Evaluating a stepping stone for Neotropical Migratory birds – the Belizean north-east biological corridor

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EXECUTIVE SUMMARY

The factors limiting populations of Neotropical migrants are becoming increasingly well understood and they may act both on the breeding and non-breeding (wintering) grounds (Holmes 2007). Theoretical work and a growing body of empirical evidence indicate that mortality during migration also has an important role in population regulation/declines (Weber *et al*. 1999; Sillett & Holmes 2002; Newton 2006). Currently the migratory routes, strategies and stopover sites used by Neotropical migrants outside of North America are poorly known and to ensure protection throughout the annual cycle, sites key to migratory success must be identified. These are likely to coincide with quality wintering habitat, as prior to spring migration migrants are expected to accumulate vital fuel reserves at these sites.

Lying on a major flyway for migrants from the eastern and boreal regions of N. America and being situated close to the main arrival and departure points for birds crossing the Gulf of Mexico, Belize is expected to provide resources to a range of species both during migration and winter. To examine how migrants use this region, we focused on an ecosystem matrix in north-east Belize that has been proposed for inclusion in a biological corridor. The study was aimed at increasing our understanding of habitat/site use and migratory strategies in Central America, whilst also generating data that can feed into the process of prioritising areas/habitats for inclusion in the biological corridor.

Methods

The study was carried out entirely in the Corozal district of Belize and two methods were used to study site/habitat use and stopover behaviour during migration: 1) Mist netting was carried out daily between Sept 2nd – Nov 3rd 2007 (autumn) and between 17th March – 14th May 2008 (spring); 2) 500 m transects were walked nearly daily in ‘dry forest’ and on three separate occasions in ‘moist forest’ in each migration period. During the ‘winter’, over 160 500 m transects were completed in five habitats: 1) Black Mangrove; 2) semi-deciduous (dry) tropical forest (TF) (low variant); 3) semi-deciduous TF (high variant); 3) evergreen broadleaf TF; 4) Milpa intermixed with habitat 2; 5) mangrove savannah. Density estimates by habitat for the commonest species were estimated using the program Distance.

Results & Discussion: Autumn & Spring Migration

Sixty-three species of Neotropical migratory landbirds were recorded during autumn and estimates for the whole corridor suggest that 14-20 million individuals passed through. During spring less species were recorded (53) and an estimated 6-9 million individuals passed through. Species of concern recorded included *Protonotaria citrea* (abundant during both migration periods), *Empidonax traillii* (abundant in autumn), and small numbers of *Hylocichla mustelina*, *Dendroica castanea*, *Oporornis formosus* and *Wilsonia Canadensis* (autumn only). In addition, the near threatened *Vermivora chrysoptera* (3 autumns, 1 spring), *Contopus cooperi* (1 autumn) and *Passerina ciris* (1 spring) were recorded. In general migrants showed a preference for forested and mangrove habitats whilst avoiding open habitats such as savannah – forest clearance in stopover areas is therefore expected to have an adverse effect on migratory success.

Migration strategies varied both within and between species and more markedly between autumn and spring. Autumn migration was more prolonged than spring, with 75% of birds captured in over 2.5 weeks either side of the peak capture day in the former versus just one week in the latter. The body mass of birds arriving in NE Belize combined with their fat score acts as an indicator of fuel reserves and subsequent stopover behaviour. In autumn, transient species generally had a continuum of fuel reserves varying from none to moderate levels, although in some species, e.g. *Empidonax traillii*, fuel reserves were minimal throughout the population. In contrast, transient species in spring arrived with large to moderate reserves and only two species, *Dendroica petechia* and *Dendroica magnolia*, displayed fuelling behaviour combined with a high abundance. These findings suggest that in autumn, birds arriving to the Yucatan from N. America do so with varying levels of fuel after the long Gulf crossing, such that the point at which they exhaust their reserves and need to refuel occurs either further north on the Yucatan, at our study site or further south still. In spring, the moderate to large reserves carried by most species suggest that areas south of NE Belize had been utilised to accumulate fuel and that the study area was only used to rest between successive nocturnal flights. Indeed, flight range calculations indicate that spring birds could cross the Gulf of Mexico before needing to refuel.

Whilst NE Belize and the wider Yucatan region appears to provide important resources to many migratory species needing to replenish their reserves having crossed the Gulf of Mexico in autumn, the fuel to make the reverse journey in spring is generally accumulated elsewhere. It is therefore crucial to identify these spring stopover areas whilst also ensuring the protection of a network of sites throughout the wider Yucatan region that meet the needs of migrants stopping over in autumn – this may require carrying out a wider reaching assessment of stopover sites and extending the current protected area system.

Over-wintering Migrants in NE Belize

We recorded 23 species of landbird migrants wintering in NE Belize at an average detection rate of migrants vs. residents of 43%. Habitat use and persistence varied highly between species during early, mid and late winter. Black mangrove showed the highest proportion of migrant to resident birds (62.4%) and had by far the highest density of migrants per km^2. Persistence, however, was not high in Black Mangrove with most species declining in number during the winter, presumably in response to reduced resources with the progression of the dry season. The variation in habitat preference between species and inter-habitat movements recorded here, demonstrate that no one single habitat on its own can provide the optimum resources for migrants. Instead, a matrix of connected habitats appears necessary to maximise overwinter survival in a range of species. Initiatives to protect non-breeding habitats must therefore clearly define their conservation goals, as the areas selected for protection need to be carefully tailored to meet the varying needs of a single focal species or a wider group of species. In the case of the existing protected area system in Belize, Black Mangrove is a highly underrepresented habitat and given its importance to many of the migratory species wintering in Belize, efforts to protect existing tracts of mangrove should be initiated.

Education and training

During the course of this study a number of education initiatives resulted in over 60 individuals participating in various activities such as bird banding demonstrations and bird walks. Eleven students were involved in the production of a migration leaflet aimed at raising awareness of the natural habitats around the village of Sarteneja and the migrants using them (see Appendix 2). A total of 30 individuals received bird banding training and the culmination of the training initiative was the formation of the University of Belize bird banding group through a ten day workshop and donation of equipment. The group is expected to provide a focal point for training in bird banding in Belize and increase the capacity for detailed ecological studies of Belize's avifauna.

CONTENTS

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STUDY OBJECTIVES

Overall

- To assess the importance of the NE Biological Corridor to Neotropical migratory birds

Specific:

- Determine which species use the corridor whilst migrating to and from their North American breeding grounds and non-breeding grounds south of Belize and their habitat preferences
- Determine the importance of the corridor as a stepping stone in the migratory journey by assessing whether migrants utilise the area to refuel
- Determine the importance of the corridor and its different habitats to migrants during the non-breeding season
- Compile the resulting data so that it can be used to inform decisions regarding the protection and management of the NE biological corridor
- Organise educational visits to raise awareness about Neotropical migrants
- Train Belizean nationals in bird banding skills
- Form partnerships with other organisations/studies investigating Neotropical migrants in their non-breeding areas and investigate the potential for data sharing

CHAPTER 1

GENERAL INTRODUCTION

Every year millions of birds make remarkable journeys, often thousands of kilometres in length, as they make their way to and from their breeding grounds. To make these incredible journeys and survive the periods in between, these migratory birds are dependent on many different habitats that span not only countries but continents. It is this dependence on suitable habitat both on their breeding and non-breeding grounds and at the many sites in between that makes them both indicators of environmental health on a global scale and also particularly vulnerable - destruction of any one of these habitats may result in population declines. For this reason, efforts to conserve migratory birds must look beyond national boundaries and seek international coalitions to ensure that the habitats migratory birds utilise are protected along the length of their journeys.

Many migratory species are already in decline and this is also true of Neotropical migrants that breed in North America and winter in Central and South America. Many of these declines have been attributed in part to the destruction of tropical forest on the non breeding grounds, yet the majority of studies have focused on the breeding grounds in North America. Belize is a Central American country which despite its small size still contains large areas of tropical forest and other key tropical habitats, and plays host to large populations of migrants during both the non-breeding period and on passage. By assessing the importance of these habitats to Neotropical migrants, the project detailed in this report aims to improve our limited knowledge of Neotropical migrants on their non-breeding grounds and examine the importance of natural habitats in north-east Belize for the conservation of migratory birds.

Neotropical Migratory Birds

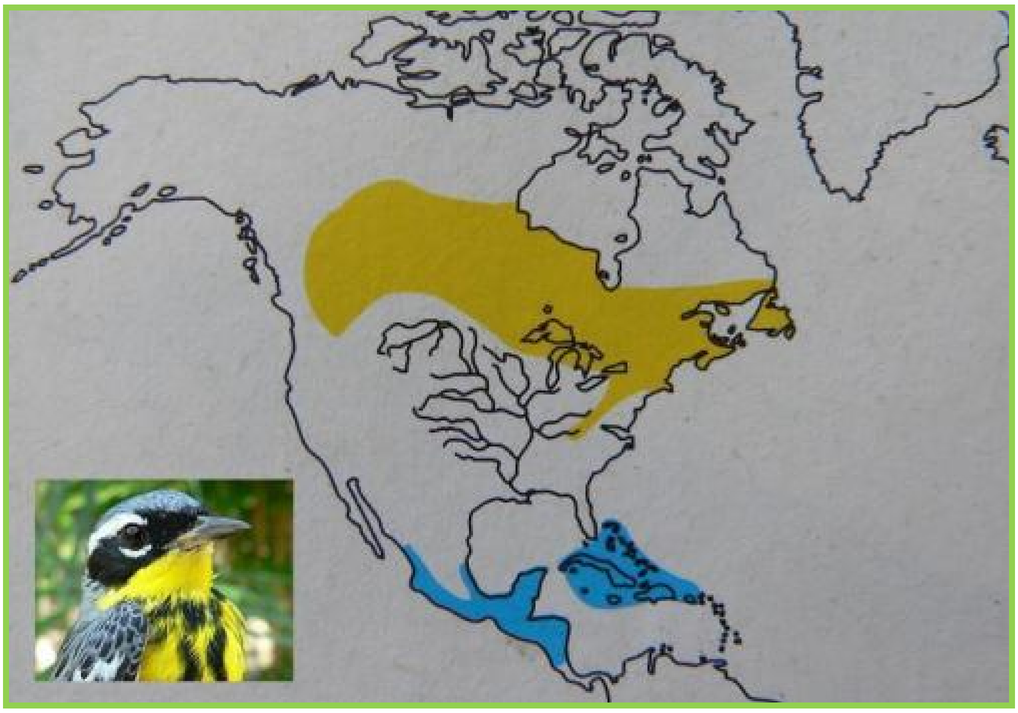
Neotropical migratory birds are a group of species that breed in North America, principally in the United States and Canada and spend the non-breeding season/North American winter in the tropical and sub-tropical regions of Central America, the Caribbean and South America (see range example in Fig. 1.1). From here on ‘non-breeding’ and ‘winter’ shall be used interchangeably to describe the period in which these migrants are not on their breeding grounds. In total, around 230 species of landbird have been classed as Neotropical migrants and there are many more migrants that favour aquatic habitats (Hagan 1992). At northerly latitudes, migrants are a significant part of the avifauna, often comprising in excess of 70% of the species in the bird community. In this respect, they are a critical component of North American ecosystems, playing a vital role in regulating insect numbers, seed dispersal and also as pollinators.

The role of Neotropical migrants in their non-breeding areas is no less significant, with migratory species often comprising over 40% of the species present in a given habitat (Inzunza *et al*. 2005) and as we shall see from this study, they are the most abundant birds in certain habitats (see Chapter 5). It is also important to note that whilst these migrants breed in North America, this only comprises four to five months of the annual cycle and thus seven to eight months of the year, e.g. the majority, is spent in non-breeding areas. As we shall see below, there is increasing evidence that populations of Neotropical migrants are limited by events during the non-breeding season as much as during the breeding season.

The distribution of migrants on their North American breeding grounds is well described and migrants can be classed into three broad groups – those that breed to the west of the Rocky mountains along the Pacific seaboard; those that breed to the east of the Rockies on the eastern seaboard and those that breed in the boreal region. The corresponding non breeding ranges broadly mirror those to the north, with Pacific seaboard species wintering along the Pacific slope of Mexico and Central America, eastern seaboard species wintering throughout the Caribbean and along the Caribbean slope of Central America, whilst many boreal species winter in Northern South America.

The routes taken between these distant breeding and wintering grounds are generally well described at a broad scale but many details are missing at a finer scale, especially on leaving North America. As this study examines species primarily from the eastern seaboard and boreal regions of North America, we shall focus on the routes taken by this group here. It is important to note that routes are time of year dependant and thus we will discuss autumn (post-breeding) routes and spring (pre-breeding) routes separately.

Figure 1.1: Breeding range (shaded yellow) and ‘wintering’ range (blue) of the Magnolia Warbler, a common Neotropical migrant during the non-breeding season and on passage in Belize. Range map adapted from Curson *et al*. (1994).



In autumn, southward bound migrants follow three main routes (Fig. 1.2). The first of these converges on the Mississippi river valley and follows it to the Gulf Coast (see also Fig. 1.1 in which the Mississippi and its tributaries can be clearly seen), from where birds make the long crossing over the Gulf of Mexico to the Yucatan Peninsula and then filter down to non-breeding areas in Central and South America. The exact route taken through Central America by these migrants is not clear. The second route takes birds down the eastern seaboard to Florida from where they make their way to wintering areas in the Caribbean or all the way across the Caribbean to South America. The final route takes birds directly from the eastern seaboard on a staggering long haul flight across the Atlantic and Caribbean to South America.

In spring, the main routes are not so well described; nevertheless, two main routes stand out. The first involves birds following the Central American and Mexican mainland all the way to North America, thereby avoiding crossing the Gulf of Mexico. The second appears to hug the Caribbean coast of Central America before cutting across the base of the Yucatan peninsula and crossing the Gulf of Mexico to make landfall in northern Mexico and Texas.

Whilst these routes may be fairly well described, the sites used are not, especially outside of North America. These sites play a critical function in the journeys of migratory birds, as they allow birds to store the energy/fuel needed to complete their journeys. These sites have been termed ‘stopovers’ and a typical migratory bird may make three or more stops at such sites in order to complete their migration. Destruction of any one of these stopover areas can result in the failure of birds to complete their migration (Weber *et al*. 1999), especially stopovers which are used to gain fuel prior

Figure 1.2: Main migration routes of migratory landbirds breeding in eastern North America. In autumn (white arrows) three main routes are followed, with the principal route following the Mississippi river valley to the Gulf Coast and then across the Gulf to the Yucatan peninsula. In spring (red arrow), birds tend to take a much more easterly route across the Gulf of Mexico.

to the crossing of so-called ecological barriers, such as the Gulf of Mexico where stopping to refuel is not an option. Identifying and protecting the main stopover sites utilised by landbirds migrating between South and North America, a journey of over 2500 km, is crucial if we are to effectively conserve Neotropical migrants. Despite impressive and wide reaching international efforts to understand and conserve migratory birds by coalitions such as Partners in Flight, the stopover biology of many Neotropical migrants is poorly known and considerable effort is required to fill this knowledge gap (Parker 1994; Mehlman *et al.* 2005).

The populations of many Neotropical migrants are large and widely distributed and thus one may ask as to why conservation efforts should be focused on this group. Indeed, whilst a number of species have shown drastic declines, many species have not declined at all or have only shown population reductions that would be considered within the realms of natural fluctuations. There are clear notes of caution, however, such as the gradual but persistent decline of ‘common’ and widespread species like the American Redstart (see Fig. 1.3). Further, following the vision of Partners in Flight - a hemispheric collaborative effort to conserve Neotropical migrants - the reasoning behind focusing on Neotropical migrants is not to reverse a disaster that has already occurred but to avert a disaster that could occur in the next 20-30 years (Hagan 1992). Whilst the exact implications of tropical deforestation for migrants are not clear yet, the predicted near wholesale clearance of tropical forests throughout Latin America in the next two to three decades would undoubtedly have a severe impact on migrant populations. In attempting to avert such a disaster, we would not only save Neotropical migrants but all the other myriad species that share those habitats. In a way, Neotropical migrants represent an umbrella group that could result in the conservation of a wide range of habitats at a scale that few other groups of organisms would require.

Declines in Neotropical migrants have affected a wide range of species but by no means all and there is no overriding factor common to all declining species. Indeed, the reasons for decline tend to be individual to each species; nevertheless, there are some patterns that emerge. For instance, those migrants that exclusively use forested habitats in their non breeding areas in the Neotropics are more likely to show declines than those species adopting open habitats (Robbins *et al*. 1989). Also species that spend the non-breeding season in South America, particularly in the tropical Andes, appear more likely to show declines (interpreted from Sauer *et al*. 2008). Of the six Neotropical migrant landbirds that are considered globally threatened, five winters in forested habitats and three have their core wintering range in South America. Of 13 migrant landbirds on the 2007 American to watch list that are either on the red list or the declining yellow list, 11 winter in forested habitats and nearly half winter primarily in South America (Table 1.1).

For those species in decline and Neotropical migrants in general a variety of factors have been identified as limiting to their populations (Holmes 2007). These include both factors that act on birds during the breeding season, i.e. in North America, and during the non breeding period. To fully understand the interplay of these factors on population size, more research is needed, however a number of studies on model species have highlighted mechanisms by which migratory populations may be regulated. Let us begin with density dependant effects on the breeding grounds. It is assumed that if density dependant population effects act on the breeding grounds, then in some way breeding habitat availability is limiting the population. Sillett & Holmes (2005) showed that this was the case for the Black-throated Blue Warbler, demonstrating that the number of young fledged was negatively correlated to adult density, as was the number of first years males recruited to the population in the following year. Thus in theory, if the amount of available breeding habitat decreases, adult density will go up and overall fecundity will decrease.

Figure 1.3: Population index for the American Redstart *Setophaga ruticilla* between 1966- 2007 throughout North America based on the American Breeding Bird Survey (BBS). Figure created using data from Sauer *et al.* (2008).

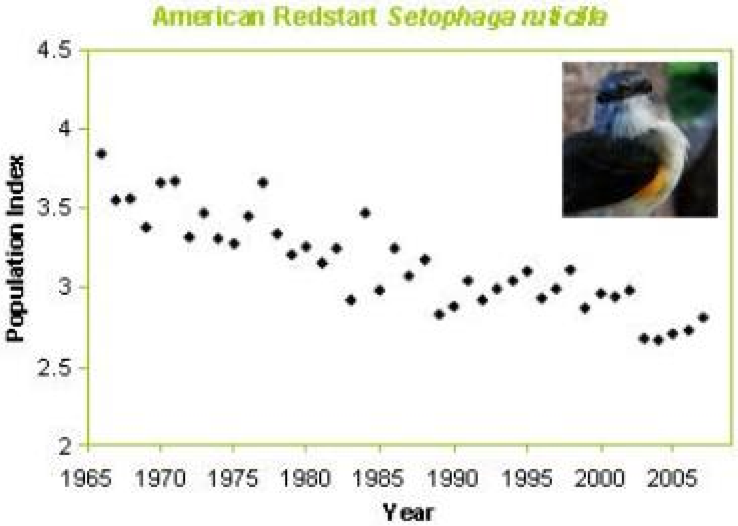


Table 1.1: Global status, population status, habitat preference and core wintering range of Neotropical migrants considered globally threatened or on the American to Watch list (Red list and Yellow List species in decline). Global Status: NT = Near-threatened; VU = Vulnerable; EN = Endangered. Population Status (Butcher *et al*. 2007): 3 = Highly variable or unknown; 4 = Moderate population decrease averaging < -0.54% per year or possible large decrease; 5 = Large population decrease averaging < -2.28% per year. Wintering range: CA = Central America; CAR = Caribbean; SA = South America.

Common Name	**Scientific Name**	**Global Status**	**Population Status**	**Habitat Preference**	**Wintering Range**
Olive-sided Flycatcher	*Contopus borealis*	NT	5	Forest	SA
Willow Flycatcher	*Empidonax trailli*		4	Forest	CA & SA
Bicknell's Thrush	*Catharus bicknelli*	VU	3	Forest	CAR
Wood Thrush	*Hylocichla mustelina*		4	Forest	CA & SA
Golden-winged Warbler	*Vermivora chrysoptera*	NT	5	Forest	CA & SA
Golden-cheeked Warbler	*Dendroica chrysoparia*	EN	5	Forest	CA
Bay-breasted Warbler	*Dendroica castanea*		5	Forest	CA & SA
Cerulean Warbler	*Dendroica cerulea*	VU	5	Forest	SA
Prairie Warbler	*Dendroica discolor*		4	Open	CAR
Prothonotary Warbler	*Protonotaria citrea*		4	Forest	CA & SA
Kentucky Warbler	*Oporornis formosus*		4	Forest	CA
Canada Warbler	*Wilsonia canadensis*		4	Forest	SA
Painted Bunting	*Passerina ciris*	NT	4	Open	CA & CAR

For Black-throated Blue Warblers and other species this is not the whole story. Extensive work on Black-throated Blue Warblers and American Redstarts on Jamaica during the non-breeding period revealed that both these species held territories, and that age and sex ratios differed between habitats (Holmes 2007). These findings indicate that resources are in some way limiting and therefore worth defending. Indeed, Lovette & Holmes (1995) demonstrated that American Redstarts spent more time foraging and deployed a greater variety of costly foraging techniques in Jamaica than they did on their breeding grounds. Further evidence has accumulated which indicates that differences in resources between habitats can actually affect survival, with higher rates of survival in American Redstarts in moist broadleaf forest versus mangrove or dry scrub (Johnson *et al.* 2006). Again, the premise here is that if high quality winter habitat is reduced then the use of lower quality habitats will lead to reduced overwinter survival and population declines.

So we have seen that factors on both the non-breeding and breeding period can regulate populations and to complicate matters further, recent work shows that the impact of one season can carry over to the next. With the clever use of stable isotopes, Norris *et al.* (2004) showed that Redstarts that spent the non-breeding period in 'wetter' habitats arrived earlier on the breeding grounds, had earlier fledging dates and ultimately fledged more young than birds wintering in drier habitats. Whilst the web of interactions that regulate migrant populations is becoming increasingly complex, the important message is that changes in habitat availability/quality at any stage in the life cycle can affect populations and conservation efforts must tackle all stages.

One such stage that has received little attention to date is during migration. Migratory birds are vulnerable in many ways during migration beyond simple resource availability. Many Neotropical migrants make long journeys across water, during which they may encounter storms, which can in rare cases lead to mass mortality (e.g. James 1956). Migrants also make use of a wide range of sites during migration and if birds experience a higher predation risk at these unfamiliar sites it may also contribute to mortality. In fact, an assessment of the mortality rates throughout the annual cycle of the Black-throated Blue Warbler indicated that up to 85% of annual mortality occurred during migration (Sillet & Holmes 2002). This finding highlights the importance of understanding how the migratory journey is organised and determining the location of stopover sites that provide the majority of energy for migration.

Neotropical Migrants in Central America and Belize

Central America is a diverse region and the wide range of ecosystems to which it plays host are critical to Neotropical migratory birds during the non-breeding period. Indeed, over 250 species of Neotropical migrants have been recorded in Central America and within Belize they account for nearly 40% of the ~570 species recorded in the country (Jones 2003). Within Central America three main groups of landbird migrants can be identified: 1) those that typically winter on the Pacific coast and within the mountains that run along the spine of much of the Central American landmass; 2) those that winter on the Caribbean coast; 3) transient/passage migrants that only pass through Central America on their way to and from South America. In Belize, the landbird migrants are dominated by those occupying the Caribbean slope that breed primarily in eastern North America but Belize is also frequented by many transient species from eastern North America and the boreal region.

Belize may be small in size but it still contains large areas of intact wintering habitat and many of Belize's forested habitats are protected. For this reason it is important to understand how the current protected area system in Belize serves to protect Neotropical migrants but also how unprotected areas and private lands may contribute to the conservation of key habitats. Much of the work in Belize to date has focused on broadleaf forest, pine savannah and citrus plantations in central and southern Belize. A further body of work details migrants on the Yucatan peninsula of Mexico and may share greater similarities with the work we undertook in north-east Belize. Many of these studies indicate that migrants will adopt a broad range of habitats (Lynch 1989; Petit *et al*. 1989; Piaskowski *et al*. 2005) and that they are distributed throughout different successional stages of forest (Lynch 1989; Smith *et al*. 2001). There are, however, species that show a greater affinity to mature broadleaf forest and whilst they appear to utilise successional habitats to a certain degree, these are expected to be sub-optimal habitats. These findings indicate that whilst mature forests are important to migrants, a range of other habitats that may not necessarily receive protection are also important. Indeed, in several studies the greatest migrant diversity exists in areas where a successional gradient existed (Petit *et al*. 1989; Lynch 1989) and both Lynch (1989) and Greenberg (1989) suggest that traditional Milpa agriculture may be important for the maintenance of migrant diversity in the Mexican Yucatan Peninsula.

That many migrants occupy both disturbed and undisturbed habitats must be interpreted cautiously, for as we noted above survival may differ between habitats (Johnson *et al*. 2006) and thus presence must not be taken as a sign of habitat quality. Further, Greenberg (1989) found that arthropod diversity decreased to a greater extent over winter in non-forested habitats vs. forested habitats and that there was an associated higher level of emigration of migrants, indicating that non-forested habitats had a lower carrying capacity. Therefore, whilst we have a good description of the habitats utilised by migrants in parts of Central America, these do not necessarily indicate preferred habitat and more detailed work is required in a range of habitats throughout Central America to fully understand habitat preferences and availability (Holmes 2007).

The habitats used by migrants in Belize and within Central America are not only important to migrants during the non-breeding season but are also crucial as birds make preparations for the long journey north to their breeding grounds (in April-May). These journeys require the storage of large amounts of energy in the form of fat, which must be derived from the resources in the habitats around them. More importantly still, there are many migrants that winter to the south of Belize, e.g. in South America, to which these forests may be crucial stepping stones as they migrate north or south through Central America. In this respect, Belize may play a vital role in enabling migrants to refuel during so called 'stopovers', although to date no studies have examined stopover behaviour within Belize. Indeed, information on areas used on stopover in Central America is very scant and is largely suggestive based on known migratory routes and observational data (e.g. Parker 1994; Inzunza *et al*. 2005). For example the Yucatan is considered an important autumn stopover area for many migratory warblers after they have crossed the Gulf of Mexico (e.g. Curson *et al*. 1994), however, there is only one published study on habitat use there (Deppe & Rotenberry 2008) and none on the magnitude of mass gains. This is a key area of investigation if we are to fully understand the needs of migratory birds during the non breeding period.

The Belizean North-east Biological Corridor

Lying at the base of the Yucatan peninsula and hosting forests intermediate in character between the dry semi-deciduous forests of the Yucatan studied by Greenberg (1989) and Lynch (1989) and the moister evergreen forests of central and southern Belize studied by Petit *et al*. (1989), the north-east corner of Belize remains largely unaffected by agricultural conversion and the progressive fragmentation of natural habitats that is occurring throughout Central America. Currently much of this area remains unprotected and for this reason it was highlighted as one of seven crucial areas for conservation in a gap analysis carried out for the Belize National Protected Areas System Plan (Meerman & Wilson 2005). The north-east biological corridor (see Fig. 2.1) is one initiative that hopes to address this situation, linking existing protected areas with a combination of new protected areas and private lands managed in a form favourable to conservation. In any such initiative it is crucial to first assess the biological resources in the region and given the variety of ecosystems that exist in the area (Fig. 2.1), it is expected to be an important wintering area for Neotropical migrants. Further, this region is situated on a major migratory flyway for birds moving along the Caribbean coast of Central America between non-breeding areas to the south and breeding areas in eastern North America. Consequently, the region may also provide refuelling opportunities to birds following this flyway, thereby serving as a key stopover. Determining which migratory birds use this region and how, may be an important step in leveraging further protection of the ecosystem matrix that exists within the proposed NE biological corridor.

Project justification and aims

There is a growing body of information relating to the migratory species that spend the non breeding period in Belize and their habitat preferences (c.f. Piaskowski *et al*. 2005). However, there is currently little or no information that we could find detailing the importance of Belizean habitats as stepping stones for migrants that only pass through Belize on their way to and from wintering areas to the south (e.g. South America). Indeed, there is a region wide lack of information relating to site use, habitat use and the refuelling behaviour of Neotropical migrants in Central America, with the majority of information pertaining to stopover behaviour in North America (e.g. Morris *et al*. 1996; Yong & Moore 1997). Filling this knowledge gap is crucial, as Holmes (2007) states "events during migration and especially the quality of migratory stopover sites are important to the maintenance of long-distance migrant populations". The quality of these migratory stopover sites is particularly important during spring migration, as mortality at this time will have a direct impact on the reproductive potential of populations as a whole (Newton 2006). This is especially true of Neotropical migrants that pass through northern Central America at the end of the dry season (April-May) when resources are at their lowest (Greenberg 1989).

In this project, our primary aim was therefore to address the knowledge gap with respect to the stopover behaviour of landbird migrants in Central America by assessing migrant use of the proposed North-east biological corridor in Belize during both autumn and spring migration. North-east Belize was chosen for three main reasons:

A. Its strategic position on a major migratory flyway and for its potential as a model for stopover behaviour in the wider Yucatan context

B. Its mosaic of intact natural habitats with affinities to both the Yucatan and the Selva Maya bioregions

C. The aim of utilising the resulting information to increase the protection of this region

The main goals with respect to describing stopover behaviour were as follows:

1. Determine which species utilised NE Belize during autumn and spring migration
2. Determine which of these species gained fuel in this region and which were transients
3. Describe the length of stopovers and the extent of fuel gains
4. Examine habitat use by passage migrants
5. Use the results to draw inferences about the migratory strategies of select migrants and the potential location of other stopover sites.

