Variation in song patterns of Antipodean *Teleogryllus* species (Orthoptera: Gryllidae) and a proposed phenetic classification

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Received March 12, 1970

MADSEN, C., V. R. VICKERY, and J. NOWOSIELSKI. 1970. Variation in song patterns of Antipodean *Teleogryllus* species (Orthoptera: Gryllidae) and a proposed phenetic classification. Can. J. Zool. **48**: 797–801.

The stridulations of eight sample populations of *Teleogryllus commodus servillei* (Saussure) and *T. oceanicus* (Le Guillou) were recorded and analyzed. Sokal's "distance coefficient" formula was used to derive a phenetic classification of the populations. The analysis indicates the same relationships as were previously indicated, by Chen *et al.* (1967) on morphological evidence, and by Lim *et al.* (1969) on cytological study.

Introduction

Chen *et al.* (1967), Lim *et al.* (1969), and Lim (1970) have all stated that the common "black" field crickets of the Antipodean area belong to two species, *Teleogryllus oceanicus* (Le Guillou, 1841) and *T. commodus* (F. Walker, 1869). The former species occurs in Australia in Queensland, Northern Territory, and in the Kimberly district of Western Australia, as well as the islands of Tasmania and Fiji. *T. commodus commodus* (Walker) occurs in the Perth area of Western Australia, while the populations of *T. commodus* occurring in South Australia, New South Wales, Victoria, and Tasmania, as well as in North Island, New Zealand, have been referred to the subspecies *T. commodus servillei* (Saussure, 1877). An additional population of *T. commodus*, from South Island, New Zealand, has been stated to differ from *T. c. servillei*, but, to date, no subspecific name has been applied to this population (Chen *et al.* 1967; Lim *et al.* 1969; Lim 1970).

The purpose of this paper is to present the results of analysis of stridulation of some of these populations, to compare them analytically, and to attempt to derive a phenetic classification of the populations.

Materials and Methods

Eight populations of the two species were studied. Six of these were *T. commodus*, from the following areas: Tasmania (*Qt*); South Australia, Adelaide, (*Qa* and *Qd*); North Island, New Zealand (*Qz*); and South Island, New Zealand (*Qk*). Unfortunately the population of *T. c. commodus* (*Qw*) from Perth, Western Australia, was not available for comparison. Two populations of *T. oceanicus* were included: Queensland, Australia (*Qn*); and Tahiti (*Qh*). In all cases, the symbols used to designate the populations are the same as those used by previous authors (Bigelow 1962; Bigelow and Cochaux 1962; Cochaux 1965; Chen *et al.* 1967; Lim *et al.* 1969; and Lim 1970).

Sample populations were taken from cultures kept by the second author at the Lyman Entomological Museum laboratories, Macdonald College. These were transferred by the first author to a quiet room, at temperature range of 75–77 °F, for the study. Stridulation was recorded of as many individuals as possible. The recordings were made with the specimens either in the gallon jars in which they were maintained, in a large aquarium tank, which allowed the crickets more freedom of movement, or in small wire cages, the latter in an attempt to improve the quality of the tapes. As far as could be ascertained, the song patterns did not differ in these different environments.

The apparatus used was as follows: Uher, 4000 Report-L tape recorder, together with a Uher microphone, M-514; audiospectrographs were made using a Kay electric sonograph, 6061-A.

Audiospectrographs were made from the recordings, and from these, four kinds of pulse rates were determined; long and short chirp pulse rates and long and short trill pulse rates. Chirp sequences, consisting of one long and several short chirps, were quantified. Chirp and trill rates per minute were determined with the aid of a stopwatch. Pulse rates for some aggressive chirps were also calculated. The pulse rates were recorded per second and an average trill length was counted in seconds. The trills were found to be characterized by a dominant phase with a longer pulse rate and an unmodified trill phase.

