

## BIRDS OF A NEOTROPICAL WOODLOT AFTER FIRE

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**Resumo.** – *Aves de uma mata Neotropical depois do fogo.* – As aves foram monitoradas 4 anos antes e 14 anos depois da passagem do fogo em metade de uma mata semi-decídua isolada de planalto, de 144 ha, no interior do estado de São Paulo, sudeste do Brasil. Foram observadas 161 espécies de aves (excluindo 7 vagantes, 7 de 10 aves aquáticas, e 51 espécies de áreas abertas). Até 20 das 82 espécies do interior da mata parecem ter desaparecido ao longo dos anos. Entretanto, somente duas elanias migrantes e uma pomba rara desapareceram logo após a passagem do fogo. Outras espécies desapareceram antes e depois, talvez com recente clima mais seco e mais quente ou perda de populações pequenas. Um tucano foi uma adição e uma sai-andorinha desapareceu, das 79 espécies de borda de mata. Os efeitos do fogo, às vezes, não foram imediatos: espécies granívoras entraram logo, mas os frugívoros e as aves que sobem troncos e cascas aumentaram em um a poucos anos após o fogo. Perda de árvores mortas e o crescimento de densos e emaranhados cipós em áreas extensas ao invés de localizadas reduziram essas três guildas para níveis anteriores ou baixos, e parecem estar reduzindo os números de algumas outras aves de sub-bosque ou de dossel muitos anos após o fogo. O fogo extenso não afeta somente uma área de mata, mas também inicia uma série temporal de sucessão que pode afetar grupos de espécies anos depois. Os emaranhados de cipós, dez anos após o fogo, criam temporariamente um habitat estranho, normalmente restrito às bordas, escarpas, ou pequenas áreas de árvores caídas.

**Abstract.** – Birds were censused four years before and 14 years after fire over half the 144 ha of an isolated semideciduous plateau woodlot in interior São Paulo, southeastern Brazil. I recorded 161 species (excluding 7 vagrants, 7 of 10 water birds, and 51 nearby open-area species). Up to 20 of 82 forest-interior birds seem to have disappeared over the years. However, only two migrant elanias and one rare dove disappeared just after the fire. Other species disappeared earlier and later, perhaps with dryer and warmer recent climate or loss of small populations. One toucan moved in, and one swallow-tanager disappeared, of 79 forest-border species. Census effects of the fire were often not immediate: seed-eating species moved in soon, but fruit eaters and trunk/bark birds increased one to a few years after the fire. Loss of fire-killed trees and growth of widespread rather than local dense vine tangles later reduced these three guilds to earlier population levels or below, and seemed to be reducing numbers of other understory and canopy birds many years after the fire. Widespread fires do not just affect a forest areally, but also start a temporal successional series that can affect groups of species years thereafter; vine tangles ten years or so after fire temporarily create a rare habitat, normally restricted to edges, escarpments, or small tree-fall areas. *Accepted 20 September 2002.*

**Key words:** Avifauna, census, fire, forest fragments, lianas, São Paulo, succession.

### INTRODUCTION

Moderately natural areas are rarely preserved in the modern world, and even these are sub-

ject to such disasters as climate change and fires. In 1984, I started studies of birds of a 144-ha semideciduous woodlot inland on the São Paulo plateau, southeastern Brazil, as one

of several long-term studies of losses and gains of birds in isolated seminatural habitats in the region. After a fire burned half the area in early September 1988, I continued censuses.

Studies of effects of fires are uncommon in the tropics (see Marini & Cavalcanti 1996), although fires are frequent (pers. observ.) and sometimes result in species loss or permanent loss of habitat. Fires can cause serious problems, as for a bromeliad tree-frog in Espírito Santo (Papp & Papp 2000), or little problem, as for mammals and other small terrestrial species in Australian scrub (Fox 1982, Friend 1993). Burns in northern coniferous woods sometimes are studied for years (Tomback *et al.* 2001). Studies of fire effects on birds (Koplin 1969, Emlen 1970, Apfelbaum & Haney 1981, Bock & Bock 1983, Artman *et al.* 2001) are often limited to a year or two. In other cases, as on grasslands and cerrados near the woodlot under study, occasional small-area fires are normal and preserve certain species and the open natural vegetation (Cavalcanti & Alves 1997, Parker & Willis 1997).

Here I report changes in the avifauna of the woodlot with the fire and other changes over the years, notably with dryer and warmer climate (“greenhouse effects”) after an unusually wet “El Niño” in 1982–83, before the start of studies. Nearby pastures and corn fields have also changed somewhat over the years, though not checked directly. Birds of natural grasslands and cerrados in the region have also been studied, and are to be reported elsewhere (Willis 1992, in prep.). Off west, birds of gallery woodlands were studied (Almeida *et al.* 1999); off north, birds of a gallery wood and cerrados and eucalyptus area (Motta-Júnior 1990, Motta-Júnior & Vasconcelos 1996); to the south, birds of different sizes of similar woodlots (Willis 1979, Willis & Oniki 2002).

## STUDY AREA AND METHODS

The 144-ha woodlot is a plateau forest remnant (740 m, 22°08'S, 47°52'W) on the north slope of the Ribeirão do Feijão, which forms the border between the townships of Itirapina off south and São Carlos to the north. A small creek in the woodlot flows west to a marsh and then south past the pastures and headquarters of Fazenda Santa Francisca do Lobo. The woodlot earlier was partly owned by Fazenda Paineiras (referring to big *Chorisia speciosa* flowering trees), which has a corn field (soybeans in 2002) and pastures just east near narrow gallery woods of the Feijão creek. It is a semideciduous upland patch, with an irregular canopy, moderately dense understory, and some bamboo or liana-tangle undergrowth. No trees have been cut recently, but valuable timber probably was removed many years ago.

