Studies have revealed that Nearctic-Neotropic migrant passerines (hereafter referred to as “migrants”) are potentially limited by factors such as stopover habitat quality, food availability, and climate, in both temperate and tropical latitudes (Moore and Yong 1991, Winker et al. 1992, Sillett et al. 2000). For example, work in the Caribbean showed that El Niño-induced dry seasons negatively affected survivorship of Black-throated Blue Warblers (Dendroica caerulescens), perhaps due to reduced food availability (Sillett et al. 2000). Recent evidence suggests that El Niño may influence migrant condition during spring migration in northeastern Costa Rica (Wolfe and Ralph 2009).

Migrants demonstrate high levels of diet and behavioral plasticity when wintering or migrating within the tropics (Levey and Stiles 1992, Blake and Loiselle 1992, Parrish 2000). Understanding the degree of migrant dietary plasticity, especially in the tropics, is necessary for the implementation of informed management decisions (Rich et al. 2004). The majority of tropical dietary studies have focused on resources being utilized during overwintering periods or fall migration (Sherry 1984, Blake and Loiselle 1992, Rappole et al. 1993, Levey and Stiles 1992, Parrish 2000); the few published studies pertaining to spring migration in Central America are, in part, contradictory (see Levey and Stiles 1992, Poulin and Lefebvre 1996, Parrish 2000). Surprisingly little is known concerning resource utilization of migrant birds during spring migration in tropical latitudes. The objective of this
study was to quantify the diet of spring migrants along the northern Caribbean coast of Costa Rica by analyzing droppings of captured birds.

**STUDY AREA AND METHODS**

Between 16 April and 5 May 2007, five banding stations with 10-15 nets each were operated 6 d per week in and around the pueblo of Tortuguero, on the northeast coast of Costa Rica, in Limon Province (10°33'51" N, 83°31'07" W). Tortuguero is dominated by lowland, wet broadleaf tropical forest (Holdridge 1987) that is dissected by canals and rivers that flow east into the Caribbean Sea. The area receives an average rainfall of > 500 cm per year, making it one of the wettest regions in the country (Ralph et al. 2005).

This study assumed that captured birds represented *migrating* individuals; this assumption is supported by documented temporal patterns of Neotropical migratory events (Francis and Cooke 1986, Moore et al. 1990, Hagan et al. 1991). Because nets were opened 15 min prior to sunrise and operated for 5 h, it is assumed that droppings represent food acquired from the Caribbean coastal plain within several h of capture. Monitoring stations were located in primary tropical forest, secondary tropical forest, and coastal scrub. Fruiting plants were common throughout the study area; *Conostegia* (family Melastomataceae) and *Costus* (Zingiberaceae) were dominant in coastal scrub monitoring stations, whereas *Pshycotria* (Rubiaceae), *Piper* (Piperaceae), and *Geonoma* (Arecaceae) were dominant in secondary and primary forest monitoring stations. Tortuguero’s wet season begins from mid to late April and continues through January. The wet season is interrupted by a short dry season, usually during September. The prolonged dry season tends to occur through February and March, but even during this period precipitation is common (Janzen 1983).

All migrants were banded with standard U. S. Fish and Wildlife aluminum bands and aged and sexed according to Pyle (1997). Droppings were collected by placing birds in a 13 × 23 cm breathable paper bag until the bird defecated. Each dropping was processed according to an augmented protocol described by Ralph et al. (1985) and Fuentes (1994); instead of steaming the droppings, each sample was gently separated by a blunt-nosed probe. Using a 10× field-scope, arthropod parts were identified to Order. Unfortunately, it was not possible to identify many of the well-digested arthropod parts (Ralph et al. 1985). Arthropod parts and fruit matter (pulp, seeds, etc.) were separated and segregated within a Petri dish. Estimates of percent volume of fruit or arthropod matter within each dropping were produced to the nearest 5%.

Four inherent confounding factors may influence dietary results presented here: (1) pieces of hard-bodied arthropods are more likely to pass through a migrant bird’s digestive tract, thereby biasing volumetric estimates in favor of hard-bodied arthropods; (2) larger seeds may be regurgitated rather than passed through a small migrant’s digestive tract, biasing results in favor of smaller seeded fruit, especially among smaller birds; (3) larger migrants apparently pass more intact arthropods through their digestive tract relative to smaller migrants, biasing arthropod volumetric estimates in favor of larger migrants; and (4) volumetric estimates of droppings are a crude and potentially inaccurate method of inferring proportion of diet.

