



THE NEOTROPICAL FLYWAYS PROJECT

Connectivity and Migratory Bottlenecks of Canada's Declining Migratory Birds



Olive-sided Flycatcher
Photo – Yuly Caicedo

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SELVA: Investigación para la Conservación en el Neotropico is a not-for-profit organization dedicated to undertaking rigorous research in benefit of the biodiversity and people of the Neotropics

Connectivity and Migratory Bottlenecks of Canada's Declining Migratory Birds

AT A GLANCE

- Over **one billion migratory landbirds** migrate between the Neotropics and N. America.
- Despite this massive movement of birds, the routes and strategies that migratory landbirds adopt in the Neotropics are almost completely unknown
- Worryingly, migration contributes **disproportionately to annual mortality**, yet most protective measures are focused on breeding and wintering habitat
- Only by identifying the **stopover sites & habitats** where birds accumulate the energy reserves for migration can we identify their needs at all stages of their life cycle
- The **Neotropical Flyways Project** aims to identify critical stopover regions and habitats across five Central American countries and the Caribbean coast of Colombia
- **Panama and Costa Rica** form a highly strategic region along the migration routes of many species
- We undertook **occupancy surveys** across Panama (fall 2017) and Costa Rica (2018)
- In Panama, we recorded **46,125** individuals of **63 species** of migratory landbirds during transects and **220,022 individuals** of **15 species** through migration counts
- In Costa Rica, **11,983** individuals of **53 species** were recorded on transects
- **Canadian at risk** species making stopovers in the region included: Olive-sided Flycatcher, Eastern Wood-pewee, Acadian Flycatcher, Cerulean Warbler and Canada Warbler
- A pilot capture-resighting study with **Cerulean Warbler** revealed **8-day stopovers** in Costa Rica
- An occupancy model for **Canada Warbler** reveals key stopover areas at mid-elevations primarily in Costa Rica's Cordillera Central and the Serranía de Talamanca in Panama and Costa Rica
- Likely critical regions for birds on stopover with **no current protection** include: 1) the foothills (500-1000 m) of the Caribbean slope of the Cordillera Central in Costa Rica and portions of the Serranía de Talamanca in the Central Valley of Costa Rica and in Panama

BACKGROUND

Close to 300 species of landbirds, whose combined populations represent billions of birds, migrate between the Neotropics and North America. Many of these species make an annual round trip of over 10,000 km, and those species that migrate farthest are often those experiencing the greatest declines. For many species, migration is by far the greatest source of mortality during their annual cycle, such that degradation of major stopover sites can lead to significant declines, threatening the viability of populations across the Western Hemisphere.

To successfully migrate between their breeding and wintering grounds, Nearctic-Neotropical migrants typically depend on a series of (stopover) sites along the length of their migratory route, which provide critical resources such as the fuel for migratory flights, safe roosting sites, and refuges where birds can make emergency stops. Outside of North America, the funnel-shaped geography of Central America and the biogeography of northern Colombia, act as bottlenecks, concentrating millions of migratory landbirds into a tiny area (relative to their breeding grounds), magnifying the importance of Neotropical stopover sites. Birds migrating through this region may also face major barriers such as the Caribbean Sea and Gulf of Mexico, necessitating the existence of vital stopover regions where the fuel for a safe crossing can be attained. Indeed, recent work in Colombia has highlighted the enormous influence that individual stopover sites can have on migratory journeys. These findings highlight an urgent need to identify Neotropical stopover regions.

To address this need, the ***Neotropical Flyways Project*** (NFP) has been operating since 2016 with the goals of: (1) rapidly discover and map new stopovers sites; (2) determine habitat quality and stopover behavior at these sites; (3) develop conservation strategies at key stopover sites; and (4) train and build capacity among in-country biologists and managers to protect sites and continue long-term monitoring. The scope of the NFP currently extends to six countries in Central and South America. Among these, Panama and Costa Rica are expected to be key regions along the routes of many species, with recent evidence implying the existence of a major stopover region on the Caribbean slope of Costa Rica for the declining and Vulnerable Cerulean Warbler (<http://www.cerulea.org>), as well as for Canada Warbler in the Talamanca mountains. Lower Central America is a highly strategic region for migratory birds, being one of the narrowest points along the entire Central American corridor. This causes millions of birds to concentrate along very narrow flyways, increasing the value of the habitats they use there. Understanding how migratory birds use the diversity of habitats and regions present in Panama and Costa Rica is therefore a priority for the NFP.

In this report, we present results from occupancy surveys carried out across Panama during fall 2017 and Costa Rica during fall 2018 that were designed to identify key stopover areas. We also present the first generation of occupancy models for Canada Warbler based on data from Costa Rica, Panama and Colombia.

METHODS

A series of study sites were established across Panama (8 primary sites) and Costa Rica (11 primary sites) in order to cover the main elevation and precipitation gradients present in the region (**Fig. 1 & 2**). Sites were also selected to cover the geography of both countries, bearing in mind where migratory birds would be expected to arrive or be concentrated by local geography.

At each site we deployed the same methodology consisting of four different protocols: passive transects; playback points; foraging observations; and migration counts (see below). In addition, a mist-netting station was established in Costa Rica and Cerulean Warbler were marked with individual color bands to facilitate Resightings and the estimation of stopover durations.

Figure 1. Study sites across Panama (2017) and Colombia (surveyed in 2016) covering the main gradients of elevation and precipitation.

