

NESTING BEHAVIOR IN A REINTRODUCED POPULATION OF CALIFORNIA  
CONDORS

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NESTING BEHAVIOR IN A REINTRODUCED POPULATION OF CALIFORNIA  
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## SUMMARY

Studies in numerous animal taxa demonstrate that early rearing experience has a profound influence on the development of later adaptive behavior. This has implications for endangered species management, particularly when animals are reared in captivity for reintroduction or in cases in which species managers play an active role in managing animals at the individual or population levels. The California condor (*Gymnogyps californianus*) is a critically endangered New World vulture that was subject to a period of extinction in the wild followed by ongoing reintroduction in portions of its native range. Though the reintroduced population in southern California is largely adapting well, several obstacles to viability remain that are largely anthropogenic in nature. The purpose of this study was to quantitatively assess nesting behavior of free-flying California condors in the southern California population to determine whether differences in parental care and nestling behavior are attributable to parental rearing conditions and experience. Differences among condors were not detected in attendance patterns across either the egg or chick phases of nesting. Variation was not detected among chicks in proportion of time spent active and inactive during the early nestling phase. Variations among older nestlings in the proportion of time spent inactive were observed, with associations detected between inactivity, pair, visibility and season. The proportion of time that parents interacted with nestlings varied from nest to nest, with associations detected between interaction, visibility and season. Finally, a potential trend towards individual differences in the propensity to bring microtrash to the nest was observed. It is concluded that some pair-level variation in nestling care and behavior is apparent, though

this variation is unlikely to be related to early rearing experience, and that methodologically it is important to account for visibility in analyses of condor nestling behavior.

# CHAPTER 1

## INTRODUCTION

Early rearing experience has a profound influence on the development of later adaptive behavior in many animal taxa (Sackett, Novak, & Kroeker, 1999). The role that early rearing experience plays in the outcome of the adult animal has serious implications for endangered species management, particularly when animals are reared in captivity for reintroduction or in cases in which species managers play an active role in managing animals at the individual or population levels.

The California condor (*Gymnogyps californianus*), was subject to a period of extinction in the wild followed by intensive reintroduction efforts in portions of its native range. The role of early experience in these captive-bred individuals is of great interest. Interestingly, though this species ranges widely in nature, it appears to fare well in captivity, breeding at rates equal to or greater than that experienced in the wild and appearing to exhibit few abnormal behaviors. Condors have been reared in captivity and released using techniques that evolved over time in response to ongoing assessment of released condors' behavior and survival. To date, however, few quantitative analyses have been conducted to examine the behavior of condors that were products of this intensive program. Questions remain as to whether members of this altricial species that were exposed to different rearing conditions exhibit differences in parental behaviors that may be important to fitness.

## **Life history of the California Condor**

### **Taxonomy**

The California condor, *Gymnogyps californianus*, is a member of the New World vulture family, Cathartidae. Currently, the Cathartidae are placed in the order Accipitroformes (*The American Ornithologists' Union Check-list of North American Birds*, 2011). The closest living relative to the California condor is the Andean condor, which is similar in size and behavior (N. Snyder & Snyder, 2005). It is worth noting that while current evidence does not suggest a close common ancestor between New World and Old World vultures (H. Snyder, 2001; N. Snyder & Snyder, 2005), convergent traits are apparent and lend insight into discussions of the behavior of the California condor.

### **Foraging**

The condor, primarily a soaring bird, may easily cover more than 80 kilometers in a typical day (Koford, 1953), and can travel up to 225 kilometers a day when foraging (H. Snyder, 2001). It is an obligate scavenger (N. Snyder & Snyder, 2005) with a spatially and temporally unpredictable, as well as ephemeral, food supply (Bukowinski et al., 2007). In southern California the condor typically forages on open grasslands (Koford, 1953). There is no evidence to date that condors use odor to locate carcasses. It likely finds its food by sight; spotting carcasses from above and by cueing in on scavenging common ravens and turkey vultures (Koford, 1953). Further, Koford (1953) suggests that finding food in condors may be a cooperative effort. Personal observations lead the author to believe that this is indeed feasible and is a potential area for experimental study.

At a carcass, both inter-and-intra-specific social interactions are complex (Koford, 1953). Snyder and Snyder (2005) remark that the complexity of intra-and-inter-specific

social interactions faced by scavenging birds may relate to their general tendency to possess relatively well-developed learning abilities and substantial intelligence. Though experimental assessment of condor learning and intelligence has yet to be explored, numerous field and anecdotal reports suggest that the condor possesses remarkable spatial, social learning, and problem-solving abilities. Behavioral testing with non-release candidates would lend insight into these abilities.

### **Courtship and Breeding**

Sexual maturity is typically reached at 6 to 8 years of age (N. Snyder & Snyder, 2005), during which the juvenile coloration (black head, mottled white underwing patches) gives way to adult coloration (pink head, more distinctly white underwing patches). Based on data collected on the historic and remnant populations, the condor has been typically characterized as socially monogamous, forming exceedingly stable pairs that typically endure until the death of one adult (N. Snyder & Snyder, 2005). Though extra-pair courtship was undocumented in those populations (Koford, 1953; N. Snyder & Snyder, 2000), systematic observations of the reintroduced population in southern California during the 2001/2002 and 2002/2003 breeding seasons uncovered an extra-pair courtship rate of 23% (Mee et al., 2004). Mee et al. (2004) observed that females actively solicit extra-pair displays and copulations and that paired females attempt to mate guard by disrupting most extra-pair courtship attempts on their mate.

Mee and colleagues (2004) suggest several possible explanations that are not mutually exclusive for the discrepancy in extra-pair courtship rates seen between the historic, remnant, and reintroduced southern California populations. 1) lack of observation of the phenomena in the historical and remnant populations due to

methodological constraints. 2) An artificially high level of extra-pair courtship in the reintroduced population that could be related to a) the increased extra-pair social opportunities at proffered feeding sites and b) mate incompatibility in the young population. 3) Inbreeding avoidance in the reintroduced population. Additionally, four instances of pair divorce in the absence of the death of either adult have been documented in this population (J. Brandt, personal communication). We may gain further insight into the question of social monogamy in the California condor if extra-pair courtship returns to previously recorded levels as the population structure matures. However, if extra-pair courtship continues indefinitely at a higher rate than was recorded historically, we will not be able to definitively determine whether this is due to methodological differences between research eras or substantive environmental differences encountered by the reintroduced population.

Courtship occurs primarily during fall and winter (Koford, 1953; N. Snyder & Snyder, 2000). During this period, condors engage in pair flights (which may serve a display function) and mutual grooming behaviors (N. Snyder & Snyder, 2005), and generally spend increased time in proximity to one another, such as when feeding or roosting (personal observations). Male condors engage in a stereotyped ground breeding display that may be followed by attempted or successful copulation (Koford, 1953; N. Snyder & Snyder, 2000). Established pairs defend a breeding territory (N. Snyder & Snyder, 2000).

A single egg is laid by the female in a cavity – typically a pothole in a sheer cliff, or the hollow of a large burned-out tree. Though the condor lays its egg directly in the substrate of the cavity (sticks and vegetation are not gathered from outside the cavity to

create a nest structure), a number of nest manicuring behaviors, such as the gathering and sifting of gravel and other debris from within the cavity to form a surface on which to lay the egg, do occur (N. F. R. Snyder, Ramey, & Sibley, 1986). Parents share incubation duties, and considerable variation in incubation times between parents in one intensively monitored historical nest was observed by Koford in the historical population (1953), though he was not able to determine which bird was male and which bird was female. Snyder and Snyder reported no statistical differences in incubation time between male and female based on their intensive studies of four nesting pairs in the remnant population, though they did report a possible general tendency for females to incubate for longer bouts than males (N. Snyder & Snyder, 2000). Variation between male and female, with a female incubating for longer periods was apparent in a quantitative study of one captive pair for their second and third seasons of nesting (figures from the pair's first season were not reported) (Harvey, Hartt, Leete, & Preston, 1994). During the pair's fourth season of nesting, the male's incubation time increased and no statistical difference in incubation time was observed between the sexes. In nest observations in the reintroduced southern California population, we have seen a general tendency towards pair differences in incubation (personal observation; USFWS unpublished data), though all years of data have yet to be examined.

As feeding habitat is typically distinct from nesting habitat, one parent generally forages while the other is incubating the egg. The egg hatches at approximately 56-58 days after lay, after which the parents take turns brooding the chick. Typically, one parent forages while the other is brooding the chick. In a historical pair, Koford observed a reversal of time spent brooding versus incubating in the sexes (Koford 1953). Brooding

and nest attendance drop off considerably after the chick is about 30 days of age (N. Snyder & Snyder, 2000). The parents' visits then consist primarily of feeding bouts and primarily affiliative interaction bouts (personal observation). Feeding rates between the sexes appear to be equal (N. Snyder & Snyder, 2000). The chick fledges at about 6 months of age, but remains partially dependent on the parents for up to a year following fledging. During this time period, the fledgling makes progressively longer flights with its parents (personal observation; USFWS unpublished data) and makes visits to communal feeding and roosting sites with its parents. It is likely that this period of time is critical for the fledgling's integration into the social hierarchy of the flock and for its learning of feeding and roosting traditions. In this vein, the Recovery Program release strategies for juveniles includes an acclimation period in a field holding pen, during which the juveniles begin to interact with free-flying flock members through a mesh barrier, followed by a soft release that somewhat mimics a natural fledging process. The juveniles then gradually "join up" with other members of the flock and begin to visit communal feeding and roosting sites. Preliminary flight and location data, though based on a small sample of animals, seem to suggest that the integration process is slower for released captive-bred juveniles than for wild-fledged animals (J. Brandt, personal communication 2009). Whether this holds for a larger sample of animals, and whether it is related to the lack of parental investment for new releases compared to wild-fledged chicks, and/or to the lack of critical learning experiences in the nest that captive-reared releases lack, remains to be seen.

### **Conservation status and behavior**

It is generally accepted that the main factor contributing to the decimation of the original condor population was the presence of lead in its food supply. Lead shot has historically been widely used in the range of the condor, and condors as well as other scavengers accidentally ingest particles of lead ammunition when feeding on carcasses or remains of field-dressed carcasses that have been left in the open by hunters. As a result, the reintroduced population partially depends on lead-free food subsidies at proffered feeding sites (sometimes referred to in the literature as “vulture restaurants”), and on frequent blood-lead level monitoring and veterinary treatment for lead poisoning. It is important to note that as the population has expanded into historical foraging range, dependence on food subsidies has declined considerably. However, the need to continually re-trap condors for blood lead level testing and replacement of transmitters has led to the upkeep of what may now be more accurately considered “bait stations.” This management is viewed as necessary until lead contamination is suitably reduced in the condor’s environment. However, mortality from lead toxicosis remains the largest source of mortality in the reintroduced condor populations. These interim management techniques, however, are not without behavioral and other consequences to the population, such as alteration of foraging patterns and possible interruption of courtship, mating, and rearing of offspring.

Though reintroduction of the southern California population of condors began in 1992, many of the individuals had not yet attained sexual maturity and breeding did not begin until 2001. Though breeding effort and hatch success by 2005 stabilized at a level comparable to those observed in the historical and recent historical populations, chick fledges had not reached levels needed for population viability (Mee, Hamber, & Sinclair,

2007). One of the major factors identified by Mee et al. (2007) to be responsible for these failures is the presence of microtrash in nests. Parents bring small items of anthropogenic trash, such as bottle caps, glass shards, and the pop-tops of soda cans back to the nest, where they are apparently ingested by nestlings. Perforations of the gastrointestinal tract and secondary infections have also been associated with the presence of microtrash in nestlings. Though items of trash were infrequently recorded in recent historical and remnant nests, the number of items is substantially higher in some current nests, trash ingestion clearly surpasses that found in the historical population, and nest failure due to microtrash was not documented in the earlier populations (Mee, Rideout, et al., 2007). Impactions sometimes result, and in these situations the nestlings' growth becomes stunted due to malnutrition. It is not entirely clear why condors in the reintroduced population are bringing more trash to their nests, but an examination of similar behavior in some Old World vultures lends insight into the issue.

Cape vultures (*Gyps coprotheres*) appear to swallow bones to feed to their nestlings, and documented skeletal deformities in nestlings have been attributed to parents' inability to find enough bone fragments for their chicks in cattle-ranching country (P.J. Mundy & Ledger, 1976). It is suspected that the vultures were bringing human artifacts such as bottle caps and fragments of china and glass to their nests as bone substitutes (Peter J. Mundy, 1983). Mendelssohn and Leshem (1983) observe that common griffons, rather than swallowing bones to feed to their nestlings as do Cape vultures, seem to carry bone-containing food to the nests, and that in Israel common griffons have been observed picking up and swallowing small stones that are likely calcareous.

Snyder and Snyder (2000) describe successful efforts by the Vulture Study Group to remedy the trash problem in Cape vultures by providing bone fragments at feeding stations (the number of trash brought to nests declined substantially after supplemental bone was provided), and argue that the California condor also faces significant difficulties in finding enough calcium for its nestlings' bone growth. However, Mee et al. (2007) argue that calcium demand is not the only viable hypothesis. Other possible, but not mutually exclusive explanations, include the idea that these small, textured items serve a rangle function (J. Grantham, personal communication 2007), or the possibility that the relaxed time budget of condors that are provided consistent feedings in restricted foraging range has led to an increased time spent seeking out and ingesting these items (Mee, Rideout, et al., 2007). An idea related to the calcium and rangle hypotheses is the hypothesis that condors reared without an established tradition have not formed appropriate search images for the items that they seek (M. Wallace, personal communication 2007). This idea has influenced some of the real-time species management and related behaviors have been incorporated into data collection to the extent possible.

### **Early learning and development**

The literature is rich with evidence of the effects of early rearing conditions on later behavioral competency and reintroduction success in a variety of taxa (see Sackett et al. for a review). The condor, a bird which is long dependent on its parents, slow to mature, and long lived with a rich social network with deep traditions related to foraging and roosting habitat, seems particularly prone to suffer lasting and devastating effects from an impoverished rearing environment. Certainly, early exposure to certain

environmental conditions at the nest have been shown in many bird species to have long lasting effects on behavior (Huber-Eicher, 2004). In the condor, potential inadequacies resulting from suboptimal rearing conditions are further complicated by the fact that the reintroduced populations were returned to an area with no existing populations and no existing traditions. Indeed, since reintroduction began in 1992, 104 condors are dead or presumed dead and 18 have been returned to captivity due to poor survival skills (which may result in predation and malnutrition) or maladaptive human-directed behavior (West, 2009). On the other hand, based on an evaluation of hand-rearing techniques in black and turkey vultures, Wallace and Temple (1983) observed that young vultures learn and readily retain new behavioral patterns, and suggested that even without the influence of wild vultures, species managements could shape the behavioral patterns of released birds into patterns that would become established as long-term traditions that could influence the behavior of subsequently released birds. Captive breeding centers and species managers have indeed been using adaptive management techniques to shape the behavioral patterns of the population, and while some behavioral challenges seem to have faded somewhat over time, others such as microtrash ingestion persist.

In this dissertation I therefore quantitatively assess nesting behavior of free-flying California condors in the southern California population to determine whether differences in parental care among condors with different rearing and experiential histories exist that may be related to offspring physical and behavioral development, and ultimately their fitness. This study will contribute to our theoretical understanding of behavioral development in this flagship species and will provide a scientific basis for improving species management toward the ultimate goal of recovery.

## CHAPTER 2

### GENERAL METHODS

#### Population and Study Site

##### Population

The study population is comprised of the southern California population of California condors. As of October 2009, at the conclusion of the third breeding/nesting season examined, this population consisted of a total of 44 free-flying individuals (USFWS, unpublished data). Of this number, 19 were adults of breeding age (6 years of age or older). Of the 19 adults, there were 7 existing breeding pairs and 5 unpaired adults. Population demographics for each year of data collection are summarized in Table 2.

**Table 2.1** Study population demographics

Breeding/Nesting Season	# Breeding Age Males		# Breeding Age Females		# Subadult Males	# Subadult Females
	<i>Paired</i>	<i>Unpaired</i>	<i>Paired</i>	<i>Unpaired</i>		
2006-2007	4 <sup>a</sup>	2	4 <sup>b</sup>	2	9	4
2007-2008	7	3	6 <sup>c</sup>	2 <sup>d</sup>	8	6
2008-2009	7	3	7	2	12	7

<sup>a</sup>5 including one 5-yr old (237)

<sup>b</sup>5 including one 5-yr old (255)

<sup>c</sup>7 including one 5-yr old (289)

<sup>d</sup>includes a 2008 release (180)

## **Study Site**

### **Habitat types and ranges.**

According to historical records, the main historic range of the California condor extended along the West Coast from southern British Columbia to the Sierra San Pedro Martir of northern Baja California, Mexico (Koford 1953) with a range that extended further inland to the east (N. Snyder & Snyder, 2000). Condors have an extensive yearly range (Koford 1953) with some demonstrated seasonal preferences (e.g., the December-May preference for the Hopper Mountain Region as documented by Koford (1953)). Seasonal preferences seem to be related to weather patterns, courtship, food availability, and the ability of nestlings to fly long distances (Koford, 1953).

The condor primarily seeks open habitat, such as savannah woodland, for foraging, areas with high snags or cliff faces for roosting, and natural cavities in cliffs or large trees, such as giant sequoias (*Sequoiadendron giganteum*) for nesting. Currently, release sites exist in Baja California, Mexico; southern California; central California, and northwestern Arizona. It is expected that the populations in Mexico and California will ultimately mix to form one metapopulation, and that the Arizona population will remain distinct. Though the primary range of the southern California population currently is distinct, members of the population on occasion travel to the central California region and intermingle with the free-flying population there (and vice-versa).

## Procedures

### Behavioral observations

#### General considerations

Movements are determined through a combination of visual identification by multiple crew biologists spread across the region, daily radio telemetry data, and hourly GPS data. Crew members primarily conduct close behavioral observations of condors at feeding, roosting and nesting sites. We view the condors from observation blinds and use high-powered spotting scopes to maximize the distance between observer and condor. These measures are taken to minimize the potential influence of human presence on the behavior of the condors. While it is impossible to determine the influence of our observations on the nesting condors since a control group would require *no* observations (thus rendering the resultant phenomena unobservable), the precedent of nesting success in the recent historical period and in the pilot years of our nest guarding program seems to suggest that our methods of observations are at the very least not causing nest failure, and at the most are increasing nest success. Additionally, because condors in the direct presence of humans do not typically exhibit signs of distress, we do not have strong reason to suspect that our observation and management strategies are causing harm.

#### Pair identification and location of nests

The methods of identifying pairs and locating nests described here were established by A. Mee of the Zoological Society of San Diego's Center for Reproduction of Endangered Species and were refined in 2006-2007 by J. Brandt, USFWS and the author of this proposal, and were outlined by J. Brandt and the author of this proposal in a research and management proposal submitted to the USFWS in December 2006. These

methods are outlined briefly in this dissertation proposal, as 1. Planned quantitative behavioral data collection was a consideration in the refinement of the methods, and 2. The methods employed are relevant insofar as they might affect the analysis of the behavioral data obtained for research purposes.

Pairs must be identified as early in the nesting season as possible so that failed breeding attempts or nesting attempts are not missed. Missing these events could lead to an inaccurate calculation of breeding effort and nest success, and could paint an inaccurate picture of each individual's reproductive history. Thus, a combination of methods is employed early in the courtship and nesting seasons to determine all breeding and nesting activity for each reproductively capable individual in the population. All breeding-aged adults are tracked via a combination of visual observations and daily ground-based radio telemetry during the pre-laying and early nesting seasons, using marking and monitoring techniques established by Wallace, Parker and Temple (1980), Snyder, Ramey and Sibley (1986) and Mee, Hamber and Sinclair (2007). Additionally, we are now able to monitor GPS data (hourly fixes) for those condors capable of carrying a patagial transmitter (because of previous wing damage, some condors are incapable of carrying such a transmitter).

By monitoring the movements of established pairs, we are able to discern precisely when they begin to frequent their nesting territory in search of suitable cavities for egg laying. From this point forward, we closely monitor the particular pair in question, particularly with direct observations in the nesting territory. While it is rare to observe an egg being laid in the wild, we are generally able to observe incubation bouts within several days of egg laying. GPS data are additionally of value, as the signal for an

incubating bird in a cavity generally is lost (the units are solar powered). By observing alternating loss of GPS signals for each member of a pair, we are able to pinpoint a suspected incubation attempt within several days of egg laying, even without direct observation of the area.

