Recruitment, Growth, and Condition of a Population of White Sucker, *Catostomus commersoni*, in Lake 223, Experimental Lakes Area, Northwestern Ontario, During the Recovery Phase of an Acidification Experiment

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ABSTRACT

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A population of white sucker, *Catostomus commersoni*, in Lake 223, in the Experimental Lakes Area, northwestern Ontario, was studied from 1984 to 1995 to monitor the responses of the fish during the recovery phase of an acidification experiment. Recruitment resumed during 1984 when the pH of the lake was 5.44 and has occurred in all subsequent years, with the exception of 1985. Growth of fish of all ages was less during pH recovery than during acidification. Growth of fish older than six years was very minimal during pH recovery and some individuals actually decreased in both length and weight. Condition factors of the white sucker in Lake 223 declined dramatically in fall, 1984, and have remained at lower values than at any time since the population was first monitored prior to acidification in 1975.

Key words: *Catostomus commersoni*; white sucker; Experimental Lakes Area; ELA; growth; Lake 223; pH; sulphuric acid; fin-ray; fork length.

RÉSUMÉ

Chalanchuk, S.M. 1997. Recruitment, growth, and condition of a population of white sucker, *Catostomus commersoni*, in Lake 223, Experimental Lakes Area, northwestern Ontario, during the recovery phase of an acidification experiment. Can. Tech. Rep. Fish. Aquat. Sci. 2140: iv + 27 p.

De 1984 à 1995, le chercheur a étudié une population de meunier noir (*Catostomus commersoni*) dans le lac 223 de la Région des Lacs Expérimentaux (nord-ouest de l'Ontario) afin de déterminer les réponses des poissons durant la phase de rétablissement d'une expérience d'acidification. Le recrutement a repris en 1984, alors que le pH s'établissait à 5,44, et s'est poursuivi au cours de toutes les années subséquentes, à l'exception de 1985. La croissance des poissons de tous âges a été plus faible durant la phase de rétablissement du pH que durant l'acidification. Celle de poissons âgés de plus de six ans a été extrêmement faible durant la phase de rétablissement du pH, certains individus accusant même une diminution de taille (longueur) et de poids. Le coefficient de condition des meuniers noirs du lac 223 a chuté considérablement au cours de l'automne 1984 et est demeuré sous les valeurs enregistrées entre le début de l'étude et l'acidification en 1975.

Mots clés : *Catostomus commersoni*; meunier noir; Région des Lacs Expérimentaux; RLE; croissance; lac 223; pH; acide sulphurique; rayon de nageoire; longueur à la fourche.

INTRODUCTION

The purpose of this study was to examine recruitment, growth, and condition of a population of white sucker, *Catostomus commersoni*, in Lake 223, in the Experimental Lakes Area, northwestern Ontario, during the recovery phase of the lake following experimental acidification.

The phenomenon of acid precipitation and its effects on fishes is well-documented in the scientific literature (Fromm 1980; Haines 1981; Rosseland 1986; Kelso et al. 1990; Sayer et al. 1993). Changes in legislation in Canada and the United States reducing sulphur dioxide emissions to the atmosphere have provided a chance for recovery of ecosystems from acidification. Partial recovery of the chemical regime of some lakes that had been acidified by atmospheric emissions has already occurred (Hutchinson and Havas 1986; Dillon et. al 1986). Some recovery of biological systems has also occurred (Beggs and Gunn 1986; Kelso and Jeffries 1988). The initiation of a recovery phase in the experimental acidification of Lake 223 provided an opportunity to monitor the responses of the white sucker population to decreasing levels of acidity and to determine the rate and extent of any recovery to pre-acidification levels of recruitment, growth, and condition of these fish. During the acidification phase of the experiment, from 1976 to 1983, recruitment failures occurred at lowest pH values, growth of fish aged two to six increased, and condition factors initially increased, then decreased to lower values than previously observed for white sucker in Lake 223 (Chalanchuk 1985). In addition, abundances of white sucker increased dramatically during lake acidification before declining at pHs of 5.0 (Mills et al. 1987).

The white sucker is one of the most widespread and abundant species of fish in North America (Scott and Crossman 1973). It is very common in lakes in the Precambrian shield and is almost ubiquitous in ELA lakes. It is an integral part of a lake ecosystem, foraging on benthic organisms and serving as a food source for predator species such as lake trout, *Salvelinus namaycush*, and northern pike, *Esox lucius*.

In this report I discuss changes in the recruitment, growth, and condition (k) of the white sucker in Lake 223 during ten years of recovery of the lake from experimental acidification.

MATERIALS AND METHODS

Lake 223 is a small (area = 27.3 ha, mean depth = 7.2 m) lake in the Experimental Lakes Area, northwestern Ontario, that has undergone experimental acidification since 1976. Information on the background chemistry, acidification, and initial results can be found in Schindler (1980), Schindler and Turner (1982), Mills (1984), Schindler et al. (1985), and Mills et al. (1987). The epilimnetic pH of Lake 223 was lowered from the background value of 6.5-6.7 (in 1976) by 0.25 pH units per year until 1981. From 1981 to 1983, the pH was held at 5.02-5.13. In 1984, the recovery phase of the experiment began as pH was allowed to increase in a stepwise manner. Values of pH in 1984-1987 ranged from 5.42-5.53, in 1988-

1990 from 5.81-5.84 and in 1991-1993 from 6.11-6.20. By 1994, the pH had increased to 6.67 (D.R. Cruikshank, Fisheries and Oceans, pers. comm.). More information about the acidification regime can be found in Cruikshank (1984,1986,1991,and1994.)

White suckers were captured during spring (late April to mid-June) and fall (early September to mid-October) each year from 1984 to 1995. Fish were captured by modified versions of the Beamish-style trap net (Beamish 1972) during spring and fall and by small-mesh multifilament gill nets (bar mesh 25-45 mm) during fall.

All fish were anaesthetized with tricaine methane sulphonate (MS-222®), sampled, and released. Each fish was weighed (to nearest g), measured for fork length (to nearest mm), and marked by scarring of dorsal fin rays (Welch and Mills 1981). Fish greater than 390 mm were also tagged with individually-numbered modified spaghetti tags (White and Beamish 1972). Two or three rays of a pectoral (for fish captured for the first time) or pelvic (for fish previously captured) fin were removed from most fish for age determinations.

Fin rays were air-dried, set in epoxy, sectioned with a Buehler® (Isomet™) low-speed saw, mounted on microscope slides with Accumount®, and aged using a compound microscope equipped with a viewing screen. Further details about the aging methods used are found in Chalanchuk (1984, 1985). Ages of older fish (aged seven or more) in this study were extremely difficult to determine due to the lack of growth and even decreases in fork length of individual fish, as discussed later in this report. Separations between annuli at the edge of the fin-ray sections of older fish were often not distinguishable. Occasionally, ages of older fish were estimated from mark-recapture histories or inferred from previous ages (for tagged fish).

Length-frequency histograms were constructed on a seasonal basis. Recruitment of young-of-the-year fish into the population each year is shown by following the progression of modes in the histograms for fall to the histograms of the next two or three seasons.

Growth of white sucker was determined by plotting fork lengths at age for fish caught during spring sampling. Trends in growth were based on comparisons of growth curves for a four or five year period. One representative growth curve was chosen for each multiple-year period for comparison to other periods.

Condition factors were calculated using Fulton's condition factor (Bagenal and Tesch 1978) : $k = 100\ w / l^3$ where w is observed weight and l is observed length. Condition factors were determined for ten fork-length groups on a seasonal basis. An overall mean for each season was also calculated. A one-way analysis of variance (Steel and Torrie 1960) was used to test for significant differences among annual means for spring sampling periods. Spring sampling periods were used because of larger sample sizes and smaller confidence limits (Chalanchuk 1985) than for fall sampling periods. Comparison of individual pairs of means was done using a Tukey test (Steel and Torrie 1960).

RESULTS AND DISCUSSION

The importance of recruitment failures in the loss of fish populations has been well-documented (Jensen and Snekvik 1972; Scofield 1976; Trojnar 1977). However, there is little documentation of resumption of recruitment in a population after pH has increased above thresholds when recruitment failure occurred. In Lake 223, recruitment failures occurred when pH values declined to 5.02-5.13 (Chalanchuk 1985; Mills et al. 1987). In 1984, when pH increased to 5.44, recruitment of young-of-the-year suckers resumed as shown by a mode at fork lengths of 85-120 mm in the fall 1984 histogram (Fig. 1a). However, the following year, a year class failure occurred despite the higher pH (Fig. 1b); the mode in the length frequency distribution at 125-175 mm represented age one fish. Since 1986, recruitment has occurred every year although year-class strength has fluctuated widely (Fig. 1b-1h). Strong year classes occurred in 1988 and 1993 with very strong year classes in 1992 and 1994. Weak year classes occurred in 1987,1989,1990,and1991.

The recruitment failures during the acidification phase and weak recruitment during the recovery phase of the experiment may have been due to physiological stress on adult fish. Very few fish with fork lengths greater than 390 mm were caught in the population after 1984 which suggests that substantial mortality of older individuals occurred. From 1976 to 1983, fish with fork lengths greater than 390 mm comprised 2-20% of the total seasonal catches. The percentage of catch made up by this size group declined to 1-3% from 1984 to 1987 and then dropped to 0.1- 1% in ensuing years. Beamish et al. (1975) found that white suckers in acidic Lake George failed to spawn. Trippel and Harvey (1987) found that mortality rates for white suckers in acid lakes increased at sexual maturity. In Lake 223, fish continued to congregate on the spawning beds every spring. However, many of the larger fish were extremely emaciated and no milt or eggs could be expressed from them. It is probable that available energy reserves were devoted to maintenance of life rather than to somatic and gonadal development. Smaller fish (200-300 mm) appeared to be in better physical condition and gonadal products could be expressed from these fish during the spawning season. However, because fecundity of smaller fish is less than that of larger fish (Bagenal 1966), the absence of larger spawners may have had a significant impact on recruitment success. The extent of egg or larval mortality in Lake 223 is not known but may also have contributed to recruitment failures.

