Phylogenetic and morphologic evidence confirm the presence of a new montane cloud forest associated bird species in Mexico, the Mountain Elaenia (*Elaenia frantzii*; Aves: Passeriformes: Tyrannidae)

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We here provide evidence to support an extension of the recognized distributional range of the Mountain Elaenia (*Elaenia frantzii*) to include southern Mexico. We collected two specimens in breeding condition in northwestern Sierra Norte de Chiapas, Mexico. Morphologic and genetic evidence support their identity as *Elaenia frantzii*. We compared environmental parameters of records across the entire geographic range of the species to those at the northern Chiapas survey site and found no climatic differences among localities.

1 **Phylogenetic and morphologic evidence confirm the presence of a new montane cloud**

2 **forest associated bird species in Mexico, the Mountain Elaenia (*Elaenia frantzii*; Aves:**

3 **Passeriformes: Tyrannidae)**

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24   **Abstract**

25   We here provide evidence to support an extension of the recognized distributional range

26   of the Mountain Elaenia (*Elaenia frantzii*) to include southern Mexico. We collected two

27   specimens in breeding condition in northwestern Sierra Norte de Chiapas, Mexico. Morphologic

28   and genetic evidence support their identity as *Elaenia frantzii*. We compared environmental

29   parameters of records across the entire geographic range of the species to those at the northern

30   Chiapas survey site and found no climatic differences among localities.

31

32   **Introduction**

33   The Mountain Elaenia (*Elaenia frantzii*) is a small New World flycatcher that breeds in

34   the high elevation forests of Central America and northern South America and is known to move

35   seasonally to lower elevations (Stiles & Skutch, 1989). Its distribution has previously been

36   reported to include isolated populations extending from Colombia and Venezuela as far north as

37   north-central Guatemala (Land, 1970; Howell & Webb, 1995; Eisermann & Avendaño, 2007),

38   but it has not been documented in Mexico (Peterson & Chalif, 1973; Hosner, 2004). Its habitat

39   consists of a variety of open humid to semi-humid forest types, including forest edges, secondary

40   growth, and farmland, in an altitudinal range of 750-3600 m. A continuum of fragmented cloud

41   forest extends from the east of the Isthmus of Tehuantepec to the Nicaraguan depression

42   (Ramírez-Barahona & Eguiarte, 2014), providing potential habitat for this bird in southern

43   Mexico.

44   We analyzed the morphological and molecular characteristics of two specimens collected

45   in Chiapas, Mexico, during August 2013 and compared them with the associated data from

46   museum specimens of other *E. frantzii*. We additionally investigated environmental parameters

47   from the previously known distribution of *E. frantzii* and compared them with those present in

48   southern Mexico to assess the likelihood that suitable conditions exist in southern Mexico to

49   support a resident population of this species.

50

51   Methods

52   *Taxon morphological description*

53   *Elaenia frantzii* is a small tyrant flycatcher with a rounded head lacking a coronal patch.

54   It has dark brown irides and narrow, pale-lemon eye-rings. Its bill is black with a pale, flesh-

55   colored base of the lower mandible and a dusky culmen and tip. The head and upperparts are

56   brownish olive, the throat and chest are grayish olive, and the belly and undertail coverts are

57   pale-lemon. The wing is dusky with conspicuous yellowish wing-bars. The edges of the remiges

58   are yellowish and the tertial edgings are white. The legs are blackish. Males and females have

59   similar external morphology (Howell & Webb, 1995; Hosner, 2004).

60   *Elaenia frantzii* has a patchy distribution throughout the mountain systems of Central and

61   South America. It inhabits open humid to semi-humid forest, forest edges, secondary growth,

62   and farmland areas where scattered bushes and trees are present. Based on geographic

63   distribution and subtle differences in plumage color and body size, four *E. frantzii* subspecies are

64   recognized (Hosner, 2004).