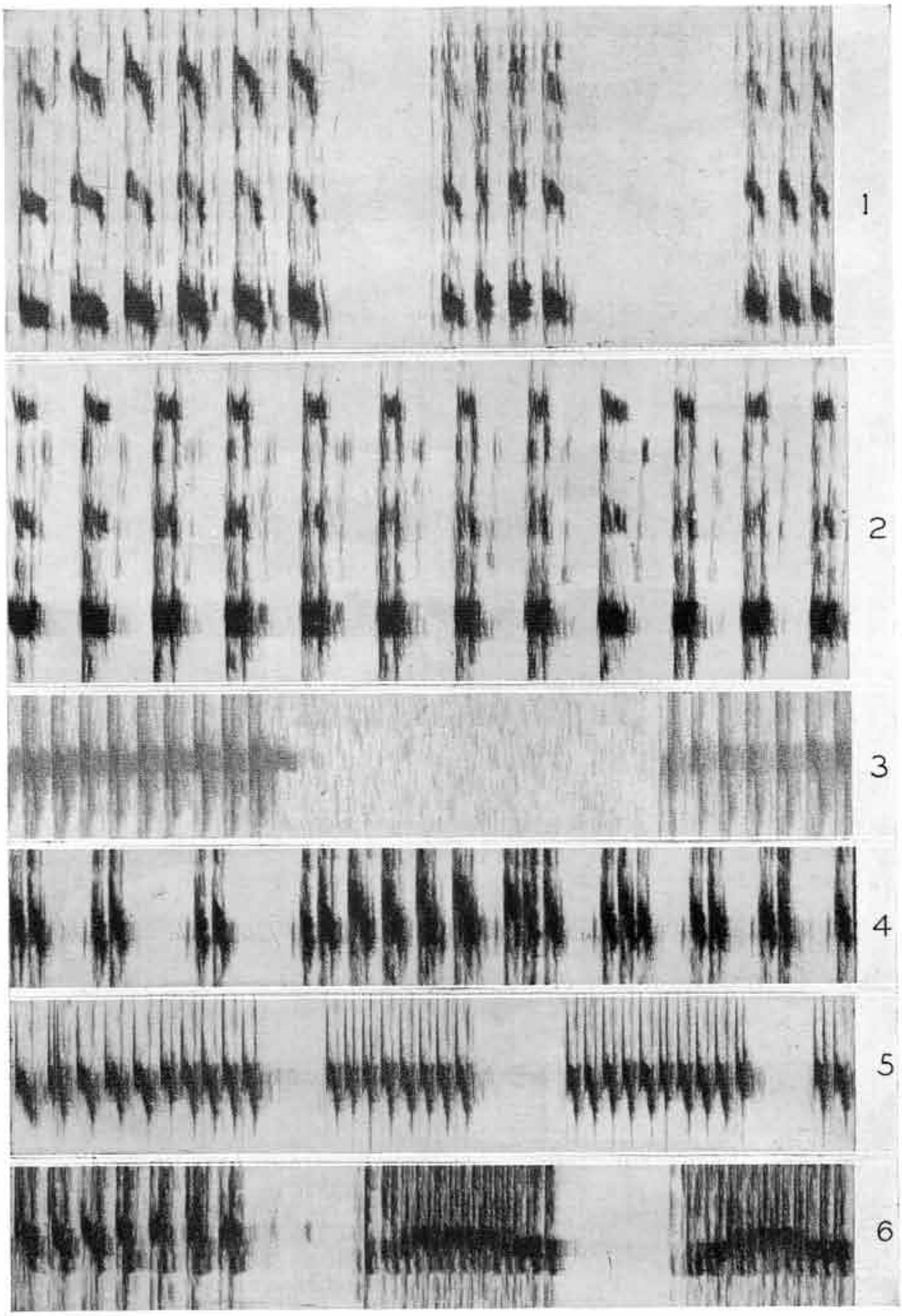
TABLE I

Quantitative character values of song patterns of eight populations of *Teleogryllus commodus* and *T. oceanicus* (v = value; f = frequency)

