Population Size and Production of Geese Nesting on the Yukon-Kuskokwim Delta, Alaska

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INTRODUCTION:

Annual assessment of nesting populations of geese on the Yukon-Kuskokwim Delta (YKD) provides information for biologists, participants in cooperative goose management plans, and Pacific Flyway technical committees. A ground-based sampling procedure has been used since 1986 to estimate the number of total nests, active nests, and eggs for Cackling Canada geese (Branta canadensis minima), Emperor geese (Chen canagica), Greater White-fronted geese (Anser albifrons frontalis), and Spectacled eiders (Somateria fischeri). Annual information on the size of the nesting population and potential number of young produced contributes to the long term data needed to understand goose population ecology and better manage these species.

METHODS:

In 1994, the ground-based sampling for nests was based on a new single stratum design. The redesign provides a general, long-term monitoring procedure for most of the medium and high density goose nesting habitat on the coast of the Yukon-Kuskokwim delta. The new sampling plan was intended to improve efficiency and the precision of estimates. Based on resampling the plot data from previous years, the precision of population estimates with 60 plots in the new single stratum were slightly better than the previous design of 5-7 strata with up to 100 plots. Coefficients of variation (CV = standard error/mean) were 14% for cacklers, 11% for emperors, 12% for whitefronts, 49% for brant, and 25% for spectacled eider. Because of the late completion of the redesign work, the 1994 plots were a random subset of plots from previous years. This allowed previously prepared field maps to be reused. Plots were redrawn from all 1990-1993 plots with a selection probability weighted by the portion of old stratum area and the inverse of the number of old plots falling into the new stratum.

Features such as lake size, prevalence of ponds, homogeneous sedge meadow, and upland tundra that were visible on Landsat images at 1:250,000 scale determined the strata boundaries. The aerial data was analyzed by a 10 stratum design that grouped the original 16 strata into 8 strata based on transect intervals of previous years and subdivided 2 of these strata into regions sampled or not sampled in 1994 by ground plots.

The aerial survey data was used each year to expand the ground-based estimates of nests, active nests, and eggs from the sampled strata to the entire YKD coastal region. The annual expansion factor was the inverse of the proportion of the aerial breeding population index found in the stratum sampled by ground plots compared to the population index in the entire area. The breeding population index for each species was based on the number of singles plus number of pairs observed. Single geese observed are assumed to be the mates of unobserved incubating females on nests. Exceptions were for brant, glaucous gulls, and mew gulls where the total number of birds observed was used, and swans where half the number of singles plus the number of pairs observed was used as the index.

Each year from 1986 to 1993, a new set of randomly-located ground plots were searched to estimate the size of nesting populations within 7 or 5 sampled strata. Beginning in 1994, the population was estimated only for the new single stratum area. Data from prior years plots located within this area were analyzed to provide comparable estimates of nest density. Even though the previous plots were randomly located in the original strata, they are not entirely random within the new single stratum. Because of this, stratification must be maintained to avoid any bias that may occur when strata differ both in sampling intensities and nest densities. The mean nest densities before 1994 were calculated with stratification based on the intersection of the old strata and the new stratum boundaries; the 8 polygons of the new stratum crossed 5 original strata boundaries to form 13 strata, although the extra strata formed were small. Although the previous sampling intensity was not very different among strata, positive bias was noticed for cackling geese, brant, and eiders when calculations were made ignoring the previous strata. Estimates with and without stratification were also calculated for 1994 which resulted in almost identical estimates of nest populations, however with stratification, the standard errors were slightly smaller. This confirmed that the 1994 plots were correctly selected with probabilities to balance out the previous stratification.

Ground plots are 805 m (0.5 mi) long and 402 m (0.25 mi) wide oriented in an east-west direction around a random center point. Computer programs (PC ARC/INFO, and custom-written TrueBASIC) randomly select plot center points and draw plot boundaries at 1:63,360 scale directly onto topographic maps. Even if most or all of a plot is within a river or a large lake, it is still included in the sample. Plot boundaries are transferred to color xerox copies of color infrared aerial photographs (1:15,000 or 1:10,000) which are available for most plots. These provide useful field maps to aid in finding plots, searching for nests, and determining exact plot boundaries.

Biologists that search each plot are transported either by Cessna 185 float-equipped aircraft or by boat. Nearly all plots are within 2 km walking distance from a lake or river suitable for landing aircraft. Each plot is searched on a single visit. Nest searching usually takes 2 people

whitefronts, and brant, mean active clutch size in 1994 ranked 6, 8, 7, and 4, respectively, from the largest mean clutch size of the previous 9 years (Table 3). In all species except common eider, clutch size was greater in 1994 than in 1993. For cackling Canada geese, the 5 earliest years (1988, 1990, 1991, 1993, 1994) had the 5 smallest average clutch sizes that ranged from 4.50 to 4.66 compared to 4.75 to 5.08 in years with later hatch dates.

For some species, clutch size showed a consistent trend with years. Cackling Canada and emperor geese showed generally decreasing clutch sizes from 1986 to 1994, while pacific loons and glaucous gulls showed generally increasing average clutch size. Spectacled eider clutch size increased each year from 1987 to 1992 although small average clutch sizes were seen in 1986, and again in 1993 and 1994.

Nesting success in 1994, ranked 6, 4, 2, and 4 for cacklers, emperors, whitefronts, and brant, respectively, in comparison to the highest unweighted nest success indices shown in the last 9 years (Table 3). In cackling geese and spectacled eiders, the index to nest success in 1994 was noticeably lower than in the previous 3 years, however the proportion of nests active were still relatively high at 81% and 72%, respectively (Fig. 3). The high rates of nest failure observed in 1982, 1984, 1985, and 1986 has not been observed since. The proportion of nests active at the time of plot search showed a similar pattern for cacklers, emperors, brant, and spectacled eiders (Fig. 3) with synchrony in the years of high and low success rates. The magnitude of variation differed among species with brant, spectacled eider, cackling Canada geese, and emperor geese showing progressively less variation. For white-fronted geese, swans, cranes, and loons, the index to nesting success was relatively constant and above 90%. The proportion of nests active at time of search may not be a good index to nesting success for cranes and loons because destroyed nests in these species are rarely found due to their minimal nest bowl structure and lack of down in the nest lining. In contrast, destroyed nests of emperor geese, swans, and whitefronts are quite obvious and, at least for these species, uniformly high nesting success from 1987 to 1994 was indicated.

