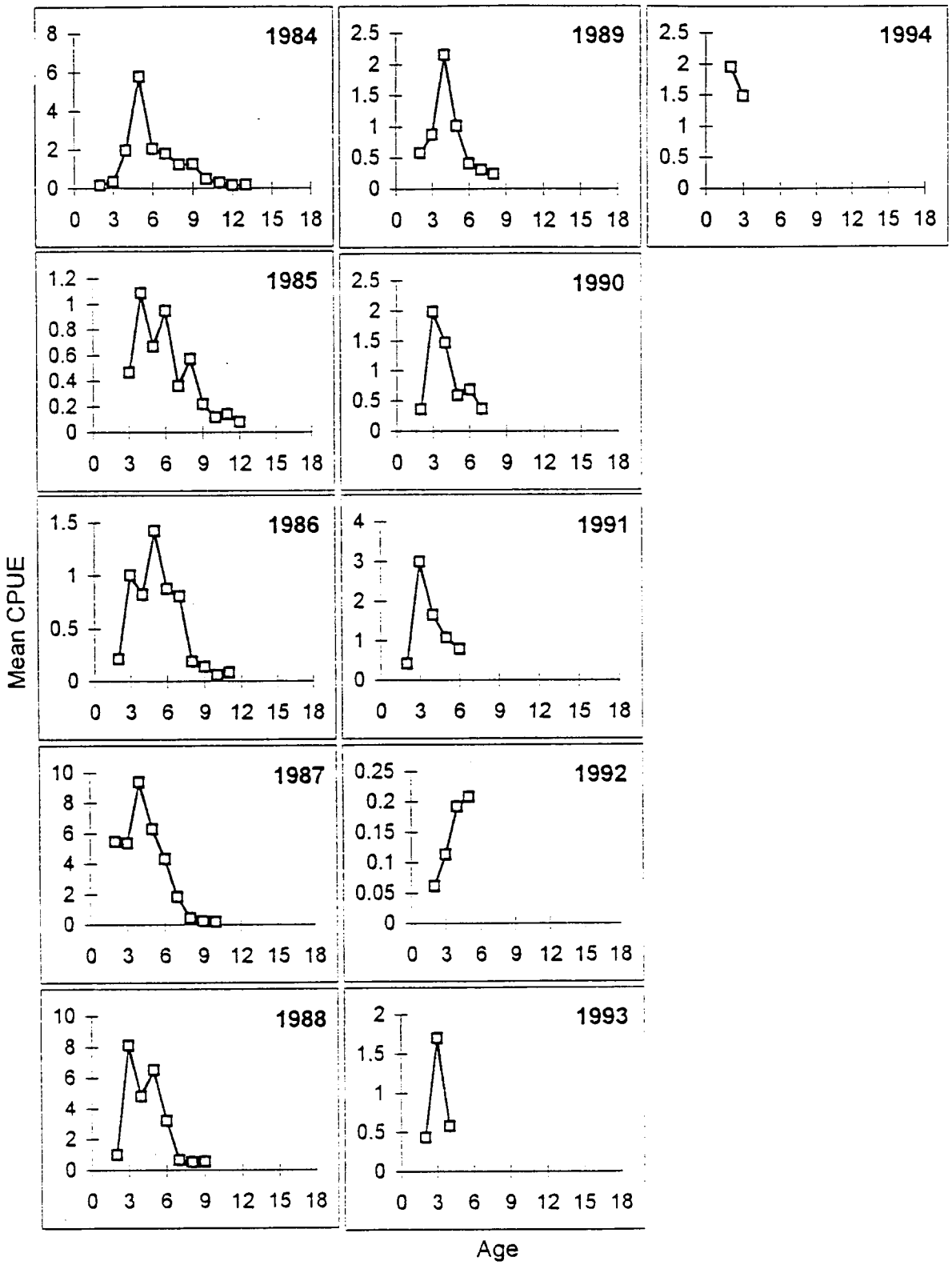

Figure A3 (con't). Catch curves of smallmouth bass as determined by mean CPUE at successive ages , 1969-1994 year classes.

