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ECOLOGICAL RELATIONSHIPS OF TRIATOMA P. PROTRACTA (Uhler) IN GRIFFITH PARK, LOS ANGELES, CALIF.[1]

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Abstract: Populations of Uhler's western conenose, *Triatoma p. protracta*, exist in houses of the *Neotoma* wood rat in at least 4 isolated canyons of Griffith Park, Los Angeles. Fecal examinations of 1759 triatomes of the 2188 collected revealed that 593 or 33.1% harbored *Trypanosoma cruzi*. The highest rate of infection was found in the Boys' Camp where 463 adults or 45.3% of 1044 triatomes examined were infected. Months of most active natural dispersal were July and August with movements confined to a thermoperiod of 15.5°C (60°F) to 24.4°C (76°) at the camp site. By xenodiagnosis, 9 of 99 *Neotoma* trapped showed parasitemias with Chagas' trypanosome. The feeding of triatomes on human inhabitants of the camp has been a serious annoyance. Severe allergic reactions have occurred. This association is due to man's use of an area in the normal dispersal flight path of the insect.

Survey of the 4060 acre Griffith Park area in Los Angeles for the presence of conenose bugs, *Triatoma p. protracta* (Uhler), has been intermittently carried out since 1941 (Wood 1942, 1950, 1960a) by searching the houses of *Neotoma* wood rats and the homes of man. Suitable natural chaparral habitats for wood rat houses harboring *Triatoma* occupy about 2700 acres. This acreage varies because of recurrent brush fires which destroy or induce animal inhabitants to migrate. Most burned areas regain their chaparral cover in seven years under conditions of normal rainfall. Most wood rat houses occur on the east slopes or in deep canyon ravines where chaparral shrubs are most abundant. At present, there are four areas known as centers of dispersal for variable sized populations of this blood feeding insect. These areas are designated from a 1955 Fire Map of the park as 10, 13, 29 & 30, and 65. The largest populations of triatomes are found in the Boys' Camp area (29 & 30) and the Girls' Camp area (65).

The presence of *Trypanosoma cruzi* Chagas in these triatomes is of special interest in relation to uses of nearby areas of the park by man, for recreation and for the Los Angeles Zoo. Natural infection of man by this trypanosome has not been demonstrated in California.

Annoyance by *Triatoma* to occupants of the youth camp in 1950 was summarized by Wood (1953b). The movement of man into these canyon habitats of the conenose bug has made it imperative to provide ample protection from nocturnal predation by both adults and

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nymphs of this hematophagous insect. Subsequent collections by the senior author, his students, and the camp caretaker, Arthur L. Gladwill, have revealed a remarkably active population of conenose bugs preying on man and other large mammals during the normal dispersal flight in the park camp area 29 & 30 at 118° 17′ W. Long. and 34° 08′ N. Lat.

Methods

Collecting of *Triatoma* has been largely from the microhabitats of the host mammals in Griffith Park. This involves locating houses of the *Neotoma* wood rat, dismantling these brush pile structures in dense chaparral shrubs or in the center of small trees, and hand collecting triatomes (Wood 1941, Linsdale & Tevis 1951, Ryckman 1962). During summer dispersal flights, triatomes were handpicked from the inside or outside surfaces of human habitations within 1.6 km of wood rat houses. Many *Triatoma* were collected from white sheeting or a white painted surface near a 15W fluorescent light (GE F15T8-B Blue) hereafter referred to as a "blue light." The back of the light receptacle was placed centrally on the nearly horizontal "reflecting surface."

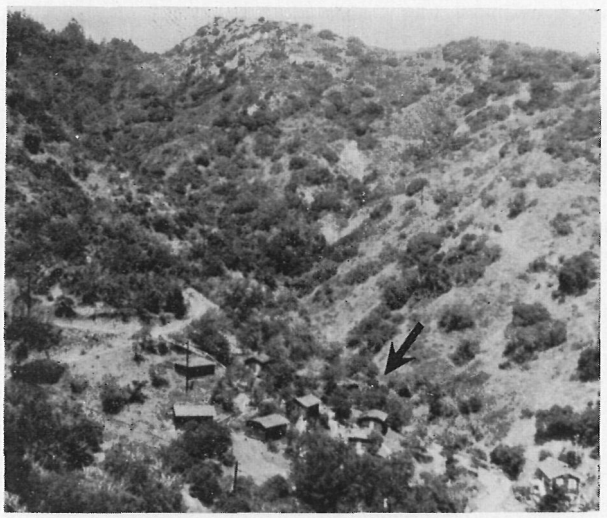

Fig. 1. Griffith Park Boys' Camp and vicinity looking west, on 17.VI.1964. The arrow points to the camp cabins to the left of the caretaker's house. The main lodge building and play area is down canyon to the right of the caretaker's house.

Triatomes were examined for the presence of *Trypanosoma cruzi* by inspecting sodium-citrate diluted specimens obtained by dissection of the rectum, forced evacuation with mechanical pressure, or collection of natural dejecta after feeding on laboratory white mice orguinea pigs.

OBSERVATIONS

Concentration of adult *Triatoma* in human housing depends on general environmental temperature controls for stimulating feeding and subsequent growth of nymphal instars in the microhabitats of nearby wood rat houses. Ample feeding opportunities for triatomes bring release of maturation hormones (Wigglesworth 1964) which stimulates metamorphosis and subsequent acquisition of wings making adult dispersal flights possible. After a period of mating and egg laying in wood rat houses, the adult triatomes, under summer temperature stress, seek larger mammals, including man, to satisfy their increased hunger drive and then spread to other areas for colonization. This natural seasonal searching or dispersal flight brings the adult triatomes into contact with human habitations and eventually in this species in a small percentage of cases, with man.

