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CONTRIBUTIONS OF BEHAVIOUR STUDY TO AGRICULTURE

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The considerable recent advances in the study of behaviour have been due, principally, to the increasing use of detailed methods of recording the activities of a wide range of animals including man. These studies have often been based on the observations of field naturalists, farmers, pet owners, veterinary and medical practitioners, and social workers. A wealth of information about behaviour has always existed and it is generally useful for the ethologist to collect and sift such information as well as to make further, more detailed observations of behaviour which allow conclusions about biological mechanisms to be reached. In studies of the behaviour of farm animals and pests of crops, those whose livelihood depends upon agriculture have much information to offer the scientific investigator, although it is sometimes difficult to distinguish fact from folklore.

Farmers have been aided by behavioural studies of domestic animals, of crop pests, and even of farm workers. Behavioural factors can affect animal production in various ways. Food intake by livestock, or some aspect of metabolism or reproductive efficiency, or susceptibility to parasites and disease may be modified. Observations of domestic animals and of the relationship between animal and stockman have helped to make stock management easier while studies in which workers carrying out tasks were carefully watched have led to improvements in the efficiency of those workers. The adverse affects of pests on growing crops and on agricultural products after harvesting have been ameliorated thanks to a wide variety of studies of pest behaviour which have resulted in either a reduction in the contact of the pest with the crop, or in improved methods of controlling pest numbers.

Domestic animal production

Feeding behaviour of domestic animals has been studied ever since man first kept them, for it is essential that the farmer should know enough about how his animals feed, and how much food they need, to allow provision of adequate, readily accessible food. Studies of feeding preferences have helped nutritionists to discover a better diet for all animals. If an animal finds the food provided for it unpalatable, it may eat less of it. The stress of eating unpalatable food may have some metabolic effect which will result in a slowing of its growth-rate. Palatability studies indicate that these effects are greater for pigs than for ruminants, but cattle fed on the herbage species which they prefer and the grass length which they prefer, increase their body weight faster than they would with less acceptable

food (Voisin 1959). A recent investigation of the preferences of heifers for pasture treated with slurry (cowshed washings) at different levels of application and at different times before grazing, has been carried out by Broom, Pain and Leaver (1975) at the National Institute for Research in Dairying near Reading. Since the animals clearly prefer not to eat the heavily tainted grass for some weeks after slurry application, but show no clear preferences if grazing is delayed beyond a certain time, it is possible to offer some advice to farmers as to the best way to use this very valuable fertiliser.

In wild conditions, food is an important factor in determining how animals distribute themselves, but other factors, including the availability of nesting and hiding places and the occurrence of predators, are also important. Man's domesticated animals are generally well protected from predators, but in trying to decide on the optimum conditions for our animals, we can benefit from studies of feral populations of domestic species (i.e. those started by escaped individuals) or of closely related wild species. The observations of McBride, Parer and Foenander (1969) on feral chickens and those of Kruijt (1964) on jungle fowl in captivity have provided valuable information on flock formation, and the development of social and sexual behaviour. Grubb and Jewell's observations of home range and social behaviour in Soay sheep on St. Kilda provide information about group sizes and space requirements of sheep which is of some use to those managing sheep in rather similar situations on hill farms. (Jewell, Milner, & Boyd 1974).

The conditions of housing and the density of stocking of farm animals are of course dictated by economic pressures. It is easy to point to a wide range of behavioural studies and to assert that the conditions are far from the optimum for the species, but if the optimum costs more but does not provide any return in the form of an adequate increase in animal production, the farmer will not change the conditions. Certain minimum standards of animal housing, below which the husbandry method is considered cruel, exist as a result of general agreement among farmers and of certain legal limits which are based on the reports of government committees such as that of Brambell. Very often it is found that conditions of rearing which seem inhumane are not the best in terms of production; if the animals really are suffering discomfort they do not grow very well. Perhaps the only exceptions to this are the husbandry methods for very artificial markets such as that for white veal. The long term selection pressure exerted by man on his domestic animals has favoured strains which can tolerate the conditions under which they are kept. (Fuller 1969).

