Running Head: NORTHERN SAW-WHET OWL SUMMARY

Northern Saw-whet Owl Summary and Comparisons of Camp Hydaway and Surrounding Virginia Coastal Plains and Mountain Regions

Tanner Eiden

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Acceptance of Senior Honors Thesis

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Gene Sattler

Gene Sattler, Ph.D.
Chairman of Thesis

Timothy R. Brophy, Ph.D.
Committee Member

Mark Harris, Ph.D.
Committee Member

James Nutter, D.A.
Honors Program Director

26 April 2006

Date

Abstract

Migrating Northern Saw-whet Owls were captured and banded at a site in the Virginia Piedmont in the fall of 2005, and the results were compared with the results of banding from the previous three years. The results were also compared to similar efforts to monitor migration that were made on the coastal plains and the mountain regions of Virginia in these same years. Migration volume was higher in the mountains compared to the piedmont and coast, and the mountains experienced the earliest migration peak, followed by the piedmont, and then the coastal plain. There was not a significant difference between adult and immature Northern Saw-whet Owls in their migration timing. Adults made up the bulk of migrating owls in the mountains and on the piedmont, which is consistent with these years being non-invasion years. The coastal site, however, had a nearly even ratio of adults to immatures, which may reflect a geographic variation in migratory route in these two age classes.

Northern Saw-whet Owl Summary and Comparisons of Camp Hydaway and Surrounding Virginia Coastal Plains and Mountain Regions

The Northern Saw-whet Owl (*Aegolius acadicus*) is one of the smallest owls in the world (Sibley 2003). The total length of males average only 18-20 cm. This is roughly the same size as an American Robin (*Turdus migratorius*). Females are a little larger at about 20-21.5 cm (Davis 1965). Males and females weigh about 75 g and 100 g respectively although their mass varies seasonally (Buckholtz et al. 1984). For example, females can weigh up to fifty percent more during egg laying (Cannings 1993).

Northern Saw-whet Owls have a large head without the ear tufts found in some owl species, and have a round facial disk that helps gather sound used to locate prey. Like other owls, their ears are asymmetrically placed in the skull, allowing for accurate prey targeting using only hearing. They have short legs that are densely feathered down to their talons, providing insulation and protection. Their iris color ranges from yellow to golden, with golden eyes being more prevalent in adults. The species has rounded wings and a short tail (Cannings 1993).

The natal plumage of Northern Saw-whet Owls consists of being completely covered in white down. Their juvenile plumage begins to appear only a week after they hatch and is finished by the time they leave the nest a month later. The chest and upperparts of juveniles are dark brown without spotting. Their facial disk is a dark almost black brown with a bright white patch between and just above the eyes. The feathers on their cheeks also contain white, but only the most anterior feathers are streaked with white. Juveniles lack white markings on their upper parts, except on their tails and wings, and have a characteristic white, Y-shaped marking between their eyes. The most basic

differences between juvenile and adult Saw-whets is their face and wing coloration. Adult Northern Saw-whet Owls' facial disks are white above, below, and between their eyes. The outer parts of their facial disks are light buff, with the feathers containing dark brown at the edges. The crown and the edges of the facial disk are streaked with white, and there are white spots on the back, nape and scapular feathers (Cannings 1993).

Juvenile Northern Saw-whet Owls undergo a molt very quickly at around two to four months of age. This molt can last for three to four weeks and can start anywhere from mid-June to the end of September. Fresh primary and secondary wing feathers in Northern Saw-whet Owls are white on the underside and tinted pink due to a protein in the blood. However, this protein disappears within a few months, and the pink color fades. The molt begins at the head and proceeds posteriorly, ending with the leg feathers. This molt ushers in the adult plumage (Cannings 1993).

The adult plumage consists of dark brown upperparts with white streaks at the crown and neck, and white spots on the back. The underparts are white with brown spots. The tail feathers, wing feathers and upper parts are dark brown on top but paler below. The upper wing and tail coverts have varying amounts of white spotting on them, while the marginal upper wing coverts are white. There are also two or three white bars across the feathers. The legs are very densely feathered and have a white to buff coloration (Cannings 1993).

Molting is an essential part of the bird's physiology and is also the basis by which individuals are aged (see below). Old feathers wear out and must be replaced with new feathers. This is a complex process that must be carefully timed otherwise the birds will be rendered flightless either because they have too many partially grown new feathers or

their flight capabilities are lessened or because they have too many old, worn feathers. Feathers serve as a source of warmth and protection as well. Thus, a bird must be able to molt only certain feathers at a defined time in order to retain its high performance flight capacities. Northern Saw-whet Owl yearlings molt their outer six primary flight feathers and their inner eight secondary flight feathers in the first year, and then molt a different set of feathers the next year. Adult birds in their first and second years can thus be aged by the feather molt pattern (Cannings 1993). However, the mismatch pattern of old and new feathers in Saw-whets that are older than three years of age make it almost impossible to age the individual owls (Buckholtz et al. 1984).

The Northern Saw-whet Owl exhibits very little geographic variation in terms of size and color within its range. However, there are two subspecies and a few related species of significance to consider. Most Northern Saw-whet Owl's are of the nominate subspecies, *Aegolius acadicus acadcius*. However, on Queen Charlotte Island, British Columbia there exists one distinct subspecies, *Aegolius acadicus brooksi.* This subspecies resembles *A. a. acadicus* except that their white underparts are replaced by buff, and they possess white spots on the upperparts, wings and tail, with a certain amount of buff. Juveniles of the two subspecies are nearly identical, except that *A. a. brooksi* has a buff crown instead of white, and spots on the primary and secondary wing feathers; its wing coverts are also infused with buff. The Unspotted Saw-whet Owl (*Aegolius ridgwayi*) is a related species found in Central America south and east of the Isthmus of Tehuantepec (Cannings 1993).

The distribution of Northern Saw-whet Owls encompasses much of North America. Their breeding range includes much of the northern United States and southern

Canada, and the breeding habitat consists of a wide range of forest types. Northern Saw-whet Owls found in the western mountains tend to be confined to mid and lower elevation forests consisting primarily of coniferous trees such as ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). In the northeastern parts of the United States and southern Canada Saw-whets prefer areas of cedar and pine forests (Cannings 1993).

Northern Saw-whet Owls winter primarily in the central and southern part of the United States (Brinker et al. 1997). They are a migratory species (Catling 1971) and have been found wintering as far south as central Florida. Most wintering Northern Saw-whet Owls in the Rocky and Appalachian Mountains migrate to lowland areas during the winter (Cannings 1993).

