

Aerial survey of waterbirds on Kanuti National Wildlife Refuge and adjacent wetlands

Robert Platte and Robert Stehn

U.S. Fish and Wildlife Service, Migratory Bird Management, 1011 E. Tudor Rd., Anchorage, AK 99503

An aerial waterbird survey has been flown on Kanuti National Wildlife Refuge since 1957 as part of the North American Waterfowl Breeding Population Survey. However this survey was limited to four segments of 16 statute miles each on 2 transects flown on the refuge and analyzed as part of Koyukuk stratum. In 1997, an expanded aerial survey was designed using a more intensive systematic sample to obtain more precise waterbird population indices and to better determine waterbird distribution (Platte 1999). Refuge staff requested Migratory Birds conduct another survey similar to the 1997 survey in 2008. Objectives of the surveys were to obtain baseline indices of population size and distribution. The survey was continued in 2009 and 2010. This field report describes methods, observation conditions, summary, and analyses completed on the observations recorded in 1997, 2008, 2009, and 2010.

Methods

The boundary of the 1997 survey area was screen-digitized around wetlands of the Koyukuk and Kanuti National Wildlife Refuges based on a digital raster graphic of a 1:250,000 topographic map. Based upon recommendations of the 1997 survey crew, the boundary was improved in 2008 by omitting marginal habitat near steeply rising terrain and to better define concentrated areas of wetlands. The original 1997 survey included 5561.1 km² in two strata (lowland and marginal) with a transect area observed of 273.8 km², a 4.9% sampling fraction. The 2008 survey sampled only 3384.7 km², 61% of the original 1997 area, excluding marginal areas that had less contiguous wetland and generally lower numbers of birds.

We used a custom True BASIC program and ArcGIS[®] (Environmental Systems Research Institute, Inc., Redlands, California) geographic information system (GIS) software to generate 2 sets of systematic transects from a random coordinate within the survey area. Transects were oriented east west along great circle routes and spaced 2 nautical miles apart (Fig. 1). The first set of transects was flown in 1997, 2008, and 2009 however the latter 2 years were on the smaller survey area. In 2010, the intermediate set of transects was flown to provide more information on bird distribution while maintaining a valid representative sample for population estimation. For final analysis of all years data, we created a stratification common to all years consisting of the main wetland area of Kanuti NWR, the area north of the northern refuge boundary, and a disjunct area west of the refuge boundary (Fig. 2). This allowed for valid comparisons of the data for all years.

The surveys generally were flown around the third week of May to coincide with egg-laying or early incubation stages for breeding waterbirds, although the 1997 survey was flown in early June (Table 1). The 1997 survey took longer to fly because it included the Koyukuk wetlands whereas subsequent surveys only took place on Kanuti NWR. Survey methods followed the standard protocol established for waterfowl breeding ground surveys in North America (USFWS and Canadian Wildlife Service 1987). A Cessna 206 amphibious aircraft (1997 and 2008) or a Dehavilland turbine Beaver (2009 and 2010) was flown at 145-170 km per hour, 30-46 m of altitude, with wind speed <24 km per hour, ceilings >152 m, and visibility >16 km. The pilot used

a global positioning system (GPS,) and moving map software displayed on an laptop computer screen to maintain a precise course while flying transects.

Both pilot and observer used a computerized data collection program called Survey Recording Program written by John Hodges (USFWS, Migratory Bird Management, Juneau, Alaska). This system consisted of a notebook computer connected with the aircraft's GPS receiver and a remote microphone/mouse. The observers voice recorded each transect number, transect start and stop points, and every bird sighted within the 200 m wide strip on either side of the aircraft into a WAV format sound file using the remote microphone/mouse. The observers identified birds to species and recorded group size as a single, pair, or number of birds in flocks. Simultaneously, at the mouse click for each sighting, the latitude/longitude coordinates (WGS84 datum) were automatically downloaded from the aircraft GPS to a computer file. We then used a computer transcription program to replay the sound files, enter header information (e.g. year, month, day, observer initials, etc.), species and group size, and combine these with the geographic coordinates to produce a final data file.

The average population index and standard error of the 4 (or 2) year mean was calculated by multiplying the appropriate stratum area by the average bird density for each species. Duck population indices were based on indicated total birds: $2 * (S + P) + F$, where S = number of single birds sighted, P = number of pairs sighted, and F = number of birds in flocks. A flock was defined as 5 or more ducks occurring together. A single male duck was assumed to represent a breeding pair because the nesting hen was usually not observable, and therefore a single male duck was doubled for all species except scaup. Scaup tend to have an unbalanced sex ratio with an excess of males in the population, therefore a single male scaup does not reliably indicate an unseen female. The indicated total bird index was calculated by doubling singles observed for all ducks (except scaup), cranes, and dark geese species. Singles observed were not doubled for the other species, i.e. loons, grebes, swans, scaup, jaegers, gulls, and raptors where the sexes are not obviously dimorphic and their population indices only included total birds sighted. Within each stratum, the sum of indicated total or observed total birds divided by the sum of sampled transect area estimated the average density. The variance of density was based on the variability among sampling units (transect sections) within each stratum determined by a ratio estimate (Cochran 1977). Density multiplied by stratum area calculated the population index. The sum of the population indices and sum of the variances for each of the strata provided the total population index and variance for each year. We did not use any visibility correction factors on the population indices.

Trend in species abundance is poorly determined by only 4 years of data. Nevertheless we made an approximate assessment of trend, limiting consideration to species with at least 3 non-zero index estimates, and an approximate annual growth rate < 0.95 (indicated as -) or > 1.05 (indicated by +). Statistical confidence intervals or tests seemed inappropriate.

Results

The 2008, 2009 (except for one transect), and 2010 surveys were flown in a single day (Table 1). Weather conditions at Bettles were well within the specifications for aerial surveys for all years and showed little differences between years (Tables 6-9). The stage chart for the Koyukuk River at Bettles for each year of the survey showed no indication of flooding. The 1997 survey was flown as part of a larger sample that also included the larger Koyukuk wetland area and Kanuti transects were flown on parts of five days. The 1997 survey was 10 days later chronologically.

