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THE EFFECT OF TIME OF DAY ON MIST-NET CAPTURES OF PASSERINES ON SPRING MIGRATION

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Abstract.—Capture times of migrating passerines mist-netted during spring migration at two sites at Prince Edward Point, Ontario, Canada, from 1976–1980 and during 1988 were analyzed. Highly significant differences among species in mean capture times, consistent across years and sites, were found. Capture times appeared to be influenced both by foraging behavior and arrival times in the study area. Thrushes and other ground-foraging insectivores were caught most frequently early in the morning, whereas aerial and foliage-gleaning insectivores were caught somewhat later. The latest species included diurnal migrants such as Blue Jays (*Cyanocitta cristata*). These results indicate a need to standardize sampling times when using banding data to estimate species numbers or relative abundance.

El EFECTO DE LA HORA DEL DÍA EN LA CAPTURA CON REDES DE PASSERIFORMES MIGRATORIOS DURANTE LA PRIMAVERA

Sinopsis.—De 1976–1980 y durante 1988 se analizaron las horas de captura de Passeriformes migratorios primaverales en dos localidades del punto Prince Edward. Se encontraron diferencias significativas entre las especies, en el tiempo promedio de captura; los resultados fueron consistentes a través de los años y las localidades de captura. El tiempo de captura pareció ser influenciado por la conducta de forrajeo y el periodo de llegada de las aves a las áreas de estudio. Los zorzales, al igual que insectivoros que forrajean en los suelos, fueron capturados más frecuentemente en la mañana, mientras que insectívoros forrajeadores aéreos y de follaje, fueron capturados algo más tarde. Las especies que se capturaron más tarde incluyeron migratorios diurnos como *Cyanocitta cristata*. Estos resultados indican la necesidad de estandardizar los tiempos de muestreo cuando se usen datos de anillamiento para estimar número de especies o abundancia relativa.

Interspecific variation in the diurnal activity patterns of birds is an important consideration when sampling bird populations. If a sample is restricted to a particular time of day, then species inactive or inconspicuous at that time will be underestimated. Significant time-of-day effects have been found in various auditory and visual censuses, including Breeding Bird Surveys, point counts, and line transects (Grue et al. 1981, Robbins 1981, Shields 1977, Skirvin 1981), although Verner and Ritter (1986) found little difference in the number of individuals recorded over the first 4 h of the morning. However, the effect of time of day on mist net captures, another technique commonly employed to sample bird populations, has been little studied, particularly during migration periods.

Robbins (1981) found significant variation in capture times among species breeding in a woodlot near Laurel, Maryland. Thrushes and many warblers were caught most frequently in the early morning, whereas

flycatching birds and titmice were caught throughout the day. Brooke (1977) found that rare migrants on Skokholm, a small island off the coast of Britain, were caught significantly later than more common species; he suggested that arrival times on the island influenced capture times.

In this paper, we examine the capture times of birds banded on spring migration at Prince Edward Point, Ontario, to determine whether species differ in capture times. We discuss factors, including arrival time and foraging behavior, that appear to influence capture times.

METHODS

Prince Edward Point Bird Observatory is located at the northeastern tip of a large peninsula jutting into Lake Ontario near Kingston, Ontario (43°57'N, 76°54'W). Nets for capturing birds were set in two areas of woodland, separated by about 1 km of old fields (Weir et al. 1980). The woods at Point Traverse, hereafter called Traverse, comprise a long narrow stretch of largely deciduous dry mixed woodland and scrub. The area known as Cedarwoods is a relatively compact area of swampy mixed coniferous and deciduous woodland and scrub.

We have concentrated analyses on data collected during 1988, but we have also used data from 1976 to 1980 for comparison. During 1988, 26 12-m mist nets were set daily at Traverse from 30 April until 3 June, but we restricted analyses to 21 d when the nets were open from before sunrise until after noon. Nets were checked at irregular intervals, usually 30–60 min, and the captured birds were taken to the banding station for processing. The capture time was recorded to the nearest 10 min as the time of arrival at the banding station.

