VERTEBRATES OF PUBLIC HEALTH IMPORTANCE IN CALIFORNIA





California Department of Public Health
Vector Control Technician Certification
Training Manual
Category D

VERTEBRATES OF PUBLIC HEALTH SIGNIFICANCE IN CALIFORNIA

Editor

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Vector-Borne Disease Section
Center for Infectious Diseases
California Department of Public Health

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Information on the certification examination for public health pesticide applicators may be obtained from the
California Department of Public Health, Vector-Borne Disease Section
1616 Capitol Avenue, MS7307
P.O. Box 997377
Sacramento, CA 95899-7377
(916) 552-9730
(http://www.cdph.ca.gov/certlic/occupations/Pages/VectorControlTechnicianProgram.aspx).

Information concerning the laws and regulations pertaining to pest control, pesticide application, and pesticide safety may be obtained from the
California Department of Pesticide Regulation
1001 I Street
P.O. Box 4015
Sacramento, CA 95812-4012
(http://www.cdpr.ca.gov/docs/license/liccert.htm).

CONTENTS

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Preface

I am life which wills to live in the midst of life which wills to live.
—Albert Schweitzer

The history of life on Planet Earth is a tale of competition. From the earliest protobacteria to the first humans who stood upright on the African savanna, the struggle for finite resources has served as an undercurrent animus for millenia of evolution. "Adapt or suffer extinction" has been the inescapable command of Nature. Even today, four billion years after the first biologic beings emerged from the primordial ooze, the challenge persists for each species to define for itself a secure and stable niche, amidst millions of others striving for the same goal.

Because of our physiologic similarities, the ecologic niches humans and other vertebrates occupy often abutt or overlap. This close association can lead to competition for sustenance and space, physical confrontation, and transmission of disease. As mankind continues to expand its domain, burgeoning in number and encroaching into previously "untamed" areas, the frequency of interactions between humans and other vertebrates will inevitably escalate, occassionally to the detriment of one or both species. To achieve a harmonious, or at least tolerable, coexistence with other vertebrates, humans must often manipulate the population of a competing species to levels which ameliorate inter-species conflicts and permit an acceptable quality of life. In the last few thousand years, humans have intentionally incorporated some vertebrate animals into their own niche. Today, many domesticated vertebrates provide humans with food, material for clothing, protection, entertainment and recreation, labor, and companionship. However, these species which we invite into our homes and backyards can also present a threat of injury or disease that necessitates control.

When the potential hazard that a fellow vertebrate poses to our health, safety, or aesthetic quality of life exceeds a tolerable threshold, some manner of abating or managing that risk becomes incumbent. The most desirable management strategy is that which is not only efficacious but least destructive of property, least injurious to non-target species, and least hazardous to the general public and persons conducting control. Generally, an integrated program that incorporates avoidance, exclusion, deterrence, habitat modification, reduction, and removal will best meet these goals. To achieve this goal, persons who design and implement these programs must possess fundamental understanding of the biology and ecology of the species in question, a thorough knowledge of the legal and ethical obligations of any actions taken, and the experiential wisdom to thoughtfully design a program that is acceptable, safe, and effective.

In California, staff of regional mosquito and vector control districts are often the first line of response called upon to address concerns of area residents regarding dangerous or nuisance animals. The California Health and Safety Code (§ 106925) specifies that any individual who applies pesticides for public health purposes in California must be certified by the Department of Public Health (CDPH) as a vector control technician in the category relevant to vectors to be controlled. In order to ensure basic knowledge and competence, the California Code of Regulations (Title 17, § 30055) mandates examination of vector control technicians in several key topical areas. One of these areas is vertebrate vector control.

This manual is intended to provide individuals desiring certification as a vector control technician in California with the salient information required for successful completion of Section D of the certification examination, Vertebrate Vector Control. Each chapter of the manual discusses a particular classification of vertebrates which are of public health importance in California. General biological characteristics of the group are described, species of especial significance in California are listed, and general guidelines for management and control are provided. This manual is intended not as an exhaustive reference on control of

vertebrates, but as a primer for essential knowledge. Those persons who desire additional information are directed to a list of suggested readings provided at the end of each chapter.

This manual represents the most accurate information available to the authors at the time of publication. However, because laws and regulations regarding the disposition of wildlife in California change frequently, it is essential that any individual or agency that is contemplating the implementation of a vertebrate management program contacts and consults with the appropriate local, state, and federal agencies to obtain the most current information.

CURTIS L. FRITZ, DVM, MPVM, PHD
Editor

Chapter 1

SNAKES AND LIZARDS (Class Reptilia)

Richard P. Meyer

INTRODUCTION

Since the beginning of recorded history, cultural perceptions of reptiles as symbols of evil and the occult have provoked fear and enmity for these creatures. Persisting into the 21st Century, these myths and misunderstandings have led to the ignorant and indiscriminate killing of millions of reptiles, particularly snakes. Most persons are unaware that both beneficial and potentially harmful species of snake exist, let alone be able to differentiate the two. The vast majority of snakes and other reptiles in North America are non-venomous and ecologically beneficial as predators of destructive rodents and arthropods (insects, spiders, etc.). The only venomous reptiles in North America are the rattlesnakes (*Crotalus* spp. and *Sistrurus* spp.), the copperhead (*Agkistrodon contortrix*), water moccasin or cottonmouth (*Agkistrodon piscivorus*), eastern coral snake (*Micruroides fulvius*), western coral snake (*Micruroides euryxanthus*), and the mildly venomous lyre snake (*Trimorphidon biscutatus*), night snake (*Hypsiglena torquata*), and gila monster (*Heloderma suspectum*). California's diverse environment supports a total of six species of rattlesnake (Figure 1-1), as well as the lyre snake, night snake, and gila monster. Because the lyre and night snakes are seldom encountered by the general public and their venom is not as toxic as that of rattlesnakes, their overall impact on public health in California is minimal. Interested readers are urged to consult some of the references listed at the end of this chapter for more information regarding these species.

RATTLESNAKES

GENERAL CHARACTERISTICS

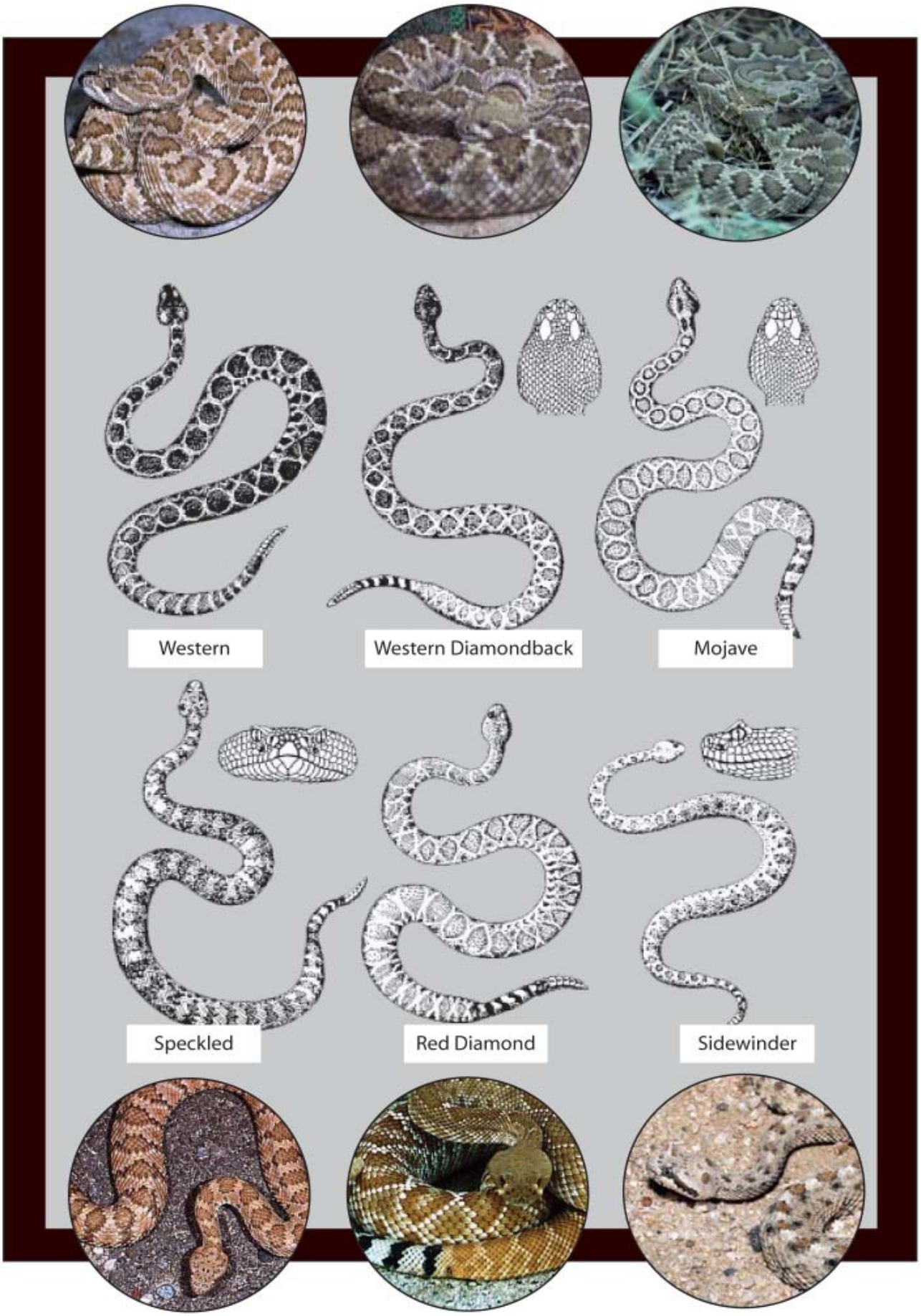
Taxonomy

Class Reptilia
Order Squamata
Suborder Ophidia (snakes)
Family Crotalidae (vipers)

Anatomy

Rattlesnakes are easily distinguished by their distinctly triangular head, a heat-sensing (infrared) loreal pit between the eyes and nostrils, and the distinctive rattles. The only non-venomous snake that is often mistaken for a rattlesnake is the common gopher snake (*Pituophus melanoleucus*). This snake is colored and patterned similarly to a rattlesnake, will instinctively expand the rear of its head, "vibrate" its tail in dried leaves, and strike when approached or disturbed. The gopher snake's close resemblance and mimicking behavior undoubtedly has resulted in the mistaken identity and indiscriminate killing of this animal.

Rattlesnakes belong to the family of pit vipers, Crotalidae, which is characterized by the presence of a specialized infrared sensory structure (loreal pit) embedded in the loreal scale of the rostrum between the nostril and eye on each side of the head (Figure 1-2a). As an infrared detector, rattlesnakes use this structure to detect the body heat of prey at close range and to locate moribund prey shortly after it has been bitten and injected with venom. In addition to the pit, rattlesnakes, as their common name suggests, possess rattles (Figure 1-2b) that have evolved as an audible warning signal to alert and ward off large mammals and potential predators. Young rattlesnakes are born with only a


Western
Western Diamondback
Mojave
Speckled
Red Diamond
Sidewinder

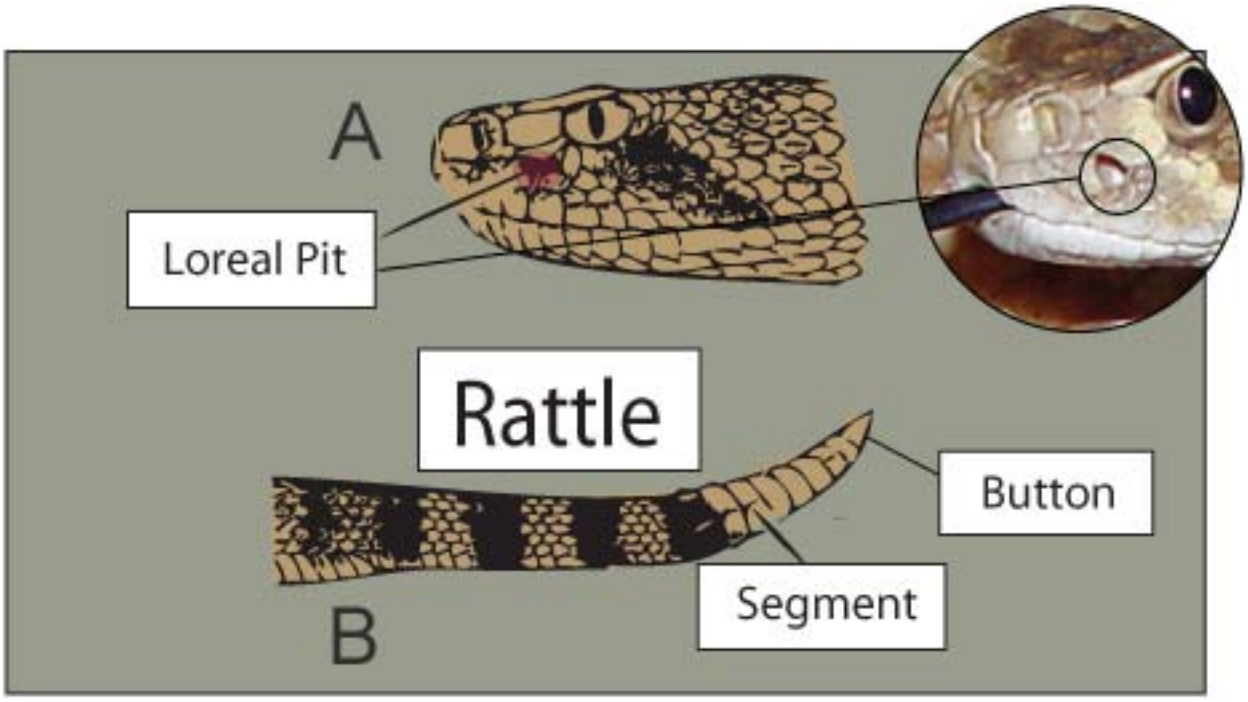


Figure 1-2

single rattle, or "button", that is incapable of producing sound. However, as the young rattlesnake grows and molts, additional rattles/segments are created until the rattle becomes functional and capable of producing the characteristic "buzz" sound. Rattle segments are interconnected with a single segment being produced each time the snake molts. It was previously thought that a segment was added for each year of the snake's life. In reality, rattlesnakes do not necessarily molt only once a year, but may shed their skin up to several times a year under favorable environments. The rattle of older individuals is seldom complete, with the button and several subtending segments usually missing.

Ecology

All reptiles, including rattlesnakes, are poikilothermic ("cold-blooded") vertebrates and are dependent upon prevailing environmental temperatures to regulate their mobility and physiological activities associated with feeding, digestion, and reproduction. Reliant upon ambient conditions, rattlesnakes are normally active during the warmer months of the year and will hibernate during the colder months between late fall and early spring. Seasonal activity patterns of California's rattlesnakes vary geographically according to climatic regions; e.g., desert species are active earlier in the spring and remaining active longer in the year than northern and montane species. Rattlesnakes overwinter ("hibernate") in gregarious underground dens with southwestern exposures to assure gaining maximum solar penetration late in the fall and early in the spring. When spring temperatures are favorable, rattlesnakes emerge from their dens to search for food, at which time they are unusually pugnacious, aggressive, and dangerous. Rattlesnakes normally will search for prey during the day, gradually shifting to greater nocturnal activity as seasonal temperatures increase. In the summer, virtually all activity and hunting occurs at night.

Reproduction

Unlike most reptiles that reproduce by hatching young from eggs (oviparous) deposited in the environment, rattlesnakes produce live young (ovoviviparous). Litters vary in size depending on the species, size, and maturity of the female, the hospitability of the environment, and the availability of prey. Litters usually consist of 4-15 young that are born during the summer months following either a fall or spring mating. The female reproductive system is equipped with specialized sperm storage vesicles that are capable of sustaining viable sperm for long periods between matings and fertilization. Mature females normally produce at least one litter per year, but at northern latitudes or in mountain environments, a single litter may be produced every two years (biannual cycle).

CALIFORNIA SNAKES OF PUBLIC HEALTH IMPORTANCE

Western rattlesnake (*Crotalus viridus*)

Description: The Western rattlesnake (37-162 cm [14-64 in] in length) usually is marked with blotches of brown to black that are edged with darker then lighter border scales. Towards the tail, the blotches narrow to cross bands that contrast with the lighter ground color (background color) of the body. The head bears a distinctive stripe extending from behind the eye to the corner of the mouth. Typical ground colors of the body scales, surrounding the blotches and bands, often blend with the soil color of the snake's immediate environment. Colors range from cream to yellow, pink, gray, greenish, brown, and black. Coastal and mountain populations tend to be darker than desert populations.
Distinguishing Characteristics: More than two internasal scales touching the rostral (nose) scale.
Range: Most common rattlesnake found in California. Distributed throughout much of the state except the Owens Valley, Mojave and Colorado Deserts. Subspecies: 1) Northern Pacific rattlesnake (subspecies *C. v. oreganus*) from the San Gabriel Mountains northward to the Oregon border and eastward to the crest of the Sierra Nevada Mountains, 2) Great Basin rattlesnake (*C. v. lutosus*) from Mono County northward on the east side of the Sierra Nevadas and Modoc Plateau to the Oregon border, and 3) Southern Pacific rattlesnake (*C. v. helleri*) from the Transverse and Peninsular Ranges southward along the coastal plain of southern California to the Mexican border.
Habitat: The Western rattlesnake frequents a variety of habitats, from shrub-covered coastal dunes and valley grasslands to timberline in the Sierra Nevada. Most often encountered on rocky outcrops, talus slopes, stream courses, and ledges.
Significance: The venom of this rattlesnake is moderately toxic.

Western diamondback rattlesnake (*Crotalus atrox*)

Description: The Western diamondback is the largest (76-215 cm [30-85 in] in length) rattlesnake in California. This rattlesnake is gray, brown, pink or yellowish with distinct diamond-shaped to hexagonal blotches mottled with dark scales and outlined with lighter contrasting scales. Smaller blotches of dark scales are present along the sides between the larger dorsal blotches. The sides of the head are marked with a light diagonal stripe that extends from behind the eye to the upper lip just before the corner of the mouth.
Distinguishing Characteristics: Tail marked with broad black and white or light gray rings of equal width that give it a distinctive "coon tail" appearance.
Range: Eastern deserts from northern San Bernardino County southward to the Mexican border.
Habitat: The Western diamondback is found in rocky and sandy desert areas where its overall ground coloration blends well with these environments. Usually encountered in desert washes and sandy areas bordering the lower Colorado River.
Significance: Considered one of the most dangerous of our rattlesnakes because of its tendency to deliver large amounts of venom when it bites. This species is more pugnacious than other rattlesnakes and will hold its ground when disturbed.

Sidewinder (*Crotalus cerastes*)

Description: The sidewinder is the smallest of California's rattlesnakes (42-82 cm [17-32 in] in length) and exceptionally colored to blend with its sandy environments. Body colors include cream, tan, and pink patterned with dorsal rectangular blotches of gray, light brown, and dark tan. Blotches are often outlined with contrasting white and black scales. A dark stripe extends from below the eye to the corner of the mouth.
Distinguishing Characteristics: Scales above the eyes are pointed and upturned, giving this snake its colloquial name of "horned rattlesnake".
Range: Widely distributed throughout the Mojave and Colorado Deserts of southern California from northern Inyo County southward along the base of the Tehachapi, San Gabriel, San Bernardino, and San Rosa Mountains to the Mexican border and eastward to Nevada and the lower Colorado River. Subspecies: 1) Mojave Desert sidewinder (*C. c. cerastes*) from southern Riverside County northward and 2) Colorado Desert sidewinder (*C. c. laterorepens*) from northern Imperial and western San Diego Counties southward.
Habitat: Largely restricted to sandy desert environments, particularly dune areas. It is a distinctly nocturnal species that preys upon pocket mice (*Chaetodipus* spp.) and kangaroo rats (*Dipodomys* spp.).
Significance: The venom of the sidewinder is mildly toxic in comparison to the venom of other rattlesnakes.

Speckled rattlesnake (*Crotalus mitchellii*)

Description: The speckled rattlesnake (57-132 cm [22-52 in] in length) has a varied ground color that may be cream, gray, yellowish, tan, pink, brown and black. The body is patterned with vague bands/blotches that may be hexagonal, narrowed in the middle, or diamond-shaped. Tail markings are more subdued in comparison to other rattlesnakes, with an alternating pattern of dark to almost black rings.
Distinguishing Characteristics: Prenasal scales on the head usually separated from the rostral scales by a row of small scales.
Range: Widely distributed throughout the Owens Valley, Mojave and Colorado Deserts to near the coast of Orange and San Diego Counties. Subspecies: 1) Panamint rattlesnake (*C. m. stephensi*) from the northern Mojave Desert and 2) Southwestern speckled rattlesnake (*C. m. pyrrhus*) from the southern Mojave and Colorado Deserts and Peninsular Ranges.
Habitat: Though widely distributed throughout the southern half of the state, the speckled rattlesnake is encountered most frequently in rocky regions of the deserts and mountains in southern California. Typical settings include sagebrush, creosote bush, and upland, in addition to thornscrub, chaparral, and pinon-juniper woodland.
Significance: Moderately toxic in comparison to other rattlesnakes. Like the Western diamondback, the speckled rattlesnake is excitable and will defend its ground when disturbed.

Red diamond rattlesnake (*Crotalus ruber*)

Description: The red diamond rattlesnake (75-162 cm [30-64 in] in length) is colored in shades of tan, pink, and red with the dorsal blotches usually indistinct or outlined with discontinuous "pepper marks". The tail is marked with alternating white and black rings giving it a distinctive "coon tail" appearance.
Distinguishing Characteristics: First pair of lower labial ("lip") scales usually divided transversely.
Range: Limited to southern California from Morongo Valley (San Bernardino County) southward through Riverside, Orange, and San Diego Counties. Absent from the Coachella Valley. Subspecies: The northern red rattlesnake (*C. r. ruber*) occurs in southern California, other subspecies are found further south in Mexico.
Habitat: The red diamond rattlesnake is found in a variety of typical southern California habitats including desert scrub, open chaparral, oak woodland, and grasslands. Occasionally found on the alluvial deposits near the base of the mountains bordering the Colorado Desert.
Significance: The venom of this rattlesnake is moderately toxic. This species is relatively timid and will seldom aggressively defend its ground when disturbed.

Mojave rattlesnake (*Crotalus scutulatus*)

Description: The Mojave rattlesnake (60-120 cm [24-48 in] in length) is marked with distinctive dark gray to brown blotches that are oval, diamond, or hexagonal and outlined with light scales. Ground color of this rattlesnake is greenish gray, olive green, or brownish to slightly yellowish. The sides of the head bear a white to yellowish stripe that originates from just behind the eye to beyond the corner of the mouth. The tail is patterned with contrasting wider light and narrower dark bands.
Distinguishing Characteristics: Scales on the snout and between the supraoculars are enlarged.
Range: Largely restricted to the Mojave Desert regions of Riverside, San Bernardino, and Kern Counties, from the base of the San Gabriel and Tehachapi Mountains eastward to Nevada and Colorado River.
Habitat: The Mojave rattlesnake is found in a variety of desert habitats throughout its range. Often encountered in barren and scrub desert, and Joshua tree/juniper woodland.
Significance: Probably the most dangerous rattlesnake in California because of the highly toxic nature of its largely neurotoxic venom. This easily excitable species often goes by its colloquial name of "Mojave green rattlesnake".

LIZARDS

Class Reptilia
Order Squamata
Suborder Sauria (lizards)

Compared to snakes, lizards in California present a far lesser threat to public health. Nevertheless, one notorious species, the gila monster (*Heloderma suspectum*), has earned a dubious reputation from the fact that its bite is venomous and some human fatalities have occurred among victims in northern Mexico. While 1% to 5% of gila monster bites are reported to be fatal, lack of ready access to medical care likely inflated this case-fatality estimate. The venom of the gila monster is similar to the hemotoxic venoms of rattlesnakes. The enzymatic action of the venom proteins degrades both muscular and visceral tissues. The likelihood that the general public will encounter a gila monster is quite low because this species occurs predominantly in uninhabited areas and moves about at night. If a gila monster is encountered, it is best left alone because the bite is not only venomous, but physically quite painful.

The western fence lizard (*Scleporus occidentalis*) and southern alligator lizard (*Elgaria multicarinata*) are included among California's reptiles of public health significance because of their role as secondary hosts of immature *Ixodes* ticks which transmit the bacterial agent of Lyme disease in California. Throughout its range and in environments supporting the western black-legged tick (*Ixodes pacificus*), fence lizards have been found infested with the larval stages of this tick. The ecological consequences of this host-ectoparasite association may favor overall tick survival by providing larval *I. pacificus* with an alternate host in areas where primary rodent host populations are either low or non-existent. Although availability of fence lizards may facilitate larger tick populations, the risk of Lyme disease may in fact be less in areas where fence lizards are prevalent. *Sceloporus* is apparently immume to infection with *Borrelia burgdorferi* because its blood carries proteins that kill the spirochetes. Therefore, areas in which ticks preferentially feed on *Sceloporus* and *Elgaria* lizards versus small rodents may present a substantually lower risk of Lyme disease, a phenomenon referred to as "zooprophylaxis".

CALIFORNIA LIZARDS OF PUBLIC HEALTH IMPORTANCE

Gila Monster (*Heloderma suspectum*)

Description: The gila monster (22-35 cm [9-14 in] in length) is the largest and only venomous lizard in North America. This species is easily identified by its heavy body, massive head, swollen tail, beaded integument and bright coloration, produced by irregular blotches/bands of red, orange, or pink scales which contrast with the predominantly black to brown scales on the body.

Distinguishing Characteristics: Body form and bead-like scales are unmistakable.
Range: Restricted to the extreme eastern Mojave Desert of San Bernardino County in the Clark, Kingstone, and Piute Mountains. Once collected from the Providence Mountains and at Imperial Dam along the lower Colorado Desert. Subspecies: 1) Banded gila monster (*H. s. cinctum*) from California and 2) Reticulate gila monster (*H. s. suspectum*) from Arizona and Sonora, Mexico.
Habitat: This rare nocturnal species usually is encountered in mesic rocky canyon bottoms and arroyos in association with succulent desert growth.
Significance: The venom of the gila monster is moderately toxic. Unlike rattlesnakes, the venom is not injected into the prey by fangs, but is expelled into the mouth from glands in the lower jaw, from which it flows down grooves in the teeth and enters the victim when the lizard bites down with a chewing motion. The bite of the gila monster is itself quite traumatic and exquisitely painful.

Western fence lizard (*Sceloporus occidentalis*)

Description: The western fence lizard (5-18 cm [2-7 in] in length) is one of the most common lizards in California. This species also goes by its alternate common name of "fence swift" or "blue belly". Most individuals are darkly colored with heavily mottled patterns of gray, brown, and black. The underside of the male bears a prominent blue patch on the throat and a pair of blue patches outlined with black or brown scales that extend from the fore to hind legs. The blue patches are less prominent or absent in females. Females also are marked differently with dark crescent bars across the back.
Distinguishing Characteristics: Scales between interparietal and rear of thighs 31-55.
Range: The fence lizard is found throughout much of California with the exception of the deserts where it is replaced by other *Sceloporus* species. Subspecies: 1) Northwestern fence lizard (*S.o. occidentalis*) found in northern and central California eastward to the Great Basin, 2) Island fence lizard (*S. o. becki*) restricted to the channel islands of southern California, 3) Great Basin fence lizard (*S. o. biseriatus*) from the Great Basin (Modoc Plateau) southward through south central California and along the Peninsular Ranges to Baja California, and 4) Sierra fence lizard (*S. o. taylori*) limited to the central Sierra Nevada Mountains and adjoining coast ranges.
Habitat: This common lizard resides in a variety of habitats including grassland, chaparral, sagebrush desert, woodlands, coniferous forest, and farmland.
Significance: This lizard may play an important role as an alternative host to tick species that are known vectors of Lyme disease in northern and coastal California. However, this species is not considered a viable reservoir of *B. burgdorferi*.

Southern allligator lizard (*Elgaria multicarinata*)

Description: A short-legged, heavy bodied lizard with a large triangular head. Total length up to 50 cm (20 in). Tail is long and prehensile; used to manuever through dense vegetation and hang from branches. Longitudinal skin folds on sides which enclose granular scales; dorsal and ventral scales squarish. Back is brown to reddish, checkered with black and white.
Distinguishing Characteristics: Long (up to twice length of the body) prehensile tail and large triangular head. Lateral folds running along both sides of the body which can expand to make the lizard appear even larger if threatened.
Range: Southern Washington to central Baja California.
Habitat: Occurs in most non-desert habitats, including cismontane shrublands, grasslands, oak woodland, lower montane forest; prefers areas with access to shade, water. Has adapted well to urban habitats and can often be found in backyards and vacant lots.
Significance: This lizard may play an important role as an alternative host to tick species that are known vectors of Lyme disease in northern and coastal California. However, this species is not considered a viable reservoir of *B. burgdorferi*. Alligator lizards are not easily intimated by humans and can inflict a vigorous, painful bite if disturbed.

PUBLIC HEALTH SIGNIFICANCE

Bacterial infections may result from contact with reptile fecal material, contaminated body surfaces, or through bites. Individuals who are accidentally bitten when handling large lizards and non-poisonous snakes typically receive inoculation against tetanus and are given antibiotics. Transmission of *Salmonella* to humans has been documented for persons handling contaminated turtles ("sliders" in the genus *Pseudemys* spp.) and other pet reptiles (e.g., iguanas) imported from outside of California and sold locally in pet stores.

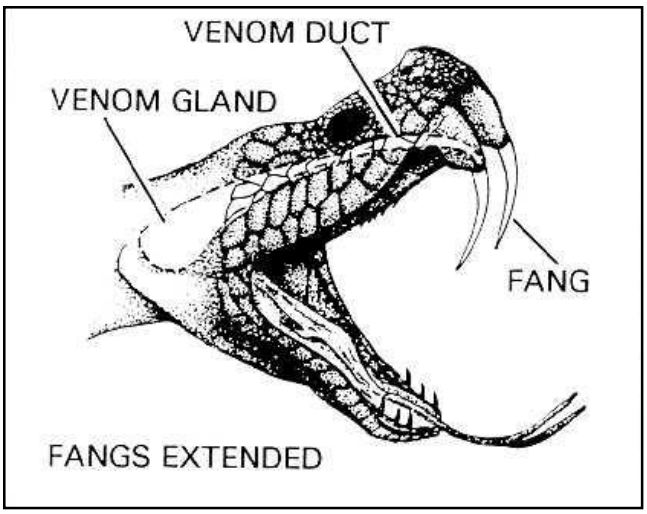


Figure 1-3

An estimated 45,000 snake bites occur annually in North America with 15-20 of these being fatal. Most of the bites and fatalities occur in the southern states where rattlesnakes are common. The victims of non-fatal bites frequently suffer debilitating or disfiguring side effects from the bites because the venom can produce massive tissue destruction and scars; in extreme cases tissue damage may demand amputation of fingers, toes, or entire limbs.

