1996, *Entomologist's Gazette* 47: 206–210

The volume of sound as an index to the relative abundance of *Cicada orni* L. (Homoptera: Cicadidae) in different habitats

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The large cicada, *Cicada orni* L., occurs very commonly around the Mediterranean, with the emerged adults reaching a peak for a few weeks in summer, usually in July in most areas. Such a large abundant insect provides an important food source for a wide range of predators, both mammals, such as badgers (*Meles meles*) and foxes (*Vulpes vulpes*) (Ciampalini & Lovari, 1985), and birds. For example, in a study of the jay (*Garrulus glandarius*) in the Maremma Natural Park on the coast of Tuscany, Italy, by Patterson, Cavallini & Rolando (1991), the birds were found to congregate at very high densities in pinewoods, where they fed mainly on cicadas. The jays occurred at higher density in this habitat than in adjacent olive groves and Mediterranean scrub and were also densest in the north-west part of the pinewood, dominated by the umbrella pine (*Pinus pinea*), than in the south-east coastal part where the maritime pine (*Pinus pinaster*) was more common. These variations in the density of jays paralleled the observers' impression of differences in the abundance of cicadas in these habitats, suggesting that the birds were responding to the density of their principal prey, as would be expected.

It was found to be very difficult to test this apparent relationship since the mobile and cryptic adult cicadas could not be counted during the study. The volume of sound produced by the singing insects, however, seemed to provide a possible means of estimating at least the relative abundance of cicadas between habitats.

The aim of the present study was to use the volume of song to measure the relative abundance of cicadas in different habitats in the Maremma Natural Park, to compare the distribution of cicada song with that of jays in the same area and thus to assess the use of the volume of sound produced by the singing insects as an index of the relative abundance of prey in different areas.

Study area and methods

The study was carried out in July in the areas of the Maremma Natural Park, Tuscany, Italy, used in the earlier study of jays by Patterson, Cavallini & Rolando (1991). The principal habitats investigated were extensive pinewoods, mainly of *Pinus pinea* in the north and mainly of *Pinus pinaster* in the south, small planted olive groves and large areas of Mediterranean scrub along the slopes of a limestone ridge (Fig. 1).

The volume of sound produced by singing cicadas was measured in each of the three main habitat types in the area. Measurements were made at five fixed points in both the pinewood and the olive grove and at five random points,

