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An ecological study of a natural population of Tribolium brevicornis Le Conte (Coleoptera, Tenebrionidae)

Gary D. Mulder

AN ECOLOGICAL STUDY
OF A NATURAL POPULATION
OF *Tribolium brevicornis* Le Conte
(Coleoptera, Tenebrionidae)

A Thesis

Presented to the

Faculty of

California State

College, San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Biology

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ABSTRACT

A natural population of Tribolium brevicornis found in decaying logs of Alnus rhombifolia Nutt. in Waterman Canyon, San Bernardino County, and its descendants, were compared and contrasted with long-established laboratory strains of this species referred to as the Riverside and Idaho strains.

Three logs were removed from Waterman Canyon and examined for T. brevicornis. Experiments were then carried out in order to determine differences between the laboratory and the feral population in regards to fecundity, morphological traits, developmental rate from egg to adult, cannibalism, flying ability and dispersion.

This study shows that the natural population differs significantly from the laboratory strains in fecundity, morphology, cannibalism, and dispersing ability. Similarities were found in developmental rate from egg to adult although the high mortality rate of the Waterman Canyon strain necessitates further investigation and experimentation in this area. Flying ability was not demonstrated by any of the three strains.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

A natural or feral population can be considered as one occurring outside of a laboratory or artificial environment, in a natural habitat. Although most populations of *Tribolium* are found in stored food products, recorded discoveries of natural populations have been made by Le Conte (1863), Okumura and Strong (1965), Strong (1965) and Sokoloff, *et al* (1977). The latter finding is of special relevance to this paper.

Sokoloff, *et al* (1977) discovered the natural population (later identified as *Tribolium brevicornis*) under the bark of white alder trees (*Alnus rhombifolia* Nutt.) lying on the bank of Waterman Canyon Creek outside the northern city limits of San Bernardino, California. The alder was also found to be inhabited by carpenter bees (*Xylocopa tabaniformis orpifex*). Linsley (1943) has indicated that *Tribolium* are often found in association with bee's nests. Sokoloff, *et al* (1977) list a number of observations made on the coexistence of *Tribolium brevicornis* with *Xylocopa* (Hymenoptera) and *Anthidium* (Apidae): "Davidson (1893) recorded *Aphanotus brevicornis* (subsequently renamed *Tribolium brevicornis*) from *Xylocopa* bee nests; Nininger (1916) extracted these beetles from nests of carpenter bees, and Hicks (1929)reported *Aphanotus brevicornis* from nests of the bee *Anthidium mormonum* fragerielium."

Overall, very little literature is available on the ecology of natural populations of *Tribolium*. Most of the species of *Tribolium* studied in the laboratory (e.g. *T. castaneum*, *T. confusum*, *T. destructor* and *T. madens*) have been associated with wheat and other cereal products for a long period of time. Natural populations have become non-existent or reduced and the flour mills and warehouses where these species inhabit have come to be regarded by some investigators as their "natural" habitat.

Contrary to the presently known "natural" habitat mentioned above, Good (1936), Linsley (1943), Butler (1949) and Magis (1954) have suggested that the original "primitive" habitat of *Tribolium* is under the bark of the trees. This observation coincides with the discovery of Sokoloff, *et al* (1977).

A study of the natural population of *Tribolium brevicornis* found in the decaying logs of *Alnus rhombifolia* could contribute to an understanding of the ecological relationships of natural populations of *Tribolium* and settle the matter whether population interactions are competition or predator prey.

The purpose of this study is to contrast the Waterman Canyon population of *T. brevicornis* with two laboratory strains of this species found in Riverside, California and Moscow, Idaho, and maintained for many years at the