From 1976 to 1980, 15–30 12-m nets were generally opened from early morning until early afternoon, but detailed records on the precise opening and closing times were not available for all days. When sufficient personnel were available, nets were set at both Cedarwoods and Traverse, but on other days only one location was used (usually Cedarwoods). In all years, nets were set on most days from early May through mid-June. Time of banding, rather than capture time, was usually recorded, so the times are not directly comparable with those in 1988. However, as most birds were banded within 30–60 min after capture, and we do not believe there were consistent differences among species in holding times, these times should still be directly proportional to the capture times. We pooled data from 1976 to 1980 to increase sample sizes and to minimize the effects of fluctuations in trapping effort within that period, but we considered each location separately.

We transformed capture times to hours after sunrise, to account for changes in day length through the spring, and excluded captures after 1500 hours because little netting was done in the late afternoons and evenings. For comparisons among species, we only considered species with at least 20 captures in a sample.

For convenience of presentation, we have grouped captures by 1-h blocks on the graphs. However, because these groupings are arbitrary

(and did not necessarily match the checking intervals), we could not use contingency analysis for comparisons, and have relied instead on comparisons among species of mean capture times.

RESULTS

Overall, 2234 birds were caught in 1988 at Traverse during the first 7 h after sunrise. Capture rates generally remained high for most of the morning, although there was a slight decline in the sixth and seventh hours after sunrise (Fig. 1). The decline in the seventh hour may have been related to early closure of nets on some days, but we could not correct for this because nets were more likely to be closed when few birds were around.

There were 32 species with more than 20 individuals caught during the study period in 1988 (Table 1). There were highly significant differences among species in mean capture times ($F_{31,1840} = 16.44$, $P < 0.0001$), as can be seen from graphs of representative species (Fig. 2). Some species, such as White-throated Sparrows (*Zonotrichia albicollis*), Gray Catbirds (*Dumetella carolinensis*) and Swainson's Thrushes (*Catharus ustulatus*), were caught mainly in the first hour after sunrise; others, such as Red-eyed Vireos (*Vireo olivaceus*), Northern Orioles (*Icterus galbula*) and Ruby-crowned Kinglets (*Regulus calendula*), were active throughout the morning, with a peak at mid-morning; and some, such as Blue Jays (*Cyanocitta cristata*), were caught mainly later in the day. We present all data in Table 1 to facilitate comparison with other sites.

We compared the mean capture times for species caught in 1988 with the mean capture times for the same species for 1976–1980, to determine whether the capture orders were consistent between sites and sampling periods. During these earlier years, 23,004 individuals were captured at Cedarwoods and 3391 at Traverse. For species with at least 20 captures in each time period, mean capture times in the Traverse (1976–1980) sample were highly correlated with those at the same location in 1988 (Pearson correlation coefficient, $r = 0.867$, $P < 0.0001$, $n = 25$). There was also a fairly strong correlation between the capture times at the different locations in the early years ($r = 0.773$, $P < 0.0001$, $n = 25$), and a weaker, though still significant, correlation between the 1988 data at Traverse and the early years at Cedarwoods ($r = 0.545$, $P < 0.0015$, $n = 31$).

Mean capture times were fairly consistent across species within some taxa. This was most striking in the thrushes, all species of which were consistently early in all samples. Sparrows also tended to be earlier than most species. Flycatchers were somewhat less consistent. Mean capture times of Eastern Wood-Pewees (*Contopus virens*), and Traill's (*Empidonax traillii*) and Least (*E. minimus*) flycatchers were close to the overall mean capture time of all species, although these species were relatively later in 1988 than in earlier years. However, the Eastern Kingbird (*Tyrannus tyrannus*) was a late species in 1988 at Traverse, but was relatively early at Cedarwoods.

