

moments it feels in its "wrist," "elbow," and "shoulder" joint, then, if the bird always adjusts its wing aerodynamics to obtain the same feeling, it will be doing the right thing. So a young bird, having learned to fly solo, will immediately adjust to any slot in the formation simply by flying so that it "feels the same."

As to the vee formation, if a bird moves ahead of the vee line it finds more power is required to keep up with the flight so that, at the same power, its speed falls until it is back in line. Aft of the vee line less power is required. This stabilizing effect is easily sensed if one assumes that the flight will not tolerate malingers who fly inside the vee where less power is required by one bird at the expense of more work for the main formation. Maybe this sheltered position is used by weaker birds. This implies that the idea that the lead bird has the most strenuous position is incorrect. Any bird can make small position changes within the general vee shape to adjust its drag; in fact, those changes in the stream-wise direction occur automatically if the bird flies at fixed power.

The analysis also shows that the formation should be in a near horizontal plane, which is always observed in nature. If the formation were for purposes of visual contact only, many other nonplanar arrangements might be as effective.

It has been suggested that the vee formation is related to the flapping wavelength. Our analysis does not consider the flapping frequency—that is, the wing efficiency as a propulsor has been assumed constant. Propulsive flapping losses could certainly be reduced by favorable unsteady interactions. Calculations of this have not been made, but we believe that the steady induced power is the dominant effect, and that the second-order flapping terms (giving the propulsive losses) are much less important. Support is provided by photographs of birds in vee formation where the wing strokes seem to be randomly phased. If flapping synchronization were the only requirement, a sheared line or a zig-zag formation would be as good. The vee formation is the only one which can equally distribute the load. The vee does not have to be symmetrical, because only the influence of the neighboring half-dozen birds is important. One might have a vee with 15 birds on one side and 10 on the other, and small changes in lateral spacing

would give even loading. The important thing is that the front bird should have others on both sides. In other words, one must always have a vee apex, but the legs can be different lengths.

It is interesting that optimal formation flight is at a lower speed than solo. This implies that observations should indicate that a formation of birds cruises at a lower speed than does a single bird of that species.

Many photographs of migrating formations exist, but because of their obliquity it is difficult to determine the

precise geometry. It would be of great interest to acquire good data of bird formation, from which actual spacing, vee angle, speed, and flapping frequency could be established.

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Sex Attractant of the Grass Grub Beetle

Abstract. *The sex attractant produced by adult females of the grass grub beetle Costelytra zealandica (White) has been isolated and identified as phenol. Field tests with phenol-water mixtures were attractive to male beetles in particular.*

We report phenol, which has been isolated from the female beetle of *Costelytra zealandica* (White) (Scarabaeidae: Coleoptera), as a sex attractant for the male beetle of the same species. The larval stage of this insect pest is of major economic importance in New Zealand, causing considerable pasture damage.

Evidence for the presence of a chemical sex attractant in the female beetle has been described by Henzell *et al.* (1). The attractant was isolated from 1500 virgin female beetles by washing their abdomens with diethyl ether. The ether extract was concentrated to 0.5 ml by rotary evaporation at 25°C and 70 mm-Hg, and then sublimed on to a condenser cooled with Dry Ice, in a short-path apparatus at 30°C and 0.001 mm-Hg for 3 hours. The biologically active sublimate in diethyl ether was chromatographed (by spotting) on silica gel plates and eluted with two systems, chloroform and 10 percent ether in hexane. Only one active area, whose R_F value was consistent with that of phenol, was obtained with each system. A similar result was obtained when the extract was chromatographed on Whatman No. 1 filter paper and eluted with water, ethyl alcohol, or a mixture (1:1) of diethyl ether and ethyl alcohol.

The active sublimate was dissolved in diethyl ether and examined by preparative gas-liquid chromatography with five different column packings: 10 percent Carbowax 20M on 60-80 mesh Gas Chrome P; 4 percent UCW98 on 60-80 mesh Gas Chrome P; 2 percent Apiezon L on 60-80 mesh Silocel; 2 percent DEGS on 60-80 mesh Gas

Chrome Z; 2 percent Altex G-1292 on 40-70 mesh Silocel.

Fractions were collected from each of the columns and bioassayed. An active fraction was obtained only from the 2 percent Altex G-1292 column. The active compound, approximately 130 µg, had a retention time of 5.2 minutes which corresponded precisely with that of phenol. This collected fraction was dissolved in diethyl ether and examined by mass spectroscopy. Its spectrum was consistent with that of a mixture of phenol in diethyl ether, and the presence of phenol was confirmed by measuring the masses of the ions at (mass to charge) m/e 94, 66, 65, and 39. These had the expected compositions of C_6H_6O , C_5H_6 , C_5H_5 , and C_3H_3 . In addition it was established by use of the "defocusing" technique that the following transitions had taken place; 94 → 66, 93 → 65, 66 → 65, and 65 → 39. There was no evidence that the ion $C_6H_6O^+$ had arisen from a precursor of higher molecular weight; therefore it can be confidently concluded that the compound under examination was phenol.