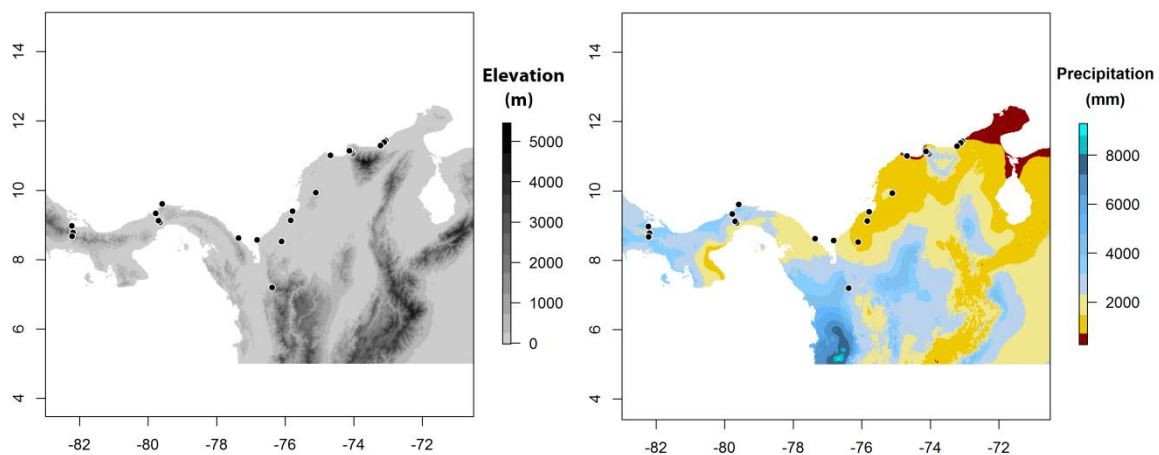
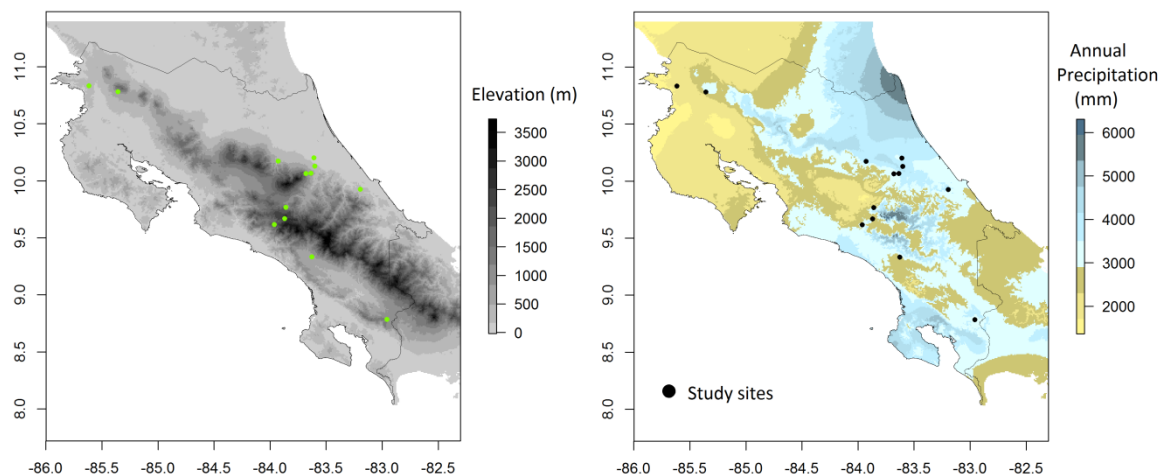


Figure 2. Eleven primary study sites and two sub-sites were established across Costa Rica covering the main gradients of elevation and precipitation.



Protocols

OCCUPANCY SURVEYS - PASSIVE TRANSECTS

- 21 August through 3 November 2017 & 2018
- 19 primary study sites, 2 sub-sites
- 8 transects (100 m in length) established per site
- Transects 150 m apart and surveyed during 10 minutes
- Transects visited on four occasions in each of seven periods (each 10 days long)
- All migratory birds heard and seen were recorded
- 28 repetitions of each transect spread across fall migration



OCCUPANCY SURVEYS - PLAYBACK POINTS

- 21 August through 3 November 2017 & 2018
- Speaker placed in the middle of each transect
- Reproduction of owl mobbing sequence during 6 minutes
- All migrants attracted to recording noted
- One playback per transect per period
- A total of 7 playbacks per transect during the study period



FORAGING OBSERVATIONS

- Timed observations of individual birds
- All attacks with bill recorded
- Attacks characterized as being directed towards: an insect, fruit or a flower
- Duration, habitat and substrate attacks recorded



TIMED MIGRATION COUNTS

- 21 August through 3 November 2017 & 2018
- Point were established across several sites for counts
- Counts lasted between 10 minutes and two hours



CAPTURE –RESIGHTINGS OF CERULEAN WARBLER COSTA RICA

- 25 August through 10 September 2018
- Capture of Cerulean Warblers and color banding
- Led by Ernesto Carman from Proyecto Cerulea



RESULTS

The following section is divided into three sub-sections covering Panama, Costa Rica and occupancy modeling for Canada Warbler.

PANAMA – FALL 2017

2105 repetitions of 100 individual transects (**Table 1**)

46,125 individuals of **63 species** of migratory landbirds recorded on transects (**Table 2**)

220,022 individuals of **15 species** recorded on migration counts (**Table 3**).

Migration phenology

Marked variation between species – early arrivers may be making stopovers (**Figure 4**)

Early birds: Western Wood-Pewee, Blackburnian Warbler, Canada Warbler, Olive-sided Flycatcher

Multiple hurricanes appeared to delay migration in several species e.g. Scarlet Tanager

Migrant Community

63 species of migratory landbirds

3 classed as **near-threatened or vulnerable**, 11 on the North American Watchlist (**Table 2**)

Commonest species included Canada Warbler, Western Wood-Pewee and

Blackburnian Warbler en route to South America (**Figure 3**)

High concentration of diurnal raptors over Sendero La Gloria (**Table 3**)

Aerial insectivores abundant on Caribbean slope of Central region (**Table 2 & 3**)

Patterns by region and elevation

Species of concern more abundant in the Serranía de Talamanca: Cerulean, Golden-winged, and Canada Warblers, Olive-sided Flycatcher (**Table 2**)

Species with preference for higher elevations: Blackburnian Warbler, Canada Warbler

Mid-elevations: Swainson's Thrush, Bay-breasted Warbler

More generalist: Red-eyed Vireo, Summer Tanager

Foraging Sequences

365 foraging sequences were recorded for 28 species, totaling 30,990 seconds

9 of 14 commonest species insectivores, 5 also consumed fruit, including Bay-breasted Warbler

Stopovers

Occupancy rates support stopovers (**Figure 6**)

Show highland concentrations for Blackburnian, Canada Warbler and Western Wood-Pewee

Analyses in progress to identify patterns in other species

Table 1. Survey effort across study sites in Panama between 4 September and 27 October 2017.

Study Site	No. Transects Established	Passive Transects (Number of Repetitions)	Playback Points (Number of repetitions)	Migration Counts (minutes)
1. Canopy Tower	8	204	46	0
2. Gamboa	8	191	42	275
3. Sierra Llorona	20	441	111	796
4. Puerto Lindo	14	304	76	390
5. Valle de la Mina	20	439	109	75
6. Fortuna Cabins	14 (+4)	288	57	115
7. RF Palo Seco	6	62	17	0
8. Sendero la Gloria	6 (+2)	176	6	1229

