Aerial Surveys Do Not Reliably Survey Boreal-nesting Shorebirds

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Aerial surveys have been used as a method for surveying boreal-nesting shorebirds, which breed in difficult-to-access terrain; however, the fraction of breeding birds observed from the air is unknown. We investigated rates of detection by conducting simultaneous air and ground surveys for shorebirds at three sites in the boreal forest of the Northwest Territories, Canada, in 2007. Helicopter surveys included both pond-based surveys where the helicopter flew around the perimeter of each wetland and transect-based surveys where observers recorded birds seen on line transects. Ground surveys involved intensive observation, territory mapping and nest searching in 5 km^2 of plots over a period of 5-6 weeks. Shorebird densities observed from the helicopter were highest near large bodies of water. No shorebirds were observed over closed forest despite breeding densities on ground surveys being highest in closed forest. Detection rates were very low, varied among species and aerial survey types, and were inconsistent over time. Ground-based observations showed that the shorebirds often did not flush in response to the helicopter passing overhead. Owing to poor rates of detection, we conclude that helicopter surveys are not an appropriate method for surveying breeding shorebirds in boreal habitats, but may have some utility for monitoring birds' use of stop-over locations.

Key Words: Lesser Yellowlegs, *Tringa flavipes*, Wilson's Snipe, *Gallinago delicata*, Solitary Sandpiper, *Tringa solitaria*, Aerial survey, shorebirds, Northwest Territories.

Due to inaccessibility, status and trends of many bird populations in the northern boreal forest are generally poorly known (Erskine 1974; Sinclair et al. 2004*). However, large numbers of waterbirds breed there, and migration counts suggest declines in breeding populations for most boreal-nesting shorebirds, including Lesser Yellowlegs (*Tringa flavipes*), Wilson's Snipe (*Gallinago delicata*) and Solitary Sandpiper (*Tringa solitaria*) (Morrison et al. 2006, Bart et al. 2007). Because travel on the ground through the boreal forest is so difficult, the data available for boreal waterbirds are almost entirely based upon aerial surveys (e.g., Bolduc et al. 2008; see Erskine 1974). Those surveys are undertaken regularly by the US Fish and Wildlife Service and Canadian Wildlife Service and which yield indices of abundance and information on habitat use (e.g., USFWS 2002*). Although those surveys were traditionally limited to waterfowl, shorebirds have recently been included (Skagen et al. 2003, Sinclair et al. 2004*). Although large birds, such as waterfowl and raptors, can be accurately surveyed from the air (Gaston et al. 1986, Smith 1995*; Anthony et al. 1999; Gilchrist and Mallory 2005; Barnhill et al. 2005), aerial surveys are seldom used for small birds and there is little information on the accuracy of aerial surveys for shorebirds (but see Nebel et al. 2008). Furthermore, most boreal birds, including shorebirds, are detected by ear, which is not possible during aerial surveys. Specifically, the concordance between aerial observations and the actual number of breeding birds (i.e., the detection rate) has not been established for boreal-nesting shorebirds, or for most small birds. With no objective measurement of bias, the reliability of aerial surveys for shorebirds is unknown (Smit 1989). In this study, we attempted to measure detection rates for aerial surveys of three species of boreal-nesting shorebirds, and examined what parameters affected detection.

