

Distribution, habitat use, and implications for the conservation of the globally threatened Azure-rumped Tanager *Tangara cabanisi* in Guatemala

KNUT EISERMANN, SUSANNE ARBEITER, GERARDO LÓPEZ, CLAUDIA AVENDAÑO and JOSUÉ DE LEÓN LUX

Summary

The Azure-rumped Tanager *Tangara cabanisi* is a globally threatened species restricted to the Pacific slope mountains of western Guatemala and Chiapas, Mexico. We studied the habitat use of this tanager on the southern slope of Atitlán volcano, department Suchitepéquez, Guatemala, applying distance sampling along transects in humid broadleaf forest and coffee plantations. The tanager was recorded in both habitat types, but encounter rates were significantly greater in broadleaf forest. The estimated density of tanagers in forest at 1,400–1,900 m was 33–93 birds km⁻². Tanagers were recorded mainly in the upper vegetation strata of forest and shade coffee plantations. In coffee plantations tanagers used mainly tall solitary trees or the canopy of shade trees, which were dominated by *Inga* spp. The number of observations of feeding tanagers in *Ficus aurea* (Moraceae) indicated a high importance of this food source. The density of *F. aurea* trees and the encounter rate of tanagers were positively correlated. From 1987 to 2009 tanagers have been recorded at nine topographic units and a total of 16 sites in Guatemala, in the departments of San Marcos, Quetzaltenango, Sololá, Suchitepéquez, and Chimaltenango. We analysed the available habitat for tanagers in the potential area of distribution (1,170 km²), ranging from 900 to 1,900 m altitude and from the Mexican border in the West to the municipality of Pochuta in the East. Broadleaf forest covers 250 km² or 21% of the potential area of distribution, and coffee plantations cover 800 km² or 68%. Assuming that population density in prime habitat throughout the potential distribution range is similar to our study area at Atitlán volcano, total tanager population in Guatemala is estimated to be 8,250–23,250 birds. Our findings support the maintenance of the IUCN Red List status of Endangered EN B1a+b(ii,iii,v). To enhance the available habitat for Azure-rumped Tanager, we propose alterations in the shade management of coffee plantations, supported by incentives and certification programmes.

Resumen

La Tángara de Cabanis *Tangara cabanisi* es una especie globalmente amenazada que está restringida a las montañas de la vertiente Pacífica en el oeste de Guatemala y a Chiapas, México. Estudiamos el uso de hábitat de esta tángara en la vertiente sur del volcán Atitlán, departamento de Suchitepéquez, Guatemala, aplicando el método de “distance sampling” a lo largo de transectos en bosque latifoliado húmedo y en plantaciones de café. Las Tángaras de Cabanis fueron registradas en ambos tipos de hábitat, pero el índice de detección fue significativamente mayor en bosque latifoliado. La densidad estimada de la población de la Tángara de Cabanis en bosque de 1,400–1,900 m fue de 33–93 individuos km⁻². Las tángaras fueron registradas principalmente en

el estrato superior de vegetación. En plantaciones de café las tángaras usaron principalmente árboles altos solitarios o el dosel de árboles de sombra, que fue dominado por *Inga* spp. El número de observaciones de tángaras alimentándose en *Ficus aurea* (Moraceae) indicó una alta importancia de este recurso alimenticio. La densidad de árboles de *F. aurea* y el índice de detección de Tángara de Cabanis estuvieron positivamente correlacionadas. De 1987 a 2009 la Tángara de Cabanis ha sido registrada en nueve unidades topográficas y un total de 16 lugares en Guatemala, en los departamentos de San Marcos, Quetzaltenango, Sololá, Suchitepéquez y Chimaltenango. Analizamos el hábitat disponible para las Tángaras de Cabanis en su área potencial de distribución (1,170 km²), cubriendo desde 900 hasta 1,900 m de altitud, y desde la frontera con México al oeste hasta el municipio de Pochuta en el este. Los bosques latifoliados cubren 250 km² ó 21% de esta área y las plantaciones de café cubren 800 km² ó 68%. Asumiendo una densidad de Tángaras de Cabanis similar al área de estudio en volcán Atitlán en todos los bosques latifoliados, la población total en Guatemala se estima en 8,250–23,250 individuos. La información de uso de hábitat y extensión de hábitat apropiado justifica mantener el estado de Amenazada EN B1a+b(ii,iii,v) en la Lista Roja de UICN. Para aumentar el hábitat disponible para la Tángara de Cabanis proponemos alteraciones en el manejo de sombra de plantaciones de café, apoyado por programas de incentivos y certificaciones.

Introduction

The Azure-rumped Tanager *Tangara cabanisi* is a species of restricted range occurring in the Pacific slope mountains of Guatemala and Chiapas, Mexico, where it has been reported from a narrow altitudinal belt between 1,000 and 1,700 m (Parker *et al.* 1976, Hilty and Simon 1977, Vannini 1989, Heath and Long 1991, Cooper 2003, Tenez 2005, Valdez *et al.* 1999, Eisermann and Avendaño 2006, 2007a). South of Lake Atitlán it was first reported in the Pachuj Reserve in 1999, later also in the Los Andes Reserve in 2000 (Eisermann and Avendaño 2006), and in the Los Tarrales Reserve in 2004 (Jones 2004).