Unproven pairs present a more challenging situation, as there is an added component to the nest search: detecting courtship and pairing activity between two previously unaffiliated individuals. The crew pays close attention to the movements and social affiliations of all breeding-aged adults, particularly those who are as yet unpaired, during the courtship and nesting seasons. In the case of an unpaired male in particular, we take close consideration of any indication that he is beginning to frequent a particular new area with any frequency, as this may indicate that he is establishing a nesting territory.

During the 2006-2007 season, our team piloted a study of balanced focal animal observations at feeding sites in an attempt to quantify social behaviors during the breeding and nesting seasons in both established and newly forming pairs. We expected that this would be particularly valuable for detecting new affiliations and predicting new pairings, and for examining Mee and colleagues' hypothesis that mate choice is female-driven in the California condor (2004). However, due to a change in management regime that resulted in greater variability in feeding sites being utilized, we did not attain enough focal observations per animal for analysis. In the 2007-2008 and 2008-2009 seasons, an even greater increase in variability in feeding sites was planned by the management team, and we modified our methods accordingly to rely more heavily on qualitative assessments of pair formation. We continued to record focal observations of all observed

courtship interaction, using an established ethogram (Appendix A) and protocol (Appendix B) to facilitate consistency of interpretation. Occurrence of affiliative interactions between birds prompted the crew to more closely monitor the birds' movements and social interactions, and for previously unpaired individuals, close examination as to whether the individuals were occupying a potential nesting territory. Again, observations of these patterns was largely qualitative as we are only able to directly observe these widely ranging birds in a limited capacity (i.e., spread out in space and time). We recently received funding to establish multiple camera stations to further assess quantitative predictions in the future. This will be especially useful logistically as the population expands in the coming years and will allow us to better evaluate the social dynamics of the southern California flock.

In cases in which egg lay date was unknown, a preliminary estimated lay date was assigned to each egg based on best available contextual information, such as pair copulation rates and particularly movement patterns . Upon egg hatch, the lay date estimation was finalized by counting backwards 57 days from hatch. In cases in which an egg did not hatch, the preliminary estimated lay date was kept.

#### Nest observations

Nest monitoring commenced as soon as a nest was is located. The field crew follows a general guideline of watching each nest for 40% of sunrise-sunset hours in order to have sufficient observational presence at each nest to detect and respond to problems when they occur. Days are balanced across the week to maximize continuous coverage (thus allowing for detection of infrequently occurring events such as incubation exchanges and feeding bouts), while minimizing gaps between observations to as fedw

days as possible so that nest problems are detected. Further, in the event of a nest failure that is not directly observed, having maintained coverage at such a regime gives us a better chance of determining the cause of failure (since the egg or chick may be quickly collected for necropsy before predation or significant decomposition occurs). While this coverage regime provides more extensive coverage than is generally required for a sufficient sample of behavioral data, we have combined monitoring with quantitative data collection to allow for analysis of infrequently occurring events, such as incubation and brooding switches between parents. Observers are assigned to nests by the USFWS with the goal of maximizing blocks of consecutive days of coverage, while minimizing the amount of time between those blocks as much as possible. Observations take place between sunrise and sunset. Behavioral data collection at nest sites has incorporated the 2001-2006 protocol established by A. Mee (ZSSD, unpublished) to allow for some direct comparisons across years. For the egg phase this includes the length of incubation shifts for each parent and the proportion of time either individual spent attending the nest. For the chick phase this includes the length of brooding shifts for each parent and the proportion of time either individual spent attending the nest. Other behaviors from 2001-2006 were recorded primarily *ad libitum* and will be difficult to quantify. All-occurrences (Altmann, 1974) of all inter-and intra-specific social interactions at nests have been recorded using a pre-defined ethogram (Appendix C) and protocol (Appendix D).

#### Observational Effort

The following tables summarize the number of attendance observations conducted per week for each nest in the study. Species management constraints precluded adherence to a strictly balanced or randomized observation schedule. Additional

observation timing constraints bear examination. Note that on some days, nests were observed for attendance patterns only. On some occasions, this was related to poor nest cavity visibility. On others occasions this was related to level of observer training (an observer may have been cleared on identifying attendance patterns but not yet cleared on scoring Activities).

As was anticipated during the study design phase, some nests were subject to a relative reduction in observations due to physical inaccessibility relative to other nests. For instance, DG07 and DG09 were both in a remote canyon with terrain that necessitated a longer hike relative to the other nests and that required climbing skills to access. Therefore, a smaller pool of observers was available to watch these particular nests. Additionally, because of the length of time it took to get to those nests, there were increased scheduling constraints.

The nests of first-time pairs typically took longer to locate than the nests of experienced pairs (e.g., DG07). However, when experienced pairs nested in new parts of their territory, nests also took relatively longer to locate (e.g., AB07, HW08). Therefore, some nests lacked coverage in the early part of the season.

Forces of nature, too, led to a reduction in observation time in some cases. On 21 October 2007, the Ranch Fire reached the Sespe Condor Sanctuary. It burned through three of the nest canyons and necessitated several weeks' evacuation of the area encompassing all four nests. Thus, observations ceased for that period of time. Further, though the Ranch Fire affected observations on all four 2007 nests equally, the frequent issuance of Red Flag Warnings by the USDA Forest Service affected some nests more than others throughout the duration of the study. The USFWS' management approach to

staff and volunteer scheduling evolved somewhat in the early phase of the study. After the Ranch Fire, staff and volunteers were not permitted to observe in nest locations designated as “remote” (so designated because hiking time required an overnight stay and/or because of poor communications access) on Red Flag Warning days. On such days, a biologist was assigned to the highest peak in the region (Hopper Peak) as a designated fire “lookout” so that the less remote nest locations could be observed. This disproportionately reduced the amount of time we were able to devote to observing “remote” nests. Tables 3 and 4 summarize the numbers of observations per week conducted per nest. Nest entry days are excluded as nest entries disproportionately influenced the birds’ behavior (personal observations). Observation days with fewer than two hours of data collection were excluded from all analyses.

**Table 2.2** Number of observations per week during the egg phase.

Egg Week	AB	AB	HC	HC	HC	KR	KR	KR	DG	DG	HB	HB	HW	3C	PC
	07	09	07	08	09	07	08	09	07	09	08	09	08	09	08
1	0	3	1	2	0	4	0	0	0	0	0	1	0	0	3
2	0	4	4	5	0	4	2	0	0	1	5		0	1	3
3	5	2	3	2	3	5	6	4	0	1	6		0	0	3
4	5	1	3	3	3	5	3	5	0	2	6		2	4	3
5	6	2	4	5	2	5	4	3	1	1	3		1	0	2
6	3	3	2	3	3	3	4	0	2	2	2		1	0	3
7	5	5	4	3	3	6	2	3	2	3	6		3	1	4
8	3	2	6	2	4	7		2	3	2	1		5	2	4
9	1		2	3	1	6		1			5		2		2
10				2			5				1				
11				6											

**Table 2.3** Number of observations per week during the chick phase.

Chick Week	AB		HC		KR		DG		HB	HW	3C	PC		
	07	09	07	08	07	08	09	07	09	08	08	09	08	
	1	7	2	6	5	3	4	4	3	5	4	7	3	0
2	4	2	4	5	1	7	7	3	1	2	2	5	0	0
3	4	3	1	4	4	6	6	4	0	2	4	4	3	0
4	7	2	4	3	2	6	6	4	0	2	6	2	3	2
5	6	4	4	3	2	5	5	4	2	2	4	2	1	4
6	5	1	6	2	2	6	6	2	4	2	4	2		2
7	2	4	6	2	3	6	6	4	4	0	5	2		3
8	4	6	4	5	6	6	6	4	4	3	4	2		6
9	5	3	6	0	2	5	5		0	2	3	1		4
10	4	2	4	2	4	6	6		5	3	4	5		5
11	6	2	6	2	4	6	6		3	4	0	4		5
12	2	2	6	4	5	6	6		5	3	2	4		1
13	5	3	4	4	5	5	5		4	3	2	6		6
14	3	2	6	4	4	4	4		3	2	2	4		5
15	2	4	5	4	6	5	5		2	4	5	4		5
16	2	1	5	4	5	5	5		4	2	4	4		6
17	6	0	6	3	5	5	5		3		4			4
18	2	2	6	4	6	5	5		3		3			0
19	4	2	5	7	2	5	5		4		5			5
20	4	3	6	5	6	7	7		3		4			3
21	4	1	2	0	6	6	6		4		2			1
22	3	3		0	6	7	7		5		5			
23	1	5		1	4	6	6		4		5			
24		1		2	5				0		6			
25				4	1				1		2			
26				2					2		4			
27									5		2			
28									3		5			
29									2		2			
30									4		4			
31											0			
32											3			

# **CHAPTER 3**

## **EFFECTS OF PARENTAL CHARACTERISTICS ON ALLOCATION OF CARE AT THE NEST**

To examine the effects of parental characteristics on allocation of care at the nest, attendance data for fourteen condors from seven stable dyads over a period of three breeding seasons were analyzed. All breeding attempts, including repeat attempts by pairs over multiple seasons, were included for a total of fourteen nests examined. The following hypotheses about parental attendance were tested:

Hypothesis 3a: Condor parents will not differ in their change trajectories for mean daily attendance throughout the egg phase.

Hypothesis 3b: Condor parents will differ in their change trajectories for mean daily attendance throughout the chick phase.

### **Data Analysis**

Parental attendance and activity budget data were analyzed using a multilevel modeling approach. The multilevel approach was particularly suited to this set of observational field data, as this specification can accommodate data sets that are unbalanced and have multiple levels of aggregation (Martjin van de Pol & Wright, 2009; Singer & Willett, 2003), as well as include time-varying predictors and interactions with time (Singer & Willett) and account for possible intercorrelation between measurements

within the same individual (M. van de Pol & Verhulst, 2006; Singer & Willett, 2003). Because the dependent variables of interest are proportions, the generalized linear approach was used. This enabled the specification of a non-normal error distribution as well as the use of a nonlinear link function (Hox, 2010a), which in this case were a binomial error distribution and a logit link function (Hox, 2010a; Raudenbush & Bryk, 2002). Data were conceptualized as repeated observations (level 1) nested within individual condors (level 2). As there was no unambiguous control group for categorical variables, the were effects coded (Cohen & Cohen, 1983; Hox, 2010b) for analysis.

Adaptive Gauss-Hermite quadrature (AGQ), which may produce more accurate approximations to the required integral for models with small level-2  $n$  (Raudenbush & Bryk, 2002), was used for integral approximation where possible. The 2<sup>nd</sup> derivative was used in these cases. In cases where the adaptive Gaussian Hessian was unable to be computed, models were estimated via Penalized Quasi-likelihood (PQL). However, it should be noted that, as observed by Breslow and Lin (1995) and further discussed by Raudenbush & Bryk (2002), PQL may produce biased and inconsistent regression coefficients in models with nested random effects, particularly when the random effects have large variances.

For each outcome variable, an unconditional growth model (Singer & Willett, 2003), also referred to as a random coefficient regression model (Raudenbush & Bryk, 2002) was first fitted assess the presence of between-condor variability in the outcome of interest. The only predictor in this model was time. This enabled a determination as to whether variation was present at each level that could potentially be explained

(Raudenbush & Bryk, 2002; Singer & Willett, 2003). The unconditional growth model takes the following form (HLM 7):

$$\begin{aligned} &\text{Level-1 Model} \\ E(OUTCOME_{ti}=1|\pi_i) &= \phi_{ti} * BINOMIAL_{ti} \\ \log[\phi_{ti}/(1 - \phi_{ti})] &= \eta_{ti} \\ \eta_{ti} &= \pi_{0i} + \pi_{1i} * (TIME_{ti}) \end{aligned}$$

$$\begin{aligned} &\text{Level-2 Model} \\ \pi_{0i} &= \beta_{00} + r_{0i} \\ \pi_{1i} &= \beta_{10} + r_{1i} \end{aligned}$$

$$\text{Level-1 variance} = 1/[BINOMIAL * \phi_{ti}; (1 - \phi_{ti})]$$

where *OUTCOME* is the dependent variable of interest,  $\pi_{0i}$  and  $\pi_{1i}$  are the individual growth parameters,  $\beta_{00}$  is the intercept for  $\pi_{0i}$  while  $r_{0i}$  is the residual variance for  $\pi_{0i}$ , and  $\beta_{10}$  is the intercept for  $\pi_{1i}$  while  $r_{1i}$  is the residual variance for  $\pi_{1i}$ . Regarding the individual growth parameters  $\pi_{0i}$  and  $\pi_{1i}$ , which in a linear model are the intercept and slope respectively, Singer and Willett (2003) explain that,

Because the level-1 logistic model is not linear in *TIME*,  $\pi_{0i}$  and  $\pi_{1i}$  take on roles that relate to, but differ from, their roles in a linear model...  $\pi_{0i}$  is *not* the intercept but it is *related* to and determines the value of the intercept...the second individual growth parameter,  $\pi_{1i}$ , is not a slope per se, but it does determine the rapidity with which the trajectory approaches the upper asymptote. (p.228)

In this dissertation, I follow Singer and Willett's convention that, for ease of presentation, I will refer to the first growth parameter  $\pi_{0i}$  as an "intercept" and the second growth parameter,  $\pi_{1i}$  as a "slope," but it should be underscored that these growth parameters are not true intercepts or slopes, but are related to them. It should also be noted that the

interpretation of the “intercept” changes further when the effects of time are recentered around some constant (Singer & Willett). In the case of several variables, time was recentered from day zero of a study phase to the midpoint of the study phase for substantive reasons. Using the unconditional growth model, then, the following four hypotheses were tested for each outcome (Singer & Willett):

### **Fixed Effects**

H<sub>0</sub>:  $\pi_{0i}$  was non-zero

H<sub>1</sub>:  $\pi_{1i}$  was non-zero

### **Variance Components**

H<sub>0</sub>: There was zero inter-condor variability in  $\pi_{0i}$

H<sub>1</sub>: There was zero inter-chick variability in  $\pi_{1i}$

The results of the hypothesis tests for each outcome informed the assessment of the overall prediction for each outcome. If the null hypothesis regarding either of the variance parameters was rejected, condor-level predictors were then explored. Results of the most interesting subset of models are presented in a table for each dependent variable, and the change trajectory is interpreted for the most compelling, or “final,” model available. Single-parameter test statistics were used to help identify which predictors to retain (Singer & Willett, 2003). Single-parameter tests for the variance components were used to help determine whether additional outcome variation was left to predict (Singer & Willett, 2003), but they can be sensitive to sample size, imbalance, and departures from normality (Longford, 2000; Raudenbush & Bryk, 2002; Singer & Willett, 2003). As the

data in this study are unbalanced and the cluster sizes are small, these test statistics should be interpreted with caution. The deviance statistic and Akaike Information Criterion (AIC) are presented (Singer & Willett, 2003) where possible. If convergence was not possible with AGQ, PQL was used and deviance-based statistics are therefore unavailable.

The residual intraclass correlation (ICC) for binomial models, assuming that the dichotomous outcome is a result of an underlying non-observed continuous variable, was calculated for each outcome according to the following formula (Hox, 2010b; Raudenbush & Bryk, 2002; Snijders & Bosker, 2012):  $\rho = \left( \tau_{00} / (\tau_{00} + \frac{\pi^2}{3}) \right)$ . In this formula, the level 1 variance is replaced by the variance of a standard logistic distribution. The ICC was used to estimate the variance attributable to the condor level (*cf.* Husum, Bjørngaard, Finset, & Ruud, 2010). All  $p$  values were set to 0.05. IBM Statistics 20 was used for descriptive analyses and HLM 7 was used for multilevel modeling.

Ideally, the analyses would have included a third level: individuals nested within dyads. Unfortunately, at the time of this study too few dyads are present in the population to meaningfully model dyadic behavior (*cf.* Kenny, Cook, & Kashy, 2006, p. 88). Because pair members share parental duties and each individual's behavior is likely to be nonindependent within each pair, and to account for repeated measures across years, I fitted pair membership and nesting season as random factors (*cf.* Canestrari, Marcos, & Baglione, 2008) at level 2 of the analysis. As the population grows, the synchronicity of pair behavior, particularly in relation to factors such as age of the pair bond and success of previous nesting attempts, should be incorporated into these models.

Lay date was conceptualized and recorded as Egg Day 0. This corresponds with Nest Day 0. Hatch day was conceptualized and recorded as Chick Day 0. Chick Day 0 typically occurred between Nest Day 56-58, unless infertility was discovered and a wooden egg temporarily placed in the nest. Because of this variability, and based on the rationale that tending to an egg is substantively different behavior than that of tending to a chick, parental behaviors were analyzed separately for Egg and Chick phases.

Individual life history characteristics of the nesting condors in this study served as independent variables at level 2 of the analysis and are summarized in Table 5. Time invariant characteristics include sex, rearing location, rearing type, hatch year, and mate during the study period. Breeding history was included as a time-varying characteristic. Only one condor, SB #21, was reared in the wild. All other breeding condors in this study were reared in isolation facilities at either the Los Angeles Zoo (LAZ) or the San Diego Wild Animal Park (SDWAP). While conducting interviews of husbandry personnel, and while inspecting each facility's records, it became apparent that rearing techniques not only changed as knowledge was gained and the program evolved, but also that protocols differed between institutions. Because records were not consistent across facilities and across staff within each facility, it was not possible to quantify this variation.

Finally, visibility of nest cavities varied widely across nests. Some cavities were in shadow for varying portions of the day, some were located behind view-obstructing vegetation, some were deep and the birds disappeared as soon as they entered, and some were farther away from the nearest observation site and were thus subject to more heat distortion through the spotting scopes. Therefore, analysis of the proportion of time each

chick spent Not Visible is presented, and based on those results visibility was included as a control variable in analyses of other outcomes.

**Table 3.1** Characteristics of individual condors.

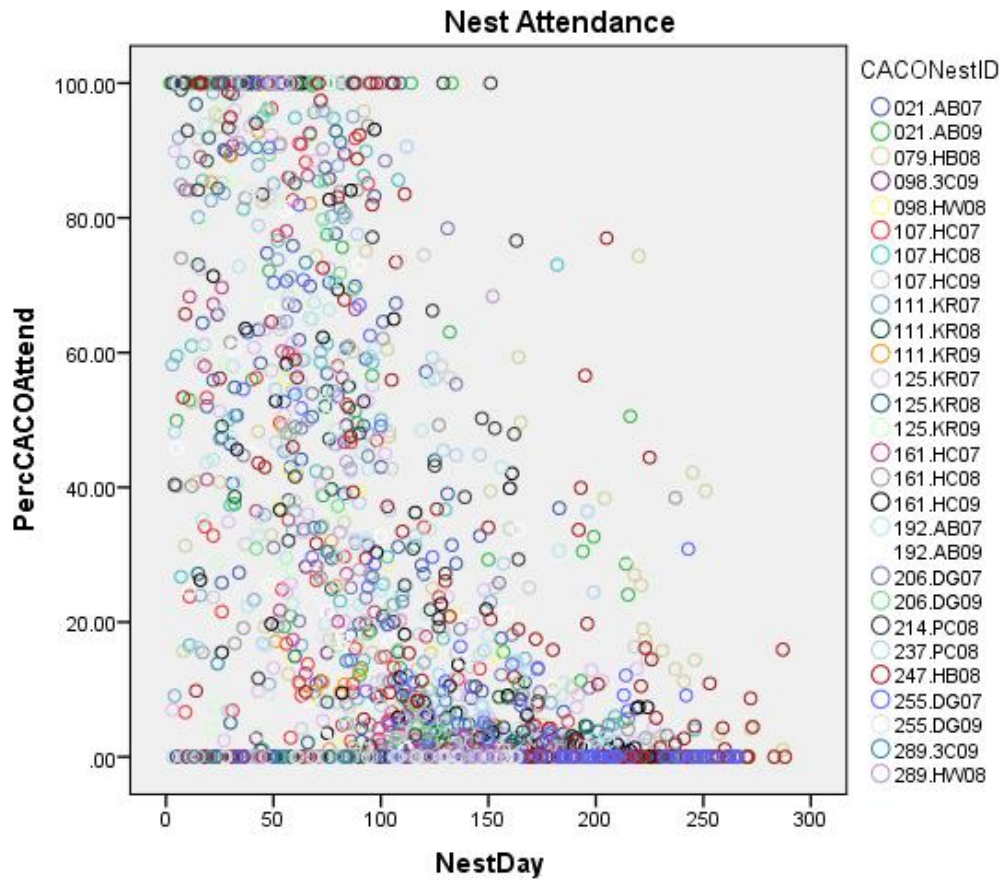
Condor	Sex	Rearing Location	Rearing Type	Breeding History	Hatch Year	Mate During Study
21	M	Wild	Parent	Successful	1980	192
79	F	LAZ	Puppet	None	1992	247
98	M	SDWAP	Puppet	Unsuccessful	1994	289
107	M	LAZ	Puppet	Successful	1994	161
111	F	SDWAP	Puppet	Successful	1994	125
125	M	SDWAP	Parent	Successful	1995	111
161	F	SDWAP	Parent	Successful	1997	107
192	F	LAZ	Parent	Unsuccessful	1998	21
206	M	LAZ	Puppet	None	1999	255
214	F	SDWAP	Puppet	Successful	2000	237
237	M	SDWAP	Puppet	Successful	2001	214
247	M	SDWAP	Puppet	None	2001	79
255	F	SDWAP	Puppet	None	2001	206
289	F	LAZ	Parent	None	2002	98

## Results

### Nest attendance

Figure 3.1 illustrates each individual condor's attendance trajectory over the life of each nest. In order to ensure that wooden 'dummy' egg days from some nests were not being compared to early chick days in others, parental attendance was analyzed separately for the egg and chick phases.