The venoms injected in the fangs of most rattlesnakes are complex amalgams of proteins. Enzymes are present that initiate the digestive process before the prey is swallowed. Other venom components may affect the nerves by significantly reducing the ability of nerves to transmit impulses. The toxicity of rattlesnake venom varies between species and is related to typical prey size and the quantity required to incapacitate or kill their prey. Venom toxicity (LD50 mg/kg) is rated by the quantity of venom required to kill 50% of a target animal (e.g., laboratory rat) population as a function of the animal's weight. Among California rattlesnakes, the venom of the Mojave rattlesnake (*Crotalus scutulatus*) is extremely toxic with an LD50 of only 0.21 mg/kg. The venom of this rattlesnake also is unique because it contains both hemotoxic and neurotoxic compounds that produce both blood and tissue degradation, as well as disruption of nerve function. The venoms of the other California rattlesnake species are significantly less toxic and composed predominantly of hemotoxic compounds. Approximate LD50s are: red diamond (3.70 mg/kg), western diamondback (3.71 mg/kg), Southern Pacific (1.29 mg/kg), Great Basin (2.20 mg/kg), and sidewinder (4.00 mg/kg).

When a rattlesnake strikes, the jaw opens to expose fangs that are rotated forward 90-degrees into the fully extended position (Figure 1-3). This extension of the fangs assures maximum penetration into the potential prey. At the instant of penetration, the venom, supplied from special glands just behind the eyes on either side of the head, is expelled through the venom ducts in the fangs deep into the site of the bite. Once injected, the venom can both cause destruction of tissue near the bite site and enter the bloodstream to be circulated throughout the prey's body and begin the digestion of other visceral organs.

Safety

There are numerous misconceptions regarding the striking distance of a rattlesnake. Rattlesnakes have been reported to be able to strike anywhere from one half to almost the full length of their body. In reality, the actual distance rarely exceeds 30-75 cm (1-2.5 ft). A large western diamondback, for example, can strike up to 60 cm (24 in) above the ground, at a level between the knee and ankle of most adult humans.

Rattlesnakes do not strike as a consequence of instinctive aggressive behavior, but either as a defensive or hunting action. The best prevention against rattlesnake bite is to 1) avoid contact, 2) wear protective clothing, and 3) use common sense when in "rattlesnake country". The following is a list of bite avoidance suggestions recommended by the Southwestern Herpetologists Society:

- Do not handle or provoke rattlesnakes and keep a safe distance once encountered.
- Watch where you place your feet; do not step "blindly" over rocks, logs and twigs.

- Watch where you place your hands; do not reach "blindly" over rocks and ledges, into crevices or animal burrows.
- Wear a sturdy pair of leather boots that extend above the ankle or don protective chaps in areas known to be heavily infested with rattlesnakes.
- Wear snake chaps, leggings, or guards when in areas heavily infested with rattlesnakes to prevent bites to feet, legs, and lower torso.

If, despite adherence to these precautions, a snake bite occurs, the victim should be kept calm, covered with a warm blanket, and transported immediately to an emergency medical facility. Cutting and suctioning venom from the bite and applying tourniquets to either side of the bite are not recommended due to a variety of complications that arise as a consequence of these radical first-aid procedures, including incipient bacterial infection. Administration of specific antivenin and support of life-sustaining systems are the only appropriate and effective treatments for snake envenomation. If the biting snake was observed and its species can be identified, this information should be conveyed to the attending medical staff as it may provide information valuable toward the proper medical management of the patient.

MANAGEMENT AND CONTROL

Legal Status

None of the rattlesnake species in California is considered either "threatened" or "endangered". Although some rattlesnakes may be "dangerous", they are nonetheless strictly protected by state law and possession of any native species without proper permits and documentation is illegal and subject to citation by the California Department of Fish and Game. Individuals or agencies considering trapping or removing rattlesnakes from private or public property should first contact local Fish and Game officials for procedures and regulations.

Exclusion

The most effective means for homeowners to protect their properties from invasion by rattlesnakes is to construct a "snake-proof" (exclusion) fence around the yard or smaller areas frequented by children and pets. A typical rattlesnake fence consists of a one-meter-high ¼-inch hardware cloth/mesh screening supported by conventional fence posts. The bottom edge of the screen should extend 10-15 cm (4-6 in) below the surface of the soil to ensure that rattlesnakes will not enter through gaps below the base of the fence. In addition to snake-proof fences, residents should inspect their home and garage for gaps (5 mm or wider) in access doors, vents, and windows. All possible entry points should then be sealed, weather stripped, or screened with ¼-inch hardware cloth.

Habitat Modification

Rattlesnakes in the wild utilize existing vegetation and other natural cover for concealment, to avoid predators, and as a hunting ground for prey. Weeds, trash, lumber and wood piles, and abandoned rodent burrows around human residences provide rattlesnakes with similar safe shelter. Eliminating these harborages and shelters can significantly reduce the attractiveness of a residence to snakes.

Trapping

In some areas of the United States, rattlesnakes are trapped at den sites during the time they enter or exit prior to and after overwintering. Snake traps are designed to "funnel" snakes to a central collection point or pitfall where they can be removed by an experienced handler. Trapping rattlesnakes routinely in residential and rural settings is not an operationally feasible control practice because the movement of snakes is difficult to predict.

Public Awareness

The single most import aspect of managing rattlesnakes is to inform the public regarding the proper disposition toward snakes and how to avoid contact. The objective of any rattlesnake awareness program is to emphasize common sense precautions and environmental management to reduce the risk of snake bite. The risk of traumatic rattlesnake encounters can be significantly reduced by wearing proper attire, maintaining properties in a manner that deters rattlesnakes from entering, and adopting an attitude of cautious awareness in areas where snakes are present.

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Chapter 2

BIRDS
(Class Aves)

Benjamin H. Sun

INTRODUCTION

Birds are highly developed animals that are found worldwide in a variety of habitats. Birds are distinguished from most other vertebrates by their adaptions for flight, including hollow bones, wings, and feathers. Birds have benefited mankind by serving as sources of food, cultural and religious symbols, sentinels of environmental hazards, large consumers of insects, pollinators of plants, and as a source of companionship and enjoyment. From a public health perspective, birds pose little direct threat to humans compared to other vertebrates; however, it is important to be aware of the potential health and safety risks that contact with birds may pose.

GENERAL CHARACTERISTICS

Taxonomy

The class Aves consists of approximately 30 orders, 200 families, 2000 genera, and nearly 10,000 species. More generally, birds can be categorized into six groups based upon their physical features, habitat, and lifestyles. Examples of birds in these six groups include:

1. Perching birds: sparrows, crows, finches, swallows, blackbirds
2. Birds of prey: hawks, falcons, vultures, owls
3. Running birds: quail, turkeys, pheasants, grouse
4. Wading birds: herons, storks, spoonbills, ibises
5. Aquatic birds: ducks, geese, swans, gulls, pelicans
6. Other land birds: pigeons, hummingbirds, woodpeckers

More than 600 wild bird species have been identified in California. Examples of bird groups found in California are listed in Table 2-1.

Anatomy

The anatomical features characteristic of species in the class Aves (Figure 2-1) include the following:

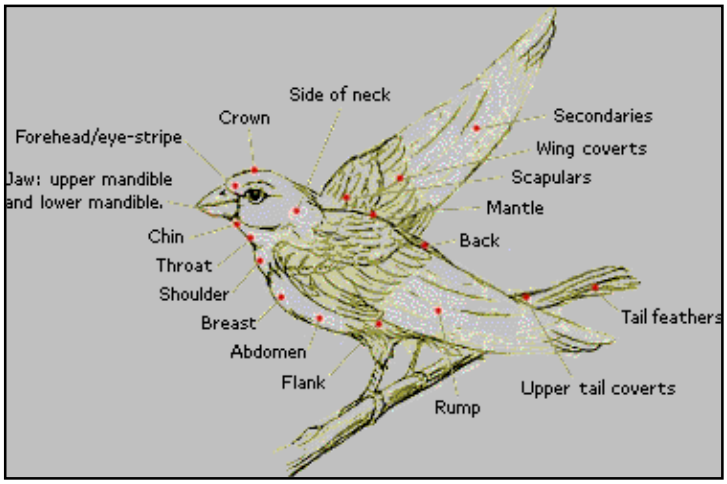

Figure 2-1

1. Epidermal covering of feathers and leg scales
2. Skeleton fully ossified with air cavities and beak with no teeth
3. Paired limbs with the forelimbs usually adapted for flying and posterior pair adapted for perching, walking, or swimming
4. Internal fertilization with large-yolked, hard shell eggs
5. Homeothermic (warm-blooded)
6. Four-chambered heart
7. Respiration by slightly expansible lungs with thin air sacs

Ecology

Birds have developed diverse and effective strategies for feeding, reproduction, and survival, and play important roles in the local ecology through control of insects and pollination and dispersion of plants.

Birds spend much of their time feeding and searching for food. Frequent, limited feeding helps to avoid excessive weight of a meal from inhibiting their ability to fly. Beak shape and size varies among species and is often specialized toward the bird's diet of insects, fish, meat, seeds, nectar, or fruit. Most birds have two specialized organs to process food. The gizzard, part of the stomach, has thick muscular walls capable of crushing large seeds and, with small stones which the bird swallows, grind up other large bits of food. The crop is a saclike extension of the esophagus that allows the bird to store and transport food for later digestion.

Birds often have complex mating rituals and visual displays. Most birds build nests in which the developing amniote eggs are deposited to incubate. In addition, most birds also provide care for their young which may hatch as naked and helpless (altricial) or feathered and able to walk and feed on their own (precocial).

Birds have developed a variety of survival strategies including keen eyesight and acute hearing, camouflage, living in large flocks, and audible alerts.

Distribution/habitat

Birds inhabit a variety of habitats worldwide and some species migrate long distances. Nuisance species (e.g., rock doves) have adapted well to filling a niche in urban areas, where they are often abundant. Of probably greater public health significance are the numerous nonnative avian species that are kept as pets in California, because people have more frequent and intimate contact with pet birds than with wild birds.

Table 2-1. Orders and examples of birds found in California

Order	Representative examples
Anseriformes	Swans, geese, ducks
Apodiformes	Swifts, hummingbirds
Caprimulgiformes	Nighthawks
Charadriiformes	Gulls, plovers, sandpipers
Ciconiiformes	Herons, ibises
Columbiformes	Doves, pigeons
Coraciiformes	Kingfishers
Cuculiformes	Cuckoos, roadrunners
Falconiformes	Vultures, hawks, falcons
Galliformes	Quail, pheasants
Gaviiformes	Loons
Gruiformes	Cranes, rails, coots
Passeriformes	Swallows, warblers, crows, jays, finches
Pelecaniformes	Pelicans, cormorants
Piciformes	Woodpeckers
Podicipediformes	Grebes
Procellariiformes	Albatrosses, shearwaters, petrels
Psittaciformes	Lories, parakeets, macaws, parrots (do not occur naturally in California)
Strigiformes	Owls

CALIFORNIA BIRDS OF PUBLIC HEALTH IMPORTANCE

American crow (*Corvus brachyrhynchos*)

Range: Common throughout California.
Habitat: Developed and undeveloped areas, agricultural land, forests and parks. May nest or roost in urban areas.
Biology: Diet is about 30% animal matter (mice, carrion, insects) and 70% vegetable matter (seeds, nuts, fruit). Nest between February and May. Lay 3-9 eggs; incubation is approximately 18 days. Crows flock after fledglings leave the nest. Crows congregate in large communal roosts at night.
Significance: Agricultural pest. Damage orchard and field crops. Large flocks can present a noise nuisance in residential areas. Important sentinel species for surveillance of West Nile virus in North America.
Legal Status: Classified as migratory non-game birds and may be taken only by property owners or tenants to abate a health hazard or nuisance.

Brewer's blackbird (*Euphagus cyanocephalus*)

Range: Common throughout California. Winters in the valleys and along the central coast.
Habitat: Farmland and undeveloped areas, as well as urban and suburban neighborhoods.
Biology: Breed and nest in February and March. Lay 3-7 eggs; incubation is 12-14 days. A second brood may be laid if first clutch of eggs does not survive.
Significance: Agricultural pest in orchards, fields, and cattle feedlots.
Legal Status: Classified as migratory birds and may be taken without federal permit if depradating agriculture or livestock.

House finch (*Carpodacus mexicanus*)

Range: Common throughout California. Most abundant in valleys and foothills.
Habitat: Woods, deserts, farmlands, suburban and urban areas.
Biology: Nest in nearly any sheltered area between March and July. Lay 2-6 eggs which hatch in 13-14 days. Broods of young and adult birds band together during the summer. Feed primarily on seeds, buds, and berries.
Significance: Consume deciduous fruit. Also destroy buds and blossoms of flowering fruit trees. Important reservoir of mosquito-transmitted encephalitis viruses.
Legal Status: Classified as a migratory nongame bird by Federal Regulations. A U.S. Fish and Wildlife Service permit must be obtained before control measures can be implemented.

House sparrow (*Passer domesticus*)

Range: Common throughout California
Habitat: Developed and agricultural areas.
Biology: Nest building begins in February. Lay 2-7 eggs in up to three broods per year. Eggs hatch in 10-14

days. Young birds and adults flock together in late summer. Feeds primarily on grain, human discards in urban areas.
Significance: Consume stored grain. Reservoir for pathogens of veterinary and human medical importance, including western equine encephalomyelitis virus and diverse fungal and protozoal parasites.
Legal Status: Classified under California Fish & Game Code as a nongame bird which may be taken at any time.

Canada goose (*Branta canadensis*)

Range: Migratory. Summer breeding grounds in Canada and Alaska, but geese of the Pacific flyway overwinter in California and other western states.
Habitat: Waterfowl. Can be found near any body of water, be it natural or man-made (e.g., city park pond).
Biology: Feed on grasses, grains, and seeds along the water's edge. Form life-long breeding pairs. Lay 3-7 eggs which take 25-30 days to hatch. Goslings are precocial.
Significance: While goose feces can contain pathogens capable of causing disease in humans, the risk of infectious disease to humans through contact with goose feces is considered quite low. Accumulated fecal material from large flocks can deface public areas (e.g., golf courses) and create hazard of injury on walkways. Because of their large size (up to 10 kg [24 lb]) and aggressive disposition when defending a nest, geese present a risk of biting injury, especially to small children.
Legal Status: Protected by state and federal law (Migratory Bird Treaty Act). One subspecies, the Aleutian Canada goose (*B. c. leucoparia*), is listed as federally endangered. A permit must be obtained from the U.S. Fish and Wildlife Service before depradating geese may be taken. Also, because geese are ground foragers, extreme care must be taken when conducting chemical control of other vertebrate pests to prevent any geese present in the area from becoming non-target victims.

Rock dove, aka. city pigeon (*Columba livia*)

Range: Widely distributed within and around developed areas of California.
Habitat: Cities, suburbs, and farmland.
Biology: Use shelters and ledges, commonly on man-made structures, for nesting sites. Lay 1-2 eggs which hatch in 16-19 days. Five or more broods are raised each year. Feed mostly on seeds and grains. In cities, may subsist on foods intentionally or inadvertantly offered by humans.
Significance: Host for several pathogens of veterinary and medical importance, including *Toxoplasma* and *Salmonella*. Pigeon feces can deface buildings, automobiles, walkways, and public art. Pigeon feces also provide an ideal medium for growth of *Histoplasma* and *Cryptococcus* fungi, both of which can cause respiratory illness in humans. Their nests can interfere with drain pipes and awnings.
Legal Status: Rock doves are not protected by federal or state law.

PUBLIC HEALTH SIGNIFICANCE

Birds pose few direct disease risks to humans compared with other vertebrate species. In general, wild bird species are of less public health concern than species used in agriculture, exhibition, or as pets, due to the amount and nature of bird and human contact. Brief exposure to birds or their droppings is not likely to result in disease transmission. However, persons with repeated and prolonged exposure are at increased risk, especially persons with compromised immune function. It is important that persons who are ill, or suspect that they may have been exposed to an infectious organism transmitted from birds, seek prompt medical attention for proper examination and treatment. Diseases transmissible between birds and humans are categorized below according to the role the avian host plays in the maintenance and transmission of the disease agent.

1. Diseases for which the bird is a natural reservoir for the disease agent, the agent causes illness in the bird, the bird sheds the agent into the environment, and humans are infected as accidental hosts.

Psittacosis (parrot fever, ornithosis). *Chlamydophila psittaci* is a bacterium transmitted from birds to humans that affects primarily the respiratory system. *C. psittaci* has been isolated from approximately 120 bird species and is most commonly identified in psittacine birds, especially cockatiels and parakeets. Approximately 75% of cases result from individuals exposed to caged pet birds, the majority of whom are bird fanciers or pet shop employees. However, transmission has also been documented from wild birds, including doves, pigeons, raptors, and shore birds. In recent years, fewer than 50 confirmed human cases of psittacosis were reported in the United States. Many more cases may occur that are not correctly diagnosed or reported. The infection is acquired by inhaling dried secretions (including feces) from infected birds. The incubation period is 6-19 days. The clinical features in humans include fever, chills, headache, muscle aches, and a dry cough. The infection usually resolves with appropriate antibiotic therapy, but rarely heart, liver, and neurologic complications may occur and fatal cases have been reported.

2. Diseases for which the bird is the natural reservoir for the disease agent, the agent does not make the bird ill, the agent is spread into the environment directly or via insect vectors, and humans are infected as accidental hosts

Dermatitis. Mites (e.g., *Ornithonyssus* spp.) that infest wild and domestic birds can occasionally infest and bite humans, causing pruritic (itchy) rashes. Persons who handle wild birds or their nests are at potential risk of infestation. Avian mites can be controlled by treating the birds and wearing protective clothing and/or spraying clothing with insect repellents prior to entering infested areas.

Hypersenstivity pneumonitis. Some persons may experience an allergic reaction to bird antigens present in dander. Exposure may cause respiratory inflammation when the antigens are inhaled. Sensitive persons can protect themselves by wearing respiratory protection and by working in well-ventilated areas.

Gastroenteritis. A variety of disease agents that cause diarrhea and vomiting, such as *Salmonella* and *Campylobacter*, may be present in bird feces. People can get these diseases by ingesting the bacteria present as surface fecal contamination on undercooked meat or poultry. People can also become infected by handling infected birds or bird feces and then contaminating food items or other surfaces by touching them without first washing their hands. Gastroenteritis can be prevented by cooking all meat well, washing hands prior to eating and drinking, and cleaning food items and utensils that come into contact with birds and bird feces.

Arboviral encephalitides. Birds can serve as reservoir hosts for several of the viruses associated with mosquito-borne viral encephalitis. In California, house finches and house sparrows are the most important reservoirs for western equine encephalomyelitis virus (WEE) and St. Louis encephalitis virus (SLE). These species are important to arbovirus transmission because they a) are abundant, b) live in close association with many human communities, c) have a relatively high proportion of infected birds, and d) maintain a persistently high viremia. Birds remain generally unaffected by infection, but mortality can be significant with the more virulent (e.g., eastern equine encephalomyelitis) or exotic (e.g., West Nile) arboviruses.

3. Diseases for which the bird is not the natural reservoir for the disease agent, but bird feces facilitate growth of environmental organisms, and humans are infected from the environment

Fungal infections. Bird feces can serve as an ideal environment for the growth of a number of fungi that can cause severe disease in some humans. Growth of certain fungi, normally present in the soil, may be promoted in the presence of bird fecal matter. In California, *Cryptococcus neoformans* is often isolated from pigeon feces. Individuals can become infected following inhalation of aerosolized dust or soil that is contaminated with pigeon feces. Only a small percentage of exposed persons develops respiratory illness; however, the risk of severe illness is increased for immunosuppressed individuals. Precautionary measures include controlling urban pigeon populations, avoiding highly contaminated areas, working in well-ventilated areas, wetting down contaminated areas prior to entry to minimize aerosolization, and the use of respiratory protection.

MANAGEMENT AND CONTROL

Waste management

In addition to providing a rich organic environment for the growth of infectious disease agents like *Cryptococcus*, bird feces can deface architecture and public art, cause hazardous and unsightly contamination of walkways and roads, and generally diminish the aesthetic appearance of public areas. Management and control of bird populations and their waste products can be difficult. Efforts should be made to clean up waste products, especially around areas where particularly susceptible individuals reside, such as hospitals and nursing homes.

Cleanup should be scheduled during evenings or weekends to reduce the risk to passersby. Barricades should be erected around the cleanup site to further deter unaware pedestrians. If the cleanup area is near or on top of a building, close all air ducts into the building prior to cleanup.

Persons conducting cleanup should don appropriate clothing and respiratory protection. Disposable coveralls, gloves, shoe coverings, and head covering should be worn. Gloves and shoe covers should be sealed to coveralls with duct tape. A NIOSH-approved full face respirator with a HEPA or N-100 filter should be worn; dust and particle masks provide inadequate protection. Eye protection should be used to prevent splash-back of infectious material.

Bird droppings present the greatest risk of infection when they are dried and capable of being stirred up into the air where they can be inhaled. Prior to cleanup, droppings should be saturated with a low-pressure fine mist of a disinfectant solution (e.g., diluted bleach). When the contaminated surface is a street or sidewalk, hosing may be used to remove small amounts of freshly deposited feces. Remove fecal material with brushes composed of nylon bristles; do not use metallic instruments that can damage building surfaces.

When complete, double-bag all fecal material, seal the bags, and transport to local landfill for disposal. Coveralls, gloves, and other attire should similarly be double-bagged and promptly disposed of.

Bird control

Bird control techniques are implemented to alleviate health concerns, avoid undue building deterioration and attendant maintenance costs, ameliorate unkempt appearances, ensure safety in the workplace and on public access ways, prevent product and property damage or loss, and preserve food hygiene. Control measures depend on the species involved, the habitat, and the level of infestation. Bird control is rarely achieved with a single product or treatment; a combination of habitat modification, use of repellents, and removal of problem birds is often necessary to effect adequate control.

Habitat modification. Nuisance birds are attracted to areas of human habitation by the availability of food, water, and shelter (for nesting or roosting). Elimination or restriction of access to these resources will help to dissuade birds from frequenting and nesting in inappropriate or undesirable locations.

1. Food

Typical food sources for nuisance birds include fruit, nuts, seeds, and insects. Some birds (e.g., crows) are opportunistic scavengers and feed on discarded organic wastes. Eliminating these sources of sustenance reduces the number of undesirable birds in an area. Around the home, residents can select and plant vegetation that does not produce attractive fruit or nuts. Nylon or plastic netting draped over fruit trees can keep birds from eating the fruit. Bird feeders should be stocked with feed

that is attractive only to desirable birds. Bird feeders can also be designed to restrict access of undesirable birds; for example, tubular wiremesh feeders are easily accessible by clinging birds (e.g., nuthatches) but are more difficult for perching birds (e.g., house sparrows) to negotiate.

2. Water

Birds require water year-round and any constant source of standing water can serve as an attractant. Unnecessary accumulations of water should be removed or drained. Necessary pools of water, such as animal watering troughs, should be maintained at a level too low for birds to reach the water while perched on the edge, yet deep enough to disallow birds from standing in it.

3. Shelter

Birds require shelter for cover, roosting, and nesting. The type of shelter varies by species and season. Removing or denying access to preferred shelter sites can help reduce numbers of unwanted birds. Nests built in undesirable locations should be removed regularly, as displaced birds will attempt to reestablish a preferred nesting site. Exclusion of birds from these sites usually provides a more easily achievable long-term solution.

Nylon or plastic netting over eaves, rafters, and trees prevents birds from using these locations to roost. Thinning trees will reduce the availability of roosting sites for large flocks of gregarious birds (e.g, American crows, European starlings) which tend to roost together in the evening. To prevent birds from roosting or nesting on eaves and ledges, a wooden or metal board can be placed at a 45-degree angle between the wall and the ledge to make it less hospitable. "Porcupine wires"—a board to which stiff heavy wires (e.g., coat hanger wire) are attached sticking out at different angles—can also be placed on ledges to discourage roosting and nesting. Large doorways to barns and sheds can be strung with long plastic strips that allow passage of people and equipment but prevent birds from access to the structure.

Repellents. Various techniques and devices have been used to frighten birds away from a particular location. Both visual and audio repellents are available. These measures are occasionally successful with some species of birds (e.g., European starlings), but seem to leave other species (e.g., rock doves) relatively undeterred. Sensory repellents should be used in conjunction with habitat modification and other components of an integrated control program and should not be relied upon as a sole means of managing nuisance birds. Further, even if initially effective, nearly all birds become accustomed to these stimuli, so it is important to change the location and/or type of repellent on a regular schedule. It is necessary to continue the repellent activity every day for a week or more to persuade birds to establish permanent roost elsewhere; otherwise, birds may temporarily roost nearby before returning to their preferred site.

Most bird species have keen vision and respond best to visual repellents. Simulations of natural predators can keep many small birds away from undesirable locations. A silhouette of a raptor pasted on a window can prevent birds from flying into the glass pane. A statue of an owl placed in a garden or on a building ledge can scare small birds away. String-tethered balloons with large "eyes" painted on them can also appear to small birds as a potential predator. Aluminum pie tins or plastic milk jugs suspended from a tree or eave by strings or wire coils (Slinky™) is an inexpensive and effective scare device.

Various noisemakers, such as alarms, distress calls, and automated explosions, can frighten birds when applied at the proper time. Scaring should begin 1½ hours before sunset, when birds are coming in to roost, and then discontinued after dark. (An additional scare period may be implemented immediately after dawn when birds leave their nests.) Distress or alarm calls should be played for 10-15 seconds every minute. Be prepared to resume scare tactics should birds return to the undesirable roosting location after the efforts have been discontinued.

Removal. Rarely do individual birds per se pose a particular nuisance. Rather, flocks or populations of birds usually present a general problem, manifest as disturbance or destruction exacted by individual representatives of the group. Removal of a few birds only creates a temporary void in the flock that will soon be filled by additional members. Thus, bird control programs are best based on the goal of population exclusion or control. Nevertheless, occasionally collection and removal of individual birds can be a useful component of an overall bird management program.

Trapping and netting of birds is an effective means of removing nuisance birds in an area where other species of bird are present. Live trapping methods include funnel traps, nest box traps, triggered traps, decoy traps, and mist nets. Before placing traps, pre-bait the area for 1-2 weeks. Place the traps using the same bait as used during the pre-bait period. Traps should be checked several times daily. Non-target birds should be removed and released with the minimal amount of trauma and stress. Target birds should be destroyed in a humane manner; check with local animal control for the most expeditious euthanasia method for the target species of interest. Finally, state, local, and federal laws restrict collection of most bird species; before initiating a bird removal program, check with the California Department of Fish and Game regarding any special permits which may be required.

Chemical control. Use of toxin-impregnated feed can be used to eliminate some nuisance birds. However, it is not always effective as some birds may refuse to take the poison. Also, as an indirect control method, the potential for poisoning of non-target species can be significant. As such, chemical control should be viewed as a last resort only when the methods described above have been attempted and proven unsuccessful. As with trapping, local animal control and California Department of Fish and Game should be contacted prior to implementation of a chemical control program.

Chemical control can be conducted without a permit only for house sparrows, European starlings, and rock doves. Avitrol7 (4-aminopyridine) is an approved chemical control agent for these species. It is available in a pellet (for starlings) and corn or wheat forms (for sparrows and rock doves). **Avitrol is a highly toxic, restricted-use poison that may be used only by a certified applicator. Read and follow the label instructions explicitly.** Select treatment areas that eliminate the potential for consumption of toxic bait by non-target species. Use of well-designed bait boxes can reduce the incidental consumption by larger birds and mammals. Treatment areas should be pre-baited with non-toxic bait for 1-2 weeks prior to treatment. Replace with toxic bait once target birds are readily consuming the bait. Remove any unconsumed bait remaining after desired bird control has been achieved.

Collect and dispose of bird carcasses promptly. In addition to the infectious disease health risks posed by numerous bird carcasses, carnivores and scavengers can be incidentally exposed to the toxin if they consume the tissues of poisoned birds. Also, the appearance of numerous dead and dying birds can incite public concern. It is important that the public be informed and aware of the bird control program prior to implementation to reduce the chances of a public relations problem.

Agencies attempting to control nuisance bird species should consult with state and local agencies before undertaking any control measures in that most birds are protected and various control methods may be prohibited. Each nuisance situation should be handled on a case-by-case basis according to the species involved, the nature of the problem, the intended outcome, the habitat, and available resources. The United States Department of Agriculture's guide "Prevention and Control of Wildlife Damage" (see References) is species specific and provides detailed control methods.

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Chapter 3

OPOSSUMS (Class Mammalia, Superorder Marsupialia)

Michele T. Jay

INTRODUCTION

Marsupials are the pouched mammals. It is hypothesized based on the fossil record that marsupials originated in North America and spread to South America and eventually to Australia, via Antarctica. The expansion probably occurred near the end of the Cretaceous Period when Australia, Antarctica, and South America were contiguous. The opossums are sometimes called "living fossils" because they have remained virtually unchanged for 50 million years.

GENERAL CHARACTERISTICS

Taxonomy

There are 16 families of marsupials that encompass 78 genera and 280 species, including the kangaroos and wallabies of Australia. The Virginia opossum, *Didelphis virginiana* (Family: Didelphidae), is the only marsupial that occurs in North America.

Anatomy

Opossums appear superficially ratlike, with a long narrow, pointed snout and a white face with prominent gray to black guard hairs. Opossums are easily distinguished from rodents by their large distinct canine teeth and prehensile tail. Opossums are about the size of a domestic cat: body 30-50 cm (12-20 in), tail 25-53 cm (10-21 in), and weight 1.8-4.5 kg (4-10 lb). Opossums' tails are long, sparsely haired, and prehensile. Combined with hind feet which bear a fifth prehensile toe, the tail is used for balance and stability while climbing; opossums do not hang from their tails. Males are usually larger than females and lack an abdominal pouch. The female reproductive tract consists of two completely separate uterine horns and vaginas (*Didelphis* = "two wombed"). The male's scrotum is in front of the penis and the penis is bifid.

Reproduction

Opossums usually mate between January and July. They typically have 2 litters of 4-10 young per year. Like all marsupials, opossums lack a complete placenta. The gestation period is only 12 -13 days, significantly abbreviated compared to that of placental mammals. The young are born almost embryonic. About the size of a bumblebee, they crawl unaided to their mother's marsupium, or pouch, where they attach to a nipple. The young emerge from the pouch after approximately two months, then may stay with their mother for awhile longer, often riding on her back.

Behavior

Opossums are omnivorous and prefer to eat insects, snails, carrion, fruits (especially over-ripe), grains, mice, bird eggs, and small snakes. Compost piles, garbage cans, and pet food provide attractive meal opportunities for opossums.

Opossums are solitary and nocturnal mammals. They usually move slowly and may exhibit an involuntary shock-like state when frightened ("playing possum"). If threatened, opossums will hiss or growl and bare their teeth, but are generally shy animals that prefer to avoid confrontation. An opossum that seems overly friendly, aggressive, or is active during the daytime is probably sick, possibly rabid, and should be avoided.

Opossums have many predators including dogs, cats, owls, coyotes, and humans. They are frequently hit by cars and also hunted for fur, typically used for trim on less expensive clothing and hats. The lifespan of an opossum in the wild generally does not exceed 2 years, but in captivity they may live up to 10 years.

Distribution/habitat

Members of the family Didelphidae occur only in the New World. Opossums have an extensive range in North America. The opossum was introduced from the southeastern United States into California near San Jose in the early 1900s, and thereafter rapidly expanded its range to include the coast, from San Diego north to Oregon, and eastward to the Sacramento Valley and San Joaquin Valley. Opossums typically inhabit regions below 1000 meters elevation. Opossums thrive in many environments, competing well with placental mammals. The natural habitat of opossums is woodland areas near streams and rivers. Opossums also adapt well to agricultural areas and backyards of suburban neighborhoods. They will use hollow trees, woodpiles, rock piles, and abandoned underground burrows as dens. In a peridomestic setting, they will live under buildings and in attics.

