

CUTICULAR HYDROCARBONS OF ADULT *LEPIDOCHORA DISCOIDALIS* GEBIEN AND *LEPIDOCHORA EBERLANZI* KOCH (COLEOPTERA: TENEBRIONIDAE)

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**Abstract**—1. The cuticular hydrocarbons of *Lepidochora discoidalis* (LD) and *Lepidochora eberlanzi* (LE) have been analysed by gas chromatography and by combined gas chromatography-mass spectrometry and comprise *n*-alkanes (LD, C<sub>23</sub>-C<sub>35</sub>, 96.5%; LE, C<sub>23</sub>-C<sub>33</sub>, 85.6%) terminally branched monomethylalkanes (LD, C<sub>30</sub>, 0.6%; LE, C<sub>26</sub>-C<sub>30</sub>, 2.0%) and internally branched monomethylalkanes (LD, C<sub>28</sub>-C<sub>30</sub>, 1.4%; LE, C<sub>26</sub>-C<sub>32</sub>, 9.0%) and dimethylalkanes (LD, C<sub>29</sub>-C<sub>31</sub>, 1.4%; LE, C<sub>27</sub>-C<sub>33</sub>, 3.4%).

2. It is suggested that a simple hydrocarbon mixture with a high proportion of nC<sub>33</sub> has contributed to the success of *L. discoidalis* as a dune beetle.

3. Similarities between the hydrocarbon mixtures of eleven tenebrionid species representing tribes, Adesmiini, Zophosini and Eurychorini, subfamily Tentyriinae are noted.

INTRODUCTION

Genus *Lepidochora*, tribe Eurychorini, family Tenebrionidae (Koch, 1952, 1962a,b) contains highly specialised species of ground beetles which are adapted for living only in the barren, shifting sand-dunes of the Namib Desert of South West Africa/Namibia (Koch, 1952). During the high temperatures of the day, members of the genus lie buried deep in sand on the slipfaces of the dunes where wind-blown vegetation collects (Kuhnelt, 1969; Louw, 1983). They emerge towards sunset, often in large numbers, to feed on the vegetation and, at certain times of the year, to copulate (Koch, 1952). Members of the genus are very sensitive to slight vibrations of the ground (Kuhnelt, 1969) and Seely and Hamilton (1976) suggest that some species, for example *Lepidochora discoidalis*, construct trenches in the sand which collect the condensed moisture of sea-fogs, which the beetles drink (Seely, 1979).

Tribe Eurychorini is included with tribes Adesmiini and Zophosini in subfamily Tentyriinae (Koch, 1955). So far in the present investigations of the cuticular hydrocarbons of adult tenebrionid beetles (Lockey, 1981), the hydrocarbons of seven species of tribes Adesmiini (Lockey, 1982a,b,c, 1984a) and those of two subgenera of tribe Zophosini (Lockey, 1984b) have been examined. In the work to be described, the hydrocarbons of *Lepidochora discoidalis* and *Lepidochora eberlanzi*, tribe Eurychorini, have been analysed by gas chromatography (GC) and by combined gas chromatography-mass spectrometry (GC-MS).

MATERIALS AND METHODS

Both species of *Lepidochora* were collected in South West Africa/Namibia in May 1980. Adult *L. discoidalis* were collected in the late afternoon on the slipfaces of the wind-blown sand-dunes near to the Namib Desert Research Station at Gobabeb, while adult *L. eberlanzi* were collected at night on slipfaces of the coastal sand-dunes near to Swakopmund.

Details of the analytical procedure used in the work are given in a previous paper (Lockey, 1984a). The adults of both species were kept alive until the time for lipid extraction when they were killed by freezing at -20°C and then refluxed with 'AnalaR' chloroform for 1 hr. Hydrocarbons were extracted from the lipids by column chromatography, using alumina (Merck, neutral, activity 1) and re-distilled petroleum spirit (boiling range 60-70°C) as the eluant.

The hydrocarbons were examined by i.r. to detect contaminants and to survey molecular composition.

The hydrocarbons were analysed with a model F17 Perkin-Elmer gas chromatograph using a 25 m wall coated open tubular (WCOT) glass capillary column coated with CP Sil 5, 0.78 µm thick. Each mixture was analysed initially by temperature programming from 50 to 325°C at 3°C/min and subsequently from 200 to 300°C at 1°C/min. Nitrogen at a flow rate of 3 ml/min was used as the carrier gas.