Figure 3.1



Egg phase

In order to determine whether variation existed in individual growth parameters, egg attendance data from one season per pair were fitted to an unconditional growth model via PQL (Table 3.2). The test statistics led to a failure to reject the null hypothesis that  $\pi_{0i}$  was non-zero ( $p = 0.465$ ), and to a rejection of the null hypothesis that  $\pi_{1i}$  was non-zero ( $p = 0.826$ ). Regarding the variance components, there was a failure to reject the hypothesis that there was zero inter-condor variability in  $\pi_{0i}$  ( $p = 0.288$ ) and a failure to reject the null hypothesis that there was zero inter-condor variability in  $\pi_{1i}$  ( $p > 0.500$ ).

The ICC was 0.061, indicating that just over six percent of variation in attendance across the chick phase was attributable to differences between parents.

**Table 3.2** Unconditional growth model for egg attendance

Egg Attendance, One Season per Condor	Parameter	UCG Model
<b>Fixed Effects</b>		<i>Coefficient (se)</i>
“Intercept” $\pi_{0i}$	$\beta_{00}$	-0.155 (0.296)
“Slope” $\pi_{1i}$	$\beta_{10}$	0.002 (0.007)
<b>Variance Components</b>		<i>Coefficient (sd)</i>
Level 2 residual variance in “intercept” $\pi_{0i}$	$r_{0i}$	0.212 (0.460)
Level 2 residual variance in “slope” $\pi_{1i}$	$r_{1i}$	0.000 (0.010)
Residual ICC		0.061

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$

### Chick phase

In order to determine whether variation existed in individual growth parameters in attendance for the chick phase, data from one season per pair were fitted to an unconditional growth model via AGQ (Table 3.3). The test statistics led to a failure to reject the null hypothesis that  $\pi_{0i}$  is non-zero ( $p = 0.465$ ), and to a rejection of the null hypothesis that  $\pi_{1i}$  is non-zero ( $p < 0.001$ ). Regarding the variance components, there was a failure to reject the null hypothesis that there was zero inter-condor variability in  $\pi_{0i}$

( $p = > 0.500$ ) and a failure to reject the null hypothesis that there was zero inter-condor variability in  $\pi_{1i}$  ( $p = 0.372$ ). The ICC was 0.001, indicating that there was little between-condor variation to explain.

**Table 3.3** Unconditional growth model for chick attendance

Chick Attendance, One Season per Condor (AGQ)	Parameter	UCG Model
<b>Fixed Effects</b>		<b>Coefficient (se)</b>
“Intercept” $\pi_{0i}$	$\beta_{00}$	0.112 (0.114)
“Slope” $\pi_{1i}$	$\beta_{10}$	-0.029*** (0.003)
<b>Variance Components</b>		<b>Coefficient (sd)</b>
Level 2 residual variance in “intercept” $\pi_{0i}$	$r_{0i}$	0.003 (0.050)
Level 2 residual variance in “slope” $\pi_{1i}$	$r_{1i}$	0.000 (0.005)
Residual ICC		0.001

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$

## Discussion

The aims of attendance analyses were to explore change trajectories over the life of the nest and to determine whether systematic condor-level differences were associated with these trajectories that could reflect differential investment.

For egg attendance, the failure to reject the hypothesis that the “intercept” of the change trajectory is non-zero may be an artifact of data collection, as nests are rarely

located on egg day zero. However, when an unconditional means model was fitted with stage day centered at the middle of the egg phase, there was also a failure to reject the null hypothesis that this parameter was non-zero at day 15 of the egg phase. A more likely explanation for the failure to find non-zero “intercept” parameters for attendance may be related to the all-or-nothing pattern of attendance bouts exhibited by each member of the pair. Since parents take turns incubating the egg, one parent necessarily scores a “zero” for attendance while its mate is attending. This could be expected to affect the “intercept” parameter for a given condor that was not attending on the day that the parameter is estimated. In the future, once more years of data are available, it will be instructive to examine one condor from each nest only to eliminate this issue.

The overall egg phase attendance trajectory, which was non-zero, appears to be consistent with those reported in the recent historic (N. Snyder & Snyder, 2000, 2005) population. The failure to detect significant inter-condor variability in the “intercept” or “slope” parameters of the egg attendance change trajectory suggests that condors do not differ systematically from one another in egg attendance patterns. Specifically, Snyder & Snyder determined that males and females of a pair share almost equally in incubation duties. However, in regard to nest attendance, Koford (1953) observed differences between a pair observed at “Nest 1” in 1939. Though he was unable to identify the sex of each bird, he reported that parent “A” spent 70% of observed time in the nest during the egg stage and 27% of observed time in the nest during the chick stage. Conversely, parent “B” spent 28% of observed time in the nest during the egg stage and 73% of observed time in the nest during the chick stage. Accordingly, he observed that parent “A” performed most of the incubation of the egg and parent “B” performed most of the

continuous brooding. Koford speculated that differences in incubation and brooding were “probably due to sex,” though he also observed behavioral differences, such as displacement trends, that he attributed to dominance, and location patterns, that he attributed to individuality. In a study of a captive condor breeding pair during the 1989, 1991, and 1992 nesting seasons at SDWAP, Harvey et al (1994) observed changes in male incubation behavior over the seasons that they suggested might be a result of several factors, including increased mate compatibility over time, social maturation, and/or increased male dominance over time. During the first and second years, the female spent more time incubating the egg, while in the third year the investigators observed no significant difference between the sexes in incubation time. However, significant differences were *not* observed between the male and female in regard to nest attendance (i.e., the percentage of time spent on the nest box and not incubating). These findings, then, are consistent with those in the reintroduced southern California population. They also suggest that it is possible that the pair Koford observed was exhibiting a pattern typical of a pair that is just beginning to bond, and the attendance pattern may have changed over time to reflect a more equal time investment from each parent. It is important to recognize, though, that in addition to the small sample size of the historical population, it was also subject to vastly different circumstances than were the recent historic and reintroduced populations. Further, when comparing wild to captive studies it is essential to recognize that nest box visits in a captive breeding pen may be substantively different from nest cavity visits in the wild,

The failure to reject the null hypothesis that nest attendance is non-zero at Chick Day Zero, like the egg phase, could have been similarly influenced by the alternating

attendance patterns of the parents at the nest. The rejection of the null hypothesis that the average true change trajectory in attendance during the chick phase has a non-zero “slope” is consistent with observations in the recent historic (N. Snyder & Snyder, 2000, 2005) population. The authors report almost continuous presence at or near the nest by one or the other parent in the first 30 days of the chick’s life, followed by a rapid decline and subsequent stabilization at a lower level at about the beginning of the twelfth week, a pattern that appeared to be present in the reintroduced population. This steep decline is consistent with reduced need to assist with thermoregulation after the chick reaches about one month in age.

The failure to find variation in attendance trajectories attributable to differences between condors in both the chick and egg phases was not consistent with early program concerns that captive-bred birds might exhibit deficient nesting behavior in the wild. Because of the differences inherent in a captive-reared versus wild-fledged environment, these results may be inconsistent with the idea that at least one aspect of parenting, nest site attendance, has a learned component. On the other hand, based on Harvey et al. (1994) it seems that condors exhibit flexibility over time in regard to parenting behavior at the nest. Indeed, based on anecdotal field reports of condor learning it may be more likely that condor are capable of learning new parenting patterns over time.

It is also inconsistent with anecdotal reports from zoos that captive male condors tend to spend more time caring for the chick during the later phase of its development (Mike Clark, personal communication 2007), as well as with evidence from a field study of a pair of Andean condors that the male provided more parental care after hatching (Lambertucci & Mastrantuoni, 2008). Of course, these results of this study should be

interpreted with caution as number of individual condors is extremely small. Additional individuals should be added to future analyses, and the interdependency of pair members' behavior more closely examined. It is possible that a condor with deficient early rearing experience may take behavioral cues from a more experienced mate. For instance, SB# 21 was reared in the wild in the 1980s. SB # 192, his mate in the reintroduced southern California population, was parent-reared by 21 in captivity. It is possible that she benefitted from her mate's early experience in a complex environment. In another case, SB# 111 was pupped-reared in captivity, while her mate in the reintroduced population, SB# 125, was parent-reared. Again, it is possible that 111 as an adult may benefit from 125's early rearing experience.

## CHAPTER 4

### OFFSPRING ACTIVITY AND DEVELOPMENT AT THE NEST

To examine differences among chicks in behaviors over time, activity data for fourteen chicks were analyzed. All hatched chicks during the three seasons of study were included in analyses. The following hypotheses about chick behavior and chick-parent interaction were tested:

Hypothesis 4a: The mean percent time a chick is not visible during days 0-30 will vary among nests.

Hypothesis 4b: The mean percent time a chick is not visible during days 31-fledge will vary among nests.

Hypothesis 4c: The change trajectory for the mean time spent “active” on a given day during chick days 0-30 will differ among chicks

Hypothesis 4d: The change trajectory for the mean time spent “inactive” (IV) on a given day during chick days 0-30 will differ among chicks.

Hypothesis 4e: The change trajectory for the mean time spent “inactive” (SA,RS) on a given day during chick days 31-fledge will differ among chicks.

Hypothesis 4f: The change trajectory for the mean time spent interacting with a parent during the entire nestling phase will differ among chicks.

## **Data Analysis**

Chick behaviors were analyzed over the course of the time spent in the nest. As with parental analyses, data were conceptualized as a two-level model with repeated measures (observation days) nested within individuals (offspring). Some behaviors that were recorded uniquely during the early chick stage were analyzed between chick days zero - thirty, while analyses for their later counterparts are presented for chick days thirty one - fledge. Finally, some behaviors are analyzed from day zero – fledge. Chick activity budgets were analyzed using the same methods outlined for analyses of parental behavior in Chapter 3.

## **Results**

### **Chick Days 0 -30**

During the first month of life, condor parents spend a considerable amount of time at the nest brooding the chick, after which it is better able to thermoregulate on its own (Joseph Brandt, personal communication 2007). During this time, it is often difficult to see the chick while it is being brooded by its parent. Additionally, the chick's small size during this time makes determining fine-scale behaviors, particularly those requiring an assessment of alertness, such as stationary alert, difficult for field observers. Therefore, with the exception of interactive and feeding behaviors, as well as clearly defined action behaviors (such as sunning), a simplified ethogram that primarily characterized the chick as either "active" or "inactive" was used for that time period. Another important category was "not visible," during which a chick either could not be seen or its behavior could not be determined.

### Not Visible

Figure 4.1 illustrates the percent time that observers scored the chick at each nest as Not Visible during Chick Days 0-30. Observers scored a chick as Not Visible if they were unable to see the chick (for instance, if it was at the back of the cavity in shadow), or if they could see all or part of the chick but could not determine what it was doing (for instance, if a chick was in a posture at a viewing angle that made the specific behavior impossible to determine).

**Figure 4.1** Chick Days 0 – 30: Not Visible

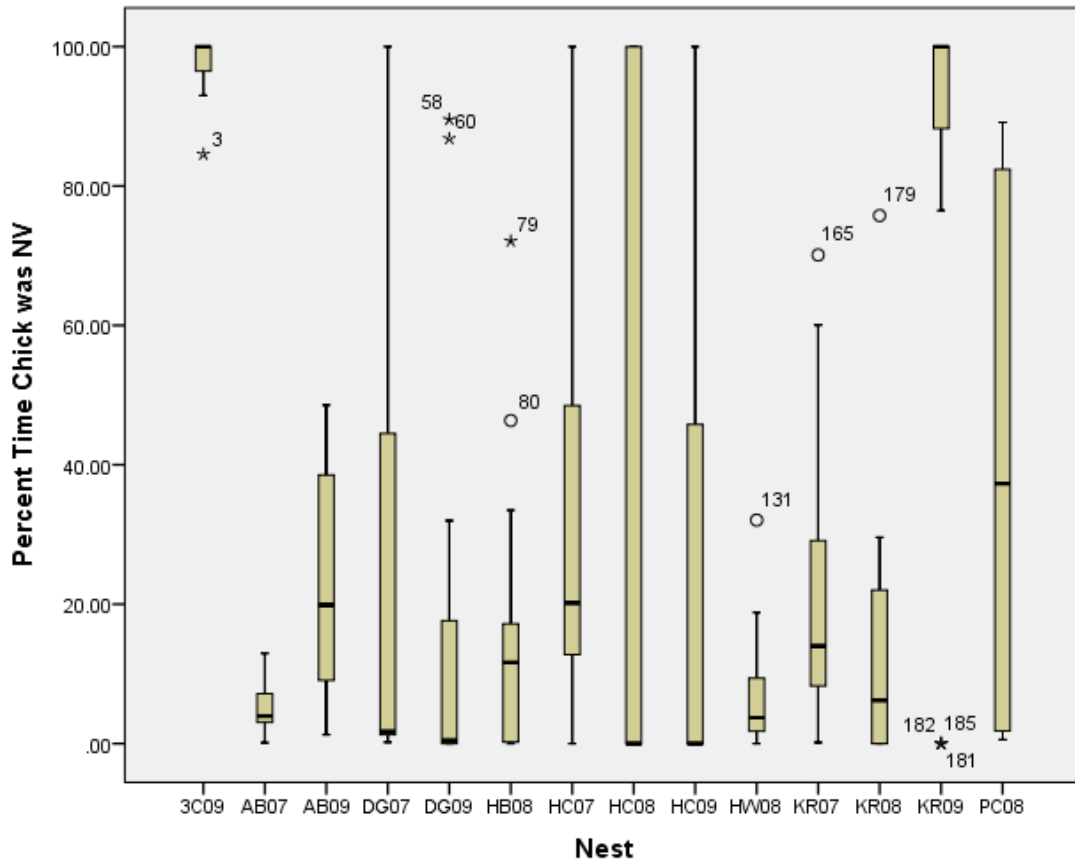


Table 4.1 summarizes a subset of multilevel models fit to the proportion of time each chick spent Not Visible between days 0-30 using PQL. Time was centered at the midpoint of the early chick phase (Day 15). The test statistics led to a rejection of the null hypothesis that  $\pi_{0i}$  was non-zero ( $p = 0.010$ ), and to a rejection of the null hypothesis that that  $\pi_{1i}$  was non-zero ( $p = 0.001$ ). Regarding the variance components, there was a rejection of the null hypothesis that there was zero inter-chick variability in  $\pi_{0i}$  ( $p < 0.001$ ), and a failure to reject the null hypothesis that there was zero inter-chick variability in  $\pi_{1i}$  ( $p > 0.500$ ). The ICC for the unconditional growth model was 0.223, indicating that over 22 percent of variation in visibility across the early chick phase was attributable to differences between chicks.

There was no statistically significant association detected between parents' hatch year difference and chick visibility, so hatch year difference was not included in the final model. Though there was no statistically significant association detected between pair identity and chick visibility, the ICC was reduced the most, to 0.081, when both season and pair identity were incorporated into the model. Therefore, pair identity was retained in the final model. There was a significant association between season and chick visibility; there was an increase in likelihood of proportion of time spent Not Visible in 2009 relative to the unweighted mean (OR: 2.678; 95% CI: 1.038 - 6.905;  $p = 0.044$ ) after adjustment for pair identity .

Because there was substantial variation in visibility among chicks from days 0 – 30, visibility, coded as a categorical variable of high/low, was accounted for in level 2 of subsequent models of early chick stage behavior.

**Table 4.1** Proportion of time Not Visible during early nestling phase

Chick Not Visible, Days 0-30, PQL	Parameter	UCG Model	Model B	Model C	Model D	Model E
<b>Fixed Effects</b>		<i>Coefficient</i> ( <i>se</i> )	<i>Coefficient</i> ( <i>se</i> )	<i>Coefficient</i> ( <i>se</i> )	<i>Coefficient</i> ( <i>se</i> )	<i>Coefficient</i> ( <i>se</i> )
“Intercept” $\pi_{0i}$	$\beta_{00}$	-0.956* (0.320)	-0.993** (0.278)	-0.600 (0.519)	-1.119** (0.410)	-1.084* (.377)
	Season					
	2009		0.772 (0.404)			0.985* (0.368)
	2008		-0.339 (0.401)			-0.762 (0.428)
	HY Diff			-0.086 (0.101)		
	Pair					
	98.289				0.813 (0.810)	0.624 (0.711)
	107.161				0.366 (0.643)	0.307 (0.540)
	111.125				0.473 (0.651)	0.393 (0.555)
	206.255				0.158 (0.867)	-0.527 (0.812)
	237.214				-0.234 (1.787)	0.494 (1.725)
	247.079				-0.692 (0.993)	0.035 (0.877)
“Slope” $\pi_{1i}$	$\beta_{10}$	0.072** (0.021)	0.073** (0.021)	0.094 (0.033)	0.086** (0.030)	0.095* (0.031)
	Season					
	2009		0.03 (0.031)			0.0411 (0.034)
	2008		-0.04 (0.028)			-0.698 (0.038)
	HY Diff			-0.005 (0.994)		
	Pair					
	98.289				-0.008 (0.070)	0.010 (0.074)
	107.161				-0.046 (0.413)	-0.642 (0.043)
	111.125				0.015 (0.047)	-0.000 (0.076)
	206.255				0.059 (0.073)	0.114 (0.130)
	237.214				0.054 (0.127)	0.029 (0.072)
	247.079				-0.032 (0.066)	0.029 (0.072)
<b>Variance Components</b>		<i>Coefficient</i> ( <i>sd</i> )				
Level 2 residual variance in “intercept” $\pi_{0i}$	$r_{0i}$	0.942*** (0.971)	0.667** (0.817)	0.881*** (0.938)	0.714*** (0.845)	0.290*** (0.539)
Level 2 residual variance in “slope” $\pi_{1i}$	$r_{1i}$	0.000 (0.019)	0.000 (0.012)	0.000 (0.014)	0.000 (0.012)	0.000 (0.007)
Residual		0.223	0.169	0.221	0.178	0.081

Chick Not Visible, Days 0-30, PQL	Parameter	UCG Model	Model B	Model C	Model D	Model E
		Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)
<i>Fixed Effects</i>						
<i>ICC</i>						

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$   
*TIME* was centered around middle status.

Active

Figure 4.2 illustrates the percent time that observers scored the chick at each nest as Active (AV) between Chick Days 0 - 30.