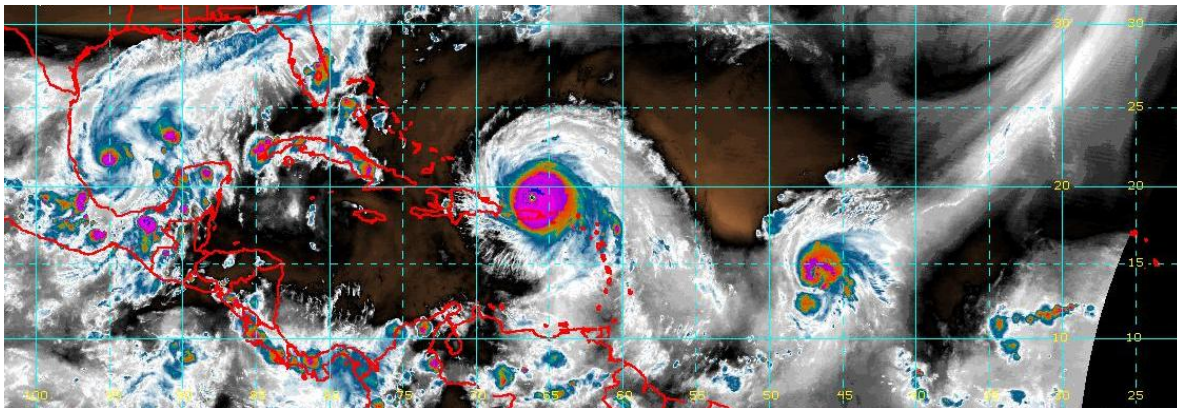
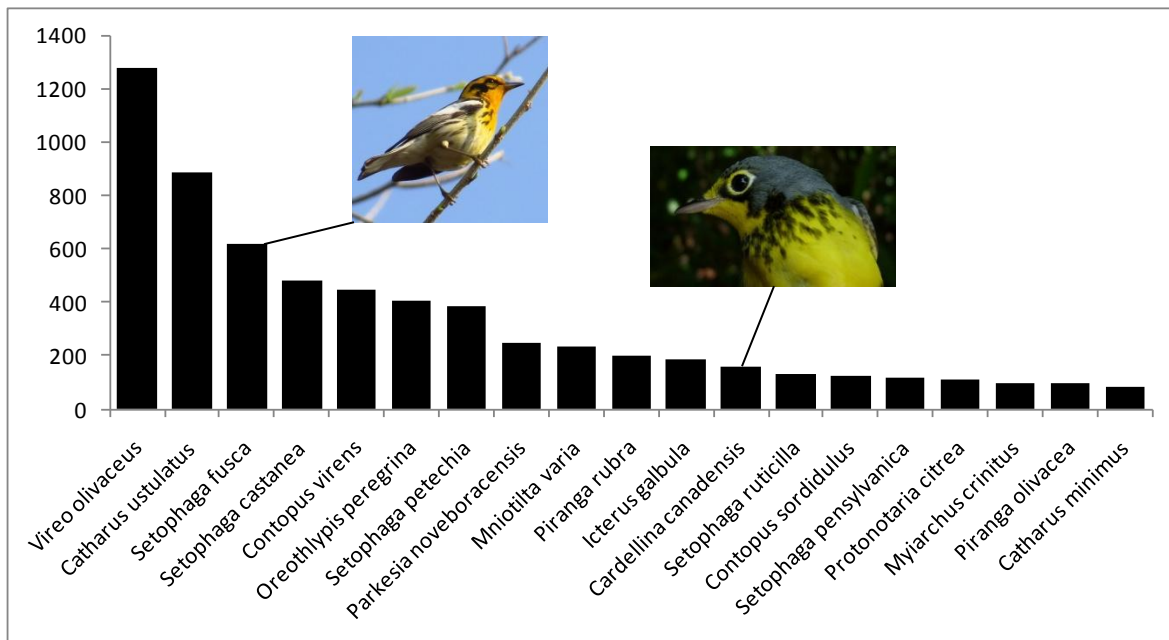
*Hurricanes in the Caribbean Basin during September 2017.***Figure 3.** The 20 most abundant migratory landbirds during surveys in Panama, excluding birds overflying study sites.

Figure 4. Fall migration phenology of 12 migratory landbirds based on totals recorded during transects and playback points in each of six equal periods between September and October 2017.

