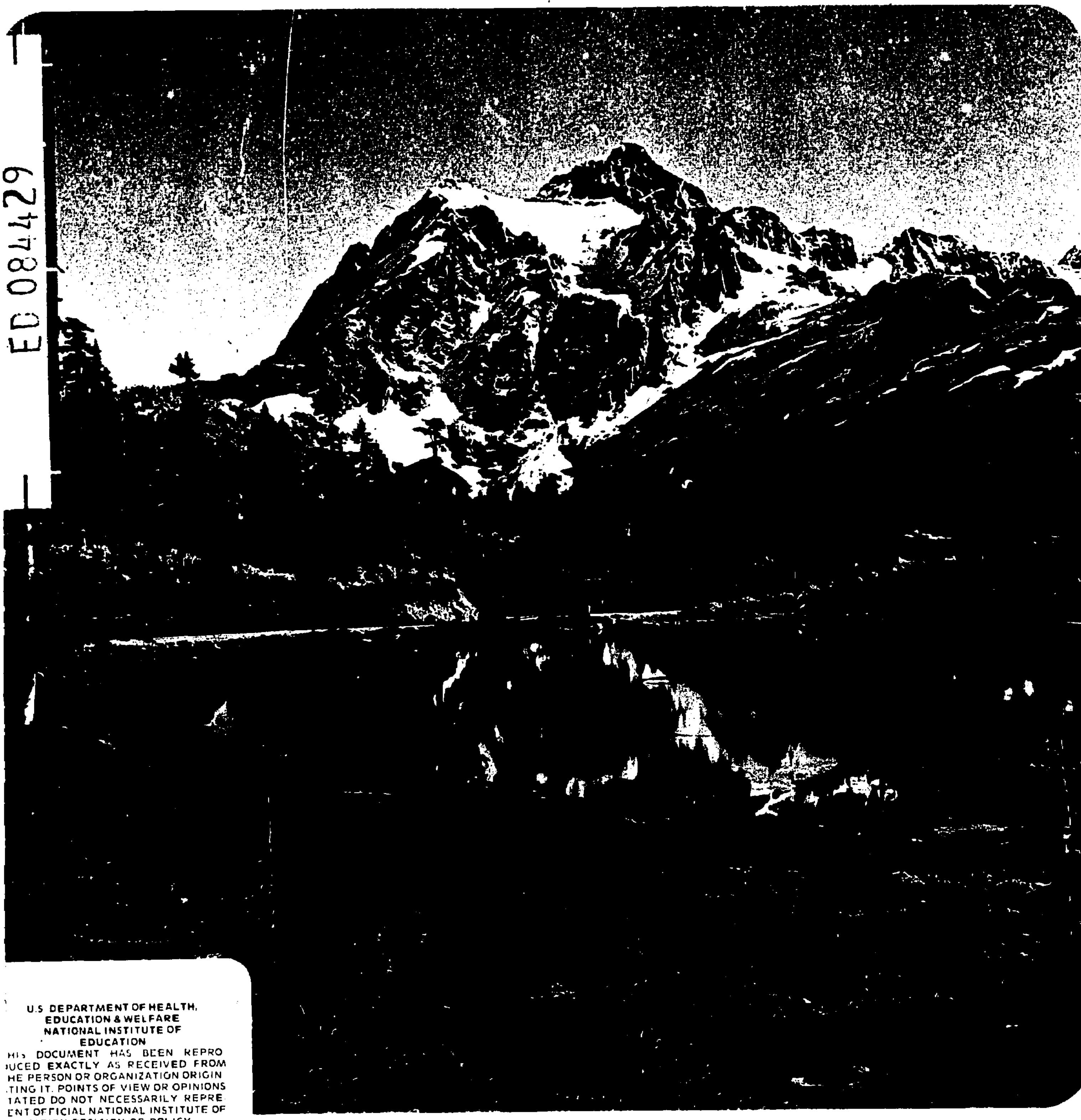
DOCUMENT RESUME

ED 084 429 CE 000 624

AUTHOR	Tulloch, Rodney W.
TITLE	Animals. Ag Ed Environmental Education Series.
INSTITUTION	Washington State Coordinating Council for Occupational Education, Olympia.; Washington State Univ., Pullman. Coll. of Education.
REPORT NO	73-3C
PUB DATE	Jul 72
NOTE	80p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Agriculture; Animal Facilities; *Animal Science; Disease Control; Entomology; *Environmental Education; High School Curriculum; *Livestock; Resource Materials; *Vocational Agriculture; Waste Disposal; Wildlife Management

ABSTRACT

Animals are the subject of the student resource unit which is to be used with high school vocational agriculture students. Animal housing and equipment, the first section, deals with controlled environment, energy requirements, esthetics, air, water, and noise. Animal waste and byproducts are covered in terms of Federal government program, some of which are reported. The public health and socioeconomic implications of animal waste disposal are described. Meat and poultry packing and dairy processing produce significant effluent. In discussing disease prevention by means of parasite and vector control, infectious diseases and their treatment are covered. Beneficial and harmful insects and their control are described. The importance of wild animals in terms of the damage they can do to agriculture and the land is significant, but the treatment of wildlife and social values are related. There is a 29-item bibliography. (MS)



Ag Ed Environmental Education Series

ANIMALS

WASHINGTON STATE UNIVERSITY IN COOPERATION WITH THE COORDINATING COUNCIL FOR OCCUPATIONAL EDUCATION.

73-3C

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Cover Photo:

Mt. Shuksan
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Environmental Education Series

- Air
- Agricultural Chemicals and Radiation
- Animals
- Land Use
- Noise
- Plants
- Understanding the Environment
- Water

ANIMALS

by

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FOREWORD

This publication is the product of a project carried on by the Coordinating Council for Occupational Education and the Department of Education, Washington State University.

The project grew out of a recognition of the need to include as a part of the high school vocational agriculture curriculum information dealing with the environment, particularly as it relates to agriculture. The project was preceded by a period of growing concern that a body of factual information and teacher resources needed to be developed in this area.

E. M. Webb, associate professor of agricultural education emeritus, first suggested that steps be taken to make available to teachers of agriculture and their students factual information on the environment and agriculture. It was through the efforts of Jay Wood, program director, agricultural education, Olympia, that a project was prepared and approved beginning in September 1970.

Valuable assistance was given the project by many persons from the following agencies: Washington State University, University of Washington, Western Washington State College, Soil Conservation Service, United States Department of Agriculture, United States Department of the Interior, Washington Parks and Recreation Department, Washington Department of Ecology, Washington Department of Natural Resources, Washington Department of Agriculture, Washington Department of Fisheries, Washington Water Pollution Control Commission, Environmental Protection Agency, and Washington Department of Game. Many other agencies provided information for the project.

Three publications were extremely useful in preparing this unit. They were *Environmental Quality: The First Annual Report of the Council on Environmental Quality*, *Environmental Quality: The Second Annual Report of the Council on Environmental Quality*, and *Wastes in Relation to Agriculture and Forestry*. Information from these publications was used as a basis for much of this unit.

Grateful acknowledgment is hereby made to the following groups of people: Dr. C. O. Loreen and Dr. Keith E. Fiscus, both teacher-educators and state supervisors in agricultural education, and Mr. Jay M. Wood, program director, agricultural education, who gave able assistance to this endeavor. Mr. Darrel Manthey, Mr. Garry Newman, and Mr. Glenn Paulson, teachers of agricultural education in Washington high schools, reviewed the unit, developed teaching materials to be used with the unit, and taught the unit to their students. Many other teachers also made valuable contributions to the project.

The following subject-matter specialists reviewed the unit: Dr. M. H. Ehlers, professor of animal sciences, Washington State University, Mr. Russel Hupe, environmentalist, Department of Game, State of Washington, Dr. J. B. Johnson, extension animal scientist, Washington State University, Dr. William McReynolds, extension animal scientist, Washington State University, and Dr. Vincent Schultz, professor of zoology, Washington State University.

This unit is one of eight being produced under the project. The other seven include: *Understanding the Environment*, *Water*, *Noise*, *Agricultural Chemicals and Radiation*, *Plants*, *Air*, and *Land Use*.

July 1972 Rodney W. Tulloch

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INTRODUCTION

As more people have become aware of the environment, one of the areas receiving considerable attention is the area of animals. Books such as *Animal Machine* by Ruth Harrison have raised questions and sometimes have been highly critical of present methods of animal production. The subtitle of this book is "An Expose of 'Factory Farming' and Its Danger to the Public." Questions about the humaneness of confining large numbers of animals in relatively small spaces have been raised. Complaints have also been raised about methods of slaughtering animals.

These and other questions are often looked at very narrowly with little regard to what alternatives are possible. This unit is being written with the hope that both a better understanding of the problems and possible solutions to the problems will be realized.

ANIMAL HOUSING AND EQUIPMENT

In constructing new animal buildings, a number of factors need to be considered - construction and maintenance costs, durability, adaptability of design to allow for multiple use, labor requirements, protection for animals including adequate space and reduction of extreme temperatures, esthetics or attractiveness of the buildings, ventilation and humidity, windows and light, cleaning and sanitation, location and design, and water supply. Many of these factors are discussed in some detail in basic books on animal production. Some of these factors have a much greater effect on the environment than others, and some of these will be chosen for discussion in more detail in this unit.

Controlled Environment

The environment required varies with the type, size, and breed of animal, as well as the time of year. For example, European cattle producing milk may function effectively in a range from about 30° to 75° F. Slow fluctuations within this range seem to have relatively little effect on milk production, but temperatures beyond this range appear to reduce production. In tropical breeds, such as Brahman, temperatures may reach as high as 100° F before production is much affected, indicating that there are some definite differences between breeds.

Controlled environment may produce faster growth and/or higher production, better quality, and may sometimes do it more economically. In controlling the environment, we cut the number or severity of stress factors affecting the animal. Some of these factors include temperature, humidity, ventilation and drafts, gas concentrations, light control, and the physical environment. Research leaves little doubt that various species and breeds respond best to certain ranges of environmental factors. The increased production or other benefits to be obtained and exact costs of controlling environmental factors have not been as carefully researched. Some things such as water have not had realistic economic values placed on them. This, in turn, makes realistic evaluations of the problems on an economic basis less than satisfactory.

There are several methods by which body temperature of animals is regulated. One method is radiation, which is the loss of heat given off by the body when air and other substances surrounding the body are lower than the body temperature. The kind and amount of surface that an animal has will affect the amount of radiation. The animal's activity and position also affect the amount of radiation. Generally, when there are a large number of animals in a relatively small area, the amount of radiation is decreased.

Heat losses due to conduction are regulated by the surface area of the animal, the type of surface exposed, the temperature of the surrounding air, and movement of air over the surface of the animal. It is through this phenomenon that breezes blowing around animals help them dissipate heat in the summertime. It is also through this phenomenon that draft may cause colds or other problems with animals in the wintertime.

Another source of heat loss may be conduction, which takes place when the animal is in contact with a surface. The losses due to conduction will depend on the temperature of the surface, the amount of surface being contacted by the animal, and the thermal conductivity of the substance. Many kinds of metal serve as excellent thermal conductors, and, therefore, it is particularly important in cold weather to provide bedding materials between animals and such surfaces to prevent large heat losses.

Another important source of heat loss occurring with many animals is that which takes place through evaporation. Evaporation of water from the skin may do a considerable amount of cooling. This is what takes place in the process of perspiration accompanied by currents of air. This phenomenon is not too important in farm animals because, with the exception of the horse, they have a small number of sweat glands. Substantial evaporation takes place, however, in the lungs through the process of breathing. Animals may compensate for hot weather by drinking greater quantities of water, breathing more rapidly, staying in the shade, wallowing (particularly in the case of pigs), eating less food, reducing activity, and assuming a position that allows better ventilation. In cold weather, animals save heat by eating more, by increasing deposits of fat, by growing longer and coarser hair, and by shivering. Heat losses may be reduced as the animals huddle together, thus reducing the surface area where heat loss is taking place.

For European dairy cattle, external temperature requirements are approximately 20° to 70° F, depending somewhat on the breed. The optimum range of temperature for milk production is approximately 50° to 60° F. The optimum temperature range for calves at birth is 50° to 60° F. The optimum range for beef cattle is 20° to 60° F. Piglets (baby pigs) are extremely sensitive to temperature changes, and the optimum temperature at birth is 80° F. This temperature can fall to 70° to 75° F at weaning time. It is interesting to note that, in contrast to the optimum temperature of the piglet, the optimum temperature of farrowing sows is 50° to 60° F. The optimum temperature for a fattening hog varies from the 70° to 75° F range at weaning time to approximately 60° F as a hog reaches the marketing weight of 190 or more pounds. In hot weather, pigs have been shown to gain better when they have access to a wallowing hole, which helps them cool down.

The optimum starting temperature for baby chicks is approximately 95° F with a 1° F per day drop to 60° F, which is about optimum for an adult chicken. The optimum range for broilers is approximately 60° to 70° F. The optimum range for laying poultry is approximately 50° to 60° F. Exposure of the young to extreme temperatures often results in higher mortality. The adults are usually much more able to cope with extreme temperatures than the young but show production losses as a result of suffering exposure to extreme temperatures. The condition of the young may also affect their ability to withstand extreme temperatures. This seems particularly true with pigs where larger piglets have been shown to be able to withstand more chilling than smaller piglets.

Much less is known about the effects of relative humidity on livestock than the effects of temperature. In many animals, experiments have shown few effects between 35% and 75% humidity. Humidity may become more important as it is combined with extreme temperatures. As humidity reaches approximately 80%, droplets often begin to form and fall from the ceilings. This adds dampness to the animals' bedding and other surrounding objects and allows them to dissipate heat at a faster rate. In cold weather, this may be particularly harmful in adding to an already uncomfortable situation for the animals. Combinations of high temperature and high humidity are particularly harmful because the animal is less able to dissipate heat by evaporation when humidity is high.

Table I shows the relative importance of temperature-humidity conditions.

Table I.—Livestock Weather Safety Index

Dry bulb temp (°F)	Relative humidity intervals (%)																			
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
75									70	70	71	71	72	72	73	73	74	74	75	75
76							70	70	70	71	72	72	72	73	74	74	74	75	76	76
77						70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78					70	70	71	71	72	72	73	74	74	75	75	76	76	77	78	78
79				70	70	71	72	72	73	73	74	74	Alert		76	77	77	78	78	79
80			70	70	71	72	72	73	73	74	74	75		76	77	78	78	79	79	80
81		70	70	71	71	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82		70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	70	71	71	72	73	73	74	75	75	76	77	78	78	79	Danger		81	82	82	83
84	70	71	72	72	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85			87
88	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84		Emergency		87	88
89	73	74	74	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	87	87	88	89	90
91	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	74	75	76	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90		
93	75	76	77	78	79	80	80	81	82	83	84	85	87	87	88	89	90			
94	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90				
95	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90					
96	76	77	78	79	80	81	82	84	84	86	87	88	89	90	91					
97	77	78	79	80	81	82	83	84	85	86	87	88	90	91						
98	77	78	79	80	82	83	84	85	86	87	88	89	90							
99	78	79	80	81	82	83	84	86	87	88	88	90								
100	78	79	80	82	83	84	85	86	87	88	90	91								
105	80	82	83	84	86	87	89	90	91											

Danger—Expect 25% or more increase in transit loss!
Emergency—Expect 45% or more increase in transit loss!!

Air movement has not been conclusively shown to be beneficial to nonsweating animals during hot weather. Winds can be harmful to animals at low temperatures. This is especially true if the animals are wet.

Even if thermometer readings are not extremely cold, frostbite may still result at extreme wind velocities. Wind increases evaporative cooling, dropping skin temperatures sharply.

U.S. Army experts have measured wind-chill factors for different temperature and room combinations to arrive at the equivalents shown in table II. The same principle applies to livestock, but not to inanimate objects.

Table II.—Wind Chill Chart

Estimated wind speed (mph)	Actual thermometer reading (°F)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	Equivalent temperature (°F)											
Calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-21	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-36	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-125
25	50	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-49	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148
Greater speeds have little additional effect.	Little danger for properly clothed person				Increasing danger			Great danger				
	Danger of freezing exposed flesh											

TO USE THE CHART, find the wind speed in the left column and the actual temperature (°F) in the top row. The equivalent temperature is found where these two intersect. For example, with a wind speed of 10 miles an hour and a temperature of -10°F, the equivalent temperature is -33°F.

Source: NANA

Another factor studied is the effect of light on animals. Pigs have shown little effect in experiments with light, so it seems natural that the minimum light required for good management is all that is needed. It has been known for many years that lengthening the day to 14 hours with artificial light can increase production of layers. (Layers are female birds that are producing eggs.) The importance of intensity of the lighting provided may often have been overemphasized. For example, light intensity may vary from less than 1 foot-candle to approximately 100 foot-candles without having any noticeable effect on growth. It may vary between 1-1/2 and 38 foot-candles without affecting egg production. Sixty-watt light bulbs spaced 9 feet apart and 6 feet above the birds will provide a light intensity of 3 foot-candles. Color of light has an effect on egg production and cannibalism. Cannibalism is when they peck at each other and can result in death. In broiler production, keeping the light intensity low has been shown to prevent excessive activity and also reduces the chances of pecking and cannibalism. As more research is carried out and a better understanding of the effects of light are obtained, alternative designs of lighting are established for the production of laying flocks. This includes both the intensity of the light and the number of hours per day that the birds are to be exposed to it. In the case of broiler production, it has been generally agreed that 24-hour light is as effective as any other method.

Stock densities (number of animals per given area) have been shown to strongly affect animals. As square feet per pig was dropped from 20 to 5 square feet, gains dropped by nearly 10%, average daily feed consumption increased, and feed per unit gained increased. Placing food and water near the animals encourages the intake of feed and water and requires the animal to use less energy to get it.

The foregoing factors and the facts included about them show that animals do better under controlled environment. However, intensive livestock production increases the possibility of disease. The poorer the control of the environment, the more the likelihood of disease. Even low-grade respiratory infections can lower conversion efficiency and rate of gain. The change in these two factors may well be the difference between profit and loss.

Most producers of animals are in the business to make a profit, which necessitates keeping expenses below the level of income from such animals. Considerable work has been done on the economics of controlled environment of poultry. The United Kingdom National Agricultural Advisory Service has compiled information from several surveys comparing the potential performances of poultry under free range and under intensive management. Their figures show that a bird in a controlled environment may be expected to produce up to 5 dozen eggs a year more than a bird on free range. The birds in a controlled environment can be expected to produce 2 dozen more eggs per year than birds kept intensively but without a controlled environment.

Feed conversion can be expected to improve from 7-3/4 pounds of feed per dozen eggs under free range to 4-1/2 pounds in a controlled environment. From figures such as these it has been estimated that increased profits in a controlled environment could be as much as 10%, depending on construction and operational costs. Chickens may produce more, however, in a fluctuating environment than a constant one.

Controlled-environment housing is not cheap. The cost of housing in a controlled environment for layers may be more than twice as much as that of free range. Some of the additional expense per square foot may be compensated for by the fact that the number of square feet per bird required for controlled environment may be cut drastically. By putting birds in cages, it may be possible to still further reduce the number of square feet required per bird.

The most important factor in deciding whether or not to go into controlled environment is the cost per unit of production. Some of the new housing units now available are very attractive. They are easy to maintain, require a minimum of labor, and provide for a maximum of growth and feed efficiency. Unfortunately, some are so expensive in original outlay that they make an operating profit nearly impossible. The return on capital may be very low at best.

Many animal producers provide well for their animals for the average conditions in their community. Perhaps their greatest error is the failure to provide for extremes. Certainly, every possibility cannot be realistically guarded against, but extremes that occur one year out of 10 or 20 should be expected each year. Statistics showing that extremes occur every so often do not imply that the same condition cannot repeat itself twice in the same year or in successive years. For instance, the experiences of a bad winter must be protected against in *all* winters, although the odds of its repetition may be only one in 10 or 20 years.

Each owner of animals who confines them in an artificial environment assumes the responsibility of providing an adequate environment. Even if the owner is willing to ignore the moral obligations, it is economically advisable to be prepared. Compare the loss of one day's milk production to the cost of a piece of equipment, then add the accumulated losses through continued lower production, increased incidence of diseases such as mastitis, inconvenience to the workers, etc.

Shared protection can include such things as portable generators, squeeze chutes, etc., which may be owned by cooperatives, farm organizations, or simply two or more neighbors. Such arrangements should be made on the basis that the likelihood of all members needing the equipment at the same time is small. Many groups already have such equipment.

Insurance can spread financial risk but cannot cover the personal hardships or *obligation of the owner to care for his animals.* Certainly, comprehensive insurance is a recommended way of spreading the risk of the numerous possible damages that occur only rarely.

The emphasis in this section has been on environmental stress or the importance of controlling the animal's environment. Research is revealing more about the optimum temperature, humidity, and other environmental factors for various animals and species. As additional information is obtained about the required environment, it must be incorporated into better design of buildings and equipment.

Other sources of stress that will be covered later in this unit are genetics, diseases, nutrition, and parasites.

Genetic stress may make the animal much less able to survive and be productive in a broad range of environmental conditions.

The most obvious and expensive losses are due to disease stress. Severe disease stress often results in death or other serious losses. Much needs to be done in the way of disease prevention rather than just disease treatment.

Many animals suffer nutritional stress due to inadequate nutrition because of lack of or poor quality feed or because nutrition is not improved during periods of stress brought on by disease, extreme environment, or high production. Improper balances of nutrients may also become a severe problem.

Parasites are another form of stress. Parasites can attack an animal either internally or externally. Because the external parasites are so much more obvious in their actions, historically more work has been done to combat them. Many of these parasites carry diseases and have other side effects that have been studied more intensively in recent years. This is particularly true of internal parasites about which new findings are being made daily.

Energy Requirements

Heat; lighting; movement of food, water, and air; as well as disposal of wastes all require energy. Production of energy is one of the leading sources of pollution. Therefore, it is important that careful planning be done in constructing buildings and equipment so as to reduce energy needs to minimal levels in the future.

Adequately insulating buildings will minimize the heating or cooling necessary. Avoiding wasted space (which must be heated or cooled) also cuts energy requirements.

A better understanding of the energy requirements of animals and satisfying these needs more optimally may increase production and efficiency. Much also remains to be done in studying animal heat and energy losses so that both production and efficiency can be improved through the application of such knowledge.

Lighting can be kept to a minimum possibly with a regulator that will allow higher intensities of light when needed. This will allow the animals to be exposed to the lower intensities most of the time, which keeps most animals less active and uses less heat but will still allow the lights to be turned up for closer examination of the animals and for other management functions.

Energy dissipation is necessary, particularly with ruminants. We often tend to keep animals at temperatures at which humans are comfortable rather than at temperatures that suit the animals.

Esthetics

Many persons enjoy the wide-open spaces of rangeland and pasture. The lush greenness of many of these areas has been improved considerably by cultural practices. Irrigation applied to rangeland and pasture has made their green appearance a sharp contrast to nearby desert-like conditions in many areas.

Pleasingly designed and well-kept buildings often add to the beauty of the countryside (fig. 1). Poorly designed or rundown buildings, on the other hand, may seriously mar the good looks of the countryside.

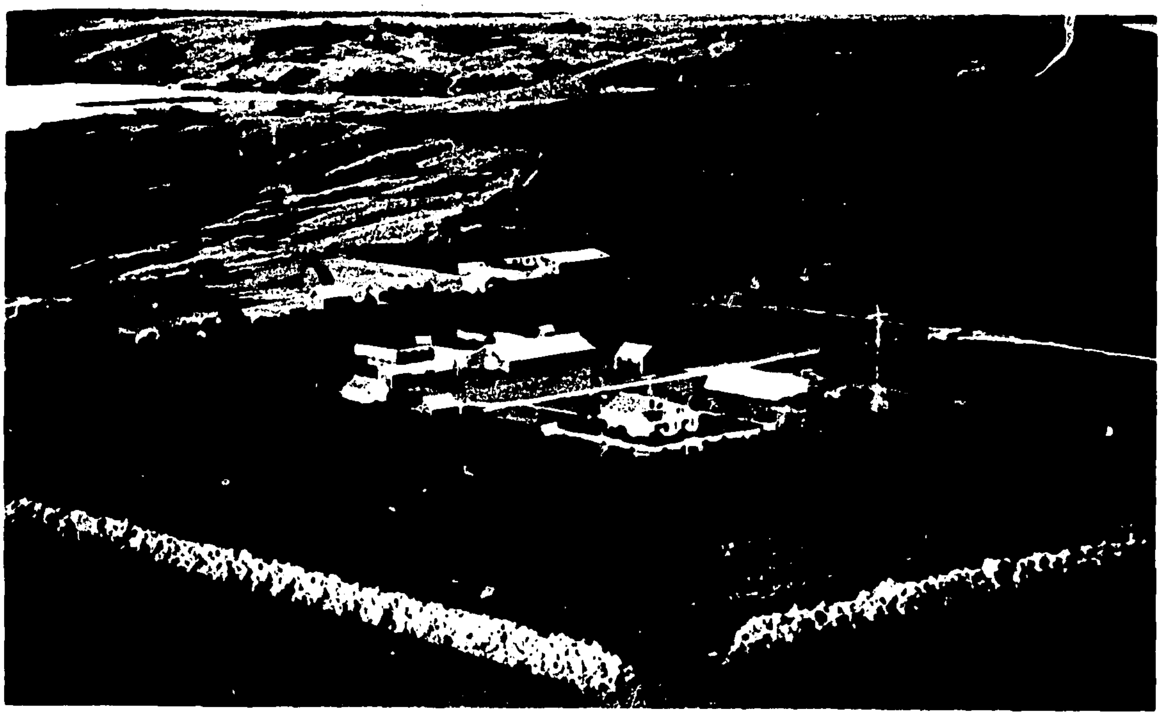

USDA Photo

Fig. 1.—Many persons would agree that well-kept buildings like these add beauty to the countryside.

