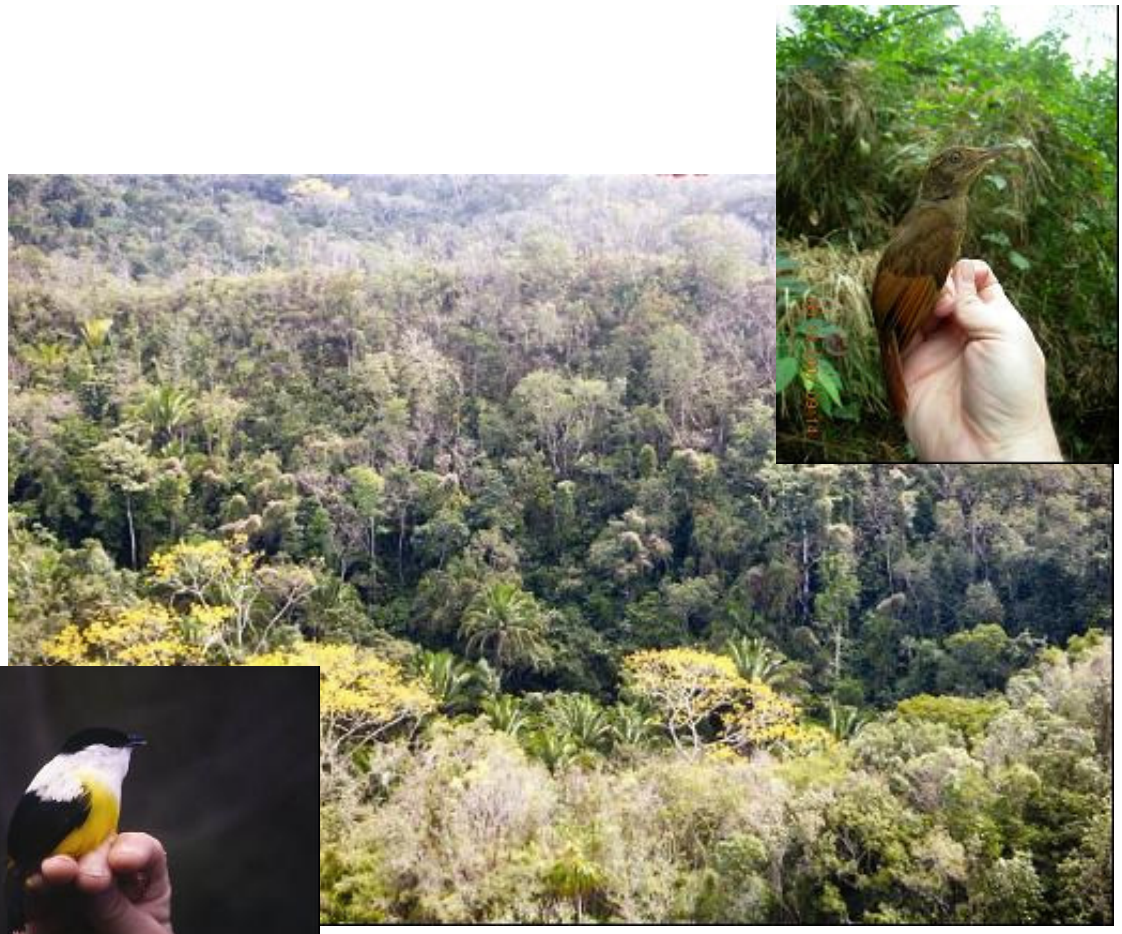
MERCURY IN TERRESTRIAL BIRDS OF BELIZE

(Report BRI 2008-05)



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Photos on front cover are of a Tawny-winged Woodcreeper and White-collared Manakin with a typical Belizean forest cover type in the background. Photos of manakin and forest are by Vicki Piaskowski. All other photos in this report are by D.C. Evers.

MERCURY IN TERRESTRIAL BIRDS OF BELIZE

(Report BRI 2008-05)

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ABSTRACT

Recent evidence of elevated methylmercury (MeHg) levels in songbirds inhabiting temperate North American forests and wetlands has changed governmental approaches for assessing the potential risk and injury of environmental mercury (Hg) loads. This paradigm shift in scientific understanding was extended to tropical forests in Belize in March, 2007. A rapid assessment of the Hg body burdens of songbirds in Runaway Creek Nature Reserve demonstrated elevated levels in both resident songbirds and neotropical migrants. Some species, such as the Hooded Warbler and Northern Waterthrush, had blood Hg burdens that exceeded adverse effect levels normally confined to highly contaminated areas in the U.S. Because blood Hg levels indicate dietary uptake of MeHg during the winter, there is compelling evidence that either tropical habitats are highly sensitive to atmospheric deposition of Hg or large point sources exist nearby. Further efforts are planned to better understand the species, habitats and geographic areas at greatest risk in Runaway Creek Nature Reserve and other areas in Belize.