65   The nominate subspecies, *E. f. frantzii* Lawrence, 1865, is found in Nicaragua, Costa

66   Rica, and Panama (Hosner, 2004). *Elaenia frantzii pudica* Sclater, 1871 is overall smaller, darker

67   above, and paler below than the nominate subspecies and inhabits the Andes mountains of

68   northern Colombia and Venezuela (Hosner, 2004). *Elaenia frantzii browni* Bangs, 1898 is

69   restricted to the Sierra Nevada de Santa Marta of northern Colombia and the Sierra de Perijá of

70 northwestern Venezuela and is yet smaller and with paler upperparts than *E. frantzii pudica*

71 (Hosner, 2004). *Elaenia frantzii ultima* Griscom, 1935 is a subspecies darker than the nominate

72 inhabiting Guatemala, Honduras and El Salvador and is the most proximately distributed

73 subspecies to southern Mexico (Hosner, 2004). See Figure 3 for a map of the distributions of the

74 subspecies.

75   *Elaenia frantzii* can be distinguished from the Yellow-bellied Elaenia (*E. flavogaster*), a

76 Mexican resident species, by the lack of a white coronal patch, more greenish coloration of the

77 upperparts and less extended yellow in the underparts. Although the coloration is similar to some

78 members of the genus *Empidonax*, *E. frantzii* differs from them in its narrow eye-ring and the

79 relative proportions of the body, head and bill.

80 *Study Area*

81   As members of a joint Museum of Vertebrate Zoology (MVZ), University of California,

82 Berkeley and Museo de Zoología "Alfonso L. Herrera" (MZFC), Facultad de Ciencias,

83 Universidad Nacional Autónoma de México team formed to survey the bird, mammal, and

84 herpetological diversity at montane sites in southern Mexico, we traveled to a tract of cloud

85 forest 6.2 km W (by road) from the center of Tapalapa on the road to Coapilla, Municipio

86 Tapalapa, Chiapas, Mexico in August 2013. We sampled the avifauna of the site using mist-nets

87 from 20-24 August 2013 under field permit FAUT-0169 granted by the Mexican government

88 agency Secretaría de Medio Ambiente y Recursos Naturales and with animal ethical approval

89 R317 granted by the UC Berkeley Institutional Animal Care and Use Committee. The mist-nets

90 were 6-12 m long, 2.5 m high, and were made of 16 mm x 16 mm mesh. We preserved a portion

91 of the captured individuals as voucher specimens and deposited them in ornithological research

92 collections at the Museum of Vertebrate Zoology (MVZ) and Museo de Zoología "Alfonso L.

93 Herrera" (MZFC). We collected tissue samples and assessed the breeding condition of each

94 voucher specimen by measuring gonads and recording any evidence of a brood patch or cloacal

95 protuberance. We also recorded data on molt, fat, skull ossification, and parasite load. After

96 returning from the field, we confirmed the species status of the collected specimens by

97 comparing their preserved external morphologies with individuals deposited in the MZFC.

98 *Bibliographic search*

99  We conducted all searches described below on 20 December 2014. We performed a

100 literature search for published observations of *E. frantzii* in Mexico. We additionally searched

101 for records of *E. frantzii* in VertNet (http://www.vertnet.org), a web-based biodiversity data

102 aggregator. We also searched eBird [(Sullivan et al., 2009), http://www.ebird.org], an online

103 checklist program, which archives lists of bird sightings submitted by professional and amateur

104 birdwatchers, for *E. frantzii* sightings most proximate to Mexico. As an assessment of whether a

105 lack of documentation of this species in Chiapas, Mexico might be a result of low sampling

106 effort or due to this species having recently expanded its range into Chiapas, we performed a

107 search in VertNet (http://www.vertnet.org) on 20 December 2014 with Record Type = "Any

108 type" and using the following Darwin Core terms: Class = "Aves", Country = "Mexico", and

109 StateProvince = "Chiapas".

110 *Laboratory protocol*

111  We gathered genetic evidence to support our morphology-based identifications by

112 sequencing 1041 bp of the mitochondrial locus Nicotinamide Adenine Dinucleotide

113 Dehydrogenase Subunit 2 (*ND2*). We first extracted genomic DNA from ~25 mg of liver tissue

114 using a DNeasy Blood & Tissue Kit (Qiagen). We then amplified the mitochondrial locus *ND2*

115 using the primers L5204 and H6312 (Cicero & Johnson, 2001). Polymerase chain reaction (PCR)

116 conditions included an initial denaturation at 94 ˚C for 3 min; then 30 cycles at 94 ˚C for 30 s, 54

117 ˚C for 30 s, and 72 ˚C for 1 min 30 s; and a final extension at 72 ˚C for 10 min. We sequenced

118 PCR products in both forward and reverse directions using BigDye terminator chemistry

119 (Applied Biosystems) on an ABI 3730 automated sequencer (Applied Biosystems). We edited

120 and constructed consensus sequences using Geneious version 7.1.7 [(Kearse et al., 2012),

121 http://www.geneious.com].

