Expanded waterbird aerial surveys on Innoko National Wildlife Refuge and Yukon River wetlands, Alaska, 1994, 1995, and 2008-2011

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Introduction

Spring aerial surveys for waterfowl have been conducted on Innoko National Wildlife Refuge (INWR) since 1957 of the North American Waterfowl Breeding Population and Habitat Survey (WBPHS Stratum 5 and a portion of Stratum 6, Mallek and Groves 2012). However, due to the large geographic extent of the WBPHS, only 9 transects cover the Innoko NWR. Therefore to improve sample distribution of this region we conducted an expanded survey in 1994 and 1995 that provided more intensive transect coverage of the area (Platte 1996). In 2008, the expanded survey was redesigned and flown to provide more current information on waterbird population abundance and distribution. One impetus to obtain contemporary abundance and distribution data was to provide baseline waterbird data prior to a potential introduction of Wood Bison in the vicinity. The primary objectives of the surveys were to estimate abundance of waterbirds and map their distributions in the survey area. We report population indices for 4 strata covering all years survey areas and average population size combining all years of data.

Methods

Survey design

The 1994 survey area included the main wetlands on the southern unit of INWR (Figs. 1 and 2 and Tables 1 and 2). The 1995 survey area included the wetlands along the Yukon River corridor starting in the south just within the border of Yukon Delta NWR south of Holy Cross, and extending northward to include the northern unit of INWR. The survey area from 1994-1995 was modified to produce a new survey area for the 2008-2011 surveys. The new survey area included wetlands within the vicinity of a potential Wood Bison introduction proposed by the Alaska Department of Fish and Game.

The design was originally intended to be a 3-year (2008-2010) rotating panel of transects equally spaced each year and offset from the other years such that after 3 years the data could be combined for distribution mapping. We used a custom True BASIC program and ArcGIS® (Environmental Systems Research Institute, Inc., Redlands, California) geographic information system (GIS) software to generate systematic transects from a random coordinate within the survey area. Transects were oriented east-west along great circle routes. In 1994, transects were spaced 3.7 km apart, in 1995, 7.4 km apart. For the remaining years, transect spacing was 3.2 km for each year. Because the survey area varied over the years, we created a stratification that included 4 strata that were sampled during the different years of the survey (Figure 2).

Data collection

The surveys were flown around the last week of May or first week of June to coincide with egg-laying or early incubation stages for breeding waterbirds (Spindler and Hans 2005). All surveys were flown with a Cessna 206 amphibious aircraft except a Cessna 185 on straight floats was used in 2010. Survey methods followed the standard protocol established for waterfowl breeding ground surveys in North America (USFWS and Canadian Wildlife Service 1987). The aircraft 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 a notebook computer screen to maintain a precise course while flying transects.

In 1994 and 1995, tape recorders were used to record bird sightings (Butler, et al. 1995). In 2008-2011, both pilot and observer (observer only in 2010) 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 a 200 m wide strip on either side of the aircraft into a WAV format sound file using a remote microphone/mouse. The observers identified birds to species or generic group 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) of the aircraft at the time of each sighting were automatically downloaded from the aircraft GPS to computer files. The recording program was also used to record coordinates every 5 seconds during flights thus providing data that was incorporated into the GIS to plot flight lines and produce strip transects by buffering each observer's track by 100 meters.

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 GPS positions of the aircraft at each bird sighting were used to represent where the birds were sighted. Each pair of sighting coordinates were offset 100m perpendicular to the transect to be ultimately located in the center of the 200-meter-wide transect to yield the best estimate of actual bird location.

Population Analysis

The average population index and standard error of the mean was calculated by multiplying the appropriate survey unit area by the average bird density for each species. Analyses followed standard aerial breeding pair survey methods (USFWS and Canadian Wildlife Service 1987). Duck population indices were calculated as 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 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 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, jaegers, gulls, and raptors) where the sexes are not obviously dimorphic and their population indices only included total birds sighted.

Within each survey unit, 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 survey unit determined by a ratio estimate (Cochran 1977). Density multiplied by survey unit area calculated the population index. The sum of the population indices and sum of

the variances for each of the units provided the total population index and variance for each year. If a survey unit was sampled in more than one year, the final population size was calculated by averaging the individual year indices. We did not use any visibility correction factors on the population indices. Because the survey was flown on different areas in different years with different observers and occurred on the same area for only a relatively few years, we did not attempt to calculate any trends in bird populations nor did we compare population indices between years.

Distribution Analysis

Bird sightings were plotted for each species and each year (Appendices 2-7). All bird sightings were input into the kernel density tool in ArcMap and density maps of sightings per square kilometer were created. Sightings were not weighted by number of birds per sighting. The densities were calculated using a search radius of 6.4 km and plotted with an output cell size of 300 m (default values based on survey area extent). Maps for each year were created by using the Jenks Natural Breaks Classification (Jenks 1967) with 9 classes in ArcMap.

Locations of individual species sightings for each year were analyzed with the average nearest neighbor tool in ArcMap to determine if the species distribution tended to be clustered, random, or dispersed. We only used species with >= 20 sightings for this analysis. The Nearest Neighbor Index is the ratio of the Observed Mean Distance to the Expected Mean Distance. The expected distance is the average distance between neighbors in a hypothetical random distribution. If the index is less than 1, the pattern exhibits clustering; if the index is greater than 1, the trend is toward dispersion or competition (Mitchell 2005). The null hypothesis was that the sightings were randomly distributed. We tested the hypothesis by calculating z-scores and p-values.

We conducted a mean center analysis for northern pintail and scaup (two of the most abundant and important species on the refuge) sightings on the Iditarod River stratum which had the best aerial coverage over five survey years. Mean centers of sightings for each year were calculated to determine if distributions changed through time. The mean center is the average x-coordinate and y-coordinate of a species sightings within the stratum. We also calculated mean centers of transects to adjust for changes in transect locations between years.

Using water bodies for the stratum from the National Hydrography Data Set, we calculated the mean center of water bodies to see if bird distribution coincided with distribution of habitat. Standard deviational ellipses (1 standard deviation ellipse contains about 68% of the sightings) were also calculated to examine the spatial variability of the distributions.

Results

Population Size

Species composition, population size, and distribution have been previously reported for the 1994 and 1995 surveys (Platte 1996). Dates of surveys, flight crews, and details of survey designs are listed in Table 2. The following results indicate average population sizes over all years combined. Northern pintails (*Anas acuta*) had the highest average population index with 12,427 birds, followed in decreasing order of abundance

by American wigeon (*Anas americana*), lesser scaup (*Aythya affinis*), northern shovelers (*Anas clypeata*), and mallards (*Anas platyrhynchos*) of the 21 species recorded (Table 3). Scoters (*Melanitta* spp.), loons (*Gavia* spp.), sandhill cranes (*Grus canadensis*), and mergansers (*Mergus* spp.) occurred in much smaller numbers and had the lowest population indices, all less than 1,000 birds. The North Yukon River stratum contained the highest population indices for American wigeon, scaup, northern shovelers, mallards and green-winged teal (*Anas crecca*) while pintails and Canada geese (*Branta canadensis*) were most abundant in the Iditarod River stratum. White-fronted geese (*Anser albifrons*) were most numerous in the Innoko River stratum. A summary of species recorded by year is given in Appendix 1.

Weather conditions at Anvik or McGrath were within the specifications for aerial surveys for all years and showed little differences between years (Fig. 3 and Table 4). Breakup date for the Yukon River at Grayling varied over the survey years: 11 May 1994, 7 May 1995, 14 May 2010, and 18 May 2011 (NOAA National Weather Service Alaska-Pacific River Forecast Center http://aprfc.arh.noaa.gov/php/brkup/getavgbrkup.php?syear=2008&eyear=2011&riverbasin=Yukon&river=Yukon+River&location=Grayling). No information for 2008 or 2009 was available. The variation in river breakup dates is an indication of differences in spring phenology between years which could have affected the migration timing of waterbirds and thus the number of birds present on similar calendar dates.

We used only the left seat observer data from 1994 due to apparent misidentification problems with the right front seat observer. Only the right seat observer recorded data on all transects in 2010 as the pilot was not trained in species identification. Due to unforeseen circumstances, only transects in the Iditarod River stratum were flown in the 2008 survey. The 2011 survey was flown to compensate for the partial survey of 2008. Complete surveys were flown in 2009 and 2011.

The originally designed rotating panel of transects was not achieved throughout the survey area. We flew the 2008 transect design in 2009 along the Yukon River wetlands so as to obtain data on the transects missed in 2008. The second year set of transects of the 3-year rotation was flown in 2009 in the northern portion of the survey area as designed. In 2010 and 2011 an intermediate set of transects was flown along the Yukon River corridor whereas the final panel of the design was flown in the Iditarod River stratum.

Distribution

Estimated relative density distributions for all bird species sightings are shown for each year in Figure 4. Birds were concentrated in the southern portion of the survey area along the Iditarod River in 1994. This area tended to show higher densities of waterbirds in the other survey years as well. In 1995, distribution of waterbirds was concentrated along the eastern portion of the Yukon River corridor except in the south where birds were concentrated in the central portion of the survey area. This general pattern of concentration in the eastern part of the survey area reflected the distribution of habitat along the corridor. Based on the vegetation classification (Boggs et al, 2012), the western half of the corridor had large amounts of Deciduous Forest with very little water habitat (Fig. 5). This pattern remained similar in the subsequent surveys in 2009, 2010, and 2011. In the northern unit of the Innoko NWR a high density area of bird sightings

occurred on the wetlands east of Kaltag in 1995. Higher densities of birds generally coincided with areas with many lakes and wetland complexes.

Individual species such as scaup, pintails, wigeon, and shovelers showed a clustered distribution of sightings (Table 5) based on the nearest neighbor analysis. Conversely mallard, mew gull, and greater white-fronted goose sightings tended to be more randomly distributed. Swans tended to be dispersed or randomly distributed.