Information on the ecology of the Azure-rumped Tanager originates mainly from observations in the Sierra Madre de Chiapas. Brodtkorb (1939) collected the first specimen there in cloud forest, and Heath and Long (1991) provided information on habitat preferences, where by this time it had only been recorded in the interior and on the edge of broadleaf forests. They reported *Ficus cookii* as the dominant tree species in Azure-rumped Tanager habitat in the El Triunfo Biosphere Reserve. *Ficus cookii* belongs to the *F. aurea* species complex (Berg 2007). Heath and Long (1991) estimated suitable tanager habitat as 1,125 km² in Chiapas. The species is considered 'Endangered' at a global level because of its small area of distribution and loss of habitat, primarily through the replacement of broadleaf forests by coffee plantations (Collar *et al.* 1992, BirdLife International 2008).

The Guatemalan Pacific slope highlands are one of the country's main areas for coffee cultivation. Recently, the Azure-rumped Tanager has been observed in both habitat types, humid broadleaf forest and coffee plantations (Dietsch 2000, BirdLife International 2008). For Guatemala, the extent of suitable habitat has not yet been quantified. Here we quantify the use by the species of forest and coffee plantations, and then analyse the extent of suitable habitat throughout Guatemala. Because we observed feeding tanagers mainly in *Ficus aurea* trees, we furthermore determine the correlation of the population density of this tree with the abundance of Azure-rumped Tanager. We provide implications for conservation of this species.

Methods

Study area

The Azure-rumped Tanager's known area of distribution in the western Pacific slope mountains of Guatemala is characterised by a chain of several major volcanoes. The altitudinal belt between

1,000 and 1,900 m is shaped by very pronounced slopes of $> 30\%$. The mean annual rainfall amounts to 2,000–4,600 mm, but can locally reach a maximum of 6,000 mm annually. The wet season extends from April to November with a mean monthly precipitation of 150–800 mm, and the dry season from December to March with mean monthly precipitation of 5–150 mm (MAGA 2002).

Annual mean minimum temperature is 15°C ; annual mean maximum is 25°C (MAGA 2002). The natural climax vegetation in this area is humid evergreen broadleaf forest, with broadleaf-conifer forest in higher and less humid areas. Much of the forest $< 1,600$ m altitude has been replaced by coffee plantations and other agricultural crops in the 19th century.

To determine habitat use by Azure-rumped Tanagers, we conducted counts along trails in the neighbouring private nature reserves Los Tarrales, Los Andes, and San Jerónimo Miramar, department Suchitepéquez, where the species had been recorded previously (Eisermann and Avendaño 2007a). The rectangle encompassing all trails had a size of 1,950 ha (geographic coordinates of the centre point of the rectangle: $14^{\circ} 32' \text{N } 91^{\circ} 10' \text{W}$; Figure 1)

Landcover

For land cover analyses in the potential area of distribution of Azure-rumped Tanager in Guatemala we used the most recent national landcover mapping at a scale of 1:50,000, based on Landsat images and ground truthing with local experts (MAGA 2006). Land cover in the study area on Atitlán volcano was mapped based on orthoimages with a ground resolution of 0.4 m, based on aerial photographs from December 2005 (MAGA 2010) and ground-truthed field observation in 2008. We mapped *Ficus aurea* trees within a total strip width of 120 m along all transects from orthoimages with some ground-truthing. Software ESRI ArcView GIS 3.2 was used for all spatial analyses.

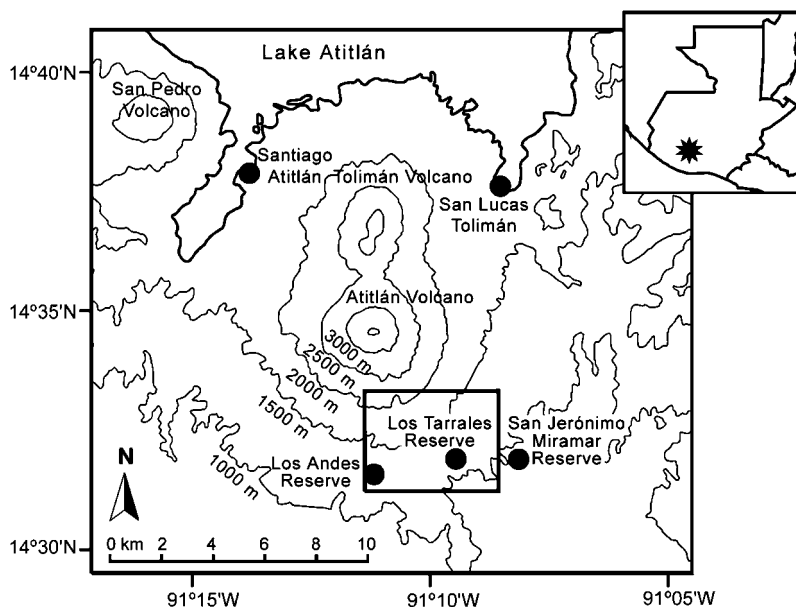


Figure 1. Study area at Atitlán volcano. The inset map shows the location of the study area in Guatemala.

Vegetation structure

We produced foliage-height profiles modified after Blondel and Cuvillier (1977) by determining vegetation density in 20 strata. We used a 9 m long telescopic pole, which was marked from 0.5 to 9 m, and a laser rangefinder (Nikon ProStaff Laser 440). Along 15 of 21 transects, four evenly spaced sites were defined using a handheld GPS device. At each site, foliage coverage was measured at six points at the perpendicular distance of 10, 20, and 30 m on both sites of the transect. At each point the telescopic pole was positioned vertically, noting whether plants touched the pole on marks at 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6, 7, 8, and 9 m. Above this height, we used the laser rangefinder to determine whether plants touched at the imaginary elongation of the pole at 10, 12, 15, 20, 25, 30, 35, and 40 m. All measurements were taken by the same observer (KE). The percentage of presence of plant parts was used as vegetation density index.