**Figure 4.2** Percent time Active during early nestling phase

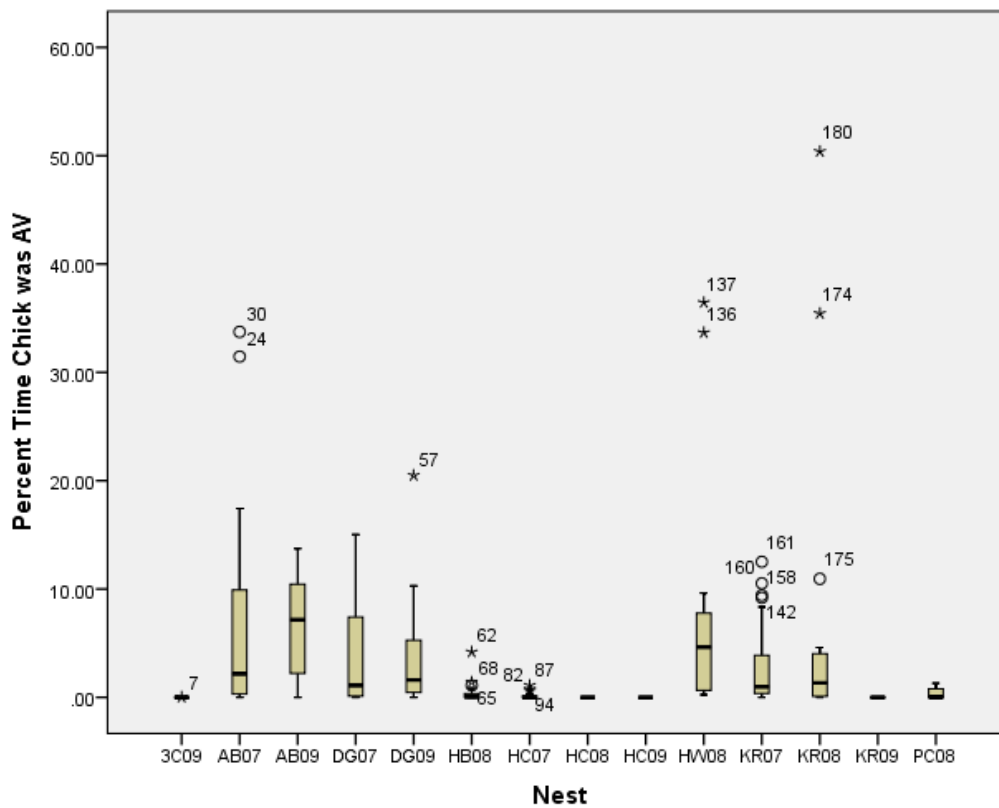


Table 4.2 summarizes the results of fitting multilevel models to the proportion of time each chick spent Active between days 0 – 30 using AGQ. Time was centered at the midpoint of the early chick phase (Day 15). The test statistics led to a rejection of the null hypothesis that that  $\pi_{0i}$  was non-zero ( $p < 0.001$ ), and to a failure to reject the null hypothesis that that  $\pi_{1i}$  was non-zero ( $p = 0.349$ ). Regarding the variance components, there was a failure to reject the hypothesis that there was zero inter-chick variability in  $\pi_{0i}$  ( $p > 0.500$ ), and to a failure to reject the null hypothesis that there was zero inter-chick variability in  $\pi_{1i}$  ( $p > 0.500$ ). The residual ICC for the unconditional growth model was 0.000, indicating that there was little-to-no between-chick variation to explain.

**Table 4.2** Proportion of time Active during early nestling phase

Chick Active, Days 0-30, AGQ	Parameter	UCG Model
<b>Fixed Effects</b>		<i>Coefficient (se)</i>
“Intercept” $\pi_{0i}$	$\beta_{00}$	-3.500*** (0.431)
“Slope” $\pi_{1i}$	$\beta_{10}$	0.044 (0.045)
<b>Variance Components</b>		<i>Coefficient (sd)</i>
Level 2 residual variance in “intercept” $\pi_{0i}$	$r_{0i}$	0.000 (0.016)
Level 2 residual variance in “slope” $\pi_{1i}$	$r_{1i}$	0.000 (0.001)
Residual ICC		0.000

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$   
*TIME* was centered around middle status.

Inactive

Figure 4.3 illustrates the percent time that observers scored the chick at each nest as Inactive.

**Figure 4.3** Percent of time Inactive during early nestling phase

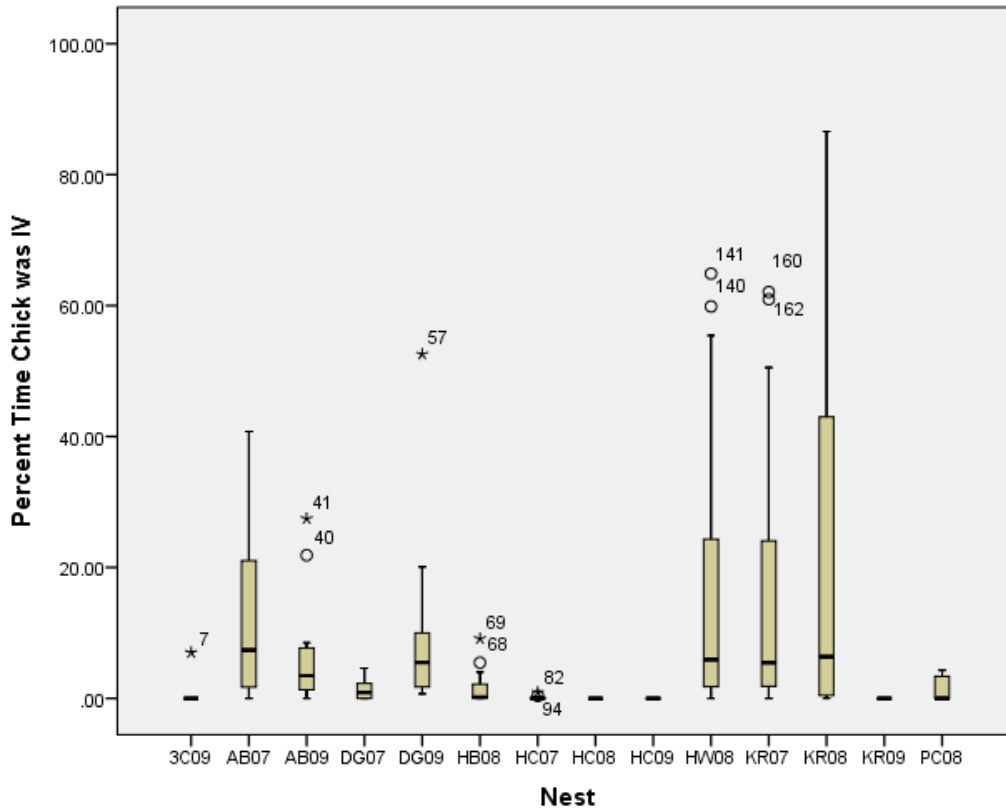


Table 4.3 summarizes the results of fitting multilevel models to the proportion of time each chick spent Inactive (IV) between days 0-30 (PQL). Time was centered at the midpoint of the early chick phase (Day 15). The test statistics for the unconditional growth model led to a rejection of the null hypothesis that  $\pi_{0i}$  was non-zero ( $p < 0.001$ ), and to a failure to reject the null hypothesis that  $\pi_{1i}$  was non-zero ( $p = 0.052$ ). The test statistics for the variance components of the unconditional growth model led to a failure

to reject the null hypothesis that there was zero inter-chick variability in  $\pi_{0i}$  ( $p > 0.500$ ), and to a failure to reject the null hypothesis that there was zero inter-chick variability in  $\pi_{1i}$  ( $p > 0.500$ ). However, the residual ICC was 0.142, indicating that despite the failure to find significant results for the variance tests there may be a substantial amount of variation among chicks. It is possible that the failure to detect significance is related to the small sample size (cf. Singer and Willett, 2003).

**Table 4.3** Proportion of time Inactive during early nestling phase

Chick Not Visible, Days 0-30, PQL	Parameter	UCG Model
		<i>Coefficient</i> ( <i>se</i> )
<b>Fixed Effects</b>		
“Intercept” $\pi_{0i}$	$\beta_{00}$	-2.831*** (0.387)
“Slope” $\pi_{1i}$	$\beta_{10}$	0.078 (0.036)
		<i>Coefficient</i> ( <i>sd</i> )
<b>Variance Components</b>		
Level 2 residual variance in “intercept” $\pi_{0i}$	$r_{0i}$	0.543 (0.737)
Level 2 residual variance in “slope” $\pi_{1i}$	$r_{1i}$	0.001 (0.036)
Residual ICC		0.142

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$   
*TIME* was centered around middle status.

### Chick Days 31 - fledge

Not Visible

Figure 4.4 illustrates the percent time that observers scored the chick at each nest as Not Visible, or NV, during Chick Days 31 – fledge. Notably, visibility appears to have improved for at least several nests.

**Figure 4.4** Percent of time Not Visible during late nestling phase

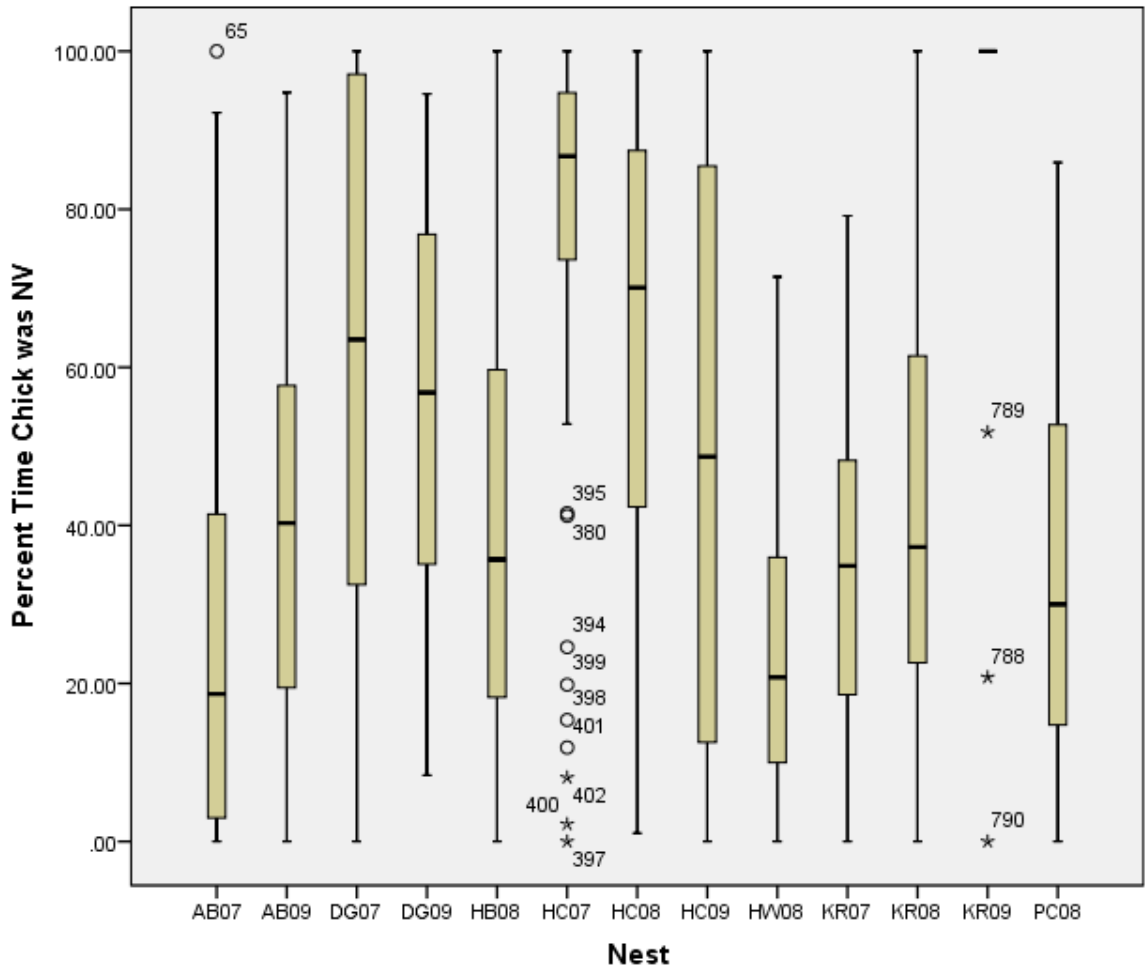


Table 4.4 summarizes the results of fitting multilevel models to the percent time each chick spent Not Visible (NV) between days 31- fledge (PQL). Time was centered at the midpoint of the late nestling phase (Day 127). The test statistics for the unconditional

growth model led to a failure to reject the null hypothesis that  $\pi_{0i}$  was non-zero ( $p = 0.076$ ), and to a failure to reject the null hypothesis that  $\pi_{1i}$  was non-zero ( $p = 0.158$ ). Regarding the variance components, there was a rejection of the hypothesis that there was zero inter-chick variability in  $\pi_{0i}$  ( $p = 0.005$ ), and a rejection of the null hypothesis that there was zero inter-chick variability in  $\pi_{1i}$  ( $p < 0.001$ ). The residual ICC for the unconditional growth model was 0.036, indicating that 3.6% of variation in visibility across the late nestling phase is attributable to differences at the chick level.

There was no statistically significant association detected between parents' hatch year difference and late-stage chick visibility. There was a significant association between season and chick time spent Not Visible; in 2009 the change trajectory decreased, on average, at a rate of 0.015 logits per day faster than that of the unweighted mean (OR: 0.985; 95% CI: 0.972-0.997;  $p = 0.029$ ) after adjustment for pair identity. There was also a significant association between pair and chick time spent Not Visible; for 107/161 the change trajectory decreased, on average, at a rate of 0.026 logits per day faster than that of the unweighted mean (OR: 0.979; 95% CI: 0.962, 0.995;  $p = 0.024$ ) after adjustment for season. The ICC was reduced the most, to 0.031, when only season was incorporated into the model. However, the ICC was similar, 0.033, when both pair identity and season were incorporated into the model. As pair identity made sense as a substantive predictor, it was retained in the final model.

Because there was substantial variation in visibility among chicks from days 31-fledge, visibility, coded as a categorical variable of high/low, was accounted for in level 2 of subsequent models of chick behavior during that time frame.

**Table 4.4** Proportion of time Not Visible during late nestling phase

Chick Not Visible, Days 31-fledge, PQL	Parameter	UCG Model	Model B	Model C	Model D	Model E	
<i>Fixed Effects</i>		Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	
"Intercept" $\pi_{0i}$	$\beta_{00}$	-0.272 (0.139)	-0.380** (0.215)	-0.180 (0.250)	-0.255 (0.226)	-0.426 (0.223)	
	Season						
	2009	$\beta_{01}$		-0.388 (0.215)			-0.568 (0.265)
	2008	$\beta_{02}$		0.055 (0.175)			0.369 (0.272)
	HY Diff	$\beta_{04}$			-0.026 (0.050)		
	Pair						
	98.289	$\beta_{05}$				0.537 (0.927)	0.338 (0.900)
	107.161	$\beta_{06}$				0.200 (0.355)	0.382 (0.317)
	111.125	$\beta_{07}$				-0.323 (0.387)	-0.321 (0.315)
	206.255	$\beta_{08}$				0.372 (0.450)	0.424 (0.409)
237.214	$\beta_{09}$				-0.395 (0.629)	-0.594 (0.589)	
247.079	$\beta_{010}$				-0.150 (0.485)	-0.348 (0.431)	
"Slope" $\pi_{1i}$	$\beta_{10}$	-0.006 (0.004)	-0.009** (0.003)	-0.015* (0.007)	-0.001 (0.005)	-0.005 (0.004)	
	Season						
	2009	$\beta_{11}$		-0.014** (0.005)			-0.015* (0.005)
	2008	$\beta_{12}$		0.009 (0.004)			0.012 (0.005)
	HY Diff	$\beta_{13}$			0.002 (0.001)		
	Pair						
	98.289	$\beta_{14}$				0.031 (0.020)	0.023 (0.018)
	107.161	$\beta_{15}$				-0.026* (0.008)	-0.021* (0.006)
	111.125	$\beta_{16}$				-0.007 (0.008)	-0.005 (0.005)
	206.255	$\beta_{17}$				-0.008 (0.010)	-0.003 (0.007)
237.214	$\beta_{18}$				0.002 (0.014)	-0.006 (0.010)	

Chick Not Visible, Days 31-fledge, PQL	Parameter	UCG Model	Model B	Model C	Model D	Model E
<b>Fixed Effects</b>		<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
		( <i>se</i> )	( <i>se</i> )	( <i>se</i> )	( <i>se</i> )	( <i>se</i> )
247.079	$\beta_{19}$				0.002 (0.011)	-0.005 (0.007)
<b>Variance Components</b>		<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
		( <i>sd</i> )	( <i>sd</i> )	( <i>sd</i> )	( <i>sd</i> )	( <i>sd</i> )
Level 2 residual variance in "intercept" $\pi_{0i}$	$r_{0i}$	0.123** (0.355)	0.106** (0.326)	0.164** (0.405)	0.213** (0.462)	0.113 (0.337)
Level 2 residual variance in "slope" $\pi_{1i}$	$r_{1i}$	0.000*** (0.013)	0.000*** (0.009)	0.000*** (0.013)	0.001** (0.011)	0.000 (0.004)
Residual ICC		0.036	0.031	0.047	0.601	0.033

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$   
*TIME* was centered around middle status.

### Inactive

Figure 4.5 illustrates the percent time that observers scored the chick at each nest as either Stationary Alert (SA) or Rest (RS), which is comparable to Inactive (IV) for chicks aged 0 -30 days old.

**Figure 4.5** Percent of time Inactive during late nestling phase

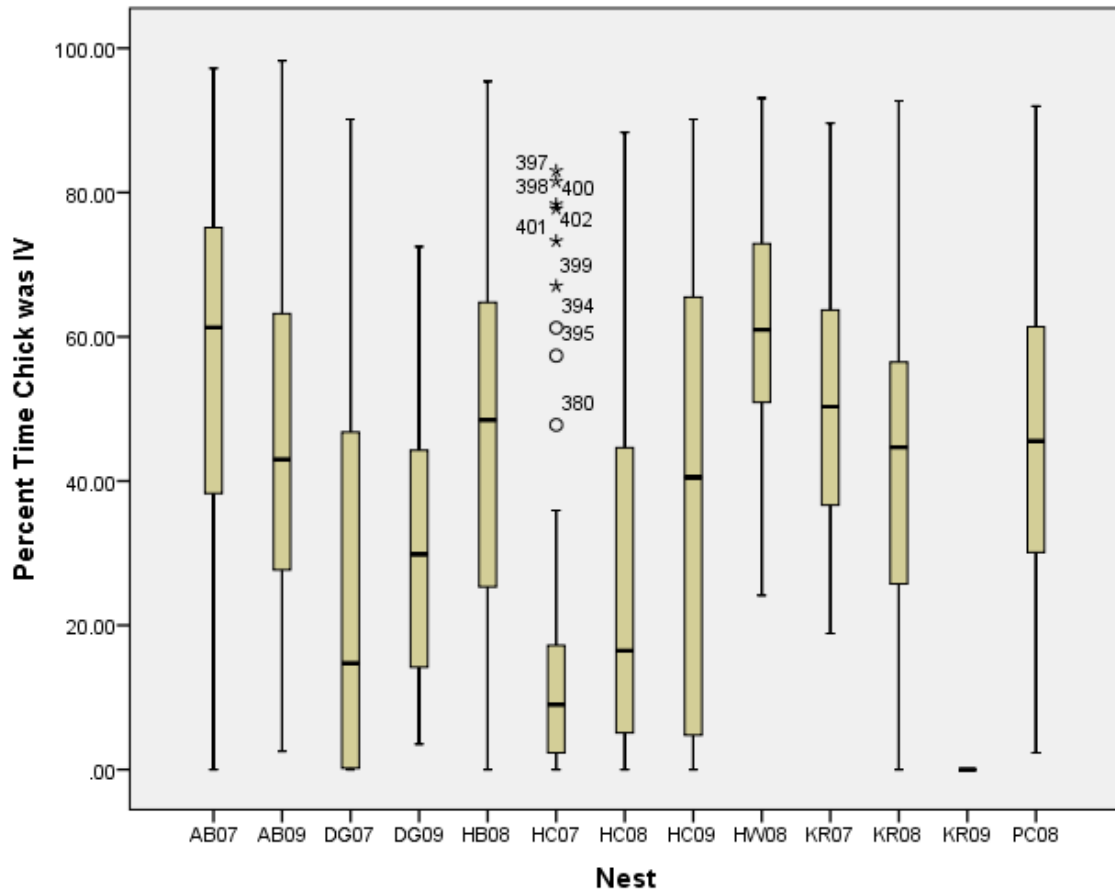


Table 4.5 summarizes the results of fitting multilevel models to the proportion of time each chick spent Inactive (IV) between days 31- fledge (PQL). Time was centered at the midpoint of the late nestling phase (Day 127). The test statistics for the fixed components of the unconditional growth model led to a failure to reject the null hypothesis that  $\pi_{0i}$  was non-zero ( $p = 0.059$ ), and to a rejection of the null hypothesis that  $\pi_{1i}$  was non-zero ( $p = 0.050$ ). The test statistics for the variance components of the unconditional growth model led to a rejection of the null hypothesis that there was zero

inter-chick variability in  $\pi_{0i}$  ( $p = 0.031$ ), and to a rejection of the null hypothesis that there was zero inter-chick variability in  $\pi_{1i}$  ( $p < 0.001$ ). The residual ICC for the unconditional growth model was 0.035, indicating that over 3 % of the variation in inactivity is attributable to differences among chicks.