Northern Saw-whet Owls are very efficient predators that feed primarily on small mammals. They hunt at night beginning just after sunset, and conclude just before sunrise. They hunt from low perches, most often along the forest edges or in forest openings. Both their excellent hearing and their vision are designed to function efficiently at low light levels, allowing them to detect prey under these conditions (Cannings 1993).

Northern Saw-whet Owls forage opportunistically, and their prey selection is influenced by their habitat. They possess a diurnal metabolic cycle that peaks in the evening between 10 PM and midnight, and again in the early morning between 4 and 7 AM. They maintain a body temperature between 38 and 39 degrees Celsius. As their temperature increases, their activity diminishes, their body feathers compress, their wings are held away from the body, and they close their eyes. They also increase heat loss by panting and gular fluttering (Cannings 1993).

The predominant prey of Northern Saw-whet Owls consists of woodland mice, such as deer mice (*Peromyscus*). Voles (*Microtus* spp.) are another prey item that the owls feed on in abundance, especially in the winter and early spring. Small birds are also eaten during the migration period when the owls migrate in large numbers at night. Insects such as grasshoppers and beetles will occasionally supplement the Saw-whet's diet as well. Saw-whets living on Queen Charlotte Island are also known to feed on inter-tidal invertebrates such as crustaceans (Cannings 1993).

Often only half of any prey item taken is consumed. Males often bring excess food to the nest, especially during egg laying. Uneaten prey items are usually stored on branches. In the winter this food is well kept and then thawed by placing it under the bird in an incubation position before it is consumed (Cannings 1993).

Like most birds, Northern Saw-whet Owls exhibit complex behaviors in order to communicate information to other birds, including an array of nine different vocalizations Northern Saw-whet Owl calls are homologous to the vocalizations made by the Boreal Owl (*Aegolius funereus)*. The Northern Saw-whet Owl is named for a "saw-whet" call, although there is dispute about which call this is, as Saw-whets make a variety of calls, and the literature is ambiguous as to which vocalization is the true "saw-whet" call. The call is said to be likened, however, to a saw being sharpened or "whetted" (Cannings 1993).

The first call that many people claim is the "saw-whet" call is an advertising call that consists of a repetitive series of notes pitched at 1100 Hz. This call is given at a rate of two calls per second and is made primarily by males although females will make a similar call during courtship. The female's variant is much softer, however, and less

consistent in both amplitude and pitch than that of their male counterparts. The male's version of this call is very loud and can be heard 300 meters away in a forest and up to a kilometer away over water. Territorial males will respond to a recorded playback of this call with a softer, lower pitched version that is more rapid, at four to five notes per second (Cannings 1993).

The second call thought to be the "saw-whet" call is a nasally whine or wail. This call is produced at about the same pitch as the previous call, but lasts for two to three seconds. The pitch will change during the call as more harmonics are added, as will the volume (Cannings 1993).

The last vocalization suggested to be the Saw-whet's namesake is probably the closest sounding call to the sound of a saw. It consists of a brief succession of loud calls that usually consists of three calls per series. This call is made by both sexes. This particular call has been described as a "ksew-ksew-ksew" call (Cannings 1993).

Northern Saw-whet Owls make a variety of other vocalizations that are primarily restricted to particular situations, such as a short buzzing call made when they are threatened. Some calls are made by one sex exclusively, such as a short, quick series of whistled notes made quietly by a male carrying food as he nears the nest. This is a visiting call made to alert the female, yet not alert predators. Northern Saw-whet Owls will also make a call that is similar to that of the American Woodcock (*Scolopax minor*), consisting of twittering notes (Cannings 1993).

Northern Saw-whet Owls have a short courtship period that is initiated by the male in the winter using the advertising call (Bent 1938). From late winter to early spring males will sing many times from a potential nest site until they are approached by

females who respond by giving out either a sharp "tsst" call or a series of whistled notes. They will many times engage in allopreening during this time. Once the female selects and has settled into the nest site the male will discontinue the advertising call. Unmated males, however, will continue to give advertising calls into late spring. Males usually sing from their selected nest sites immediately after sunset, and intermittently until just before sunrise (Cannings 1993).

Saw-whets are usually monogamous birds but have been known to be polygynous in times of prey abundance. The male will bring the female food for several days until she lays her eggs, usually around mid-March. Most nest sites are woodpecker nest cavities where the eggs are deposited on wood chips or other debris. Most nests are not reused due to the hard layer of dried prey remains that is left in the bottom of the nest. Nests are kept very clean by removing all pellets, feces and rotting food remains while the female is brooding the young, but after she is done the excess debris piles up (Cannings 1993).

The eggs are smooth white ovals and are laid at two day intervals, usually beginning a few days after the female has chosen a nest site. Clutch sizes vary, but typically five or six eggs are laid in each clutch (Udvardy and Farrand 1994). The female alone incubates the eggs, beginning after the first one is laid, and incubation lasts from 27-29 days. A female will interrupt incubation only to defecate or cough up a pellet. During this time the male will feed her, continuing this through the brooding period. The eggs hatch at roughly the same interval that they are laid, about one every two days (Cannings 1993).

Newly hatched young are blind and covered in white down. Their eyes open from a week to ten days after hatching, and their egg tooth disappears after ten days. During their first week hatchlings begin growing new feathers and gain weight quickly. By eighteen days of age the female has left the nest to roost elsewhere. This has created speculation as to whether polyandry occurs among Northern Saw-whet Owls; however, there has never been definitive evidence of this. There are, however, many cases of broods being laid in June or July, and these broods are probably second broods laid by females that have left their first brood to find another mate and have produced a second brood (Cannings 1993).

Males continue to provide all food until the female leaves the nest, at which time she will either feed the young or leave her brood. Food is given by the male to the female, who tears it apart and feeds the small nestlings first. Larger nestlings are known to feed the smaller nestlings in the absence of the female. The nestlings are continually fed for about a month until they disperse from the nest area. Fledglings are capable of flying extremely well after leaving the nest, and most nestlings are completely independent anywhere from six to eight weeks after fledging (Cannings 1993).

Approximately half of all nestlings survive to adulthood, with many dying of starvation and predators. Many species of flies will also lay eggs on the nestlings, and the blood-feeding fly larvae often weaken and kill the nestlings. Fleas are also a problem in nests because they can survive from the previous year if the nest was used then (Cannings 1993).

