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SAMPLING ANTS WITH PITFALL TRAPS : DIGGING-IN EFFECTS

By P. J. M. GREENSLADE
CSIRO, Division of Soils, Glen Osmond, South Australia, 5064.

SUMMARY

Digging-in effects were recorded while using pitfall traps in a study of ants in Southern Australia. These effects consist of high catches immediately after traps are established which subsequently decline. They are most pronounced among ants with nests close, or accessible to traps, but catches of ants from more distant traps may show delayed digging-in effects. It is suggested that the digging-in effect can be reduced by placing pitfalls, inverted, for one week prior to operating them as traps.

RÉSUMÉ

Prélèvement de fourmis avec des pièges : effets de l'enfouissement

Les effets d'enfouissement ont été observés en utilisant des pièges au cours d'une étude des fourmis du Sud australien. Ces effets consistent en de nombreuses captures, aussitôt après la mise en place des pièges, suivis d'une réduction de ce nombre. Ils sont plus marqués chez les fourmis dont les nids sont proches ou accessibles par rapport aux pièges, mais des captures de fourmis dans des pièges plus éloignés peuvent présenter des effets retardés. Il est suggéré que l'effet d'enfouissement peut être réduit en plaçant les trappes renversées une semaine avant de les utiliser comme pièges.

INTRODUCTION

While using pitfall traps to study Collembola, JOOSSE (1965) recorded a digging-in effect in which one species was trapped initially in large numbers, apparently as a result of the disturbance of establishing traps. Pitfall traps are being used in investigations of epigeic faunas in southern Australia, and digging-in effects have been noticed amongst ants.

SCHAEFFER (1972) states that criticisms of pitfall trapping by SOUTHWOOD (1966) are relevant only to « Productions-biologische », i.e. problems for which absolute estimates of populations are needed. This is not the case. SOUTHWOOD cited critical studies by a number of authors, and more recently HAYES (1971) has examined and rejected pitfall trapping as a method for sampling a sand-beach Isopod, while LUFF (1968) and GREENSLADE and GREENSLADE (1971) show how preservatives in traps can affect catches. There is no question that even for comparative work the use of pitfall traps to contrast habitats, species, seasons etc., is fraught with danger. It might be argued that one more source of error and variation, the digging-in effect, provided grounds for finally abandoning the method. To be set against this is the fact that pitfall trapping is one of the few techniques which can be applied in studies of diverse assemblages of epigaeic predators and their role in the soil and surface fauna. This applies especially to ants which present many sampling problems. From 50 to over 100 species can be found on the sites dealt with here and it would be difficult, and destructive to the habitat, to obtain an absolute population estimate for even one of them. Furthermore, there are frequent interactions between ant species and between ants and members of other groups, for example spiders, so that no single species can be considered in isolation. When studying such relationships it is possible that some of the disadvantages of pitfall traps can be put to use. Catches of any ant species, for example, depend on the size of its foraging population, the dispersion of colonies, levels of activity, the size of individual ants, and the thoroughness with which foragers cover their territory. By integrating these attributes of species, catches of pitfall traps are of potential value as an index of species' importance as competitors or predators on the soil surface. However, it is essential that all sources of irrelevant variation in catches be known, and if possible eliminated. This paper shows that digging-in effects are an important source of this kind of error.

The majority of the ants being studied nest in the soil and emerge onto the surface to forage. Here orientation may be « 1) By individuals learning restricted feeding areas to which they return repeatedly; and 2) by trail-following, in which foraging is induced and directed by a chemical trail laid by food-laden workers returning to the nest » (BROWN and TAYLOR, 1970). Both types of orientation are found in some ant species, for example *Iridomyrmex purpureus* Fr. Smith, which is discussed here.

Possible causes of catches being relatively high immediately after traps are placed and subsequently declining (« digging-in effect ») include :

1) Penetration of nest galleries when traps are dug in.

2) Exploration of a new feature of the

environment by ants that learn parts of the territory.

3) Coincidence of traps with trails between nests or between nests and permanent food sources; since these trails often depend on reinforcement from continued use, their position will tend to shift if many ants are trapped, so leading to a decline in catches.

4) Depletion of populations.

SITES AND METHOD

Traps were operated in three areas in South Australia near Adelaide, all dominated *Eucalyptus* species.

