Growth of White Sucker, *Catostomus commersoni*, in Thirty-One Lakes at the Experimental Lakes Area, Northwestern Ontario

S.M. Chalanchuk

Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6

1998

Canadian Technical Report of Fisheries and Aquatic Sciences 2207

Fisheries and Oceans Pêches et Océans

Canada

Canadian Technical Report of

Fisheries and Aquatic Sciences 2207

1998

GROWTH OF WHITE SUCKER, *Catostomus commersoni*, IN THIRTY-ONE LAKES AT THE EXPERIMENTAL LAKES AREA, NORTHWESTERN ONTARIO

by

S.M. Chalanchuk

Central and Arctic Region

Department of Fisheries and Oceans

Winnipeg, Manitoba R3T 2N6

Cat. No. Fs 97-6/2207E ISSN 0706-6457

Correct citation for this publication is:

Chalanchuk, S. M. 1998. Growth of white sucker, *Catostomus commersoni,* in thirty-one lakes at the Experimental Lakes Area, northwestern Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 2207: vi + 65 p.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (cont.)

ABSTRACT

Chalanchuk, S.M. 1998. Growth of white sucker, *Catostomus commersoni*, in thirty-one lakes at the Experimental Lakes Area, northwestern Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 2207: vi + 65 p.

Growth, based on fork lengths, was determined for populations of white sucker, *Catostomus commersoni*, in thirty-one lakes at the Experimental Lakes Area (ELA), northwestern Ontario. A wide range of growth was shown by these populations. Annual variations in growth of a population within a lake were minimal and were less than differences in growth between populations from different lakes. Seasonal variations in growth within a lake were distinguishable for young fish, but not for mature fish. Growth of white sucker was not correlated to surface areas of lakes, volumes of lakes, or maximum or mean depths of lakes. There was no discernible correlation between growth of white sucker and chl a of lakes. White sucker in lakes with fish predators present grew slightly faster than white sucker in lakes without predators. Growth of white sucker in the ELA were within the range of growth of white sucker from other lakes as established in the scientific literature.

Key words: *Catastomus commersoni*; white sucker; Experimental Lakes Area; ELA; growth; fork-length; fin-ray; annual variation; lake size.

RÉSUMÉ

Chalanchuk, S.M. 1998. Growth of white sucker, *Catostomus commersoni*, in thirty-one lakes at the Experimental Lakes Area, northwestern Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 2207: vi + 65 p.

L'auteur a déterminé la croissance, d'après la longueur à la fourche, de meuniers noirs (*Catostomus commersoni*) de trente-et-un lacs de la région des lacs expérimentaux (RLE) du nord-ouest de l'Ontario. Ces populations de meunier présentaient une large gamme de taux de croissance. Les variations annuelles de la croissance chez une population d'un même lac étaient très faibles et inférieures aux écarts notés entre des populations de lacs différents. Les variations saisonnières de la croissance étaient décelables chez les jeunes poissons, mais non chez les adultes. Le taux de croissance du meunier noir ne présentait pas de corrélation avec la superficie, le volume ou la profondeur, maximale ou moyenne, des lacs. Il n'y avait pas non plus de corrélation décelable entre le taux de croisance et la teneur en chlorophylle-a des lacs. Les meuniers des lacs abritant des prédateurs des poissons présentaient un taux de croissance légèrement supérieur à celui des meuniers des lacs sans prédateurs. Le taux de croissance des meuniers noirs de la RLE se situaient dans la gamme de ceux des autres lacs mentionnés dans la littérature.

Mots clés : *Catastomus commersoni*; meunier noir; région des lacs expérimentaux; RLE; croissance; longueur à la fourche; rayon de nageoire; variation annuelle; taille des lacs.

INTRODUCTION

Growth is an important parameter in the understanding and management of fish populations. Comparison of growth through time for an individual population can indicate changes in general well-being of that population due to increased exploitation, changes in environmental conditions such as pollution, or changes in species interactions.

Growth of fishes is influenced by environmental factors such as temperature, food supply, predation, and increasingly, by contaminants and toxicants. Both increases in growth of fishes (Ryan and Harvey 1977; McFarlane and Franzin 1978; Chalanchuk 1985) and decreases in growth (Beamish 1974; Ryan and Harvey 1980) have been cited as population responses to various pollutants. Changes in growth are thus useful indicators of changes in the aquatic environment.

Growth can also determine a fish population's susceptibility to various contaminants by influencing the rate of accumulation of these substances in tissues (Scott 1974; Bendell-Young et al. 1986). For example, Bendell-Young et al. (1986) found that the accumulation of cadmium in liver tissues of white sucker, *Catostomus commersoni*, was proportional to the rate of growth of individual fish.

The white sucker is one of the most widely distributed and abundant fish species in North America (Scott and Crossman 1973). Because of this widespread distribution and because its biology and life history are reasonably well-known, the white sucker has been proposed as an indicator species for contaminant stress to ecosystems (Munkittrick and Dixon 1989).

Very few summaries of the range of growth of white sucker are available in the scientific literature, especially for unexploited populations in unpolluted waters. Carlander (1969) provides an extensive summary of life history information including growth, but most of the data were collected forty or fifty years ago and scales were used to determine ages. Several researchers have shown that scale ages are unreliable for suckers, especially after fish reach sexual maturity (Beamish 1973; Beamish and Harvey 1969; Quinn and Ross 1982). The usual problem with scale ages is underaging older fish, which results in growth rates that are too high. Beamish (1973) presented a summary of growth curves for eleven populations of white sucker in southern Ontario lakes. However, two of these lakes had undergone acidification and in another lake, lamprey predation had affected the size structure of the population. Exploitation also affects growth of fishes. Healey (1975; 1978) found that previously unexploited populations of whitefish, *Coregonus clupeaformis,* and lake trout, *Salvelinus namaycush,* increased their growth rates with increased exploitation.

The purpose of this report is to present the range of natural variability in growth for several unexploited populations of white sucker in the Experimental Lakes Area (ELA), an unpolluted area in northwestern Ontario. Growth curves presented here will serve as reference data for future experimentation at the ELA. Seasonal and annual variations of growth of white sucker within individual lakes are discussed. Influences of surface area, lake volume, maximum and mean depth of lakes, chlorophyll a (chl a), and the presence or absence of fish predators on growth of white sucker populations are also discussed. Growth of white sucker in the ELA is compared to growth of other white sucker populations available in the scientific literature.

MATERIALS AND METHODS

White sucker were collected from 31 lakes within a 245 km^2 area at the Experimental Lakes Area. Surface areas, volumes, maximum and mean depths of lakes, chl a values, and presence of fish predators are shown in Table 1. Information in this table was collected from Cleugh and Hauser (1971), Beamish et al. (1976), and ELA staff, unpublished data. A map is included for visual comparison of relative surface areas of lakes for which morphometric data are unavailable (Fig. 1). The pH of these lakes ranged from 6.58 to 7.58, with most lakes having pHs in the 6.81 to 7.20 range.

White sucker were obtained throughout the open-water season from 1981 to 1996. Fish in Lakes 109, 110, 240, 258, 259, 374, 377, 378, 379, 438, 467, 468, 622, 623, 625, 626, 627, 628, 629, 634, 659, and 660 were captured primarily by multifilament experimental (multi-panel) gill nets (bar mesh 25-75 mm) during overnight sets. These fish were not released. Most fish in Lakes 111, 224, 239, 305, 373, 375, 442, and all fish in Lakes 260 and 382 from 1984 to 1996 were captured by modified Beamish-style trap nets (Beamish 1972) (mesh sizes 3-5 mm) with pots ranging in size from 1.2x2.1x2.4 m to 2.1x2.4x2.7 m. These fish were marked, measured, and released. Fork lengths (to the nearest mm) were recorded for all fish.

White sucker were aged using pectoral fin-ray sections. Two or three rays of a pectoral fin were removed from each fish. Fin-rays were air-dried, epoxied, sectioned, fixed, and aged using a compound microscope equipped with a viewing screen at ~160x power. Aging techniques were previously described in Chalanchuk (1984). For populations sampled by one-time surveys, younger ages were validated by analyses of length-frequency modes. For fish populations in Lakes 224, 239, 260, 305, 373, 375, 377, 382, and 442, ages were validated by analyses of length-frequency modes and by comparison of ages at release and recapture of individually marked fish. Populations of white sucker in other lakes in the ELA have been successfully aged and validated using the fin-ray method of aging (Chalanchuk 1984; 1986) and this method was chosen for aging all the white sucker populations in this study.

Growth curves were constructed by plotting mean fork length at age for white sucker in each lake. Because fish grow faster or slower at different times of the year (Lalancette 1976), comparisons of growth of white sucker were made during three sampling periods: spring (May-June), summer (July-August), and fall (September and October). When data for two or more years were available for an individual lake, composite growth curves were constructed by combining all years on a seasonal basis. These composite growth curves were compared to determine seasonal and annual variations, and relationships of growth to surface areas, lake volumes, maximum or mean depths, chl a, and presence of fish predators. Fish predators in ELA lakes studied included lake trout, burbot, *Lota lota*, and northern pike, *Esox lucius*. Upper and lower limits of growth of white sucker were constructed for data available in the scientific literature by using lowest and highest values for each age. These were compared to upper and lower limits of growth of white sucker in the ELA.

RESULTS AND DISCUSSION

Growth of white sucker in lakes in the Experimental Lakes Area varied widely (Fig.2a-2c). Data are shown in tabular form in Appendix 1. White sucker grew most rapidly in Lake 224 and most slowly in Lake 111. Differences in mean fork lengths at age between the fastest growing and slowest growing white sucker populations were over 100 mm for most ages. The smallest variation occurred at the youngest ages. For example, fish aged one had fork lengths ranging from 75 mm in Lake 111 to 187 mm in Lake 224 during fall sampling periods but were usually 85 to 150 mm in length during spring sampling periods. The biggest range in mean fork length at age occurred for fish aged four to eight years. Fish at any of these ages differed in fork lengths by as much as 200 to 300 mm from lake to lake. Differences in fork length at age for fish older than eight years were 100 to 200 mm. Plateaus in growth curves at eight to eleven years reflect the decrease in growth that occurs as most fish reach sexual maturity. This phenomenon occurs for white sucker in other lakes (Spoor 1938; Chalanchuk 1985) and is common to most fishes (Brown 1957).

Seasonal differences are distinct for young fish but are usually indistinguishable for older fish. These differences are most obvious when spring growth curves are compared with fall growth curves for the same year as shown for Lake 260 in 1989 and Lake 382 in 1985 (Fig. 3). Increases in length of fish from spring to fall are shown for fish younger than six years. Slowing of growth as fish reach sexual maturity and small sample sizes for older fish resulted in large error bars that obscured differences in growth for individual year classes. Differences in fork lengths at age show similar trends when composite growth curves are compared for an individual lake (Fig. 4). Differences between spring and fall samples were slightly higher for composite samples than for annual samples due to larger sample sizes. The period of most rapid growth of sucker occurs from early June to August (Lalancette 1976); distinct growth is usually less apparent in comparisons of growth curves for summer and fall periods.

Annual variations in growth of white sucker within a particular lake were usually minimal when growth curves were compared for similar season sampling. The pattern of growth remained consistent from year to year. For example, when growth curves for several spring seasons for L260 and fall seasons for L259 were compared, growth was within a narrow range of values for each lake (Fig. 5). (See Appendix 2 for individual growth curves and 95% confidence limits.) Composite growth curves (when available) were therefore used for comparisons of growth between fish populations in different lakes.

Growth of white sucker was not correlated to any individual physical parameter. Growth of white sucker varied widely in lakes irrespective of surface area (Fig. 6) or volume (Fig. 7). White sucker aged one to seven years tended to have higher fork lengths at age in lakes of surface areas < 25 hectares, but growth of fish older than eight years were similar in lakes of all sizes. Trippel and Harvey (1987) found that growth of white sucker was faster in deep lakes than in shallow lakes and that there was a strong correlation between maximum attainable fork lengths and maximum lake depths. In ELA lakes, no relationship occurred between growth of white sucker and either maximum (Fig. 8) or mean (Fig. 9) depths. Although the smallest maximum fork length attained was by white sucker in Lake 438, the shallowest lake, the second smallest maximum fork length attained was by white sucker in Lake 660, the deepest lake. No pattern was evident for all other lakes (Table 2). Similarly, maximum ages attained by white sucker showed no relationship to depth. Maximum ages attained by white sucker were greatest in lakes of moderate depth. Although lakes with greater surface areas usually also had greater depths and volumes, it was not possible to determine any influence of these physical parameters on differences in growth. No correlations occurred between growth of white sucker and chl a (Fig. 10). Lake 111 was an exception for all parameters; white sucker in this lake grew slower than in any other ELA lake I studied. Chen and Harvey (1995) found that growth of white sucker was faster in lakes with abundant benthic communities, especially chironomids. Unfortunately, data on food sources in all of these lakes were unavailable. It is quite likely however, that food supply determines growth of white sucker in ELA lakes because growth was not strongly dependant on any of the physical parameters studied.

Growth of white sucker was slightly faster in lakes where fish predators were present (Fig. 11). It is advantageous for a prey species such as white sucker to grow to a large size as quickly as possible because large fish are less vulnerable to predation than smaller fish.

Growth of white sucker in the ELA was similar to that reported by Beamish (1973) for eleven southern Ontario populations and to other populations aged by the pectoral fin method (Fig. 12). Growth of white sucker in ELA lakes was slightly lower than that of other populations of white sucker aged by the scale method as reported by Carlander (1969) and other authors. Maximum ages attained by white sucker in other lakes were < 15 years; in E.L.A. lakes white sucker aged 15 to 20 were relatively common. Upper and lower limits of growth for white sucker in all ELA lakes were based on spring sampling periods; limits of growth for other white sucker populations included data from all seasons.

In summary, growth rates of unexploited populations of white sucker vary greatly from lake to lake at the ELA. Seasonal variability should be taken into account when comparisons of growth curves are made within a lake, but are less important in comparisons of growth curves between lakes. Because growth is stable from year to year for same season comparisons, annual variability can be used as a tool for detecting changes in growth caused by anthropogenic or environmental changes.

ACKNOWLEDGMENTS

Funding was provided by the Department of Fisheries and Oceans. Thanks to Ken Mills for guidance throughout the study. Thank you to Lloyd Mohr and Doug Allan for field assistance. The manuscript was reviewed by Bob Fudge and John Shearer. John Shearer provided a digital copy of the E.L.A. map.

REFERENCES

Beamish, R.J. 1972. Design of a trap-net for sampling shallow water habitats. Fish. Res. Board Can. Tech. Rep. 305: 14 p.

Beamish, R.J. 1973. Determination of age and growth of populations of the white sucker (*Catostomus commersoni*) exhibiting a wide range in size at maturity. J. Fish. Res. Board Can. 30: 607-616.

Beamish, R.J. 1974. Growth and survival of white suckers (*Catostomus commersoni*) in an acidified lake. J. Fish. Res. Board Can. 31: 49-54.

Beamish, R.J., and H.H. Harvey. 1969. Age determination in the white sucker. J. Fish. Res. Board Can. 26: 633-638.

Beamish , R.J., L.M. Blouw, and G. A. McFarlane. 1976. A fish and chemical study of 109 lakes in the Experimental Lakes Area (ELA),northwestern Ontario, with appended reports on lake whitefish ageing errors and the northwestern Ontario baitfish industry. Can. Fish. Mar. Serv. Res. Dev. Tech. Rep. 607: 116 p.

Bendell-Young, L.I., H.H. Harvey, and J.F. Young. 1986. Accumulation of cadmium by white suckers (*Catostomus commersoni*) in relation to growth and lake acidification. Can. J. Fish. Aquat. Sci. 43: 806-811.

Brown, M.E. 1957. Experimental studies on growth, p. 361-400. *In* M.E. Brown (ed.) The physiology of fishes. Vol. 1. Academic Press, New York.

Carlander, K.D. 1969. Handbook of freshwater fishery biology. Vol. 1. Iowa State University Press, Ames, Iowa. 752 p.

Chalanchuk, S.M. 1984. Aging a population of the white sucker, *Catostomus commersoni*, by the fin-ray method. Can. Tech. Rep. Fish. Aquat. Sci. 1321: iv + 16 p.

Chalanchuk, S.M. 1985. Recruitment, growth, and condition of a population of the white sucker, *Catostomus commersoni*, in Lake

223, an experimentally acidified lake. Can. Tech. Rep. Fish. Aquat. Sci. 1396: iv + 18 p.

Chalanchuk, S.M. 1986. Condition and growth of white suckers, *Catostomus commersoni*, in Lake 302, a double-basin acidified lake in the Experimental Lakes Area. Can. Tech. Rep. Fish. Aquat. Sci. 1476: iv+ 13 p.

Chen,Y., and H.H. Harvey. 1995. Growth, abundance, and food supply of white sucker. Trans. Am. Fish. Soc. 124: 262-271.

Cleugh, T.R., and B.W. Hauser. 1971. Results of the initial survey of the Experimental Lakes Area, northwestern Ontario. J. Fish. Res. Board Can. 28: 129-137.

Healey, M.C. 1975. Dynamics of exploited whitefish population and their management with special reference to the Northwest Territories. J. Fish. Res. Board Can. 32: 427-448.

Healey, M.C. 1978. The dynamics of exploited lake trout populations and implications for management. J. Wildl. Manage. 42(2): 307-328.

Lalancette, L.-M. 1976. Annual growth and fat content of white sucker *Catostomus commersoni* in a Quebec lake. Nat. can. (Que.) 103: 403-416.

McFarlane, G.A., and W.G.Franzin. 1978. Elevated heavy metals: a stress on a population of white suckers, *Catostomus commersoni*, in Hamell Lake, Saskatchewan. J. Fish. Res. Board Can. 35: 963-970.

Munkittrick, K.R., and D.G. Dixon. 1989. Use of white sucker (*Catostomus commersoni*) populations to assess the health of aquatic ecosystems exposed to low-level contaminant stress. Can. J. Fish. Aquat. Sci. 46: 1455-1462.

Quinn, S.P., and M.R. Ross. 1982. Annulus formation by white suckers and the reliability of pectoral fin rays for ageing them. N. Am. J. Fish Manage. 2: 204-208.

Ryan, P.M., and H.H. Harvey. 1977. Growth of the rock bass, *Ambloplites rupestris*, in relation to the morphoedaphic index as an indicator of environmental stress. J. Fish. Res. Board Can. 34: 2079-2088.

Ryan, P.M., and H.H. Harvey. 1980. Growth responses of yellow perch, *Perca flavescens* (Mitchell), to lake acidification in the La Cloche Mountain Lakes in Ontario. Environ. Biol. Fishes 5: 97-108.

Scott, D.P. 1974. Mercury concentration of white muscle in relation to age, growth, and condition in four species of fishes from Clay Lake, Ontario. J. Fish. Res. Board Can. 31: 1723-1729.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184: 966 p.

Spoor, W.A. 1938. Age and growth of the sucker, *Catostomus commersoni* (Lacepede) in Muskellunge Lake, Vilas County, Wisconsin. Trans. Wisc. Acad. Sci. Arts Lett. 31: 457-505.

Trippel, E.A., and H.H. Harvey. 1987. Abundance, growth and food supply of white suckers (*Catostomus commersoni*) in relation to lake morphometry and pH. Can. J. Zool. 65: 558-564.

Table 1. Morphometric characteristics of 31 lakes at the Experimental Lakes Area, northwestern Ontario. Data marked with an * are from Cleugh and Hauser (1971). Data marked with a # are from Beamish et al. 1976. Data marked with a + are from Ontario Ministry of Natural Resources maps. Remaining data are from ELA staff, unpublished data. NA indicates no available data. Numbers have been rounded to the nearest whole number (except for chl a).

Lake	Area ($10^4 m^2$)	Volume ($10^5 m^3$)	Maximum Depth m	Mean Depth m	chl a ug/L	Predators
109	15	9	10	6	2.2	no
110	5	3	13	5	1.8	no
111	10	12	35	13	2.2	no
224	26	30	27	12	1.3	yes
239	56	59	30	11	1.8	yes
240	44	NA	13	NA	20	yes
258	73*	NA	41	NA	NA	yes
259	97*	NA	20*	NA	NA	yes
260	33	18	14	5	2.3	yes
305	52	79	32	15	1.3	yes
373	28	29	21	11	1.1	yes
374	528	1063	52	20	1.4	yes
375	19	22	26	12	1.2	yes
377	27	25	19	10	1.5	no
378	24	18	18	8	NA	no
379	166	NA	27	NA	NA	yes
382	37	21	13	6	2.6	yes
438	17*	NA	4*	NA	NA	no
442	15	13	16	9	2.0	yes
467	210#	NA	21#	NA	NA	yes
468	301#	NA	29+	NA	NA	yes
622	39	36	30	9	1.6	yes
623	36	24	21	7	1.3	yes
625	80	NA	40	NA	NA	yes
626	28	18	11	6	NA	yes
627	37+	NA	8+	NA	NA	no
628	NA	NA	NA	NA	NA	no
629	63	53	18	8	1.4	yes
634	NA	NA	18+	NA	NA	yes
659	NA	NA	NA	NA	NA	no
660	NA	NA	108+	NA	NA	yes

Table 2. Maximum fork length and maximum age attained by white sucker in each lake compared to maximum depth.

LAKE	Max Depth m	Max Fork L mm	Max AGE years
438	4	354	14
627	8	464	12
109	10	410	16
626	11	455	14
110	13	447	14
240	13	486	12
382	13	487	26
260	14	507	23
442	16	458	18
378	18	424	15
629	18	425	15
634	18	439	17
377	19	482	14
259	20	475	19
373	21	536	13
623	21	426	11
467	21	433	17
375	26	474	12
224	27	504	22
379	27	453	12
468	29	461	17
239	30	545	16
622	30	446	15
305	32	505	16
111	35	446	13
625	40	405	17
258	41	459	16
374	52	445	18
660	108	409	10

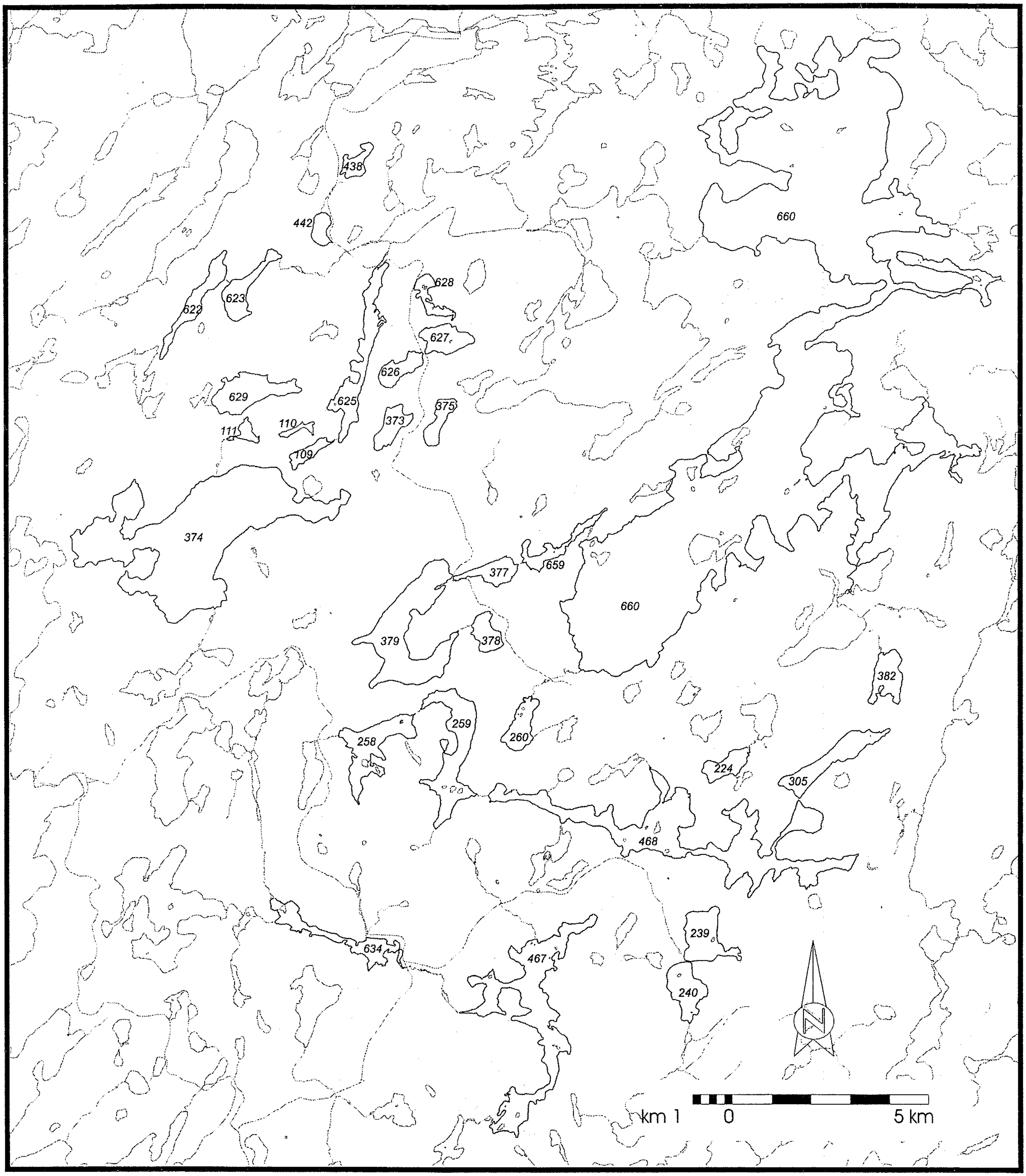


Fig. 1. A map of the Experimental Lakes Area showing relative surface areas of lakes in this study.

