VERDE RIVER NATIVE FISHES

THE IMPACTS OF ABIOTIC AND BIOTIC FACTORS

FINAL REPORT FOR HERITAGE PROJECT I96002

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INTRODUCTION

Three objectives for the overall study which encompassed the time period of the contact were addressed for the study:

1) Define:

a) the short-term (5-year) picture of annual size structure of fish populations and

b) the relative abundance of each species (native versus nonnative) in the upper Verde River fish community.

2) Characterize and determine the utilization of aquatic macrohabitat types by respective species of fishes.

3) Provide a preliminary analysis of effects of discharge and flow patterns on aquatic macrohabitat dynamics, and fish populations.

Two null hypothesis were proposed to be tested:

I) Natural hydrographs of the upper Verde River have no effect on sustainability of native fishes.

II) Introduced species of fish have no effect on sustainability of native fishes.

The first null hypothesis was tested based on data collected through Spring 1998. The upper Verde River hydrograph was analyzed to delineate its effects on aquatic habitat, species abundance, fish population structure, and fish community dynamics. The second null hypothesis was tested based on: 1) relative numbers of native and nonnative species in the total fish community, 2) possible overlap of resource use by native and nonnative fishes, and 3) whether nonnative fishes are competing with and perhaps displacing native fishes from aquatic macrohabitats.

To date, 9 papers (7 published and 2 in press) have resulted from studies on the upper Verde River and its fish community. Most of these papers are appended (see Appendix I) and will be used to both draft and complement this final report. In addition, raw data that has been collected during the study period but has not been analyzed thoroughly or drafted for publication, will supplement existing publications and this report. Figures and tables from publications are enclosed in brackets following the respective paper cited. Non-bracketed figures and tables are original to this report and are presented after the text component of the report.

RATIONALE AND SCOPE FOR STUDY

Two factors appear to interact to affect stability and integrity of native fish populations in southwestern North America: 1) alteration of the natural hydrograph through dams, diversions, or pumping, and 2) introduction of nonnative species of fish. In all but a few streams, these factors have eliminated native fish species and modified community structure and dynamics, often within a few years after the action. Streams where the native fauna remains predominant are a rarity in the Southwest. The exact mechanism that sustains native species in the presence of nonnative fishes is not understood, however, is thought related, in part, to cycles of drought and flood flows that characterize streams in the southwestern region of the United States. Because of the ever-increasing demand for water for a growing populace, and the generally imperiled status of Arizona's native fish fauna, clarification of this question is important at this time.

The Verde River between Sullivan Lake and Sycamore Creek (Figure 1), retains a native fish fauna that is largely intact; six of the eight native species are present in viable numbers, and the two extirpated species have been reintroduced (Stefferud and Rinne 1995). It is the only reach of major desert river in Arizona where flows are minimally altered by dams or diversions. However, an array of nonnative fish are established in the reach, including red shiner, fathead minnow, common carp, green sunfish, smallmouth and largemouth bass, yellow bullhead, and channel and flathead catfish (Stefferud and Rinne 1995 [Tables 1 - 2]). It is undetermined whether the native species are maintaining their populations in the presence of nonnative species, or whether the nonnative species are unable to become dominant because of flow regimes.

In 1994, the Rocky Mountain Research Station in collaboration with the Tonto and Prescott National Forests initiated research to define the relative roles and influence of physical (hydrology, geomorphology) and biological (nonnative fish, fish population and community dynamics, fish mobility) factors on the sustainability of native fishes in time (10 years) and through space (7 localities over 37 river miles) in the upper Verde River (Fig. 1). Years one to three of the study were complete upon initiation (July 1996) of Heritage Project I96002. Heritage funding greatly enhanced ongoing Forest Service research studies during years four and five of this long-term, 10-year research effort.

HYDROLOGICAL AND BIOLOGICAL EFFECTS

Monitoring the fish community following floods in 1993 and 1995 (100-year and 10-year recurrence events, respectively) indicated that fish population and community structure and aquatic habitat were affected by these natural perturbations. Total numbers of fish were considerably reduced, but in general, the native species appeared to benefit from the flood, whereas nonnative species were negatively impacted (Stefferud and Rinne 1995, Rinne and Stefferud 1996a). For example, based on 1993 data, roundtail chub produced a large year-class that is still evident in the population, and relative abundance of red shiner decreased following the 1995 flood (Fig. 5).

Stream channel morphology and aquatic habitats likewise were affected dramatically by flood events in winter 1993-94. Bed material was resorted, the active channel moved extensively laterally in some reaches, and the stream channel was reconstituted through removal of encroaching riparian vegetation. In general, floods appear to re-invigorate aquatic habitats of the upper Verde River by facilitating optimal spawning conditions (Rinne and Stefferud 1996a). Reduction of the numbers of nonnative species of fishes, post-flood, also appears to have enhanced the native species of fishes. However, these were short-term observations. The critical need is to examine what the long-term effect of these floods and ensuing hydrological regime may have on fish community structure and native/nonnative interactions.

Long-term (>5 years) studies of native fish populations in low, desert rivers similar in size to the Verde are non-existent. Several long-term studies in smaller streams are ongoing. Aravaipa Creek in southeastern Arizona has a 25-year record of fish community dynamics. Similarly, there are 10-year records of native fishes and habitat associations for several streams in the upper San Francisco and Gila River drainages in New Mexico. Whereas these existing data sets may be useful for comparing effects of floods and droughts on native species, and perhaps for defining aquatic macrohabitat associations, none of the studies are in stream reaches that have a significant nonnative fish component.

Although precipitation and stream hydrographs are stochastic and unpredictable, floods in the upper Verde River appear to occur on about 7 to 10-year cycles (Stefferud and Rinne 1995). Thus, ensuing years (i.e. post 1995) of low flows and drought conditions become more probable and indeed have occurred (1996-98). Such increased probability of low, base flows provides an excellent opportunity to study native versus nonnative fish interactions during reduced flooding and low flow conditions. These data can then be compared with measurements taken during periods of higher flows and flooding that probably will occur in the next four to six years. As designed, the Verde River research effort presents a unique opportunity to study the relative influences of abiotic (hydrograph and habitat) and biotic (nonnative species) factors on native fish populations.