Since the dusky-footed wood rat, *Neotoma fuscipes macrotis* Thomas, is their chief source

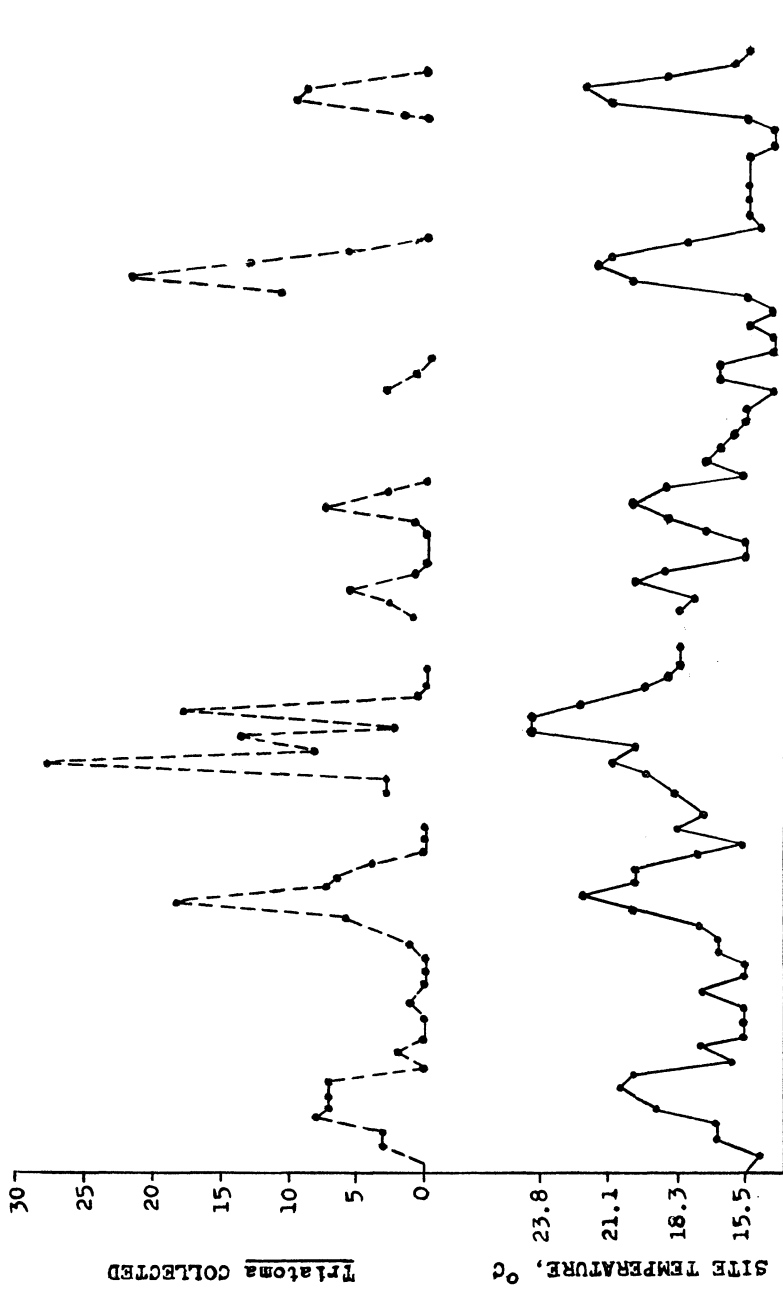

Fig. 2. Canyon site temperatures (solid line) and blue light collection of *Triatoma* (dash line) from 6 July through 25 Sept., 1964 at Griffith Park Boys' Camp. Note the close correlation of peak numbers of triatomes with maximum temperatures.

of blood in Griffith Park, a build-up of triatome populations is dependent upon a sufficient concentration of these rodents. The existence of such a population of rats was amply demonstrated by trapping during the fall and winter of 1963 and continuing into the spring and summer of 1964 when over 378 rodents, including at least 252 *Neotoma*, were removed from area 29 & 30. Some of these rodents were the xenodiagnosis specimens reported below. Thus, it was known that an ample blood supply was available for supporting the large population of triatomes captured by Gladwill during the summer of 1964, a record capture of 473 conenose bugs for one season. Since Wood (1943) has shown that *Neotoma albigula* can feed over 1000 *Triatoma* adults and nymphs at spaced intervals without harm over a six months period, the trapped population of 252 rodents is in excess of those necessary to support the triatome populations here discussed. This heavy local population of native rodents may be partially a result of enforced concentration by recent brush fires and the abundance of food at nearby picnic facilities.

The total number of triatomes collected by us and associates from 1950 to the present from buildings and grounds of the Boys' Camp area was 1396. Collecting totals by months, for 1203 of these were: 28 in June, 360 in July, 508 in August, 218 in September, 68 in October and 21 in November. Flights generally began in June and ended in October with a few collected as late as November (1964) depending upon the intensity and duration of the recurring fall "heat waves" in the area.

Recorded collections of *Triatoma*, according to data available to us, for the Boys' Camp, exclusive of wood rat houses, are 33 in 1950, an estimated 25 in 1951 (J. Rafferty, verbal commun.), 13 in 1953, 162 in 1957 (Mehringer & Wood 1958), 53 in 1958 (Wood 1960a), 189 for 1960 (Mehringer, Wood & Anderson 1961), 27 in 1961, an estimated 150 in 1962 (A. L. Gladwill, verbal communication), 204 in 1963 (Wood & Anderson 1965), 473 in 1964 (collected by A. L. Gladwill), and 67 in 1965. Of 1044 adult triatomes examined, 463 or 45.3% harbored *Trypanosoma cruzi* with 41.7% of the males and 46.6% of the females infected.

