

## COMPARISON OF MIGRANT SONGBIRD STOPOVER ECOLOGY ON TWO ISLANDS IN THE GULF OF MAINE

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**ABSTRACT.**—We compared migrant bird recapture rate, stopover time, mass gain, and fat class between Star Island, New Hampshire and Appledore Island, Maine during spring and fall migration in relation to differences in relative species abundance between the islands; and examined potential movement of migrants between the islands. The average recapture rate in spring was 5.7% on Star Island and 3.6% on Appledore Island. Five species were recaptured more frequently on Star Island and one species more frequently on Appledore Island. There was no difference in mean minimum stopover time during spring (2.4 days on Star Island; 2.5 days on Appledore Island) and fall (2.9 days on Star Island; 3.2 days on Appledore Island). Three species had a longer mean stopover time on Appledore Island than Star Island. The island with the greater percentage of recaptures and longer stopover had more captures for a given species. Mass gains were significant for six species during spring (27.3%) and 10 during fall (38.5%) on Star Island, and five (22.7%) during spring and 13 (50.0%) during fall on Appledore Island. Five species had a difference in rate of mass gain between the islands. The between-island difference in species abundance was not reflected in between-island differences in mass gain, except for Red-eyed Vireo (*Vireo olivaceus*) during fall. There was no clear pattern in species differences in fat levels and differences in captures, stopover length, or mass gain between the islands. The fat-class and mass-gain results suggest habitat use, as measured by relative abundance, is not based on the ability to gain mass at the time of stopover. The notable fall mass gains for Red-eyed Vireo illustrate the availability of food resources for some species on both islands. Only 42 of 10,437 migrant birds banded moved from one island to the other. There was little evidence of movement between islands in a seasonally-appropriate direction for continued migration, or evidence indicating a shift between islands after initial capture. Received 21 April 2010. Accepted 11 November 2011.

Stopover sites provide migrants with an opportunity to replenish critical energy supplies (Moore et al. 1995), reorient (Baird and Nisbet 1960), escape adverse winds and weather, recover from muscle fatigue or injury, evade predators (Moore et al. 1992, Cimprich et al. 2005), and avoid the dehydration of daytime flight (Moore et al. 1992). Lack of suitable stopover habitat may increase the risk of mortality during migration (Bairlein 1992, Moore et al. 1992, Hutto 1998) contributing to population declines (Moore 2000, Petit 2000).

Measuring the importance of a given stopover site and site variables (i.e., habitat type, vegetation structure, food, etc.) to migrant songbirds is challenging. Variability in weather, wind direction, and an individual's energetic condition result in variability of stopover site use in any given year, making it easy to view stopover sites as interchangeable and dismiss any given site as unimportant to passerine populations (Moore et al. 1992, Hutto 1998). Migrants may choose specific

stopover sites or may use stopover sites differently based on available resources, environmental conditions, and priorities.

Star and Appledore islands in the Isles of Shoals on the New England coast, USA, provide a unique opportunity to examine migrant stopover patterns. Large numbers of songbirds stopover during spring and fall migration (Morris et al. 1996) and the islands are <1 km apart, eliminating weather as a factor in between-site comparisons. They are on the edge of the Gulf of Maine, and most migrants travel along the coast, south or southwest during fall (Drury and Keith 1962, Drury and Nisbet 1964, Richardson 1978) and northeastward during spring (Drury and Keith 1962). Thus, the islands are not necessarily the first or last stop for a migrant before a long flight; and stopover due to extreme physiological stress is less frequent than at many other ecological barriers.

We previously (Suomala et al. 2010) found differences in the relative abundance of migrant species between Appledore and Star islands. These differences were most closely related to differences in habitat structure and area between the islands. Interspecific differences in island use during migratory stopover were most closely related to the species' breeding habitat. Star Island has lower scrub-shrub vegetation and more closely resembles a typical scrub-shrub habitat. Species that breed in scrub-shrub or open habitat

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were more common on Star Island. Appledore Island is larger and has more trees and taller vegetation. Species more common on Appledore Island were primarily area-sensitive, forest-breeding species. Suomala et al. (2010) present complete habitat and species abundance data for Appledore and Star islands.

The differences in species distribution patterns between Appledore and Star islands (Appendix) provided an opportunity to compare mass gain, recapture rate, and stopover time between the islands in relation to species distribution differences. We hypothesized that if habitat use during migratory stopover is related to foraging opportunities we should expect higher mass gain on the island where they are more abundant.

The proximity of Star and Appledore islands and their approximate north-south alignment suggest potential patterns of movement between the islands. Morning flights for habitat exploration prior to settling at a stopover site (Hutto 1985, Moore et al. 1990, Wiedner et al. 1992) should lead to habitat shifts from lower quality habitat on one island to more suitable habitat on the other island; those species more numerous on a given island should be most likely to crossover to that island. Alternatively, onward migration during morning flights (Bingman 1980, Wiedner et al. 1992), would lead to seasonally directed same-day movement between the islands.

Our objectives were to: (1) compare recapture rate, stopover time, mass gain, and fat class between the islands in relation to differences in relative species abundance between the islands; and (2) examine potential movement of migrants between the islands in relation to these factors. We hypothesized that differences in frequency and duration of stopover and mass gain among migrants would correspond to differences in species distribution between the islands. We predicted that birds would move between Star Island and Appledore Island in a seasonally-appropriate direction during morning flights and be captured on both islands.

## METHODS

*Study Sites.*—Our study sites were on Star and Appledore islands in the Isles of Shoals (42° 58' N, 70° 36' W) in the Gulf of Maine. This group of nine small islands and several ledges is 9.7 km from the nearest point of the mainland. Appledore Island, Maine is the largest of the islands at 33.6 ha and Star Island, New Hampshire

is 13.4 ha. The minimum shore-to-shore distance between Star and Appledore islands is ~0.7 km and the study sites were 1.6 km apart.

*Bird Surveys.*—Mist netting was conducted simultaneously on both islands in 1999 and 2000 during spring (11 May–8 Jun 1999, 10 May–8 Jun 2000) and fall (16 Aug–30 Sep 1999 and 2000) migration. Nets (6 × or 12 × 2.6 m, 4 shelves, 30 mm mesh) were operated from sunrise to sunset, and checked every 30 min. Up to five nets were operated on Star Island and up to 10 nets were operated on Appledore Island. Nets were placed in similar, representative habitat types for each island (habitat data in Suomala et al. 2010). Captured birds were brought to a central location on each island and banded with USGS aluminum bands. The following data were recorded for each bird captured: age, sex, degree of skull pneumatization (scale of 0–3) during fall, unflattened wing chord (0.5 mm), fat class (scale of 0–4), tail length (0.5 mm), tarsus length (0.1 mm), and mass (0.01 g). Birds recaptured on subsequent days were treated the same as initial captures. Both banding stations used identical protocols following Morris et al. (1994, 1996).

The fat classification system initially followed Morris et al. (1996) but was condensed (6 to 2 categories) during analysis. This provided an approximate separation of birds with some fat present (categories 1–4, 1 = fat lining furcula to 4 = fat extending over pectoralis; presumably sufficient fat for continued flight) and birds without fat (categories 0 and 0.5, none to a trace).

