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# TABLE OF CONTENTS

## ABSTRACT

Research within the mid-Atlantic region have shown that the majority of neotropical migrants utilizing the outer coastal plain as a migration route are young of the year, and that many are not replenishing fat reserves during times of stop-over. Research has also shown that foraging rates are higher in deciduous habitats than in pine habitats. The general composition of the forests of the mid-Atlantic coastal plain shift from pine dominated on the outer coastal plain to hardwood dominated along the fall line of the inner coastal plain. Studies were initiated to determine if these hardwood dominated habitats are better stop-over habitats than the pine dominated forests of the coastal fringe, and to determine differences in age ratios, condition, foraging rates, and energy gains of selected species of neotropical migrants using these habitats. Study sites were established within the outer and inner coastal plain to assess the availability of prey items, perform foraging observations, and capture birds for evaluation of age and condition.

Habitats on the inner coastal plain seem to be superior to the pine habitats of the outer coastal plain. While sites on the outer coastal plain produced more arthropods over all, sites on the inner coastal plain had greater numbers of arthropods associated with foliage, where migrants were observed foraging most often. Greater percentages of after hatch year birds were captured on the inner coastal plain, and although new birds captured on the outer coastal plain initially carried more fat and had higher masses, recapture data show that during stop-over birds tended to gain mass on the inner coastal plain and lose mass on the outer coastal plain. Black-throated blue Warblers on the inner coastal plain were the only birds analyzed that were ingesting sufficient numbers of prey items to meet their daily metabolic needs and produce fat. The results suggest that the hardwood dominated forest of the inner coastal plain contain superior stop-over habitats for neotropical migrants than the pine dominated forests of the outer coastal plain.

## BACKGROUND

### Context

More than one half of all North American land birds migrate from breeding areas in temperate latitudes to winter areas in Mexico, Central America, the Caribbean, and South America (Keast 1980). Such long-distance movements may be very energetically demanding (Berthold 1975, Blem 1980). The vast majority of nearctic-neotropical migratory birds are physically incapable of carrying enough energy to complete non-stop flights between breeding and winter areas (Nisbet et al. 1963, Berthold 1975, Dawson et al. 1983, Pettersson and Hasselquist 1985). To overcome this problem, migrants make periodic stops en route to replenish energy reserves. Once in stopover areas, migrants encounter unfamiliar landscapes and uncertain conditions. Individuals that are able to successfully negotiate these conditions presumably increase their probability of successfully completing migration. Since successful migration is a prerequisite for future breeding, choices about stopover areas, as well as, decisions made within stopover areas have profound fitness consequences for migrants.

One of the most important characteristics of stopover areas is the quality of available habitats. In order for migrants to successfully complete migration, individuals must locate geographic areas that provide a net energy gain. These so-called “energy sources” allow birds to accumulate the energy needed to make advances toward breeding areas. Migrants should avoid geographic areas where they can not break even energetically. These so-called “energy sinks” have a negative impact on migrant condition and may delay migration. For many species breeding in north temperate latitudes, the timing of arrival on the breeding grounds has a direct influence on reproductive performance (Gauthreaux 1982). Individuals that arrive early are able to claim the highest quality breeding territories (von Haartman 1968, Slagsvold 1976), attract mates more readily (Francis and Cooke 1986), and often produce more offspring (Eliason 1986).

Relatively little information is currently available on the distribution of areas wheremigrating land birds accumulate the energy needed to fuel migration. Equally little informtion is available on how migrants extract needed energy from stopover habitats. Such information is important both to the achievement of a broader understanding of the energetic underpinnings of migration and to the conservation of stopover habitats.

Recent research within the mid-Atlantic on geographic and landscape-scale patterns, patterns of habitat use, stop-over duration, foraging ecology, etc. have shown that, for many species, the vast majority of the birds migrating down the outer coastal plain are young of the year (Watts and Mabey 1992,1993, Watts and Wilson 1998). These studies also suggest that migrants within these coastal fringe habitats do not seem to be replenishing fat reserves. Recent research (Watts and Wilson 1998) has also shown that foraging rates for selected migrant species are three times higher in deciduous forests compared to pine forests. This finding in conjunction with the fact that forests of the inner coastal plain are hardwood-dominated and those of the outer coastal plain are pine-dominated suggests that these geographic areas may differ in their potential as refueling sites for migrants. Evaluating this possibility is essential to the formulation of long-term conservation strategies for migrant land birds.

**Objectives**

The objective of this research project is to address several interrelated questions that have direct implications to habitat management decisions within coastal Virginia. These questions include:

1) Does the age ratio of migrants differ between inner and outer coastal areas?

2) Do foraging rates attained by migrants differ between inner and outer coastal areas?

4) Are migrants maintaining positive energy budgets within inner and outer coastal areas?

5) Do prey densities differ between inner and outer coastal areas?

## METHODS

### Study Sites

Field work was conducted on both Quantico Marine Base within the inner coastal plain and on the Lower Delmarva Peninsula within the outer coastal plain (Fig. 1). Six 4-hectare grids, each divided into 100 20 m x 20 m quadrants were established at both sites to facilitate collection of behavioral data, arthropod abundance data, and vegetative density data. Every corner of each quadrant was identified with a wire survey flag labeled with a unique alphanumeric code (Fig. 2).

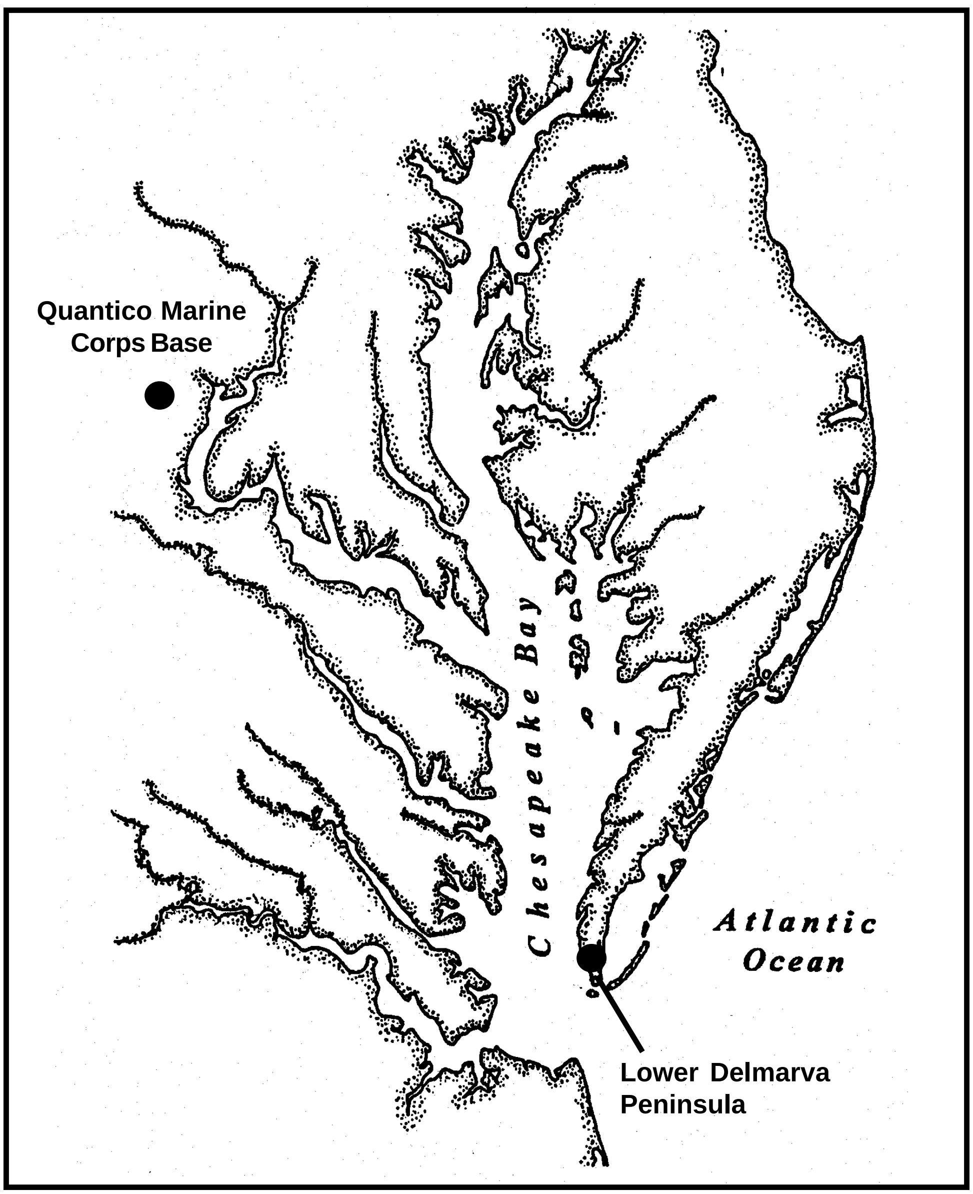
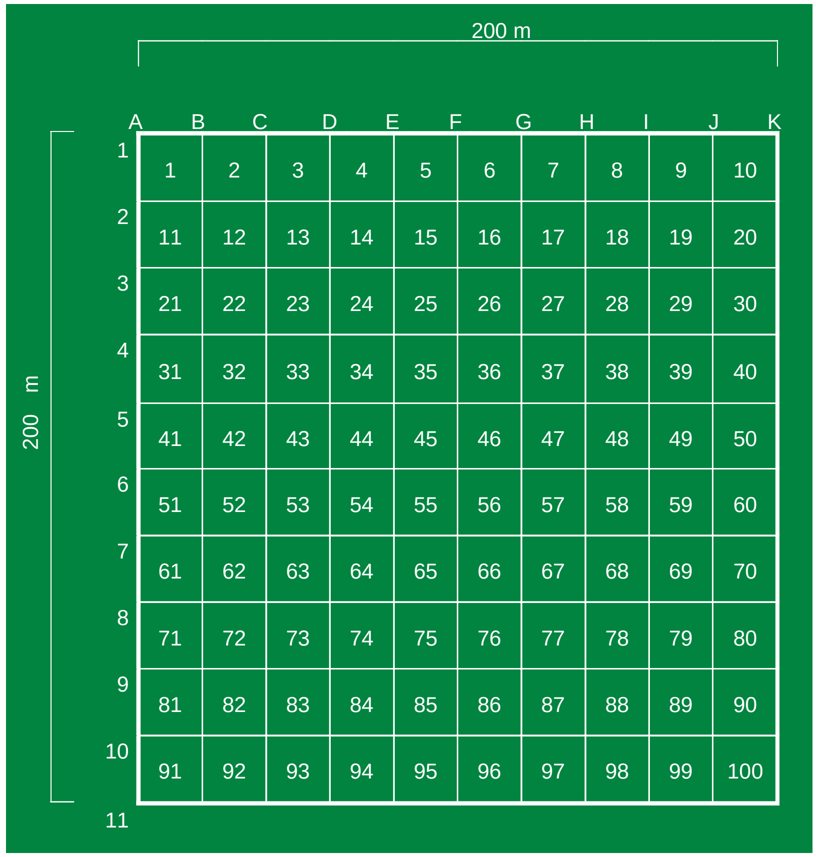



**Figure 1**: Map of the Chesapeake Bay region showing the general location of Quantico Marine Base and the Lower Delarva Peninsula of Virginia.

**Figure 2**: General layout of survey grids.




Survey grids within the Quantico Marine Base were selected, based on habitat type and infrequent use for marine training (Fig. 3). The landscape within the base is dominated by forested habitats with patches of open land created for training and building complexes, and early successional land created by timber harvesting for wildlife habitat, training areas, and forest management. All of the 6 grids were placed in forested habitats consisting of mixed hardwoods and pines. Dominant hardwood species included oaks (*Quercus* spp.), hickories (*Carya* spp.), American beech (*Fagus grandifolia*), tulip poplar (*Liriodendron tulipifera*), and maples (*Acer* spp). Understory vegetation was dominated by sapling of the aforementioned species, especially beech and maple, as well as American holly (*Ilex opaca*) and dogwood (*Cornus florida*). Ground cover was typically absent with the forest floor generally covered by a layer of leaf litter of varying thickness, although patches of grass and *Lycopodium* spp. were present in some areas.

Survey grids on the Lower Delmarva Peninsula were established within Kiptopeke State Park and the Eastern Shore of Virginia National Wildlife Refuge (Fig. 4). These areas were chosen because they provide some of the last large tracts of forested habitat remaining on the Lower Delmarva Peninsula, and for ease of access. The landscape of Northhampton county, the southern most county on the Delmarva peninsula, consists of about 39% marsh/wetland, 35% crop land, 20% forest and 5% urban/industrial (North Hampton Co. Planning and Zoning Dept 1989). The percentage of land used for

