DUNG BURIAL ACTIVITY AND FLY CONTROL POTENTIAL OF *ONTHOPHAGUS NUCHICORNIS* (COLEOPTERA: SCARABAEINAE) IN BRITISH COLUMBIA[1]

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Abstract

Onthophagus nuchicornis (Linnaeus), an accidentally introduced dung beetle, is the only scarabaeine species encountered commonly in cattle dung in British Columbia. Its dung burial efficiency and its potential for inhibiting development of coprophagous fly larvae were measured in greenhouse experiments.

The beetles buried dung most efficiently when they were present in the ratio of one pair per 40–50 g of feces. Higher or lower rates of infestation resulted in reduced burial. Survival of fly larvae was inversely related to the numbers of brood balls constructed by the beetles, and hence to the amount of dung buried. Beetle activity in the field probably has little harmful effect on the dung-breeding horn fly as the beetles cease burial activity before midsummer, when horn flies reach their greatest numbers, and as they do not bury significant amounts of dung in pastures.

The desirability and possibility of introducing exotic dung beetles into British Columbia for fly control is discussed.

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A survey of insects associated with cattle dung on rangelands in the Kamloops area of British Columbia during 1970 (Macqueen and Beirne 1974) revealed the presence of two species of dung-burying beetles: the native *Boreocanthon simplex* LeC., which was rare and thus of no possible economic significance, and the exotic *Onthophagus nuchicornis* (L.), which was sufficiently common and widely distributed to warrant evaluating its dung-burying activities and their consequences.

Our interest in dung-burying beetles resulted from the observation that cattle dung pads normally persist for long periods in British Columbia rangelands. This is in contrast to the situation described for some other countries by Halffter and Matthews (1966) where efficient dung beetle faunas are adept at disposing of much of the animal feces voided during certain periods of the year. Absence of a suitable dung beetle fauna results in various ecological problems that were listed by Bornemissza (1960) in relation to grazing of pastures by domestic animals in Australia. These problems are, however, not confined to Australia, but occur in other areas of the world to which domestic animals have been introduced and that lack a native dung beetle fauna capable of removing the feces of these immigrants.

Onthophagus nuchicornis has a wide distribution in Europe and central Asia (Balthasar 1963). It was accidentally introduced into eastern and western North America separately (Howden 1966). It was found in British Columbia first in 1945, at Creston (Hatch 1971), and has since colonized much of the southern parts of the Province. It also inhabits parts of Washington, Idaho, and Montana (Howden 1966), and of Alberta (H. F. Howden pers. comm.). Its wide range abroad indicates that it may have the potential to colonize a greater area in North America than its present range.

Field observations indicated that *O. nuchicornis* was quite effective in removing dung from shallow dung pads during spring and early summer. Larger and deeper pads, though often colonized by many beetles, were not buried to any extent. Results of experiments aimed at evaluating its efficiency as a dung-burier and at determining the consequences of dung burial to pest flies that breed in the dung are discussed here; consequences to forage grasses of recycling through burial of nutrients that otherwise

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would be immobilized in the dried dung will be discussed elsewhere (Macqueen and Beirne in prep.).

Materials and Methods

Dung Burial Tests

Breeding pairs of *O. nuchicornis* remove dung from cattle pads and form it into balls which are buried in the soil. Each brood ball receives a single egg before being sealed by the female and this constitutes the complete store of larval food for each insect. In replicated experiments different numbers of pairs of beetles were each placed in pots containing soil on which was a dung pad made to be of a uniform weight (either 200 or 250 g) and shape. After burial had ceased, the amount of dung that was left in each pad was determined by collecting the dung remains (incorporating soil excavated by the beetles) from the surface of the pot and subjecting them to oven-drying and then ashing at 600°C. The dry weight of dung that remained on the soil surface, and hence unburied, was given by the following formula:

$$\frac{y\,(\mathrm{DW}) - \mathrm{AW}}{y - x}$$

where x = proportion of dung dry weight remaining after ashing,
y = proportion of soil dry weight remaining after ashing,
DW = dry weight of dung plus soil before ashing,
AW = dry weight of dung plus soil after ashing.