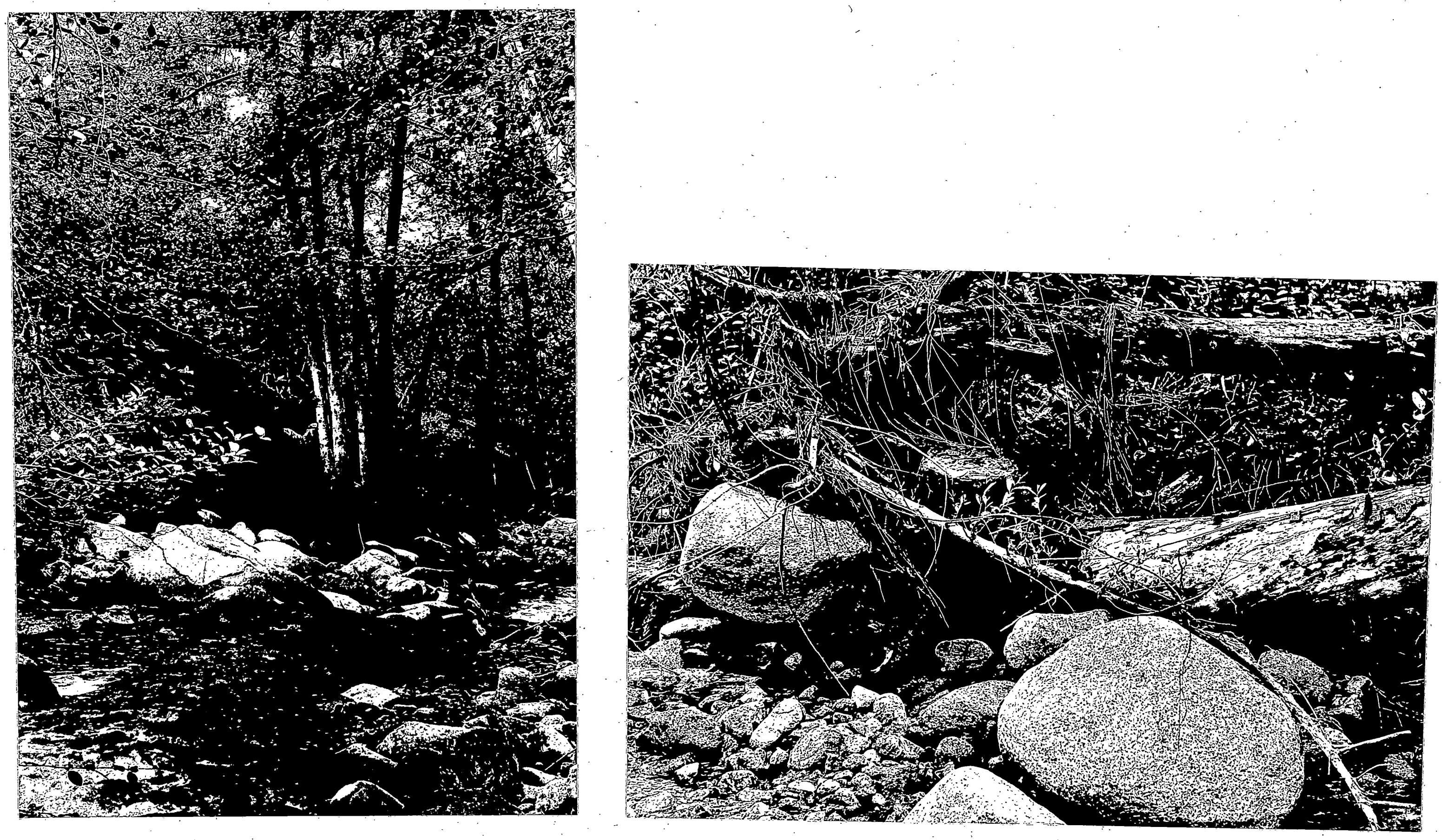
Tribolium Stock Center, California State College, San Bernardino. The biological attributes to be examined will include: (1) morphology, (2) fecundity, (3) fertility, (4) development, (5) cannibalism, (6) flying ability and (7) dispersing ability.

