and overseas. Because goats tend to concentrate locally even small numbers can retard regeneration.

The tendency to move in groups is an aspect of behaviour that could be exploited in control measures. Apart from the observation of Riney and Caughley (1959) that billies segregate from the nanny-kid herds during winter, there is little information on the movement patterns of goats. Of the many aspects of the ecology of this animal that could be studied, knowledge of movements in varying conditions of weather, topography, vegetation and population structure is of paramount importance if effective census and control measures are to be developed.

Investigation of the physiology and behaviour of goats, in particular their taste preferences, their possible dependence on salt, their inquisitive nature and their liking for high promontories or rocky outcrops might also lead to new methods of control. The present distribution of goats mapped by Wodzicki (1961) includes many areas where effective methods of control are urgently needed: National Parks, scenic reserves and potential coastline reserves as well as catchments considered critical from the point of view of soil erosion and river control.

SUMMARY OF CONCLUSIONS

1. The greatest effect of goats on vegetation is that due to browsing of the forest understorey. With high densities of goats forest on soils of moderate and high fertility is replaced by herbaceous or shrubby vegetation. On soils of low fertility the effect of goats on forest stability is not known.

2. Reciprocal effects of vegetation on goats are exemplified by the absence of significant browsing in bogs and on an alluvial terrace at Mt. Egmont, and the possible attraction to goats of vegetation containing large proportions of grass or vegetation exposed to wind-carried salt.

3. Study of the taste preferences of goats for foliage and bark may provide a biochemical basis for new methods of controlling goats.

4. Study of the daily and seasonal movements of goats in relation to weather, topography, vegetation, and population structure, appears essential for developing improved methods of census and control.

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INTERACTIONS BETWEEN MAN, DEER & VEGETATION IN MICHIGAN

RICHARD J. McNEIL*

Game Division, Michigan Department of Conservation, Lansing.

INTRODUCTION

Compared with New Zealand, ecological communities in North America are very complex. In the state of Michigan alone there are over 50 different species of mammals, about 300 of birds and perhaps 40 terrestial or partly terrestrial reptiles and amphibians. Many of

* Fulbright Scholar, with Animal Ecology Division, Department of Scientific and Industrial Research, Lower Hutt.

these species of animals are very abundant and exert considerable influences on a rich and varied flora. This short paper will, however, discuss only man and the whitetail deer *(Odocoileus virginianus)*, perhaps the two most important animals influencing the vegetation of Michigan.

Animal modification of vegetation is here restricted to the lasting or long-term changes occurring in plant communities. Hence the effects of a single deer browsing on a single plant need not be considered. Rather some effects occurring at the population or community level will be described.

Under most definitions, the vegetation presently found in Michigan is not natural. Much of the state has been logged off, burned, replanted, perhaps burned again or treated with chemicals or the plough. About one-third of the state's area has been farmed at one time or another and much of this is still in row crops, pastures and orchards.

The Ecological Setting

Michigan, in the north-central United States, is 52,000 square miles in area, or about half the size of New Zealand. It has a continental climate, with summer temperatures often over 80°F and winter temperatures in the north as low as – 30° or – 40°F. Annual precipitation is about 32 inches, but the northern parts of the state may receive 200 inches or more of snow in the winter.

Geologically, almost the entire state consists of sedimentary deposits which were covered several times by continental glaciers thousands of feet thick. Recessions of the most recent glaciers, about 20,000 years ago, have left nearly level outwash plains and rolling country characteristic of morainic deposits. Soil development since then has produced gray-brown podzols over most of the state, with rich, black, prairie soils in a few small spots in the southwestern corner. As the glaciers receded, plants and animals moved northward into Michigan from unglaciated areas to the south.

Before settlement by Europeans, there were about 15,000 American Indians in Michigan (Baird 1954). There were few settlers in the state until the early 1700's, and by 1810 Michigan's population was only 4000 (Bald 1954). Deer numbers were normally very low in the poor habitat provided by mature forests of red and white pine and climax communities of mixed beech, maple, basswood and hemlock trees. Wolves, bears and bobcats were still abundant in the state (Perry 1899).