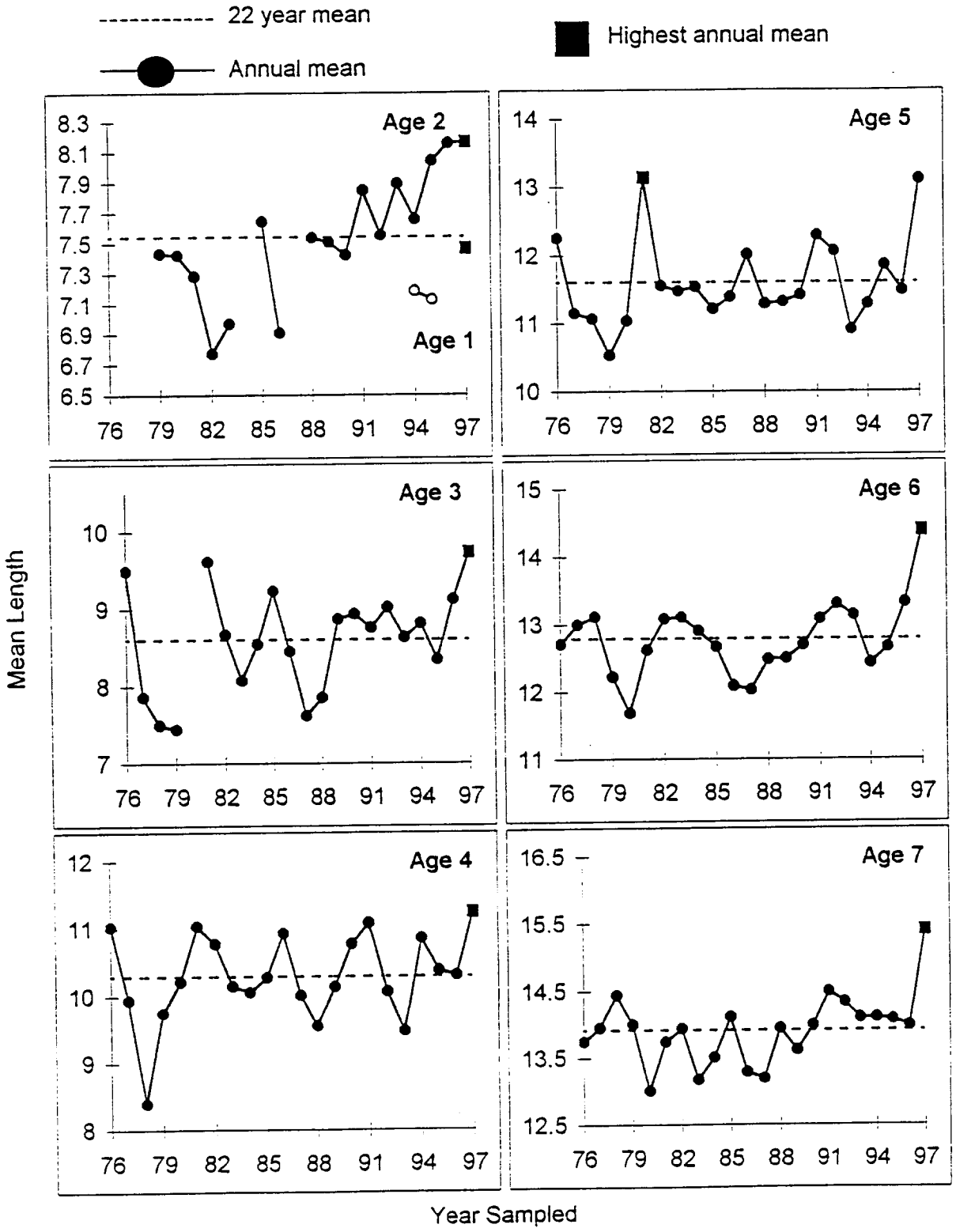

Figure A4. Mean Length at age (age 1-13) by year sampled (1976-1997) for smallmouth bass collected in August warm water assessments in the eastern basin of Lake Ontario.

