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It seems explicitly evident that animal control practices must now, and especially in the future, emphasize fuller appreciation of the habits of each kind of animal. Further, this will require consideration be given to behavioral aspects as expressed by a population as a whole of a given species, as well as each individual animal within that population. Animals react with one another and with all characteristics of their environment; and, this in turn results in an identifiable reaction or behavior of each population as a unit of social organization. Although within broad limits some aspects of these responses, whether individual or group, are reasonably predictable, many are not. But, in this day of stringent regulations on food contamination and methods of controlling pests, "reasonably predictable" is no longer acceptable. The near-perfect, if actually not the perfect, technique is becoming a requirement. Therefore, to approach this level of success, one must attempt to interpret the behavior of each mouse and/or population in every infestation.

One cannot discuss this subject without reflecting on the extensive and significant contributions of Crowcroft (1959, 1965, 1966) as well as that of Crowcroft and Rowe (1957, 1958, 1963), Crowcroft and Jeffers (1961), Brown (1953), Southwick (1955), Rowe, et al. (1964), Strecker and Emlen (1953), Strecker (1954) and Davis (1958). Peter Crowcroft's (1966) delightful book, Mice All Over, should be thoroughly read by everyone concerned with the problems of contamination by the house mouse (*Mus musculus*).

Much has been written regarding behavior, genetics and population dynamics of the carefully controlled strains of albino house mice. Unfortunately, most of these data have little application, other than implications, to actual situations of wild populations of house mice. The opportunistic circumstances for outbreeding in wild mice are so massive, it is unusual to expect much in the way of similarity between wild populations in the same area and same type of facility let alone between regions within a town, city or country. Therefore, no approach to control can ignore the necessity for precision study of each problem situation. This is to include not only detailed and complete appraisal of the physical facility which houses the mice but also the mice, including: How might they have gotten into the warehouse? From where did they come and what has been their most recent experience? How long have they been in the facility? Where is their likely "home base" in the facility? What is their likely pattern of use? All this plus much more must be related to the total aspects of the physical features of the facility so that there can be full appreciation of the unit as a "home" environment for the individual mouse and/or mouse population.

Time does not permit the full revelation of our studies and so my comments will include only limited aspects. In an effort to examine a few phases of this large problem as it might occur under reasonably natural conditions, continuously, low-lighted arenas (80 square feet) were assembled. Each of two arenas included a pallet (3' × 5') of a combination of sacked grain and corncobs, into which 2 males and 3 females of first generation laboratory-reared, wild house mice were released in April. From that time on, for approximately 6 months, observations were made of the activity of the population. To plot sites of activity as recorded during these observations, the arenas were gridded by use of string across the top of each.

Initial mouse use of the arena and activity for both arenas were similar to that recorded by Crowcroft (1966); namely, each mouse seemed to first develop a familiarity of the new area of release. This required 2-3 hours as the first mouse ventured short distances, going a little farther each time on the trips, which were spaced at 1-5 minute intervals, around the perimeter of the pallet. Upon the completion of this exploration, a trip was ventured 3 feet across open space to the perimeter of the arena. Here again the come and go from the pallet was repeated, going somewhat farther and for a somewhat longer time as the distance from the home base increased.

It was apparent that all of the members of the released group participated in these ventures. But, one adult male seemed more frequent in trip making. It appeared that there was a following of scent trails as evidenced by the sniffing; this was most apparent by their all using the same pathway across the open space. During this period of exploration no aggressive interaction was recorded. However, there was sniffing when contact was made between two mice.

Once "familiarity seemed resolved" the population virtually disappeared from further observation for nearly 1 1/2 months. The only sign, other than four sightings of animals at the gaps between two sacks in each arena, was a slight accumulation of dust particles beneath two holes to the outside of the pallet in each of two sacks, and three sites of droppings at the perimeter of the arenas.

In the case of Arena A, almost instantaneously 65 days after the introduction of the mice, four mice were observed on the surface of the pallet and 8 days later six such mice were so recorded for Arena B. These seemed restricted from living inside, and when they were disturbed so as to enter the pallet, there were noises from within and after short intervals mice appeared on the surface. Eight days later, by extracting corn husk, cobs, burlap, etc. two nests along the perimeter were constructed in one arena and one nest in the other. These were not increased in number nor was there any evidence of reproduction or development of a social hierarchy among these outcasts; all seemed subdominant in behavior.