The project had two further aims. The first of these was to describe the ‘winter’ habitat use of migrants within the north-east biological corridor, both to increase our knowledge of habitat use by migrants during the non-breeding season and to provide supporting evidence for the protection of the North-east biological corridor. Within this aim existed a subset of goals as follows:

1. Determine which species spend the non-breeding season in NE Belize
2. Define the habitat preferences of these species
3. Determine whether the distribution of migrants by habitat changes between early and late winter
4. Estimate densities by habitat for the commonest migrants
5. Extrapolate over-wintering population estimates for the proposed biological corridor using these estimates
6. Use the resulting data to support the protection of the North-east Biological corridor

The final aim of the project was to increase capacity in ornithology in Belize and raise awareness of migratory birds both throughout the country and within the village of Sarteneja.
This aim contained a number of goals as follows:

1. Carry out field visits with pupils from schools in Sarteneja
2. Complete a project to create a ‘migration leaflet’ for distribution amongst the community with a Sarteneja school
3. Maintain a website on Neotropical migrants in Belize

4. Hold demonstrations at a ringing/banding station for students and conservation professionals alike

5. Train interested Belizeans in bird banding skills

6. Carry out a full length ringing course in Belize

Hurricane Dean

Hurricane Dean passed approximately 50 km to the north of our study area on the 21st August 2007. Whilst the hurricane did not 'flatten' the forest, some areas lost over 50% of trees and canopy damage was extensive throughout the area. Consequently, the hurricane caused many logistical problems with respect to reaching study sites and to accessing sufficient trails/tracks to carry out transects. Indeed, one site, Fireburn NR, had to be abandoned altogether, as the trail system was inaccessible for up to six months following the storm. As a result we moved activities that were planned for Fireburn to Balam Na and Balam Jungle, which were located further south and where the damage was not so great and trails could be walked with relative ease.

Aside the obvious logistical problems associated with the aftermath of the hurricane, its potential impact on the results of this study must also be considered. Migratory birds are generally highly capable of assessing habitats on the ground as they migrate overhead and apart from in unfavourable conditions or where suitable habitat is unavailable, are capable of choosing appropriate habitats to land in. This raises the question as to whether migrants may have recognised storm damaged forest from healthy forest and therefore avoided our study area. Whilst this is possible, it is unclear whether migrants can make such fine habitat distinctions, for example reed dwelling warblers regularly mistake fields of maize for reed beds and water birds have been known to confuse wet roads for wetland habitats.

Regardless of whether migrants can make this distinction, all results in this study must be considered bearing the hurricane in mind. This is especially true of the assessment of abundance by habitat over-winter. Whilst birds would still be expected to chose their preferred habitat, the carrying capacity of the habitats involved may have either been reduced or enhanced as a result of the hurricane and this must be taken into account. To illustrate this point, it is possible that more damaged areas became more appealing to species preferring edges and open forest structure such as the White-eyed Vireo, as found by Greenberg (1989) following Hurricane Gilbert, whilst species favouring closed forest such as the Hooded Warbler may have been excluded.

Prothonotary Warbler

Scarlet Tanager

CHAPTER 2

GENERAL RESEARCH METHODS

Introduction

To avoid considerable repetition between chapters, methodologies deployed in the field and in analysis that are common to more than one of the research areas examined in this report have been detailed below. How each of these methodologies was applied to specific questions is detailed within the following chapters.

This study deployed two main field methodologies, mist-netting and transects, and it is worth considering here their complimentary nature and the disadvantages of using either one in isolation. Mist-netting and transects are both means of sampling bird populations and the resulting information can answer a diverse set of questions. Both methods, however, have their biases and shortfalls that are best dealt with through combining the two. In this study, the main aim of deploying transects was to determine which migratory species were present in the study area, their relative abundance and to attempt to quantify differences in abundance between the habitats found within NE Belize. Transect methodologies are ideally suited to answering the above questions for the majority of species but are often considered inferior to mist-netting for the detection of shy species that favour dense vegetation. Whilst mist-netting may be more effective for sampling rarely seen species, its ability to comprehensively sample bird communities is heavily influenced by vegetation type and structure. Mist-nets are typically erected at ground level and only effectively sample birds flying at heights between 0.2-3 metres above the ground. In tropical forests, canopy heights are typically >8m and thus mist-nets will not effectively sample canopy dwelling species. Additionally, mist net position can greatly affect capture rates and thus standardising effort between areas/habitats is not possible. To effectively sample a bird community, the combination of transects or a similar observational technique and mist-netting is often considered most effective (Whitman *et al.* 1997).

With respect to this study, mist-netting added a further crucial element to the study. Whilst transects typically provide a more accurate description of a bird community, they provide little information on the status of the birds in that community in terms of migratory condition, site usage etc. To understand how migrants are using NE Belize it is vital to determine what they are doing when they are present in the region. This is a question that can only be answered by examining birds in the hand and being able to uniquely mark individuals. Mist-netting allows this and takes the study beyond essentially providing information on presence/absence, timing and abundance. To illustrate this point, we will provide a simple hypothetical example about two researchers. In a study of migratory birds on the northern Yucatan peninsula, researcher A using transects finds that the composition and abundance of migrants in two habitats, coastal scrub and inland tropical forest, was approximately similar during autumn migration when birds are arriving from North America across the Gulf of Mexico. Researcher A therefore concludes that both habitats are important to migrants after the Gulf crossing and that they should both receive equal conservation status. Researcher B deploys mist nets in both habitats and discovers that whilst she caught more migrants in the coastal scrub, they were rarely caught again in this habitat and if they were their fat scores had not increased. Conversely, those inland were often caught again and showed evidence for fat deposition. Researcher B concludes that the difference in abundance is probably because capture probability is higher in coastal scrub due to its low canopy and that whilst migrants often land on the coast, they quickly move inland to tropical forest, whose greater resource availability enable depleted fuel reserves after the Gulf crossing to be replenished faster. She therefore promotes the conservation of the inland forests over that of the coastal scrub.

Study Area, Study Sites & Habitat Descriptions

Study Area

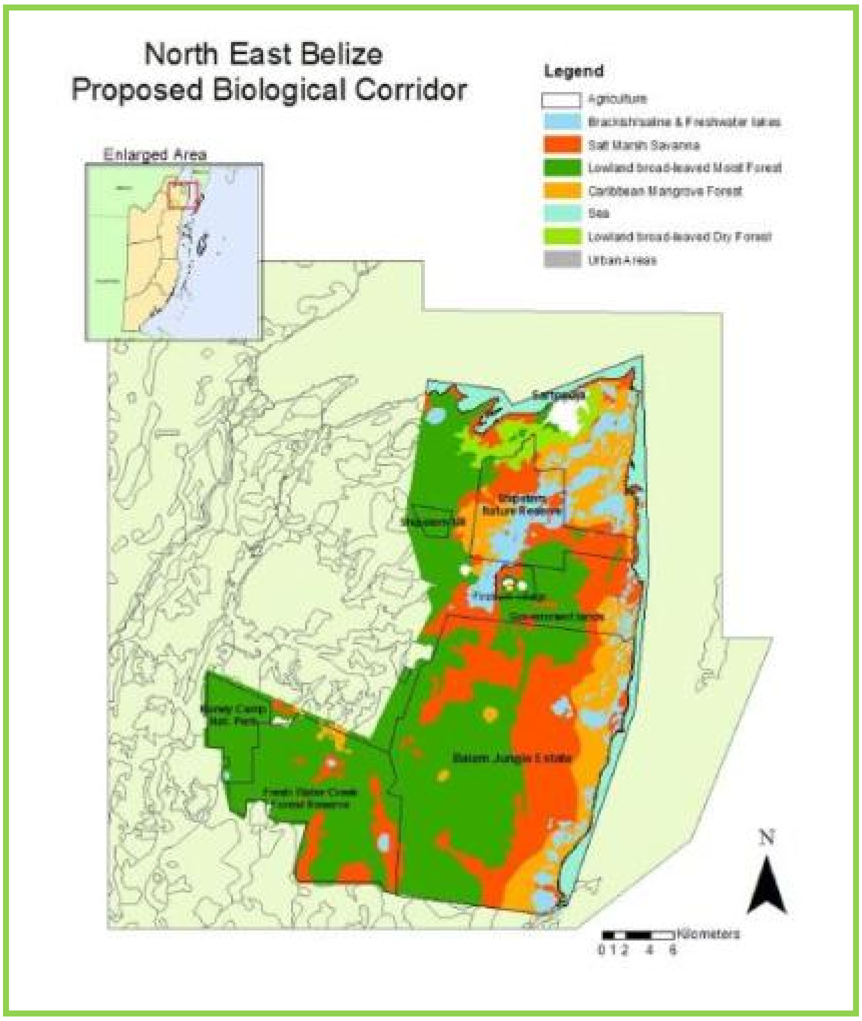
The study area was situated in the Central American country of Belize, located at the base of the Yucatan peninsula and bordered by the Caribbean Sea to the east, Guatemala to the west and south and by Mexico to the north. Within Belize the study was carried out entirely within the Corozal district in the north-east, with most activities being focused around the village of Sarteneja (see Fig. 2.1).

The climate within the study area is defined as sub-tropical and is characterised by distinct wet and dry seasons. Average annual rainfall in the north of the study area is around 1,260mm annually (Meerman & Boomsma 1993) and the Belize National Meteorological Service places the entire study region within the 1,524 mm isopleths. The majority of rainfall falls between June-January such that the dry season begins in February and may extend till the end of May. The prevailing wind direction is provided by south-east or easterly trade winds that blow for much of the year. Between October-March these may be interrupted by 'northers' which bring strong winds, cool temperatures and often rain as a cold front moves down from North America. Hurricane season spans June-November, peaking in September, and can bring heavy rainfall associated with tropical storms and occasionally hurricanes. Mean daily temperature varies from 24ºC during the 'winter' months to 29ºC during the 'summer' months.

The topography of the area reflects its location on the Yucatan platform, characterised by low lying plains that cover much of the Yucatan Peninsula. Within the study area, the land rarely rises five metres above sea level and many of the coastal savannahs and dwarf mangrove forests are sufficiently low lying that they become inundated by rising sea/lagoon levels associated with strong onshore winds. Land use within the study area is largely determined by soil depth which can be very thin over the limestone bedrock. Consequently, farming activities are restricted to areas with deeper soils, leaving much of the land with its natural vegetation cover. Areas that still retain natural vegetation cover are found within various land units including private nature reserves, private lands, government lands and government forest reserves.

The study area contained a matrix of ecosystems showing affinities to both the Yucatan and Selva Maya ecoregions. These ecosystems can be broadly classified into three types, tropical savannahs, mangrove lagoons and tropical broadleaf forests. Each of these ecosystems supports a wide range of habitat types that are detailed below.

Figure 2.1: Broad scale vegetation map of the study area and the proposed north-east biological corridor in NE Belize. Existing protected areas are outlined in black. It is important to note that classification of savannah and mangrove habitats is problematic and in many cases the two overlap in a form of mangrove/savannah, consequently the areas designated as the two habitat types below should be treated with caution. By way of example, the savannah areas within Freshwater Creek FR are more likely basin mangrove forest intermixed with freshwater, not salt marsh, savannah.



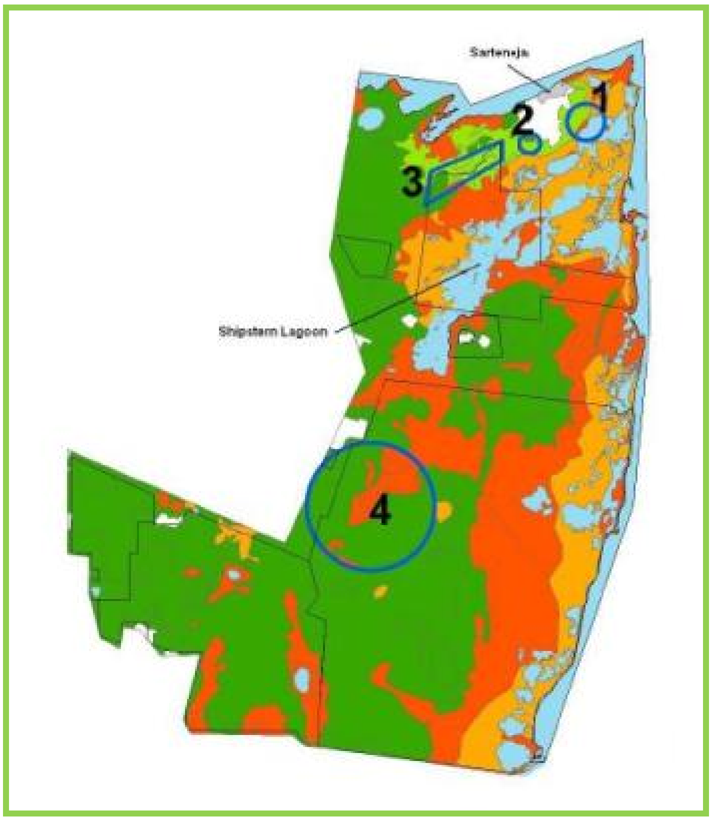
Study Sites
Within NE Belize, study sites were chosen to ensure that each of the major terrestrial habitat types within the region were sampled and to ensure that study sites were located throughout the proposed NE Biological corridor (see Chapter 1). The four main study sites, which are mapped in Fig. 2.2, were as follows:

1. **La Isla:** defined as the area within a radius of two kilometres of the La Isla (alternatively known as the Wildtracks) which was located to the south of Sarteneja village on the north-east shore of the Shipstern Lagoon (La Isla N18 20.111, W88 07.495; see Fig. 2.2)? The site was heavily used for logistical reasons and also for the habitat matrix it supported, including a Red Mangrove scrub associated with Shipstern Lagoon, Black Mangrove *Avicennia germinans*, tropical semi-deciduous broad-leaved forest (low variant), Milpa agriculture and savannah habitats. The forested areas around La Isla had been subjected to rotating Milpa agriculture and harvesting of forest products over at least the last 100 years and thus consisted of secondary growth at varying stages of maturity.

2. **Sarteneja Community Lands:** situated to the south and west of Sarteneja village, the study area took in a 1 km radius around the point N18 19.796, W88 09.327. The study area contained Milpa agriculture bordering on unbroken tropical semi-deciduous broad-leaved forest (high variant) stretching to the boundaries of Shipstern Nature Reserve. The entire area had been farmed at some point in the last 100 years and consequently forested areas consisted of secondary growth at varying stages of maturity.
3. **Shipstern Nature Reserve:** private nature reserve located to the west of Sarteneja village and containing forested areas both north and south of Shipstern Lagoon. Three areas of the reserve were utilised in this study: the eastern survey line (N18 19.091, W88 10.658); the western survey line (N18 17.871, W88 13.112) and the 'main trail' (N18 18.069, W88 12.742). The reserve was founded in 1989 by the International Conservation Foundation (ITCF). The areas utilised in Shipstern contained both tropical evergreen seasonal broad-leaved forest and tropical semi-deciduous broadleaved forest (high variant). Shipstern's reserve status meant it was the least disturbed area in recent decades but was subject to logging and agriculture disturbance prior to 1989 and consequently would also be considered to be a forest in a mature state of secondary growth.
4. **Balam:** consisted of Balam Na private nature reserve and the privately owned Balam Jungle Estate which were situated south of the Shipstern Lagoon and within the largest contiguous forest block in NE Belize (N18 06.251, W88 16.151; see Fig. 2.1 & 2.2). The Balam site consisted primarily of tropical evergreen seasonal broad-leaved forest and was interspersed with patches of tropical evergreen seasonal broadleaf lowland swamp forest and seasonally flooded swamps/savannas. Anthropogenic disturbance was least at this site with most activities involving selective logging, particularly during a concession in the late 1980's, subsequently the forests in this area could be described as mature second growth but lacked large specimens of all commercial hardwoods.

All the study sites above were affected to some degree by Hurricane Dean that passed to the north of the area on the 21st August 2007. Personal observations suggest an approximate gradient of damage from north to south, although the edges of open areas e.g. forest bordering farmland at Balam Na, were damaged to the same degree as areas further to the north. Whilst the hurricane did not flatten the forest in any of the study sites it did cause severe damage to the canopy in places and this will be considered in the evaluation of the data. The last time this region was severely affected by a hurricane was by Hurricane Janet in 1955, when anecdotal evidence suggests that the forest was devastated both by the hurricane and by a forest fire (Meerman & Boomsma 1993). Originally, the Fireburn reserve had been chosen for data collection, however the impact of hurricane Dean meant that large areas of the site were inaccessible and Balam Na, the Balam Jungle Estate and Shipstern Nature Reserve were used instead.

Figure 2.2: Main study sites (outlined in blue): 1) La Isla; 2) Sarteneja Community Lands; 3) Shipstern Nature Reserve (north); 4) Balam.



Habitat Descriptions
Habitat descriptions follow those outlined by Meerman & Sabido (2001), with the addition of our own field observations.

Milpa (UNESCO code: SPA.(1)) – Shifting cultivation called "Milpa" in Belize is a system by which a parcel of forest is cut, burned and manually farmed for one or more seasons (Meerman & Sabido 2001). It is an old practice derived from the ancestral Maya culture and in NE Belize it consists of relatively small (average of 1 ha) plots of land surrounded by forest which are cultivated with a variety of crops. Most of these plots provide goods at the household and local level and are not designed for large scale commercial production (Eastmond 1998). Normally after the crops have been harvested, the Milpa is left 'to rest' and secondary growth develops on it quickly. The result is a matrix of patches of land in different stages of succession.

Marine salt marsh, mangrove scrub and semi inundated mud flats (UNESCO codes:V.E.1.a.(1) & I.A.5.b.(1).(a)) – These open habitats associated to estuarine lagoons, occur on acidic soils over calcareous rock which are poor in nutrients and are inundated with brackish water for most of the year. It is a highly specialized ecosystem with plants adapted to extreme conditions of temperature and salinity which is often greater than 5%. The landscape is patchy with large areas of grassy and herbaceous vegetation surrounding islands of dwarf red mangroves or palms and shrubs (Meerman & Sabido 2001). Water levels are regulated by precipitation and by the wind which creates a

fluctuating flood system over vast areas in which the appearance of temporal pools are used by resident and migrant birds, in particular waders and ducks (*Pers obs*). For convenience, we refer to this array of habitats as “savannah” or “mangrove/savannah” in this study.

Black Mangrove – Patches of various sizes of Black Mangrove, *Avicenia germinans*, occur within and beside the estuarine savannas in areas where salinity is appropriate for development of this species. Due to its scarceness and patchiness it has not yet been mapped within the ecosystem map. However we have catalogued Black Mangrove as an independent habitat type due to its unique characteristics that make it an oasis for birds in the middle of the less diverse savannah habitat. While the surrounding savannah and forests dry up as the dry season advances, this process is much slower in the Black Mangrove due to the shade that prevents such a rapid evaporation. Consequently, nutrient rich mud and pools remain long into the dry season.

Tropical semi-deciduous broadleaf forest (UNESCO code: I.A.3.a.(1).(a).) - This type of forest has only been described from around Sarteneja and north of the Shipstern Nature Reserve within Belize. It has a low canopy (8-12 m) and a more deciduous aspect than most other forests in Belize and has been associated with areas of shifting cultivation (Meerman & Sabido 2001). According to the level of disturbance, hence the approximate time period since it was cleared, we divided the forests in two groups reflecting a perceived difference in bird communities: disturbed and undisturbed.

Disturbed variant – Patches of forest that have been regenerating from either past cultivation or complete clearance for the past 30 years. They are near Sarteneja and near milpa plots of various ages. In this study we refer to this habitat type as “dry forest – low”

Undisturbed variant – Exclusive to the patches of forest inside the Shipstern Nature Reserve which as a result of protection for at least 18 years are in a more advanced stage of succession. This is reflected in general structure e.g. higher canopy height (12–15 m) and in a somewhat different tree composition. In this study we refer to this habitat type as “dry forest – high”.

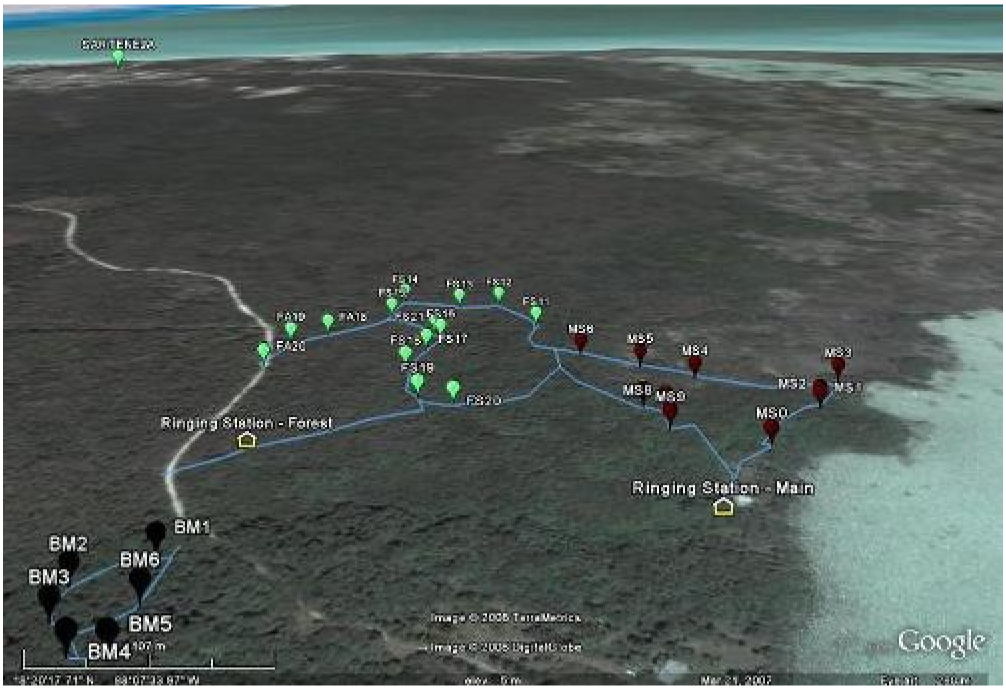
Tropical evergreen seasonal broadleaf lowland forest on calcareous soils: Yucatan Variant (UNESCO code: I.A.2.a.(1).(b).K-Y) – These forests receive slightly more annual rainfall than those further north and have a higher canopy (15- 20 m). They are characterized by the scarcity of *Attalea cohune* and *Crysophila stauracantha* palms which are common in similar forests in Belize (Meerman & Sabido 2001). The forest we sampled in the Balam Jungle Estate corresponds to this habitat type. We refer to this habitat as “moist forest” here.

Mist–netting and bird banding

Mist nets were deployed at La Isla during the two migration periods that shall be referred to as ‘autumn’ (August-Mid November) and ‘spring’ (mid-March-mid May) from here on. Mist netting effort varied to a small extent within the autumn period and markedly between autumn and spring due to a variable number of mist nets being available for use. Variability in mist netting effort will be described in Chapters 3 and 4. Mist nets varied in length between 8m - 18m with the majority of nets being 12m in length. Mesh sizes of nets included both 32mm and 36mm (spring only) nets which despite increasing the chances of sampling smaller and larger migrant species equally (Pardieck & Waide1992) was, in hindsight, a mistake as the vast majority of captures were of small warblers and thus capture numbers were considered to be lower than if only 32 mm nets had been used exclusively.

Mist-net were erected in two main habitats, dry forest (low variant) and Red Mangrove/savannah edge, during both seasons and in Black Mangrove (6 nets) in spring (Fig. 2.3). Nets were divided approximately equally between habitats and placed to maximise the area covered whilst ensuring that an empty ‘net round’ (check of the nets) lasted no more than 15 minutes. Exact net positions were selected to maximise captures where possible by closed choosing sites such as edges that birds followed and areas in the forest and mangrove where the canopy was lowest. The majority of nets were installed such that they sampled birds moving at a height between 0.4-3.0 m whilst one net was elevated higher on bamboo poles to sample birds between 1.25-4 m. Mist-nets were opened daily at dawn during both seasons and after approximately 3.5 hours if conditions allowed. Mist-nets were not opened or were closed in strong winds, rain and high temperatures. On a small number of occasions, overwhelming numbers of birds meant that only a reduced set of nets was kept open.

Figure 2.3: Mist-net positions at La Isla, NE Belize. Mist-nets in different habitats are coloured and named correspondingly such that MS (red) = Red Mangrove/savannah; FS/FA (green) = dry forest (FA = autumn only); BM (black) = Black Mangrove. Blue lines indicate tracks cut to access nets. The view is looking north from the shore of Shipstern lagoon towards Sarteneja and Chetumal Bay (see Fig. 2.2 for locality of La Isla at wider scale). Image created in Google Earth.



Once open, mist nets were checked every 40 minutes or less and all birds were extracted and brought to a ringing station in cloth bags to be processed prior to release. The time in which birds were in mist nets or being processed was kept as short as possible. To increase the capture of canopy dwelling species, a sound lure consisting of the songs of select species was played on a continuous loop by one of the nets on certain days. The sound lure was never deployed before dawn and was maintained at a volume so it was not audible at a distance greater than 50m. The species played, net at which the sound lure was deployed and the duration of use were recorded in all cases.

All new captures were fitted with a band/ring bearing a unique number and a reporting address, except for Hummingbirds and those for which an appropriate ring size was not available (all bands were obtained from ProAves of Colombia and bear the reporting address www.sna.org.co). Time allowing, the data variables in Table 2.1 were taken for each bird including recaptures. In addition to the data recorded on each bird, data on weather conditions were made from direct observations on a daily basis and a satellite image showing cloud cover and water vapour in the Caribbean region was downloaded when internet access was available.

Table 2.1: Variables recorded for birds captured in mist nets. For migratory species all variables were recorded, if time allowed, except for those marked with an **R** which were only recorded for resident/locally breeding species.

Variable	Method of determination or scoring system & reference source
Date & Time	Time was assigned as the hour of extraction from mist net
Net number & capture type	The identification number assigned to the net of capture was noted. Capture type was recorded as 1 = new, 2 = recapture, 3 = new but released un-banded
Species	Determined using either Pyle (1997), Jones (2003) or Sibley (2000)
Age	Determined using the criteria in Pyle (1997) or by applying basic principles regarding ageing birds for resident species
Sex	Determined using the criteria in Pyle (1997) or by referring to Jones (2003) or Sibley (2000)
Fat Score	Visible fat deposits were scored on a nine point scale, 0-8, following Kaiser (1993)
Muscle Score	Condition of the pectoral muscle was scored on a four point scale, 0-3, following (c.f. Redfern & Clark 2001)
Generations of feathers	The number of generations of feathers in the wing.
Wing length	Measured to the nearest 1 mm using the ‘un-flattened’ method (Pyle 1997)
Body Mass	Measured to the nearest 0.1 g using an electronic balance
Breeding Condition R	Presence/development of cloacal protuberances and brood patches were scored on four point scales
Plumage State R	Each feather tract in the wing was scored according to whether it was retained, replaced or in moult

Transects

Variable distance transects were carried out in all three study periods, autumn, spring and winter, and at all study sites. Each transect was 500 m in length, except for two transects in Black Mangrove that were 100 m and 125 m due to the limiting patch size of the mangrove, and was measured using a GPS and marked with flagging tape for future reference. The majority of transects followed existing trails, tracks or survey lines and were chosen to follow as straight a line as possible. The position of all transects used during the study can be seen in Fig. 5.1.

The majority of transects were carried out between dawn and three hours after, although some transects during the migration periods were carried out in the afternoon. Transects were walked at an even pace such that they took between 15-30 minutes and all birds seen and heard along the transect were noted. The distance of each bird from the transect was estimated and then the birds were assigned to a distance band. For transects walked between the 1st Aug 2007 – 28th Jan

2008 distance bands were as follows: 1 = 0-25m, 2 = 25- 50m, 3 = 50-100m. After the 28th Jan 2008, the number of bands was increased to improve the calculation of detection curves using the program Distance such that: 1 = 0-5m, 2 = 5-10m, 3 = 10-25m, 4 = 25-50m, 5 = 50-100m. Birds flying over the transect were noted but were not included in analyses of abundance. For each transect walked, the date, start and end time, observer and weather conditions in terms of cloud cover, wind strength and rain were also noted.

Each individual transect was assigned to one of six habitat types according to a process with varying levels of complexity. Three habitat types Black Mangrove, Savannah and Milpa agriculture, were considered relatively homogenous and easy to identify and transects were assigned to them subjectively. In the case of Milpa agriculture, each transect was scored for percentage farmland by measuring the number of metres of farmland either side of the transect and dividing by 1000 m. For transects in forest, a series of habitat variables were measured in three 5 m^2 plots per transect following a modified version of the James & Shugart (1970) method for sampling vegetation in forest and shrub systems (see Martin *et al.* 1997) (see Table 2.2). In addition three 15 x 5 m tree strips were carried out along each transect, in which the number of trees with a DBH greater than 10 cm of six common species were counted. The species included Gumbo Limbo *Bursera simarouba*, Chicle *Manilkara sapote*, Cotton Tree *Ceiba pentaphylla*, Waree Wood *Caesalpina gaumeri*, Black Poisonwood *Metopium brownei* and Salam *Lysiloma latisilquum*. The process of assigning forest transects to forest type is described in Chapter 5.

Table 2.2: Habitat structure variables recorded in three 5x5m plots located along transects in the forested habitats, North East Belize 2008.

Variable	**Method of recording (Martin *et al* 2007)**
Canopy	
Average Canopy Height	One measurement in centre of plot
Percentage canopy cover	One measurement in each corner of the plot
Tree density	
Number of snags (>10cm dbh)	Count of all trees of the specified diameter within the plot
Number large trees (> 38cm dbh)	
Number medium trees (23-37cm dbh)	
Number small trees (8-22cm dbh)	
Number large stems (2.5-7cm)	
Percentage Ground cover	
Grass	Estimation of percentage of items covering the ground. The sum must add to 100%
Shrub	
Dead wood	
Forb	
Cactus	
Leaf litter	
Rock	
Water	
Other	
Leaf litter depth	One measurement in each corner of the plot
Hurricane damage	Number of fallen and broken trees in plot.

