Rabies in Bats from Oklahoma

William Caire

Biology Department, University of Central Oklahoma, Edmond, Ok 73034

Based on literature accounts, records at the Oklahoma State Department of Health (OSDH), and identification of bat species submitted for rabies testing, bat rabies in Oklahoma is discussed. The average number of bats submitted annually to the OSDH for rabies testing from 1971 to 1996, was 61. Ten species of bats have been identified. Of those submitted from 1987 to 1996 the red bat (*Lasiurus borealis*) was the species most frequently submitted. The percentage of bats that tested positive for rabies among those submitted from 1971 to 1996 averaged 8.1% per year.

INTRODUCTION

In the United States, occurrence of bat rabies was first suspected in 1951 when an individual in Texas was bitten by a bat and later died of rabies (*1*). However, the bat was not saved for rabies diagnosis or identification. The first documented incidence of rabies in a bat in the United States was in 1953 in Florida and involved the yellow bat, *Lasiurus intermedius (2).* By the 1970s, bat rabies had been reported from all 48 contiguous states and from most insectivorous species of bats in the United States (*3*). Other than the Oklahoma State Department of Health (OSDH) epidemiological reports on rabies (*4-6*), no overall summary of the incidence of rabies in bats from Oklahoma has ever been compiled. The objective of this paper is to summarize the occurrence of bat rabies in Oklahoma.

METHODS

Transmission of rabies from bats to humans is rare (*7*), but negative publicity has caused the general public to perceive bats as a serious threat to health. Therefore, the OSDH receives bats from veterinarians, public agencies, and concerned citizens for rabies testing. Since 1987, I have encouraged the OSDH to save for identification to species, those bats submitted for rabies testing. This might provide insight into whether a particular species of bat is more susceptible to rabies. The Center for Disease Control (CDC) is currently requesting that rabid bats be identified to species in each state. Because of changes in personnel, and the poor condition of some of the bats, most but not all of the bats submitted to the OSDH through the years were saved for identification. Bats were kept frozen at the OSDH until I identified them based on external characteristics. Nomenclature follows Wilson and Reeder (*8*) for scientifc names and Caire et al. (*9*) for vernacular names. A list of species identified was submitted to the OSDH. All bats were incinerated after identification. For this paper, those records at the OSDH and CDC that pertain to rabies in bats from Oklahoma were examined and summarized.

RESULTS and DISCUSSION

Only one report that discusses the occurrence of rabies in various species of bats in Oklahoma exists (*10*). Glass, in 1959, reported rabid Brazilian free-tailed bats *(Tadarida brasiliensis)* were among specimens collected in 1956 (*10*). He collected and tested for rabies 1,338 individuals from 13 species of bats from 1954 through 1958, but no species besides *T. brasiliensis* was reported to have rabies.

Examination of the OSDH records revealed that testing of animals for rabies dates back to 1939. No records exist from the OSDH that indicate bats were submitted for rabies testing prior to 1957, when the first bat was reported as rabid. However, Glass (*10*) indicates that he submitted bats to the OSDH for rabies testing in 1955 and 1956. Brass (*11*) records two rabid bats from Oklahoma for 1956, but these two records are not listed among the OSDH records for 1956 that were provided to me. Hassler (*12*) submitted a female hoary bat *(Lasiurus cinereus)* with two young for rabies testing in 1957. The female was diagnosed as rabid. The bat was found on the ground and

picked up by an 8-yr-old boy who was subsequently bitten. The bat died 28 hr later. Prior to its death, it was described as becoming furious and killing one of its young. When the brain was examined, no Negri bodies were found, but mice injected with the brain tissue displayed typical rabies behavior after an incubation period. Hassler indicats this was the first documented incidence in Oklahoma of a human being bitten by a bat with a confirmed case of rabies. This was probably the bat reported by the OSDH as rabid in 1957. Table 1 contains the number of rabid bats reported by the OSDH from 1957 to 1996 in Oklahoma.

TABLE 1. Bats submitted to the Oklahoma State Department of Health for rabies testing, 1957–1996 and the number and percentage that were rabid.