Growth of all ages of white suckers in Lake 223 declined during the recovery phase of the acidification experiment (Fig. 2). By 1992, growth was lower than during any other year in the study. Fish aged less than six years were the fastest growing age groups during acidification (Chalanchuk 1985) and also throughout 1984-1995 (Fig. 3a-d). However, fish in these age groups grew much more slowly during recovery relative to growth of fish in these age groups during acidification (Table 1). During 1981-1983, when pH was at lowest values in the experiment, fish aged one and two were approximately 100 and 180 mm, respectively, during spring sampling. By 1991-1993, at increased pH values of 6.11-6.20, fish aged one and two were approximately 80 and 115 mm, respectively. Growth declined even further and by 1995, fish aged one and two, at 55 and 100 mm, were approximately one-half the length of same aged fish during the acidification phase of the experiment. Fish aged four years showed similar trends, but smaller declines in growth. White sucker abundances increased as much as two to three times from 1985 to 1989 (K.H. Mills, Winnipeg, Manitoba, pers. comm.) which may have adversely affected growth. However, despite substantial declines in abundances again from 1990 to 1994, growth of young white suckers continued to decline. Density-dependant factors were probably not the major influence on growth. Numbers of chironomids, a main food source for white suckers in Lake 223, were at lowest levels in 1985 and 1986, increased by 1988, and then fluctuated from 1989 until 1995 (I. J. Davies, Winnipeg, Manitoba, pers. comm.). Although chironomid numbers were at levels slightly lower than pre-acidification levels, they were much higher than during 1981 to 1984 when growth was highest. The changes in growth of young white suckers that occurred can not therefore be solely explained by changes in food supply.

The decline in growth was less pronounced for fish aged six to eight. This is approximately the age at which most of the white sucker in Lake 223 were sexually mature during acidification. During 1980-1983, when suckers in Lake 223 were growing most rapidly, plateaus in growth occurred at approximately four years of age (Fig. 4) which correlated well with onset of sexual maturity (Chalanchuk 1985). By 1990-1995, growth plateaued at approximately seven to nine years of age. Weatherley and Gill (1987) also found a correlation between decreased growth and delayed maturity. They contend that onset of first maturity is related more to size than age of fish. Therefore, slower growth would result in fish attaining a "threshold" size for onset of maturity at a later age than for fast growingfish.

Fish older than eight years essentially ceased growing during the pH recovery phase. Losses of both weight and length occurred for older fish. Mark-recapture data for individually tagged fish indicate that this was not uncommon. Some fish decreased as much as 250 g in weight and 5-10 mm in length (Table 2). Hamilton and Haines (1989) found that bones of white sucker from low pH lakes were weaker and more flexible than those from fish in a higher pH lake. They suggested that occurrences of skeletal deformities in some fish from low pH lakes could have been caused by demineralization of the skeleton to maintain calcium balances for osmoregulation and reproductive needs. It is possible that this compensatory mechanism is responsible for the decreases in length that occurred in white suckers in Lake 223. This negative growth resulted in no discernible annuli being laid down on the fin rays and consequently, errors in aging. Because of this problem of missing annuli on fin-ray sections from older fish, ages used in growth curves for tagged fish were often inferred from previous ages assigned at initial tagging of the fish. For untagged older fish, ages were estimated from the fin scarring histories of the fish and a minimum age assigned based on these data. Because growth of white suckers plateaus at sexual maturity, the general interpretation of growth curves for the population is not greatly affected by these aging errors of older large fish. Although fork lengths at age for older fish are more variable due to difficulties in age determinations and small sample sizes, a decline in growth of older, larger fish from 1984 until 1995 was discernible (Fig. 5). Fish older than eight years were in general 25-50 mm shorter in 1991 than similar aged fish at the end of the acidification phase of the experiment. After 1992, growth of older fish began to increase slightly again.

Condition factors of white sucker in Lake 223 declined substantially during the recovery phase of the experiment (Fig. 6). Differences among annual means were statistically significant based on one-way analysis of variance results ($F = 144.398$, $p < 0.001$). During the acidification phase of the experiment, condition factors initially increased and then decreased (Chalanchuk 1985). The lowest condition factors (1.24 in 1983) occurred during the acidification phase of the experiment at the lowest pH values from 1981-1983. Condition factors increased slightly in 1984 and 1985 (1.28-1.30), then dropped to a low value of 1.12 in spring 1987. From 1988 to 1995, condition factors fluctuated from 1.12-1.19, but have remained at lower values than at any other time in the experiment. A Tukey test confirmed that mean condition factors prior to 1985 were significantly different from those after 1990 with $p < 0.05$. Changes in condition factors may have responded to changes in population sizes, but only slightly. For example, population abundances increased from 1985 to 1990 (K.H. Mills, Winnipeg, Manitoba, pers. comm.); condition factors decreased from 1984 to 1987. As abundances decreased from 1991 to 1995, condition factors increased slightly from 1991 to 1993. However, fluctuations in both condition factors and population sizes were not always synchronized and occasionally increases or decreases in both parameters occurred simultaneously and not inversely.

Decreases in condition factor occurred for all fork-length groups (Table 3), but greatest declines in condition factor occurred for the smallest and largest fish. Condition factors for fish with fork lengths less than 100 mm and fish with fork lengths greater than 301 mm declined 0.20-0.38 units. As discussed previously, many older fish appeared emaciated. Lowest condition factors for fish in these age groups occurred in 1990. Since then, there is some indication that condition of fish in these fork-length groups may be increasing again. Condition factors for fish with fork lengths 101-300 mm declined only 0.02-0.15 units. Visually, there was no great change in these groups of fish throughout the experiment. Condition factors for "middle-sized" fish remained relatively stable both during acidification and recovery. Differences between highest and lowest condition factors were usually < 0.20 units.

As the pH of lake 223 increases to values approaching pre-acidification values, recovery of the population of white suckers is occurring very slowly. The resumption of recruitment of young-of-the-year fish into the population is the most obvious sign that at least partial recovery is occurring. Another promising sign is that individual fish (e.g. tag

#'s 1135 and 1146) that survived the lowest pH values have begun to recover, increasing in both length and weight after having shown significant declines in both during the early years of the recovery study. However, growth of white suckers in Lake 223 is slower than at any other time in the study and is continuing to decline for most ages of fish. Condition factors of the fish are also at lower values than at any other time in the study and show no sign of increasing. No single ecological component has been found to influence the changes in the white sucker population during the recovery phase of the Lake 223 acidification experiment. Food supply, population densities, and the chemical regime of the lake (not necessarily just pH) are still changing with time and the combined interactions of these factors will determine the length of time necessary for the white sucker population to completely recover to preacidification values.

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Table 1. Fork lengths at age for select ages of Lake 223 white suckers from 1976 until 1995.

YEAR	AGE			
	1	2	3	4
1976		204	253	321
1977	134	186	254	364
1978	87	196	246	376
1979	94	220	305	
1980	97	203	372	430
1981	99	184	387	410
1982		178	341	364
1983		171	295	398
1984			293	379
1985	120		319	447
1986		144		368
1987	110	137		375
1988	90	169	227	355
1989	87	156		345
1990	65	126	221	358
1991	74	119	197	283
1992	85	108	181	297
1993	84	115	167	318
1994	67	107	167	298
1995	54	97	170	348

Table 2. Mark-recapture histories for some individually tagged white suckers.

TAG NO.	DATE	FL(MM)	WT(G)	AGE
1146	5/08/85	372	678	6
	5/05/86	370	605	7
	9/28/89	367	548	10
	5/14/91	365	415	12
	10/09/92	368	514	13
	10/09/93	382	689	14
1135	5/03/85	376	691	6
	5/12/86	371	571	7
	9/11/90	368	535	11
	10/05/92	376	582	13
748	5/18/81	385	811	4
	9/21/89	387	563	12
1090	9/28/84	377	712	7
	10/13/86	374	505	9
	5/10/88	374	540	11
1151	5/10/85	372	685	
	5/12/86	372	596	
	5/08/87	372	529	
1020	5/30/83	378	697	5
	5/22/86	376	550	8
1145	5/08/85	410	834	6
	5/07/86	410	811	7
	5/08/87	406	715	8
	9/22/88	406	717	9
	10/06/93	412	755	14
1136	5/03/85	378	722	6
	5/28/86	373	581	7
	5/18/89	375	602	10
1357	05/08/91	402	846	10
	10/04/91	415	850	10
	09/11/92	419	922	11
	05/18/93	420	910	12
	09/20/94	438	1155	13

Table 3. Mean condition factors and 95% confidence limits at annual spring intervals from 1984 until 1995 for ten fork length groups.

FL-GRP	YEAR											
(MM)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1-50									1.19		0.90	0.85
51-100		1.06	1.26	0.97	0.92	0.84	0.71	0.62	0.89	1.11	1.01	0.95
101-150		1.25	1.19	1.12	1.21	1.09	1.24	1.16	1.18	1.19	1.10	1.09
151-200			1.15	1.16	1.21	1.23	1.27	1.17	1.21	1.20	1.14	1.13
201-250	1.21		1.10	1.17	1.19	1.20	1.15	1.16	1.16	1.15	1.19	1.20
251-300	1.31	1.32	1.19		1.18	1.19	1.14	1.15	1.16	1.18	1.26	1.24
301-350	1.30	1.28	1.17	1.08	1.12	1.11	1.02	0.99	1.07	1.17	1.26	1.30
351-400	1.32	1.27	1.15	1.05	1.10	1.12	1.01	0.99	1.05	1.07	1.17	1.31
401-450	1.25	1.24	1.13	1.06	1.08	1.09		1.30	1.28	1.23	1.23	1.34
451-500	1.02		1.46	1.23								
Mean	1.30	1.28	1.17	1.12	1.19	1.19	1.12	1.13	1.16	1.16	1.14	1.15
+95%	1.31	1.29	1.18	1.14	1.20	1.22	1.14	1.14	1.17	1.17	1.18	1.16
-95%	1.29	1.27	1.16	1.10	1.18	1.16	1.10	1.12	1.15	1.15	1.10	1.14

