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DISEASES DERIVED FROM WILDLIFE

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The specific diseases of man known to be derived from wildlife in California are: rabies, Western encephalitis, St. Louis encephalitis, Colorado tick fever, Rocky Mountain spotted fever, relapsing fever, O. fever, plague, tularemia, murine typhus, lymphocytic choriomeningitis, psittacosis, leptospirosis, salmonellosis and toxoplasmosis. A variety of bacterial infections may be contracted from wild animals, notably those caused by *Pasteurella pseudotuberculosis*, *Pasteurella multocida*, *Bacillus anthracis*, *Erysipelothrix rhusiopathiae*, *Clostridium tetani* and *Listerella monocytogenes*. Certain of the fungus diseases such as coccidioidomycosis and histoplasmosis are derived from exposure to wildlife habitats. California virus has been isolated from arthropods and Rio Bravo virus from bats collected in California. It has been shown by serological tests that these viruses may produce infection in man. In the course of field studies of arthropods, small mammals and birds in California and Oregon, several viruses have been isolated which may prove to be of importance as disease agents, that is, Modoc virus, Turlock virus, Kern Canyon virus, Hart Park virus and two yet unnamed viruses isolated from *Microtus montanus* meadow mice.

The investigation of sources of diseases in wildlife must be concerned with wildlife populations and the factors which control the flora and fauna. In searching for natural foci of disease agents in wildlife, it is logical to study habitat types which have a large and relatively stable wildlife population. In such foci one does not expect to observe disease in the reservoir wildlife hosts, but if the viruses, rickettsia, bacteria or fungi set up chains of infection in aberrant hosts, this may result in epidemics of disease, sometimes having a high mortality.

It is the temperature, precipitation and solar radiation and the constancy or variability of these factors which govern the vegetation types and associated wildlife populations. For example, moving from north to south we have the vegetation zones of tundra, northern coniferous forest, temperate deciduous forest and temperate grassland. We also find similar vegetation zones at different elevations in the mountains. Each 1000 feet of ascent is equal to a shift of about 600 miles to the north at sea level. At 10,000 feet above sea level in the mountains of Colorado we have sub-alpine or Hudsonian type vegetation such as that found near Hudson's Bay. Escarpments and mountains also have a profound effect on the vegetation type. For example, there will be increased rainfall or snowfall where a moist air mass is deflected upward and arid or semiarid conditions will prevail to the lee side of the mountains. Where the rainfall is less than ten inches a year, the vegetation is of the desert type and trees cannot survive. There is a marked difference in the vegetation and wildlife when one compares the southern exposure to the northern exposure of mountain valleys.

Where do we find the vegetation type which favors a large and relatively

*This report is based on studies conducted as a joint project of The Rockefeller Foundation and the California State Dept. of Public Health.

stable population of wildlife? The northern coniferous evergreen forest with lakes, meadows and bogs, and the semiarid highland plateau with forest, grassland and desert brushland have the largest populations of wildlife. Here one finds the large game animals such as moose, elk, deer and antelope, as well as an abundance of rodents, bats, birds, rabbits and the carnivores which feed on wildlife. Primitive man living as a hunter and food gatherer preferred the inland plateau and adjacent mountains. There was plenty of game, honey, edible insects, nuts, seeds and berries.

The deciduous forest of the Temperate Zone as well as the mixed coniferous evergreen and deciduous temperate forest is unstable because of periodic destruction by high winds, flooding and fires. Such disasters result in marked fluctuations in wildlife populations. It may take over 100 years before the forest returns to its previous vegetation type. The succession of vegetation types is from grasses and herbs to brush made up of a variety of berry and seed producing plants, then a variety of soft wooded trees and finally the dominant tree types replace the other varieties and the ground vegetation is reduced to a minimum. With the change in vegetation type there is a change in the dominant forms of mammals and birds. The peak populations are reached during the period of supremacy of the brush type vegetation. At this stage of reforestation disease agents in wildlife are apt to spread to new hosts and start epidemics, for example, this is the time we can expect tick-borne diseases.

