Breeding Ecology and Habitat Associations of the Arctic Warbler in Interior Alaska

Final Report - 2005 Field Season

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EXECUTIVE SUMMARY

The Alaska Bird Observatory (ABO) initiated a three-year study in May 2004 to describe the breeding biology and habitat associations of Arctic Warblers (*Phylloscopus borealis kennecotti*) along the Denali Highway (Milepost 23-34) between Tangle Lakes and Maclaren Summit. Arctic Warblers are a little-studied Paleotropic migrant that has been named a Species of Concern by the U.S. Fish and Wildlife Service. The North American subspecies is endemic to Alaska. In this second field season, we continued to document basic breeding phenology and behavior, band and color mark birds to identify individuals, describe habitat characteristics of nest sites, and find and monitor nests to document breeding success and productivity. One season of experience, two returning crewmembers, and the addition of a dedicated bander combined to produce a very successful summer. ABO has now amassed the largest dataset on Arctic Warblers in North America.

Arctic Warblers nested in varying densities on all 4 established study plots (10-ha each). We observed the first singing male on 7 June. A female was seen carrying moss to an incomplete nest on 17 June; the nest was finished on the following day. The first nest with eggs was found on 22 June. We monitored 41 nests; 18 within the plots (3, 1, 7, 7 on Plots 1-4, respectively) and 23 adjacent to the plots. Four nests were found during nest building, 9 during incubation, and 28 at the nestling stage. Clutch size varied from 5 to 7 with an average clutch size of 5.9. First hatch was on 6 July and the first fledging was observed on 19 July. We banded 149 nestlings from 27 nests. Thirty-eight of the 41 monitored nests fledged young; a nest success rate of 93%. All nest had fledged or failed by 30 July.

Forty-six adult birds (24 males, 20 females, and 2 of unknown sex) were captured in mist nests and color-banded. Adult birds arrived on the breeding grounds with little to no wear on their flight feathers, indicative of a protracted molt during spring migration. Ten of the 22 adults color-banded in 2004 were re-captured or re-sighted in 2005.

The general pattern of Arctic Warbler distribution among the 4 study plots was the same in 2005 as in 2004. The density of Arctic Warbler territories and nests was much lower on Plots 1 and 2 (n = 5) than Plots 3 and 4 (n = 14). Plots 1 and 2 are at lower elevation and have a dense shrub layer dominated by tall dwarf birch (*Betula nana*) or tall willow (*Salix* sp.). Plots 3 and 4 have a more open shrub layer consisting of shorter willow and more openings dominated by graminoids and forbs. The dominant species of the shrub layer, its density, and the characteristics of the substrate beneath it affect nest site preference by Arctic Warblers in our study area. Within the range of habitats along the Denali Highway, Arctic Warblers reached their highest densities in areas of 1 to 2 m-tall willow with meadow-like openings of lupine (*Lupinus arcticus*), burnet (*Sanguisorba* sp.) and the sedge (*Carex* spp.) and grass (primarily *Deschampsia caespitosa*) used to build nests (characteristic of Plots 3 and 4).

Our research on Arctic Warblers is yielding exciting results. We are rapidly expanding our understanding of the ecology of this species. All this information answers some of our original questions but also generates many new ones. Future research could include mist-netting efforts in August to examine female and juvenile molt, migration fattening patterns, and departure times, more behavioral observations to document polygyny, and additional vegetation surveys to fine-tune habitat associations.

These findings will provide guidance for future management plans for the Denali Highway district. The study area, while relatively pristine, is under increasing pressure from mining, infrastructure development, and off-road vehicle use. Increased resource development and road improvements slated for coming years may negatively affect Arctic Warblers and other species of concern in the study area.

INTRODUCTION

The Alaska Bird Observatory (ABO) initiated a three-year study in May 2004 to describe the breeding ecology and habitat requirements of Arctic Warblers (*Phylloscopus borealis kennecotti*) along the Denali Highway (Milepost 23-34) between Tangle Lakes and Maclaren Summit. The primary objectives of the 2005 field season were to: 1) document the basic breeding phenology and behavior of Arctic Warblers along the Denali Highway, 2) band and color mark Arctic Warblers within the study area to identify individuals, 3) identify and describe the habitat characteristics of Arctic Warbler nest sites and areas not used by Arctic Warblers, and 4) find and monitor Arctic Warbler nests throughout the breeding season to document breeding success and productivity.

