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WILDLIFE RABIES IN SAN DIEGO COUNTY: A HISTORY, ANALYSIS, AND EVALUATION[1/]

A Preliminary Report

by

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INTRODUCTION

The occurrence of rabies in the wildlife of San Diego County reached epizootic proportions in 1966, when 55 animals were diagnosed as rabid. This epizootic condition continued until 1970 when 2 cases of wildlife rabies were reported by the San Diego County Veterinarian. The incidence of rabies in wildlife decreased to 24 reported cases in 1967, 5 positive cases in 1968, 6 positive cases in 1969 (Figure 1), and 6 cases in 1970-1971. To combat this disease and prevent further spread of the infection the United States Department of Interior, Bureau of Sport Fisheries and Wildlife was contracted by San Diego County to effect a predator removal program in 1966. A summary of wildlife vector species trapped and clinically analyzed for rabies in San Diego County, 1966-1969 (Table 1), indicates coyotes as the predominate species removed, yet incidence of rabies in coyotes was the least of the four target species being removed. This discrepancy initiated investigation by local humane groups and trapping was discontinued July 1, 1970.

Subsequent to these investigations, a study was initiated by the Bureau of Ecology at San Diego State College to determine the effects of the disease and the predator removal program on the local populations of predators in San Diego County. Thus far, only one species, the coyote (*Canis latrans*) has been extensively studied. Currently data is being collected on the population dynamics of this species with the proposed completion, expected by January 1973. Parallel studies of the population biology of Gray Fox (*Urocyon cinereoagenteus*) and Bobcat (*Lynx rufus*) have been proposed.

The present report is an excerpt of a three-part document under preparation for the County of San Diego. The complete report will be available early in 1972, and will include: (A) Ecology of Rabies: a statement of the problem; (B) the Wildlife Rabies Epizootic in San Diego County, 1966 to 1969: history and analysis; (C) Integrated Rabies Control and Surveillance: recommendations and rationales.

I. A STATEMENT OF THE PROBLEM

The occurrence of the rabies virus (Formida inexerabilus) in the wildlife of San Diego County is an "endemic" problem. That is, the existence of the virus in our area is as an integral part of natural biotic communities. Rabies virus exists in endothermic (warm-blooded) animals throughout the world--from the deserts of Africa to the arctic ice pack. The history of the disease affecting man is as old as recorded history--probably introduced via his domestic animals from wild species. Although relatively few deaths occur from human rabies infections in the United States (only three cases in 1966 and 1967), the rabies problem has obvious social, economic and political impact on human communities. This becomes a local problem when possibly the only human death in the United States in 1969 occurred here in San Diego County. The ecological impact of rabies as an endemic disease in wildlife populations is subtle, however an important aspect. This is a subject of some general confusion, and relates critically to decisions regarding the management of any control program. Equally deservant of attention is the impact of any control program upon the wildlife populations of an area. Perturbations, both natural and man-induced, affect both level (average numbers) and balance (amplitude of fluctuations) in wildlife populations. Manipulation of these control mechanisms, and the resultant affects upon the target populations can cause an irreversable upset to the dynamic balance of many complex interrelationships between all members of the ecosystem.

I. A STATEMENT OF THE PROBLEM

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Thus we must proceed in ecologically-related matters with great care, and conscience. Irrationality has no place in such management decisions. Careful evaluation must proceed and continuously scrutinize any course of action that may have ecological consequences. Towards this goal, a review of some of the facts concerning the biology and ecology of rabies seems appropriate. The objective is to form a rationale for the control of rabies in man and his domestic animals, with the least consequence to man's economic interests and impact upon the ecosystem of which he is an integral, inseparable component.

The following is a list of some pertinent facts known about the rabies virus, its epidemiology, and its relation to wildlife species.

A. Biology of the Virus

1. Infectivity of the virus is lost in one to two weeks when exposed to air at 70°F. Sunlight, ultraviolet radiation, bichloride of mercury, formalin, strong acids and bases destroy the virus. Rabies is resistant to all known antibiotics (Johnson, 1959:415-16).
2. Rabies is restricted to mammals under natural conditions; birds may be artificially infected, but other vertebrates are refractory (Kesler, 1955:262). Johnson (1959:405) believed that the "permanent hosts" are among the Mustelidae (badgers, striped and spotted skunks, and weasels).

3. Although transmission occurs commonly through an infected animal's saliva to a new host via biting, not all infected individuals are capable of transmitting the virus (Johnson, 1959:405). Only 54 to 90% of animals diagnosed as dying of rabies had the virus in their salivary glands (Tierkel, 1959:191). Aerosol transmission of the virus may occur in certain cave environments with the source being bats (Constantine, 1962:289). Evidence indicates the virus may be transmitted in milk from one individual to another (Kesler, 1955:277, Johnson, 1959:273). Transmission in urine has been implicated due to kidney pathology (Johnson, 1959:417). Transmission through ingestion of infected tissues has been shown (Soave, 1966: 44-46). Natural transmission of rabies by arthropod vectors has not been demonstrated; when artificially introduced into ticks, rabies virus persists a relatively short time (Bell *et al.*, 1957:282).

4. The incubation period of the virus varies between 10 and 240 days (Johnson, 1959:405). When intracerebral passage of the virus occurs, incubation becomes shorter and on repeated serial passage the incubation is reduced to 6 or 7 days (Rhodes and vanRooyen, 1962:400). The virus after this type of passage causes paralytic symptoms and does not multiply in the salivary glands, and loses much of its virulence when introduced through peripheral routes (Johnson, 1959:414). Rapid passage of the virus in natural communities may cause similar attenuation of the virus; this may tend to reduce the spread of rabies (Verts, 1967:146).