Species observed are listed in (Table 3). The species listed with zero abundance indicate those species that would have been observed and recorded had they been present. Several species

are difficult to identify by aerial observations. Grebes observed included one pair of Horned Grebe compared to 52 sightings of Red-necked Grebe and 36 unidentified grebes. All swans and swan nests observed are probably Trumpeter swan (*Cygnus buccinator*). Scaup may include both Greater Scaup (*Aythya marila*) and Lesser Scaup (*Aythya affinis*). Both species are listed as common and as probable nesters on the refuge (Northern Prairie Wildlife Research Center Bird Checklists of the United States, Kanuti National Wildlife Refuge web page:

<http://www.npwrc.usgs.gov/resource/birds/chekbird/r7/kanuti.htm>). The twice-recorded small black-headed gull was probably Bonaparte's Gull (*Larus philadelphia*). All three species of scoter were recorded with Surf Scoter (n=46 sightings) being the most common of those identified, in comparison to 4 Black Scoter, 4 White-winged Scoter, and 22 unidentified scoter. We present the population index as the total for combined species of scoters. The species of large white gull was variously recorded to be Glaucous, Glaucous-winged, Herring Gull, and unidentified gull.

According to the bird checklist, Glaucous gulls are rare in spring, Herring gulls are uncommon but probably nest on the refuge, and Glaucous-winged gulls are rare in summer. Rarely recorded species included Northern Harrier (n=4), Rough-legged Hawk (1), and Peregrine Falcon (1).

Population indices of birds for each of the 4 years within the Kanuti NWR boundary are listed in Table 4. Scaup had the highest population indices of all species each year and an overall average of 6,135 birds. Northern pintails and American wigeon were the next most abundant species with an average of 2,752 and 2,143 birds, respectively. Remaining species sighted on the surveys were substantially less abundant. There was also a generally large differences in indices between years for most species.

The western stratum, while smaller in area, contained an estimated 614 scaup and 438 pintails (Table 5). The northern stratum contained very low numbers of most species except for an estimated 600 scaup, 254 Canada geese and 185 American wigeon.

There was either no trend in indices over the time period of the surveys or else a positive trend possibly indicating a general increase in numbers of most species over time (Table 4). Most species showed generally greater population indices in 2010 as compared to indices in 1997.

Latitude and longitude coordinates of the aircraft position were captured for each bird sighting and these were used to indicate bird distribution by species for each year of the survey. Figures 3-8 show species sightings by number of birds for the major species encountered during the surveys.

Discussion

Many factors associated with aerial surveys such as weather, phenology, observers, aircraft type, etc can potentially affect the numbers of birds sighted. Weather conditions during each year's survey were comparable (Tables 6-9) and should not had an effect on numbers counted. Based on river stage charts, there appeared to be no flooding in any of the survey years during the survey period that would have caused a displacement of birds and affected numbers or distribution.

A different crew conducted the survey each year until 2010 when the same crew did the survey as in 2009. These changes in observers may have contributed to the large interannual variability in population indices. There appeared to be less variability in numbers between 2009 and 2010 when the same crew flew both surveys. Additionally, the difference in survey timing being later in spring in 1997 may have contributed to lower numbers of birds encountered that year.

These surveys have accomplished the objectives of obtaining a valid systematic sample of the wetlands of Kanuti National Wildlife Refuge. While the surveys resulted in population indices uncorrected for visibility bias, we believe the results provide a baseline for waterbird population numbers and relative distribution that will be beneficial for future management of the refuge.

Literature Cited

COCHRAN, W. G. 1977. Sampling techniques. 3rd ed. John Wiley and Sons, New York.

PLATTE R. M. 1999. Water bird distribution and abundance on Koyukuk and Kanuti National Wildlife Refuges and adjacent wetlands, Alaska, 1996 – 1997. Unpub. USFWS report, Anchorage, AK. 60pp.

U.S. FISH AND WILDLIFE SERVICE AND CANADIAN WILDLIFE SERVICE. 1987. Standard operating procedures for aerial breeding ground population and habitat surveys in North America. Unpub. Manual. U.S. Fish and Wildl. Serv., Can. Wildl. Serv., Laurel MD, 103pp.

Table 1. Timing and number of aerial transects sampling the 4189 km² of wetlands for waterbirds at Kanuti NWR and adjacent wetlands.

Dates flown	DOY	Seat	Obsvr	Observer
1, 2, 3, 4, 8 June 1997	152-159	Lf	JIH	Jack Hodges
		Rf	AWB	Alan Brackney
21 May 2008	142	Lf	RDM	Rob MacDonald
		Rf	DKM	Dennis Marks
23, 24 May 2009	143-144	Lf	EJM	Ed Mallek
		Rf	DJG	Debbie Groves
24 May 2010	144	Lf	EJM	Ed Mallek
		Rf	DJG	Debbie Groves

Table 2. Number of transects, observed area, and sightings in each stratum and year.

Str	Stratum	Stratum km ²	Year	N transects	Observed km ²	Sampling fraction	Total sightings	Total birds counted
1	Kanuti NWR	2781.2	1997	28	151.8	0.055	355	633
			2008	17	144.9	0.052	449	1180
			2009	17	154.0	0.055	618	1114
			2010	16	162.1	0.058	713	1205
2	North Drainage	804.1	1997	11	34.8	0.043	29	49
3	West	603.5	1997	13	27.4	0.045	60	102
			2008	11	29.1	0.048	52	131
			2009	11	30.7	0.051	78	118
			2010	4	13.4	0.022	50	75

Table 3. Number of birds recorded by species and group sizes combining all years and transects within the strata boundaries of Kanuti NWR and adjacent wetland areas.