PUBLIC HEALTH SIGNIFICANCE

Opossums pose a potential threat to human health through direct injury or as a reservoir/carrier of infectious disease.

Bite Wounds

Opossums are generally shy and avoid contact with humans. However, if provoked (e.g., petted, picked-up, attacked by dogs/cats), they will bite. Bacterial infections can develop rapidly at bite wounds. Wounds should be immediately cleaned with soap and water and medical attention sought. Opossums are capable of transmitting rabies via bites and scratches (see below).

Chagas' Disease (American trypanosomiasis)

Chagas' disease is a febrile illness caused by a protozoal parasite, *Trypanosoma cruzi*, and transmitted by the bite of an infective Reduviidae (cone-nosed or kissing bugs). In South America, where Chagas' disease is endemic, members of the genus *Didelphis* are important reservoirs of *T. cruzi*. *T. cruzi* has been identified in approximately 15% of opossums in the southeast United States. The role of opossums in the maintenance and transmission of *T. cruzi* to humans in North America is unclear.

Enteric infections

Enteric bacteria such as *Salmonella* spp. are commonly found in the feces of many species of mammals and birds, including opossums. These bacteria and other enteric pathogens may be shed in feces and transmitted to humans by the fecal-oral route (e.g., via ingestion of pathogens in food or fomites contaminated with feces). Enteric infections are characterized by fever, malaise, and diarrhea. In the very young, the elderly, and persons with compromised immune systems these infections may be severe or even fatal.

Equine Protozoal Myeloencephalitis (EPM)

Although EPM is not known to be a human pathogen, the disease may have devastating effects on individual horses and the equine industry. Opossums are the definitive host for *Sarcocystis neurona*, the protozoan that causes EPM. An intermediate host (probably birds) ingests the protozoa in the form of a sporocyst. The protozoan encysts in the intermediate host's tissues; an opossum in turn acquires the infection by eating the infected tissue. The opossum does not become sick, but develops infective sporocysts in its gut which are shed in its feces. Horses probably ingest the sporocysts inadvertently while eating grass, hay, or grain contaminated with infected opossum feces. Protozoa aberrantly migrate into the nervous system of the horse where they cause mild to severe neurologic disease, characterized by lameness, hind limb weakness, and death.

Murine Typhus (Fleaborne typhus, Endemic typhus fever, Shop typhus)

Classic murine typhus occurs worldwide, most often as a rat-flea-rat cycle where humans represent an abnormal or "dead end" host. In suburban areas of the United States, especially southern California and southcentral Texas, the ecology of the disease has shifted to a peridomestic animal cycle involving opossums, cats, and their fleas. Seropositive opossums and

cats have been found during human case-patient investigations in Los Angeles. Infected opossums do not appear ill. The cat flea (*Ctenocephalides felis*) was the most prevalent flea species (97%) found in these investigations and opossums showed the heaviest infestations (105 fleas per animal in one study). Opossums and their fleas are important reservoirs of these human pathogens in suburban environments. Humans are at risk of bites by infective fleas which infest their pets or opossums living around human dwellings.

Rabies

Opossums are susceptible to skunk and bat strains of rabies, but represent less than 1% of animal rabies cases in California. A rabid opossum will generally exhibit unusual behavior such as daytime activity, aggression, weakness, and neurologic signs (circling, seizures, etc.). Infected opossums may shed rabies virus in their saliva and transmit the virus to humans or their pets or livestock by a bite or scratch. Potential exposure to a rabid opossum requires immediate medical attention. Dogs or cats that are bitten or scratched by an opossum should be placed in quarantine in accordance with local and state regulations. If available, the biting opossum should be tested for rabies at a public health laboratory.

Visceral and Ocular Larval Migrans

Carnivores (dogs, raccoons) are the primary carriers of roundworms that cause larval migrans in humans. *Baylisascaris* spp. and other roundworms have occassionally been documented in opossums as well.

MANAGEMENT AND CONTROL

Opossums are abundant in California and easily adapt to the peridomestic environment. For these reasons, they may become nuisance animals or even transmit illnesses to humans directly or via their ectoparasites. However, opossums play an important role in the ecosystem by providing food for natural predators and eating "pest species" such as insects and snails.

To avoid problems with opossums, the following precautions should be conveyed to the public:

- Never handle (pet, pick-up) opossums.
- Never keep opossums as pets; do not try to care for an injured or sick opossum, but call animal control for assistance. Seek medical attention immediately if bitten or scratched by an opossum.
- Keep pets away from opossums.
- Eliminate or reduce enticements (food sources, den materials) for opossums to approach or enter human dwellings. These measures include:

  - Keep feed stores on farms and stables tightly covered. Use processed grains (steam crimped, pelleted) to kill EPM parasites.
  - Keep pet food and water inside at night. Opossums are particularly attracted to dog and cat food.
  - Tightly cover grain containers, compost piles, and garbage.
  - Remove rock piles, woodpiles, brush piles, stacked lumber, and similar sources of shelter.
  - Block openings into houses and other buildings using sturdy wire mesh (¼-inch hardware cloth) to screen the openings.
  - If an opossum is living under a building, make a one-way door to allow the animal to leave but not reenter. Attach a section of ½-inch hardware cloth to the opening which is hinged at the top and left loose on the other three sides. It should be larger than the opening so it cannot swing inward. Once the opossum vacates, seal the entrance with wire mesh or similar material.
  - Opossums can climb, but not dig; mesh wire or chain link fencing and hot wire around backyards or stable areas may help keep them out.
  - Local animal control agencies should be consulted for assistance in trapping and removing problem opossums. Local ordinances may restrict the trapping and relocation of opossums.
  - No poisons are approved for opossum control. Poisons can also injure children, pets, and other non-target species in the area.

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Chapter 4

BATS
(Class Mammalia, Order Chiroptera)

Richard M. Davis

INTRODUCTION

Bats, like humans and other mammals, are warm-blooded, have fur or hair, give birth to live young, and feed their newborn milk from mammary glands. Bats are the only mammals that can fly, and their wings make any of the approximate 925 living species in the world instantly recognizable. However, the many variations in the basic structure of their anatomy and social lives reflects a greater degree of specialization than any other order of mammals.

GENERAL CHARACTERISTICS

Taxonomy

Class Mammalia
  Order Chiroptera
    Suborder Megachiroptera (Megabats)
      1 family - 166 species
    Suborder Microchiroptera (Microbats)
      16 families - 759 species (3 families - 23 species in California)

Bats comprise the order of mammals called Chiroptera, a name derived from Greek meaning "hand wing." Bats are subdivided into two major groups or suborders, the Megachiroptera (megabats) and the Microchiroptera (microbats). Megabats do not rely on echolocation, have large bodies and eyes, eat primarily fruit, and are limited in their distribution to the Old World tropics. In contrast, microbats rely on echolocation for foraging and maneuvering, have small bodies and eyes, eat primarily insects, and are widely distributed throughout the world.

Forty-two species of bats are found in the United States, all microbats. In California, there are 23 species within 3 families - the Phyllostomidae (leaf-nosed bats; 2 species), the Vespertillionidae (plain-nosed, vespertillionid, or little brown bats; 17 species), and the Molossidae (free-tailed bats; 4 species).

Anatomy

Bats are the only mammals that fly, consequently many of their unique features relate to flight (Figure 4-1). The wing is formed from skin stretched between the arm, wrist, and finger bones. Although the skin on the wings is very thin and appears delicate, it is fairly resistant to tears or punctures. Wing membranes usually attach along the sides of the body and to the hind legs. The tail membrane (uropatagium) is attached between the hind legs and encloses the tail (if present). The tail membrane also aids in flying. The size and shape of the tail membrane, and whether it completely encloses the tail, varies considerably among and within families (Figure 4-2).

The hind limbs of bats are small relative to the wings and oriented 180 degrees relative to other mammals, such that the knees point backwards. This feature aids in flight as well as in the characteristic head-down roosting posture. A special locking tendon allows bats to cling to surfaces without expending energy.

The head and facial features of bats exhibit a great deal of diversity, reflecting different foraging styles and feeding preferences. The fleshy nose leafs and facial ornamentations function in the transmission of echolocation waves. The importance of hearing in echolocation is also reflected in the tremendous variety in size and shape of the ears (Figure 4-2).

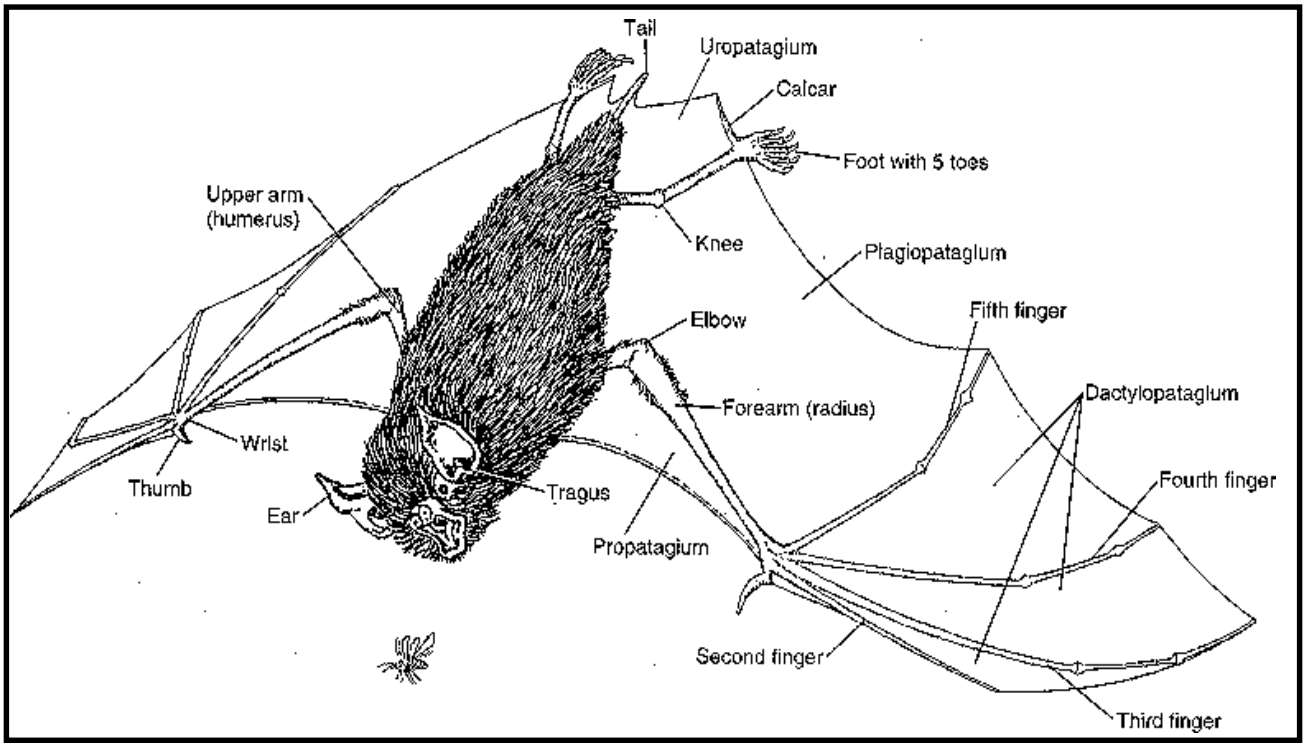


Figure 4-1. Major external features of bats. Note the upper arm (humerus), elongated forearm (radius), and fingers that form the wing. (From Feldhamer et al. 1999).

"Blind as a bat" is a misnomer; bats have perfectly functional vision. Eyes are large in megabats, which generally do not echolocate, but relatively small in microbats whose visual acuity is secondary to echolocation.

Bats exhibit a great range of body sizes, from the tiny hog-nosed or bumble bee bat of Thailand (~2 g) to the fruit-eating flying foxes (1,600 g) which have a wingspan of 2 m. However, most bats are relatively small, weighing 10-100 g. The western pipistrelle is the smallest bat in California and one of the smallest mammals at 2-6 g. The largest bat in California, the western mastiff bat, weighs 45-73 g (1.5-2.5 oz) and has a wingspan of 53-57 cm (21-23 in).

Roosting Behavior

Bats are active and feed at night. During the day, bats roost in dark, sheltered places such as caves, mine tunnels, rock crevices, hollow trees, under loose tree bark, in trees and understory vegetation, in buildings, under bridges, and in other protected places. Some species roost alone, while others form colonies that vary from a few to millions of individuals. Roosts can be subdivided into day and night roosts, hibernation roosts, summer roosts, nursery roosts, feeding roosts, and transient or resting roosts. The roosting habits of bats are adaptations that reflect the inter-relationships of social structure, diet, flight behavior, predation risks, and reproduction of each species.

Feeding Habits

Flight has allowed bats to occupy many feeding niches. Most species of bats eat insects, often taking insects in flight, but occasionally from plants or from the ground. Some species are carnivorous, taking small vertebrates such as frogs, lizards, mice, other bats, and fish. Many species, especially in the tropics, feed on fruit and the pollen and nectar from flowers. Vampire bats feed only on blood. All bats in California are insectivorous with the exception of the Mexican long-tongued bat which feeds primarily on fruit, pollen, and nectar.

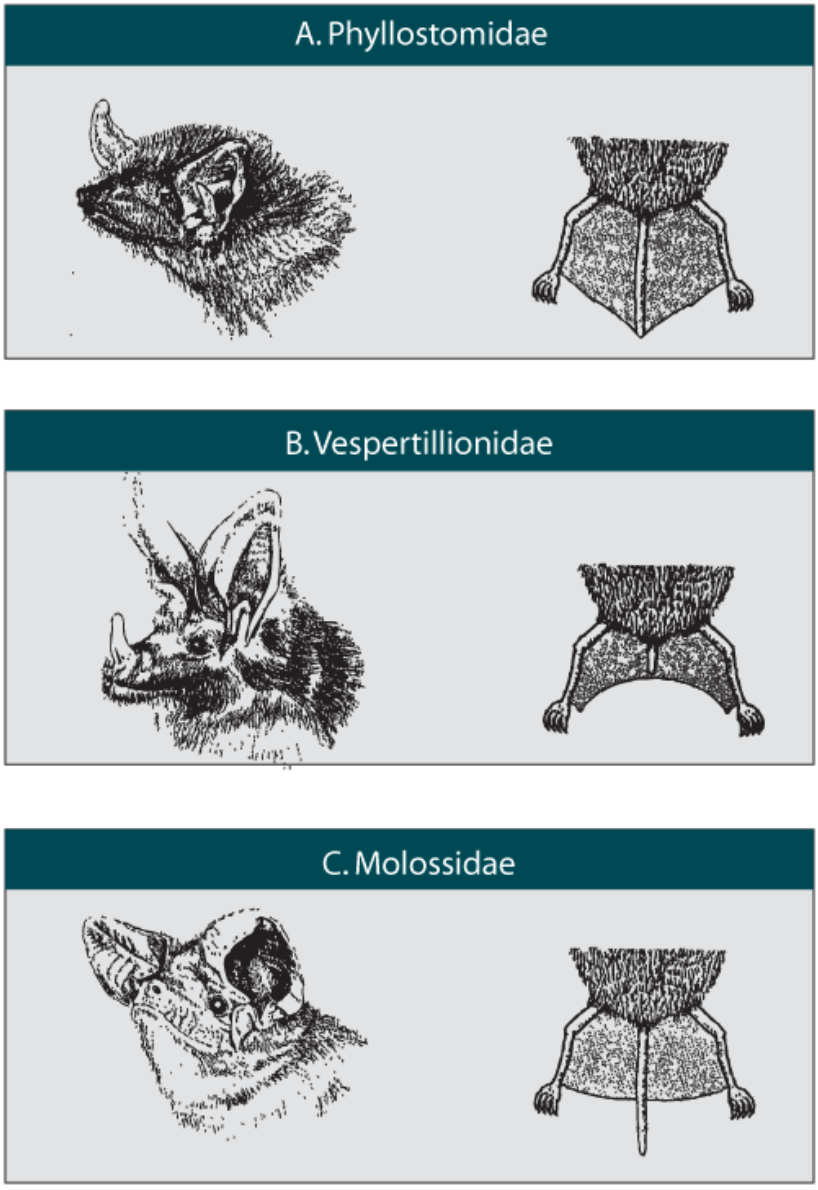
Navigation (Echolocation and Feeding Behavior)

In order to find prey items and to maneuver within their environment, most bats echolocate. Bats emit high-frequency sound impulses and discern information about objects in their path from rebounding echoes. Many of the structural characteristics of bats, including their varying shapes and sizes of ears and their occasionally bizarre facial features, relate to echolocation. Many aspects of echolocation are specific to each species and relate to foraging for food.

Key to the Families of Bats in California

1. Tail entirely or almost entirely contained within the tail membrane; if tail tip projects beyond margin of tail membrane, face has a leaf-like nose appendage 2
   Tail projecting conspicuously beyond margin of tail membrane; face without a leaf-like nose appendage ..... Molossidae

2. Face with a flat leaf-like nose appendage ..... Phyllostomidae
   Face without a leaf-like nose appendage ..... Vespertillionidae



Variations in face, tail, and uropatagium (tail membrane) of California bats. **A** represents a California leaf-nosed bat (Phyllostomidae); **B** a plain-nosed myotis (Vespertillionidae); and **C** a Mexican free-tailed bat (Mollosidae). (From Feldhamer et al. 1999; Tuttle 1988).

Figure 4-2

Hibernation and Migration
Because most bats in California eat only insects, they are active primarily during the warmer months when insect populations are more abundant and active. In the winter, bats either migrate south to a warmer climate, as many birds do, or hibernate in a protected location. The migration patterns and the seasonal distribution of many bats are unknown. In California, some migration patterns may be limited to changes of elevation.

Reproduction, Litter Size, and Longevity
Some bat species breed in the spring while others breed in the fall and delay fertilization until spring. In either case, birth coincides with the emergence of insects in the spring.

While many small mammals have several large litters each breeding season, most bats produce only a single litter per year, with typically only one, or less frequently two, young per litter. Therefore, bat populations may be very slow to recover following injury.

Bats have much longer life spans than is typical for small mammals, sometimes exceeding 30 years. Prolonged life spans may be a function of reduced metabolic rates on the bases of daily torpor, seasonal hibernation, or both.

Distribution
Because of their ability to fly, bats are the most widely distributed group of terrestrial mammals. Representatives inhabit every continent except Antarctica. While as many as 90% of species reside in tropical regions, bats are also abundant in temperate regions during the summer. Bats also utilize a wide variety of ecosystems. In the US they are abundant in both forests and deserts, and range from sea level to 15,000 feet elevation.

Twelve of the 23 species in California are found throughout California, with the exception of the southeastern deserts and the San Joaquin Valley. Seven species inhabit principally southern California, especially the southeastern desert regions. The remaining four species have limited or disjunct distributions which do not fit the other two basic patterns.

Ecological and Economic Value
Bats play an important beneficial role as the major consumers of night-flying insects, as pollinators of plants, and in the dispersal of seeds of fruits. Bats consume staggering quantities of insects every night. Mosquitoes comprise a high percentage of some bats' diets; individuals may consume as many as 1,000 mosquitoes per hour. Bats serve as pollinators and seed dispersal agents for hundreds, and probably thousands, of species of plants. A few of the better known economically valuable crop plants which rely on bats for survival are bananas, avocados, dates, figs, mangoes, cashews, and agave (tequila). Bats often account for as much as 95% of tropical forest regrowth by dispersal of seeds from consumed fruit.

Despite benefit to human communities, and their ability to adapt to various environments, bat populations are often negatively affected by environmental disturbances. Loss of cave and riparian habitats, exposure to pesticides, and human exploitation, coupled with bats' normally low reproductive potential, have left many species throughout the world in danger of extinction. Carlsbad Caverns in New Mexico once had 7 to 8 million bats in 1936, but since 1973 houses fewer than 200,000. Wanton destruction by humans devastated bat populations at Eagle Creek Cave, Arizona, which declined from 30 million bats in 1963 to less than 30,000 only six years later. The propensity of bats to congregate in huge numbers leaves them vulnerable to human disturbance. Superstition and ignorance regarding their ecologic role have contributed to the disturbance and destruction of an inestimable number of bats. Even innocent exploration of caves at the wrong time of the year can dramatically disturb hibernating bats, forcing them to use up valuable energy necessary to make it through the winter.

CALIFORNIA BATS OF PUBLIC HEALTH IMPORTANCE

FAMILY PHYLLOSTOMIDAE: LEAF-NOSED BATS

A diverse group of bats, mostly in Central and South America. Distinguished by a "nose leaf" on the tip of the snout. Some eat fruit, while others specialize on nectar, pollen, or insects. Only two species occur in California, both in the extreme southern part.

California leaf-nosed bat
(*Macrotus californicus*)

Description: Snout with simple leaf-like appendage at tip. Ears very large. Tail extends slightly beyond tail membrane.
Distribution: Extreme arid southern regions of the state. Roosts in buildings and mines.
Food: Mostly large and heavy bodied insects, such as noctuid moths, and scarabiid and carabid beetles.
Reproduction: A very unusual pattern of fertilization and development rate, differing from all other North American bats. Both mating and fertilization occur in the autumn. Embryonic development is slow for the first five months, and then accelerates in the spring, with birth following mating eight months later.
Protected Status: California Species of Special Concern.

Mexican long-tongued bat
(*Choeronycteris mexicana*)

Description: A leaf-nosed bat with a very long snout. Tail reaching less than half way to margin of tail membrane.
Distribution: Extreme southern California; San Diego County only. Roosts in the darkest regions of caves and mines.
Food: The extremely long snout and tongue are adapted for feeding on pollen and nectar of night-blooming flowers. Several species of cacti would not reproduce without pollination by these bats.
Reproduction: A single offspring is born in the spring. Until the infant is rather large, it is carried by the mother while foraging.
Protected Status: California Species of Special Concern.

FAMILY VESPERTILLIONIDAE: PLAIN-NOSED, VESPERTILLIONID, OR LITTLE BROWN BATS

The snout is always plain and simple. The tail extends to, and never beyond, the margin of the tail membrane. Many indistinct and difficult to distinguish, especially the myotis. All 17 species in California are insectivorous.

Little brown myotis (*Myotis lucifigus*)
Yuma myotis (*Myotis yumanensis*)
Cave myotis (*Myotis velifer*)
Long-eared myotis (*Myotis evotis*)
Fringed myotis (*Myotis thysanoides*)
Long-legged myotis (*Myotis volans*)
California myotis (*Myotis californicus*)
Western small-footed myotis (*Myotis ciliolabrum*)

Description: Some species vary by ear size and forearm length, but all myotis species are difficult to differentiate by physical characteristics.
Distribution: Distributed throughout most of California. A few species occur in the southeast desert region only, while some others are absent only from the southeast and central valley. Roost in a variety of places, and generally colonial or found in small groups.
Food: Diet depends upon availability, but feeds mostly on small flying insects, especially aquatic insects. A voracious appetite: known to eat half their body weight each night.
Reproduction: Mates in the fall; ovulation and fertilization in the spring (fall-spring pattern); a single young born, generally in nursery colonies.
Protected Status: None, except the subspecies, *M. lucifigus occultus*, which occurs only along the Colorado River in the southeast, and *M. velifer*, which occurs in the desert southeast. Both are California Species of Special Concern.

Silver-haired bat (*Lasionycteris noctivagans*)

Description: Dorsal fur dark brown or black conspicuously white-tipped, giving a frosted appearance; ears short and broad; tail membrane well-furred on basal half.
Distribution: Common in forested areas of northern half of California. Primarily tree-dwelling.
Food: Flying insects; fond of moths.
Reproduction: Fall-spring pattern; two young per litter is normal
Protected Status: None.

Western pipistrelle (*Pipistrellus hesperus*)

Description: Very small with light-colored fur and very dark face, ears, and membranes.
Distribution: Occurs throughout most of California, especially in open arid areas at lower elevations. Roosts singly, primarily in rock crevices, and occasionally mines and caves.
Food: Forages early in the evening; small flying insects (moths, beetles, and flies) taken close to the ground.
Reproduction: Fall-spring pattern; usually two young per litter.
Protected Status: None.

Big brown bat (*Eptesicus fuscus*)

Description: Larger than the myotis; ears and membranes are nude and dark-colored.
Distribution: Widespread and abundant throughout California. Roosts frequently in buildings and caves; colonial.
Food: A large variety of insects, especially early flying beetles and flies.
Reproduction: Fall-spring pattern; a single young.
Protected Status: None, but known to be very susceptible to pesticides.

Western red bat (*Lasiurus borealis*)

Description: Dorsal color is brick to rusty red with tips white; underparts slightly paler; tail membrane well-furred on basal half. Previously known as *Lasiurus blossevilii*.
Distribution: More common in the central foothills and coastal regions of California; not found east of the Sierra Nevada range or in the desert areas. Roosts singly, primarily in trees, and less often in shrubs.
Food: Feeds on primarily moths and beetles, but occasionally crickets and cicadas.
Reproduction: Fall-spring pattern; normal litter size is 2-4 young.
Protected Status: None.

Hoary bat (*Lasiurus cinereus*)

Description: Large; dorsal fur a dull chocolate brown with white tips, giving it a frosted or hoary appearance; tail membrane heavily furred.
Distribution: Generally distributed throughout the wooded areas of California; absent from the southeastern deserts. Roosts singly in dense foliage of medium to large trees.
Food: Feeds primarily on moths and beetles.
Reproduction: Fall-spring pattern; generally two young per litter.
Protected Status: None.

Southern yellow bat (*Lasiurus ega*)

Description: Medium-sized; dorsal fur a light yellow; tail membrane well-furred on basal half. Previously known as *Lasiurus xanthinus.*
Distribution: Limited to palm oases and riparian areas of the southeast Sonoran desert.
Food: Feeds on flying insects. Roosts in trees, especially palms.
Reproduction: Fall-spring pattern; normally 2-3 young.
Protected Status: None.

Spotted bat (*Euderma maculatum*)

Description: Black with huge ears and three large white spots on the back.
Distribution: Rare; from both montane, open coniferous forests and deserts of southern California only. Believed to roost in caves and rock crevices.
Food: Feeds primarily on moths.
Reproduction: Probably fall-spring pattern; a single young.
Protected Status: California Species of Special Concern.

Townsend's big-eared bat (*Corynorhinus townsendii*)

Description: Medium-sized, light brown, with very long ears joined at the top of the head; belly brown. Previously known as *Plecotus townsendii*.
Distribution: Found throughout California, especially in more arid areas; once common, now considered rare. Roosts primarily in caves and mines, and sometimes buildings.
Food: Prefers small moths.
Reproduction: Fall-spring pattern; single young born in nursery colonies.
Protected Status: Two subspecies, *C. t. townsendii* found in northwest California and *C. t. pallescens* found in southern California, are California Species of Special Concern.

Pallid bat (*Antrozous pallidus*)

Description: Medium-sized, buff or sandy-colored fur; ears very long and clearly separated at the base.
Distribution: Found in most of California, especially in open, lowland areas, generally below 6,000 feet. Roosts in small colonies in caves, crevices, mines, and occasionally hollow trees, buildings, and under bridges.
Food: Feeds primarily on large, flightless insects (Jerusalem crickets, June beetles, and scorpions) which it captures by foraging on the ground. Frequently utilizes night roosts, such as porches and open buildings, to consume large prey, under which is often found the uneaten legs and body parts of its prey.
Reproduction: Fall-spring pattern; usually two young per litter.
Protected Status: Although common in some areas, it is a California Species of Special Concern.

Family Molossidae: Free-tailed bats

This family is primarily tropical, but four species occur in California. They all have short, dense, dark-chocolate fur, and a tail that extends beyond the margin of the tail membrane, hence the name "free-tailed."

Brazilian or Mexican free-tailed bat (*Tadarida brasiliensis*)

Description: Small, chocolate brown, and with ears extending to the tip of the snout.
Distribution: The most common free-tailed bat in California. Found throughout the state to 1500 m. Roosts in caves, mines, under bridges, crevices, and buildings, often in large colonies. The largest colony in California is about 100,000 at Lava Beds National Monument. Migratory in most of California.
Food: Eats primarily small moths; forages above 30 m off the ground; and a very fast flyer (25 mph).
Reproduction: Fall-spring pattern; one young born in large maternity colonies.
Protected Status: None.

Pocketed free-tailed bat (*Nyctinomops femorosaccus*)

Description: Medium-sized and dark brown to gray in color. Previously known as *Tadarida femorasacca*.
Distribution: Found only in the southeastern Sonora Desert region of California. Roosts in buildings and rock crevices in high, vertical rock outcrops.
Food: Flying insects, especially moths and beetles.
Reproduction: Fall-spring pattern; a single young.
Protected Status: California Species of Special Concern.

Big free-tailed bat (*Nyctinomops macrotis*)

Description: Fur glossy, reddish brown to black, hairs light at base; large ears, which extend well-beyond the snout. Previously known as *Tadarida macrotis*.
Distribution: An extremely rare vagrant from Arizona and New Mexico found in southern California. Roosts in crevices in areas of high cliffs and rock outcrops.
Food: Primarily flying moths and beetles.
Reproduction: Fall-spring pattern; unknown in California.
Protected Status: California Species of Special Concern.

Western mastiff bat (*Eumops perotis*)

Description: Large; fur short and dull, gray or dark brown, very light at base of hairs; and broad, truncate ears that are joined across the top of the head.
Distribution: Uncommon; occurs in southwestern California, and possibly up the coast to Monterey and western Sierras. Roosts in crevices in areas of high cliffs and rock outcrops.
Food: Believed to be primarily large, high flying insects.
Reproduction: Mating and fertilization usually occur in the spring; one young born at quite variable times from April to November. Both sexes remain together.
Protected Status: California Species of Special Concern.

PUBLIC HEALTH SIGNIFICANCE

Bats are capable of transmitting to humans only two known diseases: rabies and histoplasmosis. The mortality due to these two diseases transmitted by bats is extremely low. In a recent 40-year period in the U.S. and Canada, only 16 people died of bat-borne diseases, 15 from rabies and one from histoplasmosis.

Rabies

Rabies is a viral infection of the central nervous system that, if left untreated, is almost always fatal. Worldwide, more than 50,000 humans die from rabies each year. Ninety-nine percent of these deaths are due to contact with rabid dogs, the most important vector of rabies worldwide. An effective vaccination program for dogs, initiated in the U.S. the early 1950s, has significantly reduced the risk of rabies from dog bites. Between 1969 and 1999 only 12 human deaths due to rabies were reported in California. Of the eight cases resulting from dog bites, all were acquired outside the United States. One case was acquired from a bobcat bite and three were associated with bats.

Bats and the striped skunk have replaced the dog as the primary reservoirs and vectors of rabies in California. An occasional bat may contract rabies, but bats are not aggressive and generally bite only in self-defense when handled. There are no records of house-dwelling bats transmitting rabies through the air, feces, or urine. Humans are rarely attacked or bitten by bats except when handled.

Bats are very susceptible to rabies, but only a few contract the disease. They seldom become aggressive when infected, but rather generally become paralyzed and die within a few days of onset. Widespread outbreaks have never been recorded. The lack of aggressiveness and outbreaks in bats translates to an exceptionally low risk of transmission to humans, especially when compared to skunks and some other mammals. Rabid bats can be found everywhere in California; rabies has been detected in bats from all 58 counties and from below sea level to over 3000 m in the Sierra Nevadas.