Retention indices (*I*) were calculated from retention times which were determined by adding even-numbered reference *n*-alkanes, ranging from C<sub>22</sub> to C<sub>36</sub>, to each mixture and temperature programming from 200 to 300°C at 2°C/min. (Ettre, 1964).

Olefins were detected by brominating each mixture and noting the disappearance of any component in subsequent GC analyses.

Straight-chain and branched hydrocarbons were separated by refluxing each mixture with type 5A Linde molecular sieve in *iso*-octane for 8 hr (O'Connor *et al.*, 1962).

The hydrocarbons comprising each mixture were identified by their mass spectra which were obtained with a 16F V.G. Micromass gas chromatograph-mass spectrometer using a 25 m bonded phase vitreous silica capillary column (phase: BP1, 0.25 µm thick). Each mixture was analysed by temperature programming from 200 to 230°C at 2°C/min and then from 230 to 325°C at 1°C/min. The temperature of the ion source was 230°C and the ionization voltage, 70 eV. Helium at a flow rate of 2 ml/min was used as the carrier gas.

The mass spectrometer was interfaced to a V.G. data system 2000 and mass spectral scans (MS scans), ranging from *m/z* 20 to *m/z* 650, were taken repetitively at a cycle time of 3.5 sec. MS scans were selected for examination from the total ion count (TIC) chromatogram of each mixture. Background was subtracted from the TIC chromatograms by the data system before the MS scans were examined.

\* The mass spectra of methylalkanes were interpreted according to the criteria proposed by McCarthy *et al.* (1968), Nelson *et al.* (1972), Nelson (1978) and Pomonis *et al.* (1978, 1980).

## RESULTS

I.r. analyses showed each mixture to comprise long-chain, saturated aliphatic hydrocarbons with some branched components.

The gas chromatograms of the two hydrocarbon mixtures are given in Figs 1A, B, while the approximate percentage composition, obtained by GC peak triangulation and the identity of the components of each mixture, determined by GC-MS, are given in Tables 1 and 2. Each value of percentage composition is the average of three determinations (maximum variability: *L. discoidalis*, -0.9 to +1.3; *L. eberlanzi*, -2.0 to +1.1).

Both mixtures contain the following hydrocarbon classes: A, *n*-alkanes; C, terminally branched monomethylalkanes; D and E, internally branched monomethyl- and dimethylalkanes respectively. The approximate percentage composition of each class is given in Fig. 3.

The hydrocarbon mixture of *L. eberlanzi* is more complicated than that of *L. discoidalis* and the LE mixture forms two multicomponent GC peaks containing a dimethylalkane and a 3-methylalkane (LE5) and a dimethylalkane and a 4-methylalkane (LE8). It is not possible to separate the hydrocarbon classes comprising each peak and the classes are estimated to occur in equal proportions in each peak (Table 2).

### Class A—*n*-alkanes

*n*-Alkanes comprise the bulk of both hydrocarbon mixtures. The *n*-alkanes of *L. discoidalis* (96.5%) form a complete homologous series from  $nC_{23}$  to  $nC_{35}$ , with  $nC_{33}$  (LD19, 73.4%) the most abundant and  $nC_{31}$  (LD17, 10.0%) the second most abundant *n*-alkane. A data system print-out of a MS scan of LD19 is given in Fig. 2A, which shows a molecular ion at  $m/z$  464 ( $C_{33}H_{68}$ ) and the characteristic fragmentation pattern of a *n*-alkane. The less extensive series of *L. eberlanzi* (85.6%) ranges from  $nC_{23}$  to  $nC_{33}$ , with  $nC_{31}$  (LE23, 31.0%) the most abundant *n*-alkane. Three other odd-numbered *n*-alkanes, namely  $nC_{25}$  (LD3, 12.9%),  $nC_{27}$  (LE9, 16.0%) and  $nC_{29}$  (LE18, 16.1%) occur in high proportions (Fig. 3).

The very high proportions of *n*-alkanes of the two species exceed the 78% *n*-alkane of *Renatiella scrobipennis* (Lockey, 1984a) and are the highest of all of the tenebrionid species so far examined (Lockey, 1981, 1982a,b,c, 1984a,b).

Branched alkanes account for only approx 3.5 and 14.4% of the hydrocarbons of *L. discoidalis* and *L. eberlanzi* respectively. The branched alkanes of each species were separated from the *n*-alkanes and then examined by GC-MS. This ensured adequate amounts of branched alkanes for analysis and at the same time avoided *n*-alkane overloading.