The woodlot is unusual here, as most areas on this sandstone plateau (“chapada”) had low grasslands or bushy savannas (“cerrados”) on sandy soils. It is on a patch of red-earth soil (“terra roxa”), and other woods in the region were either gallery woods along creeks or dry forests on isolated “morros” or small peaks and ridges. Pastures of introduced grasses, eucalyptus plantations, and beach houses at nearby Broa Reservoir to the southwest are gradually replacing the original vegetation except narrow strips along creeks. Near and beyond Broa, some cerrado and grassland zones are preserved. A busy paved road from São Carlos to the Broa resort passes through the west half of the woodlot, and a small side road goes east to the corn field, while there are small trails here and there. Bushy pastures and patches of scrub form the north border.

The south half of the woodlot burned, from both sides of the main road (where the fire started) over much of the area I had been censusing. I had not worked the unburned north half much earlier, and did not do so

after the fire. The understory was completely burned out, many medium-sized or small trees killed, but some large trees survived and leafed out later in the rainy season.

I censused birds along the main road, side road and east side next to the corn field, on afternoon or late-day visits (early-day visits were usually to open habitats in the Itirapina township). A few visits were early in the day or at midday, in unburned zones along the bushy north pastures, or along the Feijão. The west marsh and pastures were not checked. The one hundred and twelve visits are divided into (1) pre-fire 31 May 1984–14 August 1988, (2) post-fire 25 September 1988–11 August 1991, (3) 25 August 1991–26 June 1994, and (4) 1 November 1994–16 February 2002. The three post-fire periods are separated to give numbers of visits similar to those in the pre-fire period, with dividing lines in August or midwinter. Censuses are reported as “birds per 100 h”, multiplying the number seen by 100 and dividing by the total census hours, as there are some differences in census times for the four periods (see Willis 1979).

Some of the censuses are included in Christmas Counts for the Itirapina region (Willis 1992 and later), as this is the main forest tract in the count circle, other than dry-forest morros.

## RESULTS

From 1984 to 2002, some 226 species of birds were recorded in and near the woodlot (Appendix 1). Seven species (“V” in Appendix 1) seemed vagrants, which only casually appeared in or near the woodlot. Fifty-one others were open-area ones (“A”) nearby, or flying over, and not species of the woodlot itself, plus 10 species of creeks and water areas (“C”). Deducting these 68 species, some 158 species were birds of the woodlot itself, rather like woodlots of similar size off south-east near Campinas and Rio Claro (Willis

1979, Willis & Oniki 2002). If two “C” Ralidae and one Parulidae are included as woodlot-creek birds, the total is 161.

Of these 161, some 76 species are “border” birds (“B”) plus the 3 above “C” birds, so about half the species of the woodlot are not forest-interior birds. Many others cross open areas, hence could form “metapopulations” that theoretically could recolonize the area after local extinctions. Gallery-wood connections, upcreek on the Feijão, for instance, could also help if other woodlots were not so distant.

*Water birds.* The only marsh bird regular in the area, the Blackish Rail (*Rallus nigricans*), seemingly became more common after the fire (Appendix 1, columns 2 and 3) but decreased to earlier numbers after 1994 (column 4). It perhaps was easier to detect after the fire and while the vegetation was growing. Other species are more common than indicated, as generally off west at the bordering marsh that was not checked.

*Open-area birds.* The forest fire should have affected birds of surrounding open areas little, but could have provided habitat for them. The Spotted Nothura (*Nothura maculosa*) seemed to disappear over the years, as in other regional grasslands and pastures, perhaps due to hunters, dry years recently, or gradual increases in cattle. Lower numbers of several other species recently could be due to these causes. The Chopi Blackbird (*Gnorimopsar chopi*) has vanished since 4 January 1993 due to the cage-bird trade. The Lesser Elaenia (*Elaenia chiriquensis*) disappeared with the fire, due to loss of low edge fruits it had visited at borders in fall migration; it continues common in summer in nearby cerrados.

Cattle Egrets (*Bubulcus ibis*) of pastures nearby have certainly increased greatly in the region since they invaded the state in the 1970's and started nesting near Broa in 1984.

Red-legged Seriemas (*Cariama cristata*) and Buff-necked Ibises (*Theristicus caudatus*) likely have not changed in numbers, despite more records recently; they are mostly heard at long distances from the woods.

Six open-area species seemed to increase after the fire and decrease recently, but the Shiny Cowbird (*Molothrus bonariensis*) peak was of a flock of 30 birds on 10 June 1990 (winter wanderers?). The White-vented Violetear (*Colibri serrirostris*) peak of 15 was due to flowers of weeds in the corn field on 17 November 1989 (it is commoner in semiopen cerrados in the area). Perhaps the Aplomado Falcon (*Falco femoralis*) was easier to see flying over edges after the fire, or hunted there slightly more. In general, therefore, there was little evidence that open-area species had changed in populations or used the burned forest area.

*Border species.* Some seed-eating border species definitely increased in 1988 just after the fire, notably Double-collared Seedeaters (*Sporophila caerulescens*), Rufous-collared Sparrows (*Zonotrichia capensis*), and Blue-black Grassquits (*Volatinia jacarina*), as in gallery woods near Brasília after a fire (Marini & Cavalcanti 1996). Seed-eating Ultramarine Grosbeaks (*Passerina brissoni*) continued rare, being uncommon regionally due to the cage-bird trade. Small-billed Tinamous (*Crypturellus parvirostris*), which feed on seeds in the open and sometimes return to the woods at night, either increased for a few months or were easier to detect.

Southern Rough-winged Swallows (*Stelgidopteryx ruficollis*) and some other swallows increased, especially in 1989 on, but may just have been easier to see flying over. House Wrens (*Troglodytes aedon*) also were more common in 1989 on; they were certainly birds that use new growth, but decreased recently. The Swallow-Tanager (*Tersina viridis*) increased, as the fire allowed it to enter the woods and use

nest burrows on the ground; it quickly disappeared with regrowth of low vegetation (last seen 10 October 1993). Rufous-tailed Jacamars (*Galbula ruficauda*), which also use burrows, stayed several years but are now gone as understory density increased (but still present far from the main road, where cars may have killed them; low-level nightjars also are absent at road). Orange-headed Tanagers (*Thytopopsis sordida*) of border vine tangles and Hooded Tanagers (*Nemosia pileata*) of canopy edges became common, but decreased with further growth of the tangles in recent years. Great Antshrikes (*Taraba major*) of dense borders increased.