Northern Saw-whet Owls are solitary birds that have little interaction with other birds besides their mates and young. They are regularly mobbed by smaller birds to

protect their young. They have also been known to be killed by larger owls such as the Long-eared Owl (*Asio otus*) and the Barred Owl (*Strix varia*). Northern Saw-whet Owls respond to predators during the night hours by issuing the "ksew" call. Birds disturbed during the day react differently by taking on an erect posture in which the breast and upper back plumage are tightly compressed. The wing nearest the offender is also raised straight to the level of the beak and points to the intruder, the frontal crown feathers above each eye are raised, and the eyes are opened wide. This behavior makes the bird easy to detect and if the offender approaches more closely the bird will exhibit a different behavior. The bird will begin bobbing its head from side to side and up and down, while shifting from one foot to the other. The bird will also defecate, snap their bills and eventually take flight. A third threat behavior consists of the Saw-whets exaggerating an upright stance and fluffing up their body plumage. They will then bow their body and head, and then raise their head, letting out an insect-like buzz (Cannings 1993).

Because of its secretive nature, the Northern Saw-whet Owl was considered non-migratory until the early 1900s (Taverner and Swales 1911). It is now known, however, that a broad front migration occurs throughout the United States (Holroyd and Woods 1975). The migration of Northern Saw-whet owls is known to exhibit an irruptive pattern, in which flight volumes several times greater than normal occur, due apparently in part to prey density fluctuations (Whalen et al. 1997, Catling 1971). Saw-whet migration was first studied extensively using passive netting in the 1960s and 1970s. (Mueller and Berger 1967, Erdman et al. 1997). In the mid 1980's it was discovered that use of an audiolure of the male's advertising call increases capture rates by four to ten times (Erdman and Brinker 1997, Evans 1997). Since then, the number of Saw-whet banding

stations in the eastern U.S. has increased dramatically, which has significantly increased the opportunity to learn about Saw-whet migration dynamics.

The bulk of eastern banding stations are concentrated in southern Ontario, southern New England, Pennsylvania, Maryland and West Virginia. Some of the stations have been banding for over twenty years (Evans 1997) and have revealed much about Saw-whet migration dynamics. In Virginia, the first banding effort was initiated on the lower Delmarva Peninsula in 1994 and is shedding light on the coastal plain migration (Whalen et al. 1997, Watts 2001, Smith et al. 2006). A second effort began in Rockingham County in 2001 and is providing useful comparative data on the migration taking place in the mountainous ridge and valley region. But to date, there are no other published migration studies from Virginia.

Based on the past success of other researchers, yearly banding was begun in 2002 by the biology department at Liberty University to provide comparative data for the piedmont region of Virginia. In its first three years this study operated between 21-26 nights a season and was conducted from the end of October to early December.

This study was an extension of this previous work and was designed to answer several questions. First, we wished to establish the timing of fall migration by the Northern Saw-whet Owl in Virginia's piedmont. Collecting this data over multiple years will help define how much variation occurs among seasons and will help highlight patterns that might exist. We also hoped to discover if there was any variation in timing between the piedmont and the ridge and valley or the coastal plain regions. A second question we were addressing concerns variation in the owl's numbers among years. Northern Saw-whet Owl's periodically have an irruptive year in which a preponderance

of migrants are juveniles and in which the number of both juvenile and adult owls migrating can be several fold higher than in non-irruptive years, when adult owls make up the majority of migrants (Whalen and Watts 2002, Weir et al. 1980). Long-term data are needed to investigate this phenomenon in the piedmont. A third question addressed was the degree of variation in migration that occurs between males and females and among age classes. In many bird species, including the Northern Saw-whet Owl, males do not migrate as far south as females, on average (Duffy and Matheny 1997). They instead move a shorter distance from the breeding grounds in order to return more quickly in the spring and establish breeding territories the next year. Young birds can also show such differences by migrating further south where lower snow amounts provide easier access to rodent prey than their adult counterparts in more northerly regions. Because our banding station was one of the most southerly stations in the eastern U.S., it gave us the opportunity to add appreciable data to the above questions.

Materials and Methods

Our study was conducted at Camp Hydaway in Campbell County, Virginia from late October to early December 2005. Camp Hydaway is located at the base of Candlers Mountain, is owned by Thomas Road Baptist Church, and is located at 37° 20' 35" N, 79° 09' 40" W. Capture of Saw-whet's was accomplished by using five 61 mm mesh mist nets. Each net was 12m long and 2.6m high and was arranged in an east-west line along the southern slope of Candlers Mountain in a deciduous forest. A continuous audiolure of the Saw-whet advertising call was broadcast to attract the owls. The lure had a brief five second pause between calls with a longer twenty second pause after every three calls. Nets were opened at dusk and left open until about 11:00 P.M., with hourly checks made

for captured owls. These frequent checks ensured that netted birds experienced minimal stress.

Netted birds were placed in a cloth bag for transportation and brought to the Camp Hydaway main buildings located about a quarter-mile from the nets for processing. Each owl was weighed to the nearest tenth of a gram, and its wing length was measured to the nearest half of a millimeter. Using these measures, the sex of each owl was determined using U.S. Fish and Wildlife sexing criteria (Anonymous 1980) based on the fact that females average larger in size and weight than males (Buckholtz et al. 1984). However, there is some overlap in size, so some birds were designated as undetermined sex. The owls' molt patterns were also examined and used to age the birds. Blood proteins present in new, growing feathers fluoresce under an ultraviolet light. If the owl had all new wing feathers, it was classified as an immature bird. If new feathers are only found at the base and the end of the wing, this represents the molt pattern of a second year bird. For all other molt patterns, individuals were classified as beyond their second year. All birds older than an immature were grouped as adults. Finally, the owl was banded with a uniquely numbered U. S. Fish and Wildlife Service aluminum band and released. This band allowed for information from recaptured birds to be used in tracking the migratory movements of individual Saw-whets throughout the United States and Canada.

Comparative data was analyzed in this study for two other Northern Saw-whet Owl banding locations in Virginia. The first site was located on the southern tip of the Delmarva Peninsula in Northampton County, and is operated by the center for conservation biology of the College of William and Mary (Smith et al. 2006). It will be

referred to hereafter as the coastal site. The second was in Rockingham County at the Highland Retreat Camp, and is operated by Clair Mellinger of Eastern Mennonite University (C. Mellinger pers. comm.). It is located at 38° 46' 25" N, 78° 54" W, and will be hereafter referred to as the mountain site.