Bird surveys

Counts of Azure-rumped Tanagers were conducted along 21 line transects in forest and in coffee plantations (Table 1, Figure S1, in online supplementary material) applying the distance sampling method (Buckland *et al.* 2001). Because habitat distribution was patchy, none of the transects in coffee plantations was farther than 150 m away from the nearest forest edge. After familiarisation with the different vocalisations of the tanagers (Eisermann *et al.* 2011), two observers (SA, GL) walked along the transect at an average speed of 1 km h⁻¹ between 06h15 and 10h00 (sometimes until 15h30) under favourable weather conditions (i.e. without rain and no or low wind [wind speed not more than 3 on the Beaufort scale]). All tanagers heard and seen were recorded, together with the following data: number of individuals per flock, perpendicular distance from the

Table 1. Number of Azure-rumped Tanagers recorded at each transect line with an effective strip width of 60 m.

Transect and habitat*	Transect length (m)	Number of visits	Total length (m)	Number of individuals	Number of individuals /100 m
10 (fh)	1,040	12	12,480	55	0.44
20 (fh)	2,570	7	19,190	90	0.47
22 (fh)	350	7	2,450	5	0.20
23 (fh)	610	21	12,810	8	0.06
24 (fh)	310	5	1,550	5	0.32
26 (fh)	1,340	2	2,680	11	0.41
27 (fh)	300	2	600	11	1.83
2 (fl)	340	1	340	0	0.00
5 (fl)	450	1	450	0	0.00
8 (fl)	1,120	7	7,680	1	0.01
16 (fl)	1,470	7	10,290	7	0.07
17 (fl)	890	6	5,340	0	0.00
11 (ci)	1,480	8	11,840	0	0.00
15 (ci)	520	7	3,640	0	0.00
21 (ci)	730	7	5,110	0	0.00
29 (ci)	1,220	2	2,440	0	0.00
13 (cn)	1,220	9	10,980	8	0.07
14 (cn)	870	16	10,140	0	0.00
25 (cn)	500	5	2,500	0	0.00
30 (cn)	330	10	3,300	2	0.06
31 (cn)	240	6	1,440	0	0.00

*ci: intensive coffee plantation; cn: non-intensive coffee plantation; fh: forest at 1,400–1,900 m; fl: forest at 900–1,300 m

transect (measured with a laser rangefinder), estimated height of birds above ground and height of vegetation at the same point. Geographic coordinates of all records were recorded on the trails using a handheld GPS device (Garmin 60CSx). When tanagers were observed feeding, food source was noted. Voucher specimens of food plants were deposited in the herbarium BIGU of the School of Biology of San Carlos University, or in the herbarium AGUAT of the Faculty of Agronomy of the San Carlos University, both located in Guatemala City (Table S1). Coincidental observations of Azure-rumped Tanager were recorded together with the geographic coordinates determined with a GPS device.

Available foot trails were used for line transect counts, which were repeated between one and 21 times from 19 June to 8 August 2008. Because data from repeated transect lines are not independent, we pooled data from all repetitions and calculated with the total transect length of all repetitions, as recommended by Buckland *et al.* (2001). Density was estimated using software Distance 5.0 Release 2 (Thomas *et al.* 2006).

To compare mean encounter rates between forest and coffee plantations, we truncated data at 30 m. Each transect line was considered a replication unit and differences in mean values were compared with a randomisation test with $\alpha = 0.05$ using SsS software (Engel 1998). Means are given together with standard deviation if not otherwise indicated. Geometric Mean Regression (Ricker 1984, Krebs 1999) was applied to analyse the correlation between the distribution of *Ficus aurea* trees and encounter rate of Azure-rumped Tanagers using SsS software (Engel 1998) with $\alpha = 0.05$.

Distribution and population size of Azure-rumped Tanager in Guatemala

As a basis for derivation of total population size of Azure-rumped Tanagers in Guatemala, we compiled data on the presence of the species in other areas from published references, from our own occasional observations, from data in eBird Guatemala (<http://ebird.org/content/guatemala/>), and from Christmas Bird Counts on Atilán volcano (<http://www.audubon.org/bird/cbc/hr/index.html>). We calculated the total population size for Guatemala assuming that the population density throughout the remaining prime habitat is similar to the density determined at Atilán volcano.

Results

Vegetation cover and structure at Atilán volcano

The Atilán volcano is one of the major forest patches in the Guatemalan Pacific slope mountains, although much of the forest below 1,600 m has been replaced by coffee plantations. All coffee plantations within the study area were shaded monocultures according to a classification by Perfecto *et al.* (2005), with a shade cover of 10–30% and 1–5 species of shade trees. Within the study area we discriminated between intensive and non-intensive coffee plantations, classified by differences in shade coverage and density of coffee shrubs. Vegetation cover within the study area was as follows: broadleaf forest covered 1,411 ha (72% of the study area), intensive coffee plantations 337 ha (17%), non-intensive coffee plantations 105 ha (5%), other intensive plantations (ponytail *Beauvernea recurvata*, tea *Camellia sinensis* and others; complete nomenclature of all plant names is indicated in Table S1) 59 ha (3%), scrub 12 ha (1%), and orchard-like settlements 14 ha (1%) (Figure S1).

