# The impact of urbanization and agricultural development on vultures in El Salvador

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**Summary**

Turkey and Black vulture ranges are expanding in the Americas despite environmental change, while Old World vulture populations are declining in Eurasia and Africa. The distribution of vultures is under-researched in El Salvador, arguably the most environmentally degraded Latin American nation. This article tests the hypothesis that Turkey and Black vulture adaptation to extremely modified landcover, recorded elsewhere, ensures their survival in El Salvador. The methodology uses point count surveys of vulture species density along an urban to forest gradient (dense downtown areas, suburbs, rural villages and farms, mixed uninhabited savanna, open and closed forests). The very common Black Vulture and the slightly less common Turkey Vulture were most often recorded in downtown areas, followed successively by suburban, fallow, savanna and forests. Only downtown and suburban areas, and to a much lesser extent farm fallow, recorded significantly more vultures than the other landcover categories, despite reduced vulture numbers along the gradient towards the forest. The much rarer Lesser Yellow-headed Vulture was most often recorded in farm/grass mosaics and the rarer King Vulture was recorded in forest. Turkey and Black vultures have adapted strongly to extreme environmental change in El Salvador. This result is important as an indicator study for assessing the ecology of these vulture species in less degraded areas.

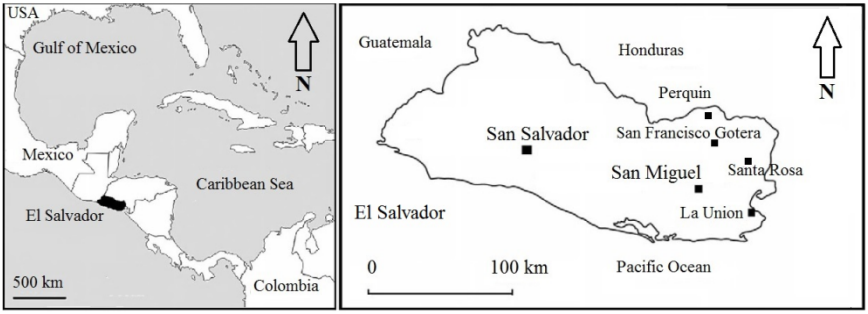
## Introduction

Environmental degradation resulting from urbanization, intensified agricultural development, landuse conflict, war and consequent

deforestation, has impacted negatively on many species, including vultures (Ferguson-Lees & Christie 2001, Murn & Anderson 2008, Campbell 2009, Mateo-Tomás & Olea 2010, Margalida *et al.* 2014). Central America, especially El Salvador, has undergone extreme environmental change from these contributory factors, resulting in animal extinctions (Vandermeer 1990, Ramos & Ricord de Mendoza, 2000, Vargas-Mena 2000, Sanchez-Azofeifa 2000, Hecht *et al.* 2006, Hecht & Saatchi 2007, Sloan 2007).

El Salvador (Figure 1) has a population of 6,052,064 people in an area of 21,041 km$^2$ and is arguably one of the most degraded and densely populated countries in Latin America (Dull 2001, Rose *et al.* 2004, Hecht *et al.* 2006, Hecht & Saatchi 2007, Caso *et al.* 2008, Campbell & Torres Alvarado 2011, Central Intelligence Agency CIA World Factbook 2013). However, the status of vultures in El Salvador is under researched (Ellis *et al.* 1983, Campbell & Torres Alvarado 2011). Deforestation and urbanization may have both negative (habitat loss, noise, pollution, intensive human presence, lower biodiversity and improved sanitation) and positive (road kills, human discards, rubbish dumps) effects on vultures (Mundy *et al.* 1992, Ferguson-Lees & Christie 2001, Campbell 2009). In North and South America, Turkey and Black vultures have adapted and even expanded ranges in response to such changes (Sauer *et al.* 2001, United States Department of Agriculture 2003, DeVault *et al.* 2005, Blackwell and Wright 2006).

Figure 1. Map of El Salvador and Study Locations.




Location of El Salvador in Central America. The study sites were in these cities and random sites in between.

In El Salvador, there are four vulture species: the Turkey (*Cathartes aura* Linnaeus 1758), Black (*Coragyps atratus* Bechstein, 1793), Lesser Yellow-headed (*Cathartes burrovianus* Cassin 1845) and King (*Sarcoramphus papa* Linnaeus 1758) (Ferguson-Lees & Christie 2001). This article analyzes the recorded density of these species in urban to forest gradients. This type of gradient is selected because the original vegetation of densely populated El Salvador, similar to most of Central America, was dense forest, while mixed vegetation (grass, shrubs and isolated tree stands, hereafter termed savanna) largely resulted from human activities, such as intensive farming, fires, urbanization and wars (Hecht *et al.* 2006, Hecht & Saatchi 2007). Hence, the gradient from maximum to minimum human interference would be from intensive urbanization to dense forest.