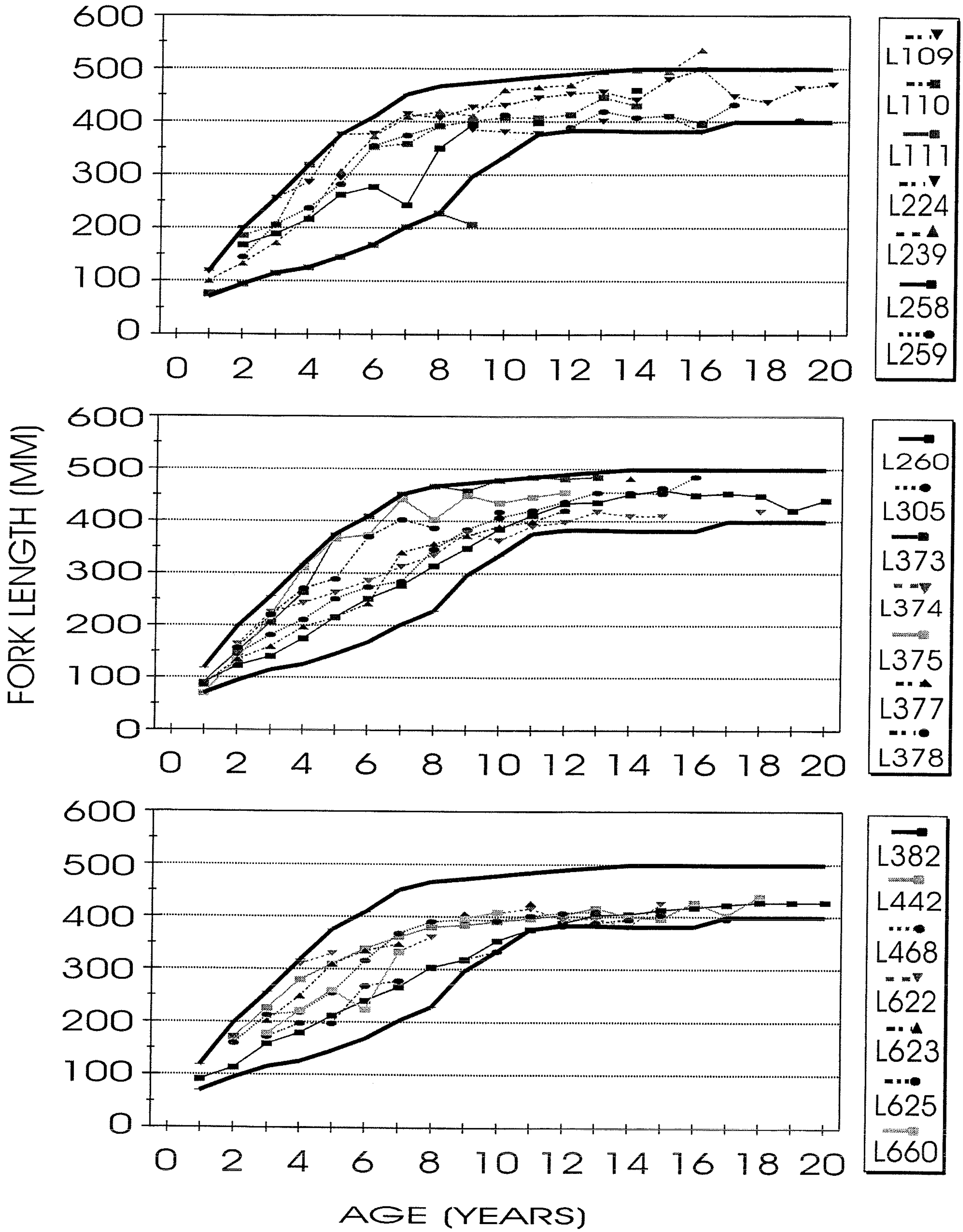


Fig. 2a. Lake to lake comparisons of white sucker growth during spring sampling periods. Heavy lines denote upper and lower limits of growth of E.L.A. white suckers.

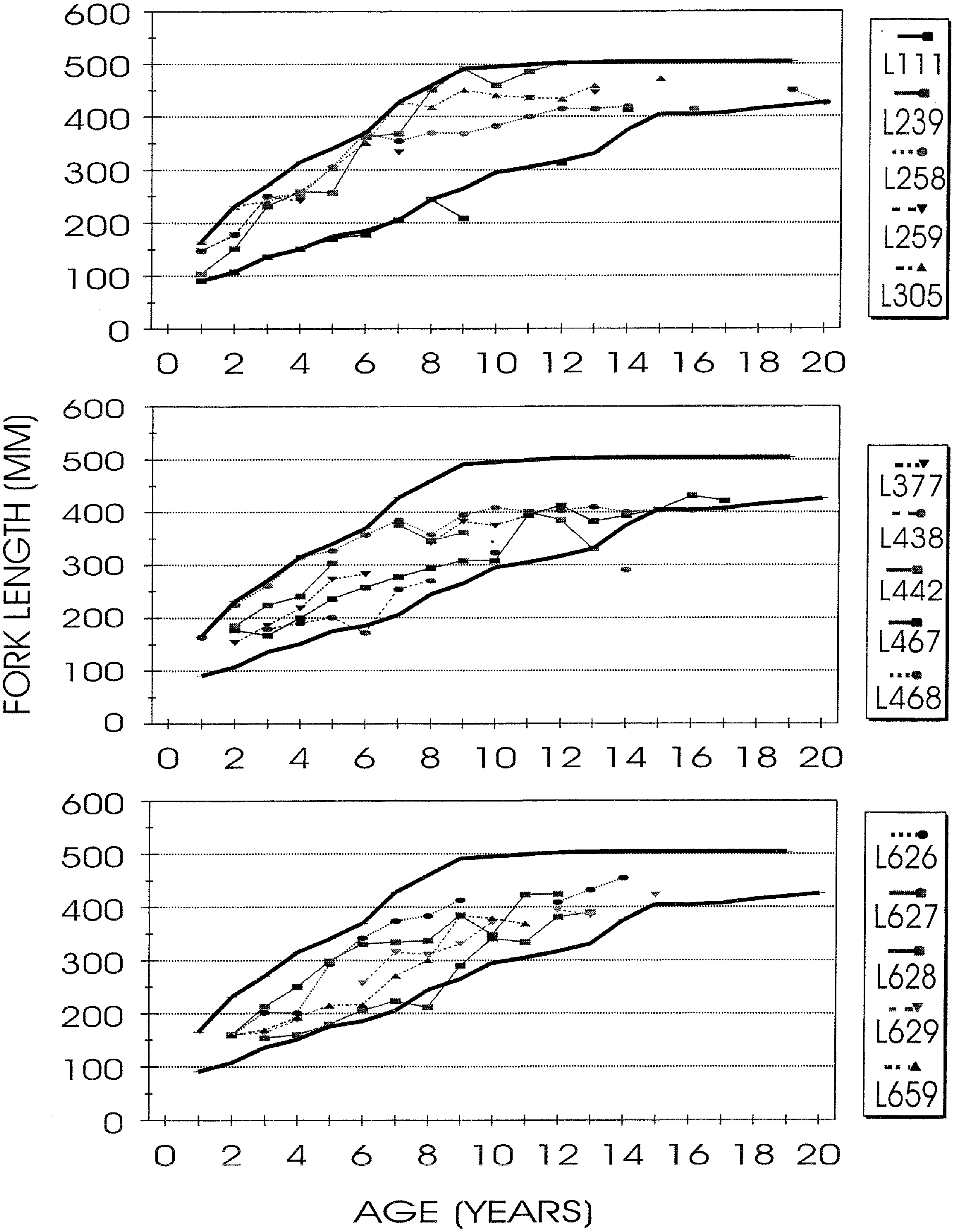


Fig. 2b. Lake to lake comparisons of white sucker growth during summer sampling periods. Heavy lines denote upper and lower limits of growth of E.L.A. white suckers.

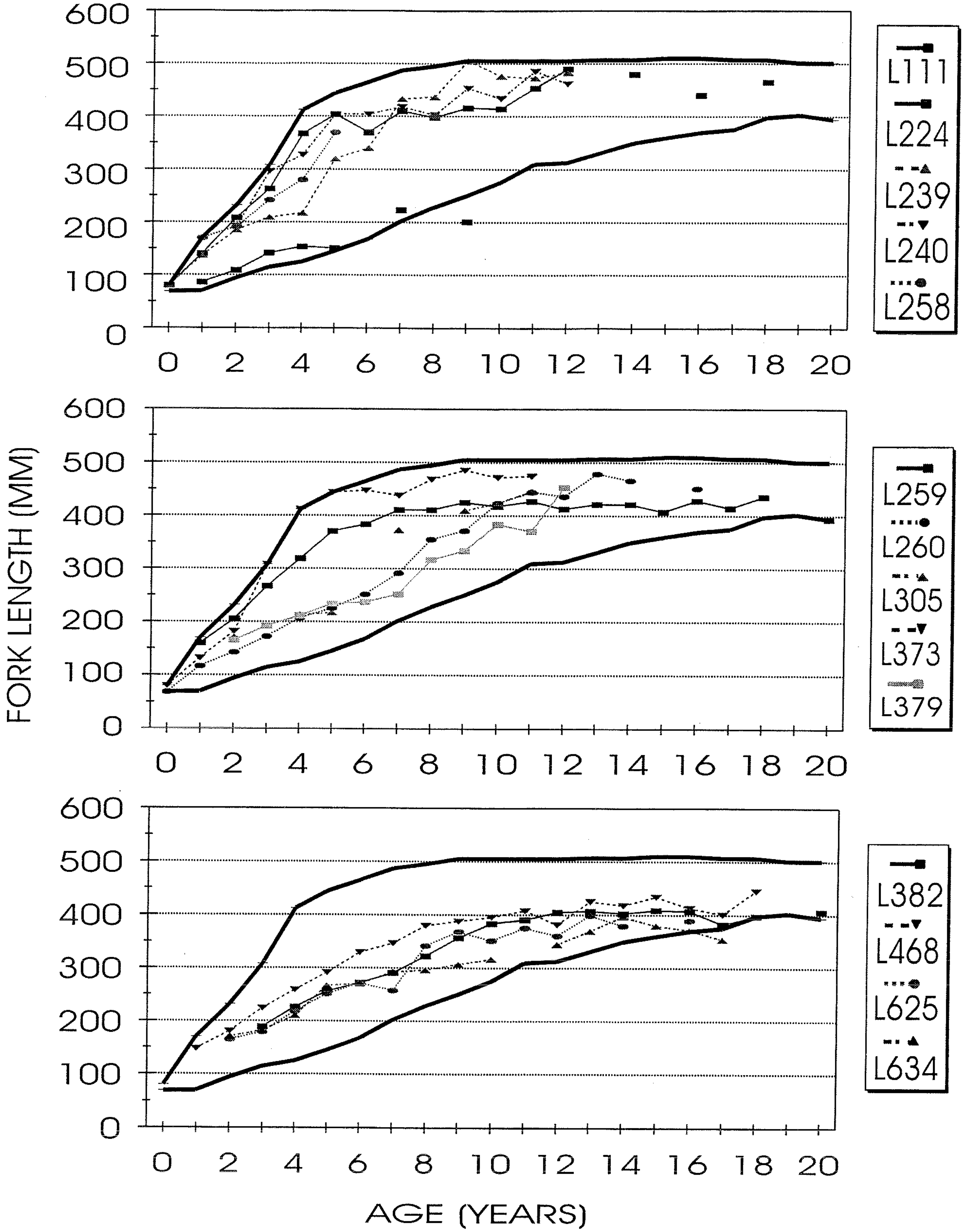


Fig. 2c. Lake to lake comparisons of white sucker growth during fall sampling periods. Heavy lines denote upper and lower limits of growth of E.L.A. white suckers.

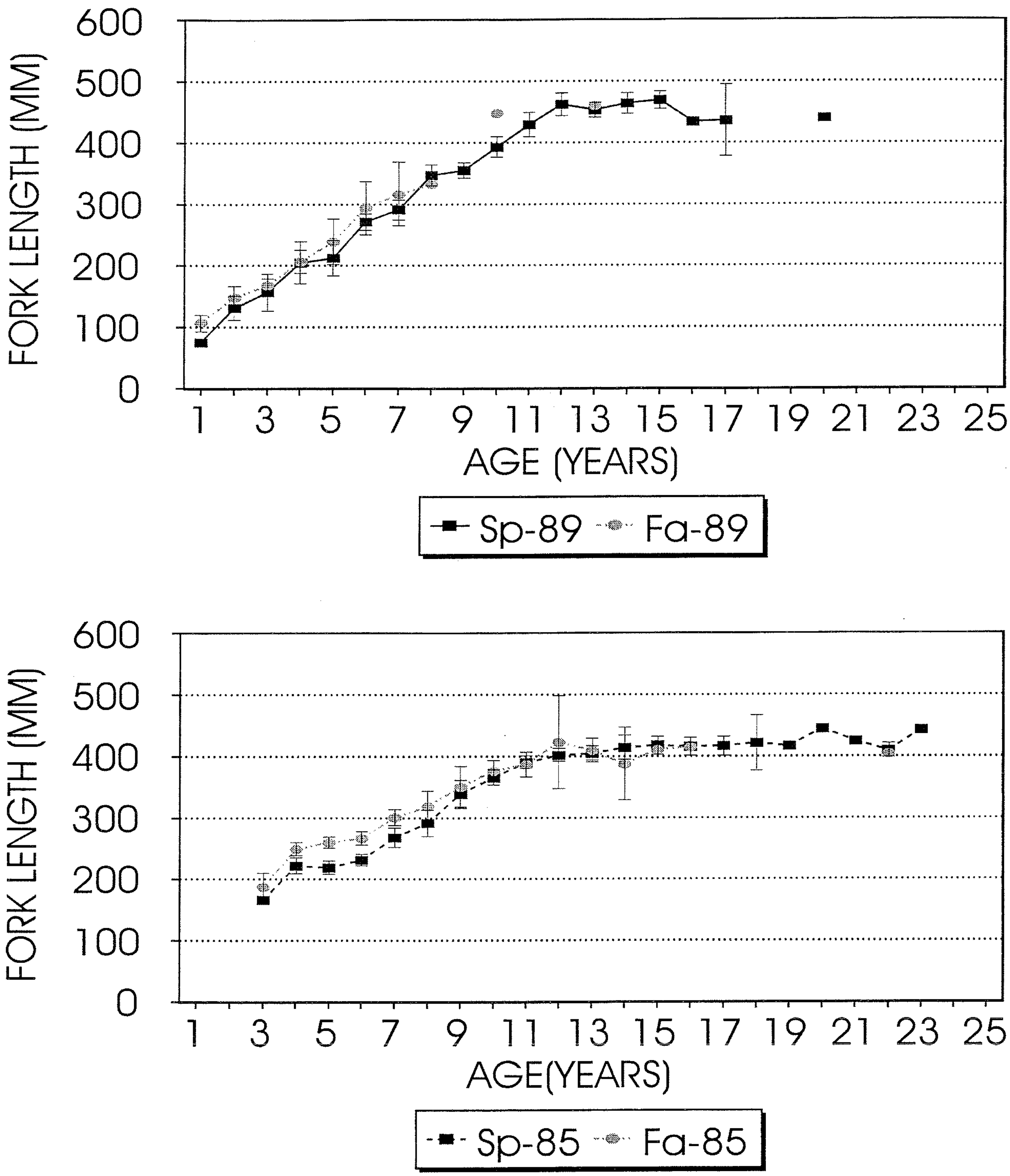


Fig. 3. Comparisons of growth (mean fork length at age and 95% confidence limits) of white sucker for spring and fall sampling periods in Lake 260 (top panel) and Lake 382 (bottom panel).

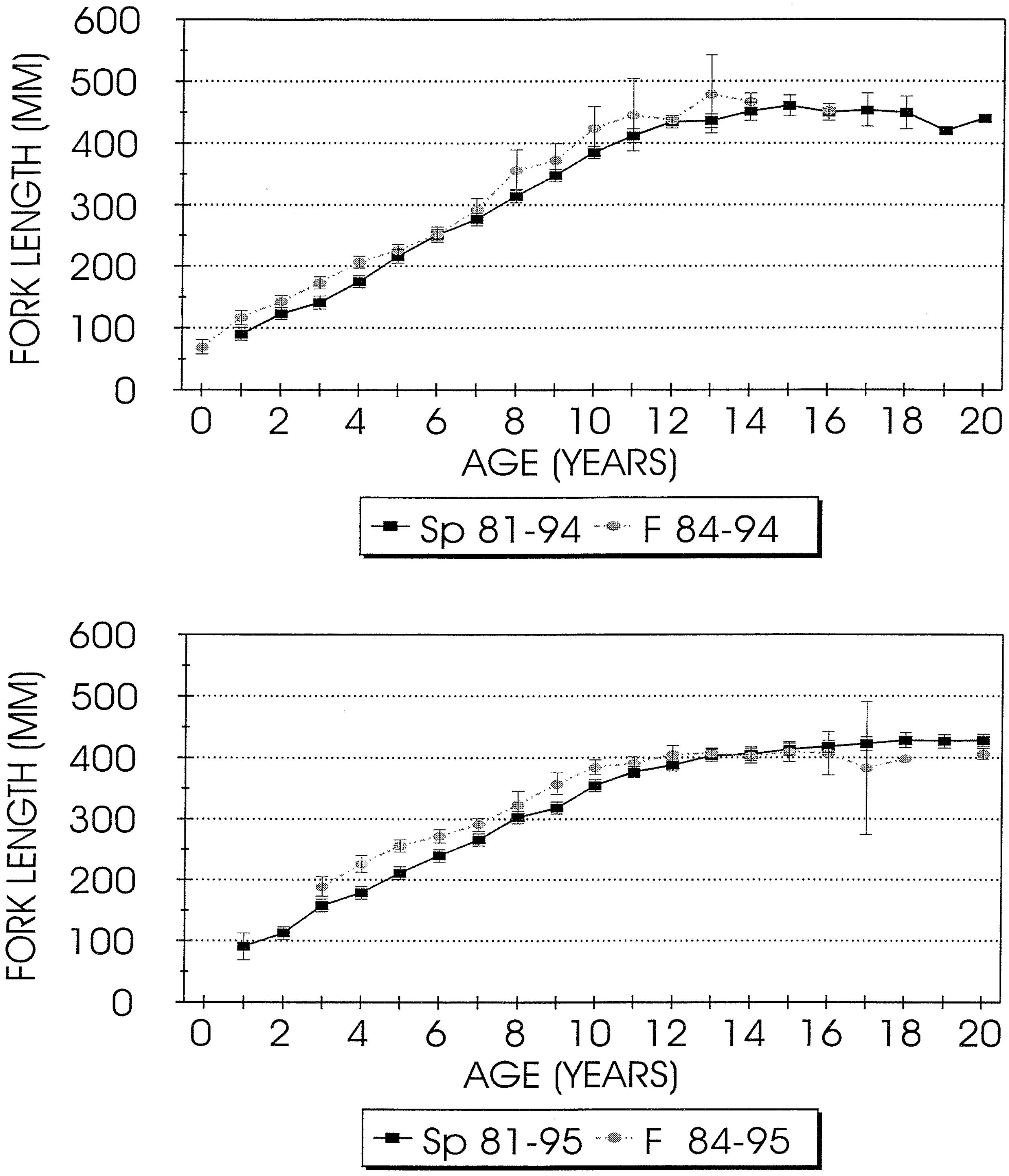


Fig.4. Comparisons of growth of white sucker for composite (multi-year) spring and fall sampling periods for Lake 260 (top panel) and Lake 382 (bottom panel).

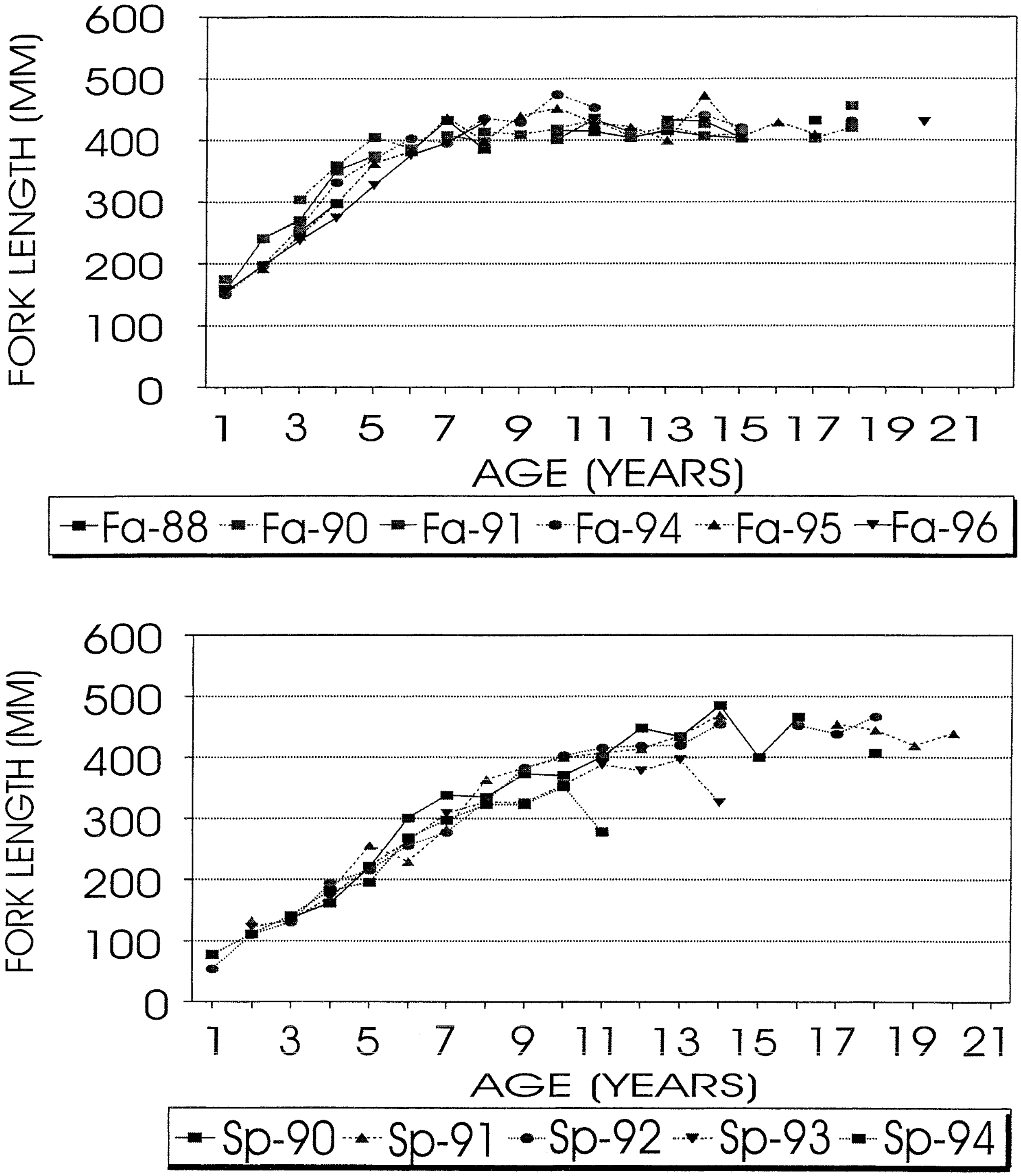


Fig. 5. Multi-year comparisons of growth of white sucker during fall and spring sampling periods in Lake 259 (top panel) and Lake 260 (bottom panel).