Mean centers of strip transects in the Iditarod River stratum shifted slightly year to year based on the rotating panel of transects but shifts were less than 4 km (Fig. 6). Northern pintail mean centers did not vary much year to year with the largest distance of about 8 km between 1994 and 2011. These shifts were a relatively small percentage of either the east west or north south extent of the stratum. Pintail standard deviational ellipses showed some variation in size and orientation however there appeared to be little indication of substantial distributional change for northern pintails between different years of surveys.

Scaup mean centers shifted between 5 and 14 km between years with the 2010 mean center furthest from the other years which tended to cluster near the center of the survey area. The 2010 standard deviational ellipse for scaup was smaller than ellipses for other years indicating a more clustered distribution of sightings for that year. Orientation of each ellipse tended to be slightly in the east-west direction but did not change substantially between survey years.

Lakes and ponds were distributed throughout the Iditarod stratum and varied greatly in size. The southern portion contained numerous small lakes whereas the northern and western areas contained fewer but larger lakes. The mean center of lakes occurred roughly in the center of the stratum. Mean centers for each northern pintail distribution, however, did not coincide with the lakes mean center but were located more northwesterly within the stratum. This seemed to indicate greater use of the northern/western part of the stratum by northern pintails. Scaup mean centers however occurred near the center of the stratum.

Discussion

There was little consistency in survey crews throughout these surveys. A different pilot flew the survey every year and the same right seat observer occurred in only 3 of the 6 years. Timing of the surveys also varied somewhat between years primarily occurring later in the spring during the 1994-1995 surveys. Survey timing relative to spring phenology can affect the number of bird sightings on aerial surveys. Weather conditions can also affect number of birds seen both due to the birds behavior during differing weather conditions and by the weather's effect on detecting birds from an airplane. However, weather varied little between survey years and was not believed to be a significant contributing factor to between year observation variability.

Differences in observers during the course of these surveys may have led to differences in density of sightings due to different detection rates between observers. For example, the 2010 right seat observer had more sightings compared to the 2011 right seat observer. Also there were large differences in numbers of green-winged teal, wigeon, black scoter, northern pintail, northern shoveler, and scaup between the 2 observers. Conversely there were small differences in number of sightings of arctic tern, Canada

goose, and white-fronted goose. The new pilot in 2011 had substantially less sightings than the more experienced pilot in 2009.

Despite the inconsistency in observers and sightings, all observers were training in low level aerial waterbird survey techniques, thus we do not attribute differences to observer error. Sampling error or actual changes in the number of birds present between the years was probably more important. Sightings maps provide the basic information on species distributions. However, it can be difficult to compare the maps through time. Spatial statistics provide a quantitative way to do these comparisons. Mean centers of distribution for abundant species can serve as baselines with which to evaluate any future changes in distribution with comparable future aerial surveys.

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Table 1. Aerial survey strata, areas, and sampled years for wetland areas in and around Innoko National Wildlife Refuge.

Stratum	Stratum	Years flown	Stratum km^2
1	Upper Innoko River	1994 only	4198.4
2	Yukon R: Grayling north to Galena	1995 only	5345.7
3	Iditarod River	1994, 2008-11	2865.9
4	Yukon R: Grayling south to Holy Cross	1995, 2009-11	3747.6

Table 2. Aerial survey years, observers, area observed, and number of transects flown in wetland strata in and around Innoko National Wildlife Refuge.

Year	1994	1995	2008	2009	2010	2011
Seat	lf	Lf-rf	Lf-rf	Lf-rf	rf	Lf-rf
Obsvr	jih	Wwl-awb	Rdm-dkm	Ksb-dkm	dkm	Hmw-pda
Stratum	Observed km2					
1	223.6					
2		289.6				
3	154		303.2	308.5	153.6	309.9
4		202.7		409.9	205.9	408.6
	Number of transect sections					
1	100					
2		49				
3	49		25	26	25	25
4		33		40	41	41

Lf = left front seat, rf = right front seat

Table 3. Average aerial index for total birds as the sum of available averaged indices across years in each stratum (sampled 1 to 5 years) with 90% confidence intervals based on estimated sampling errors within each stratum. See Appendix 1 for species names.

	Total bird index				**90% c.i.**				**Sum total index**	**90% c.i.**	**%CV**
Stratum	Innoko R	n Yukon R	Iditarod R	s Yukon R	Innoko R	n Yukon R	Iditarod R	s Yukon R			
Str N=	1	2	3	4	1	2	3	4			
Sppn											
NOPI	1991	2289	4102	4091	(1273-2708)	(1535-3043)	(2518-5686)	(3104-5078)	**12472**	**(8957-15987)**	**17%**
AMWI	1577	5483	1029	1503	(965-2190)	(4030-6936)	(567-1491)	(1018-1988)	**9592**	**(6774-12411)**	**18%**
SCAU	1765	3434	2050	2081	(869-2662)	(2151-4717)	(1219-2880)	(1188-2974)	**9330**	**(6066-12593)**	**21%**
NSHO	563	2474	763	1403	(284-843)	(1817-3131)	(363-1163)	(866-1941)	**5204**	**(3593-6814)**	**19%**
MALL	676	1994	731	1576	(343-1009)	(1182-2806)	(442-1019)	(972-2180)	**4977**	**(3162-6792)**	**22%**
UNSB			848	3623			(230-1465)	(1284-5962)	**4471**	**(491-8450)**	**54%**
AGWT	451	2252	511	777	(218-683)	(1722-2782)	(256-766)	(469-1084)	**3991**	**(2834-5148)**	**18%**
WFGO	1239	683	909	199	(306-2173)	(108-1258)	(291-1526)	(31-366)	**3030**	**(942-5118)**	**42%**
ARTE	883	388	990	677	(97-1668)	(80-695)	(504-1477)	(0-1496)	**2938**	**(845-5031)**	**43%**
GOLD	526	960	334	719	(95-957)	(472-1448)	(73-595)	(392-1045)	**2538**	**(1266-3811)**	**30%**
CAGO	451	222	1540	209	(203-698)	(54-389)	(505-2575)	(49-368)	**2421**	**(630-4212)**	**45%**
MEGU	188	757	601	824	(54-322)	(97-1417)	(230-972)	(0-2210)	**2370**	**(0-4977)**	**67%**
GLGU	225	295	730	695	(76-374)	(144-447)	(343-1118)	(101-1289)	**1946**	**(728-3164)**	**38%**
BUFF	338	775	34	189	(111-565)	(456-1095)	(0-86)	(6-372)	**1336**	**(620-2052)**	**33%**
RNGR	113	831	119	227	(41-185)	(512-1150)	(7-231)	(76-379)	**1290**	**(669-1911)**	**29%**
SWAN	94	314	241	548	(0-195)	(128-500)	(105-376)	(155-940)	**1196**	**(430-1962)**	**39%**
SUSC	150	295	448	78	(32-268)	(64-527)	(24-872)	(0-240)	**971**	**(111-1831)**	**54%**
BLSC	75	74	294	247	(0-161)	(0-158)	(28-560)	(15-480)	**690**	**(76-1304)**	**54%**
SCOT	301	0	216	0	(96-505)		(0-532)		**516**	**(0-1135)**	**73%**
PALO	0	259	80	159		(9-508)	(11-149)	(55-262)	**497**	**(39-956)**	**56%**
SACR	38	74	224	105	(0-99)	(0-158)	(98-349)	(10-200)	**440**	**(130-751)**	**43%**
RBME	113	111	78	117	(8-217)	(0-246)	(0-161)	(11-222)	**418**	**(61-776)**	**52%**
COLO	19	240	28	83	(0-50)	(106-374)	(0-64)	(19-147)	**369**	**(113-626)**	**42%**

Table 4. Weather data from McGrath (1994) or Anvik (other years), Alaska during aerial waterbird surveys of Innoko NWR (http://www.wunderground.com/history/airport/PAMC/1994/6/1/CustomHistory.htm).

Date	Mean temp	Mean dew point	Mean humidity	Mean sea level pressure	Mean visibility (miles)	Mean wind speed (mph)	Max gust
6/1/1994	52	41	68	29.75	15	6	
6/2/1994	52	40	66	29.77		6	
6/4/1994	52	40	62	29.82		5	
6/5/1994	58	43	64	29.74		5	
5/30/1995	49	34	57	29.57	10	3	
5/31/1995	48	33	59	29.65	10	4	
6/1/1995	51	35	54	29.74	10	2	
5/22/2008	48	35	59	30.18	10	7	18
5/23/2008	48	37	69	29.84	10	11	38
5/23/2009	50	35	57	30.04	10	5	16
5/24/2009	56	37	55	30.09	10	4	
5/26/2009	52	30	46	29.94	10	5	18
5/27/2009	40	25	54	29.95	10	8	23
5/22/2010	52	41	65	29.84	10	6	20
5/23/2010	48	35	63	29.77	10	7	
5/24/2010	49	35	63	29.83	10	5	
5/23/2011	48	38	71	29.9	10	7	24
5/24/2011	54	36	55	29.88	10	7	
5/25/2011	55	32	43	29.71	10	4	20

Table 5. Nearest neighbor analysis statistics for species sightings distributions: Blue shading indicates clustered distribution , yellow shading indicates random distribution, and red shading indicates dispersed distribution.