Population	Chirp sequence		Chirp rate		Long chirp pulse rate		Short chirp pulse rate		Trill length		Trill rate		Long trill pulse rate		Short trill pulse rate	
	v	*f*	*v*	*f*	*v*	*f*	*v*	*f*	*v*	*f*	*v*	*f*	*v*	*f*	*v*	*f*
Qt	1–3.0	55	63.3	14	20.8	3	35.4	3	7.6	10	6.0	1	16.9	6	45.8	6
Qd	—		—		20.9	5	—		4.0	4	10.0	2	17.3	3	52.7	4
Qc	1.0–	151	63.0	3	19.6	7	36.5	4	5.5	9	7.8	5	18.0	2	47.7	3
Qk	1–1.5	46	60.2	6	22.0	8	28.7	8	6.7	33	6.0	22	16.5	6	51.5	7
Qz	1–2.8	8	73.0	2	18.0	2	28.3	2	3.9	7	9.5	2	17.6	6	50.5	8
*Qa**	1–2.0	4	120.0	2	27.0	2	41.0	2	1.7	3	21.0	2	23.8	2	72.6	2
Qn	1–5.1	17	214.1	13	17.2	10	26.8	8	3.2	10	8.0	4	15.7	8	39.1	9
Qh	1–6.4	9	273.8	4	17.1	4	31.0	4	2.6	7	—		16.8	5	37.0	5

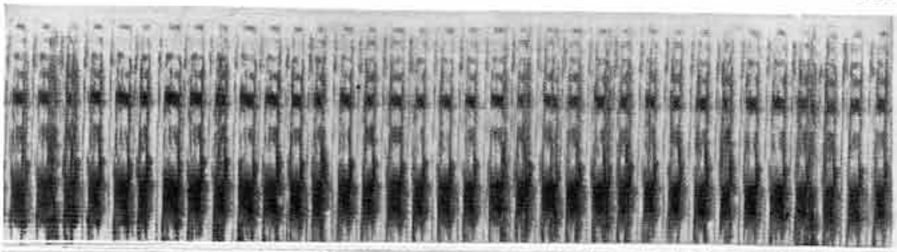
*Not directly comparable, recorded at higher temperature.

PLATE I



FIGS. 1–6. Audiospectograms of stridulation of *Teleogryllus* populations. FIG. 1. Chirps, *Qc*, half speed, pulse rate 24–38/s at 86 °F. FIG. 2. Aggressive chirps, *Qk*, half speed, pulse rate 17/s at 77 °F. FIG. 3. Chirps, *Qd*, pulse rate 21/s at 77 °F. FIG. 4. Chirp sequence, *Qn*, pulse rates, 18/s and 29/s at 76 °F. FIG. 5. Chirp sequence, *Qt*, pulse rates, 21/s and 33/s at 77 °F. FIG. 6. Trill–chirp sequence, *Qc*, pulse rates, 18/s and 57/s at 76 °F.