The lumbermen came to northern Michigan about 1850. The brush and young trees which followed logging operations provided excellent habitat for deer; in the late 1800's deer were plentiful in northern Michigan. However, widespread and repeated fires produced vast areas of grassland unsuitable for whitetail deer. Hunting for meat also produced tremendous pressures on the deer herd. In 1880, for instance, 100,000 carcasses were shipped by rail from Michigan (Jenkins & Bartlett 1959).

After the extremely low deer populations of the early 1900's the combined effects of forest fire control, restrictions on hunting, and rapidly improving habitat produced a population of at least a million deer in the state (Jenkins & Bartlett 1959). These tremendous deer populations rapidly over-browsed much of northern Michigan. About 16,000 square miles or 10 million acres are now short of winter food in the state; as many as 50,000 deer die of starvation during a severe winter (Jenkins & Bartlett 1959).

The present summer and autumn deer population in Michigan is about 700,000, or about 14 deer per square mile over the entire state. The continuing impact of these animals on vegetation which has already suffered extremely severe damage has far-reaching biological, political and social implications.

Types of Interactions

Even limiting discussion to deer, man and vegetation, six possible simple interactions may occur: man affecting deer; deer affecting man; vegetation affecting man; deer affecting vegetation; vegetation affecting deer; and man affecting vegetation.

All these interactions are very important. For instance, each year in Michigan hunters shoot about 90,000 deer (Jenkins & Bartlett 1959), and spend £10 million or more on deer hunting (Jenkins 1961). Only the last three of the interactions above will be considered here, since they are most closely related to this symposium.

DIRECT EFFECTS OF DEER UPON VEGETATION

Deer affect vegetation directly by browsing and grazing, stripping of bark with teeth, mechanical injuries to plants from trampling or lying on them, breakage of branches and injuries to bark from rubbing of antlers, urination and defecation on soil or plants. Of these, browsing, particularly on woody vegetation, is perhaps the most important.

Among the earliest and most obvious effects of deer browsing are changes in the growth-form of woody plants. "Hedging" is produced by repeated browsing on young twigs, causing multiple shoots to generate where browsed. In Michigan many shrubs, such as the thorns (*Crataegus* spp.), juneberry (*Amelanchier* spp.), dogwoods (*Cornus* spp.), viburnums (*Viburnum* spp.), and palatable trees such as the maples (*Acer* spp.), ashes (*Fraxinus* spp.) and oaks (*Quercus* spp.) are frequently severely hedged. Oak trees 20 or 30 years old may be less than two feet tall; and 30-year-old white pines (*Pinus strobus*) only about a foot tall, with nearby red pines (*Pinus resinosa*), of the same age but not favoured by deer, 20 or 30 feet tall. This hedging often appears to increase the amount of new vegetative growth available to deer in subsequent years.

Where trees have "escaped" to a height where the terminal leaders are beyond the reach of deer, a "browse line" may be developed. All available food within reach of the deer (up to about six feet for whitetail) is removed. This browse line is particularly conspicuous under Michigan conditions, where 200-300 deer per square mile may invade a conifer swamp in winter. When these swamps are composed only of a few highly palatable species, all green vegetation within the animals' reach is removed, and the browse line made still more conspicuous by the flat terrain. Less commonly, a bottom browse line occurs, caused by deep snow in winter. In summer most deer move out to higher ground, easing the browsing pressure.

Another important change in the growth form may be seen in Christmas tree plantations, which may be mowed off at the level of the snow by whitetail deer and wapiti, the terminal leader and upper branches being completely removed. Even with less severe browsing, when only the terminal leader is lightly nipped off, a new, forked leader may spoil the tree as a Christmas tree or for high quality lumber.