Significance levels were set at 0.05 for all statistical comparisons. Distributions were tested for normality using the Shapiro-Wilks W test. Sex and age ratios were distributed normally, and so were compared among localities using two-sample T-tests. All other distributions were non-normally distributed, and the nonparametric Mann-Whitney U test was used to compare the median date of passage between the locations for a given year, between years for each location, and between age classes at each location for a given year. The median date is defined as the date by which 50% of the year's total owls had arrived.

Results

Volume. The range of nights covered and the number of Saw-whets netted for the coastal and piedmont sites are presented in Tables 1 and 2. The total number of Northern Saw-whet Owls collected at the coastal site was greater than the total number of Northern Saw-whet Owls at the piedmont site. However, the coastal site was comprised of three banding stations, which banded all night as opposed to half the night at the piedmont site, where only one netting site was used. So when calculated on an owls per 100 net hours basis, the coastal site had a lower capture rate than the piedmont site, except in 2005.

Table 1

Sample effort and results of netting Northern Saw-whet owls in the piedmont region of Virginia, 2002-2005

	2002	2003	2004	2005
Trap Nights	21	26	26	38
Banding Period	Oct26-Dec14	Oct27-Dec9	Oct30-Dec14	Oct28-Dec11
Net Hours	540	640	610	805
New Owls	39	38	52	7
Owls/Trap Night	1.9	1.5	2	0.2
Owls/100 Net Hours	7.2	5.9	8.5	0.9

Table 2

Sample effort and results of netting Northern Saw-whet owls in the coastal region of Virginia, 2002-2005

	2002	2003	2004	2005
Trap Nights	37	43	46	48
Banding Period	Oct23-Dec15	Oct23-Dec15	Oct22-Dec15	Oct25-Dec15
Net Hours	7287	8279	8559	7421
New Owls	137	119	152	75
Owls/Trap Night	3.7	2.8	3.3	1.6
Owls/100 Net Hours	1.9	1.4	1.8	1.1

Table 3 presents similar data for the mountain region. The capture rate for owls per 100 net hours was three to five times higher than for the piedmont and ten to twenty times higher than the coastal sites. In contrast, the rate of capture within each site over the 2002-2005 period varied by only about two-fold. This variation occurred during years that were characterized by banding stations in the eastern U.S. as non-invasion years,

whereas during invasion years capture rates can increase by 100 fold over non-invasion years.

Table 3

Sample effort and results of netting Northern Saw-whet owls in the mountain region of Virginia, 2002-2005

	2002	2003	2004	2005
Trap Nights	12	18	19	26
Banding Period	Oct23-Nov27	Oct23-Dec9	Oct25-Dec4	Oct31-Dec5
Net Hours	226	417.3	443.5	765.9
New Owls	49	85	156	151
Owls/Trap Night	4.1	4.7	8.2	5.8
Owls/100 Net Hours	21.7	20.4	35.2	19.7

Table 4 displays the age ratios of the Northern Saw-whet Owls captured at the piedmont site. Twenty-seven immature Northern Saw-whet Owls were caught overall in the four year span of 2002-2005. This accounted for 19.8% of the total number of owls captured.

Table 4

Age ratios of owls captured in the Virginia piedmont, 2002-2005

YEAR	IMMATURE	ADULT	UNKNOWN	TOTAL
2002	11 (28.2)	28 (71.8)	0 (0)	39
2003	10 (26.3)	26 (68.4)	2 (5.3)	38
2004	6 (11.5)	43 (82.7)	3 (5.8)	52
2005	0 (0)	7 (100)	0 (0)	7
TOTAL	27 (19.8)	104 (76.5)	5 (3.7)	136

Table 5 displays the age ratios from the Northern Saw-whet Owls captured in the mountains. The average number of immatures captured was 32.7%, higher than the piedmont, but not significantly so (P=0.082).

Table 5

Age ratios of owls captured in the mountains of Virginia, 2002-2005

YEAR	IMMATURE	ADULT	UNKNOWN	TOTAL
2002	17 (32.7)	35 (67.3)	0 (0)	52
2003	32 (36.8)	52 (59.8)	3 (3.4)	87
2004	60 (37.0)	101 (62.4)	1 (0.6)	162
2005	41 (26.0)	116 (73.4)	1 (0.6)	158
TOTAL	150 (32.7)	304 (66.2)	5 (1.1)	459

Table 6 displays the age ratios from the coastal sites. Immature Northern Saw-whet Owls accounted for 54.6% of the total Saw-whets captured. This figure was significantly higher than that of both the mountain region (P=0.020) and the piedmont (P=0.006).

Table 6

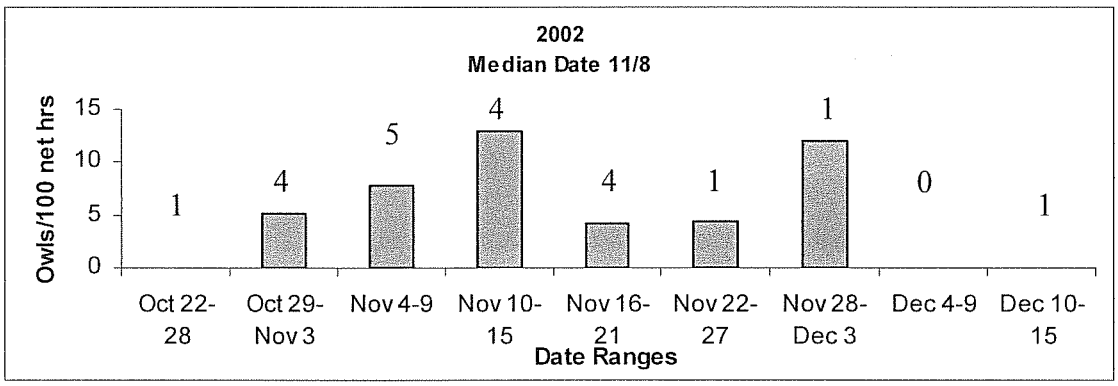
Age ratios of owls captured in the coastal sites of Virginia, 2002-2005