There was no statistically significant association detected between parents' hatch year difference and chick inactivity; hatch year was therefore excluded from the final model. When pair, season, and visibility were each factored alone into a model of inactivity that did not control for the other factors, associations were observed between each factor and inactivity. The ICC was reduced the most, to 0.000, in models that incorporated pair and season, pair and visibility, and pair, season, and visibility. Though individual predictors were not statistically significant in the model that included pair, season, and visibility, it made substantive sense to retain all three predictors.

**Table 4.5** Proportion of time Inactive during late nestling phase

Chick Inactive, Days 31- fledge, PQL	Parameter	UCG Model	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I
<b>Fixed Effects</b>		Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)
"Intercept"	$\beta_{00}$	-0.286 (0.137)	-0.237 (0.133)	-0.444 (0.219)	-0.492*** (0.106)	-0.286 (0.154)	-0.497** (0.124)	-0.115 (0.168)	0.372*** (0.044)	-0.584 (0.317)
	Season									
	2009		$\beta_{01}$ 0.255 (0.208)				0.061 (0.166)	0.435 (0.192)		-0.061 (0.344)
	2008		$\beta_{02}$ -0.006 (0.174)				-0.094 (0.127)	-0.373 (0.178)		-0.09 (0.251)
	HY Diff			$\beta_{04}$ 0.041 (0.043)						
	Visibility				$\beta_{05}$ 0.445** (0.106)		0.473** (0.117)		0.107* (0.040)	0.523 (0.310)
	Pair									
	98.289					$\beta_{06}$ -0.039 (0.718)		0.162 (0.725)	-0.494 (0.171)	-0.173 (0.758)
	107.161					$\beta_{07}$ -0.133 (0.216)		-3.680 (0.233)	0.052 (0.059)	0.248 (0.421)
	111.125					$\beta_{08}$ 0.206 (0.213)		0.289 (0.215)	0.004 (0.056)	-0.010 (0.286)
	206.255					$\beta_{09}$ -0.716* (0.252)		-0.793 (0.299)	-0.026 (0.082)	-0.166 (0.542)

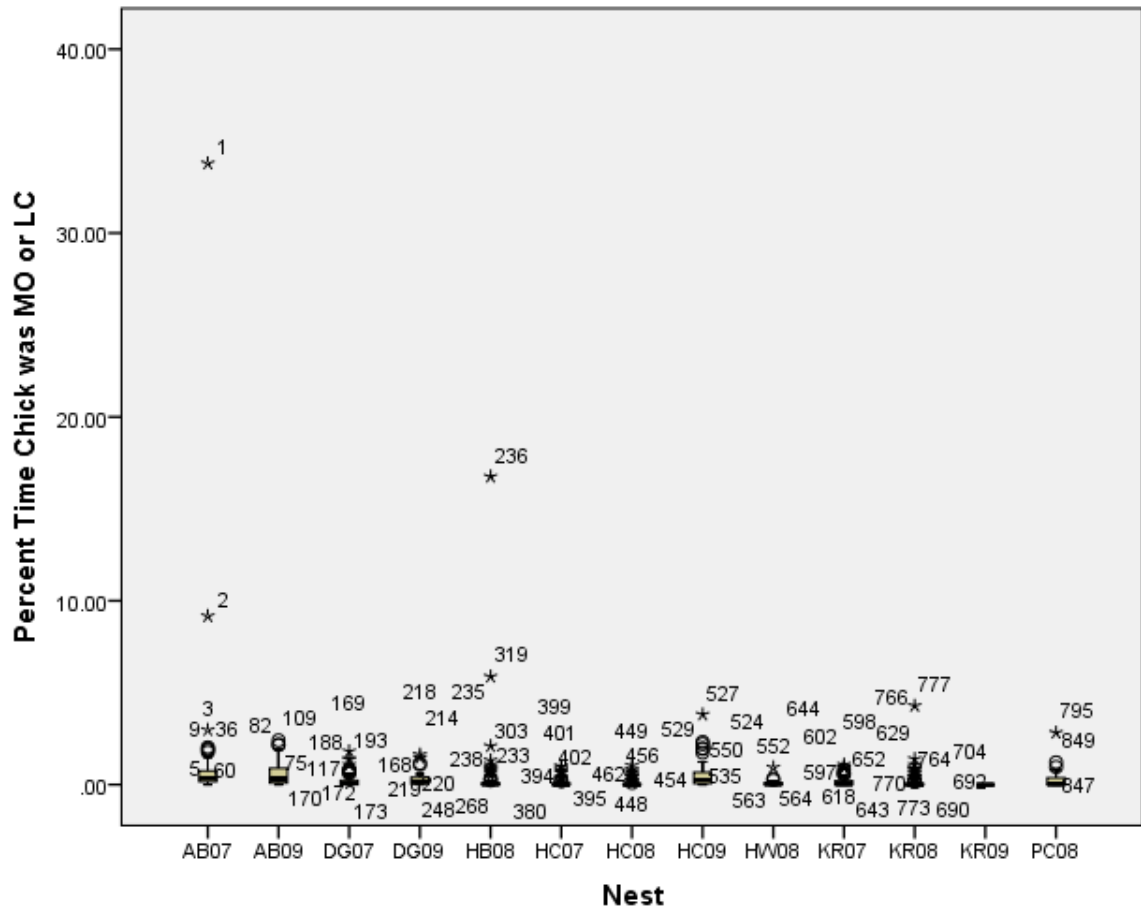
Chick Inactive, Days 31- fledge, PQL	Parameter	UCG Model	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I
<i>Fixed Effects</i>			Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
			(se)	(se)	(se)	(se)	(se)	(se)	(se)	(se)
237.214	$\beta_{010}$					0.241 (0.446)		0.443 (0.458)	0.010 (0.111)	0.108 (0.508)
247.079	$\beta_{011}$					0.115 (0.239)		0.317 (0.261)	-0.022 (0.063)	-0.019 (0.340)
“Slope” $\pi_{1i}$	$\beta_{10}$	0.009* (0.004)	0.010* (0.003)	0.015* (0.006)	0.012* (0.004)	0.004 (0.003)	0.014** (0.004)	0.007 (0.003)	-0.571* (0.183)	0.008 (0.005)
Season										
2009	$\beta_{11}$		0.012* (0.005)				0.123* (0.005)	0.012* (0.004)		0.009 (0.006)
2008	$\beta_{12}$		-0.007 (0.004)				-0.005 (0.004)	-0.008 (0.004)		-0.006 (0.005)
HY Diff	$\beta_{13}$			-0.002 (0.001)						
Visibility	$\beta_{14}$				-0.007 (0.004)		-0.009* (0.004)		-0.000 (0.003)	-0.003 (0.005)
Pair										
98.289	$\beta_{15}$					-0.019 (0.014)		-0.015 (0.014)	-0.019 (0.014)	-0.015 (0.014)
107.161	$\beta_{16}$					0.027** (0.005)		0.023* (0.006)	0.026** (0.006)	0.021 (0.008)
111.125	$\beta_{17}$					0.002 (0.004)		0.004 (0.004)	0.001 (0.004)	0.003 (0.005)
206.255	$\beta_{18}$					-0.003 (0.005)		-0.005 (0.006)	0.000 (0.007)	-0.006 (0.010)
237.214	$\beta_{19}$					-0.002		0.003	-0.002	0.002

Chick Inactive, Days 31- fledge, PQL	Parameter	UCG Model	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	
		<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	
		<i>(se)</i>	<i>(se)</i>	<i>(se)</i>	<i>(se)</i>	<i>(se)</i>	<i>(se)</i>	<i>(se)</i>	<i>(se)</i>	<i>(se)</i>	
	247.079	$\beta_{120}$				(0.008)		(0.009)	(0.009)	(0.009)	
						-0.003		0.002	-0.003	0.002	
						(0.004)		(0.005)	(0.005)	(0.006)	
		<i>Coefficient</i>									
		<i>(sd)</i>									
<i>Level 2 residual variance in "intercept" <math>\pi_{0i}</math></i>		$r_{0i}$	0.118*	0.100*	0.106*	0.006	0.003	0.006	0.000	0.000	0.000
			(0.343)	(0.316)	(0.326)	(0.075)	(0.052)	(0.074)	(0.003)	(0.002)	(0.002)
<i>Level 2 residual variance in "slope" <math>\pi_{1i}</math></i>		$r_{1i}$	0.000***	0.000**	0.000***	0.000***	0.000	0.000**	0.000	0.000	0.000
			(0.000)	(0.009)	(0.011)	(0.010)	(0.000)	(0.007)	(0.000)	(0.000)	(0.000)
<i>Residual ICC</i>			0.035	0.029	0.031	0.002	0.001	0.002	0.000	0.000	0.000

## Active

Figure 4.6 illustrates the percent time that observers scored the chick at each nest as either Move (MO) or Locomote (LC). It is important to note that although Move and Locomote would have both been scored as “Active” for chicks aged 0 – 30 days old, this measure is not directly comparable to that of the later chick phase because, due to difficulties in discerning a very young chick’s behavior from afar, specific behaviors in which the chick exhibits movement (such as Preen or Mandibulate) may have instead been more generally scored by observers as “Active” when the chick was aged 0-30 days old. This was an important wellness metric for species managers. By Day 31, however, the chicks were developed enough for observers to consistently discern specific solitary activity patterns such as Preen and Mandibulate. Therefore, between chick days 31 and fledge, observers scored only directional motion (Move and Locomote) as “Active;” while other solitary activity patterns were scored according to functional form. Thus, the “Active” category for the early chick phase, which reflects only a general state of movement as opposed to a state of inactivity, is not comparable to the “Active” category for the late chick phase.

**Figure 4.6** Percent of time Active during late nestling phase



Because Move and Locomote, the components of “Active” for the late nestling phase, occurred infrequently, it was not possible to fit the proportion of time chicks spent exhibiting these behaviors to a multilevel model. The mean proportion of time spent Active was 0.003 (*sd* = 0.014), with a range of 0.00 – 0.340.

**Chick Day Zero –Fledge**

Social Interaction

Figure 4.7 illustrates how the proportion of time each chick spent interacting with a parent (as opposed to parental attendance, which only measures overall time that each

parent spent at the nest cavity) changed over the life of the nest. This includes being brooded by a parent, interacted with affiliatively (agonistic interactions occurred too infrequently to analyze), having a parent stand directly over it (this may indicate increased vigilance over and/or attention being given to the chick), or being fed.

**Figure 4.7** Chick's Social Time With Parent

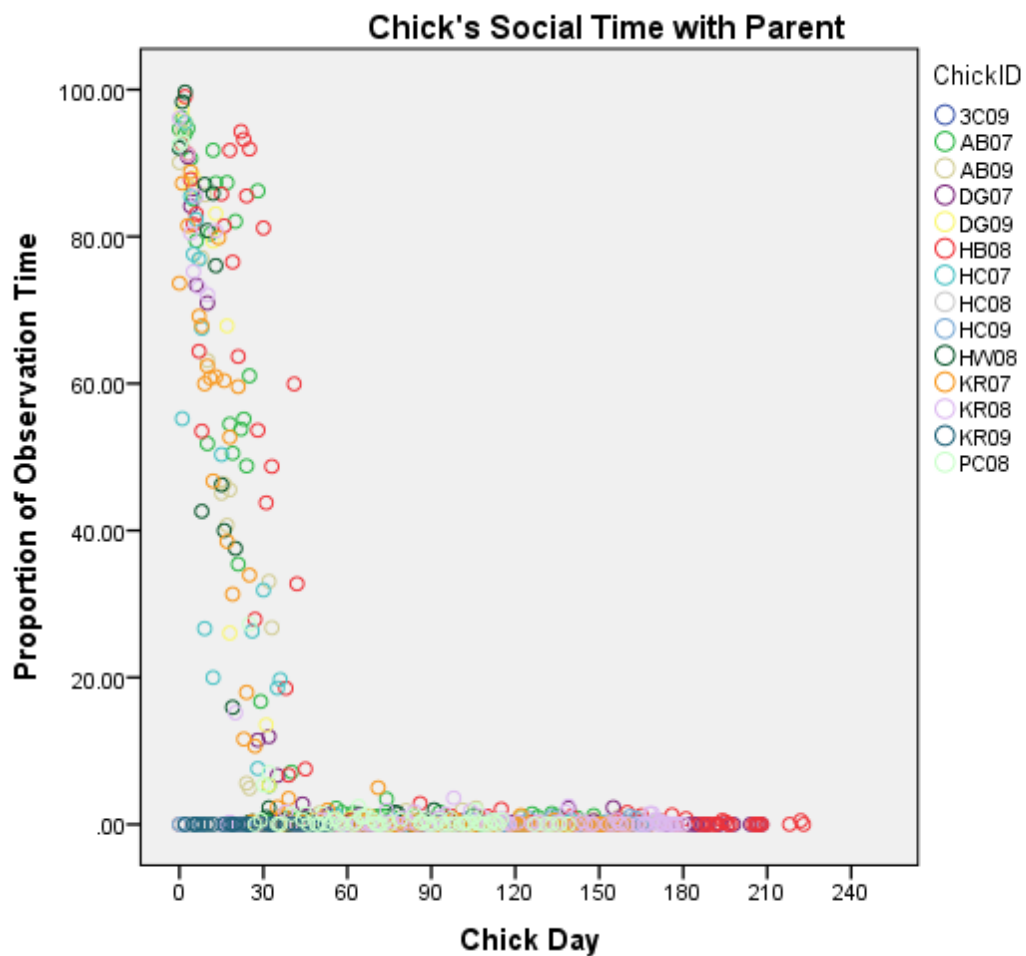


Table 4.6 summarizes the results of fitting multilevel models to the proportion of time each day that a chick was being actively cared for at the nest by either or both parents (PQL). The test statistics for the fixed components of the unconditional growth model led to a failure to reject the null hypothesis that  $\pi_{0i}$  was non-zero ( $p = 0.223$ ) and to a rejection of the null hypothesis that  $\pi_{1i}$  was non-zero ( $p < 0.001$ ). Regarding the variance components, there was a rejection of the null hypothesis that there was zero inter-chick variability in  $\pi_{0i}$  ( $p < 0.001$ ) and a failure to reject the null hypothesis that there was zero inter-chick variability in  $\pi_{1i}$  ( $p > 0.500$ ). In light of the rejection of the hypothesis that there is no variation between chicks in the “intercept” growth parameter, it seems possible that the failure to reject the hypothesis that the growth parameter for the “intercept” was non-zero may be related to the small sample size. Therefore, significant effects for that growth parameter are examined.

There was no statistically significant association detected between parents’ hatch year difference and social time, so hatch year difference was not included in the final model. The ICC was reduced the most, to 0.31, when both season and visibility were taken into account. There was a significant association between visibility and social time after adjusting for season (OR: 4.364; 95% CI: 1.258, 15.141); the average “intercept” for the high visibility condition was 2.496 logits higher than that of the low visibility condition. Because the ICC remains large after taking measured predictors into account, it appears that unmeasured predictors may be responsible for a portion of the remaining variance.

**Table 4.6** Proportion of time nestling actively cared for by a parent

Social Time (PQL)	Parameter	UCG Model	Model B	Model C	Model D	Model E
<i>Fixed Effects</i>		Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)	Coefficient (se)
"Intercept" $\pi_{0i}$	$\beta_{00}$	0.681 (0.532)	0.672 (0.570)	0.165 (0.482)	-0.067 (1.020)	0.784 (1.014)
Season						
2009	$\beta_{01}$		-1.105 (0.841)	-1.184 (0.784)	-1.218 (0.903)	-1.867 (1.411)
2008	$\beta_{02}$		0.003 (0.774)	-0.419 (0.552)	-0.021 (0.833)	0.548 (1.655)
Visibility	$\beta_{03}$			1.473* (0.559)		
HY Diff	$\beta_{04}$				0.173 (0.193)	
Pair						
98.289	$\beta_{05}$					0.331 (2.526)
107.161	$\beta_{06}$					-3.407 (2.018)
111.125	$\beta_{07}$					-0.863 (1.846)
206.255	$\beta_{08}$					1.363 (2.379)
237.214	$\beta_{09}$					0.168 (3.178)
247.079	$\beta_{010}$					0.76 (2.917)
"Slope" $\pi_{1i}$	$\beta_{10}$	-0.103*** (0.012)	-0.105*** (0.014)	-0.100*** (0.018)	-0.113** (0.028)	-0.111** (0.026)
Season						
2009	$\beta_{11}$		-0.000 (0.024)	0.002 (0.024)	0.004 (0.027)	0.019 (0.035)
2008	$\beta_{12}$		0.016 (0.018)	0.02 (0.018)	0.013 (0.020)	-0.001 (0.040)
Visibility	$\beta_{13}$			-0.015 (0.018)		
HY Diff	$\beta_{14}$				0.002 (0.005)	
Pair						

Social Time (PQL)	Parameter	UCG Model	Model B	Model C	Model D	Model E
<b>Fixed Effects</b>		<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
		( <i>se</i> )	( <i>se</i> )	( <i>se</i> )	( <i>se</i> )	( <i>se</i> )
98.289	$\beta_{15}$					-0.048 (0.083)
107.161	$\beta_{16}$					0.054 (0.044)
111.125	$\beta_{17}$					0.006 (0.047)
206.255	$\beta_{18}$					-0.026 (0.061)
237.214	$\beta_{19}$					-0.01 (0.077)
247.079	$\beta_{110}$					0.033 (0.063)
<b>Random Effects</b>		<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
		( <i>sd</i> )	( <i>sd</i> )	( <i>sd</i> )	( <i>sd</i> )	( <i>sd</i> )
Level 2 residual variance in "intercept" $\pi_{0i}$	$r_{0i}$	2.760*** (1.660)	3.064*** (1.750)	1.477* (1.215)	3.597*** (1.897)	7.900*** (2.810)
Level 2 residual variance in "slope" $\pi_{1i}$	$r_{1i}$	0.000 (0.009)	0.000 (0.012)	0.000 (0.005)	0.001 (0.030)	0.003 (0.055)
Residual ICC		0.46	0.48	0.31	0.52	0.71

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$

## Discussion

The aims of chick activity budget analyses were to explore change trajectories over the life of the nest and to determine whether systematic condor-level differences in developmental outcomes exist that could reflect different parenting strategies. Levels of activity and inactivity, social interaction, and time spent not visible were examined.

### Implications of time spent Not Visible

Analysis of chick time spent Not Visible in the early chick phase revealed significant differences among chicks at the midpoint of the phase, but not in the rate of change of visibility over time. There was a significant association between season and visibility, and the lowest model ICC was observed when both season and pair were incorporated into the model. This is not surprising, as each nest site had its own unique topography that affected its visibility to observers (personal observation). Some nest cavities had smaller openings for instance, that obscured visibility of the nestlings. Some nests were subject to greater shadow at certain times of day than were others. Because the nest cavities varied between pairs, and at times within a pair from year to year, differential chick visibility related to pair and season were to be expected.

Analysis of chick time spent Not Visible in the late chick phase revealed significant differences among chicks at the midpoint of the phase as well as in the rate of change over time. There was a significant association between season and visibility as well as between pair identity and visibility. As in the early chick phase, both predictors were retained in the final model. As in the case of visibility in the early chick phase, the relationships between pair and visibility and season and visibility are not surprising given the variability seen in the topography of nest cavities between pairs and across seasons. Visibility did appear to improve in the late chick phase relative to the early chick phase. The apparent improvement in chick visibility is likely due to the ability, and tendency, of older chicks to venture to the edge of its cavity and beyond more frequently.