In addition to the observations made during transects, general observations were made throughout all study periods especially of migratory birds seen whilst mist-netting.

Data Analysis

Lean Body Mass, Fuel Loads, Body Mass Changes and Fuel Deposition Rates

Size-specific lean body mass (LBM) for individual species was estimated from the body mass of birds with a fat score of zero by regressing body mass on wing length. Body mass changes, which reflect changes in fuel stores (Redfern *et al.* 2004), were calculated as the change in mass between successive captures of individual birds. Fuel load and fuel deposition rate (FDR) were quantified as a percentage of a bird's size-specific LBM, to take into account differences in overall structural size between individuals. Fuel load will thus be expressed as a percentage of LBM, and FDR as the percentage of LBM accumulated per day. FDR could only be calculated for birds trapped on two separate occasions. As capture effects are believed to result in mass reductions (c.f. Gosler 2001), only maximum FDRs were calculated to minimise these effects. To quantify maximum FDRs from data on mist-netted birds, the maximum observed rate of mass increase between successive captures of each re-trapped bird was calculated (for birds captured twice this was simply the rate between first and last captures).

Stopover Durations

Minimum stopover durations were calculated as the time elapsed between the first and last captures of any given bird. More accurate estimates of stopover duration can be obtained through other methods but these could not be deployed here due to small sample sizes (Morris *et al.* 2005). Various studies have demonstrated that minimum stopover durations tend to underestimate durations relative to other methods and this must be kept mind here. It is important to note that we only calculated durations for re-trapped birds and not those caught on one occasion and thus our results apply only to birds stopping in the area for certain and exclude birds that are likely only to be pausing in the study area for one day between successive nocturnal flights.

Flight Ranges

Flight ranges were calculated using version 1.15 of Pennycuick's flight program (Flight 1.15, accessed 31/03/05, **http://www.bio.bris.ac.uk/people/staff.cfm?key=95**; Pennycuick & Battley 2003) for six species (see Chapters 3 & 4) for which field measurements on live birds of wingspan and wing area had been made (see Pennycuick 1999 for methodology). To calculate ranges, birds were set up with the appropriate wingspan and aspect ratio (calculated from the wingspan and wing area measurements) and a flight altitude of 1000 m (varying flight altitude has little effect on estimates). The default setting of 0.17 was used for the flight muscle fraction. 'Fat mass' was calculated by subtracting the LBM of a bird of mean wing length from the 'empty body mass' and taking 85% of that figure. Thus 85% of any increase above LBM is expected to be fat whilst protein combined with water makes up the rest (c.f. Piersma 1990). Actual fat content may be higher given that Baggott (1986) found that fat accounted for 100% of increases above the mean LBM of a migratory warbler (N = 20). Default settings were used for all other inputs.

Species abundance estimates

Estimates of abundance for individual migratory species and migrants as a group were estimated using data from transects. Two methods were deployed to estimate abundance/densities depending on the number of observations per species. If more than 20 individuals were detected in the period of interest, estimates of density were calculated using the program Distance Version 5.0. Species with fewer observations or for which the program Distance could not reliably model detection probability, were analyzed on the conservative assumption that all individuals within 25 m of a transect were detected. This assumption by its very nature will result in underestimates of density and is only used to allow comparisons between habitats and times of year and not for making reliable estimates of densities. In all cases in which the later method is adopted, only differences receiving strong statistical support ($P<0.01$) were accepted, as differences in detectability between habitats or at different times of year may have been responsible for small differences in abundance.

What the DISTANCE program does, in effect, is to draw out a detection curve for each species and then fit a mathematical model, which describes the data. The three main models, or ‘key functions’, account for the fact that some birds are detectable over much greater distances than others and that a species may be more easily detected in one habitat than another and thus every species will have a slightly different detection curve. If necessary, these models can be adjusted to fit the data even further by using a ‘series expansion’ or a variation on the key function. To draw useful conclusions from distance sampling data, the following assumptions must be met (Buckland *et al.* 1992):

A. With regard to the statistic validity of the data and to the survey design:

1. Objects sampled (birds) are spatially distributed in the area to be sampled according to some stochastic process with rate parameter D (= number per unit area).
2. Randomly placed lines or points are surveyed and a sample of *n* objects is detected, measured and recorded.

B. With regard to the sample objects and the data:

1. Objects directly on the line or point are always detected (i.e. they are detected with probability 1.

Objects are detected at their initial location, prior to any movement in response to the observer.
Distances are measured accurately, or objects are correctly counted in the proper distance category.

Flooded mangrove mist-net ride

Mangrove/savannah mist-net ride

CHAPTER 3

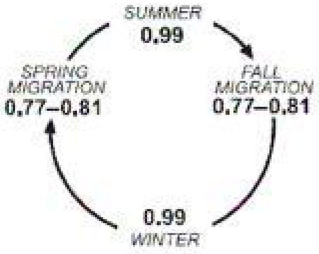
AUTUMN MIGRATION

Introduction

Migration occupies up to one third of the annual cycle of migratory birds (Mehlman *et al*. 2005) and increasingly is considered one of the most vulnerable stages of a migrant's life cycle (Holmes 2007; Newton 2006). This assertion is gradually gaining empirical support, for example, when the annual cycle of the Black-throated Blue Warbler was examined in terms of monthly survival probabilities, mortality rates were found to be highest during the two migration periods (see Fig. 3.1). When translated into annual mortality, Sillett & Holmes (2002) demonstrated that migration accounted for up to 85% of the annual total in this warbler. These findings led Holmes (2007) to conclude that 'events during migration and especially the quality of migratory stopover sites are important to the maintenance of long-distance migrant populations' in a review of the causes of population change in migratory songbirds. The importance of high quality stopover sites is made clear by the example of the Red Knot *Calidris canuta*, in which a catastrophic decline in population was linked with the overexploitation of their main food source at a critical stopover site in Delaware Bay (Baker *et al*. 2005). Despite the obvious importance of quality stopover sites for the success of migration, little study has been directed towards the stopover ecology of Neotropical landbirds.

Part of the reason for this lack of studies, is the difficulty in studying, identifying and categorising stopover sites. Migratory birds often use a wide range of sites, whose use may vary markedly between years, and therefore differentiating between sites in terms of quality can be difficult. To aid this process Mehlman *et al*. (2005) defined a framework by which to assess such sites. Based on a site's capacity to meet a migrant's needs at any point both in space and time, the framework divides sites into three categories as follows: **Fire escapes** – sites infrequently used during emergencies that ensure survival but contain minimal resources e.g. small islands during adverse weather at sea; **Convenience Stores** – as the next step up, these sites are generally small and found within a matrix of inhospitable habitat and allow birds to take a break and top up but not fully replenish reserves; **Full Service Hotels** – as their name suggests these sites meet all a migrant's needs, being high quality habitat with low levels of competition and sufficient resources for complete replenishment of fuel stores. Full service hotels are also expected to be large areas of suitable habitat, thereby diminishing size-dependant problems that smaller Convenience stores present, such as increased predation levels and the risk of resource depletion.

Figure 3.1: Monthly survival probabilities of Black-throated Blue Warblers at different stages in the annual cycle. Adapted from Holmes (2007).



Our knowledge of Neotropical migratory landbirds currently has a northerly bias. Whilst key North American stopover sites around the Gulf of Mexico have been identified (e.g. Yong & Moore 1997, Yong & Finch 2002) and in other key areas of North America (Morris *et al*. 1996, Duncan *et al*. 2002), there is little or no information from Central or South America. General routes in Latin America, as outlined in Chapter 1, are fairly well described with many species known to cross the Gulf of Mexico to make landfall on the Yucatan peninsula during autumn migration and then continue further south. Patterns of occurrence of migrants within Central America are also well described by texts such as Howell & Webb (1995) and Jones (2003) - the latter in particular gives a good indication of the relative abundance of different species and their status in terms of transient or wintering. However, even these texts admit a lack of knowledge for certain species such as the Empidonax flycatchers (Jones 2003). What these texts do not detail is how migrants are using the region in terms of replenishing reserves, stopover durations and habitat use – information also lacking in the wider literature. A study of migration in Veracruz suggests that many species are using this area but does not detail exactly how - it does however demonstrate that more species occur in lowland versus montane forest and that arrivals of migrants appear to coincide with 'nortes', southerly moving fronts over the Gulf of Mexico (Inzunza *et al.* 2005).

Located in the southerly portion of the Yucatan peninsula, Belize is situated along a major flyway for birds moving south from the northern Yucatan having crossed the Gulf of Mexico during autumn migration. Given its strategic position and wealth of natural habitats, especially forested habitats, Belize is expected to provide a range of stopover sites to transient birds that could be classed as full service hotels. To increase our understanding of migratory stopover behaviour in Neotropical migrants, how migrants use Belize and in particular how they use the proposed NE Biological corridor, we aimed to assess which species occurred in the area during migration and their relative abundances. To determine whether migrants were merely using the area as a convenience store, i.e. as a resting place between nocturnal flight where they could 'grab a snack', or whether they were replenishing reserves expended crossing the Gulf of Mexico, we examined the fat stores, stopover durations and fuel deposition rates of commonly occurring species. The manner in which migrants were using NE Belize is used to infer where key stopover sites both north and south of the area might be located.

Methods

Transects & general observations

Autumn transect work began on the 5th August 2007 and the last transect was walked on the 9th November 2007. All transects were 500 m in length, were walked at a similar pace (Mean Transect Duration ± SD = 24.67 ± 11.28; N = 115) and were generally carried out in the first three hours after dawn (mean start time 7:45 am). The recording of birds heard and seen was carried out as described in Chapter 2. Transects were carried out at two main sites, La Isla and Balam. At La Isla transects were carried out on a near daily basis in two habitats, mangrove/savannah and 'dry forest' (semi-deciduous tropical forest low variant) intermixed with regenerating Milpas (18% of transect). Due to time constraints associated with mist netting activities, transects were largely restricted to the dry forest/Milpa matrix (see Transect MI1 in Fig. 5.1). The Balam area was visited on three occasions – 30/08/2007, 7/10/2007, 1/11/2007 – during each of which approximately 5 km of transects were walked in 'moist forest' (evergreen broadleaf tropical forest). In addition to the observations made during transects, general observations were made throughout the autumn study period especially of birds seen whilst mist-netting.

Mist-netting

During the autumn up to 16 mist nets were erected across two habitats –mangrove/Savannah and dry forest (low variant). After a trial run on three days in mid-August, 15-18th, mist netting was carried out daily, weather allowing, from the 2nd September 2007 to 3rd November 2007. The number of nets opened on a given day varied depending on weather conditions and prior to the 23rd September only 13 nets were available. The resulting mean daily net effort ± SD expressed in terms of mist-net hours (1 mist-net hour = one 12m net open for one hour) was 53.8 ± 15.9 for the first period of the autumn (2nd – 23rd Sept) and 56.2 ± 17.6 for the second period (25th Sept – 3rd Nov). In total mist-nets were operated for 3260 mist-net hours between the 2nd September – 10th November, of which 1816 were in forest and 1444 in mangrove/savannah. Birds caught in mist nets were processed according to the methods in Chapter 2. To increase captures, the songs of two common passage species, Red-eyed Vireo and Prothonotary Warbler, were played at low volume next to one net on certain days.

Migratory phenology

To examine the timing of migration, daily capture totals from mist-netting were corrected for mist-net effort and the playing of sound lures. For transect data, only daily migrant totals from transect MI1 were selected.

Estimating abundance from transect and mist-netting data

To examine migrant abundance during autumn, data from both transects and mist-netting were utilised. In general transects produced insufficient records to use the program Distance to estimate densities, so a conservative approach was adopted to allow inter-habitat comparisons and make estimates of the number of birds passing through the study area. This involved treating transects as strips 500 m long and 25 m either side of a central line in which detection was assumed to be 100%. Even within 25 m detection rates are expected to be below 100% and thus all resulting estimates will underestimate true numbers – Raman (2003) suggests that underestimates may be around 19% on average across a range of species for a transect of width 30 m either side of the line. Data from transects were combined to estimate the number of individuals present in 1 km² on an average autumn day and at three periods during the autumn in three habitats. The three periods were defined by each of three visits to Balam and for La Isla all transects carried out five days either side of visits to Balam were combined. An average number of individuals/km² across the whole autumn was also calculated by summing across all transects in a given habitat and multiplying by an appropriate factor. To estimate the total number of individuals by species passing through the proposed corridor during autumn, estimates of individuals per km² from transects were multiplied by the number of days of passage (we arbitrarily chose 60 as this approximates to the period over which transects were carried out) and then by the number of km² of available habitat (dry forest = 60 km²; moist forest 350 km²; 250 km² mangrove/savannah). For transient species it was assumed that individuals recorded on different days were not the same individual, whilst for 'wintering' species, the number/km² was adjusted for the percentage re-trapped as calculated from mist-net captures (see Table 3.2). Note that these estimates do not account for birds occurring in rare habitats in the corridor. For comparison, the number of transient birds based on mist-net data was also calculated, here a conservative assumption was made that 100% of birds occurring in the 0.175 km² mist-netting area were captured and that the area of available habitat was 400 km². For wintering species, re-trapped birds were excluded from calculations.

Fuel loads, fuel deposition rates (FDR) and stopover durations

Fuel loads were calculated for six selected migrants following the methods in Chapter 2 and using first captures only. Fuel loads were then assigned to one of three fuel store classes as follows: Small = 0-10% of LBM; Medium = 10-30% of LBM; Large = >30% of LBM. FDR and minimum stopover duration were calculated following the methods explained in Chapter 2 for all individual birds that were captured more than once - in the case of known wintering species, only recaptured individuals that showed an increase in visible fat deposits between captures were included in analyses. Estimates of both FDR and stopover duration were averaged within species for presentation in Table 3.6.

Flight ranges

Flight ranges were calculated according to the methods described in Chapter 2 for three species. Calculations required an estimate of LBM, wing span and wing area, for which the following values were used based on in hand measurements and values accompanying the program Flight 1.15 in the case of American Redstart.

Red-eyed Vireo: LBM = 0.18 + 0.182*Wing length; mean wing span (N = 5) = 0.234 m; mean wing area (N = 5) = 0.0108 m.

Prothonotary Warbler: LBM = 6.1 + 0.080*Wing Length; Mean wing span (N = 4) = 0.202 m; Mean wing area (N = 4) = 0.0084 m.

American Restart: LBM = 3.29 + 0.061*Wing Length; Mean wing span (N = 5) = 0.195 m; Mean wing area (N = 5) = 0.0078 m.

Results

Species composition

Between August 1st 2007 and November 15th 2007 over 5400 individuals of 84 species of Neotropical migrants were recorded in the study area during mist-netting, transects and general observations. Of these 84 species, 63 species or 75% were primarily terrestrial species or landbirds, with the remaining 25% of species favouring wetland and marine habitats. Of the 63 landbird species, 24 or 39% are defined as transients, i.e. those species which only pass through Belize on route to non-breeding or breeding grounds (Jones 2003). In reference to the study area and not the whole of Belize, the number of transients increases to 39, due the passage through northern Belize of species that only winter in the south of the country e.g. Chestnut-sided Warbler. In terms of abundance, individuals of transient species accounted for 60% of 3994 migrant observations on transects and for 38% of 1409 new migrant captures.

The composition of migrants largely reflects what would be predicted from Jones (2003), however, there were notable omissions. Wilson’s Warbler is common in parts of the Maya Mountains in southern Belize but was not recorded during this study. Similarly, Wood Thrush and Yellow-bellied Flycatcher are both common winter residents in much of Belize but were rare on passage in our study area with nine and one observations respectively.

Notable observations of migrants included two near-threatened migrants, the Golden winged Warbler (3 captures) and Olive-sided Flycatcher (1 observation) and a species considered accidental in Belize (3 previous records; Jones 2003), the Clay-coloured Sparrow, was observed for four consecutive days following a large fall-out on the 12th October. Eight further species appeared to be new records for the Corozal district of Belize, including Chuck- Will’s Widow, Cliff Swallow, Willow Flycatcher, Alder Flycatcher, Acadian Flycatcher, Prairie Warbler, Palm Warbler and Canada Warbler.

Migratory phenology

The first landbird migrant was recorded on 12th July, following which numbers increased very gradually until mid-August. From mid-August Red-eyed Vireo and Yellow Warbler increased in numbers but there was no notable arrival of ‘early’ migrants until mid-September. From mid-September onwards passage remained relatively constant until late October, except for an obvious peak associated with a large fall-out on the 12th October and a smaller peak around the end of October (Fig. 3.2). The timing of passage by individual species followed that expected from texts such as Jones (2003) and can be roughly interpreted in terms of early, average and late migrants from Table 3.1. The phenology of three transient species is illustrated in Fig. 3.3 and demonstrates differential timing between species, as well as providing new information on Empidonax flycatchers in Belize (Lee Jones *pers. com*).

Figure 3.2: Autumn migratory phenology of all Neotropical migrants recorded in NE Belize based on two methodologies; 1) mist-net captures at La Isla corrected for mist-net effort and tape lure use; 2) observations from 500 m transects at La Isla. Days with zero values are a consequence of no mist-net or transect effort and are not an absence of migrants.

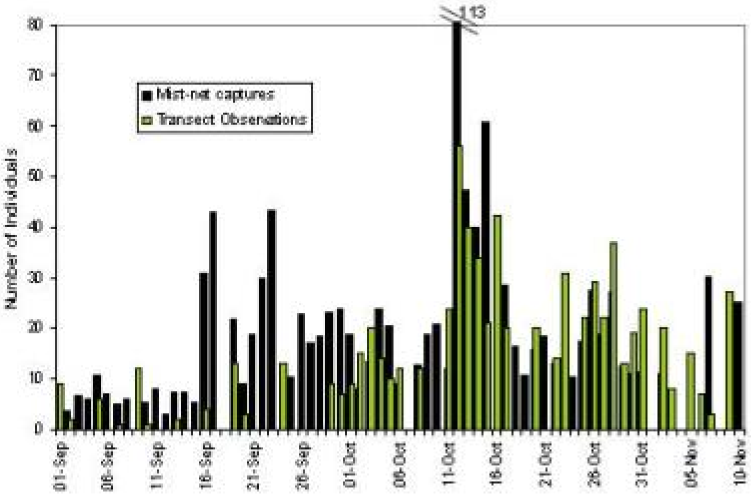


Figure 3.3: Phenology of the Swainson’s Thrush, Willow Flycatcher and Alder Flycatcher in NE Belize based on mist-net captures from La Isla.

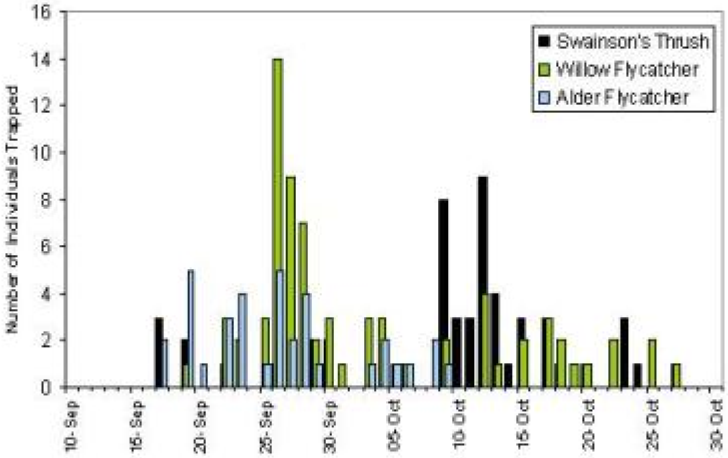


Table 3.1: Relative abundance of Neotropical migrant landbirds in two forest types and at different periods during autumn migration in NE Belize. Abundance is expressed as the number of individuals/km^2 as estimated from fixed width transects (500 m x 25 m). Forest types are abbreviated as Dry Forest = Tropical semi-deciduous broadleaved forest and Moist Forest = Tropical evergreen seasonal broadleaf forest. Periods are defined as five day periods either side of the following dates: early = 31st August; mid = 7th October; Late = 1st November and where All is the mean across all transects walked between 25th August-10th November. The number of 500 m transects used for estimates is given in brackets next to period. Species that were primarily transients in the study area have a T following their common name.

Common Name	Dry Forest				Moist Forest			
	Early (6)	Mid (8)	Late (8)	All (43)	Early (6)	Mid (10)	Late (10)	All (28)
Yellow-billed Cuckoo T		10		3.7				0.0
Eastern Wood-Peewee T		20	80	93.0		8	40	17.1
Acadian Flycatcher T				9.3		8		2.9
Alder Flycatcher T		20		5.6				0.0
Willow Flycatcher T				0.0		8		2.9
Least Flycatcher		50	30	37.2		24	8	11.4
Empidonax sp.				7.4	26.7	8	8	11.4
Great-crested Flycatcher T				3.7	13.3	8		5.7
White-eyed Vireo		20	180	55.8		8	32	14.3
Yellow-throated Vireo			10	11.2				0.0
Red-eyed Vireo T	53.3	50		24.2	146.7	16		37.1
Gray-cheeked Thrush T				0.0			8	2.9
Swainson's Thrush T			10	18.6		8	40	17.1
Wood Thrush				0.0				0.0
Gray Catbird			50	16.7			80	28.6
Warbler sp.	53.3	40	70	50.2		8	8	5.7
Blue-winged Warbler				1.9				0.0
Tennessee Warbler T			30	20.5			24	8.6
Northern Parula		50	20	27.9		8		2.9
Yellow Warbler T	106.7	30		50.2	66.7			14.3
Chestnut-sided Warbler T		10		7.4				0.0
Magnolia Warbler		30	280	128.4		16	96	40.0
Black-throated Green Warbler			20	24.2		8		2.9
Blackburnian Warbler T				1.9				0.0
Yellow-throated Warbler	13.3			1.9	13.3	8		5.7
Bay-breasted Warbler T				1.9			8	2.9
Black-and-white Warbler		20	20	26.0		24	40	22.9
American Redstart		110	90	65.1	26.7	168	160	122.9
Prothonotary Warbler T		20		13.0				0.0
Worm-eating Warbler				0.0	13.3		16	8.6
Ovenbird		50	40	35.3		8	16	8.6
Northern Waterthrush		50	160	78.1		32	40	25.7
Louisiana Waterthrush T				0.0	26.7			5.7
Kentucky Warbler				1.9		16	8	8.6
Common Yellowthroat			30	18.6			8	2.9
Hooded Warbler		220	140	120.9		56	48	37.1
Canada Warbler T		10		1.9				0.0
Yellow-breasted Chat		30	10	13.0				0.0
Summer Tanager		20	20	11.2				0.0
Scarlet Tanager T		10		1.9				0.0
Rose-breasted Grosbeak T				9.3				0.0
Indigo Bunting			80	29.8				0.0
Total Migrants/Km^2	**226.7**	**870.0**	**1370.0**	**1028.8**	**333.3**	**440.0**	**696.0**	**477.1**

Species abundance & habitat preferences

Estimates of migrant abundance by habitat type calculated from transect data are given in Table 3.1. Examination of Table 3.1 suggests that differences between ‘dry forest/milpa’ and ‘moist forest’ exist both in terms of species composition and abundance. Many of these differences reflect those found during winter for wintering species (see Chapter 5). For transient species, limited observations restrict the determination of habitat preferences, although the Eastern Wood-Pewee apparently preferred the more open dry forest/Milpa relative to the closed moist forest whilst Red-eyed Vireo showed the reverse pattern (differences not significant, $P>0.05$, but this may be due to a lack of power). Several transient species were only observed in dry forest but with surveys in moist forest restricted to just three days this is probably an artefact of the methodology. Transects carried out in Mangrove-Savannah are not summarised in Table 3.1 but generally very few migrants of either wintering or transient species were observed, such that the total number of individuals expected in 1 km^2 on an average autumn day was just 63.5 versus 477.1 in moist forest. Also excluded from Table 3.1 are diurnal (daytime) migrants recorded migrating over the study area, instead their relative abundance can be assessed from Table 3.3.

Mist-netting data revealed similar patterns to the observational data but a number of species were detected at higher rates by mist-nets. For example, Alder and Willow Flycatchers were abundant according to mist-netting data but were rarely detected during transects. Other species detected more regularly by mist-nets included all four ‘thrush’ species, Chestnut-sided Warbler, Prothonotary Warbler, Swainson’s Warbler, Worm-eating Warbler and Ovenbird. Mist-nets also detected eight migratory species that were not observed on transects whilst only two species were detected solely on transect. The mist-netting site covered two main habitats, dry forest and mangrove savannah, and approximate habitat usage can be assessed from Table 3.2, although it must be borne in mind that mist-net effort cannot be standardised between habitats unlike transect data. The percentage of adults in the population is also expected to give an indication of site/habitat preferences - if the percentage is low i.e. <10% then experienced adults may be actively avoiding the area/habitat whilst percentages >25% suggest that adults are equally as likely to use the area as inexperienced immature birds. For species known to winter in the study area, the proportion of transient individuals versus those that remained in the area can be evaluated by examining the percentage of birds that were later re-trapped in Table 3.2. For most species recaptures rates were low suggesting a high proportion of transients.

Taking into account both the transect data and mist-netting data, we estimated the number of individuals by species using the corridor during passage (see Table 3.2 & 3.4). Note that these estimates are conservative as they assume a 100% detection rate in the area surveyed, which is unlikely for both methodologies, especially the mist-nets (this probably explains why the estimates from mist-nets are lower than those from transects).

Energy reserves, fuel deposition rates and stopover behaviour

In Table 3.5 percentages of birds by fat/fuel store level are given for the commonest transient species and for the American Redstart, a common ‘wintering’ species with a large transient population. Birds with ‘small’ stores are expected to be more likely to stopover in the corridor and replenish fuel stores than those with medium to large reserves. Table 3.5 also details whether fuel reserves differ by age or habitat. Due to low recapture rates, it is difficult to determine the length of stopovers made by migrants in the corridor or to determine the rates at which they refuelled during such stopovers. In Table 3.6, however, are mean FDRs and minimum stopover durations for a range of species based on the recaptures obtained.

Table 3.2: Total mist-net captures during autumn migration at La Isla and by habitat. The percentage of birds re-trapped gives an indication of turnover rates and stopover behaviour, whilst the percentage adults may give an indication of habitat preferences (see discussion). ‘Corridor total’ is an estimate of the number of individuals by species passing through the proposed corridor during an autumn (for generation of estimates see methods).

Common Name	**Scientific Name**	**Total New**	**Mangrove/Savannah**	**Dry Forest**	**Forest Edge**	**% Re-trapped**	**% Adults**	**Corridor Total**
Chuck-will's Widow T	*Caprimulgus carolinensis*	1			1	0	10	2,286
Eastern Wood-Peewee T	*Contopus virens*	20	12	7	1	0	10	45,714
Yellow-bellied Flycatcher T	*Empidonax flaviventris*	1		1		0	0	2,286
Acadian Flycatcher T	*Empidonax virescens*	16	4	9	3	0	0	36,571
Alder Flycatcher T	*Empidonax alnorum*	35	21	11	3	3	11	80,000
Willow Flycatcher T	*Empidonax traillii*	70	45	18	7	6	0	160,000
Trail's Flycatcher T	*Empidonax traillii/alnorum*	43	33	8	2	2	5	98,286
Least Flycatcher	*Empidonax minimus*	6	2	3	1	0	0	13,714
Great-crested Flycatcher T	*Myiarchus crinitus*	3	1	2		0	0	6,857
White-eyed Vireo	*Vireo griseus*	56	27	16	13	13	31	128,000
Yellow-throated Vireo	*Vireo flavifrons*	11	4	6	1	0	55	25,143
Philadelphia Vireo T	*Vireo philadelphicus*	5	4		1	0	40	11,429
Red-eyed Vireo T	*Vireo olivaceus*	92	26	56	10	1	33	210,286
Yellow-green Vireo	*Vireo flavoviridis*	7	3	4		0	14	16,000
Veery T	*Catharus fuscescens*	6		6		0	17	13,714
Gray-cheeked Thrush T	*Catharus minimus*	6		5	1	0	33	13,714
Swainson's Thrush T	*Catharus ustulatus*	50	15	26	9	0	29	114,286
Wood Thrush	*Hylocichla mustelinus*	7		5	2	14	14	16,000
Gray Catbird	*Dumetella carolinensis*	96	53	25	18	9	29	219,429
Blue-winged Warbler	*Vermivora pinus*	3		3		0	33	6,857
Golden-winged Warbler T	*Vermivora chrysoptera*	3	1	2		0	33	6,857
Tennessee Warbler T	*Vermivora peregrina*	25	14	6	5	4	0	57,143
Northern Parula	*Parula americana*	2	2			0	0	4,571
Yellow Warbler T	*Dendroica petechia*	36	34	2		8	14	82,286
Chestnut-sided Warbler T	*Dendroica pensylvanica*	13	4	8	1	0	15	29,714
Magnolia Warbler	*Dendroica magnolia*	81	31	37	10	14	23	185,143
Black-throated Green Warbler	*Dendroica virens*	12	8	2	2	0	0	27,429
Blackburnian Warbler T	*Dendroica fusca*	1			1	0	0	2,286
Yellow-throated Warbler	*Dendroica dominica*	1	1			0	10	2,286
Prairie Warbler T	*Dendroica discolor*	1	1			0	0	2,286
Palm Warbler T	*Dendroica palmarum*	1	1			0	0	2,286
Bay-breasted Warbler T	*Dendroica castanea*	2	2			0	50	4,571
Black-and-white Warbler	*Mniotilta varia*	61	17	39	5	15	26	139,429
American Redstart	*Setophaga ruticilla*	70	45	22	3	6	30	160,000
Prothonotary Warbler T	*Protonotaria citrea*	65	28	35	2	9	21	148,571
Worm-eating Warbler	*Helmitheros vermivorus*	20	5	13	2	15	37	45,714
Swainson's Warbler	*Limnothlypis swainsonii*	6		4	2	33	17	13,714
Ovenbird	*Seiurus aurocapillus*	46	11	26	9	22	15	105,143
Northern Waterthrush	*Seiurus noveboracensis*	105	56	42	7	42	45	240,000
Kentucky Warbler	*Oporornis formosus*	7		7		0	29	16,000
Common Yellowthroat	*Geothlypis trichas*	22	12	3	7	45	27	50,286

Hooded Warbler	*Wilsonia citrina*	60	10	40	10	18	13	137,143
Canada Warbler T	*Wilsonia canadensis*	3	1	2		0	67	6,857
Yellow-breasted Chat	*Icteria virens*	11	6	4	1	27	0	25,143
Summer Tanager	*Piranga rubra*	21	3	15	3	5	43	48,000
Scarlet Tanager T	*Piranga olivacea*	9	4	2	3	0	33	20,571
Rose-breasted Grosbeak T	*Pheucticus ludovicianus*	4	2	2		0	25	9,143
Indigo Bunting	*Passerina cyanea*	24	19	4	1	0	46	54,857
	Totals	1,252	576	529	147			2,848,000

Table 3.3: Diurnal migrants recorded passing over the study area at La Isla, NE Belize. The ‘Total observed’ includes all individuals recorded overhead either on transects or opportunistically. Whilst these data do not come from timed counts, they are expected reflect the relative abundance of diurnal migrants passing over the study area.