Our domestic animals flourish in conditions which may seem to involve some prolonged slight discomfort, but they must habituate to this. Possible adverse effects on production may occur consequent upon the lack of variety in their surroundings or due to repeated major disturbances. Evidence from a wide variety

of animals suggests that animals living in more complex conditions can cope with changes in their environment better than those in simpler conditions. Domestic animals with nothing to do sometimes perform stereotyped movements which are repeated for very long periods. These may have physically deleterious effects and certainly result in utilisation of energy so that there might be greater food uptake for a given gain in weight or output of eggs or milk. The effects in domestic animals of unexpected disturbance may be exacerbated due to the boredom of their lives. Some changes, however, would be disturbing to any animal. Ely and Peterson (1941) reported that milk let-down by dairy cattle was delayed if the animals were subjected to airport noise. A study has recently been initiated by Ewbank of Liverpool University in which the effects of the noise from Concorde on domestic animals will be assessed. As a result of general observation of behaviour by farmers and scientists, intensively farmed domestic animals are usually subjected to a similar routine each day and disturbances are minimal. There still remain questions as to whether frequent husbandry practices such as the movement of herds of dairy cows to new fields every two or three days, or moving newly weaned pigs from a field to a fattening house, might have some avoidable adverse effects.

Although farmers may not always be aware that they know a great deal about the behaviour of individual animals, their knowledge is immediately apparent when they recognise quite small abnormalities of behaviour in sick individuals. The experts in the study of abnormal behaviour are those who see it most frequently and Fraser (1974) considers that "all practising veterinarians rely heavily on behavioural observations in aiding arrival at a correct diagnosis of ill health". Fraser refers to peculiarities of posture, locomotion or reflexes, and to manifestations of localised pain which can be used as indicators of various diseases. Veterinarians are also likely to notice other anomalous behaviour such as the stereotypes already mentioned or peculiarities of feeding, sexual or maternal behaviour. Sometimes these can be attributed to dietary deficiencies, for example feather picking in turkeys which Hale and others were able to eliminate by feeding the birds with a greater proportion of fibre, (Hale Schleidt & Schein 1969). Other anomalies of behaviour have been found to be due to present or past inadequacies of housing or social experience. Much detailed behavioural work is still needed in this field so that husbandry methods can be improved and the anomalies reduced or eradicated.

Our domestic animals are descended from, and still remain, social animals, so studies of interactions within groups of the animals, of sexual behaviour and of maternal behaviour have been particularly important to the agriculture industry. It is possible to discover something about the optimum group size without making observations of behaviour, but the reasons for the optima are better understood where behaviour has been studied. The best composition of any group and the

methods of dealing with groups have been worked out after a long history of behaviour observation. The pioneering studies of the structure of social groups were carried out on the domestic chicken by Schelderup-Ebbe before 1920. He introduced the term "peck order" which is now colloquially applied to all species including man. The work of Guhl over a period of thirty years, starting with the paper by Guhl and Allee (1944), has emphasised the factors which affect hierarchies in groups of chickens and, particularly, the beneficial stabilising effects of the various orders once they are established. Fighting seldom occurs among established groups, but is likely to occur if new individuals are added to a group or if groups are mixed. These facts are now well known to chicken and turkey breeders, who have modified their husbandry methods accordingly. A variety of studies such as that of Schein and Fohrman (1955) have shown the existence of a complex social structure in groups of cattle. Recent work by Bouissou (e.g. 1972) has provided further information about factors which affect social structure and shows that animals kept together since birth show fewer aggresive interactions than those placed together at six or twelve months. Again it seems that stable groups are likely to be more successful than continually changing groups. Work by the author and J. D. Leaver, which is still in progress, indicates that calves reared in spatial isolation for eight months fail to show some normal social responses and show inadequacies in maternal behaviour. It is not yet known whether there are any effects on production. There have been many other studies of communication and social behaviour which suggest the optimum housing density, group size, and composition for a variety of domestic animal species but, as has already been mentioned, it has not always been possible to demonstrate that suggested biological optima are optima for animal production.

Animal breeders necessarily take much note of studies on sexual behaviour for they must be able to ensure that successful mating or successful artificial insemination occurs. There has been much progress in our understanding of the interactions between hormones and behaviour due to the work of Beach, Harris, Lehrman and others. Most information about sexual mechanisms in mammals and birds is relevant to domestic animals even if the subjects of the original studies were other species. Certain specific problems have to be solved by observing each species individually, for example the detection of œstrus. Where animals are kept in single sex groups the breeder must discover when the female is ready for fertilisation. A widely used behavioural method for detecting œstrus in pigs was developed by Signoret (Signoret and du Mesnil du Buisson 1961) who showed that gilts (females which have not yet had young) and sows in œstrus would often adopt a rigid posture when pressed on the back, especially when the smell or sound of a boar was present. Œstrus in not very easy to detect in ewes unless a ram is present, in which case the ewe may consort with him. Some ewes may not be mated even if a ram is present, so any observations which increase the likelihood

of fertilisation occurring are of wide economic importance. Work such as that of Bryant and Tomkins (1975) has provided useful information about the best ways of treating rams and of grouping ewes and rams so as to ensure that fertilisation occurs without wasting resources on rearing rams or unmated ewes.

