Short Articles

PRIMATE DENSITIES AT RÍO PURÉ NATIONAL PARK, EASTERN COLOMBIAN AMAZONIA

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Introduction

Colombia is one of the three most megadiverse countries of the world (Mittermeier et al., 1997; Butler, 2019). Among primate diverse countries, Colombia is fifth, after Brazil, Madagascar, Indonesia and the Democratic Republic of Congo (Mittermeier, 2013) with 38 primate species and 45 taxa (APC, 2005). Protected areas in Colombian Amazonia represent a significant proportion of the known distribution area in the country of some primate species (*Lagothrix lagothricha*, *L. lugens*, *Ateles belzebuth*, *Cacajao melanocephalus,* and *Pithecia hirsuta* amongst others). Nevertheless, there is still scarce knowledge about their population status within such protected areas, as historically few research activities have been conducted either by primatologists or other researchers, due to the presence of illegal armed groups over decades, and the difficulty and logistical costs to reach very isolated regions. There are also populations of these species outside of protected areas, but in many cases, they are subject to diverse sources of anthropogenic disturbance, and information on their status is also very limited.

This gap of information does not allow us to put into perspective (qualify and quantify) the role of protected areas in conserving primate fauna and weakens government and nongovernment institutions´ strategies for protected areas and areas outside them, to effectively conserve primates and wildlife in general; it also limits the ability to make informed decisions when working with local communities to implement participative conservation strategies in their territories.

As part of an effort of Conservation International Colombia to generate data on the abundance of about 24 medium and large vertebrate species in eastern Colombian Amazonia, including within protected areas and indigenous reserves, a series of standardized line-transect surveys were carried out in four forest sites within Río Puré National Park (hereafter Río Puré NP) to document the densities of primate species in one of the most isolated regions of Colombian Amazonia.

Study site

The Río Puré NP is located in the interfluvial area between Caquetá and Putumayo rivers in the Amazonas department, southeastern Colombia (Fig. 1). The park, declared in 2002, comprises 999,880 ha of primary forest, and along with conserving biological diversity and complementing a corridor of protected areas and indigenous reserves of ca. 10 million hectares in northwestern Amazonia, protects the Yuri, a group of isolated indigenous people, in order to guarantee their decision to not have contact with the majoritarian society. The entire area of the park corresponds to a mainly flat surface, with some strongly undulating areas, but without significant altitude differences, all over an area of ancient alluvial terraces; ninety-eight percent of the park´s area is covered with dense high terra firme forest, while flooded forest comprises just 1.0 % of the area and is concentrated along the Puré River and its main tributaries (Quebrada Aguanegra, Quebrada Arapa, Caño Mateo) and the various systems of lakes dispersed along the river´s course; the remaining area corresponds to a mix of nine additional types of forests (IGAC, 1999; Instituto Sinchi et al., 2000; Murcia et al., 2014). According to the National Parks Unit (2015), based on studies of the Sinchi Institute, 1,583 species of vascular plants belonging to 133 families have been recorded in the park, among which the best represented are Rubiaceae, Annonaceae, Moraceae, Mimosaceae, Fabaceae and Sapotaceae; 252 bird species, belonging to 46 families were recorded for the park in four different sites (Alarcón-Nieto, 2007).

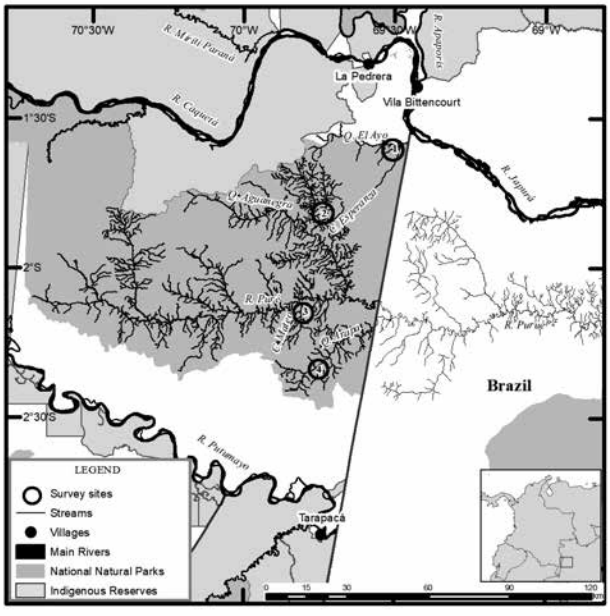

Figure 1. Interfluvial region between the Caquetá and Putumayo Rivers in Colombian Amazonia, where survey sites inside the Río Puré National Park are indicated.