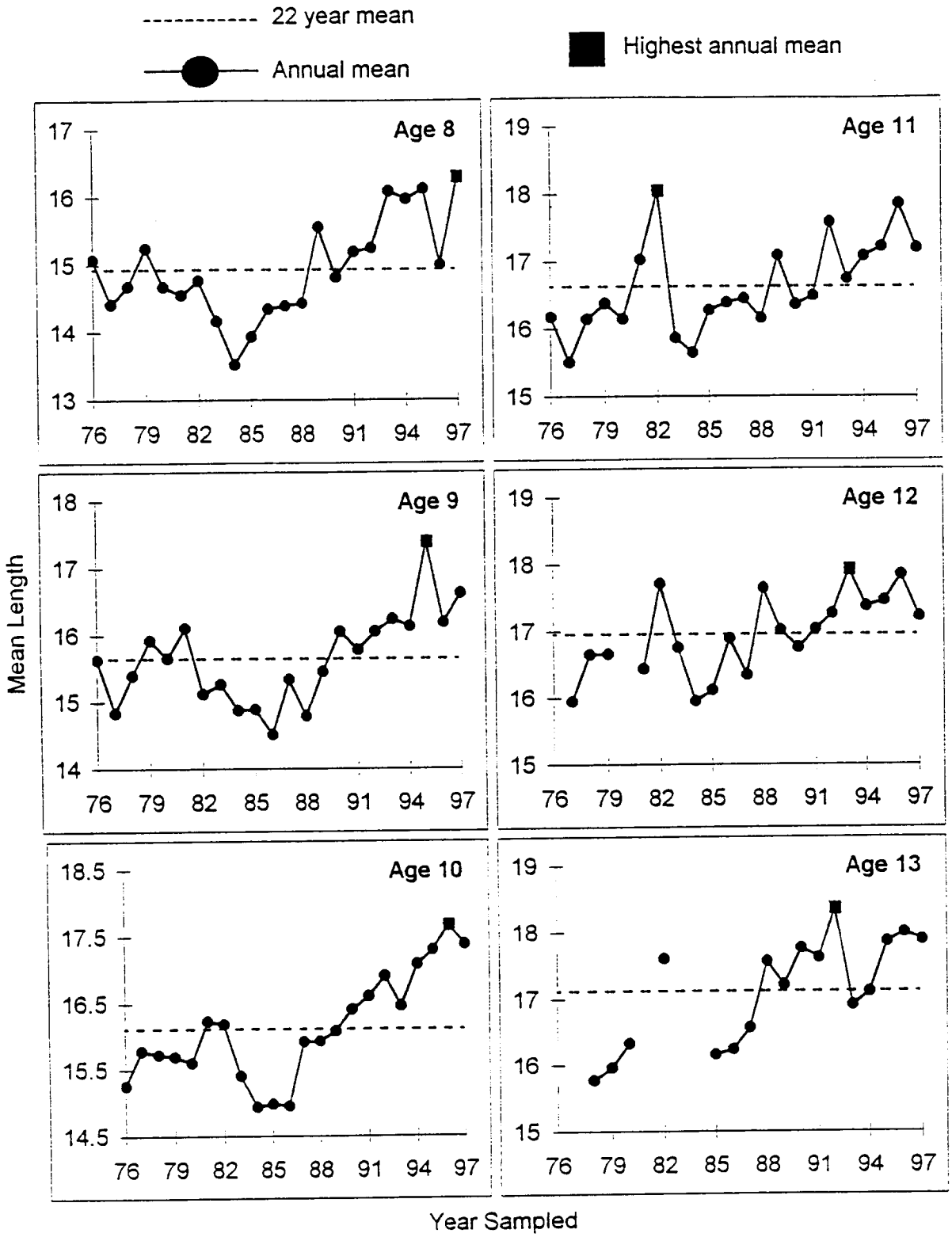

Figure A4 (con't). Mean Length at age (age 1-13) by year sampled (1976-1997) for smallmouth bass collected in August warm water assessments in the eastern basin of Lake Ontario.

