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ASSESSING METHODS FOR ESTIMATING MINIMUM POPULATION SIZE AND MONITORING ANDEAN CONDORS (*VULTUR GRYPHUS*) IN SOUTHERN ECUADOR

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Resumen. – Evaluación de métodos para estimación del tamaño mínimo y monitoreo de las poblaciones del Cóndor Andino (*Vultur gryphus*) en el sur del Ecuador. – El Cóndor Andino (*Vultur gryphus*) es una especie en peligro crítico para Ecuador y está amenazada a nivel global. Tres métodos fueron probados (estaciones de alimentación, transectos, y puntos de conteo) para estimar el tamaño de la población local de Cóndores Andinos en el Parque Nacional Cajas (PNC) en los Andes del sur del Ecuador. En las estaciones de alimentación se llevaron a cabo 128 h de observaciones en dos estaciones de alimentación, se condujo 24,8 km en 60 h a lo largo de transectos de montaña, dentro de los cuales se llevó a cabo 20 conteos de punto de 45 min (tiempo total = 15 h) situado a lo largo de los transectos. En total, se observaron seis cóndores diferentes, los seis en las estaciones de alimentación y tres de estos en los puntos de conteo. No se registraron cóndores al caminar por los transectos. Un individuo fue identificado como macho adulto, mientras que dos aves más fueron adultas de sexo desconocido. Aparentemente la baja abundancia de cóndores es el resultado de actividades ganaderas, en especial al sur de los límites del Parque Nacional Cajas (PNC), pues en estas localidades es persistente la persecución del Cóndor Andino. Las estaciones de alimentación son herramientas útiles para el monitoreo del Cóndor Andino y es recomendable su uso en los protocolos de monitoreo del PNC y otros lugares.

Abstract. – The Andean Condor (*Vultur gryphus*) is a critically endangered species in Ecuador and is threatened at the global scale. We tested three methods (feeding stations, transects, and point counts) to estimate local population size of Andean Condors in Cajas National Park (CNP) in the southern Andes of Ecuador. We conducted 128 h of observations at two feeding stations, walked 24.8 km over 60 h along montane transects, and conducted 20 45-min point counts (total time = 15 h) located along these transects. In total, six different condors were observed, three at the feeding stations and at point counts, and three others at feeding stations only. No condors were recorded while walking transects. One of the individually identified birds was an adult male, while two more birds were adults of unknown sex. The low abundance of condors possibly results from ranching and farming activities, especially at the southern border of Cajas National Park, and beyond the park borders where persecution and hunting of Andean Condors persist. Feeding stations are a powerful tool to monitor Andean Condor populations and such a protocol is recommended for CNP and elsewhere. *Accepted 19 April 2011.*

Key words: Andean Condor, *Vultur gryphus*, Cajas National Park, páramo, monitoring, feeding station, population size.

INTRODUCTION

Ecuador is known for high levels of avian species richness and endemism (Stattersfield *et al.* 1998, Ridgely & Greenfield 2001). Nonetheless, it also has a large number of threatened species, mostly the result of human degradation of natural habitats (Wege & Long 1995, Granizo *et al.* 2002). The Andean Condor (*Vultur gryphus*) ranges across the Andes from northern Colombia and Venezuela, through Ecuador, to southern Chile and Argentina (Fjeldså & Krabbe 1990). The species has been locally extirpated and is generally rare at the northern end of the range, and is only locally common further south (Fjeldså & Krabbe 1990). The Andean Condor is a critically endangered species in Ecuador (Granizo *et al.* 2002) and is considered threatened at the international level (BirdLife International 2004). Populations of the condor in Ecuador are thought to have declined because of habitat degradation, persistent hunting and poisoning, and the species' relatively low reproductive rates (Ridgely & Greenfield 2001, Granizo *et al.* 2002, BirdLife International 2004). Extensive conversion of *páramo* grasslands to pasture has also resulted in the loss of native habitat and native prey for condors which rely on these open areas for hunting and finding carcasses. This grassland conversion has forced condors to forage in pasture lands where they frequently take young cattle and other livestock. As a result, ranchers increasingly trap and kill condors to protect their livestock (Koester 2002).