The periodic inundations of large areas of floodland at the base of mountains and along river systems have had a profound effect on wildlife populations. The river valleys as they leave the mountains and plateaus have the varied wildlife and insect populations which predispose to movement of parasites from one species to another. There are well known cycles of rainfall, and flooding during periods of unusually high rainfall may produce such a high population of mosquitos that the presence of arthropod-borne viruses in the blood of a few of the migrating birds or bats will be sufficient to infect the local mosquito population and subsequently infect the resident population of birds and mammals, both wild and domesticated, if these are susceptible to infection with the virus. Irrigation of large areas of farmland serves the same purpose in producing high populations of mosquitos and the lush irrigated farmland also attracts insectivorous birds and bats.

Man, by draining the lake basins and marshes of the plateaus and lowland along rivers, has eliminated much of the normal feeding grounds of insectivorous birds and bats. They are then attracted to irrigated farmland which has replaced their normal feeding ground. Man and his domestic animals are then in danger of becoming infected with diseases introduced by migrating birds and bats.

Fluctuations in animal populations with altered environment are well known. There are also periodic high populations of wild rodents which are difficult to explain. The meadow mouse or vole has achieved enormous population from time to time in natural meadows and in newly cultivated land about old lake beds. When meadow mice and wood mice become unusually abundant there is crowding, leading to fighting and cannibalism. This is apt to result in a high rate of disease transmission. The increase of ectoparasites at times of high wildlife populations is important in disease transmission because they are apt to reach their population peak after the rodent population

is on the downgrade, resulting in shifting of ectoparasites to new hosts.

There are two epidemiological types of disease problem related to wild-life. The one type is the occurrence of sporadic cases of disease in man when he enters natural vegetation zones for cutting forest, trapping, hunting, fishing, hiking, or camping. The other and more serious type is where epidemics of disease occur in man as the result of introduction of disease agents into regions previously free of the disease, for example, the introduction of yellow fever into the United States. There are many ways in which a disease agent may be moved from the natural foci to new areas. The disease agent may spread from the long term natural host to aberrant hosts by way of intermediate arthropod hosts such as mosquitos, ticks and fleas. The infection may spread as a migrating epidemic in an aberrant host, for example, rabies in foxes, coyotes and skunks or tularemia in rabbits. Migratory birds and bats if infected can move a disease agent for long distances during the spring and fall migration. Collection of wild mammals and birds as pets may result in introduction of disease agents. Shipment of domestic animals may move disease agents. Wildlife shipped as food may introduce disease producing organisms. Man may be infected in a sylvan wilderness and travel greater distances during the period of viremia which occurs in yellow fever, and this appears to have been the means for the introduction of yellow fever into sea ports of the East Coast of the United States during the last half of 19th century.

The control of the most important epidemic diseases derived from wildlife usually involves reducing the numbers of the intermediate arthropod hosts or the wildlife vertebrate which serves as the aberrant hosts maintaining the epidemic. The epidemic cycle is evidently vulnerable and is of course subject to natural control as well. The elucidation of the true natural host of the various diseases derived from wildlife is extremely complex and we have only general ideas where the disease agents are maintained during periods when we see no evidence of their activity in the hosts known to become infected by them.

I can enumerate briefly the various diseases and the most likely sources of these disease agents in wildlife. We are now experiencing a worldwide epidemic of rabies in wildlife. The aberrant cycle of rabies in dogs has been contained in North America but a great variety of wild animals have been found infected with rabies. The disease is active from the Far North to the Tropics. The spread of the disease to insectivorous bats in North America appears to be another example of infection of a large population of wildlife normally not infected with the virus. The natural source of the virus in wildlife seems to be in the families Mustelidae and Viverridae. In California the weasel and spotted skunk appear to be the major source of the disease. At present the epidemic cycle is most active in striped skunks and bats. Control work for rabies requires immunization of dogs and reduction of the wild carnivores in foci of rabies.

The next speaker will discuss plague. It is evident that small mammals of the high plateau and certain mountain regions of North and South America do maintain the plague organism for long periods of time without any evidence of the presence of the disease agent. Periodically there will be epidemics of plague in small mammals such as ground squirrels, chipmunks, and rats. Plague is endemic in wildlife in the semiarid plateaus of Africa and Asia

and therefore I suspect that certain genera of desert animals are the most likely source of the plague organism in nature.

