

**PROTOCOL FOR GOLDEN EAGLE  
OCCUPANCY, REPRODUCTION, AND  
PREY POPULATION ASSESSMENT**



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PREY POPULATION ASSESSMENT**

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## Preamble

The Protocol for Golden Eagle Occupancy, Reproduction, and Prey Population Assessment is based on over 25 years of research on bald and golden eagles in the United States and Mexico. The protocol is research oriented, and intended to result in the productivity component of eagle population demographics. The other demographic components are mortality and survivorship of each age class, and recruitment into the breeding population (Hunt et al. 1999, 2002). The source of reproductive terminology and productivity calculations is Postupalsky (1974), who recognized the need for standardized surveys in order to compare data between different populations.

The protocol for Occupancy and Reproduction Assessment (ORA) is similar for bald eagles, which are slightly easier to survey due to their concentration along riparian corridors and other water bodies for nesting and foraging. Of course, the prey population surveys would be much different for bald eagles. Jackman and Jenkins (2004) provide a thorough protocol for evaluating bald eagle habitat and populations. Documenting occupancy in golden eagles can be more difficult, especially when nesting density is low, because breeding areas tend to be more scattered in the landscape and the species forages over a less defined geographic area.

This 2010 edition contains all of the information in the original 2008 Protocol for Golden Eagle Occupancy and Reproduction Assessment Surveys (Driscoll 2008). The prey population section has been expanded to include more detail of survey methodologies, as well as a cursory summary of plague in prairie dog colonies. The prey section is not all inclusive, rather, it is restricted to the primary prey in the southwestern United States. Golden eagles are opportunistic foragers, with a diverse array of prey ranging from deer and antelope to snakes and desert tortoises. A glossary has been added to define terminology that may not be familiar to all readers. Also, the appendix on aging golden eagle nestlings has been updated with color photographs.



Plate 1. Subadult golden eagle, Zacatecas, Mexico.

## 1.0 INTRODUCTION

This document details a standard methodology for assessing breeding area occupancy, reproduction, and food resources for the golden eagle (*Aquila chrysaetos*), a species that breeds throughout much of the northern hemisphere. Golden eagles are long-lived, slowly-reproducing organisms that require high adult survival for population stability. The many human-related mortality factors that have emerged during the past century, along with considerable habitat degradation, have recently brought into question the issue of population health, particularly in the American West. Understanding the status and dynamics of golden eagles requires data compilation over vast regions, so it is imperative that methods of data collection and output be comparable among the many field observers necessary to the task. The protocol begins with a review of those aspects of golden eagle ecology that relate most strongly to population security.

Golden eagles (*Aquila chrysaetos*) nest predominantly on cliffs, but also in trees, and build a number of alternate nests within their territory that they move between in different years. An extreme example is a golden eagle breeding area in Arizona that contains 22 nests. Eagle nests are identifiable by their large size, and the large sticks used to form the nest. However, if an eagle nest is not being used in any given year, ravens (*Corvus corax*) or red-tailed hawks (*Buteo jamaicensis*) may lay eggs in the nest, especially in a breeding area that is no longer occupied by eagles. The abandonment of a breeding area by eagles may result from significant changes in the habitat, such as increased human development and activity (Boeker 1974, Scott 1985, Hunt et al. 1999), or severe wildfires that impact prey populations (Kochert et al. 1999).

In temperate regions, pairs remain on breeding areas throughout the year (Beecham and Kochert 1975, Hunt et al. 1995, Kochert et al. 2002). Once a pair has established a breeding area they tend to remain faithful to the site, with the same individuals present year after year (Hunt et al. 1999, Marzluff et al. 1997, Watson 1997). Exceptions occur when a pair member is displaced or killed in an aggressive altercation with another eagle (Hunt et al. 1999, Haller 1996). A displaced eagle may become a pair member at another breeding area, or may wander as a floating (nonbreeding) adult (Hunt et al. 1999). If a vacancy occurs in a pair, mate replacement may be rapid, within 3-5 days (Hunt et al. 1999, Phillips et al. 1984), or may require a longer period. The rapid replacement of pair members is indicative of a healthy eagle population, with a sufficient number of floaters to fill territorial vacancies (Hunt 1998, Hunt et al. 1999, Driscoll et al. 1999).

Golden eagles usually obtain adult plumage during their fifth summer, at four years of age (Jollie 1947, Bloom and Clark 2001, Kochert et al. 2002); however, subadult eagles occasionally breed successfully (Steenhof et al. 1983, Hunt et al. 1995). The survival rate for different age classes of golden eagles varies between regions. In some areas breeding eagles regularly live for 20-40 years (Haller 1996, Watson 1997). Because serviceable breeding locations can be a limiting factor in raptor populations (Hunt 1988), it is advantageous for pairs to remain on territory even in years when prey conditions are unfavorable for reproduction (Newton 1979). If a pair abandons their territory during a year of low prey availability, they would likely lose the nest site to competitors. Poor eagle breeding conditions can occur from severe drought or wildfires that adversely impact the vegetative composition, resulting in declines in prey abundance. In extreme cases the habitat may require years to recover, even when precipitation levels return to normal (Kochert et al. 1999, Wichmann et al. 2003).

Throughout their U.S. range golden eagles prey on a variety of animal species, with mammals ordinarily composing 80%-90% of the diet (Kochert et al. 2002). Prey animals of primary importance are leporids (hares and rabbits) and sciurids (ground squirrels, prairie dogs, and marmots), followed by gallinaceous birds (pheasant, grouse, partridge, and ptarmigan). Golden eagles may refrain from laying eggs in years of low prey numbers (Smith and Murphy 1979, Tjernberg 1983, Marquiss et al. 1985, Kochert et al. 2002), and laying rates, mean brood size, and productivity are significantly correlated with prey abundance (Newton 1979, Smith and Murphy 1979, Kochert 1980, Ritchie and Curatolo 1982, Tjernberg 1983, Watson and Langslow 1989, Watson et al. 1992, Bates and Moretti 1994, Watson 1997, Steenhof et al. 1997, McIntyre and Adams 1999, McIntyre 2002, Kochert et al. 2002). The correlation between prey abundance and the percentage of pairs that lay eggs is especially apparent in regions where populations of the primary prey species are cyclic in nature (i.e., population peaks followed by drastic reductions in animal numbers), as in snowshoe hares (*Lepus americanus*), black-tailed jackrabbits (*Lepus californicus*), white-tailed jackrabbits (*Lepus townsendii*), or willow ptarmigan (*Lagopus lagopus*) (Steenhof et al. 1997, McIntyre 2002). Other natural factors that can drastically reduce prey abundance are disease, such as plague (specifically in populations of ground squirrels and prairie dogs), and heavy rains that flood burrows during months when fossorial prey are hibernating or aestivating (Hunt et al. 2002). Inclement weather can also impact eagle productivity, and may negate the positive effects of high prey density (Watson et al. 1992, Steenhof et al. 1997). In turn, mild winter weather may ease the impacts of low prey numbers (Tjernberg 1983). Although a reduction in the prey base negatively impacts eagle reproduction, low points in prey cycles did not reduce breeding area occupancy during studies in Idaho or Alaska (Steenhof et al. 1997, McIntyre and Adams 1999, McIntyre 2002). The role of carrion, especially large ungulates, is often underestimated in studies of eagle food habits and can be an important dietary component in some regions (Sanchez-Zapata et al. 2010).

In a healthy golden eagle population there are usually primary and secondary breeding areas. Primary breeding areas are located in the best habitat, and are consistently occupied and productive (Newton 1991, Newton 1998, Ferrer and Donazar 1996, Sergio and Newton 2003). Secondary breeding areas tend to be located in marginal habitat and are reproductively less consistent. Some factors of high quality golden eagle breeding habitat include: 1) nesting substrate that offers protection from weather and predators; 2) sufficient prey populations to sustain the pair throughout the year; 3) updrafts and thermals for soaring and hunting; and, 4) isolation from human disturbance and development. A key element of eagle habitat is the prey base. Eagles may nest in closer proximity to another pair, or on marginal substrate, or tolerate higher levels of human activity, in areas of abundant and available prey. In short, higher densities of prey animals can result in higher densities of eagle pairs (Watson and Langslow 1989, Watson et al. 1992). However, when pairs breed at high densities (or rates of survival and reproduction are high, and all serviceable breeding areas are occupied by pairs) territorial altercations with neighboring pairs or nonbreeding adults ("floaters") may decrease productivity (Haller 1996). The home range of an eagle pair also varies with habitat quality and prey abundance. Where prey is abundant, the home range of eagle pairs will likely be smaller than where prey animals are less dense. During the breeding season, golden eagle home ranges in the western United States average 20-33km<sup>2</sup> (Kochert et al. 2002).

**2.0 GOLDEN EAGLE OCCUPANCY AND REPRODUCTION ASSESSMENT**

When conducting occupancy and reproduction assessment (ORA) surveys, it is important to consider the impact of the survey on the animal being studied. Eagles and other large raptors are usually highly sensitive to disturbance near their nest sites. An eagle’s reaction to disturbance near the nest varies with the type and duration of the disturbance, individual tolerance levels, and the timing of the disturbance in the breeding cycle. The consequences of human disturbance to eagles are most severe just prior to eggs being laid, during incubation, and just after hatching. The more time the pair has invested in the breeding attempt, the less likely they are to abandon the nest. Nestlings cannot regulate their own body temperature until about three weeks of age, and rely on the brooding adult to keep them cool in hot weather or warm in cold weather. Thus, it is important to minimize human disturbance, including research-related disturbance, near nest sites during incubation and prior to the young becoming three weeks of age. Nest observations from the ground at a safe distance, and aerial ORA surveys conducted properly, are not likely to impact the breeding attempt. The terrain in some areas, especially on cliffs or buttes with no access to observation points above the nest, may require helicopter surveys to confirm incubation and count young. Fixed-wing aircraft should not be used, due to a bias stemming from the underestimation of the number of young in nests (Frasier et al. 1983).

Data recorded for each breeding area during ORA surveys should include the breeding area’s status (e.g., Occupied, Active, Successful, Failed), the identification number of the nest being used (if applicable), the number of eggs laid (if known), the number of young hatched, the date and age of young when first sighted, the number of young fledged or near fledging, and any comments that are pertinent or of interest to the site. Since care is taken not to disturb eagles during incubation, the number of eggs laid is often inferred from the number of young hatched. Occasionally, addled (dead) egg(s) may be seen in the nest and the number of eggs laid can be adjusted accordingly. Comments may include information on fatalities, nestling ages, identifying characteristics of adults, or possible reasons for nest failures (e.g., collapse of nest structure, nest blown off cliff, nearby disturbances, aggressive altercations with other eagles, etc.).



Plate 2. Adult female golden eagle shading two 3.5 week old young in central California.

## 2.1 Terminology

A nationwide decline in certain raptor populations, due to the effects of DDT and other factors, stimulated numerous surveys during the 1960s and 1970s. Differing terminology, survey methods, and techniques of data analysis, complicated or precluded comparisons of data collected from different regions during this period. In an effort to minimize bias and increase the comparability of productivity data, Postupalsky (1974) standardized the terminology used to describe raptor reproductive success and the status of breeding areas as summarized below.