The annual estimates of nesting population size for the single stratum design indicated increasing nest population size for all species except for spectacled eider (Fig. 4). In 1994, the total estimated nests were 54,000 cacklers, 37,000 emperors, 50,000 white-fronts, and 2600 spectacled eiders (Table 4). Annual estimates of nesting populations within the sampled area have considerable annual sampling error (Table 4). In the last 4 years, the coefficients of variation (CV) were: 9-13% for geese; 12-25% for swans, cranes, spectacled eiders, and Pacific loons; and 12-55% for brant, common eider, red-throated loon, and gulls. The rates of population change (log-linear slope), which smoothed annual sampling errors, were calculated for both the sampled and expanded populations (Fig. 4). Rate of change provided more reliable indication of population status than the percent change from the population estimate of a single previous year. From 1986 to 1994, the expanded cackling Canada goose population grew at rate of 1.149, 15% increase per year, white-fronted geese grew at 12%, and black brant populations grew at 12% per year. Emperor geese, swan, and crane populations increased by 3-4% per year, while spectacled eiders decreased at 17% per year. Except for brant and swans, aerial survey index population growth rates for each species were higher in the

Coefficients of variation (SE/mean) in estimated nests or aerial survey population indices have decreased over time. The standard errors have remained approximately constant while the mean population size has increased for most species. The ground sampling effort has become more concentrated in the single stratum area even though the total sampling effort decreased in 1994. For geese, the CV's from 1991 to 1993 were only 0 to 3% greater with 52-56 plots in the single stratum (Table 4) compared to 71-101 plots searched in the 7 or 5 strata sampled in the old survey design. For all species, the aerial survey indices had the smaller CVs than the ground plot samples for nests (Fig. 5). Additional precision in population estimates may still be possible using species-specific post-classification for reanalysis of the data.

DISCUSSION:

A primary advantage of the ground plot random sampling procedure was that it assured applicability to the entire population within the sampled area and not just the immediate areas around intensive biological study camps. The expansion of the ground sample to the entire coastal YKD based on aerial survey data assumed that the ratios of nests to observed single-pairs were the same in the sampled and unsampled areas. The proportion of nests that remain active and average number of eggs per active nest are also assumed to be the same in the ground plot sampled and unsampled areas. The aerial survey based expansion factors do not require that nest:air observation ratios are the same among years, only that they are constant across strata within a given year.

Nesting success was again high with little evidence of the severe loss to arctic fox or avian predators that was evident from 1984 to 1986. Total population sizes of cacklers, emperors, whitefronts, and brant continued to expand in 1994. Particularly for those geese wintering in California and Oregon, the combination of environmental conditions and/or management practices has resulted in rapidly increasing nesting populations. The trend has been relatively constant over the last 9 years. Growth rates were slightly greater in the ground sampled stratum that has medium to high nest density, compared to peripheral areas with lower nest density.

The population trends determined from the ground data match the trends in aerial survey observations for each species except for spectacled eider. More eiders have been observed on aerial transects in 1993 and 1994 whereas the number of nests found has remained essentially constant. The same observer has recorded data on the aerial survey since 1991 and a progressive increase in skill at observing and identifying eiders may explain a small part of the increase. Other possible explanations include: a smaller proportion of single or paired eiders have initiated nests perhaps due to a shift in age structure; more male eiders are in the population without accompanying females or nests; nests have failed during laying or early in incubation which reduces their detectability by ground observers; or both active and destroyed nests recently have been detected at lower rates. Only continued air and ground sampling, with additional data collection to estimate air and ground detection rates, will distinguish among these alternatives.

Table 1. Number of randomly located 0.324 km² (0.125 mi²) plots in various sampling regions of the Yukon-Kuskokwim delta coast that were searched in early June 1986 to 1994 during incubation.

Region	km²	1986	1987	1988	1989	1990	1991	1992	1993	1994
+Kokechik Bay	100	8	14	19	15	13	9	-	10	-
+Kokechik River	189	7	13	9	11	16	13	-	10	-
*Tutakoke coast	240	6	9	14	11	14	14	16	19	-
*Hazen Bay	266	7	13	15	10	13	15	15	12	-
*Naskonat Peninsula	275	11	8	11	10	13	14	14	19	-
*Kigigak-Baird Inlet	60	2	3	2	3	3	7	10	7	-
*Intermediate	1156	14	14	14	11	16	18	16	24	-
Central upland	1709	9	8	11	10	13	-	-	-	-
Lithkealik River	68	2	1	1	2	-	-	-	-	-
North Nelson Island	182	-	4	-	9	-	-	-	-	-
South Nelson coast	399	-	7	-	-	-	8	-	-	-
*Sub-total(5 strata)	1975	40	47	56	45	59	68	71	81	-
+Sub-total(7 strata)	2264	55	74	84	71	88	90	-	101	-
All sampled strata	4622	66	94	96	92	101	98	71	101	-
Single 1994 stratum	956	24	33	41	32	44	53	52	56	61

Table 3. Annual proportion of nests remaining active at first plot search, mean clutch size of apparently viable eggs found in actively incubated nests, and predicted mean date of hatch based on egg float angles. Means are calculated considering each nest found on a random ground plot as a sample unit rather than using cluster sampling or stratification.