Year	Total No.	No.[a] Rabid	Percent Rabid
1956	?	(2) 0	?
1957	?	1	?
1958	?	0	?
1959	?	0	?
1960	?	0	?
1961	?	1	?
1962	?	(1) 0	?
1963	?	1	?
1964	?	1	?
1965	?	36	?
1966	?	13	?
1967	?	31	?
1968	?	6	?
1969	?	(3) 2	?
1970	?	1	?
1971	66	6	9.1
1972	53	6	11.3
1973	60	4	6.7
1974	81	3	3.7
1975	30	(4) 5	16.7
1976	54	5	9.2
1977	100	5	5.0
1978	89	1	1.1
1979	118	8	6.7
1980	90	4	4.4
1981	89	4	4.5
1982	56	6	10.7
1983	58	(3) 2	3.4
1984	88	4	4.5
1985	72	6	8.3
1986	37	5	13.5
1987	53	(4) 5	9.4
1988	38	0	0.0
1989	68	6	8.8
1990	43	5	11.6
1991	38	6	15.7
1992	51	5	9.8
1993	53	4	7.5
1994	31	5	16.0
1995	29	1	3.4
1996	33	3	9.0

[a] numbers in parentheses are listed by the Center for Disease Control and differ from those listed by the Oklahoma State Department of Health.

At the time Glass (*10*) and Hassler (*12*) made their reports, most public health officials were unaware of how viruses other than rabies may lead to a false positive diagnosis for rabies in bats. Rio Bravo virus and other bat salivary gland viruses have produced rabies-like symptoms in laboratory mice that were injected with brain tissue from bats (*11*). Therefore, prior to the fluorescent antibody test (FAT) for rabies, which is one of the best methods for diagnosis of rabies (*11*), bats may have been reported as rabies positive when they were, in fact, rabies negative but Rio Bravo virus positive. Hassler (*12*) found no Negri bodies in the bat, but after being injected, the mice showed symptoms of rabies and had numerous Negri bodies; therefore, this bat probably was rabies positive.

The Brazilian free-tailed bat (*T. brasiliensis)* is reported to be a natural reservoir of Rio Bravo virus (*11*). Glass (*10*) did not indicate whether any Negri bodies were found in the brains of the bats he reported as being rabid. He did, however, indicate that brain tissue was injected into mice and that the mice succumbed. Therefore, it is difficult to rule out the possibility that the bats may have been positive for Rio Bravo virus or a similar virus, and in actuality were negative for rabies. Glass also indicated that confirmatory tests were made at the Communicable Disease Center in Montgomery, Alabama; however, I have not been able to locate the results of these tests. Because earlier tests of bats for rabies in Oklahoma may have been confounded by Rio Bravo virus, it is difficult to confirm that all the bats reported as positive for rabies were actually rabid. Fluorescent antibody testing has been used by the OSDH for approximately 22 yr (personal communication, Magie Baum, OSDH), and since the insti-

tution of this reliable diagnostic test, records of rabies positive bats from 1975 to present are presumed accurate.

For the remainder of this report and in statistical descriptions of the occurrence of rabies in Oklahoma, the conservative assumption will be that all the bats reported rabid by the OSDH, even those prior to FAT, were rabid even though some could have had a virus other than rabies. If they did have another virus, then the summary numbers and percentages listed would be even smaller than what is reported.

The total number of rabid bats in Oklahoma reported by the OSDH (1956-1996) was 207 (Table 1), averaging five per year, ranging from none (1956, 1958, 1959, 1960, 1962, 1988) to a high of 36 (1965). 1 have not located specific information about the comparatively larger number of rabid bats reported in 1965 (36) and 1967 (31), nor have I located the OSDH records that indicate the total number of bats submitted each year for rabies testing prior to 1971. Based on data available from 1971 to 1996, the average number of bats submitted per year is 61, ranging from 118 in 1979 to 29 in 1995. The mean number of rabid bats per year was four (8.1% rabid) ranging from 16.7% (1975) to 0% (1988).

TABLE 2. Bats species identified and reported rabid 1987–1996.

Species[a]	No. IDed	No. Rabid	Percent Rabid
Antrozous pallidus	1	0	0.0
Eptesicus fuscus	37	4	10.8
Lasiurus borealis	261	23	8.8
Lasiurus cinereus	8	3	37.5
Myotis grisescens	4	0	0.0
Myotis velifer	8	0	0.0
Nycticeius humeralis	20	0	0.0
Pipistrellus hesperus	1	0	0.0
Pipistrellus subflavus	9	2	22.2
Tadarida brasiliensis	14	0	0.0
Nyctinomops macrotis[b]	1	0	0.0

[a] Four rabid bats in 1987, three in 1989, and one in 1991 were destroyed before an identification could be made.
[b] Species submitted in 1977.