In Ecuador, Andean Condor populations are very small and localized (Ridgely & Greenfield 2001). In 1991, the Corporación Ornitológica del Ecuador (CECIA), estimated that there were 75 individual condors in Ecuador (Granizo *et al.* 2002), but in 1996 that estimate dropped to only 33 individuals (Granizo *et al.* 2002). Since 2000, the decline of condors in Ecuador is thought to have been continuous (BirdLife International 2008), but this is based on anecdotal evidence and data are lacking. In addition to questions of population size, only very limited information is available on the structure of condor populations in Ecuador, even though such data are necessary to create conservation and management plans for the species. The critical need for the collection of better data on condor populations has previously been recognized (Koester 2002), but we know of no attempts to accurately determine how many individuals of each sex and age class exist in different regions and at different times in Ecuador.

One of the remaining strongholds of the Andean Condor in Ecuador is Cajas National Park (CNP) (Toral 1996, Rodas & Tinoco 2003) in southern Ecuador. The park contains 28,000 ha of high elevation habitat, of which 90% is *páramo* vegetation. When condors are seen in the park they are generally reported to be in pairs or small groups (Ridgely & Greenfield 2001). Local residents indicate that it was not uncommon in the past to see 30–40 individuals in the park and its surroundings, but these numbers have not been observed in the last 20 years (PXA pers. com.). Recent reports suggest that only about 10 individuals may exist in the park (Rodas & Tinoco 2003), but a comprehensive census has not been undertaken.

Here we quantify the minimum number of condors that exist in or near CNP and test the effectiveness of monitoring protocols based on feeding stations, walking transects, and stationary point counts. Andean Condors have been monitored and population sizes estimated using feeding stations in Bolivia (Ríos-Uzeda & Wallace 2007), northern Ecuador (Meza *et al.* 2008), and Argentina (Speziale *et al.* 2008). This method appeared successful because when condors approach feeding stations they can be identified by their unique markings, thus making it possible to

sex and age individuals and monitor them through time (Ríos-Uzeda & Wallace 2007). But population estimates from these feeding stations were never formally compared to other census methods to give a better indication of their utility and reliability. Our objective in this study was to quantify the number of individual Andean Condors in Cajas National Park using feeding stations, and to compare our results to census data obtained through walking transects and stationary point counts. We use our data to evaluate the general utility of these census methods, and to develop a standard monitoring technique for condors.

METHODS

Study area. We conducted this study in Cajas National Park, in the south-western Andes of Ecuador, from February to March 2008. CNP has an area of 28,544 ha and an elevational range of 3160 to 4445 m a.s.l. (Delgado *et al.* 2006). Topography of the region is irregular, with U-shaped valleys and very steep slopes (> 25 degrees), which is evidence of past glaciations (Harden & Borrero 2005, Delgado *et al.* 2006). Mean annual precipitation is 1200 mm and the temperature ranges from 0–20°C (IERSE 2004). The park contains three types of vegetation: high elevation cloud forest, high elevation forest, and *páramo* grassland which includes > 1000 patches of *Polylepis* forest of varying sizes (<1 ha–44 ha; Baquero *et al.* 2004, Minga & Verdugo 2007). We focused this study in the *páramo* because Andean Condors are most often observed in this habitat in Ecuador (Ridgely & Greenfield 2001).

Feeding stations. We installed two feeding stations at two different sites within Cajas National Park (Fig. 1): Tugshi at 3961 m a.s.l. (UTM 17 699150 9690150), and Burín Grande at 3460 m a.s.l. (UTM 17 693349 9681136). The sites were chosen based on previous published observations of condors (Rodas & Tinoco 2003), personal observations, and reports of sightings from local people and park rangers. The feeding stations were separated by 10 km and were at least 2 km from trails, roads and tourist activities. At each feeding station we placed the carcass of a donkey with the abdomen opened.

Observation points overlooking these feeding stations were installed 160 m from each site and consisted of a small tent camouflaged with grass, shrubs, rocks and moss. Although in more open, flat grassland habitats, a greater distance between feeding stations and observation points may be preferable, it was assumed that 160 m was a sufficient distance to minimize impacts on condor behavior as the very irregular Andean topography, rock outcrops, and shrubs helped conceal our observation point, and because we did not observe any alarm behavior from feeding condors. At each observation point we installed a spotting scope (Bushnell Elite ED 20–60 x 80) with a digital camera attachment (Olympus E-500) using an adapter lens and a t-ring. With this equipment we photographed all activity near the carcass at each feeding station. We also used binoculars to watch for soaring condors.