5. The probability that an individual contracts the disease after exposure may be relatively low; only about 15% of humans bitten by rabid dogs contract the disease in the absence of treatment (Rhodes and vanRooyen, 1962:392). It is extremely difficult to estimate the relative efficiency of the normal mode(s) of transmission among wild mammals; it appears certain, however, that <u>not all</u> individuals exposed to the disease contract it (Verts, 1967:146).
6. Negri bodies (aggregations of the virus in the brain) are absent in 10 to 12% of individuals diagnosed by the mouse inoculation technique (Merchant and Packer, 1961:800). Diagnosis of rabies by the fluorescence technique and/or clinical symptoms may be comfounded by fluorescences caused by virus aggregations associated with varieties of canine "distemper" causing forms of encephalitis (Helmboldt and Junghen, 1955:465). Gross abnormalities specifically diagnostic of the disease are absent (Johnson, 1959:410-12). Thus, <u>only laboratory analysis can confirm the presence of rabies in an animal, and this is confused by the potential of both false positive and false negative diagnosis</u>.
7. Two clinical categories of symptoms are found: paralytic or dumb rabies and furious rabies. The symptoms are as their names imply (Kelser, 1955:263). No immunological differences can be demonstrated (Tierkel, 1959:189), although "intermediate: symptoms between the two extremes are sometimes observed" (Richards, 1957:64).

8. There is no specific treatment for the disease once symptoms develop, but there appears to be a growing belief that spontaneous recovery from the paralytic form of rabies can occur (Constantinesco and Biryer, 1958:739; Thiery, 1959:33; Johnson, 1959:410). Recurrent rabies and asymptomatic carriers of rabies have been demonstrated among vampire bats (Johnson, 1959:33).

9. There seems to be an inverse correlation between the quantity of virus with which animals are inoculated and the length of the observed incubation period (Sikes, 1962:1043); this appears in wild animals as related to the apparent mode of transmission (Johnson, 1969:2073).

10. There is evidence that prolonged incubation periods may be the reactivation of latent rabies virus by some unrelated stimulus (Koprowski, 1952:962). Where the virus remains during inactive periods is unknown; however, proliferation of the virus by some unrelated stimulus may occur (Koprowski, 1952:963, Patera, 1956:667-669; Soave et al. 1961:1360; Verts, 1967:148).

11. The role of the antibody response in wild mammals is unclear in relation to rabies virus biology (Verts, 1967:148). However, natural control mechanisms appear to exist: only 3 of 17 oppossums inoculated with rabies virus developed serum-neutralizing antibodies but 10 of the 14 without demonstrable SN antibodies successfully resisted infection (Baer, 1961:59-60).

B. The Ecology and Epidemiology of the Virus

1. More than 90% of the 19,462 cases of laboratory-diagnosed rabies reported among wild mammals between 1953 and 1962 occurred either in foxes (*Vulpes* spp. or *Urocyon* sp.) or skunks (*Mephitis* spp. or *Spilogale* spp.); however, no correlation exists between numbers of infected skunks and numbers of infected foxes (by state. r = -.002; Communicable Disease Center 1963a:3).
2. Discreteness of fox and skunk rabies areas may possibly be explained by a combination of factors: lower susceptibility of one species to virus strains maintained primarily by the other species, ecological and behavioral isolation of the species, and differences in continuity of populations from one area to another (Verts, 1967:151).
3. The means by which rabies perpetuates itself are complex. Rabies has been demonstrated repeatedly to be a density-dependent disease; prevalence is directly related to the density of *susceptible* hosts (Schoening, 1956:201). Thus, during epizootics (outbreaks or "wildlife epidemics") no special mechanisms are required to explain maintenance of the disease, but between such periods it is difficult to account for the origin of sporadic cases of rabies.
4. The actual incidence of rabies in wildlife species may *not* be reflected by the available data (Verts, 1967:160). The fluctuating attention given the problem by the general public and public health

agencies tends to obscure the baseline levels. As a specific example, examination of data from the San Diego County Veterinarian's Office is presented in Table 1. Examination of these data clearly show that the actual incidence of rabies in coyotes in our county is 2 to 3 orders of magnitude less than in other species. Accurate records of what, when, and where all animals were trapped would help assess the true level of rabies, coupled with the laboratory analysis of all suspected vector species (not synonymous with all trapped species).

5. Numerous cases of rabies in striped skunks (*Mephitis*), reported sporadically in time and space, are strong evidence that the species is a reservoir of the disease (Verts, 1967:172). Reactivation of latent rabies among one or more individuals within separated groups of skunks would account for the relatively widely distributed sporadic cases of rabies among striped skunks during inter-epizootic periods (Verts, 1967:172). This kind of reactivation due to various stresses (environmentally or physiologically induced) may be a generalized mechanism for the propagation of rabies in wildlife species. The stresses could, of course, vary for different species as well as in time and space.

6. Observations and data recorded by Verts (1967:143-176) strongly suggest that what have been considered fundamental principles of the epizooticology of rabies deserve critical reevaluation. This coincides with contemporary opinions on the epidemiology of all viral infections (W. Smith, 1963:20).

