SOME ECOLOGICAL ASPECTS OF FUTURE RUMINANT RESEARCH IN AUSTRALIA

(Invited Paper)

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I. INTRODUCTION

Animal products are derived from the forage produced by pasture plants, many of which have special requirements for nutrients, moisture, temperature and solar radiation. Plants convert these abiotic components of the environment into living material from which animals produce articles of use to man. Research into animal production aims primarily at enhancing the efficiency with which increased quantities of meat, milk, hides, fibres, gametes and off-spring are produced. In Australia this research needs to be conducted mainly in the context of pastoral industries, in which animals remain at pasture throughout the year.

The major ecological community is the natural assemblage of both plants and animals, which, with their habitat, have reached a survival level which is relatively independent of other assemblages of equal rank. During the first 50 years of settlement of pastoral Australia, planned changes in animal populations led to substantial (Williams 1962) and frequently degenerative changes in plant communities (Beadle 1959). During the last four decades new assemblages of plants have been introduced and maintained in extensive areas of temperate Australia. Thus in the modern concept of pastoral production man aims at controlling the assemblages of both plants and animals, so as to ensure survival of the former and maximum production from the latter. Ecology is the science of interactions between abiotic and biotic resources within communities. It provides a basic approach to the development of natural resources and it is concerned frequently with general principles that apply to both plants and animals.

The techniques of ecological research are both descriptive and experimental. The science of ecology has many important interrelations with other disciplines and ecological studies can play an integrating role for the large number of specialist contributions designed to further animal production. In his studies, the ecologist is frequently called upon to assess the use that can be made of available knowledge and to uncover problems whose solution demands the acquisition of new knowledge by specialists working in other fields, whose contributions may illuminate the ecology of domestic animals, though they may not constitute ecological research.

There is a considerable body of descriptive ecological literature dealing with natural communities. There is scope to extend this to descriptions of the stratifications within the communities basic to animal production in pastoral Australia.

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The use of such an approach might be criticized as failing to contribute new knowledge. However, the work of documenting adequate descriptions will quickly reveal deficiencies in knowledge that need to be rectified and accurate descriptive accounts can provide the starting point for meaningful measurements.

Only three facets of ecological research will be mentioned briefly in this paper.

II. THE HABITAT

Man decides on, and greatly influences the habitats that domestic animals occupy.

The settlement of pastoral Australia was largely fortuitous. After 1840, pastoralists quickly followed the routes of the explorers Mitchell, Hume and Hovel, Leichhardt, Burke and Wills, the Forrests, McDowell Stuart and Giles; within 50 years most of pastoral Australia was occupied. The available records seldom reveal why these early pioneers chose either sheep or cattle for settlement in undefined environments. Disease, parasitism, seeds which damaged the wool, the inability of either sheep or of cattle to thrive in certain localities and economic conditions prompted many of the secondary migrations that occurred. The ability of sheep to survive seems to have been the main, rather crude but effective, criterion for land use. Since 1890 the socio-economic conditions that developed respectively around the raising of sheep and of cattle have preserved the early distribution of domestic livestock. Thus the way of life of the people, the capital investment in shearing sheds and fences, and the reticulation of artesian water through bore drains have all made their contribution to maintaining various forms of land use within the pastoral ecosystem.

Changes in the distribution of domestic animals have resulted from:
(a) The provision of water for livestock.
(b) Pasture improvement, based on appropriate fertilizer treatments and the sowing of introduced pasture species. In their natural state much of the south-west of Western Australia and the south-east of South Australia were incapable of supporting domestic livestock; following pasture improvement these areas now carry large sheep populations.
(c) Reductions in the population of animals that compete with domestic animals for the available pasture.
(d) The control of parasitism which has allowed the maintenance of breeding flocks.
(e) Deterioration in the native pastures in the north-west of Western Australia and in south-western Queensland, which has led to the substitution of cattle for sheep, or the complete abandonment of extensive areas.
(f) Predation by dingoes (Canis dingo), as the result of which sheep have been displaced from some parts of north Queensland, north-west of Western Australia and central Australia.