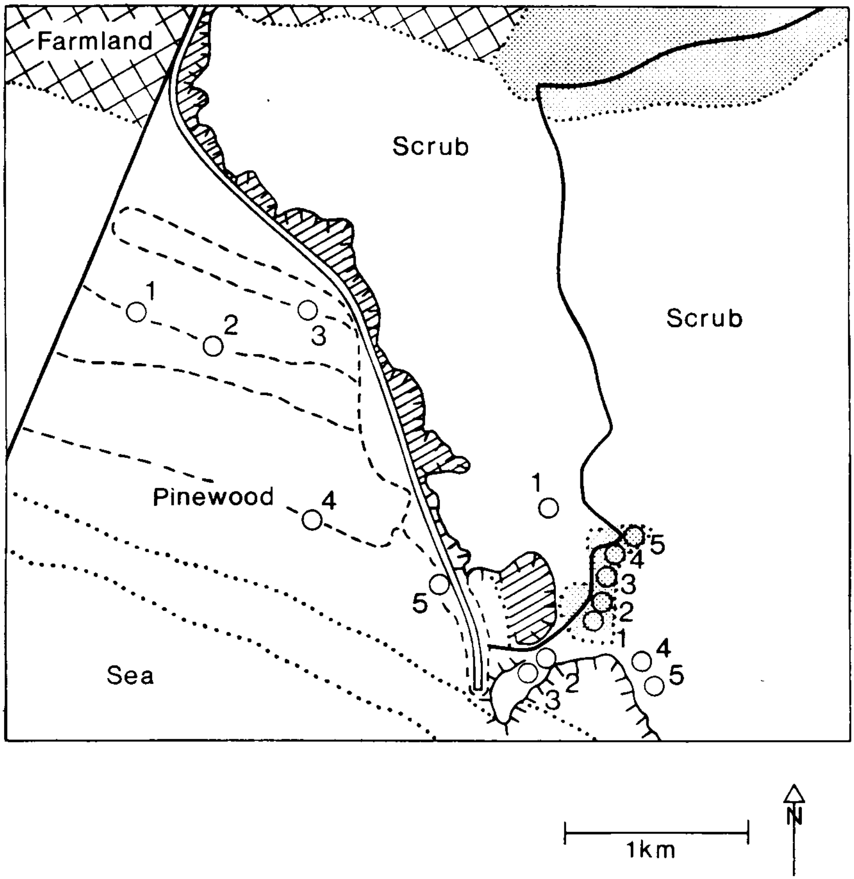

Fig. 1. The study area, showing the distribution of the main habitat types and the position of the study sites within them.

selected on each sampling occasion, in the scrub where cicadas were distributed much less evenly than in the other two habitats (Fig. 1). Between four and eight measurements (mean 5.2) were taken at each point between 18 July and 28 July 1990, always between 0930 h and 1900 h, when the shade temperature was at least 25 °C and wind speed was less than 6 km/h.

Portable field sound-measuring equipment was not available so measurements were made by an indirect method, by recording the cicada sound in the field on a portable tape recorder and later measuring the volume of sound on the tape in the laboratory (Appendix 1).

Results

Variation with date

In both the pinewood and scrub areas, the volume of cicada sound declined significantly during the study period (Fig. 2), but this did not occur in the olive grove. Since there was significant variation between habitats in the mean dates when measurements were made ($F(2,77) = 3.96$, $p = 0.023$), with data collection before 21 July only in the pinewood and olive grove (Fig. 2), the data collected prior to this date have been excluded from comparisons between habitats. The remaining data still allowed the calculation of a mean value for each study site based on at least three measurements (two sites) or four measurements (13 sites) taken on different days.

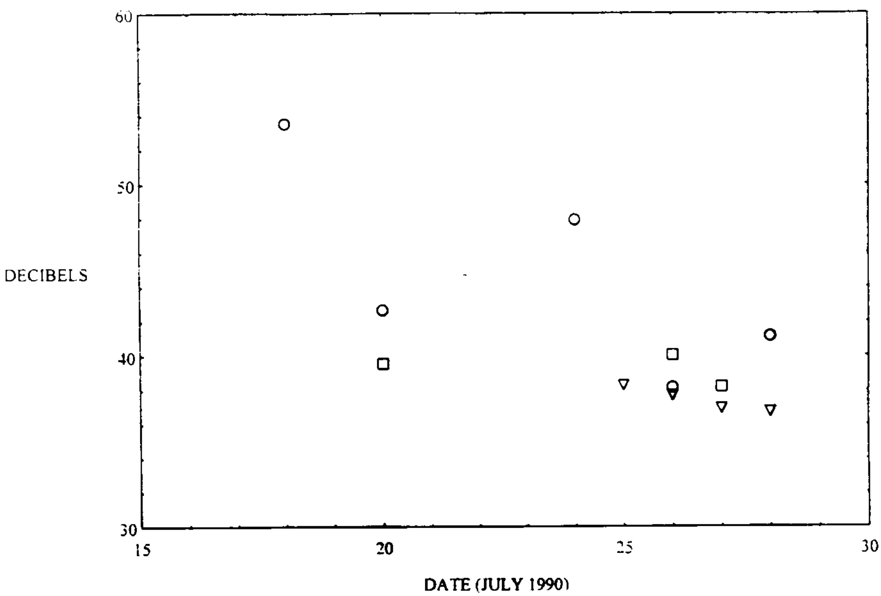

Fig. 2. Variation in mean song volume (dB) with date (July 1990) in the different habitat types, pinewood (circles), olive grove (squares) and scrub (triangles).

Variation within habitats

There was significant variation in the amount of sound between sites in the pinewood, with higher levels in the north-west part of the wood than in the south-east part, near the sea (Table 1). There was, however, no such significant variation between sites in the other two habitats (olives; $F(4,20) = 0.77$, $p = 0.56$: scrub; $F(4,22) = 0.74$, $p = 0.58$).

Table 1. Variation in cicada song volume within habitats, including data from the whole study period.