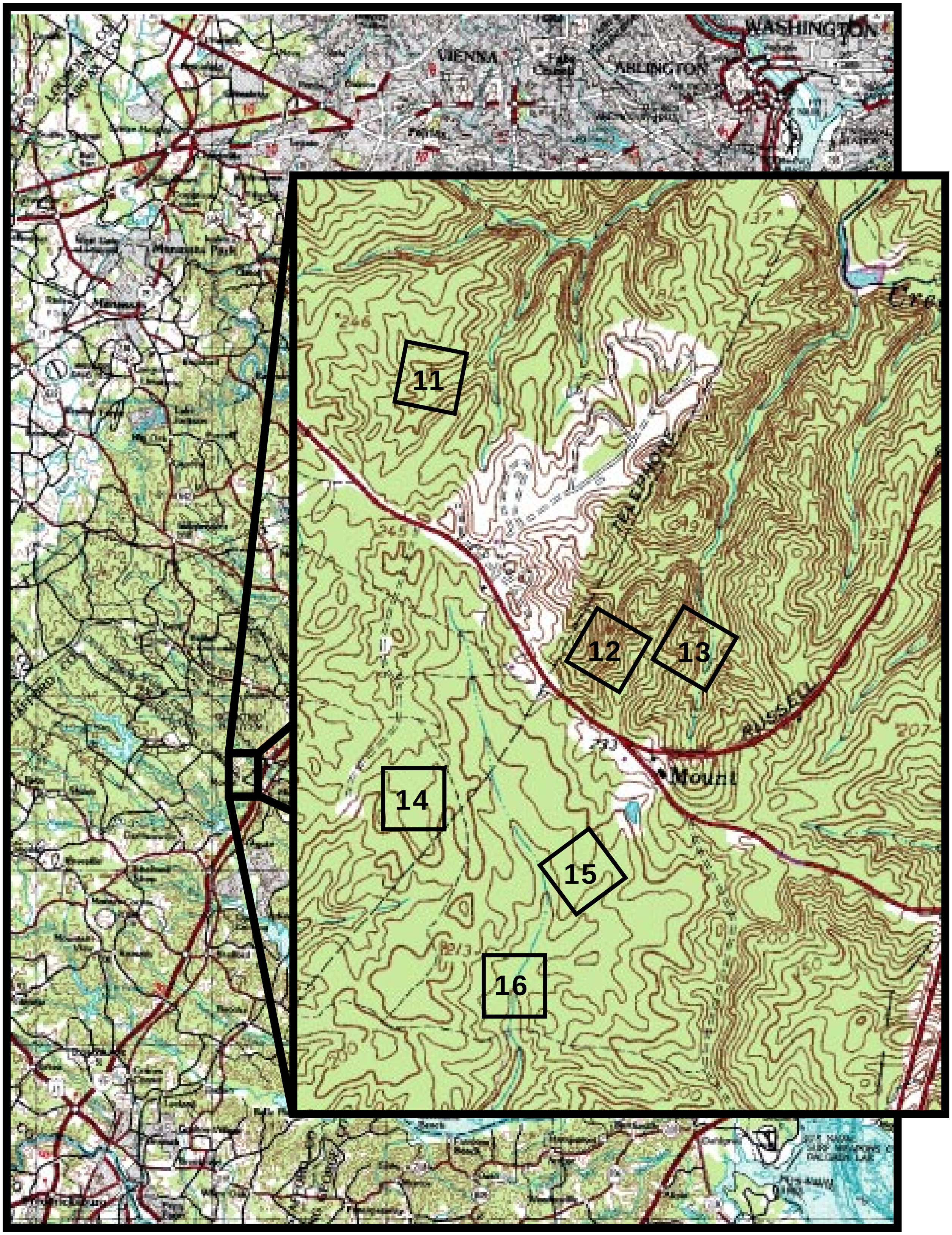



**Figure 3**:  Locations of study plots on Quantico Marine Base.

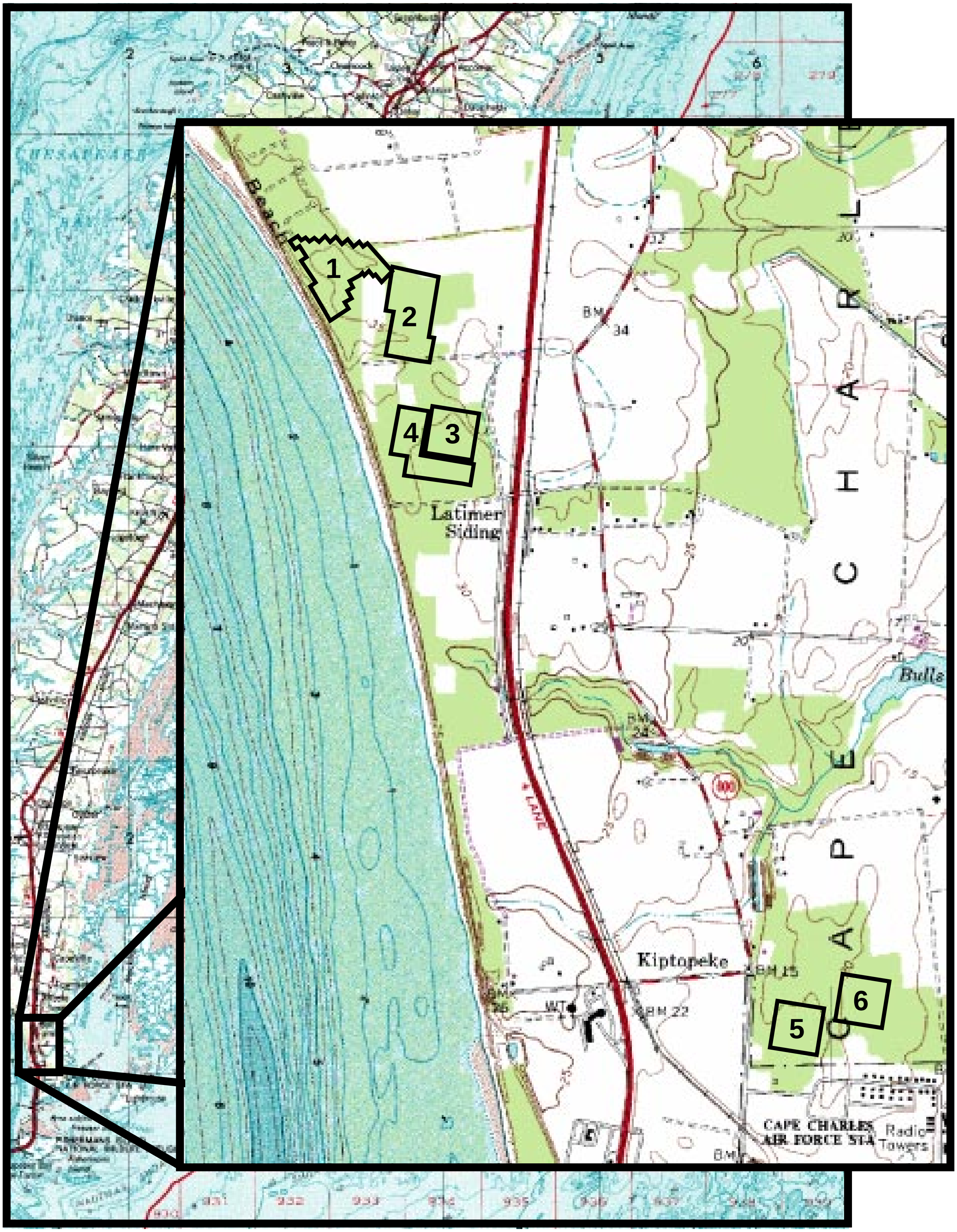



**Figure 4**: Locations of study plots on the Lower Delmarva Peninsula of Virginia.

agriculture does not seem to be increasing due to the fact that the majority of the best soils are already in cultivation, while the amount of remaining forested land is slowly decreasing as it is transferred to “alternate uses”, mainly home sites.

Survey grids were placed in patches of forest consisting of mixed hardwoods and pines. Hardwood species consisted of oaks (Quercus spp) and hickories (Carya spp), while coniferous species consisted of Loblolly pine (Pinus taeda) and Virginia pine (Pinus virginiana). Understory vegetation was dominated by American Holly (Ilex opaca), Dogwood (Cornus florida), greenbrier (Smilax spp.) and saplings of oak and hickory. Ground cover was typically absent with the forest floor generally covered by a layer of leaf litter of varying thickness, although patches of grasses and Poison Ivy (Rhus radicans) were present in some areas.

**Banding Operations**

Banding operations were conducted at Quantico Marine Base and Kiptopeke State Park from 23 August to 20 October 2000. The banding station at Quantico consisted of 35 mist nets, nets used measured 12 m long, 2 m high and were constructed of 30 mm back nylon mesh. Nineteen nets were positioned within an upland forest habitat composed of mature oaks, hickories, maples, and tulip poplars with a moderately dense understory of saplings and American holly. Nine nets were placed within a regenerating clear-cut composed of maples and pines approximately 4 m tall and 10 years of age interspersed with patches Rubus, grasses, and forbs. The remaining 7 nets were positioned on the edge of the regenerating clear-cut and upland forest.

The banding operations at Kiptopeke utilized the existing banding station. Eighteen nets of the same dimensions and construction as those use at the Quantico station were erected in 3 habitat types. Five nets were positioned in a maritime forest habitat with an understory of Wax myrtle (Myrica cerifera), 9 nets were placed in young pine/mixed forest near the edge where the forested habitat abutted a large agricultural field, and 4 nets were placed around a constructed brush pile on the edge of the agricultural field.

Daily banding operations were conducted similarly at both sites. Nets were opened near dawn and operated until approximately 1400 h at both sites. Banding operations at Quantico were conducted a minimum of 3 days per week, utilizing all 35 nets each day of operation. Banding was conducted at the Kiptopeke station daily, weather permitting, with 4 to 17 nets being used depending upon weather and bird movement. No banding operations were conducted on days with steady rain or sustained heavy winds.

Upon capture birds were removed from mist nets and placed in either; bags constructed of nylon mesh fabric or cloth, or wooden holding boxes, and transported to a temporary banding station for processing. Individuals were identified to species, placed in sex and age classes according to recognized criteria (Pyle), and banded with an appropriately sized, serially numbered United States Fish and Wildlife Service aluminum leg band. Unflattened wing chord was measured to the nearest 1 mm using a wing ruler, and mass was measured to the nearest 0.1 g using a digital balance. A visual inspection of deposited fat (Table 1) and degree of skull pneumaticization (Table 2) were made and recorded as an ordinal value. The number of the net and the time of release were recorded for all banded birds. All birds were processed and released as quickly as possible.

**Table 1**. Descriptions of fat deposition used to place birds into fat classes.

| Class | Description |
|---|---|
| 0 | No visible subcutaneous fat within interclavicular fossa. |
| 1 | Traces of subcutaneous fat in the interior corners of the interclavicular fossa. |
| 2 | Continuous sheet of subcutaneous fat across the floor of the interclavicular fossa. |
| 3 | Continuous layer of subcutaneous fat filling at least 1/3 of the interclavicular fossa. |
| 4 | Interclavicular fossa filled with subcutaneous fat and level with surface of pectoralis muscles. |
| 5 | Subcutaneous fat filling interclavicular fossa to bulging beyond pectoralis muscles, subcutaneous fat deposited on flanks and abdomen. |

**Table 2**. Descriptions of skull pneumaticization used to place birds into skull classes.

| Class | Description |
|---|---|
| 0 | Limited pneumaticization at base of cranium and along mid-line. |
| 1 | Pneumaticization along mid-line of cranium and extending up from the base and covering approximately 1/3 of skull. |
| 2 | Pneumaticization extending up from base a considerable degree and covering approximately 2/3 of skull. |
| 3 | Pneumaticization complete. |

### Behavioral Observations

Behavioral observations were used to collect data for describing the foraging ecology of selected migrant species during stopover. Data collected was used to quantify time budgets, movement rates and foraging parameters. Observers walked slowly through study grids until an individual bird of a target species was encountered. Target species included: Black-throated blue warblers, Black and white warblers, Ovenbirds and Redstarts. These species were chosen because they are common fall migrants along Atlantic coastal plain, they forage in the forest understory (making them easy to observe), and and they utilize different foraging tactics. If no individuals of the target list were encountered observations were made on any neotropical migrant found. In the event that no birds suitable for observation were found on the study grids, searches were made in the immediate vicinity just off the established grids. Birds chosen for observation were identified to species and sexed by plumage if possible. The study grid and quadrant observations were made in were noted and the bird was followed for a period of 0.5 to 10.0 min. Efforts were made to continue observations with minimum disturbance for 10.0 min or until the target bird could no longer be followed.

Observations were made 5 days per week between 0.5 and 5 hours after sunrise, 1 day per week between 1200 and 1400 h, and 1 day per week between 1500 and 1700 h. All observations were made in real time and recorded on micro-cassette recorders. Recorded observations were transcribed to data sheets using stopwatches to quantify the length of behavioral activities. Behavioral activity categories used are:

Foraging – Birds are considered to be foraging if they are actively searching through substrates or pursuing prey.

Chasing – Birds are considered to be chasing if they are aggressively pursuing other birds.

Preening – Birds are preening if they are conducting plumage maintenance.

Inactive – Birds are inactive if they are simply perched and not engaged in other activities.

If observed birds were classified as foraging additional observational data was collected including; foraging tactics, taxa of prey items taken, size of prey items, foraging substrates, foraging strata, and movement rates. Each foraging bout was classified as one of the following foraging tactics:

Gleaning – A maneuver in which a standing or hopping bird takes a stationary prey item from a substrate surface. Gleaned prey are typically spotted nearby (<0.3 m) and the attack does not involve a flight component.

Hovering – This maneuver includes all attacks in which a prey item is picked from a substrate surface while the bird is in flight.

Flush-chase – This maneuver involves the chasing of prey flushed by the bird, usually in a long downward flight. The bird is essentially following a prey that it has flushed from a substrate.

Hawking – In this maneuver, flying prey are pursued and captured by birds in flight. The prey is already in flight when detected. The bird detects the flying prey from a perch or while flying and pursues.

Probing – This maneuver involves the insertion of the bill into blind areas to root out prey. Blind areas may be under leaves on the ground, into deep bark crevices, under flaking bark, into curled leaves, etc.

Whenever possible, prey items taken by the bird under observation were identified and placed in to one of the following taxonomic categories:

Larval Lepidoptera – Caterpillars.

Adult Lepidoptera – Butterflies and moths.

Larval Coleoptera – Grubs.

Adult Coleaptera – Beetles.

Arachnida – Spiders.

Adult Diptera – Flies, Mosquitoes, Gnats.

Adult Hemiptera – True bugs, stink bugs, etc.

Adult Homoptera – Leaf hoppers, etc.

Unidentified – Arthropod that was observed but could not be identified.

Other – Arthropod that was identified but did not fall into above categories.

Prey size was estimated relative to 0.5 bill length intervals. The majority of neotropical warblers observations were made on had bill lengths of approximately 10 mm in length. In the event that a prey item was obviously taken, bird made a foraging attempt and then exhibited bill movements to indicate that it had been successful, but no prey was observed, prey item was classified as unknown with a size of 2.5 mm.

Substrates upon which prey item were taken from were identified as one of the following:

Live Leaves – Surfaces of leaves that are not dried.

Dead Leaves – Leaves either attached or on the ground that are dead and dried.

Pine Needles – Pine needles and clusters.

Twigs – Small, outer, terminal branches often supporting leaves or other structures.

Outer Branches – Branches < 2 cm in diameter supporting twigs.

Inner Branches – Larger branches > 2 cm in diameter.

Trunk – Main stem of tree supporting limbs (in some trees may be multiple).

None (air) – Applies to flying insects.

Bare Ground – Dirt or bare ground.

Movement information was recorded for every bird under observation. In addition to a visual estimate of the total distance moved, each significant movement was placed into one of these four classes:

Hop – Movement distance < 1 m.

Short Flight – Movement distance 1 – 3 m.

Medium Flight – Movement distance 3 – 5 m.

Long Flight – Movement distance > 5 m.

The strata of the forest observed birds spent the majority of the observation period in was visually estimated to the nearest meter. Or, if an individual bird spent equal time at several different strata levels, an average height above forest floor was estimated.

**Arthropod Abundance**

To quantify the availability of prey to insectivorous migrants, arthropods were sampled weekly within the outer and inner coastal plain. Three different sampling approaches were used to represent different components of the arthropod community. Approaches used were 1) foliage samples, 2) flying arthropod traps, and 3) leaf litter samples. Three samples using each technique were collected weekly within each study grid between 28 August 2000 and 26 October 2000. Random grid coordinates were used to determine the three quadrants to be sampled within each survey grid.

Foliage arthropods were sampled by taking leaf clippings and removing arthropods from the clipped leaves. Leaves were collected from within an individual sample quadrant between 0.5 and 5 h after sunrise. Efforts were made to sample evenly throughout the quadrant, the first 3 1-m strata layers, and available tree/shrub species. Leaves were clipped into 1-gallon zip-lock bags with care taken to avoid escape of any arthropods, until 75 g of leaves were obtained. Mass of leaves was determined using a pesola spring scale zeroed to the weight of the sample bag. Bags were then sealed, labeled and stored in a cooler for transport to a temporary processing station.

Ground arthropods were sampled by collecting leaf litter samples and extracting arthropods from the litter. One leaf litter sample was collected from each of the selected quadrants by placing a 20 x 20 cm wooden square onto the forest floor and running a knife blade around the edge of the wood square to create a 20 x 20 cm leaf litter sample. Without removing the wooden square, leaf litter from around the sample was brushed away and the resulting sample, left underneath the wooded square, was placed into a 1-gallon zip lock bag, being careful to avoid escape of any arthropods. Litter was collected down to bare soil and any large sticks or rocks were removed from samples after inspection for arthropods. Bags were then sealed, labeled and stored in a cooler for transport to a temporary processing station. Litter samples were collected between 0.5 and 5 h after sunrise

Upon reaching the temporary processing facility all litter and foliage samples were placed in a standard kitchen freezer, set at approximately 0 degrees Fahrenheit, for a period of not less than 0.5 hours to slow down arthropod activity. Samples were removed from the freezer one at a time and the contents transferred to a plastic bin, measuring approximately 45 cm long x 30 cm wide x 30 cm deep, for processing. Visual inspections were made to ensure that no arthropods were remaining in or on the sample bag. Foliage samples were then examined by picking out each leaf and inspecting upper and lower surfaces for attached arthropods. Upon the completion of all leaf inspections the plastic bin was examined for arthropods. All arthropods found were identified to broad taxa, sized, tallied and placed into sample vials labeled with the corresponding site and quadrant number for further process in a laboratory. Leaves examined were counted and every tenth leaf of individual samples were placed a sheet newspaper, labeled with the date, site and quadrant number and stored in a plant press for further processing.