Methods

Our study area stretched across the Northwest Territories from the Alberta border to Inuvik. As such, habitat varied from aspen parkland in the south to the treeline in the north. Nonetheless, the majority of habitat could be classified as within the Taiga Shield (Western Taiga Shield Ecoprovince) or Taiga Plains Ecozones, with one of the intensive survey plots and the middle sections of the pipeline survey route being within the Taiga Plains Ecozone and the remainder being within the Taiga Shield Ecozone. We selected the Yellowknife intensive plots as representative of the Taiga Shield. Topography was dominated by outcrops of bedrock that cover 25-30% of the land surface. The terrain was flat to slightly rolling between outcrops and is composed of glacial deposits of clay, silt, sand, and gravel. It contained a patchwork of dry Jack Pine forest (*Pinus banksiana*) on outcrops, mesic birch (*Betula* spp.)-White Spruce (*Picea glauca*)-aspen (*Populus* spp.) stands and alder (*Alnus* spp.) thickets, and low, wet Black Spruce (*Picea mariana*)-Tamarack (*Larix laricina*) bogs and willow (*Salix* spp.) thickets. Wetlands were common, with typical ponds ranging in size from 0.1 to 18.2 ha. Some natural ponds had abrupt shorelines of outcrop or shrubs, but most were bordered by floating sedge mats of various widths. We selected the Fort Simpson intensive plot as representative of the Taiga Flats. Topography was flat and dominated by Black Spruce forest, open muskeg, flooded swamps and ponds. Mesic uplands forested with white spruce, jack pine, and a variety of deciduous species were also present.

In 2005, we conducted aerial surveys along a continuous overland transect near the Mackenzie River (the proposed route for the Mackenzie Gas Pipeline) and along the Mackenzie River between Norman Wells and Inuvik, 24-27 May and 3-6 June. In 2006, surveys were conducted at 15 locations along the pipeline route between the Alberta border and Norman Wells, 19-23 May, selected non-randomly to include areas with open wetlands (Figure 1). These surveys consisted of five transects parallel to the proposed pipeline route, each 10 km long and separated by 500 m. An additional 30 transects were completed along the Mackenzie River in 2006 (Figure 1). In 2007, we conducted aerial transect surveys within the two Yellowknife intensive study plots (described below) and on two additional nearby 22.5 km^2 plots on 23 May and 2 June. We also conducted aerial transect surveys on four 25 km^2 plots near Fort Simpson, including a 1 km^2 intensive study site (described below) on 25 May and 6 June. In both 2006 and 2007, we also conducted "pond surveys", where we followed the shoreline of the larger ponds within the study area or, in smaller ponds or wetlands, flew down the middle of the water body.

Surveys were flown in a Bell 206 helicopter, with one observer located in the front passenger seat and one in the rear behind the pilot. Observations were recorded with handheld digital voice recorders. The location of bird sightings was established by logging a timed location of the aircraft using GPS and recording the time of bird sightings on the voice recorders, which recorded the time of each observation. Transect surveys were flown at a speed of 80km/h at a height of 30m above the ground. For the purpose of determining detection ratios, transects ran north–south along the long axis of the intensive plots, with 500m between the centre lines. Pond surveys were initially flown lower and slower (tree height level and 40 km/hr). After a short initial trial, pond surveys were changed and became identical to transect survey speed and height due to safety concerns. We recorded all sightings within 100m of either side of the aircraft, as that is the standard width for aerial shorebird surveys in the Arctic. In both transect and pond surveys, shorebirds were identified to species where possible or were otherwise assigned to size classes. Calidrids, Spotted Sandpipers (*Actitis macularia*) and phalaropes were grouped as "small" shorebirds. American Golden-Plovers (*Pluvialis dominica*), Killdeer (*Charadrius vociferus*), Lesser Yellowlegs, Solitary Sandpipers, Wilson's Snipe and dowitchers were grouped as "medium" shorebirds. Whimbrel (*Numenius phaeopus*) and Hudsonian Godwits (*Limosa haemastica*) were grouped as "large" shorebirds. Habitat within the aerial survey plots was classified broadly as pond, taiga, closed forest, and other, and boundaries of each of these habitat types within the surveyed areas were estimated on a GIS layer using Google Earth data. Georeferenced observations of birds were overlain on this layer to determine coarse-level habitat associations.