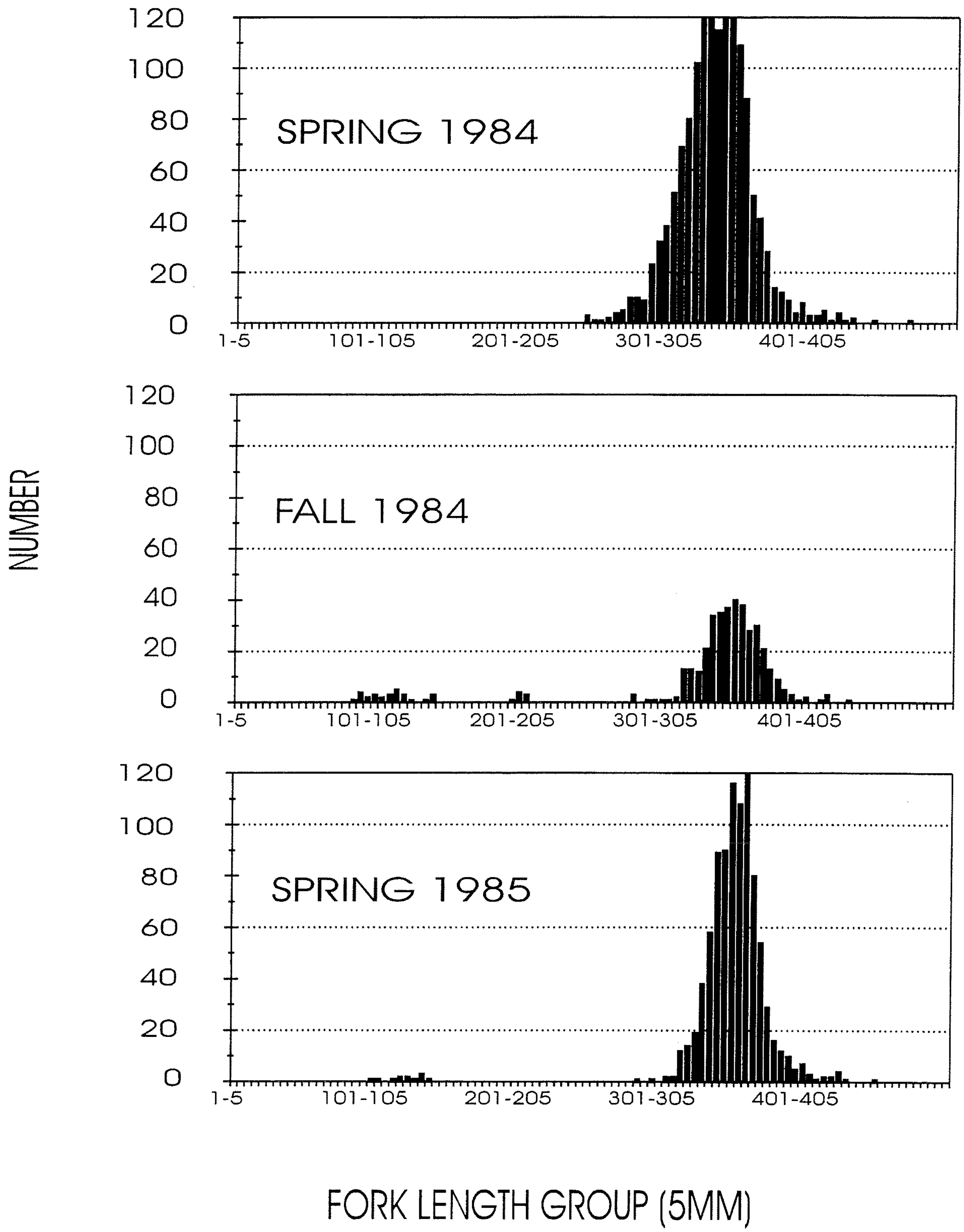

Fig. 1a. Length frequency histograms from spring 1984 until spring 1985.

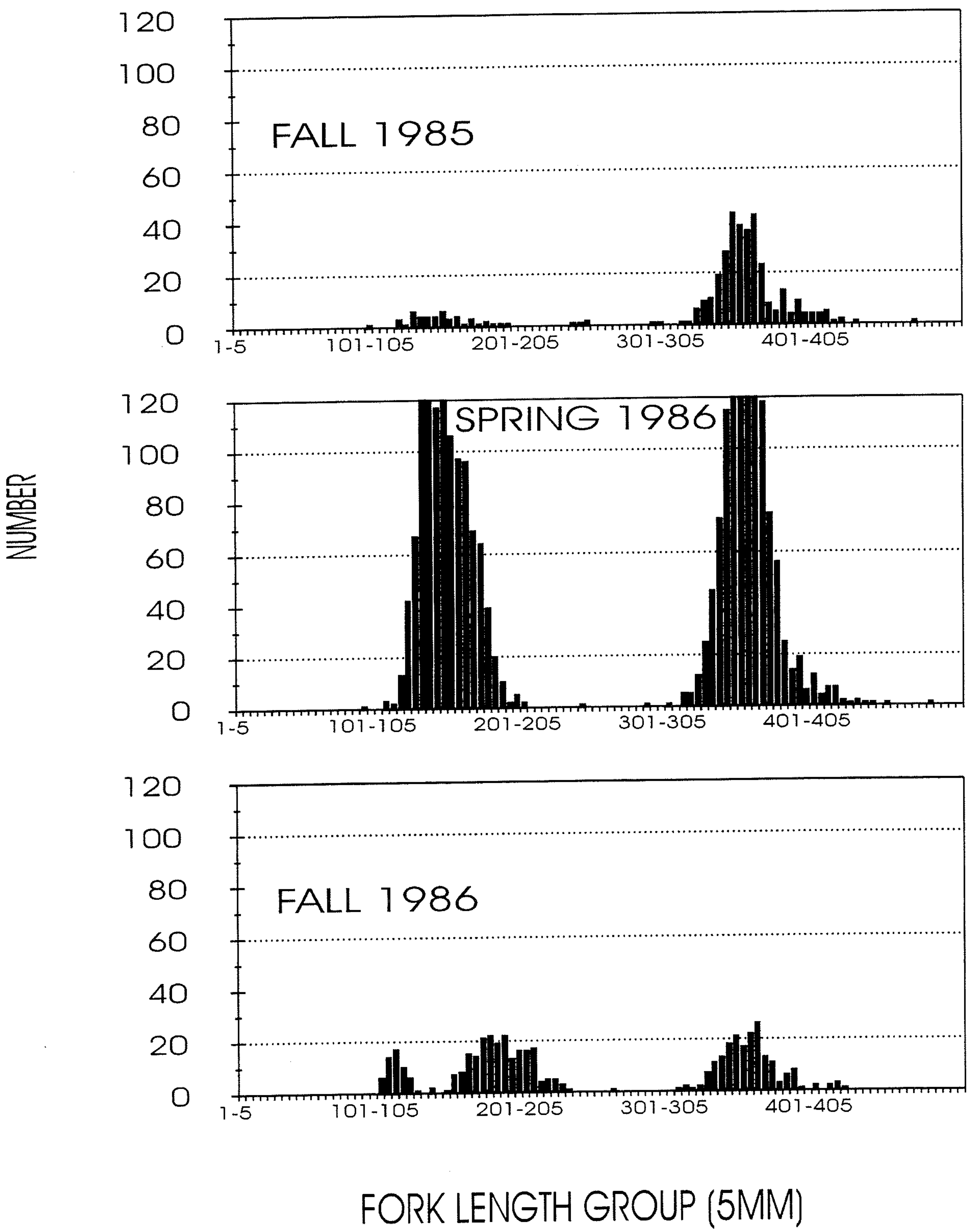

Fig. 1b. Length frequency histograms from fall 1985 until fall 1986.

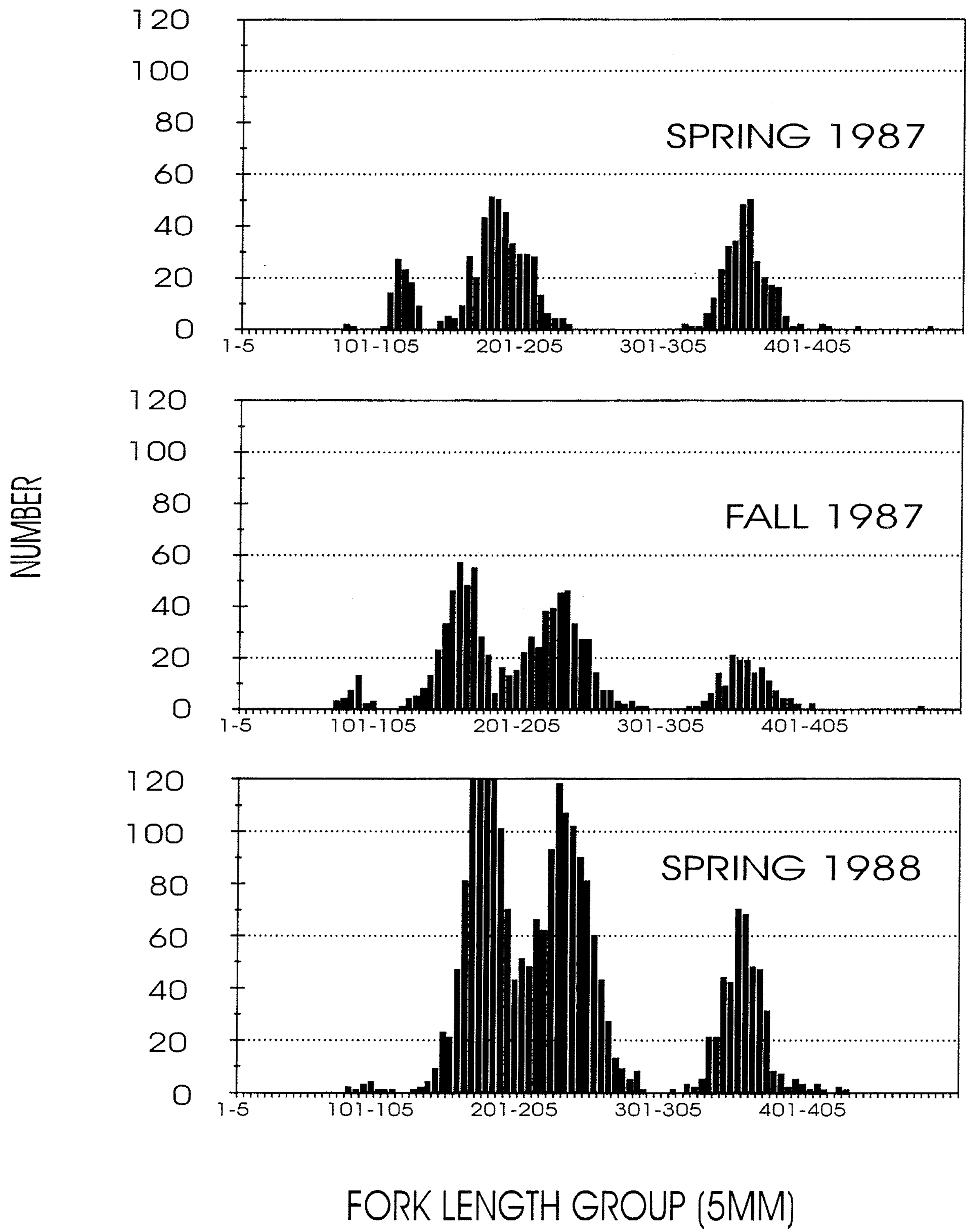

Fig. 1c. Length frequency histograms from spring 1987 until spring 1988.