*Data Analyses.*—The analyses included only those species that do not breed on the Isles of Shoals; thus, all individuals were considered stopover migrants. We used Systat Version 10 (SPSS Inc. 2000) for statistical analyses. We did not use Bonferroni corrections in the analyses to reduce the chance that real differences or relevant patterns would be missed (Jones et al. 2002, Gotelli and Ellison 2004). There is a risk of Type I error, but there is also a risk of missing relevant patterns when Bonferroni corrections are used (Gotelli and Ellison 2004), overlooking important biological differences.

Species recapture percentages were analyzed for each sampling period to learn if there were differences between seasons and years. We did not statistically adjust recapture analyses for the different number of nets between the islands because the Star Island nets occupied a much higher percentage of available habitat than nets on

Appledore Island, increasing recapture likelihood and compensating for the increased chance of recapture due to greater netting effort on Appledore Island.

We analyzed spring and fall separately. We pooled data within a season from 1999 and 2000 for mass gain/loss analysis to better represent typical conditions (Dunn 2000); data from Morris et al. (1996) also showed similarities in mass gain on Appledore Island between years. We used the same pooling of data for stopover time and fat class analyses so the results could be compared to the mass change results. We compared differences in fat class between islands using a Chi-square test and analyzed only those species with 20 or more individuals captured on each island.

We compared the number, stopover length, and mass change of recaptured birds for those migrants that stayed for a minimum of one night, and were recaptured at least 1 day after their initial capture. Migrants recaptured only on the day of initial capture were not included in the analyses of recaptured birds. We compared the number of individuals recaptured between islands using Fisher's exact test (Zar 1999). We calculated the minimum length of stopover by subtracting the initial date of capture from the date of the last recapture for each individual (Cherry 1982, Moore and Kerlinger 1987, Morris et al. 1994), and compared differences in mean minimum stopover length between islands using a two sample *t*-test. We analyzed only those individual species with 20 or more individuals banded on each island and five or more recaptured on at least one island for both tests.

We calculated mass change during stopover for each recaptured individual by subtracting mass at first capture (initial mass) from mass at last capture (final mass) (Morris et al. 1994, 1996). We used a Chi-square test to compare the number of birds gaining and losing mass during stopover between islands and analyzed only those species with 10 or more recaptured individuals on each island. We calculated percent mass change during stopover as (final mass-initial mass)/initial mass  $\times$  100 (Bairlein 1985; Morris et al. 1994, 1996). We used a two sample *t*-test to compare mean percent mass change for all recaptures between the islands and analyzed only those species with five or more recaptured individuals on each island. We did not adjust the mass of recaptured individuals to a standard time of day following Bairlein (1985) and Winker et al. (1992). We also

analyzed mass gain for the same species on each island individually using paired *t*-tests to compare initial mass and final mass.

We analyzed hourly mass change by analyzing mass at first capture of all birds captured using a linear regression of mass on time of day (Winker et al. 1992, Morris et al. 1996, Dunn 2000). We conducted a multiple regression analysis of mass on time of capture with wing length included as an independent variable (Dunn 2000). Time of capture was measured in hours since sunrise. Wing length outliers were removed if outside the range for that species in Pyle (1997). We used ANCOVA to compare regressions from each island to examine if there was a significant difference in hourly rate of mass gain or loss between islands. Only those species with a minimum total of 20 captured (1999 and 2000 combined) were analyzed.

## RESULTS

*Birds.*—We banded 1,572 migrants during spring and 2,261 during fall on Star Island and 3,240 migrants during spring and 3,364 during fall on Appledore Island. Scientific names of species and numbers captured are in the Appendix. The majority of birds captured during fall were young (hatching year; Star Island, 87.2%; Appledore Island, 93.0%).

*Fat Class of Birds Captured.*—Appledore Island had consistently higher percentages of birds with some fat for all species combined; this difference was significant for both spring and fall (spring:  $\chi^2 = 29.141$ ,  $df = 1$ ,  $P \leq 0.001$ ; fall:  $\chi^2 = 5.803$ ,  $df = 1$ ,  $P = 0.016$ ). Two species had a greater percentage of individuals with some fat on Star Island, both during fall; 13 species had a greater percentage with fat on Appledore Island, six during spring and seven during fall (Table 1).

*Recapture Rates.*—The average recapture rate in spring was 5.7% (91 individuals) on Star Island and 3.6% (116 individuals) on Appledore Island. Star Island had a higher recapture rate than Appledore Island in both spring sampling periods but the difference was only significant in 1999 ( $P \leq 0.001$ ; 2000,  $P = 0.160$ , Fisher's exact test). The average recapture rate in fall was 9.7% (215 individuals) on Star Island and 12.3% (411 individuals) on Appledore Island. Appledore Island had a higher recapture rate than Star Island in both fall sampling periods but the difference was only significant in 2000 (1999,  $P = 0.325$ ;

TABLE 1. Comparison of fat class of birds captured on Star Island (SI) and Appledore Island (AP) in spring and fall using Chi-square analysis ( $df = 1$  for all tests). Some fat is defined as those individuals with a fat class of 1 or more;  $n$  is the number of birds captured on each island. Island is the location with the significantly greater percentage of individuals with some fat. Based on banding data from 1999 and 2000.