Ever since the description of sexual imprinting by Heinroth and by Lorenz (1935) the effects of early rearing conditions have been considered as possible causes for anomalous sexual behaviour. Much subsequent work on this subject has been carried out using poultry or, in some cases, ruminants as experimental animals, so the results can be directly applied to farming. Animals reared without contact with potential mates may address their sexual responses to inappropriate partners or may be unable to copulate adequately. The latter problem is normally solved by practice, but some individuals who respond sexually to man or to their own sex may never breed normally. This is a particular problem with turkeys (Hale, Schleidt, and Schein 1969) and rearing conditions may also lead to some difficulties with rams and other species.

Once fertilisation has occurred, changes in behaviour are apparent before egg-laying or parturition. Farmers need to know when these events will occur and the readily detectable symptoms are largely behavioural, so once again veterinarians are often expert in recognizing them (Frazer 1974). Nesting of hens has been much studied, for example, by Wood Gush (1971) who, together with Gilbert, has discovered much about the interaction of hormones and nesting behaviour. Consequent upon such work, conditions which are more favourable to egg-laying can be provided for hens.

Mother mammals must accept their young and allow them to suckle. The previous experience of the mother may adversely affect her maternal behaviour, or the young may be unable to feed due to housing conditions or husbandry methods. Studies by Selman and others have emphasised the importance of the first milk (colostrum) for calves and have shown that the behaviour of the mother and the preferences of the young are important in ensuring that essential proteins are ingested by the calf. Collias (1956) reported that sheep and goats might reject their young if separated from them for more than a few hours immediately after parturition, and in several recent studies Baldwin and Shillito have demonstrated the methods used by ewes for recognizing their lambs, so husbandry methods have taken some account of this. The selection pressure on domestic mammals has been in favour of good maternal behaviour, but the reverse applies in chickens where broodiness is undesirable.

A point which will be apparent from the problems of domestic animal husbandry mentioned so far, is that the effects of the previous experience of the animals can often be experimentally studied and such effects may be important. The vast literature on problem solving by animals is also relevent to animal husbandry, for there is a trend towards elaborate methods for providing the desired

amount of food and water and these often require that the animal performs a complex movement in order to feed or drink. For example, some self feeders for pigs are at least as complex as the average learning test chamber for laboratory rats or pigeons.

Farm workers

The management of farm animals is a skill which can be acquired with practice, but that acquisition is much accelerated if the observations of those trained in the study of behaviour are heeded. The farm animal and the farm worker are most vulnerable to accident in conditions where the animal is restrained or is being restrained. Methods of handling in such situations have been reviewed by Ewbank (1968), by Fraser (1974), and in several animal husbandry books. Many other points about domestic animal behaviour are also relevant, for contented animals are easier to manage. A further way in which learning studies have aided farmers is in the training of sheep-dogs. The dogs are invaluable on many sheep farms and have been efficiently trained for many years before experimental studies were carried out, but the collection of information about training methods and the integration of this with the knowledge gained from other learning studies now allows a beginner to attempt the training procedures.

Farm workers can be assisted not only by observations of domestic animals, but also by observations of the time and effort which they themselves use in order to complete a task. Boss and Pond (1947) recommended careful observation of the ways in which jobs are carried out so that any possible simplifications of body movements or reduction in travel be made, whether the job be picking potatoes or feeding cows. Similar advice is offered by Blagburn (1961) who also points out that changes in procedure are useful only if they enable each member to handle more productive units and if the value of any change is adequately communicated to all those involved in the work.

Pest control

Most of the animals which are pests of agriculture compete with man directly by eating our growing crops or by eating stored crops or products made from crops. Some animals attack our domestic animals and, like the tsetse fly, their effects may be reduced by studying the behaviour and distribution of the pest and trying to avoid it as much as possible. Pests of crops may be combatted by reducing the incidence of their contact with the crop by scaring them, diverting them elsewhere, or repelling them chemically or physically; or by controlling their numbers with chemicals, guns, traps, or biological methods. Behavioural observations may be important for all control measures. Even where pesticides are used, the response of the pest to lethal or sub-lethal doses must be ascertained.

Pest scaring is most important where the pests are birds or mammals. The African finch *Quelea quelea* is of great economic importance in various equatorial African countries, and most control methods have proved either impossibly expensive or ineffectual. The use of bird scarers, such as people, visually alarming objects or exploders has been found to be the best method of reducing their depredations in intensively farmed areas (Crook & Ward 1968). The behaviour of the pest when startled must be studied in detail in order to choose the best method. Various other birds and mammals are controlled in part by scaring and there are some examples of this method being used for insects: Cherrett et al (1971) report that nocturnal oviposition by the European corn-borer moth *Ostrinia nubilalis* is more than halved by simulating the sounds of the bat which preys on the moth.