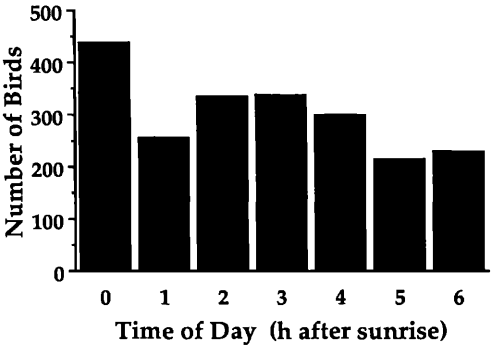

FIGURE 1. Mist-net captures of all birds at Traverse in 1988 during the first 7 h after sunrise on the 21 d when nets were open from before sunrise until at least noon.

Warblers were the most variable group. The mean capture times for foliage-gleaning warblers, such as Nashville (*Vermivora ruficapilla*), Yellow (*Dendroica petechia*), Yellow-rumped (*D. coronata*), Magnolia (*D. magnolia*), and Chestnut-sided (*D. pensylvanica*) warblers, were generally slightly later than the overall mean. American Redstarts (*Setophaga ruticilla*) were slightly earlier, closer to the overall mean, as were Common Yellowthroats (*Geothlypis trichas*). However, Ovenbirds (*Seiurus aurocapillus*), which feed on the ground, resembled the thrushes in being among the earliest species. Similarly, Northern Waterthrushes (*Seiurus noveboracensis*), which feed like Ovenbirds, were actually the earliest species at Cedarwoods, although insufficient numbers were caught at Traverse for analysis.

DISCUSSION

Arrival times in the study area at Prince Edward Point appeared to influence capture times for a few species, such as Blue Jays, Red-winged Blackbirds (*Agelaius phoeniceus*), and American Goldfinches (*Carduelis tristis*) that are primarily diurnal migrants (Bellrose 1971, Hall and Bell 1981, Schorger 1964). These were among the species captured latest in the day, and flocks of presumed migrant Blue Jays and blackbirds have often been observed flying into and over the study area late in the morning (Fred Cooke, pers. comm.; Weir 1972).

Most of the remaining species were nocturnal migrants that are thought to complete their overnight migrations before dawn (Bellrose 1971, Gauthreaux 1971, Lowery 1951, Richardson 1971). Nocturnal migrants have not been reported flying into Prince Edward Point during daylight hours by banders or bird-watchers, despite extensive coverage, suggesting that most individuals were in the study area before sunrise. Thus, arrival times probably had much less influence on the capture times of nocturnal than diurnal migrants. However, diurnal movements in and around Prince Edward Point are poorly understood, and there may be some interspecific