- 1) Breeding Area – An area containing one or more nests within the range of one mated pair of birds. [The term Territory is often used synonymously with breeding area; however, Territory more accurately refers to the defended area surrounding the nest.]
- 2) Occupied Breeding Area – An area containing a nest at which one of the following occurred:
  - a) Young were raised;
  - b) Eggs were laid;
  - c) An adult was observed sitting low in the nest, presumably incubating;
  - d) Two adults were observed perched on or near the nest;
  - e) An adult and a bird in immature plumage were observed at or near the nest, if courtship behavior occurred; or,
  - f) Recent repairs (fresh sticks or lining), mute, or feathers were visible at or near the nest.
- 3) Unoccupied Breeding Area – An area containing a nest at which none of the above indicators was observed.
- 4) Active Nest – A nest in which eggs have been laid.
- 5) Failed Nest – An active nest in which the eggs did not hatch, or the young died before reaching an advanced stage of development.
- 6) Successful Nest – An active nest in which at least one young survived to an advanced stage of development.
- 7) Nest Success – The proportion of occupied breeding areas (for which the outcome of nesting is known) which produce at least one young to an advanced stage of development.  
Nest Success = The percentage of occupied breeding areas producing (fledging) young.  
Nest Success = Number of successful nests / Number of occupied breeding areas.
- 8) Mean Brood Size – The number of young produced (fledged) per successful nest.  
Mean Brood Size = Number of young produced (fledged) / Number of successful nests.
- 9) Productivity – The number of young produced (fledged) per occupied breeding area.  
Productivity = Number of young produced / Number of occupied breeding areas.  
Productivity = Nest Success x Mean Brood Size.

Since it is not always possible to document fledging during reproductive surveys, Steenhof and Kochert (1982) suggested that an advanced stage of development (as in items 5, 6, and 7 above) equates to 80 percent of fledging age. Golden eagles normally fledge at 10 weeks of age, therefore, 80 percent of fledging age would be 8 weeks. Additional terminology is presented in the Glossary of Terms (Section 6.0).



## 2.2 Nest Inventory

Prior to conducting the initial occupancy survey in a region, any known breeding area records should be assembled and a map of potential nest sites created. Sources of eagle nest site information might include landowners, bird groups, or state and federal agencies. Topographic maps should be referenced to identify suitable nesting habitat, which can aid in the discovery of unknown pairs during nest inventory surveys. In the best circumstances, these areas should be surveyed for nests during the fall or winter prior to the initial occupancy survey. In regions where eagles nest predominantly on cliffs, nests may persist for decades and most are visible during ground or aerial surveys. Nest locations should be identified by Global Positioning System (GPS) technology to assimilate a nest inventory for the region. Knowing the locations of nests will improve the odds of locating pairs during occupancy surveys.

A helicopter survey is often the most efficient method of nest inventory. During aerial surveys, nests are often located in rapid succession and care must be taken to ensure data are associated with the correct nest. Universal Transverse Mercator System (UTM) GPS coordinates can be acquired in the North American Datum of 1927 (NAD 27) or 1983 (NAD 83) and it is important to ensure that all coordinates are acquired using the same datum, since one datum will generate a point many meters distant from another. NAD27 provides more accurate locations of points placed on a topographic map, or ArcGIS map layer, and NAD83 provides more accurate earth surface locations. ArcGIS can convert coordinates to either datum. Photographs should be taken and the photo numbers recorded on the data form with other nest information (Figure 1).



Plate 3. Large golden eagle nest, containing two young, that has been used for many years.



### 2.3 Occupancy Surveys

Breeding area occupancy is the standard on which raptor productivity is measured (Postupalsky 1974). It is important that occupancy surveys be conducted during courtship, prior to the onset of incubation. Eagle pairs tend to become more secretive once eggs are laid, and since one eagle will be in incubation position (often below the level of the nest rim and not visible, or hidden by foliage), it can be more difficult to confirm occupancy from the ground. Also, conducting occupancy surveys prior to incubation reduces the bias associated with pairs that do not lay eggs or fail early in the egg stage (Steenhof and Kochert 1982). This bias may be exacerbated following severe winters, which can decrease the proportion of pairs that lay eggs (Steenhof et al. 1997). A simplified data form is often convenient for ORA helicopter flights (Figure 2); however, a more detailed data form is recommended for nest visits on the ground (Figure 3).

During the month or two before eggs are laid eagle pairs tend to be conspicuous. Adults perform courtship flights, copulate, and construct new nests or refurbish existing nests. Courtship flights consist of “pair soaring” (when the pair soars around the breeding area together), and undulations or “sky dancing”. Undulating flights are performed by both sexes; however, more frequently and in deeper undulations by the male. They consist of a series of “U” shaped flights, deep drops (performed by folding the wings in toward the body) followed by rapid upward climbs. Undulation flights are generally a territorial display, and may be performed if an intruding eagle is spotted in the distance. The flight serves as a way of advertising that the breeding area is occupied so as to discourage other eagles from entering the territory.

Occupancy surveys are best conducted by two observers located a safe distance from the nest cliff, 400m to 800m ( $\frac{1}{4}$  to  $\frac{1}{2}$  mile) if possible, to allow for observation of the pair while reducing the chances of influencing their behavior. When the site is approached, it is important to scan the area before setting up scopes. Some pairs that are less tolerant of intrusion, or do not regularly see humans, may attempt to depart the cliff without being seen. One observer should use a scope to scan the cliff for nests and perched eagles, while the other uses binoculars to monitor the airspace above and surrounding the cliff. This method decreases the chances of an eagle pair being overlooked, or a secretive eagle dropping off a perch and gliding out of the area unnoticed. In areas where cliffs are convoluted, or on mesas and buttes, observers should scan the cliffs from various vantage points to ensure an eagle is not perched in a less visible location.

In regions where eagle pairs nest in lower densities, pairs tend to have larger territories and thus may be more difficult to locate than in high density areas. It may require several visits to the site to confirm occupancy by a pair. A breeding area should not be recorded as unoccupied unless a minimum of four site visits have been conducted, on four separate days, totaling at least four hours duration. In addition, nearby cliffs should be surveyed for the presence of alternate nest sites, since it is common for golden eagles to move among alternate nests in different years. It is possible that a pair may not be located during occupancy surveys, but later found incubating or with young in a previously unknown nest location. Thus, it is suggested that apparently unoccupied breeding areas be resurveyed during the incubation and nestling phases. However, if a new pair is located in a previously unknown breeding area after incubation surveys, that territory should not be included in the current year’s reproductive estimate, due to the bias of nests with young and mute present being easier to locate than nests that may have failed in the egg stage or pairs that did not lay eggs (Steenhof and Kochert 1982, Steenhof 1987).



Figure 3. Golden Eagle Occupancy and Reproduction Assessment Nest Form.

GOLDEN EAGLE OCCUPANCY AND REPRODUCTION ASSESSMENT NEST FORM

Date: \_\_\_\_\_ Time: \_\_\_\_\_ to \_\_\_\_\_ Breeding Area: \_\_\_\_\_

Observers: \_\_\_\_\_ Percent Cloud Cover: \_\_\_\_\_ Temperature (°C) \_\_\_\_\_

Wind Speed (KPH): \_\_\_\_\_ Wind Direction: \_\_\_\_\_ Precipitation: Rain Hail Snow Sleet None

NEST VISIT DATA

Number of Adults Observed: 0 1 2 3 4 Any Subadult Pair Member(s)? Unknown No Yes Male Female

Behavior of Adults: Nest Building Soaring Undulating Copulating Perching Hunting Incubating Brooding

Breeding Area Status: Unknown Unoccupied Occupied Occupied-1 Active Failed Successful

Number of Eggs in Nest: Unknown 0 1 2 3 4 If Failed, Last Date Observed Active: \_\_\_\_\_

Number of Young in, or Fledglings near Nest: Unknown 0 1 2 3 4 Estimated Age of Young (weeks): \_\_\_\_\_

Nest ID: \_\_\_\_\_ UTM Easting: \_\_\_\_\_ Northing: \_\_\_\_\_ Nest Aspect (360°): \_\_\_\_\_

ALTERNATE NEST DATA

Any Known Nests Collapsed? Yes No Nest ID(s): \_\_\_\_\_ Any New Nests Located? Yes No

New Nest ID: \_\_\_\_\_ Easting: \_\_\_\_\_ Northing: \_\_\_\_\_ Nest Aspect (360°): \_\_\_\_\_

New Nest ID: \_\_\_\_\_ Easting: \_\_\_\_\_ Northing: \_\_\_\_\_ Nest Aspect (360°): \_\_\_\_\_

New Nest ID: \_\_\_\_\_ Easting: \_\_\_\_\_ Northing: \_\_\_\_\_ Nest Aspect (360°): \_\_\_\_\_

New Nest ID: \_\_\_\_\_ Easting: \_\_\_\_\_ Northing: \_\_\_\_\_ Nest Aspect (360°): \_\_\_\_\_

HABITAT CONDITIONS

Grazing Level: None Low Moderate Heavy Livestock Type: Cattle Horses Sheep Goats Other: \_\_\_\_\_

Agriculture: None Low Moderate Heavy Crop Type: \_\_\_\_\_

Recreation: None Low Moderate Heavy Type: ATV - OHV Hiking Rock Climbing Hunting Shooting

NOTES

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Steenhof (1987) stated that the presence of a single adult at an established breeding area usually indicates occupancy by a pair. However, unless the adult is incubating or tending young, caution should be used when recording sites as occupied based on the observation of a single adult, and additional site visits are recommended to verify occupancy by a pair. A population in decline lacks a sufficient number of floaters to fill vacancies in breeding pairs (Hunt 1998, Hunt and Hunt 2006). Thus one of the first indicators of decline is the frequent occurrence of subadults or single adults in normally occupied breeding areas. The special “Occupied-1” breeding area status (see Figure 3) should be used to identify sites where only one adult has been observed.

#### **2.4 Incubation Surveys**

Golden eagles in temperate regions may begin laying eggs in January; however, mid-February is a more typical period. Clutch size varies from 1-3 eggs. Golden eagle eggs are off-white to cream colored, with variable amounts of reddish-brown splotching and stippling. Egg size varies, even among eggs in the same clutch. The mean length of 63 eggs was 74.5mm (range 67.5 – 85.7mm), and mean breadth was 58.0mm (range 49.4 – 64.3mm) (Kochert et al. 2002). In multiple egg clutches, the second egg is usually laid 3 days following the first (Kochert et al. 2002). The normal gestation period for golden eagle eggs is 45 days (6.5 weeks). The female usually spends more time incubating than the male, especially in the first weeks after the eggs are laid; however, the male also incubates and delivers prey to the nest for the female. As mentioned, eagles tend to become secretive during incubation and it can be difficult to see the incubating bird from an observation point below the level of the nest. Confirmation of incubation often requires watching the nest for the eagle to reposition itself on the eggs, or an incubation exchange (the mate arriving to incubate) to occur. Conducting incubation surveys in the first weeks after eggs are laid reduces the bias associated with missing pairs that fail early in the egg stage. Care must be taken to avoid disturbing pairs during the incubation period.