The percentage burial for any pad on a dry weight basis was then given by

$$\%\ \text{burial} = \frac{100\,(\text{weight control pads} - \text{weight unburied dung})}{\text{weight control pads}}\,.$$

These procedures overestimated the absolute amount of dung buried because fresh dung without beetles invariably lost some dry matter when it was exposed on a soil surface. Correction factors were found by use of control pads and these were subtracted from the apparent per cent burial figures to give the actual amount buried.

Brood balls left in each pot were also counted as each experiment was dismantled.

Effect on Fly Breeding

A series of laboratory tests was aimed at defining effects, if any, of dung tunnelling and dung removal by *O. nuchicornis* on pest flies whose larvae live in and feed on the dung. Preliminary tests were made with larvae of the house fly, *Musca domestica* L., because it is easily reared in the laboratory and its larvae develop satisfactorily in fresh cattle feces, though adult females normally prefer slightly older dung for oviposition. Later in the tests, larvae of horn fly *(Haematobia irritans* (L.)) were used.

The tests were made with 250-g dung pads that rested on pots of damp soil. Pads were seeded with the requisite number of house fly larvae or horn fly eggs (because horn fly eggs are easier to handle than larvae) and cloistered with beetles that were removed after a few days when they came to the surface in search of fresh dung. Pots were then left undisturbed until all flies had emerged and died. Flies were then counted and weighed, remains of pads were retained for estimation of per cent burial, and the brood balls in each pot were counted.

Results

Effectiveness of O. nuchicornis *as a Dung Burier*

Results of an experiment in 1972 are shown in Fig. 1. They are in general agreement with results of preliminary experiments in 1971. In both years the results indicated that the greatest number of brood balls are buried from a 250-g pad when four or five pairs of beetles are present. The mean number of balls per pot was 23.6 when two pairs of beetles were present and 40.2 with four pairs, but was down to 31 with eight pairs and 26.2 with 16 pairs. The mean total quantity of dung removed by four pairs was about 60% more than by two pairs. The quantities of dung removed from the pads by beetles at the two highest densities were about the same as by four pairs, although the numbers of balls were smaller.

A highly significant relationship ($N = 10$; $Y = 4.14 + 1.08X$; $r = 0.961$; $P < 0.001$) was shown by regression of per cent dung on number of balls buried by two or four pairs of beetles. The number of brood balls recovered was therefore a direct indication of the amount of burial activity in each pot when beetles were present at these densities.

A t-test showed that there were no significant differences between the mean amounts of dry dung removed for each brood ball buried by two and four pairs (0.32 g and 0.30 g respectively). At these lower beetle densities the mean amount of dung removed per ball buried probably indicates the extent to which the dung was utilized by each breeding pair; this includes dung eaten by the beetles. The figures indicate that approximately 2.5 g of fresh dung, or about 0.3 g of dry dung, was removed from the pad for each ball buried by *O. nuchicornis*.

Dung removed per buried ball was greater ($P < 0.05$) with eight pairs of beetles than with four, and greater ($P < 0.01$) with 16 pairs than with two or four. Those figures show that when eight or 16 pairs (i.e., high densities) were present the beetles removed considerably more dung from the pads than they formed into balls. Most of the missing dung presumably was eaten by the beetles, or mixed into the soil by them, so that it could not be recovered. The extraneous losses tended to increase in relation to the number of beetles present.

The main conclusion is that *O. nuchicornis* is not a particularly efficient dung-burier; at the best it actually buried little more than one third of a laboratory dung pad in 5 days, though it may bury a greater proportion of certain small pads in the rangeland when favourable conditions are encountered. This, as shown elsewhere (Macqueen and Beirne in prep.), can have a distinctly beneficial effect on the growth of rangeland grasses. Whether or not it can have a beneficial effect in reducing the