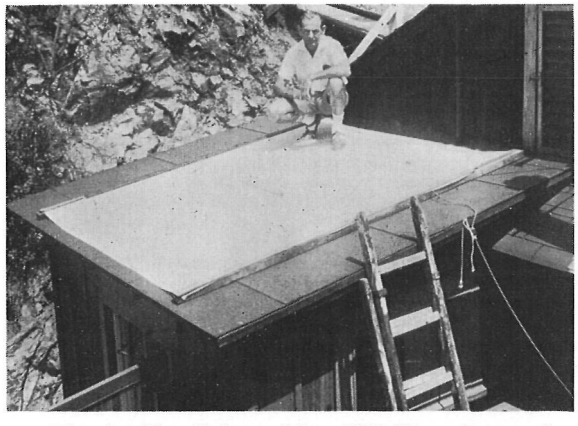

Fig. 3. Blue light position, NW–SE, and general location on the roof of the utility shed attached to the main lodge building. The *Triatoma* collection site for 1964 and Gladwill photographed 12. VIII.1964. Elevation 224.9 m.

The most complete data for any year on record is 1964, as noted above, when 473 triatomes were collected by Gladwill (fig. 3) from the UNOCCUPIED Boys' Camp (fig. 1). The number of *Triatoma* flying to a white sheet with a blue light oriented NW-SE at the center (fig. 3) is shown in fig. 2. The curve for the daily total of all triatomes found correlated with "site temperatures" was very similar. Temperatures were read by Gladwill from a Taylor thermometer in permanent shelter near the caretaker's home. Distribution of triatomes for 1964 was as follows: June 4, July 148, August 160, September 106, and October 55. Buildings searched yielded 165 triatomes,

Table 1. Invasions of Camp Director's Homes in Griffith Park by Uhler's Western Conenose.

Year	Triatomes collected	Triatomes examined	Infected with *Tryp. cruzi*	Per cent infection
		Boys' camp (Areas 29 & 30)		
1950	24 adults	2♂, 6♀	1♂	12.5
1953	5♂, 5♀	5♂, 5♀	1♀	10.0
1957	1♂, 6♀	1♂, 6♀	2♀	28.5
1958	2♂, 4♀	2♂, 4♀	2♀	33.3
1960	6♂, 12♀	3♂, 8♀	6♀	54.5
Totals	65	42	12	28.5
		Girls' camp (Area 65)		
1957	22♂, 15♀	30 adults	2♀	6.6
1958	7♂, 9♀	7 adults	1♂	14.2
1960	28♂, 48♀	15♂, 34♀	4♂, 4♀	16.3
1964	1♂, 6♀	1♂, 6♀	1♀	14.2
Totals	136	93	12	12.9

and 303 were taken at the blue light. The evening search pattern of Gladwill was to set up the light station before dark and to alternate search of the nearby main lodge and the caretaker's quarters (fig. 5), and captures from the light (fig. 3), as the triatomes appeared. During evenings when conenose bugs were numerous, the buildings were searched before and after captures were made at the light. The blue light was located on a small, slanting roof at the rear of the main lodge building at 224.9 m above sea level as previously described by Wood & Anderson (1965).

For 472 triatomes examined from the area in 1964, 118♂♂ and 107♀♀ were positive for *Trypanosoma cruzi* and 143♂♂ and 104♀♀ were negative resulting in an infection rate of 47.6%. The examination of the feces of 472 *Triatoma* for trypanosomes was carried out in groups as collected, stored, and supplied by Gladwill. The dates, number of triatomes, and infection rates by groups as examined were as follows: 14.VII, 59, 45.7%; 28.VII, 61, 50.8%; 4.VIII, 35, 60%; 12.VIII, 30, 46.6%; 1.IX, 8, 37.5%; 10.IX, 22, 50%; 22.IX, 54, 37%; 7.X, 57, 35.6%; 13.X, 12, 25%; 22.X, 12, 33.3%; and 1♂ negative. Thus, there tended to be a higher proportion of infected triatomes during July and August than September and October. Since this camp was not in use during 1964, the population sample is accurate for the methods of interception employed. Each night that the blue light was used, no other lights were on to detract from the collecting light. This 1964 sampling compares with previous highs of 204 for 1963 and 189 for 1960 (Mehringer 1962) when bugs were collected over the entire occupied camp area with many lights burning. The 1964 collection was made from the lodge building, caretaker's home, and light source ONLY. These collections verify the previous prediction of Mehringer & Wood (1958) of a sizeable reservoir of vectors in the wood rat houses scattered through the chaparral covered slopes of area 29 & 30 in Griffith Park.

During the 1965 summer at the Boys' Camp, additional observations were made for the 67 triatomes from the caretaker's quarters and the ground floor foundation of the former director's home at 229.2 m elevation. A central 2.2 m square area of lineoleum floor tile was painted "off white" and the blue light was placed in the center oriented in a NE-

SW direction (fig. 4). This reflecting surface, as measured from the outside edge at an elevation of 1 m with a light meter (Weston Master II, Model 735), gave a reading of 3.2 foot candles from NE, NW, and SW and 4.8 foot candles from the SE in full darkness from both a blue and then a black light (Table 2). This elevation placed the light meter in an area of maximum light intensity or at an angle of 45° to the light source.

The caretaker's home is two stories, the upper being the living quarters and the lower serving as a garage and storage area (fig. 5). Seventeen *Triatoma* were collected by Gladwill during 1965. Of 8 picked up inside the home, 3♂ and 3♀ harbored *Trypanosoma cruzi* and 2♀ were negative. Of 7 found in the garage and storage area, 4♀ were positive, 2♂ negative and 1♂ was not examined. For 2 triatomes found on the outside steps leading to the living quarters, 1♀ was positive and 1♂ was negative.