	Proportion of Nests Active		Clutch Size Active Eggs		Predicted Hatch Date (June1=601, July1=701)			
year	prop.	n	eggs	n	avg.	min	max	n
Cackling Canada Goose								
86	0.589	265	4.82	156	629.6	614	713	144
87	0.907	270	5.08	245	628.7	621	718	83
88	0.769	281	4.59	215	623.8	613	710	68
89	0.853	434	4.84	370	629.9	621	710	53
90	0.742	512	4.58	380	623.3	612	706	175
91	0.857	669	4.66	573	622.2	611	703	351
92	0.895	669	4.75	599	629.6	620	718	390
93	0.885	705	4.51	624	623.8	609	706	359
94	0.814	625	4.59	509	618.8	609	709	411
Emperor Goose								
86	0.684	158	5.40	108	627.0	91	709	98
87	0.914	232	5.19	212	627.1	619	707	90
88	0.889	217	5.10	193	621.0	616	704	66
89	0.916	322	5.12	295	630.0	619	707	63
90	0.863	336	4.95	290	620.3	610	630	88
91	0.947	380	4.97	360	619.2	611	702	256
92	0.959	270	5.02	259	628.3	620	709	181
93	0.954	306	4.86	292	621.2	612	705	139
94	0.939	328	4.92	308	618.6	611	630	192
White-fronted Goose								
86	0.937	63	4.17	59	626.9	622	712	54
87	0.930	86	4.55	80	626.6	620	702	39
88	0.963	82	4.45	79	621.9	615	703	31
89	0.991	112	4.52	111	627.4	621	704	21
90	0.936	173	4.60	152	621.5	610	629	52
91	0.935	214	4.65	200	621.0	611	703	138
92	0.971	204	4.48	198	629.0	619	708	110
93	0.970	199	4.31	193	623.3	617	706	84
94	0.973	222	4.36	216	618.6	610	629	129
Black Brant								
86	0.631	111	4.14	70	625.9	622	629	6
87	0.933	313	4.39	292	625.9	622	701	18
88	0.644	222	3.41	143	618.9	613	703	36
89	0.929	1011	3.76	939	626.7	620	706	40
90	0.710	428	3.26	304	619.1	615	627	50
91	0.867	542	3.70	470	618.4	613	701	184
92	0.963	898	3.95	865	626.0	619	706	152
93	0.852	562	3.54	479	620.6	613	628	107
94	0.883	274	3.86	242	616.2	610	628	93
Tundra Swan								
86	1.000	14	3.89	14	627.8	624	701	9
87	1.000	17	3.79	17	627.7	621	702	8
88	1.000	24	4.60	24	626.5	617	705	4
89	1.000	24	4.29	24	630.7	627	703	4
90	0.964	28	4.09	27	623.9	620	626	4
91	0.926	27	4.20	25	624.1	617	708	12
92	1.000	20	3.80	20	630.0	624	708	8
93	0.964	28	4.04	27	626.0	619	702	6
94	1.000	27	4.33	27	621.3	611	630	9

Table 3. (Continued) Annual proportion of active nests, mean clutch size, and predicted mean date of hatch.

	Proportion of Nests Active		Clutch Size Active Eggs		Predicted Hatch Date (June1=601, July1=701)			
year	prop.	n	eggs	n	avg.	min	max	n
Glaucous Gull								
86	0.800	30	2.22	24	625.8	622	705	10
87	1.000	49	2.33	49	628.2	621	710	16
88	0.932	74	2.44	69	624.8	615	708	9
89	0.894	47	2.49	42	622.4	622	623	3
90	0.839	56	2.64	47	617.0	617	617	2
91	0.826	92	2.75	76	617.7	612	703	26
92	0.947	75	2.75	71	626.1	622	704	23
93	0.983	59	2.64	58	619.2	615	707	11
94	0.981	54	2.77	53	616.4	611	627	17
Mew Gull								
86	0.923	13	2.25	12	703.5	622	712	10
87	1.000	19	2.29	19	627.1	621	704	5
88	0.977	43	2.68	41	618.0	614	624	4
89	0.918	49	2.58	45	622.0	622	622	1
90	0.960	25	2.54	24	621.4	617	626	2
91	0.857	42	2.58	36	619.4	614	702	8
92	0.941	34	2.56	32	627.0	623	704	10
93	1.000	92	2.76	92	624.1	617	702	7
94	0.963	27	2.54	26	614.4	610	621	8
Sabine's Gull								
86	1.000	9	1.78	9	623.7	615	707	6
87	1.000	13	2.08	13	621.3	615	704	6
88	0.929	14	2.46	13	624.5	618	708	8
89	1.000	15	2.67	15	701.0	621	711	2
90	1.000	20	2.30	20				
91	1.000	20	1.94	20	614.5	609	622	9
92	1.000	18	2.22	18				
93	0.967	60	2.24	58	617.2	615	623	8
94	1.000	38	2.71	38	611.3	609	616	6
Arctic Tern								
86	1.000	5	2.60	5	623.4	617	703	4
87	1.000	6	1.33	6	626.0	626	626	2
88	0.857	7	1.67	6	624.0	624	624	2
89	1.000	7	1.86	7	622.0	622	622	1
90	1.000	10	1.74	10	623.3	623	623	1
91	1.000	8	1.88	8	616.5	612	619	4
92	1.000	15	1.93	15	630.3	625	710	6
93	1.000	28	2.18	28	616.6	615	620	3
94	1.000	8	2.12	8	614.5	615	615	1

Table 4. (continued) Annual estimates of nest density and population size.