It is important to keep in mind that a given condor's behavior "...when visible may not be a random sample of total behavior." (Crockett, 1996, p. 562) For instance, it is possible that the bulk of the time a chick was scored as Not Visible was spent in

relatively inactive pursuits, such as resting in the shaded back portion of its nest cavity, as opposed to relatively active pursuits, such as hop-flapping or locomotor play which necessarily use a larger portion of the nest cavity and surrounding porch, leading to better visibility. Further, this potential bias might be expected to change over the life of the nest as the chick grows larger, begins to venture out of the nest, and thus has access to more visible areas.

### **General Activity Levels**

Analysis of chick time spent both Active and Inactive in the early nestling phase did not reveal significant differences among chicks. This does not support the initial prediction that general activity levels would differ among chicks. Chicks suffering from maladies such as heavy parasite loads, trash ingestion, and West Nile Virus infection might be expected to show reduced overall activity levels. However, because species managers were actively guarding nests, it is possible that natural variation was smoothed out in this regard. Chicks were routinely vaccinated against West Nile Virus, and treated for heavy parasite loads and for trash ingestion if necessary.

Between chick days 31 and fledge, Inactive was broken up into Stationary Alert and Rest, though these behaviors were collapsed for analyses so that they could be compared to inactivity in the early chick phase. Both the growth and intercept parameters for the trajectory of proportion of time spent Inactive varied among chicks during the late nestling phase. This supports the initial hypothesis that general activity levels would differ among chicks. Pair, season, and visibility were all associated with the proportion of time a chick was observed to be Inactive.

During the early nesting phase, chicks are not very mobile and are therefore generally restricted to a small area, the nest cavity proper. Thus they might be expected to show few or no individual differences in activity levels. During the late nestling phase, the individual differences exhibited by chicks may be explained by varying nest topographies across pairs and seasons. Some chicks had access to nearby vegetation and cavities for exploration, while other chicks had only a small pothole with a sheer drop to the canyon below. One would not expect to observe effects of this until the chicks had reached a state of development at which exploration both inside and outside the cavity is more common. Again, after day 30 chicks are able to thermoregulate on their own, are therefore being brooded less, and are more independent.

As specified in the Results section, the behavioral category “Active” had a more restrictive definition in the late nestling phase relative to the early nestling phase due to visibility and management concerns. The resultant measurement for the “Active” behavioral category, not surprisingly, was too low for analysis. In addition to the behavioral category having a more restrictive definition, the nest cavities offered little area for sustained directional movement; though other types of activity may have varied during the late nestling phase, there was little room for variation in sustained locomotion. Though some topographies offered greater area for exploration, such activity was generally undertaken cautiously; short bouts of directional movement fewer than 5 seconds (too short to be scored; see Appendices C and D) were frequently interspersed with exploratory behaviors such as the mandibulation of vegetation.

### **Social Interaction**

Because the occurrence of social interactions was relatively infrequent, the time a chick spent being actively cared for by a parent was calculated by summing all social interactive behaviors, including Brood, Interact, Feeding Session, and Stand Over. The proportion of daily time that a chick was actively cared for by a parent dropped off sharply near Chick Day 30. This is consistent with the decreased need for brooding in chicks at this age.

Analysis of social interaction time revealed significant between-chick differences at day 0 of the nestling phase, but not in the trajectories over time. Variation at day zero was associated with visibility; with a larger “intercept” value associated with better visibility. This may be attributable to a decreased likelihood of a chick that is not visible being involved in a social interaction, as social *contact* in the small cavity was generally visible, and was scored as such even if the *specific* social activity could not be determined. In other words, there was a bias towards scoring social activity. Season, too, was associated with among-chick variation. It is possible that during some seasons food availability was better than others, or concentrated either closer or farther away geographically. It is also possible that in some seasons a given pair or pairs may have been preoccupied with a chick from a previous season, which would have affected the proportion of time spent with a newly hatched chick.

## **CHAPTER 6**

### **MICROTRASH**

#### **Patterns of Microtrash Presence in the Nest**

##### **Observations and Discussion**

At the time of this writing, too few data points are available to statistically analyze the relationship between microtrash in the nest and levels of chick behaviors of interest. Data were recorded on only 54 of 70 potential nest entry occasions. Missing data are attributable to a variety of factors, including species management concerns (i.e., unless there was a nest failure threat, nests were not entered at Egg Day 30 so as to avoid disturbing the nest). In other cases this was attributable to nest failure, and in others logistical constraints. Though only descriptive data are available at this time, this is the first time that trash in condor nests has been systematically measured at regular intervals and it is instructive to examine observations to date for indications of possible trends.

Table 6.1 presents the number of items of microtrash found in the substrate available to each nestling at the time of nest entry. Rather than counting only the items of trash that were in the immediate cavity substrate, biologists sifted any surface that was physically available to the chick at the time of the nest entry (for instance, nest porches). Note that additional trash items were recovered from the crop of the AB07 chick during the 60-day nest entry (4 items) and from the crop and ventriculosis of the HW08 chick during an evacuation on Day 98 (11 and 119 items respectively). A possible trend towards higher numbers of trash collected at chick days 30, 60, and 90 than egg day 30 or chick day 120 is apparent. Additionally, there appears to be considerable variation

between pairs in the propensity to bring trash to the nest. This seems to be consistent with anecdotal observation, via satellite telemetry, of particular pairs frequenting trash-heavy locations (Jesse Grantham, personal communication 2007; personal observation).

**Table 6.1** Number of microtrash items available to the chick on nest entry days

(rounded to the nearest 15 days).

<b>Nest</b>	<b>Egg 30</b>	<b>Chick 30</b>	<b>Chick 60</b>	<b>Chick 90</b>	<b>Chick 120</b>
<b>AB07</b>	N/A	50	61	45	54
<b>AB09</b>	0	56	4	0	0
<b>HC07</b>	N/A	0	0	2	1
<b>HC08</b>	N/A	0	26	0	0
<b>HC09</b>	11	33	22	36	1
<b>KR07</b>	0	2	4	37	0
<b>KR08</b>	1	10	0	0	0
<b>DG07</b>	1	2	9	27	0
<b>DG09</b>	30	4	0	10	#
<b>HB08</b>	N/A***	0	0	0	0
<b>HW08</b>	25	28	35	23	0*
<b>PC08</b>	N/A##	0	46	60	9

*\*10 items in ventriculous of chick*

*# Chick was evacuated at 109 days; died during evacuation.*

*\*\*\* 0 items during Egg days 13, 54, and 61.*

*## 0 items during Egg days 52 and 55*

Individual differences in the propensity to bring trash to the nest may be a result of many possible factors, such as developmental differences that result in a mistaken search image (M. Wallace, personal communication 2007) or chance experiences (such as encountering a trash site while searching for nesting habitat). Notably, the HB08 pair, which nested for the first time together in 2008, did not have any trash items in the nest. Population managers began aggressive efforts to expand the foraging range of the

southern California population in 2007. By 2008, the range had expanded considerably (USFWS, unpublished data; personal observation) It remains to be seen as to whether this change in foraging patterns may result in fewer pairs developing the habit of frequenting trash sites. Ultimately, though, controlled studies in captivity are called for if the motivations and mechanisms of this behavioral pattern are to be uncovered.

## **CHAPTER 7**

### **OVERALL CONCLUSIONS**

#### **Thesis Summary**

Quantitative behavioral data were collected at condor nests over a three-year period to inform an investigation into behavioral variation in parenting behavior and outcomes in reintroduced California condors. In Chapter 3, attendance patterns were examined across the life of each of fourteen nests belonging to seven stable dyads. Differences among condors were not detected in attendance patterns during either the egg or chick stages of development. The failure to detect differences among individuals with different backgrounds and behavioral histories suggests that early rearing experience may not be critical to the ontogeny of this behavior. On the other hand, it is worth noting that neither parent- nor puppet-reared condors in captivity experienced a natural developmental environment; it could be that the differences in environment between captive parent- and –puppet reared condors are few, particularly in relation to those who are fledged in the wild. Another factor to consider is the great care that captive species managers have taken over the years to provide a captive rearing environment that provides behavioral opportunities for normal behavioral development. It is possible that their careful techniques have resulted in specimens who adapt well to release, though it is worth noting that techniques evolved significantly over the years. Some of the birds in this study were peer-reared for instance, while others were mentor-reared (a condition that more closely resembles that experienced by a wild nestling). One must also consider

that some condors self-selected out of the release program through injury, death, or atypical behavioral patterns that resulted in their return to captivity. It is likely that the sample studied here resembles the most behaviorally flexible of all released condors.

In Chapter 4, behaviors of nestlings were examined for variation that might be accounted for by differences in their parents. Variation was not detected among chicks in proportion of time spent Active or Inactive during the early nestling phase. Variation among older nestlings in time spent inactive was observed, with associations found between inactivity and pair, season, and visibility. The sources or sources of pair-level variation, however, remain unclear. As predicted, the proportion of time that parents interacted with nestlings varied from nest to nest; associations with season and visibility were apparent. However, a large proportion of between-chick variance remained after taking known predictors into account. It is possible that unmeasured predictors could be responsible for a portion of the remaining variance.

Finally, a descriptive summary of the quantity of microtrash observed throughout the life of the nest was presented. There is a possible trend towards individual differences in the propensity to bring trash to the nest, though the reasons for this are as yet unclear. As the population matures, the question of whether newer pairs that lack experience with a very contracted foraging range exhibit this behavior less frequently will be elucidated.

### **Future Directions**

There were a number of limitations to this work. Some of these limitations were a product of partitioning limited staff and volunteer resources at remote field locations

where active population management was taking place. Other limitations were a direct result of the difficulties of the exploring a sufficient spectrum of explanatory variables, as well as attempting to statistically control for environmental confounds, with an extremely small data set. As more pairs are observed over time, additional insights may be gained into possible sources of variation among individual condors in parenting and development. Technology, too, opens up possibilities. Parents' location data, which give insight on foraging and roosting patterns, will later be examined in relation to behaviors observed at the nest. Finally, the team is transitioning to remote video monitoring which will allow for more consistent data collection across nests.

**APPENDIX A**

**COURTSHIP ETHOGRAM**

<b>CACO Courtship Behavior Ethogram</b> (Prepared by E. Sandhaus and J. Brandt, adapted from Condor Ethogram for Social/Sexual/Affiliative Behaviors (ZSSD, unpublished) and Field Ethogram 1985 (N. Snyder, unpublished))			
<b>BEHAVIOR - SOCIAL</b> - Specify both actor and recipient by studbook number.			
<b>CODE</b>	<b>SCORE</b>	<b>ACTIVITY</b>	<b>DEFINITION</b>
DY	AO	Wing out-head down display	As in Snyder 1985: "This is the main courtship display in condors. The displaying birds' body is nearly vertical, wings are dropped open from the shoulders so that the white wing-linings show as a valentine shape. Head is lowered, then moved up and down, as are the feet, as the bird turns in back and forth through a 30- to 180-degree arc." Note duration in seconds. The response of the target bird should be scored as either positive (pos), negative (neg), or neutral (neu): <b>pos:</b> within 5 seconds, target bird responds with an affiliative (AL, AF, FO) or sexual (e.g., assuming a squat position or moving tail aside for cloacal contact) behavior; <b>neg:</b> within 5 seconds, target bird responds with agonistic behavior (NA, CA, DP) or by leaving the area; <b>neu:</b> within 5 seconds, target bird responds with no discernible behavioral change
MD	AO	Mutual wing out-head down display	Two birds perform wing out-head down display to each other. Note duration in seconds.
AD	AO	Approach Display	During a bird's display to a target bird, a non-target bird approaches and appears to observe the displaying bird. Example: 98 is displaying to 112, and 192 approaches and appears to observe 98.
ID	AO	Interrupt Display	A non-target bird interferes with a displaying bird which results in a termination of the display.

CO	AO	Copulation	Mount that concludes with cloacal contact and ejaculation. Indicated by males tail tucked down, and wings flapping.
AC	AO	Attempted copulation	Mount that does not conclude with cloacal contact and ejaculation
FN	AO	Female negative adjust	As in ZSSD - Female resistance to copulation that results in incomplete mount or copulation, including moving around a lot (results in male having a difficult time mounting or staying mounted), not assuming a squat position, and not moving tail aside for cloacal contact.

**The following behaviors are no longer scored at feeding census sites. The definitions are provided to assist the observer in making a determination as to whether a receiving bird's reaction to a display or attempted copulation is positive, negative, or neutral.**

CODE	SCORE	ACTIVITY	DEFINITION
<i>FO</i>	<i>AO</i>	<i>Follow</i>	<i>One bird follows another bird, in effect maintaining or reducing social distance. The follow must occur within 5 seconds of the target bird moving. Example: For Bird A and bird B are perched in a snag 3 m away from each other. Bird A flies to a snag 30 feet away and within 5 seconds bird B flies to the same snag and perches in the same snag as bird A. Note that in such a case the original social distance of 30 feet may not be precisely maintained due to unavailability of nearby perches.</i>
<i>NA</i>	<i>AO</i>	<i>Noncontact aggression</i>	<i>Any threatening behavior that does not include physical contact. Includes erect scapulars, head down threat, head up threat, lunge, chase, biting, and attempts at biting, pecking, or striking with wing or foot, etc.</i>
<i>CA</i>	<i>AO</i>	<i>Contact aggression</i>	<i>Any aggressive behavior in which physical contact is made. Includes biting, pecking, foot strike, wing strike, bill strike.</i>
<i>DP</i>	<i>AO</i>	<i>Displace</i>	<i>Within 5 seconds of another bird approaching within three wing-lengths of another bird, another bird's arrival to a location (e.g., feeding site), or another bird's agonistic behavior (noncontact or contact aggression), a bird moves more than three wing-lengths away from the approaching/arriving/agonistic bird or it yields access to a resource (e.g., carcass, perch, water).</i>

<i>AG</i>	<i>I</i>	<i>Social agonistic</i>	<i>Bird is engaged in social interaction that is characterized by agonistic behaviors - includes NA, CA, DP</i>
<b>LOCATION</b> - Use the following abbreviations when specifying "Location" on each data and summary sheet.			
<b>ABBRV</b>	<b>MEANING</b>	<b>ADDITIONAL LOCATION INFORMATION</b>	
SPFS	Hopper Mountain NWR	Hopper Mountain NWR	
LPR	Lower Pinnacles Ridge F.S.	Hopper Mountain NWR	
UPR	Upper Pinnacles Ridge F.S.	Hopper Mountain NWR	
PTFS	Pit Trap Feeding Site	Bitter Creek NWR	
WRFS	White Rabbit feeding site	Bitter Creek NWR	
FPFS	Flight Pen Feeding Site	Bitter Creek NWR	

**APPENDIX B**  
**COURTSHIP PROTOCOL**

**CACO Social Behavior Scoring Protocol – Southern California**

You will be recording the behavior of breeding-aged condors, primarily at feeding sites and roost locations, using a pre-defined ethogram and protocol. These data will facilitate early identification of the formation of new breeding pairs and will enable the prediction of upcoming nesting events. Intensive observations will ensure that potentially problematic situations, such as polygynous pairings, that may be resolved by management actions will be quickly identified. Rates of social behaviors of interest will be calculated and examined in comparison to breeding effort and nest success.

**Equipment needed:**

CACO Reproductive Behavior Data Sheet  
Clipboard  
Pen  
Stopwatch

**Overview:**

You will take note of all displays, attempted copulations and copulations seen for **ANY** CACO using the Reproductive Behavior sheet. Use this sheet to record **ALL** such interactions that you encounter during your shift, even if this means transcribing the interactions from your field notebook. Record the start time of each interaction in the “Start” column. Record the sequence of behaviors of interest in the “Behavioral Sequence” column. Record the end time of each interaction in the “End” column. At the end of your observations, be sure to fill out the summary section of the Reproductive Behavior sheet.

**Questions that arise regarding scoring protocol should be directed to Estelle Sandhaus or the Santa Barbara Zoo Nesting Technician.**

**Notes and Examples:**

*Displays – Characterizing a female’s reaction to a male’s display*

A female’s reaction to a male’s display provides insight into the social dynamics of pairings. You will characterize each female’s response to each individual display event as either positive (abbreviate as “pos”), negative (abbreviate as “neg”), or neutral (abbreviate as “neu”), according to the following definitions:

**pos:** within 5 seconds, target bird responds with an affiliative (AL, AF, FO) or sexual (e.g., assuming a squat position or moving tail aside for cloacal contact) behavior;

**neg:** within 5 seconds, target bird responds with agonistic behavior (NA, CA, DP) or by leaving the area;

**neu:** response of target bird for 5 seconds following the display is neither positive nor negative (e.g., bird remains in same place without changing body posture). Remember: a lack of overt behavioral change in a receiving bird is in itself a neutral response that we must keep track of!

Note: If a male displays to another male, be sure to characterize the recipient male's reaction to the displaying male as either positive, negative, or neutral.

***Displays and Copulations – How to annotate these events***

Displays can often involve more than one female during the same bout either simultaneously or separately. In order to address this while scoring this behavior the following annotation should be used. For each female separately involved during the same display bout note each duration of time directed at any female separately with the corresponding female. For instances where females are simultaneously displayed to females should be grouped with a single duration of time. The following examples illustrate several types of situations you will likely encounter.

**A single male to single female display:**

From 14:00:00 to 14:00:45, 237 displays to 214. 214 responds by remaining standing in the same posture and location.

Start Time	Behavioral Sequence	End Time
140000	237DY214-neu(45s)	140045

**Separate females during the same display:**

At 11:00:00, 107 begins to display to 161 for 30 seconds, and then during the same display turns towards 111 (away from 161) and continues displaying for 45 seconds. Both 161 and 111 remain standing in the same posture and location.

Start Time	Behavioral Sequence	End Time
110000	107DY16-neu(30s)111-neu(45s)	110115

**Simultaneous females during the same display:**

107 displays while 108 and 156 are both within one wing-length each of 107 and facing him. The display lasts from 12:00:00 to 12:01:30. 108 remains standing in the same location and does not change posture at all. 156 responds by allopreening 107.

Start Time	Behavioral Sequence	End Time
120000	107DY108-neu156-pos(120s)	120130

Note that in the above example, the duration of the display (120s) is the same for both females. Therefore, the duration is only annotated **once** for this behavioral sequence.

**The previously described annotations might be combined when females either leave or approach a displaying male:**

98 displays to 112 and 216 for thirty seconds. 112 moves away and 98 continues his display to 216 for another minute. In this situation, you should characterize 216's response to the display only **once**, as this does not constitute two separate display events towards 216. The function of separating out the duration of 30s of the display from the remaining 60 seconds in notation is to preserve in notation that the context switched from a simultaneous display to a singular one.

Start Time	Behavioral Sequence	End Time
090000	98DY112-neg,216(30s)216-neu(60s)	090130

Summarizing Data:

At the end of your observation period, be sure to summarize the reproductive data using the chart on the bottom of the reproductive data sheet. The Santa Barbara Zoo Nesting Technician will use these summary tables to tabulate **ALL** of the season's breeding behaviors for the southern California flock.

Example:

Your observed a feeding at FPFS from 070000-140000. Your data sheet contains the sequences depicted in the table below. 107 arrived at the feeding site at 090000, and 161

arrived at 090100. 161 departed at 090900, and 107 departed a minute later at 091000. Various other breeding-aged birds arrived and departed throughout the observation session, but they did not exhibit breeding behaviors.

Start Time	Behavioral Sequence	End Time
090000	<b>107DY161(pos)(30s)</b>	090030
100000	<b>107DY161(neg)(45s)</b>	100045

You will summarize as follows:

Actor	Behavior	Recipient	Total	Total Time Actor Pres	Total Time Recipient Pres	Total Overlap Time	Comments
107	DY	161	2	10:00	8:00	7:00	107 arrive 09:00:00, depart 09:10:00; 161 arrive 09:01:00, depart 09:09:00
161	pos	107	1	"	"	"	
161	neg	107	1	"	"	"	

You will be keeping track of arrival times and departure times of each bird in your field notebook. Be sure to transcribe into your summary the approach and departure times for each bird for which a behavioral sequence is recorded.