Bats found on the ground, active during the day, in a place where bats are not normally seen (for example, in a swimming pool, caught by a cat or dog, etc.), or unable to fly are more likely to be rabid. However, less than 10% of bats tested by public health laboratories are infected, and this sample likely overestimates the infection proportion in the general bat population (estimated to be about 0.2%). Nevertheless, no bat should be handled without a net or gloves.

Persons bitten by a bat, or who experience contact with bat saliva, should wash the affected area thoroughly with soap and water and seek immediate medical attention. Whenever possible, the bat should be captured and sent to the local county public health laboratory for rabies testing. Although most people recognize when they have been bitten by a bat, bite marks from bats' small teeth may not always be evident. Therefore, awakening to find a bat in your room or that of a child is also indication to seek medical attention and have the bat tested.

Histoplasmosis

Histoplasmosis, infection with the fungus *Histoplasma capsulatum*, most commonly manifests as a flu-like respiratory disease. If infection becomes disseminated, symptoms can be severe and occassionally fatal. Histoplasmosis can be contracted by breathing dust stirred up from areas where bat or bird (especially pigeon) droppings accumulate. Buildings, attics, caves, and other enclosed areas where bats congregate can present a particular risk. Persons working in these areas should always use a properly fitted respirator capable of filtering particles as small as two microns in diameter. Histoplasmosis occurs most commonly in the midwestern U.S., and is not believed to exist in California.

Parasites

Like all mammals, bats may harbor ectoparasites such as fleas, ticks, mites, and other parasites, including bat flies and a specific bed bug. In most cases, these parasites are host-specific to bats and usually only a single species. Therefore, they rarely bite people or pets. Extensive research has never shown that any of these parasites transmits disease to humans. However, when long-established colonies of bats are excluded from homes, some ectoparasites may seek out an alternative host upon which to feed, including humans.

Table 4-1. Bats of California

	Distribution	Status
Leaf-nosed Bats (Phyllostomidae)		
California leaf-nosed bat (*Macrotus californicus*)	SE only	SC
Mexican long-tongued bat (*Choeronycteris mexicana*)	San Diego Co. only	SC
Plain-nosed Bats (Vespertillionidae)		
Little brown myotis (*Myotis lucifugus*)	N, SE	
Arizona myotis (*M. l. occultus*)	SE only	SC
Yuma myotis (*Myotis yumanensis*)	nearly all	
Cave myotis (*Myotis velifer*)	SE only	SC
Long-eared myotis (*Myotis evotis*)	all but SE & CV	
Fringed myotis (*Myotis thysanodes*)	all but SE & CV	
Long-legged myotis (*Myotis volans*)	all but SE & CV	
California myotis (*Myotis californicus*)	all	
Western small-footed myotis (*Myotis ciliolabrum*)	all but NW, CV, SE	
Silver-haired bat (*Lasionycteris noctivagans*)	N, GB	
Western pipistrelle (*Pipistrellus hesperus*)	C, S	
Big brown bat (*Eptesicus fuscus*)	all	
Western red bat (*Lasiurus borealis*)	C, SW	
Hoary bat (*Lasiurus cinereus*)	all but SE	
Southern yellow bat (*Lasiurus eqa*)	SE only	
Spotted bat (*Euderma maculatum*)	GB, S	SC
Townsend's big-eared bat (*Corynorhinus townsendii*)	all	
Townsend's western big-eared bat (*C. t. townsendii*)	NW	SC
Pale big-eared bat (*C. t. pallescens*)	S	SC
Pallid bat (*Antrozous pallidus*)	all but NW & high Sierra	SC
Free-tailed Bats (Molossidae)		
Brazilian or Mexican free-tailed bat (*Tadarida brasiliensis*)	all but NW & high Sierra	
Pocketed free-tailed bat (*Nyctinomops femorosaccus*)	SE only	SC
Big free-tailed bat (*Nyctinomops macrotis*)	San Diego Co. only	SC
Western mastiff bat (*Eumops perotis*)	C, SW	SC

Key: Distribution: **N** = north, **NW** = northwest, **S** = south, **SE** = southeast, **SW** = southwest, **C =** central, **CV** = Central Valley, **GB** = Great Basin

Status (Protected): **SC** = California Species of Special Concern

MANAGEMENT AND CONTROL

In the U.S., six bat species are federally listed as Endangered. In California, eight species and three subspecies of bats have experienced declining populations and are designated Species of Special Concern by the Department of Fish and Game (Table 4-1). As such, individuals called upon to address "bat problems" should be well-versed in the special care and restrictions required when working with these species.

Removal

Bats are reclusive by nature and will attempt to avoid human contact, and more likely will seek to escape an encounter. If a bat appears in your house, do not immediately leave, as you will not know whether it escaped or found a temporary hiding place. If it is able to fly, keep the bat in sight while closing off any doors to the rest of the house and opening any doors or windows to the outside. Otherwise, wait until the bat lands and approach it slowly to avoid frightening it back into flight. Then either net it or place a small box or coffee can over it, and slide a piece of cardboard under the container to trap the bat inside. Release the bat outdoors if it is able to fly.

If found roosting in the daytime or during winter months, bats will most likely be torpid (asleep) or hibernating. Torpid bats have a much lower body temperature and metabolic rate, and may not awaken immediately. These bats can be so lethargic as to appear sick or even dead. As they arouse, they may bare their teeth and squeak, leading people to believe they are vicious. In reality, they are responding in defense to a perceived threat during a period of relative helpless-

Figure 4-3. Possible bat entry locations. Arrows point to predictable entry routes of a typical house. Close inspection of suspected entry points usually reveals brown stains from body oils. Mouse-like droppings may occur on the side of the building or on the ground below entry points. (From Tuttle 1988).

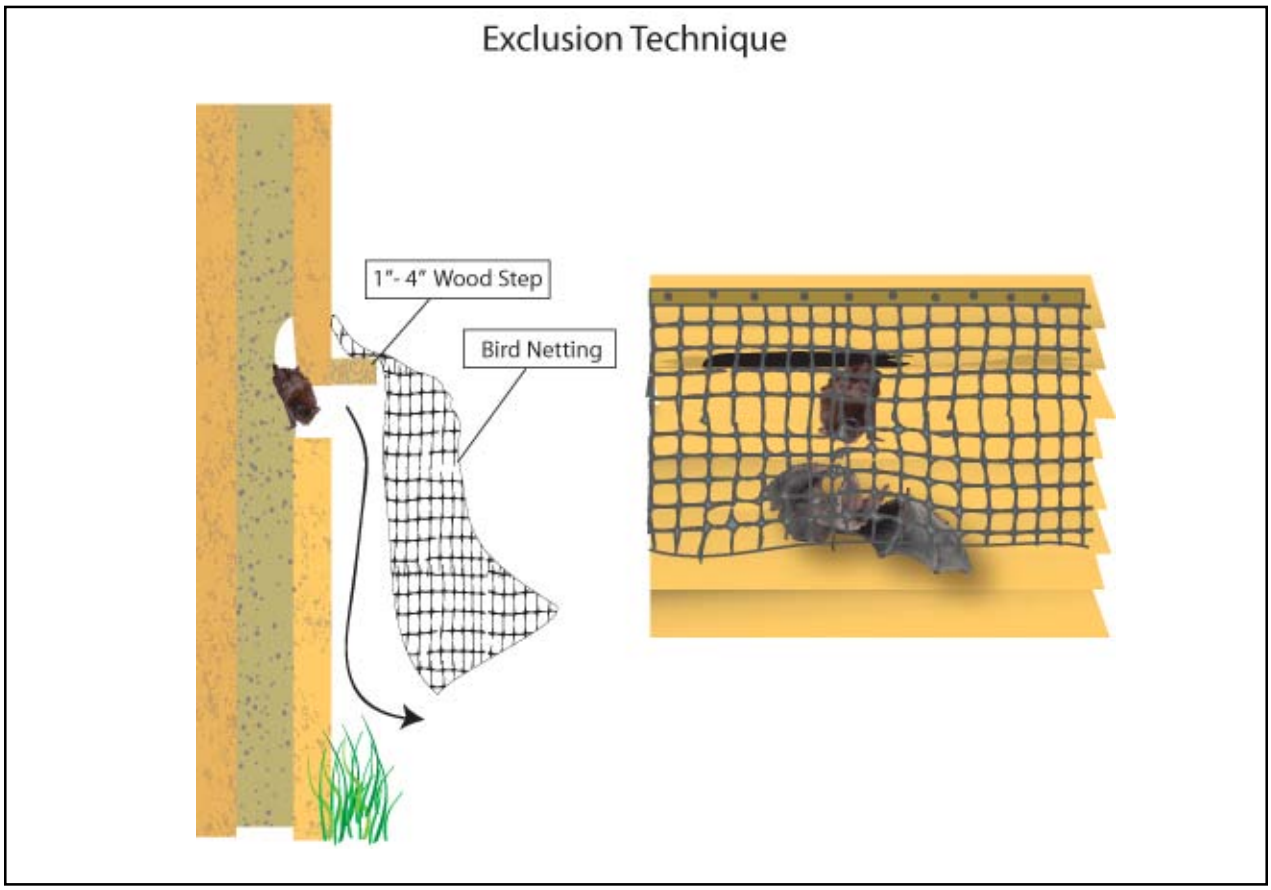


Figure 4-4. Exclusion technique for bats. Bird netting properly suspended over entry locations, allows emerging bats to crawl under and out, but returning bats are unable to find their way back under. (From Tuttle 1988).

ness. As they are more likely to bite during this time, leather gloves are required if it is necessary to handle them.

Exclusion

Bats that suddenly appear in houses or other buildings have usually entered through rather predictable routes (Figure 4-3), the most obvious of which are an open door or window. Other common routes are unguarded chimneys, loose window or door screens, or uncovered air vents. A piece of ¼- or ½-inch mesh hardware cloth over the top of the chimney or air vent or a tighter fitting screen should eliminate most accesses. Any hole or opening more than 1/2 by 1 inch should be closed or sealed, especially those leading to the attic or outer walls. Small holes and cracks can be sealed with silicone caulking, and larger openings with a foam sealant, or even duct tape. Unlike rodents, bats do not chew holes or electrical wiring.

Large numbers of bats living in an attic or wall space can become a nuisance resulting from their odor, noise, or both. Fortunately, most colonies are small, often remaining unnoticed for years. When noise or bat droppings (guano) require a solution, eviction and exclusion are the only acceptable and permanent remedies. A bat colony large enough to become a real nuisance affords enough individuals to easily locate their point of entry and roosting place. In the early evening, when they emerge to feed, watch the building to locate where they exit. Closer inspection during the day should reveal the holes or cracks used for entry and exit. These openings will often be under eaves, behind a chimney, under loose boards, beneath a roof ridge cap, or through a hole made by squirrels or birds. Some openings may be further identified by stains from body oils or droppings, or by an accumulation of droppings below. (Bat droppings are easily crushed into fine fragments; by contrast, mouse droppings are firm and do not readily

disintegrate.) The relative blackness and fresh appearance of the surface droppings will suggest if there is an active colony present. High pitched squeaking, rustling, and odor also give evidence that bats are present. Temporary, night-time roosts may show evidence of uneaten insect remains and droppings. Once exits have been located, then the bats can be excluded. Do not close openings while the bats are still inside. Nor should exclusion be attempted during spring or early summer; flightless young are left behind at night while the parents forage for food and excluding the parents will starve and kill the young.

Exclusion is best conducted in the late fall or winter after most bats have migrated or changed their roosting location. If there is assurance that no young, nonflying bats are present, a simple exclusion technique using 1/2 inch polypropylene bird netting is very effective. This inexpensive netting is normally used to protect fruit trees from birds and can be easily acquired at many hardware or farm supply stores. If netting is unavailable, bat exclusion kits and assistance can be obtained from: Wildlife Control Technology (2501 N. Sunnyside Ave., #103, Fresno, CA 93727; phone (800) 235-0262 or (209) 294-0262). The bird netting can be hung during the daylight hours above areas where the bats emerge, using duct tape or staples. A strip of netting hung one to four inches in front of bat exit holes, and extending at least a foot or two below and to each side of exit points will allow the bats to easily emerge (Figure 4-4). Do not seal off the sides and bottom; this will allow them an easy exit. However, upon return they will be unable to make their way back to the hole, thus forcing them to find another roost site. The netting acts as a simple one-way excluder until repairs can make the exclusion permanent. During cool periods in spring or fall, at least one week should be allowed to pass to insure that all bats have vacated.

Harmless repellents, such as ultrasound devices have never proven effective, despite the seeming sensitivity of bat's acute hearing. Although advocated as a repellent in the past, naphthalene (moth balls, crystals, or flakes) has proven ineffective and potentially toxic to humans. Poisons used against bats may pose serious health hazards to humans and are also ineffective. For this reason, there are no poisons or chemicals licensed for use against bats, and it is a direct violation of federal law to use any chemical or poison in any way other than that for which it is strictly intended. In most cases, the only safe, permanent solution is exclusion.

Aerosol dog and cat repellents may temporarily discourage bats from using a particular spot for roosting. These roosting sites can be sprayed during the day when bats are not present. Aerosol repellents are not an adequate substitute for exclusion and, because they may be toxic to bats in a confined environment, should never be applied when bats are roosting. Suspending aluminum or mylar strips may deter bats from roosting in an undesirable location.

Safety Precautions

- Bats of all sizes will bite in self-defense, but rarely attack people without provocation. By not handling bats, you avoid the risk of being bitten and possibly contracting rabies.
- If you must handle a bat, wear thick gloves, wrap the bat in a heavy towel, or capture and retain the bat in a net or other container.
- If you are bitten or handle a sick or dead bat with your bare hands, wash your hands thoroughly with soap and water and see a physician immediately. Do not discard the bat. It should be retained for possible rabies testing.
- It is illegal and dangerous to keep bats as pets.
- Wear a respirator while working in a confined area that contains bat droppings.
- Persons who have frequent contact with bats or other potentially rabid animals should consider receiving pre-exposure rabies vaccination. Vaccinated persons should have their titer checked every two years.
- Poisons and chemicals are illegal and ineffective against bats, and potentially hazardous to humans. The only safe, permanent solution is exclusion.

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Chapter 5

CARNIVORES
(Class Mammalia, Order Carnivora)

Todd W. Walker

INTRODUCTION

The first mammals arose approximately 200 million years ago in the Triassic Period. These mammals were small and shrew-like. The first carnivores did not evolve until approximately 65 million years ago in the early Paleocene Epoch of the Tertiary Period. Today, most of the major terrestrial predators are carnivores. This Order includes carnivores which have become domesticated such as dogs and cats. Our fascination with these mammals probably stems from fright, fascination, and even hatred because they are at times in direct competition with humans for resources. The sheer power and presence of a large carnivore can be awe-inspiring.

GENERAL CHARACTERISTICS

Taxonomy

Eleven families and approximately 271 species of carnivores are currently identified. In California, there are approximately 23 species, including feral dogs and cats.

Anatomy

Carnivores are quite diverse in size and appearance. Terrestrial carnivores range from the least weasel, at 35 g (1.3 oz), to the grizzly and polar bears weighing as much as 800 kg (1760 lb). Common to all North American carnivores are three pairs of small incisor teeth and one pair of large strong canine teeth on the upper and lower jaw (Figure 5-1). These canine teeth are the most characteristic feature of the Order.

Figure 1

Reproduction

Most species produce one litter per year. Young are born blind and dependent on parental care for an extended period of time. Carnivores do not truly hibernate but will "winter sleep" or remain in their dens during periods of exceptionally cold weather.

Food

"Carnivore" means "flesh-eating", but this label is overly restrictive in that the diets of many carnivores also contain large amounts of fruits, berries, roots, and vegetation. Bears, for example, subsist almost exclusively on plant material. Some carnivores require freshly killed prey; others will scavenge and eat carrion. Some are solitary hunters while others hunt in groups or packs.

Habitat/Distribution

Carnivores inhabit all continents except Australia and have adapted to a variety of terrestrial and aquatic habitats. The distributions of individual carnivore species naturally follow the distribution and density of their preferred prey. Carnivore populations and distribution are molded by natural selection to maximize nutritional intake within a range of ecological parameters. The task of finding and gathering food under these parameters affects a species' density, distribution, and social behavior. Human activity and encroachment into previously undeveloped areas, especially within the last hundred years, has greatly disrupted the carrying capacity of these habitats for numerous species and, consequently, for the carnivores which prey upon them.

CALIFORNIA CARNIVORES OF PUBLIC HEALTH IMPORTANCE

The following California carnivore species have been selected for description because of their potential for being a nuisance pest, causing physical harm, serving as a source of disease transmission, or having a protected species status.

FAMILY CANIDAE: DOGS, COYOTES, FOXES, AND WOLVES

Coyote (*Canis latrans*)

Description: Coyotes are grizzled gray or reddish gray with a buff color on their underside. They have rust or yellowish legs with a dark vertical line on lower forelegs; their tails are bushy with a black tip. They weigh 9-18 kg (20-40 lb) with a total length of 105-130 cm (41-52 in). Tail length is 30-40 cm (12 -16 in).
Distribution/habitat: Coyotes are found in eastern Alaska, northwestern Canada, all of the western United States east to Louisiana, Tennessee, Ohio, and northern New York. Coyotes are very adaptive predators that are tolerant of human activities. They can rapidly adjust to changes in the environment. In the West, they inhabit mostly open plains.
Food: Coyotes are opportunists that will eat insects, birds, reptiles, amphibians, fruit, and eggs, but their primary diet is mice, rats, ground squirrels, and carrion.
Reproduction: Pairs tend to remain together for life. They have one litter per year, with an average of 5-6 offspring per litter.
Significance: Occasionally prey on domestic pets and livestock. Can serve as reservoir for disease agents infectious to humans and domestic dogs. Important sentinel species in plague surveillance programs.
Protected Status: Non-game species.

Red Fox (*Vulpes vulpes*)

Description: Red foxes are small, dog-like canines that are rust-red in color with white underneath the chin and throat. Coat can be reddish-brown, with a dark cross on the shoulders, or black with silver-tipped hair. They have black feet. These foxes weigh 3.5-8 kg (8-15 lb). Their height at the shoulders is about 40 cm (16 in). Their total length is 89-102 cm (35-40 in) with the tail 35-43 cm (14-17 in).
Distribution/habitat: Red foxes are found in most of Canada and the United States except for southwest California, northern Nevada, and Arizona. *Vulpes vulpes necator* are found in the Cascades, Siskiyou Co., and from Lassen Co. to Tulare Co. Preferred habitat includes mixed cultivated and wooded areas.
Food: They are opportunists that feed on insects, earthworms, fruit, carrion, mice, ground squirrels, gophers, birds, woodrats, and marmots.
Significance: Occasionally preys on domestic pets and livestock, particularly fowl. Can serve as reservoir for disease agents infectious to humans and domestic dogs.
Protected Status: California Subspecies (*V. v . necator*): California Threatened. Introduced Populations: Fur-bearing species.

Kit Fox *(Vulpes macrotis)*

Description: Kit foxes are smaller and faster than red foxes. Their color is buff-yellowish above and white underneath. The tail is black or it is the color of the body with a black tip. Feet are light in color. Kit foxes weigh approximately 1.5-3 kg (3-6 lb). Their total length is 60-80 cm (24-32 in). The tail length is 23-30 cm (9-12 in). The height at the shoulders is about 30 cm (12 in).
Distribution/habitat: Kit foxes inhabit the arid regions of the southern half of California. Kit foxes inhabit open level areas where there is little human disturbance. Preferred habitat is a loose-textured soil with scattered shrubby vegetation.
Food: The principal foods of kit foxes are black-tailed hares and desert cottontails, rodents, insects, reptiles, small birds, and eggs.
Reproduction: Kit foxes have one litter per year with an average of 4 offspring per litter.
Significance: Rarely presents a nuisance or disease threat.
Protected Status: San Joaquin Kit Fox (*V. m. macrotis*): Federal Endangered and California Threatened.

Gray Fox *(Urocyon cinereoargenteus)*

Description: Gray foxes are grizzled gray above, reddish underneath, and reddish in color on the back of the head. The throat is white. The tail is black on the top and black at the tip. The feet are rust-colored. The total length is 80-112 cm (32-44 in). Tail length is 23-43 cm (9-17 in). Height at the shoulders is 36-38 cm (14-15 in). Gray foxes weigh 3-6 kg (7-13 lb).
Distribution/habitat: Gray foxes inhabit the eastern United States to eastern North and South Dakota, Nebraska, Kansas, Oklahoma, most of Texas, New Mexico, Arizona, California, northern Colorado, southern Utah, southern Nevada, and western Oregon. They inhabit shrublands, brushy and open-canopied forests that are interspersed with creeks, streams, rivers, ponds, or lakes.
Food: Gray foxes are opportunists that feed on fruits, cottontail rabbits, mice, voles, and insects.
Reproduction: Gray foxes have one litter a year with an average of 4 offspring per litter.
Significance: Occasionally preys on domestic pets and livestock. Can serve as reservoir for disease agents infectious to humans and domestic dogs.
Protected Status: Fur-bearing species.

Island Fox (*Urocyon littoralis*)

Description: Island foxes are one-half to two-thirds the size of their cousin the gray fox. The island fox's color closely resembles that of the gray fox. The total length of island foxes is approximately 38-60 cm (15-24 in). The tail ranges from 10-28 cm (4-11 in). Island foxes weigh 2-3 kg (4-6 lb).
Distribution/habitat: They are found on Santa Cruz, Santa Rosa, San Clemente, San Nicolas, San Miguel, and Santa Catalina islands. Island foxes inhabit rocky places and also areas with dense brush.
Food: Island foxes are opportunists that feed on small mammals, fruits, berries, insects, birds, and eggs.
Reproduction: They have one litter per year. Generally two offspring are raised to maturity each year.
Significance: Beneficial predator of *Peromyscus* mice on the Channel Islands.
Protected Status: California Threatened.

Feral domestic dog (*Canis familiaris*)

Description: Feral dogs represent domestic dogs which dissociated from a commensal relationship with humans one or more generations previous. They are more independent of and more aggressive toward humans than stray or abandoned dogs.
Distribution: May be found anywhere that domestic dogs are abandoned and uncontrolled.
Food: Unlike stray dogs which usually scavenge on garbage, feral dogs typically prey on small to medium-sized wild or domestic animals.
Reproduction: Feral dogs often form well-organized packs that communally rear litters of pups. Because of uncontrolled inter-breeding, feral dogs tend to resemble a hybridized mongrel breed of domestic dog.
Significance: Aggressive disposition and accustomation to humans poses an increased risk of injury and disease transmission to humans and domestic animals compared to wild canids. Feral dogs may serve as a reservoir for disease agents infectious to domestic dogs in areas of human habitation.
Protected Status: None

FAMILY URSIDAE: BEARS

Black Bear (*Ursus americanus*)

Description: In the West, the black bear's color ranges from black to cinnamon with a white patch on the chest. Total length ranges from 1.2-1.8 m (5-6 ft). Tail is 7-18 cm (3-7 in). Height at the shoulders is about 1 m (3 ft). Black bears weigh from 90-270 kg (200-600 lb).
Distribution/habitat: Black bears inhabit most of Canada, Alaska, Washington, and Oregon; parts of California, Rocky Mountain states to Mexico; northern Minnesota, Wisconsin, and Michigan; in New England, New York, Pennsylvania south through the Appalachians; in the South, most of Florida, parts of Arkansas, and southern Louisiana. In the West, black bears inhabit forests and wooded mountains below 2100 m (7000 ft) elevation. In the East, these bears inhabit forest and swamps.
Food: Black bears are opportunists that feed on roots, fruits, nuts, insects, fish, rodents, and carrion.
Reproduction: Black bears have one of the lowest reproductive rates of the large land mammals in North America. Females give birth to young about every two years. Usually twins or triplets are born.
Significance: May become a nuisance or destroy property when they enter human habitations in quest of food. Infrequently present risk of physical injury. Important sentinel species in plague surveillance programs, particularly in montane forest habitat.
Protected Status: Game species.

FAMILY PROCYONIDAE: RINGTAILS AND RACCOONS

Ringtail (*Bassariscus astutus*)

Description: Ringtails have a catlike body with a fox-like face. They are yellowish-gray in color above and whitish-buff underneath. Their tail is bushy, very long, and black and white banded. Ringtails weigh about 1 kg (2 lb). Their total length is 60-80 cm (24-32 in). Tail length is 30-43 cm (12-17 in).
Distribution/habitat: Ringtails are found in southwestern Oregon, California, and southern Nevada. Ringtails inhabit forests and shrublands in close association to rocky areas or areas adjacent to bodies of water. They are primarily active at night (nocturnal).
Food: Ringtails primarily feed on woodrats, mice, and rabbits; they also feed on birds, eggs, insects, fruit, nuts, and some carrion.
Reproduction: Ringtails have one litter per year with an average 3 offspring per litter.
Significance: Minimal public health importance.
Protected Status: California Fully Protected: May not be taken under any circumstances.

Raccoon (*Procyon lotor*)

Description: Raccoons are reddish-brown and black above and gray underneath. They have a bushy tail with alternating bands of black and brown or brownish gray. Their most distinguishing characteristic is the black mask or band across the eyes. Their body length is 60-94 cm (24-37 in). The tail is 20-40 cm (8-16 in). Raccoons weigh 5.5-22 kg (12-48 lb).
Distribution/habitat: Raccoons are found throughout the United States except portions of the Rocky Mountain states, central Nevada, and Utah; they are also found in the southern portions of the Canadian provinces bordering the United States. Raccoons inhabit wetlands and the areas along bodies of water in forestlands and shrublands. They are most common along wooded streams. They are nocturnal.
Food: Raccoons are opportunists that feed on crayfish, fish, insects, amphibians, small mammals, birds, and eggs in the spring. During the summer and fall, they feed primarily on fruits, nuts, acorns, and grains.
Reproduction: Offspring are born between March and May with an average of 3-4 young per litter.
Significance: Large peridomestic populations may present a nuisance and destroy property. Occasionally may cause injury (bite, scratch) to humans and domestic pets. Present risk of infectious disease transmission, including rabies and *Baylisascaris*.
Protected Status: Fur-bearing species.

FAMILY MEPHITIDAE: SKUNKS

Striped Skunk (*Mephitis mephitis*)

Description: Striped skunks are black with two broad white stripes on their back that meet on top of the head. There is a thin white stripe down the middle center of the face. They have a bushy black tail that is either tipped with or fringed with white. Their total length is 53-81 cm (21-32 in), and their total tail length is 18-41 cm (7-16 in). Striped skunks weigh 2.5-6.5 kg (6-14 lb).
Distribution/habitat: Striped skunks are distributed throughout the United States and southern Canada. They are found throughout most of California except parts of the Mojave and the Colorado deserts. These skunks inhabit deserts, woodlands, grassy plains, and suburbs. Striped skunks are nocturnal.
Food: The striped skunk's diet is primarily insects, small mammals, birds, eggs, amphibians, reptiles, fruits, and some carrion.
Reproduction: They have one litter per year with an average of 4 offspring per litter. Young are usually born from April through June.
Significance: An important reservoir for rabies in California. Occasionally damage property and prey on laying fowl and their eggs. Defensive spraying can be transiently irritating to humans and domestic pets. Predation on rodents may locally decrease the risk to humans of some infectious diseases carried by rodents.
Protected Status: Non-game species.

Western Spotted Skunk (*Spilogale gracilis*)

Description: Spotted skunks are smaller than other skunks. They are black with horizontal white stripes on the neck and shoulders, and irregular vertical white stripes and elongated spots on their sides. The tail has white spots on the top and a white tip. Spotted skunk's total length is 33-56 cm (13-22 in) in length. The tail is 7.5-23 cm (3-9 in) in length. Spotted skunks weigh about 0.9 kg (2 lb).
Distribution/habitat: Western spotted skunks are found in the western United States except in the high mountains and very dry areas such as the Mojave and Colorado Deserts. These skunks inhabit moderately open shrub and forest habitats that have streams or bodies of water associated with them. They are also found in areas with rocky lava rims and outcrops. Spotted skunks are nocturnal.
Food: Spotted skunks' diet is primarily insects and small mammals; they will also eat fruits, grains, reptiles, birds, eggs, and carrion.
Reproduction: They have one litter per year with an average of 4 offspring per litter. The young are usually born in April or May.
Significance: An important reservoir for rabies in California. Important sentinel species for plague surveillance in lava rim and rocky outcrop habitats. Occasionally damage property and prey on poultry and their eggs. Defensive spraying can be transiently irritating to humans and domestic pets.
Protected Status: Non-game species. Subspecies *S. g. amphiala*: California Species of Special Concern.

FAMILY MUSTELIDAE: WEASELS, MINKS, MARTENS, WOLVERINES, BADGERS, AND OTTERS

Badger (*Taxidea taxus*)

Description: Badgers have a flattened body that is wider than long. Their legs are short and bowed. Feet are dark. They have a shaggy grizzled grey to brown coat. There is a white stripe that runs from the shoulder down the forehead to the tip of the nose. Males are larger than females. The total length is 53-86 cm (21-34 in). The tail is 10-15 cm (4-6 in) long. Badgers weigh from 3.5-11 kg (8-25 lb).

Distribution/habitat: Badgers are found in the western United States east to eastern Texas, Oklahoma, northern Illinois, northern Indiana, and northern Ohio. In Canada, they inhabit southeastern British Columbia, Alberta, Manitoba, and southern Saskatchewan. Badgers inhabit plains, farmlands, and occasionally the edge of woods where the soil is usually dry and friable.

Food: Badgers primarily feed on ground squirrels, pocket gophers, rats, mice, and chipmunks. Occasionally, they feed on reptiles, insects, earthworms, birds, eggs, and carrion.

Reproduction: Offspring are usually born in March or April. On average, there are 2-3 offspring per litter.

Significance: May respond aggressively to threats, causing physical injury. May infrequently prey on domestic fowl. Extensive burrows may destroy property and pose risk of hazardous injury. An important sentinel species in plague surveillance in areas where they live in close association with large ground squirrel populations.

Protected Status: Fur-bearing species.

FAMILY FELIDAE: CATS, MOUNTAIN LIONS, AND BOBCATS

Mountain Lion *(Felis concolor)*

Description: Mountain lions are yellowish to tawny. The underneath side of the body is white overlaid with buff. The tail is long with a black tip and the same color as the body. Their total length is 1.5-2.8 m (59-108 in). The tail is 53-91 cm (21-36 in) in length. The adult mountain lion weighs from 34-125 kg (75-275 lb).

Distribution/habitat: Mountain lions are found in western North America from British Columbia and southern Alberta south through western Wyoming to California and west Texas. They are also found in southern Texas, southern Louisiana, parts of Tennessee, southern Alabama, and the southern tip of Florida. Mountain lions inhabit mountainous regions, hilly northern forests, semiarid regions, tropical and subtropical forests and swamps.

Food: They feed primarily on deer, but will also feed on coyotes, porcupines, beaver, marmots, rabbits, raccoons, mice, and insects.

Reproduction: Litters are produced every 2 years with 1-6 offspring per litter. Offspring are usually born midsummer.

Significance: May occasionally prey on domestic pets and livestock. Infrequently reported as a cause of human injury and death. Valuable sentinel species in plague surveillance programs.

Protected Status: Specially protected species. May not be taken except by the California Department of Fish & Game or their specifically authorized agent. Property owner may take a mountain lion only if it poses an immediate threat of injury or death to livestock or domestic animals. (Fish & Game Code: Section 4800-9) *F. c. browni*, California Species of Special Concern.