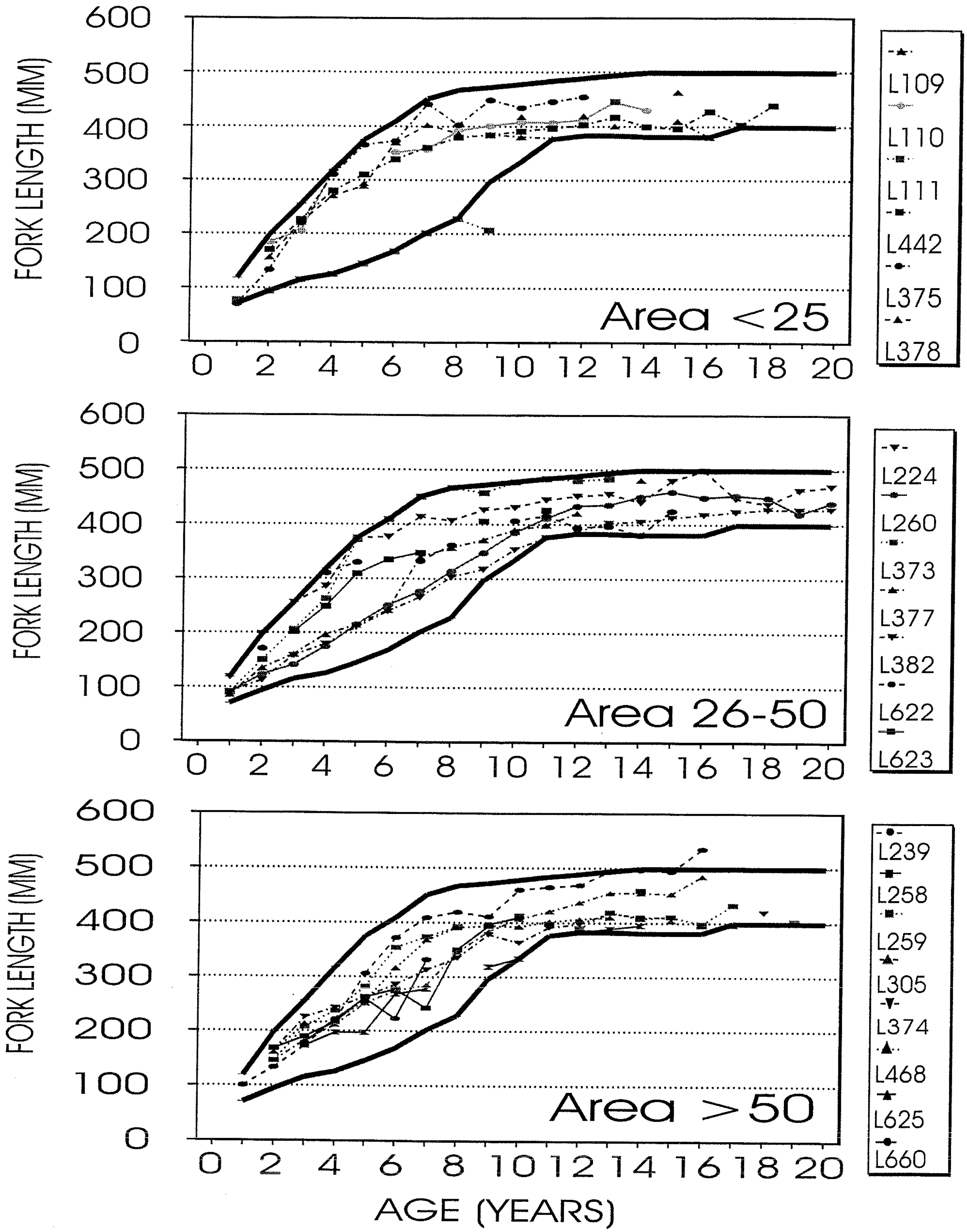


Fig. 6. Comparisons of growth of white sucker in lakes with surface areas < 25, 26-50, and > 50 hectares. Heavy lines denote upper and lower limits of growth of E.L.A. white sucker.

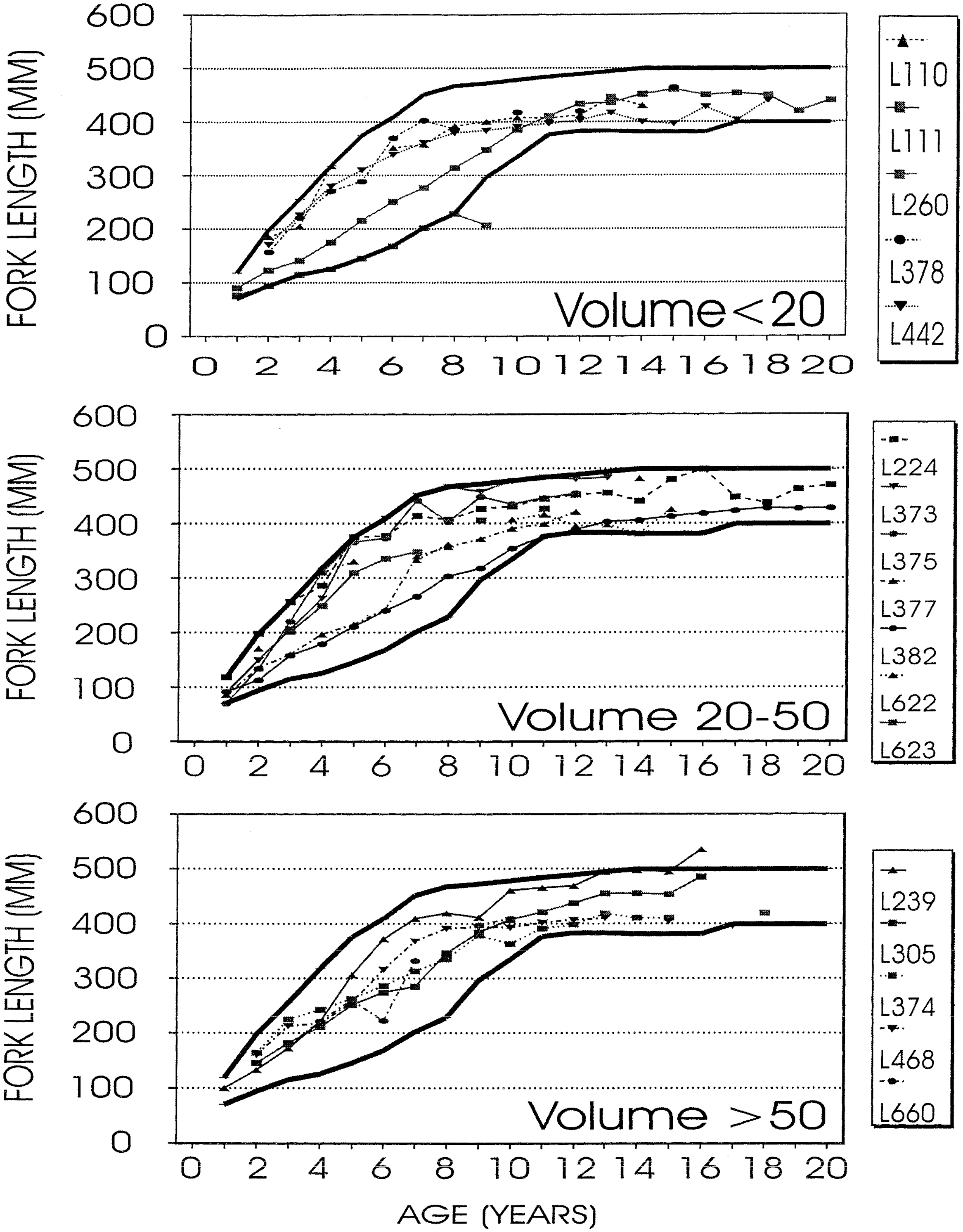


Fig. 7. Comparisons of growth of white sucker in lakes with volumes <20, 20-50, and >50 $10^5 m^3$. Heavy lines denote upper and lower limits of growth of E.L.A. white suckers.

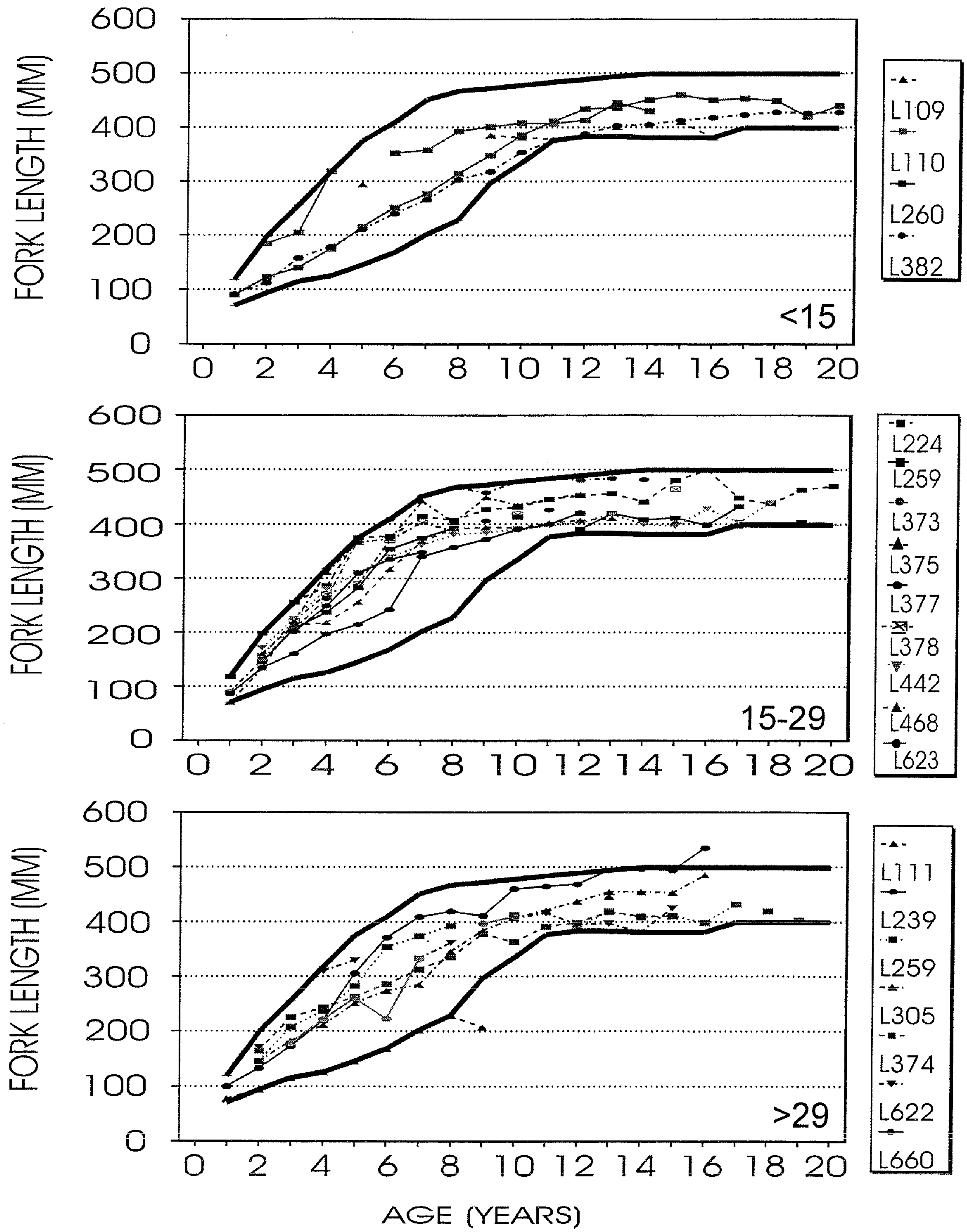


Fig. 8. Comparisons of growth of white sucker in lakes with maximum depths <15, 15-29, and >29 m. Heavy lines denote upper and lower limits of growth of E.L.A. white suckers.

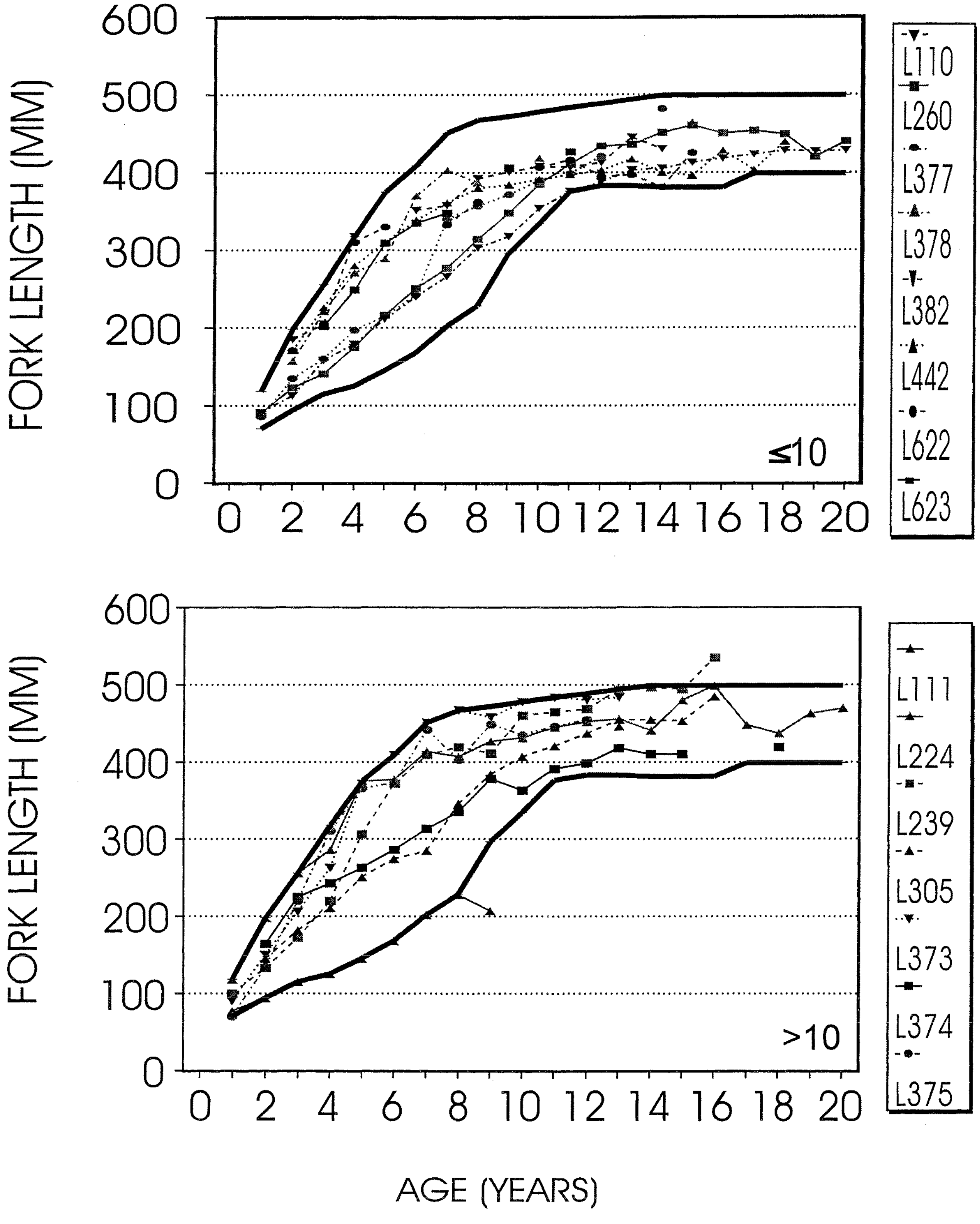


Fig. 9. Comparisons of growth of white sucker in lakes with mean depths ≤ 10 and > 10 m. Heavy lines denote upper and lower limits of growth of E.L.A. white sucker.

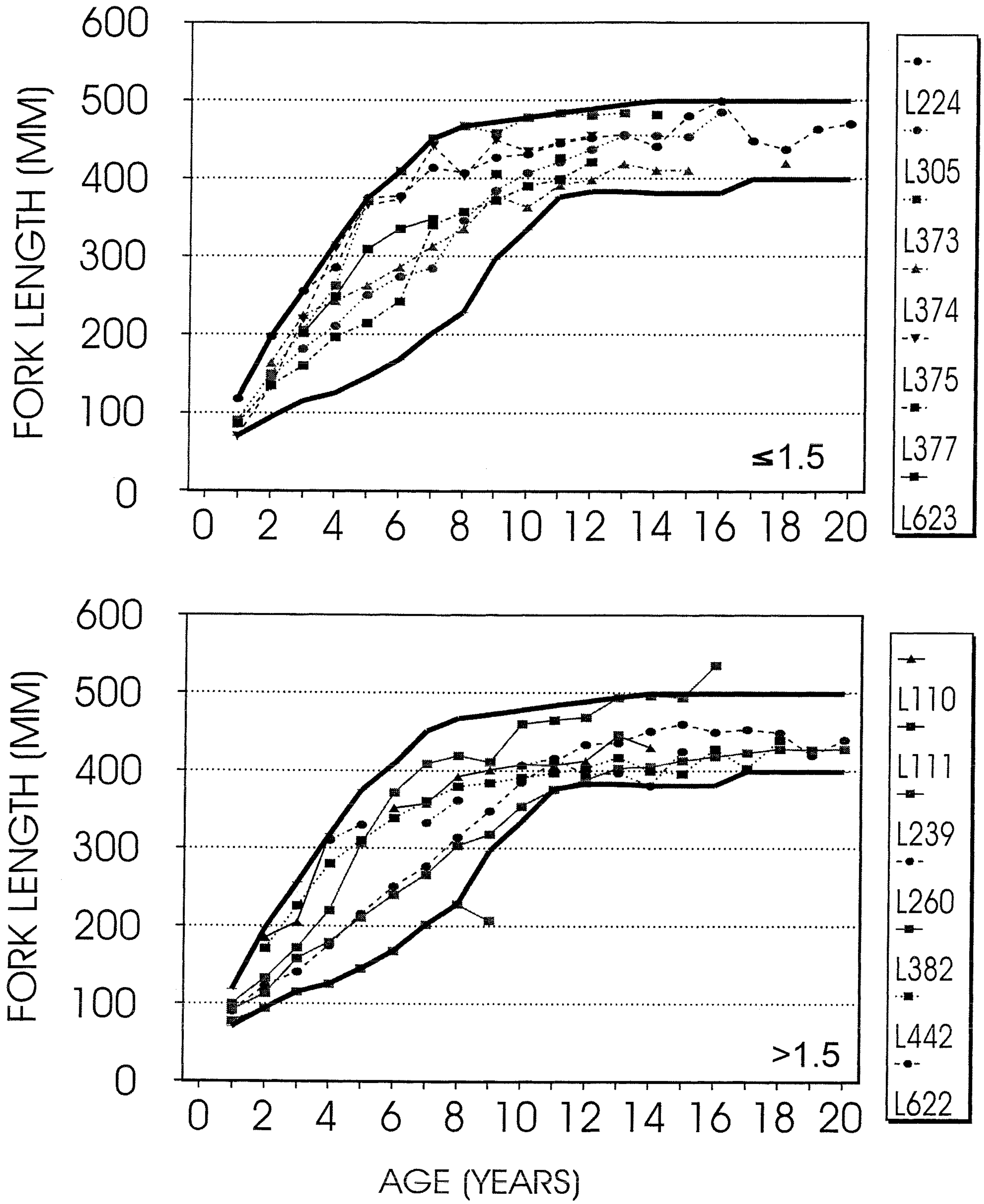


Fig. 10. Comparisons of growth of white sucker in lakes with chl a ≤1.5 and > 1.5 ug/L. Heavy lines denote upper and lower limits of growth of E.L.A. white sucker.

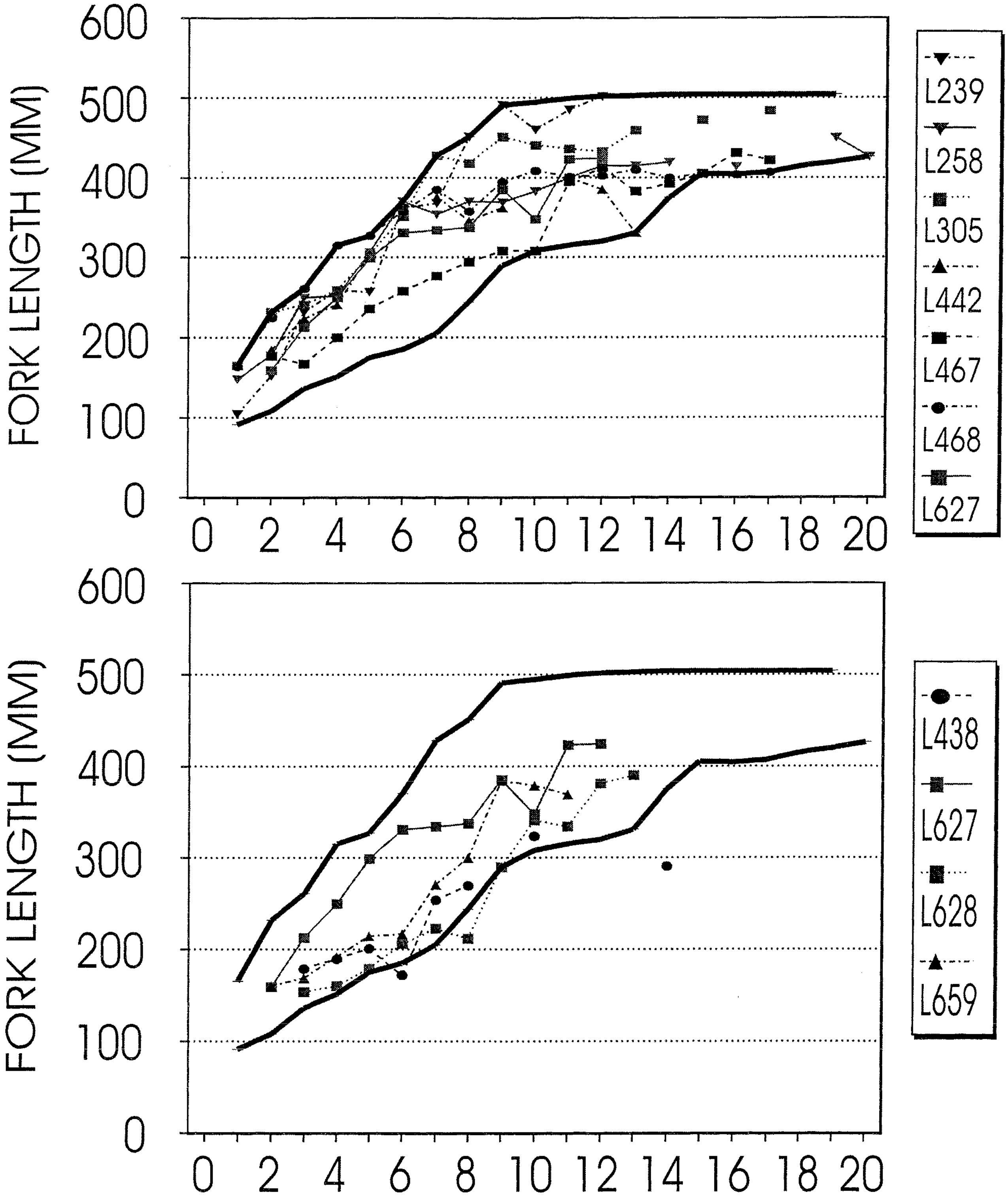


Fig. 11. Comparisons of growth of white sucker in lakes with fish predators (top panel) and lakes with no fish predators (bottom panel). Heavy lines denote upper and lower limits of growth of E.L.A. white suckers.