#### **2.5 Nestling Surveys**

The female usually spends more time brooding the young than the male in the first weeks after hatching. The adults will brood closely for the first two weeks and it can be difficult, from an observation point below the nest, to determine if the young have hatched. The first nestling survey, to count the number of young hatched, should be conducted 2-3 weeks after hatching as long as observers remain a safe distance from the nest. Eaglets can be seen from a distance with the aid of a scope, especially during feedings or when an adult returns to the nest with prey. Young eagles are capable of thermoregulation (controlling their own body temperature) at about 3 weeks of age, after which the adults may leave the nest unattended for longer periods. The second nestling survey, to count the number of young surviving to an advanced stage of development, should be conducted when the young are about 8 weeks old. Eaglets will fledge, fly from the nest for the first time, at around 10 weeks of age. The fledglings may remain in the breeding area for up to two months prior to dispersing, and the adults continue to supply prey for the young during this post-fledging period.

Rarely are the exact dates of egg laying and hatching known; however, these can be estimated using a technique known as back-dating. Plumage characteristics can be used to approximate the age of nestling golden eagles (see Section 2.6 and Appendix 1), whose hatch date can be estimated by subtracting the age from the date of observation. The egg-laying date can then be estimated by subtracting 45 days, the normal golden eagle gestation period, from the hatch date.

## 2.6 Aging Young

Young golden eagles are relatively easy to age (in weeks) based on plumage characteristics. The following descriptions are based on Sumner (1929a and 1929b), Hoechlin (1976), Watson (1997), and photographs of known age young taken in central California by S.K. Carnie (1950s) and D.E. Driscoll (1990s) (see Appendix 1). During their first week, eaglets are covered with an off-white “pre-pennae” down, which is progressively replaced by a snow-white “pre-plumulae” down in the second week of age. During the third week, primary, secondary, and rectrix feathers begin growing in their sheaths, but the body is still covered in snow-white down. In week four the primaries and secondaries emerge 8-12cm (4-5 inches) and rectrices emerge 5-8cm (2-3 inches) from their sheaths, and small feathers begin emerging from the snow-white down on the body. At five weeks of age, contour feathers have erupted on the dorsal surface of the wings and the upper back; however, the head, throat, and lower back are still snow-white down. At six weeks old the eaglet’s body is covered with dark contour feathers, although patches of down show through in places, and the head is still white down. During the seventh week the body is covered in dark contour feathers and dark feathers appear in the head; however, some white down is still visible in the head, especially in a line along the center of the crown. By eight weeks of age the head is mostly dark, although some down tufts may show through, and a ring of white down may be apparent at the base of the neck. At nine weeks old the eaglet’s body and head are completely dark, and the white band on the tail is conspicuous. There is not much visible change in plumage during the tenth week, although the flight feathers are still growing.

## 2.7 Nestling Fatalities

Young eagles may succumb to a variety of mortality factors while in the nest. Siblicide, the older/larger nestling killing its younger/smaller sibling, may occur if food is in short supply; happening regularly in some populations and rarely in others. Siblicide is most common within the first two weeks of age, especially if a female eaglet hatches first (Beecham and Kochert 1975, Edwards and Collopy 1983). Young eagles cannot thermoregulate until about three weeks of age, and can die from prolonged exposure to cold or heat before that time. Heat stress can kill eaglets at any stage of development, and young may be more susceptible to heat stress during infestations of bloodsucking parasites (Beecham and Kochert 1975, Hunt et al. 1992, Driscoll et al. 1999). High winds may blow young out of nests and blow nests completely out of trees or off cliffs. Human disturbance can force young to jump from nests prematurely. Predation by great-horned owls (*Bubo virginianus*), bobcats (*Lynx rufus*), and other eagles can also be a factor (Hunt et al. 1992, 1995, 1996, 1999).

Nestling fatalities can occur from infestations of nest parasites. The Mexican chicken bug is a bloodsucking ectoparasite of the Cimicidae family (Order Hemiptera). Although well known as a parasite of poultry, the bug has also been found in nests of raptor species such as California condors (*Gymnogyps californianus*), great horned owls, barn owls (*Tyto alba*), prairie falcons (*Falco mexicanus*), red-tailed hawks, golden eagles, and bald eagles (*Haliaeetus leucocephalus*) (Usinger 1947, Lee 1955, Platt 1975, M. Kochert and R. Lehman pers. comm., Grubb et al. 1986, Hunt et al. 1992, Driscoll et al. 1999). Mexican chicken bugs are more prevalent in cliff nests than those in trees (Platt 1975, Hunt et al. 1992, Driscoll et al. 1999). Mexican chicken bugs live in the cracks and crevices of nest or roost structures, or in the nest lining, and emerge to feed on the young and/or adults at night (Lee 1955, Usinger 1966, Philips 1990). However, Hunt et al. (1992) found the bugs feeding on nestling bald eagles (and biologists) during the day, and

Driscoll (unpublished data) observed the bugs feeding diurnally on nestling and adult golden eagles. Philips (1990) reported that females lay hundreds of eggs, and that all stages can go for months without feeding. Axtell and Arends (1990) noted that nymphs of the bed bug (*Cimex lectularius*), a close relative of the Mexican chicken bug, can withstand starvation for 70 days, and the adults can live without feeding for up to 12 months. Lee (1955) explained that the eggs require 5.1 days to hatch, and they develop into adults in 36.5 days. If nest infestations are severe, the bugs can kill young eagles by depleting body fluids and making them more susceptible to heat stress (Hunt et al. 1992, Driscoll et al. 1999).

Nests infested with Mexican chicken bugs tend to harbor the parasites each year the eagles use that particular nest. The parasites can be killed by a thorough application of diatomaceous earth after young have fledged, or in extreme cases, during nest climbs to band young (J. Driscoll pers. comm.). Nest infestations could possibly be controlled by the application of pyrethrins (a naturally occurring neurotoxin insecticide made from *Chrysanthemum cinerariaefolium* flowers) after the young have fledged, or in extreme cases, during nest climbs to band young. Young can also be sprayed with a pyrethrin solution. If a particular nest is not accessible to climbing, diatomaceous earth or pyrethrins could potentially be applied by use of a shotgun or a paint-ball gun from a helicopter. Synthetic pyrethroids (Bifenthrin, Permethrin, and Cypermethrin) are currently produced commercially.

## 2.8 Breeding Area Density

The density of breeding eagles and other raptors in a landscape is primarily a factor of habitat quality and prey abundance (Newton 1979, Newton 1989, Hunt 1988, Hunt 1998, Hunt et al. 1995), and is limited by the overall distribution of serviceable breeding locations (SBL). An SBL is an area, containing a nest site and foraging habitat, in which the expectation of reproductive output outweighs, in evolutionary terms, the risks of death and physiological exposure inherent in a nesting attempt (Hunt 1988). Golden eagles nest predominantly on cliffs; therefore, the number of breeding pairs would be limited by; 1) the overall distribution of suitable cliff ledges, 2) the abundance of prey animals, and, 3) territorial behavior which excludes other eagle pairs from an area.

The number of eagle breeding areas within a region may not be clear upon initial nest inventory, but will be more discernable following baseline occupancy surveys. It is important to remember that one breeding area may contain many alternate nests. The estimation of which nests are associated with individual eagle pairs may be subjective at first, based on the proximity or clustering of the nests in the vicinity of a certain pair. Breeding area records from state and federal agencies or bird groups may aid in the initial distinction of individual breeding areas. As surveys progress, and eagles are observed performing courtship flights or patrolling their territory, the designation of which nests belong to which pairs will become more apparent.

The number of occupied breeding areas within a region must initially be quantified to provide a baseline on which to compare future data. For example, in southwestern Idaho, Kochert et al. (1999) found that when wildfires destroyed jackrabbit habitat and jackrabbit numbers declined, the number of occupied golden eagle breeding areas also declined. Breeding areas that could no longer sustain a pair of eagles were vacated, and pairs that remained on site incorporated the neighboring breeding area into their own. Although hypothetically the population may still



produce the same number of young per occupied breeding area, there are fewer occupied sites. Without baseline data, an ORA survey conducted after the fires would not have identified the decline in the number of golden eagle pairs. The circumstances reported by Kochert et al. (1999) are a prime example of how habitat quality affects prey abundance, which in turn affects the density of breeding eagles in an area. The same principal would apply to other factors that reduce habitat quality, such as overgrazing, development, or severe drought.

**2.9 Productivity Calculations**

Postupalsky (1974) developed standard calculations for raptor productivity based on breeding area occupancy (see Section 2.1). The reproductive parameters necessary for calculations will be obtained by summarizing breeding area data obtained during ORA surveys (Table 1). Beginning with the number of “Occupied Breeding Areas”, the following parameters should be compiled:

- 1) Active Nests – Number of pairs that laid eggs;
- 2) Failed Nests – Number of Active Nests in which eggs did not hatch, or the young died before reaching an advanced stage of development; and,
- 3) Successful Nests – Number of Active Nests in which at least one young survived to an advanced stage of development (8 weeks of age in golden eagles).
- 4) Young Produced – Number of young surviving to an advanced stage of development.

Note that the sum of “Failed” and “Successful” nests should equal the number of “Active” nests.

Based on the numbers generated in steps 1-4, we can calculate:

- 1) Nest Success – The percentage of occupied breeding areas producing (fledging) young;
- 2) Mean Brood Size – The number of young produced (fledged) per successful nest; and,
- 3) Productivity – The number of young produced (fledged) per occupied breeding area.

Productivity is the most important of the three reproductive parameters.

The mathematical formulas for calculating Nest Success, Mean Brood Size, and Productivity are:

- 1) Nest Success = Number of successful nests / Number of occupied breeding areas;
- 2) Mean Brood Size = Number of young produced (fledged) / Number of successful nests;
- 3) Productivity = Number of young produced / Number of occupied breeding areas; or,
- 4) Productivity = Nest Success x Mean Brood Size.

The two formulas for Productivity result in the same number. Using the figures from Table 1.

Nest Success = 4/5 = 0.80 = 80%      Mean Brood Size = 6/4 = 1.5 Young per Successful Nest

Productivity = 6/5 = 1.2 Young      Productivity = 1.5 x 0.80 = 1.2 Young per Occupied BA

Table 1. Example of a Table Summarizing Golden Eagle ORA Data.

Breeding Area	BA Status	Nest ID	# Eggs	# Young	# Fledged	Comments
El Pajaro	Occupied	EP01	0	0	0	Subadult Female in Pair
La Contadora	Successful	LC03	3	2	1	Rockfall killed one 2wk old young
La Playa	Successful	LP01	2	2	2	Adult male tagged on 6-26-08
La Olla	Successful	LA02	2	1	1	One whole egg in nest on 4-3-08
Zacatecas	Successful	ZT04	2+	2	2	Eggshells in nest suggest >2 eggs
Total BAs = 5	Occupied BAs = 5		9+	7	6	Successful Nests = 4    Failed = 0

### 3.0 PREY POPULATION ASSESSMENT

Data on the natural history, behavior, abundance, and availability of prey can provide insight into golden eagle habitat quality and management. Prey abundance has been correlated with eagle reproductive parameters, and also with habitat use by nonbreeding eagles, such as juveniles, subadults, and floaters (Hunt et al. 2002). There are a number of methodologies for estimating prey abundance and density; the optimum method applied varying with prey species and the degree of accuracy necessary to fulfill study objectives. Prey abundance usually varies with habitat type; therefore, it is important that surveys are conducted in each of the various habitat types present within a study area.