Patterns of plant distribution may change even under moderate animal populations, certain plants rapidly becoming scarce. Ground hemlock *(Taxus canadensis)*, a shrubby conifer highly palatable to deer, has been virtually extirpated from northern Michigan during the past 20 years. Northern white cedar *(Thuja occidentalis)*, which may take 20 years to reach a height of 5 or 6 feet, will almost certainly disappear from the swamps of northern Michigan. There are many mature trees of this species in the forest but no seedlings or saplings since the advent of high deer densities. Many native orchids, trilliums, violets, and similar beautiful flowering herbs are becoming exceedingly rare in many localities because of the heavy browsing of deer and other mammals. Yellow birch *(Betula lutea)*, an extremely valuable timber tree, will probably become rare in most of the state.

Three species of aspen, big-tooth aspen *(Populus grandidentata)*, trembling aspen *(P. tremuloides)*, and Balm of Gilead *(P. balsamifera)*, occur commonly in northern Michigan after disturbances such as fire or logging. The first two species are valuable for paper pulp and are freely eaten by deer. Balm of Gilead is nearly worthless commercially and also not preferred by deer. Consequently when commercial cutting operations have created favourable conditions for the growth of all three of these aspens, browsing by deer has often suppressed the commercially valuable aspens and produced a nearly pure stand of valueless Balm of Gilead. Wood-using industries now face serious problems with their planned cutting cycles, since new supplies of raw materials are not becoming available as anticipated. More subtle shifts in patterns of plant distribution, changes in age structure or proportions of different plant species in a stand will follow lower densities of deer.

Semi-direct effects of deer upon vegetation include increasing the vulnerability of trees to fungus attack at points of damage, soil compaction and its many ramifications, dispersal of seeds, maintenance of openings and clearings in the forest, fertilization and poisoning by urination and defecation, and exposure of bare soil through pawing the ground.

Direct Effects of Vegetation upon Deer

Patterns of animal distribution and density are, of course, intimately involved with plant distribution. In Michigan, deer numbers have fluctuated from almost none to over a million and down again to little more than half a million, largely as a result of vegetative conditions. Geographical distribution has also varied markedly.

Starvation in winter, besides killing many deer, may also produce a profound impact on the animals surviving the winter. In southern Michigan, where food conditions are very good, a $1\frac{1}{2}$-year-old buck will have, on the average, six-point antlers. Bucks of the same age, from starvation areas of northern Michigan, will have about three antler points per deer (Ryel & Fay 1962), and average about 30 pounds lighter in total weight. Other body measurements are similarly smaller.

In addition, reproductive rates are markedly influenced by the conditions under which the animals have been living. Adult female deer in southern Michigan produce an average of 2.0 fawns per doe. Poorly fed females from northern parts of the state will carry as few as 1.2 fawns per doe in particularly poor years (Ryel & Fay 1962). Verme (1962) has also suggested that "nutritive failure" kills many fawns just after birth, either because the fawn is too small or weak to nurse properly, or the doe produces insufficient quantity or quality of milk.

Changes in food habits of deer must occur if favoured food plants disappear or become rare. In Michigan, deer no longer have access to white cedar or ground hemlock, and aspens, according to many observers hardly touched 20 years ago, are now freely eaten.

Indirect (Man-produced) Effects of Deer on Vegetation

Deer have influenced man's effects on vegetation both through the management of the land or the vegetation for the benefit of deer, and, through their pressure on vegetation managed for other purposes.

Management practices specifically planned for the benefit of deer include controlled burning of "scrub" or non-merchantable timber; planting of conifers for shelter and escape cover; disking to promote the sprouting of food plants; herbicide sprays to maintain openings in the forest; and knocking down and crushing non-merchantable, scrubby forest edges to make available food from upper branches of trees and to encourage growth of young food plants.