Each time a condor was observed we noted the date, location, time of beginning and end of the observation, direction of flight, and age and sex when possible. Adult condors have white secondary feathers while sub-adults lack these feathers. Juveniles are browner in color and lack white secondary feathers and white feathers in their tail (Ríos-Uzeda & Wallace 2007, Ridgely & Greenfield 2001). We also photographed each condor in order to identify unique markings (patterns of molting flight feathers; shape and wear of feathers) for individual identification. We spent nine consecutive days at each feeding station from 07:00 h ECT to 17:00 h. The total hours of observations, however, varied

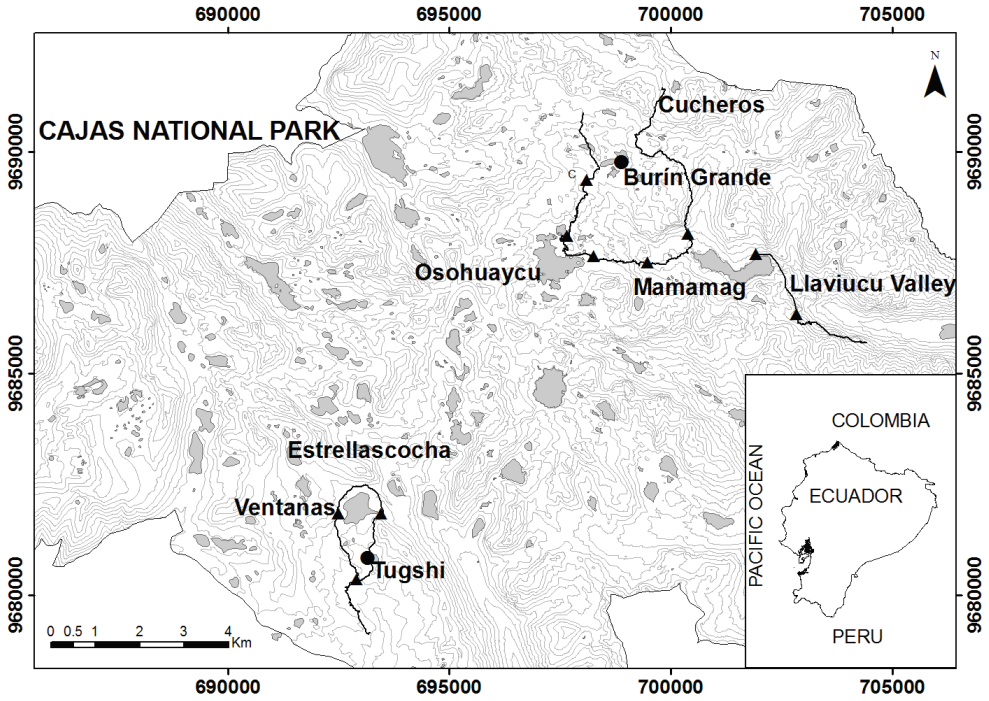

FIG. 1. Study area and location of two feeding stations (filled circles), three transects (solid lines), and ten point count locations (filled triangles). Grey polygons are lakes.

across days because of weather conditions. We did not make observations during periods of rain, fog and low visibility.

Transects. We conducted a transect census of condors by using existing trails that traverse the park. We walked three transects (Fig. 1): (a) Burines – Osohuaycu – Mamamag – Cucheros was a 12.3 km route which began in the northern end of the park, passed towards the center, and returned towards the north; (b) San Antonio – Mamamag was a 5 km route which began at the eastern border of the park and terminated towards the center of the park; and (c) Estrellascocha – Tugshi – Ventanas was a 7.5 km route which started in the southern end of the park, traversed towards the center of the park, and terminated at the southern border. We walked each transect twice during March and April 2008, and only walked transects on days with clear weather conditions. We spent 10 hours per day (07:00–17:00 h) per transect making observations (total = 60 h).