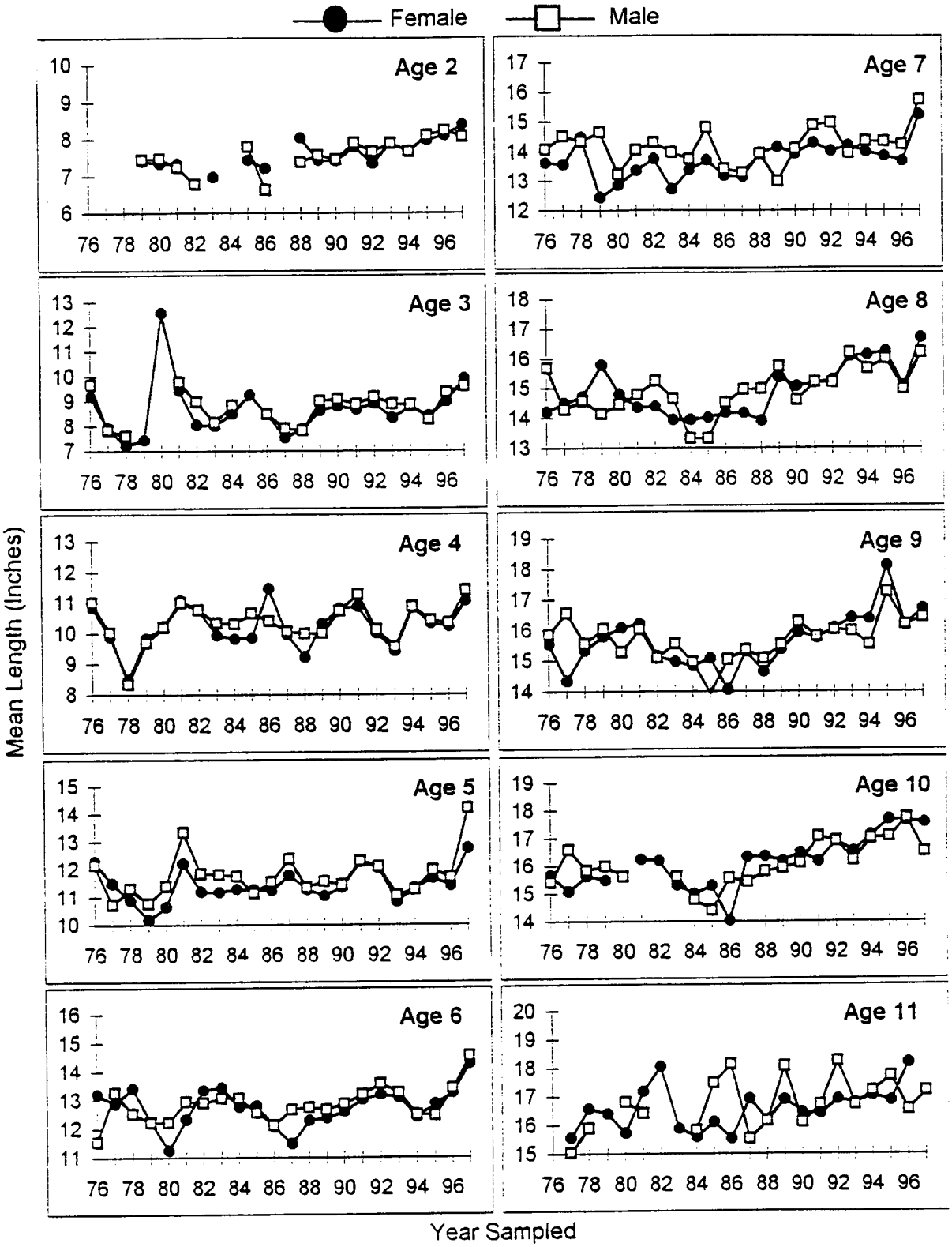

Figure A5. Mean length at age (age 2-11) by year sampled (1976-1997) for female and male smallmouth bass collected in August warm water assessments in the eastern basin of Lake Ontario.