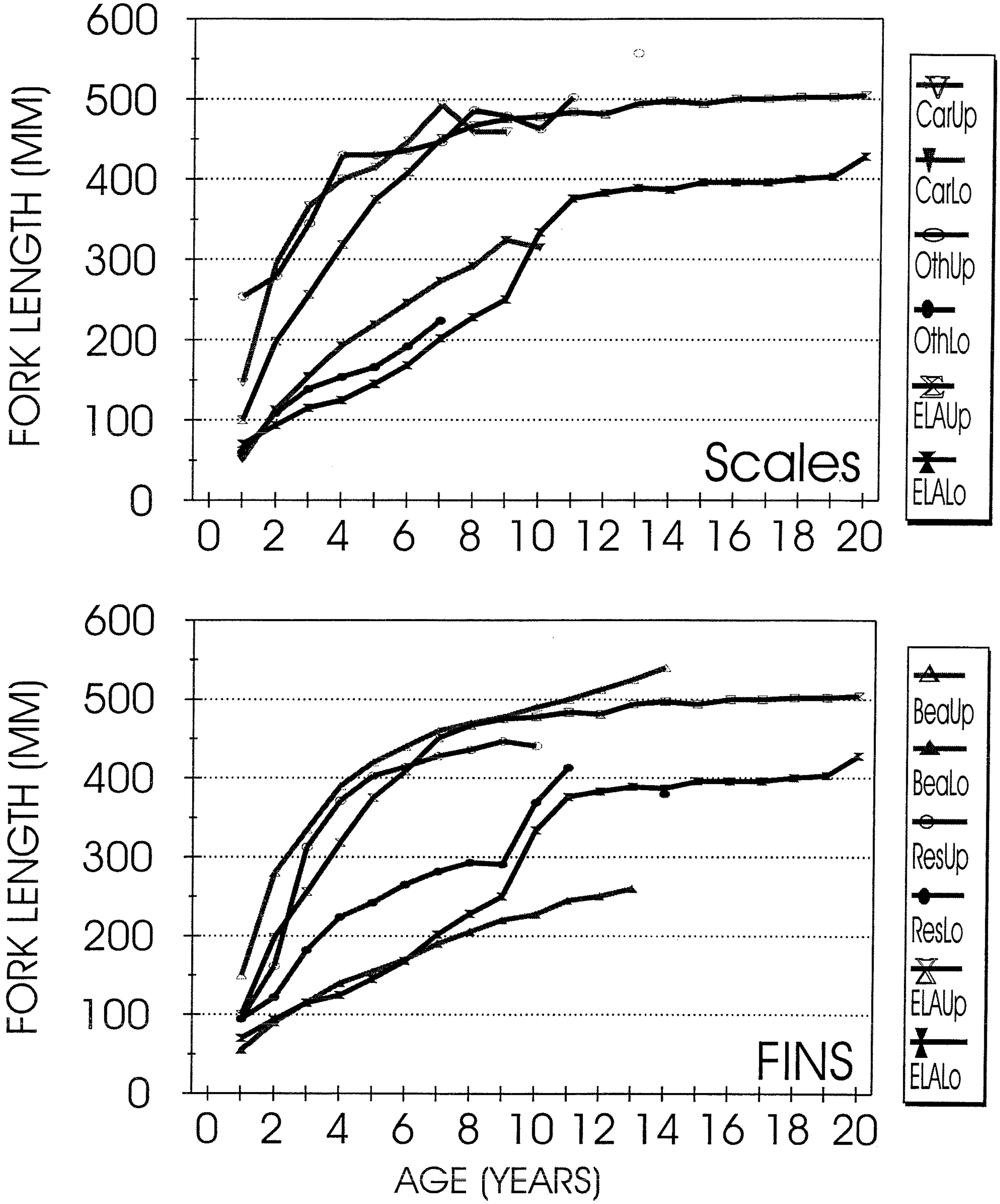


Fig. 12. Comparisons of upper and lower limits of growth of white sucker in E.L.A. lakes and in lakes listed in the scientific literature (Car-from Carlander 1969, Oth and Res-from various other authors, Bea-from Beamish 1973; see Appendix 3 for references). Ages in other lakes were determined from scales (top panel); and fins (bottom panel).

APPENDIX 1 A. Mean fork lengths at age (mm) for white sucker in lakes at the Experimental Lakes Area during spring sampling periods. Data for lakes marked with an * indicate single samples. All remaining lakes include data from multiple years.

AGE	L109*	L110	L111	L224	L239	L258	L259*	L260	L305	L373	L374
1			77	100	97			90		89	
2		185	94	166	137	168	145	123	145	150	164
3		205	115	214	168	189	207	141	181	206	225
4		318	125	284	216	216	237	175	224	268	243
5	294		145	370	260	262	282	216	252	371	263
6		352	168	379	373	277	354	251	292	406	286
7		358	202	410	412	243	374	277	309	451	313
8		392	228	401	413	350	393	314	344	470	335
9	385	401	207	414	418	394		348	382	458	378
10	381	408		414	459		413	385	406	478	363
11	378	407		442	466	398		411	420	481	391
12		413		446	477		390	434	436	481	398
13	401	445	446	456	494		419	436	450	489	418
14		430		441	497	459	408	451	457	500	410
15	410			480	494		411	460	455		410
16	381			499	535	395	398	450	461		
17				448			432	453	465		
18				437				449			419
19				463			403	420			
20				470				440			
Total N	18	127	85	777	222	53	64	1554	775	610	108

APPENDIX 1 A (continued)

AGE	L375	L377	L378*	L382	L442	L468	L622	L623	L625	L660
1	70	86		91						
2	134	135	157	113	155	162	171			
3	220	160	221	158	226	230		202	172	178
4	311	197	271	180	279	261	310	249	197	221
5	366	215	289	211	310	322	330	309	197	260
6	373	242	370	240	339	305		335	268	223
7	442	340	403	267	361	373	333	348	278	332
8	403	357	387	305	380	394	362			
9	449	372		323	384	388		406	319	397
10	435	390	418	345	391	392	407		334	409
11	446	399		376	397	406	416	426		
12	455	421	420	388	403	403	395		383	
13				403	417	406	397		389	
14		482		406	400	423	381		395	
15			464	413	396	398	425			
16				418	428					
17				424	403	396			396	
18				427	439					
19				427						
20				428						
Total N	246	296	43	2529	476	172	36	88	67	101

APPENDIX 1 B. Mean fork lengths (mm) at age for white sucker in lakes at the Experimental Lakes Area during summer sampling periods. Data for lakes marked with an * indicate single samples. All remaining lakes include data from multiple years.

AGE	L111	L239*	L258	L259*	L305	L377*	L438*	L442*
1	91	104	148	148	165			
2	108	152	178	178	232	154		185
3	136	232	250	250	241	186	179	224
4	151	259	252	242	259	219	190	241
5	170	257	306		303	273	201	304
6	178	362	370		351	283	172	
7	205	368	354	333	428		254	376
8	244	451	370		418	342	270	346
9	209	491	369		451	383		362
10		460	383		441	375	324	
11		485	400	435	436	394		400
12	313	502	415		433			385
13			415	446	459			331
14	412		419				291	
15					472			
16			414					
17					484			
18								
19			450	450				
20			426					
Total N	95	37	190	84	287	49	38	36

APPENDIX 1B (continued).

AGE	L467*	L468	L626*	L627*	L628*	L629*	L659*
1		164					
2	177	225	159	159		161	160
3	167	261	202	213	154	163	169
4	200	315	201	250	160	188	192
5	236	327	293	299	179		215
6	258	358	342	331	206	257	217
7	277	385	374	337	223	315	271
8	294	358	384	337	212	311	300
9	308	395	413	385	290	331	384
10	308	409		348	341	372	379
11	395	401		423	334		369
12	412	403	409	424	381	394	
13	383	410	432		390	385	
14	393	400	455				
15	405	405				423	
16	431	404					
17	422	407					
18							
19							
20							
Total N	118	468	91	115	32	61	48

APPENDIX 1 C. Mean fork lengths (mm) at age for white sucker in lakes at the Experimental Lakes Area during fall sampling periods. Data for lakes marked with an * indicate single samples. All remaining lakes include data from multiple years.

AGE	L111*	L224	L239	L240*	L258*	L259	L260
0		80	80				69
1	86	140	137		170	160	117
2	109	210	184	192	191	203	143
3	142	266	209	296	242	250	173
4	154	367	213	327	280	314	207
5	151	404	295	404	370	346	226
6		370	319	404		382	252
7	223	419	433	418		409	292
8		398	437	403	401	413	356
9	201	416	505	453		423	372
10		414	476	434		418	424
11		454	473	486		428	445
12		490	483	462		413	437
13						423	479
14		480				423	467
15						407	
16		440				429	452
17						412	
18						436	
19							
20						403	
Total N	24	228	95	25	44	488	369

APPENDIX 1 C (continued).

AGE	L305	L373	L379*	L382	L468	L625*	L634*
0		80					
1		132			148		
2	172	182	165		179	165	171
3		308	192	189	224	179	182
4	213	412	211	226	258	218	210
5	217	444	234	256	291	251	267
6		448	237	272	328	272	270
7	373	438	252	291	354	258	293
8		469	317	323	380	342	296
9	410	486	334	357	389	369	307
10	424	472	384	384	396	352	317
11	446	475	371	391	389	376	
12			453	405	387	361	345
13				407	407	399	370
14				403	418	380	397
15				409	434		380
16				407	413	390	372
17				383	397		354
18				398	418		
19							
20				406			
Total N	26	128	54	301	753	93	84

APPENDIX 1 D. Mean fork lengths at age (mm) for white sucker in lakes at the Experimental Lakes Area for individual years and seasons.

AGE	L109 Sp83	L110 Sp83	L110 Sp93	L111 Su82	L111 Su87	L111 Sp88	L111 Fa89	L224 Sp79	L224 Sp87	L224 Fa87	L224 Sp88	L224 Fa88	L224 Sp89	L224 Sp90	L224 Sp91
1					97	75	86		125	187		148		97	
2		185			108	94	109			208	209	223	147		159
3			205	167	126	115	142		284	317	284	400	186		
4			318	171	136	125	154	326		281	312	380	252	337	263
5	294			185	155	145	151		434		311		388	413	332
6		352	363	181	177	169		400	438			469	365	428	349
7		353	387	198	218	204	223	440	455				462	407	417
8		399	399		244	228		422	443				463		408
9	385	407	405		209	202	201	398	475	420	469		473	485	
10	381	416	400					432	383				472		
11	378	418	413						437				439	473	
12			445		313				432				495		
13	401					446		410	462					472	
14		430		412					442		473				
15	410								463				480		
16	381								499						
17									435			465	484		
18									437						
19													463		
20															
Total N	18	15	112	30	64	79	24	20	66	19	178	38	140	31	49

APPENDIX 1 D (continued).

AGE	L224 Sp92	L224 Sp95	L224 Fa95	L224 Sp96	L239 Su81	L239 Sp82	L239 Su83	L239 Fa83	L239 Sp88	L239 Fa88	L239 Sp89	L239 Sp90	L239 Sp93	L239 Sp95	L239 Fa95
1			110	63	104						103	97	110		
2		137	174	114	152		170	193	134	197			135	121	184
3	205	205	250	170	232		196	232			205		162	146	197
4	224	251	259	259	259		195	249	228	277	218	252	250	183	212
5	273			236	257			370		303		302	292		
6	372	370	322	436	362	414	369	349	332	339			314	371	343
7	391	407		396	368	409	467		446				374		461
8	395	390	378	382	451	430		451	403		373	455		423	443
9		379	391	393	491	412	472	512	406	498	420	405			
10				388	460	476		468	446		418	487	479	480	
11			431		485	517		491	442		475		476		
12					502				428	483	476	522			
13						499			488		452				
14									504		483				
15									494						
16									535						
17															
18															
19															
20															
Total N	26	53	107	149	37	41	14	18	46	23	24	12	16	14	18

APPENDIX 1D (continued).

AGE	L239 Sp96	L240 Fa90	L258 Sp81	L258 Su81	L258 Su82	L258 Sp85	L258 Su86	L258 Fa93	L259 Su86	L259 Sp87	L259 Fa88	L259 Fa89	L259 Fa90	L259 Fa91	L259 Fa92
1	80						148	170			159		175	156	
2		192	156			173	178	191	190	145		222		241	205
3	147	296	180			209	250	242		207	251		304	270	324
4	195	327	216		279		242	280	289	237	298		359	351	
5	222	404	245		306			370	363	282		338	405	375	378
6		404	259	328	373	347			378	354	382		387		
7	463	418	243	321	366	284	333		337	374	433			408	410
8	379	403	298	400	362			401		393	386		414	398	429
9	456	453	412	395	365	375							410		447
10	457	434		367	386				388	413	416	414	419	401	435
11	458	486	398	429	389		435		413		414		433	434	
12	450	462		415	416				423	390	404	405	406	413	441
13	492			422	405		446		431	419	416	431	423		419
14				414	425	459				408	407	418	407	427	
15			400						409	411	403		410		
16				432	395	390			406	398					
17									400	432	432		403		
18									418				420	456	
19							450		397	403					
20															
Total N	32	25	14	26	79	24	84	44	36	64	49	14	39	21	21

APPENDIX 1 D (continued).

AGE	L259 Fa93	L259 Fa94	L259 Fa95	L259 Fa96	L260 Sp81	L260 Fa84	L260 Sp85	L260 Fa85	L260 Sp86	L260 Sp87	L260 Sp88	L260 Fa88	L260 Sp89	L260 Fa89	L260 Sp90
1		151		155		113	99	130	94				75	107	
2	213	197	192	197	138	139	136	147	125	120	108		131	148	
3	267	257	245	237	151	179	152	168	146	137			156	167	137
4	365	332	297	274	245	210	188	192	160	165	170		204	206	162
5		370	363	327	226	224	226	207	194	195	221		212	239	220
6	366	403	382	376	267	244	240	240	243	140	246	268	271	294	301
7	412	396	437	396	271	286	256	281	269	272	283	303	291	316	338
8		436	399	430	346	377	296	373	276	288	322	320	347	333	335
9	424	430	440		377	435	384	409	424	322	331	360	355		373
10		475	452		378	389	404	464	422	293	376	411	393	448	370
11		453	428	436	455	458	429	418	418	415	395	460	429		401
12			422				468	437	452	427	440		462		448
13		431	400	433	432		439	489	415	427	447		453	460	434
14		441	473	431			451	466	447	437	434	468	464		485
15		420	405	403			416		485	434			469		400
16			429				460	452	430		467		434		466
17			410	404					478	507			436		
18		431													407
19									439						
20				430									440		
Total N	24	70	87	133	41	196	228	64	212	154	258	14	204	68	64

APPENDIX 1 D (continued).

AGE	L260 Fa90	L260 Sp91	L260 Sp92	L260 Sp93	L260 Sp94	L305 Fa80	L305 Su81	L305 Sp83	L305 Fa85	L305 Su86	L305 Sp89	L305 Sp90	L305 Sp91	L305 Fa91	L305 Sp92
1			54		78	140									
2	96	133	110	122	111	203	165	170		152			131	182	154
3			131	134	141		240	164	175	173			177	176	177
4	199	180	194	171	182	235	253	216	219	222	288	303	194	22 0	197
5	239	256	215	222	196	345	256	289	263	275		298	222	217	214
6		230	256	263	268		285	309	329	307		269			269
7	306	283	277	308	297	377	414		379	341	341	273	212		285
8	345	364	328	327	323	352	447	217		394		382	246		362
9	360	383	383	326	323	422	414				410	414	306	386	301
10	386	400	403	355	352	461	452	310		421	421	421	235		404
11		407	416	388	278	433	440	439			432	407	428	442	411
12		414	419	378		359	433				415	480	458		429
13		436	420	397			428		458	447			462		439
14		469	455	326			459					485			
15									457				490		453
16			453				472						481		
17		455	439												
18		445	467				484								
19		420						488							
20		440													
Total N	17	52	112	157	73	22	226	154	62	68	35	112	41	13	119

APPENDIX 1 D (continued).

AGE	L305 Sp93	L305 Sp94	L305 Sp95	L305 Sp96	L373 Sp87	L373 Fa87	L373 Sp88	L373 Fa88	L373 Sp89	L373 Sp90	L373 Sp91	L373 Sp92	L373 Sp93	L373 Sp94	L373 Sp95
1					104	132	80	129	88	85	75	89			84
2	132		182		132	182	132	169	142	144	160	167		151	148
3	184	162	216	163	206	287	183	210	184	190	222	240	218	215	216
4	213	212	207	259	280	412	247	229	236	248	243	277	301	262	262
5	223	250	283	253	425	444	439		278	296	291	299	330		345
6	272	259	281	335			441	453	445				327		365
7	304	357	254	337				418	457	457	392		495		467
8	365		336	322						463			480		446
9	367	382	369	372				476			433		490		440
10	331	403	391	397		443	481						490	462	485
11	437	437	391	418									463		
12	466	448	395	434		415									485
13	477	467	468	424											484
14		452	401	465											
15		464	448	477											
16				470											
17															
18															
19															
20															
Total N	134	22	105	162	92	58	101	102	254	73	72	40	40	21	118

APPENDIX 1 D (continued).

AGE	L374 Sp83	L375 Fa88	L375 Sp89	L375 Sp90	L375 Sp91	L375 Sp92	L375 Sp93	L377 Sp82	L377 Su84	L377 Sp90	L378 Sp82	L379 Fa80	L382 Sp81	L382 Fa84	L382 Sp85
1		204		78	55					86					
2	164	364			131	138	139	173	154	127	157	165	169		
3	225	409	338	225	199	208	202	188	186	156	221	192	169	210	166
4	243		419	255	206	377	275	242	219	197	271	211	213	215	222
5	263		423	374	322	350	388		273	255	289	234	245	225	219
6	286			272	415		437		283	248	370	237	275	282	231
7	313			384	418	453	472	359		376	403	252	314	272	268
8	335			365			454	382	342	356	387	317	356	334	292
9	378						449	376	383	355		334	362	378	339
10	363				435			400	375	407	418	384	386	397	366
11	391					446		405	394			371	410	405	390
12	398						455			421	420	453	431	422	402
13	418												409	448	405
14	410												414		414
15	410										464		413		418
16													400		416
17															417
18	419														422
19															417
20															445
Total N	108	31	23	39	56	27	101	20	49	145	43	54	212	74	297

APPENDIX 1 D (continued).

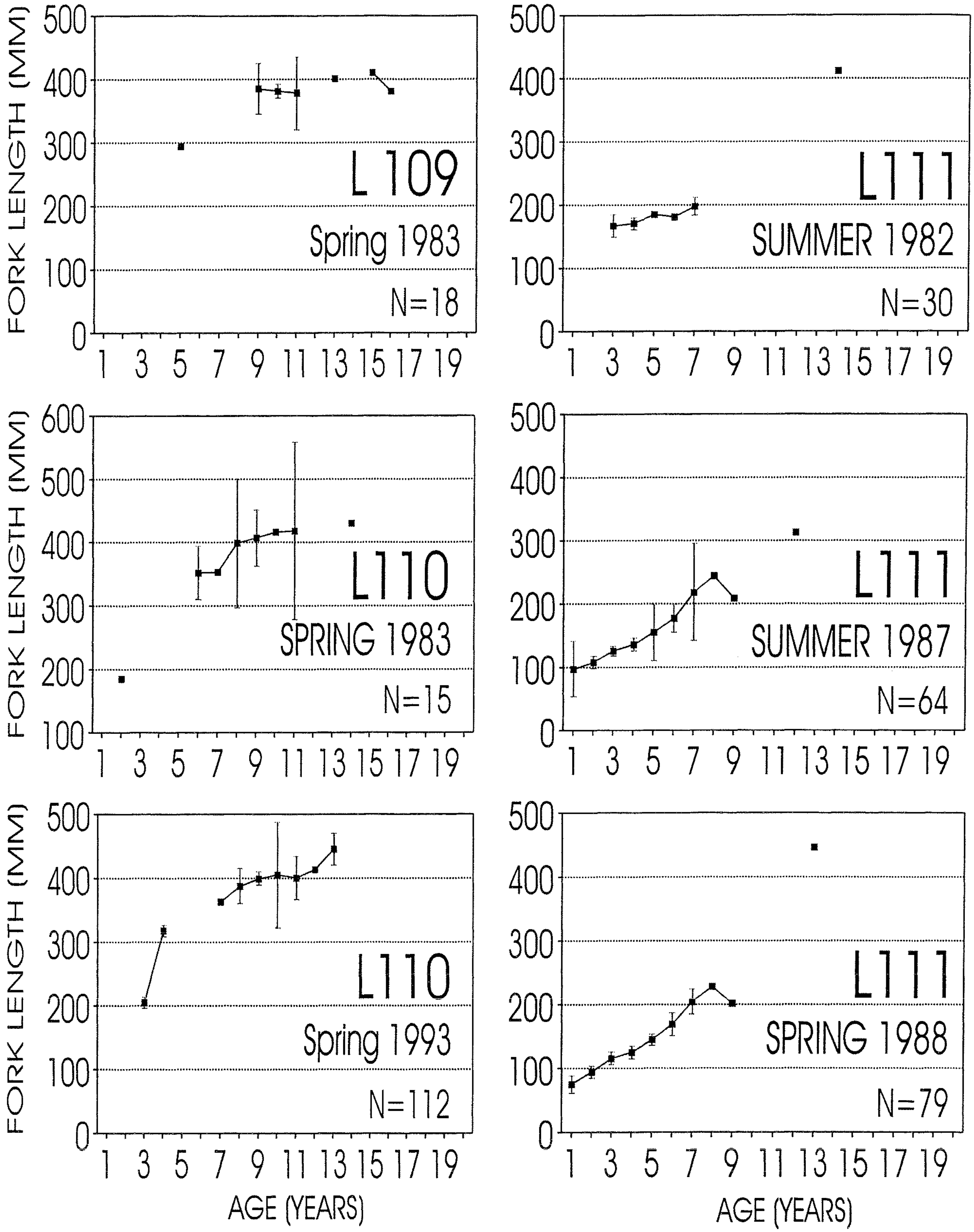
AGE	L382 Fa85	L382 Sp86	L382 Sp87	L382 Sp88	L382 Sp89	L382 Sp90	L382 Sp91	L382 Sp92	L382 Sp93	L382 Sp95	L438 Su83	L442 Su82	L442 Sp90	L442 Sp91	L442 Sp92
1			91												123
2		120	99	106						171		185	146	200	137
3	187			131	144	147			168	196	179	224	235		228
4	249	180	146		161	177	172			205	190	241	275	289	264
5	260	197	198	217	205	187	215	204		228	201	304	314	306	308
6	267	222	209	243	212		247	247	228	245	172		350	341	328
7	301	244	300	235	267		355	284	268	299	254	376	369	369	356
8	319	289	297	318	257	284	334		299	323	270	346	381	382	378
9	351	282	339	314	327	333	377	384		313		362	395	380	385
10	377	364	356	345	326	357	383	379	400	350	324		386	399	384
11	387	389	357	361	356	369	376	399	404	397		400	395	380	414
12	423	392	381	379	364	360	402	395	402	420		385	411	400	403
13	410	405	396	396	392	357	406	419	414	417		331	429	440	423
14	388	412	391	399	402	380	401	399	412	428	291		377	396	405
15	411	421	396	406	406	420	410	407		420			408	405	421
16	415		409	420	422	408	428	432	411	439				413	424
17			398	427	431	425	411	433	466	440					
18			430	412		399	434	443						458	432
19				412				432		427					
20			387			414	424	432		452					
Total N	153	309	246	218	205	163	145	115	141	161	38	36	137	110	106

APPENDIX 1 D (continued).