Pasture improvement resulted from the study of the available records for rainfall and evaporation, research into the nutrients essential to plants and to animals, and from the introduction of pasture species that would thrive under specific climatic conditions. However, there is still a serious lack of precise information about the Australian pastoral environment. Less than a score of pertinent contributions have been noted in the Australian climatological literature.
Few authors have used comparable methods and only Davidson (1936), Lawrence (1937), Trumble (1937, 1939), Prescott (1938), Hounam (1947), Farmer, Everist and Moule (1947), and Everist and Moule (1952) attempted to relate climatic data to pastoral regions.

Data giving daily rainfall and maximum and minimum temperatures are difficult to obtain; data for radiation, the daily march of air temperatures, and in many instances for evaporation, do not exist.

The ecology of many important native plants that provide forage for sheep and cattle is unknown. There is only partial documentation of the enormous ecological changes, which have occurred in the indigenous plant communities of Western Australia (Suijdendorp 1953), South Australia (Osborn, Wood and Palt-ridge 1932), New South Wales (Condon 1949; Williams 1962) and in south-western Queensland (Ratcliffe 1936, 1937).

Inadequate information is available about the effects of the physical environment upon ruminants in Australia (Macfarlane 1962). The place of the animal within its environment and interactions between domestic animals and components of their environment have been reviewed recently (Moule 1962a). The implications of field investigations are revealed by some initial observations made (Arnold 1960a) upon the diel activities of sheep grazing row cultured lucerne (Medicago sativa) and Phalaris tuberosa. Stocking rates were adjusted so that the consumption by the sheep exceeded the rate of plant growth. As the sheep preferred leaf to stem, they selected material that had the highest nitrogen content. However, their daily nitrogen intake decreased as the result of selective grazing and heavy stocking rates. When the sheep were confined on a Phalaris-Trifolium subterraneum pasture grazed at different stocking rates, grazing time increased as the amount of forage available decreased (Arnold 1960b). The maintenance requirements of sheep at pasture (Lambourne 1961) appear to be related roughly to both the live weight and the time that animals spend grazing. Thus two avenues for future ecological research which should prove fruitful are:

(a) More precise regional definitions of the various environments where ruminants occur.

(b) The interactions between the nutritional components of the environment and animals that influence production.

(c) The response physiology of animals exposed to different environments.

III. ANIMAL POPULATIONS

The sizes of the animal populations and the rapidity with which they can be increased are the most important factors influencing animal production.

In the various statistical registers data are available about changes in the populations of domestic animals in Australia as well as in individual States and, in some instances, in extensive regions.

The available statistics for populations of sheep and cattle show trends typical of the logistic curves that portray the changes that occur when a new species is introduced into an environment it can exploit. Following the early introductions, animal numbers increased slowly at first, and then rapidly until a plateau was reached.
In Queensland, the sheep population has fluctuated around a mean of about 20 million, first attained over 70 years ago. New South Wales was unable to maintain its peak population of 62 million sheep first attained in 1892; 64 years elapsed before the State’s sheep population again reached 62 million. However, in the decade 1880-1890 irreparable damage was done to plant communities in the Western Division (Beadle 1948). In Victoria, sheep numbers have not increased rapidly with the development of improved pastures, but marked increases have occurred in the number of beef cattle. In Tasmania, South Australia and Western Australia a second steep increase is occurring in sheep populations. These increases have been due largely to the development of pasture improvement and to reductions in the rabbit populations.

These changes in the growth curves of the populations of domestic animals reflect changes in the amounts of forage available. Such trends can be understood only if the causal relations are known between increases in the animal production and:

(a) The rate at which pasture improvement proceeds.
(b) The capacity for increase of the species comprising the populations of domestic animals.
(c) The interactions between rate of pasture improvement, the capacity for increase, and the management imposed by man.

The rate at which pasture improvement proceeds is likely to be controlled largely by financial considerations. Aspects of this problem, which seem likely to be worthy of future attack, include studies to determine:

(a) The optimum rate at which to proceed with pasture improvement on any one property.
(b) The safest way to obtain maximum animal production from improved pasture.

The urgency that surrounds finding a solution to these problems is reflected by two figures recently reported by the Bureau of Agricultural Economics. So far, pastures have been sown in only one third of the area suited to improvement in the Mediterranean environment. Current estimates are that the gap between an adequate level of use of improved pasture and the present general level of use is so large that each acre of improved pasture has added only 1.3 ewe equivalents to the national flock (Kinsman and McLennan 1961), although many field experiments indicate that this figure could be doubled or trebled.