Manure piles and improperly functioning lagoons, besides being a source of bad odors, may look bad because of the dark color of the water or runoff sludge and also because of any accompanying growth. Water near feedlots and manure sources may become so heavily loaded with organic materials that bacteriological decomposition changes from aerobic to anaerobic. This causes noxious gases and vile odors and turns the water dark. Winds blowing around feedlots may also pick up feed, hay and straw, manure, and other dust. The air then becomes clouded with the foreign material and deposits it on buildings, equipment, cars, houses, and anything else in the vicinity, further deteriorating the esthetics of the area.

Air

Animals are affected both directly and indirectly by air pollution. Indirectly, air pollution may affect the plants that animals eat, cutting down the quality or the quantity of feed from these plants. Some of the chemicals from the plants may be taken directly into the animal's body, causing severe problems. An example of one problem is a bone disease in cattle called fluorosis. Fluorosis is caused by fluoride and is particularly prevalent near such industries as steel, aluminum, and phosphate mills. The presence of fluoride may first be seen in a brownish discoloration of the animal's teeth. In some cases, as length or rate of exposure is increased, the animal may lose its teeth. In extremely severe cases of fluorosis, animals cannot bear the pain of standing (fig. 2).

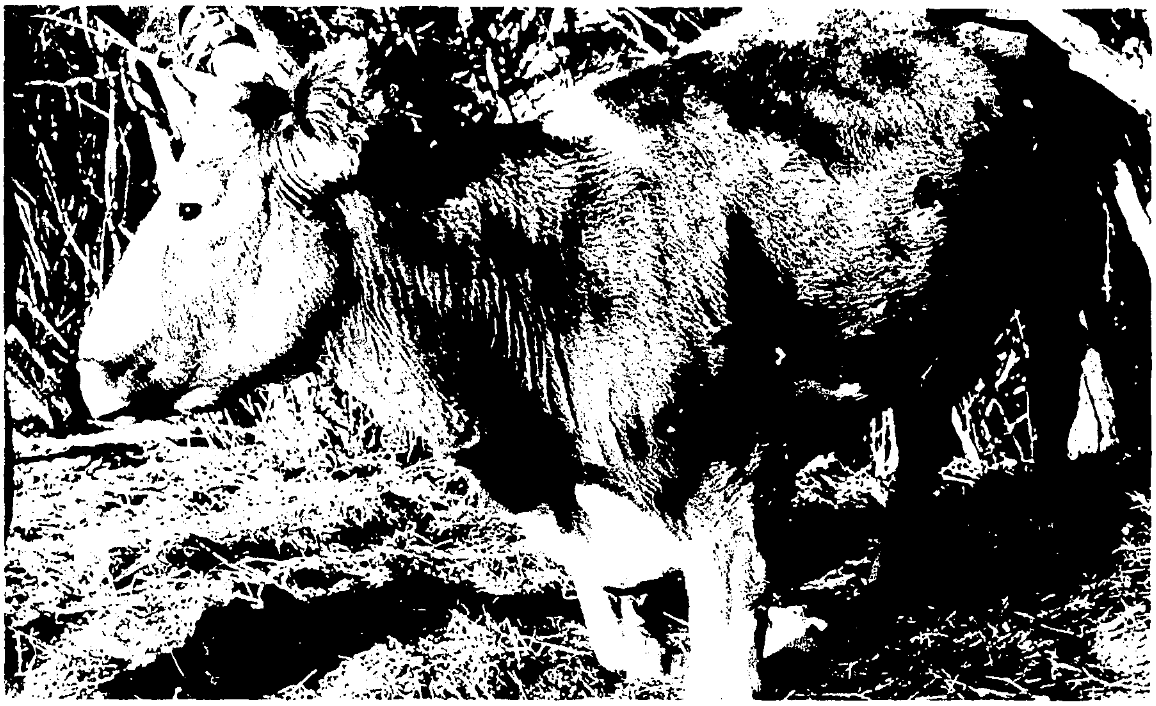


Photo courtesy William F. Harris, D.V.M., Puyallup, Wa.

Fig. 2.—This cow is suffering from a bone disease caused by fluoride poisoning; note the bone damage to the skeleton. In extreme cases, animals cannot tolerate the anguish of standing.

Dust storms have been shown to adversely affect livestock and poultry. Irritation to eyes, nose, and other parts of the body, as well as increased mortality rates and incidences of certain diseases, have been detected.

Water

Water quality may have a considerable influence on animal health and well being. A severe lack of water, even for a relatively short time, can weaken an animal and have important detrimental effects on feed efficiency and rate of gain. A shortage of water can, therefore, limit the number of animals or even make animal production impractical.

In the *1938 Yearbook of Agriculture* it was estimated that a billion tons of manure was being produced annually by livestock on American farms. It was also estimated that this manure was capable of producing $3 billion worth of increased crop production. A drastic change in attitude toward the usefulness of manure occurred because of several factors. One of these factors is the concentrated production of livestock and poultry. Large-scale confinement-type enterprises have made it possible to raise on a few acres the hundreds of thousands of head of livestock and poultry that formerly required hundreds or even thousands of acres to produce.

Problems involved in the concentration of the excrements of these animals in such small areas are obvious. What can be done about this is not so obvious. Waste production by domestic animals in the United States is approximately equivalent to waste from a human population of 1.9 billion persons. On the basis of feces and urine alone, sewage treatment for this volume of waste is almost unimaginable. Then, compounding the problem, these wastes are much more concentrated or less water-diluted than normal municipal sewage, so they require a greater volume of water for treatment than the same amount of human waste.

Another problem contributing to the buildup of animal waste was found in economic studies that indicated that the cost of applying manure to the land is greater than the cost of chemical fertilizers. More efficiency in handling manure would improve the economy of using it on land. Adding to the problem is the fact that a feeding practice in feedlots is to use salt to increase intake. The manure thus contains salt, which the farmers do not want to add to their land.

As the amount of animal waste continues to accumulate, the amount in the runoff from each rain storm also continues to increase. This buildup of animal waste becomes a source of increased organic matter, nitrates, phosphates, and other materials that pollute our streams, rivers, and lakes. Bacteria and other organisms may also be washed into both surface and subsurface water supplies. Nitrates may also be carried in or leached into underground water supplies. (For more information on water see the *Water* unit.)

Noise

Large concentrations of animals, especially in a small space, can create a noise problem. A large modern poultry house is likely to be a constant source of noise. The level of noise depends on the number of birds, design of the building, and other factors.

Loud, sudden noises can also frighten animals. This may cause injury to the animals or they may pile up, as chickens sometimes do, and smother each other. Animals subjected to repeated noises such as "sonic booms" may gain more slowly and less efficiently. More research as to the effects of noise on animals needs to be done, and buildings must be designed to better meet the needs of animals.

ANIMAL WASTE AND BYPRODUCTS

Federal Government Programs

Much of the following is taken from *A Report to The President: Control of Agriculture–Related Pollution*, submitted in January 1969.

Animal wastes in this country probably exceed wastes from any other segment of our agricultural-industrial-commercial-domestic complex. Approximately 1.7 billion tons of animal wastes are produced annually, a third of which is liquid. Used bedding and litter add significantly to the problem. As much as 50% of this waste can come from concentrated production systems.

The trend in livestock, milk, poultry, and egg production is toward automation and centralization. Consequently, animal wastes tend to be more concentrated at point locations than in the past when they were distributed widely in the rural areas (fig. 3).

USDA Photo

Fig. 3.—Cattle in a feedlot concentrate much waste in a small area.

The expansion of urban and suburban developments into former agricultural areas and the concentration of animal production have accentuated health and pollution problems associated with livestock and poultry production and with conventional methods of manure disposal on the land.

A large number of beef cattle receive their final feeding, growth, and fattening in large and centralized feedlots. A beef animal may spend the final 3 to 5 months of its life under concentrated and confined feeding conditions. This concentrated feeding provides for more and better beef at a lower cost to the consumer, but it also results in greater concentrations of waste.

Single feedlots may contain more than 10,000 cattle. An accumulation of several inches of manure in the feedlot is not unusual. Under these conditions, fly breeding, odors, and manure dust also become problems. Runoff and leaching created by cleaning operations and rainfall may result in stream and ground-water pollution.

The trend toward confinement production is also fairly established in the swine, poultry, and dairy industries. Units marketing 300 to 1500 hogs per year are not uncommon, and further expansion can be anticipated. The number of poultry handled in a single operation often exceeds 20,000, and the waste produced can exceed 5 tons daily. In modern mechanized dairies, milk-cow populations of 100 and above are common. Rapid strides have been made in developing efficient housing, exercise, feeding, and milking areas, but waste handling remains a major problem.

Although the concentration of animals in fewer and larger operations offers size advantages for economy of operation, the problem of waste management is increased. Our technology must be improved and applied to collect, handle, treat, reclaim, or ultimately dispose of the increasing volume of wastes.

Economic studies indicate that the high cost of handling manure has reduced its competitive position as a fertilizer. Feedlot operators who formerly realized some profit from sale of manure now pay to have it trucked away.

Two somewhat counterbalancing points should also be discussed. First, as animal concentrations have increased, there has been a tendency to do away with litter. Thus we come close to having only the feces to be disposed of. An example of such a system is loose-stall housing where very little litter is used. The animals are allowed to run free but have small stalls with bedding to sleep and rest in. Most of the waste behind the cow misses the bedding and can be scraped up or washed away. The second point is that there has been a reduction in the number of cows. There are now about 13.1 million milk cows—half the 1945 number. There are approximately the same number of cows now in the United States as there were in 1877. While each cow with her higher production produces more waste than cows in 1945, the reduced numbers and lower bedding usage are pluses in the waste disposal problem.

There are many possibilities for improved management and reclamation of animal wastes. Treatment and handling methods must be developed to conform with the various water- and air-quality standards developed by the States and by the Federal Government.

Spreading manure on the land to reclaim nutrients is not now economically competitive with the application of mineral fertilizers. Three control approaches can be taken to minimize pollution from animal-feeding operations:

1) Increase use and application of existing technology.
2) Enforce regulations where improvement is technically feasible.
3) Develop more effective, complete, and economically feasible waste-management systems.

The Department of Agriculture has developed information on specific animal-waste handling processes. Much of this information has been applied on a limited basis and is potentially adaptable to wider use. The Department of Health, Education, and Welfare and the Department of the Interior also are studying animal-waste management. For example, the Department of the Interior is demonstrating the application of existing treatment and management techniques in both farm and concentrated feeding operations.

Industry also has developed information on specific waste-handling techniques that are adaptable to animal-waste management. In addition, modified techniques from associated programs in municipal and industrial waste treatment, such as the activated sludge processes, chemical treatment for phosphate removal, and denitrification, should be adaptable to the liquid wastes from concentrated animal-feeding operations. Also, the numerous methods for handling and transporting domestic sludge and low-water-content sewage can be modified.

Under the Water Quality Act of 1965, each State is obligated to develop standards for the quality of receiving waters. Receiving waters are rivers, lakes, oceans, or other watercourses that receive treated or untreated waste waters. All the States have developed these water-quality standards, and the Department of the Interior has accepted almost all of them. Under both Federal and State standards, enforcement of effluent and receiving-water quality is handled primarily by the States with the Department of the Interior providing additional enforcement resources when required. Many programs rely on a good deal of voluntary compliance since enforcement is impossible on the large scale that would be necessary.

Efforts must be intensified to ensure compliance with existing zoning regulations and to introduce more stringent zoning requirements to provide buffer zones around both urban and agricultural areas. Many agricultural concerns have had problems as people moved closer to them. Well-planned zoning should reduce such problems. This will leave more space between cows and people. These actions must be designed to protect both the public and the animal industry. (See the *Land Use* unit for more detail.)

Animal-waste management must be integrated and coordinated with the total national pollution-abatement plan. The importance of pollution control in the total management concept of the animal-feeding industry must be recognized now and integrated into planning and operations. Long-range control demands more effective, complete, and economical waste management to meet pollution problems of the future. Intensified research and development are needed in all phases of animal-waste management, including characteristics of manures, removal from animal quarters, runoff, storage, transport, treatment, ultimate disposal, and economic evaluation to ensure improvement of environmental quality with minimum disruption of current production-efficiency levels.

The following areas are included in the Federal Government's programs aimed at controlling animal wastes.

Minimizing Pollution by Improved Use of Existing Technology As Well As by Developing New and Improved Animal-Management Methods and Facility Design

The Department of Agriculture is performing research to identify the characteristics of animal wastes and the nature of pollution arising from livestock operations. Research has been initiated, with emphasis on cattle and poultry operations, to develop improved techniques and facility designs to handle and dispose of wastes in a manner that will reduce air and water pollution.

USDA action programs are directed toward (1) educational programs that recommend designs and management techniques that will alleviate pollution through use of current knowledge; (2) technical assistance within soil conservation districts and through extension specialists; and (3) loans to individuals or groups of farmers who need to improve their animal-waste handling facilities. USDA expects expansion in all types of activities and considers incentive payments particularly necessary in this area. More information about these programs can be obtained from county cooperative extension, ASCS, FHA, and other USDA offices.

The primary function of the Department of Health, Education, and Welfare in this area is to develop manuals, guides, and criteria for use and application by solid-waste program administrators in dealing with the off-farm problems of animal solid wastes, particularly in those situations where interfaces (interacting boundaries) exist between large feedlots and urban environments. Technical assistance supported by organized training programs will be provided to interested control and health agencies.

The Department of the Interior has research and demonstration programs to develop improved techniques and facility designs for handling animal wastes in a manner that permits discharges to meet existing water-quality standards. In addition, it has a large program of research, development, and demonstration in the broad area of industrial pollution control and abatement. Under these programs, the Department is investigating various means for modifying the source, quantity, and quality characteristics and to develop means for prevention, control, and treatment of animal wastes. USDI feels that existing legislation is adequate but that increased funds are necessary to implement the program.

Minimizing Pollution by Improved Use of Existing Technology As Well As by Developing New and Improved Waste Treatment and Disposal Methods

The Department of Agriculture's research program is directed toward methods of treating and disposing of animal wastes through a variety of techniques such as lagoons, oxidation ditches, and application to cropland. Additional research will be performed, including the investigation of other methods of disposal and of the capacity of cropland to accept animal wastes without damage to crops and land.

USDA action programs are generally in the form of educational and technical assistance provided directly to individuals or groups of livestock producers in rural communities. Loan assistance for treatment and disposal systems is currently available for groups of farmers or associations. Cooperative and watershed organizations are expected to be utilized in the development of loan, grant, and research participation reimbursement programs for use in developing needed treatment and disposal systems.

The Department of Health, Education, and Welfare (DHEW) is supporting research on new methods of disposal of animal wastes on land such as injection, composting to produce a product that can be disposed of more readily, lagooning, and incineration. While it is not anticipated that economically profitable methods will evolve in the near future, a substantive saving in costs of disposal may be possible.

The results of these studies will permit DHEW to establish standards of disposal and to set up a technical assistance program to State and local authorities to accelerate application of the standards. It is anticipated that demonstration grants (under the Solid Waste Act) and loan of personnel will be made in support of this program. The Department proposes keying this program to the need of large-scale producers such as feedlot operators and poultry producers.

The primary thrust of the program in the Department of the Interior is to use existing technology and develop new or improved treatment and disposal methods. The Department supplies direct technical aid to help resolve the water-pollution problems from feedlot operations and has a program of research, development, and demonstration of numerous unit processes and systems to minimize pollution from animal feedlot operations. The existing program involves the development and demonstration of improved techniques for controlling and treating liquid wastes from concentrated animal feeding operations. Included in this effort are lagoons, oxidation ditches, chemical treatment, activated sludge, biological denitrification, ultrafiltration, and other concepts from the advanced waste treatment program being adapted for application to animal-waste treatment.

Minimizing Pollution by Improved Use of Existing Technology As Well As by Developing New and Improved Methods for Converting Wastes to Useful Products

The Department of Agriculture has conducted research on techniques and uses of animal wastes for profit, or at least on offsetting disposal costs, for several years. The conversion of poultry feathers into a protein feed is a classic example. Research for both on-farm and off-farm uses and processes is expected to continue. Action programs in this area of emphasis are primarily in the form of technical assistance in the construction of processing plants. (As new developments arise, educational and technical assistance programs will probably be coordinated by the Environmental Protection Agency.)

Research in the development of useful products is being supported by the Department of Health, Education, and Welfare. Examples of research include conversion of animal wastes to animal feed, solid conditioners, or fertilizer carriers, and extraction of protein for use as food supplement. The potential for reuse or recycling of these wastes is also being studied. As indicated previously, the objective at this point is to effect a reduction in cost of disposal without necessarily realizing a profit. Demonstration grants will constitute the basic support mechanism of DHEW in the translation of the laboratory and pilot plant findings into full-scale operations. A technical assistance program to State and local agencies and private entrepreneurs will be established.

The Department of the Interior, in its efforts to dispose of treatment plant sludges, has as part of its projects the conversion of waste material into useful products or energy sources.

Minimizing Pollution Through Assisting in Establishment and Enforcement of Standards and Providing Criteria for Land-Use Planning

The Department of Agriculture research in this area is currently addressed toward land-use planning as a basis for developing criteria that are realistic in terms of the capability of the producer to meet them and in proper balance with other forms of pollution control. Research is needed to develop sound plans and implementation techniques for accomplishing protective zoning for agricultural production.

USDA action programs are currently very limited; they consist primarily of educational programs to help rural communities and rural areas develop plans and legislation for rural development and planning in which pollution control is one of the considerations. Expansion of this activity, as well as a grant program for planning and implementation of standards and rural zoning, is considered necessary. USDA has no authority for establishing or enforcing standards in this area.

The problems of land-use planning have been given little consideration as they relate to installations producing animal wastes. Land-use planners must be supplied with criteria that, if met, will permit the location of agricultural production centers in the vicinity of urban areas and the labor supply. The development and use of the appropriate criteria, as planned by DHEW, would provide the tools for progress and enlist the support and cooperation of the planners.

Water quality standards adopted by all 50 States and approved by the Secretary of the Interior include plans for implementation for interstate streams, lakes, and coastal waters. With few exceptions, these standards deal effectively with municipal and industrial wastes and their effect on water quality. However, with regard to agricultural waste in general, many difficulties have been encountered in developing appropriate and workable standards. Additional technical information is needed on the characteristics of runoff and on the effectiveness of the numerous treatment concepts being considered to implement the existing standard requirements.

Manure

Waste disposal has profound public health and socioeconomic implications. Manure (urine, feces, bedding and litter, and feed wastes) can produce such undesirable effects as disease. Biological vectors (living organisms that carry disease), including any living agent, may serve to spread the pathogens present in waste. (More details can be found under the "Animal Health" section of this unit.)

Direct contact with fresh waste is an immediate potential source of exposure to disease, including brucellosis, tuberculosis, and leptospirosis. Water supplies in farm ponds are contaminated from washing animal areas such as feedlots and stables and tend to perpetuate disease. Wastes can contaminate animal and human food by the use of the animal waste as fertilizers and by contamination of animal carcasses at slaughter. The July 10, 1969 issue of *Mechanical Memo*, a special safety issue, contained the following.

> There's a real need to warn farmers of the danger from liquid manure gases. Two people died in a dairy manure storage tank near Red Deer, Alberta, according to J. Les Reid, head, Agricultural Engineering Branch, Alberta Department of Agriculture.
>
> The circumstances were as follows: The tank had been almost emptied. The scrape-in safety grill had fallen into the tank and the first man went down to retrieve it. He collapsed and fell face down in 6 to 8 inches of liquid manure. The second man went down to rescue him and he too fell face down. A third went down to the rescue and collapsed falling backwards. A fourth man fortunately took down a rescue rope but held his breath while in the tank. By following this procedure, he removed the three bodies. The first two men drowned (lungs contained liquid manure on autopsy) while the third recovered.
>
> Recently, Les has been measuring hydrogen sulfide (H_2S) concentrations around storage tanks both before and during agitation. He has observed concentrations up to 800 parts per million at the slat level immediately following agitation of 7-month-old dairy manure. The effects of varying concentrations of H_2S on humans are stated in the Alberta Workmen's Compensation Board publication, *The Killer! H_2S*, as follows:

1 ppm*	Can smell
10 ppm	Allowable for 8 hours' exposure. Over the allowable concentration, protective equipment will be necessary.
100 ppm	Kills smell in 3 to 15 minutes. May burn eyes and throat.
200 ppm	Kills smell rapidly. Burns eyes and throat.
500 ppm	Victim loses sense of reasoning and balance. Respiratory disturbances in 2 to 15 minutes. Needs prompt artificial resuscitation.
700 ppm	Victim becomes unconscious quickly. Breathing will stop and death result if not rescued promptly. Immediate artificial resuscitation.
1000 ppm	Unconscious at once. Permanent brain damage.

*ppm—parts of gas per million parts of air by volume

> Breathing apparatus (similar to SCUBA gear) can be used for H_2S protection. Air contained in a cylinder is supplied to the wearer so that he is completely independent of the surrounding atmosphere.
>
> This incident opens two further questions.
>
> First, the prime cause of this accident was the retrieval of the scrape-in safety grill. Round covers of a larger diameter than the opening would be safest but not practical. Rectangular covers can be relatively safe if the opening is rabbeted or the cover is lipped on all four sides.
>
> Second, is a ladder a safety device or an invitation to enter the tank? What is your opinion?

An extension soil and water specialist at Washington State University, C. B. Harston, writes:

> Ammonia may become airborne quickly, as anyone knows who has sniffed a bottle of washday ammonia water. It may be masked by other odors from a cattle feedlot but the ammonia may be just as strong from that source. About 90% of the urinary nitrogen excreted by animals can be volatilized directly from the feed yard.
>
> This ammonia can be absorbed by bodies of water. Tests in Colorado showed that lakes a mile from large feedlots can absorb as much as 30 pounds of nitrogen as ammonia per acre per year. The closer the lake and the larger the feeding operation the more ammonia was absorbed.
>
> Nitrogen is one of about 16 factors which determine the growth of algae. About one-half part per million of nitrogen in a lake is sufficient to promote algae bloom, which signals the death or eutrophication of a lake. The 30 pounds per acre per year found by the Colorado studies is roughly three times the amount of nitrogen needed in a lake averaging 20 feet in depth.
>
> Obviously, there is more to the problem of animal waste disposal than meets the eye.

Complex socioeconomic factors add to the perplexing problems. The stress of odor from waste and the possibility of legal action are also involved.

Table III is taken from *Environmental Quality: The First Annual Report of the Council on Environmental Quality* and shows the relationships of various types of animal waste.

Table III.—Wastes From Domestic Animals

	Animal population (in millions) (1)	Ratio of waste output of single animal to output of a human (2)	Total animal wastes expressed as equivalent number of humans (in millions of humans) (3)
Cattle	107	16.40	1754.8
Horses	3	11.30	33.9
Hogs	53	1.90	100.7
Sheep	26	2.45	63.7
Chickens	375	0.14	52.5
Total[a]	564		2005.6

[a]Col. 1 times col. 2 equals total in col. 3.

Source: *Environmental Quality: The First Animal Report of the Council on Environmental Quality.*

The rest of this section on manure is largely taken from newsletters prepared by Grady F. Williams, extension dairy specialist at the Western Washington Research and Extension Center, Puyallup, Washington.

Farm soils are excellent recipients for animal waste. Numerous experiments show that manure increases crop production more than its equivalent amount of commercial nitrogen-phosphorous-potassium (N-P-K). The next question is how much manure can be applied without causing pollution? Several factors are involved.

Contrary to popular opinion, water absorption into the soil is not a major factor. Admittedly, if the soil is already saturated, pumping additional liquid onto the ground will result in runoff and pollution of public waters. However, all of the liquid and solid wastes from four cows, when diluted with equal volumes of water and evenly distributed over 1 acre of ground, will add only 1 inch of liquid slurry per year. With a little bit of attention to weather and soil conditions throughout the year, the wastes from four cows could easily be applied to 1 acre of ground without moisture problems.

However, the manure from four cows in 1 year's time would add about 620 pounds of nitrogen. Crops would be hard-pressed to use that much nitrogen each year.