Common Name	Scientific Name	Total Observed
Swallow-tailed Kite	*Elanoides forficatus*	1
Broad-winged Hawk	*Buteo platypterus*	1
Chimney Swift	*Chaetura pelagica*	22
Cliff Swallow	*Petrochelidon pyrrhonota*	14
Eastern Kingbird	*Tyrannus tyrannus*	474
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	8
Purple Martin	*Progne subis*	361
Bank Swallow	*Riparia riparia*	12
Barn Swallow	*Hirundo rustica*	679

Table 3.4: Estimated number of transient individuals by species using the proposed NE biological corridor during autumn migration. Only species for which estimates were >100,000 are included, whilst the ‘total’ is for all species recorded. Estimates are based on transect data having corrected for the number of birds expected to remain in the corridor in ‘wintering’ species (see methods). The area of available habitat was as follows: Dry Forest = 60 km²; Moist Forest = 350 km²; Mangrove/Savannah = 250 km².

Common Name	**Scientific Name**	**Dry Forest**	**Moist Forest**	**Mangrove /Savannah**	**Corridor Total**
Eastern Wood-Peewee	*Contopus virens*	334,884	360,000	0	694,884
Least Flycatcher	*Empidonax minimus*	133,953	240,000	0	373,953
Empidonax sp.	*Empidonax sp.*	26,168	234,419	34,473	295,060
Great-crested Flycatcher	*Myiarchus crinitus*	13,395	120,000	0	133,395
White-eyed Vireo	*Vireo griseus*	175,814	262,500	0	438,314
Red-eyed Vireo	*Vireo olivaceus*	86,123	771,522	0	857,645
Swainson's Thrush	*Catharus ustulatus*	66,977	360,000	0	426,977
Gray Catbird	*Dumetella carolinensis*	54,628	543,750	287,868	886,246
Warbler sp.	*Parulidae sp.*	180,837	120,000	0	300,837
Tennessee Warbler	*Vermivora peregrina*	70,727	172,800	0	243,527
Northern Parula	*Parula americana*	100,465	60,000	0	160,465
Yellow Warbler	*Dendroica petechia*	165,767	275,000	0	440,767
Magnolia Warbler	*Dendroica magnolia*	399,380	725,926	91,503	1,216,809
Black-throated Green Warbler	*Dendroica virens*	87,070	60,000	0	147,070
Yellow-throated Warbler	*Dendroica dominica*	6,698	120,000	0	126,698
Black-and-white Warbler	*Mniotilta varia*	79,933	409,180	0	489,113
American Redstart	*Setophaga ruticilla*	221,023	2,432,571	0	2,653,595

Worm-eating Warbler	*Helmitheros vermivorus*	0	153,000	0	153,000
Ovenbird	*Seiurus aurocapillus*	99,592	140,870	0	240,461
Northern Waterthrush	*Seiurus noveboracensis*	163,423	313,714	184,538	661,675
Louisiana Waterthrush	*Seiurus motacilla*	0	120,000	0	120,000
Kentucky Warbler	*Oporornis formosus*	6,698	180,000	0	186,698
Common Yellowthroat	*Geothlypis trichas*	36,533	32,727	57,754	127,014
Hooded Warbler	*Wilsonia citrina*	355,535	637,000	0	992,535
Summer Tanager	*Piranga rubra*	38,272	0	67,227	105,499
Indigo Bunting	*Passerina cyanea*	107,163	0	0	107,163
	Total	**3,288,068**	**9,081,551**	**723,363**	**13,092,981**

Table 3.5: Fuel stores in five transient species and in the American Redstart, a species that both wintered and occurred in large numbers as a transient. Fuel stores were first expressed as a percentage of lean body mass (LBM) to facilitate cross-species comparisons and then classified as either: Small = 0-10% of LBM; Medium = 10-30% of LBM; Large = >30% of LBM. The influence of age and habitat (both containing two levels, immature/adult and dry forest/mangrove savannah respectively) on fuel stores was tested using a general linear model containing both terms - the resulting P-values and coefficients are given below.

	Fuel Reserves			**Tests for factors influencing fuel reserves**			
	% Small	**% Medium**	**% Large**	**Age**	**Adult Coefficient**	**Habitat**	**Dry Forest Coefficient**
Willow Flycatcher	89.0	9.6	1.4	*	*	P = 0.881	0.17
Alder Flycatcher	86.1	13.9	0.0	P = 0.031	3.99	P = 0.176	1.74
Red-eyed Vireo	45.7	44.6	9.8	P = 0.723	0.49	P = 0.031	-3.20
Swainson's Thrush	33.3	51.0	15.7	P = 0.049	3.54	P = 0.030	4.25
Prothonotary Warbler	42.3	46.5	11.3	P = 0.889	-0.27	P = 0.607	-0.84
American Redstart	74.2	25.8	0.0	P = 0.079	1.83	P = 0.990	-0.01

Table 3.6: Mean fuel deposition rates (FDRs) and minimum stopover durations by species, as calculated from all recaptured individuals in transient species and only for birds displaying a visible increase in fat in known 'wintering' species. Mean FDR is expressed as the percentage of lean body mass accumulated per day whilst the Mean +ve FDR excludes birds with negative FDRs. Max FDR is the fastest rate recorded in each species. Mean Stopover durations were calculated from minimum stopover durations and Max Stopover is the longest duration recorded by species. For Willow Flycatcher, three Trails Flycatcher were included in calculations, two of which were most probably Willow on measurements and one that fell directly between Willow and Alder.

	N	**Mean FDR**	**Mean +ve FDR**	**Max FDR**	**Mean Stopover Duration**	**Max Stopover**
Willow Flycatcher	6	2.23	2.23	3.50	1.3	8
Red-eyed Vireo	1	5.13	5.13	5.13	1	1
Wood Thrush	1	0.82	0.82	0.82	5	1
Tennessee Warbler	1	-2.54	*	-2.54	1	1
Yellow Warbler	3	-0.41	1.44	1.48	6.7	14
Prothonotary Warbler	5	-1.64	1.00	2.14	2.2	4
Worm-eating Warbler	2	1.97	1.97	3.10	1.2	6
Ovenbird	1	0.86	0.86	0.86	6	6
Northern Waterthrush	3	3.66	3.66	6.27	2.7	5

ALL BIRDS	**23**	**0.84**	**2.14**	**3.26**

Flight ranges

Flight ranges were calculated for three species in order to represent the range of possible onward migration strategies in migrants present in the study area. It is important to note that the ranges plotted in Fig. 3.4 are maximum ranges for the given level of fuel, however, with favourable winds these distances could be extended. Possible onward strategies are to fly to forested areas in eastern Honduras and north-east Nicaragua (350-700 km) or directly to South America e.g. north-west Colombia (1700 km). For Red-eyed Vireos and Prothonotary Warblers with large fuel stores, a flight direct to South America is possible while birds with small/medium sized stores would be expected to make one or more stops.

Discussion

Large numbers of Neotropical migrants were both observed and trapped in the study area during autumn migration, confirming that north-east Belize, like the rest of Belize, provides stopover habitat for many passage migrants (Jones 2003) and fits with the known role of the wider Yucatan region as a major arrival point/flyway for birds crossing the Gulf of Mexico (e.g. Curson *et al.* 1994). Whilst the presence of migrants indicates the area's/region's importance during autumn migration, we must answer further key questions to address the potential role of the proposed corridor in the maintenance of migratory landbird populations. These include questions such as the relative abundance of species of concern and defining the area in terms of stopover site categories (see Mehlman *et al.* 2005) – is the corridor just a convenience store or does it qualify as a full service hotel?

Which species are using the corridor? Composition, abundance, habitat use and timing

Eighty-four species of Neotropical migrants were recorded during autumn migration of which the majority were landbirds (63). These totals indicate that the proposed corridor plays host to the majority of landbird species that migrate from the boreal and eastern regions of North America to Central and South America. The same cannot be said of all regions of Central America, for example, in Honduras many migrants are for the most part only observed in a relatively thin strip along the Caribbean coast and are virtually absent from the interior (Howell & Webb 1995). In this respect, the study area is geographically important for migratory birds and may be more heavily used than sites further inland, e.g. the Peten, that hold larger areas of suitable stopover habitat.

Whilst the corridor plays host to a diverse set of migrants, it is important to assess relative abundances and interpret this information in relation to population size and conservation status. Overall our estimates suggest that the proposed corridor may be used in some form another by anywhere between 2.8-13 million transient individuals. Given that both of our estimates were based on conservative assumptions such as a 100% detection rate within 25 m during transects, true estimates may be >20 million (based on a mean detection rate/meter of 0.59 for a 25 m strip, as calculated from detection functions generated by Distance for American Redstart and Magnolia Warbler wintering in dry forest in Chapter 5). Determining the significance of these estimates is difficult as no precedent for doing so exists, however, we can refer to the Important Bird Area criteria laid out by Birdlife International in which a congregation of over 20,000 waterfowl or an area that holds over 1% of the global population of a congregatory species are both qualifying criteria. In this respect, our estimates of around 20 million individuals would appear worthy of attention.

Several species of concern occurred in the corridor (see Table 1.1) and noteworthy were the large numbers of Willow Flycatcher (~5% of World population) and Prothonotary Warbler (~8% of World population) recorded (Table 3.2). Both of these species are on the America to Watch List as species in decline (Butcher *et al.* 2007) and the corridor may reflect the importance of the wider Yucatan region as a stopover for these species. Five further species in decline were recorded in lesser numbers, Wood Thrush, Prairie Warbler, Baybreasted Warbler, Kentucky Warbler and Canada Warbler, and the corridor is unlikely to play a significant role in the maintenance of their populations. The same would appear to be true of two Near Threatened species recorded, Golden-winged Warbler and Olive-sided Flycatcher, although the conservative estimate of 6,857 individuals for the former represents 3% of the global population (210,000) and thus must not be dismissed. Whilst they may not be of concern now, other species that have either shown gradual declines, e.g. American Redstart (Fig. 1.3), or regularly use increasingly threatened forested habitats, appear to use the corridor in large numbers. For example, amongst the primarily transient species, Red-eyed Vireo, Swainson's Thrush and Eastern Wood-Peewee were highly abundant, whilst amongst 'wintering' species American Redstart, Magnolia Warbler, Hooded Warbler, Gray Catbird and Northern Waterthrush all appeared to have large transient populations.

Migrants used a range of habitats in the study area, with the highest abundances apparently occurring in dry forest (Table 3.1), whilst savannah/mangrove habitats supported very low numbers. Having said this, mangrove habitats bordering both forest and savannah produced high capture rates of both Willow Flycatcher and Prothonotary Warbler (Table 3.2) and thus the mangrove component of this habitat must not be ignored. Generally composition and abundance were similar between the two forest types surveyed, indicating that the results from the more intensively surveyed dry forest can be generalised to other forest types. Overall, our results suggest that forests of all types, including mangrove, are heavily used during migration in preference over open habitats such as savannah and most likely areas of open agriculture.

The timing of migration by different species reflects that recorded in a number of different texts (e.g. Jones 2003), however, due to their near inseparability in the field, such information was largely lacking for the Empidonax Flycatchers. The information presented here fills that knowledge gap not just in terms of timing but also with respect to the relative abundance of the two species. This study also confirms their passage through the northern half of the Yucatan, and for the Canada Warbler as well, both of which had not been confirmed prior to the publication of Howell & Webb (1995).

How does stopover behaviour vary between species?

Whilst the proposed corridor area is heavily used by transient migrants during autumn migration, it is important to ask how birds are using the area. To assess use we must draw on a variety of data including the magnitude of fuel stores, the percentage of birds re-trapped, the percentage of adults in the population, stopover durations and evidence for fuel deposition.

In Table 3.5 the fuel stores of six common passage migrant are assessed and two patterns emerge. For the Empidonax flycatchers the majority of birds were carrying small fuel stores, whereas in contrast around half the population of Red-eyed Vireo, Swainson's Thrush and Prothonotary Warbler were carrying medium or large stores, with just under half carrying small reserves. To some extent the American Redstart falls between these two patterns but tends towards that for Empidonax. For individuals with small reserves the corridor would be expected to provided important resources facilitating the replenishment of depleted fuel stores, whilst for birds with medium or large stores, the corridor was probably acting like a convenience store: somewhere to briefly top up reserves before moving on. Under this interpretation the corridor would be expected to be an important stopover site for Empidonax flycatchers whilst for species like the Swainson's Thrush, the majority of birds may already have replenished their reserves further north on the Yucatan having crossed the Gulf of Mexico. The size of reserves was found to vary in some species with age and it is apparent that adults generally carried more fuel and thus may rely to a lesser degree on the corridor than immature birds. Habitat, in terms of dry forest vs. mangrove/savannah, had a limited affect on fuel reserves between species, although in Swainson's Thrush birds with larger reserves tended to be trapped in the forest.

Based on the evidence from fuel stores we would expect varying proportions of each species' population to stop in the study area to refuel. To look for evidence of such stopovers, we must first check to see whether birds were re-trapped after their initial capture. Recapture rates were actually very low for transient species (<10%) and only reached higher levels in species with wintering populations. This could be interpreted as a low rate of stopover, however, it is more likely a function of the probability of recapture. Mist nets were located in a large area of continuous habitat and consequently if a bird moved just 250 m from the mist netting area, it would be extremely unlikely to be re-trapped. Even for birds that were trapped a second time and thus had remained in or close to the trapping area, the probability of recapture on any given day was 0.41. Differentiating between a low stopover rate or a low recapture rate is not possible here and further study is required to explore this question. For those individuals which were recaptured (see Table 3.6), there is a general trend of increasing body mass/fuel stores at low to medium rates (in comparison to other studies e.g. Schaub & Jenni 2000), indicating that some birds were using the corridor to refuel. The mean stopover duration (3.26 days) suggests a relatively short stop, however, if we consider the low recapture rate and that the method of calculating stopover duration consistently underestimates durations by around 50% (interpreted from Bayly & Rumsey 2007), stopover durations may be closer to six days. A stopover of six days combined with the mean positive FDR for all species, gives an increase of fuel close to 13% of LBM, giving birds a moderate level of fuel to continue their journey.

A final measure of corridor use by different species is the percentage of adults versus immatures in the population. In theory, experienced adults should be better at optimising their migratory behaviour, thus an increasing percentage of adults stopping over in an area should indicate increasing importance and quality (Ralph 1981). Further, adult birds are much more likely to return to breed in the following year (e.g. Holmes 2007) and thus sites essential to their survival should receive more attention than those used by immature birds. Here we will assume that the percentage of adults in the greater population is between 25-50% (Ralph *et al*. 2005) and thus values less than 25% indicate that stopping over in the corridor is not an optimal strategy. Of the 20 species with more than 20 captures just over half (12) had adult percentages above 25% and they included species that other lines of evidence indicate use of the corridor such as Red-eyed Vireo, Swainson’s Thrush, Prothonotary Warbler, American Redstart and Northern Waterthrush. Amongst those species with low percentages, were Alder and Willow Flycatcher, and the Eastern Wood-Peewee.

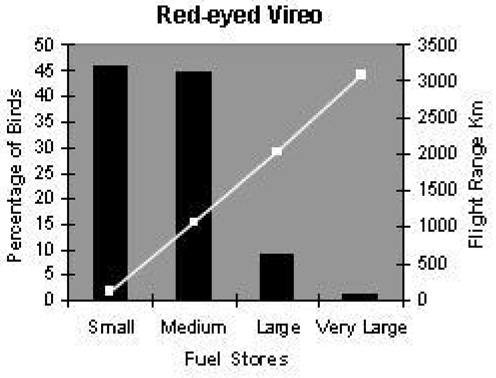
Summary

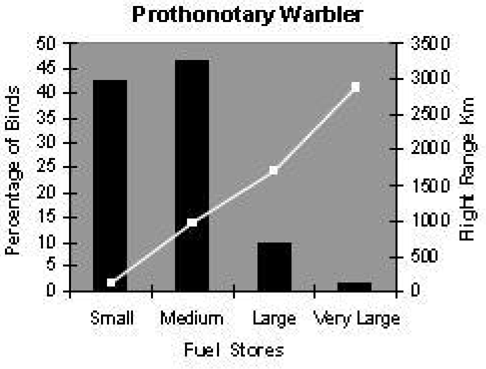
The different lines of evidence presented here point to the corridor being an important resource to a diverse set of Neotropical migrants. Exactly how each species uses the corridor varies and similar variation can also been seen between individuals within a species. Thus for many of the transient species, e.g. the declining Prothonotary Warbler, the corridor is used both to rest between successive nocturnal flights by birds carrying moderate to large fuel stores and also by birds replenishing depleted fuel stores. In reality, the stopover behaviour of species like the Prothonotary Warbler is likely to represent a continuum of strategies, with the needs of each individual varying between the two extremes. For other species, the evidence from fuel stores suggest that a much greater proportion of the population may be using the corridor like a full service hotel, e.g. the Willow Flycatcher, however an alternative explanation must be considered. Whilst some species migrate by a series of long hops, others may make much shorter flights and thus have no need to accumulate large fuel stores. This could be the case in Empidonax flycatchers whose feeding ecology does not lend itself to rapid rates of fuelling and the accumulation of large reserves. Thus while the corridor may have an important function in facilitating this strategy, it is not one in a few sites used, as would be the case for other species, but one of many.

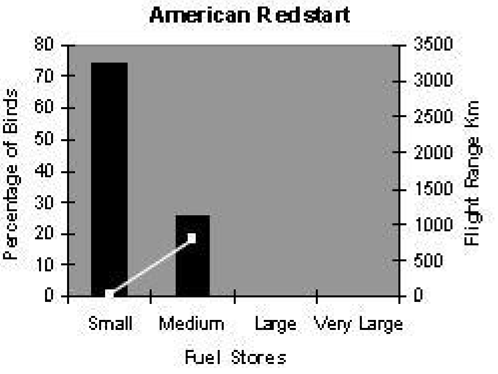
The conclusions we have drawn here about the strategies of birds in NE Belize can also be used to make inferences about migrants in the wider region. The finding that typically just over half the individuals trapped of certain species were carrying moderate to large fuel stores, suggests that sites to the north of the study area were utilised by this portion of the population to refuel. The logical conclusion would therefore be that birds arriving to the Yucatan from North America do so with varying levels of fuel after the long Gulf crossing and thus some individuals must stop immediately on reaching land to refuel while others can continue their journey south before needing to refuel. In view of this, much of the Yucatan where suitable habitat exists is probably used by Neotropical migrants to refuel and the protection of a network of sites throughout the wider Yucatan region is required to meet the needs of migrants stopping over in the area. Such a network already exists, with a considerable area of the region already contained within protected areas, however, gaps are still likely to exist and a wider reaching assessment of stopover sites is required to ensure that the key areas are protected.

On leaving the Yucatan, migratory species may need to refuel again before they reach their wintering grounds. Once again we can utilise the information on fuel stores to determine which species might need to stop and where. In Fig. 3.4 the theoretical flight ranges for three species with varying fuel levels are given. For Red-eyed Vireo and Prothonotary Warbler, both of which winter primarily in South America, flight ranges indicate that with a moderate level of fuel, a flight as far as Honduras, Nicaragua or Costa Rica is possible (500+ km) or with a large fuel reserve, to South America (1750 km). Thus in the main transient species with wintering ranges in South America, a one or two stage strategy appears most likely, with a stopover potentially in the Mosquita of Honduras and Nicaragua or along the Caribbean coast.

Figure 3.4: Estimated flight ranges for three Neotropical migrants according to their level of fuel stores. Flight ranges (white lines) were calculated using the Program Flight (see methods) and are plotted alongside the percentage of birds with a given fuel load (black bars), as calculated from birds trapped at La Isla. The fuel status levels correspond to fuel loads as follows: small = <10% of LBM; Medium = 10-30% of LBM; Large = 30-50% LBM; Very Large = > 50% LBM.







CHAPTER 4

SPRING MIGRATION

Introduction

As was the case for autumn migration, there is little evidence for which areas are used as stopovers during spring migration in Central America. Migrants are believed to use two main routes during spring migration, one which involves a trans-Gulf flight leaving from the lower Yucatan peninsula and arriving mainly in NW Mexico or Texas and a second following the Central American landmass through Mexico to North America. For South American wintering species a range of Central American stopovers are therefore available and a variety of migration strategies are likely to exist. In the case of Cerulean Warbler, this stopover appears to take place in montane regions in Belize, Honduras and Guatemala (Parker 1994; Welton *et al*. 2008), but this species is alone in being well studied during spring migration.

For those species that regularly cross the Gulf of Mexico in spring, the accumulation of a moderate to large fuel load is necessary to complete the 1,400 km over-water flight. Given Belize's position at the base of the Yucatan, we hypothesise that a number of species may make a stopover here to prepare for the Gulf crossing. Further, the Yucatan experiences an increasingly severe dry season as one travels north and as the timing of migration is primarily at the height of the dry season, one would expect a stopover in the southern Yucatan to be favoured over the northern part of the peninsula. For individuals wintering in Belize, undergoing pre-migratory fuelling for the crossing at their wintering sites would also be expected to be favoured over travelling to sites further north.

Identifying spring pre-migratory fuelling and stopover sites is an important step for the conservation of Neotropical migrants, as the success of spring migration has been identified as a potentially population limiting factor (Newton 2006). This is not just in terms of survival but also in terms of reproductive success, as arrival dates and condition on arrival can both affect productivity. Indeed, it has long been known that the first males to arrive secure the best territories and typically the best females (e.g. Aebischer *et al*. 1996), which in turn can influence the number of offspring fledged. Recent work has linked arrival times to wintering habitat in American Redstarts, showing how resource availability in wintering habitats can influence both arrival time and condition, such that birds originating from low quality habitats arrive later, produce their first egg later and nurture fewer young to maturity (Norris *et al*. 2004). Factors affecting fuel deposition rates at stopover sites, such as reductions in resource availability, would therefore be expected to influence migration speed and consequently both arrival time and reproductive output. In extreme cases, the removal of suitable habitat close to large barriers could greatly impact survival if birds were unable to accumulate sufficient fuel to reach stopover sites beyond the barrier. As was demonstrated in Figure 3.1 (Chapter 3), mortality during migration accounts for the majority of annual mortality, therefore identifying and protecting spring stopover sites, especially those utilised prior to crossing the Gulf of Mexico, is crucial if we are to adequately protect Neotropical migrants throughout their life cycle.

Methods

Transects & general observations

Spring transect work began on the 14th March 2008 and the last transect was walked on the 14th May 2008. All transects were 500 m in length, were walked at a similar pace (Mean Transect Duration ± SD = 19.9 ± 5.1 min; N = 60) and were generally carried out in the first three hours after dawn (mean start time 6:15 am). The recording of birds heard and seen was carried out as described in

Chapter 2. Transects were carried out at two main sites, La Isla and Shipstern Nature Reserve (see Fig. 2.2 & 5.1). At La Isla transects were walked on a near daily basis in 'dry forest' (semi-deciduous tropical forest low variant) intermixed with regenerating Milpas (18% of transect). Shipstern was visited on three occasions – 13/04/08, 26/04/08 & 05/05/08 – and on each visit 2 km of transects were walked in an area of mature 'dry forest' (semi-deciduous tropical forest high variant) intergrading with 'moist forest' (evergreen broadleaf tropical forest). In addition to the observations made during transects, opportunistic observations were made throughout the spring.

Mist-netting

During the spring study period, up to 26 mist nets were erected across three habitats – mangrove/savannah (10 nets), Black Mangrove (6) and dry forest low variant (10) (see Fig. 2.3). Mist-netting was carried out daily, weather allowing, from the 17th March – 14th May 2008. The number of nets opened on a given day varied depending on weather conditions, manpower and capture rate and generally Black Mangrove nets and mangrove/savannah nets were opened only in combination with the forest nets and not simultaneously. In addition to 22 morning sessions, Black Mangrove nets were opened for 13 afternoon sessions, starting three hours before sunset on average. The mean daily net effort ± SD expressed in terms of mist-net hours (1 mist-net hour = one 12m net x one hour) was 79.3 ± 24.1. In total mist-nets were operated for 4679 mist-net hours of which 2724 were in dry forest, 1355.5 in mangrove/savannah and 599.5 in Black Mangrove. Effort was most constant in dry forest, with an average effort of 47 ± 10.6 mist net hours across 58 days. Birds caught in mist nets were processed according to the methods described in Chapter 2. To increase captures, the songs of two common passage species, Red-eyed Vireo and Yellow Warbler, were played at low volume next to one net on certain days.

Migratory phenology

To examine the timing of migration, we primarily used observations of migrants from a 500m transect (MI1) that was walked on a daily basis in dry forest/Milpa near La Isla. To differentiate between the presence of wintering and transient birds, species that were observed wintering in the area were examined separately. In addition, un-corrected daily capture totals of new birds from mist-nets placed in dry forest are compared to observational data.

Estimating abundance from transect and mist-netting data

Transect data produced insufficient records for the majority of species to use the program Distance to estimate densities, so a conservative approach was adopted to allow inter-habitat comparisons and estimate numbers present in the study area. This involved treating transects as 500 m long strips with a width of 25 m either side of a central line as described in Chapter 3. Within the two habitats surveyed, results from transects were summed by visit for Shipstern and multiplied to give estimates for individuals/km², whilst all transects carried out two days either side of visits to Shipstern were processed in the same way for La Isla. An average number of individuals/km² across the whole spring was also calculated from all transects walked in both habitats, although in the case of La Isla this was restricted to transects walked between 14th April – 14th May to reflect the main period of passage (see Fig. 4.1).

To estimate the total number of individuals of the commonest species passing through the proposed corridor during spring, estimates of individuals per km² for the whole spring were multiplied by the number of days of passage (we arbitrarily chose 30 as this approximates to the length of the main passage period, Fig. 4.1) and then by the number of km² of available habitat (dry forest = 60 km²; moist forest 350 km²). For transient species it was assumed that individuals recorded on different days were not the same individual, whilst for 'wintering' species, the number/km² was adjusted for the percentage re-trapped as calculated from mist-net captures (see Table 4.2). Note that these estimates do not account for birds occurring in mangrove/savannah or rare habitats in the corridor. For comparison, the number of transient birds based on mist-net data was also calculated, here a conservative assumption was made that 100% of birds occurring in the

0.2 km² mist-netting area were captured and that the area of available habitat was 400 km² (Table 4.2). For wintering species, re-trapped birds were excluded from calculations.

Fuel loads, fuel deposition rates (FDR) and stopover durations

Fuel loads were calculated for eight commonly trapped migrants following the methods in Chapter 2 using first captures only. To represent the fuel loads of transient species caught in low numbers, fuel loads were calculated for four South American wintering migrants, Veery, Swainson's Thrush, Bay-breasted Warbler and Scarlet Tanager and combined to give the variable 'Transients' in Table 4.4. Fuel loads were then placed into one of three fuel store classes as follows: Small = 0-10% of LBM; Medium = 10-30% of LBM; Large = >30% of LBM. For individual migrants of all species that were recaptured more than once both FDR and minimum stopover duration were calculated following the methods explained in Chapter 2. In the case of known wintering species, only recaptured individuals that showed an increase in visible fat deposits between captures were included in analyses. Estimates of both FDR and stopover duration were then averaged within species and for known wintering species, individuals were divided into two groups: 1) bird first trapped in 2007 and therefore assumed to be wintering birds; 2) birds caught for the first time in 2008 and therefore assumed to be transients (see Table 4.5). Whilst some individuals may have been wrongly assigned to a group, clear differences between groups are evident and thus the division appears to reflect biological reality.

Flight ranges

Flight ranges were calculated according to the methods described in Chapter 2 for six species. Calculations required an estimate of LBM (g), wing span (m) and wing area (m²), for which the following values were used based on in-hand measurements and values accompanying the program Flight 1.15 in the case of American Redstart.

Red-eyed Vireo: LBM = 0.18 + 0.182*Wing length; mean wing span (N = 5) = 0.234 m; mean wing area (N = 5) = 0.0108 m².

Prothonotary Warbler: LBM = 6.1 + 0.080*Wing Length; Mean wing span (N = 4) = 0.202 m; Mean wing area (N = 4) = 0.0084 m².

Indigo Bunting: LBM = 12.70; Mean wing span (N = 5) = 0.203 m; Mean wing area (N = 5) = 0.0087 m².

Northern Waterthrush: LBM = 7.31 + 0.098*Wing Length; Mean wing span (N = 3) = 0.218 m; Mean wing area (N = 3) = 0.0099 m².

Magnolia Warbler: LBM = 3.63 + 0.065*Wing Length; Mean wing span (N = 5) = 0.180 m; Mean wing area (N = 5) = 0.0070 m².