Four hypotheses are derived from the literature covering vulture behaviour and ecology: (1) Turkey Vultures are commonest in urban and agricultural areas, but more common than Black Vultures in forested areas, due to their sense of smell, which they use for foraging (Garrett and Dunn 1981, Unitt 1984, Olrog 1985, Kiff 2000, Stolen 2000, Feguson-Lees & Christie 2001, Airola 2011); (2) Black Vultures are commonest in urban and open agricultural/ savanna areas, avoiding the canopied forests due to their lack of a sense of smell (Stewart 1978, Wallace & Temple 1987, Hill & Neto 1991, Buckley 1996, 1999, Avery 2004, Novaes & Cintra 2013); (3) Lesser Yellow-headed Vultures (also named the Savanna Vulture) are rarer than either the Black or Turkey vulture, but commonest in open agricultural and savanna landcover (Houston 1984, 1988, 1994, Braun *et al.* 2007, Martínez-Sánchez & Will 2010, Zilio *et al.* 2013); (4) King Vultures are rare but mostly limited to forested areas (Clinton-Eitniear 1986, Berlanga & Wood 1992, Beason 2003, Restall *et al.* 2006).

**Methodology**

The field research was conducted between August 2010 and April 2013, in central and eastern El Salvador, in the urban centres of San Salvador, San Miguel, La Union, Conchagua and Santa Rosa, and the fallow-savanna vegetation grading from these urban centres to the dense forest in Morazon and other forested areas. The study areas followed an urban gradient to forest gradient, as in all cases farm, fallow and savanna landcover were recorded between

urban and dense forest landcover.

Landcover types were classified as: (1) *Downtown.* Dense city centres, especially in the large city of San Salvador and parts of smaller towns, with intensive residential, commercial, industrial, transportation and asphalt landcover, and virtually no vegetation; (2) *Suburbs*. Less dense suburban mostly residential, recreational and commercial landuse, with 20 to 40 percent mixed tree/grass landcover, these comprising most of the smaller towns of La Union and Conchagua; (3) *Fallow savanna*. Mixed agricultural, fallow and small settlement residential landuse, this having more animals due to hunting, livestock rearing and bush clearance; (4) *Mixed savanna*. Mixed agricultural and shrub/grass landcover, with no houses, less or no livestock and forest patches covering about 10 percent of the landcover; (5) *Open forest*. Forest with grass and shrub patches comprising 20 to 50 percent of landcover; and (6) *Closed forest*, with open canopy and shrub/grass vegetation less than 20 percent of landcover. All the forest sites were located at least 500 m from open landcover. Farmland was classified with mixed grass/shrub mosaics as most of the latter was fallow farmland.

The point count method was used, as defined by Campbell (2008) to record vultures in each of the landcover types at a series of observation points. Observation points were randomly selected within each of the landcover types. Each observation point was visited for at least ten minutes, five times between 9 am and 6 pm on different days. All vultures sighted, including perchers, feeders and flyovers were recorded. Flying altitudes were estimated using the methodology of Stolen (2000). For each observation point, the landcover was approximately similar within a radius of at least one kilometre.

The landcover type of each observation point was classified according to the percentage cover over a radius of approximately 500 metres (using field surveys and field and aerial photographs). For downtown areas, urban substrate (roads, buildings, pavements, car parks, plazas and markets) comprised 80 to 100% cover and vegetation cover less than 20%. For the suburbs, urban substrate ranged from 50% to 70%, the remainder comprising grass and tree /shrub parks and urban farms. For fallow areas, the dominant landcover was savanna (grass/shrub mosaics, 50 – 70%), with some urban substrate (20 – 40%) and tree cover (approximately 10%). For savanna

areas, savanna mosaics were approximately 70% of the landcover, with some forest stands (20%) and urban substrate such as roads and pavements (8 - 10%). Open forest was approximately 60% tree stands, with the rest savanna and a few roads. Closed forest was 90% tree stands, with a few savanna patches. Forty observation points were located in urban areas (20 in the downtown and 20 in the suburbs). Forty observation points were located in the open landcover (20 in the fallow and 20 in the mixed savanna. Forty more observation points were located in forest areas (20 in open and 20 in the closed forest). Although the savanna and agricultural areas covered the largest areas of the country, and hence a smaller proportion of this landcover type than urban or forest landcover was covered in the survey, the survey examined vulture density over similarly-sized areas.