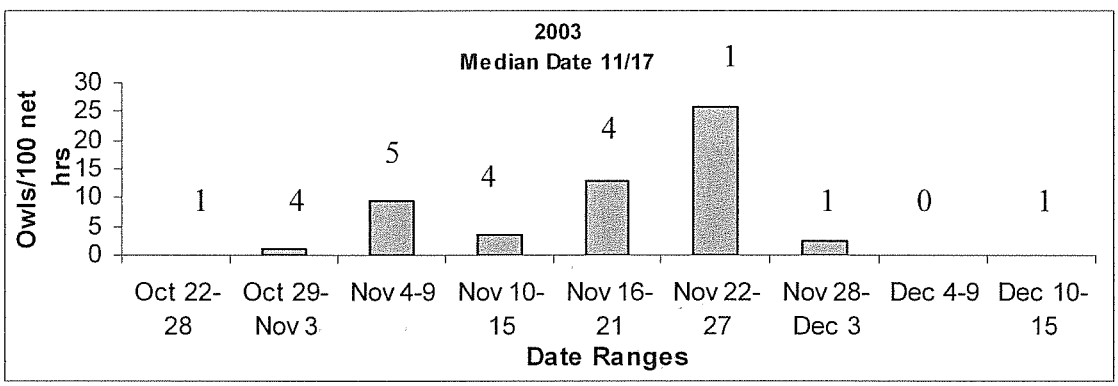
YEAR	IMMATURE	ADULT	UNKNOWN	TOTAL
2002	58 (42.3)	79 (57.7)	0 (0)	137
2003	71 (59.7)	48 (40.3)	0 (0)	119
2004	77 (51.0)	74 (49.0)	0 (0)	151
2005	57 (76.0)	18 (24.0)	0 (0)	75
TOTAL	263 (54.6)	219 (45.4)	0 (0)	482

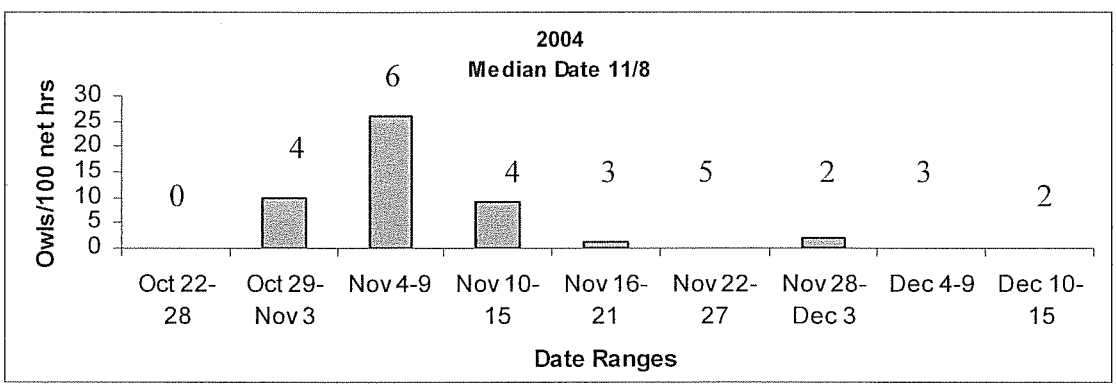
Timing. The piedmont site had a median date range of November 8 through November 18 for the four years (Figure 1). The pattern seen was of an early to moderate migration in 2002, 2004, and 2005 and a later migration in 2003. The median date of

November 21 in 2003 was significantly later than for 2002 (P=0.001). The coastal site had a median date range of November 9 through November 21 (Figure 2). The pattern observed was of an early migration in 2004, a moderate migration in 2005, and a later migration in 2002 and 2003. The early migration in 2004 differed significantly from 2002 (P<0.001) and 2003 (P=0.001), and the moderate migration in 2005 differed significantly from 2003 (P=0.010). The mountain site had a median date range of November 4 through November 11 (Figure 3). The pattern was of an early migration in 2002 and 2004 and a later migration in 2003 and 2005, with the two pairs of years differing significantly from each other (P=0.022 to P<0.001).

Figure 1. This 2002-2005 data displays the timing and captures rates of Northern Saw-whet Owls for every 100 net hours for Piedmont, Virginia. Numbers above each date range indicate the number of nights that were sampled during that period. The median date of movement is also given for each under the title.







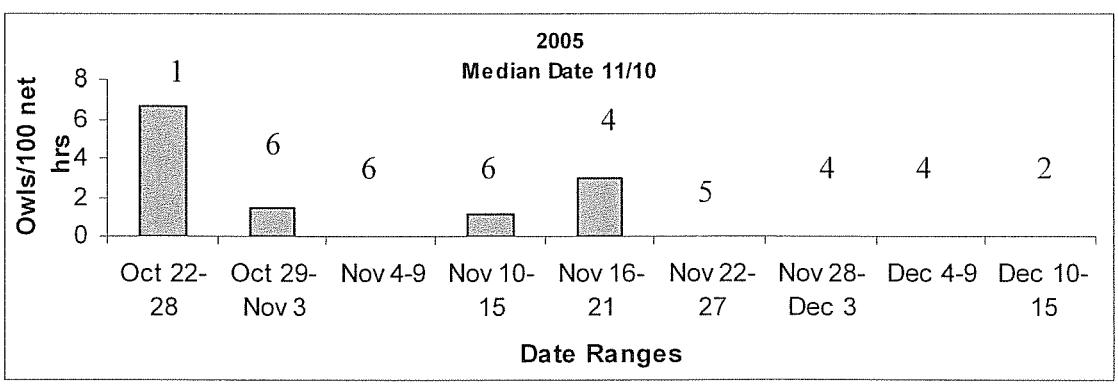
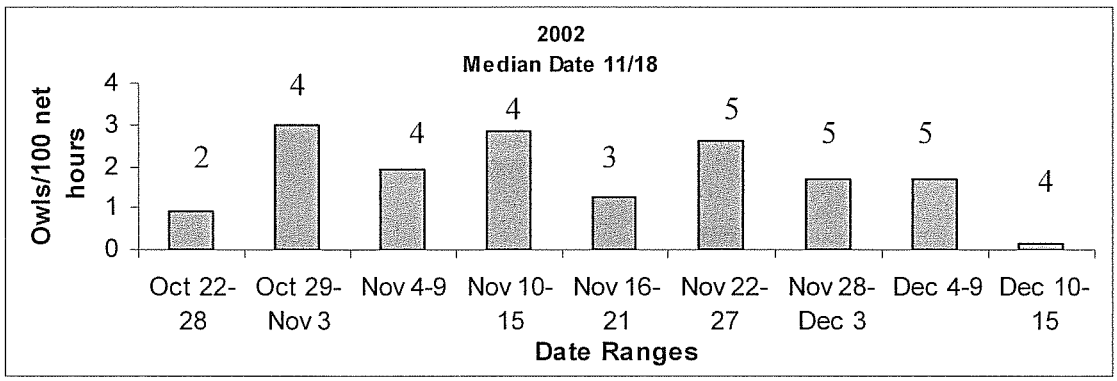
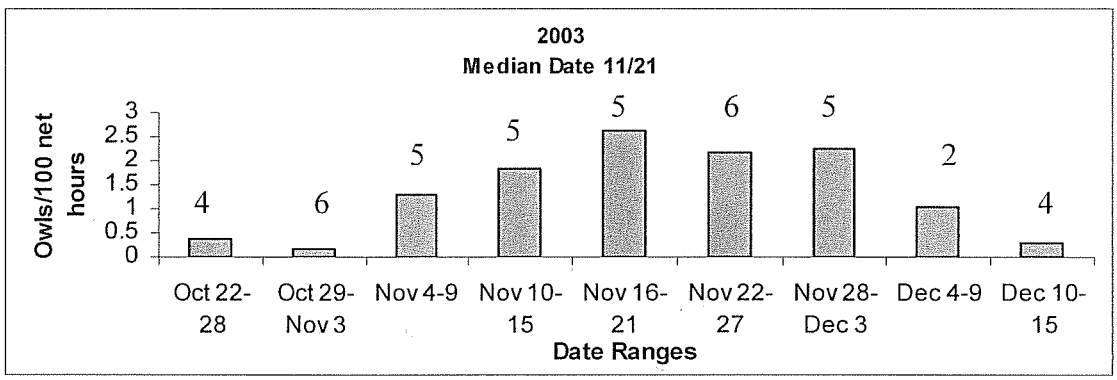
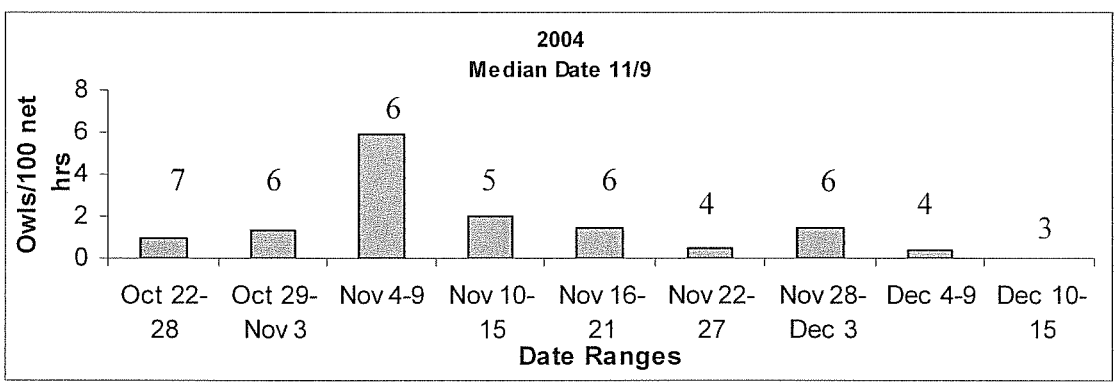