II. HYPOTHESIS ABOUT THE BIOLOGY, EPIDEMIOLOGY AND ECOLOGY OF RABIES

In light of present knowledge, there appear to be four possible courses when an individual is naturally inoculated with rabies virus (Verts, 1967:148-149):

1. No symptoms develop, and virus cannot be demonstrated in any tissues.
2. Symptoms develop after a "normal" period of incubation and death ensues several days thereafter. Transmission of virus may or may not be possible during or just prior to symptomatic stages.
3. The virus becomes latent, to be activated after several months, possibly because of some unrelated stimulus (internal and/or external to the individual).
4. No symptoms develop, but transmissible virus occurs in the saliva irregularly or continuously for several months.

These alternative hypotheses are testable with adequate data collected on <u>all</u> animals taken in rabies control and livestock protection programs.

It has been proposed that the sporadic appearance of rabies among both wild and domestic species occurred in three potential ways (Scatterday <u>et al</u>, 1960:945-46):

1. A primary reservoir (of rabies virus) exists in bats and/or other small mammals directly infecting carnivores;
2. Enzootic rabies among species recognized to be occasionally involved in epizootics (e.g., skunks and foxes);
3. A multi-species complex.

The explanation of sporadic, or disjunct appearances of epizootic rabies in time, space and species is a very complex problem to attack. However, certain inferences can be drawn, and guidelines for analysis set out. First, if a reservoir species exists, it must possess some mechanism by which the virus can be maintained for a relatively long period, longer than the normal incubation and symptomatic period. Secondly, passage of the virus from reservoir species, across ecological and behavioral barriers, to other species, could explain occurrence of rabies in species sporadically infected. Thirdly, the evidence indicates that virus maintained within a single species for several passages becomes progressively less virulent for other species. All of these considerations tend to implicate a limited number of reservoir species - and the identification and monitoring of these species should be a goal of any scientifically-based control program.

The studies by Verts (1967:175-176) indicated a working hypothesis for striped skunks in Illinois to account for the behavior of the rabies virus:

"Undoubtedly, certain individual striped skunks from time to time are subjected to stresses of greater intensity than are experienced by most of the other members in the population. These stresses might reactivate rabies among individuals harboring latent infections; the virus then might be directly transmitted to other individuals in a local group by biting. Within small groups, the disease should rapidly run its course and die out because of depletion of susceptible hosts. An inexplicable sporadic case of rabies among striped skunks would result from the diagnosis of the disease in one of the infected animals in this group."

This is a tenable, working hypothesis that is not limited to a single species: the complex ecology of global rabies can utilize this approach. Most likely, any given geographic and ecological area will involve different species and changes in stress factors, all couched in the dimension of time.

III. RECOMMENDATIONS FOR AN INTEGRATED APPROACH TO THE RABIES PROBLEM

The suggestions presented here implement the recommendations of the WHO Expert Committee on Rabies (WHO Expert Committee on Rabies 5th Report, 1966: Sections 10.3a, 7.3.3e, 8.1). This committee strongly urges investigations into the ecology of vector species, improvement of the reporting system, and interpretation of diagnostic laboratory findings in the context of the epidemiology of the disease. Although the only operational program for control of rabies in wildlife has been removal of potential vector species, the ultimate effects of this concept have been questioned. At a recent WHO meeting on rabies control in Europe (Frankfurt-am-Main, 1968), the delegates were largely unanimous in agreeing that vector over-kill or crash efforts at stamping out the disease were likely to have the very reverse of the effect intended; the aim of control programs should be the regulation of population levels, not the indiscriminate destruction of individuals or populations (J. Hillaby, *New Scientist*, 13 June 1968, quotations from 1968 WHO meeting).

The total program proposed here has two broad objectives. The first is to provide a set of procedural instructions designed to control the possibility of epizootic rabies in wildlife species, with particular emphasis on reducing the spread of rabies contacts within the wildlife populations themselves, as well as, reducing potential contacts of wildlife vectors to humans and domestic species. This aspect of the proposed program differs from current policies in several significant ways: it includes self-evaluation, flexibility of implementation to meet changing situations, and logically-based decision points for the modification or discontinuation of each application.

The second objective is to evaluate the impact of the rabies control program on the population levels of vector species. The information obtained from this effort would be of considerable heuristic value in redefining other aspects of this proposed wildlife rabies program.

The operational procedures outlined below have evolved from the basic recommendations submitted to Dr. H. C. Johnstone, County Veterinarian by Dr. Coulombe (Memorandum, March 10, 1970; jointly submitted to the Board of Supervisors March 11, 1970). Feasibility of various suggestions have been discussed by the authors of this report, and a cost analysis of some logistic aspects is necessary before operational procedures are implemented.

The proposed procedures are designed around the observation that, between epizootics, positive wildlife rabies cases are sporadic in their time distribution and are usually received from sources other than current predator-trapping programs. Thus the Control/Surveillance aspects of the proposed program are divided into three areas: (A) Diagnosis and Surveillance, (B) Disposition of Material and Information, (C) Implementation of Vector Removal and Criteria for Modification or Discontinuation.

A. Diagnosis and Surveillance. The Office of the County Veterinarian would be responsible for the examination of all specimens of potential rabies vectors submitted to his office (specifically, coyotes, bobcats, foxes, skunks, and bats). The diagnostic technique would be the florescent antibody method (currently in use here and at the Berkeley Public Health Laboratory). This technique requires about 0.3 man-hours per determination. All predators from County Livestock Protection and Rabies Control removal programs would be processed. Periodically, specimens from all input sources could be processed in an attempt to cover a wide geographical source of potential rabies carriers. This extension of analysis can be tried, and limited as the practical limitations of available facilities are reached or when redefined by other aspects of the program.