CHAPTER II

MATERIALS AND METHODS

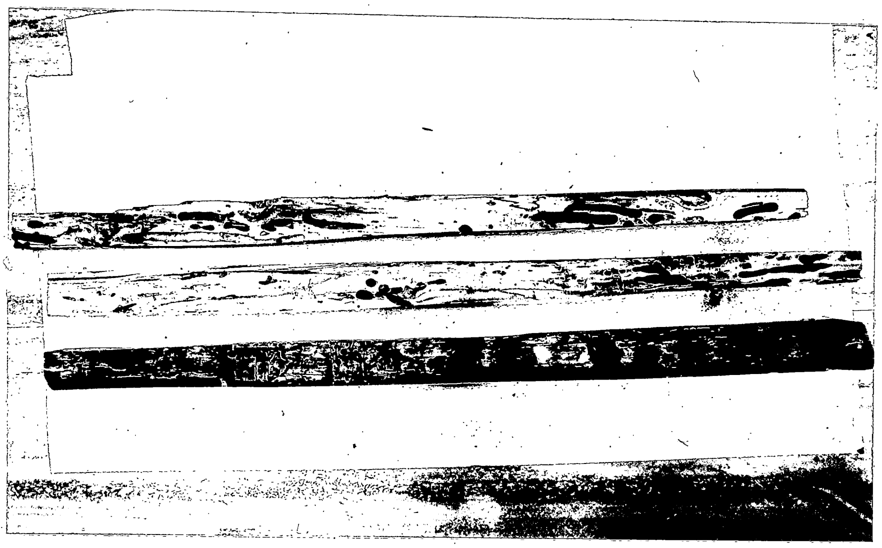
Three white alder logs were obtained from Waterman Canyon Creek just outside the San Bernardino City limits (See Fig. 1). One of these logs probably had been cosmetically removed from the top of a dead white alder by the County Highway Department. The remaining two logs were removed from dead alder trees resting approximately 1.5 m. from the river-bank. Two of the logs were cut into longitudinal sections of 1 to 1.3 m in length and 6 to 9 cm in width while the third was cut into circular slices about 2.2 cm thick varying from 15 to 22 cm in diameter as shown in Figure 2. The log fragments were examined for *Tribolium*. The sawdust obtained after the logs had been sectioned was sifted in a coarse silk bolting cloth sieve and examined for larvae and pupae.

All *Tribolium* collected were sexed and weighed. The length of the elytra and femur of each was measured. Larvae and pupae were incubated at 32° C. and about 50 - 60 percent relative humidity. Measurements taken were later compared with those made on *T. brevicornis* from the Riverside and Idaho stock supplied by Dr. A. Sokoloff from the California State College San Bernardino Tribolium Stock Center. Mean, median, and coefficient of variation was calculated for each sex and stock.



A B

Figure 1. *Alnus rhombifolia* along Waterman Canyon Creek: A. stand of trees along the creek; B. stump of tree from which one log section was removed



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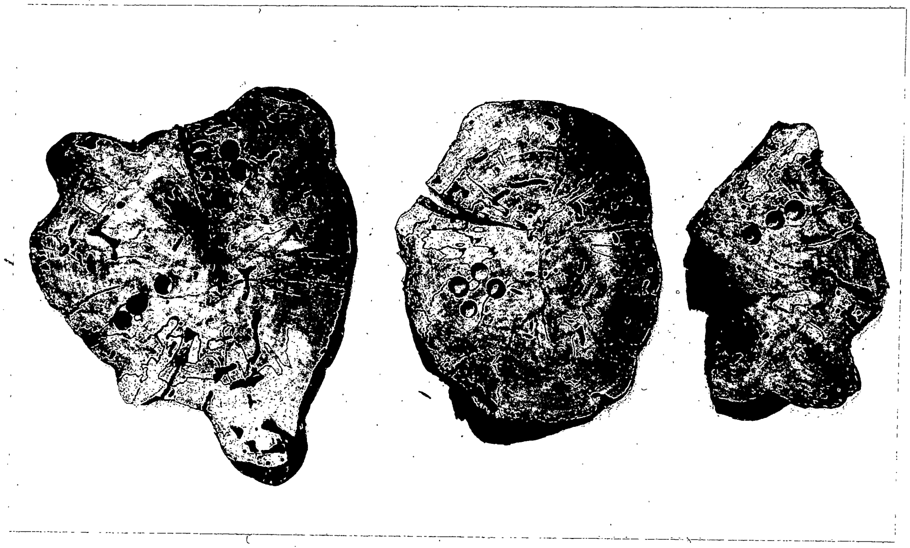

B

Figure 2. Sections of <u>Alnus</u> <u>rhombifolia</u> examined in the laboratory: A. tangential sections showing galleries of <u>Xylocopa</u>; B. Circular sections giving a different view of galleries of <u>Xylocopa</u>

Developmental rates, fecundity and fertility were examined by crossing ten males and ten females from each of the three stocks (Waterman Canyon, Riverside, and Idaho). Ten pairs of beetles were placed in a vial, one pair per vial, containing approximately 1.5 gm of standard medium (19 parts by weight flour: 1 part yeast). *Tribolium* were transferred to a fresh medium every three days and the old medium was examined for eggs. Vials containing eggs were re-examined every three days in order to determine the time required for larvae and pupae to emerge. All vials were kept incubated at 32° C. and about 50 to 60% relative humidity between examinations. The rate of development for each strain was recorded.