Species		1994	1995	2008	2009	2010	2011
American green-winged teal	Observed Mean Distance:	4971.0	3807.9	3865.6	6671.8	7021.5	5733.3
	Expected Mean Distance:	6061.5	4676.5	5967.0	6975.9	7190.6	7080.8
	Nearest Neighbor Ratio:	0.820	0.814	0.648	0.956	0.976	0.810
	z-score:	-2.434	-3.641	-3.013	-0.486	-0.255	-2.091
	p-value:	0.015	0.000	0.003	0.627	0.799	0.036
	number of sightings	50	105	20	34	32	33
American wigeon	Observed Mean Distance:	2729.8	2137.6	4300.5	6671.8	2599.6	2920.0
	Expected Mean Distance:	4351.9	3298.9	4273.0	6975.9	4969.4	4008.0
	Nearest Neighbor Ratio:	0.627	0.648	1.006	0.956	0.523	0.729
	z-score:	-7.023	-9.782	0.077	-0.486	-7.467	-5.270
	p-value:	0.00	0.00	0.939	0.627	0	0
	number of sightings	97	211	39	71	67	103
Arctic tern	Observed Mean Distance:	3736.3	4595.3	3039.9	3082.0		5398.2
	Expected Mean Distance:	6319.5	6776.9	3503.9	4130.1		5997.4
	Nearest Neighbor Ratio:	0.591	0.678	0.868	0.746		0.900
	z-score:	-5.304	-4.355	-1.929	-4.781		-1.296
	p-value:	0.000	0.000	0.054	0.000		0.195
	number of sightings	46	50	58	97		46
Black scoter	Observed Mean Distance:				3050.5		3526.5
	Expected Mean Distance:				8135.3		6132.2
	Nearest Neighbor Ratio:				0.375		0.575
	z-score:				-5.979		-5.392
	p-value:				0		0
	number of sightings				25		44

Table 5 continued. Nearest neighbor analysis statistics for species sightings distributions: Blue shading indicates clustered distribution , yellow shading indicates random distribution, and red shading indicates dispersed distribution.

Species		1994	1995	2008	2009	2010	2011
Bufflehead	Observed Mean Distance:		6637.6				
	Expected Mean Distance:		7878.0				
	Nearest Neighbor Ratio:		0.843				
	z-score:		-1.832				
	p-value:		0.067				
	number of sightings		37				
Canada goose	Observed Mean Distance:	2159.3		2457.8	5085.6	8291.1	7051.9
	Expected Mean Distance:	4853.1		3260.1	5810.9	8876.3	7553.4
	Nearest Neighbor Ratio:	0.445		0.754	0.875	0.934	0.934
	z-score:	-9.378		-3.854	-1.672	-0.578	-0.684
	p-value:	0.000		0.000	0.095	0.563	0.494
	number of sightings	78		67	49	21	29
Common loon	Observed Mean Distance:						8981.3
	Expected Mean Distance:						8481.6
	Nearest Neighbor Ratio:						1.059
	z-score:						0.541
	p-value:						0.589
	number of sightings						23
Goldeneye species	Observed Mean Distance:		7756.4		5413.9	4721.6	
	Expected Mean Distance:		8099.9		6203.1	5535.4	
	Nearest Neighbor Ratio:		0.958		0.873	0.853	
	z-score:		-0.480		-1.596	-2.067	
	p-value:		0.631		0.110	0.039	
	number of sightings		35		43	54	

Table 5 continued. Nearest neighbor analysis statistics for species sightings distributions: Blue shading indicates clustered distribution , yellow shading indicates random distribution, and red shading indicates dispersed distribution.

Species		1994	1995	2008	2009	2010	2011
Large gull species	Observed Mean Distance:	4351.3	7744.7	4265.2	3296.6	5543.7	5237.8
	Expected Mean Distance:	6777.0	8606.6	5135.5	4412.0	6513.4	5997.4
	Nearest Neighbor Ratio:	0.642	0.900	0.831	0.747	0.851	0.873
	z-score:	-4.331	-1.067	-1.685	-4.459	-1.779	-1.643
	p-value:	0.000	0.286	0.092	0.000	0.075	0.100
	number of sightings	40	31	27	85	39	46
Mallard	Observed Mean Distance:	8059.5	3572.6	3679.8	2650.1	4016.7	2372.1
	Expected Mean Distance:	8248.6	4338.5	4328.9	3697.9	5124.7	4027.6
	Nearest Neighbor Ratio:	0.977	0.823	0.850	0.717	0.784	0.589
	z-score:	-0.228	-3.730	-1.768	-5.963	-3.283	-7.942
	p-value:	0.820	0.000	0.077	0.000	0.001	0.000
	number of sightings	27	122	38	121	63	102
Mew gull	Observed Mean Distance:	7477.8	6664.2	2174.2	3295.6		4930.0
	Expected Mean Distance:	7825.3	8898.5	3812.2	4361.0		5084.5
	Nearest Neighbor Ratio:	0.956	0.749	0.570	0.756		0.970
	z-score:	-0.465	-2.587	-5.754	-4.359		-0.465
	p-value:	0.642	0.010	0.000	0.000		0.642
	number of sightings	30	29	27	87		64
Northern pintail	Observed Mean Distance:	1110.6	1931.8	903.2	1166.3	1278.6	2507.0
	Expected Mean Distance:	2929.9	3776.6	1496.4	1890.4	2562.4	4438.2
	Nearest Neighbor Ratio:	0.379	0.512	0.604	0.617	0.499	0.565
	z-score:	-17.378	-11.857	-13.524	-15.768	-15.215	-7.629
	p-value:	0.000	0.000	0.000	0.000	0.000	0.000
	number of sightings	214	161	318	463	252	84

Table 5 continued. Nearest neighbor analysis statistics for species sightings distributions: Blue shading indicates clustered distribution , yellow shading indicates random distribution, and red shading indicates dispersed distribution.

Species		1994	1995	2008	2009	2010	2011
Northern shoveler	Observed Mean Distance:	2613.2	3338.8	3479.3	4739.9	2177.7	3792.1
	Expected Mean Distance:	5400.0	4488.1	5689.3	6975.9	4130.1	5387.7
	Nearest Neighbor Ratio:	0.484	0.744	0.612	0.679	0.527	0.704
	z-score:	-7.836	-5.230	-3.486	-3.576	-8.907	-4.278
	p-value:	0.000	0.000	0.000	0.000	0.000	0.000
	number of sightings	63	114	22	34	97	57
Pacific loon	Observed Mean Distance:		9636.1				
	Expected Mean Distance:		9584.0				
	Nearest Neighbor Ratio:		1.005				
	z-score:		0.052				
	p-value:		0.958				
	number of sightings		25				
Red-necked grebe	Observed Mean Distance:		6365.9		6329.2		
	Expected Mean Distance:		6461.5		6779.4		
	Nearest Neighbor Ratio:		0.985		0.934		
	z-score:		-0.210		-0.762		
	p-value:		0.834		0.446		
	number of sightings		55		36		
Red-throated loon	Observed Mean Distance:			4512.6			
	Expected Mean Distance:			4645.3			
	Nearest Neighbor Ratio:			0.971			
	z-score:			-0.314			
	p-value:			0.754			
	number of sightings			33			

Table 5 continued. Nearest neighbor analysis statistics for species sightings distributions: Blue shading indicates clustered distribution , yellow shading indicates random distribution, and red shading indicates dispersed distribution.

Species		1994	1995	2008	2009	2010	2011
Scaup species	Observed Mean Distance:	1615.4	1385.8	1035.9	1924.5	2695.0	1378.9
	Expected Mean Distance:	3399.1	3532.7	2288.2	3299.3	4605.7	2388.6
	Nearest Neighbor Ratio:	0.475	0.392	0.453	0.583	0.585	0.577
	z-score:	-12.658	-15.770	-12.210	-9.828	-7.009	-13.772
	p-value:	0.000	0.000	0.000	0.000	0.000	0.000
	number of sightings	159	184	136	152	78	290
Scoter species	Observed Mean Distance:	5486.0					
	Expected Mean Distance:	7959.1					
	Nearest Neighbor Ratio:	0.689					
	z-score:	-3.201					
	p-value:	0.001					
	number of sightings	29					
Small shorebird species	Observed Mean Distance:				4555.6		
	Expected Mean Distance:				5387.7		
	Nearest Neighbor Ratio:				0.846		
	z-score:				-2.231		
	p-value:				0.026		
	number of sightings				57		
Surf scoter	Observed Mean Distance:	6566.4		3054.8			937.3
	Expected Mean Distance:	9353.1		5967.0			9095.5
	Nearest Neighbor Ratio:	0.702		0.512			0.103
	z-score:	-2.612		-4.175			-7.674
	p-value:	0.009		0.000			0.000
	number of sightings	21		20			20

Table 5 continued. Nearest neighbor analysis statistics for species sightings distributions: Blue shading indicates clustered distribution , yellow shading indicates random distribution, and red shading indicates dispersed distribution.

Species		1994	1995	2008	2009	2010	2011
Swan species	Observed Mean Distance:		9872.2	6788.2	4673.6	9378.7	5202.6
	Expected Mean Distance:		9781.6	5564.2	5752.5	8672.2	4932.7
	Nearest Neighbor Ratio:		1.009	1.220	0.812	1.081	1.055
	z-score:		0.087	2.018	-2.537	0.731	0.863
	p-value:		0.931	0.044	0.011	0.465	0.388
	number of sightings		24	23	50	22	68
White-fronted goose	Observed Mean Distance:	8339.3		2619.1	6445.4		3827.8
	Expected Mean Distance:	9138.0		4717.3	7828.2		7426.5
	Nearest Neighbor Ratio:	0.913		0.555	0.823		0.515
	z-score:	-0.784		-4.813	-1.756		-5.078
	p-value:	0.433		0.000	0.079		0.000
	number of sightings	22		32	27		30

Fig. 1. Survey area and transects for 1994, 1995, and 2008-2011 aerial surveys on Innoko NWR and Yukon River wetlands, Alaska.