1) Belair, mean annual rainfall 760 mm, summer 1971, open forest with a patchy, sclerophyllous understorey.

2) Cambrai, rainfall *ca* 300 mm, summer 1972, a sand-dune supporting mallee (tall shrubland of *Eucalyptus* species with multiplie stems arising from a lignotuber) with a sparse groundcover.

3) Glen Osmond, rainfall 618 mm, autumn 1972, open grassy woodland.

Traps consisted of glass specimen tubes mouth diameter 1.8 cm, about one third filled with ethanol, plus a little glycerol, as a killing agent. This appears to have no attractant or repellant effect on ants (Greenslade and Greenslade, 1971). The layout of traps is described below for each site.

RESULTS

Belair.

Sets of traps, each composed of five traps within 3 m of each other, were established on three occasions (groups A-C) in February and March, in an area of 200 × 200 m in which the ant, *Iridomyrmex purpureus* was very abundant.

Group A, established 5 February, seven sets of traps;

Group B, established 8 February, two sets of traps;

Group C, established 3 March, seven sets of traps.

Traps were cleared every two to four days and catches over the first few weeks are shown in figure 1, for *I. purpureus,* other ants (of which 30 species were trapped in this period), and all other arthropods occurring in the traps except Collembola, Diptera, and winged Hymenoptera. Included among the other arthropods were groups known to be attracted to alcoholic preservatives in traps (Greenslade and Greenslade, 1971), and cursorial predators, other than ants, notably spiders. No marked digging-in effect would be expected for these other arthropods which lack the permanently aggregated populations and social organization possessed by ants and the effect is not evident in figure 1. In contrast, catches of ants did show a digging-in effect, since they tended to be high at first in all groups of traps, the only exception being other ants in group B. To take one example of the digging-in effect, catches of *I. purpureus* in group C traps, at the end of March, closely followed catches of A, but the numbers in C were distinctly greater than in A over the first three days (7-10 March).

Mean daily catches of *I. purpureus* for 12-29 March, after the period in which there