Based on the number of bat rabies cases reported from each state in the United States from 1956 to 1992 by Brass (*11*), the average percent of all rabid bats reported from Oklahoma was 1.22% ranging from 0 to 7.44%. Whether or not this is comparatively low or high is biased by the unequal number of bats submitted for rabies testing from each state. States with larger geographical areas and higher population densities of bats may have more rabid bats because of their larger size and the increased likelihood of a bat being found by the public and submitted for rabies testing. For example California and Texas averaged 17.56% and 13-56%, respectively, of the total rabid bats for these same years).

The percentage of rabid bats reported in Oklahoma and in other states is probably higher than what naturally occurs. The bats tested for rabies by state health departments are those that, if rabid, may have caused human or domestic animal exposure. Therefore, these samples do not provide an accurate indication of the extent of rabies in natural populations of bats. Tuttle and Kern (*7*) reported that rabies probably occurs in less than 1/2 of 1% of the bats in most natural populations. Yancey et al. (*13*) examined 171 freeflying bats from the Big Bend region of Texas and found none positive for rabies. They estimated that the prevalence of rabies in the natural population was less than 1.74%. The only study in Oklahoma that approximates a sample from a natural population and tested the bats for rabies was that done by Glass (*10*) from 1954 to 1958. Of the 1,338 individuals of 13 species he examined for rabies, only five, 0.3%, at the most (he pooled some samples) were reported as positive for rabies. The rabid bats reported by Glass were sick or moribund individuals taken from cave floors and were not active, flying bats. As suggested earlier, these bats may have been infected with Rio Bravo virus rather than rabies virus, resulting in no bats with rabies in his sample. Either finding would indicate rabies is not common in natural populations of bats.

Of the bats submitted for rabies testing to the OSDH from 1987 to 1996, I have identified 363 to species (Table 2). Of the 21 different species of bats known to occur in Oklahoma (*9*), 11 have been found among the OSDH specimens (Table 2). Only our species, *Eptesicus fuscus*, *L. borealis*, *L. cinereus*, and

TABLE 3. Bat species identified each month, 1987–1996. Abbreviation for each species is: Ap, *Antrozous pallidus*; Ef, *Eptesicus fuscus*; Lb, *Lasiurus borealis*; Lc, *Lasiurus cinereus*; Mg, *Myotis griseens*; Mv, *Myotis velifer*; Nh, *Nycticeus humeralis*; Ph, *Pipistrellus hesperus*; Ps, *Pipistrelleus subflavus*; Tb, *Tadarida brasiliensis*.

YEAR[a]	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1987		1 Ef 1 Lb	1 Lb	20 Lb	5 Lb 1 Mg	2 Lb 2 Ps			
1988				1 Ef 3 Lb 1 Nh	8 Lb 1 Lc	1 Ef 1 Lb 1 Nh	1 Lb 1 Lc		
1989				7 Lb	4 Lb	1 Ap	3 Lb 1 Lc	2 Lb 1 Lc	1 Lb
1990		1 Lb 1 Tb	2 Ef 1 Lb 1 Lc	1 Ef 6 Lb	1 Ef 15 Lb	2 Ef 3 Lb	3 Lb 2 Mv 1 Ps	1 Ef 3 Mv	1 Ef
1991	1 Tb	1 Lb	1 Ef 3 Lb	1 Ef 9 Lb 1 Nh	1 Ef 4 Lb 2 Nh	1 Ef 4 Lb 1 Nh	1 Ef 1 Nh	1 Ef 1 Lb 1 Nh	
1992	1 Ef 1 Lb		1 Lb	1 Ef 24 Lb 1 Tb	2 Lb 1 Mv	2 Ef 1 Lb 1 Mg	7 Lb 2 Lc 1 Nh	1 Lb	1 Lb
1993		1 Lb	1 Mg 2 Lb 1 Tb	17 Lb 3 Ef	10 Lb 1 Nh 1 Tb	1 Tb	1 Ph	3 Lb 1 Nh	1 Lb
1994			1 Ef 2 Lb	1 Lb	12 Lb	1 Ef 1 Lb 1 Nh 1 Tb	1 Ef 3 Lb 1 Lc	2 Ef 1 Mg	1 Lb
1995			1 Lb 1 Nh 1 Ps	6 Lb	10 Lb 1 Ps	1 Ef 1 Lb 1 Nh	1 Ef 1 Lb	1 Ef 1 Tb	1 Tb
1996	1 Ps	1 Lb		10 Lb	1 Ef 6 Lb 1 Mv 2 Ps	1 Ef 1 Lb	2 Lb 1 Nh	1 Nh	1 Ef 1 Lb 1 Mv
TOTAL	4	7	20	113	90	33	35	21	9