122 *Maximum likelihood tree*

123   We retrieved complete *ND2* gene sequences for 20 additional individuals representing 10

124 tyrannid taxa from GenBank (accession numbers appended to the end of taxon names in Figure

125 4). We aligned sequences using MUSCLE (Edgar, 2004) and constructed a maximum likelihood

126 tree using RAxML version 8.1.20 (Stamatakis, 2014). We used the GTRGAMMA model,

127 searched for the tree with the highest likelihood, and estimated node support using 1000

128 bootstrap pseudoreplicates.

129 *Environmental characterization and species distribution model*

130   We downloaded all available georeferenced *E. frantzii* occurrence records from the

131 Global Biodiversity Information Facility (http://www.gbif.org). We constrained our examination

132 of ecological parameters to the area accessible to the species (Peterson et al., 2011). We

133 considered this to be the area from the Isthmus of Tehuantepec, Mexico, to northwestern South

134 America including the Andes Mountains from Ecuador to Northern Venezuela, which is the

135 expanse that includes all vouchered records available for the species. We used a set of 19

136 bioclimatic variables obtained from the WorldClim project [(Hijmans et al., 2005),

137 http://www.worldclim.org] and five topographic variables; obtained from the Hydro1k project

138 (https://lta.cr.usgs.gov/HYDRO1K), which summed to 24 variables to characterize the

139   environment of the potential distribution of *E. frantzii* (Table 1).

140   We summarized the ecological variation across the distribution of *E. frantzii* by

141   performing a principal component analysis (PCA) on the values of the 24 ecological variables

142   from the sites of georeferenced *E. frantzii* occurrence records using the package ENMGadgets

143   (Barve & Barve, 2014) in R version 3.2.2 (R Core Team, 2015). This reduced the

144   multidimensionality of the 24 ecological variables. We then associated all of the records of *E.*

145   *frantzii* with the PCA output, obtained PCA values for each locality, and plotted PC1 and PC2 of

146   each *E. frantzii* record.

147   We employed Maxent 3.3.3k (Phillips, Anderson & Schapire, 2006) to model the

148   distribution of *E. frantzii* and assess the suitability of the new Chiapas location as compared with

149   the sites of other *E. frantzii* occurrences. We used the package raster (Hijmans, 2015) and the

150   implementation of the Pearson correlation index in R version 3.2.2 (R Core Team, 2015) to

151   select a subset of 13 of the 24 bioclimatic and topographic variables with correlation values

152   below 0.85 (Table 1) to avoid over parameterization of the model (Elith et al., 2006; Elith &

153   Leathwick, 2007). We used the 13 environmental variable subset and all of the georeferenced *E.*

154   *frantzii* occurrence records in Maxent 3.3.3k (Phillips, Anderson & Schapire, 2006) to generate

155   ten model replicates (using the subsample replicated run type) using 30% of the sample records

156   to test the variability produced by a random selection of the training data (random seed). We

157   obtained suitability values from the Maxent model and mapped them along with all of the *E.*

158   *frantzii* occurrence records using ArcMap 10.0 (ESRI).

159

160   **Results**

161   *Bibliographic search*

162   We found no published observations of *E. frantzii* in Mexico. The northernmost record of

163 this species in VertNet is a 1.41 s audio recording of a call from northeast Utah, United States of

164 America made in May 1999 (BLB:Recordings:27930). This record is likely a misidentification

165 or, if not, it documents a vagrant and does not indicate a breeding population as there are no

166 other records of *E. frantzii* within 3000 km of this location. The records of *E. frantzii* closest to

167 Mexico along the land axis of Central America are in southwestern Guatemala

168 (CLO:ML:140002, USNM:Birds:69831, USNM:Birds:80404). The sightings closest to Mexico

169 publicly visible in eBird [(Sullivan et al., 2009), http://www.ebird.org] as of 20 December 2014

170 were made in July 2001 at 14.7173609°N and 91.5309191°W, WGS84, Santa María de Jesús,

171 Departamento Quetzaltenango, Guatemala (Berry, 2001) and in February 2013 at 15.4769771°N

172 and 90.3913987°W, WGS84, Cobán, Departamento Alta Verapaz, Guatemala (Cahill, 2013).