PLATE II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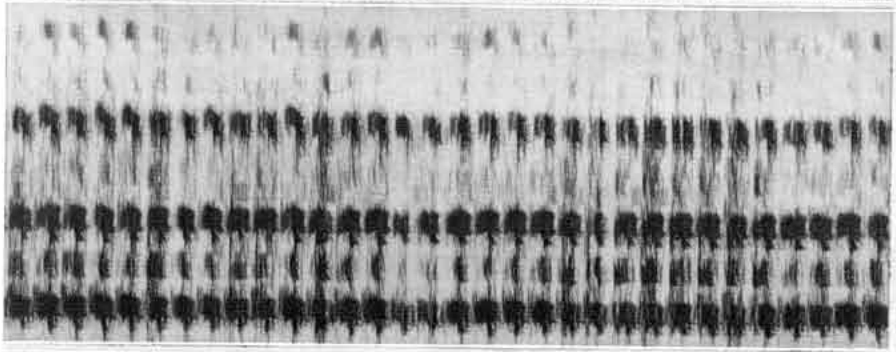
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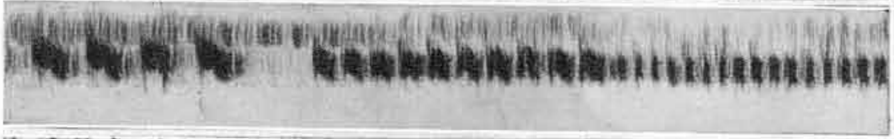
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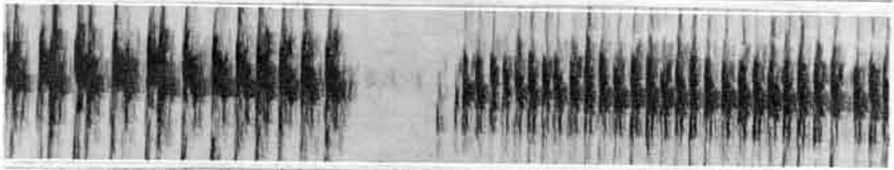
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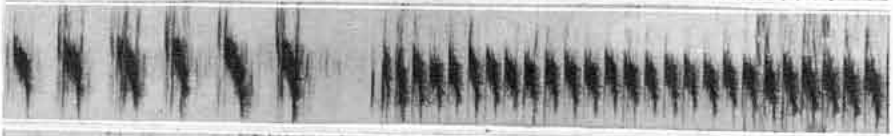
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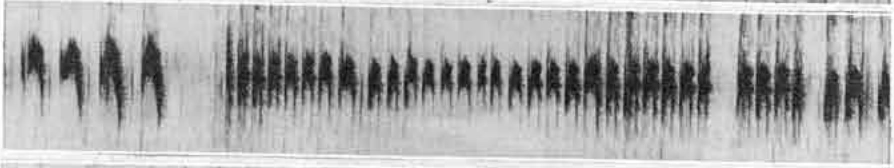
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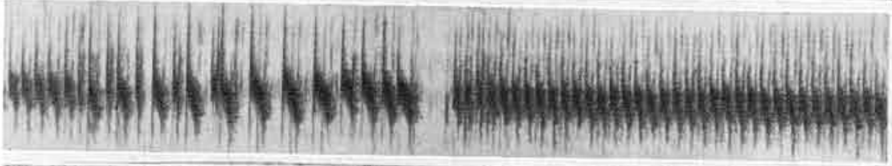
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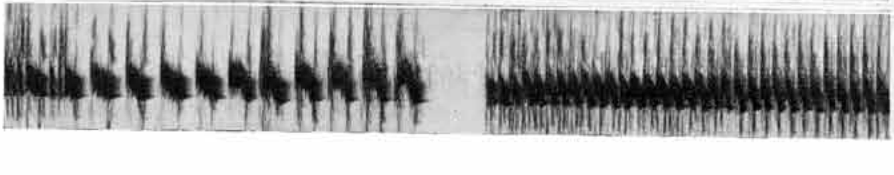
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TABLE II

Ranked character values. Song patterns of eight populations of *Teleogryllus commodus* and *T. oceanicus* (highest value = 1.000)

Population	Chirp sequence	Chirp rate	Long chirp pulse rate	Short chirp pulse rate	Trill length	Trill rate	Long trill pulse rate	Short trill pulse rate
Qt	0.375	0.256	0.748	0.800	0.791	0.319	0.744	0.715
Qd	—	—	0.774	—	0.597	0.476	0.727	0.726
Qc	0.156	0.230	0.725	0.889	0.821	0.371	0.756	0.657
Qk	0.234	0.220	0.815	0.700	1.000	0.286	0.693	0.709
Qz	0.438	0.267	0.667	0.690	0.582	0.452	0.739	0.696
*Qa**	0.313	0.438	1.000	1.000	0.254	1.000	1.000	1.000
Qn	0.800	0.782	0.637	0.654	0.478	0.381	0.660	0.539
Qh	1.000	1.000	0.633	0.756	0.388	—	0.706	0.510

*Not directly comparable, recorded at higher temperature.