American Restart: LBM = 3.29 + 0.061*Wing Length; Mean wing span (N = 5) = 0.195 m; Mean wing area (N = 5) = 0.0078 m².

Results

Species Composition

Between the 15th March and the 15th May 2008, 2188 individuals of Neotropical migrants were recorded in the study area during mist-netting (842), transects and general observations (1346 combined). These belonged to 67 species, the majority of which were landbirds (54). Of the landbird migrants 35% or 19 species are considered transients in Belize, while 50% can be considered as transients in the study area. The percentage of individuals that were known transients varied markedly between methods, from just 22% of 1395 migrants from observations to 65% of 842 migrants trapped.

Species composition differed in a number of ways from autumn, with the occurrence of three species known largely as spring migrants in Belize (Jones 2003), the Ruby-throated Hummingbird, Mourning Warbler and Dickcissel. Other species that were abundant in autumn were conspicuously absent in spring, in particular the trio of Empidonax flycatchers, Acadian, Alder and

Willow. Notable observations included the sighting of a Golden-winged Warbler (Near-threatened) and the capture of a Painted Bunting (Near-threatened). Just prior to the main spring migration period, over 110 Swallow-tailed Kite were observed over Sarteneja and were presumed to belong to the threatened North American population.

Migratory phenology

Transient species began arriving as early as the beginning of March and early migrating species such as Prothonotary Warbler and Ruby-throated Hummingbird had largely passed through by the end of March/beginning of April. For the majority of transient species, however, the major movement occurred between the 20th April and the 12th May, especially during a concentrated ten-day period of movement centred around the 1st May (see Fig. 4.1). Whilst Figure 4.1 suggests that overall migrant abundance was high at the end of March/beginning of April, both the low capture rate of new birds and lack of transients suggests that these were primarily birds that had wintered in the area. In Figure 4.2, the large contribution of both the Magnolia Warbler (wintering and transient) and Yellow Warbler (primarily a transient) to the peak in passage can be seen. Again the capture data show how new Magnolia Warblers did not begin to arrive till the 23rd April, whilst wintering birds were present throughout.

Figure 4.1: Timing of passage at La Isla, NE Belize during spring migration. Bars represent the number of individual migrants observed on a 500 m transect through 'dry forest' intermixed with Milpa. The green bars represent only known transients whilst totals for the black bars are expected to include wintering individuals. Zero values for observational data generally indicate days on which the transect was not walked, e.g. 26th April. Raw capture totals from mist-netting are provided to allow a comparison between methods (orange line).

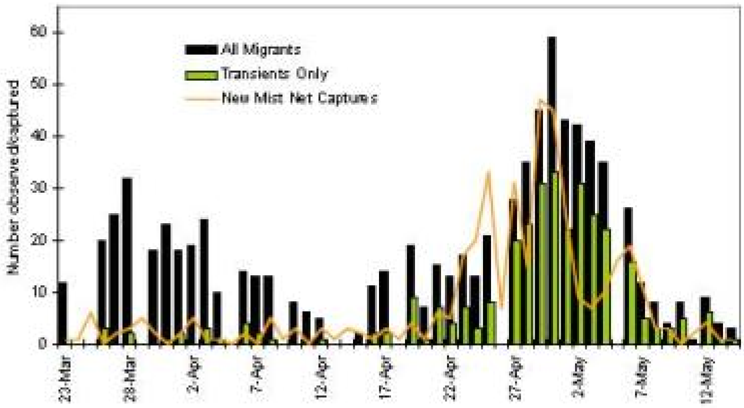
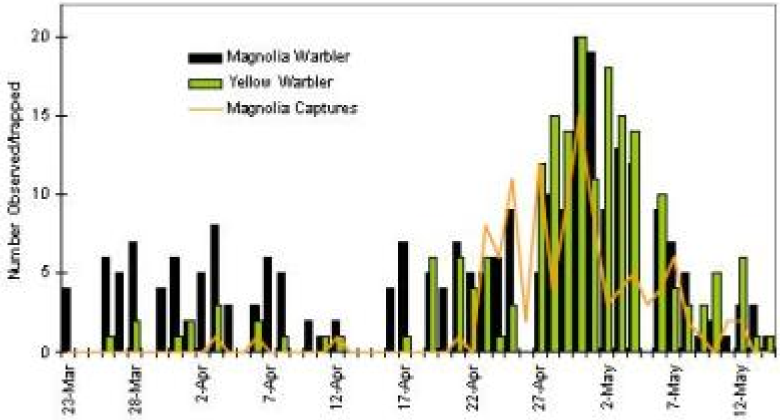


Figure 4.2: The timing of migration by Magnolia and Yellow Warblers at La Isla, NE Belize. Bars represent daily totals observed on a 500 m transect through 'dry forest' and regenerating Milpa, whilst the orange line represents uncorrected daily capture totals of new birds from mist-nets. Zero values for observational data generally indicate days on which the transect was not walked, e.g. 26th April and 5th May.



Species abundance & habitat preferences

Both mist-netting and observational data indicate that spring passage in NE Belize was dominated by a small number of species and that the majority of species recorded only passed in small numbers (Table 4.1 & 4.2). Observations and captures in forested habitats were made up primarily of Magnolia Warbler and Yellow Warbler, with Red-eyed Vireo coming in some way behind. In lesser numbers still were Tennessee Warbler, American Redstart and Scarlet Tanager. Mist-net captures also indicate that in mangrove habitats both Prothonotary Warbler and Northern Waterthrush were passing in high numbers.

Evidence for habitat preferences in transient species are indicated by both observations and mist-netting (Table 4.1 & 4.2). The Yellow Warbler, for example, was markedly more abundant in dry forest versus moist forest from observations, whilst mist-net captures corrected for effort suggest that Black Mangrove supports higher numbers than dry forest. The mist-net totals by habitat must be treated with caution as net placement can have a significant affect on capture rates, often more so than effort – nevertheless general observations and findings from winter habitat surveys for certain species (see Chapter 5) support the differences found from mist nets in Table 4.2.

In Table 4.3 estimates for the total number of individuals of the commonest species passing through the corridor in different habitats are given. Once these totals are adjusted for the area of each habitat in the corridor, the commonest species remain the same with Magnolia Warbler being the most abundant and Yellow Warbler the second most. The total for all species is greater than that for mist-nets in Table 4.2 but this is due to the more conservative nature of the mist-net estimate. Species recorded mainly by mist-netting such as Northern Waterthrush and Prothonotary Warbler would also feature in Table 4.3 if transects had been carried out in mangrove and savannah habitats.

Table 4.1: Spring migrant abundance by habitat and during different time periods in NE Belize. Abundance is expressed as the number of birds occurring in 1 km^2 as estimated from fixed width transects (500 m x 25 m). Forest types are abbreviated as Dry Forest = Tropical semi-deciduous broadleaved forest (low variant) intermixed with regenerating Milpa and Moist Forest = Tropical evergreen seasonal broadleaf forest intergrading into Tropical semi-deciduous broadleaved forest (high variant). Periods are defined as two day periods either side of the following dates: early = 14th April; mid = 26th April; Late = 5th May and where 'All' refers to the average across all transects carried out between 14th April – 14th May. The number of 500 m transects used for estimates is given in brackets next to period. Species that were primarily transients in the study area have a T following their common name.

Common Name	Dry Forest				Moist Forest			
	Early (4)	Mid (4)	Late (4)	All (27)	Early (4)	Mid (4)	Late (4)	All (12)
Eastern Wood-Peewee T			30	**4.4**		20	10	**10.0**
Least Flycatcher	10	10		**4.4**	10			**3.3**
Eastern Kingbird T				**1.5**				**0.0**
White-eyed Vireo				**3.0**		10		**3.3**
Yellow-throated Vireo				**0.0**				**0.0**
Red-eyed Vireo T		40	20	**14.8**	30	130	100	**86.7**
Veery T				**0.0**		20		**6.7**
Swainson's Thrush T				**0.0**			10	**3.3**
Wood Thrush				**0.0**		10		**3.3**
Gray Catbird		10		**3.0**		10		**3.3**
Warbler sp.	30	20	10	**14.8**	20			**6.7**
Golden-winged Warbler T				**0.0**		10		**3.3**
Tennessee Warbler T	10	90	70	**63.7**	50	150		**66.7**
Northern Parula				**1.5**				**0.0**
Yellow Warbler T	20	280	400	**253.3**		20	10	**10.0**
Chestnut-sided Warbler T		10		**8.9**		10	10	**6.7**
Magnolia Warbler	70	260	370	**253.3**	110	100	50	**86.7**
Yellow-rumped Warbler				**0.0**				**0.0**
Black-throated Green Warbler	20			**1.5**	20	20	10	**16.7**
Prairie Warbler T				**1.5**				**0.0**
Bay-breasted Warbler T		10	20	**11.9**				**0.0**
Black-and-White Warbler	20			**3.0**	10	30		**13.3**
American Redstart	20	50	20	**22.2**	80	50	20	**50.0**
Prothonotary Warbler T	10		20	**5.9**				**0.0**
Worm-eating Warbler				**0.0**				**0.0**
Ovenbird				**0.0**				**0.0**
Northern Waterthrush				**0.0**		10		**3.3**
Mourning Warbler T			10	**1.5**				**0.0**
Common Yellowthroat		10		**3.0**				**0.0**
Hooded Warbler	10	10		**4.4**	10	10		**6.7**
Summer Tanager				**0.0**				**0.0**
Scarlet Tanager T		20	20	**8.9**		140	20	**53.3**
Rose-breasted Grosbeak T		10	10	**3.0**				**0.0**
Indigo Bunting		10		**19.3**		20		**6.7**
Dickcissel T			10	**5.9**				**0.0**
Baltimore Oriole				**0.0**				**0.0**
Total Migrants/Km^2	**220**	**840**	**1010**	**718.5**	**340**	**770**	**240**	**450**

Table 4.2: Mist-net capture totals by species during spring migration at La Isla (total new) and expected numbers by habitat if mist-net effort had been equal to that in dry forest throughout. The percentage of birds re-trapped gives an indication of turnover rates and stopover behaviour, whilst the percentage adult may give an indication of habitat quality (see discussion). ‘Corridor total’ is an estimate of the number of individuals by species passing through the proposed corridor during a spring (for generation of estimates see methods).

Common Name	**Scientific Name**	**Total New**	**Dry Forest**	**Mangrove/Savannah**	**Black Mangrove**	**% Re-trapped**	**% Adults**	**Corridor Total**
Solitary Sandpiper	*Tringa solitaria*	**1**	0	0	5	0	*	2,286
Yellow-billed Cuckoo T	*Coccyzus americanus*	**1**	0	2	0	0	100	2,286
Eastern Wood-Peewee T	*Contopus virens*	**4**	0	0	18	0	33	9,143
Least Flycatcher	*Empidonax minimus*	**1**	0	0	5	0	100	2,286
Great Crested Flycatcher T	*Myiarchus crinitus*	**1**	1	0	0	0	86	2,286
White-eyed Vireo	*Vireo griseus*	**9**	6	2	9	56	0	20,571
Yellow-throated Vireo	*Vireo flavifrons*	**2**	1	2	0	0	50	4,571
Red-eyed Vireo T	*Vireo olivaceus*	**82**	73	6	27	1	78	187,429
Yellow-green Vireo	*Vireo flavoviridis*	**6**	4	4	0	0	100	13,714
Veery T	*Catharus fuscesens*	**10**	5	6	9	0	40	22,857
Gray-cheeked Thrush T	*Catharus minimus*	**3**	1	4	0	0	33	6,857
Swainson's Thrush T	*Catharus ustulatus*	**5**	5	0	0	0	60	11,429
Wood Thrush	*Hylocichla mustelina*	**7**	6	0	5	0	14	16,000
Gray Catbird	*Dumetella carolinensis*	**20**	15	6	9	5	45	45,714
Blue-winged Warbler	*Vermivora pinus*	**1**	1	0	0	0	0	2,286
Tennessee Warbler	*Vermivora peregrina*	**21**	17	4	9	0	15	48,000
Northern Parula	*Parula americana*	**7**	2	0	23	0	43	16,000
Yellow Warbler T	*Dendroica petechia*	**136**	80	34	177	3	35	310,857
Chestnut-sided Warbler T	*Dendroica pensylvanica*	**5**	5	0	0	0	0	11,429
Magnolia Warbler	*Dendroica magnolia*	**139**	122	6	64	6	13	317,714
Yellow-rumped Warbler	*Dendroica coronata*	**4**	0	8	0	0	50	9,143
Black-throated Green Warbler	*Dendroica virens*	**2**	2	0	0	50	0	4,571
Bay-breasted Warbler T	*Dendroica castanea*	**9**	7	2	5	0	11	20,571
Black-and-white Warbler	*Mniotilta varia*	**15**	10	6	9	27	47	34,286
American Redstart	*Setophaga ruticilla*	**21**	11	8	27	10	48	48,000
Prothonotary Warbler T	*Protonotaria citrea*	**28**	10	18	41	14	25	64,000
Worm-eating Warbler	*Helmitheros vermivorus*	**1**	1	0	0	0	100	2,286
Ovenbird	*Seiurus auricapillus*	**4**	4	0	0	25	75	9,143
Northern Waterthrush	*Seiurus noveboracensis*	**45**	11	18	114	20	35	102,857
Kentucky Warbler	*Oporornis formosus*	**1**	1	0	0	0	100	2,286
Common Yellowthroat	*Geothlypis trichas*	**20**	5	22	18	30	35	45,714
Hooded Warbler	*Wilsonia citrine*	**14**	11	0	14	14	36	32,000
Yellow-breasted Chat	*Icteria virens*	**1**	0	2	0	0	100	2,286
Summer Tanager	*Piranga rubra*	**1**	1	0	0	0	100	2,286
Scarlet Tanager T	*Piranga olivacea*	**5**	3	0	9	0	80	11,429
Rose-breasted Grosbeak T	*Pheucticus ludovicianus*	**3**	2	0	5	0	67	6,857
Blue Grosbeak	*Guiraca caerulea*	**1**	0	0	5	0	0	2,286
Indigo Bunting	*Passerina cyanea*	**25**	9	6	59	8	44	57,143
Bunting T	*Passerina ciris*	**1**	1	0	0	100	100	2,286
	Totals	**669**	**438**	**169**	**668**			**1,513,143**

Table 4.3: Estimated number of transient individuals by species using the proposed NE biological corridor during spring migration. Only species for which over 100,000 individuals were expected to have passed through the corridor are listed, whilst the 'total' is for all species recorded during transects. Estimates are based on transect data, the assumptions of which are detailed in the methods. The area of each habitat available was estimated as follows: Dry Forest = 60 km²; Moist Forest = 350 km².

Common Name	**Scientific Name**	**Dry Forest**	**Moist Forest**	**Corridor Total**
Eastern Wood-Peewee	*Contopus virens*	8,000	105,000	113,000
Red-eyed Vireo	*Vireo olivaceous*	26,341	898,902	925,244
Tennessee Warbler	*Vermivora peregrina*	114,667	700,000	814,667
Yellow Warbler	*Dendroica petechia*	442,588	101,912	544,500
Magnolia Warbler	*Dendroica magnolia*	426,475	851,079	1,277,554
Black-throated Green Warbler	*Dendroica virens*	2,667	175,000	177,667
Black-and-White Warbler	*Mniotilta varia*	3,911	102,667	106,578
American Redstart	*Setophaga ruticilla*	36,190	475,000	511,190
Scarlet Tanager	*Piranga olivacea*	16,000	560,000	576,000
	Totals All Species	**1,234,570**	**4,520,766**	**5,755,335**

Energy reserves, fuel deposition rates and stopover behaviour

Levels of energy reserves varied between species, with transient species carrying large reserves whilst a greater proportion of individuals in wintering species had low levels of reserves (Table 4.4). Fuel reserves did not appear to vary significantly with age, although there was a tendency for adults to be heavier, and the habitat in which a bird was trapped had no significant affect on reserves in any species (Table 4.4).

In Table 4.5 the fuel deposition rates of the majority of species are positive and indicate that some birds were using the study area to gain fuel. Mean minimum stopover duration for re-trapped individuals assigned to the transient group was 6.2 days, which supports the assertion that birds were stopping over in the study area.

Flight ranges

Flight ranges were calculated for six species, ranging from entirely transient species, e.g. Redeyed Vireo, to species with both transient and wintering individuals, e.g. Magnolia Warbler. The resulting estimates in Figure 4.3 assumed still air conditions and thus real potential flight ranges are expected to be longer as near-constant east/south-east trade winds during the spring period increase flight speeds.

Table 4.4: Magnitude of fuel reserves and analysis of factors affecting reserves in eight migrants and a group of transients in NE Belize. Individual species were chosen if they were represented by more than 20 captures. The group of transients consists of four species that winter in South America and were trapped in small numbers (see methods). Tests for the affect of Age and Habitat on reserves were carried out using General Linear Models and the resulting P-values and coefficients are given. Fuel reserve levels represent fuel loads (mass of fuel expressed as a % lean body mass) between the following levels: Small = 0-10% of LBM; Medium = 10-30% of LBM; Large = >30% of LBM.

	Fuel Reserves			**Tests for factors influencing fuel reserves**					
	% Small	**% Medium**	**% Large**	**Age-P-value**	**Adult Coefficient**	**Habitat P-value**	**Dry Forest**	**Mangrove/ Savannah**	**Black Mangrove**
Red-eyed Vireo	8.8	21.3	70.0	0.220	2.6	0.186	-7.8	6.1	1.6
Tennessee Warbler	0.0	42.9	57.1	0.873	-0.5	0.333	-9.8	12.0	-2.2
Yellow Warbler	66.9	26.5	6.6	0.978	0.0	0.434	-1.5	0.6	0.9
Magnolia Warbler	58.2	31.3	10.4	0.352	1.3	0.378	0.8	-4.6	3.8
American Redstart	71.4	14.3	14.3	0.090	5.1	0.429	-3.3	-2.0	5.3
Prothonotary Warbler	25.0	53.6	21.4	0.200	3.3	0.118	3.1	-7.1	3.9
Northern Waterthrush	31.1	44.4	24.4	0.010	3.7	0.920	-1.3	0.9	0.4
Indigo Bunting	28.0	28.0	44.0	0.152	4.2	0.077	-3.4	-5.1	8.5
Transients - (SA)	3.6	25.0	71.4	0.242	-2.9	0.089	-7.3	0.5	6.8

Table 4.5: Mean fuel deposition rate (FDR = %Lean Body Mass accumulated/day), minimum fuelling duration (days) and potential fuel load (fuel mass expressed as % of LBM) in all species in which at least one bird was re-trapped during spring migration in NE Belize. In wintering species, individuals were divided into 'wintering' birds or 'transients' depending on whether they were trapped in the previous autumn (see methods). Max FDR is the maximum FDR recorded in each species. Fuel load = mean duration recorded in transient individuals x max FDR.

		Wintering		**Transients**			
	N	**Mean FDR**	**Durations**	**Mean FDR**	**Duration**	**Max FDR**	**Fuel Load**
American Redstart	2			1.39	17.0	2.33	39.6
Black-and-white Warbler	3	0.34	14.0	-0.29	4.0	2.35	9.4
Black-throated Green War	1	1.65	37.0			1.65	
Hooded Warbler	1	2.31	7.0			2.31	
Indigo Warbler	2			1.53	3.5	7.72	27.0
Magnolia Warbler	11	0.97	23.5	2.21	4.6	5.79	26.4
Northern Waterthrush	9	0.25	15.0	2.49	3.8	9.52	35.7
Painted Bunting	1			3.31	4.0	3.31	13.2
Prothonotary Warbler	4			0.71	3.0	2.53	7.6
Red-eyed Warbler	1			-7.56	1.0	-7.56	
White-eyed Warbler	6	-0.21	9.3	0.86	10.7	2.42	25.8
Yellow Warbler	5			0.26	12.2	2.27	27.7
Common Yellowthroat	4	0.87	19.0			1.54	
Grand Total	**50**	**0.72**	**17.2**	**1.28**	**6.2**	**2.78**	**23.6**

Discussion

As in autumn a large number of migratory landbirds (53 species) were observed in NE Belize during spring migration, however, aside a small group of species many occurred at low abundances. Further, the passage of many species was concentrated in just two weeks at the end of April and the beginning of May. This timing is extremely similar to that recorded over 1400 km to the north-east in the Gulf states of Texas and Louisiana (Fig. 4.4) and suggests that many species make the journey across the Gulf of Mexico shortly after arriving in Belize. The fuel reserves and estimated flight ranges for transient species support this hypothesis, with most birds carrying sufficient fuel to fly across the Gulf and beyond (Table 4.4 & Fig. 4.3). Certain species occurring as both wintering and transient birds in Belize were recorded in large numbers (Table 4.1 & 4.2) and demonstrated unequivocal fuelling behaviour (Table 4.5) and thus for some species the corridor is a key stopover site prior to the long flight across the Gulf of Mexico.

Which species are using the corridor? Composition, abundance, habitat use and timing

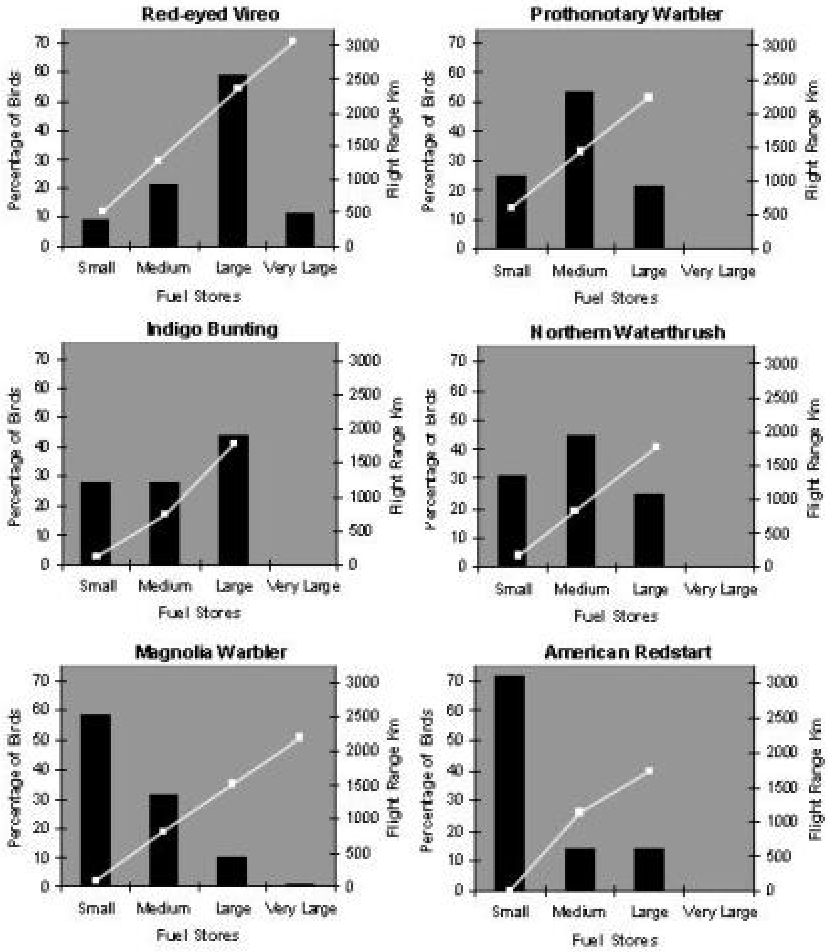
The species composition of migrants during spring followed that expected from Jones (2003) and included a number of species that for the most part only occur as spring transients in Belize such as Ruby-throated Hummingbird, Mourning Warbler and Dickcissel. The status of transient Empidonax flycatchers in Belize is poorly known (Jones 2003) and the capture of not one Willow, Alder or Acadian Flycatchers relative to >150 in autumn suggests that these species are not passing through NE Belize, or all of Belize most probably, at this time of year. Of the 27 species recorded that are considered to be transients in the study area only four species were either trapped or observed in significant numbers (occurring at >150 km² in a habitat or period; Table 4.1): Red-eyed Vireo, Tennessee Warbler, Yellow Warbler and Scarlet Tanager. A further four species were recorded in lower numbers and may have been using the corridor in relatively large numbers, particularly Prothonotary Warbler and Indigo Bunting. Of the wintering species, evidence for the arrival of a large transient population from other wintering areas was only presented by the Magnolia Warbler and Northern Waterthrush. Overall abundance of transient birds throughout the corridor was estimated at around 5.75 million and given that the method used to reach this estimate is likely to underestimate by around 41% (see Chapter 3), the number may be closer to 9.75 million. The main contributors to this total according to corridor wide estimates include, in decreasing abundance, Magnolia Warbler, Yellow Warbler, Tennessee Warbler and Red-eyed Vireo.

In terms of species of concern, only Prothonotary Warbler was recorded in large numbers, otherwise just small numbers of Bay-breasted Warbler and Wood Thrush were recorded. In addition, there were singles of Golden-winged Warbler (near-threatened) and Painted Bunting (near-threatened).

Habitat use appeared to vary between those species with sufficient observations to indicate a difference. Both Red-eyed Vireo and Scarlet tanager were observed in greater numbers in ‘moist’ versus ‘dry’ forest, whilst the opposite pattern was true of Yellow Warbler and Magnolia Warbler (see Table 4.1). Mist-net captures are not an ideal measure of abundance due to variation in capture probability with height of habitat and strong affects of mist-net placement. However, some of the stronger relationships in Table 4.2 are expected to reflect preferences and it is evident that Northern Waterthrush favoured Black Mangrove whilst Prothonotary Warbler favoured general mangrove habitats over forest.

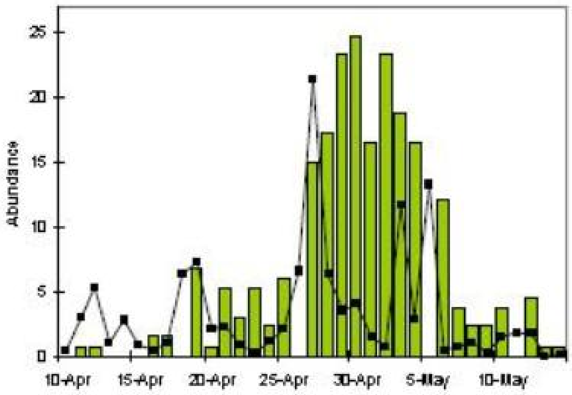
The timing of passage in spring was remarkably concentrated in a period between mid-April and mid-May and 75% of new captures occurred in just one week either side of the peak capture day (29th April). Whilst a variety of transient species were involved in this peak in passage, the main contribution came from Magnolia and Yellow Warblers and to a lesser extent by Red-eyed Vireos. Other transient species were recorded outside of this main period of passage, in particular the Prothonotary Warbler (a known early migrant) largely passed through before this date and Scarlet Tanager also began arriving earlier in April. Some species such as White-eyed Vireo, Ovenbird,

Figure 4.3: Estimated flight ranges for six Neotropical migrants according to their level of fuel stores. Flight ranges (white lines) were calculated using the Program Flight (see methods) and are plotted alongside the percentage of birds with a given fuel load (black bars), as calculated from birds trapped at La Isla. The fuel status levels correspond to fuel loads as follows: small = <10% of LBM; Medium = 10-30% of LBM; Large = 30-50% LBM; Very Large = > 50% LBM.



have departed from the area by mid-April. A marked peak in migration Wormeating Warbler and Common Yellowthroat were recorded primarily in March and appeared to in the last week of April and the first week of May as observed at our study site has also been observed on the Gulf coast of North America in states such as Texas (Fig. 4.4). Indeed the phenology of migration in this area is very similar to that recorded in Belize and indicates that many species birds are flying directly from Belize to North America without stopping for any significant period of time.

Figure 4.4: Timing of passage on the Gulf Coast of Texas and Louisiana in 2008 by the main transient species in Belize (black line) against transient phenology in Belize (green bars). Data extracted from E-bird.



How does stopover behaviour vary between species?

With its proximity to the Gulf of Mexico, a major barrier in the journey north for many Neotropical migrants, we hypothesised that a variety of species may use NE Belize to accumulate fuel for the long over-water crossing. Whilst this appeared to be true of some species (see below), for many transient species, especially those that winter primarily in South America, the majority of birds arrived already carrying sufficient reserves for the crossing (Table 4.4 & Fig. 4.3). The fact that these species had already fuelled up elsewhere also explains why captures for many species were low. By way of an example, the *Catharus* thrushes that might have been expected to occur in larger numbers, occurred at low abundance and those individuals that were trapped were generally carrying large fat reserves (>30% LBM). The Red-eyed Vireo was the main exception to this, being caught in large numbers but like other transient species the majority of individuals had large reserves. Indeed, potential flight ranges indicate that 70% of Red-eyed Vireos could have covered the 1400 km to the Gulf coast of North America (see Fig. 4.3) and around10% had sufficient reserves to reach North America and penetrate 1500 km inland. For many transient species it would therefore appear that NE Belize is used as an area to rest between successive nocturnal flights and is not a key stopover site used to accumulate reserves of the Gulf crossing. Observations of ‘fat’ birds on release support this conclusion, with a number of individuals flying just a short distance to a tree/shrub providing cover and then remaining immobile, rather than commencing feeding rapidly as many lean birds do.

Not all individuals/species arrived in the study area with large fuel reserves and in a small group of species there is strong evidence for birds making a stopover in order to increase their fuel reserves (see Table 4.5). In particular, Yellow Warbler, Magnolia Warbler and Northern Waterthrush were trapped in large numbers and displayed clear evidence of fuelling. There is also evidence for individuals that were considered to have wintered in the area increasing their fuel stores, which suggests that wintering areas have a crucial secondary role in providing the resources required to fuel migration. To give an indication of the extent to which birds were fuelling, the maximum rate of fuel deposition by species was multiplied by the mean duration between captures for transient individuals in Table 4.5. Combining species (excluding the single Red-eyed Vireo with negative mass gain) and taking the mean gives an average increase in fuel mass equivalent to 24% of lean body mass. This is close to the fuel load required to cross the Gulf of Mexico and given that the method of estimating stopover duration typically underestimates durations by around 50% (interpreted from Bayly & Rumsey 2007), it is likely that individuals were accumulating sufficient fuel in the study area to fly to North America without refuelling. It must also be considered that flights across the Gulf are assisted by south-easterly/easterly trade winds during spring migration and thus ranges are likely to be greater than those in Fig. 4.3 which assumed still air conditions.