The method for preparing colored flour for studies on cannibalism is similar to that suggested by Rich (1956) and Sonleitner (1964). Approximately 43 gm of fine sifted standard medium was mixed with .22 gm of neutral red (.5% by weight). Ho (1967) applied this technique for marking to eggs from *T. castaneum* and *T. confusum* and indicated that this dye (when less than 15% by weight) does not appreciably affect the eggs or their cannibalism by adults. The dye-flour mixture was incubated for ten days in a humid incubator following which the color of the flour became purple-red. At this point, the dyed medium was partitioned into three glass creamers each containing about 6 gm of the sifted, dyed medium. Ten males and ten females from each stock were then added to the creamers (one creamer per stock). Four days later fifty dyed eggs were counted out from each creamer and divided into two vials of unbleached medium, 25 eggs per vial. Nine males and nine females from each of the three stocks were then isolated and placed separately into the three pairs of creamers, along with the 25 stained eggs. Three days later, the medium in each vial was sifted and examined to determine the number of eggs remaining.

Flying ability was determined by placing nine males and nine females from each of the three stocks in six separate empty 100 x 15 mm glass petri dishes located approximately 26 cm from a similar dish containing 20 gm of standard medium. The beetles were unable to escape from the dishes by any means other than flying. The room in which the experiment was performed was devoid of any other food source. Room temperature was 24° C. Examinations were made 15 days later for presence of beetles in the dishes.

Experimental apparatus used to study dispersing ability is similar to that used by Prus (1963) and Ritte, et al (1967). The beetles to be tested were placed in vial A (containing 8 gms unsifted flour) which was connected by a rubber tube to vial B (containing 4 gms unsifted flour). A thin thread leaves the surface of the flour in vial A and enters vial B by means of the tubing. The thread does not touch the surface of the flour in vial B. Beetles falling into vial B are unable to return to vial A. The beetles were initially placed in vial A and left for five days in order to allow conditioning to the new medium and environment following which vial A was connected to vial B. The experiment was conducted at a room temperature of 28° C. under constant light conditions. Dispersants were considered to be beetles found in vial B after fifteen days. Dispersants were counted and sexed. Four separate groups of beetles were used in this experiment: (1) original *T. brevicornis* taken from Waterman Canyon logs, (2) two populations of lab-reared offspring derived from the Waterman Canyon stock, (3) *T. brevicornis* from the Riverside stock and (4) *T. brevicornis* from the Idaho stock.

CHAPTER III

RESULTS

A total of forty-four *Tribolium brevicornis* adult beetles were collected from the alder tree logs between October 1, 1977 and February 1, 1978. Table 1 gives the mean weights for the four strains of *Tribolium brevicornis*. Tables 2 and 3 give the mean for the elytra and femur length respectively.

Results indicate that the beetles removed from the Waterman Canyon logs are of approximately the same weight and have similar measurements as the Idaho population except for slightly larger elytral lengths. The greatest difference in elytral length is found in the Waterman Canyon group (2.7 to 4.1 mm for males, 28 to 4.0 mm for females). The smallest range is exhibited by the Idaho group (3.8 to 4.2 mm for males, 3.3 to 3.5 mm for females). Measurements for the Riverside population range from 3.1 to 4.1 mm for the males and 3.3 to 4.1 mm for the females. The largest variations in measurements of morphological characteristics were noted in the Waterman Canyon population from the logs. The largest male in the latter group (16.8 mg) weighs almost four times more than the smallest male (4.6 mg); the largest female (15.2 mg) also weighs approximately four times more than the smallest (3.4 mg) female.

Interestingly, the laboratory-reared offspring of the

Table 1 Weight of Waterman Canyon, Riverside and Idaho strains of *Tribolium brevicornis* (values are the mean ± 1 standard deviation, in mg followed by the coefficient of variation for samples (N) of varying size)

	Total			Male			Female		
	N	$\bar{m}$ ± S.D.	C.V. (%)	N	$\bar{m}$ ± S.D.	C.V. (%)	N	$\bar{m}$ ± S.D.	C.V. (%)
Waterman Canyon	44	9.8 ± 3.8	38.78	28	10.8 ± 3.5	32.41	16	7.8 ± 5.2	66.67
Waterman Canyon Offspring	20	12.3 ± 3.3	26.83	10	14.2 ± 3.2	22.54	10	10.8 ± 3.6	33.34
Riverside	20	11.1 ± 1.6	14.41	10	12.0 ± 1.7	14.17	10	10.1 ± 1.5	14.85
Idaho	20	9.3 ± 2.1	22.58	10	10.5 ± 1.5	14.29	10	8.2 ± 2.6	31.71