Linear regression was used to determine the landcover types as predictors of vulture presence and absence, and ANOVAs (Post Hoc Tukey) to determine the significance of differences between mean numbers of vultures for each landcover type (SPSS v. 22 x 64, 2014). The categorical predictor variables were the six landcover types with increasing levels of urban substrate. Dependent variables were the number of each vulture species recorded at the observation points in the landcover types. Standardized beta coefficients determined the relationship between the dependent variables and the independent predictor variables. These beta values show the variation in the standard deviations of the dependent variable, when the independent variable changed by one standard deviation.

**Results**

Black Vultures were most common in the dense, urbanized areas, followed by the urbanized suburbs, then the mixed village/farm/shrub and grass, then the uninhabited savanna and least in the forested areas (Table 1). Using linear regression, percent urban substrate was a significant predictor of Black Vulture presence ($r^2$ 0.439, $F$ = 92.198, $p < 0.05$). Using standardized Beta coefficients, the percentage of urban substrate was a significant positive predictor of Black Vulture presence (0.662, $p < 0.05$). Fallow and savanna landcover were not predictors of Black Vulture presence and forested landcover was a negative predictor ($r^2$ 0.314, $F$ = 53.928, $p < 0.05$, Beta -.560).

**Table 1:** Numbers and percentage of vultures according to landcover type, recorded in different landcover types in El Salvador. Percentage of totals in parentheses.

| **Vulture** | **Downtown** | **Suburb** | **Fallow** | **Savanna** | **Open Forest** | **Closed Forest** |
|---|---|---|---|---|---|---|
| Black Vulture | 196(44%) | 105(24%) | 78(18%) | 44(10%) | 16(4%) | 3(1%) |
| Turkey Vulture | 90(41%) | 48(22%) | 32(15%) | 23(11%) | 18(8%) | 8(4%) |
| LYH* Vulture | 3(21%) | 3(21%) | 3(21%) | 3(21%) | 2(14%) | 0(0%) |
| King Vulture | 0(0%) | 0(0%) | 1(7%) | 2(14%) | 2(14%) | 2(14%) |

* Lesser Yellow-headed Vulture.

Turkey Vultures were also commonest in the urban downtown and suburb areas, but less so than the Black Vultures (Table 1). Using linear regression, Turkey Vultures were also commonest in the dense urban areas, but less so than the Black Vultures (Table 1). Using linear regression and standardized Beta values, percentage urban substrate was a significant positive predictor of Turkey Vulture presence while savanna and forest percentage landcover were both significant negative predictors ($r^2$ 0.272, $F$ = 21.864, $p < 0.05$, Beta values for urban, savanna and forest landcover percentage were 0.519, -0.337, -0.530 respectively, $p < 0.05$). For the Lesser Yellow-headed and King vultures, the numbers recorded were too low for a reliable analysis (Table 1).

Table 2 is matrix that compares the mean numbers of Black and Turkey vultures in each of the landcover types. In some cases, the mean number of vultures recorded in one landcover type (e.g. downtown) was significantly greater than the mean number of vultures recorded in another landcover type (e.g. fallow). In Table 2, such significant differences are recorded as plus signs. White circles are recorded where there was no significant difference between the two means. The mean numbers of Black and Turkey vultures recorded in downtown areas

were significantly higher than the means for all other landcover types. For the Black Vulture mean numbers in suburbs and fallow were also significantly higher than means recorded in the two forest classes. For the Turkey Vulture, mean numbers in the suburbs (but not fallow) were also significantly higher than means in the closed forest (not open forest). There were no significant differences between the mean numbers recorded in other landcover types (Table 2).

Black and Turkey vultures in urban areas were recorded over all types of urban landcover, including unsanitary markets, abattoirs, fish unloading zones, residential areas, financial centres, hotel districts and transportation networks, rooftops, electric poles, roads and trees. They flew singly or in grouped kettles (a kettle is defined as a large circling crown flock of soaring birds, McWilliams & Brauning 2000), which were commoner in urban than in savanna areas, and not recorded over forest areas. They were also commonly recorded in low and middle level flyovers above farms and beaches, possibly as both farming and fishing were productive of dead animal organic matter in urban interfaces with the savanna and the coast.