Summary

A wide variety of migrant landbirds were detected in the study area during spring migration and there are two clear strategies that emerge in the species passing through. For many species, especially transient species which are likely to have spent the winter in South America, abundance was generally low and evidence from fuel stores suggests that a refuelling stop was not required. Indeed, flight range estimates indicate that most individuals could cross the Gulf of Mexico to North America before a stopover is required. For a smaller group of species, large numbers of individuals were present in the corridor and their fuel reserves were generally small (Fig. 4.2), suggesting that a stopover was required. In these species, evidence from recaptured individuals showed that they were both accumulating fuel and remaining in the area for at least six days. Combining fuelling rates with expected stopover durations yields a final fuel reserve sufficient for the Gulf crossing. Thus for these species, which include Magnolia Warbler, Yellow Warbler and Northern Waterthrush, the corridor is likely to act as a ‘full service hotel’ during the spring, allowing birds to accumulate the reserves required for the next stage of their migration. To a lesser extent this may also be true of the declining Prothonotary Warbler, in which some individuals seemed to make a stopover whilst others arrived with large reserves. For the majority of species however, the corridor is essentially acting as a ‘convenience store’, an area where birds can pause their migration between successive nocturnal flights whilst also potentially topping up their reserves.

The important question arising from these findings, is where are birds accumulating fuel for such a long journey if they are not stopping over in NE Belize? Two main areas would appear likely: 1. NE Nicaragua/Honduras; 2. Northern South America. If the former is the case, then the amount of fuel that must be accumulated at stopover sites would not be much more than the loads birds arrive with in Belize (in some cases, e.g. Swainson’s Thrush, southern Belize may actually be used as a stopover; Parker 1994). Northern South America, however, is approximately 1750 km from Belize and thus birds would be storing sufficient fuel to cover a journey of over 3000 km. Whilst this is possible – see Red-eyed Vireo flight ranges in Fig. 4.3 – it would mean that birds are highly dependent on encountering resource rich sites in northern South America and such sites could be crucial to the conservation of long-distance Neotropical migrants. Determining the location and ensuring the protection of spring stopover sites is an important step if we are to reverse the declines of the last 40 years.

CHAPTER 5

OVER–WINTER HABITAT USE

Introduction

Determination of habitat use and habitat quality for Neotropical migrants throughout their life cycle has been recognized as a "priority research need" in order to direct conservation efforts across their range (Donovan *et al.* 2003; Ruth *et al.* 2003). In the case of tropical wintering habitats this is particularly important because habitat quality during the winter months might play a crucial role in limiting reproductive success on the breeding grounds (Norris *et al.* 2003).

That conditions during the winter might be one of the limiting factors influencing the populations of migratory birds has been called the "winter limitation hypothesis" (Sherry & Holmes 1996). This hypothesis arises from the fact that Neotropical migrants spend more time in the tropics than anywhere else and that habitat modification is occurring there at a faster rate than in the temperate breeding areas. It is therefore assumed that conditions during the winter months and changes in land use will affect overwinter survival and therefore might have contributed to population declines in Neotropical migrants (Robbins *et al.* 1989). Despite this, 'comprehensive data on habitat availability and habitat-specific demography in the winter period are lacking for most Neotropical migrants, but such information is needed for a full assessment of the importance of the winter period as a limiting season' (Holmes 2007).

That overwinter habitats are limiting is supported by the observation that many migrants are territorial in their non-breeding areas. Active competition between individuals over territories/habitats can result in high quality habitats becoming saturated and subsequently the habitat a bird ends up in, will determine its overwinter survival probability (Sherry & Holmes 1996; Norris *et al.* 2003; Gunnarson 2005). By measuring the abundance of migrants in different habitats we can begin to understand habitat preferences. Under certain scenarios higher densities should indicate greater carrying capacity of a habitat and therefore a measure of relative quality. However, this may not always be true as dominant individuals may be able to maximize survival by defending larger areas in high quality habitat thereby forcing subordinate individuals to occupy lower quality habitats at higher densities. From a practical point of view, determining the quality of the habitats available for different migrants allows us to understand how habitat changes could affect these species and also how we can mitigate any negative effects when planning for development and management in different habitat types.

Interestingly, Neotropical migrants have been shown to use a great variety of habitats both natural and human modified (Johnson *et al.* 2006) and it has generally been found that migrants, unlike resident species, are more resilient to certain habitat modifications. Some of these modifications, such as clearing forest for cultivation, may even enhance presence of certain species adapted to open areas (Morton 1989; Petit *et al.* 1989; Lynch 1989; Saab & Petit 1992). Recent data, however, have shown that despite migrant presence, these modified habitats are of lower quality than their natural counterparts and that migrants using them have lower survival rates and reduced reproductive success through carryover effects. Habitat modification may therefore lead to further population declines in certain migratory species (Norris *et al.* 2003; Johnson *et al.* 2006). Habitat quality may change through modification but also through natural seasonal changes and thus it is important to examine habitats at different stages of the non-breeding season. For many regions where migrants winter, the dry season roughly coincides with the non-breeding season such that differential drying of habitats may impact on their quality to migrants (Marra & Holmes 2001).

In Belize a number of studies, primarily based on the use of mist-nets, have produced good baseline information on the presence of Neotropical migrants wintering in different natural and human modified habitats (e.g. Lloyd & Evans 1989; Petit *et al.* 1989; Mills & Rogers 1992; Krisher &

Davis 1992; Piaskowski *et al.* 2005). All of these studies give estimates and proportions of migrants found in different habitats, mostly for central and southern Belize. There is a general consensus that migrants are using both fragments and extensive forests, pastures and scrub, citrus plantations and Milpas. However, aside from studies by Lynch (1989a, 1989b) and Greenberg (1989), the relative abundance estimations produced for Belize and the wider Yucatan to date have been generated using mist-net data and thus must be viewed with considerable caution due to the inherent biases of utilizing mist netting to census bird communities (Morton 1989). In contrast, standard distance sampling (point counts and transect surveys) gives a more reliable estimate of general abundance and can be used to calculate accurate densities of birds providing that the assumptions of the methods are met (Morton 1989; Buckland *et al.* 1992). In this study we attempt to fill an information gap about Neotropical migrants wintering in various habitats in the north-east portion of Belize, an area not sampled for migrants before. Our study area still held large tracts of intact natural habitats and therefore posed an exceptional opportunity to evaluate migrant use of a habitat matrix that has largely escaped human modification and therefore is expected to reflect values closer to "natural" densities. Unlike previous studies in Belize, we deployed distance sampling methods to ensure that comparisons between habitats and at different stages in the winter could be made. Through distance sampling in established transects, we produce estimates of migrant density for the most common species across five different natural habitats and one human modified habitat, and we use these to make inferences about habitat quality.

Methods

Distance sampling

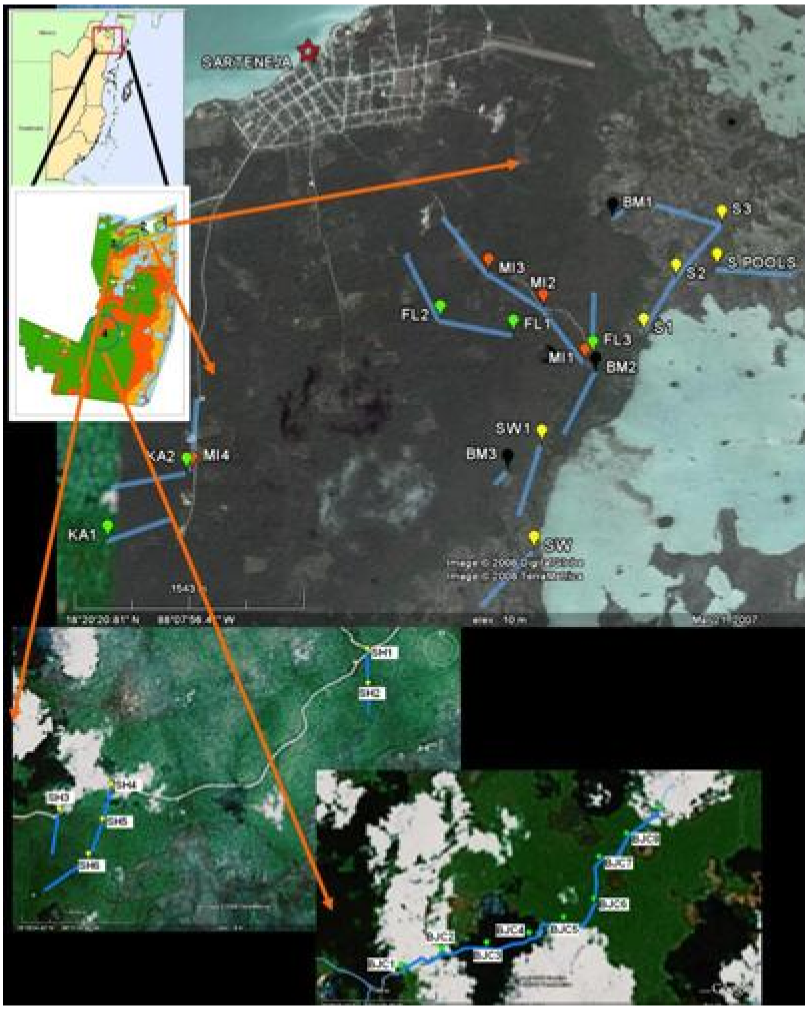
To determine abundances of migrants wintering in North East Belize, we employed standard distance sampling in established transects between the 21st November 2007 - 4th March 2008 following the methods described in Chapter 2. Transects were placed in six different habitat types (see Fig. 5.1) and were sampled at approximately equal time intervals during the winter months. To detect variations in species composition, presence and persistence during the winter in each of the habitat types, we divided the sampling periods into early winter (21st November - 13th of December), mid winter (15th January - 15th February) and late winter (18th February - 4th March).

Vegetation structure

Vegetation structure was measured in each of the forest transects (excluding savannah, black mangrove and Milpa) as described in Chapter 2. This data served to test if the habitat types perceived by us and as described in the literature (Meerman & Sabido 2001), were actually reflecting differences in bird composition. To achieve this we analyzed two sets of data:

1. Assuming changes in the bird community would reflect changes in habitat, we constructed a matrix with the abundances of all the migrant bird species detected per transect.
2. A matrix containing the habitat structure data per transect.

Figure 5.1: Maps showing transect distribution in NE Belize. Most transects are 500m in length. Colour marks indicate the starting point of each transect & blue tracks indicate the route. The figure shows an enlargement of NE Belize and three detailed maps with transects at study sites 1-4 (Fig 2.2). Transect letter codes correspond to the following habitats: FL & KA = dry forest – low, S = Savannah, BM = Black Mangrove, MI = Milpa, SH = dry forest - high and BJC = Moist forest.



With these matrices we carried out independent cluster analyses to group transects according to their similarity in bird composition and in vegetation structure. Cluster Analysis was carried out using program MINITAB, with parameters set as average linkage between groups, distance calculated through correlation and displayed graphically through dendrograms. This enabled us to confirm our perception of the habitat types with the actual bird community distribution within them and also to point out similarities and differences in vegetation structure.

Abundance and density by habitat

To represent overall abundance, encounter rates by species were calculated. To achieve this, the total number of detections/500 m transect in each habitat was calculated first and then corrected for the number of kilometres walked in each habitat. All habitats were then combined to obtain an average encounter rate per species across all habitats. To examine species abundance by habitat, pie charts were created by first calculating the number of individuals by habitat and then correcting for the total distance of transects in each habitat. These distance corrected totals, were then converted into a percentage of the total across all habitats (N.B. these abundances do not account for differing rates of detection between habitats; see Table 5.2).

To examine abundance by habitat with greater accuracy, we first calculated the density of migrant birds (regardless of species) by habitat using DISTANCE version 5.0 and the allocations of transects to habitats described above. To convert these densities by habitat into corridor wide estimates of migrant populations we multiplied by the area available of each habitat in the corridor – areas were calculated using ArcGIS and a detailed map of ecosystems in NE Belize (Meerman & Sabido 2001). Densities by habitat were also estimated at the individual species level when more than 20 records per habitat were available. For all density calculations we only used detections of birds made after the 28th January when distance bands were modified to improve calculation of the detection curve (see Chapter 2) and to represent ‘late winter’ when habitats are expected to be at their most limiting due the effects of the dry season. In the models run in DISTANCE, habitats were stratified and models were selected from the model set listed below using Akaike Information Criteria and a Goodness of fit chi probability value (Buckland *et al.* 1992). The models presented in the results represent the best-fitting model without a process of model averaging.
Model Set:

- Uniform with cosine and simple polynomial adjustments
- Half normal with hermite polynomial adjustment
- Hazard rate with cosine adjustment

Seasonal persistence in habitats
To calculate migrant abundance at different stages of the winter, we constructed a series of matrices of number of individuals encountered in 25 m strips either side of all transects in a given habitat across three periods (Early 21st Nov-13th Dec; Mid 15th Jan-15th Feb; Late 18th Feb-4th Mar) and corrected them for total transect length. As the aim was to assess changes in abundance within habitats with time of year, there was no need to correct for detection probabilities. To see if changes in abundance between winter periods were significantly different we carried out a GLM analysis by transforming the count data with the following formula: $yi' = ½ (\sqrt{yi} + \sqrt{yi} + 1)$, where yi' = transformed value, yi = observation. The transformation was reversed to calculate the abundance of individuals shown in the graphs with their standard errors.

Figure 5.2: Cluster analysis showing differences in forest types according to vegetation structure and common tree species composition in NE Belize. BJC – Moist forest transects at Balam; SH – Dry forest high transects at Shipstern Nature Reserve; FL – Dry forest low transects near La Isla; K&A – Dry forest low transects on Sarteneja Community Lands.

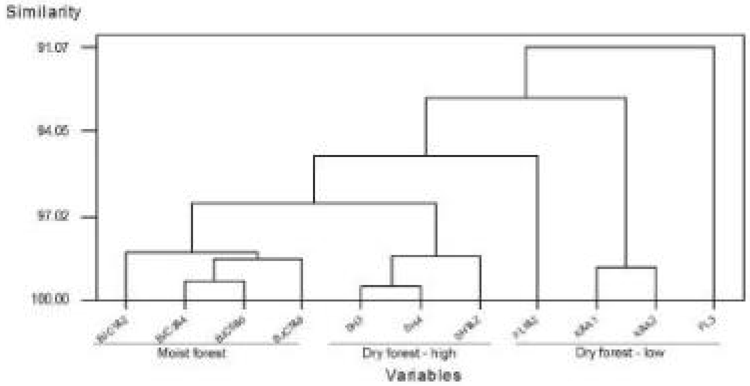
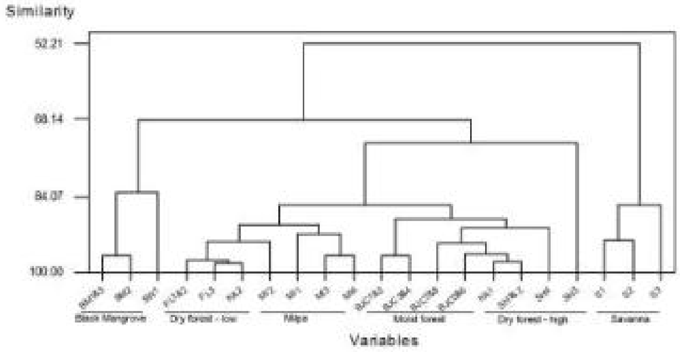


Figure 5.3: Cluster analysis showing habitat differences according to migrant bird composition during the winter months in NE Belize. BM – Black Mangrove transects; FL – Dry forest low transects near La Isla, K&A – Dry forest low transects near on Sarteneja Community Lands; MI – Milpa transects, BJC – Moist forest transects at Balam; SH – Dry forest high transects at Shipstern Nature Reserve, S & SW – Savannah transects.



Results

Habitat differentiation through cluster analysis

Habitat clustering, both through vegetation structure/tree composition and through migrant species composition, confirmed the assignment of transects to different habitat types (see Figs 5.2 and 5.3). The habitat separation therefore agrees with the descriptions found in the literature and confirms that birds are perceiving the differences between habitats measured by ourselves and through satellite imagery. To produce density calculations we adopted the forest habitat clustering shown in Fig. 5.2, which enabled us utilise existing ecosystem maps that also adopt these classifications to convert density estimates into population estimates for the whole corridor by habitat. As migrants appeared to perceive certain habitats as very similar (see Fig. 5.3), when evaluating habitat use and preference we follow the groupings in Fig. 5.3.

Abundance and density by habitat

We completed 84.7 km of transects and observed 2,225 individuals of 23 landbird migrant species during the non-breeding season (Table 5.1). Of all birds detected during transects, regardless of habitat, 43.3% were migratory. However this proportion varied between habitats with Black mangrove having the highest percentage of migrants vs. residents (62.4%), followed by dry forest – low (45.8%), then Milpa (40.0%), savannah (32.6%), moist forest (28.6%), and lastly dry forest – high (27.5%). Overall abundance varied markedly between migrants with some species being highly abundant (Magnolia Warbler) and others occurring only in very low numbers (Blue-winged Warbler; Table 5.1). Considerable variation also existed in habitat use between migrants, with some species apparently favouring Black Mangrove whilst other were more generalist or favoured tropical forest (Fig. 5.4). Almost all species were found in more than one habitat, suggesting that no one habitat can ensure the survival of most of the species found in the region.

The highest density of migrants during the winter months, having accounted for different detection probabilities between habitats, occurred in Black mangrove with almost six times more individuals than any other habitat (Table 5.2). The forested habitats displayed similar densities whilst savannah held the lowest densities of all habitats. According to our habitat area estimates and to extrapolations from the densities obtained of migrants per habitat, we expect that more than 2 million individuals spend the winter in the proposed NE Belize biological corridor.

Individual species densities per habitat were only calculated for those individuals with enough observations in each habitat type (Table 5.3). Thus absence of a species from Table 5.3 does not necessarily mean that the species was not detected in that habitat, just not enough times. Agreeing with the pattern found for overall migrant densities, Black mangrove had the largest number of species with sufficient records and the highest densities. Individual density estimates by species indicate the degree of habitat specialisation versus generalisation in each, and could be useful in comparison to estimates from other areas/regions/habitat types. The density of species such as Least Flycatcher and White-eyed Vireo indicate a preference for disturbed habitats such as Milpa, whilst Hooded Warbler and American Redstart favour forested habitats and finally the Magnolia Warbler appears to be the ultimate generalist.

Table 5.1: Encounter rate of migrant species detected per km of transect in all habitats during the winter months in NE Belize 2008. Figures were obtained by adding the total number of detections per transect and dividing by total distance covered in Km for every habitat type. Afterwards all habitats were combined to obtain a general encounter rate by species. Species are ordered from most encountered to least.

Species	Scientific Name	TOTAL
Magnolia Warbler	*Dendroica magnolia*	17.11
American Redstart	*Setophaga ruticilla*	9.02
Gray Catbird	*Dumetella carolinensis*	8.68
Black-throated Green Warbler	*Dendroica virens*	7.64
White-eyed Vireo	*Vireo griseus*	7.01
Northern Waterthrush	*Seiurus noveboracensis*	6.99
Hooded Warbler	*Wilsonia citrina*	6.09
Common Yellowthroat	*Geothlypis trichas*	4.78
Northern Parula	*Parula americana*	4.63
Black-and-White Warbler	*Mniotilta varia*	4.45
Least Flycatcher	*Empidonax minimus*	1.78
Yellow-rumped Warbler	*Dendroica coronata*	1.64
Wood Thrush	*Hylocichla mustelinus*	0.48
Summer Tanager	*Piranga rubra*	0.44
Yellow-breasted Chat	*Icteria virens*	0.3
Worm-eating Warbler	*Helmitheros vermivorus*	0.28
Yellow-throated Warbler	*Dendroica dominica*	0.23
Yellow-throated Vireo	*Vireo flavifrons*	0.21
Ovenbird	*Seiurus aurocapillus*	0.21
Kentucky Warbler	*Oporornis formosus*	0.19
Yellow-bellied Flycatcher	*Empidonax flaviventris*	0.13
Yellow Warbler	*Dendroica petechia*	0.1
Blue-winged Warbler	*Vermivora pinus*	0.05

Table 5.2: Densities (individuals/km$_2$) of all species of migrants detected during ‘mid and late’ winter, calculated for each habitat type in NE Belize. Also shown is the estimate of individuals expected to winter in the NE Biological corridor calculated from total areas of each habitat in the corridor (Meerman 2004).

Habitat	Migrant Density *(+/- SE)*	Detection probability	n	Estimated area of habitat (*km*^{2})	Estimate No. of Wintering Individuals
Black Mangrove	23,829 (+/-1845.4)	62.8%	448	29.6	706,029
Dry Forest - low	3,829 (+/-379.6)	71.1%	352	49.3	188,850
Milpa	3,476 (+/-355.9)	63.9%	264	8.7	30,261
Dry Forest - high	2,444 (+/-317.1)	55.0%	132	10.2	24,832
Moist Forest - high	1,332 (+/-145.7)	50.0%	167	676.9	901,329
Savannah	570 (+/-119.3)	55.3%	51	377.4	214,982
				TOTAL	**2,066,286**

Figure 5.4: Pie charts showing abundance by habitat for the ten commonest species wintering in NE Belize.

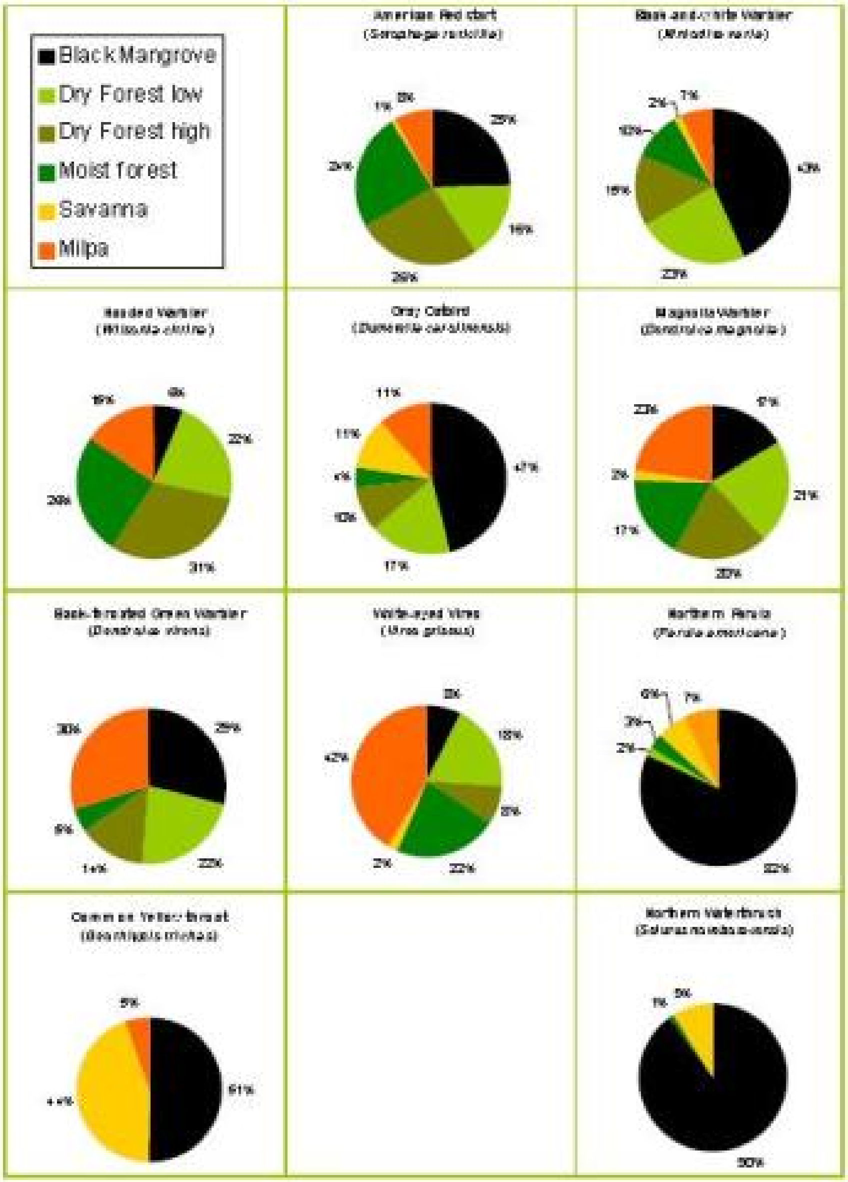


Table 5.3: Late winter densities of the most common species calculated for each of the habitat types sampled in NE Belize during the winter months (rounded to whole numbers). Density is given in individuals per km^2; *n* = number of detections. Where density estimates are missing is not an indication of non-use of a habitat but that too few birds were recorded to perform density calculations.

Species	**Black Mangrove Density** ***(+/- SE)***	**n**	**Dry Forest – low Density** ***(+/- SE)***	**n**	**Milpa Density** ***(+/- SE)***	**n**	**Dry Forest – high Density** ***(+/- SE)***	**n**	**Moist Forest** ***(+/- SE)***	**n**
Least Flycatcher (*Empidonax minimus)*	-	-	-	-	558 (+/- 151)	29	-	-	-	-
White-eyed Vireo (*Vireo griseus*)	-	-	945 (+/-269)	37	1138 (+/- 253)	49	-	-	-	-
Gray Catbird (*Dumetella carolinensis*)	1538 (+/-286)	44	438 (+/-125)	25	-	-	-	-	-	-
Northern Parula *(Parula americana*	3121 (+/-847)	34	-	-	-	-	-	-	-	-
Magnolia Warbler (*Dendroica magnolia*)	3373 (+/-606)	52	1272 (+/-175)	104	822 (+/-131)	75	749 (+/- 162)	36	249 (+/- 42)	43
Black-throated Green Warbler (*Dendroica virens*)	2994 (+/-654)	35	759 (+/-130)	56	506 (+/- 98)	44	-	-	-	-
Black-and-White Warbler (*Mniotilta varia*)	2983 (+/-1026)	28	624 (+/-192)	27	-	-	-	-	-	-
American Redstart (*Setophaga ruticilla*)	1807 (+/-311)	42	675 (+/-129)	47	-	-	566 (+/- 137)	34	-	-
Northern Waterthrush (*Seiurus noveboracensis*)	7794 (+/-3182)	127	-	-	-	-	-	-	-	-
Common Yellowthroat (*Geothlypis trichas*)	2803 (+/-1192)	48	-	-	-	-	-	-	-	-
Hooded Warbler (*Wilsonia citrina*)	-	-	335 (+/- 76)	32	-	-	413 (+/- 119)	20	235 (+/- 61)	24

Seasonal persistence in habitats

We found differences in abundance/persistence of migrants between the early, mid and late winter periods within different habitat types. The significance of these differences varied relative to species and habitat type suggesting differential habitat use at different times of the winter (Fig. 5.5 a & b). American Redstarts showed significant decreases in Black mangrove from early to mid winter (P = 0.01), whilst increasing in dry forest – high from early to mid winter (P = 0.02). Magnolia Warbler showed a significant decrease in Black mangrove from early to mid winter (P = 0.04) as did Gray Catbirds (P < 0.01). Finally, Black-throated Green Warblers showed a significant increase in dry forest low (P = 0.01) and in Milpa (P = 0.05) from early to mid winter. The other changes evident in the graphs were not statistically significant but illustrate the dynamics which are taking place in the habitats and their uniqueness by species.

Other species for which no graphic information is displayed here, showed similar patterns of change. For example the Northern Waterthrush showed a significant increase in Black mangrove (P = 0.05) from early to mid winter, as did the Northern Parula (P < 0.01), whilst both decreased from mid to late winter (though not significantly). Hooded Warbler showed a non-significant increase in dry forest – high from early to mid winter and decreased in both Milpa and dry forest low as the winter advanced.

Figure 5.5a: Relative densities (+/- SE) of American Redstart and Magnolia Warbler, as calculated from detections within 25m strips of transects, in four habitats compared during early, mid and late winter in NE Belize. Savannah and Moist forest were not included in this analysis because they were not sampled during mid winter or early winter in the case of the latter.