The capacity for increase of hypothetical in flocks and herds can be easily calculated, but there is a serious lack of data from which reasonable estimates can be made of the respective contributions to low reproduction rates by the environment, by management imposed on breeding flocks and the interaction between these two factors.

Animal populations have general attributes that are worthy of detailed investigations. In summary these are:

(a) A structure and comparison, which are constant at any moment, but which change with age. There is scope for the use of mathematical models in studying the age and sex structure of populations. For instance, optimal yields from herds of beef cattle can be calculated from formula already available (Granger and Walsh 1960). However, no publication reporting the vital statistics of cattle
herds has been noted. There is also a lack of information about vital statistics of sheep flocks. Some data may be derived from a number of papers (Allden 1956; Dun, Ahmed and Morant 1960; Granger 1944; Morley 1948; Turner, Dolling and Sheaffe 1959), but there are sufficient data in only one (Moule 1964) to permit the calculation of the capacity for increase of Merino flocks. Because of the low reproduction rates of Australian flocks and herds, difficulty may be encountered in achieving the changes in flock structure that the model approach may reveal to be desirable for either meat or wool production. Thus the main fields of biological research within species lie in those factors that influence the pivotal age (Andrewartha and Birch 1954) of first mating, death and hence survival rates, fertility and female fecundity. Interactions between species within a population do not appear to have been examined except in such obvious matters as cross-infections of disease and parasites. Such other facets as competition for forage and the effects of photosynthetic rates of species-differences in grazing habits, the translocation of nutrients and the combined effects of these factors on the structure and composition of animal populations, including those below the soil, offer scope for fruitful investigation.

(b) Ontogenesis, i.e. an ability to grow, differentiate, maintain numbers, or to senescence and die. Decisions basic to the management of breeding flocks will influence this attribute of populations of domestic animals, but this does not imply that there is no scope for investigations into factors that influence ontogenesis. The decreases in lamb marking percentages which occur with decreasing latitudes (Moule 1962b) and the inability of flocks in the north-west of Western Australia to maintain their numbers (Suijdendorp 1953) provide challenging examples of problems worthy of more detailed study. There is also need for work on the ontogenesis of populations of native and feral animals that may influence the productivity of the pastoral ecosystem. These include such animals as earthworms, pasture pests, rabbits, kangaroos and feral donkeys, which compete for the available pasture, and dingoes which prey on live stock.

(c) An heredity, whose use is based on relatively simple concepts (Rae 1962). Heredity provides opportunities to change animal production, as for example by the selection of fine, rather than strong wool producing sheep. Current concepts of selection within breeds assume that productive characters are controlled by many genes, each with small additive effects. The main applications of these concepts in animal breeding have been the calculation of heritabilities of various traits, the use of measurements as an aid to phenotypic selection and the use of progeny or family tests, and of genetic correlations to increase the accuracy of genotypic selection for such characters as tractability, longevity in adverse environments and for high levels of production of offspring, milk, growth of body tissues and of useful fibres. Very slow progress can be made from the application of these genetic principles in any programme of animal breeding. In consequence some people are inclined to suggest that existing breed and stud structures be ignored and that new breeds be developed. The establishment of new breeds would probably take 20 years for sheep and perhaps 50 years for cattle. Other problems would then have to be overcome; sufficient numbers of animals belonging to the new breeds would then have to be produced to influence the nations flocks and herds. Thus no
optimistic forecasts can be given for the immediate ecological outcome of work on animal breeding that diverges markedly from existing breed structures.

Thus the main avenues for investigations in the immediate future appear to be:

(i) The establishment and use of genetic correlations between physiological characters that can be easily recognized in young animals and those which influence production. Evaluations of the characters which exert important influences upon production are a pre-requisite to the development of such an approach.

Consideration of factors that influence adaptation to tropical conditions may be especially necessary as such a large portion of the beef cattle and some sheep occur in northern Australia. Until recently, few serious attempts were made to integrate genetic and ecological factors in animal research.