We carried out two types of ground surveys. In 2005, we completed 17 ground surveys away from the river and 12 along the river's edge. All ground surveys were along the flight path of the helicopter. Ground surveys were 10-minute point counts (2005, away from the river) or transects (2005, along the river; 2006, all surveys) where observers recorded all birds seen or heard. As the topography limited straight-line travel and distance-sampling, the transects consisted of random walkabouts along approximately straight lines by the observers and were roughly 10 min in duration and 500 m in length. More intensive ground surveys were conducted at two sites. Two observers intensively surveyed a 1 km^2 plot near Fort Simpson 18 May to 21 June 2007 (264 person-hours) and an additional two observers surveyed two 2 km^2 plots near Yellowknife 7 May to 28 June 2007 (344 person-hours). As few nests were found (six in total), breeding territories were delineated by territory mapping. Locations of territorial (displaying or mate-defense) and copulating birds were recorded with GPS. Individuals were differentiated by simultaneous detections. GPS locations, mapped territory boundaries and corresponding notes were used to determine the number of territories on the intensive survey plots. We determined the location of territory centroids for birds near the boundary of the plots, but because of low densities, this complication was rare. For each intensively surveyed plot, we calculated detection rates as the number of birds counted during aerial surveys divided by the actual number of territories observed during intensive surveys (Anthony et al. 1999; Bart and Earnst 2002). As we expect more than one bird per territory on average, "ideal" detection rates (if all birds present are seen) would be close to two. Detection rates were calculated for each type of aerial survey and for each aerial survey date. Shorebird behavior in response to aerial surveys was investigated by positioning observers on the ground along aerial flight lines at known shorebird locations. Shorebird response (if, when, and where a bird flushed in relation to the helicopter) was recorded. These observations were compared to the aerial survey results to determine if flushed birds were spotted by the aerial surveyors. Values are reported ± SE.

Results

Aerial surveys away from the Mackenzie River ("Mackenzie Gas Pipeline route") accounted for many