The ammonia salts, through the process of nitrification (addition of oxygen), become nitrites. Nitrites are broken down to a lower state of oxidation. This process is called denitrification and often releases nitrogen into the air. In order for denitrification to take place, nitrification must have first taken place. Also, there must be carbon available for the organisms (commonly bacteria) to work. The oxygen must be reduced to 3% to 5% for denitrification to take place. The acidity level and amount of water present will also affect the rate of denitrification. Nitrogen (as nitrate) on the other hand, will move downward in the soil if applied in excess. Fast-growing grasses or corn would use the nitrogen from two cows. Heavier applications on a continuing basis could eventually cause nitrogen buildup in subsurface waters.

The buildup of nitrogen in subsurface waters may be detrimental to human and animal health in quantities as low as 45 ppm nitrate (NO_3) (10 ppm elemental nitrogen). Much higher amounts are beneficial if the water is used to grow farm crops. If nitrate percolates into small, sluggish streams or lakes, it will stimulate algae growth and eventual oxygen insufficiency for fish. If it percolates into fast-flowing streams or salt waters, the nitrate effect would be negligible.

The absorption and percolation of manure into soil depends upon the kind and amount of surface and subsurface soil. Clay absorbs more moisture, while sand allows faster percolation downward. These two facts are sometimes confusing.

The most critical soil effect is subsurface structure, which is very difficult to evaluate. Liquids may move downward for several hundred feet or they may reach an impermeable barrier a few inches below the surface. Lateral movement over the impermeable barrier can be for considerable distances, sometimes as a flowing underground stream.

In summation, nitrates moving downward are dangerous if they reach wells used for drinking water, slow-moving or stagnant streams, or lakes. Otherwise, huge quantities of nitrates could be applied for an extended period of time without causing any damage at all.

Very high amounts of manure will inhibit plant growth for a short period of time. Grasses survive better than legumes. With liquid manure sprinkler systems, a clean water rinse will cleanse the irrigation equipment and plants, too. However, avoid applying enough to cause liquid runoff.

Active fecal organisms survive at a poor rate when applied to the soil, due to the sun effects and inhibition by soil organisms. Downward progression is very limited; most move less than an inch. Wisconsin studies show that 98% of coliforms (a type of bacteria) are removed within the top 14 inches of soil. Others show no recovery at 3 or 4 feet. However, rock or shale strata may permit considerable liquid flow, as evidenced by contaminated wells. Most coliforms disappear from the soil in 10 to 20 days.

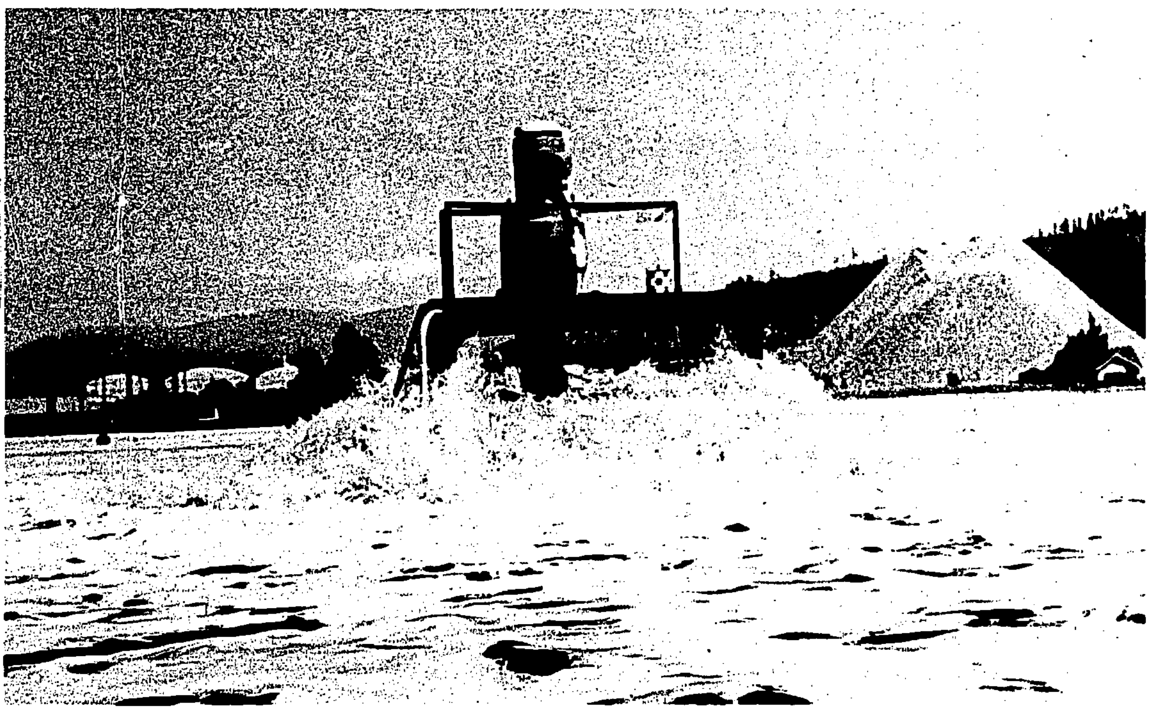
Lateral progression of bacteria is virtually zero unless carried by flood water. While flood waters will already be badly polluted, addition of fecal material is not esthetically desirable.

While most coliforms disappear rapidly, it must be recognized that a few Bacilli, Leptospira, Brucella, etc., are dangerous in water supplies. Therefore, extreme caution must be taken to prevent animal excreta from entering public waters.

In the past, animals were not fenced from streams. Also, numerous wild animals will still contaminate streams. This does not remove the owners of domesticated animals from their responsibility to prevent stream contamination. Human disease has been traced to contamination by farm animals of irrigation ditches and streams in this State.

Open lagoons have been used with varying success for both human and animal waste disposal. There is a distinct difference in the fibrous content of wastes from humans, simple-stomached animals, and from ruminant animals. Human lagoons are mostly for dissipation of water, with solids a minor concern. With cattle, solids are usually the major concern.

In arid and warm climates, fermentation of solids and evaporation of liquids is extensive. Given sufficient time and adequate surface exposure, waste removal is almost complete (fig. 4).



Weyerhaeuser Photo

Fig. 4.–Sunlight, algae, and oxygen work together to purify waste water in a lagoon or oxidation pond.

In cool, humid climates, such as Western Washington, lagoons must be considered primarily as storage vessels. As such, they may have an effective part in waste disposal. Liquids can be stored in wet seasons and pumped to fields in dry seasons. There is a problem of adequate mixing in large tanks or lagoons. Smaller vessels, by recirculation of material, can be mixed and emptied easily but the amount of storage is limited. However, some dairymen can decrease liquid runoff from fields if they can store manure for a few days.

Liquid manure pumping should be stressed on days when ground absorption is highest and avoided, if possible, when the ground is already saturated.

There is some cause for concern regarding transmission of organisms from open lagoons by flying insects and birds. This is more important with human waste than cattle because a fibrous crust will eventually cover lagoons containing cattle manure. For some reason, bird transmission of disease is largely ignored by most books.

Flying insects will deposit eggs in manure when moisture percentages are between 50 and 85. Neither dry manure nor liquid manure is a problem. The dry crusts on lagoons are an effective barrier to insect breeding, but some attention must be given to the interphase between the dry crust and liquid beneath, particularly around the edges of the lagoons. Crusts vary and when new material is not being added to the lagoon the crust may sink. After a while, presumably with the drainage of some material, the crust may rise again. In between, liquid is exposed. Insecticides approved for farm usage may be applied occasionally.

Unless blown by the wind, most insects do not fly very far. Therefore, fly multiplication is chiefly a problem for the immediate vicinity of the lagoon. Also, most of the insects attracted to lagoons are harmless species that ordinarily stay away from cattle and farm buildings. Hornets are seen around lagoons in considerable numbers while houseflies are not.

Anaerobic fermentation, faster than aerobic, proceeds after formation of the fibrous crust. The crust also traps undesirable gaseous odors. However, the liquid phase will have a very putrid smell. To minimize air pollution when lagoons are emptied, some attention should be given to wind direction, time of day, and humidity. Decomposition of the fibrous crust is very, very slow, so eventually it must be removed. As mentioned earlier, sludge in the bottom of lagoons is difficult to mix completely for liquid pumping.

Before extreme emphases are placed on lagoons for cattle wastes, it should be stressed that, in this climate, actual degradation is far from complete; putrid odors develop; and the systems may eventually fill with solids forcing abandonment of solid sludge removal. In this climate, they must be regarded as storage vessels and should be emptied as soon as soils will absorb the moisture from the slurry.

It is theoretically possible to decompose animal wastes completely, but it is not economically feasible.

It is possible to mechanically separate the solids from liquids. By the use of settling basins or centrifuges, the liquids can be cleared for chlorination and discharge into flowing streams. Also, removal of the more fibrous portions greatly enhances soil absorption of the liquids. The clearer portions could also be recirculated to wash animal loafing areas, but there is a question of spread of disease organisms. However, as mentioned earlier, disposal of liquids is not as much of a problem as many think.

At Davis campus, University of California, eight small manure lagoons (4 feet in diameter and 7 feet deep) were constructed, with natural earth bottoms. Various loading rates with chicken, dairy, and swine manure were studied, with weighed amounts added at weekly intervals for periods of 771, 398, and 232 days for the respective species.

In appearance, all lagoons differed tremendously. A lightly loaded poultry lagoon was clear on the surface. Heavier loads of chicken manure resulted in "pink" ponds. Still heavier loads developed a manure-and-feather mat on the surface that supported larva of the drone fly. After 3 months, all dairy manure lagoons had a surface layer of hay stems and grain. The crust supported grain and weed seed growth but no fly breeding. The University of California researchers stated that the crust seemed to be a benefit in that it trapped and masked the sewage odors. The swine manure lagoon had a crust that periodically floated, sank, and floated again. The liquid was dark in color but clear. The liquor supported drone fly larva in the summer. Sludge appearance was black, well flocculated, and similar in appearance for all species. The authors considered sludge appearance as a good indicator of actual lagoon performance.

In odor, species differences were great; with chicken manure unquestionably objectionable, dairy manure relatively odor-free, and swine manure intermediary. These odors were in addition to a reported "rotton manurey" odor that was prevalent in the lagoon area but poorly defined. The senses were quickly deadened toward the latter odor, but the odor clung to clothing and hair like tobacco smoke and remained on the person after he left the area. Hydrogen sulfide was always released from the crust of the dairy lagoons when they were punctured.

Fly problems were limited to the drone fly in chicken and swine manure. As the drone fly is not attracted to human habitats, it is not significant to lagoon operation (fig. 5).

Fig. 5.—Research continues to find out more about flies, including the effects of light, sound, and radio waves.

Losses by filtration into the soil were larger in the small experimental lagoons than expected. The researchers concluded that sediment would not seal the lagoons in sandy loam soil and that contamination of subsurface water is a definite risk.

Degradation of organic matter was not measured completely in the experiment. Forty percent of the organic matter of cattle manure was removed in the floating crust. Therefore, something less than 60% degradation occurred. The dairy farmer must realize that the lagoons will not destroy a great amount of the organic matter. Degradation of poultry manure was approximately 90%. Significantly large amounts of potassium, due to its high solubility, was lost by soil infiltration. Nitrogen was lost as a gaseous ion. Considerable phosphorous was retained in the lagoons.

The pH of the lagoons was alkaline and relatively constant. Gas analyses of poultry sewage were almost completely methane, with negligible carbon dioxide.

The authors concluded that 795 cubic feet of lagoon per 1000-pound cow, 13.6 cubic feet per 5-pound chicken, and 124 cubic feet per 100-pound hog approached the minimum size requirements. Depths of 8 to 12 feet were recommended where soil structure and safety fences are permitted. Daily additions of manure should be discharged into the center of the lagoons at 2 to 3 feet from the bottom. Water levels must be maintained, even if addition of water is necessary.

With temperatures of 70°F or higher, gasification and sludge lifting occurs. The resulting agitation is desirable, increasing digestion and decreasing bad odors.

At present, many projects are being carried out on animal waste disposal. Some of these pertain to using soils as a medium for animal waste disposal. One of the obvious problems here is that in many States numerous associations and literally hundreds of soil types exist within a State. All of these with their varying characteristics may likewise have varying effects when being used as mediums for disposing of manure.

Meat and Poultry Packing

Waste from meat and poultry packing includes waste products such as unusable parts of an animal, paunch manure, blood, and any water used in processing. Even the tanning of hides requires some water, which may be somewhat polluted. Ways of using more of the animals are constantly being found, but more remains to be done.

In the past, sometimes only meat, hides, wool, tongues, and some fat was used from animals. The rest of the animai was burned, buried, or dumped in a river. Today, these products are used in producing glue, fertilizer, buttons, and many other products. Even so, in a year's time, the meat packing industry produces effluent with oxidative demands that are double those of the raw sewage from metropolitan Chicago.

Table IV extracted from *Wastes in Relation to Agriculture and Forestry* shows the pollution potential of selective agricultural processing industries. The second column of the table presents data on the amount of product that is produced and processed in the United States annually.

The fourth column lists the pounds of biochemical oxygen demand (BOD) required per 1000 pounds of product processed.

Table IV.—Estimated Pollution Loadings of Selected Agricultural Processing Industries

Processing industry (1)	Annual production (million pounds) (2)	5-day BOD: Data in literature (3)	Pounds BOD per 1000 pounds processed (4)	Potential daily load (1000 pounds) (5)	Potential daily population equivalent (millions) (6)
Hides and leather	1,300	650 gal. 1500 ppm per 100 lb hides	81	300	0.18
Meat (slaughtering and packing)	59,400	14 lb BOD per 1000 lb live weight	14	2300	13.7
Poultry	8,200	33 lb BOD per 1000 birds	10	225	1.3
Wool scouring	130	8 gal. 4000 ppm	267	100	0.6

Source: S. R. Hover and Leonore B. Jasewitz, "Agricultural Processing Wastes," paper presented at Amer. Assoc. Adv. Sci. Symposium, Washington D.C., Dec. 27, 1966.

The fifth column lists the potential daily load of BOD from the processing of a given product, based on a 365-day year. Some agricultural products tend to be seasonal and thus require the greatest amount of water over a short period of time and dump the greatest amount of waste during the same period of time. The season that this happens may often coincide with relatively low levels of water.

The concentration of processing further intensifies the problems. The sixth column presents the population equivalent (PE) of the BOD load shown in column 5. One PE of a processing waste is an amount of liquid waste equivalent in BOD to the normal sewage contributed by one person. The base value of 0.167 pounds of BOD per capita per day is used.

The parts per million of BOD depends greatly on the amount of water added to the material. In many municipalities, great quantities of water used for various purposes end up in the sewage system, thus diluting the sewage and lowering the parts per million of BOD. Many agricultural processing plants have developed highly efficient techniques that use relatively small quantities of water and thus lower the dilution rate and increase the parts per million of BOD. The high parts per million of BOD with its oxygen-depleting ability is certainly an important consideration in stream pollution (table IV). For a more complete discussion of this topic see the *Water* unit.

Dairy Processing

In a year's time the dairy industry produces potential effluent with oxidative demands that are four times those of metropolitan Boston. In the dairy industry, processing of such things as fluid milk, evaporated milk, nonfat dry milk, cheddar cheese, cheddar whey, and cottage cheese produces considerable quantities of high-BOD waste. Because of the stringent cleanliness demands of the dairy processing industry, considerable quantities of water are used to keep the facilities clean.

Expanded uses for dairy byproducts are constantly being found. At the same time, new methods of extracting waste and byproduct materials are being developed. Many researchers are not overly optimistic about finding great new breakthroughs in these areas but hope to find methods that will do what we are presently doing more economically and efficiently.

Table V shows some of the waste being produced in the dairy processing industry.

Table V.—Estimated Pollution Loadings of the Dairy Processing Industry

Dairy processing industry (1)	Annual production (million pounds) (2)	5-day BOD			Potential daily population equivalent (millions) (6)
		Data in literature[a] (3)	Pounds BOD per 1000 pounds processed[b] (4)	Potential daily load (1000 pounds) (5)	
Fluid milk	59,000	10	1.0	162	1.0
Evaporated milk	1,888	10.5	2.25	11.6	0.07
NFDM	2,176	25.0	26.4	157	0.945
Cheddar cheese	1,157	24.5	24.5	77.6	0.465
Cheddar whey (dried)	20% of total	17.0		9.7	0.06
Cheddar whey	50% of total	350		500	3.0
Cottage cheese	1,424	350	26.5	64.5	0.38
Cottage cheese whey	7,500	350	165	1000	6.0

Source: S. R. Hover and Leonard B. Jasewitz, "Agricultural Processing Wastes," paper presented at Amer. Assoc. Adv. Sci. Symposium, Washington D. C., Dec. 27, 1966.

[a]Pounds BOD/10,000 pounds milk equivalent
[b]Milk equivalent

ANIMAL HEALTH, DISEASE PREVENTION, AND PARASITE CONTROL

Nutrition

Milk, meat, and other animal products are important in the human diet as well as to the economics of agriculture. Milk products alone represent about 20% to 25% of the total volume and cost of the American diet. These high-quality products are produced by ruminant animals (all cloven-hoofed animals such as cows, sheep, deer, and buffalo), which have a special digestive apparatus that enables them to digest plants with high cellulose content. These plants with high cellulose content are for the most part indigestible by humans.

The ruminant stomach has four sections. The first (reticulum) and second (rumen) are somewhat continuous, with only a partial muscular septum dividing them. For digestion, consider both as a huge fermentation vat where live bacteria and protozoa live on the consumed feeds. This fermentation breaks down the complex cellulose fibers into simpler volatile fatty acids. The third section (omasum) is mostly a filtration device, functioning to retain moisture and large particles in the rumen. The fourth section (abomasum or true stomach) functions in the same way as all simple-stomached animals (dog, cat, swine, etc.) and human beings.

The ruminants are different from pseudoruminants (horse, rabbit, etc.) that have an enlarged cecum, after the true stomach, which also functions as a fermentation organ but with reduced efficiency.

Bacteria and protozoa assimilate food nutrients from the rumen into their cells, using some energy. Their cells are, in turn, digested by the animal as they pass through the true stomach.

This two-step digestion process is an inefficient conversion of plant energy. If foods that can be digested by humans, such as corn or beans, are fed to animals, there will be a loss in total energy but an improved quality of food produced in the form of meat. However, the ruminant can take foods such as alfalfa or grass that are not digestible or palatable to humans and convert them into human foods. Also, bacteria and protozoa can assimilate (take in and convert to food) organic products, such as ammonia from urea, making them available for animal feed and, indirectly, palatable human food.

Corn silage is very deficient in protein, calcium, and phosphorus. Urea can be added to forage going into the silo or being taken from the silo for feeding to increase the protein content. Standard recommendations are to add 10 pounds of urea per ton of silage, preferably at about 30% dry matter. Ten pounds of urea raises the protein-equivalent level in silage a maximum of only 1.41%. This is a definite improvement. It must, however, not be considered as "balancing" the protein in the total ration. Also, large amounts of calcium and phosphorus must be supplemented. This can be done with the use of either steamed bone meal or dicalcium phosphate at 1% to 2% of the grain ration plus allowing all of the minerals that cattle will eat by free choice. Silage levels of carotene and vitamin A are variable. Also, urea may reduce carotene conversion to vitamin A. Therefore, modest supplements of vitamin A are suggested. When these supplements are supplied, corn silage is an excellent, economical roughage for cattle. It is generally recommended that urea in silage and grain not be used simultaneously.

There has been considerable concern about the nitrate content of cattle feeds. Applications of large amounts of nitrogen greatly increase forage and grain production. Lower prices for commercial nitrogen fertilizers encouraged higher applications in recent years. Also, greater concentration of cattle on small acreages has resulted in heavy manure applications.

It is known that consumption of extremely high levels of nitrate (NO_3) will cause animal death. Nitrite (NO_2) is extremely toxic. At the critically high level, oxyhemoglobin of the blood is converted to methemoglobin, interfering with normal oxygen and carbon dioxide transport. Death by asphyxiation can result. Therapy to convert methemoglobin back to oxyhemoglobin is effective. Even lower amounts have been suggested as causing poor animal performance, lower milk production, slow growth, and abortions.

Nitrogen compounds, including nitrate, are absolutely necessary for all plant and animal life. Furthermore, maximum performance requires large amounts daily with no significant animal or plant reserves. Nitrate is a normal constituent of plants. The amount of nitrates that plants contain varies with the kind of plant, the amount of fertilizer applied, and the growing conditions. The maturity of the plant may also greatly influence the amount of nitrates the plant contains. The part of the plant also varies considerably as to the amount of nitrate it may contain. The higher the leaf, the lower the nitrate content tends to be. The seed or grain part of a plant contains very little nitrate. When conversion of nitrate to amino acids and plant protein is slowed down because of the lack of light, nitrates may tend to accumulate.

Another consideration in animal nutrition is milk fever. Milk fever is a paralysis or tetany caused by an insufficient amount of calcium in the circulating blood stream. The incidence of milk fever is probably as high as it has ever been and varies from near zero to more than 50% of entire herds for each lactation period. Milk fever generally occurs soon after calving, usually within 48 hours.

Complicating the fact that calcium may be in short supply is the fact that an excess of either calcium or phosphorus interferes with the utilization of the other. An insufficiency of either calcium or phosphorus prevents normal bone formation. Bone is about 84% $Ca_3(PO_4)_2$ with a ratio of calcium to phosphorus of about 2:1. There is active metabolism of bone. Radioactive tracers show that half of the scapula (shoulder blade) is replaced in 50 days in rabbits. Deposition or resorption of both minerals is concurrent with each other. This is important in understanding the complexity of milk fever.

Vitamin D increases calcium assimilation and phosphorus resorption, especially in older animals. There must be adequate supplies of vitamin D at all times for assimilation of the two minerals from the intestinal tract for resorption from bone reserves. Vitamin D is produced by ultraviolet rays (primarily direct sunlight) changing 7-dehydrocholesterol in the animal's skin. There is some body storage of vitamin D, depending upon the amount of calcium-phosphorus metabolism. In most dairy areas, vitamin D is not a problem. However, if cows are kept inside barns or in areas where long periods of fog or cloudy conditions occur, vitamin D must be supplemented. This includes most dairies in Washington State during the fall and winter months, and all year for some dairies.

Phosphorus should be supplemented to all dairy cattle, and calcium should be supplemented unless very large amounts of legume roughages (usually alfalfa) are fed.

Milk fever is often complicated by ketosis, either at calving or later. It is often difficult to determine which disease occurs first. Clinically, low calcium causes paralysis while ketosis (high amounts of ketones in blood, respiration, gases, milk, and urine) does not. However, extremes of one may quickly cause the other. First-calf heifers seldom have milk fever.

Calcium assimilation decreases with maturity so that milk fever incidence is greatest in the older animals. High milk production obviously increases the likelihood of low calcium, but it can occur in all cows and even in beef animals. Cows with previous histories of milk fever are most likely to repeat. Obviously, any situation that limits feed intake without immediately lowering production will lower the circulating blood levels of calcium. This could be brought about by rancid feeds, insufficient feed or water, extreme excitement, and by injuries to the alimentary canal.

Ketosis, or acetonemia, is a metabolic disorder and is not contagious. The most logical explanation seems to be that the energy needs for production exceed the energy consumed by the cow and she is forced to mobilize her body reserves to keep on producing. She may be able to do this for a while without getting into trouble, or she may mobilize available fat, become thin, and reduce production. If the situation is too prolonged or the deficit is too great, and the body fat is readily available, she mobilizes such large amounts that her liver becomes fatty and cannot function normally. Ketone bodies are produced in large amounts from this mobilized fat, as well as from butyric acid present in the rumen and from certain amino acids. Although she uses these ketones for energy, they are produced in such large amounts that some spill over into the urine and milk. While the ketones themselves do not cause abnormalities, their level in the blood, milk, or urine is the best indicator of how serious the condition is.

The problem seems to be initiated by the drain on the blood to supply sugar needed to make milk lactose. When the sugar is low, larger amounts of ketones are produced from the mobilized fat and other materials. Often the condition may be brought on simply by underfeeding the high-producing cow after calving.

Ketosis usually occurs 10 days to 6 weeks following calving in the higher producing cows. About 3 weeks after calving seems to be the most critical time. The first and most obvious symptom is a lack of appetite. The cows usually refuse first grain and then silage but may continue to eat some hay. There are all degrees from small feed refusal to almost complete failure to eat. Usually there is rumen inactivity and constipation. Most often the cow is depressed and dull and listless, but occasionally there is the so-called "nervous" type in which the cow is wild and easily excited. Sometimes there may be incoordination, particularly in the hind legs, and the cow may weave when she walks. To go along with these symptoms, there is decreased milk production and loss of weight. These can occur in any degree from slight to severe. Only an occasional cow dies from ketosis, but when one does, the most obvious finding on post mortem examination is a fatty liver.