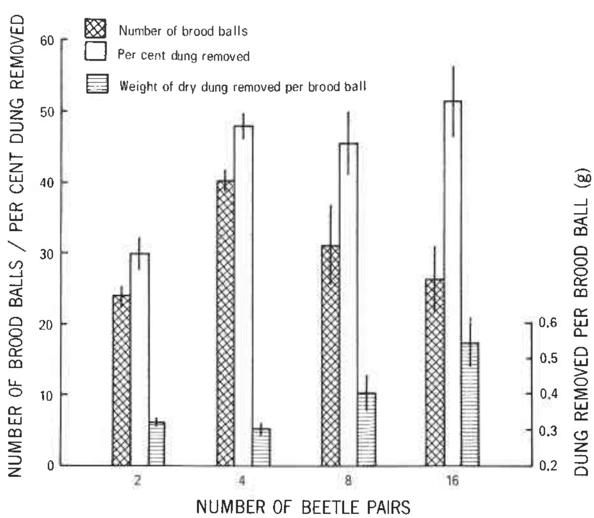

FIG. 1. Amounts of dung buried by various numbers of pairs of *Onthophagus nuchicornis* that were provided with 200 g of fresh dung. Values given are means of five replicates and vertical lines represent standard errors.

numbers of pest flies that breed in cow dung was indicated by results of the experiments described below.

Impact of O. nuchicornis *on Coprophagous Flies*

Artificially formed dung pads of 250 g containing 0, 2, 4, or 6 pairs of *O. nuchicornis* were seeded with 100 newly hatched house fly larvae to determine effects of burial on survival of house fly larvae. Treatments were replicated three times. Dung burial at these low beetle densities again bore a significant relationship to the number of brood balls formed ($N = 12; Y = 14.02 + 0.88X; r = 0.985; P < 0.001$). Results showed (Fig. 2) that, under the conditions of the tests, fly larval mortality increased with increases in the amounts of dung removed by the beetles. Mortality in the controls, which were without beetles, was high: a mean of only 51 adults resulted from each 100 larvae. Results of subsequent experiments suggested that the relatively low survival in controls was because of competition induced when the outer layers of the small experimental pads had dried quickly. Bay *et al.* (1970) found that larvae of a similar-sized fly, *Musca autumnalis* De Geer, require approximately 2.0 g of fresh dung for optimum development. House fly larvae in the current experiment started with 2.5 g of dung per larva, but this ratio apparently fell rapidly below 2.0 g/larva under the conditions of the test. Thus a certain degree of larval competition was preordained even in control pads, so that any further dung removal of dung by beetles was immediately detrimental to the flies. A corollary of this observation could be that for beetle activity to affect fly survival, the fly larvae must be present at such a density that they are at least on the verge of competing even in the absence of beetle activity. The chances of this happening frequently in this rangeland are somewhat remote (Macqueen and Beirne in prep.) but were examined in the following experiments.

In the Kamloops area seldom more than 400 horn flies emerged from naturally-dropped dung pads (1500–2000 g) that were maintained free of other insects. To determine possible effects of dung burial by *O. nuchicornis* on horn fly production 0, 2, 4, and 8 pairs of beetles were placed on 250-g dung pads that had each been seeded with 55 horn fly eggs. Each treatment was replicated five times. The 55 eggs produced a mean of about 50 larvae per 250-g dung pad (i.e., 400 per 2000-g pad). This larval and beetle density is probably seldom exceeded in the field in the Kamloops area. No correlations could be found between numbers of dung balls buried per pad and the numbers of horn

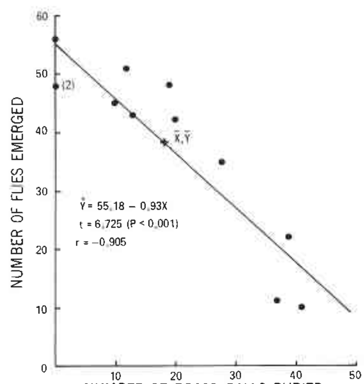

FIG. 2. Regression of number of house fly larvae that reached the adult stage on the number of brood balls buried by *Onthophagus nuchicornis* beetles. Each pad contained 100 larvae at the start of the experiment. Pads from which no brood balls were buried contained no beetles.

flies produced. Moreover, the mean body weights of flies that emerged from pads with no beetles were no greater than those of flies from pads with beetles, which indicated that dung-burying by the beetles was not sufficient to affect the normal development of the fly larvae. These results indicate that the numbers of *O. nuchicornis* normally present in the dung pads in the Kamloops area cannot bury sufficient amounts of dung to reduce the production of horn flies significantly or at all.