Foliage-height profiles show that broadleaf forest along transects was up to 40 m high, with a dense understorey of herbs and shrubs (including palms) and a dense canopy (Figure 2a,b). Vines were included in the class of shrubs, which were more abundant in forest at 900–1,300 m than in high-elevation forest at 1,400–1,900 m. Coverage of *Ficus aurea* trees in the canopy was higher in high-elevation forest.

Coffee plantations had a shrubby understorey with an open canopy of shade trees (Figure 2c,d). Non-intensive coffee plantations had a low density of coffee shrubs in the understorey, where

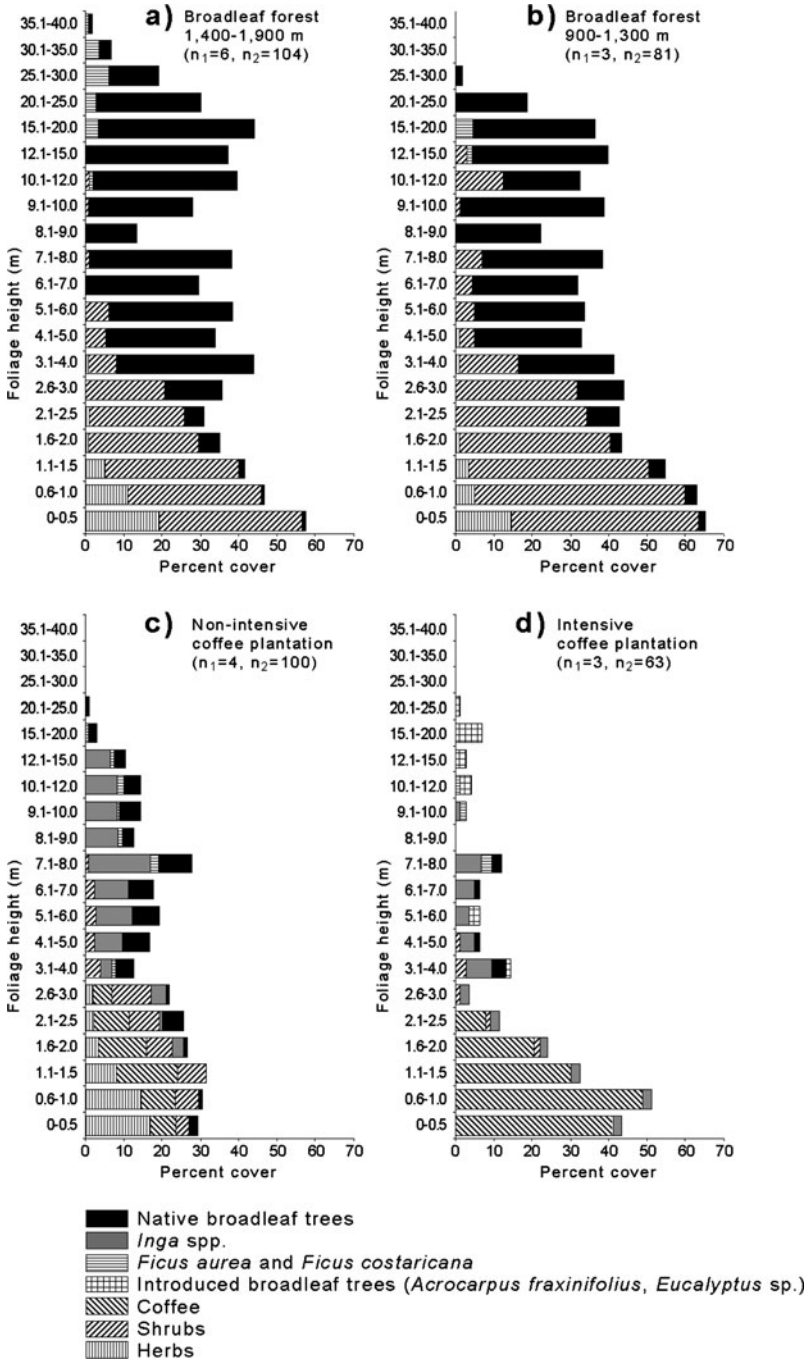


Figure 2. Foliage height profiles of a) broadleaf forest at 1,400–1,900 m, b) broadleaf forest at 900–1,300 m, c) non-intensive coffee plantation, and d) intensive coffee plantation. n_1 indicates the number of transects and n_2 the number of points where vegetation cover was measured. Percent cover represents the mean percentage of plant touches on a pole in the indicated height classes.

they compete with native shrubs and herbs. Herbs were absent in intensive coffee plantation because of intensive use of herbicides. The canopy of shade trees in non-intensive plantations was dominated by *Inga* spp. trees (mainly *Inga micheliana*, but also *I. spuria*, *I. rodrigueziana*, and *I. laurina*) with a dense cover. *Inga* trees in intensive plantation were heavily pruned and these plantations also had non-native species of shade trees (*Acrocarpus fraxinifolius*, *Eucalyptus* sp.).