Table 2 Elytra length of Waterman Canyon, Riverside and Idaho strains of *Tribolium brevicornis* (values are the mean ± 1 standard deviation in mm followed by the coefficient of variation for samples (N) of varying size)

	Total					Male					Female				
	N	$\bar{m}$	±	S.D.	C.V. (%)	N	$\bar{m}$	±	S.D.	C.V. (%)	N	$\bar{m}$	±	S.D.	C.V. (%)
Waterman Canyon	44	4.3	±	.9	20.93	28	3.6	±	.8	22.22	16	3.3	±	1.3	39.39
Waterman Canyon Offspring	20	4	±	.3	7.5	10	4.2	±	.3	7.14	10	3.8	±	.4	10.53
Riverside	20	3.7	±	.3	8.11	10	4	±	.3	7.5	10	3.4	±	.4	11.76
Idaho	20	3.6	±	.3	8.33	10	3.9	±	.3	7.69	10	3.4	±	.1	2.94

Table 3 Femur length of Waterman Canyon, Riverside and Idaho strains of <u>Tribolium brevicornis</u> (values are the mean ± 1 standard deviation in mm followed by the coefficient of variation for samples (N) of varying size)

	Total			Male			Female		
	N	$\bar{m}$ ± S.D.	C.V. (%)	N	$\bar{m}$ ± S.D.	C.V. (%)	N	$\bar{m}$ ± S.D.	C.V. (%)
Waterman Canyon	44	1.2 ± .07	5.83	24	1.4 ± .24	17.14	16	1.1 ± .1	9.09
Waterman Canyon Offspring	20	1.4 ± .4	28.57	10	1,4 ± .3	21.43	10	1.3 ± .17	13.08
Riverside	20	1.2 ± .17	14.17	10	1.3 ± .2	15.38	10	1.1 ± .17	15.45
Idaho	20	1.2 ± .1	8.33	10	1.3 ± .1	7.69	10	1.1 ± .14	12.73

Waterman Canyon population have an overall larger mean weight and femur length than any of the other groups measured. There is also a larger range in elytra measurements (4.6 mm to 9.2 mm) than the natural population taken from the white alder logs.

Tables 4 and 5 list developmental information for the Waterman Canyon, Riverside, and Idaho strains. All three strains have similar emergence times for the eggs, larvae and pupae. A slight deviation in time is seen in Table 4. Waterman Canyon pupae developed a few days later than the Riverside and Idaho stocks. Waterman Canyon beetles also produced fewer eggs per female than either of the other two populations.

Tables 6 and 7 list results for experiments performed to determine developmental rates on laboratory-reared Waterman Canyon beetles. The development period determined for eggs through the adult stage for the Waterman Canyon population (53-65 days) is similar to 52-63 days observed by Mills (1972) in a comparable study of the Riverside strain.

From the total number of eggs produced, 76% of the eggs in Mills' (1972) study reached adulthood, but only 34% of the eggs in the two Waterman Canyon populations studied (See tables 6 and 7) reached adulthood. In all tests, the greatest mortality in beetles occurred between the egg and larval stage. This period appears to have the highest

Table 4 Length of development of the egg, larval, and pupal stages for three populations of *Tribolium brevicornis*.

Experiment I

Population*	Days	Stage	Number per Vial									
			A	B	C	D	E	F	G	H	I	J
WC	5	eggs	3	2	0	X	3	0	0	0	3	1
R	5	eggs	0	3	10	7	0	0	4	X	6	4
R	5	larvae	0	5	4	0	0	0	3	X	1	4
I	5	eggs	X	7	13	X	3	14	X	X	X	4
I	5	larvae	X	4	4	X	0	1	X	X	X	0
WC	7	larvae	1	0	0	0	0	0	0	0	0	0
R	7	larvae	0	6	9	3	0	0	4	X	5	3
I	7	larvae	X	8	11	X	1	6	X	X	X	2
WC	15	larvae	1	1	0	0	2	0	0	0	1	0
R	15	larvae	0	6	9	5	0	0	4	X	5	3
I	15	larvae	X	8	11	X	1	8	X	X	X	2
WC	41	pupae	0	0	0	0	0	0	0	0	0	0
R	41	pupae	0	1	4	5	0	0	1	X	1	2
I	41	pupae	X	2	3	X	0	2	X	X	X	2
WC	50	pupae	1	0	0	0	2	0	0	0	1	0
R	50	pupae	0	6	8	5	0	0	3	X	5	3
I	50	pupae	X	7	10	X	1	7	X	X	X	2
WC	54	adult	1	0	0	1	0	0	0	0	0	0
R	54	adult	0	1	1	1	0	0	1	X	2	0
I	54	adult	X	4	2	X	1	1	X	X	X	0
WC	66	adult	1	0	0	0	1	0	0	0	1	0
R	66	adult	0	5	8	5	0	0	3	X	4	2
I	66	adult	X	7	9	X	1	7	X	X	X	2