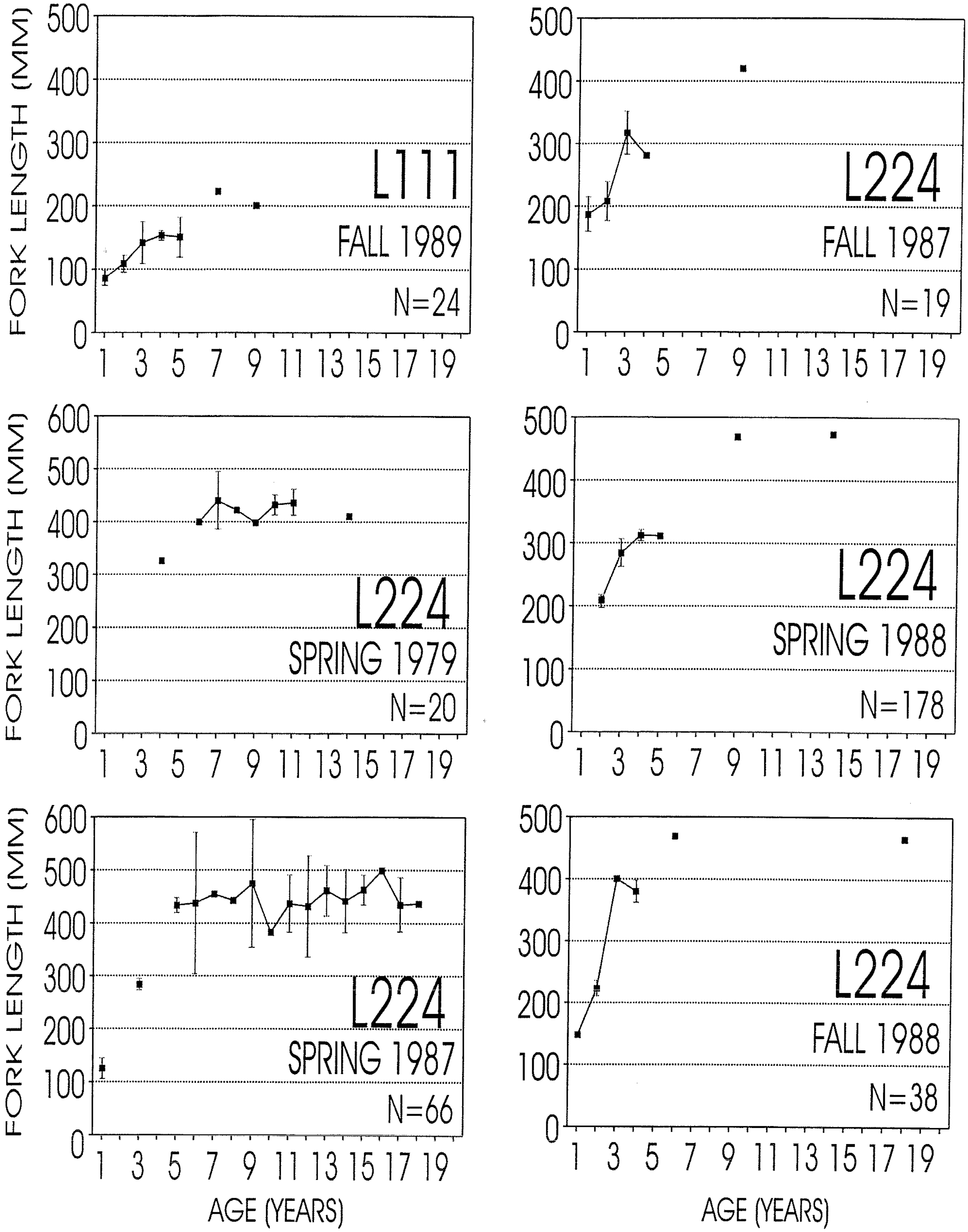
AGE	L442 Sp94	L442 Sp95	L467 Su81	L468 Wi78	L468 Su81	L468 Fa81	L468 Fa83	L468 Su84	L468 Sp85	L468 Su86	L468 Fa88	L468 Fa89	L468 Fa90	L468 Fa91	L468 Fa92
1											148				
2		189	177		166	175	154	166	160	163	206	179	177	181	188
3	154	243	167		221	243	253	237	213	217	234	221	220	204	228
4	240	282	200		253	280	362	287	218	249	267	253	258	259	180
5	285	319	236		309	309	325	339	255	279	298	267	333	294	300
6		344	258	345		371	278	315	316	330	355	336	303	344	347
7	354	369	277	357	331	395	405	391	368	373		307	349	353	363
8	365	380	294	387	385	395		397	391	380	405	361		373	375
9	357	383	308	376	343	392	405	386	394	353	417	387	399	398	379
10	303	395	308	378	395	424		391	393	400	391				375
11		411	395	388		385		409	402	409				406	401
12			412	400		423	387	399	407	405	425	397			
13	355		383	423		411	414	397	410	409		413		429	428
14		396	393			422	418	423		396		385	426		
15		386	405	433				396	404	406	425			439	
16			431							405		413			
17	397		422				392		396	404			401		
18						395				407	444		446		
19															
20															
Total N	26	82	118	21	61	126	26	98	74	77	70	86	56	61	56

APPENDIX 1 D (continued).

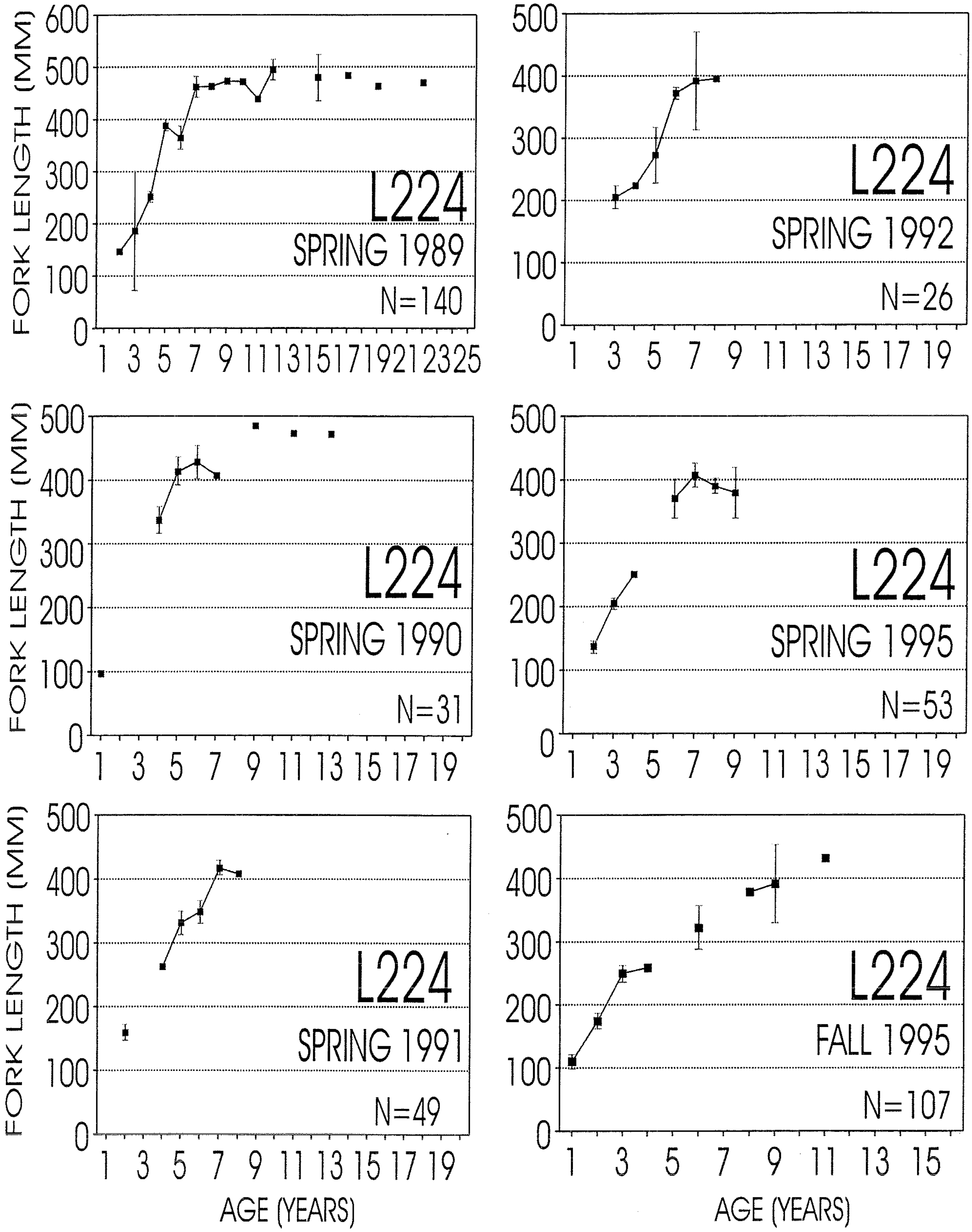
AGE	L468 Fa93	L468 Fa94	L468 Fa95	L468 Fa96	L622 Sp83	L623 Sp83	L625 Sp83	L625 Fa90	L626 Su82	L627 Su82	L628 Su82	L629 Su82	L634 Fa81	L659 Su83	L660 Sp83
1															
2	167	172	187	174	171			165	159	159		161	171	160	
3	214	217	230	216		202	172	179	202	213	154	163	182	169	178
4	253	251	257	244	310	249	197	218	201	250	160	188	210	192	221
5	298	279	316	287	330	309	197	251	293	299	179		267	215	260
6	303	257	337	322		335	268	272	342	331	206	257	270	217	223
7	346		334	353	333	348	278	258	374	334	223	315	293	271	332
8	372	399	382	381	362			342	384	337	212	311	296	300	
9	389	383	382	392		406	319	369	413	385	290	331	307	384	397
10	427	388	394	397	407		334	352		348	341	372	317	379	409
11	432		406	391	416	426		376		423	334			369	
12			324	387	395		383	361	409	424	381	394	345		
13					397		389	399	432		390	385	370		
14					381		395	380	455				397		
15					425							423	380		
16								390					372		
17							396						354		
18															
19															
20															
Total N	60	56	125	93	36	88	67	93	91	115	32	61	84	48	101



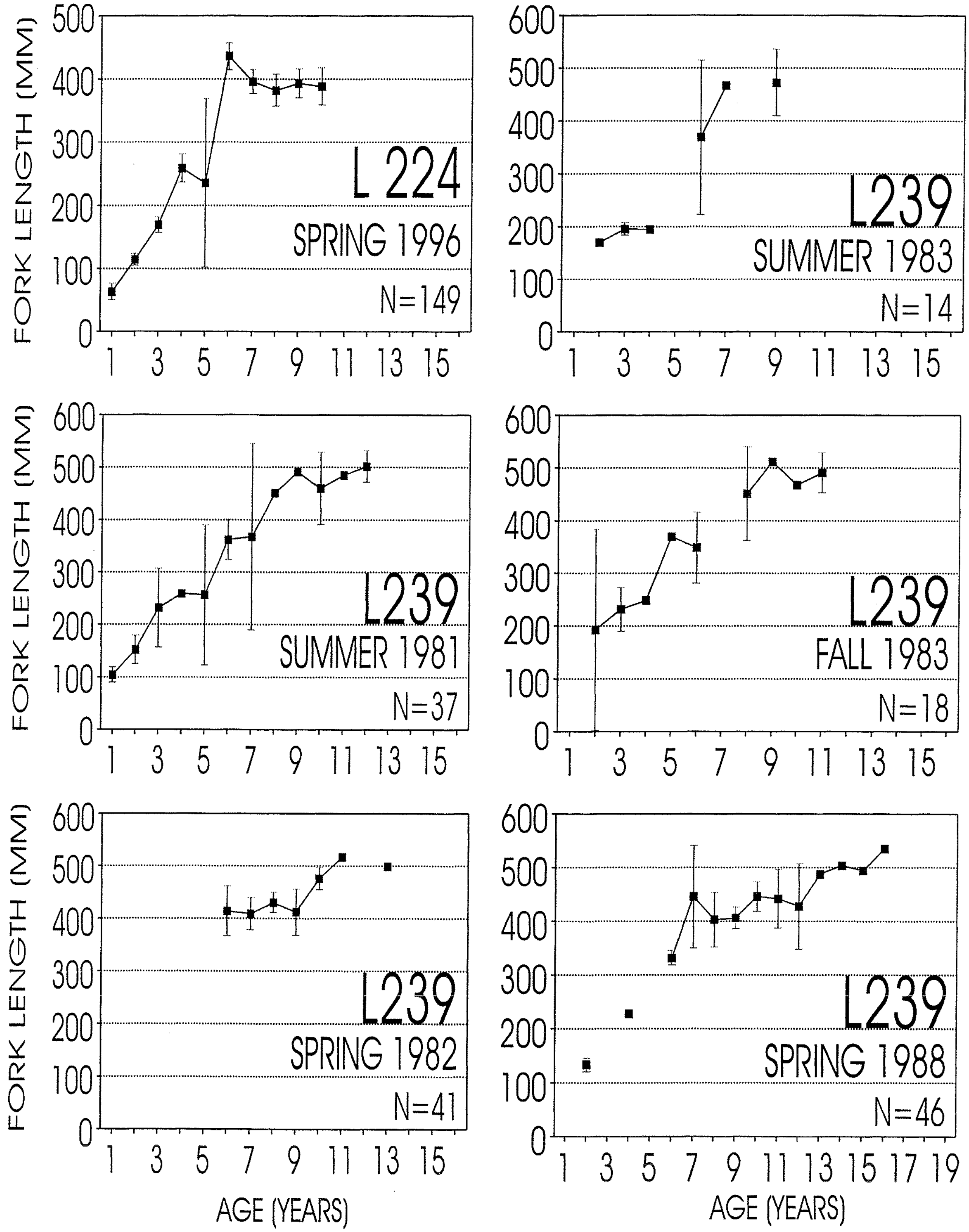
APPENDIX 2, Fig. 1a. Growth (fork length at age) of white sucker in Lakes 109,110, and 111 during various seasons and years.



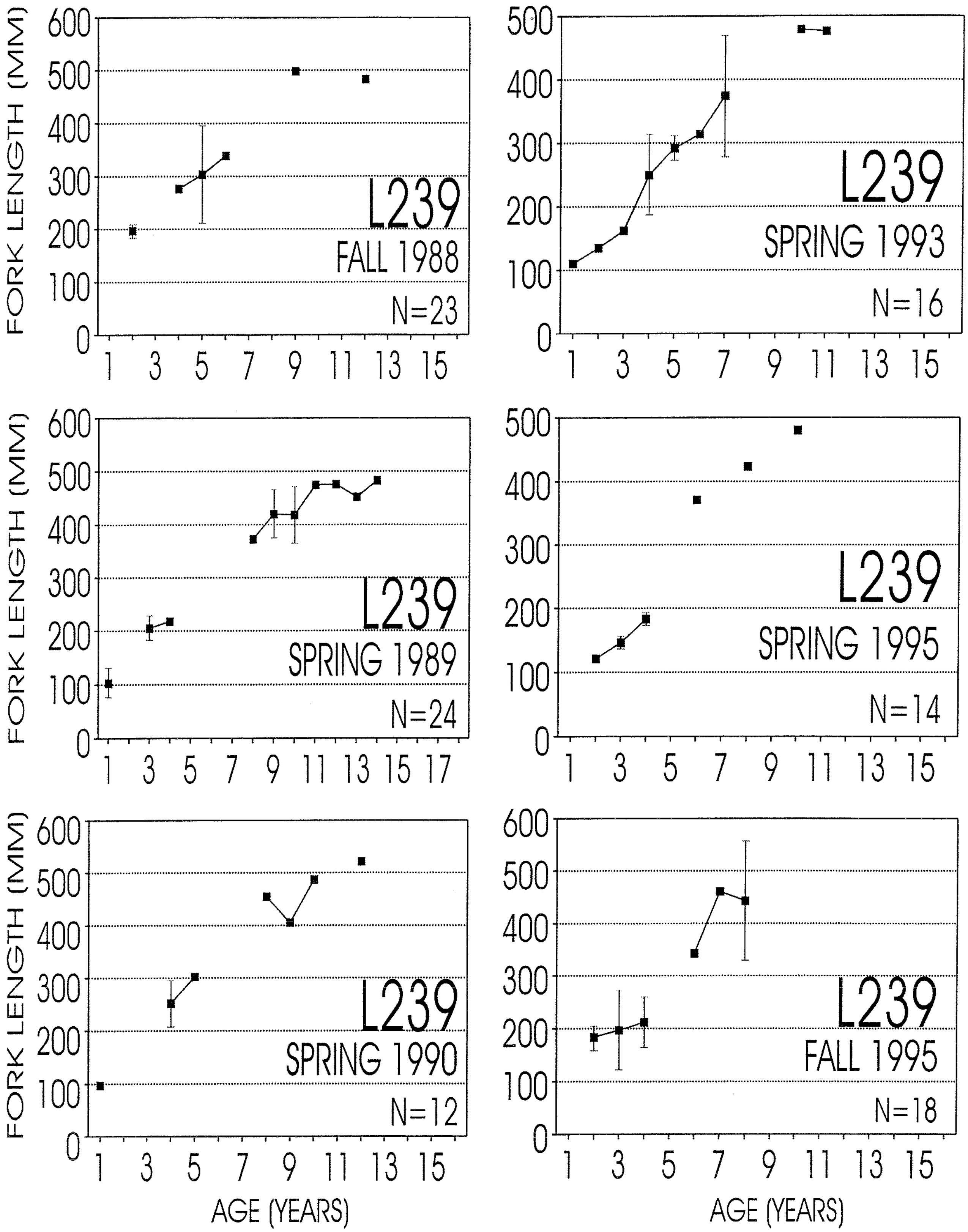
APPENDIX 2, Fig. 1b. Growth (fork length at age) of white sucker in Lakes 111 and 224 during various seasons and years.



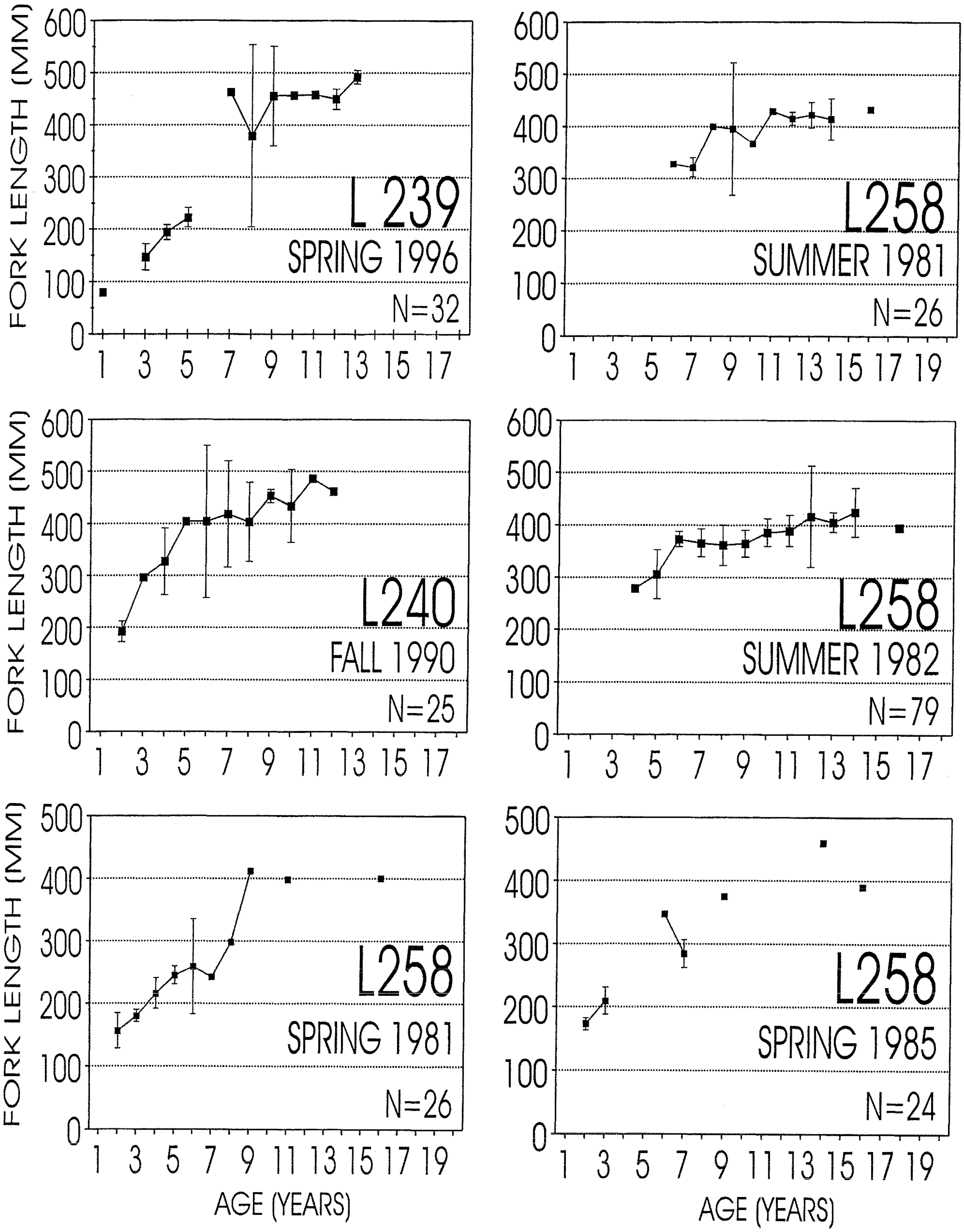
APPENDIX 2, Fig. 1c. Growth (fork length at age) of white sucker in Lake 224 during various seasons and years.



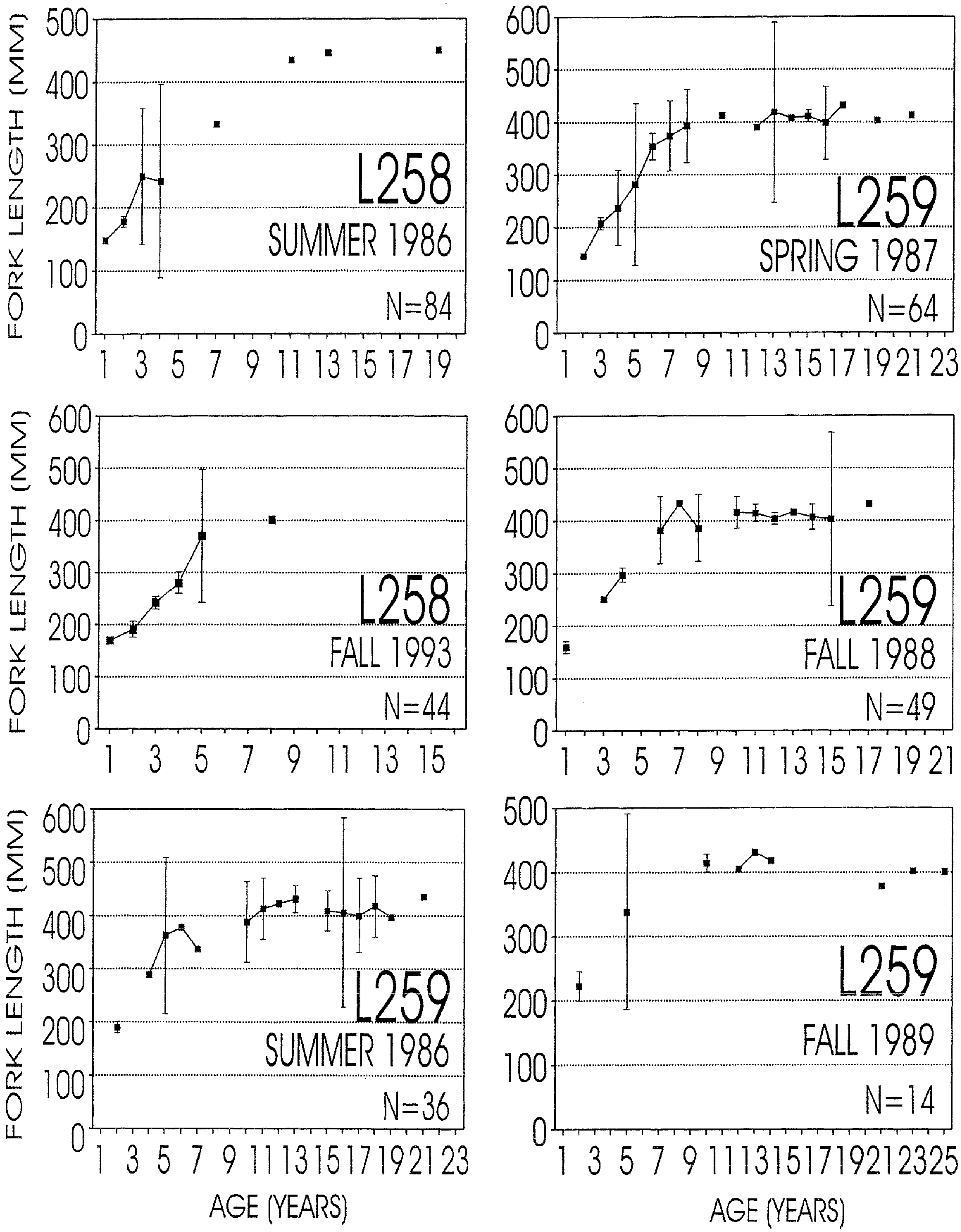
APPENDIX 2, Fig. 1d. Growth (fork length at age) of white sucker in Lakes 224 and 239 during various seasons and years.