There have been spectacular epidemics of Western encephalitis and St. Louis encephalitis in Central and Western United States. The epidemics of horse encephalitis in 1912 and 1919 occurred in the newly developed farmlands of the Great Plains of Central United States during periods of high rainfall. The Western encephalitis virus responsible for this disease was isolated for the first time in California in 1930 during an epidemic of horse encephalitis. St. Louis encephalitis virus was isolated in 1933 from fatal cases of encephalitis in man in St. Louis. In 1941 there was a severe epidemic of encephalitis in Central and Western United States and South Central Canada. Both Western and St. Louis encephalitis viruses were active in this epidemic. There were epidemics of encephalitis in California in 1952 and in Texas in 1954, 1956 and 1957. With the development of large scale irrigation systems in Central and Western United States there has been a constant problem of mosquito-borne encephalitis. Irrigation of certain types of vegetation such as natural pasture, cotton and sugar beets are especially likely to produce high populations of the *Culex tarsalis* mosquito, which is the principal arthropod vector of encephalitis viruses in California. Migratory birds evidently move the viruses from place to place and wherever there are high populations of resident birds, such as sparrows, the virus may be amplified and spill over to a variety of aberrant hosts, including man and horses. The Brewer's and red-winged blackbirds appear to be especially important in the spread of encephalitis viruses in Central and Western United States. There are certain small mammals which need to be studied as possible sources of arthropod-borne viruses. The meadow mouse, wood mouse and red backed vole deserve study as possible reservoirs of arthropod-borne viruses.

The tick-borne diseases have their natural focus in the high plateau and mountain region of Western United States. The juniper sagebrush vegetation is the natural vegetation type associated with Colorado tick fever, Rocky Mountain spotted fever, and Q. fever. The small mammals found infected with Colorado tick fever in California include the pocket mouse, golden mantled ground squirrel, yellow pine chipmunk and the wood rat. The golden mantled ground squirrel appears to be an aberrant host but is probably one of the most important sources for infection of ticks. Little is known about the natural vertebrate hosts of Rocky Mountain spotted fever and Q fever but the *Dermacentor andersoni* tick is the main arthropod host for Colorado tick fever and these rickettsial diseases in Western United States. Relapsing fever is spread by *ornithodoros* soft ticks and the amplifying host appears to be the chipmunk in foci of this disease in California. This disease is prevalent in the pine forest and brush environment of the Sierra Mountains and some of the coastal mountains.

Tularemia is known to cause die-offs of meadow mice in the farmland about old lake beds but it is not known where the tularemia organism is maintained between outbreaks of tularemia in meadow mice. The tularemia organism may produce migrating epidemics in rabbits, with ticks and flies serving to spread the infection from one animal to another. Murine typhus is present in the rodent population of the arid foothill and mountain environment of Central and Southern California but the reservoir host is not known. Infection of man occurs in a sporadic fashion, evidently from exposure to fleas left behind when

rodents are killed or driven off from newly developed urban communities. The disease organism may move into rat populations in warehouses and produce small outbreaks of marine typhus in man. Lymphocytic choriomeningitis is evidently maintained by house mice. Psittacosis is ordinarily introduced by pet psittacine birds but the psittacosis organism may also produce epidemics in turkeys and pigeons. This disease is also called ornithosis. Leptospirosis is maintained in wildlife but except for the spread of the disease to man after it becomes established in cattle, it seldom produces disease in man. Leptospirosis is evidently associated with house rats, and sewer workers and miners are prone to become infected with this disease because of exposure to an environment potentially contaminated by rats. The disease is common in swine herders and rice field workers in some countries. Salmonella infections may be derived from a great variety of wild birds, rodents and cold blooded animals. Toxoplasmosis is maintained in rodents. Pasteurella pseudotuberculosis and Pasteurella multocida are found in both rodents and birds. The anthrax organism is found in all domesticated animals but is especially common in cattle and deer. The tetanus organism is found in all the common domestic animals but the epidemiology of the disease indicates that the horse is the principal source of the organism as it occurs near human habitation. The Listerella organism has been found in cattle and skunks in California. The coccidioidomycosis organism seems to be limited to the lower Sonoran type of desert vegetation zone and the small mammals of the desert appear to be responsible for the maintenance of this organism. The histoplasmosis organism is associated with bat and bird roosts.

We do not know much about the long term hosts of most of the diseases mentioned but our chances of determining the natural foci of these diseases should improve if we shift the emphasis in research from the foci of epidemic activity where the aberrant hosts are known to areas where there are large populations of wildlife without evidence of disease.