The principle survey techniques for several of the primary prey of golden eagles in the southwestern United States are presented below, but keep in mind that modification of these methodologies may be necessary for specific areas. Also note that carrion may be an important component of the golden eagle diet in some seasons and regions.

#### 3.1 Black-tailed Jackrabbits

Black-tailed jackrabbits are the primary prey of golden eagles in many areas of the western United States (Kochert et al. 2002). Since golden eagle reproduction is highly correlated with prey abundance (see Section 1.0), it is important to understand the cyclic nature of jackrabbit populations. The speed of jackrabbit population increase and decline is spatially and temporally variable; however, the basic pattern is a rise to peak numbers followed by an abrupt or gradual crash. Rarely is research duration long enough to document a complete jackrabbit population cycle in one area. However, five studies conducted in Utah and southern Idaho focused on black-tailed jackrabbit cycles over twenty years. Currie and Goodwin (1966) and Gross et al. (1974) studied jackrabbits in northern Utah from the late 1950s through 1970, while French et al. (1965) conducted surveys 185km north in southern Idaho in the mid- to late 1950s, Woodbury (1955) 160km south in the Salt Lake region of Utah in the early 1950s, and Smith and Murphy (1979) 200km south in eastern Utah during 1966-1970. The five studies showed jackrabbit peaks in 1951, 1959-1960, and 1969-1970. If these data are representative of true jackrabbit cycles, peaks may occur at 8-10 year intervals. In Idaho, Johnson and Peek (1984, in Marzluff et al. 1997) and Steenhof et al. (1997) found peaks at 7-12 year intervals.

Excepting their cyclic nature, the density of jackrabbits in any region is likely dependent on vegetative composition. In southwestern Idaho, Smith and Nydegger (1985) found the highest jackrabbit densities in black greasewood and big sagebrush habitats. During 1962-1970 in northern Utah, Gross et al. (1974) found fall jackrabbit densities higher than spring densities, with a fall 1970 peak of 102 rabbits/km<sup>2</sup> and a fall 1967 low of 12/km<sup>2</sup>. In southwestern Idaho, Steenhof et al. (1997) found spring jackrabbit densities peaked at 55/km<sup>2</sup> in the first year (1971) followed by lows of 10-15/km<sup>2</sup> (1973-1978), a second peak near 40/km<sup>2</sup> (1979-1980) followed by lows near 1/km<sup>2</sup> (1984-1986), rising to a third peak of 25/km<sup>2</sup> (1992) followed by a low near 5/km<sup>2</sup> (1993). Also in southwestern Idaho (1979-1983), Smith and Nydegger (1985) found a peak in 1980-1981 (mean = 0.65 rabbits/hectare, or 65 rabbits/km<sup>2</sup>) followed by a low in 1982 (mean = 0.14 rabbits/hectare, or 14 rabbits/km<sup>2</sup>).

To obtain a more recent estimate of the jackrabbit population cycle, a survey was sent to biologists studying eagles in various western states. Although specific data on densities were not available, high jackrabbit numbers were reported for 2005 – 2007 throughout the western United States (Kansas, North Dakota, South Dakota, Colorado, Nebraska, Wyoming, California, and Arizona – M. Lockhart, T. Maechtle, G. Doney, H. Peters, P. Bloom, and D. Mikesic, in lit.).

Black-tailed jackrabbits in the Southwestern United States breed from January through August, producing 4-5 litters each year. Litter size ranges from 1-6 young (mean 2.2-3.0 young) with the largest litters born during April through July (Gross et al. 1974). A female born in the first or second conception period (first two litters of the year) can become pregnant and birth her first litter in the same year. The gestation period is six weeks, and young jackrabbits generally remain in the warren (not available to surveys) for the first 4-6 weeks of life (Gross et al. 1974). Black-tailed jackrabbit home range size varies from less than 1km<sup>2</sup> to 3km<sup>2</sup>, and the rabbits are most active during well-lit nights (Smith 1990). Some black-tailed jackrabbits have been found to move 5km within 2-10 days, and long distance movements of up to 35km have been reported (Smith et al. 2002).

Several survey methods have been used to estimate black-tailed jackrabbit abundance. Drive counts have been used to arrive at an index of jackrabbit population density (Gross et al. 1974). In this method, plots 2.6km<sup>2</sup> are prepared by clearing 5m strips around the perimeter and across the plot at 0.4km intervals, creating 4 parallel subplots 0.4km wide and 1.6km long. Personnel spaced at 20-30m intervals walk the length of the subplot, driving the jackrabbits ahead. Observers in towers at the end of the plot count the jackrabbits as the animals enter the cleared strips. This method is likely too labor intensive for most eagle studies, and the diurnal human presence and habitat modifications would preclude its use near eagle breeding areas.

A method that is relatively easy to employ and has been used to estimate rabbit numbers in golden eagle prey population studies (Bates and Moretti 1994, Steenhof et al. 1997), is the spotlight line-transect method (Smith and Nydegger 1985). In this method, marked transects are established through various habitat types along two-track roads (“jeep trails”), preferably with a strip of vegetation in the center, offering good visibility of surrounding habitat. Narrow two-track or single lane roads are preferred over wider roads, to minimize avoidance of the road area by rabbits (G. Smith pers. comm.). Transects are surveyed at night by two observers in an open-bed truck. One observer drives slowly (8-16kph, 5-10mph), identifying rabbits in front of the vehicle. The other observer operates a spotlight from the back of the truck identifying rabbits seen within a 180° arc to each side of the centerline. When a rabbit is seen, the odometer reading and perpendicular distance from the centerline to the rabbit are recorded (Smith and Nydegger 1985). Recent advances in rangefinder and GPS technology provide accurate estimates of animal distance and observer location, while decreasing human disturbance in the transect area. For example, a UTM location can be collected at the point perpendicular to the rabbit’s location, and the distance to the rabbit estimated with a rangefinder.

To minimize the bias of rabbits responding to the vehicle before detection, transects should be surveyed on nights with no, or very little, moon (G. Smith pers. comm.). However, since rabbits are most active during well-lit nights (Smith 1990), transects are currently being conducted to test whether surveys during the new moon or the full moon period result in better estimates of

rabbit numbers (Driscoll unpublished data). Similar natural light conditions can be somewhat maintained over monthly surveys by; 1) Scheduling rabbit transect surveys within 3 days either side of the new (or full) moon, and, 2) Starting surveys one hour after sunset and terminating at least one hour prior to first light. Environmental factors such as wind, temperature, and precipitation, may impact rabbit activity and introduce variance into the survey data, so these should be recorded on the data form for each transect. Using hand-held weather gauges (see KestrelMeters.com) will result in accurate estimates of environmental factors. If transects cannot be completed due to road conditions, or lightning storms, the ending GPS location should be recorded. Transects should be established in each major vegetation type for comparison of rabbit densities in various habitat types across the study area, and also near golden eagle breeding areas for comparison of rabbit densities with eagle reproductive parameters. Information collected during lagomorph surveys should be recorded on Rabbit Transect data forms (Figure 4), along with incidental sightings of predators such as bobcats, puma, kit fox, red fox, coyotes, badgers, black-footed ferrets, ringtail cats, etc. Surveyors should focus on perfecting their ability to detect sitting rabbits. Although this technique was developed primarily for black-tailed jackrabbits, it can be used to count other lagomorph species as well. If multiple prey species are encountered on the same transect, such as cottontail rabbits (*Sylvilagus* sp.), their numbers should be counted and the species indicated on the data form.



Plate 4. Cottontail rabbit near a rock outcrop.



### 3.2 California Ground Squirrels

The California ground squirrel (*Spermophilus beecheyi*) is the primary prey of golden eagles in the Diablo Range of central California (Hunt et al. 1995, 1997). California ground squirrels are susceptible to plague (Storer 1930, Evans and Holdenried 1943), but the disease is generally not as devastating as in prairie dogs (Fitch 1948). The breeding season ranges from December to February (Grinnel and Dixon 1918, Evans and Holdenried 1943, Fitch 1948), with a 28-30 day gestation period followed by six weeks of lactation (Holekamp and Nunes 1989). Young squirrels emerge from burrows during March through June, at 6-7 weeks of age. Mean litter size, about 7, varies with food supply, female condition, and age (Snyder 1923, Holekamp and Nunes 1989). The sex ratio of young born to the population is 1:1 (Evans and Holdenried 1943, Fitch 1948, Stroud 1983, Holekamp and Nunes 1989, Boellstorff and Owings 1995). Variation in the breeding cycle does occur, and pregnant females have been found throughout the year (Storer 1930). In central California, emergent juveniles were seen in late October, indicating August copulations (Hunt et al. 1995). A population of California ground squirrels can quadruple as litters are born; however, the cohort of young suffers reduction prior to emergence (Fitch 1948).

Almost all female squirrels in the population breed (Grinnel and Dixon 1918, Evans and Holdenried 1943, Fitch 1948, Tomich 1962) and less than 10 percent are reproductively unsuccessful (Holekamp and Nunes 1989). Females are monestrous, producing only one litter per year (Grinnel and Dixon 1918, Evans and Holdenried 1943, Fitch 1948, Tomich 1962, Holekamp and Nunes 1989). The period of behavioral estrus for each adult female is 4-5 hours, and the female is only receptive one day each year (Holekamp and Nune 1989, Boellstorff et al. 1994). Mating is promiscuous (Grinnel and Dixon 1918, Fitch 1948, Boellstorff and Owings 1995), and receptive females solicit and mate with multiple males, which result in 89 percent of litters sampled being multiply sired (Boellstorff et al. 1994). The sex ratio of adult squirrels in the population is 1:1 (Grinnel and Dixon 1918, Evans and Holdenried 1943, Fitch 1948, Stroud 1983, Holekamp and Nunes 1989, Boellstorff and Owings 1995). Evans and Holdenried (1943) found no evidence of females giving birth in the same season in which they were born.

During the years of government control measures, Fitch (1948) found a mean density for breeding adults of 5.7 per hectare near Madera, California, while Evans and Holdenried (1943) reported a total population density (adults and young) of 17.3 per hectare at Calaveras Reservoir in Alameda County. Although anticoagulant poisoning of California ground squirrels continues in some counties, including Alameda County, Boellstorff et al. (1994) found densities of 70.4 and 92.5 adult squirrels per hectare in two consecutive years at Camp Ohlone in Alameda County. Evans and Holdenried (1943) found the monthly weight of adult males ranged from 650-800g and adult females from 500-650g, and the weight of emergent juveniles from 70-200g.