[a] No bat was identified in January, February, or December except these three: 1990 Jan, 1 Ef; 1992 Dec, 1 Ef; 1993 Jan, 1 Nh.

Pipistrellus subflavus, have had individuals that tested positive for rabies. In addition to these species are the questionable specimens of *T. brasiliensis* reported by Glass (*10*) as rabid. All 21 species of bats in Oklahoma are susceptible to rabies, and Constantine (*3*) has shown that rabies does occur in most of these species in other states. The species most often identified in annual samples at the OSDH is *L. borealis*, the red bat, 261, 71%, of the 363 bats.

There is a significant difference (log-likelihood ratio test, $X^2 = 447.1$; $P \leq 0.000$) in the number of bats submitted each month to the OSDH, for rabies testing. Table 3 reveals that 95.2% of the bats identified at the OSDH, for which the month of submission was also listed, were submitted during spring, summer, and early fall, April to October, the time of year when bats are most active in Oklahoma. Within this time period, 63.6% of the bats were submitted during June and July. These two months correspond closely to the season when most young are born (*9,14,15*).

Of the 203 bats submitted in June and July, 176 were red bats (*L. borealis*). Of these 176 red bats, 27 were females carrying pups-71 total pups, mean number per female was 2.6, ranging from one to five. Red bats roost in trees, and June and July are the months when females are either pregnant or nursing. On windy days, female bats could have been blown

from tree roosts ending up on the ground. Because of the additional weight of the young, it could have been difficult for the females to regain flight. Thus, these bats were often found by the public and submitted to the OSDH for rabies testing.

If adults of all four species of bats, *E. fuscus, L. borealis, L. cinereus,* and *P. subflavus*, that had rabies reported for some of the specimens submitted are pooled, and the frequency of occurrence of rabies between female and male bats is compared, a significant difference between sexes still exists (log-likelihood ratio test, $X^2 = 8.502$, $P \leq 0.0035$). This difference is probably influenced by the relatively larger number of red bats.

Besides the red bat, only *E. fuscus* was submitted in large enough numbers to analyze statistically for differences in the occurrence of rabies between males and females. There was no significant difference in the frequency of occurrence of rabies in male and female *E. fuscus* (log-likelihood ratio test, $X^2 = 0.275$, $P \geq 0.6003$). Of the adult red bats identified, 46 were males and 124 were females. Eleven, 23.9%, of the 46 adult males, but only 10, 8.1%, of the 124 adult females, were reported positive for rabies. A log-likelihood ratio test positive of these data indicates a significant difference, $X^2 = 5.834$, $P \leq 0.0157$, in the frequency of occurrence of rabies in male and female bats. Why nearly two and a half times as many male as female red bats were rabid is not obvious. Males could have been more aggressive and fought among themselves more than did females, facilitating a higher transmission rate of rabies among males. Rabid bats have been known to attack other bats and possibly transmit rabies (*16*). Interestingly, none of the females submitted with pups nor any of the pups tested positive for rabies.

The identification of bats submitted for rabies testing at the OSDH has and will continue to add to our knowledge of bat ecology, reproduction, and distribution in the state. For example, the second occurrence of *Nyctinomops macrotis* (*17*), the big free-tailed bat, in Oklahoma would have gone unnoticed except for its identification among bats submitted for rabies testing. Three individuals of the endangered Gray Bat, *Myotis grisescens,* have been found in samples. The Hoary bat, *L. cinereus,* is also uncommonly reported by bat researchers in Oklahoma (*14*), but it has been identified on several occasions among OSDH specimens. The examination of the numerous female red bats and associated pups increases our understanding of reproduction in Oklahoma of this species.