For 19 "LIGHT NIGHTS" during June and July 1965 only 6 triatomes were collected (5♂, 1♀) in contrast to 72 for 19 nights in 1964. Distance distributional data for 20 triatomes on 5 light nights revealed 14 alighting within 60 cm of the blue light, the closest bug being 15.2 cm away; 5 were found in the dark zone 121 to 182 cm from the attractant light and off the white reflector surface; and 1 was picked up between 60 and 121 cm from the light. Five triatomes apparently alighted on their backs. Gladwill (verbal commun.) reports that specimens were collected on the light itself in 1964. Directional data for distribution of 26 triatomes revealed that 2 came to the light from the South, none SW, 2 W, 6 NW, 3 N, 3 NE, 3 E, and 7 SE. Wood rat houses were closest to the light on the NW side, at 45 m, and farthest on the SE side, across the main canyon. Of 28 triatomes examined for Chagas' trypanosome, 13♂♂ and 5♀♀ were negative and 7♂♂ and 3♀♀ were positive, a 34.5% infection rate. The record night capture was 11.VIII.1965 when 16 *Triatoma* were picked up at the light between 7 : 15 (23.8°C or 75°F) and 8 : 30 (22.2°C or 72°F) PM, Pacific Standard Time. There were 8♂ and 3♀ negative triatomes and 4♂ and 1♀ infected for an infection rate of 31.2%. The infected triatomes appeared at 7 : 34, 7 : 50 (2), 7 : 51, and 8 : 05 PM, PST, while the negative *Triatoma* were picked up at 7 : 26, 7 : 28, 7 : 29, 7 : 30, 7 : 37, 7 : 49, 7 : 51, 7 : 55, 7 : 58, 8 : 11, and 8 : 13 although the area was watched closely until 8 : 30 PM. The first 10 triatomes were ♂♂, the ♀♀ appearing at 7 : 51, 7 : 55, 8 : 05, and 8 : 13. On the basis of body weight and meal size, ♂♂ should appear first since they are lighter and take smaller meals. However, the larger body and meal size of ♀♀'s are probably offset by egg production so that the hunger drive for the two sexes may remain the same.

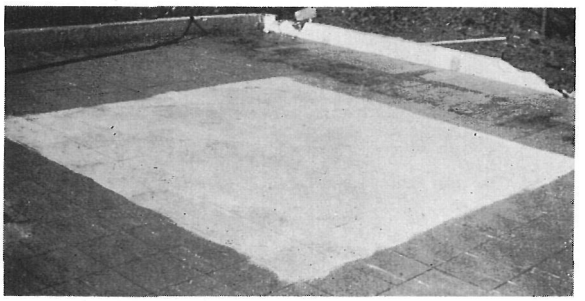

Fig. 4. Floor area of the former camp directors' home, site of the 1965 blue light collection, photographed on 8.IX.1965. The side of the razed residence can be seen in the upper right corner of Fig. 5. Elevation 229.2 m.

The data for the Girls' Camp in area 65, el. 213.3 m, at 118°18′ W Long. and 34°07′ N Lat., extends from 1957 to date. The total collection known to the writers was 341 triatomes. Distribution by months for 166 bugs was: June 21, July 143, August 119, and September 41. Collections on record for the Girls' Camp were 78 in 1957 (Mehringer & Wood 1958), 48

in 1958 (Wood 1960a), 158 in 1960 (Mehringer, Wood & Anderson 1961), 22 in 1961, and 18 in 1964. Of 293 bugs examined for trypanosomes, 25 or 8.5% were infected, including 10.3% of 106♂♂ and 7.4% of 187♀♀. The greater disturbance of natural vegetation by removing, replanting, and heavy trimming at the Girls' Camp, plus intentional removal of wood rat houses, and heavy treatment with insecticides of buildings and shrubbery (Wood & Wood 1964) have reduced the triatome population as evidenced by the 126 collected in 1957 and 1958 and only 40 in 1961 and 1964. A down-canyon flight pattern continues to funnel triatomes into this camp during the normal dispersal flight period, however, as shown above in the maximal seasonal collection of 1960.

Uhler's western conenose in Griffith Park originates in the houses of *Neotoma* wood rats. Eventually, with replacement of the natural plant cover in landscaping, the habitat of the reservoir rodent may disappear but in the meantime it is primarily responsible for maintenance of a remarkably stable zoonosis of Chagas' trypanosome. Total collections of triatomes from wood rat houses in Griffith Park known to the writer include 451 specimens with 422 examined and 105 or 24.8% infected with *Trypanosoma cruzi*. The 11.7% discrepancy in detection of trypanosome infection in bugs between examinations of daytime-searched wood rat houses and nocturnal home and the blue light collections (av. 36.5% of 1337 triatomes examined) by man probably indicates a higher rodent-triatome infection rate than has been obtained by the chance sampling methods employed. One wood rat house searched thoroughly by A. L. Gladwill, 15.XII.1963, revealed 49 triatomes (4♂, 7♀, 10–5th, 8–4th, 15–3rd, and 5–2nd instar nymphs) of which 42 or 85.7% were infected with *Tryponosoma cruzi*. The negative triatomes were 1–5th, 1–4th, 2–3rd, and 3–2nd instar

Table 2. The 1964 blue and black light triatome collections at Griffith Park, Los Angeles Co., and San Dimas Canyon, San Bernardino Co., Calif.

	Griffith park	San Dimas Canyon
Total Captures at Lights	303	398
First Triatome	24 June	17 June
Last Triatome	21 October	21 October
Maximum Number per Night	28, August 5th	22, July 24th
Light Source, Wavelength Peak	15W GE F15T8-B, 4400 Å	15W GE F15T8-BL, 3650 Å
Light Numbers	1 single	3 double
Light Placement	Flat on reflecting surface, beamed in all directions	Vertical on reflecting surface, beamed in 3 directions
Other Lights	None	Spotlight on Home
Elevation	200–457 m	750–830 m
Area Occupied by Rodent Reservoir	216 acres	164 acres
Closest Point of Ocean Shoreline	22.5 km SW	55.5 km SW
Triatome Peaks at Lights	26 July 5, 9 August & 10 September	6–12, 20–26 July, 3–9, 17–23 August & 7–13 September
Flight Thermoperiod	15.5–24.4°C (60–76°F)	19.5–29°C (67–84°F)
♂♂, ♀♀, Total	261, 211, 472	208, 147, 355
Percent Infection with *T. cruzi*	47.6 (472)	15.2 (355)

nymphs. This is one of the heaviest concentrations of infected triatomes ever recovered from one wood rat house.