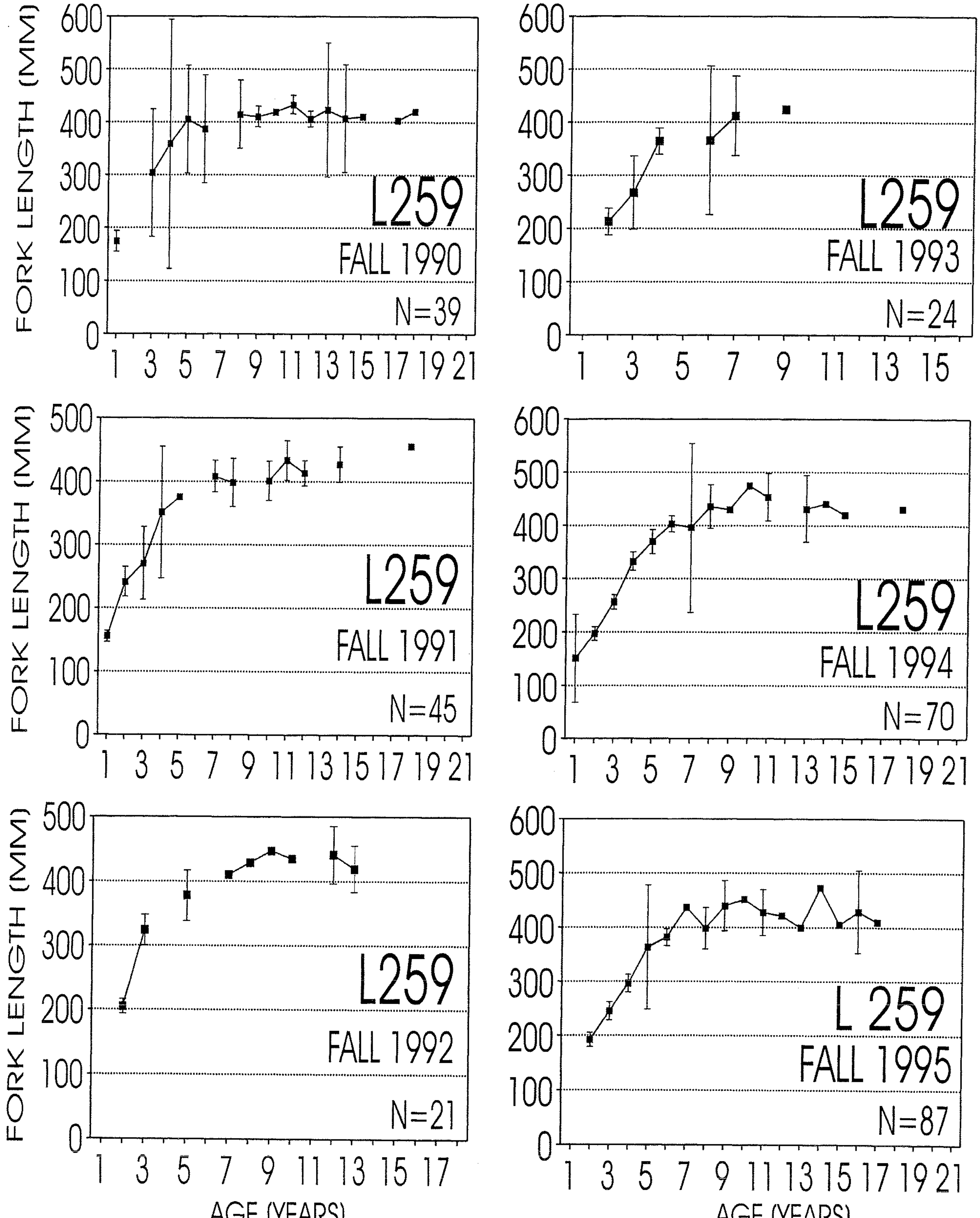
APPENDIX 2, Fig. 1e. Growth (fork length at age) of white sucker in Lake 239 during various seasons and years.



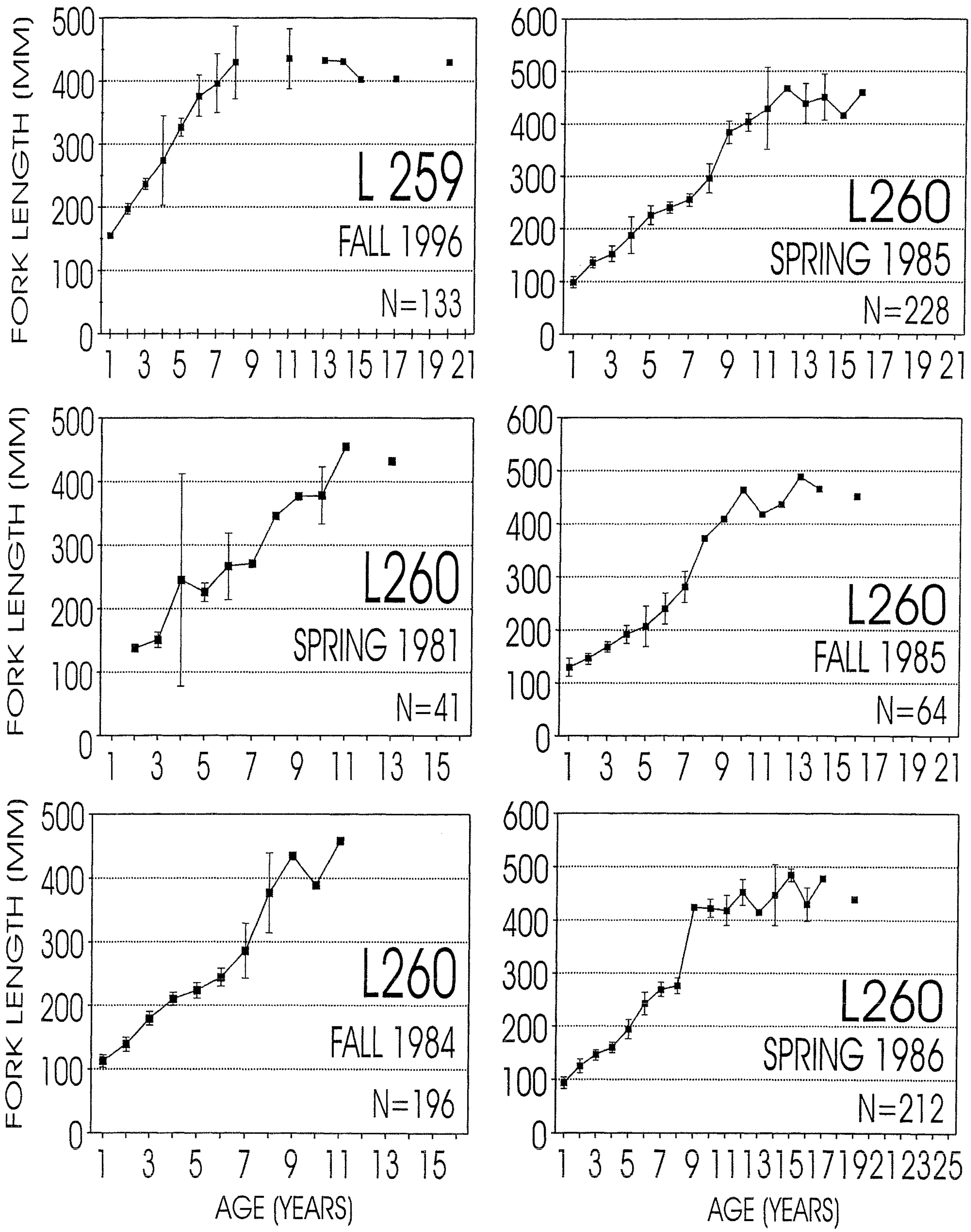
APPENDIX 2, Fig. 1f. Growth (fork length at age) of white sucker in Lakes 239, 240, and 258 during various seasons and years.



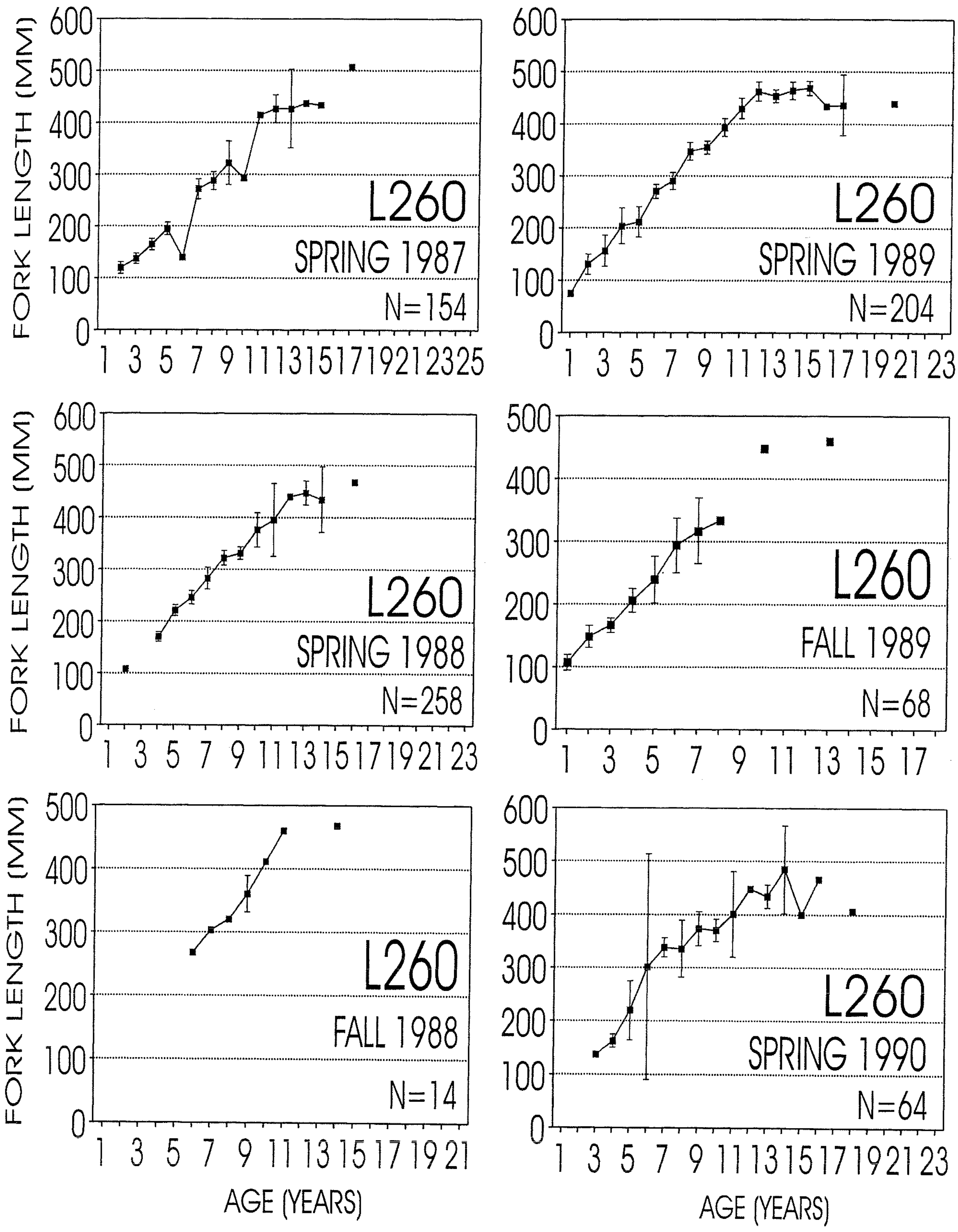
APPENDIX 2, Fig. 1g. Growth (fork length at age) of white sucker in Lakes 258 and 259 during various seasons and years.



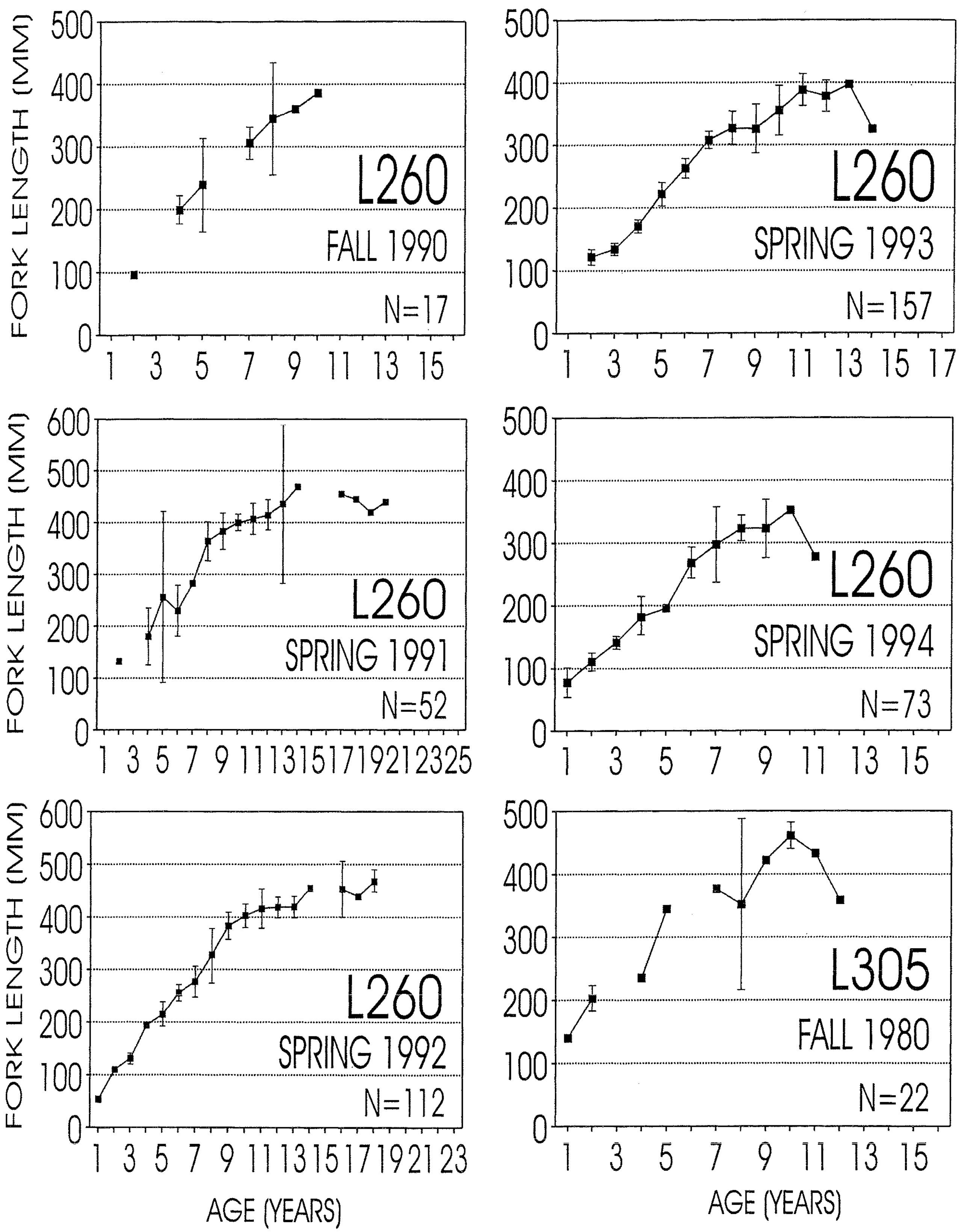
APPENDIX 2, Fig. 1h. Growth (fork length at age) of white sucker in Lake 259 during the fall season in various years.



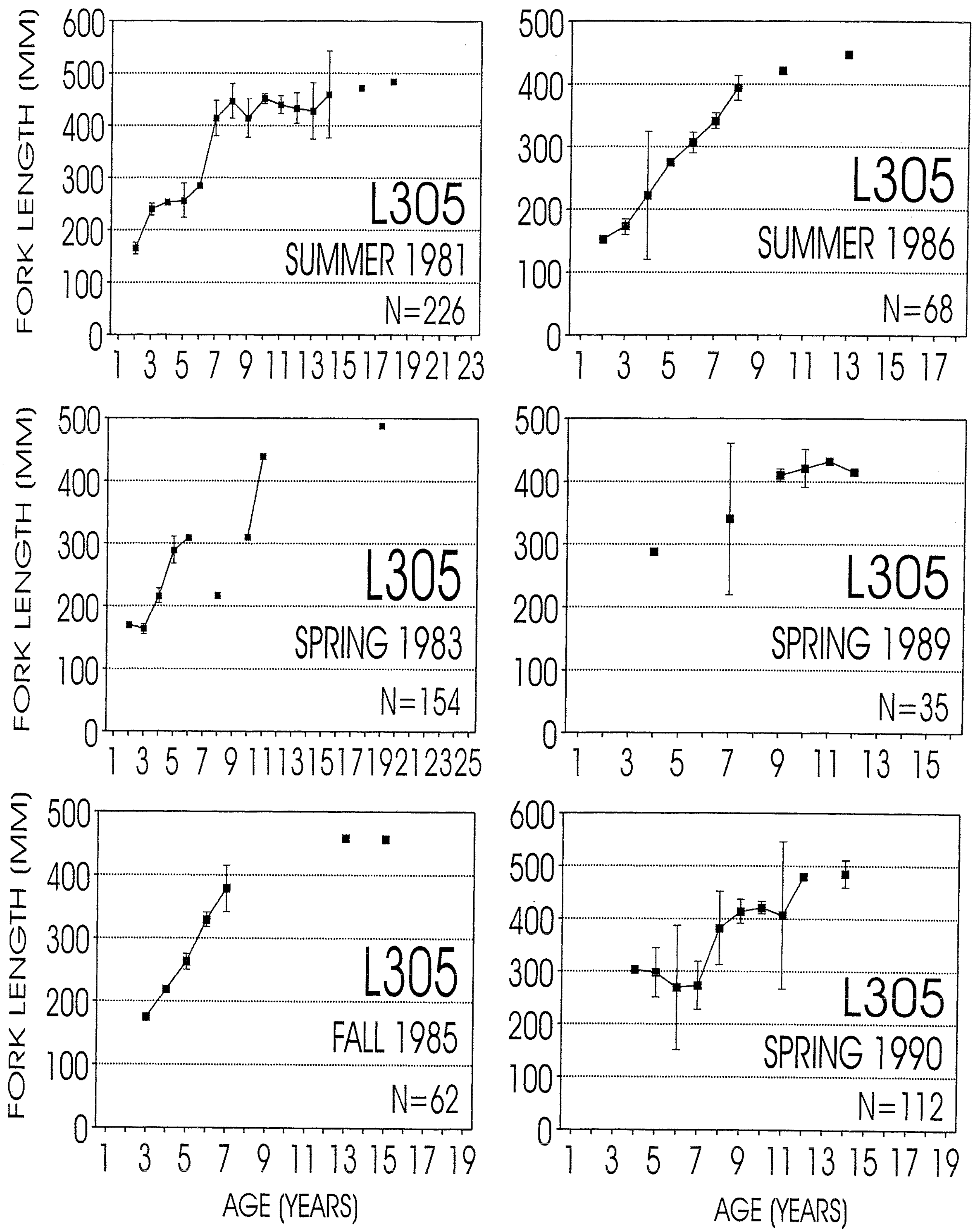
APPENDIX 2, Fig. 1i. Growth (fork length at age) of white sucker in Lakes 259 and 260 during various seasons and years.



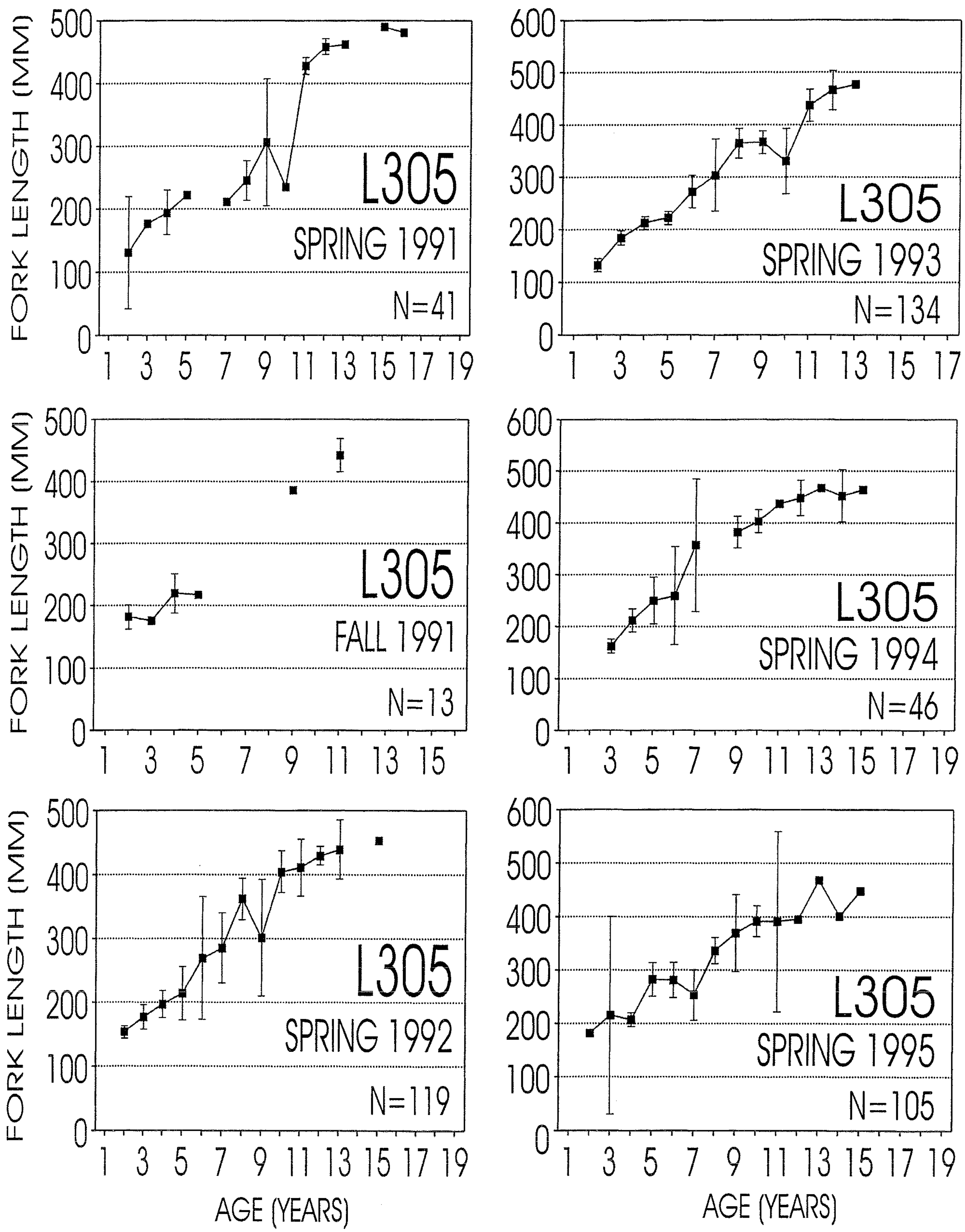
APPENDIX 2, Fig. 1j. Growth (fork length at age) of white sucker in Lake 260 during various seasons and years.