Methods

Linear transects

Between 2000 and 2006 I carried out surveys in four sites in Río Puré NP: Quebradón El Ayo (1°35'S, 69°30'W), Caño Mateo (2°08´S, 69°49´W), Caño Esperanza (1°50'S, 69°43'W) and Quebrada Arapa (2°19´S, 69°44´W) (Fig. 1). All of these sites except Q. El Ayo are located in the core area of the park, between 42 and 70 km away from the closest human settlement, including those of the Yuri people, more than 80 km away. Access to these sites is only possible by

river, after navigating the Caquetá/Japurá River to reach the mouth of the Purué River (Puré in Colombia) and then navigating it further within Brazilian lands to reach the border between Brazil and Colombia; a boat trip of nearly 600 km, plus 12-120 km after leaving the Puré River and navigating towards the headwaters of its first and second order tributaries, selected in advance to establish the survey transects. Camps sites were always at least 3 km in a straight line from the closest major water course (from Japurá River, 9.5 km Q. El Ayo; from Puré River, 3.5 km C. Mateo and 24 km Q. Arapa, and, from Quebrada Agua Negra –the major tributary of Puré River, 10 km C. Esperanza), and high ground was always selected, given that water level in such small second order (12-15 m wide) tributaries varies significantly according to local rainfall, causing variations of up to 2 meters in the water level from one day to another. At each site (except in the Ayo, where just two were cut), three 5-km linear transects were cut and marked with colored flagging tape every 50 meters to facilitate the accurate positioning of sightings, and they were left to rest at least for one day before starting censuses. Starting points of transects were positioned at least 300 m away from the camp sites. Sightings were recorded in accordance with standardized and widely used methodologies (Peres and Cunha, 2011). Each transect was walked by an independent observer during days without rain at a continuous speed of 1.25 km/h, between 06:30-11:15 h and between 13:30-16:30 h; during return walks, average speed increased slightly (1.6 km/h) but this did not affect detection probabilities. Over the years, a group of 8 people from local indigenous communities of the lower Caquetá River (ca. 120 km north towards the Park) has been trained in line transect methodology and participated in large vertebrate surveys in eastern Colombian Amazonia, including those at Río Puré NP. At each survey site a team of four people was able to alternate walks on the different transects in order to minimize estimation biases for perpendicular distances. Every 3 days a different member of the team was able to rest. We expected to carry out a 300-km census at each site, but this was not possible due to adverse weather conditions; census effort totaled 989.7 km (200.7 km Q. El Ayo, 288 km C. Mateo, 251 km C. Esperanza and, 250 km Q. Arapa).

Every time we detected any of the target species, we recorded its location along the transect and the perpendicular distance to the animal observed. We recorded the number of individuals, and, to the extent possible, we attempted a complete count of the group´s individuals, for which we did not spend more than 15 minutes. Sightings made during return walks were also recorded and contributed to the detection models, and allowed us to get a more accurate estimate of the mean group sizes (see Palacios & Peres, 2005). Group spread distance for large non-cohesive groups (e.g., woolly monkeys or squirrel monkeys) were also estimated.

Population density estimates

Data were analyzed with DISTANCE 5 software. Either the hazard rate or half-normal models with a cosine adjustment (Buckland et al., 1993) were used to obtain group density estimates, using ungrouped perpendicular distances from transect to the first animal sighted. Animals detected by acoustic signals but not sighted within the transect area were not included in the analysis. Whenever necessary, I truncated five percent of the outlying data, and pooled data across different sites for those species with a small number of detection events, in order to strengthen the site-specific density estimates. For this subset of species with a limited sample size, density estimates (D) were calculated using:

$$D = ND/L * 2(ESW)$$

where:

D = Group density (groups per km^2);
ND= Number of sightings for each species;
L = Cumulative transect length walked in each site;
ESW = Effective strip width, defined as the largest perpendicular distance observed for each species, but excluding obvious outliers.