			singles	pairs	flocks of 3-5	flocks 6-30	Flocks of 31+	Total
YBLO	Yellow-billed Loon	<i>Gavia adamsii</i>	0	0	0	0	0	0
COLO	Common Loon	<i>Gavia immer</i>	12	14	0	0	0	26
PALO	Pacific Loon	<i>Gavia pacifica</i>	15	28	0	0	0	43
RTLO	Red-throated Loon	<i>Gavia stellata</i>	8	10	0	0	0	18
RNGR	Red-necked Grebe	<i>Podiceps grisegena</i>	52	60	3	0	0	115
CAGO	Canada Goose	<i>Branta canadensis</i>	15	66	11	36	0	128
BLBR	Black Brant	<i>Branta bernicla nigricans</i>	0	0	0	0	0	0
EMGO	Emperor Goose	<i>Chen canagica</i>	0	0	0	0	0	0
SNGO	Snow Goose	<i>Chen caerulescens</i>	0	0	0	0	0	0
WFGO	White-fronted Goose	<i>Anser albifrons frontalis</i>	13	62	40	89	0	204
SWAN	Swan spp	<i>Cygnus spp.</i>	18	52	5	0	0	75
SWANN	Swan nest	<i>Cygnus spp.</i>	7	0	0	0	0	7
SACR	Sandhill Crane	<i>Grus canadensis</i>	18	6	13	8	0	45
MALL	Mallard	<i>Anas platyrhynchos</i>	121	166	0	13	0	300
NOPI	Northern Pintail	<i>Anas acuta</i>	192	270	0	22	0	484
AMWI	American Wigeon	<i>Anas americana</i>	125	260	5	18	0	408
NSHO	Northern Shoveler	<i>Anas clypeata</i>	37	108	0	8	0	153
AGWT	Green-winged Teal	<i>Anas crecca</i>	66	110	0	6	0	182
GADW	Gadwall	<i>Anas strepera</i>	0	0	0	0	0	0
CANV	Canvasback	<i>Aythya valisineria</i>	3	8	0	0	0	11
REDH	Redhead	<i>Aythya americana</i>	0	0	0	0	0	0
RNDU	Ring-necked Duck	<i>Aythya collaris</i>	9	44	3	0	0	56
SCAU	Scaup spp	<i>Aythya spp.</i>	213	1000	20	168	75	1476
GOLD	Goldeneye spp	<i>Bucephala spp.</i>	11	26	0	0	0	37
BUFF	Bufflehead	<i>Bucephala albeola</i>	41	42	5	0	0	88
LTDU	Long-tailed Duck	<i>Clangula hyemalis</i>	7	20	0	0	0	27
RBME	Red-breasted Merganser	<i>Mergus serrator</i>	6	24	0	7	0	37
COME	Common Merganser	<i>Mergus merganser</i>	0	4	0	0	0	4
COEI	Common Eider	<i>Somateria mollissima</i>	0	0	0	0	0	0
KIEI	King Eider	<i>Somateria spectabilis</i>	0	0	0	0	0	0
SPEI	Spectacled Eider	<i>Somateria fischeri</i>	0	0	0	0	0	0
STEI	Steller's Eider	<i>Polysticta stelleri</i>	0	0	0	0	0	0
BLSC	Black Scoter	<i>Melanitta americana</i>	2	4	0	0	0	6
WWSC	White-winged Scoter	<i>Melanitta fusca</i>	0	8	0	0	0	8
SUSC	Surf Scoter	<i>Melanitta perspicillata</i>	18	42	0	0	0	60
SCOT	Scoter spp	<i>Melanitta spp.</i>	5	34	0	0	0	39
JAEG	Jaeger spp	<i>Stercorarius spp.</i>	2	0	0	0	0	2
GLGU	Glaucous Gull	<i>Larus hyperboreus</i>	7	2	0	0	0	9
MEGU	Mew Gull	<i>Larus canus</i>	20	10	9	0	0	39
BOGU	Bonaparte's Gull	<i>Larus philadelphia</i>	1	2	0	0	0	3
ARTE	Arctic Tern	<i>Sterna paradisaea</i>	18	6	15	26	0	65
BAEA	Bald Eagle	<i>Haliaeetus leucocephalus</i>	2	0	0	0	0	2
GOEA	Golden Eagle	<i>Aquila chrysaetos</i>	0	0	0	0	0	0
SEOW	Short-eared Owl	<i>Asio flammeus</i>	0	0	0	0	0	0
SNOW	Snowy Owl	<i>Bubo scandiacus</i>	0	0	0	0	0	0
CORA	Common Raven	<i>Corvus corax</i>	3	0	6	8	0	17

Table 4. Aerial survey population indices for waterbird species in Kanuti NWR estimated by aerial surveys flown in 1997, 2008, 2009, and 2010.

sppn	N sightings				Indicated total birds index				<i>SE ind. total birds index</i>				Average	SE	trend
	1997	2008	2009	2010	1997	2008	2009	2010	1997	2008	2009	2010			
COLO	6	0	6	4	128	0	163	120	69	0	71	56	103	57	0
PALO	8	4	9	4	220	115	217	103	71	78	99	68	164	80	0
RTLO	0	8	1	0	0	173	36	0	0	84	37	0	52	46	
RNGR	11	4	35	24	238	96	903	600	82	67	245	150	459	153	+
CAGO	5	4	15	21	256	154	813	824	119	86	290	492	512	295	+
WFGO	6	11	26	13	403	787	1571	635	201	497	919	250	849	546	+
SWAN	7	10	10	16	183	307	271	532	90	111	98	266	323	158	+
SACR	1	5	12	6	37	230	578	206	37	97	128	78	263	91	+
MALL	15	24	67	77	550	922	2420	2642	197	232	726	797	1633	560	+
NOPI	15	111	76	91	879	4262	2745	3122	513	677	707	733	2752	663	+
AMWI	47	14	75	97	1997	538	2709	3328	503	161	611	796	2143	567	0
NSHO	6	5	33	29	220	192	1300	995	134	104	374	311	677	258	+
AGWT	14	15	41	42	513	653	1481	1441	168	250	226	209	1022	215	+
GADW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
CANV	0	2	1	4	0	77	36	137	0	55	35	101	63	60	+
REDH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
RNDU	5	3	13	8	147	96	415	257	71	52	136	122	229	101	0
SCAU	141	158	145	216	4250	7026	5923	7343	793	2683	1851	2404	6135	2064	0
GOLD	0	4	2	14	0	154	72	480	0	119	52	124	177	90	+
BUFF	12	6	19	18	440	230	686	618	151	97	327	197	493	211	0
LTDU	4	6	2	1	147	230	72	34	143	85	69	35	121	92	0
RBME	1	3	5	8	37	115	271	275	37	64	149	102	174	98	+
COME	1	1	0	0	37	38	0	0	36	38	0	0	19	26	
SCOT	15	13	25	13	550	499	903	446	237	243	199	195	599	219	0
JAEG	0	2			0	38			0	26			19	18	
GLGU	4	4			73	96			33	41			85	37	
MEGU	14	5			348	173			121	79			260	102	
SAGU	0	2			0	58			0	41			29	29	
ARTE	13	9			586	288			254	120			437	199	
BAEA	1	1	0	0	18	19	0	0	18	19	0	0	9	13	
GOEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
SEOW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
CORA	0	2	0	3	0	38	0	240	0	28	0	200	70	101	

Table 5. Average aerial survey population indices for waterbird species in river drainage wetlands to the north or west of Kanuti NWR as estimated by aerial surveys flown in 1997, 2008, 2009, and 2010.