Associated with this expulsion of certain members, there was very rapid disintegration of the pallets, so that soon the floors of the arenas were littered with material from the pallets. This littering resulted primarily from the foraging efforts of those forced to the outside. With this breakdown of pallets there was an increase of these social outcasts, so that there was much greater activity not only on and around the pallets but throughout much of the arenas. Literally, this activity probably lowered significantly the carrying capacity of pallets because of reduced space in the interior; this probably caused greater stress within the social hierarchy. These outcasts, when they left the pallet, did not display the exploratory habits of the initial releases; there seemed not to be time for this.

The data gained from the area use observations were interpreted in terms of total use per time period on a per day basis. The times of lowest activity were from 1800-0130; the rest of the 24-hour period reflected a generally high but oscillating level of activity. Further speculations on the activity pattern cannot be made in regard to specific most active periods; but it is suggested that the environment of the colony, namely the constantly and evenly lit enclosure, was the factor most responsible for smoothing of any rhythm of activity as usually found in wild colonies. Another factor to be considered as the study progressed is the high population density within the enclosure; interactions between individuals undoubtedly resulted in increased and irregular activity.

Often during periods of observation there was a noticeable difference between the number of mice visible in one enclosure as compared with the other. Because external factors were the same for each colony, each colony probably had inherent social differences that were responsible for this phenomenon.

During the last 1 1/2-2 months of the 6-month period very little change in activity or pattern of arena and pallet use seemed evident. Thus, it seemed an appropriate time to determine the success of a removal plan. Four live-traps (Ketch-All Automatic Mouse Trap, Kness Mfg. Co., Albia, Ia.) were established in each arena, each being placed at the established sites (previous observations) of greatest activity within the arena. Captures, however, did not faithfully reflect the numbers of mice observed at these sites. Trapping success fluctuated extensively between 24-hour intervals, but as the period of capture continued there was a continual decline of success so that at day 12 there were no further captures. A subsequent continuous, 72-hour period of observation revealed no further mice active in either arena.

Arenas were then entered and cleaned, revealing 16 mice (7♂ & 9♀) in one and 6 (1♂ & 5♀) in the other. Based on captured and living, one arena had a theoretical population at the commencement of trapping of 69 and the other 80 mice. Trapping success for the two enclosures, then, was 91.3 and 80.0 percent, respectively. Examination of the total captures by sex showed that about 90 percent of the males were removed compared to around 80 percent of the females. Only two of the females removed were pregnant, suggesting that reproduction had virtually ceased. This is one of several types of inherent measures exhibited by a given population to strive for a balance between numbers and carrying capacity of the habitat. All animals were in acceptable condition as evidenced by weight and appearance.

In another experimentation an arena was set up, as previously outlined, to test acceptance of new foods as potential toxicant carriers or trap baits. At 2-week intervals for a period of 4 months, four foods not previously experienced by the mice, but which had been established as top acceptance by earlier experimentation, were introduced for a 24-hour period. The stations were located around the perimeter of the arenas. Initial acceptance of these was clearly limited, as very small amounts were taken, until the fourth 24-hour trial when consumption increased 500% and without particular selection of food type. Observations showed that this sudden increase in food consumption was due not only to an increased mouse population but also to mice which were no longer permitted (social outcasts) to remain in or on the pallet, or to return to feed without harassment. Hence, they were opportunistic in capitalizing on a new source of food, not having to scavenge or try to feed at the pallet when dominants were inactive. An interesting aspect of this study was a temperature decline from 75° to 30-35° for a 5-day period during the 11th week of experimentation. Almost immediately there was a marked reduction in mouse activity and 70 percent fewer mice were observed. It can only be assumed that the ejected had been allowed to retreat into the pallet.

The same experimentation utilizing the areas was repeated during July-December for the purpose of evaluating use of a toxicant rather than traps as a population removal technique. The results were similar as 76.2% and 87.6% of the population in Arenas A and B, respectively, were found dead. Of interest was the fact that population levels for the two Arenas were 15.6 and 18.2 percent higher than in the trapping experiment. Here, as in the trapping experimentation, males (89%) were more vulnerable to removal than females (78%). Further, 12% of the-females were pregnant. This may suggest that the carrying capacity was possibly greater in the second study and that possibly the upper assymptote of the population level had not been reached when the study was terminated. However, evident too may have been genetical and behavioral differences in the mice used in the two sets of experiments.