Nine other border species that increased a year or more after the fire but decreased later were Pale-vented Pigeons (*Columba cayennensis*), Turquoise-fronted Parrots (*Amazona aestiva*), Streaked (*Myiodynastes maculatus*), Variegated (*Empidonomus varius*) and Boat-billed (*Megarynchus pitangua*) flycatchers, Great Kiskadees (*Pitangus sulphuratus*), Social Flycatchers (*Myiozetetes similis*), Burnished-buff (*Tangara cayana*), and Sayaca (*Thraupis sayaca*) tanagers. All eat fruits and insects on tall trees, which may have produced more fruits a year or two after surviving the fire. Other high-level fruit eaters that increased and continue commoner than before the fire were Toco Toucans (*Ramphastos toco*), White-eyed Parakeets (*Aratinga leucophthalmus*), Short-crested Flycatchers (*Myiarchus ferox*) and White-winged Becards (*Pachyrhamphus polychopterus*), plus "forest" Canary-winged Parakeets (*Brotogetis chiriri*) and Scaly-headed Parrots (*Pionus maximiliani*) (below). The two former species are increasing in the whole region, as are *Amazona* parrots, perhaps as cage-bird traders are less active recently, or as the climate became warmer and drier.

Decreases after the fire, with later recovery, were noted for Picazuro Pigeons (*Columba picazuro*), which is an open-area seed-eater but roosts and feeds on fruits in low-level edge

trees. Two swifts have almost disappeared regionally, in part as they roost and nest near ecotourism waterfalls off southwest. Border species that continue less common or decreasing are Black Vultures (*Coragyps atratus*) (perhaps with loss of roost trees or fewer dead cows thrown in nearby cerrado edges), Roadside Hawks (*Buteo magnirostris*), Laughing Falcons (*Herpetotheres cachinnans*) (hunters?), Ruddy Ground-Doves (*Columbina talpacoti*), White-tipped Doves (*Leptotila verreauxi*), Blue-winged Parrotlets (*Forpus xanthopterygius*), Fuscous Flycatchers (*Cnemotriccus bimaculatus*) and Blue Dacnises (*Dacnis cayana*) (edge habitats destroyed by fire, but decreases gradual and dense edges now growing back?). Loss of understory fruit trees (as *Trema micrantha*, see below) may help explain decreases in the parrotlet, dacnis and White-tipped Doves.

One low-level winter visitor, the Blue-billed Black-Tyrant (*Knipolegus cyanostris*), dropped off when the area burned and has returned with the growth of forest-edge shrubs. Eleven other winter species from the south (“W”) occur in the woodlot, plus four species from North America (“N”) in the southern summer. All are rather uncommon. Summer woodlot species (“S”) are 15, migrants three (“M”), many being border species. Two summer flycatchers (above) seemed to increase for a time with upper-level fruits, but two lower-level fruit-eating migrants (below) disappeared. One summer species, the Ashy-tailed Swift (*Chaetura meridionalis*), seemed to fly over more just after the fire, but perhaps was more easily seen.

The Toco Toucan is a new border species that appeared over the study period, and the Swallow-Tanager was lost. The former is invading woodlots in eastern São Paulo lately, either favored by clearings and drought years or less hunted recently. The Swallow-Tanager wanders widely to forest patches, but is somewhat rarer recently in the region, perhaps with

loss of burrows for nests near fruit trees in woods (see above).

*Forest birds.* Ten of 82 forest species disappeared since 1984. Two, migrant White-crested (*Elaenia albiceps*) and Small-billed (*E. parvirostris*) elaenias, disappeared because the *Trema micrantha* edge bushes where I saw them in the fall were burned. The only other species that disappeared with the fire was the Gray-fronted Dove (*Leptotila rufaxilla*), rare in dry woods like these and more a species of creek-side woods. Five species already were unrecorded a year or two before the fire: Blue Ground-Doves (*Claravis pretiosa*; rare regionally, more common in dry woods westward), Amethyst Woodstars (*Calliphlox amethystina*; hard to see, canopy, probably still present), Rufous-breasted Leafscrapper (*Sclerurus scansor*; disappeared or rare in many regional woods, perhaps drought), Ferruginous Antbirds (*Drymophila ferruginea*; more in cooler and wetter woods east), and Spot-backed Antshrikes (*Hypodaleus guttatus*; lost in many other small woodlots). Rufous-winged Antwrens (*Herpsilochmus rufimarginatus*) and Sirystes (*Sirystes sibilator*) of the canopy gradually disappeared after the fire, probably with reduced populations. Ten other species seem to have disappeared recently: four other hummingbirds, the Eye-ringed Tody-Tyrant (*Hemitriccus orbitatus*), plus a migrant flycatcher, thrush, warbler, tanager, and euphonia (Appendix 1). They may still occur, as earlier present only in small numbers.

Some 26 forest species are decreasing in numbers in the woodlot. Five hummingbirds (plus the five lost species) and border Bananaquits (*Coereba flaveola*) have decreased recently, canopy species perhaps because some flowering “paineira” trees were lost in the fire. Understory nectar-eaters may have fewer flowers with gradual post-fire growth of understory vines. Sombre Hummingbirds (*Aphantochroa cirrochloris*) and Black Jacobins