sppn	Wetlands west of Kanuti NWR				Wetlands north of Kanuti NWR		
	N sightings	Average indicate d total birds index	SE average index	Appro x trend	N sightings	Average indicate d total birds index	SE average index
COLO	3	17	14		0	0	0
PALO	3	32	37		1	46	49
RTLO	4	36	47		0	0	0
RNGR	9	81	61	0	0	0	0
CAGO	7	88	81	0	3	254	187
WFGO	4	167	257	+	0	0	0
SWAN	1	10	22		1	23	25
SACR	2	37	60		0	0	0
MALL	21	324	191	0	1	46	48
NOPI	36	438	263	+	0	0	0
AMWI	22	324	168	+	4	185	63
NSHO	19	306	238	+	0	0	0
AGWT	10	140	77	+	0	0	0
GADW	0	0	0		0	0	0
CANV	0	0	0		0	0	0
REDH	0	0	0		0	0	0
RNDU	3	37	53		0	0	0
SCAU	61	614	374	0	15	600	250
GOLD	4	54	63	0	0	0	0
BUFF	6	82	70		2	92	81
LTDU	4	43	51		0	0	0
RBME	2	33	43		0	0	0
COME	0	0	0		0	0	0
SCOT	3	31	44		0	0	0
JAEG	0	0	0		0	0	0
GLGU	0	0	0		0	0	0
MEGU	9	119	68		0	0	0
SAGU	0	0	0		0	0	0
ARTE	5	183	156		1	23	22
BAEA	0	0	0		0	0	0
GOEA	0	0	0		0	0	0
SEOW	0	0	0		0	0	0
CORA	1	5	10		0	0	0

Table 6. Hourly observations of weather at Bettles for June 3, 1997 from Weather Underground web site. (survey was conducted over multiple days, June 3 chosen as representative)

Time (AKDT)	Temp.	Dew Point	Humidity	Sea Level Pressure	Visibility	Wind Dir	Wind Speed	Conditions
11:54 AM	59.0 °F	41.0 °F	51%	29.90 in	40.0 miles	ENE	6.9 mph	Mostly Cloudy
12:52 PM	64.4 °F	44.6 °F	49%	29.90 in	40.0 miles	ENE	8.1 mph	Mostly Cloudy
1:51 PM	66.2 °F	41.0 °F	40%	29.91 in	40.0 miles	Calm	Calm	Mostly Cloudy
2:50 PM	68.0 °F	39.2 °F	35%	29.90 in	40.0 miles	Calm	Calm	Mostly Cloudy

Table 7. Hourly observations of weather at Bettles for May 21, 2008 during aerial survey from Weather Underground web site.

Time (AKDT)	Temp.	Dew Point	Humidity	Sea Level Pressure	Visibility	Wind Dir	Wind Speed	Conditions
1:53 PM	59.0 °F	30.9 °F	35%	30.07 in	10.0 miles	SE	6.9 mph	Mostly Cloudy
2:53 PM	57.9 °F	33.1 °F	39%	30.06 in	10.0 miles	ESE	11.5 mph	Mostly Cloudy
3:53 PM	57.0 °F	35.1 °F	44%	30.07 in	10.0 miles	SSE	11.5 mph	Mostly Cloudy
4:53 PM	57.0 °F	36.0 °F	45%	30.07 in	10.0 miles	North	4.6 mph	Mostly Cloudy
5:53 PM	60.1 °F	33.1 °F	36%	30.07 in	10.0 miles	North	6.9 mph	Mostly Cloudy
6:53 PM	60.1 °F	32.0 °F	35%	30.07 in	10.0 miles	North	3.5 mph	Mostly Cloudy
7:53 PM	60.1 °F	28.9 °F	31%	30.07 in	10.0 miles	Variable	3.5 mph	Mostly Cloudy

Table 8. Hourly observations of weather at Bettles for May 23, 2009 during aerial survey from Weather Underground web site.

Time (AKDT)	Temp.	Dew Point	Humidity	Sea Level Pressure	Visibility	Wind Dir	Wind Speed	Conditions
11:53 AM	64.0 °F	28.0 °F	26%	30.06 in	10.0 miles	Variable	5.8 mph	Mostly Cloudy
12:53 PM	64.9 °F	28.9 °F	26%	30.06 in	10.0 miles	Variable	4.6 mph	Mostly Cloudy
1:53 PM	66.9 °F	30.0 °F	25%	30.05 in	10.0 miles	Variable	4.6 mph	Mostly Cloudy
2:53 PM	64.9 °F	33.1 °F	31%	30.05 in	10.0 miles	Calm	Calm	Mostly Cloudy

Table 9. Hourly observations of weather at Bettles for May 24, 2010 during aerial survey from Weather Underground web site.

Time (AKDT)	Temp.	Dew Point	Humidity	Sea Level Pressure	Visibility	Wind Dir	Wind Speed	Conditions
1:53 PM	64.0 °F	41.0 °F	43%	29.80 in	10.0 miles	Calm	Calm	Mostly Cloudy
2:53 PM	64.9 °F	37.9 °F	37%	29.81 in	10.0 miles	ESE	9.2 mph	Scattered Clouds
3:53 PM	64.9 °F	37.0 °F	36%	29.79 in	10.0 miles	ESE	6.9 mph	Scattered Clouds
4:53 PM	68.0 °F	37.0 °F	32%	29.78 in	10.0 miles	Variable	3.5 mph	Partly Cloudy
5:53 PM	69.1 °F	39.0 °F	33%	29.77 in	10.0 miles	Variable	4.6 mph	Partly Cloudy



Fig. 1. North American Waterfowl Breeding Population Survey transects, 1997 expanded survey area and transects, and 2008-2010 expanded survey area and transects, Kanuti National Wildlife Refuge, Alaska. 2008 and 2009 transects overlaid the 1997 transects, but were in a smaller survey area. 2010 transects were in the smaller survey area but were located halfway between the previous years transects. Transects in 2 western polygons were not flown in 2010.