| Species                   | Season | $n$ |     | % with some fat |      | $\chi^2$ | $P$    | Island |
|---------------------------|--------|-----|-----|-----------------|------|----------|--------|--------|
|                           |        | SI  | AP  | SI              | AP   |          |        |        |
| Eastern Wood-Pewee        | Spr    | 39  | 76  | 15.4            | 10.5 | 0.569    | 0.451  |        |
| Yellow-bellied Flycatcher | Spr    | 37  | 75  | 43.2            | 53.3 | 1.009    | 0.315  |        |
|                           | Fall   | 24  | 64  | 4.2             | 25.0 | 4.861    | 0.027  | AP     |
| Traill's Flycatcher       | Spr    | 82  | 75  | 6.1             | 25.3 | 11.193   | <0.001 | AP     |
|                           | Fall   | 52  | 49  | 36.5            | 38.8 | 0.054    | 0.817  |        |
| Least Flycatcher          | Spr    | 29  | 49  | 20.7            | 36.7 | 2.202    | 0.138  |        |
|                           | Fall   | 41  | 47  | 31.7            | 31.9 | 0.000    | 0.983  |        |
| Blue-headed Vireo         | Fall   | 28  | 31  | 35.7            | 38.7 | 0.056    | 0.812  |        |
| Philadelphia Vireo        | Fall   | 23  | 46  | 26.1            | 47.8 | 3.005    | 0.083  | AP     |
| Red-eyed Vireo            | Spr    | 88  | 320 | 51.1            | 59.1 | 1.773    | 0.183  |        |
|                           | Fall   | 185 | 583 | 55.1            | 61.6 | 2.430    | 0.119  |        |
| Red-breasted Nuthatch     | Fall   | 32  | 96  | 43.8            | 40.6 | 0.097    | 0.756  |        |
| Golden-crowned Kinglet    | Fall   | 85  | 120 | 7.1             | 20.0 | 6.670    | 0.010  | AP     |
| Ruby-crowned Kinglet      | Spr    | 63  | 33  | 46.0            | 75.8 | 7.776    | 0.005  | AP     |
|                           | Fall   | 49  | 58  | 18.4            | 22.4 | 0.266    | 0.606  |        |
| Cedar Waxwing             | Spr    | 36  | 21  | 50.0            | 33.3 | 1.496    | 0.221  |        |
|                           | Fall   | 132 | 119 | 51.5            | 51.3 | 0.002    | 0.968  |        |
| Northern Waterthrush      | Fall   | 165 | 361 | 80.0            | 63.2 | 14.872   | <0.001 | SI     |
| Black-and-white Warbler   | Spr    | 28  | 128 | 57.1            | 68.8 | 1.393    | 0.238  |        |
|                           | Fall   | 47  | 138 | 59.6            | 61.6 | 0.060    | 0.806  |        |
| Nashville Warbler         | Fall   | 42  | 61  | 35.7            | 54.1 | 3.378    | 0.066  | AP     |
| Mourning Warbler          | Fall   | 23  | 28  | 56.5            | 46.4 | 0.515    | 0.473  |        |
| American Redstart         | Spr    | 109 | 271 | 53.2            | 54.2 | 0.033    | 0.855  |        |
|                           | Fall   | 118 | 304 | 28.0            | 38.2 | 3.866    | 0.049  | AP     |
| Northern Parula           | Spr    | 36  | 135 | 72.2            | 83.7 | 2.463    | 0.117  |        |
|                           | Fall   | 24  | 20  | 37.5            | 40.0 | 0.029    | 0.865  |        |
| Magnolia Warbler          | Spr    | 296 | 510 | 60.1            | 60.2 | 0.000    | 0.986  |        |
|                           | Fall   | 80  | 85  | 23.8            | 24.7 | 0.021    | 0.886  |        |
| Blackburnian Warbler      | Spr    | 21  | 29  | 28.6            | 65.5 | 6.650    | 0.010  | AP     |
| Chestnut-sided Warbler    | Spr    | 32  | 50  | 46.9            | 44.0 | 0.065    | 0.799  |        |
| Blackpoll Warbler         | Spr    | 78  | 194 | 74.4            | 90.2 | 11.375   | <0.001 | AP     |
|                           | Fall   | 26  | 106 | 40.5            | 36.0 | 0.372    | 0.542  |        |
| Black-thr. Blue Warbler   | Spr    | 23  | 99  | 39.1            | 57.6 | 2.557    | 0.110  |        |
|                           | Fall   | 26  | 106 | 11.5            | 14.2 | 0.121    | 0.728  |        |
| Yellow-rumped Warbler     | Spr    | 50  | 26  | 66.0            | 69.2 | 0.081    | 0.776  |        |
|                           | Fall   | 343 | 66  | 27.1            | 25.8 | 0.052    | 0.820  |        |
| Black-thr. Green Warbler  | Spr    | 24  | 31  | 45.8            | 71.0 | 3.561    | 0.059  | AP     |
| Canada Warbler            | Spr    | 21  | 94  | 4.8             | 29.8 | 5.700    | 0.017  | AP     |
| Wilson's Warbler          | Spr    | 48  | 28  | 73.5            | 69.0 | 0.182    | 0.669  |        |
|                           | Fall   | 71  | 51  | 46.5            | 29.8 | 3.684    | 0.055  | SI     |
| Yellow-breasted Chat      | Fall   | 59  | 31  | 81.4            | 67.7 | 2.106    | 0.147  |        |
| Lincoln's Sparrow         | Spr    | 23  | 37  | 87.0            | 83.8 | 0.112    | 0.738  |        |
| Swamp Sparrow             | Spr    | 71  | 48  | 71.8            | 81.3 | 1.379    | 0.240  |        |
| White-throated Sparrow    | Spr    | 68  | 132 | 60.3            | 79.5 | 8.439    | 0.004  | AP     |
|                           | Fall   | 121 | 145 | 28.9            | 10.3 | 14.919   | <0.001 | SI     |
| Baltimore Oriole          | Fall   | 36  | 55  | 41.7            | 63.6 | 4.242    | 0.039  | AP     |
| Purple Finch              | Fall   | 42  | 30  | 19.0            | 66.7 | 16.698   | <0.001 | AP     |

TABLE 2. Comparison of number of birds recaptured by species between Star Island (SI) and Appledore Island (AP) using Fisher's exact test. Island is the location with the significantly greater percentage of recaptures for that species;  $n$  is the number of birds recaptured on that island. Based on banding data from 1999 and 2000.

| Species                 | Sampling period | Number captured |     | Recaptured $n$ (%) |           | $P$    | Island |
|-------------------------|-----------------|-----------------|-----|--------------------|-----------|--------|--------|
|                         |                 | SI              | AP  | SI                 | AP        |        |        |
| Traill's Flycatcher     | Fall 00         | 34              | 34  | 1 (2.9)            | 6 (17.6)  | 0.105  |        |
| Red-eyed Vireo          | Fall 99         | 69              | 230 | 7 (10.1)           | 61 (26.5) | 0.005  | AP     |
|                         | Fall 00         | 116             | 354 | 10 (8.6)           | 59 (16.7) | 0.035  | AP     |
| Red-breasted Nuthatch   | Fall 99         | 32              | 94  | 3 (9.4)            | 19 (20.2) | 0.190  |        |
| Ruby-crowned Kinglet    | Spr 99          | 47              | 28  | 5 (10.6)           | 0 (0.0)   | 0.150  |        |
| Cedar Waxwing           | Fall 99         | 56              | 70  | 5 (8.9)            | 1 (1.4)   | 0.088  | SI     |
| Northern Waterthrush    | Fall 99         | 66              | 133 | 13 (19.7)          | 23 (17.3) | 0.698  |        |
|                         | Fall 00         | 100             | 228 | 12 (12.0)          | 35 (15.4) | 0.496  |        |
| Black-and-white Warbler | Fall 00         | 33              | 93  | 1 (3.0)            | 10 (10.8) | 0.286  |        |
| American Redstart       | Spr 99          | 67              | 133 | 4 (6.0)            | 11 (8.3)  | 0.777  |        |
|                         | Fall 99         | 34              | 96  | 1 (2.9)            | 12 (12.5) | 0.182  |        |
|                         | Fall 00         | 85              | 208 | 15 (17.6)          | 45 (21.6) | 0.524  |        |
| Magnolia Warbler        | Spr 99          | 137             | 258 | 11 (8.0)           | 2 (0.8)   | <0.001 | SI     |
|                         | Spr 00          | 159             | 254 | 8 (5.0)            | 3 (1.2)   | 0.026  | SI     |
|                         | Fall 00         | 57              | 61  | 9 (15.8)           | 3 (4.9)   | 0.068  | SI     |
| Yellow-rumped Warbler   | Fall 99         | 199             | 47  | 39 (19.6)          | 1 (2.1)   | 0.002  | SI     |
|                         | Fall 00         | 145             | 20  | 12 (8.3)           | 0 (0.0)   | 0.364  |        |
| Lincoln's Sparrow       | Spr 00          | 21              | 28  | 3 (14.3)           | 6 (21.4)  | 0.714  |        |
| White-throated Sparrow  | Fall 99         | 95              | 119 | 12 (12.6)          | 5 (4.2)   | 0.039  | SI     |
| Purple Finch            | Fall 99         | 42              | 31  | 8 (19.0)           | 1 (3.2)   | 0.069  | SI     |

2000,  $P \leq 0.001$ ; Fisher's exact test). No migrants were recaptured between years.

Twenty-eight species were recaptured on Star Island and 28 species were recaptured on Appledore Island during spring; 17 were recaptured on both islands. Forty species were recaptured during fall on Star Island and 42 species were recaptured on Appledore Island; 31 were recaptured on both islands. Five species were recaptured more frequently on Star Island: Cedar Waxwing, Magnolia Warbler, Yellow-rumped Warbler, White-throated Sparrow, and Purple Finch. Only the Red-eyed Vireo was recaptured more frequently on Appledore Island (Table 2).