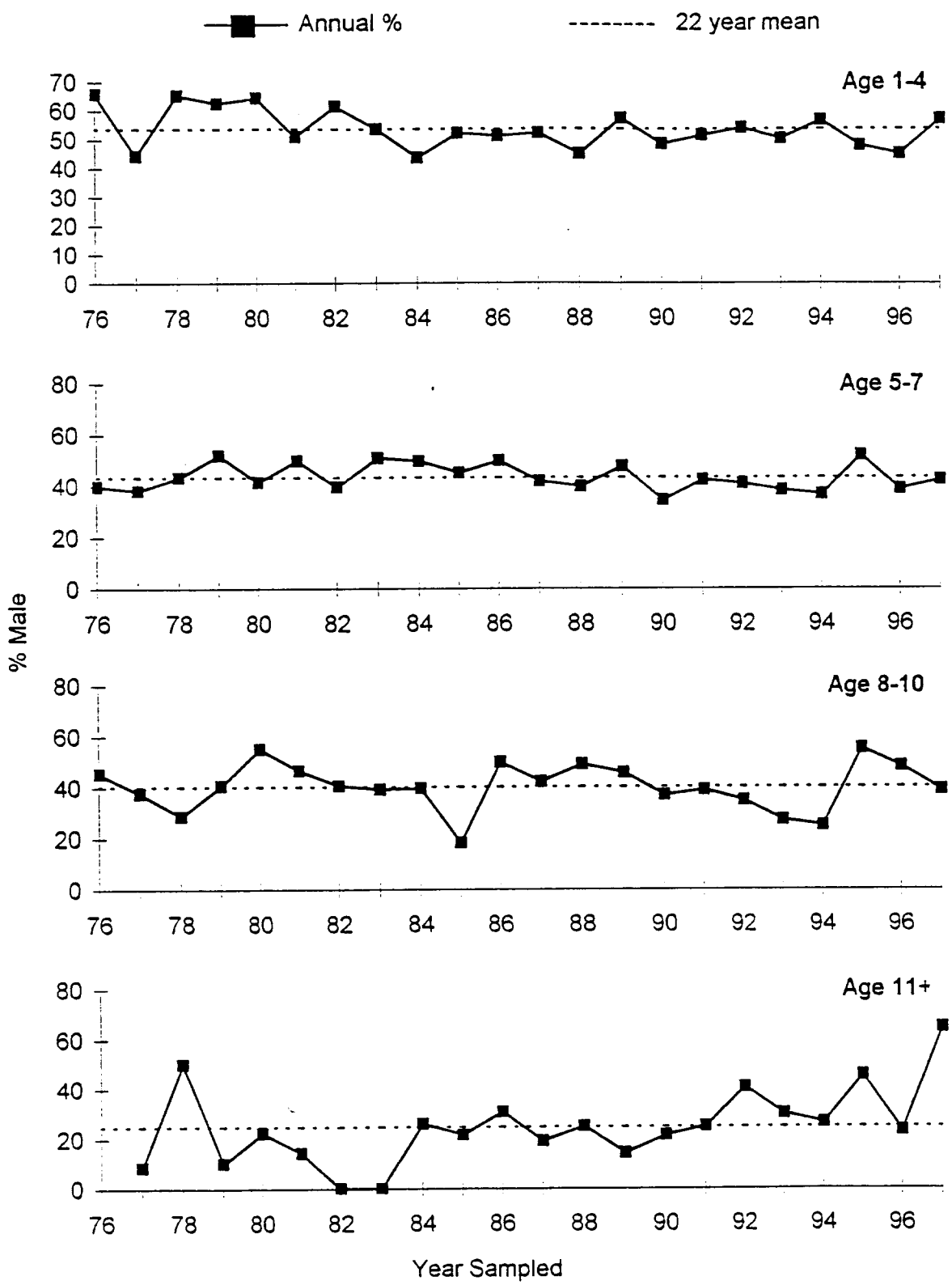

Figure A6. Proportion of male smallmouth bass (age 1-4, age 5-7, age 8-10, and ages 11+) collected in August warm water assessments in the eastern basin of Lake Ontario.