Analyses of the data derived from these observations suggest a number of facts regarding the response and behavior of individual mice and a given population of mice.

1. A continuously-lighted environment disrupts the characteristic nocturnal-diurnal activity pattern of house mice to the extent that there is some activity at almost any time. One might assume that this would enhance mouse contact with bait stations or traps. However, such activity is sporadic and allows much more opportunity for an individual mouse to miss such contact. Yet, with few mice active at a given time, evidence of social hierarchy is less, thus reducing the amount of interference sub-dominants would experience in moving around. It would appear that limited periods of activity, which would yield greater concentration of activity, would result in more mouse-bait or mouse-trap contact and yield more profitable catch as well as effort (man-hours) in control practices.

2. With the growth in mouse population there was increased mouse activity outside the pallet. On the basis of known effects of social hierarchy, these mice were those social outcasts or pioneers no longer a part of the established population occupying the pallet. Theoretically, then, these were the only animals fully susceptible to control measures. Also, they represented the nucleus for new populations elsewhere.

   The differential in the effectiveness in removing females is important; as they represent the start of a new infestation, as it is very likely some will be pregnant. Significant is the fact that both removal techniques failed to remove any pregnant females despite their presence.

   The data clearly establish that where social status, security and metabolic needs are provided, such as inside a pallet, mice so housed are virtually immune to capture by any technique that requires their appearance outside the pallet.

   Further, only with change in the physical environment of these entrenched mice, which requires re-establishment of familiarity, will there be temporary (2-3 hours at most; but may be as little as 15 minutes) loss of the social hierarchy and non-directive scurrying around to develop new patterns of movement and activity that will insure survival in the new arrangement. Hence, the more active the storage area the less opportunity for entrenchment and population development, and the greater the opportunity for contact with individual mice which have not yet become organized into a social system. It must be remembered that social organization is essential to survival and hence many animals exhibit this behavior.

3. It must be appreciated, too, that mice gaining access to a building via openings, etc. will respond differently as individuals and in population development than those being introduced within the packages, sacks or pallets moved into the building. The latter will probably not show, or at least will show less, of the initial erratic behavioral patterns exemplified by that recorded in the arena studies. It may simply be good policy to have a continuing program of control so as to be in a position to capitalize on mouse adjustment to a "new home" at all times in a given storage area.

   It was clear that sites of greatest activity changed as mice were removed. This was probably due to readjustment in the social organization as well as the removal of mice using given areas due to reduction in population size. This means that a productive trap or bait site on Monday may have dissipated by Tuesday.

4. As pointed out by Crowcroft (1966) individual pallets provided idealistic environments for the development of many individual social units, all of which might be completely inaccessible at a given time to control measure. In contrast, however, larger units of storage, although contributing fewer opportunities for individual population units, are less mobile and hence less manageable insofar as there being good access for control of infestations. Even with extensive population growth, the outcasts and pioneers are relatively secure for a longer period of time following the time of infestation. Actually, very small units of storage probably provide the least opportunity for harboring mice, the greatest opportunity for eradication and a reduction in potential food contamination.

5. Lowered temperatures result in reduced mouse activity because there is an apparent reduction in antagonistic interaction in the social hierarchy. This also results in reduced reproduction; but it ordinarily does not completely terminate. The significance of this to control practices is questionable. Certainly, greater interaction contributes to the vulnerability of subdominants and the pioneers; but, it also results in greater reproduction and more mice, and thus opportunity for new social units and sites of infestation due to dispersal. The low temperature results in not only entrenchment of the social unit but also the subdominants because they tolerate one another and may literally huddle together for warmth.

6. Introduction of new food, previously proven to be highly acceptable, obviously did not attract mice which did not leave the pallet. More so, until the population reached high levels and food was most likely a problem, the new foods were sampled but they did not replace that to which the population had been accustomed.

In conclusion, permit me to recognize the several students, especially Gerald Gaffney, Donald Younker, Ronald Kirby, John Schulte and Wayne Cook who contributed long and tedious hours to this research. Particularly do I wish to acknowledge the financial support and encouragement of the National Pest Control Association.

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