Litter samples were examined by removing whole leaves and twigs and inspecting all surfaces for attached arthropods. The remaining leaf pieces and detritus were then thoroughly examined. All arthropods found were identified to broad taxa, sized, tallied and placed into sample vials labeled with the corresponding site and quadrant number for further process in a laboratory.

Flying insects were sampled using a series of insect traps. Traps were constructed by stringing 3, 24-oz drink bottles on nylon monofilament with a distance of 1 m between each bottle. A hook made of stiff wire was attached to the top end of the monofilament to facilitate hanging the trap array from branches. The outside flat surface (244 x 124 mm) of each bottle was coated with a layer of Tree Tanglefoot insect glue, approximately 2 mm thick. One trap array, consisting of 3 bottles, was hung from a branch in each of the selected quadrants. Traps were positioned so that the spacing of the bottles were 1, 2, and 3 m above the forest floor and that traps would not get tangled in adjacent branches or stuck to leave in moderate winds. After a period of not less than 110 min traps were inspected. Size classes, taxa and numbers of all captured arthropods and the time of deployment and retrieval were recorded and the traps were cleared of all arthropods and wrapped in cellophane. Before each deployment the coating of Tanglefoot was inspected and reapplied as needed. Flying arthropod traps were set between 0.5 and 5 h after sunrise and retrieved between 1300 and 1600 h.

**Data Analysis**

Banding data were summarized only for days in which both Quantico and Kiptopeke were in operation. Comparisons between sites included station effort (number of nets x number of hours of operation = net h) species richness, bird abundance (standardized to number of birds captured per 100 net hours), age ratios, mass difference, and fat class differences. Standard t-tests were used to compare mass differences with site being the independent variable. To examine temporal patterns capture rates birds were categorized as residents, temporal migrants, or neotropical migrants. Residents are species that are considered to have stable, year round populations in the study areas. Temperate migrants are species that breed in the northern United States and Canada and fly relatively short distances to winter in the mid and lower latitudes of the United States. Neotropical migrants are species that breed in North America and winter in Mexico, Central America, the Caribbean, and South America. Rates of capture were compared for three time periods including early (23 August-9 September), middle (10 September-30 September), and late (1 October-20 October).

Arthropod abundance data were summarized by week and site to generate total arthropod abundance, species abundance and size class abundance. For flying arthropods abundance a rate of capture was calculated by dividing the total number of captured individuals by the amount of time the trap was deployed and standardizing the rate to number or arthropods captured per hour. Abundance was compared using standard t-tests with site as the independent variable.

Foraging observations for species that had sufficient numbers of observations at both sites (Black-throated Blue Warbler, Black-and-white Warbler, and Ovenbird) were analyzed using site as the independent variable. Due to differences in observation length all dependent variables (prey intake, position changes, and distance moved) were converted to rates, and compared using standard t-tests.

Published relationship values were use to convert prey intake to energy gain or loss. First, the dry weight (biomass) of captured prey items was calculated using observed body lengths and correlation equations published in Sample et al. 1993. This equation, $\log(y)=b+a\log(x)$, where y=biomass and x=body length, was used, with corresponding taxa values for a and b, to calculate biomass for each prey item taken. Biomasses for each observation were then summed, divided by the observation length in seconds, and multiplied by 3,600 to produce a rate of g/h and extrapolated to g/day by multiplying by 12 h, the average day length during the study period. G/day was converted into units of metabolizable energy using the estimate that 18.0 kj of metabolizable energy are contained in each gram dry weight of insects (Nagy, 1987). These calculations assume that observed species were foraging at a constant rate throughout the day.

A field metabolic rate (FMR) for each species was calculated using average body mass of banded birds and the equation, $\log(y)=0.949+0.749\log(x)$ (Nagy, 1987), to estimate the daily energetic requirements for each species. Differences in the FMR and estimated daily energy intake were calculated for each observation and species were compared using t-tests with site as the independent variable.

## RESULTS

### Bird Banding

Throughout the 2000 fall season, banding operations at Kiptopeke were operated for a total of 1,875 net hours and at Quantico for a total of 6,291.3 net hours. These efforts resulted in 2,020 birds of 66 species, or 107.7 birds/100 net hours at Kiptopeke (Appendix 1) and 492 birds of 66 species, or 7.8 birds/100 net hours at Quantico (Appendix 2). At both banding stations neotropical migrants were the most diverse class of migrant followed by temperate migrants and resident birds. However, differences were seen between the two stations in terms of abundance. At Quantico most (60.2%) captured birds were neotropical migrants, while at Kiptopeke the percentage of neotropical migrants was 46.9%. The majority (51.9%) of birds captured at Kiptopeke were temperate migrants with residents making up the remaining 1.2%. At Quantico temperate migrants and residents accounted for 30.3% and 9.5% respectively (Table 3).

**Table 3**. Numbers and percentages of species within each migrant class captured at Quantico Marine Base and Kiptopeke State Park.

| | Kiptopeke Banding Station | | | | Quantico Banding Station | | | |
|---|---|---|---|---|---|---|---|---|
| | Neotropical Migrants | Temperate Migrants | Residents | Total | Neotropical Migrants | Temperate Migrants | Residents | Total |
| **Number of Individuals** | 947 | 1049 | 24 | 2020 | 296 | 149 | 47 | 492 |
| **Percentage of Total** | 46.9 | 51.9 | 1.2 | 100 | 60.2 | 30.3 | 9.5 | 100 |
| **Species Richness** | 46 | 17 | 3 | 66 | 40 | 17 | 9 | 66 |
| **Percentage of Species** | 69.7 | 25.8 | 4.5 | 100 | 60.6 | 25.8 | 13.6 | 100 |

Within individual migration classes, and for the entire species list, species were not equally abundant at both Quantico and Kiptopeke. At Kiptopeke 62.6% of neotropical migrants captured consisted of 4 species (American Redstart, Gray Catbird, Common Yellowthroat, and Black-throated Blue Warbler). The overwhelming majority (81.9%) of temperate migrants were Myrtle Warblers. And, of the 3 species of resident birds captured, Northern Cardinals made up 50% of the total (Figure 5). Of the 296 neotropical migrants captured at Quantico, 52.7% were accounted for by 5 species (Ovenbird, Black-throated Blue Warbler, Magnolia Warbler, Swainson's Thrush, and Wood Thrush). Temperate migrants were dominated by Ruby-crowned Kinglets, Hermit Thrushes, Golden-crowned

Kinglets, Yellow Palm Warblers, and Blue Jays, which represented 67.8% of the total. Eastern Tufted Titmice, Carolina Wrens, Northern Cardinals and Carolina Chickadees were the most common resident birds, accounting for 85.1% of residents captured (Figure 6).

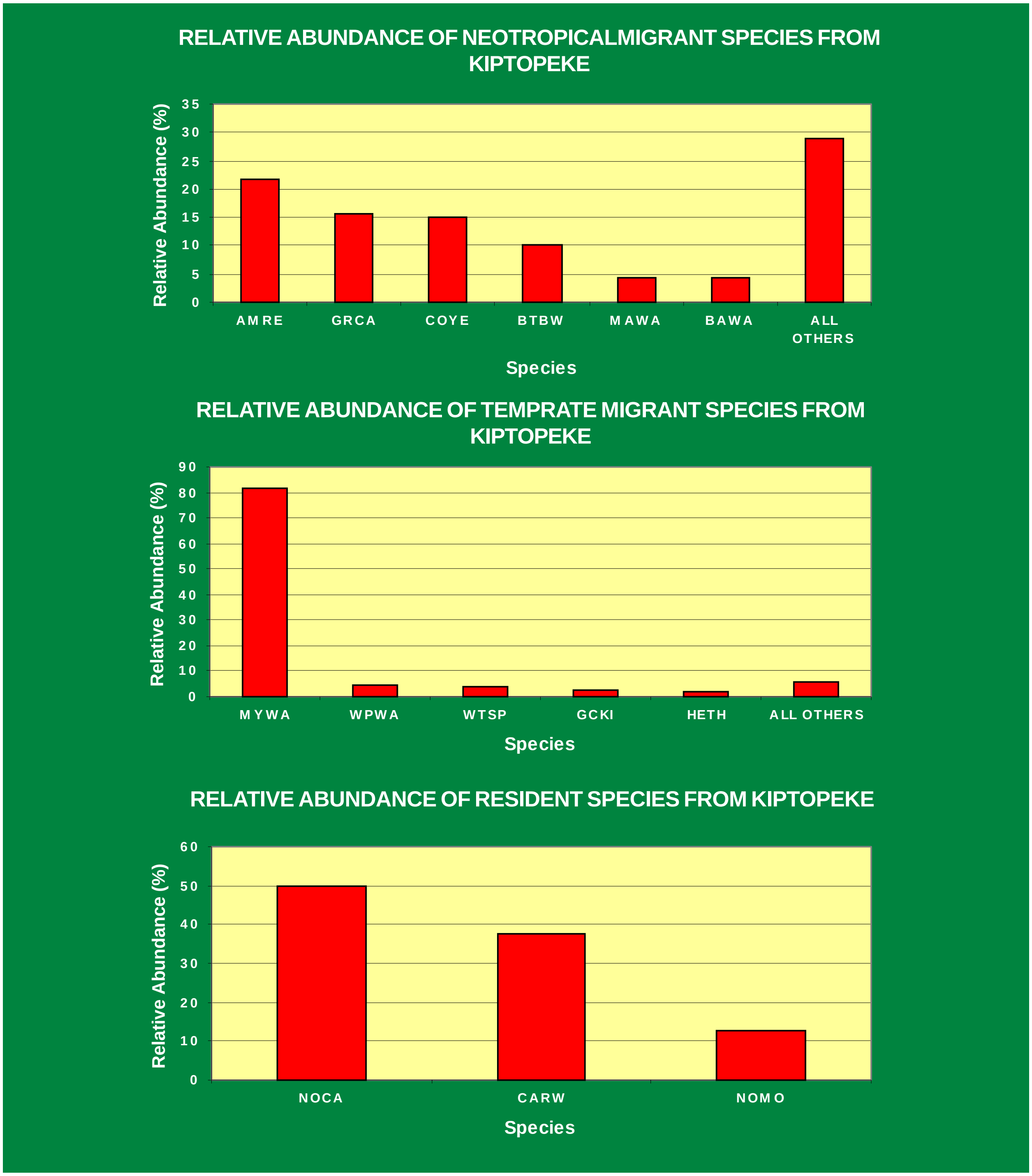



**Figure 5**. Relative abundance of species in the three migration classes captured at Kiptopeke.

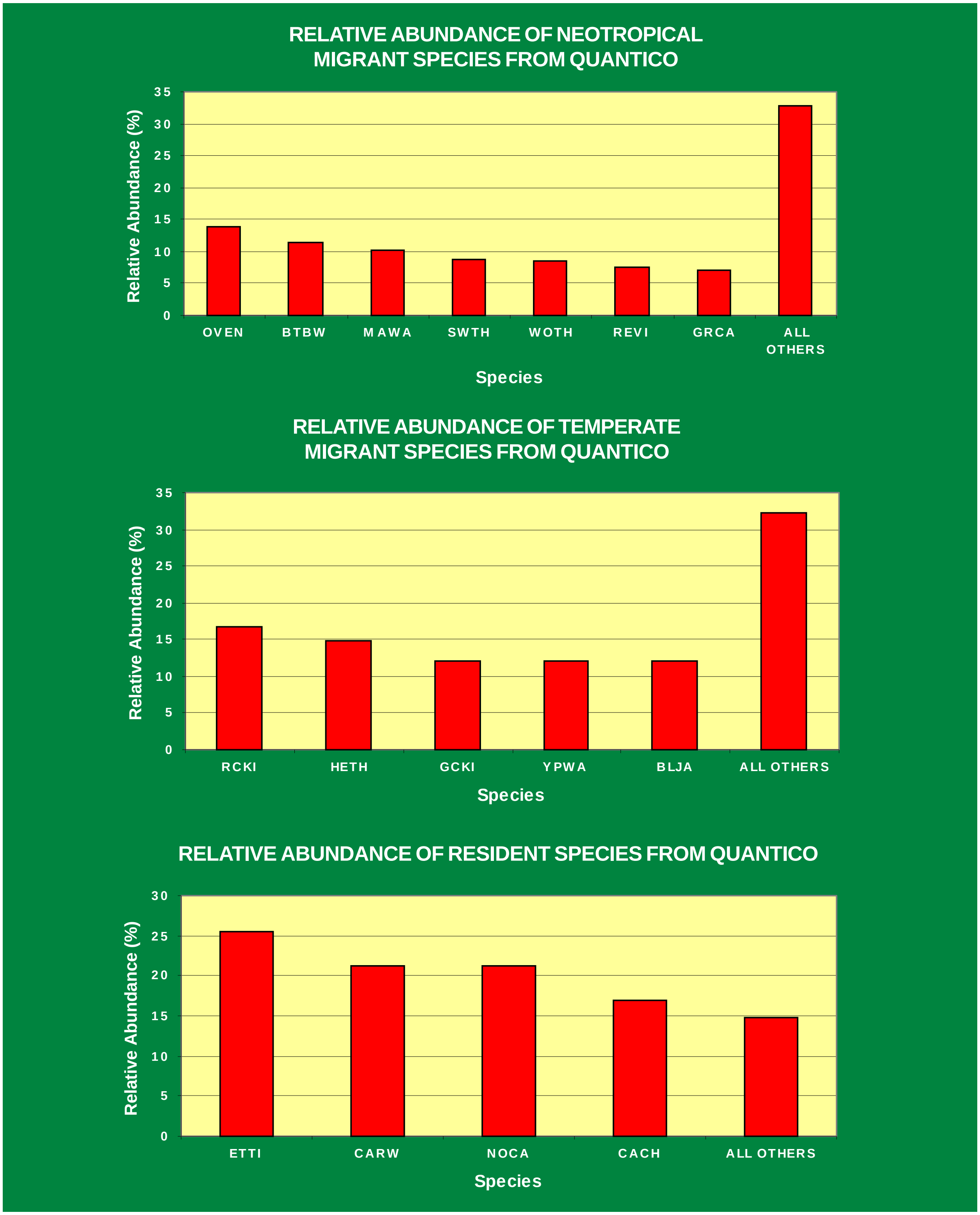



**Figure 6**. Relative abundance of species in the three migration classes captured at Quantico.

Temporal patterns for both migrant groups varied at both banding stations. If the dates on which banding operations were conducted are subdivided into early (August 23 – 9 September), middle (10 September - 30 September), and late (1 October – 20 October) periods, both sites show similar seasonal patterns of capture frequency within the different migrant classes. Observed patterns suggest that most neotropical migrants moved through the study areas in the middle of the banding period, while the majority of temperate migrants seemed to move through during the late period (Figures 7 and 8).

