Journal of the American Mosquito Control Association, 12(1):8–16, 1996

ELEVATIONAL DISTRIBUTION OF MOSQUITOES IN A MOUNTAINOUS AREA OF SOUTHEASTERN WYOMING

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ABSTRACT. During the summer of 1984, mosquito sampling with CDC miniature light traps and standard mosquito dippers was used to investigate the elevational distribution of different species of mosquitoes. Of 27 species found in significant numbers in the study area in southeastern Wyoming, 8 were found primarily in the lower elevations (2,134 and 2,591 m). Nine additional species were found in both the middle and lower elevations (2,134–3,048 m), whereas 8 occurred only in the middle areas (2,592–3,048 m). A single species (*Aedes punctor*) was found in both the middle and upper elevations (2,439–3,292 m), and yet another species (*Aedes impiger*) was found primarily in the upper (alpine) area, from 3,049 to 3,292 m. There is some evidence to indicate that restriction in elevational distribution is a result of habitat specificity.

INTRODUCTION

In mountainous areas of the western USA, mosquitoes seriously impact outdoor recreation and livestock agriculture (Harmston and Lawson 1967). In spite of their importance as pests of man and animals, mosquitoes in Wyoming have not been well studied ecologically. Yet, the success of future control efforts will depend on a clear understanding of their ecology.

Early studies in Wyoming that included the mosquitoes of the southeastern area (Dyar 1923, Olson and Keegan 1944) resulted in lists of species but provided no information concerning habitats or seasonal distribution. Later studies provided information about the habitats (Gerhardt 1951a, 1951b[2]), as well as economic impact and some observations on elevational distribution (Owen 1951). Several publications contained brief descriptions of larval habitats (Gerhardt 1951a, 1951b[2]; Owen 1951; Owen and Gerhardt 1957; Harmston and Lawson 1967). Carpenter (1961a, 1961b, 1962a, 1962b, 1968) examined several montane species, and developed extensive information regarding all these parameters, in the mountains of California.

The habitats that are available to mosquitoes differ with elevation; therefore, mosquito species that are specific for a habitat should be distributed according to elevation (Goff and van Riper 1980). Carpenter's series reported that this was indeed the case in California, at least for the 9 snowpool *Aedes* species he worked with (Carpenter 1961a, 1961b, 1962a, 1962b, 1968). The objective of our study was to determine how mosquito species, including the snowpool *Aedes* as well as others, were distributed with regard to elevation in the mountains of southeastern Wyoming.

MATERIALS AND METHODS

The study was conducted in 1984 in Albany and Carbon counties of southeastern Wyoming. The study area included the North Platte River Valley east of the river near Saratoga, Wyoming, the west and east slopes of the Snowy Range of the Medicine Bow Mountains, the Laramie River Valley, and the western slope of the Laramie Mountain Range (Fig. 1). Light trap sites and temporary larval collection sites were located in 4 vegetation zones as defined by Porter (1962): alpine (3,201–3,292 m), timbered mountain slopes (2,592–3,200 m), lodgepole pine–mountain stream valleys (2,439–2,591 m), and river bottoms and major river valleys (below 2,438 but above 2,134 m).

Five light trap sites were located in the major river valleys. Larval habitats in this region were primarily flooded river bottoms, flood-irrigated fields, and seepage from lakes and reservoirs. Three light trap sites were located in the lodgepole pine–mountain stream valleys. In the early spring, an abundant larval habitat occurred along the valley bottoms due to flooding, caused by both snow melt and beaver dams. Eight light traps were placed on the timbered mountain slopes, where a majority of the larval sites resulted from snow melt. Two light trap sites were located in the alpine zone at the top of the Snowy Range. Larval sites in this zone occurred in wet alpine meadows as the result of snow melt.

Adult mosquitoes were collected in CDC miniature light traps, each supplemented with 2 kg of dry ice. The traps were activated between