As far as possible, all specimens would be received intact (see Section C), and held until the diagnostic procedure was completed. When a positive case is found, further examination of the specimen to determine the extent of demonstratable rabies virus in body tissues other than the brain would be accomplished. This would provide invaluable information for research in determining cause(s) and origin(s) of the rabies virus in wildlife species.

When a positive case in a wild or domestic species is found, the procedures outlined in Part C would be implemented within four days from the time of submission of the specimen.

B. <u>Disposition of Material and Information</u>. Close collaboration between the County Office and local scientific institutions would allow the preservation of specimens submitted for analysis for several research and educational purposes in the County. The County would be able to make available, material for numerous scientists and students involved in many aspects of research. These persons would provide assistance in the collection of additional information from the processed specimens vital to the interpretation of population dynamics and physiological condition of wildlife vectors for many types of zoonoses epidemeology.

The integration of the information obtained from the laboratory aspects of the program with information obtained from field workers on population densities, and similar information from other California counties, should be managed by the responsible state agencies. The anticipated output would include scientific papers concerning the analysis and interpretation of wildlife rabies in our area, and a procedural manual for agencies charged with rabies control programs, based on the procedures evolved during the proposed program, and jointly-developed with concerned governmental agencies. Any additional research funds for this aspect could be solicited from federal granting agencies, jointly with local academic institutions.

C. Implementation of Vector Removal and Criteria for Modification or Discontinuation. When a positive rabies diagnosis is made (Part A), within four days of the submission of the specimen, an on-site task force would visit the area that was the source of the positive diagnosis. As much detailed information as possible about the source of exposure (particularly for domestic animal positives) and the local vector population status would be obtained first-hand. The specific plans based on the procedures outlined below would be set out, and potential sources of further contacts systematically removed and examined.

Vector removal policies can be divided into four categories: (1) Where to focus removal, (2) How to trap, (3) What to trap, and (4) How long to trap in the focus area. The following suggestions are tentative, contingent upon the complete analysis of the records available for San Diego County (see Section IV).

1. Where to focus removal. Traplines around potential human and/or domestic animal contacts with target species would be set up within the focus area to buffer possible contacts with the human community. Traplines would also be set up around the foci following logistically feasible perimeters based on drainages, ridges, roads and factors of accessibility, acting as containers to the projected extent of potential contacts with infected individuals of the vector species.

The focus area would be determined by the onsite inspection team, taking into consideration the history of the disease in the area and the species involved, its area of movement and population density in the immediate area and in surrounding areas, together with reports of abnormal behavior patterns of vector species noted by residents of the area and field personnel of other governmental agencies. As an example, the following criteria could be applied in an area of normal population densities with no indications of unusual population trends or history of positive cases. In this instance, the theoretical perimeter of the focus area could be bounded by an area twice the diameter of the estimated normal daily range of the primary target species. This area would be operationally governed by the logistic considerations defined above, and provides a working point of departure. Input from other sources (such as the Bureau of Sport Fisheries and Wildlife, the veterinary public health sections of the National Communicable Disease Center, and the State of California) should be sought to evaluate and readjust the proposed criteria.

2. <u>How to trap</u>. The actual traps used would be of multiple types--all lines consisting of traps of various sizes of accommodate all potential contact species. Priorities of species-specific capture are outlined in Part 3. All traps will be checked every 24 hours, and adjusted within the boundaries of the designated traplines to have maximum effectiveness for target species removal. All designated target species thus obtained, would be dispatched by non-damaging techniques, and placed

intact in a polyethelene bag with appropriate label data; these specimens would then be held in cold storage until transported to laboratory facilities for processing and laboratory diagnostic procedures. Non-target species should be tagged for future identification, appropriate data collected (sex, age, condition) and released. (Data collection and format are expanded upon in Section IV).

3. What to trap. Since foxes (genera *Vulpes* and *Urocyon*) and skunks (*Mephitis* and *Spilogale*) are consistently involved in the ecology of rabies throughout the nation, these species should always be considered target species in designated foci until results of the program indicate otherwise. These species can be selectively trapped through the use of small box-type traps, baited with such items as scent-treated eggs (skunks) or sardines (foxes). When coyotes or bobcats are not the primary target species (initial positive diagnosis), circumstances where the onsite inspection or implemented trapping procedures indicate exceptionally high densities of either species, removal trapping should be extended to include the potential source of epizootic contacts as governed by the criteria in Section 4.

4. How long to trap in the focus area. In the event that no positive diagnoses are made in species other than the primary target species, several discontinuation criteria are tenable relative to local population densities. Such criteria are subject to modification by the results of Section IV.

One criterion could be based on trap yield. If traps in all suitable areas for foxes and skunks cease to produce after the estimated maximum time for an individual to encounter a trap in its home range, the trapline can be discontinued. This situation would occur in low density areas. The time would be extended if coyotes or bobcats were the primary target species, to allow for known "trap avoidance" encountered in these species.

A second criterion could be related to the relative population densities of all potential vectors in the foci. As data are collected and interpreted regarding "normal and abnormal (low or high)" predator densities, estimates of the probabilities of transmission (intra- and inter-specific) can be made. With quantitative knowledge of these probabilities, logical decisions can be predetermined for the discontinuance of vector density reduction in each specific instance.