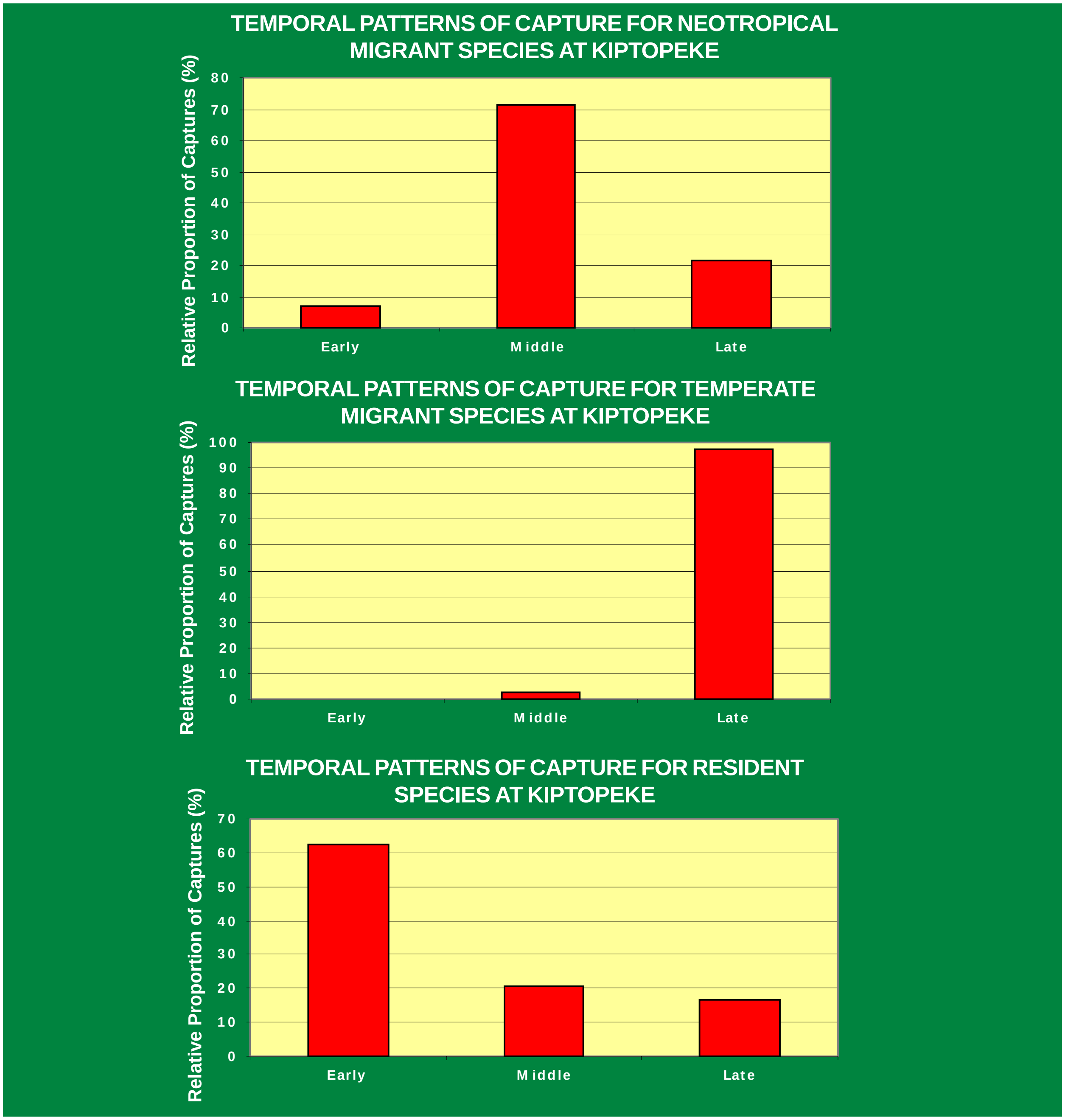



**Figure 7**. Temporal patterns of capture for the 3 migration classes at Kiptopeke.

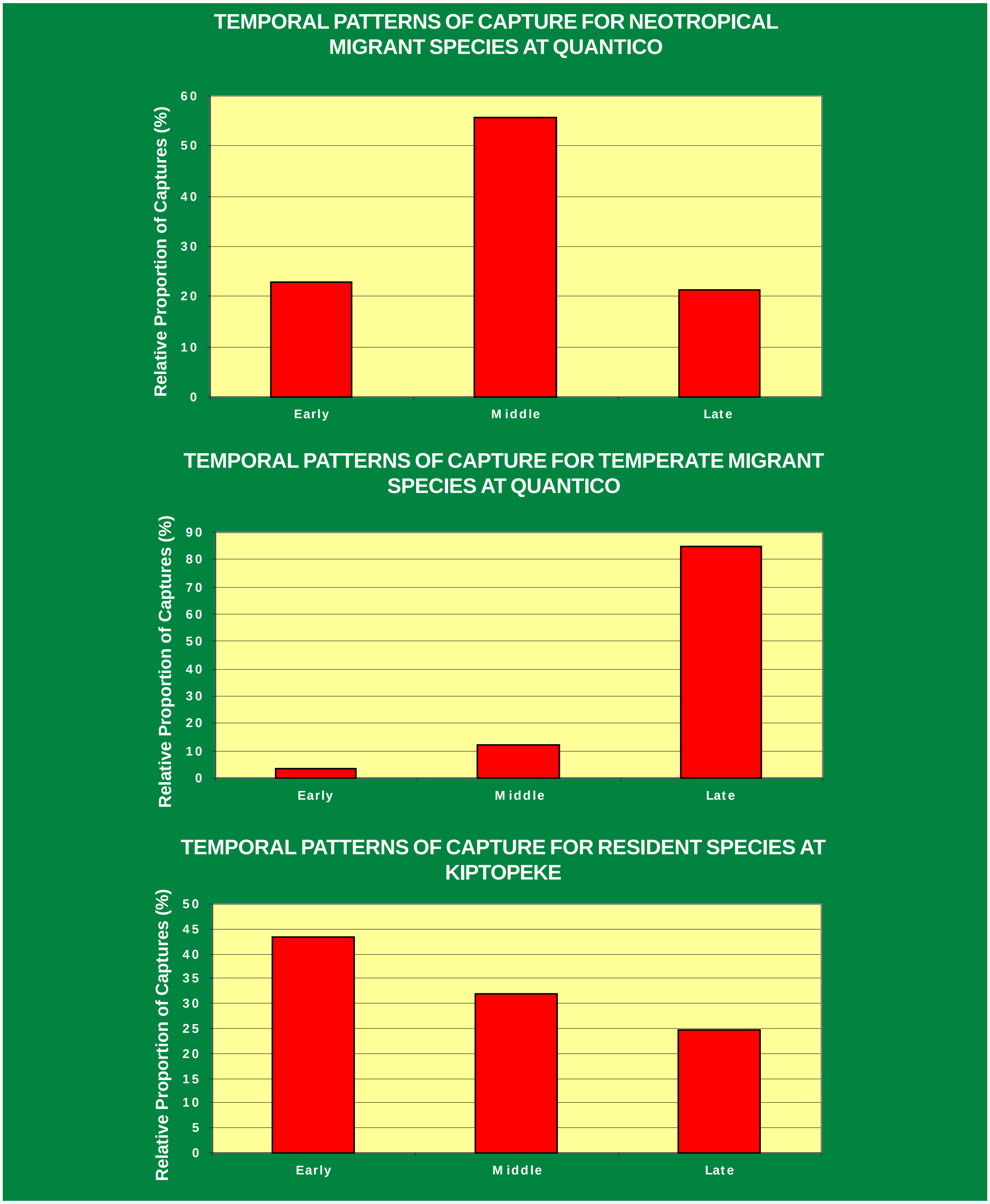



**Figure 8**. Temporal patterns of capture for the 3 migration classes at Quantico.

A greater proportion of after-hatch-year (AHY) migrants were captured at Quantico than at Kiptopeke. This trend was observed with all migrant species and migrant groups compared (Table 4). Mean body masses for selected AHY insectivorous neotropical migrants were consistently higher than those of hatch year (HY) migrants for all species compared (except Red-eyed Vireos at Kiptopeke, where only one AHY individual was captured) (Table 5). Significant differences were observed between AHY an HY Black-throated Blue Warblers at Quantico with mean body masses of 10.6 g ± 1.56 SD and 9.7 g ± 0.83 SD respectively (t-test: t=2.10, $P < 0.05$, n=15, 19), and Ovenbirds at Quantico with AHY birds having a mean body mass of 20.3 g ± 2.17 SD and HY birds having a significantly lower mean body mass of 18.9 g ± 1.12 SD (t-test: t=2.61, $P < 0.05$, n=23, 18).

Due to the low sample size of AHY birds from Kiptopeke, comparisons of body condition between sites were restricted to HY birds. Overall, selected species of insectivorous neotropical migrants captured at Kiptopeke tended to carry more fat than those captured at Quantico (Table 6 and 7). Of the HY birds at Kiptopeke, 33.3% were carrying a fat class of 3 or higher compared to 12.9% of the individuals at Quantico (Table 8). Mean masses for all species compared were found to greater at Kiptopeke, though none of these differences were found to be significant (Table 9).

Stopover duration for recaptured birds during the entire banding period ranged from 1 to 19 days for the 26 recaptures at Quantico and form 1 to 32 days for 45 recaptures at Kiptopeke. Mean stopover durations were significantly higher at Quantico with insectivorous neotropical migrants staying an average of 6.3 days ± 4.31 SD, compared to only 3.2 days ± 4.77 SD for recaptures at Kiptopeke (t-test: t=2.74, $P < 0.05$, n=26, 45). Changes in body mass during these periods of stopover differed between the two sites. Insectivorous neotropical migrants at Quantico gained a mean of 1.6% ± 7.24 SD of their respective body mass while birds of the same migrant class at Kiptopeke lost a mean of 0.2% ± 5.90 SD of their body mass. When only days when both station were in operation were considered, the mean stopover durations increased slightly at both stations, increasing to 6.4 days ± 4.44 SD at Quantico and 4.6 days ± 6.08 SD at Kiptopeke. The range of duration did not change at Quantico although the number of recapture decreased to 24. At Kiptopeke the number of recaptures decreased to 13 and the range of stop over duration fell to 1 to 24 days. The trend in body mass change remained positive for Quantico, rising to 2.5% ± 8.41 SD, and negative for Kiptopeke, decreasing to -1.4% ± 5.92 SD.

**Arthropod Abundance**

Arthropod sampling at Quantico and on the Lower Delmarva Peninsula produced a total of 9,635 individual arthropods. Quantico accounted for 3,113 or 32.3% of the total while the Lower Delmarva Peninsula accounted for 6,522 or 67.7%. A high number of flying arthropods resulted in such a large percentage of the total coming from the Lower Delmarva Peninsula plots.

**Table 4**. Comparison of numbers and percentages of AHY and HY birds from Quantico Marine Base and Kiptopeke State Park.

| | | Quantico | | Kiptopeke | |
|---|---|---|---|---|---|
| Species | | AHY | HY | AHY | HY |
| **Neotropical Migrants** | | | | | |
| Red-eyed Vireo | # | 4 | 18 | 1 | 25 |
| | % | 18.2 | 81.8 | 3.8 | 96.2 |
| Black-throated Blue Warbler | # | 15 | 19 | 6 | 90 |
| | % | 44.1 | 55.9 | 6.3 | 93.8 |
| Magnolia Warbler | # | 14 | 16 | 6 | 34 |
| | % | 46.7 | 53.3 | 15.0 | 85.0 |
| Ovenbird | # | 23 | 18 | 3 | 19 |
| | % | 56.1 | 43.9 | 13.6 | 86.4 |
| Gray Catbird | # | 4 | 17 | 4 | 145 |
| | % | 19.0 | 81.0 | 2.7 | 97.3 |
| Swainson's Thrush | # | 17 | 9 | 4 | 25 |
| | % | 65.4 | 34.6 | 13.8 | 86.2 |
| Total | # | 77 | 97 | 24 | 338 |
| | % | 44.3 | 55.7 | 6.6 | 93.4 |
| **Temperate Migrants** | | | | | |
| Golden-crowned Kinglet | # | 6 | 12 | 0 | 23 |
| | % | 33.3 | 66.7 | - | 100.0 |
| Hermit Thrush | # | 13 | 9 | 3 | 20 |
| | % | 59.1 | 40.9 | 9.1 | 90.9 |
| White-throated Sparrow | # | 5 | 5 | 12 | 27 |
| | % | 50.0 | 50.0 | 30.8 | 69.2 |
| Total | # | 24 | 26 | 15 | 70 |
| | % | 48.0 | 52.0 | 17.6 | 82.4 |
| **Species Groups** | | | | | |
| Thrushes | # | 30 | 34 | 6 | 47 |
| | % | 46.9 | 53.1 | 11.3 | 88.7 |
| Vireos | # | 5 | 27 | 5 | 34 |
| | % | 15.6 | 84.4 | 12.8 | 87.2 |
| Warblers | # | 69 | 89 | 75 | 557 |
| | % | 43.7 | 56.3 | 11.9 | 88.1 |

**Table 5**. Comparison of mean body masses (± SD) of AHY and HY insectivorous neotropical migrants captured at Quantico Marine Base and Kiptopeke State Park.

| | Quantico | | Kiptopeke | |
|---|---|---|---|---|
| Species | AHY | HY | AHY | HY |
| Red-eyed Vireo | 18.5 g ± 1.69 | 18.0 g ± 1.91 | 16.7 g ± 0.00 | 18.4 g ± 1.76 |
| Ovenbird | 20.3 g ± 2.17 | 18.9 g ± 1.12 | 21.0 g ± 2.63 | 19.9 g ± 2.52 |
| Black-throated Blue Warbler | 10.6 g ± 1.56 | 9.7 g ± 0.83 | 10.1 g ± 1.28 | 9.9 g ± 1.29 |
| Magnolia Warbler | 8.6 g ± 0.51 | 8.2 g ± 0.56 | 8.8 g ± 0.91 | 8.6 g ± 1.28 |

Flying arthropod traps at both sites resulted in 4,848 individual arthropods. The Lower Delmarva Peninsula accounted for 4,240 (87.5%) while Quantico accounted for only 608 (12.5%). Weekly totals for each site ranged from 121 to 983 on the Lower Delmarva Peninsula and from 64 to 140 at Quantico. The trend of greater numbers of flying arthropods on the Lower Delmarva Peninsula was the same when arthropod numbers were converted to rates based on length of time traps were deployed. Weekly flying arthropod catch rates for the Lower Delmarva Peninsula ranged from 1.3 arthropods/h ± 0.67 SD to 7.8 arthropods/h ± 7.96 SD, while the ranges of rates at Quantico were 0.5 arthropods/h ± 0.21 SD to 1.5 arthropods/h ± 0.85 SD. A sharper rate of decline in the rate of capture throughout the season was observed on the Lower Delmarva Peninsula than at Quantico (Figure 9). A higher proportion of larger arthropods were captured at Quantico than on the Lower Delmarva Peninsula. Arthropods in the size classes of less than 2.5 mm and 2.5 - 5.0 mm accounted for 69.9% and 23.5%, respectively, for all flying arthropods measured. On the Lower Delmarva Peninsula the percentage was skewed toward the smaller size class with 91.4% being less than 2.5 mm and 6.9% measuring 2.5 - 5.0 mm in length (Figure 10). Insects of the order Diptera, Coleoptera, and Hymenoptera, as well as Arachnids were the most abundant arthropods at both sites making up 98.5% of the total on the Lower Delmarva Peninsula and 94.2% at Quantico. At both sites insects of the order Diptera were by far the most abundant accounting for 92.1% of the total at Kiptopeke and 74.8% at Quantico (Figure 11).