Point counts. We conducted point count observations every ~ 2 km along each of the transect routes described above. Point-counts were located at high points in the *páramo* so as to facilitate the widest possible angle for observing the sky. The distance between points was chosen to maximize the number of counts in the defined area while minimizing the amount of time necessary to walk between points. In addition, the distance between points was sufficient, given the rug-

ged topography, that most points overlooked different mountain valleys. While double-counting of individuals is a potential problem with any point count, we were confident that this would be minimized as we were able to identify individuals through plumage differences. In total, we spent 45 minutes at each of 20 point-counts (total = 15 h of observation time), and noted the same information about each individual condor we observed as was noted in the feeding observations. A mean number of observations per point was not calculated because we were not interested in comparing observations among points but only in assessing the completeness and efficiency of the point count method for estimating minimum population size.

RESULTS

Feeding stations. We monitored feeding stations for a total of 128 h. During this period we encountered Andean Condors 64 times for a mean encounter rate of 0.50 individuals per observation hour. However, it was determined that these 64 encounters represented only six individual condors, with four observed at Tugshi and two seen at Burín Grande (Table 1). While no condors were observed descending to feed at either station, we suppose that they were attracted to the area by the carcass, and we were able to recognize individuals using binoculars and the spotting scope. Typically, condors were observed flying above the feeding station at ~ 14:00 h, spending a maximum of 15 min circling overhead.

At the Tugshi feeding station we recorded three adult condors of unknown sex and one individual of unknown sex and age (Table 1). Two individuals were always observed flying together, while two were observed flying alone. At the Burín Grande feeding station we observed one adult of unknown sex and one adult male; these birds flew as a pair (Table 1). All condors at both stations only approached after the third day of monitoring. These condors were observed flying near the station for five days at Tugshi station and for four days at Burín Grande station.

Transects and point counts. We walked a total of 24.8 km across transects. No condors were observed while walking transects. We spent 15 h conducting point counts along the transects. We observed six condors, representing three individuals, resulting in a mean encounter rate of 0.40 individuals per observation hour. These three condors were determined to be three of the same individuals that were recorded at the feeding stations (Table 2). Two adult condors of unknown sex flying in a pair observed from a point count along Transect 3 were also observed at the Tugshi station. In addition, one adult male condor recorded on a point count along Transect 1 was also observed at the Burín Grande feeding station.

DISCUSSION

Our combined counting methods of feeding stations, walking transects, and point counts yielded only six sightings of individual Andean Condors, indicating that this species is very rare in CNP, and supporting the assumption of an ongoing population decline of Andean Condors in the area (Koenen & Gale 2000). Koester (2002) reported that the main threats to this species in Ecuador are loss of prey items and hunting. Native animals in the park and in the *páramo* in general, are relatively rare (Sánchez & Carbone 2009). Furthermore, while cattle have become increasingly important in the diet of Andean Condors (Ridgely & Greenfield 2001), all livestock have been removed from park lands (Bucheli 2007). As a result, condors may have problems finding sufficient food resources within the park and may be forced to forage

TABLE 1. All six Andean Condors observed at two feeding stations in Cajas National Park, Ecuador.

Age	Sex	Direction of approach	Status	Site	Elevation (m a.s.l.)
Adult	Unknown	South-east	Solitary	Tugshi	3961
Adult	Unknown	West	Pair	Tugshi	3961
Adult	Unknown	West	Pair	Tugshi	3961
Unknown	Unknown	North-east	Solitary	Tugshi	3961
Adult	Male	East	Pair	Burín	3460
Adult	Unknown	East	Pair	Burín	3460

outside of CNP boundaries. Our own casual observations support this hypothesis; for instance, we have seen condors feeding on the remains of horses within about 10 km of the park on several occasions. Nonetheless, the CNP may still serve as a safe-haven from hunting and persecution, even when foraging continues outside the park boundaries. The park's prohibition of hunting of condors appears to be successful, as the killing of condors within the park by poisoning and hunting has not occurred in many years (Bucheli 2007). In contrast, outside of the park dead condors have been reported (Rodas & Tinoco 2003), and we encountered a dead female condor in late-2009. However, comprehensive data on the severity of this threat are non-existent and local residents who may have first-hand knowledge of hunting practices refuse interviews for fear of punishment.