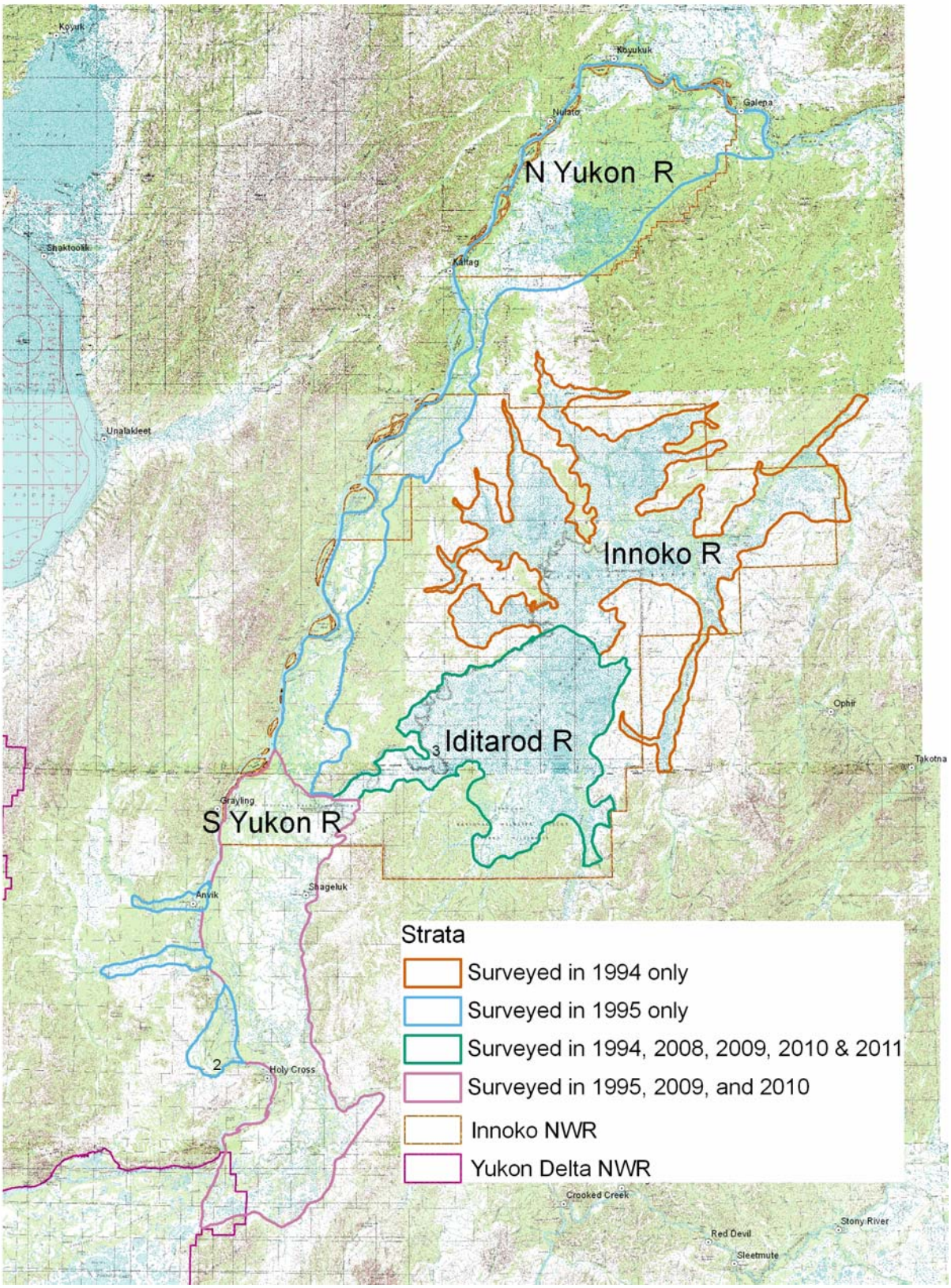


Fig. 2. Strata surveyed in different years for waterbird abundance and distribution on Innoko National Wildlife Refuge, Alaska and adjacent wetlands

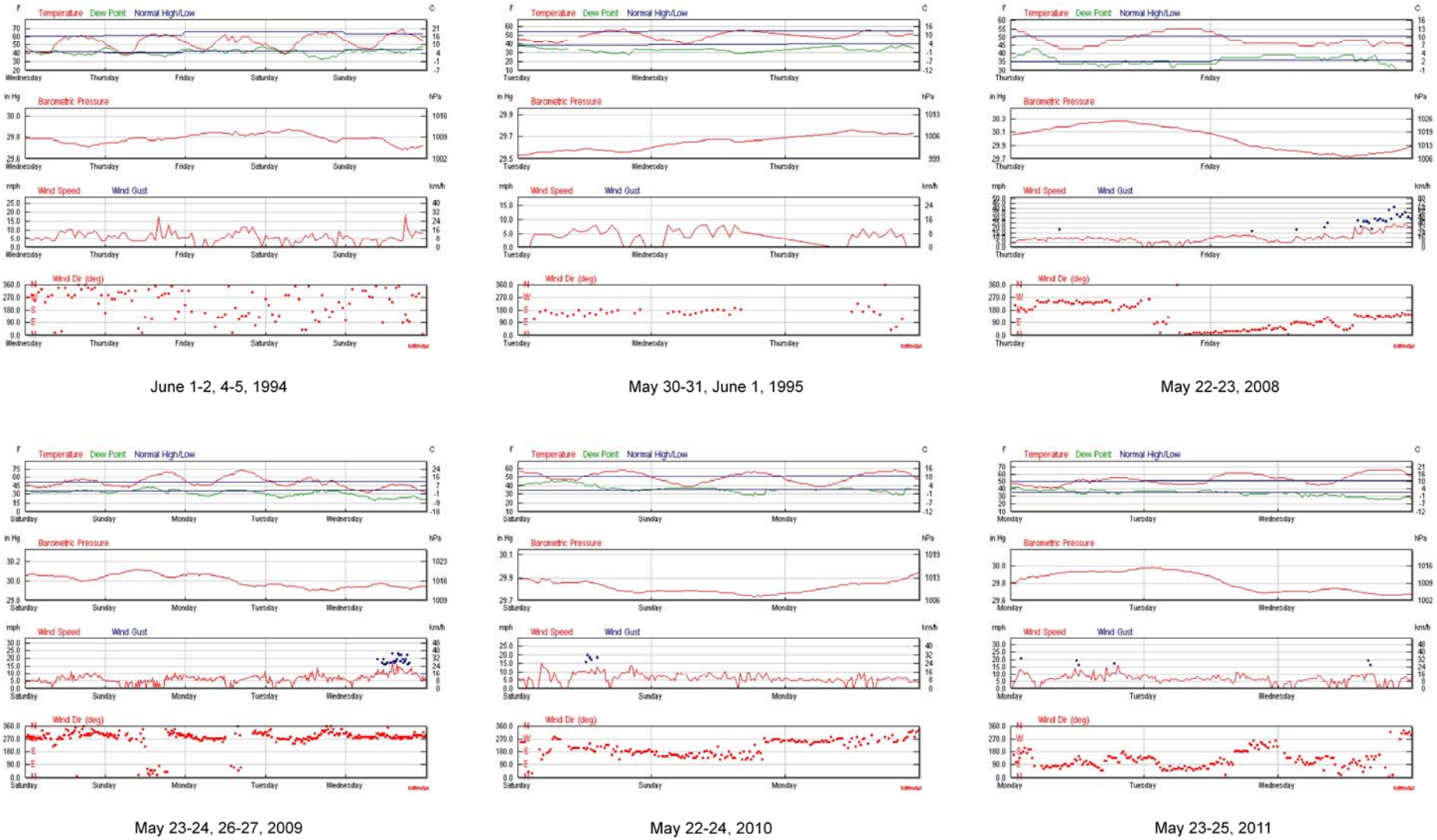


Fig. 3. Weather conditions at McGrath (1994) and Anvik (other years) during aerial waterbird surveys of Innoko National Wildlife Refuge and Yukon River corridor wetlands, Alaska.
http://www.wunderground.com/history/airport/PANV/2011/5/24/WeeklyHistory.html