Based on data compiled from the OSDH and the CDC, bats comprised a smaller percentage, 4%, of all mammals testing positive for rabies in Oklahoma from 1957 to 1996 (Fig. 1) than skunks, 68.9%; livestock, 16.3%; and dogs and cats, 9.3%. In the south central region of the United States, skunks have been most often reported as rabid and possibly serve as the major terrestrial reservoir of rabies in the wild (*18*).

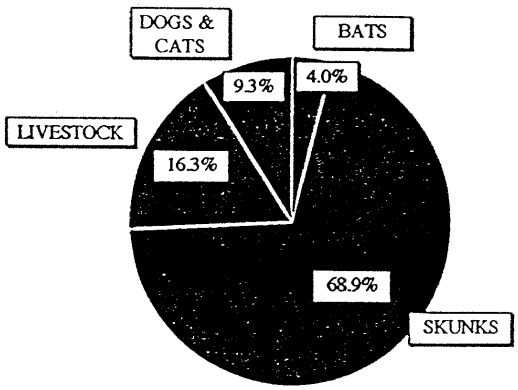

Figure 1. The percentages of various mammals reported rabid by the Oklahoma State Department of Health from 1957 to 1996.

Bat rabies potentially is present in all Oklahoma counties. Based on the available data from 1967 to 1996 (county data were not available for some of the bats in 1968, 1971-73, and 1975), 138 rabid bats have been reported from 42 counties (Fig. 2). Sixty-five, 47%, of the rabid bats have been reported from just three counties: Tulsa, 31; Oklahoma, 25; and Cleveland, 9. These counties have large urban centers, and encounters between bats and people probably are more frequent than in rural settings. These data should not be interpreted as indicating a lesser potential for rabid bats in rural areas of Oklahoma or a greater potential for urban settings. Large populations

of bats, for example *T. brasiliensis* and *M. velifer,* exist in western Oklahoma (*9*), and rabies could occasionally exist in those populations. However, because few people reside in those areas, fewer bats are in contact with humans and fewer are submitted for testing. In Austin and San Antonio, Texas, large populations of Brazilian free-tailed bats live fairly close to humans, yet no cases of human rabies have been attributed to those populations of bats. Until an unbiased sampling of bats for rabies in the state is made, any suggestions of differences in the geographical occurrence of rabies in the state will be conjecture.

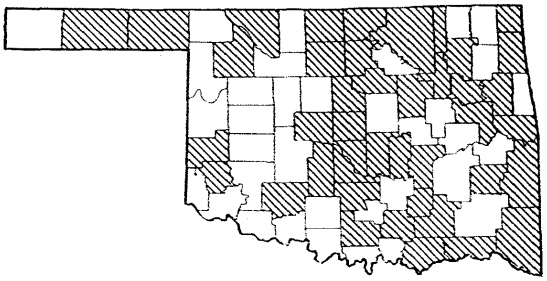

Figure 2. Cross-hatched areas are Oklahoma counties from which rabid bats have been reported.

Infection of humans with rabies from bats is a concern even though it is a relatively rare occurrence. From 1980 to 1996, 28 cases of human rabies have occurred in the United States (*18*). Krebs et al. (*18*) indicated 15 of the 28 cases were due to bat rabies variants, but the actual exposure history of many of the individuals remains unclear. None of the human rabies cases associated with a bat viral variant have been from exposure in Oklahoma. Three different bat rabies viral variants have been identified in the human cases: the silverhaired bat, *Lasionycteris noctivagans,* variant; the Brazilian free-tailed bat, *T. brasiliensis,* variant; and a myotis bat, *Myotis* sp., species variant. Individuals of all these species of bats occur in Oklahoma. The silver-haired bat is uncommon in Oklahoma (*9*); it is, apparently, a seasonal migrant across the state in spring and early fall (*9*). Human contact with silverhaired bats in Oklahoma is minimal, but how it interacts with other species of bats is unknown. Brazilian free-tailed bats are known to occur in southeastern and western Oklahoma (*9*). The largest populations of Brazilian free-tailed bats exist in western Oklahoma, but they occur in just a few caves and in rather remote areas. This reduces the chances of humans being exposed. Even though there are several species of *Myotis* in Oklahoma (*9*), and they occur statewide, human contact is uncommon.