BACKGROUND

Mercury in the environment: Mercury (Hg) is a growing international concern needing an integrated global response. In China alone, a new Hg-generating coal-burning power plant is being introduced each week. Such concerns are being recognized by the United Nations Environment Programme (Selin 2005, UNEP 2005) with some actions being undertaken through their Global Mercury Assessment Plan. Although scientists have made great strides in understanding Hg in North America (Evers and Clair 2005, Harris et al. 2007) and policy-makers have used this science to make changes in Hg emission regulations (Smith and Tripp 2005), such efforts in tropical regions of the Western Hemisphere are severely lacking.

Despite scientific and policy strides in North America (Evers and Driscoll 2007), they have had little influence on Hg emission and effluent sources in Central America. Further, understanding and awareness of the potential harm from Hg contamination on human and ecological health are not generally realized by medical professionals, agency officials, or the public in Central America. This is particularly alarming since a large proportion of the Central American population rely on seafood, the primary source of potential Hg poisoning. An inadequate knowledge of Hg cycling in terrestrial tropical ecosystems further compounds this issue.

The United Nations Environmental Programme (UNEP) has initiated international efforts supporting a greater understanding of Hg impacts. Through their report "Global Mercury Assessment," the Governing Council has decided to undertake a global assessment of Hg in cooperation with other members of the Inter-Orgnaization Programme for the Sound Management of Chemicals. High priorities in the UNEP report are: (1) assessment and monitoring of Hg in fish and wildlife and (2) the collaboration of nations dealing with this issue.

In a recent UNEP sponsored event, "Regional Awareness-raising Workshop on Mercury Pollution" on 18-21 January 2005 in Port of Spain, Trinidad and Tobago (UNEP 2005), five key questions were developed concerning toxic Hg problems in Central America and the Caribbean Islands:

1. Is there sufficient knowledge of the main sources and quantities of Hg released into the environment?
2. Are the levels of Hg in media and biota sufficiently known?
3. Are there sufficient data on Hg exposure for humans and wildlife?
4. Based on existing data available, what issues and problems are of greatest concern?
5. What are the barriers faced in trying to better understand Hg contamination?

In general, respondents representing 14 Caribbean countries acknowledged both existing data gaps and a paucity of data regarding Hg loading, standardization of Hg data collection, identification of hotspots, and education on Hg poisoning. An electronic information network should be developed to minimize current barriers for better understanding Hg issues at the governmental and public levels.

An understanding and awareness of Hg in tropical ecosystems can be greatly improved by applying known paradigms in North America with local empirical information. An investigation into the potential ecological and human health impacts of Hg in terrestrial and other ecosystems in Belize can provide the insight needed for science-based decision-making. This report focuses on one aspect – Hg levels in birds of terrestrial ecosystems.

Mercury in wildlife: Globally, research increasingly documents the negative effects of Hg on reproductive performance, lifetime productivity, growth and development, behavior, and

survivorship in wildlife (Wolfe et al. 1998, NWF 2006), particularly birds (Evers 2005, Scheuhammer et al. 2007). It is assumed that such bioaccumulation could eventually result in a disruption of ecosystem function (Blaustein et al. 2003).

Piscivorous birds in North America, such as the common loon (*Gavia immer*) and bald eagle (*Haliaeetus leucocephalus*), frequently accumulate elevated levels of Hg that are now shown to cause reproductive impairment in wild breeding populations (DeSorbo and Evers 2008, Evers et al. 2008). However, recent evidence also indicates that invertivore Hg levels within wetland-based foodwebs often exceed those of piscivores (Evers et al. 2005; Cristol et al. *In Press*). For example, along the Sudbury River, Massachusetts (U.S.) Hg levels in the red-winged blackbird (*Agelaius phoeniceus*) ranged up to 9.4 ppm (avg. 4.5 ppm, ww), while belted kingfishers (*Megaceryle alcyon*) only ranged up to 1.3 ppm (avg. 0.84 ppm, ww). Invertivores, birds and other taxa, therefore may be at high risk of significant negative impacts from Hg.