A number of factors have played a part in the recovery of triatomes (Table 1) at the Camp Director's home. Allergic sensitivity to the feeding of *Triatoma* has allerted all occupants to a high degree of awareness for the presence of this unwelcome nocturnal visitor leading to an early evening search and capture of actively wandering insects. Additional heavy applications of insecticidal sprays have flushed out the triatomes from hiding places. The small size of the human habitation, 22.2 m^2 floor space at the Boys' Camp, also aided in more quickly spotting the triatomes. The reaction of triatomes to insecticides under heat stress stimulated DAYTIME dispersal movements as was previously noted at the San Joaquin Experimental Range (Wood 1951). The presence of two large dogs, bedded outside the home, first at the Boys' Camp and later at the Girls' Camp have aided the recovery of *Triatoma* due to their attractiveness (verbal communciations from kennel owners) as blood sources for this bug. These pet dogs probably attracted some of the triatomes which fed on the human occupants of the nearby home.

Fig. 5. Griffith Park Boys' Camp caretaker's house. Collecting site for 1964 (fig. 3) is to the right of the carport and below the canyon wall supporting the former camp director's house. Note the thermometer shelter to left of the tree in the yard. Photographed 17.VI.1964.

One of the unexpected discoveries from this study of *Triatoma* is that they can be collected from a blue light. As noted below, the average number of triatomes in 977 wood rat houses in SW United States has been 3.4 Thus, by "digging" into wood rat houses nearly 4 triatomes per hour can be obtained. Gladwill showed that with a blue light in 1963 on July 19th and 20th, an average of 13.3 triatomes per hour could be collected at the Griffith Park Boys' Camp. In 1964 he collected on 14 nights when an average of 23.6 triatomes per hour were obtained or 1 triatome each 2.5 minutes! The highest figure for Gladwill was 29 triatomes per hour on 5 August 1964 with the site temperature at 21.1°C (70°F).

'Walking' the roadbed and sidewalks of the Mulholland Overcrossing, we averaged 11.6 triatomes per hour in 1960 in obtaining 180 adult *T. protracta*. The maximum of 46 adults was collected 11 August giving an average of 23 triatomes per person per hour at a site temperature of 25.5°C (78°F) (Wood & Wood 1964).

Although no actual counts have been made of the number of individual wood rat houses in area 29 & 30, which includes the Boys' Camp, an estimate of 150 was made by the senior author for the general region (Wood 1953b). Since 1941, 83 wood rat houses have been disassembled in Griffith Park. From these, 451 triatomes were collected. This averages 5.4 triatomes per house compared to a general average of 3.5 for 3441 triatomes from 981 wood rat houses searched throughout SW United States. Very little is known of the survival rates for *Triatoma* in wood rat houses. Many potential arthropod enemies as scorpions,

pseudoscorpions, solpugids, mantids, spiders, and lizards exist in this habitat (Wood 1944, 1967, Linsdale & Tevis 1951). Therefore, the 473 triatomes collected in 1964 are a good approximation of the normal dispersing population of *Triatoma* for area 29 & 30.

Xenodiagnoses

From Feb. 1941–Oct. 1965, 159 rodents from Griffith Park have been subjected to xenodiagnosis shortly after being trapped by feeding laboratory-raised, trypanosome-free triatomes on them. There were 99 *Neotoma fuscipes macrotis*, 56 *Peromyscus californicus insignis*, 2 *P. maniculatus gambelii*, 1 *Reithrodontomys megalotis longicaudus*, and 1 *Mus musculus*. Most (113) of these rodents were trapped in 1963 and 1964 by Gladwill to test the theory that cold stress stimulates the flare-up of *Trypanosoma cruzi* in field rodents as shown by Kolodny (1939, 1940) to be true for laboratory rodents and as demonstrated in mammals from Arizona by Wood (1949). Of 73 *Neotoma* tested in 1963–64, 6♂♂ and 2♀♀ were positive for Chagas' trypanosome. Thus, 9 or 9% of the 99 *Neotoma* sampled in Griffith Park were carrying *Trypanosoma cruzi* at the time sampled. All the positive mammals sampled were trapped in December (1–1952, 4–1963) or January (4–1964) which are the months of greatest cold stress in southern California. Since 4 of 12 *Neotoma* sampled (33.3%) were positive in December and 4 of 36 (11.1%) in January, December was the most productive month for effective xenodiagnosis.

The 578 triatomes used in xenodiagnosis included 1♂, 26–5th, 48–4th, 184–3rd, 208–2nd, and 111–1st instar nymphs of 286 *Triatoma p. protracta*, 175 *T. p. navajoensis*, 106 *T. rubida uhleri*, and 11 *T. recurva* (*longipes*). Twenty-two triatomes became infected, including 2–5th, 3–3rd, 13–2nd, and 2–1st instar nymphs of *T. p. protracta*, and 1–5th and 1–2nd instar nymphs of *T. rubida uhleri*. Nearly all examinations were made by applying pressure with forceps to the dorsal surface of the terminal abdominal segments. If the triatome was "plump" from a recent blood meal, a gentle squeezing with forceps resulting in dorsoventral pressure on the terminal abdominal segments usually produced a good fecal sample as judged by fluid volume and numbers of uric acid spherules. The results summarized above are probably minimal for the technique employed because most of the examinations were carried out during the cooler period of the year when there were fewer motile parasites in the rectum. If all triatomes had been fed regularly and carried over to the summer period of higher environmental temperatures, a higher percentage of positives undoubtedly would have been found. This is one of the prime reasons why triatomes once used in xenodiagnosis cannot be used for a 2nd xenodiagnosis since very light trypanosome infections may be undetected by one fecal examination.