Which variants of rabies virus predominately exist in Oklahoma bats is unknown. J.S. Smith (personal communication) at the CDC indicated that no bats confirmed with rabies from Oklahoma have been examined there to determine exactly which rabies viral variant is present. As in other regions of the United States, probably each species of bat confirmed to have rabies will be shown to harbor a unique, species-specific variant form of the virus (J. S. Smith, CDC, personal communication). Seemingly, all variants of the virus are transferable among all species of mammals. Epidemiologically, bat rabies is reported as being distinct from rabies in terrestrial mammals (*18*), and circulation of these bat variants among the various species of bats is much less well understood than those in terrestrial mammals (*18*).

A full understanding of the natural history of rabies in bats in Oklahoma is far from complete. It will remain so until unbiased samples of natural populations can be made. Only then will variations in its frequency of occurrence within and among species, its geographical extent, and the etiology and epizoology of the disease in bats be comprehended.

ACKNOWLEDGMENTS

I thank the individuals at the Oklahoma State Department of Health for their cooperation and patience, the time spent preserving the bats for my later identification, and the retrieval of data from early records. The manuscript was improved as a result of comments from Dr. Kristy Bradley (OSDH) and Dr. Gloria Caddell (UCO).

REFERENCES

1. Sulkind SE, Greve MJ. Human rabies caused by bat bite. Texas J Med 1954;50:620-621.

2. Venters HD, Hoffert WR, Scatterday JE, Hardy AV. Rabies in bats in Florida. Amer J Public Health 1954;44:182-185.

3. Constantine DG. An updated list of rabies-infected bats in North America. J Wildlife Dis 1979;15:347-349.

4. Caire W. Bat rabies in Oklahoma. OSDH Epidemiology Bull 1993;93(3):4-5.

5. Calhoun J. Annual review of animal rabies, Oklahoma, 1988. OSDH Epidemiology Bull 1989;89(3):1-4.

6. Graves T, Spocogee M. Rabies in Oklahoma, 1991. OSDH Epidemiology Bull 1992;92(4):1-3.

7. Tuttle MD, Kern SJ. Bats and Public Health. Milwaukee Public Mus Contrib Biol and Geol 1981;48:1-11.

8. Wilson DE, Reeder DM. Mammal Species of the World, A Taxonomic and Geographic Reference. Washington (DC): Smithsonian Insitution Press; 1993. 1207 p.

9. Caire W, Tyler JD, Glass BP, Mares MA. Mammals of Oklahoma. Norman (OK): Univ. Oklahoma Press; 1989. 567 p.

10. Glass BP. Recovery of rabies virus from the Mexican freetailed bat in Oklahoma. Proc Okla Acad Sci 1959;39:83-84.

11. Brass DA. Rabies in Bats. Ridgefield (CT): Livia Press; 1994. 335 p.

12. Hassler FR, Rabies in a bat. Morbidity and mortality report, N.O.V.S., U.S.P.H.S., for week ending July 27, (1957).

13. Yancey FD, Raj P, Neill SU, Jones C. Survey of rabies among free-flying bats from the Big Bend region of Texas. Occa Papers Mus, Texas Tech Univ 1997;165:1-5.

14. Caire W, Hardisty RM, Lacy KE. Ecological notes on *Lasiurus cinereus* (Chiroptera: Vespertilionidae) in Oklahoma. Proc Okla Acad Sci 1986;66:41-42.

15. Caire W, Hardisty RM, Lacy KE. Capture heights and times of *Lasiurus borealis* (Chiroptera: Vespertilionidae) in southeastern Oklahoma. Proc Okla Acad Sci 1988;68:51-53.

16. Bell GP. A possible case of interspecific transmission of rabies in insectivrous bats. J Mammal 1980;61:528-530.

17. Pyle RA, Caire W. Second record of *Tadarida macrotis* (Gray) (Chiroptera: Molossidae) in Oklahoma. Southwest Nat 1979;24:371-390.

18. Krebs JW, Strine TW, Smith JS, Noah DL, Rupprecht CH, Childs JE. Rabies surveillance in the United States during 1995. J Amer Vet Med Assoc 1996;209:2031-2044.

Received: 1998 Mar 17; Accepted: 1998 Aug 31.