Laboratory bioassay was carried out as described (1), except that each fraction was placed on a paraffin dummy which was then dropped among ten male beetles confined under an inverted filter funnel (12 cm in diameter). Beetles responded within a few minutes to dummies treated with 0.1, 1.0, and 10.0 µg, respectively, of pure phenol, by attempting to copulate with the dummies as well as with one another. Eighty percent of the males responded to each amount of phenol on the dummy. Analysis by gas-liquid chromatography (2) of

ethereal extracts of female abdomens indicated that each beetle contains between 0.5 and 1.0 μg of phenol, which corresponds to approximately 10 to 20 parts per million by weight. No phenol was detected in ethereal extracts of male abdomens.

Field tests were carried out to examine the attractiveness of phenol. Pure phenol mixed with water at concentrations varying from 500 to 10 ppm were attractive to the male beetle in particular. Two liters of the phenol-water mixtures was placed in open tins and tested at dusk when beetle flights occurred. On one such evening a total of 71 males and no females were caught in seven traps each containing approximately 100 ppm of the phenol-water mixture. On the following evening 222 males and 19 females were caught in the same traps. Control traps containing water and placed alongside each baited trap did not catch any beetles.

Reports on insect sex attractants have revealed structural characteristics that

allow the attractants to be classified into three major groups: unsaturated alcohols and their esters, aliphatic acids, and terpene-like compounds (3). Phenol obviously does not fit into any of these groups. In fact, to our knowledge, while phenol occurs in plants (4), its presence has never been reported in insects.

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References and Notes

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5. We thank Dr. R. Hodges of Massey University for his mass spectral analysis and Dr. E. P. White of this Centre for advice and constructive criticism during this project.

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census was made to obtain data on growth of young. At each census I captured nearly all bats in the tunnel and could tell which bats (marked by banding) occupied which hole. A few bats may leave holes during a census and may sometimes enter (and be captured in) other holes. It is not always possible to be certain which bats have done this, but the error in ascribing hole occupancy to a particular bat is probably small.

Table 1 summarizes data relating to the frequencies of recapture, group size, and hole usage. Sexes were treated separately and bats less than 12 weeks old were excluded. The frequency of recapture differed significantly from that expected from random recapture for both sexes (6). For males and females more bats were recaptured zero to one time, and, for males, more were recaptured seven or more times than would be expected. For some males, therefore, site attachment to the tunnel is more strongly expressed than for others; but there is no suggestion that this is true for females. Many bats (male and female) recaptured zero or one time were less than 1 year old at both capture and recapture. Mortality of, or dispersal by, this age class could explain why more bats were recaptured zero or one time than would be expected. Males are more often found alone than would be expected; females are more often found in groups; females are not attached to specific holes and in fact may use the same hole less often than would be expected; and males captured five or more times tend to use certain holes repetitively and other holes less often than would be expected. This last arises because specific males tend to be associated with specific holes. Thus, for all but 1 of the 14 males captured five or more times a "favored" hole was evident, and 40 of the 91 captures of these bats were made in favored holes. For six bats half or more of their captures were in the favored hole. With one exception the favored hole of one male was not the same as that of another male; in this case one individual occupied the hole in question only after the other had disappeared from the tunnel.

The holes used by any resident male (male taken five or more times) are, on average, closer together than the holes used by females captured the same number of times. Thus for 14 resident males the average displacement per recapture, measured from the hole of first capture, was 3.03 ± 1.74

Social Organization in the Bat *Myotis adversus*

Abstract. *Studies in which the Australian bat Myotis adversus was marked and recaptured showed that mature males tend to be solitary, are strongly attached to a particular site, and apparently defend home sites. Harem formation concurrent with mating has been observed, and the bond between the mother and her young extends beyond nursing.*

A few megachiropteran bats are known to exhibit a range of vocal, olfactory, and tactile signals (1), and Australian flying foxes (*Pteropus*) show premating territorial behavior, mate selection, and polygamous groupings within large daytime camps (2). Microchiropteran bats, however, have been viewed as a socially conservative suborder of solitary and colonial species. In many of the latter species, nursing aggregates of mothers and young are recognized, but, beyond this, sociality is usually seen as a combination of passive aggregation with differing degrees of group stability and site attachment. Clustering behavior has been interpreted in terms of its physiological advantage (3). *Tadarida brasiliensis mexicana* appears to show an extreme of this mode of sociality, with aggregations of millions and with reduction of those interactions calling for recognition of one individual by another—even the bond between the mother and her young may be lost (4). In southeastern Australia, sociality in *Miniopterus schreibersii* differs from

the above. Clustering appears to function as a social spacing mechanism; age classes (particularly of males) tend to be segregated at different roosts, especially at times of reproductive activity; and stable mating aggregates of adult males serve to fertilize large numbers of transient females (5). I report here a pattern of social organization in the Australian large-footed myotis *Myotis adversus* that does not conform to previously recognized social systems in microchiropteran bats.

I observed bats in an abandoned railway tunnel at Samford, about 21 km northwest from Brisbane (southeastern Queensland). The *M. adversus* are found in holes (approximately 10 cm in diameter and 30 to 45 cm deep) situated about 3.5 m above the floor and about 3 m apart along each wall of the tunnel. Holes on one wall lie directly opposite holes on the other wall, and a total of 26 pairs of holes are available to the bats. Between April 1968 and February 1969, 11 complete censuses of the tunnel were made. In early November 1968 an incomplete