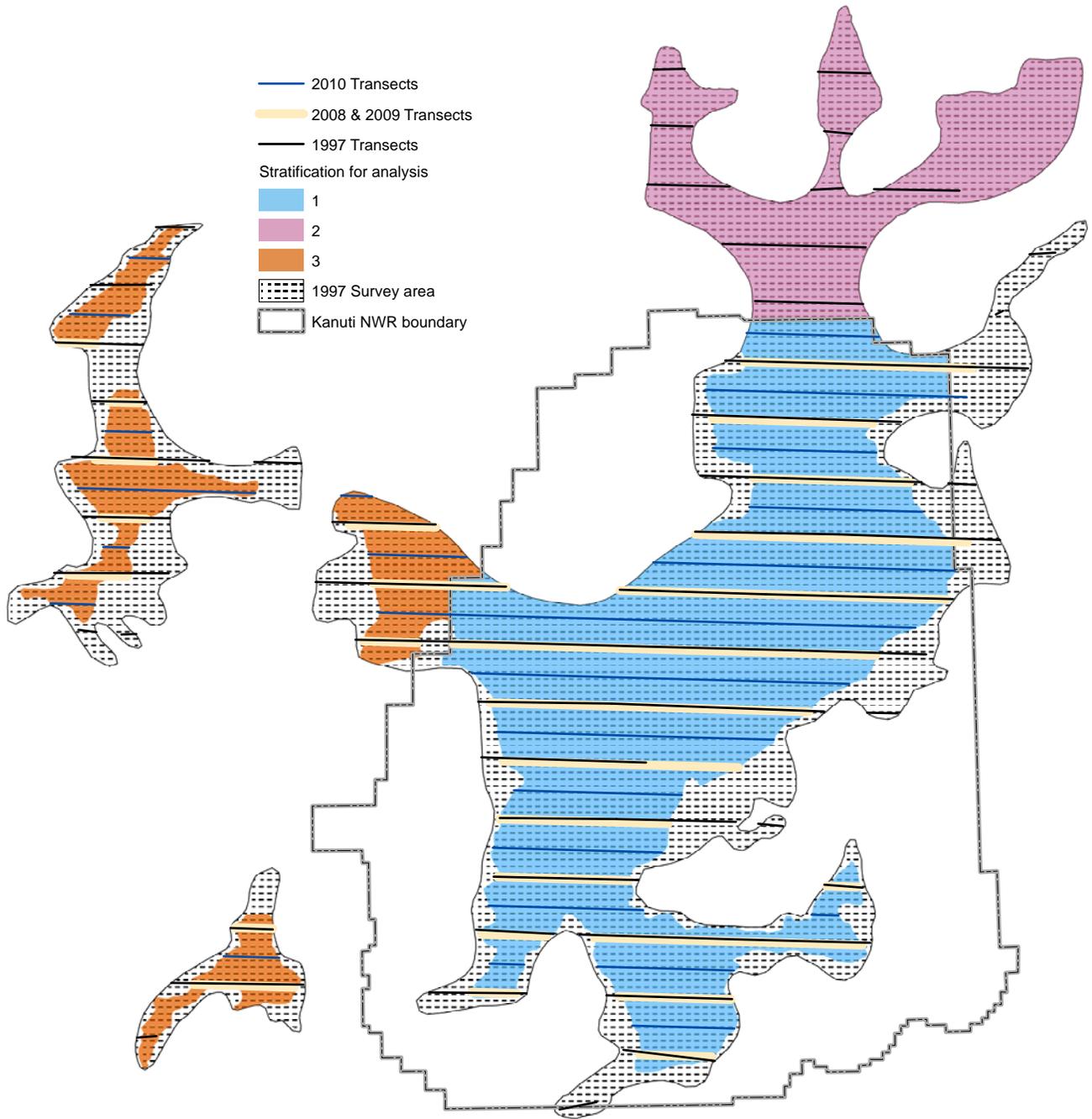


Fig. 2. Stratification for population analysis of 1997, and 2008-2010 aerial waterbird survey data on Kanuti National Wildlife Refuge, Alaska. Also shown are strip transects for each year of survey. The design changed over time to remove marginal habitat and the final stratification allows annual comparisons on the core area within the refuge boundary.

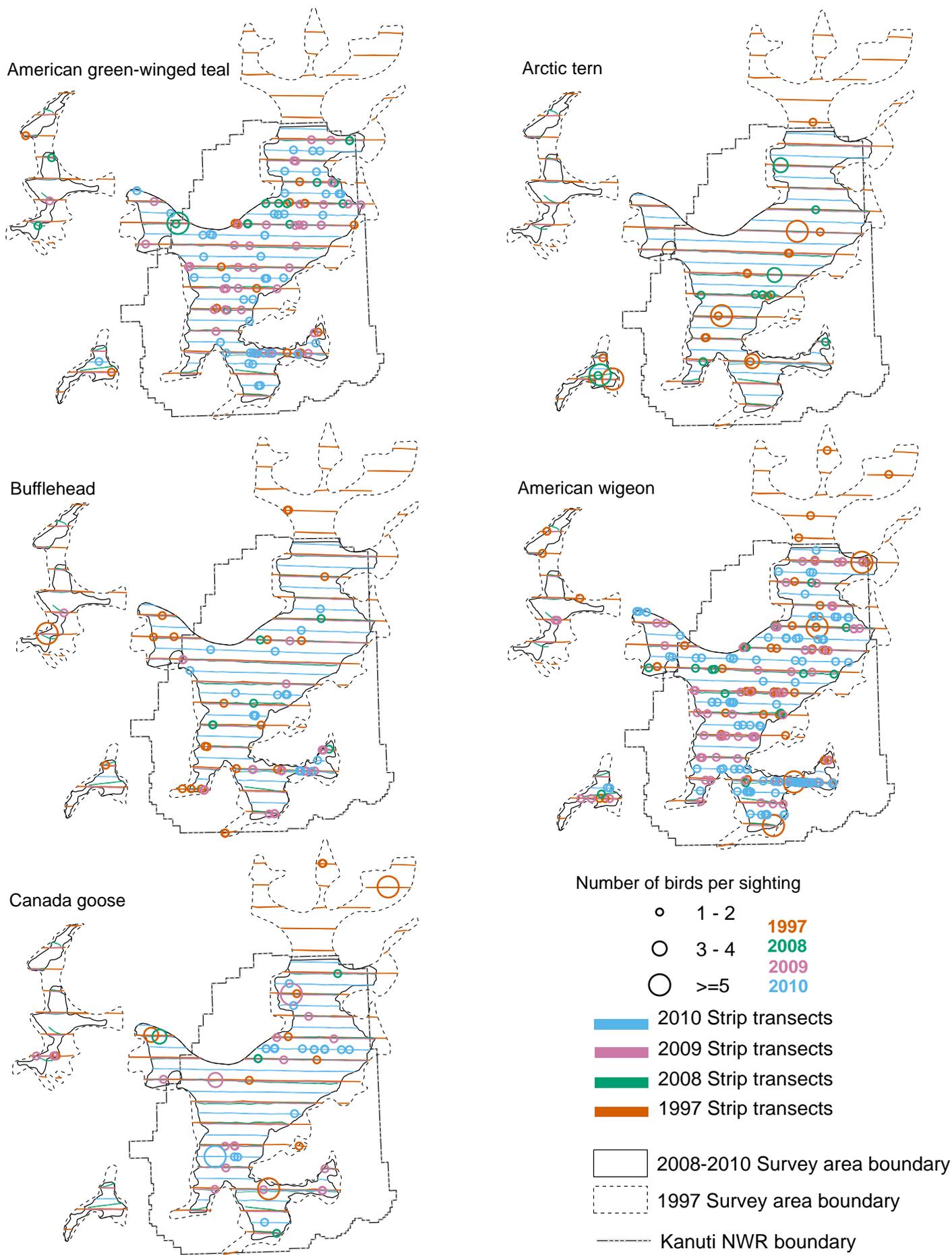


Fig. 3. Species sightings from aerial surveys of Kanuti National Wildlife Refuge, Alaska, 1997, 2008, 2009, and 2010.