*symbols WC = Waterman Canyon; R = Riverside; I = Idaho

Table 5 Length of development of the egg, larval and pupal stages for three populations of *Tribolium brevicornis*.

Experiment II

Population*	Days	Stage	Number per Vial									
			A	B	C	D	E	F	G	H	I	J
WC	3	eggs	1	0	0	X+	0	0	1	0	0	2
R	3	eggs	7	3	8	1	0	3	2	7	X	1
I	3	eggs	X	7	0	2	X	7	X	X	X	2
WC	7	larvae	0	0	0	X	0	0	0	0	0	1
R	7	larvae	5	2	5	0	0	3	1	6	X	4
I	7	larvae	X	6	2	X	X	4	X	X	X	2
WC	21	larvae	0	0	0	X	0	0	0	0	0	1
R	21	larvae	4	0	4	0	0	2	1	4	X	2
I	21	larvae	X	6	1	X	X	4	X	X	X	1
WC	41	pupae	0	0	0	X	0	0	0	0	0	0
R	41	pupae	3	0	1	0	0	1	1	1	X	1
I	41	pupae	X	3	0	X	X	2	X	X	X	2
WC	44	pupae	0	0	0	X	0	0	0	0	0	1
R	44	pupae	3	0	2	0	1	1	2	2	X	1
I	44	pupae	X	4	1	X	X	3	X	X	X	2

*symbols: WC = Waterman Canyon; R = Riverside; I = Idaho
+symbols: X = one or both of beetles died

Table 6 Length of development of a laboratory reared population of <u>Tribolium brevicornis</u> (Waterman Canyon)

Experiment I

Days	Stage	Number per Vial						
		A	B	C	D	E	F	G
4	eggs	0	6	7	0	2	6	0
7	eggs	0	6	7	0	2	6	0
11	larvae	0	4	3	0	1	3	0
14	larvae	0	5	3	0	1	4	0
39	larvae	0	5	3	0	1	4	0
43	pupae	0	1	2	0	1	0	0
47	pupae	0	2	3	0	1	1	0
50	pupae	0	3	3	0	1	2	0
53	adult	0	1	2	0	0	2	0
56	adult	0	3	2	0	1	2	0
59	adult	0	3	2	0	1	2	0
61	adult	0	3	2	0	1	2	0
Total Percentage		0	50%	29%	0	50%	34%	0

Table 7 Length of development of a laboratory reared population of Tribolium brevicornis (Waterman Canyon)

Experiment II

Days	Stage	Number per Vial						
		A	B	C	D	E	F	G
3	eggs	2	7	3	2	0	6	0
7	eggs	2	7	3	2	0	6	0
10	larvae	1	4	2	1	0	3	0
14	larvae	1	5	3	1	0	3	0
17	larvae	1	5	2	1	0	3	0
46	larvae	1	5	2	1	0	3	0
50	pupae	0	3	1	0	0	2	0
53	pupae	1	2	1	1	0	3	0
56	adults	0	1	0	0	0	0	0
59	adults	0	1	0	0	0	1	0
62	adults	0	2	1	0	0	2	0
65	adults	1	2	1	0	0	2	0
Total Percentage		50%	29%	34%	0	0	34%	0

mortality rate for all groups studied.

The results for the cannibalism studies are given in Table 8. The data indicate that 20% of the eggs were cannibalized by the Waterman Canyon males and 26% by the Waterman Canyon females. While 8% of the eggs were cannibalized by the Riverside males, none of the eggs were cannibalized by the Riverside and Idaho females or the Idaho males.

The tests for dispersing ability suggest that Waterman Canyon beetles disperse more readily than both the Riverside and Idaho stocks. The results are listed in Table 9. Neither the Riverside nor the Idaho populations dispersed within the period of study while 53% of the original Waterman Canyon population were found in vial B (27% males and 20% females). The percent dispersion for the two Waterman Canyon offspring groups is as follows: set 1: 0 females, 19% males; set 2: 11% males, 4% females.