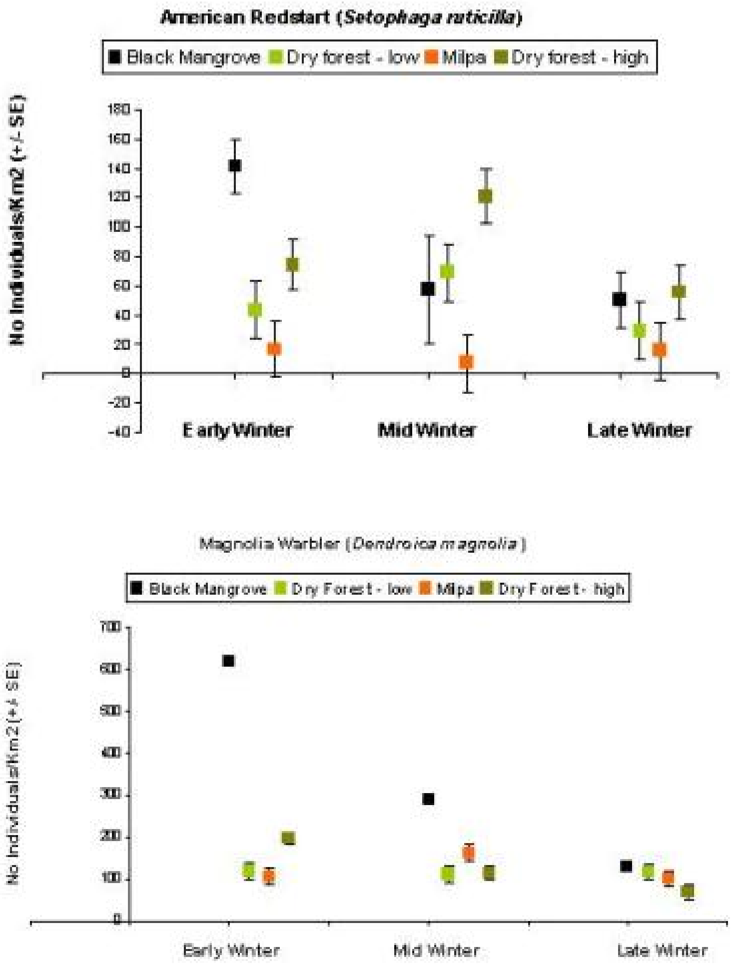
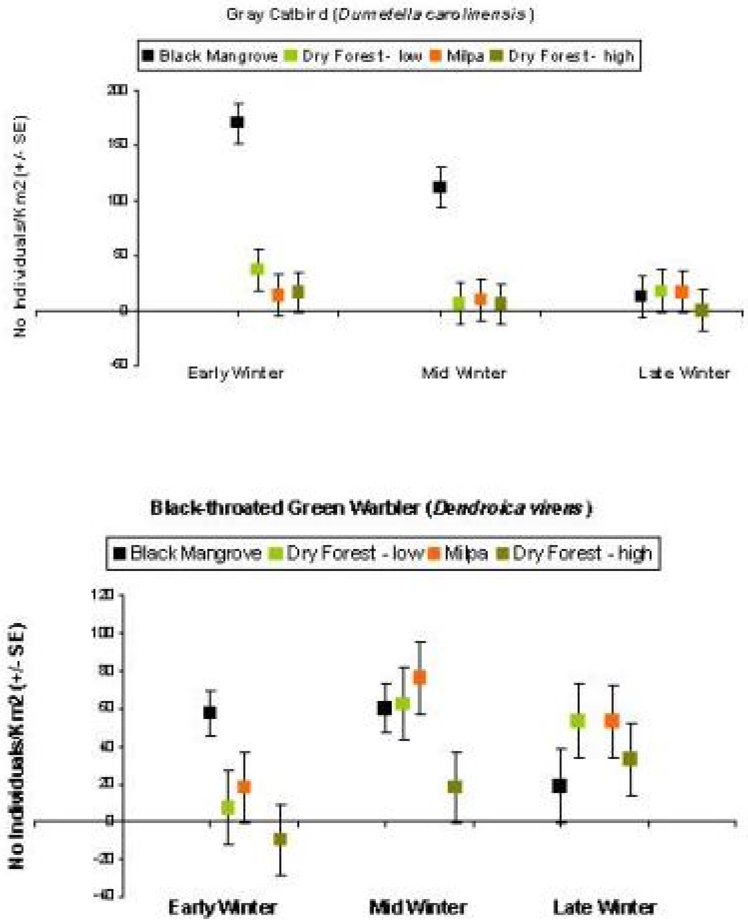


Figure 5.5b: Relative densities (+/- SE) of Gray Catbird and Black-throated Green Warbler, calculated from detections within 25m strips of transects, in four habitats compared during early, mid and late winter in NE Belize. Savannah and Moist forest were not included in this analysis because they were not sampled during mid winter or early winter in the case of the latter.



Discussion

We found a similar set of species wintering in NE Belize as had been found for other areas of the country, however, the commonest species in the north-east are somewhat different to those reported for Runaway Creek (Piaskowski *et al.* 2005). Whilst Magnolia Warbler and Gray Catbird were also amongst the commonest further south, Runaway Creek has a much higher presence of Wood Thrushes and Kentucky Warblers compared to our site, as do the Maya Mountains (pers. obs.). The composition at our study site reflects more closely that recorded further north on the Yucatan Peninsula of Mexico (Greenberg 1989).

The average proportion of migrants to resident birds detected in this study (43%) is similar to what has been found in other areas of Belize (Piaskowski *et al.* 2005). However, comparisons of our data with those in the literature, must take in account that there are inherent differences between data collected through mist netting and that collected through observations. The proportion of migrants to residents per habitat type reflected a general pattern of habitat use in which Black Mangrove appeared as the most important for Neotropical migrants with nearly 20% more presence of migrant species than the next habitat in line.

Abundance and density by habitat

Careful interpretation of density estimates can be a useful tool in understanding the relationships between species and the habitats they use. Whilst a habitat displaying higher densities of a given species presumably offers more or a higher quality of resources than a habitat with lower densities, it cannot be ignored that higher densities may be a consequence of competitive exclusion from the highest quality habitat. When examining density data, it is therefore critical that we relate it to the ecology of the species involved and to scale dependent factors at the landscape level that could also be influencing distribution and abundance of individuals. Ideally, initial density estimates should be used to make hypotheses that can be tested through detailed studies of relative survival between habitats, before ultimately using the data to make decisions about protecting and managing habitats.

In this study we found that almost all species occurred in more than one habitat which agrees with studies that support the hypothesis that many migrant species tend to be generalist in habitat use, at least more so than many resident species (Greenberg 1989, Piaskowski *et al.* 2005). However, we found significant differences in densities of migrants wintering in each habitat type. In fact, the average density of migrants of all species in Black mangrove was six times higher than any of the other habitats. Such high densities in Black mangrove could be interpreted as a higher preference for this habitat in many migrant species presumably due to its superior quality - it has been shown some species that individuals wintering in Black mangrove have higher survival rates than those wintering in dry scrub (Marra & Holmes 2001).

Although we do not doubt that migrant use of Black mangrove was greater than other habitat types, there are various characteristics of the Black mangrove patches we sampled that may be contributing to an overestimate of density. For instance, the habitat patches of Black mangrove in our study site were essentially small islands of habitat within much larger continuous areas of forest or savannah. The small size of these patches may have resulted in double counting, as birds moved within a relatively confined area. Alternatively, the small size of patches of this rich habitat may have resulted in abnormally high densities relative to densities in larger areas of Black mangrove. In any case, more study is needed to compare other areas of Black mangrove and to evaluate scale dependent use of this habitat and others.

The lower densities of migrants found in other habitat types do not mean that those habitats are not important, especially as these represent the most widely available habitats. Indeed, scale-dependant effects may also be governing densities in these habitats, such that high availability of moist forest within the study area results in lower densities, even though its quality may be similar to other forest types. Nevertheless, migrants in the study area did show a preference for ‘forested’ habitats (we include Black mangrove and Milpa under this definition here) over savannah in terms of densities, with just three species regularly occupying the later habitat (Common Yellowthroat, Yellow-rumped Warbler & Northern Waterthrush). The savannah essentially reflects the effect of large scale forest clearance for agriculture and other activities and provides a stark warning for the potential impact on Neotropical migrant populations.

Seasonal persistence in habitats

Just as the proportion of migrants varied between habitats, so did the persistence of individual species in each habitat throughout the winter months. Most species showed changes in abundance during the winter within the different habitats but these changes were not always significant. However, a common pattern shared by several species was high densities in early winter in Black mangrove followed by a decrease in density as the winter progressed (Fig. 5.5 a & b) – in some cases this decrease was dramatic, e.g. Gray Catbird. Decreased persistence in Black mangrove, particularly in NE Belize where the dry season is harsher than the rest of the country, is most likely a response to reduced resources caused by drying conditions. Thus whilst Black mangrove is clearly a high quality habitat in the early winter, many individuals leave this habitat for others as the dry season progresses, making it critical that a series of interconnected habitats exist. Such connectivity still exists in NE Belize and further study is required to determine how movements between habitats may enhance survival or whether they are only performed by subordinate birds that are forced out of habitats as resource levels decrease.

At the individual species level a number of interesting patterns in abundance over winter were detected. In the Gray Catbird a significant decrease in almost every habitat was detected from early to late winter and suggests not just a movement to a different habitat but away from the study area altogether. This may be evidence for within season movements of this species, indicating that more than one region may be utilised during the non-breeding season. The Black-throated Green Warbler appeared to show the opposite pattern with a significant increase in individuals in preferred habitats between early and mid-winter. It may be that both species were reacting to drying conditions, with Gray Catbirds being pushed south and away from our study site whilst Black-throated Green Warblers were being pushed south to our study site by conditions to the north. Regardless of the exact ecological factors governing such movements, it is important that they are considered when studying wintering habitats and planning conservation actions such that all habitats/regions used during the winter are included.

Summary

The NE biological corridor offers an array of habitats to the community of migrants occupying the region during the non-breeding season and it is evident from differing habitat use between species that all these habitats are required to sustain the entire community. The data presented here on abundance and density by habitat confirm clear patterns in habitat preference demonstrated by previous authors, e.g. the preference for disturbed/Milpa habitats by Least Flycatcher and White-eyed Vireo, but also demonstrate which species use previously understudied habitats such as Black Mangrove and Savannah. The findings in Black Mangrove could have important implications for the conservation of Neotropical migrants in Belize and Central America and further study is urgently needed to understand the use of this habitat where it occurs in larger patches and at the landscape scale.

The variation in habitat preference between species and inter-habitat movements recorded here, demonstrate that no one single habitat on its own can provide the optimum resources for migrants. Instead, a matrix of connected habitats appears necessary to maximise overwinter survival in a range of species. Initiatives to protect non-breeding habitats must therefore clearly define their conservation goals, as the areas selected for protection need to be carefully tailored to meet the varying needs of a single focal species or a wider group of species. Intensive studies still need to be carried out to fully understand the needs of migrant species during the winter and the implications of the conditions they face during the winter on their annual cycle.

Wood Thrush

CHAPTER 6

SUMMARY OF RESEARCH FINDINGS

In this chapter we summarise the main findings from research activities under this project in a form that we hope can be easily understood, interpreted and applied by conservation and management practitioners alike. We also address important new questions arising from this research and future directions.

Migration

- 84 and 67 species of Neotropical migrants occurring in autumn and spring migration respectively
- An estimated 14-20 million individuals passing through the corridor in autumn and 6-9 million in spring
- Short stopovers made by a wide range of migrants during autumn migration
- Only a restricted set of migrants using corridor as a stopover in spring prior to crossing the Gulf of Mexico
- Species of conservation concern which utilise the corridor in large numbers during migration include Willow Flycatcher and Prothonotary Warbler, mangrove habitats in the corridor may be important to both
- 3% or more of the World population of the Near-threatened Golden-winged Warbler use the corridor in both spring and autumn
- Densities of passage migrants in forested habitats were 7.5 times greater or more than open savannah habitats (surrogate for open agricultural lands)

The Yucatan Peninsula, where the proposed north-east Belize biological corridor is located, has previously been identified as a major flyway for Neotropical migratory birds. Given this precedent it is not surprising that 115 species of Neotropical migrant were recorded in the corridor during the entire study, with 84 and 67 species occurring in autumn and spring migration respectively. In addition to a diverse range of species utilising the corridor, large numbers of individuals were also recorded, with conservative estimates putting the number in autumn at somewhere between 14-20 million individuals and 6-9 million in spring. Whilst large numbers of migrants pass through the corridor, presence alone cannot be taken as evidence of use or as an indication of the importance of the corridor to passage migrants. We must therefore examine other lines of evidence.

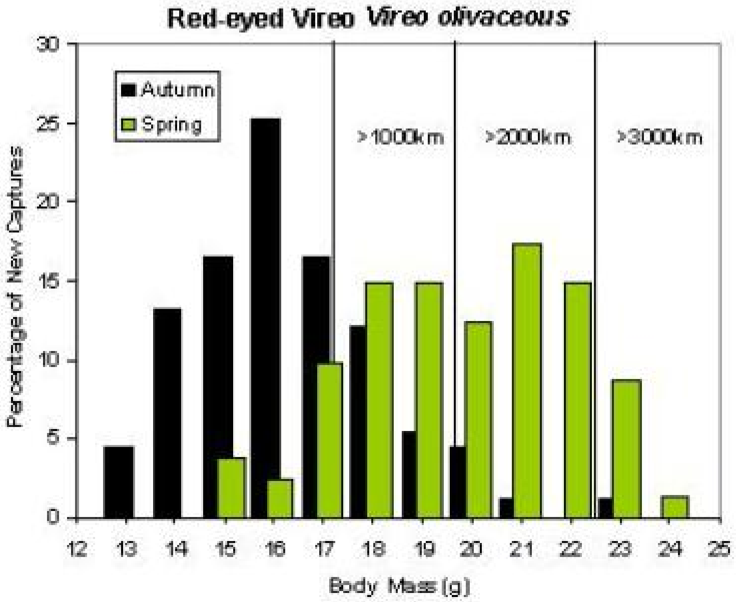
A comparison of autumn and spring migration is highly informative when trying to understand how migrants use the corridor. To begin with, species composition and abundance varied considerably between autumn and spring migration, with more species and more individuals being present in autumn (Table 3.1 & 4.1). The difference in abundance but not in species diversity might be explained by high numbers of immature birds in the post-breeding autumn population but not in species where differences are large. Such differences are most striking in three species of Empidonax flycatchers, all of which were recorded in large numbers in autumn but were completely absent in spring. We hypothesise that species such as these are adopting a spring migration route that does not pass through NE Belize or a strategy that does not require a stopover in NE Belize or potentially the wider Yucatan region. Overall, the evidence points to the corridor being used by a wider range of Neotropical migratory species during autumn migration than during spring and may reflect a greater need to stopover in the Yucatan region during the latter, having recently consumed large amounts of fuel/fat crossing the Gulf of Mexico.

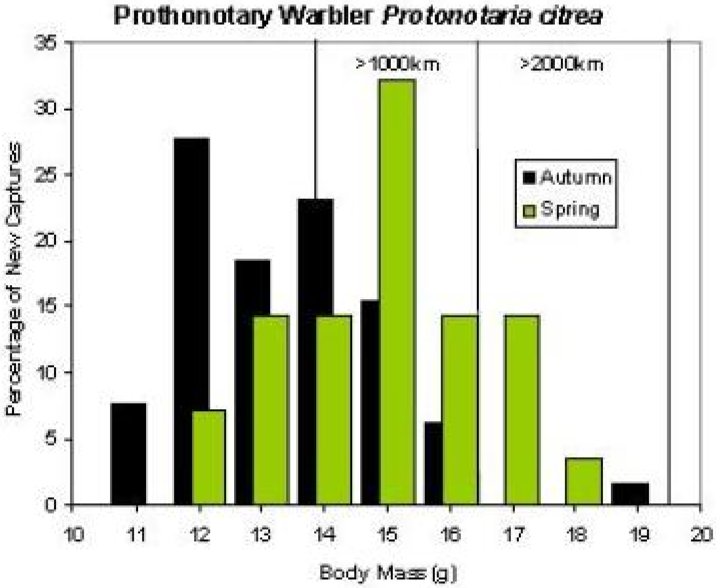
A second line of evidence that helps us understand use is a comparison of body mass/fat stores between seasons. The reasoning behind this comparison is that when fat stores and body mass are high, one would not expect birds to need to stop to accumulate further fuel reserves. In reverse, large numbers of individuals with low body masses/fat reserves suggests that many individuals in the population may need a refuelling stop. In the majority of species this comparison reveals that body mass and fat scores were higher in spring than autumn, supporting the conclusion above that a stopover in the corridor is more likely in autumn than in spring. Indeed, if one examines the Red-eyed Vireo graph in Fig. 6.1 it is evident that nearly 85% of individuals in spring most likely arrived in NE Belize already carrying sufficient fuel to complete a flight to North America (distance approx. 1400 km). The data for a combination of South America wintering species that occur only as transients in Belize (Table 4.4), lend further support to this conclusion, with over 70% of individuals carrying large reserves. That these individuals/species stop at all raises an interesting question and it is likely that the stop is largely made to rest after long over-water flights from South America and potentially to avoid migrating in the heat of the day when dehydration becomes a risk (Klaassen 1996). Whilst an autumn stopover appears more common than a spring stopover in most species, a small group of species arrived in spring with low body masses and were expected to stopover in the corridor. A final consideration when examining body mass/fuel store data is that those birds making landfall and being trapped may not represent the wider population. Indeed, in general the wider population is likely to contain a higher proportion of birds with larger fuel reserves than seen on the ground as these individuals most likely overfly the study area.

Abundance and body mass data indicate which species would be expected to stopover but further evidence in the form of stopover durations and evidence for increases in fuel stores are required to understand stopover behaviour fully. Whilst recapture rates were generally very low, a number of individuals both in autumn and spring demonstrated an increase in mass/fat score on second capture. The average number of days between captures, which is adopted as an index of stopover duration here, was significantly shorter in transient species in autumn relative to spring ($P = 0.017$), whilst the rate of mass gain/FDR was not significantly different between the two periods ($P = 0.588$). Overall increases in fuel stores are therefore expected to be greater in spring than autumn due to longer stopover durations. In conclusion, it would appear that whilst a wider range of species stopover in the corridor in autumn, many of these may be treating the area like a convenience store to accumulate small amounts of fuel whilst to a restricted set of species in the spring the corridor is a full service hotel – providing the resources necessary to make long unbroken flights to North America. In addition to transient species, individuals of species wintering in the corridor also appear to rely heavily on its resources to prepare for the cross-Gulf flight (Table 4.5).

The evidence presented in preceding chapters and summarised above point to the corridor being an important resource to a wide range of Neotropical migratory landbirds, providing resources to recover and refuel after the Gulf crossing in autumn and to facilitate fuelling for the reverse crossing in spring. At this stage, however, it is important to consider whether these conclusions would still hold firm with more than one year's data and without the impact of Hurricane Dean on the study area. It is well known that routes, body condition during migration and locations of 'fall outs' can vary between years (Mehlman *et al*. 2005) and thus the high numbers of Willow Flycatchers that were trapped in autumn, for example, may have been due the presence of a tropical storm in the Gulf of Mexico and may not reflect a common strategy. Accounting for the impact of Hurricane Dean is extremely difficult as evidence for the impact of storm damaged habitats on stopover behaviour is non-existent, however a number of suppositions can be made. The main affect of the hurricane in the study area was a reduction in both foliage and fruit in the forest canopy but also an increase in standing water leading to a mass emergence of mosquitoes. One might therefore predict that for fruit eating species the corridor became less attractive and that their use of the corridor may increase as the forest recovers, whilst for insectivores the impact may have been negative or positive depending on foraging strategies, e.g. gleaning from foliage vs. sallying for mosquitoes.

Figure 6.1: Distribution of body mass in individuals trapped during autumn and spring in two species of transient migrants in NE Belize. Potential flight ranges as estimated by program Flight 1.15 are indicated in bands by vertical black lines.





Conservation Significance During Migration and at a Regional Level

When determining the conservation importance of a site or region, one may focus solely on species of conservation concern or consider measures such as overall biodiversity and the extent to which given ecosystems/habitats are included within protected area systems as well. Here we will first focus on species of conservation concern, as most conservation initiatives for Neotropical migrants are directed at these species. A number of high profile threatened Neotropical migrants were observed during this study including three Near-threatened species, Olive-sided Flycatcher, Golden-winged Warbler and Painted Bunting. Just one individual was observed for each of these species except for Golden-winged Warbler which was recorded three times in autumn and once in spring. Converting these observations into corridor wide estimates suggests that over 6000 individual

Golden-winged Warblers may have utilised the corridor during autumn and even more during spring (caution is necessary here with just one observation) – with a global population estimated at 210,000 individuals, these estimates represent around 3% of the World population and indicate that the wider Yucatan may represent an important stopover region for this species.

Aside globally threatened species, a number of species appearing on the America To Watch List occurred in the corridor in large numbers. Of particular note were Willow Flycatcher (~5% of World population) and Prothonotary Warbler (~8% of World population) whilst lesser numbers of Bay-breasted Warbler and Kentucky Warbler were also present. Dropping another level in terms of conservation priorities, the corridor supported a diverse range of migrants during both migration seasons and with estimates suggesting that over 30 million individuals passed through, the areas importance to migratory landbirds as a group cannot be ignored.

In terms of defining conservation priorities, it is important to compare the corridor to other sites/areas at a regional level. Unfortunately, for the migratory periods there is a lack of published information from both Belize and the wider Yucatan, however, some information does exist. In an ongoing project at the Sian Ka'an Biosphere Reserve to the north of our study site in Mexico, capture totals for 2007 were similar for the majority of species but differed in several ways. Alder, Willow and Acadian Flycatchers were all relatively abundant in our study but completely absent from Sian Ka'an, the same was true of Yellow-throated Vireo (*unpublished data,* Angeles Raymundo). Prothonotary Warbler appeared more abundant at our study site but this may be more to do with habitat. In terms of species of concern, there were no records of Golden-winged Warbler at Sian Ka'an in 2007 but two were trapped in 2008 (*pers. comm*. Angeles Raymundo). Personal observations from other areas of Belize suggest that the moist forests of the Maya Mountains may be used to a greater extent by species of concern such as Canada Warbler, whilst similar numbers of Willow Flycatcher maybe present in central Belize relative to our study site. The Maya Mountains have also been highlighted as a spring stopover site for the Near-threatened Cerulean Warbler (Welton *et al*. 2008) and potentially Golden-winged Warbler (Parker 1994) making them an important region for the conservation of Neotropical migrants. In general, the corridor would appear to compare favourably with other areas and the protection of the remaining forest and mangrove habitats in this region would greatly benefit not only Neotropical migrants but also a wide range of threatened wildlife such as Jaguar, Baird's Tapir and Black Catbird.

WinteringMigrantsInTheCorridor

- 23 species of Neotropical migrant landbirds recorded regularly wintering in NE Belize at an average detection rate of migrants vs. residents of 43%
- An estimated 2 million individuals wintering within the proposed biological corridor
- Habitat use and persistence varied between species during early, mid and late winter
- Black mangrove showed the highest proportion of migrant to resident birds (62.4%) and had by far the highest density of migrants per km2 (6 times more than other habitats)
- Persistence was not high in Black Mangrove with most species declining in number during the winter
- The realisation of a biological corridor containing a combination of forested and mangrove habitats would protect a diverse community of Neotropical landbird migrants

Prior to this study, detailed studies of wintering migrants had not been carried out in NE Belize. Information from this study complements that of sparse records and anecdotal data from the area, and somewhat completes and confirms the inventory of migrants that winter in Belize. Within the two million individuals estimated to winter in the proposed corridor, are various species of concern whose population status may benefit from protection of moist forest in the corridor e.g. Wood Thrush, Kentucky Warbler and Worm-eating Warbler. In terms of conservation priorities though, these species appear far more abundant in the forests of western and southern Belize (e.g. Piaskowski *et al*. 2005; *pers. obs.*) and thus ensuring protection these areas first would be a priority.

One of the most important conclusions from this study, is that not one single habitat on its own can provide the optimum resources for migrants. Instead, a matrix of connected habitats appears necessary to maximise overwinter survival in a range of species. The variation in habitat use and persistence during the winter demonstrated here, shows how individuals of a certain species might depend on more than one habitat during a season. More detailed studies are needed at the species level to fully understand the dynamics of habitat use, habitat quality and its implications on the life cycles of these birds.

The importance of Black Mangrove to Neotropical migrants during the winter must not be underestimated. Our results show that the highest concentrations of migrants occur in this habitat and this is not due to just one or two highly abundant species but because a range of species utilise this habitat. In terms of protected areas within Belize, Black Mangrove is a highly under-represented habitat and efforts to both map and protect existing areas of Black Mangrove would be highly beneficial to the conservation of Neotropical migrants in Belize. This is not only true for wintering species but also for declining species such as the Prothonotary Warbler that uses this habitat during passage.

Future Directions

As with many initial studies, our findings have generated more questions than they have answers. The aim of the yearlong study documented here was to gather baseline information on how Neotropical migrants were using an area of NE Belize at a community level. This study has largely satisfied this aim, revealing which species migrate through the area, which spend the non-breeding season there, habitat preferences between species and initial data on stopover behaviour. At the community level this information provides an excellent starting point for understanding how the NE biological corridor could contribute to the conservation of Neotropical migrants, however, at the level of individual species further study is necessary.

Winter habitat quality

One key area requiring more attention is how habitats vary in quality for different species during the non-breeding season. Many species occurring in the region can be found in more than one habitat and whilst estimates of abundance and density can be used to assess habitat quality where large differences between habitats exist, abundances cannot be used to measure habitat quality when they are approximately similar between habitats. Instead, other measures of habitat quality are needed, such as relative survival between habitats or changes in body condition over winter (see Johnson *et al*. 2006). For species of concern such as Wood Thrush and Kentucky Warbler that regularly winter throughout Belize, detailed studies of habitat quality are needed to ensure that high quality habitats are receiving adequate protection. It would also be highly beneficial to examine connectivity between reproductive areas and non-breeding areas in Belize.

Stopover behaviour

Our understanding of stopover behaviour generated by this study is relatively limited and for species of concern, e.g. Willow Flycatcher and Prothonotary Warbler, focused studies in which captures and recaptures are maximised through methods such as sound lures or targeted net placement could increase our understanding greatly. The use of colour rings would also greatly increase the power of stopover studies by increasing recapture frequencies through re-sightings, thereby allowing more detailed analyses of stopover duration (e.g. Morris *et al*. 2005). For species such as Prothonotary Warbler, it would be highly beneficial to examine habitat quality during stopover by examining whether fuel deposition rates and take-off mass vary between different mangrove and forest types, especially given the current pressure on coastal mangroves exerted by development projects in many parts of Central America.

Regional perspective

To truly understand the migratory strategies of Neotropical migrants along the length of their journeys it is crucial that further studies, like that presented here, are carried out throughout Central America and also in northern South America. Without further studies, efforts to prioritise key stopover areas for conservation action will fail for a lack of information. The findings from this study suggest a number of areas that would be priorities for further investigation. Within the context of Belize, the extensive forests of the Maya Mountains are a high priority in order to determine how this conservation block contributes to the conservation of Neotropical migrants. The montane forests found there may provide important resources for species such as Cerulean Warbler, Canada Warbler and Golden-winged Warbler and further investigation, especially for Cerulean Warbler and Golden-winged Warbler in spring, is required. During the non-breeding period, the Maya Mountains also appear to host large populations of both Kentucky Warbler, Wood Thrush and Worm-eating Warbler (*pers. obs*.) and further investigation into habitat and altitudinal preferences would be beneficial. The mountains may also harbour an undiscovered wintering population of Golden-winged Warbler.

Outside of Belize, this study indicates that the wider Yucatan region most probably represents an important autumn stopover following the crossing of the Gulf of Mexico for many South American wintering species. Further study at different latitudes across the Yucatan and in different habitats would be beneficial in order to identify key sites/habitats at a regional scale. This is especially true for species of concern such as Golden-winged Warbler and Prothonotary Warbler that stopover here in autumn. Other regions deserving attention during autumn, include the extensive tropical forests in eastern Honduras and Nicaragua. With respect to spring migration, this study raises a number of important questions. Many species arrived at the study site carrying large reserves, indicating that the main fuelling/stopover sites were south of Belize. We speculate that individuals of these species may be adopting one of two possible strategies: 1) Accumulate sufficient reserves in northern South America, potentially during pre-migratory fuelling at non-breeding sites, to fly to North America without refuelling; 2) accumulate sufficient fuel at non-breeding areas in northern South America to reach stopover sites in eastern Honduras/Nicaragua where the fuel to reach North America can be accumulated. The priority in this case is to examine how non-breeding areas in South America are utilised during pre-migratory fuelling and determine whether they are a crucial factor affecting both winter survival and migratory success. If hypothesis 1 is true, land use changes in these non-breeding areas could have a dramatic impact on migratory success and on reproductive success through knock on effects (see Norris *et al*. 2004).

CHAPTER7

EDUCATION & TRAINING

Introduction

Virtually all interactions between researchers and the communities around them have the potential of being educational in some way. Even day to day conversations and giving an example of a way of living, 'teach' different things and transmit messages to the people that receive and participate in them. With a little guidance and focus, a small educational initiative can reach a wider audience and be more effective than initially expected. This was the case with the education and training activities under this project. Whilst initially aims were to complete two school visits, train two Belizeans in bird banding and print an educational leaflet, we managed to involve more than 60 students in the education activities, gave bird banding training to 30 Belizean nationals and transformed the leaflet into a school initiative, thought, constructed and presented entirely by the students with a little guidance on our part. Overall our education and training efforts were focused in three main areas. The first was that of general diffusion of the project both at a local and an international level. The second was concerned with local involvement and increasing awareness about migratory birds and finally considerable effort was exerted in providing high quality bird banding training - a key skill for bird conservation work. The activities carried out under each of these general areas are described in this chapter.

Methods

General diffusion of the project

The major diffusion tool of the project was a 'blog' website that was created in the early stages of the project (www.belizemigrants.wordpress.com). The site featured daily updates on captures during the migration seasons and regular updates during the 'winter' months. The blog also included information on the background and aims of the project, the researchers and the resident species in the study area. To increase exposure of the website, the web address was distributed among our ornithological contacts and through various ornithology orientated mailing lists. Aside the website, further diffusion was achieved through general talks to volunteers and visiting scientists, and dissemination of records through a Belizean ornithological mailing list and to the BERDS, AKN and E-bird databases.

Finally, in order to give exposure to our project and findings at the international level, we presented posters at two conferences attended by both ornithologists and conservation practitioners. The International 'Partners in Flight' conference held in Texas in February 2008 was attended by bird researchers/conservationists from all over the Americas and provided an excellent opportunity to diffuse results to the wider community. The Cerulean Warbler and Golden-winged Warbler summit in Bogota in October 2008 gave us the chance to display our more detailed results to individuals with a specific interest in migratory birds.