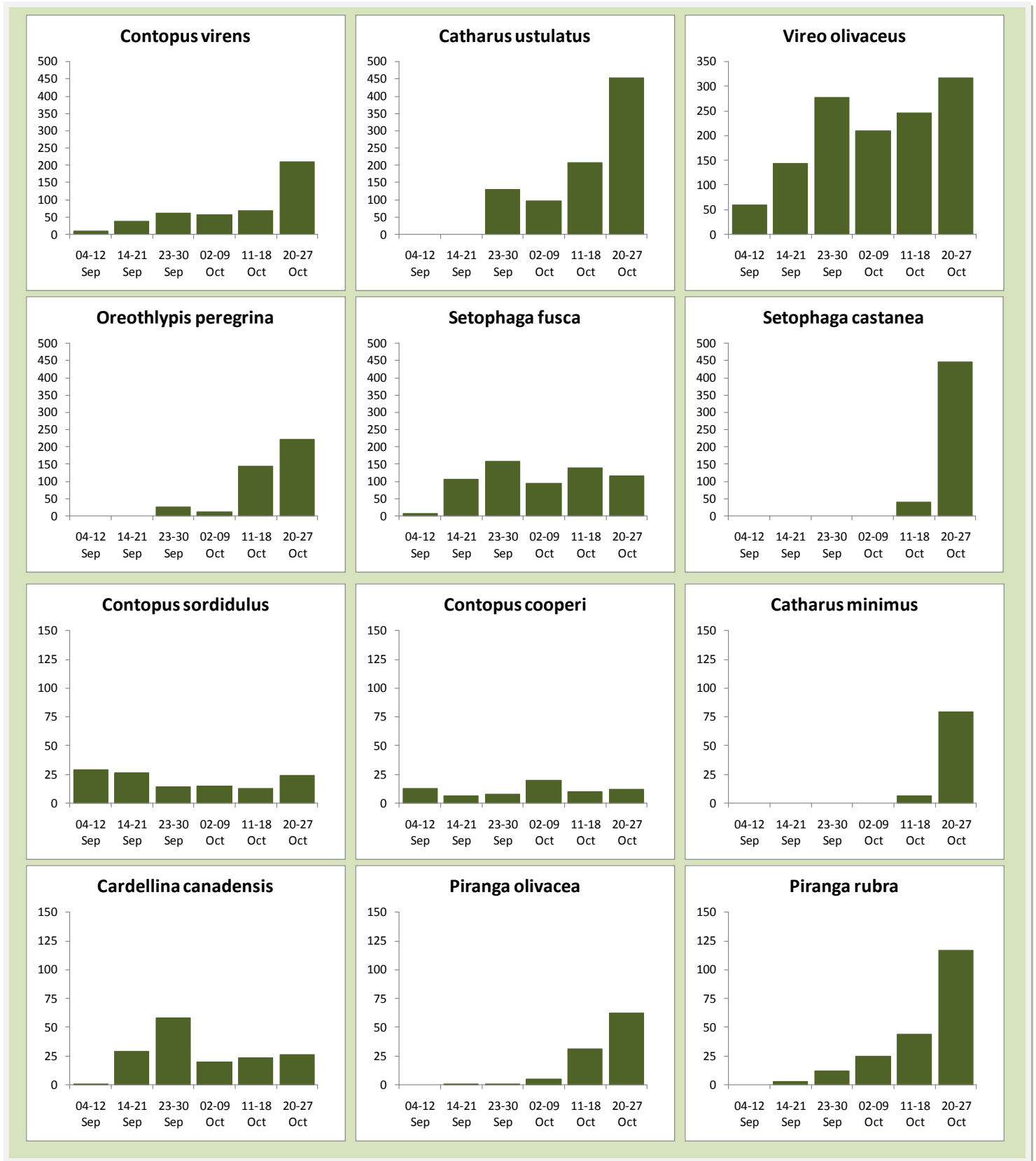


Table 2. Total number of individuals by species recorded at each of the eight study sites in Panama through passive transects and playback points between the 4 September and 27 October 2017.

Common Name	Puerto Lindo	Gamboa	Canopy Tower	Sierra Llorona	Valle de la Mina	Fortuna Cabins	RF Palo Seco	Sendero la Gloria	Total
	Elevation 15 m	50 m	100 m	255 m	1200	800 m	500 m	100 m	
Turkey Vulture	660	800	175					18	1653
Osprey	5	4		4				16	29
Swallow-tailed Kite								20	20
Mississippi Kite		6	189	20				15708	15923
Broad-winged Hawk	14	1204	189	9				8383	9799
Swainson's Hawk		142	26	1				208	377
Merlin	1			4				2	7
Peregrine Falcon	12	1		3					16
Black-billed Cuckoo YL						1			1
Yellow-b. Cuckoo CD CO	2			3		1			6
Common Nighthawk CD	3	1	2	123					129
Black Swift YL CO								81	81
Chimney Swift CD CO	41	52		1366				111	1570
Olive-s. Flycatcher NT CO	3	4	4	3	12	1		42	69
Eastern Wood-Pewee CO	38	47	88	161	22	27	7	54	444
Western Wood-Pewee			5	2	49	35	3	27	121
Acadian Flycatcher CO		4	28	8	6	9	1	6	62
Willow Flycatcher	2								2
Alder Flycatcher	2		1	2					5
Trails Flycatcher	1			2	2	7	2	9	23
Great-crested Flycatcher	2	7	8	69	11		2	1	100
Sulphur-bellied Flycatcher	4	2		6					12
Eastern Kingbird	318		20	203				270	811
Gray Kingbird	3								3
Bank Swallow CO	276	141	213	409				266	1305
Barn Swallow CD CO	1353	123	43	258				333	2110
Cliff Swallow	144	44	23	163	48			285	707
Swallow sp.					109	53		4493	4655
Veery	1		3	9	7	3			23
Gray-cheeked Thrush	1	4	27	27	22	4			85
Swainson's Thrush	42	27	72	99	379	145	3	120	887
Gray Catbird						2			2
Yellow-throated Vireo	1	1	3	2	16		1		24

Common Name	Puerto Lindo	Gamboia	Canopy Tower	Sierra Llorona	Valle de la Mina	Fortuna Cabins	RF Palo Seco	Sendero la Gloria	Total
Red-eyed Vireo	83	45	93	389	337	221	62	47	1277
Yellow-green Vireo					32	12	3		47
Black-whiskered Vireo	1								1
Baltimore Oriole	36	7	3	89	33	6		15	189
Orchard Oriole	1								1
Black-and-white Warbler	5	6	7	20	162	27	2	7	236
Golden-w. Warbler NT CO				1	8	3			12
Tennessee Warbler	71	12	10	167	102	25	4	13	404
Yellow Warbler	172	171	1	26		1	3	10	384
Chestnut-sided Warbler	2	18	8	5	28	27	4	23	115
Cerulean Warbler VU CO					4	3	2		9
Blackburnian Warbler	4	2	1	15	291	202	75	31	621
Magnolia Warbler	2			6					8
Palm Warbler				2					2
Bay-breasted Warbler	49	61	51	190	34	71		29	485
American Redstart	10		5	13	98	2		1	129
Northern Waterthrush	77	39	17	1	57	21	3	32	247
Louisiana Waterthrush CO	1				4	2	1		8
Prothonotary Warbler CO	102	8		1					111
Worm-eating Warbler	3				3				6
Common Yellowthroat	1			1	1	6			9
Kentucky Warbler YL					2	1			3
Mourning Warbler	2	10		5	11	26			54
MacGillivray's Warbler						1			1
Canada Warbler YL CO	2	1	9	8	98	26	5	9	158
Wilson's Warbler CD					70				70
Summer Tanager	25	12	6	63	45	36		15	202
Scarlet Tanager	11	1	3	49	7	20		9	100
Bobolink YL CO	1								1
Dickcissel	17	2		92					111
Indigo Bunting	2							2	4
Rose-breasted Grosbeak	3	4		4	11	30			52

YL = Yellow listed species in North America; **CD** = Common species showing sharp declines; **NT** = Near-threatened; **VU** = Vulnerable; **CO** = COSEWIC Species defined as at risk in Canada

Table 3. Total number of diurnally migrating landbirds recorded over 6 study sites in Panama between September and October 2017. Counts were typically carried out once every 10 days at each site.

Common Name	Puerto Lindo	Gamboia	Sierra Llorona	Valle de la Mina	Fortuna Cabins	Sendero la Gloria	Total
Turkey Vulture	98	1150	43			12702	13993
Osprey	1	5				74	80
Swallow-tailed Kite						47	47
Mississippi Kite		8				33819	33827
Broad-winged Hawk	14	560	45			90153	90772
Swainson's Hawk		15				26771	26786
Hawk sp.						13883	13883
Merlin						9	9
Peregrine Falcon	10	2	15			4	31
Common Nighthawk CO	1098	8	1654				2760
Black Swift CO			80				80
Chimney Swift	331		66			1578	1975
Bank Swallow CO	223	68	960			585	1836
Barn Swallow CO	1057	96	619			4014	5786
Cliff Swallow	898	100	1998	200		3102	6298
Swallow sp.						21856	21856
Dickcissel	3						3
	3733	2012	5480	200	0	208597	220022



COSTA RICA – FALL 2018

2981 repetitions of 104 individual transects

11,983 individuals of **53 migrant landbird species** recorded on transects/playbacks (**Table 4**)

37,709 individuals of **14 species** recorded on migration counts

Top 20 most abundant species included Cerulean Warbler and Acadian Flycatcher (**Fig. 5**)