STUDY AREA AND METHODOLOGY

General location of study sites were chosen based primarily on reasonable access and linear disposition over the 37-mile reach. Specific location was based on channel morphology and types of habitat present. Seven sites (Figure 1, circles) starting at a point 4.8 miles east of Sullivan Lake and ending at the confluence of Sycamore Creek were sampled during 1994 and 1995. Sites are linearly separated by distances of 2.0 to 10.0 miles. All sites are sampled annually in spring (April-May). Two sites, Burnt Ranch and Sycamore Creek, are sampled again annually in autumn (October).

Exact length of each sample reach is dependent on habitat complexity, but ranges from 1,000 to 2,000 linear feet of river. In general, a riffle-pool sequence was selected, then the study site was expanded to include other significant aquatic macrohabitats present. Macrohabitats initially were defined by subjective descriptions of channel shape and turbulence, substrate composition, and relative position in the stream channel (Rinne and Stefferud 1996b).

Macrohabitats within a reach were sampled for fishes, progressing in sequence from downstream to upstream. Standard sampling methods for riverine fish, including backpack DC electrofishing units, seines, dipnets, and trammel nets were used relative to macrohabitats sampled. All fish captured within a macrohabitat were identified to species and counted. Total length of all specimens $\geq$6 inches were thus obtained. A subsample of individuals < 6 inches were measured, and weighed to define population demographics. Once measured, all fish except for periodic voucher specimens of nonnatives, were returned alive to the stream.

Each aquatic macrohabitat within a sample reach was numbered in sequence and named (e.g., lateral scour pool, mid-channel pool, backwater pool, glide, run, low and high gradient riffles, and edgewater (Rinne and Stefferud 1996b). Length, width, depth, velocity, and substrate for each macrohabitat were estimated and recorded. Gradients were measured with a laser level, substrates using methodology outlined in Bevenger and King (1995), and velocity with a direct readout digital current meter. For future reference and to enable estimates of habitat dynamics within a study reach, a map of the entire site is sketched annually and location of macrohabitats noted.

Stream gages operated by the U.S. Geological Survey at Paulden and Clarkdale (Figure 1, triangles) continuously record discharge. These data were used to relate discharge and annual streamflow to the dynamics of the fish community.

Our sampling is designed to expeditiously gather data that will describe the fish community and characterize the aquatic habitats. With these data, we were able to initially delineate relative, qualitative macrohabitats (mean length, width, depth, velocity, and substrate). Refinement of definition of aquatic macrohabitats was considered necessary. Accordingly, increased sampling intensity and rigorous statistical analyses have resulted in greater accuracy in classifying aquatic macrohabitats in the upper Verde River (Sponholtz and Rinne 1997).

RESULTS OF STUDY

<u>Objective 1.</u> Define the short-term (5-year), annual size structure of fish populations and relative abundance of species in the total fish community.

Year Class Structure of Species

Size structure of the two suckers and roundtail chub during 1995-97 are in Figures 2-4. Histograms illustrate the abundance of small-sized individuals of both Sonora and desert sucker and roundtail chub immediately (Spring 1994) after the 1993 flood (Stefferud and Rinne 1995). Respective size classes or cohorts are evident based on annual spring sampling. Low year class strength for all three of the large-sized native cypriniforms in successive years (1996 and 1997) are attributed to poor reproductive success in those years, increased influence of non-native species, or both.

In Spring 1994, the modal size of 38 spikedace was 60 mm (mean =54 mm). Modal size of 72 spikedace in Spring 1995 was again 60 mm (mean = 58 mm). Autumn 1995 sampling reveals that successful reproduction occurred based on modal size of 71 spikedace collected (45 cm; mean size, 43 mm). Of 138 spikedace collected in Spring 1996, modal size again was near 55 mm (mean size =56 mm). Only six spikedace (mean size 52 mm) were taken in Autumn 1996 and none have been collected since at any of the established sampling sites. Longitudinal sampling of the entire upper river in May 1995 and again in 1997 further document the reduction in the spikedace population in the upper Verde. Only 15 spikedace were collected in the total sampling effort in the upper river in May 1997 compared to almost 140 in May 1995. No spikedace were captured in spring 1998 sampling at the seven established sites or in a survey of the entire upper river. Although the species is noted for these characteristic cycles in abundance, continued and intensified monitoring of this population is recommended.

Fish community structure.

The three large-sized, cypriniform species comprised a major component (60%) of the total fish community and 73% of the native fish fauna in spring 1994 (Stefferud and Rinne 1995 [Table 1], Rinne and Stefferud 1996a, Figure 5). By spring 1995, these three species comprised almost 80% of the native fish fauna before dropping down to 60% of the native fish community in Spring 1996. By spring 1997, these three species comprised 92% of the native fish fauna. Speckled dace were essentially absent and spikedace were absent in samples from established sample reaches. Overall, natives comprised greater than 80% of the total fish community between 1994 and 1996 (Rinne and Stefferud 1996a [Table 1, Fig. 1]). However, by spring 1997 the native component of the total fish community had declined markedly to 19% (Table 1).

A dramatic increase in the number of red shiners in spring 1997 sampling was largely responsible for the inversion of relative numbers of natives to nonnatives from spring 1996 to 1997 (Fig. 5). We predicted that 1998 spring (April) sampling would reveal similar population structure of natives and non-native species if no significant flow events occur before that time. By contrast, if a significant (5+-year) flow event occurs, we predicted overall fish numbers will be yet be low, but proportions will shift again to favor the native fish component of the total fish community. The former occurred and our predictions were correct.

Spikedace numbers were greatest in spring 1994, dropped in 1995, elevated again in 1996, and disappear from the seven established sampling sites in Spring 1997 and 1998 (Table 1). Sampling optimum habitats in the entire upper river from Burnt Ranch to Sycamore Creek in 1995 resulted in 140 spikedace being taken. Similar sampling was not achieved in spring 1996, however, the same sampling regimen in spring 1997 resulted in only 15 spikedace being collected in the entire 60-km reach of river.