Year	N. plots	Ground plot sampled area: Nests /km²	Total nests	SE	CV	Active nests	Active eggs	Prop. nests active	Aerial expansion factor	Expanded to entire coast: Total nests	Active nests	Active eggs
Tundra Swan												
86	24	1.19	1130	288	0.255	1130	3812	1.000	0.176	6437	6437	21713
87	33	1.23	1173	323	0.275	1173	4267	1.000	0.182	6448	6448	23455
88	41	1.47	1400	321	0.229	1400	6490	1.000	0.199	7044	7044	32655
89	32	1.22	1166	336	0.288	1166	5268	1.000	0.174	6683	6683	30193
90	44	1.48	1408	250	0.177	1375	5886	0.977	0.165	8525	8325	35638
91	53	0.97	922	196	0.213	873	3411	0.947	0.174	5307	5025	19635
92	52	1.46	1392	173	0.124	1392	5266	1.000	0.158	8831	8831	33408
93	56	1.42	1351	258	0.191	1333	5288	0.987	0.165	8164	8055	31953
94	61	1.40	1335	258	0.193	1335	5786	1.000	0.161	8300	8300	35971
					0.216			0.990	0.173			
Sandhill Crane												
86	24	0.67	641	243	0.380	641	879	1.000				
87	33	0.93	884	312	0.352	766	1353	0.867	0.123	7190	6230	11005
88	41	1.64	1563	319	0.204	1563	3030	1.000	0.146	10709	10709	20759
89	32	0.70	668	223	0.333	566	1132	0.847	0.108	6198	5252	10504
90	44	1.98	1886	312	0.165	1837	3254	0.974	0.110	17153	16708	29596
91	53	1.75	1669	378	0.226	1669	3122	1.000	0.114	14583	14583	27279
92	52	1.55	1474	285	0.193	1416	2474	0.961	0.137	10752	10329	18047
93	56	1.25	1195	294	0.246	1071	1641	0.896	0.126	9513	8526	13064
94	61	1.63	1555	256	0.165	1555	2797	1.000	0.152	10260	10260	18455
					0.252			0.949	0.127			
Spectacled Eider												
86	24	3.06	2915	828	0.284	1867	8307	0.640				
87	33	2.41	2299	439	0.191	1684	8545	0.732				
88	41	2.33	2220	676	0.305	2072	10044	0.933	0.421	5273	4922	23858
89	32	2.20	2095	485	0.232	1861	8994	0.888	0.377	5563	4942	23882
90	44	2.12	2021	415	0.205	1838	9899	0.909	0.452	4473	4068	21911
91	53	1.58	1502	362	0.241	1315	6905	0.875	0.636	2360	2066	10851
92	52	1.38	1318	283	0.215	1127	6168	0.855	0.678	1943	1662	9094
93	56	1.50	1425	327	0.229	1216	5293	0.853	0.802	1777	1517	6602
94	61	1.84	1752	298	0.170	1290	6233	0.736	0.685	2559	1884	9105
					0.230			0.825	0.450			
Common Eider												
86	24	0.05	49	49	0.988	0	0	0.000				
87	33	0.29	279	149	0.534	160	991	0.573				
88	41	0.36	347	172	0.496	347	1736	1.000	0.429	810	810	4051
89	32	1.37	1309	528	0.403	1309	7220	1.000	0.000			
90	44	0.31	293	118	0.401	198	873	0.676	0.000			
91	53	0.70	671	308	0.460	597	2818	0.890	0.142	4725	4204	19843
92	52	0.95	903	439	0.486	883	4539	0.978	0.000			
93	56	0.46	436	188	0.431	259	1337	0.594	0.402	1086	645	3329
94	61	0.69	659	262	0.397	579	2465	0.879	0.720	915	804	3422
					0.511			0.732	0.188			
Combined eider species												
86	24	3.11	2965	832	0.281	1867	8307	0.630				
87	33	2.71	2578	499	0.194	1845	9536	0.716				
88	41	2.70	2568	764	0.297	2419	11780	0.942	0.392	6547	6167	30030
89	32	3.57	3404	713	0.209	3170	16214	0.931	0.476	7156	6664	34086
90	44	2.43	2314	479	0.207	2036	10772	0.880	0.482	4801	4224	22348
91	53	2.28	2172	539	0.248	1912	9723	0.880	0.445	4884	4300	21864
92	52	2.33	2222	541	0.244	2011	10707	0.905	0.631	3519	3185	16957
93	56	1.95	1861	405	0.217	1475	6630	0.793	0.719	2590	2053	9227
94	61	2.53	2411	404	0.168	1869	8698	0.775	0.699	3451	2675	12449
					0.229			0.828	0.549			

Table 5. Average of annual estimates from ground plot and aerial transect samples on the YKD (Table 4) for coefficients of variation, weighted proportion of nests active, proportion of the aerial population index within the ground sampled area (expansion factor), and the ratio of nests found to single-pair (sgpr) and total bird (total) aerial observations. CVs are calculated for the single stratum area to compare stratified and unstratified analysis of nests found on ground plots, the aerial single-pair observations, and aerial total bird observations.

	Coefficients of variation				Wgtd.prop.		Nests:aerial index	
species	nests (str.)	nests (unstr.)	air sgpr	air total	of nests active	Expansion factor	nests/ sgpr	nests/ total
Cackling Canada goose	0.140	0.167	0.085	0.087	0.819	0.569	3.26	1.54
Emperor goose	0.120	0.136	0.101	0.116	0.909	0.408	7.22	2.89
White-fronted goose	0.149	0.168	0.109	0.121	0.971	0.226	6.02	1.39
Black brant	0.480	0.554	0.232	0.322	0.851	0.493	11.46	1.47
Tundra swan	0.216	0.241	0.084	0.246	0.990	0.173	1.21	0.25
Sandhill crane	0.252	0.245	0.095	0.126	0.949	0.127	1.59	0.97
Spectacled eider	0.230	0.256	0.216	0.220	0.825	0.579	5.70	4.12
Common eider	0.511	0.523	0.411	0.462	0.732	0.423	10.35	7.44
combined eider species	0.229	0.256	0.172	0.177	0.828	0.549	3.99	2.98
Pacific loon	0.216	0.270	0.151	0.154	0.939	0.087	2.30	1.86
Red-throated loon	0.435	0.461	0.260	0.263	0.949	0.162	1.48	1.18
combined loon species	0.208		0.128	0.130	0.942	0.097	2.10	1.69
Glaucous gull	0.281	0.374	0.105	0.267	0.895	0.276	1.79	0.41
Mew gull	0.452	0.532	0.121	0.194	0.961	0.256	2.17	1.08

Figure 1. Geographic area of high density goose nesting on the Yukon-Kuskokwim delta on the western coast of Alaska. The map indicates boundaries (thin lines) of the 16 strata previously used to sample geese. and the boundary (heavier line) that includes all areas with medium to high nesting density based on 1985-1993 air or ground sampling data.

Figure 2. Locations of the 1994 random plots searched for nests (black rectangles) and the potential plots selected but not searched (light gray rectangles) within the new single stratum boundaries.