Sampling for arthropods on foliage resulted in 3,694 individuals captured. Quantico accounted for 2,071 or 56.1% of the total while the Lower Delmarva Peninsula accounted for the remaining 1,623 or 43.9%. Weekly totals for Quantico ranged from 145 to 310 captured arthropods while the weekly totals for the Lower Delmarva Peninsula ranged from 125 to 278. Throughout the season a decline was observed in arthropods captured on the Lower Delmarva Peninsula, while increases were observed in the numbers of arthropods at Quantico (Figure 12). Proportions of size classes were similar at both sites with arthropods measuring 10 mm or less accounting for 89.9% of all arthropods measured on the Lower Delmarva Peninsula and 91.9% at Quantico (Figure 13). Arachnids were the most abundant arthropod found within foliage samples at both sites, making up 67.3% and

**Table 6**. Numbers and percentages of selected insectivorous neotropical migrants from Kiptopeke exhibiting the different fat classes. See Table 1 for criteria used for placing birds into individual fat classes.

| Species | | Fat Classes 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Red-eyed Vireo | HY # | 3 | 3 | 6 | 10 | 3 | 0 |
| | HY % | 12.0 | 12.0 | 24.0 | 40.0 | 12.0 | - |
| | AHY # | 1 | 0 | 0 | 0 | 0 | 0 |
| | AHY % | 100.0 | - | - | - | - | - |
| Black-throated Blue Warbler | HY # | 18 | 23 | 24 | 10 | 8 | 7 |
| | HY % | 20.0 | 25.6 | 26.7 | 11.1 | 8.9 | 7.8 |
| | AHY # | 1 | 2 | 2 | 0 | 1 | 0 |
| | AHY % | 16.7 | 33.3 | 33.3 | - | 16.7 | - |
| Magnolia Warbler | HY # | 3 | 7 | 14 | 7 | 1 | 2 |
| | HY % | 8.8 | 20.6 | 41.2 | 20.6 | 2.9 | 5.9 |
| | AHY # | 1 | 0 | 2 | 1 | 2 | 0 |
| | AHY % | 16.7 | - | 33.3 | 16.7 | 33.3 | - |
| Ovenbird | HY # | 3 | 3 | 5 | 4 | 2 | 2 |
| | HY % | 15.8 | 15.8 | 26.3 | 21.1 | 10.5 | 10.5 |
| | AHY # | 0 | 0 | 1 | 0 | 2 | 0 |
| | AHY % | - | - | 33.3 | - | 66.7 | - |

**Table 7**. Numbers and percentages of selected insectivorous neotropical migrants from Quantico exhibiting the different fat classes. See Table 1 for criteria used for placing birds into individual fat classes.

| Species | | Fat Classes 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Red-eyed Vireo | HY # | 2 | 3 | 7 | 4 | 0 | 2 |
| | HY % | 11.1 | 16.7 | 38.9 | 22.2 | - | 11.1 |
| | AHY # | 0 | 1 | 1 | 2 | 0 | 0 |
| | AHY % | - | 25.0 | 25.0 | 50.0 | - | - |
| Black-throated Blue Warbler | HY # | 2 | 11 | 5 | 1 | 0 | 0 |
| | HY % | 10.5 | 57.9 | 26.3 | 5.3 | - | - |
| | AHY # | 1 | 1 | 5 | 2 | 3 | 3 |
| | AHY % | 6.7 | 6.7 | 26.3 | 13.3 | 20.0 | 20.0 |
| Magnolia Warbler | HY # | 1 | 10 | 5 | 0 | 0 | 0 |
| | HY % | 6.3 | 62.5 | 31.3 | - | - | - |
| | AHY # | 0 | 7 | 4 | 2 | 1 | 0 |
| | AHY % | - | 50.0 | 28.6 | 14.3 | 7.1 | - |
| Ovenbird | HY # | 7 | 6 | 3 | 2 | 0 | 0 |
| | HY % | 38.9 | 33.3 | 16.7 | 11.1 | - | - |
| | AHY # | 6 | 4 | 5 | 3 | 3 | 2 |
| | AHY % | 26.1 | 17.4 | 21.7 | 13.0 | 13.0 | 8.7 |

**Table 8**. Comparison of numbers and percentages of selected HY species exhibiting fat classes of 0-2 and 3-5 from Quantico Marine Base and Kiptopeke State Park. See Table 1 for criteria used for placing bird into individual fat classes

| | | Quantico | | Kiptopeke | |
|---|---|---|---|---|---|
| **Species** | | **Fat Class 0-2** | **Fat Class 3-5** | **Fat Class 0-2** | **Fat Class 3-5** |
| Red-eyed Vireo | # | 12 | 6 | 12 | 13 |
| | % | 66.7 | 33.3 | 48.0 | 52.0 |
| Ovenbird | # | 15 | 2 | 11 | 8 |
| | % | 83.2 | 11.8 | 57.9 | 42.1 |
| Black-throated Blue Warbler | # | 18 | 1 | 65 | 25 |
| | % | 94.7 | 5.3 | 72.2 | 27.8 |
| Magnolia Warbler | # | 16 | 0 | 24 | 10 |
| | % | 100 | - | 70.6 | 29.4 |
| Total | # | 61 | 9 | 112 | 56 |
| | % | 87.1 | 12.9 | 66.7 | 33.3 |

**Table 9**. Comparison of mean body masses (± SD) of selected HY insectivorous neotropical migrants captured at Quantico Marine Base and Kiptopeke State Park.

| Species | Quantico | Kiptopeke |
|---|---|---|
| Red-eyed Vireo | 18.0 g ± 1.91 | 18.4 g ± 1.76 |
| Ovenbird | 18.9 g ± 1.12 | 19.9 g ± 2.52 |
| Black-throated Blue Warbler | 9.7 g ± 0.83 | 9.9 g ± 1.29 |
| Magnolia Warbler | 8.2 g ± 0.56 | 8.6 g ± 1.28 |