August is the time of greatest horn fly abundance. Adults of *O. nuchicornis* are common at that time. They feed and tunnel in the dung but do not bury it. Zero, 4, 8, and 16 pairs of beetles were placed on 250-g pads each of which was seeded with 200 horn fly eggs (which produced a mean of 181 larvae per pad). This created extremes of both beetle and fly infestations that would almost certainly never be encountered in the field. Analysis of variance showed no differences in numbers of horn flies produced or their mean weights between different treatments. Thus high numbers of tunnelling but non-burying *O. nuchicornis* had no apparent harmful effect on the production of horn flies even when the fly larvae were abundant.

Discussion

The results of the tests with house fly larvae indicate that *O. nuchicornis* is capable of reducing the survival of coprophagous flies by dung-burying. But the results of the tests with horn fly larvae indicate that it does not normally exert any practical control on this species in the field in the Kamloops area. In fact there is an indication that it may benefit the horn fly in a minor way, as in one test the flies that emerged from 250-g pads colonized by two or four pairs of beetles were significantly larger than those from pads without beetles (Macqueen unpub.).*

Onthophagus nuchicornis is ineffective in controlling horn fly in British Columbia for several reasons. First, its period of greatest burial activity does not coincide with the period of maximum horn fly abundance. Second, it is seldom capable of burying an entire pad, or of burying a large proportion of it sufficiently quickly to produce competition between fly larvae for food or to make the pad physically unsuitable for their survival. At a density of one pair of beetles per 40 g of dung *O. nuchicornis* removed 40% of a pad whereas a related exotic tropical species, *O. gazella* F., at a density of approximately one pair per 100 g, could remove all or most of a pad within 48 h (Bornemissza 1970). Another exotic species, *O. quinquedens* Bates, can bury pads in as little as 3 to 4 h in the field (CSIRO 1972). In Bornemissza's experiments, when the dung was colonized by beetles that are capable of utilizing all or nearly all of it, the survival of fly larvae is related to the speed of burial; and results of experiments by Blume *et al.* (1973) indicate that a large proportion of any dung pad has to be buried to affect horn fly development significantly. *O. nuchicornis* is not usually capable of utilizing the whole pad, and seldom utilizes more than half of it. Furthermore, increasing the number of beetles beyond a certain density resulted in reduced dung burial in the insectary. Mutual interference was probably responsible. Field observations in the Kamloops area revealed that burial by *O. nuchicornis* had little impact on large pads, though it sometimes had a significant effect on small pads, such as are made by cattle defecating while walking, but these represent only an insignificant fraction of the total dung deposited.

It may be possible to achieve some control of dung-breeding pest flies in the southern Interior of British Columbia by introducing and establishing species of dung-burying beetles that are more effective than is *O. nuchicornis*. This form of biological control of coprophagous insects has been applied with some apparent success in other countries. The climate of the area limits the species that might be considered, mainly to those that inhabit cold temperate regions. This excludes the highly effective

*Macqueen, A. 1973. Horn fly breeding, nitrogen loss and nutrient immobilization associated with cattle dung in the southern Interior of British Columbia. Ph.D. Diss., Simon Fraser University, Burnaby, B.C.

exotic species of *Onthophagus* mentioned above but leaves possible candidates elsewhere in Canada and in the Palearctic.

No species inhabiting Eastern Canada appears to be a particularly effective dung-burier (H. F. Howden pers. comm.). There is a possibility that effective buriers of bison dung existed but became extinct over most of the West when their host was virtually exterminated. This possibility was explored by surveying the dung fauna of bison in the one area where they have survived continuously: Wood Buffalo National Park in N.E. Alberta. The survey was made by the senior author in August 1970. No dung-burying beetles were found. It therefore seems unlikely that there was recently an effective dung-burying fauna in Canada, and there are apparently none that might be used in the Interior of British Columbia.

There are areas in the Palearctic that are climatically similar to the southern Interior of British Columbia (Walter and Lieth 1964, 1967). Some of them, for example the Kirgiz area of the USSR (Protsenko 1968), have indigenous species of beetles that utilize dung of domestic cattle and that are within the general area of bovid origin. The introduction of selected species of dung beetles into British Columbia is the only apparent potentially feasible way of reducing both the existing bottleneck in nutrient cycles and the abundance of horn flies.

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