Figure 2. This 2002-2005 data displays the timing and captures rates of Northern Saw-whet Owls for every 100 net hours for the Lower Delmarva Peninsula. Numbers above each date range indicate the number of nights that were sampled during that period. The median date of movement is also given for each under the title.







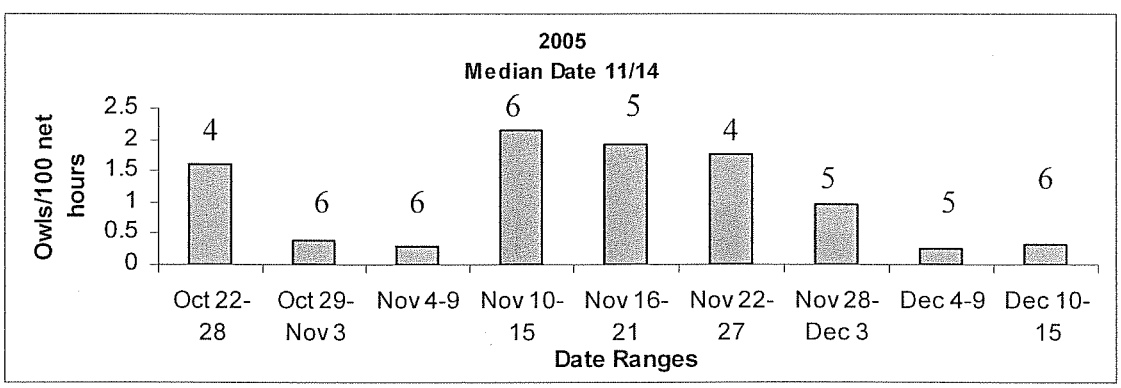
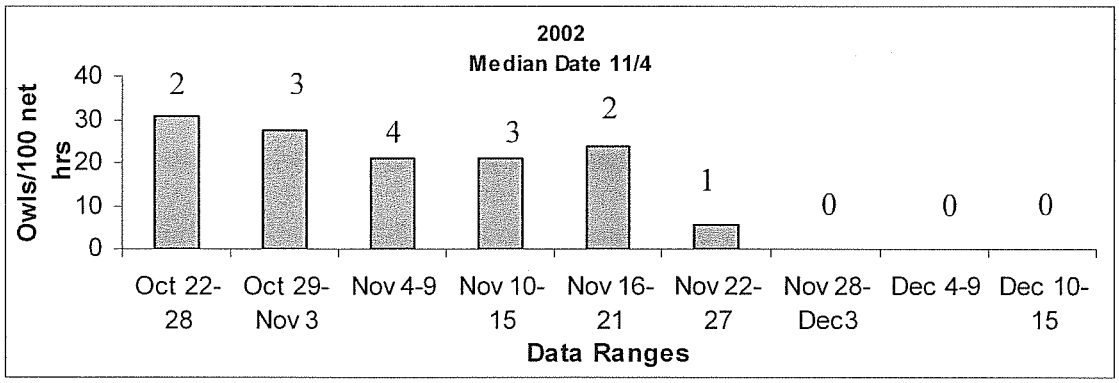
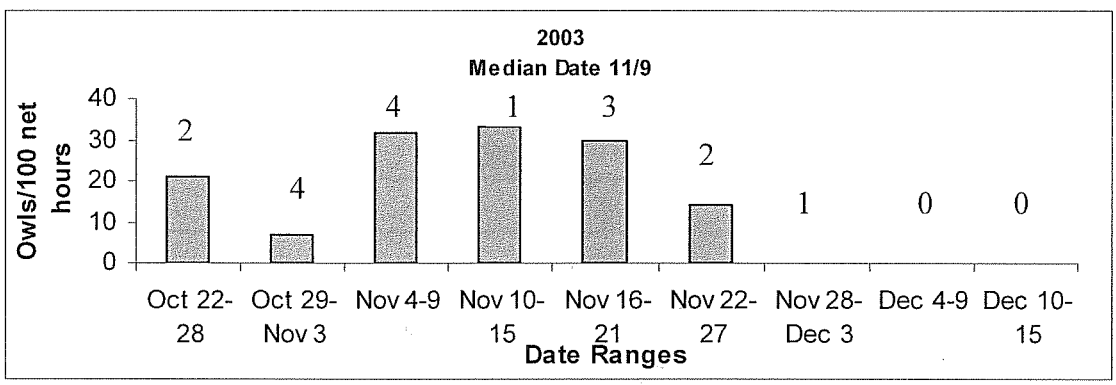
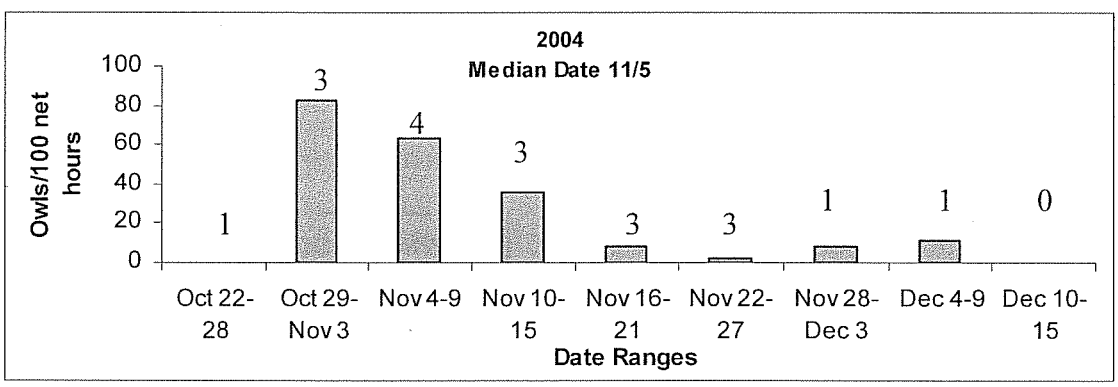