(*Melanotrochilus fuscus*) did flock to a few high flowering trees in 1990. Three insect and fruit-eating canopy tanagers and relatives [Chestnut-vented Conebills (*Conirostrum speciosum*), Rufous-headed Tanagers (*Hemithraupis ruficapilla*), Purple-throated Euphonias (*Euphonia chlorotica*)] and one flycatcher [Gray Elaenias (*Myiopagis caniceps*)] seem to have declined recently rather than after the fire, as hunted Rusty-margined Guans (*Penelope superciliaris*). Vine-tangle Eared Pygmy-Tyrants (*Myiornis auricularis*) and Gray-headed Tody-Tyrants (*Todirostrum poliocephalum*) should have increased, but instead decreased recently. Fourteen understory birds declined gradually, without evident drop at the fire [Squirrel Cuckoo (*Gaira cayana*), Surucua Trogon (*Trogon surrucura*), Rufous-capped Spinetail (*Synallaxis ruficapilla*), White-eyed Foliage-Gleaner (*Automolus leucophthalmus*), Rufous Gnateater (*Conopophaga lineata*), Tufted Antshrike (*Mackenziaena severa*), Variable Antshrike (*Thamnophilus caerulescens*), Greenish Elaenia (*Myiopagis viridicata*), Swallow-tailed Manakin (*Chiroxiphia caudata*), White-bellied (*Basileuterus hypoleucus*) and Flavescent (*B. flaveolus*) warblers, Silver-beaked (*Ramphocelus carbo*) and Black-goggled (*Trichothraupis melanops*) tanagers, Saffron-billed Sparrows (*Arremon flavirostris*)]. Yellow-olive Flycatchers (*Tolmomyias sulphurescens*) of midlevels decreased somewhat at and after the fire. Silver-beaked Tanagers are hit by speeding cars along the main road, too (specimen, as of the monkey *Cebus apella*).

Records of some 15 forest species increased after the fire (17 if Sombre Hummingbirds and Black Jacobins included), even though most have dropped again. Some probably were easier to see [Long-tailed Tyrant (*Colonia colonus*)] or hear as they searched more for army ants [White-winged Fire-Eyes (*Pyriglena leucoptera*)] or other insects [Rufous Motmot (*Baryphthengus ruficapillus*)]. Notable were temporary increases in woodpeckers, wood-

creepers and Streaked Xenops (*Xenops rutilans*), probably checking dead trunks and limbs killed by the fire. Five thrushes (including one of borders and one not seen recently) seemed more common two to four or so years after the fire, perhaps eating fallen fruits as the understory grew back (but they seem to hop on the ground and do well in city parks and other areas where the understory is somewhat cleared out). The White-necked Thrush (*Turdus albicollis*), the only really forest one, continues common after the understory has closed in again. Canary-winged Parakeets and Scaly-headed Parrots are upper-level fruit eaters that continue more common after the fire, though the Black-billed Tityra (*Tityra cayana*) dropped off later, as well as several border frugivores (above).

Fifteen other species seem about as common or rare as earlier: Tawny-browed Owl (*Pulsatrix koenigswaldiana*), Semicollared Night-hawk (*Lurocalis nattereri*), Plain Antvireo (*Dysithamnus mentalis*), Euler's Flycatcher (*Lathrotricus euleri*), White-throated Spadebill (*Platyrrinchus mystaceus*), Swainson's (*Myiarchus swainsoni*) and Sepia-capped (*Leptopogon amaurocephalus*) flycatchers, Green-backed Becard (*Pachyrhamphus viridis*), Red-eyed Vireo (*Vireo olivaceus*), Rufous-browed Peppershrike (*Cycalbarhis gujanensis*), Ruby-crowned Tanager (*Tachyphonus coronatus*), Red-crowned Ant-Tanager (*Habia rubica*), Black-throated Grosbeak (*Pitylus fuliginosus*), and Sooty Grassquit (*Tiaris fuliginosa*). Four others, rare Rufous-thighed Kites (*Harpagus diodon*), Yellow-billed (*Coccyzus americanus*) and Pavonine (*Dromococcyx pavoninus*) cuckoos, and Sharp-tailed Streamcreeper (*Lochmias nematura*), have been seen after the fire.

## DISCUSSION

The fire itself seemed to have little immediate effect on birds, although many individuals must have been displaced. There was little

effect on water and open-area birds. Border species that eat low fruits (especially migrating elaenias) did lose out, but House Wrens and some seed-eating species increased for a time with fast growth of edge weeds. Oddly, after a fire in North America (Emlen 1970), House Wrens were more in unburned areas.

Increases in several upper-level fruit eaters one to a few years after the fire, plus increases in forest-understory thrushes that probably were eating fallen fruits, could indicate a possible response of surviving trees: more fruits to take advantage of open understory produced by the fire. Several authors (Apfelbaum & Haney 1981, Bock & Bock 1983, Artman *et al.* 2001) noted increases in thrushes after fires. However, the understory is now well shaded by dense vines and tall saplings, and fruit-eater numbers have mostly decreased again. Flower-visitors only increased in a few tall trees, mainly two years after the fire, but I did not check them in detail, and they now seem to have decreased. Flower and fruit production of trees could drop off when understory vines become abundant, a subject for future research.

Understory birds of bark and trunks increased after the fire, probably using insects from the dead trees and saplings. Others have reported increases in woodpeckers after fire (Koplin 1969, Apfelbaum & Haney 1981). Most dead trees and limbs have now fallen, reducing food supplies and nest sites to a level below normal for a forest, and some such birds are reduced in numbers. One cannot assume that a widespread fire is like normal treefalls, creating clearings and dead trees here and there, and providing regular niches. A widespread but temporally limited niche of this type can create a later break in food supplies for these birds, just as sudden fruit production (preceding paragraph) may drop off for several years with the dense understory growing back. Temporal as well as spatial problems can exist for small populations of

birds in a burned woodlot like this one.

A few species that disappeared at the time of the fire or later may have been reduced to small numbers by the woodlot fire, notably Gray-fronted Doves of the understory and Rufous-winged Antwrens and Sirystes of the canopy. Gradual decreases in 14 understory species well after the fire, plus a number of canopy species, may be a consequence of dense vine-covered saplings growing toward the irregular canopy of scattered trees that survived the fire, or gradual loss of birds that survived the fire by competing with others already present in unburned stretches or the north half of the woodlot. Recent years have also been rather dry and hot, compared to the early 1980's, perhaps another factor involved in these gradual decreases as the forest grows back. Cars on the increasingly busy road kill understory birds and monkeys, too. Vine clutter must reduce feeding niches in a regenerating fire area, though vine-tangle birds do not seem to have increased much. This is another case where occasional treefall clearings are different from fire zones, which produce wide but temporary areas of one vegetation type.

In another study of a burned zone in the lowland Atlantic forest of southeastern Bahia, Brazil, I noted that treetop birds can move near the ground in a burned zone, using low saplings before vines grow up (Willis 1996). This type of bird movement was seldom noted here, but could affect censuses because the birds would still be recorded.