Increasing awareness through local involvement

Bird banding demonstrations were a fun and effective way of increasing awareness about migratory birds and birds in general at the local level. Our demonstrations consisted of a morning's banding session in which people of all ages and backgrounds could see and actively participate in the practical part of our field work whilst learning about the birds they saw up close in the hand.

In a project with a school in the local village, Sarteneja, we researched and designed a leaflet on bird migration alongside students. Originally we had planned to produce the leaflet independently but the collaboration with the Cornerstone Christian Academy school was an excellent opportunity to increase the power of this educational tool and promote a deeper understanding of migratory birds in the local area. The main aim of the leaflet/project was to learn about the importance of the different habitats around Sarteneja to migrant and resident birds. To research the leaflet, the students began by carrying out bird watching walks in four habitats and familiarizing themselves with the birds and different habitat characteristics. During the walks the students learned about bird identification and took photos of salient habitat features. Students also visited our ringing site to see migratory birds up close in the hand. To complement the field research, students participated in an internet research session in which they searched for information on common migratory species and the habitats visited. With the information learned from these two research techniques, the contents and the design of the leaflet was determined in further sessions. When the leaflets were ready and printed, the students invited the local community and other local schools to an official presentation in which they explained the results of their work and distributed copies of the leaflet.

Bird banding Training

The banding training was probably the most important of the educational activities we planned to carry out and considerable effort was put into giving as high a level of training as possible. Our training method, whilst emphasising on the health and safety of the birds, allowed the trainees to actively learn and participate from day one. We mixed intensive practical experience in the field with a series of talks on different subjects such as ageing and sexing techniques and personalized training such each individual could advance at their own pace. Key materials used during training included field guides, laminated field sheets with illustrations of coding systems (e.g. muscle, fat, brood patches, cloacal protuberances), talks with information on ageing and sexing techniques and lots of photos and examples of plumages and moulting strategies. We also used and made reference to the North American Banding Council - NABC bander's study guide and trainer's guide (NABC 2001).

To ensure a lasting impact of our training activities in Belize, we spearheaded the formation of bird banding group at the University of Belize alongside Dr. Elma Kay. To initiate the group we organised a ten day training course in September 2008 and donated equipment to the group that in turn had been donated to our project by IdeaWild. The group was expected to provide a focus for bird banding in Belize in perpetuity and provide a safe environment for continued practice under the guidance of Dr. Elma Kay and experienced banders from the Belizean NGO, Birds Without Borders.

Results

General diffusion of the project

The website received more than 1800 hits between September 2007 and August 2008, displaying peaks of visits during the migration periods when daily updates were being made. It proved to be an efficient way of reaching diverse audiences interested in the subject and allowed us to make contact with other researchers working in similar or related projects. The blog also served as a good reference point for our donors to check on the advances of the project and to create links from their sites to ours and vice versa, thus increasing the potential exposure of our work.

Neotropical Migrant Birds in Belize

The residents steal the show

Talks about bird migration and about our project were given to more than 70 individuals including GVI Volunteers (20), University of Belize students (10), students from the Sarteneja Cornerstone Academy (35) and members of the Eagles Environmental Club from Corozal Community College (11). Participation in the 4th International Partners in Flight Conference held in McAllen, Texas from the 14th – 17th of February 2008, where we displayed a poster of the project, allowed over 700 researchers and conservationists interested in bird migration to learn about our project and of Belize's importance to migrants. It is worth noting that after the conference, our website received a boost of visits. In Bogota at the Cerulean and Golden-winged Warbler summit over 70 individuals with a direct interest in bird migration learned of our main results through a different poster. Finally, 4755 bird records were uploaded onto the Belizean BERDS database.

A. Bird migration talks at the Sarteneja Cornerstone Academy, Oct 2007.

ASSESSING THE IMPORTANCE OF THE BELIZE NE BIOLOGICAL CORRIDOR FOR NEOTROPICAL MIGRANTS

WWW.BELIZEMIGRANTS.WORDPRESS.COM

B. Poster displayed at the 4th Partners in Flight Conference, Texas, Feb 2008.

Increasing awareness through local involvement

We carried out a total of four banding demonstrations which were attended by 11 students belonging to the Eagles Environmental Club of Corozal Community College, five students from the Sarteneja Cornerstone Academy and four wardens from the nearby Shipstern Nature Reserve. During a morning's banding session, we worked with participants on bird identification as well as giving explanations on ageing and sexing techniques. Safety and basic handling were explained and in most cases visitors had the chance to handle and release birds.

Banding demonstrations for students in North East Belize including bird identification in the hand, safe handling of birds and release after processing and data collection.

Seventeen students from the Sarteneja Cornerstone C. Academy's environmental club, accompanied by their teacher Erlindo Novelo, participated in the 'Bird Migration Leaflet' Project. The students took parts in two field trips, carried out research through the internet and produced the texts and photos for the leaflets. The leaflets were printed both in English and in Spanish in order to reach all sectors of the local community. More than 100 people attended the presentation of the leaflet in which the students explained the process by which the leaflet was produced, read its contents out loud and voiced their expectations for similar projects in the future. The majority of the audience consisted of students from Sarteneja primary schools and a smaller number of parents. The presentation was advertised through posters and by a public announcement on the local TV channel. The leaflet can be seen in Appendix 2.

A. Field trips to different habitats around Sarteneja (Savannah, Black Mangrove and Milpa), with students from the Sarteneja Cornerstone C. Academy.

B. Leaflet presentation day with attendance of more than 100 members of the community.

C. Sarteneja Cornerstone C. Academy Environmental Group.

Bird banding training

Our first opportunity to carry out bird banding training came through participation as instructors on the first University of Belize Natural Resource Management field course organised by Dr Elma Kay in January 2008. The course was based at Las Cuevas Research Station and for three days we worked with a group of eight students covering bird monitoring techniques through talks and running two banding sessions in which students grasped the basics of the technique.

Our main focus for training was during spring migration and individuals from across Belize came to our field site for varying periods of time. In total 20 individuals received training and all learnt, to at least a basic level, how to catch and band birds, take a range of data and understand the applications of the data collected. Trainees varied from university students to college students to Nature Reserve wardens. All the trainees showed great enthusiasm for learning and the training either complemented their already advanced knowledge of the local birds or initiated a strong interest in them to keep learning. A list of individuals that attended training is given in Appendix 3.

‘Trainees in action’ during the spring training sessions, North East Belize 2008.

Our spring training sessions gave trainees a solid basis in bird banding techniques but all required further practice in order to guarantee the safety of the birds and the quality of data collected. Given the high potential of the trainees we worked with and a concern about the lack of opportunities for them and others to continue practicing their skills in Belize, we decided to spearhead the formation of Belize’s first bird banding group. In partnership with the University of Belize and professor Dr. Elma Kay we held an intensive ten day banding workshop in September 2008. Ten university students, including two who had received training during the spring, received a full training experience including nine mornings of field work and afternoon/evening talks on ageing and sexing techniques, safety, project design, data management and data analysis. In addition to ourselves, training was provided by experienced Belizean bird banders from Birds Without Borders and the Harpy Project at BFREE. Importantly, Birds Without Borders has agreed to support the bird banding group during its first six months, to ensure that the learning process continues and that the group receives the supervision it needs in these early stages. Dr Elma Kay, who is committed to leading the group and becoming a trainer herself, had the opportunity during the course to practice her training skills.

With authorization from IdeaWild, who donated the equipment to our project, we donated a full set of banding equipment to the group to enable them to continue practicing their skills and in time develop monitoring and conservation projects focusing on Belize's diverse avifauna.

A. Learning to furl nets.

B. Extracting birds from the mist nets supervised by David from Birds Without Borders.

D. Working at the banding table

E. Dr. Kay checking measurements to ID an *Empidonax* flycatcher.

F. Practicing the photographers grip on a Yellow Breasted Chat.

G. Attempting to age a bird during the moult quiz.

H. Belize's first bird banding group.

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APPENDIX 1

All neotropical migrants recorded in NE Belize during the study are listed below along with details of relative abundance at different times of year and habitat use. Abundance was determined using totals for transect and mist-netting data combined by period - as mist-nets were not deployed in winter slightly different criteria are adopted for this period.

***** = Absent/unrecorded
R = rare <10 individuals recorded
S = scarce 10-50 individuals recorded
C = common 50-200 individuals recorded (50-150 in winter)
A = abundant 200+ individuals recorded (150+ in winter)

Habitat codes are as follows: **CS** = coast/sea; **LM** = lagoon/mudflats; **MS** = mangrove savannah; **BM** = Black Mangrove forest; **MI** = Milpa/agricultural land; **TV** = Town/village; **DF** = dry forest; **MF** = moist forest; **OV** = migrating/flying over various habitats.

Common Name	Scientific Name	Autumn	Winter	Spring	Habitat
American White Pelican	*Pelecanus erythrorhynchos*	R	R	*	CS
Great Blue Heron	*Ardea herodias*	S	S	R	CS LM MS BM
Great Egret	*Egretta alba*	C	C	R	CS LM MS BM
Snowy Egret	*Egretta thula*	S	S	*	LM MS
Little Blue Heron	*Egretta caerula*	S	S	S	CS LM MS
Tricolored Heron	*Egretta tricolor*	C	S	S	CS LM,MS
Green Heron	*Butorides virescens*	S	S	R	CS LM MS BM
Black-crowned Night Heron	*Nycticorax nycticorax*	R	R	*	CS LM MS
Blue-winged Teal	*Anas discors*	C	C	R	CS LM MS BM
Northern Shoveler	*Anas clypeata*	*	R	*	LM
Osprey	*Pandion haliaetus*	R	R	*	CS LM
Swallow-tailed Kite	*Elanoides forficatus*	R	*	C	OV
Northern Harrier	*Circus cyaneus*	R	*	*	MS
Broad-winged Hawk	*Buteo platypterus*	R	*	*	OV
Merlin	*Falco columbaris*	R	*	*	MS
Peregrine Falcon	*Falco pereginus*	R	*	R	MS
American Coot	*Fulica americana*	*	R	*	LM
Black-bellied Plover	*Pluvialis squatarola*	S	R	*	CS LM MS
Semipalmated Plover	*Charadrius semipalmatus*	R	R	*	CS LM MS
Killdeer	*Charadrius vociferus*	*	S	*	MS
Greater Yellowlegs	*Tringa melanoleuca*	C	C	R	CS LM MS
Lesser Yellowlegs	*Tringa flavipes*	S	R	*	LM MS
Solitary Sandpiper	*Tringa solitaria*	*	R	R	BM
Spotted Sandpiper	*Actitis macularia*	S	R	R	CS LM MS
Whimbrel	*Numenius phaeopus*	*	*	R	LM MS
Western Sandpiper	*Calidris mauri*	*	R	*	LM MS
Least Sandpiper	*Calidris minutilla*	C	S	R	LM MS
Pectoral Sandpiper	*Calidris melanotos*	R	*	*	MS
Short-billed Dowitcher	*Limnodromus griseus*	R	R	*	LM
Long-billed Dowitcher	*Limnodromus scolopaceus*	C	C	*	LM
Common Snipe	*Gallinago gallinago*	R	*	*	MS
Laughing Gull	*Larus atricilla*	C	C	C	CS LM

Common Name	Scientific Name	Autumn	Winter	Spring	Habitat
Caspian Tern	*Sterna caspia*	R	R	*	LM
Royal Tern	*Sterna maxima*	C	C	C	CS LM
Sandwich Tern	*Sterna sandvicensis*	*	R	*	CS
Black Tern	*Chlidonias niger*	R	*	*	CS LM
Yellow-billed Cuckoo	*Coccyzus americanus*	R	*	R	DF MI
Lesser Nighthawk	*Chordeiles acutipennis*	S	R	S	DF MF MS
Common Nighthawk	*Chordeiles minor*	R	*	*	OV
Chuck-will's Widow	*Caprimulgus carolinensis*	R	*	*	DF
Chimney Swift	*Chaetura pelagica*	S	*	*	OV
Vaux's Swift	*Chaetura vauxi*	*	R	*	OV
Ruby-throated Hummingbird	*Archilochus colubris*	*	*	R	DF MI BM
Belted Kingfisher	*Ceryle alcyon*	R	R	R	LM
Yellow-bellied Sapsucker	*Sphyrapicus varius*	*	R	*	DF
Olive-sided Flycatcher	*Contopus cooperi*	R	*	*	MF
Eastern Wood-Peewee	*Contopus virens*	A	*	S	DF MF BM MI
Yellow-bellied Flycatcher	*Empidonax flaviventris*	R	R	*	DF MF
Acadian Flycatcher	*Empidonax virescens*	S	*	*	DF MF
Alder Flycatcher	*Empidonax alnorum*	S	*	*	DF MF MI MS
Willow Flycatcher	*Empidonax traillii*	C	*	*	DF MF MS
Least Flycatcher	*Empidonax minimus*	C	C	S	DF MI MF
Great crested Flycatcher	*Myiarchus crinitus*	S	*	R	MF DF
Sulphur-bellied Flycatcher	*Myiodynastes luteiventris*	*	*	R	DF MF
Eastern Kingbird	*Tyrannus tyrannus*	A	*	S	OV
Scissor-tailed Flycatcher	*Tyrannus forficatus*	*	R	*	MS
White-eyed Vireo	*Vireo griseus*	C	A	C	DF MI MF BM
Yellow-throated Vireo	*Vireo flavifrons*	S	R	R	DF MF BM
Philadelphia Vireo	*Vireo philadelphicus*	R	*	*	DF MS
Red-eyed Vireo	*Vireo olivaceus*	A	*	C	MF DF BM
Yellow-green Vireo	*Vireo flavoviridis*	R	*	R	DF MI MF
Purple Martin	*Progne subis*	A	*	R	OV
Tree Swallow	*Tachycineta bicolor*	*	C	S	MS
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	C	C	S	MS LM
Bank Swallow	*Riparia riparia*	S	*	R	OV
Cliff Swallow	*Petrochelidon pyrrhonota*	S	*	*	OV
Barn Swallow	*Hirundo rustica*	A	*	C	OV
Veery	*Catharus fuscescens*	R	*	S	MF DF BM
Gray-cheeked Thrush	*Catharus minimus*	R	*	R	MF DF
Swainson's Thrush	*Catharus ustulatus*	C	*	R	MF DF
Wood Thrush	*Hylocichla mustelinus*	S	S	R	MF DF
Gray Catbird	*Dumetella carolinensis*	C	A	S	MF DF BM MI MS
Blue-winged Warbler	*Vermivora pinus*	R	R	R	DF
Golden-winged Warbler	*Vermivora chrysoptera*	R	*	R	DF MF
Tennessee Warbler	*Vermivora peregrina*	C	*	C	MF DF
Northern Parula	*Parula americana*	S	C	S	BM DF
Yellow Warbler	*Dendroica petechia*	C	R	A	DF BM MI MF
Chestnut-sided Warbler	*Dendroica pensylvanica*	S	*	S	DF MF
Magnolia Warbler	*Dendroica magnolia*	A	A	A	DF MI MF BM
Yellow-rumped Warbler	*Dendroica coronata*	*	C	S	MS BM DF
Black-throated Green Warbler	*Dendroica virens*	C	A	S	DF MI BM MF
Blackburnian Warbler	*Dendroica fusca*	S	*	*	MF DF

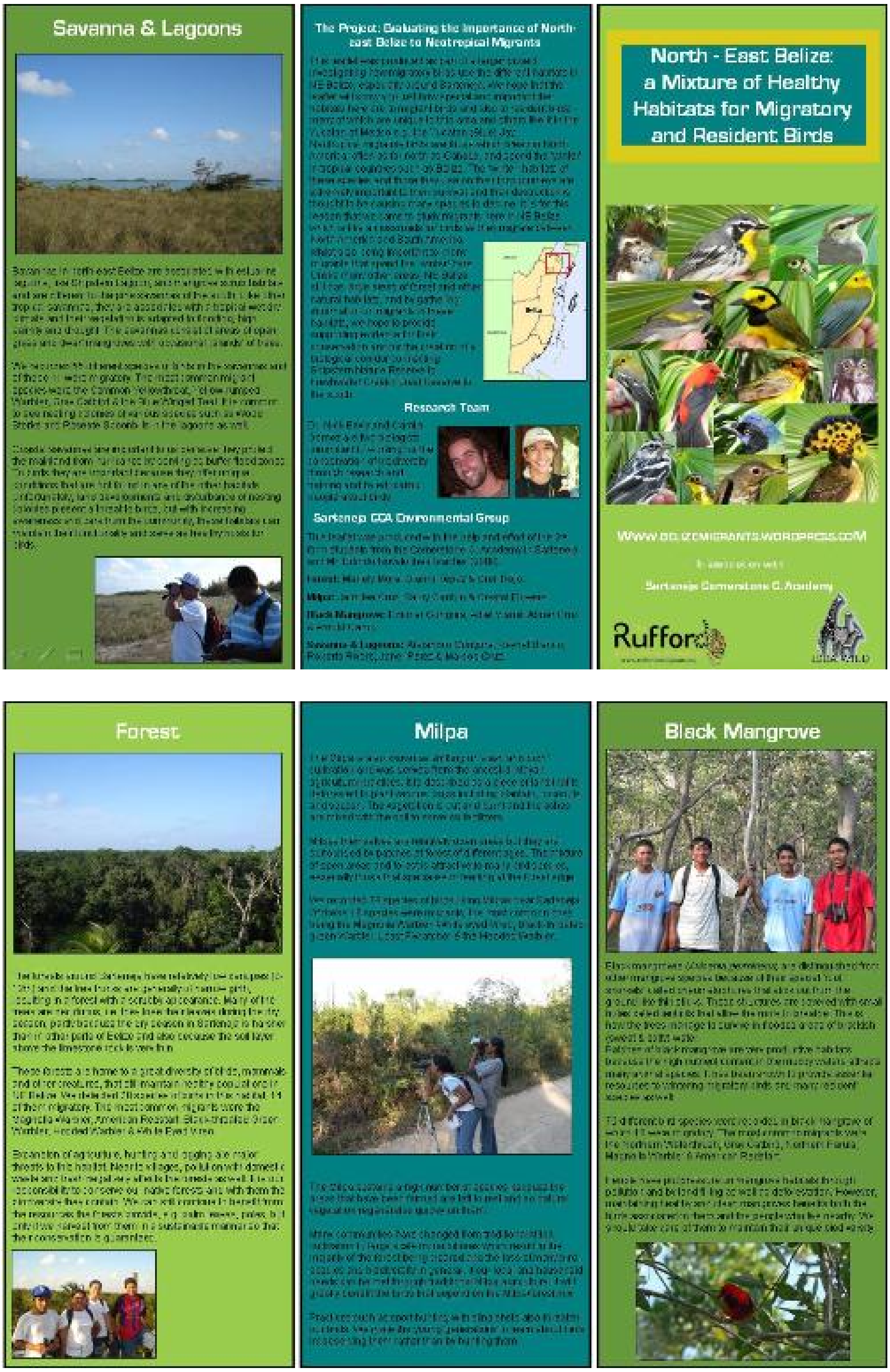
Common Name	Scientific Name	Autumn	Winter	Spring	Habitat
Yellow-throated Warbler	*Dendroica dominica*	R	R	R	TV MI
Prairie Warbler	*Dendroica discolor*	R	*	R	MS DF
Palm Warbler	*Dendroica palmarum*	R	*	*	MS
Bay-breasted Warbler	*Dendroica castanea*	R	*	S	DF MF
Black-and-White Warbler	*Mniotilta varia*	C	C	C	BM MF DF MI
American Redstart	*Setophaga ruticilla*	A	A	C	BM MF DF MI
Prothonotary Warbler	*Protonotaria citrea*	C		S	BM MS MF
Worm-eating Warbler	*Helmitheros vermivorus*	S	S	R	MF DF
Swainson's Warbler	*Limnothlypis swainsonii*	R	R	*	DF MF
Ovenbird	*Seiurus aurocapillus*	C	R	S	MF DF
Northern Waterthrush	*Seiurus noveboracensis*	A	A	A	BM MS MF DF
Louisiana Waterthrush	*Seiurus motacilla*	S	*	*	MF
Kentucky Warbler	*Oporornis formosus*	S	R	R	MF DF
Mourning Warbler	*Oporornis philadelphia*	*	*	R	DF
Common Yellowthroat	*Geothlypis trichas*	C	C	C	MS MI BM
Hooded Warbler	*Wilsonia citrina*	A	A	C	DF MI MF
Canada Warbler	*Wilsonia canadensis*	R	*	*	DF MF
Yellow-breasted Chat	*Icteria virens*	S	R	R	BM MS MI
Summer Tanager	*Piranga rubra*	C	S	S	DF MF MI BM TV
Scarlet Tanager	*Piranga olivacea*	S	*	S	DF MF BM
Clay-colored Sparrow	*Spizella pallida*	R	*	*	MI
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	S	*	R	MI DF MF
Blue Grosbeak	*Passerina caerulea*	*	R	R	MI
Indigo Bunting	*Passerina cyanea*	C	R	C	MI BM DF
Painted Bunting	*Passerina ciris*	*	*	R	DF
Dickcissel	*Spiza americana*	*	*	S	DF OV
Orchard Oriole	*Icterus spurius*	*	R	*	MI
Baltimore Oriole	*Icterus galbula*	R	*	R	MI MS

***** = Absent/unrecorded
R = rare <10 individuals recorded
S = scarce 10-50 individuals recorded
C = common 50-200 individuals recorded (50-150 in winter)
A = abundant 200+ individuals recorded (150+ in winter)

Habitat codes are as follows: **CS** = coast/sea; **LM** = lagoon/mudflats; **MS** = mangrove savannah; **BM** = Black Mangrove forest; **MI** = Milpa/agricultural land; **TV** = Town/village; **DF** = dry forest; **MF** = moist forest; **OV** = migrating/flying over various habitats

APPENDIX 2

Migration leaflet constructed by students from the Cornerstone Academy and presented to the Sarteneja community.



Savanna & Lagoons

The Project: Evaluating the Importance of North-east Belize to Neotropical Migrants

Research Team

Sarteneja ECA Environmental Group

North - East Belize: a Mixture of Healthy Habitats for Migratory and Resident Birds

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Sarteneja Cornerstone C. Academy

Forest

Milpa

Black Mangrove

APPENDIX 3

List of individuals who received bird banding training either during the spring sessions or during the full training course held at the University of Belize, Belmopan.

Name	Organization/Institution
Melissa Castillo	University of Belize
Eduardo Barrientos	University of Belize
Angel Young	University of Belize
Jamani Balderamos	University of Belize
Kamal Munoz	University of Belize
Hope Amadi	University of Belize
Celishia Guy	University of Belize
Rudolph Williams	University of Belize
Gail McNab	University of Belize
Elma Kay	University of Belize
Marvin Vasquez	University of Belize
Emerson Garcia	University of Belize
David Bustamante	St Mathews Village
Stephen Mitten	St John's College
Antonio Hagar	St John's College
Kareena Mahung	St John's College
Liberato Pop	Harpy Project at BFREE
William Garcia	Harpy Project at BFREE
Pedro Che H	Harpy Project at BFREE
Wilfred Mutrie	Harpy Project at BFREE
Joel Diaz	Shipstern Nature Reserve Wardens
Miguel Perez	Shipstern Nature Reserve Wardens
Damian Aldana	Shipstern Nature Reserve Wardens
Dolores	Shipstern Nature Reserve Wardens
Kent Garcia	Belize Audubon Society Park Wardens
Dereck Hendy	Belize Audubon Society Park Wardens
Israel Manzanero	Belize Audubon Society Park Wardens
Marcelo Pau	Belize Audubon Society Park Wardens

APPENDIX 4

BUDGET & EXPENSES REPORT

Summary of expenses according to budget items

Budget Item	Funds approved by Rufford	Spent	Left over
Equipment	£530	£561.75	-£32.25
Living Costs	£3,748	£3,701.27	£46.93
Environmental Education and training	£600	£579.81	£20.19
TOTAL	**£4,878**	**£4,842.83**	**£34.87**

Detailed Expenses Report

Equipment		Date	Cost (BZ $)	Cost (GBP) = 3.95BZ	Not spent
From Rufford Various £100	Chord	31/07/2007	7.5	£1.90	
	File	31/07/2007	2.25	£0.57	
	Machetes x 2 (13.75)	31/07/2007	27.5	£6.96	
	Weighing Cup	31/07/2007	1	£0.25	
	Rubbers x 2	16/08/2007	1	£0.25	
	Tyre Inflator	16/08/2007	9.75	£2.47	
	Flagging tape	16/08/2007	5.25	£1.33	
	Karabiner x 8 ($1 each)	06/08/2007	8	£2.03	
	Umbrella (2 x $3.75)	06/08/2007	7.5	£1.90	
	Batteries for balance	16/08/2007	4	£1.01	
	Rulers (2*0.5)	06/08/2007	1	£0.25	
	Clipboards (2*4.5)	06/08/2007	9	£2.28	
	Off insect repellent	02/09/2007	15.25	£3.86	
	Inner tube for bike	04/09/2007	5	£1.27	
	Photocopying data forms	19/09/2007	14	£3.54	
	Off insect repellent	26/09/2007	12.3	£3.11	
	Camila mangrove shoes	25/10/2007	35	£8.86	
	Nick Mangrove shoes	20/12/2007	50	£12.66	
	String	11/03/2008	7.5	£1.90	
	Clothes clips	17/03/2008	3.5	£0.89	
	Off insect repellent	24/03/2008	14.35	£3.63	
	Gas tank bunkhouse	14/04/2008	30	£7.59	
	Batteries for balance & net	06/05/2008	30	£7.59	
	speakers Duck tape	12/05/2008	3.5	£0.89	
	SWEET centre use x 2 months	07/06/2008	50	£12.66	
	Printing of Final report	10/11/2008	150	£37.97	
	Shipping report to Belize Forestry	15/11/2008	100	£25.32	
			604.15	£152.95	-£52.95
From Rufford Rings £337	6650 Rings of Sizes A to H	01/09/2007		£312.60	
Note: paid for in pounds					
			1171.05	£312.60	£23.90

From Rufford Bikes £93	Nick Bike	02/07/2007	190	£48.10	
	Camila Bike & Pump	31/07/2007	190	£48.10	
			380	£96.20	-£3.20
Total available from Equipment					**-£32.25**

Living Costs		**Date**	**Cost (BZ $)**	**Cost (GBP) = 3.95BZ**	**Not spent**
From Rufford Research permit £65	Travel to Belmopan	26/07/2007	60	£15.19	
	Research Permit	26/07/2007	200	£50.63	
					-£0.82
From Rufford Visa costs + Entrance Visa £245	Camila Belize Visa	21/05/2007	200	£50.63	
	FedEx Camila Passport	21/05/2007	100	£25.32	
	Nick Visa	02/07/2007	50	£12.66	
	Travel to Belmopan	06/08/2007	150	£37.97	
	Travel to Belmopan	15/11/2007	150	£37.97	
	Camila multiple entry visa	15/11/2007	200	£50.63	
					£29.81
From Transport to Transect Sites + Use of vehicle £405	Trip to Balam Jungle	29/08/2007	150	£37.97	
	Trip to Balam Jungle (1 day)	07/10/2007	150	£37.97	
	Trip to Balam Jungle (1 day)	02/11/2007	150	£37.97	
	Transport to field course UB	06/01/2008	60	£15.19	
	Trip to Balam Jungle (2 day)	01/03/2008	200	£50.63	
	Transport to La Isla - Trainees	16/03/2008	10	£2.53	
	Transport trainees BFREE	18/04/2008	50	£12.66	
	Transport to Shipstern	27/04/2008	10	£2.53	
	Transport trainees Audubon	28/04/2008	30	£7.59	
	Transport to field course UB	23/05/2008	60	£15.19	
	Moving to Belmopan	26/05/2008	400	£101.27	
			1270	321.52	£83.48
From satellite internet access (£20 month) & fuel for electricity (£20 month) £480	12 months electricity		960	£243.04	
	12 months internet		960	£243.04	
			1920	486.08	-£6.08
From Food at Wildtracks (2 researchers x £106/month x 12 months) £2,553	12 months food		10,320	£2,612.66	
			10320	£2,612.66	-£59.47
Total available from Living Costs					**£46.93**

Environmental Education and Training		**Date**	**Cost (BZ $)**	**Cost (GBP) = 3.95BZ**	**Not spent**
From Stippend for Belizean trainees £400	Trainees food first day	16/03/2008	19.8	£5.01	
	E. Barrientos (5 days + transport) M.	17/03/2008	130	£32.91	
	Castillo (5 days + transport) David	17/03/2008	130	£32.91	
	Bustamante (5 days)	24/03/2008	100	£25.32	

	Elma Kay (3 days)	28/03/2008	30	£7.59	
	Emerson Garcia (3 days)	31/03/2008	60	£15.19	
	BFREE (4 trainees x 5 days)	13/04/2008	400	£101.27	
	Emerson Garcia (1 day)	27/04/2008	20	£5.06	
	Audubon (4 trainees x 4 days +$10 each for arrival day)	28/04/2008	360	£91.14	
	Monitor banding workshop	05/09/2008	250	£70.22	
					£13.37
From Education materials & school visits £50	Poster for PIF conference	10/02/2008	40	£10.13	
	Printing Cartridge for forms, lists etc	08/04/2008	100	£25.32	
	Transport school visit to ringing site	06/05/2008	20	£5.06	
	Internet research day (leaflet project)	15/05/2008	16	£4.05	
	TV notice of leaflet presentation	05/06/2008	10	£2.53	
	Refreshments for leaflet presentation	06/06/2008	10	£2.53	
					£0.38
From Training Materials £50	Pyle Guide	08/08/2007		£29.19	
	CD bird songs	06/06/2008	1.75	£0.44	
					£20.37
From Illustrated Leaflets £100	Printing of Leaflets	03/06/2008	450	£113.92	
					-£13.92
Total available from Environmental Education & Training					£20.19