The home range of California ground squirrels varies with habitat and food supply, often overlapping the range of other individuals (Evans and Holdenried 1943, Fitch 1948, Holekamp and Nunes 1989, Boellstorff and Owings 1995). A males range is relatively exclusive of other males, while the ranges of females overlap extensively (Evans and Holdenried 1943, Owings et al. 1977). The range of an adult male may overlap that of 2-4 adult females (Holekamp and Nunes 1989), while the range of an adult female can overlap that of 7 males (Boellstorff and Owings 1995). Young males disperse to new areas from July through September (Grinnel and Dixon 1918, Evans and Holdenried 1943), usually remaining within 1200 yards of their natal

site. Young females; however, establish burrows in areas overlapping or adjacent to their mother's home range (Boellstorff and Owings 1995).

Survey methods used to estimate ground squirrel abundance include visual surveys, burrow counts, and mark-recapture techniques. The social behavior and alarm calls of many fossorial (burrowing) species result in animals disappearing into burrows, making visual surveys difficult. California ground squirrels often run into burrows upon sighting humans over 100m away and may remain underground for an extended period (Grinnel and Dixon 1918, Fitch 1948). Emergent young are also less conspicuous than older squirrels in visual counts, and may remain underground for days (Fitch 1948). Adverse weather such as wind, cold fog, and rain limits the surface activity of ground squirrels (Fitch 1948), and counts on such days should be avoided.

Burrow entrance counts have been found inaccurate when sampling numbers of Townsend's ground squirrels (*S. townsendii*) and California ground squirrels (Fitch 1948, Van Horne et al. 1997). For example, permanently occupied burrows of the California ground squirrel usually have 10-50 separate holes (Fitch 1948). Fitch found an average of 17.2 open holes and 7.1 burrow systems for each ground squirrel. The most accurate population estimates for ground squirrels have been obtained by mark-recapture techniques (Evans and Holdenried 1943, Fitch 1948, Smith and Johnson 1985, Van Horne et al. 1997); however, this method is labor and cost intensive. In a mark-recapture study of the California ground squirrel virtually every adult squirrel was trapped each year, during late winter and spring, and the numbers trapped closely approximated the actual breeding population (Fitch 1948).

Road transect counts and point counts can be used to estimate the abundance of California ground squirrels, provided the observer remains inside the vehicle (Point Counts) and the vehicle speed (<10mph, Road Transect Counts) does not cause animals to run into burrows (Hunt et al. 1996, 1999, 2002). For California ground squirrels, periods of surface activity lengthen during the spring with increased daylight and warmer temperatures. As the temperature continues to increase in summer, surface activity becomes bimodal, with squirrels retiring to their burrows or to shaded areas during the mid-day heat. The normal summer surface activity periods are 5-9 AM and 4 PM to dusk (Fitch 1948). On cloudy or unseasonably cool days the squirrels may be active all day. It is important to conduct visual surveys of fossorial animals during periods of maximum surface activity, and on days with good weather conditions.



Plate 5. California ground squirrel.



Plate 6. Golden eagle nest, with two large young, in central California oak savanna habitat.

### 3.3 Prairie Dogs

There are five species of prairie dogs in North America, black-tailed (*Cynomys ludovicianus*), white-tailed (*C. leucurus*), Gunnison's (*C. gunnisoni*), Utah (*C. parvidens*), and Mexican (*C. mexicanus*), the latter of which is restricted to Mexico (Pizzimenti and Hoffman 1973, Hoffmeister 1986, Hygnstrom and Virchow 1994). Prairie dogs are social animals that live in grassland and short shrub habitats, in colonies up to 400 hectares in size. The largest colony on record, in Texas, measured nearly 65,000km<sup>2</sup> (25,000 square miles) and contained an estimated 400 million black-tailed prairie dogs (Hygnstrom and Virchow 1994). In the late 1800s, an estimated 283 million hectares were occupied by prairie dogs in the western United States; however, by 1971 that area had declined to 600,000 hectares (Cully 1993). Estimates suggest prairie dogs currently occupy less than two percent of their historical range (Miller et al. 1994).

Prairie dogs may be an important component of the diet of golden eagles in areas where prairie dog colonies are large. In regions where colonies are smaller and scattered in the landscape, prairie dogs may be an important component of the diet of certain eagle breeding pairs. Prairie dogs also compose over 90 percent of the diet of the endangered black-footed ferret (*Mustela nigripes*), which use prairie dog burrows as their sole source of shelter (Sheets et al. 1972, Campbell et al. 1987, Biggins et al. 1993, Oldemeyer et al. 1993).



In the southwestern United States, prairie dogs emerge from hibernation during February to March, although some above ground activity may occur on warm, clear, winter days. Males typically emerge 2-3 weeks prior to females (Menkens et al. 1987, Lupis et al. 2007). The breeding season begins when the females emerge in March, and can extend into May (Hoogland 1997). Females of the white-tailed, Gunnison's, and Utah prairie dog species are sexually mature at one year of age (Hoogland 1999, Lupis et al. 2007); however, black-tailed prairie dog females require two years to reach sexual maturity (Hygnstrom and Virchow 1994, Buseck et al. 2005). Females are only in estrus for a period of 4-5 hours on one day each year (Hoogland 1999, Buseck et al. 2005, Lupis et al. 2007). Multiple males surround, fight over, and breed with females in estrus, resulting in litters sired by up to five different males (Hoogland 1998). The average gestation period is 30 days (range 28-32 days), and 3-8 young (mean =5) per litter are born in early May (Bakko and Brown 1967, Pizzimenti and Hoffman 1973, Hoffmeister 1986, Hoogland 1997, Buseck et al. 2005). Young remain underground for the first 4-6 weeks, emerge in June, and are independent by early July (Rayor 1985, Hoogland 1999, Lupis et al. 2007).

Within a prairie dog colony there are small family groups called coterie. The composition of the coterie varies among species, but in black-tailed prairie dogs usually consists of a breeding male, 2-3 breeding females, and 1-2 yearlings of both sexes (Garrett and Franklin 1988, Hoogland 1982, Buseck et al. 2005). Females tend to remain close to the coterie, while the males disperse throughout the colony, and occasionally young males disperse to different colonies up to 5km distant (Garrett and Franklin 1988, Hoogland 1982, Buseck et al. 2005). Dispersal distance in Gunnison's prairie dogs ranged from 38-221m for females, and 34-575m for males (Hoogland 1999), while white-tailed prairie dog dispersal ranged from 50m to 300m (Lupis et al. 2007). A prairie dog complex has been defined as a group of colonies that are within 7km (the range of a black-footed ferret) of the nearest adjacent colony (Biggins et al. 1993).

Home range size varies with habitat quality, and the range of one male usually includes that of 4-5 females (Hygnstrom and Virchow 1994). The median home range of Gunnison's prairie dogs in Colorado was 0.07 to 0.08 hectares (0.17-0.20 acres), while that of white-tailed prairie dogs ranged from 0.15 to 1.9 hectares (0.37 to 4.7 acres) (Rayor 1988, Lupis et al. 2007). The mean range of black-tailed prairie dogs was 0.3 hectares (0.74 acres), ranging from 0.05 to 1.0 hectares (0.12 to 2.47 acres) (Buseck et al. 2005).

Average weight (250-1350g) and length (30-43cm) varies with age among prairie dog species, and weight also varies with habitat conditions and temporal factors. Males are generally larger than females (Fitzgerald et al. 1994, Hoogland 2003). Published mean weights and lengths for prairie dogs are as follows; 1) black-tailed 712g and 36-43cm; 2) white-tailed 820g and 30-40cm; 3) Gunnison's 900g and 30-39cm; and, 4) Utah 750g and 30-37cm (Pizzimenti and Hoffman 1973, Hoffmeister 1986, Coffeen and Pederson 1993, Biggins et al. 1993, Fitzgerald et al. 1994, Hoogland 1996). Prairie dog burrows can be over two meters deep and five meters long, with seven entrance holes and five lateral tunnels just below the surface (Hygnstrom and Virchow 1994). Prairie dogs plug many burrow entrances by mid-October, and are rarely seen by the end of October (Hoffmeister 1986). Adult males are the first to retreat into burrows for hibernation, followed by adult females, and then juveniles (Menkens et al. 1987). All four species of prairie dogs are susceptible to outbreaks of sylvatic plague.

### 3.3.1 *Plague in Prairie Dogs*

Sylvatic plague is a flea (*Oropsylla* sp.) transmitted disease caused by the bacterium *Yersinia pestis*, and prairie dogs are considered major amplifying hosts in the western U.S. where the disease is endemic and often epizootic (Barnes 1993). During epizootic amplification, plague tends to expand its distribution geographically, often for great distances, involving chance victims among ecologically associated animal species that enter or live in the affected areas (Barnes 1993). *Yersinia pestis* can grow at temperatures as low as 4°C, and survives much lower temperatures, thus plague epizootics can survive hibernation or aestivation with their hosts, to emerge in the spring (Barnes 1993). In humans, infection can result in pneumonia (pneumonic plague), septicemia (septicemic plague), and swelling of the lymph glands (bubonic plague). Bubonic plague was the “Black Death” which spread through the human population of Medieval Europe from 1347-1353.

Plague was introduced to the United States from Asia in 1899, in San Francisco, and an epidemic followed in China Town in 1900 (Gregg 1985, Fitzgerald 1993, Barnes 1993). The first record of plague in native North American mammals was from California ground squirrels near Berkeley, CA (Cully 1993), and the disease has since spread throughout the western U.S. (Barnes 1993). Plague was first observed in Gunnison’s prairie dogs in northwestern Arizona in 1932, eastern Arizona in 1937, and New Mexico in 1938; in Utah prairie dogs (Utah) and white-tailed prairie dogs (Wyoming) in 1936, and in black-tailed prairie dogs (Texas) in 1946 (Cully 1993). By the mid-1940’s, plague was established across the entire distributional range of the genus *Cynomys* (Fitzgerald 1993). Barnes (1993) reported evidence of plague infection in 76 species of six mammalian orders (Rodentia, Lagomorpha, Insectivora, Artiodactyla, Carnivora, and Primates – humans) in the United States. The last urban epidemic of pneumonic plague in the U.S. occurred in Los Angeles, CA during 1924-1925, stemming from rats and California ground squirrels (Barnes 1993). Barnes (1993), Cully (1993), and Fitzgerald (1993) provide thorough histories of plague in the United States, and these sources are recommended for further information.

Plague is a disease pertinent to the study of golden eagle populations, because of its sudden and devastating impact to prairie dog colonies. Barnes (1993) reported that mortality among prairie dogs during plague epizootics is extremely high, often approaching 100 percent in Gunnison’s prairie dogs and black-tailed prairie dogs, and 85 percent in white-tailed prairie dogs (Lechleitner et al. 1968, Rayor 1985, Barnes 1993, Cully 1993, Cully and Williams 2001). Infected fleas may persist in burrows for several years following plague epizootics, further infecting surviving prairie dogs. The disease can result in significant decline of populations and localized extinction of colonies (Cully 1993), and in the case of Gunnison’s prairie dogs, significant retraction of the range (Fitzgerald 1993). Wagner and Drickamer (2003) reported that for a sample of 293 Gunnison’s prairie dog colonies in Arizona the number of active colonies decreased from 270 (92%) during 1988-1996 to 86 (29%) during 2000-2001, and attributed the decline to plague.