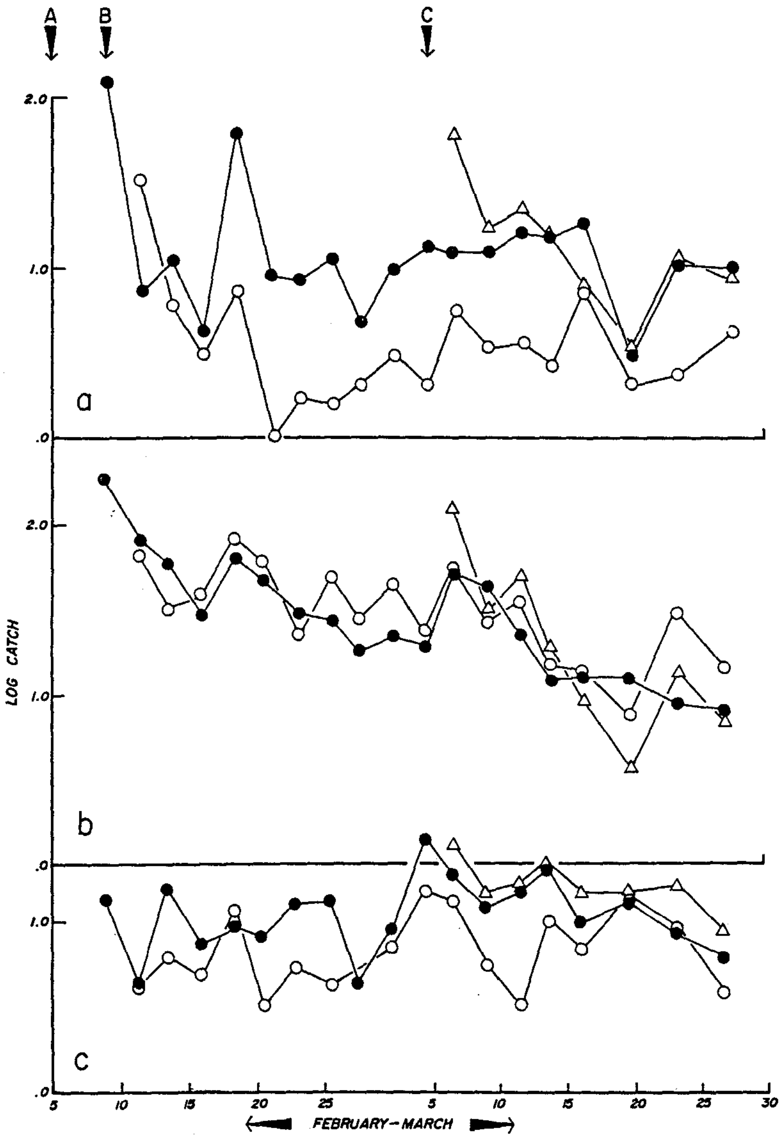

FIG. 1. — Catches in three groups of traps (A-C) set up successively at Belair : a) *Iridomyrmex purpureus*, b) other ants, c) other groups : •, group A traps; O, B; △, C. Arrows indicate the dates on which each group of traps was established. Catches are shown as log. catch/trap/2 days.

were any obvious digging-in effects, are taken as showing the typical trend of catches for each of the 16 sets of traps over the February-March trapping period. As there were no strong seasonal or weather-induced trends in catches of *I. purpureus* at this time (fig. 1) all three groups of traps, A-C, can be considered together. In figure 2,

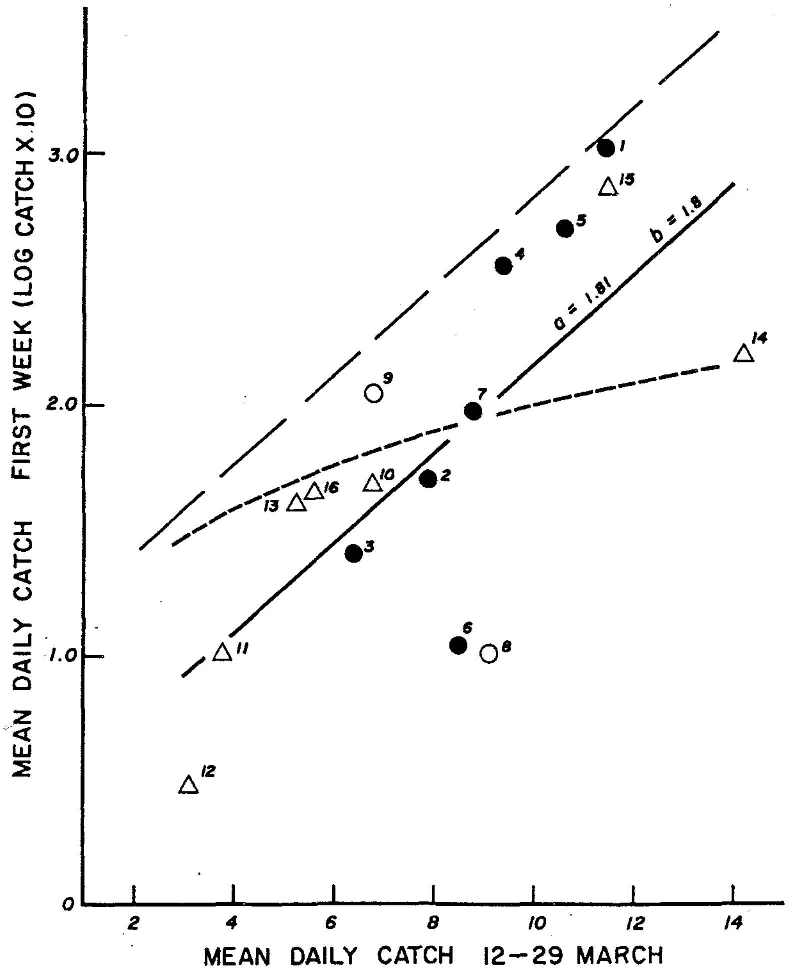

FIG. 2. — Early and later catches of *Iridomyrmex purpureus* at Belair, symbols as in figure 1, traps numbered as in table I. See text for explanation of broken and dashed line.