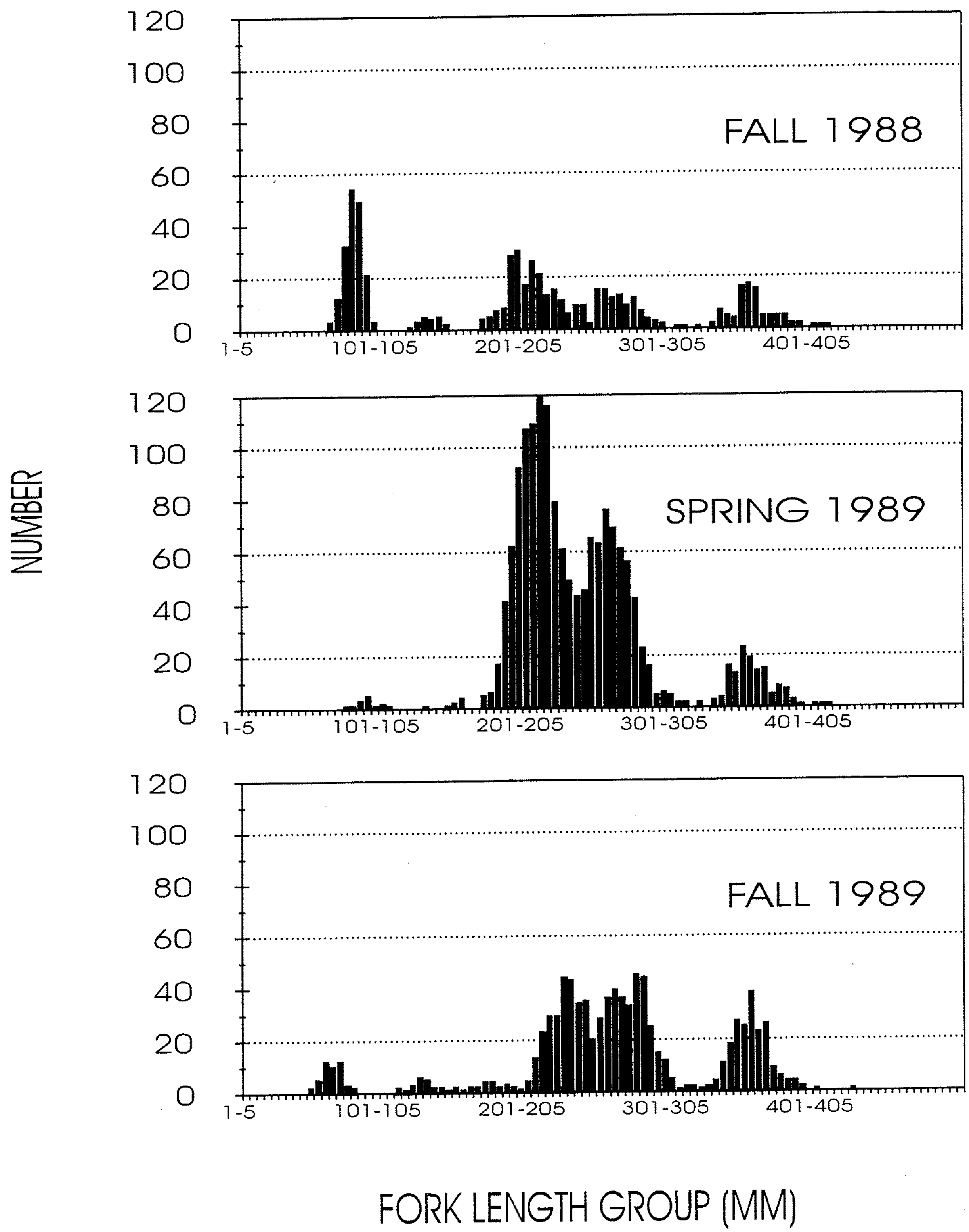

Fig. 1d. Length frequency histograms from fall 1988 until fall 1989.

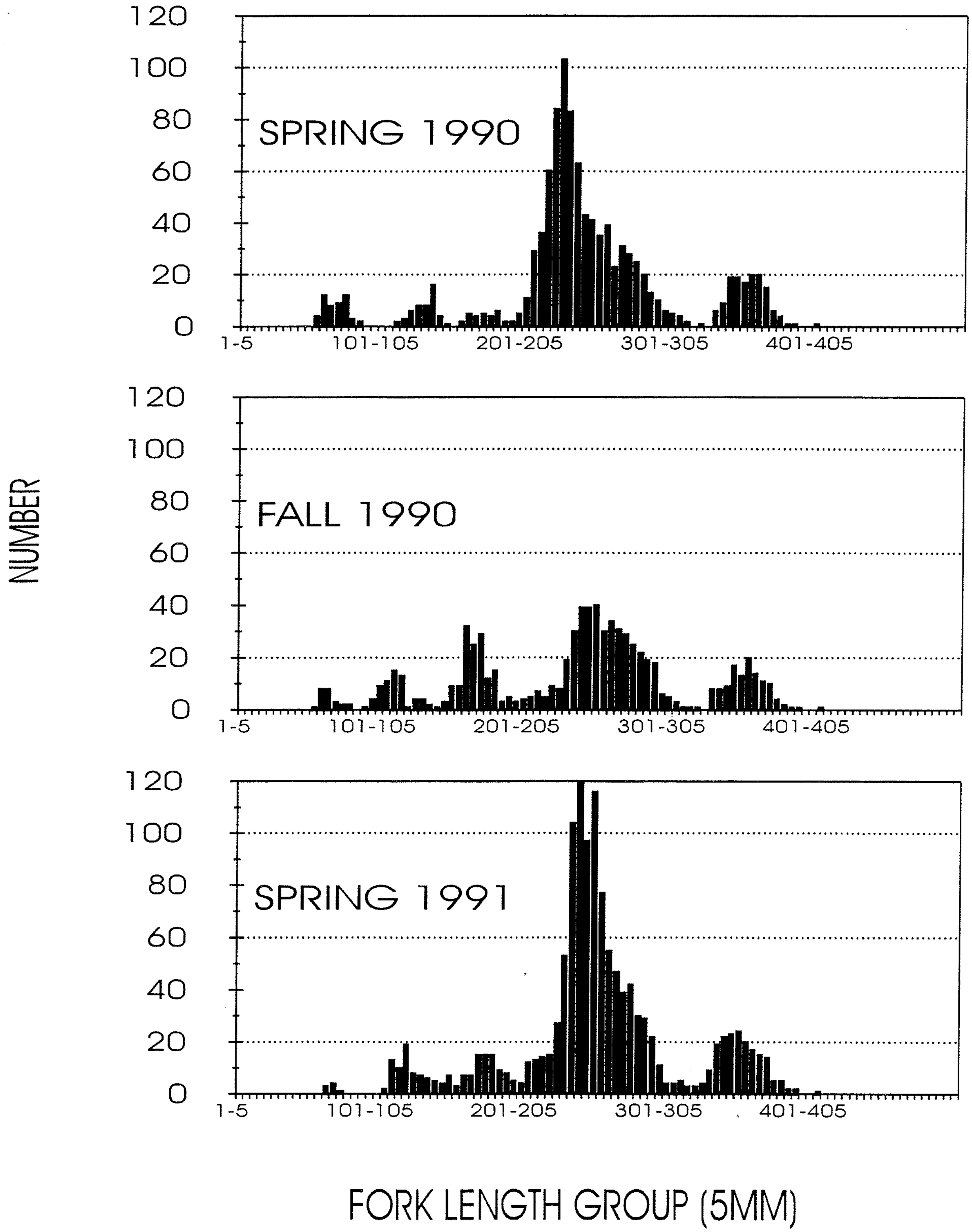

Fig. 1e. Length frequency histograms from spring 1990 until spring 1991.