Our findings will provide new information on the ecology of Arctic Warblers in North America and provide guidance for future management plans for the Denali Highway district and other areas of habitat for this species. The study area, while relatively pristine, is under increasing pressure from mining, infrastructure development, and off-road vehicle use. Increased resource development and road improvements slated for coming years may negatively affect Arctic Warblers and other species of concern in the study area.

METHODS

Staffing

We were fortunate in 2005 to have two returning crewmembers; their familiarity with the site and the birds was invaluable. We also added a bander to the crew to concentrate on color banding males and females. This doubled the number of birds color-banded on the study area and gave other crewmembers additional time to concentrate on finding nests and following birds. As a result, we were able to find more nests, increase our accuracy at assigning pairs to nests, and broaden the scope of behavioral observations.

Plots and spot mapping

We worked in the same study area and followed the same basic methodology employed in 2004 (Ring et al. 2004). Fieldwork began on 3 June with reflagging of our four 10-ha study plots (Figure 1) and making observations of birds and plant phenology. This year we placed weather stations on each of plots. We recorded temperature at 30-min intervals with data loggers and precipitation with a rain gauge. We also placed 3-m PVC tubing at 50-m intervals to better mark the study plot grids for behavioral observations and spot mapping.

Each plot was spot mapped several times between 8 June and 9 July 2005. All spot-mapping surveys were conducted between 0300 and 0900 ADT. The location of each Arctic Warbler seen or heard was recorded on a grid map of the plot. The type of behavior observed (singing, calling, feeding, etc.) and time of observation were recorded to aid in territory mapping. In addition to spot mapping, banded males were followed to ascertain territory boundaries.

Nest searching and monitoring

Each plot was searched for Arctic Warbler nests from 17 June – 27 July. Various search methods (Martin and Geupel 1993) were used: focusing on areas of high-activity noted during spot mapping, returning to areas where copulation or birds carrying nest material had been observed, following calling adults, and in Plots 1 and 2, walking through known Arctic Warbler territories.

Nests were checked at least once every four days until they were within 2 days of expected fledge date, then they were checked more frequently. Nests of other species found were also documented and monitored. All nest locations were recorded using a Global Positioning System unit.

Mist netting, banding, and color marking

Adults

We used two, standard 6-m mist nets to target Arctic Warblers on each plot (13 June – 20 July). We focused on territorial males from 13 – 30 June. Banding effort was divided among plots based on our observations of unbanded singing males during spot mapping. Mist nets were set up near the singing male and a recording of Arctic Warbler song was played to attract him to the nets. From 1 – 20 July we captured females at nest sites. No recordings were used; instead, nets were set up over the nest opening and birds were flushed into the net. This method was only used during incubation or days 1-6 of the nestling stage. Adults were banded with a USFWS aluminum band and a unique combination of three plastic color bands. Age, sex, unflattened wing chord length, tarsus length, furcular fat, presence of a brood patch or cloacal protuberance, feather wear, molt, and mass were recorded for each individual.

Nestlings

We banded nestlings on day 7 or 8 after hatch with a USFWS numbered aluminum band. Mass, wing chord, tarsus length, degree of pin break, and percent of down still present were recorded after banding.

Habitat selection

We measured vegetation and other habitat variables at every nest using the same methods employed in 2004 (James and Shugart 1970, Ring et al. 2004). Broad vegetation categories follow followed those in Kessel (1998). In 2005, we also collected habitat data in areas from Plots 1 and 2 that did not contain Arctic Warbler territories in either year of the study. These data will be used to characterize the unused habitat areas within these two plots. We followed the nest-centered vegetation protocol but the sampling centered on randomly chosen grid points. Similar measurements were not taken on Plots 3 and 4 because nearly all of the area on these plots has been used by Arctic Warblers in the past two years of the study.

To further evaluate habitat that is not used by Arctic Warblers, we conducted four off-plot transects (Figure 1) in mid-June. Each transect had a random start point within a kilometer of the Denali Highway. Transects followed a set trajectory for 2-km and then returned in a parallel line at least 250 m to the east. The presence or absence of singing Arctic Warblers and vegetation characteristics were recorded at 16 points along each 4-km transect. Points were at least 250 m apart. The observer listened for Arctic Warblers for 8 minutes at each point.