Bobcat (*Felis rufus*)

Description: Bobcats are tawny with indistinct black spotting. The upper legs have black or dark horizontal bars. The tail is short with a black tip and 2-3 black bars. The total body length is 71-125 cm (28-49 in). The tail length is 10-18 cm (4-7 in). Bobcats weigh 6-31 kg (14-68 lb).
Distribution/habitat: Bobcats are found from southern Canada into Mexico, though their distribution is spotty. They are absent to scarce in the Midwest. Bobcats are most plentiful in the Far West. Bobcats inhabit scrubby country, broken forests, swamps, farmlands, and rocky or brushy arid lands.
Food: Bobcats eat rodents, young deer, birds, reptiles, amphibians, and invertebrates. They will also eat fruits and vegetation.
Reproduction: Bobcats have one litter per year with 2-3 offspring per litter. Young are born in April to early May.
Significance: Valuable sentinel species in plague surveillance. May occasionally prey on domestic pets, small livestock, and poultry.
Protected Status: Non-game species.

Feral domestic cats (*Felis domesticus*)

Description: Feral cats are domestic cats that have been abandoned and adapted to the wild. Physically, they share the variety of colors and coat lengths present in their domestic kin.

Due to their feral existence, most are slightly thinner than domestic cats, averaging 1.5-3.5 kg (3-8 lb).
Distribution: May be found in any urban or suburban area where domestic cats are abandoned. They prefer vacant or infrequently used buildings or other structures for shelter.
Food: Opportunistic feeders that will prey on any small animal, especially rodents and birds. They will also consume garbage and uneaten pet food.
Reproduction: Feral cats can be quite fecund, capable of 3-4 litters a year of 3-6 offspring each. However, due to harsh environmental pressures, only a small percentage of offspring likely survive to sexual maturity.
Significance: Source of injury and infectious disease to humans and domestic cats. Depredation on native bird species may be significant if large, unregulated colonies are present.
Protected Status: Domestic cats are personal property of their legal owner. If ownership cannot be established, they are the property of the landowner on whose property they reside. Local ordinances vary in their legal consideration of feral domestic cats.

PUBLIC HEALTH SIGNIFICANCE

Carnivores can pose a threat of both physical trauma and transmission of infectious disease agents to humans and domestic animals. Coyotes, foxes, black bear, mountain lions, bobcats, raccoons are known to have killed domestic livestock, destroyed crops, and attacked humans. As human populations continue to expand into previously undeveloped areas of the state, these types of encounters between wild carnivores and humans are likely to increase.

Bites & physical trauma

All carnivores will attack if cornered or threatened in an attempt to defend themselves. In many cases these attacks result in bites and trauma. Unprovoked attacks by black bears and mountain lions are probably not as common as the media hyperbole surrounding the few reported instances implies. Nevertheless, as human activity in previously wild territories in the U.S. increases, the opportunity for these attacks will continue to rise.

Disease

Any mammal can pose a theoretical risk of rabies transmission. However, because of their well-developed dentition and efficient anatomy designed for hunting, carnivores are of particular concern as carriers of rabies. Also, because of their relatively large size, carnivores are more likely to survive an encounter with a rabies-infected animal and thus more likely to develop disease and shed virus weeks to months later. The primary reservoirs for rabies in California are skunks and various species of bats. In 1999, skunks represented over half of all animals detected with rabies in California. Rabies is detected sporadically in other California carnivores including foxes, raccoons, coyotes, bobcats, and ringtails.

In California, carnivores are an important component of surveillance programs for plague in enzootic areas. Most large carnivores do not develop illness when exposed to the plague organism. However, they usually develop antibodies to the plague bacillus which can be detected on blood test. Thus, carnivores can provide evidence that plague is circulating in a particular environment long before an epizootic is evident among vulnerable species, such as ground squirrels, or risk of transmission to humans becomes significant. Carnivore species in California in which plague is most frequently detected include black bears, coyotes, bobcats, mountain lions, spotted skunks, raccoons, and pine martens. Detection of plague antibodies among carnivores should be followed by additional surveillance of rodent and flea species in the area to determine the level of plague activity which is occurring.

Raccoons are probably the most notorious of the carnivores for being a pest and a health threat to humans and domestic animals. Besides killing domestic livestock and destroying crops, they carry rabies, tularemia, leptospirosis, Chagas' disease, trichinosis, and canine distemper. Raccoons commonly are infected with intestinal roundworms (*Baylisascaris procyonis*) the larvae of which can be spread to humans through ingesting or inhaling roundworm eggs from the feces of infected raccoons. While rare, the disease caused by these migrating larvae can be devastating, leading to brain or vision disorders, coma, and death.

Numerous other infectious disease agents have been associated with carnivore species including trichinosis (bear, mountain lions), tularemia (foxes, coyotes, skunks), and leptospirosis (skunks).

MANAGEMENT AND CONTROL

The control and relocation of carnivores should be left to professionals. Harassment, injury, or removal of many of these animals is restricted by federal and state legislation. Failure to abide by these restrictions can result in fines and imprisonment. All wildlife in California are classified as game (e.g., bear), non-game (e.g., skunk), fur-bearing (e.g., raccoon), or specially protected (e.g., mountain lion) (California Fish and Game Code, Sections 2000-2085, 3950-4190). Game and fur-bearing animals may be taken subject to season, quantity, permit, and collection method provisions. Nongame animals can generally be taken any time of year, but other restrictions and permits can still apply. Specially protected animals may not be taken unless they pose an immediate threat to the safety or life of a person or domestic animal. Even then, numerous restrictions apply to how the animal is taken. The list of Threatened and Endangered species is updated quarterly and is available at the California Department of Fish & Game (CDFG) Web site (http://www.dfg.ca.gov). It is critical before implementing any carnivore control program that one consult the CDFG, local animal control agencies, the County Agriculture Commissioner, law enforcement authorities, U.S. Fish and Wildlife, the United States Department of Agriculture Wildlife Services, or State/National Park Service personnel to ensure that the proposed program complies with all current laws and regulations.

Some management and control options for specific carnivore species are listed below. As with any animal control effort, an integrated program that includes habitat modification, exclusion, deterrence, food source restriction, and removal should be designed. Prioritization should be given to management options that are least injurious to the environment, nontarget species, and human health and habitation.

Badgers

Professional control is recommended. Mesh fencing buried to a depth of 30-46 cm (12-18 in) can be an effective exclusion technique. Eliminating the badger's principal prey (gophers, squirrels) can reduce problems associated with badger diggings. Bright lights can frighten badgers from certain areas. A 1.75 coil spring or #3 or #4 leg-hold trap and box traps can be used to capture badgers. Body grip traps can be used, such as a #220 or #330.

Bears

Installation of electrified fencing is an effective means of excluding bears from sensitive areas, but is expensive and requires constant maintenance. Deployment of bright lights and placement of human effigies can be used to frighten bears away from areas of human activity. However, these scare methods may lose their effectiveness over time as bears become accustomed to them. It is important to vary the type, location, duration and hour of deployment of scare methods to prolong their effectiveness. Sources of food that can attract bears should be eliminated or placed in containers that reduce attractive odors and prevent access. Garbage should be buried or regularly removed. Capsaicin repellent and use of strong fences and bear-proof buildings and garbage containers can reduce food odors and further dissuade bear activity around human dwellings. Problem bears may need to be removed; barrel and culvert traps baited with fish, candy, or molasses are effective at attracting and catching bears. Bears should be relocated at least 50 miles away and in an area where the potential for human contact is minimal. Bears that become habituated to human activity may lose their fear and need to be destroyed.

Felids

Bobcats. Fencing at least 2 m tall around sensitive areas (e.g., poultry coops) can dissuade bobcats from preying on domestic animals. Bobcats shy from open areas that lack cover; keeping trees and shrubs cleared for several meters around homes and building can reduce the attractiveness of these areas to bobcats. Loud noises and bright, flashing lights can temporarily frighten bobcats. Bobcats can be controlled by the use of a #330 body grip trap (where legal), kill or live snare sets (where legal), #2, #3, or #4 leg-hold traps (where legal), and box traps. However, it may be difficult to place traps such that bobcats are attracted to them; bobcats are less enticed by the odor of bait than are canids. It is difficult to lure bobcats more than a few meters from their normal course of travel.

Mountain lions. Because mountain lions are a protected species in California, any and all management and control programs must be conducted by, or in full collaboration with, California Department of Fish and Game officials. Exclusion and frightening techniques as described above for bobcats may be effective for mountain lions as well.

Feral domestic cats. Feral cats must be differentiated from stray cats. Feral cats should be maintained in well-managed colonies by an informed and responsible caretaker. Colonies should be restricted to a defined geographic area that minimizes risk to human health and sensitive wildlife species. Individual colony members should be identifiable by tag or subcutaneous microchips. Caretakers should adhere to a written protocol describing how the colony is to be fed, watered, provided health care, and periodically censused. The contribution and cooperation of local veterinarians toward the monitoring the health of the colony should be documented. Health care programs should include routine examinations, vaccinations, dewormings, serologic screening for infectious diseases, sterilization surgery, and euthanasia of cats for which ill health or other factors prevent their reintroduction to the colony. Abandoned and stray cats that are not part of a managed colony should be removed from the environment and dealt with in accordance with local animal control regulations.

Canids

Coyotes. Prevention of damage and predation by coyotes relies on appropriate exclusion and avoidance methods; efforts to remove all coyotes is neither practical nor effective. Solid fencing can often reduce, though usually not permanently eliminate, predation of livestock by coyotes. Fencing should rise 2 m above the ground and extend 0.8 m below the ground. Installation of electrically charged wire, particularly at the top of the fence, can provide additional deterrence. Steady, intermittent, or strobe lights which automatically turn on at dusk may be placed around livestock enclosures or other sensitive areas. Lights should be relocated at irregular intervals to minimize accustomation by coyotes. Auditory, olfactory, and gustatory repellants have been less successful in frightening coyotes. Two toxicants—sodium cyanide and sodium fluoroacetate (Compound 1080)—are available in various delivery devices, including spring-loaded traps and livestock collars. However, both chemicals are restricted-use pesticides under the California Code of Regulations and may be used only by trained and certified government officials. Traps and snares may be used to remove individual nuisance or predatory coyotes; an experienced trapper should be consulted regarding the most appropriate trap and best means of deploying it.

Foxes. Control methods, and restrictions thereof, are similar to those used for coyote.

Feral domestic dogs. Control methods are similar to those used for wild canids. Abandoned and stray dogs should be dealt with in accordance with local animal control regulations. Successful long-term management and elimination of feral dogs is dependent upon responsible ownership of domestic dogs, including confinement, health care, sterilization, and appropriate disposition of unwanted dogs.

Raccoons

Exclusion is the most effective means of counteracting raccoon damage. Doors, windows, and other potential entry points to buildings should be tightly closed. Fences should be placed around sensitive areas and an electrically charged “hot wire” positioned at the top of the fence. Raccoons can be deterred from activity in and around areas of human habitation by removing attractive sources of food. Garbage cans and grain storage bins should be securely sealed. Unconsumed pet food should be regularly removed from around human residences. Lights, noises, scarecrows, chemical repellants, and other devices intended to frighten raccoons have generally proved ineffective. A sturdy cage-type live trap, at least 25 X 30 X 80 cm (10 X 12 X 32 in), may be used to capture and remove individual raccoons.

Skunks

Skunks can be excluded from sensitive areas through installation of fencing that is buried 40-60 cm (1.5–2 ft) below the surface. Garbage containers should be securely sealed and garbage regularly disposed of to remove the attraction of food for skunks. Wood and debris piles provide shelter for skunks and should be removed from around human residences. Chemicals are available for fumigation of skunk burrows, but these are non-specific and great care should be taken to minimize the risk of exposure by non-target species. Individual nuisance skunks can be trapped and relocated to an area at least 16 km (10 miles) away.

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Chapter 6

RODENTS
(Class Mammalia, Order Rodentia)

Minoo B. Madon

INTRODUCTION

Rodents are the most common group of mammals in the world. It is estimated that over 40% of all mammals living today are rodents, encompassing over 2000 species in 28 families. Rodents were the first placental mammals to emerge during the Late Paleocene Epoch (63-58 million years ago), at the apex of the Great Age of Dinosaurs. Today, species of rodents can be found in nearly every ecologic niche on Earth, on nearly every continent. Among the vertebrates, they represent one of the most successfully adapted groups--also one of the most notorious. The history of Western Civilization, if not mankind itself, is inextricably linked with that of the rodent. The most significant public health event of the last millenium was arguably the Black Death of the 14th Century which reduced the world's population by a third. And yet, this pandemic of plague, fomented by the lowly rat and its baggage of fleas, set the stage for the remarkable social transformations that followed, including the end of feudalism, the Renaissance, and the Reformation.

Today, rodents continue to be both boon and bane to human health and economy. Fur-bearing rodents such as beaver and chinchilla provide a natural source of income for many societies. On the other hand, rodents wreak billions of dollars of damage to agriculture every year. Pet hamsters, gerbils, and other small rodents provide companionship to many households, while their brethren simultaneously cause considerable consternation as intrusive pests. Finally, rodents are useful models and subjects in scientific research which advances the quality of human life, but are also reservoirs and vectors for numerous infectious disease agents. In the animal kingdom, perhaps only insects can rival the importance of rodents to contemporary human civilization.

GENERAL CHARACTERISTICS

Anatomy

Rodents are a diverse group, ranging from miniscule mice of just a few inches in length to the South American capybara which can reach lengths of 1.3 m (4 ft) and weigh up to 50 kg (120 lb). Feet, legs, and other body parts can also be highly specialized for digging, climbing, swimming, or even gliding. As a group, rodents are readily distinguished from other mammals by their large incisor teeth—two upper and two lower (Figure 6-1). The incisors have a hard enamel on the front surface with a softer dentine in the back.

Figure 6-1

The incisors grow continuously, necessitating the rodents to constantly gnaw to keep them sharp and of manageable length. (*Rodentia* comes from the Latin *rodere*, meaning "to gnaw".) A gap between the incisors and cheek teeth called a diastema allows for maximum use of the incisors to manipulate food. The jaw muscles and skull structure are important criteria for classifying different rodents.

Taxonomy

Class Mammalia
- Order Rodentia
  - Family Muridae
    - Subfamily Murinae (Old World rats and mice)
    - Subfamily Sigmodontinae (wild mice, wood rats, and others)
  - Family Sciuridae (ground squirrels, tree squirrels, and marmots)

California rodents may be classified into two groups which are distinct in their phylogeny, behavior, and habitat. The commensal, or domestic, rodents are Old World rodents which were imported to North America. The native, or wild, rodents include various species of squirrels, chipmunks, field mice, meadow mice, and woodrats. Because the ecology, behavior, and public health significance of these rodent groups are distinct, each group will be discussed separately in this chapter.

COMMENSAL (DOMESTIC) RODENTS (FAMILY MURIDAE, SUBFAMILY MURINAE)

The three species of domestic rodents are also correctly referred to as commensal rodents because they live in close association with humans. These commensal rodents are not indigenous to North America but accompanied humans as stowaways on their ships of emigration and trade. The roof rat, *Rattus rattus*, originated from the southeast Asian mainland, spread along the ancient caravan routes from India across the Middle East, to East Africa and the eastern Mediterranean. By the Middle Ages, it was distributed throughout most of Europe. Roof rats were probably introduced to the New World during the 15th or 16th Century, first reaching South America in the mid 1500s. The first record of roof rats in the United States was in the early 1600s. The Norway rat, *Rattus norvegicus*, was introduced later, migrating westward from Central Asia, first appearing in the beginning of the 18th Century. The first record of its introduction into the United States (possibly from Europe) was in the late 1700s. The house mouse, *Mus musculus*, also spread westward from central Asia, through the Middle East, to the Mediterranean shores and Europe. These mice were probably introduced into Latin America aboard ships from Spain and Portugal and subsequently spread into the southern United States and California.

GENERAL CHARACTERISTICS

Sensory abilities

Vision. Commensal rodents are nocturnal (active at night). Though their eyes are specialized for vision in low light, acuity is generally poor. Most rodents are color blind, perceiving light in shades of gray.

Touch. The vibrissae ("whiskers") and the long guard hairs on their bodies are extremely sensitive to tactile stimuli. The vibrissae and guard hairs serve as guides ("thigmotaxis") along vertical walls and nearby objects, providing compensation for rodents' poor vision.

Smell. Commensal rodents have an acute sense of smell. They leave odor trails as they move about. These odors aid them in recognition of kin and in locating sexually active mates. Commensal rodents are accustomed to human activity and thus lingering human odors do not usually dissuade them from traps and baits.

Taste. The sense of taste is well developed in commensal rodents. They prefer fresh food to old or spoiled food. Some species seem especially sensitive to extremely minute quantities of bitter or other unpleasant substances included in toxic baits. Hence, repeated sublethal applications can lead to bait-refusal or bait-shyness among survivors.

Hearing. Commensal rodents have a keen sense of hearing and can detect vibrations in the ultrasonic range. They are extremely sensitive to sudden or loud noise.

Physical capabilities

Gnawing. As mentioned earlier, the incisors of rodents grow throughout their lifetime requiring constant gnawing to keep them at manageable length. Rodents can gnaw through any material that is softer than their enamel, including wood, aluminum, sheetrock, poor quality concrete, asphalt, hard rubber hoses, electrical wiring, and plastic tubing. Since they cannot gnaw through galvanized sheet metal and galvanized hardware cloth, these materials can be used as rodent exclusion materials in structures.

Climbing. Rats and mice have prominent footpads and well developed claws. They have four toes on their front feet and five toes on their hind feet (Figure 6-2). They use their tails, which are typically scaly and sparsely haired, to balance their bodies when climbing. Commensal rodents are excellent climbers and have little or no difficulty climbing rough surfaces of vertical wooden beams or walls, and can traverse utility and telephone wires with relative ease. Norway rats can ascend vertical pipes up to 7 cm in diameter.

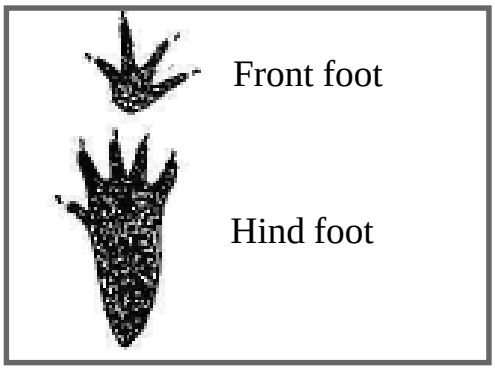

Figure 6-2

Jumping. Rats are known to jump vertically over 75 cm (2 ft). Adult house mice can jump vertically up to 35 cm (1 ft).

Swimming. All three species of commensal rodents are good swimmers. Rats can swim continuously from one to almost three days if necessary, and can remain submerged for almost 30 seconds. Rats have been known to enter homes by swimming through the water seal in toilets.

Burrowing. Norway rat nests are located up to about 50 cm (18 in) underground. They may dig much deeper in loose soil. Their burrows consist of several connecting tunnels and have more than one exit. They may burrow into poultry and other animal manure or into the ground when infestations are encountered on ranches and in animal quarters. When living outdoors, house mice will construct shallow burrows in the open or cultivated fields, or live under piles of rubbish.

Behavior

Periods of activity. Commensal rodents are primarily nocturnal and usually have two peaks of night-time feeding activity. Weaker and less-dominant individuals may be forced to be active during daytime. Significant daytime activity observed among primarily nocturnal species may indicate increased population density.

Home range. The home range of most rodents is generally small. Home ranges may overlap with individuals of one or more other rodent species, depending on the type and carrying capacity of the environment. Commensal rodents are relatively tolerant of changes to the environment given their association with human habitation. Rats accustomed to living in areas where human activity or changes to the environment are frequent may be easier to control than populations where interaction with humans is less common. House mice are by nature curious and less neophobic than rats, tending to investigate objects that are recently introduced in their environment.

Seasonal movements/migration. Weather can significantly affect rodent movement. In cooler weather, during late fall or early winter, commensal rodents tend to move indoors to warmer areas. In late spring or early summer they return to the outdoors, or might remain indoors if food and suitable harborage are available.

Reproduction

Rodents are, in general, prolific breeders. Most species reach sexual maturity in 3-5 months. Gestation is generally no more than 3-4 weeks, so sexually active females can have several litters during a single breeding season. Number of young per litter ranges from one to a dozen or more. Rodents in the wild rarely live more than a single year; however, in captivity some species may live up to 3-4 years.

Economic importance

Commensal rodents can cause significant economic loss to agriculture, especially through consumption and destruction of fruit orchards and vegetable crops. Fecal contamination of foodstuffs for humans or other animals can lead to disposal and subsequent loss of revenue for producers or distributors. Rodents can also disrupt agricultural activities indirectly through destruction of property such as hoses, storage containers, and seeds. Rodents can cause economic damage to human residences by gnawing insulation on electric wires which can lead to fires; up to 5-20% of fires of “unknown origin” may be caused by rodents. The estimated total economic losses caused by commensal rodents in the United States may exceed $1 billion annually.

CALIFORNIA COMMENSAL RODENTS OF PUBLIC HEALTH IMPORTANCE

Roof rat (*Rattus rattus*)
(black rat, fruit rat, ship rat)

Description: The roof rat is a moderate-sized rodent, slightly smaller than the Norway rat. The body is slender, adults averaging 225-285 g (8-10 oz). The total length (tip of nose to tail-end) is approximately 35-45 cm (14-18 in). Tail is longer than the head and body, measuring 18-26 cm (7-10 in), sparsely haired, and uniformly colored. The body is covered with softer fur and long, prominent guard hair. Roof rats in California vary in color from black with a gray belly to brownish-black with a whitish belly. Color variants may occur in the same litter and the color of fur cannot alone be considered a good characteristic for identification. The nose of the roof rats is pointed; the eyes are large. Ears are prominent, hairless, usually more than 2 cm (¾ in) long and can be pulled over the eye.

Food: Although omnivorous, roof rats prefer vegetables, fruits, nuts, and cereal grains. Their daily requirement is about 15-30 g (0.5-1 oz) of food and up to 30 ml (1 oz) of water. Droppings are medium-sized, about 1.5 cm (0.5 in) long, sausage- or spindle-shaped, and usually pointed at both ends.

Reproduction: Sexual maturity in 3-5 months. Gestation period averages 22 days. 6-8 young per litter. 2-6 litters per year. Life expectancy of about one year.

Habitat: Roof rats are semi-arboreal species, preferring to live in fruit and nut orchards, in the crowns of palm trees, in shrubs and vines, and dense growths of Algerian ivy. They prefer to nest above ground, often in attics, within walls, and in enclosed spaces of cabinets and shelving. Older residential neighborhoods with overgrown vegetation and newer residential suburban developments amidst former orchards are likely habitats. Other common habitations include Himalayan blackberry thickets, grain mills, poultry ranches, animal stables, sea-going vessels, and sewer systems.

The home range of roof rats is dependant upon the availability of food and harborage. If both are readily available, it may range 30-60 m (100-200 ft) or more. Roof rats can readily travel for several blocks along utility wires and overhead vegetation. Roof rats usually occur in smaller family groups and are not as gregarious as the Norway rats. Roof rats are the predominant rodent species in suburban areas and waterside habitats (riprap of shorelines) of the southern coastal and inland valleys of California. Roof rats are also found at elevations up to 1070 m (3500 ft) in the Sierra Nevada foothills of California.

Significance: Roof rats can cause considerable damage to buildings, equipment, vegetation, and other periresidential structures. Within the home they can destroy and contaminate food. They frequently destroy agricultural crops, particularly tree fruits. Numerous infectious disease agents are associated with roof rats, including *Salmonella*, *Streptobacillus* (rat bite fever), and *Leptospira*. They are a natural host for *Ornithonyssus bacoti*, the tropical rat mite, which may infest humans if its rodent host is removed. Although plague associated with *Rattus* spp. has not been observed in California since 1946, the possibility for transfer of infected fleas from wild to commensal rodents during an epizootic remains a theoretical risk wherever these species coexist. A single plague-positive roof rat was found in Los Angeles in 1981.

Norway rat (*Rattus norvegicus*)
(brown rat, sewer rat, wharf rat, house rat, barn rat)

Description: The Norway rat is the largest of the commensal rodents. The body is heavy and stocky, averaging 200-600 g (7-20 oz) in adults. The total length is approximately 32-46 cm (13-18 ½ in). The tail is bicolored (dark above and lighter below), 15-21 cm (6-8 ½ in) in length, and sparsely covered with stiff hairs.

The fur is coarse and usually brownish-gray on the back and grayish-white on the belly, although coloration is highly variable. The muzzle is blunt, the eyes are small, and the ears are small, rarely over 2 cm (¾ in) long, close-set, and covered with fine hairs.

Food: Norway rats are omnivorous, but prefer meat, poultry, fish and other sea food, garbage, and cereal grains. They require 22-30 g (0.75-1 oz) of food and about 15-30 ml (0.5-1 oz) of water per day. Droppings are comparatively large, up to 2 cm (0.75 in) in length, capsule-shaped, and usually with blunt ends.

Reproduction: Sexual maturity in 3-5 months. Gestation period averages 22 days. 8-12 young per litter. 2-7 litters per year. Life expectancy of 9-12 months.

Habitat: Norway rats are primarily a burrowing species. Outdoors, they burrow in the ground, under foundations of buildings, in soil banks, rock piles, along the banks of ditches, streams, rivers, and marshes. In the absence of sanitary landfills, they also occupy poorly managed rubbish and garbage dumps. They can also be encountered in sewers, in wharf areas, and in the riprap of shores. In older urban communities they frequent cellars, stores, warehouses, slaughterhouses, and rendering plants. In rural and farming communities they infest poultry ranches, barns, animal quarters, silos, and granaries. Norway rats are a common problem in rice fields. Norway rats are gregarious and have a home range of usually 30-60 m (100-200 ft).

Significance: Similar to the roof rat in many regards. The Norway rat is the natural host of the oriental rat flea, *Xenopsylla cheopis*, the classic vector of plague. Plague-positive Norway rats were found in four San Francisco Bay area counties and two southern California counties between the early 1900s and the 1940s.

House mouse (*Mus musculus*)

Description: The house mouse is small and resembles a young roof rat. The body of the house mouse is slender averaging 15-20 g (0.5-0.75 oz). The total body length is 14-19 cm (5½ -7½ in). The tail is uniformly gray in color and equal to, or slightly longer than the head and body, measuring 7.5-10 cm (3-4 in). Fur is gray to brown with the underside slightly lighter, varying from white to gray. The muzzle is pointed, eyes are prominent, and ears are large, about 1.3 cm (0.5 in) long.

Food: They prefer cereal grains, but will feed on any edible materials. They are nibblers rather than steady feeders, with a daily food requirement of about 0.1 oz (3 g). If water is available, they imbibe about 9 ml (0.3 oz) per day. House mice can survive in a dry habitat without available water, as they are capable of hydrolyzing water from the grains they feed upon. Droppings are small, 0.3-0.7 cm (0.1-0.25 in) long, rod or spindle-shaped, and usually pointed at both ends.

Reproduction: Sexual maturity in 1½-2 months. Gestation period averages 19 days. 5-6 young per litter. As many as 8 litters per year. Life expectancy is less than one year.

Habitat: House mice will occupy any convenient space between walls, inside cabinets, in or under furniture, warehouses, and storage areas. When conditions are favorable, house mice can live outdoors quite independently of humans, in weeds, grasslands and in piles of rubbish. Their home range is very limited, usually 3-10 m (10-30 ft), as they prefer to have their nesting sites close to a food source.

Significance: Cause damage through consumption and contamination of food stores. Damage walls, cupboards, electrical boxes which they use for nest sites. Principal reservoir for lymphocytic choriomeningitis virus. They are also often infected with *Salmonella* and carry mites capable of transmitting rickettsialpox.

PUBLIC HEALTH SIGNIFICANCE

Because of their close association with human habitat, commensal rodents pose a substantial risk for transmission of infectious disease agents. In addition to fecal contamination of foodstuffs, commensal rodents serve as a reservoir or vector for numerous microbiologic pathogens that are potentially infectious to humans. A partial list of these diseases and their most frequently associated rodent host is provided in Table 6-1. Rodent-borne diseases are transmitted directly by contamination of human food with their feces or urine, contact with infected body fluids and/or rodent blood, or indirectly by way of rodent ectoparasites such as fleas or mites.

Rats are also a potential source of traumatic injury through bites exacted inadvertently or during attempts to protect themselves. In older, larger metropolitan areas, rat bite estimates range from 5 to 10 per 100,000 persons, though this is likely an underestimate as rat bites are not routinely reported. Infants, the elderly, or other persons who are incapable of protecting themselves may be more susceptible to rat bites. If not properly treated, bites from rats, as with any animal bite, can lead to localized or systemic bacterial infection.

MANAGEMENT AND CONTROL

Recognizing evidence of infestation

Commensal rodents are habitually nocturnal and usually secretive. They are rarely seen during daytime unless populations are large. Their presence is usually determined by indirect evidence of activity. From these signs, one can ascertain species of rodent, the population density, and whether the infestation is current or old.

Droppings. Fresh droppings are usually shiny, soft, and moist. Color of droppings may vary with the food eaten. Older droppings are usually dull, grayish, hard, dry, and will crumble easily. (Figure 6-3)

Runways. Rodents will generally use the same, familiar pathways from their harborage to obtain food and water, navigating by continual body contact with a vertical wall, fence, or other surface. Indoors, these runways are evident as grease marks along walls, steps, and on rafters at the juncture of cross beams. Outdoors, the runways can be seen as narrow beaten pathways leading to entrances of burrow systems.