Objective 2 Characterize and determine the utilization of aquatic macrohabitats by respective species of fishes.

Characterization of habitat types

Initially (1994-95), aquatic habitats were visually and subjectively defined for sampling purposes (Stefferud and Rinne 1995). Aquatic macrohabitats in the upper Verde were next defined based on direct physical measurement of gradient, velocity, depth, and substrate composition by Rinne and Stefferud (1996b). Measurements were then made and statistically summarized by the previous, initial subjective classifications. Gradients were first estimated 1995 with the use of a laser level. Gradient estimates successively paralleled subjective, lotic habitat classifications: glides < 0.3%, runs >0.3 to 5%, low gradient riffles (0.6 to 1%) and high gradient riffles > 1% (Rinne and Stefferud 1996b [Fig. 1]).

Pools displayed a high degree of variabili⁺
averaged the same as glide habitats sugge
classifications. Pool classification difficult
dozen) subjective types of pools (e.g. side char
were grouped in the pool category. Mean velocity o
the lotic scale from run through high gradient riffle habita
1996b [Table 1]). Similarly, substrate type changed from a g
small material (sand-gravel) in glides and runs in comparison to that
gradient riffles (Rinne and Stefferud 1996b [Fig. 2]).

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Increased sampling intensity within study reaches was established in 1 sampling by placing sample transects every three meters within a habitat type (Sponholtz and Rinne 1997). Previously (1994-95), habitat parameters were measured at only three transects, irrespective of length of habitat type. Normally, four to six transects resulted from the more intensive, detailed, 1996 sampling. As a result, data points for depth and velocity increased three-fold. In addition, gradient was measured in all habitats after initially being estimated at only 14 random habitats in 1995 (Rinne and Stefferud 1996b [Figure 1]). Qualitative habitat descriptions in Spring 1996 were used to delineate habitat type based on selected decriptors (Sponholtz and Rinne 1997 [Table 1]). Pebble counts were performed in all macrohabitats, with 30 "hits" used to estimate substrate type. Rigorous statistical analyses employing ANOVA, and Classification and Regression tree (CART) were performed on data (Sponholtz and Rinne 1997).

ANOVA indicated higher variability in data among transects than among individual points, therefore data were averaged for transects prior to statistics being calculated. Results of analysis suggested depth and velocity were not sensitive enough to detect differences between either of the two riffle types (i.e. high and low gradient) or between run and glide habitats. Gradient was the only variable that most consistently (71% of the time), and clearly, defined aquatic macrohabitat type. Further, when used with depth and velocity, it becomes an even more powerful, descriptive variable providing greater than 80% correct classification of aquatic macrohabitat types.

Habitat utilization by native species

Overall, the native fishes were collected in pool habitats in the upper Verde (Rinne and Stefferud 1996b [Figure 3]). This can be attributed, in part, to the predominance of two of the three large species (Sonora sucker and roundtail chub) which inhabit pools and comprised 30 to 50% of the native fauna in 1994 and 1995, respectively (Rinne and Stefferud 1996b [Table 3]). Further, desert sucker ,which comprised 25 to 30% of the native fauna, were captured in pools 20% of the time (Rinne and Stefferud 1996b [Figure 4]). Finally, the great variability in water velocity in pool habitats comprised of multiple (i.e. a dozen) pool categories increased the probability that individual fish would be captured in "pool habitat types." Longfin dace were captured primarily in low gradient riffles and runs [Fig.

5a], spikedace in runs and glides [Fig. 5b], and speckled dace in low and high gradient riffles [Fig. 5c] (Rinne and Stefferud Fig. 5b, see also Neary et al 1996.

Habitat utilization by nonnative species

Nonnative species primarily (29%) used glide habitat. Red shiner were taken in 119 habitats, however, larger numbers (i.e. > 10 individuals) generally were taken in glide habitat. Green sunfish, yellow bullhead, and smallmouth bass were collected in 91 habitats comprised of 45% pools, 22 % glides, 20% runs and 13 % riffles. Common carp was collected in pools over half the time. In addition, Rinne and Neary (1997) demonstrated yellow bullhead and smallmouth bass frequented streambank habitat, because of cover. Further, where these nonnatives were present, native species were absent. These studies are ongoing, but suggest possible competition for habitat and/or predation effects of these two nonnative, predatory species on the smaller native species such as longfin dace and spikedace. Unpublished laboratory data using bullhead and smallmouth bass as predators and red shiners as a surrogate for both the small cyprinid species and young-of-year of the three large cyprinids suggests that predation effect on native fish populations potentially could be substantial.

Objective 3 Provide a preliminary analyses of the effects of discharge and flow patterns on channel morphology, aquatic macrohabitat dynamics, and fish populations.

Flow effects on habitat

Based on annual peak discharges and mean annual discharges over the past three decades, flows in the upper Verde River, as typical of southwestern rivers and streams, were highly variable (Stefferud and Rinne 1995, Rinne and Stefferud 1996a). Neary and Rinne (1997) documented that base flows in the upper Verde have increased over the past two decades. Cycles of flood and drought appear to follow a 7-10 year cycle. Although we have no specific data on channel morphology prior to the 1993 flood, morphology was observed to change dramatically after this 75-100 year event.

By comparison, the 10-year event in 1995 did alter aquatic habitat as evidenced in changes in the relative abundance of habitat types (Table 2). Based on aquatic macrohabitat type, most of the major sample reaches do change in relative aquatic macrohabitat from year-to-year (Table 2). Lack of significant flood events following 1995 sampling, or ensuing low, drought flows have had significant effects on macrohabitats (raw data). Stream channels have narrowed and aquatic macrophytes have encroached from stream margins, reducing mean stream width. Depths of aquatic habitats also have been reduced because of a lack of bankfull, or greater, scouring flows.