Recent analyses of "hotspots" of Hg bioaccumulation and studies of environmental factors promoting such areas, indicate that biomagnification appears to be most intense in locations receiving both elevated levels of Hg deposition and having key characteristics promoting biological uptake, including: (a) greater Hg methylation in wetlands, particularly areas associated with low pH and/or high dissolved organic carbon, (b) extensive forest canopy, and (c) areas that are experience frequent wetting and drying events (Driscoll et al. 2007, Evers et al. 2007) (Figure 1). Recognition of these factors allows for construction of a predictive model identifying areas and habitats of higher versus lower risk of methylmercury (MeHg) biomagnification.

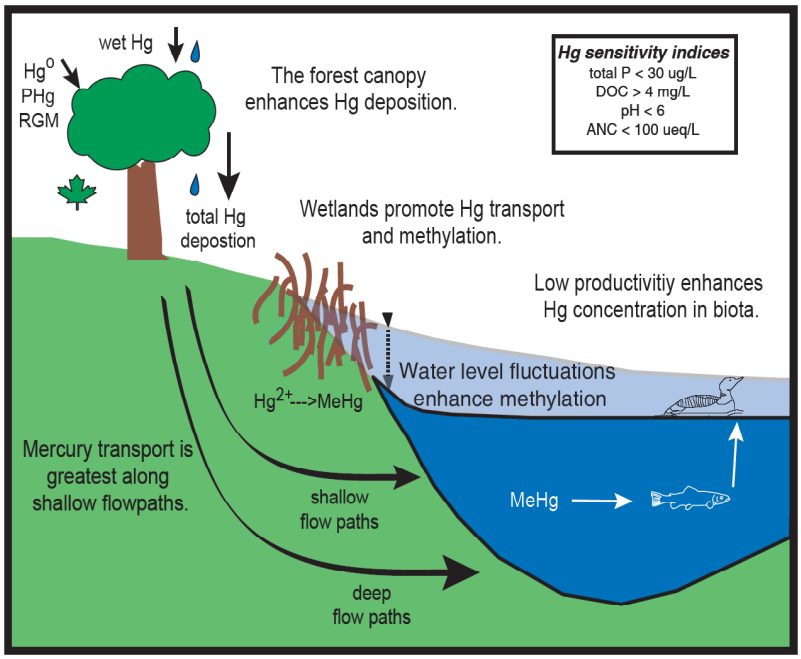

Figure 1. Mercury cycle cartoon.

OBJECTIVES

1. Develop an exposure profile for Hg in terrestrial tropical birds;
2. Document Hg geographic hotspots and habitats with highest Hg levels;
3. Determine Hg sources within hotspots and relate to management and/or changes in policy;
4. Relay information to communities and governmental agencies to increase awareness of potential harm to ecological and human health.

STUDY AREA & METHODS

Study Area: All birds were captured and sampled on the Runaway Creek Nature Reserve (RCNR) with assistance from Birds Without Borders - Aves Sin Fronteras, P.O. Box 97, Belmopan City, Cayo District, Belize. Sampling locations were in upland forests (Figure 2). A description of the habitats and birds in RNCR is characterized by Piaskowski et al. (2005, 2006).

***Figure 2**. Karst hill broadleaf forest in Runaway Creek Nature Reserve, Belize.*

Bird Capture and Sample Collection: We captured birds using 12m mist nets with a 36mm mesh in March 2007 (Figure 3). Sampling efforts were timed so that Hg body burdens measured in the blood would strictly reflect winter MeHg uptake. Nets were checked every 20-40 minutes. Captured birds were removed and placed in cotton holding bags until processing. All birds were released unharmed 15-45 minutes after capture. Birds were captured in the morning.

Figure 3. Upper right, ovenbird briefly caught in mist net. Lower panel from left to right of wood thrush being banded, measured for bill length, and blood sample taken from wing.

All captured birds were banded; neotropical migrants received bands with a U.S. origin and resident birds were fitted with Belizean bands. Birds were often measured for standard wing, tail, tarsi, bill, and mass measurements. We also collected information on age and sex. For all birds, we used 26 gauge disposable needles to puncture a cutaneous ulnar vein in the wing to collect a small blood sample. We also collected second secondary feathers from adults for Hg analysis. Each blood sample was collected in a 75 cc capillary tube, which was then sealed on both ends with Critocaps ® and placed in a labeled plastic 7 cc vacutainer. Generally, 2-4 capillary tubes half-filled with blood were taken. Feathers were placed in a labeled plastic bag and archived for future analyses. All samples were stored in a field cooler with ice, and samples were later transferred to a freezer/refrigerator (blood in the freezer, feathers in the refrigerator).