### Class C—terminally branched monomethylalkanes

2-Methylalkanes (Class  $C_1$ ) were not detected in either hydrocarbon mixture. Only one member of class  $C_2$  (3-methylalkanes) was detected in the *L.*

*discoidalis* mixture. This was 3-methylnonacosane (LD15, 0.6%) which occurs as a shoulder on the trailing edge of GC peak LD14 (Fig. 1A). The 3-methylalkanes of *L. eberlanzi* account for about 2.0% of the hydrocarbon mixture and form a complete homologous series ranging in carbon number from 26 to 30. The 3-methylisomers of  $C_{27}$  (LE14, 0.9%) and  $C_{29}$  (LE21, 0.7%) are the most abundant members of the series (Fig. 3).

*dI* is the difference between the retention index of a branched alkane and that of a *n*-alkane with the same carbon number. The *dI* values of the 3-methylalkanes of *L. eberlanzi* range from 22 to 25 with an average value of 24. The 3-methylalkane of *L. discoidalis* (LD15) has a *dI* value equal to 23 (Tables 1 and 2).

### Class D—internally branched monomethylalkanes

*L. discoidalis* has only a small proportion of class D hydrocarbons (approximately 1.4%), comprising the monomethylisomers of  $C_{27}$  (LD7, 0.2%) and  $C_{29}$  (LD12 and LD13, total 1.2%) (Table 1, Fig. 3).

In contrast, the class D hydrocarbons of *L. eberlanzi* represent about 9% of the hydrocarbon mixture and form a homologous series ranging in carbon number from 26 to 32 (Fig. 3). The monomethylisomers of  $C_{27}$  (LE10, LE11 and LE12, total 4.5%) are the most abundant members of the series. A data system print-out of a MS scan of GC peak LE10 is given in Fig. 2B which shows a M-15 ion at  $m/z$  379 ( $C_{27}$ ) and enhanced ion doublets at all even-numbered ion clusters from  $m/z$  140/1 ( $C_{10}$ ) to  $m/z$  280/1 ( $C_{20}$ ), which is interpreted as the fragmentation pattern of a mixture of 9-, 11- and 13-methylheptacosane (Table 2). The ion doublet of low abundance at  $m/z$  308/9 ( $C_{22}$ ) in the MS scan derives from 7-methylheptacosane which constitutes GC peak LE11 and which forms a shoulder on the trailing edge of GC peak LE10 (Fig. 1B).

Like the species of tribe Adesmiini (Lockey, 1982a,b,c, 1984a) and tribe Zophosini (Lockey, 1984b), *L. eberlanzi* has homologous series of 5-methyl- and 7-methylalkanes. *L. eberlanzi* however, lacks a homologous series of 4-methylalkanes, having only 4-methylhexacosane (LE8).

### Class E—internally branched dimethylalkanes

Both species have only small percentages of dimethylalkanes (LD, 1.4%; LE, 3.4%) (Fig. 3). The dimethylalkanes of *L. discoidalis* comprise the dimethylisomers of  $C_{27}$  (LD8, 0.2%),  $C_{28}$  (LD10, 0.2%) and  $C_{29}$  (LD14 and LD16, total approx 1.0%). Most of the dimethylalkanes of *L. discoidalis* conform to type 1, which have their methyl side chains positioned centrally and separated usually by three methylene groups (Lockey, 1984a). A data system print-out of a MS scan of GC peak LD14, a typical type 1 dimethylalkane, is given in Fig. 2C. This MS scan shows a M-15 ion at  $m/z$  421 ( $C_{30}$ ), ion doublets at  $m/z$  168/9 ( $C_{12}$ ), 196/7 ( $C_{14}$ ) and  $m/z$  224/5 ( $C_{16}$ ) and enhanced fragment ions at  $m/z$  239 ( $C_{17}$ ),  $m/z$  267 ( $C_{19}$ ) and  $m/z$  295 ( $C_{21}$ ), which is interpreted as the fragmentation pattern of a mixture of 11-, 15- and 13-, 17-dimethylnonacosane (Table 1). The relatively low abundance of the fragment ions of the latter com-