Flow effects on fishes

The fish community in the Verde River is very responsive to flow regime (Stefferud and Rinne 1995, Rinne and Stefferud 1996a). In general, very large, peak flood events such as the 1993, 100-year event, drastically reduce the total fish community. Our sampling did not commence until 1994, but sampling by personnel from the Arizona Game and Fish Department in Spring 1993, immediately following massive flooding that winter, suggests all species were drastically reduced in abundance. Spring 1994 compared to spring 1995 data indicate that the fish community expanded by the former sample date and then dropped after the less dramatic flood events of spring 1995 (Rinne and Stefferud 1996a [Table 2]). Sampling in 1996 documents native species rebounding, along with red shiner (Fig. 5). Continued low flows and lack of significant flooding in 1996, and prior to 1997 Spring sampling, resulted in a dramatic increase in red shiner, smallmouth bass and yellow bullhead (Table 1, Rinne and Stefferud 1996a [Table 2], Fig. 5).

In summary, the total fish community in the upper Verde definitely responds to the hydrograph. That is, very large floods cause a marked reduction in both native and nonnative species. Native species rebound very quickly apparently as a result of optimal spawning and recruitment (Figs. 2-4) and reduced numbers of nonnatives. Nonnatives then increase relative to natives as lack of flooding and base or drought flows are sustained.

CONCLUSIONS

Null hypothesis I obviously has to be rejected based on the response of fishes in the upper Verde River relative to flood and drought flows. Null hypothesis II also has to be rejected based on both relative community composition and the utilization of streambanks by nonnative species and their probable predatory effects on native fishes.

The relative influences of abiotic versus biotic (i.e. hydrological regime vs nonnative fishes) cannot be unequivocally stated at this time. We have suggested (Rinne and Stefferud 1996a) that the abiotic factors (flows and habitat) are of primary importance and the controlling factors in sustaining native fishes in the upper Verde. Introduced fishes (biotic) and their interactions with native species are of perhaps secondary significance in legislating numbers, distribution and sustainability of native fishes in the upper Verde River. Probably the best interpretation is that the interactions of the two are actually the real process. That is, flood flows reduce the overall fish community in numbers and distribution, however, the native species appear to recover and predominate the fish community immediately post-flood. The cessation of flood events then results in nonnative species becoming, steadily and increasingly, more abundant (Rinne and Stefferud 1996aa, Table 1). Once nonnatives predominated the fish community, the biotic factor may then become the variable that controls or delimits fish community structure.

The size of the flow event necessary to effect a significant change in fish community structure cannot been defined based on data collected to this point in time. Obviously, 100-year events are more than adequate to reduce or remove nonnative species. Ten-year events also have an effect based on our data from the upper Verde. The threshold below which flow events have no significant impact on the nonnative proportion of the fish community and their predominance becomes the controlling factor on native fish populations (through more successful reproduction, recruitment, predation, and competition for food and space) is not offerable at this time. The stochastity of flows over the next five years may aid in refinement of this definition.

DISCLAIMER

The findings, opinions, and recommendations in this report are those of the investigators who have received partial funding from the Arizona Game and Fish Department Heritage Fund. The findings, opinions, and recommendations do not necessarily reflect those of the Arizona Game and Fish Commission or Department,

or necessarily represent official Department policy or management practice. For further information, please contact the Arizona Game and Fish Department.

LITERATURE CITED

Bevenger, G. S. and R. M. King. 1995. A pebble count procedure for assessing watershed cumulative effects. USDA Forest Service Research Paper RM-319:1-17.

Neary, A. P.,J. N. Rinne, and D. G. Neary. 1996. Physical habitat use by spikedace in the upper Verde River, Arizona, pp 23-28. In, Hydrology and Water Resources in Arizona and the Southwest. Vol. 26. Proc. of the 1996 meetings of the Ariz. Section, Amer. Water Resour. Assoc. and the Hydrology Section, Arizona-Nevada Acad. of Sciences, April 20, 1996, Tucson, Arizona.

Neary, D. G. and J. N. Rinne. 1997. Baseflow trends in the upper Verde River relative to fish habitat requirements, pp 57-63. In, Hydrology and Water Resources in Arizona and the Southwest. Vol. 27. Proc. of the 1997 meetings of the Ariz. Section, Amer. Water Resour. Assoc. and the Hydrology Section, Arizona-Nevada Acad. of Sciences, April 19, Las Vegas, Nevada.

Rinne, J. N. and J. A. Stefferud. 1996a. Factors contributing to collapse yet maintenance of a native fish community in the desert Southwest (USA), pp 157-162. In, D. A Hancock, D. C. Smith, A. Grant, and J. P. Beaumer (eds). Developing and Sustaining World Fisheries Resources: The state of science and management. Second World Fish Congress, Brisbane, Australia. July 28-Aug 2, 1996.

Rinne, J. N. and J. A. Stefferud. 1996b. Relationships of native fishes and aquatic macrohabitats in the Verde River, Arizona, pp 13-22. In, Hydrology and Water Resources in Arizona and the Southwest. Vol. 26. Proc. of the 1996 meetings of the Ariz. Section, Amer. Water Resour. Assoc. and the Hydrology Section, Arizona-Nevada Acad. of Sciences, April 20, 1996, Tucson, Arizona.

Rinne, J. N., and D. G. Neary. 1997. Stream channel and fish relationships: Preliminary observations, Verde River, Arizona, Pp 475-482. In, Proc. AWRA Sympos, Water Resources Education, training, and practice: Opportunities for the next Century.

Rinne, J. N. J. A. Stefferud, A. Clark, and P. Sponholtz. In press (1998). Fish population structure in a large desert river relative to anthropogenic influence: Verde River, Arizona, USA., pp - . In, International Symposium and Workshop on Management and Ecology of River Fisheries. Mar. 30-April 3, 1998. Hull, England.

Stefferud J. A. and J. N. Rinne. 1995. Preliminary observations on the sustainability of fishes in a desert river: The roles of streamflow and introduced fishes, pp. 26-32. In, Hydrology and Water Resources in Arizona and the Southwest. Vols. 22-25. Proc. of the 1995 meetings of the Ariz. Section, Amer. Water Resour. Assoc. and the Hydrology Section, Arizona-Nevada Acad. of Sciences, April 22, 1995, Flagstaff, Arizona. 114 pp.