Blood indicates local diet: Local dietary uptake of MeHg is best represented in the bloodstream of a bird. Although the half-life of MeHg in songbird blood is not known, evidence from other birds indicates that after two months, blood Hg levels of an overwintering songbird will closely reflect MeHg concentrations from the winter diet (Evers et al. 2005, Rimmer et al. 2005).

Sample Analysis: Laboratory analyses were conducted by College of William and Mary, Williamsburg, Virginia, U.S. Blood samples were analyzed for total Hg using direct Hg analyzer DMA 80 by Milestone Inc. Mercury concentrations are presented on a wet weight (ww) basis. Instead of analyzing MeHg levels, we focused on total Hg because it is less costly, and approximately 95% of total Hg in songbird blood is in MeHg form (Rimmer et al. 2005).

RESULTS AND DISCUSSION

A total of 79 birds, representing 21 resident species and 15 neotropical migrants were captured for sampling between 21-24 March, 2007. Of these, 18 resident species (n=31) and 14 neotropical migrants (n=34) had blood samples taken for Hg analysis (Appendix I). Except for the American pygmy kingfisher, all birds sampled were songbirds. Mean blood Hg levels and their comparisons do not include this kingfisher.

Total blood Hg levels were determined for 65 individuals. Mean blood Hg levels (+/- sd) were 0.12 +/- 0.14 ug/g (ww) for resident species and 0.30 +/- 0.59 ug/g (ww) for neotropical migrant species. While a tendency exists for neotropical migrants to have higher blood Hg levels than residents, there is no significant difference between these two bird groups ($t=1.52$, $df=59$, $p=0.13$).

A ranking of species by mean blood Hg levels indicates relatively low blood Hg levels in the majority of species sampled (Figure 4). However, blood Hg levels are more elevated than predicted based on extensive sampling efforts in temperate forests of New England and New York in the United States. Background blood Hg levels for upland forest songbirds in the United States range up to 0.20 ug/g (ww) (Evers and Duron 2006). A total of 32% of the songbird species sampled (n=10/31) included individuals exceeding these background levels (see orange line on Figure 4).

While elevated levels of Hg in RCNR are relatively unexpected, individuals exceeding lowest observed adverse effect levels (LOAELs) are surprising[1]. A preliminary LOAEL used and developed by BioDiversity Research Institute is 1.18 ug/g (ww). In the U.S., this blood Hg level is generally only exceeded at highly contaminated sites, such as U.S. Environmental Protection Agency Superfund sites, and in habitats highly sensitive to Hg input, such as bogs and estuaries.