173 Figure 3 includes these records. Our class Aves-based VertNet search indicated that there have

174 been avian records from montane regions in Chiapas from every decade spanning the years

175 1880-2009, but *E. frantzii* has never been detected in this region.

176 *Morphological identification*

177   We surveyed for a total of 283.39 12-m net hours and captured two individuals, which we

178 gave a preliminary designation of *E. frantzii* based on plumage and morphology and assigned to

179 the collector numbers CRH019 and ZRH814. We captured CRH019 on 20 August 2013. It did

180 not display any evidence of molt and was a male in breeding condition with a right testis of 7 x

181 4.8 mm. We captured ZRH814 on 23 August 2013. ZRH814 was a female in breeding condition

182 with an 8 x 4 mm ovary containing two collapsed follicles. It had extensive fat layers, a fully

183 ossified skull, and no evidence of molt.

184   We deposited a round skin voucher specimen and tissue sample of CRH019 in MZFC as

185 MZFC:26000. We archived a tissue sample of CRH019 in MVZ as MVZ:Birds:188004. We

186 deposited a round skin voucher specimen and tissue sample of ZRH814 in MVZ as

187 MVZ:Birds:188003. We archived a tissue sample of ZRH814 in MZFC as ZRH814.

188   We confirmed the identity of the Chiapas specimens through comparison with *E. frantzii*

189 museum skins. Compared with the *E. f. frantzii* specimen AMNH:Birds:07902 collected in Costa

190 Rica, the newly collected specimens are darker in the upperparts, tail, and wings. The chest and

191 flanks are more olive-colored and darker overall. The edges of the remiges are narrower and

192 contain less yellow. The bill is wider at the distal edge of the nostrils (4 mm in our specimen vs.

193 3 mm in the Costa Rica specimen) (Figure 1). These differences are in agreement with the

194 description of the subspecies *ultima* compared to *frantzii* (Hosner, 2004).

195 *Molecular identification*

196   We obtained the complete *ND2* gene sequence, 1041 bp, from specimens MZFC:26000

197 and MVZ:Birds:188003, which shared the same *ND2* haplotype. We deposited newly generated

198 sequences in GenBank (accession numbers KU312259-KU312260). The maximum likelihood

199 tree grouped the Chiapas *E. frantzii ND2* sequence with sequences of *E. frantzii* from El

200 Salvador and Panama (GenBank accession numbers EU311059 and EU311049, respectively)

201 with 100% bootstrap support (Figure 4).

202 *Environmental characterization and species distribution model*

203   The first two principal components of the 24 bioclimatic and topographic variables

204 included 63.24% of the cumulative ecological variance for the species. The variables which have

205 higher eigenvectors for component 1 are mainly associated with temperature variables whereas

206 those for component 2 are primarily associated with precipitation (Table 1). Values of the

207 environmental variables at the new Chiapas locality fall within the variation of those variables at

208 *E. frantzii* occurrence sites in populations from Central America and South America (Figure 2).

209   We chose the median Maxent model of the ten replicates we generated in order to

210 account for the variation produced by the random selection of sample record seeds in each

211 replicate. The suitability value at the site of the new record of *E. frantzii* in Chiapas is 0.24. The

212 highest suitability value in our model was 0.87. The sites of 94% of the *E. frantzii* records have

213 suitability values greater than or equal to 0.24 (Figure 3). Georeferencing error, sink populations,

214 or vagrant birds may account for a portion of the *E. frantzii* locations situated at sites with low

215 suitability (Peterson et al., 2011).