**Table 2**: Significance of sample mean differences of Turkey and Black vultures.

| **Black Vulture** | **Downtown** | **Suburb** | **Fallow** | **Savanna** | **Open Forest** | **Closed Forest** |
|---|---|---|---|---|---|---|
| Downtown | X | | | | | |
| Suburb | + | X | | | | |
| Fallow | + | ○ | X | | | |
| Savanna | + | ○ | ○ | X | | |
| Open Forest | + | + | + | ○ | X | |
| Closed Forest | + | + | + | ○ | ○ | X |
| **Turkey Vulture** | **Downtown** | **Suburb** | **Fallow** | **Savanna** | **Open Forest** | **Closed Forest** |
| Downtown | X | | | | | |
| Suburb | + | X | | | | |
| Fallow | + | ○ | X | | | |
| Savanna | + | ○ | ○ | X | | |
| Open Forest | + | ○ | ○ | ○ | X | |
| Closed Forest | + | + | ○ | ○ | ○ | X |

+ = significant difference, ○ = insignificant difference, using ANOVA Tukey Post Hoc

In savanna, and especially forests, mostly smaller flocks of three to five or single birds were seen, occasionally perching in trees or on the ground. Vultures were rare in the forests, even when dead animals were sighted in forest clearings. Several dead animals were recorded; a Jaguarundi *Puma yagouaroundi* (Geoffroy Saint-Hilaire, 1803) in the forest, several goats on the forest savanna boundary and a horse along a road in fallow farmland near a town. However, only the horse was attended by vultures (26 Black Vultures and one Turkey Vulture).

**Discussion**

The findings of this paper are consistent with the first hypothesis that Black and Turkey vultures are more common in urban and agricultural areas than the Lesser Yellow-headed and King vultures. Consistent with the second hypothesis, Black Vultures were much more common in urban areas, followed by farmed and savanna areas and then forests. The fundamental factor appears to be food availability; some areas within the studied urban areas have poor sanitation, while wildlife depletion in savannas and forests would have reduced food opportunities in these areas. Turkey vultures were the commonest forest species, but were still far more common in urban areas than elsewhere, this being partially inconsistent with the third hypothesis. It is possible that this indicates a shift from forest foraging to urban specialization, as reported in the literature (Feguson-Lees & Christie 2001; Airola 2011).

The formation of vulture kettles over urban downtown areas could be a combination of foraging and utilization of the urban heat island effect for thermal soaring. The results indicate that intensive human habitation, with consequent sanitation problems, decaying organic matter on open concrete, combined with urban thermals are beneficial for adaptive vulture species, to the extent that the negative human contributed features are insufficient to repel Black and Turkey vultures. The attractive features were however insufficient for the Lesser Yellow-headed and King vultures which, consistent with the hypotheses and reports from elsewhere, were limited to more natural landcover, despite possibly lower feeding opportunities (Houston 1984, 1988, 1994, Clinton-Eitniear 1986, Berlanga & Wood 1992, Schlee 1995, Beason 2003, Restall *et al.* 2006 Braun *et al.* 2007, Martínez-Sánchez & Will 2010, Zilio *et al.*

2013). The rarity of the King Vulture precludes a definitive statement on its foraging habits. Possibly this species is more affected than the other species by the extinction of large mammals and deforestation in El Salvador, as it has been described as rare in several parts of its range, with deforestation a principal factor (Clinton-Eitniear 1986; Ferguson-Lees & Christie 2001; Beason 2003; Restall *et al.* 2006).

**Conclusions**

Urban colonization by vultures is an increasingly important issue in the United States and some South American countries. The findings of this article suggest that urbanization and environmental degradation do not deter Black and Turkey Vulture populations and may rather result in substantial colonization. However, as the unsanitary nature of many urban areas facilitates their foraging success, increased sanitation, in addition to further wildlife depletion are crucial topics for future research. It may be inferred that El Salvador, one of the most environmentally degraded countries in the Americas, is a good case study as it may represent the future state of some currently less degraded countries. Therefore, further research would benefit from including El Salvador in comparative, international studies for the assessment of vulture ecology.

**Keywords:** vulture, urbanization, environmental change, El Salvador, conservation.

**References**

Airola, D.A. 2011. Dynamics of an Urban Turkey Vulture Roost in Sacramento, California. *CVBC Bulletin* 1 - 8.