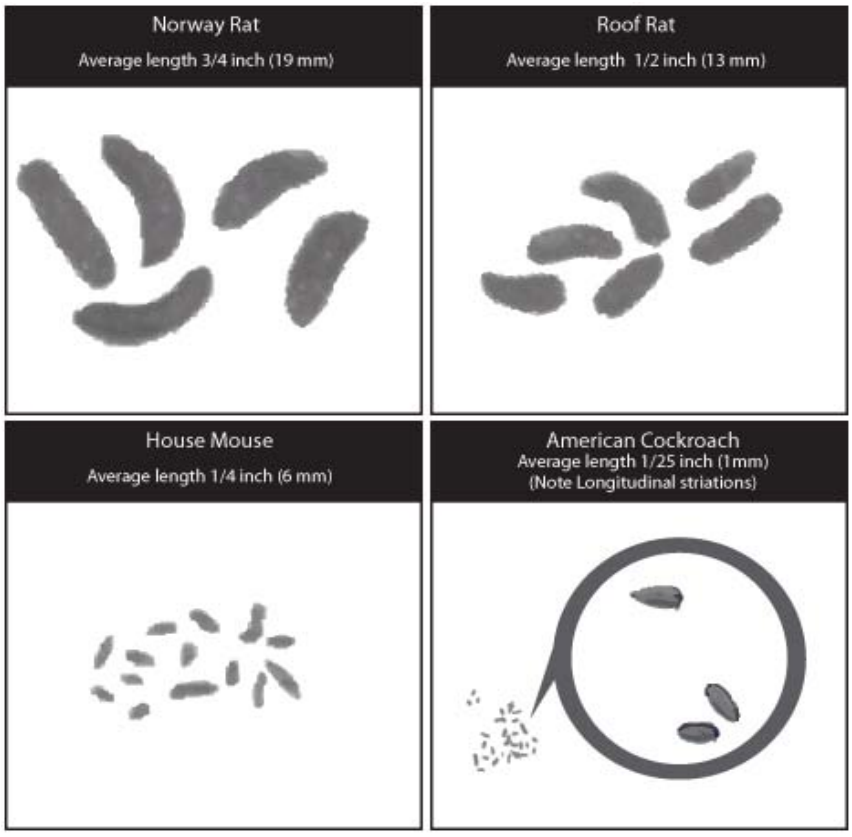

Figure 6-3

Table 6-1. Selected infectious disease associated with California rodents

Disease	Etiologic (causative) Agent	Reservoir	Vector/s-Mode of Transmission
Plague • Urban • Sylvatic	**Bacteria** *Yersinia pestis*	Commensal rodents Ground squirrels, chipmunks, woodrats	**Fleas** - *Xenopsylla cheopis* - *Oropsylla montana, Hoplopsyllus anomalus*, and several other species of wild rodent fleas
Lyme Disease	**Bacteria** *Borrelia burgdorferi*	*Peromyscus* spp., *Neotoma* spp.	**Western black-legged tick** *Ixodes pacificus*
Relapsing Fever	**Bacteria** *Borrelia hermsii*	Chipmunks	**Soft tick** *Ornithodoros hermsi*
Leptospirosis	**Bacteria** *Leptospira* spp.	Commensal rodents, dogs, cattle, swine	Urine contamination
Ehrlichiosis • Monocytic (HME) • Granulocytic (HGE)	**Bacteria** *Ehrlichia chaffeensis* *Ehrlichia equi*	Wild rodents, possibly *Neotoma* spp.	*Ixodes pacificus* and possibly other tick species
Murine Typhus • Urban • Sylvatic	**Bacteria** *Rickettsia typhi* *Rickettsia felis*	Norway rats Opposums	Infected flea feces scratched into flea-bite wound Cat flea, *Ctenocephalides felis*, feces scratched into flea-bite wound
Salmonellosis	**Bacteria** *Salmonella* species	Numerous wild and domestic animals	Fecal contamination of food products & water; fecal-oral transmission from person-to-person
Tularemia	**Bacteria** *Francisella tularensis*	Wild rodents and other wildlife, especially rabbits & hares	Bite of tick or deer fly, direct contact or consumption of contaminated tissues, consumption of contaminated water, inhaling contaminated dust
Q Fever	**Bacteria** *Coxiella burnettii*	Wild rodents and lagomorphs	Inhalation of aerosolized particles; direct contact with infected animals
Lymphocytic choriomeningitis	**Virus** Arenavirus	House mice, Guinea pigs, swine, monkeys, dogs & hamsters	Virus shed in urine, feces, saliva of infected animals; contaminated food or dust; possibly arthropods?
Colorado Tick Fever	**Virus**	Chipmunks, squirrels, *Peromyscus* spp.	**Wood tick** *Dermacentor andersoni*
Hantavirus Pulmonary Syndrome	**Virus** Sin Nombre virus	*Peromyscus maniculatus*	Inhalation of aerosolized excreta
Babesiosis	**Protozoan** *Babesia sp.* WA1	Presumably wild rodents	Bites by infected *Ixodes* ticks, blood transfusion
Giardiasis	**Protozoan** *Giardia lamblia*	Humans, beaver, other domestic and wild animals	Ingestion of cysts in fecally contaminated water
Rate mite dermatitis	**Mite** *Ornithonyssus bacoti*	Commensal rodents	Living in or entering areas with heavy rodent infestations
Trichinellosis	**Nematode** *Trichinella spiralis*	Numerous domestic and wild animals	Consumption of raw or insufficiently cooked meat

Rub marks. Norway rat rub marks are usually near ground or floor level, whereas rub marks caused by roof rats are more common overhead among beams in attics. "Swing marks" can be seen at the juncture point of cross beams as the roof rats travel along rafters, or where the rafters connect to the walls (Figure 6-4). Unless a heavy infestation is present, house mice do not commonly leave rub marks.

Figure 6-4

Sound. Sounds of running, gnawing, and scratching between walls and floors, and in attics and crawlspaces, may provide evidence of rodents, especially roof rats.

Live rodents or carcasses. Because they are nocturnal and secretive, live rodents are rarely observed. However, when infestations are heavy, rodents may be seen during daytime. Carcasses may indicate either a current or past infestation. If carcasses are encountered, care should be taken for proper disposal.

Burrows. Depending upon the species encountered, burrows may or may not be seen. Burrow systems are usually located near a source of food and water. The presence of fresh food fragments and freshly dug earth will indicate current activity.

Gnaw marks. Rodents gnaw to gain entrance, to obtain food, and to keep constantly growing incisors in check (Figure 6-1). The gnaw marks made by these incisors are very characteristic of rodents. Freshly gnawed marks will show distinct tooth marks, but as they get older, the gnawed areas become darker with grease and smoother with repeated body contact.

Tracks. Laying smooth tracking patches of flour or talc along runways may bring to light rodent activity. The five-toed hind feet may leave more distinct tracks than the four-toed front feet.

Miscellaneous. Urine stains may or may not be readily observed in normal light. A portable ultraviolet light usually helps fluoresce suspected urine stains. Rats and mice shed great amounts of hair. These may be found lodged around entry points, in their feces, and in contaminated food products. Characteristic musty odors may be present when heavy infestations occur, especially in damp, poorly ventilated areas.

Planning an integrated rodent control program

Because of the complexity of biological and behavioral factors involved, control of commensal rodents, whether community-wide or on a local scale, should be carefully planned. A comprehensive control strategy should include all of the following actions:

- Identify the rodent species and estimate the size and extent of infestation.
- Document extent of damage to property, contamination of food.
- Identify sources of food, water, harborage, and entry (re-infestation) points.
- Assess the motivation, knowledge, attitude, and acceptance of affected persons towards the control program.
- Cooperate with local and regional governmental agencies and community organizations.
- Consult with building code enforcement agencies.
- Consider potential legal implications.
- Estimate costs and relative benefits of control program.
- Implement rodent suppression measures (e.g., trapping).
- Evaluate the need for concomitant ectoparasite control.
- Conduct environmental sanitation/modification, structural modification (exclusion), and preventive maintenance.
- Educate the public and encourage active participation by the community.
- Evaluate program efficacy.
- Establish ongoing monitoring and surveillance.

Population reduction

A "population" is the estimated number of pest rodents within the area of concern, be that a city block, regional sewer system, or a single residence. Depending upon the size and distribution of the population, necessary components of an effective rodent suppression program can include trapping, poison-baiting, use of tracking powders, ectoparasite control, or a combination of these.

Trapping. Trapping is often the preferred initial step for controlling small number of rodents within homes, schools, food processing/handling plants, hospitals, and other environments in which sanitation and limited exposure to toxic agents is desired. The commonly available snap trap is the most effective and widely used method for removing rats and mice (Figure 6-5). Snap traps with expanded triggers can enhance effectiveness. "Pre-baiting"—placing baited traps for several days without setting them—can indicate whether the rodents will accept the bait and ultimately enhance the efficacy of trapping efforts. Bait selection for snap traps can be a complex matter and the most effective bait can vary between different populations of the same rodent species. Although rodents are omnivorous, they have specific food preferences: Norway rats prefer meats and meat products, bacon, and fresh, smoked, or dried fish; roof rats prefer nuts, fruits, and vegetables, but will also feed on meat or meat products; house mice prefer grains and cereal products. Peanut butter, especialy the "chunky" variety, is often accepted by all three species.

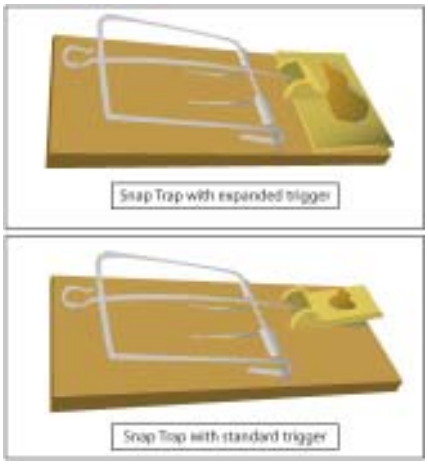

Figure 6-5

Proper placement of traps is important. Check the operation of the traps before placement to ensure that they are working properly. Place the traps in areas rodents frequent, including runways, at entry points, and in close proximity to nesting areas. Snap traps should be placed with the trigger ends facing the wall (Figure 6-6). Traps should be anchored to prevent an injured rodent from dragging the trap away to an inaccessible area. Preferably, two traps should be placed next to each other at each location in case one malfunctions. Snap traps can be nailed on to vertical rafters or near "swing-marks" at the junction of rafters and cross beams (Figure 6-7). If rodents are observed traversing water pipes, two traps should be fastened to the pipe, with the trigger ends of each trap facing in the opposite directions. Traps should be examined and reset daily. Wear gloves to remove captured rodents and dispose of the carcasses in a secured plastic bag.

Figure 6-6

Unless a disease surveillance or special scientific study is being conducted, the use of live-animal traps is not generally recommended as a control method because of the potential for transmission of diseases and ectoparasites while handling live rodents. Individuals interested in conducting live trapping of rodents should consult with an experienced professional before embarking on such a project.

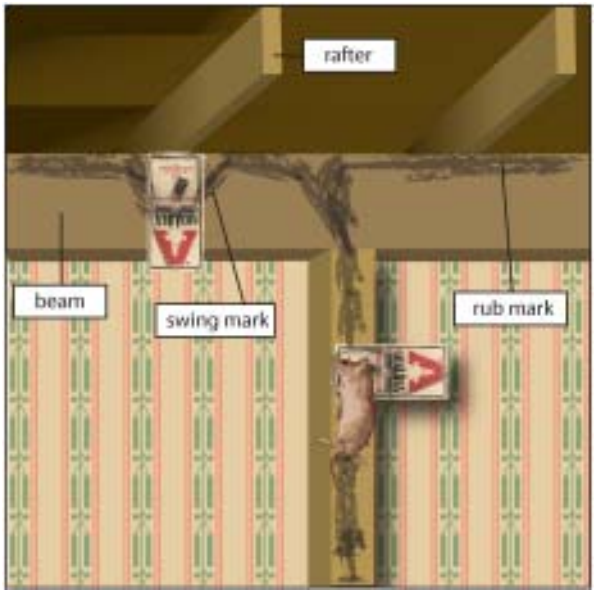

Figure 6-7

Glue boards. Glue boards are commercially available, but they are not recommended if rodent control is planned on a community-wide basis. In a small area, glue boards may be effective for controlling naturally curious mice, but roof rats are cautious and tend to avoid them. Glue boards must be placed out of the reach of children and pets and out of sight of the public. Exposure to dust, sun, and moisture tend to render glue boards ineffective unless they are placed inside EPA-approved containers. Persons collecting glue boards should be cautious to avoid rodent bites while handling rodents that are still alive in the glue boards.

Tracking powders. Tracking powders containing toxic chemicals (e.g., diphacinone, chlorophacinone, isovaleryl, zinc phosphide) are not consumed like bait, but collect on the rodents' fur and are then ingested by the rodent during grooming. Because house mice groom often, tracking powders are a good option for control in areas where bait acceptance is poor or natural food is readily available. Best placement areas are wall voids and dead spaces at or below ground level, preferably on dry surfaces. Use of powders above ground level may result in the dust "floating" down to lower areas through cracks and crevices, creating a potential health hazard. Steps should be taken to avoid spreading powder by air movement and foot traffic. Tracking powder should be placed in specially designed, EPA-approved, tamper-resistant stations to reduce the risk of exposure to non-target organisms and spread of the material. Use of tracking powders alone to control Norway and roof rats may not be effective, as these species are cautious and do not groom as often as mice do.

Anticoagulants. Anticoagulants are widely used for commensal rodent control throughout the world. Anticoagulants are toxicants that disrupt the blood-clotting mechanism causing fatal internal hemorrhages. Commonly used anticoagulants include the hydroxycoumarins (e.g., warfarin, brodifacoum, bromadiolone) and the inandiones (e.g., diphacinone, chlorophacinone, Pival). Because of their cumulative action, most anticoagulants need to be ingested over a period of several days to be effective. Anticoagulant baits are commercially available in a variety of forms (e.g., wax-impregnated bait blocks, pellets, packets of grain).

Bait-shyness and resistance are generally not concerns because commensal rodents readily accept anticoagulant baits and the concentration of the toxicant used is very low. However, following several decades of routine, unwavering use, warfarin resistance in commensal rodents became a significant problem in the 1980s. Concern over anticoagulant resistance motivated further research toward developing new "second generation" anticoagulants, such as brodifacoum and bromadiolone, that are more potent and do not require several feedings.

Rodenticides. Acute rodenticides are classified as extremely, moderately, or minimally hazardous; their use should explicitly follow label directions. Use of rodenticides inside homes and occupied buildings is not recommended due to the risk of poisoned rodents dying in inaccessible areas. Also, children and pets may have access to poisoned bait if placed insecurely or in unapproved containers. EPA-approved tamper-resistant bait stations should be used. A variety of these are commercially available, or agencies may construct their own, according to EPA guidelines. Care and adherence to safety precautions must be taken when using acute rodenticides as there is the potential for primary and secondary poisoning of non-target domestic and wild animals and contamination of the environment.

Zinc phosphide is the only rodenticide currently registered for use in California, but it is not generally recommended in the home environment. Zinc phosphide is a fine grayish-black powder having a sharp taste and a garlic-like odor. It is a moderately fast-acting toxicant; rodents die from heart failure usually within an hour. The characteristics (odor, taste, color) that make zinc phosphide attractive to rodents seem to make it unattractive to other mammals. The only formulation available for commensal rodent control is as a tracking powder.

Ectoparasite control. Ectoparasites of rodents, including fleas and mites, can be a health concern to humans. Deprived of their natural rodent hosts following a successful population control program, these ectoparasites will seek out a new host upon which to feed, including humans. Because infestations with these ectoparasites can present not only a direct health concern but the possibility for transmission of infectious diseases, it is imperative that an ectoparasite control program be implemented before, or concomitant with, any rodent population reduction efforts. Insectide may be applied to areas of frequent rodent activity, or impregnated in bait boxes, to reduce fleas on rodents prior to initiation of the rodent removal program. Acaracidal sprays may be applied to rooms and spaces where rodent activity is heavy to kill mites that are present in the building.

Environmental modification

Environmental modification is the physical alteration of the environment to deny rodents a favorable habitat. Since suppressive measures such as poisoning or trapping provide only short-term solutions, integrated management concepts should incorporate good sanitation practices, environmental modification, and rodent exclusion measures to achieve long-term control.

Environmental sanitation. The abundance of food, water, and harborage in a given environment determines the population size each environmental niche can support ("carrying capacity"). If the capacity of the environment is changed, there may follow a corresponding change in the rodent population. When the carrying capacity within an environment is reduced (e.g., removal of harborage), this usually leads to stress, reduced fecundity, and the long-term demise of the rodent population.

Good sanitation practices that deny rodents access to food, water, and harborage are critical for rodent population control. Sanitation is the responsibility of the owner/s or occupant/s of the property. Handling, storage, and disposal of garbage can significantly influence rodent populations. Garbage should be stored in containers that meet the current standards of approval with tight-fitting lids. The number of containers should be appropriate to accommodate all wastes between collections. Rooms or shelters where containers are stored should be designed for easy cleaning and not themselves provide harborage for rodents.

Warehouse food products should be stored in approved containers and stacked neatly on shelves or racks (Figure 6-8). Shelving with at least 30 cm (12 in) clearance above the floor and away from the walls will provide a deterrent to rodent traffic. This will also aid visual inspections for evidence of rodent activity, and control measures if necessary.

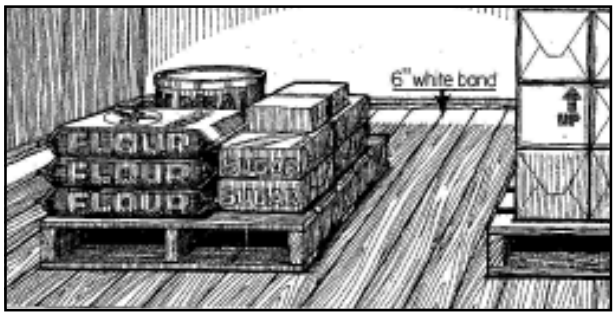

Figure 6-8

Outdoors, harborages exist in many forms. Lumber and other materials should be stored away from buildings. Open areas can be mowed or tilled to reduce harborage. In suburban residential neighborhoods, ornamental shrubs and plants used for landscaping can create a favorable environment for roof rats (Figure 6-9). Developments that are 15 or more years old are of particular concern, as mature vegetation provides favorable harborage and structures may be in need of maintenance and repairs.

Algerian ivy (*Hedera canariensis*) is used extensively as ground cover in California along freeway embankments, around homes, and in hillside areas to prevent erosion. It is also a major source of harborage and food, particularly in dense vertical growths on fences, trees, utility poles or buildings. Other ornamental plants such as pyracantha, honeysuckle, juniper shrubs, and, in rural areas, Himalayan blackberry thickets serve as excellent nesting sites. These thick shrubs should be regularly thinned and maintained in smaller patches. Fallen and unwanted fruit (e.g., walnuts, oranges, avocados, seeds and nuts of ornamentals) should be regularly collected and promptly disposed of.

Pet food should be stored in metal containers with tight-fitting lids; unconsumed pet food should be removed from bowls. Pet droppings should be promptly removed. Snails should be controlled as they are a preferred food of roof rats. Leaky outdoor water faucets and pipes should be repaired to remove a source of water for rodents. Compost piles should be covered and maintained to exclude rodents.

Exclusion. Rodents, such as mice, can enter openings as narrow as 2 cm (0.75 inch) in diameter; therefore effective exclusion requires that all such potential points of entry, above ground and at ground level, be identified and corrective measures be implemented. A variety of materials can be used to seal the openings: ¼-inch galvanized hardware cloth, steel wool, sheet metal, mortar, concrete, and expanding foam are a few examples. To prevent access to toilet bowls, a good precaution is to seal the open end of the toilet vent pipe with hardware cloth, fastened by a hose clamp.

Ultrasonic devices are not recommended as they have not been successful in repelling rodents from structures. Research has demonstrated that ultrasonic devices are expensive, are directional, have a limited range, and produce "sound shadows" where rodents are unaffected.

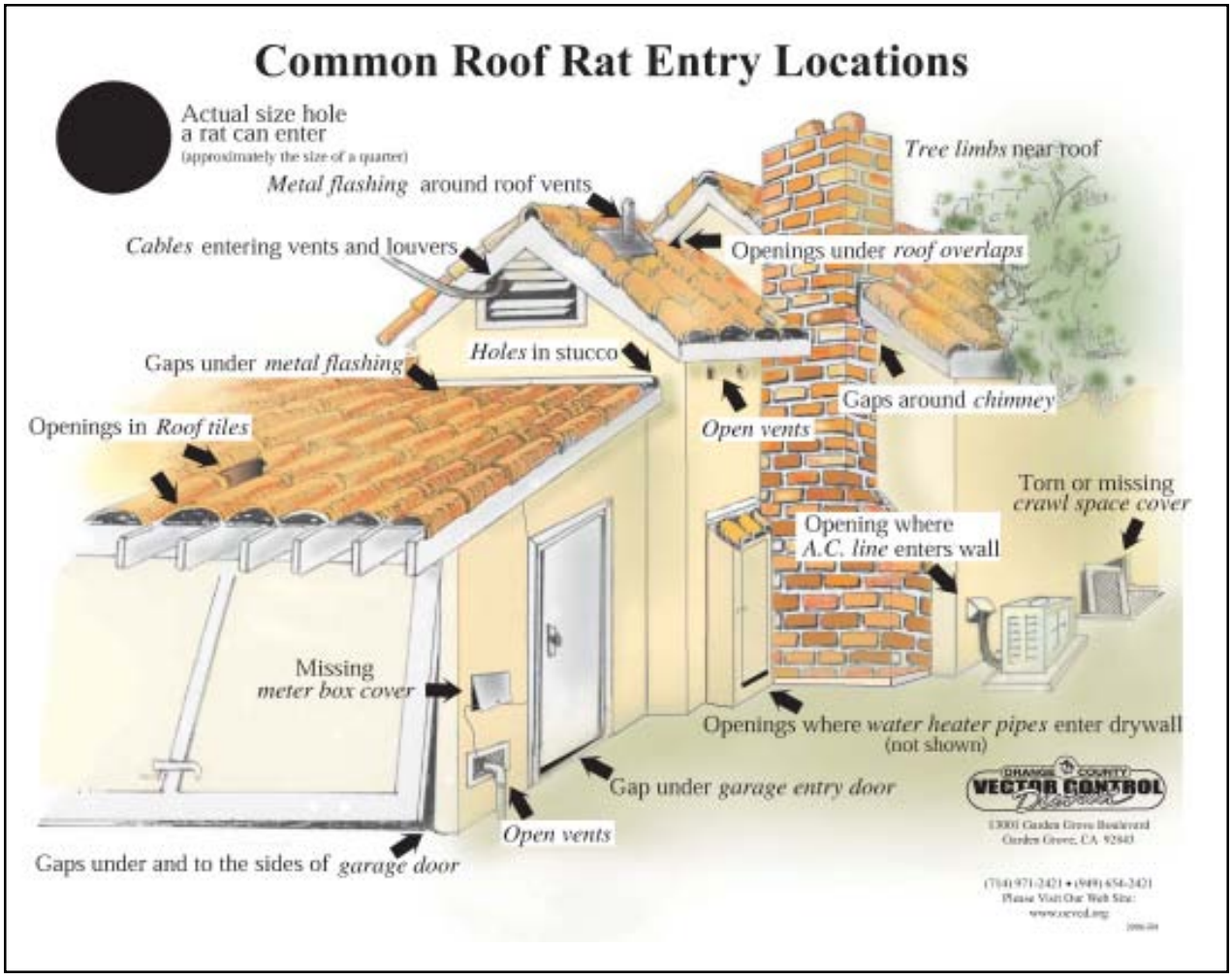

Figure 6-9

Interagency cooperation

Comprehensive commensal rodent control programs on a community-wide basis require careful planning and cooperation among numerous agencies, as well as education of, and participation by, the public. Responsibility for developing such a program usually rests with the local environmental health agency or a special vector control district which offers rodent control services. Cooperation and coordination should be implemented between the lead agency, various other governmental entities such as housing authorities, building and safety code enforcement, public works, waste disposal, planning and zoning, utilities, fire departments, and possibly private organizations concerned with the well-being of the public. It is essential that coordinating agencies establish firm commitments if long-term program objectives are to be achieved.

Public education

Integrated management concepts require innovative approaches. An important element in any comprehensive management program is to educate and motivate the community to actively participate in the program and provide the necessary support. Rodent prevention and exclusion on private property are usually the responsibility of the property owner or occupant. The wealth of educational material available should be selected and modified to suit the individual needs of each agency and the target community. Following a successful control effort, it is essential to continue surveillance to ensure that rodent problems are maintained at the accepted tolerance levels within the particular community. Continued education of the public on their responsibilities as residents and property owners will further secure the long-lasting effect of a rodent control program.

WILD RODENTS
(FAMILIES SCIURIDAE, HETEROMYIDAE, AND MURIDAE [SUBFAMILIES SIGMODONTINAE AND ARCIVOLINAE])

California has an abundance of wild native rodent species: 28 species in the family Sciuridae and 27 species in the subfamily Sigmodontidae. Several wild rodent species are important to public health as they are involved in maintenance or transmission of some serious and occasionally fatal infectious diseases to humans. Wild rodents of California that have public health or economic significance will be discussed below.

CALIFORNIA WILD RODENTS OF PUBLIC HEALTH IMPORTANCE

FAMILY SCIURIDAE

California ground squirrel (*Spermophilus beecheyi*)

Description: California ground squirrels are large rodents with generally gray-brown fur, often with lighter-colored flecks. Stripes are conspicuously absent. Total adult length is 35-50 cm (15-20 in) weight is 350-600 g (11-22 oz).
Reproduction: The breeding season varies greatly throughout California. Mating may occur as early as January and extend into June or July. Females produce one litter per year, with an average of 6-8 young per litter. The gestation period is 25-30 days. Young are weaned in about 6 weeks and scatter to new territories in April or June. They are full-grown in 7-8 months and may live five years or more in the wild.
Distribution: California ground squirrels are found throughout California with the exception of the Mojave and Colorado desert regions. They occur from sea level to about 3300 m (11,000 ft) elevation. In the warmer lowland areas, they may aestivate (summer sleep) in July and August, and will hibernate in late fall through winter at higher elevations, most of them emerging by March. Aestivation and hibernation vary greatly depending upon weather and habitat. The California ground squirrel is diurnal.
Food: California ground squirrels are omnivorous, preferring seeds, nuts, fruits, and green herbage. They also feed on proteinaceous foods such as insects, bird eggs, carrion, and in outdoor recreational areas they will eat almost any food offered to them by campers.
Habitat: They construct an elaborate burrow system with many entrances. Rocky areas, bases of trees, tree stumps, fallen logs and other ground cover are preferred sites for burrows. They prefer open areas, natural rangelands, meadows, pastures, grain fields, rocky ridges, embankments along roadsides, and terraced hillsides and other disturbed areas of newer housing developments. They avoid thick chaparral and dense woods, preferring open spaces. Home range is usually limited to a 140 m (450 ft) radius. Population density averages 2-4 squirrels per acre.
Significance: In large numbers can become a nuisance, especially in parks and campgrounds. Numerous burrows can destroy property and present a hazard of incapacitance to agricultural equipment or injury to humans and other animals. Can cause considerable loss of agricultural crops. The California ground squirrel is the most important wild rodent involved in plague epizootics in California. Sudden decreases in squirrel populations can indicate a plague epizootic and the need to implement control measures to reduce risk of disease transmission.

Belding's ground squirrel (*Spermophilus beldingi*)

Description: Belding's ground squirrels are stout with gray-brown fur, darker on the dorsum. Legs and underside are often pinkish. The tail is very short, reddish, and scantily furred. Total length is 26-30 cm (10-12 in) and weight is 125-300 g (5-10 oz).

Reproduction: Mating occurs soon after emergence from hibernation. Following a gestation period of about 28 days, the young are born in May to July.
Distribution: The Belding's ground squirrel ranges from Fresno, Tulare, and Inyo Counties along the high Sierra Nevada to the Oregon border. They are also prevalent north of the Sierra Nevada in the Cascade and Warner Mountains and the inter-mountain valleys of northeastern California. In the eastern Sierra Nevada, they range from 1500-3000 m (4900-9000 ft), and on the western side of the Sierra Nevada from the higher elevations down to 1900 m (6000 ft). They may aestivate during the summer and hibernate up to eight months of the year. Their period of greatest activity is from March through June. Timing of emergence may vary according to weather conditions.
Food: They feed on a variety of grasses, leaves, stems, bulbs, fruits, and seeds, and also insects and carrion.
Habitat: Prefer meadows, perennial grassy areas, alpine dwarf-shrub, bitterbrush, sagebrush, and chaparral with grassy understories. Their burrows are often found in open areas, commonly near water sources within patches of bunchgrass and shrubs. Belding's ground squirrels tend to occur in large, semi-colonial populations. They are diurnal, emerging from their burrows at sunrise and at dusk to avoid the midday heat. They tend to remain near their burrows.
Significance: Similar to California ground squirrel.

Golden-mantled ground squirrel (*Spermophilus lateralis*)

Description: Golden-mantled ground squirrels are medium-sized (total length, 23-30 cm [9-12 in]) with distinct white stripes, bordered by black stripes, on their sides. They appear superficially like a large chipmunk, but lack stripes on the sides of their face.
Reproduction: They mate from March-May. The gestation period is about 4 weeks and young are born in May-June. Females produce 1-2 litters per year, with an average of 5 young per litter. They reach sexual maturity in one year.
Distribution: Golden-mantled ground squirrels are abundant in forested areas of Jeffery, ponderosa, and lodgepole pines. They are abundant in montane forests and meadow edges of the Klamath, Siskiyou, Cascade, Sierra Nevada, and North Coast ranges, as well as the San Bernardino Mountains. They are found at elevations from 1500-3300 m (4800-11,000 ft). They will hibernate at the higher elevations from fall through winter, emerging in spring.
Food: Preferred foods include underground fungi, pine nuts, seeds, bulbs, flowers, insects, bird eggs, and carrion.
Habitat: They prefer to burrow under rocks, logs, tree stumps and other sheltered areas. Golden-mantled ground squirrels are very common at campgrounds. Their burrow systems can be elaborate but inconspicuous with little or no earth mounds at the two or more openings. They have a home range of 1-2 acres, with a territory of about 30 m (100 ft) around the burrow entrance. Like other species of ground squirrels, they are diurnal.
Significance: Similar to California ground squirrel. They are less of a problem in agricultural areas, but can cause damage in mountainous recreational areas. They can be significantly involved in plague epizootics in areas where they occur.

Yellow-bellied marmot (*Marmota flaviventris*)

Description: The marmot is a large squirrel: total length is 47-70 cm (18-28 in) and weight 1.2-4 kg (3-8 lb). Fur is rust-colored with lighter yellowish beneath. Tail is comparatively short.
Reproduction: They mate in early spring soon after emergence. Young are born in late spring following a gestation period of about four weeks. They have one litter per year with an average of 4-6 young per litter.
Distribution: Yellow-bellied marmots range from the Sierra Nevada and Cascades in southern Tulare County, north to the Oregon border. They are widespread in or near rocky areas within grasslands, meadows, sub-alpine conifers, alpine dwarf-shrubs and lodgepole pine forests. They are also common in the montane riparian, red fir, eastside pine, Jeffery pine, montane chaparral, sagebrush, bitterbrush and piñon-juniper habitats. At higher elevations, they hibernate from early

autumn to spring; populations at lower elevations may aestivate in June and July.
Food: They forage during mid-morning and again in the late afternoon on grasses, shrubs, seeds, flowers, leaves, and insects.
Habitat: Their burrow systems are usually under rocks, at the bases of trees. They have a home range from ½-5 acres. Marmots may congregate in colonies or pairs, or be solitary. Yellow-bellied marmots are diurnal.
Significance: Minimal public health significance.

Tree squirrels

Four species of tree squirrels occur in California:

Western gray squirrel (*Sciurus griseus*)
Eastern gray squirrel (*S. carolinensis*)
Eastern fox squirrel (*S. niger*)
Douglas's squirrel (*Tamiasciurus douglasii*)

Description: Tree squirrels are easily distinguished from the ground squirrels and chipmunks by their long and bushier tails, uniformly grayish to dark grayish in color, and lack of dorsal spots or stripes. Unlike the ground squirrels, tree squirrels do not possess internal cheek pouches.
Reproduction: They have 1-2 litters per year, with an average of 1-5 young per litter. In comparison to the other wild rodents, tree squirrels are long-lived and live up to six years in the wild.
Distribution: The Western gray squirrel is fairly common and more widespread in California than the other species of tree squirrels. It occurs in the conifer-hardwood forest habitats of the Klamath, Cascade, Transverse, Peninsula and Sierra Nevada Ranges. In the Sacramento valley they inhabit the riparian stands. They range along the coastal range from San Luis Obispo County south to the Mexican border.

The Eastern gray squirrel was introduced from the eastern U.S. into Golden Gate Park in San Francisco, and is established in niches in Calaveras, San Joaquin, and possibly Sacramento and Stanislaus Counties. They are also found in orchards, vineyards, urban areas, and possibly in foothill riparian areas.