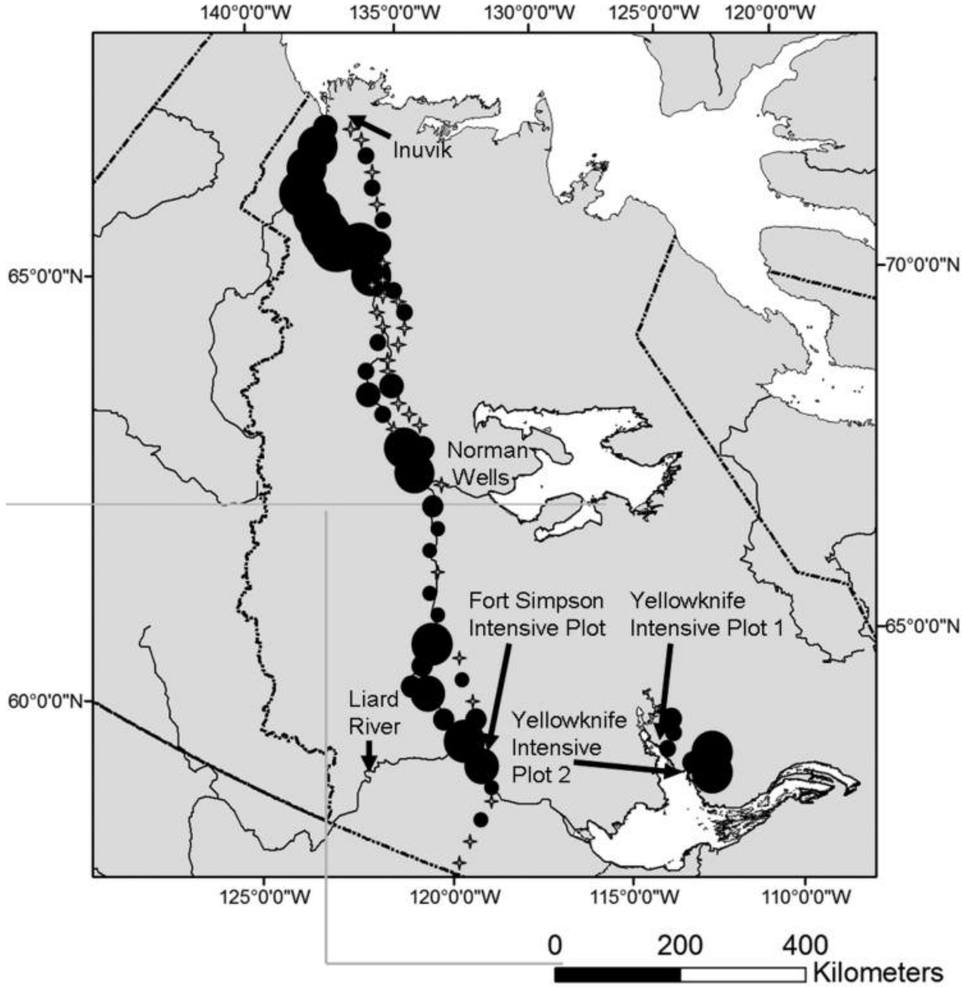

FIGURE 1. Shorebird densities in the boreal forest of the Northwest Territories, as detected during aerial surveys. Aerial surveys covered the Mackenzie River, the overland portions of the proposed Mackenzie Gas Pipeline route, survey blocks near Yellowknife, and three intensive plots. Densities are 0 (crosses), 0-0.1 (small circles), 0.1-0.5 (medium-small circles), 0.5-1.0 (medium-large circles) and 1.0+ (large circles) birds per km^2.

fewer birds and lower diversity than surveys along the river (Figure 1); Killdeer, Least Sandpiper (*Calidris minutilla*), Red-necked Phalarope (*Phalaropus lobatus*), Sanderling (*Calidris alba*), Semipalmated Plover (*Charadrius semipalmatus*), Semipalmated Sandpiper (*Calidris pusilla*), Whimbrel and White-rumped Sandpiper (*Calidris fuscicollis*) were all recorded only along the river sections whereas Hudsonian Godwit was the only species recorded away from the river. Highest concentrations were seen on the northern survey sections of the river, where birds may have still been staging or migrating northward in late May and early June or where two rivers or river channels met (e.g., intersection of the Liard River, Figure. 1). Many of the birds seen on the river surveys were clearly non-breeders. The higher densities seen on the river appeared to occur because non-breeding birds tended to congregate at these locations, making them easier to disturb and detect from the helicopter. No birds were detected by aerial surveys over closed forest, but 19% of Solitary Sandpipers, 18% of Lesser Yellowlegs and 41% of Wilson's Snipe were recorded at wetlands, and 31% of Solitary Sandpipers, 83% of Lesser Yellowlegs and 57% of Wilson's Snipe were recorded within 50 m of open water. The remaining sightings were over "other" habitats, which includes drier meadows and cleared areas. In general, the number of shorebirds seen increased with waterbody size (Figure 2).

TABLE 1. Total birds observed during "pond" and "transect" type aerial surveys of a 1 km^2 "intensive plot" (Fort Simpson) and two 2 km^2 "intensive plots" (Yellowknife), and detection ratios (DR, observed number of birds divided by actual number of territories present, shown in parentheses) for Lesser Yellowlegs (LEYE), Wilson's Snipe (WISN), Solitary Sandpipers (SOSA) and all shorebirds (ALL). The total number of breeding territories in the plot, estimated from intensive ground surveys is also shown ("Total Ground"). "ALL" includes shorebirds not identified to species. No detection rate was calculated for locations without birds observed during the ground surveys.