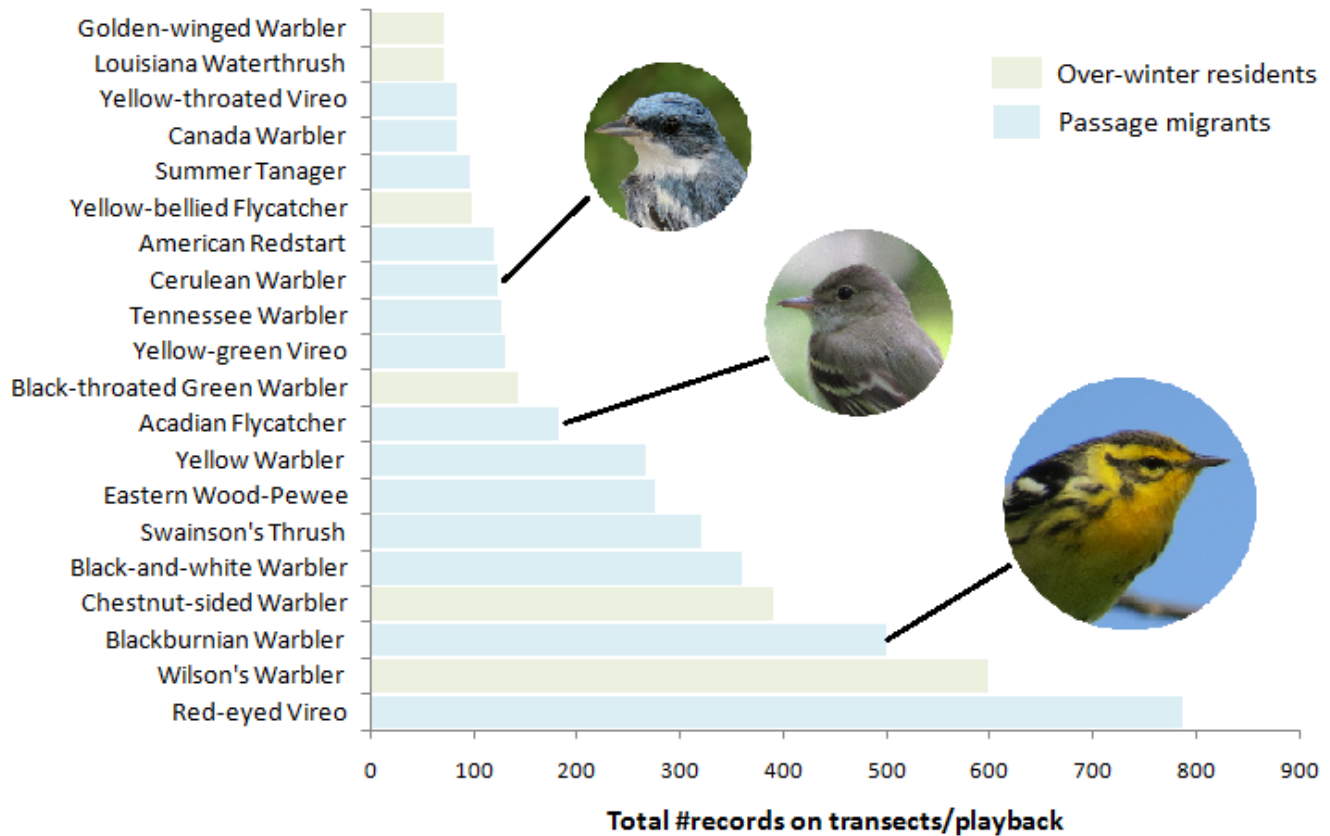


Figure 5. Top 20 migratory landbirds recorded on transects and during playback in Costa Rica.

Foraging Sequences

341 foraging sequences were recorded for **30 species**, totaling 18,845 seconds

42 sequences for Cerulean Warbler covering 2,306 seconds

Capture-Resightings Cerulean Warbler

11 Cerulean Warblers were marked with individual color bands

9 individuals were resighted at least one day later

Longest stopover = **8 days**



	Site	Las Brisas Erick	Veragua Rainforest	Las Brisas Arriba	Ojo de Agua	Rio Macho	Cerro de la Muerte - Madre Selva	Santa Maria - Nubotropico	San Vito	Los Cusingos	Rincón de la Vieja	Santa Rosa
	Average elevation	250 m	400 m	850 m	1300 m	1540 m	2525 m	2075 m	1200 m	700 m	825 m	290 m
	Region	Caribbean lowlands		Caribbean Slope		Serranía de Talamanca			Pacific slope moist		Pacific dry	
Sulphur-bellied Flycatcher	<i>Myiodynastes luteiventris</i>	5	6								4	3
Eastern Kingbird	<i>Tyrannus tyrannus</i>		3									
Western Kingbird	<i>Tyrannus verticalis</i>											1
Bank Swallow ^{CD CO}	<i>Riparia riparia</i>	62	124	5								6
Barn Swallow ^{CO}	<i>Hirundo rustica</i>	30	273	1	10							7
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>	177	2907	17			33	7			78	9
Veery	<i>Catharus fuscescens</i>		5	1	2							
Gray-cheeked Thrush	<i>Catharus minimus</i>	2	9	1								
Swainson's Thrush	<i>Catharus ustulatus</i>	27	169	70	9	1		22	1	7	10	4
Yellow-throated Vireo	<i>Vireo flavifrons</i>	4		1	1	8		13	6	2	13	35
Philadelphia Vireo	<i>Vireo philadelphicus</i>					5	1	1			2	1
Red-eyed Vireo	<i>Vireo olivaceus</i>	142	285	158	47	26		1	16	4	23	75
Yellow-green Vireo	<i>Vireo flavoviridis</i>	1	5	1						4		119
Baltimore Oriole	<i>Icterus galbula</i>	2	2	2	1	1		2	7			1
Black-and-white Warbler	<i>Mniotilta varia</i>	11	4	62	14	48	37	89	45	9	32	3
Golden-winged Warbler ^{NT CO}	<i>Vermivora chrysoptera</i>	4		6	2	15	7	21	6	4	6	
Tennessee Warbler	<i>Oreothlypis peregrina</i>			4			4	10	17	11	17	64
Yellow Warbler	<i>Setophaga petechia</i>	3				1				20	13	229
Chestnut-sided Warbler	<i>Setophaga pensylvanica</i>	68	19	61	2	17			145	72		7
Cerulean Warbler ^{VU CO}	<i>Setophaga cerulea</i>	19	6	59	7	2					3	5