**Minimum Stopover Time.**—There was no difference (spring:  $t = 0.158$ ,  $df = 205$ ,  $P = 0.875$ ; fall:  $t = 1.460$ ,  $df = 624$ ,  $P = 0.145$ ) in mean minimum stopover time between islands during spring (2.4 days on Star Island,  $n = 91$ ; 2.5 days on Appledore Island,  $n = 116$ ) or fall (2.9 days on Star Island,  $n = 215$ ; 3.2 days on Appledore Island,  $n = 411$ ). Five migrant species were recaptured in sufficient numbers to compare stopover time between islands. Three species had a longer mean minimum stopover time on Appledore Island: Red-eyed Vireo in fall (but not spring), American Redstart in spring (but not fall),

and Northern Waterthrush in fall (but not spring) (Table 3).

**Mass Change.**—There were no significant differences between islands in number of recaptured birds that gained or lost mass during either spring or fall stopover for all species combined. Three species (Red-eyed Vireo, American Redstart, Northern Waterthrush) were recaptured in sufficient numbers (fall only) to compare mass gain between islands. A higher percentage of each species gained mass on Appledore Island, but the difference between islands was not significant (spring:  $\chi^2 = 0.139$ ,  $df = 1$ ,  $P = 0.709$ ; fall:  $\chi^2 = 0.206$ ,  $df = 1$ ,  $P = 0.650$ ).

The difference between islands in mean percent mass change of all recaptures was not significant for either spring or fall (Table 4). Only the Red-eyed Vireo had a difference in percent mass change in either season with a greater increase on Appledore Island during fall (Table 4).

Thirty-three species were captured in adequate numbers to analyze mass change using multiple regression of all birds captured (Table 5). We analyzed 15 species during both spring and fall, 11 during fall only, and seven during spring only. The majority of species gained mass (72.7% during spring and 76.9% during fall on Star

TABLE 3. Comparison of stopover times by recaptured birds between Star Island (SI) and Appledore Island (AP) using a *t*-test. Mean stopover time is the average minimum stopover time in days for recaptured individuals; *n* is the number of recaptured birds analyzed on that island; and Island is the location with the significantly greater mean stopover time for that species. Based on banding data from 1999 and 2000.

| Species              | Season | Mean stopover (days) $\pm$ SD ( <i>n</i> ) |                     | <i>P</i> | Island |
|----------------------|--------|--|---------------------|----------|--------|
|                      |        | SI   | AP                  |          |        |
| Red-eyed Vireo       | Spr    | 3.5 $\pm$ 1.8 (6)                          | 2.3 $\pm$ 2.0 (6)   | 0.304    |        |
|                      | Fall   | 2.0 $\pm$ 1.6 (17)                         | 3.3 $\pm$ 2.6 (120) | 0.039    | AP     |
| Northern Waterthrush | Fall   | 2.8 $\pm$ 2.3 (25)                         | 4.1 $\pm$ 3.1 (58)  | 0.011    | AP     |
|                      | Spr    | 1.4 $\pm$ 0.5 (7)                          | 2.6 $\pm$ 1.6 (14)  | 0.085    | AP     |
| American Redstart    | Fall   | 2.4 $\pm$ 1.8 (16)                         | 3.1 $\pm$ 2.8 (57)  | 0.367    |        |
|                      | Spr    | 2.1 $\pm$ 1.4 (19)                         | 2.0 $\pm$ 1.4 (5)   | 0.941    |        |
| Magnolia Warbler     | Fall   | 2.6 $\pm$ 2.4 (10)                         | 1.8 $\pm$ 1.3 (5)   | 0.498    |        |
|                      | Fall   | 5.6 $\pm$ 3.8 (13)                         | 3.7 $\pm$ 3.4 (6)   | 0.296    |        |

Island; 72.7% during spring and 84.6% during fall on Appledore Island). Mass gains were significant for six species during spring (27.3%) and 10 species during fall (38.5%) on Star Island, and five (22.7%) during spring and 13 (50.0%) during fall on Appledore Island (Table 5). Significant mass loss occurred only during spring: Black-throated Green Warbler on Star Island, and Red-eyed Vireo and Cedar Waxwing on Appledore Island. Five species had a difference in the rate of mass gain between islands (Table 5). Philadelphia Vireo, Red-eyed Vireo, Cedar Waxwing, and Purple Finch had a larger rate of mass gain during fall on Appledore Island and Lincoln's Sparrow during the spring (Table 5).

*Inter-island Movement.*—Only 42 individual migrants moved from one island to the other. Seven (0.44%) of 1,572 migrants banded on Star Island during spring and 23 (1.02%) of 2,261 migrants banded during fall were recaptured on Appledore Island. Eight (0.24%) of 3,240 migrants banded on Appledore Island during spring and four (0.12%) of 3,364 migrants banded during fall were recaptured on Star Island.

Six of 15 spring crossovers were same-day recaptures (3 to Star Island and 3 to Appledore Island) and five of 27 fall crossovers were same-day recaptures (all to Appledore Island). The majority of crossovers were recaptured within 3 days of initial banding (32 of 42) but, during fall 1999, seven individuals were recaptured 4 or more days after banding, including a Northern Waterthrush recaptured 10 days after banding and a Purple Finch recaptured 24 days after banding. The most numerous (3 or more occasions) crossover species were Red-eyed Vireo and Northern Waterthrush (Table 6).

## DISCUSSION

We expected those species captured more frequently on one island to be recaptured more frequently and stop longer on the same island. Differences in percent recaptures and stopover time were consistent with this hypothesis. The island with the greater percentage of recaptures and longer stopover was the one with more captures (Appendix). However, there were a number of species that did not have significant differences in recapture rate or stopover time despite a difference in captures between the islands. Our results showed no clear pattern between differences in fat levels and differences in captures, stopover length, or mass gain. This is consistent with other studies that found little relationship between these factors (Moore and Kerlinger 1987, Kuenzi et al. 1991, Wang et al. 1998).

The between-island difference in species abundance (Suomala et al. 2010) was not reflected in between-island differences in mass gain, except for the Red-eyed Vireo during fall. The fat-class and mass-gain results suggest habitat use, as measured by greater relative abundance on a given island, was not based on the ability to gain mass. Species more common on one island did not gain more mass or fat on that island, as would be expected if they chose that island because there was more food. Red-eyed Vireo and Yellow-rumped Warbler lost mass in the spring, even on the island where they were most abundant. Our mass gain results were similar to those of Rappole and Warner (1976) who found the majority of species and individuals at a stopover site did not use the local food resources, but a small percentage

TABLE 4. Comparison of mass change of recaptured individuals on Star Island (SI) and Appledore Island (AP), based on banding data from 1999 and 2000. Mass gain on each island was analyzed with a paired *t*-test comparing initial and final mass; *n* is the number of recaptured individuals analyzed on each island. Percent mass change was used to compare mass gain between islands with a *t*-test. Island is the location with the significantly larger mean increase in mass by percent of body weight gained.