216

217 **Discussion**

218   Morphological and molecular evidence confirm the presence of a breeding population of

219 *E. frantzii* in Mexico. These records warrant an extension of the range of *E. frantzii* to include

220 the state of Chiapas, Mexico. The closest locality of a publicly available, georeferenced voucher

221 (an audio voucher in this instance) to our new records is 360 km away (by air) in Guatemala

222 (140002, Macaulay Library Audio and Video Collection, Cornell Lab of Ornithology). Our

223 collection site is 190 km from the Guatemalan border in the northwestern Sierra Norte de

224 Chiapas at the northern limit of Nuclear Central America (NCA), the area between the Isthmus

225 of Tehuantepec and the Nicaraguan depression (Schuchert, 1935). It is not surprising that *E.*

226 *frantzii*'s range could include the extreme northern portion of NCA as its previously known range

227 includes much of the rest of NCA, across which environmental conditions are largely similar

228 (Ramírez-Barahona & Eguiarte, 2014). Our ecological niche analyses indicate that climatic

229 conditions where *E. frantzii* is found in Central and South America are present in Chiapas,

230 Mexico. This distributional pattern of inhabiting cloud forests from Chiapas south through NCA

231 is exhibited by other species of montane birds, such as *Chlorospingus ophthalmicus, Catharus*

232 *frantzii*, and *Atlapetes albinucha* (Howell & Webb, 1995), which we also recorded at this

233 locality. After we completed our literature searchers and began to prepare this manuscript, a

234 group of bird watchers visited several sites in the vicinity of our survey site near Tapalapa,

235 Chiapas, México on 7-13 July 2015. The birders sighted multiple *Elaenia frantzii* (Martinez,

236 2015; Hoyer, 2015) and made several recordings of their calls (Hoyer, 2015a,b,c). These

237 detections indicate that the population that we surveyed appears to be persisting.

238 It is remarkable that this species was previously unknown to Chiapas, despite sampling

239 having been conducted at montane sites in the area over the past century. It is possible that this

240 species has been misidentified in past surveys and collections due to its resemblance to other

241 flycatcher species in the genus *Empidonax*, whose distributions are known to include Chiapas.

242 Although biological and geological evidence supports the idea of a barrier located at the

243 Motagua-Polochic-Jocotán fault system in central Guatemala with phylogenetic implications for

244 the biota (Morrone, 2001; Gutiérrez-García & Vázquez-Domínguez, 2013; Ríos-Muñoz, 2013),

245 our limited sampling cannot confirm the existence of a differentiated population in Mexico. We

246 recommend further studies to assess population size and conservation status for this species in

247 Mexico.

248

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258   at the Evolutionary Genetics Laboratory, Museum of Vertebrate Zoology.

259

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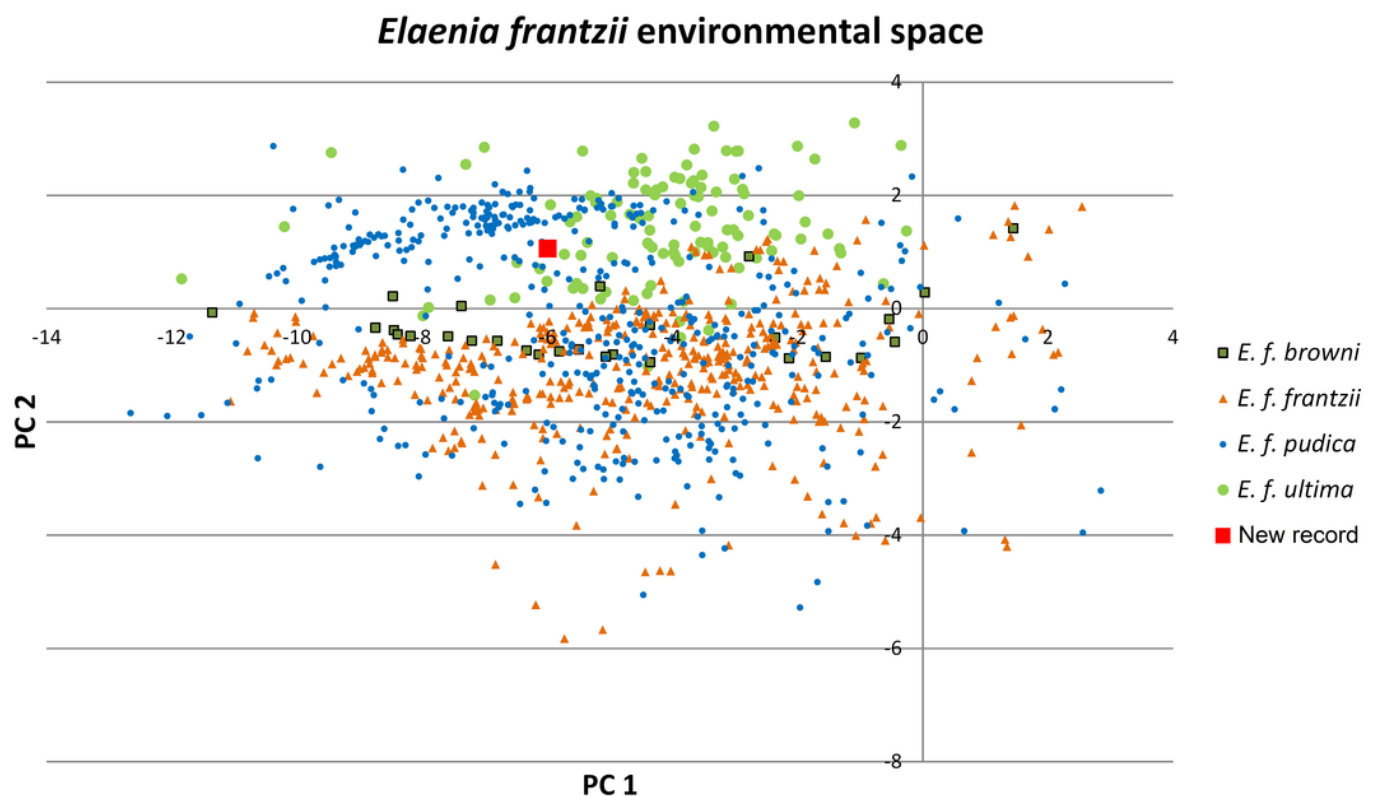
1