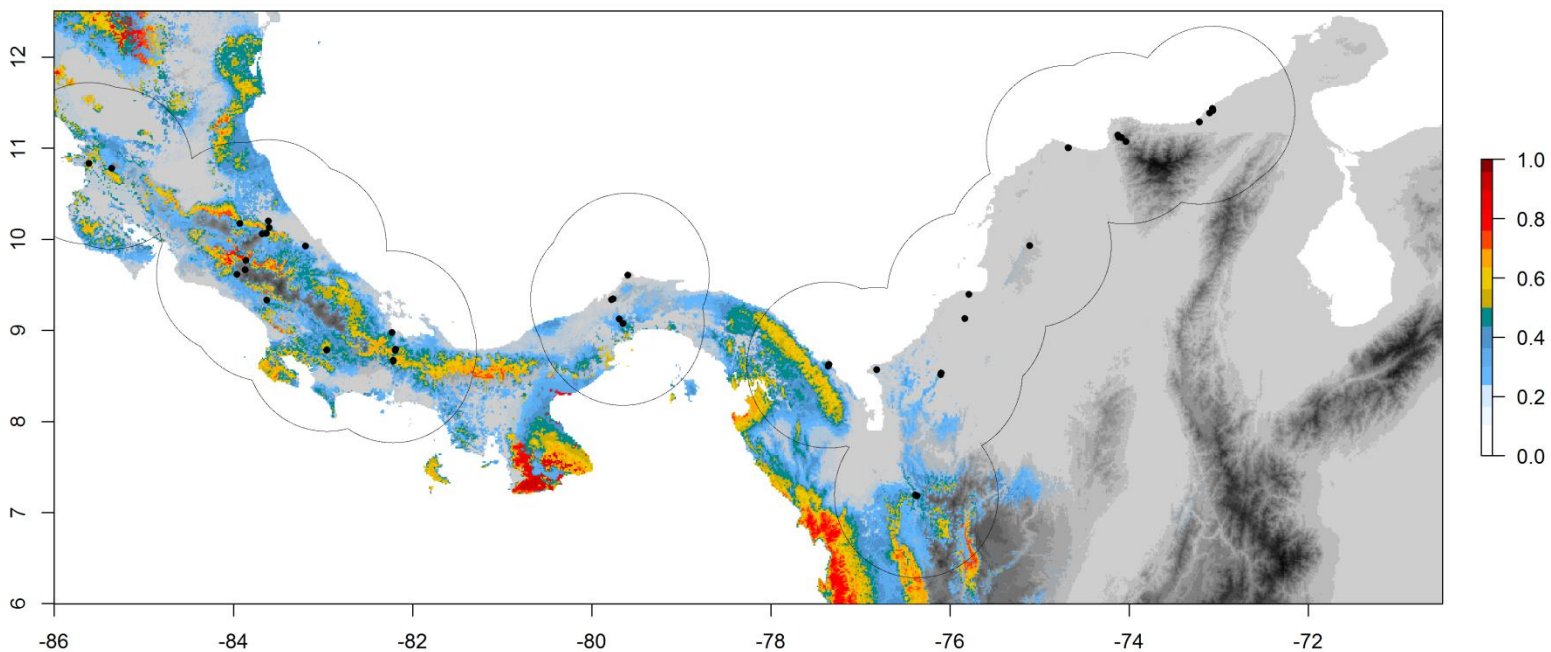
		Las Brisas Erick	Veragua Rainforest	Las Brisas Arriba	Ojo de Agua	Rio Macho	Cerro de la Muerte - Madre Selva	Santa Maria - Nubotropico	San Vito	Los Cusingos	Rincón de la Vieja	Santa Rosa
	Site											
	Average elevation	250 m	400 m	850 m	1300 m	1540 m	2525 m	2075 m	1200 m	700 m	825 m	290 m
	Region	Caribbean lowlands		Caribbean Slope		Serranía de Talamanca			Pacific slope moist		Pacific dry	
Townsend's Warbler	<i>Setophaga townsendi</i>						4	3				
Black-throated G. Warbler	<i>Setophaga virens</i>				1	4	78	60				
Blackburnian Warbler	<i>Setophaga fusca</i>	14	28	109	68	90	22	85	42	2	13	25
Bay-breasted Warbler	<i>Setophaga castanea</i>	29	7	20	2							
American Redstart	<i>Setophaga ruticilla</i>	13	5	65	4	4			8	3		4
Ovenbird	<i>Seiurus aurocapilla</i>	1						1			6	
Northern Waterthrush	<i>Parkesia noveboracensis</i>			1					11			26
Louisiana Waterthrush ^{CO}	<i>Parkesia motacilla</i>	1		13		31	14	4		1	6	
Prothonotary Warbler ^{CO}	<i>Protonotaria citrea</i>					1			1			3
Worm-eating Warbler	<i>Helmitheros vermivorum</i>										8	
Kentucky Warbler ^{YL}	<i>Geothlypis formosus</i>	1		5	1						13	7
Mourning Warbler	<i>Geothlypis philadelphia</i>								4			1
Canada Warbler ^{YL CO}	<i>Cardellina canadensis</i>	17	5	16	4	6	1	3	1	2	10	19
Wilson's Warbler ^{CD}	<i>Cardellina pusilla</i>			1	1	80	279	228	5		3	1
Summer Tanager	<i>Piranga rubra</i>	8	6	6	12	19	1	15	21	3	4	1
Scarlet Tanager	<i>Piranga olivacea</i>	1	5	4	13	2		1	2		1	
Dickcissel	<i>Spiza americana</i>											238
Rose-breasted Grosbeak	<i>Pheucticus ludovicianus</i>		3			1			1			

YL = Yellow listed species in North America; **CD** = Common species showing sharp declines; **NT** = Near-threatened; **VU** = Vulnerable; **CO** = COSEWIC (Canada species at risk)

Modeling occupancy rates of Canada Warbler across Colombia, Panama and Costa Rica

288 records from 397 transects spread across 31 sites in Colombia, Panama and Costa Rica were used to model how occupancy rates of Canada Warbler vary with a suite of variables including latitude, longitude, elevation, precipitation, forest cover and fine scale vegetation variables, such as canopy cover, canopy height and understory density. The resulting top models included the following variables: elevation; annual precipitation; longitude; latitude; forest cover; presence of pastures, and understory density. Occupancy rates peaked at mid-elevations (500-1000 m), at intermediate levels of precipitation (1000-2500 mm) and at more westerly sites. Occupancy increased with increasing forest cover and understory density, and was negatively related to the presence of wooded pastures. The model receiving the greatest support from AIC values was used to make spatial predictions at the regional level but we urge caution in the interpretation of these beyond a radius of 100 km around survey sites (see [Figs. 6, 7, & 8](#)).

Figure 6. Spatial prediction of occupancy rates for Canada Warbler across Colombia, Panama and Costa Rica. Average expected occupancy rate between mid-September and mid-October are represented by colors, with warm colors indicating rates close to 1 and cold colors areas where the species rarely occurs. Black points represent study sites and gray outlines enclose areas within 100 km of study sites and are expected to represent the region within which it is reasonable to extrapolate from the occupancy models.