Discussion

Prior to 1957, there was only one girl's youth camp in Griffith Park in area 29 & 30. A new Girls' Camp was occupied during the summer of 1957 in area 65. Therefore, all data and references to youth camps in Griffith Park prior to 1957 refer only to the camp area 29 & 30. Since 1957, there has been a Boys' Camp in area 29 & 30 and a Girls' Camp in area 65. The Boys' Camp which is being rebuilt has remained unoccupied except for the caretaker from 1962 through 1965.

Mehringer (1962) established a positive correlation between general environmental temperature and time of appearance of *Triatoma protracta* at the youth camps in Griffith Park

between 15 June and 30 Sept., 1960. The largest number of triatomes were captured when temperatures were highest or slightly thereafter as judged by records of the Los Angeles Civic Center Office, United States Weather Bureau, el. 82.2 m. Sharp decreases in the daily temperature resulted in sharper drops of numbers of triatomes early and late in the season while gradual decreases in temperature generally resulted in a gradual decrease in their numbers during July and August excepting for the capture of the season's maximum number of bugs which occurred several days AFTER the peak seasonal temperature of July 20th as shown in Mehringer's Fig. 7. He summarizes his results as follows: "The data (fig. 7) would indicate that a minimum daily high temperature of approximately 24.4°C (76°F) could initiate flight from the wood rat houses." This study indicates that the month of July may be the most suitable month for mass capture of freely dispersing *Triatoma* as summarized by Mehringer, Wood & Anderson (1961) and verified by Sjogren & Ryckman (1966). The exact time of flight is of interest to public health workers and pest control operators. Certainly, from evidence presented here, both July and August are especially favorable for dispersal flights but locally favorable thermoperiods can bring out adult triatomes in September and October as well, especially in protected canyons favored by insolation.

As noted by Wood (1953b), the Boys' Camp area is in a canyon facing NE while the Girls' Camp is in a canyon facing SE (Mehringer 1962). These two camps are separated by a ridge reaching 457.2 m above sea level in the eastern end of the Santa Monica Mountains and are 2.2 km apart. Both areas offer down canyon flight patterns for *Triatoma*. From the position of the reservoir mammal habitat and the known flight pattern of these insects, it is probable that the two populations do not mix. The climatic microhabitats are likewise diverse in their geographic positioning which would affect the air flow patterns in the two regions. The Boys' Camp area would be favored by many more down-canyon air patterns due to the generally prevailing westerly winds sweeping over the ridge above it and this condition would favor triatome movements if the air temperature was above 15.5°C (60°F). Yet, minor local movements of air in the canyons may be more significant than the prevailing major flow since *Triatoma* appear to be more responsive to certain velocities and "puffs" of air on slightly humid nights according to Gladwill (verbal commun.). It is possible that the early evening "cross valley circulations" of Sutton (1964) may account for the triatome distribution pattern observed in 1965 and the "flight pulse" reported by Sjogren & Ryckman (1966).

Collecting at the blue light in the summer of 1965, as noted above, was in a nearby location in the Boys' Camp due to recent demolition of the former collecting site at the old lodge building. This site is 229.2 m above sea level in contrast to 224.9 m for the roof site used in 1964. Both sites are within 15 m of each other in the down canyon flight path of *Triatoma* from the foot hills above which reach elevations of 457.2 m. During June and early July in 1965, the thermoperiods at the collecting site were too cold for *Triatoma* between 7 : 30 and 8 : 30 PM, PST. Only 6 triatomes, 5♂ and 1♀, were intercepted during this period compared with 37 for the same period in 1964! Heavy rains in April, followed by the coolest June recorded by the L.A. Weather Bu. (Mean av. 16.3°C or 61.4°F) since 1944 (Mean av. 17.4°C or 63.4°F) delayed the development of *Triatoma* in Griffith Park wood rat houses. The average monthly temperature at a location close to Griffith Park, the LACC Weather Station, 103.6 m above msl, was 17.1°C (62.9°F) as compared with the expected normal of 19.3°C (66.9°F) from the 88 year records of the LA Civic Center Office

of the U.S. Weather Bureau. Another possible factor explaining the fewer triatome captures of 1965 may be the depletion of the rodent reservoir by intensive trapping.

Temperatures at the collecting site for the first 17 days of July in 1964 averaged 16.8°C (62.3°F) with a range from 15–20.5°C (59–69°F) whereas those for 19 blue light nights in late June and early July of 1965 averaged 15.6°C (60.2°F) with a range from 13.3–17.7°C (56 to 64°F). The 15.5°C is close to the lower limit of favorable flight temperatures for *Triatoma protracta* since no bugs were caught at the light below that temperature in 1964 and 1965. These data would suggest that an evening reading of 24.4°C (76°F) at the LA Weather Bu., Civic Center Sta., el. 82.2 m, is necessary to stimulate the flight of *Triatoma* in Griffith Park. The highest site temperatures for triatomes at the blue light were 7 & 8 August 1964 when 24.4°C (76°F) was recorded. Thus, at this canyon location, the favorable thermoperiod for flight of triatomes was 15.5–24.4°C (60–76°F) in contrast to 19.5–29°C (67–84°F) in San Dimas canyon, 125 km E (Sjogren & Ryckman 1966).

Some comparisons possible for the two separate 1964 triatome collections from light traps in southern California are indicated in Table 2. The two sites, a canyon in Griffith Park, Santa Monica Mtns., L. A. Co., and San Dimas Canyon, Crafton Hills, San Bernardino Co. (Sjogren & Ryckman 1966), are 125 km apart in an E-W axis with corresponding minor differences in microclimates. The infection rates of triatomes by groups as collected beginning 14 July and ending 22 Oct. for Griffith Park Boys' Camp were 45.7, 50.8, 60, 46.6, 37.5, 50, 37, 35.6, 25, and 33% as compared with 15.9% (138 July), 11.5% (108 August), 14.3% (60 Sept.), and 9.3% (39 Oct.) for the San Dimas site.