Sponholtz P. and J. N. Rinne. 1997. Refinement of aquatic macrohabitat definition in the upper Verde River, Arizona, pp 17-24. In, Hydrology and Water Resources in Arizona and the Southwest. Vol. 27. Proc. of the 1997 meetings of the Ariz. Section, Amer. Water Resour. Assoc. and the Hydrology Section, Arizona-Nevada Acad. of Sciences, April 19, Las Vegas, Nevada.

Sponholtz, P. D. Redondo, B.P. Deason, L. Sychowski, and J. N. Rinne. In press (1997). The influence of stock tanks on native fishes: Verde River, Prescott National Forest, pp - . In, Proc. Sympos on Environmental, Economic, and Legal Issues Related to Rangeland Water Developments. Nov 13-15, ASU, Tempe, Arizona.

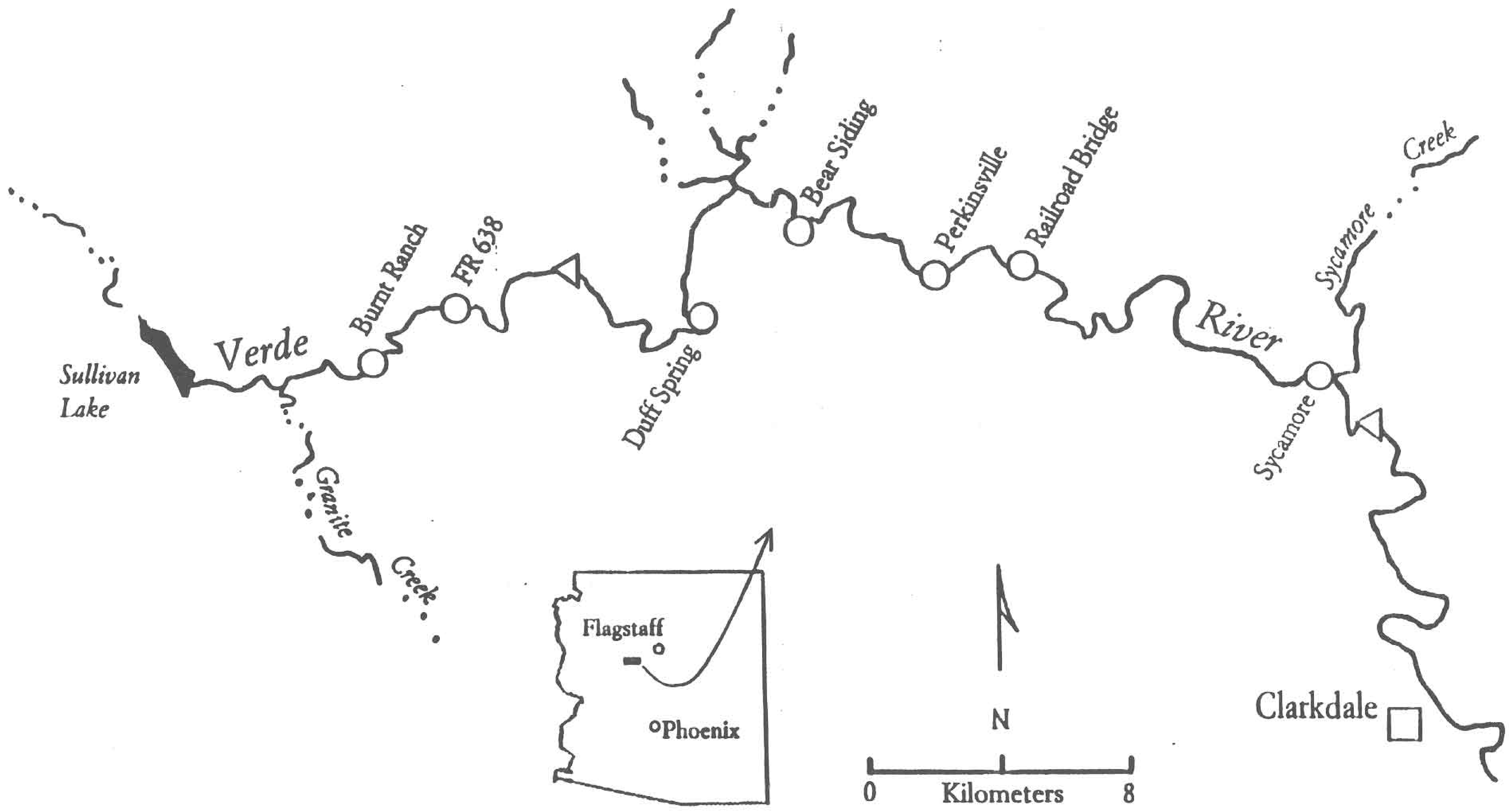

Figure 1. Map of upper Verde River study area indicating the seven established sample sites (circles), and USGS Guages (triangles).

Figure 2. Length frequency of sonora suckers in the upper Verde River during spring 1994 to 1997.