mean daily catches of individual sets of traps, for 12-29 March (numbered as in table I), are plotted against each set's mean daily catch over the first week. The broken line is the curve that would be obtained if the initial and later catches were identical. A semi-log. transformation is employed since there was very wide variation between the early catches of different sets of traps. The straight line represents the observed relationship and shows that the higher-catching traps contributed disproportionately to the digging-in effect. In addition, the regression line for observed catches intersects the expected (broken) line and is not just displaced above it (e.g. to give the dashed line in figure 2), as would be anticipated if the magnitude of the initial digging-in effect varied directly with the level of average, later catches. This suggests the possibility of a « negative digging-in effect » in the lower-catching sets of traps : i.e. catches low at first, subsequently increasing. However, the scatter of points in figure 2, even with a log. transformation of initial catches, is such that it is not feasible to make a direct test of the statistical significance of the deviation of the fitted line from the dashed and broken line alternatives. Instead the reasons for this variability can be considered.

TABLE I. — CATCHES OF *Iridomyrmex purpureus* IN SETS OF PITFALL TRAPS AT BELAIR

TRAPS	INDEX OF DIFFICULTY OF ACCESS	1 MEAN CATCH PER DAY, FIRST WEEK	2 MEAN CATCH PER DAY 12-29 MARCH	RATIO 1/2
1.	10	106.6	9.40	11.4
2.	22	5.0	0.60	7.9
3.	74	2.7	0.40	6.4
4.	65	37.0	3.90	9.4
5.	43	51.3	4.80	10.6
6.	109	1.1	0.13	8.5
7.	67	9.4	1.07	8.8
8.	75	1.0	0.05	9 1
9.	54	11.1	1.63	6.8
10.	110	4.7	0.70	6.8
11.	154	1.0	0.26	3 8
12.	18	0.3	0.10	3.0
13.	164	3.9	0.70	5.3
14.	20	15.7	1.10	14.2
15.	24	74 6	6.49	11.5
16.	46	4.4	0.79	5.6

The distribution of the nests and territories inhabited by each colony of *I. purpureus* on this site was mapped in January 1971 so that the position of each set of traps is known in relation to the nest from which it derived its catch. Subsequently the performance of each colony has been followed with monthly records of the numbers of nests occupied and of nest entrances in use. In table I, traps are scored according to an index of difficulty of access, obtained from the distance from the nest and the nature of the intervening ground-cover. All else being equal, catches of ants or other epigaeic fauna in pitfall traps vary with the difficulty to movement presented by different types of ground-cover. Here each metre of bare ground between nest and trap is scored 1; each metre of short vegetation is scored 2, and scrub and dense vegetation are scored 3. The sum of distance × difficulty gives the index in table I. Catches were low in five sets of traps (2, 3, 8, 9, 12 in table I) which lay in the territories of colonies that had declined, or were declining in vigour, but their foraging areas had yet to be taken over by adjacent colonies. The other traps show an inverse relation between catch for 12-29 March, and the index of difficulty of access (table I). The ratio of early to later catches (table I) is a measure of the magnitude of digging-in effects. If the five sets of traps in which catches were low because of the decline of colonies are excluded, there is an inverse relation between indices of difficulty of access and these ratios. The relationship is linear (with a square root transformation of the ratios), and gives a significant, negative correlation ($r = -0.73$, $p < 0.01$). This means that initial digging-in effects are most pronounced in traps which are closest and most accessible to nests, as would be expected since the traffic of ants is densest there. But it implies also that statistical significance can be attributed to the lower than expected, early catches of distant, inaccessible traps. A possible explanation for this is the existence of a delayed, digging-in effect, due to relative scarcity of foraging ants. This would reduce both the probability of a trap's being discovered [factor 2) in the « Introduction »], and the likelihood of foraging columns passing near it [factor 3)]. Thus, for inaccessible traps catches over the initial period may represent the « typical » level, while subsequent, higher catches constitute a delayed, digging-in effect. A similar example comes from the traps on the dune at Cambrai.

Cambrai.