Habitat use, density, and abundance of Azure-rumped Tanagers at Atilán volcano

Azure-rumped Tanagers were recorded on the south-eastern slope of Atilán volcano from 860 to 1,900 m in primary humid broadleaf forest, in coffee plantation, and in edge habitat. A total of 134 observations of Azure-rumped Tanager involving 282 birds were recorded during transect counts between 19 June and 8 August 2008. In the forest interior (> 30 m from habitat edge) 92 observations (202 birds) were recorded; in forest edge habitat (< 30 m to forest edge) 21 observations (38 birds); in the interior of non-intensive coffee plantations three observations (six birds); in non-intensive coffee plantation edge habitat 11 observations (21 birds); and in intensive coffee plantation edge habitat 7 observation (15 birds). No tanagers were recorded in the interior of intensive coffee plantations. Because the sample size of tanagers in the interior of coffee plantations is too small to calculate a detection probability in this habitat, we compare encounter rates between habitats. For that we used only data of tanagers observed in the interior (> 30 m from the edge) of the sampled habitat, and truncated data at 30 m in order to lower the effect of higher detection probabilities in coffee plantations than in forests. Mean number of individuals recorded per 100 m of transect with a strip width of 60 m (Table 1) was significantly higher in forest (both types of forest pooled) than in coffee plantations (both types of coffee plantations pooled) (randomisation test, differences in means 0.303, $P < 0.05$, based on 1,000 permutations). Mean number of tanagers was also significantly higher in high-elevation forest (tanager's prime habitat) versus non-intensive coffee plantation (randomisation test, differences in means 0.507, $P < 0.05$, based on 792 permutations).

Although tanagers were recorded as low as 860 m above sea level, mean encounter rate in forests 1,400–1,900 m (0.53 ± 0.59 birds/100 m) was significantly higher than in forests at 900–1,300 m (0.02 ± 0.03 birds/100 m) (permutation test, differences in means 0.517, $P < 0.05$, $n = 972$ permutations), indicating that high-elevation forest is the tanager's main habitat. Sample size in forests at 1,400–1,900 m was sufficient to model detection probability. Along seven transect lines in forest at 1,400–1,900 m with a total sampling effort of 49.2 km, 89 detections of Azure-rumped Tanager were recorded. Data from distance sampling procedure fitted best a hazard-rate distribution, using Akaike's Information Criterion (AIC) for model selection and best goodness-of-fit tested with chi-square test for each interval. A good model fit was achieved with data truncation at 65 m and classification in five distance intervals (Figure 3). Mean flock size was 2.17 individuals (SE 0.07; 95% confidence interval: 2.02–2.33). Estimated density of Azure-rumped Tanagers in forest at 1,400–1,900 m was 26 flocks km^{-2} (95% confidence interval: 15–43 flocks km^{-2}) or 56 birds km^{-2} (95% confidence interval: 33–93 birds km^{-2}) from June to August 2009. Thus, population size of Azure-rumped Tanager in the approximately 5 km^2 of forest between 1,400 and 1,900 m within the study area at Atilán volcano is estimated to be 165–465 individuals.

The largest flock seen during transect counts consisted of five birds. During occasional observations of Azure-rumped Tanager, birds were seen usually in pairs or small groups of 3–4 individuals during the breeding season. After fledging, larger groups were seen. A flock of seven birds was seen on 3 September 2009 (GL pers. obs.), among them were two young birds. At least 14 tanagers were observed on 13 August 2008 (GL pers. obs.) moving in the canopy of a *Ficus aurea* tree in primary forest, among them were at least five young birds. We never observed Azure-rumped Tanagers in true mixed foraging flocks. On occasions when we recorded them together with other species, for instance with White-winged Tanager *Piranga leucoptera* on 11 July 2008 (SA and GL pers. obs.) in Los Trrales, and with Common Bush-tanager *Chlorospingus ophthalmicus* on 15 August 2009 in the forest reserve of San Rafael Pie de la Cuesta (KE and CA,

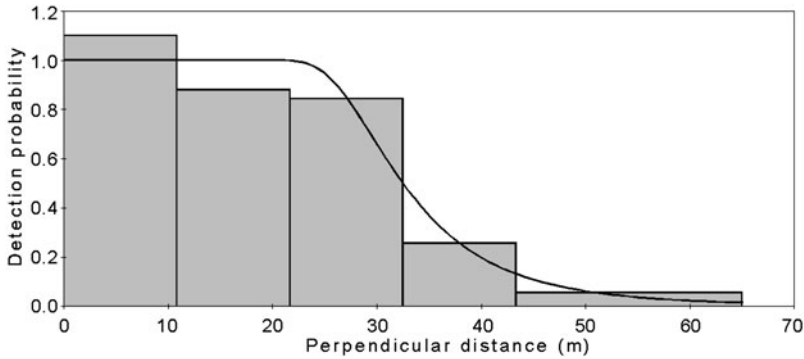


Figure 3. Histogram of the distance data for Azure-rumped Tanagers detected in forest between 1,400 and 1,900 m, and detection function obtained by fitting the hazard-rate model (software Distance 5.0 Release 2) to the data which were truncated at 65 m, and grouped into five distance classes.

pers. obs.), they were apparently together in the same fruit tree by coincidence, and did not move on together.

The height of observed Azure-rumped Tanagers in vegetation was recorded during transect counts for 90 detections in forest and edge, and for 16 detections in coffee plantation and edge. The height above ground ranged in forest from 8–36 m (24.3 ± 6.1 , $n = 90$) and in coffee plantation from 8–30 m (18.9 ± 7.2 , $n = 16$). Tanagers stayed mainly in the upper vegetation strata, mean relative height in vegetation was $83\% \pm 17$ ($n = 90$) in forests and $83\% \pm 20$ ($n = 16$) in coffee plantations. In coffee plantations tanagers were recorded mainly in solitary large trees (*Ficus aurea* and *F. costaricana*) or in the canopy of shade trees (*Inga* spp.). Occasionally tanagers were also seen very low in the understorey, foraging on fruiting shrubs in the forest or collecting nest material from coffee shrubs as low as 1 m above ground.