Two major changes from the normal occur in the blood. One is a decrease in blood sugar. The other is an increase in what are called blood ketones. This explains the origin of the name ketosis. One of these ketones is acetone. Hence, the other name acetonemia, which means acetone in the blood. When these ketones reach high levels in the blood, they pass into the urine and the milk. Some dairymen can identify cows with ketosis by smelling the sweet and somewhat sharp odor of acetone. For many years, the testing of the urine for acetone has been a common tool for diagnosis used by the veterinarian and some dairymen. A small amount of urine is placed on a special pill or powder. The development of a purple color constitutes a positive reaction.

The following points regarding the urine test for ketosis should be made clear. If the test is negative, the cow does not have ketosis. If the test is positive, several possibilities exist. She may have ketosis and may need treatment. She may have some degree of ketosis but may not require treatment. Many high-producing cows will show a positive urine test to some degree during their peak production period shortly after calving. Other factors that may throw a cow off feed may also test out as showing the presence of ketosis when actually the ketosis is a secondary rather than a primary ailment. The urine test is still a good diagnostic tool and, if it is definitely positive and there are no complicating ailments, ketosis is indicated.

Recently, milk tests have increased in popularity. Research work in Wisconsin shows that the level of ketone bodies in milk is about half that of the blood, while the urine level exceeds the blood level by about four times. This means that the milk test is less sensitive and often may prove to be a more accurate indication of the need for treatment. Milk is also easier to obtain than urine, and the time at which the sample is taken in relation to milking does not alter the results appreciably. The test does not work well on colostrum milk, however, and obviously it will not differentiate between primary and secondary ketosis. It is estimated that a third of all ketosis cases are complicated with something else.

Over the years, at least 25 different treatments for ketosis have been suggested. The fact that some cows may recover spontaneously without treatment makes evaluation of the treatments difficult. The treatments most widely used at present include the injection of sugar into the vein, injection of hormones or oral administration of propylene glycol or sodium propionate. It is difficult to say that any of these treatments is the best since each has its advantages and disadvantages. It is wise when such problems arise to discuss them with an expert such as your local veterinarian.

Obviously, prevention of ketosis would be more satisfactory than treatment if the methods involved were practical. Unfortunately, at the present time there seems to be no way to attain 100% freedom from ketosis. Suggestions for reducing the incidence of ketosis can, however, be made. Although there is disagreement regarding the basic cause of ketosis and the extent to which hormones are involved, most research workers are agreed that factors that would tend to balance feed intake with milk production without throwing the cow off feed would be beneficial.

These are examples of the kinds of problems that can arise from improper nutrition.

Vectors and Parasites

First, let's define vectors and parasites. A vector is an organism (an insect, for example) that transmits a pathogen or cause of a disease (viruses, for example). Vector control is the scientific suppression of insects and other animals adversely affecting public health and well being through environmental conservation measures aided by appropriate chemical and biological controls technology. Parasites are organisms that depend upon a host for their existence either throughout their life or through some phase of their life cycle.

Some parasites occur in both animals and people and are spread from one to the other. Some parasites use animals as an intermediate host in earlier stages and man as the definitive, or final, host. Others use man as an intermediate host and animals as the final host. Man usually acquires parasites by eating the intermediate animal hosts or accidentally swallowing small insects.

Even among the parasites that live only in man or only in animals there are often great similarities. Farm animals, domestic animals such as cats and dogs, and even rats and mice are involved in spreading parasites to man. A better understanding of parasites, their life cycles, insecticides, sanitation, and hygiene has led to better control of many of these enemies of man and beast.

Flukes

Flukes are one type of parasite. Many species of flukes infest the livers of warm-blooded animals. Because all liver flukes of domestic animals must have one or more intermediate hosts for completion of their life cycles, it is hard to develop control measures that apply to all species.

Four well-known species attack cattle, sheep, and other domestic livestock. They are the common liver fluke, the giant liver fluke, the large American fluke, and the lancet fluke.

Many millions of dollars worth of loss are caused by flukes in cattle and sheep each year. In addition to the loss caused by condemnations of livers at slaughter time, there is also the loss from unthriftiness, lack of condition, poor feed efficiency, and extra management required in the production of the animals.

The common liver fluke is widely distributed and is found in abundance in the State of Washington. The adult fluke found in the bile ducts is flat and leaf-like. The parasite is about an inch long in sheep and a little longer in cattle. It may live in an animal for many years. The life cycle of the common fluke has been known since 1882. The intermediate host for the common liver fluke has now been shown to include about 14 Lymnaeid snails, which are vectors of the parasite throughout the world.

The common fluke deposits its eggs in the bile duct in enormous numbers. They pass out of the host in the droppings. The eggs embryonate when they reach water and hatch in 2 to 6 weeks, depending on temperature.

The liberated larva, or Miracidium, swims about in the water until it comes in contact with a suitable snail, into which it bores. It then changes into a form known as a Sporocyst. After changing form many times, it finally becomes what is known as a Redia. Large numbers of minute stages, shaped like minute tadpoles and known as Cercariae, are produced in the Redia. These eventually escape from the snail, swim about, and become encysted on grass or other vegetation or under the surface of the water. Development within the snail takes 50 to 80 days.

When encysted Cercariae, or Metacercariae, are taken into the body of cattle, sheep, or other hosts, they are encysted in the small intestine, penetrate its walls, and reach the abdominal cavity. There thev wander about, penetrate the capsule of the liver, and eventually reach the bile duct, where they mature in about 3 months.

The most obvious injury to cattle is to the liver, where the parasites cause irritation of the bile ducts, enlargement and thickening of the walls, and fibrosis of the liver tissue. The lumen of the bile ducts is heavily encrusted with deposits of calcium phosphate. Such livers are unfit for human use.

Sheep are particularly susceptible. Sheep cannot be raised profitably in many places without a regular system of medication. A further complication to sheep raising in areas in Western States where flukes are a problem is "black" disease or infectious necrotic hepatitis, a condition caused by the bacterium *Clostridium novyi.* This organism does not seem to cause disease in normal animals, but in sheep whose livers are extensively damaged by flukes it may cause rapid death.

The giant liver fluke is much like the common fluke, but is much longer and its ends are less pointed. It is the common liver fluke of India, other Southern Asian countries, and Africa. It is also common in Hawaii.

The large American fluke is a fleshy and leaf-like parasite. It may be 3 inches long when it is fully extended. It has been found in British Columbia and Idaho, among other areas. Its definitive hosts in North America are cattle, sheep, goats, several species of deer, bison, and elk. It has also been found in horses.

The young giant flukes, which gain access to the liver in the same way as do those of the common fluke, wander through the liver tissue and form extensive channels. Finally they come to rest as a result of the host tissue reaction. They become surrounded by connective tissue and complete their sexual development within these cysts.

The cysts in cattle are thick-walled and have no access to the bile ducts. Therefore, the eggs of the parasites cannot escape, and the life cycle is not completed. In deer and related mammals and in sheep and goats, the cyst wall is thin, bile ducts are open, and the eggs and other material from the cysts flow freely into them and escape from the body in a normal manner. Consequently, it is generally believed that cattle and closely related ruminants are not important in the spread of infection.

The lancet fluke is the smallest of the liver flukes that infect livestock. The lancet fluke is seldom more than 1/2 inch long and has pointed ends. Most of the reported infestation of the lancet fluke has been in 11 counties in central New York.

An example of diseases that may be carried by flukes is salmon poisoning disease (SPD). Salmon poisoning disease is a *Rickettsial* disease that affects dogs, bears, foxes, raccoons, and other animals that eat raw salmon or trout that have been infected with Metacercariae of the fluke *Nanophyetus Salmincola.*

The usual incubation period after an animal has eaten fish that have the parasites is 7 days, but signs occur as early as 5 days. The animal is likely to respond with temperatures of 103.5° to 107.0° F. This decreases for 6 to 8 days and is then followed by hypothermia (subnormal temperature) and death.

Considerable research on salmon poisoning disease shows that the disease is marked with depression, anorexia (loss of appetite especially for a long time), extreme thirst, emesis, lymph node enlargement, and progressive diarrhea (often bloody). Any disease that results in death is serious, but it is considered especially so when it may also affect man as is the case with salmon poisoning disease.

In Japan, where more raw and smoked fish are eaten than in many other countries, persons have been shown to have died from salmon poisoning disease. Since some salmon, steelhead, and trout are known to be carriers of this disease, it would seem wise to cook these species rather thoroughly for human consumption. Figure 6 illustrates the life cycle of the fluke that causes salmon poisoning disease.

Tapeworms and Bladder Worms

Domestic ruminants in the United States may harbor three species of adult tapeworms and five species of bladder worms or larval tapeworms. These larval tapeworms develop to maturity in certain nonruminant hosts, such as dogs and related animals, and humans.

Adult tapeworms of ruminants are flat, ribbon-like, segmented parasites that may be several yards long and 3/4 inch wide. They are attached to the lining of the small intestine by a small head that has four suckers without hooks. The segmented body consists of hundreds of segments. Because of their large size, tapeworms are readily seen by farmers and recognized as an important parasite. When microscopic tapeworm eggs are voided in the pasture with droppings of infected ruminants, the eggs already contain small tapeworm larvae. Oribatid mites eat the tapeworm eggs with their food. Inside the mite, the larvae penetrate to the body cavity and develop into the next larval stage, known as a Cysticercoid, in about 2 months. Great numbers of Oribatid mites live in the humus layer of soil and migrate onto forage plants, especially in the early morning, when the grass is moist with dew. Ruminants swallow infected mites while grazing on contaminated pastures. Once in the

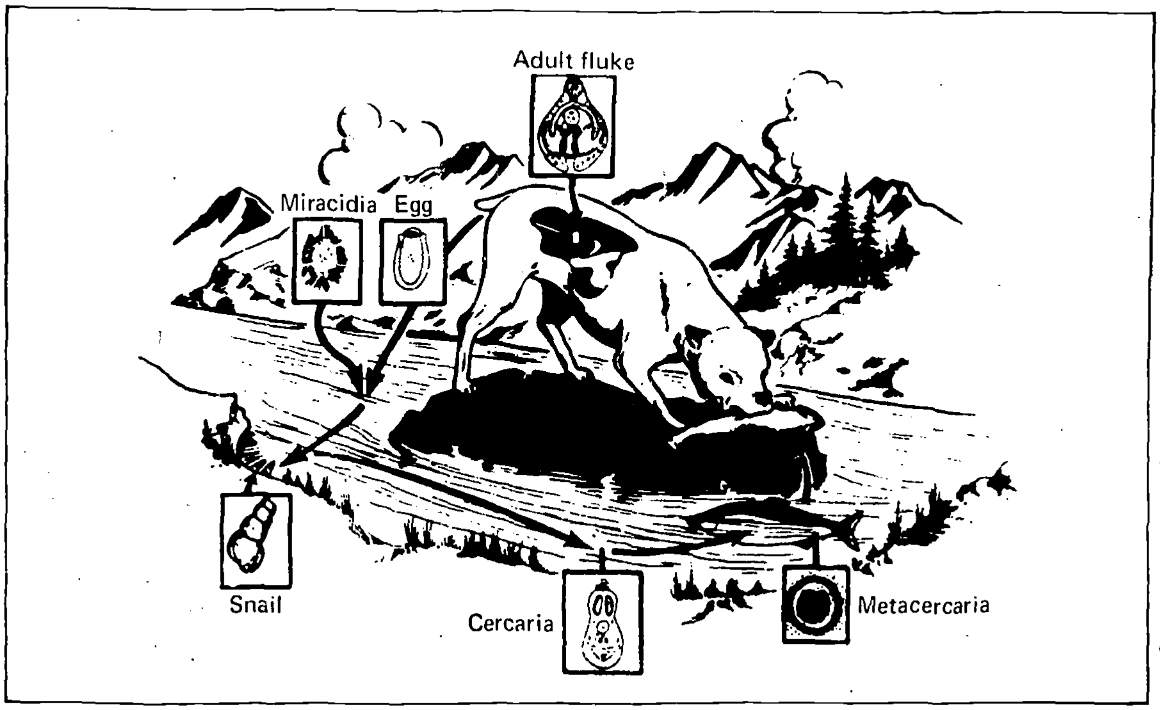


Fig. 6.—Life cycle of the fluke Nanophyetus salmincola.

digestive tract, the Cysticercoids escape from the mites. The young head of the tapeworm attaches itself to the lining of the small intestine and proceeds to grow to the great size previously mentioned. The tapeworms become mature in about 35 days and begin to produce eggs which are discharged with the droppings.

Bladder worms actually use ruminants such as cattle, sheep, and goats as an intermediate host. A bladder worm is a larval tapeworm with a small head that is inverted into a small membranous, bladder-like sac or cyst that contains fluid. The head of the larva is similar to but smaller than that of the adult.

Dogs harbor adult tapeworms after eating the cysts in dead animals left unburied on the range or the offal from cattle and sheep slaughtered on the farm or at unsupervised slaughter houses where there is improper disposal of viscera and diseased parts of carcasses. Infection of man occurs through eating the bladder worm in raw or incompletely cooked beef. Adult tapeworms produce large numbers of eggs, which leave the host in the feces.

The ruminant host acquires bladder worms by eating tapeworm eggs eliminated in feces. Once the eggs are swallowed, larvae hatch from them in the digestive tract. These active organisms then penetrate the intestinal wall and are carried by means of the circulating blood and their own movements to various locations in the body, where development into bladder worms is completed.

Tapeworms and bladder worms in sheep and cattle cause losses in meat production alone conservatively estimated at more than two-thirds of a million dollars per year.

Ticks

Ticks are a very common parasite. They are blood feeders and transmit disease-producing organisms to man and domestic animals. In man, several tick-borne diseases are known in the United States including Rocky Mountain spotted fever, Colorado tick fever, and tick paralysis. Ticks also spread a number of diseases among domestic animals. In 1954, it was estimated that the annual tick-caused losses of cattle was nearly $14 million. This estimate was made after the eradication of tick fever in the United States. Previously, cattle tick fever caused estimated losses of $40 million each year.

Not all ticks are known to transmit disease-producing organisms. They may cause injury by secondary infections of the wounds produced during feeding, by injection of toxic substances, and by removal of blood.

When ticks are numerous, they may actually cause death of both domestic and wild animals. In 1909, a case was reported in which a horse died of acute anemia because of the blood loss due to blue ticks. Fourteen pounds of blood-filled ticks were removed from the horse in 3 days, and it was estimated that that was only about half of the ticks present. Ticks vary considerably in size depending in part on whether they are engorged (having sucked blood to the limit of capacity) or not. Body length of an unengorged female of the smallest species may be less than 0.05 inch; the engorged female of the largest known species may exceed 1.1 inch.

Ticks must have a meal of blood if they are to produce eggs, and some can wait 9 or 10 years for it. Ticks are also adaptable to most temperature ranges, except for the extremely frigid zones. Some species are restricted in their distribution by lack of suitable hosts or by climate requirements. Two of the most common species, the brown dog tick and the fowl tick, have become established in most of the tropical and temperate areas of the world.

Flies

Flies affect animals in two particular ways—by biting them and sucking their blood and by transmitting diseases. The common house fly, which occurs wherever livestock are raised, is a nonbiter but is capable of mechanically spreading filth and disease organisms, and it serves as an intermediate host of certain internal parasites.

Dairy cows protected from horn flies were shown to produce 10% to 20% more milk than unprotected cows. Before suitable controls of farm flies were developed, it has been estimated that $150 million worth of damage was done by them each year.

Modern sprays can be used to kill most types of flies rather effectively, and in some cases lice and tick control can be taken care of at the same time.

Mosquitos

Mosquitos are basically thought of as a hazard to man. There is little question that they cause discomfort and irritation to man, and that they may actually stop development of industrial, agricultural, and recreational areas. They may also transmit appalling diseases such as filariasis, yellow fever, encephalitis, and malaria (fig. 7).

Mosquitos can transmit encephalomyelitis, anaplasmosis, swamp fever, fowl pox, and other diseases to livestock animals. Mosquitos also irritate the cattle and cause them to mill around, stamp, and swing their heads in efforts to fight off the insects. That and the loss of blood from bites cause losses in weight and milk production. Livestock can actually be killed by large swarms of mosquitos.

Some of the species are localized and of little economic importance while others are widespread. The species vary in their habits, but all have the common characteristics of developing larvae only in water. Not all species breed in all types of water. Some prefer fresh water and cannot tolerate alkaline, highly acid, or polluted water. Others prefer brackish water in salt marshes or in tree holes. Others develop in fresh, alkaline, or polluted water. Larvae do not breed in rapidly flowing streams, canals, or irrigation ditches, but they may be present in quiet backwaters of streams or in vegetation-choked channels.

The best control of mosquitos starts with an understanding of them: the places where their larvae breed and the adult habits. Most good control programs start by controlling and eliminating larva breeding areas (fig. 8).

Biting Gnats

Many species of biting gnats affect livestock. These may be classified into two major groups. The black fly group consists of small, hump-backed, dark-colored insects commonly known as buffalo or turkey gnats. In the other group are the much smaller gnats, which are usually grey or black and have spots on the wings. These smaller gnats are particularly hard to see and are sometimes referred to as no-see-ums.

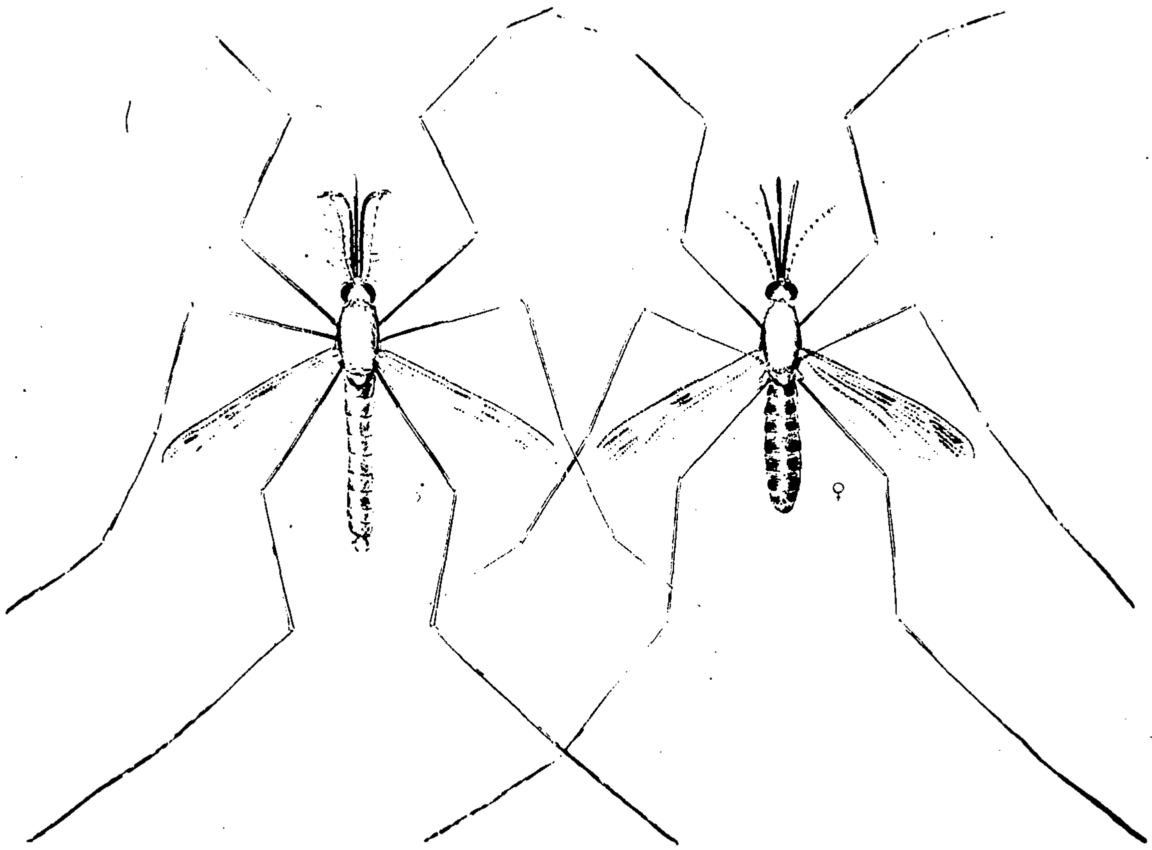
Black flies suck blood from livestock and poultry, thus irritating them, interfering with their feeding, and sometimes even killing them. In outbreaks such as occur in the Mississippi Valley, thousands of head of livestock have been killed by these vicious biters. Some black flies carry diseases and protozoa and other parasites of turkeys and ducks. At least 80 different species of black flies occur in the United States. They breed most abundantly in swift streams. They also are found in slowly moving streams and irrigation canals. The larvae and pupae are attached to stones, vegetation, and other objects in streams. In northern regions, the climate allows but one generation to reproduce each year.

Infectious Diseases

Before the 1840s in the United States, many of the diseases that are such problems today were little known. This was particularly true of the native livestock found before colonization of America. Later animals transported from the European Continent brought diseases with them. The lack of transportation limited the spread of these diseases. As the country grew and livestock production grew, the livestock disease problem grew.

Some of the better livestock producers were continually improving breeds through the importation of the choicest animals from the best herds and flocks of the Old World. In 1883, a year before the establishment of an organized animal-disease-eradication program, it was estimated that there were 146,388,329 animals valued at over \$2-1/3 billion in the United States. In round figures, these animals consisted of 11 million horses, 2 million mules, 41 million cattle, 49 million sheep, and 43 million hogs.

Up until 1833, livestock diseases had received little attention from State or national government. As an example, \$25 to \$30 million worth of hogs were dying each year from hog cholera. Sheep production had become a very risky business in many sections of the country because of scab and other parasitic diseases. Tuberculosis and brucellosis were spreading. Anthrax and blackleg were on the increase in most of the States. Of even greater



USDA drawings

Fig. 7.—Drawings of the *Anopheles quadrimaculatus*, malaria-carrying mosquito.

USDA Photo

Fig. 8.—This reflection pool could become a breeding ground for mosquitoes.

psychological importance was the fact that the causes of many of the important diseases were unknown or being disputed. With few known cures for the many infectious diseases spreading across the country, livestock producers were basically defenseless. To further add to the problem, infectious diseases were found not to stop at political boundaries. Thus, while many felt strong opposition to "Government interference," others envisioned the need for State and Federal aid in developing research and carrying out quarantines and other measures to eradicate diseases.

One of the early research projects carried out was to discover the cause of tick fever. Farmers were the first to suspect the cattle tick. After it was found that tick fever was caused by a protozoan parasite in the blood, it was not long until the relationship of the disease to ticks was also proven. This research cost $65,000 and today saves farmers at least $60 million a year. An even more important outgrowth of this research is the fact that the mysteries of such human diseases as malaria, yellow fever, typhus, bubonic plague, and Rocky Mountain spotted fever were also discovered. After finding that the tick was spreading the disease, the next obvious step was to find a way of eradicating the tick.

Finding methods to eradicate the tick took several more years before these efforts became very successful.

Many persons felt that eradication of diseases was either impossible or impractical and were not overly cooperative in ventures to quarantine or destroy animals. Some farmers saw the value of their livestock production decrease because of quarantines placed on their stock limiting the area in which the stock could be sold. Others saw their livestock destroyed or faced the possibility of having their livestock destroyed to try to eradicate disease. These harsh methods were often not received with great enthusiasm. People in the Federal Government and in other high positions could see, however, that eradication was necessary to keep diseases from spreading from poor herds to even the very best and well-managed herds.

The importance of animal diseases can be seen in a few simple statistics about American agriculture. American farms produce approximately a third of the world's yearly production of red meat and a fourth of the yearly production of milk. These figures are due in part to the increased efficiency gained through improved health by controlling and eradiciating diseases. The importance of this production can be seen by the well-balanced diets available to most Americans at reasonable costs as compared to the improper and nutritionally poor diets consumed by millions of persons in other parts of the world. In some of the countries where animal diseases are the worst, people may eat fewer livestock products in a year than Americans use in a week.

The United States today is one of the safest nations in the world in which to raise stock. Even here, diseases, parasites, and insects still take a heavy toll. Each year 10% of all farm animals can be expected to die from disease or from parasitism. Even greater economic losses come from diseases that do not necessarily kill but debilitate or maim the animals and otherwise interfere with efficient production. Reducing these losses is a challenge that continues to face American agriculture.

The incidences of many diseases in this country have been lowered to the point that they are quite difficult to detect and stamp out while still being high enough to remain dangerous. An example of one such disease is tuberculosis among cattle.

Many factors contribute to the problems that we still have in this country. One factor is that the animals have not had many diseases so they are not immune and are susceptible to any of a number of diseases that may strike. Thus, often when a disease does strike, it has rather disastrous results as compared to the same disease striking in another country where many of the animals may have been exposed previously to the disease.