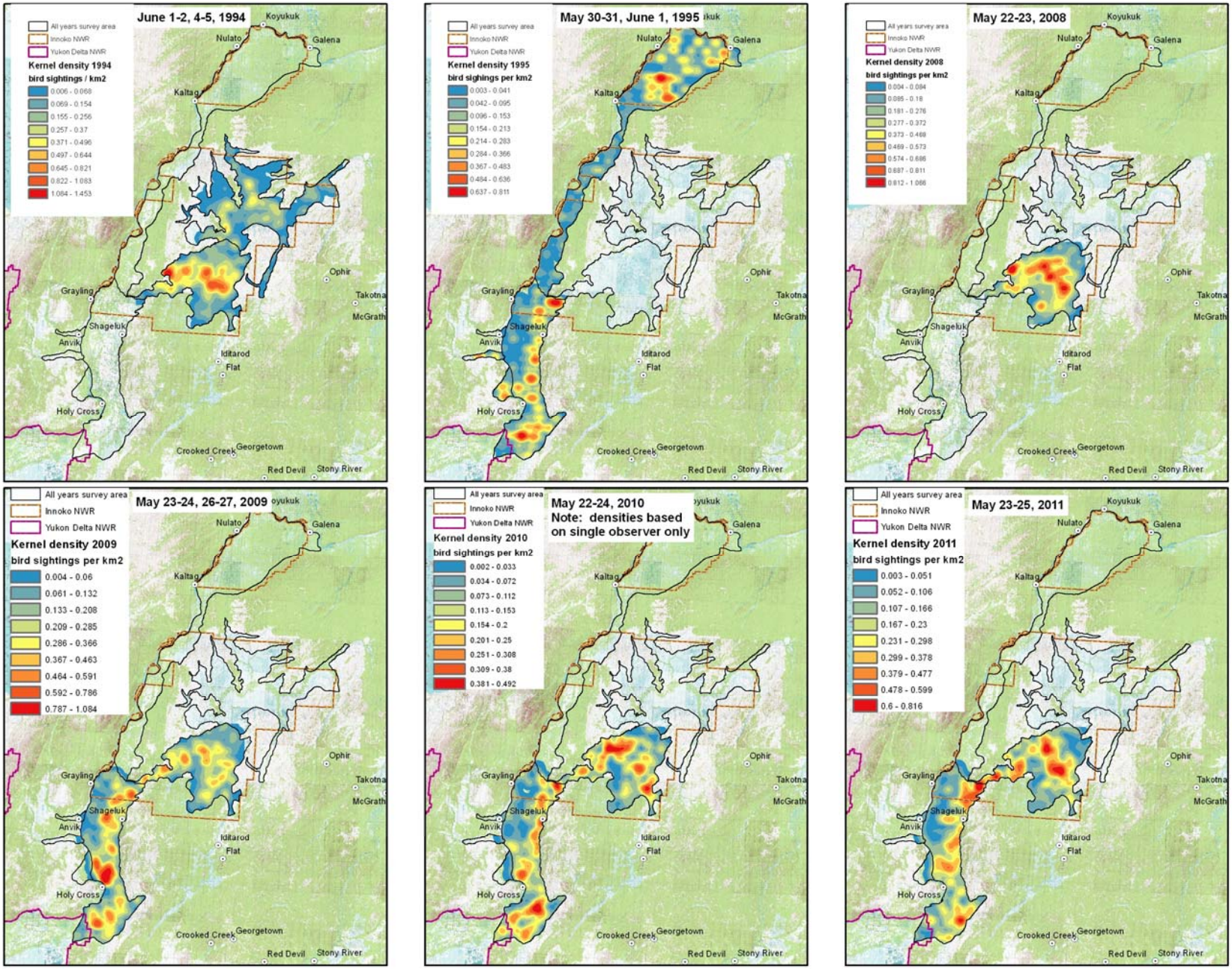


Fig. 4. Estimated relative density distribution of bird sightings from aerial waterbird surveys on Innoko NWR and adjacent wetlands.

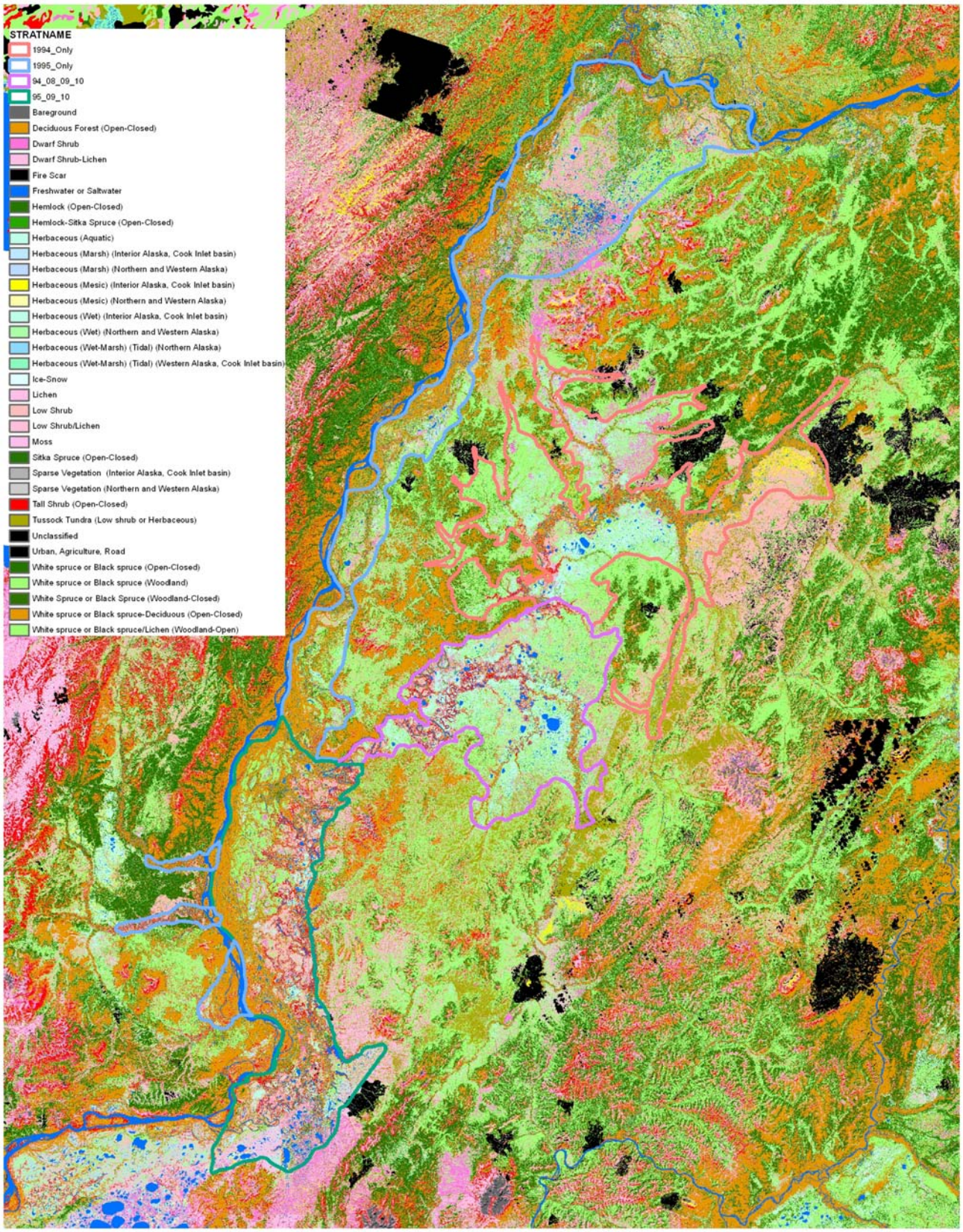


Figure. 5. Aerial survey units (see Fig. 2) overlain on Alaska Natural Heritage Program vegetation classes on Innoko National Wildlife Refuge and adjacent wetlands, Alaska.