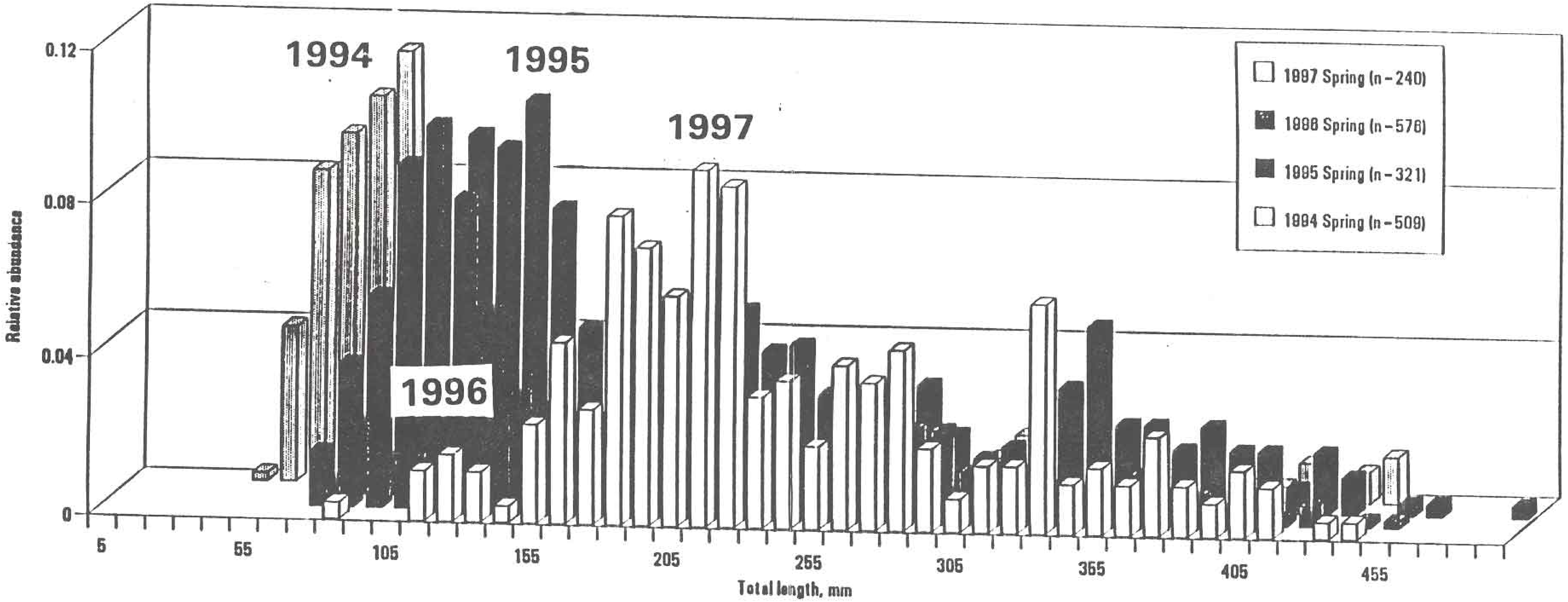

Figure 3. Length frequency of desert suckers in the upper Verde River during spring 1994-1997.

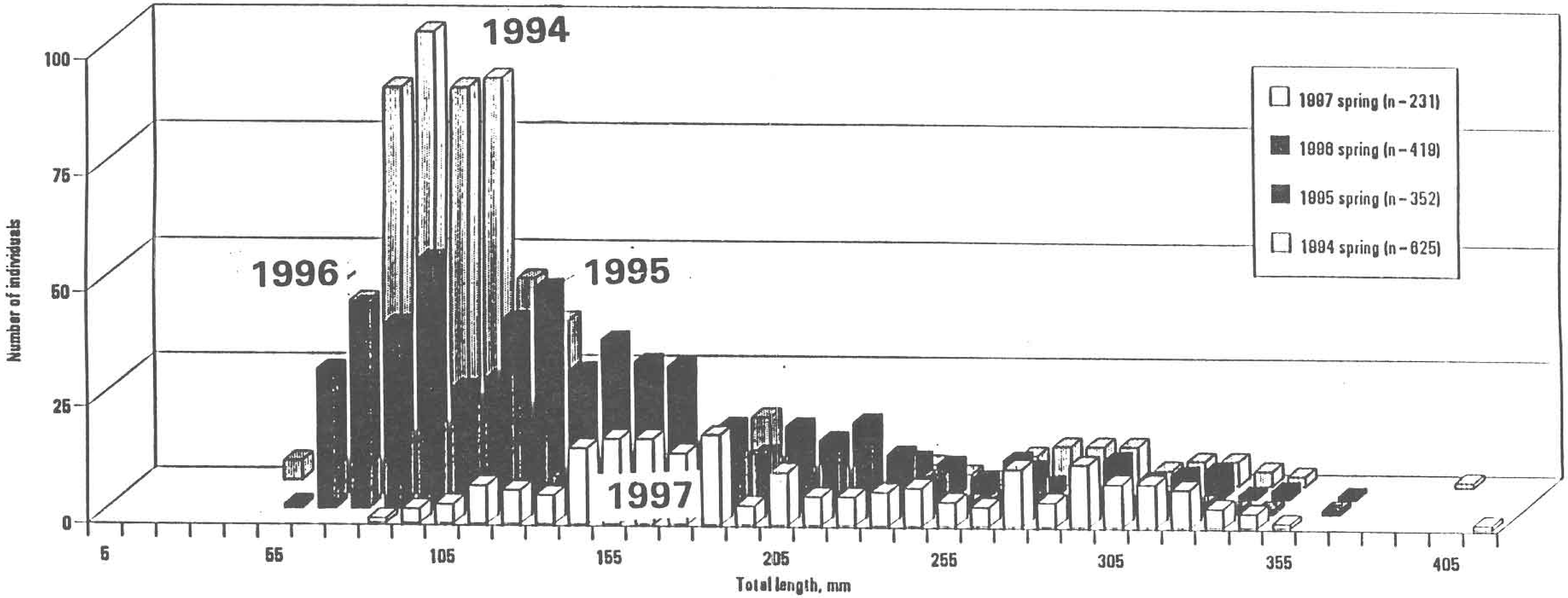

Figure 4. Length frequency of roundtail chubs in the upper Verde River during spring, 1994 to 1997.