| Species              | Season | Mass gain (g)<br>mean ± SD ( <i>n</i> ) |                      | SI              | % Mass change<br>mean ± SD ( <i>n</i> ) |             | P (df) | Island |
|----------------------|--------|---|----------------------|-----------------|---|-------------|--------|--------|
|                      |        | SI                                      | AP                   |                 | SI                                      | AP          |        |        |
| All migrants         | Spr    |   |                      | 1.2 ± 7.5 (89)  | 0.9 ± 9.0 (116)                         | 0.787 (203) |        |        |
|                      | Fall   |   |                      | 4.0 ± 8.7 (215) | 5.5 ± 11.6 (406)                        | 0.115 (619) |        |        |
| Red-eyed Vireo       | Spr    | -0.72 ± 0.79 (6)*                       | -1.30 ± 1.07 (6)*    | -4.5 ± 4.9 (6)  | -8.3 ± 6.4 (6)                          | 0.272 (10)  |        |        |
|                      | Fall   | 0.46 ± 1.22 (17)                        | 1.52 ± 2.36 (118)*** | 3.0 ± 7.6 (17)  | 8.9 ± 14.1 (118)                        | 0.093 (133) | AP     |        |
| Northern Waterthrush | Fall   | 0.67 ± 1.82 (25)*                       | 1.24 ± 1.87 (57)***  | 4.2 ± 10.9 (25) | 7.6 ± 11.3 (57)                         | 0.214 (80)  |        |        |
|                      | Spr    | 0.37 ± 0.52 (7)                         | 0.02 ± 0.55 (14)     | 4.9 ± 6.7 (7)   | 0.4 ± 6.2 (14)                          | 0.151 (19)  |        |        |
| American Redstart    | Fall   | 0.30 ± 0.90 (16)                        | 0.27 ± 0.58 (56)**   | 4.2 ± 11.7 (16) | 3.5 ± 7.4 (56)                          | 0.783 (70)  |        |        |
|                      | Spr    | 0.04 ± 0.60 (19)                        | 0.29 ± 0.78 (5)      | 0.7 ± 7.9 (19)  | 4.1 ± 10.0 (5)                          | 0.423 (22)  |        |        |
| Magnolia Warbler     | Fall   | 0.21 ± 0.51 (10)                        | 0.26 ± 0.77 (5)      | 2.8 ± 6.6 (10)  | 4.3 ± 11.8 (5)                          | 0.760 (13)  |        |        |
|                      | Fall   | 0.92 ± 1.70 (13)*                       | 0.26 ± 1.86 (6)      | 4.2 ± 7.2 (13)  | 1.3 ± 7.1 (6)                           | 0.423 (17)  |        |        |

\* = 0.05 < *P* < 0.10, \* *P* < 0.05, \*\* *P* < 0.01, \*\*\* *P* < 0.001.

remained longer and gained mass. However, there was wide variation between species, seasons, and individuals, similar to that found by Morris et al. (1996) over 10 years on Appledore Island.

Caution should be used in interpreting the mass change results of the ANCOVA analysis. This analysis measures differences in the rate of mass gain that might indicate differences in food supplies and quality, but is based on the assumption of equal foraging time for all birds (i.e., arrive at or before dawn). Thus, mass measurements represent changes that occurred at the stopover site (Dunn 2000). Birds that stray to the east of the Isles of Shoals over the Gulf of Maine may have to continue flying past sunrise (Baird and Nisbet 1960), arriving well after sunrise in a fat-depleted condition. Their condition would be unrelated to stopover habitat quality and represents a confounding factor in the analysis. This phenomenon may contribute to the small number of species with significant mass gains estimated by regression analysis on either island, as suggested by Morris et al. (1996). However, the results of our regression and recapture analyses were consistent. This suggests the ANCOVA analysis was not affected by large numbers of fat-depleted birds arriving later in the day or that Star and Appledore islands were similarly affected and a between-island comparison is valid, although the slope of the regression may be flattened. Small sample size may also be a factor in the lack of significant trends in the mass-change regression analysis due to high individual variation in condition (Winker et al. 1992, Winker 1995a, Dunn 2001).

The general lack of significant differences between the islands in percent mass change among recaptures, percent of recaptures gaining mass, and diurnal mass gains of all species provides a strong indication that factors other than food availability, as measured by the ability to increase mass, influence stopover at the Isles of Shoals. Winker (1995b) also found that capture rate did not correspond with mass gain and abundance did not correlate with use of food resources as measured by fat deposition (Winker et al. 1992), suggesting that food availability is not the only factor in site selection. We hypothesize that migrants may select stopover sites based on habitat structure that is similar to familiar breeding habitat, regardless of the actual food availability at that site (Suomala et al. 2010).

The islands may also function as an important stop for rest, reorientation, muscle repair, or water-

TABLE 5. Multiple regression analysis of the relationship between mass at first capture and time since sunrise. Two-tailed probability ( $P$ ) is given. The +/- column indicates whether birds lost (-) or gained (+) mass, and parentheses indicate the hourly mass gain or loss was not significant ( $P > 0.1$ ). Island comparison shows the results of ANCOVA comparing hourly rate of mass gain or loss between Star Island (SI) and Appledore Island (AP). Island indicates the location with the largest rate of mass gain or the smallest rate of mass loss (L). Based on banding data from 1999 and 2000.