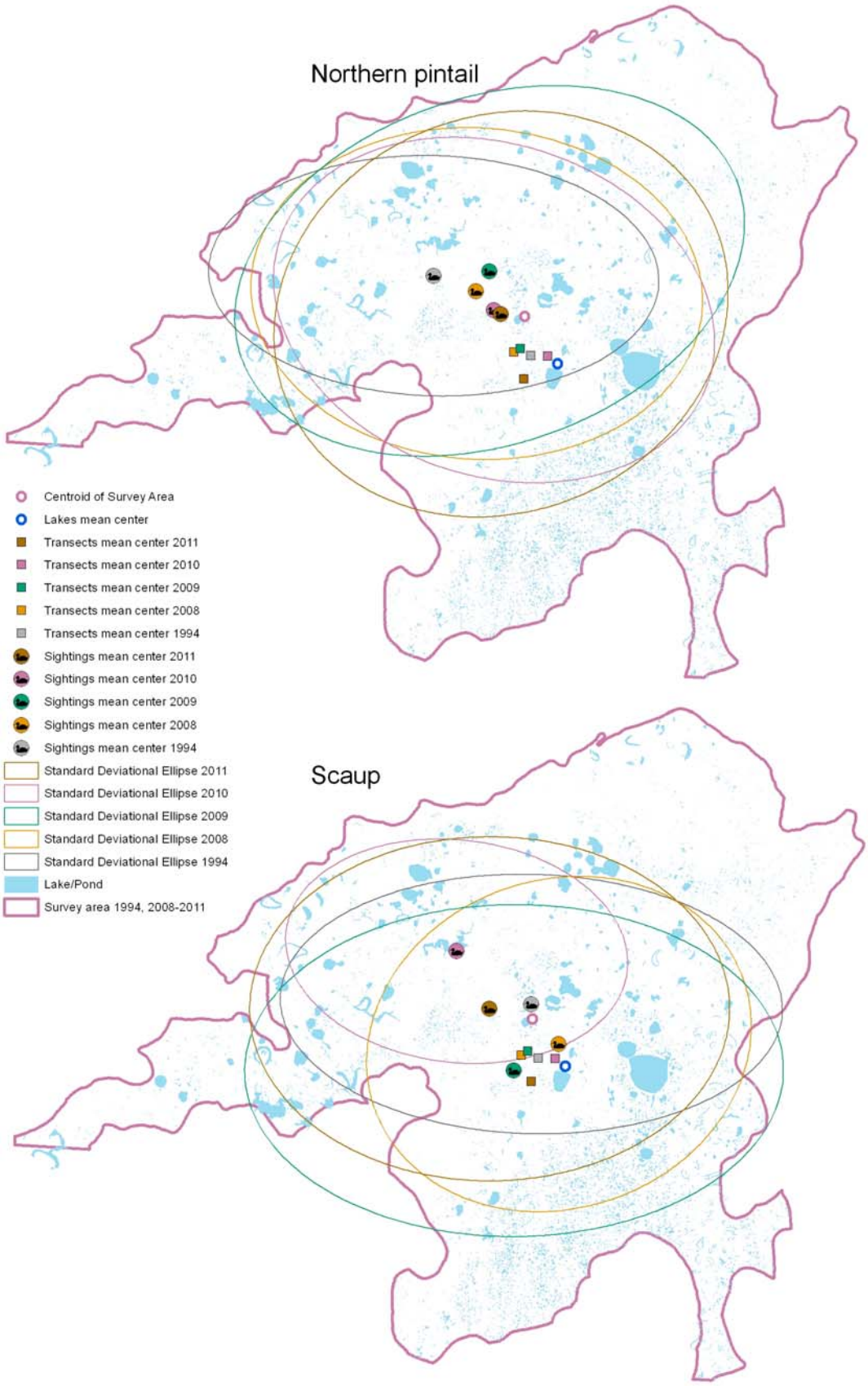


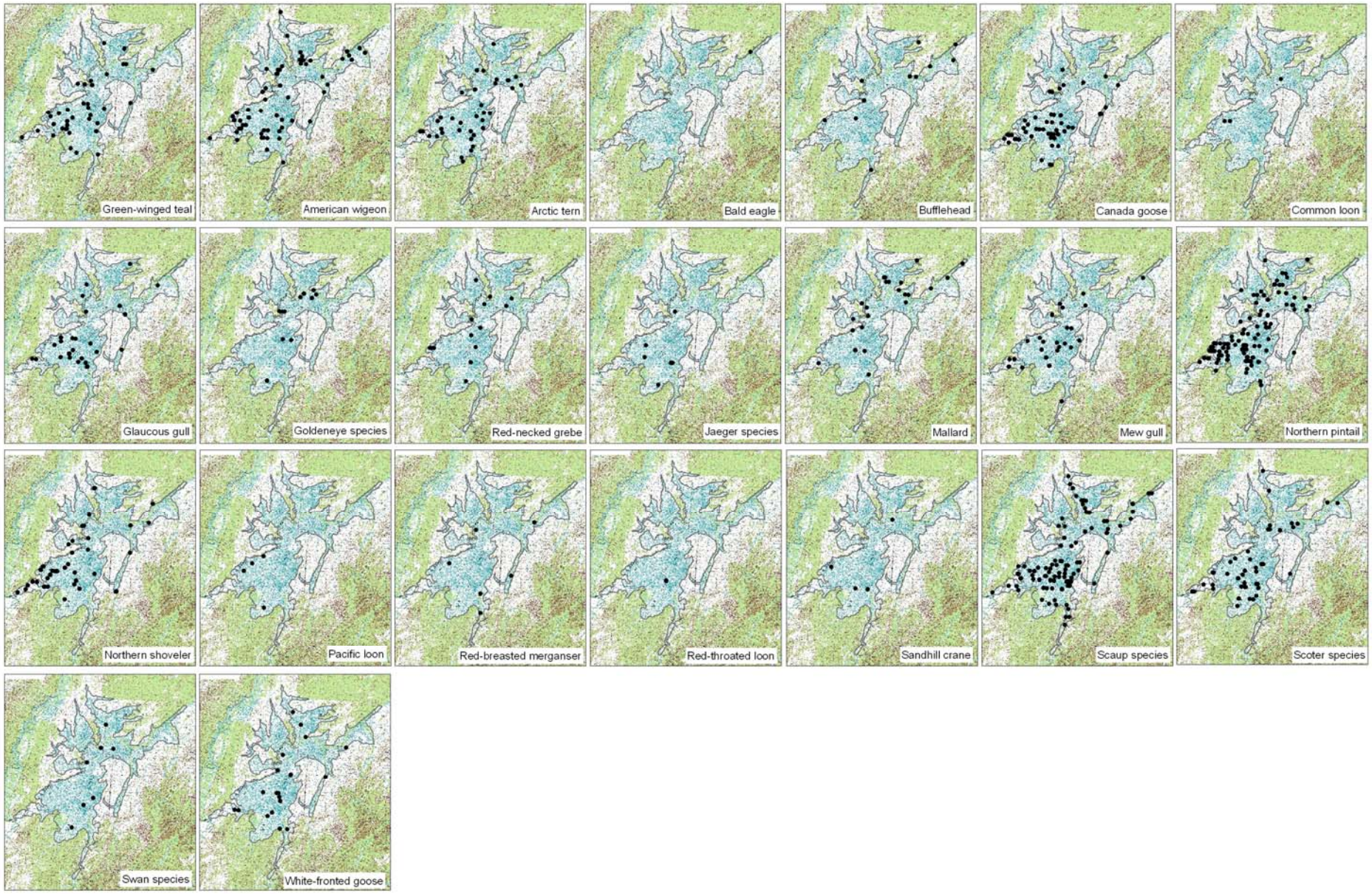
Fig. 6. Mean centers for strip transects, lakes, and pintail and scaup sightings, along with standard deviational ellipses for pintails and scaup.

Appendix 1. Common and scientific names of species recorded by year during aerial surveys of Innoko NWR, Alaska. 1 indicates species was recorded that year.

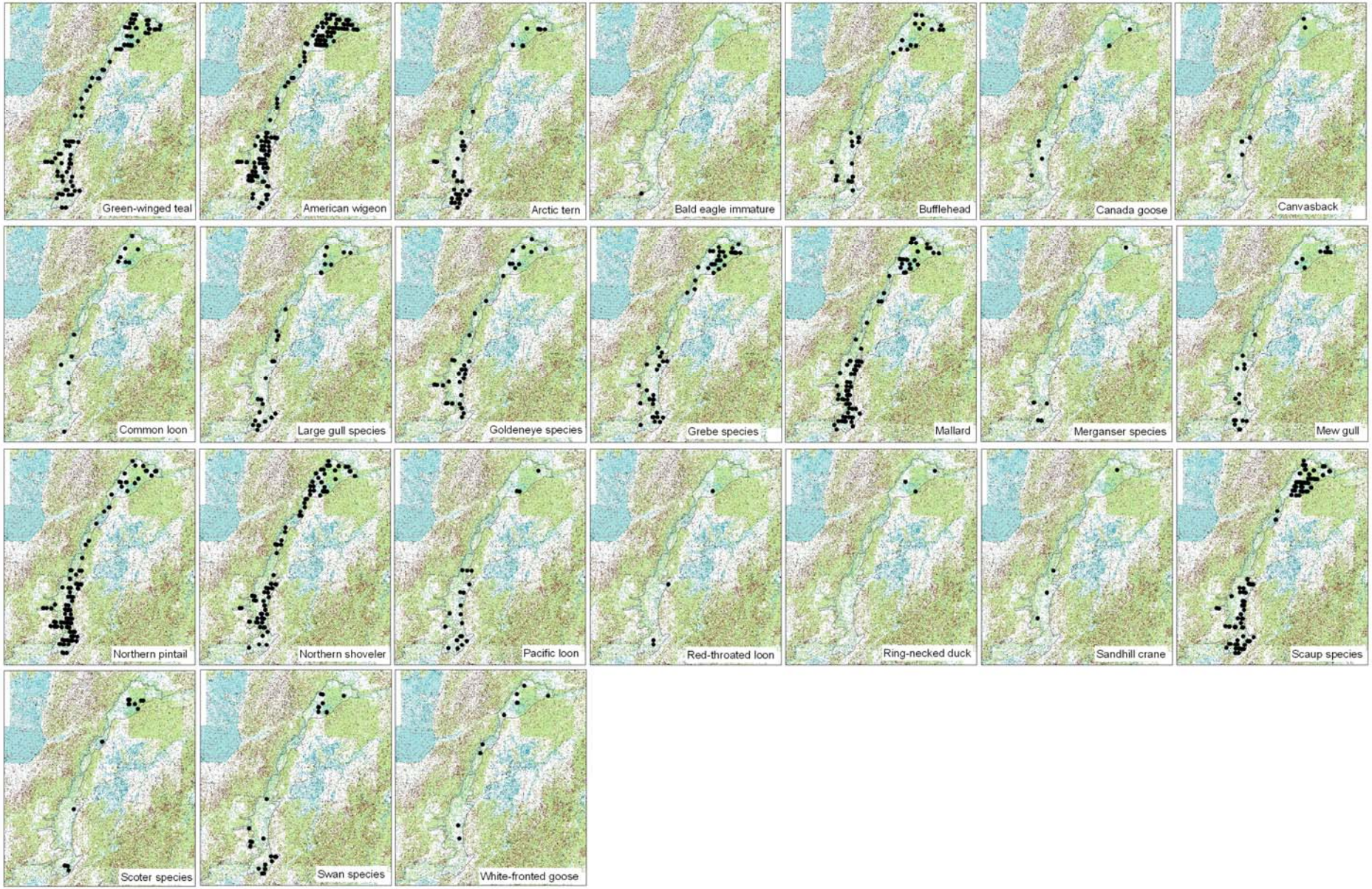
Species code	Species	1994	1995	2008	2009	2010	2011
AGWT	American green-winged teal - *Anas crecca*	1	1	1	1	1	1
AMWI	American wigeon - *Anas americana*	1	1	1	1	1	1
ARLO	Arctic loon – *Gavia pacifica*	1					
ARTE	Arctic tern – *Sterna paradisaea*	1	1	1	1	1	1
ARTEN	Arctic tern nest				1		
BAEA	Bald eagle – *Haliaeetus leucocephalus*	1		1	1	1	1
BAEAI	Bald eagle immature				1		
BEAR	black or brown bear				1	1	1
BEIM	Bald eagle immature		1				
BLBE	Black bear	1	1				
BLSC	Black scoter *Melanitta nigra*	1	1	1	1	1	1
BOGU	Bonaparte's gull – *Larus philadelphia*	1					
BUFF	Bufflehead – *Bucephala albeola*	1	1	1	1	1	1
CAGO	Canada goose *Branta canadensis*	1	1	1	1	1	1
CAGON	Canada goose nest						1
CANV	Canvasback *Aythya valisineria*		1	1	1	1	
CARI	Caribou				1		1
CMOOS	Cow moose					1	
COGO	Common goldeneye *Bucephala clangula*		1				
COLO	Common loon *Gavia immer*	1	1	1	1		1
COME	Common merganser *Mergus merganser*		1				1
CORA	Common raven *Corvus corax*	1	1	1	1	1	1
EAGLN	Eagle nest				1	1	1
FOX	Red or arctic fox			1			
GADW	Gadwall *Anas strepara*	1	1				1
GHOW	Great horned owl *Bubo virginianus*	1					
GLGU	Glaucous gull *Larus hyperboreus*	1		1	1	1	1
GLGUN	Glaucous gull nest				1		
GOLD	Goldeneye species			1	1	1	1
GWGU	Glaucous-winged gull *Larus glaucescens*		1				
HARD	Harlequin duck *Histrionicus histrionicus*					1	