During transect counts a total of 41 observations of feeding tanagers were recorded, of which 35 were feeding on fruit of the strangler fig *Ficus aurea* (Moraceae), one on *Ficus costaricana*, two on *Rhamnus discolor* (Rhamnaceae), one on *Trema micrantha* var. *strigillosa* (Ulmaceae), one in mistletoe *Phoradendron heydeanum* (Verbanaceae), and one in *Perrottetia longistylis* (Celastraceae). During occasional observations throughout the tanager's range in Guatemala, the species was seen feeding also on fruit of *Miconia* sp. (Melastomataceae) (KE and CA pers. obs.), on *Cecropia obtusifolia* (Cecropiaceae) (KE, JLL, EB pers. obs.), on *Chomelia brachypoda* (Rubiaceae), on *Cestrum* sp. (Solanaceae) (KE and CA pers. obs.), and on *Urera* sp. (Urticaceae) (J. L. Yuxón pers. comm.) (see Table S1 for complete nomenclature of all plant names). Tanagers were also seen foraging among inflorescences of *Meriana macrophylla* (Melastomataceae), probably on invertebrates (KE and CA pers. obs.).

The number of observations of feeding tanagers in *Ficus aurea* suggests a high importance of that food source. *F. aurea* is semi-deciduous and the trees are leafless for some weeks in the dry season and identifiable on orthoimages. The density of *F. aurea* trees within a strip width of 120 m ranged from 0–2 trees ha^{-1} along all forest transects (Table S2). The slope (0.626 ± 0.149 SE) of the Geometric Mean Regression line comparing density of *F. aurea* trees from Table S2 versus number of Azure-rumped Tanagers per 100 m of transect from Table 1 is significantly different from 0 (Student's t-test, $t = 4.21$, $df = 10$, $P < 0.005$), indicating a positive correlation between the abundance of Azure-rumped Tanager and density of *F. aurea* trees (Figure 4).

Distribution in Guatemala

The Azure-rumped Tanager has been reported in Guatemala from nine topographic units and a total of 16 sites from 1987 to 2009, located in the departments of San Marcos, Quetzaltenango,

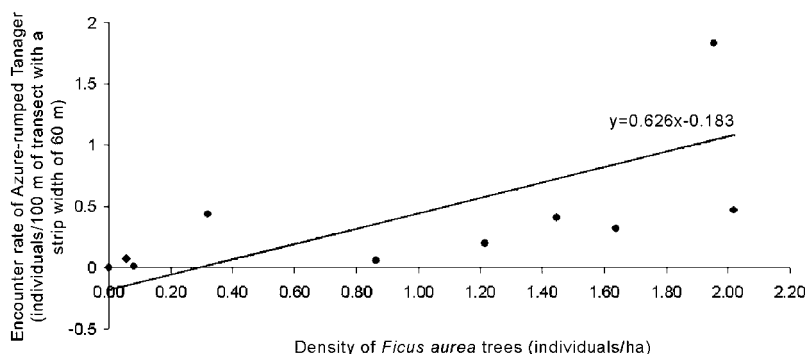


Figure 4. Encounter rate of Azure-rumped Tanagers in relation to the density of *Ficus aurea* trees. The slope of the geometric mean regression line is significantly different from 0 (Student's *t*-test, $t = 4.21$, $df = 10$, $P < 0.005$).

Sololá, Suchitepéquez, and Chimaltenango (Table S3, Figure 5a). The easternmost record is from Unión Victoria ($14^{\circ} 34'N$ $91^{\circ} 03'W$), former Finca El Salvador, municipality Pochuta, 5 km northeast of Pochuta. The potential area of distribution of Azure-rumped Tanager in Guatemala can be limited by the upper and lower altitudinal limits of all records, as well as the easternmost record and the Mexican border. This area has a size of $1,170 \text{ km}^2$.

From information on habitat use in our study area at Atitlán volcano we derived the coverage of adequate habitat within the potential area of distribution. Based on a nationwide land cover mapping on the scale 1:50,000 (MAGA 2006), broadleaf forest covers approximately 250 km^2 or 21% of the entire potential area of distribution of Azure-rumped Tanager in Guatemala (Figure 5b). Most of the potential area of distribution is covered by coffee plantations (approximately 800 km^2 or 68%). Largest forest patches are located south of San Marcos (northern part of the municipalities Tumbador, Nuevo Progreso, and La Reforma), on the southern slope of Lacandón volcano, on the south-eastern slope of Chicabal volcano, on the southern slopes of Santa María, Santo Tomás, and Atitlán volcanoes, and on the southern part of the municipality Santiago Atitlán, and in the valley of the Río Madre Vieja southeast of San Lucas Tolimán (Figure 5b). Assuming that the density of Azure-rumped Tanagers in all broadleaf forests is similar to the value determined in the study area at Atitlán volcano, total population of Azure-rumped Tanagers in Guatemala is estimated to be 8,250–23,250 birds.