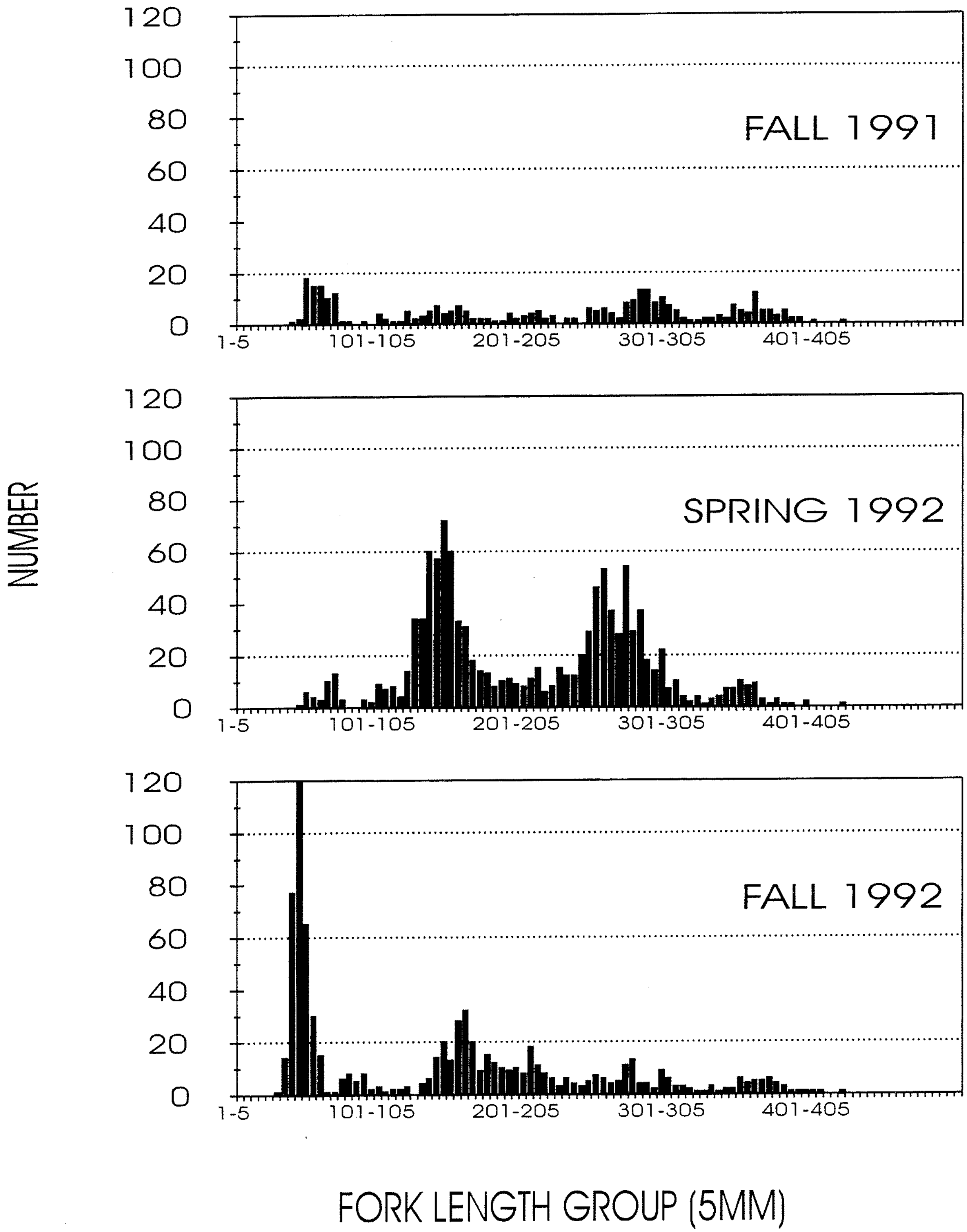

Fig. 1f. Length frequency histograms from fall 1991 until fall 1992.

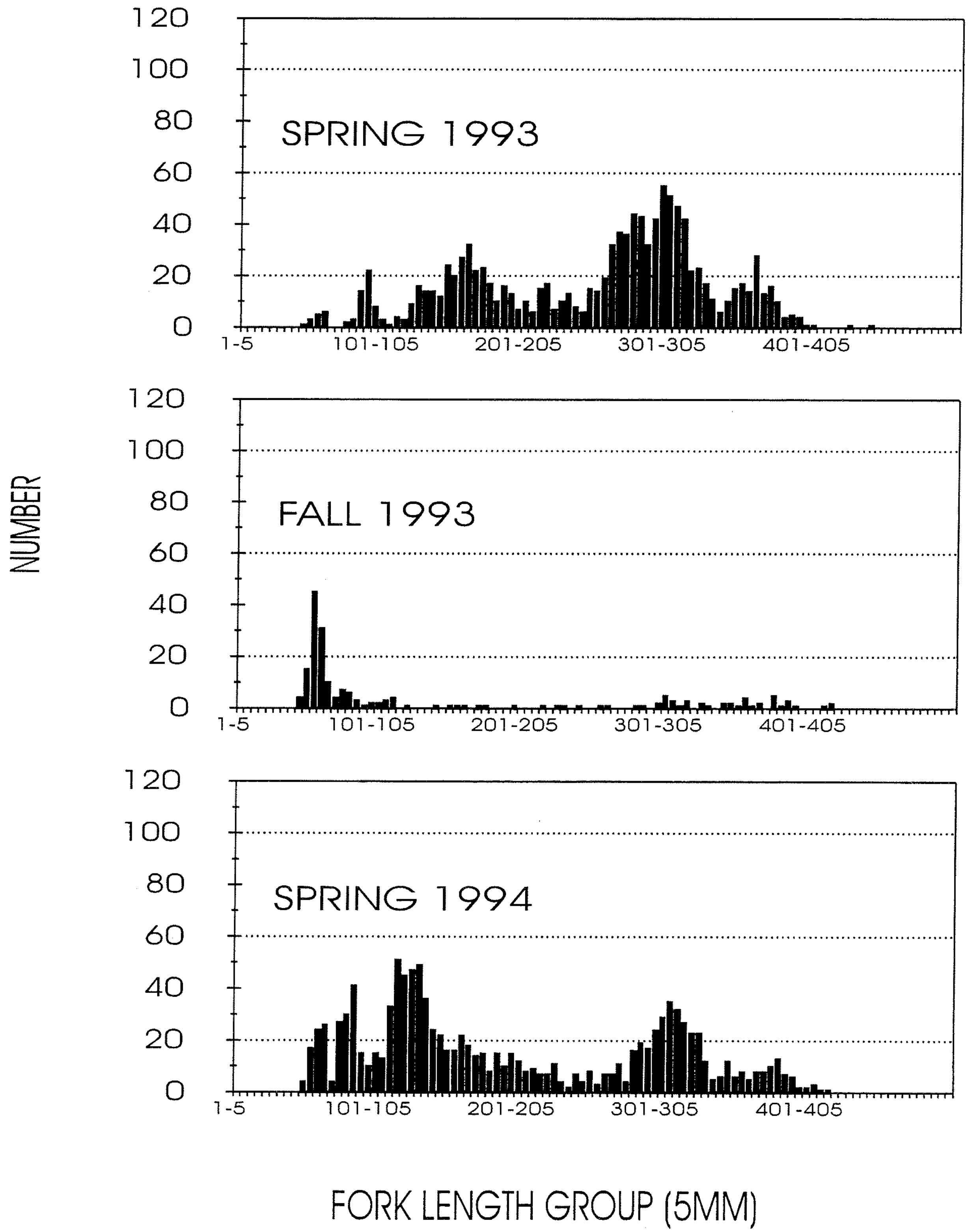

Fig. 1g. Length frequency histograms from spring 1993 until spring 1994.

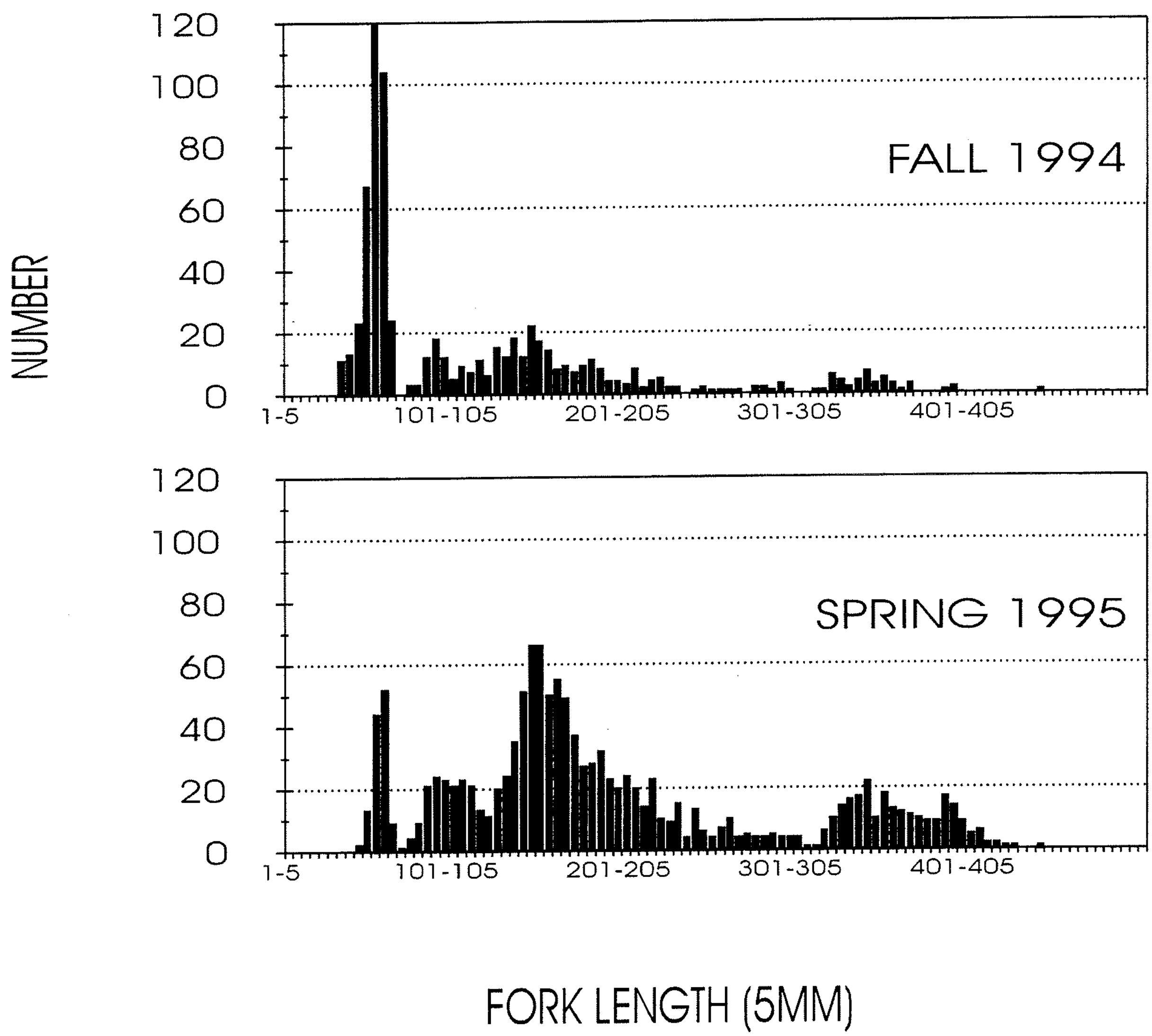

Fig. 1h. Length frequency histograms from fall 1994 until spring 1995.