RESULTS AND DISCUSSION

Phenology

The first Arctic Warbler, a singing male, was detected on 7 June (compared to 8 June in 2004). A female Arctic Warbler was seen carrying moss on 17 June. We located her nest that day; it was an incomplete dome of only moss with no eggs. The nest was complete when we returned the following day. The first eggs were found on 22 June (females were incubating full clutches or brooding nestlings when nests were found in 2004). The first nestlings were observed on 6

July (7 July in 2004) and the first fledgling on 19 July (versus 16 July in 2004). All nests had fledged or failed by 30 July.

Nest searching and monitoring

Increased effort and crewmember experience allowed us to find more nests in 2005 than in 2004 (41 vs. 24 nests). Four were found during the nest-building stage, 9 during incubation, and 28 during the nestling stage. Having associated at least one nest for all but one banded male on the plots, we expanded our search area beyond the delineated study plot grids to increase the sample size of nests.

Nest success and predation

Of the 41 nests, 38 fledged, 2 were depredated, and 1 was abandoned during incubation. Combining both years, 60 of 65 Arctic Warbler nests fledged young. This very high rate of nest success is one of the more interesting results of the study to date. Although the 93% success rate is extremely high for a ground-nesting passerine (Martin 1993), it is not unprecedented for *Phylloscopus borealis.* Price and Beck (1989) observed no failures among the 11 Arctic Warbler nests they monitored on Alaska's Seward Peninsula and Danilov et al. (1984, *in* Lowther 2001) found a high rate of nest success (87%) in their study of *P. b. borealis* in northwestern Siberia. The cryptic character of Arctic Warbler nests may explain the low predation rates. Norment (1993) studied two species of *Zonotrichia* in somewhat similar habitat and found nest site selection (especially the degree of concealment) within these habitats to have a marked effect on nest predation (85% vs. 62% success).

One post-fledging mortality was observed; an Arctic Warbler fledgling attempted to fly across Upper Tangle Lake, landed in the water, and was immediately taken by a Mew Gull (*Larus canus*). None of the fledglings banded in 2004 were re-sighted in 2005. In future years, attempting to identify Arctic Warbler staging areas and recapture hatch-year birds may help us understand fledgling mortality in and around the study site prior to migration.

Nest failures

Only three nests failed: two were depredated during the nestling period and one was apparently abandoned during incubation. Potential predators were seen regularly on the study plots. Avian predators observed on or over the study areas included Mew Gulls, Long-tailed Jaegers (*Stercorarius longicaudus*), Short-eared Owls (*Asio flammeus*), Northern Hawk Owls (*Surnia ulula*), Northern Harriers (*Circus cyaneus*), Common Ravens (*Corvus corax*), Gray Jays (*Perisoreus canadensis*), Northern Shrikes (*Lanius excubitor*), Merlins (*Falco columbarius*), and Gyrfalcons (*F. rusticolus*). Of these, ravens, Gray Jays, gulls and jaegers were most frequently seen. Groups of three or more Arctic Warblers were documented mobbing a Short-eared Owl (Plot 4), a Northern Hawk Owl (Plot 1), and a family group of Gray Jays (Plot 1). This Gray Jay mobbing was in the vicinity of a nest on Plot 1 that was depredated 7 to 9 days later, apparently by avian predators. In 2004 Arctic Warblers were seen mobbing Gray Jays near a nest 50 m south of the 2005 depredation; this nest was later depredated.

Potential mammalian predators include Arctic ground squirrels (*Spermophilus parryii)* (very common on Plots 3 and 4), short-tailed weasels (*Mustela erminea*) (observed for the first time on Plot 2 in August 2005), and red fox (*Vulpes vulpes*) (observed on Plot 3).

Clutch size, brood size, productivity, and brood reduction

In 2005, mean clutch size was 5.9 eggs (SD = 0.61, range 5 to 7, n = 18) and mean brood size (nestlings per successful nest) was 5.3 (SD = 1.10, range 2 to 7, n = 40). Brood reduction (mortality of one or more nestlings) occurred in only two nests. Productivity was 5.2 fledglings per successful nest (SD = 1.10, range 2 to 7, n = 38).

Although we were working with a relatively small sample size, differing nest monitoring intensities, and nest detection abilities between 2004 and 2005, it is interesting to note that mean clutch and brood size were the same in both years. Productivity was lower in 2004 (5.2 vs. 4.4) but it is difficult to determine if this is a real effect or the result of the aforementioned caveats.