(ii) The introduction of genes controlling physiological characters that influence production and which are required by animal populations in order to meet the impact of specific environments. This approach receives enthusiastic support from a number of animal workers. Genetic research with large animals is slow and expensive. The introduction of new genes and the ensuing hybrid vigour creates new problems, whose correction may retard the rate of progress. Therefore, it is suggested that it would be advisable to investigate adequately the range of genetic material among animals already available in Australia before embarking on a programme of importation.

(iii) Attempts to change by selection the established pattern of production. Work within C.S.I.R.O.'s Division of Animal Genetics, which aims at increasing the numbers of primary follicles per follicle group, or alternatively work which might be undertaken to increase the secondary : primary follicle ratio in Merino sheep provides challenging examples of this approach.

(d) Integration by both genetic and ecological factors, which operate independently, take place within ecosystems. Few such occurrences have been investigated for domestic animals in Australia. For instance, cattle with rough coats (Dowling 1960) and sheep with wrinkly skins (Dun 1956a, b) may be less productive in hot climates than those with smooth coats or plain skins respectively. Theoretically, the rate at which integration occurs and the direction in which it proceeds can be influenced by the selection of animals suited to particular environments or by modifying the environment. Unfortunately, only recently have attempts been made to investigate this possibility.

(e) An ability of animal populations to meet the impact of the environment and, reciprocally, to alter the effective environment present the research worker with formidable problems. It is inevitable that grazing pressure will induce changes in pasture; questions about the cognizance that will be taken of these changes are difficult to answer when experiments are being designed. Two approaches seem to have been used: Some animal workers have chosen to ignore such changes and some agronomists have recorded them without due consideration of the grazing periods of moisture shortage emerges as being fundamental to future research into done it may be necessary to devise better techniques for measuring effective changes in both plant and animal communities.
IV. THE COMMUNITY

The productive community is concerned essentially with the conversion of solar energy into such useful products as meat, milk, fibre and population increases. This conversion is achieved first by the process of photosynthesis and, secondly, through the energy metabolism of the grazing animal. The next few years will see techniques which will permit reasonable estimates under field conditions of the energy requirements for reproduction, lactation, body growth, etc. These data will be useful to measure the efficiency of different forms of animal production. Such studies will probably reveal that low insolation is not a factor limiting animal production; adverse effects of low insolation have been recognized only during cloudy winters in southern Victoria and Tasmania (Franklin 1953).

It is likely that the most promising avenues for increasing the rate of energy flow through system lies in research designed to:

(a) Control the assemblages of plants. There is considerable scope for the use of ecotypes and for the development of new varieties of plants particularly suited to the wheat-sheep zone, adjacent to the high rainfall zone with a Mediterranean climate. Agronomic considerations will be important in the selection of such plants, but the special nutritional requirements of ruminants must also be kept in mind.

(b) Reveal grazing pressures which will ensure that an optimum proportion of the solar radiation is captured by the available leaf area. High stocking rates which increase the rate of pasture consumption will increase the rate at which energy flows through the system, but the optimum rate of energy flow needs to be determined.

The development of such an approach is likely to commence with a study of the soil. Severe limitations on animal production in Australia have been removed by appropriate manurial treatments. However, no reports have been noted of studies of the rate at which essential elements circulate through productive ecosystems. Topdressing with superphosphate is expensive and a very large proportion of the phosphorus it provides is quickly bound in the soil and is either lost, or later released slowly for uptake by the plant. The intermediary metabolism of phosphorus has been studied in a number of animal species, whose requirements are known. A phosphorosis is said to be common in cattle in semi-arid pastoral Australia but the occurrence and etiology of the condition is inadequately documented. Large amounts of phosphorus are removed in bone, meat and milk; but the initial limitation on the availability of phosphorus to pasture plants means increasing soil stores which are prone to loss through leaching, erosion, etc. Similar situations, which may prevail with such other elements as copper, cobalt, sulphur, selenium and nitrogen are worthy of study.

Investigations into factors which control the rates at which different elements circulate through the system can be of interest for a number of reasons including:

(a) The intrinsic value of understanding the mechanisms underlying animal production.

(b) The effects of different circulatory rates of minerals upon animal production.