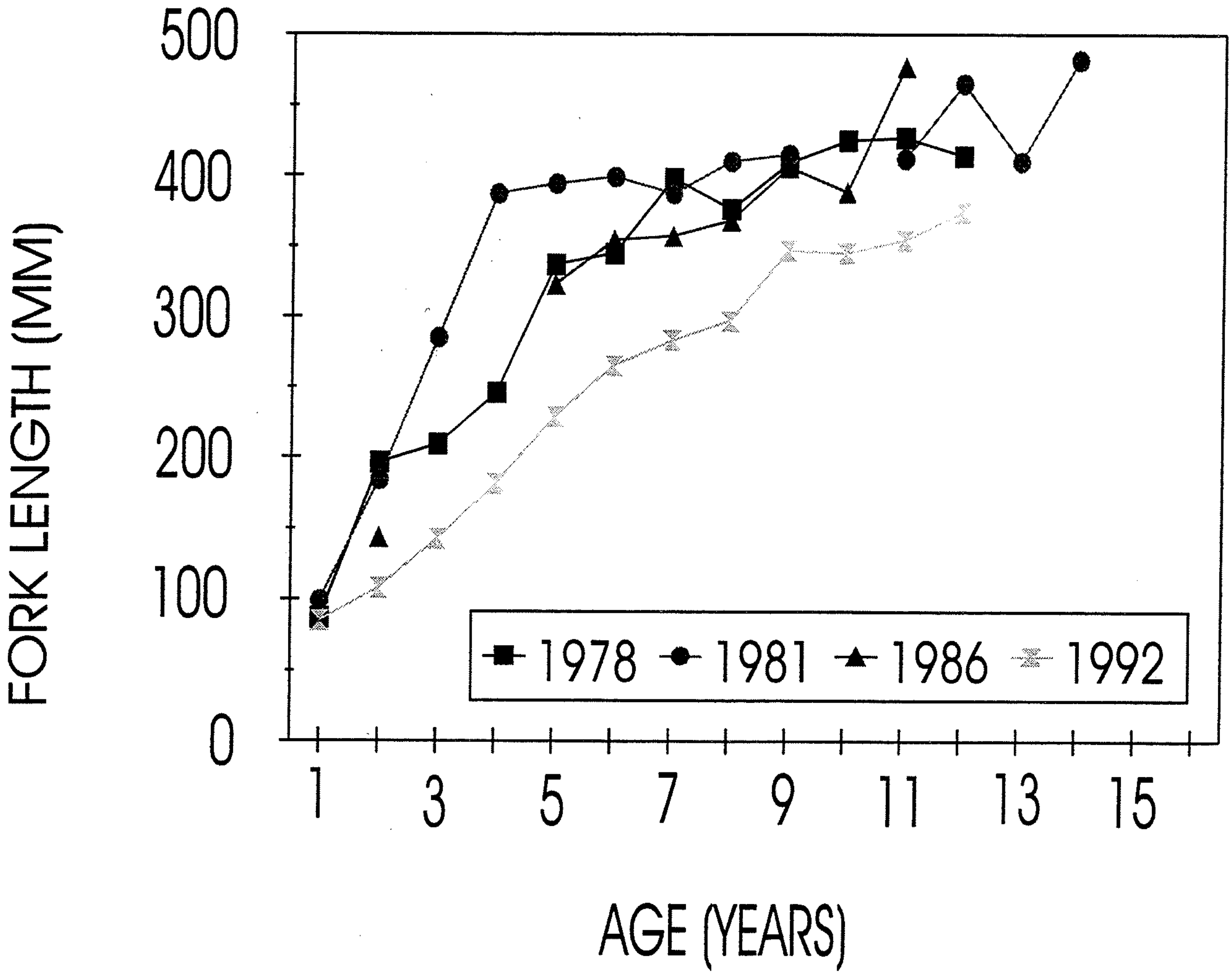

Fig. 2. Comparison of growth (mean fork lengths at age) of white sucker from 1976 until 1995 using representative growth curves for each multi-year period.

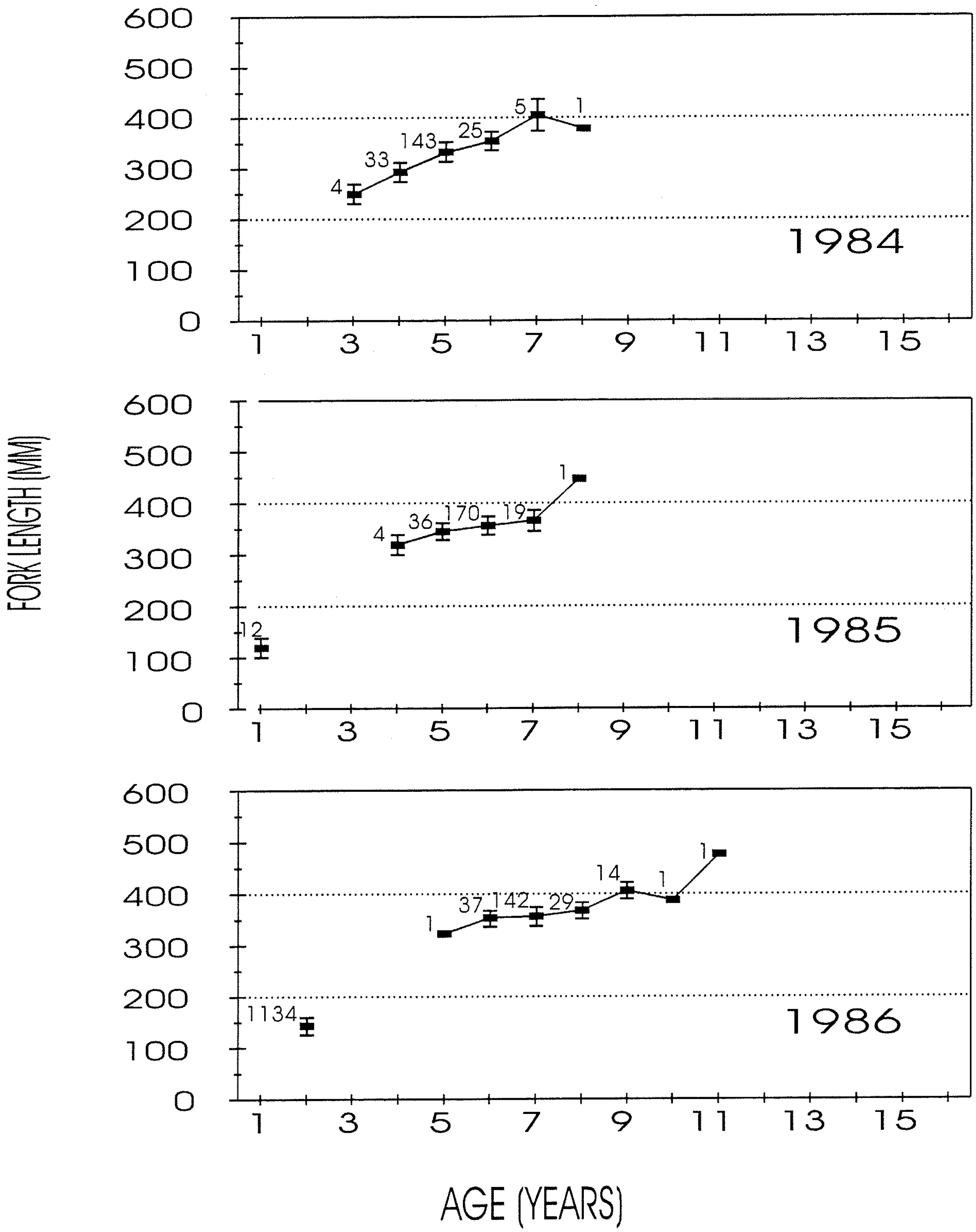

Fig. 3a. Growth (fork length at age) and 95% confidence limits of white sucker from 1984 until 1986. Numbers beside points indicate sample sizes.