Avery, M.L. 2004. Trends in North American vulture populations. In Timm, R.M. and Gorenzel, W.P. (eds.) *Proceedings of the 2lst Vertebrate Pest Conference*, 116–121. University of California, Davis.

Beason, R.C. 2003. *Through a Birds Eye: Exploring Avian Sensory Perception*. USDA Wildlife Services, Washington, D.C.

Berlanga, M. & Wood, P. 1992. Observations of the king vulture *Sarcoramphus*

*papa* in Calakmul Biosphere Reserve Campeche Mexico. *Vulture News* 26:15-21.

Blackwell, B. F. & Wright, S. E. 2006. Collisions of red-tailed hawks (Buteo jamaicensis), turkey (Cathartes aura), and black vultures (Coragyps atratus) with aircraft: implications for bird strike reduction. *Journal of Raptor Research* 40:76–80.

Braun, M.J., Finch, D.W., Robbins M.B. & Schmidt, B.K. 2007. A *Field Checklist of the Birds of Guyana*, 2nd Ed. Smithsonian Institution, Washington, D.C.

Buckley, N.J. 1996. Food finding and the influence of information, local enhancement, and communal roosting on foraging success of North American vultures. *Auk* 113: 473-488.

Buckley, N.J. 1999. Black vulture (Coragyps atratus). In in Poole, A. and Gill, F. (eds.) *The Birds of North America, No. 411*.The Birds of North America, Inc. Philadelphia.

Campbell, M. 2009. Factors for the presence of avian scavengers in Accra and Kumasi, Ghana. *Area* 41(3): 341–349.

Campbell, M. & Torres Alvarado, M. 2011. Public perceptions of jaguars *Panthera onca* pumas *Puma concolor* and coyotes *Canis latrans* in El Salvador. *Area* 433: 250–256.

Caso, A., Lopez-Gonzalez, C., Payan, E., Eizirik, E., de Oliveira, T., Leite-Pitman, R., Kelly, M. & Valderrama, C. 2008. "*Panthera onca" IUCN Red List of Threatened Species Version 2011*. International Union for Conservation of Nature, Gland.

Central Intelligence Agency 2013. A World Factbook Available at https://wwwciagov/library/publications/the-world-factbook/geos/eshtml Accessed 10/12/2013.

Clinton-Eitniear, J. 1986. King vulture conservation and research program. *Endangered Species Technical Bulletin* 3:1-2. University of Michigan, Ann Arbor.

DeVault, T.L., Reinhart, B.D., Brisbin, Jr., I. L. & Rhodes, Jr, O.E. 2005. Flight behavior of black and turkey vultures: implications for reducing bird–aircraft collisions. *Journal of Wildlife Management* 69: 592–599.

Dull, R. 2001. *El Bosque Perdido: A Cultural-Ecological History of Holocene*

*Environmental Change in El Salvador.* PhD Dissertation, University of California, Berkeley.

Ellis, D.H., Glinksi, R.L., Goodwin, JR., J.C. & Whaley, W.H. 1983. New World vulture counts in Mexico, Central America, and South America. In Wilbur, S.R. and Jackson, J.A. (eds.) *Vulture Biology and Managemen*t, 124 - 132. University of California Press, Berkeley.

Ferguson-Lees, J. & Christie, D. A. 2001. *Raptors of the World*. Christopher Helm, London.

Garrett, K. & Dunn, J. 1981. *Birds of southern California: status and distribution*. Los Angeles Audubon Society, Los Angeles.

Hecht, S.B, Kandel, S., Gomes, I., Cuellar, N. & Rosa, H. 2006. Globalization forest resurgence, and environmental politics in El Salvador. *World Development* 34, 308–23.

Hecht, S.B. & Saatchi, S.S. 2007. Globalization and forest resurgence changes in forest cover in El Salvador. *Bioscience* 57: 663–672.

Hill, J.R. & Neto, P.S. 1991. Black vultures nesting on skyscrapers in southern Brazil. *Journal of Field Ornithology* 62(2):173-176.

Houston, D.C. 1984. Does the King Vulture *Sarcoramphus papa* use a sense of smell to locate food? *Ibis* 126167-69.

Houston, D.C. 1988. Competition for food between Neotropical vultures in forest. *Ibis* 130: 402-417.

Houston, D.C. 1994. Family Cathartidae (New World vultures). In del Hoyo, J, A. Elliott, & J. Sargatal (eds.), *Handbook of the Birds of the World*. Vol. 2. New World vultures to guineafowl, p24-41, Lynx Edicions, Barcelona.