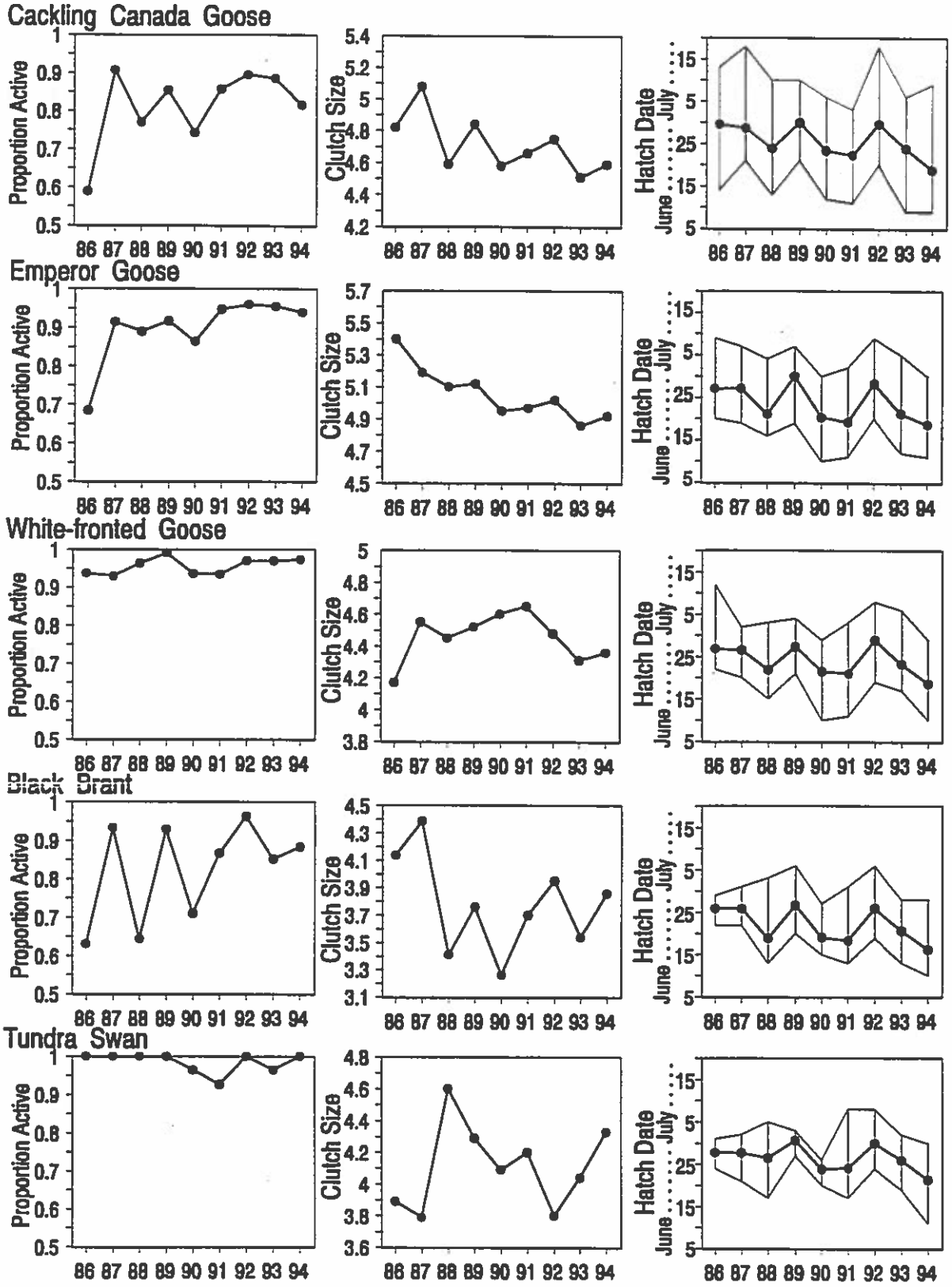

Figure 3a. Average proportion of nests remaining active when found at first plot search, clutch size in active nests, and average hatch date predicted by egg float angles. Data are based on all nests found on randomly located ground plots. Vertical lines indicate the range of predicted hatch dates.