Devastating plague epizootics are more common among Gunnison’s prairie dogs than the other three species (Fitzgerald 1993), and have been reported from various localities in the Southwestern U.S. in each year during 1973-1992 (Barnes 1993). Small isolated prairie dog colonies may not recover, and colonies that do recover may require 4-5 years to regenerate to their former levels (Cully 1993 and 1997, Wagner and Drickamer 2003). White-tailed prairie dogs occur in much lower density colonies than black-tailed or Gunnison’s prairie dogs

(Menkens and Anderson 1991, Cully 1993), and some colonies have recovered from epizootics of sylvatic plague within 1-2 years (Menkens et al. 1991). When colonies are scattered in the landscape, plague may infect separate areas or regions in different years. Control of plague in prairie dog colonies includes the use of permethrin micronized dust (Barnes 1993).

### **3.3.2 *Prairie Dog Density Estimates***

Colony sizes, and densities of prairie dogs within colonies, vary with species, habitat conditions, frequency and severity of plague epizootics, and the prevalence of poisoning and other human persecution. Typically, white-tailed prairie dogs occur in lower density colonies than black-tailed or Gunnison's prairie dogs (Cully 1993, Lupis et al. 2007). Densities of Gunnison's prairie dogs, are often as high as black-tailed prairie dogs, and can cover very large areas (Cully 1993). Due to the often devastating impacts of plague epizootics (85-100 percent mortality), the density of prairie dogs within a colony may fluctuate significantly between and within years. Significant reductions in prairie dog densities have been documented in periods as short as 2 to 4 months (Cully 1993, Warner and Drickamer 2003). Even in the absence of plague, prairie dog populations within the same colonies have been found to fluctuate by more than 50 percent in consecutive years (Menkens et al. 1987). Densities of Utah and Gunnison's prairie dogs can also vary with elevation and proximity to agricultural fields (Seglund et al. 2005), ranging from 3 to 70 per hectare (1-28 per acre).

Survey methods used to estimate prairie dog abundance include visual surveys, burrow counts, and mark-recapture techniques. The most accurate population estimates for prairie dogs have been obtained by mark-recapture techniques (Menkens and Anderson 1993, Biggins et al. 1993); however, this method is labor and cost intensive. As with California ground squirrels, the social behavior and alarm calls of prairie dogs result in animals disappearing into burrows, making visual surveys difficult. Attempting to acquire accurate visual estimates of black-tailed prairie dogs, Powell et al. (1994) parked their vehicle near prairie-dog towns, waited 30 minutes, then counted the area twice with a scope, recording the highest number of the two counts. They conducted these counts every 20 minutes during three-hour observation periods, noting that maximum surface activity occurred 1-2 hours before sunset (Powell et al. 1994). In white-tailed and Gunnison's prairie dogs, summer above ground activity was bimodal (sunrise to 1030 hours, and 1500 to 1800 hours), with the period of maximum surface activity occurring in the morning (Tileston and Lechleitner 1966, Pizzimenti and Hoffman 1973, Fitzgerald and Lechleitner 1974). Menkens and Anderson (1993) recommend conducting several counts during the period of maximum surface activity (morning), and averaging the counts for visual density estimation. Adverse weather such as wind, cold fog, and rain limits the surface activity of prairie dogs (Menkens and Anderson 1993, Powell et al. 1994), and counts on such days should be avoided.

Prairie dog colonies are routinely counted in summer, when population levels peak from the addition of the annual cohort of young. Visual counts of white-tailed and black-tailed prairie dogs underestimate densities when compared to mark-recapture and radio-telemetry data, respectively, for the same colonies (Biggins et al. 1993). Biggins calculated that the observability index for white-tailed prairie dogs was 0.495, and that for black-tailed prairie dogs was 0.566, or roughly half of the best estimate for the population. For example, a visual count of 10 White-tailed prairie dogs equates to 20.2 animals ( $10 / 0.495 = 20.2$ ), and a visual count of 10 black-tailed prairie dogs equates to 17.7 animals ( $10 / 0.566 = 17.7$ ). As with visual counts, the

correlation between estimates of white-tailed (Biggins et al. 1993) and black-tailed (Powell et al. 1994) prairie dog density and the density of total burrows was weak; however, Biggins et al. (1993) found a strong correlation when only active burrows were counted.

Biggins et al. (1993) developed a technique for estimating prairie dog density by counting the number of active burrows in a colony. They walked 1000m transects with a measuring wheel fitted with a 3m section of conduit, creating a 1000m x 3m (0.3 hectare) strip transect. Separate counts are kept for active and inactive burrows, the ratio between the two being an index of colony health (Biggins et al. 1993). New technological developments allow modification of this technique, using a hand held GPS and a lightweight telescoping 3m aluminum extension pole. The surveyor should ensure adherence to the directional line by walking toward a distant object or monitoring the GPS track. Directional transect lines can be mapped in advance, at any interval, using, for example, the Measured Grid feature in ArcGIS software. (Note that the grid will not appear in Data View, but will appear in Layout View, and can be turned on and off). When using a GPS unit, surveyors should ensure points are collected in the correct coordinate system (e.g., NAD27 vs. NAD83), and that the GPS is set to True North.

Key elements of Biggins et al. (1993) active burrow count technique are detailed below.

- 1) A burrow is counted if more than half of the opening is within the transect area.
- 2) Only count burrows with at least a 7cm diameter opening, and no visible end.
- 3) Count burrows dug-out by badgers, as prairie dogs often keep using these.
- 4) Consider a burrow active if fresh prairie dog scat is in, or within 0.5m of, the opening. Fresh droppings are greenish, black, or dark brown. Old scat is dried hard and bleached white. Criteria such as fresh digging, tracks, and sightings of prairie dogs entering burrows are not used, due to lack of consistency between observers.
- 5) A maximum of 10 seconds per burrow is sufficient; active burrows are often obvious.
- 6) Sample intensively enough to estimate the mean burrow density within 10%, at the 95% confidence interval. A 5% sample is usually sufficient.
- 7) Use systematic sampling, rather than random sampling.  
Select a direction across the colony and locate transects at equal intervals.  
For a 5% sample, using the 3m width, transects can be 60m apart ( $3\text{m} / 0.05 = 60\text{m}$ ).  
If ArcGIS is used to establish a transect grid, it can be efficient to utilize 50m intervals.
- 8) More transects may be necessary as colony size decreases, or as variation in burrow density and activity rate increases, such as after a plague epizootic.
- 9) Start at one end of the colony, walk the transect line, move over the designated interval, reverse your direction, and walk the next transect line back, so you traverse the colony multiple times prior to reaching the opposite end.
- 10) Orientation of the transect line is determined by a compass heading. Identifying a distant point or landscape feature along the line can assist in maintaining a straight line. Surveyors can also follow the heading on a GPS track. Toggling between the compass arrow and the UTM page on a GPS will ensure adherence to the designated transect line.
- 11) Colonies should be mapped prior to conducting surveys. However, if the colony has not been previously mapped, a UTM location (waypoint) should be recorded at the beginning of each transect line, and at the first burrow encountered. This will mark the start of the colony. The surveyor should remain vigilant of burrows on the transect line. If the surveyor has walked 50m since the last burrow, a waypoint should be recorded to end the colony. The surveyor then

continues on the transect line, and records a waypoint at the next burrow encountered, to mark the beginning of a new colony. (It is possible that an isolated burrow may be encountered. If no other burrows are located within 50m, the burrow should not be counted.) A waypoint should be recorded at the end of each transect line. The surveyor then moves over the predetermined interval (e.g., 60m or 50m), and walks back on a new transect line.

12) GPS waypoints should be uploaded to a computer daily. Colony boundaries can then be drawn using ArcGIS, and transect and colony area estimated.

13) Do not let the distribution of burrows bias the direction of the transect line; adhere to the predetermined interval and compass heading.

14) Surveys should be conducted during mid-June to September, after young have emerged, and data recorded on prairie dog colony survey forms (Figure 5).

Biggins et al. (1993) report that the best estimate of animal numbers in the survey area is achieved by multiplying the number of active burrows by an index of 0.073 for white-tailed prairie dogs and 0.179 for black-tailed prairie dogs. For example:

White-tailed prairie dog count =  $0.073 \times$  number of active burrows; and,

Black-tailed prairie dog count =  $0.179 \times$  number of active burrows.

An estimate of prairie dog density within the colony can then be calculated by dividing the animal count by the total transect area for the colony.

An index for calculating the best estimate of Gunnison's prairie dogs from the number of active burrows could not be located in the literature. Since densities of Gunnison's prairie dogs are more similar to that of black-tailed prairie dogs than white-tailed prairie dogs (Cully 1993), it may be plausible to use the index for black-tailed prairie dogs to estimate Gunnison's prairie dog numbers from active burrow counts. However, in an effort to avoid overestimation of Gunnison's prairie dog numbers, an average of the two indices (0.126) may provide a better estimate. If a Gunnison's prairie dog index is developed in the future from mark-recapture data, that index will be updated in the protocol.

Black-tailed prairie dog colonies can be mapped with the aid of aerial photography (Biggins et al. 1993, Johnson et al. 2003, 2004a). Although colonies of white-tailed and Gunnison's prairie dogs cannot be mapped as accurately with aerial imagery, the technique can still identify colony locations (Biggins et al. 1993, Johnson et al. 2004b, 2006). Johnson et al. (2010) identified Gunnison's prairie dog disturbance from high resolution aerial imagery (Digital Orthophoto Quarter Quadrangles – DOQQs), with 80 percent accuracy (range 77%-83%). In areas where prairie dog colonies have not been mapped, and a complete survey of prairie dog habitat is not economically feasible, it is beneficial to have an idea of where to begin transects. If aerial golden eagle ORA surveys are being conducted, GPS locations of prairie dog colonies can be obtained by monitoring the terrain while in route to golden eagle nesting habitat and helicopter fueling locations. GPS locations of prairie dog colonies can also be obtained during other field activities. Prairie dog colony boundary maps should be updated every few years, to account for any colony movement.



**3.4 Abundance of Non-Fossorial Prey Species**

The objectives of some studies may simply require broad estimates of the abundance of prey animals or annual variation of prey populations. Walking established line transects through various habitat types for lagomorphs (hares and rabbits) and other prey species such as grouse, ptarmigan, deer, and carrion, can detect broad differences in the abundance of prey species between study areas or habitat types (Smith and Murphy 1979, Watson et al. 1992). Also, annual variation in prey species abundance can be roughly estimated by recording the number of prey animals observed during routine field activities (snowshoe hare and willow ptarmigan – McIntyre 2002), or by monthly tallies of road-killed animals (black-tailed jackrabbits – Smith and Murphy 1979). Recently, remote cameras have been used to record golden eagle use of large ungulate carcasses (Sanchez-Zapata et al. 2010).

Rabbit transects can be established on two-lane roads or highways and surveyed at night by two people in a vehicle. One person drives slowly (48-64kph, 30-40mph), while the observer counts live and dead rabbits within each mile-post section of the road (Figure 6). Similar natural light conditions can be somewhat maintained each month by; 1) Scheduling surveys within 3 days either side of the new (or full) moon, and, 2) Starting surveys at least one hour after sunset and terminating at least one hour prior to first light. Environmental factors such as wind, temperature, and precipitation, may impact rabbit activity and introduce variance into the survey data, so these should be recorded on the data form for each transect. Using hand-held weather gauges (see KestrelMeters.com) will result in accurate estimates of environmental factors. If multiple prey species are encountered on the same transect, such as black-tailed jackrabbits and cottontail rabbits, the species should be indicated on the data form.