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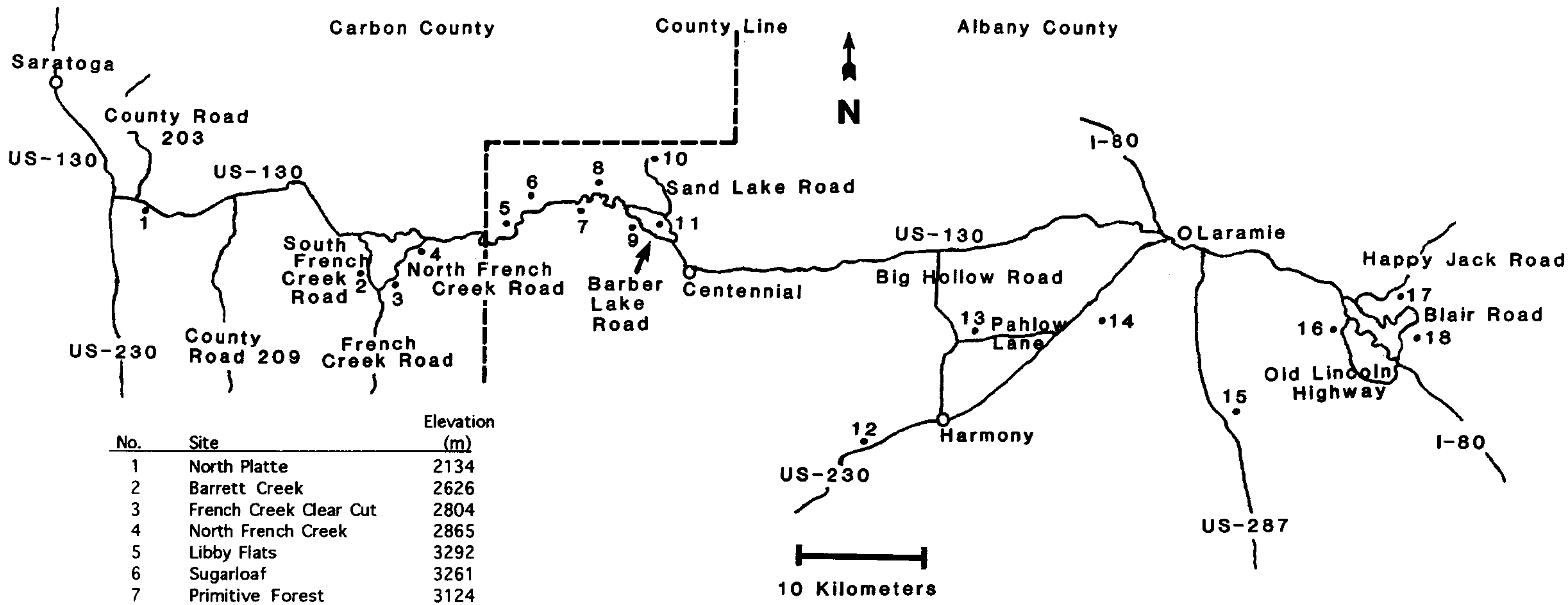
[2] Gerhardt, R. W. 1951b. The mosquitoes of Wyoming. M.Sc. thesis, University of Wyoming, Laramie.



No.	Site	Elevation (m)
1	North Platte	2134
2	Barrett Creek	2626
3	French Creek Clear Cut	2804
4	North French Creek	2865
5	Libby Flats	3292
6	Sugarloaf	3261
7	Primitive Forest	3124
8	Green Rocks	3048
9	Upper Barber Lake	2804
10	Sand Lake Road	2576
11	Libby Creek	2627
12	Sodergreen	2253
13	Gelatt	2211
14	Paradise	2185
15	Leazenby Lake	2232
16	Pole Mountain	2682
17	Happy Jack	2499
18	Blair	2454

Fig. 1. Location of the study area and light trap sites in Carbon and Albany counties of southeastern Wyoming.

Table 1. Numbers of mosquitoes collected at collection sites between May 30 and September 21, 1984.

Elevation (m)	Site name	Adults: No. mosquitoes[1]	Adults: No. species	Larvae: No. mosquitoes	Larvae: No. species	No. sites
Major river bottoms						
2,134	North Platte	9,100	21			
2,185	Paradise	26,250	12			
2,211	Gelatt	6,553	12			
2,232	Leazenby Lake	530	15			
2,253	Sodergreen	3,250	12			
2,134–2,438	Total interval	45,000	28	444	24	23
Lodgepole pine–mountain stream valleys						
2,454	Blair	210	25			
2,499	Happy Jack	571	21			
2,576	Sand Lake Road	370	22			
2,439–2,591	Total interval	1,150	26	217	15	12
Timbered mountain slopes						
2,626	Barrett Creek	188	20			
2,627	Libby Creek	315	25			
2,682	Pole Mountain	325	12			
2,592–2,743	Total interval	640	27	78	7	9
2,804	NFCR clear cut	263	11			
2,804	Upper Barber Lake	850	19			
2,865	North French Creek	130	11			
2,744–2,896	Total interval	1,240	23	82	11	5
3,048 2,897–3,048	Green Rocks	430	18	54	5	5
3,124 3,049–3,200	Primitive forest	535	11	58	6	5
Alpine						
3,261	Sugarloaf	25	8			
3,292	Libby Flats	160	6			
3,201–3,292	Total interval	185	10	29	3	5
Total		50,000	29	962	24	64

[1] Numbers over 500 are approximate.