| Species                   | Season    | Star Island |       |       |        | Appledore Island |     |       |       | Island comparison |     |        |        |
|---------------------------|-----------|-------------|-------|-------|--------|------------------|-----|-------|-------|-------------------|-----|--------|--------|
|                           |           | $n$         | $r^2$ | Slope | $P$    | +/-              | $n$ | $r^2$ | Slope | $P$               | +/- | Island | $P$    |
| Northern Flicker          | Fall      | 27          | 0.08  | 4.98  | 0.646  | (+)              | 59  | 0.09  | -5.01 | 0.609             | (-) | SI     | 0.492  |
| Eastern Wood-Pewee        | Spr       | 39          | 0.42  | 2.26  | 0.069  | +                | 75  | 0.39  | 1.42  | 0.031             | +   | SI     | 0.571  |
| Yellow-bellied Flycatcher | Spr       | 37          | 0.42  | 0.31  | 0.642  | (+)              | 74  | 0.13  | 0.23  | 0.605             | (+) | SI     | 0.821  |
|                           | Fall      | 25          | 0.21  | -0.46 | 0.634  | (-)              | 64  | 0.20  | 1.11  | 0.087             | +   | AP     | 0.187  |
| Traill's Flycatcher       | Spr       | 81          | 0.43  | 0.74  | 0.256  | (+)              | 75  | 0.53  | 0.69  | 0.210             | (+) | SI     | 0.764  |
|                           | Fall      | 52          | 0.18  | 1.07  | 0.336  | (+)              | 49  | 0.27  | 0.63  | 0.693             | (+) | SI     | 0.906  |
| Least Flycatcher          | Spr       | 29          | 0.21  | -0.15 | 0.847  | (-)              | 49  | 0.29  | 1.34  | 0.018             | +   | AP     | 0.130  |
|                           | Fall      | 41          | 0.51  | 1.77  | 0.004  | +                | 45  | 0.15  | 0.56  | 0.421             | (+) | SI     | 0.200  |
| Blue-headed Vireo         | Fall      | 28          | 0.06  | 0.88  | 0.400  | (+)              | 31  | 0.10  | 2.83  | 0.062             | +   | AP     | 0.206  |
| Philadelphia Vireo        | Fall      | 23          | 0.00  | -0.62 | 0.749  | (-)              | 46  | 0.20  | 3.13  | 0.035             | +   | AP+    | 0.061  |
| Red-eyed Vireo            | Spr       | 88          | 0.21  | 0.41  | 0.675  | (+)              | 317 | 0.09  | -1.11 | 0.076             | -   | SI     | 0.148  |
|                           | Fall      | 185         | 0.05  | 1.00  | 0.250  | (+)              | 577 | 0.10  | 2.99  | <0.001            | +   | AP*    | 0.047  |
| Red-breasted Nuthatch     | Fall (99) | 32          | 0.02  | -0.83 | 0.449  | (-)              | 94  | 0.14  | -0.49 | 0.304             | (-) | AP (L) | 0.730  |
| Golden-crowned Kinglet    | Fall      | 85          | 0.24  | -0.16 | 0.414  | (-)              | 119 | 0.13  | -0.24 | 0.306             | (-) | SI (L) | 0.823  |
| Ruby-crowned Kinglet      | Spr       | 63          | 0.05  | 0.74  | 0.033  | +                | 32  | 0.00  | 0.48  | 0.340             | (+) | SI     | 0.553  |
|                           | Fall      | 49          | 0.27  | 1.02  | 0.018  | +                | 56  | 0.17  | 0.83  | 0.011             | +   | SI     | 0.827  |
| Cedar Waxwing             | Spr       | 32          | 0.00  | 0.79  | 0.780  | (+)              | 21  | 0.12  | -6.69 | 0.053             | -   | SI     | 0.312  |
|                           | Fall      | 128         | 0.13  | 1.41  | 0.299  | (+)              | 117 | 0.28  | 11.75 | <0.001            | +   | AP***  | <0.001 |
| Northern Waterthrush      | Fall      | 166         | 0.02  | 0.84  | 0.194  | (+)              | 358 | 0.10  | 2.06  | <0.001            | +   | AP     | 0.192  |
| Black-and-white Warbler   | Spr       | 26          | 0.14  | 0.95  | 0.483  | (+)              | 127 | 0.03  | 0.75  | 0.299             | (+) | SI     | 0.717  |
|                           | Fall      | 46          | 0.13  | 1.76  | 0.062  | +                | 138 | 0.08  | 1.80  | 0.005             | +   | AP     | 0.947  |
| Nashville Warbler         | Fall      | 42          | 0.01  | 0.17  | 0.802  | (+)              | 58  | 0.06  | 1.53  | 0.033             | +   | AP     | 0.222  |
| Mourning Warbler          | Fall      | 23          | 0.19  | 2.54  | 0.046  | +                | 27  | 0.33  | 5.14  | 0.013             | +   | AP     | 0.224  |
| American Redstart         | Spr       | 109         | 0.44  | 1.40  | <0.001 | +                | 269 | 0.25  | 1.08  | <0.001            | +   | SI     | 0.547  |
|                           | Fall      | 119         | 0.25  | 0.57  | 0.083  | +                | 133 | 0.21  | 0.93  | 0.018             | +   | AP     | 0.646  |
| Northern Parula           | Spr       | 37          | 0.09  | -0.55 | 0.517  | (-)              | 135 | 0.24  | 0.33  | 0.464             | (+) | AP     | 0.293  |
|                           | Fall      | 23          | 0.11  | 1.52  | 0.428  | (+)              | 20  | 0.13  | -0.56 | 0.789             | (-) | SI     | 0.569  |
| Magnolia Warbler          | Spr       | 293         | 0.16  | 0.23  | 0.320  | (+)              | 511 | 0.20  | 0.17  | 0.432             | (+) | SI     | 0.784  |
|                           | Fall      | 80          | 0.13  | 0.88  | 0.014  | +                | 85  | 0.14  | 0.55  | 0.229             | (+) | SI     | 0.539  |
| Blackburnian Warbler      | Spr       | 21          | 0.12  | 2.18  | 0.047  | +                | 29  | 0.16  | 0.71  | 0.448             | (+) | SI     | 0.227  |
| Chestnut-sided Warbler    | Spr       | 33          | 0.24  | 1.76  | 0.045  | +                | 50  | 0.18  | 0.63  | 0.396             | (+) | SI     | 0.328  |
| Blackpoll Warbler         | Spr       | 78          | 0.06  | 1.46  | 0.314  | (+)              | 192 | 0.10  | -0.54 | 0.522             | (-) | SI     | 0.218  |

TABLE 5. Continued.

| Species                  | Season    | Star Island |                |       |        | Appledore Island |     |                |       | Island comparison |     |       |
|--------------------------|-----------|-------------|----------------|-------|--------|------------------|-----|----------------|-------|-------------------|-----|-------|
|                          |           | n           | r <sup>2</sup> | Slope | P      | +/-              | n   | r <sup>2</sup> | Slope | P                 | +/- | P     |
| Blackpoll Warbler        | Fall      | 73          | 0.03           | 2.36  | 0.149  | (+)              | 101 | 0.00           | 1.40  | 0.452             | (+) | 0.519 |
| Black-thr. Blue Warbler  | Spr       | 23          | 0.07           | 1.51  | 0.199  | (+)              | 98  | 0.14           | 0.63  | 0.179             | (+) | 0.377 |
| Yellow-rumped Warbler    | Fall      | 26          | 0.00           | 0.51  | 0.656  | (+)              | 104 | 0.15           | 0.23  | 0.619             | (+) | 0.536 |
|                          | Spr       | 50          | 0.00           | -0.37 | 0.771  | (-)              | 26  | 0.03           | -1.58 | 0.422             | (-) | 0.991 |
|                          | Fall      | 344         | 0.18           | 1.49  | <0.001 | +                | 66  | 0.13           | 1.39  | 0.252             | (+) | 0.983 |
| Black-thr. Green Warbler | Spr       | 24          | 0.17           | -2.46 | 0.019  | -                | 31  | 0.18           | -1.04 | 0.293             | (-) | 0.848 |
| Canada Warbler           | Spr       | 21          | 0.14           | 0.47  | 0.539  | (+)              | 94  | 0.14           | 0.61  | 0.142             | (+) | 0.896 |
| Wilson's Warbler         | Spr       | 50          | 0.09           | 0.30  | 0.511  | (+)              | 29  | 0.00           | -0.34 | 0.550             | (-) | 0.329 |
|                          | Fall      | 70          | 0.15           | 0.88  | 0.023  | +                | 56  | 0.04           | 0.94  | 0.145             | (+) | 0.775 |
| Yellow-breasted Chat     | Fall      | 59          | 0.15           | 6.01  | 0.002  | +                | 31  | 0.16           | 5.45  | 0.109             | (+) | 0.922 |
| Lincoln's Sparrow        | Spr       | 23          | 0.18           | -3.10 | 0.248  | (-)              | 37  | 0.10           | 2.62  | 0.068             | +   | 0.058 |
| Swamp Sparrow            | Spr       | 69          | 0.20           | 3.06  | 0.017  | +                | 43  | 0.32           | 2.43  | 0.045             | +   | 0.706 |
| White-throated Sparrow   | Spr       | 68          | 0.09           | -1.29 | 0.499  | (-)              | 132 | 0.10           | 2.04  | 0.146             | (+) | 0.160 |
|                          | Fall      | 122         | 0.27           | 3.24  | <0.001 | +                | 145 | 0.39           | 4.51  | <0.001            | +   | 0.371 |
| Baltimore Oriole         | Fall      | 36          | 0.21           | -2.70 | 0.300  | (-)              | 53  | 0.00           | 2.11  | 0.512             | (+) | 0.195 |
| Purple Finch             | Fall (99) | 42          | 0.28           | -1.35 | 0.270  | (-)              | 30  | 0.10           | 4.91  | 0.047             | +   | 0.016 |