This was the case for the white-fronted capuchin (*Cebus albifrons*), the squirrel monkey (*Saimiri cassiquiarensis*), and the red howler (*Alouatta seniculus*), which were regularly recorded three or fewer times at a given site. For species living in large, non-cohesive groups—such as the woolly monkey (*Lagothrix lagothricha*) —which can spread out over hundreds of meters in the forest, I added one third of the mean group spread to the ESW estimated by DISTANCE in order to avoid inflated-density estimates (Peres, 1997). Mean group sizes, derived from reliable group counts, were then multiplied by group density estimates in order to obtain mean population densities at each site. Crude population biomass was calculated using the mean body weight of a given species, defined as 80 percent of the average adult body weight of males and females of each species (Peres, 1993), multiplied by its density estimate.

Results

The mean primate population density for all sites was 64.4 individuals per square kilometer. The highest total primate density was found at Quebradón El Ayo (86.9 ind/km^2), while the lowest was at Caño Mateo (42.5 ind/km^2). Both, Quebrada Arapa and Caño Esperanza had similar intermediate total primate densities (Table 1). Total aggregated biomass showed a somewhat similar pattern, with the highest primate biomass at Quebradón El Ayo (169.5 kg/km^2) and Quebrada Arapa (157 kg/km^2), and the lowest at Caño Mateo. Biomass at Caño Esperanza reached an intermediate value (Table 1). Mean aggregated biomass for the four surveyed sites was 133.9 kg per square kilometer. Differences in density and total biomass between sites were driven both by the large-bodied woolly monkeys, *Lagothrix lagothricha*, and the medium-sized brown capuchin, *Sapajus apella*. For example, woolly monkey densities at C. Esperanza and Q. Arapa were between 1.5 and 2.0 times higher than in C. Mateo and Q. Ayo and represented 47.2 and 60.9 percent of their total

primate biomass, while this species only represented 28.5 percent and 36.0 percent of the total primate biomass at Q. El Ayo and C. Mateo respectively. On the other hand, *S. apella* density at Q. El Ayo represented a very particular case, as it was between 4.1 and 15.2 times higher than in any other site surveyed in this study. Consequently, its biomass at Q. El Ayo represented 35 percent of the total primate biomass. There were also remarkable differences in the densities of *Cebus albifrons*, *Saimiri cassiquiarensis* and *Leontocebus fuscus* between the surveyed sites, especially for *L. fuscus* (1.3 to 3.7 times higher at C. Esperanza and Q. Arapa), but these did not significantly affect the total primate biomass at any particular site. Other species such as *Alouatta seniculus*, *Cheracebus lucifer* and *Pithecia hirsuta* showed minor differences in their densities. Primate biomass represented between 36 percent and 49.1 percent of the total large vertebrates aggregated biomass at the surveyed sites (Palacios, unpublished data). During census walks we never recorded *Cebuella pygmaea*, but at Caño Esperanza, on a rainy afternoon before starting censuses, at around 17:30h three individuals of the species got tangled in a mist net we inadvertently left unfolded after carrying out bird sampling.

Discussion

Population densities of mid-sized and small primates were similar to those estimated for other forests in western Amazonia (Peres, 1990). In the majority of cases the densities of *Leontocebus fuscus*, *Saimiri cassiquiarensis*, *Cheracebus lucifer*, and *Pithecia hirsuta* were in the range of densities previously reported for other sites in Amazonia. The remarkable difference in *Sapajus apella* densities across sites in the study suggests that particular ecological factors could be determining the abundance of this species. For instance, the densities for the species at Caparú Biological Station and Caño Pintadillo at the black-water lower Apaporis River, and Q. El Ayo (20.4 – 30.9 ind/km^2) (Palacios and Peres, 2005) differ greatly from those at C. Mateo and C. Esperanza (2 – 3.4 ind/km^2), which in turn, are slightly higher to those estimated for the species at Curare indigenous community (1.2 ind/km^2) (E. Palacios, unpublished data). Curare is an area subject to hunting pressure but, can be considered as reflecting natural density of *S. apella*, as only five of 1,337 hunting events recorded in that community during ca. 10 years correspond to this species (E. Palacios, unpublished data).