1930 and 2100 h, and mosquitoes were removed between 0600 and 0800 h. Specimens were immediately preserved by freezing on dry ice, transferred to a laboratory freezer, and held for later identification and enumeration.

Extremely large light trap collections, from the lowest elevational interval, were subsampled. First, the mosquitoes were spread over a printed grid, and all unusual (darker, lighter, larger, smaller) specimens were removed. There were usually between 10 and 15 of these unusual specimens per sample. Thirty to 35 additional mosquitoes were then selected randomly for identification from the remaining collection, resulting in a sample of 45 specimens for identification. The total of specimens in the very large collections was estimated volumetrically (*ca.* 150 mosquitoes filled a 10-ml beaker).

Adult mosquitoes were collected from May 30 to September 21, 1984, with light trap collections being made every other week and larval collections made weekly. Depending on weather, between 5 and 7 days were required to collect a sample from all light trap sites, beginning with the easternmost location (the Blair site) and ending at the westernmost location (the North Platte site). Frequently, higher elevation sites were inaccessible in June or September because of inclement weather or impassable roads. The number of light trap collections per site ranged from 4 at the highest elevations to 8 at the lowest elevation (Table 1).

Beginning May 1, 1984 and ending in mid-July, mosquito larvae were collected from larval sites in the vicinity of the light traps as well as from sites that were observed from the roads that were traveled between the light trap sites. There was an average of 10 larval sites for each light trap site. Larvae were collected in vials and preserved in Cellusolve® (2 ethoxyethanol). Earlier stage larvae were reared to 4th instar before being killed. Specimens were identified using Darsie and Ward (1981) and confirmed by R. Kumar, University of Wyoming.

RESULTS AND DISCUSSION

The number of mosquitoes varied among collection sites (Table 1). Of the nearly 50,000 mosquitoes, about 45,000 were collected in light traps in the major river valleys. More than half of the total collection was from the trap at the Paradise Farm, west of Laramie. This area is in the Laramie River floodplain, at the base of a large wet meadow, both of which contain large numbers of larval habitats.

In general, there were fewer species per site with increasing elevation. The lowest elevation interval produced the greatest number of specimens but did not produce a correspondingly greater number of species. Twenty-five species were identified as larvae, compared with 29 species as adults (Table 1). In addition, Lloyd and Pennington (1976) identified all mosquitoes they collected at the Paradise Farm and found no additional species. Carpenter (1961a) recorded only 2 species of the snowpool *Aedes* from his lowest elevations, with a distinct increase in the number of species in the higher elevations. However, these records are of only the 9 "snowpool" species, and the elevations extend considerably lower than our lowest interval. In the region corresponding to our lowest interval (2134–2438 m.), Carpenter (1961a) recorded 8 of the 9 species, excluding only *Aedes pullatus* (Coq.), which we also found in rather low numbers in that region.

Considerable variation in number of species was noted between traps within an elevation interval. The North Platte River trap yielded 21 species, which was much greater than the number of species collected in the other 4 traps in the major river valleys (12–15 species). Although the greatest number of species was collected in the major river valleys, the diversity of species caught in individual traps was less than in traps located in the mountain stream valleys, the next highest interval. Carpenter (1961a) also found a greater diversity of species in the areas near the middle of his elevational range, although his reports cover only the snowpool *Aedes*. This may have been due in part to greater habitat homogeneity around the lower elevation traps. Carpenter (1961a) indicated that the eastern slope of the mountains contained the greatest variety of habitats: this slope area includes his middle elevational ranges. It has been suggested by Macdonald and Traub (1960) that simple habitats containing only a few types of larval sites will produce large numbers of a few species. Approximately 47% of the specimens collected from the major river valleys comprised 3 species: *Aedes dorsalis* (Meigen), *Aedes spencerii idahoensis* (Theobald), and *Aedes vexans* (Meigen) (Table 2).