Kiff, L.F. 2000. The current status of North American vultures. In Chancellor, R.D. & Meyburg, B.-U. (eds.) *Raptors at Risk*, 175–189. WWGBP/HancockHouse. Berlin and Surrey, Canada.

Margalida, A., Campion, D. & Donazar, J. 2014. Vultures vs livestock: conservation relationships in an emerging conflict between humans and wildlife. *Fauna & Flora International* Oryx 1 – 5.

Martínez-Sánchez, J.C. & Will,T. 2010. Thomas R. Howell's Check-list of the birds of Nicaragua as of 1993. *Ornithological Monographs* 68:1-107.

Mateo-Tomás, P. & Olea, P.P. 2010. When hunting benefits raptors: a case study

of game species and vultures. *European Journal of Wildlife Research* 56:519–528.

McWilliams, G.M. & Brauning, D.W. 2000. *The Birds of Pennsylvania*. Cornell University Press, Ithaca.

Mundy, P., Butchart, D., Ledger, J. & Piper, S. 1992. *The Vultures of Africa.* Academic Press, London.

Murn, C. & Anderson, M.D. 2008. Activity patterns of African White-backed vultures *Gyps africanus* in relation to different land-use practices and food availability. *Ostrich* 79(2):191–198.

Nassar-Montoya, F. and Crane, R. (eds) *Actitudes hacia la fauna en Latinoamérica*, 85 – 95. Humane Society Press, Washington DC.

Novaes, W.G. & Cintra, R. 2013. Factors influencing the selection of communal roost sites by the Black Vulture *Coragyps atratus* (Aves: Cathartidae) in an urban area in Central Amazon. Zoologia 30 (6): 607–614.

Olrog, C.C. 1985. *Status of Wet Forest Raptors in Northern Argentina.* ICBP Technical Publication :191 - 197.

Ramos, L.A. & Ricord de Mendoza, Z. 2000. Tenencia de fauna silvestre en El Salvador. In Nassar-Montoya, F. and Crane, R. (eds) *Actitudes hacia la fauna en Latinoamérica*, 85 – 95. Humane Society Press, Washington DC.

Restall, R., Rodner, C. & Lentino, M. 2006. *Birds of Northern South America: An Identification Guide*. Vol. 1. Christopher Helm/A&C Black Publishers Ltd, London.

Rose, W., Bonner, J., Lopez, D., Carr, M. & Major, J. (eds) 2004. *Natural hazards in El Salvador.* USGS, Boulder.

Sanchez-Azofeifa G.A. 2000. Land use and cover change in Costa Rica In Hall, C. (ed) *Quantifying Sustainable Development*, 477–505. Academic Press, New York.

Sauer, J. R., Hines, J. E. & Fallon, J. 2001. The North American Breeding bird Survey, Results, and Analysis 1966 – 2000. Version2001.2, U.S.G.S. Patuxet Wildlife Research Center, Laurel, MD.

Schlee, M.A. 1995. Nest records for the King Vulture *Sarcoramphus papa* in Venezuela. *Journal of Raptor Research* 29: 269-272.

Sloan, S. 2007. Fewer people may not mean more forest for Latin American forest frontiers. *Biotropica* 39: 443–446.

Stewart, P. A. 1978. Behavioral interactions and niche separation in Black and Turkey vultures. *Living Bird* 17:79-84.

Stolen, E.D. 2000. Foraging behavior of vultures in central Florida. *Florida Field Naturalist* 28(4): 173 - 181.

Unitt, P. 1984. The birds of San Diego County. *San Diego Society of Natural History Memoir* 13.

Vandermeer, J. 1990. The Political Ecology of Sustainable Development: The Southern Atlantic Coast of Nicaragua. CICLAES, Michigan State University, East Lansing.

Vargas-Mena, E. 2000. Significados culturales de la tortuga verde (Chelonia mydas) en el Caribe costarricense. In Nassar-Montoya, F. and Crane, R. (eds) *Actitudes hacia la fauna en Latinoamérica*, 161–176 Humane Society Press, Washington DC.

Wallace, M.P. & Temple, S.A. 1987. Competitive interactions within and between species in a guild of avian scavengers. *Auk* 104: 290-295.

Zilio, F., Bolzan, A., de Mendonça-Lima, A., da Silva, A.O., Verrastro, L. & Borges-Martins, M. 2013. Raptor assemblages in grasslands of Southern Brazil: species richness and abundance and the influence of the survey method. *Zoological Studies*: 52:27.

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