This country more than many other countries has gone to concentrated production of animals to increase efficiency (fig. 9). Although increased efficiency can often be gained, one disadvantage of such arrangements is an increase in disease problems. Many common animal diseases increase geometrically or four times as fast as the increase in number of animals. Another factor that must be considered is improved transportation, which has allowed rapid movement of livestock across the country and internationally. For example, a steer may be raised in three or four States, sent for slaughter to another State, and be sold in still another State. Complicating the mobility factor is the mingling factor where cattle or other animals are allowed to mill around together for even short periods where disease may spread to susceptible animals. An example of the change that has taken place because of mobility and mingling can be seen in the fact that tick fever of cattle moved across North Carolina at a rate of 4 miles a year in the 1870s. When vesicular exanthema of hogs broke out in California in 1952, the disease was diagnosed in 20 States within 3 months.

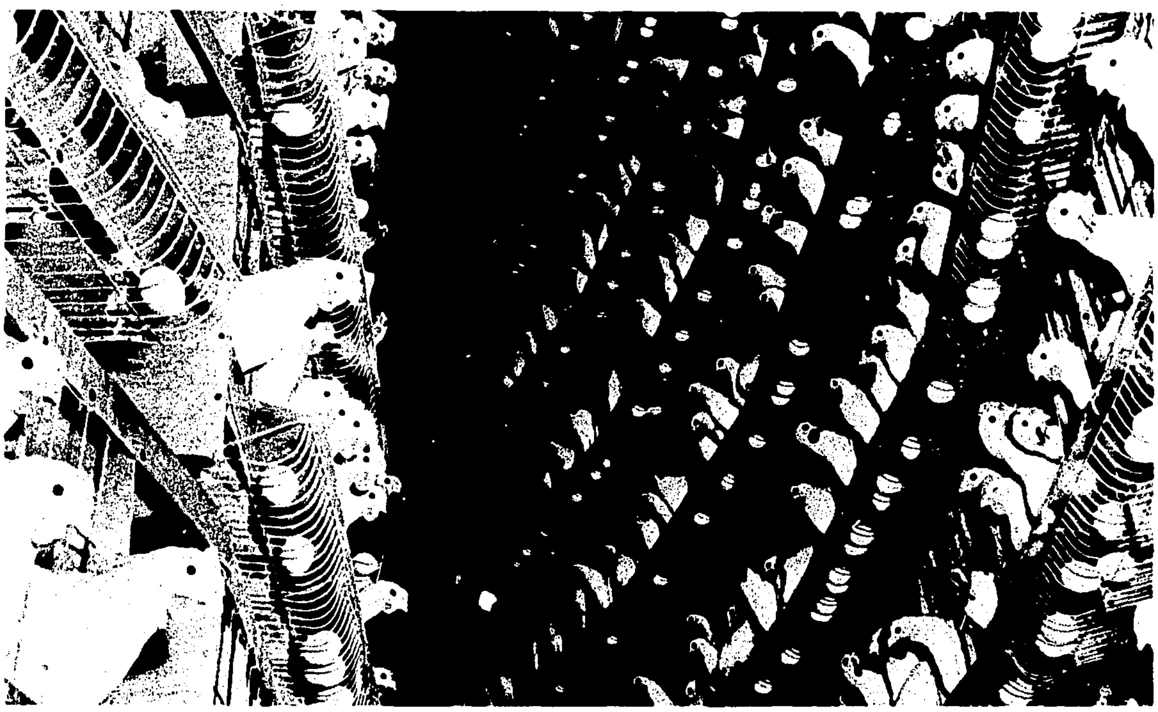


Photo Courtesy: *The Progressive Farmer* by J. McKinney

Fig. 9.—Neighbors are rather close in this futuristic egg-in-round operation with rotating tiers of hens. Such concentrations geometrically increase disease problems.

Reducing and eradicating diseases is not simply a matter of giving medication to animals. The immediate need is often to control the spectacular outbreak of disease. Each time that this happens, however, it necessarily detracts from the amount of available resources that can be brought to bear on the chronic, nonfatal disorders. For example, mastitis causes an estimated 5% loss in total milk production in this country.

Other problems arise because new diseases arise. Some diseases just appear, and often we do not know where they come from. Viruses, bacteria, and parasites are very prolific in their reproduction; are often persistent and elusive to the processes of eradication; and carry on their great amounts of damage while being practically invisible.

An example of an animal disease and the amount of damage it can do can be seen in bovine mastitis or inflammation of the udder. Mastitis may be either infectious or noninfectious. Infectious mastitis may be produced by many kinds of bacteria and some yeasts. The two main types of bacteria causing mastitis are *Streptococci* and *Staphylococci*. Other types of bacteria have been increasing as causative agents in mastitis cases. Fortunately, many of the strains of bacteria that cause mastitis are harmless to consumers. When milk is pasteurized properly, practically all danger is eliminated. This includes bacteria that can invade the udder and cause tuberculosis, brucellosis, scarlet fever, or streptococcus sore throat in man.

The bacteria that cause mastitis are usually carried from diseased cows to the teats of healthy cows on the hands of milkers or in the teat cups of milking machines during milking. Bacteria also can be spread by flies or by contacts with contaminated bedding or floors. Injury to the teat opening and teat canal and the improper use of teat tubes and dilators also are responsible for some udder infections.

The teat canal is of considerable importance in preventing infection and should be protected from injury as much as possible. Once the bacteria enter the opening of the teat, they then pass up the teat canal and establish themselves in the milk cistern or lower part of the gland.

Mastitis exists in two forms—acute and chronic. Acute mastitis is readily detectable and is the form most familiar to the cattle owner. The affected quarter is hot, tense, hard, and tender. Milk secretion is largely or entirely suspended. The milk may be watery, straw-colored, or blood-tinged and may contain few or many clots. A general systemic disturbance, such as depression, fever, and loss of appetite may be present. In acute mastitis, the organisms have invaded and inflamed much of the involved quarter.

Chronic mastitis is not readily recognized. That is because a general balance exists between the infecting organisms and the udder, with the result that few observable symptoms develop, although damage to the secretory tissues does occur. Although inflammation may exist, it may be hard to spot because of the small area of secretory tissue being attacked at any one time. Consequently, the gland may not appear to be swollen and the milk may appear normal, but at the same time inflammation will change the composition of the milk. The milk does not contain the usual amounts of butterfat or milk sugar, and the number of leucocytes, the salt content, and the products resulting from inflammation and bacterial activity increase. Even those changes will not be found if the areas of inflammation involved are microscopic. While it is so difficult to find these lingering chronic cases, they may be a constant source of infection to other cows.

Noninfectious mastitis is the result of injury, chilling, bruising, or rough or improper milking.

It has been estimated that mastitis costs American dairymen and, indirectly, the consumer more than $400 million each year.

Several things can be done to help prevent mastitis. First, utmost caution should be used in making replacements in the cattle herd, and it is best to purchase heifers before they have freshened. Good sanitation of equipment and premises helps alleviate buildups of the bacteria that cause most mastitis. Use disinfectants that will kill the bacteria and prevent spread of it. Milking should be rapid, regular, and thorough. The milking machine should be properly adjusted, checked, and cared for. Ample supplies of clean bedding should be used. Precautions should be taken to prevent udder injury, and cows should not be crowded or hurried, since this is where many udder injuries take place.

When prevention has not worked, then treatment and control become necessary. Early diagnosis is one of the important control measures. As with any severe disease, a veterinarian should be consulted. The usual treatment then is injection of antibiotics, sulfa drugs, and other medications by intramammary injection. The veterinarian will also suggest other control measures such as milking all diseased cows last. Use a strip cup before milking to identify new cases of mastitis. Wash udders with clean individual towels placed in a sanitizing solution. After milking, dip the ends of the teats in a sanitizing solution. Before milking each cow, wash hands with soap and water. Disinfect them with chlorine solution and wipe them dry, preferably with paper towels. After milking, the equipment should be thoroughly cleaned and disinfected.

Constant improvement of tests that can be used by individual dairymen are being developed to check for increased leucocyte counts. These tests, of course, do not take the place of thorough laboratory procedures that can identify, not only the amount of mastitis taking place, but also the bacteria causing the mastitis (fig. 10).

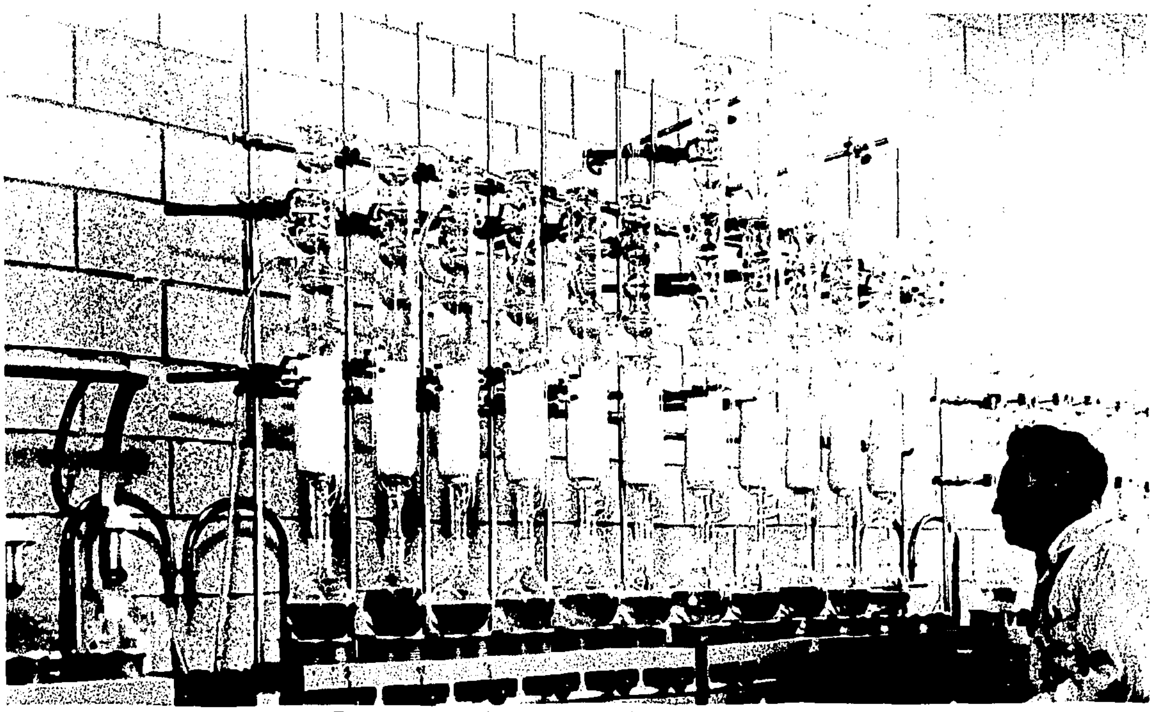

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Fig. 10.—Milk is being tested in the laboratory.

Improved antibiotics and other medicines are improving dairymen's ability to overcome the great economic losses from mastitis. However, it is important to note that when antibiotics and other medicines have been used as an infusion into the udder that the milk must not be used for human consumption for the proper period of time specified on the medicine. If milk is marketed without observing the prescribed withdrawal period after infusing antibiotics in the udder, the bacteria required for cheese production are killed by the antibiotics, thus rendering the cheese process invalid.

This is one example of the damage that can be done by diseases to animals. Many other diseases also raise havoc with animal production and cause considerable economic loss. Some infectious diseases interfere with reproduction. Vibriosis, trichomoniasis, and brucellosis are examples and can be extremely costly in a breeding herd. Of the more than 200 communicable diseases of animals approximately half are considered infectious to man, and more than 80 are transmitted naturally between vertebrate animals and man.

Treatment of Disease

Treatment of disease may include any effort to cure a disease, arrest its course, lessen its severity, or alleviate the pain and inconveniences that disease causes (fig. 11). Actions taken may include the administration of drugs or medicines, physical therapy including massage, exercise, immobilization with bandages or splints, and application of heat or cold. Changes in management, including the method of feeding or handling, may also be made to ensure recovery.

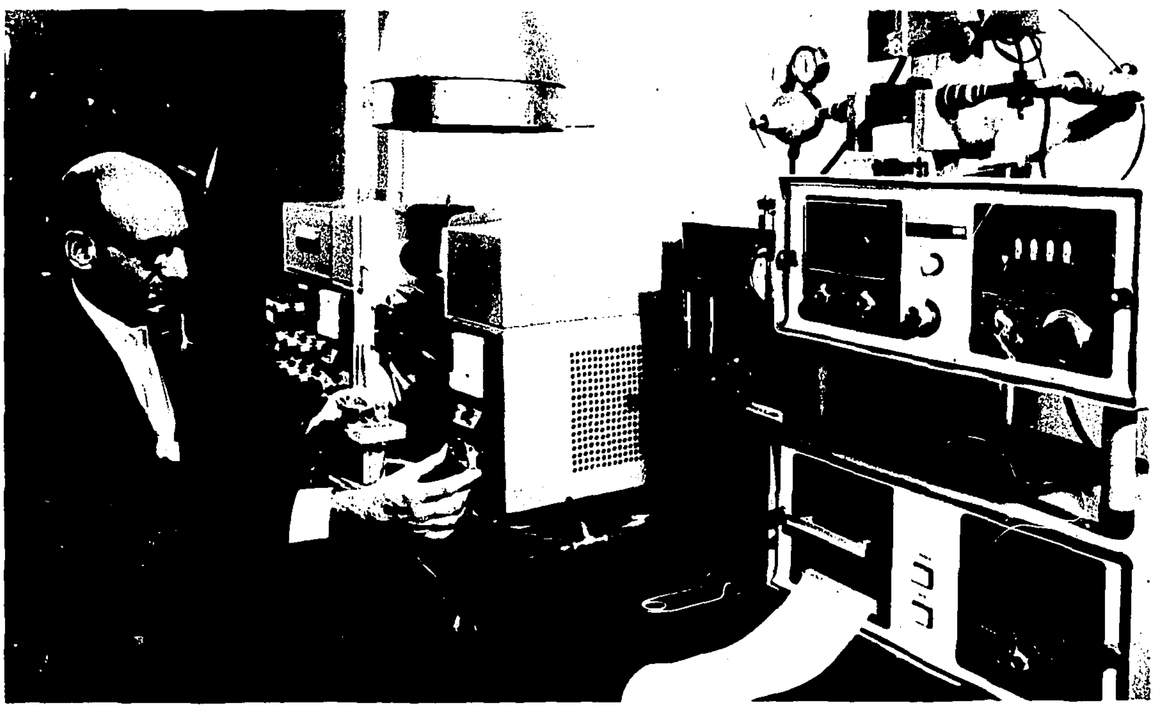
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Fig. 11.—Research continues to locate disease-causing organisms.

As in many other scientific fields, studies of animal disease and medication have increased rapidly over the past several years. The first real breakthrough in animal medication came within the last century or so. Two of the major problems were: first, there was a need for a better understanding of animal diseases and the organisms that cause them and, second, there was also a need for a better understanding of the chemicals and drugs that could be used to help treat these diseases. Many of the remedies used for animal diseases, parasites, and even injuries have been shown in recent years to have little effect in ensuring an animal's good health. There are instances in which the common remedies of less than 100 years ago have been shown to actually have a detrimental effect upon the animal.

Complicating research efforts has been the fact that the very same drug may affect different species of animals quite differently. For example, morphine will put dogs to sleep but causes cats to become restless and excited. Another example is the fact that chloroform is a fairly safe anesthetic for the horse but a dangerous one for the hog.

Drugs may be classified in many ways. It is important to know whether a drug affects only a small area where it is injected or if it will enter the bloodstream and circulate throughout the body.

Drugs may be classified by the actions that they produce in the animal. A listing of such common categorizations would include stimulants, depressants, anesthetics, irritants, antiseptics, narcotics, and antibiotics. Drugs may have more than one effect, having a desirable effect in curing a disease while at the same time causing problems in another organ in the body. For example, turpentine is a fairly effective treatment for the coughing that accompanies certain types of diseases, but it is also an irritant to the kidney. The same drug may vary in its effects, depending on how it's applied. For example, alcohol taken internally acts as a depressant but when rubbed externally onto the skin acts as a mild stimulant. Some of the most active antibiotics have harmful side reactions, so they must be used with a great deal of caution.

Sometimes the treatment is merely replacing necessary constituents of the normal body. This can be done intravenously as the injection of a form of soluble calcium is used in cows as a treatment for milk fever. This kind of treatment can have dramatic results. A cow that appears to be, and may actually be, near death can well be on her feet in 10 to 15 minutes after the injection is completed. Injection of hormones into animals suffering hormone deficiencies may likewise have speedy and dramatic effects.

Although it is theoretically possible to give animals medicine in all the ways that they can be given to humans, there are practical limitations. A good example is that many human medicines are taken orally. The best way to give many animals oral medicine is by mixing the medicine with the feed or with water. However, many sick animals will also be off feed, may not want to drink, and may not even lick at salt and other such materials. Some medications also have rather undesirable odors or tastes so that the animal will not eat them. In these cases, it is sometimes possible to disguise the odors or flavors so that the animal will still eat them. Thus, bad-tasting drugs administered orally to most farm animals have to be given as drenches with a dose syringe or injected directly into the stomach with a stomach tube. Pills, capsules, and boluses must be placed far back in the mouth if they are to be swallowed.

All of these procedures are time consuming. Many of them are difficult and may even be dangerous if the animal is not properly handled. Medications improperly administered may end up in the windpipe and/or the lungs and in many cases cause pneumonia followed by death. Placing pills, boluses, or capsules far enough back on the tongue so they will be swallowed may result in having fingers or hands bitten.

A factor that is sometimes not considered, especially by the inexperienced, is that the excitement and struggle the animal is put through in the administration of the drug may be more harmful than the drug will do good.

Because of the problems mentioned, more and more medication is being given by the hypodermic syringe. Most medicines that will dissolve in water and are not irritating can be given in this way. As long as sterile syringes and needles are used to inject sterile solutions, there is little danger.

A goodly number of drugs are applied directly to the area to be treated. Examples are ointments, lotions, and antiseptics applied to the skin; eye washes; and medication injected into the udder through the teat canal.

Keeping a few good medications around the farm may allow faster treatment of some diseases and save a trip for the veterinarian in other cases. However, for the most part, these drugs should be kept to a bare minimum and should be used only in emergencies. It is generally a good idea to consult a veterinarian as to which drugs should be kept on hand. In general, the high-powered, quick-acting, and severe drugs should be avoided.

A livestock owner should have a clinical thermometer for taking temperatures of sick animals.

The first concern of the owner should be comfortable quarters. If the sick animal is housed, the inside temperature should be moderate. The animal should be kept dry, protected from drafts, and given plenty of dry bedding. It should be remembered that many animals are comfortable at much lower temperatures than are humans so that care should be taken that artificially heated quarters are not too warm. Dark quarters may make animals with inflamed eyes more comfortable. Deep bedding may make animals that are lame more comfortable. Good quality feed of the kind that the animal is accustomed to eating should be placed before sick animals at least two or three times a day. Water should be available at all times. Animals that have been accustomed to drinking from a stream may not adjust readily to drinking from a pail and should be allowed to drink from the stream if at all possible. Sick animals should be kept quiet and free from excitement.

Parasites and parasitic diseases offer special problems. Because of the many different life cycles involved in parasites, generalized treatment procedures are impossible. Since most parasites are readily spread from one animal to another, entire herds or flocks must be treated at one time to eliminate the parasite, even for a short period of time. Since minor infestations of many types of parasites may go undetected, or at least be very difficult to detect without careful use of the microscope, medication is often given as a preventative measure at periodic intervals.

Since these parasites have various numbers of hosts and go through varying types of life cycles, it is important to identify the period in their life cycle when they can best be attacked to have the most thorough eradication.

Chemical control measures are generally immediate in their effects, economical, and often simple to apply. If, however, other eradication means, such as good sanitation, can control the disease, it may be much more desirable to avoid the use of chemicals.

External parasites have been controlled by the use of many types of insecticides. Some of these, such as DDT, methoxychlor, benzine hexachloride, lindane, and chlordane have received considerable criticism. Many of these chemicals have long-lasting effects and may, therefore, wash into waterways and be carried long distances where they may build up in fish and other water life. For a more thorough discussion of the use and problems of agricultural chemicals, see the unit *Agricultural Chemicals and Radiation.*

Some of these chemicals that are used to remove or eradicate parasites may find their way into milk, meat, or other livestock products. Many of the most effective chemicals can be absorbed through the skin of an animal, stored in fat tissues, or excreted in milk. This has made the avoidance of residues one of the chief concerns in the safe use of many kinds of parasite controls.

Three groups of disease-producing agents—bacteria, viruses, and rickettsiae—include most of the infective disease-producing agents that attack animals as well as man. Bacteria are the largest of the organisms, and a bacteria such as anthrax can be seen when magnified only a few hundred times. Viruses are the smallest of the three and may be seen only with the aid of an electron microscope, which gives a magnification of many thousands of times. Immunization procedures have been improving through the years and, in 1945, took a great step forward with the development of live-virus and modified live-virus vaccines (fig. 12). Another area of advancement of immunization procedures has been the development of methods using sprays, dusts, and drinking water. This was first done with Newcastle disease in chickens and has saved the handling of each bird individually, thus avoiding exciting the birds and decreasing the amount of labor required. An additional advantage has been eliminating the necessity of employing vaccinating crews to do this laborious job. This also has cut down the possibility of disease being carried from one flock to another.

USDA Photo

Fig. 12.—This animal is being given live virus.

Veterinary biological products may be classified generally as antiserums, antitoxins, bacterins, mixed bacterins, diagnostics, diagnostic antigens, and vaccines and viruses.

For the production of antiserums, animals are injected with appropriate amounts of antigens to stimulate the tissues to create antibodies. In the production of anti-hog-cholera serum, the hog-cholera virus is the antigen that is produced from the blood of pigs that become sick from inoculation with hog-cholera virus.

An antitoxin is a substance formed because of the addition of a toxin to the bloodstream of a living animal, which in turn produces antibodies. This may be a rather lengthy process and may take from several days to up to 3 months for antibodies to develop in sizeable quantities after injection of the toxin. The toxin, as is the case in tetanus, is the antigen (antibody stimulating substance). After antibodies have been built up in an animal, blood is extracted and processed into antiserums and antitoxins. These antitoxins can then be used to overcome effects of the toxin in other animals.

Bacterins are produced from bacterial organisms grown in artificial media. An example of an artificial media is nutrient agar. After incubation, the bacteria are harvested and activated by chemicals or other means, standardized to contain the required number of organisms, and put into containers. Bacterins may contain up to three different organisms designed to stimulate immunity in animals against specific disease conditions. They are referred to as named bacterins. Mixed bacterins are prepared from four or more bacterial organisms.

Diagnostics and diagnostic antigens are used for the detection and diagnosis of diseases. They are produced in much the same way as bacterins. They are designed and developed to detect specific disease conditions.

Vaccines and viruses include a large number of important biological products that have attained greater and greater use in recent years. Vaccines are mostly produced from virus agents, but a few may be of bacterial origin. Because vaccines vary greatly as to origin, makeup, relative effectiveness, and in their ability to be effectively modified for use in prevention of disease, it is somewhat hard to generalize about them. It can be stated that, in general, there are three types of vaccines: killed virus, live virus, and modified live virus.

The production of killed-virus vaccine usually entails the injection of the virus or bacterial agents into a susceptible animal. After the animal has contracted the disease, the animal is sacrificed at the height of infection. Selected tissues are harvested and processed into a vaccine. In the process of manufacturing the vaccine, the virus is usually inactivated with a chemical agent. Such vaccines cannot multiply when injected. Killed-virus rabies vaccine is an example.

The preparation of the live-virus vaccines entails the use of a mild live-virus agent inoculated into a medium such as a developing chick embryo. The virus grows in the new medium, and when it has reached adequate growth it is harvested and processed into a vaccine. An example is live-virus, B_1 strain, Newcastle disease vaccine.

Modified live-virus vaccines are made by repeatedly injecting a viral agent into an unnatural host until it has lost its ability to infect but still retains its ability to stimulate immunity.

It is important to remember that immunity is relative and that the degree of protection may range from mild resistance to solid protection. A severe challenge may overcome moderate protection, but at the same time it must be remembered that the cost of vaccines must be kept at a reasonable level if livestock producers are to be able to make full use of them.

Antibiotics are produced during the normal growth of many types of thread-like soil-inhibiting micro-organisms. Antibiotics inhibit the growth of bacteria that compete with the soil micro-organisms for the available foodstuff. Antibiotics have been isolated and purified for use in controlling disease-producing bacteria. As dry powders, antibiotics are stable indefinitely. Most antibiotics are stored in air-tight containers or capsules. When exposed to air, many antibiotics decompose within a day.

When adequate concentrations of antibiotics are present, they will kill bacteria. Lesser concentrations may only inhibit the growth of the bacteria. Antibiotics are most effective during the greatest period of bacterial multiplication. Old cultures of bacteria beyond the stage of rapid growth show less response. Obviously, quick treatment is important to stop these bacteria. Oral administration of antibiotics to animals can have undesired effects in that they may suppress the important cellulose-splitting and vitamin-synthesizing bacteria normally present in the digestive tract.