**RESULTS**

A total of 86 individual spring migrants were captured, representing six species: Red-eyed Vireo (*Vireo olivaceus*), Eastern Wood-Pewee (*Contopus virens*), Canada Warbler (*Wilsonia canadensis*), Mourning Warbler (*Oporornis philadelphia*), Northern Waterthrush (*Seiurus noveboracensis*), and Swainson’s Thrush (*Catharus ustulatus*). Ten of the 86 fecal samples were predominantly uric acid (milky white consistency) which contained no visible arthropods or fruit and were, therefore, not included in the analysis. Migrant dietary composition varied across species but was dominated primarily by arthropods, with only two species producing droppings which contained substantial quantities of fruit: Swainson’s Thrush and Red-eyed Vireo (Table 1). Northern Waterthrush was the only other species that also had droppings which included fruit (Table 1). Canada Warbler, Eastern Wood-Pewee, and Mourning Warbler produced droppings that only contained arthropods. Several grains of undigested pollen were identified in a sample derived from a single Red-eyed Vireo capture.

**DISCUSSION**

One Red-eyed Vireo fecal sample contained pollen; this was unusual given that pollen is often completely assimilated during the digestive process (Roulston and Cane 2000). Due to low sample sizes and a lack of visual corroboration with foraging observations, the extent and ultimate causation of pollen ingestion is unknown (e.g., actual targeting of pollen or byproduct of foraging for insects within

Little is known concerning the relationship between a stochastic climate and the dietary patterns of migrating birds within tropical latitudes. The 2007 spring migration immediately preceded El Niño like conditions (Climate Prediction Center, National Oceanic and Atmospheric Administration), which can induce a dry signal in the Caribbean (Ropelewski and Halpert 1987, Sillett et al. 2000). Climatic variability can alter the phenology of flowering plants and the abundance of arthropods, even in areas without distinct seasonality.

For example, within wet-tropical forests, dry periods are associated with asynchronous flowering events which may deplete available fruit resources (Wright et al. 1999, Williamson and Ickes 2002). Janzen (1973) documented higher levels of insect abundance during dry seasons in relation to wet seasons in wet lowland Costa Rican forests with “mild-dry seasons.” The potential synchronous relationship between fruit depressions and elevated insect abundance may have promoted higher levels of insectivory during this study. Unfortunately, previous diet studies have not been conducted at Tortuguero and the general dietary patterns of spring migrants passerines in tropical latitudes are largely unknown. More research is necessary in order to determine the plasticity of migrant diet in association with climatic stochasticity within tropical latitudes. Understanding how migrants respond to climatic variability within a dynamic habitat, such as low-land tropical rainforests, may ultimately improve our ability to manage Neotropical stopover sites.

**ACKNOWLEDGMENTS**

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**LITERATURE CITED**


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### Table 1. Composition of fecal samples from spring Nearctic-Neotropical migrants in Tortuguero, Costa Rica.

<table>
<thead>
<tr>
<th>Species</th>
<th>n</th>
<th>Percent Arthropods</th>
<th>Percent Fruit</th>
<th>Percent Pollen</th>
<th>Arthropod Orders Identified in Droppings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada Warbler</td>
<td>4</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>Coleoptera, Diptera, Hymenoptera, Lepidoptera larvae</td>
</tr>
<tr>
<td>Eastern Wood-Pewee</td>
<td>6</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>Diptera, Hymenoptera, Coleoptera</td>
</tr>
<tr>
<td>Mourning Warbler</td>
<td>17</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>Orthoptera, Hymenoptera, Coleoptera</td>
</tr>
<tr>
<td>Northern Waterthrush</td>
<td>22</td>
<td>95</td>
<td>5</td>
<td>0</td>
<td>Coleoptera, Homoptera</td>
</tr>
<tr>
<td>Red-eyed Vireo</td>
<td>9</td>
<td>70</td>
<td>30</td>
<td>5</td>
<td>Coleoptera, Diptera, Hymenoptera, Orthoptera, Homoptera</td>
</tr>
<tr>
<td>Swainson’s Thrush</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>Coleoptera, Diptera, Araneae</td>
</tr>
</tbody>
</table>
WOLFE — DIET OF LANDBIRD MIGRANTS IN COSTA RICA

Press, Washington, DC.