Defler (2003) has suggested that some type of ecological displacement between *Sapajus apella* and *Cebus albifrons* could be the cause of the lower densities of the latter when both species are present in the same area. This suggestion is partially supported by the density estimates of both species at sites inside indigenous reserves north towards Río Puré NP (Curare and Borikada, 1.2 and 8.8 ind/km^2 of *S. apella* respectively, vs. 0 and 2.7 ind/km2 of *C. albifrons* – Palacios unpublished data), sites in the Yaigojé Apaporis indigenous Reserve/National Park (Caparú and Caño Pintadillo, 30.9 and 20.4 ind/km^2 of *S. apella* respectively, vs. 3.6 and 1.8 ind/km^2 of *C. albifrons* – Palacios and Peres, 2005) and at Quebradón El Ayo (30.4 ind/km^2 of *S. apella* vs. 2.5 ind/km^2 of *C. albifrons*). Nevertheless, the opposite situation occurred in C. Mateo and C. Esperanza (6.5 and 4.6 ind/km^2 of *C. albifrons* respectively, vs. 2.0 and 3.4 ind/ km^2 of *S. apella*), suggesting that such ecological displacement may operate in both ways, although ecological factors directing it are still unknown.

Total primate density at all but one of the four sites (Caño Mateo) surveyed in Río Puré NP was higher than that reported by Defler (2013) (47.9 ind/km^2) for his site on the right bank of the Puré River. C. Mateo is ca. 23 km away from Defler´s site, and both sites are relatively close to the Puré´s main course, therefore being more accessible to commercial hunters of spotted cats, that during the late 60´s and the 70´s intensively used large primates and other medium and large-sized vertebrates as bait. Hunters´ parties periodically entered into the current Río Puré NP area and established camps along the Puré river and its tributaries for long periods (2-3 months) during which they processed and accumulated the skins and then took them to La Pedrera to the merchants who sponsored such raids (Elías Yucuna and Julián Yucuna, Pers. comm.). The primate density figures for these two sites are 25 %-51 % lower than those for the three additional sites surveyed in Río Puré NP and might reflect the impact of hunting on the local primate populations. Defler (1980) reported that primate populations in the Mirití-Paraná River, Colombia, affected by 20th century hide trade hunting had recovered, and Antunes et al. (2016) indicated that 70 % of all populations of the lowest-fecundity and most prized game species affected by subsistence hunting (including Ateline primates) currently occur at carrying capacity at both landscape and basin-wide scales.

Nevertheless, it should be considered that in most recent times (during the decade of the 90´s, and through the first five years of the 2000´s) dozens of dredges for gold mining were permanently installed along the river and small tributaries, especially in the Brazilian portion (Purué River), but also in the lower Puré at the Colombian side, entering to the west farther than the C. Mateo, and also going upstream the Quebrada Agua Negra; in addition, during late 1990´s and early 2000´s a timber camp was established and active very near to the Colombian-Brazilian border, near to Defler´s site. It is likely that the continuous need of protein for dredge crews and loggers may have been fulfilled using the local wildlife populations, including large primates such as *Lagothrix*. Density and primate biomass figures for the species in all sites surveyed in this study except Caño Mateo lie in the range of the figures for the species in 29 Amazonian non-hunted oligotrophic forests (Peres et al., 2016). However, density of *Lagothrix* in Caño Mateo (4.5 ind/km^2) was below the lower end (6.42 ind/ km^2) of the range of values calculated by Peres et al. (2016); primate biomass (36 %) was slightly higher than the lower end (28 %) at Caño Mateo, and right at the lower end at

Table 1. Density (individuals/km**2**) and biomass (kg/km**2**) of primate species present at four sites in Río Puré National Park, eastern Colombian Amazonia.