	Fort Simpson					Yellowknife (two separate plots)						
Date	25 May		6 June		Total	23 May	2 June	Total	23 May	2 June	Total	
Type	Transect	Pond	Transect	Pond	Ground	Transect	Pond	Ground	Transect	Transect	Pond	Ground
LEYE	1 (0.25)	0 (0)	0 (0)	0 (0)	4	6 (1.2)	2 (0.4)	5	6 (0.75)	0 (0)	13 (1.6)	8
WISN	0 (0)	0 (0)	0 (0)	2 (0.09)	23	0 (0)	1 (0.08)	12	0 (0)	1 (0.09)	0 (0)	11
SOSA	0 (0)	0 (0.08)	0 (0)	0 (0)	12	0 (-)	0 (-)	0	0 (-)	0 (-)	3 (-)	0
ALL	1 (0.03)	0 (0.05	0 (0)	3 (0.08)	39	7 (0.41)	3 (0.18)	17	7 (0.37)	1 (0.05)	18 (0.95)	19

Ground transects along the Mackenzie Valley reported 1.0 ± 0.3 Solitary Sandpipers and 15.5 ± 2.6 total shorebirds per kilometer whereas aerial transects reported 0.7 ± 0.1 Solitary Sandpipers and 1.0 ± 0.2 total shorebirds per kilometer. Away from the river, ground transects reported 4.0 ± 1.1 total shorebirds per kilometer whereas aerial surveys reported 0.3 ± 0.1 (transect) and 0.8 ± 0.2 (pond) total shorebirds per kilometer. Thus, aerial surveys detected fewer birds than ground surveys, and, within aerial surveys, pond surveys detected more birds than transect surveys (see also Table 1). This trend was true for Lesser Yellowlegs, Solitary Sandpiper, and Wilson's Snipe.

Detection rates for aerial surveys varied greatly between species (Lesser Yellowlegs: 0.47 ± 0.19; Wilson's Snipe 0.029 ± 0.014; Solitary Sandpiper 0.00 ± 0.00; Table 1). Detection rates for Wilson's Snipes were consistent, but extremely low (between 0.1 and 0), but rates for Lesser Yellowlegs varied with survey type and date of survey (Table 1). Detection rates greater than 1 occurred on several occasions for Lesser Yellowlegs, which often flew erratically in response to the helicopter and were possibly double-counted (Table 1).

Observations on the ground at the time the helicopters flew past supported the low and variable detection rates. Often, if birds flushed at all, they did so a few seconds after the helicopter passed by (Table 2). The helicopter surveys did not flush many of the birds on the ground, at least until after the helicopter had already passed by, and that even those that were flushed were often missed (Table 2).

Discussion

Two aerial survey methods were tested during this study: transect-based and pond-based surveys. Transect-based surveys took more time and fuel flying over closed forest habitats where no shorebirds were sighted. Pond-based surveys recorded more shorebirds but likely had a higher rate of double-counting, and involved safety risks due to sharp turns at slow speeds. Both survey types had low (in many cases, null) and variable detection rates. Ground observations showed that it was not observer error or inexperience that led to these low detection rates. In the majority of cases, birds were missed because they either did not flush until the helicopter had passed, or they did not flush at all. For example, in over half of surveys, no Wilson's Snipe were seen from the air even though during the surveys observers on the ground watched individuals that were below or adjacent to the helicopter flight path (Table 2). Other shorebird species were more often counted from the air, but counts varied greatly within and between survey types and dates (Table 1).

Wetland-based surveys are used by the USFWS and CWS to obtain population estimates of boreal breeding waterfowl (Smith 1995*, USFWS 2002*). However, the methodology restricts surveys to wetlands that are 1 ha or greater in size and relies on the fact that most of the waterfowl are on the water (Smith 1995*; USFWS 2002*). Even for those larger birds, detection probabilities for aerial