Five sets of traps in an area 100 × 200 m, were operated from 24 January to 29 February. Each set consisted of four individual traps, cleared at three-four day intervals (minimum two days, maximum six). At first the weather was hot and dry, but in the latter part of the sampling period there were two falls of rain, temperatures were relatively low, and catches of ants declined (fig. 3 *a*). All traps were started on the same date and it is difficult to dissociate any digging-in effect from the influence of weather. However the initial catches of a number of ant species seemed to be excessive. Here interest centres on *Melophorus*, 30 species of this genus being trapped. They are diurnal ants, active in the hottest weather, foraging individually and running very rapidly in a zig-zag fashion. Colonies are frequent, based on simple nests in soil, and contain only a few hundred adult workers. The areas in which individual colonies forage are rela-

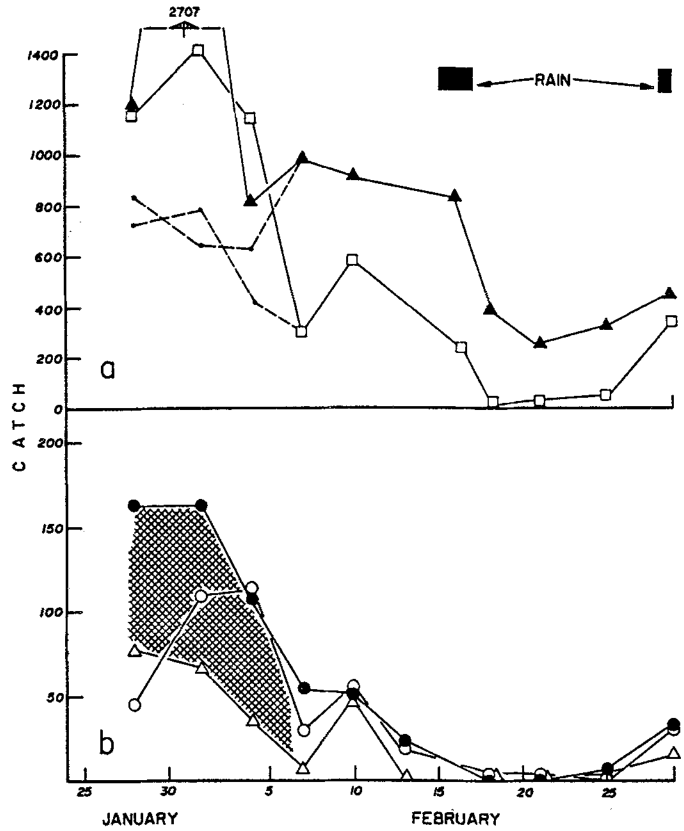

FIG. 3. — Catches per four days of *Melophorus* and other ants at Cambrai. a) ▲, all ants, and, □ *Melophorus* species × 5; broken lines, catches corrected for digging-in effects. b) Catches of groups of *Melophorus* species : ●, abundant; O, intermediate; △ scarce, × 3.

tively small, in the order of 1/10-1/100 of the area of *I. purpureus* territories which may extend over linear distances of more than 100 m. From their behaviour, *Melophorus* are very susceptible to being trapped, and the effects of the distance of traps from nests should be clear. First, the difficulty factor is not important on the dune since the surface of the ground was relatively uniform and free of obstructions. Secondly, there are steep gradients of declining mean density of foragers with increasing distance from nests. These are caused by variation in the length of foraging trips in summer, ranging from the normal, longer type in warm to hot weather, to rapid darts out of the nest entrance when temperatures are extremely high, e.g. air temperatures around 40° C and soil surface temperatures perhaps 10° higher. In addition colonies of *Melophorus* species should be liable to significant depletion [factor 4) in the « Introduction »] as a result of small colony size combined with susceptibility to pitfall trapping.

Catches of *Melophorus* species are shown in figures 3 and 4. Two comparisons are made. Time trends of the catches of abundant species can be compared for sets of traps taking many individuals and traps taking few. Then, trends in catches of abundant species, which potentially exhibit digging-in effects since early catches were high (fig. 4), are compared with trends in scarce species, which, by definition, cannot show this effect since no large catches were made. Four species were abundant in traps with total catch/species > 100 individuals (*Melophorus* species 1-3, 12), five showed intermediate abundance with catches of 25-100/per species (*Melophorus* species 4-7, 9) and there were 21 scarce species, catches < 25.