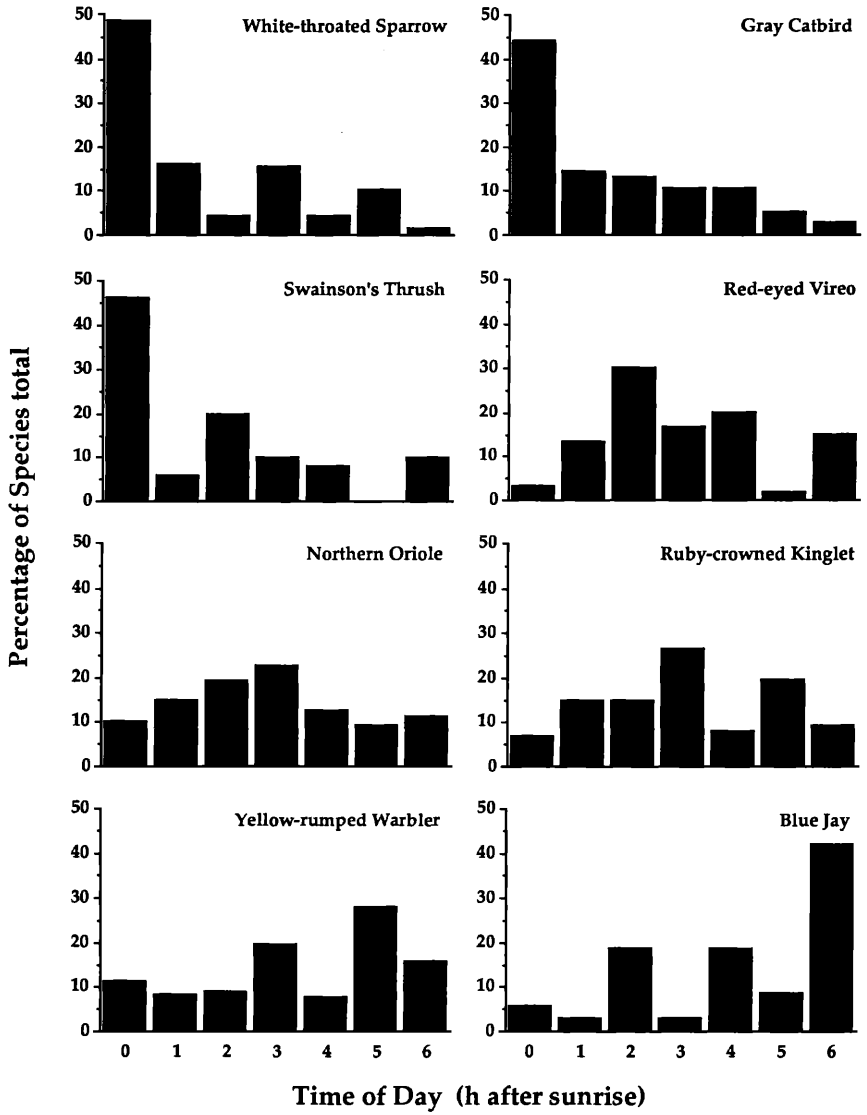

FIGURE 2. Percentage of mist-net captures each hour of representative species in 1988 at Traverse during the first 7 h after sunrise on the 21 d when nets were open from before sunrise until at least noon.

variation in, for example, departures from the study area or movement among habitats. Resumption of migration in a dawn flight by nocturnal migrants (Gauthreaux 1978), or delays in arrival caused by crossing large bodies of water (Gauthreaux 1971, 1972; Hebrard 1971) may also influence capture times.

TABLE 1. Capture times at Traverse in 1988. Includes only species with $n > 20$ in 1988.

Species	Total captured	Numbers captured per hour after sunrise								Mean capture time
		0	1	2	3	4	5	6	7	
Eastern Wood-Pewee (*Contopus virens*)	32	6	1	8	5	5	2	3	2	3.5
Traill's Flycatcher (*Empidonax traillii/alnorum*)	29	1	5	5	6	6	1	3	2	3.8
Least Flycatcher (*E. minimus*)	37	8	7	4	5	6	3	2	2	3.2
Eastern Kingbird (*Tyrannus tyrannus*)	24	0	1	1	3	7	1	6	5	5.2
Blue Jay (*Cyanocitta cristata*)	80	4	2	13	2	13	6	29	11	5.5
House Wren (*Troglodytes aedon*)	26	15	2	4	1	2	1	1	0	2.0
Ruby-crowned Kinglet (*Regulus calendula*)	87	6	13	13	23	7	17	8	0	3.6
Veery (*Catharus fuscescens*)	33	15	7	5	1	2	2	0	1	1.7
Swainson's Thrush (*C. ustulatus*)	51	23	3	10	5	4	0	5	1	2.2
Wood Thrush (*Hylocichla mustelina*)	34	30	1	1	0	2	0	0	0	0.7
American Robin (*Turdus migratorius*)	43	18	7	7	5	2	2	1	1	2.0
Gray Catbird (*Dumetella carolinensis*)	78	34	11	10	8	8	4	2	1	2.5
Cedar Waxwing (*Bombycilla cedrorum*)	24	0	1	7	0	7	0	6	3	5.1
Red-eyed Vireo (*Vireo olivaceus*)	61	2	8	18	10	12	1	9	1	3.7
Nashville Warbler (*Vermivora ruficapilla*)	42	3	1	4	13	6	9	4	2	4.2
Yellow Warbler (*Dendroica petechia*)	168	23	22	26	28	26	14	25	4	3.7
Chestnut-sided Warbler (*D. pensylvanica*)	23	2	2	3	4	4	2	4	2	4.1
Magnolia Warbler (*D. magnolia*)	69	1	9	16	12	21	6	1	3	3.8
Yellow-rumped Warbler (*D. coronata*)	204	23	17	18	40	16	57	32	1	4.0
American Redstart (*Setophaga ruticilla*)	23	1	2	6	6	4	1	2	1	3.5
Ovenbird (*Seiurus aurocapillus*)	23	3	6	9	1	4	0	0	0	2.5
Common Yellowthroat (*Geothlypis trichas*)	40	5	6	6	5	7	2	6	3	3.8
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	63	11	2	11	18	10	2	8	1	3.4

TABLE 1. Continued.