**Areas in red on the Azuero Peninsula in Panama and along the Pacific coast of Colombia are believed to be over-predictions. Indeed, there are no records of Canada Warbler from the Azuero Peninsula in September/October and only one record from Colombia's Pacific coast.*

Figure 7. Spatial prediction of occupancy rates for Canada Warbler across Colombia, Panama and Costa Rica and the presence of protected areas (transparent green shapes). Average expected occupancy rate between mid-September and mid-October are represented by colors, with warm colors indicating rates close to 1. Black points represent study sites. The area of prediction (gray outlines) has been limited to those areas within 100 km of study sites.

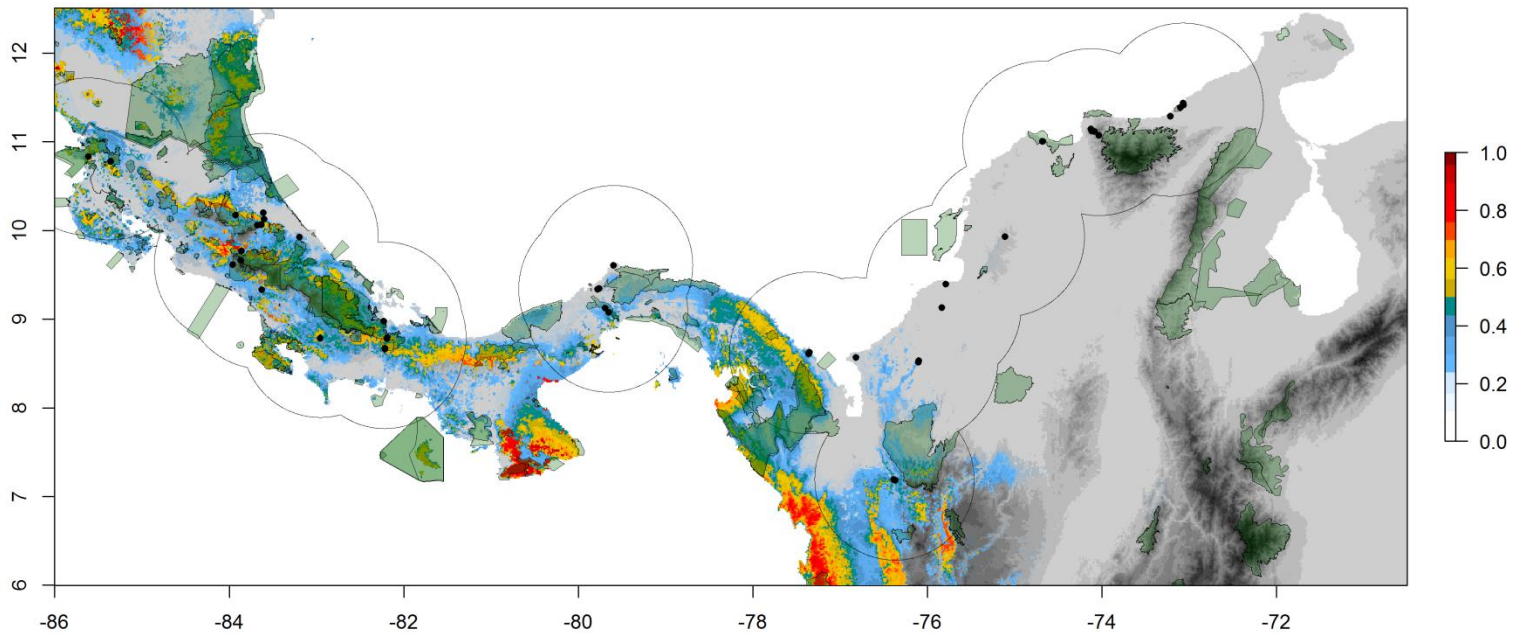
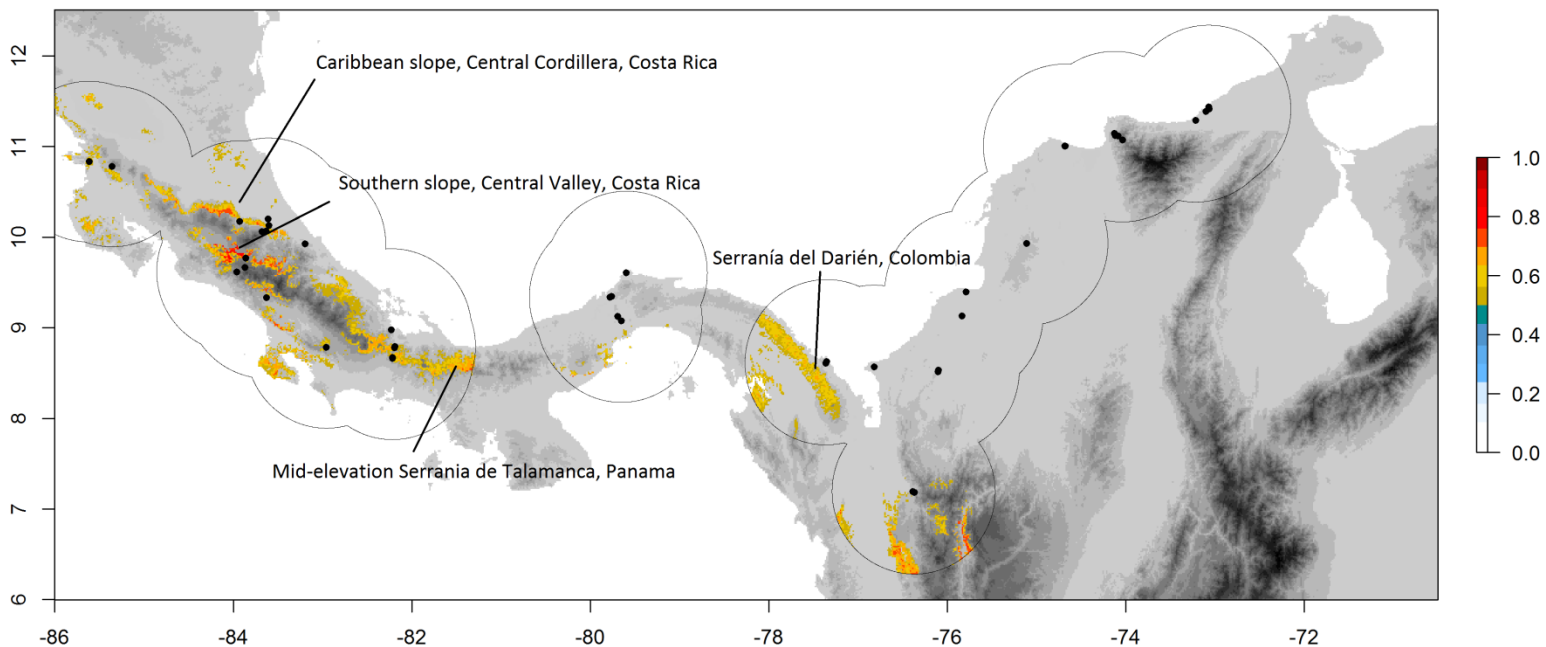


Figure 8. Priority stopover regions for Canada Warbler on fall migration across northern Colombia, Panama and Costa Rica. Priority areas were defined as those having an average occupancy rate >0.5 during four 10-day periods covering the peak of migration of the species through the region. Key areas currently lacking protection are labeled.