Nests of other species

Twenty-five nests of 7 other species were located within our study plots while we were searching for Arctic Warbler nests. These included Gray-cheeked Thrush (*Catharus minimus*), Blackpoll Warbler (*Dendroica striata*), Wilson's Warbler (*Wilsonia pusilla*), American Tree Sparrow (*Spizella arborea*), Savannah Sparrow (*Passerculus sandwichensis*), White-crowned Sparrow (*Zonotrichia leucophrys*), and an unidentified duck species. These species represent a mix of ground and shrub-nesting birds. Nests were found at various stages (incubation, nestling) and casually monitored until fledging. Seventeen of the 25 had fledged by the end of June, almost 3 weeks before the first Arctic Warbler nest fledged. Although anecdotal, it is interesting to note that all 25 nests fledged young.

Nesting phenology and nest characteristics

As with other high-latitude breeders, nesting phenology was synchronized (Briskie, 1995); 68% of the nests fledged between 21 and 23 July and all but 2 nests fledged between 19 and 25 July.

As in 2004, all nests found in 2005 were located on the ground, dome-shaped with a side entrance, and constructed of dried grass (primarily *Deschampsia caespitosa*) and moss, sometimes lined with moose (*Alces alces*) hair. Nests often were built around dead or live shrub stems. Live forbs grew up through some nests, furnishing additional concealment.

All Arctic Warbler nests were collected after fledging, and further analysis of their construction and thermal characteristics is being conducted as a senior thesis by a student at Swarthmore College.

Territoriality

For purposes of estimating territory boundaries, we considered a nest "on-plot" if it was found within 50 m of a grid point of one of our study plots. Using this criterion, the number of nests actually "on-plot" in 2005 (18 nests) was comparable to 2004 (20 nests). On Plots 3 and 4 the minimum distance between nests was approximately 60 m.

With one exception we found the nests of all singing territorial males on the study plots, suggesting that the number of singing males is a fairly good indicator of the number of nests in a given area (Ring et al. 2004). Complete analysis of territory size is pending.

Plots 1 and 2, the plots with the least Arctic Warbler activity in 2004, were used even less in 2005. Some areas where Arctic Warblers were banded or spot-mapped, or nests found, in 2004, had no activity in 2005. Additional discussion of between-plot differences follows in the section on habitat preferences.

Mist netting, banding, and color marking

Adults

Having a dedicated bander on staff for six weeks allowed us to capture and color-mark nearly all of the singing male Arctic Warblers on the study plots, 49% of the females on monitored nests, and 5 birds on the periphery of the study plots. We captured 46 adult Arctic Warblers (24 males, 20 females, and 2 of unknown sex). Of these, four had been banded as adults in 2004. Some birds that could not be sexed in hand were later determined to be male or female according to behavior. Both males and females were caught upon being flushed from the nest. After banding, all females returned to the nest and continued to care for their young. Mean mass at banding was 9.3 g (SD = 0.37, n = 22) for males and 9.8 g (SD = 0.64, n = 20) for females, mean wing length was 66.0 mm (SD = 1.1, n = 22) for males and 60.4 mm (SD =1.21, n = 20) for females and mean tarsus length was 18.7 mm (SD = 0.43, n = 21) for males and 18.1 mm (SD = 0.72, n = 19) for females.

This year we collected more detailed information on molt. Adult birds arrived on the breeding grounds with little to no wear on their flight feathers, indicative of a protracted molt during spring migration. Further investigation of this molt pattern is warranted. Males underwent a prebasic molt, starting in mid-July, consisting of a full body molt and replacement of secondaries 7-9 (tertials). We did not observe any molt among adult females; they may delay their molt until their young have fledged.

Nestlings

We banded 149 nestlings from 27 separate nests between 12 and 26 July. Nestlings received only a USFWS leg band. Mean mass at banding was 9.3 g (SD = 1.15, n = 149), mean wing length was 29.5 mm (SD = 4.27, n = 149) and mean tarsus length was 18.9 mm (SD = 2.27, n = 149). Collecting information on nestling development would be valuable.

Recaptures/resightings

In 2005 we resighted or recaptured 10 of the 22 Arctic Warblers banded as adults in 2004. All were recaptured on or adjacent to the same study plot where they were originally banded. None of the 48 nestlings banded in 2004 were resighted or recaptured.