Figure 3. This 2002-2005 data displays the timing and captures rates of Northern Saw-whet Owls for every 100 net hours for the Mountain Regions of Virginia. Numbers above each date range indicate the number of nights that were sampled during that period. The median date of movement is also given for each under the title.







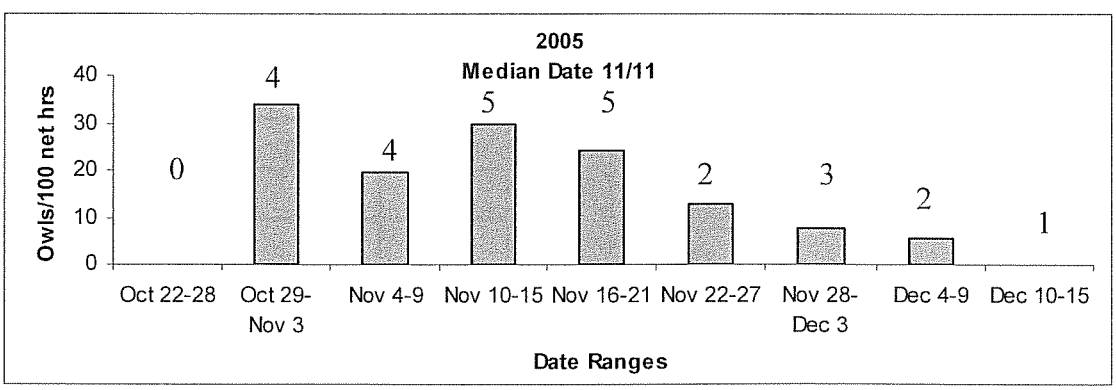


Table 7 compares the timing among locations each year from 2002-2005. The pattern that emerged consistently was that the mountains dates were earliest, followed by the piedmont sites (with the exception of 2005, which consisted of a small sample size), and finally the coastal sites in median dates. The distributions for each site were compared to one another (Table 8). For 2002 and 2003 each of these differences was significant, and in 2004 and 2005 the comparisons were either significant or somewhat suggestive of a relationship.

Table 7

Median dates from each Virginia site for the years 2002-2004

Locations	2002	2003	2004	2005
Mountains	4-Nov	9-Nov	5-Nov	11-Nov
Piedmont	8-Nov	17-Nov	8-Nov	10-Nov
Coastal	18-Nov	21-Nov	9-Nov	14-Nov

Table 8

P values of the Mann-Whitney U tests between each location for each year's timing distribution of the Northern Saw-whet Owls

2002	Coast	Pied	Mts
Coast	X	0.003	<0.001
Pied		X	0.033
Mts			X

2003	Coast	Pied	Mts
Coast	X	0.004	<0.001
Pied		X	0.001
Mts			X

2004	Coast	Pied	Mts
Coast	X	0.108	<0.001
Pied		X	0.001
Mts			X

2005	Coast	Pied	Mts
Coast	X	0.188	0.02
Pied		X	0.292
Mts			X

The timing of the immature owls and the adult owls for each location and year displayed no consistent trend (P=0.16-0.87). The only significant comparison was for the piedmont region in 2004 (P=0.001), when the adult's median date was earlier than the immature's median by 5.5 days. However, there was a small sample size of immatures for that year.

Sex and age ratios. Table 9 shows the sex ratios for each location between the years 2002-2005. The coastal site had a significantly higher percentage of males caught compared to the piedmont (P=0.006) and mountains (P=0.026), while the mountains had a significantly higher number of females caught compared to the piedmont (P=0.007) and the coast (P=0.009).

Table 9

Average sex ratio of owls at each Virginia location for 2002-2005

	Males	Females	Unknown
Mountains	2.4	90.2	7.4
Piedmont	4.4	74.3	21.3
Coastal	17.4	62.3	20.3

Table 10 shows the age ratios for 2002-2005 for each location. The coastal site had a higher percentage of immatures compared with the piedmont (P=0.006) and mountains (P=0.020) and a lower percentage of adults compared with the piedmont (P=0.009) and the mountains (P=0.026).

Table 10

Average age ratios of owls at each Virginia location for 2002-2005

	Immatures	Adult	Unknown
Mountains	32.7	66.2	1.1
Piedmont	19.8	76.5	3.7
Coastal	54.6	45.4	0

Discussion

Volume. There were notable differences in owls per 100 net hours between each location (Tables 1-3). The coastal plain had the smallest volume of migration (except in 2005), the piedmont had a higher volume, and the mountains had the highest capture rates. However, several cautions must be taken in interpreting these data.