Ventral, lateral and dorsal views of two *Elaenia frantzii*.

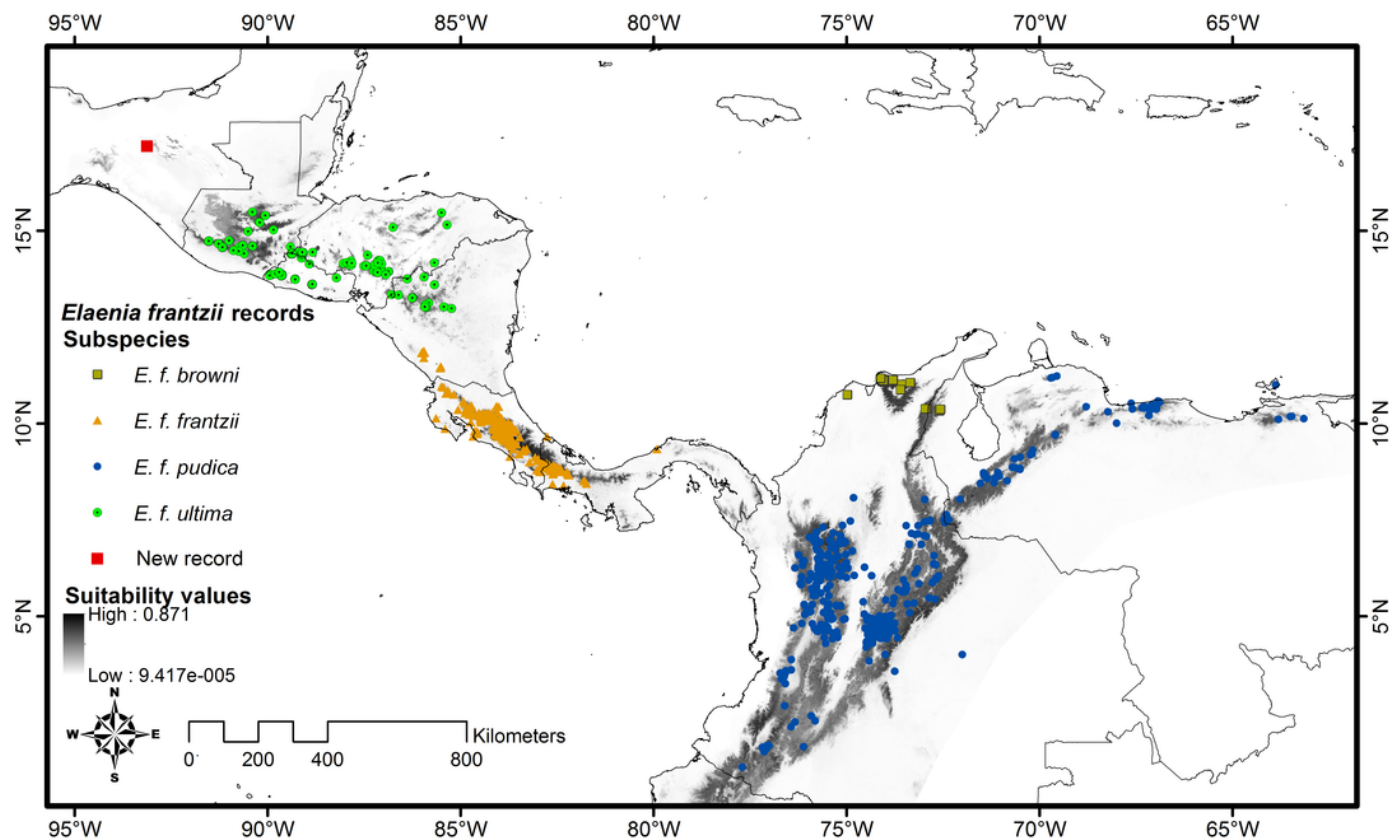
Panels A-E: a specimen of E. f. frantzii collected in Costa Rica (AMNH:Birds:07902). Panels F-J: a specimen of E. frantzii collected in Chiapas, México (MZFC:26000). Note the pronounced darker coloration of the Chiapas specimen, especially in the dorsal and lateral views.