(c) The conservation of natural resources.
(d) The contributions by different forms of animal production to the transference of nutrients either from the system or to other parts of it.

Considerable scope exists for the identification and selection of pasture plants which will be more highly productive of forage suited to production by ruminants. Stress has been laid upon the need for a high nitrogen content of pastures to be grazed by wool growing sheep (Marston 1954). The validity of this hypothesis is now in doubt. As the result of fermentation in the rumen, degradation of plant protein occurs; a large proportion of the available nitrogen is absorbed through the rumen wall as ammonia; some is recirculated through the saliva as urea (McDonald 1962). Bacterial protein provides most of the nitrogen reaching the abomasum and small intestine, and the efficiency of production may well depend upon the ability of ruminants to use amino acids derived from this source.

Present evidence suggests that, once the minimum nitrogen requirements of ruminants are met, the energy content of the pasture may exert the greatest effect on animal production. Thus future agronomic work might well concentrate a large part of its effort on the production of special purpose pastures for ruminants (Johns, Ulyatt and Glenday 1963). The ability of consumed forage to produce, upon fermentation in the rumen, large quantities of volatile fatty acids could be an extremely important criterion for the selection of pasture plants.

Sophisticated and useful work has been done in temperate Australia on various phases of pasture production ranging from studies in plant nutrients, the role of Rhizobia in the nodulation of legumes and the influence of leaf area index on photosynthetic rates. By comparison, the soil flora and fauna of tropical areas have received scant attention. Similarly studies of the physiological responses of animals to their physical environment have only just commenced. Until these have been advanced it will be difficult to interpret the results of any thorough analysis of the Australian pastoral environment.

Many environmental factors influence the productivity of animals. Considerable attention has been paid to such components of the physical environment as ambient air temperatures and photoperiodism (Hutchinson and Wodzicka-Tomaszewska 1961). However, a few attempts seem to have been made to identify which is the master factor that exerts the greatest influence over the physiology underlying production. For instance, there is a considerable amount of literature claiming that photoperiodism controls seasonal changes in reproduction, coat shedding and growth (Yeates 1954).

In most of these experiments the animals have been subject to a constant nutritional level in an attempt to isolate the effects of photoperiodism. However, in their true ecological setting ruminants are subject to many influences. Of these, the level of nutrition, with special reference to the availability of green forage (Williams and Schinckel 1962), may overrule, or at least modify, the influences exerted by changing day length and air temperature. Hence the need to study the effects of a number of environmental factors before attempting to extrapolate from isolated experiments to field conditions.

At the present rate of increase, Australia will carry approximately 200 million sheep and 20 million cattle by 2,000 A.D. Such rates of increase are too slow to keep pace with the demands of increasing human populations. It is likely that economic considerations will also demand more rapid increases in production.
The sizes of the animal populations and the rapidity with which they increase are the most important factors influencing animal production. Thus work that will provide knowledge which will allow different communities to carry more animals, and on the ways in which animal numbers can be increased is likely to be most fruitful in increasing production from ruminants. Experiments designed to give quantitative estimates of the law of diminishing returns will yield the most valuable economic data, provided reproduction is included as one of the criteria by which the results are judged. But the successful outcome of such investigations will lead to further problems arising out of increased density of animal populations.

The central problem in the study of every animal population is the difference between the potential and the actual life expectation. The history of animal production in Australia has been one of severe fluctuations in animal numbers, due largely to the occurrence of drought. Animal numbers have been limited by the amount of forage available during drought years, and the productivity of individual animals by the amount of forage available during periods of minimum plant growth. These problems are likely to be accentuated by increased density of animal populations. Thus investigations into the effects on whole communities of stressful periods of moisture shortage emerges as being fundamental to future research into the ecology of animal production in Australia.

V. CONCLUSIONS

The aim of ecological research into animal production is to further existing knowledge, and to provide new opportunities for industry. The application of useful research findings will lead to increased animal numbers. The maintenance of their productivity will depend largely on the way in which factors within the ecosystem can be controlled and husbanded. To do this efficiently, the present state of our knowledge needs to be expanded, with particular reference to the environments that domestic animals are required to use, the nature of the populations of productive animals and the communities from which animal products will be derived.

VI. REFERENCES


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