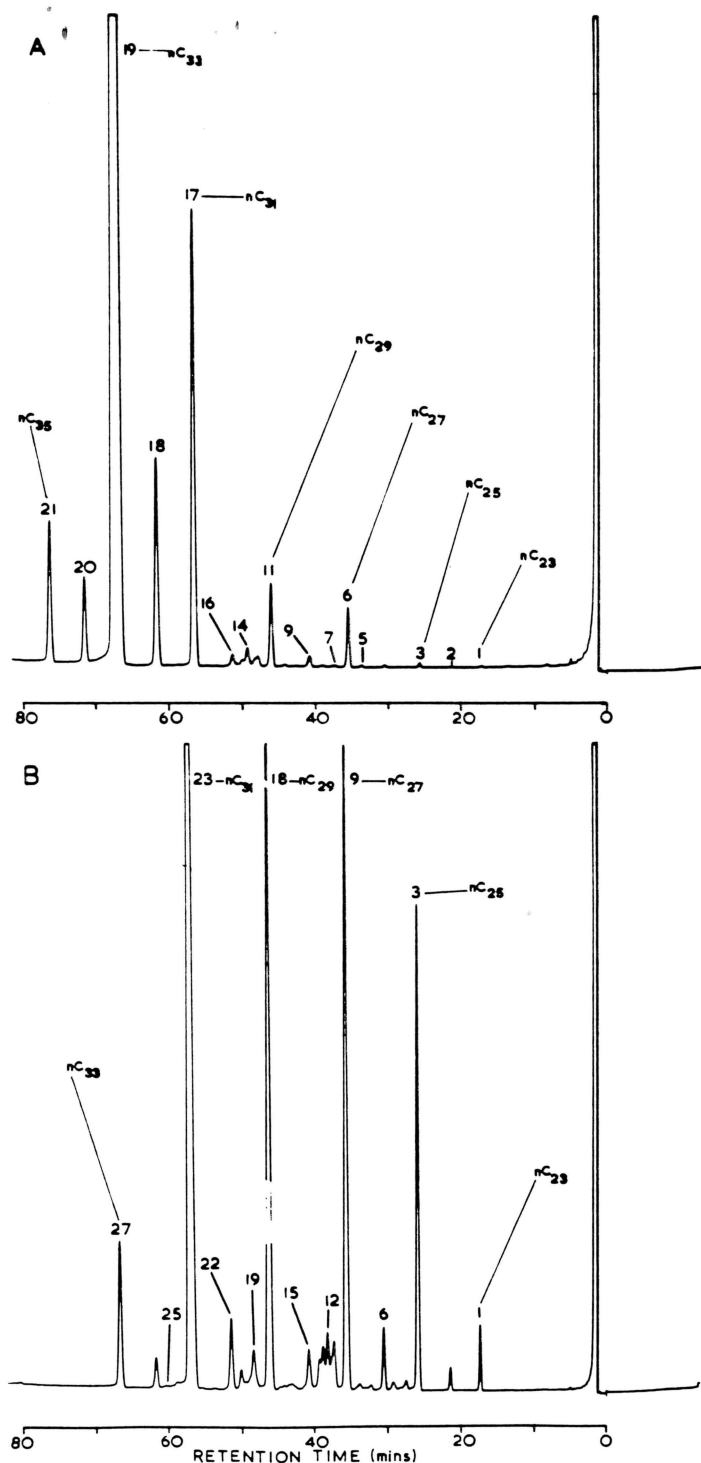


Fig. 1. Gas chromatograms of the hydrocarbons of *Lepidochora discoidalis* (A) and *Lepidochora eberlanzi* (B). GC analyses on a 25 m WCOT glass column coated with CP Sil 5 and temperature programmed from 200 to 300°C at 1°C/min. Carrier gas: nitrogen at 3 ml/min.

ponent indicates that it forms only a small proportion of the mixture.

Clear MS scans of the small GC peak LD10 (0.2%) could not be obtained and the peak is tentatively identified as 10,14-dimethyloctacosane (Table 1).

Type 2 dimethylalkanes have their side chains positioned terminally and separated by an odd and variable number of methylene groups (Nelson *et al.*, 1980; Lockey, 1984a). Only one type 2 dimethylalkane was detected in the *L. discoidalis* mixture,