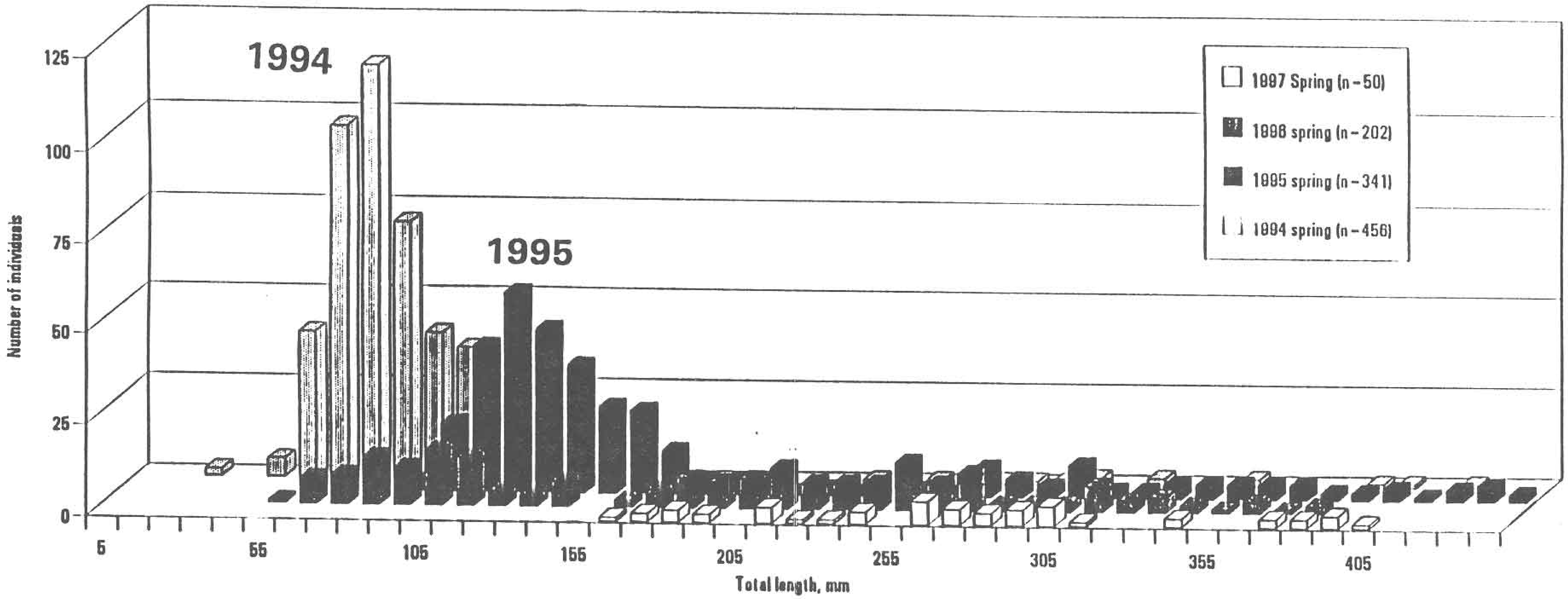

Figure 5. Abundance of fishes at seven regular sampling sites, upper Verde River, 1994-1997.

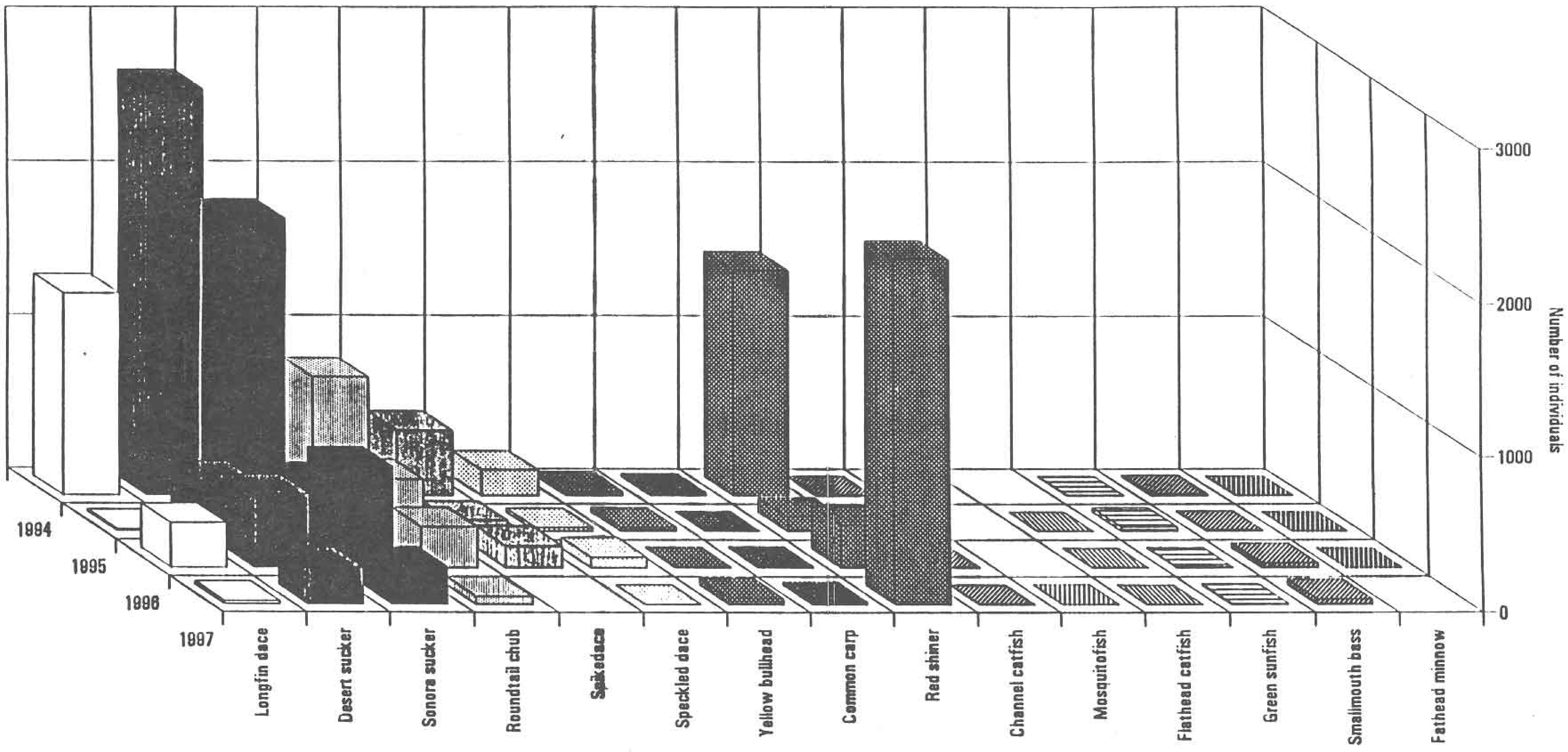

Table 1. Total numbers of fish collected at seven established sampling sites in the upper Verde River during spring, 1994-1997.