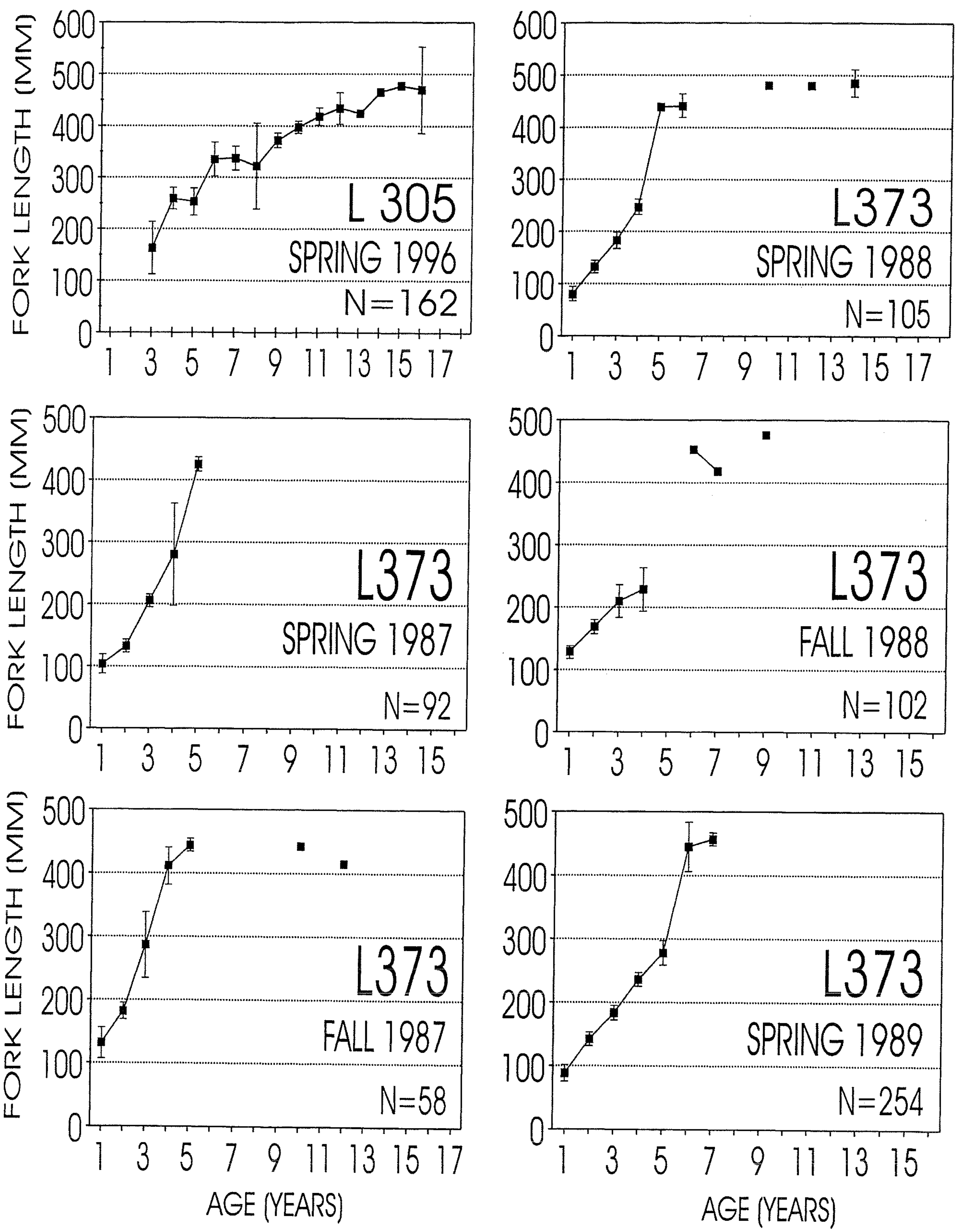
APPENDIX 2, Fig. 1k. Growth (fork length at age) of white sucker in Lakes 260 and 305 during various seasons and years.



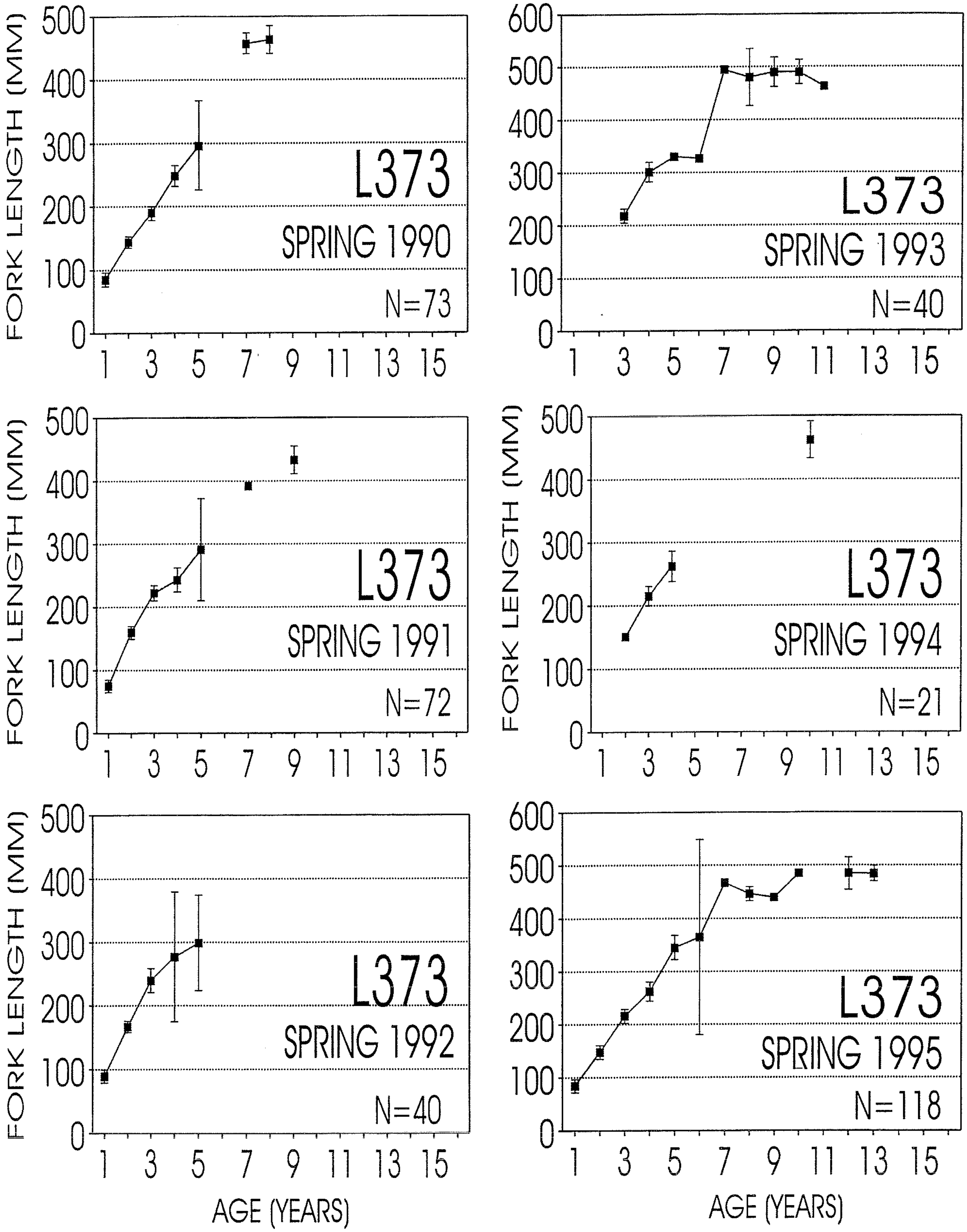
APPENDIX 2, Fig. 1l. Growth (fork length at age) of white sucker in Lake 305 during various seasons and years.



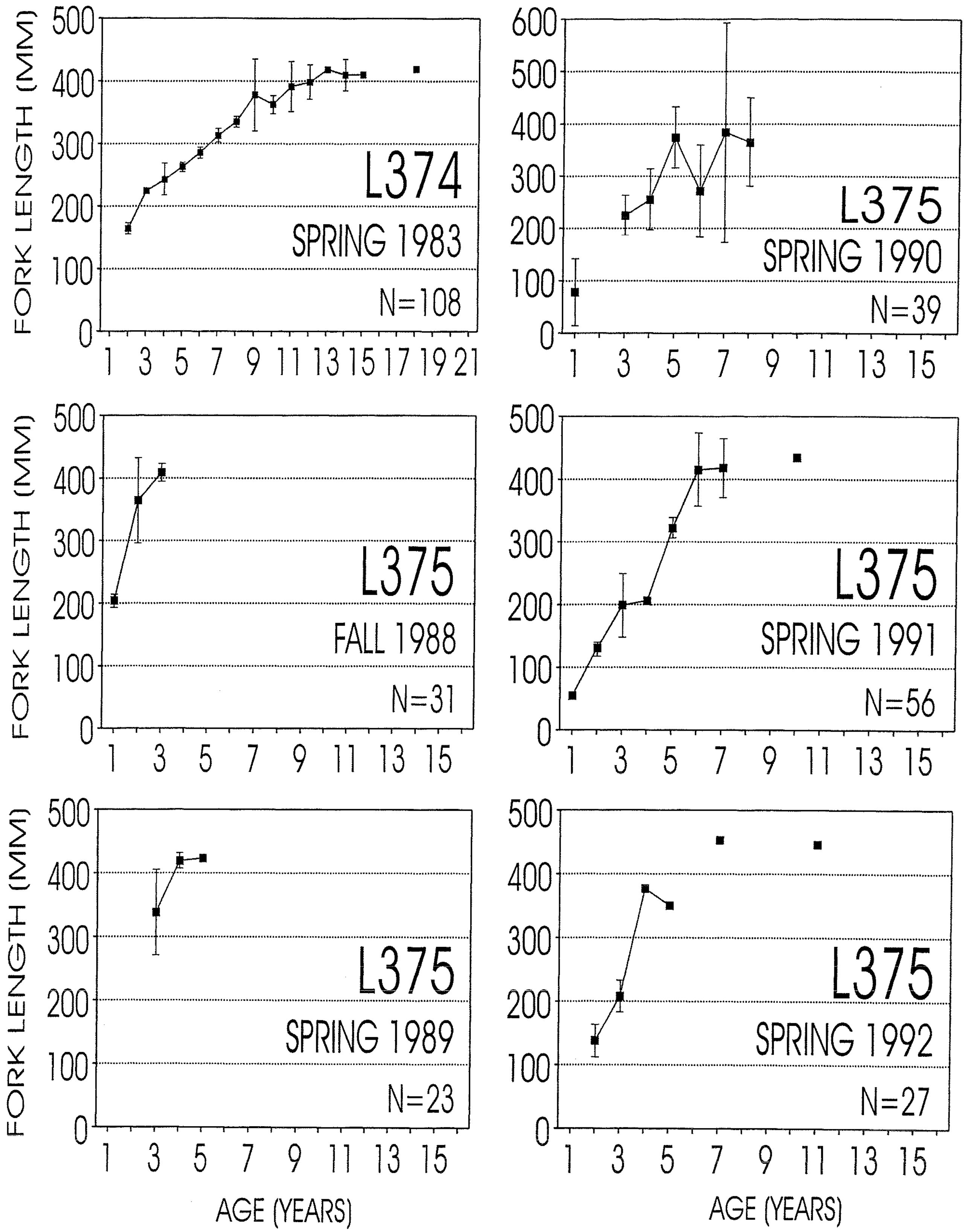
APPENDIX 2, Fig. 1m. Growth (fork length at age) of white sucker in Lake 305 during various seasons and years.



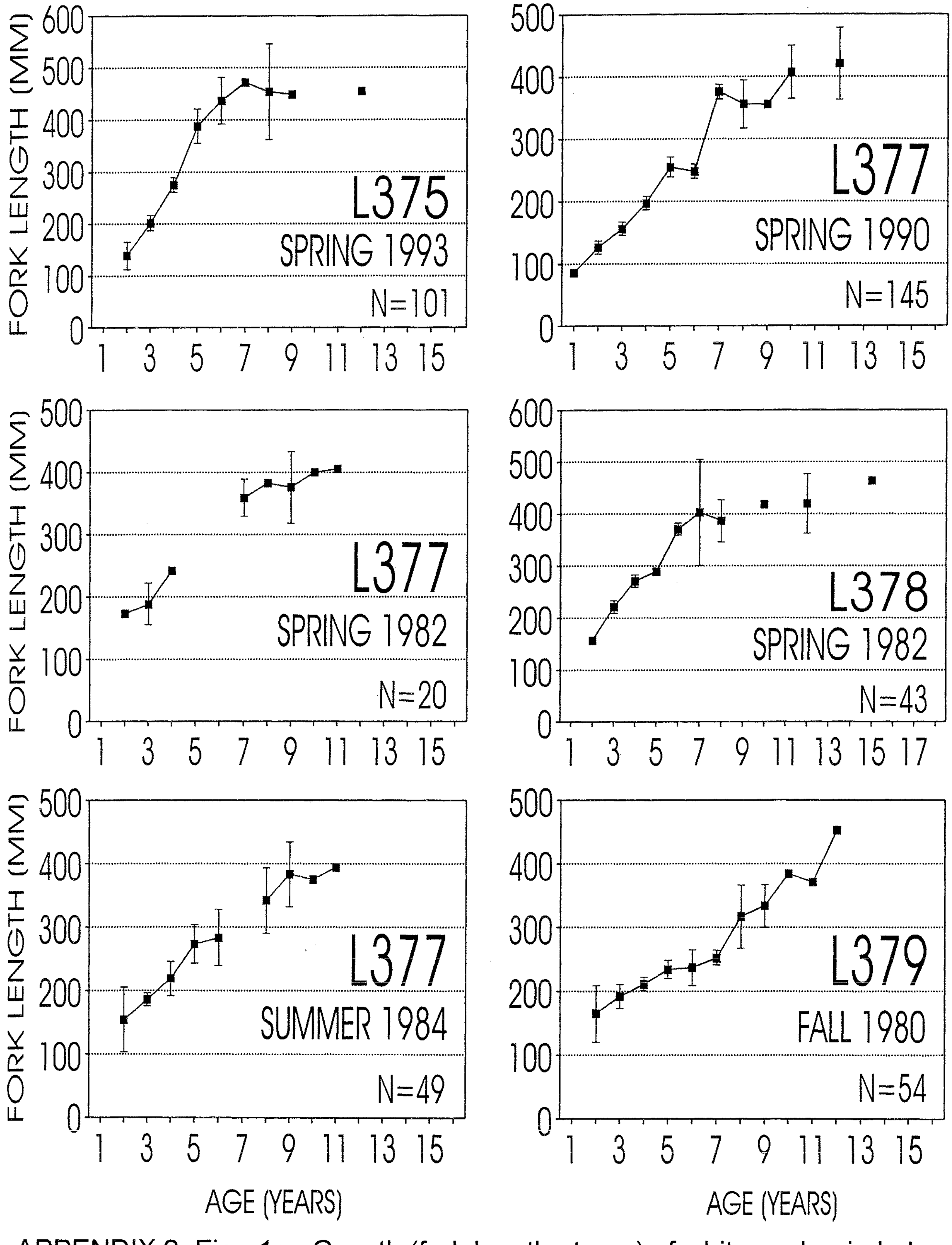
APPENDIX 2, Fig. 1n. Growth (fork length at age) of white sucker in Lakes 305 and 373 during various seasons and years.



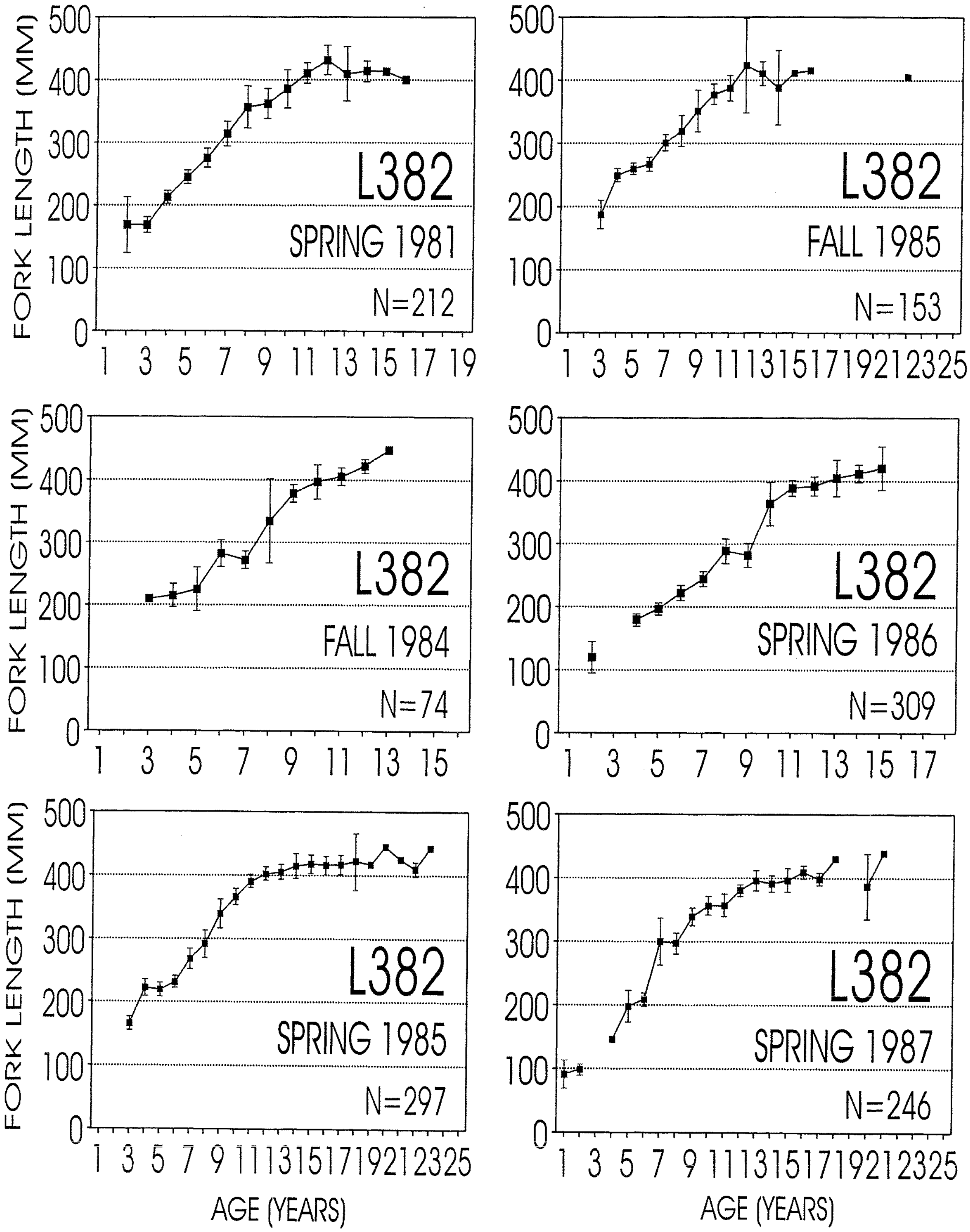
APPENDIX 2, Fig. 1o. Growth (fork length at age) of white sucker in Lake 373 during various seasons and years.



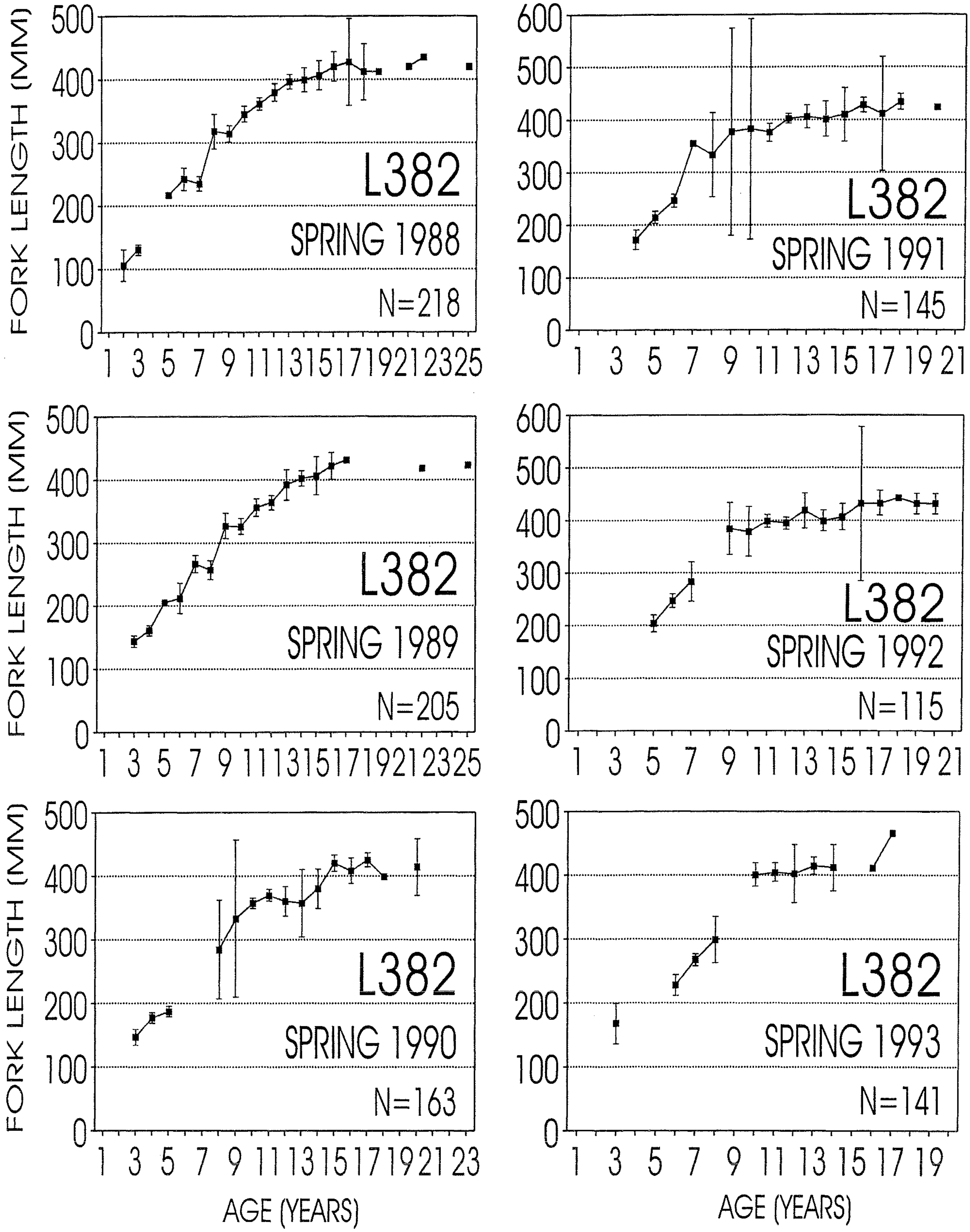
APPENDIX 2, Fig. 1p. Growth (fork length at age) of white sucker in Lakes 374 and 375 during various seasons and years.