Most antibiotics are low in toxicity to most animals when they are used properly. This relatively low toxicity, combined with the relatively high antibacterial activity, has made antibiotics one of the most important groups of therapeutic drugs. It should be noted that some animals may have allergic reactions to penicillin or other antibiotics, and these must be carefully noted and administration of the drug stopped before serious damage is done to the animal. Besides allergic reactions, other reactions may be produced through extended use or high dosages of antibiotics. It is, therefore, imperative that a veterinarian be brought in so that serious consequences may be avoided.

Development of the great numbers of antibiotics now available has in too many cases given livestock producers a feeling of safety and produced slackness in hygiene and management. Better use of antibiotics and less dependence on them can come about by good sanitation and good management, including methods that decrease the chance of spreading of diseases.

The sulfa drugs, although less effective than antibiotics, have continued to be used. Antibiotics have proven to be both more effective and less toxic. Sulfa drugs are not able to kill bacteria, even at high dosages, but merely help control the growth of numbers of the bacteria until the body is able to build up antibodies and defend itself. The major reason that sulfa drugs continued to be used, even with the availability of antibiotics, is their relatively low cost and ability to be used in water or feed to treat entire herds or flocks.

Sanitation and Disinfection

A livestock producer and his workers must know what good sanitation is, why it is important, and how to obtain it before good sanitation can be expected on a regular basis. Good sanitation can be important in controlling and preventing diseases. The first step is removal of such obvious items as manure and bedding. The next step is to remove any further waste and wash surfaces thoroughly with a detergent and brush. Another way is to use a spray to remove this material. To wash the material away, the spray must have considerable pressure (at least 150 pounds per square inch) and enough volume to carry the material away. Once the surfaces are thoroughly cleaned they can be treated with a disinfectant (fig. 13).

Treating unclean surfaces with a disinfectant has been proven to almost always be ineffective in controlling disease organisms. A disinfectant works only when it comes in contact with the micro-organisms it is supposed to control. If the micro-organisms are embedded in organic soil or other such material, the disinfectant will obviously be ineffective.

Most disinfectants are adversely affected by low temperatures. A significant exception is lye, which is little affected in its efficiency down to temperatures of 32° F. Disinfectants should not be used at temperatures below freezing. Some disinfectants act as wetting agents or have wetting agents added to them so that they have detergent-like qualities that aid them in coming into contact with the desired micro-organisms.

Other factors, such as the acidity or alkalinity of the disinfectant or the thing to be disinfected, should be considered. Lye, for example, is extremely corrosive to metal, so it cannot be used as a general cleaner where metal is involved.


USDA Photo

Fig. 13.—Pens are thoroughly cleaned and disinfected.

The relative changes that take place when various disinfectants are diluted to 50% strength are fantastic. It is possible that the effect of the solution will be cut in half or on the other hand be lowered more than 50 times in its effectiveness. Hard water has more effect on some disinfectants than others. These examples show why it is important to read the directions on disinfectants carefully and follow them exactly.

ANIMAL PRODUCTS

In the American economy, supply and demand of many products has been shown to be greatly affected by per capita income. Therefore, demand for animal products, which tend to be relatively high priced, increases considerably as per capita income increases. In the past few years, per capita income has been increasing substantially as has the demand for animal products. One of the most notable changes in our food consumption in recent years has been the increase in the use of meat. While the consumption of meat products has been increasing, the consumption of milk and milk products has decreased slightly. Many factors, including economics, affect the amount and saleability of animal products. Increased demands for meat have necessitated mass production processing as shown in figure 14.

The average amount of meat consumed by Americans is several times that of people in the Near and Far East. The types of diets consumed by individuals, however, vary to a considerable extent so that it cannot be generalized that all Americans have adequate diets. In a nationwide 1965 survey, the results shown in figure 15 were found.

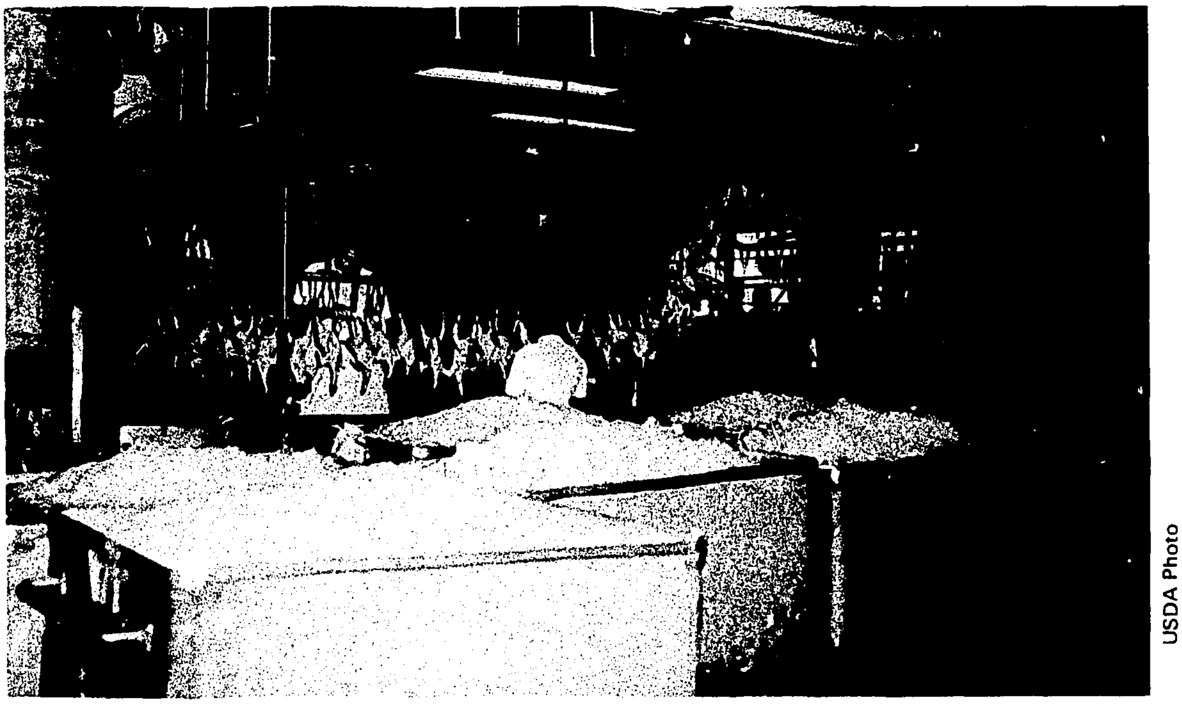
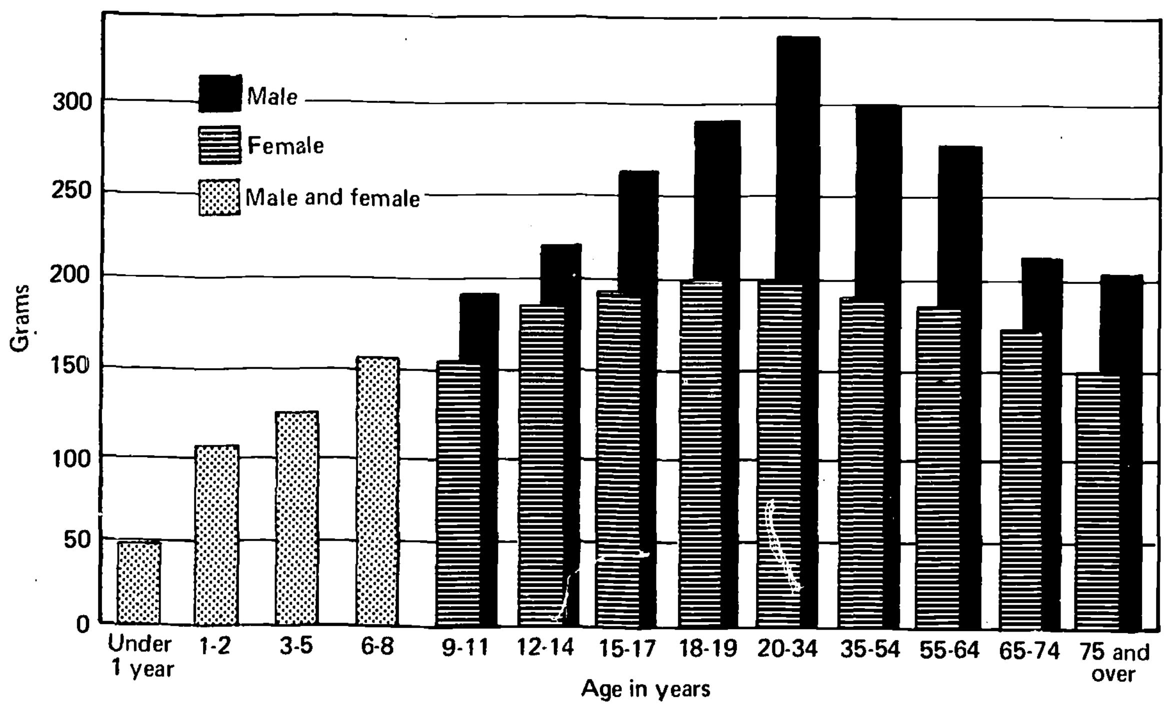


Fig. 14.—Mass production has come to poultry and livestock processing.



Source: *1969 Yearbook of Agriculture*

Fig. 15.—Quantity of meat, poultry, and fish consumed per person in a day.

TYPES OF INSECTS

How many types of insects are there? This question cannot be answered exactly since no one knows. Most scientific estimates place the numbers of types of insects between two-thirds of a million and one and one-half million.

Beneficial Insects

Many kinds of insects cooperate in giving us food, flowers, and comfort. An examination of a few of the insects that are beneficial to man will help us overcome the idea that insects are necessarily bad. Some types of insects improve the soil. They burrow through the soil, allowing organic matter to penetrate along with air and in some cases bring subsoil back to the surface. Some insects help to tear to pieces leaves, twigs, and other organic matter so that they decay and return to the soil more rapidly. Other insects speed up the decay of animal bodies, thus speeding up their return to the soil and reducing the possibilities of the spread of disease from the carcasses. Some insects that may be beneficial to the soil may also be detrimental in that during some stage in their life they eat desired plant parts, particularly roots.

Two very interesting groups of insects are the predators and the parasites. Predator insects prey on other insects and in many cases kill or devour the insect. Some of these predatory insects are of considerable economic importance. Among these are the dragonfly, damsel fly, aphis-lion, ground beetle, ladybird beetle, and syrphid flies (fig. 16).

USDA Photo

Fig. 16.—An adult Chrysopa oculata or lacewing predator.

Dragonflies and damsel flies are familiar insects. The gauzy-winged, brilliantly colored creatures called dragonflies live around ponds, lakes, and swamps. Their large eyes made up of as many as 20,000 sight units allow them to see in all directions at once. The ability to see well, along with the ability to fly speedily, enable the dragonfly to catch prey, such as mosquitos and other small insects while in flight. It catches its prey with its legs shaped somewhat as a basket into which the small insects are scooped. While still flying, the dragonfly devours the insects with its stout jaws.

The damsel flies are smaller, more delicate, and flit about more leisurely than the dragonfly. They prey on soft, small-bodied insects.

The 15 families of aphis-lions are all predators. They destroy many kinds of destructive insects, the eggs of many caterpillars, all stages of plant-feeding mites, scale insects, aphids, and mealy bugs. Aphis-lions are the young, or larvae, of delicate gauzy-winged insects with rather long antennae and beautiful golden eyes. They are often seen crawling about on leaves or flying rather clumsily from plant to plant.

Praying mantis are relatives of the grasshopper. They are so named because of the way they look when they are resting or stalking prey. The mantis is cannabalistic, and the female devours the male with whom she mates and often eats her own young.

Ladybird beetles do not exactly live up to their name. Both the young and adult beetles kill and greedily eat various soft-bodied insects. You are probably familiar with the bright reddish-yellow species which has black spots on the wing covers. The ladybird beetle's action in destroying the eggs and young of destructive aphids, scales, and other soft-bodied plant-feeding insects is of great value.

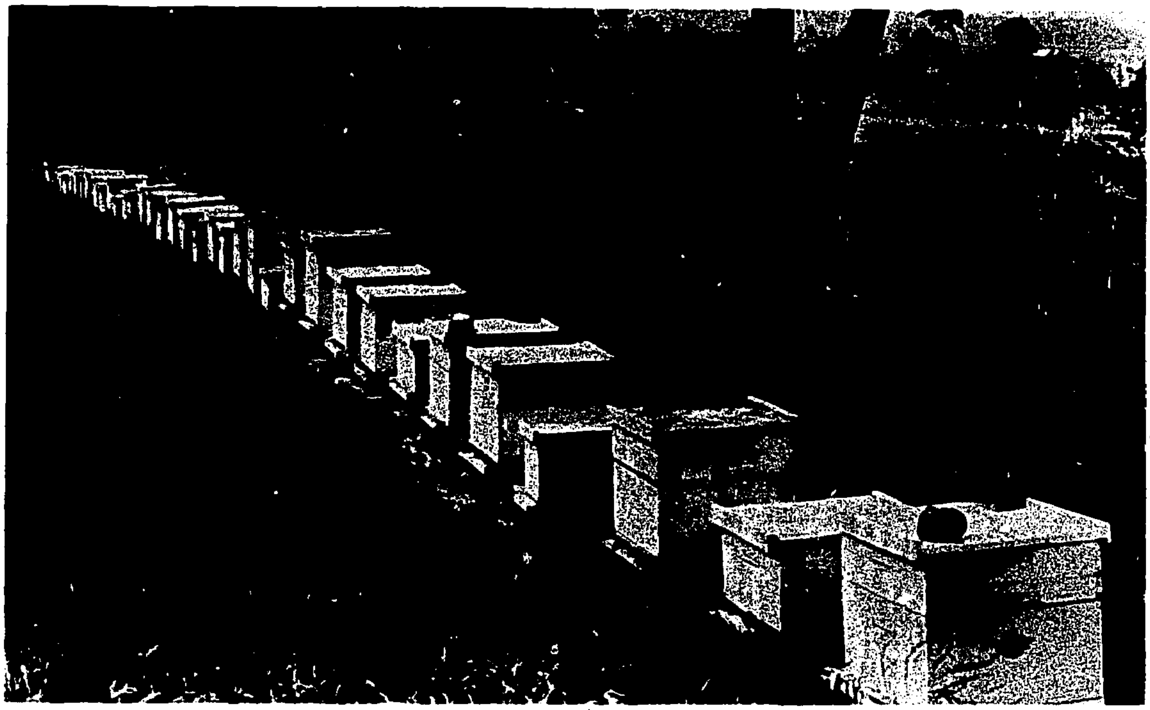
Parasitic insects are less spectacular but are often more interesting and helpful to man. There are many parasitic insects, but two of the most abundant and important are the two-winged flies and the wasps. Parasites attack insects of all types in all stages of development. Usually the host is not killed at once. The parasite usually enters the body of the host and feeds on its tissues until it is nearly grown. At this point, the host dies. The parasite may then pupate within the dead body or emerge and pupate on or nearby the remains of the host insect.

Parasitic wasps help man by combating destructive insects of practically all kinds. Unfortunately, like many other parasitic and predatory insects, they do not confine themselves to injurious insects.

Another important aspect of the beneficial nature of insects is their ability to serve as pollenizers of plants. Some of the insects that serve us in this way include thrips, butterflies, ants, beetles, flies, wasps, and, of course, bees. There are many crops that depend for any real production at all upon pollenization by bees and other insects (fig. 17). These crops include red and white clover, onions, most varieties of apples, sweet cherries, and plums.

It has been estimated that 37,000 loads of nectar are required to make a pound of honey. It is estimated that a strong hive of bees of 60,000 or more workers could polleniate 300,000 flowers a day if each make 10 trips to the field. This observation shows how important bees can be in fertilizing crops and how this aspect overshadows their value as producers of honey and wax. It should, however, be remembered that bees produce approximately 200 million pounds of honey and 4 million pounds of wax each year in the United States.

Another benefit of certain insects to man includes silk, which originates in the spittle of an insect. Production of the silkworm has been a part of the daily activity during the summer months of Chinese and Japanese for a long, long time. The silk industry began in China where the source of silk was kept a secret for more than 2000 years. Attempts to take



USDA Photo

Fig. 17.–Bees can be an important business.

silkworm eggs out of the country were punishable by death. Even today, much of the silk is grown in China, Japan, India, and the Mediterranean region. The low cost of labor in these sections make it completely impractical to raise silk worms for production of silk in the United States on a competitive basis, even though it is physically possible.

Many insects do not feed on plants that men are interested in growing. Some of these insects feed on weeds. In some cases, insects have been used to destroy certain types of weeds.

Harmful Insects

Every minute of every day billions of insects are chewing, sucking, biting, and boring away at our crops, livestock, timber, gardens, homes, mills, warehouses, and at human beings. It is very difficult to estimate the total damage done since there are so many variables involved. The damage done by a particular insect to a particular crop may vary considerably from year to year in the same place.

Infestations of insects not only destroy crops and animals, they lower the quality, increase the cost of production and harvesting, and require additional capital to purchase materials and equipment to control. Almost all crops and livestock infested by insects have to be more carefully handled, graded, washed, and screened, or they may be considered unfit for human or even livestock feed because of the infestation of insects or the presence of the insecticides used to try to rid the crop of insects.

Previous sections of this unit told of the great damage done by insects to livestock. This damage included only the direct physical damage, which may require that portions of a carcass be discarded. Other damage may include a decrease in quality, in usable livestock products, or just slower growing or a lower feed efficiency rate.

Even the losses caused by mosquitos, ticks, and flies would be extremely difficult to estimate accurately. First, there is the toll in human diseases and in efficiency. Then there is also the monetary value of time lost from work, the cost of screens on homes, interference with crop production or the harvesting of crops, and the loss of business at resort places, to name a few.

Insects cause direct losses in timber production. Some of these are rather obvious as trees are killed or damaged by boring insects and leaves are removed by chewing insects. Furthermore, diseases may be spread from tree to tree. Some of the indirect losses may not be so evident. How about the fire hazards of an insect-killed tree in the forest? What is the effect of insects on conservation? What is the value of the beauty that is spoiled in parks and other scenic areas and on streets and properties in towns and cities by insects?

Even after grains are harvested and stored, insects may attack them and devour and destroy great quantities. Insects attack dried fruits, stored vegetables, cereal, flour, and other staples. Some insects attack clothes, carpets, and other cloth and woven materials. Still other insects such as termites invade homes, damaging the timbers of the house.

The problems caused by insects could fill page after page with descriptions of the crop losses, the livestock losses, loss of forest products, loss of processed and packaged foods, and loss of other goods as well as the transmission of human and animal diseases and the suffering that these bring. Conservative estimates of the cost, including lost food and fiber, time and materials used in combating insects, and the lost time and efficiency of men who have been given diseases by insects, are in the billions of dollars per year.

INSECT CONTROL

Natural Enemies

Biological control by itself is seldom sufficiently effective to protect a crop adequately. Of the many potentially useful micro-organisms for control of insects only one bacteria, *Bacillus thuringiensis*, is commercially available at the present time. This bacteria has been tested in several situations in Washington and cannot be recommended as sufficiently effective for any of the major problems in the State of Washington. A fungus in the genus *Beauveria* has been thoroughly explored nationally but does not seem ready for commercial development. At the Fourth International Colloquium on Insect Pathology, held at the University of Maryland, it was pointed out that there are approximately 280 viral entities with good potential for insect control and that perhaps a dozen or two of these could be developed now. One of these viruses will be tested on 10,000 acres of cotton. This virus affects a moth larva that attacks several crops. It has been tested in Washington and was found to be not sufficiently effective against corn earworms to be recommended.

Although a few viruses tested have been proven to be relatively effective they do not compete satisfactorily against presently available insecticides. Another problem dealing with biological controls is that over 200 viruses affecting man and animals are transmitted by insects. It is little wonder that there has not been a great rush to register these pathogens and produce them on large commercial scales. Some of these biological controls could become a Pandora's box of nearly unimaginable consequences if wrongly developed and not properly controlled.

The value of insect predators and parasites has been widely discussed. Although reductions in numbers of insects through insect predators and parasites has been accomplished to a degree, true control of most insects does not seem a reasonable expectation for some time to come.

A promising development is the organization of a truly worldwide body termed the International Organization for Biological Control. If true international cooperation can be obtained, greater gains in research and biological control should result.

The development of commercial production of parasites and predators for purchase and mass release could continue to grow over the next several years. At present, several small firms are involved in producing promising predators and parasites, but they have been used only to a very limited extent.

Another interesting development is the application of food supplements to encourage the increase of parasites and predators under field conditions thus saving the artificial production and release of predators and parasites. Synthetic aphids have been produced, which are amino-acid-based nutrient solutions covered by a thin coating of paraffin wax. These artificial aphids have been used successfully in the laboratory for rearing the immature stages of ladybird beetles and lacewings. If this and similar methods can be done in field operations rather economically, advances in biological control may be forthcoming on at least limited numbers of insects.

One experimental method that is showing promise is the addition of buffer solutions to make existing insecticides last longer and also more importantly to make them more effective against target pests while making them less toxic to pollinators or useful predators and parasites. It is likely that several of the existing insecticides can be made much more selective and useful through this process.

Another possible future line of investigation would be selecting pollinators, predators, and parasites that are tolerant to insecticides. Because of the limited size of populations from which to select in the laboratory it is doubtful how successful this method will be in laboratory research.

It has long been known that insects can be controlled by modifying the environment in which they are found. For example, a recommended procedure in mosquito control has long been to fill or drain pools of water in which larvae develop. It is possible to control and change other environmental factors or at least modify them to help in the control of insects. It would be difficult to change field temperatures to any great extent, but you can increase humidity through the use of irrigation. It is also possible to lengthen the number of daylight hours through the use of artificial light. Since some insects respond to short day length as a means for preparing for hibernation, it is possible to artificially lengthen the day so that they will not develop their usual state of winter hardiness. This has been tried both in the laboratory and in the field with the codling moth and it is hoped that some useful programs may be developed along these lines.

Repellents have been effective in some cases. Work is being done to develop more repellents (fig. 18).

In a speech titled "Promising Strategies for Insect Control," Dr. Robert F. Harwood, chairman, Department of Etomology, Washington State University, told the society of Sigma Xi on February 24, 1971, that ". . . I am certain that the present state of our art requires insecticides now and for some decades in the future, if not for all time. For one thing, with biological control we must accept increased amounts of damage of the finished product. Yet, bear in mind that the Food and Drug Administration regards both insect parts and insecticide residue as food contaminants."

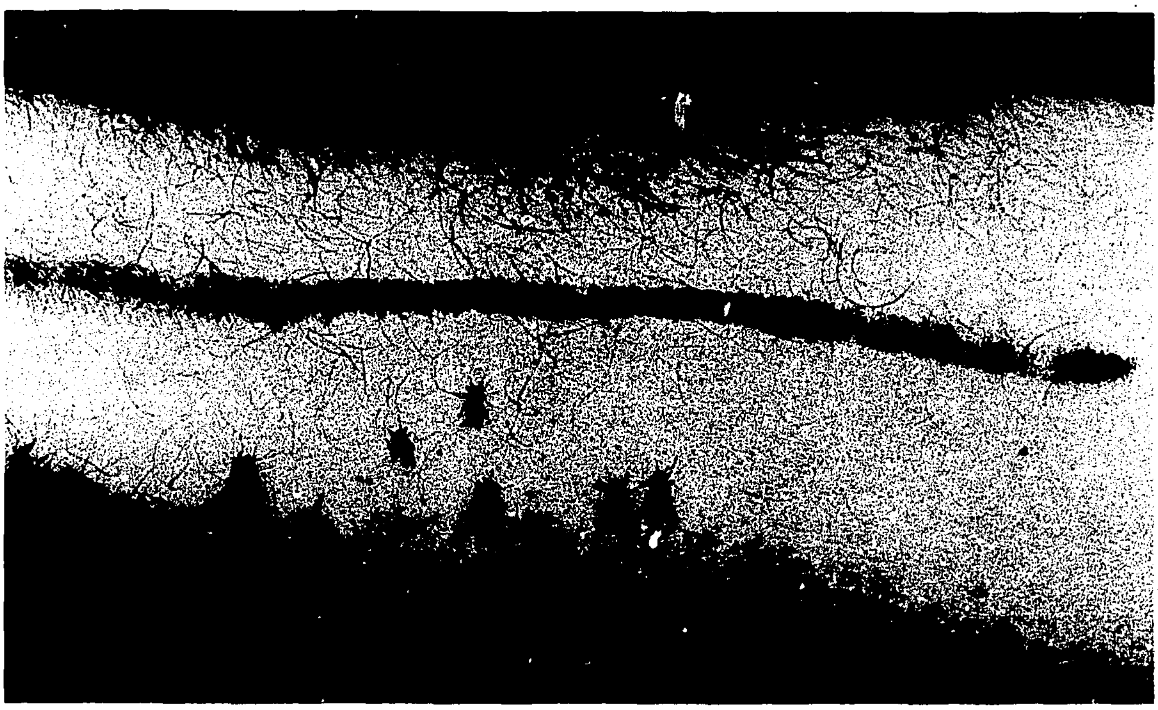

USDA Photo

Fig. 18.—Top of arm has been coated with a repellent and is effectively keeping mosquitoes off.