*Prepared by E. Sandhaus and J. Brandt*

APPENDIX C

NESTING ETHOGRAM

CACO Nest Watch Ethogram

<b>ACTIVITIES - GENERAL (May occur for adults and chick)</b>			
<b>CODE</b>	<b>S-E</b>	<b>ACTIVITY</b>	<b>DEFINITION</b>
SA	S	Stationary Alert	Bird is stationary, but attending to external stimuli (typically evidenced by some movement of its head or neck), and is not engaged in incubating, brooding, or standing over. Score regardless of posture, as long as the bird is stationary. <b>This behavior should not be scored for a chick of 0-29 days of age. Prior to day 30, IV should be used instead.</b>
RS	S	Rest	Bird is sitting or lying quietly, either awake or asleep. It is not attending to external surroundings or engaged in incubating, brooding, or standing over. <b>This behavior should not be scored for a chick of 0-29 days of age. Prior to day 30, IV should be used instead.</b>
EC	E	Excretion	Bird voids excrement (includes both defecation and urohydrolysis)
PR	S	Preen	Bird nibbles and pulls at its feathers with its bill.
SN	SLE	Sun	Bird stands with wing or wings extended out to the side, fully horizontal. Note that in chicks, wings may be resting on the ground.
OM	SLE	Other Maintenance	Bird engages in other maintenance activities (other than excretion, preening, or sunning), including stretching, headshakes, etc. Describe behavior in "Description" column.

MN	SLE	Mandibulate	Bird picks at/picks up substrate, cave walls, vegetation, or items from cave floor. If possible, describe items in "Brief Description" section of logbook. We are particularly interested in microtrash items and bone chips.
LC	S	Locomote	Bout of directional travel between two points, including walk, run, hop, jump, fly. <b>This behavior should not be scored for a chick of 0-29 days of age. Prior to day 30, AV should be used instead.</b>
RG	SLE	Regurgitate Ground	Outside of a Feeding Session (FS), the bird regurgitates onto the ground. If possible, note substance (e.g., trash) in the "Brief Description" column. If the bird regurgitates onto the ground as <i>part</i> a feeding session, then RG should <b>not</b> be scored in the Activity column. In this case, please score RGf in the "Description" column as part of the Feeding Session.
BG	E	Beak Gape	Bird gapes beak <b>while stretching its neck forward</b> . This may have the appearance of an attempted regurgitation (i.e., one in which movements are made but no material is expelled).
OT	SLE	Other	The bird's behavior, while clearly visible to the observer, is not described in the ethogram. Describe in "Brief Description" section of logbook. This should be used sparingly: only for behaviors which truly defy classification based on our current scheme.
NV	S	Not Visible	The bird ( <b>or its behavior</b> ) is not visible to the observer. Note if bird is visible in "Description" column. . Example: 107 is facing away, back and tail visible, but head/behavior NV.
<b>ACTIVITIES - ADULT ONLY</b>			
<b>CODE</b>	<b>S-E</b>	<b>ACTIVITY</b>	<b>DEFINITION</b>

NP	E	Nest Pass	Bird circles past nest, usually just prior to landing.
EN	E	Enter Nest	Bird enters the nest cave.
EX	E	Exit Nest	Bird flies away from the nest cave.
IN	S	Incubate	Bird sits on and incubates the egg. As indicated in the behavioral hierarchy in the protocol, Incubate supersedes other behaviors, such as maintenance, that may occur during incubation. Take care to score IM and II instead of IN where appropriate.
IM	SLE	Incubate while Mandibulating	Bird is mandibulating while it sits on and incubates the egg.
SO	S	Stand Over	Bird stands over egg or chick. It may make postural adjustments (perhaps shifting its weight side-to-side), or look at the egg or chick. If the bird is in a partial sit (rather than a stand) over the egg, or chick, and is clearly not incubating the egg or brooding the chick, then SO may be scored. If the bird is standing over the egg or chick, and its explicit behavior is not clear (for instance, it may be facing the rear of the cave and you may see slight head movement), this should be scored as SO and not as NV. Rationale: we do not want to underestimate the time that the bird is directly attending to the egg or chick by excluding time periods during which the bird is posturally attending to the egg or chick but might be engaged in rolling the egg, moving the chick, or other similar behaviors. If the parent is engaged in an explicitly defined behavior (such as FB or AL) with the chick, then Int supersedes SO.
<b>ACTIVITIES - ADULT ONLY (continued)</b>			
<b>CODE</b>	<b>S-E</b>	<b>ACTIVITY</b>	<b>DEFINITION</b>
SM	SLE	Stand Over while Mandibulating	Bird is mandibulating while it is Standing Over egg or chick.

ER	SLE	Egg Roll	Bird turns/rolls/moves egg with beak or head.
EK	E	Egg Kick	Bird kicks egg with foot or leg. This behavior should only be scored for distinct kicks. For other manipulations with feet or legs, score Egg Other.
EO	SLE	Egg Other	Bird manipulates egg in a manner other than Egg Roll or Egg Kick.
BR	S	Brood	Bird broods the chick (under body or wing). As indicated in the behavioral hierarchy in the protocol, Brood supersedes other behaviors, such as maintenance, that may occur during brooding. Take care to score BM and BI instead of BR where appropriate. <b>Because both adult and chick are engaged in this activity, be sure to indicate that both the adult and chick are recorded in the Bird ID column. Use a slash between their numbers (e.g., 192/WC13).</b>
BM	SLE	Brood while Mandibulating	Bird is mandibulating while it broods the chick (under body or wing). This behavior should <b>only</b> be recorded for the mandibulating bird (the non-mandibulating bird remains in a bout of BR).
BI	SLE	Brood while Interacting	Bird is engaged in an adult-adult social interaction while brooding the chick. This behavior should <b>only</b> be recorded for the interacting bird (the non-interacting bird remains in a bout of BR).
MC	SLE	Move chick	Bird moves chick to another area, by pushing, rolling, pulling, or shoving it. <b>Because both adult and chick are engaged in this activity, be sure to indicate that both the adult and chick are recorded in the Bird ID column. Use a slash between their numbers (e.g., 192/WC13).</b>

SC(y/n)	E	Visual Scan for Nonattending Adults	Every hour on the hour <b>visually</b> scan the area for adults not present at the nest cavity. Record "SCy" (yes) if you <b>see</b> the nonattending adult(s) and "SCn" if you do not see the nonattending adult(s).
CD(p/o/d/nv)	E	Change Distance	Record changes in chick social distance as they occur. "CDp" for proximate (chick within one adult wing length of another bird), "CDo" for chick between one and three adult wing lengths of another bird, "CDd" for greater than three wing lengths, and "CDnv" if a change in distance has occurred, but you can't tell which distance category it falls into (e.g., when the chick ventures out of view into the back of a cave). Be sure to record a starting distance at the <b>beginning</b> of your observation session!
<b>ACTIVITIES - CHICK ONLY</b>			
<b>CODE</b>	<b>S-E</b>	<b>ACTIVITY</b>	<b>DEFINITION</b>
IV	S	Inactive	Chick is stationary and inactive. This should be used in the initial stages of chick development, <b>days 0-29</b> of the chick stage only. <b>Neither RS nor SA should be scored during days 0-29.</b>
AV	S	Active	Chick is moving. This should be used in the initial stages of chick development, <b>days 0-29</b> of the chick stage only. If the chick <b>clearly</b> engages in a different "movement" behavior, other than LC or MO, that is explicitly defined in the ethogram (e.g., WF, HF, PR), score that behavior <b>instead</b> of AV. If you are unsure as to whether the "movement" behavior satisfies the explicit definition of another behavior, you should score AV.

MO	S	Move	<b>Initial</b> stages of <b>directional</b> movement. Chick attempts to move from the area but stays within three wing lengths. Directional movement beyond three wing lengths for a chick should be scored as Locomote. <b>This behavior should not be scored for a chick of 0-29 days of age. Prior to day 30, AV should be used instead.</b>
WF	SLE	Wing Flap	Chick flaps its wings while its body is stationary.
HF	SLE	Hop Flap	Chick jumps up and down while flapping its wings.
HA	SLE	Hyperactivity	A bout of solitary, extremely active behavior that may involve multiple elements (e.g., object manipulation and locomotor behaviors). Movement is typically exaggerated, behavioral elements often occur out of sequence (for instance, you may see a single hop-flap rapidly followed by mandibulation of a feather), and these elements may occur out of their usual context. In the description column, please describe as accurately as possible the sequence of elements and any objects involved, though as these bouts unfold rapidly, capturing each and every element will be a challenge.
<p><b>BEHAVIOR - SOCIAL INTERACTIVE AND FEEDING</b> - Specify both actor and recipient by studbook number. <b>Bolded entries in the following section are Activities. Entries that are not bolded are individual behaviors that are recorded in the "Description" column during each Activity bout.</b> In the context of Social Interactions, record either Int, IntMN, II, or SI in the "Activity" Column of the Logbook, and any associated behaviors in the "Description" column of the Logbook. In the context of Feeding Sessions, record either SD or FS where appropriate, and record any associated behaviors in the "Description" column of the Logbook.</p>			
<b>CODE</b>	<b>S-E</b>	<b>ACTIVITY</b>	<b>DEFINITION</b>

<b>Int</b>	<b>SLE</b>	<b>Interact</b>	<b>Int should be recorded in the "Activity" Column of the Logbook for each separate social interaction bout (as opposed to recording each discrete social behavior in the Activity Column). Discrete social behaviors, such as ML and DY, should be recorded in the corresponding "Description" Column.</b>
<b>IntMN</b>	<b>SLE</b>	<b>Interact while Mandibulating</b>	<b>Int MN should be recorded for periods of time during social interaction bouts during which mandibulation is occurring. This behavior should be recorded <i>only</i> for the mandibulating bird.</b>
<b>II</b>	<b>SLE</b>	<b>Incubate while Interacting</b>	<b>Bird is engaged in an <i>adult-adult</i> social interaction while it sits on and incubates the egg.</b>
<b>SI</b>	<b>SLE</b>	<b>Stand Over while Interacting</b>	<b>Bird is Standing Over while it is engaged in an <i>adult-adult</i> social interaction.</b>
CODE	S-E	BEHAVIOR	DEFINITION
AL		Allopreen/allorub/allonibble	Bird rubs its head, beak or neck against, preens the feathers of, or nibbles at the beak, feathers, head, throat, or ankle of another bird.
ML		Mutual Allopreen/allorub/allonibble	As in AL, but mutual.
AF		Affiliative Other	Bird engages in any non-aggressive contact behavior with another bird, excluding AL, ML, CO, AC.

DY	Wing Out-Head Down Display	As in Snyder 1985: "This is the main courtship display in condors. The displaying birds' body is nearly vertical, wings are dropped open from the shoulders so that the white wing-linings show as a valentine shape. Head is lowered, then moved up and down, as are the feet, as the bird turns in back and forth through a 30- to 180-degree arc." Note duration in seconds. The response of the target bird should be scored as either positive (pos), negative (neg), or neutral (neu): <b>pos:</b> within 5 seconds, target bird responds with an affiliative (AL, AF, FO) or sexual (e.g., assuming a squat position or moving tail aside for cloacal contact) behavior; <b>neg:</b> within 5 seconds, target bird responds with agonistic behavior (NA, CA, DP) or by leaving the area; <b>neu:</b> response of target bird for 5 seconds following the display is neither positive nor negative (e.g., bird remains in same place without changing body posture).
MD	Mutual Wing Out-Head Down Display	Two birds perform wing out-head down display to each other. Note duration in seconds.
AD	Approach Display	During a bird's display to a target bird, a non-target bird approaches and appears to observe the displaying bird. Example: 98 is displaying to 112, and 192 approaches and appears to observe 98.
IP	Interrupt Display	A non-target bird interferes with a displaying bird which results in a termination of the display.

NA		Noncontact Aggression	Any threatening behavior that does not include physical contact. Includes erect scapulars, head down threat, head up threat, lunge, chase, biting, and attempts at biting, pecking, or striking with wing or foot, etc. If a bird attempts to poke/nudge its mate off the egg, this alone does <i>not</i> constitute Noncontact Aggression.
CA		Contact Aggression	Any aggressive behavior in which physical contact is made. Includes biting, pecking, foot strike, wing strike, bill strike. If a bird pokes/nudges its mate off the egg, this alone does not constitute Contact Aggression.
<b>BEHAVIOR - SOCIAL INTERACTIVE AND FEEDING (continued)</b>			
CODE	S-E	BEHAVIOR	DEFINITION
CO		Copulation	Mount that concludes with cloacal contact and ejaculation.
AC		Attempted Copulation	Mount that does not conclude with cloacal contact and ejaculation.
FN		Female Negative Adjust	As in ZSSD - Female resistance to copulation that results in incomplete mount or copulation, including moving around a lot (results in male having a difficult time mounting or staying mounted), not assuming a squat position, and not moving tail aside for cloacal contact.
DP		Displace	Within 5 seconds of another bird approaching within three wing-lengths of another bird, another bird's arrival to a location (e.g., perch), or another bird's agonistic behavior (noncontact or contact aggression), a bird moves more than three wing-lengths away from the approaching/arriving/agonistic bird <i>or</i> it yields access to a resource (e.g., perch). This does not include incubation or brood exchanges.

OS		Other Social	Other social behaviors not described in the ethogram. This category should also be used if two birds are engaged in a <i>definitive</i> social interaction but you are unsure of which specific social behavior (e.g., FB, AL) they are engaged in.
<b>FS</b>	<b>SLE</b>	<b>Feeding Session</b>	<b>FS should be recorded in the "Activity" Column of the Logbook for each separate feeding session (as opposed to recording each discrete feeding bout behavior in the Activity Column). Discrete feeding behaviors (i.e., FB and WBr) should be recorded in the corresponding "Description" Column. A Feeding Session must BEGIN with a Feeding Bout and must END with a Feeding Bout.</b>
<b>SD</b>	<b>SLE</b>	<b>Social Direct</b>	<b>SD should be scored in the Activity column for a bird when it directs an unreciprocated social behavior at another bird (the other bird is therefore necessarily engaged in a solitary Activity). Currently, the only situation in which this applies is for Wing Beg.</b>
CODE	S-E	BEHAVIOR	DEFINITION
FB		Feeding Bout	Record length (seconds) of each individual feeding bout (begin with bill-bill contact, end with break of bill-bill contact) within a feeding session. This behavior should be recorded in the "Description" column (FS should be recorded in the corresponding "Activity" column). Do not round to the nearest 5 seconds for Feeding Bouts.

RGf		Regurgitate Ground - Feeding Session	Bird regurgitates onto the ground during a Feeding Session. If possible, describe what the animal has regurgitated (e.g., trash). If the bird regurgitates onto the ground <i>outside</i> of a Feeding Session, then RG should be scored in the Activity column.
WBr		Wing Beg - reciprocated	Chick solicits food by wing-flapping and opening beak and this behavior is <b>reciprocated</b> in that the parent responds with a Feeding Bout within 5 seconds of the occurrence/end of the Wing Beg. If WBr occurs during a feeding session, then "FS" should be recorded in the activity column and WBr should be recorded in the description column. If WBr does not occur during a feeding session (i.e., this occurs before the first Feeding Bout of a Feeding Session, then record WBr in the Description Column with a corresponding "SD" in the Activity Column.
WBU		Wing Beg - unreciprocated	Chick solicits food by wing-flapping and opening beak and this behavior is <b>unreciprocated</b> in that the parent <b>does not</b> respond with a Feeding Bout within 5 seconds of the occurrence/end of the Wing Beg. This behavior occurs only outside of feeding sessions. WBU should be recorded in the Description Column with a corresponding "SD" in the Activity Column. Refer to the Scoring Protocol for further explanation and examples.

WBnv		Wing Beg - unknown reciprocation	Chick solicits food by wing-flapping and opening beak, but the observer cannot tell whether this behavior is reciprocated or unreciprocated (usually because of visibility; i.e., the observer is unable to tell whether the Wing Beg is followed by a Feeding Bout or not).
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Prepared by E. Sandhaus and J. Brandt (USFWS). References: Condor Ethogram for Social/Sexual/Affiliative Behaviors and Ethogram and Protocol for Parent and Chick Behaviors (ZSSD, unpublished), Field Ethogram 1985 (N. Snyder, unpublished), and Condor Nest Data Recording Protocol (A. Mee, unpublished)

## APPENDIX D

### NESTING PROTOCOL

#### Nest Observation Protocols 2009

##### **Introduction**

The purpose of these data is to identify potential signs of concern or problems during both the egg and chick stages of the nest. We mean to prevent nest failures by intervening when problems are observed using a number of different strategies. To do this during the egg stage we will be collecting data on attendance activities (incubation bout length, frequency of egg manipulation, and periods without incubation), pair interactions (incubation shift length, social behaviors during exchanges, and interference by extra pair individuals) and predatory concerns (raven activity.) During the chick stage, data will be collected to determine levels of chick activity, show how often the chick is being fed (feeding rates), identify the presence of harmful micro-trash, and determine social behaviors occurring between the parents and chick. This data collection necessitates long periods of observation due to the varying levels of behavior. Long periods of inactivity still must be observed closely because some behaviors happen quickly and could be missed. Durations of inactivity are also important in their own right. It will take patience and a keen eye combined with standardized methods for success. In doing so we will have maximized nesting success producing the next generation of wild hatched condors and will have increased our knowledge of the nesting biology of this endangered species.

##### **Data Logbooks**

Data will be collected in a data logbook. In order for the data collected to be quickly and efficiently analyzed, it is important that the manner of its collection is consistent in both degree and format (over time and between observers.) Poor levels of observation or the failure to record observation breaks create an unreliable data set. Too much detail or the failure to follow the proper format can lead to a cumbersome data set that is difficult to extract meaningful information from, which slows our ability to identify problems that can result in nest failure. The Santa Barbara Zoo (“SBZ”) Intern Nesting Technician will regularly inspect data to ensure that appropriate formats are being followed and that data are being summarized properly.

##### General Logbook Format

Each page of the Data Log will follow the same format. Page numbers, dates, stage day, observer, and observations all will be recorded in the exact same way. Do not deviate from the standard format! The more similar we can make each of our records the more easily it can be summarized. Diagram 1 follows the description of page format; refer to this diagram as a visual aid.

*Page #:* page # should be recorded on the outer edge of the logbook page in the upper corner so that it is readily identifiable when referring back to specific log entries and to help keep photocopies organized and in order.

*Observer Initials:* Record your assigned initials in the inner upper corner of the log (opposite of page number.) This consists of your first initial followed by your last name (e.g., J. Brandt).

*Date:* The date should be recorded above the first line on the left hand side of each page. Date format should read DD-month's abbreviation-YYYY (12-Jan-2007.) Begin a new page when there is a change in date (Data from 2 separate days should not be recorded on the same page.)

*Stage Day #:* The stage and day number of that stage should be recorded on the same line as the date on the opposite side of the page (e.g. Chick Day 37).

### Entering Observations:

Each entry should consist of four parts: start time, SB#(s) of individual(s) involved, a brief written description of observation, a behavioral code, and the duration of behavior or observation.

*Start Time:* Record in the left hand column of the page as HH:MM:SS. All entries require a time.

*SB#(s):* List all individuals involved in the observation in the second column in from the left side of the page. For entries that do not require SB#, such as observation breaks, weather entries, and starts or ends to observation periods, leave blank.

*Behavioral Code:* Use the provided ethogram to score each observation with the behavioral code that the observation falls under and record this in the third column from the left. Required!

*Duration:* The fourth column is used in two important situations. 1) If an event (notated by an "E" in the "S-E" column in the Ethogram) is recorded in the Activity column, then, record a dash ("-") in the duration column. 2) If a state-like-event (notated by a "SLE" in the "S-E" column in the Ethogram) is recorded in the Activity column and this state-like-event has lasted for **fewer than five seconds**, then record a dash ("-") in the duration column. This step is **critical** for the accounting of time in our database.

*Descriptions:* Briefly record in the wider final column what is being observed. Only use abbreviations that are included in the ethogram (e.g., RS for rest, LC for locomote). Starts, ends, weather, and breaks should also be recorded here. Social behaviors should be recorded in this space using the appropriate codes and scoring. Attempt to be brief and specific in your descriptions. Avoid using nonspecific qualitative terms that are difficult to interpret.