DISCUSSION

Occupancy surveys in Panama

The observations undertaken during the fall migration of 2017 provide detailed information about the routes, regions, habitats and elevations used by Neotropical migratory landbirds in Panama for the first time. The preliminary analyses presented here identify various patterns in terms of distribution and the relative abundance of a handful of species, patterns which we hope to refine and expand to other species as more rigorous analyses of the data are undertaken. Application of additional occupancy models, covering a range of species and including data from neighbouring countries, such as Colombia, will be fundamental for identifying those regions and habitats with a greater probability of being used during migration for gaining vital energy reserves.

Nonetheless, the crude data reveal a number of fascinating patterns that deserve further investigation and that suggest the existence of important stopover sites for some species. The Fortuna forest reserve and its surrounds in the Serranía de Talamanca, in particular, held high abundances of several species during extended periods (weeks) of the fall migration, implying the likely existence of multi-day stopovers in a number of species. These species include those that arrived earliest and were present during much of September and the first half of October, such as Western Wood-Pewee, Canada Warbler and Blackburnian Warbler. Others arrived later but also show a prolonged period with high abundance during October, such as Swainson's Thrush. Further, this region was also responsible for the majority of records of species of high concern, such as Acadian Flycatcher, Cerulean Warblers and Golden-winged Warblers, highlighting the need for additional research on both slopes of this mountain range, in order to understand in greater detail how individual species are using it.

As analyses using occupancy models advance and more data from neighboring countries, like Costa Rica, are included, our understanding of how the wider community of migratory landbirds use different regions will increase, as we have demonstrated for Canada Warbler. These future analyses will make it possible to identify key conservation regions for this declining group during the most vulnerable stage of their annual cycle – migration.

Occupancy surveys – Costa Rica

A successful fall migration season at sites across Costa Rica provided a wealth of information on which species likely make stopovers in Costa Rica and those that don't, as well as providing unprecedented detail on specific site use, in terms of Caribbean vs. Pacific slope, elevation preferences, precipitation preferences and fine scale habitat use. Future analyses will add further value to these data but an initial inspection of the data reveal several marked patterns ([Table 4](#)).

For example, among those species that winter primarily in South America and are expected to make stopovers in Central America, the following were sufficiently abundant to speculate that they were stopping to recharge fuel reserves in Costa Rica: Olive-sided Flycatcher, Eastern Wood-Pewee, Western Wood-Pewee, Acadian Flycatcher, Swainson's Thrush, Red-eyed Vireo, Cerulean Warbler, Blackburnian Warbler, and Canada Warbler. Most of these species, aside Western Wood-Pewee, concentrated along the Caribbean slope between 400 and 1000 m, and generally avoided higher elevations (>1500; except Blackburnian Warbler) and the Pacific slope. This suggests that low to mid-elevations along the Caribbean slope of Costa Rica's Cordillera Central, may be a major stopover area for a range of species. Nonetheless, some species were unexpectedly abundant on the Pacific slope, particularly in areas dominated by dry forest, including Eastern Wood-Pewee, Blackburnian Warbler, Cerulean Warbler and Canada Warbler, suggesting a potential role for these dry forests as stopover habitat during the rainy season.

Similarly marked geographic patterns were apparent among species that are primarily winter residents in Costa Rica. For example, Black-throated Green and Wilson's Warblers were limited to the highest elevations in the Talamanca range, while Yellow-bellied Flycatcher, Yellow-throated Vireo and Yellow Warbler were largely restricted to the Pacific slope and lowlands.

Finally, it is notable that certain South American wintering species were rare on passage in Costa Rica. In particular, Yellow-billed Cuckoo, Alder Flycatcher, Eastern Kingbird, Veery, Gray-cheeked Thrush, Mourning Warbler, Scarlet Tanager, and Rose-breasted Grosbeak, were scarce when compared to surveys carried out in Colombia using the same methodology.



Canada Warbler stopover – Colombia, Panama & Costa Rica

The occupancy modeling exercise for Canada Warbler revealed both expected and unexpected patterns. Based on data from Colombia (2016) and Panama (2017), we had expected that most Canada Warblers would be detected at mid-elevations in the Serranía de Talamanca. It was therefore a surprise to detect birds on the drier Pacific slope of Costa Rica and more so in lowland dry forest. Despite these unexpected observations from Costa Rica, the final model still emphasizes the importance of montane areas between 500 and 1500 m in elevation, primarily along the Cordillera Central of Costa Rica and the Serranía de Talamanca in Costa Rica and

Panama. The high predicted occupancy in the Azuero peninsula of Panama is likely an artifact of the records from the Pacific of Costa Rica and is not supported by current records in eBird.

Of the main regions with high occupancy rate, it is noteworthy that several areas are currently outside of protected areas. In Costa Rica, the lower Caribbean slope of the Central Cordillera does not overlap with protected areas that typically cover forests at elevations above those preferred by Canada Warbler. The same is true of the northern slope of the Talamanca range in Costa Rica, where it drops into the Central Valley. In Panama, while protected areas cover much stopover habitat in the Talamanca range, areas to the east of the Fortuna Forest Reserve are located primarily in indigenous reserves and may benefit from additional national protected status.

Take home messages

- Costa Rica and Panama likely hold stopover populations of 9 species of Neotropical migratory birds that winter in South America
- Including 5 species on the Canadian at risk list (COSEWIC): Olive-sided Flycatcher, Eastern Wood-pewee, Acadian Flycatcher, Cerulean Warbler and Canada Warbler
- Most species appear to make stopovers in the Caribbean foothills
- The Caribbean slope is also a major passage region for diurnal migrants including declining aerial insectivores, especially in Panama
- Occupancy models for Canada Warbler highlight important stopover areas in the Central Cordillera of Costa Rica and the Talamanca range in Panama and Costa Rica
- 8-day stopovers recorded in Cerulean Warblers confirm multi-day stopover in Costa Rica



Bay-breasted Warbler feeding on Miconia fruit – Reserva las Brisas, Costa Rica (Photo Nick Bayly)

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