TABLE III

Dendrogram of coefficients of distances of ranked character values

	Qt	*Qd*	*Qc*	*Qk*	*Qz*	*Qa**	*Qn*	*Qh*
Qt	—	.11	.09	.10	.10	.35	.35	.41
Qd	.11	—	.12	.20	.04	.34	.17	.17
Qc	.09	.12	—	.17	.15	.38	.34	.47
Qk	.10	.20	.17	—	.18	.32	.36	.50
Qz	.10	.04	.15	.18	—	.32	.24	.38
*Qa**	.35	.34	.38	.32	.32	—	.45	.43
Qn	.35	.17	.34	.36	.24	.45	—	.12
Qh	.41	.17	.47	.50	.38	.43	.12	—

*Not directly comparable, recorded at higher temperature.

The eight song characters thus quantified were subjected to analysis by "numerical evaluation of the affinity or similarity between taxonomic units and the ordering of these units into taxa on the basis of their affinities" (Sokal and Sneath 1963). Sneath (1964) has summarized the steps involved.

The operational taxonomic units (O.T.U.) were the sample populations from which the recordings and audiospectrographs were made (*Qd*, *Qz*, *Qc*, *Qt*, *Qk*, *Qh*, and *Qn*). The eighth population (*Qa*) was not included, as recording of this group was done at a higher temperature, and comparison of this stridulation with the others would not be valid.

Overall phenetic resemblance between O.T.U.'s was determined by comparison of each O.T.U. with each of the others. Sokal's distance coefficient was calculated by the following formula (Sokal and Sneath 1963):

$$djk = [i = 2\ (Xij - Xik)^2]/n$$

where d = average distance; Xij = mean numerical value of character "i" in O.T.U. in "j"; Xik = mean numerical value of "i" in O.T.U. "k"; n = number of characters examined (8).

Quantitative character values for song patterns of all populations are shown in Table I, while Table II shows the ranked character values for song patterns of these populations.

O.T.U.'s were sorted on the basis of overall resemblance into groups called phenons. A cluster analysis, using the weighted variable group method was carried out at this stage, producing a dendrogram of the relationships among the populations on a two-dimensional scale (Table III).

Observations

Many crickets have a repertoire of one or several types of stridulation, either chirping or trilling, but *Teleogryllus* is somewhat unusual in having both chirping and trilling sequences. Several types of songs are associated with cricket behavior; for example, calling and courtship songs, aggressive chirps, and sometimes also a postcopulatory 'triumphal' song. In this study, more emphasis has been placed on composition

FIGS. 7–14. Audiospectograms of stridulation of *Teleogryllus* populations. FIG. 7. Trill, *Qt*, half speed, pulse rate 50/s at 76 °F. FIG. 8. Trill, *Qz*, half speed, pulse rate 44/s at 77 °F. FIG. 9. Trill sequence, *Qa*, half speed, pulse rates, 24/s, 46/s, and 72/s at 86 °F. FIG. 10. Trill sequence, *Qk*, pulse rates, 24/s and 50/s at 76 °F. FIG. 11. Trill sequence, *Qn*, pulse rates, 13/s and 34/s at 75 °F. FIG. 12. Trill sequence, *Qh*, pulse rates 18/s and 34/s at 75 °F. FIG. 13. Trill sequence, *Qt*, pulse rates, 24/s and 50/s at 76 °F. FIG. 14. Trill sequence, *Qz*, pulse rates, 18/s and 51/s at 77 °F.

of the songs, but only the first three types were found. Males tended to remain silent for some time after copulation, no triumphal song being observed, and, similarly, any external disturbance, other than by another cricket, tended to silence the animals.

Trilling sequences did not appear to be associated with a different behavior pattern from chirp sequences. A slight tendency was observed for the chirp sequences to accompany calling song behavior when the male was alone or not in contact with a female, while trilling often occurred with tactual courtship of a female. However, the opposite associations were also observed.

Aggressive chirps are illustrated from the South Island, New Zealand population (*Qk*) in Fig. 3.