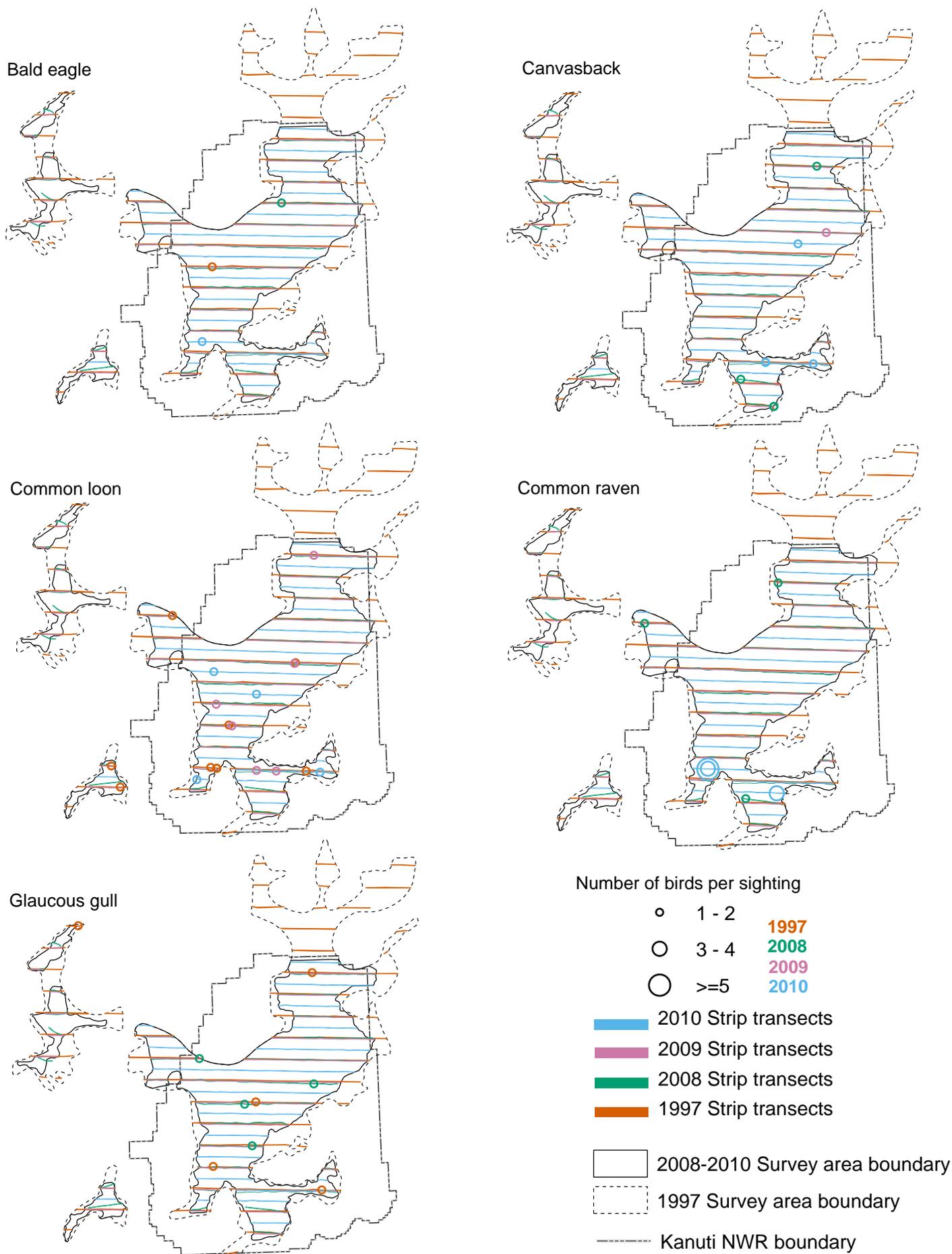


Fig. 4. Species sightings from aerial surveys of Kanuti National Wildlife Refuge, Alaska, 1997, 2008, 2009, and 2010.