Discussion

Distribution and conservation status

The type specimen of Azure-rumped Tanager was collected in Costa Cuca (Cabanis 1866, Sclater 1868; type specimen ZMB 18921 reviewed). In the 19th century, Costa Cuca was not a town or village, but a region of about $1,300 \text{ km}^2$, which is today the southern part of the department of Quetzaltenango (Gallini 2009). The type locality has been erroneously attributed to the village Flores Costa Cuca (elevation 500 m) in several publications (Heath and Long 1991, Collar *et al.* 1992). All recent records are from the altitudinal range of 860–1,900 m, which is a narrow belt about 10 km wide. Therefore the type specimen had most likely been collected in the upper part of the former Costa Cuca area. After the type specimen of Azure-rumped Tanager was collected in the 19th century, only recently have additional localities been reported in the modern department of Quetzaltenango (Heath and Long 1991, Cooper 2003, Eisermann and Avendaño 2006, 2007a). This study documents an expansion of the altitudinal (860–1,900 m) and longitudinal range (east

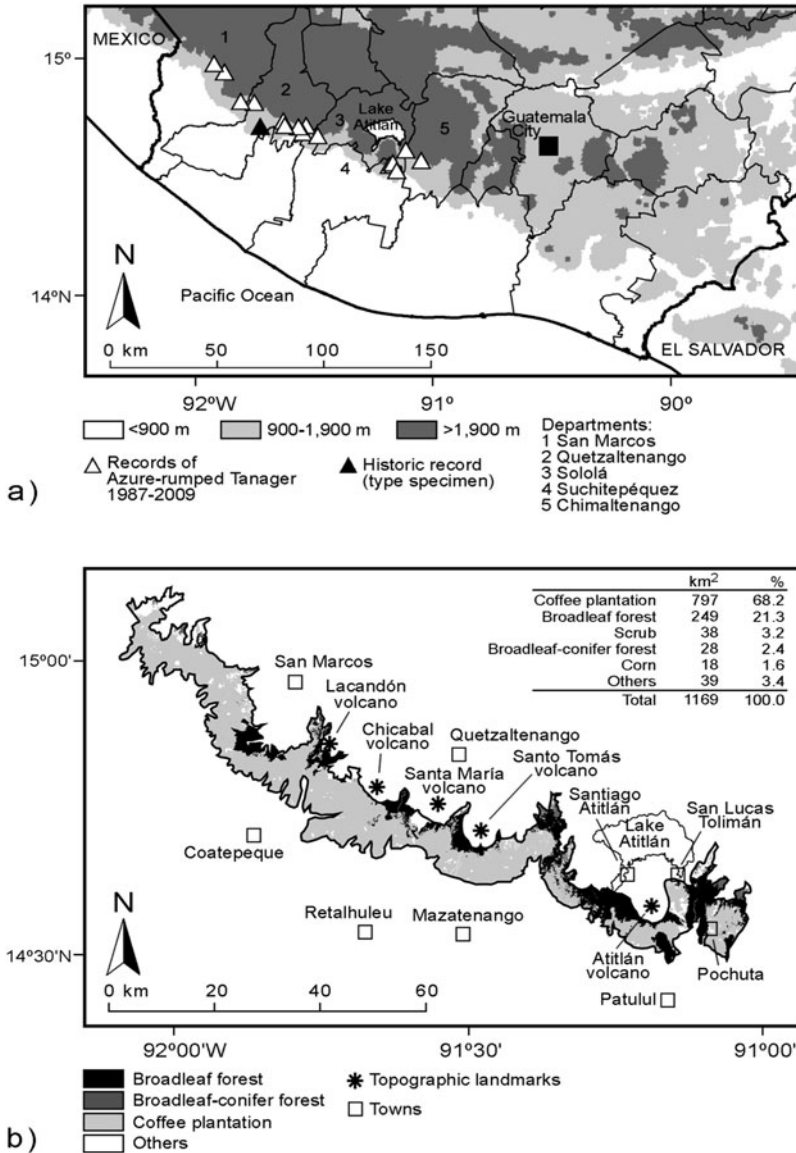


Figure 5. Distribution and habitat availability of Azure-rumped Tanager in Guatemala. a) Locations of all records in Guatemala, altitudinal zones, and department limits. b) Landcover in the potential area of distribution, limited by the Mexican border in the West and the easternmost record, and by contour lines of 900 m and 1,900 m, representing approximate altitudes of the lowest and highest records.

of the valley of the Nicán river). This species may be expected even further east in Guatemala, such as on the southern slope of Fuego and Agua volcanoes in the department of Sacatepéquez, which is supported by an anecdotal record at Pacaya volcano on 12 April 2010 (Dan Poalillo pers. comm.).

The Azure-rumped Tanager has been reported previously from humid broadleaf forest and also from coffee plantations (Dietsch 2000, BirdLife International 2008). Our comparison of encounter rates in forest and coffee plantation shows that the species is more abundant in humid broadleaved forest. In addition, most of our records from coffee plantations were within a distance of 30 m from forest edge. Thus, the Azure-rumped Tanager is primarily a forest bird, which also uses forest edge and adjacent open habitat as do many other tanagers (Isler and Isler 1987).