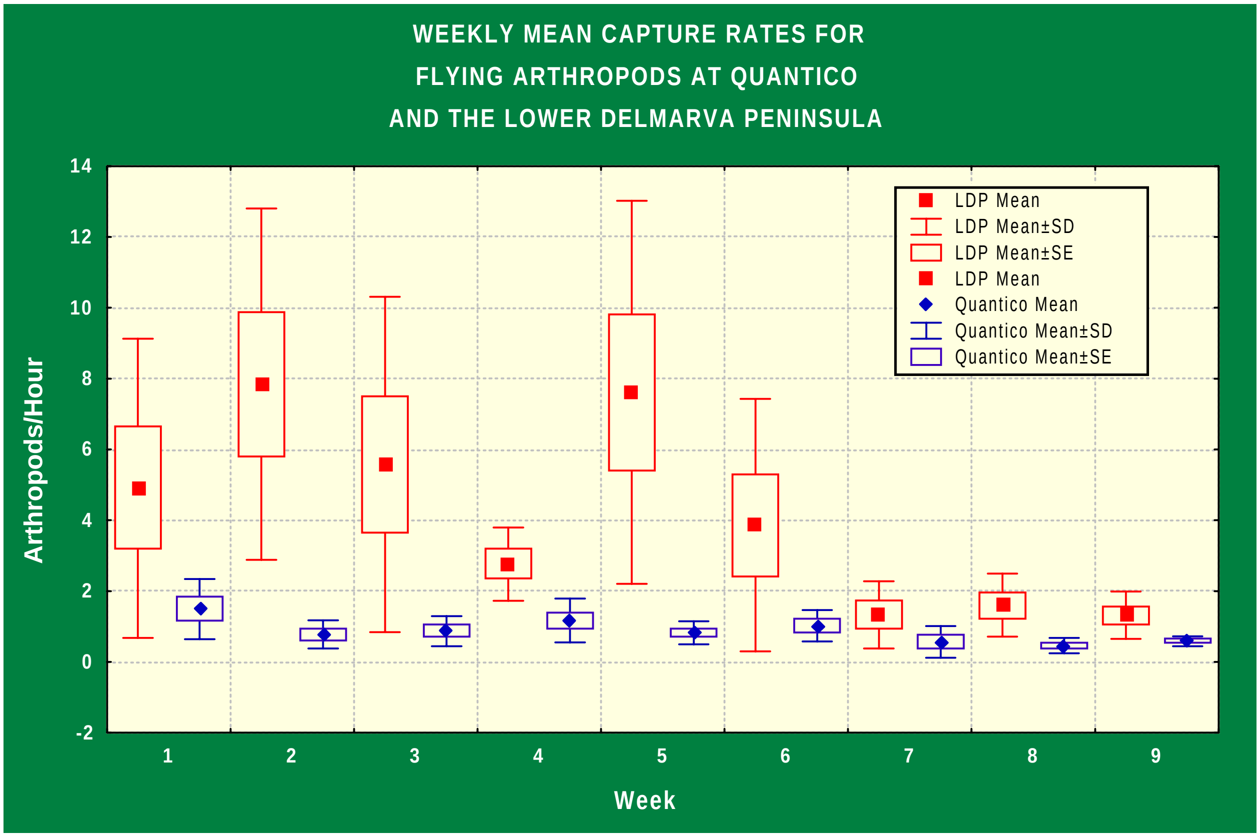



**Figure 9**. Weekly capture rates for flying arthropods at Quantico and the Lower Delmarva Peninsula.

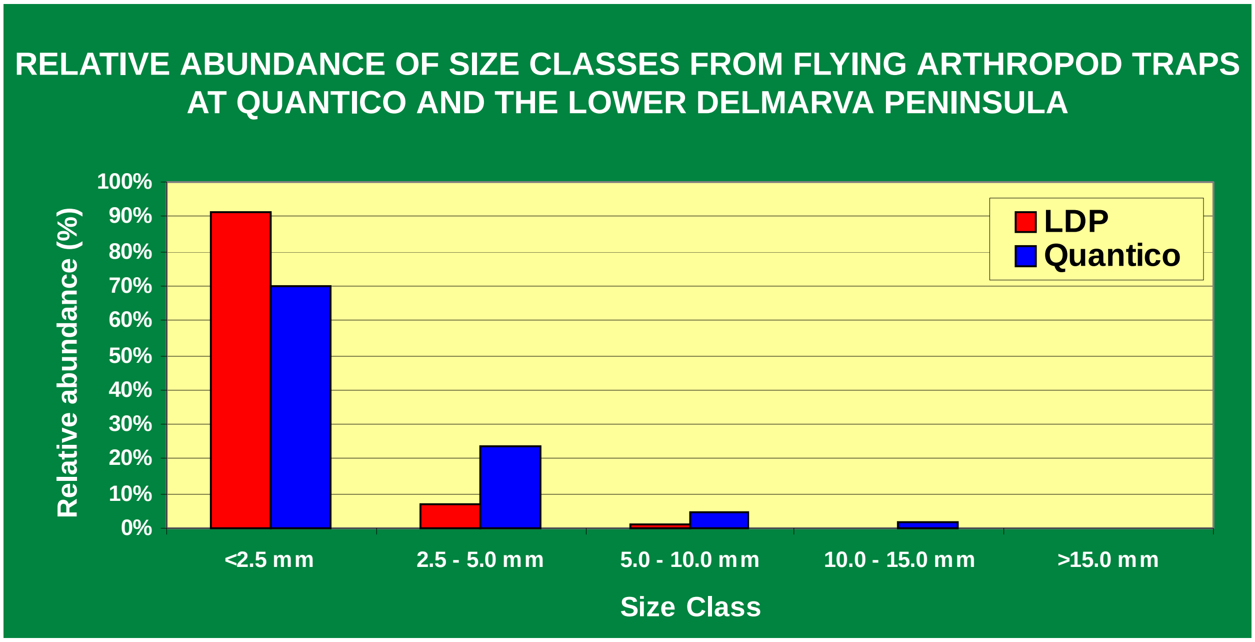



**Figure 10**. Relative abundance of flying arthropod size classes at Quantico and the Lower Delmarva Peninsula.

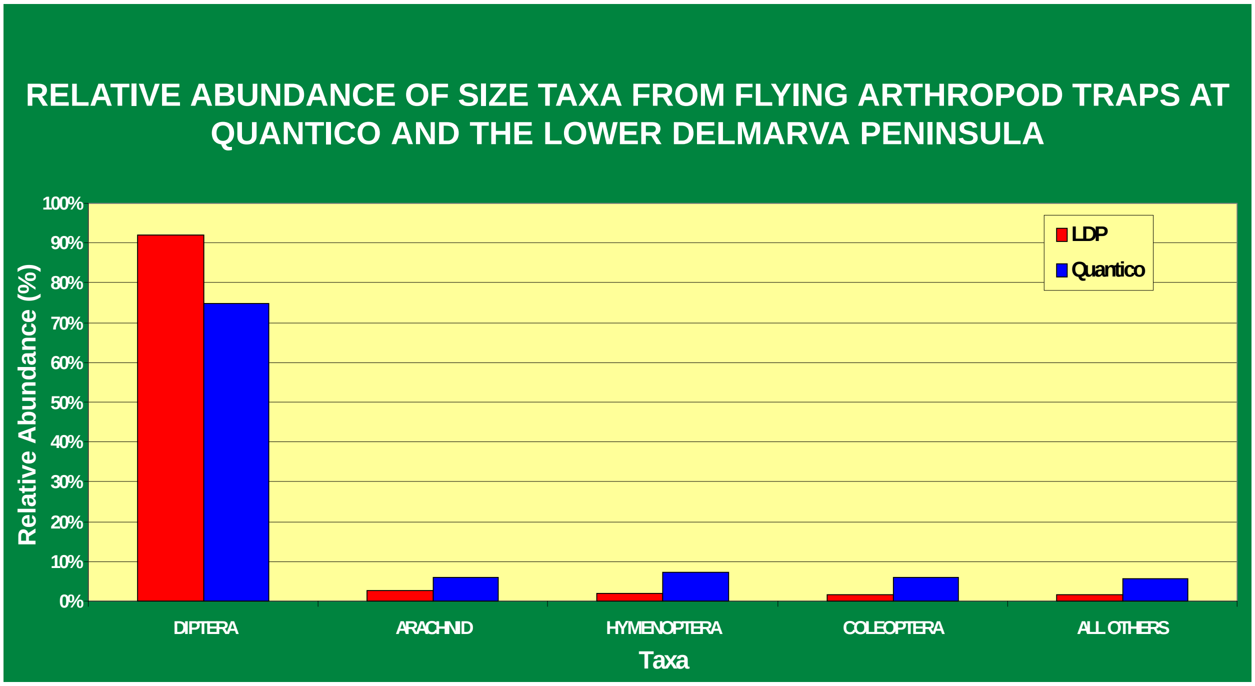



**Figure 11**. Relative abundance of flying arthropod taxa at Quantico and the Lower Delmarva Peninsula.

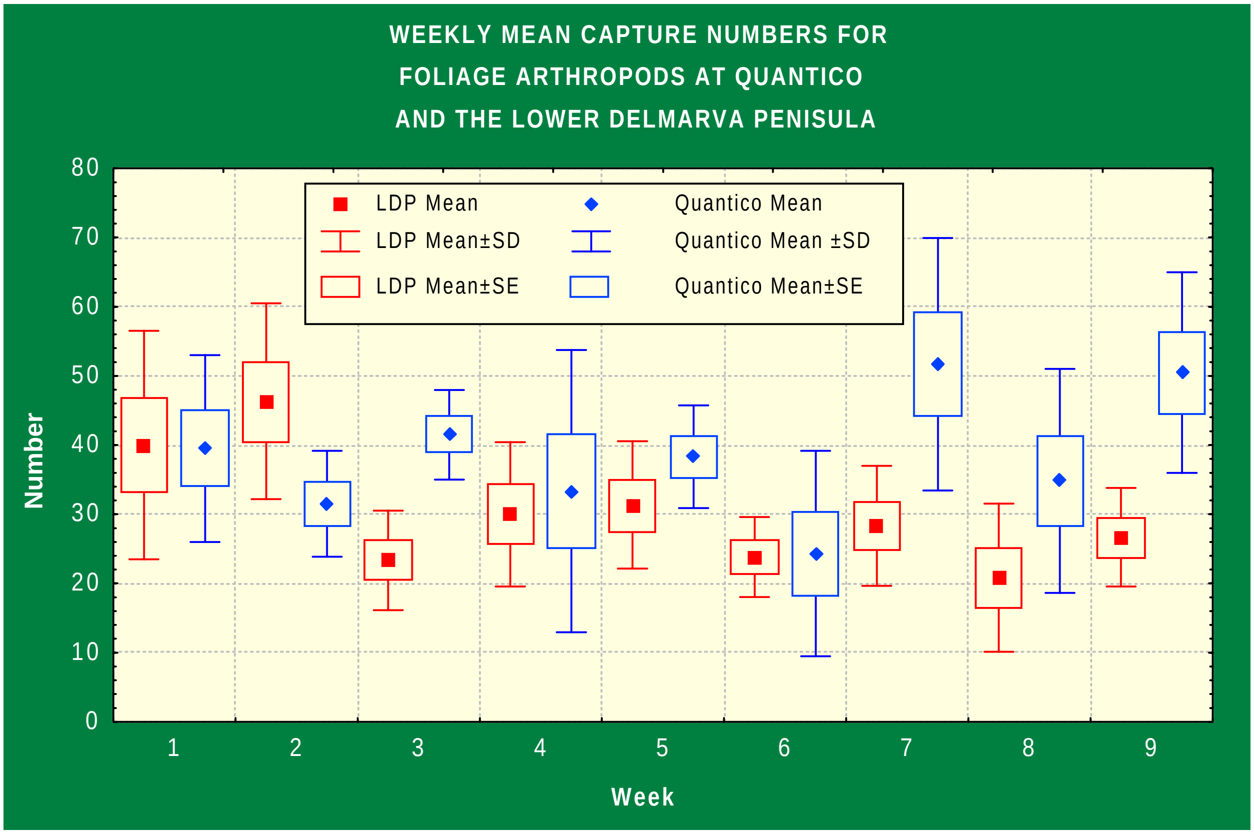



**Figure 12**. Weekly means for foliage arthropod numbers from sites at Quantico and the Lower Delmarva Peninsula.

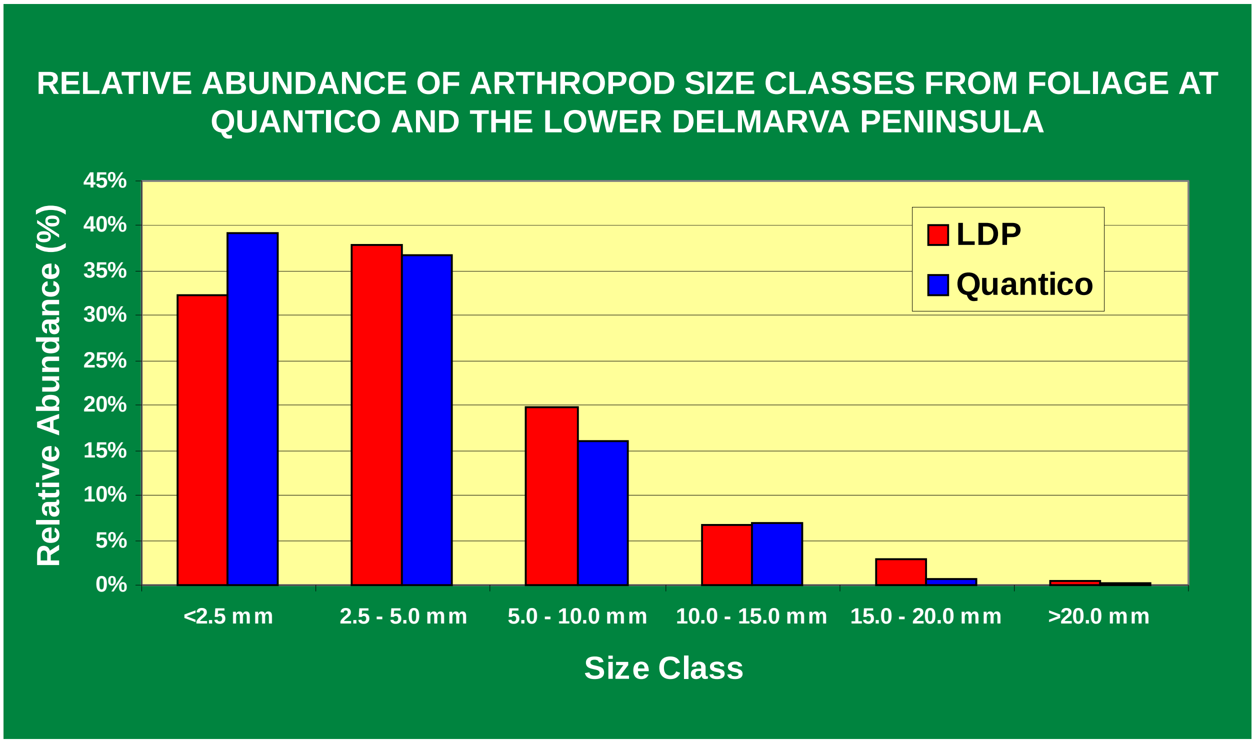



**Figure 13**. Relative abundance of foliage arthropod size classes at Quantico and the Lower Delmarva Peninsula.

37.1% of the total on the Lower Delmarva Peninsula and Quantico respectively. Other classes of arthropods abundant at both sites included Diptera and larval Lepitoptera (Figure 14).

Extraction of arthropods from leaf litter samples resulted in 1,093 individuals. Samples from the Lower Delmarva Peninsula produced the most arthropods with 659 (60.3%), while samples from Quantico accounted for 434 or 39.7%. Weekly totals ranged from 30 to 95 on the Lower Delmarva Peninsula and from 29 to 72 at Quantico. Rates of decline were similar at both sites (Figure 15). Distribution of size classes were similar at both sites with arthropods measuring 2.5 to 5.0 mm, <2.5 mm, and 5.0 to 10.0 mm respectively being the most abundant (Figure 16). Arachnids were the most abundant identified arthropods found in litter sample at both sites, accounting for approximately 29.5% of collected arthropods at both sites. Hymenoptera (ants) were the second most abundant arthropod at Quantico and on the Lower Delmarva Peninsula accounting for 17.1% and 8.8% respectively (Figure 17).

## Foraging Observations

A total of 54,115 seconds of foraging observations were made on 383 individuals of