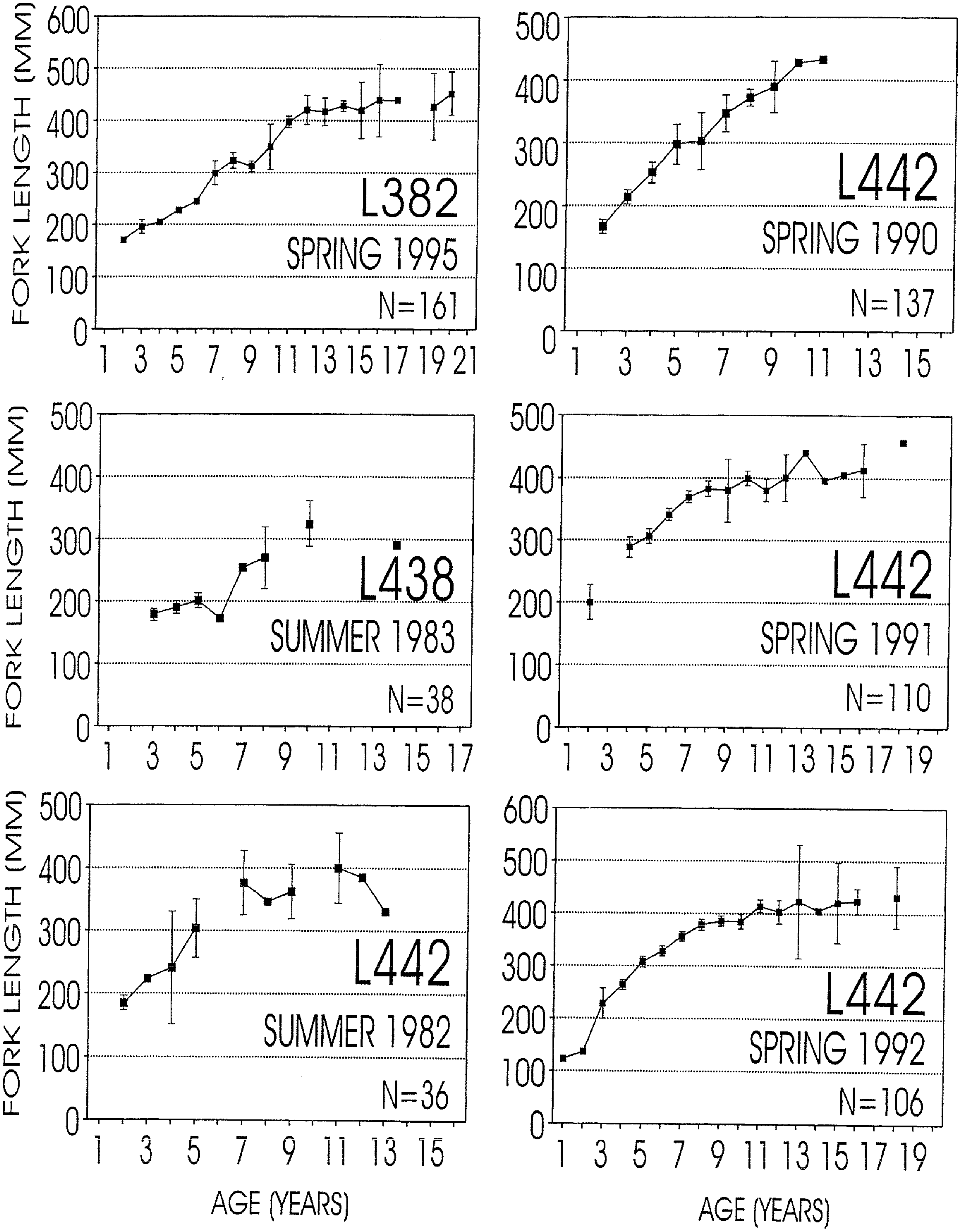
APPENDIX 2, Fig. 1q. Growth (fork length at age) of white sucker in Lakes 375, 377, 378, and 379 during various seasons and years.



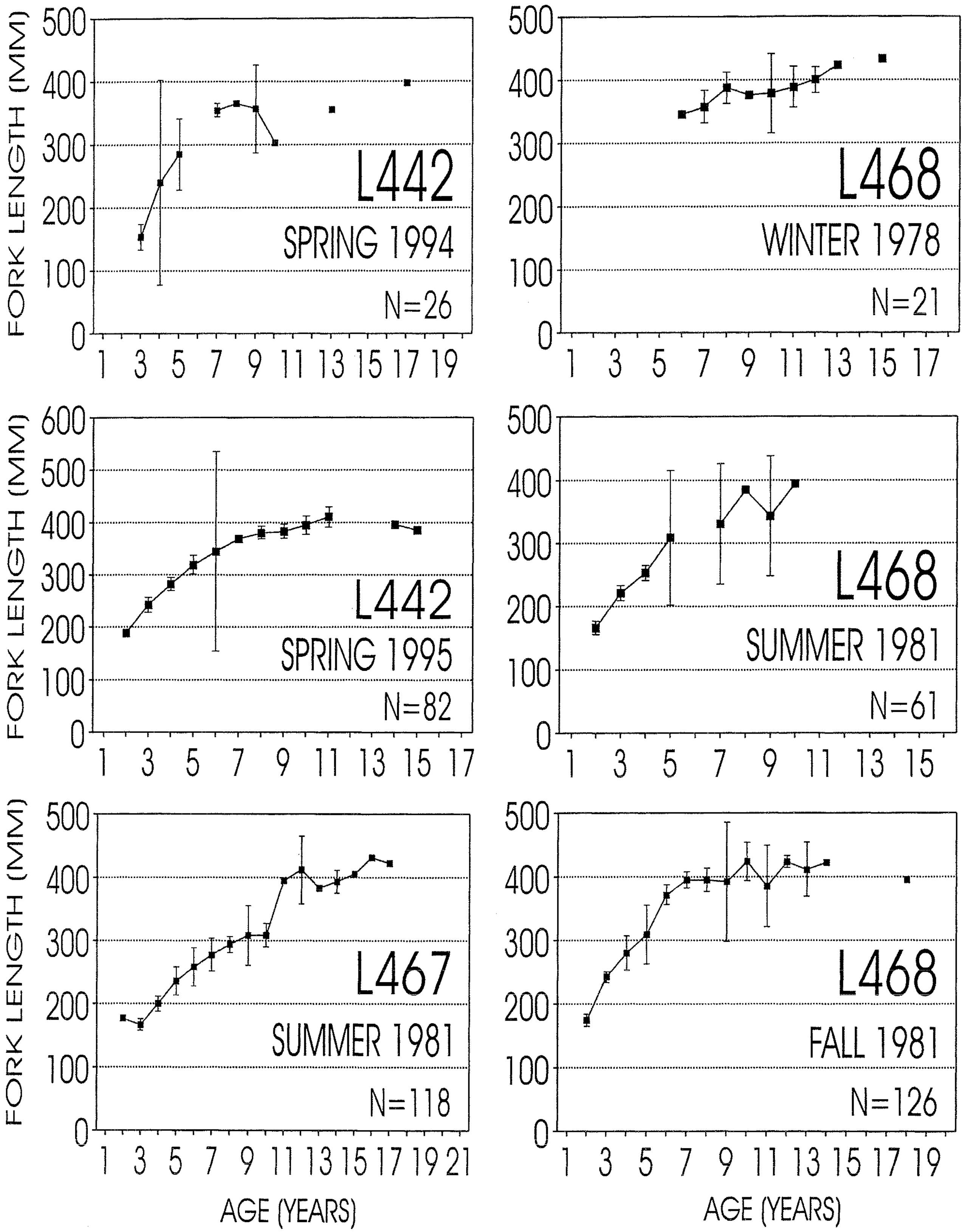
APPENDIX 2, Fig. 1r. Growth (fork length at age) of white sucker in Lake 382 during various seasons and years.



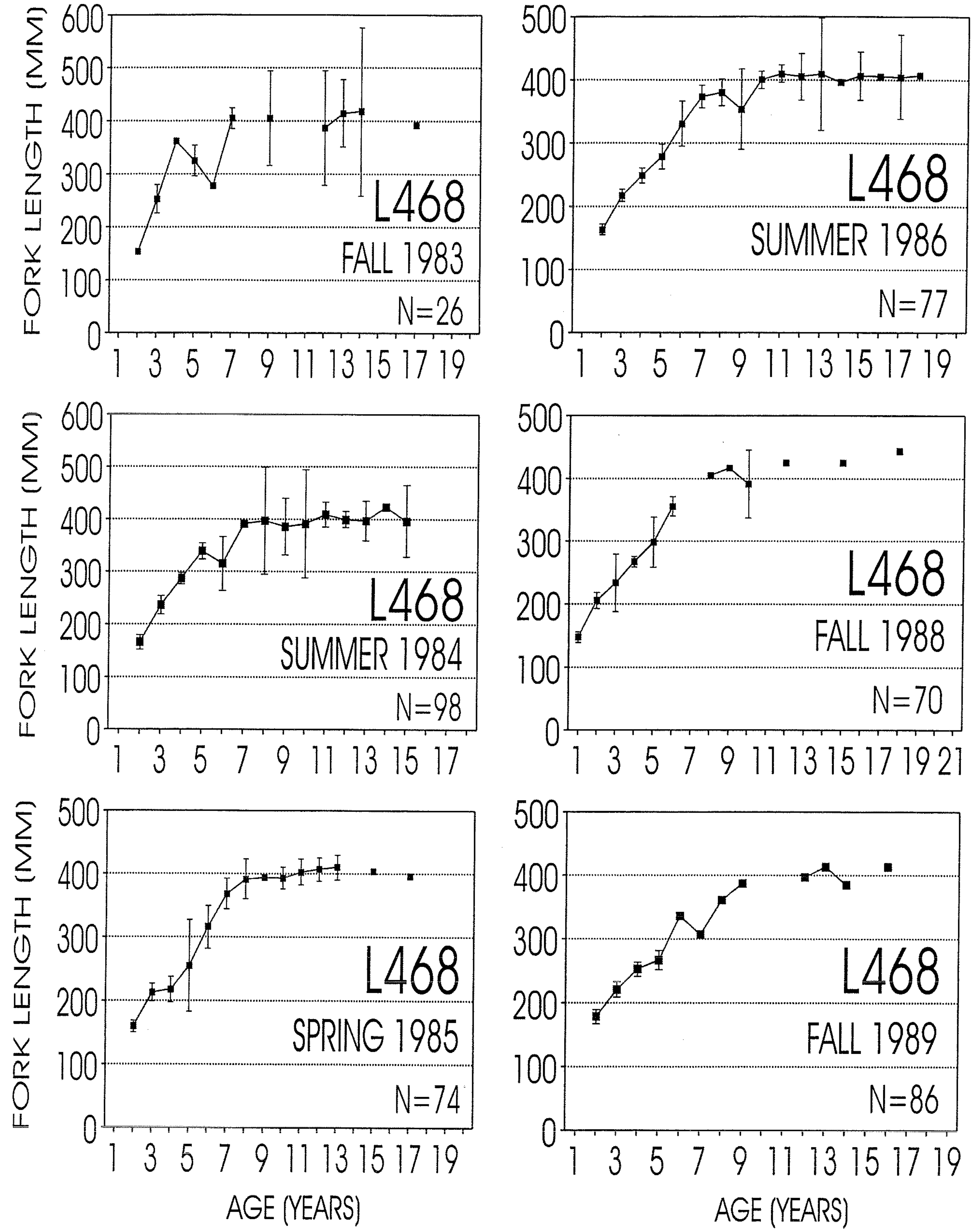
APPENDIX 2, Fig. 1s. Growth (fork length at age) of white sucker in Lake 382 during the spring in various years.



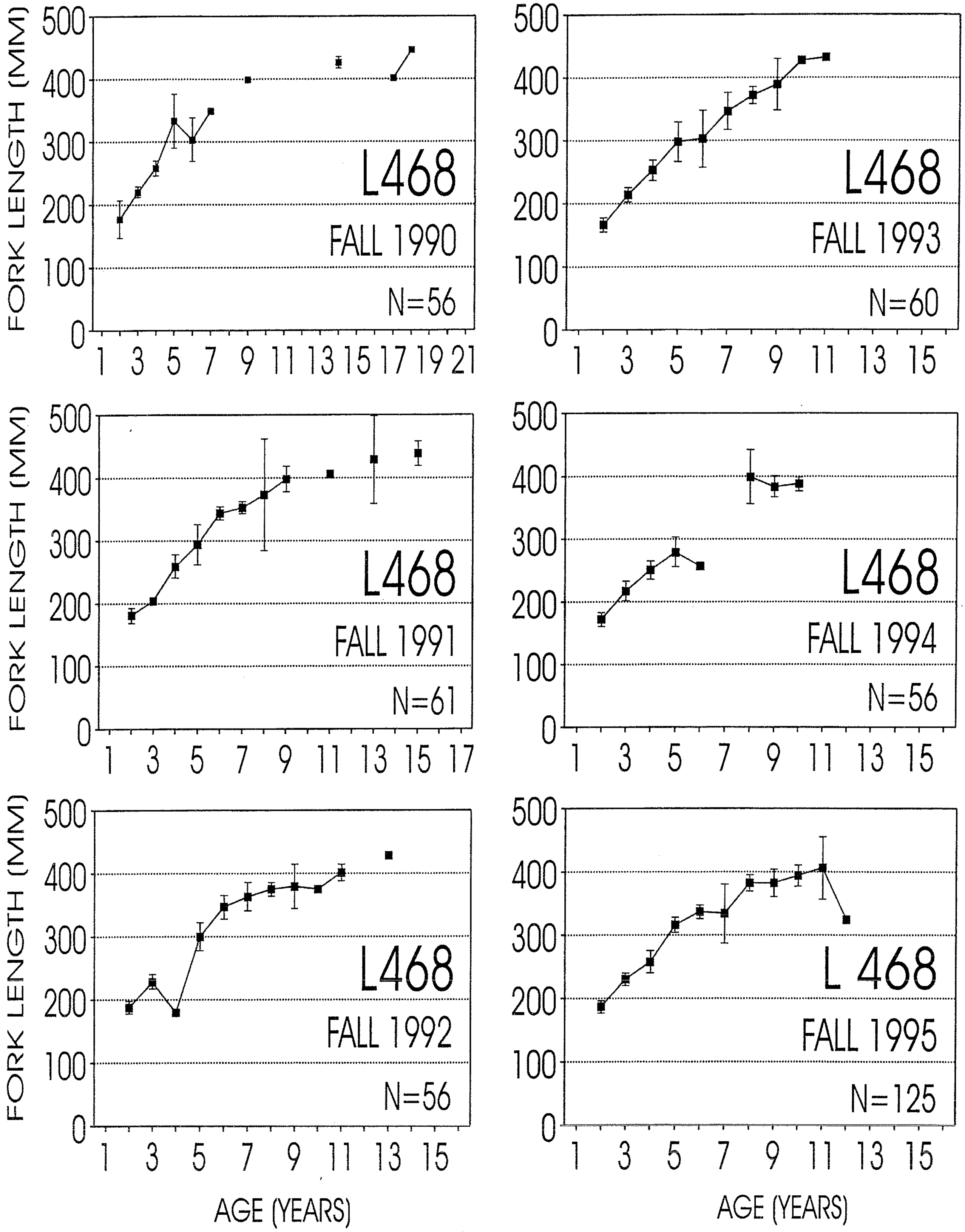
APPENDIX 2, Fig. 1t. Growth (fork length at age) of white sucker in Lakes 382, 438, and 442 during various seasons and years.



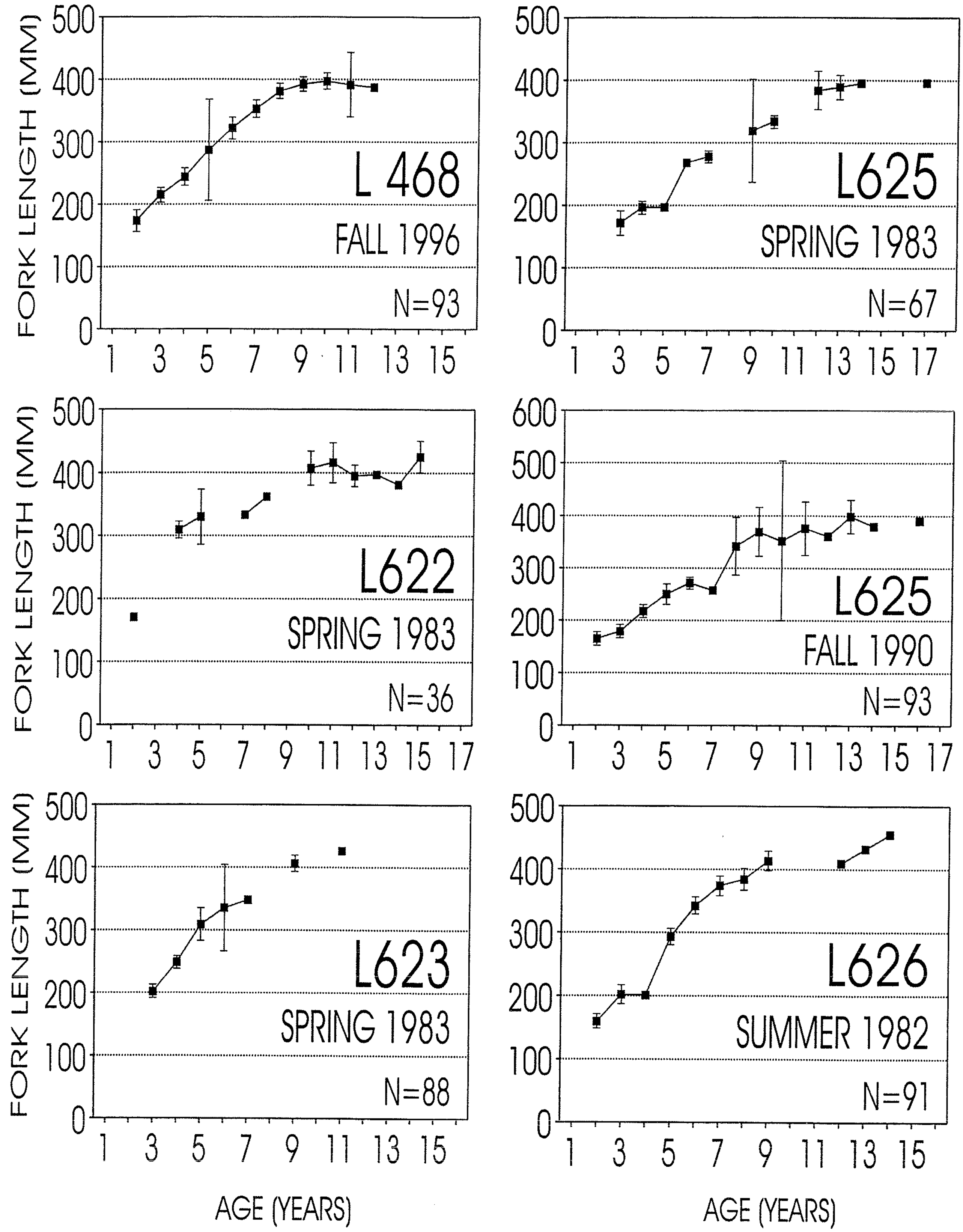
APPENDIX 2, Fig. 1u. Growth (fork length at age) of white sucker in Lakes 442, 467, and 468 during various seasons and years.



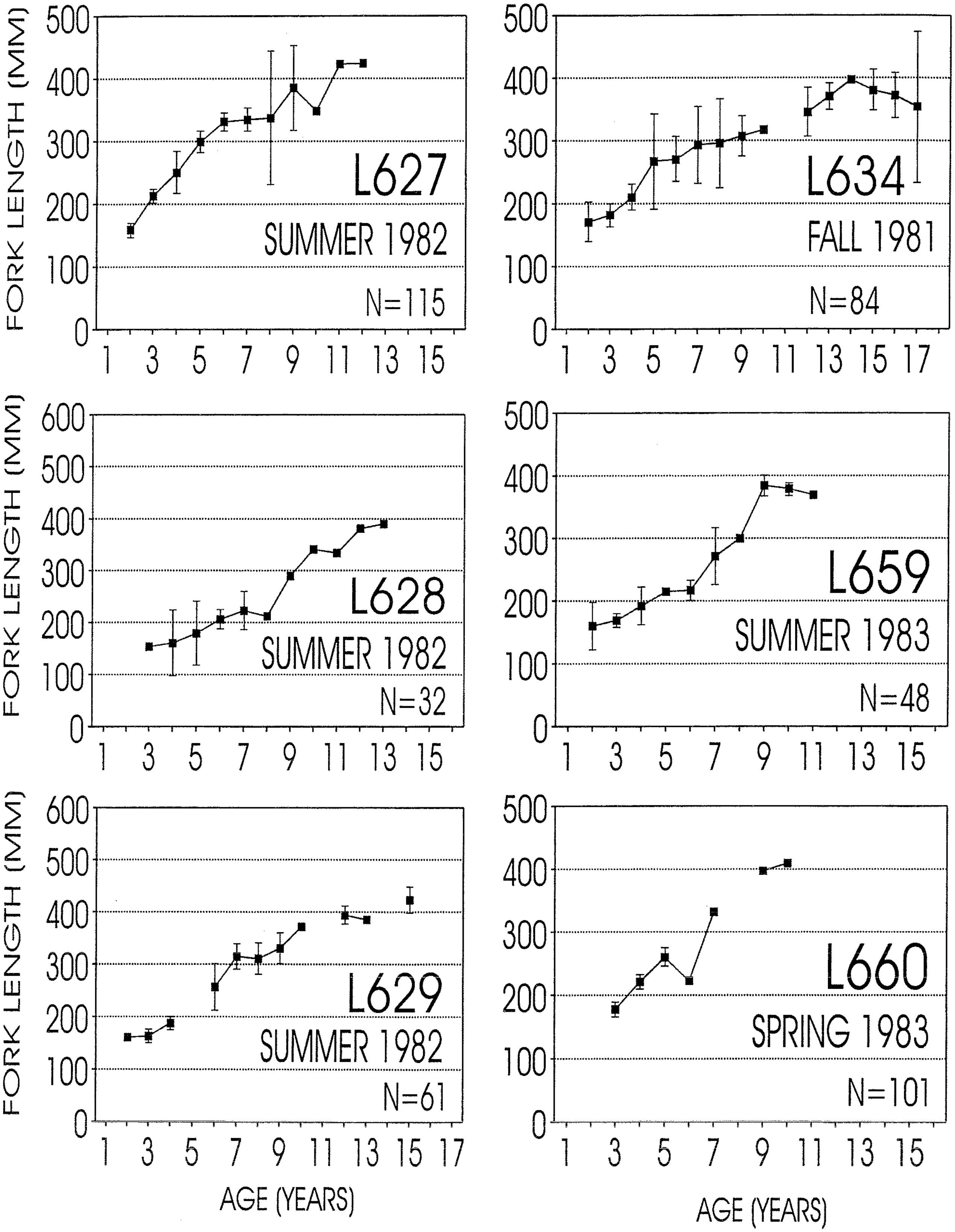
APPENDIX 2, Fig. 1v. Growth (fork length at age) of white sucker in Lake 468 during various seasons and years.



APPENDIX 2, Fig. 1w. Growth (fork length at age) of white sucker in Lake 468 during the fall in various years.



APPENDIX 2, Fig. 1x. Growth (fork length at age) of white sucker in Lakes 468, 622, 623, 625, and 626 during various seasons and years.



APPENDIX 2, Fig. 1y. Growth (fork length at age) of white sucker in Lakes 627, 628, 629, 634, 659, and 660 during various seasons and years.

APPENDIX 3

List of references used in fork length at age comparisons in Figure 12:

Scales used for aging:

Carlander, K.D. 1969. Handbook of freshwater fishery biology. Vol. 1. Iowa State University Press, Ames, Iowa. 752 p.

Lalancette, L.-M. 1976. Annual growth and fat content of white sucker *Catostomus commersoni* in a Quebec lake. Nat. can. (Que.) 103: 403-416.

McCrimmon, H.R., and A. H. Berst. 1961. The native fish population and trout harvests in an Ontario farm pond. Prog. Fish-Cult. 106-113.

Raney, E.C., and D. A. Webster. 1942. The spring migration of the common white sucker, *Catastomus c. commersoni* (Lacépède), in Skaneateles Lake Inlet, New York Copeia 3: 139-148.

Rawson, D.S. 1951. Studies of the fish of Great Slave Lake. J. Fish. Res. Board Can. 8: 207-240.

Smith, M.W. 1952. Limnology and trout angling in Charlotte County Lakes, New Brunswick. J. Fish. Res. Board Can. 8: 383-452.

Pectoral fins used for aging:

Beamish, R. J. 1973. Determination of age and growth of populations of the white sucker (*Catostomus commersoni*) exhibiting a wide range in size at maturity. J. Fish. Res. Board Can. 30: 607-616.

Kelso, J.R.M. 1985. Standing stock and production of fish in a cascading lake system on the Canadian Shield. Can. J. Fish. Aquat. Sci. 42: 1315-1320.

MacCrimmon, H.R. 1979. Comparative annulus formation on anatomical structures of the white sucker, *Catostomus commersoni* (Lacépède). Fish. Mgmt 10: 123-128.

Quinn, S.P., and M.R. Ross. 1982. Annulus formation by white suckers and the reliability of pectoral fin rays for ageing them. N. Am. J. Fish. Mgmt. 2: 204-208.

Verdon, R., and E. Magnin. 1977. Croissance en longeur du meunier noir *Catostomus commersoni commersoni* (Lacépède) du lac Croche dans les Laurentides, Québec. Nat. can. (Que.) 104: 187-195.