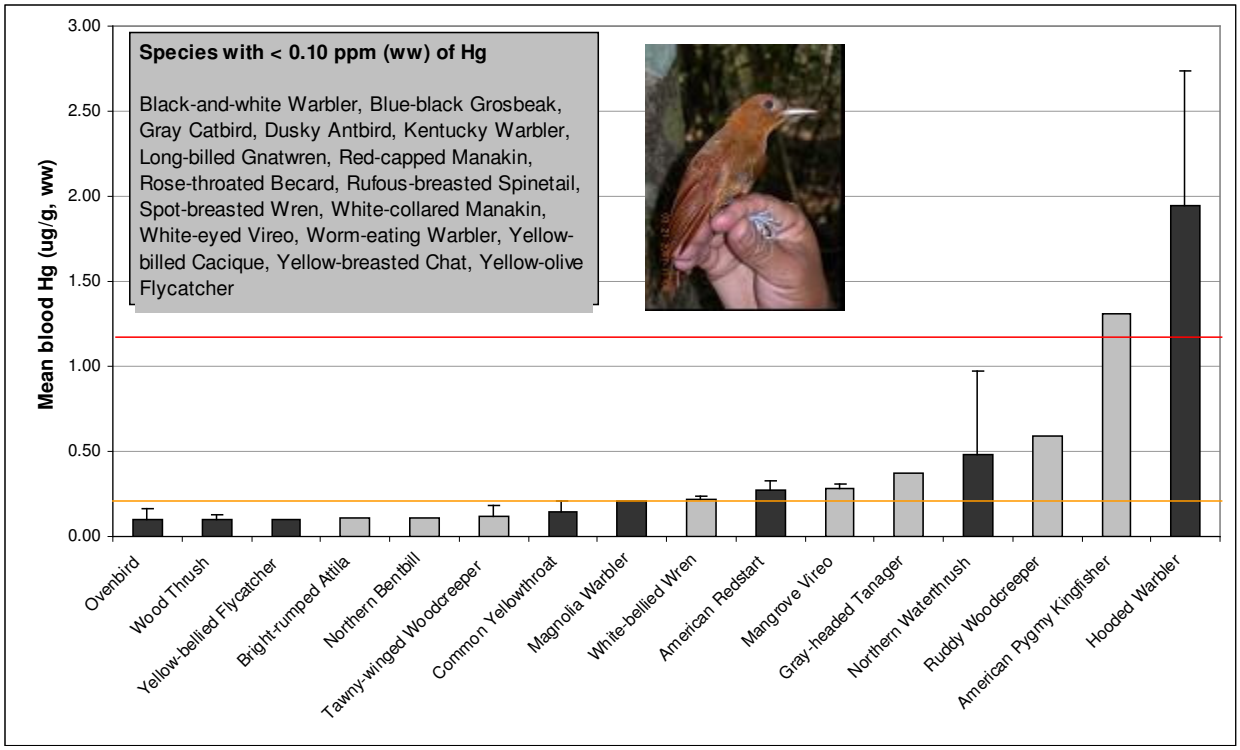

Figure 4. Exposure blood Hg profile for terrestrial tropical birds in central Belize. Orange line indicates background songbird blood Hg levels in upland forests in the U.S., while red line indicates lowest observed adverse effect levels (BRI unpubl. data). Photo of Ruddy Woodcreeper.

In RCNR, two species exceed the LOAEL – Northern Waterthrush and Hooded Warbler. Both species are neotropical migrants. Resident songbird species of greatest concern are the Ruddy Woodcreeper and Gray-headed Tanager. Preliminary comparison of three species at RCNR with corresponding U.S. locations, with and without Hg point sources, indicates several patterns (Figure 5): (1) locations in the U.S. not having point sources tend to be lower in blood

[1] LOAELs are based on unpublished models by BioDiversity Research Institute and are part of a federal effort that establishes the level of impaired reproductive success in songbirds (G. Heinz, pers. com.).

Hg levels than RCNR; (2) some species, such as the Hooded Warbler, have blood Hg levels in RCNR that exceed those levels found at contaminated sites in the U.S.; and (3) some species could encounter highly elevated MeHg concentrations in both their breeding and wintering areas.

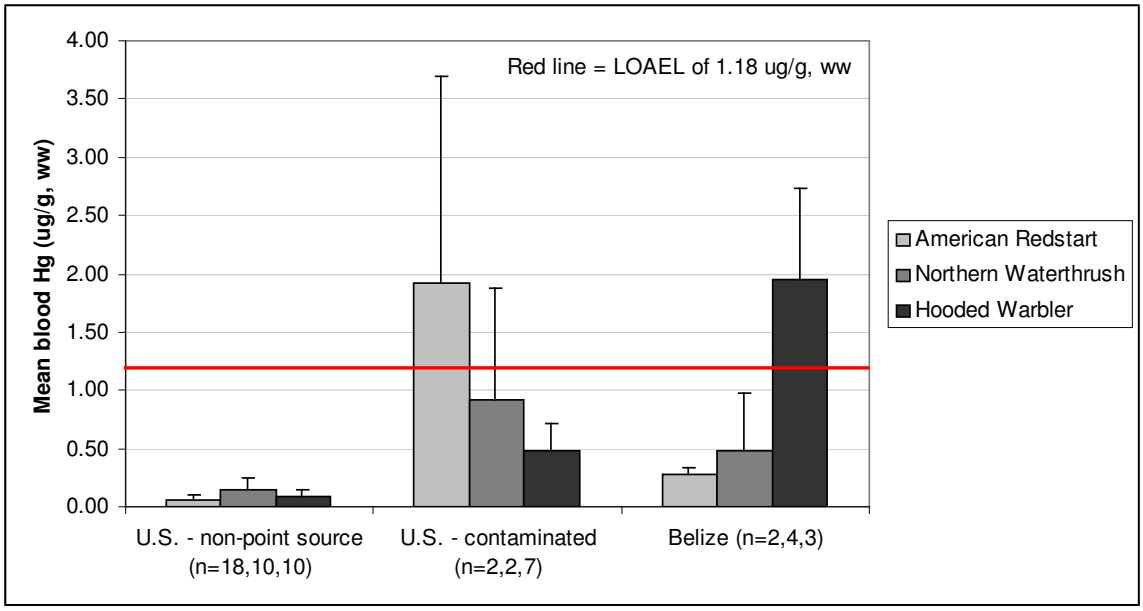

Figure 5. Comparison of blood Hg levels for three neotropical migrants - U.S. vs. Belize. Red line indicates lowest observed adverse effect levels (BRI unpubl. data).