Habitat selection

The general pattern of Arctic Warbler distribution among the 4 study plots was the same in 2005 as in 2004. The density of Arctic Warbler territories and nests was much lower on Plots 1 and 2 (n = 5) than Plots 3 and 4 (n = 14). Plots 1 and 2 were at lower elevation and had a denser shrub layer dominated by tall dwarf birch (*Betula nana*) or tall willow (S*alix* sp.). The most dense, shrub-dominated areas of Plots 1 and 2 were characterized by a lack of both graminoid vegetation and Arctic Warblers. The ground under these thick, > 2 m tall willow areas on both plots was shaded with a sparse ground cover of leaf litter. No Arctic Warbler nests were found in these areas in either 2004 or 2005, although nests were found in adjacent openings. Dense dwarf birch-dominated portions of Plot 2 also had relatively few Arctic Warbler nests. These nests were usually located near small openings where nest material was available. Plots 3 and 4 had a more open shrub layer consisting of shorter willow and more openings dominated by graminoids and forbs. In light of these results, the availability of grass, sedge (*Carex* spp.), and moose hair may be a factor in nest-site selection and/or nest success.

Nest-centered and non-nest-centered vegetation sampling

A summary of the sampling of nest-site and non-nest site vegetation are presented in Table 1. On Plot 1, areas surrounding nests had shorter vegetation and were largely dwarf-birch dominated with scattered white spruce (*Picea glauca),* with less total coverage of the medium shrub layer than the unused area of the plot. Unused areas on Plot 1 were dominated by saturated ground and willow dense and tall enough to greatly reduce ground coverage of forbs and graminoids. However, two Blackpoll Warbler nests were found in this tall willow habitat.

On Plot 2, Arctic Warblers avoided the near-monoculture of dwarf birch at the center of the plot. Nests occurred in or near more open areas, such as small grassy openings, the disturbed areas near the Denali Highway, and in wetter areas with a mixture of dwarf birch and willow at the eastern end of the plot. Unused areas of the plot had a higher coverage of dwarf birch and dwarf shrubs and lower coverage of willow, graminoids, and forbs than the area around Arctic Warbler nests.

Plots 3 and 4 were dominated by a shorter and thinner shrub layer made up almost entirely of willow. These plots also contained small meadow-like patches of forbs and grasses. As stated before, over the course of 2004 and 2005 field season almost all of the area within Plots 3 and 4 were used for nesting. There were no unused portions of these plots.

Off-plot surveys

Transect 1 ran through predominantly ≥ 2-meter tall willow along a riparian and beaver pond area south of Plot 2. Arctic Warblers were not detected in this area, though Blackpoll Warblers were abundant. This confirmed our findings in similar habitat in Plots 1 and 2. Transect 2 was south and west from Plot 4, increasing in elevation to the dwarf shrub and grass-dominated tundra. A few Arctic Warblers were observed in dry, west-facing slopes dominated by open, dwarf birch-dominated habitat. None were observed in the low tundra habitat on the upper south-facing slopes of Whistle Ridge, while numbers of birds similar to Plots 3 and 4 were observed in mid-elevation, snow-melt fed slopes dominated by 1- to 2-m willow, habitat much like that on Plot 3. Transect 3 crossed the esker-dominated area between Tangle Lakes Lodge and Round Tangle Lake, with dry, little-vegetated gravelly ridges interspersed with tall willow in the swales. No Arctic Warblers were detected on this transect. Transect 4 crossed an area dominated by low dwarf birch (≤1 m), with grassy openings, west of the esker at mile 22.5 of the Denali Highway. Arctic Warblers were not detected along this transect, but were observed using areas of *Salix* along the highway and small off-road vehicle trails, and heard singing from isolated white spruce west of the transect.