Table 1. Hydrocarbons of *Lepidochora discoidalis*

GC Peak No.	Retention Index(I)	Carbon No.	dI	Hydrocarbon class	% Composition	Hydrocarbon
LD 1	2300	23	-	A	< 0.1	n-Tricosane
2	2400	24	-	A	< 0.1	n-Tetracosane
3	2500	25	-	A	0.2	n-Pentacosane
4	2600	26	-	A	0.1	n-Hexacosane
5	2643				0.1	
6	2700	27	-	A	1.9	n-Heptacosane
7	2735	28	65	D	0.2	11- and 13-Methylheptacosane
8	2764	29	136	E	0.2	11,15-Dimethylheptacosane
9	2800	28	-	A	0.3	n-Octacosane
10	2866	30	134	E	0.2	*10,14-Dimethyloctacosane
11	2900	29	-	A	1.9	n-Nonacosane
12	2934	30	66	D	0.5	11- and 13-Methylnonacosane
13	2944	30	56	D	0.7	5- and 7-Methylnonacosane
14	2961	31	139	E	1.0	11,15- and 13,17-Dimethylnonacosane
15	2977	30	23	C <sub>2</sub>	0.6	3-Methylnonacosane
16	3000	30	-	A	0.4	n-Triacontane
		31	100	E	< 0.1	3,9- and 3,15-Dimethylnonacosane
17	3100	31	-	A	10.0	n-Hentriacontane
18	3200	32	-	A	4.3	n-Dotriacontane
19	3300	33	-	A	73.4	n-Tritriacontane
20	3400	34	-	A	1.6	n-Tetatriacontane
21	3500	35	-	A	2.4	n-Pentatriacontane

\* Estimate

namely, 3,9- and 3,15-dimethylnonacosane (LD16, <0.1%) (Table 1).

The dimethylalkanes of *L. eberlanzi* form a more extensive homologous series than those of *L. discoidalis* and range in carbon number from 27 to 33. The series is incomplete in that it lacks the dimethylisomers of C<sub>30</sub> (Fig. 3). Most of the dimethylalkanes are of type 1 (total, 3.1%), while type 2 dimethylalkanes are represented by the dimethylisomers of C<sub>27</sub> and C<sub>29</sub> (LE16 and LE22, total 0.3%). The dimethylisomers of C<sub>27</sub> (LE13 and LE16, total 2.4%) are the most abundant dimethylalkanes of *L. eberlanzi* in contrast to *L. discoidalis* which has the dimethylisomers of C<sub>29</sub> in the highest proportion (Fig. 3).

#### DISCUSSION

Both *L. discoidalis* and *L. eberlanzi* have exceptionally high percentages of *n*-alkanes (LD, 96.5%; LE, 85.6%). The *n*-alkane mixture of *L. discoidalis* consists largely of nC<sub>33</sub> (73.5%) while that of *L. eberlanzi* contains high percentages of the four odd-numbered *n*-alkanes, nC<sub>25</sub> to nC<sub>31</sub> (Fig. 3). The qualitative differences between the hydrocarbon mixtures of the two species arise mainly from the small number of branched alkanes in the *L. discoidalis* mixture (Table 1). For example, while 85% of the hydrocarbons of *L. discoidalis* occur in *L. eberlanzi*, only 33% of the latter's hydrocarbons are found in *L. discoidalis*. The qualitative differences between the

two species are greater than those between other examined congeneric species (Lockey, 1978a,b, 1982a,c).

Hadley and Louw (1980) in their analysis of the hydrocarbons of *Lepidochora discoidalis* found the percentage composition of the *n*-alkanes and branched alkanes to be 93.6% and 6.4% respectively. This gives a *n*-alkane/branched alkane ratio equal to 14.4 which differs from the present work where the ratio for *L. discoidalis* equals 27.6 and that for *L. eberlanzi*, 5.9. These are unusually high *n*-alkane/branched alkane ratios for adult insects. For example, the ratios of the eighteen species of adult tenebrionid beetles examined so far range from 0.15 in *Cylindrinotus laevioctostriatus* (Lockey, 1981) to 3.5 in *Renatiella scrobipennis* (Lockey, 1984a), with an average value for all of the species equal to 1.0. The reason for high *n*-alkane/branched alkane ratios remains obscure. In an earlier paper (Lockey, 1984a) it was noted that high ratios occur in the less advanced species of tenebrionid and this is also true of the adult bomicid hymenopteran, *Nomia bakeri*, which has a ratio equal 24.6 (Hadley *et al.*, 1981).

Both *L. discoidalis* and *L. eberlanzi* avoid high day-time temperatures by burrowing in sand-dunes (Kuhnelt, 1969; Louw, 1983). Burrowing is likely to cause cuticular abrasion, which is known to increase the water permeability of cuticle and to lead to death by desiccation at low humidities (Alexander *et al.*, 1944; Wigglesworth, 1945). In *L. discoidalis* nC<sub>33</sub>