Controlling Reproduction

Hormones control growth and reproduction in insects. It has been thought for some time that molting hormones and juvenile hormones, or their derivatives, could be used to prevent completion of insect development (fig. 19). These chemicals would not be thought of as insecticides in the usual sense since they do not cause acute toxicity or poisoning. Instead, the insect would be induced to complete growth at a time of unfavorable climatic conditions or remain in an immature form and ultimately die because it could not complete its normal growth. The chemical nature of these hormones has been well explored, and many derivatives have been synthetized. Laboratory experiments suggest that these materials will be quite useful in insect control. However, more research must be done to establish what the effect will be upon other organisms in nature. For example, crustacea (crayfish, crabs, lobsters), which are of commercial importance, also have similar hormonal systems.

In one experiment, it was shown that males of a true bug could be treated with a chemical relative of juvenile hormone so that when they mated with normal females the latter became sterilized by the hormone. Even more importantly, when these females mated with further males they carried through and sterilized additional females. If not properly controlled, the results of such experimentation could start to sound like science fiction.

At present, there are at least two commercial companies on crash programs trying to develop hormonal derivatives for Federal registration and sale. Hormonal derivatives must meet all the tests required for insecticide registration.

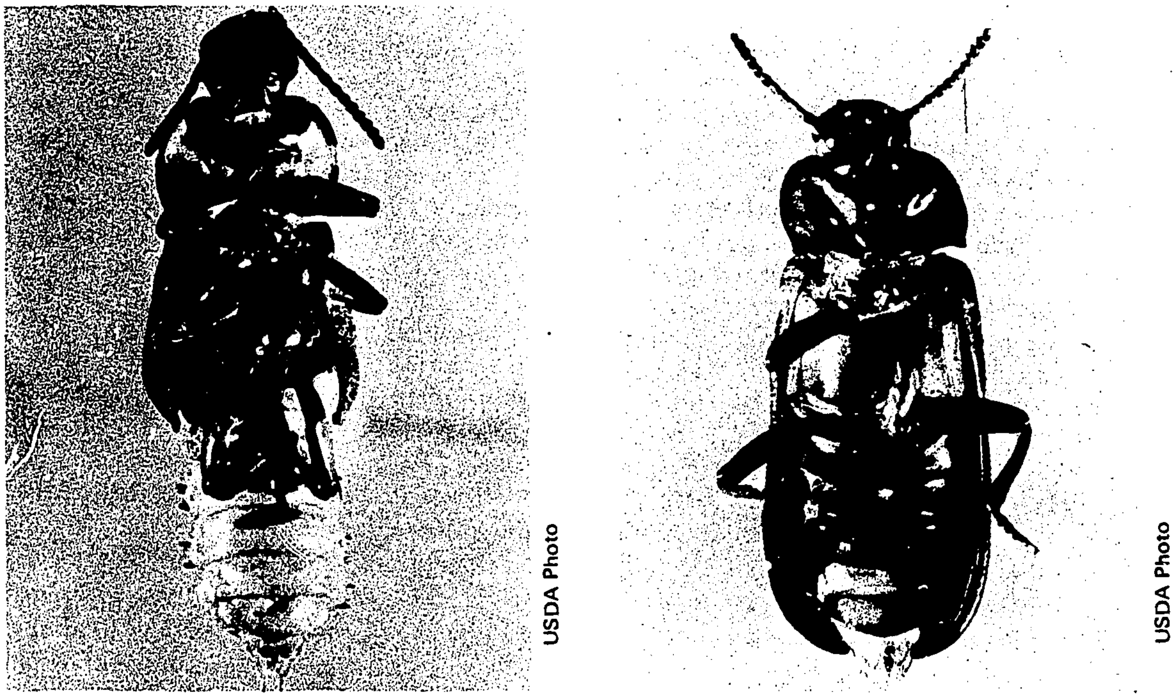


Fig. 19.—Synthetic hormone caused yellow mealworm, left, to develop adult head and thorax, but kept it from developing adult abdomen. Normally developed adult is at right.

Much of the communication among insects is through natural chemical compounds termed pheromones. Chemicals produced by one sex to attract the opposite sex of its species are called sex pheromones. Research is being done currently in the State of Washington with sex attractant pheromones that attract males of the two-spotted spider mite and the codling moth. The latter compound is being especially extensively tested. Such methods control insect population by reducing their reproduction.

Another possibility for reducing reproduction is through sterilization. Sterilization may be accomplished through the use of hormones or related chemicals or by irradiation. Another possibility is to develop a strain that produces only males. Yet another possibility is the overflooding of a natural population with males from sexually incompatible strains or races. This method has been used successfully by the World Health Organization in controlling a limited population of a mosquito species in Burma.

Cultural Practices

Farmers combat insects when they follow good cultural practices, many of which can be carried out without extra cost in time, money, or convenience. The improvement in cultural practices often requires only minor adjustments in the usual procedures. Good cultural practices to control insects are particularly important with crops that have small per acre values so that repeated spraying and other such practices are not economically feasible. This makes cultural practices most important on cereal and forage crops. It should be noted, however, that some cultural practices can also be applied to insects on vegetables, fruits, forests, and other crops.

A marvelous example of a cultural practice that can improve yields through reducing insect infestations is the delaying of the seeding of winter wheat until after the fly-free date. This happens when the wheat is planted late enough so it does not come up until after the Hessian fly has completed its fall flight. It is important to know the fly-free date so that wheat can be planted as early after this time as possible, since excessive delays in planting will decrease the yield. Late planting will also allow more winter injury due to heaving of the soil or blowing of the soil. Yearly tests have been made to determine the fly-free date for principal wheat-growing areas. These yearly tests have shown that the safe date for sowing winter wheat to escape Hessian fly injury usually coincides relatively well with the proper time for sowing to secure maximum yields of grain. In order to receive the fly-free date for your area you should consult with the county agent or the nearest Experiment Station. The fly-free date depends on many factors, including the latitude, altitude, longitude, weather fluctuations, and other local conditions. It varies considerably in broken or hilly country, even on the same farm, since it is considerably later on the southern slopes of a hill than on the northern slopes.

Moderately late plantings of corn have been shown to be damaged less than early plantings by corn root worms, bud worms, and the European corn borer. In some areas, adjusting the time of plantings of field dry beans, snap beans, and lima beans has been shown to be effective against the larva of the seed corn maggot. Early grain sorghum plantings have been shown to lower the amount of chinch bug damage in some years. Late plantings of potatoes have been shown to require fewer insecticidal treatments for control of the Colorado potato beetle than early planted potatoes.

Another effective means is to harvest the crop somewhat earlier than usual so as to prevent losses from insects that attack the crops near harvest time. Examples are early harvest of alfalfa to prevent damage by the alfalfa weevil. Early harvesting of wheat in Montana and North Dakota has been shown to save grain that otherwise might have been lost when the stems were infested by wheat stem sawflies so they would break over and not be harvested by the mechanical harvester. Early picking of corn may save many ears that would not be recovered by mechanical harvesters if the fields had been attacked by European corn borer and the stalks were breaking and the ears dropping.

Other cultural practices that help man win the battle against insects would include all practices that promote the growth of crops. The use of good seed that is adapted to the area and is a vigorous variety is a big step in the right direction. Proper fertilization and/or irrigation may also promote growth of plants and aid in the fight against insects. Rotating crops so that the same crop is not grown for several years in a row on the same piece of land may help control some insects. Making plantings of small grains and corn at sufficient distance may help prevent the spread of chinch bugs from one crop to the other. Some consideration might also be given to making plantings so that they are not located directly in the line of prevailing winds coming from sources of insect infestations.

In timber, cutting overmature stands has helped to cut losses by spruce bark beetles because vigorous second-growth stands can resist insects better than overmature stands. Since some insects use certain favorite species as hosts, through good management, these species may be eliminated from the forest.

A mixing of species may also be desirable in preventing bad infestations of insects. For example, mixed stands of white pine and hardwood are rarely badly infested by the white pine weevil, but adjacent pure pine stands are often so heavily attacked that their future value for clear lumber is destroyed. This same type of practice may be applied to field crops by the use of strip cropping or other such practice where drastically cutting the amount of concentrated stand of one crop may make it much more difficult for some types of insects to spread across such a mixed field.

Resistant Varieties of Crops

The ideal way of overcoming insects in many crops is to protect the crop from damage through resistant varieties. A good resistant variety may allow the farmer to grow a crop free of serious insect damage without changing his cultural practices or paying the cost for increased insecticides (fig. 20). Although many species of plants have been found to be resistant to many species of insect pests, including such serious pests as aphids, beetles, borers, caterpillars, flies, grasshoppers, leaf hoppers, sawflies, scales, and wire worms, the word "resistance" must be defined. "Resistance" is often used to mean the ability of a variety to avoid, tolerate, or recover from the attack of an insect to a greater degree than do certain other varieties. Resistance may be due to one or more characteristics in one variety and an entirely different set of characteristics in another variety of the same crop. A particular variety may show complete immunity to a particular species of insects, or it may still be called resistant but have only moderate immunity to a particular species of insects. The amount of resistance a particular plant may have may vary considerably with other environmental factors under which the plant is grown.


USDA Photo

Fig. 20.—Bountiful snap bean is susceptible to the Mexican bean beetle; some other varieties are resistant and would not suffer this damage.

Resistance of plants to insect infestation or injury may be due to many characteristics, including hardness or toughness of tissues, hairiness of leaves and stem, or to the lack of nutritive value for the insect in its tissue or sap. Examples of such selectivity would include the fact that granary weevils destroy the grains of soft varieties of wheat much more rapidly than they do the grains of hard wheat. The hairs on soybean plants make them unfavorable to attack by leaf hoppers. The tighter and more thorough the covering given an ear of corn by its husk the less its chances of damage by ear worms. The stem sawfly larva develops inside the hollow stem of many varieties of wheat. Part of overcoming this problem came with developing a variety of wheat in which the stem was mostly filled with a pithy substance.

New vigorous hybrids of many species are able to largely overcome insect infestations and still produce good yields. Although this is not resistance in a true sense, it is a valuable trait in reducing crop losses caused by insects.

Insect-resistant varieties are produced by four main methods. First is the introduction of varieties from foreign countries or other places where they may have developed greater resistance than varieties grown locally. A second method is the selection of resistant strains from existing varieties. A third method is to cross resistant species with nonresistant species and then select the plants with the most desirable characteristics. Finally, resistant varieties can sometimes be produced by the grafting of susceptible species or varieties on the root stalks of resistant varieties.

Some varieties brought in from foreign lands were not known to be resistant until they were tried in another country where the particular insect was a problem, and then they were found to be resistant.

The discovery and improvement of insect-resistant crop varieties is usually a result of long-term intensive research. Development of insect-resistant varieties is not a cure-all for all our problems. It will not replace cultural and insecticidal methods of control. Even if complete immunity to a particular insect is developed in a plant species, it may have other undesirable qualities that will not allow it to compete economically with more desirable varieties. Breeding resistant varieties, then, in either plants or animals may have limitations since the qualities that make a plant or animal most unattractive to insects may also be unappealing or detrimental to humans.

Quarantine

To effectively use quarantines, it is necessary to first understand the way insects enter the country or spread from place to place. As is the case with animals, insects have certain ranges of environment in which they can thrive. Over a period of time, many insects can develop some changes and can thus change to live in somewhat different environmental conditions.

Air currents and storms bring insects to the United States from the Caribbean Islands, Mexico, Central and South America, and Canada. Even insects classified as weak fliers, such as aphids and leaf-hoppers, have been found at altitudes up to 14,000 feet. From such altitudes, it is obvious that these insects may be carried for many, many miles and be carried to the shores of the United States by winds from countries a great distance away.

Some insects with stronger wings migrate annually from tropical areas and, no doubt, also take advantage of prevailing winds to make their trip. An example of such an insect is the cotton leaf worm moth, a widespread pest in South America, which has moved northward into the United States and in a few more generations may reach Canada. The winter destroys these insects but a new horde of insects can be expected for the next year. There is no way to stop these insects from traveling, so the only answer at present seems to be to try to control them in their country of origin.

After a storm, vegetation, seeds, branches, logs, and other debris that has traveled from West Indian Islands can be found along Gulf and Eastern coastal beaches. It is expected that many types of insects, particularly wood- and seed-boring species, have been brought into Florida and other coastal areas in this manner. For the most part, however, seas have served as an effective barrier against the migration and spread of insects.

Man also serves as a spreader of insects. In fact, most of the insects brought into this country from other countries have been brought in by man and, chiefly, aboard ship. He may carry insects on his person or clothing, in his baggage, or in cargo aboard automobiles, trucks, trains, and airplanes. Vehicles may also transport insects in various ways: as adult hitchhikers that get inside the vehicle; as eggs, adults, or any intermediate stage attached to plants, fruits, seeds, and plant products; or as eggs or larvae attached to the vehicle, including within the tread of the tires. Some insects may also be transported in or on domestic animals that are moved from one country to another or even from one area to another.

Many of the most important species of insects already have worldwide distribution. Even if an adult insect, which is probably the most likely to succeed in living through a voyage across the seas by ship, reaches our shores, it faces several stiff challenges. Some of the important factors include the sex of the insect, its distance from food plants and good egg-laying sites, and prevailing weather. However, even when a ship is discovered to have stowaway insects, no easy solutions to ridding the ship of these insects has yet been found.

Because of the high altitudes and extreme cold obtained by exterior parts of aircraft, the basic problem of insect spread is one of the interior of the plane. As better understanding of insects' habits, insecticides, and related research has been achieved, better control programs have been established. Airplanes traveling from countries that are known to have high infestations of undesirable insects are particularly scrutinized and cared for so as to prevent the spread of insects.

The military has long been a spreader of insects. Invading armies through the years have had little regard for quarantines or regulations pertaining to insect control of a country that they were invading. The Hessian troops that landed at New York during the Revolutionary War are believed to have brought the Hessian fly in their straw bedding. In view of such knowledge, it certainly seems well that we have never since suffered a large-scale invasion of foreign troops. During wartime, with military aircraft flying missions to many faraway points and back, it becomes impossible to take the usual precautions, and insects may gain entry in great numbers. The Oriental fruit fly, one of the most destructive pests ever to strike the Hawaiian Islands, gained entrance during World War II because it was impossible to keep proper precautions regarding military aircraft. Many other insects have also been found to be transported by military planes in time of war. Many night-flying insects are attracted to the lights inside an airplane or the reflections from windows or metallic surfaces. These insects flying toward the lighted areas or reflections may enter open doorways and other open hatches and then travel for hundreds or thousands of miles in the airplane.

Nursery stock has long been considered an important and dangerous means of introduction of foreign insect pests. Commercial importations of nursery stock made before present regulations, which require that such plants must be carefully inspected and free of dangerous insects and/or be treated in certain ways, brought in such important pests as the Japanese beetle. Diseases and insects can also be brought in with fruits, vegetables, cut flowers, seeds, and other such materials. Even the wood shipping containers used for such items as dishes and bottle goods may harbor insect pests.

Logs and other lumber products may also carry disease or insects. An example is Dutch Elm disease. One of the European beetles that transmits it to healthy trees came into the United States in elm logs.

Many insects that are not serious pests in this country were brought in through one port and in many cases stayed within a few miles of that port for several years after their importation. Early identification and eradication of these species could have saved millions of dollars in insecticide use, damage to crops and livestock, and spared untold animal and human suffering each year in this country. Some of the very serious insect pests in this country were brought here purposely. In 1869, before we had legislation to hinder such things, the gypsy moth was purposely brought into Massachusetts by an amateur entomologist engaged in research on silkworms. Through his carelessness, the insects escaped and became established as a serious pest of trees in the Northeast.

Unfortunately, even negative inspection findings are no guarantee that material is free of pests. Many insects are very small in size and their eggs may be even smaller. Therefore, treatment is also needed. Plants that will stand fumigation are usually fumigated. Other treatments have to be used for those that cannot stand fumigation.

Although the emphasis here has been on quarantines of insects and diseases entering the country, it should be noted that there are also quarantines set up within the country. When infestations of an insect are found in an area, a quarantine on that area may prevent spread of the insect to many other areas where it would also have injurious results.

Chemical Control

There are many kinds of agriculture pesticides; several of these have at least indirect consequences that lead toward controlling insects. Some of these serve as more direct means of controlling insects and are called insecticides (fig. 21). The purpose of insecticides is very simply to control insects. Most insecticides are highly toxic to at least some insects and in many cases also toxic to man and animals.

Insects can be eradicated with integrated programs of control. However, integrated methods using a combination of one or more insecticides, along with cultural practices, biological control, and other methods, often become very complex in their interrelationships. Many examples could be given to show that insects have been eradicated from entire States or areas.

Two major methods have been used to develop insecticides. First is the discovery of plants that are to some extent toxic to certain kinds of insects. The chemical nature of these plants has been studied and products synthesized that are the same as or nearly the same as the natural substance. The second way is to simply take compounds of known structures and to test their toxicity on many species of insects. After many hours, days, or even years of research, insecticides are sometimes developed that prove to be effective. However, they are not yet ready to be marketed. The insecticides must meet many standards so as to protect the American public in their use. Another important problem is the cost of the insecticides. If an insecticide is too expensive it likely will not be used for many purposes.

USDA Photo

Fig. 21.—Insecticides are being applied with an airblast sprayer.

Insecticides are usually mixed in either a powder or liquid form. Many insecticides in a pure state are coarse or sticky solids or viscous liquids so that they cannot be readily applied in the pure state. Application is made simpler by adding wetting agents and other materials to help make the material spreadable and effective in economic quantities. Proper mixing is often of extreme importance to obtain the correct results at reasonable prices. The material used for mixing is often chosen so as to enhance the properties of the finished product for the purpose that it is being manufactured. An example is that in applying insecticides to wooden posts to keep insects from attacking them, oil is often used to mix the insecticides. The oil helps the insecticide penetrate into the interior of the post to protect more than its surface and may also be useful in preventing decay of the wood.

Five types of insecticide formulations are employed to control insect pests. They are dusts, wettable powders, emulsions, solutions, and aerosols. Which one of these is most effective may depend on many factors, including method of application, the material to be treated, the value of the type of inert ingredients that may be used in each kind of preparation, the amount of area to be covered, and even the weather conditions.

Some insecticides may be very specific in the kinds of insects to which they are highly toxic. Such insecticides are often called by names like "miticide" since they are meant to kill mites.

The following discussion deals with some ways that pesticides work in controlling insects. Some insecticides may operate in only one of the following ways while others will operate in many of the following ways. Stomach insecticides are those in which the insect pest consumes the toxic material while eating a part of the growing plant. Stomach insecticides may be sprayed or dusted on the crop and usually serve to protect it from chewing insects such as caterpillars and grasshoppers. An example of a group of widely used stomach insecticides are the chlorinated hydrocarbons.

Many insects, such as aphids, eat by sucking liquid from plant tissues, so stomach poisons are of limited use. An effective means of controlling such insects is with contact poisons. These poisons are applied so as to directly contact the insect or are placed on the leaf where the insects will contact the poison. Most contact poisons have short-term effects and are often washed from the plant or otherwise become ineffective within a matter of hours or at most a few days after application. Examples of widely used contact poisons are malathion and parathion, which kill insects very rapidly upon contact.

A relatively new area of work is in the area of systemic insecticides. Systemic insecticides are absorbed into the plant or animal and will then be taken up by insects that suck on the plant or animal, as the case may be. Many materials have been developed for use in both plants and animals and have been shown to be effective for many sucking-type insects. Systemic insecticides have been successfully used to kill cattle grubs.

Another process of insect control that has been used for many years in grain is the process of fumigation. Many grain seed producers have used fumigants to be sure that insects did not attack their valuable seed while it was in storage. In recent years, more research and actual application of fumigants to soils have taken place. Fumigants applied to the soil have been shown to rid the soil of many kinds of insects, among the most important of which are the nematodes which attack nearly every kind of growing plant in nearly every climate.

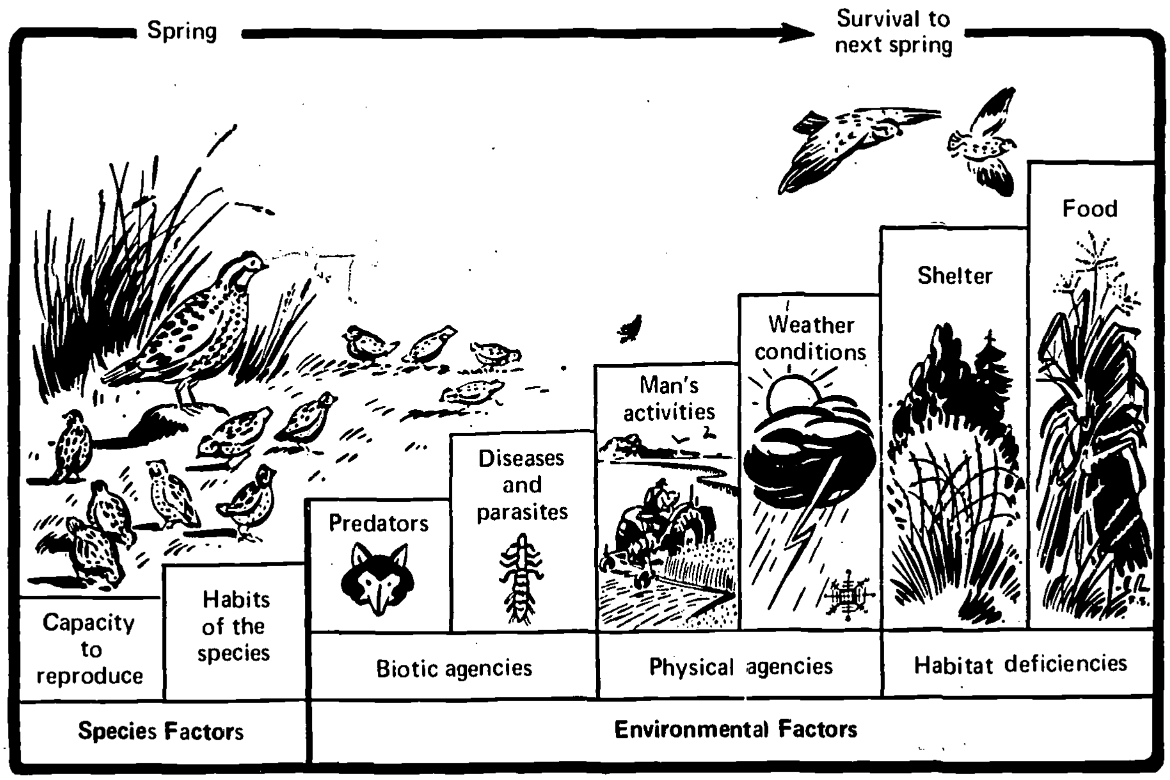
Some insecticides, such as DDT, act on insects in many ways. These materials destroy pests that eat them, are touched by them, or breathe their vapors. Many of these types of insecticides also have the advantage to the farmer of being effective for a relatively long time after application. It is this same long-lasting effect that has been the cause of considerable research and discussion as to what the long-term effects of some of these insecticides will prove to be. For a more thorough discussion of insecticides, see the *Agricultural Chemicals and Radiation* unit.

HABITAT FOR WILDLIFE

An understanding of plants is important in understanding how wildlife habitat affects wildlife. All animals, including wildlife, are dependent either directly or indirectly upon plant life as the source of their food. It is, therefore, obvious that an understanding of wildlife requires an understanding of the animal's requirements and the plants that affect their welfare.

Habitat can be defined as the natural surroundings of a plant or animal. Any changes in these natural surroundings will eventually, if not suddenly and directly, have an effect upon the wildlife of the area. The fact of change in habitat is particularly important in areas of agricultural production where changes are constantly taking place as part of the production operation. A single production operation, such as harvesting a grain crop, may produce both favorable and unfavorable changes in wildlife habitat. For example, in harvesting wheat or corn, valuable cover for wildlife may be destroyed but at the same time the mechanical harvesting machine may leave behind kernels of grain that are available for wildlife food.

Many of the factors necessary for good habitat for wildlife are also those desired by man in his environment. It is often said, therefore, that wildlife populations are an indicator of the quality of man's environment.



Source: USDA Farmers Bulletin 2035

Fig. 22.–Factors that hold down wildlife populations.

Figure 22 shows the factors that hold down wildlife populations. These factors are shown as hurdles over which wildlife, including the birds in the diagram, must pass to survive to the next spring. Only a few of these limiting factors can be practically controlled by man. The species factors, much as the weather, are unchangeable. The effects of predators may be changed or modified but with uncertain results. In most cases, little can be done to control diseases and parasites. Some of man's activities, such as time of tillage, could be changed while others, such as time of mowing, are pretty well determined by the growth rate of the particular crop.