In order to direct pests from crops, or to decide upon a suitable bait for posoning the pest, it is necessary to study the preferences of the pest. Substances may be attractive because they are like food, or like sexual partners, or social companions in some way. Pigeon and duck shooters have long used decoys to attract birds down to the ground, but most of the economically important uses of such methods relate to olfactory attractants. One of the best examples of the use of a chemical attractant is that reported by Beroza (1970). The Mediterranean fruit fly *Ceratitis capitata* and the oriental fruit fly *Dacus dorsalis* have sometimes been accidentally imported into the U.S.A. and have caused much damage to fruit before being brought under control by expensive pesticide spraying operations. The discovery that the artificially produced substances Trimedlure and methyl eugenol are very attractive to these flies has allowed the capture of a very high proportion of the flies arriving at ports by means of traps baited with these substances. An example of the use of naturally occurring substances as bait for traps is the work of Tumlinson et al (1970) on the cotton boll weevil *Anthonomus grandis*. A chemical which can be extracted from the male is a pheromone which is more attractive to both males and females than is cotton, so very large numbers of the weevils can be trapped in the cotton fields. Other attractants are foods or are substances which pests will eat such as metaldehyde which is used as slug bait.

Research into the behavioural responses of pests to various naturally occurring or artificially produced chemicals has also revealed the existence of repellents like dimethyl phthalate and N N diethyl-m-toluamide which repel biting insects when spread on the skin. The use of repellents protect crops against pests is at present being explored for bird, mammal and insect pests. Some bird repellents and many insect repellents are available and the use of tar-rings on apple trees to prevent female gypsy moths from crawling up them is an example of such methods in operation. Stored products are fequently protected physically by their containers, but pests can sometimes be kept away from the products by observing their general behaviour and altering the storage methods appropriately. Crops can be protected physically by means of netting which excludes birds or insects.

The effects of toxic chemicals can be assessed by the changes in the pest population, but sometimes undesirable side effects occur due to the modification of the behaviour of the pest by the pesticide. Cherrett et al (1971) quote the example of the increase in the incidence of virus diseases on plants treated with a systemic insecticide to control aphids. The aphids carry virus diseases and detailed observation showed that they probed a plant and moved on much more frequently if the insecticide was present, so they were likely to transmit the disease to several plants instead of staying to feed on one plant. The behaviour of rats is also altered if they eat poisoned grain. Rzóska (1954) showed that after eating one of a variety of poisons, rats showed increasing hesitation before eating and then refused further bait. If the animal had not taken a lethal dose of the poison, it might refuse similar food for as much as one year and might communicate its unwillingness to eat the food to other rats. This behavioural observation has altered the ways in which bait is distributed by those trying to control rats by poisoning. Another method of controlling rats is to trap them, but the ways in which traps are set have been altered as a result of behaviour studies such as that of Shorten (1954). She reviewed the responses of rats to new objects in areas familiar to them. Traps, or any other novel objects, were often avoided for many days or even weeks even if baited, so novelty must be minimised when trapping rats.

General studies of the behaviour of pest animals are of value whatever the control method to be used. Studies of small mammal pests have provided information on the best places to put traps or poisoned bait. Wide ranging animals whose habitat preferences are known may even be avoided altogether by refraining from planting crops in places preferred by the pest. Studies of sexual behaviour have been essential in attempts to control insect pests by the introduction of large numbers of sterile males into the population. The times of flying or other activity, and studies of responses to physical factors, such as the work of Kennedy (e.g. 1966) on aphid settling behaviour, are important to those who have to decide when and how to spray crops. Work on the behaviour of bees has been of considerable importance to agriculture. The foraging, navigation, and communication of bees has been carefully investigated (Ribbands 1953) and the results have led to improved methods of keeping bees and hence to improvements in the efficiency of pollination of certain crops. It has been essential to discover the responses of bees to pesticides where the crop is pollinated by bees.

Conclusions

The importance of behaviour study to a wide variety of problems of agriculture is increasing. Many other lines or research must also be pursued, but the increase in the efficiency of farming methods, which sometimes results in greater density of domestic animals and crops, means that behavioural factors, which have not always been of obvious importance in the past, are now seen to be worthy subjects

for research. The increasing sophistication of methods used in behavioural research should allow this challenge to be met.

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