A third criterion might be governed by analysis of interaction potentials, both intra- and inter-specific in nature. The specific behavioral patterns of each potential vector species can be ranked and summed, providing an estimate of which species is most likely to have contact with a given rabid vector. For example, our preliminary interaction analyses indicate that the Gray Fox is the most likely species to perpetuate rabies in the chaparral ecosystem, based upon intra- and inter-specific patterns of behavior, distribution, and relation to human densities in San Diego County.

The most realistic criterion for decision-making concerning discontinuance of control procedures would be influenced by the interplay of all the above-mentioned criteria. Another important factor, not yet introduced, is that of the age structure of the vector populations. The age structure of the vector populations will modulate the effectiveness of trapping, the expected "normal" density, the degree of species' interactions, and (perhaps most importantly) the expected dispersal of infected individuals. Age structure may also modify the degree of natural immunity to the prevalent form of rabies virus. Equally important to consider are the possible inducers of physiological stress that may transform latent rabies infections into epizootics (Verts, 1967:172). These "inducers" may be environmental, rather than purely biological as we usually tend to focus upon.

5. Additional Surveillance Techniques. The likelihood that a trapping program in a focus area will sample the majority of infected individuals appears small. Only two of 90 positive rabies cases (Table 1) were trapped; both were foxes, thus only 1/335 trapped foxes were rabies-positive in 1966 to 1969. Thus to augment and assess the trapping program the field trappers should initiate other observations to canvass the area for untrappable individuals. There is no substitute for the observations of trained field biologists, as are available through the BSFW, Division of Wildlife Services. Additional time spent in searching for carcasses of vector species that may have died from rabies seems desirable, coupled with other removal techniques not damaging to the local ecological balance. Personal contacts with local residents and field personnel from other agencies could provide additional observations and

help locate infected animals in the area. The local residents should be encouraged to protect the operation of the focus program from disturbance or vandalism.

IV. EVALUATION OF PROJECTED RABIES CONTROL PROGRAMS

The follow-up of any intensive removal program is recommended to assess the impact on the populations of vector species around the established primary foci. The animals trapped through removal trapping should have as complete an autopsy analysis performed as feasible. This is not only for basic data on the ecology of rabies, but also for the monitoring of other zoonoses. Data on the population dynamics and ecology of predators could easily be obtained during any trapping program. Standard information such as the date, location, and number of trap-nights should be kept on all trapping activities as well as other species-specific information. A proposed record card for each animal captured as well as a card for each trap-line is illustrated in Figure 3. These data can then be used to accurately assess population trends in carnivore communities. From these and other ecological studies, the epidemiology of rabies can be better defined and optimistically predicted. The format of these data shown in Figure 1 was developed by discussions with representatives of laboratory clinicians, field biologists and trappers, and data processing personnel. The coding system shown, provides both rapid completion by field and laboratory personnel, and a presentation of key-punch coding easily followed by non-biologically oriented data processing personnel.

The accumulation and analysis of such data for predator populations is extremely crucial for the future monitoring of these populations in relation to human interests, economic and health, as well as to the management of the ecological systems of which they are an integral part.

Since rabies is predominately a disease of carnivorous predators, immediate research is needed on the principal vector species to determine the population dynamics and natural history of these species so that accurate predictions can be made concerning their probable involvement in a rabies epizootic. Movement and activity parameters are essential for these species so that foci areas of removal trapping can be precisely designated. These parameters are essential to predict the possible spread of an endemic rabies outbreak and to confine the disease in as small an area as possible. The inter-species relationships among these predators is also needed to determine contact between species and help resolve the ecology and epidemiology of this disease.

The importance of data collected during rabies control programs is underscored by the analysis of records from the San Diego County rabies epizootic (1966-1969). The lack of information recorded during the first three years, allows only relative estimates of predator densities in retrospect. Current studies of the coyote population on Camp Elliot (Swick, 1971. Special Wildlife Invest. Report., Cal. Fish and Game. July, 1971) have allowed some comparisons for a limited area. Coyote and bobcat populations in this area, which had no diagnosed cases of wildlife rabies, were essentially the same during the removal trapping program (1969-1970) as found during the current study (1971-1972). Thus, a preliminary indication is that any reduction in density of these two species (under the above conditions) can be regained after one breeding season. This observation needs to be supported (or modified) by similar investigations in a variety of geographical areas with epizootic histories.

The role of vector densities in the perpetuation of wildlife rabies epizootics is not clear. Schoening (1956:201) states that wildlife rabies has repeatedly been related to the density of susceptible hosts during epizootics. Grimes and Schwichtenbert (1968) suggest that the greater the incidence of rabies during an epizootic, the more self-limiting the disease becomes. These concepts, when combined and integrated, further suggest, that both the rate of transmission <u>and</u> the duration of a rabies epizootic are directly dependent upon the <u>density patterns</u> of vector species within the geographic scope of any specific outbreak of wildlife rabies.

Some insight into the nature of these complex inter-relationships can be gained by "hindsight". The complexity of these inter-relations can be seen by inspection of the data given in Table 1. The chronological history of these data are given in Figure 2; two major phenomena are apparent. First, a true "multi-species epizootic" is evident from

March, 1966 to about June, 1967 -- a total of 16 months includes about 77% of all wildlife rabies for the four-year period. This "epizootic" period was followed by sporadic, perhaps endemic, rabies cases for the following 48 months, in terrestrial vectors. Several questions emerge: Was the decline of this "epizootic" due to the initiation of an increased control program in December, 1966? If so, was a substantial decrease in vector density the key factor? Or, was the termination of the "epizootic" a result of the self-limiting characteristics of the disease?