+ 0.05 &lt; P &lt; 0.10, \* P &lt; 0.05, \*\* P &lt; 0.01, \*\*\* P &lt; 0.001.

balance (e.g., Kuenzi et al. 1991, Moore et al. 1995, Aborn and Moore 2004). Competition for resources occurs among migrants (Moore and Wang 1991) and the ability to gain mass may be related to the ability to obtain a transient feeding territory (Rappole and Warner 1976). Predation can be a significant risk during migration (Moore et al. 1990) and migrants may prefer locations with fewer predators or dense vegetation to better escape raptors. Merlins (*Falco columbarius*), the most common raptor at the Isles of Shoals, are seen more frequently on Appledore Island than Star Island (SRM and RWS, unpubl. data). Raptors are also known to perch on isolated trees and watch for prey during migration (Moore et al. 1990), a behavior seen for Merlins on Appledore Island but Star Island lacks suitable perches (RWS and D. W. Holmes, pers. obs.).

There was little evidence of movement between islands in a seasonally-appropriate direction for continued migration. Nor was there evidence indicating a shift between islands after initial capture, as would be expected if birds were exploring habitat prior to settling for the day. If birds were searching available habitat, we would expect those that landed in low quality habitat on one island would move to the island with more suitable habitat and be recaptured there. Our data suggest that decisions regarding stopover habitat at the Isles of Shoals were made without apparent exploration and were unrelated to the ability to gain weight. This is consistent with Winker's (1995b) observations and suggestion that birds are able to rapidly select habitat with no observable exploration.

Cedar Waxwing and Purple Finch crossover results were consistent with both species roving among the Isles of Shoals for several days to follow food supplies and crossing to Appledore Island where there was a better chance of mass gain. Both were more numerous on Star Island but gained significantly more weight on Appledore Island in the fall. These species are highly frugivorous in fall and have irregular migration patterns that vary with local food sources (Wootton 1996, Witmer et al. 1997). The two Red-eyed Vireos that crossed during fall from Star Island to Appledore Island (the island with more initial captures and greater mass gain) may also have moved to gain more mass. However, so few birds crossed over that it is difficult to gain any insight into the relationship of crossovers to species distribution at initial capture or mass gain differences between the islands.

TABLE 6. Birds captured on either Star Island (SI) or Appledore Island (AP) and recaptured on the other island. Based on banding data from 1999 and 2000.

| Species                 | Spring            |                   | Fall              |                   | Totals |
|-------------------------|-------------------|-------------------|-------------------|-------------------|--------|
|                         | North<br>SI to AP | South<br>AP to SI | North<br>SI to AP | South<br>AP to SI |        |
| Northern Flicker        |                   |                   | 1                 |                   | 1      |
| Eastern Wood-Pewee      |                   | 1                 |                   |                   | 1      |
| Traill's Flycatcher     | 1                 | 1                 | 1                 |                   | 3      |
| Eastern Phoebe          |                   |                   | 1                 |                   | 1      |
| Blue-headed Vireo       | 1                 | 1                 |                   |                   | 2      |
| Red-eyed Vireo          | 1                 | 1                 | 4                 |                   | 6      |
| Blue Jay                |                   | 1                 |                   |                   | 1      |
| Red-breasted Nuthatch   |                   |                   | 1                 |                   | 1      |
| Cedar Waxwing           | 1                 |                   | 2                 |                   | 3      |
| Northern Waterthrush    |                   |                   | 2                 | 2                 | 4      |
| Black-and-white Warbler |                   |                   |                   | 1                 | 1      |
| Nashville Warbler       |                   | 1                 | 1                 |                   | 2      |
| American Redstart       |                   | 1                 | 2                 |                   | 3      |
| Northern Parula         | 1                 |                   | 1                 | 1                 | 3      |
| Blackpoll Warbler       |                   |                   | 1                 |                   | 1      |
| Yellow-rumped Warbler   |                   | 1                 | 2                 |                   | 3      |
| Yellow-breasted Chat    |                   |                   | 1                 |                   | 1      |
| Indigo Bunting          | 2                 |                   |                   |                   | 2      |
| Purple Finch            |                   |                   | 3                 |                   | 3      |
| Totals                  | 7                 | 8                 | 23                | 4                 | 42     |

Limited crossover was most consistent with movements to reorient at sunrise and regain land (Wiedner et al. 1992, Murray 1976), compensate for wind drift (Baird and Nisbet 1960, Moore 1990), or avoid crossing water (Baird and Nisbet 1960, Wiedner et al. 1992, Gellin and Morris 2001). Northward crossovers from Star Island to Appledore Island in fall were consistent with other northward daytime flights reported at many locations on the Atlantic seaboard (Baird and Nisbet 1960, Murray 1976, Wiedner et al. 1992); Gellin and Morris (2001) found significant northward and westward movement of birds banded on Appledore Island in the fall.

#### CONSERVATION IMPLICATIONS

The notable fall mass gains for Red-eyed Vireo in this study and on Block Island, Rhode Island (Parrish 1997), illustrate the availability of food resources for some species on coastal islands. Red-eyed Vireos did not maintain a threshold weight during fall stopover on Lake Erie in Canada (Dunn 2001) where there was suitable habitat for insects but no mention of fruit. The coastal habitat, which remains frost-free later into the fall and contains many fruit-bearing shrubs that provide a more reliable and less energetically 'expensive' source

of food than insects during the fall (Parrish 2000), may be important to survival of young birds during their first migration. The availability of habitat where migrants can meet other physiological needs may be as critical as habitat for feeding during stopover (Aborn and Moore 2004). The aggregation of many sites may provide the critical resources coastal migrants require.

There are few studies with notable mass gains in passerines during migration (e.g., Rappole and Warner 1976, Winker et al. 1992, Winker 1995b, Dunn 2001, this study) and researchers often attribute a lack of measurable gains to small sample size, high variation in individual condition, and other factors such as age and sex of individuals (Winker et al. 1992, Winker 1995b, Dunn 2001). These factors influence our ability to detect gains, but we raise the question of whether the typical stopover ecology of these broad front migrants contributes to inherently low mass gain. It is unlikely that a single location could provide adequate resources for all birds with so many individuals passing through in a short time. Thus, the gradual loss of stopover habitat may have a greater cumulative impact on migrant populations than can be easily measured or observed at individual stopover sites.

## ACKNOWLEDGMENTS

This project was made possible by support from the Star Island Corporation and New Hampshire Audubon, grants from the Eastern Bird Banding Association and the University of New Hampshire Graduate School, and the generous donations of many individuals. This effort would not have been possible without help of volunteers at New Hampshire Audubon, the Star Island banding station, and the Appledore Island Migration Banding Station, supported in part by the Shoals Marine Laboratory. This paper is contribution #17 of the Appledore Island Migration Banding Station and contribution #154 of the Shoals Marine Laboratory.