The more inland position, higher elevation, and generally drier location of the San Dimas site which is shielded from cool marine air by the Santa Ana Mtns. help to explain the differences in thermoperiods and peak abundance of appearance of triatomes. The 5 & 9 August peaks for Griffith Park accounted for 70 (23.1%) of the triatomes collected at blue light. The peak dispersal at Griffith Park occurred 2 days before the peak summer temperature was recorded at the camp site yielding the maximum blue light collection of 28 triatomes for any one time period. Although specifications for the black light cited by Sjogren & Ryckman (1966) are incomplete, it must be the same as that used by Anderson (15W GE F15T8-BL) from 25 July—21 August 1963 in Griffith Park since the wavelength peak is the same (Wood & Anderson 1965).

Therefore, temperature not only controls the dispersal movements of the adult insect vector of Chagas' trypanosome, but as a sequel also controls the appearance of the developmental stages of *Trypanosoma cruzi* in the vector and in the mammal hosts for very effective transmission of this anthropozoonosis in nature.

A good evaluation of the degree of annoyance from feeding of this triatome on man is indicated in Table 1. The 76 *Triatoma p. protracta* reported from one human habitation by Mehringer, Wood & Anderson (1961) represent the maximal known seasonal human domiciliary disturbance in California. The continued presence of two large dogs as attractants at this location may be partially responsible for the high triatome counts. Although the high rate of infection with trypanosomes in conenose bugs in the Boys' Camp would favor possible transmission to man, the small number of known human contacts with infected vectors would not. The higher number of contacts in the Girls' Camp would favor possible transmission to humans but the lower infection rate of the triatomes there would not. The virulence of the parasite for man is also questionable although it infects

rats and mice readily. Thus, ecological conditions plus avoidance of contacts by man in the presence of a weak vector and parasite and active program of chemical control (Wood 1960 & Wood & Wood 1964) protect man from this tropical blood parasite in Griffith Park.

Unanswered questions of special interest are the apparent lack of virulence of the endogenous trypanosomes and the relationship, if any, to the presence of *Trypanosoma cruzi* imported in zoo animals and the availability of these parasites from zoo animals to the native *Triatoma* reservoir in this public park. Undoubtedly, native *Triatoma* have fed on imported mammals at the Los Angeles Zoo, since triatomes have been collected in zoo animal cages (p. 42, Mehringer & Wood 1958). Many of the Mexican, Central and South American mammals could harbor virulent *Trypanosoma cruzi.* Experiments of Wood (1953a) transferring a Brazilian strain of *T. cruzi* with *Triatoma p. protracta* and more recently observations by Ryckman (1965 Pt. V) have revealed reduced virulence in transferred trypanosomes. Controlled environment temperature for both the triatome and the vertebrate would be essential for definitive answers to determination of changes of virulence in different hosts. The lowered "winter" laboratory temperatures should have stimulated the infections in the laboratory mice and rats used by Wood (1953a), but the whole developmental process was slowed down by the smaller number of metacyclic trypanosomes being released by the "cold" *Triatoma.* This condition was not recognized by the senior author at the time due to incomplete knowledge of the specific role of temperature in regulating the cyclical development of Chagas' trypanosome in both triatomes and mammals.

The above cited experiences with *Trypanosoma cruzi* of known higher virulence for mammals would indicate that although this human blood parasite may be transmitted to native reservoir *Triatoma* in Griffith Park from imported exotic animals, the parasites are undergoing a reduction in virulence in the native triatome vector. This condition would not necessarily interfere with their transmission to native rodents where additional resistance might not occur in the new adaptation of the trypanosome. Therefore, it seems logical to conclude from the ecological relationships discussed and in the absence of the demonstration of Chagas' disease in man in southern California, that, although a very successful zoonosis is being maintained and possibly increased by occasional reintroductions of "foreign" *T. cruzi,* the parasite is not being transmitted to man due to the inadequacies of the triatome vector heretofore cited and the high degree of protection afforded by insect-proofed housing. Is it possible that a higher-than-apparent rate of natural infection of California mammal hosts with native *T. cruzi* may, in effect, vaccinate them against becoming carriers of more virulent introduced sources? A partial answer to this question is offered by the recent studies of Ferrialli & Barretto (1965) in Brazil where sylvan *Trypanosoma cruzi* of rodents has been found to protect laboratory infected white mice from the highly virulent Y strain from human infections.

Summary

A sporadic sampling program in Griffith Park, Los Angeles, from 1941 to 1965 has revealed four populations of *Triatoma p. protracta* in isolated canyons in brush-pile houses of *Neotoma fuscipes macrotis.* Fecal examinations of 1759 of 2158 triatomes collected showed 593 or 33.1% naturally infected with *Trypanosoma cruzi.* The highest rate of infection was found in the Boys' Camp where, of the 1044 adults examined, 463 triatomes of 45.3% were infected. Collections from a blue light for 1963 through 1965 produced 423 triatomes

of the 1044 examined. Of 341 bugs collected from the Girls' Camp, 293 were examined and 25 or 8.5% were infected. Search of *Neotoma* houses throughout Griffith Park produced 451 triatomes with 422 examined and 105 or 24.8% showing Chagas' trypanosome. One wood rat house contained 42 infected triatomes, or 85.7% of the 49 collected.