Detailed information (such as that outlined in Figure 1) may have provided direct evidence to substantiate or refute these hypotheses. At this stage in the analysis of past records, only a few statements can be made and no clear-cut conclusions have emerged. These limited statements are summarized below:

1) The repeated occurrence of bobcat rabies in San Diego County is unique. From 1966 to 1970 twenty-three cases of bobcat rabies were reported in San Diego County. This was nearly twice the number reported throughout the entire state from 1920 to 1960; thirteen rabid bobcats were reported during that 40 year interval, of which, three (23%) were from San Diego County.

2) During the "endemic" phase, (June 1967 to late 1970) bobcats dominated the wildlife rabies cases in the county (43% of all wildlife rabies during those 48 months). This, in combination with (1), suggests that rabies may be endemic, latent, or both in the local *Lynx rufus* population.

3) As a rough index, for the density of each vector species from 1966 to 1969, the total number captured per year was divided by the corresponding "man-year" effort, resulting in a "yield per unit effort." As a tentative hypothesis, one could assume that if either the vector removal theory or the self-limiting concept of the disease were valid (or both), a reduction in vector density would appear from 1967 onward. Yield per unit effort is a crude test of this assumption; for bobcats and skunks this parameter remains essentially constant for the total period. For coyotes, the "yield per unit effort" remains approximately constant, except for an increase in 1969. The only species that shows a decrease in "yield per unit effort" is the Gray Fox, which was the least frequently captured of the four vector species (Table 1), yet showed the greatest occurrence of rabies (Table 1 and Figure 1).

4) It has been suggested, that, on a long-term perspective wildlife rabies has a natural cycle. In considering the San Diego area as a discrete eco-geographical unit for a fifty-year period, one finds little substantiation for this hypothesis (Figure 2). It is reasonable to assure, that relatively minor attention was given to rabies in wildlife before 1940, due to the low human population density of the wilderness areas of San Diego County, which may account for the relatively infrequent contact between man and wildlife. Conversely, outbreaks of canine rabies may be a reasonable indicator of wildlife incidences. From about 1929 until 1949 a rough cycle of 4 to 6 years can be imagined (Figure 2). However, this speculation is discounted by the 6 to 7 years

absence of virtually any rabies (1954-1960). One question does arise: Do the "peaks" of historical rabies outbreaks have a feature in common with the 1966-67 "epizootic"? The relation of any control program during the historical cases has to be resolved to gain resolution of this question.

Table 1. Summary of wildlife vector species trapped and clinically analyzed for rabies in San Diego County, 1966-1969. Data from County Veterinarian's Office.

Species	Year	Number Trapped	Number Analyzed	#Analyzed/ # Trapped	Number Positive Rabies	# Positive/ # Analyzed	# Positive/ # Trapped	68-69 State Incidence[4]
Coyote	1966	545	31	5.6%	3	9.6%	0.5%	
(*Canis latrans*)	1967	1,931	26	1.3	3	11.5	0.1	
	1968	980	11	1.1	0	0.0	0.0	
	1969	858	14	1.6	2	14.2	0.2	
	Total	4,042	82	2.0	8	9.7	0.1	0.5%
Bobcat	1966	142	32	22.5	10	31.2	7.0	
(*Lynx rufus*)	1967	600	20	3.3	8	40.0	1.3	
	1968	219	6	2.7	2	33.3	0.9	
	1969	111	21	18.9	3	14.2	2.7	
	Total	1,072	79	7.3	23	29.1	2.1	1.0
Gray Fox	1966	207	72	34.7	38	52.7	18.3	
(*Urocyon cinereoargentius*)	1967	366	30	8.1	7	23.3	1.9	
	1968	84	25	29.7	2	8.0	2.3	
	1969	12	7	58.3	0	0.0	0.0	
	Total	669	134	20.0	47	35.0	7.0	2.0
Skunks	1966	81	29	35.8	4	13.7	4.9	
(*Mephitis mephitis* and	1967	302	29	9.6	2	6.8	0.6	
Spilogale putorius)	1968	209	27	12.9	1	3.7	0.4	
	1969	136	33	24.2	0	0.0	0.0	
	Total	728	118	16.2	7	5.9	0.9	80.0
Opossum (*Didelphis marsupialis*)	All	53[1]	0	---	--[2]	---	---	---
Raccoon (*Procyon lotor*)	All	14[1]	0	---	--[2]	---	---	---
Badger (*Taxidea taxus*)	All	10[1]	0	---	--[2]	---	---	---
Mountain Lion (*Felis concolor*)	All	1[1]	0	---	--[2]	---	---	---
Miscellaneous	All	111	---	---	2[3]		---	---
GRAND TOTAL		6,700	413	6.2%	90	21.8%	1.3%	---

[1] Data for FY '67 and '68 only, included in miscellaneous for '66 and '69.
[2] Released after capture.
[3] Bats in 1967.
[4] Breakdown of positive cases only: that is, 80% of positive cases in the state, 1968-1969, were skunks. Data to analyze state breakdown by actual incidence not immediately available.