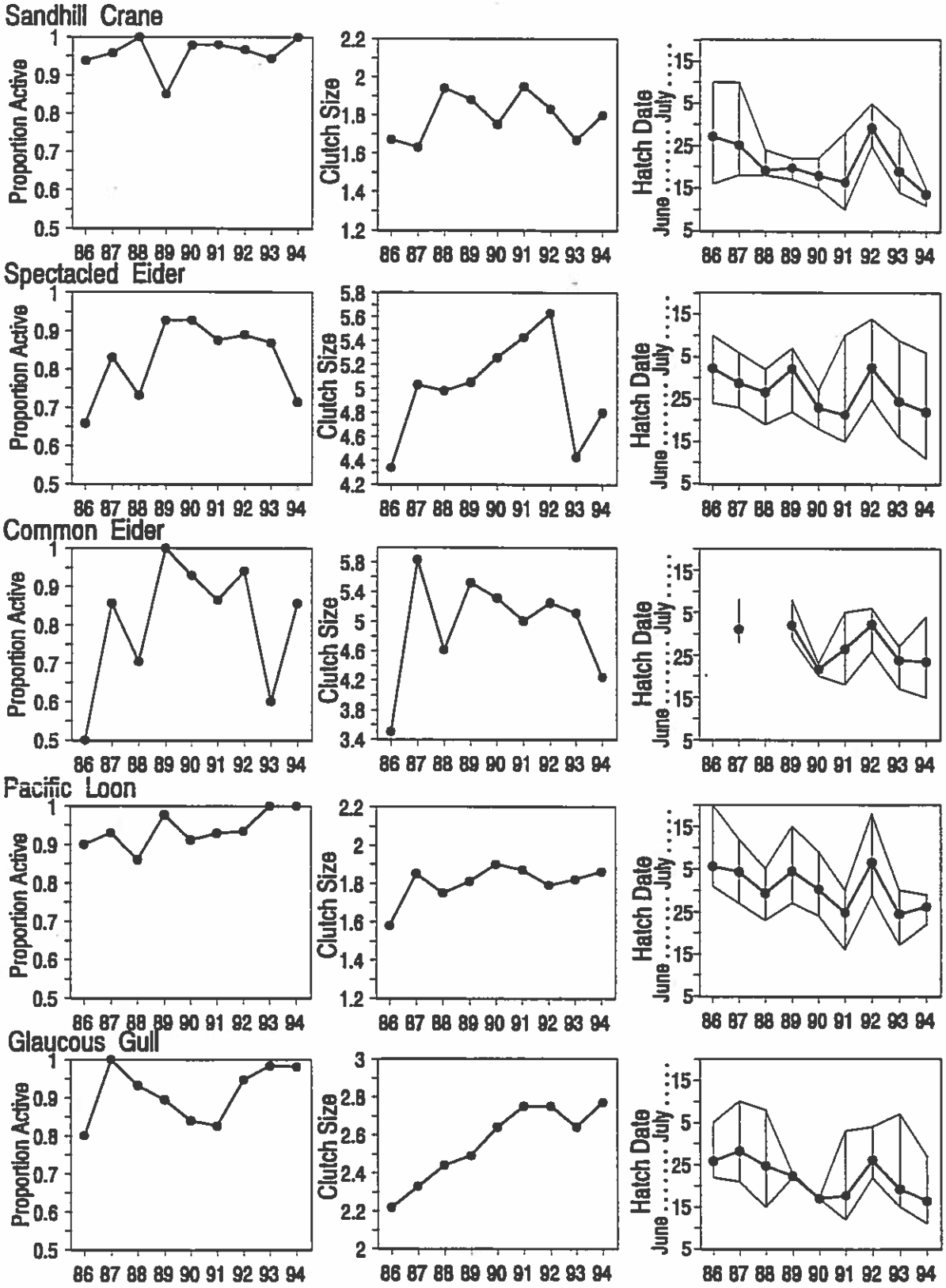

Figure 3b. Average proportion of nests remaining active when found at first plot search, clutch size in active nests, and average hatch date predicted by egg float angles. Data are based on all nests found on randomly located ground plots. Vertical lines indicate the range of predicted hatch dates.

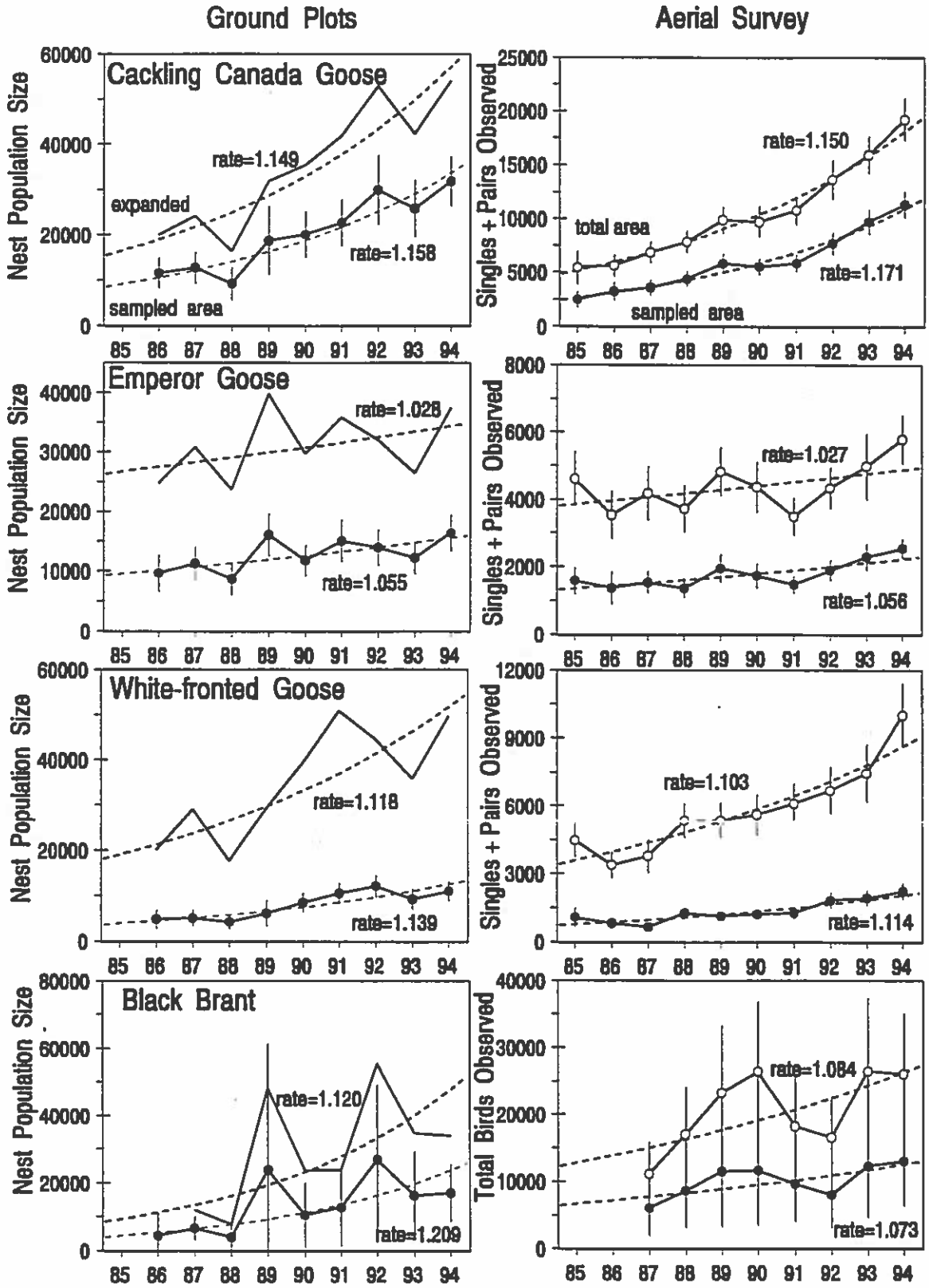

Figure 4a. Nest population size estimated for the 956 km2 area sampled by ground plots. Vertical lines indicate 95% confidence intervals. The ratio of aerial-observed population sizes for the ground-sampled area and the total YKD coast, graphed on the right, provided the expansion factor for the total nest population. The dashed line indicates the log-linear regression fit for each data set. The slopes of these lines are annual rates of population growth.