Table 2. Hydrocarbons of *Lepidochora eberlanzi*

GC Peak No.	Retention Index(I)	Carbon No.	dI	Hydrocarbon class	% Composition	Hydrocarbon
LE 1	2300	23	-	A	1.7	n-Tricosane
2	2400	24	-	A	0.7	n-Tetracosane
3	2500	25	-	A	12.9	n-Pentacosane
4	2539	26	61	D	0.4	9-,11- and 13-Methylpentacosane
	2545	26	55	D	0.1	7-Methylpentacosane
	2555	26	45	D	0.1	5-Methylpentacosane
5	2575	27	125	E	0.2*	9,13- and 11,15-Dimethylpentacosane
		26	25	C <sub>2</sub>	0.2*	3-Methylpentacosane
6	2600	26	-	A	1.6	n-Hexacosane
7	2637	27	63	D	0.2	11-,12- and 13-Methylhexacosane
	2650	27	50	D	0.1	6-Methylhexacosane
	2660	27	40	D	0.1	5-Methylhexacosane
8	2668	27	32	D	0.1*	4-Methylhexacosane
		28	132	E	0.1*	11,15-Dimethylhexacosane
	2678	27	22	C <sub>2</sub>	0.1	3-Methylhexacosane
9	2700	27	-	A	16.0	n-Heptacosane
10	2735	28	65	D	1.6	9-,11- and 13-Methylheptacosane
11	2742	28	58	D	1.1	7-Methylheptacosane
12	2754	28	46	D	1.8	5-Methylheptacosane
13	2763	29	137	E	2.2	7,11-,9,13- and 11,15-Dimethylheptacosane
14	2775	28	25	C <sub>2</sub>	0.9	3-Methylheptacosane
15	2800	28	-	A	0.9	n-Octacosane
16	2804	29	96	E	0.2	5,9-,5,11- and 5,13-Dimethylheptacosane
17	2842	29	58	D	0.7	7-,9-,11-,12-,13- and 14-Methyloctacosane
	2852	29	48	D	0.1	5- and 6-Methyloctacosane
	2864	30	136	E	0.1	10,14-,11,15- and 12,16-Dimethyloctacosane
	2877	29	23	C <sub>2</sub>	0.1	3-Methyloctacosane
18	2900	29	-	A	16.1	n-Nonacosane
19	2939	30	61	D	0.7	9-,11-,13- and 15-Methylnonacosane
	2945	30	55	D	1.3	7-Methylnonacosane
	2958	30	42	D	0.5	5-Methylnonacosane
20	2965	31	135	E	0.4	9,13-,11,15- and 13,17-Dimethylnonacosane
21	2977	30	23	C <sub>2</sub>	0.7	3-Methylnonacosane
22	3000	30	-	A	1.5	n-Triacontane
	3010	31	90	E	0.1	3,7-Dimethylnonacosane
23	3100	31	-	A	31.0	n-Hentriacontane
24	3143	32	57	D	0.1	7-,9- and 11-methyltriacontane
25	3172	33	128	E	0.1	7,11-Dimethylhentriacontane
26	3200	32	-	A	0.7	n-Dotriacontane
27	3300	33	-	A	2.5	n-Tritriacontane

\* Estimate

accounts for just under three quarters of the hydrocarbon mixture. The melting point of nC<sub>33</sub> is 71.8°C and the bulk of the hydrocarbon mixture is likely to remain crystalline at the environmental temperatures which *L. discoidalis* normally encounters. *L. discoidalis* is the most widely distributed species of genus, *Lepidochora* (Koch, 1962a) and it may be that part of the success of this dune beetle rests with the crystalline hydrocarbon mixture which hardens the cuticular lipid layer thus increasing its resistance to abrasion. In addition, *L. discoidalis* has a simple hydrocarbon mixture composed of only 26 hydrocarbons. If continual replacement of cuticular lipid is needed because of cuticular abrasion then biosynthesis and secretion will be that much simpler and quicker than in *L. eberlanzi* with its hydrocarbon mixture of 65 hydrocarbons. Another sand-burrowing species with a simple hydrocarbon mixture is the cockroach, *Arenivaga investigata*, which has 27 hydrocarbons (Jackson, 1983).

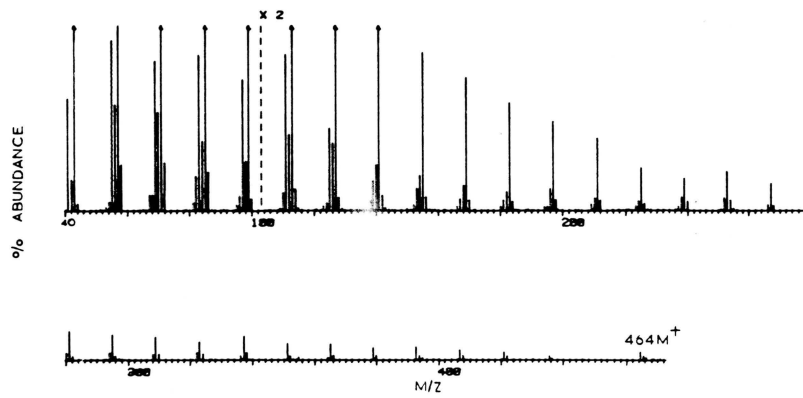
The hydrocarbon mixtures of representative species of tribes Adesmiini, Zophosini and Eurychorini, subfamily Tentyriinae, have now been investigated. In earlier work (Lockey, 1982a,b,c, 1984a), the hydrocarbon mixtures of seven species of tribe Ade-