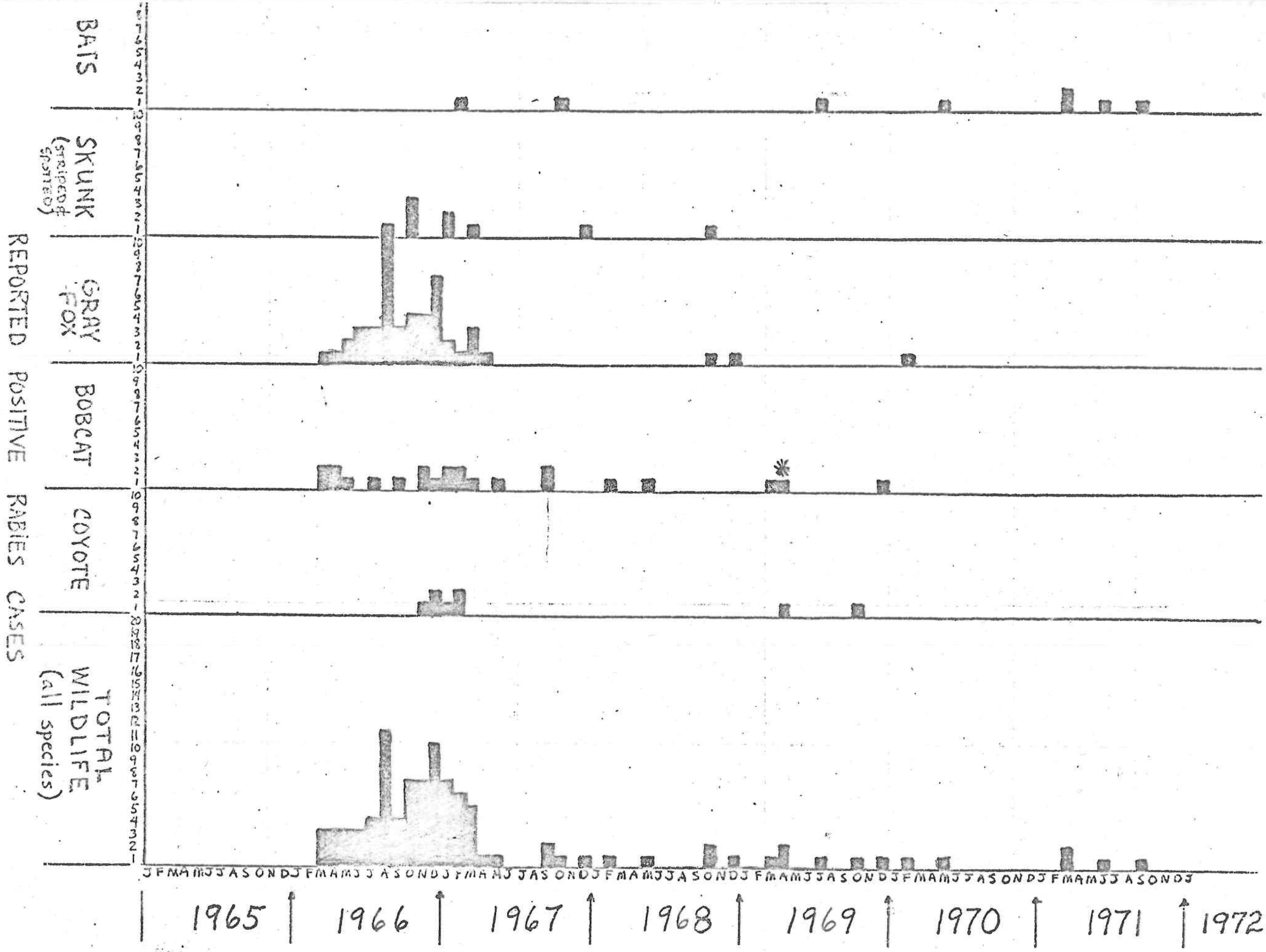

Fig. 1 -- Chronological sequence of wildlife rabies in San Diego County, 1965 through 1971.