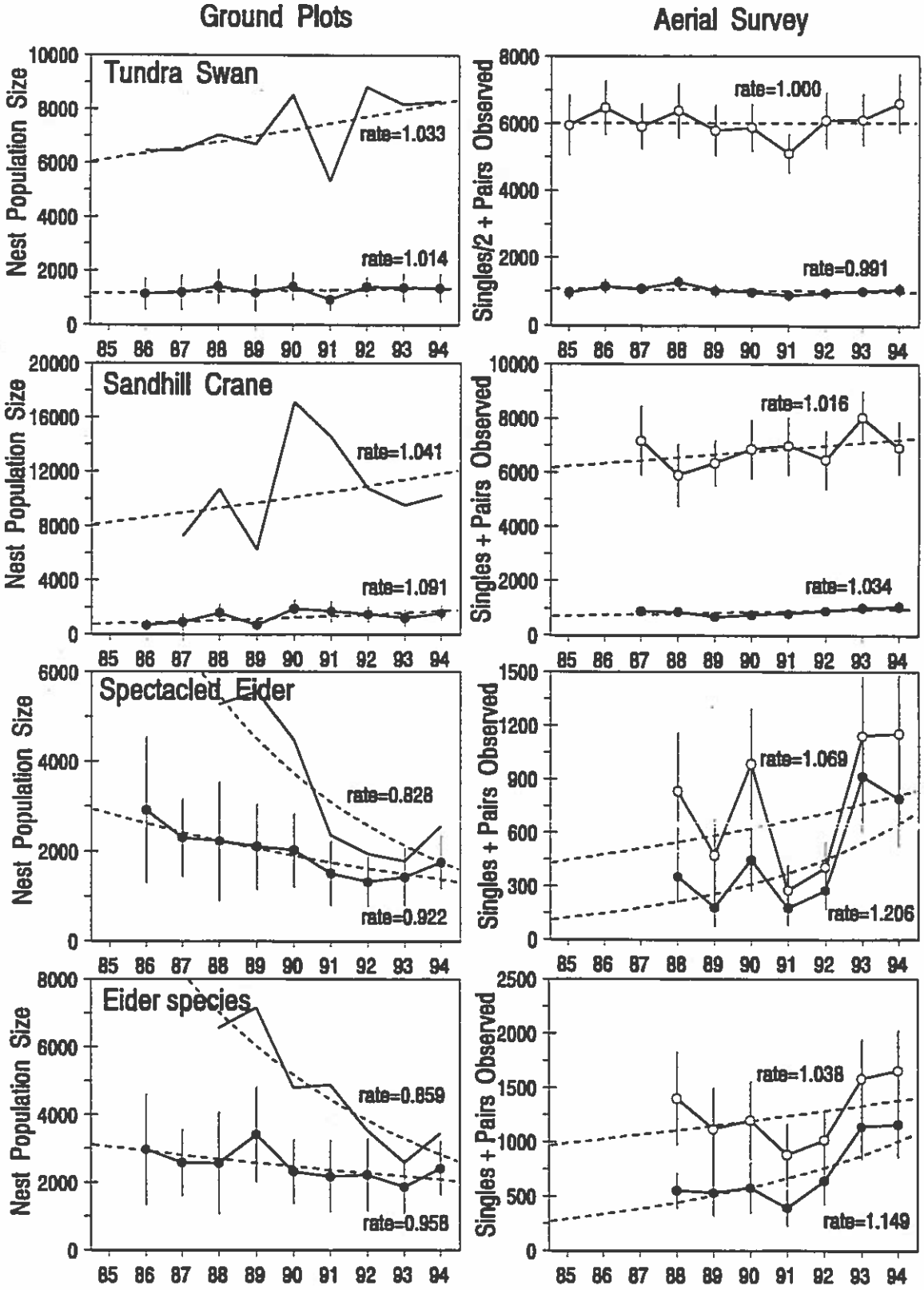

Figure 4b. Nest population size estimated for the 956 km2 area sampled by ground plots. Vertical lines indicate 95% confidence intervals. The ratio of aerial-observed population sizes for the ground-sampled area and the total YKD coast, graphed on the right, provided the expansion factor for the total nest population. The dashed line indicates the log-linear regression fit for each data set. The slopes of these lines are annual rates of population growth.