The Eastern fox squirrel, also an introduced species, has been reported from Sacramento, Santa Cruz, San Mateo, San Francisco, Los Angeles, Ventura, and San Diego Counties. They are also found in Santa Clara, Merced, and from Lake County south to San Benito and Fresno Counties. They occur as focal populations in city parks and eucalyptus groves of urban areas and in foothill riparian, redwood-hardwood habitats in adjacent rural settings.

The Douglas's squirrel is commonly encountered in the conifer-hardwood and riparian habitats of the Sierra Nevada, Cascade, Klamath, North coastal and Warner Ranges, from sea level to 3300 m (11,000 ft) elevation.
Food: Tree squirrels feed mostly on the seeds and nuts of coniferous and deciduous trees. Leaves, buds, and fruits also occasionally comprise their diet.
Habitat: Tree squirrels are diurnal, most active in early morning or late afternoon. They are arboreal and usually nest high above ground in tree holes, enlarged woodpecker holes, and cavities of trees. They are not known to hibernate and are usually active year-round.
Significance: Tree squirrels can damage forest trees by removing bark or consuming cones and green stems. Around residences, they can damage power lines and destroy fruit and nut trees. In urban areas, they can damage buildings and other structures through gnawing into walls. Western gray squirrels frequently show evidence of infection with the Western equine encephalomyelitis virus (WEE) and thus may play a role as reservoir for WEE. They are also important reservoirs for the agents of relapsing fever and plague in mountainous areas of northern California.

Chipmunks (*Tamias* spp.)

Thirteen species of chipmunks occur in California:

Alpine chipmunk (*Tamias alpinus*)
Yellow-pine chipmunk (*T. amoenus*)
Merriam's chipmunk (*T. merriami*)
Least chipmunk (*T. minimus*)
California chipmunk (*T. obscurus*)
Redwood chipmunk (*T. ochrogenys*)
Panamint chipmunk (*T. panamintinus*)
Long-eared chipmunk (*T. quadrimaculatus*)
Shadow chipmunk (*T. senex*)
Siskiyou chipmunk (*T. siskiyou*)
Sonoma chipmunk (*T. sonomae*)
Lodgepole chipmunk (*T. speciosus*)
Uinta chipmunk (*T. umbrinus*)

Description: California chipmunks are smaller than other species of squirrel. Most species are brightly colored with four lightly colored stripes on their backs, separated by darker stripes, and dark stripes on the sides of their face. These stripes on the face distinguish chipmunks from golden-mantled ground squirrels. Although their tails are fully haired, they are not as bushy as the other species of squirrel.

Reproduction: Mating occurs from April to June. Females produce 1-2 litters per year, with 2-7 young per litter. Gestation is about 4 weeks and young are born in May-June. They are weaned in 6 weeks and appear aboveground a month following birth. They become sexually mature the following spring.

Distribution: Chipmunks are found in most mountain ranges in California. They are found in diverse habitats including coniferous forests, piñon-juniper woodland, oak woodland, sagebrush, chaparral and rocky areas with a brushy habitat. At the higher elevations, they go into winter hibernation in November and emerge in early spring. They are not known to aestivate during the warmer season. They are active longer in the year than the other species of squirrels.

Food: Chipmunks have the same food preferences as ground squirrels. Chipmunks do not build up large quantities of fat and depend on the cached food within their nests.

Habitat: Like most other ground squirrels, chipmunks are common in campgrounds and outdoor recreational areas and when abundant can be a nuisance to campers. Chipmunks are diurnal; activity begins about an hour before sunrise until shortly before sunset. They tend to escape the midday heat by remaining in shade or within their burrows. Their burrows are less conspicuous than those of other squirrels and burrow entrances are often inapparent, sheltered under rocks, ledges, tree stumps, and hollow logs. The tunnels may reach depths of up to 1.2 m (4 ft). Some chipmunks (e.g., *T. senex*) nest high in trees and are quite arboreal in activity.

Significance: If present in large numbers, chipmunks can become a nuisance by consuming grain and feed stores. They are an important indicator species for plague, though susceptibility varies with species. In northern California, *T. senex* and *T. quadrimaculatus* are relatively resistant to infection and may serve as reservoir species. In central and southern California, *T. amoenus* and *T. merriami* may function in a similar capacity.

Family Heteromyidae

Kangaroo rats (*Dipodomys* spp.)

Pocket mice (*Chaetodipus* spp., *Perognathus* spp.)

Approximately 10 species of pocket mice and 14 species of kangaroo rats occur in California.

Description: They are small to medium-sized rodents modified for life in arid and semi-arid environments.

Most have reduced forelimbs and enlarged hind limbs. Kangaroo rats are aptly named for both their appearance and their means of hopping on their enlarged hind limbs. Tail is often elongated. Cheeks have fur-lined pouches.

Reproduction: Breeding is highly dependent on food availability. In years with abundant food, females may have 2-3 litters of 5-7 young each. Number of litters and young per litter may be significantly reduced in poor years. Young are born in the spring and early summer.

Distribution: Typically abundant in sparsely vegetated, seasonally arid or desert areas. Most occur in the southeastern and northeastern desert regions of California, but a few occur in the Central Valley and along the coastal regions of southern California. All are nocturnal. May hibernate in the winter and aestivate in the hot, dry summer.

Food: Seeds and vegetation comprise their diet. Fur-lined cheek pouches are used to transport seeds to storage caches. Water is obtained through metabolism of oils in seeds.

Habitat: Occur in sparsely vegetated and loose, sandy soils. Generally reside in underground burrows during the day, often plugging the entrance.

Significance: Kangaroo rats can serve as a reservoir for *Borrelia burgdorferi*, the bacterial cause of Lyme disease. Six species and subspecies of kangaroo rat are listed as endangered or threatened by the U.S. Fish and Wildlife Service. Persons conducting rodent surveillance and collection should be skilled in identification of these species and familiar with the regulations regarding their capture and handling.

FAMILY MURIDAE, SUBFAMILY SIGMODONTIDAE

White-footed mice (*Peromyscus* spp.)

Six species of *Peromyscus* mice occur in California:

Brush mouse (*Peromyscus boylii*)
California mouse (*P. californicus*)
Canyon mouse (*P. crinitus*)
Cactus mouse (*P. eremicus*)
Deer mouse (*P. maniculatus*)
Piñon mouse (*P. truei*)

Description: All *Peromyscus* species are small (total length, 15-30 cm [6-12 in]), mouse-like rodents. Eyes are dark and beady; ears are membranous and often large. Fur is variably brown, rust, or gray on dorsum, white on ventrum and feet. Deer mice are relatively small (15-20 cm) with a bicolored tail that is <50% of body length. The piñon mouse is moderately large (18-20 cm) with very large ears. The California mouse is the largest of the *Peromyscus* spp. at 22-29 cm.

Reproduction: They have a tremendous reproductive capability, usually breeding year-round. The females are sexually mature at 5-6 weeks. *Peromyscus* spp. have 1-4 litters per year with 1-8 young per litter. Gestation period is 22-25 days. Most breed from spring through early fall; some species may breed year-round.

Distribution: The deer mouse is the most abundant *Peromyscus* species and is found throughout California and most of North America, except the southeastern states.

The California mouse is found along the coast from the San Francisco Bay to the Mexican border. It ranges partially eastward along the south coastal ranges, and from the central portion of Kern County northwards to Mariposa County along the lower elevations of the western Sierra Nevada. *P. californicus* are found usually below 1600 m (5000 ft) elevations, but have been recorded from as high as 2800 m (8000 ft).

The piñon mouse ranges from sea level to 2600 m (8600 ft). They are not known to occur in the Central Valley, most of the Mojave Desert, the Owens Valley, or the higher elevations of the Sierra Nevada.

Food: *Peromyscus* spp. are omnivorous, feeding on a wide variety of items including seeds, nuts, acorns, fruits, leaves, fungi, and insects.

Habitat: *Peromyscus* can be found in a variety of habitats, especially woodlands, grasslands, brush, and chaparral. Deer mice are found in virtually every dryland habitat, from the desert areas to above the timberline, in grazed as well as ungrazed sagebrush habitats, and coastal grasslands and strand. Deer mice prefer to nest under cover of brush piles, rock ledges, logs, and tree litter. Occasionally, when open fields are disturbed, they will infest existing buildings. The California mouse is most prevalent in hardwood forests of the southern coastal range. The piñon mouse can be found in open woodlands of the coastal range, Sierra Nevada, and Cascades.

Significance: *Peromyscus* mice serve as reservoirs for several infectious diseases of public health importance. Deer mice are the principal reservoir for Sin Nombre virus, the cause of hantavirus pulmonary syndrome in the western United States, which they shed in urine

and feces. Other *Peromyscus* mice may also become infected with Sin Nombre virus, but their capacity to maintain infection and shed virus in urine and feces is unknown. *Peromyscus* mice are also a reservoir for the bacteria that cause plague and can serve as a source of infection for epizootics among susceptible rodents (e.g., chipmunks). *Peromyscus* mice are involved in the enzootic maintenance cycle of *Borrelia burgdorferi*, the Lyme disease spirochete, in California, though probably to a lesser extent than woodrats. *Peromyscus* mice may also be involved in the maintenance of agents of other tick-transmitted diseases, such as *Ehrlichia* and *Babesia*, in California.

Woodrats (*Neotoma* spp.)

Three species of woodrats occur in California:

Dusky-footed woodrat (*Neotoma fuscipes*)
Desert woodrat (*N. lepida*)
Bushy-tailed woodrat (*N. cinerea*)

Description: Woodrats resemble a large (total length, 26-44 cm [10-17 in]) deer mouse with prominent eyes and ears. Fur is gray to grayish-brown on dorsum and pale or white beneath. The tail is faintly bicolored and sparsely haired in *N. fuscipes*, distinctly bicolored in *N. lepida*, and bushy in *N. cinerea*.

Reproduction: Breeding season is usually from mid-spring to early autumn. Usually one litter per year, though *N. fuscipes* may have up to five if conditions permit. Average of 3-4 young per litter.

Distribution: The dusky-footed woodrat is a common inhabitant of the coastal range of California, from the Oregon border to the Mexican border, the northern interior, and the entire western slope of the Sierra Nevada. They are absent from agricultural and open grasslands of the Central Valley.

The desert woodrat is found in the Great Basin area of eastern Modoc to southeastern Lassen Counties, throughout southern California, and northwards along the Coastal Range to San Francisco Bay. They range throughout the Mojave Desert to the northern border of Inyo and southern tip of Mono Counties, from the Tehachapi and San Bernardino Mountains to north-central Tulare County.

The bushy-tailed woodrat occurs from the Oregon border south through the Trinity Mountains, the Central Sierra Nevada, and south to northeastern Tulare County. It is also found in southeastern Mono and north-central Inyo counties.

Food: They forage on the ground as well as on bushes and trees, feeding on a wide variety of vegetation.

Habitat: *N. fuscipes* prefer the moderate canopies of forest and chaparral; in the north, they are prevalent in juniper woodlands and oak chaparral. *N. lepida* prefer desert habitats, including Joshua tree, piñon-juniper, chaparral, and sagebrush. *N. cinerea* are found in rocky outcrops, rimrock and rockslide areas of high mountains, riparian, hardwood, conifer, and other montane habitats. *N. cinerea* is also common in lava rim and lava cave habitat in northern California. Woodrats build elaborate conical-shaped huts consisting of sticks and leaves, located at the base of trees or shrubs for *N. fuscipes*, cactus or creosote bushes for *N. lepida*, and at the entrance to rocky crevices for *N. cinerea*. Some woodrat huts reach a height of 2.5 m (8 ft). Woodrats are active year-round, mostly nocturnal, but may be active during the day.

Significance: Principal California reservoir for *Borrelia burgdorferi*, the agent of Lyme disease. May also serve as reservoir for *Ehrlichia* spp and the arenavirus Whitewater Arroyo. Dusky-footed woodrats are an important host for the kissing bug, *Triatoma* sp., the bite of which can cause a severe allergic reaction or possibly transmit the agent of Chagas' disease. Woodrats are in general susceptible to plague and may serve as an early warning indicator for epizootics. Bushy-tailed woodrats are involved in plague epizootics in the lava rim habitat of northern California.

Western harvest mouse (*Reithrodontomys megalotis*)

Description: Buff or brown on top; white underneath with occasionally a buffy spot on the chest. Tail also bicolored. Ears fairly large. Total length is 11-15 cm (4.5-6 in).

Reproduction: Breeds in spring and possibly again in autumn. Usually 3-5 in litter.

Distribution: Throughout California, from lowlands to midrange elevation.
Food: Grasses and seeds.
Habitat: Grasslands and other uncultivated areas where grasses and weeds are present. Nests made of dense grasses and found on the ground or in a bush slightly above ground.
Significance: Reservoir of El Moro Canyon virus, a hantavirus not yet associated with any human disease.

FAMILY MURIDAE, SUBFAMILY ARVICOLINAE

California vole (*Microtus californicus*)

Description: Small (total length, 16-21 cm [6-8 in]), darkly colored rodent with small eyes and partially furred ears. Tail less than one-third of body length.
Reproduction: May breed throughout the year. Gestation period is 20 days, 2-5 litters per year, with an average of 4 young per litter. Females reach sexual maturity in 1 month.
Distribution: Common from Shasta County to San Diego County, from the Sierra Nevada and the Cascades west to the Pacific coast. They are active year-round.
Food: Herbivorous, preferring leaves, grasses, and fresh seeds. They are capable of causing considerable damage to field crops and orchards.
Habitat: Preferred habitats are wet meadows, montane riparian, and dense annual grasslands. They seek cover in the dense grass, brush piles and logs. Burrows are shallow and generally built in soft soil with obvious pathways.
Significance: Reservoir of Isla Vista virus, a hantavirus not yet associated with any human disease. Also a reservoir species for plague and tularemia in some regions of California.

PROTECTED STATUS

A collecting permit must be obtained from California Department of Fish and Game before surveillance or control actions are initiated for any rodent species, though certain disease surveillance activities may be exempted from such requirements. Most of the ground squirrels, chipmunks, *Peromyscus* mice, voles, and woodrats are classified as non-game mammals by the California Fish and Game Code. Because they are considered economic and public health pests, they may be taken at any time or in any manner by the owner or tenant of the premises. They may also be taken by officers or employees of the California Department of Food and Agriculture or by federal, state, or county officials or employees when acting in their official capacities pursuant to the provisions of the Food and Agriculture Code pertaining to pests.

Many species of kangaroo rat are listed as state or federal Endangered Species and are thus restricted in their collection or harassment. Some subspecies of pocket mouse, woodrat, and vole are considered California State Species of Special Concern. Although there are currently no restrictions on their collection, protection designations change frequently and one should discuss the status of particular species with California Fish and Game officials when obtaining the collection permit and before initiating any rodent collection or control.

PUBLIC HEALTH SIGNIFICANCE

Plague

Wild rodents are the primary reservoir for *Yersinia pestis*, the plague bacillus, in California. Numerous rodent species have been associated with plague in California, including chipmunks, ground squirrels, woodrats, *Peromyscus* spp., voles, and, formerly, *Rattus* spp. In general, the California ground squirrels are an amplifying host for the plague bacillus (mortality usually occurs when they are infected), but in a few selected areas of California they may serve as a reservoir. Historical evidence indicated plague susceptibility among Belding's ground squirrels, but there has been little additional evidence since the 1940s. Chipmunks and golden-mantled ground squirrels are frequently involved in plague epizootics in California's mountainous regions. Several species of fleas infest California ground squirrels; the most important species relative to plague transmission are *Oropsylla montana* (formerly *Diamanus montanus*), *Hoplopsyllus anomalus* (ground squirrels), and *Eumolpianus eumolpi* (chipmunks). Most human cases of plague in

California are associated with a bite from one of these species of rodent flea.

Epizootics of plague among colonies of wild rodents pose a threat to economic as well as physical health of individuals in the area. If the risk to humans is deemed sufficiently great, restriction of public access to and activity in the affected area can be imposed by public health officials until such time as the risk is considered abated. In California, plague epizootics are often identified in parks and outdoor recreational areas; prevention and control measures that temporarily bar human access can negatively impact many local businesses which rely on seasonal visitors.

Tick-transmitted diseases

Wild rodents are the known or suspected maintenance host for several pathogens that are transmitted to humans by tick bite. The dusky-footed woodrat is the principal reservoir for *Borrelia burgdorferi*, the spirochete that causes Lyme disease in humans. Woodrats may also serve as a reservoir for the rickettsiae (*Ehrlichia* spp.) that cause ehrlichiosis in humans. Chipmunks which enter and build nests in mountain cabins are a common source of soft ticks that transmit relapsing fever spirochetes to humans who later occupy the infested building after the rodents have abandoned it. Small rodents (e.g., *Peromyscus* spp.) are a common feeding host for larval and nymphal ticks and thus areas where these rodents are abundant may support a larger population of ticks.

Hantaviruses

The deer mouse is the sole reservoir for Sin Nombre, the virus that causes hantavirus pulmonary syndrome in the western United States. Other species of *Peromyscus* may become infected with Sin Nombre virus, but their capacity to serve as competent vectors is unknown. Deer mice acquire the virus as juveniles and are believed to remain infected for life. Deer mice do not appear to be adversely effected by the virus. The virus is shed in urine, feces, and possibly saliva. Humans are most susceptible to infection when they disturb enclosed, poorly ventilated areas contaminated with rodent excreta. Because of their ubiquity in western North America and propensity to enter human dwellings in search of food and nesting materials, deer mice and the hantavirus they carry are a considerable public health concern in California.

The Western harvest mouse (*R. megalotis*) has been identified as a carrier of another strain of hantavirus, El Morro Canyon. Isla Vista, another hantavirus strain, has been found in the California vole (*M. californicus*). There is no evidence to date that either of these strains of hantaviruses is pathogenic to humans. The cotton rat, *Sigmodon hispidus*, is the reservoir of Black Creek Canal virus in the southeastern United States—a strain of hantavirus which has been associated with a few cases of hantavirus pulmonary syndrome. No case of hantavirus pulmonary syndrome in California has been associated with cotton rats.

MANAGEMENT AND CONTROL

Control of wild rodents on a large scale is time-consuming, expensive, and usually unsuccessful, and therefore is not generally recommended. However, when localized populations of certain species, such as California ground squirrels, golden-mantled ground squirrels, Belding's ground squirrels, or chipmunks become a nuisance or potential threat for disease transmission to humans, efforts to reduce population size may be attempted. Many of the techniques previously discussed for control of commensal rodents may also be implemented for localized populations of wild rodents. A Special Local Needs (SLN) registration may be required for use of some chemical control agents on wild rodent populations. SLNs are issued to the California Department of Public Health (CDPH) or another cooperating agency by the California Department of Pesticide Registration. Although it is the responsibility of the property owner or the resident of the premises to initiate the control measures, these activities must be carried out under a permit issued by the county agriculture commissioner, and under the appropriate supervision of the commissioner or other certified personnel of the local agriculture department, vector control agency, local health departments, or CDPH.

Safety

As rodent species are ubiquitous in California, the potential for contact between humans and rodents is significant. While only a few California rodent species have been specifically associated with human disease, it is a good general policy to consider any rodent as a potential source of disease. Activities that pose a potential risk for rodent-borne diseases include:

- Occupying or disturbing rodent-infested areas during outdoor recreational activities.
- Occupying buildings or dwellings that were previously vacant.

- Visiting or residing in areas where there is a substantial sudden change in rodent population density.
- Inhabiting or cleaning rodent-infested dwellings, barns, outbuildings, intermittently occupied summer homes/cabins.
- Working in rodent-infested structures.

For the general public, the opportunity for rodent contact, and transmission of rodent-borne pathogens, is greatest in and around the home or during outdoor recreational activities. The continuing trend of encroachment of housing developments into previously wild areas, and the alteration of the natural ecosystems of the California landscape, have increased the risk of human exposure to zoonotic diseases. The mission of public health professionals is to prevent potential disease outbreaks in the human population. For rodent-borne diseases, information can be compiled through intensive and continued surveillance of the animal reservoir populations, as well as conducting ecologic studies and epidemiologic surveys. This knowledge base will aid local agencies in developing guidelines for safety precautions requested by the general public. Some of the areas in which recommendations can be made to the public on prevention of rodent-borne diseases include:

- Recommendations on rodent and ectoparasite suppression techniques.
- Good hygiene and household sanitation practices.
- Use of gloves and respirators or dust-masks.
- Environmental modification and rodent exclusion recommendations.
- Guidance on proper clean-up of rodent-contaminated areas and household items.
- Proper disposal of possibly contaminated items, such as rodent carcasses, nesting materials, and excreta.
- Avoiding contact with rodents.
- Use of currently recommended disinfectants such as 10% household bleach, 5% hospital-grade Lysol®, and other general-purpose household disinfectants.

For some individuals (e.g., field biologists, vector control technicians), occupational activities can pose a significant risk of contact with infected rodents. Persons with occupational exposure to rodents need to have a basic understanding of the complexity of factors that contribute to creating a hazardous situation. These factors include disease ecology, patterns of seasonal occurrence, nature of the etiologic (pathogenic) agent, species of rodent host and arthropod vectors, and patterns of human activity and behavior. A detailed discussion of safety guidelines for persons conducting disease surveillance in rodents is presented in Chapter 7 of this training manual.

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Chapter 7

SAFETY GUIDELINES FOR HANDLING AND SAMPLING RODENTS

Richard M. Davis

INTRODUCTION

Infectious disease surveillance

In the spring of 1993, a cluster of human cases of adult respiratory distress syndrome in the southwestern United States came to the attention of public health officials. The rapid progression of the disease and the high case-fatality caused considerable alarm. Numerous agencies working together rapidly identified the infectious agent and the mechanism for its spread. The microorganism causing the illness was identified as a hantavirus that infected rodents. The virus has since been named Sin Nombre virus (SNV) and the associated human disease called hantavirus cardiopulmonary syndrome (HCPS). The principal reservoir species in the Southwest is the deer mouse, *Peromyscus maniculatus*. Although the deer mouse is the primary reservoir of SNV, other species of rodents may serve as competent hosts for SNV or other hantaviruses.

The primary mode of infection to humans is believed to be inhalation of infectious airborne virus excreted in urine, feces, and saliva from infective rodents. Exposure is most likely to occur when contaminated soil, litter, or nesting materials are stirred up into the air within a poorly ventilated space.

Hantaviruses in the United States are of significant public health importance because of their potential for severe and often fatal disease. Epidemiologic surveys and ecological studies of reservoir populations are necessary to identify areas of risk and to help establish guidelines for risk reduction.

Disease surveillance cannot be achieved by simple observation of rodents, but necessitates their capture and handling. Individuals who handle rodents as part of surveillance efforts place themselves at increased risk of contact with infectious material. Persons who engage in these surveillance activities should educate themselves on proper safety precautions and adhere strictly to them to reduce their risk of infection.

Safety guidelines objectives

These guidelines are intended for persons who handle rodents as part of ecological and epidemiological studies of hantavirus and other rodent-borne diseases. The procedures outlined are appropriate for any study of rodent or small mammal populations in which exposure to an infectious zoonotic agent is possible. Individuals and agencies engaged in these activities are encouraged to review additional detailed information available in the references listed at the end of this chapter.

In addition, individuals must obtain a Scientific Collecting Permit from the California Department of Fish and Game. While there is no fee associated with this permit for government and local agency employees, it is nonetheless required before any surveillance activities may begin.

Trapping and processing rodents

In addition to knowledge of the risks posed from handling live and dead rodents, principles of humane treatment of mammals should be practiced by all persons conducting disease surveillance and research.

Figure 7-1

Care and handling of rodents. Mammals should always be collected and handled using humane procedures and professional judgment that maximize the scientific data obtained from a minimum of individuals or samples, while causing minimal pain or distress. Trapped animals should be collected and processed in a timely manner to minimize the stress of capture. After processing, animals should be released at their site of capture as soon as possible.

Threatened habitats and species. Local, state, and federal regulations govern scientific collecting, transport, and possession of all specimens taken. Individuals collecting mammals for scientific study must comply with all relevant laws and regulations. Ignorance of the law or inadvertent violation of regulations is never a valid excuse and may result in prosecution. Persons who survey mammals in threatened habitats must proceed with sensitivity and careful judgment so that populations will not be adversely affected. The welfare of the threatened species should be the foremost concern.

Collecting and transporting rodents. Live-capture traps, suitable for the rodent species to be captured, are preferred over kill-type traps for collecting specimens when blood samples are required. Traps in which rodents were captured should be disinfected as part of normal processing cleanup. No special clothing or equipment is required for setting and baiting clean traps, although a long-sleeved shirt, long pants, socks, and sturdy lace-up shoes are recommended for all field work.

Workers checking or retrieving traps should wear rubber gloves in addition to normal field attire. When a closed trap is encountered, workers may carefully peer inside while holding the trap at arm's length. Traps containing rodents of the desired species should be placed in a plastic bag before transporting to the processing site, and kept out of direct sunlight to prevent overheating (Figure 7-1). Gloved hands should be washed or disinfected, and hands thoroughly cleaned after removing the gloves. Transport bagged rodents in the back of a pickup truck or other compartment isolated from passenger sections.

Choosing a processing site. It is essential that an adequate processing area be located before trapping is begun. The field processing site should be in a secluded area, away from other humans or domestic animals. A table and other work surfaces should be of a nonporous material that can be easily disinfected and cleaned. Weather permitting, outdoor processing is preferred because of greater ventilation and penetration of natural ultraviolet light. All required equipment and supplies should be placed inside the processing area within easy access of protected workers. Only workers wearing proper safety attire should be permitted in the designated area once processing begun (Figure 7-2). If processing must be conducted indoors, there should be adequate ventilation to the outside.

Figure 7-2

Personal protective wear

Respirators. Because the primary mode of transmission of hantavirus to humans is through inhalation of infectious airborne virus, it is important that anyone working closely with potentially infected rodents wear a proper respirator. There are several different types of respirators that provide adequate protection against viral particles: maintenance-free (disposable) half mask respirators, reusable half mask respirators (Figure 7-3a), full-face respirators, and supplied-air respirators (Figure 7-3b). Regardless of which type is used, the respirator should fit well, not be clogged or damaged, and provide adequate filtering of the smallest particles (N-100 or HEPA filter designation). Some of the respirators require a respiratory fit test and a medical evaluation. The newer (and more expensive) supplied-air respirators reduce the dangers of a poor fit, especially for users with facial hair, by supplying a continuous flow of filtered air from a battery-powered source through a head covering, across the face, and out the base of the head covering. These supplied air units (PAPRs, powered air purifying respirators) are more comfortable than the other half- or full-mask negative pressure respirators, and also provide protection for the head, eyes, nose, and face. Respirators should receive regular maintenance and be checked for proper functioning before entering a hazardous area.

Figure 7-3a

Figure 7-3b

Clothing. While conducting any field work it is preferable to wear a long-sleeved shirt, long pants, socks, and shoes or boots. Disposable or non-disposable coveralls provide an additional level of safety while handling rodents (Figure 7-4). If the coveralls are non-disposable, they should be removed soon after completing rodent handling activities, placed in a plastic bag, and thoroughly laundered with hot soapy water before reuse.

Figure 7-4

Gloves. When handling traps that contain captured rodents or are potentially contaminated by rodents, a pair of thick rubber gloves should be worn. When handling rodents, disposable latex gloves (or another thin type of material that will not compromise dexterity) should be worn (Figure 7-5). If a tear occurs, a quick spray of disinfectant should be applied and a new glove placed over the tear. Gloves should be sprayed with a disinfectant before removal and hands washed after their removal.

Figure 7-5

Eye protection. Individuals wearing a half mask respirator should also wear additional eye protection (e.g., safety glasses or goggles).

Other. Rubber boots, disposable shoe covers, and other protective wear can be considered for use (Figure 7-6); all materials should be either disposable or readily disinfected.

Figure 7-6

Anesthesia

Invasive and non-invasive techniques can be used to sample tissues from live mammals. Humane considerations, professional judgment, and the scientific data desired will help determine which technique is appropriate. Any procedure that causes pain or significant distress mandates the use of an appropriate anesthetic.

Animals should not be handled outside of traps unless they have been anesthetized. Inhalant anesthetics are recommended over injectables because they reduce or obviate the use of needles and ensure that ectoparasites are also immobilized. Carbon dioxide (dry ice) is not recommended as it may stimulate flea activity. If an animal escapes prior to anesthesia, attempts to recapture it by hand should be avoided.

Animals in live-capture traps may be anesthetized by placing the entire trap into a plastic bag containing gauze or cotton soaked with an inhalant anesthetic. Alternatively, animals may be run into an anaesthetic chamber, such as a glass mason jar, containing the anaesthetic (Figure 7-7). Steps should be taken to prevent contact between the rodent and the liquid anaesthetic agent.

Figure 7-7

Anesthetics used in rodent surveillance are potentially hazardous to workers. Therefore, personnel should take care to minimize inhaling anesthetic during these procedures. Use inhalant anesthetics in well-ventilated areas and keep containers tightly closed. Containers should be kept away from flame as should plastic anesthesia bags, anesthesia chambers, and cotton or gauze which has been wetted with anesthetic. Extreme caution should be used with chloroform, as it is toxic and a potential carcinogen. Halothane has a potential for hepatic damage, and ether is flammable and explosive. Metofane is no longer available. Isoflurane is becoming a more common choice because of its safety and larger therapeutic margin of error. These agents should be stored securely and away from passenger compartments of vehicles.

Blood collection

Although aseptic techniques are difficult in the field, cleanliness in all surgical or invasive techniques is essential to minimize the potential for infection and to provide reliable biological samples.

Obtaining blood samples. Small amounts of blood can be obtained from rodents by an incision at the tip of the tail. Moderate blood samples can be obtained from the retrobulbar sinus of anesthetized rodents, but this technique requires practice and dexterity (Figure 7-8). However, sampling from the retrobulbar sinus has the advantage of reducing the risk of needle-stick injury to the worker and being least injurious to the rodent. Cardiac puncture can also yield moderate amounts of blood from anesthetized rodents with low risk of mortality (Figure 7-9). Because some species are highly sensitive to anesthesia and cannot be bled from the orbital sinus, the use and choice of anesthesia and technique should be weighed against the risk of mortality.

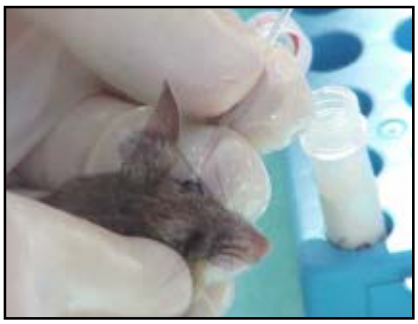

Figure 7-8

Figure 7-9

Syringes and syringe safety. All syringes and needles should be kept in their sterile condition and never be reused. Match the syringe and needle size to the approximate size of the rodent. For small rodents (e.g.,

deer mice) it is best to use a 1cc syringe with a 5/8-inch 25 gauge needle or approximate equivalent. For larger rodents (e.g., woodrats and squirrels) it is best to use a 3cc syringe with a 1-inch 23 gauge needle or approximate equivalent.

Extreme caution should be used to avoid needle-stick injury. Use a clean needle and syringe for each animal, never replace the plastic cap on the needle, never remove the needle from the syringe after use, and never place your hand or finger in the path of the needle. Dispose of the needle and syringe in a leak-proof, puncture-resistant sharps container immediately after use (Figure 7-10). Use extreme care when expelling the blood sample into a blood tube/vial or onto a filter paper strip to avoid splashing or aerosolization of blood.