Species code	Species	1994	1995	2008	2009	2010	2011
HAWK	Hawk species			1	1	1	1
HOGR	Horned grebe *Podiceps auritis*		1				
JAEG	Jaeger species *Stercorarius spp.*			1	1		1
LTDU	Long-tailed duck *Clangula hyemalis*			1	1	1	1
MALL	Mallard *Anas platyrhynchos*	1	1	1	1	1	1
MDSH	Medium-sized shorebird				1		
MEGU	Mew gull *Larus canus*	1	1	1	1		1
MEGUN	Mew gull nest				1		1
MOOS	Moose	1	1	1	1	1	1
NOGO	Northern goshawk *Accipiter gentilis*		1				
NOHA	Northern harrier *Circus cyaneus*	1	1				
NOPI	Northern pintail *Anas acuta*	1	1	1	1	1	1
NSHO	Northern shoveler *Anas clypeata*	1	1	1	1	1	1
OLDS	Oldsquaw (Long-tailed duck)		1				
PALO	Pacific loon *Gavia pacifica*	1	1	1	1	1	1
RBME	Red-breasted merganser *Mergus serrator*	1	1	1	1	1	1
RING	Ring-necked duck *Aythya collaris*		1				
RIOT	River otter				1	1	1
RNGR	Red-necked grebe *Podiceps grisegena*	1	1	1	1	1	1
RNGRN	Red-necked grebe nest				1		
RTLO	Red-throated loon *Gavia stellata*	1	1	1	1	1	1
SACR	Sandhill crane *Grus canadensis*	1	1	1	1	1	1
SAGU	Sabine's gull *Xema sabini*			1	1	1	
SCAU	Scaup species *Aythya spp.*		1	1	1	1	1
SEOW	Short-eared owl *Asio flammeus*		1	1	1	1	1
SNGO	Snow goose *Chen caerulescens*					1	
SUSC	Surf scoter *Melanitta perspicillata*	1	1	1	1	1	1
SWAN	Swan species *Cygnus spp.*			1	1	1	1
SWANN	Swan nest			1	1	1	1
TRNE	Trumpeter swan nest		1				
TRSW	Trumpeter swan *Cygnus buccinator*		1				

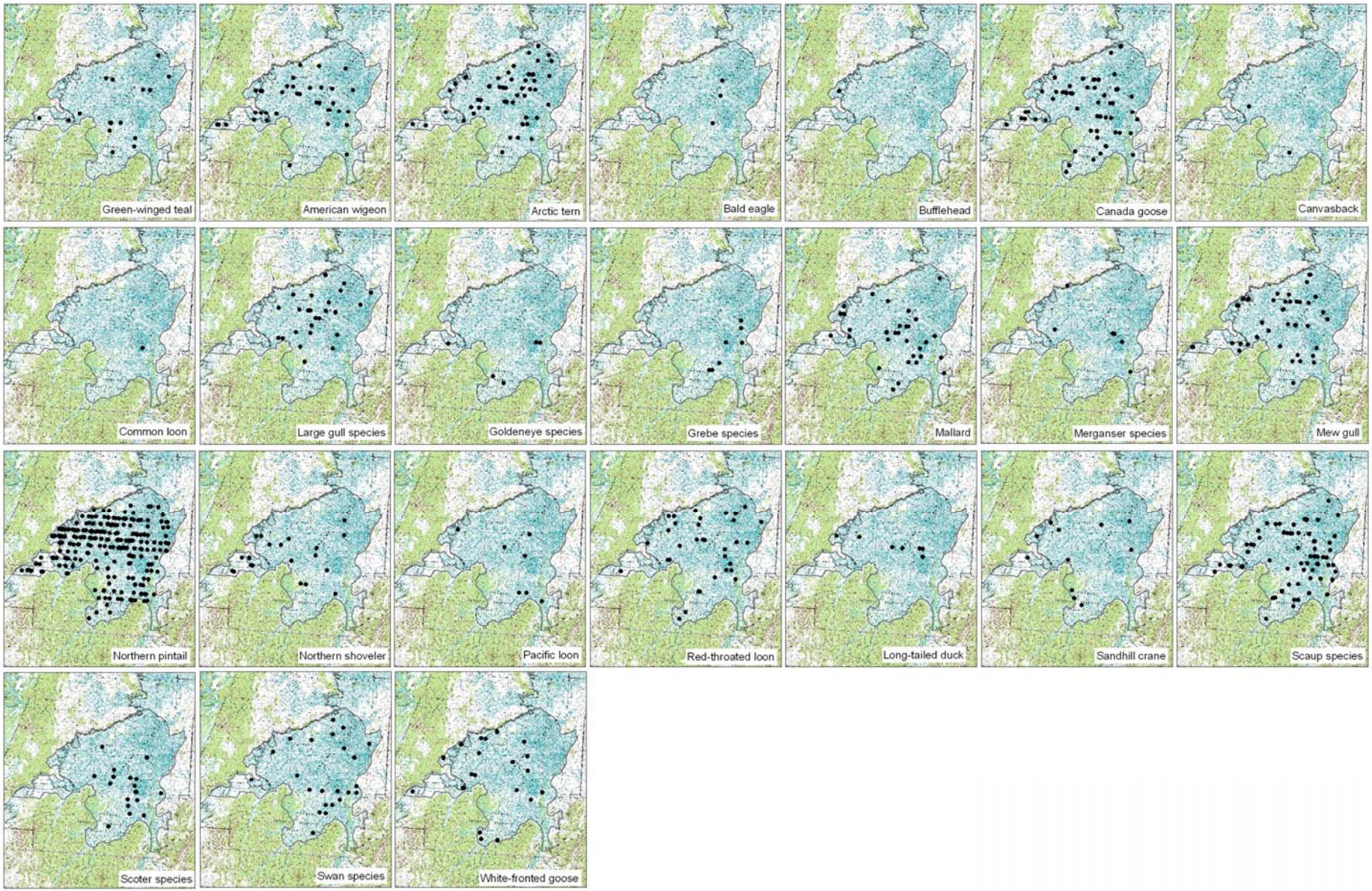
Species code	Species	1994	1995	2008	2009	2010	2011
TUSW	Tundra swan *Cygnus columbianus*	1					
ULSB	Large shorebird species			1	1		
UNGO	Goldeneye species *Bucephala spp.*	1	1				
UNGR	Grebe species *Podiceps spp.*	1					
UNJA	Jaeger species *Stercorarius spp.*	1					
UNME	Merganser species *Mergus spp.*		1				
UNSC	Scaup species *Aythya spp.*	1					
USCO	Scoter species *Melanitta spp.*	1					
USSB	Small shorebird species			1	1	1	
WFGO	White-fronted goose *Anser albifrons*	1	1	1	1	1	1
WIPT	Willow ptarmigan *Lagopus lagopus*						1
WWSC	White-winged scoter *Melanitta fusca*		1				



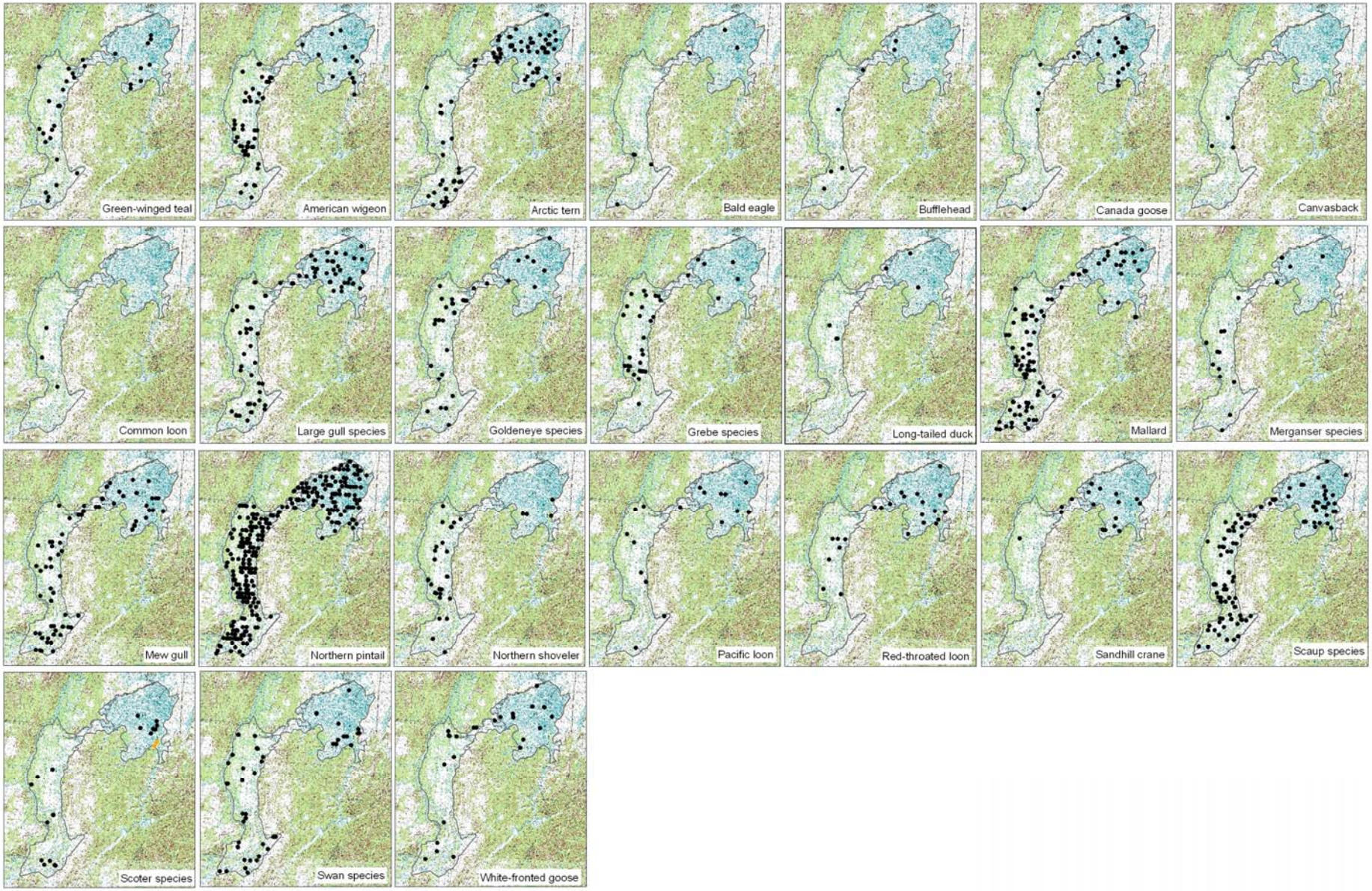
Appendix.2. Bird sightings by species from systematic transect aerial surveys of Innoko NWR, Alaska, June 1-2, 4-5, 1994.