	Quebradón El Ayo (200.7 km)						Caño Mateo (288 km)						Caño Esperanza (251 km)						Quebrada Arapa (250 km)					
Species	**MGS**	**N**	**SR**	**GD**	**ID**	**B**	**MGS**	**N**	**SR**	**GD**	**ID**	**B**	**MGS**	**N**	**SR**	**GD**	**ID**	**B**	**MGS**	**N**	**SR**	**GD**	**ID**	**B**
				Groups/ km^2	Ind/ km^2	Kg/ km^2				Groups/ km^2	Ind/ km^2	Kg/ km^2				Groups/ km^2	Ind/ km^2	Kg/ km^2				Groups/ km^2	Ind/ km^2	Kg/ km^2
Leontocebus fuscus	5.6	16	0.64	3.02	16.9	5.24	4.7	18	0.5	1.52	7.1	2.2	5.68	31	1.23	4.67	26.5	8.2	5.8	24	0.96	3.7	21.5	6.7
Cheracebus lucifer	2.6	7	0.35	2.63	6.8	6.52	2.4	21	0.58	2.8	6.7	6.4	2.4	15	0.6	1.91	4.6	4.4	2.7	17	0.68	2.5	6.8	6.5
Saimiri cassiquiarensis	18	1	0.05	0.63	11.3	8.47	7.3	15	0.42	0.69	5	3.8	9.25	4	0.2	0.4	3.7	2.8	5	6	0.24	0.7	3.5	2.6
Sapajus apella	7.2	11	0.55	4.24	30.4	70.8	5.6	30	0.83	1.16	6.5	15.1	5.7	10	0.4	0.7	4.8	11.2	5.7	11	0.44	1.3	7.4	17.3
Cebus albifrons	10	1	0.05	0.25	2.5	5.4	6.7	7	0.19	0.3	2	4.3	6.87	8	0.3	0.6	4.2	9.1	6.7	3	0.12	0.32	2.1	4.5
Pithecia hirsuta	4	18	0.9	2.8	11	19.36	3.14	65	1.8	2.94	9.2	16.2	3.27	26	1.03	3.26	10.7	18.8	3.7	22	0.88	2.3	8.5	15
Alouatta seniculus	5	1	0.05	0.21	1.05	5.46	3.4	7	0.19	0.44	1.5	7.8	p	p	p	p	p	p	10.5	2	0.08	2.3	1.7	8.8
Lagothrix lagothricha	12.7	19	0,76	0.54	6.9	48.3	6.7	14	0.38	0.67	4.5	31.4	11	29	1.2	0.6	6.6	48.8	20.2	20	0.8	0.75	13.7	95.6
TOTALS		74		14.3	86.9	169.5		147		10.52	42.5	87.2		123		12.14	61	103.3		105		13.87	65.2	157

MGS: Mean group size, N: Number of observations, SR: Sighting rate (number of sightings per 10 km of walked transect), GD: Group density,
ID: Individual density, B: Biomass, p: species present at the site but not recorded during the censuses.

Quebradón El Ayo (28.5%). It is also well below the density estimated for the species in the high Algodón River (16.3 ind/km^2) and just above the figure in the mid Tamboryacu River (3.5 ind/ km^2), in the Napo-Putumayo Rivers interfluvium in Perú, both sites highly affected by subsistence hunting and timber extraction (Aquino et al., 2016).

As previous surveys in eastern Colombian Amazonia have shown (Palacios & Peres, 2005; Defler, 2013), low primate densities and biomass at the forest sites surveyed at Río Puré NP seem to be a consequence of the limited habitat primary productivity as a result of the very low fertility of soils in eastern Colombian Amazonia (IGAC, 1997, 1999; Defler, 2003). Soil data from samples collected at Quebradón El Ayo, Caño Mateo and Caño Esperanza, every 800 – 1,000 m along each survey transect and analyzed at the Soils Laboratory of Instituto Geográfico Agustín Codazzi in Bogotá D. C. (E. Palacios, unpublished data), show they are very to extremely acidic soils (pH 3.7 – 4.7; 4.1 – 4.9, and 3.8 – 4.6 respectively), have a low to very low Cationic Exchange Capacity (1.2 – 15.2 meq/100g; 0.8 – 13.2, and 4.5 – 22.3), and a moderate to low fertility, following a typical pattern of oligotrophic terra firme forests of remote interfluvial areas (sensu Peres, 1999) along Amazonia lowland forests, due to their geochemical characteristics, and their severe nutrient limitations (Irion, 1978).