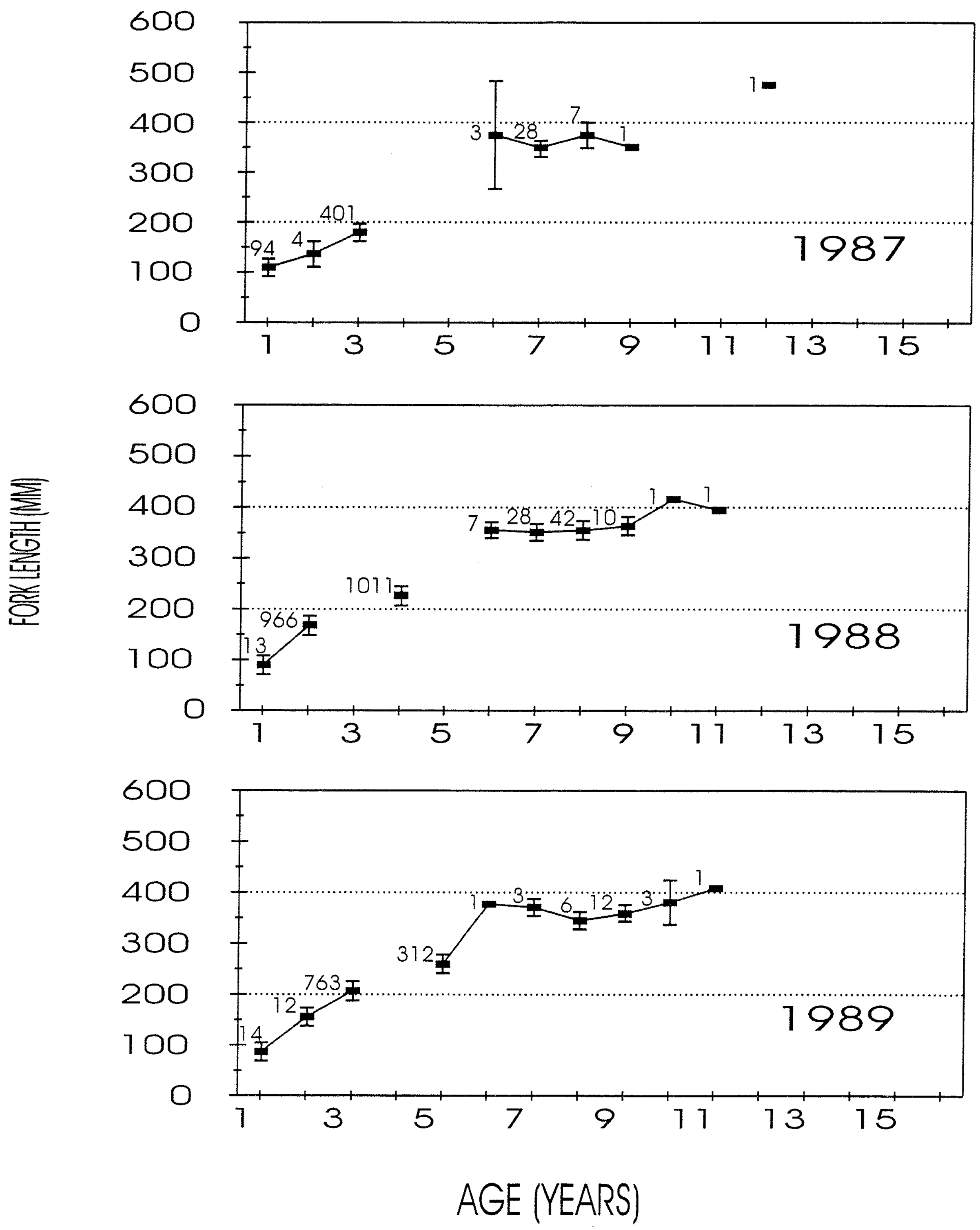

Fig. 3b. Growth (fork length at age) and 95% confidence limits of white sucker from 1987 until 1989. Numbers beside points indicate sample sizes.

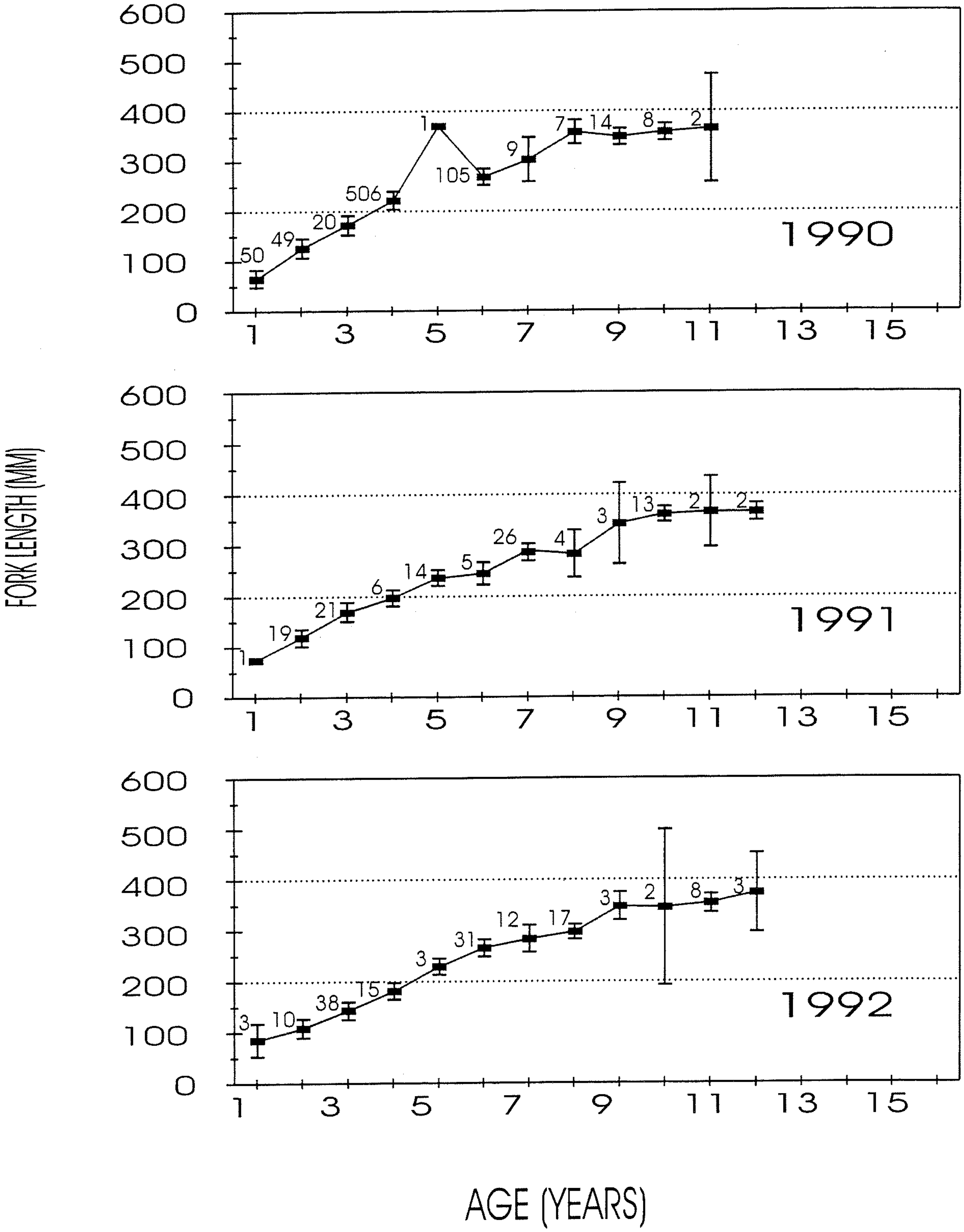

Fig. 3c. Growth (fork length at age) and 95% confidence limits of white sucker from 1990 until 1992. Numbers beside points indicate sample sizes.

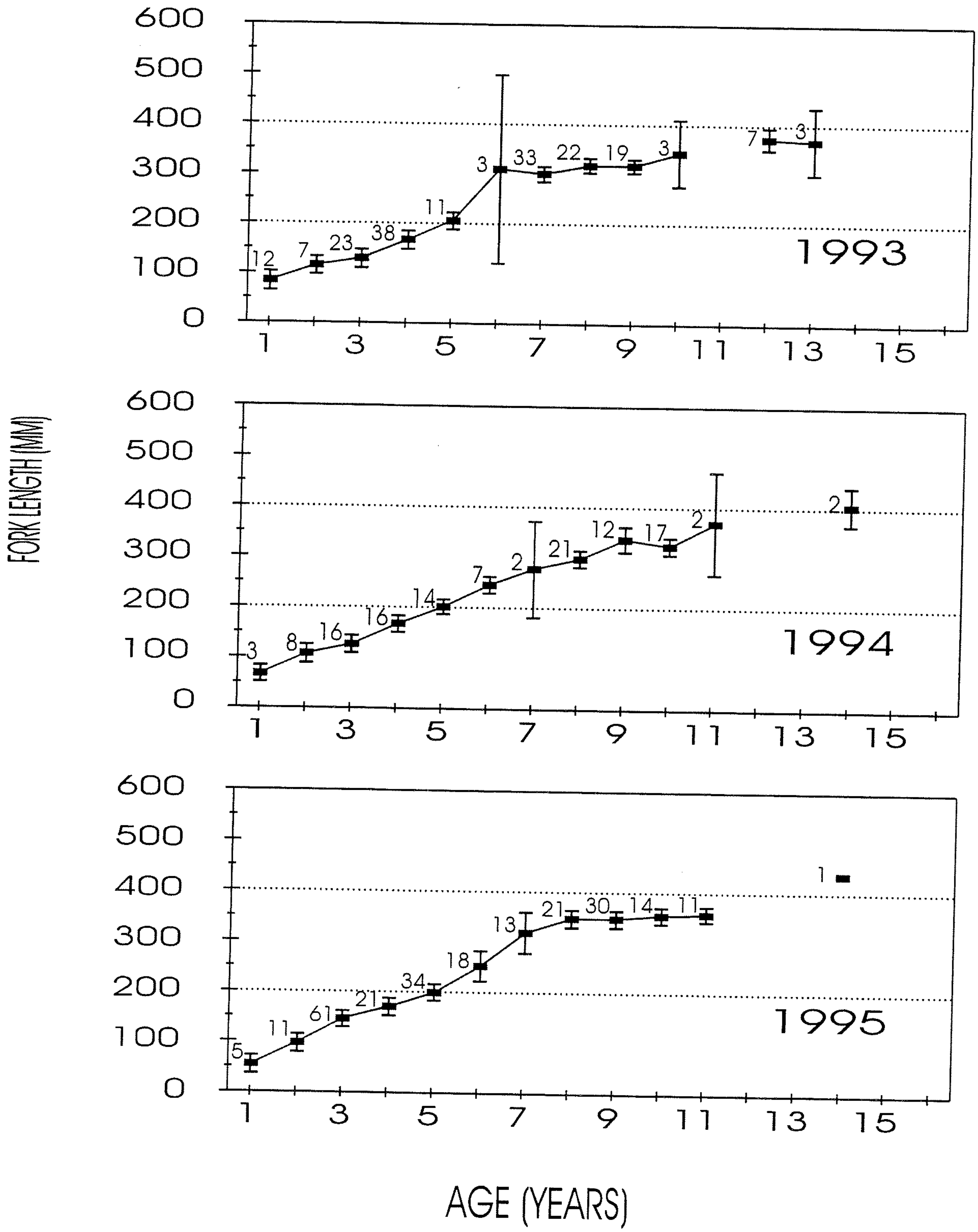

Fig. 3d. Growth (fork length at age) and 95% confidence limits of white sucker from 1993 until 1995. Numbers beside points indicate sample sizes.