CONCLUSIONS

Although Belize is considered a country with few sources of Hg emissions and effluents, environmental Hg loads appear to be elevated. In some areas and for some species, MeHg availability is above lowest observed adverse effect levels for songbirds[2]. Reasons for elevated levels in Runaway Creek Nature Reserve are likely not unique to this protected area. Although knowledge of the transport and cycling of Hg in aquatic and terrestrial ecosystems is poorly understood for the tropics (Lacher and Goldstein 1997), wetland habitats are likely sensitive to Hg methylation as are high trophic invertivores, such as those feeding in foodwebs that regularly include spiders. These are potentially the places and taxa at greatest risk. Further efforts to better quantify the exposure and effects of Hg at Runaway Creek Nature Reserve in songbirds and other biota will elucidate mechanisms of MeHg transport in the foodweb and establish linkages with sources. Such efforts will also contribute toward a better understanding of potential harm to human health by identifying food items and locales with greatest Hg risk.

[2] The endpoint used to determine significant effect levels was egg hatching success in a laboratory dosing study.

RECOMMENDATIONS

1. Continue sampling resident and neotropical migrant birds in RCNR to establish a Hg exposure profile for the bird community;
2. Emphasize sampling species that exhibit elevated blood Hg levels, including the Hooded Warbler, Northern Waterthrush, and species of woodcreepers;
3. Identify habitats potentially sensitive to Hg input (e.g., wetlands) and establish sampling stations that can be repeatedly monitored;
4. Sample invertebrate communities and other invertivores (e.g., bats) to better understand the mechanisms of MeHg cycling in terrestrial tropical habitats.

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AMERICAN PYGMY KINGFISHER

APPENDIX I. List of species and numbers captured in Belize, March 21-24, 2007.

Species	Genus	Species	Number Captured	Number Sampled
American pygmy kingfisher	Chloroceryle	aenea	2	1
American redstart	Setophaga	ruticilla	2	2
black-and-white warbler	Mniotilta	varia	2	2
blue-black grosbeak	Cyanocompsa	cyanoides	1	1
blue-winged warbler	Vermivora	pinus	1	
bright-rumped attila	Attila	spadiceus	1	1
common yellowthroat	Geothlypis	trichas	2	2
dusky antbird	Cercomacra	tyrannina	4	3
gray catbird	Dumetella	carolinensis	5	5
gray-headed tanager	Eucometis	penicillata	1	1
gray-throated chat	Granatellus	sallaei	1	
hooded warbler	Wilsonia	citrina	5	4
Kentucky warbler	Oporornis	formosus	2	2
long-billed gnatwren	Ramphocaenus	melanurus	1	1
magnolia warbler	Dendroica	magnolia	2	2
mangrove vireo	Vireo	pallens	7	3
northern bentbill	Oncostoma	cinereigulare	1	1
northern waterthrush	Seiurus	noveboracensis	4	4
ovenbird	Seiurus	aurocapilla	4	4
red-capped manakin	Pipra	mentalis	3	2
rose-throated becard	Pachyramphus	aglaiae	1	1
ruddy woodcreeper	Dendrocincla	homochroa	1	1
rufous-breasted spinetail	Synallaxis	erythrothorax	1	1
spot-breasted wren	Thryothorus	maculipectus	3	2
tawny-winged woodcreeper	Dendrocincla	anabatina	2	2
white-bellied Wren	Uropsila	leucogastra	2	2
white-collared manakin	Manacus	candei	3	3
white-collared seedeater	Sporophila	torqueola	2	
white-eyed vireo	Vireo	griseus	3	1
wood thrush	Hylocichla	mustelina	2	2
worm-eating warbler	Helmitheros	vermivorus	2	2
yellow billed cacique	Amblycercus	holosericeus	3	2
yellow-bellied flycatcher	Empidonax	flaviventris	1	1
yellow-breasted chat	Icteria	virens	3	3
yellow-green vireo	Vireo	flavoviridis	1	
yellow-olive flycatcher	Tolmomyias	sulphurescens	1	1
			82	**65**