Table 10 shows no differences in results for flying ability in any of the four groups tested. It is probable that <u>T. brevicornis</u> has lost the ability to fly.

Table 8 Cannibalism of eggs by male and female *Tribolium brevicornis* obtained from Waterman Canyon, Riverside and Idaho stock.*

Stock	No. of beetles per vial		Original No. dyed eggs per vial		No. of eggs cannibalized after 3 days		Percentages cannibalized	
	♂	♀	♂	♀	♂	♀	♂	♀
Waterman Canyon	9	9	25	25	5	7	20	28
Riverside	9	9	25	25	2	0	8	0
Idaho	9	9	25	25	0	0	0	0

*The male and female symbols indicate the sex of the adult adult beetles in those vials.

Table 9 Dispersing ability of Waterman Canyon, Riverside, and Idaho stocks of *Tribolium brevicornis*.

Stock	Original No. of beetles in vial A		Dispersants found in vial B		Total No. Dispersed	Percentage dispersed
	♂	♀	♂	♀		
Waterman Canyon	7	8	4	3	7	47
Waterman Canyon Offspring Set I	6	9	3	0	3	20
Waterman Canyon Offspring Set II	14	13	3	1	4	15
Riverside Stock	9	9	0	0	0	0
Idaho Stock	9	9	0	0	0	0

Table 10 Flying ability for three different stocks of *Tribolium brevicornis*.

Stock	No. of beetles in original dish		No. found in dish with flour	Percentage dispersed
	♂	♀		
Waterman Canyon	9	9	0	0
Riverside	9	9	0	0
Idaho	9	9	0	0

CHAPTER IV

DISCUSSION

The present work was an attempt to establish the differences between two laboratory strains, henceforth referred to as the Riverside and Idaho strains, and a feral strain, henceforth referred to as the Waterman Canyon strain, of *T. brevicornis*.

Similarities were found in flying ability and developmental rate from egg to adult. Tests performed to determine flying ability did not provide any evidence that *T. brevicornis* could fly in any of the three strains tested. The time required to complete the life cycle was also the same for the three strains.

Differences existed in cannibalism of eggs, fecundity, developmental rates, morphological traits and dispersion. No solid differences in developmental rate could be demonstrated owing to the high mortality of the Waterman Canyon strain. Although differences are suggested for this trait, further experimentation is needed.

Tests on dispersion indicate that the Waterman Canyon beetles disperse more readily than either of the other two strains. None of the Riverside or Idaho beetles dispersed.

One possible reason for the variability in the morphological measurements and fecundity within the Waterman Canyon population is the lack of uniform conditions prevailing in the natural habitat, as compared to the uniform conditions of standard flour medium in laboratory environments. Waterman Canyon beetles were found in logs which varied in both moisture content and physical condition of the wood. Fluctuations in temperature, relative humidity, and other climatological and environmental factors occurring in nature may be in sharp contrast with the constant conditions of an incubator.

Differences in energy sources and nutritional optima may exist between species and account for the differences in fecundity and morphology. The Riverside and Idaho strains studied had already become adapted to the standard medium used in the experiments, while the Waterman Canyon population had not yet become adapted to the new environment.

Studies have been made on the differences in nutritional requirements and diets of different species of *Tribolium*. Franklin, Chandra, and Sokoloff (1967) suggested that various optima exist and affect the productivity of *T. castaneum* and *T. confusum*. Such optimum conditions may have been changed when rearing the Waterman Canyon population in the laboratory, thereby affecting their egg-laying capacity.

Studies on *T. castaneum* by Mukerji and Sinha (1953) indicated that mean daily output per female varied depending on the particular diet of the beetle. Bano, Gundu Rao, and Majumder (1966) demonstrated that particle size of the medium may have a marked effect on the growth of *T. castaneum* in whole wheat grains. A maximum increase in population size and growth was noted in beetles reared in fine flour in contrast with beetles reared in coarse flour. The type of medium may also have a stunting effect on growth and egg-laying capacity.

