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SELECTED BIOLOGICAL ASPECTS OF *GOMPHURUS OZARKENSIS* (WESTFALL) (ANISOPTERA : GOMPHIDAE)

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The currently recommended status for *Gomphurus ozarkensis* (Westfall) is rare because it has a restricted range, it frequents upland stream habitats, Ozark Mountain tourism poses a threat and little is known of its life history. A population of this species along the South Fork of Spring River in Eastern Fulton County, Arkansas, United States, was studied by direct observation and mark-recapture. One hundred twenty-five teneral, immature adult and reproductive adult individuals were marked. *G. ozarkensis* is a spring species, emerging early in the year and having a short synchronous emergence period and an early emergence peak. The maturation period approximates 18 days for males and 25 days for females. The reproductive period was 30 days. The population estimate was determined for resighting records using the Fisher-Ford method. The survival rate was calculated to be 0.633, and the composite mean age of marked individuals was 3.5 days. The majority of the population (64.8%) was composed of males.

INTRODUCTION

Adults of this species were described by WESTFALL (1975). HUGGINS & HARP (1985) described the nymph. This dragonfly is endemic to the Ouachita and Ozark Geographic Provinces of Arkansas, extreme eastern Oklahoma, extreme southeastern Kansas and southern Missouri (BICK, 1983 ; HUGGINS & HARP, 1985). BICK (1983) classified *G. ozarkensis* as rare because it has a restricted range, it frequents upland stream habitats, Ozark Mountains tourism poses a threat and little is known of its life history.

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The purpose of this study is to describe selected biological aspects of *G. ozarkensis*. Those aspects reported here include emergence patterns, maturation period, flying season, an estimate of population size and sex ratio.

The population studied resides along the South Fork of Spring River in eastern Fulton County, Arkansas, United States. The study site included two areas. One of these was a 100 m reach of hardwood forest, primarily sycamore, along the river's east bank. The woodline extended inland approximately 50 m. At the upstream border was an island with a riffle on either side. The bank gradually changed from a gentle slope covered with gravel and rubble upstream to a steep 6 m bank of mostly humic soil, covered with ground vegetation, at its terminus. The second portion of the study site was a meadow immediately east of the woodline. It measured approximately 650 by 150 m and was vegetated primarily by various grasses and herbs. It was maintained as a meadow through hay harvest twice each summer. The study was conducted on the east side only, because initially deep, swift waters prevented safe stream crossings.

The study site is relatively undisturbed. Canoers and fishermen occasionally use the site to launch their boats. This traffic has created a path along the meadow margin (meadow path) and through the tree line (tree path) to the access point. The path was a corridor that many teneral individuals used during their maiden flight. Once attained, the meadow was utilized by teneral and older individuals as a perching site.

MATERIALS AND METHODS

The study began on 4 May 1984 and continued for 57 days, through 29 June. At the onset of the study observations began at sunrise, in an attempt to observe emergence. Later, observations began at 8 : 00 AM CDT, when it was established that *G. ozarkensis* does not become active until around 10 : 00 AM. Observations were recorded until late afternoon.

One hundred twenty-five teneral, immature adult and reproductive adult individuals were captured, using an aerial net. Great care was taken in handling tenerals to avoid damaging their wings. The sex, time of capture and location were recorded. Each individual was marked with a unique pattern, using red acrylic paint similar to the method of BORROR (1934). Red was chosen because there is no red in the body color of this species. The marking, approximately 4 mm in diameter, did not appear to affect observed behaviors. Our observations in this respect concur with those of STEWART & MURPHY (1968). BORROR (1934) noted that his marklings were distinct after 24 days. In this study the marks were still obvious 28 days after application.

Specimens were not physically recaptured. Visial recognition of an individual by its unique pattern allowed specific identification. Each resighting was considered a recapture. When resighting occurred, the time of day and location of the sighting were recorded. Dispersal was studied in this manner.

Selected climatic conditions were monitored ; air and water temperature, humidity, barometric presure and cloud cover (SUSANKE, 1986). Since none of these parameters affected the behaviors observed, those values are not given here.