Plate 7. Remote camera photo of five golden eagles at a deer carcass in southern California.





#### **4.0 SUMMARY**

The Protocol for Golden Eagle Occupancy, Reproduction, and Prey Population Assessment details methodologies for estimating the productivity component of eagle population demographics, and densities of the primary prey in the southwestern United States. Golden eagle breeding chronology begins with an increase in courtship flights and nest refurbishment in December and January (Figure 7). Some eagle pairs lay eggs as early as January; however, mid-February is more typical. Severe winter weather can delay the onset of egg-laying, and decrease the proportion of pairs that lay eggs. The incubation period for golden eagles is 45 days. Young hatch from mid-March through April and remain in the nest for a period of 10 weeks, fledging in June. Fledglings remain in the breeding area for up to two months, during which the adults continue to feed them. Juveniles disperse from the breeding area during July and August.

The schedule for ORA and prey survey tasks (Figure 8) is based on golden eagle breeding chronology in the southwestern U.S., and may need to be adjusted for eagles nesting in more northern climes. Prior to initial ORA surveys in a region, existing breeding area records should be assembled and topographic maps examined to identify potential eagle nesting habitat. Ideally, these areas should be surveyed and nest locations inventoried in the fall when eagle pairs are not as focused on their nest sites. Occupancy surveys should begin in January, when eagles tend to be conspicuous due to courtship behavior. Incubation surveys should be conducted in the first weeks after eggs are laid (February to March), as long as observers remain a safe distance from nests. The first nestling survey should occur 2-3 weeks after hatching (April to May); again remaining a safe distance from the nest. The second nestling survey, to count the number of young surviving to an advanced stage of development, should be conducted when the young are about 8 weeks of age (May to June). Breeding areas that are apparently unoccupied should be revisited during the incubation and nestling phases, and nearby cliffs searched for the presence of unknown alternate nests. Before a breeding area is recorded as unoccupied, a minimum of four site visits, on four separate days, totaling at least four hours duration should be performed.

If a new pair is located in a previously unknown breeding area after incubation surveys, that territory should not be included in the current year's reproductive estimate, due to the bias of nests with young and mute present being easier to locate than nests that may have failed in the egg stage or pairs that did not lay eggs.

Rabbit and ground squirrel transects should be established and marked, then surveyed from April to October. It is beneficial to map prairie dog colonies prior to conducting surveys, during June to September, and update colony boundaries annually.

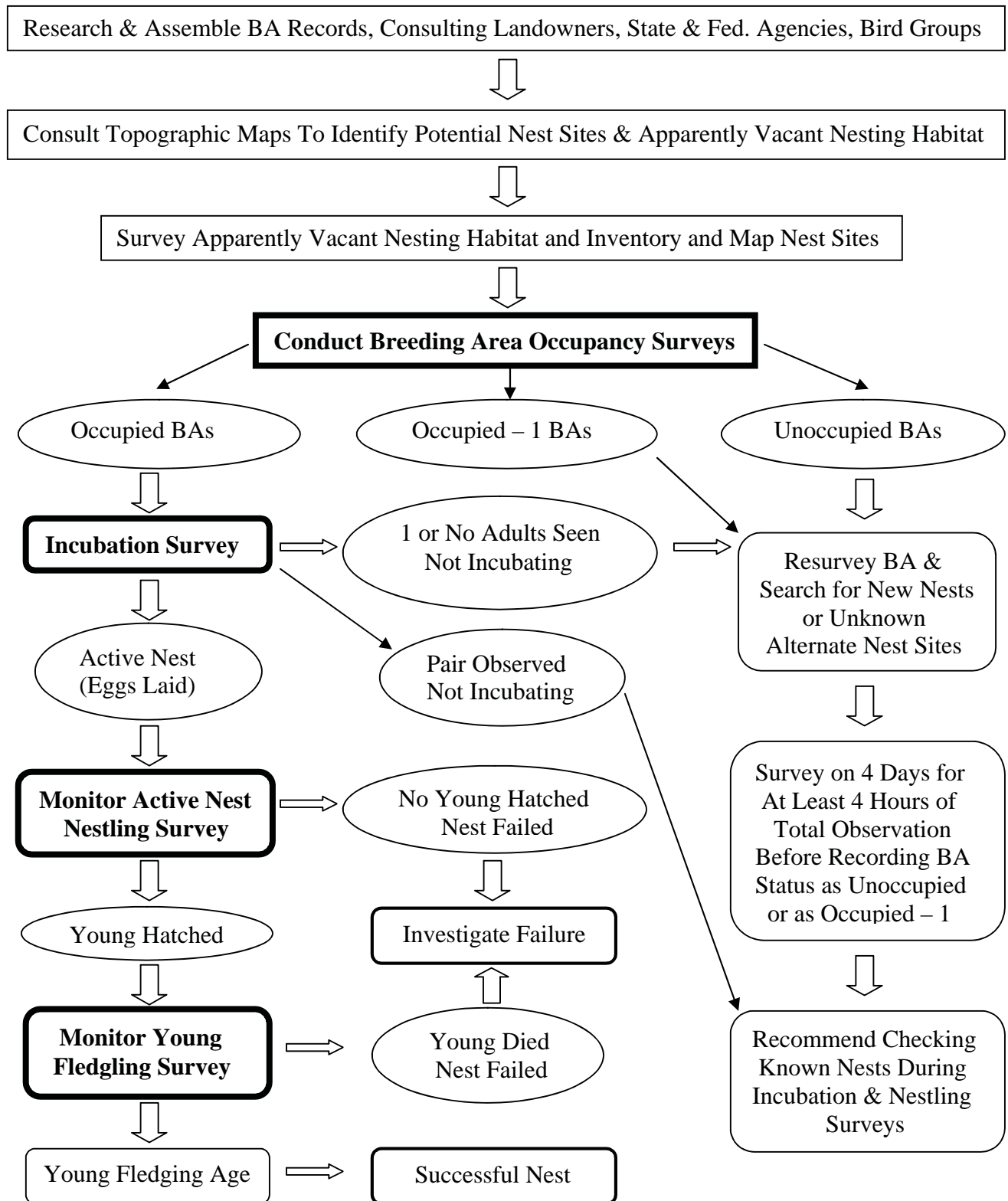
A flow diagram detailing golden eagle ORA protocol tasks, and procedures based on the results of surveys, is provided in Figure 9.

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Figure 9. Golden Eagle Occupancy and Reproduction Assessment Protocol Task Flow Diagram (See Glossary for definition of terms, BA = Breeding Area).



## 6.0 GLOSSARY OF TERMS

**Active Disturbance** – potential disturbance to eagles by humans present in a sensitive area.

**Active Nest** – a nest in which eggs have been laid.

**Adult** – a golden eagle in fully brown plumage, at least in its fifth calendar year (4 years of age).

**Aerie** – a raptor nest site (see also Eyrie).

**Alternate Nest** – a nest in a territory in addition to the existing active nest; usually constructed and used during previous years, it may be occupied again in the future.

**Biomass** – the live weight (in grams) of a prey animal.

**Breeding Area** – an area containing one or more nests within the range of one mated pair of birds. (The term Territory is often used synonymously with breeding area; however, Territory more accurately refers to the defended area surrounding the nest. See Territory.)

**Cohort** – the total production of fledgling eagles within a defined area in a single year.

**Eaglet** – a nestling eagle, from hatching until its first flight from the nest.

**Eyrie** – a raptor nest site (see also Aerie).

**Failed Nest** – an active nest in which eggs did not hatch, or the young died before reaching an advanced stage of development (8 weeks of age).

**Fledge** – to fly from the nest for the first time (typically at 10 weeks of age).

**Fledgling** – an eaglet that has recently flown from the nest. For survey purposes, a nestling eagle can be considered fledged at 80 percent of fledging age (see Section 2.1).

**Floater** – a non-breeding adult eagle.

**Floating Population** – that population segment containing adults that are not members of breeding pairs or defending serviceable breeding locations.

**Foraging Range** – the area frequented by a pair of eagles for hunting purposes. This area is often difficult to differentiate from home range, due to the opportunistic foraging behavior of golden eagles (see Home Range).

**GPS** – “global positioning system” – a satellite-based system for geographic location.

**Historical Breeding Area** – a breeding area which has remained unoccupied for a period of at least ten years. (see Occupied Breeding Area). Also, a breeding area which has been absorbed by an adjacent pair.

**Home Range** – the area frequented by a pair of eagles during the course of the nesting season (see Soaring Range).

**Juvenile** – a post-fledging eagle in its first year.

**Lagomorph** – members of the taxonomic order Lagomorpha, of which there are two families, the Leporidae (hares and rabbits), and the Ochotonidia (pikas), which are gnawing herbivorous mammals having two pairs of incisors in the upper jaw one behind the other.

**Local Effect** – an effect on a subset of the larger population of eagles.

**Mean Brood Size** – the number of young produced per successful nest; calculated as follows:  
$$\text{Mean Brood Size} = \text{Number of young produced (fledged)} / \text{Number of successful nests.}$$

**Mute** – raptor excrement; “whitewash”.

**Mortality Sensor** – a mercury triggered mechanism within a telemetry transmitter that causes a discernable increase in pulse rate when the transmitter has remained motionless for a predetermined time period (e.g., 6 hours).

**Natal Dispersal** – the distance from an animal’s place of birth to its ultimate breeding location.

**Nestling** – an eaglet from hatching to fledging.

**Nest Success** – the proportion of occupied breeding areas (for which the outcome of nesting is known) which produce at least one young to an advanced stage of development (8 weeks of age in golden eagles). Nest Success is reported as the percentage of occupied breeding areas producing (fledging) young, and is calculated as follows:

$$\text{Nest Success} = \text{Number of successful nests} / \text{Number of occupied breeding areas.}$$

**Occupied Breeding Area** – an area containing a nest at which one or more of the following occurred:

- a) Young were raised;
- b) Eggs were laid;
- c) An adult was observed sitting low in the nest, presumably incubating;
- d) Two adults were observed perched on or near the nest;
- e) An adult and a bird in immature plumage were observed at or near the nest, if courtship behavior occurred; or,
- f) Recent repairs (fresh sticks or lining), mute, or feathers were visible at or near the nest.

**Occupied – 1** – a breeding area with a documented history of occupancy, at which only one adult was observed in the current survey year.

**Occupancy and Reproduction Assessment (ORA)** – an annual survey of breeding areas to estimate their occupancy by pairs, and the number of young fledged per occupied breeding area.

**Passive Disturbance** – an existing human development fixed permanently or semi-permanently on the landscape (e.g., road, campground, house, trailer, etc.).

**Pirating** – the act of stealing a prey item from another animal (also kleptoparasitism).

**Plague** – a severe acute or chronic infectious disease caused by the bacterium (bacteria or bacillus) *Yersinia pestis*. Symptoms begin with chills and fever, quickly followed by prostration, often with delirium, headache, vomiting, and diarrhea. The disease is transmitted to humans and other mammalian species by flea bites, or can be passed from person to person.