smiini were shown to share a number of features such as high proportions of C<sub>27</sub> and C<sub>29</sub> hydrocarbons, homologous series of 4-methyl- and 5-methylalkanes and complex mixtures of C<sub>28</sub> and C<sub>30</sub> class D hydrocarbons. It was later shown (Lockey, 1984b) that *Zophosis* (*Gyrosis*) species, tribe Zophosini shared these characteristics.

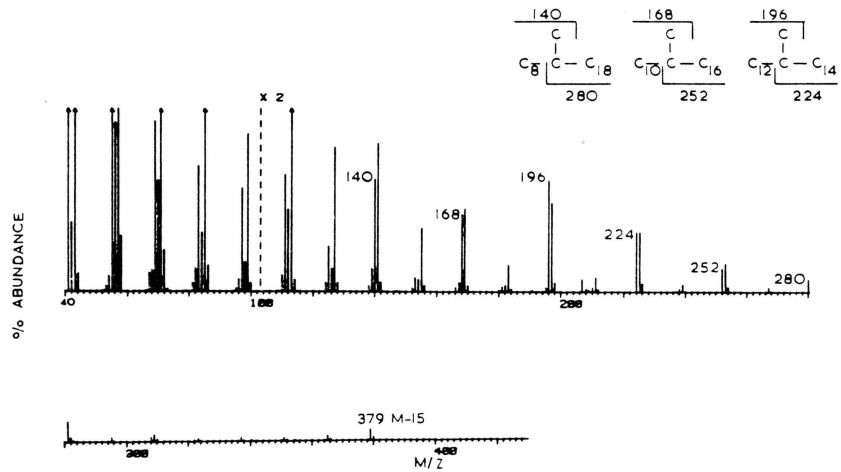
Of the species, *Lepidochora discoidalis* and *L. eberlanzi*, tribe Eurychorini, the former shares some of these characteristics namely, a homologous series of 5-methylalkanes and a complex mixture of C<sub>28</sub> class D hydrocarbons. In addition, both species have in common with *Renatiella scrobipennis*, tribe Adesmiini (Lockey, 1984a) high proportions of *n*-alkanes. In both *L. eberlanzi* and *R. scrobipennis* the bulk of the hydrocarbon mixture comprises the four odd-numbered *n*-alkanes nC<sub>25</sub> to nC<sub>31</sub>, though the proportions in which these *n*-alkanes occur differ in the two species.

Thus, while the hydrocarbon mixtures of *L. discoidalis* and *L. eberlanzi* share a number of features with those of the examined species of tribes Adesmiini and Zophosini, including a lack of unsaturated hydrocarbons, it is possible to distinguish the two species of genus, *Lepidochora* from the examined

## A LD19 n-TRITRIACONTANE



## B LE10 9-,11-, and 13-METHYLHEPTACOSANE



## C LD14 11,15- and 13,17-DIMETHYLNONACOSANE

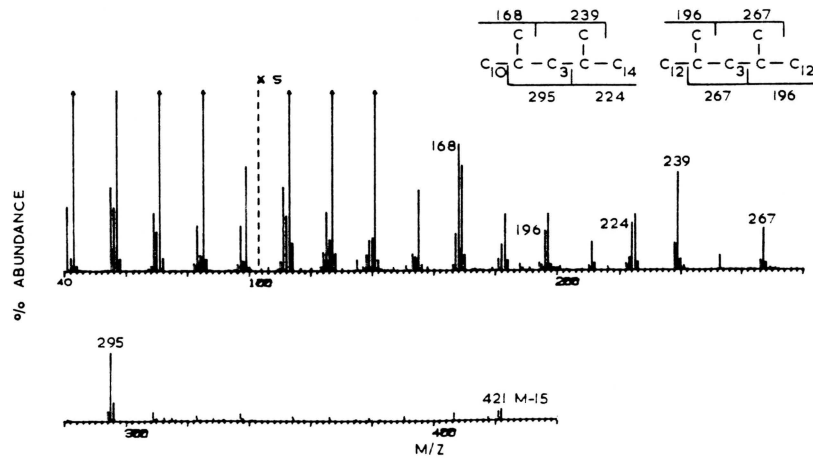


Fig. 2. MS scans of GC peaks LD19 (A), LE10 (B) and LD14 (C).