The population estimate was also determined from resighting records, using the FISHER & FORD (1947) method, which was appropriate for this study. The total number of individuals caught either for the first time or recaptured is represented by n_i. The number of days survived by the marked individuals caught on day_i was represented by $\sum_j m_{ij}(i-j)$, where j is the day the individual was first marked, and m_i represents the number of marked individuals caught on day_i. The observed total days survived by the entire population was determined by the equation $\sum_i \sum_j m_{ij}(i-j)$. This number is then used to determine the survival rate, or φ, in the equation $M_{i+1} = \varphi(M_i + r_i)$, where M_i equals the number of marked individuals at risk on day_i, and r_i is the number of individuals released after marking on day_i (and, therefore, usually equal to n_i). The mean age of marked individuals on day_{i+1} was determined by the equation

$$A_{i+1} = \frac{A_i(M_i)}{M_i + r_i} + 1$$

The estimate of the population size on day_i was obtained by the equation

$$\hat{N}_i = \frac{(n_i + 1)}{(M_i + 1)} M_i$$

The estimate of the number added to the population between day_i and day_{i+1} was obtained by equation $\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}(\hat{N}_i)$. The equation $\hat{L}_i = (1 - \hat{\phi})\hat{N}_i$ gave the estimate of losses from the population between day_i and day_{i+1}.

RESULTS AND DISCUSSION

EMERGENCE PATTERNS

During 1979-82 at the study site *G. ozarkensis* first emerged on 5 or 6 May. In each instance mass teneral sightings were made either at river's edge or in the meadow or in both areas. Individuals moving along the tree path would first appear in the meadow at approximately 10 : 00 AM CDT. However, during this study rain fell continually from 4-8 May, and the first individual was not observed until 10 May, at 9 : 50 AM. This female was first observed at the south end of the meadow, at the junction of the meadow and tree paths, and had probably just left the tree path.

Characteristically the maiden flight of odonates is away from water (CORBET *et al.*, 1960). In those odonate species with synchronized emergence, mass maiden flights usually follow visual pathways. *Agria moesta* has been reported to move from the river through woods via air drains that had been cut to ventilate an orchard (BORROR, 1934). In this study the tree path served as such a visual pathway.

The approximate emergence dates for this population of *G. ozarkensis* during 1984 were 10 May through 3 June. This implies an emergence period of approximately 24 days. In species having an early, closely synchronized emergence, the annual duration of emergence is usually just short of a month (CORBET, 1980). Further, approximately 55% of the tenerals captured in this

study emerged during the first third of the emergence period. Since *G. ozarkensis* emerges early in the year, has a short synchronous emergence period and has an early emergence peak, it is categorized as a spring species.

Maturation Period

During the maturation period the dragonfly's body and wings typically undergo color changes and its gonads mature. Anisoptera individuals usually reach sexual maturity within two weeks, but the range may be from 6-45 days (Corbet, 1980).

During the first several weeks of this study the colorations of *G. ozarkensis* individuals were unchanged. The eyes were grey but clear, the green pigmentation of the thorax and abdomen was bright and the yellow pigment on the club tail was moderately intense. After the first week in June the color intensities changed. The eyes became bright blue, the green coloration of thorax and abdomen faded, and the yellow on the club tail intensified. These changes coincided with a color change in the meadow grasses, from green to a predominantly golden hue.

Sexual behavior was first observed in *G. ozarkensis* six days after the first teneral was sighted. This pair is believed to have been in the maturation phase because the copulation was observed in the meadow, not at stream side, and this observation occurred seven days before the first sighting of any individual having returned to the water.

The first individual observed at stream side, an unmarked male, was sighted on 23 May, or 13 days after the first sighting of a teneral. A male teneral marked on 12 May was sighted 18 days later, perched on the stream bank three m from the water. On 14 May a female teneral was marked on the tree path. On 5 June, 25 days later, she was observed perching on a water willow at river's edge, about 450 m downstream from the original sighting.

The maturation period can only be approximated from the preceding data. It is understood that the sightings may not represent the first time an individual returned to water. It is estimated that the maturation periods for males and females are no more than 18 and 25 days, respectively.

Population Dynamics

The last sighting of a *G. ozarkensis* adult was on 22 June, 43 days after the first teneral was seen. During this time we attempted to capture and mark all individuals of this species that were sighted. A total of 125 individuals was marked. Of these, 28 were resighted only once, 13 were resighted twice and two were resighted four times (Fig. 1). In other words, 43 individuals (34%) were resighted at least once, and total resightings equaled 62.