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APPENDIX. Number and distribution of migrant species used in the comparison analysis of birds captured on Star Island (SI) and Appledore Island (AP) in 1999 and 2000. The number in the *n* column is the total birds captured on each island in 1999 and 2000 combined; the number used in each individual analysis varies. A – in More captures indicates no difference in that species' relative abundance between the islands; a blank indicates numbers were insufficient for analysis. The island with more captures is from Suomala (2005) and Suomala et al. (2010).

| Species                   | Scientific name               | Season | <i>n</i> |     | More captures |
|---------------------------|-------------------------------|--------|----------|-----|---------------|
|                           |                               |        | SI       | AP  |               |
| Northern Flicker          | <i>Colaptes auratus</i>       | Fall   | 27       | 60  | –             |
| Eastern Wood-Pewee        | <i>Contopus virens</i>        | Spr    | 39       | 76  | –             |
|                           |                               | Fall   | 16       | 26  | –             |
| Yellow-bellied Flycatcher | <i>Empidonax flaviventris</i> | Spr    | 37       | 75  | –             |
|                           |                               | Fall   | 25       | 64  | –             |
| Willow/Alder Flycatcher   | <i>E. traillii/E. alnorum</i> | Spr    | 82       | 75  | SI            |
|                           |                               | Fall   | 52       | 49  | SI            |
| Least Flycatcher          | <i>E. minimus</i>             | Spr    | 29       | 49  | –             |
|                           |                               | Fall   | 41       | 47  | –             |
| Eastern Phoebe            | <i>Sayornis phoebe</i>        | Fall   | 17       | 31  | –             |
| Blue-headed Vireo         | <i>Vireo solitarius</i>       | Spr    | 12       | 51  | AP            |
|                           |                               | Fall   | 28       | 31  | SI            |
| Philadelphia Vireo        | <i>V. philadelphicus</i>      | Fall   | 23       | 46  | –             |
| Red-eyed Vireo            | <i>V. olivaceus</i>           | Spr    | 88       | 320 | AP            |
|                           |                               | Fall   | 185      | 584 | AP            |
| Blue Jay                  | <i>Cyanocitta cristata</i>    | Spr    | 5        | 21  | –             |
| Red-breasted Nuthatch     | <i>Sitta canadensis</i>       | Spr    | 9        | 17  | –             |
|                           |                               | Fall   | 32       | 96  | –             |
| Brown Creeper             | <i>Certhia americana</i>      | Fall   | 9        | 49  | AP            |

## APPENDIX. Continued.

| Species                  | Scientific name                  | Season | n   |     | More captures |
|--------------------------|----------------------------------|--------|-----|-----|---------------|
|                          |                                  |        | SI  | AP  |               |
| Golden-crowned Kinglet   | <i>Regulus satrapa</i>           | Fall   | 85  | 120 | –             |
| Ruby-crowned Kinglet     | <i>R. calendula</i>              | Spr    | 63  | 33  | SI            |
|                          |                                  | Fall   | 49  | 58  | SI            |
| Veery                    | <i>Catharus fuscescens</i>       | Spr    | 9   | 22  | –             |
|                          |                                  | Fall   | 6   | 27  | AP            |
| Swainson's Thrush        | <i>C. ustulatus</i>              | Spr    | 15  | 73  | AP            |
|                          |                                  | Fall   | 11  | 29  | –             |
| Cedar Waxwing            | <i>Bombycilla cedrorum</i>       | Spr    | 36  | 21  | SI            |
|                          |                                  | Fall   | 132 | 120 | SI            |
| Ovenbird                 | <i>Seiurus aurocapilla</i>       | Spr    | 17  | 171 | AP            |
|                          |                                  | Fall   | 9   | 56  | AP            |
| Northern Waterthrush     | <i>Parkesia noveboracensis</i>   | Spr    | 18  | 96  | AP            |
|                          |                                  | Fall   | 166 | 361 | AP            |
| Black-and-white Warbler  | <i>Mniotilta varia</i>           | Spr    | 28  | 128 | AP            |
|                          |                                  | Fall   | 47  | 138 | AP            |
| Nashville Warbler        | <i>Oreothlypis ruficapilla</i>   | Spr    | 18  | 30  | –             |
|                          |                                  | Fall   | 42  | 61  | –             |
| Mourning Warbler         | <i>Geothlypis philadelphia</i>   | Spr    | 15  | 46  | AP            |
|                          |                                  | Fall   | 23  | 28  | –             |
| American Redstart        | <i>Setophaga ruticilla</i>       | Spr    | 109 | 271 | –             |
|                          |                                  | Fall   | 119 | 304 | AP            |
| Northern Parula          | <i>S. americana</i>              | Spr    | 38  | 136 | –             |
|                          |                                  | Fall   | 24  | 20  | –             |
| Magnolia Warbler         | <i>S. magnolia</i>               | Spr    | 296 | 512 | SI            |
|                          |                                  | Fall   | 80  | 85  | SI            |
| Blackburnian Warbler     | <i>S. fusca</i>                  | Spr    | 21  | 29  | –             |
| Chestnut-sided Warbler   | <i>S. pensylvanica</i>           | Spr    | 33  | 50  | –             |
|                          |                                  | Fall   | 9   | 25  | –             |
| Blackpoll Warbler        | <i>S. striata</i>                | Spr    | 78  | 194 | –             |
|                          |                                  | Fall   | 74  | 102 | –             |
| Black-thr. Blue Warbler  | <i>S. caerulea</i>               | Spr    | 23  | 99  | AP            |
|                          |                                  | Fall   | 26  | 106 | AP            |
| Yellow-rumped Warbler    | <i>S. coronata</i>               | Spr    | 50  | 26  | SI            |
|                          |                                  | Fall   | 344 | 67  | SI            |
| Black-thr. Green Warbler | <i>S. virens</i>                 | Spr    | 24  | 31  | –             |
|                          |                                  | Fall   | 19  | 25  | –             |
| Canada Warbler           | <i>Cardellina canadensis</i>     | Spr    | 21  | 94  | AP            |
|                          |                                  | Fall   | 14  | 36  | –             |
| Wilson's Warbler         | <i>C. pusilla</i>                | Spr    | 50  | 29  | SI            |
|                          |                                  | Fall   | 71  | 57  | SI            |
| Yellow-breasted Chat     | <i>Icteria virens</i>            | Fall   | 59  | 31  | SI            |
| Savannah Sparrow         | <i>Passerculus sandwichensis</i> | Spr    | 23  | 7   | SI            |
| Lincoln's Sparrow        | <i>Melospiza lincolni</i>        | Spr    | 23  | 37  | –             |
|                          |                                  | Fall   | 21  | 5   | SI            |
| Swamp Sparrow            | <i>M. georgiana</i>              | Spr    | 71  | 48  | SI            |
|                          |                                  | Fall   | 24  | 6   | SI            |
| White-throated Sparrow   | <i>Zonotrichia albicollis</i>    | Spr    | 68  | 133 | –             |
|                          |                                  | Fall   | 123 | 145 | SI            |
| Rose-breasted Grosbeak   | <i>Pheucticus ludovicianus</i>   | Spr    | 12  | 41  | –             |
| Indigo Bunting           | <i>Passerina cyanea</i>          | Spr    | 7   | 5   | –             |
|                          |                                  | Fall   | 4   | 6   | –             |
| Baltimore Oriole         | <i>Icterus galbula</i>           | Spr    | 12  | 21  | –             |
|                          |                                  | Fall   | 36  | 55  | –             |
| Purple Finch             | <i>Carpodacus purpureus</i>      | Spr    | 8   | 2   | SI            |
|                          |                                  | Fall   | 42  | 31  | SI            |