Mickel and Standish (1946) observed that T. confusum could not develop normally in certain soy products. The optimal conditions of the environment and diet of each strain are known to affect egg-laying capacity and morphological traits. Tests by Sokoloff, et al (1966b) on T. castaneum and T. confusum suggested that differences in dietary requirements for optimum productivity may exist between species. These investigators indicated that different media may affect productivity of a single species as well as productivity of different species in the same medium. Studies on T. castaneum by Oosthuizen (1945) have demonstrated that food preference may also affect fecundity. In summary, the different strains of Tribolium may have different nutritional and food source requirements. The diet may have a profound effect on morphology and fecundity.

In considering the effects of laboratory medium on developmental rates and morphology of T. brevicornis, the question arises concerning the nature of the natural food source of the Waterman Canyon beetle. The lack of information on flour beetles' energy sources outside of laboratory conditions makes answering this question difficult.

Obviously, the natural population is not supplied with the abundant standard medium found in the laboratory. Further investigation is needed to determine whether the food source is plant material (carbohydrates under the bark, or fungi), animal material, or both plant and animal material.

Sokoloff (personal communication) has suggested that T. brevicornis might be a predator on the carcasses, larvae or pupae of Xylocopa. Linsley (1944) notes that Aphanotus (i.e. Tribolium) brevicornis is found in many parts of the Pacific coast and states, " the latter... is primarily associated with wood-nesting bees (Xylocopa)" and that "...Aphanotus brevicornis breeds regularly in cells of Xylocopa and has been reported in those of Anthidium." Davidson (1893), Nininger (1916), Linsley (1943), Roth and Willis (1951) and Hicks (1929) recorded T. brevicornis under the bark but mainly in nests of Xylocopa (Hymenoptera, Apidae) or Anthidium (Hymenoptera, Apidae) in the United States. (Sokoloff, 1974)

Although the majority of adult T. brevicornis removed from the Waterman Canyon logs were found in the vicinity of the bark, two were removed from the galleries belonging to Xylocopa tabaniformis orpifex, one of which contained the dried remains of a carpenter bee. Three possible explanations can be offered for the presence of beetles in the galleries; (1) they were there to prey on the live eggs, pupae or larvae of the bees, (2) they were there to scavenge on the dead bee remnants, (3) they were there for purely coincidental reasons, i.e. hiding or wandering.

Another factor relative to the feeding habits of T. brevicornis, is the cannibalistic tendency of the Waterman Canyon strain. Data on cannibalism indicate that the Waterman Canyon strain, under laboratory conditions, is more cannibalistic than either the Riverside or Idaho strains. These greater cannibalistic tendencies, in view of the common habitat of Xylocopa and Tribolium, suggest the possibility of a predator-prey interaction. Sokoloff (1974) suggests that "...the presence of Tribolium in the nests (of bees or ants) may have been due to a deliberate invasion, in order to scavenge or steal the food stored by other insects, and even consume the carcasses of dead bees or attack eggs, grubs, or bee pupae in their cells."

Another explanation for the cannibalism might be a need by T. brevicornis to satisfy its requirements for certain nutrients not available in the laboratory medium. Cannibalism for the purpose of supplementing diet has been suggested by both Inouye and Lerner (1965) and Sokoloff (1974).

Tests on dispersion indicate that the Waterman Canyon population disperses more readily than the Riverside or Idaho groups. Sokoloff (1974) suggests that changes in environmental conditions may bring about dispersion. Such fluctuations in the physical environment are likely to occur in the habitat of the Waterman Canyon population, and help to explain its greater tendency to disperse, compared to the Riverside and Idaho strains. Genetic differences might also offer partial explanation for the greater dispersion of the Waterman Canyon population. Prus (1966) investigated the migration of *T. castaneum* and *T. confusum* and suggested that dispersion has a strong genetic component.

Further observations are needed to determine more precisely the reasons for the differences in dispersion, cannibalism, and developmental rates observed in the Waterman Canyon, Riverside, and Idaho strains of *T. brevicornis*.

CHAPTER V

SUMMARY

A natural population of *Tribolium brevicornis* and its descendants derived from Waterman Canyon in the San Bernardino mountains, just north of San Bernardino, California, were compared and contrasted with two laboratory populations of the same species, referred to as Riverside and Idaho strains. Significant differences were found in dispersing ability, cannibalism, fecundity, and morphology. The Waterman Canyon population differed from the Riverside and Idaho populations in the following ways: (1) greater dispersibility was evident, (2) cannibalistic tendencies were greater, (3) fewer eggs were laid per female, and (4) differences in weight and length of the elytra and femora were observed.

The three strains do not differ significantly in flying ability nor in the time of development from egg to adult.

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