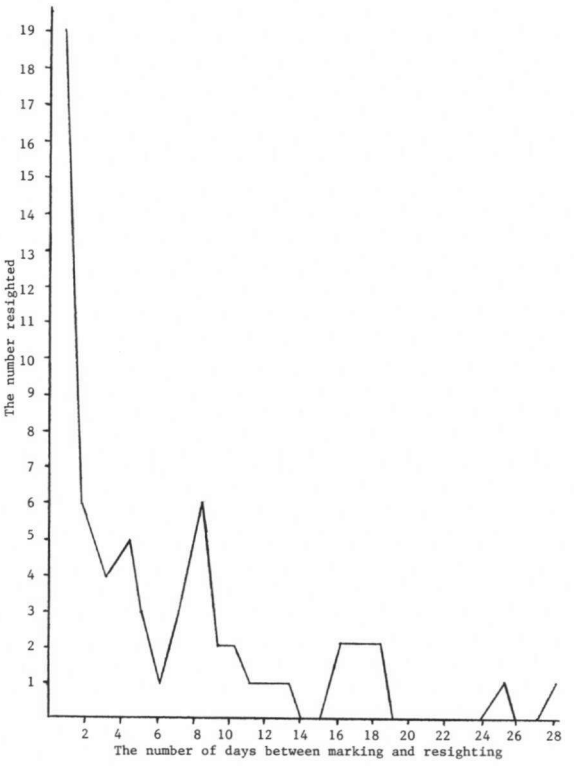

Fig. 1. The number resighted and the length of time between resightings and the original markings.

These sightings provided enough data to use the Fisher-Ford mark-recapture method for determining population size. This method is appropriate for long study periods, and it allows for a lower recapture number because population estimates are obtained by grouping data to produce a survival rate, which is assumed to be constant. For various reasons (SUSANKE, 1986), the only mark-recapture data used in estimating population size are those collected after 27 May. While the sampling period is thus shorter than the maximum life span, the population size estimates are not affected (PARR & PARR, 1979).

Marked individuals were recaptured a total of 40 times (Table I). The largest number of recaptures was on day_{10}, with seven. This number is one-half of the total number of marked individuals at risk on that day (M_i). The largest number of individuals caught, marked or not, was 14, on day_2 (n_i). Although the number caught fluctuated greatly from day to day, the pattern was one of gradual decrease from beginning to end. The total number of

Table I

Results of the Fisher-Ford Method, with data beginning day$_i$ on 28 May

day$_i$	m_i	n_i	r_i	Surv*	M_i	A_i	$A_i m_i$	$\hat{N}_i$	$\hat{B}_i$	$\hat{L}_i$
1	0	11	11	0	0	0	0	0	26.1	0
2	3	14	14	3	6.96	1	3	26.1	13.34	9.58
3	3	8	8	4	13.27	1.33	3.99	29.86	21.48	10.96
4	0	2	2	0	13.46	1.83	0	40.38	23.39	14.82
5	1	9	9	4	9.79	2.59	2.59	48.95	10.62	17.96
6	3	13	13	14	11.89	2.35	7.05	41.61	36.66	15.27
7	2	11	11	5	15.75	2.12	4.24	63.0	- 22.95	23.12
8'	0	0	0	0	16.93	2.25	0	16.93	32.16	6.21
9	2	11	11	10	10.72	3.25	6.5	41.88	- 8.23	15.74
10	7	10	10	32	13.75	2.60	18.2	18.91	33.12	6.94
11	2	8	8	8	15.03	2.51	5.02	45.09	11.55	16.55
12	3	10	9	21	14.58	2.64	7.92	40.09	4.48	14.71
13	2	5	5	15	14.93	2.63	5.26	29.86	6.32	10.96
14	4	9	8	32	12.61	2.97	11.88	25.22	10.13	9.25
15	3	7	7	24	13.05	2.82	8.46	26.10	- 3.83	9.58
16'	0	0	0	0	12.69	2.83	0	12.69	0	4.66
17'	0	0	0	0	8.03	3.83	0	8.03	7.62	2.95
18	1	4	4	4	5.08	4.83	4.83	12.7	- 2.92	4.66
19	3	3	3	39	5.75	3.70	11.1	5.75	1.90	2.11
20'	0	0	0	0	5.54	3.43	0	5.54	0	2.03
21'	0	0	0	0	3.51	4.43	0	3.51	2.22	1.29
22	0	1	1	0	2.22	5.53	0	4.44	- 0.77	1.63
23'	0	0	0	0	2.04	4.81	0	2.04	0	0.75
24'	0	0	0	0	1.29	5.81	0	1.29	0	0.47
25'	0	0	0	0	0.82	6.81	0	0.82	0	0.30
26	1	1	1	15	0.52	7.81	7.81	0.52		0.19
Total	40	137	135	230	230.24		107.85	552.3		
Mean						3.33				

*Surv = $\Sigma_j m_{ij}$ (i - j).
' = no field observations on this day.

individuals caught was 137; of these 135 were released after marking (r_1). The other two were found dead. Because capture only relied on resightings, individuals found dead were considered caught but were not included in the number released.

The greatest number of days that a mark could have survived was 39 according to the Fisher-Ford method, while the longest observed life span of an individual was 28 days. This individual was resighted four times.