The dominant species of the shrub layer, its density, and the characteristics of the substrate beneath it affect nest site preference by Arctic Warblers in our study area. Within the range of habitats along the Denali Highway, Arctic Warblers reached their highest densities in areas of 1 to 2 m-tall willow with meadow-like openings of lupine (*Lupinus arcticus*), burnet (*Sanguisorba* spp.) and the sedge (*Carex* spp.) and grass used for nests (characteristic of Plots 3 and 4). Arctic Warblers apparently avoided areas of uniformly dense dwarf birch with a ground layer of dwarf shrubs, moss, and lichen. However, if other features (scattered white spruces, nearby roadside or wetland willow-dominated areas) increased the complexity of the habitat structure, they nested in dwarf birch areas. This indicates that roadside surveys such as the Breeding Bird Survey may overestimate Arctic Warbler abundance and therefore, population trends. We found Arctic Warblers to be concentrated along the band of tall (>2.5 m) *Salix alaxensis* where the soil had been disturbed along the Denali Highway, but largely absent from dwarf birch monocultures adjacent to the road edge. Our findings should also be considered with caution, as habitat preference among passerines is known to vary regionally within species. *Phylloscopus borealis borealis* are known to nest in forested habitats in Finland (Cramp 1992 and Pullianen et al. 1986 *in* Lowther 1992) and the Alaska subspecies has also been associated with riparian areas and other areas of tall *Salix* (Price and Beck 1989).

Behavioral Observations

Song rates and qualities

We recorded singing rates from the birds' arrival at the study site until song activity decreased noticeably with the onset of incubation. Males gave from 3.7 to 16 calls per minute (mean = 6.3, SD = 2.6, n = 54). Most of the higher song rates occurred during the nest-building period and were usually accompanied by 1 to 3 buzzy call notes given between each song. On 17 June, as territory establishment, nest building, and copulation were taking place, males repeatedly gave an unusual higher pitched, two-toned song that had swallow-like overtones. Contrary to descriptions of its song as a "monotonous" trill (Cramp 1992 *in* Lowther 2001), it was not uncommon to hear singing males change the pitch (and sometimes speed) of its trill mid-song. Arctic Warblers were observed on several occasions singing in mid-flight, a behavior not previously reported (Lowther 2001). One banded male on Plot 3, that apparently did not find a mate but which maintained its territory and regular singing perches, continued singing vigorously throughout the incubation and nestling periods when other paired males sang sparingly.

Females at 2 nests responded to flushing from the nest with a loud, scolding call reminiscent of a house wren, accompanied in one case by briefly running over the ground a few meters from the nest a "broken-wing" display, similar to plovers. This vocalization and behavior were not mentioned in Lowther's (2001) overview of the species. We learned to identify fledgling contact calls, which were similar to adult call notes but less sharp and buzzy. It was a common sound on the plots in the days following fledging.

Mating system

Our data suggest that breeding pairs of Arctic Warblers occupy fixed territories. In 2005, with more of the population color marked, we were able to confirm more instances of extra-pair birds (more often males) at nests. Arctic Warblers often responded to alarm calls from nests that were not their own, but there were no confirmed instances of more than 2 adults feeding nestlings at a given nest. As in 2004, we suspect at least 1 case of polygny occurred in 2005; a male with a known nest was seen feeding newly fledged young within 10 m of another nest and over 100 m from his known nest. This second nest fledged upon discovery; thus, the identity of the nestlings being fed could not be confirmed.

Parental care

In 2005 we conducted behavioral observations during the nestling stage to better understand parental care. Both parents fed young and removed nestling fecal sacs. Total number of feeding trips per hour ranged from 19 to 40 visits per hour (mean = 25.3, SD = 5.3, n = 19). Observers sat between 4.5 and 30 meters away from the nest depending on the amiability of the nesting pair. Since the observers' presence did cause varying degrees of alarm and may have reduced feeding frequency, these estimates are likely conservative, and actual feeding rates may be higher. Among observations where both parents could be identified, females appeared to forage closer to the nest and to make 1 to 2 times as many feeding trips per hour as did males. One nest fledged during an observation; 3 of the fledglings traveled 60 m away from the nest in their first hour after fledging, while the remaining nestling traveled just 5 m.

Foraging and diet

Arctic Warblers were most commonly seen feeding on mosquitoes. They also fed on larger Dipterids (possibly Ephemeroptera (mayflies)) and both adult and larval Lepidopterans. Arctic Warblers obtained most of their food by gleaning dwarf birch or willow shrubs. Hawking from the shrub layer was not uncommon; the resulting bill-snaps were sometimes audible over distances of 20 m or more. Occasionally, these forays reached heights of 10 m with the birds turning a somersault at the peak of flight after capturing a moth or Dipterid. This impressive display may be a territorial or breeding behavior, although such behavior was observed well into the nestling period when there was relatively little singing, chasing, or other evident mating behaviors. Arctic Warblers were also observed to feed while hovering, particularly near the crowns of white spruce on Plot 1. Adult Arctic Warblers even fed on mosquitoes when in banders' hands.