Comparisons between sets of traps can be made only for three of the abundant species (fig. 4) as *Melophorus* species 12 was moderately numerous in several sets of traps. Two of the other species show a typical digging-in effect in figure 4 *a*, *b*, with high catches in certain traps which were, presumably rather close to their nests. In the other traps, which are likely to have been more distant, there were lower and later peaks in catches. These are unlikely to have been caused by weather since daily patterns of activity, and reactions to weather seemed to be similar in all the *Melophorus* species (see below), and maxima in catches occurred on separate occasions for the two species. There were two delayed peaks in catches of the third species and again the earlier one was the greater (fig. 4 *c*).

Figure 3 *b* shows overall trends in catches of abundant, intermediate and scarce species; the last category is shown $\times 3$ so that their catches in the latter part of the trapping period correspond with those of the other two abundance groups. Average catches per set of traps of the species with intermediate abundance, 15 individuals/species, over the whole trapping period, were almost the same as catches of abundant species in the « other traps » in figure 4, with 16 individuals per species. This suggests that in both cases nests were at equivalent, relative distances from traps, and it is significant that catches of the intermediate species in figure 3 *b* also gave a delayed maximum. This indicates a delayed digging-in effect due to late discovery of, or activity near traps. This agrees with the steep gradients of forager density around nests in *Melophorus*, which should be conducive to immediate and pronounced digging-in effects for traps near nests, and later effects for more distant ones.

It is possible to calculate a correction for digging-in effects by comparing trends in catches of species differing in their abundance in traps. After the period of initial and delayed digging-in effects, say, after the first week in February, changes in cat-

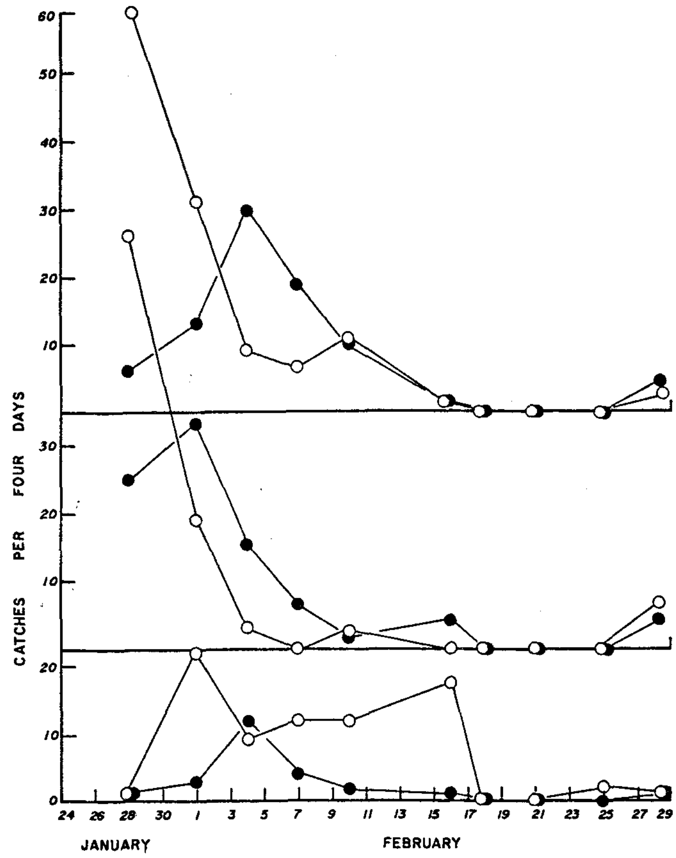

FIG. 4. — Trends in catches of three abundant *Melophorus* species at Cambrai. Catches per four days in the sets of traps in which they were most numerous (○), and in other traps (●). *Melophorus* sp. 1, top, to *Melophorus* sp. 3, bottom.

ches of abundant, intermediate and scarce species were similar and can be related to weather. The ability of *Melophorus* species to be active in very hot conditions is balanced by a marked decline in activity in cool weather, as in the latter part of the trapping period (fig. 3 *a*). Catches of the scarce species, in January and early February, should reflect the real trends in activity, as determined by weather, and these should be applicable to the intermediate and abundant species as well. Therefore, initial differences between catches of scarce species × 3, and of abundant and intermediate species (hatched in figure 3 *b*) represent catches due to digging-in effects. Corrected catches can be calculated by subtracting captures supposedly caused by the digging-in effect and are shown in figure 3 *a*. By making similar comparisons of the time-trends in different sets of traps digging-in effects can be detected and allowed for in other species : again the effect is recognised as a very high early catch in traps in which a species tends to be abundant, while the « real » trends in captures, with no digging-in effect, are taken to be those in the other traps, and an appropriate correction can be made. An analysis of the ant fauna of this dune, listing the species, is in preparation; digging-in effects occurred in *Pheidole* species 1, *Meranoplus* species 1, *Monomorium* species, *Iridomyrmex purpureus,* and *Iridomyrmex* species 6 as well as the *Melophorus* species. Observed and corrected catches of the whole ant fauna are shown in figure 3 *a.*