Commercial logging in state and federal forests has also been modified to assist deer. In the swamps or "deeryards", where most deer spend their winters, cutting is allowed only during the winter so that the deer may make use of the tops and branches left from logging operations. The spacing of commercial cutting ventures is planned to be of the greatest possible benefit to the deer. In some localities milling permits have been granted for areas of 200 acres or more in the hope that plant regeneration will be so prolific that much will escape the deer. Because acorns are such a valuable food for deer, logging permits sometimes specify that certain numbers of mature oaks be left standing.

Other changes in man's activities have been less voluntary. In Michigan, 10-20,000 acres of public land, as well as much private land, are planted to pine trees each year in a continuing reforestation programme. In the past, most of these trees were white pines, but it has recently become necessary to substitute the less valuable red pine over most of the state since the latter is less preferred by deer. Wild rice *(Zizania aquatica)*, formerly planted as waterfowl food, is no longer used, partly because deer tend to destroy entire plantings. Other food crops planted for smaller species of wildlife are also heavily used by deer.

The large deer populations have also changed agricultural patterns. Apple and cherry orchards, Christmas tree plantations, and valuable market-garden crops such as celery, lettuce and strawberries have been most affected. Planted crops have often been severely damaged, and tentative plans drastically altered or abandoned because of deer.

The Future in Michigan and New Zealand

Most of these conditions will continue in Michigan for some time. Various methods of setting back plant succession to earlier "pioneer" stages will be widely used. Modifications to hunting laws will depress deer numbers until compatible with the existing winter range conditions. The eventual results will be: fewer deer for several years, improvement of deer habitat, then more deer, decreased damage to forest plants, and an altered flora.

New Zealand has a similar history of logging, followed by the plough or fire, or similar disturbances. In addition, since all the ungulates have been introduced in a short time, biologically speaking, the native plants are generally ill-adapted to maintain themselves under heavy browsing pressure. An inevitable imbalance between animal numbers and the amount of available food has resulted.

The eventual status of deer in New Zealand may be much the same as in Michigan: (1) browsing pressure by ungulates will continue strong for some time, resulting in changes in species composition of various plant communities; (2) continued control measures will reduce deer numbers and inevitably an altered flora and fauna will evolve (some native species probably becoming rare or extinct); (3) eventually a balance between plant and animal numbers (probably artificially depressed by shooting) will occur; (4) political and social problems will continue to play an important role in natural resource management.

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DISPERSAL AND DESTRUCTION OF SEED IN CENTRAL NORTH ISLAND PODOCARP FORESTS

A. E. BEVERIDGE

Forest Research Institute, Rotorua

Introduction

Over the past six years studies have been carried out, mainly in dense podocarp stands of Pureora and Pouakani Forests, to gather information about the periodicity, abundance, and soundness of seed crops, the animals that disperse or destroy seed, and how they do so. The ultimate objective is to find out what part each bird, rodent or insect plays in assisting or limiting regeneration of timber species.

Methods

Seed crops were assessed subjectively until 1961, when pairs of seed traps were placed beneath crowns of permanent seed trees of rimu *(Dacrydium cupressinum)*, totara *(Podocarpus totara)*, kahikatea *(Podocarpus dacrydioides)*, miro *(Podocarpus ferrugineus)* and matai *(Podocarpus spicatus)*. Since 1961, the number of sound and defective seeds collected in the traps has been counted annually.

Seed dispersal and destruction have been studied by observing the feeding habits of birds and by examining seed and droppings on the ground, on collection sheets, and in seed traps, some of the latter being rodent and bird proof. Seed has also been fed to captive rats and insects. Recently the populations of rodents in different forest types have been studied by systematic trapping with break-back traps baited with peanut butter.

In January 1962, at Pureora, P. C. Bull of the Animal Ecology Division, D.S.I.R., demonstrated that mist nets can be used in native forest to capture birds so that their role as seed dispersers can be studied.

Results

SEED CROPS AS A FOOD SUPPLY

Podocarps

There is a marked periodicity in fruiting amongst some podocarp species but no regular interval between good seed crops has been