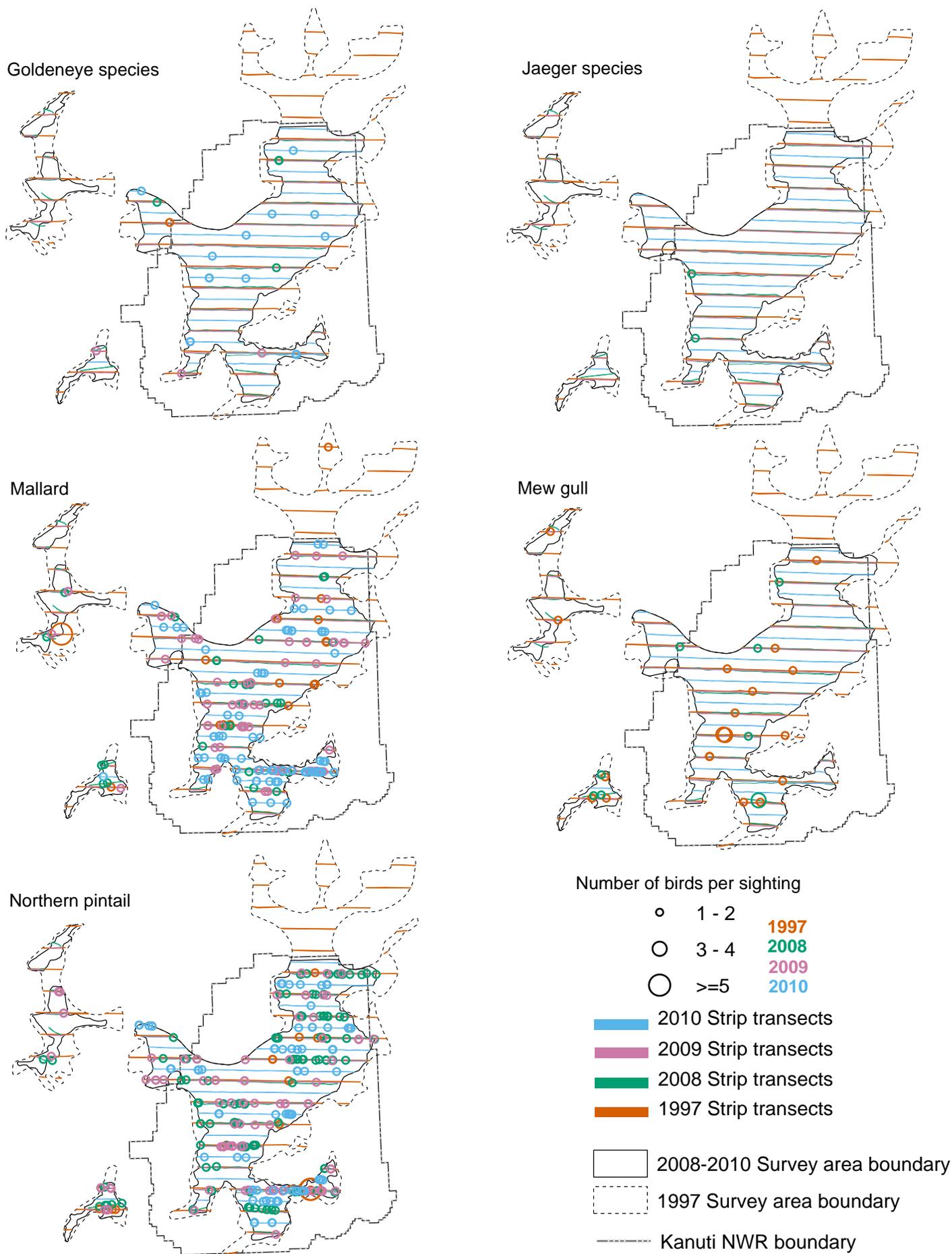


Fig. 5. Species sightings from aerial surveys of Kanuti National Wildlife Refuge, Alaska, 1997, 2008, 2009, and 2010.

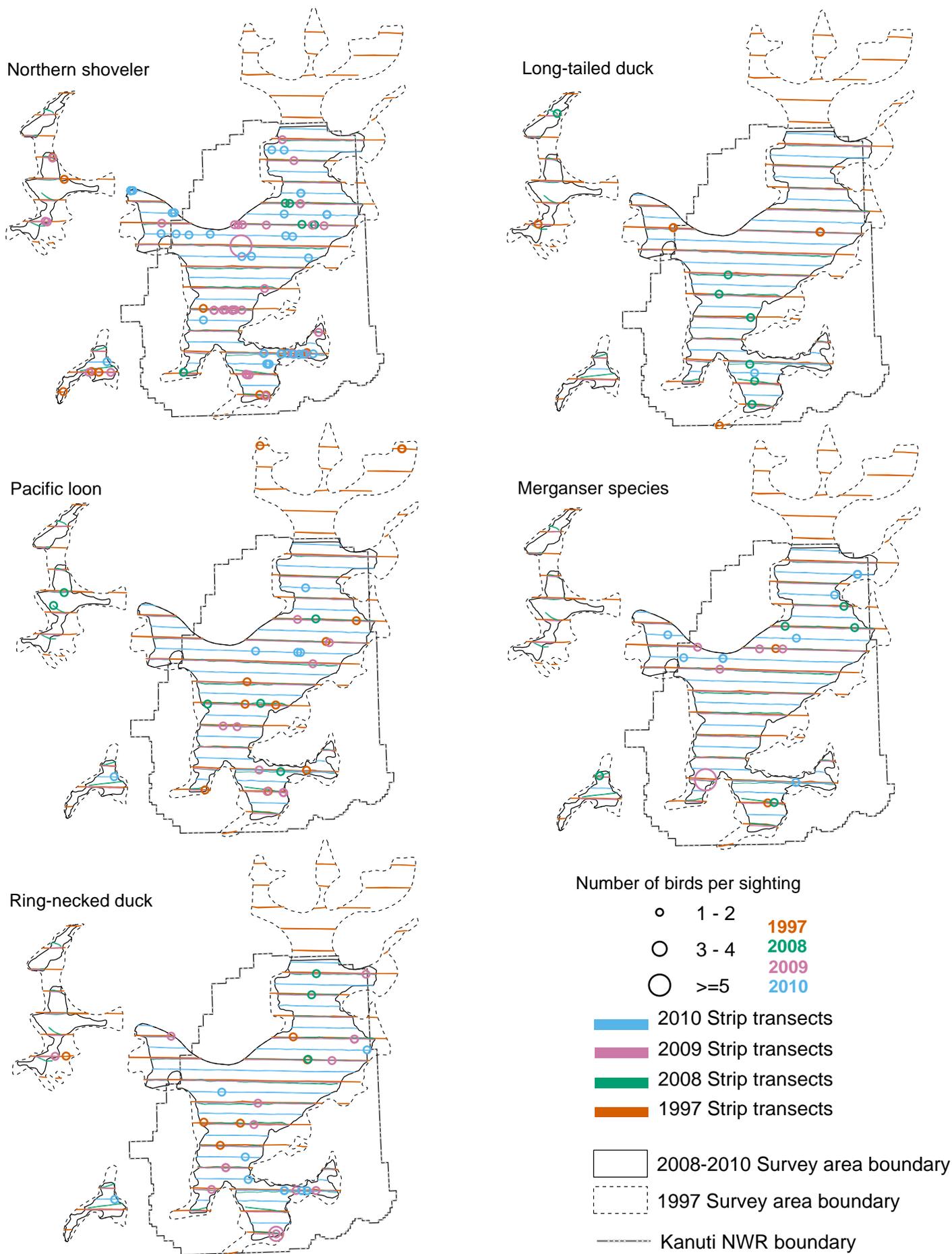


Fig. 6. Species sightings from aerial surveys of Kanuti National Wildlife Refuge, Alaska, 1997, 2008, 2009, and 2010.