Bathing

A single Arctic Warbler was observed bathing in a meltwater streamlet on Plot 4. Bathing behavior has not previously been observed and reported for the Alaskan subspecies.

IMMEDIATE PLANS AND RECOMMENDATIONS FOR FUTURE STUDY

Our research on Arctic Warblers is yielding exciting results. We have assembled the largest database on this species in North America, and our results are rapidly expanding our understanding of the ecology of this species. Aside from locating a high-density breeding population that exhibits incredibly high nesting success, we are learning about nest-site fidelity, productivity, habitat selection, and behavior. All this information answers some of our original questions but also generates many new ones. The following summarizes further analysis of present data, preliminary plans for the third field season, and ideas for future study.

We plan to further analyze nest data running Mayfield estimates. And we will begin to develop a habitat model with our existing dataset. There are also many hours of behavioral observations to glean to estimate territory size.

Plans for the third season are still evolving but at this time we plan to continue collecting basic information on breeding biology (arrival dates, site fidelity, nest success), color banding adults and banding nestlings. Analysis of the vegetation data will dictate whether more habitat data will be collected. We may have a chance to address portions of some of the following questions.

What factors drive habitat selection in Arctic Warblers? Focusing on adult and nestling Arctic Warbler diet, foraging behavior, and nest construction may help better elucidate habitat preferences in the study area. Additional presence/absence surveys after the breeding season in surrounding areas, such as known staging areas at the mouth of Rock Creek and the Gulkana Glacier area, may broaden our understanding of Arctic Warbler habitat requirements after the breeding season.

The intriguing new information on molt begs the question – when do females molt? Mist-netting efforts in August at the migration staging areas mentioned above may produce information about female and juvenile molt, migration fattening patterns, and departure times.

To what extent does polygyny and extra-pair copulation influence the breeding ecology of Arctic Warblers? Detailed behavioral observations of banded birds would help us better understand this dynamic. Based on observations of banded individuals during copulation and nest building, we strongly suspect extra-pair copulations take place, although the extent is difficult to assess. However, the skulking habits of Arctic Warblers and the structure of the habitat make behavioral observations challenging, and time and effort spent on behavioral observations would also result in less time available for nest searching.

Why is Arctic Warbler productivity so high and nest predation so low at the study site? Is the high success rate a characteristic of the habitat, the species, some combination, or just influenced by the vagaries of the weather? In future years it may be valuable to find and follow more nests other species breeding in the same area, particularly Partners in Flight Species of Special Concern such as Gray-cheeked Thrush and Blackpoll Warbler. This will allow us to better understand the unusually high degree of nesting success not only of Arctic Warblers but possibly of other species sharing the ecosystem.

Our success in finding and monitoring nests gives us the ability to document some additional basic information about Arctic Warbler's breeding in North America. Egg measurements and photos of nestling development are two cases where new information is easily attainable.

We can also integrate our information with other methods of monitoring Arctic Warbler populations. An established Breeding Bird Survey (BBS) route runs along the road by all 4 Arctic Warbler plots. We have a unique opportunity to compare BBS data with breeding information on the local population.