Basio et al. (1970), Bhat (1975) in Uttar Pradesh, India, and Scanlon and Esah (1965) in northern Thailand also found a decrease in the number of mosquito species at the higher elevations. Basio et al. (1970) suggested that the larger numbers of mosquito species collected at lower elevations were due to increased human disruption in those areas. Our findings were similar to theirs in that the number of species remained relatively constant for the first 600 m of the lowest interval, then decreased. Human disruption of habitat in the area follows a similar pattern. However, even at the lowest elevations, human activity has been minimal. It is likely that a more fundamental force is at work here. The causes of increased diversity may include climatic stability and high primary productivity, as well as spatial heterogeneity and a long evolutionary history. Because of the climatic constraints, fewer plant species grow at higher elevations, leading to a more homogeneous environment than exists at lower elevations (Uetz 1975). Recent glacial episodes have kept the evolutionary history of the higher regions in our study area very short. All of these have combined to produce a much smaller number of habitats for larval mosquitoes at the upper elevations, as well as for the various animals that can serve as blood meal sources for the adult females. A larger number of species, therefore, would be found in the lower elevational intervals, as is supported by our data. In addition, the species found in the higher elevations seem to have less rigid habitat requirements (Carpenter and LaCasse 1955, Owen and Gerhardt 1957, Harmston and Lawson 1967).

Of the 29 species of mosquitoes collected, 27 were restricted in their elevational distribution (Table 3). Two additional species, *Culex tarsalis* Coq. and *Culex pipiens* Linn., were represented by 6 and 3 specimens, respectively, which was an inadequate sample to make any statements regarding distribution.

Prior to grouping the species, we grouped the collection sites by habitat type as defined by

Table 2. Larval (L) and adult (A) mosquito specimens of each species identified from different elevational intervals.

Species	2,134-2,438 m		2,439-2,591 m		2,592-2,743 m	
	L	A	L	A	L	A
Aedes campestris Dyar and Knab	29	51	0	11	0	10
Ae. canadensis canadensis (Theobald)	3	6	5	2	0	2
Ae. cataphylla Dyar	5	19	3	1	0	3
Ae. cinereus Meigen	0	6	0	2	0	1
Ae. communis (De Geer)	5	1	2	28	6	0
Ae. dorsalis (Meigen)	14	243	0	68	0	33
Ae. excrucians (Walker)	16	0	0	5	0	21
Ae. fitchii (Felt and Young)	29	16	0	22	0	15
Ae. flavescens Theobald	11	3	0	0	0	0
Ae. hexodontus Dyar	1	1	21	10	52	0
Ae. impiger (Walker)	2	0	6	2	3	0
Ae. implicatus Vockeroth	25	20	29	14	0	7
Ae. increpitus Dyar	13	18	7	0	0	13
Ae intrudens Dyar	1	7	0	8	2	11
Ae. melanimon Dyar	7	54	0	6	0	7
Ae. mercurator Dyar	4	1	16	1	0	5
Ae. nigromaculis (Ludlow)	0	2	0	6	0	1
Ae. pionips Dyar	0	0	3	4	7	0
Ae. punctor (Kirby)	2	3	2	7	0	7
Ae. pullatus (Coquillett)	2	11	57	0	16	71
Ae. schizopinax Dyar	50	18	8	0	0	3
Ae. spencerii idahoensis (Theobald)	86	34	1	10	1	4
Ae. sticticus (Meigen)	1	0	0	3	0	3
Ae. ventrovittus Dyar	15	7	7	31	1	3
Ae. vexans (Meigen)	53	73	0	4	1	3
Culex pipiens Linn.	0	1	0	0	0	2
Cx. tarsalis Coquillett	0	2	0	0	0	4
Cs. impatiens (Walker)	1	13	1	23	0	17
Cs. inornata (Williston)	57	42	1	4	1	5

Porter (1962). This resulted in the sites from 2,592 to 3,200 m being defined as one interval. The species were divided into 5 groups, with species having similar elevational distributions being grouped together. Species were grouped according to a majority of the specimens, rather than by either larval or adult specimens.

The majority of the specimens were collected between 2,134 and 2,591 m (Table 3). The larvae of these species, which included *Aedes campestris* Dyar and Knab, *Ae. dorsalis, Aedes flavescens* Theobald, and *Aedes melanimon* Dyar, were typically found in flood pools. Baker (1961), who performed a larval survey in Colorado, found the same species at lower elevations (Table 3). Owen (1951) also collected a similar group of species, which he called "plains species," at the lower elevations.