It is difficult to make rigorous comparisons of curves such as those in figures 3 *b* and 4 on account of variability in the activity of these ants, and their strongly aggregated distributions, leading to high variance-mean ratios for almost any population parameter, and hence large statistical errors. Yet some check on the accuracy of these corrections is desirable as a test of the validity of conclusions relating to digging-in effects. This applies especially in the case of delayed effects since there are many problems in obtaining more supporting evidence than is already available from this site and Belair.

A suitable test is provided by comparison of trends in these corrected catches and weather. The ants can be classified, according to the timing of foraging activity, as nocturnal or diurnal with further subdivisions; it can be shown that corrected catches of these groups vary in the response to weather, particularly temperature, in an explicable way. For example, according to the account of the dune fauna that is in preparation, trends in corrected catches of species that are strictly diurnal and active during the hottest part of the day, correspond very closely with trends in maximum temperature. On the other hand, a number of primarily diurnal species have very flexible foraging rhythms, being active at dawn, and again at dusk and into the early part of the night in hot weather, and in the middle of the day under cool conditions; corrected catches of these species show the least fluctuation in response to variation in weather. It is unlikely that these results would be obtained if the corrections for digging-in effects were grossly inaccurate.

The effect of weather, reducing catches of *Melophorus* in the latter part of the trapping period, obscures any significant depletion. The similar rate of recovery by all three abundance groups when temperatures rose during the final sample (fig. 3 *b*), is inadequate evidence that depletion did not occur since numbers trapped were low.

Glen Osmond.

Eleven traps were established in the usual way on 12 May and their catches were compared with those of 11 other traps that had been dug in first, on 5 May, but left inverted for one week. Traps were arranged 2 m apart in a line on a grassy hillside. The experiment was discontinued after only two days' trapping as autumn rains were imminent. Nevertheless, the

TABLE II. — CATCHES OF 11 NORMAL TRAPS, AND 11 TRAPS THAT HAD BEEN DUG IN ONE WEEK PREVIOUSLY AND LEFT INVERTED

Ant species	Type of trap	
	Normal	Previously inverted
Rhytidoponera metallica	1	—
Pheidole sp.	42	24
Meranoplus sp.	4	2
Chelaner sp.	1	2
Monomorium sp. 1	13	1
Monomorium sp. 2	1	—
Iridomyrmex sp. 1	9	8
Iridomyrmex sp. 2	1	1
Melophorus sp.	—	2
Prolasius sp.	1	—
Notoncus sp.	—	2
Total	73	42

previous placing of inverted traps did appear to reduce digging-in effects (table II), presumably by disrupting trails and allowing ants to become familiar with a new feature in their foraging areas. Most individuals were taken in the normal traps and for the most numerous species, a *Pheidole*, a t-test suggested a significant difference between catches of the two types of trap ($t_{10} = 3.08$, $P < 0.05$).

DISCUSSION

Of the different types of digging-in effect noted in the « Introduction », type 4), depletion of the population, can be reduced if traps are used at moderate densities, and other types of digging-in effect can be avoided. Type 1), penetration of galleries, is readily answered by moving the position of traps if necessary. The pilot experiment at Glen Osmond indicates that first establishing traps in a inverted position may help to solve the problems of type 2) and 3).

An important element in catches after the period of digging-in effects consists of foragers that are returning to the nest with prey or other articles. In *Iridomyrmex purpureus* these individuals move directly and rapidly towards the nest and obvious items of prey, such as dismembered insects, are commonly found with trapped ants. Many other catches are likely to be the result of recurrent, delayed digging-in effects, as new ants are recruited to a colony's force of foragers, and temporary trails are formed in response to variation in the distribution of resources within the foraging area.

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