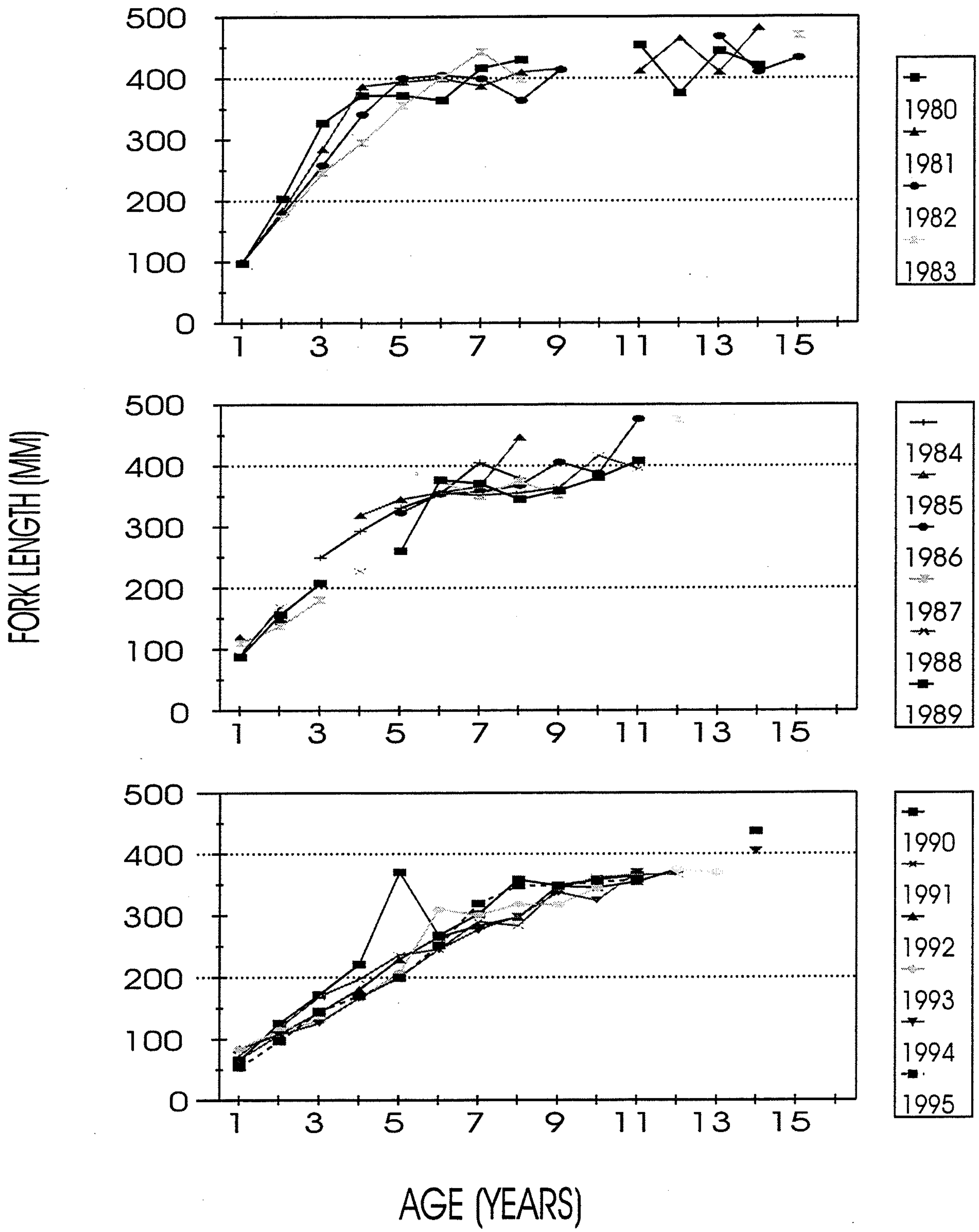

Fig. 4. Comparisons of growth (fork length at age) of white sucker from 1980 until 1983, from 1984 until 1989, and from 1990 until 1995.

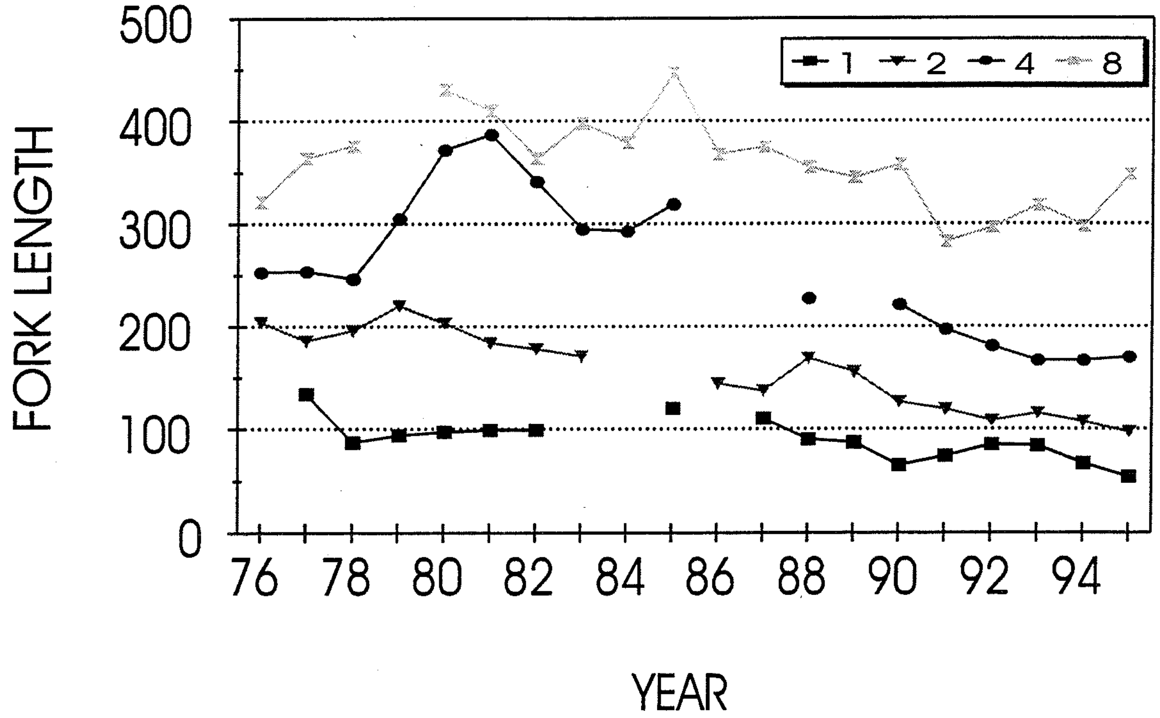

Fig. 5. Fork lengths at age for select ages of white suckers from 1976 until 1995.

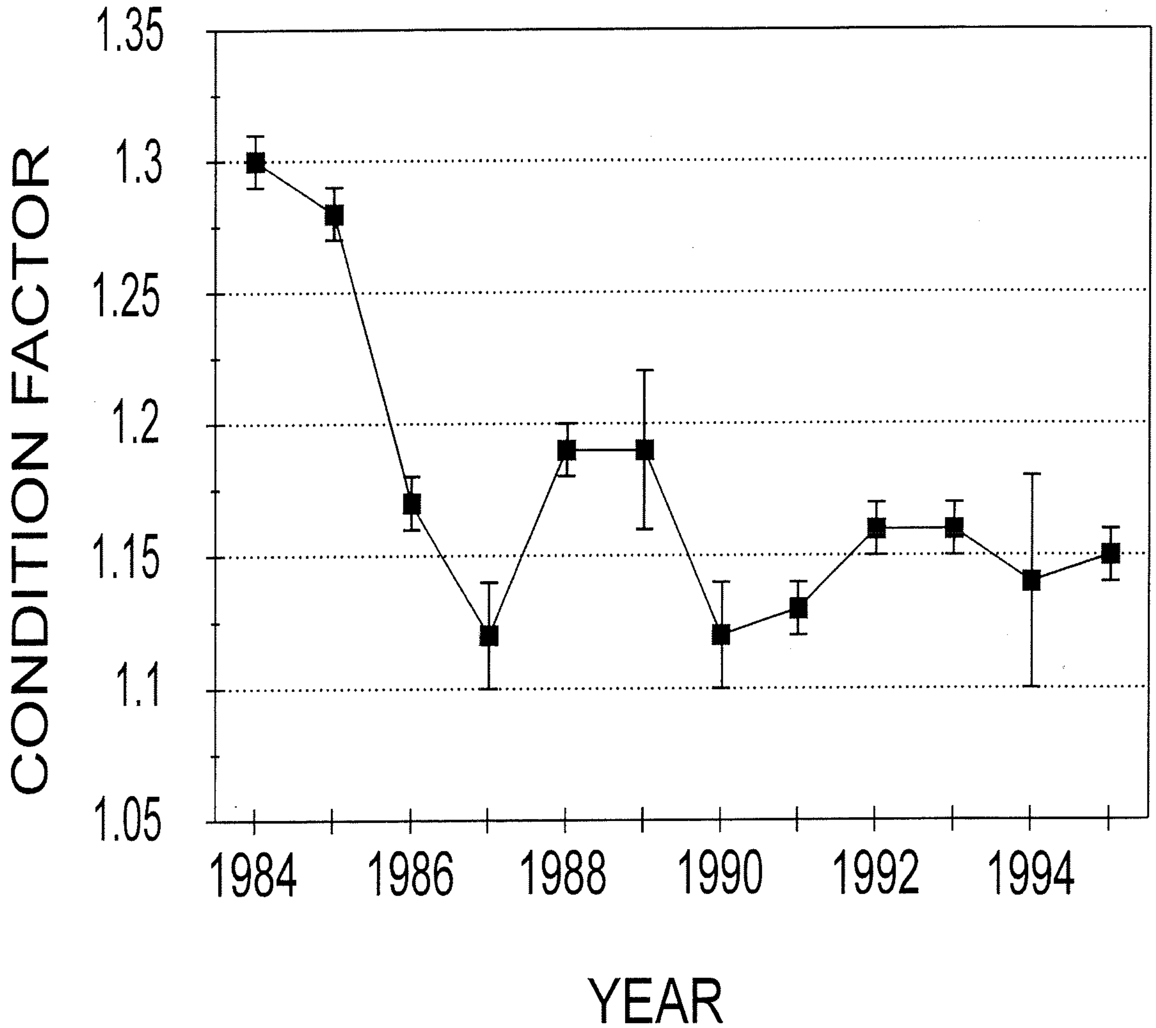

Fig 6. Mean condition factors and 95% confidence limits of white sucker during spring sampling periods from 1984 until 1995.