One can conclude that immediate effects of this fire were not very obvious, other than displaced birds that did not change counts (could be heard at a distance, moved down or to conspicuous sites, or I moved somewhat to unburned zones). Marini & Cavalcanti (1996) also noted limited change in a gallery wood near Brasília. Fires in logging areas are much more serious than these fires in natural forests (Siegert *et al.* 2001), and could reduce bird

numbers much more. However, delayed effects that would be missed by one or two years of study (dead-tree, fruits and vine-tangle cycles) may affect many species that one thinks are going to survive as the forest grows back. The growing forest is not a normal diverse forest, it is a temporal series of successional stages that provide different species with food at each stage. The question is, where does a species go before or after its seral stage?

In a woodlot like this, far from others, there is little outside forest for even a “metapopulation” or open-crossing forest species. Also, vine-tangle habitats after fires are abnormally widespread and can cause problems for many species. The number of species in and near the woodlot is decreasing (Appendix 1), though other small woodlots in the region are also losing species even without fires (see Willis & Oniki 2002). Researchers will need to study fire effects for years, not just briefly.

In lower natural vegetation, such as grasslands or cerrados, or Australian scrub (Fox 1982, Friend 1993), the vegetational cycles are much shorter after a fire, and birds can often find appropriate sub-habitats in a mosaic of refugia. However, a treefrog of a terrestrial bromeliad area was almost lost with fire (Papp & Papp 2000). Also, if large tracts of forest or other habitat are present, or connected by corridors, the birds can escape fires or post-fire effects.

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## APPENDIX 1. Birds per 100 h of census

Species	Periods			
	1	2	3	4
Small-billed Tinamou ( <i>Crypturellus parvirostris</i> ) B	56	93	47	18
Spotted Nothura ( <i>Nothura maculosa</i> ) A	11	7	-	-
Rusty-margined Guan ( <i>Penelope superciliosus</i> )	11	9	10	2
Muscovy Duck ( <i>Cairina moschata</i> ) C	-	3	2	5
Whistling Heron ( <i>Syrigma sibilatrix</i> ) A	16	7	8	14
Cattle Egret ( <i>Bubulcus ibis</i> ) A	-	-	234	517
Black-crowned Night-Heron ( <i>Nycticorax nycticorax</i> ) C	-	2	-	1
Great Egret ( <i>Ardea alba</i> ) C	3	3	-	-
Green Ibis ( <i>Mesembrinibis cayennensis</i> ) C	3	3	-	-
Buff-necked Ibis ( <i>Theristicus caudatus</i> ) A	-	11	9	2
Southern Lapwing ( <i>Vanellus chilensis</i> ) A	18	28	3	8
Upland Sandpiper ( <i>Bartramia longicauda</i> ) AN	2	-	-	-
Red-legged Seriema ( <i>Cariama cristata</i> ) A	5	16	23	38
Blackish Rail ( <i>Rallus nigricans</i> ) C	14	26	18	7
Ash-throated Crake ( <i>Porzana albicollis</i> ) A	-	14	8	-
Slaty-breasted Wood-Rail ( <i>Aramides saracura</i> ) C	5	2	-	-
Gray-necked Wood-Rail ( <i>Aramides cajaneus</i> ) B	2	2	2	4
Black Vulture ( <i>Coragyps atratus</i> ) B	594	436	371	179
King Vulture ( <i>Sarcoramphus papa</i> ) V	-	2	-	-
Plumbeous Kite ( <i>Ictinia plumbea</i> ) SV	-	-	2	2
Gray-headed Kite ( <i>Leptodon cayanensis</i> ) V	-	2	-	-
White-tailed Kite ( <i>Elanus leucurus</i> ) A	2	2	-	-
Rufous-thighed Kite ( <i>Harpagus diodon</i> ) S	2	-	-	2
Sharp-shinned Hawk ( <i>Accipiter striatus</i> ) B	2	2	-	-
Short-tailed Hawk ( <i>Buteo brachyurus</i> ) B	3	-	15	10
Swainson's Hawk ( <i>Buteo swainsoni</i> ) NV	-	2	-	-
Roadside Hawk ( <i>Buteo magnirostris</i> ) B	71	46	20	28
White-tailed Hawk ( <i>Buteo albicaudatus</i> ) A	2	2	-	-
Savanna Hawk ( <i>Buteogallus meridionalis</i> ) A	3	-	-	2