**Sylvatic Plague** – plague in wild mammals, such as ground squirrels and prairie dogs, which serve as a reservoir from which humans and other mammals may be infected.

**Bubonic Plague** – symptoms usually appear in 2-5 days and include swelling of the lymph nodes, which form buboes (smooth lumps) in the femoral (thigh), inguinal (groin), axillary (armpit), and cervical (neck) regions.

**Pneumonic Plague or Pulmonic Plague** – symptoms usually appear in 2-3 days and include a rapidly progressive, highly contagious pneumonia with extensive involvement of the lungs and productive cough with mucoid, bloody, foamy, plague bacilli-laden sputum.

**Septicemic Plague** – the person usually dies before symptoms appear. A deadly blood infection which causes disseminated intravascular coagulation, resulting in tiny clots throughout the body and possibly ischemic necrosis (tissue death due to lack of circulation). There is bleeding into the skin (red spots) and other organs causing red or black patches, and hemoptysis or haemoptysis (coughing up or vomiting of blood). Other symptoms include fever, chills, and abdominal pain.

**Population Effect** – an effect on the entire population of eagles.

**Prey Delivery** – a prey item brought to the nest by an adult eagle.

**Prey Item** – a prey animal, or part thereof, that is utilized by an eagle.

**Productivity** - the number of young fledged per occupied breeding area, calculated as follows:

Productivity = Number of young produced / Number of occupied breeding areas; or,  
Productivity = Nest Success x Mean Brood Size.

**Raptor** – a bird of prey, such as an eagle, hawk, falcon, or owl.

**Recruitment** – the condition in which non-breeding eagles join the breeding population, usually by filling vacancies within pairs.

**Recruitment Deficit** – a condition of population demographics in which there are not enough floaters (non-breeding adult eagles) to fill the vacancies in pairs caused by breeder fatalities. Under this condition, we would expect to see a high percentage of subadults as members of pairs, possibly followed by an increase in the number of unoccupied breeding areas.

**Reproductive Rate** – see Productivity.

**Serviceable Breeding Location (SBL)** – an area containing a nest site and foraging habitat, in which the expectation of reproductive output outweighs, in evolutionary terms, the risks of death and physiological exposure inherent in a nesting attempt. An SBL is optimal where its various components (habitat, food supply, absence of predators, etc.) combine to produce a maximum number of surviving young while minimizing reductions in parental survivorship and future fecundity (see Hunt 1988).

**Siblicide** – the killing of a nestling eagle by its sibling.

**Soaring Range** – the area of soaring and territorial patrolling by a nesting pair of eagles; the soaring range may extend beyond the home range.

**Stratified Random Sampling** – a form of sampling where a region is broadly divided into zones (strata) based on vegetation or other characteristics believed to affect habitat quality. By randomly selecting sampling points within each zone separately, one overcomes the analytical bias of under representing some strata and over representing others.

**Subadult** – a golden eagle in plumage characteristic of its second, third, or fourth calendar year (1-3 years of age). The three years between the juvenile year and full adulthood.

**Successful Nest** - an active nest in which at least one young survived to an advanced stage of development (8 weeks of age in golden eagles).

**Territory** – specifically, the area around the nest that is defended by a pair of adult eagles; also generally, an entire breeding area (the territory plus the rest of the home range).

**Transmitter** – a small radio unit attached to the back or tail feather of an eagle which emits a radio pulse that is used to locate the eagle and determine its behavior.

**Unoccupied Breeding Area** - an area containing a nest at which none of the criteria of occupancy are fulfilled (see Occupied Breeding Area).

**UTM** – Universal Transverse Mercator System – a metric grid-based coordinate system for identifying geographic locations.

**Vital Rates** – annual rates of reproduction and survival.

**Waypoint** – a set of coordinates that identify a geographic location; often identified and saved in a GPS receiving unit (see GPS).

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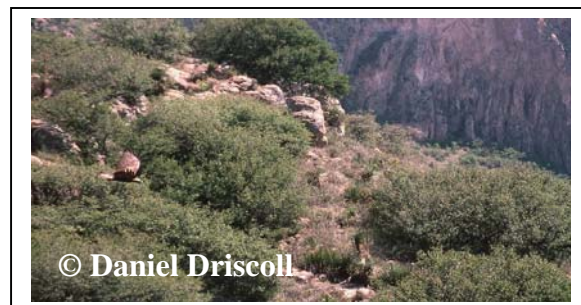


Plate 8. Adult golden eagle in desert scrub habitat, La Contadora, San Luis Potosi, Mexico.



**PROTOCOL FOR GOLDEN EAGLE  
OCCUPANCY, REPRODUCTION, AND  
PREY POPULATION ASSESSMENT**

**APPENDIX 1**

**A PHOTOGRAPHIC GUIDE TO AGING NESTLING  
GOLDEN EAGLES**

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**AGING NESTLING GOLDEN EAGLES**

Young golden eagles are relatively easy to age (in weeks) based on plumage characteristics. The following descriptions are based on Sumner (1929a and 1929b), Hoechlin (1976), Watson (1997), and photographs of known age young taken in central California by S.K. Carnie (1950s) and D.E. Driscoll (1990s).

Eggs	Off-white to cream colored, with variable amounts of reddish-brown splotching and stippling. Egg size varies, but averages 74mm x 58mm.
Incubation	45 day incubation period.
0-1 Week	Eaglets are covered with an off-white “pre-pennae” down.
2 Weeks	Snow-white “pre-plumulae” down replaces off-white “pre-pennae” down.
3 Weeks	Eaglets covered with snow-white down. Flight feathers begin erupting from their sheaths.
4 Weeks	Primaries and secondaries emerge 8-12cm from their sheaths. Rectrices emerge 5-8cm from their sheaths. Small feathers begin emerging from the snow-white down on the body.
5 Weeks	Contour feathers erupted on dorsal surface of wings and upper back. Head, throat, and lower back are still snow-white down.
6 Weeks	Eaglet’s body covered with dark contour feathers. Patches of down show through in some areas of body. Head is still white down.
7 Weeks	Body is covered in dark contour feathers and dark feathers appear in the head. Some white down is still visible in the head, especially in a line along the center of the crown.
8 Weeks	Head is mostly dark, although some down tufts may show through. A ring of white down may be apparent at the base of the neck.
9 Weeks	Eaglet’s body and head are completely dark. White band on the tail is conspicuous.
10 Weeks	Primaries, secondaries, and rectrices are still growing longer. Normal age of fledging (first flight) from nest.





Plate 1. Three golden eagle eggs from central California. Note the variation in size and color.



Plate 2. Adult golden eagle incubating (45 day incubation period).



Plate 3. Adult golden eagle with 1 week old nestling (off-white “pre-pennae” down).



Plate 4. Golden eagle nestling at 2 weeks of age (snow white “pre-plumulae” down).



Plate 5. Golden eagle nestlings at 3 weeks of age (covered in snow white down).



Plate 6. Golden eagle nestlings at 3.5 weeks of age (flight feathers erupt from sheaths).



Plate 7. Golden eagle nestling at 4 weeks of age (primaries and secondaries emerge 8-12cm).



Plate 8. Golden eagle nestlings at 4-4.5 weeks of age (small feathers emerge on body).



Plate 9. Golden eagle nestling at 5 weeks of age (contour feathers erupting on wings and back).



Plate 10. Golden eagle young at 6 weeks (head downy, body feathered but down patches remain).

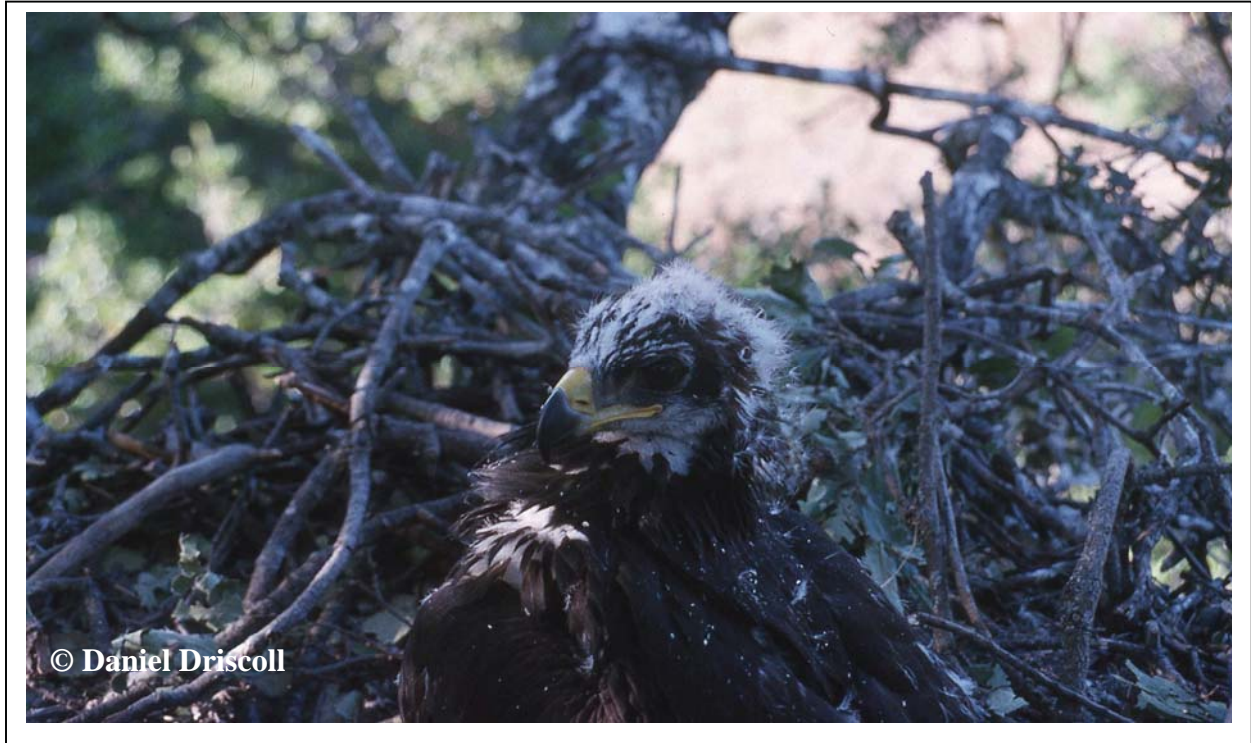


Plate 11. Golden eagle nestling at 7 weeks of age (dark feathers appear on the head).



Plate 12. Golden eagle young at 7.5 weeks of age (down line along center of crown is common).





Plate 13. Golden eagle nestling at 8 weeks of age (head dark, down line may remain along crown).



Plate 14. Golden eagle nestling at 9 weeks of age (body and head completely dark).



Plate 15. Golden eagle nestling at 10 weeks of age (fledging age, flight feathers still growing).



Plate 16. Golden eagle in typical juvenile plumage. Amount of white on wings is variable.



Plate 17. Golden nape may be present at fledging, and becomes more prominent in the first year.



Plate 18. Eagle petroglyph on the Colorado Plateau.