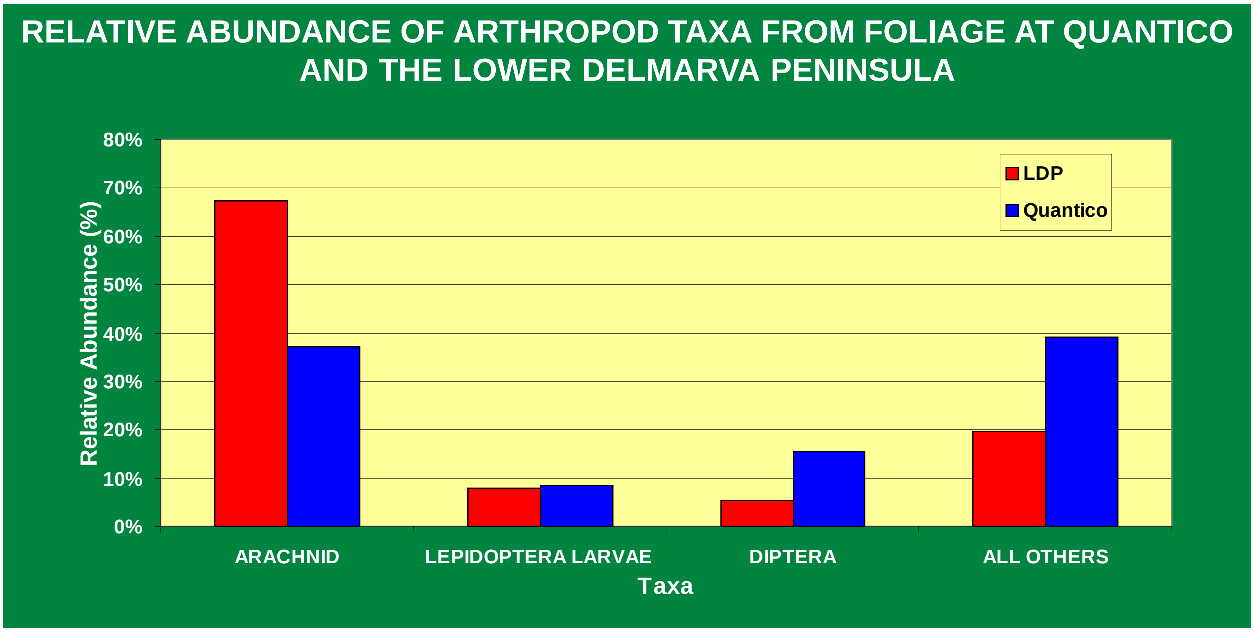



**Figure 14**. Relative abundance of foliage arthropod taxa at Quantico and the Lower Delmarva Peninsula.

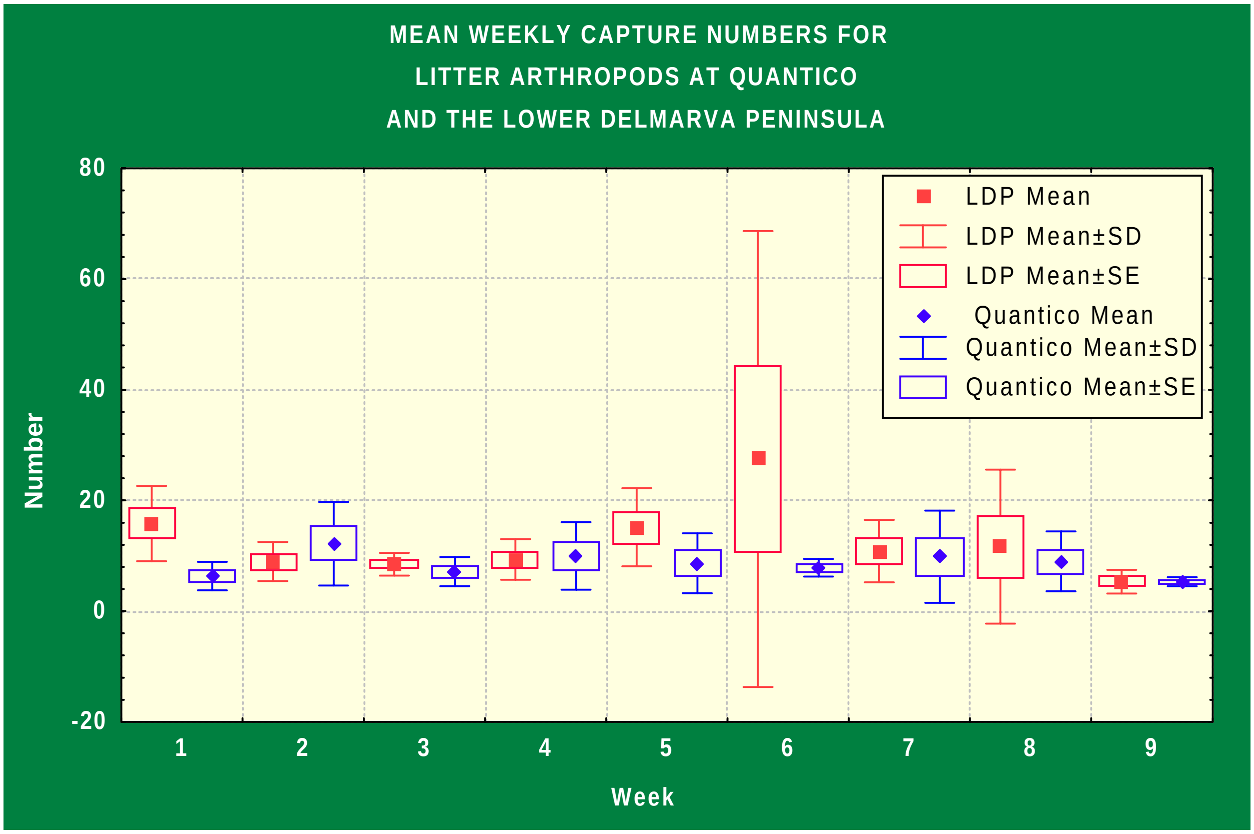



**Figure 15**. Weekly means for foliage arthropod numbers from sites at Quantico and the Lower Delmarva Peninsula.

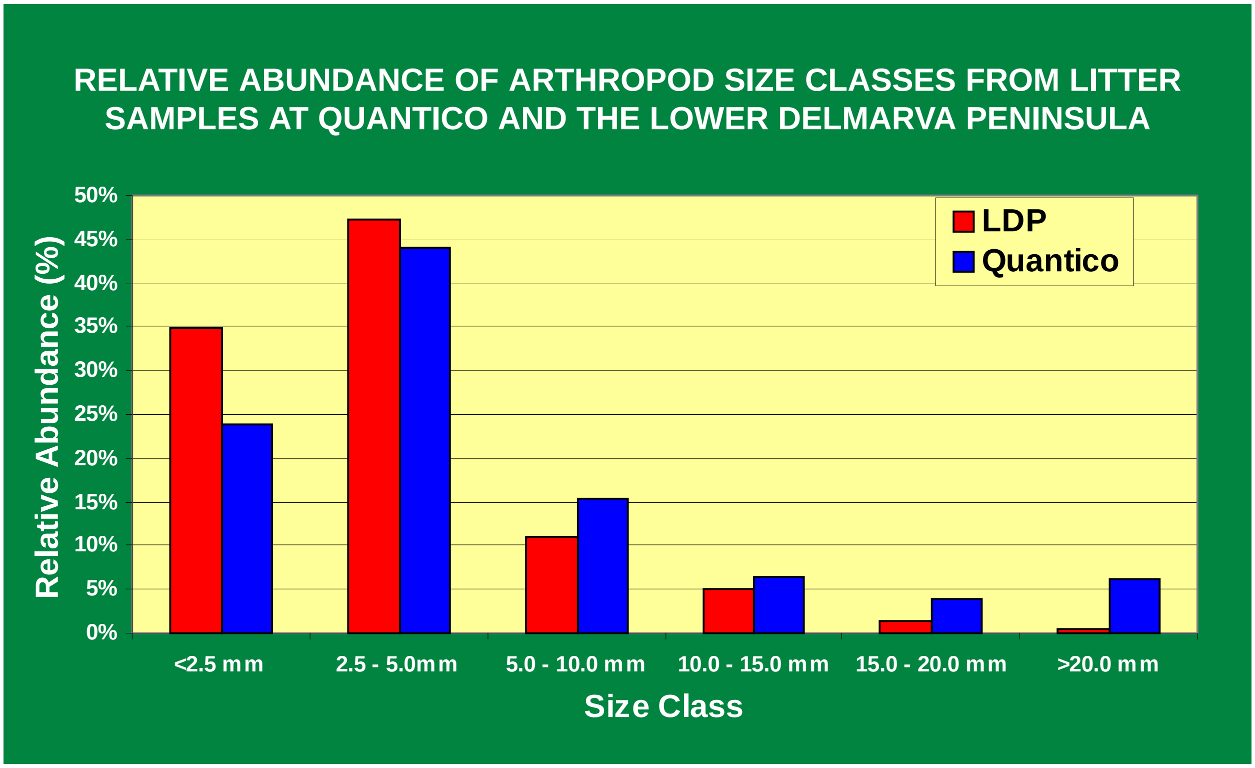



**Figure 13**. Relative abundance of litter arthropod size classes at Quantico and the Lower Delmarva Peninsula.

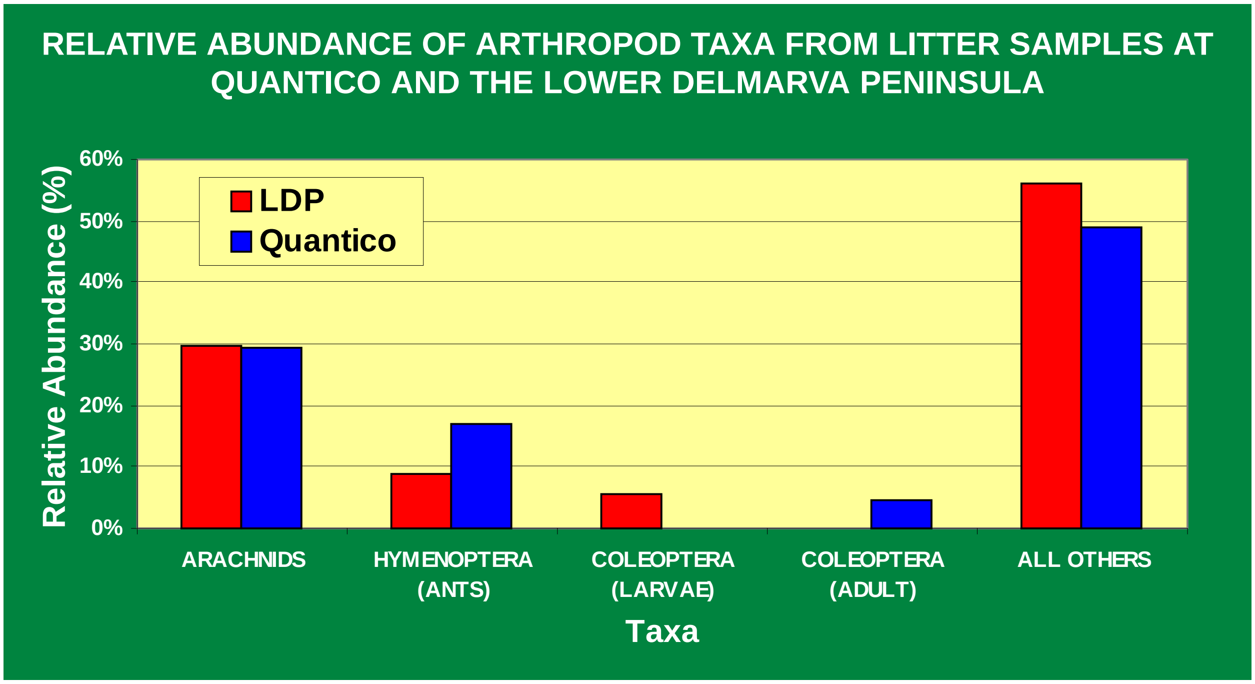



**Figure 14**. Relative abundance of litter arthropod taxa at Quantico and the Lower Delmarva Peninsula.

21 neotropical migrant species. Due to low sample size for many species only Black-throated Blue Warblers, Black-and-white Warblers, and Ovenbirds were used for direct species comparison between sites (Table 10).

Percentages of time spent foraging were similar for the 3 target species between sites. Black-throated Blue Warblers spent approximately 96% and Black-and-white Warblers spent approximately 98% of the observation time foraging at both sites. Ovenbirds at both sites spent approximately half of the observation time foraging. Actual percentages of time spent foraging were 41.4% at Quantico and 58.7% on the Lower Delmarva Peninsula (Table 11). Although the 3 target species spent about the same amount of time foraging between sites, birds at Quantico consistently captured more prey items per unit time compared to birds on the Lower Delmarva Peninsula. Black-throated Blue Warblers at Quantico captured 3.6 prey items/min ± 2.49 SD, while the same species on the Lower Delmarva Peninsula captured 1.8 prey items/min ± 1.29 SD. Black-and-white Warblers observed at Quantico ingested 4.8 prey items/min ± 2.92 SD compared to 1.84 prey items/min ± 1.85 SD for this species on the Lower Delmarva Peninsula. Ovenbirds were taking prey items at a rate of 1.1 prey items/min ± 1.85 SD and 0.4 prey items/min ± 0.42 SD items/min at Quantico and on the Lower Delmarva Peninsula respectfully.

Based upon foraging observations Ovenbirds and Black-and-white Warblers did not seem to be capturing enough prey at either site to meet their daily field metabolic rate (FMR). Ovenbirds at Quantico were ingesting a dry weight of arthropods of 1.5 g/day ± 4.65 SD, resulting in an energy yield of 27.0 kj/day. Ovenbirds on the Lower Delmarva Peninsula were taking in a greater amount of biomass, 2.5 g/day ± 7.22 SD, yielding 45.0 kj/day. Neither of these rates of foraging meet the calculated FMR for Ovenbirds of 83.6.

Black-and-white Warblers were ingesting dry weights of arthropods at a rate of 1.9 g/day ± 3.00 SD at Quantico and 2.5 g/day ± 7.30 SD on the Lower Delmarva Peninsula. These rates resulted in 34.2 and 45.0 kj of metabolizable energy per day which does not meet the FMR for this species of 53.9 kj/day.

The Black-throated Blue Warbler at Quantico was the only species of bird analyzed that exceeded its FMR. Individuals at Quantico were ingesting arthropods at a rate of 4.0 g/day ± 17.98 SD, this equates to 72.0 kj/day exceeding this species' FMR of 50.2 kj/day by 43.4%. Black-throated Blue Warblers at Kiptopeke were obtaining only 2.2 g/day ± 5.99 SD, yielding 39.6 kj/day, failing to meet their FMR by 21.1% (Table 12).

**Table 10**. Number, total seconds, and mean length (± SD) of observations for the three target species at Quantico Marine Base and Kiptopeke State Park

| Species | Site | Number of Observations | Seconds of Observation | Mean Length of Observation |
|---|---|---|---|---|
| Black-and-white Warbler | Quantico | 22 | 2021 | 91.9 ± 122.77 |
| | Kiptopeke | 43 | 5504 | 128.0 ± 121.91 |
| Black-throated Blue Warbler | Quantico | 60 | 6463 | 107.72 ± 88.20 |
| | Kiptopeke | 73 | 9647 | 132.15 ± 124.35 |
| Ovenbird | Quantico | 27 | 6359 | 235.52 ± 184.72 |
| | Kiptopeke | 12 | 3618 | 301.50 ± 281.10 |
| Total | Quantico | 109 | 14843 | 136.17 ± 136.79 |
| | Kiptopeke | 128 | 18769 | 146.63 ± 151.75 |

**Table 11**. Activity time budgets the three target species at Quantico Marine Base and Kiptopeke State Park

| | | Percentage of time spent in each activity | | | |
|---|---|---|---|---|---|
| Species | Site | Foraging | Chasing | Preening | Inactive |
| Black-and-white Warbler | Quantico | 99.1 | 0.4 | - | 0.4 |
| | Kiptopeke | 97.9 | - | - | 2.1 |
| Black-throated Blue Warbler | Quantico | 96.1 | 0.3 | 1.0 | 2.6 |
| | Kiptopeke | 95.0 | - | 1.6 | 3.4 |
| Ovenbird | Quantico | 41.4 | - | 1.9 | 56.7 |
| | Kiptopeke | 58.7 | - | 11.5 | 29.8 |

**Table 12**. Comparison of mean prey intake rate, mean daily biomass intake, energy yield, and relative gain or loss of energy for the three target species at Quantico Marine Base and Kiptopeke State Park.

| Species | Site | Prey items/minute | Biomass intake/day | Energy yield | Energy gain/loss |
|---|---|---|---|---|---|
| Black-and-white Warbler | Quantico | 4.8 ± 2.92 | 1.9 g ± 3.00 | 34.2 kj/day | -36.5% |
| | Kiptopeke | 1.8 ± 1.85 | 2.5 g ± 7.30 | 45.0 kj/day | -16.5% |
| Black-throated Blue Warbler | Quantico | 3.6 ± 2.49 | 4.0 g ± 17.98 | 72.0 kj/day | +43.4% |
| | Kiptopeke | 1.8 ± 1.29 | 2.2 g ± 5.99 | 39.6 kj/day | -21.1% |
| Ovenbird | Quantico | 1.1 ± 1.85 | 1.5 g ± 4.65 | 27.0 kj/day | -67.7% |
| | Kiptopeke | 0.4 ± 0.43 | 2.5 g ± 7.22 | 45.0 kj/day | -46.2% |

## DISCUSSION

Differences in bird abundance (capture rates) between Quantico and Kiptopeke can be attributed to the location of the banding stations. The Kiptopeke banding station is situated near the tip of the Delmarva peninsula, a migration bottle-neck that concentrates avian migrants hesitant to cross the Chesapeake Bay. Where as, the banding station at Quantico does not benefit from any bottle-neck effect, making the relative density of migrants much less than at Kiptopeke. This is clearly evident by the capture rate for Kiptopeke of 107.73 birds per 100 net hours compared to the capture rate of 7.82 birds per 100 net hours for Quantico.

Differences in temporal patterns of abundance between the two migrant classes were observed at both sites. Neotropical migrants at both sites were captured with higher frequency during the early fall, while temperate migrants at both sites were captured with higher frequency later in the fall. This pattern of migration is consistent with other fall migration data collected within the mid Atlantic region (Sykes 1986, Watts and Mabey 1993, 1994, Watts and Wilson 1998, and unpublished data from Kiptopeke banding station). The difference in migration timing between neotropical and temperate migrants is generally believed to correspond to the availability of food items utilized by the two groups of migrants. Most neotropical migrants that pass through the mid-Atlantic region utilize arthropods as food sources. Arthropods are generally more abundant earlier in the fall than later in the season. In contrast, the majority of temperate migrants feed upon fruits and/or seeds, which generally ripen or are more abundant later in the fall.

The disparity in age ratios between the two sites for thrushes and warblers was to be expected. Age ratios of nearly 1:1 were observed at Quantico, while at Kiptopeke young birds dominated with nearly a 9:1 ratio over after hatch year birds. Years of data at the Kiptopeke station has shown that the majority of neotropical migrants moving down the Delmarva peninsula are young of the year, while a greater proportion of adult bird migrate further inland and down the Appalachians.

Stop-over duration and body mass changes at Quantico suggest that the inner coastal plain habitats may be of better quality than those of the outer coastal plain. Insectivorous neotropical migrants at Quantico had longer mean stop-over durations, 6.27 versus 3.16 days, than at Kiptopeke. During these stop-over periods, birds using habitats at Quantico tended to gain mass, mean mass gain of 1.64% of body mass, while birds a Kiptopeke tended to lose mass, mean mass loss of 0.18% of body mass. Although birds from Kiptopeke tended to be fatter and heavier upon initial capture than birds from Quantico, this is not an accurate indicator of the area’s stop-over habitat quality. New birds captured are generally migrants that have just moved into the area from regions to the North. Measuring mass and levels of fat deposition may not accurately reflect stop-over habitat quality near the station, but may in fact reflect the quality of stop-over habitat further north along the migration route.

Sampling showed significantly more flying arthropods at Kiptopeke than at Quantico.  This disparity is attributed to the close proximity of numerous wetland habitats. These wetland habitats produce a plethora of Dipterans (mosquitoes, midges, gnats, and flies) that made up 92.14% of the captures for flying arthropods at Kiptopeke.  While traps at Quantico produce significantly fewer arthropods, a greater proportion of arthropods in the larger size classes were present.  Kiptopeke also produced slightly more ground arthropods from leaf litter samples than Quantico.  Foliage collections from Quantico, however, showed slightly greater numbers of arthropods than Kiptopeke.  This may be attributed to the greater numbers of deciduous trees on the inner coastal plain.

While all 3 target species (Ovenbird, Black-and-white Warbler, and Black-throated Blue Warbler) spent nearly the same percentage of time foraging between sites, birds at Quantico were more successful, taking approximately twice the prey items per unit time as birds at Kiptopeke.  This may be due to greater amounts of prey available to each bird, therefore, less competition among and between species.

Based upon foraging observations, none of the 3 target species at Kiptopeke were taking in enough energy to reach their daily field metabolic rate (FMR), and only one species at Quantico, the Black-throated Blue Warbler, exceeded it's daily FMR.  Black-throated Blue Warblers at Quantico were ingesting 4.74 grams of arthropod dry mass per day exceeding this species daily FMR by 69.83%.

Analysis of Black-throated Blue foraging rates, arthropods numbers from vegetation, age ratios of neotropical migrants, and changes in body mass during periods of stopover suggest that inner coastal plain habitats may be of superior quality than habitats on the outer coastal plain.  However, it is difficult to draw conclusions based upon one year's data.  Analysis of this years data, coupled with that of last year, may reveal more answers to the questions of habitat qualities and bird use of the inner and outer coastal plain.

## ACKNOWLEDGEMENTS

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**APPENDIX I**: List of species, numbers, and migration modes of birds captured.

| Common Name | Scientific Name | Quantico Number Captured | Kiptopeke Number Captured | Migration Mode |
|---|---|---|---|---|
| Sharp-shinned Hawk | *Accipier striatus* | 1 | 6 | Neotropical Migrant |
| Eastern Screech Owl | *Otus asio* | 1 | - | Resident |
| Yellow-billed Cuckoo | *Coccyzus americanus* | 3 | 1 | Neotropical Migrant |
| Hairy Woodpecker | *Picoides villosus* | 3 | - | Resident |
| Downy Woodpecker | *Picoides pubescens* | 1 | | Resident |
| Yellow-bellied Sapsucker | *Sphyrapicus varius* | - | 2 | Temperate Migrant |
| Red-bellied Woodpecker | *Melanerpes carolinus* | 1 | - | Resident |
| Yellow-shafted Flicker | *Colaptes auratus* | 5 | 2 | Temperate Migrant |
| Eastern Kingbird | *Tyrannus tyrannus* | - | 1 | Neotropical Migrant |
| Eastern Phoebe | *Sayorinus phoebe* | 2 | 8 | Neotropical Migrant |
| Eastern Wood-Pewee | *Contopus virens* | 1 | 2 | Neotropical Migrant |
| Yellow-bellied Flycatcher | *Empidonax flaviventris* | - | 1 | Neotropical Migrant |
| Acadian Flycatcher | *Empidonax virescens* | 6 | 3 | Neotropical Migrant |
| Traill's Flycatcher | *Empidonax spp.* | - | 10 | Neotropical Migrant |
| Least Flycatcher | *Empidonax minimus* | 1 | 1 | Neotropical Migrant |
| Blue Jay | *Cyanocitta cristata* | 18 | 3 | Temperate Migrant |
| White-throated Sparrow | *Zonotrichia albicollis* | 10 | 39 | Temperate Migrant |
| Chipping Sparrow | *Spizella passerina* | - | 2 | Temperate Migrant |
| Field Sparrow | *Spizella pusilla* | 3 | 3 | Temperate Migrant |
| Slate-colored Junco | *Junco hyemalis* | 2 | 4 | Temperate Migrant |
| Song Sparrow | *Melospiza melodia* | - | 6 | Temperate Migrant |
| Swamp Sparrow | *Melospiza georgiana* | 2 | 8 | Temperate Migrant |