Overall, my results provide additional arguments supporting that soil fertility and vertebrate abundance are strongly correlated in Amazonian forests (Peres, 2008). Considering the low densities of primates, and in general of other medium and large sized terrestrial vertebrate species in terra firme forests that are not subject to hunting pressures in eastern Colombian Amazonia, it is important to implement monitoring schemes to generate information on their natural population dynamics, particularly on those areas subject to varying levels of anthropogenic activities around protected areas. Acknowledging that indigenous reserves cover more than fifty percent of the Colombian Amazon and include hundreds of square kilometers of habitats for more than 12 primate species, and about eighteen additional game species, strengthening their capacities to implement such schemes in their territories is also key. Indigenous authorities are in many cases willing to have their people trained and to develop these type of activities, in order to get technical information that can be articulated with their own knowledge, to complement their decision-making processes, on the use and management of resources that are of vital importance for their well-being, and whose state of conservation is an indicator of the role indigenous territories can play in maintaining healthy populations of mid-sized to large vertebrates in Amazonian forests.

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NEW RECORDS OF *BRACHYTELES ARACHNOIDES* (É. GEOFFROY, 1806) (PRIMATES: ATELIDAE) IN THE SOUTHERN ATLANTIC FOREST, IN PARANÁ STATE, BRAZIL

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Introduction

Primates of the genus *Brachyteles* Spix, 1923, popularly known as muriquis or monos (Auricchio, 1995), are endemic to the Atlantic Forest (Graipel, 2017). This biome is composed in large part of extremely fragmented and reduced areas (Ribeiro et al., 2009), and is considered one of the most threatened biomes in the world (Myers et al., 2000). Two species of muriqui are acknowledged to occur in different forest physiognomies: the northern muriqui, *Brachyteles hypoxanthus* (Kuhl, 1820) in the states Minas Gerais, Espírito Santo, Rio de Janeiro and Bahia, and the southern muriqui, *Brachyteles arachnoides* (É. Geoffroy, 1806) in the states of Rio de Janeiro, São Paulo and Paraná. The second species is typically found in the phytoecological unit of Dense Rainforest, although there are also records of the species in Seasonal Semi-deciduous Forest and in Mixed Rainforest (Araucaria Forest), as well as in transition zones (Cunha et al., 2009). The muriquis, like other large primates, tend to occupy the higher strata of the forest (Peres, 1994).

According to information on the distribution of muriqui in the state of Paraná, its occurrence extends to the north of the state in the municipality of Castro (Cunha *et al*., 2009). However, the distribution is restricted and poorly known, with records in 1994 that mention its occurrence in the municipalities of Jaguariaíva and Guaraqueçaba (Martuscelli et al., 1994). Almost a decade later, a more southern population was registered by Koehler and collaborators (2002) in an isolated and unprotected fragment in the municipality of Castro. The third confirmed record for *Brachyteles arachnoides* was in Olho D'Água farm, municipality of Doutor Ulysses (Ingberman et al., 2016). Apart from these few occurrence records, the distribution and southern limit of this species is little known, a concern for its conservation; the species is classified as "critically endangered" in Paraná state (Paraná, 2010) and as "endangered" nationally (ICMBio, 2018) and internationally (IUCN, 2019).

Information related to the distribution and occurrence of populations of the southern muriqui is fundamental for the proposal of conservation measures. Here we contribute new occurrence records of the southern muriqui for Paraná state.

Methods

We registered the occurrence of *Brachyteles arachnoides* during mammalian fauna monitoring in two areas (Fig. 1). The first area is a High Conservation Value area located at Taquarussu Farm, with 1,367 ha of preserved forest (24°47'44.2" S, 48°47'53" W) in the municipality of Adrianópolis, PR, in the Vale do Ribeira region. The second area is a Private Reserve, the Reserva Particular do Patrimônio Natural (RPPN) Vale do Corisco (24°12'16" S, 49°21'26" W), with 396.6 ha, located at the eastern border of the Environmental Protection Area (APA) of the Devonian Scarp, in the municipality of Sengés, PR. Both areas belong to the company Arauco Forest Brasil.

Mammalian fauna were monitored in these areas between January 2015 and December 2019, for a total of 48 months of sampling, with an average of three days per month spent in monitoring. Censuses were based in the analysis of direct (visualization and acoustic signals) and indirect methods (analyses of footprints, marks and carcasses), together with camera traps. Species identification was made according to specialized field guides (Becker and Dalponte, 2013; Reis et al., 2009, 2014).

Monitoring was always performed by at least two observers in non-linear transects in search for traces of the