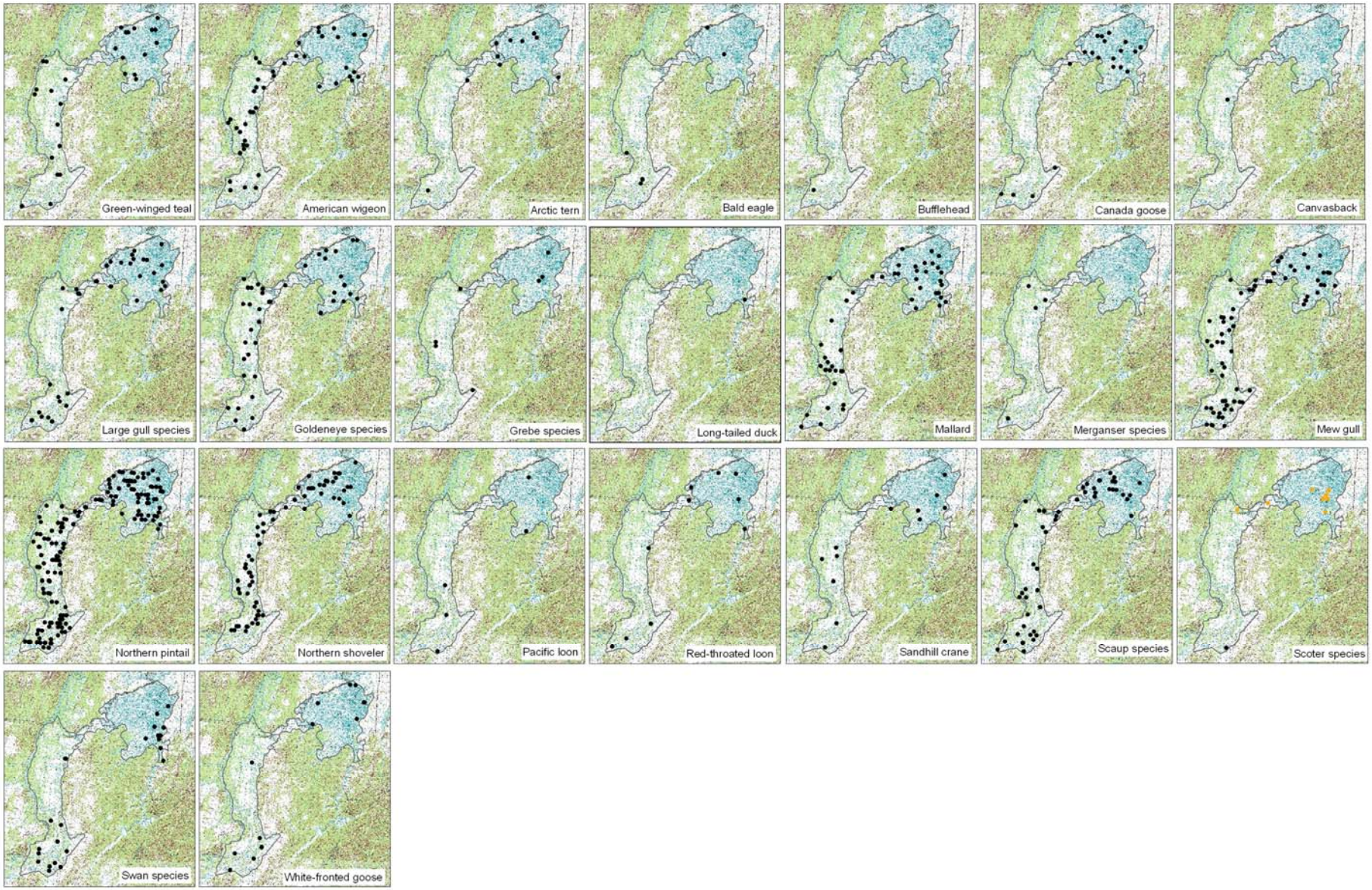
Appendix 3. Bird sightings by species from systematic transect aerial surveys of Innoko NWR, Alaska, May 30-31, June 1, 1995.



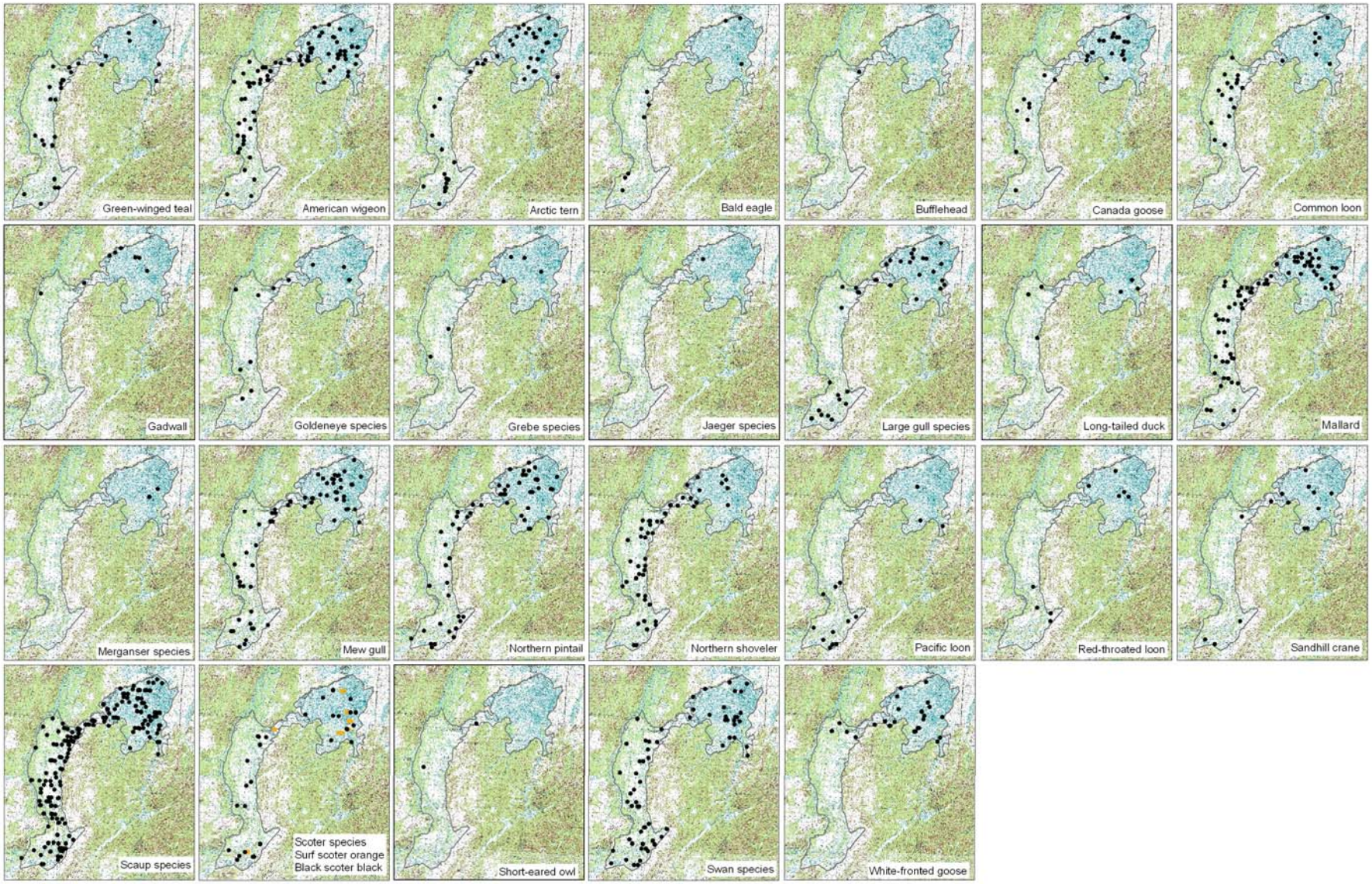
Appendix 4. Bird sightings by species from systematic transect aerial surveys of Innoko NWR, Alaska, May 22-23, 2008.



Appendix 5. Bird sightings by species from systematic transect aerial surveys of Innoko NWR, Alaska, May 23-24, 26-27, 2009.



Appendix 6. Bird sightings by species from systematic transect aerial surveys of Innoko NWR, Alaska, May 22-24, 2010.



Appendix 7. Bird sightings by species from systematic transect aerial surveys of Innoko NWR, Alaska, May 23-25, 2011.