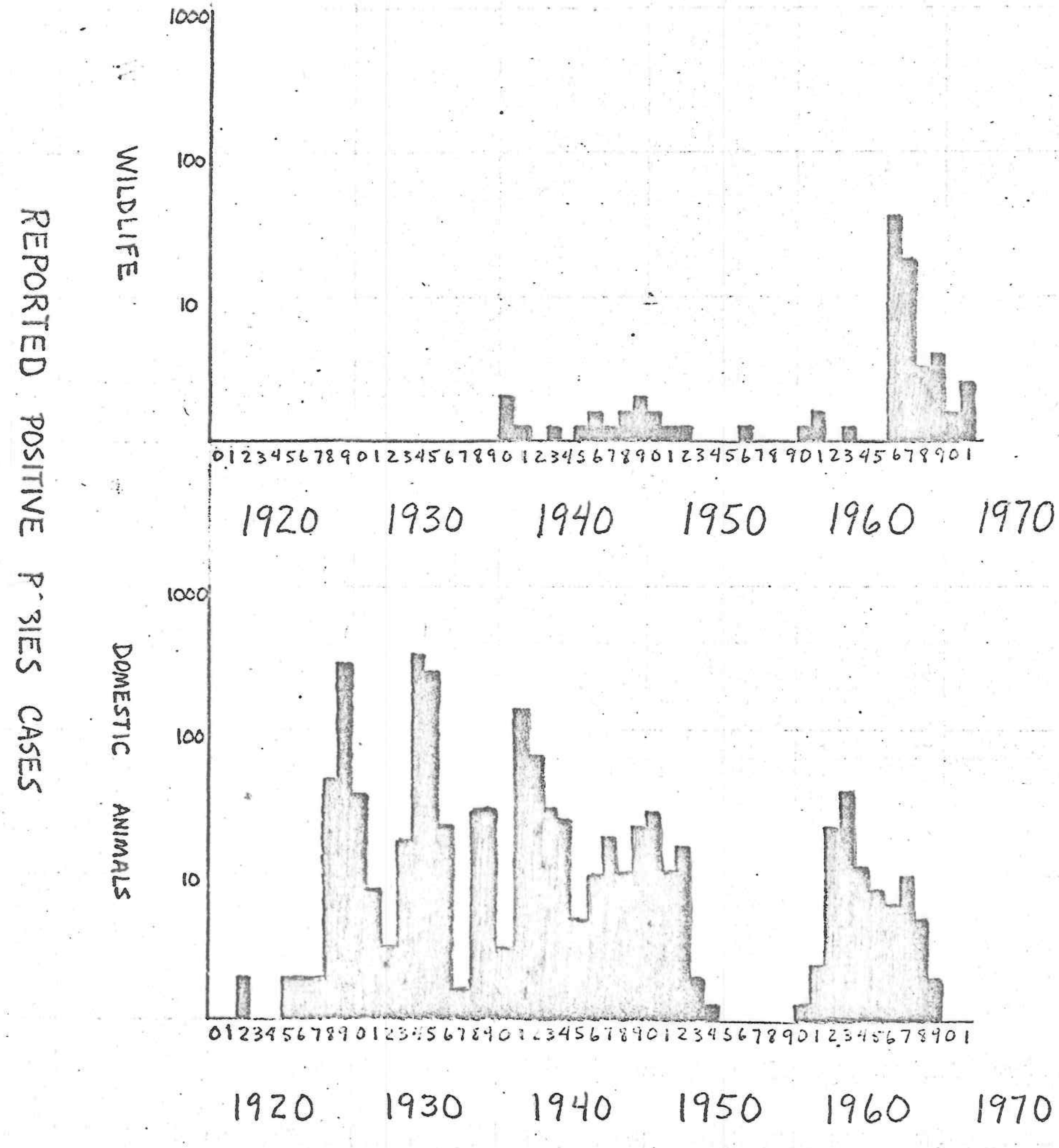

Fig. 3. -- Chronological history of rabies in wildlife and domestic animals in San Diego County, 1922 to 1972.

Individual Records (completed by both Field and Laboratory personnel)

- SIDE A -

SPECIMEN RECORD CARD

COLLECTOR 1 2 | LINE NO. 3 4 5 | MO. 6 7 | DAY 8 9 | YR. 10 11 | ANIMAL NO. 12 13 14

(15) SOURCE
1 Jaw Trap
2 Box Trap
3 ....Trap
4 Shot
5 Found Dead
6 Road Kill
7 Unknown
8 ....
9 Lab Subm. (SEE OVER)

(17) TRAP BAIT
1 Urine
2 Gland
3 Egg
4 Fish
5 Pet Food
6 Fetid
7 Other: ....

(19) SPECIES
1 Coyote
2 Bobcat
3 Gray Fox
4 Strip. Sknk.
5 Spot. Sknk.
6 Badger
7 Opossum
8 Raccoon
9 ....

(21) DISPOSAL
1 Removed
2 Released
3 Tagged
4 Recapture

TAG NO. 23 25

(29) AGE
1 Unweaned
2 Young
3 Adult
4 Old
5 Unkn.

(30) SEX
1 Male
2 Female
3 Unkn.

(31) REPRCD. STATUS (MALES)
1 Testes Develp.
2 Testes Regres.
3 Unkn.
(FEMALES)
4 Eosterus
5 Embryos
6 Resorbtion
7 Lactating
8 Unkn.

EMBRYO NO. 33

OVER

- SIDE B -

LABORATORY DIAGNOSIS

LAB NO. (35 TO 40)

WEIGHT (Lbs) 42 45

(47) RABIES TEST
1 Flur. Antbdy.
2 Mse. Inoc.
3 Negri Bdy.

(49) DIAGNOSIS
1 Positive
2 Negative
3 Not Done

ADDITIONAL INFORMATION

LOCALITY: ....

T.S. 51 | R.E. 54 | SEC. 57 | ELE. 60 63

(65) SOURCE (Lab. Sbm.)
1 Found Dead
2 Dead on Rd.
3 Shot
4 Trapped
5 ....

(67) CONTACTS
1 Multiple
2 Human
3 Dog
4 Cat
5 Livestock
6 ....
7 Unkn.

LAB SUBMISSIONS
NAME ....
ADDRESS ....
TELEPHONE ....

Field Records (completed by trappers)

TRAPLINE RECORD

COLLECTOR 1 2 | LINE NO. 3 4 5 | MON. 6 7 | DAY 8 9 | YR. 10 11

(13) TYPE
1 Rabies Control
2 Livestock Prot.
3 Combination
4 Pop. Status
5 ....

No. Box Traps 15 16
No. Jaw Traps 17 18
No. other 19 20

NO.	BAIT
22	Urine
25	Gland
28	Egg
31	Fish
34	Food
37	Fetid
40	....

LENGTH (Mi) 42 45
DAYS IN USE 52 54
MILES ADDED 47 50
HOURS SPENT 56 59

LOCATION .... VEGETATION ....

T. S. 61 | R.E. 64 | SECS. 67 69 71 73 75 77 79

Fig. 3 . -- Recommended data format for field and laboratory records of rabies vectors in computer-compatible numerical coding.

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