The audiospectrogram of *Qc* (Victoria population of *T. commodus*) (Fig. 1) is representative of most of the populations with a sequence of one long to two short chirps, with the long chirp having a lower pulse rate. This population, however, also had an unusual trill-rate chirp sequence (Fig. 6), an example of the blending of the two types of song which sometimes occurred. In *Qa*, *Qk*, and sometimes *Qt*, there appeared a tendency to increase the pulse rate within the long chirp (Figs. 2, 10, and 5). Trill pulses, as shown by *Qt* (Fig. 7) and *Qz* (Fig. 8), tended to be shorted and unmodulated, giving a faster pulse rate with more harmonics and a higher dominant frequency.

Qa had an aberrant trill, with three pulse types and rates (long, medium, and short (Fig. 9) rather than the usual two) but, as previously stated, this population was recorded at a higher temperature than the other groups. It is not included in the analyses or in the dendrogram diagram (Fig. 15), since Walker (1962) has indicated that temperature is the only climatic factor which affects actual rates of stridulation.

The trills of the two species did not differ greatly but *oceanicus* had a slower pulse rate (Figs. 11 and 12) than *commodus* (Figs. 13 and 14). The two species have quite different chirp sequences: *oceanicus* with five to seven short pulses to each long pulse; *commodus* has a sequence of one to five short pulses to each long pulse, with differentiation being in pulse rate rather than in number of pulses per chirp (compare Figs. 4 and 5).

It was observed that extrinsic sounds appeared to have no effect upon singing rate. Aging of the crickets does not slow the rate significantly, nor does prolonged singing for periods of more than one-half hour. Damage to the tegmina affects the frequency of resonating and thus the frequency of produced sounds, but does not change the rate or patterns. The song patterns tend to be remarkably stable under most conditions, making them good characters for this type of study.

Discussion

Sokal and Sneath (1963) state that a minimum of 40 characters should be used in application of numerical taxonomic methods. In spite of the fact that only eight characters were used in this study, and that some of these (chirp and pulse rates) are interrelated, the results are suggestive. They cannot be considered conclusive, but they do indicate the major differences. The validity of the results presented here is strengthened by the fact that they are so similar to those obtained by Chen *et al.* (1967) on morphological comparison and by Lim *et al.* (1969) on cytological comparison, as is shown by Table III and the dendrogram diagram (Fig. 15).

The very good correlation between results obtained by application of the three different methods morphology, cytology, and analysis of stridulation indicates that even with as few as eight characters, numerical procedures can be used in classification.

Since all recordings other than that of *Qa* were made at relatively constant temperatures, they are comparable. In general, the conclusive difference is the phenetic classification of the two

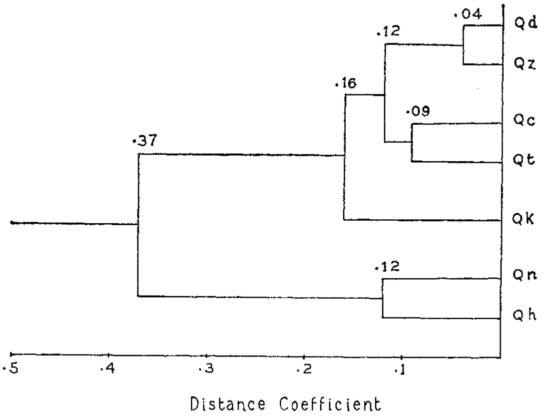

FIG. 15. Diagram of relationships produced by cluster analysis of distance coefficients.

species, *T. commodus* and *T. oceanicus*, which differ consistently. However, the study also indicates that populations of *T. commodus servillei*, while exhibiting variation, clearly are closely related, and the South Island, New Zealand (*Qk*), population shows a divergent tendency from *T. c. servillei*. It was unfortunate that the nominal subspecies, *T. c. commodus*, was not available for comparison.

Acknowledgments

The authors thank Professor R. E. Lemon, Department of Zoology, McGill University, for the loan of the tape recorder and sonograph, and Mrs. E. Smythe, who maintained the cultures of the various populations of crickets.

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