A second group of species was also found in the lower areas, but their distributions extended into the middle elevations, up to 3,048 m. These included *Aedes cataphylla* Dyar, *Aedes excrucians* (Walker), *Aedes fitchii* (Felt and Young), *Aedes implicatus* Vockeroth, and *Aedes mercurator* Dyar, as well as *Aedes schizopinax* Dyar. Although the lower elevation species were generally represented by species whose adult distribution paralleled the larval distribution, the distributions of these species were often less clear-cut, indicating that the adults might be migrating longer distances and over wider elevational ranges. In addition, larval habitats were more difficult to find in the upper reaches of these distributions, as is reflected in the abrupt drop in larval numbers after 2,592 m. For the species he reported on (*Ae. cataphylla, Ae. fitchii,* and *Ae. schizopinax*), Carpenter (1961a, 1961b, 1962a, 1962b) found similar distributions in California.

The species collected at middle elevations (2,439–3,048 m) were associated with snow pools and flood pools on timbered mountain slopes. Generally, these species were less abun-

Table 2. Extended.

2,744–2,896 m		2,897–3,048 m		3,049–3,200 m		3,201–3,292 m		
L	A	L	A	L	A	L	A	Total
0	1	0	0	1	0	0	0	103
0	1	0	0	0	0	0	0	19
0	1	0	7	0	0	0	0	39
0	0	0	1	0	0	0	0	10
27	0	1	3	4	0	0	0	77
0	3	0	5	0	2	0	4	372
0	19	0	1	0	0	0	0	62
0	10	0	1	0	3	0	0	96
0	0	0	0	0	0	0	0	14
2	2	37	0	3	15	5	16	165
0	3	0	1	0	6	0	24	47
0	21	0	10	0	17	0	7	150
0	2	0	0	0	0	0	0	53
0	10	0	1	0	4	0	5	49
0	0	0	0	0	0	0	0	74
0	0	0	0	0	0	0	2	29
0	1	0	0	0	0	0	0	10
0	11	5	0	3	0	0	3	36
0	10	3	0	0	12	0	9	55
26	0	13	0	32	3	11	22	264
0	7	0	2	0	1	0	0	89
0	8	0	4	0	0	0	0	148
0	5	0	1	0	0	0	0	13
0	15	0	16	0	5	0	5	105
0	2	0	0	0	0	0	0	136
0	0	0	0	0	0	0	0	3
0	0	0	0	0	0	0	0	6
0	6	0	1	0	0	0	0	62
0	2	0	2	0	1	0	0	115

dant than lower elevation species (Table 3). A majority of the species in this group did not display a definite pattern in their distribution, other than a trend toward more specimens on the timbered mountain slopes. Like Baker (1961), we found *Aedes communis* (De Geer), *Aedes hexodontus* Dyar, *Aedes pionips* Dyar, and *Aedes pullatus* in the "middle elevation" group. Although Carpenter (1961a) did not report *Ae. pullatus* from this elevational interval, he did report it from the same general habitat (1968). We also found *Aedes intrudens* Dyar, *Aedes nigromaculis* (Ludlow), and *Aedes sticticus* (Meigen), as well as *Ae. ventrovittus* Dyar, in this region. *Aedes nigromaculis* was collected only as an adult, so this specimen may represent a migrant, because most authors record it as being a "plains" species, which implies lower elevations (Carpenter and LaCasse 1955, Owen and Gerhardt 1957, Harmston and Lawson 1967). Neither Baker (1961) nor Owen (1951) reported on the other 3 species, but *Ae. intrudens* and *Ae. sticticus* are both described as from wooded areas by Carpenter and LaCasse (1955), whereas *Ae. ventrovittus* is listed as from between 1,829 and 3,048 m. Carpenter (1961a) does not include *Ae. intrudens* or *Ae. sticticus* in his reports, but his data for *Ae. ventrovittus* are similar to ours. These observations are similar to what we observed in our study. *Aedes sticticus* and *Ae. ventrovittus* were both collected in larger numbers as larvae from the lowest elevational interval, indicating that some of the adults collected in the upper areas may have been migrants, in which case at least some of the specimens were not from wooded areas because the lower portions of the study area are not wooded.