Figure 7-10

If a needle stick, bite, or other injury which breaks the skin occurs, stop work and cleanse the injury site with disinfectant. Leave the processing area, remove the glove or other skin covering, wash hands with soap and water while trying to express blood or fluid from the wound, and clean the site of injury thoroughly with disinfectant. Report the injury immediately to your supervisor. If swelling, pain, or discharge from the injury site occurs within 7-10 days, or fever, muscle aches, or other influenza-like symptoms appear within 45 days, seek medical attention and alert the attending physician to the possibility of infection.

Clean-up and Disinfection

Site cleanup. After the processing of rodents has been completed, the processing area and all work surfaces, equipment, and remaining supplies should be sprayed and wiped down with disinfectant. All equipment should be allowed to air dry before handling and storage. All soiled paper towels, trap bedding, disposable gloves and clothing, and any remaining bait or feces should be placed in a plastic bag, sealed, and disposed. If processing was done indoors, the floor should be sprayed with disinfectant and the area well-ventilated before permitting access to persons without respirators.

Trap cleanup. Traps previously occupied by rodents should be disinfected and cleaned before reuse. With Sherman traps, this process is best done with 5-gallon buckets, one with disinfectant and another with rinse-water. A brush will aid in removing fecal material (Figure 7-11). After traps have been cleaned, disinfected, and rinsed, they should be allowed to air dry, preferably in the sun, before reuse or packing them away (Figure 7-12). When cleaning traps, wear heavy rubber gloves over disposable gloves to avoid sharp edges and any potential tears or punctures. Safety glasses or goggles should be worn to prevent splash-back of disinfectant into the eyes. Larger Tomahawk-type traps can be sprayed with disinfectant, cleaned, rinsed, and air-dried. Studies have demonstrated that the use of disinfectants is not a deterrent to trap success.

Figure 7-11

Figure 7-12

Disinfectants. Careful use of appropriate disinfectants is one of the simplest and most effective means of reducing the risk of the spread of hantavirus. Hantaviruses are sensitive to dilute hypochlorite solutions (10% household bleach), quaternary ammonium solutions, phenolics, detergents, and most general-purpose household disinfectants.

An appropriate disinfectant should be used for thefollowing:

- to decontaminate traps that contained or were soiled by rodents,
- to clean gloved hands before removal and disposal of gloves,
- to disinfect any instruments used while processing rodents,
- to disinfect or wipe down any work surfaces or other items which might have become contaminated while processing rodents.

Household bleach is inexpensive and readily available. A 1% solution (1:100 dilution) of bleach is an adequate surface disinfectant for wiping down potentially contaminated surfaces. For heavily soiled areas or items, a 10% solution (1:10 dilution) is more effective. A bleach solution breaks down, so it should be made fresh each day. Lysol® is an effective disinfectant, which is stable for extended periods. A 5% solution (1:20 dilution in tap water) of hospital-grade Lysol can easily be made in the field and can be used to disinfect materials and equipment that may corrode with bleach (e.g., metal traps). Use any hospital-grade disinfectant according to label instructions. Five-gallon plastic buckets are convenient for cleaning and disinfecting Sherman traps in the field (Figure 7-13). A canister (handcan) sprayer is better for larger traps (Figure 7-14). A plastic spray bottle is a convenient method of delivering disinfectant to hands, work surfaces, instruments. After removing gloves, hands should be vigorously washed with soap and water.

Figure 7-13

Figure 7-14

Transport and disposal of hazardous waste. All bagged waste material should be disposed of in accordance with state and local requirements. Full sharps containers should be turned over to a local hospital or laboratory for disposal in accordance with regulations for infectious materials.

Packing and shipping specimens. Packing and shipping of biologic specimens are strictly regulated, and should be done in accordance with the latest regulations. Contact the laboratory or agency designated to receive the specimens for appropriate instructions, and to advise them prior to shipment. All persons who transport infectious or potentially infectious material must carry a current hauling permit from the California Department of Public Health Medical Waste Management Program.

Other infectious disease concerns. Personnel conducting field work and collecting and handling small mammals are at increased risk for many zoonotic infections. Precautions to prevent infection with hantavirus should also be effective in preventing other infections spread by aerosol or direct contact. Rat bite fever is a systemic infection which can result from the bite of an infected rodent; risk can be minimized by handling only anesthetized rodents.

Several infections may be transferred from animals by ectoparasites (e.g., plague, Colorado tick fever, Lyme disease, babesiosis, ehrlichiosis, Rocky Mountain spotted fever, and tularemia). Efforts to prevent tick and flea bites are important. When processing animals, disposable gloves should be pulled over the cuffs of clothing and taped to deny fleas access to the arms.

SUMMARY

These guidelines are for persons performing ecological and epidemiological studies involving populations of rodents which are potentially infected with hantavirus. However, the procedures outlined are appropriate for any study of rodent or small mammal populations when an infectious zoonotic agent which can cause mortality or severe illness is involved. It is generally best to treat all rodents and other small mammals as though they can transmit a disease. Strict adherence to these procedures will significantly decrease risk of disease transmission to persons conducting small mammal surveillance.

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Chapter 8

ZOONOTIC DISEASES ASSOCIATED WITH CALIFORNIA VERTEBRATES

Curtis L. Fritz

VIRAL DISEASES

Rabies

Agent: Rabies virus (*Lyssavirus*).
Reservoir: Principally bats and skunks in California, though any mammal can become infected and transmit the virus, including domestic pets and livestock.
Transmission: Contamination of bite or scratch with virus-laden saliva of rabid animal.
Symptoms/signs: Incubation usually 3-6 weeks, but can be several months. Symptoms are initially headache, fever, malaise. Progressing to weakness, paralysis, convulsions, delirium. Invariably fatal 2-7 days after onset.
Diagnosis: Characteristic staining of brain tissue.
Treatment: None once symptoms arise. Prophylaxis (i.e., vaccination) prior to or immediately following exposure to an infected animal is highly effective.
Significance: Fifteen human deaths due to rabies have occurred in California since 1975. Between 300 and 500 cases of rabies in terrestrial mammals are reported each year in California. Skunk and bat strains of rabies virus are endemic in California and these mammals represent approximately 80% and 14%, respectively, of rabies-positive animals detected annually.

Hantavirus cardiopulmonary syndrome (HCPS)

Agent: Sin Nombre virus (SNV) in western United States.
Reservoir: Deer mice (*Peromyscus maniculatus*). Possibly, to a lesser extent, other *Peromyscus* spp.
Transmission: Inhalation of aerosolized virus-laden urine or feces of deer mice.
Symptoms/signs: Incubation generally 1-2 weeks, rarely up to 6 weeks. Symptoms are initially flu-like: fever, headache, muscle pain, gastrointestinal upset. Progress to rapid onset of severe respiratory distress. Case-fatality ~40%.
Diagnosis: Serology or identification of SNV in lung tissue of fatal cases.
Treatment: None specific. Support of cardiopulmonary function.
Significance: 48 cases of HCPS identified in California residents (ca. October 2008); approximately half with exposure likely in eastern Sierra Nevada. Deer mice prevalent throughout the state; overall SNV infection is ~11%.

Lymphocytic choriomeningitis (LCM)

Agent: LCM arenavirus.
Reservoir: House mouse (*Mus musculus*).
Transmission: Virus is shed in rodent's urine and feces. Humans infected by consumption or inhalation of virus-contaminated excreta or contact with infected rodents.
Symptoms/signs: Diverse symptoms include fever, headache, and muscle pain. Rash, neurologic symptoms, and arthritis may occur in some patients. Death occurs rarely.
Diagnosis: Isolation of virus from blood or spinal fluid; serology.
Treatment: None.
Significance: No cases of LCM have been reported in California since it was made a reportable disease in 1996.

Arboviral encephalitides

Agent: West Nile virus (WNV), Western equine encephalomyelitis virus (WEE), St. Louis encephalitis virus (SLE).
Reservoir: Wild birds.
Transmission: Bite of infected mosquito, primarily *Culex tarsalis*.
Symptoms/signs: Most infected persons experience no symptoms or mild, flu-like illness. Some persons, especially children and the elderly, develop fever, head-

ache, neck pain and stiffness that may lead to severe neurologic symptoms and possibly coma and death.
Diagnosis: Serology.
Treatment: No specific treatment.
Significance: WNV, WEE and SLE are enzootic in birds in California. Surveillance of mosquitoes and sentinel chicken flocks between late spring and autumn detect evidence of transmission of these viruses. 300-400 cases of WNV infection are reported each year in California. Clinical cases of WEE and SLE among humans in California are currently rare.

RICKETTSIAL DISEASES

Ehrlichiosis, anaplasmosis
Agent: *Ehrlichia chaffeensis, Anaplasma phagocytophilum*.
Reservoir: Unknown; possibly wild rodents.
Transmission: Bite of infected tick, most likely *Ixodes pacificus*.
Symptoms/signs: Ranges from asymptomatic to fatal. Fever, headache, muscle ache, and chills are common. Severe complications include neurologic symptoms and organ failure. Case fatality is 2% to 10%.
Diagnosis: Observation of inclusion bodies on blood smear; serology.
Treatment: Antibiotics (tetracyclines).
Significance: Cases of both ehrlichiosis and anaplasmosis have been identified in California. Most cases occurred in northern coastal counties. Illness in horses due to infection with *A. phagocytophilum* (formerly *Ehrlichia equi*) has been recognized in California since the 1960s.

Murine typhus (flea-borne typhus, endemic typhus)
Agent: *Rickettsia typhi, Rickettsia felis*.
Reservoir: Commensal rodents (*Rattus* spp.); in southern California, the opossum (*Didelphis virginianus*).
Transmission: Contamination of bite from infected flea (*Ctenocephalides felis*) with flea feces.
Symptoms/signs: Fever, headache, chills, muscle ache, macular rash on trunk that spreads to most of the body. Case-fatality <1%.
Diagnosis: Serology.
Treatment: Antibiotics (tetracycline).
Significance: Typhus is enzootic in the opossum population of some selected regions of Los Angeles County. Approximately 10-20 cases of murine typhus, >90% from Los Angeles County, are reported in California each year.

Rickettsialpox
Agent: *Rickettsia akari*.
Reservoir: House mouse (*Mus musculus*).
Transmission: Bite of infected mite, *Liponyssoides sanguineus*.
Symptoms/signs: Rash that begins at mite bite site and spreads over the body, except palms and soles. Lymph nodes are often swollen.
Diagnosis: Serology or immunostaining of skin lesions.
Treatment: Antibiotics (tetracyclines)
Significance: Incidence in California is unknown but is believed to be quite low. Risk is greatest in areas where plentiful food stores or poor sanitary conditions support extensive *M. musculus* populations.

BACTERIAL DISEASES

Salmonellosis
Agent: Numerous serovars of *Salmonella enterica*.
Reservoir: A wide range of wild and domestic animals. Recently, pet reptiles have emerged as a frequent source of human infection. (Wild reptiles may pose a similar risk of infection.)
Transmission: Consumption of fecally contaminated water or food. Hand-to-mouth contact with infected animals.
Symptoms/signs: Sudden onset of diarrhea, abdominal pain, nausea, headache, and fever. Symptoms usually abate in a few days. Rarely, may infect other organ systems (e.g., spinal cord, kidneys).
Diagnosis: Isolation of *Salmonella* organisms from feces.
Treatment: None generally necessary for uncomplicated illnesses.
Significance: 4000 to 6000 cases of salmonellosis are reported in California each year. This likely represents an underestimate of the true incidence. The animal source of the infection is rarely definitively identified.

Plague
Agent: *Yersinia pestis*.
Reservoir: Wild rodents, primarily chipmunks, ground squirrels, and mice.
Transmission: Saliva from bite of infected flea; contact with tissues, secretions, or respiratory particles from infected animals, especially domestic cats.
Symptoms/signs: Most commonly fever, malaise, swollen painful lymph node. If untreated, may progressive to infection of blood and lungs. Case-fatality of plague pneumonia is greater than 90%.
Diagnosis: Serology, identification/culture of organism from lymph node aspirate, blood, sputum.
Treatment: Antibiotics (streptomycin, tetracyclines).

Significance: Plague is enzootic in wild rodent populations in much of California. When epizootics occur, the risk for human infection increases. An average of 1-2 human cases of plague occur each year in California. Plague acquired through contact with an infected cat is more likely to be pneumonic and more likely to be fatal. Listed by CDC as Category A (top priority) bioterrorism threat agent.

Tularemia

Agent: *Francisella tularensis*.

Reservoir: Rabbits and some rodents.

Transmission: Handling of tissues of infected animals (esp. rabbits, beaver); ingestion of undercooked tissues of infected animals; consumption of contaminated water; arthropod bite (ticks, deerflies); rarely, inhalation of dust from contaminated soil or dried vegetable matter.

Symptoms/signs: Variable by route of infection and biovar of organism. Most commonly, ulceration of skin and swollen lymph nodes. Pneumonia, pharyngitis, and gastrointestinal manifestations also possible. Can often resemble plague.

Diagnosis: Serology, identification/culture of organism from ulcer/lymph node.

Treatment: Antbiotics (streptomycin, also tetracyclines, gentamicin).

Significance: Zero to 10 cases of tularemia are reported in California each year. Listed by CDC as Category A (top priority) bioterrorism threat agent.

Leptospirosis

Agent: Over 200 serovars of *Leptospira interrogans* (esp. *canicola*, *pomona*, *icterohemmorhagiae*).

Reservoir: Numerous wild and domestic mammals.

Transmission: Contact of abraded skin or mucus membranes with animal urine or consumption of water contaminated with animal urine (esp. rats, cattle, swine, dogs).

Symptoms/signs: Varies with infecting serovar. Fever, headache, chills, muscle pain common initially. Later may resemble encephalitis/meningitis.

Diagnosis: Serology

Treatment: Any of several antibiotics can be effective.

Significance: One to 15 cases of leptospirosis are reported in California each year. Clusters of cases among persons with common exposure to a contaminated water source occasionally occur.

Lyme disease

Agent: *Borrelia burgdorferi*.

Reservoir: Wild rodents, principally *Neotoma* spp. in California.

Transmission: Bite of infected ixodid (hard) tick; in California, the western black-legged tick (*Ixodes pacificus*).

Symptoms/signs: Red, expanding rash and flu-like symptoms early; if untreated can progress to arthritis and neurologic symptoms

Diagnosis: Based on clinical symptoms, especially characteristic rash; supported by serology.

Treatment: Oral antibiotics (e.g., tetracyclines) for early symptoms; intravenous antibiotics (e.g., ceftriaxone) for later neurologic disease.

Significance: About 50 cases are reported in California each year. Highest incidence is in coastal counties north of the Bay Area–Sonoma, Mendocino, Humboldt, Trinity. Lower percentage of ticks infected in California compared to East Coast due to *I. pacificus* feeding on lizards which eliminate the spirochetes.

Tick-borne relapsing fever

Agent: *Borrelia hermsi*.

Reservoir: Wild rodents, particularly chipmunks.

Transmission: Bite of infected argasid (soft) tick, usually *Ornithodoros hermsii*. Ticks feed on humans when preferred rodent hosts are unavailable.

Symptoms/signs: Fever (to 106 ^{o}F) that lasts for a few days, disappears, then reappears a few days later. Several (up to 20) relapses can occur if not treated.

Diagnosis: Observation of *Borrelia* spirochetes on blood smear.

Treatment: Antibiotics (tetracyclines) usually relieve fever within 24 hours.

Significance: Five to 20 cases of relapsing fever are reported in California each year. Most cases are acquired while occupying and sleeping in buildings located in undeveloped areas between 1200 and 2700 m elevation. Clusters of cases among persons sharing sleeping quarters are not uncommon.

Psittacosis (ornithosis, parrot fever)

Agent: *Chlamydophila psittaci*.

Reservoir: Psittacine birds (e.g., parrots, parakeets), occasionally other wild and domestic fowl and wild mammals.

Transmission: Inhalation of organism from feces or other secretions of infected birds, generally within an enclosed space. Also, handling of contaminated birds or their tissues.

Symptoms/signs: Fever, headache, chills, cough, chest pain. Can be severe. Rarely fatal.

Diagnosis: Serology. Recovery of organism from sputum.
Treatment: Tetracycline for 10-14 days.
Significance: Fewer than 10 cases are reported annually in California, but this disease is likely considerably under-diagnosed. Pet store staff and exotic bird fanciers are at particular risk of exposure.

Rat bite fever
Agent: *Streptobacillus moniliformis*, *Spirillum minus*
Reservoir: Any rodent, but most commonly associated with *Rattus* spp.
Transmission: Bacteria shed in saliva and urine. Transmission usually through rodent bite. Rarely, infection occurs through contact of broken skin with contaminated surfaces (e.g., rodent cage) or consumption of contaminated water.
Symptoms/signs: Abrupt onset of fever, chills, headache, muscle pain 3-10 days after exposure. A rash on the arms and joint swelling may follow in 1-3 days. Infection of heart tissue and brain may occur in severe, untreated cases. Case-fatality is approximately 10%.
Diagnosis: Isolation of the organism from blood or other infected tissues.
Treatment: Antibiotics (e.g., penicillin) for 7-10 days.
Significance: Cases are rarely reported, but the true incidence is unknown. Nevertheless, there is an ever present risk to anyone who handles rodents as the infectious organism has been found in the saliva of 10-100% of healthy laboratory rats and 50-100% of wild rodents.

FUNGAL DISEASES

Cryptococcosis
Agent: *Cryptococcus neoformans*.
Reservoir: Ubiquitous environmental saprophyte that grows in bird feces, especially pigeons.
Transmission: Inhalation of contaminated soil or pigeon droppings.
Symptoms/signs: Organism localizes in the lungs, then spreads to other parts of the body. Symptoms are commonly pneumonia and meningitis (fever, headache, stiff and painful neck); also kidney, bone, skin can be affected. If untreated, cryptococcal meningoencephalitis is 100% fatal.
Diagnosis: Observation of fungal bodies in spinal fluid; serology; culture of fungi from skin lesions.
Treatment: Antifungal drugs (Amphotericin B, 5-fluorocytosine).
Significance: The most common fungal disease in immunocompromised individuals (e.g., AIDS, cancer patients), in whom cryptococcosis is more severe and 10-25% fatal.

Histoplasmosis
Agent: *Histoplasma capsulatum*.
Reservoir: Fungus frequently found in soil with high organic content. Grows readily in accumulations of bird guano.
Transmission: Inhalation of airborne fungus.
Symptoms/signs: Several clinical forms recognized: asymptomatic; acute respiratory disease (fever, headache, cough); disease involving other organ systems (liver, spleen, intestines); chronic debilitating disease; chronic respiratory disease (similar to tuberculosis).
Diagnosis: Culture or visualization of fungus in sputum, blood, or other tissues. Serology.
Treatment: Antifungal drugs (e.g., ketoconazole, itraconazole).
Significance: One to 15 cases reported in California each year. Less common cause of fungal respiratory disease in California than *Coccidiodes immitis*, "Valley fever" (700-1000 cases per year).

PROTOZOAL DISEASES

Babesiosis
Agent: *Babesia duncani*.
Reservoir: Unknown. Believed to be wild rodents.
Transmission: Bite of infected tick. Rarely through transfusion of blood products from infected person.
Symptoms/signs: Infection is probably asymptomatic or mild in most persons. Clinical illness includes fever, chills, and muscle ache. Some cases progress to anemia, blood clotting problems, and respiratory difficulty. Rarely, babesiosis is fatal.
Diagnosis: Observation of organisms on blood smear; serology.
Treatment: Similar to malaria: quinine and clindamycin for seven days.
Significance: Five cases of babesiosis have been documented in California since 1992. Serologic studies suggest that asymptomatic exposure to this organism may be much higher than incidence of symptomatic cases, especially in areas where ticks are prevalent.

Chagas' disease
Agent: *Trypanosoma cruzi*.
Reservoir: Opossums (*D. virginianus*).
Transmission: Reduviid bugs (e.g., *Triatoma* spp.) shed organism in feces while feeding. Contaminated feces are rubbed into bite wound, mucus membranes, or conjunctiva.

Symptoms/signs: Asymptomatic in many individuals. Acute illness includes fever, malaise, enlarged lymph nodes, edema of the eyelids. Rare chronic infection may result in cardiac or gastrointestinal dysfunction.
Diagnosis: Observation of organism in blood.
Treatment: Nifurtimox, benznidazole
Significance: Occurs primarily in South and Central America and Mexico. Human cases have been rarely reported from California and Texas. *T. cruzi* has been isolated from two species of Reduviidae native to California, *Triatoma protracta* and *T. rubida*.

Giardiasis
Agent: *Giardia lamblia*.
Reservoir: Many species of domestic and wild mammals. Beaver are the most frequently implicated source of infection.
Transmission: Ingestion of cysts present in fecally contaminated water.
Symptoms/signs: Chronic diarrhea, abdominal cramps, weight loss. Often asymptomatic.
Diagnosis: Observation of cysts in feces.
Treatment: Metronidazole.
Significance: Around 2000 cases of giardiasis are reported in California each year. At greatest risk are hikers, campers, and others who consume unfiltered water from natural sources in mountainous areas.

PARASITIC DISEASES

Visceral/ocular larval migrans
Agent: Roundworm larvae of *Toxocara canis*, *Baylisascaris procyonis*.
Reservoir: Wild and domestic dogs for *Toxocara*; raccoons for *Baylisascaris*.
Transmission: Consumption of embryonated eggs shed in feces of canids (*Toxocara*) and raccoons (*Baylisascaris*).
Symptoms/signs: Usually asymptomatic in adults. In children, symptoms referable to tissues/organs to and through which roundworm larvae migrate: commonly eye (endophthalmitis) and central nervous system (encephalopathy). Occasionally fatal; long-term sequelae possible in children with heavy infection.
Diagnosis: Serology, identification of larvae on tissue biopsy.
Treatment: Anthelminthics (e.g., thiabendazole) are variably effective.
Significance: Clinical cases of larval migrans are rarely diagnosed in California, though exposure to the infectious ova is likely quite common. Three cases of *Baylisascaris* larval migrans were diagnosed in California children in the 1990s.

Trichinosis (Trichinellosis)
Agent: *Trichinella spiralis.*
Reservoir: Bear, wild and domestic swine.
Transmission: Consumption of raw or undercooked meat (esp. pork, bear) containing encysted larvae.
Symptoms/signs: Initially, muscle pain, edema of eyelids, ocular pain, photophobia. Progressing to fever, chills, prostration, profuse sweating, weakness. Later symptoms referable to muscle tissue to which larvae migrate and encyst, often myocardial failure.
Diagnosis: Biopsy of affected muscle.
Treatment: Anthelmintics: mebendazole, thiabendazole.
Significance: 1-3 cases each year in California, representing approximately 20% of trichinosis cases reported nationwide. Exposure among California cases is associated with consumption of bear meat (~30%) and commercial or home-butchered pork products (~20%); approximately half of California trichinosis case-patients do not recall consumption of a specifically suspicious animal product.

Mite dermatitis
Agent: *Ornithonyssus bacoti*, *O. bursa*, *O. sylvarium*.
Reservoir: *Rattus* spp. for O. *bacoti*, birds for *O. bursa* and *O. sylvarium*
Transmission: Humans become accidental hosts for these mites following contact with infested animals or when the mites' preferred hosts are unavailable (e.g., following rodenticide population control).
Symptoms/signs: Mite bites produce a painful, itchy rash. Some persons may experience an allergic reaction to mite bites.
Diagnosis: Human infestations typically involve only a few mites, so detection is difficult. Diagnosis usually based on rash and history of contact with rodents or birds.
Treatment: Treatment is symptomatic to relieve pain and itching. Control measures in the environment should be taken to prevent re-infestation.
Significance: A few cases of rat mite dermatitis are informally reported to public health officials each year. The true incidence and risk of infestation with these mites in California is unknown.

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GLOSSARY

Acute. Referring to a health effect that is brief; sometimes also used to indicate severe. (cf. Chronic)

Anthelminthic. An agent or substance that destroys or expels parasitic worms, esp. intestinal worms.

Arboreal. Inhabiting or frequenting trees.

Arbovirus. ("Ar-bo" = "arthropod-borne"). General term for viruses which are transmitted from individual to individual by way of biting arthropods (e.g., mosquitoes).

Arthropod. Member of the Phylum Arthropoda, characterized by possession of a chitin exoskeleton and jointed appendages. (e.g., insects, crustaceans, arachnids)

Asymptomatic. Without, or producing no, symptoms.

Bacillus. Strictly, a bacterium that is a member of the genus *Bacillus*. Loosely, any rod-shaped bacterium.

Bacteria. A single-celled organism that possesses a cell wall, lacks a nucleus, and typically reproduces by cell division.

Biopsy. Process of removing a tissue sample from a living patient for diagnostic purposes.

Biovar. A group of bacterial strains distinguishable from other groups within the same species based on physiological characteristics.

Black Death. Common name given to the pandemic of plague that occurred throughout Europe in the 14th Century.

Cardiac. Relating to the heart.

Cardiopulmonary. Relating to the heart and lungs.

Case-fatality. The proportion of patients with a particular illness who die.

Chronic. Referring to a health effect that is long-lasting.

Commensal. Living with or deriving benefit from another species. Specifically where one species benefits and the other species is neither benefitted nor harmed.

Conjunctiva. The mucous membrane surrounding the anterior surface of the eyeball and posterior surface of the eyelids.

CSF. Cerebrospinal fluid.

Dermatitis. Inflammation of the skin.

Diurnal. Active or occurring during the day.

Dysfunction. Impaired or abnormal function.

Edema. Swelling of a tissue or organ due to retention or infiltration of excessive fluid.

Encephalitis. Inflammation of the brain.

Encephalopathy. Any disorder of the brain.

Encyst. Formation of a membranous wall around an organism or other foreign substance within living tissue.

Endemic. A condition, typically a disease, that persists within a population of humans at a constant level (cf. Enzootic, Epidemic).

Endophthalmitis. Inflammation of the tissues within the eyeball.

Enteric. Relating to the intestine.

Enzootic. A condition, typically a disease, that persists within a population of animals at a constant level.

Epidemic. The occurrence of a disease within a population of humans at a level in excess of normal (cf. Endemic, Epizootic).

Epizootic. The occurrence of a disease within a population of animals at a level in excess of normal (cf. Epidemic, Enzootic).

Estivation. To pass the summer months in a state of torpor–a condition of physical inactivity (cf. Hibernation).

Etiologic. Relating to the cause of a disease.

Excreta. The product of a tissue or organ that is expelled from the body. Commonly used to refer specifically to urine and feces.

Fecundity. The production of live offspring.

Fertility. The ability to conceive offspring.

Gastrointestinal. Relating to the stomach and intestines.

Gestation. The process or period of conception and development of offspring.

Gregarious. Tending to reside or function in a group.

Guano. Excrement, usually of birds or bats, which accumulates in the environment.

Hard tick. Ticks belonging to the Family Ixodidae and possessing a dorsal scutum (e.g., *Ixodes pacificus*, the Western black-legged tick, vector of Lyme disease in California).

Hemorrhage ("bleeding"). An escape of blood from a ruptured vessel.

Hibernation. To pass the winter months in a state of torpor–a condition of physical inactivity (cf. Estivation).

Homeothermic ("warm-blooded"). Capable of maintaining a constant body temperature. (cf. Poikilothermic)

Incidence. The number of new cases of a disease that occur in a defined population over a specified period of time.

Inclusion bodies. Visual evidence of a foreign substance or organism within a cell or tissue, usually as observed under microscopy.

Incubation. The period of time between exposure to a disease agent and onset of symptoms.

Larval migrans. Migration of a larval worm, typically a nematode, through tissues of an abnormal host without maturation to an adult worm.

Lymph. A clear, faintly yellow fluid that is collected from the tissues of the body and transports proteins and other wastes by vessels through nodes and eventually into the blood.

Lymph node. One of numerous round or bean-shaped bodies located throughout the body and connected to the lymphatic vessels which process wastes collected from cells.

Macular. Different in color than surrounding tissue; often used in reference to discoloration of skin rashes.

Meningitis. Inflammation of the membranous covering of the brain and spinal cord.

Meningoencephalitis. Inflammation of the brain and its membranous covering.

Mite. Small, eight-legged, parasitic arthropods that bite or burrow into the skin of humans and other animals; occassionally serve as vectors of disease.

Mucous membrane. Cells lining various passages and cavities of the body which communicate with the exterior.

Myocardial. Relating to the muscles of the heart.

Neophobic. Fearful of the new or unfamiliar.

Niche. The ecologic role and position of a species in a community.

Nocturnal. Active or occurring at night.

Ocular. Relating to the eye.

Omnivorous. Tending to include both animal and vegetable matter as part of its normal diet.

Oviparous ("egg-laying"). Young develop in eggs outside the maternal body.

Ovoviviparous. Young develop in eggs retained within the maternal body.

Pandemic. Denoting an outbreak of a disease that occurs over an extensive region, country, or continent (cf. Epidemic).

Parasite. An organism that lives in or on another and derives its sustenance therefrom.

Pathogen. A substance or organism capable of causing disease.

Pathogenic. Capable of causing disease.

Peridomestic. In and around site of human habitation.

Pharyngitis. Inflammation of the pharynx, the junction between the mouth and nasal passages.

Photophobia. Sensitivity to or avoidance of light.

Phylogeny. The evolutionary development of a species.

Placental mammals. Group of mammals that support the metabolic needs of the developing offspring in the uterus through a direct connection between the maternal and fetal blood circulation.

Piroplasm. Any protozoan of the Subclass Piroplasmia, including several tick-borne blood parasites of animals and humans.

Pneumonia. Inflammation of the lung tissue and filling of the air spaces with fluid.

Poikilothermic ("Cold-blooded"). Varying in body temperature according to the temperature of the surrounding environment (cf. Homeothermic).

Prophylaxis. Prevention of a disease, before or after exposure to the agent.

Prostration. Marked loss of strength, exhaustion.

Raptor. Bird of prey.

Reservoir. Living or nonliving source capable of supporting growth and multiplication of a disease agent and serving as a source of transmission, directly or indirectly, to susceptible animal.

Rickettsia. Genus of small bacteria that are obligate intracellular organisms and are often transmitted by biting arthropods.

Roundworm. A member of the Phylum Nematoda, characterized by elongated shape, complete digestive tract, and an outer cuticle.

Saprophyte. An organism that grows on dead organic matter.

Sequelae. Conditions which follow as a consequence of disease.

Serology. General class of laboratory tests in which serum is used to measure the presence of antibodies to disease agents.

Serovar. A group of bacterial strains distinguishable from other groups within the same species based on antigenic characteristics.

Soft tick. Ticks belonging to the Family Argasidae and lacking a dorsal scutum (e.g., *Ornithodoros hermsi*, vector of relapsing fever in California).

sp. Abbreviation referring to any single species within a genus.

spp. Abbreviation referring to multiple species within a genus.

Spirochete. Spiral-shaped bacteria; specifically members of the genus *Spirochaeta*.

Sputum. Thick fluid produced in the respiratory passages during disease.

Symptomatic. Relating to dysfunctions or departures from normal health associated with disease.

Systemic infection. Presence and distribution of a disease agent throughout an organ system or the whole body.

Thigmotaxis. Movement oriented by contact with surfaces or objects.

Ubiquitous. Present everywhere.

Vector. An animal (esp. arthropod) that is capable of transmitting an infectious disease agent, generally from a reservoir species to a susceptible species.

Vertebrate. Group of animals within the Phylum Chordata that have a hollow nerve cord enclosed within a bony or cartilaginous spinal column.

Viremia. Presence of viruses in the blood.

Viviparous. Relating to organisms that bear live young.

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INDEX OF TABLES

INDEX OF FIGURES