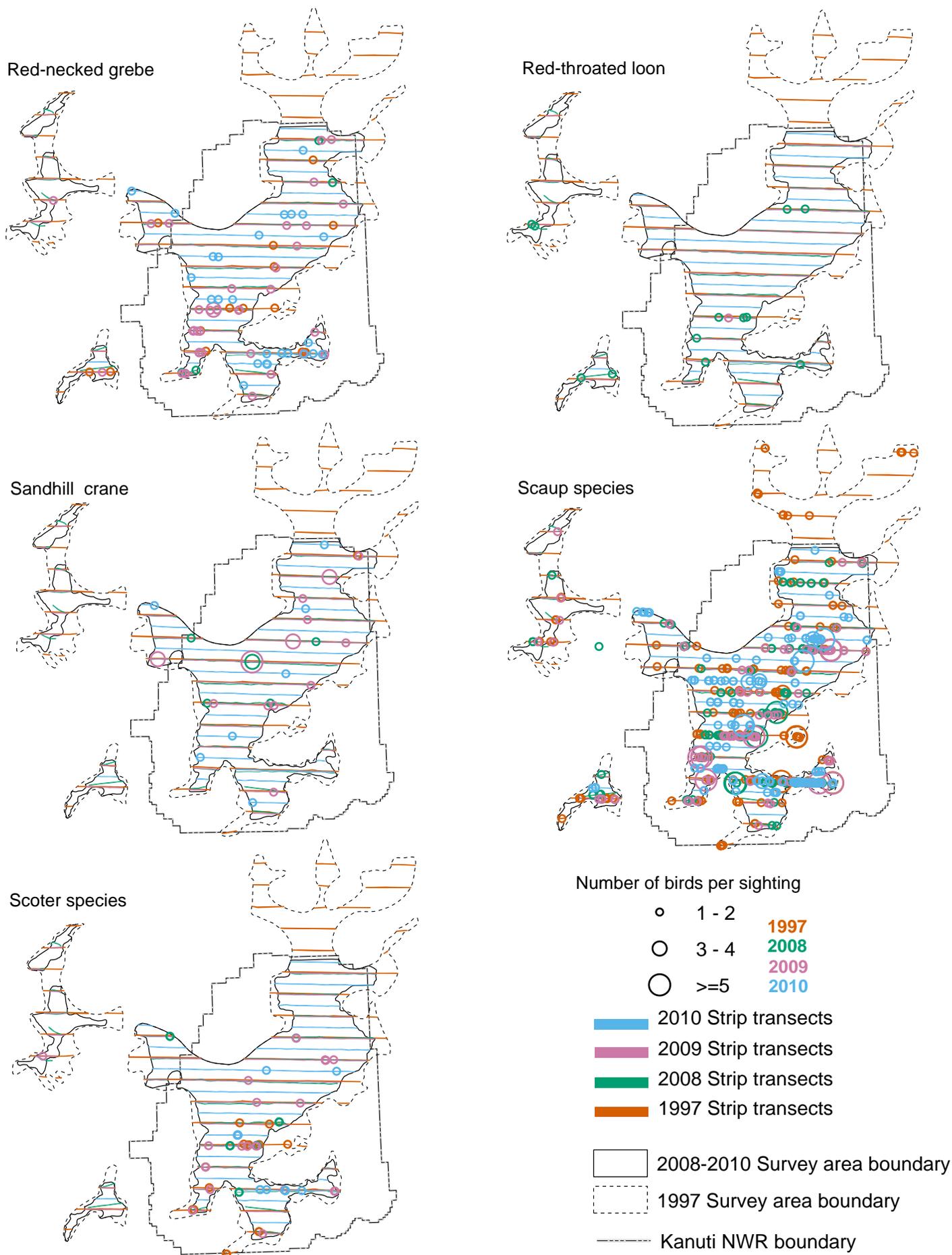


Fig. 7. Species sightings from aerial surveys of Kanuti National Wildlife Refuge, Alaska, 1997, 2008, 2009, and 2010.

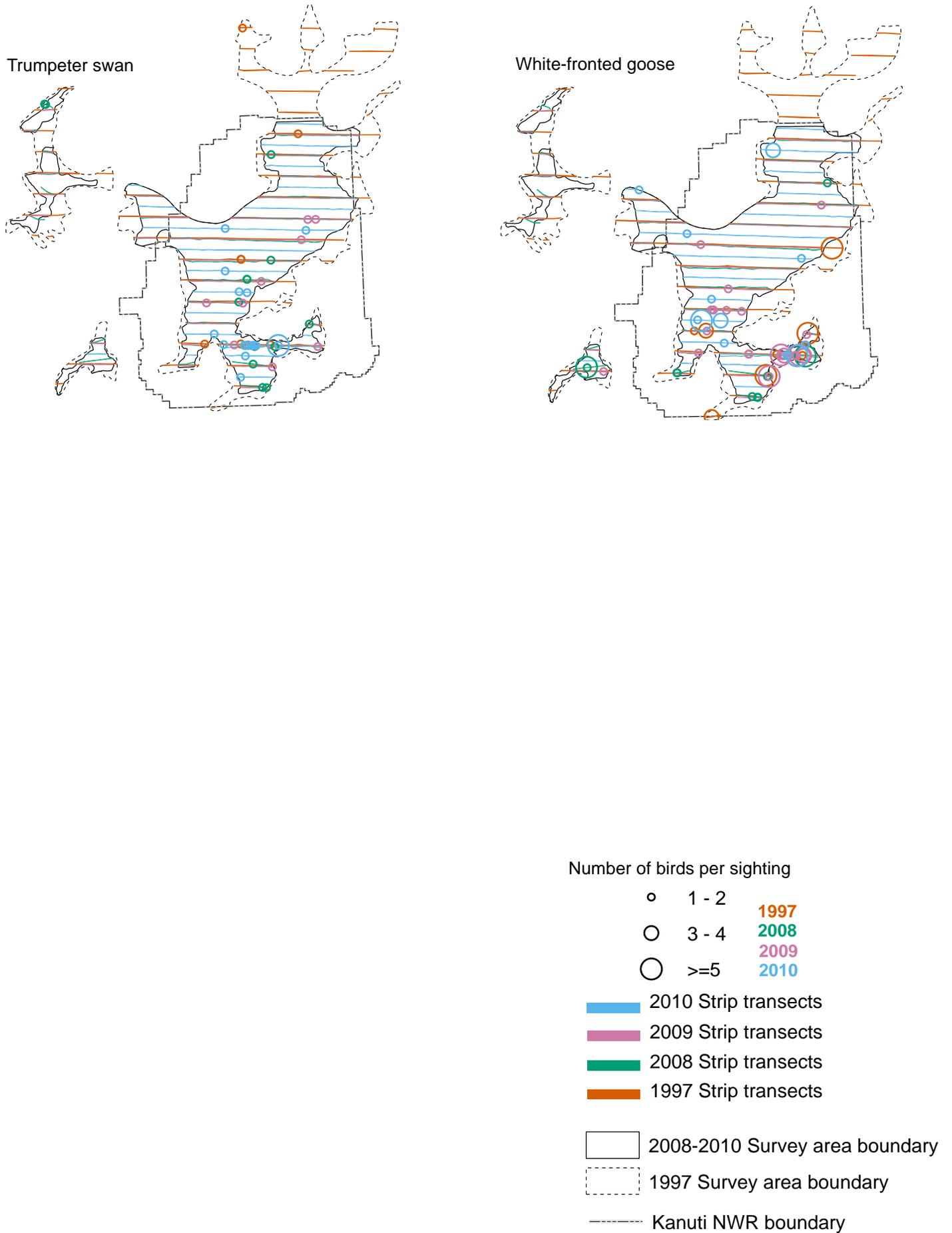


Fig. 8. Species sightings from aerial surveys of Kanuti National Wildlife Refuge, Alaska, 1997, 2008, 2009, and 2010.