Two species were found primarily in the upper portions of the study area. *Aedes impiger* (Walker) and *Aedes punctor* (Kirby) were collected primarily as adults above 3,201 m, al-

Table 3. Elevational distribution of mosquito species during the summer of 1984 and as reported in Owen (1951) and Baker (1961). The description of the distribution as "lower elevation," etc., is by the individual authors.

Denke (1984[1])	Owen (1951)	Baker (1961)
Lower elevation species: 2,134–2,591 m		
Aedes campestris	*Ae. campestris*	*Ae. campestris*
Ae. cinereus	—	—
Ae. dorsalis	*Ae. dorsalis*	*Ae. dorsalis*
—	*Ae. excrucians*	—
—	*Ae. fitchii*	—
Ae. flavescens	—	—
—	*Ae. increpitus*	—
Ae. melanimon	*Ae. melanimon*	—
—	—	*Ae. schizopinax*
Ae. spencerii idahoensis	*Ae. spencerii idahoensis*	—
—	—	*Ae. trivittatus*
Ae. vexans	*Ae. vexans*	*Ae. vexans*
—	*Culex tarsalis*	*Cx. tarsalis*
—	—	*Cx. territans*
—	—	*Culiseta impatiens*
Cs. inornata	*Cs. inornata*	*Cs. inornata*
Lower and middle elevation species: 2,134–3,048 m		
Ae. canadensis canadensis	—	—
Ae. cataphylla	—	—
Ae. excrucians	—	—
Ae. fitchii	—	—
Ae. implicatus	—	—
Ae. increpitus	—	—
Ae. mercurator	—	—
Ae. schizopinax	—	—
Cs. impatiens	—	—
Middle elevation species: 2,592–3,048 m		
—	—	*Ae. cataphylla*
Ae. communis	—	*Ae. communis*
—	—	*Ae. fitchii*
Ae. hexodontus	—	*Ae. hexodontus*
—	—	*Ae. implicatus*
Ae. intrudens	—	—
Ae. nigromaculis	—	—
Ae. pionips	—	*Ae. pionips*
Ae. pullatus	—	*Ae. pullatus*
—	—	*Ae. punctor*
Ae. sticticus	—	—
Ae. ventrovittus	—	—
—	—	*Cs. impatiens*
—	—	*Cs. incidens*
—	—	*Cs. inornata*
Middle and upper elevation species: 2,592–3,292 m		
Ae. punctor	—	—
Upper elevation (alpine) species: 3,049–3,292 m		
—	*Ae. cataphylla*	*Ae. cataphylla*
—	*Ae. communis*	*Ae. communis*
—	—	*Ae. fitchii*
—	—	*Ae. hexodontus*
—	—	*Ae. impiger*

Table 3. Continued.

Denke (1984[1])	Owen (1951)	Baker (1961)
—	—	*Ae. pionips*
—	*Ae. pullatus*	*Ae. pullatus*
—	*Ae. punctor*	*Ae. punctor*
—	—	*Cs. incidens*
—	—	*Cs. impatiens*

[1] Denke, P. M. 1984. Elevational and seasonal distribution of mosquitoes in Albany and Carbon counties, Wyoming. M.Sc. thesis, University of Wyoming.

though the distribution of the latter extended down to 2,592 m.

Species that are more widely distributed, such as those that occur in both the lower and middle elevations, or the middle and upper elevation species, are generally described as being less restricted in their larval habitats. Larvae of more ubiquitous mosquito species, e.g., *Ae. implicatus* and *Aedes increpitus* Dyar, exist in a wide variety of habitats, and those of the more restricted species, e.g., *Ae. impiger,* occur in a smaller number of defined habitats (Carpenter and LaCasse 1955, Owen and Gerhardt 1957, Harmston and Lawson 1967, Siverly 1972, Means 1979). Thus, *Ae. implicatus,* which has nonspecific habitat needs, is more widely distributed than is *Ae. dorsalis,* which in turn is present over a wider range of elevations than is *Ae. impiger,* which has very specific habitat requirements. Elevation may limit niche availability, resulting in elevational distribution. Consequently, the elevational distribution of a species may also give an indication of its habitat specificity.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of R. Kumar, M. Riley, R. E. Pfadt, R. J. Lavigne, D. W. Watson, G. Smith, F. Holbrook, E. W. Spackman, C. Lynn, M. Lluberas, and C. J. Jones, as well as G. Johnson, S. Knapp, and A. Slipinski. Special thanks are due to E. Sturgeon. This work was supported in part by a grant-in-aid of research from the University of Wyoming Chapter of the Society of Sigma Xi.

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