Species	Total captured	Numbers captured per hour after sunrise								Mean capture time
		0	1	2	3	4	5	6	7	
Chipping Sparrow (*Spizella passerina*)	79	19	2	15	15	15	8	5	0	3.1
Field Sparrow (*S. pusilla*)	29	12	7	3	3	3	0	0	1	1.7
Song Sparrow (*Melospiza melodia*)	33	11	11	2	1	1	3	4	0	2.2
Lincoln's Sparrow (*M. lincolnii*)	21	7	3	5	2	1	1	2	0	2.4
Swamp Sparrow (*M. georgiana*)	24	14	2	3	2	1	1	1	0	1.6
White-throated Sparrow (*Zonotrichia albicollis*)	149	72	24	6	23	6	15	2	1	1.8
Red-winged Blackbird (*Agelaius phoeniceus*)	36	0	4	2	11	2	4	11	2	4.8
Northern Oriole (*Icterus galbula*)	92	9	13	17	20	11	8	10	4	3.6
American Goldfinch (*Carduelis tristis*)	71	0	2	18	12	19	11	8	1	4.3

Nonetheless, the most important influence on capture times of nocturnal migrants was probably behavior pattern within the study area. Much of the variation among species appeared to be related to foraging guilds, possibly due to differences in the timing of prey availability. Species such as thrushes and Gray Catbirds, which prefer soft moist prey on the ground (Blake and Hoppes 1986), were caught mainly early in the morning. Their prey is likely to be most active early in the day before the ground becomes hot and dry. Foliage-gleaning species, such as many warblers, kinglets and vireos, were caught most often in mid-morning. Foliage insects such as caterpillars tend to become more active and thus more visible as air temperatures rise (Avery and Krebs 1984). Sallying insectivores, such as smaller flycatchers, tended to be caught slightly earlier than the warblers. This may occur because insects exposed to sunlight in treetops and open zones become active earlier than those shaded by leaves (Balda 1969).

The similarities within some taxa were probably due to similar foraging behavior within those groups. The influence of foraging behavior on capture time is further supported by comparison of taxonomically diverse, but ecologically similar, species. Northern Waterthrushes and Ovenbirds, although warblers, have similar morphological adaptations to thrushes, and feed in similar habitats (Blake and Hoppes 1986, Rappole and Warner 1980). Like thrushes, and unlike most other warblers, their mean capture times were earlier than the overall mean. American Redstarts, which overlap ecologically with Least Flycatchers (Sherry 1979), were earlier than most of the foliage-gleaning warblers and only slightly later than Least Flycatchers.

These general patterns were similar to those found by Robbins (1981) on the breeding grounds, where the birds were presumably not moving out of the study site, thus providing further evidence that differences in activity patterns were the main factors affecting capture times at Prince Edward Point. However, it is quite possible that arrival times could be much more important at other sites, particularly where many species are actively migrating during the day.

Regardless of the causes of interspecific variation, it is clear from this study that time of day will often need to be considered when using mist-net data to estimate relative abundance of species. Early morning sampling will underestimate species active later in the morning, and vice-versa. If there is variation among locations or years in the times that nets were open, simple indices such as number of birds per net hour will be misleading. Ideally, the timing of netting should be kept constant in all areas, but this may not be possible in practice. In such cases, simple corrections, such as analyzing only birds caught within a limited period, may be adequate if the same factors affect capture times at all sites. However, if the patterns differ among sites then more complex statistical procedures may be necessary, and comparisons among sites may be, at best, rough approximations.

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