## APPENDIX 1. Continuation.

Species	Periods			
	1	2	3	4
Yellow-headed Caracara ( <i>Milvago chimachima</i> ) A	-	3	2	7
Crested Caracara ( <i>Caracara plancus</i> ) A	18	25	13	14
Laughing Falcon ( <i>Herpetotheres cachinnans</i> ) B	16	12	5	2
American Kestrel ( <i>Falco sparverius</i> ) A	5	-	-	4
Aplomado Falcon ( <i>Falco femoralis</i> ) A	-	12	7	1
Picazuro Pigeon ( <i>Columba picazuro</i> ) B	218	42	123	126
Pale-vented Pigeon ( <i>Columba cayennensis</i> ) B	87	161	153	54
Eared Dove ( <i>Zenaida auriculata</i> ) A	83	3	7	5
Blue Ground-Dove ( <i>Claravis pretiosa</i> )	2	-	-	-
Ruddy Ground-Dove ( <i>Columbina talpacoti</i> ) B	331	154	62	60
Scaled Dove ( <i>Columbina squammata</i> ) V	-	-	-	4
White-tipped Dove ( <i>Leptotila verreauxi</i> ) B	207	191	128	84
Gray-fronted Dove ( <i>Leptotila rufaxilla</i> )	3	-	-	-
Squirrel Cuckoo ( <i>Piaya cayana</i> )	79	65	62	44
Yellow-billed Cuckoo ( <i>Coccyzus americanus</i> ) N	-	-	-	1
Striped Cuckoo ( <i>Tapera naevia</i> ) B	18	25	15	6
Pavonine Cuckoo ( <i>Dromococcyx pavoninus</i> )	2	-	-	1
Smooth-billed Ani ( <i>Crotophaga ani</i> ) A	21	19	18	11
Guira Cuckoo ( <i>Guira guira</i> ) A	8	1	3	23
Blue-winged Parrotlet ( <i>Forpus xanthopterygius</i> ) B	112	93	92	9
Canary-winged Parakeet ( <i>Brotogeris chiriri</i> )	104	137	245	81
White-eyed Parakeet ( <i>Aratinga leucophthalmus</i> ) A	10	37	98	116
Scaly-headed Parrot ( <i>Pionus maximiliani</i> )	3	7	7	12
Turquoise-fronted Parrot ( <i>Amazona aestiva</i> ) B	3	14	3	5
Barn Owl ( <i>Tyto alba</i> ) A	3	2	-	-
Tropical Screech-Owl ( <i>Otus choliba</i> ) B	5	3	2	5
Tawny-browed Owl ( <i>Pulsatrix koeniswaldiana</i> )	2	3	3	1
Burrowing Owl ( <i>Athene cucularia</i> ) A	-	-	-	4
Common Potoo ( <i>Nyctibius griseus</i> ) B	-	2	-	-
Pauraque ( <i>Nyctidromus albicollis</i> ) B	16	9	12	10
Scissor-tailed Nightjar ( <i>Hydropsalis torquata</i> ) A	3	2	7	10
Little Nightjar ( <i>Caprimulgus parvulus</i> ) AS	-	9	-	-
Rufous Nightjar ( <i>Caprimulgus rufus</i> ) V	-	-	-	1
Semicollared Nighthawk ( <i>Lurocalis nattereri</i> ) S	8	11	12	20
Common Nighthawk ( <i>Chordeiles minor</i> ) AN	3	-	2	1
White-collared Swift ( <i>Streptoprocne zonaris</i> ) B	34	81	111	-
Sooty Swift ( <i>Cypseloides fumigatus</i> ) BS	10	5	-	-
Ashy-tailed Swift ( <i>Chaetura meridionalis</i> ) BS	10	30	5	-
Planalto Hermit ( <i>Phaethornis pretrei</i> )	26	28	20	7
Violet-capped Woodnymph ( <i>Thalurania glaucopis</i> )	10	2	8	1
Sapphire-spangled Emerald ( <i>Amazilia lactea</i> )	16	16	8	2
Versicolored Emerald ( <i>Amazilia versicolor</i> )	10	14	7	1
White-throated Hummingbird ( <i>Leucochloris albicollis</i> ) W	6	7	13	-
White-vented Violetear ( <i>Colibri serrirostris</i> ) A	-	26	-	-

## APPENDIX 1. Continuation.

Species	Periods			
	1	2	3	4
Gilded Hummingbird ( <i>Hylocharis chrysura</i> ) A	2	2	2	-
Swallow-tailed Hummingbird ( <i>Eupetomena macroura</i> ) B	3	3	-	4
Black-throated Mango ( <i>Anthracothorax nigricollis</i> ) S	3	9	-	-
Sombre Hummingbird ( <i>Aphantochroa cirrochloris</i> )	10	26	8	2
Black Jacobin ( <i>Melanotrochilus fuscus</i> )	19	35	23	-
Glittering-bellied Emerald ( <i>Chlorostilbon aureoventris</i> ) B	-	2	8	-
Stripe-breasted Starthroat ( <i>Heliomaster squamosus</i> )	5	11	8	-
Amethyst Woodstar ( <i>Calliphlox amethystina</i> )	5	-	-	-
Surucua Trogon ( <i>Trogon surrucura</i> )	42	32	32	20
Ringed Kingfisher ( <i>Ceryle torquata</i> ) C	-	-	-	1
Rufous Motmot ( <i>Baryphthengus ruficapillus</i> )	3	23	8	2
White-eared Puffbird ( <i>Bucco chacuru</i> ) A	-	-	-	1
Rufous-tailed Jacamar ( <i>Galbula ruficauda</i> ) B	19	33	22	9
Toco Toucan ( <i>Ramphastos toco</i> ) B	-	-	15	6
Arrowhead Piculet ( <i>Picumnus albosquamatus</i> )	26	28	48	18
White Woodpecker ( <i>Melanerpes candidus</i> ) A	2	12	15	1
Campo Flicker ( <i>Colaptes campestris</i> ) A	13	19	3	18
Green-barred Woodpecker ( <i>Colaptes melanochloros</i> ) B	10	12	5	-
Little Woodpecker ( <i>Veniliornis passerinus</i> )	59	107	72	28
Lineated Woodpecker ( <i>Dryocopus lineatus</i> )	21	30	52	15
Robust Woodpecker ( <i>Campybilus robustus</i> )	11	16	13	14
Lesser Woodcreeper ( <i>Lepidocolaptes fuscus</i> )	5	58	40	35
Narrow-billed Woodcreeper ( <i>Lepidocolaptes angustirostris</i> ) B	6	2	8	7
Olivaceous Woodcreeper ( <i>Sittasomus griseicapillus</i> )	87	154	133	83
Planalto Woodcreeper ( <i>Dendrocolaptes platyrostris</i> )	2	5	5	1
Rufous Hornero ( <i>Furnarius rufus</i> ) A	5	7	3	5
Sharp-tailed Streamcreeper ( <i>Lochmias nematura</i> )	2	-	-	1
Rufous-breasted Leafscraper ( <i>Sclerurus scansor</i> )	2	-	-	-
Spix's Spinetail ( <i>Synallaxis spixi</i> ) B	35	39	40	17
Sooty-fronted Spinetail ( <i>Synallaxis frontalis</i> ) B	30	33	47	27
Rufous-capped Spinetail ( <i>Synallaxis ruficapilla</i> )	202	196	160	126
Pale-breasted Spinetail ( <i>Synallaxis albescens</i> ) A	-	3	-	-
White-eyed Foliage-Gleaner ( <i>Automolus leucophthalmus</i> )	66	77	47	46
Streaked Xenops ( <i>Xenops rutilans</i> )	39	70	63	12
Tufted Antshrike ( <i>Mackenziaena severa</i> )	120	96	92	39
Spot-backed Antshrike ( <i>Hypodaleus guttatus</i> )	3	-	-	-
Great Antshrike ( <i>Taraba major</i> ) B	21	53	67	52
Barred Antshrike ( <i>Thamnophilus doliatus</i> ) B	18	11	18	11
Rufous-capped Antshrike ( <i>Thamnophilus ruficapillus</i> ) A	3	-	-	-
Variable Antshrike ( <i>Thamnophilus caerulescens</i> )	165	177	120	65
Plain Antvireo ( <i>Dysithamnus mentalis</i> )	50	61	53	43
Ferruginous Antbird ( <i>Drymophila ferruginea</i> )	18	-	-	-
Rufous-winged Antwren ( <i>Herpsilochmus rufimarginatus</i> )	11	3	3	-
Rusty-backed Antwren ( <i>Formicivora rufa</i> ) A	-	-	1	1