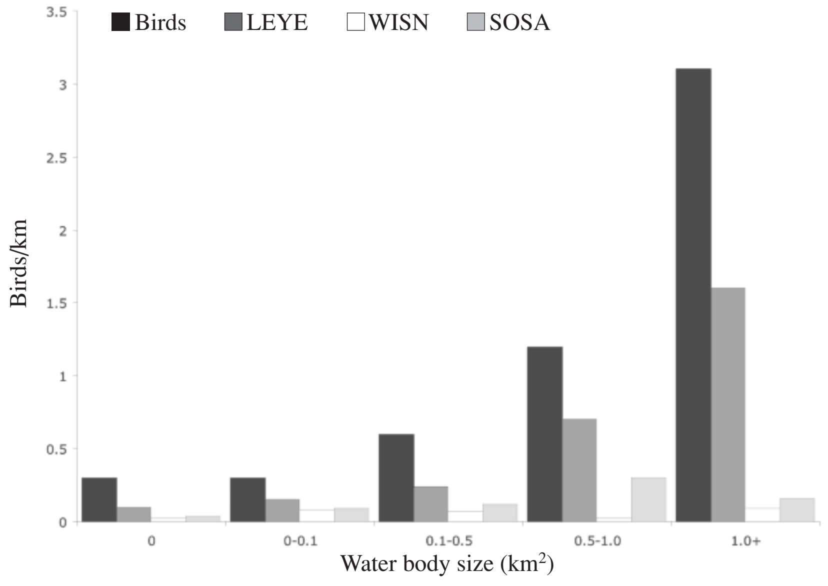

FIGURE 2. Birds detected per kilometer on aerial surveys over different-sized water bodies. River surveys excluded.

TABLE 2. Responses of resting or foraging Lesser Yellowlegs (LEYE), Wilson's Snipe (WISN) and Solitary Sandpipers (SOSA) to helicopter passes, as observed by ground observers. "Distance" represents the horizontal distance of the closest approach by the helicopter. Birds that flushed after the helicopter passed are shown with an asterisk. The column "observed" denotes whether the birds were recorded by aerial surveyors.

LEYE	WISN	SOSA	Distance	Flushed?	Observed?
2	3		50 m	All	None
2			Overhead	None	None
4	2		100 m	None	None
4	2		50 m	1 WISN; all*	None
		2	Overhead	1 SOSA	None
	3		50 m	1 WISN*	None
		1	Overhead	None	None

surveys vary according to survey date, species, group size, observer and observer position within the aircraft (Rumble and Flake 1982; Gabor et al. 1995; Naugle et al. 2000; Conroy et al. 2008). Shorebirds are often present on tiny wetlands, and nest territories include, but are not restricted to these wetlands. Birds are usually beside rather than on the water, where they are harder to detect; therefore, one aerial flight over a wetland will miss many shorebirds. In contrast, circling the wetlands increases the chances of double-counting and could be less safe than traditional transect flying.

Species-habitat associations complicated the sampling of boreal-nesting shorebirds using aerial surveys. We found that the number of shorebirds detected increased with the size of the water body, and we recorded no shorebirds over closed forest. This bias in detection rate among habitats could result in misleading information. For example, if birds feeding on large water bodies are non-breeders, aerial surveys may suggest highest population levels in years when breeding failure is highest (i.e., when large congregations of non-breeders are on large water bodies). Conversely, aerial surveys may be useful for surveying non-breeding shorebirds at stop-over or wintering sites where they are largely out in the open or near large waterbodies (Morrison et al. 2004; Nebel et al. 2008).

In conclusion, detection rates for boreal-nesting shorebirds during aerial surveys were low, and varied among species, survey types, habitats and even dates. The variability was sufficiently high that the results of aerial surveys are of little value for estimating population size and trends for shorebirds breeding in boreal habitats. Aerial surveys may be useful for monitoring relative importance of sites to shorebirds, or may be used to track abundance indices at large, open staging sites. However, variability in detection may be problematic even for these coarse indices. Furthermore, aerial surveys have a large carbon footprint, and the positive benefits of that footprint (public awareness or policy change) would need to be weighed against negative costs (miniscule increase in emissions) for each boreal shorebird species (e.g., Grémillet 2004). We recommend that boreal aerial surveys for shorebirds be replaced with systematic ground surveys provided that they include the adoption of dual-observer or double sampling methods with statistical rigor and site-specific studies of detection rates (Crête et al. 1991, Bart and Earnst 2002; Collins 2007; Conroy et al. 2008).

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