Human disturbance is likely the cause of the observed wariness of Andean Condors and their reluctance to descend to our feeding stations. The closest distance we observed a condor was an individual that flew in circles about 20 m above the donkey carcass. This wariness is in contrast to similar work in Bolivia (Ríos-Uzeda & Wallace 2007), northern Ecuador (Meza *et al.* 2008) and Argentina (Speziale *et al.* 2008) where condors readily fed on bait. For instance, in Bolivia, 108 individuals descended to feed at stations during 162 h of observation. There are several possible reasons why condors in our study might have been unwilling to descend to the ground to feed. In addition to the threat from hunting, we occasionally observed farmer's dogs and cows near one of our study sites, which may have disturbed the birds. Alternatively, the condors may have noticed our observation tents. Meza *et al.* (2008), who used feeding stations to study condors in northern Ecuador, suggested that observation tents may cause the birds not to descend. We attempted to minimize this possibility by siting the feeding station in rugged terrain, using a very small tent (290 cm x 145 cm x 120 cm), placed 160 m away from the carcass, obscured with shrubbery. The donkey carcasses did attract several Carunculated Caracaras (*Phalcoboenus carunculatus*) and an Andean Fox (*Lycalopex culpaeus*), suggesting that our feeding stations were effective at attracting scavengers. Given the care taken to be as inconspicuous as possible, and the fact that we occasionally observed farmers in the surrounding area, we suspect that the main reason why the condors did not descend was their wariness of potential hunters.

Despite the condors not descending to feed, among the three census methods that were tested, we had the most success with the feeding stations. The number of sightings of condors per observation hour was highest at the feeding stations, and we found that the feeding stations attracted six different individ-

TABLE. 2. All three Andean Condors observed at point counts in Cajas National Park, Ecuador.

Age	Sex	Direction of approach	Status	Site	Elevation (m a.s.l.)
Adult	Unknown	West	Pair	Ventanas	3610
Adult	Unknown	West	Pair	Tugshi	3610
Adult	Male	East	Solitary	Osohuaycu	3980

ual condors, with no additional individuals being recorded with other census methods. Even though condors did not descend to feed on our bait, we think feeding stations can be used to study condors and will be useful for assessing population size and monitoring condors as recommended by Ríos-Uzeda & Wallace (2007) and Meza *et al.* (2008). We suggest that feeding stations could be combined with other techniques to decrease dependence on field personnel and thus make census and monitoring work even more practical in certain situations. For example, motion-sensitive cameras may be utilized to identify numbers of individual birds and other scavengers attracted to the bait. In addition, raptors frequently shed feathers at feeding stations, which can be collected and genotyped to sex and identify individual birds (Rudnick *et al.* 2005).

The feeding stations as operated allowed us to count condors that were approaching and circling above the carcass, and we were able to recognize individuals by plumage differences. While this was a helpful tool in our census, we caution that there is limited knowledge regarding the molt pattern of Andean Condors, especially the length of persistence of these marks (Meza *et al.* 2008). We used photographs of individual birds at feeding stations to identify the same individuals at point counts approximately two weeks later, thus we can surmise that condors can be identified by feather wear patterns over these short time periods. However, it would be useful to determine if longer term identification of individuals, and individual monitoring, is possible using this method, as well as how often and in what months the replacement molt of flight feathers occur in condors.

Finally, we recommend a census and monitoring strategy for Andean Condors in Cajas National Park and elsewhere in the Andes based on feeding stations. The use of feeding stations has proven the most effective in terms of attracting the largest number of Andean Condors, and in many cases may be the easiest of the three protocols to implement and complete. While unintended disturbances, especially by farmers and ranchers, will continue to be a problem with this method, this may be alleviated somewhat by locating feeding stations more centrally within the park, and thus further away from humans who may be a perceived threat for the condors. The critical need for continued monitoring of CNP's Andean Condor population was recently underscored with the report of yet another condor poisoning at Llano Largo (2 km from the western border of Cajas National Park). This kind of threat faced by condors remains a serious problem for conservation (Koester 2002, BirdLife 2008), and the effect of high mortality could result in a skewed age structure in the population (Koenen & Gale 2000) or outright extirpation of the species from Ecuador. Our challenge is to determine the best methods for monitoring Andean Condors, and to then intensively use these methods, population estimates, and monitoring data in the development of conservations plans for the species. Together with

some targeted community education efforts, we may yet reverse the Andean Condor population decline in Ecuador.

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