A Total number of fish collected at seven sites in upper Verde River, April-May 1994.

	Longfin dace	Desert sucker	Sonora sucker	Roundtail chub	Spikedace	Speckled dace	Common carp	Red shiner	Fathead minnow	Yellow bullhead	Green sunfish	Smallmouth bass	Channel catfish	Flathead catfish	Total
	Species														
Burnt Ranch	1072	339	278	15	257		1	39		2		2			2005
FR638	227	230	154	18	2			61		3					695
Duff Spring		192	329	28	1		3	32		1		4			590
Bear Siding		382	357	249	1	3	4	227		1		3	1		1228
Perkinsville	19	885	442	244	37	81	11	1109	7	12	4	2	4		2837
Railroad Bridge		237	27	57	38	88		2		2					451
Sycamore Creek	1	379	223	165	92	19	4	3		10		3			899
Total 1994	1319	2644	1810	776	428	171	23	1473	7	31	4	14	5		8705

B Total number of fish collected at seven sites in upper Verde River, May 1995.

	Longfin dace	Desert sucker	Sonora sucker	Roundtail chub	Spikedace	Speckled dace	Common carp	Red shiner	Fathead minnow	Yellow bullhead	Green sunfish	Smallmouth bass	Channel catfish	Flathead catfish	Total
	Species														
BurntRanch		15	60	3	33			7		2		3			123
FR638	11	48	57	4	2		1	8		3	8	1			143
Duff Spring		65	73	50			1	55		17	5	6	2	1	275
Bear Siding		45	47	22				10		5	10				139
Perkinsville	1	90	10	115	1	23	1	4		1	3				249
Railroad Bridge		36	38	43	19	2	1	8			1				148
Sycamore		29	37	104	17		2	5		1	2				197
Total 1995	12	328	322	341	72	25	6	97		29	29	10	2	1	1274

C Total number of fish collected at seven sites in upper Verde River, April-May 1996.

	Longfin dace	Desert sucker	Sonora sucker	Roundtail chub	Spikedace	Speckled dace	Common carp	Red shiner	Fathead minnow	Yellow bullhead	Green sunfish	Smallmouth bass	Channel catfish	Flathead catfish	Total
	Species														
BurntRanch	91	79	92	23	33		1	88		1	1	5			414
FR638	179	127	307	81	53	1	5	112			1				866
Duff Spring	6	32	51	17			5	1		1		12			125
Bear Siding		50	25	8		1	1	27			2	10			125
Perkinsville	5	112	76	57		63		36		4		1		1	355
Railroad Bridge		33	62	50	3	3		2			2	4			159
Sycamore	1	38	41	25	51		1	9							166
Total 1996	282	471	654	259	140	68	13	275		6	6	32		1	2207

Table 1. Continued

D

Total number of fish collected at seven sites in upper Verde River, spring 1997.

Site	Longfin dace	Desert sucker	Sonora sucker	Roundtail chub	Spike-dace	Speckled dace	Yellow bullhead	Carp	Red shiner	Channel catfish	Mosquito-fish	Flathead catfish	Green sunfish	Smallmouth bass	Fathead minnow	Total
Burnt Ranch		66	68	24			13	3	1		3		4	8		189
FR638	19	76	57	8			10	1	82					1		254
Duff Spring	2	0	11	5			0	12	830	1				6		867
Bear Siding		18	4						8			1	3	11		46
Perkinsville		15	28			1	1		1222				1	1		1269
Black Bridge		44	34	13					77					2		170
Sycamore		12	38				16	3	17					6		92
	21	231	240	50		1	40	19	2238	1	3	1	8	35		2888

E

Total number of fish collected at seven sites in upper Verde River, spring 1998.

Site	Longfin dace	Desert sucker	Sonora sucker	Roundtail chub	Spike-dace	Speckled dace	Yellow bullhead	Carp	Red shiner	Channel catfish	Mosquito-fish	Flathead catfish	Green sunfish	Smallmouth bass	Fathead minnow	Total
Burnt Ranch		21	43	12				1	27		5		9	11		129
FR638	12	28	27	19				1	101		1		1	5		195
Duff Spring		10	16	23			9	2	79			1	2	19		161
Bear Siding		15	9	1			4	4	6				6	4		49
Perkinsville		35	10	5		12	5		701				1	3		772
Black Bridge		13	11	4			8		132				2	17		187
Sycamore	1	4	8				7	1	1					5		27
	13	128	124	64	0	12	33	9	1047	0	6	1	21	64	0	1520

Table 2. Relative abundance (%), number, and surface area of aquatic macrohabitats in time and space, upper Verde River, 1994-97.

Sample Reach Year	Glide	Run	LGR	HGR	POOL	Number	Surface area, m^2
	Habitat type						
Burnt Ranch							
1994	1	57	35	0	7	10	2124
1995	78	0	9	0	13	14	1712
1996	38	7	23	8	24	11	965
1997	15	16	22	0	47	13	828
FR 638							
1994	33	14	37	11	5	11	1411
1995	48	30	9	11	3	12	2674
1996	32	11	26	13	18	12	1450
1997	21	26	29	10	15	18	1134
Bear Siding							
1994	19	19	12	11	38	10	1486
1995	16	0	27	9	48	13	5157
1996	37	5	26	13	19	13	2231
1997	51	4	5	12	29	14	1283
Duff Spring							
1994	67	6	15	9	3	10	1913
1995	36	8	7	3	47	13	2483
1996	22	0	4	2	72	13	1554
1997	12	15	8	10	55	16	2303
Perkinsville							
1994	21	30	16	25	7	10	2279
1995	36	10	10	12	33	11	3307
1996	47	7	0	39	7	7	2150
1997	47	8	26	11	9	14	969
Black Bridge							
1994	33	37	30	10	0	7	1185
1995	10	25	18	7	41	11	2390
1996	23	19	0	23	35	11	1303
1997	6	18	26	0	49	11	812
Sycamore							
1994	0	40	27	21	11	10	2111
1995	24	21	24	0	32	10	4970
1996	42	29	0	22	6	8	1953
1997	6	58	26	3	7	15	766