	Mean volume (dB) at different sites								
	Pine			Olive			Scrub		
Site*	Mean	SE	N	Mean	SE	N	Mean	SE	N
1	47.79	2.26	7	38.27	0.58	5	37.35	0.40	5
2	45.63	3.02	5	38.43	1.11	5	37.90	0.44	6
3	39.72	1.54	4	40.39	0.84	5	37.18	0.16	6
4	40.62	1.80	5	39.35	1.25	5	37.08	0.37	6
5	39.40	1.61	5	39.57	1.04	5	37.65	0.71	4
F		3.13			0.77			0.74	
P		0.028			0.555			0.576	

* positions shown in Fig. 1.

Table 2. Variation in cicada song volume (dB) between habitats, excluding data collected before 21 July.

	Pine	Olive	Scrub
Mean volume (dB)	42.22	39.01	38.86
SE	1.32	0.33	0.30
N (sites)	5	5	5

$F(2, 12) = 5.53, p = 0.020$

Tukey tests: pine vs olive, $p = 0.039$; pine vs scrub, $p = 0.031$; olive vs scrub, $p = 0.991$

Variation between habitats

There was significant variation in sound levels between habitats, with the mean value in the pinewood significantly higher than those in the olive grove and scrub (Table 2). There was no significant difference between the mean sound levels in the latter two habitats.

Discussion

The results confirm that the measurements of sound volume can show consistent differences between habitats and thus can be used as an index of the relative abundance of cicadas. It is desirable of course that the method be calibrated against known cicada densities, but there are considerable practical difficulties in doing so. The use of insecticide fogging to bring down cicadas into collecting trays is unacceptable on conservation grounds and cages to capture all of the adults emerging from particular areas are subject to problems of differential mortality or emigration after emergence in the different habitats.

The study also showed clearly that the amount of sound produced by cicadas in the different habitats paralleled closely the variation in the density of jays shown by Patterson, Cavallini & Rolando (1991), with a significantly higher mean volume in pinewoods than in olive groves and scrub. The volume within pinewoods also decreased from north to south just as jay density did. This suggests that (unless jays and cicadas were responding similarly to some unknown environmental factor) the birds were responding to cicada density, either through their rate of encounter or capture or by a direct response to the volume of cicada song. This latter possibility could be tested experimentally by broadcasting cicada song at high volume and observing the jays' response.

References

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Appendix 1. Method of sound volume measurement

A simple Philips portable tape recorder, with its recording gain control taped at a set position, was used with a multi-directional microphone. At each recording point, the microphone was placed on the ground facing upwards and the tape recorder was started 5 min. later, after the nearest cicadas had resumed singing. Recording was continued for at least 60 s. at each position. Background noise was recorded in the morning, just before the cicadas began to sing, at several positions in each habitat. There was, however, no difference between habitats in the (low) mean level of background noise, and it was ignored in subsequent comparisons.

In the laboratory, the single cicada songs were analysed on an oscilloscope, and their dominant frequency was found to lie in the 1–10 KHz band, with most energy around 5 KHz. Subsequent analyses used a filter to exclude sounds outside this range and so reduce the effect of extraneous noise, e.g. from distant traffic or boats.

For the analysis of the recordings taken in each habitat, the output of the oscilloscope, at a standard amplifier setting, was connected to a voltmeter which gave a digital reading of the signal strength on the tape. A total of 10 samples at intervals of 5 s. were taken from each recording to provide a mean mV value, and the overall mean mV level for all the recordings at each site was calculated.

To calibrate the mV values in terms of dB, the recording system was calibrated by recording samples of sound generated at 5 KHz by a signal generator ('Advance' Type 91A). The sound levels were set at a series of dB values, in steps of 5 dB above background sound level, using a Dawe 1400G sound level meter. The same microphone and tape recorder (with the same settings as in the field) were used, the microphone being substituted for the probe of the sound level meter after each sound level was set up. The signal strength of each recording was then determined from the mean of 10 samples, in exactly the same way as for the field recordings. The mV values so obtained were calibrated by obtaining a linear calibration curve and calculated regression line, from the square root of the dB values and the logarithm of the mV values (square root dB = 1.01 + 0.904 log mV; $r = 0.984$, $r^2 = 96.8\%$, $p<0.001$, $n = 6$).