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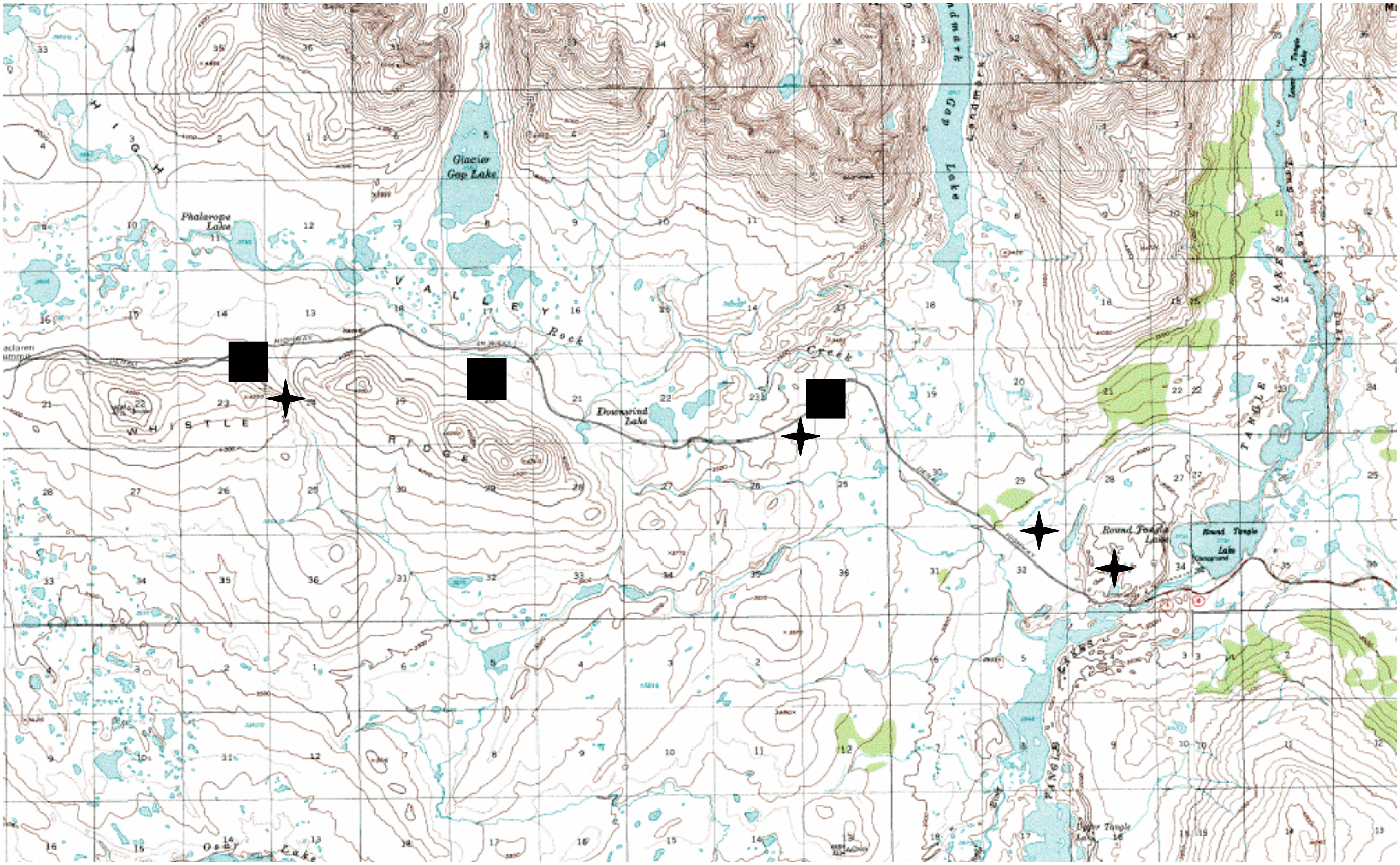

Figure 1. Location of Arctic Warbler study plots 1-4 along the eastern end of the Denali Highway. Size of boxes not to scale with study plot size. Locations of the off-plot transects are indicated by ✦.

Table 1. Comparison of key nesting habitat variables across 4 10-ha study plots along the Denali Highway, 2005. Data are reported as means with standard deviation, n = number of areas sampled.

Plot	**Medium Shrub Layer Height (m)**	**Dwarf Birch % Cover**	**Willow % Cover**	**Total Combined Dwarf Shrub % Cover**	**Graminiod % Cover**
Nest Habitat					
1 (n=5)	1.2 (0.03)	26.6 (23.6)	12.3 (15.0)	47.8 (14.3)	0.8 (1.2)
2 (n=3)	1.0 (0.03)	33.5 (31.2)	22.8 (34.4)	42.5 (19.5)	6.2 (7.8)
3 (n=17)	0.9 (0.1)	0 (0)	38.1 (16.8)	4.6 (8.8)	8.2 (9.5)
4 (n=16)	0.9 (0.3)	0.2 (0.8)	32.0 (13.4)	15.3 (15.3)	10.0 (9.8)
Unused Habitat					
1 (n=4)	2.5 (1.1)	0.9 (1.4)	68.8 (23.9)	26.9 (23.0)	4.8 (6.9)
2 (n=4)	0.9 (0.03)	56.2 (12.5)	13.4 (17.5)	60.2 (11.4)	1.8 (1.4)