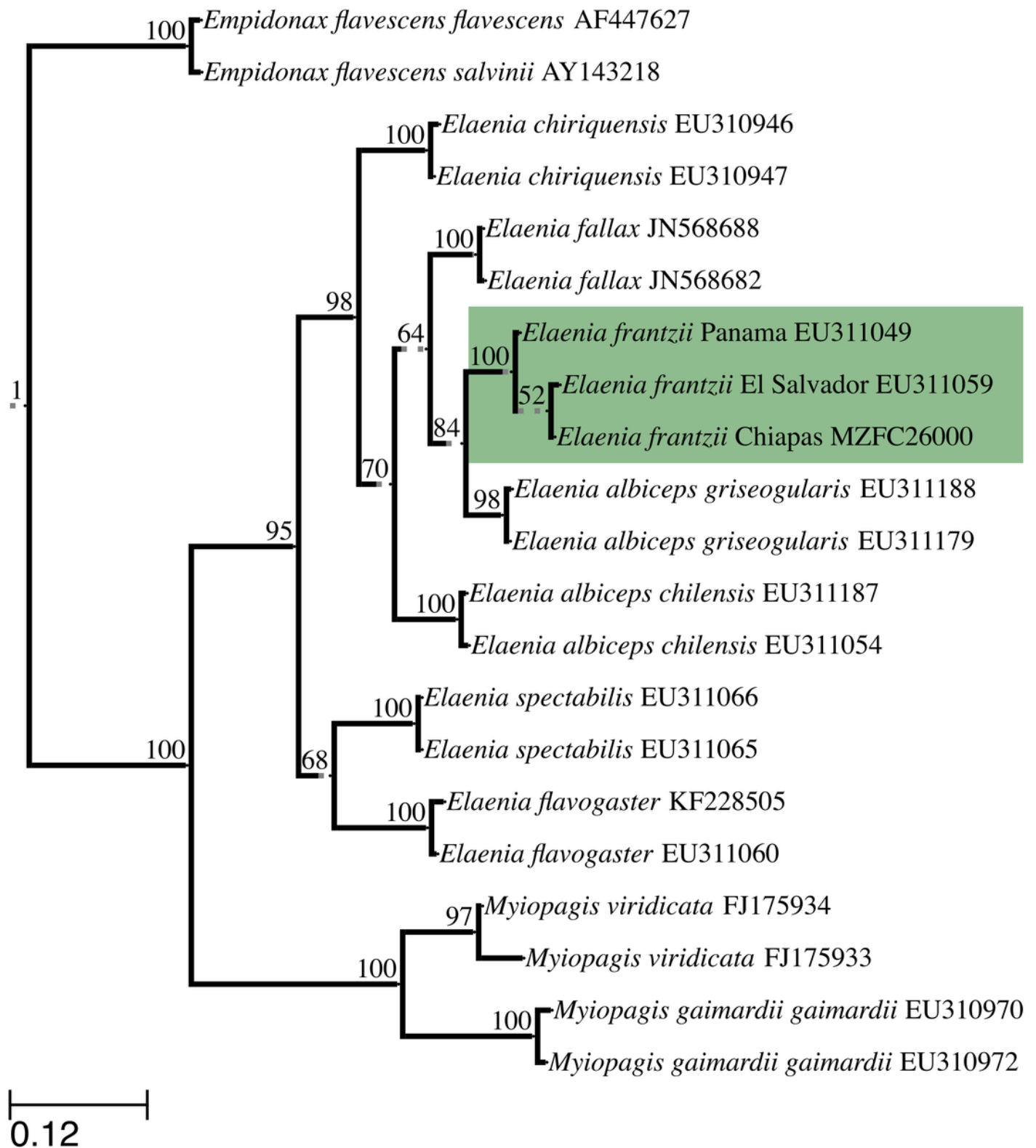
2

Principal components plot of environmental parameters at sites of *Elaenia frantzii* records.

Green squares: *E. frantzii browni* of extreme northern South America; orange triangles: *E. f. frantzii* of Costa Rica and Panama; blue circles: *E. frantzii pudica* of northern South America; green circles: *E. f. ultima* of northern Central America; red square: new *E. frantzii* record from Chiapas, México.

3

Distribution map of *Elaenia frantzii* with suitability values displayed geographically.

Gray shading indicates the geography of the suitability values predicted by the Maxent model. Darker shades indicate areas with higher suitability while lighter shades denote areas with lower suitability. We have mapped *E. frantzii* records on top of the suitability predictions and color-coded them by subspecies. The red square indicates the site of the new records in Chiapas, Mexico.

Maximum likelihood topology constructed with *ND2* sequences from *E. frantzii* and other tyrant flycatchers (Tyrannidae).

We have highlighted the *E. frantzii* clade in green. We labeled branches with bootstrap support values (%) from 1000 pseudoreplicates. Grayed, broken lines denote branches that have been artificially elongated for the sake of clarity in the figure. We rooted the topology with the common ancestor of the *Empidonax* group. The scale bar indicates the branch-lengths that correspond to the maximum likelihood estimate of the number of substitutions that have occurred on average per site between two nodes in the tree.