## APPENDIX 1. Continuation.

Species	Periods			
	1	2	3	4
White-backed Fire-Eye ( <i>Pyriglena leucoptera</i> )	87	124	72	73
Rufous Gnatcatcher ( <i>Conopophaga lineata</i> )	87	84	75	73
White-rumped Monjita ( <i>Xolmis velata</i> ) A	-	-	-	2
Streamer-tailed Tyrant ( <i>Gubernetes yetapa</i> ) C	2	7	-	-
Blue-billed Black-Tyrant ( <i>Knipolegus cyanirostris</i> ) BW	27	-	10	9
Long-tailed Tyrant ( <i>Colonia colonus</i> )	152	215	153	99
Euler's Flycatcher ( <i>Lathrotriccus euleri</i> )	59	77	80	74
Fuscous Flycatcher ( <i>Cnemotriccus bimaculatus</i> ) B	27	5	7	14
Bran-colored Flycatcher ( <i>Myiophobus fasciatus</i> ) B	22	18	10	6
Yellow-bellied Elaenia ( <i>Elaenia flavogaster</i> ) B	13	30	18	7
White-crested Elaenia ( <i>Elaenia albiceps</i> ) M	11	-	-	-
Small-billed Elaenia ( <i>Elaenia parvirostris</i> ) M	7	-	-	-
Highland Elaenia ( <i>Elaenia obscura</i> ) B	2	3	-	-
Lesser Elaenia ( <i>Elaenia chiriquensis</i> ) AS	6	-	-	-
Gray Elaenia ( <i>Myiopagis caniceps</i> )	74	82	55	33
Greenish Elaenia ( <i>Myiopagis viridicata</i> ) S	6	5	-	1
Greenish Tyrannulet ( <i>Phyllomyias virescens</i> ) W	-	-	2	-
Yellow-olive Flycatcher ( <i>Tolmomyias sulphureus</i> )	58	32	40	37
Common Tody-Flycatcher ( <i>Todirostrum cinereum</i> ) B	2	2	13	7
Gray-headed Tody-Flycatcher ( <i>Todirostrum poliocephalum</i> )	122	152	143	62
Eye-ringed Tody-Tyrant ( <i>Hemitriccus orbitatus</i> )	-	2	5	-
Tawny-crowned Pygmy-Tyrant ( <i>Euscarthmus meloryphus</i> ) AS	-	5	-	1
Eared Pygmy-Tyrant ( <i>Myiornis auriculatus</i> )	66	53	100	33
White-crested Pygmy-Tyrant ( <i>Serpophaga subcristata</i> ) B	2	-	-	1
White-throated Spadebill ( <i>Platyrinchus mystaceus</i> )	2	3	7	2
Cliff Flycatcher ( <i>Hirundinea ferruginea</i> ) A	2	-	-	-
Yellow-browed Tyrant ( <i>Satrapa icterophrys</i> ) B	-	3	-	-
Tropical Pewee ( <i>Contopus cinereus</i> ) BW	6	26	12	2
Southern Beardless-Tyrannulet ( <i>Camptostoma obsoletum</i> ) B	19	12	20	17
Sirytes ( <i>Sirytes sibilator</i> )	6	7	5	-
Short-crested Flycatcher ( <i>Myiarchus ferax</i> ) B	29	54	58	46
Swainson's Flycatcher ( <i>Myiarchus swainsoni</i> ) S	40	53	38	62
Brown-crested Flycatcher ( <i>Myiarchus tyrannulus</i> ) A	10	5	3	6
Streaked Flycatcher ( <i>Myiodynastes maculatus</i> ) BS	43	65	58	35
Variiegated Flycatcher ( <i>Empidonomus varius</i> ) BS	22	42	33	10
Boat-billed Flycatcher ( <i>Megarynchus pitangua</i> ) B	22	33	20	4
Social Flycatcher ( <i>Myiozetetes similis</i> ) B	21	33	28	4
Great Kiskadee ( <i>Pitangus sulphuratus</i> ) B	13	54	25	9
Cattled Tyrant ( <i>Machetornis rixosus</i> ) A	-	2	-	2
Tropical Kingbird ( <i>Tyrannus melancholicus</i> ) BS	45	54	45	38
Fork-tailed Flycatcher ( <i>Tyrannus savana</i> ) AS	6	2	15	18
Sepia-capped Flycatcher ( <i>Leptopogon amaurocephalus</i> )	19	25	27	21
Shear-tailed Gray-Tyrant ( <i>Muscivipra vetula</i> ) BW	-	-	2	-
Swallow-tailed Cotinga ( <i>Phibalura flavirostris</i> ) BW	5	-	-	-