**APPENDIX I**: (continued)

| Common Name | Scientific Name | Quantico Number Captured | Kiptopeke Number Captured | Migration Mode |
|---|---|---|---|---|
| Eastern Towhee | *Pipilo erythrophthalmus* | 5 | 5 | Temperate Migrant |
| Northern Cardinal | *Cardinalis cardinalis* | 10 | 12 | Resident |
| Rose-breasted Grosbeak | *Pheucticus ludovicianus* | 2 | - | Neotropical Migrant |
| Blue Grosbeak | *Guiraca caerulea* | - | 1 | Neotropical Migrant |
| Indigo Bunting | *Passerina cyanea* | 2 | 8 | Neotropical Migrant |
| Scarlet Tanager | *Piranga olivacea* | 1 | 3 | Neotropical Migrant |
| Red-eyed Vireo | *Vireo olivaceus* | 22 | 26 | Neotropical Migrant |
| Philadelphia Vireo | *Vireo philadelphicus* | - | 1 | Neotropical Migrant |
| Blue-headed Vireo | *Vireo solitarius* | 2 | 5 | Neotropical Migrant |
| White-eyed Vireo | *Vireo griseus* | 8 | 7 | Neotropical Migrant |
| Black-and-white Warbler | *Mniotilta varia* | 3 | 40 | Neotropical Migrant |
| Worm-eating Warbler | *Helmitheros vermovora* | 2 | 3 | Neotropical Migrant |
| Nashville Warbler | *Vermivora ruficapilla* | 3 | 6 | Neotropical Migrant |
| Tennessee Warbler | *Vermivora peregrina* | 2 | - | Neotropical Migrant |
| Northern Parula | *Parula pitiayumi* | 1 | 14 | Neotropical Migrant |
| Cape May Warbler | *Dendroica tigrina* | 2 | - | Neotropical Migrant |
| Black-throated blue Warbler | *Dendroica caerulescens* | 34 | 96 | Neotropical Migrant |
| Myrtle Warbler | *Dendroica coronata coronata* | 3 | 859 | Temperate Migrant |
| Magnolia Warbler | *Dendroica magnolia* | 30 | 40 | Neotropical Migrant |
| Chestnut-sided Warbler | *Dendroica pensylvanica* | 2 | 4 | Neotropical Migrant |
| Bay-breasted Warbler | *Dendroica castanea* | 1 | 3 | Neotropical Migrant |

**APPENDIX I**: (continued)

| Common Name | Scientific Name | Quantico Number Captured | Kiptopeke Number Captured | Migration Mode |
|---|---|---|---|---|
| Blackpoll Warbler | *Dendroica striata* | 12 | 4 | Neotropical Migrant |
| Blackburnian Warbler | *Dendroica fusca* | - | 1 | Neotropical Migrant |
| Black-throated green Warbler | *Dendroica virens* | 4 | 1 | Neotropical Migrant |
| Western Palm Warbler | *Dendroica palmarum palmarum* | 4 | 47 | Temperate Migrant |
| Yellow Palm Warbler | *Dendroica palmarum hypochrysea* | 18 | - | Temperate Migrant |
| Prairie Warbler | *Dendroica discolor* | - | 5 | Neotropical Migrant |
| Ovenbird | *Seiurus aurocapillus* | 41 | 22 | Neotropical Migrant |
| Northern Waterthrush | *Seiurus noveboracensis* | 1 | 21 | Neotropical Migrant |
| Louisiana Waterthrush | *Seiurus motacilla* | 1 | 1 | Neotropical Migrant |
| Kentucky Warbler | *Oporornis formosus* | - | 1 | Neotropical Migrant |
| Connecticut Warbler | *Oporornis agilis* | 2 | - | Neotropical Migrant |
| Common Yellowthroat | *Geothlypis trichas* | 3 | 142 | Neotropical Migrant |
| Yellow-breasted Chat | *Icteria virens* | 2 | 4 | Neotropical Migrant |
| Hooded Warbler | *Wilsonia citrina* | 9 | 7 | Neotropical Migrant |
| Wilson's Warbler | *Wilsonia pusilla* | 1 | 3 | Neotropical Migrant |
| Canada Warbler | *Wilsonia canadensis* | 1 | 8 | Neotropical Migrant |
| American Redstart | *Setophaga ruticilla* | 2 | 206 | Neotropical Migrant |
| Northern Mockingbird | *Minimus polyglottos* | - | 3 | Resident |
| Gray Catbird | *Dunetella carolinensis* | 21 | 149 | Neotropical Migrant |
| Brown Thrasher | *Toxostoma rufum* | 6 | 12 | Temperate Migrant |
| Carolina Wren | *Thryothorus ludovicianus* | 10 | 9 | Resident |

**APPENDIX I**: (continued)

| Common Name | Scientific Name | Quantico Number Captured | Kiptopeke Number Captured | Migration Mode |
|---|---|---|---|---|
| House Wren | *Troglodytes aedon* | 1 | 28 | Neotropical Migrant |
| Winter Wren | *Troglodytes troglodytes* | 3 | 2 | Temperate Migrant |
| Brown Creeper | *Certhia americana* | 1 | - | Temperate Migrant |
| White-breasted Nuthatch | *Sitta carolinensis* | 1 | - | Resident |
| Eastern Tufted Titmouse | *Baeolophus bicolor* | 12 | - | Resident |
| Carolina Chickadee | *Poecile carolinensis* | 8 | - | Resident |
| Golden-crowned Kinglet | *Regulus satrapa* | 18 | 24 | Temperate Migrant |
| Ruby-crowned Kinglet | *Regulus calendula* | 25 | 9 | Temperate Migrant |
| Blue-gray Gnatcatcher | *Polioptila caerulea* | - | 1 | Neotropical Migrant |
| Woodthrush | *Hylocichla mustelina* | 25 | 1 | Neotropical Migrant |
| Veery | *Catharus fuscescens* | 6 | 14 | Neotropical Migrant |
| Gray-cheeked Thrush | *Catharus minimus* | 7 | 6 | Neotropical Migrant |
| Bicknell's Thrush | *Catharus bicknelli* | - | 3 | Neotropical Migrant |
| Swainson's Thrush | *Catharus ustulatus* | 26 | 29 | Neotropical Migrant |
| Hermit Thrush | *Catharus guttatus* | 22 | 22 | Temperate Migrant |
| American Robin | *Turdus migratorius* | 4 | - | Temperate Migrant |
| Total | | 492 | 2020 | |

**APPENDIX II**: List of species, numbers, and rate of capture for birds captured at Kiptopeke.

| Species | Number of Individuals | Percent of Total | Captures / 100 net hours |
|---|---|---|---|
| Sharp-shinned Hawk | 6 | 0.30 | 0.32 |
| Yellow-billed Cuckoo | 1 | 0.05 | 0.05 |
| Yellow-bellied Sapsucker | 2 | 0.10 | 0.11 |
| Yellow-shafted Flicker | 2 | 0.10 | 0.11 |
| Eastern Kingbird | 1 | 0.05 | 0.05 |
| Eastern Phoebe | 8 | 0.40 | 0.43 |
| Eastern Wood-Pewee | 2 | 0.10 | 0.11 |
| Yellow-bellied Flycatcher | 1 | 0.05 | 0.05 |
| Acadian Flycatcher | 3 | 0.15 | 0.16 |
| Traill's Flycatcher | 10 | 0.50 | 0.53 |
| Least Flycatcher | 1 | 0.05 | 0.05 |
| Blue Jay | 3 | 0.15 | 0.16 |
| White-throated Sparrow | 39 | 1.93 | 2.08 |
| Chipping Sparrow | 2 | 0.10 | 0.11 |
| Field Sparrow | 3 | 0.15 | 0.16 |
| Slate-colored Junco | 4 | 0.20 | 0.21 |
| Song Sparrow | 6 | 0.30 | 0.32 |
| Swamp Sparrow | 8 | 0.40 | 0.43 |
| Eastern Towhee | 5 | 0.25 | 0.27 |
| Northern Cardinal | 12 | 0.59 | 0.64 |
| Blue Grosbeak | 1 | 0.05 | 0.05 |
| Indigo Bunting | 8 | 0.40 | 0.43 |
| Scarlet Tanager | 3 | 0.15 | 0.16 |
| Red-eyed Vireo | 26 | 1.29 | 1.39 |
| Philadelphia Vireo | 1 | 0.05 | 0.05 |
| Blue-headed Vireo | 5 | 0.25 | 0.27 |
| White-eyed Vireo | 7 | 0.35 | 0.37 |
| Black-and-white Warbler | 40 | 1.98 | 2.13 |
| Worm-eating Warbler | 3 | 0.15 | 0.16 |
| Nashville Warbler | 6 | 0.30 | 0.32 |
| Northern Parula | 14 | 0.69 | 0.75 |
| Black-throated blue Warbler | 96 | 4.75 | 5.12 |
| Myrtle Warbler | 859 | 42.52 | 45.81 |
| Magnolia Warbler | 40 | 1.98 | 2.13 |
| Chestnut-sided Warbler | 4 | 0.20 | 0.21 |
| Bay-breasted Warbler | 3 | 0.15 | 0.16 |
| Blackpoll Warbler | 4 | 0.20 | 0.21 |
| Blackburnian Warbler | 1 | 0.05 | 0.05 |
| Black-throated green Warbler | 1 | 0.05 | 0.05 |
| Western Palm Warbler | 47 | 2.33 | 2.51 |

**APPENDIX II**: (continued)

| Species | Number of Individuals | Percent of Total | Captures / 100 net hours |
|---|---|---|---|
| Prairie Warbler | 5 | 0.25 | 0.27 |
| Ovenbird | 22 | 1.09 | 1.17 |
| Northern Waterthrush | 21 | 1.04 | 1.12 |
| Louisiana Waterthrush | 1 | 0.05 | 0.05 |
| Kentucky Warbler | 1 | 0.05 | 0.05 |
| Common Yellowthroat | 142 | 7.03 | 7.57 |
| Yellow-breasted Chat | 4 | 0.20 | 0.21 |
| Hooded Warbler | 7 | 0.35 | 0.37 |
| Wilson’s Warbler | 3 | 0.15 | 0.16 |
| Canada Warbler | 8 | 0.40 | 0.43 |
| American Redstart | 206 | 10.20 | 10.99 |
| Northern Mockingbird | 3 | 0.15 | 0.16 |
| Gray Catbird | 149 | 7.38 | 7.95 |
| Brown Thrasher | 12 | 0.59 | 0.64 |
| Carolina Wren | 9 | 0.45 | 0.48 |
| House Wren | 28 | 1.39 | 1.49 |
| Winter Wren | 2 | 0.10 | 0.11 |
| Golden-crowned Kinglet | 24 | 1.19 | 1.28 |
| Ruby-crowned Kinglet | 9 | 0.45 | 0.48 |
| Blue-gray Gnatcatcher | 1 | 0.05 | 0.05 |
| Woodthrush | 1 | 0.05 | 0.05 |
| Veery | 14 | 0.69 | 0.75 |
| Gray-cheeked Thrush | 6 | 0.30 | 0.32 |
| Bicknell's Thrush | 3 | 0.15 | 0.16 |
| Swainson’s Thrush | 29 | 1.44 | 1.55 |
| Hermit Thrush | 22 | 1.09 | 1.17 |
| Total | 2020 | 100.00 | 107.73 |

**APPENDIX III**: List of species, numbers, and rate of capture for birds captured at Quantico

| Species | Number of Individuals | Percent of Total | Captures / 100 net hours |
|---|---|---|---|
| Sharp-shinned Hawk | 1 | 0.20 | 0.02 |
| Eastern Screech Owl | 1 | 0.20 | 0.02 |
| Yellow-billed Cuckoo | 3 | 0.61 | 0.05 |
| Hairy Woodpecker | 3 | 0.61 | 0.05 |
| Downy Woodpecker | 1 | 0.20 | 0.02 |
| Red-bellied Woodpecker | 1 | 0.20 | 0.02 |
| Yellow-shafted Flicker | 5 | 1.02 | 0.08 |
| Eastern Phoebe | 2 | 0.41 | 0.03 |
| Eastern Wood-Pewee | 1 | 0.20 | 0.02 |
| Acadian Flycatcher | 6 | 1.22 | 0.10 |
| Least Flycatcher | 1 | 0.20 | 0.02 |
| Blue Jay | 18 | 3.66 | 0.29 |
| White-throated Sparrow | 10 | 2.03 | 0.16 |
| Field Sparrow | 3 | 0.61 | 0.05 |
| Slate-colored Junco | 2 | 0.41 | 0.03 |
| Swamp Sparrow | 2 | 0.41 | 0.03 |
| Eastern Towhee | 5 | 1.02 | 0.08 |
| Northern Cardinal | 10 | 2.03 | 0.16 |
| Rose-breasted Grosbeak | 2 | 0.41 | 0.03 |
| Indigo Bunting | 2 | 0.41 | 0.03 |
| Scarlet Tanager | 1 | 0.20 | 0.02 |
| Red-eyed Vireo | 22 | 4.47 | 0.35 |
| Blue-headed Vireo | 2 | 0.41 | 0.03 |
| White-eyed Vireo | 8 | 1.63 | 0.13 |
| Black-and-white Warbler | 3 | 0.61 | 0.05 |
| Worm-eating Warbler | 2 | 0.41 | 0.03 |
| Nashville Warbler | 3 | 0.61 | 0.05 |
| Tennessee Warbler | 2 | 0.41 | 0.03 |
| Northern Parula | 1 | 0.20 | 0.02 |
| Cape May Warbler | 2 | 0.41 | 0.03 |
| Black-throated Blue Warbler | 34 | 6.91 | 0.54 |
| Myrtle Warbler | 3 | 0.61 | 0.05 |
| Magnolia Warbler | 30 | 6.10 | 0.48 |
| Chestnut-sided Warbler | 2 | 0.41 | 0.03 |
| Bay-breasted Warbler | 1 | 0.20 | 0.02 |
| Blackpoll Warbler | 12 | 2.44 | 0.19 |
| Black-throated Green Warbler | 4 | 0.81 | 0.06 |
| Western Palm Warbler | 4 | 0.81 | 0.06 |
| Yellow Palm Warbler | 18 | 3.66 | 0.29 |
| Ovenbird | 41 | 8.33 | 0.65 |

**APPENDIX III**: (continued)

| Species | Number of Individuals | Percent of Total | Captures / 100 net hours |
|---|---|---|---|
| Northern Waterthrush | 1 | 0.20 | 0.02 |
| Louisiana Waterthrush | 1 | 0.20 | 0.02 |
| Connecticut Warbler | 2 | 0.41 | 0.03 |
| Common Yellowthroat | 3 | 0.61 | 0.05 |
| Yellow-breasted Chat | 2 | 0.41 | 0.03 |
| Hooded Warbler | 9 | 1.83 | 0.14 |
| Wilson’s Warbler | 1 | 0.20 | 0.02 |
| Canada Warbler | 1 | 0.20 | 0.02 |
| American Redstart | 2 | 0.41 | 0.03 |
| Gray Catbird | 21 | 4.27 | 0.33 |
| Brown Thrasher | 6 | 1.22 | 0.10 |
| Carolina Wren | 10 | 2.03 | 0.16 |
| House Wren | 1 | 0.20 | 0.02 |
| Winter Wren | 3 | 0.61 | 0.05 |
| Brown Creeper | 1 | 0.20 | 0.02 |
| White-breasted Nuthatch | 1 | 0.20 | 0.02 |
| Eastern Tufted Titmouse | 12 | 2.44 | 0.19 |
| Carolina Chickadee | 8 | 1.63 | 0.13 |
| Golden-crowned Kinglet | 18 | 3.66 | 0.29 |
| Ruby-crowned Kinglet | 25 | 5.08 | 0.40 |
| Woodthrush | 25 | 5.08 | 0.40 |
| Veery | 6 | 1.22 | 0.10 |
| Gray-cheeked Thrush | 7 | 1.42 | 0.11 |
| Swainson’s Thrush | 26 | 5.28 | 0.41 |
| Hermit Thrush | 22 | 4.47 | 0.35 |
| American Robin | 4 | 0.81 | 0.06 |
| Total | 492 | 100.00 | 7.82 |