Environmental variables and their eigenvectors from the principal component analysis (PCA).

PC1 and PC2 refer to the first two principal components of the PCA. We have highlighted the three highest loading values for each principal component in bold. Variables with a trailing asterisk (*) comprise the 13 variables with Pearson correlation index below 0.85 used in the Maxent modeling.

Original environmental variables	PC1	PC2
Annual mean temperature	**3.34E-01**	2.98E-04
Mean diurnal range	-2.25E-02	1.79E-01
Isothermality	-1.03E-01	-2.05E-01
Temperature seasonality	8.24E-02	1.73E-01
Maximum temperature of warmest month*	3.27E-01	5.96E-02
Minimum temperature of the coldest month*	3.19E-01	-6.72E-02
Temperature annual range*	4.07E-02	2.49E-01
Mean temperature of wettest quarter	3.31E-01	1.41E-02
Mean temperature of driest quarter	**3.32E-01**	-1.65E-02
Mean temperature of warmest quarter*	**3.35E-01**	2.15E-02
Mean temperature of coldest quarter*	3.26E-01	-2.53E-02
Annual precipitation*	4.48E-02	**-3.66E-01**
Precipitation of wettest month*	7.53E-02	-2.92E-01
Precipitation of driest month	-2.19E-02	**-3.50E-01**
Precipitation seasonality	8.91E-02	2.66E-01
Precipitation of wettest quarter	7.97E-02	-3.05E-01
Precipitation of driest quarter*	-1.99E-02	**-3.60E-01**
Precipitation of warmest quarter	-4.20E-02	-3.04E-01
Precipitation of coldest quarter	7.19E-02	-3.10E-01
Altitude*	-3.26E-01	5.18E-03
Slope*	-2.29E-01	6.67E-03
Eastness slope*	-7.92E-03	-5.50E-03
Northness slope*	5.48E-03	4.93E-03
Topographic index*	1.83E-01	-5.61E-03