Diagram 1: Data Log Page Format

Pg#		Nest Initials Parents' #s=Chick #			Obs. Initials	Pg#		Nest Initials Parents' #s=Chick #			Obs. Initials	Pg#	
DD-Month-YYYY					Stage: Day #	DD-Month-YYYY					Stage: Day #		
Time HH:MM:ss	SB#	code	Dur.	Description	Time HH:MM:ss	SB#	code	Dur.	Description				
			Duration ('-' if less than 5s)	Brief Description (use ethogram for abbreviations)				Duration ('-' if less than 5s)	Brief Description (use ethogram for abbreviations)				

**Observation periods**

Types of observation:

“Eye to scope” observation intervals are meant to catch all parent or chick behaviors that occur within that interval. Do your best to miss as little as possible within these periods by watching through the scope. Record the start and end times of eye to scope observation as these intervals will be used as the interval in which the data are summed and compared. Do your best to adhere to a minimum of two-hour eye to scope intervals, but we understand that this may not always be possible (e.g., you absolutely must take a bathroom break). Be sure to record the total number of minutes observed eye-to-scope in the logbook next to the ending time of each eye-to-scope interval.

You are permitted to engage in short time periods of “gross” observation intervals between bouts of eye to scope observations. These time intervals of gross observations are meant to help with eye fatigue and to give observers a period to mentally prepare for the next round of eye to scope observation. Gross observation is meant to provide a period of rest but is not meant to be a period where the general nest activities are completely ignored. Please limit these time periods to no longer than 20 minutes if possible. **Observers should still be watching the nest to identify the large-scale events**

**such as stops in incubation, arrivals and departures to and from the nest site, feedings, and other social interactions. If such a major event commences, resume eye to scope observation for observations *immediately* until such behavior subsides.**

Breaks:

A break occurs when there is a break in observation. You are expected to take breaks. A full day of dawn to dusk observation is demanding for even the most seasoned observer. Fatigue can decrease one's ability to observe quickly and accurately thus it is better to take a needed break to rest one's eyes, stretch, or answer the call of nature. Try to keep breaks limited to a 10 to 15 minute period. If you are not actively observing the nest, you are taking a break! **RECORD ALL BREAKS!** This cannot be emphasized enough, as break periods **MUST** be excluded from data analyses to ensure accurate estimates of time spent engaged in various activities.

Multi-day Observations:

Ideally every day of observation would be from dawn to dusk. This ideal tends not to be the case in many instances so it is necessary to address the issue of potential biases produced in a data set when certain periods of the day are consistently missed. For example, if we cut short our observations an hour before dusk on the majority of the days observed, the level of activity during that period may be underrepresented in our analyses. The same could be said for the early morning if the infrequent data collection also occurs then. Therefore if you need to observe less than the full dawn to dusk do so by balancing the periods of early morning vs. late evenings missed. These periods of the day are when peak levels of activity occur for many species, so it is important that we have these periods represented equally in the data set.

Recording Observation Start and Finish:

Record blind entrance and exit times, *and* the start and end of each eye to scope and each gross observation interval. **BE SURE TO RECORD BREAKS.**

### **Recording Activities**

When observing an active nest, the activities of the attending parent or chick should be recorded by identifying changes in the state. For each change in state record the start time, the bird SB#, the behavioral code (from the ethogram) and a brief description. To identify changes the birds must be watched closely at all periods of observation. Changes in activity can be short or subtle such as a short bout of preening or changing from being alert to being at rest. At other times the chick and or parent may move out of view from the nest observation point (OP); this must also be recorded in the log because the level of activity during this period is unknown.

As a new activity or status is observed, record the start time in the first column in the log followed by the SB# (or temporary egg number for newly hatched chicks) for the appropriate individual. Record to the nearest 5 seconds. (This rounding is meant to reflect the reduced level of precision we get as a result of the observer sequence of looking away from the scope to the stopwatch, down at the logbook, and back to the scope). Write the behavioral code in the appropriate columns and as time allows a short description. **Only record behavioral changes; do not re-record the same behavior if a change has not taken place.** It is unnecessary to do this and will not help in any way. By recording only changes, calculating durations will be made easier and the data will be easier to summarize. Remember that resuming an "inactive" status such as resting or stationary

alert is itself a change in activity and must be recorded. When following the activities of multiple birds be sure to calculate the durations correctly (referring to times specific to each individual.)

If a bird exits the immediate nest area, follow it visually to the best of your ability and describe its behavior in the “Brief Description” section of the logbook. Behaviors of note to describe include flying with other birds (note proximity of other birds, etc.), chasing of predators, etc.

States vs. Events:

In general the behaviors observed can be characterized as either **states** or **events**. For those behaviors classified as events, we are concerned with their instantaneous occurrence. Events are generally relatively short in duration. States, on the other hand, are generally relatively long in duration and we are interested in the duration of time during which they occur. Most behaviors can be recorded as either a state or an event and the type of questions being asked will indicate which approach to take. For example, we can record the act of standing as an event or the period that the chick remained standing as state.

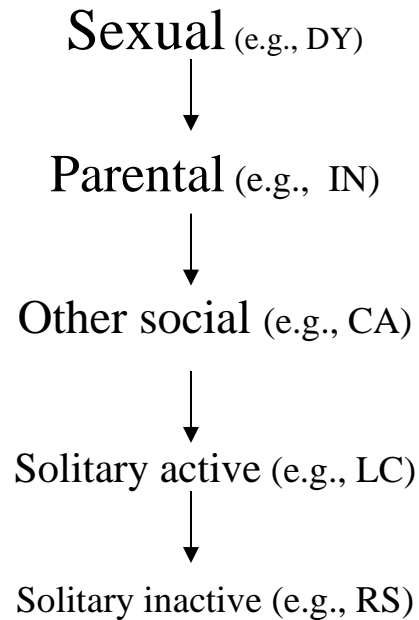
The majority of the behaviors we are interested in will be recorded as states and will be recorded with durations. The ethogram will indicate whether a behavior is considered a state or an event. State behaviors, such as locomotion (LC), will be scored as bouts using a **5-second rule**. (i.e., these behaviors must occur for greater than 5 seconds to be scored). If the behavior is stopped or interrupted for less than 5 seconds and then resumed, it is considered to be **within the same bout with a single duration**. It is very important to **employ the 5-second rule for states BEFORE rounding the activity time to the nearest 5 seconds!** (As an example, we do not want to “round” a 3-second occurrence of LC, which should by definition not be scored as a state, up to 5 seconds, as that would result in it being inappropriately scored as a state. However, after deciding that a behavior satisfies the 5-second rule for scoring a behavior as a state (for instance, a 7-second occurrence of LC) you **should** round the time on your watch to the nearest 5 seconds before recording it in the Activity Column. Again, this is to reflect the time lost by looking away from your scope to the stopwatch and to the logbook.

Events do not interrupt states. Events should be recorded without durations whenever they occur but be careful not to record just an event behavior if there was also a change in state (as indicated by the occurrence of a new state behavior (or state-like event; see below) for more than 5 seconds).

Some behaviors are not easily categorized as either states or events, For example, an Egg Roll (ER), which is usually an event, may on occasion occur for longer than 5 seconds (making it in some respects like a state behavior). We refer to these behaviors as “state-like events” (after Swaisgood, unpublished giant panda behavioral protocol). State-like events need not occur for greater than 5 seconds to be scored. For the purposes of this research, if a state-like event occurs for less than 5 seconds, it does not interrupt the previous state. If a state-like event occurs for greater than 5 seconds, it interrupts the previous state. Because of this distinction, **it is essential to record a dash (“-“) in the “duration” column of the logbook if a state-like event occurs for less than 5 seconds**. This distinction affects the manner in which durations of surrounding states are calculated in our database. Regarding “bouts” of behavior, **a state-like event must be interrupted for more than 5 seconds before another bout of the same behavior is scored**.

In some instances, an animal will engage in more than one state or state-like event behavior at the same time (for instance, it may peck at another bird while locomoting), and because states and state-like-events (in the latter case, those lasting 5 or more seconds) cannot be simultaneously scored, we must decide which of the behaviors takes precedence. In such instances, please refer to the below behavioral hierarchy to guide your decision as to which behavior takes precedence (listed in order of highest precedence):

*Behavioral Hierarchy for Activities*



Note that in some instances, a defined ethogram behavior may implicitly combine more than one of the above categories (e.g., Brood Interact; BI includes both Parental and Other social).

Age-specific behaviors:

**Some behaviors on the ethogram are designated as adult-only, chick-only, or are designated for certain chick developmental periods.** Please pay close attention to these designations in the ethogram. For example, it is **never** appropriate to score “Inactive,” “Active,” or “Move” for an adult condor!

**Area attendance, nest attendance, and parent-chick social distance:**

We will be monitoring parental care in terms of proximity to the chick and nest in three ways:

1. Area attendance: Every hour on the hour, do a **visual** scan of the area and note whether any nonattending parent is in your visual field. Note “SCy” or “SCn”

in the Activity column. To keep this hourly sample consistent, be sure to set a repeat hourly chime on your watch when you begin your observations! Do not use your telemetry receiver; this is a visual scan only.

2. Nest attendance: We will be keeping track of this through the Activities EN and EX, so you need not do anything additional here.
3. Parent-chick social distance: After the chick hatches, you will be keeping a **continuous** record of parent-chick social distance. As with behavioral states, you will only note changes. “CD” (“change distance”) is the appropriate activity code to indicate any change in distance. At the beginning of your observation, you will note a social distance, using the appropriate “CD” code to reflect the starting distance. Use the following codes:

CODE	NAME	DEFINITION
CDp	Proximate	Bird is within one wing-length of another bird.
CDo	Out-of-reach	Bird is between one and three wing-lengths of another bird.
CDd	Distant	Bird is greater than three wing-lengths away from another bird.
CDnv	Not visible	A change in distance has occurred, but you can't tell which distance category it falls into (e.g., when the chick ventures out of view into the back of a cave).

**Scoring Example:**

You arrive at the nest OP and begin observations at 10:30. Neither parent is visible in the area. The chick, 428, is visible, standing outside the nest cavity on the north side of the entrance. It is 12:10 and twenty seconds when you observe the chick move inside the nest and sit down in the substrate. It is 12:10 and twenty five seconds when the chick stops moving and shuts its eyes while in the nest cavity. At twelve thirty you end your observations and take a break.

Entries in the logbook would be recorded as the following:

Time	SB#s	Activity	Duration	Brief Description
10:30:00				Begin observations
10:30:00	192	CDd	---	Not visible in area.
10:30:00	21	CDd	---	Not visible in area.
10:30:00	428	SA		Standing north side of nest entrance
12:10:20	428	LC		Moves inside cavity and sits
12:10:25	428	RS		Sits with eyes shut
12:30				Stop Observations

**Recording Social Interactions**

All social interactions at the nest, including interspecific interactions, should be recorded. Avoid taking breaks or ending observations when a social interaction is likely (when both parents or a parent and chick are present at the nest or if a parent is signaled moving towards a nest.) During periods of observer rest or when taking breaks be on the lookout for incoming birds, if a parent arrives during a break resume observations as soon as possible so that the social interaction is not missed. If for some reason you can't identify a bird (e.g., the wing bearing the ID tag is not visible), record "unk" in the studbook number column and record the animal's behavior as you would for an identified bird.

Behavioral Scoring:

In the description column you will record all-occurrences of pre-defined social behaviors between any condors present at the nest site. Use studbook numbers to indicate actors and recipients of social behaviors.

As many social behaviors are brief in nature and unfold quickly, you will not record durations of most individual social behaviors (displays are an exception). Instead, record the start time and end time of each social interaction bout between animals (as

distinct from behavioral bouts, which will occur within social interaction bouts). Begin timing each social interaction bout with the initiation of a social behavior. A social interaction bout between animals ends when five seconds have passed without the occurrence of a social behavior between them. Designate social interactions in the activity column by the ethogram code “Int”.

Example 1 (mid-stream):

From 08:45:10→08:45:40 237 allopreens 412. At 08:45:40, 237 breaks contact with 412 and begins to preen while 412 remains standing and looking from side to side. You record:

Time	SB#s	Activity	Duration	Brief Description
08:45:10	237,412	Int		237AL412
08:45:40	237	PR		
08:45:40	412	SA		

Example 2:

At 08:42:00 you begin observations. 214 is not visible in the area. 237 and 412 are within one wing-length of one another. Both are lying on the ground with necks tucked and eyes closed. From 08:45:10→08:45:40 237 allopreens 412. At 08:45:40, 237 breaks contact with 412 and begins to preen while 412 remains standing and looking from side to side. At 08:45:50, 237 moves two wing-lengths away from 412 (walking; 2 seconds in duration) and resumes preening. At 08:45:55 you end observations.

Time	SB#s	Activity	Duration	Brief Description
08:42:00				Begin observations.
08:42:00	214	CDd	---	Not visible in area.
08:42:00	237	CDp	---	
08:42:00	237	RS		
08:42:00	412	RS		
08:45:10	237,412	Int		237AL412
08:45:40	237	PR		
08:45:40	412	SA		
08:45:50	237	CDo	---	
08:45:55				End observations.

(Keep in mind that a change in distance is not always accompanied by a change in state. Often an animal's movements are too brief to count as a "Locomote")

Example 3 (mid-stream):

From 08:45:10→08:45:17 255 allopreens 206 (7 seconds), from 08:45:17 → 08:45:20 255 pauses (3 seconds), and resumes allopreening until 08:46:10, at which time she breaks contact with 206 and begins to mandibulate a dropped feather while 206 begins to preen.

Time	SB#s	Activity	Duration	Brief Description
08:45:10	255,206	Int		255AL206
08:46:10	255	MN		Dropped feather
08:46:10	206	PR		

(This is scored as only one bout of allopreening because the behavior was not interrupted for 5 or more seconds).

Example 4 (mid-stream):

From 08:45:10→08:45:17 255 allopreens 206 (7 seconds), and from 08:45:22→ 08:45:27 255 pauses, after which both birds stand still, looking around, and not touching one another (5 seconds). 255 then resumes allopreening 206 from 08:45:28 → 08:46:28 (60 seconds), after which each bird stands still, looking around, and not touching one another. You record:

Time	SB#s	Activity	Duration	Brief Description
08:45:10	255, 206	Int		255AL206
08:45:20	255	SA		
08:45:20	206	SA		
08:45:30	255, 206	Int		255AL206
08:45:30	255	SA		
08:45:30	206	SA		

(This counts as two separate bouts of social interaction and of Allopreen/allorub/allonibble).

*Feeding Sessions:*

When scoring a feeding session, begin with the first feeding bout (i.e., beak-to-beak contact between the adult and chick). The feeding session will continue as long as a feeding behavior is taking place (such as regurgitation by the adult into the chick or wing

begs by the chick). The feeding session ends with the last feeding bout (unless a lapse of 5 or more seconds occurs between feeding behaviors. In this case, a new feeding session will be recorded). You will record feeding bouts and wing begs in the description section of the feeding session. Record the amount of time in seconds (not rounded) for individual feeding bouts, but this is not required for wing begs.

When scoring wing begs during a feeding session, WBr (wing beg – reciprocated) should be used when a period of less than 5 seconds occurs between the end of the wing beg and the beginning of the next feeding bout. However, a wing beg may continue into a feeding bout, which would still be scored as WBr. For wing begs occurring outside of feeding sessions, SD (social direct) should be used. Record SD in the activity column and the specific wing beg code (i.e. WBr, WBU, or WBNV) in the description section. If a period of 5 or more seconds occurs between the end of the wing beg and the beginning of the feeding bout, then WBU (wing beg – unreciprocated) should be recorded. When unsure if a wing beg is reciprocated or not, record WBNV (wing beg – unknown reciprocation) in the description section.

**Regurgitation by the adult should not be recorded during a feeding session unless the bird regurgitates directly onto the ground** (rationale: regurgitation into the chick is implicit in a feeding bout). If the bird does regurgitate directly onto the ground, record RGf in the **description** section of that feeding session and if possible, describe what the animal has regurgitated (e.g., trash). **If the bird regurgitates onto the ground outside of a feeding session, then RG should be recorded in the activity column.** However, if the regurgitation ends *within* 5 seconds of the beginning of a feeding bout (i.e. the beginning of a feeding session), then OT (other) should be recorded in the activity column, and regurgitation should be written in the description section.

Example 1 (mid-stream):

From 10:00:00→10:00:14 (14 seconds), WC18 wing begs toward 111 while 111 preens. From 10:00:09→10:00:21 (12 seconds), 111 feeds WC18. From 10:00:20→10:00:36 (16 seconds), WC18 wing begs toward 111. From 10:00:34→10:00:41 (7 seconds), 111 feeds WC18. From 10:00:40→10:00:48 WC18 wing begs toward 111, while 111 stands stationary, but alert to her surroundings. You record:

Time	SB#s	Activity	Duration	Brief Description
10:00:00	111	PR		
10:00:00	WC18	SD		WC18 WBr 111
10:00:10	111, WC18	FS		111 FB WC18 (12 seconds), WC18 WBr 111, 111 FB WC18 (7 seconds)
10:00:40	WC18	SD		WC18 WBU 111
10:00:40	111	SA		

Example 2 (mid-stream):

From 08:30:00→08:30:09 (9 seconds), 111 regurgitates onto the ground. From 08:30:09→08:30:16 (7 seconds), 111 feeds WC18. From 08:30:15 →08:30:24 (9 seconds), WC18 wing begs toward 111, yet you can no longer see 111's beak nor the chick's.

Time	SB#s	Activity	Duration	Brief Description
08:30:00	111	RG		
08:30:10	111, WC18	FS		111 FB WC18 (7 seconds)
08:30:15	WC18	SD		WC18 WBnv 111

Example 3 (mid-stream):

From 10:00:00→10:00:29 (29 seconds), 111 and WC18 are standing side-by-side and in contact with one another. From 10:00:29→10:00:40 (11 seconds), WC18 wing begs to 111, but remains in direct contact with her as she does so. From 10:00:40→10:01:10, 111 and WC18 remain standing side-by-side and in contact with one another, after which each bird stands still, looking around, and not touching one another. You record:

Time	SB#s	Activity	Duration	Brief Description
10:00:00	111, WC18	Int		111,WC18 AF, WC18 WBU 111
10:01:10	111	SA		
10:01:10	WC18	SA		

*Displays:*

You may encounter display behavior between adult condors at or near a nest site. Though this will be relatively infrequent, it is important to accurately record these events.

***Characterizing a female's reaction to a male's display***

A female's reaction to a male's display provides insight into the social dynamics of pairings. You will characterize each female's response to each individual Display event as either positive (abbreviate as "pos"), negative (abbreviate as "neg"), or neutral (abbreviate as "neu"), according to the following definitions:

**pos:** within 5 seconds, target bird responds with an affiliative (AL, AF, FO) or sexual (e.g., assuming a squat position or moving tail aside for cloacal contact) behavior;

**neg:** within 5 seconds, target bird responds with agonistic behavior (NA, CA, DP) or by leaving the area;

**neu:** response of target bird for 5 seconds following the display is neither positive nor negative (e.g., bird remains in same place without changing body posture). Remember: a lack of overt behavioral change in a receiving bird is in itself a neutral response that we must keep track of!

Note: If a male displays to another male, be sure to characterize the recipient male's reaction to the displaying male as positive, negative, or neutral.

### *Displays and Copulations – How to annotate these events*

Displays can often involve more than one female during the same bout either simultaneously or separately. For each female separately involved during the same display bout note each duration of time directed at any female separately with the corresponding female. For instances where females are simultaneously displayed to females should be grouped with a single duration of time. At a nest site, however, you are most likely to encounter a single male displaying to a single female, as in the following example.

Example: From 14:00:00 to 14:00:45, 237 displays to 214. 214 responds by remaining standing in the same posture and location.

Time	SB#s	Activity	Duration	Brief Description
14:00:00	237,214	Int		237DY214-neu(45s)

### **OBSERVER SUMMARY:**

At the end of your observation day, please include a brief summary. You should record the total time of eye-to-scope observations for the day, the total time of gross observations for the day, the parent(s) present at the nest, the number of incubation exchanges, the time of each period of egg and/or nest nonattendance, and the total time that the egg and/or nest was left unattended. Make note of any important or unusual occurrences (e.g., the presence of predators of the nest, unusual aggression between the parents, the presence of a non-breeding adult condor).

A final note on scoring behavior – If in doubt, write it down, and always indicate if you are uncertain about any observation. If you are unsure about how to code a behavior, describe it as completely as possible in the “Brief Description” section of the logbook and consult with FWS or SBZ staff as soon as possible after your shift so that the behavior may be appropriately coded.

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