The months of most active dispersal were July and August with movements beginning in June and extending into November at a thermoperiod of 15.5–24.4°C (60–76°F) at the Boys' Camp. Triatomes fly in response to hunger, heat and light in a down-canyon pattern in the semi- or total-darkness of the early evening following daytime temperatures above 14.4°C (58°F) if these are maintained at least one hour after dark, the optimum being 21.1°C (70°F). Major annoyance by triatomes feeding on man and sometimes involving severe allergic reactions has been controlled by hand collecting, insecticidal spraying, rodent capture, and mammal microhabitat removal. Annoyance to man in Griffith Park is seasonal and due principally to summer use of an area within the normal seasonal dispersal flight path of *Triatoma protracta*.

Nine of 99 *Neotoma* trapped in the Boys' Camp were positive for Chagas' trypanosome by xenodiagnosis.

LITERATURE CITED

Ferrialli, Jr., F. & M. P. Barreto. 1965. Estudos sôbre reservatórios e vectores silvestres do *Trypanosoma cruzi*. VI. Infecção natural do roedor *Akadon arviculoides cursor* (Winge, 1885) por tripanosomo semelhante ao *Trypanosoma cruzi*. *Rev. Inst. Med. Trop.*, São Paulo **7**(2): 72–81.

Kolodny, M. H. 1939. Seasonal variations in the intensity of experimental infection with *Trypanosoma cruzi* in young rats. *Am. J. Hyg. Sect. C.* **29** (3): 131–33.

1940. The effect of environmental temperature upon experimental trypanosomiasis (*T. cruzi*) of rats. *Am. J. Hyg. Sect. C.* **32** (1): 21–23.

Linsdale, J. M. & L. P. Tevis, Jr. 1951. The dusky-footed wood Rat (Berkeley, U. C. Press) 664 pp.

Mehringer, Jr., P. J. 1962. The activity of *Triatoma protracta* (Uhler) (Hemiptera: Reduviidae) in southern California as related to its ecology. (M. A. Thesis, California State College at Los Angeles) 44 pp.

Mehringer, Jr., P. J. & S. F. Wood. 1958. A resampling of wood rat houses and human habitations in Griffith Park, Los Angeles, for *Triatoma protracta* and *Trypanosoma cruzi*. *Bull. S. Calif. Acad. Sci.* **57** (1): 39–46.

Mehringer, Jr., P. J., S. F. Wood & R. A (=C). Anderson. 1961. Conenose bug (*Triatoma*) annoyance and *Trypanosoma cruzi* in Griffith Park in 1960. *Bull. S. Calif. Acad. Sci.* **60** (3): 190–92.

Ryckman, R. E. 1962. Biosystematics and hosts of the *Triatoma protracta* complex in North America (Hemiptera: Reduviidae) (Rodentia: Cricetidae). *Univ. Calif. Publ. Ent.* **27** (2): 93–240.

1965. Epizootiology of *Trypanosoma cruzi* in southwestern North America. Part V. Host parasite specificity between *Trypanosoma cruzi* and Triatominae (Kinetoplastida: Trypanosomidae) (Hemiptera: Triatominae). *J. Med. Ent.* **2** (1): 96–99.

Sjogren, R. D. & R. E. Ryckman. 1966. Epizootiology of *Trypanosoma cruzi* in southwestern North America. Part VIII. Nocturnal flights of *Triatoma protracta* (Uhler) as indicated

by collections at black light traps (Hemiptera: Reduviidae: Triatominae). *J. Med. Ent.* **3** (1): 81–92.

Sutton, G. 1964. Micrometeorology. *Sci. Am.* **211** (4): 62–76.

Wigglesworth, V. B. 1964. The hormonal regulation of growth and reproduction in insects. *In* Advances in Insect Physiology by J. W. Beamont et al **2**: 247–336.

Wood, S. F. 1941. Notes on the distribution and habits of reduviid vectors of Chagas' disease in the southwestern United States. I. & II. (Hemiptera, Reduviidae). *Pan-Pacif. Ent.* **17** (2): 85–94, 115–18.

1942. Observations on vectors of Chagas' disease in the United States. I. California. *Bull. S. Calif. Acad. Sci.* **41** (2): 61–69.

1943. Observations on vectors of Chagas' disease in the United States. II. Arizona. *Am. J. Trop. Med.* **23** (3): 315–20.

1944. Notes on the food of reptiles with special reference to their possible control of cone-nosed bugs. *Bull. S. Calif. Acad. Sci.* **43** (2): 86–91.

1949. Additional observations on *Trypanosoma cruzi* Chagas from Arizona in insects, rodents, and experimentally infected animals. *Am. J. Trop. Med.* **29** (1): 43–55.

1950. The distribution of California insect vectors harboring *Trypanosoma cruzi* Chagas. *Bull. S. Calif. Acad. Sci.* **49** (3): 98–100.

1951. Bug annoyance in the Sierra Nevada foothills of California. *Bull. S. Calif. Acad. Sci.* **50** (2): 106–12.

1953a. Hematologic differentiation of the intramuscular developmental forms of *Trypanosoma cruzi* Chagas. *Am. J. Trop. Med. & Hyg.* **2** (6): 1015–35.

1953b. Conenose bug annoyance and *Trypanosoma cruzi* Chagas in Griffith Park, Los Angeles, Calif. *Bull. S. Calif. Acad. Sci.* **52** (3): 105–09.

1960a. Conenose bug annoyance in Griffith Park in 1958. *Bull. S. Calif. Acad. Sci.* **59** (1): 50–52.

1960b. A potential infectivity index for *Triatoma* harboring *Trypanosoma cruzi* Chagas. *Exptl. Parasitol.* **10** (3): 356–65.

1967. Notes on possible natural control agents for triatomes (Hemiptera, Reduviidae). (In preparation).

Wood, S. F. & R. C. Anderson. 1965. Conenose bugs (*Triatoma*) visit unoccupied boys' camp in Los Angeles. *J. Med. Ent.* **1** (4): 347–48.

Wood, S. F. & F. D. Wood. 1964. Nocturnal aggregation and invasion of homes in southern California by insect vectors of Chagas' disease. *J. Econ. Ent.* **57** (5): 775–76.