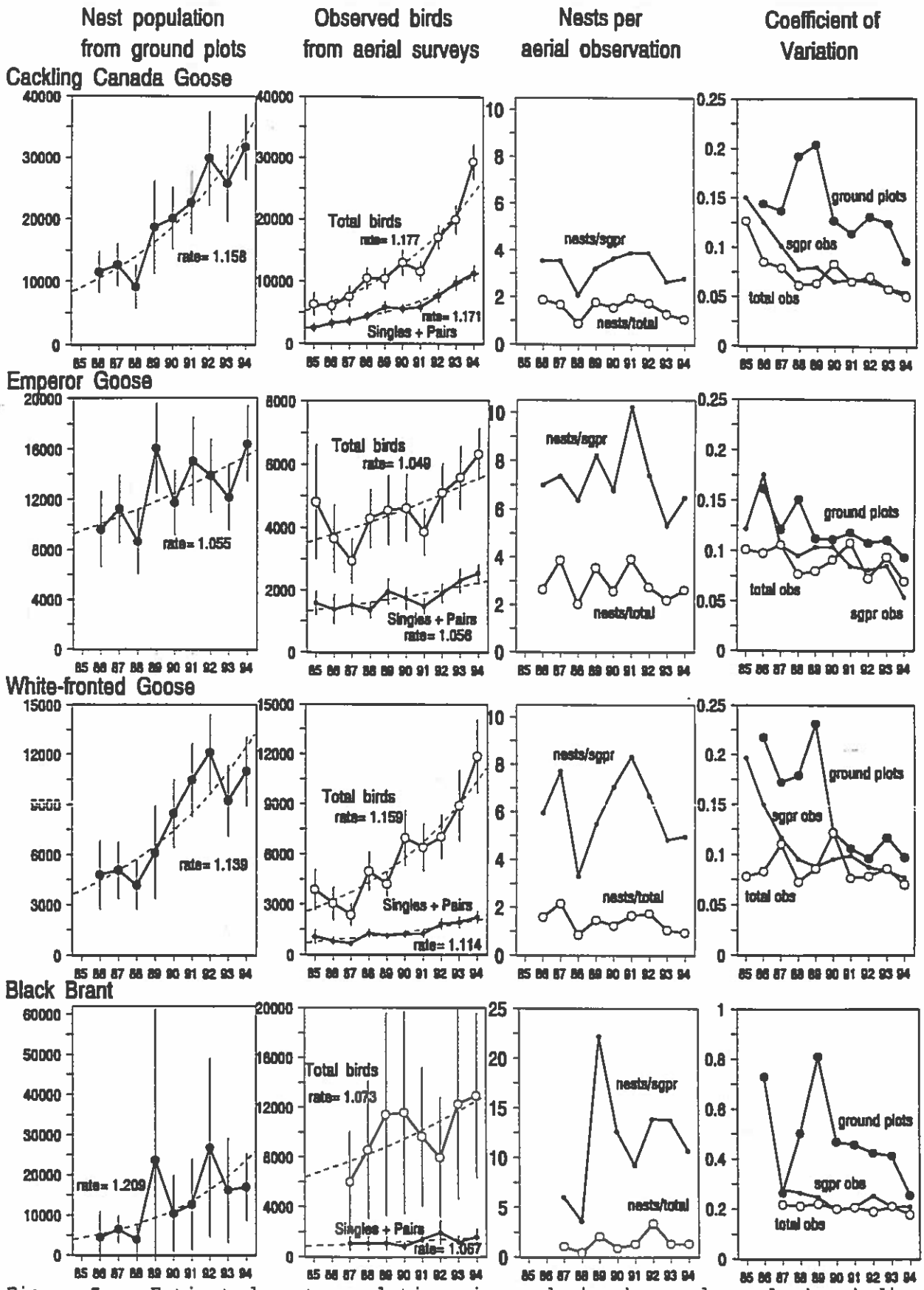

Figure 5a. Estimated nest population size and air-observed population indices for the sampled stratum on the central YKD coast. Vertical lines indicate 95% confidence intervals. The third column shows the ratio of the first two estimates; nests per observed single-pair or total birds. The relative precision of each estimate is graphed by the coefficient of variation.

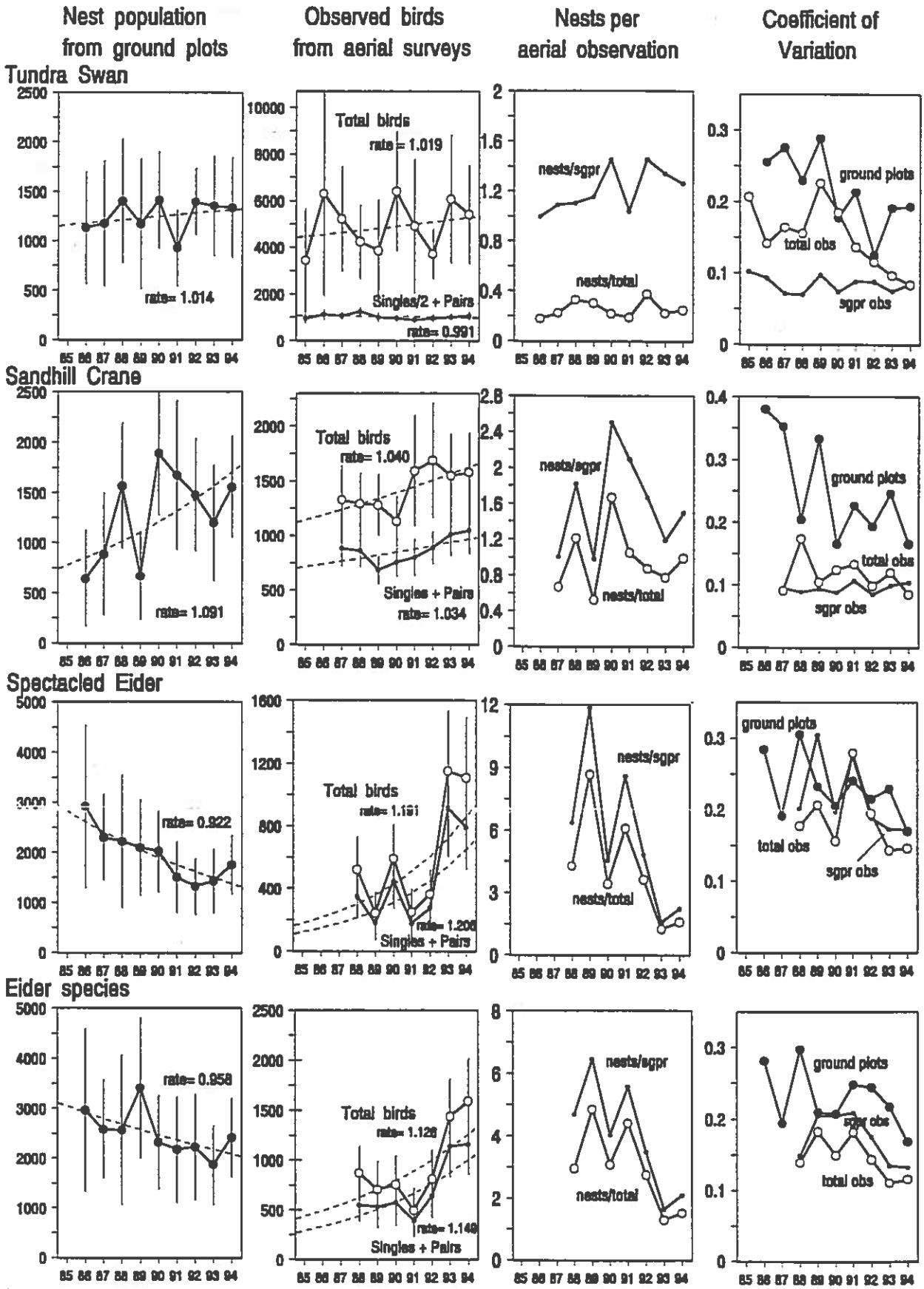

Figure 5b. Estimated nest population size and air-observed population indices for the sampled stratum on the central YKD coast. Vertical lines indicate 95% confidence intervals. The third column shows the ratio of the first two estimates; nests per observed single-pair or total birds. The relative precision of each estimate is graphed by the coefficient of variation.