It is indeed fortunate that the greatest changes can be made in the most important factors. These most important factors include the provision for wildlife of abundant amounts of good quality food, cover, and water. Many practices that can be applied by farmers can improve wildlife habitat at the same time that other conservation measures are being improved.

Important among useful conservation practices are crop rotations that include plants that serve as sources of food for wildlife. Liming and fertilizing may also improve wildlife habitat by increasing the amount of food and cover. Soil-holding capacity is improved by the growing crops thus reducing erosion sediment and other undesirable factors. Strip cropping also serves a useful purpose in providing food and cover for wildlife. Strip-cropped fields attract about twice as many ground nesting birds as undivided fields (fig. 23). Each strip has an edge that often serves as a valuable asset to wildlife in bringing food and cover close together.

Fig. 23.—Stripcropped fields attract about twice as many ground-nesting birds as undivided fields.

Another good practice is the use of cover crops that provide winter cover for game and also allow for the protection of the land during a period of time when it might otherwise be left uncovered. Stubble-mulch tillage is also useful in returning organic matter into the soil and helping rainfall enter the soil rather than running off, which in many cases causes erosion.

Delaying mowing of water courses, headlands, roadsides, and other areas until after ground nesting birds have left the nest, usually about grain harvest time, can be very beneficial to wildlife. Trees and brush growing along drainage ditches may provide excellent cover for wildlife but may render the ditches nearly useless for the purpose for which they were intended. On the other hand, drainage ditches may be seeded with grasses and legumes that will prevent erosion and provide for wildlife food and cover while still allowing the ditch to adequately drain the area for which it was intended.

Instead of using ordinary wire fences, in climates where they grow effectively, multiflora roses are being used as living fences. These have become a common sight in the Midwest and South. Even when first planted as hedges, they provide travel lanes for many kinds of wildlife and are used as homesites by birds, small mammals, and predacious insects that help control insect pests. In a few years, they also serve as excellent fences that will keep cattle, hogs, and other livestock from passing through them. They can, however, spread and cause problems. In some cases, established fence rows can be improved in beauty and used as wildlife food and cover by planting such things as sweet clover.

Many farms have small odd areas that could be used for wildlife. These odd areas include such places as fence corners, rocky spots, bare knobs, blowouts, sink holes, and other such areas as well as areas isolated by ditches, streams, gullies, or roads. Although many of these areas are small, they exist on many farms across the country and in total amount to somewhere around 10 million acres for the entire United States.

Properly managed watershed protection projects help maintain a natural habitat for stream fish. Control of siltation and excessive water level fluctuation are two of the main objectives in the protection of valuable streams and rivers. To carry out a good program of watershed conservation it may be necessary to strip crop or contour the area, plant contour hedges and windbreaks, build structures to retard runoff and plan logging operations so border strips of trees are left along streams and rivers; then, one might expect that body of water to be able to support a quality fishery.

Figure 24 shows an area that has received watershed protection. A green belt of trees bordering the river does much to maintain a quality river environment by containing the stream in its natural state.

Washington State Game Department Photo

Fig. 24—Watershed protection does much to maintain a natural habitat for stream fish. By keeping watershed run-off within a normal pattern, siltation, which is one of the serious pollutants of our fishing waters, is held down to tolerable limits.

Another area in which farmers have changed wildlife habitat is through the construction of farm ponds. Farm ponds that are properly designed and constructed can produce from 100 to 300 pounds of fish per acre each year for hook-line fishing. Farm ponds with grasses, legumes, shrubs, and trees planted around them provide water, food, and homesites for many types of wildlife. In some of these manmade ponds, ducks and other water wildlife species have found all the necessary habitat and have increased their numbers by thousands and thousands. Each type of area, such as a forest, rangeland, or a field in agricultural production, has a maximum potential for the production of wildlife. When this potential is exceeded and the point of overuse is attained, the factors that make the area suitable for wildlife degenerate rapidly. Factors such as overpopulation of deer and, therefore, overbrowsing of a range area may also produce erosion, increased production of weed species, and many other undesirable characteristics. Large numbers of animals can also cause serious crop damage (fig. 25). It is, therefore, often necessary to control the population of certain species to prevent the abuses of overuse. If population is not controlled, good habitat may be destroyed and animals of greatly inferior quality may result.

USDA/SCS Photo by E. W. Cole

Fig. 25.—Deer can cause serious crop damage when their numbers become too plentiful in or near agricultural lands.

WILDLIFE POPULATION

Wildlife population can fluctuate due to many factors. Some of these factors were discussed in the previous section, "Habitat for Wildlife." Agricultural operations often affect habitat and may often affect wildlife populations in other ways. Some agricultural operations, such as mowing, give rise to some extremely dangerous situations for wildlife. Certain precautions can be taken to cut the danger, such as mowing ditch banks and other similar areas late in the season after the young are out of the nest, older, and able to escape, and also by using a device called a flushing bar. Careful observation while cultivating may allow a farmer to avoid hitting a ground-nesting bird, such as killdeer, and its nest. These are just a couple of examples of the kinds of things that farmers can do to help protect wildlife and increase wildlife populations.

Importance to Agriculture

One of the important aspects of wildlife is the damage that it does to agriculture. This will be covered later.

Many persons have viewed the importance of wildlife very narrowly. It has not been generally recognized that all forms of wildlife play a role that may be important to the health and stability of the environment. A rather obvious example is that the removal of predators could allow for a rapid population explosion of rodents, which, in turn, could spread disease or cause damage to other species.

It is not being realized that the Nation's wildlife is of significance for more than its esthetic, scientific, recreational, and resource values. Wildlife plays a role in maintaining environmental quality and may be an important indicator of environmental quality.

One of the benefits of wildlife is the esthetic pleasure it provides. Most persons are somewhat thrilled to see a deer loping across a field or other wild animals or birds. Because of the large numbers of people who are beginning to crowd national parks, recreation areas, national forests, and other such areas, more attention is being paid to agricultural practices that have a direct bearing on wildlife populations.

Scientific study of wildlife has been carried on for many years. Much of this study has produced findings that are applicable to domestic animals and in some cases even to man himself.

Many species of wildlife have long served as game for hunters (figs. 26 and 27). Much of the research done on populations has been done with the game species in which hunters are greatly interested. Just the observation of wildlife serves as recreation for many persons; bird watching, along with the observation of other wildlife, seems to be on the increase.

Many species of wildlife have also served as important sources of food, clothing, oil for lamps, and many other purposes. The amount of wildlife has often decreased as the human population in an area has increased, simply because human activity has inhibited wildlife.

Whether or not persons in agriculture become more aware of the importance of wildlife, it can be expected that more will be done to protect wildlife in the future. In October of 1970, the New York State Court of Appeals ruled in favor of the Mason Act, which protects the depleted and endangered species of wildlife. The ruling was made on the grounds that it was necessary to protect the animals, not only for their esthetic value and for scientific study, but also for their key ecological role. In essence, the court ruled that the protection of wildlife is essential for the welfare of society.

Endangered Species

Many factors have contributed to the extinction of various wildlife species. Many of these factors are still working toward the extinction of some present-day species. The most important factor is that of habitat. The removal of large acreages of forest and brush for agricultural purposes has lowered the available cover for wildlife. Even more importantly in many cases is the fact that these trees and shrubs provided food, such as nuts, berries, acorns, or even forage, for many kinds of wildlife. A second important factor was disease. Many infectious diseases spread at epidemic rates through large herds or flocks of wildlife. The greater the concentration of a single species of wildlife, the more likely a disease is to reach epidemic proportions simply because it spreads more easily through the dense population of wildlife. Severe storms and other natural agents have produced death in great numbers of many species of wildlife.

USDA/Forest Service Photo by R. W. Neslands

Fig. 26.—Deer hunting is exciting and challenging for many hunters.

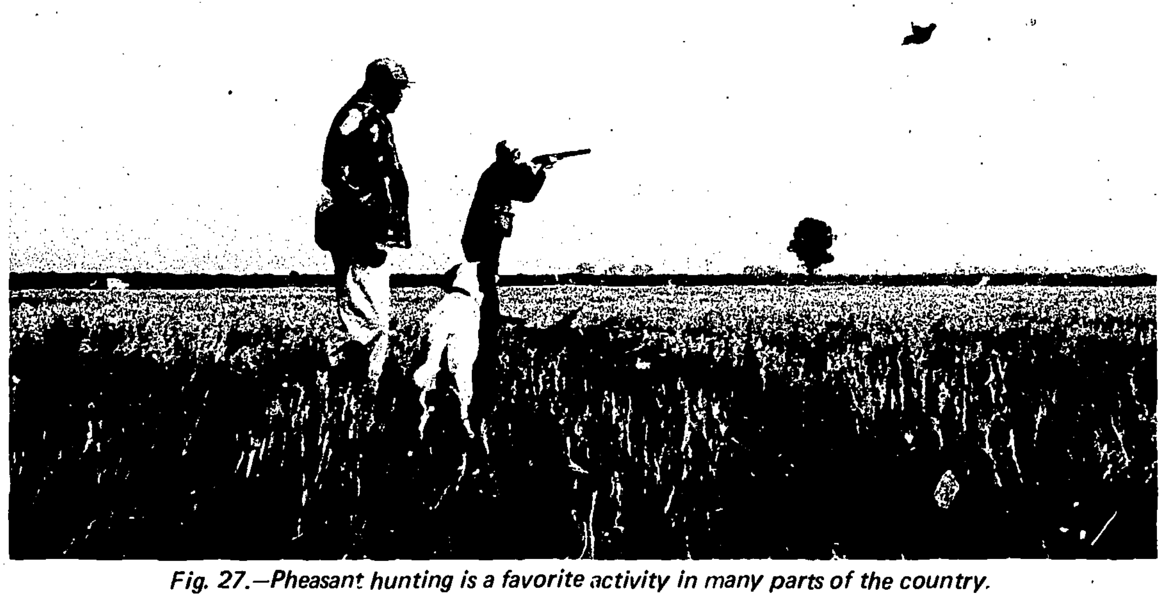


Fig. 27.—Pheasant hunting is a favorite activity in many parts of the country.

One example of how nature can kill is when an animal trying to get a drink moves out onto an ice-covered lake and then falls in and is drowned. Another factor is the low biotic potential of some species. Although many species have the ability to reproduce young in large numbers, others reproduce young only one at a time. This low biotic potential makes any increase in numbers a slow process at best. It is thought that the reduction of the numbers of animals or birds in herds or flocks has led to a disintegration of the social structure and reduced normal reproduction as well.

Some species of wildlife have been speeded down the road toward extinction because one or more of their body parts became valuable, and they were hunted and sold. A present-day example of such an animal is the alligator. The alligator's hide has attained a value high enough that persons are willing to break the law and try to kill the animals to get the price that is paid for the hides. The valuable ivory tusks of elephants caused many hunters to kill these animals.

The passenger pigeon became extinct in 1914. These birds were sold for 2 cents a bird to be served in plush restaurants in Chicago, Boston, and New York. Approximately 15 million pigeons were shipped from a single nesting area near Petoskey, Michigan, in 1861. At the same time, habitat was changing, thus adding to the rapid extinction of the passenger pigeon.

It has been reported that a professional hunter like Buffalo Bill Cody was sometimes able to kill 200 buffalo in one day. These hunters were often professionally employed by railroads that hauled hides to Eastern markets. The hides sold for $3 each, and less than 1% of the meat was marketed. It has been estimated that over 100,000 animals were killed just for their tongue, which was considered a delicacy. The rest of the carcass was often left to rot. Later, some of the bones were picked up and shipped to Kansas and Minnesota for processing into fertilizer. In a period of 13 years, Kansas plants paid $4.5 million for bones.

An even more pathetic story may be the tremendous decreases in numbers of waterfowl. Early explorers reported areas of thousands of acres that seemed to be covered with waterfowl. Flocks of many of these species of waterfowl often darkened the air. Many of these early reports mentioned the loud noises made by the huge flocks of birds. Not only were large numbers of these waterfowl slaughtered for human consumption, but many of them were literally wasted on the way to market. Reports indicate that ducks and other waterfowl rotted by the hundreds on railroad station platforms during hot weather and had to be hauled away to dumping grounds. Habitat also changed, making it more difficult for many species to survive. It is doubtful if some of these species could survive today, even if they had not been killed off.

The number of wildlife species on the official endangered list has jumped from 78 in 1967, to 89 in 1969, to 102 in 1970, and seems to be continuing to rise. A concentrated effort will have to be made if these species are to be saved from extinction.

Some of the losses in numbers of wildlife has been due to the misuse of agricultural chemicals. The misuse of many of these chemicals has rightly been attacked by wildlife groups, and the increased knowledge and awareness brought about has been shown to be useful in some instances. More research as to the long-term effects of agricultural chemicals, particularly those with long-lasting residues such as the chlorinated hydrocarbons, needs to be done (fig. 28).

Many states have enacted laws that now require a license for pesticide applicators. This requires larger applicators of agricultural chemicals to have passed a test showing that they have at least a minimum knowledge about chemicals and their application. The Cooperative

USDA Photo by M. Lemmon

Fig. 28.—USDA scientists pluck a feather from a sandhill crane for chromosome count. Their studies may save the whooping crane and other wild birds from extinction. By careful breeding, scientists seek to overcome genes that make a species unable to adapt to the changing world. Another potential result is major improvements in domestic fowl.

Extension Service and other governmental agencies, as well as many other educational agencies, have offered workshops and courses to help increase the knowledge available about the use and application of agricultural chemicals.

Damage Done by Wildlife

The damage done by wildlife has been lamented by groups of persons for many years. In the early years of the 20th century, a few foresters were becoming very perturbed by the damage they saw and wrote articles about the devastation being done by porcupines to new stands of trees.

Although porcupines received considerable attention in earlier years, they have received less attention in recent years. Porcupines have done considerable amounts of damage and remain a hazard to reforestation in some areas. They are a particular problem in Western Washington and Oregon where it is difficult to control them because of the dense habitat and their ability to hide.

Pocket gophers burrowing under the snow have probably been responsible for the removal of bark from trees long blamed on porcupines. Gophers can certainly do a great amount of damage in tree plantations.

Snowshoe hares also chew on seedlings, and the best method of repellent is foliar (leaf-applied) sprays. Quick replanting of a forest after cutting may also help avoid problems as it will take some time for hares to move into a recently cut area, so the seedlings may be able to obtain enough growth to be less susceptible to hares by the time they get there.

Meadow mice, which can do a great deal of damage to trees, have long been taken care of in fruit tree orchards by the application of 3 to 4 pounds of wheat treated with 2% zinc phosphide, usually applied from the air. Although little research has been done in this area, this method may also be effective in other types of tree plantations such as Christmas trees.

Deer and other animals will eat fruit such as apples and in large numbers may do a considerable amount of damage to a fruit crop. Deer also may browse on foliage of trees, particularly the smaller ones, or eat seedlings.

Many types of wildlife attack, eat, and in some cases destroy grain crops. Rats and mice destroy large quantities of grain each year (fig. 29). Raccoons, squirrels, and other wildlife may carry off full ears of corn, attaching them high in nearby trees to be eaten as required. Considerable quantities of small grain crops may be eaten by birds such as pheasants. Cabbages and other vegetables may be severely chewed by many types of wildlife. Those that burrow may dig into the roots of plants, destroying whole plants or leaving obnoxious tunnels in a lawn. Other burrowing wildlife may leave fairly large holes that can be stepped into, thereby injuring humans, farm animals, and even other wildlife.

USDA Photo

Fig. 29.—Rats and mice do a great deal of damage.

One of the problems in protecting young trees against animals is that the same methods or repellents will not work with all types of wildlife. In fact, many are specific to only one kind of wildlife. This is due to the many different ways that wildlife attacks plants and how the various repellents affect them.

Many kinds of wildlife carry diseases that are communicable to man or to other animals. Foxes and skunks have been implicated in the spread of many types of diseases. Bats have been suspected of playing an important role in the spread of rabies.

Many birds spread disease and raise havoc in many other ways. The damage to cherries and other fruit crops by birds is an important threat to many fruit growers. Starlings and blackbirds are two species that have done a particularly great amount of damage to many types of crops.

EFFECTS OF THE ENVIRONMENT ON ANIMAL AND WATER LIFE

Water is necessary for both plant and animal life. It seems natural enough, then, that great concentrations of water life should be found near sources of clean surface water. There is more life in the water than on the surface of the earth. As with forms of land-inhabiting wildlife, many of the creatures found in water also are highly dependent upon habitat. Almost all of man's activities change the habitat or food situation for water wildlife. These changes may be beneficial or harmful or sometimes beneficial to one species while being harmful to another species, thus making decisions as to what should be done very difficult.

The long-term effects of some of man's activities may have either beneficial or harmful effects while the short-term effects may be just the opposite. An example would be the addition of chemicals to remove plants, fish, or other wildlife species from water. This might seem to cause disastrous short-term effects, but as new, more desirable species are planted and grow rapidly in the absence of predators that may previously have bothered them, the long-term effects may be very desirable.

American waterfowl populations have been decreasing, and much of the problem is the lack of wetland habitat suitable for their production. Many of these wetlands are fairly level, abundantly rich, and relatively easy to drain, making them ideal for agricultural production and other purposes. Large acreages of marshlands are nearly uninhabitable for many types of waterfowl because of the dense marsh vegetation. Even relatively small potholes, on the other hand, may be inhabited by many species of waterfowl and can virtually become "duck factories." Small potholes or marshland areas can be turned into useful water wildlife areas. Ponds or larger potholes for waterfowl can be made by the use of heavy equipment like a drag line or by marsh blasting.

Another practice carried out on many farms, which has improved habitat for waterfowl and other water creatures, is the building of ponds (fig. 30). The suitability of ponds for various types of water life depends in part on the depth and size of the pond. Many farm ponds have been fairly small so as to limit themselves to wildlife that can adapt to this kind of habitat. Many of these ponds have been planted with fish, and some are now producing abundant numbers of fish each year.

In producing fish in ponds, many factors must be considered, including temperature, oxygen, fertility, acidity, and alkalinity, water weeds, muddiness, and the amount of water that flows through the pond. If you are interested in constructing a farm pond, Soil Conservation Service personnel can offer good technical advice to help you design and manage a pond. It is possible that funding may be obtained from the Agricultural Stabilization and Conservation Service (ASCS) for construction of the pond.

USDA Photo

Fig. 30.—Farm ponds can serve as water sources for cattle and as homes for fish and waterfowl.

Many agriculture practices, or lack of practices, influence water life. Sediment, which comes from agriculture and other sources, provides the greatest volume of waste entering surface waters. Sediment can fill in water areas, thus destroying them for wildlife. Silt and other sediment floating in the streams can kill fish and severely damage water life.

Plant nutrients also directly affect the environment of many forms of water life. Many nutrients are essential for fish and other water life as a source of food. Added plant nutrients also tend to produce algae and other plants used as food for water life in many cases. On the other hand, plants may grow that turn an area into a marsh densely covered with vegetation that is of little use to many types of waterfowl.

Inorganic salts and minerals can become concentrated in the drainage of effluent from irrigated areas. If the level of these minerals and salts become high enough, they can cause problems with water life.

Large quantities of organic waste are produced in agricultural production and processing. If these wastes are dumped in rivers and streams, they require considerable amounts of oxygen to break them down. When the quantity of organic material becomes too great, the demand for oxygen increases to the point where fish and other water life may be killed through the lack of oxygen. Wastes from livestock may also carry bacteria and other organisms that may damage fish and other water life. More research needs to be done to study the effects of animal waste products on water life.

Agricultural pesticides often find their way into waterways. The effects of these pesticides on water life varies with the species, but few are beneficial to any species, and some tend to cause severe problems including death. Many of the serious problems caused by agricultural pesticides have been due to misuse of the material in application, storage, or disposal of leftover material.

Some other problems that have been changing the environment but may not be as directly related to agriculture include the dumping of waste into streams at a higher temperature than the stream, thus causing thermal pollution. Thermal pollution may have several effects on a stream. First, if the rise in temperature is only slight, it may cause a change in the species of fish that inhabit the waters. If the temperature change is rather drastic, it may kill some of the fish in the stream. A change in the temperature of a stream may also change the plant life growing in the stream and, therefore, change the food and habitat of the species that inhabit the stream.

Another area receiving considerable attention is the building of dams on many of our rivers and streams. As with many environmental questions there seems to be two sides to the issue. Dams provide water for agriculture, industry, and other uses. Often the dam is also used to produce electricity. On the other hand, the dam may cause stagnation of water, which will bring a buildup of mosquitos and other undesirable insects and, possibly, increase undesirable species of water life. Water passing over a dam at a rapid rate may mix with air in such a way as to build up large quantities of nitrogen in the water. This process, called nitrification, may kill fish in the water. Dams put on streams that are used for spawning of such species as salmon have often kept the fish from getting back to their spawning grounds. In some cases, this problem has been overcome in part through the use of fish ladders.

Other issues that have been gaining headlines in the news include the debate over whether to use phosphate or nonphosphate detergents, whether to use leaded or nonleaded gasoline, and what could or should be buried or dumped into water.

Another problem that has received wide attention in the press is oil spills. One of the important factors is the type of material spilled—whether it will mix with water, sink, or float on top. If the material stays mainly on top, it may be that little damage will be done to fish in the area. On the other hand, material that stays on top may kill waterfowl in the area. Detergent-type chemicals have been developed to clean birds that have been soaked with oil, but they may also cause problems by removing the birds' natural feather oil. Once the natural feather oil has been removed, the bird may enter the water, soak water up in its feathers, sink, and drown. With the natural feather oil removed, it usually takes a molt in which the bird receives a new crop of feathers before it again has natural protection. It may be 6 months to a year before the birds molt, so they must be protected for this long period of time if they are to survive. Another problem is the fact that just grabbing a bird to wash it, even though the washing may be done in 3 minutes, may cause the bird to go into shock. Much research remains to be done before we are ready to meet the problems that arise from an oil spill.

EFFECTS OF ANIMAL AND WATER LIFE ON THE ENVIRONMENT

The emphasis is almost always on the environment and its effects on wildlife. However, it is also important to look at the effects that wildlife has on the environment.

An overabundance of one species can eat up the food and destroy the habitat of an area so that it is unsuitable for almost any type of wildlife. Species of wildlife can just as easily overgraze a range or meadow as can domestic livestock. The resulting erosion and sedimentation may be just as severe as on an overgrazed pasture. The sediment produced by wildlife can be very disastrous to water life, particularly fish.

Many types of wildlife, including wild waterfowl, may carry diseases that can affect both man and domestic animals.

Wildlife, including waterfowl, produce fecal waste that contains fecal coliform bacteria. These bacteria are dangerous to humans, and the major method of making drinking water safe has been to use chlorine to kill them. Many experts agree that the problem of waste from wild game is minimized by the fact that it is spread over such large areas and can be easily absorbed by the quantities of water into which it is passing. Research continues to be done to find the coliform count as well as many other factors about pollution of fecal wastes from wildlife. At present it seems safe to state that there is little hope of potty training most types of wildlife.

WILDLIFE AND SOCIAL VALUES

When we consider our history, it should come as no surprise that many persons in this country are little concerned about wildlife. The early settlers found forests and rich soils in what they thought were inexhaustible quantities. Many of these early settlers regarded high quality and quantities of air, water, and wildlife as gifts of nature to be used as man saw fit. Many of these early settlers worked very hard to eke out a living, so, if destroying an area of forest would provide them with more fertile land to provide them with a better living, there was little question in their minds about what they should do.

USDA Photo by Dr. R. Congden

Fig. 31.—Mountain goats on Snoqualmie.

In more recent years, greater and greater demands have been made upon our natural resources. The increasing demand for these resources has been accompanied by a growing realization that fresh air, clean water, wildlife, and even scenery are not unlimited.

All of man's activities have not necessarily had a detrimental effect on wildlife. Areas of New England were covered with 250-foot towering pine trees under whose soaring canopy little but a forest floor of pine needles was found. Dead pine needles simply do not provide food for wildlife. After some of these areas were cleared and second growth or agricultural production took place, the amount of wildlife actually increased in comparison to what originally existed in the natural habitat.

Areas of State and Federal property, such as forests, parks, and water areas, support numerous species of wildlife (fig. 31). Some of the Government-owned property is highly restrictive as to hunting and fishing so as to build up greater numbers of desired species.

Many decisions that have gravely affected the environment and wildlife have been made with little regard to either the environment or wildlife. One possibly overlooked example is the building of dams for power production when many of the other factors, such as the changes in habitat for fishing and other wildlife, have been given little consideration.

The very fact that some species of wildlife have become extinct has brought about an awareness in many people that something needs to be done. This awareness and further observation and study of what is happening to wildlife has, in some cases, changed our attitudes and values toward wildlife management.

Many of the decisions that we make are based on a combination of feeling and fact. Many of the decisions that have been made affecting the environment have been made with a minimal amount of facts, and much research is needed to provide a better basis for future wildlife management. We also need better dissemination of this information through news media and our educational system so that we may become more aware of the problems and better able to support programs of wildlife management.

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