The observed total days survived by the entire population was 230. This value was used to determine the survival rate (φ), which was calculated to be 0.633.

GARRISON (1978) attributed his overall low survival rate to the low number of recaptures. In this study, after 27 May, 97 individuals were marked. Only

28 marked individuals, or 29%, were recaptured. The total of 40 recaptures results from some of these individuals being recaptured more than once. As in GARRISON's (1978) study, we believe the low number of recaptures has caused a low survival rate to be calculated. PARR & PARR (1979) stated that as the proportion of marked specimens increases in the population, the population estimates will become more accurate. Even in this study it can be seen that as the number marked increased from 97 to 125, that is to say that when one considers all of the marking data, the recaptures increased from 28 to 43, and the calculated recapture rate also increased, from 29% to 34%. The recapture percentage for *G. ozarkensis*, 29%, is nevertheless comparable to those reported by others for zygopteran species. BORROR (1934) reported a recapture rate of 27%, as did GARRISON (1978), and ROBINSON *et al.* (1983) reported 28%.

The composite mean age of marked individuals was calculated to be 3.5 days. The sum of the estimate of the days survived by marked individuals caught in the day_i sample is 107.85 ($A_i m_i$). This is considerably lower than the observed total days survived by marked individuals in the population, 230. Estimated values for $\hat{N}_i$ (estimate of the population size on day_i), $\hat{B}_i$ (estimate of the number added to the population between day_i and day_{i+1}) and $\hat{L}_i$ (estimate of losses from the population between day_i and day_{i+1}) may also be low, since their calculations are based either directly or indirectly on the low number of captures or recaptures.

The largest number the *G. ozarkensis* population attained was 63 individuals, on day_7 of the study. Population growth was rapid from day_1 through day_7. This was followed by a general decline, with minor fluctuations (Fig. 2). Although the estimated population size may be low, the pattern of population growth and decline should nevertheless be descriptive. The negative values calculated for B_i suggest that the estimate of the emergence rate is derived from an estimated survival rate and estimated population numbers which contain errors. This often leads to negative estimates, thus making the estimate of the birth rate unreliable. The estimate losses from the population on each day followed the same fluctuations as the daily $\hat{N}_i$ values.

SEX RATIO

The sex ratios reported for various Odonata vary greatly. BORROR (1934) found 67.3% of the population he studied to be female. LUTZ & MCMAHAN (1973) reported 52.4% of their study population of *Gomphus exilis* to be females. In this study, 11 of the first 13 individuals captured were males, and the marked total was 64.8% males. The more active an individual was, the greater was its risk of being captured. Our results may merely reflect a greater activity on the part of the male.

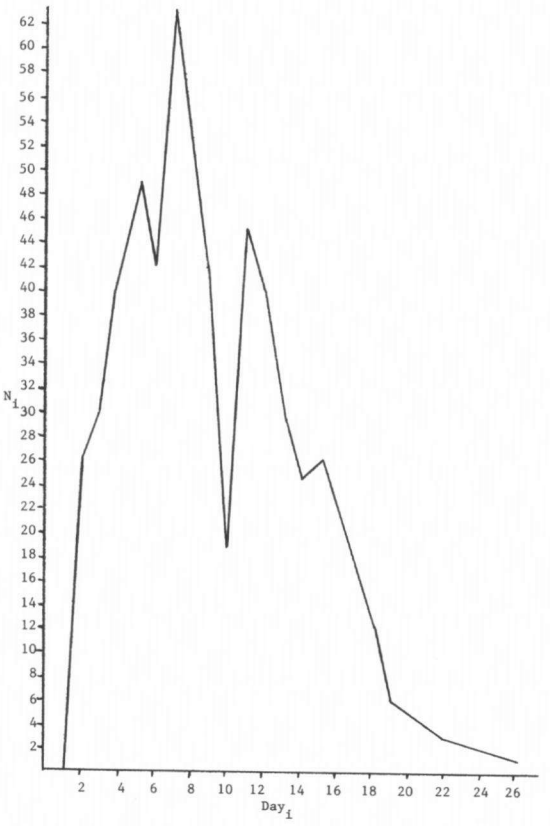

Fig. 2. Estimation of population size on day_i.

CONCLUSIONS

G. ozarkensis is categorized as a spring species because it emerges early in the year, has a short synchronous emergence period and has an early emergence peak. It is estimated that the maturation periods for males and females are no more than 18 and 25 days, respectively. The flight season approximates 43 days. The survival rate was calculated to be 0.633, and the composite mean age of marked individuals was 3.5 days. The population attained its largest size on day_7 of the study, 63 individuals. Males comprised 64.8% of the marked individuals.

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