## APPENDIX 1. Continuation.

Species	Periods			
	1	2	3	4
Green-backed Becard ( <i>Pachyrampus viridis</i> ) W	2	3	3	1
Crested Becard ( <i>Pachyrampus validus</i> ) B	2	2	2	-
White-winged Becard ( <i>Pachyrampus polychopterus</i> ) BS	2	18	20	15
Black-tailed Tityra ( <i>Tityra cayana</i> ) S	-	12	3	2
Black-crowned Tityra ( <i>Tityra inquisitor</i> ) V	-	-	2	-
Swallow-tailed Manakin ( <i>Chiroxiphia caudata</i> )	64	47	37	26
Helmeted Manakin ( <i>Antilophia galeata</i> ) A	2	-	-	-
Blue-and-white Swallow ( <i>Notiochelidon cyanoleuca</i> ) B	24	47	27	17
Southern Rough-winged Swallow ( <i>Stelgidopteryx ruficollis</i> ) B	75	100	63	26
White-rumped Swallow ( <i>Tachycineta leucorrhoa</i> ) B	-	-	13	4
Cliff Swallow ( <i>Petrochelidon pyrrhonota</i> ) BN	8	-	-	-
Gray-breasted Martin ( <i>Progne chalybea</i> ) BS	6	9	-	7
Purple Martin ( <i>Progne subis</i> ) BN	2	-	-	-
Plush-crested Jay ( <i>Cyanocorax chrysops</i> ) B	5	-	-	-
Curly-crested Jay ( <i>Cyanocorax cristatellus</i> ) A	2	-	10	5
House Wren ( <i>Troglodytes aedon</i> ) B	3	26	25	18
Black-capped Mockingbird ( <i>Donacobius atricapillus</i> ) C	-	2	-	-
Chalk-browed Mockingbird ( <i>Mimus saturninus</i> ) A	3	9	2	9
Rufous-bellied Thrush ( <i>Turdus rufiventris</i> )	26	53	13	9
Pale-breasted Thrush ( <i>Turdus leucomelas</i> ) B	-	18	8	5
Creamy-bellied Thrush ( <i>Turdus amaurochalinus</i> )	10	49	17	4
White-necked Thrush ( <i>Turdus albicollis</i> )	14	30	35	23
Slaty Thrush ( <i>Turdus nigriceps</i> ) M	2	7	-	-
Yellowish Pipit ( <i>Anthus lutescens</i> ) A	6	-	-	-
Red-eyed Vireo ( <i>Vireo olivaceus</i> ) S	67	79	78	65
Rufous-browed Peppershrike ( <i>Cycarbis gujanensis</i> )	152	173	145	120
Gray-eyed Greenlet ( <i>Hylophilus amaurocephalus</i> ) B	2	-	2	-
Tropical Parula ( <i>Parula pitayumi</i> ) B	3	2	7	1
Masked Yellowthroat ( <i>Geothlypis aequinoctialis</i> ) C	13	11	8	2
White-bellied Warbler ( <i>Basileuterus hypoleucus</i> )	194	247	145	90
Golden-crowned Warbler ( <i>Basileuterus culicivorus</i> ) W	-	-	2	-
Flavescent Warbler ( <i>Basileuterus flaveolus</i> )	79	60	47	59
Bananaquit ( <i>Coereba flaveola</i> ) B	71	75	38	11
Swallow-Tanager ( <i>Tersina viridis</i> ) B	13	30	15	-
Chestnut-vented Conebill ( <i>Conirostrum speciosum</i> )	104	110	106	33
Blue Dacnis ( <i>Dacnis cayana</i> ) B	32	21	23	6
Rufous-headed Tanager ( <i>Hemitraupis ruficapilla</i> )	75	91	67	35
Chestnut-headed Tanager ( <i>Pyrrhocoma ruficeps</i> ) BW	-	-	2	-
Orange-headed Tanager ( <i>Thlypopsis sordida</i> ) B	45	77	53	23
Hooded Tanager ( <i>Nemosia pileata</i> ) B	13	33	35	9
Sayaca Tanager ( <i>Thraupis sayaca</i> ) B	51	84	63	42
Silver-beaked Tanager ( <i>Ramphocelus carbo</i> )	74	56	55	27
Red-crowned Ant-Tanager ( <i>Habia rubica</i> )	14	19	3	16
Ruby-crowned Tanager ( <i>Tachyphonus coronatus</i> )	50	60	42	65

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APPENDIX 1. Continuation.

Species	Periods			
	1	2	3	4
Black-goggled Tanager ( <i>Trichothraupis melanops</i> )	95	86	52	51
Burnished-buff Tanager ( <i>Tangara cayana</i> ) B	14	25	15	5
Fawn-breasted Tanager ( <i>Pipraeidea melanonota</i> ) W	2	-	3	-
Blue-hooded Euphonia ( <i>Euphonia musica</i> ) BW	-	-	30	-
Violaceous Euphonia ( <i>Euphonia violacea</i> ) W	3	2	3	-
Purple-throated Euphonia ( <i>Euphonia chlorotica</i> )	43	39	38	6
Green-winged Saltator ( <i>Saltator similis</i> ) B	3	11	2	7
Black-throated Saltator ( <i>Saltator atricollis</i> ) A	2	-	2	1
Black-throated Grosbeak ( <i>Pitylus fuliginosus</i> )	45	67	48	48
Ultramarine Grosbeak ( <i>Passerina brissoni</i> ) B	6	2	2	2
Red-crested Finch ( <i>Coryphospingus cucullatus</i> ) A	10	-	12	1
Sooty Grassquit ( <i>Tiaris fuliginosa</i> ) W	2	3	5	1
Blue-black Grassquit ( <i>Volatinia jacarina</i> ) B	55	149	110	10
Double-collared Seedeater ( <i>Sporophila caerulescens</i> ) B	58	88	33	12
Wedge-tailed Grass-Finch ( <i>Emberizoides herbicola</i> ) A	-	3	3	1
Grassland Sparrow ( <i>Ammodramus humeralis</i> ) A	-	3	12	11
Rufous-collared Sparrow ( <i>Zonotrichia capensis</i> ) B	66	133	95	78
Saffron-billed Sparrow ( <i>Arremon flavirostris</i> )	37	53	27	23
Chopi Blackbird ( <i>Gnorimopsar chopi</i> ) A	16	-	5	-
Shiny Cowbird ( <i>Molothrus bonariensis</i> ) A	11	53	5	1
Yellow-rumped Marshbird ( <i>Pseudoleistes guiraburo</i> ) A	-	-	18	1
Visits	26	29	26	31
Hours	62.3	57.1	60.1	81.1
Species	184	173	167	162

A: Open-area birds, B: border species, C: creek and marsh birds, M: migrant nesting off south, N: northern migrant, S: summer bird, V: vagrant, W: winter bird.