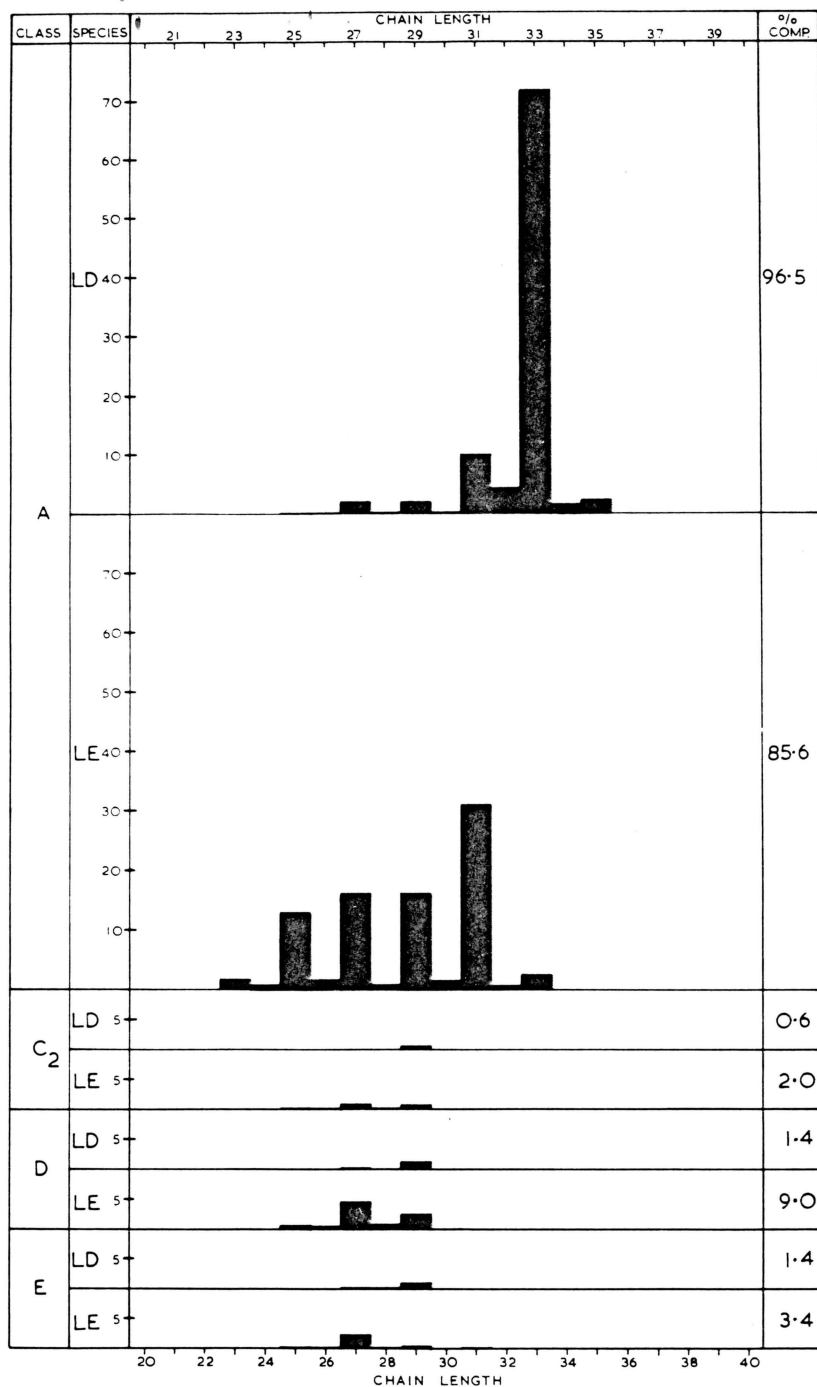


Fig. 3. Percentage composition of the hydrocarbons of *Lepidochora discoidalis* (LD) and *Lepidochora eberlanzi* (LE). Class A, *n*-alkanes; C<sub>2</sub>, terminally branched monomethylalkanes; D and E, internally branched monomethyl- and dimethylalkanes respectively.

species of the other two tribes by their high proportions of *n*-alkanes and their *n*-alkane compositions.

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