Most of the prime habitat of Azure-rumped Tanager in Guatemala has been converted to coffee plantations and only 250 km² of potential habitat remain (Figure 5b). The tanager is fairly common and occurs with a density of 33–93 birds km⁻² on the southern slope of Atitlán volcano. It is also common at other sites such as in the departments of San Marcos (Cooper 2003) and Quetzaltenango (Table S3). However, the species is vulnerable to population declines, because most of the suitable habitat is located in a zone especially favourable for agriculture, except for the steepest canyons and mountain slopes. According to recent information on protected areas (CONAP 2009), within the potential area of distribution, only 370 km² (32%) occur within protected areas, and 138 km² (55%) of the remaining broadleaf forest in this area are legally protected (Table S4), but none of the reserves is a strictly protected area in IUCN categories I or II (IUCN 1994). Efficient conservation of habitat cannot be guaranteed in the short term in any of the reserves. Although many of the privately protected areas currently are among the best protected preserves in Guatemala, driven by a strong personal interest of owners, national law of protected areas (Decreto 4–89, Congreso de la República de Guatemala) and its rules (Acuerdo Gubernativo 759–90) do not require a long-term commitment of owners for conservation, nor do they require continued conservation from future land owners. Guatemala's state reserves lack adequate management and law enforcement, which makes them vulnerable to illegal invasions followed by an advancing agricultural border, illegal extraction of forest resources and hunting (ParksWatch 2002, 2005, Godoy 2008). The remaining suitable habitat of Azure-rumped Tanager in Chiapas was estimated to be 1,120 km² in the 1980s (Heath and Long 1991), but rapid human population growth in Chiapas (1.6% annual growth rate from 2000 to 2005; INEGI 2008) combined with an ongoing human pressure on the Sierra Madre de Chiapas (Richter 2000) suggest recent considerable loss of habitat there. The total extent of occurrence in both countries (minimum convex polygon encompassing all sites of occurrence) is less than 2,500 km². We expect a further decline of the extent of suitable habitat because of continued growth of human population, which in Guatemala is expected to double between 2010 and 2050 to a total of 27.9 million (CEPAL 2007). The maintenance of the IUCN Red List status of 'Endangered' is justified according to the IUCN (2001) Red List criteria EN B1a+b(ii,iii,v).

Conservation implications and population monitoring

The survival of the Azure-rumped Tanager depends on conservation of natural habitat and habitat restoration in and outside of protected areas. The necessity of conservation efforts in human-used landscape in Guatemala has been recognised during the identification of Important Bird Areas (Eisermann and Avendaño 2007b, 2009a,b), and it has also been recognised on a regional level in Mesoamerica (Harvey *et al.* 2008, Chazdon *et al.* 2009, Gardner *et al.* 2009). Because most of the tanager's range in Guatemala is covered with coffee plantations, these areas need to be considered in a conservation strategy. Coffee is being cultivated under a variety of management systems, ranging from intensive unshaded monoculture with an intensive use of agrochemicals, to rustic coffee plantations, which are cultivated under the shade of the natural forest. Between these extremes exist a variety of plantation types differentiated by species richness of shade trees and shade cover (Perfecto *et al.* 2005, López-Gómez *et al.* 2007, Hernández-Martínez *et al.* 2009). The conservation value of coffee plantations has been discussed since the 1990s (Komar 2006), and plantations with a diverse shade have been identified as the most valuable for biodiversity (Perfecto *et al.* 1996, Perfecto *et al.* 2003, Philpott *et al.* 2008).

Most coffee plantations in the potential range of Azure-rumped Tanager in Guatemala are shaded monocultures. The use of forest edge and single trees within coffee plantations by foraging tanagers suggests that the area of suitable habitat could be augmented considerably by some shade alterations among plantations. The dense network of maintenance roads in coffee plantations could be used to establish lines of native trees, especially *Ficus aurea*, which would provide both food and nesting sites. In many plantations we saw *Eucalyptus* spp. trees planted along roads, so there would be little loss of cultivated area by replacing *Eucalyptus* or other non-native trees with *Ficus aurea* and other fruit trees. The creation of tree rows could even benefit the coffee plantations. Pollination experiments in Costa Rica showed that pollination of coffee blossoms is higher within a distance of 100 m from forest fragments and that forest-based pollinators increased coffee yield by 20% (Ricketts 2004, Ricketts *et al.* 2004). Increased shade and plant species richness in coffee plantations increases bird abundance (Philpott *et al.* 2008). Bird exclosure experiments in Chiapas showed that avian predation on Lepidoptera larvae was significantly higher in plantations with high floristic diversity (Perfecto *et al.* 2004). A similar test in Jamaican coffee plantations concluded that birds reduced significantly the infestation by coffee berry borers *Hypothenemus hampei*, Coleoptera: Scolytidae (Kellermann *et al.* 2008), which is also a common pest in Guatemalan coffee plantations. Johnson *et al.* (2009) pointed out that greater shade cover in a Jamaican coffee plantation increased predation on arthropods by birds, but it also increased fungal leaf damage on the coffee shrubs. Local environmental conditions vary widely, and the task is to find for each farm the balance between high coffee yield and satisfying support for biodiversity conservation. Incentives and certification programmes could play an important role in promoting these efforts. Habitat restoration measures should be accompanied by population monitoring of Azure-rumped Tanager. To continue monitor the distribution of the tanager we would appreciate receiving reports of observation sent by e-mail or submitted to eBird Guatemala at <<http://www.ebird.org/content/guatemala/>>.

Supplementary Material

The online supplementary materials for this article can be found at journals.cambridge.org/bci

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KNUT EISERMANN,* SUSANNE ARBEITER, CLAUDIA AVENDAÑO
 PROEVAL RAXMU Bird Monitoring Program, Cobán, Alta Verapaz, Guatemala. c/o P.O. Box
 98 Periférico, Guatemala City, Guatemala.

SUSANNE ARBEITER
 University of Applied Sciences Eberswalde, Friedrich-Ebert-Str. 28, 16225 Eberswalde, Germany.

GERARDO LÓPEZ AND JOSUÉ DE LEÓN LUX
 Los Tarrales Reserve, Km 164.2 Ruta Nacional 11, Patulul, Suchitepéquez, Guatemala.

*Author for correspondence; e-mail: knut.eisermann@proeval-raxmu.org

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