First is the possible influence of microhabitat that might be present at each site. There is anecdotal evidence to suggest that the habitat near banding sites influences capture rates (Duffy and Matheny 1997). Support for this is evident at the coastal banding location that actually consisted of three netting sites within ten square kilometers. Over the course of its operation, one site has consistently captured between 15 and 20% of the total owls, and the other two stations have each captured between 40 and 50% of the yearly owl numbers, a difference of two to three fold between the sites (Smith et al. 2006).

A second consideration is that the piedmont site did not have a continuous sampling effort throughout the season from 2002 through 2004 like the coastal site did. Resources were limited, preventing nightly coverage throughout each season. More effort will have therefore likely occurred under more favorable conditions or peak migration periods, resulting in a bias. This might be evident when considering the 2005 numbers

when the piedmont station was continuously operated, and the capture rates decreased during this period. However, it is also true that only a few owls were captured during the peak migration period in 2005 for the piedmont, so the increased coverage does not appear to be the only reason for a decline. This is also supported in that the coastal site capture rate also declined from 2004 to 2005 in spite of continuous coverage.

A third consideration in comparing migration volume among locations is that the three coastal sites located within ten square kilometers of one another were likely not independent of each other as sampling units because of their close proximity. These close sites allow for opportunities to study stopover dynamics of Northern Saw-whet Owls traveling from one banding site to the next. However, with that comes the likelihood of sampling overlap, which could lead to lower efficiency in sampling because the three stations are sampling a part of the same migrant population.

Nonetheless, it still seems likely that the mountain location experienced a greater migration than both the coastal and piedmont sites, given the size of the capture rate difference. This suggests that the mountain region may serve as a significant flyway for Northern Saw-whet Owls. One possible reason for this could be the reliability of stopover habitat in that region compared with the coastal and piedmont regions that have more fragmented woodland habitat. Additional years of comparative data on capture rates among these locations with additional continuous coverage could clarify whether these differences are genuine.

All three sites experienced some variation in flight volume among years (Figures 1-3). The piedmont, during the years 2002-2004, had relatively consistent owl capture rates with the exception of a noticeable decline in 2005 (Figure 1). Each of these four

years has been recognized as non-invasion years (Smith et al. 2006). Because there was continuous coverage at the piedmont site in 2005, at least for the first half of the night, it is reasonable to assume that this decline in 2005 was real and not the result of poor sampling during this time. Also, the piedmont region was not the only area to show a decline; for example the coastal site also experienced a moderate decline (Figure 2), although not as dramatic as the piedmont site. The mountain site (Figure 3), on the other hand, experienced no appreciable decline in 2005. This variation in numbers among locations suggests that migration dynamics might vary geographically. And because reports from northern banding sites indicated normal numbers of owls migrating in 2005, this suggests that these birds did not migrate as far south in 2005 in the piedmont region of Virginia as they did in the three prior years.

Timing. The data on median dates of migration do not clearly illustrate a consistent pattern among locations of migration being early one year and normal or late another year. (Tables 7 and 8). This again evidences the role geographic variation might play in migration dynamics. One possible factor causing the median dates to not be correlated between sites for a given year is climate differences, with the coastal area being milder and inland locations being cooler. Temperature is likely to be one factor at least partially responsible for influencing migration timing (Duffy and Matheny 1997). Prey abundance could also influence migration dynamics, either in response to climate or to some other factor. Some geographic variation in migration timing could therefore point to the existence of different flyways that different subpopulations might take. Geographic variation has been suggested to take place in Broad-winged Hawks (*Buteo platypterus*)

for example, with separate coastal and inland populations exhibiting different migration schedules during migration seasons (Miller et al. 2002).

The median dates compared between locations did show a consistent pattern of differences among years (Tables 7 and 8), with the mountain median dates being the earliest, followed by the piedmont location a little later, and finally the coastal location median dates being latest. Because the coast has the mildest climate among the three sites, and temperature gradually decreases inland, this suggests that climate is a factor directly or indirectly influencing migration timing. It has been suggested among owl banders, for example, that owls begin migrating when the leaves begin falling. The median date data is consistent with this hypothesis because the leaves typically begin falling first in the mountains and latest on the coastal plain.

There was no significant difference between adults and immatures in migration timing. In another study it was found that immature birds migrated earlier than adults. (Whalen and Watts 1999). However, the differences in timing were not large, and the evidence suggested that timing varied among years, as the pattern was not seen every year.

Sex and age ratios. The three sites varied in the ratio of males to females captured (Table 9). The mountain and piedmont regions each had a small percentage of males captured relative to the coastal region. This might be explained if males do not migrate as far south as females in order to stay closer to the breeding grounds, so that they can return earlier in the spring and establish breeding territories (Cannings 1993). Females would then predominate in Virginia samples because females are the ones predominantly migrating this far south. Also noted was the presence of more males in the coastal site

sample relative to both inland sites, which might indicate a geographic difference in routes between the sexes, with males showing some preference for the coastal migration routes in greater numbers than females.

Another possible explanation for the skewed sex ratio that must be considered is an audiolure bias. An audiolure bias could exist if the lure attracts more females, with males being less likely to respond to it. Evidence for such an audiolure bias was found by Whalen and Watts (1999), who observed that larger female owls were captured closer to lures on average. Duffy and Matheny (1997) likewise found evidence for an audiolure bias, as their proportion of females increased by 25% when they began using an audiolure. But as their samples were still biased towards females before they began using an audiolure, a lure bias does not appear to completely explain the skewed sex ratio.

Finally, the piedmont and mountain locations differed from the coastal region in that a larger portion of captured owls were adults than immatures, which is typical of a non-invasion year (Table 10). This pattern has been seen in other bird species. For example, it was found that in Sharp-shinned Hawks (*Accipitor striatus*) the coastal region had a larger proportion of immature birds that migrate through it relative to the Appalachians (Clark 1985, Goodrich 1989). At another coastal location for Northern Saw-whet owls, a higher proportion of adults have likewise been observed (Duffy and Kerlinger 1992).

This study has provided the first insights into the migration dynamics of Northern Saw-whet Owls in the Piedmont of Virginia, and put it in the context of migratory movements in the mountains and on the coastal plain. To expand on these initial findings,

more yearly data will be useful towards helping to understand long-term changes in the Northern Saw-whet Owl's migration dynamics.

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